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6359-200, Plenary Session

Advanced laser remote sensing for four-dimensional aerosol observations

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The role of aerosols in the Earth system can hardly be underestimated. Aerosols play an important role in the climate system, their direct and indirect effects cause major uncertainties of present climate predictions. They play a major role in atmospheric chemistry and hence affect the concentrations of other potentially harmful atmospheric constituents, e.g. ozone. They are an important controlling factor for the radiation budget, in particular in the UV-B part of the spectrum. At ground level, they can be harmful, even toxic, to man, animals, and plants. Because of these adverse effects that aerosols can have on human life, it is necessary to achieve an advanced understanding of the processes that generate, redistribute, and remove aerosols in the atmosphere. A quantitative dataset describing the aerosol vertical, horizontal, and temporal distribution, including its variability on a large range of scales, is urgently needed.

There is now general agreement that no single instrument can provide all the required information on aerosols, an integration of many different technologies is necessary to cover at least the most important aspects. Laser remote sensing plays a key role because only lidar methods can provide sufficient information on the vertical distribution of aerosols which is mandatory for studies of transport and transformation. While relatively simple instruments can observe the time-height-distribution of aerosol layers from ground level to the stratosphere, advanced methods can also determine optical properties in a quantitative way. When measurements at several wavelengths are combined and advanced retrieval methods are applied it is possible to estimate micro-physical properties like size distribution, refractive index, or single scattering albedo. A network of such ground-based lidars is presently the only system that covers all 4 dimensions in routine observations, although the coverage is necessarily sparse. The combination of ground-based and space-borne lidar with passive satellite imagery and in-situ monitoring programs appears as the best choice for a future global observation system for aerosols.

6359-201, Plenary Session

Cloud remote sensing from space in the era of the A-Train

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Clouds play an important role in the hydrologic cycle, influence global energy balance, and represent a significant yet poorly understood component of global climate change. As a result, quantitative global observations of liquid and ice cloud microphysical and radiative properties continue to be a focus of a growing number of satellite-based sensors each having an associated suite of retrieval algorithms. While a number of these algorithms have successfully been applied to map clouds, many can only be applied under specific conditions (eg. during the daytime) or over a limited dynamic range (eg. optically thin cirrus) often leading to unphysical discontinuities when one seeks to compile a complete picture of the global distribution of clouds. Furthermore, discrepancies exist between products of different algorithms when they are applied to the same scene by virtue of differences in the information provided by distinct combinations of measurements.

With the emergence of spaceborne cloud radar (CloudSat) and backscattering lidar (CALIPSO) systems as part of the constellation of the A-Train and with potential for combining these observations with more conventional satellite observations of other satellites of this constellation, the promise of new ways of observing clouds is fast approaching. In preparation for understanding how the data from these new sensors might be used optimally with these more conventional radiometric data, it is important to deliberate on the respective information content contained in the measurements of the different sensors. This presentation reviews the problem of cloud microphysical property retrievals using conventional satellite radiance observations and demonstrates how the concept of information content can be used to guide combinations of observations from the A-train. Discussion on how these types of observation might be merged with the observations from the active sensors to provide improved cloud and precipitation will also be presented. It is also expected that Early results from CloudSat will be described.

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6359-01, Session 1

Non-stationary time-series analysis of AVHRR datasets for monitoring vegetation phenology and snow and ice cover

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The United Nations Framework Convention on Climate Change has defined the need for terrestrial environment climate variables as specified by the Global Terrestrial Observing System. These variables include snow cover, ice cover and vegetation phenology. A number of modern satellite sensors are now in place with spectral wavelengths designed to monitor vegetation, snow and ice. However, for climate relevant data sets, the long (25+ years) time series of NOAA AVHRR imagery is essential. One challenge working with this imagery is the lack of specific bands for cloud versus snow separation and atmospheric correction. This paper discusses an alternative approach to estimating cloud free time series of surface reflectances using NOAA AVHRR imagery and then applying this time series for montoring snow cover, lake ice and vegetation green up.

A robust iterative loess regression approach is discussed that allows for estimation of continuous reflectance trends that contain variability due to BRDF but minimize atmospheric contamination. The regression approach is applied with spatially adaptive algorithms to estimate fractionof snow cover, ice cover nad leaf area index over selected sites across Canada from 1985-2005. The retrieved daily time series of terrestrial variables are evaluated by comparison to existsing in-situ networks. An approximation to the robust loess approach is implemented to facilitate processing of the large global historical archive of NOAA imagery. This implementation , based on recursive rank filters, provides similar agreement between phenology products and in-situ networks with approximately 2 orders of magnitude savings in computation. The current effort to reprocess phenology related variables over Canada using this approach are discussed.

This work is supported by the Natural Resources Canada Earth Sciences Sector Climate Change Programme and the Canadian Space Agency Government Related Initiatives Programme.

6359-02, Session 1

Date of snow disappearance at 60º and 70º North Latitude from satellite observations

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In this paper, we show changes in the dates of snow disappearance in the Arctic between the late 1960s and the early 2000s, at 60º and 70º north latitude, using National Oceanic Atmospheric and Administration (NOAA) satellite observations. The date the snowline retreats during the spring (when it first moves north of the 60º and 70º parallels), for many Arctic locations, has occurred approximately a week earlier in recent decades compared to the late 1960s. During this same period, substantial portions of the Arctic have been experiencing higher temperatures and a conspicuous diminution of sea ice, especially in the past 10 years. Our results generally agree with these observations — the tendency toward earlier snowmelt previously observed was sustained until about 1990. Since this time, however, the date of snow disappearance has not been occurring noticeably earlier.

In Antarctic, portions of the East Antarctic Ice Sheet have been observed to be growing - gaining approximately 45 billion metric tons of mass per year between 1992 and 2003. Furthermore, Antarctic sea ice extent has also been increasing in recent years. It is not unexpected that climate signals may appear to contradict one another, temporally and spatially. Different features may respond to warming, or cooling, in different ways. Similarly, during the past 15 years, a relative stability in the date of snow cover disappearance in the high Arctic (or even a slightly later date at some locations), should not be construed as a sign that the earlier snowmelt observed in the 1970s and 1980s was an aberration. Still, it demonstrates that the evidence for global warming is not completely incontrovertible, even in the Arctic.

6359-03, Session 1

Determination of soil heat capacity through an energy balance evaluated by upwelling and downwelling thermal infrared measurements: experimental and theoretical study

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Since quite a decade, the use of thermal infrared sensors for retrieval of cloud cover has been widely described and investigated.(Gillotay et al.- 2001/ Besnard et al.- 2005). Pointing pyrometric devices to the ground and to the sky provide brightness temperatures. The energy balance through these measurements could be evaluated in order to measure heat capacity.

Experimental data used have been obtained with a CIR-4 instrument upgraded with the addition of an extra down watching pyrometer for surface state temperature estimation.

Surface temperatures observed could be properly described a regular Fourier heat transfer model.

6359-04, Session 1

A new approach to reduce inconsistency between MODIS and ASTER land surface temperature products

Y. Liu, Y. Yamaguchi, T. Hiyama, Nagoya Univ. (Japan)

Land surface temperature (LST) controls most physical, chemical, and biological processes of the Earth system. Satellite-derive LST provides large-scale observation and is very useful to environmental studies. Among numerous satellite sensors, the MODerate resolution Imaging Spectroradiometer (MODIS) and the Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER) are onboard the same satellite platform TERRA. MODIS MOD11_L2 and ASTER AST_08 LST products have a spatial resolution of 1-km and 90-m, respectively. Our previous scaling study revealed 2.2K on-average differences between the MODIS and the upscaled ASTER LST over a heterogeneous semiarid area in the Loess Plateau of China (SPIE Proc., 5967: 58670O-1-8). Because the retrieval algorithm for MODIS 1-km LST product is subject to uncertainty in emissivity estimate over semiarid and arid areas, this paper uses ASTER emissivity data to reduce the LST inconsistency. Based on the MODIS LST retrieval algorithm, a new algorithm is derived. The algorithm does not rely on the coefficients used in the MODIS algorithm such that it can be implemented without acquisition of the raw MODIS datasets. The MODIS LST and band-31 emissivity as well as the upscaled ASTER emissivity are the necessary inputs to the proposed algorithm. Using the same datasets as in our previous study, the output MODIS LST achieved the satisfied agreement with the upscaled ASTER LST. This study also suggested that the uncertainty in LST induced by retrieval algorithm could be larger than the scale induced uncertainty.

6359-05, Session 1

Retrieval of land surface properties from the high-spectral resolution infrared sounders: AIRS, IASI, and CrIS

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A new methodology to retrieve the land surface infrared properties of effective skin temperature and land surface emissivity is presented that takes advantage of the high spectral resolution observations of a new generation of polar orbiting weather satellites. The NASA Atmospheric Infrared Sounder (AIRS) on the EOS Aqua platform was the first of a series of high spectral resolution sensors that includes the operational Infrared Atmospheric Sounding Interferometer (IASI) on Europe's METOP platforms and the Cross-track Infrared Sounder (CrIS) on the U.S. National Polar Orbiting Environmental Satellite System platforms. The full methodology will be applied to several case studies covering different geographic

regions. Validation with in situ observations will be made where possible, including a well-instrumented site in the mid-Continental United States. Application to regions of interest will be made in sub-polar winter conditions, e.g. Scandinavia, Siberia, Alaska/Yukon, and Antarctica, and semi-arid regions, e.g. sub-Saharan Africa. Both the cold sub-polar and hot desert conditions provide challenges for the identification and removal of cloud effects. In the sub-polar winter the mid-level clouds can be 40 degrees warmer than the surface in adjacent clear regions. The effective identification of clear sounder fields of view is an important part of making these data useable in Numerical Weather Prediction data assimilation. In sub-Saharan Africa the challenge is to discriminate among variable clouds, surface, and aerosol dust in the interpretation of satellite observations.

6359-07, Session 1

2D weather radar data simulator using specific reflectivity and phase measurements for the rain rate estimation algorithms validation

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A modular simulator of 2D polarimetric rain radar measurements images has been developed based on the Rayleigh approximation. A dual physical-statistical model of the rain and a description of the rain downpour geometry are presented in order to generate a set of the specific measurements needed in the rain rate estimation process starting from known physical properties of the rain drops. The proposed simulator is able to produce images corresponding to polarimetric weather radar data. It is a flexible tool that allows the user to choose among a variety of parameterizations of the rain process as well as the radar system involved in the measuring of the polarimetric variables. It has been illustrated on one example how the proposed simulator gives expected results from generated data. The simulator was also used as a laboratory tool to validate and to compare some rain rate estimation algorithms. The obtained results go in harmony with known results in the literature. It is envisageable to implement additional modules in the simulator, such as the Mie and the T-Matrix approximations and the Doppler radial wind modules.

6359-08, Session 1

Land surface modeling and satellite passive microwave imagery: a comparison of top soil moisture and surface temperature estimates

B. T. Gouweleeuw, M. Owe, NASA Goddard Space Flight Ctr. (USA)

Improved accuracy in defining initial conditions for fully-coupled numerical weather prediction models (NWP) along with continuous internal bias corrections for baseline data generated by uncoupled Land Surface Models (LSM), is expected to lead to improved short-term to long-range weather forecasting capability. Because land surface parameters are highly integrated states, errors in land surface forcing, model physics and parameterization tend to accumulate in the land surface stores of these models, such as soil moisture and surface temperature. This has a direct effect on the model's water and energy balance calculations, and will eventually result in inaccurate weather predictions.

Surface soil moisture and surface temperature estimates obtained with a recently improved retrieval algorithm from the Advanced Microwave Scanner Radiometer (AMSR) aboard NASA's Earth Observing System (EOS) Aqua satellite are evaluated against model output of the Community Land Model (CLM) operated within the Land Information System (LIS) forced with atmospheric data of the European Centre of Medium Range Weather Forecast (ECMWF) for the United States Mid-West.

Preliminary analysis presented here reveals the off set between the two data sets, although distinct, is relatively constant, which suggests a potential for improved initialization and bias correction by an optimized accuracy and spatial representation of the soil moisture data fields.

6359-09, Session 1

Analysis of southern Italy NDVI fluctuations from 1994 to 2006: a search for a climate change indicator

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Seasonal and interannual vegetation dynamics and trends for a macro-region of Southern Italy, comprising Apulia, Campania, Basilicata, Calabria and Sicily regions, were analyzed for the last twelve years, in order to detect indications of climate changes and associated desertification processes. Vegetation index data for the whole Europe and North Africa can be retrieved from the DLR archive of thematic maps (http://taurus.caf.dlr.de:8080/index.html) in the form of daily, weekly and monthly composite NDVI maps. The DLR archive dates back to 1994, thus the analysis was only carried out for the last twelve years. A specific procedure, based on the commercial software TeraScan (www.seaspace.com), allowed the extraction of the area of interest from the whole map and the preparation of the data set for the successive analysis.

According to the methods described by Myneni et al. (1998), the statistical analysis of temporal vegetation variations was carried out by implementing specific routines which provided objective measurements of vegetation anomaly.

Two main issues were specifically investigated: i) NDVI anomaly in relation to annual and seasonal variations; and ii) regional NDVI extents, in order to compare different local trends.

Results of this analysis for the selected macro-region of Southern Italy, from 1994 to 2006, will be presented and discussed. The next phase of this study will investigate the correlation between NDVI and rainfall data, these latters being obtained from the German Global Precipitation Climatology Centre (GPCC).

REFERENCES: Myneni et a. (1998), Interannual variations in satellite-sensed vegetation index data from 1981 to 1991. J. Geophys. Res. vol. 103, NO. D6, 6145-6160.

6359-10, Session 1

The use of ATLAS data to quantify surface radiative budget alteration through urbanization for San Juan, Puerto Rico

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The additional heating of the air over the city is the result of the replacement of naturally vegetated surfaces with those composed of asphalt, concrete, rooftops and other man-made materials. The temperatures of these artificial surfaces can be 20 to 40 o C higher than vegetated surfaces. Materials such as asphalt store much of the sun's energy and remains hot long after sunset. This produces a dome of elevated air temperatures 5 to 8 o C greater over the city, compared to the air temperatures over adjacent rural areas. This effect is called the "urban heat island". Urban landscapes are a complex mixture of vegetated and nonvegetated surfaces. It is difficult to take enough temperature measurements over a large city area to characterize the complexity of urban radiant surface temperature variability. However, the use of remotely sensed thermal data from airborne scanners are ideal for the task. The NASA Airborne Thermal and Land Applications Sensor (ATLAS) operates in the visual and IR bands was used in February 2004 to collect data from San Juan, Puerto Rico with the main objective of investigating the Urban Heat Island (UHI) in tropical cities. In this presentation we will examine the techniques of analyzing remotely sensed data for measuring the effect of various urban surfaces on their contribution to the urban heat island effect. Results from data collected from other US cities of Sacramento, Salt Lake City and Baton Rouge will be used to compare the "urban fabric" among the cities.

6359-12, Session 2

Historical data set of satellite derived global land surface moisture

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A historical data set of satellite derived global land surface moisture is being developed by the NASA Goddard Space Flight Center and the Vrije Universiteit Amsterdam. The data consist of surface soil moisture retrievals from both historical observations and currently active satellite microwave sensors, including Nimbus SMMR, DSMP SSM/I, TRMM TMI, and AQUA AMSR-E. The data sets span the period from November 1978 through 2005. The soil moisture retrievals are made with the Land Parameter Retrieval Model, which was developed jointly by researchers from the above institutions. The various sensors have different technical specifications, including primary wavelength, radiometric resolution, and frequency of coverage. Consequently, the soil moisture sensing depth also varies between the different sensors. It is expected that the data will

be made available for download by general science community within four to six months. Specifications and capabilities of different sensors, and how they affect soil moisture retrievals are discussed, and examples of the different sensor retrievals are presented for comparison.

6359-13, Session 2

Forest changes assessment using satellite remote sensing imagery

M. A. Zoran, National Institute of Research & Development for Optoelectronics (Romania); L. V. Zoran, Univ. Politehnica Bucuresti (Romania)

The synergistic use of multi-temporal and multi-spectral remote sensing data offers the possibility of long-term forest change monitoring.Forested ecosystems in Romania are undergoing accelerated change due to natural and anthropogenic disturbances. Change detection is a remote sensing technique used to monitor and map landcover change between two or more time periods and is now an essential tool in forest management activities. We compared the ability of Multitemporal Spectral Mixture Analysis (MSMA), and maximum likelihood (ML) classification , Principal Components Analysis (PCA) techniques to accurately identify changes in vegetation cover in a south-eastern part of Romania study area between 1984 and 2004 for Landsat TM, ETM and SAR images. Fuzzy logic approach provides a mathematical formalism for combining evidence from various sources to estimate the significance of a detected change Supervised classification accuracy results were high (\> 68% correct classification for four vegetation change classes and one no-change class).For spatial patterns of changes assessment, has been applied change vector analysis .Classification accuracies are variable, depending on the class and the comparison method as well as function of season of the year. To solve urgent needs in application of remote sensing data, forest cover changes must be detected based on monitoring spatial and temporal regimes across landscapes. Specific aim of this paper is to assess, forecast, and mitigate the risks of forest system changes and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the basis of spectral information derived from satellite data .

6359-15, Session 2

Processing and analyzing advanced hyperspectral imagery data

A. H. El Nahry, National Authority for Remote Sensing and Space Sciences (Egypt)

The main objective of the current work is to recognize the dominant and predominant clay minerals of South Port Said plain soils, Egypt using the high advanced remote sensing techniques of hyperspectral data. Spectral analyses as one of the most advanced remote sensing techniques were used for the aforementioned purpose. Different spectral processes have been used to execute the prospective spectral analyses. These processes include 1-The reflectance calibration of hyperspectral data belonging to the studied area, 2- Using the minimum noise fraction (MNF) transformation.3-Creating the pixel purity index (PPI) which used as a mean of finding the most “spectrally pure”, extreme, pixel in hyperspectral images. Making conjunction between the Minimum Noise Fraction Transform (MNF) and Pixel Purity Index (PPI) tools through 3-D visualization offered capabilities to locate, identify, and cluster the purest pixels and most extreme spectral responses in a data set. To identify the clay minerals of the studied area the extracted unknown spectra of the purest pixels was matched to pre-defined (library) spectra providing score with respect to the library spectra. Three methods namely, Spectral Feature Fitting (SFF),Spectral Angle Mapper (SAM) and Binary Encoding (BE) were used to produce score between 0 and 1, where the value of 1 equal a perfect match showing exactly the mineral type. In the investigated area four clay minerals could be identified i.e. Vermiculite, Kaolinite, Montmorillinite, and Illite recording different scores related to their abundance in the soils. In order to check the validity and accuracy of the obtained results, X ray diffraction analysis was applied on surface soil samples covering the same locations of the end-members that derived from hyperspectral image. Highly correlated and significant results were obtained using the two approaches (spectral signatures and x-ray diffraction).

6359-16, Session 2

Extended spatial logit models of deforestation due to population and relief energy in East Asia

S. Tanaka, Shimane Univ. (Japan); R. Nishii, Kyushu Univ. (Japan)

Tanaka and Nishii (2005) figured out that deforestation can be elucidated quantitatively by nonlinear logit regression models in four East Asian test fields: forest areal rate F as a target variable, and human population size (N) and relief energy (R: difference of minimum altitude from the maximum in a sampled area) as explanatory variables, whose functional forms were suggested by step functions fitted to one-kilometer square high precision grid-cell data firstly in Japan (n=8697):

log(F/(1-F}) = β_0 + g(N) + h(R) + error,

where g(N) and h(R) are regression functions of explanatory variables N and R, respectively. Likelihood functions with spatial dependency were derived, and several deforestation models were selected for the application to four regions in East Asia by calculating relative appropriateness to data. For the measure of appropriateness, Akaike’s Information Criterion (AIC) was used.

To formulate East-Asian dataset, landcover dataset estimated from NOAA observations available at UNEP, Tsukuba for F, gridded population of the world of CIESIN, US for N, and GTOPO30 of USGS for R, were used. The resolutions were matched by taking their common multiple of 20 minuets square.

Tanaka and Nishii (2005) omitted the data with F = 0.0 and F = 1.0 to employ the logit models. Unfortunately the reduction of the data size for regression led to instability of parameter estimation. As for the test field in Harbin, China, n = 76 for 0.0 < F < 1.0, but n = 504 for 0.0 <= F <= 1.0.

In this study, we therefore compare the models based on all data, especially with F = 1.0, by the following extended logit transformation with two additional positive parameters of κ and λ:

log(F+κ)/(1-F+λ)= β_0 + g(N) + h(R) + error.

Estimated coefficients of the models in all four test fields in East Asia were examined if they should be useful as effective environment indicators. The values tangibly showed regional differences in terms of man-forest relationship.

(Note:xxx above means “xxx” is a variable or a parameter)

Reference: Tanaka and Nishii (2005). Verification of deforestation in East Asia by spatial logit models due to population and relief energy, Proc. of SPIE Vol.5976, 59760W—159760W-10 (BRUGES).

6359-17, Session 2

Estimating timber-volume in a commercial Eucalyptus plantation from Landsat ETM+ imagery: results from two approaches

P. J. Baruah, T. Endo, The Univ. of Tokyo (Japan); K. Toru, Mitsubishi Group (Japan); Y. Yasuoka, The Univ. of Tokyo (Japan)

Spatial estimation of timber volume is important in context of the businesses involved which aim to manage plantations more efficiently for optimum harvests in terms of both quality and quantity. Moreover, spatial estimates of the same can provide an accurate quantification of the above-ground carbon stock that can be traded under ‘Clean Development Mechanism’ projects of Kyoto Protocol.

Here, a case study of two approaches to estimate timber-volume in several multi-age Eucalyptus Globulus plantation plots in Chile are presented and the results from both approaches compared. In the first approach, timber volumes for the plantation plots are estimated using temporal landsat-ETM+ imagery. Geometrically and atmospherically corrected ETM+ reflectances are empirically related to 4 years of allometric data to produce temporal timber-volume maps. The results show that, mid-IR band followed by the green band of ETM+ are the strongest estimator of timber volume for our study area. Out of more than ten vegetation indices often used for estimating timber volume, NDVIc is found to be most effective as it eliminates the effect of canopy greenness and takes into account the background reflectances. In the second approach, which is an indirect way to spatially estimate timber volume but has prognostic capability, integrates remote sensing with a specie-specific plant growth model. It uses temporal climate data and ETM+ derived vegetation index map to estimate and predict timber volume at the plantation plots. The errors, sensitivities, merits as well as demerits of both the approaches

are discussed based on appropriate analyses and by comparing the results produced by them.

6359-19, Session 2

Hyperspectral data and methods for coastal water mapping

K. G. Nikolakopoulos, Univ. of Athens (Greece); V. Karathanassi, D. Rokos, National Technical Univ. of Athens (Greece)

Motivated by the increasing importance of hyperspectral remote sensing, this study investigates the potential of the current-generation satellite hyperspectral data for coastal water mapping.

Two narrow-band Hyperion images, acquired in summer 2004 within a nine day period, were used. The study area is the Chalkis gulf, Evia, Greece. Underwater springs, inwater streams, urban waste and industrial waste are present in the gulf. Thus, further research regarding the most appropriate methods for coastal water mapping is advisable. In situ measurements with a GPS have located the positions of all sources of water and waste. At these positions groundspectro-radiometer measurements were also implemented.

Two different approaches were used for the reduction of the Hyperion bands. First, on the basis of histogram statistics the uncalibrated bands were selected and removed. Then the Minimum Noise Fraction was used to classify the bands according to their signal to noise ratio. The noisiest bands were removed and thirty-eight bands were selected for further processing.

Second, mathematical and statistical criteria were applied to the in situ radiometer measurements of reflectance and radiance in order to identify the most appropriate parts of the spectrum for the detection of underwater springs and urban waste. This approach has determined nine hyperspectral bands.

The Pixel Purity Index and the n-D Visualiser methods were used for the identification of the spectra endmembers. Both whole (e.g. SAM) and sub pixel methods (e.g. Linear Unmixing) were used for further analysis and classification of the data.

The spatial resolution of the Hyperion hyperspectral data does not allow the detection of underwater springs. Inwater streams and chlorophyll are satisfactorily classified. The SAM classification method seems to work better as the number of endmembers increases. In contrast the Linear Unmixing classification method gives better results as the number of endmembers decreases.

6359-20, Session 2

Ecosystem management using remote sensing and GIS: a case study from India

M. Govindaraju, Bharathidasan Univ. (India)

Ecosystems are very sensitive which behaves an ecological indicator against the pollution problem of any regional environment. A new approach is applied here to study the system in detail and effectively with the help of remote sensing data.Geographic Information System is a tool to apply the spatial data analysis. The study area has been classified indifferent ecosystem based on their Biogeographic characteristics derived from the satellite imagery. This classification is more useful to monitor the ecological changes. Here the ecosystem classes are identified as Agro-ecosystem, Coastal ecosystem, Marine ecosystem, urban ecosystem and Wetland ecosystem. Overall land use / land cover classification map has prepared with the use of mutilated data. Also Field survey, sample collection and analysis has done and obtained the significant results. The study revels that study are has started to loss its ecological characteristics by the impact of various pollutants enter into the each ecosystem. The rate of impact and spatial distribution and management planning strategies are suggested in the final stage of the study. All the factor influencing the regional environment was interpreted in detail in the full length paper.

6359-21, Session 3

Remote sensing of chlorophyll and nitrogen status

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Recommended fertilizer nitrogen (N) application rates and timing for cotton are not updated for the latest varieties in the Khorezm region, Uzbekistan. This may lead to environmental problems or yield losses. The challenge is to adjust the fertilizer N rates and timing to the actual cotton N status of the newer cotton varieties on farmers´ fields. This paper evaluates the performance of vegetation indices (VIs) applied to CHRIS-PROBA imagery for estimating chlorophyll and N status in cotton fields in Khorezm, Uzbekistan. This integrated agronomic and remote sensing research is carried out within the ZEF/UNESCO project on “Economic and Ecological Restructuring of Land and Water Use in Khorezm, Uzbekistan”. The analysis is based on cotton N status, leaf area and reflectance data collected for a calibration field and a farmer-managed validation field. Laboratory analyses of chlorophyll, N and leaf area of leaves from the calibration field with different fertilizer rates of Khorezm-127 variety were carried out for establishing empirical relationships between chlorophyll a+b, N and Minolta SPAD-502 readings. Based on the laboratory analysis and ASD Fieldspec PRO readings resampled to CHRIS data, statistical relationships were established between VIs and chlorophyll content at the canopy level. Following a grid-based sampling of LAI and SPAD readings, the spatial distributions of LAI, chlorophyll a+b and plant N status were obtained for the validation field. Radiometrically and geometrically corrected CHRIS scenes were used to test the relationships between the different VIs and canopy chlorophyll status. The calibration of SPAD-502 chlorophyll meter readings with chlorophyll and N data analyzed in the laboratory was successful. Spatial units of different LAI values and chlorophyll concentrations were demarcated within the validation field. The CHRIS-VIs were evaluated according to their performance to predict chlorophyll and N concentrations. Since this pilot study was successful, research in 2006 will address the N status during the prime growth stages of cotton with coordinated CHRIS image acquisitions and field measurements during May, June and July. For these periods crop N status will be investigated by radiative transfer model inversion for determining appropriate N-fertilizer rates.

6359-23, Session 3

Estimation of canopy structure parameters using multiangular measurements of scattering component abundances

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Leaf area index and leaf angle distribution parameters are commonly estimated by inverting remote optical measurements with canopy models. Air/space-borne measurements often use models for overall canopy reflectance, while ground-based measurements often use multi-angular gap fraction measurements. Factors to be taken into account in such measurements include mixed pixels as well as mixed light scattering components, e.g., double scattering and specular reflection. This study investigates the potential of an alternative approach based on multi-angular measurements of scattering component abundances, e.g., sunlit and shaded vegetation, sunlit and shaded soil, specular reflection, etc.. In earlier work, it was shown that if the spectra of the illuminants and the materials are known it is possible to separate multiple scattering components using linear spectral unmixing. The idea in this method is to couple the abundances of the scattering components to canopy structure parameters. The expected component abundances are predicted using stochastic simulation in a Poisson canopy model with an ellipsoidal leaf angle distribution which is specified by a single shape parameter. The model predictions are matched against the observed component abundances, and a numerical method is used to search for the leaf area index and mean leaf angle that give the best match. An iterative approach based on gap fraction inversion is investigated, where the estimated scattering component abundances are converted to gap fraction using predictions from the current canopy model parameters, and these gap fractions are then inverted to update the model parameters. The method is evaluated against ground truth data using ray-traced images from a ground-based above-canopy measurement scenario.

6359-24, Session 3

Leaf area index determination of wheat indicating heterogeneous soil conditions

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The early and exact recognition of drought stress of crops is of substantial importance for an efficient crop production and prevention of food shortages.

This study, which is a part of the project "crop drought stress monitoring by remote sensing" (DROSMON), aimed to assess leaf area index (LAI) in wheat (Triticum aestivum) by means of remote sensing methods, based on physical models of canopy reflectance. LAI, which characterizes the actual status of the crops and therefore the potential yield, may be seen as the most important model parameter indicating medium term drought stress.

Inversion of PROSPECT+SAIL model was performed to assess LAI from wheat canopy reflectance, acquired with the ASD FieldSpec-Pro spectrometer on different points on a wheat field near Vienna, Austria. As a result of former river meanders, the soil, a Tschernosem, is interrupted by bands of lighter soil. The higher content of sand in the latter leads to a lower water storage capacity, and therefore to a decrease in wheat growth. The temporal evolution of LAI - measured in different parts of the field - showed lower values in dryer soil conditions.

Due to widespread uncertainties in indirect LAI measurements, we compared 3 different direct and indirect LAI determination methods. The techniques included destructive sampling, measurements with LAI-2000 canopy analyzer (LI-COR) and hemispherical canopy photography. Additionally LAI was modelled with the CERES-Wheat crop model.

Results of measurements and model simulations were compared and will be presented, indicating needs of further improvement of the used techniques.

6359-25, Session 3

Cost-effectiveness of vegetation biophysical parameters retrieval from remote sensing data

F. Vuolo, Univ. degli Studi Napoli Federico II (Italy); L. Dini, Agenzia Spaziale Italiana (Italy); G. D'Urso, Univ. degli Studi Napoli Federico II (Italy)

In the context of vegetation studies Earth Observation (E.O.) data have been extensively used to retrieve biophysical parameters of land surface. In some cases, thanks to the availability of near-real-time data, tools and applications have been developed and implemented in the fields of precision agriculture, water resources monitoring and management.

So far, empirical approaches based on vegetation indices (VIs) have been successfully applied. They may provide a satisfactory level of accuracy in the estimation of important vegetation biophysical parameters (e.g. LAI, fractional ground cover, biomass, etc). Such methods, however, require a reliable reference data-set to calibrate empirical formulas on different vegetation types; furthermore, they are generally based on a few spectral bands, with a consistent under-exploitation of the full spectral range available in new generation sensors. Alternative approaches based on inversion of radiative transfer models of vegetation represent a challenging opportunity for the estimation of vegetation parameters from data with high dimensionality.

This work evaluates the effectiveness, in terms of accuracy and computational complexity, for retrieving the Leaf Area Index, on one hand, by means of empirical relationships, such as the simple CLAIR model proposed by Clevers (1989) and based on the Weighted Differences Vegetation Index (WDVI), and, on the other hand, by means of mathematical inversion of the combined radiative transfer model PROSPECT and SAILH (PSH). Both approaches, i.e. empirical relationship LAI (WDVI) and radiative transfer model inversion, have been tested by using super-spectral and multi-angular data in the solar domain from the Compact High Resolution Imaging Spectrometer on the PROBA experimental satellite.

These data were used for the inversion of PSH models using Marquardt-Levenberg optimization algorithm. Data from the view-angle closest to nadir in the red and near-infrared bands were considered for estimating the LAI by means of the empirical approach.

The inversion process resulted highly demanding in terms of computational time and complexity. Moreover, the accuracy and the stability of the inversion technique was very variable accordingly to the accuracy of atmospheric correction procedures and identification of model parameters.

In particular, the model inversion required a good initial parameter approximation, through the introduction of an a-priori information on parameters themselves.

The level of accuracy of the two approaches, however, was comparable. On the other hand, the simplicity of the empirical approach sacrifices other useful information such as the geometry of the canopy and the chlorophyll content.

A feasibility analysis of the implementation of the two approaches is discussed in view of a definition of an operative routine for the application of E.O. data in irrigation advisory services.

6359-26, Session 3

A cross-combined land use classification system for remote sensing detection of irrigated crops

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In the irrigation planning, the calculation of crops water requirements (CWR) is a key element. The available algorithms and calculation models need of very detailed land use data, considering that CWR can change between different varieties of the same cultivation. Furthermore, due to the rotation/crop shifts, the irrigated land uses are significantly variable from year to year, especially in horticulture areas.

To respond to this need a methodology and a classification system, based on the combined use of airborne hyper-spectral and high resolution scanner (CASI) and LANDSAT TM has been developed and applied on a test site in Sardinia (Italy). The methodology is based on the definition of clusters of crops with similar WR and spectral firm, and the combination of automatic image classification and video-interpretation techniques.

The use of CASI (Compact Airborne Spectrographic Imager) allowed to classify crops with a combined cluster analysis (crops with similar CWR and spectral signature) to derive a classification applicable to commercial medium resolution satellites image processing for agricultural water use monitoring.

The complete procedure is based on the use of CASI data only sporadically, for crop thematic and geometric classification, cluster definition, and validation purposes, and LANDSAT TM images yearly or seasonally for cluster detection.

6359-28, Session 3

Crop yield prediction using integrated multipolarization radar and multitemporal visible/infrared imagery

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The prediction of agricultural crop yields remains a difficult problem. Improving yield prediction at high spatial resolution during the growing season can assist with smart farming by enabling interventions to be taken at the most appropriate times, such as the selective application of fertilizers or pesticides. This paper describes research undertaken on the improvement of within-field yield forecasting for crops such as wheat using a combination of multi-temporal visible/infrared data and multi-polarization radar imagery. In principle, multi-polarization radar should help to discriminate background soil effects from variations in crop state. Experiments have been carried out using dual polarization ASAR imagery from Envisat combined with nine bands of ASTER level 1B imagery from the Terra satellite at 15m resolution during the summer growing season of 2005. The experimental test site covers an agricultural area in the county of Lincolnshire, UK. The satellite imagery has been integrated using an artificial neural network which has been trained as a predictor of the spatial distribution of yield per unit area (tons / hectare). The Trajan neural network simulator package has been used for this purpose. Ground truth information in the form of yield maps from combine harvesters have been used to train the neural networks and to evaluate accuracy. The results demonstrate that the use of dual polarization radar data was able to improve the overall yield prediction at the test site. This paper will review the experimental set up and provide information on the results achieved in terms of overall improvement of yield prediction accuracy. The limitations of the approach will also be considered, especially the effect of cloud cover on reducing the availability of ASTER data and the overall effect on usability of the approach.

6359-29, Session 3

The use of MODIS-simulated spectral bands for monitoring plant water stress as an help for dynamic fire risk assessment

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Forest fire is one of the major environmental issues for large areas of Southern Italy, and more generally of Mediterranean Europe. Biomass burning reduces carbon sticks in terrestrial vegetation. Risk of soil erosion increases in burned areas because of physic-chemical alteration of the soil surface. Mapping fire risk helps allocating available resources to most effective interventions both for fire prevention and afforestation.

Various factors, either static or dynamic, contribute to the definition of fire risk. Among them, the forests susceptibility to fire increases with increasing plant water stress and biomass dryness. A tool is needed to allow a timely detection of such forest conditions to help preventing fire spread. Space- and airborne remote sensing is a very effective tool in this context.

Many authors have demonstrated the usefulness of remote sensing for the assessment of dynamic fire risk. Various multispectral systems have been reported to be useful, such as Landsat TM, SPOT or NOAA AVHRR. We have recently started a research to evaluate fire risks in the rural environment of Southern Italy using the Moderated Resolution Imaging Spectrometer (MODIS), carried on board of EOS Terra and Aqua satellites. The MODIS systems have 20 spectral wavebands in the reflective range (405-2155 nm), eleven of which in the visible (spectral resolution 10-50 nm), six in the near infrared (10-50 nm) and three in the shortwave infrared (24-50 nm).

This paper describes the results of a preliminary experiment to identify the most useful bands or band combinations (spectral indexes) for the detection of biological indicators of plant water stress, such as leaf water potential, leaf moisture content, leaf area index (LAI) and leaf chlorophyll content. To this end, a set of field plant spectra (350-2500 nm) and related biological indexes from a data-base available at CNR-ISAFoM were used. Results highlighted the potential of single and combined simulated MODIS bands in the retrieval of vegetation stress indicators related to fire risk.

6359-30, Session 3

Study of the diurnal cycle of stressed vegetation for the improvement of fluorescence remote sensing

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Chlorophyll fluorescence (CF) emission allows estimating the photosynthetic activity of vegetation directly, a key parameter for the carbon cycle models. However, measuring CF is difficult because it represents a small amount of the radiance measured by the sensor.

The aim of this paper is to analyse the relationship between the solar induced fluorescence emission of vegetation and the photosynthetically active radiation (PAR) in plants under various stress conditions. The solar induced fluorescence emission is measured at leaf level by means of three different methodologies. Firstly, relative fluorescence measurements are provided by the commonly used PAM-2000 fluorimeter, which indicates the effective quantum yield. Secondly, a quantitative measurement of the CF signal is derived from the leaf radiance by using the corrected Fraunhofer Line-Depth (FLD) method. This method allows estimating the solar induced CF emission at high atmospheric absorption bands, where the amount of incoming radiation is of the same order than CF emission. Finally, the actual radiance spectrum of the leaf fluorescence is measured by a field spectroradiometer using a device that filters out the incident light in the CF emission spectral range.

In the experimental section, the diurnal cycle of fluorescence emission is measured for both healthy control plants and plants under stress conditions. These passive measurements of solar induced CF will serve as a study previous to plan remote sensing fluorescence acquisitions. For instance, determining the best time of the day to maximize signal-to-noise ratio while identifying vegetation stress status. In this context, FLD can provide quantitative fluorescence measurements from remote platforms although modulated by the reflected radiance, while the fluorescence emission spectrum provides much more reliable measurement at field level. The latter can be used to validate the remote sensing measurements, and to improve the knowledge about the plant's photosynthetic mechanisms.

The main achievements of this work have been: (1) successful radiometric measurement of the solar induced fluorescence; (2) identification of fluorescence behaviour under stress conditions; and (3) establishing a relationship between full spectral measurements with the signal provided by the FLD method. These results suggest a best practices protocol to identify suitable conditions for CF measurements from satellite platforms.

6359-31, Session 4

Operational tools for irrigation water management based on Earth Observation: the DEMETER project

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Irrigated agriculture is the major consumer of water resources in Europe and large parts of the world. For example, it uses 75% of freshwater resources worldwide and up 90% in semi-arid areas). Increasing the efficiency of water use in agriculture is mandatory in view of the scarcity of water and the increasing competition from other sectors, like sanitation, industry, environment, and recreation. Improving the efficiency of water use is a major challenge which cannot be met by means of modernizing the irrigation systems alone. It equally requires the use of new technologies like Earth Observation, Geographical Information Systems, and Information and Communication Technology. Their combination provides irrigation management with innovative tools to generate and handle information at different spatial scales and to transmit this information via internet or mobile telephones to end-users. It even offers the user personalized information (through special access conditions), which allows the farmer to see the development and status of each single plot in their farm before deciding on the optimum water amount for irrigation in each case. An operational system that integrates these technologies into routine Irrigation Advisory Services (IAS) has been developed in the research and demonstration project DEMETER (Demonstration of Earth observation Technologies for Routine irrigation advisory services) , www.demeter-ec.net. A prototype of this "on line" Space-assisted Irrigation Advisory Service (e-SAIAS) was operating in a test environment in 2004. The operationality of the space segment was demonstrated during the 2005 irrigation season in Albacete, Spain. Further pilot zones were actives in Portugal and Italy. Out of the umbrella of DEMETER project, which ended 30 of November of 2005, a complete operational system integrating ground segment and space segment, e-SAIAS-ITAP, is currently running along 2006 irrigation season operated by the users, Irrigation Advisory Services of Instituto Técnico Agronómico Provincial, IAS-ITAP in Albacete, Spain. The major improvement achieved by the use of EO in the generation of basic IAS information products like crop coefficients is twofold. Firstly, the spatial coverage is enhanced significantly, both extending to larger areas and providing within-field heterogeneity information. Secondly, the spatially resolved EO data can easily be combined with cadastral information in a geographical information system (GIS), which allows for personalization of the irrigation scheduling recommendation provided on real time. Conventional IAS provide average irrigation recommendations per crop type, while the new space-assisted IAS is able to provide specific recommendations for each individual plot, based on the actual state of that plot. The DEMETER concept of near-real-time delivery of EO-based irrigation scheduling information to IAS and farmers has proven to be valid. Extra-fast image delivery and quality controlled operational processing make the EO-based Kc maps available at the same speed and quality as ground-based data (point samples), while significantly extending the spatial coverage and reducing service cost. Complete, high-quality datasets for the entire irrigation seasons of 2003, 2004, and 2005 provide the expert database on local phenology of the major representative crops in each pilot zone needed to backup the system in case of EO missing data.

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DEMETER partners (full version)

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6359-32, Session 4

Monitoring crop coefficient of orange orchards using energy balance and the remote sensed NDVI

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The structure of the vegetation is paramount in regulating the exchange of mass and energy across the biosphere-atmosphere interface. In particular, changes in vegetation density affected the partitioning of incoming solar energy into sensible and latent heat fluxes that can influence both local or global air temperature changes and that may result in persistent drought through reductions in agricultural productivity and in the water resources availability. Therefore, vegetation cover reflectance, vegetation indices (NDVI, WDVI) and the main biophysical features (i.e., leaf area density, crop height, biomass production, photosynthetic activity, etc...) data might contribute to deal the interactions between complex plant structures, soil components and crop water requirements. The study is focused on the resolution of the energy balance equation to derive latent heat flux density (LE) using measures of net radiation (Rn) and soil heat flux density (G) and estimate of sensible heat flux density (H) from high frequency temperature measurements above the canopy coverage using the Surface Renewal (SR) technique. Meanwhile, a simple empirical reflectance-based crop coefficient (Kc) approach, for the estimation of the evapotranspiration fluxes of the monitored crop, was pursued using the high-resolution IKONOS satellite sensor. Satellite estimate of evapotranspiration fluxes, Kc, and albedo were compared with the values of the same variables measured through the Surface Renewal-Energy Balance station located within the experimental area. The chosen case study in an irrigation area (covered by orange orchards) located in Eastern Sicily (Italy) during the irrigation season 2005.

6359-33, Session 4

A real-time crop classification system for evapotranspiration estimates in irrigated areas

C. M. Neale, Utah State Univ. (USA); L. Mateos, M. P. Gonzalez-Dugo, Instituto de Agricultura Sostenible (Spain)

One of the approaches of estimating crop evapotranspiration over large areas using remote sensing is the use of canopy reflectance (vegetation indices) derived from multi-temporal satellite imagery to estimate and update evapotranspiration crop coefficients. When this method is applied after the irrigation season is over, a spectral crop classification using one or more of the images can be conducted to produce a crop type map of the entire area, allowing the application of the appropriate crop coefficients on a field-by-field basis. However, if the application is to be run in real-time during an irrigation season using satellite images as they are obtained, a different classification scheme is required as early season images might not be optimally suited for a traditional spectral classification.

This paper presents a real-time method of classification based on a combination of spectral classification and logic using the prior knowledge of the crop types and growth curves in the region. The method is applied to images acquired every two weeks over the 2004 and 2005 seasons at the Lebrija Irrigation District on the Guadalquivir River in Southern Spain. Classification accuracy is assessed with ground truth information from the irrigation district.

6359-34, Session 4

Integrated remote sensing and hydrological models for water balance in mountain watersheds

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Remote sensing data, and meteorology data along with DEM data have been utilized to evaluate water balance in semi-arid Taihang Mountain watersheds in North China integrated remote sensing and hydrological models. The evapotranspiration (ET) is one of the most important components of the water balance the watershed and the spatial distribution and seasonal variation of ET will directly impact the stream flow volume and the amount of lateral recharges to the aquifers of mountain front plain. This study used a remote sensing model for mapping ET distribution in the watersheds. By employing the computed ET distribution, as inputs to SWAT, a distributed hydrological process model, we simulated the stream flow and water balance of this basin for the past twenty years. With the high precise DEM and the function of hydrology analysis of the model, the study attempted to calculate groundwater lateral recharge in the piedmont by modeling water balance in the moutain watershed. MODFLOW, a grid-based groundwater model, was performed the validation of groundwater lateral recharge based on the fluctuations of groundwater level in mountain front plain.

6359-35, Session 4

Actual evapotranspiration estimation by means of airborne and satellite remote sensing data

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The improving of evapotranspiration estimates in the mediterranean regions is a very important task for water managements purposes, especially in the irrigated areas, where water scarcity and semi-arid climate often cause fragility and severe damages in the agro-ecosystems. Following these needs, during the last the two decades, the scientific community developed detailed mathematical models for simulating the processes of exchange of mass and energy in the Soil-Plant-Atmosphere system (SPA). These models can be applied in large areas and with a spatial distributed approach using measurements retrieved from satellite/airborne remote sensed data which supplies information on the vegetation status and cover and allows to estimate evapotranspiration rates by means of a surface energy balance modelling approach.

A district scale application in combination with multispectral (LandaSat 5/7 TM data) and iperspectral airborne MIVIS data has been carried out to test the potentialities of the well known SEBAL model (Bastiaannssen et al.,1998) to estimate evapotranspiration fluxes from a set of tipical mediterranean crops (wine, olive, citrus). The different spatial and radiometric resolutions of Mivis (3m x 3m) and LandSat (120m x 120m /

60m x 60m for thermal band) images suggested to compare the evapotranspiration estimates in terms of spatial and radiometric resolution in order to test the sensitivity of the model to the parameterization of the land surface fluxes over a sparsely vegetated crops.

6359-36, Session 4

Comparison of remote sensing-based methods for estimating crop evapotranspiration

M. P. Gonzalez-Dugo, Instituto de Agricultura Sostenible (Spain); C. M. U. Neale, Utah State Univ. (USA); L. Mateos, Instituto de Agricultura Sostenible (Spain); W. P. Kustas, U.S. Dept. of Agriculture (USA)

Remote sensing of evapotranspiration has become more common during the last decade. Two of the approaches being used are the reflectance-based crop coefficient method and the energy balance method. In the energy balance approach, surface temperature is used to calculate sensible heat flux and long wave radiation and depending on the complexity of the model, different methods are used to handle the aerodynamic temperature term. More recently, crop coefficients derived from multiespectral vegetation indices (VI) using satellite imagery have been used as a simple and robust approach that simulates the FAO procedure for determining crop evapotranspiration. All these models must be evaluated comparatively to assess their accuracy and practicability under the same conditions. This paper compares the VI-based crop coefficient approach with three approaches based on the energy balance: (i) one layer energy balance model (ii) one-layer energy balance model with sensible heat bounded within the extremes detected in the region considered; and (iii) two-layer energy balance model. The four approaches are compared using a set of comprehensive field and remote sensing measurements of model input data and actual evapotranspiration measured with a dense network of eddy covariance stations.

6359-37, Session 4

A methodology to conduct diagnostic analyses and simulation

Z. Daniele, L'Istituto Agronomico Mediterraneo di Bari (Italy); C. M. U. Neale, Utah State Univ. (USA); N. Lamaddalena, L'Istituto Agronomico Mediterraneo di Bari (Italy)

A study is being conducted on 2 large-scale irrigation schemes located in southern Italy to develop the capability to perform diagnostic analyses and simulation of operation on existing pressurized irrigation delivery networks. The ultimate goal of the study is developing an analytical framework to conduct modernization of low-performing irrigation systems.

The utilized approach involves a combined use of high-resolution remote sensing and of a simplified agro-hydrological model to generate flow hydrographs of the irrigation delivery network. The application of remote sensing is conducted on existing irrigation schemes for mapping the land use, for identifying the specific extent of different cropped areas and to account for the spatial variability of parameters related to crop evapotranspiration over the scheme areas. The agro-hydrological model takes spatially-distributed inputs from the remote sensing application and, by maintaining a soil-water-balance in the cropped areas, allows generating disaggregated information on soil water deficit and thus on timing and volumes of irrigation events. These aspects are relevant for simulating the flow regimes resulting within the pressurized distribution networks over multi-crop irrigated areas, particularly when these systems are operated on-demand. Results from simulation are validated against historical records on irrigation events obtained by downloading data records from multi-user electronically-fed hydrants equipped with the AcquaCARD(r) technology. These comparisons allow investigating any deviation of actual water deliveries to farms from the simulated ones, to account for uncertainties due to farmers' behavior, and for validating the reliability of the proposed methodology for real-case modernization processes.

6359-38, Session 4

Stress detection in orchards with hyperspectral remote sensing data

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A technique is presented for detecting vegetation stress from hyperspectral data. Compared to traditional vegetation stress indexes, the proposed approach uses the complete hyperspectral reflectance spectrum. Experiments are conducted on peach trees. It is shown that stress can be detected reliably on hyperspectral spectra. During an extensive field campaign, foliar reflectance has been measured with a portable field spectroradiometer. A similar data set is obtained for top of canopy (TOC) using a cherry picker. Finally, real airborne hyperspectral data is acquired over the orchard with the AHS sensor (covering visual, near infrared and thermal part of the spectrum). The three level approach (leaf, top of canopoy, top of atmosphere) very well separates the complexity of the problem and shows the potential and limitations of hyperspectral remote sensing on the different levels. The peach orchard is induced with iron chlorosis. Some of the trees received more iron than others, so to obtain a dynamic range of chlorophyll content in the leaves. A regression analysis linked chlorophyll to the reflectance measured at the leaf level and Top of Canopy (TOC). A relationship is obtained between the stress symptoms in the measured spectra and the biochemical parameters via inversion of both a directional homogeneous canopy reflectance model (ACRM) and the PROSPECT leaf model. This is achieved numerically by minimizing the difference between the measured reflectance samples and modeled values using an optimization routine.

6359-39, Session 4

Ensemble Kalman filter for one-dimensional soil moisture assimilation: assimilating passive microwave brightness temperature

C. Huang, Cold and Arid Regions Environmental and Engineering Research Institute (China)

Ensemble Kalman filter is a popular sequential data assimilation algorithm and has been widely applied in atmospheric, oceanographic and hydrological data assimilation. The method is derived from nonlinear filter theory and Monte-Carlo method, which can resolve the nonlinearity and discontinuity existed within model operator and observation operator. In this work, we developed a one-dimensional soil moisture data assimilation scheme based on ensemble Kalman filter (EnKF). We adopted Simple Biosphere Model (SiB2) as model operator and chose AIEM (advanced integral equation method) as observation operator. Our scheme was tested with the TMI (TMMR Microwave Imager) brightness temperature and GAME-Tibet soil moisture observations at the depth of 4cm, 20cm, and 100cm from July 6 to August 9, 1998, at the MS3608 site on the Tibetan plateau. When observations exist, TMI brightness temperature of vertical polarization at 10.7GHz are assimilated into land surface model (SiB2) and the best estimations of soil moisture at the surface layer, the root zone and the deep layer are calculated. The experiments show that the results of assimilation in surface layer and root zone are closer to observations in 4cm and 20cm than those of simulation, respectively. In comparison with results of simulation in deep layer, the assimilation results match well to the mean of observations in 20cm and 100cm. This work proved that EnKF is both practical and effective for assimilating low frequency temperature into land surface models to improve the estimation of soil moisture.

6359-40, Poster Session

Spaceborne high-resolution remote sensing data for the estimation of urban sealed areas

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The objective of the presented study is the estimation of currently sealed urban areas from actually acquired QuickBird data of the city of Tuebingen, Germany. The city administration needed information on sealed areas for the calculation of a sewage water fee based on the built up area on each plot. In Germany, every city which is getting together more than 12 % of their water costs for wastewater treatment, has to disclose the fee individually for each citizen. So each inhabitant has the right for a fair calculation on his own sealed area, excluding public areas like roads or plazas etc. The satellite data is georeferenced and radiometrically enhanced. Determination of the sealed area is first based on an object oriented classification procedure considering also shadowed areas. Later on, the calculation of the urban NDVI in 10 slices focuses only on masked out urban areas, which is then transferred into Leaf Area Index for correlation with ground measurements carried out with HemiView equipment in three selected test sites (industrial area, city centre, housing area). Interpretation and assessment of the three test sites is followed by a classification of the whole city area. Finally all the data is integrated with cadastral GIS data for the calculation of the individual sewage water fees. This is then checked again in the field before sending out invoices.

The methodology applied here is promising compared to airborne estimations.

6359-41, Poster Session

Remote characterization of fuel type use on satellite data

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The characterization of fuel types is very important for computing spatial fire hazard and risk and simulating fire growth and intensity across a landscape. However, due to the complex nature of fuel characteristic a fuel map is considered one of the most difficult thematic layers to build up. The advent of sensors with increased spatial resolution may improve the accuracy and reduce the cost of fuels mapping.

This study aims to ascertain how well remote sensing data can characterize fuel type at different spatial scales in fragmented ecosystems. For this purpose, multisensor and multiscale remote sensing data such as, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and MODIS have been analysed for some test areas of southern Italy that are characterized by mixed vegetation covers and complex topography. Fieldwork fuel types recognitions, performed at the same time as remote sensing data acquisitions, were used as ground-truth dataset to assess the results obtained for the considered test areas.

The method comprised the following three steps: (I) adaptation of Prometheus fuel types for obtaining a standardization system useful for remotely sensed classification of fuel types and properties in the considered Mediterranean ecosystems; (II) model construction for the spectral characterization and mapping of fuel types; (III) accuracy assessment for the performance evaluation based on the comparison of satellite-based results with ground-truth.

Two different approaches have been adopted for fuel type mapping: the well-established classification techniques and spectral mixture analysis.

Results from our investigations showed that remote sensing data can provide valuable information for the characterization and mapping of fuel types and vegetation properties at different temporal and spatial scales from global, regional to landscape level.

6359-42, Poster Session

Application of rangefinder for small forest fire detection

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Experimental and numerical results obtained during the last ten years show that lidar is an effective technique for detection of smoke of small forest fire. Laser rangefinders use the same detection technology as lidars, but are significantly cheaper, and their application in fire surveillance results in more cost-effective and easy-to-commercialize equipment. This work is devoted to detection of forest fires with a small cheap rangefinder based on 905 nm laser diode and having 2 cm telescope and 1200 m solid-target range. Reliable detection of experimental forest fires (20 x 25 m2 fire plot, burning rate of ~3 kg/s) was observed for the range of ~260 m. In parallel with experiments, a theoretical model of mixing of the burning products and ash with air in the wind was developed. It is based on three-dimensional system of Navier-Stokes equation and commercial software PHOENICS. Using the model, the range of smoke detection by the rangefinder can be estimated as 240 m, indicating good agreement between the theoretical and experimental data. On the basis of this theoretical model an estimation of the smoke detection range for a rangefinder based on 1540 nm Er:glass laser and 4 cm telescope with a 20 km detection range for solid targets was made, leading to a detection range for small forest fire of 6500 m. The obtained results demonstrate that rangefinders are promising devices for early forest fire detection.

6359-43, Poster Session

Error analysis of scaling evapotranspiration over heterogeneous land surface

Y. Liu, T. Hiyama, Y. Yamaguchi, Nagoya Univ. (Japan)

Evapotranspiration (ET) is an important component of hydrological cycle and large-scale ET is of great concern in numerous studies of global environmental change. The large-scale ET can be estimated using remotely sensed data and the energy balance based approach, in which the homogeneous land surface is assumed. The difficulty in application of the approach with the homogeneity assumption to the heterogeneous land surface can be released by spatial scaling approach. On the other hand, measurement error always exists even over the homogeneous surfaces, and the error unavoidably propagates into the scaled ET. However, error propagation in scaling received rare attention. To this issue, this paper describes the energy balance based approach and the physics-based scaling functions for expanding the application to heterogeneous surface. Surfaces at a fine-scale are assumed to be homogeneous enough to represent a heterogeneous surface at a coarse-scale. From error analysis, a general form of error propagation in ET is derived and then applied to ET at the two scales. Multi-scale analysis results suggest that error in ET estimate, introduced by measurement errors in the relevant variables at the fine-scale, would decline rather than be enhanced, when the variables are scaled up into the coarse-scale using the scaling functions. Therefore, using the coarse-scale data would be appreciated if the proper scaling approach were adopted.

6359-44, Poster Session

Comparison of different approaches to retrieve plant water content of summer barley canopies from spectroradiometric measurements

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A balanced water supply is essential for plant life and profitable yields of agricultural crops. In this context, the plant water content is an important indicator for the detection of possible water deficiencies implying reduced plant productivity. For its assessment, different ecophysiological methods are well known, but they are practicable only for a limited number of samples and cannot be applied in situ, but need analysis in the laboratory. To overcome these limitations, the development of adapted approaches for a rapid analysis seems to be expedient.

For this purpose, this study analyses the relationship between spectral reflectances of summer barley plots and their water contents, the latter gravimetrically measured in the laboratory. In the field, reflectance measurements were performed over a complete phenological cycle using an ASD FieldSpec II spectroradiometer providing continuous spectra from 400 - 2500 nm. For possible upscaling to image data, spectra were additionally resampled to HyMap resolution afterwards.

Reflectance spectra (both measured and resampled) were used to test the potentials of different empirical and physically-based approaches for estimating canopy water content. In detail, spectral indices, partial least squares analysis and radiative transfer modelling, the latter performed by coupling the PROSPECT and SAIL models, were investigated for their prediction power. The results obtained suggest the practical application for precision farming purposes.

6359-45, Poster Session

Improvement of land cover mapping accuracy through NDVI correction

Y. Park, K. Han, J. Yeom, Y. Kim, Pukyoung National Univ. (South Korea)

Land surface parameters play an important role in the climate change near ground. So it has been required to identify surface climate variation. Many kinds of vegetation indexes have been formulated to study climate change, ecosystem, agriculture meteorology and ecoclimatology, etc. The Normalized Difference Vegetation Index (NDVI) is one of the most commonly used vegetation index especially for land cover classification. SPOT/VEGETATATION provides 10-day synthesis product (S10) including NDVI data, which is produce from Maximum Value Composite (MVC) technique merging of data strips from 10 consecutive days. Although MVC algorithm is selected highest NDVI value during 10-day composite period, low peak noises is frequently appeared in the NDVI MVC time-series profile. These are related to various contaminated sources, such as pixel misregistration (by cloud, snow, and land ice), small effects of bidirectional reflectance variation, wet ground condition after precipitations. So we identify these contaminated NDVI pixels through iterated statistical processing. The objective of the study is to improve the land cover accuracy using this corrected NDVI, and to evaluate qualitatively the corrected NDVI ability through a comparative analysis with land cover using non-corrected NDVI. Land cover classification is carried out using unsupervised clustering classification method over Korea. UMD (the University of Maryland's 1km Global Land Cover product), IGBP (International Geosphere Biosphere Programme) and USGS (United States Geological Survey) land cover databases are used to label

undefined clusters. PKNU (Pukyung National University) very high resolution land cover for small part of Korea is collected for validation process.

6359-46, Poster Session

Estimating global specific leaf area from MODIS leaf area index using a terrestrial ecosystem model

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Specific leaf area (SLA) is an important leaf trait that is universally correlated positively to leaf nitrogen, leaf turnover rates, relative growth rate and most importantly, photosynthetic capacity. Though SLA is genetically encoded, it is often spatially variable within a specie and within a single biome due to variable environmental conditions. However, without a global SLA map, global ecosystem models that use SLA generally fix a single value for a particular biome. In this study, we developed a methodology to estimate global SLA from a related key ecosystem variable, leaf area index, estimated from remote sensing using a terrestrial ecosystem model SimCYCLE. SimCYCLE uses climatic inputs, land-cover data and biomass-allocation to estimate leaf biomass in a process-based scheme. Model-estimated foliage mass and MODIS leaf area index are assumed to represent the most-accurate ground condition to estimate SLA for the entire globe at 0.5 degree resolution. Validation of estimated specific leaf area is done with an available and published collection of field-sampled global dataset, and additional field-sampled SLA data collected from other publications. The validation data is also used for rectification of unrealistic values of estimated SLA to produce a global SLA map, which we strongly believe, would be valuable to improve estimates of carbon dynamic across individual biomes upon assimilation with the ecosystem models.

6359-47, Poster Session

Pinewood Lai and Fapar estimation by multispectral and multi-angular satellite data

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Hyper-Spectral and multi-directional images from CHRIS-PROBA satellite are used to extract Leaf Area Index (LAI), soil reflectance and hence fraction of Absorbed Photo-synthetically Active Radiation (fAPAR) over the Mediterranean pine forest of San Rossore, a test site in the coastal plain near Pisa (Central Italy). The originality of the proposed approach resides in direct spectral measurements on pine shoots from which the scattering and absorption coefficients of these basic elements are straightforwardly derived by a simple best fit method. Such measured coefficients are inserted into the two streams approximation of the radiative transfer problem, whose solution for NIR and RED wavelengths allows to retrieve the LAI values. Additionally, the needed soil line equation is directly extracted from the satellite images by means of an algorithmic and reproducible procedure, while the soil reflectance at all available wavelengths can be calculated and suitably used for the fAPAR evaluation. The so obtained vegetation parameters are finally compared to in-situ measurements, acquired quasi-simultaneously to the CHRIS-PROBA overpasses.

6359-49, Poster Session

Paddy rice mapping of the Caspian Sea coast using microwave and optical remotely sensed data

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Remote sensing technology has shown its ability to record data and provide information about different objects and phenomena of the earth surface.

In this research, an attempted has been made to map paddy rice of the southern coastal areas of Caspian Sea using multi-temporal Radarsat and Landsat TM optical images acquired in different seasons of the year 1998. After geometric and radiometric correction of all images, two major tasks of land use map preparation and Change detection studies were implemented. Land use land cover maps of the study area were prepared using optical, microwave and a combination of both (fused data) based on Minimum Distance to Mean, Mahalanobis distance and Maximum Likelihood algorithms. Due to the presence of clouds, some parts of the prepared TM based land use map were not completed. So, land use maps prepared with the use of Radarsat images and fused images based on multiplicative, Brovey and principal component algorithms.

For change detection studies, Correlation coefficients between radar images with and without applying different filters such as Median, Frost, Mean, Local region, Gamma map and Lee-sigma were calculated. The most correlated images were selected and image differencing algorithm used to derive the changed areas. Land use map were clipped based on changed areas within change image. Most of the changed areas belonged to agricultural lands (Paddy fields). Accuracy assessment of derived maps was made based on available and already prepared land use land cover maps.

Results of this study showed that the fused image based on Brovey algorithm has not only eliminated the cloudy areas of TM data but also has more information on landuse land cover of the study area in comparison with Radarsat images alone. So, Brovey fused images used for preparing land use land covers maps of the study area. In case of using Radarsat images alone, ML and minimum distance algorithms showed better performances on agriculture and forest mapping respectively. However, it is reverse in case of using fused images. Mean filter derived images showed better correlation coefficients and used in change detection process. Comparison between landuse changed map and image derived from change detection studies showed a high correlation between agricultural lands (Paddy fields) and changed areas within the change image.

6359-50, Poster Session

Retrieval of soil moisture spatial distribution and drought discrimination based on remote sensing

Y. Li, Shandong Agricultural Univ. (China)

Soil moisture monitoring acts as a important role in water resource reasonable utilization and scientific management and decision-making of drought-fight. Soil moisture has relation with vegetation growth and land surface temperature(LST).This paper adopted LST retrieved from TM/ETM+ by mono-window algorithm and earth reflection retrieved by COST model from the same data and the modified soil adjustment vegetation index(MSAVI) based on ground soil spectrum line,analyzed the linear relation between LST and MSAVI,put forward soil moisture indicators derived in terms of three geometrical expressions based on the two extreme points of the LST-MSAVI scatterplots and drought discrimination function, builded the retrieved model illuminating soil moisture special distribution depending on linear regress analysis. The result showed that the more information was mined by combining LST and MSAVI;and length indicator could present valuable information for drought based on TM/ETM+;and it wasn't remarkable that the retrieved soil moisture tested by T-test,and the retrieved model from LST was better and more valuable than which from MSAVI.

6359-51, Poster Session

Determination of NDVI for image processing

B. S. Tirkappaa, B. S. Tirkappaa, Vishveshvaraya Institute of Technology (India)

Remote sensing is the process of measuring parameters of an object or target or an item without physically coming in contact with it. There are many types of remote sensing. The most widely used one is the one which is used for sensing earth with the help of sensors mounted on artificial satellites. Magnetic resonance imaging, X- ray scanning of a human body form another class of example of remote sensing. In astronomy distant stars, galaxies are sensed through radio telescopes, spectrometers, radiometers etc. This also is nothing but remote sensing. Out of these three my concentration is on the satellite remote sensing. Once we think of sensors placed on satellites the main target of interest is earth's surface. A remote sensing system usually has a source of electromagnetic radiation which beams on the target, which reflects the energy which is sensed by a sensor through a transmission medium. In my case where we want to study the earth the target or object is earth and sun is the source of electromagnetic energy and sensor is mounted on an artificial satellite.

Once we think of earth the main aim of land use investigations is to study vegetation cover, water resources, canopies, cloud top temperatures, storms developments, cloud tops and the list grows like this. In this paper

the aim is to sense the vegetation cover and derive a widely accepted index called "Normalised Difference Vegetation Index" for gray tone image processing. Coming to image processing it is the process of generating 8 bit pixel value for the pixel out of raw data given by the sensor. The green vegetation is sensed in near infrared and visible red regions as red is most and near infrared is absorbed least by the leaf chlorophyll and hence we can tell that the inverse sensitivity of the sensor is more in red band and sensitivity is more in NIR bands. Also the contrast between land and vegetation is more in these bands and hence they are preferred. The scaled NDVI value spreads from 0- 200 and when this value is above 100 it represents vegetation and values below this indicate barren land and oceans. The gray tone value can have 256 values which could be decided by the scaled NDVI. NDVI value can be processed for colour images also. Only colour images convey very little information and hence colour composite images are preferred, where two or more spectral bands' counts from sensor are over lapped. Normally a "three colour composite" is prefered. Derivation of NDVI and algorithms for colour composites formation are the two important tools of image processing. In this paper the light is thrown on the derivation of NDVI.

Key-words: - Difference, Vegetation, Index, composites, NDVI

6359-52, Poster Session

Study on oasis landscape fragmentation in northwest China using remote sensing and GIS: a case study of Jinta Oasis

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The goal of our study was to investigate the landscape fragmentation of oasis in the arid regions, northwest of China. We take Jinta oasis as a study area. Landscape maps of this region were compiled using GIS based on Landsat TM images in 1990 and 2000, landscape indices used for evaluating fragmentation consist of patch density, corridor density, and split index, as well as patch size coefficient of variation. The results showed several interesting patterns. 1) During the period from 1990 to 2000, the landscape fragmentation in Jinta Oasis descended slightly. 2) At the class level, the area of the matrix decreased, and the landscape fragmentation of the matrix (bare soil) increased, reflective of the increasing influence of human activities on matrix. The opposite occurred with the irrigated farmland, which were larger and more aggregated in 2000 than in 1986. 3) Dense corridor system is one of most extrusive characteristics of the arid regions, and is one of the key factors resulting in the landscape fragmentation, especially the fragmentation within the same patch types. The corridor density of irrigated farmland, residential area and forest land were quite large in this area both in 1990 and 2000. Our results also suggest that the pattern of Jinta oasis embodies the characteristics of typical agriculture oasis embedded in Gobi and desert which has been influenced by intense human activities.

6359-53, Poster Session

Correlation analysis of simulated MODIS vegetation indices and rice leaf area index and leaf chlorophyll content

Q. Cheng, X. Wu, Zhejiang Gongshang Univ. (China)

This paper studied the correlations between rice leaf area index(LAI), leaf chlorophyll content(CHL.C), hyperspectral data, normalized difference vegetation index(NDVI), enhanced vegetation index(EVI), and red-edge position(REP). The REP may be defined using the first derivative spectrum. The three bands of the Moderate Resolution Imaging Spectroradimeter (MODIS), band 1(620-670 nm, red), band 2(841-876 nm, NIR) and band 3(459-479 nm, blue) were simulated and MODIS-NDVI and EVI were calculated by averaging the continuous reflectance factor (350-1000 nm) over the spectral range of each band. The results showed that LAI had a close corelation with visible and NIR bands and CHL.C had the highest corelation with red band. A strong non-linear corelation was found between the LAI and REP of two rice varieties. For common rice, REP, EVI and NDV1 were well related with LAI, but for hybrid rice, REP and EV1 were more sensitive than NDVI to LAI. In 2003, REP, EVI and NDV1 were well related with CHL.C.

6359-54, Poster Session

Analysis of difference between NOAA/AVHRR and MODIS vegetation indices

X. Wu, Q. Cheng, Zhejiang Gongshang Univ. (China)

The difference of vegetation indices of NOAA/AVHRR and the Moderate Resolution Imaging Spectroradimeter (MODIS) were reported in this paper. NOAA/AVHRR and MODIS data of September 2st, 2002 covering the whole of Zhejiang Province and Xianju country were acquired respectively and the vegetation indices of NOAA/AVHRR and MODIS were calculated. The results showed that MODIS-VI were less sensitive to plants than NOAA/AVHRR because of saturation problems. The MODIS-EVI showed the same histogram structure with MODIS-NDVI, but was biased toward the lower end of the VI dynamic range, and tended to maintain distribution of VI values over such high biomass conditions. MODIS-NDVI saturated for high VI values while the MODIS-EVI demonstrated improved sensitivity for high biomass. The MODIS-EVI has several advantages over the AVHRR-NDVI. The MODIS atmosphere correction scheme includes the effect of atmospheric gases, aerosol, thin cirrus clouds, water vapor, and ozone, whereas there are only corrections for Rayleigh scattering and ozone absorption in the AVHRR-NDVI products.

6359-55, Poster Session

A three-band algorithm to retrieve land surface temperature from MODIS data for agricultural drought monitoring in China

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Land surface temperature (LST) is an essential parameter in agricultural drought monitoring. This paper intends to present a three-band algorithm utilized to retrieve land surface temperature from EOS/MODIS data extensively employed in agricultural drought monitoring, which involves only one parameter (emissivity). We build three radiance transfer equations for MODIS band 29, 31 and 32, which involve eight unknown parameters (land surface temperature, average atmosphere temperature, three transmittance and three emissivity). We also build the relationship between transmittance and water content of atmosphere and sensor view angle by simulation of MODTRAN in different atmospheric conditions and view angle, so the three transmittance can be replaced with a water content parameter. And then, we propose a method for estimate emissivity using NDVI data, which can be calculated from MODIS band1 and band2. Thus, the number of unknown of the three radiance transfer equations becomes to three (land surface temperature, average atmosphere temperature and water content). Due to complexity, we develop a numerical method for solution of LST from the equations using iterative approach. We also perform sensitivity analysis of our algorithm to evaluate the probable LST estimation error due to the possible error in emissivity. The proposed three-band algorithm does not require atmospheric parameter for LST retrieval, hence is better than the widely used split-window algorithms. That is, we need not water content of atmosphere, which is difficult to evaluate accurately.

6359-56, Poster Session

Forest canopy density mapping and monitoring based on ETM+ imagery data

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The Three Gorge Project (TGP) of China resettles of over 1 million population (mostly farmers) to more rugged and isolated mountain area than their original settlements. And yet at the same time thousands of hectares from the Three Gorge Areas (TGA) are destroyed every year. Forests have a special place in economic development and stability of water and soil. For better management of the forests, the change of forest area and rate of forest density should be investigated. It is possible that there isn¡¯t any change in the area of forest during the time but the Forest Canopy Density (FCD) is changed. Therefore, accurate and rapid monitoring of the forest Canopy Density is a key factor in remote sensing imagery. So the Forest Canopy Density (FCD) Mapping and monitoring model is applied to the study area in this paper. This model calculates Forest Canopy Density using the four indexes of vegetation, bare soil, shadow and thermal. For this, the LANDSAT ETM+ images from different dates are used. The results show that the approach of remote sensing mapping is of good practical value. Overall accuracy 87% and kappa

coefficient 0.79 for ETM+ image was achieved, suggesting that the method is suitable to mountain area.

6359-57, Poster Session

Estimating canopy chlorophyll and nitrogen concentration of rice from EO-1 Hyperion data

J. Chen, Q. Tian, Nanjing Univ. (China)

Accurate remotely sensed estimates of the chemical concentration of vegetation canopies provide a valuable aid to the understanding of ecosystem function and real-time agricultural decision-making. Hyperspectral remotely sensed imagery provides an effective way for biochemical estimates in a large scale promptly. In this study, investigation was designed to determine whether hyperspectral EO-1 Hyperion image could be used to estimate canopy chlorophyll and nitrogen concentration of rice at a spatial resolution of 30m. Continuum-removal analysis enables the isolation of absorption features of interest and minimizes the background influence, thus increasing the coefficients of determination and facilitating the identification of more sensible absorption features. So continuum-removed spectra were extracted after accurate geometric correction and accurate image spectra rebuilt. Red edge analysis and absorption feature analysis as well as stepwise regression analysis were utilized to determine the characteristic bands and parameters for the canopy-level chlorophyll and nitrogen concentration retrieval. Then vegetation pixels were recognized from the EO-1 Hyperion image through Normalized Difference Vegetation Index (NDVI) values, and the rice pixels were recognized through the difference between Land Surface Water Index (LSWI) and Enhanced Vegetation Index (EVI). At last, the best estimation equations were applied to all the rice pixels of the image so that a chlorophyll concentration distribution map and a nitrogen concentration distribution map of rice were obtained. The values in the chlorophyll and nitrogen concentration distribution maps were quite consistent with those of field measurements. The distribution agreed with the growth status distribution. Therefore to some extent, the estimation equation was validated. So it's possible, feasible and time-saving to

estimate canopy chlorophyll and nitrogen concentration at a large scale by using hyperspectral remotely sensed imagery.

6359-58, Poster Session

Quantitative retrieving forest ecological parameters based on remote sensing in Liping County of China

Q. Tian, Nanjing Univ. (China); J. Chen, Univ. of Toronto (Canada); G. Zheng, X. Xia, J. Chen, Nanjing Univ. (China)

Forest ecosystem is an important component of terrestrial ecosystem and plays an important role in global changes. Aboveground biomass (AGB) of forest ecosystem is an important factor in global carbon cycle studies. The purpose of this study was to retrieve the yearly Net Primary Productivity (NPP) of forest from the 8-days-interval MODIS-LAI images of a year and produce a yearly NPP distribution map. The LAI, DBH (diameter at breast height), tree height, and tree age field were measured in different 80 plots for Chinese fir, Masson pine, bamboo, broadleaf, mix forest in Liping County. Based on the DEM image and Landsat TM images acquired on May 14th, 2000, the geometric correction and terrain correction were taken. In

addition, the "6S"model was used to gain the surface reflectance image. Then the relationship between Leaf Area Index (LAI) and Reduced Simple Ratio (RSR) was built. Combined with the Landcover map, forest stand map, the LAI, aboveground biomass, tree age map were produced respectively. After that, the 8-days- interval LAI images of a year, meteorology data, soil data, forest stand image and Landcover image were inputted into the BEPS model to get the NPP spatial distribution. At last, the yearly NPP spatial distribution map with 30m spatial resolution was produced. The values in those forest ecological parameters distribution maps were quite consistent with those of field measurements. Therefore to some extent, the estimation equations were validated. So it's possible, feasible and time-saving to estimate forest ecological parameters at a large scale by using remote sensing. Quantitative retrieval of forest ecological parameters from remotely sensed imagery at a large scale provides the basic and effective information for the forest sustainable development and management.

6359-59, Poster Session

Water resource management through remote sensing and GIS for Thoothukudi Taluk of Tamil Nadu, India

M. Govindaraju, Bharathidsan Univ. (India)

Water is one of the most precious resources. Water resources depletion is one of the major universal existing problems in the world facing today. It causes mainly by environmental pollution contamination in water resources, poor resource management planning and over exploitation. Over exploitation of ground water is one of the major problems in the developing country like India. Population pressure, urban development and industrilisation are the main reasons. The study area of Thoothukudi taluk occupies Middle Eastern sector of Thoothukudi district in Tamil Nadu, stretching over an area of 327.35 sq.km. It consists of 25 panchayat villages and one town. Thoothukudi taluk is covered by 8 * 40'N to 8 * 51'N latitudes and 77 * 56'E to 78 * 12'E longitudes. The study carried out an analysis of geomorphic characteristics with the support of other parameters like geology, soil, slope, and watershed, water quality status and land use / land cover through satellite data in the platform of Geographic Information System (GIS) by table criterion analysis method. Based on the thematic layers of the terrain condition it is estimated that there are five different levels of water resource within the study area, such as excellent, good, moderate, poor and very poor. The results shows that maximum geographical area falls under the poor and very poor conditions of groundwater taking into consideration both quantity and quality. A detailed discussion has been made in the full length paper.

6359-60, Poster Session

Modification and application of a GIS-based distributed hydrological model on streamflow prediction for a high-altitude cold semi-arid mountainous catchment

W. Zhang, Regional Ctr. for Temperate East Asia (China) and The International Institute for Earth System Science (China); D. Zhang, Q. Huang, Nanjing Univ. (China)

Soil and Water Assessment Tool (AVSWAT2000), a distributed hydrologic model integrated with geographic information system (GIS) to simulate the hydrological processes and runoff generations on a mountainous catchment, was applied to the Heihe River Basin located in Qilian mountain range in northwestern China. Simulations at present were preliminary focused on examining its adoptability in predicting the continuous daily streamflow in a high altitude, cold, semi-arid 10009-km2 catchments with the total control hydrological station of Yingluoxia, and further exploring the possibility to modify the version AVSWAT2000 for better performance of the model on hydrological simulations. In this paper, stream flow generation processes and their calculation principles in AVSWAT2000 were described and discussed with the modification for improvement on simulations in the study catchment. The modification on AVSWAT2000 in current study mainly concentrated on 1) Development of soil grain size transfer generator and pro-processing module of Weather Generator (WGEN); 2) Weather Generator (WGEN) module; 3) Spatial integration approach of meteorological forcing data; 4) Penman-Monteith (PM) evapotranspiration estimation module embedded in AVSWAT2000. The basic data layers driven the AVSWAT2000 and improved version of AVSWAT2000 include Digital Elevation Model (DEM), soil and land use/cover digital maps and distributed forcing meteorological data provided by GIS analyses. DEM utilized in this study was generated from a 1:250000 contour maps with spatial resolution of 120 m. Digital soil and land use/cover maps were made from the 1:1000000 soil reconnaissance maps provided by Chinese Academy of Science. Four meteorological stations within or near the study catchments were selected to derive the distributed input meteorological parameters. Based on the topographic features, soil and land use/cover distribution patterns, AVSWAT2000 and its modified version delineated the catchments into 157 hydrologic response unit (HRU), each of which represents a particular feature of soil and land use/cover combinations within the sub-watershed and a group of soil and land use/cover parameters were assigned to them for charactering its hydrological responses. Simulations on daily streamflow were conducted for the period of 1990-2000. Results from these 11 year's simulation with AVSWAT2000 suggested a Nash-sutcliffe coefficient (R2) about 0.8 with relative error around 0.16 in precipitation rich years, but for those less-rainfall years, the modeling performance is relatively poor. With the improved version of AVSWAT2000, the modeling performance was fairly improved, demonstrated by the fact that the average daily R2 reaches to 0.88, and the relative error between the observed and simulated stream flow was less than 11%.

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6359-61, Poster Session

Rainfall runoff simulations based on improved TOPMODEL to a meso-scale mountainous catchment over Heihe River Basin, nothwestern China

W. Zhang, Regional Ctr. for Temperate East Asia (China) and International Institute for Earth System Science (China); J. Han, Regional Ctr. for Temperate East Asia (China); D. Zhao, Nanjing Univ. (China)

This paper describes a distributed modeling approach based on improved TOPOMODEL applied for simulation of rainfall_runoff to a 10039 km2 Yingluoxia watershed on the middle range of the Qilian Mountains in Heihe River Basin, Northwest China. The simulation processes mainly assembled a modeling system centered on TOPMODEL, but the improvement was made on 1) the input parameter, precipitation, was given in a distributed mode through spatially interpolation from seven rain gauges to account for the spatial variations of precipitation due to strong orographic affection in mountainous watershed by means of PRISM approach in consideration of topography, slopes, facets, distances to the meteorological stations as well as land use/covers; 2) simulation of saturated excess runoff was mainly based upon topography, but slightly modified following Campling et al., (2002) to allow for the fact that in the upland sections of the hillslope the water table is not parallel to the surface topography by introducing a reference topographic index into the local storage deficit calculation, the other components deemed relevant to the hydrologic processes in the basin, however, were simulated not only upon the topography but also the Geographic Information System (GIS) data. Procedures were developed to generate grid model input files of basic meteorological components based on Digital Elevation Model (DEM) and land resource inventory GIS data. Model elements were 15 sub-watersheds delineated upon the channel network generated from DEM and a specified stream order threshold. Model element parameters are linked to GIS information averaged over each sub-watershed. Reference evapotranspiration was estimated following FOA Penman-Monteith formula; a kinematic wave channel routing algorithm was applied on each sub-watershed to generate outlet total streamflow. Totally 7 years of data series available for simulation study were broken in two parts and first part i.e. 1990-93 was used for model parameter calibration and remaining data series i.e. 1994-1999 was used for model validation. Simulation results are encouraging. Model efficiency was more than 0.82 both for model calibration and validation on independent data series. Streamflow simulation are sensitive to uncertainty in the precipitation due to its significant spatial variability, and this uncertainty takes predominate role among all the possible sources such as air temperature and albedo...etc.

6359-62, Poster Session

Distributed hydrological modeling study with the dynamic water yielding mechanism and RS/GIS techniques

D. Zhang, Nanjing Univ. (China); W. Zhang, Regional Ctr. for Temperate East Asia (China)

Water yielding in the hydrologic cycle is a temporally and spatially varied process. However, water yielding mechanics expressed in hydrological simulations seldom accurately characterize such dynamic processes thus weakens the simulation capabilities of present hydrological modeling systems. In this study a new dynamic water yielding scheme integrating infiltration and saturated excesses mechanics by means of RS, GIS and data mining techniques was proposed to accurately determine the temporally and spatially varied mechanics of water yielding processes upon the comparison of real-time computed rainfall and soil water variables over the basic simulation element. A conceptual distributed hydrological model named ESSI was built for the long term water resource management studies on the basis of the proposed dynamic water yielding scheme. This distributed hydrological modeling system has two significant characteristics: 1) excellent weather adoptability to ensure the model be well performed in either wet and dry whatershed simulations; 2) fully distributed simulation capability makes the model produce about 20 grided hydrological process components such as evapotranspiration (potential and actual), canopy storage, and soil moisture contents in different soil depths with different time scales.

Calibration and validation of the modeling system was conducted to two carefully selected typical watersheds in China, one called as Jiangkou watershed (drainage area: 2413 km2) developed in the typical humid climate condition, located in upper stream of Hanjiang River Basin and another the Yingluoxia watershed (drainage area: 100029 km2) situated in cold and arid Heihe Mountainous Basin. Simulation experiments in hourly, daily, monthly and yearly time scales to these two watershed suggested that the modeling system fairly well reproduce the flooding events with enough high resolutions on both experimental watersheds, Daily simulations for both watersheds perform well with the Nash-Sutcliffe coefficients varied between 0.68 and 0.75, monthly and yearly results based on the statistics of daily simulations were above 0.90, which implies that the ESSI could perfectly fulfill the tasks for the long term simulation and prediction of rainfall - runoff processes.

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6360-01, Session 1

The use of measured RF power signals to evaluate feasibility of inverse methods to retrieve refractivity parameters

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The radio wave propagation over sea paths is influenced by the local meteorological condition at the atmospheric layer near the surface, especially during ducts. The duct condition can be determined by measurements of local meteorological parameters, by weather forecast models or by using inverse methods. In order to evaluate the feasibility of using inverse methods to retrieve the refractivity profiles a measurement of RF signals and meteorological parameters were carried out at a test site in the Baltic. During the measurements, signal power from two broadcast antennas, one at Visby and one at Västervik, were received at Muskö, an island south of Stockholm. The measurement were performed during the summer 2005 and the data was used to test the software package for inversion methods, SAGA (Seismo Acoustic inversion using Genetic Algorithms, by Peter Gerstoft UCSD, US). The refractivity profiles retrieved by SAGA were compared with the refractivity profiles calculated from measured parameters, during parts of the experiment, from rocket sounding, radio sounding, local meteorological measurements using bulk model calculations, and also obtained by the Swedish operational weather forecast model Hirlam. The surface based duct height are predicted in relative many situations even though the number of frequencies or antennas height has to be increased to diminish the ambiguous of the refractive index profile.

6360-02, Session 1

Observation of 3 Meddies from in situ and altimetry data in the Azores region

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Within the framework of OPALINA (PDCTE/CTA/49965/2003) project, an oceanographic cruise aboard the R/V “Arquipélago” was accomplished in August 2005 in the vicinity of the Mid-Atlantic ridge (MAR), between the Azores archipelago and the Azores current. Thirty six CTD stations casts were made. Results suggest that the cross-sections surpassed 3 Mediterranean eddies (Meddies), registered as positive salinity/temperature anomalies. One Meddy over the Azores rise and another behind the MAR were substantially shattered. For the most pronounced Meddy, east of the MAR, the salinity anomaly reached 0.4 psu, and the temperature anomaly was up to 2 oC. The Meddies had horizontal dimensions of 100 - 300 km and were positioned between 700 and 1200 m depth. All the Meddies had surface signature, observed in altimetry as anticyclonic vortexes, suggesting extension of their dynamic influence throughout the water column. These results imply that deep water structures, as Meddies, are potentially observed from space. The upper layer anticyclonic signatures of the Meddies were horizontally shifted relative to the Meddy centre at the core depth. Inclination of the vorticity tubes may be a result of the tubes distortion by surface currents (Pedlosky, 1987). Attempt to follow the Meddies back in time from the altimetry data was not successful. Meddy signals in the upper ocean layer can be disguised by surface circulation patterns and presumably are the most pronounced over the regions with steep bottom slopes.

6360-03, Session 1

The polarization properties of reflectance from coastal waters and the ocean-atmosphere system

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Polarization characteristics of the water leaving radiance can provide important information on the bio-optical properties and composition of coastal water, as well provide data needed for polarization discrimination techniques, recently developed by us, for the separation of chlorophyll fluorescence from elastic reflectance spectra. Knowledge of water leaving radiance polarizations, is also important for assessing their contribution to top of atmosphere polarization signals, and can used for the retrieval of the atmospheric aerosol properties from satellite observations. We report the results of simulations using a coupled ocean-atmosphere vector radiative transfer code (NASA GISS) to obtain polarization components of reflectance for various water compositions typical for coastal zones, as functions not only of wavelength, solar and viewing angles, but also as functions of the azimuth angles, and surface roughness. Results show that sensor positions can be optimized outside of the main scattering plane, thereby minimizing undesirable sun glint effects, while at the same time maintaining a high degree of observable water leaving radiance polarization, close to the maximum values observable in the main scattering plane. Simulations are complemented by laboratory and field measurements in eastern Long Island and Chesapeake Bay. Results confirm a general picture of reflectance spectra in coastal waters dominated by scattering from mineral particles modified by passage through, and absorption by algae and CDOM, with the residual water-leaving light retaining the original scattering polarization. These results, supported both by experiments and theoretical radiative transfer simulations, have important implications for the successful separation of chlorophyll fluorescence from elastically scattered components in the same spectral region, and for the separation of atmospheric and oceanic components.

6360-04, Session 1

Imagine spectroscopy for coastal biogeochemistry of estuaries and plumes

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The coastal zone is an extremely dynamic system. Variations in the concentration of its major constituents occur rapidly over space and time. This is in response to changes in bathymetry and tidal forces coupled with the influences of fronts, upwelling zones and river inflow. Today’s researches on the functionning of estuarine and coastal ecosystems, as well as attempts to quantify some of their biogeochemical fluxes are based on highly time consuming and costly sea campaigns and laboratory analyses.

On September 2002, an airborne campaign using CASI-SASI sensors covered part of the Scheldt estuary (Belgium-Netherlands coastal zone). A 13 sampling stations field survey was realised in order to cover as quickly as possible the wide range of water quality encountered from the mouth of the estuary to the outer limit of the plume. Correlation was searched between classical ground truth measurements and the rich information provided by numerous CASI-SWIR spectral bands carefully chosen. These relations were not sufficient enough to derive synoptic view of the spatial distribution of many biogeochemical parameters in the Scheldt estuary and plume.

The goal of this research is to explore the potential of developed imagine spectroscopy technique as the MF (Matched filtering) and the MTMF (Mixture Tuned Matched Filtering) in retrieving some of the biogeochemical parameters of interest in estuaries and plumes. The research will show that using those processing techniques, the derivation and the spatial distribution of phytoplankton pigments and species concentration, particulate organic matter, coloured dissolved organic matter and mineral suspended matter were better performed in comparison to the traditional statistical techniques in the Scheldt Estuary.

6360-05, Session 1

Time-variable gravity as a new remote sensing tool for global hydrospheric mass transports

B. F. Chao, National Central Univ. (Taiwan)

Temporal variations of the Earth’s gravity field (or “time-variable gravity” TVG) have been observed by studying the perturbations of orbiting satellites using Satellite Laser Ranging for over twenty years. More recently

the Gravity Recovery And Climate Experiment (GRACE) space mission, dual-satellites equipped with satellite-to-satellite tracking and on-board accelerometers, is opening a window on global TVG with much improved resolutions and precision. While the present detectability threshold is still moderate: on the order of cm-level equivalent water thickness on spatial extent of over ~1000 km at monthly sampling rate, improved signal extraction algorithms have been demonstrated promising to increase the spatial and temporal resolutions by several fold. TVG signals the temporal variations of distribution of mass on or in the Earth, a primary source of which is the hydrospheric mass transport. Thus, this represents a new type of remote sensing tool and data source useful for comparison with relevant global observations and models. For example, the large seasonal water mass variation of the Amazon basin has been well detected. Finer variations elsewhere of perhaps even higher interest, either seasonal or non-seasonal and for potentially anywhere on the Earth, are being observed and studied. We will also show an example in obtaining a low-resolution estimate for the global land runoff by combining the P-E (precipitation minus evapotranspiration) from global atmospheric model output and the water mass variation from GRACE TVG data.

6360-06, Session 2

Infrared multiscale sea surface modeling

K. Caillault, S. Fauqueux, P. Simoneau, ONERA (France)

In the field of performance evaluation of optronic systems, models of background signatures must be in adequacy with the new high spatial resolution sensors models. Background radiation modeling must take into account high spatial variability of optical properties as well as larger scale variability. Moreover, multi-resolution approaches are required to meet the requirements in scenes generation with the different observation configurations: from nadir to grazing angles, for ground-based, airborne or shipborne sensors.

In this context, a model of IR sea background signatures has been developed, taking into account surface variability up to 1 m. Only wind-driven waves (from gravity to capillarity) are considered, as they are the main element that originates the sea surface. Since the infrared wavelengths are much smaller than the radius of curvature of the sea surface, geometric optics can be applied. In this study, we are interested in the evaluation of sea optical properties (emissivity and reflectivity).

When the ground footprint of a pixel IFOV is large enough to include the whole statistic properties of the process, a standard stochastic approach is used. It is based on the knowledge of the sea spectrum and the slope density probability. In this case, no sea surface generation is needed. Otherwise, we introduce a new “double-scale” approach. This model consists in separating the surface in two roughness scales: a low frequency scale and a high frequency one. This latter approach combines geometrical generation of the sea surface and stochastic approach. The continuity between the low and middle/high resolution models is guaranted.

Infrared ocean optical properties have been evaluated with various environmental conditions (solar angles, wind, fetch) and observation configurations. In one dimension, results have been compared with those obtained by a geometrical approach based on a high discretization of the surface.

6360-07, Session 2

Integration of wave curvature in calculating reflectivity from one-dimensional rough surfaces by ray tracing technique including multiple reflections

P. Schott, Ecole Supérieure d’Informatique Electronique Automatique (France)

Furthering the work presented in the IGARSS03 paper, the aim of the final paper is to quantify the effect of the sea curvature in the calculation of the sea reflectivity. In other words, the sea surface points are bound by a quadratic function. The numerical and analytical approaches will be compared according to the surface roughness parameters (slope rms, surface height spectrum like Gaussian and ocean) and the incidence angle in order to quantify the importance of the multiple reflection on the sea.

6360-08, Session 2

Sensitivity analysis of irradiance reflectance to the shape factor using an iterative layered approximation to the radiative transfer equation in an aquatic environment

L. H. Huddleston, NASA Kennedy Space Ctr. (USA); C. R. Bostater, Jr., Florida Institute of Technology (USA)

A sensitivity analysis of the irradiance reflectance to the shape factor, or fraction of total light scattered in the backward direction relative to the incident direction of light is presented. An iterative, layered, two-flow equation approximation of the radiative transfer equation (RTE) with a collimated or specular component is used to calculate the sensitivity of the shape factor on irradiance reflectance for a variety of optical conditions in the aquatic environment. Variables used in the calculations include upward and downward mean cosines, shape factors, absorption, and backscattering coefficients.

6360-09, Session 2

A grid enabled a Monte Carlo hyperspectral synthetic image remote sensing model (GRID-MCHSIM) for coastal water quality algorithm research

G. Chiang, Univ. of Cambridge (United Kingdom); C. R. Bostater, Jr., Florida Institute of Technology (USA)

Previous research (Bostater, 2002) indicated that utilizing the power of a Beowulf cluster, within a Monte Carlo (MC) based parallelized hyperspectral remote sensing model, to generate scientifically based synthetic imagery, is quite feasible. However, due to the limited computational power within a single local cluster, one can only generate one to three bands or channels within a reasonable timeframe. However, in order to generate a MC based hyperspectral cube (~250 channels) it could take weeks and months of computational time depending on the size of the local cluster and the number of photons simulated at each pixel or spatial location. In this paper we discuss the capability of using GRID computing where the so called cyberinfrastructure is utilized to integrate distributed computing resources as an integrated computational system. In this paper, the utilization of synthetic image generation middleware is described as a method to integrate or broker the resources which are geographically distributed over the network in order to act as a single virtual computer with huge computational abilities and storage spaces.

The technique demonstrated and generated output presented in this paper allows one to create or build a Mesoscale-GRID infrastructure in order to test the feasibility of the Grid-Enabled Monte Carlo Hyperspectral Synthetic Image Model (GRID-MCHSIM).

6360-10, Session 3

Remote Sensing of Deep Coral Reefs in Puerto Rico and the U.S. Virgin Islands Using the Seabed Autonomous Underwater Vehicle

R. A. Armstrong, University of Puerto Rico at Mayaguez (USA); H. Singh, Woods Hole Oceanographic Institution (USA)

The basic geomorphology, benthic community structure, and biodiversity of deep hermatypic (zooxanthellate) coral communities in the U.S. Caribbean remain largely unknown. This includes ecologically-relevant parameters such as percent coral cover, reef rugosity, incidence of disease, and species richness and diversity. Deeper reefs appear to be healthier than their shallow water counterparts and are known habitats of commercially important fish species. Due to the exponential attenuation of light in the water column, coral reefs and other benthic communities present below 20 m depth are beyond the limit of airborne and satellite optical remote sensing and require the use of in situ platforms such as autonomous underwater vehicles (AUVs). The Seabed AUV, which was designed for high-resolution underwater optical and acoustic imaging, was used to characterize the deeper (30-100 m) coral reefs of Puerto Rico and the US Virgin Islands. We found luxuriant hermatypic coral cover at depths of 40-47 m in the Hind Bank Marine Conservation District (USVI) and at 50 m depth off western Puerto Rico. The digital photo transects obtained by the Seabed AUV provided quantitative data on living coral, sponge, gorgonian, and macroalgal cover as well as coral species richness and diversity. Rugosity, an index of structural complexity, was derived from the pencil-beam acoustic data. The AUV benthic assessments could

provide the required information for selecting unique areas of high coral cover, biodiversity and structural complexity for habitat protection and ecosystem-based management. These quantitative, georeferenced AUV surveys and photomosaics could also provide the baseline data required for future change detection of the deeper coral reef zones.

6360-11, Session 3

Development of a Field Test Environment for the Validation of Coastal Remote Sensing Algorithms: Enrique Reef, Puerto Rico

J. Goodman, M. Velez-Reyes, R. A. Armstrong, University of Puerto Rico at Mayaguez (USA)

Remote sensing is increasingly being used as a tool to quantitatively assess the location, distribution and relative health of coral reefs and other shallow aquatic ecosystems. As the use of this technology continues to grow and the analysis products become more sophisticated, there is an increasing need for comprehensive ground truth data as a means to assess the algorithms being developed. The University of Puerto Rico at Mayagüez (UPRM), one of the core partners in the NSF sponsored Center for Subsurface Sensing and Imaging Systems (CenSSIS), is addressing this need through the development of a fully-characterized field test environment on Enrique Reef in Southwestern Puerto Rico. This reef area contains a mixture of benthic habitats, including areas of seagrass, sand, algae and coral, and a range in water depths, from a shallow reef flat to a steeply sloping forereef. The objective behind the test environment is to collect multiple levels of image, field and laboratory data with which to validate physical models, inversion algorithms, feature extraction tools and classification methods for subsurface aquatic sensing. Data collected from Enrique Reef currently includes airborne, satellite and field-level hyperspectral and multispectral images, in situ spectral signatures, water bio-optical properties and information on habitat composition and benthic cover. We present a summary of the latest results from Enrique Reef, discuss our concept of an open testbed for the remote sensing community and solicit other users to utilize the data and participate in ongoing system development.

6360-12, Session 3

Benthic Habitat Mapping using Hyperspectral Remote Sensing

M. Vélez-Reyes, J. Goodman, University of Puerto Rico at Mayaguez (USA); L. O. Jimenez-Rodriguez, Univerisity of Puerto Rico at Mayaguez (USA); R. A. Armstrong, S. D. Hunt, University of Puerto Rico at Mayaguez (USA)

This paper will give an overview of different algorithms to map benthic habitats using hyperspectral remote sensing. We will discuss procedures that combine partial or full removal of water column effects before classification as well as algorithms that combine water column removal with unmixing for abundance estimation in low spatial resolution pixels. Experimental results using Hyperion and AVIRIS data will be used to demonstrate the different concepts.

6360-13, Session 3

Implementation of a ground truth process for development of a submerged aquatic vegetation (SAV) mapping protocol using hyperspectral imagery

C. R. Hall, Dynamac Corp. (USA); C. R. Bostater, Jr., Florida Institute of Technology (USA)

Protocol development for science based mapping of submerged aquatic vegetation (SAV) requires comprehensive groundtruth data describing the full range of variability observed in the target. The Indian River Lagoon, Florida, extends along 250 km of the east central Florida coast adjacent to the Atlantic Ocean. The lagoon crosses the transition zone between the Caribbean and Carolinian zoogeographic provinces making it one of the most biologically diverse estuaries in North America. For large scale mapping and management we recognize 4 common and 3 uncommon species of seagrasses and 3 broad groups of macroalgae, red, green and brown. Based on technical and cost limitations we established twenty, 10 km long by 1 km wide flight transects for collection of 1.2 m spatial resolution hyperspectral imagery covering the length of the lagoon, with special emphasis near the Sebastian River and adjacent Sebastian Inlet. Twenty six groundtruth transects, 40m long, were established in the lagoon. White 1m2 floating panels were used to mark each end of the transect. Each panel was located in the field using high precision GPS. Transects were positioned to cover all water depths, SAV densities, mixed and monotypic species coverages, water quality conditions and general sediment types. Along each transect we established a 3 m wide by 30 m long 1m2 grid centered on the transect to avoid spectral influences of the white targets. In each grid cell we measured water depth, identified species of seagrasses, estimated vegetation cover percentage, estimated epiphytic density and measured canopy height. This GPS based grid arrangement in conjunction with the white targets in the imagery allowed for the extraction of the hyperspectral signatures directly associated with the individual groundtruth grid cells.

6360-14, Session 4

Analysis of the impact of ASCAT's pulse compression

N. G. Manise, X. Neyt, M. Acheroy, Royal Belgian Military Academy (Belgium)

The primary measurement objective of the Advanced Scatterometer ASCAT, a spaceborne real aperture C band radar, is the determination of wind fields at the ocean surface. Unlike AMI instruments on-board ERS satellites, ASCAT uses the Linear Frequency Modulation (LFM) measurement principle on the basis of long transmit pulses with linear frequency modulation (chirps) allowing the application of low peak transmission power and frequency domain processing.

This paper will focus on the impact of the use of pulse compression in particular on the location accuracy of the samples in presence of external perturbations. An eventual location error has important consequences on the normalization as well as on the node appartenance of the sample, hence on the end products delivering wind speed and direction on the ocean surface.

6360-15, Session 4

Altimeter range determination and applications using a transponder

E. Cristea, Austrian Academy of Sciences (Austria)

Satellite altimetry provides a precise measure of the vertical distance of the satellite borne altimeter to the instantaneous sea surface. The accuracy of this distance depends on the calibration of the altimeter, the quality of the reflecting target and the proper estimate of path delay.

The general design characteristics for absolute altimeter calibration implies a large number of measurements to reduce the random errors, diversity of measurement techniques and independent data analysis, to reduce the susceptibility to systematic errors.

Part of the altimeter calibration can be undertaken by comparison against in situ tide gauge data and GPS buoys, by inter-comparison between two altimeter data sets from concurrent satellites, or at crossing points.

A different, convenient and independent technique is the use of a dedicated transponder, a device that receives the signal from the altimeter, amplifies it and re-sends it back to the satellite. Opposite to the ocean surface, a transponder disposes of a stable and very precise reflection reference (few millimeters), which allows for a very precise determination of the vertical distance between the satellite and the transponder. The accuracy of such a determined range depends on the ability to estimate the path delays caused by the atmosphere, the precision of the orbit and the GPS positioning of the transponder.

The applications deriving from the use of a transponder in the context of satellite altimetry are: altimeter calibration, along-track orbit improvement and height transfer from the mainland to the sea surface.

6360-16, Session 4

On the combined use of sun glint Modis signatures and SAR data to detect oil slicks

M. Adamo, Univ. degli Studi di Bari (Italy); G. De Carolis, V. De Pasquale, G. Pasquariello, Consiglio Nazionale delle Ricerche (Italy)

SAR spaceborne capability to detect marine oil spills through damping of short gravity-capillary waves has been extensively demonstrated during past years. In contrast, it has not yet been found the optimal use of VIS/NIR imaging sensors for detection and monitoring of oil polluted areas. We propose the use of Modis images acquired in sun glint conditions to reveal smoothed regions such as those affected by oil pollution. According

to Cox and Munk model, the physical mechanism that allows detection of oil slicks under sun glint imaging of clear sea surface is based on the modification of the wind-generated wave slopes distribution due the action of mineral oils.

The methodology is demonstrated for a number of case studies occurred in the Mediterranean Sea and North Atlantic from 2001 to 2004. For each case, the oil slicks were detected by ERS SAR imaging and the corresponding Modis images were acquired within a few hours the SAR passage under sun glint conditions.

The implemented procedure compares the water-leaving Cox and Munk sun glint reflectance with the reflectance measured by Modis at the top of the atmosphere (TOA). To accomplish the task, the Modis imaging parameters and an estimate of the wind vector are provided as input. The ECMWF analysis wind fields are considered for the purpose. It was found that the ratio between the TOA reflectance and the C&M reflectance enhances the capability to detect oil slicks. Moreover, an extensive analysis of the atmospheric effects on oil slick detection has been carried out by performing simulations using the 6S code. Preliminary results show that atmosphere contribution to the reflectance has little impact on oil slick detection, so that implementation of a surveillance procedure could be envisaged.

6360-17, Session 4

An ultrawideband airborne radar measurements of thickness of snow over sea ice

S. Gogineni, P. Kanagaratnam, R. Willyard, The Univ. of Kansas (USA); T. Markus, D. J. Cavalieri, NASA Goddard Space Flight Ctr. (USA)

Snow cover over sea ice plays a crucial role in the climate and ecosystem of the polar regions. Snow is a very good thermal insulator and controls to a large extent the heat exchange between the atmosphere and the ocean. Thus accurate knowledge of snow thickness on sea ice is essential for determining the overall heat budget in the polar regions, which impacts the global ocean circulation and climate. We developed an ultrawideband radar that operates from 2 to 8 GHz with a vertical resolution of about 3 cm, which can directly separate the air-snow and snow-ice interface reflections.

We collected data with this radar from a sled on snow-covered Antarctic sea ice during the Austral spring of 2003 and successfully measured snow thicknesses ranging from about 4 cm to 85 cm. We modified and improved the radar performance for operation from an airborne platform. We installed the radar on NASA's P-3 aircraft and collected data over Arctic sea ice during March 2006. Before and after end of each flight we collected data over smooth sea ice to calibrate the radar. Our preliminary results show that we can measure snow thickness over most of the flight lines. In this paper, we will present details of the radar design, calibration, signal processing and sample results from our airborne experiments.

6360-18, Session 5

Application of an integrated Digital Terrain Model to monitoring of shore areas in the Rance estuary (Golf Normand-Breton, west France)

K. Zeineb, Univ. de Marne-la-Vallée (France)

The management of the tidal power station of the Rance estuary (inauguration by General de Gaulle in 1966) may exert modifications of the basin's topobathymetry. This study aims at complete onshore offshore digital terrain model (DTM) based on several different datasets (1) marine echosounder maps (acquired between 1953 and 1960) for the chanel, (2) topographic data of the shore area extracted from classical aerotriangulation of 1953 aerial photographs, and (3) the BDAlti(r) French IGN DTM data base, settled in the 1970's dealing the topography of the surroundings. This numerical topo-bathymetric will give topographic information before the building of the tidal power station. The second part of this paper deals with the monitoring of the shore through time with a set of aerial photographs in order to illustrate the evolution of the onshore-offshore of the Rance estuary after the construction of the tidal power station.

The study of the Rance shore dynamics which is based on the comparison of aerial photographs acquired in 1953, 1982 and 2002 and the shore slope derived from the numerical topobathymetric. This study shows the changes of the onshore-offshore boundary and especially its moving back, revealing the reduction of shore areas to both higher water level and longer time at high tide in the estuary.

6360-19, Session 5

A pixel to pixel hyperspectral synthetic image model inter-comparison study

L. Bassetti, C. R. Bostater, Jr., Florida Institute of Technology (USA)

The purpose of this paper is to present simulation results in order to compare a Hyperspectral Monte Carlo Model (MC) which generates synthetic images with realistic water wave surface to an iterative layered radiative transfer model used to generate hyperspectral synthetic images with realistic water wave surfaces. The MC model developed by Bostater and Gimond (2002) and Bostater and Chiang (2002) is divided into 5

steps: (1) Generation of the photons, (2) tracking of the photon optical path and simultaneously (3) recording of the photon's location within the water column, (4) then a tabulation of the sampling and its conversion to meaningful radiometric quantities and finally (5) a calculation and processing of the event probabilities between successive photons. This model will then be compared to the ILRT which is analytical and uses an iterative method to converge on the solution to a layered, iterative two flow radiative transfer model developed by (Bostater et al., 2002). The purpose of this research and the presentation will be to describe the effects of spectrally derived wave facets and the foam estimation coverage in order to assess the differences between the above modeling approaches, and to develop a better scientific understanding of the influence of water waves on the remote sensing signal from 400 to 750 nm, as well as the coupled influence of water waves and shallow bottom reflectance effects due to benthic aquatic habitat features such as submerged vegetation, corals, and other objects submerged within the water column as well as effects due to waves at the air-sea interface. The spectral wave models used include the wave (Phillips, Jonswap, Pierson-Moskowitz and TMA) that will help to simulate what a sensor sees from a low flying aircraft. In order to evaluate the wave models the Inverse Fast Fourier Transform

(IFFT) is applied and results described.

6360-20, Session 5

Modeling and data analysis of GPS reflections from LEO

K. Bian, S. Mackin, Univ. of Surrey (United Kingdom)

GPS reflectometry studies the forward scattering of GPS reflections for the purposes of determining surface characteristics. When compared with simulations, the processed data can be used to extract useful information such as sea states, soil humidity and polar ice age. Theoretical and experimental works have been mainly carried out on ground and airborne platforms. If this technique can be applied from space, it would provide a high spatial-temporal coverage of Earth observation, increasing the system's capacity for disaster monitoring.

Currently UK-DMC represents the only LEO satellite able to routinely schedule GPS reflection observations from ocean surface. Earlier data processing has proven that the delay-Doppler Maps (DDMs) as extracted from GPS reflections, although weak, have been found to vary with different geometry and sea states.

This paper investigates the model of GPS reflections from the ocean surface. Previous two dimensional data-model fittings will be presented and analysed, furthermore, potential research direction in reversing DDMs back to spatial maps will be proposed. Preliminary work has produced evidence of the feasibility of the inversion methodology. Key algorithms and difficulties will be discussed along with initial simulated results.

6360-21, Session 5

Optimal band selection in hyperspectral remote sensing of aquatic benthic features

C. R. Bostater, Jr., Florida Institute of Technology (USA)

The optimal selection of remote sensing channels or bands from hyperspectral imagery is demonstrtated using a mixed derivative wavelet analyses and is compared to an automated feature extraction methodology. Although the automated approach uses "learning based" user input, it can be applied with little prior scientific undersatanding or knowledge of the phenomena being studied. The optimal band selection approach, demonstrates ease of use as well, but derived images can be improved if prior understanding of the spectral features, rather than the spatial edge characterisitcs of reflectance imagery are utilized. Outputs and images from the above 2 methods suggest the ability to develop routine methods or "protocols" for applications of hyperspectral sensors to mapping of shallow water coastal benthic targets and features.

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6360-22, Session 5

Sensor motion control and mobile platforms for aquatic remote sensing

C. R. Bostater, Jr., Florida Institute of Technology (USA)

Airborne and other mobile platforms for sensing aquatic environments require engineering considerations related to sensor motion and platform motion effects which can influence the image quality as well as temporal and spatial characterisitcs of the image products. In this paper is presented a sytsematic review of related motion control issues and considerations for applications aboard “mobile remote sensing platforms for aquatic remote sensing applications.

6360-23, Poster Session

Remote sensing of the sea surface by millimeterwave SAR

H. Essen, H. Fuchs, A. Pagels, S. Stanko, FGAN-FHR (Germany)

On several occasions the sea surface has been measured with the mmW radar MEMPHIS in SAR geometry. This research was mainly aimed to investigate the ability of SAR for imaging of disturbances of the water surface at mm-wave radar bands. As for classical wavelengths, SAR imaging of the sea surface can be harnessed without a full understanding of the phenomena involved, but an adequate understanding is required for oceanographic purposes or for the utilization of responses of ships, ship traces etc.. While most of the available millimeterwave data have been collected with a resolution of 75 cm, improvements of the MEMPHIS radar now allow a resolution of about 20 cm.

The reflectivity of the sea surface depends on various environmental parameters such as significant wave height, wave direction, wind speed, wind direction, presence of a groundswell, etc.. Beside the environmental properties, the measured reflectivity depends also on the radar system itself, e.g. the radar wavelength, transmit/receive polarization and its resolution. Furthermore the geometry, depression angle, range and the aspect angle between the radar look direction and the wavefronts is of high importance.

The paper describes the measurement set-up, the evaluation methods and discusses the influence of resolution on sea clutter characteristics.

6360-24, Poster Session

Ice of the Arctic: the processes of self-organized dynamics and mechanics

V. N. Smirnov, A. E. Chmel, L. V. Panov, Arctic and Antarctic Research Institute (Russia); T. V. Tulaikova, Institute of Geosphere’s Dynamics (Russia)

There are presented the results of investigation of behavior of the Arctic ice. The horizontal accelerations of ice show the self- dynamics of its motion. Analysis of the horizontal accelerations permit receive the statistical equivalent distribution of energy by interaction in different scales. It was founded that the sequence of asseveration in ice field has the invariance to time. The cyclic asseverations are one of the main reasons for deformations and forming the real structure of ice field. The sputnik photos demonstrate the fractal geometry of ice field. The scale invariance of dynamics and long-scale mechanics of sea ice together with their fractal dimension allow consider the Arctic ice as the fractal dimension-time domain, it means the system with the sefl-organized limitation. The calculated value of the fractal dimensions was D=1.13 for the different regions in Arctic ice. The horizontal motion of ice tends to the self-oscillations in different time and dimensional scales. The accelerations and slowing downs are measured according to the amplitudes of ice motion; these results will be presented as a graphs. The spectrums of such motion are analyzed. These many-componential dynamical system show the preliminary no-stable state for the Arctic ice. There are presented the results of the statistical processing of the data of Arctic ice.

6360-25, Poster Session

Neural networks and fuzzy logic for hyperspectral imaging

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This paper reports on a novel approach to the optical information processing for the hyperspectral remote sensing systems by means of developed unification algorithm of the two mathematical tools: the fuzzy logic and the neural network. New neuro-fuzzy classification algorithm for hyperspectral remote sensed images has been proposed. It is able to replace complicated empirical formulae, which require the knowledge of dependences of many input parameters that rapidly change during of range time and difficult for crisp determination.

6360-26, Poster Session

DOA estimation of ocean currents based on multistage Wiener filter

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High frequency (HF) ground wave radar systems are attractive for sea state remote sensing by virtue of their over-the-horizon capability. By spectrum estimation techniques the useful information about ocean currents can be obtained from the Doppler power spectrum of scattered echoes. This paper presents the DOA estimation of ocean currents. First preprocessing is implemented on the received signals scattered from ocean waves to extract the broadening first-order Doppler spectrum, then for each spectral point (corresponding to different flow velocity of currents) the Multi-Stage Wiener Filter (MSWF) based on Correlations Subtractive Structure (CSS) is presented to estimate the DOA of ocean currents. The signal subspace and noise subspace can be obtained by the recursive algorithm, which does not require the estimation and the eigen-value decomposition of the covariance matrix, and is thus computationally advantageous as well. In addition compared with the Multi-Stage Nested Wiener Filter (MSNWF), there is no need for forming blocking matrices, therefore the computational complexity can be reduced further, which is necessary for the real time system. Finally the measured data obtained by HF ground wave radar are analyzed with this method, by comparison with other super-resolution methods it is shown that this method can detect the ocean currents efficiently and effectively.

6360-27, Poster Session

Satellite-derived chlorophyll-A concentration in the Taiwan Strait

N. Kuo, C. Ho, National Taiwan Ocean Univ. (Taiwan)

A series of the Orbview-2/SeaWiFS (Sea-viewing Wide Field-of-view Sensor) images during the period from 1997 to 2003 is used to understand the spatial and temporal distribution of the chlorophyll-a (Chl-a) concentration in the Taiwan Strait (TS). It is found that the area with higher Chl-a concentration is mainly along the western TS; it extends more offshore in cold seasons. The lowest Chl-a concentration is always inside the deep Peng-Hu Channel, it can spread further northward in summer. From the mode 1 results of the Empirical Orthogonal Function (EOF) analysis, we find the Chl-a concentration in La Niña years (from the period from June 1998 to May 2001) showing greater variation than the other El Niño or normal years. Meanwhile, the greatest Chl-a variation was in the 1999/2000 La Niña year. The Chl-a EOF1 results also indicate the maximum Chl-a always in the late summer and the 1997/1998 El Niño summer was the lowest one, while the minimum Chl-a was mainly in winter, but its interannual variation is not so clear.

6360-28, Poster Session

Operational use of marinal airborne multispectral spectrometer(MAMS) in algal bloom detection inland lake

X. Zhang, Zhejiang Univ. (China)

The Marine Airborne Multispectral Spectrometer(MAMS) installed recently on the marine surveillance aircraft is a new generation of spectrometer developed by Shanghai Institute of Technical Physics, Chinese Academy of Sciences for quantitatively detecting marine environmental indices and monitoring marine emergency events. The MAMS instrument provided high radiometric sensitivity (24 bit) in 11 spectral bands ranging in wavelength from 0.2 μm to 12.5 μm. In this study, by the support of hi-tech research and development program of China, Airborne spectrometer, limnological and optical measurements of Taihu Lake, which is located in Changjiang River Delta, China were carried out simultaneously in a survey organized by the Sencond Institute of Oceanography, SOA on 26, Oct, 2005. Hyperspectral measurement showed that the peak of water leaving radiance near 700 nm transferred to 750-780 nm as the water covered

with increasing density of blue-green algal bloom. The height of reflectance peak varied correspondingly to the Chl-a concentration. The airborne obtained reflectance showed that water bloom has the significant difference with that of non-water bloom water. The research suggested that MAMS fluorescence data is appropriate for blue-green algal bloom detection. Varied combination of band ratio of channel 7 and channel 8 were also used for detection of algal bloom, comparison were made between different methods. Inversion algorithms of water environmental quality parameters such as Chl-a and suspended sediment and CDOM were also studied.

6360-29, Poster Session

Satellite observations of oil spill in the waters adjacent to Taiwan

C. Ho, S. Liu, F. Su, N. Kuo, S. Huang, National Taiwan Ocean Univ. (Taiwan)

Synthetic Aperture Radar (SAR) images from European Remote Sensing (ERS) satellites are used to investigate oil spill from ship navigations in the water adjacent to Taiwan. A total number of 136 images taken from 1993 to 1997 are used in this study. On the 136 images, only 46 images showing the possibility of oil spill which are based on the position and the shape of the discharge, the path of the ship, the sea characteristics of the area, and the weather conditions. The result shows that oil spill occurs most frequently in spring and least in winter. The sea area off eastern Taiwan has a probability which far surpassed the other areas, followed by the western sea area, the northern sea area, and the southern sea area. Regarding the oil spill in the different regions with the distance to the shore, the oil spill in the western sea area, with an average distance of 50 kilometers, is closer than those in the other areas. The statistical analysis demonstrates that the oil spill around Taiwan mostly occurred over 44 kilometers away from shore. Therefore, it is obvious that the probability of oil spill occurring as a ship leaves the harbor is not high. Instead, the majority of oil spill takes place from middle to long distance navigating fishing boats and from oil and cargo freighters navigating international waterways.

6360-31, Poster Session

The method to develop the artificial ice for Arctic

T. V. Tulaikova, Institute of Geosphere's Dynamics (Russia); S. R. Amirova, Moscow Institute of Physics and Technology (Russia)

The work for the creation of artificial ice for Arctic was began with the aim of stop the ice melting to save environment. There are large non stable areas in Arctic seas, where the ice is fast melted last years. The overcooled water contain the small peaces of ice with their meter's sizes, consequently, the small additional affords should allow transform these vibrated ice peaces in the stable large platform of natural ice. The method suggest the introducing of artificial (polymer) rafts, films and bridges. The physical core of proposed method serves for strong decrease of vibrated amplitudes for ice peaces by introduction of large artificial rafts. The influence of different forms, material and size of the artificial element was analyzed, including different boundary conditions, and the real excitation of vibrations by complicated real waves was analyzed. Additional aspects were analyzed, first is the viscosity increases for the overcooled water. Secondly, the coefficient of reflection of the Sunbeams is increased during the reflection from the most of polymers (n»1.6) in comparison with the reflection from water surface (n»1.3). So, this artificial raft will serves as good mirror for the reflection of the more significant part of Sunbeam. The set of experiments were performed in Winter, at period of initial formation of ice in the natural water. Some polymer samples were developed and paced in river, having waves and current of water, in windy and sunny days. The presented experiments show the acceleration of ice formation near artificial polymer films, they prove the positive action of proposed method.

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6361-32, Poster Session

Sensor network parametric routing protocol simulation and test performance

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We have developed and tested a set of multi-path, parametric probabilistic routing protocols against the existing, established set of routing protocols. Measuring both full-fledged QualNet simulation in addition to live mica2 tests, our set of protocols are tested to determine if they provide efficient and reliable communication in sensor networks. Our protocols require no neighborhood maintenance and only make local broadcast decisions based on hop-count, current distance to destination, and source distance to destination. In this sense, our routing protocols are similar to a gossip strategy with the distinction that each packet contains metrics that will modify the broadcast probability. This makes the parametric protocols more computationally attractive than a protocol with regular maintenance and global network knowledge requirements, such as AODV, which can be especially sensitive to misinformation. Demonstrating that parametric routing protocols provide as good or better end-to-end performance than protocols with these requirements will give our protocols a clear robustness advantage without compromising quality of service.

In addition, we have developed a passive SmartMonitoring system that is able to unify multiple sensor monitoring stations to output a real-time global description of every packet being sent and received by sensors in the network. In this way, we can directly compare simulation results (where global packet knowledge is a given) against mica2 test results. We are also able to observe the immediate effects of changes in network topologies without being confined by the space and protocol interfering constraints of saving packet data locally on the mica2's for later retrieval.

6361-01, Session 1

Overview of Japanese Earth observation programs

H. Shimoda, Japan Aerospace Exploration Agency (Japan)

Three programs, i.e. TRMM, ADEOS2 and ASTER, are going on in Japanese Earth Observation programs. TRMM and ASTER are operating well, though TRMM operation after June 2005 is still unclear. ADEOS2 was failed, but AMSR-E on Aqua is operating. On 24th, Jan. 2006, ALOS (Advanced Land Observing Satellite) was launched successfully from Tanegashima Space Center by HIIA launcher. ALOS carries three instruments, i.e., PRISM (Panchromatic Remote Sensing Instrument for Stereo Mapping), AVNIR-2 (Advanced Visible and Near Infrared Radiometer), and PALSAR (Phased Array L band Synthetic Aperture Radar). PRISM is a 3 line panchromatic push broom scanner with 2.5m IFOV. AVNIR-2 is a 4 channel multi spectral scanner with 10m IFOV. PALSAR is a full polarimetric active phased array SAR. PALSAR has many observation modes including full polarimetric mode and scan SAR mode. The spacecraft is operating well as well as all the 3 sensors are operating well. Next generation satellites will be launched in 2008-20011 timeframe. They are GOSAT (Greenhouse Gas Observation Satellite), GCOM-W and GCOM-C (ADEOS-2 follow on), and GPM (Global Precipitation Mission) core satellite. GOSAT will carry 2 instruments, i.e. a green house gas sensor (TANSO-FTS : Thermal and Near Infrared Sensor for Carbon Observation) and a cloud/aerosol imager (TANSO-CAI). TANSO-FTS is a Fourier transform spectrometer (FTS) and covers 0.76 to 15 μm region with 0.1 to 0.2 cm-1 resolution. TNASO-CAI is a 5 channel pushbroom scanner to observe aerosols and clouds. GCOM-W will carry AMSR follow on and possibly a scatterometer. GCOM-C will carry SGLI (GLI follow on). GPM is a joint project with NASA and will carry two instruments. JAXA will develop DPR (Dual frequency Precipitation Radar) which is a follow on of PR on TRMM. Another project is EarthCare. It is a joint project with ESA and JAXA is going to provide CPR (Cloud Profiling Radar). Discussions on future Earth Observation programs have been started including discussions on ALOS F/O.

6361-02, Session 1

PALSAR initial calibration

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The phased array type L-band Synthetic Aperture Radar (PALSAR) onboard ALOS will be launched in December of 2005, to 691.65 km-altitude sun-synchronous 46 day-recurrent cycle orbit. Supported by the enhanced capability of the data storage of High Storage of Solid State Memory (HSSM), larger power allocation by the satellite, and availability of the data relay satellite, the PALSAR can observe the Earth surfaces globally and regionally with higher resolution than its mother, the JERS-1 SAR. These enhanced functions may powerfully assist the Earth science and monitoring.

In this paper, we will introduce the current status of the ALOS/PALSAR, initial calibration results of the single, dual polarization mode, and the SCANSAR data. The calibration will be temporally conducted using the artificial target of the corner reflector, and the natural target of the Amazon rain forest.

6361-03, Session 1

Preliminary results of calibration for ALOS optical sensors and validation of generated PRISM DSM

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The Advanced Land Observing Satellite (ALOS, the nickname is Daichi) has been successfully launched on 24th January, 2006. ALOS has three mission instruments i.e., an L-band Synthetic Aperture Radar called PALSAR and two optical sensors called PRISM and AVNIR-2. PRISM stands for the Panchromatic Remote-sensing Instrument for Stereo Mapping, and consists of three panchromatic radiometers for forward-, nadir-, and backward-looking, will be mainly used to generate Digital Surface Model (DSM) that is related to terrain height. AVNIR-2 stands for the Advanced Visible and Near Infrared Radiometer type 2, which is the successor AVNIR sensor mounted on the Advanced Earth Observing Satellite (ADEOS). One of our tasks is the evaluations of image accuracies and qualities for each ALOS products. We have been established the international Cal/Val and Science Team (CVST) due to perform the calibration and validation activities effectively.

In this paper, we introduce the preliminary results of calibration and validation for PRISM and AVNIR-2 sensors using actual images. We are analyzing the actual images acquired during initial three months after ALOS launch defined as the Initial Check Out (ICO) phase, and three to eight months as the Initial Calibration Phase (ICP). We already established many Cal/Val test sites worldwide based on CVST activity, and made the operation plans of PRISM and AVNIR-2 over these areas during ICO and ICP. The initial radiometric calibration is conducting to evaluate the radiometric performances and the relative radiometric calibration (de-striping) using the images over homogeneous targets i.e., the nighttime observations, oceans, deserts, ice and snow fields, and the Antarctica. The initial geometric calibration, which is especially important for the PRISM, and is performing by the absolute orientation techniques with the images over ground control points (GCPs). The validation of generated DSMs by PRISM triplet images are also evaluated over the test sites where are prepared the reference DSMs/DEMs.

6361-04, Session 1

Status of the GCOM-W and onboard AMSR follow-on instrument

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One of the series of satellite for the Global Change Observation Mission (GCOM) is the GCOM-W that will carry the Advanced Microwave Scanning Radiometer (AMSR) follow-on instrument. Feasibility to install microwave scatterometer like SeaWinds onboard the Midori-II satellite is still being

discussed to enhance capability to observe ocean wind vector. To keep the continuous observation by the current AMSR for the EOS (AMSR-E) on the Aqua satellite, an earliest launch date is desired. Current proposed launch year is 2010 in Japanese fiscal year. The AMSR-E instrument has been successfully operated for about 4-years and expected to continue providing measurements with high-spatial resolution and in C-band channels that are used to estimate all-weather sea surface temperature and land surface soil moisture. The total dataset period will be over 20-years if the AMSR-E observation can last until the GCOM-W launch. Among the GCOM mission objectives, GCOM-W will focus on the long-term observation of variations in water and energy circulation. In addition, further practical uses including numerical weather forecasting, maritime and meteorological monitoring, and ice applications will be promoted.

The AMSR follow-on instrument will be a six-frequency, dual polarized passive microwave radiometer system to observe water-related geophysical parameters. It takes over the basic sensor concept of the AMSR-E instrument with some essential improvements on the calibration system and mitigation of radio-frequency interference (RFI) in C-band channels. Regarding the calibration system, some issues particularly for the warm load target will be investigated and improved based on the AMSR and AMSR-E experiences. Although mitigating the RFI problem is a difficult issue, some preliminary aircraft measurements of anthropogenic radio emissions have performed in Japan and used for assessing the possibilities of sub-band configuration in C-band. Prototyping the several critical components including the above has already started in the last Japanese fiscal year.

6361-05, Session 1

The possibility of SGLI/GCOM-C for global environment change monitoring

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The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that many collective observations gave a aspect of a global warming and other changes in the climate system. It is very important to understand this process accurately, and to construct the model by whom an environmental change is accurately forecast. Future earth observation using satellite data should monitor global climate change, and should contribute to social benefits. Especially, human activities has given the big impacts to earth environment. This is a very complex affair, and nature itself also impacts the clouds, namely the seasonal variations. JAXA (former NASDA) has the plan of the Global Change Observation Mission (GCOM) for monitoring of global environmental change. SGLI (Second Generation GLI) onboard GCOM-C (Climate) satellite, which is one of this mission, is an optical sensor from Near-UV to TIR.

SGLI can provide the various high accuracy products of aerosol, cloud information, various biophysical parameters (Biomass, Land Cover, Albedo, NPP, Water Stressed Vegetation, LST, etc.), coastal information (CDOM, SS, PAR, CHL, SST, etc.), and cryospheric information (Albedo, Snow/Ice Cover, NDII, Sea ice type, Snow Grain Size, NDSI, Snow Surface Temperature, etc.).

This paper shows the introduction of the unique aspects and characteristics of the next generation satellite sensor, SGLI/GCOM-C, and shows the preliminary research for this sensor.

6361-06, Session 2

Status of ESA Earth observation missions

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The Earth Observation Programmes of the European Space Agency includes two main classes of missions:

- Science missions (“Explorers”) which aim at an improvement of the understanding of Earth processes or at the demonstration of emerging techniques for future operational missions. These Explorer missions are selected following a public call for proposals and a stepwise study and down-selection process.

- Application missions, which are of an operational nature. These missions support a wide range of applications, including meteorology (MSG, METOP) and global land, ocean and atmospheric monitoring (the “Sentinels” of the GMES programme).

The paper will outline the status of the Explorer missions under development and the result of the evaluation of Earth Explorer mission proposals. The status of the GMES implementation and the preliminary design of the Sentinels will be described.

6361-07, Session 2

Next generation of optical sensor systems for photogrammetry and remote sensing

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Recent developments on the fields of detectors, focal planes and telescopes on one hand and a significant change of national and international political and commercial constraints on the other hand led to a large number of proposals and projects for spaceborne sensor systems focusing on Earth observation in the last months.

Due to the commercial availability of TDI lines and fast readable CCD-Chips new sensor concepts are feasible for high resolution sensor systems regarding geometry and radiometry und their data products. Systemic approaches are essential for the design of complex sensor systems for dedicated tasks. Starting with system theory optical, mechanical and electrical components are designed and deployed. Single modules and the entire system have to be calibrated using suitable procedures.

The paper gives an overview about current activities at German Aerospace Center on the field of innovative sensor systems for photogrammetry and remote sensing.

6361-08, Session 2

The Geostationary Atmospheric Sounder Instrument: GAS

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Millimeter and Sub-mm-wave imagers/sounders are considered for future meteorological geostationary satellite missions. A novel interferometric atmospheric sounding instrument concept has been developed and a concept demonstrator is under construction. The concept is a response to the requirements of observations for nowcasting and short range forecasting in 2015-2025, as determined by EUMETSAT for post-MSG operational satellites observations.

Prioritized parameters include vertical profiles of temperature and humidity with high temporal and horizontal resolution (15 min and 30 km) under all weather conditions. Frequency bands around 53GHz, 118GHz, 183GHz, 380GHz have the highest user priority and are all supported by the GAS instrument.

The main technical challenges are the very large antenna aperture required for achieving the required spatial resolution from GEO (40 folds increase in the distance to the Earth as compared to the LEO) and the necessity for imaging of two-dimensional scanning due to the absence of a relative spacecraft-Earth movement. The requirements derived from this application include an effective aperture diameter of more than 8 m, which can not be fulfilled by a classical reflector-based instrument.

The instrument relies on an innovative configuration of interferometer elements which enables the use of a sparse array and simplifies calibration. This is covered by a patent application being processed. The concept and results will be presented at the conference.

The front-end of the instrument comprises a large number of dual polarized tightly integrated Sub-mm front-end receivers. Technology advancements for low noise, highly integrated sub-mm MHEMT MMIC will enable realization of the instrument in the 2015 time frame. The central part of the back-end of the instrument includes an advanced high speed CMOS cross correlation processor that sample the visibility space. Visibility data are linked to ground, where measurements are calibrated and transformed to spectral images of the full earth disc and its atmosphere.

6361-09, Session 2

A wide-band nadir-sounding spectroradiometer for the characterisation of the Earth’s outgoing long-wave radiation

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The Earth’s outgoing long-wave radiation (OLR) is greatly affected by the

effect of water content of the atmosphere, both in terms of water vapour and clouds. The water vapour, in particular, can be considered the main greenhouse gas, but is also the most difficult to monitor due to the great vertical and, to some minor extent, horizontal variability.

The most of the contribution of water vapour and clouds to OLR come from the upper tropospheric emission in the far-infrared region, a part of the Earth's atmospheric emission spectrum relatively unexplored and not well modelled. The characterisation of this region is expected to improve our models, and also give us the capability of monitoring the climate signatures of water content in the upper troposphere.

To demonstrate this concept a balloon-borne wide-band Fourier transform spectrometer named REFIR-PAD (Radiation Explorer in the Far InfraRed - Prototype for Applications and Development) was developed. The instrument provides nadir-sounding radiance measurements in the 100-1400 cm-1 range, covering the most of the OLR and including both the far-infrared range and the better known middle-infrared region.

The REFIR-PAD instrument features a fully uncooled design, with pyroelectric detectors, Germanium coated Mylar beam-splitters and a misalignment-compensated two-input two-output ports optical scheme. The control electronics are designed for stand-alone operation, low power and on-board data storage, so that the integration on a balloon platform is straightforward.

In this configuration the instrument was flown as a piggy-back payload on the CNES LPMAA-IASI stratospheric balloon gondola in June 2005 from Teresina, Brasil.

Instrument performance during flight have been assessed from acquired data obtaining radiometric calibration and stability, noise performance and thermal behaviour of the system in an environment similar to space.

The data collected in this mission, supported with a parallel analysis of the state of the art in terms of spectroscopy and radiative transfer model, will provide the feasibility of a future space mission aimed to the operational monitoring of the upper troposphere water vapour and clouds in order to identify possible climate signatures.

6361-10, Session 2

MARSCHALS: airborne simulator of a future space instrument to observe millimeter-wave limb emission from the upper troposphere and lower stratosphere

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MARSCHALS is the airborne simulator of a proposed future satellite instrument to measure millimetre-wave limb emission from O3, H2O, CO and other trace gases in the upper troposphere and lower stratosphere. To achieve comparatively high vertical resolution and pointing stability, MARSCHALS scans the atmospheric limb in 1km vertical steps using a 220mm antenna controlled by a dedicated gyro. A quasi-optical network directs radiation from the antenna or an ambient (~300K) or cold (~90K) calibration target into three front-end receivers and suppresses each unwanted side-band by \>30dB using multi-layer frequency selective surfaces. Each receiver comprises a waveguide mixer pumped subharmonically by a phase-locked LO and a wideband IF preamplifier. The IF outputs are directed to channeliser spectrometers of 200MHz resolution which instantaneously and contiguously cover 12GHz wide (RF) frequency bands centred near 300, 325 and 345 GHz. To identify clouds, images of near-IR sunlight scattered into the limb direction are recorded concurrently by an 850nm wavelength camera. MARSCHALS has been built under ESA contract by a consortium led by Rutherford Appleton Laboratory in the UK, and had its first flights on the Russian Geophysica (M55) aircraft during 2005, culminating in a deployment during the SCOUT-O3 campaign based in Darwin, Australia. This paper will describe the MARSCHALS instrument and an initial assessment of its performance, determined on ground and during flight.

6361-11, Session 3

NASA's Earth observation programs

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The purpose of NASA's Science Mission Directorate's Earth Science Division (ESD) is to develop a scientific understanding of Earth's system and its response to natural or human-induced changes, and to improve prediction of climate, weather, and natural hazards. ESD conducts and sponsors research, collects new observations from space, develops technologies and extends science and technology education to learners of all ages. We work closely with our global partners in government, industry, and the public to enhance economic security, and environmental stewardship, benefiting society in many tangible ways. We conduct and sponsor research to answer fundamental science questions about the changes we see in climate, weather, and natural hazards, and deliver sound science that helps decision-makers make informed decisions. Using the view from space to study the Earth, researchers can better predict critical changes to Earth and its space environment. ESD has a critical role in implementing three major national directives:

- Climate Change Research through the Climate Change Science Program
- Global Earth Observation System of Systems through the Interagency Working Group on Earth Observations (IWGEO)
- Vision for Space Exploration

NASA's ESD currently has a system of spacecraft collecting observations of the Earth system and in the months and years ahead will deploy new satellites and constellations with advanced measurement capabilities. These missions' technical and programmatic details and status will be presented.

6361-12, Session 3

A spaceborne microwave radar system for looking inside clouds

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CloudSat is a NASA ESSP (Earth System Science Pathfinder Mission) that will provide from a space the first global survey of cloud profiles and cloud physical properties, with seasonal and and geographical variations. The data obtained will allow for clouds and cloud processes to be more accurately represented in global atmospheric models leading to improved climate change predictions, and eventually, weather forecasting. To achieve this ambitious goal, JPL (Jet Propulsion Laboratory) in collaboration with CSA (Canadian Space Agency) designed, developed, and tested a W-band/microwave cloud profiling radar system derived from airborne systems that have flown successfully. The CloudSat Project team will soon have an opportunity to witness how well the instrument performs during in-flight operations with launch scheduled for 21 April 2006.

This paper will describe the physics behind selection of the 94 GHz operating frequency, the fundamental design of the instrument including the technology requirements and basic lifetime considerations, experiences during and results of ground testing, and the initial results of in-flight operations.

6361-13, Session 3

CALIPSO on-orbit engineering performance assessment

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The CALIPSO satellite is a joint NASA and CNES (Centre National d'Etudes Spatiales) ESSP (Earth System Science Pathfinder) mission that will provide unique new measurements, from space, of Earth's clouds and atmospheric aerosols. The CALIPSO payload consists of the following three co-aligned, nadir-viewing instruments: the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), the Imaging Infrared Radiometer (IIR), and the Wide-Field Camera (WFC). The CALIOP and WFC were both developed for and with the cooperation of NASA by Ball Aerospace, and the IIR is provided by our French counterparts at CNES. CALIPSO and CloudSat were both successfully launched into space from a Delta II rocket on April 28, 2006. CALIPSO will then undergo a nominally 45-day commissioning phase prior to a nominally 45-day assessment phase from which point the Payload engineering team will have completed hand over of the Payload to science mission operations team for the remainder of the 3-year mission. This paper will briefly describe the CALIPSO Payload before proceeding to describe the on-orbit engineering performance, through assessment phase (nominally 90 days after launch), of the CALIPSO payload with particular focus on the Lidar and the Wide-Field Camera and their signal-to-noise performance.

6361-14, Session 3

Helping to accurately measuring sea surface height: the JPL instrument suite on OSTM (Ocean Surface Topography Mission)

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OSTM (Ocean Surface Topography Mission) will provide continuity of ocean topography measurements that began with TOPEX/Poseidon and is currently being carried out by Jason-1. Measurements made by the three missions will allow scientists to better understand ocean circulation, climate change processes, and sea level rise on a multi-decadal scale. Societal benefits include El Niño and La Niña forecasting, hurricane strength and path predictions, and marine navigational aids. While CNES (Centre National d'Etudes Spatiales) will provide the primary satellite instrument, a nadir-pointed altimeter, and a precision orbit determination system, JPL (Jet Propulsion Laboratory) will provide an instrument suite that will serve to provide the necessary measurement accuracy. The first of these is the AMR (Advanced Microwave Radiometer). The instrument will measure the water vapor content in the atmosphere to determine how it affects the accuracy of the altimeter readings. The second is the GPSP (Global Positioning System Payload). GPSP measurements will be used to enhance the CNES precision orbit determination system and more accurately pin-point the position of the satellite above the ocean surface. Finally, there is the LRA (Laser Retroreflector Array). A passive, supporting instrument that will allow ground-based laser ranging stations to pin-point the position of the satellite. The data obtained will be used in the calibration and validation of the CNES precision orbit determination system and the GPSP.

This paper will describe the fundamental design aspects of the JPL instrument suite, plans for and initial results of ground-based tests, and plans for in-flight calibration and validation.

6361-15, Session 3

Precise monitoring of terrestrial aerosols and total solar irradiance: introducing the NASA Glory Mission

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The NASA Glory mission will support the U.S. Climate Change Science Program (USGCRP) by continuing and improving upon long-term monitoring of key forcings influencing global climate. Specifically, Glory is an Earth-orbiting observation and scientific data evaluation mission designed to achieve three critical objectives. One is to determine the global distribution, microphysical properties, and chemical composition of natural and anthropogenic aerosols and clouds with accuracy and coverage sufficient for a reliable quantification of the aerosol direct and indirect effects on climate. The second is to continue the 27-year total solar irradiance (TSI) measurement record to quantify the effect of solar variability on the Earth's climate. A third is to demonstrate the operational weather benefits of these measurements for eventual adoption by the National Polar-orbiting Environmental Satellite System (NPOESS) to meet three Aerosol and Cloud Climate Data Records (CDRs) incorporated into the NPOESS Integrated Operational Requirements Document (IORD-II) in 2001. These objectives are met by implementing two separate science instruments. The Aerosol Polarimetry Sensor (APS) has the ability to collect multi-angle photopolarimetric measurements of the troposphere along the satellite ground track within the visible, near- and short-wave infrared spectral regions from 400 to 2200 nm. Based on a proven technique demonstrated by the aircraft Research Scanning Polarimeter (RSP), APS is essential for NPOESS because it can provide aerosol measurements to an IORD minimum-required accuracy ten times better than possible with intensity radiometry offered by current sensors such as MODIS and MISR or the Visible Infrared Imager/Radiometer Suite (VIIRS) under development for NPOESS. The Total Irradiance Monitor (TIM) will measure sunlight incident on the Earth's atmosphere by collecting high accuracy and precision measurements of TSI. Glory is expected to be launched in December of 2008 and fly as part of the A-Train constellation of Earth-orbiting spacecraft, which will include the EOS Aqua and Aura, CALIPSO, CloudSat, OCO, and PARASOL satellites. APS data will be contemporaneous and synergistic with data from several other key A-Train instruments. Glory observations will improve retrievals of aerosol climate forcing parameters and global aerosol assessments with other A-Train instruments as well as paving the way for improved operational results from NPOESS. The scientific knowledge provided by the Glory mission will be essential to understanding climate change for sound, scientifically based economic and policy decisions related to environmental changes caused by climate variability as well as to offer significant improvements in operational weather observations and forecasting. It is expected that both Glory instruments will be subsequently flown on NPOESS platforms to continue their benefits to operational weather as well as climate trend assessments well beyond the initial Glory mission demonstration. The Glory TIM is a rebuild of the proven TIM currently flying on the SOlar Radiation and Climate Experiment (SORCE), so will maintain continuity of the 27-year TSI record. Further information can be found at the Glory Mission science website http://glory.giss.nasa.gov.

6361-17, Session 4

Aquarius/SAC-D mission overview

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Aquarius/SAC-D is a cooperative international mission developed between the National Aeronautics and Space Administration (NASA) of United States of America (USA) and the Comisión Nacional de Actividades Espaciales (CONAE) of Argentina.

The overall mission objective is to contribute to the understanding of the total Earth system and the consequences of the natural and man-made changes in the environment of the planet. Major themes are: ocean surface salinity, carbon, water cycle, geo-hazards, and cryosphere. The prime instrument of the mission, Aquarius, provides maps of salt concentration on the ocean surface. The data is needed to study the heat capacity of the ocean's which in turn affects Earth's climate and the water cycle.

Over the last decade, the Argentine space agency, CONAE, has successfully developed three consecutive science application satellites in cooperation with NASA. More than 17 university, corporate, government and international institutions are also involved in the Aquarius/SAC-D mission. NASA uses the term Aquarius for the mission within its ESSP (Earth System Science Pathfinder) program. CONAE uses SAC-D (Scientific Application Satellite-D) in reference to its previous missions.

For this joint mission, Argentina is providing the SAC-D spacecraft, additional science instruments and the Mission Operations Center (MOC), while NASA provides Aquarius, a salinity measuring instrument and the Launch Vehicle (LV). The SAC-D portion of the mission is managed by CONAE whereas NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, manages the Aquarius development for NASA's Science Mission Directorate (SMD) based in Washington, D.C. NASA's Goddard Spaceflight Center (GSFC) in Greenbelt, Maryland, will build the radiometer portion of the Aquarius instrument and will process and generate the Aquarius science data products after launch. The data products will be made available to the science community through the Physical Oceanography Distributed Active Archive Center (PO.DAAC) at JPL. CONAE will also distribute the SAC-D science data products from it's facility in Buenos Aires, Argentina.

The Aquarius science goals are to observe and model the processes that relate salinity variations to climatic changes in the global cycling of water and to understand how these variations influence general ocean circulation. Accurate measurements of SSS (Sea Surface Salinity), along with sea surface temperature, will determine the sea surface density, which controls the formation of water masses and regulates the 3-dimensional ocean circulation. The goals of Aquarius/SAC-D are closely aligned to the goals of NASA's SMD program and to the National Space Program of Argentina.

Aquarius was confirmed by NASA in 2005 as part of the Earth System Science Pathfinder (ESSP) small-satellite program missions. The NASA ESSP class of mission performs a first-of-a-kind exploratory measurement that will help answer fundamental questions about how our planet works and how it may change in the future.

This innovative mission, targeted for launch in 2009, is currently in Implementation phase (detail design, manufacture and test). The Observatory (which is the spacecraft bus and the science instrument) will be launched using a Boeing Delta II rocket for a five-year mission from NASA's Western Test Range (WTR) located at Vandenberg Air Force Base (VAFB) in California, USA.

6361-18, Session 4

Mapping ocean surface topography with a synthetic-aperture interferometry radar

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Despite the revolutionary impact of radar altimetry achieved over the past quarter century, its sampling capability has always been a compromise between the spatial and temporal requirements. As a result, high spatial resolution can only be achieved in the along-track direction, leading to asymmetry in the radar's mapping capability. A new technology has been demonstrated by the Shuttle Radar Topography Mission for mapping the earth's land topography using the technique of radar interferometry. We propose to use the same technique with synthetic aperture radar to achieve spatially uniform high resolution for mapping the ocean surface topography. The intrinsic resolution is in the range of tens of meters. After spatial averaging, we can achieve centimetric precision at 1 km resolution, which is less than the smallest eddy scales in the ocean by an order of magnitude. For the first time, ocean eddies which account for 90 % of the kinetic energy of the ocean can be fully resolved from space. This new measurement will enable the calculation of ocean surface currents and marine gravity anomalies with much improved accuracies. It can also be applied to mapping the elevation of water surface on land as well as the free board of sea ice and elevation of land ice. The measurement principle and anticipated benefits as well as some of the design issues such as the selection of orbit and radar parameters will be discussed.

6361-19, Session 4

GeoSTAR: a microwave sounder for geostationary applications

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The Geostationary Synthetic Thinned Aperture Radiometer, GeoSTAR, is a new concept for a microwave atmospheric sounder intended for geostationary satellites such as the GOES weather satellites operated by NOAA. A small but fully functional prototype has recently been developed at the Jet Propulsion Laboratory to demonstrate the feasibility of using aperture synthesis in lieu of the large solid parabolic dish antenna that is required with the conventional approach. Spatial resolution requirements dictate such a large aperture in GEO that the conventional approach has not been feasible, and it is only now - with the GeoSTAR approach - that a GEO microwave sounder can be contemplated. Others have proposed GEO microwave radiometers that would operate at sub-millimeter wavelengths to circumvent the large-aperture problem, but GeoSTAR is the only viable approach that can provide full sounding capabilities equal to or exceeding those of the AMSU systems now operating on LEO weather satellites and which have had tremendous impact on numerical weather forecasting. GeoSTAR will satisfy a number of important measurement objectives, many of them identified by NOAA as unmet needs in their GOES-R pre-planned product improvements (P3I) lists and others by NASA in their research roadmaps and as discussed in a white paper submitted to the NRC Decadal Survey. The performance of the prototype has been outstanding, and this proof of concept represents a major breakthrough in remote sensing capabilities. The GeoSTAR concept is now at a stage of development where an infusion into space systems can be initiated - either on a NASA sponsored research mission or on a NOAA sponsored operational mission. GeoSTAR is an ideal candidate for a joint "research to operations" mission, and that may be the most likely scenario. Additional GeoSTAR related technology development and other risk reduction activities are under way, and a GeoSTAR mission is feasible in the GOES-R/S time frame, 2012-2014.

6361-20, Session 4

Adaptive targeting of a space-based Doppler wind lidar: data and technology implications

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As more active optical remote sensors are being considered for use in space, the issues of platform accommodation become more challenging. This is particularly true of power demanding lidars such as scanning Doppler Wind Lidars. A Mission Definition Team in the USA is pursuing the design of a dual technology (coherent/direct detection) instrument that would employ scanning the beam in a step-stare fashion and use adaptive targeting to reduce average orbit power demand. Simulation experiments continue to support the concept of adaptive targeting as having both acceptable data and technology implications. The current notional concept is a 10% duty cycle with one 10 minute "on" time per 90 minute orbit. This approach results in 14-16 targets per 24 hours. Target selection becomes a major element in mission success. Ongoing Observing System Simulation Experiments are demonstrating the benefits of intelligent adaptive targeting over a random on/off strategy.

The technology implications of adaptive targeting include the risks (on/off transition failures) and benefits (laser lifetimes) to the laser subsystem; the challenges of power and thermal management; and the benefits of overall lower power demand. The interplay between the technology requirements and several adaptive targeting schemes will be presented with results of on-going design studies.

6361-21, Session 5

Global precipitation measurement development

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Understanding the Earth's climate and how it responds to climate perturbations relies on knowledge of how atmospheric moisture, clouds, latent heating, and the large-scale circulation vary with changing climate conditions. The physical process that links these key climate elements is precipitation. The Global Precipitation Measurement (GPM) mission will be key to answering the following related research questions:

- How are global precipitation, evaporation, and the cycling of water changing?
- How are variations in local weather, precipitation, and water resources related to global climate variation?
- How can weather forecast duration and reliability be improved by new space-based observations, data assimilation and modeling?

GPM is a joint initiative with the Japan Aerospace Exploration Agency (JAXA) and other international partners that integrates previously planned and dedicated missions in a scalable and evolving constellation of multiple spacecraft and data processing and validation ground systems. Its science objectives are:

- to improve ongoing efforts to predict climate by providing near-global measurement of precipitation, its distribution, and physical processes
- to improve the accuracy of weather and precipitation forecasts through more accurate measurement of rain rates and latent heating
- to provide more frequent and complete sampling of the Earth's precipitation.

It is a potential component of the Global Earth Observation System of Systems (GEOSS) as envisioned by the intergovernmental Group on Earth Observations (GEO). GPM will consist of a core spacecraft to measure precipitation structure and to provide a calibration standard for the constellation spacecraft, an international constellation of NASA and contributed spacecraft to provide frequent precipitation measurements on a global basis, calibration/validation sites distributed globally with a broad array of precipitation-measuring instrumentation, and a global precipitation data system to produce and distribute global rain maps and climate research products. GPM is now in formulation phase. The current status and plans for the program will be discussed.

6361-22, Session 5

Development of spaceborne dual frequency precipitation radar for the global precipitation measurement mission

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Global Precipitation Measurement (GPM) is an international mission that provides more accurate and frequent observation data of precipitation over the region wider than TRMM (Tropical Precipitation Measuring Mission). The accurate measurement of precipitation will be achieved by the Dual-frequency Precipitation Radar (DPR) installed on the GPM core satellite. DPR on the GPM core satellite is being developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT).

JAXA/EORC is responsible for the algorithm development for precipitation estimation and the quality of the products. JAXA is in charge of developing GPM/DPR algorithms as the sensor provider. JAXA also have to take part

in producing and delivering 3-hourly global precipitation map in order to make the data useful for various research and application areas, (i.e., the prediction of the floods). To secure the quality of estimates, the mission must place emphasis on validation of satellite data and retrieval algorithms.

One of the important findings in TRMM validation is that simple conventional rain data comparison is not enough. We need some synthetic validation data for radiometrically consistent rain retrievals. To create them, the detailed comprehensive three-dimensional precipitation structure is required. For DPR, the so-called surface reference technique could be more complicated and improved from TRMM PR. The surface backscattering cross sections should also be measured. For the surface observation, dense gauge network is essential. From the comprehensive observations, a simulation of satellite measurements can be performed using forward calculations. Rain profiling algorithms for DPR and GMI can be applied to the simulated measured quantities, such as measured radar reflectivities at two wavelengths and microwave brightness temperatures. Comparing the results, error characterization could be performed.

6361-23, Session 5

Global precipitation measurement (GPM) microwave imager (GMI)

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The Global Precipitation Measurement (GPM)

Microwave Imager (GMI) instrument is a multi-channel, conical-scanning, microwave radiometer serving an essential role in the near-global-coverage and frequent-revisit-time requirements of GPM. As a part of its contribution to GPM, NASA will provide a GMI instrument and a spacecraft for the Core observatory and is considering the acquisition of a second GMI instrument for placement aboard a constellation spacecraft with a payload and orbit to be defined. In March 2005, NASA chose Ball Aerospace & Technology Corporation to provide the GMI instrument(s).

This paper describes the GMI instrument, the technical performance requirements, its role within the combined passive and active microwave measurements on the Core observatory, and the timeline for GMI development and acquisition.

6361-24, Session 5

Global precipitation measurement (GPM): core spacecraft systems engineering challenges

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The Global Precipitation Measurement (GPM) Mission is a collaboration between NASA, JAXA, and other partners, with the goal of providing a measurement of precipitation over the surface of the earth. These measurements will be used to improve current climate models and weather forecasting, and enable improved storm and flood warnings.

Key elements of the mission are its constellation of spacecraft containing microwave imagers, a core spacecraft with Dual Precipitation radars, several ground validation sites, and a global data management information system for collecting, archiving, processing, and disseminating precipitation data to the user community.

Instrumentation for the first NASA-provided spacecraft (core) includes a Dual Precipitation Radar (DPR), provide by JAXA, and a GPM Microwave Imager, being built by Ball Aerospace and Technologies Corporation, in Boulder, CO.

GPM mission project management and systems engineering is provided by NASA/Goddard Space Flight Center. The project is currently in the formulation phase with an expected launch date for the core spacecraft of December 2010.

This paper will discuss core spacecraft design trade studies undertaken to meet NASAs policy for limiting orbital debris, including the development of hardware which will completely demise upon re-entry through the earth's atmosphere. It will also summarize some of the key systems engineering trades that are under study, including optimized orbit constellation and orbit maintenance strategy.

6361-25, Session 6

Four years of Aqua MODIS on-orbit radiometric calibration

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MODIS is currently operated onboard NASA's EOS Terra and Aqua spacecrafts, launched in December 1999 and May 2002, respectively. Together, Terra and Aqua MODIS have generated over 10 years of global observations for the studies of changes in the Earth's land, oceans, and atmosphere. Each sensor produces more than 40 science data products using measurements from its 36 spectral bands with wavelengths spanning from 0.41 to 14.4 micrometers. MODIS on-orbit radiometric calibration is performed using a solar diffuser (SD) and a solar diffuser stability monitor (SDSM) for the reflective solar bands (RSB) and a blackbody (BB) for the thermal emissive bands (TEB). In addition, regularly scheduled lunar observations are used to track RSB radiometric calibration stability. This paper discusses Aqua MODIS radiometric calibration performance using four years of on-orbit calibration data. Results include noise characterization (SNR for the RSB and NEdT for the TEB), short- and long-term stability and trending, optics (scan mirror and solar diffuser) degradation, and changes of response versus scan-angle (RVS). The Aqua MODIS overall radiometric performance is also compared with Terra MODIS.

6361-26, Session 6

Four-years of on-orbit spectral characterization results for Aqua MODIS reflective solar bands

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The Moderate Resolution Imaging Spectroradiometer (MODIS) flight model 1 (FM-1) was launched on-board NASA's EOS Aqua spacecraft on May 04, 2002. MODIS has 20 reflective solar bands (RSB) with wavelengths from 0.41 to 2.2 micrometers and 16 thermal emissive bands (TEB) with wavelengths from 3.7 to 14.4 micrometers. RSB spectral characterization includes measurements of relative spectral response (RSR) or spectral response functions (SRF), center wavelengths and bandwidths (CW and BW). During the sensor's pre-launch calibration and characterization, these parameters were measured by the instrument vendor using a spectral measurement assembly (SpMA). In order to track on-orbit spectral performance, MODIS includes a unique on-board calibrator, the spectro-radiometric calibration assembly (SRCA), which is capable of monitoring the sensor's RSB spectral performance. This presentation describes Aqua MODIS spectral characterization methodologies and operational activities, summarizes the results form its four-year on-orbit spectral measurements, and discusses lessons learned for future sensor design and development. On-orbit changes of the Aqua MODIS RSB center wavelengths and bandwidths have been very small, typically less than 0.5nm for CW and 1nm for BW, which meet the sensor's design requirements.

6361-27, Session 6

Status of Aqua MODIS spatial characterization and performance

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NASA's EOS Aqua spacecraft was launched on May 04, 2002. The Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the six Earth-observing sensors aboard the EOS Aqua spacecraft. MODIS is the highest spatial resolution instrument on the Aqua platform with data products generated in 250m, 500m, and 1000m resolutions (nadir). It has 36 spectral bands, a total of 490 detectors, located on four focal plane assemblies (FPAs) with two of them controlled during operation at 83K by a passive radiative cooler. In addition to radiometric calibration and spectral characterization, MODIS spatial performance was extensively characterized pre-launch, including measurements of band-to-band registration (BBR), FPA to FPA registration (FFR), line spread function (LSF), modulation transfer function (MTF), and instantaneous field-of-view (IFOV). On-orbit the sensor's spatial characterization is monitored by an on-board calibrator, the spectro-radiometric calibration assembly (SRCA). In this presentation, we will briefly describe MODIS SRCA spatial

characterization methodologies and operational activities. We will focus on the sensor's spatial performance using four years of on-orbit observations and, consequently, evaluate the SRCA's performance. On-orbit results of key spatial characterization parameters (BBR, FFR, and MTF) will be examined and compared to pre-launch measurements and design requirements.

6361-28, Session 6

Radiometric calibration of the EO-1 Advanced Land Imager: 5 years on-orbit

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The Advanced Land Imager (ALI) was developed as a prototype sensor for follow on missions to Landsat-7. Its spectral bands include bands similar to the ETM+ instrument on Landsat-7, plus several additional ones. It was launched in November 2000 on the Earth Observing One (EO-1) satellite as a nominal one year technology demonstration mission. As of this writing, the sensor has continued to operate in excess of 5 years. In addition to on-board lamps, which have been significantly more stable than the lamps on Landsat-7, the ALI has a solar diffuser and has imaged the moon monthly since launch. This combined calibration dataset allows understanding of the radiometric stability of the ALI system, its calibrators and some differentiation of the sources of the changes with time. The solar dataset is limited as the mechanism controlling the aperture to the solar diffuser failed approximately 18 months after launch. Results over 4.5 years indicate that: the shortest wavelength band (443 nm) has degraded in response about 1%; the 482 nm and 565 nm bands did not change significantly; the 660 nm, 790 nm and 868 nm bands degraded about 4%; the 1250 nm and 1650 nm bands did not change significantly and the 2215 nm band increased in response about 1%. The continued radiometric performance trending of ALI has been enhanced by the development of the ALI Image Assessment System (ALIAS), a risk reduction effort of the Landsat Data Continuity Mission.

6361-29, Session 6

Evaluation of the Landsat-5 TM radiometric calibration history using desert test sites

B. L. Markham, J. A. Barsi, NASA Goddard Space Flight Ctr. (USA)

The U.S. radiometric calibration procedure for the Landsat-5 Thematic Mapper was updated in May 2003. This update was based on a model of the performance of the instrument developed from its response to the best-behaved internal calibration lamp and on a cross calibration with Landsat-7 ETM+ that occurred in June 1999. Since this update was performed, there have been continued attempts to validate the model. These validations have relied primarily upon data acquired over deserts of the world. These studies have been limited by the amount of data available over any one site for the 22 year life of the mission. Initial attempts over the desert Southwest of the United States were inconclusive, though they were suggestive of additional degradation occurring in the shorter wavelength channels. More recently, significant holdings from European Space Agency of data over North Africa have been made available for analysis. The North Africa test area results to date for one site in Libya are considerably less noisy than the North American datasets. They indicate an approximately linear change of about 14%, 10% and 6% for TM bands 1, 2 and 3 over the first 10 years of operation. This is as opposed to changes indicated in the current model of roughly the same magnitude, but with the change occurring more rapidly so that nearly all the change is completed in 4 years. These results are roughly consistent with independent work going on outside of this effort. Additional sites will be analyzed as data become available.

6361-30, Session 6

Onboard calibration status of ASTER

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ASTER is a high-resolution optical sensor for observing the Earth on the Terra satellite launched in December1999. ASTER consists of three radiometers. VNIR has three bands in the visible and near-infrared region, SWIR has six bands in the shortwave infrared region, and TIR has five bands in the thermal infrared region. The onboard calibration devices of VNIR and SWIR were halogen lamps and photodiode monitors which were used once in thirty-three days. These calibrators were duplicated and used as a set to increase the reliability. The offsets of VNIR and SWIR were checked by observing the dark side of the Earth. In orbit three bands of VNIR showed a rapid decrease in the output signal while all SWIR bands seemed stable. The TIR is unable to see the dark space. The temperature of the onboard blackbody of TIR remains at 270 K in the short-term calibration for the offset calibration, and is varied from 270 K to 340 K in the long term calibration for the offset and gain calibration once in thirty-three days. The long term calibration of the TIR showed a drift after launch which was most remarkable at band 12.

6361-31, Session 7

Application of a comprehensive radiometric validation protocol for the CERES Earth radiation budget climate record sensors

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The CERES Flight Models 1 through 4 instruments were launched aboard NASA's Earth Observing System (EOS) Terra and Aqua Spacecraft into 705 Km sun-synchronous orbits with 10:30 a.m. and 1:30 p.m. equatorial crossing times. These instruments supplement measurements made by the CERES Proto Flight Model (PFM) instrument launched aboard NASA's Tropical Rainfall Measuring Mission (TRMM) into a 350 Km, 38-degree mid-inclined orbit. CERES Climate Data Records consist of geolocated and calibrated instantaneous filtered and unfiltered radiances through temporally and spatially averaged TOA, Surface and Atmospheric fluxes. CERES filtered radiance measurements cover three spectral bands including shortwave (0.3 to 5 microns), total (0.3 to <100 microns) and an atmospheric window channel (8 to 12 microns).

The CERES Earth Radiation Budget measurements represent a new era in radiation climate data, realizing a factor of 2 to 4 improvement in calibration accuracy and stability over the previous ERBE climate records, while striving for the next goal of 0.3%/decade absolute stability. The current improvement is derived from two sources: the incorporation of lessons learned from the ERBE mission in the design of the CERES instruments and the development of a rigorous and comprehensive radiometric validation protocol consisting of individual studies covering different spatial, spectral and temporal time scales on data collected both pre and post launch. Once this ensemble of individual perspectives is collected and organized, a cohesive and highly rigorous picture of the overall end-to-end performance of the CERES instrument's and data processing algorithms may be clearly established. This approach has resulted in unprecedented levels of accuracy for radiation budget instruments and data products with calibration stability of better than 0.2% and calibration traceability from ground to flight of 0.25%.

The current work summarizes both the philosophy and results of the protocol designed to rigorously quantify the quality of the data products as well as the level of agreement between the TRMM, Terra and Aqua climate data records.

6361-32, Session 7

Determination of wavelength-dependent spectral darkening occurring on a broadband Earth observing radiometer: application to clouds and the Earth's radiant energy system (CERES)

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In order to best detect real changes in the Earth's climate system it is estimated that space based instrumentation measuring the Earth Radiation Budget (ERB) must remain calibrated with a stability of 0.3% per decade. This level of stability is beyond the specified accuracy of existing ERB programs such as the Clouds and the Earth's Radiant Energy System (CERES, using three broadband radiometric scanning channels: the shortwave (SW 0.3 - 5um), total (0.3 - \>100um), and window (8 - 12um)). When in low earth orbit, it has been shown that optical response to blue-UV radiance can be reduced significantly due to UV hardened contaminants deposited on the surface of the optics. With typical onboard

calibration lamps emitting very low energy in the blue-UV region, this darkening is not directly measurable using standard internal calibration techniques. This paper describes a study using a model of contaminant deposition and darkening in conjunction standard established in-flight vicarious and internal calibration techniques to derive the spectral shape of the darkening to which a broadband instrument is subjected. The results of the model when applied to the CERES instruments are shown. Given comprehensive validation of the model, these results will allow the CERES spectral responses to be updated accordingly prior to the forthcoming Edition 3 data release in an attempt to reach the optimum stability target that the climate community requires.

6361-33, Session 7

Sources of differences in on-orbit total solar irradiance measurements

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There is a 5 W/m2 difference between current on-orbit Total Solar Irradiance (TSI) measurements. On 18-20 July 2005, a workshop was held in Gaithersburg, Maryland that focused on understanding these differences, through an examination of the appropriate measurement equations. The instruments studied in that workshop included ACRIM III on ACRIMSat, TIM on SORCE, VIRGO on SoHO, and ERBE on ERBS. Presentations for each instrument included descriptions of its design, its measurement equation, and its uncertainty budget. The workshop also included a session on satellite- and ground-based instrument comparisons and a session on laboratory-based comparisons and the application of new laboratory comparison techniques. The workshop has led to investigations of the effects of diffraction and of aperture area measurements on the differences between instruments. In addition, a laboratory-based instrument comparison is in preparation that uses optical power measurements (with lasers that underfill the apertures of the TSI instruments), and irradiance measurements (with lasers that overfill the apertures of the TSI instruments), and a cryogenic electrical substitution radiometer as a standard for comparing the instruments. A summary of the workshop and an overview of the ongoing research efforts are presented here.

6361-34, Session 7

APEX calibration facility: status and first commissioning results

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The paper presents the current status of the operational calibration facility that can be used for radiometric, spectral and geometric on-ground characterisation and calibration of imaging spectrometers. The European Space Agency (ESA) co-funded this establishment at DLR Oberpfaffenhofen within the framework of the hyper-spectral imaging spectrometer Airborne Prism Experiment (APEX). It was designed to fulfil the requirements for calibration of APEX, but can also be used for other imaging spectrometers.

A description of the hardware set-up of the optical bench will be given. Signals from two sides can alternatively be sent to the hyper-spectral sensor under investigation. Frome one side the spatial calibration will be done by using an off-axis collimator and six slits of different width and orientation to measure the line spread function (LSF) in flight direction as well as across flight direction. From the other side the spectral calibration will be performed. A monochromator provides radiation in a range from 380 nm to 13 μm with a bandwidth between 0.1 nm in the visible and 5 nm in the thermal infrared.

For the relative radiometric calibration a large integrating sphere of 1.65 m diameter and exit port size of 55 cm x 40 cm is used. The absolute radiometric calibration will be done using a small integrating sphere with 50 cm diameter that is regularly calibrated according to national standards.

This paper describes the hardware components and their accuracy, and it presents the software concept for automation of the measurements.

6361-35, Session 7

Enhancement of diffusers BSDF accuracy: spectral features effect

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This paper reports the activities performed in the framework of the ESA contract 18432/04/NL/AR: Enhancement of diffusers BSDF Accuracy, which are related to the so-called Spectral features effect.

The ESA study was conducted to investigate properties of various diffusers. Diffusers are widely used in space instruments as part of the on-board absolute calibration. Knowledge of the behaviour of the diffuser is therefore most important.

The Spectral features effect is related to the design parameters of the optical system and the scattering properties of the diffuser. It is a noise like structure superimposed on the BSDF. To observe this effect, spectral and spatial (partially) coherence light is needed. High-resolution spectrometers provide the spectral coherence and a narrow field of view provides the spatial coherence. Modern space spectrometers have high spectral resolution and/or a small field of view (high spatial resolution).

Different diffusers create different speckle patterns leading to different Spectral Features amplitudes. Therefore the choice of diffuser can be very critical with respect to the required absolute radiometric calibration of an instrument. Even if the Spectral Features are small it can influence the error budget of the retrieval algorithms for the level 2 products.

In this presentation diffuser trade-off results are presented and the Spectral Features model applied to the optical configuration of the MERIS instrument is compared to in-flight measurements of MERIS.

6361-36, Session 7

Radiometric calibration concept of the GOCI (Geostationary Ocean Color Imager)

G. Kang, Korea Aerospace Research Institute (South Korea)

Korea Aerospace Research Institute (KARI) has a plan to launch COMS for consistent monitoring of the Korean Peninsula. The GOCI (Geostationary Ocean Color Imager) is one of the main payloads of COMS which will perform monitoring of ocean-colour around the Korean Peninsula from geostationary platform. Ocean color observation from geostationary platform is required to remedy the coverage constraints imposed by polar orbiting platforms. The GOCI will provide the multi-spectral data of 6 visible channels and 2 near-infrared channels (400nm ~ 900nm) with high sensitivity (SNR \>1000). The high radiometric absolute accuracy (4%) is required for the GOCI at the end of life. In this paper the calibration strategy in order to achieve the high calibration accuracy is introduced. The GOCI has two on-board solar calibration devices. The one is the solar diffuser which will be made of the material having strong characteristic to radiation environment. The whole GOCI instrument including the optic and the FPA can be calibrated using solar diffuser since the solar diffuser is located at the front of the GOCI optic module. The diffuser will be the transmission type and used for the every day solar calibration. The other is the solar diffuser monitoring device which will be used to correct the degradation of the solar diffuser.

6361-37, Session 7

On ground Italian volcanic area spectral characterization for the validation of remote sensing data

S. Amici, L. Merucci, Istituto Nazionale di Geofisica e Vulcanologia (Italy); S. Pugnaghi, S. Corradini, Univ. degli Studi di Modena e Reggio Emilia (Italy)

Remote sensing data acquired by satellite or airborne sensor need on ground validation measurements. As concern volcanoes monitoring, important information may be retrieved by observing these targets in the InfraRed and Thermal InfraRed spectral range.

The * FTIR (Fourier Transform Infrared) operating at INGV in Roma, is capable of making sensitive and accurate measurements of radiance and emissivity of surface in the (2-16) * m spectral range with a spectral resolution of 2cm-1.

These kinds of measurements are very important firstly for the validation of remote sensed data and secondly for the improvement of many gas models used in volcanology for the diagnosis of volcano inner state. On

2003 * FTIR measurements have been carried out on selected test sites on Mount Etna. This area was observed also by a Fourier interferometer (MIROR) on board on a Dornier 228 and by the satellite borne ASTER sensor in the same spectral range. The MIROR and ASTER data have been calibrated and compared with ground measurements. The good quality of data suggested to organize periodic measurements on selected test sites of Italian volcanic regions e.g. Solfatara or Stromboli volcano.

6361-38, Session 8

New results for CMOS image sensors developed for space applications

O. Saint-Pe, M. Tulet, R. Davancens, F. Larnaudie, M. Breart de Boisanger, EADS Astrium (France); P. Magnan, F. Corbiere, P. Martin-Gonthier, M. Estribeau, École Nationale Supérieure de l'Aéronautique et de l'Espace (France)

This paper will present new and original performances results obtained for detectors recently developed by EADS Astrium and Supaéro/CIMI for Earth Observation programs. After a short introduction recalling why CMOS Image Sensors (CIS) are of strong interest for optical instruments developed for remote sensing applications, the authors will present the architecture of devices recently developed for Earth observation and for new technological investigations. Results (mainly related to electro-optics parameters) of characterisations of these devices will be presented, with particular emphasizes about dynamics management and radiation hardening.

6361-39, Session 8

Smart FPA's: are they worth the effort?

J. Leijtens, TNO (Netherlands)

CMOS APS technology allows to include signal processing in the sensor array.

Inclusion of functionality however will come at a cost both financially and in the field of limited applicability.

Based on two real world examples (micro digital sunsensor core and lightning flash detector for MTG) it will be demonstrated that large system gains can be obtained by devising smart focal planes.

6361-40, Session 8

Quantum dot infrared photodetector (QDIP) focal plane arrays for space instruments

S. D. Gunapala, Jet Propulsion Lab. (USA)

We have exploited the artificial atomlike properties of epitaxially self-assembled quantum dots for the development of high operating temperature long wavelength infrared (LWIR) focal plane arrays (FPAs). QDIPs are expected to outperform quantum well infrared detectors (QWIPs) and are expected to offer significant advantages over II-VI material based FPAs. QDIPs are fabricated using robust wide bandgap III-V materials which are well suited to the production of highly uniform LWIR arrays. We have used molecular beam epitaxy (MBE) technology to grow multi-layer LWIR quantum dot structures based on the InAs/InGaAs/GaAs material system. JPL is building on its significant QWIP experience and is basically building a Dot-in-the-Well (DWELL) device design by embedding InAs quantum dots in a QWIP structure. This hybrid quantum dot/quantum well device offers additional control in wavelength tuning via control of dot-size and/or quantum well sizes. The most recent devices exhibit peak responsivity out to 8.1 microns. Peak detectivity of the 8.1 μm devices has reached ~ 1 x 1010 Jones at 77 K. Furthermore, we have fabricated the first long-wavelength 640x512 pixels QDIP FPA. This QDIP FPA has produced excellent infrared imagery with noise equivalent temperature difference of 40 mK at 60K operating temperature. In addition, we have managed to increase the quantum efficiency of these devices from 0.1% (according to the data published in literature) to 20% in discrete devices. This is a factor of 200 increase in quantum efficiency. With these excellent results, for the first time QDIP performance has surpassed the QWIP performance. Our goal is to operate these long-wavelength detectors at much higher operating temperature than 77K, which can be passively achieved in space. This will be a huge leap in high performance infrared detectors specifically applicable to space science instruments.

6361-41, Session 8

QWIP from 4μm up to 18μm

E. M. Costard, A. Nedelcu, X. Marcadet, J. A. Robo, P. F. Bois, Thales Research & Technology (France)

Standard GaAs/AlGaAs Quantum Well Infrared Photodetectors (QWIP) are now seriously considered as a technological choice for the 3rd generation of thermal imagers [1], [2].

Since 2001, the THALES Group has been manufacturing sensitive arrays using QWIP technology based on AsGa techniques through THALES Research and Technology Laboratory. This QWIP technology allows the realisation of large staring arrays for Thermal Imagers (TI) working in 8 to 10μm spectrum. A review of the current QWIP products is presented (LWIR, MWIR and dual color FPAs).

The main advantage of this GaAs detector technology is that it is also used for other commercial devices. The duality of this QWIP technology has lead to important improvements over the last ten years and it reaches now an undeniable level of maturity. As a result, the processing of large substrate and a good characteristic uniformity, which are the key parameters for reaching high production yield, are already achieved. Concerning the defective pixels, the main common features are a high operability (above 99.9%) and a low number of clusters including a maximum of 4 dead pixels for full TV format.

Another advantage of this III-V technology is the versatility of the design and processing phases. It allows customizing both the quantum structure and the pixel architecture in order to fulfill the requirements of any specific applications. The spectral response of QWIPs is intrinsically resonant but the quantum structure can be designed for a given detection wavelength window ranging from MWIR, LWIR to VLWIR.

6361-42, Session 9

From LWIR to VLWIR FPAs made with HgCdTe at Defir

O. Gavrand, E. De Borniol, G. L. Destefanis, CEA-LETI (France); A. Manissadjian, P. M. Tribolet, C. Pautet, P. Chorier, Sofradir (France)

The HgCdTe infrared detector technology developed by CEA-LETI and industrialized by Sofradir is mature and reproducible, and the n on p planar ion implanted diode junction formation, that is well mastered for lot of years, allows high yields to be achieved in production. Even if most of the devices produced today are FPAs with increasing complexities (megapixel) operating in MWIR bands, , HgCdTe FPAs with longer and longer cut off wavelengths become more and more available.

Arrays of 384x288 with a pitch of 25μm are already available in production at Sofradir for LWIR bands (9-10μm & 11μm and operating temperature 77-85K & 70K respectively).

Improvement of both the material (with state of the art CdZnTe lattice matched substrates, state of the art HgCdTe epitaxial layers grown by liquid phase (LPE)), and of the photovoltaic detector process (improved dark current technology), have allowed FPAs with longer cut off wavelengths (VLWIR) to be fabricated.

These VLWIR (cut-off wavelengths in the 12-16μm range) dedicated to spectroscopy or broadband low flux applications operate at low temperatures around 50K and exhibit a very low dark current compatible with low flux applications.

In this paper we present the latest developments of VLWIR FPAs of TV/4 typical size made in Defir (LETI-Sofradir joint laboratory).

6361-43, Session 9

AIM Activities for space-qualified HgCdTe photo-voltaic detector arrays from 0.9-μm to 15-μm spectral range

M. Haiml, H. Bitterlich, M. Bruder, K. Eberhardt, K. Hofmann, H. Lutz, H. Nothaft, J. C. Wendler, R. Wollrab, J. Ziegler, AIM Infrarot-Module GmbH (Germany)

Remote sensing from space is a fast growing market for applications in security, climate research, weather forecast, and global environmental monitoring, to mention a few. In particular, next generation systems drive the need for large, two-dimensional arrays in the short (SWIR, 0.9-2.5 μm) and the very long wavelength infrared (VLWIR) spectral range up to 15 μm.

AIM's infrared developments for space applications benefit from AIM's experiences in high-performance thermal imaging and seeker-head applications.

Last year, AIM has delivered a 13 μm cut-off demonstrator for a high resolution Fourier-transform imaging spectrometer in limb geometry. For this 128 x 128 pixel sensor we measured a response of 100 LSB/K and a noise equivalent temperature difference of 20 mK for the following parameters: 50 K operation temperature, 285 K blackbody temperature, F# of 2.0, A/D-converter resolution of 14 bit, and 67.5 μs integration time. The substrate and epitaxial layer grown at AIM exhibit very good uniformity and low dark currents.

Currently, AIM develops a 1024 x 256 SWIR detector (0.9-2.5 μm) with a capacitance trans-impedance amplifier (CTIA) for hyperspectral imaging.

The radiation hardness of AIM's FPA technology (MCT sensor and Silicon read-out integrated circuit) has been tested by a total ionization dose (TID) experiment using ESTEC's Cobalt-60 gamma-source. Our reference module withstands 30 krad TID without any significant degradation.

In summary, AIM will be able to supply space qualified detector modules covering the spectral range from 0.9 to 15 μm in the near future.

6361-44, Session 9

Curved focal plane array technologies enabling compact wide field of view optical systems

S. Nikzad, M. E. Hoenk, T. J. Jones, Jet Propulsion Lab. (USA)

Small and low-cost missions place exacting requirements on power, volume, and mass budgets. Curved focal plane arrays (CFPAs) can reduce the optical complexity of instruments by substantially reducing the number of optical elements required and subsequently reducing instrument size, mass, and cost, while increasing the field of view (FOV) and maintaining excellent imaging performance. The development of CFPAs could have a beneficial and significant impact on the design and construction of space-borne optical instruments such as orbiter cameras, ultra wide-angle imagers for mapping the sky, star trackers, rover panoramic cameras, and spectrometers.

CFPAs can potentially enable significant miniaturization and improvement of optical systems. In most optical systems the focal surface is naturally curved, while most detector arrays are flat. While other aberrations depend on the stop and conjugate positions within an optical system, field curvature generally depends only on the basic constructional parameters of the system and the throughput. It is thus very difficult to change, and can be regarded as intrinsic to an optical system. The designer has more degrees of freedom in controlling other aberrations than in controlling field curvature. CFPAs offer a way out of this dilemma by permitting the designer to concentrate on the correction of other aberrations rather than having to abandon a certain design approach due to excessive field curvature.

Two relatively simple approaches to convert flat solid state FPAs into CFPAs are under development at our laboratory. In these techniques, the curvature of the back surface is independent from the front surface VLSI fabrication process of CCDs or other imaging arrays. We have modified fully-processed thick, high-purity detectors and thinned membrane CCDs to have a curved imaging surface. We will discuss the range of required curvatures for FPAs, our two approaches for fabrication of CFPA, and the results on CFPAs.

6361-45, Session 9

Focal plane electronics for the GAIA focal plane demonstrator

H. Michaelis, Deutsches Zentrum für Luft und Raumfahrt e.V. (Germany); T. Behnke, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

The GAIA mission of the European Space Agency (ESA) comprises two Astro telescopes with a very large common focal plane. The focal plane assembly consist of about 180 CCDs and accompanying video chains. The CCDs are operating in a TDI mode with complex windowing- and binning modes. Low noise, large dynamic range, linearity are mandatory for success of the Mission. Therefore, ESA has initiated a technology demonstrator, which should demonstrate the technical feasibility. Astrium-SAS in Toulouse and DLR-IPF in Berlin have successfully performed the study, in which

DLR has developed the CCD- video electronics and the Interconnection Modules for the Focal Plane Demonstrator. The requirements, the conceptional design and the results are presented during the conference.

6361-46, Session 9

Latest Sofradir technology developments usable for space applications

M. Vuillermet, P. Chorier, Sofradir (France)

Sofradir started to work in the field of space applications and especially in the earth observation domain in the beginning of the 1990th. Thanks to the work done with the support of the French Ministry of Defense and the European Space Agency, Sofradir has acquired a large know-how and became a major supplier for European space industry.

Nowadays, Sofradir technologies offer possibilities to develop a large panel of high reliable detectors like long linear arrays or two dimensional arrays covering bandwidth from visible to 15 μm based on qualified Mercury Cadmium Telluride (MCT) technology. In a near future, latest technology developments will enable to offer new detectors features in order to simplify instruments designs. In particular, these latest developments concern dual band detectors, increase in format, pitch reduction and implementation of new functions on the FPA like analogue to digital converter.

This paper proposes an overview of Sofradir technology capabilities for design of custom space detectors. In particular this paper presents latest technology developments with new results in visible, long wavelength and dual band technology capabilities. Then, the different approaches for future space FPA are discussed based on examples of manufacturing.

6361-47, Session 10

Design of the GOSAT interferometer

F. J. Châteauneuf, M. A. Soucy, G. P. Perron, L. E. Lévesque, ABB Inc. (Canada); J. Tanii, NEC TOSHIBA Space Systems, Ltd. (Japan)

The Greenhouse gases Observing SATellite (GOSAT) is designed to monitor the global distribution of carbon dioxide (CO2) from orbit. It is a joint project of Japan Aerospace Exploration Agency, the Ministry of Environment (MOE), and the National Institute for Environmental Studies (NIES). JAXA is responsible for the satellite and instrument development, MOE is involved in the instrument development, and NIES is responsible for the satellite data retrieval. It is scheduled to be launched in 2008. As existing ground monitoring stations are limited and still unevenly distributed, the satellite observation has advantages of global and frequent observations. The objective of the mission is in response to COP3 (Kyoto Protocol): Observation of Green House Gases (GHGs) including CO2 with 1% relative accuracy in sub-continental spatial resolution and to identify the GHGs source and sink from the data obtained by GOSAT in conjunction with the data from the ground instruments, with simulated models. In order to detect the CO2 variation of boundary layers, the technique to measure the column density and the retrieval algorithm to remove cloud and aerosol contamination are investigated. The simultaneous observation of methane (CH4), which is the second largest contribution molecule, is studied. A Fourier transform spectrometer with high optical throughput and spectral resolution is currently under design for the GOSAT mission. This paper presents the design of the GOSAT interferometer as well as expected system level instrument performances.

6361-48, Session 10

The VENμS super-spectral camera

J. M. Topaz, Electro-Optics Industries Ltd. (Israel); F. Tinto, O. Hagolle, Ctr. National d'Études Spatiales (France)

A 5m GSD satellite camera with 12 narrow spectral bands in the VNIR region is being developed by El-Op, Israel, for a cooperative project between CNES (France) and the Israel Space Agency. The satellite, called "VENμS" (Vegetation and Environment monitoring on a New Micro-Satellite) will enable evaluation of the use of high-resolution, high repetitivity, super-spectral imaging data for vegetation and environmental monitoring. The camera, based on an earlier development project, the "DAVID" MSRS camera, has 4 three-band CCD-TDI detectors in the focal plane of a 25 cm diameter catadioptric objective.

The camera will image a limited number of selected sites around the globe with a two-day revisit interval. Highly demanding requirements for signal-to-noise ratio, radiometric accuracy, band-to-band registration and precise location on the ground will ensure the validity of the data, which will serve to demonstrate the benefit of a mission combining high resolution, high revisit capability and superspectral measurements. It will also help to define the optimal set of bands and the image processing algorithms of future

instruments in the framework of the GMES program.

The satellite bus will be built by Israel Aircraft Industries and will also carry an experimental ion propulsion system developed by Rafael (Israel).

6361-49, Session 10

Contour mapping of Europa using frequency diverse spatial heterodyne imaging

R. L. Kendrick, Lockheed Martin Advanced Technology Ctr. (USA); J. C. Marron, Lockheed Martin Coherent Technolgies (USA); J. T. Pitman, Lockheed Martin Advanced Technology Ctr. (USA)

Three dimensional imaging of planetary and lunar surfaces has traditionally been the purview of Synthetic Aperture Radar payloads. We propose an active imaging technique that utilizes laser frequency diversity coupled with spatial heterodyne imaging. Spatial heterodyne imaging makes use of a local oscillator which encodes pupil plane object information on a carrier frequency. The object information is extracted via Fourier analysis. Snapshots of the encoded pupil plane information are acquired as the frequency of the illumination laser is varied in small steps (GHz). The resulting three dimensional data cube is processed to provide angle-angle-range information. The range resolution can be adjusted from microns to meters simply by adjusting the range over which the illuminator laser frequency is varied. The proposed technique can provide fine resolution contour maps of Europa on future missions. This information can be used to better understand the geological processes that form the surface features of Europa and other interplanetary moons. In this paper we present simulations and experimental data that will demonstrate the concept.

6361-50, Session 10

Characteristics of COMS Meteorological Imager

Y. Cho, Korea Aerospace Research Institute (France); H. Youn, Korea Aerospace Research Institute (South Korea)

Communication Ocean Meteorological Satellite (COMS) for the hybrid mission of meteorological observation, ocean monitoring, and telecommunication service is planned to be launched onto Geostationary Earth Orbit in 2008. The mete-orological payload of COMS is an imager which will monitor meteorological phenomenon around the Korean peninsular intensively and of Asian-side full Earth disk periodically. The meteorological imager (MI) of COMS has 5 spectral channels, 1 visible channel with the resolution of 1 km at nadir and 4 infrared channels with the resolution of 4 km at nadir. The characteristics of the COMS MI are introduced in the view points of user requirements, hardware characteristics, and operation features.

6361-51, Session 10

Spectral angle mapper-based assessment of detectability of man-made targets from hyperspectral imagery after SNR enhancement

S. Qian, H. Othman, Canadian Space Agency (Canada); J. Lévesque, Defence Research and Development Canada (Canada)

The Canadian Space Agency (CSA) is developing a pre-operational spaceborne Hyperspectral Environment and Resource Observer (EHRO). HERO will be a Canadian optical Earth observation mission that will address the stewardship of natural resources for sustainable development within Canada and globally. Signal-to-noise ratio (SNR) is one of the key parameters in design and building a satellite. Satellite data users always prefer to receive data with high SNR in order to better serve their applications. Design and building a hyperspectral satellite with a considerably high SNR is one of the challenges, as high SNR can be prohibitively expensive and constrained by technology availability. To deal with this challenge CSA has developed a novel technology to improve SNR of hyperspectral data by removing noise in the data using wavelet shrinkage (Othman & Qian, IEEE Transactions on Geoscience & Remote Sensing, vol.44, no.2, pp.397-408, Feb. 2005). It can improve SNR up to 98% for the test hyperspectral data sets. This paper is to assess the performance of the noise removal technology to examine whether the SNR enhanced hyperspectral data can better serve Earth observation applications. A hyperspectral data set acquired using an airborne Short-wave-infrared Full Spectrum Image II (SFSI-II) with man-made targets was tested. Spectral angle mapper (SAM) and end-members of the targets were used to measure the superficies of the targets and to assess the detectability of the targets in the scene of the data sets before and after applying the noise removal technology. The experimental results show that small targets in the noise-removed data set can be detected, which cannot be detected in the original data set due to the lower SNR and insufficiently high spatial resolution.

6361-52, Session 10

The flight test of Pi-SAR(L) for the repeat-pass interferometric SAR

H. Nohmi, NEC Corp. (Japan); M. Shimada, Japan Aerospace Exploration Agency (Japan); M. Miyawaki, NEC Aerospace Systems, Ltd. (Japan)

This paper describes the experiment of the repeat pass interferometric SAR using Pi-SAR(L). The air-borne repeat-pass interferometric SAR is expected as an effective method to detect landslide or predict a volcano eruption. However, to obtain a high-quality interferometric image, it is necessary to make two flights on the same flight pass. Also the antenna of the Pi-SAR(L) is secured to the aircraft, it was necessary to fly at same drift angle to keep the observation direction same.

We built the navigation system using an automatic landing system which has been installed in the airplane. This navigation system measures position and altitude precisely at a rate of 20Hz by a differential GPS, and the PC Navigator outputs the difference from the desired course as LOC signal and GS signal to the Auto Pilot system. Unlike the normal landing approach, the gain of control system needed to be adjusted because the air density is thin and the speed is high at high altitude. The observation direction could be controlled to some extent by adjusting the flight speed to adjust the drift angle.

The repeat-pass flight was conducted in Japan for three days in late November. The optimal gain scale was determined after adjusting the gain of the control system. The flight was stable within a few meters for both horizontal direction and altitude. Even in the gust, the flight was made with in 5 meters. Thus, the interferometric image was obtained by repeat-pass.

6361-53, Session 11

New generation of space capabilities resulting from US/RF cooperative efforts

T. W. Humpherys, Utah State Univ. (USA); V. Sinelshchikov, V. Misnik, TsNPO Kometa (Russia); A. T. Stair, Jr., J. Carpenter, Visidyne, Inc. (USA); J. Watson, The Aerospace Corp. (USA); D. V. Chvanov, Space Dynamics Lab. (Russia); V. Khatulev, Khrunichev State Research & Production Ctr. FGUC (Russia)

Previous successful international cooperative efforts offer a wealth of experience in dealing with highly sensitive and often emotional issues. Cooperative remote sensing for monitoring and understanding the global environmental is in the national interest of all countries. Cooperation between international partners is paramount, particularly with the Russian Federation, due to its technological maturity and strategic political and geographical position in the world. Based on experience gained from over a decade of collaborative space research efforts, continued cooperation is not only an achievable goal, but essential to understanding the trends in our environment. :

Past cooperative space research efforts demonstrate the ability of the U.S. and Russian Federation to develop a framework for cooperation, working together on a complex, state-of-the-art joint satellite program. These efforts consisted of teams of scientists and engineers, who overcame numerous cultural, linguistic, engineering approaches and political differences. Among these major achievements are, (1) field measurement activities with U. S. satellites: MSTI and MSX, and the Russian RESURS-1 satellite as well as the joint experimental use of the U.S. FISTA aircraft; (2) successful joint Science, Conceptual and Preliminary Design Reviews; (3) joint publications of scientific research technical papers, (4) Russian investment in development, demonstration and operation of the Monitor-E spacecraft (Yacht satellite bus), (5) successful demonstration of the conversion of the SS-19 into a satellite launch system, and (6) negotiation of contractual and technical assistant agreements.:

In this presentation, we will discuss a new generation of science and space capabilities available to the Remote Sensing community. Specific topics include: Joint requirements definition process and work allocation for H/W and responsibility for S/W development; the function, description

and status of Russian contributions in providing space component prototypes and test articles (Designers Technological Model); summary of completed conjunctive experiments and planned experimental measurements and simulations; results of the current and planned ROKOT launch system, including trajectory approvals out of Plesetsk; performance of the Monitor-E spacecraft; prototype joint mission operations control center; and a Handbook for Success in satellite collaborative efforts based upon a decade of lesson learned.

6361-54, Session 11

Real-time beamforming synthetic aperture radar processor

R. F. Rincon, L. Hilliard, D. Bradley, S. Sheikh, J. Lucey, NASA Goddard Space Flight Ctr. (USA)

This paper discusses the design and fabrication of a real-time Digital Beamforming Synthetic Aperture Radar (DBSAR) processor for airborne radar which can achieve fine spatial resolutions and wide swaths. The development of the DBSAR processor enables important scientific measurements that require fine resolution over large areas such as surface water, polar ice sheet velocity, snow thickness, surface deformation, land cover usage, and vegetation biomass, among many others. The development of this technology also serves as a prove-of-concept for planetary exploration missions since the same benefits provided on Earth are applicable to the exploration of the Moon, Mars, and other bodies in the solar system.

A unique aspect of DBSAR is that it achieves fine resolutions over large swaths which cannot be met with real aperture radars or with the conventional push broom SAR systems. DBSAR synthesizes multiple cross-track beams simultaneously using digital beamforming techniques. Each beam is then processed using SAR techniques to obtain the fine ground resolution. The technique enables large swaths without compromising fine range and Doppler resolutions. In addition, each beam can be synthesized with different beamwidths and side lobe levels so as to maintain constant swath widths and minimize side lobe contamination.

DBSAR will use an FPGA-based architecture to implement synthetic aperture radar (SAR), pulse compression, and beamforming techniques enabling ground resolutions of 30 m or better and large swaths. DBSAR would be capable of processing data from different radars. However, as a test bed, we will use the newly developed airborne L-Band Imaging Scatterometer (LIS) recently developed at the Goddard Space Flight Center.

6361-56, Session 11

Rapid full-spectrum hyperspectral scene simulation for sensor trade studies

R. L. Sundberg, Spectral Sciences, Inc. (USA); S. C. Richtsmeier, Spectral Sciences, Inc (USA); R. E. Haren, F. O. Clark, Air Force Research Lab. (USA)

This paper will discuss the formulation and implementation of an acceleration approach for the MCScene code, which is a high fidelity model for full optical spectrum (UV to LWIR) hyperspectral image (HSI) simulation. MCScene provides an accurate, robust, and efficient means to generate many HSI scenes for algorithm validation and sensor design trade studies. The MCScene simulation is based on a Direct Simulation Monte Carlo approach for modeling 3D atmospheric radiative transport, as well as spatially inhomogeneous surfaces including surface BRDF effects. The model includes treatment of land and ocean surfaces, 3D terrain, 3D surface objects, and effects of finite clouds with surface shadowing. This paper will review an acceleration algorithm that exploits spectral redundancies in hyperspectral images. In this algorithm, the full scene is determined for a subset of spectral channels, and then this multispectral scene is unmixed into spectral endmembers and endmember abundance maps. Next pure endmember pixels are determined at their full hyperspectral resolution and the full hyperspectral scene is reconstructed from the hyperspectral endmember spectra and the multispectral abundance maps. This algorithm effectively performs a hyperspectral simulation while requiring only the computational time of a multispectral simulation. The acceleration algorithm will be demonstrated on several scenes containing representative terrain types and a variety of materials. Sample calculations will be presented to demonstrate how the model can be used for sensor design trade studies.

6361-57, Session 11

Non-radiation hardened microprocessors in space-based remote sensing systems

R. J. DeCoursey, NASA Headquarters (USA); R. Melton, Ball Aerospace & Technologies Corp. (USA); R. R. Estes, Jr., NASA Langley Research Ctr. (USA)

The CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) mission is a comprehensive suite of active and passive sensors including a 20Hz 300mj Nd:Yag lidar, a visible wavelength Earth-looking camera and an imaging infrared radiometer. CALIPSO flies in formation with the Earth Observing System Post-Meridian (EOS PM) train, provides continuous, near-simultaneous measurements and is a planned 3 year mission. CALIPSO was launched into a 98 degree sun synchronous Earth orbit in April of 2006 to study clouds and aerosols and acquires over 4 gigabytes of data every 24 hours.

Spaced based remote sensing systems that include multiple instruments and/or instruments such as lidar generate large volumes of data and require robust real-time hardware and software mechanisms. Due to onboard storage restrictions and telemetry downlink limitations these systems must pre-process and reduce data before sending it to the ground. This onboard processing and real-time requirement load may mean that newer more powerful processors are needed even though acceptable radiation-hardened versions have not yet to be released. CALIPSO's single board computer payload controller processor is actually a set of four (4) non-radiation hardened Power PC 603r's.

CALIPSO mitigates common radiation concerns through the use of redundant processors, radiation-hardened application specific integrated circuits (ASIC), Error Detection and Correction (EDAC), processor and memory scrubbing, onboard fault detection and resolution and power management.

In this paper, we describe the CALIPSO payload controller processor package and memory architecture and how this non-radiation hardened but radiation tolerant system is optimized for use in space.

6361-58, Session 11

Air liquid cryocoolers for space applications

J. Buquet, T. Trollier, J. Tanchon, A. Ravex, P. Crespi, Air Liquide (France)

AL/DTA became a major supplier in the field of space cryogenics for the European Space Industry. From MELFI project for ISS to HERSCHEL and PLANCK projects for Cosmic Vision, AL/DTA has acquired a large know-how in space cryogenics systems. Convinced by the great interest of Pulse Tube Technology for Space Applications and especially for Earth Observation or Surveillance Tracking, AL/DTA started its first development in mid nineteenths. Then the European Space Agency started to support the development in 2000. Industrial partnerships were decided with CEA/SBT (France) and Thales Cryogenics B.V. (the Netherlands) in order to take advantage of the competencies and experience of each other. Based on the will to improve important issues such as reliability and mechanical constraints, technology improvements are now available in AL/DTA Pulse Tube coolers.

This paper proposes an overview of AL/DTA cryocoolers for space applications following by a detailed description of Pulse Tube Coolers and particularly their integration.

6361-60, Poster Session

Airborne remote sensor of sea environment monitor (MAMS)

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It is uniquely advantaged to monitor and survey the characteristics of seas from the space. The result of the observation of sea surface by using the aircraft-borne and the satellite-borne remote sensors proves that it is feasible to obtain the data of the sea surface temperature and the color by means of remote sensing technology. We can obtain the information about the deposition suspension, the plankton and the chlorophyll, etc. of the sea by the remote sensing application of sea. Then, through the inversion, we can get the chlorophyll density, the sea primarily productive forces and all the essential factors of the water color. This article introduces a new remote sensor of sea environment monitor developed by Shanghai Institute of Technical Physics Academy of Science ¨C-Marine Aircraft-borne Multi-spectral Scanner (MAMS). We present its

main technical specification, performance and use in the article as well.

When optics remote sensing monitors the sea environment from the space, it is mainly passive to receive the sunlight reflection from the sea surface in the scope where the visible light is near the infrared spectrum. Since the sea water index of reflection generally only has a few percentages, a magnitude lower than land goal, the absorption spectrum of the sea matters is not very obvious. Therefore, we request the high detection sensitivity of the remote sensing. Usually, we hope that the signal to noise ratio (S/N) achieves higher than 500. The radiation quantity of the sea matters is related to the distribution of the sea surface temperature, and the multi-channel aircraft-borne scanner has the hot infrared channel (8 ~ 12.5 microns), so it is feasible to survey the sea surface temperature by using the multi-channel aircraft-borne scanner.

6361-61, Poster Session

Laser cryogenic gravimeter for high-sensitivity gravitational measurements

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Detailed information about the Earth's gravitational field is necessary for fundamental sciences and practical applications. A basic part of gravitation monitoring systems is gravity meter (or gravimeter), a device used to measure the relative acceleration g of the gravity force. In this report, we present a superconducting gravity meter, its mathematical model, and a nonlinear controller that stabilizes a probe at the equilibrium state. Our cryogenic-optical gravimeter measures the acceleration of the earth's gravity field at a level of 10^{-10} g, improving the measurement resolution by 10^{-2} compared to the gravimeters used nowadays.

The sensor is based on a new type of free suspension of the probe of the superconducting gravimeter. Its functioning is based on the magnetic levitation phenomenon of the probe and on the measurement of its displacement with subsequent data processing. A free suspension of a probe is realized using the magnetic potential well effect.

A mathematical model of the superconducting suspension which is based on HTSC thin films and on magnetic levitation, is presented. The nonlinear properties of a magnetic levitation system are studied. The phenomenon, in which a macroscopic HTSC superconducting ring levitates, is considered. We find that if a non-linear feedback is used then the probe moves chaotically near an equilibrium state. We also analyze the applicability of hybrid nanostructures and nanomagnets for novel superconducting gravimeters and accelerometers. Our report concentrates on thin films such as YBCO which can be used to create a superconducting suspension. Such suspensions have a good perspective in order to create a high sensitive cryogenic-optical sensor.

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6362-01, Session 1

Science on a budget: genesis of modern sun photometry

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In 1969 the author designed and implemented a multiwavelength sunphotometer for his dissertation project at the University of Arizona, just at the time when well- blocked, accurate interference filters became available from Barr associates, and when stable PIN solid state photodetectors emerged on the marketplace. This combination became the genesis of precision multiwavelength sun photometry. A network of instruments using this technology were soon installed across India, and then adopted by NASA in the United States. In the intervening years, the author has used versions of this photometer and spectral scanning sky radiometers to carry out numerous science projects on all seven continents. Based on such measurements, we discovered that the northern polar zone are generally contaminated with an Arctic Haze in late winter that has global climatic consequences and that the residence time for submicron aerosol is roughly a month over the Antarctic Ice Sheet. I also one time ruined my wife's vacation in Hawaii by driving up and down Mauna Loa volcano measuring optical properties of haze layers that were later interpreted to be dust from the Gobi Desert carried across the Pacific. Such long range transport of aerosols had previously been thought impossible. In a later experiment the instruments were trundled down the Alaska highway to southern Arizona, thereby establishing a latitudinal profile of air pollution in North America. With small portable instruments like these, it has also been possible to deduce the optical characteristics of volcanic plumes, establish to one percent the absolute value in SI units, the solar spectral irradiance, derive passably good estimates of the aerosol size probability distribution. One can also use such instruments to significantly lower the present large uncertainty due to aerosols in the global warming debate.

6362-03, Session 1

Remote sensing of absorbing aerosols and precipitable water vapor using MFRSR measurements

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We present further development of our analysis algorithm for Multi-Filter Rotating Shadowband Radiometer (MFRSR) data. The new additions include techniques allowing us to retrieve spectral aerosol single scattering albedo (SSA) and column amount of precipitable water vapor (PWV). The SSA retrievals employ MFRSR measurements of both direct normal and diffuse horizontal irradiances. We present a detailed sensitivity study indicating ranges of optical thickness and other aerosol parameters in which SSA retrievals are reliable. Possible instrumental influences on the data will be also discussed. The algorithm has been tested on a long-term dataset from the local MFRSR network at the DOE Atmospheric Radiation Measurement (ARM) Program site in Southern Great Plains (SGP). Our results are compared to AERONET's almucantar retrievals of SSA from CIMEL sun-photometer co-located with the MFRSR at the SGP Central Facility. A constrained variant of the algorithm (assuming zero nitrogen dioxide column values) has been also used for this comparison and to study the influence of the uncertainty associated with this atmospheric gas on the retrieved aerosol absorption properties. Precipitable water vapor column amounts are determined from the direct normal irradiances in the 940 nm MFRSR spectral channel. HITRAN 2004 spectral database has been used to model the water vapor absorption, while a range of other databases (HITRAN 1996, 2000, ESA) has been used in sensitivity study. The results of the PWV retrievals for SGP's MFRSR network were compared with correlative measurements by Microwave Radiometers (MWR), GPS stations, AERONET, and MODIS satellite product. In the latter case an innovative interpolation technique has been used to determine spatial structure of water vapor field from the network data and to create a 2D dataset comparable with satellite data.

6362-04, Session 1

Ultraviolet aerosol optical properties retrieved during the 2006 MIRAGE-Mex experiment: initial results

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Values for aerosol optical properties in the ultra-violet (UV) spectral range, including total ozone column (TOC), asymmetry factor (g) and seven wavelength channel (300-, 305-, 311-, 317-, 325-, 332- and 368-nm) aerosol optical depths (AOD) and aerosol single scattering albedos (SSA), were obtained from direct and diffuse ground-based irradiance measurements via an optimal estimation algorithm. The measurements were made by UV-MultiFilter Rotating ShadowBand Radiometers (UV-MFRSR), owned and operated by the United States Department of Agriculture's UV Monitoring and Research Program (USDA UVMRP), which were deployed at three different sites during the 2006 Megacities Impact on Regional And Global Environment, Mexico City Pollution Outflow Experiement (MIRAGE-MEX) field campaign. The Tropospheric Ultraviolet-Visible (TUV) radiative transfer model was utilized as the forward model in the retrieval algorithm.

The TUV model and retrieval algorithm were specifically characterized for use at each of three Mexico City field sites. Initial results of the aerosol optical properties at each site were analyzed and intercompared to results obtained from independent methods. Intercomparisons were also made between the three field sites, which were located at elevations of 2188, 2270 and 2400 meters at various points in and around the city. This data set, in conjunction with many others collected during the campaign, will help to address MIRAGE-MEX science objectives related to the aging of air pollution and the evolution of the radiative properties of gases and aerosols.

6362-05, Session 1

Aerosol climatology in Kathmandu using sunphotometry

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In this study, observation of aerosol optical depth (AOD) in Kathmandu (27.7N, 1350 m above sea level) is presented. Observations were made using a microprocessor controlled portable ozone-meter and aerosol-meter (MICROTOPS II). Clear sky direct solar UV irradiance was monitored at 305, 312, and 320 nm in ozone-meter whereas at 340, 380, 440, 500 and 675 nm in aerosol-meter. Observations show typical variation of AOD as a function of time during some of measurement days. Daily average AOD varies within 0.1 to 0.6 in summer whereas within 0.2 to 0.8 in winter/spring in Kathmandu. Usually, Angstrom's turbidity coefficient β decreases rapidly before local noon and becomes almost constant in the afternoon. It is found that α varies from time to time and becomes smaller during midday indicating existence of higher proportion of tiny particles in lower atmosphere in day time. In addition, UV index calculated from the irradiance measurement from ground based UV measuring instrument is also discussed. The effect of aerosols on UV is highlighted.

6362-06, Session 2

Increasing trend of submicron aerosol particles over East Asian waters observed in 1998-2004 by sea wide field-of-view sensor (SeaWiFS)

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The study is to analyze changes in monthly-averaged aerosol parameters derived from the SeaWiFS observations over East Asian waters from January 1998 through December 2004. All the SeaWiFS GAC Level 1 data (4 by 4 km spatial resolution data) that cover the Northeast Asian area (22-52°N, 117-146°E) were collected and processed by the standard atmospheric correction algorithm released by the SeaWiFS Project to produce daily aerosol optical thickness (AOT) and Angstrom exponent imageries. Cloud screening was applied if AOT at 490 predicted from the aerosol look-up tables embedded in the algorithm exceeded 0.7. From

the daily composite images, monthly average AOT and Angstrom exponent values were extracted for each one of the six study areas chosen from the surrounding waters of Japan, including an area around Marcus Island where maritime aerosol prevails throughout the year. The results showed the followings: 1) Seasonal variability of AOT ranged mostly 0.2-0.4 except around Marcus Island where it varied 0.2-0.3. 2) Angstrom exponent varied 0.2-0.8 in Japan Sea areas, 0.2-0.5 in East China Sea and South/East Japanese coastal areas but with minimum variability of 0.1-0.2 around Marcus Island. 3) Although annual mean of AOT did not show any trend, +0.06-0.08 increase in Angstrom exponent in all areas except Marcus Island was observed over the study period. This increase is interpreted as 4-5% increase in submicron fraction (SMF), or the ratio of contribution of submicron aerosol particles to the total AOT, and will be interpreted as an increase of submicron particles due to the enhanced anthropogenic activities in East Asia.

6362-07, Session 2

The Earth surface reflectance retrieval by exploiting the synergy of TERRA and AQUA MODIS data

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The Earth surface reflectance is required for retrieval of many land parameters. In this paper we attempt a solution to the problem of retrieval of surface reflectance by exploiting the synergy of TERRA and AQUA MODIS data. A new Earth surface reflectance retrieval method proposed in this paper showed encouraging results and promising potential to address surface reflectance retrieval for land even for higher reflective surface. By exploiting the synergy of MODIS data from two successive orbit of lesser interval for the same area, SYNTAM method can be used to derive the information of aerosol such as Aerosol Optical Thickness over various ground surfaces, including high reflective surface, further to remove the atmosphere effects for surface reflectance retrieval. No other parameters need to be assumed to retrieve aerosol optical thickness in our method, which allows the AOT retrieval to be more objective and possibly more accurate to remove the atmosphere effects for possibly more accurate surface reflectance retrieval. Uncertainties of our method are mainly introduced by factors such as aerosol and water vapour spectral absorption, registration of two temporal images, sub-pixel cloud contamination, and our assumptions on invariant α and the ratio for compensating the ground surface bi-direcional properties effects, which should be taken in to account in future research. Further validation with in situ land surface reflectance measurement data should be carried out if possible. This method could be used over various ground surfaces, including high reflective surface.

6362-08, Session 2

Estimation of dust effects on AIRS radiances and retrievals

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The Atmospheric Infrared Sounder (AIRS) has been operating since Sept.2002 and is being used operationally by several weather centers. Routine retrieval processing is done by NASA. The almost continous spectral coverage of AIRS in both the 10-12 and 3.7 micron atmospheric windows allows excellent detection of the presence of dust. Depending on the season, significant fractions of AIRS observations (upto 10% over tropical oceans) are contaminated by dust blowoff from arid areas. Dust signals can often survive the cloud-clearing process used in the NASA retrieval system for AIRS, contaminating the low-altitude temperature and water vapor retrieval products. We present progress on techniques we are developing to both operationally detect and mitigate the effects of dust on AIRS retrieval products.

6362-09, Session 2

Results of 50 year ground-based measurements in comparison with satellite remote sensing of two prominent dust emission sources located in Iran

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Mineral dust, as the most important type of aerosols, play an important role in climate forcing by altering the radiation balance in the atmosphere through the scattering and absorption of radiation. Also, they terribly affect the human health, living in the vicinity of large persistent emission sources; especially located in the arid or hyper arid regions of the Middle Eastern countries like Iran. Thus, on a local scale, dust mobilization appears to be dominated by natural sources and its emission rate measurement is very necessary. Dust activity is extremely sensitive to many environmental and physical parameters.

In this paper, we systematically evaluate two local prominent emission sources, the first one is Sistan basin which is located between Iran and Afghanistan at ~31°N,61.5°E and the second are Hourol-azim wetlands which are located between Iran and Iraq at 31°N, ~46°E. Evaluation includes the 50 year ground-based measurements in comparison with satellite remote sensing results based on data from Moderate Resolution Imaging SpectroRadiometer (MODIS) on the Terra/Aqua satellites.

Ground-based measurements are the most related synoptical parameters to dust emission, such as temperature, precipitation, wind speed, number of dusty days and visibility which are derived from data records of synoptical weather stations located in the vicinity of two case study points.

Compared to ground-based measurements, satellite imagery, due to their large spatial coverage and reliable repeated measurements, provide another important tool to monitor mineral dusts and their transport patterns.

Local identification of major sources will enable us to focus on critical regions and to characterize emission rates in response to environmental conditions. With such knowledge we will be better able to improve global dust models and to assess the effects of climate change on emissions in the future.

6362-59, Session 2

Aerosols detection for urban air pollution monitoring

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In the context of reducing the impact of atmospheric pollution on public health in cities. Previous studies have shown that optical sensors aboard satellites may be sensitive to the level of pollution because of the relation between radiances and aerosol loading and especially particulate matter (PM). The purpose of this paper is to add to this evidence by studying cloud-free satellite images and ground measurements, and then to show that urban aerosols concentrations variations can be detected and quantified by the means of satellite images. We used the radiative transfer model (6S). We simulated the reflectance at pixel level in the Landsat-TM and Envisat-MeRIS bands. The effects and contributions of parameters (H2O content, O3 content, albedo, aerosols and atmosphere optical thickness) are studied thanks to experimental design approach. Change in aerosol loading is the major contributor to change in reflectance. We thus demonstrate and quantify the sensitivity of reflectance to PM. We find that channel TM4 of Landsat and channels 12 and 13 of MeRIS are the appropriate bands, which corresponds to wavelengths around 815 nm. However, when taking into account the gain of the sensor, we recommend TM1. On TM1 image, a difference of 71 DN (digital number) represents a variation of 120 μg/m3. The minimal concentration variation detectable is around 2.6 μg/m3.

6362-10, Session 3

Development of a fast-forward model for IASI

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The Infrared Atmospheric Sounding Interferometer (IASI) is a modern satellite sensor with 8461 channels and a spectral resolution of 0.25 wavenumber. It provides a wealth of information on atmospheric and surface properties. Due to the high spectral resolution, a large number of Radiative Transfer (RT) calculations through the inhomogeneous atmosphere are needed. Usually, only subsets of channels are used to perform physical inversions for atmospheric profiles. This paper presents a novel radiative transfer model based on principal component analysis. The Principal Component-based Radiative Transfer Model (PCRTM) predicts PC scores and associated derivatives with respect to various atmospheric and surface properties in PC space directly. Usually, less than 200 PCs are needed to regenerate the original radiance spectrum with accuracy better than instrument noise level. Therefore, the dimension of the spectrum is reduced by an order of magnitude for hyper spectral

sensors with thousands of channels. The reduction in dimension and the fast RTM make the physical inversion algorithm very fast and efficient. Due to its significant savings in computational time, the approach uses information from all measured channels. There is no need to use only subset of channels. The parameterization of the PCRTM model is derived from properties of PC scores and instrument line shape functions. It is physical and accurate.

6362-11, Session 3

Atmospheric correction of airborne infrared hyperspectral images using neural networks

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The retrieval of surface emissivity and temperature from infrared radiances measured by an airborne hyperspectral sensor closely depends on the ability to correct the acquired data from atmospheric effects. In this paper we present a new atmospheric correction scheme based on sounding techniques and neural networks.

A key problem of neural network is to select relevant entries and outputs. Therefore, a preliminary sensitivity analysis that takes into account atmospheric conditions as well as the surface emissivity and temperature variations is carried out. It shows that only the first three or four PCA coefficients of atmospheric profiles have a significant influence on the radiance measured in the 4.26 μm carbon dioxide and the 6.7 μm water absorption bands. But these coefficients allow to rebuilt temperature and water profiles with enough accuracy for the addressed problem.

This lead us to develop two groups of neural networks, the first one to estimate the main PCA coefficients of temperature profile, and the second one to retrieve the related water PCA coefficients. The atmospheric profiles thus obtained are then used to derive the “ground” radiances.

Eventually we evaluate the accuracy of surface temperature and emissivity obtained wtih the derived atmospheric profiles.

6362-12, Session 3

Application of the opacity distribution function (ODF) technique to the Non-LTE radiative transfer in the molecular bands in planetary atmospheres

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The increasing number of space and ground-based observations of the planetary atmospheres as well as the development of the General Circulation Models requires fast and accurate methods of calculating radiative transfer in the molecular bands.

Additionally, expanding measuring and modeling range to higher altitudes where the frequency of the molecular collisions is insufficient to thermalise the molecular vibrational levels requires efficient methods that work both for LTE and non-LTE conditions.

However, the existing lines-by-line codes, though exact, are computationally expensive, while various parameterizations are often inaccurate. We describe the application of the “opacity distribution function” (ODF) technique used in the stellar astrophysics [Mihalas, 1978; Hubeny and Lanz, 1995] to the radiative transfer in the molecular bands in planetary atmospheres. Compared to correlated k approach [Goody and Yung, 1989], which is widely used in atmospheric LTE radiative transfer calculations, the ODF technique works both for LTE and non-LTE conditions. It allows treating each branch of the ro-vibrational band as a single line of a special shape that can be parameterized in respect to pressure and temperature variations. This approach has been tested for Martian and Earth’s atmospheres and has demonstrated good results for the calculation of vibrational level populations and radiative cooling/heating rates for CO2, O3, and H2O molecules. Utilizing the ODF approach provides acceleration of calculations by a factor close to a number of lines in the branch (about 100 times for CO2 and about 1000 times for O3 and H2O bands).

6362-14, Session 3

Variations of solar radiation at the Earth’s surface during the total solar eclipse of 29 March 2006

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On 29 March 2006, a total eclipse of the Sun was visible from within a narrow corridor starting in Brazil and extending across the Atlantic, northern Africa, and central Asia. The only location in Europe on the path of the Moon’s shadow was the Greek island Kastelorizo (36.150°N, 29.596°E) . An extended set of instruments was installed in this island by three European research groups in order to measure the variability of different components of the radiation field (global irradiance, direct irradiance, actinic flux density, radiance distribution and degree and orientation of polarization) during the eclipse. Seven spectroradiometers (two scanning double monochromators measuring especially in the UV range, 4 photo diode array instruments and one CCD-spectrograph for the UV and visible wavelength range) performed measurements during 28 and 29 March. A narrow band multi-filter radiometer and two broadband erythemal and UVA radiometers were operated with about 1 sec temporal resolution. Two sun-photometers were used to measure the ozone column and the aerosol optical depth. The weather conditions on March 28 were almost perfect, whereas on 29 March thin cirrus clouds occasionally were present in front of the sun.

Details about the observed changes in UV radiation on the eclipse day are presented. The absolute changes of the different components and their wavelength dependencies are discussed. Different methods of ozone retrieval are compared to study spectral effects of limb darkening.

6362-15, Session 3

The retrieval of surface solar insolation using SMAC code with MTSAT-1R data

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Surface Solar Insolation is important for vegetation productivity, hydrology, crop growth, etc. In this study, Surface Solar Insolation is estimated using Multi-functional Transport Satellite (MTSAT-1R) in clear and cloudy conditions. SMAC (Simplified Method for Atmospheric Correction) produces not only the surface channel reflectance but also important atmospheric factor, such as, ozone transmission, water vapour transmission, rayleigh scattering and aerosol scattering. Therefore, this study aims at an evaluation on the ability and applicability of atmospheric factors produced through SMAC for the insolation estimation. The SMAC’s atmospheric estimation modules are transplanted to Kawamura’s physical insolation model, because this model is optimized to GMS (Geostationary Meteorological Satellite) data, which is previous version of MTSAT. For the Cloudy sky cases, the surface solar insolation is estimated by taking into account the cloud transmittance and multiple scattering between cloud and surface. This model integrated Kawamura’s model and SMAC code computes surface solar insolation with a 5kmX5km spatial resolution in hourly basis. The daily value is derived from the available hourly Surface solar irradiance, independently for every pixel. To validation, this study uses ground truth data recorded from the pyranometer installed by the Korea Meteorological Agency (KMA). The validation of estimated value is performed through a match-up with ground truth. Various match-up window sizes are tested with 3X3, 5X5, 7X7, 9X9, 10X10, 11X11, 13X13 pixels to define the spatial representativity of pyranometer measurement, and to consider drifting clouds from adjacent pixels across the ground station during the averaging interval of 1 hour are taken into account.

6362-16, Session 3

Radiation transfer in global heterogenic spherical system

T. A. Sushkevich, M. V. Keldysh Institute of Applied Mathematics (Russia)

T.A. Sushkevich was the first in the world who elaborated 40 years ago a model of solar radiation transfer in spherical atmosphere of the Earth for the scale of entire planet [1, 2]. Pioneer results have been obtained concerning aerosol and ozone layers remote sensing and many applied problems have been solved of space exploration and space research. Development of new mathematical tools to be realized on high-output multi-processor computer systems [2] is needed to solve direct and inverse problems of radiation transfer theory for natural media as related to international cooperation on air-space global monitoring of the Earth as well as to an international global project on research

Original mathematical tools are proposed for the first time to model

radiation transfer in multi-layer non-homogenous heterogenic natural media with different radiation regimes within separate regions of the system. “Free atmosphere - multi-layer cloudiness - near surface layer of the atmosphere - Earth surface (ocean, land)” system is heterogenic, in particular. The proposed approach is based on construction of generalized solutions in the form of matrix functionals; vectors of influence functions for each layer of the system serve as kernels of the functionals. The influence functions of the layers with different aerosol and molecular characteristics of scattering and absorption and radiation regimes can thus be calculated by various methods in different approaches of radiation transfer theory.

Such assertion of the problem has become actual in connection with problems of photo-radiation chemistry of the Earth (troposphere, stratosphere and ozone-sphere in conditions of twilight, Sun rise, terminator, polar regions); information supply of tomography of the Earth atmosphere including refraction-metric methods and space systems operating in observations through horizontal traces; polar regions remote sensing; construction of models of spectral and radiation budget of the Earth; phase radiance of the Earth for space navigation instruments (space-craft return on the Earth, space-craft navigation via the Earth, etc.); realization of projects related to additional sources of energy on space-craft by utilization of solar radiation reflected by the Earth and so on.

New opportunities of the proposed model are linked with verification of engineering applied techniques and plain layers approach which are often used for an express-analysis of space data and in radiation blocks for models of climate, circulation, forecast, photo-chemical kinetics, dynamics of ozone-sphere, trans-boundary displacement of pollutions for an air basin, etc.

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6362-32, Session 3

Hyperspectral remote sensing of aerosol plumes :a semianalytical model

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A semianalytical forward model for the radiative effects of optically thick aerosol plumes is proposed using hyperspectral images in the spectral range 0.4-2.5 micrometers.

The scene is modelled by an atmospheric layer (molecules and standard aerosols) located above a plume layer. The reflectance at bottom of the plume is then the sum of a pure aerosol reflectance and a function related to plume transmission, plume spherical albedo and ground reflectance. In a first step, each term depends on the viewing angles (i.e., sun and sensor locations), the aerosol optical depth, single-scattering albedo and asymmetry parameter. Numerical coefficients are derived from MODTRAN4 simulations. The DISORT option is used to provide a sufficiently accurate calculation of multiple scattering effects which are important for dense smokes. In a second step, the spectral dependency of optical properties is modelled using empirical laws involving a few parameters (e.g., Angström law) related to physical properties. Using these relations within the model yields a simplified expression for the aerosol plume signal.

The model is valid for optical depths greater than 0.5 (extending the single scattering formulae often used for optically thin layers), single-scattering albedos between 0.5 and 0.95, and positive asymmetry parameters. Comparisons between MODTRAN4 simulations and the proposed semianalytical model exhibit an error lower than 5% rms for most cases. It can thus be used to retrieve aerosol characteristics like size distribution or integrated particles concentration from smoke plumes as emitted by forest fires, volcanoes, industrial plants by means of hyperspectral data.

6362-17, Session 4

Global analysis of cloud geometrical properties using ADEOS-II / GLI data for radiation budget studies

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It is of great interest to investigate the radiative properties on the cloud optical, microphysical, and geometrical properties of clouds that play crucial role in the climate system. Here, top height, base height, and geometrical thickness of cloud layer are considered as cloud geometrical properties.

Several studies show that information of some spectral regions including oxygen A-band, enables us to retrieve the cloud geometrical properties as well as the optical thickness, the effective particle radius of cloud. In this study, an algorithm was developed to retrieve simultaneously the cloud optical thickness, effective particle radius, top height, and geometrical thickness of cloud layer with the spectral information of visible, near infrared, thermal infrared, and oxygen A-band channels.

This algorithm was applied to ADEOS-II / GLI dataset so as to retrieve distribution of cloud geometrical properties. The retrieved results around Japan were compared to other observation, which suggested this algorithm would work for cloud system over ocean at least. Sensitivity studies were also carried out and turned out that this algorithm would be applicable to the whole troposphere without smaller optical thickness nor smaller effective droplet size conditions. Consequently, this study will expand to global analyses and be anticipated to contribute to surface radiation budget studies in terms of cloud optical, microphysical, and geometrical properties.

6362-18, Session 4

Recent field campaigns with CERES instruments

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CERES instruments on board the Terra and Aqua satellites have been used in various field campaigns since their respective launches in 2000 and 2002. The major objective of these campaigns is to increase sampling of radiation of specified Earth targets or sampling in a prescribed azimuth direction. This goal is accomplished by putting the CERES instruments in a programmable azimuth plane scan (PAPS) mode as a satellite flies over an Earth’s target.

Health of CERES instruments and consistency of their measurements have been closely monitored since the beginning of their mission. Various analyses show a small drift in the consistency of their measurements in order of 0.2% a year. This drift is continuously corrected, however, its cause is still under investigation. It appears to be a correlation between the drift and exposing scanners to scanning in a forward direction. Therefore, an effort is made to avoid ram directions to determine their effect on the instruments’ stability. The ongoing investigation puts restrictions on scanning modes including the PAPS.

The presentation will provide an overview of the CERES instruments’ current (2006) field campaigns under new restrictive scan rules. The main objective of these campaigns is to provide Earth’s radiation budget data for cross-referencing with the GERB (Geostationary Earth Radiation Budget) instrument. The talk will discuss CERES participation in (a) SCALES, or the GERB ground validation campaign over the Valencia Anchor Station, (b) CERES/GERB comparison campaign during the summer solstice, and (c) AMMA/RADAGAST or radiative divergence using ground stations in Africa

6362-20, Session 4

Atmospheric heat budget estimated from Aqua satellite

T. A. Fan, B. Lin, NASA Langley Research Ctr. (USA)

Cloud distributions and their effect on atmospheric heat budgets are very variable for different cloud types and regions. This study classifies clouds into nine types (deep convection, cirrostratus, cirrus, nimbostratus, altostratus, altocumulus, stratus, stratcumulus, and cumulus) based on cloud top pressure and optical depth as defined in the International Satellite Cloud Climatology Project (ISCCP). The statistics of radiative and latent heat fluxes for these nine cloud types are compared. Terra and Aqua satellites fly on sun synchronizing orbits with equator crossing times 10:30 AM and 1:30 PM, respectively. Data from MODIS and CERES instruments on board these satellites are collocated based on the CERES footprints for March 2005. MODIS measured narrow band radiations are used to retrieve cloud properties, and CERES broad band data provide radiative flux estimates at both top of atmosphere (TOA) and surface. The TOA CERES observations include reflected shortwave (SW) and outgoing longwave (LW) radiative fluxes, while at surface, we have both downward and net SW and LW radiation. The atmospheric radiative fluxes (RADI) are, then, calculated from the TOA and surface estimates. The latent heat

component of the atmospheric heat budget is estimated from rainfall amounts. Finally, the total atmosphere heat (TOTAL) fluxes are the sum of RADI and latent heat fluxes. Combined Terra and Aqua observations show that although higher and thicker clouds allow less solar radiation into the earth's climate systems and are infrequent, they retain significant amounts of radiative energy in the atmosphere, and are the major contributor of latent heat fluxes. Since most convective clouds are over tropical area, the TOTAL are generally positive in these latitudes. Negative values are found in all rest areas. The global mean of atmospheric heat fluxes is about -11W/m^2. The outoff balance in the atmospheric heat fluxes is basically caused by the sensible heat from surface to the atmosphere and the latent heat release of warm light rains. We have not included these two heat terms in current study. Further details about the influence of different cloud types for the atmospheric total heat budget will be discussed in our presentation.

6362-21, Session 4

Improvement of the FRESCO O2 A-band cloud retrieval algorithm for GOME and SCIAMACHY

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GOME on ERS-2 and SCIAMACHY on ENVISAT are two UV/visible spectrometers with spectral resolution about 0.2-0.4 nm. SCIAMACHY also has near Infrared channels. GOME and SCIAMACHY are widely used in atmospheric composition studies. However with GOME and SCIAMACHY we have an unique opportunity for an independent measurement of clouds, namely via the absorption of oxygen. Since oxygen is a well-mixed gas, the reflectance in and around the oxygen A-band is a direct measurement of the amount and altitude of clouds. FRESCO (Fast Retrieval Scheme for Clouds from the Oxygen A-band) cloud algorithm retrieves cloud top pressure and effective cloud fraction by simulating the measured reflectance at TOA from 758-766 nm. Until now in FRESCO only O2 absorptions are considered in the reflectance simulation. The reflectances are pre-calculated, and stored as a look up table. The FRESCO products are mainly used in the cloud correction for trace gas retrievals from GOME and SCIAMACHY measurements. Recent work also shows the possibility to perform climate studies using FRESCO cloud products. We present an improvement of the FRESCO cloud algorithm by adding the single Rayleigh scattering in the reflectance database and the retrieval. The reflectances are calculated using the latest HITRAN 2004 database and the line-by-line calculations are also improved. The new reflectance database has been compared with multiple scattering radiative transfer simulations with the DAK model (Doubling Adding KNMI). We have tested the new FRESCO algorithm with SCIAMACHY measurements. In the new version of FRESCO the change in the effective cloud fraction is smaller than 0.05. The main improvement is in the cloud top pressure for less cloudy pixels.

6362-22, Session 5

A data-driven coupled non-LTE radiation transfer and ionospheric plasma model for studying the E-region response to solar-geomagnetic storms

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Observations of thermospheric infrared emission from the TIMED-SABER instrument have fostered development of new data products, models, and analysis tools for the study of upper atmospheric and ionospheric response to solar-geomagnetic disturbances. The focus of this paper is on analyzing SABER 4.3 um limb emission measurements to study the E-region response to solar-geomagnetic storms. Enhancements in nighttime 4.3 um emission during storm periods are due vibrational excitation of NO+, caused by auroral electron dosing and subsequent ion-neutral chemical reactions, followed by prompt emission at 4.3 um. Since the E-region is largely inaccessible to observation, especially on a global scale, SABER measurements provide a novel dataset for analyzing E-region chemistry and energetics. The CO2 contribution to 4.3 um is subtracted from the SABER 4.3 um measured radiance in order to derive NO+ volume emission rates (VER), which is an excellent proxy for analyzing the E-region response to solar storms. NO+ 4.3 um VER is derived using SABER-retrieved temperature and density and the SABER non-LTE CO2 model and radiative transfer algorithms. Indirect auroral effects on CO2 4.3 um radiation transfer are modeled by coupling output from the field-line interhemispheric plasma (FLIP) model with the non-LTE CO2 model. FLIP simulations needed in this study are production rates of vibrationally excited N2 due to chemical reactions and inelastic electron collisions. FLIP is dynamically driven in the D- and E-region by SABER temperature and density data and auroral electron energy characteristics measured by the NOAA/POES satellite. Storm periods analyzed are April 2002 and October-November 2003.

6362-25, Session 5

Signatures of mesospheric fronts

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We review the signatures of mesospheric fronts, as seen primarily in CCD airglow imagers, and show that an important class of fronts known as mesospheric bores corresponds to nonlinear wave excitations on internal-gravity-wave ducts. These are analogous to channel bores seen in estuaries in association with the tide. In the mesosphere, the internal-wave ducts are formed by temperature and wind structure, and the stable wave-ducting region is often associated with a temperature-inversion layer. With a separability assumption valid in the long-wave limit, the solutions of the fluid equations separate into a product of solutions of the Taylor-Goldstein (TG) equation, describing the vertical dependence of the mode function, and of the Benjamin-Davis-Ono-Burgers (BDOB) nonlinear wave equation, describing the horizontal and temporal behavior of the front. We discuss the bore signatures in terms of the TG modes and the BDOB solutions. We show that the bores are primarily phase fronts rather than fluid motions, can be either undular or turbulent ("foaming"), and can break up into a string of solitons. We also compare the numerical wave-equation predictions with airglow observations of mesospheric fronts.

6362-54, Session 5

Global measurements and modeling of 4.3 um NLTE using AIRS

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The Atmospheric Infrared Sounder (AIRS) has been operating since Sept.2002 and is being used operationally by several weather centers. Routine retrieval processing is done by NASA. Daytime AIRS measurements in the 4.3um region show large (upto 12 K) brightness temperature shifts compared to nighttime observations. The daytime shifts result from the preferential absorption of solar radiance in the upper atmosphere by CO2 and othermolecules. This energy is transferred to many of the 4 um CO2 bands, driving them into a state of Non-Local Thermodynamic Equilibrium (NLTE). We presentcomparisons of observations against the results of a Fast Model we developed for the AIRS instrument, that includes this effect. This algorithm is fast enough to be used for retrievals, and will be especially useful for the 4.3um R branch head channels that are used for temperature sounding.

6362-56, Session 5

Radio holographic studying internal waves in the atmosphere on a global scale

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We show that high-precision signals emitted by Global Positioning navigational System (GPS) satellites can be applied for remote sensing of the internal wave in the atmosphere with a global coverage. We use a new radio holographic technique to locate the layered structures in the atmosphere based on simultaneous observations of radio wave temporal intensity and phase variations in satellite-to-satellite links. The cornerstone of this method consists in combination of the amplitude and phase variations of GPS occultation signal. A new technique was applied to measurements provided during CHAllenging Minisatellite Payload (CHAMP) radio occultation (RO) mission. We establish the atmospheric

origin of the amplitude and phase variations in RO signal at the altitudes 10 - 26 km. We observed in the first time in the RO practice examples of the internal wave breaking at the altitudes between 38 and 50 km. We obtained the geographical distributions and seasonal dependence of the atmospheric wave kinetic and potential energy at different altitudes with global coverage for period 2001 - 2003 years and revealed an asymmetry in distribution of the wave activity at the 12 km level in the atmosphere. The maximal wave activity occurs in the summer polar region. At the 14 - 16 km levels the wave activity is centered in the moderate latitudes both in the Northern and Southern Hemisphere. At 18 and 20 km levels, most of the internal wave's activity is concentrated in the equatorial areas. The local seasonal dependences are clear for some regions, e.g. Siberia at the height of 14 km in the winter, with a low wave activity and a high wave activity in the summer.

6362-75, Session 5

A microwave radiometer for the remote sensing of nitric oxide and ozone in the middle atmosphere

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Nitric oxide, which reacts catalytically to destroy ozone, can be produced in great abundance in the middle atmosphere during energetic particle precipitation triggered by solar storms. During the Antarctic winter, the strong polar vortex can rapidly transport the nitric oxide downward, and this process has been identified as a mechanism that can link ozone recovery in the upper stratosphere with solar activity. As part of the Sun Earth Connection programme at the British Antarctic Survey, a new microwave radiometer is being developed to simultaneously measure profiles of ozone and nitric oxide between 30 and 80 km deep within the Antarctic polar vortex. Operating near 250.8 GHz, the semi-autonomous instrument will be coupled to moderate- and high-resolution chirp spectrometers to provide simultaneous spectra of the nitric oxide ant ozone in separate sidebands. In addition, a second local oscillator will be used to periodically examine carbon monoxide at 230.538 GHz to infer the vertical descent rate within the Antarctic vortex. The science goals of the programme will be discussed, and a description of the instrument and projected performance will be presented.

6362-26, Session 6

Lidar mixing height determination during Helsinki testbed

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Helsinki Testbed is a research project of mesoscale meteorology running from January 2005 till September 2007. Six commercial lidar ceilometers situated in and around Helsinki, Finland are involved in this measuring campaign. The enhanced single lens optical concept of these Vaisala CL31 ceilometers improves the ability to investigate surface inversions in the lowest 100 m of the atmosphere. Attenuated backscatter profiles report interval for the Helsinki Testbed campaign has been set to 16 s, range resolution is 10 m. Wind and temperature profiles from a wind profiler with RASS option and from regular radiosoundings at two different sites are available for comparisons. Two different methods of mixing height assessment have been applied, a gradient method and the idealized backscatter method introduced by the Finnish Meteorological Institute (FMI) that fits ideal attenuated backscatter profiles with variable entrainment zones to measured profiles. Results from evaluation of data collected during a period of several months of unattended operation will be presented with special focus on the advantages and limitations of each method. At one of the six sites additional ceilometers of the same type are installed, differences in the reported mixing heights will be investigated. The measurement set-up enables studies of the influences of local weather on the diurnal boundary layer evolution in different places of an urban environment. Additionally, variations in aerosol density and its dependency on wind and other parameters will be studied.

6362-29, Session 6

Determination of mixing layer height from ceilometer backscatter profiles

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A method is developed for the automatic determination of mixing layer height (MLH) from backscatter profiles of the Vaisala-Impulsphysik LD-40 ceilometer. This eye-safe instrument is able to detect aerosol backscatter within the boundary layer continuously. We present the results of a Wavelet method and a gradient/variance combined method for MLH determination.

This work is carried out in order to monitor characteristics of the MLH and its spatial and temporal variation in The Netherlands for a planned observational period of 1.5 years. Mixing layer height is one of the key parameters in tracing the sources and sinks of green house gases by inverse modeling. This research is carried out in the framework of the Dutch BSIK program "Climate for Space" which focuses on the effects of climate change.

An evaluation of the algorithm is performed by comparison with MLH estimations from radiosonde data, as well as from wind profiler observations. Furthermore, results have been compared with MLH derived by the research lidar of RIVM (National Institute for Public Health and the Environment). An analysis of mixing layer heights determined for a six year data set for De Bilt gives satisfactory results with respect to availability and quality as can be inferred from the diurnal and seasonal cycle.

Problems arise in case of multiple strong developed layers, which makes the choice for the correct mixing layer top ambiguous. These multiple layers, for example caused by advection, easily confuse the algorithm in the detection of MLH. In addition, mixing layers that are not very well pronounced in terms of aerosol backscatter are the main cause of outliers in MLH time series. A quality control procedure is considered to identify these situations.

6362-30, Session 6

Observation of clouds on MIRAI in the Pacific Ocean with the millimeter-wave FM-CW radar at 95 GHz

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It is getting more important to know the global environment and the global change of climate for the human beings. It is necessary to know balance of solar energy coming to the Earth and cycle of water for the comprehension. One of the most significant features to know them is cloud. Information on 3-dimensional structures of clouds, sizes and distribution of cloud particles, and so on are desirable to solve role of clouds. Observations of clouds with radars in millimeter waves would be most powerful method to derive three dimension informations of clouds than other methods. We have designed and developed a cloud profiling FM-CW radar at 95GHz at Chiba University. Developed radar is stable enough and can detect clouds that have around -35 dBZ at afound 5 km height. Using the developed millimeter-wave FM-CW radar, we observed clouds on Mirai, a Japanese scientific research vessel, in 2004 and 2005 in the wide area in the Pacific Ocean: in the Bering Sea and the Arctic Ocean, and the west and north Pacific Ocean. The radar provided good and sensitive data in theses long-term observations. Height distribution of clouds shows strong dependence on the latitude. Global characteristics of clouds are presented with obtained data on the cruises.

6362-31, Session 6

Automated backscatter lidar for PBL and troposphere measurements: experience from one-year operation

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We report a summary of the experience and selected results from one-year unattended operation of an automatic backscatter lidar. The lidar is realised as optimal for measurements at altitudes of Planetary Boundary Layer (PBL) and the troposphere. Such lidar has been developed and tested to answer the necessity for operation at remote sites an/or during atmospheric measurement campaigns. During the one-year of test operation, the lidar was remotely controlled via Internet, including also the data transfer. Here we present examples of lidar measurements of daily cycles of PBL development. In these examples the lidar measurements in selected time intervals are compared with the visual control of the synoptic situation documented by automatic camera, as well as with variation of meteorological parameters. We also present a statistics of the mixed layer height determination, obtained during the

one-year observation period. The results are presented and discussed in view of the application of the automatic lidar for long-term operation, as part of aerosol lidar network.

6362-58, Session 6

Polarization lidar for identifying aerosol type

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Polarization lidar techniques have the unique ability to discriminate between spherical and nonspherical particles, and thus determine unambiguously cloud thermodynamic phase. In addition, there is increasing evidence showing that laser backscatter depolarization is useful for identifying the type of aerosols suspended in the atmosphere because of its sensitivity to exact particle shape. This skill is particularly important in assessing the radiative impact of aerosols, and their indirect effect on clouds. We will describe current research at the Arctic Facility for Atmospheric Remote Sensing (AFARS) involving three polarization lidars (0.532, 0.693, 1.06, and 1.574 um wavelengths) to study clouds, aerosols, and their interactions. Whereas spherical aerosols (e.g., haze and most smoke particles),produce no depolarization, nonspherical particles can generate considerable depolarization depending on the exact particle shape and size (relative to the incident wavelength). Examples will be given of the depolarizing properties of layers of forest fire smoke, artic haze, volcanic dust, transported Asian dust, and tree pollen. Those aerosols most likely to affect many cloud properties have dimensions similar to lidar wavelengths, indicating that multiple-wavelength depolarization measurements are especially significant. Such data combined with Raman or High Spectral Resolution Lidar methods are very promising for characterizing the type and size of atmospheric aerosols.

6362-13, Session 7

Parametric model for determination of UVB irradiance versus cloud planar distribution

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Through a significant number of communications, we showed our interest for the determination of cloud planar and spatial distribution. This model is based on the knowledge of the cloud spatial distribution around the solar spot, the horizontal visibility and the total ozone column column value. The activity presented in this communication is an intermediate step prior to the retrieval of UVB irradiance versus cloud spatial distribution.

6362-33, Session 7

Influence of surface reflectivity on radiation in the Antarctic environment

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We demonstrate the importance of surface reflectivity for the radiation field in polar regions by a combination of measurements and radiative transfer calculations. Results from measurements of spectral albedo, radiance and irradiance from 280 to 1050 nm at German Neumayer Station in Antarctica in summer 2003/2004 as well as measurements of UV irradiance during summer 1997/1998 at Australian Davis Station, Antarctica are presented. The impact of surface albedo inhomogeneity is investigated by 3-D Monte Carlo modelling. We found that high surface reflectivity in the ultraviolet and visible parts of the spectrum due to the snow covered surface in Antarctica modifies the radiation field considerably compared to mid-latitudes. A change of the spectral reflectivity, which happens as a consequence of climate change will have a large impact in the radiation properties in polar regions and vice versa.

6362-34, Session 7

International intercomparison of multiband filter radiometers in Oslo 2005

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Multiband filter radiometers (MBFR) are extensively used in national networks for UV climate monitoring and information to the public about the potential risk of solar UV exposure. In order to provide an international, uniform expression of the Global UV index measurements, a harmonized calibration scale is needed. In this paper we present the results of the first international intercomparison of MBFRs held in Oslo in 2005. The purposes are to evaluate the UV-index scale of different instruments and to provide a harmonized UV-index scale based on the instruments individual directional and absolute spectral response functions. In total 43 MBFR instruments and 4 high accuracy spectroradiometers were assembled, representing UV-monitoring networks operated by institutions in US, Spain, Greece, Poland, Belgium, UK, Austria, Norway, Sweden and Finland. The instruments are operating worldwide, with stations in the Antarctica and Arctic, North- and South-America, Africa, Europe, Middle-East and Nepal. The weather conditions were highly variable during most of the core time of global sky measurements, but one day had almost perfect clear sky conditions. All kinds of sky conditions were thus realised, which enable us to study the agreement in measurements for all realistic weather conditions. All the objectives planned for the intercomparison were fulfilled and the campaign worked out successfully.

6362-35, Session 7

Long-term evaluation of the calibration of YES UVB-1 broadband radiometers of the Central UV Calibration Facility (1994-2005) and the USDA UV Monitoring Network

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A long-term calibration history is presented for the three reference YES UVB1 radiometers of the U.S. Central UV Calibration Facility (CUCF) at the National Oceanic and Atmospheric Administration (NOAA) of the Earth Systems Laboratory (ESRL). The three YES UVB-1 broadband radiometers have operated in the field at the CUCF's Table Mountain Test Facility (TMTF) since 1994. These three reference broadband radiometers are run simultaneously against a reference U111 Spectroradiometer developed by Atmospheric Science Research Center (ASRC) at SUNY since 1999. The temporal stability of the erythema calibration factors of the CUCF reference YES UVB-1 radiometers will be shown under clear skies. Erythemally weighted irradiance from the U111 spectoradiometer will be compared to erythema measured by the CUCF reference YES radiometers for the year 2005 under a variety of atmospheric conditions. The USDA UV Monitoring Program has 46 UV broadband radiometers that are characterized and calibrated approximately once per year by the CUCF since 1997. The UVB broadband radiometers are characterized for changes in the spectral and cosine response in the laboratory. The average annual changes in the calibration is presented for the 46 USDA YES UVB broadband radiometers.

6362-36, Session 7

Methodology for calibrating UVB-1 broadband radiometers at El Arenosillo laboratory

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The recent increase in the ultraviolet radiation that reaches the ground, mainly due to the decrease in stratospheric ozone, demands high quality measurements over the world. For this goal the use of broadband instruments to measure erythemaly-weighted irradiance is widely extended due to their low cost and easy maintenance and use. Nevertheless considerable efforts in quality assurance and quality control (QA/QC) are requiredin order to obtain a homogenised eryhtemal radiation from different regional and national networks over whole Europe. The laboratories which provide the calibration to these networks must guarantee reliable methodologies. For this purpose, the WG4 (Quality Control) within the COST-726 European action (Long term changes and climatology of the UV radiation over Europe) is promoting the inter-laboratory intercomparison and the adoption of common procedures. In this work the procedures for calibrating broadband radiometers adopted by the laboratory "El Arenosillo" in Huelva, Spain, are presented. Firstly, this methodology is validated by a UVB-1 biometer calibration intercomparison with the ECUV (European Reference Centre for Ultraviolet Radiation Measurements) at the JRC (Joint Research Centre in Ispra, Italy). The activities of ECUV have been recently moved to the PMOD/WRC (World Radiation Centre) in Davos (Switzerland), through a collaboration agreement with the JRC-Ispra. Additionally the cosine correction for the Brewer spectrophotometer operatively working at the "El Arenosillo" is presented and validated against the instrument used as reference for the QASUME project (Quality Assurance of Spectral Ultraviolet Measurements in Europe).

6362-37, Session 7

Quality considerations on ground based measurements of global radiation to be used for modeling UV radiation

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'Norwegian Institute of agricultural and environmental research' is the owner of a network of agro meteorological stations, established in 1987. About 45 of the stations are measuring global radiation, hourly values of this parameter. These time series of measurements are to be used as one of the input parameters for modelling UV-radiation.

A discussion on quality of these data contains general conceptual considerations on the concept of quality, specific considerations on the methods for making measurements at the specific series from a few sites as well as specific quality considerations on several other available time series of meteorological parameters, like the albedo, precipitation, relative humidity of the air, temperature of the air etc. from the sites, relevant to be used in models.

Some elements connected to the description of the chosen sites are mentioned, like information on the horizon of the sites, the geographical coordinates, the ground cover etc.

The availability of independent time series of measurements of ozone, cloudiness, precipitation(measurements by weather radar), content of aerosol and the vertical distributions of humidity to be used in models is also shortly discussed.

6362-38, Session 7

Ship-borne measurements of UV irradiance on a north-south Atlantic transect

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Ship-borne measurements of spectral as well as biologically effective UV irradiance have been performed on the German research vessel Polarstern during the Atlantic transect from Bremerhaven, Germany, to Cape Town, South Africa, from 13 October to 17 November 2005. Such measurements are required to study UV effects on marine organisms. They are also necessary to validate satellite-derived surface UV irradiance.

Cloud free radiative transfer calculations support the investigation of this latitudinal dependence. Input parameters, such as total ozone column and aerosol optical depth have been measured on board as well. Using these measured parameters, the modelled cloudless noontime UVA irradiance (320-400 nm) shows the expected dependence on varying minimum solar zenith angles (SZA) at different latitudes. The modelled cloudless noontime UVB irradiance (290-320 nm) does not show this clear dependence on SZA due to the strong influence of ozone absorption in this spectral range.

The maximum daily dose of erythemal irradiance with 5420 J/m(c)˜ was observed on 14 November 2005, when the ship was in the tropical Atlantic south of the equator. The expected UV maximum should have been observed with the Sun in the zenith during local noon (11 November). Stratiform clouds reduced the dose to 3835 J/m(c)˜. In comparison, the daily erythemal doses in the mid-latitudinal Bay of Biscay only reached values between 410 and 980 J/m(c)˜ depending on cloud conditions. The deviation in daily erythemal dose derived from different instruments is around 5%. The feasibility to perform ship-borne measurements of spectral UV irradiance is demonstrated.

6362-39, Session 7

Validation of ozone and aerosol retrieval methods with UV rotating shadowband spectroradiometer (RSS)

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The data from the Rotating Shadownband Spetroradiometr UV-RSS deployed at Table Mountain, Boulder Colorado since June 2003 are used to retrieve ozone column and aerosol Angstrom coefficients in the 290nm-380nm range. The retrievals are performed from Langley regression and from direct normal instantaneous irradiance measurements. The results from retrievals are used to verify assumption on ozone absorption cross-sections and ozone vertical profiles. A comparison between UV-RSS retrievals and those from the collocated instruments like UV-MFRSR, Dobson and ozone sondes and TOMS is performed.

6362-40, Session 8

Use of the visibility in the radiation transfer modeling in UV range

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One of the main goals of COST Action 726 is to estimate the UV climatology over Europe on the base of the reconstructed UV radiation. To achieve this, the past values of the input parameters for the reconstruction models should be known. Among these parameters there are optical properties of atmospheric aerosols. In the absence of ground measurements of the aerosols the meteorological parameters might be used to describe aerosols in radiative transfer modelling.

The paper presents the results of the work aimed at the application of visibility (meteorological visual range) data for UV modelling in Poland for summer season. In the first step, the meteorological visibility data were processed in order to obtain the monthly mean visibility maps that correspond to aerosols distribution over Poland. The usefulness of such maps was then validated through the comparison with AERONET data as well as the results of the UV radiation transfer model calculations.

The comparison with AERONET data shows that monthly mean values of aerosol optical depth, calculated from visibility data, are in a good agreement with ground measurements for most summer months.

The monthly mean visibility maps were then used in the UV radiation transfer modelling. The results of the comparative analysis performed for three Polish stations: Leba, Legionowo, Zakopane are presented and discussed.

It has been shown that use of monthly mean visibility values leads to an improvement in the UV calculations quality as opposed to the calculations done with a priori assumed aerosol conditions.

6362-41, Session 8

UV climatology from quality controlled ground-based spectral UV-measurements

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Solar spectral UV-monitoring data for 8 European sites with at least 5-10 years of data, and covering a latitudinal range from 41 degrees North to 67 North have been re-evaluated and resubmitted to the European UV-

database (EUVDB) in Finland as part of the EU-project

SCOUT-O3. All 420000 spectra from these sites were quality flagged, checked and corrected with respect to wavelength scale errors and spectral distortions using the SHICrivm software package. Additional data products provided by the SHIC-software are standardized spectra, spectral atmospheric transmissions, and biologically weighted UV-irradiances for a wide variety of biological action spectra (erythema, DNA-damage, vitamin-D etc). The resubmitted spectra were shown to have improved on the basis of the EUVDB quality flagging criteria. Spectral and effective irradiances were integrated and summed in a standardized way to obtain daily, monthly and yearly UV-doses. The full data set is used to analyze the daily, monthly and yearly variability in UV-doses received at the ground. Using co-located ozone and pyranometer measurements results of a generic UV-modelling approach, derived in a specific low albedo and low surface elevation environment, are systematically compared to the UV-doses obtained for all sites. Agreements and deviations with respect to the application in a high surface albedo and high altitude environment will be evaluated addressing the impact of the solar zenith angle, height, ground albedo, clouds and atmospheric downward reflection and there interplay.

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6362-42, Session 8

Modeling solar UV radiation in the past: comparison of algorithms and input data

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The variation of UV irradiance during the last decades is of interest for skin cancer development and other long time studies of UV effects. Thus, a UV-climatology for Europe with high spatial and temporal resolution is the goal of COST 726. Due to the lack of measured solar UV irradiance such a climatology must be modelled and the models should take into account the variation of all relevant parameters, i.e. ozone, cloudiness, aerosol properties and surface albedo.

In COST 726 we have explored the availability of algorithms and their required input parameters as well as the availability of these parameters. Thirteen models have been compared on the basis of measured and modelled daily UV dose for 2 years at 4 stations: Bergen, Potsdam, Davos and Thessaloniki. Cloud effects have been modelled using cloudiness, sunshine duration, solar irradiance and transmittance for solar radiation. Aerosol effects have been modelled using climatic values, visibility and boundary layer height. Albedo effects have been modelled using different snow parameters.

Results of the comparison will be illustrated using various statistical quantities.

Details of some of the algorithms will be discussed in other papers during the conference.

6362-43, Session 8

Year-to-year variations of the vitamin D synthesis related UV-B radiation in Estonia in autumn and spring

K. Eerme, U. Veismann, I. Ansko, S. Lätt, Tartu Observatory (Estonia)

The period when the incident UV-B irradiance remains below the threshold of vitamin D synthesis in human skin lasts approximately from the first days of November through the middle of February at the Tartu-Tõravere Meteorological Station (58o.16'N, 26o.28'E, 70 m a.s.l.). As a threshold level we have used 1 mWm-2nm-1 at the wavelength 306 nm supposing an invariable shape of spectra at shorter wavelengths. Before and after the "vitamin D winter" the availability of UV-B irradiance also manifests significant year-to-year variations depending on cloudiness and total ozone. The availability of the UV-B radiation above the threshold of biologically active dose (BED) at 306 nm has been studied for the time intervals from the autumnal to start of the "vitamin D winter" and from its end to the vernal equinox. The exposures above a threshold have been integrated for both intervals. The statistical relationships between the UV-B at 306 nm, direct broadband irradiance and total ozone have been derived to reconstruct the BED for the years before the beginning of direct measurements in the UV-B region.

The range of variance of broadband direct irradiance during both periods is about 40-180 % relative to the average with standard deviation exceeding 30 %. No systematic trend has been found in autumnal period. During the period 1988-1995 late winters have occurred systematically darker and milder than average.

Attenuation by clouds of the UV-B (306 nm), erythemal and broadband irradiance is compared during the period from the vernal equinox to the autumnal equinox.

6362-44, Session 8

Long-term erythemal UV at Abisko and Helsinki estimated using total ozone, sunshine duration, and snow depth

A. V. Lindfors, Finnish Meteorological Institute (Finland); B. Holmgren, The Royal Swedish Academy of Sciences (Sweden); G. H. Hansen, Norwegian Institute for Air Research (Norway)

Recently, a method has been presented for estimating past doses of ultraviolet radiation using total ozone column, sunshine duration and snow depth as input. The method enables UV estimates to be made for several decades back in time. So far, it has been applied to Sodankylä (northern Finland) and Davos (Switzerland), where daily erythemally weighted UV doses were estimated back to 1950 and 1926, respectively. In this paper we apply the method to Abisko (northern Sweden), and Helsinki (southern Finland). Both stations hold long records of sunshine duration and snow depth measurements that are used, together with measurements and climatological values of the total ozone column, to study the variations in the UV radiation levels since the early 20th century. This paper presents the time series of estimated UV for these two stations, and discusses the factors contributing to the changes seen in the UV levels over the years.

6362-45, Session 8

On UV climatology in Belgium from ground-based and space measurements

D. J. Gillotay, D. Bolsee, C. Depiesse, Belgian Institute for Space Aeronomy (Belgium)

Since the end of the 80's, the Belgium Institute for Space Aeronomy (IASB) has developed automatic stations to measure continuously the UV (UV-B & UV-A) - Visible Solar irradiance (280-600 nm) at the Earth's surface. Three stations are presently operational in Belgium.

The IASB stations consist in a combination of instruments including spectro-radiometers, filter-radiometers and broadband radiometers providing absolute values of the total, direct and diffuse components of the Solar irradiance.

These data are linked with O^3 and SO^2 total column determinations, ozone profiles, aerosol contents, and ancillary measurements as meteorological conditions, cloud cover, cloud ceiling and type.

From this 18-years period of continuous measurements, it is possible to define the major characteristics of the UV climatology in Belgium and by extension in the 50°-latitude area.

The major results will be presented and discussed in terms of correlation between the UV-B irradiances and the main atmospheric parameters like Ozone, SO^2, Clouds cover, Aerosols...

Ground based measurements will be compared with satellite data (mainly from TOMS and GOME). Potential trends will also be discussed.

6362-46, Session 9

Modeling natural surface UV radiation with satellite data: examples of applications

J. Verdebout, European Commission (Italy)

The method for modelling surface UV radiation basically consists in using a standard radiative transfer code (UVspec) and in exploiting various sources of information to assign values to the parameters influencing the surface UV radiation. GOME, TOMS or TOVS data are used for the total column ozone. The tropospheric aerosols are taken into account by using observations at ground meteorological stations and the surface altitude by means of a digital elevation model. METEOSAT or MSG is used to derive cloud optical thickness and surface UV albedo. In this way, a climatological data set of erythemal daily doses over Europe, starting in January 1984 has been generated. The possibility of providing the UV information in principle anywhere and anytime has been and is exploited in impact studies. For example, the modelled UV data have supported a study on the influence of UV on the codfish population strength in the northern Atlantic (UVAC project). At JRC, the method is used in a human UV exposure model to estimate doses received by an individual, according to his/her activities and behaviour. Data were delivered to external partners to support other impact studies such as UV effects on crop yield, exposure of schoolchildren or vitamin D deficiency assessments. Results were also compared with ground measurements at a number of stations and included in studies of local UV conditions. With direct MSG data acquisition, a version of the processor was developed to generate near-real time UV index maps over Europe.

6362-47, Session 9

On the use of quantitative diurnal cloud information for the calculation of UV daily dose maps over Europe

M. van Weele, R. van der A, R. Roebeling, Koninklijk Nederlands Meteorologisch Instituut (Netherlands)

The UV daily dose is the integral over the day of the UV irradiance incident at the Earth surface. It is typically expressed in kilojoules per square meter. Since this year at KNMI the UV daily dose is mapped quasi-operationally over Europe using spaceborne observations, and taking into account the spatiotemporal variations in the ozone and cloud distributions. Currently the UV daily dose is presented on maps at a latitude/longitude grid with cells measuring 0.5 by 0.5 degrees. The UV dose map over Europe for yesterday is calculated from daily 3D analyses of the ozone field at local solar noon and half-hourly 2D fields of cloud optical depths. The 3D ozone analysis is obtained by assimilation of total ozone column data from Sciamachy onboard Envisat in a 3D global chemical-transport model driven by ECMWF analysed wind fields. The half-hourly cloud optical depths are obtained in near-real time from cloud retrievals using Meteosat-8 radiance observations.

The presented UV doses are weighted with the erythema (reddening of skin) action spectrum. The algorithm that is used applies a functional relation between the erythemal UV index, the local solar noon ozone fields and the solar zenith angle at local solar noon, as well as a simple functional relation between cloud transmission, solar zenith angle and cloud optical depth. Three additional corrections are applied to further improve the UV dose estimates include a correction for the varying Earth-Sun distance, a correction for the elevation and a correction for ground albedo. Because of as yet lacking near-real time availability of spaceborne aerosol observations the spatiotemporal variations in aerosol amount and composition are still neglected, except for a zero-order climatological correction. Besides the UV monitoring activities KNMI also provides a UV forecasting service based on Sciamachy total ozone data. Global clear-sky UV index forecast are made available up to nine days ahead.

6362-48, Session 9

The UV service of the ESA-GSE Project PROMOTE

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In Europe about half a million skin cancer cases are occuring per year and this is strongly associated with personal habits in relation to sun exposure and its UV component. Within the frame of the European GMES-Program the ESA-GSE Project PROMOTE addresses this problem by developing and implementing a UV information service that aims to reach as many as possible citizens of Europe (EU25). The overall PROMOTE UV service contains a forecast and a monitoring service. The underlying methods, the use of satellite data, the various UV products including related user interfaces, as well as validation activities and their results are described. One central ambition of the PROMOTE project is the close interaction between providers and users. Therefore experiences that have been made with user organizations and also the service evaluation on part of the PROMOTE core users and their emerging demands are discussed.

6362-49, Session 9

Requirements for the spatial resolution, temporal resolution, and measuring uncertainties of total ozone measurements to calculate the erythemally effective UV radiation with a pre-selected accuracy

A. W. Schmalwieser, G. Schauberger, Veterinaermedizinische Univ. Wien (Austria); M. Janouch, Czech Hydrometeorological Institute (Czech Republic); T. Erbertseder, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); G. Coetzee, South African Weather Service (South Africa); P. Weihs, Univ. für Bodenkultur Wien (Austria)

In this study we have analysed the sensitivity of the erythemally effective radiation to uncertainties in operationally measured total ozone content of the atmosphere (TOC).These uncertainties result from a restricted spatial resolution, a restricted temporal resolution or the restricted accuracy of measured TOC. Daily operational total ozone measurements from different instruments made over several years were applied. Measurements were gained space born by EPTOMS, ERS-2/GOME and TOVS and from the ground by Dobson and Brewer Spectrophotometers for the locations of Hradec Kralove (Czech Republic, 50°N), a region at 30°N, Nairobi (Kenya, 1°S) and Springbok (Rep. of South Africa, 30°S).

The measurement uncertainties were analyzed by an intercomparison of modeled erythemally effective UV radiation when using different sources of TOC. The evaluation of the uncertainties due to temporal delays was done in using TOC values with different temporal shifts. The influence of spatial gaps in TOC measurements was estimated separately in longitude and latitude up to distances of 1000km around the measuring sites.

From this analysis, requirements on the spatial resolution, temporal resolution and measuring uncertainties of total ozone measurements to calculate the erythemally effective UV radiation with a pre-selected accuracy can be derived in dependence of location and season.

6362-28, Poster Session

905-nm biaxial lidar ceilometer prototype

E. Gregorio López, F. Rocadenbosch, A. Comerón, Univ. Politècnica de Catalunya (Spain)

A 905-nm 5-kHz rep. rate diode-laser biaxial lidar ceilometer (cloud height monitoring) prototype is presented. The prototype uses a low-cost Fresnel lens and a low-NEP avalanche photodiode (APD) optoelectronic receiver. The article presents the opto-mechanical engineering of both the system and main subsystems involved as well as the system energy link budget.

The reception subsystem is based on a low-cost Fresnel-lens telescope and collimating and focusing adjustable parts, which include a rectangular slit diaphragm to minimise background radiance. Equivalent focal length, background radiance rejection gain, confusion circle and imaged spot characteristics onto the photodiode surface are also formulated and discussed by means of a geometrical optics approach.

The emission subsystem uses a beam expander to ensure eye-safety (maximum exposure levels) and ad-hoc mechanics to provide enough degrees of freedom for emission-reception overlap factor (OVF) adjustment. At this point, an overview of future alternative mechanical solutions for enhanced pointing accuracy and trade-offs among different laser diode-based solutions is presented. This part is complemented with OVF simulations of the prototype designed.

Finally, preliminary test measurements at our premises in North Campus (UPC) are introduced as raw and range-corrected processed signals

6362-61, Poster Session

Remote Sensing of Eddy Currents Under Cloud Cover

E. O. Sheybani, G. Javidi, Virginia State Univ. (USA)

With the existence of satellites that operate in the visible EM band and that can be used to accurately measure the ocean surface color one effectively has a color tracer in the ocean. Eddy currents would stir up the water column and can be expected to leave a surface expression of different color where such tracers exist. These color tracers leave strong enough impressions on the image to be recognized beyond cloud cover if appropriate filters are applied. One example of such filters is wavelet decomposition filter. This paper describes the structure of wavelet based decomposition filter and it application in Eddy current detection under cloud cover.

6362-62, Poster Session

Atmospheric particles over an urban area

S. Mukai, I. Sano, Kinki Univ. (Japan)

It is known that synthetic information of atmospheric aerosols and the surface-level particulate matte (SPM) is useful when studying air quality and aerosol properties, especially over an urban area.

Simultaneous measurements of atmospheric aerosols and suspended particulate matter (SPM) have been undertaken at Kinki University campus in Higashi-Osaka, Japan in order to monitor the urban environment during more than two years. The sun/sky photometry has been made as a NASA/AERONET station since 2002, and the SPM-613D (Kimoto Electric) has been taking measurements of the SPM concentrations such as TSP, PM10, PM2.5, and OBC at the same site since March 15, 2004. This long term simultaneous monitoring of aerosols and SPM provides us with typical aerosol types over an industrial city of Higashi-Osaka and the relationship between aerosol properties obtained from radiometry with AERONET and the SPM measurements as:

1. The air quality of the Higashi-Osaka site is poor due to not only anthropogenic particles by local emissions, such as diesel vehicles and chemical industries, but also due to dust particles and biomass-burning aerosols by large scale climatic conditions.

2. Fine anthropogenic particles dominate at Higashi-Osaka even during dust events. It is of interest to mention that dust events at Higashi-Osaka seem to be caused by a mixture of non-absorbing coarse dust and other small haze particles.

3. The value of aerosol optical thickness during aerosol event is more than double its usual value.

4. There is a linear correlation between SPM concentrations and aerosol properties, which indicates that aerosol characteristics can be estimated from SPM data, and vice versa.

5. Strong correlations exists between the PM2.5 concentrations and the fine mode aerosol optical thickness.

6362-63, Poster Session

New inversion algorithm for determination of aerozol microparticles' size distribution

A. I. Bilyi, Ivan Franko National Univ. of L'viv (Ukraine); R. O. Bilyy, National Academy of Sciences of Ukraine (Ukraine); V. B. Getman, Ivan Franko National Univ. of L'viv (Ukraine)

The determination algorithm of aerosol micro particles' size distribution by iteration process is described. In the described method the particle, registered by optoelectronic devices is characterized by parameters of amplitude and duration of impulse. Distribution of particles' size is determined from the measured functional dependence of number of registered particles from amplitude and duration of the proper electric impulses on the output photo receiver. Given dependence, within limits of statistical errors, is repeated when performing measurement series in the medium with identical optical parameters. It is linked by functional dependence to relative particles' fraction of different sizes, which is expressed by first kind integral Freudgolhm equation.

6362-65, Poster Session

Aerosol retrieval based on combination use of POLDER and GLI data

I. Sano, Kinki Univ. (Japan); Y. Okada, Kobe Univ. (Japan); S. Mukai, O. Nakashima, Kinki Univ. (Japan)

Understanding of aerosol climatology is an important issue for Earth's radiation budget. This work proposes a new approach to estimate aerosol properties based on combination use of satellite multi-dataset. In this work, we use the both of POLDER(Polarization and Directionality of Earth Reflectances) and GLI (Global Imager) on Japanese satellite ADEOS-2(Advance Earth Observing Satellite-2), which was operated in 2003. POLDER sensor has such a unique facility as directional polarization measurements with three channels, and GLI provides high-resolution images over the wide range of wavelength from near ultra violet to the thermal infrared. This fact looks promising that combining both sensor data presents effective information of aerosols.

So far aerosol optical thickness and its wavelength tendency have been obtained from POLDER data alone[1]. Our proposed algorithm for aerosol retrieval over the land, in addition to forgoing POLDER oriented procedure, involves following processes as:

1) Cloud screening using GLI and POLDER data.

2) Classification of non-absorbing and absorbing aerosols based on GLI data in the near ultra violet and the violet channels.

Obtained results are evaluated with the ground based sun photometric data such as AERONET.

[1] Sano, I., (2004) : Optical thickness and Angstrom exponent of aerosols over the land and ocean from space-borne polarimetric data, Adv. Space Res., 34(4), pp 833-837.

6362-66, Poster Session

A preliminary study on neural network nonlinear time series analysis of satellite remote sensing of rainstorms

L. Xu, J. Ding, X. Deng, Chengdu Univ. of Information Technology (China)

Rainstorms will cause great or sudden disasters with terrible accidents of human lives and economic society in the world. The knowledge of formation and evolution of rainstorms, and their forecasting are crucial to studies of weather, climate, and environment problems. It is difficult to solve the satellite retrieval problems in cloudy atmospheres with rainstorms using the traditional and classical optical retrieval approach. Therefore, it is imperative and vital important to develop new and modern theory and method for satellite optical remote sensing of severe storms with disasters. Artificial neural networks are a high complex nonlinear dynamical system with powerful signal processing capability and have all demonstrated superior performance in many engineering applications. To overcome the difficulty mentioned, in this paper one of frequently used neural networks, i.e., a radial-based function network (RBFN) with Gaussian activation functions is employed to study the nonlinear time series by carrying out the characterization experiments for GMS-5 satellite 11μm IR observations of rainstorm processes. The proposed methodology mainly uses RBFN to approximate the nonlinear time series signals first; then the characteristics of the weighting functions changed with time are analyzed. The difficulty due to the effects of high noise on the signal processing using neural networks is addressed. Thus, finally a more integrated method combining the neural network analysis with wavelet packet decomposition is introduced. The preliminary results show that the proposed approach for nonlinear time series analysis is efficient and promising.

6362-67, Poster Session

Cloud detection and height estimation through registration of DMC imagery

D. C. Bamber, S. Mackin, P. L. Palmer, Univ. of Surrey (United Kingdom)

For the purposes of detecting clouds over large areas it is necessary to use satellite imagery. Although a variety of techniques for cloud detection and cloud height estimation exist, they often make assumptions concerning the radiometry and spectral coverage available to the sensor payload. This paper explores the use of registration shifts observed between dual-bank single-band image pairs from the DMC multi-spectral imager to detect and estimate the height of clouds.

The Disaster Monitoring Constellation (DMC) comprises a network of five disaster-monitoring micro-satellites that have been built by Surrey Satellite Technology Ltd (SSTL). Each DMC satellite has a multi-spectral imager (MSI) consisting of 2 banks of 3 channels pairs.

The proposed technique uses a narrow angle between imagers to discern altitude and is comparable to stereo imaging but able to distinguish absolute cloud height without reference to the ground surface, using satellite telemetry. The inter-imager geometric distortions are highly susceptible to perturbations in attitude rate. A new technique detailing the extraction and separation of attitude rates and altitude using angularly displaced push-broom sensors is therefore introduced and discussed.

Simulations have shown that with a sub-degree angle between imagers and appropriate sub-pixel level registration scheme, vertical accuracies in the order of a few hundred metres may be extracted alongside arcsecond rate measurements. Preliminary results using phase correlation registration to ensure sub-pixel accuracies between DMC imagery have helped confirm the viability of the technique and will be presented alongside simulations.

6362-68, Poster Session

Polysulphone and spore-film UV-dosimeters compared to two radiation transfer models and an instrument that measures the UV-index: an evaluation for a UV-dosimetry study of preschool children in Stockholm

U. Wester, Swedish Radiation Protection Authority (Sweden)

Measurements of global solar ultraviolet radiation (UV) with two types of dosimeters are compared: polysulphone badges with plastic film that changes its transmission after UV-exposure, and dosimeters which function by UV-induced DNA-damage to dried bacteria spores. The dosimeters agree well and are sufficiently precise. They agree also with data of daily global solar UV by two services (the European Commission´s Joint Research Centre “JRC” and the Swedish Meteorological and Hydrological Institute “SMHI”) which provide maps with radiation transfer (RT) model calculations of UV-exposures on a horizontal surface based on weather and ozone parameters from satellites. For full day exposures the two model calculations agree with each other and with results from a UV-monitoring instrument.

The evaluation of polysulphone film UV-dosimeters and how they compare to bacteria spore dosimeters was desired for a study May 24 - June 9 2004 of preschool children´s UV-exposure. Polysulphone film badges measured UV-exposures of 199 children at eleven daycare centers and how the exposures depend on different physical surrondings and shade structures of playgrounds. At three sites, on roofs or at positions with a free horizon, polysulphone badges in parallell with bacteria spore dosimeters (BioSense, Germany) recorded total global UV-exposure from dawn to dusk on a horizontal surface. The accuracy of the dosimeters has been evaluated by comparing daily global exposures from one of the sites to a solar UV monitoring instrument and from all three sites to data from JRC´s and SMHI´s radiation transfer models.

6362-70, Poster Session

Comparison of cloudiness derived from MSG satellite data with standard surface observations: preliminary results for Poland

B. M. Lapeta, I. Dyras, D. Serafin-Rek, Instytut Meteorologii i Gospodarki Wodnej (Poland); Z. Ustrnul, Instytut Meteorologii i Gospodarki Wodnej (Poland) and Univ. of Silesia (Poland)

The standard surface measurement network (SYNOP) provides detailed however, a very localised information about the cloud cover. On the other hand, the satellite data provide the continuous information on the state of the atmosphere for much larger area.

The recently launched geostationary meteorological satellite METEOSAT-8 with the excellent temporal resolution as well as with well suited spectral channels of SEVIRI instrument is a useful source of the information about cloud cover .

The paper presents the work aimed at the validation of the cloud mask derived from MSG/SEVIRI data with the use of the NWC SAF software. The total cloudiness amount obtained from satellite data for each Polish synoptic station was compared with the simultaneous surface observation. The analysis was performed for three hourly observations.

The preliminary results for the day time conditions show a good coherence of the satellite cloudiness retrieval with ground observations. However, during the night, in snow conditions, the cloudiness is grossly overestimated by the satellite.

The detailed results' discussion will be presented and elaborated taking into account the different conditions of surface cover (snow/no snow) and illumination (day/night).

6362-71, Poster Session

Study on methods of cloud identification and data recovery for MODIS data

X. Wu, Q. Cheng, Zhejiang Gongshang Univ. (China)

MODIS data have great potential in rice growth monitoring and yield estimation due to the low cost and high time resolution. Unfortunately, cloud-free image is quite rare during rice growth period due to cloudy weather. Therefore, cloud contamination is one of the main obstacles in rice growth monitoring and yield estimation using MODIS data. Based on spectral characteristics of cloud, this paper puts forward threshold, infrared difference algorithm, texture, classification and synthetic analysis methods to detect cloud contamination. The result shows that classification and synthetic analysis are the simple and effective methods to detect cloud . After geometric correction, the cloud-free images are obtained through interpolating using time series MODIS data and ratio value using same date data of different year. At last the cloud detection results gained by different ways are testified each other and analyzed by comparison. It found that the results are consistent, which shows that the cloud-contaminate pixels are detected successfully.

6362-72, Poster Session

Influence of cloud layer dynamic in the cloud cover retrieval

T. Besnard, M. Collet, ATMOS (France); C. N. Long, Pacific Northwest National Lab. (USA); L. Berger, ATMOS (France)

In previous communications, we presented basically through numerical simulations specificities of the thermal infrared monitoring of the cloud cover. In the present communication, we will investigate in details influence of the cloud layer dynamic on the cloud/no cloud threshold and on statistical data relative to the pseudo-brightness temperature.

6362-74, Poster Session

Ground-based remote sensing of the atmospheric ozone over Moscow at millimeter waves

S. B. Rozanov, S. V. Solomonov, E. P. Kropotkina, A. N. Ignatyev, A. N. Lukin, P.N. Lebedev Physical Institute (Russia)

Results of regular ground-based measurements of vertical ozone distribution (VOD) in the stratosphere and mesosphere over Moscow region are presented for the last years. The observations were done using low-noise heterodyne spectrometer of the Lebedev Physical Institute (LPI) operating at frequencies of the 142.175 GHz ozone line. Tikhonov's method was used for retrieval the ozone mixing ratio profiles from the experimental spectra.

Previously the LPI spectrometer was incorporated into global networks for ozone measurements during the DYANA (1990), CRISTA/MAHRSI (1994 and 1997), and SOLVE (1999-2000) campaigns.

Both seasonal changes in ozone and more short-term ozone variations with time scales from several days to several weeks were recorded. It was found that the most noticeable changes in the ozone layer occurred in cold seasons. Correlations between ozone content and other parameters of the atmosphere were established for different altitudes. It was shown that the VOD over Moscow is strongly influenced by large-scale atmospheric dynamics. Considerable deformations of the stratospheric ozone profiles were detected in winter months, when both decreased ozone content at altitudes of 25-45 km and local minimum near 30 km were observed many times. Appearance of the secondary (in the lower thermosphere around 90 km) and tertiary (in the mesosphere at altitudes of 55-75 km) maxima in the ozone profiles in night hours, and strong variations in the night ozone at the altitudes were measured. A comparison of the LPI data with results of satellite measurements has shown good coincidence of the ozone profiles obtained from the ground level and from space.

6362-76, Poster Session

Industrial lidar sensor for cloud height and visibility detection

S. Frey, H. Hünninger, H. Wille, JENOPTIK Laser, Optik, Systeme GmbH (Germany); M. Pesch, Technische Univ. Berlin (Germany)

We have developed a laser ceilometer ready for serial production for cloud height and visibility measurements with a maximum range of 15 km and a spatial resolution of 15 m. Laser remote sensing allows for the necessary range finding and precise atmospheric extinction measurements all at once. Emphasis was given to reliable stand alone operation and data evaluation under severe environmental conditions, and operator convenience. Examples of design benchmarks are the simultaneous detection of boundary layer visibility and thin cirrus clouds with an optical depth as low as 0.003 over 500 m in a typical distance of 10 km and eye safe operation. The sensor control and data evaluation algorithms permit unattended continuous measurements and data evaluation under various atmospheric and climatic conditions. An additional post-processing package is available for interactive or automatic data evaluation and presentation.

The Paper will discuss the data evaluation algorithms, error analysis and signification of existent standards, like the German VDI 3786, for cloud height and vertical visibility detection. Data from various comparison measurements between laser ceilometers of the same type, powerful scientific aerosol lidars and radar systems will be presented.

The laser ceilometer is designed to be a reliable, powerful workhorse for users, like weather services, maritime, air traffic and road safety agencies and research institutions in need of continuous automatic monitoring of clouds and visibility, who don't want to be bothered with details of the method, without missing the possibility for the experienced researcher to analyse the accessible raw data.

6362-77, Poster Session

Incorporating weather conditions and various scatterers into volumetric radar clutter

R. I. Kerminen, J. Jylhä, J. V. Vihonen, T. K. Ala-Kleemola, A. J. E. Visa, Tampere Univ. of Technology (Finland)

This paper presents a method for generating volumetric clutter for air surveillance radar simulation. Because radar data has unknown factors, it is problematic for testing purposes. In the presented simulation, radar clutter signal is created from magnitude and phase distribution and then filtered imitating the radar signal formation.

Complex valued radar signal consists of magnitude and phase. Radar geometry can easily be integrated to the simulation by manipulating magnitude, phase, and phase difference matrixes. Magnitude is affected by range bin size and distance from radar. Also weather condition and polarization affect the signal. These can be controlled with adjustments to the distribution the matrix is created from. Both, pulse shape and azimuth beam pattern, are assumed Gaussian.

This solution offers a simple way to create background to realistic radar simulation. Different distributions are used for signal magnitude and phase of various clutter sources. Typically, volumetric clutter source consists of many evenly sized scatterers. Preliminary phase, originating from randomly distributed particles, can be considered evenly distributed. Phase difference in long time, on the other hand, shows the radial movement of particles. Therefore, phase difference can be modeled, for example, with Gaussian distribution and magnitude with Weibull distribution, of course, depending on true environment. As example cases, chaff and rain clutters are simulated in differing weather conditions.

6362-79, Poster Session

Heterodyne detection technique using laser radiation as a possible approach for remotely senses the aerosol back scatter and wind velocity

M. S. Edan, Mekkah Topnotch Institute (Saudi Arabia); Y. M. Fadel, Ibb Univ. (Yemen)

Heterodyne detection can be used as a possible approach for remotely senses the distribution of wind velocity and possible aerosol back scatter sensor. In this research study, the laser heterodyne detection (LHD) technique was comprehensively investigated as an approach for detecting weak signals.

The basic principle depends on mixing two beams to achieve the beating frequency, which impinges on the photo-detector surface. Several parameters affecting the aforementioned; technique were investigated. These parameters are namely;

A: the local oscillator power, which proves to have great effect on increasing the beating frequency efficiency. It's value must be several times greater than the reflected signal from target.

B: Atmospheric attenuation, this parameter proves to have effect on the laser power particularly the humidity influence on CO2 laser beam.

C: The reflectivity of some targets which shows great absorption to the CO2 laser beam.

D: The signal to noise ratio from which conclusions were drawn regarding the comparison between direct & indirect detection efficiency.

A computer controlled laser radar system for measuring target velocities with both CO2 & laser diode were constructed on laboratory scale using a Mercury Cadmium Tellurium & Silicon detectors respectively.

Different moving targets with different velocities were used. Furthermore, Doppler shifts, modulation frequencies & laser wavelengths were transferred to a personal computer. From the previous parameter the personal computer was able to present target velocity. Furthermore, special software and the relevant electronic card (type HP-Gb-Ib designed for spectrum analyzer) were used for noise cancellation and for measuring velocity. A number of laser modulation techniques were investigated and compared to each other to optimizer the Doppler shift

6362-80, Poster Session

A straightforward signal-to-noise ratio estimator for elastic/Raman lidar signals

M. N. Md Reba, F. Rocadenbosch, M. Sicard, Univ. Politècnica de Catalunya (Spain)

In this paper we estimate the signal-to-noise ratio (SNR) at the opto-electronic receiver output of both elastic and Raman lidar channels by means of parametric estimation of the total voltage noise variance affecting the lidar system.

In the most general case, the total noise variance conveys contributions from photo-induced signal-shot, dark-shot and thermal noise components. While photo-inducted signal-shot voltage variance is proportional to the received optical signal (lidar return signal plus background component), dark-shot and thermal noise variance components are not. This is the basis for parametric estimation, in which noise in any receiving channel is characterised by means of a two-component vector modelling equivalent noise parameters.

The algorithm is based on simultaneous low-pass and high-pass filtering of the observable lidar returns and on weighted constrained optimization of the variance noise model when fitting an estimate of the observation noise.

A noise simulator is used to compare different noisy lidar channels (i.e., with different pre-defined noise parameters) with the two-component noise vector estimate retrieved. Both shot-dominant and thermal-dominant noise regimes, as well as a hybrid case are studied. Finally, the algorithm is used to estimate the SNR from lidar returns from tropospheric elastic and Raman channels with satisfactory results.

6362-81, Poster Session

AIRS retrieval validation during the EAQUATE

D. K. Zhou, NASA Langley Research Ctr. (USA); W. L. Smith, Sr., Hampton Univ. (USA) and Univ. of Wisconsin/Madison (USA); V. Cuomo, Istituto di Metodologie per l'Analisi Ambientale (Italy); J. P. Taylor, United Kingdom Meteorological Office (United Kingdom); C. D. Barnet, National Oceanic and Atmospheric Administration (USA); A. M. Larar, X. Liu, NASA Langley Research Ctr. (USA); P. Di Girolamo, Univ. degli Studi della Basilicata (Italy); G. Pappalardo, Istituto di Metodologie per l'Analisi Ambientale (Italy); S. M. Newman, C. Lee, United Kingdom Meteorological Office (United Kingdom); S. A. Mango, National Oceanic and Atmospheric Administration (USA)

The inversion algorithms and retrieved parameters from satellite sounders must be validated to demonstrate the capability and accuracy of both observation and inversion systems. The European AQUA Thermodynamic Experiment (EAQUATE) was conducted mainly for validation of the Atmospheric InfraRed Sounder (AIRS) on the AQUA satellite. Detailed inter-comparisons were conducted and presented using different retrieval

methodologies, measurements from airborne ultraspectral Fourier transform spectrometer, aircraft in-situ, dedicated dropsondes and radiosondes, and ground based Raman Lidar, as well as the European Center for Medium range Weather Forecasting (ECMWF) modeled thermal structures. The outcomes of this study do not only illustrate the quality of the measurements and retrieval products but also demonstrate the capability of these validation systems which are put in place to validate current and future hyperspectral sounding instruments and their scientific products.

6362-84, Poster Session

Analysis of pseudo-noise for IR sounder instruments in geostationary orbit

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Increasing user and service needs in the domain of Numerical Weather Prediction impose an Infrared Sounding (IRS) mission on Meteosat Third Generation (MTG) platforms. A major objective of the IRS mission is to provide a vertical sounding capacity in the vicinity of clouds, above clouds and below semi-transparent clouds. Thus, cloud contamination has to be severely controlled at instrument or at system level.

Pseudo-noise is defined as the measurement error generated by scene heterogeneity. Spectrally correlated, it affects the information content of the vertical sounding and thus the quality of high-level products. An IRS pseudo-noise estimation model has been developed in view of supporting the consolidation of observational requirements during the upcoming detailed instrument design and system specification process. Geophysical inputs to the model are a spatial atmosphere distribution and the corresponding high-resolution radiance spectra. Major instrument inputs are a PSF model and an ISRF model.

The paper presents a mathematical specification of pseudo-noise components and their quantification upon current design assumptions for the two possible instrument concepts (DS: dispersive spectrometer, FTS: Fourier Transform Spectrometer). The IRS pseudo-noise budget is established for selected geophysical scenarios, taking account of spectral correlations as well as of the correlation between different pseudo-noise components. The associated observational requirements are derived and discussed, providing useful orders of magnitude for the users to further iterate the trade-off between instrument specifications and system requirements.

The IRS pseudo-noise estimation model is applicable as a performance estimator to current and future instrument design hypotheses. The model output provides valuable and original data for quantitative investigations of the pseudo-noise impact at retrieval level.

6362-85, Poster Session

Estimation of UV irradiance from ancillary data and comparison with measurements at Thessaloniki, Greece (40.5oN, 23oE)

A. Kazantzidis, A. Bais, C. Meleti, Aristotle Univ. of Thessaloniki (Greece)

The decrease in stratospheric ozone observed during last decades and the possible relationship with the observed increase UV-B radiation in biosphere has been extensively discussed in relevant studies. However, detection of UV trends is difficult due to lack of long-term measurements of UV radiation at the Earth's surface, and the large variability introduced by changes in cloudiness, aerosols and surface albedo.

Recently, several methods for reconstruction of UV radiation levels for the past at single sites have been proposed. In most of these studies, measurements of total ozone and empirical or model derived relations for the impact of clouds and surface albedo on UV transmittance have been used. In this study, a method for estimating erythemal (CIE) UV doses using measurements of total ozone and total solar radiation is presented for Thessaloniki, Greece (40.5oN, 23oE). Measurements of total solar radiation and UV erythemal dose for five years period (2000-2004) were used to estimate the effect of clouds and aerosols. The method is then tested, when compared with measurements from previous years.

6362-86, Poster Session

Quality assurance of the Greek UV network

A. Kazantzidis, A. F. Bais, C. Meleti, S. Kazadzis, Aristotle Univ. of Thessaloniki (Greece); C. S. Zerefos, National and Kapodestrian Univ. of Athens (Greece); C. Topaloglou, K. Garane, M. M. Zempila, Aristotle Univ. of Thessaloniki (Greece)

The stratospheric ozone depletion during the last two decades, the increase of UV-B irradiance levels at the ground and the possible impact on the biosphere has led scientists to develop and use instruments of high accuracy for UV measurements.

During the last two years, a number of UV stations have been established in different environments in Greece and Cyprus, with the aim to establish a long-term monitoring network. The instruments of the network (NILU-UV multichannel filter radiometers) can provide measurements of irradiance in the UV and the visible part of the solar spectrum.

In this study, first results from the calibration measurements and the quality control and assurance procedures are presented. Comparisons with spectral measurements and lamp tests are performed in order to examine the magnitude of drifts on channel sensitivity and derive the relevant calibration factors.

6362-87, Poster Session

Spectral solar UV monitoring: worth it?

T. V. Koskela, A. Heikkilä, J. Kaurola, A. V. Lindfors, A. Tanskanen, Finnish Meteorological Institute (Finland); P. den Outer, Rijksinstituut voor Volksgezondheld en Millieu (Netherlands)

The Brewer Mk-III spectroradiometer of Jokioinen Observatory, Finland, has been continuously operated since 1994 to monitor the terrestrial solar UV irradiance. The instrument is one of the three Scandinavian Brewers capable of fulfilling the WMO requirements of a level S-2 instrument suitable for the detection of trends in UV irradiance. In addition it has been used for the monitoring of total ozone column.

The spectral data collected can be used for calculating effective dose rates with any action spectrum, as well as daily, monthly, or annual sums of doses. Any of these quantities could have been retrieved by other methods, too. They all are based on modelling tools and differ in which input they receive, either standard meteorological information, space-based radiance measurements or ground-based irradiances from broadband or multiband UV radiometer or from pyranometer. A comparison will be presented on the strengths and weaknesses of these methods in retrieving different desired quantities during a selected period of time. An attempt will also be made to roughly estimate the cost of each approach.

6362-88, Poster Session

UV reconstruction modeling for selected European sites

A. Curylo, Instytut Meteorologii i Gospodarki Wodnej (Poland)

For climatological studies it is most important to have data from long time series observations. Available UV measurement series are usually not longer than 15 years. The UV reconstruction algorithms pretend to enhance UV data series, using the available solar radiation measurements up to the 1950'. In the frame of the COST 726 Action - Long term changes and climatology of UV radiation over Europe - the research on the UV reconstruction is currently performed and tested.

Two UV reconstruction algorithms are presented. The first algotithm, explored within the COST Action, is based on the relation of the quotient of UVB radiation - observed/modelled to the quotient of global solar radiation - measured/modelled. The second algorithm, which is a new approach, is based on temporal variability analysis. It searches for analogues in series of data using the Fourier transform and wavelet methods. The algorithms can be applied for UV reconstruction, using auxiliary information on global solar radiation, total ozone and aerosols. The STREAMER and libRadtran radiative transfer models are used for modelling clear-sky solar radiation. The testing of the proposed UV reconstruction algorithms is performed on the available good quality data taken from the selected European sites representing different climatological conditions in Europe. The results of the UV reconstruction models will be compared between each other and against measured data.

6362-89, Poster Session

A first approach in measuring, modeling, and forecasting the vitamin D effective UV radiation

A. W. Schmalwieser, G. Schauberger, Veterinaermedizinische Univ. Wien (Austria); W. B. Grant, Sunlight, Nutrition and Health Research Ctr. (USA); S. Mackin, S. Pope, Solartech, Inc. (USA)

UV radiation (UVR) may cause a variety of damages in the human organism. However there are also positive effects like Vitamin D synthesis or positive effects on mental health. A sufficient vitamin D level can nowadays being associated with reducing the risk for different diseases (e.g. rickets), for several kind of cancers (e.g. prostate, breast, colon) and for age caused dismantling (e.g. osteoporosis which affects 30% of all postmenopausal women). More than 90% of plasma vitamin D is produced endogenously due to exposure to UVR and UVR regulates the vitamin D level by degrading remaining vitamin D in the skin.

Information about the recent and seasonally effectiveness of solar radiation in producing Vitamin D could therefore a very helpful tool for health care and prevention. For this we have adapted a fast spectral model to calculate the Vitamin D effective UV radiation which enables also a world wide forecast for cloudless skies. The calculations are done for a vertical oriented receiver as well as for a horizontal one. While the vertical orientation corresponds closer to the human face, the horizontal one is today's standard orientation for operationally measurements. Therefore we have also examined the possibility of operationally measurements of the Vitamin D effective UV radiation by broadband meters. In the case of the Vitamin D effective UV radiation special attention has to be put on the size of the exposed area, the tan and the age of the exposed person.

6362-90, Poster Session

Validation of TOMS UV irradiance with Brewer ground-based measurements at southwestern Spain

M. Antón, Univ. de Extremadura (Spain); V. E. Cachorro, Univ. de Valladolid (Spain); J. M. Vilapana, Instituto Nacional de Técnica Aeroespacial (Spain); N. A. Krotkov, Univ. of Maryland/Baltimore (USA); A. Serrano, Univ. de Extremadura (Spain); C. Toledano, Univ. de Valladolid (Spain); B. de la Morena, Instituto Nacional de Técnica Aeroespacial (Spain); J. R. Herman, NASA Goddard Space Flight Ctr. (USA); M. L. Cancillo, Univ. de Extremadura (Spain)

Long-term ground-based UV radiometers and satellite UV spectrometers have been utilised for detecting trends in UV radiation and for establishing its climatology. The aim of this work is to compare noon erythemal (CIE) UV irradiance data from NASA Total Ozone Mapping Spectrometer (TOMS) with ground-based measurements from a Brewer spectrophotometer. The Brewer instrument is located at the Atmospheric Sounding Station "El Arenosillo" (ESAt) in Huelva, Southwestern Spain. ESAt, with a high number of cloud-free days per year, is particularly suitable for atmospheric-radiation studies and satellite validation.

The period of study covers the years 2000 to 2004. The effect of clouds and aerosols on the satellite vs ground-based bias is evaluated under different atmospheric conditions regarding aerosol load and cloudiness. It is found that under all sky conditions TOMS overestimates the noon CIE irradiance. This bias is even higher for cloud-free days, showing statistically significant correlation with the aerosol optical depth at 440 nm as measured by a co-located CIMEL-AERONET sunphotometer. However, for thick clouds (high TOMS reflectivity) the bias becomes negative. Regarding aerosols, the bias increases as the aerosol load increases, showing the highest values during dust events. All these facts suggest the need to correct the TOMS UV products mainly under dust conditions.

6362-92, Poster Session

Calibrating six years of multiband UV measurements at Ushuaia and Marambio for model and satellite comparisons

O. I. Meinander, Finnish Meteorological Institute (Finland); C. Torres, Instituto Nacional de Meteorología (Spain); K. Lakkala, T. Koskela, Finnish Meteorological Institute (Finland); A. Redondas, E. Cuevas, Instituto Nacional de Meteorología (Spain); G. Deferrari, Ctr. Austral de Investigaciones Cientificas (Argentina); A. Tanskanen, Finnish Meteorological Institute (Finland)

An Antarctic UV-monitoring network established in 1999 as a Spanish-Finnish-Argentinian co-operation consists of multiband filter NILU-UV instruments located at Ushuaia, Marambio and Belgrano. At high latitudes the changes in UV radiation have been the largest, and ground based stations few. The use of satellite data for polar regions is challenged by the high albedo and the big solar zenith angles, and ground reference data by quality assurance in the harsh climate and behind long distances. The quality assurance of the Antarctic NILU-UV radiometers is based on bi-weekly lamp tests, as well as on site visits of calibrated travelling reference instruments. In addition to the absolute calibration of each NILU-UV radiometer, the relative calibration coefficients of the Antarctic UV network data of Ushuaia and Marambio have been produced two ways: i) using raw voltage values to calculate channel specific calibration coefficients on the basis of solar comparison data, and ii) using these coefficients to scale the polynomial fitting of the bi-weekly performed relative lamp test data. On the basis of these results, we discuss the importance and methods of calibrating the UV measurements under the harsh Antarctic conditions. These calibrated data sets can be used for time series analysis, and compared with the modeled UV data, as well as with the satellite based UV estimates. Examples of such cases are given.

6362-93, Poster Session

Surface UV radiation monitoring at two Italian Brewer stations (Rome and Ispra): a first comparison with OMI data

A. M. Siani, I. Ialongo, R. Giannini, G. R. Casale, M. Cacciani, Univ. degli Studi di Roma/La Sapienza (Italy)

Currently there is still low spatial coverage of ground-based instruments measuring UV irradiance (spectral or broad band) and the length of time over which reliable UV observations have been made is still only around 10 years. Solar spectral irradiance (from 290 to 325 nm at 0.5nm wavelength step) has been measured at the stations of Rome (41.9°N, 12.5°E, 75m a.s.l) and Ispra (45.8°N, 8.6°E, 240m a.s.l.), by means of Brewer single monocromator spectrophotometer since 1992. In this study a climatological characterization based on the time series of UV index (UVI) is presented. The mean of maximum UV indexes is (7.2±0.2) at Ispra and (8.1±0.4) at Rome under clear sky conditions. Low exposure category (UVI<2) is frequent at Ispra, while high (6<UVI<7) at Rome. The seasonal variation is clearly evident, with higher values in summer (up to 8) and low ones (<3) during winter. A comparison between these data sets showed the latitudinal dependence of UV index and the role of meteorological and atmospheric conditions at these sites.

Episodes of high UVI values (\>8) were observed in both stations and they were investigated taking in account total ozone amounts and aerosol optical depth. In addition the influence of Föhn events on UVI values at Ispra was also studied.

Results of a preliminary investigation on clear sky noontime surface UV radiation estimates, provided by Ozone Monitoring Instrument (OMI) will be carried out. For this validation exercise Brewer UV data will be used and the results of the comparison will be interpreted taking into account the effect of atmospheric conditions of the urban site.

6362-94, Poster Session

Reconstruction of daily solar UV irradiation by an artificial neural network (ANN)

U. Feister, Deutscher Wetterdienst (Germany); J. Junk, Univ. Trier (Germany)

Long-term records of solar UV radiation reaching the Earth's surface are scarce. Radiative transfer calculations and statistical models are two options to re-construct decadal changes in solar UV radiation from long-term records of measured atmospheric parameters that contain information on the effect of clouds, atmospheric aerosols and ground albedo on UV radiation. Based on earlier studies, where the long-term variation of daily solar UV irradiation was derived from measured global and diffuse irradiation as well as atmospheric ozone by a non-linear regression method (Feister et al. 2002), we have chosen another approach for the re-construction of time series of solar UV radiation. An Artificial Neural Network (ANN) has been trained with measurements of solar UV irradiation taken at the Observatories Potsdam and Lindenberg in Germany as well as measured parameters with long-term records such as global and diffuse radiation, sunshine duration, horizontal visibility and column ozone.

This study is focused on the re-construction of daily broad-band UV-B (< 315 nm), UV-A (315 - 400 nm) and erythemal UV irradiation. Due to fast changes in cloudiness at mid-latitude sites, solar UV irradiance shows an appreciable short-term variability. One of the main advantages of the statistical method is that it uses doses of highly variable input parameters calculated from individual spot measurements that are taken at short time steps, and thus do contain the short-term variability of solar irradiance. Our study has been supported by the European SCOUT-O3 project funding. The ANN model results have been evaluated within the European action COST726.

Feister, U., E. Jäkel and K. Gericke (2002): Parameterization of daily solar global ultraviolet irradiation. Photochemistry and Photobiology, 76, 281 - 293.

6362-95, Poster Session

Validation of OMI UV products: first results of comparisons with two Austrian ground stations

P. Weihs, S. Simic, H. Rieder, Univ. für Bodenkultur Wien (Austria)

The ozone monitoring instrument (OMI) onboard the EOS/AURA satellite was launched on 15. July 2004. The OMI products include among other things total column ozone, total column NO2, cloud characteristics, aerosol optical thickness and single scattering albedo, SO2, UV-B, HCHO and BrO. A first validation of the products has been performed, a more thoroughly validation is now being performed.

In this presentation we show comparisons of OMI retrieved ground UV with ground measured UV for two stations: Sonnblick (12.8 E, 47.05 N, 3106 m altitude) and Grossenzersdorf (16.57 E, 48.20 N, 156m altitude) for one full year.

First satellite UV is compared with ground UV for cloudless sky conditions. Influence of changes in ground albedo, in turbidity on the accuracy of the ground retrieved UV is analysed.

Second we perform the comparison for totally cloud covered conditions. The accuracy of retrieved ground UV here mostly depends on the appropriate determination of the cloud optical depth.

6362-96, Poster Session

Exact analytical solution of 3D radiative transfer equation for remote sensing of clouds

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The urgent problems of photometry in remote sensing of clouds call a necessity of the fundamental investigations directed to the improvement of the analytical methods solution of the radiative transfer equation (RTE) for the real scattering phase function. The problem of light scattering function by an aggregation of particles is one of the most complex problems of the atmosphere optics. It is very difficult to mathematically describe the interaction of light with such a system when it is necessary to take into account the multiple scattering. However, this is required in the most important problems of optical diagnostics of clouds. Because of the multiparametricity and complexity of interaction of light with a particle, till now the solution of such problems were based on the numerical methods. The numerical data obtained by approximate methods hampers to the analysis of the real geometrical and physical factors determining the properties of the scattered radiation. Because of this, at present, much attention is being given to the development of methods based on the use of analytical solution of the RTE. The main difficulty of analytical solution of the RTE, which is considered to be incurable, as is known, is taking into account the infinitely large number of the spherical functions. For the atmospheric aerosol, for example, a good approximation is provided by their number equal or larger than 400. The known analytical approximations are very idealized and, as a rule, do not provide the obtaining of physical right results. For example, the method of spherical harmonics leads to significant lasses of the information at small scattering angles. The method of small-angle approximation, by contrast, ignores the very informative region of large scattering angles. The new method developed by the author and presented in this work is in free of the indicated drawbacks. We have realized a new of solution of the RTE, which implies that the infinite system of spherical functions is replaced by a finite orthogonal basis of the G-functions satisfying the complexity conditions. The G-functions forms the class of functions belonging in the finite functional G-space. The high sensitivity of the scattering effects to the properties of particles imposes very high requirements on the new method developed for solution of the transfer equation, namely, the solution should involve the whole information contained in the real phase function. As the object of investigation, we considered a three - dimensional volume for aggregation of particles with an arbitrary scattering function. The exact solutions of the RTE for intensity of scattered light by clouds are present in the form of a finite series in the G-function space.

6362-97, Poster Session

Wide-band spectrally resolved measurement of the Earth's up-welling radiation with the REFIR-PAD spectroradiometer

G. Bianchini, L. Palchetti, C. Belotti, Istituto di Fisica Applicata Nello Carrara (Italy)

In June 2005 the REFIR-PAD (Radiation Explorer in the Far InfraRed - Prototype for Applications and Development) Fourier transform spectroradiometer was successfully used in a stratospheric balloon flight from Teresina, Brasil, obtaining the first spectral measurement of the Earth's emitted radiation to space in the 100 to 1400 cm-1 spectral range, with a resolution of 0.5 cm-1. During the 8 hours flight, performed at a constant altitude of 34 km, nadir, limb and sky emission spectra have been collected. Nadir spectra in particular, have been acquired both in clear sky condition and in presence of clouds. Radiometrically calibrated emission spectra obtained in the different acquisition conditions experienced during flight are presented, from the analysis of which both information on the chemical and microphysical properties of the atmosphere has been derived. The measurement of both the water vapour rotational band in the far-infrared and the vibrational band in the mid-infrared will enhance the capability of sampling different layers of the atmosphere, in particular will improve the sensitivity in the characterisation of the radiative properties in the upper troposphere, both in terms of water vapour content and cirrus clouds. From the measured atmospheric emission spectra water vapour vertical profiles are retrieved, also, from the comparison between cloud and clear-sky spectra, the infrared signature of clouds can be inferred. The measurement of the Earth's atmospheric emission spectra in a spectral region mostly unexplored will also help in the field of spectroscopic modelling providing a reference framework for validation purposes.

6362-98, Poster Session

Fog recognition using satellite information

M. A. Pajek, Instytut Meteorologii i Gospodarki Wodnej (Poland)

No abstract available.

6362-100, Poster Session

The use of laser radiation to study the effect of atmosphere on the FSO communication

M. K. Al-Bokhaiti, Ibb Univ. (Yemen)

In this paper we introduce a study that describes the ability to build a laser communication system in free space. We concern our interest in the environmental factors which greatly affect any unguided communication system, the performance of a Free Space Optical (FSO) link is primarily dependent upon the climatology and the physical characteristics of its installation location. In general, weather and installation characteristics that impair or reduce visibility also affects FSO link performance. A typical FSO system is capable of operating at a range of two to three times that of the naked eye in any particular environmental condition. The primary factors affecting performance include atmospheric attenuation, scintillation, window attenuation, alignment or building motion, solar interference, and line-of-sight obstructions.

Analytical study carry out to evaluate the atmospheric attenuation due to scattering and also the raindrop attenuation. This study based on experimental data was taken from Civil Aviation & Meteorology Authority - Yemen Meteorological Service.

The main conclusion which have arisen out of this research study is that the atmospheric conditions are the major conditions which affect the laser communication systems.

6362-101, Poster Session

A New Model for Calculating Infrared Background Radiance at all altitudes including atmospheric clutter and clouds (stand-by oral presentation)

R. L. Sundberg, Spectral Sciences, Inc. (USA)

No abstract available

6362-102, Poster Session

Validation of the QUick Atmospheric Correction (QUAC) algorithm for VIS-SWIR multi- and hyperspectral imagery (Stand-by oral presentation)

R. L. Sundberg, Spectral Sciences, Inc. (USA)

No abstract available

6362-103, Poster Session

Factors affecting UV radiation at Barrow, Alaska

G. Bernhard, Biospherical Instruments Inc. (USA)

No abstract available

6362-27, Session 10

Continuous mixing layer height monitoring by ceilometer in complex terrain

K. Schäfer, S. M. Emeis, C. Jahn, Forschungszentrum Karlsruhe (Germany); C. Münkel, Vaisala GmbH (Germany)

Automatic mixing layer height monitoring was performed by continuous ceilometer measurements in the Inn valley near Innsbruck, Austria. The Vaisala ceilometer LD40 was used which is an eye-safe commercial lidar and designed originally to detect cloud base heights and vertical visibility for aviation safety purposes. Special software for this ceilometer provides routine retrievals of mixing layer height from ceilometer data.

Particular emphasis is given to the detection of thermally stable layers and inversions within the lower troposphere and their temporal development. Such elevated layers influence the diurnal variations of air pollution.

A comparison was performed with parallel mixing layer height retrievals from a SODAR. In clear and cold winter nights sometimes several layers could be detected with both instruments which strongly influenced the air quality in that valley. In the absence of low clouds and precipitation ceilometers can estimate the mixing-layer-height fairly well. Ceilometer and SODAR partly complement each other.

6362-50, Session 10

Highway emission study by DOAS within the Inn valley near Innsbruck

K. Schäfer, H. Hoffmann, A. Krismer, Forschungszentrum Karlsruhe (Germany); J. Wittig, J. Vergeiner, F. Obleitner, Leopold-Franzens-Univ. Innsbruck (Austria)

To study the development of high air pollution episodes in a valley with urban areas, industry and transit traffic a highway emission study was performed in the Inn valley near Innsbruck, Austria. A DOAS with emitter/receiver unit and three retroreflectors was used for this study. One retroreflector was installed at a telephone emitter mast on the other side of the highway (120 m path length) so that the path was about 10 m above highway level. Another retroreflector was set up for a path parallel to the highway and the third retroreflector was used to operate a path perpendicular and away from the highway. The path across the highway was directly above the immission station Vomp which is only three meters away from the motorway.

A measurement campaign was performed between October 2005 and February 2006 which was started by an inter-comparison of the DOAS with in situ measurement devices for NO and NO2 during one week at a site (near Schwaz) in some distance to the main source.

The concentrations of NO and NOx above the highway are clearly dominated by the traffic volume. Higher concentration values were found during week days than during the weekend.

The concentrations above the highway are compared to those measured at the other DOAS paths, in situ nearby the highway at the ground as well as in situ at the background site nearby in a distance of about 1 km (near Schwaz). The daily differences in air pollution e.g. due to temporal variations of highway emissions (10 times higher during peak hours in the morning and afternoon compared to night hours) and meteorological conditions (stable from late afternoon until mid-morning) are investigated. Further, the influence of variations of the highway emissions upon air pollutants as a function of the altitude above the valley ground and the mountain wind system (valley and slope winds) are studied.

6362-52, Session 10

Airport air quality studies by remote sensing

K. Schäfer, G. Schürmann, C. Jahn, Forschungszentrum Karlsruhe GmbH (Germany); E. Flores-Jardines, Univ. Nacional Autónoma de México (Mexico); S. Utzig, H. Hoffmann, A. Krismer, S. M. Emeis, R. Steinbrecher, Forschungszentrum Karlsruhe GmbH (Germany); J. Wittig, J. Vergeiner, F. Obleitner, Leopold-Franzens-Univ. Innsbruck (Austria); C. Münkel, Vaisala GmbH (Germany)

Airport air quality is influenced by traffic mainly. These are emissions from road traffic and aircraft. The scientific questions for investigations of airport air quality are

- NOx chemistry within the aircraft exhaust plume
- Transfer of final aircraft exhaust compounds to ambient air
- Determination of CO, NO, NO2, particulate and VOC emission indices for aircraft during operational conditions at airports
- Small-scale emission inventory of airports for local-scale numerical simulation of airport air quality
- Influence of airport emissions upon air quality in the surroundings including odour as well as meso-scale numerical simulation of air quality
- Representativity of airport air quality monitoring sites for characterisation of airport air quality, influence of airport emissions upon air quality in the surroundings as well as validation of local- and meso-scale numerical simulations

The quantification of these emission sources requires remote sensing methods because the airport operations should not be disturbed. The available instruments for this task are FTIR and DOAS in passive and open-path mode as well as LIDAR. Specific measurement concepts are developed to perform airport air quality studies with this instrumentation. Scanning imaging spectrometry was developed and applied for determination of aircraft emission indices also.

Results of measurement campaigns at the airports Vienna, Zurich, Budapest and Paris CDG will be presented. Open questions and required further developments will be discussed.

To study the development of high air pollution episodes in a valley with urban areas, industry and transit traffic a highway emission study was performed in the Inn valley near Innsbruck, Austria. A DOAS with emitter/receiver unit and three retroreflectors was used for this study. One retroreflector was installed at a telephone emitter mast on the other sidte of the highway (120 m path length) so that the path was about 10 m above highway level. Another retroreflector was set up for a path parallel to the highway and the third retroreflector was used to operate a path perpendicular and away from the highway. The path across the highway was directly above the measurementimmission station Vomp (?)which was set up three meters from the highway is only three meters away from the motorway.

A measurement campaign was performed frombetween October 2005 untiland February 2006 which was started by an inter-Automatic mixing layer height monitoring was performed by continuous ceilometer measurements in the surroundings of Mexico City and the Inn valley near Innsbruck, Austria. The Vaisala ceilometer LD40 was used which is an eye-safe commercial lidar and designed originally to detect cloud base heights and vertical visibility for aviation safety purposes. The software of this ceilometer provides routine retrieval of mixing layer height from ceilometer data.

The comparison with mixing layer height retrievals from a SODAR is continued in a valley atmosphere. Several layers could be detected during special meteorological situation which are strongly influencing air quality in that valley. In the absence of low clouds and precipitation ceilometers can estimate the mixing-layer-height fairly well. The instruments partly complement each other. comparison of the DOAS with in situ measurement devices for NO and NO2 during one week at a site (near

Schwaz) where the air is well-mixed in some distance to the main source. The concentrations of NO and NOx above the highway are clearly dominated by the traffic volume. Higher concentration values were found during week days than during the weekend.

The concentrations above the highway are compared to those measured at the other DOAS paths, in situ nearby the highway at the ground as well as in situ at the background site nearby in a distance of about 1 km (near Schwaz). The daily differences in air pollution e.g. due to temporal variations of highway emissions (10 times higher during peak hours in the morning and afternoon compared to night hoursthe day than during night) and meteorological conditions (stable from late afternoon until mid-morning) are investigated. Further, the influence of variations of the highway emissions influences upon air pollutants in dependence fromas a function of the altitude above the valley ground and the mountain wind system (valley and slope winds) are studied.

All data are used to evaluate mixing layer height information.

6362-53, Session 10

Quantitative analysis of open-path FTIR spectra by using artificial neural networks

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Quantitative analysis of absorbance spectra to retrieve gas concentrations in open-path FTIR air monitoring is not always a straightforward task. Most of commercial software use classical-least-squared (CLS) algorithms to retrieve the unknown concentrations. These codes usually work in real time and give appropriated results. However, sometimes these codes fail when the background reference spectrum presents absorption lines of the gas to be monitorized. This effect is frequent in some applications. Line-by-line (LBL) approaches give satisfactory results because these codes solve the problem associated to the reference spectrum generating a synthetic reference background. The main drawback is that these algorithms do not work in real time, and need a skilled operator.

In this work we propose the use of artificial neural networks to analyse absorbance spectra in real time, by using synthetic reference spectra generation. In addition, capabilities of the method to solve spectral overlapping will be studied. In this sense, simultaneous analysis of four atmospheric gases (CO2, CO, H2O and N2O) will be included in this first version. The effectiveness of the method will be evaluated from the experimental point of view. Experimental open-path FTIR spectra (0.5 cm-1 of spectral resolution) will be analysed with the proposed method, as well as with CLS and LBL codes for comparison purposes. Moreover, in these experiments CO concentration has been measured by using standard extractive equipment and can be compared with the values provided by our method. Finally, some indications will be pointed to extend the method to other gases and spectral regions.

6362-104, Session 10

Ground-based remote sensing of gas emissions from Teide volcano (Tenerife, Canary Islands, Spain) by means of optical remote sensing

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Teide volcano, the Spanish highest peak (3716 m), is located in the central part of Tenerife, Canary Islands. An anomalous seismic activity was detected in and around Tenerife Island since middle of 2001 reaching a peak of seismicity in may 2004 by the National Seismic Network (IGN). Volcanic gases can provide a valuable information about this volcanic unrest at Tenerife; therefore, measurements of major and some minor volcanic gas components emitted by the fumarolic activity at the summit crater of Teide volcano were performed by means of optical remote sensing on September 2005. During this measurement campaign an UV-DOAS system and three op-TDL systems were used to monitor major and minor volcanic gas components in the open atmosphere inside the summit crater. The UV-DOAS system was used for monitoring SO2 and CS2, while three TDL-systems were used for monitoring CO2, H2S and HF. It could be demonstrated successfully, that the optical remote sensing instruments used (UV-DOAS and op-TDLs) were very appropriate to monitor continuously these volcanic gas components. In addition CO2 flux measurements were performed at the summit crater of Teide volcano by means of well established methods. By multiplying CO2 flux data by (gas)i/CO2 ratios provided by optical remote sensing measurements, it is possible to estimate flux values for several detected volcanic gas components during this measurement campaign.

6362-24, Session 11

Validation of ozone, NO^2, and aerosol products retrieved from SAGE III limb scatter measurements: application to OMPS

D. F. Rault, NASA Langley Research Ctr. (USA); R. P. Loughman, Hampton Univ. (USA)

The Ozone, NO^2 and aerosol extinction vertical profiles retrieved from SAGE III limb scatter measurements are compared with correlative measurements made either on other space platforms (SAGE II, SAGE III in occultation, POAM, HALOE and OSIRIS) or with balloon sondes and Lidars. It is shown that SAGE III limb scatter measurements can produce Ozone density with an accuracy of 5-10% from tropopause to 40 km and a vertical resolution of 1-1.5km, NO^2 density with an accuracy of 25% from 20 to 35 km and a vertical resolution of 2km, and stratospheric aerosol extinction (at 520,600,670,750,870, 1020nm) with an accuracy of about 10-40%. The results obtained with SAGE III are being applied to characterize the OMPS instrument which will rely on the Limb Scatter method to continue Ozone profiling data record for the next 10-15 years.

6362-55, Session 11

Low-cost microsatellite UV instrument suite for monitoring ozone and volcanic sulphur dioxide

J. A. Fernandez-Saldivar, C. I. Underwood, S. Mackin, Univ. of Surrey (United Kingdom)

A new ultraviolet instrument suite operating in a microsatellite constellation is proposed with the objective of monitoring ozone and volcanic sulphur dioxide.

The potential of microsatellites for atmospheric monitoring in ultraviolet (UV) has been proved already. The Ozone Layer Monitoring Experiment (OLME) on board FASat-Bravo microsatellite has retrieved ozone in the UV with low-spatial-resolution data (150 x 150 km) providing global coverage; as well as a high-resolution imager (4 x 4 km) with quantitative retrievals in agreement with TOMS (Underwood 2003).

Recent analysis of data obtained with this experiment indicates the detection of Nyamuragira's volcanic cloud of October's 1998 eruption as a higher ozone content anomaly. Ozone discrimination and estimation of sulphur dioxide content were obtained with the instrument model and using look-up tables from a radiative transfer code (MODTRAN). The results were compared with those obtained from TOMS-EP.

Founded on these potential capabilities for SO2 detection, an enhanced version of OLME is proposed adding spectroscopic instrumentation. The spectral and radiometric requirements under a diversity of atmospheric conditions will be discussed along with the instrument's design. The instrument is based on UV-sensitive solar-blind silicon carbide (SiC) detectors and a high-efficiency transmission grating. These features will enable better discrimination from ozone than its predecessor for sulphur dioxide retrievals.

This suite can be incorporated in a group of spacecrafts like the Disaster Monitoring Constellation (DMC) microsatellite constellation developed in Surrey Satellite Technologies Limited (SSTL) with a lower cost than a single traditional earth observation mission (da Silva Curiel, 2003).

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6362-57, Session 11

Climate research with the atmospheric infared sounder

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The Atmospheric Infrared Sounder (AIRS) was launched in 2002, along with two companion microwave sounders. This AIRS sounding suite is the most advanced atmospheric sounding system to date, with measurement accuracies far surpassing those of current operational weather satellites. From its sun synchronous polar orbit, the AIRS system provides more than 300,000 all-weather soundings covering more than 90% of the globe every 24 hours. As the “retrieval” system used to derive atmospheric and other parameters from the observations is being optimized and those parameters characterized and validated, usage of the AIRS data - which is available to anybody through the archive system operated by NASA - is spreading throughout the atmospheric and climate research community. An ongoing validation effort has confirmed that the system is very accurate and stable and is close to meeting the goal of providing global temperature soundings with an accuracy of 1 K per 1-km layer and water vapor soundings with an accuracy of 20% throughout the troposphere - surpassing the accuracy of radiosondes. This unprecedented data set is already being used for operational weather prediction in a number of countries, with significant positive impact on forecast accuracy and range, and is enabling a number of investigations that were previously not possible or used to shed new light on current issues in atmospheric and climate research. In addition to the basic soundings related to the hydrologic cycle, AIRS also measures a number of trace gases - the latest such product being the global distribution of carbon dioxide. We discuss some examples of recent research with AIRS data.

6363-19, Poster Session

Bistatic SAR simulation for ocean

X. Wang, Institute of Electronics (China)

The mechanism and experiment for single station SAR ocean signal have been studied in many papers.Bistatic SAR is now a hot topic in SAR research. The mechanism of bistatic SAR ocean signal is much more complex than single station SAR, but it can give us more information about ocean. The bistatic SAR will be a powerful tool in ocean remote sensing. In this paper, the model of bistatic SAR ocean simulation is studied and a two dimensional simulation of bistatic SAR for ocean is realized. Some simulation results of X-band and L-band are compared and analyzed in the end of paper.

6363-22, Poster Session

A new method to extract internal wave parameters from SAR imagery

W. Huang, Second Institute of Oceanography (China)

A new method to extract internal wave parameters from synthetic aperture radar (SAR) imagery has been developed based on the empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis. Internal wave parameters have been retrieved from the ERS-1 SAR imagery. The new method has been compared with the 2D FFT model. It is shown that the new method is better than the 2D FFT model.

6363-23, Poster Session

SAR image modeling of ships on sea surface

X. Xu, Y. Wang, Y. Qin, Beihang Univ. (China)

Modelling of the electromagnetic (EM) scattering and synthetic aperture radar (SAR) images of ships on sea surface is a great challenge due to the extremely complicated scattering mechanisms between the complex target and the dynamical sea surface. In this work, we present an approximate but practical technique for high-frequency EM scattering and SAR image modelling of ships on sea surface, where major scattering mechanisms from both the ship body itself and the multipath interaction between the ship and the sea surface are included. The ship body is geometrically represented using a facet plus edge model. Physical optics (PO) method is used to calculate the facet scattering, and the incremental length diffraction coefficients (ILDC) technique is applied to calculate the edge diffraction. Based on area projection and PO method, combining with reentrant polygon clipping (RPC) technique in the context of computer graphics, a recursive rapid algorithm for multiple scattering (RRAMS) is developed and applied to calculate the multiple scattering among the facets on ship body. The multipath interaction between the ship body and the sea surface is considered by summing up the scattering contribution from the four major radar-ship-sea interaction paths using a bistatic EM scattering calculation procedure. Typical computational results for radar cross section (RCS) and SAR images are presented and compared with those from the direct scattering path only, demonstrating the validity and usefulness of the current technique.

6363-24, Poster Session

On the performance of dual polarimetric SAR detectors

J. Chong, Z. Han, M. Zhu, Institute of Electronics (China)

Target detection algorithms using polarimetric information in fully polarimetric Synthetic Aperture Radar image have shown that the exploitation of polarimetric information can greatly improve the target detection performance compared with single channel detectors.

The ENVISAT Advanced SAR (ASAR) can operate on Alternating Polarization (AP) mode, which can provide three different dual polarization combinations: HH/HV, VV/VH, and HH/VV. Different polarization channel shows different target detection performance. Studies on ENVISAT carried out before launching by ESA indicate the HH/HV combination is the defaulted mode for ship target detection. Recently, Olsen et. al. analyzed different polarization signature for different dual polarimetric combinations and summarized that cross polarized data gives better contrast for automated detection compared to co-polarized data when the incidence angle is small.

To obtain quantified results, this paper derives target detectors for three different dual polarization combinations with probabilistic targets in the presence of complex-Gaussian clutter. The detection performance is compared with single polarimetric channel detector by Receiver Operating Characteristic (ROC), indicating that dual polarimetric information has greatly improved the detection performance. Further comparison of different dual polarimetric combinations indicates that HH/HV yields the best detection performance, shedding a bright light to prospective target detection application with ENVISAT ASAR AP mode data.

6363-01, Session 1

Performance analysis of bistatic SAR configurations

M. Tesauro, Univ. della Basilicata (Italy)

Nowadays satellite missions are being planned and based on the bistatic and multistatic concept, where transmitter/receiver subsystems are located on different platforms. In a bistatic/multistatic configuration, the illumination is provided by a given SAR transmitter, while the scattered signal is simultaneously recorded by a set of independent receivers. The whole system can be optimised to increase the spatial resolution or facilitate applications as continuous monitoring and single-pass across-track interferometry.

A bistatic configuration has several advantages. For instance, in military applications the vulnerability of the system is reduced, because the transmitter can be positioned far away, while the passive receiver is difficult to locate.

In this work we focus on the analysis of the integration time, the Doppler parameters (centroid frequency and bandwidth) and geometric resolutions (both azimuth and range and Cartesian coordinates). The kinematics of the transmitting and receiving antennas is modelled as a motion at a constant velocity along a linear path. Orbits can be at different heights above the ground, have a spatial baseline and be divergent. Antennas can have different velocities and be characterized by a temporal baseline. The kinematical properties allows different integration-time regimes to be identified. For each target within the covered area on the ground, the Doppler frequency history is computed and the Doppler bandwidth derived. The spatial resolution capabilities of bistatic SAR configurations are studied and quantified for different configurations of interest. Performances of bistatic SAR configurations are compared to those of monostatic ones. Results of a numerical analysis are also presented.

6363-02, Session 1

Ambiguity functions and noise floor suppression in random noise radar

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Noise radar can be used in a great number of applications including SAR. Wide bandwidth gives high range resolution, and the non-periodic waveform suppresses the range ambiguity. The ambiguity functions of different types of random noise radar are reviewed. Due to the randomness of the waveform, a noise floor limiting the possible side lobe suppression accompanies the correlation integral involved. In strong clutter scenes with dominant reflectors, the induced noise floor can be too high and further suppression is needed. Improved clutter cancellation methods have mainly been discussed in connection to pseudo-random bi-phase pulse compression radar. In this paper, mismatched filtering is also applied to suppress the side lobes of random noise radar. An iterative subtraction algorithm for cancellation of noise floor due to dominating reflectors is analysed and is successfully tested on random step frequency radar data and noise sodar data.

6363-03, Session 1

Evaluating Dynamic Logic Estimation for SAR Using Sparse-Array Spotlight Mode Simulations

R. J. Linnehan, Air Force Research Lab. (USA); J. Schindler, D. Brady, ; L. Perlovsky, Air Force Research Lab. (USA)

We describe a method of combining detection and estimation of stationary targets in SAR images using dynamic logic (DL). Furthermore, we evaluate the efficiency of this new estimator, i.e., how close error variances of the position and reflectivity estimates approach the corresponding Cramer Rao bounds (CRB). The evaluation is performed by collecting statistics of point scatterer estimation in images created using sparse-array spotlight mode simulations. In this paper we will describe the DL detector/estimator and the computationally efficient method of forming perfectly focused SAR images with a sparse spotlight synthetic array.

In previous work we showed how DL is used to detect targets in SAR images that are moving below the minimum detectable velocity of ground moving target indication radar. The dynamic logic algorithm (DLA) is a model-based approach that relates data to models but mitigates combinatorial complexity by comparing all models and data simultaneously. Each model acts independently by refining its parameters to extract maximum target information from the data.

Simulating SAR images to test the efficiency of an estimator is not practical with the computational limitations of a desktop computer using a full synthetic array. This problem is mitigated by dramatically reducing the PRF and adjusting the noise power to maintain the desired SNR. Grating lobes that appear due to the undersampled array will not affect the result as long as they are physically located beyond the target area of interest in the azimuth dimension. However, this undersampled array does not properly correlate the receiver noise during the process. We will show that a sparse array, in conjunction with spotlight mode SAR, can replicate a full array without computational encumbrance.

6363-04, Session 1

Ground imaging using wavelength-resolution LORA SAR in the VHF/UHF-band

L. M. H. Ulander, A. Gustafsson, Swedish Defence Research Agency (Sweden)

The Swedish Defence Research Agency (FOI) has designed and implemented the airborne ultra-wideband Synthetic Aperture Radar LORA ("low-frequency radar") operating in the VHF/UHF bands. The system has been operated since 2002 and has participated in a number of flight trials since then in order to evaluate system performance. Major flight campaigns over ground areas were conducted in 2004 and 2005, respectively, which have given a large data base for application development. Both military and civilian applications are anticipated with LORA, in particular for detection of concealed objects, forest mapping, search-and-rescue operations, as well as archaeological and topographic mapping. The main system features of LORA include a large fractional bandwidth in the frequency band 200-800 MHz, a large synthetic aperture angle (90 degrees) and horizontal polarization on transmit and receive. Data acquisition, frequency synthesis, radio-frequency filtering and image formation processing result in high-resolution radar images of the ground. Presently, a geometric resolution of 0.6 m has been achieved using the frequency band 225-470 MHz. Higher frequencies are difficult to use due to strong interference from digital broadcasting TV signals. LORA SAR images have also been compared with SAR images of the same ground area obtained using both higher and lower frequency radar bands. The low frequency band together with the high resolution of LORA shows several unique characteristics, e.g. discrimination of single tree stems in dense forests, low attenuation into foliage, unique radar signatures for object classification.

6363-05, Session 2

Polarimetric SAR observables for land cover classification: analyses and comparisons

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Classification of the Earth surface represents one of the main applications of polarimetric synthetic aperture radar (SAR) data.

In this contribution, we report a study on some of the possible representations of such data, testing and comparing as well different classification algorithms.

Part of this work will be dedicated to the study of the dependence of the classification results on the varying size of averaging windows of pixels. Such an analysis will permit to prove if the polarimetric parameters under consideration describe only of point-like physical properties of the targets or if they also contain "extended", local information.

Our goal is to provide an objective estimate of the amount of information carried by each polarimetric parameter and afford, in this way, their comparison in terms of their usefulness.

6363-06, Session 2

An algorithm based on Neural Networks for generating multi-temporal soil moisture maps from ENVISAT/ASAR images

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Soil moisture is an important factor for all the hydrological applications, such as the water resources management, the flood forecast and the agricultural planning. However, the local measurements of soil moisture content (SMC) are strongly affected by spatial variability, besides being time-consuming and expensive. Moreover, the use of hydrological models for extending the forecast of soil moisture over larger areas is not easy, and depends on the homogeneity of the selected areas and the information available on them (soil properties, i.e. hydraulic characteristics, and permeability, together with meteorological and climatological data, etc.). Microwave satellite sensors, with the complete and frequent coverage of the Earth's surface, make it possible to estimate soil moisture on a large scale. However, the only available frequency from space is C band, operational on ERS-2, RADARSAT, and ENVISAT satellites, which is not the optimal for this aim. The retrieval of soil moisture maps at C-band is, in fact, still challenging, since the effects of soil surface roughness and vegetation cover on the backscattering coefficient at this frequency is high, and needs the use of correcting procedures.

In spite of these problems, multi-temporal soil moisture maps have been produced in two Italian sites starting from ENVISAT/ASAR images, collected in 2003 and 2004, by using a Neural Network algorithm. In this case, several SAR images were analyzed for a flat agricultural area, located close to Alessandria in North-west Italy, and a mountainous site on the Cordevole watershed (Arabba) on the Italian Alps. All the SAR images acquired at different dates over the Cordevole test site were geocoded by using a DEM of the area and the orbital parameters. Direct measurements of soil moisture (with a TDR probe) and fresh biomass of vegetation were carried out during the ENVISAT overpasses.

The soil moisture maps were obtained by using a feed-forward neural network having some hidden layers of neurons between the input and output, and trained by using the back-propagation (BP) learning rule. The available backscattering dataset was divided in two parts: the first portion was used to generate a training set and the second one to test the ANN performances. Furthermore, the experimental training set was increased by simulating radar backscattering through the Integral Equation Model, which was driven with soil data taken from ground measurements. Once the training set was generated, several configurations of hidden layers/neurons were tested to optimise the performances of the ANN. The obtained results, compared with ground data, showed a satisfactory agreement with ground truth data and meteorological conditions, and enabled us to generate maps with 4-5 levels of soil moisture of both the test sites from the available ENVISAT ASAR images.

A further validation of the retrieval algorithm was carried out by using two ENVISAT images collected on the Kemjoki area in Finland, on May 7, 2004 and July 27, 2005. Unfortunately, due to the well-known user conflicts, one of the ENVISAT ASAR image was in HH polarization and the other one in VV polarization, at 23° incidence angle. In spite of the problems related to the difference in polarization configuration, the wideness and non-homogeneity of the area, and the lack of detailed ground measurements, the results obtained by using the Artificial Neural Network were satisfactory. Since actual ground measurements of soil moisture were not available, the results were compared with a hydrological model outputs. Although with some discrepancies, the maps of SMC obtained both from the ENVISAT images and from the hydrological model were rather similar. An additional check was carried out by using the data of a geological station (Finnish Geological Survey), Naruska (67°08'N-29°17'E), which measured a local SMC value of 11%. The corresponding value estimated from the inversion algorithm was 13%.

6363-07, Session 2

Generation and use of topographic features for improving the classification of the regional scale GBFM Siberia SAR mosaic

J. Kropacek, G. De Grandi, Joint Research Ctr. (Italy)

Information on terrain features like slope, orientation and convexity may be very useful for thematic interpretation of single band satellite radar data. The accuracy of the co-registration is the key issue. The map-projected GBFM radar mosaic of Siberia has been co-registered with a digital elevation model, using a cross-correlation technique in the Fourier domain. The mosaic was produced in the framework of the Global Boreal Forest Mapping Project, an initiative of the Aerospace Exploration Agency of Japan (JAXA), and is based on JERS-1 data acquired in years 1997-8. The SRTM digital elevation data (90 m horizontal resolution) have been used for areas up to 60 degrees of latitude and the USGS GTOPO30 elevation data (500 m horizontal resolution) for the rest of the area. Since SAR and DEM data-sets capture completely different features of the landscape and SAR imagery is affected by geometric and radiometric (shadow and layover) distortions due to elevation and local terrain slope, the automatic matching of the radar image to the DEM image is not possible. Due to the unavailability of SRTM data at the time of the mosaic processing and, in any event, due to computational constraints (the mosaic is composed of some 400 SAR strip-images covering 135 000 km2 each) the classical geo-coding procedure using slant range data had to be ruled out. The a-posteriori solution entailed the simulation of the radar reflectivity dependency on the local incidence angle based on available DEM and radar viewing geometry. The radar mosaic was then matched with the simulated image. The cross-correlation moving window was composed of mutually overlapping squares (60 by 60 pixels) in a regular grid with 20 pixel spacing between the centers. The co-registration gives good level of correlation not only for mountainous areas but also for hilly ones. High correlation occurs also in flat areas with pronounced hydrological features like river courses and lake shores that are reflected in SRTM as fine-detail features. The density of control points was on average 1400 points per 100 square kilometers. The geometric effect of topography (like shortening of the slopes oriented towards the radar) has been then corrected by inversion of the same model which had been used for generating the simulated image. Radar backscattering coefficient dependency on local incidence angle was modeled and corrected by a simple inverse sinus model. The corrected radar image was then fed to a classification algorithm together with layers extracted from the DEM, such as slope and convexity. Preliminary thematic classification results based on this technique are reported.

6363-08, Session 2

On the comparison between soil moisture values retrieved from SAR images and ground truth point measurements

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One major concern in the retrieval procedure lies in the procedure for its validation. This procedure implies a comparison between retrieved values and in-situ measurements.

Even in the ideal case the ground and satellite measurements are fundamentally different, since the ground data can be sampled continuously in time but at a discrete point, while a satellite samples an area average but a snapshot in time.

In this paper a retrieval algorithm for the estimation of soil moisture from SAR images has been applied to the following data sets:

- SIRC/XSAR mission with L and C band SAR images acquired on 6 fields in an Italian test site (Matera, 1994);

- ERS-2 and ENVISAT ASAR data acquired on Matera test site (Italy) during some campaigns carried out in 2001-2003;

- AirSAR images acquired on vegetated fields during the SMEX'02 experiment carried out in Iowa in 2002.

The retrieval procedure, based on a Bayesian approach, consists of two modules, one is pertinent to bare soils while the other one is useful for the determination of soil moisture in presence of vegetation. The last one uses the synergy with optical images to correct for the contribution of vegetation water content.

These above-mentioned missions have been chosen because, along with radar observations, extensive ground truth measurements were acquired.

The main aim of the paper is to investigate how well an average value of the ground variable, such as soil moisture, that is obtained by inverting the satellite data, correspond to a simple average of the same variable over a finite region determined from ground truth data. This is what happens when satellite derived measurements are compared with point measurements.

The following comparison have been considered:

- comparison between the measured and extracted soil moisture average values over the whole field with the respective standard deviations;

- comparison between the measured and extracted soil moisture average values over the different parts of the field which include at least 4 ground measurements that are the minimum required to determine soil moisture content values in agricultural fields.

The comparisons between the two averages have to be carefully treated when the size of the area, over which the satellite estimates are calculated, is comparable to the correlation length of the ground truth values.

6363-09, Session 3

Automatic processing of interferometric SAR and the accuracy of surface deformation measurement

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Interferometric Synthetic Aperture Radar (InSAR) is one of the typical application techniques of SAR data. InSAR is an effective tool to detect and measure the amount of spatial surface displacement caused by earthquake, volcanic activity, landslide, land subsidence and others. InSAR using L-band provides a great interferogram which keeps a spatial continuity fringe, because L-band microwave penetrates vegetation and is scattered stably on the earth surface. However, InSAR processing requires a lot of manual operations and its results are different in every analysis. Therefore, the author developed automatic InSAR processing software for the purpose to remove problems in applying InSAR. In this study, we applied InSAR technique to JERS-1/SAR data for Zonguldak coal area, Republic of Turkey, observed in 1995.

Zonguldak coal area is located 240 km to the east of Istanbul and is along the Black Sea. In this region, the activity of underground coal mining has been going on since 1848 and 3 million ton per year of hard coal has been produced. Recently, the effect of land subsidence due to underground coal mining was found around this area. Because the whole damage has not been grasped, we tried to measure the amount of surface deformation using InSAR. As a result, some phase anomalies were detected on mining tunnel, the maximum amount of deformation was approximately 200 mm per 4.5 months. In addition, the result of measurement by InSAR accorded with that by GPS measurement within 7 mm.

6363-10, Session 3

Impact of the surface characteristics on the generation process of INSAR and LIDAR elevation data

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Due to upcoming new data driven technologies in the modern aviation the impact of digital terrain data is growing conspicuously. Especially for ground near operations (helicopter) reliable terrain information is necessarily demanded. Based on modern earth observation technologies a new generation of elevation data is obtainable. However it shall be analysed how far data derived from remote sensing techniques like INSAR or LIDAR can be applied for aviation purposes.

Formerly terrain data are represented in relation to the bare earth to obtain a "Digital Terrain Model" (DTM). For aviation purposes a "Digital Surface Model" (DSM) representing the real surface of the earth including all cover like vegetation and buildings is recommended. Due to the characteristics of active remote sensors the derived model always describes an in between of the two elevation representations. To estimate the deviation the Technische Universität Darmstadt (TUD) deals with the determination of the influencing factors which affect the quality of the terrain models during the generation processes. In order to enhance the integrity of the data a "safety buffer" is created to allow the usage for dedicated applications.

In this scope the TUD examines the impact of topographic conditions, slope as well as reflection characteristics of the surveyed territory. Hereby the focus will be laid on the interpretation of SAR images and reflux intensity of LIDAR. Based on the determined error the elevation model is corrected and accurately verified to guarantee the reliability for safety critical aviation application.

6363-12, Session 3

A segment-based speckle filter for polarimetric SAR

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Synthetic aperture radar (SAR) is a remote sensor with abilities of all-weather, day-and-night observation and can be represented as various polarimetric aspect. Due to the coherent imaging of SAR, it is always with the drawback of speckle. In order to further use SAR image for applications, the speckle reduction is an essential task. Lee Filter is a very famous filter to reduce speckle in a SAR image. The particular characteristic of Lee Filter is that it employs eight different direction non-square windows to preserve the edge sharpness of SAR image. However, it is still insufficient to preserve the edge sharpness in the area whose land-cover has irregular shape. This study is trying to combine the K-means clustering and Wishart distance to construct filtering window that has more exact shape to approach the land-cover for better preserving the edge sharpness after speckle reducing. The pilot results show that the filtering scheme mentioned above can perform better edge-sharpness preserving. But the filter efficiency and the parameters decision need further study to find out the optimal setting.

6363-13, Session 3

Analysis of ASAR data for geo-location accuracy and desert signatures

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Envisat ASAR data has been extensively used for the retrieval of geophysical parameters and SAR Interferometry applications. Also good number of publications are seen in the literature on the geo-location accuracy and calibration of ASAR data. In this paper, an attempt is made to study the desert signatures of ASAR data and its geo-location accuracy.

Seven ASAR SLC scenes were procured from ESA-ESRIN under the projects code AO-245 and Category 1 code 3807; during the time April 2004 to June 2005. The data has been processed using BEST module for generating calibrated images. EnviView package is used for extracting the geo-locations of intersections of road network and other important land marks. Around 100 locations were identified. Trimble 5700 GPS systems were used to measure the geo-locations of these points for validation. ERDAS image processing package is used to extract the signatures of well known land features. About 20 land features such as open desert where grazing takes place, fenced regions where grass is protected from grazing, built up areas, military camps & parks, airport areas and marshlands were identified for this study. The locations were spread all over Kuwait within 100 x 100 km area. The number of pixels in each signature varies from 12,000 to 270,000 which is a very good number for statistical analysis

Kuwait receives rain during December - February and so higher backscattering coefficient (σ°) is expected due to more moisture in the soils. As the soils dries down, the σ° is supposed to decrease. However, no such trend is observed in the data. The SLC images are speckled filtered to reduce the noise and calibrated using BEST module. The average Standard Deviation (STD) of the signature is 1.33% of its actual value. The variation in σ° from January to June 2005 is within the STD which is surprising to note.

Regarding the geo-location accuracy, the analysis is carried out in two steps namely (1) internal consistency and (2) absolute accuracy. The internal consistency is verified by comparing the road intersection derived from April, 2004, January 2005 and June 2005 ASAR images. About 100 locations were identified spreading all over the image. The internal consistency was found to be very good with in 2 - 3 pixels. The absolute validation is carried by comparing with Trimble-5700 GPS measurements. The absolute accuracy of geo-location of ASAR data is of the same order. The details discussion of the results will be presented in the full paper

6363-14, Session 4

Modeling the electromagnetic response of Titan's surface features observed by Cassini Radar

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The Cassini spacecraft, launched in 1997, begun the exploration of the Saturnian system in July 2004. 44 flybies of the Saturn largest moon Titan are planned during the four years of the Cassini mission and 16 are Radar passes. The Radar mounted on Cassini has been developed jointly by JPL, ASI and Alenia Spazio. The instrument operates at 13.8 GHz Ku band and has passive (radiometer) and active (scatterometer, altimeter, SAR imaging) capabilities; in the active mode, interleaved passive measurements are also obtained [1].

Until April 2006, six (Ta, T3, T4, T7, T8, T13) of the 16 Radar planned passes have been accomplished. The data are processed by the JPL. and stored in the Basic Image Data Records (BIDR) files, thus obtaining SAR images and brightness temperature profiles of a significant fraction of Titan's surface. The Radar Cross Section, RCS, derived from the SAR imagery, reflects the complex Titan's surface morphology [2]. Data, with correction of incidence angle effects, also provided in BIDR files, show RCS variations in excess of 20 dB between the "brightest" and the "darkest" areas. These variations are mainly due to the different degrees of roughness, with the smoother surfaces also candidate to be covered by a layer of liquid hydrocarbons. Moreover, in the most recent passes, periodic structures have been observed: in this case the RCS variations can be described in terms of tilt angle effect, thus modifying the local incidence angle.

In this paper, the RCS behaviour of the observed features is studied in detail by the means of the Integral Equation Model, IEM. The dependence of the backscattering coefficient on the surface's physical properties, composition and roughness of different areas is obtained. Surfaces are modeled as Gaussian stationary processes.

The data of the IEM model are compared with numerical simulations based on the Kirchhoff approximation with auto similar surfaces [3,4] performed as preparatory work in the preliminary stage of the Cassini mission. The RCS data simulated for some likely scenarios of Titan surface are well consistent with the real radar data and can help their interpretation in terms of physical and morphological surface properties. IEM approach can be also used to evaluate the influence of surface roughness on the radiometer brightness temperature, mainly depending on physical temperature, dielectric constant and observation angle.

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6363-15, Session 4

Extraction of wind and surface current patterns from SAR imagery

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The capacity of synthetic aperture radar (SAR) to observe the sea surface and its potential for evaluating the wind and surface current patterns, interpretation of atmospheric and oceanic phenomena make it a very useful tool for monitoring marine patterns. The study is divided into two parts: the first part is extracting the surface current patterns and the second is extracting the wind patterns from SAR image. The CMOD-4 and

CMODIFR2 models are applied in the extraction of speed and wind direction. SAR wind field retrieval is a two-steps process. The first step is to retrieve wind directions, which is an important input to the second step to retrieve wind speeds. The SAR wind speed retrieval is dependent upon the accuracy of wind directions. The wind speeds algorithm derived from the normalized radar cross section (NRCS) is used to extract the wind speed and direction of the calibrated SAR image. RADARSAT-1 image over the Straits of Malacca was used for testing and validation.

6363-16, Session 4

Windowing technique in FM radar realized by FPGA for better target resolution

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Remote sensing systems, such as SAR usually apply FM signals to resolve near targets (objects) and improve SNR.

Main drawback in the pulse compression of FM radar signal that it can add the range side-lobes in reflectivity measurements. Using weighting window processing in time domain it is possible to decrease significantly the side-lobe level (SLL) of output radar signal that permits to resolve small or low power targets those are masked by powerful ones. There are usually used classical windows such as Hamming, Hanning, Blackman-Harris, Kaiser-Bessel, Dolph-Chebyshev, Gauss, etc. in window processing.

Additionally to classical ones in this paper we also use a novel class of windows based on atomic functions (AF) theory (see, for example V. F. Kravchenko, New synthesized windows, Doklady Physics, American Institute of Physics, V. 47, No. 1, pp 51-60, 2002). For comparison of simulation and experimental results we applied the standard parameters, such as coefficient of amplification, maximum level of side-lobe, width of main lobe, etc.

We also proposed to implement the compression-windowing model on a hardware level employing Field Programmable Gate Array (FPGA) that offers great benefits like instantaneous implementation, dynamic reconfiguration, design, and field programmability. This work aims at demonstrating a reasonably flexible implementation of FM-linear signal, pulse compression and windowing employing FPGA's. To realize the radar pulse operation and windowing the Kit Altera FPGA was used.

It has been investigated the pulse compression design on FPGA using classical and novel AF window technique that permits to reduce the SLL taking into account the noise influence and increasing the SNR and detection ability of the small or nearly placed targets in the imaging radar, such SAR. The advantage of FPGA is that can do parallelism in real time processing permitting to realize the proposed algorithms.

Paper presents the experimental hardware results of windowing in FM radar resolving several targets for classical rectangular, Hamming, Kaiser-Bessel, and novel Up(x), Fup1(x), sigma(x), fup4,2(x)B2(x), Fup4(x)D3(x), Fup4(x)D3.5(x), Fup6,2(x)G2,2(x), Fup6(x)G3(x), Fup6,2(x)G3(x) functions windows. It is possible to conclude that windows created by use the atomic functions offer sufficiently better decreasing of the SLL in case of noise presence and when we move away of the main lobe in comparison with classical windows.

6363-18, Session 4

The diffraction gratings to reduce the tsunami waves

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There are the theoretical consideration of the possibility of the small periodical actions to the tsunami wave in ocean to reduce its powerful. In another words, the diffraction gratings could be applied to the propagated tsunami wave. It is known the set of effective methods for reflection, deflection and splitting of the propagated waves based on the diffraction grating's mechanisms in optics, for example. The analogous approach will be transformed here for tsunami wave in the frame of theory for the Long Waves, where the set of small periodical actions in the direction of wave's propagation will be done, as assumed. This diffraction grating in ocean could be realized by artificial method, such gratings could be done as the numbers of periodical explosions with co-ordinations in time. The model assumed the periodical disturbances in the upper water layer in ocean, in the area where the tsunami exists, and with the out of phase joint action. Firstly, the periodical local modulations of water velocity up to negative values (and zero ones) are considered in the system of non linear equations for the theory of long waves. The second in the waveguide approach, where the concrete ocean depth is assumed as the waveguide with appropriate spectrum of propagated wave modes. The periodical surface modulation (relief grating) has interactions with different waveguides modes, the result efficiency will be analyzed and presented.

Conference 6364: Optics in Atmospheric Propagation and Adaptive Systems IX

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6364-01, Session

Atmospheric propagation and system aspects

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Advances in detector technology for imaging and advances in image processing pose additional pressure on system adaption with respect to atmospheric constraints. Problems are discussed for specific imaging systems working from UV to IR.

6364-02, Session 1

Measurements of refractive variability in the marine boundary layer in comparison with mesoscale meteorological model predictions

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In the marine boundary layer, air-sea interaction processes have an impact on radar and infrared propagation. Range performance near the sea surface depends on the meteorological conditions and sea surface roughness. Strong gradients of humidity and temperature close to the air-water interface are most often the reason for abnormal propagation effects such as ducting or mirage. For ship borne radars the evaporation duct is the dominant propagation mechanism affecting the maximum detection range of horizon-search radars. Ducting can also increase sea clutter return within and beyond the geometric horizon. Surface-based ducts can enhance land clutter return from extended ranges.

During a sea trial in the Baltic Sea in 2005, FWG characterized the environmental boundary layer. In-situ measurements included recordings of atmospheric and sea surface parameters. Simultaneous investigations were carried out at the land based test site and on board two ships. Based on FWG-buoy measurements and radiosoundings the sea surface and meteorological conditions were analyzed to study refractive variability within the maritime boundary layer. We compared measurement results with predictions of the mesoscale meteorological Local Model (LM), developed by German Weather Service.

Radar propagation was measured in addition to atmospheric conditions. A research vessel was illuminated by radar operating at X-band on outbound and inbound runs. The radar system was located at the pier of the land based test site. Radar propagation characteristics were measured on board the ship with two omni directional antennas mounted in 5.5 m and 16.8 m height above mean sea level.

Results of refractive variability are presented in conjunction with radar propagation data and model outputs.

6364-03, Session 1

Prediction of optical path deviations under stable conditions in maritime environments

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Bulk Monin-Obhukov modeling of atmospheric profiles is extensively employed in conjunction with ray-tracing to account for refraction-induced ray-bending in sensor simulation studies. Last year, accuracy of such method was assessed on a large diversity of conditions by consolidating data obtained from two different measurement campaigns. Model predictions of path deviations were found to agree with measurements within plus or minus 0.1 mrad in most cases, except for air-sea temperature differences greater than about 2 C where much larger discrepancies were obtained. In this paper, bulk models of temperature and humidity profiles under stable conditions are discussed. Calculations using two modeling approaches found in the literature are compared against measurements, and suggestions are made for model improvement.

6364-04, Session 1

Refraction effects and wavelength dependence

J. Claverie, Ecole de Coetquidan Service (France); D. Dion, Defense Research and Development Canada-Valcartier (Canada)

The performances of Electro-Optical (EO) systems such as visible or infrared cameras, lasers, operating within the Marine Surface Boundary Layer (MBSL), i.e. at heights up to a few tens of meters above the sea surface, are disturbed by various propagation mechanisms: molecular attenuation, aerosol extinction, refraction and turbulence. Refraction is responsible for focusing and defocusing of rays, detection range limitations, mirage formation and angular deviation.A meteorological bulk model (such as PIRAM developed in France or LWKD developed in Canada) can easily be linked with a ray tracing algorithm to predict the refraction effects. The former versions of PIRAM and LWKD assumed the atmospheric refractive index to be independent of the wavelength within each of the main optical transmission bands (Visible, near IR, mid IR and far IR). More complex wavelength dependences can also be found in the literature and we decided to analyse the real impact of these formulations in terms of EO systems prediction performances. Two different parameters have been computed: the apparent target elevation and the real optical horizon at a given target height.For a target 10 km away from the observation point, the apparent elevation angle may vary by 20 μrad within the [8-12 μm] band. If one assumes a camera resolution of 10 μrad, the consequence is an image displacement by 2 pixels.For a quasi neutral atmosphere, assuming a target height of 20 m and an observation point height of 7 m, the variation of the optical horizon within the [8 - 12 μm] band is more than 500 m. Simulations showed less important variations for strong unstable conditions.The wavelength dependence of the atmospheric refractive index should not be considered as negligible, especially for the performance prediction of future hyperspectral EO systems.

6364-05, Session 1

MATISSE: version 1.4 and future developments

P. Simoneau, K. Caillault, S. Fauqueux, T. Huet, J. Krapez, L. Labarre, C. Malherbe, C. Miesch, ONERA (France)

No abstract available

6364-06, Session 1

Determination of aerosol size distribution from multiband transmissometer data in the southern Baltic Sea during the VAMPIRA trials

A. Jong, TNO Defense, Security and Safety (Netherlands)

The presence of aerosols along the line of sight of infrared and electro-optical sensors greatly determines their range performance. The collection of accurate data on the particle size distribution (PSD) of these aerosols is rather difficult. One of the reasons is the variation of the PSD along the path, which is likely to occur in a coastal area such as the Eckernforde Bucht, the location of the VAMPIRA trials, held in March-April 2004. One way to overcome these problems is the use of a multi-band transmissometer, operating at wavelengths comparable to the dominant particle diameter (0.2-2 micrometer). A tool has been developed to simulate the transmission behavior in various spectral bands and to investigate the possibilities to retrieve the PSD from multi-band transmission data. The slope in the plots of the transmission versus wavelength is directly related to the slope Je of the PSD, which is assumed to behave as the well known Junge distribution log(dN/dD)=log(Jc) + Je*log(D) with exponent Je and coefficient Jc. The principle of the methodology is illustrated with data, collected during the VAMPIRA trials. In this campaign a seven-band optical-infrared transmissometer was used, with wavelength bands between 0.4 and 14 μm, providing data over the 8.6 km path over water. Simultaneously PSD data were collected with Particle Measurement Systems on one of side locations. A comparison of the data from both systems will be presented.

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6364-07, Session 1

TOMS AAI for ELTs Moroccan sites studies

E. A. Siher, Cadi Ayyad Univ. (Morocco)

A previous study showed a direct link between aersol index measured by the TOMS/Nimbus7 satellite and the astronomical extinction measured in back ground in Canary Islands. Other studies attemp to use the aerosol optical thickness for a qualitative study of the Moroccan sites chosen to be candidacy of telescopes ELTs. In our work, we will debate on this topics by using all TOMS absorbed aerosol index (AAI).

6364-08, Session 1

Code MEDEX for predicting atmospheric aerosol extinction in the marine surface layer

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Advanced version of the code MEDEX to predict the performance of EO systems in the marine atmospheric surface layer has been developed.

Based on an extensive series of measurements conducted on the Porquerolles Island in the Bay of Toulon (France) and on the Black Sea coastal zone, an empirical aerosol model for the coastal zone formulated the advanced version of MEDEX, in which coastal effects are modeled as a function of fetch, has been developed.

Code MEDEX is constantly improved computer program for an estimation of a signal energy at a detection point in which the key entrance parameter is fetch. The program assesses spectral aerosol extinction as the function of standard meteorological parameters, aerosol microphysical structure, a sensor spectral range and geometry of a path of supervision. Aerosol extinction can be presented both numerically and graphically form.

User interface MEDEX is completely mouse-controlled, and operates on standard PC on basis Windows. Time of calculation of the spectral aerosol extinction depends on the necessary spectrum resolution and at the high resolution does not exceed tens seconds. Other calculated characteristics carry out almost instantly.

Probable applications of computer program MEDEX include an estimation of efficiency of application EO systems, a choice and optimization sensors, and also performance of calculations in the scientific and educational purposes.

6364-09, Session 1

A precise texture-color based forest detection in urban environment

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Remote sensing represents a useful source of urban data, providing spatially consistent coverage of large areas with both high geometric detail and high temporal frequency, including historical time series. Recent availability of commercial high-resolution satellite imaging sensors such as IKONOS and Quick-Bird provide an important source of data for urban remote sensing applications. The high spatial resolution of the imagery reveals fine details in urban areas and greatly facilitates the recognition and extraction of urban-related features.

Inherent spatial variability of urban land use and acute spectral heterogeneity between pixel values in high resolution images has typically led to low interpretation accuracy. Methodologies to improve accuracy have ranged from the manipulation of neighbouring pixel values to the incorporation of information from beyond the spectral domain, usually during the classification process.

Dynamic urban change processes associated with constantly increasing populations affect natural systems and their environment at all time and space scales. Often this extension is made at the expense of vegetated areas, which play an important role in the regulation energy and water transfers between the land and the atmosphere. Mapping vegetation at high thematic resolutions remains a significant challenge for the remote sensing community but it is key element in urban planning and growth. Succesfull forest mapping and monitoring in and around cities provide necessary tool, not only for forest management, but for air and water quality studies as well. In this paper we present a methodology for precise forest cover extraction in an urban setting using multispectral IKONOS images.

This achieved by increasing the amount of information that can be extracted from theses images by taking into account both spectral and textural information in a multi-resolution wavelet based scheme. Thus, texture and color were processed as a unique pattern in order to insure local interactions within the same channel and local inter-channel correlation. The extracted feature called texture-color was computed over the wavelet transformed channels.

Our test area is located in Sherbrooke city in the Estrie region of Canada. It consists of various types of land use, such as road network, agricultural, residential, and commercial uses. Different land cover types composing the region are bare soil, grass, shrubs and forest.

In order to estimate the accuracy of our forest detection, a comparison with an existing forest map was performed. The results show that forests detection was performed with great accuracy and high boundaries precision. The forest mask obtained has great thematic and geometric precision and can be a usefull tool for studies aimed at detecting urban expansion or monitoring vegetated land within urban settings. It can also be used to detect land cover species within large vegetated areas.

6364-10, Session 1

IR propagation in coastal environment - results of the VAMPIRA trial

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ABSTRACT

The detection and tracking of missiles flying at a low altitude above the sea surface is one of the most urgent problems in ship self defense. These tasks are mainly managed by IR-Search and Track systems in the mid and long wave IR and by RADAR Systems. Both systems suffer severe limitations. The range efficiency of IR-systems is limited by atmospheric effects in the marine boundary layer.

The NATO AC/323 SET-56/RTG32 on Integration of Radar and Infrared for Ship Self Defense has investigated the radar and infrared synergism with respect to propagation in a coastal environment. In spring 2004, the members have held the Validation Measurements for Propagation in the Infrared and Radar (VAMPIRA). To have a direct comparison of RF and EO behavior, several systems were set up at the same altitude above sea level (approx. 19 m). This paper deals with the results of the IR-measurements.

To simulate point-like targets at low altitudes, hot sources at different temperatures were installed onboard a small boat. Numerous mid and long-wave IR sensors made simultaneous measurements on the boat to analyse extinction versus range, maximum detection ranges and refraction effects. One efficient propagation models for the IR is IRBLEM (IR Boundary Layer Effects Model), developed by DRDC. The measurements of the boat runs were compared to the model predictions. Most of the measured data analyzed in this paper were gained by DDRE, DK. Based on the Danish results on the signal variations with range, a comparison with a Thermal Range Model for Point Target Detection (TRP) was done. TRP is an analytic model which had been developed at FGAN-FOM to estimate the range performance of a point target detection system working in the infrared.

6364-11, Session 1

Radar propagation in coastal environments: Vampira Results

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The performance of sensors operating in coastal environments is severely influenced by the actual atmospheric conditions and the sea surface. Propagation models are in existence, which cope with the varying environment and allow a performance prediction for sensors in different bands of the electromagnetic spectrum. Model calculations give evidence for a complementary performance of sensors operating in the IR region and at radar frequencies ranging from X- to W-band. To validate existing radar propagation models like TERPEM and to compare IR with mm-wave propagation over sea under various atmospherically conditions, joint experiments with IR- and radar sensors were conducted over transmission ranges well beyond the horizon. For the measurements a naval vessel was moving on outbound and inbound courses ranging from the sensor site over the horizon, carrying corner reflectors acting as point targets at different heights above sea. This allowed a thorough investigation of duct propagation at different heights above the sea surface. The measurements were accompanied by a detailed environmental Characterization of the sea surface and the atmosphere.

The paper describes the experimental approach and gives representative results for measurement and simulation. The implications on performance especially for a multispectral (IR/mmW) approach are discussed.

6364-12, Session 2

Influence of photodetector response time on operation

V. P. Lukin, V. Nosov, E. Nosov, N. N. Botugina, O. N. Emaleev, A. Torgaev, Institute of Atmospheric Optics (Russia)

Papers describe the algorithms of a measuring method of integrated turbulence intensity based on airborne observations. The measured characteristic is the jitter variance of astronomical images. The device realizing this method in practice is designable as an onboard turbulence measurer. The measurer can be both monostatic (one photodetector), and bistatic differential (two separated receivers). Specificity of airborne measurements assumes the use of CCD matrixes. Their response speed is not great. Even good modern matrixes provide frame frequency no more 300 Hz usually. Therefore during the receiver response (it is the length of one frame) characteristics of turbulence on an optical path change appreciably (because of large velocity of the airplane, no less than 500 km/h). The random process strong averaging by the receiver takes place, which is expressed in fluctuations suppression.

In the present paper the influence of photodetectors response time on operation of onboard turbulence measurers is analyzed. Time correlation functions of the image jitter in monostatic and bistatic measurers (on horizontal and inclined routes) are investigated, finite time of photodetectors response is taken into account. Theoretical expressions for functions of the receiver's response are constructed and studied. Function of the response shows how much the variance registered by the inertial equipment decreases in comparison with date obtained by inertialess equipment.

It is shown, that in bistatic measurer at typical parameter values the decrease of response function by one order occurs at frame frequency 220 - 180 Hz. It is established that for decrease of influence of response time (for increase of response function) it is necessary to increase the separation between channels. The peak deviation of bistatic response function from a monostatic one is observed at a zero angle between velocity vectors of the airplane and receiver separation (vectors are collinear). With growth of this angle the bistatic response function approaches a monostatic one, and partial averaging influence decreases. The best situation is observed for perpendicular vectors. In this case it is possible to use not too quick response CCD matrixes, 30 - 100 Hz.

6364-13, Session 2

Scintillation in ground-to-satellite laser link : physical approach and numerical simulation

J. Conan, V. Michau, M. J. F. Séchaud, ONERA (France)

No abstract available

6364-14, Session 2

Propagation through shear layers

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Propagation of optical radiation through a shear layer such as turbulent jet, is affected mainly by the fluctuations of the density field. Calculation and measurement of these fluctuations is very difficult and modeling is not fully validated.

In most reported computations1-6 the calculation of turbulent effects is done by assuming Kolmogorov turbulence, namely defining the structure constant of turbulent in a similar way to that done for atmospheric turbulence. This approach was justified by the agreement obtained with experimental results.

In previous works5-6 I presented several effects of propagation through the atmosphere and through shear layer mainly turbulent jets. The propagation through the shear layer was calculated using preliminary results and basic fluctuation models. Kolmogorov turbulence was used as well.

In this work I present an investigation of propagation of an optical radiation through shear layer. The main difference from the previous works is that the propagation is calculated using basic principles and density field distribution.

I will also implement density fluctuations models7 with the results obtained by CFD calculation and then calculate propagation using realizations of the density field, to obtain the statistical behaviour of optical turbulence.

Then I will compare the results to those calculated using Kolmogorov turbulence. Comparison to experimental results will be made with those obtained recently by Sjöqvist et. al.4

I will also show a new model of density fluctuations, then compare the results computed by the various density fluctuations models7 and to available experimental results and deduce which model is better suited for the various flow conditions.

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6364-15, Session 2

Turbulence statistics in littoral area

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The structure constant of refractive index fluctuations, Cn2, is the parameter most commonly used to describe the atmospheric turbulence. FGAN-FOM had carried out a long-term experiment to measure Cn2 over sea in moderate climate, Central Europe. A Boundary Layer Scintillometer was installed along 1.7 km path crossing a bay of the Baltic Sea (Eckernförder Bucht) at a height of 4.7m above water level. Meteorological parameters were simultaneously measured.

One of the main parameter, which effects Cn2 is the temperature difference between air and ground, larger temperature difference causes stronger turbulence. Over sea, the air-sea temperature difference, ASTD, is generally smaller than the air-ground temperature difference over land, which implicates smaller Cn2 values. Turbulence over sea significantly differs from turbulence over land. The diurnal run of Cn2 does not show the characteristic maximum at midday, Cn2 values measured during night are not generally smaller than those measured during at noon, and Cn2 values measured in the daytime during summer are not generally larger than those measured during winter. Since Cn2 usually changes with environmental conditions, its influence on the effectiveness of electro-optical systems can normally only expressed in a statistical way. We worked out the statistical database for atmospheric turbulence over sea accordingly to our turbulence database over land. The cumulative frequency of occurrence was calculated for a period of one month for a two-hours time interval during daytime and during night time. Results will be presented.

We applied the LWKD model of the Defence Research and Development Canada, DRDC Valcartier, to calculate Cn2 for the measured meteorological parameters as a function of ASTD. The correlation of Cn2 and ASTD indicates larger Cn2 values for the measurement than for the calculation.

6364-16, Session 2

Measurement of the refractive-index structure constant and its profile in the ground level atmosphere by moiré technique

S. Rasouli, Institute for Advanced Studies in Basic Sciences (Iran); M. T. Tavassoly, Univ. of Tehran (Iran)

Atmospheric turbulence may have strong impact on astronomical imaging, aerial surveying, terrestrial geodesy, optical ranging, and wireless optical

communication. Major effects are beam broadening, irradiance fluctuations (scintillations), and angle of arrival (AA) fluctuations. The interesting effects of atmospheric turbulence for optical propagation studies are the variation (gradient and fluctuations) of refractive index. The corresponding refractive index structure constant is the parameter most commonly used to describe the strength of atmospheric turbulence. Good image quality requires refractive index structure constant being as small as possible. In this work we present an easily applicable and accurate method, based on moiré technique, for the measurement of the atmospheric refractive-index structure constant, and its profile in the ground level. In this technique from a low frequency sinusoidal amplitude grating, installed at certain distance from a telescope, successive images are recorded and stored in a computer. By superimposing all images, one by one, on one of the image, a large number moiré patterns are formed. To produce the required moiré patterns the first frame was rotated by an angle equal to 4 degree and multiplied by the other frames rotated by -4 degree. By finding the traces of the moiré fringes in the patterns, the fluctuations of the traces are obtained. These fluctuations correspond to AA fluctuations distribution. From the AA fluctuations distribution in successive patterns, the refractive-index structure constant, and its profile in vertical direction are deduced. This technique renders to measure several other atmospheric parameters that will be discussed in the paper.

6364-17, Session 2

Characterization of compensation for nonuniform image distortions due to atmospheric turbulence

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The full system of the nonlinear Navier-Stokes equations has been used for modeling weak and strong turbulent fluctuations of density and their temporal evolution. The method of computation is based on the fundamental solution to the parabolic system. An iterative procedure has been applied. Convergence of the procedure is analyzed. The effect of nonlinearity is evaluated. The compensation for random non-uniform distortions of images is investigated. Characteristics of compensation which connect noise factor and compensation accuracy have been deduced. Possibilities of the focusing of a laser beam propagating through turbulent atmosphere are discussed. Numerical examples are presented.

6364-18, Session 3

Wavefront measurements and conjugation in strong speckle-modulation conditions

M. A. Vorontsov, Army Research Lab. (USA) and University of Maryland, College Park (USA); V. V. Kolosov, Institute of Atmospheric Optics (Russia); A. Kohnle, FGAN-FOM Research Institute for Optronics and Pattern Recognition (Germany)

Laser illumination of extended targets results in strong (~ 100%) speckle modulation of the received signal, leading to a dramatic (\>10x) decrease in the signal-to-noise ratio for target designation, target ID, and tracking systems. Target-induced speckles prevent measurement and compensation of atmospheric turbulence-induced phase aberrations in high-energy laser (HEL) beam control systems.

The major focus of this research is analysis of the instantaneous and speckle-average return field wavefront phase, as well as potential utilization of target-return wavefront phase measurements for outgoing beam phase control in Target-in-the-Loop (TIL) laser beam projection systems. We analyze and compare the efficiency of conventional phase-conjugation and complex field-conjugation techniques for various TIL propagation scenarios. In this research two new phenomena have recently been observed in numerical simulations of HEL TIL propagation: target hot-spot attachment to a moving target surface, and a turbulence-induced super-focusing effect.

At first glance the existence of both new effects is quite surprising. It is shown that under certain conditions the laser beam target hot-spot formed during the phase conjugation process can travel together with the target surface over a distance that significantly exceeds the spot size. The hot-spot speed of travel exactly equals the target surface speed, so that the target hot-spot is attached to the same location on the target surface area. The super-focusing effect suggests that during phase conjugation the presence of atmospheric turbulence may result in significant performance improvement of laser beam projection systems, resulting in a target hot-spot size that is smaller than the diffraction-limited spot size.

6364-19, Session 3

The new scheme of formation bistatic laser guide star

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Laser guide sources are one their major elements of modern adaptive optical system. It is known, that there is a problem of measurement of the general inclination of wave front with use of a signal from a laser guide star (LGS). We shall consider here some approaches to its decision which open new schemes of formation of LGS.

At carrying out of our analysis we shall apply all information available us on high-altitude distribution of intensity and outer scale of atmospheric turbulence . Jittering of the image of a natural star (the general inclination of wave front) we shall describe a vector , describing fluctuations of angular position of the center of gravity of the image, formed by a plane wave in a focal plane of a telescope. The measured angular position of the image of LGS we shall characterize a vector .

The technique of realization of the scheme with a laser guide source in the form of two crossed lines is possible. It is possible even to speak about a laser guide star in the form of a guide cross. For this purpose it is used two narrow laser beams and we shall carry out their very fast angular scanning. Thus two narrow focused beams are radiated from a point located near to the aperture (but outside of it) the basic telescope. Beams carry out angular scanning in two mutually perpendicular directions. Frequency of such angular modulation is a lot of above characteristic frequencies of turbulent jittering of the focused beams. Due to enough fast angular scanning these two beams in a plane of their focusing there is a shone object - LGS in the form of two crossed lines - a laser guide cross. The result of correction of fluctuations of the general inclination of wave front here appears better, than for any known bistatic schemes. We shall specify advantages of the offered scheme: are not necessary additional telescopes, two laser illuminator can be on the general mount of a telescope that removes a problem joint pointing a telescope and laser illuminators, formation of laser beams occurs outside of the aperture of the basic telescope, therefore there is no phosphorescence of an optical path, there is no dependence of the useful signal providing correction of the general inclination of wave front from parameters of laser beams, only change of an operating pressure optical scanners laser beams it is possible to change the size of a laser basic cross.

6364-20, Session 3

Measurement of modulation transfer function (MTF) of the atmosphere in the surface layer by moiré technique

S. Rasouli, Institute for Advanced Studies in Basic Sciences (Iran); K. Madanipour, M. T. Tavassoly, Univ. of Tehran (Iran)

The turbulence of the atmosphere puts an upper limit on the quality of the image of a ground object obtained by long-exposure photography from low or high altitudes in the atmosphere or in the space. By using good optics and high resolution film or CCD and a stable platform, this limit could be approached but not exceeded. A useful quantity for indicating the magnitude of this limit is the integral of the modulation transfer function (MTF) associated with the turbulence. In this work, we introduce a new method for measuring the MTF of the atmosphere in the surface layer by moiré technique. In this technique from a low frequency Ronchi grating, installed at a certain distance from a telescope, successive images are recorded and stored in a computer. By rotating each image by +4 degree and -4 degree, and superimposing the resulted images, a large number moiré patterns are formed. The transmission function of the superimposed image gratings in a moiré fringe interval is then measured. The latter function is measured by scanning the moiré pattern by a slit parallel to moiré fringes. It is shown theoretically that from the Fourier transform of the latter function the MTF of the atmosphere can be deduced, if the MTFs of the telescope and the grating are given or their effects are ignored. Due to having access to a large volume of data the average MTF can be deduced with high precision. The atmospheric MTF has been measured at different turbulence conditions. Also, we have studied the behavior of the atmospheric MTF respect to exposure time.

6364-21, Session 4

The statistical foundation of chi square laser system pointing estimation

G. W. Lukesh, S. M. Chandler, Nukove Scientific Consulting, LLC (USA)

In 1997, Susan Chandler and Gordon Lukesh began a comprehensive study of the data contained in the total reflected time-series signal for

ground-to-space illumination experiments performed at Starfire Optical Range on Kirtland AFB, New Mexico. The initial objective was to estimate laser system pointing errors, known as jitter and boresight using only the received time-series signal. Several papers have been presented at this conference. No complicated imaging systems need be used, nor any target sensor boards (usually available in the laboratory but not in space). The approach has been expanded to the estimation of target shapes and is chi square based.

Chi square techniques generally require that the data obey reasonable statistics. This is interpreted as follows: The occurrences within a chi square bin should exhibit Poisson, Gaussian or binomial behavior. For example, a fair coin tossed ten times has expected occurrences of heads five and has a follows a Gaussian distribution when the experiment is repeated. Because the authors' techniques are chi square based, a study was undertaken to determine the statistical foundation of the approach.

This paper presents results that show the behavior within chi square bins follows to a very high degree of confidence binomial statistics, thus justifying its use. The paper begins with a review of the general technique and the fundamental issue of the justification of the chi square approach. Results for a variety of pointing errors coupled with data fits are presented as well as statistical analysis.

6364-22, Session 4

Random fluctuations of optical signal path delay in the atmosphere

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Atmospheric turbulence induces random delay fluctuations to any optical signal transmitted through the air. We have created a suitable model of this effect in order to predict its influence on the precision of satellite laser ranging (SLR). The atmospheric turbulence along the ground-to-space and space-to-ground beam path induces random errors to the measured range. We have found an appropriate theoretical model that allows us to predict the amplitude of the random delay fluctuations for different observing conditions. The input of the model is either a vertical profile of the turbulence strength or an astronomical seeing measured along the beam path using a distant point light source. We have successfully proved the applicability of this model by a series of experiments, directly determining the amplitude of the turbulence-induced pulse delay fluctuations by analysis of the SLR data acquired using picosecond laser pulses and ultra-precise timing electronics, enabling submillimeter range resolution. Moreover, we have also shown that the standard theoretical approach based on diffractive propagation of light through inhomogeneous media, which is routinely used in adaptive optics to predict the turbulence-induced wavefront corrugation, is not suitable for modeling of the optical signal delay fluctuations. The models and codes based on diffractive propagation predict the turbulence-induced optical path length fluctuations of the order of micrometers, whereas the fluctuations predicted by our model (in agreement with our experimental data) are generally larger by two orders of magnitude, i.e. in the submillimeter range.

6364-23, Session 4

Reconstruction of the optical field phase from phase gradient in presence of branch points

A. V. Falits, V. A. Banakh, Institute of Atmospheric Optics (Russia)

The least squares method is widely applied to phase reconstruction both from the Hartmann-sensor or shearing-interferometer measurements of wave slopes and in radar interferometry. The least squares method has a smoothing and filtering effect, for it is based on the potential part of the phase gradient vector and does not allow reconstruction of the so-called hidden phase determined by the solenoidal component of phase gradient. In the area, where the solenoidal part of the phase gradient does not equal zero, the phase jumps by 2pin, where n is an integer, which is often caused by noise. With the least squares method, noise is filtered. However, when propagating the random optical fields or when the deterministic optical fields propagate in random media, there can occur situations of a strong random spatial intensity modulation of the propagating wave. Here, in those areas where the intensity is close to zero, there take place wave front dislocations (branch points), the indication of which is the non-zero solenoidal component of the phase gradient vector. In this case, the use of the least squares method leads to loss of useful information on the phase.In this work, we suggest an algorithm of phase reconstruction from phase gradient on basis of the Fried complex exponential reconstructor[1] and the least squares method. An advantage of this algorithm is that it does not require determination of phase branch point locations.

1. Fried D.L. Optics Communications, 200, 43-72 (2001)

6364-24, Session 4

The optical differentiation technique in wavefront sensing

J. E. Oti, V. F. Canales, M. Perez Cagigal, P. J. Valle, Univ. de Cantabria (Spain)

The use of high order compensation adaptive optics systems is required to get full advantage of the next generation of extremely large telescopes. Such adaptive optics systems need a high resolution description of the atmospherically distorted wavefront phase. This demanding requirement drives the development of new wavefront sensors like the optical differentiation wavefront sensor. This new wavefront sensing, that relays on the optical differentiation technique, provides a high resolution sensing with energy efficiency comparable to other sensors. This wavefront sensor is composed of a telescopic system in which focal plane an especially designed amplitude mask is placed. The final image is detected onto and imaging device like a CCD camera. The focal mask presents a linearly increasing amplitude transmission that allows the estimation of the first derivative of the incoming wavefront phase. In order to use all the available energy this mask is implemented using a semireflective mirror with an appropriate transmission/reflection profile so both, the transmitted and reflected energy, are used to estimate the wavefront phase local slope. It is estimated along the direction in which the amplitude transmission varies. Then, the wavefront reconstruction is performed using a standard procedure. We describe the amplitude masks required to estimate the wavefront phase derivative and how the reconstruction accuracy varies as a function of the mask size.

6364-29, Session 4

Optical fringe formation in Earth-based Michelson Stellar Interferometry in the presence of atmospheric turbulence

V. Gamiz, Air Force Research Lab. (USA)

We examine the pairwise fringe formation process for an Earth based Michelson stellar imaging interferometer, focusing specifically on how the complex fringe visibility degrades with spatial sub-aperture de-correlations, including the effects of the turbulent atmosphere. The fringe intensity is formulated for spatially incoherent sources, radiating or re-radiating, thermal light over a spectral interval where the quasi-monochromatic and cross-spectral purity approximations can be invoked. The imaging geometry is such that the source in distant enough to use the far-field approximation, and that a unique optical transfer function exists consistent with isoplanatic, or equivalently, linearly shift invariant imaging systems. It is shown that the complex fringe visibility is functionally dependent on the optical transfer function although the stellar interferometer does not form an image directly as would conventional imaging. The complex visibility is derived from the fringe intensity. Three forms of the complex visibility are developed and each formulation is interpreted. The effect of finite sub-apertures on fringe visibility is quantified and an example is given. This is followed by a discussion of the effects of the turbulent atmosphere on the fringe formation process and imaging.

6364-25, Poster Session

The characteristic of the cracked beam spots

Z. Feizhou, Y. Li, Institute of Applied Physics and Computational Mathematics (China)

The beam spot will break up into some cracks when the beam propagates through the turbulent atmosphere. In this paper, the characteristic of the cracked beam spot are studied statistically for different emitting beam shapes, beam qualities, and with different turbulent effects. It is shown that, with the degeneration of the beam quality and the turbulence being stronger, the total radius of the beam spot and the number of the fragments will increase; meanwhile the radius of the fragments will keep invariable almost: about the radius of the bucket which contains 63% of the total energy. The physical hypostasis of Fourier transformation is discussed, and two special situations are analyzed to understand the above results.

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6364-26, Poster Session

Influences of thermal distortions and atmospheric turbulence on image resolution of remote sensing system and adaptive optics correction

X. Zhang, X. Yu, J. Yan, B. Dong, C. Zhao, Beijing Institute of Technology (China)

The imaging performance of optical remote sensing system depends on two aspects, one is the design, manufacture and assembly of system, the other are the space influencing factors which occur in the system operating, for example, the thermal distortions, gravitation distortions, satellite flatform jitter, atmospheric turbulence and so on. In this paper, the influences of thermal distortions and atmospheric turbulence on image resolution of remote sensing system are analyzed respectively. The thermal distortions of different material and shape mirrors in different thermal conditions are studied. Zerdour is the best one according to the thermal distortion effects, Be is the worst. There are no apparent thermal distortions differences between different shape mirrors. The mirror surface distortions from different thermal loadings are Linear and symmetry to the initial temperature. Applying arrival angle-method method, some engineering examples are selected to analyze the turbulence influences on image resolution based on three different atmospheric turbulence models quantificationally, for space-borne remote sensing system, the resolution errors caused by the atmospheric turbulence are around 1cm. Besides, the spatial frequency characters of above influencing errors are present, and the Adaptive Optical system used to correct above errors is studied.

6364-27, Poster Session

Millimeterwave propagation within the marine boundary layer in European and tropical regions

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Naval units have to be prepared to take part in world wide missions. This is especially true since the struggle against terrorism has been tackled by the international community. In this context the detection of small ships, rubber inflatable boats or even divers at short to medium ranges is of high importance for the self protection of naval vessels. Due to the extreme multipath situation involving low level target sensor geometries, severe problems are due to radar sensors operating at classical frequencies up to 18 GHz. Millimeterwave radar sensors exhibit much less vulnerability due to multipath effects, as the sea surface is much rougher in comparison to the radar wavelength than at lower frequencies. However systems using this region of the electromagnetic spectrum, are determined in their performance through the marine boundary layer by atmospheric effects, which can be mainly attributed to refraction and turbulence effects.

During recent years measurement campaigns have been conducted to result in a data base representative for propagation in the marine boundary layer at radar bands ranging from X- to W-band, which is valid for ocean areas typical for Europe. New radar measurements have been done in the sea area around Singapore, which is a typical tropical environment. The data have been analysed and propagation models have been tested using the relevant environmental information. It turned out that atmospheric conditions exist, which are considerably different from the known situations.

The paper describes the experimental approach and compares typical results for European and tropical conditions.

6364-28, Poster Session

Method of refraction accounting in radiative transfer equation for atmosphere-ocean spherical system

A. B. Gavrilovich, Instytut Fizyki (Belarus)

The theoretical modeling of the field of optical radiation scattered by the air and water envelopes of the atmosphere - ocean system (AOS) is based on the solution of a boundary problem for the radiative transfer equation (RTE). The setting of the problem on the optical-radiation transfer in the AOS requires a consideration of a great number of parameters determining the character of interaction of light with a medium inside it as well as at the boundaries including the boundary between the media air - water. Because of this, approximate methods based on the introduction of different simplified suppositions, such as a plane geometry of the system, a single-interaction of light with the Frenel boundary between the media air - water, and the absence of the refraction of light rays, are widely used. The multiparametrisity of the problem and the impossibility of the obtaining of simple solutions generate a need for the search of new methodical approaches taking into account the spherical geometry of the system, the singularities of boundary conditions, the real profile of the refractive index and the refraction effect determining the deviation and refraction of light beams.

The refraction theory is based on the differential equation of refraction describing the change in the direction of a beam propagating in a medium with a varying refractive index. The inclusion of it in the problem on the scattering of light in the AOS leads to a change in the RTE and in the boundary conditions, which complicates the problem. Because of this the practically important question arises: if the boundary problem on the radiation transfer in the AOS can be reduced to a more simple form that not explicitly involve the refraction effect. The work provides the positive answer to this question and gives a mathematical substantiation of this possibility. This method is based on deformation of spherical coordinates in accordance with the spatial distribution of light refractive index in the atmosphere - ocean spherical system. It is shown, that the differential operator of the transfer equation in the deformed space, accounting the real refraction, takes the more simple form corresponding for rectilinear propagation of light, including the boundary between the media air - water.

Conference 6365: Image and Signal Processing for Remote Sensing XII

Wednesday-Thursday 13-14 September 2006

Part of Proceedings of SPIE Vol. 6365 Image and Signal Processing for Remote Sensing XII

6365-01, Session 1

Markov random fields for SAR image analysis and 3D reconstruction

F. Tupin, École Nationale Supérieure des Télécommunications (France)

No abstract available

6365-02, Session 1

Robust detection and spectrum estimation of multiple sources from rotating-prism spectrometer images

R. W. Deming, S. D. Higbee, D. Dwyer, M. Welser, L. I. Perlovsky, P. W. Pellegrini, Air Force Research Lab. (USA)

In this work we describe a new approach for automatically detecting and characterizing multiple point sources of energy from rotating-prism optical or infrared spectrometer images. The approach is specifically designed for analyzing difficult cases including (a) multiple closely-spaced sources, (b) dim sources and/or noisy backgrounds, (c) transient events, and (d) images acquired in the presence of significant sensor motion or jitter. The algorithm is developed within the framework of modeling field theory (MFT), a biologically-inspired mathematical method that has demonstrated practical value in many diverse areas of signal and image processing. Using MFT, a generic model is first developed in which parameters include the structure and location of point-source signatures and background clutter. Next, the model evolves to fit the measured data by efficiently optimizing model parameters and mappings between image pixels and sources, or clutter. The optimized set of parameters is then used for detection, localization and characterization of the multiple sources.

A significant challenge in this application - as in any multi-target detection, localization, or tracking application - is “data association”, i.e., the problem of correctly associating each pixel with its corresponding point-source or to the background clutter. This problem is especially acute for highly-cluttered images, or when sources are closely spaced such that their signatures overlap. If data association is incorrect, the characterization of targets will be skewed by including extraneous data. Traditional approaches for data association, such as multiple hypothesis testing, involve an exhaustive evaluation of all mappings between sources and pixels, and are therefore subject to a combinatorial explosion with increasing numbers of sources and/or pixels. A pre-detect stage will alleviate this burden by reducing the number of pixels under consideration. The downside of pre-detection is it prevents the detection of dim sources whose signature amplitudes lie below the threshold. In contrast, our MFT-based approach handles data association in a robust and efficient manner, so that computational complexity scales only linearly with increasing numbers of sources and pixels. Furthermore, since data association is handled probabilistically, overlapping target signatures can be resolved without catastrophic failure. Since we do not require pre-detection, we can typically detect very dim sources buried in significant background clutter. In the paper we will show results computed using experimental data.

6365-03, Session 1

A Cramér-Rao lower bound analysis of noise reduction limits in blind deconvolution for pixel-based point-spread-function estimation with the use of a support constraint

C. L. Matson, A. Haji, Air Force Research Lab. (USA)

In many imaging applications, it is desired to reconstruct a high-resolution image of an object from one or more blurred and noisy measured data frames. A key component of the reconstruction process is deconvolving the blurring point spread functions (PSFs) from the measured data frames. When the blurring PSFs are known a priori or can be measured separately to the desired degree of accuracy, the deconvolution process is straightforward. However, in many situations, the blurring PSFs are both not known a priori and there are no separate measurements of them. One such situation is imaging through atmospheric turbulence where the measured data frames are a sequence of one or more short-exposure images where the atmospheric turbulence blurring is not known and is different for each data frame. For these situations, the blurring PSFs must be estimated jointly with the object from the measured data frames. Algorithms that carry out this joint estimation process are known as blind deconvolution algorithms. There are at least two important issues in blind deconvolution. The first issue is whether or not there exists a unique solution to the inverse problem. Based upon extensive experience as well as theoretical investigations reported in the literature, it appears that there exist essentially unique solutions for incoherent imaging problems as long as the dc values of the true object and all the blurring PSFs are kept fixed and the appropriate additional knowledge is included to the estimation process. Typical types of additional knowledge typically included are the positivity and support constraints as well as knowledge that the blurring occurs as a result of atmospheric phase distortions in the pupil of the imaging system. The second issue is understanding the signal-to-noise properties of blind deconvolution algorithms as a function of the measurement noise, the blurring PSFs, and the additional knowledge used in the algorithm. An algorithm-independent way to explore the signal-to-noise properties is with the use of the Cramér-Rao lower bound (CRB) theory. This theory provides lower bounds to the variances of any set of parameters to be estimated. In this presentation we apply CRB theory to the single-frame and multi-frame blind deconvolution problem for the case of estimating both the true object and the blurring PSFs pixel-by-pixel in the image domain when employing a support constraint. We show that the CRBs are strongly dependent on the size of the support-region constraint. When the support constraint is exactly the true support of the object, the CRBs for blind deconvolution are higher than but are within an order of magnitude of the CRBs for the associated non-blind case. However, they increase dramatically as the support size increases. We also show the dependence of the CRBs on the number of data frames used in the estimation process. The CRBs we calculate mirror experience accurately in that the noise reduction achieved by including just a few frames in the blind deconvolution algorithm as compared single-frame blind deconvolution is significant. Beyond a few frames of data, the decrease in the reconstructed-image noise levels has the standard root(N) dependence, where N is the number of data frames.

6365-05, Session 1

Order statistics vector directional filters to process multichannel images

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Spaceborne and airborne remote sensing systems usually use multichannel sensors, so image processing of vector image information is important one. In here we introduce novel methods to process multichannel images that are based on order statistics and vectorial processing techniques. We propose the Video Adaptive Vector Directional (VAVDF) and the Vector Median M-type K-Nearest Neighbour (VMMKNN) Filters. They are derived from the adaptive vector processing, directional processing and RM-estimators (V. I. Ponomaryov, et al. “Real-Time Color Imaging Based on RM-Filters for Impulsive Noise Reduction”, J. Imaging Science and Technology, 49(3), pp. 205-219, 2005).

We show that novel algorithms can suppress impulsive noise and, so they present good effectiveness in comparison with different other methods in 3D video colour/multichannel sequences.

Let us denote an image pixel as I(x,y,t), where (x,y) and t indicate the spatial and temporal pixel location, respectively in the video sequence received by remote sensing system. The 3D window contains pixels (x1, y1, t1) in a 3D window 3*3*3, where (x, y ,t) is a central pixel. The direction processing into the 3D window is defined selecting image vector E that satisfies to minimum angle deviation value among all the vectors. To find vectors with minimum angle deviation from the set of vectors we use the Video Generalized Vector Directional Filter (VGVDF). Finally, vectors are passed through a magnitude processing filter and proposed noise detector to produce an only output vector. Such a procedure describes the algorithm of proposed VAVDF filter. Additionally, the Vector Median M-type K-Nearest Neighbour (VMMKNN) filter to process 3D images is proposed here.

Simulation results presented in the paper have been obtained using different video sequences, such as “Miss America” and “Flowers”, etc., which were corrupted by noise. Several filters were applied: the KNNF known from literature; the VGVDF with 3D median filter as a magnitude

one; the VMMKNN filter; and, finally the proposed VAVDF with α-trimmed mean filter as a magnitude one (this filter is now called VAVDATM).

The standard criteria widely used: PSNR (in dB), MAE and NCD in the case of 15% noise contamination of the sequences demonstrate that the VAVDATM filter has shown the best performances in each a criterion. Another simulation results expose the performances of proposed filters in terms of PSNR and NCD criteria for video sequences. The KNNF presents good performance in PSNR and NCD criteria for low corruption, but has worse performance for high corruption levels. The proposed VAVDAMT filter demonstrates the best PSNR and NCD values until 30% degradation and for high contamination from 35% to 50% excellent results are obtained using the VMMKNN filter. Visual results also show that the images processed by proposed filtering techniques appear to have a very good subjective quality.

6365-04, Session 2

Image empirical mode decomposition: texture analysis using image HHT

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A relatively new technique has been developed to perform general analysis of highly transient time-domain signals, called the Hilbert-Huang Transform (HHT). It has shown great utility in time-frequency analysis of dispersive, nonlinear, or non-stationary signals and systems, designed specifically for nonlinear and nonstationary signals. The transform uses the Empirical Mode Decomposition (EMD), with which the signal is decomposed into a redundant set of Intrinsic Mode Functions(IMFs) and a residue. Adding all the IMFs together with the residue reconstructs the original signal without information loss or distortion. The original purpose for the EMD was to find a decomposition which made it possible to use the instantaneous frequency in the time frequency analysis of the signal. A problem with using the instantaneous frequency is that it only provides one value at each time. A signal usually consists of many intrinsic frequencies and this is where the EMD is used, to decompose the signal into its IMF, where only one frequency component is present at each time so that a well-defined instantaneous frequency can be computed. EMD provides a decomposition method that analyses the signal locally and separates the component holding locally the highest frequency from the rest into a separate IMF. Within this IMF both high and low frequencies can coexist at different times. By applying the Hilbert transform to each IMF we get a set of analytical signals representing the input signal. The HHT calculates the instantaneous frequency of each transformed IMF and presents the result as a time-frequency analysis in a Hilbert spectrum plot.

Image Empirical Mode Decomposition (IEMD) is the EMD concept expanded into two dimensions for the use on images. IEMD provides a tool for image processing by its special ability to locally separate spatial frequencies. Instantaneous frequency estimation in images take advantage of the properties of quadrature filters instead of using Hilbert transform in two dimensions. A quadrature filter suppresses all negative frequencies and produces a filtered analytic signal. By introducing a direction in the filtering and using different center frequencies we obtain a number of frequency responses. This method is normally used on images directly, but then makes little sense since an image is composed of a multitude of superposed spatial frequencies. By applying the instantaneous frequency estimation on the IEMD instead we have a powerful representation of the image to be used in any image processing. The instantaneous frequency estimation applied on IEMD is denoted Image HHT. Texture analysis is achieved using the IEMD representation. Each position in this representation holds a vector valued feature describing the instantaneous frequency information in the image at this position. Once the feature vectors are created the texture analysis is done by using standard clustering algorithms.

In this paper we give an overview of state of the art methods to decompose an image into a number of IMFs and a residue image. We also review the method for instantaneous frequency estimation in images and present the result of combining these two methods into a texture analysis method. This paper concentrates on the IEMD as a new tool for texture analysis and aims at displaying the advantages and shortcomings of the method.

6365-06, Session 2

Can multiresolution fusion techniques improve classification accuracy?

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The goal of this paper is to analyze the effects of the multiresolution fusion process on the accuracy provided by supervised classification algorithms. The rationale of this analysis consists in understanding in what conditions the merging process can increase/decrease the classification accuracy of different labeling algorithms. On the one hand, it is expected that the multiresolution fusion process can increase the classification accuracy of simple classifiers, characterized by linear or “moderately” nonlinear discriminant functions. On the other hand, the spatial and spectral artifacts unavoidably included in the fused images can decrease the accuracy of more powerful classifiers, characterized by strongly non- linear discriminant functions. In this last case, in fact, the classifier is intrinsically able to extract and emphasize all the information present in the original images without any need of a merging procedure. These effects may be different by considering different fusion methodologies and different classification techniques.

6365-07, Session 2

Spatial resolution enhancement of EO-1 ALI bands

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In the mid-1980s, image fusion received significant attention from researchers in remote sensing and image processing, as SPOT 1 (launched in 1986) provided high-resolution (10m) Pan images and low-resolution (20m) MS images. Since that time, much research has been done to develop effective image fusion techniques. Image fusion is a technique used to integrate the geometric detail of a high-resolution panchromatic (Pan) image and the color information of a low-resolution multispectral (MS) image to produce a high-resolution MS image.

Many methods such as Principal Component Analysis (PCA), Multiplicative Transform, Brovey Transform, and IHS Transform have been developed in the last few years producing good quality fused images. These images are usually characterized by high information content, but with significantly altered spectral information content. There are also some limitations in these fusion techniques. The most significant problem is color distortion. A major reason for the significant color distortion in fusion provoked by many fusion techniques is the wavelength extension of some satellite panchromatic images. Unlike the panchromatic image of the SPOT and IRS sensors, the wavelength range of the new satellites is extended from the visible into the near infrared. This difference significantly changes the gray values of the new panchromatic images. Therefore, traditional image fusion techniques - useful for fusing SPOT Pan with other MS images - cannot achieve quality fusion results for the new satellite images.

More recently new techniques have been proposed such as the Wavelet Transform, the Pansharp Transform and the Modified IHS Transform. Those techniques seem to reduce the color distortion problem and to keep the statistical parameters invariable.

Ideally, the methods used to fuse image data sets should preserve the spectral characteristics of the original multispectral input image. While many technologies exist and emphasize the preservation of spectral characteristics, they do not take into account the resolution ratio of the input images. Usually the spatial resolution of the panchromatic image is two (Landsat 7, Spot 1-4) or four times (Ikonos, Quickbird) better than the size of the multispectral images. This paper is an attempt to fuse high-resolution panchromatic and low-resolution multispectral bands of the EO-1 ALI sensor. ALI collects nine multispectral bands with 30m resolution and a panchromatic band with 3 times better resolution (10m). ALI has a panchromatic band narrower than the respective band of Landsat7. It has also two narrower bands in the spectral range of Landsat7 band 4. It has also an extra narrower band near the spectral range of Landsat7 band 1.

In this study we compare the efficiency of seven fusion techniques and more especially the efficiency of Gram Schmidt, Modified IHS, PCA, Pansharp, Wavelet and LMM (Local Mean Matching) LMVM (Local Mean and Variance Matching) fusion techniques for the fusion of ALI data. Two ALI images of the same area collected with two years have been used.

In order to quantitatively measure the quality of the fused images we have made the following controls: Firstly, we have examined the optical qualitative result. Then, we examined the correlation between the original multispectral and the fused images and all the statistical parameters of the histograms of the various frequency bands.

All the fusion techniques improve the resolution and the optical result. In contrary to the fusion of other data (ETM, Spot5, Ikonos and Quickbird) all the algorithms provoke small changes to the statistical parameters.

6365-08, Session 2

Neural disparity computation for IKONOS stereo imagery

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There is a growing interest within Remote Sensing community in the use of 1 meter resolution Ikonos stereo imagery for high accuracy 3D surface modelling, planimetric features and elevation data extraction.

Stereoscopic image analysis is a well known technique to recover the third dimension, intensively investigated within the Computer Vision community. The accuracy of the results depends on the accuracy with which the correspondence problem is solved. It concerns the matching of points or other kinds of primitives in the two stereo images such that the matched image points are the projections of the same point in the scene. Stereo matching involves then pixel based or feature based recognition sub-task producing the map of disparities, i.e the differences in location of matched points, that can be used to compute in a subsequent step the 3D positions of the scene points.

A substantial amount of work has been done on dense stereo matching, producing disparity estimations in all image regions. A variety of novel approaches have been proposed attempting to improve upon existing early methods and satisfy the high accuracy demand in diversified application domains.

Despite important achievements, the accuracy of most innovative dense stereo techniques may not be adequate especially in those situations where errors in the depth map create visible undesirable artefacts. The problem originates from the fact that most stereo algorithms ignore occlusions analysis or address it in a post processing stage within a more general smoothing task.

Occlusions are the major source of errors in stereo matching; they are widespread in stereo imagery and even when images with small disparity jumps are processed, they drastically affect the accuracy of the overall reconstruction process.

In previous works we investigated the potential of neural adaptive learning to solve the correspondence problem in presence of occlusions (1). A novel method was proposed based on an explicit representation of occlusions within the overall matching procedure.

According to the taxonomy proposed by Scharstein and Szelinsky, novelties concern aggregation and disparity computation phases (2). Within the aggregation phase a strategy is introduced based on disparity space image aimed to exploit occlusion and/or discontinuity information. These information are then processed in the next phase where a neural supervised classification task attempts to improve reliability in computing disparity.

In this paper we present an experimental evaluation of an improved version of the neural based stereo matching method when applied to one meter resolution Ikonos stereo images. Disparity maps obtained are compared with those obtained by other stereo matching algorithm. We followed the evaluation methodology proposed by Scharstein & Szelinski evaluating performances based on suggested quality metrics.

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6365-09, Session 2

Road extraction for EuroSDR contest

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1. Introduction

In the framework of EuroSDR, the project 'Automated extraction, refinement, and update of road databases from imagery and other data',

(http://www.bauv.unibw-muenchen.de/institute/inst10/oeepe/) aims at the detection of roads in order:

- To survey the data specification needs of important data producers;
- To evaluate the current status of research;
- To test and compare existing semi- or fully automated methods using various data sets and high quality reference data;
- To identify weak points and to propose strategies and methods that lead to a fast implementation of operational procedures for road extraction, update, and refinement.

A contest was setup to compare approaches on the same data set relatively to completeness, correctness and the localization precision of detected roads.

2. Approach

First, the Gradient Line Detector (V. Lacroix, M. Acheroy 'Feature extraction using the constrained gradient', ISPRS Journal of Photogrammetry and Remote Sensing, April 1998) is used to highlight bright lines. These are made 1-pixel wide thanks to a non-maxima deletion process.

Secondly, linear straight segments were extracted by imposing a minimal contrast and a minimal length while constraining the shape to be straight enough, with the straightness measured as the square root of the principal moment of inertia of segment points.

Thirdly, extracted linear segments received a value based on the NDVI of segment points. If a segment NDVI value is above the median of the values, the segment is rejected.

3. Discussion

This simple procedure delivers bright roads (as appearing in such images). Typical false alarms are aligned bright roofs, with a width similar to roads. Missing segments are dark, hidden or shadowed parts of roads.

Parameter about contrast and straightness were roughly estimated and are not critical. The length parameter (20 pixel) was set as a compromise between rejecting spurious edges and keeping short segments.

No 'High-Level' processing has been applied (segment linking, segment completion) and would be the major improvement.

4. Results

The algorithm was applied on image 'ikonos1_sub1', the most difficult example of the set of images available from the website of the contest.

Based on ground truth, three performance indices were evaluated. The completeness (0.48) indicates the percentage of detected segments relatively to the total number of real road segments. The correctness (0.69) gives the percentage of correctly detected segments relatively to all the detected segments. RMS (1.30), expressed in pixels, gives the precision in localization as the root mean square error between the detected segments and the manually digitized ground truth.

Our figures compare well relatively to challengers. Completeness figures of all algorithms are quite low due to the complexity of the scene: in the urban areas, many roads suffer from occlusion or shadowing.

5. Conclusions

A method for road detection has been developed and tested in a unified testbed for objective analysis and comparison. Results are encouraging relatively to the time devoted to development and to challenger's results. The dependence to the parameters is low. A possible improvement is expected from the use of higher level processing like line linking and completion.

6365-10, Session 3

Image registration using RST-clustering and its applications in remote sensing

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In this paper we address the problem of registering images acquired under unknown conditions including acquisition at different times, from different points of view and possibly with different type of sensors, where conventional approaches based on feature correspondence or area correlation are likely to fail or provide unreliable estimates. The result of image registration can be used as initial step for many remote sensing applications such as change detection, terrain reconstruction, image-based sensor navigation and photomosaic generation.

The key idea of the proposed method is to estimate a global parametric transformation between images (e.g. perspective, affine or other transformation) from a set of local, region-based estimates of rotation-scale-translation (RST) transformation. These RST- transformations form a cluster in rotation-scale space. Each RST- transformation is registered by matching in log-polar space the regions centered at locations of the corresponding interest points. Estimation of the correspondence between interest points is performed simultaneously with registration of the local RST-transformations. Then a sub-set of corresponding points or, equivalently, a sub-set of local RST-transformations is selected by a robust estimation method and a global transformation, which is not biased by

outliers, is computed from it. The method is capable of registering images without any a priori knowledge about the transformation between them. However, if known, search constraints are incorporated to speed-up the processing.

The method was tested on many images taken under different conditions (time, points of view) by different sensors (SPOT, Landsat, IKONOS, TK-350, SAR, aerial cameras, hand-held digital cameras, medical images) and on thousands of calibrated image pairs. In all cases the method showed very accurate registration results. We demonstrate the performance of our approach using different datasets and compare it with other state-of-the-art methods.

6365-11, Session 3

Multitemporal change detection with kernels

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Kernel methods in general and Support Vector Machines (SVMs) in particular have shown good results in hyperspectral image classification due to their ability to work with few labeled training samples and high dimensional spaces [Camps-Valls, 2004, 2005]. The good classification performance demonstrated by kernel methods using the spectral signature as input features has been recently improved by including contextual (and even textural) information in the classifier by means of composite kernels [Camps-Valls, 2006]. In this work, we explicitly formulated a full family of kernel-based classifiers that simultaneously take into account spectral, spatial, and local cross-information in a hyperspectral image. This paper extends the composite kernel framework for land cover change detection in multi- and hyperspectral remotely sensed images. For this purpose, we have developed two different strategies. First, the composite kernel accounts for the cross-information between samples in two subsequent time instants, and modulates its relevance with a convolutional kernel accounting for the spatial coverage changes through the cross-information spatial kernel. Second, since the scheme requires modularity and adaptation to future time instants, the relevance of the change is modulated by means of an adaptive parameter based on a wrapper methodology. Our proposals are tested in both synthetic and real images. Synthetic images contain all possible temporal situations (class masking, diffussion, change, replacement and noise burying), and serve as good benchmark for the real case scenario. In the case of real images, two datasets were used. First, we focused on a series of three different multi-temporal images obtained in the SPARC 2003-04 and Sen2Flex05 campaigns for crop monitoring. Second, images from Naples (Italy) in two different dates were used for urban monitoring. In this case, the composite kernel approach was additionally used as a fusion methodology to combine SAR and multispectral data. Good results are observed in almost all scenarios. Results and theoretical insight will be given at the time of the conference.

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6365-12, Session 3

An adaptive split-based approach to unsupervised change detection in large-size multitemporal images

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In the last few years the frequency of natural disasters has shown a rapid increase. Examples of this trend are related to floods, earthquakes, avalanches, hurricanes, tsunami, etc. These dramatic events increased the interest of the politic and the scientific community in the definition of methodologies capable to prevent them and to perform a rapid damage assessment. In this context, the development of change-detection techniques for the automatic analysis of multitemporal remote sensing images has obtained evermore importance. In the literature, many techniques have been proposed for change detection in both optical and SAR remote sensing images [1],[2]. Most of them produce change-detection maps under the assumption that the prior probability of the class of changed pixels is sufficient to properly model this class with a statistical significant mode in the histogram of the difference/ratio image (this image is usually derived by comparing pixel-by-pixel, according to a differencing or a ratio operator, a pair of multispectral or SAR images acquired on the same geographical area at different times). As the aforementioned kinds of disasters typically affect wide areas (e.g., regions or states), a proper damage assessment requires the analysis of wide scenes and thus of large images. This often results in a decrease of the prior probability of the class of changed areas, which may affect the capabilities of the thresholding techniques proposed in the literature to properly detect changed pixels. For this reason, it is necessary to develop advanced change-detection methods capable to properly handle and extract the change information in large images (e.g., in a full scene acquired by a satellite sensors).

In order to overcome the aforementioned problems, in this paper we propose an unsupervised and automatic approach to change detection in large multitemporal images. The proposed method automatically splits the considered difference or ratio image in a set of sub-images of user defined size. Then the sub-images are sorted out according to their probability to contain a significant amount of changed pixels. This task is carried out according to the computation of the standard deviation (or the coefficient of variation) of the pixels of each split, which in the difference (or ratio) image represents a proper index of the probability of having changes. High values of the standard deviation (or of the coefficient of variation) point out a high probability to have a significant amount of changes in the sub-image; low values indicate a low probabilities to have changes. Afterward, the subset of splits having a high probability to contain changes are selected and analyzed according to standard change-detection techniques (i.e., Kittler and Illingworth thresholding criterion, Bayesian decision rules, etc.) and a set of threshold values is defined (one for each sub-image). It is worth noting that each threshold value is optimized on a specific sub-image; thus any of these values could be selected as a possible threshold for the full-scene. However, in order to properly extract the change information from all the scene, proper fusion techniques are applied to set of thresholds obtained on the different sub-images. In this way, according to simple statistical operators (e.g. mean value, median values, etc.) it is possible to select a robust, stable, unique and consistent threshold value to be applied to the entire image.

The proposed method has been tested on two images acquired by the SAR sensor of the RADARSAT satellite over the Sumatra Island (Indonesia) in April 1998 and in January 2005. Between the two acquisitions a tsunami destroyed large parts of the coast. Experimental results showed that the proposed technique properly identifies a threshold value which allows to produce a change-detection map having a high accuracy over the whole full-scene (also in those parts where the probability of change is low). It is worth noting that the application of the threshold-selection procedures to the entire image in this case results in unreliable threshold values. This further confirms the interest of the proposed technique, which can be applied to any change-detection application dealing with large size images.

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6365-13, Session 3

Targeted information collection for nuclear verification: a combination of object-oriented images analysis and pixel-based change detection with very high resolution satellite data exemplified for Iranian nuclear sites

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Since the availability of high-resolution satellite imagery, the use of remote sensing data has become very important for nuclear verification and safeguards purposes. Due to technical improvements regarding the spatial and spectral resolution, satellite imagery can now build the basis of complex systems for recognizing and monitoring even small-scale and short-term structural features of interest within nuclear facilities. Examples are construction of buildings, plant expansion, changes of the operational status, planning of underground activities etc.

For the detection of small structural objects in high-resolution imagery recent object-oriented procedures are more precise and meaningful than the traditional pixel-based ones. In comparison to the purely spectral features analyzed within the pixel-based approaches, the utilization of object features, e.g., the size or orientation of the objects, their shape or texture and the relations between the objects in different scales, extends the image analysis possibilities. Analyzing satellite image data in an object-oriented way also offers the possibility to involve specific knowledge in the classification or recognition process.

A key purpose for nuclear verification is the detection of changes within facilities over time. According to the large amount of image data the change detection analysis has to be automated and should be able to discriminate the significant changes from the background changes. Besides the detection of changes an identification and interpretation of the detected changes is crucial.

This paper proposes an new combined targeted change detection methodology for the verification of the Non-Proliferation-Treaty for Nuclear Weapons. A pixel-based change detection technique in combination with an object-oriented image analysis is used to detect, identify and interpret significant changes in multitemporal satellite data. The methodology itself and its application to case studies on Iranian nuclear facilities will be presented. Regarding the automation of the image processing, aspects of standardisation and transferability will be discussed.

6365-14, Session 4

A modified band add-on spectral angle mapper (BAO-SAM) distance metrics: a new tool to evaluate lossy compression of hyperspectral imagery

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Technological advances in imaging spectrometers have lead to the acquisition of data that exhibit extremely high spatial, spectral, and radiometric resolution. The increment in spectral resolution, in particular, has motivated the extension of vector signal/image processing techniques to hyperspectral data and the development of distortion models aimed at quantifying the performance of analysis algorithms that are usually employed. Typical distance metrics compare two pixel spectra and return a scalar value. The Euclidean minimum distance (EMD) and the spectral angle mapper (SAM) are usually adopted. They possess mathematical properties that match physical problems typically under concern. A few years ago, the spectral information divergence (SID) was introduced for the analysis of hyperspectral data [1]. In a recent paper [2], the characteristics of such metrics are examined and a band add-on (BAO) technique is derived. Spectral bands are iteratively selected in order to increase the angular separation between two pixel spectra by exploiting a mathematical decomposition of SAM. As a consequence, only a subset of the original hyperspectral bands contributes to the new distance metric, referred to as BAO-SAM, whose operational definition guarantees its monotonicity as the number of bands increases. Thus, BAO-SAM is potentially more useful than SAM for classification, as well as for the evaluation of distortions between pixel spectra, since SAM tends to exhibit an asymptotic constant value as the spectral resolution increases.

In order to meet the quality issues related to the transmission and archiving of hyperspectral data, differential pulse code modulation (DPCM) is usually employed for lossless/near-lossless compression, i.e., the decompressed data have a user-defined maximum absolute error, being zero in the lossless case. DPCM basically consists of a prediction followed by entropy coding of the quantized differences between original and predicted values. A unit quantization step size allows reversible compression as a limit case. Several variants exist in DPCM prediction schemes, the most sophisticated being adaptive [3]. Such distortion metrics as mean square error (MSE), maximum absolute distortion (MAD), average and maximum SAM, are usually adopted to assess compression algorithms. Unfortunately, when the number of bands increases, SAM partially loses its discrimination capability, as it saturates. BAO can be adopted to overcome this problem as discussed in [4], to characterize distortions of hyperspectral data. This issue is relevant since a data compression method of general validity should not be specialized to a specific application but optimized in terms of a distortion metrics, e.g., MAD (as it happens with "near-lossless" compression) but also SAM if possible. This strategy has the advantage that the detection/classification/unmixing accuracy in application contexts will depend on the chosen distortion metrics, on which the compression algorithm is optimized.

In this work, we investigate the behavior of BAO-SAM in the case of MSE-bounded and MAD-bounded (i.e., near-lossless) lossy compression of AVIRIS data. Concerning near-lossless compression, a different step size depending on the estimated standard deviation of the noise (virtually lossless compression [5]), is used to quantize prediction residuals of each spectral band, thus determining band-varying MAD values. Comparisons with the uncompressed originals show that BAO-SAM is useful for characterizing the spectral distortion of hyperspectral data, thereby conveying an additional information that cannot be directly derived from SAM and EMD. Although a compression algorithm capable of producing reconstructed spectral vectors with upper-bounded BAO-SAM is not directly feasible, experiments show that, for a given compression ratio, BAO-SAM error is reduced, in both average and maximum values, when quantization takes into account the standard deviation of the noise, as it happens with virtually lossless compression [5].

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6365-15, Session 4

Lossless compression of hyperspectral imagery via lookup tables with predictor selection

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We propose a new low complexity algorithm for lossless compression of hyperspectral imagery using lookup tables along with a predictor selection mechanism. We first compute a locally averaged interband scaling (LAIS) factor for an estimate of the current pixel from the co-located one in the previous band. We then search via lookup tables in the previous band for the two nearest causal pixels that are identical to the pixel co-located to the current pixel. The pixels in the current band co-located to the causal pixels are used as two potential predictors. One of the two predictors that is closest to the LAIS estimate is chosen as the predictor for the current pixel. The method pushes lossless compression of the AVIRIS hyperspectral imagery to a new high with an average compression ratio of 3.47.

6365-16, Session 4

Retrieval sensitivity based compression of hyperpectral data

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Hyperspectral infrared sounding instruments obtain overwhelming amounts of data which will only increase when the next generation instruments come online. This makes it critical to compress the data before it is transmitted wirelessly over channels with strictly limited bandwidth. Recent lossless compression algorithms have been developed which exploit the special structure present in hyperspectral data. For example, an approach that out-performs generic compression algorithms is based on clustering followed by multiple-eigenspace decompositions. This model appears to fit the data distribution well. To achieve lossless compression, the data is stratified into components. One component is the projection of the data into a space that can be parameterized by the model. The second component is the residual error. By increasing the number of parameters, the residual error may be made negligible. However to avoid over-fitting, the number of parameters are chosen to optimize the compressed file size.

While source coding (compression) removes the redundancy, channel coding makes the file more robust to transmission noise by employing error correcting encoding. Based on the separation principle (established by Claude Shannon in his landmark paper of 1949), source and channel

coding may performed independently without loss of optimality. However, this principle assumes the message to be infinitely long, and does not take into account coding delay. In a practical system, joint consideration of the source and channel coding can achieve superior results. Trade-offs between source coding and channel coding are not at all obvious. In particular cases, like the one considered here, when the prioritization of the data is possible, and loss is unavoidable, it is essential to minimize loss rates for the data.

In our previous work, we proposed to use variable strength error correction to take into account the fact that the sensitivity of the reconstruction error is concentrated in the component of the compressed data that has been fit to the model. This makes it possible to minimize impacts of errors on reconstruction error without significantly increasing file size. The same error sensitivity analysis also indicates that near-lossless compression can be employed in situations where bandwidth is so severely limited that transmission of the losslessly compressed data is impossible to minimize reconstruction error.

While accurate reconstruction of the data is a top priority, it is absolutely essential that both variable error correction schemes and near-lossless compression prioritize minimizing impacts of errors in end data products. Rather than hold the compression algorithm constant and modify the error correction to best protect the data, we will show here that more flexibility is achieved by varying the compression parameters. We propose to optimize the parameters of the multiple-eigenspace compression technique to minimize memory size under the constraint that no errors are introduced into a representative set of final data products, under different noise assumptions. We present a statistical analysis based on AIRS showing how the maximal compression ratio varies under different levels of noise.

6365-17, Session 4

Multiband semifragile watermarking for multi and hyperspectral images based on iterative tree structured vector quantization

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Multi and hyperspectral imaging has gained an increased attention by the research community in the last few years, since new uses and applications of this area are often reported. High precision farming, water pollution control or natural resources management, among others, are well-known uses of remote sensing.

Hyperspectral images have an inherent high economic value since their acquisition involves expensive mechanisms like plane flights or satellites. Such an economic value must be preserved when hyperspectral images are used in different applications where a third party pays for such usage. Some data hiding schemes, such as watermarking, have been proven successful in order to protect images in several ways, such as resolving authoring disputes,obtaining traceability in illegal image distribution issues or detecting changes in the images aimed to produce a forged copy.

Many watermarking algorithms are based on robustly embedding an imperceptible mark into the image in such a way that the mark can be recovered later in spite of possible image manipulations. Every watermarking scheme can be described in two stages: mark embedding and reconstruction, although the real issue is where and how place the hidden mark. Intuitively, as much information as possible should be embedded in the original image to ensure that most of

such information will be detected in a manipulated image.

Nevertheless, the embedded mark should not be perceptible and should not be easily removed by simple manipulations of the digital content, thus a tradeoff between robustness and perceptual quality must be achieved.

In hyperspectral imaging applications, the most useful watermarking schemes aimed to detected changes in the image are semifragile. Semifragile schemes are able to overcome some minor modifications, as those produced by near-lossless compression, but reveal the existence of traitorous manipulations. Most existing semifragile watermarking applications can be applied on monochromatic images, and thus, can be extended to hyperspectral images by treating several bands independently. However, in this paper, a semifragile watermarking scheme specially developed for hyperspectral images is presented. This method works with all the bands at the same time and, thus, provides uniform protection for hyperspectral imaging applications. The method can be tuned to embed the mark according to band importance, depending on the content to be protected.

In this paper, we propose to use the hyperspectral image as a whole, using a vector quantization approach. The original multispectral (CASI) or hyperspectral (AVIRIS) image is segmented in blocks of MxNxb, where M and N determine the spatial resolution of the embedding and detection algorithm, and b is the number of bands employed for building the tree structured vector quantizers.

For each block, a tree is built, and these trees are manipulated using an iterative algorithm until the resulting image satisfies all the imposed conditions by the built trees. Each tree is partially modified accordingly to a secret key in order to avoid copy-and-replace attacks, and this key determines the internal structure of the tree, and and also the resulting distortion, in order to make the resulting image robust against near-lossless compression. We also measure the influence of our watermarking scheme on the results obtained with an unsupervised classification algorithm, for distortion evaluation purposes.

6365-18, Session 4

MST-embedded JPEG-LS: application to lossless compression of ultraspectral sounder data

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JPEG-LS is the new ISO/ITU standard for lossless and near-lossless compression of 2D continuous-tone images. For contemporary and future ultraspectral sounder data that features good correlations in disjoint spectral channels, we propose an MST-embedded JPEG-LS (Minimum Spanning Tree embedded JPEG-LS) for achieving higher compression gains through MST channel reordering. Unlike previous non-embedded MST work with other cost functions used only for data preprocessing, the proposed MST-embedded JPEG-LS uniquely uses the sum of absolute median prediction errors as the cost function for MST to determine each optimal pair of predicting and predicted channels. The proposed MST with this cost function can be embedded within JPEG-LS because of the same median predictor used in JPEG-LS. The advantage of this embedding is that the median prediction residuals are available to JPEG-LS after MST channel reordering without recalculation. Numerical experiments show that the MST-embedded JPEG-LS yields an average compression ratio of 2.81, superior to 2.46 obtained with JPEG-LS for the 10 standard AIRS ultraspectral granules.

6365-19, Session 5

Issues in training SVM classifications

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No abstract available

6365-20, Session 5

Contextual unsupervised classification of remotely sensed imagery with mixels

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It is known that land-covers of the earth are dependent upon each other spatially. Contextual classification of remotely sensed imagery, therefore, has been received increasing attention. By using spatial information such as the state of neighborhood pixels, classification can be processed more accurately. We proposed a contextual unsupervised classification method. The method is based combination of Ward clustering method and a spatial distribution of the land-covers based on Markov random fields (MRF). Image is clustered into land-cover categories by using not only spectrum of pixels but also spatial information. For the classification of remote sensing data of low spatial resolution, the consideration of mixed pixel is importance. From the knowledge that most of mixels locate in boundaries of land-covers, we first detect edge pixels and remove them from the image. We here introduce a new measure of spatial adjacency of the classes. Spatial adjacency is used to Ward clustering and MRF-based updating. Clustering of edge pixels are processed as final step. It is shown that the proposed method gives higher accuracy than conventional clustering method does.

6365-22, Session 5

AdaBoost with different costs for misclassification and its applications to contextual image classification

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Consider a confusion matrix obtained by a classifier of land-cover categories. Usually, misclassification rates are not uniformly distributed in off-diagonal elements of the matrix.Some categories are easily classified from the other categories, and some are not. The loss function used by AdaBoost ignores the difference. If we derive a classifier which is efficient to classify categories which are close to the remaining categories, the overall accuracy may be improved. AdaCost [1] considers different costs for false-positives and false-negatives in binary class problems.

In this paper, the exponential loss function with different costs for misclassification is proposed in multiclass problems. The loss function is given by an external parameter (smooth parameter [2]). As a special case, it gives a naive zero-one loss function in multiclass problems. Furthermore, it coincides with AdaCost in binary class problems. Put large costs for categories which are close to the remaining categories, and minimize the empirical risk based on the cost. Then, classifiers efficient to classify such categories are tuned, and consequently, the overall accuracy will be improved.

6365-49, Session 5

Exctraction of spatial and spectral scene statistics for hyperspectral scene simulation

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No abstract available

6365-23, Session 6

Comparison of kernel-based methods for spectral signature detection and classification of hyperspectral images

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The intent of the classification process for remote sensing applications is to categorize all pixels in a digital image into one of several land cover classes, or themes. Normally, multispectral or hyperspectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization. Kernel Methods are a new class of pattern analysis algorithms which can operate on very general types of data and can detect very general types of relations. In the last years, a number of powerful kernel-based learning machines, i.e., support vector machines (SVMs), kernel Fisher discriminant (KFD) analysis, and kernel principal component analysis (KPCA), have been proposed. These approaches have shown practical relevance not only for classification and regression problems but also, more recently, in general learning approaches. In kernel-based learning methods [1] a linear algorithm is first implicitly formulated in a high-dimensional feature space by using a nonlinear mapping, which is implemented by a kernel function. The algorithm is still linear in the high-dimensional feature space but has a corresponding nonlinear version in the original input space.

A recent paper by Kwon and Nasrabadi [2] proposed a kernel-based classification algorithm, namely KOSP, which shows very good performances in single-class classification problems, i.e., in spectral signature detection tasks. The authors have demonstrated the effectiveness of the KOSP algorithm for detecting mines, roof tops, and roads, in three different hyperspectral datasets. KOSP has been compared to other nonlinear classifiers, in particular to SVM's and two main advantages have been evidenced: 1. KOSP is able to classify spectrally mixed pixels or detecting subpixel targets; 2. KOSP needs only one prototype exemplar for the desired target spectral signature, which can be obtained from a small number of training samples or from a spectral library, while SVM requires a sufficient number of training spectral signatures for both target and background in order to generate the appropriate supporting vectors to discriminate between two classes.

In practical applications on hyperspectral data, classification problems may differ significantly from specific detection tasks which are relevant for detecting anomalies among known spectral signatures, but are less significant for multi-class mapping in complex scenarios, e.g., for classification of hyperspectral images for agricultural applications. Mine detection differs from the classification of similar, heterogeneous, agricultural classes for which well-defined prototypes are generally not available. Nevertheless, the results obtained by KOSP are impressive and require further investigation.

The purpose of this paper is to objectively compare two different approaches to multi-class classification, KOSP and SVM (using the same kernel), on a common hyperspectral dataset.

To this aim, the widely used "Indian Pine" Aviris dataset is adopted. All classes present in the ground truth data are considered, independently on how they are populated. A common "test protocol" is considered: the one-vs-rest strategy for SVM [3], and an equivalent approach for KOSP, i.e., the detection of each spectral signature (one of the N classes) by considering the spectral signatures of the remaining N-1 classes as background. The same dimensionality of the training set is also considered in both approaches: for SVM, about 10% of the available ground truth data set is used for training, while the remaining 90% is used as the test set; for KOSP, 10% of the ground truth is used to derive the class prototype exemplar and the rest is used for test. The problem of how to determine the prototype spectral signature for each class in the case of the KOSP algorithm is discussed as well. Different approaches are compared: mean, median, and other combinations of the "training" spectral signatures are investigated. The objective comparison between the two different kernel approaches will be presented in terms of classification accuracy, not in terms of ROC curves, as in [2], which are commonly used to assess the performances of detection algorithms.

Preliminary results show that the selection of the best kernel algorithm is not straigthforward, since it depends on the dimensionality of the training set and the specific spectral features of a given class: heterogeneous vs. homogeneous classes, class distance to the background, textural characteristics.

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6365-24, Session 6

An advanced semi-supervised SVM classifier for the analysis of hyperspectral remote sensing data

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Classification of hyperspectral data is one of the most challenging problems of the analysis of remote sensing images. The complexity of this process depends on both the properties of data (non-stationary spectral signatures of classes in the spatial domain, intrinsic high dimensionality) and the practical constraints in ground-truth data collection (which result in a small ratio between the number of training samples and the number of spectral channels). Among the most promising methods proposed in the literature for classification of hyperspectral images, semi-supervised procedures (which integrate in the learning of the classifier both labeled and unlabeled samples) and systems based on support vector machines (SVMs) seem to be particularly promising. On the basis of this observation, in previous work we developed a semi-supervised SVM (S3VM) classifier (called Transductive SVM), which integrates in the learning process both labeled and unlabeled samples [1]-[2]. The iterative procedure defined for the semi-supervised learning process proved its effectiveness in ill-posed multispectral problems and provided preliminary promising results on hyperspectral problems. However, it suffers of some limitations: i) empirical definition of the number of iterations of the semi-supervised learning procedure; ii) nonoptimized model selection procedure; iii) possible instability in the semi-supervised learning process. These limitations are particularly critical in presence of complex hyperdimensional feature spaces as in the case of hyperspectral data. In this paper we address classification of hyperspectral images by proposing a novel semi-supervised technique based on SVMs. This technique addresses the semi-supervised learning procedure in the dual formulation, according to a novel iterative self-labeling procedure which improves the one developed in [1] by removing the aforementioned limitations. It consists of a self-labeling algorithm, which includes in the cost function

of a standard inductive SVM also unlabeled patterns. The inclusion of unlabeled samples in the learning process is done according to an iterative procedure that considers a properly chosen subset of unlabeled samples at each iteration. This allows to control both the stability and the reliability of the learning process. The convergence criterion fits the specific investigated problem and the user is not required to fix an expected number of iterations, which might be a difficult task (especially in cases where few prior knowledge about the examined data is available). In addition, on the basis of the proposed technique, a novel model selection strategy has been defined, which: i) properly integrates the choice of the values of the novel transductive parameters with the choice of the standard regularization and kernel parameters; ii) implicitly evaluates the effects of the selected parameters on the unlabelled samples used in the semi-supervised learning phase. The main advantages of the proposed approach (with respect to the one presented in [1]) are: i) the adaptive selection of the number of iterations of the semi-supervised learning procedure; ii) the definition of an effective model-selection strategy; iii) the stability of the learning procedure. To assess the effectiveness of the proposed approach, an extensive experimental analysis was carried out on an hyperspectral image acquired by the Hyperion sensor over the Okavango Delta (Botswana). The results provided by the proposed S3VM classifier were compared between them and with those obtained by both the technique presented in [1]-[2] and supervised SVM. On the basis of this comparison, we can conclude that the proposed novel approach provided better accuracy and generalization ability of the reference methods, resulting in very promising algorithm for hyperspectral image classification.

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6365-25, Session 6

Modeling of spatial and spectral systematic noise patterns on CHRIS/PROBA hyperspectral data

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Remote sensing hyperspectral images are generally affected by standard random noise, which varies with time and determines the minimum image signal-to-noise ratio (SNR); and non-periodic partially deterministic disturbance patterns, which are due to the image formation process and are characterized by high degree of spatial and spectral coherence. In this work, we focus on modelling and correcting the coherent spatial and spectral structures produced by these systematic disturbances.

In particular, this work analyses the Compact High Resolution Imaging Spectrometer (CHRIS), which is mounted on board the European Space Agency (ESA) small satellite platform called PROBA (Project for On Board Autonomy). This push-broom imaging spectrometer consists of Charge Coupled Device (CCD) 2D array and generates images by separating the spectral and spatial information in each of the CCD dimensions. The radiometric response for the CHRIS instrument can be treated as two overlapping components: the optical system response and the CCD response. With regard to the optical system response, spectral shift (shifted spectrum along the CCD columns) and spatial shift (slit irregularities across the CCD) appear due to the seasonal variation of the in-orbit CHRIS instrument temperature. With regard to the CCD response, the 2D map of pixel-to-pixel responses is relatively stable with temperature and time.

The proposed approach processes the spatial and spectral domains independently, by taking into account these two overlapping components, which produce systematic spatial and spectral patterns in the across-track direction (image rows). Both approaches, spatial and spectral, somehow produce a response matrix of the instrument independently.

- Concerning the spatial domain, each spectral band image is acquired by the same row of CCD elements. Therefore, each image column is affected by a different CCD pixel response (constant factor different for each spectral band), and a different optical slit response (constant factor equal for all spectral bands). The combination of these non-uniform spatial responses, which are constant in columns, superimposes a systematic pattern of noise organized by vertical lines (stripe noise). The proposed correction is based on the hypothesis that the vertical disturbance presents higher spatial frequencies than the surface radiance. Therefore, it models the noise pattern by suppressing the surface contribution in the image rows in two different ways: avoiding the high frequency changes and subtracting the low frequency horizontal profile.

- Concerning the spectral domain, each image column is affected by a different spectral calibration, which is driven by two main effects. On the one hand, shifts from the nominal wavelengths of the instrument are likely to occur. These shifts may be non-linear in the across-track direction (smiling effect), and are corrected by seeking for the shift that produces the smoothest surface reflectance around gaseous absorptions. On the other hand, the sensitivity of the elements of each CCD column modulates the radiometric calibration of the corresponding image column. However, atmospheric absorptions affect all the image pixels making impossible the estimation of the calibration factors from an average smoothed curve (as it is done in the spatial domain). Thus, the proposed method is based on the correlation of a set of image radiance spectra with their synthetic spectra. The slope of the linear regression between the real and the modelled spectral curves, carried out on a per-wavelength basis, provides the updated calibration coefficients.

Performance of the proposed algorithm is tested on a large number of sites of different nature, several acquisition modes and covering the full range of possible temperatures (although Barrax, Spain, was selected as the main test site since it has been the core site of previous studies). Results show an excellent rejection of the noise pattern with respect to the original CHRIS images. This noise reduction is also assessed in terms of correlation between the modelled noise and the corrected images. In addition, the dependency of the noise patterns with the sensor temperature has been found to agree with the theoretical one, which confirms the robustness of the presented approach.

6365-26, Session 6

Target detection in hyperspectral imagery using noise adjusted principal component analysis and orthogonal subspace projection

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Orthogonal subspace projection (OSP) has been used in hyperspectral image processing for automatic target detection and image classification. But all the approaches of OSP so far introduced in the literature require the knowledge of all undesired signatures present in the image in advance for target detection. An OSP based ratio along with the noise adjusted principal component analysis (NAPCA) has been proposed in this paper for target detection in hyperspectral imagery. This method can perform target detection without any priori knowledge of the signatures of other objects present in the image. The length of any pixel vector containing the target is decreased by a great ratio when it is projected to a direction orthogonal to the target signature. Thus the ratio of the original pixel vectors to the projected pixel vector gives a very high value at the pixels containing the target. For noisy images, the NAPCA algorithm is used before the OSP based decision is made. The NAPCA technique helps in reducing the noise and the spectral dimension and thereby gives better target detection and computational efficiency. In the cases when no noise or a very small amount of noise is present in the image, the principal component analysis (PCA) may be used instead of the NAPCA algorithm. The OSP based processing requires that the number of bands must be less than that of spectrally distinct signatures present on the image. But the proposed method has been found seen to give good result even when this criterion is not satisfied.

6365-28, Session 7

Dark formation detection using recurrent neural networks and SAR data

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In this paper a classification scheme based on recurrent neural networks is presented. Neural networks may be viewed as a mathematical model composed of many non-linear computational elements, called neurons, operating in parallel and massively connected by links characterized by different weights. It is well known that conventional feedforward neural networks can be used to approximate any spatially finite function given a

set of hidden nodes. Recurrent neural networks are fundamentally different from feedforward architectures in the sense that they not only operate on an input space but also on an internal state space - a trace of what already has been processed by the network. This capability is referred as internal memory of the recurrent networks.

The general objectives of this paper are to describe, demonstrate and test the potential of simple recurrent artificial neural networks for dark formation detection using SAR satellite images over the sea surface. The type and the architecture of the network are subjects of research. Input to the networks is the original SAR image. The network is called to classify the image into dark formations and clean sea.

Elman's and Jordan's recurrent networks have been examined. Jordan's networks have been recognized as more suitable for dark formation detection. The Jordan's specific architecture with five inputs, three hidden neurons and one output is proposed for dark formation detection as it classifies correctly more than 95.5% of the data set.

6365-29, Session 7

Classification methods for oil spill detection by SAR imaging

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Pollution arising from illegal oily discharges from tank cleaning or bilge pumping represents a serious threat to the marine environment. Oil spills appear as dark areas in the SAR images because the oil dampens the capillary waves of the sea surface. A combined use of satellite-based SAR and aircraft surveillance flights is a cost-effective way to monitor large areas.

Automatic algorithms that can help in screening the images and prioritise the alarms will be of great benefit.

A major part of the oil spill detection problem is to distinguish oil slicks from other natural phenomena (look-alikes) that create dark patches in the SAR image. Our approach can be divided into detection of dark areas, extracting features for all dark areas, and then classifying spots as oil spills or look-alikes. This paper addresses the classification step.

In the literature, various classifiers have been applied to classify a slick as oil or look-alike.

These studies are however performed on different data sets and different methodology is used.

For this reason, the results are not directly comparable.

In this paper, we present the first results from a study on classifiers applied to ENVISAT ASAR images. First, based on our basic classifier (described in [1,2]), we have improved that classification performance by introducing regularization of the covariance matrices. Second, we are comparing our statistical classifier with Support Vector Machines (SVM) and Neural Network (NN) techniques.

In [1,2], a prior distribution and a probability density for the features are combined through Bayes theorem to obtain the posterior probability for a detected spot being an oil slick.

Even within each wind level both the oil slicks and the look-alikes may vary quite a lot in shape and other features. Describing the feature density by a unimodal density such as the Gaussian is therefore not appropriate. Different densities depending on the value of a shape descriptor and the wind level were assumed in [2]. The wind level (w) is first used to divide the samples in two different subclasses and then these are further divided into five subclasses based on the shape descriptor (g). The densities within each subclass are assumed Gaussian.

Given (w,g), equal diagonal covariance matrices for the oil slick subclass and its corresponding look-alike subclass were used in [2] because the look-alike classes had many times more observations than the oil spill classes, resulting in a large variance bias.

Adapting the classifier to ENVISAT images, we suggest using the following regularization of the common covariance matrices: $\Sigma'_{w,g}(\alpha) = \alpha[\mathrm{diag}\{\Sigma_{w,g}\}] + (1 - \alpha)\Sigma_{w,g}$ where α in [0,1] is the regularization parameter and $\Sigma_{w,g}$ is the normal covariance matrix.

Our data set consists of 56 training images and 27 test images. α is estimated based on the leave-one-out method on the training set. When comparing classification accuracy on the test set from using common diagonal covariance matrices vs. common regularized covariance matrices, we find that the number of correctly detected look-alikes has increased from 80% (9782 detected segments out of 12177) to 87% (10567 out of 12177), while the number of correctly detected oil spills almost stays unchanged with a decrease from 78% (47 out of 60) to 77% (46 out of 60).

We have recently received 20 new scenes. Based on this larger training set, we will also experiment with common vs. class-conditional covariance matrices for some of the subclasses. The results from the experiments on SVM and NN are not yet ready, but will be presented at the conference.

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6365-30, Session 7

Oil spill detection using evolved neural networks

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Optimal neural network topology has been one of the major research topics since the first application of neural networks in remote sensing appeared in 1990. There are two commonly used approaches in determining network topology. The first type of approaches refers to use a heuristics that express the number of nodes in the hidden layer as well as the number of hidden layers as a function of input and output dimensions. The second type is a more systematic search for optimal topologies via pruning or growing algorithms that regard the weight of a link as the measure of its performance. Furthermore, feature selection is used in order to increase accuracy and reduce the dimensionality of the input network by disregarding redundant and noisy inputs. It is often found that pruning results to marginal increase in overall accuracy while at the same time it produces significantly more compact neural network structures.

In this paper we deploy computational intelligence, which in this case refers to the synergy of neural networks and genetic algorithms. The determination of optimal neural network structure is sought via optimization using a genetic algorithm. Initially we use a standard multilayer perception as the basis for method comparison. We establish the topologies using the commonly used in the remote sensing literature Kanellopoulos - Wilkinson rule. We then proceed by testing pruning and growing algorithms to investigate the possible accuracy increase. Having established a framework for comparison we move to optimizing the structure of the neural networks by genetic algorithms. The network topology is coded as a binary string and the optimal skeleton is sought by evolution mechanisms (selection, crossover and mutation). The input dimensions are also included as parts of the binary string (chromosome) used in the genetic optimization. In other words, we also apply the genetic optimization as a means for feature selection.

Illicit vessel discharges are traditionally monitored by SAR images. Oil spill detection systems, after isolating the dark detected formations on SAR images, calculate several statistical features (e.g. mean backscattering values, area, texture, etc) in order to make the decision whether the dark detected formation is an oil spill or a look-alike. The absence of a systematic research on the extracted features and their contribution to classification accuracy force researchers to arbitrary select quantitative and qualitative statistical features in order to use them as input to their systems. The present paper is a step forward in establishing a more systematic and theoretically sound method to select the features that are most useful for oil spill detection. Several SAR images containing oil spills and look-alikes are used in order to evaluate the proposed methodology.

Method comparison is presented in terms of overall accuracy classification as well as in terms of omission and commission errors in an accuracy matrix. Conclusions are given with respect to the performance of the genetic algorithm in selecting the neural network structure. Finally, future extensions and directions on how to more efficiently merge the two components of computational intelligence presented here are discussed.

6365-31, Session 7

Non-parametric image partitioning of SAR images

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The automatic partitioning of Synthetic Aperture Radar (SAR) images is an important step in many image processing algorithms. This is for example the case for segmentation, for target detection or parameter estimation in SAR images. Due to their physical origins (i.e. illumination

with a coherent wave) SAR images are degraded by speckle noise that makes the images grainy and that deteriorates image processing techniques. In order to optimise the performance of processing techniques it has appeared important to adapt the algorithms to the strong fluctuations introduces by the speckle noise.

Among the segmentation and the partitioning into homogenous regions techniques, one can quote edge detection or direct region based approaches. The purpose of edge-based image segmentation is to find out the transitions between uniform areas rather than directly identifying them. The algorithms based on this technique generally use an edge detection filters. However, it has been shown [1] that these edge-based detectors introduce a bias and increase the variance in the estimation of the edge position when the window has not the same orientation as the edge. Other approaches such as region growing, region merging, Markov random fields or variational methods have also been developed. However the regularization terms introduced in the functional to optimize with these approaches cannot be in general easily determined automatically and can lead to difficult optimization problems.

A new parametric approach adapted to Gamma probability density function (pdf) of SAR image segmentation has been proposed in [2]. This technique is based on a polygonal grid model with an a priori unknown number of regions with arbitrary topologies. With this approach the number of regions and the number of nodes of the polygonal description of the partition are estimated by minimizing the stochastic complexity which is a criterion without free parameter. However, the previous parametric technique has to be improved when the gray level values of SAR images are not correctly described by Gamma pdf, like in textured speckle images or with high resolution SAR images.

We shall describe and analyse a generalization of the approach mentioned above [2] to non parametric noise models. The partition is obtained by minimizing the stochastic complexity of a quantified version on Q levels of the SAR image and lead to a criterion without parameters to be tuned by the user. One will analyse the reliability of the proposed approach on synthetic images and on real SAR images. The quality of the obtained partition will be studied for different possible strategies. In particular, one will discuss the reliability of the proposed optimization procedure. Finally, we will precisely study the performance of the proposed approach in comparison with the statistical parametric technique adapted to Gamma pdf [2]. These studies will be led by analyzing the number of misclassified pixels, the standard Hausdorff distance and the number of estimated regions.

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6365-32, Session 8

Detection of under-water objects with satellite remote sensing

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Remote sensing is defined as the technique of obtaining information about objects through the analysis of data collected by special instruments that are not in physical contact with the objects of investigation. One of the more recent satellite remote sensing capabilities to have made an impact in this regard has been the synthetic radar satellite which was conceived as an orbiting platform that would be capable of measuring the

Earth’s atmospheric and surface properties with a high degree of accuracy. It uses active microwave emissions to collect global measurements and images independent of time of the day or weather conditions. It also undertakes the measurements of many parameters not covered by existing satellite systems, including those of sea state, sea surface winds, ocean circulation and sea and ice levels. With synthetic aperture radar (SAR), very slight variations in the sea surface roughness (to which radar wavelengths are very sensitive in terms of the reflectivity) can be detected and mapped. Such variations are caused by the dilation and compression of the small-scale sea-surface waves, effectively advected by large-scale surface currents caused by internal waves. As an internal wave propagates, it generates tubular convection cells that create small surface currents of alternate compressive and dilative divergence, resulting in bands of light and dark SAR images. The remarkable part of this observation is that the vessel need not be on the sea surface to leave such a trail. Submerged vessels leave turbulent wake trails, invisible by direct means.

6365-33, Session 8

Comparison of independent-component-analysis (ICA) algorithms for GPR detection of non-metallic land mines

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The detection of landmines is an important mission to save lives of many innocent victims. Detection of anti-personnel (AP) non-metallic landmines using Ground Penetrating Radar (GPR) has shown promising results in recent years. The weak signal reflected from AP land mines is normally obscured by strong background clutter and noise. The clutter sources are the cross talk between the transmitter and receiver antennas as well as scattering from the ground surface and within the soil. Furthermore, other objects are generally buried under the ground, that may appear, as targets. The clutter signal due to the reflection from the ground surface may represent the main problem for many of the cases. The detection problem in this case can be described as how to separate the target signal from the ground reflection. Consequently, the GPR data should be separated into two complementary subspaces, namely the signal and clutter subspaces, in order to make their separation possible. In addition, a proper representation is needed to convert the collected data into a form which is suitable for such a separation. Because of its computational and conceptual simplicity, a linear transformation is often assumed for such a representation. As such a transformation linearly mixes the target and clutter signals, it is usually expressed as a so-called mixing matrix. The main goal of the detection here is to estimate the target and clutter signals (source signals) without any knowledge of the mixing matrix. Such a problem is usually called blind source separation and may be efficiently solved using the Independent Component Analysis (ICA). ICA is a statistical method for transforming the data into components that are statistically independent. Many ICA algorithms have been successfully applied in many fields to achieve blind source separation. As compared to correlation-based transformation methods such as the Principal Component Analysis (PCA), ICA does not only decorrelate the signals (2nd order statistics) but also reduces higher-order statistical dependencies. Thus, it attempts to make the signals as independent as possible.

In this contribution, four of the most common ICA methods are studied and compared to each other as regarding their ability to separate the target and clutter signals. These are the extended Infomax, the FastICA, the JADE, and the SOBI. The four algorithms have been applied to the same data set which has been collected by using an SF-GPR operating on the frequency range from 1.5 GHz to 20 GHz with 1601 samples for each A-scan. A sand filled wood box with dimensions 1.1 x 1.1 x 1.1 m, with absorbing walls has been used to simulate unbounded surrounding. The sand height is 0.5 m. The measurement grid covers the area x = 27-76 cm and y= 39-89 cm with a step 1 cm in both x and y directions.

The area under the Receiver Operating Characteristic (ROC) curve has been used to compare the clutter removal efficiency of the different algorithms. All four methods have given approximately consistent results. However both JADE and SOBI methods have shown better performances over Infomax and FastICA.

6365-34, Poster Session

Feature detection from IKONOS pan imagery based on phase congruency

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This paper introduced Phase Congruency as a new method to detect features from IKONOS Pan imagery. Phase Congruency model postulates that features are perceived at points in an image where the Fourier components are maximally in phase and that the type of features depends on the value of the phase. Four objects were selected from the IKONOS Pan imagery of Nanjing, i.e. paddy, road, factory and house, each of which had an image size of 128x128 pixels. The raw Phase Congruency images were obtained by applying Phase Congruency model to the images with two-octave Log Gabor wavelets filters over 5 scales and 6 orientations. For qualitative comparison, the output of the Canny detector was also presented. It was then shown the result that Phase Congruency respond value was more prominent than that of Canny detector. Unlike the Canny that detected features in a dull and flat way, Phase Congruency provided a significant sketch for image. The other obvious difference was that the Canny detector produced responses on each side of line features, whereas

the Phase Congruency detector produced a response centered on the line, e.g. ridge in the paddy image, and roof in the factory image. The paper then compared the effect of noise in the feature detection between Phase Congruency and Canny method. In conclusion, Phase Congruency adapts to detect features from high-resolution remotely sensed imagery. With this invariant image feature detector, further work into multi-spectrum band remotely sensed imagery for Phase Congruency may be needed so that better image segmentation and orient-object image recognition is possible.

6365-35, Poster Session

Urban vegetation extraction from very high resolution satellite imagery based on fractal theory

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Automatic information extraction is one of the main research aspects of processing and analysis of Very High Resolution (VHR) remotely sensed images. Effective extraction of urban vegetation information, such as spatial distribution, type and quantity from VHR satellite imagery plays an important role in environmental protection and urban planning. Compared with the medium/low resolution remote sensing data, while VHR remote sensing data presents particularly detailed ground surface information, the complexity of data processing also increases. Moreover, it is difficult to completely and effectively separate different kinds of urban vegetation from each other and also from other ground objects if only the object spectrum characteristics are considered. Making use of the self-similarity of complex phenomena that occur in nature, fractal theory has great capability in description of spatial information and detailed texture features. Effective fractal models could accurately simulate the fractal characteristics of different vegetation and achieve the maximum discrimination among the vegetation and between the vegetation and other ground objects. Based on the fractal theory, first of all, this paper compared and analysed the performance of using the Discrete Fractal Brownian Random field (DFBR) model, Differential Box Counting (DBC) model, and the model of box-counting based on probability estimation in urban vegetation extraction while taking the spatial structure and grey distribution features of each kind of urban vegetation on the VHR remote sensing imagery into account. In the second place, by integrating the fractal dimension with the spectral information, urban vegetation information was effectively extracted from the VHR satellite imagery. Illustrations were given by using IKONOS and QuickBird imagery respectively.

6365-36, Poster Session

Wavelet-based algorithm with application in remote sensing PCA

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High resolution and multispectral remote sensing images are an important data source for acquiring large-scale and detailed geospatial information for a variety of applications. Most Earth observation satellites provide both panchromatic images at a higher spatial resolution and multispectral images at a lower spatial resolution. The image fusion technique is an effective approach which can integrate spatial details of panchromatic image and spectral characteristics of multispectral image into one image. This paper presents a new technique for image fusion using wavelet decomposition method. It reproduces the spectral characteristics of original multispectral image and preserves spatial information of the panchromatic image very well. The spectral and spatial effects of the proposed approach were evaluated mainly by visual methods comparing with those of PCA (principal component analysis), Brovey and Wavelet-based fusion methods.

6365-37, Poster Session

Hybrid classification method based on spectral, spatial, and textural features for remotely sensed images

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BACKGROUND: As shown in IKONOS or Quickbird, remotely sensed images have had very high spatial resolution. It is difficult for the most of conventional classification methods to obtain land use maps by using such high resolution images, because these methods are too sensitive to variations of pixel intensity in the same land use area. The reasons are as follows: 1) these methods are only based on spectral (color) and spatial (shape) information; 2) these methods process the target images in pixel-by-pixel. Therefore, a new image classification method based on not only spectral and spatial information but also texture information is required to obtain land use maps similar to visual interpretation results. So, we have proposed a new rotation and translation invariant texture quantification method for remotely sensed images using the Normalized Zernike Moment Vector (NZMV) and has applied the method to supervised texture classification. We have also proposed an appropriate training area selection method based on the genetic algorithms (GA-ATAS)[1] for accurate supervised texture classification. In this article, we describe new hybrid classification method using both of conventional (spectral, spatial) features and textural feature.

Some experimental results are also shown.

METHODS: Proposed hybrid classification method uses N-channel multispectral images acquired from spaceborne or airborne sensors. These multispectral images are reconstructed by principal component analysis. The highest contrast image (primal principal component image) processed by unsupervised texture classification method based on NZMV and GA-ATAS is added to original multispectral image as an new channel.

Then, these N+1-channel multispectral images are processed by a classification method based on spectral and spatial features.

However, spectral channels of the original image and newly added textural channel cannot treat in an equal weight. Therefore, we examine to determine the appropriate weight between spectral and textural channels.

RESULTS AND DISCUSSION:

Some experiments are conducted to evaluate the capability of the proposed hybrid classification method by using images from Brodatz's photo album and airborne MSS images.The experimental results show good properties of the proposed method.

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6365-38, Poster Session

The evaluation of different fitness functions integrated with genetic algorithm on unsupervised classification of satellite images

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In traditional unsupervised classification method, the number of clusters usually needs to be assigned subjectively by analysts, but in fact, in most situations, the prior knowledge of the research subject is very difficult to acquire, so the suitable and best cluster numbers are very difficult to define. Therefore, in this research, an effective heuristic unsupervised classification method-Genetic Algorithm (GA) is introduced and tested here. The method can not only be adopted to analyze the satellite image directly through the spectrum reflection from objects on the earth, but also can be through the mathematical model and calculating procedure of optimization to determine the best cluster numbers and centers automatically. In addition, two effective and famous indices, Davies-Bouldin's and Xie-Beni's models, which adopted by most research for the applications in pattern classification, are integrated with GA as the fitness functions here. Therefore, the main purpose of this research is to establish the best GA model for image analysis and test, and in the meanwhile, the different fitness functions will be compared for improving its accuracy. I.e., in this research, a heuristic method¾Genetic Algorithm (GA), is adopted and integrated with two different indices as the fitness functions to automatically interpret the clusters of satellite images for unsupervised classification. And the classified IKONOS image is compared with digitized reference data serving as ground truth for the estimation of classification accuracy together with their error matrices. All image-processing program is developed in MATLAB, and the GA unsupervised classifier is tested on several image examples.

6365-40, Poster Session

Analysis of the classification accuracy of a new MNF based feature extraction algorithm

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Hyperspectral sensors (HSs) split into a large number of contiguous and narrow bands the radiation reflected or emitted by the observed surface. HSs allow different materials or natural backgrounds to be discriminated on the basis of their spectral signatures. This capability is very interesting for applications such as surface surveillance and land cover classification, which enable the users to monitor natural resources and to collect information on the environment.

Although HSs discriminate different classes better than multispectral sensors, they exhibit a considerable spectral redundancy, manifested as high correlations between adjacent bands. Such redundancy not only increases data volume and computational load, but also degrades classification accuracy if not enough training data are available.

In the framework of hyperspectral imaging, many applications require data reduction without loss of key information, so that images can be efficiently stored and processed. This trade-off is typically solved by resorting to feature extraction techniques. Some examples are provided by the Principal Component Analysis (PCA), which represents a standard tool for data reduction, and the more recently proposed Maximum/Minimum Noise Fraction (MNF) transform. Such transformations produce a new data cube in which every component or feature is a linear combination of the original spectral bands. In particular, the first Principal Component (PC) and the first MNF feature explain the maximum variance and the maximum/minimum noise fraction of the original data, respectively. This arrangement allows only the most informative features to be extracted, i.e. the ones containing more data variance or signal to noise ratio. Reducing noise in hyperspectral data, a better separation between classes is expected and classification performance can be improved. Opposite to PCA, the MNF transformation requires the knowledge of noise covariance matrix. In actual applications such knowledge is not available a priori, thus the noise covariance matrix must be estimated from the image or from dark reference measurements.

In the literature, an MNF based feature extraction algorithm, called Min/Max Autocorrelation Fraction (MAF), has been proposed where the noise covariance matrix is estimated from the image itself by differentiating neighboring pixels. However, the MAF exploits only the spatial correlation in the image, while the spectral correlation is not taken into account.

In the paper, a novel MNF based feature extraction technique is presented and its impact is evaluated on the classification performance of a hyperspectral image. The proposed technique exploits a reliable estimate of the noise covariance matrix and the procedure can be computed directly on the image in an unsupervised fashion. The estimate is obtained by resorting to a multiple linear regression method, which removes not only the spatial (within a band) correlation, but also the spectral (between the bands) one. In particular, the image is divided into non-overlapping small blocks and each is independently decorrelated both in the spectral and spatial domain. A statistical test is applied to each band to select a subset of blocks with homogeneous variance, and the selected blocks are used to estimate the noise covariance matrix. Then, such matrix is exploited to compute the MNF transform, which projects the original data into the feature space spanned by the MNF eigenvectors.

To the best of our knowledge the MNF transform is usually performed for noise removal, and its impact on applications such as image classification is not well explored in the literature. The proposed feature extraction technique is performed on an experimental AVIRIS data set, acquired over the Indian Pine test site. The original data set is projected into the MNF feature space and the resulting image is classified by adopting the maximum likelihood classifier. To evaluate effectiveness of the result, the classification accuracy is computed as a function of the number of features. Moreover, the accuracy is compared with the one obtained by adopting the PCA and the MAF transform.

6365-41, Poster Session

Novel method for reprojection of MODIS level 1B images based on concurrent gradient search

K. Khlopenkov, A. P. Trishchenko, Y. Luo, Canada Ctr. for Remote Sensing (Canada)

The reprojection is a necessary step in transformation of satellite swath image into a regular geographic projection. This is a nonlinear and complicated procedure, especially for scanners with large swath width, such as MODIS and AVHRR imagers. The reprojection is particularly complex for MODIS spectroradiometer when multiple detector arrays scan the swath of about 2000 km wide. The field-of-view of the detector arrays is significantly wider at large view zenith angles, which leads to an overlap between the consequently scanned image segments (the bow-tie effect). At the sides of the swath, the overlap can be as much as 40%.

Here, we propose a novel algorithm to address the reprojection issue for MODIS level 1B imagery. The method is based on the simultaneous 2D search in the both latitude and longitude fields using local gradients. It can also be applied to reprojection of the imagery obtained by a single-detector scanning systems, such as AVHRR. In the case of MODIS, the gradient search is realized in two steps: inter-segment and intra-segment search. This helps to resolve the discontinuity of the latitude/longitude fields caused by overlapping. The structure of the algorithm allows equal efficiency in both the nearest-neighbor and the bilinear interpolation modes.

Our tests showed that the gradient search method performs about 2-3 times faster than the standard MODIS Reprojection Tool (MRT) (v.2.1) and provides more robust results when processing L1B images with missing pixels and lines. The developed algorithm also handles the singularity in granules containing North Pole. The method achieves high geolocation accuracy and includes optional on-the-fly conversion of raw counts into physical parameters (reflectance and brightness temperature). The routine is designed for batch processing of large data volumes and has been employed to generate Canada-wide coverage from multiple granules of MODIS data at 250 m and 500 m.

This work was conducted as part of the Program “Reducing Canada’s Vulnerability to Climate Change” of the Earth Sciences Sector, Department of Natural Resources Canada. This work was also supported by the Canadian Space Agency under the Government Related Initiative Program (GRIP) grant to CCRS.

6365-42, Poster Session

An efficient approach for site-specific scenery prediction in surveillance imaging near Earth’s surface

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Surveillance camera automation and camera network development are growing areas of interest due to increasing computation power. Applications depend strongly on the camera’s site. The landscape constitutes the background against which interesting targets appear. Thus the scene dictates the attainable surveillance performance. Consequently, for all imaging systems observing the Earth surface, the utilization of Geographic Information Systems is a promising technique. If the camera platform is located near the ground, the landscape consists of sky and terrain with miscellaneous objects. Then, with up-to-date elevation and terrain information, the background below horizon proves partially deterministic. In other words, it has predictable features.

This paper presents an efficient approach to predicting the background’s deterministic characteristics when the camera is near Earth’s surface. Visible terrain is assessed based on straight-line ray trajectories and then projected to image plane. That is to say, the lowest possible path that light can propagate between the terrain and the camera is determined. The efficiency arises out of propagation computation: the insight is reduced dimensionality in calculation. The approach takes into account Earth’s spherical shape and uses auxiliary information about the environment: ground elevation model, terrain class model, and a flight obstacle register. Simultaneously, with visibility prediction, the procedure returns shadow regions and their height above ground. Ground elevation plays the biggest role in the shadow region formation, but vegetation contributes to it too. For example, coniferous forest limits the visibility and causes shadow regions. Utilized terrain class model includes information about the soil and the vegetation. Hence the vegetation is considered as well in the terrain profile. Approximate height of the particular vegetation is assumed. With the shadow region estimation, it is possible to attach additional objects realistically to the environment model before the back projection. The scenery below horizon is labeled with predicted distance from the camera and the terrain class such as coniferous forest, field, urban site, lake, or mast. The performance of the approach is studied by comparing a photograph of Finnish forested landscape with the prediction. The resulting background prediction is well-fitting, and the potential knowledge-aid for various purposes becomes apparent.

The scenery prediction allows several appealing applications. Via deterministic features, the camera may be oriented with the world

coordinate system, an appropriate site may be selected in advance, or even the location may be assessed possibly if other positioning systems are unavailable. Inherent enhancements to surveillance image processing tasks such as object detection, classification, and tracking are evident owing to improved background characterization. In fact, the greatest expectations are in infrared imaging applications.

6365-45, Poster Session

A comparison of stereo matching techniques for cloud-top height retrieval

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This paper presents an ongoing study for the estimation of the cloud-top height by using only geometrical methods. It is based on the hypothesis that an infra-red camera is on board a satellite and couples of images concern nearly the same scene. Stereo-vision techniques are therefore explored in order to find the best methodology for height retrieval and in particular several techniques of stereo matching are compared. This study includes both area-based and feature-based matching algorithms by implementing the basic versions, without considering any further steps of optimisation to improve the results. Dense depth maps are the final outputs, even for those algorithms where disparities are evaluated not on a pixel by pixel basis. In this case dense maps are obtained post processing the sparse ones. Two approaches are used in order to evaluate the results. One is based on error statistics computed with respect to a set of Digital Terrain Elevation Data, used as ground truth for a set of nearly cloud free images. The second one consists of the evaluation of the images warped by means of the retrieved maps. A set of real couples of images from the Along-Track Scanning Radiometer2 11μm data set, has been considered. The ATSR2 is a multiangle instrument onboard the ERS2 satellite, that records two different views with a temporal gap of 120 sec, in 7 spectral bands. Results and their evaluation are discussed in the paper.

6365-46, Poster Session

Quasi-optimal compression of noisy optical and radar images

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It is quite often necessary to compress remote sensing data such as optical or radar images. This is needed for transmission via communication channels from satellites and/or for storing in databases for later analysis of, for instance, temporal scene changes. Such images are generally corrupted by noise and this factor should be taken into account while selecting a data compression method and its characteristics, in the particular, compression ratio (CR) [1]. While in the case of transmission via communication channel, the channel capacity can be the crucial factor in selecting the CR, in the case of archiving original remote sensing images the CR can be selected using different criteria. The basic requirement could be to provide such a quality of the compressed images that will be appropriate for further use (interpreting) the images after decompression.

We propose a blind approach to quasi-optimal compression of noisy optical and side look aperture radar images. It presumes that the noise variance is either known a priori or pre-estimated using the corresponding automatic tools. Then, it is shown that it is possible (in an automatic manner) to set such a CR that produces an efficient noise reduction in the original images while introducing minimal distortions to remote sensing data at compression stage. For radar images, it is desirable to apply a logarithmic type homomorphic transform before compression and the corresponding inverse transform after decompression. Real life examples confirming the efficiency of the proposed approach will be presented.

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6365-48, Poster Session

Motion compensation on synthetic aperture sonar images

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High resolution sonars are required to detect and classify mines on the sea-bed. Synthetic aperture sonar increases the sonar cross range resolution by several orders of magnitudes while maintaining or increasing the area search rate. The resolution is however strongly dependent on the precision with which the motion errors of the platform can be estimated. The term micro-navigation is used to describe this very special requirement for sub-wavelength relative positioning of the platform. Therefore algorithms were designed to estimate those motion errors and to correct for them during the (omega,k)-reconstruction phase. To validate the quality of the motion estimation algorithms a single transmitter/multiple receiver simulator was build, allowing to generate multiple point targets with or without sway and/or yaw motion errors. The motion correction algorithms are also validated on real data, which were taken during a sea trial in November of 2003 with the low frequency (12 kHz) side scan sonar (LFSS) moving on a rail positioned on the sea-bed near Marciana Marina on the Elba Island, Italy.

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6366-01, Session 1

Progress in soil moisture estimation from remote sensing data for for agricultural drought monitoring

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Abstract: Soil moisture is one of the most important indicator for agricultural drought monitoring. In the paper we present a comprehensive review to the progress in remote sensing of soil moisture, with focus on discussion of the questions existing in soil moisture estimation from remote sneisng data and the method details in the estimation. Both optical and microwave remote sensing are highly applicable in successful estimation of soil moisture. A number of methods have been developed for the estimation. Thermal inertia and crop water stress index (CWSI) can be used for soil moisture estimation unver bare soil and vegetated environments respectively. Nomalize difference vegetation index (NDVI) directly relates to crop growing state and agricultral drought. Anomaly vegetation index (AVI) and vegetation condition index (VCI) are another alternative methods for soil moisture estimation. Both NDVI and land surface temperature (LST) are considered in temperature vegetation index (TVI), vegetation supply water index (VSWI) and vegetation temperature condition index (VTCI) at the same time, which makes the physical meaning of estimating soil moisture reasonable. Hyperspectral remote sensing are powerful in correlating soil spectral reflectivity and its moisture content. Microwave remote sensing is the most effective technique for soil moisture estimation. Passive microwave remote sensing data have more potential for large-scale agricultural drought monitoring. In order to improve the accuracy of soil moisture retrieval from remote sensing data, many efforts are required to devote into the model development for soil and remote sensing, retrieval methods, digital soil project and international cooperation.

6366-02, Session 1

Effects of different vegetation indices to the spatial changes desert environment using EOS/MODIS data: a case study to Sangong inland arid ecosystem

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Abstract: Sangong River Basin in the north piedmont of Tianshan Mountains is a typical inland arid ecosystem in China. Desert environment especially land cover and land use in the basin changes dramatically in recent decades under the anthropogenic impacts. In order to develop an approach to highlight the environmental changes, we present a case study in the paper to examine the effects of different vegetation indices to the spatial changes of desert environment in the basin using MODIS data. First we compute the different vegetation indices including NDVI and EVI for the basin from MODIS data and then compare their applicability to indicate the seasonal changes and spatial variation of vegetation in the basin. The results show that the value of vegetation indices of the groundwater-overflow areas is much higher in the marginal zone of alluvial fans than in the hilly regions and the dune-fixed desert. This spatial variation reflects the gradient change of the desert vegetation in the basin. The discrete degree of EVI values is lower than the NDVI values of the groundwater-overflow areas in the marginal zone of alluvial fans. Therefore EVI can be used to highlight vegetation growth over the alluvial fans while NDVI is suitable to monitor vegetation growth in the hilly regions. With this finding, we further develop an approach to examine the desert environment changes in the basin. Using this approach we thoroughly study the phenological phenomenon of the inland arid ecosystem and explain the phenomenon with relevance to the anthropogenic impacts on the ecosystem in recent decades. Based on the examination, several policy recommendations have been proposed in the study for better administration and utilization of arid land resources in the basin.

6366-03, Session 1

Assessment of pasture degradation in Turkmenistan using remote sensing

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In Turkmenistan the most prominent cause for desertification is inappropriate land use practices. A large portion of the country is under various degrees of desertification processes (66.5%). The natural arid pastures have limited carrying capacity and any changes of the fragile balance can lead to the destruction of this valuable resource.

One of the most appropriate tools for monitoring these processes is change detection through remote sensing imagery. Accurate monitoring of changes on Earth's surface is important to understand the relationship between man and nature and to provide decision makers with relevant information. The information on vegetation change is the most important of these relationships. Vegetation cover is also a useful indicator of the magnitude of land degradation that is easily assessed by multi-spectral remote sensing. The reduced vegetation cover causes an increase in Albedo, which can also be monitored by remote sensing. The combination of these two parameters can give us a better map of the pasture status and its degradation rate.

Landsat 5 and Landsat 7ETM+ images were processed to maps of land use/land cover changes in Transunguz Karakum Desert in northern Turkmenistan.

The data were further processed in GIS and revealed the shrinking and the degradation of the pasture area. From the 1970's a total of ~4000km2 of pasture were transformed into agricultural land, increasing the grazing pressure in the remaining areas.

By applying advanced techniques for image based end-member retrieval and spectral mixture analysis a sub-pixel fraction was obtained for each end-member. The fractions of soil and vegetation emphasize the most degraded/rehabilitated sectors of the study area. Our results indicate the reduction of vegetation only in specific areas while most of the desert experiences an increase in the vegetation cover, what can be regarded as rehabilitation.

Our current study focuses on combining the spectral mixture analysis products with other degradation criteria such as Albedo to produce a more detailed assessment and understanding of the processes leading to these changes.

6366-04, Session 2

MTF measuring based on interactive live-wire edge extraction

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When we want to acquire the Modulation Transfer Function the sharp edges is usually used. But for noises in the image, fully automated locating the expected edge is still an unsolved problem. Live-wire edge detection is a new interactive tool for efficient, accurate, and reproducible edge extraction which requires minimal user input with a mouse. Optimal boundaries are computed and selected at interactive rates as the user moves the mouse starting from a manually specified seed point. When the mouse position comes in proximity to an object edge, a "live-wire" edge snaps to, and wraps around the object of interest. Input of a new seed point "freezes" the selected edge extraction, and the process is repeated until the boundary is complete. This paper proposes a novel method of live wire for measuring the on orbit Modulation Transfer Function (MTF) for high spatial resolution imaging satellites. We add the no-linear filter in the local cost function to ensure the accurateness of the extraction of edges. It can both de-noise and do not affect the shape of the edges when we extracting the edges, so that the calculation of the MTF is more reasonable and precision.

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6366-05, Session 2

Supporting the update of maps by object-oriented classification of orthophoto

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The update of land use databases, if done on the basis of high-resolution orthophotos, is usually carried out by means of visual interpretation, a both time-consuming and expensive task. In this paper an object-oriented classifier is used to support the update process by highlighting where changes have taken place. Basic land cover types are first identified in the orthophotos and then compared to the land use data to create a change map. The map is created on the basis of plausibility, assigning each class combination to either identical, plausible, questionable or new. As these assignments are user defined, they can be adjusted to suit different data sets and update tasks.

The procedure was developed using true-color orthophotos and highly detailed land use data for a study area in Austria. Special emphasis was put on the identification of urban features. The resulting change map was compared to an independently updated version of the land use data base, showing the high reliability of the results. The methodology was then tested on data sets provided by mapping agencies of Germany and Switzerland during the project "Change Detection" carried out within the framework of EuroSDR. Here the emphasis was laid on the transferability of the classification procedure to the different orthophotos as well as the inclusion of the very different land use data sets. The results are very consistent and even though they may not always meet the specific demands of the different mapping agencies, its potential for routine updating could be clearly shown.

6366-06, Session 2

Updating the 1:50.000 topographic maps using ASTER and SRTM DEM: the case of Athens, Greece

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The 1:50.000 topographic maps present a nominal horizontal accuracy of 20 meters and a nominal vertical accuracy of 10 meters with 90% confidence. The data were in most cases extracted with photogrammetric techniques from aerial stereo-photographs during the 80's. The usual update rate for these maps ranges from ten to twenty years.

The Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) offers along-track stereoscopic viewing capability. Its viewing geometry is suitable for DEM generation even without the use of ground control points. Recent studies have proved that in this case the vertical accuracy of DEM is about 20m with 95% confidence. The horizontal geolocation accuracy appears to be limited by the spacecraft position accuracy which is considered to be better than 50 m. Other studies have shown that the use of GCP's resulted in a plannimetric accuracy of 15 m and in a near pixel size vertical accuracy.

The Shuttle Radar Topography Mission (SRTM), used an Interferometric Synthetic Aperture Radar (IFSAR) instrument to produce a near-global digital elevation map of the earth's land surface with 16 m absolute vertical height accuracy at 30 meter postings. An SRTM 3-arc-second product (90m resolution) is available for the entire world.

In this paper we examine the possibility of updating the 1:50.000 topographic maps using ASTER and SRTM DEMs. The area of study is the broader area of Athens, Greece.

Presupposing, that the horizontal and vertical accuracy of the ASTER and SRTM DEMs is similar to the relative accuracies of the DEM from digitized contours, optical comparison of the DEMs and statistical analysis (difference, correlation) can immediately prove if there is any need for update to the topographic maps.

A DEM from digitized contours from the 1:50.000 topographic maps was created and compared with ASTER and SRTM derived DEMs. Almost five hundreds points of known elevation have been used to estimate the accuracy of these three DEMs.

The resulted accuracy of the SRTM and ASTER derived DEMs was satisfactory, therefore they are considered as suitable for updating 1:50.000 topographic maps.

6366-07, Session 2

A method for downscaling MODIS land channels to 250-m spatial resolution using adaptive regression and normalization

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The Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the most advanced sensors used for wide range of land, ocean and atmosphere application. It has 36 spectral channels with spatial resolution varying from 250 m to 1 km at nadir. The MODIS channels 1 (red) and 2 (near-infrared) are available at 250 m spatial resolution. Five MODIS channels designed for land applications (channels 3 to 7) are available at 500 m spatial resolution. For many applications, it is very desirable to have these channels at higher spatial resolution. It has been shown that there is a significant correlation between MODIS channels, and channels 1 and 2 carry substantial information about the general shape of the pixel spectrum. Based on this fact, we propose a method to enhance spatial resolution of channels 3 to 7 to 250 meters. The method is based on adaptive regression technique with final normalization to original 500 m imagery in order to preserve the image integrity at 500 m spatial scale. The adaptive regression is constructed for each individual MODIS L1B granule of 500 m spatial resolution by splitting the area into smaller blocks and generating nonlinear regression between each of the channels from 3 to 7 and channels 1 and 2. The regression is produced for each small bin of reflectivity for channels 1 and 2, as well as normalized difference vegetation index. Once a set of regression coefficients is generated based on 500 m image containing all 7 land channels, it is then applied to 250 m image containing only channels 1 and 2 to produce 5 intermediate channels 3 to 7 at 250 m spatial resolution. Final step involves normalization to original 500 m image. Normalization is applied to pixel box of 2 x 2 pixels from 250 m intermediate image to preserve the corresponding value in 500 m image. The developed method was applied to generate Canada-wide clear-sky composites containing all 7 MODIS land channels at 250 m spatial resolution.

Examples of imagery and statistics will be presented, and application of developed technique will be discussed.

This work was conducted as part of the Program "Reducing Canada's Vulnerability to Climate Change" of the Earth Sciences Sector, NRCan. This work was also supported by the Canadian Space Agency under the Government Related Initiative Program (GRIP) grant to CCRS.

6366-08, Session 2

Assessing forest fragmentation and connectivity: a case study in the Carpathians

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This study focuses on forest monitoring at landscape level on the basis of a methodology combining satellite mapping and image morphology. It aims to contribute to report on trends in fragmentation and connectivity that is one headline indicator to address the 2010 target to halt biodiversity loss used in the Convention for Biodiversity (CBD). The Carpathians were selected as a study area.

Changes of forest cover were quantified using five Landsat images for end of 80's and 2000. Single-date forest - non-forest maps were derived by image segmentation and supervised classification including the use of ancillary data (CORINE Land Cover and a digital elevation model). These maps were an input for the post-classification change detection. Morphological image processing was applied to map forest spatial pattern with six classes (core, patch, edge, perforated forest, corridors, branches). Statistics are on the proportion of forest that favours (1) interior species, (2) edge species. Further, connectivity and fragmentation processes were assessed on the basis of the pattern classes, respectively (corridors, branches) and (core, patches, perforation). Further, additional metrics were computed to address the distance criteria and the landscape matrix.

The accuracy of the forest - non-forest maps of year 2000 was assessed with orthophotos and Google EarthTM interface and found in all cases above 90%. We found a general trend in forest increase over the last decade, but different connectivity and fragmentation processes were observed in the five case studies. We conclude, that this methodology allows assessing trends in forest fragmentation and connectivity at approximately 1 ha minimum mapping unit.

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6366-09, Session 3

Study of buried archaeological sites using vegetation indexes

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The identification of buried archaeological structures, using remote sensing technologies (aerophotos or satellite and airborne images) is based on the principle that any buried ruins, either of human or natural origin, affects over time, soil surface characteristics creating anomalies.

These anomalies are due to different factors, such as soil physical and chemical features, and vegetation cover status. The above factors are strictly connected and are responsible of surface spectral responses.

Several images processing are applied and their results compared in order to define the one that fits better the various archaeological research goals. Among them, Vegetation Indexes revealed to be very useful archaeological study.

Spectral Vegetation indexes are important products in observing spatial and temporal variations of vegetation biophysical properties and photosynthetic activities, by which is possible to analyze the effects of buried ruins presence on vegetation cover status.

The aim of this work is to assess the usefulness of vegetation indices in order to identify archaeological traces and verify the quantitative estimates of presence of buried archaeological structures in every type of elaboration (NDVI, SAVI, NDWI, SR, etc.).

Statistical analysis were conducted on several italian archaeological test sites processing by hyperspectral MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) various typologies of vegetation cover.

The MIVIS spectrometer is a passive remote sensing instrument which collect the earth surface radiation from an airborne platform. The detector separates incoming radiation into four optical ports covering the Visible, the Near-InfraRed, the Mid-InfraRed, and the Thermal-InfraRed region; total 102 spectral bands.

6366-10, Session 3

Land use/cover classification through multiresolution segmentation and object oriented neural networks classification

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In this paper is presented a land use/cover classification methodology of the rural/urban fringe, by means of the application of a neuronal network, with resource to the multiresolution image segmentation, construction of complex elements through object oriented analysis and integration of not spectral (ancillary) information. The study area is the municipality of Almada, located in the south bank of tagus river and corresponding to one of the core regions of the Lisbon Metropolitan Area (Portugal). The data used was 2004 HRVIR SPOT images fused with supermode panchromatic image and the Portuguese urban quarter statistical data.

The developed procedure is based on 4 phases: (i) image multiresolution segmentation strategy for construction of different scales objects that have good similarity with the shape of the land use/cover final objects (polygons); (ii) objects attributes acquisition, mainly, context, texture, spectral information, shape, among others; (iii) acquisition of statistical ancillary data proceeding from the GBIR - Geographic Base of Information Referencing (urban quarters statistics); (iv) integration of the different data types in a neuronal network for polygons classification and posterior discriminated analysis of the land use/cover spatial units.

6366-11, Session 3

Spectral unmixing with nonnegative matrix factorization

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This work represents an attempt to treat endmember extraction and abundance estimation in spectral unmixing (or mixed pixel classification) problems not as separate stages but as a joint optimization problem aimed at fitting the image pixels, considered as vectors in a high dimensional space, in a convex polyhedral set. The vertices of this set are the endmembers that the algorithm detects in the image and the mixing coefficients for each image pixel are the endmember abundances. For this purpose we developed a variation on the Nonnegative Matrix Factorization Algorithm. Our algorithm makes use of the method of Alternating Quadratic Programming. We first initialize the endmembers and then proceed to solve a quadratic program to get the abundances that fit a given pixel best in a Euclidean norm sense, subject to the constraint that the abundances are nonnegative and sum to one. We then fix these abundances and solve a quadratic program to get an update on the endmembers that fit the data best in a Euclidean norm sense with an additional penalty based on the energy and the (lack of) smoothness in the resulting endmembers, subject to the constraint that these endmembers are positive. We iteratively switch between these two minimizations until our overall objective converges to a stationary point. This algorithm can be viewed as a form of coordinate descent.

The initial estimates of the endmembers are obtained as the centroids of a clustering stage based on a dissimilarity measure based on the correlation of the image pixels.

6366-13, Session 3

Applying Advanced and Existing Sensors in Dealing with Potential Natural Disasters

S. Habib, NASA Goddard Space Flight Ctr. (USA)

As an integrated observing strategy, the concept of sensorweb for Earth observations is appealing in many aspects. For instance, by increasing the spatial and temporal coverage of observations from space and other vantage points, one can eventually aid in increasing the accuracy of the atmospheric models which are precursor to hurricane track prediction, volcanic eruption forecast, and trajectory path of transcontinental transport of dust, harmful nuclear and chemical plumes. In reality, there is little analysis available in terms of benefits, costs and optimized set of sensors needed to make these necessary observations. This is a complex problem that must be carefully studied and balanced over many boundaries such as science, defense, early warning, security, and surveillance. Simplistically, the sensorweb concept from the technological point of view alone has a great appeal in the defense, early warning and security applications. In fact, it can be relatively less expensive in per unit cost as opposed to building and deploying it for the scientific use. However, overall observing approach should not be singled out and aligned somewhat orthogonally to serve a particular need. On the other hand, the sensorweb should be designed and deployed to serve multiple subject areas and customers simultaneously; and can behave as directed measuring systems for both science and operational entities. Sensorweb can be designed to act as expert systems, and/or also provide a dedicated integrated surveillance network. Today, there is no system in the world that is fully integrated in terms of reporting timely multiple hazards warnings, computing the loss of life and property damage estimates, and is also designed to cater to everyone's needs. It is not an easier problem to undertake and more so is not practically solvable. At this time due to some recent events in the world, the scientific community, social scientists, and operational agencies are more cognizant and getting together to address such colossal problems. Increasing our knowledge of the home planet, via amplified set of observations, is certainly a right step in a right direction. Furthermore, this is a pre-requisite in understanding multiple hazard phenomena's. This paper examines various sensorweb options and observing architectures that can be useful specifically in addressing some of these complex issues. The ultimate goal is to serve the society by providing potential natural hazards information to the decision makers in the most expeditious manner so they can prepare themselves to mitigate potential risks to human life, livestock and property.

6366-14, Session 4

Indian remote sensing satellite Cartosat-1: technical features and data products

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India has established the National Natural Resources Management System (NNRMS) for which the Department of Space (DOS) is the nodal agency. NNRMS is an integrated resource management system aimed at optimal utilization of the country's natural resources by a proper and systematic inventory of resource availability using remote sensing data in conjunction with conventional techniques. The major elements of NNRMS encompass conceptualization and implementation of space segments with the necessary ground-based data reception, processing and interpretation systems and integrating the satellite-based remotely sensed data with conventional data for resource management applications.

The Indian Remote Sensing (IRS) satellites form an important element of the NNRMS for providing continuous remote sensing data services for

the management of natural resources of the country. A series of IRS satellites have been launched by India starting with IRS-1A in March 1988. There are six remote sensing satellites in service at present — IRS-1C, IRS-P3, IRS-1D, OCEANSAT-1, TES and RESOURCESAT-1 — making IRS system the largest civilian remote sensing satellite constellation in the world. CARTOSAT-1 is the latest satellite under the IRS programme.

CARTOSAT-1 will be followed by CARTOSAT-2, which will have a spatial resolution of about one meter. A Radar Imaging Satellite (RISAT), carrying a C-band Synthetic Aperture Radar (SAR) with a spatial resolution of 3 to 50 m and a swath of 10 km to 240 km is under development. With all weather remote sensing capability, RISAT will enhance remote sensing applications in the areas of agriculture and disaster management. RISAT is slated for launch by 2006.

The data from IRS is utilized for several applications. They include land use/cover mapping for agro-climatic zones planning, wasteland mapping, forest cover mapping, wetland mapping, Crop Acreage and Production Estimation, National River Action Plan for Sewerage Treatment Plants, Coastal Zone Regulation mapping, Integrated Mission for Sustainable Development, National (Natural) Resources Information System, etc. In addition, different application studies of local/regional level are also being carried out by many organizations. With high-resolution imageries of CARTOSAT-1, cadastral level applications will receive further impetus.

With ISRO Satellite Center (ISAC), Bangalore, as the lead Centre, CARTOSAT-1 was realized with major contributions from Space Applications Center (SAC), Ahmadabad, Liquid Propulsion Systems Center (LPSC) at Bangalore, and ISRO Inertial Systems Unit (IISU), Thiruvananthapuram. ISTRAC is responsible for initial and in-orbit operation of CARTOSAT-1. The National Remote Sensing Agency, under the DOS receives processes and distributes the data from IRS satellites to various users. The imagery from IRS satellites are disseminated worldwide on a commercial basis through Antrix Corporation of DOS.

6366-15, Session 4

The EnMAP Hyperspectral Imager: an advanced optical payload for future applications in Earth observation programmes

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Contracted by the German Space Agency DLR, the feasibility study on the hyperspectral satellite EnMAP (Environmental Mapping and Analysis Programme) has been successfully completed. EnMAP is considered as a next German satellite mission, scheduled for launch in the 2009 time frame. The instrument performance allows for detailed monitoring, characterisation and parameter extraction of rock/soil targets, vegetation and inland and coastal waters on a global scale.

The EnMAP HIS (Hyperspectral Imager) has over 200 continuous spectral bands in the wavelength range between 430 - 2450 nm with a ground resolution of 30 m x 30 m. The sensor works in a push broom configuration being designed for a sun synchronous orbit at 643 km. With the hyperspectral data set, the broad science and application community can draw from an extensive and highly resolved pool of information supporting modelling and optimisation processes of our environment. The operation of an airborne ARES system, starting to support a national hyperspectral network at the end of 2006, and the evolution concerning data handling and information extraction procedures will push forward the transfer activities of hyperspectral data processors as well as optimisations in the space based sensor design.

In the paper, all aspects from the sensor and satellite design will be highlighted. Additionally, mission operation and the multiple science cases including the generation of data products meeting the challenging future demands of the EO community will be considered. The Hyperspectral Imager HSI on the EnMAP satellite is primary designed to fulfil the scientist's requirements being at the same time a so-called 'pathfinder' for future commercial systems with further optimised instrumentation.

6366-16, Session 4

Using high-resolution multispectral imaging to map Pacific coral reefs in support of UNESCO's World Heritage Central Pacific Project

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Concern over worldwide declines in marine resources has prompted a search for innovative solutions to their conservation and management, particularly for biodiversity hotspots such as coral reef ecosystems. It has been shown that effective protection of marine environments requires representation of all habitat types, connected biologically and distributed along environmental gradients. Rapid advances in sensor resolution and image analysis techniques tailored to the unique optical problems of marine environments have allowed the derivation of detailed benthic habitat maps from multispectral imagery, representing coral reefs' main ecological communities. UNESCO's new World Heritage Central Pacific Project (WHCPP) will afford protection through World Heritage recognition to a number of islands and atolls in the central Pacific Ocean, including the Phoenix and Line Archipelagos. Most of these atolls and islands lack natural resource maps, needed for the identification of priority areas for inclusion in a marine reserve system. Our project provides assistance to UNESCO's World Heritage Centre by developing benthic habitat maps from high-resolution multispectral imagery. The approach involves: (i) the analysis of new Quickbird multispectral imagery for the Phoenix and Line Islands, a test area within the WHCPP; and (ii) the use of MARXAN, a simulated annealing algorithm. Analysis of satellite imagery was performed with ENVI(r), and includes standard radiometric and geometric corrections, removal of atmospheric effects using ATCOR (a MODTRAN4 radiative transfer model), de-glinting and water column correction algorithms, and a number of unsupervised and supervised classifiers. Ground-truth data collected in-situ is used to assess the accuracy of the resulting habitat maps, which are then used as input in a GIS environment where MARXAN identifies a proportion of each habitat in a spatial arrangement that accounts for connectivity among habitats and distribution along environmental gradients.

6366-17, Session 4

Satellite remote sensing of the oceanic environment in China

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Satellite remote sensing technique has been used to monitor the oceanic environment. This paper presents the technique development and applications of satellite remote sensing to the oceanic environment in China. The technique development includes the development of algorithms and of methodology for extracting oceanographic parameters from satellite data. Applications of satellite remote sensing range from environmental monitoring to oceanographic research. Future technique development and applications of satellite remote sensing to the oceanic environment are discussed.

6366-18, Session 5

Using remote sensing techniques in lithological discrimination and detection of gold-bearing alteration zones at Wadi Defeit Area, southeastern desert, Egypt

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Wadi Defeit area in the extreme South Eastern Desert of Egypt is occupied mainly by Precambrian ophiolitic and island-arc assemblages. The ophiolitic rocks are principally represented by serpentinite, talc-carbonate and listwaenite thrusted over the metasediments and island-arc schistose metavolcanics and intruded by syn to late tectonics intrusions of gabbro-diorite, tonalite (G1) and monzogranite (G2). For lithological discrimination of the basement rocks covering the study area, tracing the major structural features and detection of the gold bearing alteration zones. The Enhanced Thematic Mapper (ETM+) with 7 bands composition and resolution about 15 m was processed where the geometric corrections and radiometric balancing to the image were carried out. The image enhancement techniques including spatial and spectral enhancement, ratioing and stretching have been applied and different band ratios were testes, the band selection for different ratio images used is based on the spectral signatures of these rocks. The study revealed that, based on the spectral signatures of the different basement rocks forming Gabal Al Adraq area, the RGB band ratio ETM image (5/7, 5/, 4) is proved to be very effective in

the lithological discrimination as well as the detection of the gold bearing alteration zones.

Gold mineralization is genetically related to the ophiolitic and island-arc groups as it is hosted mainly in listwaenites, the alteration zones within the schistose metavolcanics and in the quartz veins. In listwaenites, the gold is introduced into the alteration zones and quartz veins during the sulfidization processes, the remobilization of gold took place along the thrust zones during listwaenization. This study indicates that the alteration zones in the metavolcanics and the listwaenites in the study area are promising and need more detailed exploration for Au and Ag mineralizations to evaluate their potentiality.

6366-19, Session 5

A Michelson interferometer for seismic wave measurement: theoretical analysis and system performances

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Laser interferometry is one of the most sensitive methods for small displacements measurement. This technique was successfully used in several fields of physics, giving very good performances also for the large availability of optical components and high quality and relatively low cost of laser sources. In this paper, we present a laser interferometric sensor for seismic wave propagation measurement. We demonstrate that a Michelson Interferometer with one fix arm behaves as a velocimeter for a seismic wave. In the paper the methodology for choosing the optimal system parameters is presented and the performances of the interferometric system are analyzed in comparison with a standard accelerometer. The result are encouraging although some problems, mainly connected with the sensitivity and the stability of the interferometric system, have to be better studied.

6366-20, Session 5

Problems related to the use of multisource multitemporal geospatial datasets for glacier volumetric change detection

F. Savopol, Natural Resources Canada (Canada)

The paper will analyze the problems related to the use of multi-temporal and multi-source geospatial datasets for volumetric change detection of glaciers in the Canadian North. The general objective of the present work is to obtain the best estimation of volumetric changes for the Grinnell Glacier on Baffin Island (Nunavut Territory) over the longest period of time using existing (historical) geospatial data sets and new remote sensing data and ground surveys.

Remote areas such as the Canadian Arctic present unique challenges for monitoring changes over long periods of time. Repeated ground and aerial surveys are expensive and present logistical difficulties. New high resolution satellites such as QuickBird and IKONOS are interesting alternatives and were used for delineation of glacier extension but the only precise historical (over 50 years old) data sets for the Grinnell Glacier are the aerial photography stereo-pairs from the National Aerial Photo Library (NAPL). New elevation data set are GPS ground surveys and LIDAR data sets from 2004 - 2005.

Traditional change detection methods using two data sets have as prerequisite the need to have a good alignment between the two data sets. Any difference in alignment is interpreted as a change. For the present work, we used multiple data sets of 4 types of data: historical stereo aerial photos (from 1952,1959 and 1966), aerotriangulation control data from the Air Survey Database (ASDB), recent high resolution satellites imagery, LIDAR data and GPS ground measurements. The comparison is made between data recorded by different data acquisition systems with different resolutions and, in most cases, using a different geometry

We investigated the multi-temporal data integration and data fusion process taking into account the multi-source and multi-resolution aspect of the problem.

The presented work was done at the Centre for Topographic Information / Natural Resources Canada in the frame of the 'Reducing Canada's Vulnerability to Climate Change' Program and partially under the program 'Geomatics for the Northern Development'.

6366-35, Poster Session

Identification and spatial characterization of buried remains using VHR satellite images

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In the last century panchromatic aerial images have been the only tools employed in the aerial archaeology. The use of satellite remote sensing data have been generally restricted due to the limited spatial resolution of conventional imagery, such as TM (30 m) or Spot (10 m). The recent availability of Very High Resolution (VHR) satellite images, such as IKONOS (1999) and Quickbird (2001), can provide new perspectives in the field of archaeological remote sensing.

This paper deals with the potentialities of QuickBird data to detect the typical marks (shadow, soil and crop marks) expected in the presence of archaeological buried remains.

Test sites are relative to some medieval abandoned villages located in the Basilicata Region (Southern Italy). They were founded in the early Middle Ages and disappeared during the Middle Ages as was common throughout Europe during that age, thus, the phenomenon of deserted villages has become a very popular and relevant historical and archaeological topic.

The investigated test sites present different features from the geological, pedological and land-use point of view, thus allowing a detailed analysis of the spectral responses observed for the different features. The application shows the feasibility of QuickBird data not only for the detection but also for the spatial characterization of buried archaeological structures. Such results provided valuable information for planning archaeological excavations and for increasing the cultural value of the site.

6366-36, Poster Session

Analysis of urban surface biophysical parameters from remote sensing imagery

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Remote sensing is a key application in global-change science, being very useful for urban climatology and landuse-landcover dynamics analysis.Multi-spectral and multi-temporal satellite imagery (LANDSAT TM , ETM ;SAR) over 1984 - 2004 period for Bucharest metropolitan area provide the most reliable monitoring technique of different urban structures regarding the net radiation and heat fluxes associated with urbanization at the regional scale. Bucharest City, the biggest industrial, commercial center in Romania experienced a rapid urban expansion during the last decades. A large amount of forest and agricultural land have been converted into housing, infrastructure and industrial estates. The resultant impervious urban surface alters the surface energy balance and surface runoff, which in turn could pose serious environmental problems for its inhabitants (e.g., urban waterlogged and thermal pollution).Investigation of radiation properties, energy balance and heat fluxes is based on satellite data from various satellite sensors and in-situ monitoring data , linked to numerical models and quantitative biophysical information extracted from spatially distributed data and net radiation. The changes over the years of surface biophysical parameters are examined in association with landuse changes to illustrate how these parameters respond to rapid urban expansion in Bucharest and surrounding region. For detailed landuse classifications in a digital form these properties were analyzed in a statistical way .This study attempts to provide environmental awareness to urban planners in future urban development. The land cover information, properly classified, can provide a spatially and temporally explicit view of societal and environmental attributes and can be an important complement to in-situ measurements.

6366-37, Poster Session

Multisensor image ffusion for Romanian Black Sea coastal zone analysis

L. V. Zoran, Univ. Politehnica Bucuresti (Romania); M. A. Zoran, National Institute of Research & Development for Optoelectronics (Romania)

The aim of this paper is to describe applications of satellite data fusion for changes assessment and environmental impact in spatial phenomena over Romanian North -Western Black Sea and Danube deltaic and coastal

areas needed for the protection and restoration.. Since single sensor solutions for automatic object recognition provide only partial answers , was proposed a multi-sensor, multi-resolution approach to be effective tool of exploiting the complimentary nature of different data types for change-detection studies.In order to extract environmental features for determining surface patches and surface boundaries, grouping surface patches based on spatial proximity, geometric and radiometric properties was performed object recognition for North-Western Black Sea coastal zone based on different satellite data (Landsat TM, ETM, ERS and MODIS) . Preliminary results show significant coastline position changes of North Western Black Sea during the period 1975-2004. The direct impacts are clearly shown, but it is less straightforward to link the changes in coastline to indirect impacts of the changing land use/cover. As an indication of land use/cover change, the extension of the road network and the urban areas is compared. The growth of coastal urban areas generates a range of threats to the nearby shoreline habitats. Direct physical damage is caused by construction works on harbors, airports and tourist resorts .Also the coastline change is examined and linked to the urban expansion in order to determine if the changes are mainly human induced or natural. A distinction is made between landfill/sedimentation processes on the one hand and dredging/erosion processes on the other.

6366-38, Poster Session

Integrate RS and GIS: a primary study of adding remotely sensed image processing functions to ArcGIS8.3 using Matlab COM Builder and AO

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This paper systematically introduces the practice of adding remotely sensed image processing functions to ArcGIS8.3 using Matlab COM Builder and AO. We also compare the performance of our system with that of the proprietary RS software ERDAS IMAGE8.5. The performance of our system is a bit lower than ERDAS IMAGINE, but the availability of power functions, the high efficient development methods and the integrated application environment provide us with large probabilities of the integrated applications of RS and GIS. Furthermore, it is possible for not only the field of remotely sensed image processing but also any other fields, which need to integrate the functions from GIS and Matlab to improve efficiency, low cost, mine and couple the functions from different professional software packages.

6366-39, Poster Session

Fusion of Quickbird satellite images for vegetation monitoring in previously mined reclaimed areas

E. Ieronimidi, S. P. Mertikas, D. Hristopoulos, Technical Univ. of Crete (Greece)

The intent of this paper is to monitor the status of re-vegetation growth in a reclaimed, previously mined region on the island of Milos, Greece using remotely sensed images. Quickbird multispectral (spatial resolution 2.4m x 2.4m) and panchromatic (spatial resolution 0.6m x 0.6m) images have been fused to obtain an optimal combination of the initial spatial and spectral resolution. The Blue (450nm-520nm), Green (520nm - 600nm) and Near Infrared (760nm - 900nm) bands of the multi-spectral image have been used. Different fusion methods, like the Principal Component Analysis, the Intensity-Hue-Saturation technique and the Wavelet Analysis have been applied to the available images.

Both statistical (correlation coefficient, accuracy measures, entropy, etc.) and subjective (i.e., visual) measures have been used to evaluate the produced fused images. In that way, the degree to which each of the fused images retains the spectral and spatial features of the initial images has been estimated.

It has been found that the Wavelet Analysis effectively preserves most of the spectral information of the original multi-spectral image. On the other hand, the Principal Component Analysis retains most of the spatial information of the panchromatic image. On the other hand, the Intensity-Hue-Saturation technique offers a compromise between the spectral and spatial content of the fused image.

Results have been used for environmental monitoring of previously mined areas.

6366-40, Poster Session

Inspiration of foreign metropolis development on arable land protection in Beijing, China

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Population growth, urban expansion, land degradation result plant natural resources for food and agriculture at risk in many places. Beijing as the capital of China also faces menace of food safety. How to result the conflict of arable land protection and economic development is the key problem to Beijing. The purpose of this paper is to provide reference for arable land protection in Beijing by analyzing the change of structure in land use of international metropolis by remote sensing data. Through compare the characteristic of Beijing and other abroad metropolis, Tokyo and Paris are selected for this research.

Tokyo and Paris are the typical internationalization metropolis. Built-up area expands gradually and arable land decreases in Tokyo for population boom. But, there is still some cropland in the city zone for supplying the fresh vegetable to citizens. The proportion of greenbelt exceeds 60% in Paris. A lot of parks and natural protection zones are distributed in the city area. Data used in this research are Landsat TM in 80 decades in 20 century and ETM+ in 21 century whose spatial resolution is 30m. Identifying the land use categories through the supervised classification method and the training samples collected from the map of land use actuality. The final map of classification includes four categories, arable land, forest or other greenbelt, built-up and traffic etc staunch area, and water area.

Through analyzing the proportions of different land use categories in different time of three cities, study area is in the administration boundary of these cities. The results include: (1) the proportion of built-up area is 55.55% in 2001 in Tokyo which increased 9.03% from 1987 to 2001. The increasing of built-up area almost came from arable land for the restriction of mountain in the west. (2) the proportion of built-up area is 16.79% in 2001 in Paris, arable land is 50.14%. The structure of land use is stabilization from 1987 to 2001. (3) the proportion of built-up area is 18.85% in 2001 in Beijing which increased 12.20% from 1987 to 2001, arable land is 22.70% which decreased 7.39% from 1987 to 2001. The rate of decreasing in arable land and increasing in built-up land is the fastest in Beijing. But the proportion can not reflect the real instance of these cities because the proportion is relevant to area of whole city. These index is not high relevant to the environment of the city zone.

The value of arable land not only considers the productive capacity but the ecological value. The quality, location and the environment function of arable land have take into account to protect strictly that restrict it convert to other staunch area. How to harmonize the relation between different interest bodies must be paid much attention in protection and using of arable land. Treating arable land as the greenbelt in the city zone is a new attempt to city planning. It can satisfy not the need of greenbelt rate in city planning but the aim to protect arable land.

6366-41, Poster Session

GIMS-based approach to the remote sensing of vegetation covers

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The solution of the majority of applied problems within agrometeorology, forestry, animal husbandry, and other areas of human activity directed toward the protection of nature is difficult for the reason that effective methods of control of the soil-plant formation (SPF) are insufficiently developed. During the last few years, the global carbon cycle problem has acquired a special significance because of the greenhouse effect. Knowledge of the state of the SPF allows one to have a real picture of the spatial distribution of the carbon sinks and sources on the Earth's surface.

As is well known, among the types of remote sensing techniques, microwave radiometry proves effective for observations of SPF environmental parameters. However, these observations are a function of different environmental conditions mainly depending on the SPF type. That is why it is necessary to develop data processing methods for microwave monitoring that allow the reconstruction of the SPF characteristics with consideration of the vegetation types and that provide the possibility of synthesizing their spatial distribution.

The problem of microwave remote sensing of the vegetation cover requires the study of the attenuation of electromagnetic waves (EMW) within the vegetation layer. The solution of the problems arising here is made possible

by the combination of experimental and theoretical studies. The vegetation cover commonly is characterized by varied geometry and additional parameters. Therefore, a knowledge of the radiative characteristics of the SPF as functions of time and spatial coordinates can be acquired by means of a combination of on-site measurements and models. General aspects of such an approach have been considered by many authors. But these investigations were mainly restricted to the investigation of models describing the dependence of the vegetation medium on environmental properties, as well as the correlation between the morphological and biometrical properties of the vegetation and its radiative characteristics.

One prospective approach to the solution of the problems arising here is GIMS-technology (GIMS=GIS+Model). A combination of an environmental acquisition system, a model of the functioning of the typical geoecosystem, a computer cartography system, and a means of artificial intelligence will result in the creation of a geoinformation monitoring system for the typical natural element that is capable of solving many tasks arising in the microwave radiometry of the global vegetation cover. The GIMS-based approach, in the framework of the EMW attenuation by the vegetation canopies, allows the synthesis of a knowledge base that establishes the relationships between the experiments, algorithms and models. The links between these areas have an adaptive character giving an optimal strategy for experimental design and model structure. The goal of this report is to explain and assess the application of the GIMS method to the tasks of reconstructing the spatial and temporal distribution of the SPF radiative characteristics.

The objective of this report is threefold: 1) To present a working methodology for the combined use of modeling technology and microwave remote sensing measurements in the assessment of attenuation of electromagnetic waves by the vegetation cover; 2) To illustrate this methodology with computer calculations of the attenuation for various soil-plant formations; 3) To give a perspective of the developed methodology applied to the study of global environmental change, including the radiative forcing problem.

6366-42, Poster Session

Derivation of maps from remotely sensed and topographic data sources

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We consider multi-date SPOT X band data of Durian Tungal minor catchment of Malaysia to map surficial features. These mapped features are delineated by employing visual techniques and certain semi-automated transformations. Besides this exercise, stream network is traced from surveyed topographic map, and is considered to generate a possible flood zone map by performing simple multiscale morphological closing transformation. These two step-study provides an insight to understand the land use/cover features that fall under various flood zones, which further provides an understanding on prioritization aspects.

6366-43, Poster Session

Total variation of image restoration based on inverse diffusion

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In the method of total variation image restoration, the regulation term can de-noise and preserve the edge in some sense. But from point of view of the diffusion filters, the regulation is only a common no-linear diffusion filter, so it will also smooth away some details and edges in the image. Furthermore it can generate the step effect. In this paper we propose to add the inverse diffusion in the regulation term of the total variation function. Compare to the general method of total variation, our regulation term can switch the diffusion process from a forward to a inverse mode according to a given set of criteria. To avoid the effect of an explosive in stability, we diminish the value of the inverse diffusion coefficient at high gradients. In this way, after the singularity exceeds a certain gradient it does not continue to affect the process any longer. So it not only can preserve the edge, but also can better enhance the detail in the process of deconvolution. At the same time, the inverse diffusion term associates with the forward diffusion term can very well prevent the oscillation and instability in the iteration of the deconvolution.

6366-45, Poster Session

Hybrid control and acquisition system for remote sensing systems for environmental monitoring

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In this paper we describe the architecture and the performances of a hybrid acquisition system prototype we implemented in Napoli for remote sensing applications, which allow the fusion of multi-source data produced by environmental noise sources. In particular, we discuss how the system is able to integrate geographically distributed sensors for seismic, electromagnetic, acoustic, etc. noises, sampled at different frequencies, too. This system is an improvement of the environmental monitoring system developed by our group for interferometers for gravitational wave detection. In this paper we discuss the system, together with its characteristics and performances in connection with its application for the implementation of a geographically distributed monitoring system.

6366-46, Poster Session

Effects of radiometric normalization of multitemporal Landsat TM data on mapping environmental change and land reclamation

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Landsat TM multi-temporal data have effectively and consistently been used to monitor environmental land cover change. Generally, multi-date satellite observations provide an effective alternative of extensive and repetitive coverage over large areas in comparison to field observations. However, the use of multiple Landsat TM scenes requires a certain degree of radiometric normalization to generate consistency and reliability for accurate change maps. The primary objectives of this research are to compare two radiometric normalization methods with respect to mapping, monitoring environmental change and land degradation due to industrial mining activities. The first methodology uses invariant bright and dark target areas for generating a set of linear regression statistics to perform the radiometric normalization. The second approach uses the Theil-Sen regression to generate similar statistics between scenes from multiple dates. This method in particular is insensitive to ~29% outliers and be applied with a minimal sample size.

Our study area, the city of Sudbury (Ontario, Canada) and its vicinity, had undergone ecological changes due to the mining activities in the region over the last 100 years. Serious impacts have affected the vegetation and forest cover, airborne pollution from the mines, and acid generating mine tailings. An aggressive program of land cover restoration was initiated during early 1970s. The program goals were concentrated in re-vegetating large segments of the seriously affected parts and enhancing the vegetation cover. The preliminary results indicate that change maps generated using the Theil-Sen method are more accurate and in reasonable agreement with our field measurements in comparison to the maps generated using the bright and dark target method. Change maps indicate that as the soil and atmospheric conditions improved, the vegetation cover showed sizable expansion for a larger number of restoration sites.

6366-47, Poster Session

Application of remote sensing technology to agricultural tri-dimension pollution control in China

Z. Qin, L. Zhang, Chinese Academy of Agricultural Sciences (China); W. Li, Umeå Univ. (Sweden); M. Gao, Nanjing Univ. (China)

Abstract: agricultural pollution has been an increasing environmental problem in China due to the rapid development of modern agricultural farming with intensive inputs of materials such as pesticide and fertilizer chemicals. The severity of agricultural pollution in China has extended into a tri-dimensional fashion in recent decades, which has threaded the sustainable development of agriculture and food safety for health. The paper analyzes the situation of current Chinese agricultural pollution problem and examines the applicability of remote sensing technology to agricultural pollution especially pollution monitoring in regional scale. Specific focuses will be given to the applications of remote sensing to

water pollution monitoring, soil contamination evaluation, crop-growing assessment and air pollution from agricultural activities. Finally we examine integration of remote sensing with geographic information system techniques for establishment of agricultural pollution management systems for spatial modeling of agricultural pollutants cycling among the spheres of farmland soil, water bodies and atmosphere and controlling the pollutant movement in the spheres. Therefore, remote sensing of agricultural pollution is a front area of academic investigation in both remote sensing and agricultural pollution, which has not been widely examined within China. It is very necessary to promote the academic investigation of this front area. This is not only the requirement of remote sensing science but also the demand of agricultural pollution control in China.

6366-48, Poster Session

Comparative research on the landscape patterns of the arid mountain ecosystem in northwestern China

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.Located in the middle section and the east section of Qilian Mountain respectively, the up reaches of Heihe river and the Shiyang river are the main body of forest landscape ecosystem of Qilian mountain. There are different landscape and vegetation distribution pattern in the two area because of the difference of local climate ,water and heat resources and social economic activities. This paper take the two border of the up reaches of of Heihe river and Shiyang river as landscape unit to compare the landscape patterns using remote sensing image , under the help of Geographic Information System. The basic landscape type maps are complied based on the landuse maps interpreted from TM images in two sections in 2000.The spatial distribution features of all the landscape components in the two areas are analyzed and compared by superposing the DEM map and the slope-facing map with landscape type maps .The correlative landscape metrics are calculated to compared heterogeneity, diversity, connectivity and fragmentation of the two sections by using the landscape structure analysis software - FRAGSTATS, including total number of paths, mean patch size , percentage of landscape types, largest patch indices, total edge density, path cohesion index, aggregation index, fractal Double-logged, shanonn-weaver diversity index, shanonn-weaver evenness index and Nearest index. The results help to describe the change character of ensemble spatial structure in Qilian mountain, demonstrate the relationship between natural arid and semi-arid mountain ecosystem structure and social economic activities, and provide a scientific reference for management of Qilianshan Natinal Nature Conservation.

6366-49, Poster Session

The topological relation model for indeterminate geographical objects based on fuzzy close-degree

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The topological relationship is uncertain because of the fuzziness of geographical objects themselves, the imprecision of the gathering, storage, modeling, analysis, application of geographical information, and the vagueness of the mankind cognition. So the topological relationship between indeterminate geographical objects should be modeled by using of fuzzy approaches. However, the existed topological relationship models for indeterminate geographical objects almost are based on enumerating approaches, and many topological predicates are defined such as 44 topological relationships of broad boundary model, 46 topological predicates of egg-yolk model. Which defectiveness of the classical approaches is just as the following two aspects: on the first aspect, to use crisp topological predicates to express the uncertain geographical phenomena is unreasonable for logic; on the other aspects, too many predicates are not coincide with the cognitive habit of mankind for spatial relationships as well as inconvenient for memory and applications. Based on these, we deem that the topological relationship for indeterminate geographical objects should be just to compute the memberships of uncertain topological relationships belonging to the basic topological relationship set, which is used by people daily. So, by adopting the approaches of fuzzy pattern recognition, we can get the resolvent of uncertain topological modeling. Where the characteristic vector and the basic pattern space are two necessary components for this method. Since the RCC5 model have a completed logic axioms system for reasoning, and the five predicates of DR, PO, PP, PPi and EQ have been used successfully in diverse application domains, we adopt them as the basic topological relationship set, denoted as Top={DR, PO, PP, PPi, EQ}. At the same time, based on the P operator (here P is the parthood relation), we design a tri-tuple to construct the characteristic vector of topological relationships as characteristic space for pattern recognition, denoted as CXY=£¯P(X,Y)£¬P(X,)£¬P(Y,X)£(c). With these, the pattern space is just as the following:

So, the topological relationship between two indeterminate geographic objects A and B can be calculated with the following three steps: ¢Å compute the characteristic vector CAB=£¯P(A, B)£¬P(A,)£¬P(B, A)£(c); ¢Æ calculate the fuzzy close-degree between the CAB and PS3¡Á3 ; ¢Ç get the memberships of the uncertain topological relationship belonging to the basic topological relationship set of Top, which just is the result. In order to test the validation of the model, we take the uncertain topological relationship representation between indeterminate forestland area and farmland area gotten from the remote sensing image as a case to have a case study, which results show that the topological relationship is reasonable and according with human cognition.

6366-50, Poster Session

Study on the shortest path algoritm in land trade sample grading method based on GIS

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In the developed areas where there are rich samples of land trading, the trading land information can reflect the conditions of location, social economy and the supply and demand of land market properly. The expressive force of the differences between land quality and relations among land locations is strong. Therefore, we can evaluate land value according to the trading samples. Compared with the multi-factors integrated grading method, the land grading method based on trading samples is simpler and more feasible. This method usually has two modes of interpolation algorithm: the spatial interpolation algorithm and the mobile trend surface interpolation algorithm. These interpolation algorithms ignore the effect of obstructions for land price. Generally, we take the distance of space as the arithmetic operators instead of the road network distance. However, in space of land price, the distribution of land price is not even because of the obstruction. It is more reasonable to use the road network distance than to use the spatial distance in land grading. In this paper, we develop the interpolation algorithm and present the shortest path algorithm. Based on the computer and GIS technologies, we discuss the key issues of dealing with the blocking feature and realizing the shortest path algorithm in land trade sample grading method. This algorithm solves the blocking feature issue. The test results show that this interpolation algorithm adopted shortest path is more reasonable than another interpolation algorithm, and prove that the land grading method based on the shortest path is feasible and practical.

6366-51, Poster Session

Research of general land use planning based on SD-MOP integrated model in Huangpi District of Wuhan City

G. Jian, Wuhan Univ. (China)

General land use planning is the sticking point of the land resource management. It is the basic measure to reasonably scheme the land resource and macroscopically regulate the national economy£¬and it plays an important role in the land resource management in our country. Owning to lacking of comprehensive study and overall planning, some serious consequences were appeared, especially the disharmonious development among in the economics and environment, the exploitation and protection of resources, population, environment and resources. It is prevented to exert the implementary effect of national general land use planning. On the other hand, the simple analytic model, which set up according to a kind of causality existed in the land use and national economics, population scale, social living, bio-environment, cannot settle the complicated problems; Moreover, the general land use planning are involved in land policy, industrial structure, capital assignment, plan-oriented management system. It is required that the general land use planning combined with some factors, such as national economics, social development, economics, social development, population scale, bio-environment.

In this paper, the author firstly generalizes the deficiency of the current technique of general land use planning in our country, and brings forward a method of general land use planning basing on the SD-MOP Integrated

Model. Secondly, the author explains the feasibility and superiority of SD-MOP integrated model in general land use planning.

The author takes Huangpi country of Wuhan city for example ,and the integrated process of the SD-MOP model ¡¢the systemic analysis¡¢the variable gather of SD model¡¢the flow chart of system¡¢the parameter estimate¡¢Valuation of SD Model in Huangpi General Land Use Planning is carefully studied.

Then the author studies the numerical-simulation of SD model and solution of MOP model in Huangpi district.In this part,history verification of SD Model¡¢analysis of sensitive degree and identification of sensitive factors¡¢the estimation of the model parameter and the identification and optimization of the sensible parameter is carefully introduced.

The paper also introduces simulative run and outcome analysis of general land use planning .In the part , original run Scheme and optimization planning scheme are detailedly compared. According to the comprehensive compare from all aspects, the optimization planning scheme are obvious advantaged than original one, which realized the harmony development of population, resources and environment as well as kept fast, sound and sustainable development of national economics. It is the optimum planning to accord with the development of social economics in Huangpi district.The planning scheme adopt the optimum route, which apply the outcome of SD-MOP Model through combining with the sustainable development of national economics, the realization of dynamic balance of total farmland amount and the social, economic and biological benefits of land use.

Finally, the author prospect application of SD-MOP Integrated Model in land use planning, which fishes out a new method for the scheme study of general land use planning.

6366-52, Poster Session

A spatio-temporal data model for dynamic monitoring land use

W. Hao, Wuhan Univ. (China)

With the development of landuse dynamic monitoring by using remote sensing technique, the cumulated amount of monitoring data will be very large. Meanwhile, the types of these data are various. It is an exigent problem how to manage and use different period landuse data and produce the landuse data effectively. In dynamic monitoring of land use, The change of land use is of interest, It has been demanded that a temporal GIS (TGIS) needs to provide functionality for spatio-temporal data storage, data handling, analysis as well as visualization. These functions are usually more complex than that of conventional GIS. the key issue is lack of a suitable spatio-temporal data model to support handling land use data. This paper proposes a compositive data model which will be used for managing and analying data of dynamic monitoring landuse.

6366-53, Poster Session

Applying GIS into the thermal resources estimation over small grids in the District of City Lasa in Tibet, China

Y. He, Y. Hou, R. Lin, China Meteorology Academy (China)

While estimating the thermal resources over small grids, in most of the works in thermal resource mapping in agro-ecological zoning activities, only the regional distributed climatic factors have been included into the interpolation functions and the non-regional distributed climatic factors have not been involved. Actually, in the rugged mountain areas, like the areas around City Lasa in Tibet plateau, the thermal resources distribution are not only determined by the regional distributed climatic and geographical factors, like longitude, attitude and altitude, but also influenced by the none regional distributed climate factors, like the aspect, slope and the characteristics of the land surface.

In this paper, the resources thermal over small grids of 0.5 by 0.5Km have been estimated by the supports of geographic information system (GIS) in the district of City Lasa in Tibet, China. Firstly, there is bout 41-year time series meteorological data has been collected from 15 typical meteorological stations which equably distributed over the whole study area, including the elements of annual and monthly average minimum and maximum temperature and rainfall. Secondly, the whole study area has been divided into several sub-regions according to the climatic characteristics and the regression equations have been set up respectively by analyzing the relationships between the thermal resources and the regional distributed climatic factors (longitude, latitude and elevation) and then the thermal resources (annual/monthly temperature) have been estimated by the regression equations related to each sub-regions respectively. After having the thermal resources estimation over the whole regions, the corrections have been applied to some of the special areas, where there are some influences on the thermal resources from the non-climatic distributed factors. With the supports of GIS by using the spatial analysis functions of overlay and the buffer techniques, the influences from the hot-spots (hot springs, cities' heat islands) and from the nearby rivers and lakes and so on have been reduced immediately. After the corrections, the accuracy of the estimated thermal resources in the mountain areas have been improved obviously and become more reasonable while comparing to the general knowledge of the thermal characteristics in this region. Furthermore, what's the most important is that, the thermal resources map generated by this method showing more details about the characteristics of the thermal resources in this region while comparing to the old ones, which only demonstrated by the thermal isolines. From here it also showed that GIS is a powerful tool for agro-ecological zoning in this region.

6366-54, Poster Session

Valuation of rangeland ecosystem degradation with remote sensing technology in China

Z. Qin, Chinese Academy of Agricultural Sciences (China); R. Wang, L. Jiang, L. Lu, Nanjing Univ. (China); W. Li, Umeå Univ. (Sweden)

Rangeland is mainly arid and semiarid ecosystems in north China. Due to heavy population pressure and overgrazing, the ecosystems are facing challenges of degradation in recent decades. Valuation of the ecosystem degradation is thus urgently required for better administration of the rangeland ecosystem for sustainable development. In the paper we develop an approach to use remote sensing technology for valuation of rangeland ecosystem degradation. Generally speaking, the valuation can be done through two aspects: direct economic loss and ecological function loss when degradation occurs to an ecosystem. This provides possibility to apply satellite multiple-channel remote sensing data to construct the required models for the valuation. Because vegetation is the most important part of rangeland ecosystem, the degradation can be indicated by the status of vegetation growth. In the study we relate NPP (net primary productivity) to the degradation because it is an important indicator of biomass pertaining to rangeland ecological degradation, which can be assessed through the services provided by the ecosystem for mankind, such as gaseous adjustment, nutriment circulation, contaminant purification, CO2 absorption and tourism. The NPP can be estimated from remote sensing data. We establish a valuation model to assess the services of the rangeland ecosystem through the approach of NPP computed from MODIS remote sensing data. Finally we apply the model to the rangeland in north China for valuation of the arid and semiarid ecosystems. Our preliminary results show that the GDP growth in the rangeland region is obvious less than the degradation value of the ecosystems in recent years. Spatial variation of the degradation values is also examined in the region. Some policy suggestions have also been formulated for the rangeland administration to improve the ecosystem functioning in the region.

6366-56, Poster Session

Comparison of LAI derived from SPOT-VEG data with MODIS LAI products in arid and semi-arid northwestern China

H. Peng, H. Li, X. Li, Cold and Arid Regions Environmental and Engineering Research Institute (China)

Leaf area index (LAI) is a critical vegetation parameter for the studies of ecology, hydrology and climatology. The MODIS LAI products were lack of validation in China, especially in arid and semi-arid Northwestern China. In this paper, we compared the LAI derived using empirical method from SPOT-VEG data with MODIS LAI products in arid and semi-arid Northwestern China. The study area was the Heihe River basin that has a large-scale area and diverse vegetation types. There were 7 types of vegetation to be mapping LAI using the methodology. They were irrigated, dry, forest, shrub, dense grass, moderate-dense grass and alkaline lands. The LAI was derived for the different type vegetation using SVI-LAI

empirical method from SPOT-VGT and landuse data. The parameters of vegetations were derived based on the study area and vegetation types by their own histograms. The MODIS LAI was from global 1km LAI products. The two LAI datasets were validated using field LAI of the year of 2002 and compared with each other. The results suggested that the LAI derived from SPOT-VGT and landuse data using empirical method was better than that of MODIS. The possible reasons are that: (1) the landuse data used with big scale was derived from TM images of the year of 2000, which was better realistic than MODIS six classifications about the land surface vegetation distribution; (2) the parameters used in equations were derived based on the vegetation types in their own region, not based on the literature.

6366-57, Poster Session

Using BRDF model to derive LAI in arid and semi-arid northwestern China

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Leaf area index (LAI) is a critical vegetation parameter for the global and regional scale studies of the climatic and environmental change. There are many LAI data sets at global scale, and most of them are based on biomes. In those datasets that based on plant functional types (PFTs), e.g., community land model (CLM), the vegetation types are coarse to be applied to China regional study. Vegetation is represented as patches of PFTs, the leaf physiology and carbon allocation is measurable and the PFTs can be a directly linkage of climate and ecosystem models to simulate the environmental changes. In this paper, LAI is deduced based on PFTs, and the vegetation types are more than CLM. There are many methods can be used to estimate LAI. Here an approach that can estimate LAI based on different PFTs in absence of LAI measurements is chosen since we have large-scale region with diverse vegetation types. This approach, developed by Qi et al. (2000), combines the advantages of empirical and modeling approaches and circumvents their limitations. This approach includes three steps: the first step is model inversion, using BRDF model to produce LAI with pixels chose stochastically in one vegetation type region; the second step is quality control, removing the outliers; the final step is LAI mapping, using the LAI from second step and satellite data NDVI to fit equation, and then selecting the best equation and applying to the whole vegetation type region to mapping spatial LAI distribution. The results derived using above approach compared with measurements if the measurements are available, otherwise compared with MODIS LAI. The results suggest that this method is feasible in arid and semi-arid northwestern China based on different vegetation types, and the LAI dynamics for PFTs shows the expected temporal and spatial variation. The results are very promising for modeling studies in China region.

6366-58, Poster Session

POS supported sparse bundle adjustment and its application

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In this paper, a mathematic model for POS based bundle adjustment is introduced. The model is made up of four types of linearized observation equations. The intention of the POS based bundle adjustment is to minimizing the error between the four types of observed value and it's model value. The Levenberg-Marquardt algorithm has been proven to be the most successful method to achieved this purpose. Our work is supported by China 863 program titled 'airborne multiangular imaging technique in power line inspection'. The purpose of this program is to monitor the distances between the power lines and the objects beneath them with accuracy as high as 0.5 meters. A number of high-resolution images must be captured along the power lines to ensure the accuracy. Based on an automatic matching method proposed by other team members in this program, hundreds of homonymous points can be extracted in one image. About 40 to 50 images are used in one block adjustment. As a result, large number of unknowns will contribute to the minimized error, and numerous equations should be solved. So, the minimization algorithm must incur the high computational costs in the problem. Fortunately, the normal equations reconstructed from the observation equations above exhibiting a sparse block structure. Considering the sparse characteristic of the normal equation, we propose a sparse bundle adjustment method based on Levenberg-Marquardt algorithm to save the computation cost.

A software package is developed based on this algorithm. A comprehension test was performed to investigate the performance of the algorithm. We used a data set provided by a field experiment in Wuhan, China. It is found that our algorithm showed both high accuracy and high efficiency in the test.

6366-60, Poster Session

Study on dynamic change of land desertification in the source region of the Yellow River, Qinghai Plateau by remote sensing and GIS: a case study of Maduo County

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The land desertification is one of the major environmental problems in the Source Region of the Yellow River, southern -Qinghai Plateau. Maduo county was selected as the study area, because its land dersertification is the most serious in the region. The objectives of this study was to monitor and analyze the dynamic changes of land desertification and investigate the desertified land types and desertified level from 1986 to 2000 based on remotely sensed data and Geographic Information System (GIS). According to the surface landscape indices, the desertified land had been divided into light level, moderate level, severe level and heavily level, and the sandy land had been divided into four types, such as shifting sandy land, semi-shifting sandy land, semi-fixed sandy land and fixed sandy land corresponding. The data of sandy land in these two dates had been interpreted and derived by visually interpreting TM images in 1986 and 2000, respectively. The data of dynamic changes of reversing from sandy land and desertified land had been obtained by overlaying databases in these two periods. The study results show that the areas of deserified land increased by 18147.55 hm2 during 14 years in Maduo County, and is mainly from the desertification of middle overlay grassland. The desertified area of middle overlay grassland accounts for 76.80% of newly desertified land. The desertified areas of high and low overlay grassland cover 6.35% and 3.95% in newly desertified land, respectively. The newly desertified land types were mainly severe desertified land grades, and it covers 85.38% of desertified land.

6366-61, Poster Session

Land and water resource management through remote sensing and GIS for Thoothukudi Taluk of Tamil Nadu, India

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Land and water resource are the most important sources for any living organisms in the world. Resources depletion is the common practice in developing countries because of their poor awareness and knowledge about the resources and its importance. The study area has very good resource potentials earlier. The study area of Thoothukudi taluk occupies Middle Eastern sector of Thoothukudi district in Tamil Nadu, stretching over an area of 327.35 sq.km. It consists of 25 panchayat villages and one town. Thoothukudi taluk is covered by 8 * 40'N to 8 * 51'N latitudes and 77 * 56'E to 78 * 12'E longitudes. The study carried out an analysis of geomorphic characteristics with the support of other parameters like geology, soil, slope, and watershed, water quality status and land use / land cover through satellite data in the platform of Geographic Information System (GIS) by table criterion analysis method. Based on the thematic layers of the resource status is estimated that there are five different levels of land and water resource within the study area, such as excellent, good, moderate, poor and very poor. The results show that the available status of resources and its spatial distribution is limited. Nearly 50% of the geographical area has good to moderate resources. Moderate to poor land and water resource areas need to be reclemated to restore and improve its resource status. Scientific approaches for resource management planning have been suggested.

6366-63, Poster Session

Mono-window algorithm for derivation of land surface net long-wave radiation in mountainous area

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Land surface temperature and net radiation are two important energy terms in the land surface energy balance. Over the rugged terrain in the mountainous region, however, routine measurements or remote sensing based inversion techniques, which are widely used for obtaining these

two energy terms to relative flat area, are not effective usually either owning to the maintaining difficulties for routine measurements or due to the lack of applicable algorithms for precise reversion with remotely sensed data. The proposed algorithm for retrieval of surface net radiation in this study was constructed in two parts. First of all, net short wave radiation was computed with an improved algorithm for atmospheric correction based on dark object scheme associated with an introduction of a DEM to account for the topographic affect on radiant transformations, and then an approach for accurate retrieval of net long wave radiation by using surface temperature derived with extended mono-window algorithm to integrate with surface energy balance equations in association with mountainous thermal radiant transfer model was established. Pixel based surface net radiation can thus be calculated with above mentioned two terms by introducing the component of the thermal radiation from surrounding land surface based on the thermal radiation transfer model. Atmospheric downward long wave radiation was calculated by means of an empirical formula related to surface temperature. An evident advantage of this model is that only two atmospheric parameters, i.e. atmospheric mean effective temperature and surface temperature, are needed.

The proposed approach was experimentally applied to a mountainous region located in the Hanjiang Basin, China. 6S code was utilized to simulate the surface and atmospheric radiative parameters under different geographic zones at selected climatic conditions to examine the performance of the proposed algorithm. It was suggested that the maximum error in albedo derivation by the proposed algorithm is about 17% with mean error less than 10%, the maximum error in retrieved short wave net radiation and long wave net radiation is about 15% and 12% with mean error about 11% and 9% respectively.

6366-64, Poster Session

Remote sensing based on the coupled Ginzburg-Landau chains dynamics

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A new type of remote sensing has been proposed. Coupled Ginzburg-Landau chains dynamics interacting with medium having random fluctuations has been numerically studied. The results of the analysis have demonstrated that parameters of any dynamical system with many degrees of freedom (physical, chemical, biological, geophysical) can be distantly studied through arranging in a body of a sensor an interactive dynamical process between the Ginzburg-Landau coupled chains and a medium with random fluctuations similar to the medium under study. An experimental receiver has been developed in a form of a physical analog of coupled chains of the Van der Pol equations realized by nonlinearly coupled long electrical lines. The receiver and a generator based on this principle were used for for a distant communication through the sea water electrolyte medium. Accounting the specific properties of the recurrence waves formed in the physical analog of coupled Ginzburg-Landau chains to interact with medium fluctuations, a new type of remote sensing can be elaborated and used for a distant analysis of different media by studying parameters of their fluctuations.

6366-65, Poster Session

A evapotranspiration (ET) model based GIS using LANDSAT data and MODIS data with improved resolution

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In this work, we integrate a popular remote sensing technique with ArcGIS to build a ArcMap tool bar, named rGIS-ET, for estimating regional evapotranspiration (ET) from Landsat data and Modis data with with improved resolution. The development of rGIS-ET enables quick processing of large amount of remote sensing and other spatial data. It also provides user-friendly interfaces for modeling, output display and result analyses. We use daily ET measurements from a weighting lysimeter in our experimental station to verify the performance of rGIS-ET. We develop algorithms for estimating surface temperatures and albedo of winter wheat and summer maize field from MODIS data at 250-m spatial resolution during different seasons. Both surface temperatures and albedo are key parameters for calculating ET using Surface Energy Balance Algorithm. The verification confirms the reliability of ET calculation, whose errors during crop growing season are less than 10 %. We apply rGIS-ET to eight plain counties of Shijiazhuang city, a typical agricultural region in North China Plain, to demonstrate its utility for calculating regional ET and evaluating agriculture water resource usage.

6366-66, Poster Session

Research on land degradation in arid and semi-arid region

C. Lv, China Land Surveying and Planning Institute (China)

This article analyzed land degradation in Hebei province of China located in arid and semi-arid region. TM images of 1991 and 2001 were used to describe the general vegetation conditions of the area, and land use surveying data from the ministry of land and resources, P.R.C were used to complement information. Based on GIS and statistic methods, land degradation index and reconstruction index were used to study land degradation and reconstruction processes in the study area. The results showed that degradation of land had been increasing from time to time in the study area, such as desertification, land salinity, degradation of grass, deforestation, wetland loss and so on. The area of sandy land increased, mainly due to arable land degradation, grazing, and deforestation. Wetland lost, accounting for 30.64% of the total area of degraded land, because some beach was reclaimed, and house and factory increased. The area of grass land and forest land decreased. On the other land, eco-environment reconstruction was paid more attention to. Grain-for-Green project was carried out, eco-environment improved in some degree. At last, according to the land resources degradation process, natural resources and social economical condition in the region, some advice was given to construct eco-environment in Hebei province.

6366-67, Poster Session

Remote sensing of plants by the LIF method at nitrogen pollution of ground

N. L. Fateyeva, A. V. Klimkin, Institute of Atmospheric Optics (Russia); O. V. Bender, M. S. Yamburov, Institute for Monitoring of Climatic and Ecological Systems (Russia)

The investigations presented in this work are aimed at detection of LIF peculiarities of the cedar pine and the warty birch at different concentrations of nitric acid derivatives (nitrogenated substances). Researches included remote sensing and the analysis of experimental and control plants. The LIF signals are measured in bands λ =685 and 740 nm, pigments concentrations in needles and leaves, and also nitrogen in ground. Various reactions of plants on nitrogen surplus in ground are demonstrated.

6366-68, Poster Session

A new initiative of research and applications: cloud-prone and rainy areas remote sensing (CARRS)

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In this paper a new initiative named “Cloud-prone and Rainy-area Remote Sensing” (CARRS) was presented. The main objective of the CARRS is to formulate a framework under which a series of theoretical and applied researches can be carried out for observing, monitoring, and modeling world cloudy and rainy areas through advanced remote sensing technology. The heritage of the CARRS initiative roots from the great advancements achieved by the various global change programs conducted since the 1990s (e.g. the Earth Radiation Budget Project, the International Satellite Climatology Program, The Global Precipitation Program, Global Energy and Water Cycle experiment). Although significant progresses have been made through these projects and using remote sensing data to quantify physical and biophysical processes and to characterize atmospheric, terrestrial and marine ecosystems, such progress is still lagging behind for regions with frequent cloud cover, haze, and/or precipitation. It is within this context that the CARRS program was initiated aiming at advancing our understanding on the roles that this region plays as a unique and important component of the Earth system. Some of our recent research and applications using multi-source remote sensing data in cloudy and rainy regions of South China are presented.

6366-70, Poster Session

The use of remote sensing and GIS for monitoring the Algerian steppe degradation risk

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We present a study of steppe pilot area located in the Aflou region, which is known for its ancestral pastoral activity. This area is now confronted with land degradation problems that may impinge the future of this important economic activity. In view of the complexity of the region and of the problem to address, we designed a methodology based on powerful tools such as GIS and remote sensing.

We produced a land use map which includes a characterization of the various grazing paths of the region, based on an analysis of Landsat imagery, as well as of land cover maps and change maps spanning a 19 years period (1976-1995), which were obtained from Landsat TM and MSS imagery.

We integrated the results and other data relevant to the study area in a GIS, as a starting point for our SIG-STEPPE application for grass resources management. The application is conceived based on the principle of double-prototyping method. Within the application we have designed a functionality that allow producing a map of grazing path degradation at the commune level. In this case, we combined physical data (such as surface and condition of grazing paths) and socio-economic data (number of herds per commune) to compute a “carrying capacity index”. This index, which is expressed as the ratio between the number of heads and the surface of corresponding grazing paths, is believed to be the best way to estimate grazing pressure on the grazing paths.

6366-71, Poster Session

Application of large-scale geological hazard survey with remote sensing technology

Y. He, China Land Surveying and Planning Institute (China); Z. Zhang, China Aero Geophysical Survey & Remote Sensing Ctr. for Land and Resources (China)

The geological survey was used to a common method before, in which the representation form of the survey results also was very old, especially aspects of location distributing, growth dimensions for hazard bodies, etc. It is thought a lack of veracity in work. This paper, by the geological hazards survey in Fengjie-Badong sect (case study) regarded as an example, illuminates to be capable of rightly drawing the size and position of hazard bodies with application of satellite remote sensing technology and assistant aerial images. It will most important for externally showing the status of geological hazard growth and for truly expressing the disserving of the whole Sanxia immigrant project caused by geological hazard. This remote sensing application has established foundation for carrying through geological hazard survey in the whole Sanxia reservoir areas.

6366-72, Poster Session

Integrated remote sensing and GIS approach for delineating ground water potential zonee in GIRI catchment: Uttaranchal Pradesh, India

O. K. Dissanayake, Univ. of Moratuwa (Sri Lanka)

Abstract. Remote Sensing and integrated GIS technique is a cost-effective technique in natural resources management and is widely used in the field of hydrology and water resources management and development. One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation.

Groundwater is a precious resource of limited extent. In order to ensure a judicious use of groundwater, proper evaluation is required. Integrated remote sensing and GIS can provide the appropriate platform for convergent analysis of diverse data sets for decision making in groundwater management and planning. In this study, weighted index overlay method has been used to delineate groundwater potential zones in the Giri catchment ,Himachal Pradesh, India and identified the suitable sites for human consumption.

Based on final hydrogeomophological map about 3.6 % area representing valley field deposits offers very good groundwater potential. Dissected hills of Sandstone, limestone, metamorphic and granitic rock distributed through out remaining area, depicted moderate(33.92%), low(52.25%) and very low(3.2%) groundwater potential respectively. Where as highly fractured areas show high ground water potential(7%).Water analysis results indicated very high hardness (\> 300mg/l) in most areas of the region but it is in the permissible limit (<600mg/l) .In some areas iron (Fe) content is exceeded the permissible limit (0.3mg/l) and not suitable for human consumption.

6366-75, Poster Session

Monitoring grassland ecosystem degradation using EOS/MODIS data in north China

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Abstract: Several sandstorms invading the capital of China in recent years cause many concerns to the issues of ecosystem degradation in arid and semiarid grassland region of north China. Actually the degradation can be viewed as the decrease of primary productivity in the grassland. This provides the possibility to monitoring the degradation using satellite remote sensing technology. In the study we present our experiences in conducting the monitoring of grassland ecosystem degradation in north China. Using the EOS/MODIS data, we develop an applicable method for the monitoring on the basis of net primary productivity (NPP). Since productivity is the most important for grassland ecosystem, the monitoring of ecosystem degradation can be based on NPP retrieved from EOS/MODIS data. The approach has been extensively employed in environment studies. We develop a method for the monitoring through NPP using MODIS data. We assume that there is always a turf without degradation in the area of the same hydrothermal condition and type of grassland. We then use the NPP of the turf to determine the level of degradation in this area. The grassland region in north China can be divided into a number of small sub-regions for the determination and the division of sub-regions can be done according to the types of grassland. If the area of some sub-regions is too big, we can split it two smaller sub-regions so as to make the sub-regions having the similar hydrothermal condition. As far as every sub-region is concerned, we take the max NPP as the base line to determine the degradation of other pixels in the sub-region. The degradation can be graded into five levels: high degradation, moderate degradation, normal, moderate improvement and high improvement. Finally we apply the method to analyze the spatial characteristics of grassland degradation in north China in the year 2005. The results show that spatial variation of grassland ecosystem degradation is very obvious in north China.

6366-76, Poster Session

Development of the global cloud free data set of MODIS

O. Yoshinari, T. Shoji, S. Yuzo, Hiroshima Institute of Technology (Japan)

With the objective of developing accurate global basic data and to find the effects of difference of observation time, an attempt is made to generate reliable global cloud free data set of Terra and Aqua MODIS utilizing personal computers. Out of 36 bands seven bands (Band 1 through 7) with similar spectral features to those of Landsat-7 ETM+ are selected. These bands cover the most important spectra to derive land cover features. The procedure of the data set generation is as follows. (1) Download the global Terra and Aqua MODIS daytime data of 500 meter resolution (MOD02 HKM HDF Data: Level-1B Calibrated Geolocation Data Set) from NASA web site. (2) Separate the data into several BSQ (Band SeQuential) image and several text (geolocation information of pixels) files. (3) The geolocation information is given to the pixels of several kms interval. Based on the information, resampling of the data are made at 1/2 degrees intervals of latitude and longitude, thus the resampled pixels are distributed in the latitude and longitudinal axis plane at 1/2 degrees intervals. (4) A global data for one day is composed. (5) Compute NDVI for each pixel. (6) Compare the value of NDVI of successive days and keep the larger NDVI. At the same time keep the values of each band of the day of the larger NDVI. Repeating this process for a few or several weeks then the global cloud free data set of the respective season (or month) is completed. It is interesting to notice that the digital values of Nov. 2005 indicates that the value of Aqua MODIS is a little larger than those of Terra MODIS while the value of the difference is negligible in case of NDVI.

Conference 6366: Remote Sensing for Environmental Monitoring, GIS Applications, and Geology VI

6366-78, Poster Session

Applied research of wavelet transform fusion

Y. He, China Land Surveying and Planning Institute (China)

Image fusion is a very useful technique of obtaining high-resolution multi-spectral images from low spatial resolution multi-spectral and high-resolution panchromatic images. Nowadays many fusion techniques are available. However, those conventional fusion techniques existed also some shortcomings, which could not keep balance for preserving spectral information very well in a fused image with high-resolution spatial information. Hence, in this research a recent and efficient technique of fusion based on wavelet transformation was applied. The results presented the wavelet transform method is proved to be the best option for visual appreciation, preserving most 93% of the spectral information content, and as well improving the interpretability of low-resolution multi-spectral image classification. Meanwhile the results also further show the application potentiality of fusion technique based on wavelet transform for improving urban land classes in urban fringe.

6366-21, Session 6

Environmental changes induced by dump pollution analyzed through historical orthophotos and multispectral images

C. Notarnicola, Istituto Nazionale di Fisica Nucleare (Italy)

The presence of dumps in a landscape represents a critical element for the environmental safety due to their risk for human health and then their difficult social acceptability.

An important use of satellite imagery is to provide information on land surface properties for monitoring polluted areas. Low and medium resolution sensors can give an overview of the territory, putting in evidence large and strong pollution phenomena. Satellites with on board high resolution sensors, such as Ikonos and Quickbird, allow the detection of small degraded areas such as dumps if an appropriate approach is used.

For dumps that have been on the territory for decades, it is important to monitor the environmental changes produces by its presence.

To this purpose a set of historical orthophotos along with multi-spectral images has been analyzed:

- Orthophoto acquired in1953 previous to dump settledown;
- Orthophoto acquired in 1973 at the beginning of the dump activity;
- Orthophoto acquired in 1986 during the full dump activity;
- Orthophoto acquired in 2002 at the end of dump activity;
- Landsat image acquired in 2000 at the end of dump activity;
- Aster image acquired in 2001 at the end of dump activity.

All the orthophotos have been coregistered considered the multi-spectral images as base images. Subsequently a radiometric correction has been applied to orthophotos.

Threee different kind of analysis have been carried out on the orthophotos and images:

- change detection analysis to individuate the major changes of the area during the last 50 years;

- texture analysis in order to find a characteristic feature that makes dumps distinguishible from agricultural fields;

- thermal analysis carried out at the end of the dump activities to detect the thermal anomalies due to the material degradations.

In the first step, major cover classes are individuated with the help of hystorical and actual photos, and then an object-oriented classification is carried out in order to extract the classes and detect the relative changes.Within anthropogenic landscape, long-term changes are the results of changes in the landscape structure, land management practise and ecosystem processes. For this reason, the changes detected through the images classification have been analyzed and integrated with land management data obtained from interviews to local land managers.

In the second step, landscape metrics, as measures of spatial structures used to describe agricultural area features, are proposed as quantitative analysis. Some spatial indices, such as Shannon's diversity index (SHDI) ad contiguity index, have been found suitable to distinguish the characteristic texture of a dump from that of other fields.

For temperature anomaly determination some limiting factors should be taken into account due to the difficulty of calculating land surface temperature and the pixel size that is big enough and include contributions derived from surrounding fields. For further work, some airborne hyperspectral data will be considered for the thermal anomaly detection.

6366-23, Session 6

Using LIF method of plants for remote sensing of nitrogen and oil pollution

N. L. Fateyeva, G. G. Matvienko, Institute of Atmospheric Optics (Russia)

The investigations presented in this work are aimed at detection of LIF peculiarities of the cedar pine (Pinus sibirica Du Tour) and the warty birch (Betula pendula Roth.) at different concentrations of nitric acid derivatives (nitrogenated substances). In the work primary optical indications and time spans of visual signs occurrence at organic contamination surplus are also determined and presented. Nature experiments using LIF chlorophyll have been carried out, the results are presented. Along with remote methods of control, analysis of pigment content in the experimental specimens has been carried out.

6366-24, Session 6

Using remote sensing and GIS to integrate various environmental factors into malaria studies

R. Ngom, A. Siegmund, Pädagogische Hochschule Heidelberg (Germany)

The importance of Remote Sensing and GIS into malaria studies has been widely demonstrated. Most of the studies that integrate remote sensing are analysing the link between environmental factors and potential mosquito's nidus presence, but focusing only on some few ecological variables. Therefore the complexity and biological dynamism of malaria transmission lead to the integration of multiple remote sensing based environmental variables into a model for a rural area in Burkina Faso.

From based topographical variables of the SRTM to the NDVI as well as land cover information, a set of multi-thematic and multi-temporal variables covering the whole study area of the Kossi Province in Burkina-Faso have been processed. All these data are integrated into a GIS, layered with other ground data sources of climate and epidemiological origin.

Since there are only four villages' points into the Kossi province where data of epidemiological relevance have been measured, the general challenge is to use the derived satellites environmental variables as malaria transmission risks predictors into the whole study area. Another challenge is to avoid predictors' redundancy, which means taking into account the interaction factors effects of all the environmental variables. The last challenge is to deal with spatial autocorrelation since the work is based at a high geographical resolution.

For these purposes the intelligence between Remote Sensing and GIS tools is of a focal utility. The first one is acting as the privileged data sources for predictive purposes, while the second one is managing the spatial and geostatistical side of the study.

6366-25, Session 7

Extraction of vegetation cover rate in urban areas by mixel analyses of Landsat data

S. Takeuchi, Hiroshima Institute of Technology (Japan)

This study aims to establish a practical image analysis method for the use of middle-scale resolution images like Landsat as the complementary data sources of higher resolution images like IKONOS for the purpose of environmental monitoring of wide-range areas. For this purpose, an image analysis based on mixel analyses is tested as one of the effective approaches. As the information target, vegetation cover rate (VCR) in urban areas is selected because it is one of the important environmental factors to affect urban environment like heat island.

In order to realize easy and efficient computation for estimating the mixture rate of vegetation categories, the linear mixture model using two main categories, vegetation and non-vegetation, is employed combined with the least square estimation of multi-regressive coefficients for vegetation cover rate (VCR) and non-vegetation cover rate (non-VCR) with six bands data of Landsat TM/ETM+ data. In addition, two sub-categories for both of vegetation and non-vegetation categories are introduced to specify representative pixel values as correct as possible, that is, trees and grasses for vegetation, and buildings and bare-soils for non-vegetation respectively, and their optimal mixture rates are estimated as well as the

mixture rate of vegetation and non-vegetation categories. For this purpose, an iterative procedure is employed, in which each mixture rate of two sub- categories for vegetation and non-vegetation are varied by ten percent steps and the least square estimation is applied with all combinations of mixture rates of sub-categories for vegetation and non-vegetation.

The experiments for VCR extraction were conducted with the test area of Hiroshima-city and with Landsat TM or ETM+ data acquired in three different dates (08/15/00, 05/23/02, and 04/10/03). First, the proposed method was tested at eight test urban spots with three different data and with the ground survey of them. Then the VCR distribution map of Hiroshima urban areas was created. The experimental results showed fairly stable VCR conditions among three different observation dates in the terms of spatial distribution of VCRs and average VCR values. The average VCR values in Hiroshima urban areas were almost same and around twenty percents in three different observation dates. These results suggest that it is possible to compare the VCR conditions among different cities, and also to extract the yearly changes of VCR conditions. At the conference, some additional results of change detection and inter-city comparison of VCR conditions will be presented.

6366-26, Session 7

A modified change vector analysis of vegetation change detection for urban areas

H. Yu, Y. Jia, Wuhan Univ. (China)

This study sought to develop a modified change vector analysis(CVA) using normalized multi-temporal data from Landsat TM to detect urban vegetation change. Because of complicated change in urban areas, modified CVA application based on classification and mask techniques can minify the effect of non-vegetation changes and improve upon efficiency to a great extent. Moreover, drawing from methods in Polar plots, the extended CVA technique measures absolute angular changes and total magnitude of perpendicular vegetation index (PVI) and two of Tasseled Cap indices (greenness and wetness). Polar plots summarized change vectors to quantify and visualize both magnitude and direction of change, and magnitude is used to determine change pixels through threshold segmentation while direction is used as pixel's feature for classifying change pixels through supervised classification. Then this application is performed with Landsat ETM+ imageries of Wuhan in 2002 and 2005, and assessed by error matrix, which finds that it could detect change pixels 90.56% correct, and could classify change pixels 81% correct in six change classes through performing supervised classification with direction angles. The technique demonstrates the ability of change vectors in multiple biophysical dimensions to vegetation change detection, and can trends as an efficient alternative to urban vegetation change detection and classification.

6366-27, Session 7

A GIS-based hedonic modeling of urban land value spatio-temporal patterns

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Land value changes are the results of complex social, economic, human and physical driving forces interactions acting over temporal and spatial scales.¡£Compared to other economic goods£¬land has special characteristics: the supply and location of land are fixed, and the externality which means that use of a parcel of land affects the use and value of surrounding parcels and often gives rise to government intervention. The special characteristics, the externalities, and intervention make an analysis of the land market rather complicated.

Hedonic model characterize the pricing of bundles of attributes and the demand and supply of these attributes under different assumptions about market structure, preferences, and technology. The research objective is to use the GIS-based hedonic regression model to identify the attribute factors affecting the spatial distribution pattern of land value. If there are relationships between the values of land parcels and a factor, we will try to investigate and reveal how and to what extent they are related.

This paper begins with a brief literature review concerning hedonic land value modeling, following which is a section illustrating research objective and study area. In the next section basic data collection and preparation are introduced and research methods and steps, including variable measurement and modeling process are stated thoroughly in the fourth section. Then analyze and discuss the results of modeling in the fifth section. The paper ends with conclusion and discussion about the limitation of the research and future research issues.

6366-28, Session 7

GIS and remote sensing for 3D urban modeling by means of VRML technology

U. Michel, Univ. Osnabrück (Germany); T. Bockmühl, Die Univ. der Bundeswehr München (Germany)

A 3D representation of a city embedded in an internet environment is not a new technology. It is already used in many projects which presenting tourist information. But 3D modelling assumes a lot of manual operations and are still not fully operational to handle. Even if there exist special software (e.g. CyberCity) nowadays, that support the generation of 3D sceneries. The emphasis of this paper is to present a method for improving the automation of 3D VRML sceneries by using simple and adapted procedures which were implemented in a GIS environment. Our goal was to create a backdrop which is easily modifiable and replaceable. Especially within a city we find areas (e.g. shop windows), whose appearance changes continuously. Their representations can be replaced by simple work steps in the 3D workflow. A 3D environment is based on a pool of different data e.g. cadastral maps, floor plans, and aerial images, which should have a minimum resolution of 50 cm, to guarantee the recognition of all important items. The cadastral maps should be controlled by using current aerial images to eliminate errors. More complex buildings are assembled from several simplified building sections. Subsequently an automated modelling takes place, after adding a few parameters (building height, roof form, etc.).

For a realistic natural representation, the texturizing was assisted by using digital photographs of the building face side. The whole VRML-scene is modular. Each wall was generated as an individual VRML-file and turned and shifted into the suitable position. Every single wall can be addressed individual, which facilitates the adjustment of the textures enormously. In those way small changes of the buildings could be easily maintained, without generating the whole VRML-scene again.

Finally the modular city file was loaded into a main file with optional additives such as trees, view-points etc. Also this additional information could be generated likewise automatically.

For orientation purposes a general map was integrated, in which the position and line of sight of the user is indicated by an arrow.

In conclusion it can be stated that the proposed method and its implementation have been proved to be a very valuable and reliable method for automated 3D urban modelling.

6366-29, Session 7

Spatial pattern of settled dust in different urban dwellings

A. Chudnovsky, E. Ben-Dor, Tel-Aviv Univ. (Israel)

Attention has been directed to dust exposure by inhalation (dust suspended in the air) whereas settled (or sediment) dust-oriented research for occupied houses is rare. In 45 buildings within Tel-Aviv city settled dust measurements were performed on glass traps during April, 2005 in two rooms in each building: living and bedroom. The influence of total mass loaded and the sensitivity of spectral measurements were tested. A multivariate data analysis based on Partial Least Squares (PLS) regression was run on the manipulated spectra. For this purpose, the relationship between spectroscopic measurements and total gravimetric weight was used and models predicting the relationship between dust loads and reflectance were generated. The first derivative of difference index was found to provide the best results (RMSEP of 4.5%). This RMSEP value is quite impressive when taking into account the relatively small amount of settled dust with a narrow gravimetric weight of ±0.01 mg (min and max values are 0.1-3.8 mg).

Spatial pattern of settled indoor dust was obtained using interpolation technique in ArcInfo/GIS software. Iso-Dust maps, generated from the gravimetric and spectrally predicted values demonstrated that physical and anthropogenic factors plays an important role in total amounts of settled dust. It should be highlighted that each sampling location was built in different historic periods according to Tel-Aviv city development,

from 1900 (Q3, 5) till nowadays (Q1, 2). Therefore, buildings were characterized not only by the different structural characteristics, but also by the different morphology of the urban fabric. Therefore, the structural and urban built environment characteristics were inseparable. High amounts of dust were measured in high densely populated area houses (Q3, Q5), orientated to the road where at least half of a window was constantly opened allowing the fresh and polluted air penetrate the dwelling. On the contrary, sampling locations where the vegetation areas are prevailed (Q1-2), houses oriented to the vegetated inner side of a building characterized by low amounts of dust (under the same indoor conditions). Moreover, even "old" sampling location houses (densely populated area Q3, Q5) oriented to the garden were characterized by low amounts of dust. ANOVA test was applied in order to explore the most important physical and anthropogenic factors in settled dust dynamics.

6366-30, Session 8

Analysis of the visual integration in the landscape of routes with low-density traffic

M. Gil Docampo, Univ. de Santiago de Compostela (Spain); I. Cañas Guerrero, Univ. Politécnica de Madrid (Spain); A. Tobar, J. Armesto, Univ. de Santiago de Compostela (Spain)

This paper concerns the study of the characteristics and the suitability of routes in the landscape through the use of remote sensing. Basic indicators are created which can be useful for the characterisation of routes from the fused images Landsat TM and Spot P. The visual impact of these to their environment is also evaluated. The area which is the object of study is the Ancares Wildlife Reserve (Lugo, Spain).

This paper focuses on the digital processing for rural roads study by the use of satellite images through the application of linear enhancing, directional filters, supervised and unsupervised classifications, masking applications and operations between images.

A procedure has been developed which permits the establishing of qualitative classes of visual integration of routes in the landscape from the association of three variables: route linearity, integration in vegetation and visibility of the route.

The results are reflected in a thematic map at a scale of 1:50.000. The final map of integration of routes constitutes the result in the digital evaluation of the adequacy of the roads of low density traffic to the countryside in the Wildlife Reserve.

Fieldwork has allowed verification of the ground-truth between the physical reality of the area and the obtained thematic mapping.

A digital procedure for the study of the visual integration of roads into the countryside has been developed employing Landsat TM and SPOT P images as an alternative to traditional study methods.

6366-31, Session 8

Image classification with LiDAR and GIS-data: moving from land cover to land use

F. P. Kressler, K. Steinnocher, ARC systems research (Austria)

Classification of remote sensing images has always been hampered by the missing third dimension. With the inclusion of LiDAR (Light Detection And Ranging) data the identification of image objects can be significantly improved both in terms of accuracy as well as in terms of automation. Object-oriented classification is an obvious choice for the classification with its ability of integrating and processing data with very different properties.

Using image and LiDAR data the identification of image objects has been improved but the classification is still mainly on the level of land cover. In order to move to land use it is suggested to include information typically stored in GIS data bases. As many data bases are indexed using street addresses, image objects identified as houses in the classification, are first linked to the appropriate addresses using a database containing postal addresses georeferenced with high precision. Now it is possible to link the objects to any data base that uses street addresses as a reference. As an example the classification is improved by linking it to the yellow pages. This allows the identification of buildings used for commercial as well as public services down the specific branches. Inversely, all other buildings can be assumed to be residential. Now a highly detailed land use map is available. Another example is the inclusion of population data, available on a census tract basis. This population data can now be projected only the residential areas, improving the calculation of population density. Further improvements can be achieved by included the high information for the density calculation.

6366-32, Session 8

Visual perception based different scale remote sensing images fusion with multiwavelet transform

Y. Na, Xidian Univ. (China); M. Ehlers, Univ. Osnabrück (Germany); W. Yang, Xidian Univ. (China)

Panchromatic images of high spatial resolution can provide detail geometric information, while multi-spectral images with lower spatial resolution can provide detail spectral information. Multi-spectral images of high spatial resolution can be obtained with images fusion methods. Many image fusion methods have been presented in recent years, such as wavelet transform based fusion method, IHS fusion method and PCA fusion method.

The fusion ability of human visual system to maintain the correct perception of scenes performs better than that of any man-made systems available. So, it is very appealing to apply the physiological mechanism to guide image fusion research.

Multi-wavelets can be simultaneously orthogonal, symmetric, short supported and of high vanishing moments that wavelets can not. All these properties can be used to maintain the spatial information of panchromatic images and the spectral information of multi-spectral images, such as texture and edge information.

A visual perception based different scale remote sensing images fusion scheme with multi-wavelet transform is presented in this paper. Based on the properties of band contrast processing and contrast orientation of visual receptive fields, a directive contrast is introduced. The fusion procedure is that: first, multi-wavelet decomposition of Panchromatic and multi-spectral images. Second, the construction of directive contrast sequences at different decomposition levels. Third, the construction of fused multi-wavelet coefficients. Finally,the acquisition of fused image with inverse multi-wavelet transform.

Experiment results show that visual perception based different scale remote sensing images fusion with multi-wavelet transform method can provide a very good fusion image. This method is better than ordinary wavelet transform based fusion method, IHS fusion method and PCA fusion method.

6366-33, Session 8

On image fusion and segmentation

M. Ehlers, Univ. Osnabrück (Germany)

While the increase in spatial resolution for digital images has been hailed as a significant progress, methods for their automated analyses (i.e. land cover mapping, change analysis, GIS integration) are still in the process of being developed. Object (or segment) based preprocess-ing techniques seem to be an adequate methodology because inter-class variances can be minimized and the image interpretation techniques of the human eye be mimicked. A number of papers has proven the validity of an segment based image analysis for automated processing, however, the question of appropriate data fusion techniques within this context has hardly been addressed. In this paper, we will investigate techniques for the combination of image fusion and segment based image analysis. The examples include

- Color preserving iconic fusion with subsequent segmentation and classification;
- 'Cookie cutter' approach for the integration of high resolution RGB and low resolution hyperspectral image data for urban class material detection; and
- Decision based integration of panchromatic high resolution data with multispectral im-ages for the identification of settlement areas.

We will show that the combination of segment based image analysis and fusion techniques at iconic, feature and decision level does indeed improve the final analysis and can be seen as a first step to a an automated result driven processing line. It has to be noted that there is no general theory for segment based image fusion although the feature level fusion seems to be the most promising path for a combination of the two processing paradigms.

Conference 6366: Remote Sensing for Environmental Monitoring, GIS Applications, and Geology VI

6366-34, Session 8

A preliminary simulation to study the potential of integration of LIDAR and imagery

W. Zhang, Beijing Normal Univ. (China) and State Key Lab. of Remote Sensing Science (China) and Beijing Key Lab. for Remote Sensing of Environment and Digital Cities (China)

LIDAR has revolutionized the acquisition of digital elevation data for large scale mapping applications. Integrated with airborne GPS and inertial measurement systems (IMU), it is possible to compile digital terrain model (DTM) data from an aircraft platform through laser distance measurements. Generally, Airborne LIDAR system integrates a digital camera hard hounded to the LIDAR sensor. Images captured by the integrated digital camera are mainly used to provide the necessary visual coverage of the area and generate the orthimages.

As we know, the precision of laserscanner slant distance measurement is primarily determined by the precision of time-of-flight measurement. It is about 2mm now. But the distance measurement accuracy is not equivalent to the final 3D coordinate measurement accuracy. The final accuracy also depends on the precision of airborne GPS and IMU. This accuracy varies with flying height. The height precision of a single ground point is often in the order of 10-15 cm, with a typical precision in the order of 0.5-1.0 meter at a flying height of 1000 meter above ground.

These truths motivate us to find a way to integrate LIDAR and imagery, so that the final 3D measurement errors can be suppressed. A simple simulation system is developed to study the potential of integration of LIDAR and imagery. There are about 100 check points to contrast the 3D ground points reconstructed only by LIDAR and by integration of LIDAR and imagery. And the preliminary result shows that, both average error and stander deviation of integration bundle adjustment method are smaller than the former.

Conference 6367: Lidar Technologies, Techniques, and Measurements for Atmospheric Remote Sensing II

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6367-01, Session 1

EARLINET-ASOS: programs and perspectives for the aerosol study on continental scale

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EARLINET, the European Aerosol Lidar Research Network, is the first aerosol lidar network, established in 2000, with the main goal to provide a comprehensive, quantitative, and statistically significant data base for the aerosol distribution on a continental scale. At present, 24 stations distributed over Europe are part of the network.

The EARLINET-ASOS (Advanced Sustainable Observation System) EC Project, starting on the EARLINET infrastructure, will contribute to the improvement of continuing observations and methodological developments that are urgently needed to provide the multi-year continental scale data set necessary to assess the impact of aerosols on the European and global environment and to support future satellite missions.

The main objective of EARLINET-ASOS 5-year project, started on 1 March 2006, is to improve the EARLINET infrastructure resulting in a better spatial and temporal coverage of the observations, continuous quality control for the complete observation system, and fast availability of standardized data products. This will be reached by defining and using common standards for instruments, operation procedures, observation schemes, data processing including advanced retrieval algorithms, and dissemination of data.

The expected outcome is the most comprehensive data source for the 4-D spatio-temporal distribution of aerosols on a continental scale.

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6367-02, Session 1

Five years of lidar ratio measurements over Potenza, Italy

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Lidar technique is the most suitable for high vertical and temporal resolution aerosol profiling. In particular the Raman/elastic lidar combined approach allows independent determination of aerosol extinction and backscatter coefficient without any assumption about their relationship. On the other hand the pure backscatter lidar, the most common aerosol lidar technique, is based on assumptions about the lidar ratio, i.e. the ratio of aerosol extinction and backscatter coefficients. Since lidar ratio depends on microphysical aerosol properties, the lidar ratio values applied in the retrieval of aerosol backscatter coefficient by elastic lidar must be carefully selected. In April 2006, the first satellite-borne elastic lidar, CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations), will be launched, providing global high vertical resolution aerosol profiles. In order to improve aerosol backscatter coefficient accuracy in the case of pure elastic backscatter lidar, a climatology of lidar ratio values for specific aerosol types is necessary.

Five years of systematic lidar ratio measurements have been collected by means of a Raman/elastic lidar system operational at CNR-IMAA, since May 2000 in the framework of EARLINET, the first lidar network for tropospheric aerosol study on continental scale. A climatological analysis of the lidar ratio measurements in the Planetary Boundary Layer (PBL) and for Saharan dust intrusions is carried out. In addition, lidar ratio measurements concerning forest fires and volcanic eruptions are also analyzed.

6367-03, Session 1

Observation and characterization of atmospheric aerosols above ALOMAR (69°N) by tropospheric lidar, sun-photometer, and VHF radar

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At ALOMAR (Arctic Lidar Observatory of Middle Atmosphere Research,

69°N, 16°E) an exemplary co-location of tropospheric lidar, sun-photometer and VHF radar is used for aerosol investigations. Recently the University of Oslo, the Norwegian Institute for Air Research and the Andøya Rocket Range started to operate a new troposphere lidar system. The system uses two elastic backscatter channels (1064nm, 355 nm), two polarization channels (532p nm and 532s nm) and a Raman channel (387nm). The co-located sun photometer is of Cimel type and the VHF Radar is operating at 53 MHz. The data from the Cimel instrument are collected in cooperation with a group from Valladolid (Spain) and the radar is operated by the Institute for Atmosphere Physics, Kühlungsborn (Germany).

The location of ALOMAR, north of the Arctic Circle and on an island, a few hundred meters from seashore and about 30 km off the continent, makes it ideal for investigations related to Sub-Arctic aerosols. Depending on the synoptic weather situation at the location, air masses characterized by strong marine or continental influenced aerosol content can be observed. For trajectories from the north and north-west ALOMAR represents a reference station for almost unpolluted, clear air.

The present paper presents the first results from simultaneous and collocated tropospheric measurements. We compare aerosol stratification derived from lidar data with simultaneous measurements of total aerosol content, derived from Cimel data in dependence of simultaneous winds, stratified layers (synoptic weather fronts) and turbulence from radar data. Diurnal cycles both summertime and wintertime are compared.

6367-04, Session 1

Compact eye-safe backscatter lidar for Arctic aerosols and boundary layer studies: concept design for full Stokes polarization analysis

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We report a novel Eye-Safe Backscatter Lidar with polarization diverse at 1.574 μm. The instrument is based on a previously designed, single-channel Compact Eye-Safe Backscatter Lidar CESBL assembled in a compact optical bench instrumentation platform. The instrument was upgraded for polarization selectivity (linear and circular) in the laser emission and linear polarization discrimination in the receiver unit. The lidar instrument is computer controlled polarization selectivity in the laser emission and is able to perform sequential measurements at different polarization modes including both linear and circular polarization. The lidar design focuses on high accuracy, better than 60 dB, in polarization emission and polarization discrimination accuracy over 50 dB. These

features allow depolarization ratios and polarimetric parameters retrieval to of ~0.1%. In this article we discuss the instrumental concept design and the electronic synchronization necessary to achieve the polarization diverse in the emission. Preliminary applications will be also discussed.

6367-05, Session 1

Observations of noctilucent clouds and temperature structure from 1-105 km by co-located lidars at 54°N

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At the mid-latitude location of Kühlungsborn (54°N, 12°E) resonance and Rayleigh-Mie-Raman lidars are operated to observe e.g. the occurrence and particle properties of noctilucent clouds (NLC) and to measure continuous temperature profiles from the troposphere to the lower thermosphere. For the temperature profiles two lidars (RMR lidar and potassium lidar) and three different measurement methods (rotational Raman, Rayleigh/vib. Raman, Doppler resonance) are combined. This allows retrieving temperatures and temperature variations by night with a resolution of 1 km vertical and 15 min temporal. The profiles clearly show fluctuations caused by gravity waves and tides with amplitudes of up to +/- 20 K in the mesopause region. We will present examples of wave properties in summer and winter, including amplitudes and vertical wavelengths. In summer during the cold phases of waves the temperature above 80 km drops occasionally below the frost point temperature. However, the mean temperature it is a few Kelvin above the frost point. Therefore, the existence of NLC ice particles above our site is only allowed in the cold phases of waves. We will present lidar-observations of NLC and temperatures below and above the NLC layer showing the coupling of the NLC to supersaturated air in the mesopause region. The mean NLC altitude has been found at 83.1 km with a standard deviation of 1.3 km. Particle properties calculated from soundings with up to four different wavelengths (355 nm, 532 nm, 589 nm, 770 nm) give particle radii similar to observations at more polar latitudes (about 25-60 nm), while the backscatter coefficient is smaller (about 2.5e(-10)/m/sr)

6367-06, Session 1

Polarization lidar sounding of tropical clouds

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Cloud lidar observations are sparse over tropics and more so in India. Clouds in the lower part of the atmosphere can play an important role in nowcasting, pollution transfer, and boundary layer and radiative (indirect effects in particular) processes. Unlike in clear-air, the cloud medium generates strong return signals due to the well known fact of multiple scattering resulting from large backscattering cross-sections and internal reflections between cloud droplets. This information is useful for precise measurement of cloud parameters such as ceiling and base heights and locations of discontinuity (layer clouds). Moreover, the fine scale variations in scattered signal strength in the sub-cloud air layer and polarization characteristics provide more insight into the structure and composition of clouds. These measurements at multiple laser probing wavelengths offer more reliable means to study cloud evolution and microphysics. Less dense and shallow clouds generally allow the penetration of low power laser beams and hence determination of both cloud-base and top heights is possible with high degree of accuracy. In the case of high density clouds, the corresponding parameters can be determined in the lower part of the cloud without regards for the influence of multiple scattering effects. With the increased interest in cumulus-topped mixed layers, cloud-base heights provide information on venting of pollutants through clouds.

One of the most important components that is missing in the tropical counties such as India is multi-dimensional mapping of aerosol properties and cloud structures during both day and night over different environments (associated with complex terrain and meteorological conditions). In this context, the Dual Polarization Micro Pulse Lidar (DPMPL) that has been developed and installed very recently at the Indian Institute of Tropical Meteorology (IITM), Pune (18°32'N, 73°52'E, 559 m AMSL), India would play an important role in atmospheric aerosol and cloud physics research (aerosol and cloud climatology) and environmental monitoring. This will also serve as very valuable input information to the climate models, especially aimed at accounting for aerosols and cirrus cloud characterization and associated radiative forcing in different spatial and time scales. Since this lidar can also be operated during daytime, the most important phenomena such as daytime boundary layer structure and stratification, convection. It is a portable and real-time observing system. The transmitter is a DPSS Nd:YAG laser with Lambda=532 nm, 20 microJ/pulse power \@10KHz, 2-50 KHz PRR, 10-12 ns pulse width, alternate parallel and perpendicular polarization at switching rate \@ 2KHz laser PRR. The receiver is a 14-inch Schmidt Cassegrain telescope with a narrow-band interference filter/Fabry Perot etalon, Peltier cooled PMTs, and a versatile data acquisition (~ 500 MHz sampling rate) and processing system. This unique lidar facility now available in India is also expected to provide a variety of interesting and important information on issues like cloud-aerosol interactions and their impact/feed-back processes on hydrological cycle and climate variability. Complete system details and capabilities of this newly-built compact lidar for atmospheric research will be presented.

6367-07, Session 1

Lidar and sunphotometry observations on the long-range transport of smoke and dust events

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The remote sensing techniques of Lidar and Sunphotometry are well suited for understanding the optical characteristics of aerosol layers aloft. Lidar has the ability to detect the complex vertical structure of the atmosphere and can therefore identify the existence and extent of aerosols that have undergone long-range transport. Inversion techniques applied to Sunphotometry data can extract information about the aerosol fine and coarse modes. As part of the REALM network (Regional East Atmospheric Lidar Mesonet), routine measurements are made with a vertically-pointing lidar at the Centre For Atmospheric Research Experiments (CARE). In addition, a CIMEL sunphotometer resides at CARE (part of AERONET) yielding an opportunity to achieve an optical climatology of aerosol activity over the site. Environment Canada's mobile lidar facility called RASCAL (Rapid Acqusition SCanning Aerosol Lidar), operating in zenith mode only, was also deployed to Western Canada during the months of March and April, 2005 to provide an opportunity to measure the long-range transport of trans-Pacific pollutants that impact the coastal areas of British Columbia frequently. During that time a long-range transport event was observed on 13-14 of March 2005. Further analysis has shown the event originated from North African dust storms during the period 28 February to 3 March. The optical coherency of these active and passive remote sensors will be presented, along with other supporting observations, for forest fire smoke plumes transported over CARE (in 2003) and the first documented case of Saharan dust to impact Western North America.

6367-08, Session 1

Potential and range of application of elastic backscatter lidar systems using polarization selection to minimize detected skylight noise

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We examine the potential, range of application, and limiting factors of a polarization selection technique, recently devised by us, which takes advantage of naturally occurring polarization properties of scattered sky light to minimize the detected sky background signal and which can be used in conjunction with linearly polarized elastic backscatter lidars to maximize lidar receiver SNR. In this approach, a polarization selective lidar receiver is aligned to minimize detected skylight, while the polarization of the transmitted lidar signal is rotated to maintain maximum lidar backscatter signal throughput to the receiver detector, consequently maximizing detected signal to noise ratio. Results presented include lidar measurements at 532 nm which show as much as a factor of improvement in signal-to-noise ratio over conventional un-polarized schemes. For vertically pointing lidars, the largest improvements are limited to symmetric early morning and late afternoon hours. For non-vertical scanning lidars, significant improvements are achievable over much more extended time periods, depending on the specific angle between the lidar and solar axes. A theoretical model that simulates the background skylight within the single scattering approximation showed good agreement with measured SNR improvement factors. Diurnally asymmetric improvement factors, sometimes observed, are explained by measured increases in PWV and subsequent modification of aerosol optical depth by dehydration from morning to afternoon. Finally, since the polarization axis follows the solar azimuth angle even for high aerosol loading, as demonstrated using

radiative transfer simulations, it is possible to automate the technique using solar position calculators.

6367-09, Session 2

New Raman water vapor and temperature lidar at JPL Table Mountain Facility: optimization, validations, and Sonde intercomparison

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The Jet Propulsion Laboratory currently operates lidar systems at Table Mountain Facility (TMF) California (34.4°N, 117.7°W at 2300m) and Mauna Loa Observatory (MLO), Hawaii (19.5°N, 155.6°W at 3400m) under the Network for the Detection of Atmospheric Composition Change (NDACC, formerly NDSC). To compliment existing NDACC Lidars at TMF, which acts as a primary site for inter-comparisons, a new water vapor and temperature lidar has begun routine operation with typically 3 to 4 nightly profiles per week. As water vapor is a key greenhouse gas, and is highly variable on annual and seasonal cycles, accurate long term measurements are necessary for predictions of climate change and to increase our understanding of the atmospheric processes it contributes towards. The new TMF lidar has demonstrated high spatial and temporal resolution, with a high degree of optimization of the system being achieved over the past year, although the authors believe further improvement may yet be possible. The lidar has been designed for accuracies of 5% up to 12km in the free troposphere with the capability to measure to the tropopause and lower stratosphere with accuracies of 1 ppm. It is anticipated that the data sets provided will be used for AURA validation and for incorporation into NDACC archives. Validation results for the optimized system are presented with intercomparisons using Vaisala RS90 radiosondes.

6367-10, Session 2

High spatial and temporal resolution measurements of water vapor, temperature, and aerosol with by Raman LIDAR for turbulent observations

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A new generation Raman LIDAR system with very high spatial (1.5 m) and temporal (1 s) resolution for humidity and temperature measurements in the lower atmosphere is presented. A multi-telescope array configuration with almost range-independant overlap function allows operational range from 10 m out to 500 m. The system is operated in the solar blind spectral region to allow daytime water vapor measurements and the data is corrected for ozone and aerosol influences. A prism polychromator with throughput greater than 90 % is used for the separation of the rotational-vibrational Raman bands of water vapor, nitrogen, and oxygen molecules. The temperature measurements are carried out by the pure rotational Raman method. The rotational signals are isolated from the lidar signal by a double, grating polychromator. The LIDAR system will ultimately be used to study the structure of the lower atmosphere over complex terrain and in particular advance our understanding of turbulent blending mechanisms in the unstable atmosphere using LES. First results will be presented at the conference.

6367-11, Session 2

Water vapor Raman lidar for meteorology

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In this paper we describe the optical design and performance simulations of a Raman lidar for continuous day and night profiling of atmospheric water vapour and we present first measurement results. The system is developed for the Swiss meteorological service (Meteoswiss) and will be used to supply water vapor data complementary to radiosonde and GPS data needed for operational forecasting. In order to use the lidar data for weather prediction the measurement accuracy should be better than 10% in the vertical range 150 m to 5 km during daytime and 150 m 7.5 km night-time. In all cases 50 to 300 m vertical resolution and 15 to 30 min temporal resolution is required.

To satisfy the requirements for the day and night time vertical operational range of the lidar the narrow-band, narrow field-of-view (NB-NFOV) approach is adopted. The lidar transmitter is based on a tripled Nd:YAG laser. A 15 x beam expander is used to attain 0.12 mrad beam divergence needed for NFOV operation and to satisfy the eye-safety requirements. A fiber-coupled multi-telescope configuration formed by four identical 300 mm, f/3.33 parabolic mirrors is used in the lidar receiver. The receiver has 0.2 mrad FOV for day light background reduction. An additional “near range” fiber installed in one of the telescopes improves the signal level from distances below full overlap. The spectral separation of water vapor and nitrogen is carried out by a diffraction grating polychromator. The pass-band of the polychromator is 0.33 nm (at FWHM) in all detection channels for further reduction of the solar background. An additional oxygen Raman channel is used for aerosol correction of water vapor profiles.

6367-12, Session 2

Comparisons of the Raman lidar measurements of the tropospheric water vapor profiles with radiosondes, meteorological observation tower, and GPS at Tsukuba, Japan

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The vertical distributions of the water vapor mixing ratio (w) were measured with the Raman lidar at the Meteorological Research Institute, Japan in 2000-2004. The measured data were compared with those obtained simultaneously with three types of radiosondes (Meisei RS2-91, Vaisala RS80-A, and Meteolabor SnowWhite), two types of hygrometers (Vaisala Humicap and Rotoronic Hygroclip) on the meteorological observation tower, and two Global Positional System (GPS) antennas (Trimble and Ashtech) near the lidar site.

The values of w obtained with the lidar in October-November 2000 agreed well with those obtained with RS2-91 radiosonde with a mean relative difference of 5% for w \> 0.5 gkg-1, whereas they were systematically higher than those obtained with RS80-A radiosonde with a mean difference of 23%. The difference in w between the lidar and these radiosondes increased to over 50% at w < 0.5 g kg-1. The vertical variations of w obtained with the lidar on March 2004 were similar to those obtained with RS2-91, whereas those obtained with Snow White radiosonde showed less vertical variations for w < 1 gkg-1. The temporal variation of w obtained with the lidar at heights between 50 and 213 m were similar to those obtained with the hygrometers on the meteorological tower on 19-20 March 2001 for a time scale larger than about 10 minutes, although the absolute values differed systematically due to the incomplete overlap of the laser beam and the receiver’s field of view at the lower heights. The temporal variation of the precipitable water vapor obtained with the lidar on 24-25 October 2000 generally agreed with those obtained with GPS except for the period when large horizontal and vertical inhomogeneity of w was present.

6367-13, Poster Session

Engineering of a water-vapour Raman elastic-backscatter lidar at the Politechnical University of Catalonia (Spain)

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Implementation of the pure-vibrational Raman spectra lidar method for simultaneous measurements of atmospheric water vapour, aerosol extinction and backscatter coefficients is reported. A Q-switched Nd:YAG laser provides the three elastic wavelengths of 1064, 532 and 355 nm. The returned signal is collected by a single 20-cm aperture telescope. A spot-to-spot fiber bundle conveys the light to a specific polichromator which has been especially simulated and designed with care on minimizing the optical losses and reducing the dimensions of the polichromator. The reception field of view, limited by the fiber bundle characteristics, is the same for all wavelengths. By means of 4 customized dichroic filters and a beam splitter, the light is separated into the 3 elastic wavelengths, as well as the 386.7- and 607.4-nm N2-Raman-shifted wavelengths and the 407.5-nm H2O-Raman-shifted wavelength. Signal detection is achieved using avalanche photodiodes at 1064 and 532 nm, and photomultiplier tubes and fast photon counters at the rest of the wavelengths. A specific design of the optoelectronics of the receiving channels is controlled by a distributed CPU thanks to a user-friendly LabViewTM interface. User-

configurable scanning tools are built, but can also be customized. In this work, the simulation of end-to-end transmissitivities will be discussed for the main channels involved. The first measurements have already made at 1064, 532 and 607.4nm.

6367-32, Poster Session

Aerosol extinction profile within the planetary boundary layer measured by a multiwavelength Raman lidar and ground-based in situ instruments at Gwangju, Korea

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Most of atmospheric aerosols exist within the planetary boundary layer (PBL). Lidar is a useful tool for measurement of the vertical structure of aerosol extinction. However, overlap problem associated with Lidar system makes it difficult to measure it within the PBL. In order to investigate the vertical structure of aerosol extinction within the PBL combined observations of atmospheric aerosols with the GIST multi-wavelength Raman lidar and ground based in-situ instruments had been made 15~31 October 2005 at Gwangju (35°10'N, 126°53'E), Korea. Backscattering coefficient can be measured down to 200m by the GIST Raman lidar. However, extinction coefficient can't be derived below 800m due to the uncompleted overlap between the laser beam and the receiver field of view of the lidar system. It has been corrected down to 200m from backscattering coefficient with an assumption that lidar ratio is invariant within the PBL. Scattering and absorption coefficients of aerosols at the surface were also measured by a nephelometer (NGN2) and an aethalometer, respectively. Aerosol extinction profile has been extrapolated down to surface based on the results of Raman lidar and surface in-situ instruments. Aerosol extinction increased with the altitude during two cases of high aerosol loading events. Aerosol optical depth (AOD) derived by a sunphotometer showed better agreement with that derived by combining Raman lidar and surface in-situ instruments results.

6367-33, Poster Session

Measurement simulation of spatial coherence and density degree by turbulence of aerosol and CO2 in atmospheric environment

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As examples of the objects having a significant influence on atmospheric pollution and warming in the human environment, detection of aerosol and CO2 gas is tried using satellite data.

In this experiment, a laser beam is used as an optical source and the densities of aerosol and CO2 gas causing turbulence of the laser beam are estimated by a simulator.

The aerosol and the CO2 gas are generated from cigarettes and dry ice, respectively, in a chamber in which a 40 m-laser beam is multi-reflected by 20 mirrors. The smoke of a cigarette contains 20 milligrams of minute particles, and the density of the CO2 gas is measured by Anagas CD 98.

As experimental results, as the densities of the aerosol and the CO2 gas increase and the turbulence of the laser beam coming through them gets higher, the spatial coherence degrees decrease. The spatial coherence degrees are obtained by calculation of the visibility of interference fringes, which are made by the laser beam through a double slit. The fringes are photographed by a digital camera, and the visibility of the fringes is obtained by computer analysis of the photographs.

These results indicate that the density of a substance causing turbulence of light can be measured by estimation of spatial coherence degrees of the light.

6367-34, Poster Session

Direct-detection Doppler wind lidar based on Fizeau interferometer

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When talking about direct-detect Doppler wind lidar, Fringe technique is preferred to edge technique in the range of troposphere, however, most fringe-technique Lidar systems have been developed to date are based on conventional Fary-perot interferometer. The purpose of this paper is to introduce our Fringe-technique lidar based on Fizeau interferometer in which the signal can be detected more conveniently using commercial linear detector. System design of the lidar system is described firstly including interferometer's optimum design, the choice of multianode detector, the effect of circle interferometer's aperture, and then, the hard target experience is given. The hard target experience shows that the lidar system can measure velocity with error of less than 1m/s.

6367-35, Poster Session

A compact diode-pumped injection-seeded ultraviolet laser for wind Doppler lidar

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A compact diode-pumped, injection-seeded and frequency- tripled Nd:YAG laser was developed for a mobile, direct detection Doppler wind lidar system. The laser is configured with the master oscillator power amplifier (MOPA). The oscillator consists of E-O Q-switched, thermal stability, diode pumped cavity. Laser rod with a diameter of 3 mm is uniformly side-pumped from nine directions. The total laser diodes are 36 bars with peak power of 60 W. The oscillator is injection seeded by a monolithic, diode-pumped Nd:YAG seeder laser with power of 200mW. The technique of resonance detection is used to lock slave laser frequency in order to satisfy with the mobile environment. The output laser from oscillator is single-way amplified. The amplifier is a rod crystal, and also side-pumped by 45 bar with a peak power of 100 W. The amplifier is implemented on 250 microseconds. Frequency triple is realized with a Type II KTP crystal and Type I BBO.

The laser can be working on single frequency without mode jumping. The output pulse is about 15 ns at 355 nm, the linewidth is reached to the limit of Fourier transfer. The output energy is 100 mJ of 1064 nm at 100 Hz, and the beam quality is about M2 of 1.3 at both directions. The frequency- triple efficiency is over than 30%. After a long time test, the laser will be installed on a mobile lidar system.

6367-36, Poster Session

Laser radiation attenuation as an approach for estimating humidity and pollution

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Humidity is considered as one of the factors causing high absorption for several Laser radiation wavelenghts,namely the 10.6Micrometer.The aforementioned wavelengths is produced by carbon dioxide laser.Humidity was found to have great influence on this wavelength.In this reported research project, a compact system for measuring humidity, pollution and Laser transmission was constructed on Laboratory Scale. It consists of wooden box,which have two holes as inlet and outlet for laser beam. A third hole for water vapor flow was made on the wooden box. Furthermore, the box contains two thermometers for measuring temperature.By using Beer-Lambert law,the laser transmission was measured to be 86% at 10% humidity and 4% at 90% humidity.The suggests the great influence of humidity and similarly pollution (e.g. dust) on reducing the laser radiation transmission.We found the possibility of using the experimentally obtained laser transmission results as an accurate indication to estimate humidity and pollution.

6367-37, Poster Session

Use of lidar measurements of aerosol extinction coefficients as a part of assessing aerosol field from meteorological weather forecast models and scattering calculations

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A lidar system for determining the vertical profiles of the aerosol extinction coefficient operating with 355 nm and 532 nm laser wavelength is presented. The lidar measurements will be performed in the European collaboration named EARLINET and data will be used as a part of the assessing of the method developed for predicting the atmospheric system range using meteorological weather forecast models. The existing lidar system has been extended with a detector channel for 532 nm and channels for the backscattering N2-Raman wavelength at 386 and 607

nm to give the opportunity to measure the aerosol extinction coefficient. Later the data will be used to compare extinction coefficient received from predicted the aerosol field of the atmospheric volume of interest. The aerosol field will be predicted by use of the meteorological weather forecast models, Hirlam, and atmospheric scattering calculations, Match. The first stage of assessment, meaning the construction of the lidar system and the first measurement from this system, will be presented.

6367-14, Session 3

An expert lidar data analysis toolset for explosive debris plumes

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Open-air explosive activities are carried out by a variety of institutions, including government agencies and private organizations. These activities result in debris plumes that contain elements of the explosive package as well as substantial amounts of entrained environmental materials. While Lidar monitoring technology for these situations has been around for years we developed a unique, interactive, post-experiment Lidar Data Analysis Toolset (LIDATO) that allows the expert user to determine the location, intensity distribution, concentration, volume, and boundaries for general debris plumes at any given time. This is true with the exception of the early development and transport of the plume where the plume is typically opaque to the Lidar and only the plume edge facing the Lidar system can be mapped. For this reason we incorporated video coverage, using multiple cameras. While the analysis of the video is handled separately we used the resulting analyzed data and combined them with the LIDATO results. The Data-Fusion product refines the separately gained results and increases the data set accuracy in all aspects for the early stages of the explosion.

6367-15, Session 3

Lidar fluorescent method for remote monitoring of the effects on the vegetation

G. G. Matvienko, Institute of Atmospheric Optics (Russia); V. I. Timofeev II, Moscow State Univ. (Russia); A. I. Grishin, N. L. Fateyeva, Institute of Atmospheric Optics (Russia)

The vegetation is in constant interaction with the environment and, above all, by way of the channels of feeding through the soil and photosynthesis. The state of the photosynthetic vegetation apparatus, which undergoes the effect of the general physiological state of a plant, can be analyzed remotely on a basis of the investigation of laser-induced fluorescence using a fluorescent lidar. In this respect the fluorescent lidar can be a technical means of remote sensing of effects on the vegetation including chemical soil pollution. For a series of applications of interest is the development of lidar technique for detecting the effects of oil products as well as mechanical disturbances.

This paper is devoted to the application of the lidar fluorescent technique for monitoring of mechanical and chemical impacts on the wood vegetation typical for Siberia. A physical base of this technique is red fluorescence of chlorophyll of green plants excited by the second harmonic radiation (532 nm) of Nd:YAG laser.

Red fluorescence of plants consists of two bands with centres 685 and 740 nm conditioned by functioning of two photosystems. As field experiments have shown, the indicated photosystems and, respectively, the intensity of band fluorescence respond variously to the occurrence of feeding disturbances and mechanical impacts, making informative the increase of the fluorescence intensity in bands and their relation. Criterial fluorescence characteristics in time were obtained at single and multiple effects on the vegetation. The paper describes the lidar system corresponding to the requirements of detecting the effects on the vegetation.

6367-16, Session 3

Emission spectroscopy and energy transfer in Tm3+, Tm3+-Ho3+ and Tm3+-Yb3+ doped tellurite fibres

B. Richards, S. Shen, A. Jha, Univ. of Leeds (United Kingdom)

This paper examines the steady state and time resolved emission spectroscopy of Tm3+ doped and Tm3+-Ho3+, Tm3+-Yb3+ co-doped tellurite fibres for mid-IR fibre laser design which find applications for lidar. These doped fibres show promising properties for compact and tunable laser sources in the visible and mid-IR when pumped at 800 nm, 980 nm and 1480 nm which can be used for remote chemical sensing and atmospheric monitoring. Tellurite glass has a lower cut-off phonon energy than silica glass and is more environmentally stable than fluoride glass, and coupling these properties with its high rare-earth ion solubility and high refractive index make this glass a very interesting material in which to study the fluorescence properties of these rare earth ions. We have measured the mid-IR fluorescence properties in varying lengths of multi-mode and single-mode fibre for the 3H4-3H6 (~1.85 μm), 3H4-3F4 (~1.46 μm) transitions in Tm3+ and the 5I7-5I8 (~2.05 μm) transition in Ho3+. We have also measured the visible emission from these fibres due to excited state absorption (ESA) as there is strong red and green emission in Tm3+ and Tm3+-Ho3+ doped fibres respectively when pumped at 800 nm, and strong red and blue emission in the Tm3+-Yb3+ when pumped at 980 nm. These results in fibre are compared to bulk glass results and are used to describe the pumping schemes and energy transfer mechanisms of these rare earth ions in tellurite fibre.

6367-17, Session 3

Pulsed high-peak-power and single-frequency fiber laser design for LIDAR aircraft safety application

F. Liegeois, C. Vercambre, M. Salhi, Y. Hernandez, D. Giannone, Multitel (Belgium)

Fibre laser technology has reached during the past decade a level of maturity sufficient for commercialisation. Indeed fibre lasers represent a very attractive solution for a large number of applications, including telecommunications, medical, gas sensing, pollution detection, free space optical transmission and LIDAR.

Fibre lasers are ideal candidates for remote sensing applications due to their intrinsic advantages in terms of flexibility, cost effectiveness, compactness, and efficiency. The advancements in the design of such lasers permit to develop narrow linewidth, tuneable or pulsed sources that can be conveniently used for DIAL or Doppler LIDAR sensing systems. Furthermore, the possibility to operate such sources in the eye-safe 1.55 μm window, is a key advantage probably making this technology the most promising one for airborne sensing in both civilian and military applications.

Laser wind velocimeters work by monitoring the Doppler shift on the light that is backscattered by aerosols in the air. Recently there has been interest in developing systems operating at wavelengths near 1.5μm and based on all fibre lasers configuration.

We propose a new laser for Doppler velocimetry, which makes use of an all fibre technology, and that has been specifically developed for aircraft safety applications. We report here the experimental demonstration of a narrow linewidth (8 kHz) fibre laser, modulated and amplified through an all fibre MOPA configuration. The final characteristics of the laser are 1 kW of maximum peak power, and an energy of 10 μj per pulses of 10 ns duration at 50 kHz frequency repetition rate.

6367-18, Session 4

Water vapour emission in vegetable fuel: absorption cell measurements and detection limits of our CO2 Dial system

P. Gaudio, C. Bellecci, L. De Leo, M. Gelfusa, T. Lo Feudo, S. Martellucci, M. Richetta, Univ. degli Studi di Roma/Tor Vergata (Italy)

In the early forest fire detection, Lidar technique present considerable advantages compared to the passive detection methods based on infrared cameras currently in common use, due its higher sensitivity and ability to accurately locate the fire.

The combustion phase of the vegetable matter causes a great amount of water vapour emission, thus the water molecule behaviour will be studied to obtain a fire detection system ready and efficient also before the flame propagation.

A first evaluation of increment of the water vapour concentration compared to stan-dard one will be estimated by a numerical simulation.

Experimental results relevant to different kinds of vegetable fuels were carried out in ad hoc absorption cell using a CO2 Dial system.

In the paper the comparison between experimental data and theoretical results will be shown.

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6367-19, Session 4

Frequency chirped differential absorption LIDAR

A. P. Lytkine, J. Tulip, W. Jäger, Univ. of Alberta (Canada)

We propose a new concept design of the differential absorption LIDAR (DIAL). A frequency chirped emission of a pulsed quantum-cascade laser (QCL) with wavelength in the range of fundamental absorption band of target compounds is used to derive gas concentrations using standard DIAL technique. Depending on the ratio of the laser frequency chirp interval to the width of the target absorption line, a single- or multi-mode QCL can be utilized. If the laser frequency chirp interval is greater than the width of absorption line, the absorbed and not absorbed portions of the laser pulse can be treated as on- and off-line signals, respectively. If the frequency chirp covers a small portion of the absorption line, a multi-mode Fabry-Perot QCL can be used. The frequency of one of the longitudinal modes will be turned by QCL substrate temperature to the peak of an absorption line, and the other mode will provide the off-line signal. The on- and off-line return signals will be separated by a diffraction grating. Experimental results on the application of the method to the detection of ammonia in the atmosphere with a pulsed single-mode QCL operating near 10.3 μm will be presented. To cover the absorption line of ammonia the QCL was driven with 100-ns injection current pulses. A return signal was obtained using a retroreflector. A diffraction grating spectroscope capable of resolving the longitudinal modes of Fabry-Perot QCLs will be described. Compact portable QCL-based DIALs for laser monitoring of the atmosphere can be developed.

6367-20, Session 4

DSA laser measurements and atmospheric diffusion models for the estimation of the gas emission flux by spot source fields

F. Cuccoli, L. Facheris, O. Vaselli, Univ. degli Studi di Firenze (Italy)

Through DSA (Differential Spectroscopy Absorption) based IR portable laser systems, gas concentration of molecular species along open air optical paths can be determined in real time. In particular, we can measure in-situ concentration in the air volume where soil gas emission phenomena are present (i.e. volcanic, geothermal and industrial sites) just above the emission areas.

In this paper we propose a method for estimating the CO2 emission flux by spot source fields based on the use of IR laser measurements and atmospheric diffusion models. We show that an ad-hoc (i.e., accounting for the wind direction) arrangement of the optical links around the emission area allows to measure the gas concentration along directions that are parallel and orthogonal to that of the wind. The concentration measurements gathered on this optical link arrangement allow to retrieve the real time atmospheric diffusion conditions, able to provide the diffusion parameters for defining the atmospheric diffusion model.

Once the atmospheric diffusion conditions have been evaluated, the gas emission flux is estimated by inverting the atmospheric model applied to the concentration measurements collected in real time over the emission area by means of the IR laser system.

The proposed method is fully described and discussed. Moreover, some experimental results about the application of the proposed method on the CO2 emission from selected geothermal areas in Tuscany (central Italy) are reported.

6367-21, Session 5

Performance and initial results from CALIOP

D. M. Winker, W. H. Hunt, A. H. Omar, NASA Langley Research Ctr. (USA)

Satellite lidars are now beginning to add significant new capabilities for atmospheric sensing. Following the Lidar In-space Technology Experiment (LITE) on the Space Shuttle in 1994, and the Geosciences Laser Altimeter System (GLAS) on ICESat in 2003, the CALIPSO satellite was launched in Spring 2006 for a three year on-orbit mission. Carrying CALIOP, a two-wavelength polarization lidar, along with two passive imagers, CALIPSO provides unique measurements to improve our understanding of the role of aerosols and clouds in the Earth's climate system. CALIOP is the Cloud-Aerosol LIdar with Orthogonal Polarization. Using a linearly polarized laser and polarization-sensitive receiver, the instrument allows the discrimination of cloud ice/water phase and the identification of non-spherical aerosols. The instrument will also retrieve the vertical distribution and optical properties of aerosols and clouds. CALIPSO was developed within the framework of a collaboration between NASA and CNES. This talk will discuss mission status and initial results from CALIPSO.

6367-22, Session 5

Selection algorithm for the CALIPSO lidar aerosol extinction-to-backscatter ratio

A. H. Omar, D. M. Winker, M. A. Vaughan, NASA Langley Research Ctr. (USA)

The extinction-to-backscatter ratio (Sa) is an important parameter used in the determination of the aerosol extinction and subsequently the optical depth from lidar backscatter measurements. We outline the algorithm used to determine Sa for the Cloud and Aerosol Lidar and Infrared Pathfinder Spaceborne Observations (CALIPSO) lidar. Sa for the CALIPSO lidar will either be selected from a look-up table or calculated using the lidar measurements depending on the characteristics of aerosol layer. Whenever suitable lofted layers are encountered, Sa is computed directly from the integrated backscatter and transmittance. In all other cases, the CALIPSO observables: the depolarization ratio,the layer integrated attenuated backscatter, and the mean layer total attenuated color ratio, together with the surface type, are used to aid in aerosol typing. Once the type is identified, a look-up-table developed primarily from worldwide observations, is used to determine the Sa value. The CALIPSO aerosol models include desert dust, biomass burning, background, polluted continental, polluted dust, and marine aerosols.

6367-23, Session 5

Using ICESat observations to obtain CFLOS statistics for use in the design of space-based lidars

G. D. Emmitt, S. Greco, Simpson Weather Associates, Inc. (USA)

As the community designs future laser-based remote sensors for space, the issue of clouds will have a significant impact on the both the instrument design as well as its operations plan. While space based imagers have provided the community with cloud statistics for several decades, those data have been derived mainly from images with a few kilometers resolution. Furthermore, in most cases, the accounting for multiple layers of clouds has been hampered by pixel resolution and lack of direct ranging. The 14 day LITE mission in 1994 provided the first opportunity to develop cloud statistics with sampling on the scale of a few 100 meters. More recently, global measurements of aerosol and cloud properties with <70 m sampling resolution have been provided by the Geoscience Laser Altimeter System (GLAS) instrument on-board the Ice, Cloud and land Elevation Satellite (ICESat).

Simpson Weather Associates (SWA) has been tasked by NASA to investigate and analyze the cloud data from GLAS to construct cloud and cloud penetration statistics that can be used to guide the design of future lidars in space. Specifically, SWA was to look at the following statistics and issues which will covered in the presentation:

- probability of Cloud Free Line Of Sight (CFLOS) penetration for a laser beam with a footprint less than 100 meters in diameter
- probability of multiple level intercept by clouds
- probability of contiguous CFLOSs for various duration of beam stares and shot integration for a series of trade studies involving energy per pulse and pulse repetition frequency

6367-24, Session 5

Turbulence and mountain wave conditions observed with an airborne 2-micron lidar

E. H. Teets, Jr., NASA Dryden Flight Research Ctr. (USA)

Joint efforts by NASA, the Department of Defense and industry are enhancing the capability of airborne wind and turbulence detection. The Advanced Coherent Lidar for Airborne Measurements (ACLAIM) has flown on three series of flights to assess its capability over a range of altitudes, air mass conditions and gust phenomena. Highlights of two flight experiences, both from April 2003, are presented. Events describing light to moderate turbulence induced by mountain wave flow over the Tehachapi and Sierra Nevada ranges are illustrated. Data examples are taken from times when forward-looking lidar line-of-sight velocity fields predicted approaching mountain wave-induced turbulence and are compared with the subsequent aircraft measured true air speed (TAS) signatures were experienced.

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6367-25, Session 5

Simulation of retrieval of wind velocity and vortex observation in a turbulent atmosphere by speckle photography

V. A. Banakh, A. V. Falits, Institute of Atmospheric Optics (Russia); T. Halldorsson, EADS Deutschland GmbH (Germany)

The paper is aimed to study the application of particle image velocimetry (PIV) concept to the atmospheric flow measurement. PIV is a technique which enables instantaneous measurement of the flow velocity at several positions in a plane. Based on the computer simulation, this concept is proved for the atmospheric conditions in the paper. Illuminating laser beam propagates in a turbulent atmosphere and the images of laser spot on aerosol (molecular) atmospheric slice are recorded by CCD camera in a focal plane of the receiving telescope at short intervals. The transverse wind and vortex velocity is simulated by shifting the turbulent phase screens. The pairs of consequent speckle images are cross-correlated to extract wind and vortex velocity from these records. It is shown that such approach enables to detect the atmospheric wind and vortex behind aircraft.

6367-27, Session 6

Boundary layer and air quality monitoring with a commercial lidar ceilometer

C. Münkel, Vaisala GmbH (Germany)

The Vaisala Ceilometer CL31 is a compact and low-cost all-weather lidar designed to report cloud base height and vertical visibility. It works 24 hours a day in fully-automated, hands-off operation mode. Its enhanced optical and electronic concept enables it for tasks that go far beyond its standard duties.

Four different areas will be treated in the scope of this paper:

1. Mixing height assessment from attenuated backscatter profiles with examples from the six ceilometers taking part in the Helsinki testbed research project of mesoscale meteorology.

2. Comparison of particulate matter concentration and near-range ceilometer backscatter with special emphasis on the 22.11.2005 when PM10 concentration values in the Helsinki area exceeded 200 $\mu g/m(c)^{-}$. Additionally, results from a measuring campaign involving a ceilometer, several visibility sensors and a PM10 concentration sensor will be presented.

3. Backscatter profiles from a ceilometer that was installed for one year in an industrial area pointing in a nearly horizontal direction were evaluated in respect of possibilities to monitor chimney plumes, dust concentration, spray caused by cars driving on a wet road, and other phenomena.

4. The standard profile report frequency of the CL31 ceilometer is 0.5 Hz. If the measuring range is reduced to 100 m, the profile report frequency can be raised to 100 Hz, opening new fields of application like the investigation of falling hailstones.

6367-28, Session 6

Methodology of dimensionless multiplicative decomposition for atmospheric lidar evaluation

R. R. Agishev, Kazan State Technical Univ. (Russia); B. M. Gross, City College/CUNY (USA); A. Comerón, Univ. Politècnica de Catalunya (Spain)

We present a multiplicative decomposition methodology as a generalization and expanding a series of works [1-4] we recently performed. It can be widely used to evaluate a broad range of lidar system capabilities for a variety of lidar remote sensing applications and to serve as a basis for selection of appropriate lidar system parameters for a specific application.

Analysis of lidar performance is traditionally based on examination of a SNR, which comprehensive nature makes it a useful tool for assessing a given lidar system. However, it is also a weak point, because it obscures the impact of the different components. When assessing lidar capacities, a significant number of parameters and external factors must be taken into account, and it is often not clear how each system and/or environmental parameter can quantitatively affect the ultimate performance.

To overcome the weak points mentioned, in [1], we introduced a dimensionless spatial filtering efficiency criterion to compare different lidar instruments stability against background radiation. In [2-3], we obtained a SNR multiplicative decomposition, applicable for backscattering lidars, DIAL and topographic lidars to be able determining the achievable operation range, minimum detectable gas concentration, etc. In [4], we used the dimensionless parameterization to study the typical lidar detectors performance.

The present extension and generalization of approaches mentioned, provides uniform and objective methodology to evaluate a broad range of lidar types (aerosol, Raman, DIAL), operating on different targets (backscatter or topographic) and can be used within the lidar community to compare different lidar instruments.

References.

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2. R.Agishev at al. Applied Physics B, vol. 79, No.2, pp.255-264 (2004).

3. R.Agishev at al. Applied Physics B, vol. 80, No. 6, pp. 765-776 (2005).

4. R.Agishev at al.Optics and Lasers in Engineering (2006, accepted).

6367-29, Session 6

A simulation approach for airborne DIAL systems

A. Boerner, C. Kiemle, M. Wirth, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

Trace gases are components of the Earth's atmosphere influencing weather and climate significantly. They play an important role in atmosphere's chemistry.

Terrestrial and airborne Differential-Absorption-Lidar-Systems (DIAL) designed for atmospheric investigations are operational for almost 20 years. Based on the long-time experience in development and operation, DLR Lidar group initiated an airborne water vapour Lidar experiment, which will perform it's first test flight in 2006.

Software simulation is one of the major tools during development of such complex opto-electronic systems. It allows the optimization of system parameters and observation conditions, the development and test of data processing software and the estimation of the capabilities of the sensor system in terms of product quality.

The paper describes the physical basics and the DLR DIAL concept. The simulation approaches end results are presented.

6367-30, Session 6

Improving estimation accuracy of gas concentration in differential absorption lidar

S. Yin, W. Wang, Univ. of Electronic Science and Technology of China (China)

In industry and military region, industrial emission and chemical agents releases are harm to people. To protect the health and safety of civilians and military personnel, there is a critical need for remote sensing of this hazardous gas. Differential absorption lidar has been proven to be a sensitive method for remote sensing path-integrated pollutant and chemical gas concentration over large area.

As DIAL systems are affected by various noise factors such as atmospheric turbulence, target speckle, detection noise and so on, the measured concentration is corrupted by noise, and cannot be estimated accurately. However, when observations, predictions, estimations, and various covariance of Kalman filter algorithm are decomposed into lower resolution levels, due to filtering effects of wavelet transform, noise can be restrained while behavior of concentration is exposed. In this paper, the multiresolution Kalman filter approach is applied to estimate the path-integrated concentration (CL) from DIAL time series data where measurements are available at only one resolution level, and uses the wavelet transform as a means for mapping data between different resolution levels.

The approach was evaluated for a variety of synthetic lidar data created with a program designed to model the various noise sources, including atmospheric turbulence, reflective speckle, and detection noise, which affect lidar signals. The simulations show that our algorithm is effective for improving the measurement accuracy of gas concentration in DIAL and performs better than Kalman filtering and wavelet transform visually and quantitatively.

Optics/Photonics in Security & Defence Plenary Presentations

6394-200, Session 1

Optics and Photonics for Defence and Security: A Swedish Perspective

L. M. Klasen, Swedish Defence Research Agency (Sweden)

Many important defence and security issues involve optics and photonics. This presentation will discuss the role of optics and photonics in Defence and Security from a Swedish perspective. Examples of some relevant results in optical systems and technology under reseach and development will be given. Important problem areas will be highlighted and directions for future reserach will be proposed.

6394-201, Session 1

United States Air Force Sensor Challenges

P. F. McManamon, Air Force Research Lab. (USA)

The Sensors directorate of the Air Force Research Laboratory will be briefly described. This directorate spent $456M last year, and employed about 750 government people, and about 1250 people, including support personnel. Then the new cross directorate initiatives of the Air Force research Laboratory will be described. These are called Focused Long term Challenges, or FLTCs. There are 8 FLTCs. Sensors play a key role in 3 of these. Lastly a number of long term visions for sensing and countermeasures will be described. This will describe the main new thrusts we are pursuing in the Sensors directorate.

Conference 6394: Unmanned/Unattended Sensors and Sensor Networks III

Monday-Tuesday 11-12 September 2006

Part of Proceedings of SPIE Vol. 6394 Unmanned/Unattended Sensors and Sensor Networks III

6394-01, Session

Critical unmanned vehicle and unattended sensor technologies

G. R. Gerhart, U.S. Army Tank-Automotive Research, Development and Engineering Ctr. (USA)

This talk will discuss current and future unmanned ground vehicle (UGV) capabilities for military and commercial applications. Key technologies include network communications, platform mobility and control, power and energy, intelligent behaviors, sensor integration and fusion, perception, human-machine interface and payload deployment. Platform sensors play an important role in terrain localization, operator perception, dynamic stability, area surveillance, and health monitoring. These systems need to be cost effective, reliable, modular "plug and play," and low power.

Unmanned Ground Vehicles (UGVs) provide a safe standoff distance for soldiers and their civilian counterparts in many physical security and force protection applications. Intelligent mobile platforms with diverse sensor payloads can execute complex behaviors associated with target tracking, mine and innovative explosive device (IED) detection and mitigation, security checkpoint screening, wide area surveillance, and many others. A unique opportunity exists to automate many security processes by integrating UGVs and unattended ground sensors (UGSs) into a network with human supervisory control of these assets. Some attention will be given to the tradeoffs between near term human supervisory control and higher levels of autonomy for these types of robotic systems.

6394-03, Session 1

Coordination of mobile robots to complement sensor networks

K. Schilling, M. Hess, M. Saska, Univ. Würzburg (Germany)

Mobile robots offer interesting potential to adaptively position sensor payloads at appropriate places in order to characterize a dynamically changing environment in cooperation with a static sensor network. A typical example in fire fighting applications relates to dissipation of pollutants, which are dangerous for humans. This contribution provides details about robust unmanned rovers (outdoor MERLIN) as well as helicopters, acting both as mobile sensor carrying device. Coordination strategies are addressed, such that these mobile robots complement in a suitable way an available static sensor network. In particular adaptive path planning approaches are outlined in order to plan an efficient trajectory for the mobile robots in reaction to the measured environment data and their dynamics. On basis of localisation data the payload measurements from the different sources will be fused to provide a consistent scenario. Related data flow concepts integrating mobile teams composed of humans and mobile robots have been developed and tested within the European Union research project PeLoTe.

6394-04, Session 1

Cohort: UxV - UGS teams in support of complex operations

B. L. Digney, Defence Research and Development Canada (Canada)

No abstract available

6394-05, Session 1

A software design approach for heterogeneous systems of unattended sensors, unmanned vehicles and monitoring stations

W. J. Smuda, U.S. Army Tank-Automotive Research, Development and Engineering Ctr. (USA)

The design and implementation of software for network systems of diverse physical assets is a continuing challenge to sensor network developers. The problems are often multiplied when adding new elements, and when reconfiguring existing systems. For software systems, like physical systems, explicit architectural descriptions increase system level comprehension. Coupled with well defined object oriented design practices, system extensibility is defined and software reuse and code composition are enabled.

Our research is based on model driven design architecture. High level system models are defined in the Unified Modeling Language (UML), the language of the software engineer. However, since most experimental work is done by non-software specialists, (electronics Engineers, Mechanical Engineers and technicians) the model is translated into a graphical, domain specific model. Components are presented as domain specific icons, and constraints from the UML model are propagated into the domain model. Domain specialist manipulate the domain model, which then composes software elements needed at each node to create an aggregate system.

6394-06, Session 1

Behavior guided UAV sensors for IED defeat

K. Bharadwaj, Northrop Grumman Corp. (USA)

In this paper we present a framework to analyze behavior patterns based on human anthropology that guides the conventional sensor payloads in IED detection. Current work to combat the IED threat is on actual physical detection of the explosive material or transmitters. However, the problem is adaptability of the adversaries, who switch to new materials or triggering mechanisms as soon as a detection technique is developed. The approach we outline in this paper is to develop a capability that will enable the detection of behavioral patterns of the adversary such as hostile intent, supply chains, command and control structures, etc. We would like to stress that the proposed approach may be used in conjunction with or in addition to conventional methods for IED detection and forensics, such as the use of chemical sensors, or electronic jamming systems like the Shortstop Electronic Protection System (SEPS) or Warlock Green.

We will show a technical approach to build models of the urban environment and of the terrain, including a map of the battlefield together with data that could be used to determine the possible distribution of the enemy combatants and their ammunition resources, a model of enemy behavior in terms of the IED threat, and a model of the currently deployed friendly forces. We will use a combination of lattice-theoretic formal concept analysis and machine learning to develop models of the battlefield, behavior of the enemy, and current deployment of friendly forces, from data obtained from level 1 target tracking (e.g., obtained from sensors, human informants etc.) and a record of previous histories of enemy behaviors.

References:

K. Bharadwaj, T. Sathyan, A. Sinha, and T. Kirubarajan, "Intelligence-aided multitarget tracking for urban operations: a case study - Counter terrorism", SPIE Defense & Security Symposium, April 17-21 2006.

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6394-08, Session 2

Electro-optical signature analysis for personnel detection in urban environments

J. M. Cathcart, Georgia Institute of Technology (USA)

Georgia Tech has initiated a research program into the issues surrounding the detection of covert personnel present in a wide variety of scenarios. This program focuses on a detailed phenomenological analysis of human physiology and signatures with the subsequent identification and characterization of potential observables - particularly in the context of urban environments. For this current effort, several electro-optical sensing modalities have been evaluated for use as a component in an unattended sensor suite designed to detect personnel. These modalities include active sensors (e.g., vibrometry) and passive sensors (e.g., multi-spectral, thermal). This paper will discuss the utility of these various electro-optical signatures in this application, their impact on sensor requirements, and proposed sensor designs that meet the detection objective. A discussion of the utility of electro-optical sensors as components in a multi-modal sensor platform will also be presented.

This work is supported under a grant from the Army Research Office.

6394-09, Session 2

Multifunctional self-sensing microcantilever arrays for unattended detection of chemicals, explosives, and biological agents

J. D. Adams, B. Rogers, R. Whitten, Nevada Nanotech Systems, Inc. (USA)

Unattended sensing applications necessitate robust, compact, low-cost, low-power sensor units. The microcantilever-based Self-Sensing Array (SSA) technology developed by Nevada Nanotech Systems, Inc (NNTS) is a strong candidate for such units. SSA technology is expected to provide the selectivity, sensitivity, durability, low cost, and low power needed for unattended sensors and sensor networks. The sensor employs a variety of sensor coatings and the ability analyze the electrical and thermal properties of molecules on the cantilevers. This so-called Lab-on-a-Tip(tm) technology could lead to enhanced chemical identification capabilities of the trace detection platform.

6394-10, Session 2

Nanomechanical chemical sensors based on functionalized MEMS arrays

P. G. Datskos, N. Lavrik, Oak Ridge National Lab. (USA); M. J. Sepaniak, P. Dutta, P. J. Chapman, The Univ. of Tennessee (USA)

Developments in micro-electro-mechanical systems (MEMS) and nano-electro-mechanical systems (NEMS) have enabled the use of new transduction modes that involve mechanical energy and are based primarily on mechanical phenomena. While MEMS and NEMS represent a diverse family of designs, devices with simple cantilever configurations are especially attractive as transducers for chemical and biological sensors. In the present work we use arrays of differentially coated cantilevers to detect chemicals based on the response patterns of the array. The use of pattern recognition with differentially-responding sensors is the scenario that is employed in electronic noses and tongues. However, we have demonstrated that using larger, well designed arrays of differentially coated cantilevers coupled with artificial neural network (ANN) techniques can provide information on the identity and concentration of target chemicals. We will present our results and discuss future directions.

6394-11, Session 2

Progress on integrated multiparameter MEMS sensor

S. Rajic, The Univ. of Tennessee (USA); W. R. Lawrence, Tesla Technologies Inc. (USA); P. G. Datskos, The Univ. of Tennessee (USA)

We present the results of our work-in-progress for an integrated MEMS based multi-mode multi-parameter sensor. This type of orthogonal sensing platform can produce a very high confidence signal in a very low-cost and miniature package. An example of the parameters that are being simultaneously incorporated are acoustic, infrared, magnetic, and chemical. Additionally we have recent data on individual parameters such as nuclear, biological and inertial that can eventually also be incorporated into this type of sensing architecture. The readout of the individual MEMS devices is based on piezoresistive and optical beam/CCD. In one embodiment, over a million devices can be read essentially simultaneously providing substantial sensor element redundancy. In addition, this massively paralleled approach can form a system with both large dynamic range and high sensitivity.

6394-31, Session 2

Autonomous vision networking: miniature wireless sensor networks with imaging technology

G. Messinger, Avaak Inc. (USA)

The recent emergence of integrated PicoRadio technology, the rise of low power, low cost,

System-On-Chip (SOC) CMOS imagers, coupled with the fast evolution of networking protocols and digital signal processing (DSP), created a unique opportunity to achieve the goal of deploying large-scale, low cost, intelligent, ultra-low power distributed wireless sensor networks for the visualization of the environment. Of all sensors, vision is the most desired, but its applications in distributed sensor networks have been elusive so far. Not any more.

The practicality and viability of ultra-low power vision networking has been proven and its applications are countless, from security, and chemical analysis to industrial monitoring, asset tracking and visual recognition, vision networking represents a truly disruptive technology applicable to many industries. The presentation discusses some of the critical components and technologies necessary to make these networks and products affordable and ubiquitous - specifically PicoRadios, CMOS imagers, imaging DSP, networking and overall WSN system concepts. The paradigm shift, from large, centralized and expensive sensor platforms, to small, low cost, distributed, sensor networks, is possible due to the emergence and convergence of a few innovative technologies. Avaak has developed a vision network that is aided by other sensors such as motion, acoustic and magnetic, and plans to deploy it for use in military and commercial applications. In comparison to other sensors, imagers produce large data files that require pre-processing and a certain level of compression before these are transmitted to a base-station, in order to minimize the load on the network. Some of the most innovative chemical detectors currently in development are based on sensors that change color or pattern in the presence of the desired analytes. These changes are easily recorded and analyzed by a CMOS imager and an on-board DSP processor. Image processing at the sensor node level may also be required for applications in security, asset management and process control. Due to the data bandwidth requirements posed on the network by video sensors, new networking protocols or video extensions to existing standards (e.g. Zigbee) are required. To this end, Avaak has designed and implemented a ultra-low power networking protocol designed to carry large volumes of data through the network. The low power wireless sensor nodes that will be discussed include a chemical sensor integrated with a CMOS digital camera, a controller, a DSP processor and a radio communication transceiver, which enables relaying of an alarm or image message, to a central station. In addition to the communications, identification is very desirable; hence location awareness will be later incorporated to the system in the form of Time-Of-Arrival triangulation, via wide band signaling. While the wireless imaging kernel already exists and will be demonstrated, specific applications for chemical detection are under development by Avaak, as part of a co-founded program from ONR and DARPA. Avaak is also designing vision networks for commercial applications - some of which are undergoing initial field tests.

6394-32, Session 2

Sensor network parametric routing protocol simulation and test performance

M. Nassr, A. M. Mielke, J. R. Frigo, S. Eidenbenz, M. C. Smith, A. Hansson, Los Alamos National Lab. (USA)

We have developed and tested a set of multi-path, parametric

probabilistic routing protocols against the existing, established set of

routing protocols. Measuring both full-fledged QualNet simulation in addition to live mica2 tests, our set of protocols are tested to determine if they provide efficient and reliable communication in sensor networks. Our protocols require no neighborhood maintenance and only make local broadcast decisions based on hop-count, current distance to destination, and source distance to destination. In this sense, our routing protocols are similar to a gossip strategy with the distinction that each packet contains metrics that will modify the broadcast probability. This makes the parametric protocols more computationally attractive than a protocol with regular maintenance and global network knowledge requirements, such as AODV, which can be especially sensitive to misinformation. Demonstrating that parametric routing protocols provide as good or better end-to-end performance than protocols with these requirements will give our protocols a clear robustness advantage without compromising quality of service. In addition, we have developed a passive SmartMonitoring system that is able to unify multiple sensor monitoring stations to output a real-time global description of every packet being sent and received by sensors in the network. In this way, we can directly compare simulation results (where global packet knowledge is a given) against mica2 test results. We are also able to observe the immediate effects of changes in network topologies without being confined by the space and protocol interfering constraints of saving packet data locally on the mica2's for later retrieval.

6394-33, Session 2

Field testing of new unattended small size seismic modules for detection of various targets

A. Pakhomov, T. Goldburt, General Sensing Systems, LLC (USA)

General Sensing Systems (GSS) has achieved outstanding results in the performance of its seismic systems with near zero false alarm rates for

the detection of walking, running, and jumping persons. These results were realized in a number of detection systems and in particular in small size seismic detection modules. Preliminary testing of the seismic module in various environment noise conditions showed that such a small unattended module can be successfully used for other target detection. Potential targets include light and heavy vehicles, helicopters, aircraft, ships, etc. This paper describes some preliminary results of such target detection and preliminary experimental data about corresponding detection range. We show that the new unattended, small size detection module demonstrates sufficient, highly reliable performance in various environment conditions.

6394-13, Session

Real time automated 3D sensing, imaging and monitoring of dynamic microscopic biological events

B. Javidi, I. Moon, S. Yeom, Univ. of Connecticut (USA); E. M. Carapezza, Defense Advanced Research Projects Agency (USA)

No abstract available

6394-12, Session 2

Battery-free power for unattended ground sensors

V. A. Moldt, Ambient Control Systems Inc. (USA); V. Acharya, M. DeJong, U.S. Army Research, Development and Engineering Command (USA)

With a significant shift in the nature of war fighting from high intensity, large scale, advanced weaponry based conflicts to low intensity, low technology, long- term insurgencies, the C2D Army Power Division at Ft. Monmouth, NJ sought to address the requirements of current military operations. In this regard, C2D focused on exploring, developing and deploying power technologies that support the unique power requirements of our current missions, which rely more heavily on Unattended Ground Sensors (UGS) for wide area monitoring and persistent surveillance.

To address these critical issues, C2D Division conducted a 2 part program with Ambient Control Systems, developer of a battery-free power source that can operate for 10-20 years in extreme temperature conditions. Phase I identified, characterized and selected UGS that could significantly benefit from a robust, long-term power source, based on UGS capability, mission duration, power requirements and user respective. In Phase II, Ambient began the development a NEPAL (Never Ending Power from Ambient Light) module designed to power the selected UGS in the operational environment of its designated mission area. The configuration will consist of a solar array of high efficiency solar cells (HEPV), utilized by Ambient to optimize the energy converted from light over a wide range of light conditions, and a capacitor bank to store the energy for use during periods of inadequate light. The NEPAL is designed to field and forget - eliminating frequent battery replacements that may compromise the mission by giving away UGS locations and putting battery replacement teams at risk.

6394-14, Session 3

Parallelization and automation of a blind deconvolution algorithm

C. L. Matson, Air Force Research Lab. (USA); K. Borelli, KJS Consulting (USA)

Blind deconvolution is a method to jointly estimate both an object being imaged and the system blurring functions from one or more blurred and noisy images of the object. Blind deconvolution has been used with great success in imaging both space objects and terrestrial scenes. However, because blind deconvolution algorithms are iterative in nature, the processing time required to reconstruct a single image can be on the order of seconds to hours depending upon the number of data frames included in the reconstruction process. Furthermore, in their current state of development, blind deconvolution algorithms tend to require a 'human in the loop' to obtain the highest-quality reconstructions. In order to make blind deconvolution techniques suitable for unmanned and unattended sensor applications, they must be fast and be able to process imagery without human interaction. In this talk, we discuss progress we have made in both algorithm speed improvements and in automating algorithm parameter selection. Our speed improvements are based upon using parallel processing techniques with an emphasis on distributed memory architectures, where each frame of data is split among multiple processors on multiple nodes. We show that, even with the communication overhead associated with distributed memory architectures, significant speed improvements are possible. We also discuss progress we have made in automatically determining from the data itself optimal values for parameters used by in the blind deconvolution process.

6394-15, Session 3

Orthoscopic long-focal-depth 3D integral imaging

M. Martínez-Corral, R. Martínez-Cuenca, G. Saavedra, Univ. de València (Spain); B. Javidi, Univ. of Connecticut (USA)

Currently, much visual information is presented to users through computer monitors, TV screens, or even through cellular-phone or PDA screens. The information society increasingly demands the display of not only plane images but also of 3D images with continuous perspective information. Although the search for optimum 3D imaging and display techniques has been the subject of research from much more than for a century, it has been in the last several years when sensor technology is approaching the level required for realization of 3D imaging systems. The so-called integral imaging, which is a 3D imaging technique specially suited for the above requirements, works with incoherent light, and provides with autostereoscopic images without the help of any special glasses. In an integral-imaging system, an array of microlenses generates, onto a sensor such as a CCD, a collection of plane elemental images. Each elemental image has a different perspective of the 3D object. In the reconstruction stage, the recorded images are displayed by an optical device, such as a LCD monitor, placed in front of another microlens array. This setup provides the observer with a reconstructed 3D image with full paralax. Since its inception, InI has satisfactorily tackled many of its challenges. In this sense the useful methods have been proposed to improve the spatial resolution, to enhance the limited depth of field or to expand the viewing area. Other drawbacks still need for smart strategies to face them. In this contribution we show that two of most important challenges of InI can be overcome by a very simple digital signal processing consisting in a global pixel mapping within the elemental images set. Our proposals are supported by both numerical simulations and experimental results.

6394-16, Session 3

Visible and near-infrared combination of images to produce high-security ID tags for automatic identification

E. Pérez-Cabré, M. S. Millán García-Varela, Univ. Politècnica de Catalunya (Spain); B. Javidi, Univ. of Connecticut (USA)

Verification of a piece of information and/or authentication of a given object or person are common operations carried out by automatic security systems that can be applied, for instance, to control the entrance to restricted areas, the access to public buildings, the identification of cardholders, etc. Such security systems are vulnerable to a considerable extent depending on the ease of counterfeiting the information used as a piece of identification for verification and authentication. To protect data against tampering, the signature that identifies an object is usually encrypted to avoid an easy recognition at human sight and an easy reproduction using conventional devices for imaging or scanning. To make counterfeiting even more difficult, we propose to combine data from visible and near infrared (NIR) spectral bands. By doing this, neither the visible content nor the NIR data by their own are sufficient to allow the signature recognition and thus, the identification of a given object. Only the appropriate combination of both signals permits a satisfactory authentication. In addition, the resulting signature is encrypted following a fully-phase encryption technique and the obtained complex-amplitude distribution is encoded in an ID tag. Spatial multiplexing of the encrypted signature allows us to build a distortion-invariant ID tag, so that remote authentication can be achieved even if the tag is captured under rotation or at different distances. We also explore the possibility of using partial information of the encrypted signature to simplify the ID tag design.

6394-17, Session 3

High secure authentication by optical multifactor ID tags

M. S. Millán García-Varela, E. Pérez-Cabré, Univ. Politècnica de Catalunya (Spain); B. Javidi, Univ. of Connecticut (USA)

Optical ID tags have been proposed as satisfactory items to achieve remote and real-time optical authentication. On the one hand, efforts have been focused on the tag design in order to provide a positive identification

of a given object by recognising a piece of relevant information related to the sought object, even though the receiver captured the ID tag under some types of distortion, such as rotation or variations in scale. On the other hand, demands on increasing security require to cipher the information related to the object (signature) prior to include it in the ID tag. Two proposals were suggested by applying optical encoding techniques: the double-phase or amplitude-based encryption and the fully-phase encryption. Both have in common the scrambling of the signature over a resulting complex-amplitude encrypted image that mostly resembles a noise distribution, and that has no visible relationship with the original signature. A recognition step based on the correlation between the retrieved signature and a stored reference determined the authentication or rejection of the object under surveillance. In this work, we propose to achieve a higher level of security. We combine optical ID tags with the multifactor authentication procedure proposed recently. Instead of basing the identification on a unique signature o piece of information, our goal is to authenticate a given object, or vehicle in our example, by the simultaneous recognition of several factors. Some of them are intrinsic to the vehicle under control. Other factors, act as keys of the authentication step. The information of the whole set of factors used for authentication is included in the designed ID tag. Remote identification of all factors is achieved. We propose this system to be applied to control the access of vehicles in restricted areas, where the demands of security are high.

6394-18, Session 3

Decision fusion strategy for target recognition in hyperspectral images

M. Greco, N. Acito, G. Corsini, M. Diani, Univ. di Pisa (Italy)

The great amount of spectral information collected by hyperspectral sensors leads to a considerable improvement in the performance of target recognition processes. This characteristic makes hyperspectral signal processing very attractive in a lot of military and civilian remote sensing applications, such as automatic target recognition (ATR) and surveillance of wide areas. In this framework there is a growing interest toward the algorithm architectures providing immediate assessment of the observed scenario (real time processing).

A very promising algorithm for target recognition is the Constrained Energy Minimization (CEM) detector. Its popularity stems from the different real time processing architectures proposed in the literature, such as the one based on the line-by-line analysis of the image. However, experimental results have shown that sometimes the CEM filter introduces false alarms (FAs) that correspond to rare objects, whose spectral signatures are very “different” from the spectrum of the target and of the natural background classes in the image.

In this paper we propose a decision fusion strategy to overcome the cited CEM weakness. It exploits the spectral differences among the target of interest and the FAs experienced in actual applications. In particular, the proposed strategy consists of two steps: first, the CEM is applied to the whole image and then, the decisions are refined by measuring the spectral angle between the revealed pixels and the target spectrum, i.e. by using the Spectral Angle Mapper (SAM) algorithm.

In the paper the effectiveness of the fusion strategy is experimentally shown on a real data set acquired over a rural scenario. In particular, the performance of the classical CEM filter and the ones of the two stages algorithm are compared in terms of experimental receiver operating characteristics.

6394-19, Session 3

Introducing secure modes of operation for optical encryption

B. M. Hennelly, T. J. Naughton, T. Dowling, National Univ. of Ireland/ Maynooth (Ireland); B. Javidi, Univ. of Connecticut (USA)

We analyse optical encryption algorithms using the techniques of conventional cryptography. We start from the position that all textbook conventional encryption algorithms are vulnerable to attack. In conventional cryptography, one way to counteract this is to use secure modes of operation. We introduce the concept of secure modes to optical encryption and analyse the results in the context of known conventional and optical attacks. We analyse only the mathematical algorithms themselves, and do not consider the additional security that arises from employing these algorithms in physical optical systems.

6394-20, Session

The network: a revolutionary capability for the warfighter

J. A. Parmentola, U.S. Army (USA)

No abstract available

6394-22, Session 4

Discriminating mortar launch/impact events utilizing acoustic sensors

M. E. Hohil, S. V. Desai, U.S. Army Research, Development and Engineering Command (USA); A. Morcos, U.S. Army Research, Development and Engineering Ctr. (USA)

Feature extraction methods based on the discrete wavelet transform and multiresolution analysis facilitate the development of a robust classification algorithm that reliably discriminates between launch/impact artillery events via acoustic signals produced during detonation. Distinct characteristics arise within the different explosive event’s acoustic signatures. Impact events emphasize concussive and shrapnel effects, while launch events utilize explosives designed to expel and propel artillery rounds from a gun tube. Both event types’ acoustic signatures have inherent evidence of these readily identifiable characteristics. The ensuing acoustic signatures are characterized by variations in the corresponding peak pressure and rise time of the waveform. Also differences in the ratio of positive pressure amplitude to the negative amplitude, variations in the prominent frequencies associated with the blast events and variations in the overall duration of the resulting waveform provide distinguishing features. Unique attributes can be identified that depend upon the properties of the gun tube, projectile speed at the muzzle, and the explosive/concussive properties associated with the explosive agent. The discrete wavelet transform is used to extract the predominant components of these characteristics from the aforementioned acoustic signatures at ranges surpassing 2km. Highly reliable discrimination is achieved with a feedforward neural network classifier trained on a feature space derived from the distribution of wavelet coefficients and higher frequency details found within different levels of the multiresolution decomposition. The resulting algorithm provides the capability to reliably classify events (i.e. launches/impacts) with an accuracy exceeding 88%.

6394-23, Session 4

Implementation of algorithms to discriminate between chemical/biological air burst and high explosive air burst

S. V. Desai, M. E. Hohil, U.S. Army Research, Development and Engineering Command (USA)

No abstract available

6394-24, Session 5

An innovative approach for through-wall imaging

A. Beeri, Camero, Inc. (Israel)

An innovative approach is introduced herein for three-dimensional (3D) imaging of objects or people hidden behind obstacles such as walls. The Xaver 800, new micro-power Ultra Wideband (UWB) radar utilizes unique signal processing and image processing algorithms, enabling real time acquisition and presentation of 3D images with high resolution of objects hidden behind walls. ‘Xaver 800’ offers the ability to perform life-saving operations with greater success and with a smaller risk to the operatives and to those they are trying to protect.

Many technical challenges are imposed while working in real world environment. Tough link budget, distortions and de-focusing while traveling through complex walls constructions are only partial list of the problems an effective through-wall-imaging system should overcome.

In this paper we will reviewing some of the unique approaches of signal and image processing facing these main challenges to be a tool the user can trust on in the field in order to be able to take the right decisions in real time.

6394-25, Session 5

Characterizing varying and heterogeneous radar land clutter: a site-specific simulation in Finnish environment

J. Jylhä, R. I. Kerminen, J. V. Vihonen, T. K. Ala-Kleemola, A. J. E. Visa, Tampere Univ. of Technology (Finland)

Land clutter is often a crucial issue against which radars have to operate. Utilizing Geographic Information Systems, knowledge-aided approaches have taken a steady foothold in land clutter modeling and simulation. With a large amount of available information, clutter areas and even certain point clutters are predictable. Still notable stochastic elements remain. First, a model can not contain every stone or exact shapes of the ground which may form dominant clutter sources. Hence precise spatial occurrence of them is unpredictable. Second, individual swaying objects, such as masts, cause unforeseeably fluctuating but, perhaps, spatially deterministic clutter. Last, vegetation produces altogether random clutter. A need for incorporating deterministic and stochastic attributes realistically into a model or a simulation exists.

This paper augments the depth of site-specific clutter models with a simulation. An example case considers a pulsed, air surveillance radar and low-angle clutter in Finnish environment. Included auxiliary information consists of an elevation model, a terrain class model, and a flight obstacle register. Basically, the underlying clutter generation mechanism rests on a well-known signal model, but the application is novel. This knowledge-aided approach determines land and sea visibility and uses peculiar characterization for different terrain types such as coniferous forest, field, and lake. Terrain clutter consists of surface (ground) and volumetric (vegetation) components. Point clutters (masts) have own unique statistics. Immobile clutter sources deserve special treatment through potential non-fluctuating behavior. The substance originates from a truthful radar signal formation model and from an insight into the clutter characterization involving spatiality, stationarity, and heterogeneity.

6394-26, Session 5

Depth-of-focus (DOF) in synthetic aperture radar (SAR) imagery

U. K. Majumder, Air Force Research Lab. (USA)

Depth-of-Focus emulates confocal microscopy that provides crisp 3D resolution by using “Full Aperture / Single Pass” and desired imaging geometry where “Full Aperture” means making a complete circle around the target. The idea is to examine the scene at different focus planes in order to determine at what slice a particular target is in focus. With this information for all targets, we can create a 3D rendering by “mosaicing” all the focused targets together. A DOF equation needs to be developed for creating 3D renderings, as it will tell how long a target at a given location can remain in focus as we alter the focus plane. The payoff will be new 3D resolution in SAR imagery from single pass, full aperture systems. In addition to conventional depression angles, DOF research could examine the benefits of utilizing increased depression angles when collecting data along a full aperture with a single pass of the scene.

6394-27, Session 6

A reconfigurable low-cost thermal imager for unattended ground sensors

P. A. Manning, N. J. Parkinson, T. Phillips, D. A. Beale, QinetiQ Ltd. (United Kingdom)

Thermal imaging detectors built using only CMOS foundry materials and processes (Foundry UNcooled Thermal Imaging - FUNTI) have been described previously, primarily aimed at civil applications such as automotive air-bag control. A prototype thermal imaging sensor using this technology has now been developed, which is suitable for use in military Unattended Ground Sensor networks. A key feature of this sensor design is the ability to switch between a conventional 2-d imaging mode and a linear array operating mode. The linear mode offers a greatly reduced data-rate whilst retaking an imaging capability for moving targets, which enables the power consumption and data rate of the sensor to be optimised for the constraints of particular operational scenarios. The paper will describe the sensor architecture, compare the two operating modes and provide comparative examples of imagery captured between the operating modes.

6394-28, Session 6

Two-interferometer fiber optic sensor

M. Szustakowski, M. Kondrat, W. M. Ciurapinski, Wojskowa Akademia Techniczna (Poland)

Ordinary perimeter security systems consist of many individual sensors with detection range 200-300 meters. These limitations are connected with physical phenomena that are used in microwave and infrared barriers as well as in ground and fence cable sensors. On the contrary, fiber optic perimeter sensors can be applied in the range of many kilometers and zone length 200-300 meters is degradation of their possibilities.

This paper presents investigation results of a new generation of the fiber optic perimeter sensor in a two Sagnac and Michelson interferometers configuration. This system can detect a potential intruder and determine its position along a protected zone.

We propose a method that makes use of the inherent properties of both interferometers. After demodulation of signals from both interferometers, obtained amplitude characteristic of the Sagnac interferometer depends on position of a disturbance along the interferometer, while amplitude characteristic of the Michelson interferometer do not depend on this position. So, quotient of both demodulated characteristics is proportional to the position of the disturbance.

Arrangement of a laboratory model of the sensor and its signal processing scheme is presented. During research of a laboratory model, it was possible to detect the position of the disturbance with resolution of about 40m along a 6-km long sensor.

6394-29, Session 6

Application property of hybrid FRP reinforcing rods for sensing and self-diagnosing of concrete fracture

S. Park, Daejeon Univ. (South Korea)

For investigating self-diagnosis applicability, a method based on monitoring the changes in the electrical resistance of hybrid FRP(Fiber Reinforced Plastic) (having electrical property) reinforced concrete has been tested. Then after examining change in the value of electrical resistance of carbon fiber in CFRP (non-hybrid type), CFGFRP and CFAFRP (hybrid type) before and after the occurrence of cracks and fracture in non-hybrid and hybrid FRP reinforced concrete at each flexural weight-stage, the correlations of each factors (the changes in electrical resistance and load as a function of strain, deflection and e.t.c) were analyzed. As the results, it is clarified that when the carbon fiber tows fracture, the electrical resistance of it increase largely, and afterwards hybrid FRP composites can be resist the load due to the presence of the reinforced fiber, for example, glass fiber or aramid fiber tows. Therefore, it can be recognized that hybrid FRP (including carbon fiber) reinforcing rods could be applied for sensing and self-diagnosing of fracture in reinforced FRP concrete.

6394-30, Session 6

Partial polarization characterization based on the Kullback relative entropy

P. Réfrégier, Institut Fresnel (France); F. Goudail, Univ. Paris-Sud II (France)

The analysis of polarization and of depolarizing capabilities of materials is a technique of growing interest in different domains of applications. This is also the case for defence and security for which the determination of material characteristics can be of great interest in remote sensing and control application. However, until now, the analysis of polarization properties has been essentially limited to second order statistical characteristics such as Stokes vectors and/or Mueller matrices. There nevertheless exist other physical properties that cannot be characterized by such second order statistical characteristics.

We will demonstrate that the Kullback relative entropy leads to a relevant characterization of different properties that cannot be obtained by the measurements of Stokes vectors and/or Mueller matrices. For that purpose we will show how the Kullback relative entropy, which is a physically meaningful measure of proximity between probability density functions (PDF), allows one to compare a partially polarized light with different optical states of reference.

In particular, for optical waves with Gaussian fluctuations, the standard degree of polarization is a simple function of the Kullback relative entropy between the considered optical light and a totally depolarized light of the same intensity. It will be demonstrated that one can generalize this relation between partially polarized light and different optical states of reference in order to measure new characteristics such as a degree of anisotropy and a degree of non gaussianity. We will discus experimental configurations that can be discriminated with these new degrees of partially polarized light.

Conference 6395: Electro-Optical and Infrared Systems: Technology and Applications III

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6395-01, Session 1

Swedish IR and E/O system research

I. G. E. Renhorn, Swedish Defence Research Agency (Sweden)

Infrared and electro-optical spectral imaging has numerous important military applications, such as night vision and aerial surveillance. Growing commitments in international operations gives rise to increasing demands on reconnaissance and surveillance systems, precision targeting, E/O warfare and stealth technologies, sensor networks and information processing.

In broadband imaging, target detection and classification is primarily based on the target to background contrast and the observed shape of objects in the scene. This spatial signature varies strongly with the posture of the target. The spatial signature is also strongly affected by partial obscuration of the target, for example under a partial cover of vegetation and by camouflage. Spectral detection and classification relies on the spectral signature of the surface. The near-invariance of spectral signatures, in comparison with the large variations possible in a spatial signature, is a main factor underlying the interest in spectral imaging for targeting purposes.

Swedish research on infrared and electro-optical sensor systems comprised of combinations of sensors characterized by high spatial or spectral resolution will be discussed. For hyperspectral imaging in particular, the amount of information collected per pixel can be larger than for any other imaging technique. This amount of information cannot be readily interpreted by a human operator. Instead, images must be processed by computers in order to extract information of interest.

6395-02, Session 1

Optimisation of QWIP performance for high-temperature and low-background applications

A. Gromov, C. Asplund, S. Smuk, H. Martijn, Acreo AB (Sweden)

The ultimate performance of QWIP implies hard requirements on the response-to-dark-current ratio for both high temperature and low background, e.g. space, applications. A way to improve this ratio by finding the optimal combination of band structure and material parameters was suggested. The experiments were conducted on GaAs/AlGaAs structures optimised for 8.5 and 14.5 μm with similar types of band profile.

The doping concentration in quantum well (QW) is the principal parameter in such optimisation because it affects linearly the photocurrent and exponentially the dark-current. As a result of the first experiment series we found the optimal value of QW doping concentration corresponding to the maximum response-to-dark-current-ratio, verifying thus the validity of the widely used hydrodynamic model.

In order to compensate for reduction in quantum efficiency, caused by decreased in the first series doping concentration, the quantum well density was varied. This variation changes the balance between the quantum efficiency and photoconductive gain for the QWIP of same thickness. A critical thickness of the main detector barrier, when the temperature-independent component of the dark current increases drastically, was determined from the experiment.

For low background applications, especially in combination with long wavelength detection, it is not enough to only reduce the thermally-assisted and sequential tunnelling components of the dark current. Other sources of the dark current usually neglected at high temperature start to play a role. Interface shape and background doping in the barriers are examples of increasingly important factors. We discuss the contribution of these factors to the dark current.

6395-03, Session 1

MOMS: multi-optical mine detection system: project overview

A. Linderhed, S. K. Sjökvist, O. Steinvall, D. Letalick, G. Tolt, T. R. Chevalier, S. Nyberg, H. Larsson, M. Uppsäll, D. Menning, Swedish Defence Research Agency (Sweden)

The objective of this paper is to present the Swedish land mine and UXO detection project “Multi Optical Mine Detection System”, MOMS. The goal for MOMS is to provide knowledge and competence for fast detection of mines, especially surface laid mines. The first phase, with duration 2005-2009, is essentially a feasibility study which focuses on the possibilities and limitations of a multi-sensor system with both active and passive EO-sensors. Sensor concepts used, in different combinations or single, includes 3-D imaging, gated viewing, retro reflection detection, multispectral imaging, thermal imaging, polarization and fluorescence. The aim of the MOMS project is presented and research and investigations carried out during the first years will be described.

6395-04, Session 1

Compact multichannel optical Fourier spectrometer

A. Manuilskiy, H. Andersson, G. Thungström, H. Nilsson, Mid Sweden Univ. (Sweden)

In this work are shown the principle, design and first experimental results of a new type of multi channel Fourier transform (FT) spectrometer for visible (VIS) and infrared (IR) region operating in real time. The main principle of this spectrometer is that measured collected and collimated wide spectra radiation passes through a linear array or matrix of optical Fabry-Perot interferometers. This is fabricated as an optical stepped wedge or wedge made e.g from Si. Each interferometer is placed in front of and close to each element of the array detector. By processing the signal the spectrum of the optical radiation can be extracted. This design does not require intermediate optics between interferometer and array detector and allows for a reliable and extremely compact construction. Production cost can be low because the design allows integration of the simple wedge type interferometer with existing array or matrix detectors, e.g. CCD camera. One other benefit is that the shape of the interferometer determines whether spectrometer is suitable for measuring wide spectra radiation or has the ability to discriminate optical coherent radiation. It can also be designed with one type of interferometer and matrix detector to operate as a multifunctional system for different applications. Experimental results achieved for VIS and NIR range of spectra are promising.

The principals of this design can be used for a variety of applications besides as a spectrometer. For example warning systems for lasers and restricted coherency sources and also filtering of optical signals and for measuring the spectral content working in a wide spectral range.

6395-06, Session 1

Experimental evaluation of underwater range-gated viewing in natural waters

M. Tulldahl, A. Andersson, A. Olsson, P. Andersson, Swedish Defence Research Agency (Sweden)

Neutralizing an underwater mine threat through mine hunting requires identification of the detected and classified underwater object. This is typically accomplished through visual inspection by divers or by a remotely operated vehicle carrying a conventional video camera and illumination. These techniques have range limitations that can potentially be overcome by using laser illuminated range-gated imaging.

In this work we evaluate the imaging performance of a range-gated underwater system in natural waters. Trials have been performed in both turbid and clear water. The field trials show that images can be acquired at significantly longer distances with the gated camera, compared to a conventional video camera. The distance where a target can be detected is increased by a factor of 2. For images suitable for mine identification, the range improvement factor is about 1.3. We also show examples of image processing of the range-gated images, which increases the performance significantly.

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6395-07, Session 1

Measurements of the effect of falling snow on imaging with infrared cameras

A. D. Van Rheenen, L. T. Heen, E. B. Madsen, E. Brendhagen, Norwegian Defense Research Establishment (Norway)

We present results from imaging experiments performed in Norway during the 2005/06 winter season. Pairs of infrared sources with different temperatures are placed at different distances, ranging from 50 to 1200 m, from two focal plane array infrared cameras. One of the cameras is sensitive in the 3 - 5 μm wavelength range and the other in the 8 - 12 μm wavelength range. During the winter months digital sequences of the IR-sources were recorded, under different meteorological conditions. These conditions ranged from perfectly clear, cloudless weather to heavy snowfall. Analysis consists of comparing the perceived contrast, as measured with the cameras, with the "real" contrast as defined by the temperatures of the IR-sources. It is assumed that the transmission coefficient is the product of the atmospheric transmission (without snow) and a transmission factor associated with the falling snow. FASCODE simulations, using the pertinent temperature and humidity data that were measured during the recordings, are performed to characterize the atmospheric transmission coefficient (without snow). A comparison of the experimental results and the simulation results allows one then to estimate the effect of the falling snow on the perceived contrast through an extinction coefficient. Finally, the goal is to correlate the value of the estimated extinction coefficient with the pertinent meteorological parameters.

6395-08, Session 1

Optical signature modeling

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Computer programs for prediction of optical signatures of targets and backgrounds are valuable tools for signature assessment and signature management. Simulations make it possible to study optical signatures from targets and backgrounds under conditions where measured signatures are missing or incomplete. Several applications may be identified: Increase understanding, Design and assessment of low signature concepts, Assessment of tactics, Design and assessment of sensor systems, Duel simulations of EW, and Signature awareness.

At FOI (the Swedish Defence Research Agency) a two-year project has been carried out with the aim of studying methods and modeling programs for detailed prediction of the optical signature of a target in background. Several commercial programs have been used previously at FOI. The project focused on two commercial optical signature prediction programs available at FOI CAMEO-SIM, and RadThermIR. Related to the project was also the McCavity signature prediction program. The main tasks of the project have been: Assembly of a database of input data, Gain experience of different computer programs, In-house development of complementary algorithms and programs, and Validation and assessment of the simulation results.

This paper summarizes the activities in the project and the results obtained. It is organized as a walk-through of all the necessary steps in creating and running a signature modeling case. Some application examples will be given as well as results from validations. The test object chosen is the MTLB which is a tracked armored vehicle. It has been used previously at FOI for research purposes and therefore measurement data is available.

6395-09, Session 1

Evaluation of GSIM: a simulator for missile seekers

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GSIM is a simulator of infrared missile seekers. It simulates a missile flight scenario in a 3D environment from launch to arrival at the target. The radiation from objects and background is calculated using weather parameters, e. g. solar radiation and air temperature. After adding atmospheric transmission and sensor properties, the resulting seeker image is created. The primary output from GSIM is a sequence of images, generated by the seeker during the flight.

In April 2005 helicopter trials were performed, where missile-like image sequences were recorded. The helicopter followed a slant path towards a number of ground vehicles, standing in a field. The recorded data has been used for evaluation of GSIM. At the evaluation, modelled temperature on background and targets was compared with radiometrically measured temperature. Simulations in GSIM were made of a selection of the recorded sequences.

The difference between modelled and measured temperature is about 1 - 2 K, for both targets and background. When comparing the simulated and the original sequence, the visual impression is that there is an apparent similarity between the images. Long distance images show the strongest resemblance to reality, due to the limited level of detail in the background model.

6395-42, Session 1

A compact combined polarimetric and hyperspectral imager

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There is significant interest in utilizing spectral and polarimetric signatures for target detection. Combining these phenomenologies into a single sensor often results in a complex optical system. Here we present a simple optical arrangement to record simultaneously hyperspectral images and broadband polarimetric images. This is implemented as a modification of the HySpex hyperspectral imager operating in the spectral range from 0.4 to 1 micrometres. The resulting images provide horizontal/vertical polarization information as well as spectral information. Results from calibration and testing will be presented.

6395-10, Session 2

Single carbon nanotube based infrared sensors

N. Xi, Michigan State Univ. (USA)

As a one-dimensional nanostructural material, carbon nanotube (CNT) has many unique properties that can be used to build different nano electronic devices and nano sensors. In this paper, the infrared (IR) response of individual single walled carbon nanotube (SWNT) is studied. A single walled carbon nanotube is assembled onto a pair of electrodes to make an electrical connection. Two Schottky barriers are formed at the contacts between the carbon nanotube and the two electrodes. Incident infrared light can introduce electron-hole pairs within the carbon nanotube. The electrons and holes are separated by an applied external electric field between the two electrodes. The separated carriers contribute to the current flowing through the carbon nanotube and form photocurrent. By monitoring the photocurrent, the infrared incident to the carbon nanotube can be detected and quantified. Based on this principle, a single carbon nanotube based infrared sensor is designed and a deterministic fabrication and assembly process is developed. Using robotic nano manipulation system as the assembly tool, a single carbon nanotube based IR sensor can be efficiently and reliably assembled. Furthermore the new fabrication process also enable us to make an individual carbon nanotubes based infrared sensor array that was difficult to fabricate with other fabrication method. The infrared responses of single carbon nanotube based IR sensors are experimentally measured and analyzed in the paper. Experimental results show the single walled carbon nanotube has high sensitivity to the infrared light, and demonstrate the strong potential to be an excellent infrared material.

6395-11, Session 2

Optimisation of quantum dot infrared photodetectors (QDIPs) for imaging applications

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Quantum dot infrared photodetectors are a maturing technology that offer a number of intrinsic advantages over competing detector technologies. As the devices utilise intraband rather than interband transitions to absorb light the devices can be grown from wide-bandgap III-V materials, and thus benefit from uniform growth technology for large area focal plane arrays. The three dimensional confinement of carriers within the dot makes QDIPs intrinsically sensitive to normally incident light, unlike their QWIP counterparts which require scattering gratings to be fabricated onto their surface. The discrete nature of the bandstructure within the dot also makes it difficult for photo-excited carriers to relax to the ground state, the so-called phonon bottleneck, which improves the QDIP's responsivity.

These advantages coupled with two-colour operation makes QDIPs an extremely promising technology for infrared imaging systems.

It is somewhat surprising therefore that relatively little work has been published showing how one should approach designing a QDIP with particular performance. Here we present an engineering study showing how altering various aspects of the growth parameters of an InAs dot within an InGaAs well (DWELL) QDIP affects its performance. Amongst our findings, we show capability to control the absorption wavelength both during and after growth by altering the size of the dots and via the quantum confined Stark effect respectively. Additionally, we show that we can grow a stack of 10 DWELL absorbing regions without strain compensating layers and low dark current, whilst achieving high responsivities. The addition of AlGaAs current blocking layers is shown to reduce deleterious dark current by over two orders of magnitude.

6395-12, Session 2

Uncooled amorphous silicon IRFPAs with 25-μm pixel-pitch

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This paper reviews characteristics and performance of the amorphous silicon microbolometers with a pixel-pitch of 25 μm.

We first present the advantages of amorphous silicon uncooled microbolometer technology which enables the production of high volume and low cost uncooled IRFPA.

IRFPAs are then described in terms of ROIC architecture, packaging, operability and electro-optical performances. The 25 μm pixel architecture profits from the low thermal time constant of 45 μm pixel detector to design a higher pixel thermal insulation and to develop a 25 μm version which has a better performance despite the pixel pitch reduction. Thanks to a new pixel design and by pushing the design rules even further, a high fill factor has been kept, without the use of complex, as well as expensive, two-level structure.

New read out integrated circuits structure have been specially developed for this pixel pitch. High level functions like gain, offset correction, image flip and windowing could be operated through a serial link to minimize the number of electrical interconnections.

At a 60Hz frame rate, focal planes with less than 50mK (f/1) NETD are now achieved with low spatial fixed pattern noise after sensor gain and offset compensation.

6395-13, Session 2

IR detectors life cycle cost and reliability optimization for tactical applications

X. Breniere, P. Tribolet, Sofradir (France)

Infrared (IR) applications are more and more demanding regarding reliability and cost. Moreover contracts are getting further than simple cost acquisition considerations, asking for life cycle cost requirements. Life cycle cost approach is the way to combine increase of reliability with reduction of costs. Starting from the design of a IR detector and taking in consideration some specific tactical system constraints, the whole cost and reliability analyses have to be made including maintenance approaches. The key parameters for the detectors are the thermal cycles behavior, the cooler reliability and the vacuum behavior.

Based on Sofradir experience of life cycle cost contracts and on IR staring arrays results, this paper discuss the optimization of life cycle cost and reliability as well as future trends regarding IR detectors and reduction of life cycle cost.

6395-14, Session 2

Latest developments on MCT staring arrays

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HgCdTe (Mercury Cadmium Telluride / MCT) staring arrays for infrared detection do show constant improvements regarding their compactness and performances. New detectors are now proposed offering system solutions in the different IR wavebands and taking advantages on the latest technology improvements as well as MCT performance advantages and cost reduction. As a matter of fact, the size of MCT wafer as well as the uniformity of Focal Plan Arrays (FPA) has been improved and exhibit outstanding results, read-out circuits include new functions as the Analogic to Digital Conversion (ADC), and finally the Reliability of the whole dewar detector assembly has been drastically increased.

In mid-wave (MWIR), the Jupiter 1280x1024 MCT detector is presented as well as results from a 640x512 15μm pixel pitch detector with integrated ADC. Finally high performances staring arrays for long wave imaging systems as well as the development trends for low cost and future IR detectors are presented.

6395-15, Session 2

Albion: cost-effective 3rd generation high-performance thermal imaging in the UK

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The first generation of high performance thermal imaging sensors in the UK was based on two axis opto-mechanical scanning systems and small (4-16 element) arrays of the SPRITE detector, developed during the 1970s. Almost two decades later, a 2nd Generation system, STAIRS C was introduced, based on single axis scanning and a long linear array of approximately 3000 elements. This paper addresses the development of the UK's 3rd Generation High Performance Thermal Imaging sensor systems, under a programme known as "Albion".

Three new, high performance detectors manufactured in mercury cadmium telluride, operating in both MWIR and LWIR, providing high resolution and sensitivities without need for opto-mechanical scanning systems will be described. The MCT material is grown by MOVPE on low cost substrate and bump bonded to the silicon read out circuit (ROIC). All three detectors are designed to fit with existing standard Integrated Detector Cooling Assemblies (IDCAs).

The two largest detectors will be integrated with field demonstrator cameras providing MWIR and LWIR solutions that can rapidly be tailored to specific military requirements. The remaining detector will be a LWIR device with a smart ROIC, facilitating integration times much longer than can typically be achieved with focal plane arrays and consequently yield very high thermal sensitivity. This device will be demonstrated in a lab based camera system.

6395-16, Session 2

Demonstration of multifunctional bi-colour-avalanche gain detection in HgCdTe FPA

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One of the most challenging tasks in the development of the next generation of Infra Red Focal Plane Arrays, IRFPA, is the integration of multiple functions into the detection circuit. In the case of multifunctional FPAs realised in HgCdTe, MCT, this task is also stimulating as this material is particularly well adapted for the realisation of complex heterostructures. So far, the efforts have mainly been focused on the development of multi-colour detectors, which allow detecting separate wavelength bands, in particular for target recognition. In this communication we report on a multifunctional two-colour-avalanche gain FPA in which one of the bands can be used in avalanche mode to produce current gain with low excess noise at low dark current.

The multifunctional FPA is based on a bi-colour pseudo-planar MCT detector structure, developed at the CEA-LETI, which superposes two planar type diodes with different composition of Cd. An avalanche gain of M=1000 has been achieved in the shorter MW wavelength diode, with a cut-off wavelength of 5.3μm, at an inverse polarisation Vpol=-10V, by a modification of the junction profile to reduce the tunnelling currents. The electro-optic characteristics of the multifunctional LW-MW-avalanche gain detectors will be reported for 256x256 30μm pitch arrays hybridised on a bi-colour read-out circuit, and for direct measurements on 30μm pitch test arrays. The results will be discussed in view of the wide scope of applications which are enabled by the multifunctional FPAs.

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6395-17, Session 2

LWIR HgCdTe FPA variations with epitaxial structure properties

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Performance of small-sized pixels of HgCdTe focal plane arrays could depend strongly on design of basic multi-layer structure and physical phenomena in thin layers and interfaces forming it. Calculation and analysis of electrical and photoelectrical performance of small-pitched LWIR photoconductors (PC) and photodiodes (PD) was done. Narrow-gap low-doped n-Hg1-xCdxTe (x = 0.20-0.22) material with electron concentration at liquid nitrogen temperature (77 K) n77≈(1-10)x1014 cm-3 is preferably used by all manufacturers of infrared (IR) radiation detectors as absorbing layer (n-absorber) of high performance Long-Wave (LWIR) photoconductors (PC) covering spectral range from 8 to 14 μm. Traditionally LWIR FPA is based on PD with n+-p junction (p-absorber) but novel FPA based on photodiodes (PD) with p-n junction could have lower dark current value than same size n+-p junction. It is very desirable for adequate multiplexing of PD arrays by Silicon Read-out Integrated Circuits (ROIC). Objective of the present work was to examine and analyze some physical parameters of HgCdTe multi-layer structures and impact of LWIR PC and PD device performance on their variation.

6395-18, Session 3

Infrared and visible combat identification marking materials

E. S. O'Keefe, A. J. Butler, A. J. Shohet, M. Swan, QinetiQ Ltd. (United Kingdom)

Historically, it is believed that fratricide accounts for up to 15% of friendly casualties during operations and a UK MoD report identifies that almost half of all such casualties occur in situations involving ground units only. Such risks can be mitigated, to an extent, via operational awareness and effective communications. However, recent conflicts have involved a much more dynamic, complex and technically sophisticated battlefield than previously experienced, for example, Operation Telic (Desert Storm) with almost one million combatants and ten thousand armoured vehicles in the coalition force advancing across an extensive battlefront at high speed during daylight and at night making effective use of a range of electro-optic sensors. The accelerated tempo of battle means that front lines can undergo rapid, punctuated, advance that can leave individual combat units with a much degraded situational awareness, particularly of where they are in relation to other 'friendly' combatants. Consequently there is a need for a robust, low cost, low weight, compact, unpowered, interoperable, Combat Identification technique for use with popular electro-optic sensors which can be deployed, and is effective, at the individual combat unit level. In this paper we discuss ground-to-ground combat identification materials that meet these requirements based on the air-to-ground Mirage(tm) vehicle marking material. We show some preliminary ground-to-ground and air-to-ground data collected in recent experimental trials of the new variant Mirage(tm) material conducted during the day, evening and at night.

6395-19, Session 3

Middle East desert aerosol size distribution measurements and modeling in urban, coastal, and continental regions

S. L. Bendersky, N. S. Kopeika, Ben-Gurion Univ. of the Negev (Israel)

Various experiments have been carried out recently in the Middle East desert regions for prediction of aerosol particle concentration and size distribution. The differences between urban and non-urban desert coastal environments, and urban and non-urban desert continental environments, are of interest for us. During these experiments aerosol particle concentrations for similar weather but different environmental conditions were measured and analyzed. The well-known MODTRAN urban, desert, maritime, and continental aerosol models were tested for aerosol particle distribution prediction for our cases. Unfortunately, many of those models did not predict correctly the aerosol distributions in different types of arid environments. Comparison of results leads to the following interesting conclusion: the aerosol distribution for each of our environments, such as urban-coastal-desert, non-urban-coastal-desert, urban-continental-desert, and non-urban-continental-desert, can be predicted by multiplying desert aerosol model parameters with semi-empirical correct functions or factors. The functions are different for coastal and continental environments, and for urban and non-urban environments. The models proposed in this work better describe effects of different atmospheric conditions for desert aerosol modeling.

6395-20, Session 3

Aerosol size distribution measurements and modeling in urban environments for rainy atmospheric conditions

S. L. Bendersky, N. S. Kopeika, Ben-Gurion Univ. of the Negev (Israel)

Various experiments have been carried out recently in the Middle East urban (Beer Sheva, Israel) environment for prediction of aerosol particle concentration and size distribution. During these experiments aerosol particle concentrations for different weather conditions were measured and analyzed. A new urban aerosol size distribution model is described in this work for aerosol size distribution prediction, based on an extensive series of measurements. The model introduces coefficients and characteristics of processes of absorption and scattering by aerosol particles in urban inhomogeneous areas for rainy atmospheric conditions. Several parts of the results are compared with those obtained through measurements in different geographic and climatic environments, as well as with different aerosol distribution models. Effects of different atmospheric conditions for urban aerosol modeling are better described by the model proposed in this work.

6395-33, Poster Session

Data association for infrared search and track system

C. Li, Xi'an Jiaotong Univ. (China)

Data association is one of the key techniques on bearing-only tracking with Infrared Search and Track (IRST) system. A new data association algorithm based on information fusion theory is proposed in this paper. Various simulation experiments have been conducting under different conditions to verify the approach and the results have demonstrated the performance of the proposed data association method. Firstly, by considering the special feature of IRST system, the new method constructs several kinds of evidences that are based on the multi-type information, such as angular measurement, intensity level and etc.. And then all results from different aspects are fused by utilizing Dempster combination rule. Finally, the association decision is obtained by maximizing the final mass function. Comparing with the traditional data association methods, the simulation results show that the proposed approach has improved performance. As observation conditions deteriorate, the advantage of new method becomes obvious. For uncertain data, this new data association algorithm based on evidence theory is excellent by utilizing reasonably the measurements.

6395-34, Poster Session

A laser imaging system for helicopter avoidance obstacle

W. Wang, H. Yuan, Univ. of Electronic Science and Technology of China (China)

Rotorcraft flying in low-altitude is endangered by power lines or telephone wires. The development of automated tools that can detect obstacles in the flight path and warn the crew would significantly reduce the workload of pilot and increase the safety. Detection and warning are rudimental demand and desire for HAOY (Helicopter Avoidance Obstacle System). And that, an advanced HAOY may be capable of classifying thin obstacles and enhanced vision with distances of obstacles. A laser 3D imaging system for HAO had been developed successfully. The laser 3D imaging helicopter avoidance obstacle system can not only detect thin obstacles but also catch more information of all objects of the area in front of the helicopter as possible. Then the information is transformed into intuitionist 3D image modality. In this paper, special features and characteristic of the laser imaging system for HAO are analyzed and discussed. Several design gist for this system are proposed. Especially the developed zero backlash imaging technology and real-time dynamic imaging synchronizing with radar space scanning are described. The problem of dynamical distortion amendment is discussed as well. Finally, the results of system ground test are presented. The ground test of the developed laser imaging system has demonstrated that the developed imaging system performance can achieve and satisfy commendably the requirements of the mission to prevent "wire strike".

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6395-35, Poster Session

Anomaly gas tracking using field-portable imaging radiometric spectrometer

E. Ohel, S. R. Rotman, Ben-Gurion Univ. of the Negev (Israel); D. G. Blumberg, Ben Gurion Univ. of the Negev (Israel); L. Sagiv, Ben-Gurion Univ. of the Negev (Israel)

Using a set of radiometric hyperspectral data cubes, we developed an algorithm which detects the formation of an anomalous gas cloud. Once we've established the presence of the cloud in the later images, we determine the origin of the cloud in the earlier images and track its propagation. Because gas usually expand from very small sources, it is difficult to know that it is significant when it initially occupies a few pixels in the image. After the gas size expands, it is easier to analyze as an interesting anomalous gas.

Our algorithm includes techniques such as the improved K-Means classification, spectral angle mapper (SAM), match filter and tracking; in the paper we will show results based on real data taken by the "FIRST" camera (Field-portable Imaging Radiometric Spectrometer Technology).

6395-37, Poster Session

Using optical flow for the detection of floating mines in IR image sequences

A. Borghgraef, M. Acheroy, Royal Belgian Military Academy (Belgium)

In the first Gulf War, unmoored floating mines proved to be a real hazard for shipping traffic. An automated system capable of detecting these and other free-floating small objects, using readily available sensors such as infra-red cameras, would prove to be a valuable mine-warfare asset, and could double as a collision avoidance mechanism, and a search-and-rescue aid.

The sea provides a noisy background, making it difficult to detect small floating objects in the scene.

Contrast-based detection methods often have difficulties distinguishing between the mines and wave-heads, which have similar reflection characteritics. Similarly for methods based on segmentation by size. Shape-based methods work only in the case of a very calm sea, as its mechanism is totally negated by wave occlusion on rough seas.

These problems lead us to look at the sequence of images for temporal detection characteristics. The target's apparent motion is such a determinant, given the contrast between the bobbing motion of the floating object and the strong horizontal component present in the propagation of the wavefronts.

To obtain all-weather capacity, we have chosen to take test footage with both 3-5 and 8-12μm IR camera's of both cilindrical and spherical practice mines, in various sea conditions. In order to extract the motion characteristic, we apply the Proesmans optical-flow algorithm to the IR video footage, calculating the motion field of each subsequent pair of images. Segmentation of the motion field allows for the detection of moving objects in the footage. This way, we are able to detect the floating target by a directional filter, after compensating for the sensor platform's motion.

6395-38, Poster Session

Three-dimensional measuring method of head and eye tracking system using a single camera

M. Nishida, K. Sakamoto, Shimane Univ. (Japan)

Conventional 3D movie systems with the special glasses such as polarized glasses provide us touchable spatial images. However, these 3D imaging systems require the observer to wear the glasses. Our research group would like to realize the glasses-less 3D imaging system to construct an interactive spatial imaging environment. The authors have researched the 3D displays and applications. We have ever proposed 3D displays using the slit as a parallax barrier, the lenticular screen and the holographic optical elements(HOEs) for displaying active image.

A display system requiring no special glasses is useful for 3D images. The parallax barrier display system has superior characteristics, such as having a planar screen and a thin panel. Parallax barrier displays have generally 2-views stereoscopic images and 4 or 8 views at most. These stereoscopic 3D displays have defect that it occurs an observer watches the left image by right eye and vice versa when the user moves from side to side. The positions of the observer's head or eyes must be measured to solve this problem and display 3D image correctly.

In the stereoscopic 3D display, the key technology of stereoscopic viewing is to separate left and right images and to deliver a separate image to each eye correctly. Hence, the display system needs to detect head or eye positions of users so as to be viewed left and right images by each eye. In this paper, we describe the 3D measuring method using a single camera.

Generally, we can get the 3D information such as the position of an object using the stereovision measuring method. However it is possible to measure the 3D position by the captured scene of the single camera when the measuring system has already known the parameter such as an interval of eyes in this case. In this paper, the authors show the geometric analysis of single camera method and the results of measuring system.

6395-39, Poster Session

Mobile viewer system for virtual 3D space using infrared LED point markers and camera

K. Sakamoto, S. Taneji, Shimane Univ. (Japan)

The authors have developed a 3D work space system using collaborative imaging devices. A stereoscopic display enables this system to project 3D information. In this paper, we describe the position detecting system for a see-through 3D viewer.

A 3D display system is useful technology for virtual reality, mixed reality and augmented reality. We have researched spatial imaging and interaction system. We have ever proposed 3D displays using the slit as a parallax barrier, the lenticular screen and the holographic optical elements(HOEs) for displaying active image. The purpose of this paper is to propose the interactive system using these 3D imaging technologies. The observer can view virtual images in the real world when the user watches the screen of a see-through 3D viewer.

The goal of our research is to build the display system as follows; when users see the real world through the mobile viewer, the display system gives users virtual 3D images, which is floating in the air, and the observers can touch these floating images and interact them such that kids can make play clay.

The key technologies of this system are the position recognition system and the spatial imaging display. The 3D images are presented by the conventional parallax barrier 3D display. Here the authors discuss the measuring method of the mobile viewer using infrared LED point markers and camera in the 3D workspace (argumented reality world). The authors show the geometric analysis of proposed measuring method, which is the simplest method using a single camera not the stereo camera, and the results of our viewer system.

6395-40, Poster Session

Single camera 3D measuring for finger pointing in virtual space

H. Nakayama, K. Sakamoto, Shimane Univ. (Japan)

We developed interaction media systems in the 3D virtual space. In these systems, the artist draws a picture in the 3D workspace. In this virtual drawing system, for example, the finger-pointed points are superimposed on the captured scene when the user indicates the point on the floor. Hence the user can draw the line art in the virtual space. This virtual drawing system consists of the Windows PC connected with the USB camera for PCs. The drawing system software functions as the video capture, the recognition and detection of interested regions for the motion capture, the measurement for estimating the position of finger pointing and the operation of an interaction. We used the method of measuring the position of fingertip and finger pointing using a single camera without stereo-pair images. The main point of our proposal is this 3D measuring method using a single camera.

We have developed a prototype finger pointing system using a single camera and a personal computer. This paper proposes the measuring method of the position of finger using a single camera. This finger recognition and measuring system realizes the finger pointing such that user points at a virtual 3D object floating outside the display. We evaluated the result of specified positions by prototype system and made sure the performance required for practical use.

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6395-41, Poster Session

A modified algorithm for information acquisition from satellite images

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Image preprocessing of remote sensing satellites are considered as a vital process for satellite images. The received video data is converted into easy understandable raster images and any image distortions that are results through the system manufacturing process or data acquisition and transmission are eliminated.

This paper proposes a modified preprocessing algorithms that should be performed on the received data from remote sensing satellites with Visible and Infra-Red (VIR) sensors. Starting from reception of data by antenna at the Ground Data Reception Station (GDRS) until delivery of level 1A product (radiometrically corrected image). Briefly, the received data should be processed in two levels; level 0 to produce the raw image, and level 1 to produce radiometrically and geometrically corrected image. The paper is concluded by:

- Applying preprocessing algorithms to construct, calibrate and enhance the received data.
- Constructing the image after unpacking of the received data.
- Calculation of RMS noise value to estimate the quality of the received images.
- Applying low and high pass filters for enhancing of the image features.
- Improvement of the image contrast using two techniques.
- Comparison study for the obtained results.

6395-22, Session 4

Anti-reflective sub-wavelength patterning of IR optics

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Thermal IR lenses require efficient anti-reflection coating. Recently, sub-wavelength 2D gratings, called moth-eye structures, have demonstrated their ability to reach a very high transmission for a wide wavelength and angular range. The use in thermal IR is simplified by the lower resolution for lithographic technology, compared to visible waveband. However, deeper structures must be engraved and lithography must be adapted to IR materials. In order to be cost-effective, the patterning must be produced by replication techniques, such as embossing. Our laboratory is now experimenting hot embossing of moth-eye patterns in chalcogenide substrates.

In this paper, theoretical analysis, micro-lithographic technology and manufacturing processes are detailed.

6395-23, Session 4

Experimental realization of high-performance thermal imaging with a singlet and pupil plane encoding

G. D. Muyo, A. R. Harvey, Heriot-Watt Univ. (United Kingdom); A. Singh, M. Andersson, Saab Bofors Dynamics AB (Sweden)

Pupil plane encoding has shown to be a useful technique to extend the depth of field of optical systems. Recently, further studies have demonstrated its potential in reducing the impact of other common focus-related aberrations (such as thermally induced defocus, field curvature, etc) which enables to employ simple and low-cost optical systems while maintaining good optical performance. In this paper, we present for the first time an experimental application where pupil plane encoding alleviates aberrations across the field of view of an uncooled LWIR optical system formed by F/1, 75mm focal length germanium singlet and a 320x240 detector array with 38-micron pixel. The singlet was corrected from coma and spherical aberration but exhibited large amounts of astigmatism and field curvature even for small fields of view. A manufactured asymmetrical germanium phase mask was placed at the front of the singlet, which in combination with digital image processing enabled to increase significantly the performance across the entire field of view. This improvement is subject to the exceptionally challenging manufacturing of the asymmetrical phase mask and noise amplification in the digitally restored image. Future research will consider manufacturing of the phase mask in the front surface of the singlet.

6395-24, Session 4

Results from real-time polarimetric imaging

G. Innes, D. L. Jordan, D. Hayter, QinetiQ Ltd. (United Kingdom)

There is strong evidence to suggest that polarimetric techniques offer significant improvements in the ability of electro-optic sensors to detect difficult targets in cluttered backgrounds. One example of this is detection of landmines laid in fields: the problem conventional imagers have is that the landmine may appear to be a rock or piece of vegetation, whereas a polarimetric imager will only detect the mine because the natural objects tend to be unpolarised. Previous attempts to quantify the potential benefits have been hampered by an inability to gather all the polarimetric data simultaneously from a scene. Sequential data gathering can lead to artefacts in the polarimetric data, which in turn lead to spurious and erroneous conclusions being drawn. To overcome the difficulties caused by taking sequential measurements, QinetiQ has designed and built real time visible and near-infrared polarimetric sensors that measure all four Stokes parameters simultaneously in every image pixel to an accuracy of +/- 2%. To the authors knowledge, they are the first of their kind in Europe.

Following construction the sensors have been used to gather a wide range of data. This has then been used to quantitatively compare passive polarimetric target detection with conventional intensity detection in terms of both mean target-to-clutter ratio and probability of detection / probability of false alarm. The results show that the use of polarimetric imaging greatly enhances target detection and reduces false alarms. The advantages of polarimetric imaging are expected to be even greater in the infrared waveband, and to this end a study has been carried in this programme to identify the design options for a LWIR sensor.

6395-25, Session 4

High-resolution long-range oblique IR imaging from an airborne platform

V. Petrushevsky, El-Op Electrooptics Industries Ltd. (Israel)

Dual band (VNIR / MWIR) optical configuration with an aplanatic Cassegrain telescope and a dichroic beam splitter became preferential in long-range oblique photography (LOROP) systems in recent decade. ELOP's successful Condor2 camera is an example of such configuration, achieving consistent performance at long stand-off ranges from a high-altitude fast jet platform.

The dual-band feature offers the advantage of day-and-night operation with the same camera. However, the long range IR imaging through the Cassegrain optics is especially challenging because of central obscuration of the aperture and relatively high F-number. Combined with considerable atmospheric attenuation and widely-variable temperature of the camera, these factors cause some inherent limitations on the IR resolution performance.

The paper presents main features of the IR band's design, operation and calibration. Regarding the further improvement potential, a generalized parametric study is presented which analyzes how the resolution is influenced by the optical transmittance, F-number, camera temperature and detector's excess current. Both reflecting (EO/IR) and refracting (IR-only) optical configurations are considered.

6395-27, Session 5

Automatic spatial alignment of visible and infrared images

F. M. Porikli, Mitsubishi Electric Research Labs. (USA)

Pixel-accurate registration of different modality images, e.g. visible, near IR, and thermal IR, is becoming more and more important as the number of such multi-modal integrated systems increases thanks to the decreasing cost of the thermal IR cameras. The main challenge is to automatically find a spatial transfer function between these images that are acquired synchronously from different cameras without using a preset calibration pattern, which is often a heat radiating device with a visible pattern on it, or requiring any user interaction to mark up point matches. To accomplish this, it is required to select salient features and establish feature point correspondence between the images of different modalities. However, not all the features are apparent between color and thermal IR images. That is, the edges extracted from the visible image do not necessarily correspond to the edges present in the thermal IR image. We developed a feature selection and mutual-information boosting estimation method that extracts SIFT-like spatial features from all modalities and applies a

robust optimization algorithm to determine the parameters of an affine image transfer function between the images. The transfer function is used to map multiple images onto a single base image for further analysis and display tasks. We also analyzed the affects of wider baseline distances between the visible and IR cameras on the performance of registration.

6395-28, Session 5

Image-based prediction of thermal imaging performance

S. Bobrov, Rafael (Israel); Y. Y. Schechner, Technion - Israel Institute of Technology (Israel)

Some imaging systems require estimation of their performance in specific scenes, prior to their operation. These occur in system design, as well as in tasks of high risk or cost. Specifically, when considering disposable systems such as probes sent from planetary spacecraft, or guided imaging missiles, there is a need to predict whether the images taken by the system would have sufficient quality to enable successful completion of the mission.

To predict the performance, we propose a hybrid approach, which is both image-based and physics-based. We give a rigorous analysis of the image formation processes, from scene photons, to image gray-levels. This analysis includes all the optical, electrical and digital sources of signal distortion and noise. Based on this analysis and on our access to the camera parameters, we devise a simple image-based algorithm. It transforms a baseline high quality image, to render an estimated outcome of the system we wish to operate or design. We demonstrate our approach on thermal imaging systems.

6395-29, Session 5

Automatic selection of infrared image restoration techniques

M. Lemaitre, J. Blanc-Talon, Ctr. d'Expertise Parisien (France)

The main image degradation occurring in long distance ground-to-ground infrared video acquisition is due to atmospheric turbulence. The turbulence strength depends essentially on atmospheric conditions and on the distance between the scene and the camera. Atmospheric turbulence can show dramatically different effects but in the case of horizontal observations in the troposphere, at a distance over a couple of kilometers, it can be simulated efficiently by local blurring and warping. Some additive noise may be detected depending on atmospheric conditions and on the acquisition system. In such conditions, the isoplanatic angle is larger than the pixel resolution: this is called local isoplanatism. The degraded images can then be split into areas degraded by the same perturbation. The goal of this paper is to test the most classical so-called local restoration methods on real images, in order to deduce some criterion allowing automatic selection of the most suited method. The first part of the paper is devoted to the physical explanation of local isoplanatism (LI). In the second part, once the case study has been shown to fit with LI assumptions, we show that global restoration techniques do not work properly. Restoration results computed within uniform areas and transition areas are compared so as to find the best restoration technique. Several examples are shown.

6395-30, Session 5

Sensor data association for the Seawolf Mid-Life Update (SWMLU) Programme: an update

M. Bernhardt, C. R. Angell, Waterfall Solutions Ltd. (United Kingdom); D. M. Patel, C. Wardell, BAE Systems plc (United Kingdom)

The Seawolf Mid-Life Update (SWMLU) programme is a major upgrade of the UK Royal Navy's principal point defence weapon system. The addition of an Electro-Optic sensor to the pre-existing 'I' and 'K' band radars presents a significant engineering challenge. The processing of the data from the 3 sensors into a fused picture such that a coherent view of which objects represent targets and own missiles is a key element of the overall system design and is critical to achieving the required system performance. Without this coherent view of the detected objects incorrect guidance commands will be issued to the Seawolf missiles resulting in a failure to successfully intercept the target. This paper reviews the sensor data association problem as it relates to the SWMLU system and outlines identified solution strategies.

The SWMLU sensors provide complementary data that can be exploited through data association to maximise tracking accuracy as well as maintaining performance under sensor lost-lock conditions. The sensor data association approach utilises radar and EO properties from spatial and temporal domains. These characteristics are discussed in terms of their contribution to the SWMLU data association problem where it will be shown that the use of object attributes from the EO sensor and their behaviour over time is a critical performance factor. Recovery from incorrect associations is an issue that must also be addressed as part of the processing development. A robust implementation approach is outlined and the potential performance improvements are discussed.

6395-31, Session 5

Small craft identification discrimination criteria (N50 and V50) for visible and infrared sensors in maritime security

K. A. Krapels, Office of Naval Research (USA); R. Driggers, U.S. Army Night Vision & Electronic Sensors Directorate (USA)

The growth in maritime security requirements, for both shore installation and sea platform protection, has resulted in a need for electro-optical/infrared imager design and evaluation tools which predict field performance discriminating small craft. In the design of imaging systems for target acquisition, a discrimination criterion is required for successful sensor realization. It characterizes the difficulty of the task being performed by the observer and varies for different target sets. This criterion is used in both assessment of existing infrared sensor and in the design of new conceptual sensors.

In this experiment, we collected 15 small craft signatures (patrol, commercial and recreational) in the visible/LWIR/MWIR bands during the day and the LWIR and MWIR spectra in the night environment. These signatures were processed to determine the targets' characteristic dimension and contrast. They were also processed to bandlimit the signature's spatial information content (simulating longer range) and a perception experiment was performed to determine the task difficulty (N50 and V50). The results are presented in this paper and can be used for Maritime imaging sensor design and evaluation and requirements generation.

6395-32, Session 5

Point target tracking in whitened IR sequence using a dynamic programming approach

O. Nichtern, Ben-Gurion Univ. of the Negev (Israel); S. R. Rotman, Ben Gurion Univ. of the Negev (Israel)

In this paper, we introduce a novel tracking system based on the Track Before Detect Approach (TBD). Each IR sequence we work on is preprocessed first by using a whitening algorithm. This stage is used to reject clutter and emphasize targets. Afterwards, we use a Dynamic Programming Algorithm (DPA) for numerous frames in the sequence. The algorithm, a descendent of the well known Viterbi Algorithm, gives each pixel in the image a score based on the current frame and the previous one. By doing so, we utilize the temporal behavior difference between targets, clutter and noise to distinguish between them, and give scores accordingly. At the end of this stage, after the last frame of the IR sequence has been processed, the pixel with the highest accumulated score is chosen as the Target, and its path is found. The paper deals with the different issues characterizing the system, enabling it to have versatility over a wide range of scenes. Future work will involve the use of the system for tracking of targets in hyperspectral cubes.

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6396-01, Session 1

Sensor development in the Sensors Directorate of the US Air Force Research Lab.

P. F. McManamon, Air Force Research Lab. (USA)

Current and recent sensor development programs within the Sensors directorate will be described, with an emphasis on electro-optical sensor development. These will include efforts in 3D laser radar and automatic target recognition using 3D laser radar. Target detection programs will also be described, and one current effort which is attempting to bring together many of the existing efforts into a single focused effort.

6396-02, Session 1

TBA

M. D. Turner, Defense Advanced Research Projects Agency (USA)

No abstract available

6396-03, Session 1

TBA

D. Schneider, Air Force Institute of Technology (USA)

No abstract available

6396-04, Session 2

High-resolution LADAR sensor for autonomous vehicle collision avoidance

R. J. Grasso, G. F. Dippel, L. E. Russo, L. E. Vigezzi, BAE Systems (USA)

BAE Systems reports upon a collision avoidance (CA) sensor that provides obstacle detection and situational awareness for autonomous vehicles during flight; including both high-speed transit in open areas and low-speed maneuvering in obstacle laden environments. Detection must occur within sufficient time to permit safe passage over or around these obstacles. In the DARPA Organic Air Vehicle (OAV) II Program, BAE Systems developed this sensor to interface with intelligent collision avoidance (ICA) algorithms permitting the OAV II to fly at very low altitudes and within urban canyons and avoid obstacles such as wires, cables, transmission lines, towers, poles, structures, and terrain. BAE Systems is continuing development of this sensor to function on fully autonomous ground vehicles providing obstacle detection. To meet the challenges for an autonomous vehicle CA sensor, BAE Systems incorporated a judicious design incorporating a high peak power fiber laser source, a receiver aperture sized to provide the required power-aperture at range, and the resolution to detect a low cross section targets that may be present in the foreground of trees and terrain. BAE Systems use of proven and reliable technology affords the autonomous vehicle community a practical and affordable CA solution with the use of proven and low risk technology.

BAE Systems CA sensor, based upon an advanced, high resolution, laser radar (LADAR) provides both airborne and ground-based autonomous vehicles a compact and affordable collision avoidance sensor that can be used with 2D and 3D vehicle control algorithms. This sensor was recently demonstrated as part of the DARPA OAV II program where it exceeded obstacle detection requirements by a significant margin. To meet the challenges for a CA system that permits autonomous vehicles to avoid collisions with wires, trees, poles, towers, structures and other naturally occurring and manmade structures, BAE Systems assessed the most relevant technologies for meeting the demands and requirements with respect to air vehicle flight dynamics, response envelope, and concept of operations (CONOPS). The technologies examined were based upon performance evaluation and simulation and modeling results, the fiber laser-based LADAR showed the best detection and obstacle warning performance and was selected as the objective system architecture. BAE Systems is now in the process of incorporating this sensor and vehicle control algorithms on a ground-based platform for all-terrain operation.

BAE Systems continues to develop this sensor for both manned and unmanned platforms for air and ground environments. Results to be presented include collision avoidance technology assessment, scanner selection and performance trades, field-of-view and field-of-regard issues driven by platform maneouvering envelopes, laser power and pulse repetition frequency issues, and aperture considerations. Also, BAE Systems will discuss several algorithms successfully implemented to provide obstacle detection, vehicle routing, and autonomous operation. An important issue is how these algorithms function with the LADAR data to provide rapid convergence to a platform maneouvering solution. High resolution 3D LADAR imagery obtained from the sensor in typical obstacle-laden operational environments will be presented.

6396-05, Session 2

Calibration of the fast range imaging camera SwissRangerTM for the use in the surveillance of the environment

T. Kahlmann, H. Ingensand, ETH Zürich (Switzerland)

Many security & defense systems need to capture their environment in one, two or even three dimensions. Therefore adequate measurement sensors are required that provide fast, accurate and reliable 3D data. With the upcoming range imaging cameras, like the SwissRangerTM introduced by CSEM Switzerland, new cheap sensors with such ability and high performance are available on the market. Because of the measurement concept these sensors long for a special calibration approach. Due to the implementation of several thousand distance measurement systems as pixels, a standard photogrammetric camera calibration is not sufficient. This paper will present results of investigations on the accuracy of the range imaging camera SwissRanger. A systematic calibration method is presented which takes into consideration the different influencing parameters, like reflectivity, integration time, temperature and distance itself. The analyzed parameters with respect to their impact on the distance measuring pixels and their output data were determined. The investigations were mainly done on the high precision calibration track line in the calibration laboratory at ETH Zurich, which provides a relative accuracy of several microns. In this paper it will be shown, under which circumstances the goal accuracy of the sub centimeter level can be reached. To prove the calibration approach, control measurements were made. The results of this work can be very helpful for users of range imaging systems to increase their accuracy and thus the reliability of their systems. As an example the usefulness of a range imaging camera in security systems for room surveillance is presented.

6396-06, Session 2

Remote concealed weapon detection in mm-wave region: active and passive

S. Stanko, D. Nötel, M. Hägelen, F. Klöppel, J. Huck, S. Erukulla, H. Essen, H. Fuchs, FGAN-FHR (Germany)

Concealed weapon detection is getting more and more important, especially after the terror attacts of 11th of september. But the attacs on the London tube showed that not only sensible areas like airports have to be monitored, but also subway stations should be subject to survaillance, which makes the use of very fast scanning systems necessary. New sensors used for security purpose have to cover the non invasive control of men, baggage and letters with the aim to detect weapons, explosives and chemical or biological threat material. Because of the different sites of usage these sensors have to cope with different evironmental conditions and optimally should be able to control people over longer distances.

Currently emphasis is put into system concepts and technology for this type of applications employing millimeterwave-, submillimeterwave- and terahertz sensors. This is based on the capability of these frequency bands to look through textile material and the possibility to achieve a geometric resolution, which is sufficient to resolve critical items within the necessary range. Working at multiple frequencies promises to give more detailed information about the structure of the observed objects. Further more, to overcome the limitations of passive millimeter- and submillimeterwave sensors which depend on indirect illumination, also active systems are tested.

6396-07, Session 2

Image quality for range-gated systems during different ranges and atmospheric conditions

O. K. Steinvall, T. R. Chevalier, P. Andersson, M. Elmquist, Swedish Defence Research Agency (Sweden)

Range-gated or burst illumination systems have recently drawn a great deal of attention concerning the use for target classification. The development of eye safe lasers and detectors will make these systems ideal to be combined with thermal imagers for long range targeting at night but also for short range security applications like reading of signs and licence plates, looking into cars and buildings etc.

Examples of imagery collected for different range and atmospheric conditions will be presented and discussed with respect to image quality and processing techniques. A comparison with theoretical performance modelling and simulation will also be presented and discussed.

6396-10, Session 3

A laser radar system for range-gated viewing at 1.5 μm

M. Elmqvist, P. Andersson, Swedish Defence Research Agency (Sweden); E. Wall, Saab Avitronics (Sweden); G. Lidö, FMV (Sweden)

A demonstrator system for laser illuminated range-gated viewing at the wavelength 1.57 μm has been developed in cooperation between the Swedish Defence Research Agency and Saab Avitronics. The work is commissioned by the Swedish Defence Materiel Administration. The system integrates a thermal imager with a pulsed laser transmitter and a range-gated viewing camera, an Intevac model 400C. The thermal imager is used for target detection and tracking. The system has the capacity to track targets both spatially and in range. Algorithms for image processing and registration are integrated in the system as an aid to the operator. Results, images and applications will be presented in this paper.

6396-11, Session 3

Registration and change detection techniques using 3D laser scanner data from natural environments

G. Tolt, P. Andersson, T. R. Chevalier, C. A. Grönwall, H. Larsson, A. Wiklund, Swedish Defence Research Agency (Sweden)

In this paper, we present techniques related to registration and change detection using 3-D laser scanner data. First, an experimental evaluation of a number of registration techniques based on the Iterative Closest Point algorithm is presented. As an extension, an approach for removing noisy points from the registration process is also proposed. Since the success of accurate registration is typically dependent on a satisfactorily accurate starting estimate, coarse registration is an important functionality. We address this problem by proposing an approach for coarse 2-D registration, which is based on detecting vertical structures (e.g. trees) in two point sets and then finding the transformation that gives the best alignment.

Furthermore, two approaches for change detection are described. In one approach, changes are viewed as clusters of points in one data set having no correspondences in the other (aligned) data set. This information is readily obtained as an intermediate result in the ICP algorithm. The other approach is based on voxelization of the (registered) data sets, i.e. partitioning the (x,y,z) space into a 3-D cell grid. Cells in which the point density have changed significantly are then detected as changes.

6396-12, Session 3

Contrast enhancement for target detection by means of active polarimetric and multispectral laboratory demonstrator

M. Alouini, A. Grisard, J. Bourderionnet, D. Dolfi, Thales Research & Technology (France); F. Goudail, Univ. Paris-Sud II (USA); I. Baarstad, T. Løke, P. Kaspersen, Norsk Elektro Optikk A/S (Norway); X. Normandin, Thales Optronique (USA)

The increasing capability in terms of image acquisition, data storage, and fast processing enables today multidimensional imaging. As a result, the characteristics, such as wavelength and polarization, of the light backscattered by a given scene, can be analyzed and taken into account when displaying the final image. In very low contrast images the additional information brought by investigating the different properties of light allows the image details, that are hardly visible in standard intensity images, to be revealed. Following this approach, we have been investigating, in the past few years, the benefits of combining active polarimetric and multispectral imaging. This work has led to the design and realization of a compact laboratory demonstrator providing at the same time both polarimetric and multispectral images. The reception part of this demonstrator consists of a hyperspectral imager covering the spectral range 800-2200 nm. At the emission side, a PPMgLN optical parametric oscillator has been designed to provide polarized optical pulses containing simultaneously several wavelengths. Polarization control of the received light is achieved thanks to a fast PLZT based polarization rotator.

After a brief description of the laboratory demonstrator, we propose to illustrate and discuss some of the results obtained with this system. In particular, we show that the polarimetric image brings additional information on the scene content, especially when interpreted in conjunction with its counterpart intensity image, these images being complementary in most cases. Moreover, although, hyperspectral imaging might be mandatory for recognition of small targets, we evidence that the number of channels can be limited to a set of few wavelengths as far as target detection is considered. In particular, in the case of anomaly detection, increasing too much the number of channels can even lead to a decrease of detection sensitivity of the system.

6396-27, Session 3

Electro-optic remote sensing in the UK EMRS Defence Technology Centre

S. S. Duncan, SELEX Sensors and Airborne Systems Ltd. (United Kingdom)

No abstract available

6396-14, Session 4

Hyperspectral multiple approach fusion for the long-range detection of low observable objects like mines: MUF2

P. W. Yuen, G. J. Bishop, BAE Systems plc (United Kingdom)

Highly efficient target detection algorithms in hyperspectral remote sensing technology, particularly for the long range detection of very low observable objects like mines which exhibit extreme small detection cross sections, are in great demand. This is more so for a near or real time application. Conventional methods to achieve better detection using multiple approach fusion (MAF) techniques, which fuse detection outputs from various detectors using either logical operators, or, via a model based estimation of the joint detection statistics from all detectors, are found to be not sufficient for detecting very low observable objects. In this paper, a multiple approach fusion algorithm which employs a low level fusion of detectors within the algorithm level, as well as fusion at a higher level of detection output, is reported. The low level fusion has been implemented using a mixture modelling and a spectral unmixing technique within an anomaly detection framework. The detection performance of this two-level fusion approach have been found highly efficient, capable of detecting targets from a 20K pixels imagery accurately within ~minutes of processing time by using a PC on a Matlab platform. Validation of this mixture modelling and spectral unmixing fusion in 2 levels [MUF2] algorithm have been assessed using three different sets of data, and the result from the mine detection set will be presented in this paper.

This work formulates part of the research programme supported by the EMRS DTC established by the UK MOD.

6396-16, Session 4

Texture analysis using image empirical mode decomposition

A. Linderhed, Swedish Defence Research Agency (Sweden)

The Hilbert-Huang Transform (HHT) method is a highly efficient and signal adaptive method, designed specifically for the analysis of nonlinear and nonstationary signals, The transform uses the Empirical Mode Decomposition (EMD), with which the signal is decomposed into a redundant set of Intrinsic Mode Functions(IMFs) and a residue. We use the concept of empiquency, short for empirical mode frequency, instead of a traditional Fourier-based frequency measure to describe the signal oscillations. Image Empirical Mode Decomposition (IEMD) is the EMD concept expanded into two dimensions for the use on images. IEMD

provides a tool for image processing by its special ability to locally separate spatial frequencies. Texture analysis is achieved using the IEMD representation which holds the empiquency values as a vector valued feature. Once the feature vectors are created the texture analysis is done by using standard clustering algorithms. In this paper we give an overview of state of the art methods to decompose an image into a number of IMFs and a residue image. We also review the method for estimating empiquency in images and present the result of combining these two methods into a texture analysis method. This paper concentrates on the IEMD as a new tool for texture analysis and aims at displaying the advantages and shortcomings of the method

6396-17, Session 4

Environmental effects on the spectral properties of terrain backgrounds and objects

J. M. Cathcart, Georgia Institute of Technology (USA)

Georgia Tech is conducting a research program on phenomenological studies of hyperspectral signatures of landmines and backgrounds in the visible and infrared wavebands. Current efforts have focused on developing models of the spectral optical properties of terrain features to support these studies. These models provide a mechanism to study the impact of various environmental factors and processes (e.g., subsurface processes) on spectral infrared signatures. In addition, data from these models are employed in the analysis of hyperspectral and polarimetric signatures from landmines, covert targets, and background features. Results from these analyses and models are subsequently used in the development of physics-based algorithms for object detection and clutter rejection. An overview of these models, computational results for the optical properties, and the impact of various environmental effects on these properties will be presented in this paper. Their use as a component in the algorithm development process will also be discussed.

This work is supported under a grant from the Army Research Office.

6396-18, Session 4

Hemispherical radiometer for angle resolved measurement of IR scatter and radiation behaviour

C. F. Hahlweg, H. Rothe, Helmut-Schmidt Univ. (Germany)

For certain applications the angular distribution of IR radiation from materials and surfaces could be interesting. Various cases have to be taken into account, such as passive scattering, active radiation from material at a given temperature or the response to a thermal excitation. In further development of a full hemispherical scatterometrical device based on an elliptical mirror, an angular resolved IR radiometer has been developed. In contradiction to traditional goniometer designes the set-up allows to measure a hemispherical radiation distribution without moving parts. One application could be the fast acquisition of large amounts of BRDF data in IR range to be compiled into libraries. The use of imaging sensors reduces the measurement time, therefore even time dependence can be addressed. The paper deals with the instrument design, the calibration, and gives some measurement results.

6396-20, Session 4

Wide-area monitoring using satellite imagery retrieval and mining

I. Niemeyer, Technische Univ. Freiberg (Germany)

Seeing the expected technical improvements as to the spatial and spectral resolution, satellite imagery could more and more provide a basis for complex information systems for recognizing and monitoring even small-scale and short-term structural features of interests within nuclear facilities, for instance construction of buildings, plant expansion, changes of the operational status, underground activities etc. The analysis of large volumes of multispectral satellite data from different sensors will then definitely require a high degree of automation for (pre-) processing, analysis and interpretation in order to extract the features of interest. In order to process the image analysis steps on the numerous satellite imagery datasets stored in a database, the relevant areas of interests are usually retrieved by a query on the metadata (coordinates, acquiring date, etc.) first and analyzed afterwards. As a more advanced approach the analysis is performed within the retrieval process as an image content-based query. Thus, queries like “find areas with huge construction projects”, “find areas with significant changes of industrial sites between 2002 and 2004”, “find all areas with industrial sites located nearby water”, and others can be realized for the database image data. However, in this paper we developed an image retrieval and mining approach for nuclear-safeguards related, wide-area monitoring using satellite imagery. The given monitoring system will enable the users to apply their specific analysis task directly to the satellite imagery in the database.

6396-24, Poster Session

Pulsed and modulated CW lidar capacities intercomparison by multiplicative decomposition strategy

R. R. Agishev, Kazan State Univ. (Russia)

An alternate approach to the commonly used pulsed lidars for spatially-resolved detection of atmospheric pollutions is based on the energy equivalence between systems using high peak power, short pulses at low repetition frequency with continuous-wave frequency modulated (CWFM) systems of low average power and long observation times. In the radar community, ranging methods using CWFM systems are well known and showed their potential to provide light, compact and reliable architectures.

The general purpose of the present paper is to show under what conditions the CWFM-lidar can be energetically equivalent to pulsed incoherent (PIC) lidar and in what cases the CWFM-lidar can exceed the PIC-lidar potential. As an instrument for comparative analysis of the key system capabilities, we use the dimensionless parametrization methodology developed earlier and applied to overall lidar and its subsystems.

Analytical comparison of key capabilities of CWFM- and PIC-lidar is presented. We provide a classification of CWFM and PIC lidars based on specific features of the receiver and signal processing methods. Principles of CWFM-lidar architectures building-up are described and the atmospheric CWFM-lidar equation is derived. The SNR multiplicative decomposition strategy [1-3] is applied to both broad- and narrow-band lidars to perform their detailed estimates and intercomparison of the operation range and sensitivity. Estimations of operating range of both broad- and narrow-frequency-band (BB and NB) lidars as well as the operating range gain of NB-lidars over the BB ones are given. A quantitative analysis of the sensitivity of BB and NB CWFM lidars in comparison with PIC lidars is performed.

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6396-25, Poster Session

A numerical technique for gradient-type interface in the inverse scattering problems

M. Razzaghi, Mississippi State Univ. (USA)

In the application of radar, reflected electromagnetic energy is used to generate velocity profiles which are important for remote sensing, target or gradient-type interface , and nondestructive testing. Several papers have dealt with scattering problems for the time-dependent wave equation.

Furthermore, various methods of reconstructing different profiles through inversion are presented in the literature. The gradient-type interface is an interface at which the velocity profile suffers a jump in first derivative. The time domain approach to scattering from gradient-type interface leads to an integro-differential equation involving the impulse response. A solution given to this problem in the literature is an iterative algorithm that is shown to be fast and produces good results only when the depth of penetration is short, i.e. shallow regions. In this paper we present a new approach to the solution of the inverse problem that represents the gradient-type interface in a nonhomogeneous medium. Our approach is based on a spectral collocation method (pseudospectral method) in which we construct the Nth degree interpolating polynomials to approximate the impulse response and solve the integro-differential equation that represents the inverse problem. These polynomials are defined by using Legendre-Gauss-Lobatto points as the collocation points and Lagrange polynomials as the trial functions. Usually, in target recognition a priori knowledge of the type of the interface is not available. We are applying

inverse scattering to reconstruct different profiles as part of a recognition process, therefore it is important to generate accurate profiles in shallow and deep regions. It is demonstrated through examples that the numerical scheme presented here generates velocity profiles of a gradient-type interface which are accurate in both shallow and deep regions.

6396-21, Session 5

Forward modeling of linear mixing in thermal IR ground leaving radiance spectra

L. K. Balick, Los Alamos National Lab. (USA); A. R. Gillespie, Univ. of Washington (USA); M. F. McCabe, Los Alamos National Lab. (USA); A. Mushkin, Univ. of Washington (USA)

Hyperspectral thermal IR remote sensing is an effective tool for the detection and identification of gas plumes and solid materials. Virtually all remotely sensed thermal IR pixels are mixtures of different materials or temperatures. As sensors improve and hyperspectral thermal IR remote sensing becomes more quantitative, the concept of homogeneous pixels becomes inadequate. The contributions of the constituents to the pixel ground leaving radiance are weighted by their temperatures, or more correctly, temperature distributions. Planck's Law defines a relationship between temperature and radiance that is strongly wavelength dependent, even for blackbodies. The relative contribution to pixel GLR from each constituent varies with wavelength if they have different temperature distributions or emissivity spectra. Spectral GLR from mixed pixels is temperature dependent and the relationship between observed radiance spectra from mixed pixels and library emissivity spectra of mixtures of 'pure' materials is indirect.

This paper presents a model of linear mixing of subpixels with different temperatures and emissivity spectra. A pixel consists of one or more materials each with a temperature distribution and an emissivity spectrum. Temperature distributions obtained from high resolution thermal images are used as inputs to the model. The impact of spatial-temporal fluctuation of skin temperature on skin temperature variability will be discussed. The results show the strong sensitivity of spectral GLR at shorter wavelengths to temperature and significant variation of radiance mixture proportions with wavelength in the mid-infrared (3-5 * m). Spectral GLR of mixtures in the 8-12 * m domain are more modestly impacted but the impact of subpixel mixing and variability is still significant. The sensitivity of the model results to its input temperature distributions, material spectra, and mixture proportion are examined.

6396-22, Session 5

An accurate modeling, simulation, and analysis tool for predicting and estimating Raman LIDAR system performance

R. J. Grasso, L. E. Russo, J. L. Barrett, J. E. Odhner, P. I. Egbert, BAE Systems (USA)

BAE Systems presents the results of a program that models the performance of Raman LIDAR systems for the remote detection of atmospheric gases, air polluting hydrocarbons, chemical and biological weapons, and other molecular species of interest. Our model, which integrates remote Raman spectroscopy, 2D and 3D LADAR, and USAF atmospheric propagation codes permits accurate determination of the performance of a Raman LIDAR system. The very high predictive performance accuracy of our model is due to the very accurate calculation of the differential scattering cross section for the specie of interest at user selected wavelengths. We show excellent correlation of our calculated cross section data, used in our model, with experimental data obtained from both laboratory measurements and the published literature. In addition, the use of standard USAF atmospheric models provides very accurate determination of the atmospheric extinction at both the excitation and Raman shifted wavelengths.

Raman LIDAR is a useful and powerful tool for remote probing of the atmosphere where one can accurately determine the identification and concentration of a molecular specie of interest. Raman scattering may be considered as the generation of Rayleigh scattering sidebands caused by a modulation of the electric dipole of the molecule at a characteristic internal vibrational or rotational frequency. Raman sidebands appear at optical frequencies shifted from the incident frequency by plus or minus the values of the internal molecular frequencies. Hence, this process works will with laser excitation. While Raman scattering fundamentals in spectroscopy are well understood both theoretically and experimentally, few models exist to predict the performance of Raman LIDAR systems. Raman specrtoscopy is a valuable tool for the study of molecular structure, and Raman LIDAR is a simple, reliable, and accurate tool for remote sensing of gases, liquids, solids, and other molecular species of interest, and, is used with great effect as a stand-off detector with an operational range from several to hundreds of kilometers. BAE Systems Raman LIDAR model can be used to accurately predict the Raman LIDAR system performance, specie concentration and identification, and the feasibility for making Raman measurements. When inverted, the BAE Systems model can be used to isolate and identify a specific molecular species.

The use of Raman LIDAR in remote sensing is motivated both by the limitations of conventional in-situ probes and limitations of remote sensing techniques such as Mie, DIAL, and LIBS, and by the many desirable characteristics of the Raman process which include: 1) Specific Wavelength Shift - spectral shift of the Raman scattered light is uniquely identified with a specific type of molecule and its associated excitation level; 2) Well Determined and Independent Response - Raman line intensity is directly proportional to the number density of the Raman scattered specie and independent of the density of other molecules; 3) Three Dimensional Resolution - instantaneous response of the Raman process enables dimensional LIDAR techniques to be employed, and; 4) Accessibility of Temperature Information - Raman spectrum for gases in thermal equilibrium is a function of both specie concentration and temperature.

6396-23, Session 5

A new approach to the modeling of optical remote sensing systems using vortical scattering parameters

A. Belmonte, Univ. Politècnica de Catalunya (Spain); A. Lazaro, Rovira i Virgili Univ. (Spain)

Computer-aided design (CAD) of microwave circuits has allowed a better understanding of particular design problems and lead to a significant decrease in the time and cost of experimental investigations. The scattering matrix is the most common used technique to study propagation waves in transmission lines and microwave systems. Optical systems and microwave circuits share many fundamental properties: Both of them describe fields and physics devices in terms of linear differential operators and consider the principle of superposition. However, for all intents and purposes the application of scattering theory in optics has usually been limited to multilayer propagation of plane waves and the analysis of spatial diffraction, the most characteristic effect of any optical element, has had to be considered through techniques much less competent. All in one, computer-aided methods using a unified approach for solving optical problems are not yet became readily available because of the difficulties to put together a systematic able to deal simultaneously with all those intrinsic properties of optics.

This paper describes the use of a generalized modal scattering matrix theory as a fast, efficient approach to the analysis of optical systems. In contrast with other methods, the new technique uses a type of optical vortices, called Bessel beams. This rigorous modelling technique has interest in areas of optics as diverse as optical communications, spectrometry, and remote sensing systems. The tactic allows solving both multilayered reflections problems and spatial diffraction phenomena using scattering parameters (like in microwave systems) associated with the transmitted and reflected vortical spectrum.

Conference 6397: Technologies for Optical Countermeasures III

Tuesday 12 September 2006

Part of Proceedings of SPIE Vol. 6397 Technologies for Optical Countermeasures III

6397-01, Session 1

Swedish Defensive Aids Suite (DAS) project

O. Grönlund, Swedish Armed Forces (Sweden)

The need of Electro optical countermeasures in DAS (Defensive Aids Suite) will be discussed including a short description of the Swedish DAS project together with examples of tactical scenarios where EOCM could be the solution.

6397-02, Session 2

Microstructured fibres: a positive impact on defence technology?

E. J. O'Driscoll, M. A. Watson, T. Delmonte, BAE Systems plc (United Kingdom); M. N. Petrovich, X. Feng, J. C. Flanagan, D. J. Richardson, Univ. of Southampton (United Kingdom)

In this paper we seek to assess the potential impact of microstructured fibres for security and defence applications. Recent literature has presented results on using microstructured fibre for delivery of high power, high quality radiation and also on the use of microstructured fibre for broadband source generation.

Whilst these two applications may appear contradictory to one another the inherent design flexibility of microstructured fibres allows fibres to be fabricated for the specific application requirements, either minimising (for delivery) or maximising (for broadband source generation) the nonlinear effects.

In platform based laser applications such as IRCM, remote sensing, and laser DEW a suitable delivery fibre providing high power, high quality fibre delivery would allow a laser to be sited remotely from the sensor/device head. This opens up the possibility of several sensor/device types sharing the same multi-functional laser, thus reducing the complexity and hence the cost of such systems.

For applications requiring broadband source characteristics, microstructured fibres can also offer advantages over conventional sources. By exploiting the nonlinear effects it is possible to realise a multifunctional source for applications such as active hyperspectral imaging, countermeasures, and biochemical sensing.

These recent results suggest enormous potential for these novel fibre types to influence the next generation of photonic systems for security and defence applications. However, it is important to establish where the fibres can offer the greatest advantages and what research still needs to be done to drive the technology towards real platform solutions.

6397-03, Session 2

Thulium fibre laser pumped mid-IR source

I. Elder, D. Thorne, I. Jones, SELEX Sensors and Airborne Systems Ltd. (United Kingdom)

We present here a concept for an efficient, compact laser source of high average power in the 3-5 * m range. The laser architecture uses a high power thulium fibre laser as the pump source for a bulk Q-switched Ho:YAG laser. 60% conversion efficiency to 2.09 * m with excellent beam quality (M2 = 1.3 * 0.2) has been achieved using an L-shaped Ho:YAG resonator to allow double-passing of the pump light through the 1% doped laser rod. The maximum Ho:YAG output power achieved was 16.5 W at a Q-switch PRF of 20 kHz. The Ho:YAG output was used to pump a ZGP OPO, resulting in 8.1 W in the 3.8-4.8 * m wavelength range (a conversion efficiency of 52% from pump power incident at the ZGP), with beam quality M2 * 2. The ZGP OPO used a single 15 mm long crystal, with double-passing of the pump; maximum pump beam fluence at the ZGP was limited to 0.5 J.cm-2.

6397-04, Session 2

High-power fibre-laser-pumped mid-infrared laser sources

E. Lippert, S. Nicolas, G. Arisholm, K. Stenersen, A. S. Villanger, G. Rustad, Norwegian Defense Research Establishment (Norway)

There is an urgent military need for efficient mid-infrared (IR) countermeasure sources for protection of military and civilian platforms against heat seeking missiles. Recently, FFI has developed a compact and rugged mid-IR laser source intended for use in field trials against IR seekers. This source uses a 1.9 μm thulium fiber laser to pump a 2.1 μm holmium laser, which is Q-switched at 20 kHz pulse rate. The holmium laser, in turn, pumps a ZGP-based optical parametric oscillator (OPO) to generate tuneable output in the 3-5 μm region. Starting with 15 W pump from the fiber laser, we obtain 9.8 W from the Ho:YAG laser and 5 W of high beam quality mid-IR output from the ZGP OPO.

We will discuss the principles and characteristics of this source, together with recent progress in scaling it to higher output powers. By using a 70 W thulium fiber laser pump source, we have so far achieved about 40 W output power from a modified holmium laser, and are working on improvements that should increase the output even further. The main challenge is to handle the substantial thermal load in the laser rod. This requires careful choices of rod length, doping concentration, resonator geometry, pump beam diameter, and cooling arrangement. We will present results from numerical simulations of the laser characteristics and the influence of the mentioned parameters on the laser performance, and compare these results with the experimental data. We will also discuss the prospects for converting the output of this powerful source to both the 3-5 μm and 8-10 μm spectral bands.

6397-05, Session 3

End-pumped Q-switched Nd:YVO4 laser

I. Elder, D. Legge, J. Beedell, SELEX Sensors and Airborne Systems Ltd. (United Kingdom)

A laser diode end-pumped Q-switched Nd:YVO4 laser operating over a 25% to 100% duty cycle range has been built and characterised. A maximum average output power of 23.5 W has been achieved for 54 W of diode power (optical to optical conversion efficiency 44%). The Q-switch PRF was 200 kHz, 100 kHz and 50 kHz respectively for duty cycles of 25%, 50% and 100%. The Q-switch optical pulse width was * 25 ns independent of duty cycle. The beam quality factor M2 was measured to be 1.2, with a far-field beam jitter of 9 * rad (<0.3% of the far-field beam divergence). Operation at reduced duty cycles was achieved by appropriate modulation of the current to the pump diodes. The combination of output power, Q-switch optical pulse width, stability and beam quality make this an ideal laser source for pumping OPOs for a number of applications including optical countermeasures.

6397-06, Session 3

Diode laser bars deliver \> 400-W peak CW power from 800-nm to 980-nm enabling wide range of applications

P. A. Crump, nLight Corp. (USA)

Peak optical power from single 1-cm diode laser bars is advancing rapidly across all commercial wavelengths. Progress to date has allowed us to demonstrate \> 400-W peak output from single 1-cm diode laser bars at emission wavelengths from 800-nm to 980-nm. The available range of emission wavelengths has also been increased, with 90-W bars shown at 660-nm and 24W at 1900-nm, complementing the 100-W bar previously demonstrated at 1470-nm. Peak power is seen to correlate closely peak power conversion efficiency. Further advances in diode laser efficiency and low thermal resistance packaging technology continue to drive these powers higher. The most critical improvements have been the reduction in the diode laser operating voltage through optimization of hetero-barriers (leading to 73% efficient 100-W bars on copper micro-channel) and a reduction in packaging thermal resistance by optimizing micro-channel performance (leading to < 0.2-°C/W thermal resistance). Ever-increasing power levels (projected to eventually exceed 1-kW per bar) reduce the cost in Euro per W of diode laser systems, enabling broader application in military, industrial and medical markets. In addition, increasing availability of high powers at new wavelengths is enabling many new applications.

6397-07, Session 3

Development of 3.7-micron InAsSb DH and QW diode laser and LED sources grown by liquid phase epitaxy

M. Yin, A. Krier, R. Jones, Lancaster Univ. (United Kingdom)

The mid-infrared spectral region contains an atmospheric transmission window near 3.6-3.8 * m which is of interest for infrared countermeasures,

free space optical communications, gas detection and other applications. However, uptake of this technology is currently limited by the availability of inexpensive un-cooled LEDs and diode lasers. In this work we summarise our recent efforts to realize improved performance of these sources using liquid phase epitaxy (LPE). We report on the use of gettering for the growth of double heterostructure (DH) 3-4 * m lasers and the development of linear rapid slider boat technology for the production of quantum well (QW) structures based on InAs and InAsSb. Typical characteristics of some of these prototype sources are presented and analysed, including the results of SEM, X-ray diffraction, photo- and electroluminescence characteristics of prototype QW & DH devices. To improve performance and decrease non-radiative recombination, we focused on reduction of the inter-diffusion of phosphorus and zinc dopants into the active region during growth. Device annealing was also briefly investigated. A comparison of devices with ring resonators as well as conventional FP resonators was also made.

6397-09, Session 4

Novel laser beam steering techniques

H. D. Tholl, Diehl BGT Defence GmbH & Co. (Germany)

The paper reviews novel beam steering techniques for DIRCM and laser-based sensing applications. Principles, advantages and disadvantages of novel mechanical, micro-mechanical and non-mechanical techniques will be illuminated based on information from the open literature. Micro-lens based coarse beam steering in combination with liquid crystal phase control for fine steering will be presented in more detail. The outline of the paper will be roughly as follows:

1. Motivation.
2. Review of mechanical laser beam steering.
3. Review of micro-mechanical and non-mechanical laser beam steering.
4. Evaluation of the techniques for different applications.
5. Conclusion.

6397-11, Session 4

Experimental study of mid-IR laser beam wander close to a jet engine exhaust

M. Henriksson, Swedish Defence Research Agency (Sweden) and Royal Institute of Technology (Sweden); L. J. Sjöqvist, O. K. S. Gustafsson, Swedish Defence Research Agency (Sweden)

An increasing interest in lasers placed on aircrafts for active countermeasures and active imaging is seen. There remain unsolved issues on the propagation effects close to the jet engine exhaust and the possibilities of compensating them with adaptive optics. Experiments of laser beam propagation parallel to the exhaust of a downscaled jet engine test rig have been performed. The experiments were carried out with nanosecond laser pulses at 1.6 and 3.5 μm wavelength. The laser spots were projected on a screen and the centroid motion were imaged by cameras. Root mean square magnitudes of the beam wander between 50 and 150 μrad were observed for different engine conditions and geometries. The 3.5 μm system had a frame rate of 607 Hz and could partly resolve the time variation of the beam wander. A correlation time (3 dB) of 3.5 ms was observed for the beam wander. Deflections of several hundred μrad due to the average gradients in temperature and pressure were also found when the engine was turned on. In addition to beam wander intensity scintillations and beam break-up have been studied.

6397-12, Session 4

Multiwavelength laser propagation experiments

O. K. Steinvall, L. J. Sjöqvist, F. Berglund, L. Allard, T. Larsson, K. Karlsson, F. Kullander, Swedish Defence Research Agency (Sweden)

Atmospheric propagation experiments for active and passive EO systems were performed over a 2.5 and 8 km path. Single and double path propagation effects were studied using retroreflectors, resolution targets and hot point targets for both imaging and non imaging systems. The systems used include laser systems at 1.5 and 3.5 μm wavelength as well as imaging systems in the visible, 1-2 and 8-9 μm regions. A scintillometer operating at 0.8 μm wavelength was also used for the shorter path. Experimental data will be presented and evaluated concerning statistics and compared with theoretical modelling. The results will be discussed mainly from a laser countermeasure and imaging point of view.

6397-13, Session 4

IR laser induced heating in Hg0.75Cd0.25Te

A. Villanger, T. Brudevoll, K. Stenersen, Norwegian Defense Research Establishment (Norway)

Electro-optical sensors exposed to high-energy laser countermeasures may be permanently damaged due to excessive heating of the detector material. We present results from a numerical study on heating in Hg 0.75Cd 0.25Te induced by 3-5 μm laser pulses in the ns to μs regime. A number of highly nonlinear mechanisms contribute to the heating process, their relative importance being dependent on the instantaneous irradiance and the material temperature. The mechanisms include one- and two-photon absorption across the band gap, stimulated emission, inter-valence band absorption between the light- and heavy hole bands, electron-hole recombination, free-carrier absorption, hot-carrier generation, and refractive index changes. A special feature of this material is the fact that the direct band gap increases with temperature. This eventually terminates one-photon absorption processes from the valence to the conduction band. The varying band gap also introduces changes in the electron- and light hole masses and thereby in the separation between the light- and heavy hole bands, thus strongly affecting inter-valence band absorption. Therefore first principles electronic structure calculations were used to determine the band structure and the inter-valence band absorption. We find that two-photon absorption is essential for sustaining a high free carrier concentration, which enhances the inter-valence band absorption and ensures steady heating of the lattice towards the melting point. The simulations also show that hot carrier effects can have a significant influence on the amount of energy the material can absorb.

6397-14, Session 4

Inadvertent lasing hazards to space systems: methodology and analysis

L. A. Ridolfi, L-3 Titan (USA)

With the proliferation of lasers for ranging and atmospheric studies, satellite system operators have become concerned about the possibility of laser illumination on their vehicles. This paper contains the results of a risk analysis involving the inadvertent laser illumination of satellites from ground-based lasers. The methodology used for the probability analysis is discussed and specific examples are provided. The methodology begins with a discussion of the assumptions used; the principles involved; and then details of four specific cases using the methodology. The final case is for a notional polar orbiting, earth resource satellite with a steering optical sensor against a diverse, globally dispersed laser network. The author proposes this methodology be used for the systematic analysis of the probability of inadvertent laser illuminations against specific scenarios for satellite operations. For the notional cases examined in the paper we find the probability of a laser strike ranges from 10-5 to 10-9 for a single satellite lifetime of a decade. These extremely low probabilities imply lasers do not present an inadvertent hazard to satellite operations.

6397-15, Session 4

A self-contained native fluorescence detector for measurement of organic molecules and chemicals of life

A. I. Tsapin, Univ. of Southern California (USA); W. F. Hug, Photon Systems Inc. (USA); R. Bhartia, Jet Propulsion Lab. (USA); R. D. Reid, Photon Systems Inc. (USA)

We are developing a submersible deep ultraviolet laser induced native fluorescence (UVLINF) instrument to detect and identify trace levels of chemicals of life and other organic chemicals in subglacial lake environments in Antarctica. The instrument wills also measure and log temperature, pressure and conductivity of the ambient water environment. The instrument is solar-blind and can operate up to depths of few hundred meters. This instrument is intended to replace or supplement present measurement methods. The proposed concept uses a 224.3nm laser to excite and measure fluorescence in multiple UV and visible wavebands as a function of depth in a body of water. These fluorescence measurements can then be interpreted to classify organic material discovered during submersion of the instrument. The fluorescence instrument has the advantage that very sensitive measurements can be made in microseconds so that vertical profiling of a body of water can be done rapidly. The instrument also can be used for fast analysis of water quality from different sources.

6397-16, Session 5

Imaging seeker surrogate for IRCM evaluation

H. M. A. Schleijpen, TNO (Netherlands)

NATO-SCI-139 and its predecessor groups have more than a decade of history in the evaluation and recommendation of EO and IR Countermeasures against anti-aircraft missiles. Surrogate Seekers have proven to be a valuable tool for this work. In the past the group has deployed surrogate seekers successfully in several international and national field trials.

The use of surrogate seekers in international co-operations has several advantages over the use of an operational seeker, which is in service or in development:

- the system is flexible (not a point design), allowing both hardware and software modifications to be made in order to test the effectiveness of specific IRCM techniques;
- the seeker design is open - every last parameter is available to the science team, allowing detailed, end-to-end validation of software models and simulations;
- the availability of an unclassified seeker facilitates open discussions on CM issues between the participants in the NATO-group.

The next generation seekers will be using imaging devices. Therefore, stimulated by the success of previous experience in using surrogate seekers, the group decided to acquire an Imaging Seeker Surrogate (ISS).

Testing of high intensity countermeasures (for example based on lasers) needs a system with realistic seeker optics, with proper representation of optical scatter, which differs from scatter in commercial infrared camera optics.

A technical description of the ISS will be given: an overview of the optical design and the detector, the principle of the tracking software and the possibilities to implement alternative tracking algorithms in order to represent different threat CCM techniques. The ISS is built for use both in the laboratory and in the field. Finally, some experimental results will be presented.

6397-17, Session 5

Modeling the improved protection of fast jets from the IR MANPADS threat

M. A. Richardson, N. Tranquillino-Minerva, Cranfield Univ. (United Kingdom); B. Butters, R. Walmsley, R. Ayling, N. Millwood, Chemring Countermeasures (United Kingdom)

Anti-aircraft infrared (IR) guided missile systems, such as man-portable air defence systems (MANPADS), may be equipped with a variety of counter-countermeasure techniques. One such technique could be to look at the trajectory differences of a fast moving jet aircraft and a deployed flare countermeasure (this is often known as relative kinematics). This paper investigates, via simulation, what improvement in aircraft protection against MANPADS might be achieved by modifying these trajectory differences through the use of advanced flare decoys and forward firing techniques.

6397-18, Session 5

Quantitative optimisation of expendable countermeasures

H. Hovland, Forsvarets Forsknings Institute (Norway)

Self-protection systems using expendable pyrotechnics have been in operational service for several decades, and still enjoy a significant popularity on military platforms, due to potentially high efficiency, low cost and versatility. Recent developments in advanced materials as well as spatial and temporal behaviour optimization using advanced simulation tools also contribute to continued success against threat systems of ever-increasing sophistication.

One of the most significant drawbacks of these systems is the limited capacity of the countermeasures dispensers of such a system. The risk of emptying the countermeasures dispensers leads to restrictions in the acceptable false-alarm-rate, again leading to a reduced detection probability. The approaches for optimization known to the author have been either one of Monte-Carlo simulations or a functional threat countering analysis. Neither of these brings insight into the parameters relating the overall performance of the self-protection system against one missile attack and the overall platform survivability on a mission.

In this work, a new model is presented where an overall survivability probability can be calculated and optimized, including the effect of a limited dispenser capacity versus countermeasures program size as well as missile approach warning systems key parameters, such as detection probability and false-alarm-rate. The model is extended to allow independently variable missile attack- and false-alarm probabilities. Criteria for choosing optimal flare programs are presented. It is shown that a dynamic update of the self protection system can enhance the performance of self-protection systems deploying expendable countermeasures. Monte-Carlo-simulations are shown to be in good agreement with the model.

6397-19, Session 5

PALMA: protection of airliners against manpads attacks

G. Fournier, EADS CCR (France)

Security of air transport is a major concern. Airplanes are vulnerable and attractive targets for terrorists. Recent events showed that Man Portable Air Defence Systems (MANPADS) have become a new weapon in the hands of terrorists.

Aircraft protection against missiles is already mastered in the military field but a mere adaptation of existing products will not match the much more demanding requirements of the civilian environment. Research activities and development of new technologies are necessary to fit these very specific constraints.

The presentation will give an overview of the PALMA project, selected in PASR 2005 by the European Commission, and dedicated to specific research, analysis and demonstrations to evaluate the potentialities and the limitations of self-protection systems, prepare the operational concepts and technology orientations necessary for future solutions.

6397-20, Session 5

Modeling of EO countermeasure systems in a network perspective

C. Wigren, Swedish Defence Research Agency (Sweden)

With (small scale) network centric warfare it should be possible to automatically share information between platforms and units in such a way that information from e.g. warning sensors on one platform can be used to increase the survivability of another platform within the same unit. However, it is very important to study the abilities and limitations of Electronic Warfare (EW) systems when used in a network since they are operating outside their normal boundaries. For instance, warning sensors in a network should warn not only against objects approaching the platform of the sensor but also objects approaching other platforms in the unit. Also, time from receiving a warning on one platform to deploying countermeasures from another platform can increase drastically due to delays when communicating sensor data. Issues such as these are, initially, best studied using simulations.

This paper describes and demonstrates a method where it is possible to configure and simulate an entire scenario with several platforms in a network and where EW is an integrated part. The method utilizes a multispectral (radio, radar, electro-optics) framework, EWSim (Electronic Warfare Simulation interface model), for distributed EW simulations. In the framework it is possible to design scenarios which can assess the few-against-few duel, in a single user mode or in an assessment duel where teams can compete against each other.

6397-10, Poster Session

Sub-μrad laser beam tracking

I. Buske, W. Riede, German Aerospace Ctr. (Germany)

For long-range tracking applications like free-space laser communication, there is an increasing need for high precision beam steering systems capable to achieve sub-μrad pointing and tracking accuracy. In this paper we compared active optical elements based on different technologies to accomplish the requirements of a 2-dim. fine tracking control system. A cascaded optically and electrically addressable spatial light modulator (OASLM) based on liquid crystals (LC) was used for refractive beam steering. Spatial light modulators provide a controllable phase wedge to generate a beam deflection. In combination with diffractive beam steering a continuous coverage of deflection angles up to several millirads is possible. Additionally, a competing tip/tilt mirror approach operated with piezomechanic actuators was investigated. The different beam steering

systems are evaluated concerning laser power threshold, resonance oscillations, cut-off frequency, maximal deflection angle, angle accuracy and angle resolution.

A digital PID controller is implemented in the closed-loop system. Beam tracking with an accuracy of 0.2 μrad had been laboratory-confirmed. An associated step function response better than 50 ms was achieved.

6397-21, Poster Session

One theoretical method for designing combustor of DF chemical laser

J. Lei, L. Lin, Z. Wang, National Univ. of Defense Technology (China)

In order to design combustor of combustion driven DF chemical laser with given output power, one theoretical method has been developed. F-atom density is critical parameters in laser and it can be calculated from the given output power. So the first step of this method is to build the model which can estimate the production of F-atom at the nozzle exit plane by using control volume analysis and one-dimensional reacting gasdynamics. In this model, the correlation between F-atom flow rate and the mass flow rate of fuel, oxidant and diluent is established using thermochemistry and conventional hest flux balance. The second step is to confirm the optimal match of fuel and oxidant, the optimal match of fuel and diluent. This step is accomplished by using theoretical deducting and numerical simulating. Also the effects on the laser performance such as F-atom density, combustor temperature and assistant production components with different match of reactant are investigated. The last step is to design combustor configuration parameters including injector throat area, injecting pressure and so on. This method has been applied to design one refinement combustor of low power, single throat DF chemical laser which is used for research on mixing performance of HYLTE nozzle. The combustor has been manufactured in special structure such as water-cooled wall, high mixing performance injector with several four-hole muzzles. Such a method is valuable for primary designing and need to be improved in the aspects of model and numerical simulation. Also it can be applied to other laser combustor design.

6397-22, Poster Session

Method research on mixing measurement in DF chemical laser

J. Lei, L. Lin, Z. Wang, National Univ. of Defense Technology (China)

Mixing performance is the critical index in combustion driven continuous wave DF chemical laser nozzle design. The feasibility of several measurements which are used to evaluate the mixing performance of a designed HYLTE (HYpersonic Low TEmperature) nozzle has been studied. Schlieren visualization is the most used experimental method in cold flowfield visualization, but this photograph is not clear enough to study the mixing mechanism in the supersonic cross flow of HYLTE nozzle. LIIF (Laser Induced Iodine Fluorescence) is an advanced technology to visualize flowfield, and its precision is higher than ordinary measurement, but it has one evident disadvantage. Because iodine can react with the components in the HYLTE nozzle, this technology can not be used to visualize the reacting flowfield. The reacting flowfield measurement is the important problem in laser experiment. We investigated three visualization technologies including high-speed imaging, NPLS (Nanometer Plane Laser Scatter) and Acetone-PLIF to study the reacting flow process in HYLTE nozzle. In order to visualize the expanding part that includes transverse jet and mixing process, a single throat nozzle laser with window has been designed and manufactured. All experiments were operated on this equipment and some results were obtained.

Conference 6398: Optically-Based Biological and Chemical Detection for Defence III

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6398-01, Session 1

Future directions in chemical and biological detection

E. C. Wack, S. Lennon, C. Wilhide, R. Floyd, R. Newton, Joint Program Executive Office for Chemical and Biological Defense (USA)

The JPEO-CBD, in conjunction with other members of the defense community, is actively assessing future system architectures for Major Defense Acquisition Programs (MDAPs) such as the Future Combat Systems (FCS). Sensors, networks and information superiority are key elements of FCS, and the JPEO will provide the critical capability that enables complete situational awareness of CB hazards. After a brief overview of the JPEO-CBD program, this paper discusses early insight into how FCS operations and platforms affect CB sensors. Key challenges will be highlighted, such as sensor/platform integration, broad spectrum detection, and sensor performance.

6398-02, Session 1

C/B detection strategy

M. McLoughlin, HSARPA (USA)

No abstract available

6398-03, Session 1

Development of biological agent detectors for a range of threat scenarios

T. H. Jeys, MIT Lincoln Lab. (USA)

No abstract available

6398-04, Session 2

CBS3: Phase II report

M. Munley, Booz Allen Hamilton (USA)

No abstract available

6398-05, Session 2

Scenario modeling

M. Shatz, MIT Lincoln Lab. (USA)

No abstract available

6398-06, Session 2

Fluorescence excitation-emission maps database of biological agents

M. Wlodarski, M. Kaliszewski, M. Kwasny, K. Kopczynski, Z. Zawadzki, Z. Mierczyk, J. Mlynczak, Military Univ. of Technology (Poland); E. Trafny, M. Szpakowska, The General Karol Kaczkowski Military Institute of Hygiene & Epidemiology (Poland)

Fluorescence methods can be applied for detection of biological material due to presence of endogenous fluorophores. The aim of our work was to create a database of excitation-emission (EX-EM) maps and fluorescence cross-sections of various bacteria, spores, fungi and pollens suspended in water. Moreover, acquired 3D fingerprints revealed differences in EX-EM spectra depending on culturing conditions including various media, viability (death kinetics) and washing.

Presented EX - EM fluorescence matrices provide also very important information on distinction between pure samples and potential threat agents due to presence of media residues and used stabilizers.

The analysis of fluorescence profiles ensures selection of multiple excitation wavelenghts suitable for discrimination of different kinds of biological material. The presented data are a basis for design of devices for detecting biological material in air aerosol with LIF.

6398-08, Session 2

A rugged early-warning spectroscopic system for real-time environment water monitoring

B. Ling, M. Zeifman, Migma Systems, Inc. (USA)

Many of BWA-s and CWA-s significantly absorb electro-magnetic energy in the UV and/or IR regions. Unfortunately, the absorption spectra of the agents heavily overlap with each other and with absorption spectra of harmless species. The traditional approach of spectral discrimination usually involves estimation of concentration of each constituent, wherein the first- and second derivatives are being used as the spectrum features, and the linear relationship between these features and the concentrations is sought by, e.g., the partial least squares or principal component regression. These algorithms may not be suitable for real-time early warning detection of BWA/CWA, especially taking into account the inevitable presence of environmental constituents with unknown spectra. In this paper, we present a new approach suitable for ragged, real-time spectral discrimination. In our system, we collect an array of spectra and then use an independent component analysis (ICA) technique to unmix the mixture into independent spectral components. To classify the components, we use our unique CWF (Complex Wavelet Fourier) features. Once the features are available, we classify each unmixed component via a hierarchical classifier. The presence of a species with an unknown spectrum, therefore, does not pose a challenge, whereas the ICA procedure is capable of reliable unmixing of both abundant and trace species. We have tested the procedure experimentally using a ragged fiber-optics NIR spectrometer and mixtures of organic liquids. The obtained results clearly demonstrate the applicability of the proposed system to the early warning “trigger”-type detection suitable for real-time environment water monitoring.

6398-43, Session 2

Integrated network solutions for CBRN detection

S. M. Maurer, L. Gilbert, Lockheed Martin Co. (USA)

The Lockheed Martin Biological Aerosol Warning System (BAWS) is designed to provide early warning of the possible presence of a biological agent aerosol cloud released over a medium-to-large grid area. The system is based on detecting and counting particles in the air of a size commensurate with a biological agent and uses an ultraviolet-LED induced fluorescence (UV-LIF) detector in order to discriminate between biological and non-biological samples. The BAWS system uses an integrated sensor network along with the requirement that the particles must fluoresce and be in the respirable range to consider them a biological threat, to effectively minimize false alarms. The BAWS system consists of two main elements: 1) Remote Sensors which are positioned out as sentinels and 2) a Base Station where an operator can monitor, collect remote sensor data, and manage the entire network. The system is powered by commercially available rechargeable lithium ion batteries, vehicle power or other available power sources. An example of system expansion and flexibility of the BAWS sensor network hub is the ability to augment the system with automated point and stand-off chemical / biological detectors for longer range and system tier performance. Recent developments of the Chemical, Biological, and Radiological Early Warning System (CBREWS) have taken the BAWS sensor network concept and integrated onboard, chemical, biological, and radiological sensors. The ruggedized BAWS system offers rapid deployment, ease of operation, low maintenance and therefore provides an early warning capability for both the battlefield and the perimeters of key facilities.

6398-09, Session 3

Overview of compact, rapid-point detection for BWA

A. V. Nurmikko, Brown Univ. (USA)

No abstract available

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6398-10, Session 3

Experimental performance of a novel aerosol sorting and deposition system for bio-threat sensing applications

T. A. Pletcher, J. McGinn, D. Keller, Sarnoff Corp. (USA); V. Sivaprakasam, A. L. Huston, J. D. Eversole, Naval Research Lab. (USA)

Sarnoff Corporation, The Naval Research Laboratory, and ChemImage Corporation, through support from HSARPA, have been developing an automated, high throughput bio-aerosol sampling and identification system designed for use as part of a biological-threat protection system. The Biological Detect-to-Protect System (BioD2P) is a spectrographically based system that combines three unique technologies to create a detection scheme capable of near real-time acquisition speeds (i.e. 2 - 5 minutes per sample), high sensitivity (i.e. \>= 25 threat particles per liter) and threat specificity while maintaining a low rate of false alarms (i.e. Pfa <= 4 x 10-5, or about one false alarm per month).

The system achieves this performance with a combination of physical and virtual enrichment of the sampled aerosol. The system is partitioned into three main functions. The physical enrichment function consists of an air-to-air concentrator that samples the ambient atmosphere at a rate of 400 liters per minutes and produces a one-half liter per minute output with an effective concentration ratio of approximately 400:1. The one-half liter per minute output is then interrogated by a dual wavelength UV-LIF trigger that detects the presence of biological particles in the airflow. A signal is produced when a biological particle is present and is used to activate an electrostatic deposition circuit that subsequently deposits the detected particle onto a metal substrate.

The enriched sample is then presented to a suite of optical sensors that use microscopic visible and fluorescent imaging techniques to select specific areas from the deposition plane that are most likely to contain potential threat particles. The selected areas are then interrogated by a Raman imaging spectroscopy system that produces multiple independent Raman spectra each defined by a 2.5 um field of view at the deposition surface. These spectra are then analyzed to determine the specific identity of the threat particles. Finally, combinatorial statistics are utilized to achieve the low false alarm rate.

This paper will present an abbreviated overview of the system described above. The main focus of the paper will be the performance of the physical enrichment feasibility system consisting of a laser based trigger system combined with an electrostatic particle sorting and deposition system. A laboratory-based system was constructed at Sarnoff Corporation to evaluate the achievable enrichment factor using fluorescent polystyrene beads varying in size from 1um particle diameter to 3um particle diameter. Aerosol particle classification was based upon particle size and the enrichment factor at the deposition surface was determined using fluorescent microscopic particle counting techniques. A large number of particle sorting scenarios were evaluated and the results of these trials will be discussed with respect to the applicability of this physical enrichment technique for spectrographic and other bio-detection techniques.

6398-11, Session 3

A compact aerosol sensor and spectroscopic sorting with UV LEDs

K. M. Davitt, Y. Song, W. R. Patterson III, A. V. Nurmikko, Brown Univ. (USA); Y. Pan, R. K. Chang, M. Gherasimova, J. Han, Yale Univ. (USA); P. J. Cobler, P. D. Butler, V. Palermo, Vtech Engineering Corp. (USA)

We demonstrate a compact system, incorporating a 32-element linear array of ultraviolet (290 nm and 340 nm) light-emitting diodes (LEDs) and a multi-anode photomultiplier tube, to the in-flight fluorescence detection of aerosolized particles. Custom electronics mange a standalone system and enable real-time processing of spectral data, which is used to cue a miniaturized aerodynamic deflector for physical particle separation.

Our compact front-end system improves the prospects for many second-stage analysis methods by reducing the background particle burden and providing a suspicious-particle enriched sample. The performance of UV LED arrays as an excitation source for bio-aerosols is established by the ability to detect emission from NADH and tryptophan in aerosol samples. On-the-fly fluorescence collection, operation of a real-time spectral algorithm, and aerosol concentration is demonstrated by separating particles that exhibit a specific spectral feature from a high background of otherwise fluorescing particles. The resulting sorted sample provides a direct measure of the success of the optical system and fluorescence algorithm in identifying classes of fluorophores.

By the application of emerging UV semiconductor light emitters in conjunction with custom-designed electronics and a miniaturized aerodynamic deflector, we significantly reduce the size of the entire sensor system while maintaining both the capability of real-time fluorescence spectral detection and analysis, and physical sorting of particles, tasks that are traditionally the realm of table-top size systems. This opens the possibility of creating truly portable aerosol warning sensors or front-end sensor networks.

This work is supported by the Defence Advanced Research Projects Agency SUVOS program under SPAWAR Systems Center Contract No. N66001-02-C-8017.

6398-12, Session 3

Terahertz imaging for biological detection

R. M. Woodward, HT Consultants Ltd. (United Kingdom)

No abstract available

6398-13, Session 4

Integration of optical CBRNE technologies with ICX technologies

D. W. Cullin, ICx Technologies Inc. (USA)

ICx Technologies is a developer and producer of sensing technologies covering the broad range of threats of concern to military as well as homeland security organizations. ICx offers a range of hand held, tactical sensors capable of detecting Chemical, Biological, Radiological and Explosive Threats as well as a series of laboratory grade products for higher fidelity sensing. In addition, ICx also produces a series of high resolution radar systems, thermal and visible band camera systems and software products which when combined offer unsurpassed integrated physical surveillance solutions.

This talk will provide an overview of mature products and ongoing developmental activity underway within ICx. The discussion will particularly focus on the application of optical techniques and technologies in our series of CBRNE sensors. Some are direct interrogation of threats of interest, some rely on the sensing of changes within a specific chemical or biological system. Finally, the discussion will focus on the integration of products to provide broad spectrum solutions across the threat space. Specific examples of those integrated solutions will be presented.

6398-14, Session 4

Biological aerosol detection with the tactical biological (TAC-BIO) detector

A. Poldmae, J. B. Cabalo, M. De Lucia, F. Narayanan, D. W. Sickenberger, U.S. Army Research, Development and Engineering Command (USA)

A lightweight, tactical biological agent detection network offers the potential for a detect-to-warn capability against biological aerosol attacks. Ideally, this capability can be achieved by deploying the sensors upwind from the protected assets. The farther the distance upwind, the greater the warning time.

The challenge to this concept is the biological detection technology. Here, cost, size and power are major factors in selecting acceptable technologies. This is in part due to the increased field densities needed to cover the upwind area and that the sensors, when deployed forward, must operate autonomously for long periods of time with little or no long-term logistical support.

The Solid-state Ultraviolet Optical Source (SUVOS) program offered an enabling technology to achieving a detector compatible with this mission. As an optical source, these devices emit an excitation wavelength known to be useful in the detection of biological aerosols. This wavelength is absorbed by the biological aerosol and results in visible fluorescence. Detection of a biological aerosol is based on the observed intensity of this fluorescence signal compared to a background reference. Historically, this has been accomplished with emission sources that are outside the boundaries for low cost, low power sensors. The SUVOS technology, on the other hand, provides the same basic wavelengths needed for the detection process in a small, low power package.

ECBC's Tactical Biological (TAC-BIO) detector program is an effort to develop these micro UV sensors that make network arrays feasible. This

paper presents an overview of the TAC-BIO detector design and recent results.

6398-15, Session 4

Spectral detection of ultraviolet laser induced fluorescence from individual bio-aerosol particles

P. Jonsson, F. Kullander, C. Vahlberg, Swedish Defence Research Agency (Sweden); M. Tiihonen, KTH - Royal Institute of Technology (Sweden); P. Wästerby, T. Tjärnhage, Swedish Defence Research Agency (Sweden); M. Lindgren, Swedish Defence Research Agency (Sweden) and Norwegian Univ. of Science and Technology (Norway)

We present results of a measurement system designed for detecting the fluorescence spectrum of individual aerosol particles of biological warfare agents excited with laser pulses at wavelengths around 266, 290 or 340 nm. The biological aerosol is prepared and directed into a narrow air beam. A red laser is focused on the aerosol beam and a trigger photomultiplier tube monitor the presence of individual particles by measuring the scattered light. When a particle is present in the detection volume, a laser pulse is triggered from an ultraviolet laser and the fluorescence spectrum is acquired with a spectrometer based on a diffraction grating and a 32 channels photomultiplier tube array with single-photon sensitivity. The spectrometer measures the fluorescence spectra in the wavelength region from 300 to 800 nm. In the experiment we used different simulants of biological warfare agents. These bioaerosol particles were excited by two different commercial available lasers, a solid state laser (266 nm) and a gas laser (337 nm), and a laser (290 nm) that we have developed based on an optical parametric oscillator with intracavity sum-frequency mixing. In the analysis of experiments we compare the measured signals (fluorescence spectra, total fluorescence energy and the scattered energy) from the individual bioaerosol particles excited with the three different ultraviolet wavelengths.

6398-16, Session 4

Optical chamber design for aerosol particle fluorescent measurements

A. Rostedt, M. Putkiranta, M. Marjamäki, J. Keskinen, Tampere Univ. of Technology (Finland); K. Janka, R. Reinivaara, L. Holma, Dekati Ltd. (Finland)

The interest to develop high quality methods for biological and chemical warfare agent detection and identification has increased because of the threat of terrorist attacks. One of the most promising techniques to distinguish biological aerosols from the other aerosols is the UV-induced fluorescence.

In this study an optical chamber to measure fluorescence spectrum from individual aerosol particles was designed and built. This work is part of the European Defense Agency project FABIOLA. The chamber includes a two-nozzle flow system with sheath air flow and an integrated virtual impactor concentrator. The virtual impactor concentrates particles larger than 2 μm. The nozzle system passes the aerosol sample through the chamber in a narrow well defined jet. Chamber includes two couplings for lasers. A red diode-laser is used to trigger the pulsed UV-laser that induces the fluorescence. Triggering system enables the hitting of individual aerosol particles with UV-laser. Triggering and UV-laser beams are both perpendicular to the aerosol flow. Fluorescent light is collected with an elliptical mirror to the detector. The main challenge is to combine wide-angle collection optics, a proper airflow system and two laser beams to one optical chamber.

According to CFD-calculations, the width of the aerosol jet is about 0.6mm and variations in aerosol velocity are low. Low velocity differences in different parts of the jet are important to ensure maximum accuracy for the triggering system. Experimental flow visualizations confirm that the flow system operates as it was designed and sheath air around the aerosol jet ensures that the chamber is not contaminated from the particles in the sample flow. Aerosol jet passes on the other focal point of the mirror. UV-laser beam is directed and focused to the same focal point of the mirror. Collection optics are designed to focus the fluorescent light on the other focal point, where the detector is located. Depending on the detector set-up, fluorescent spectrum, intensity or the time decay can be measured.

6398-17, Session 4

Low-cost sensor network for bioaerosol detection

C. J. Call, E. L. Merrill, S. Albanna, R. K. DeFreez, MesoSystems Technology, Inc. (USA)

A fluorescence sensor (AirSentinel(r)) employing light ultra-violet light emitting diodes is described. Measurements of sensitivity verses false alarm rates are presented for several indoor environments. The sensor is employed to detect biological threats by assessing change in ambient bioaerosol levels, which are inferred from the fluorescence measurements.

The AirSentinel been configured to fit into new or existing building control networks. The distributed network of low cost sensors is similar to the smoke alarm approach used in buildings today. If a sensor detects an event, an alarm is sent via the building control system.

An aerosol sample collector has also been integrated into the AirSentinel sensor. When an alarm has been generated, the aerosol sampler is activated for a 5 minute sample collection. The sampler incorporates a rotating impaction technology that collects the aerosol onto an impeller disk. The collection impeller disk is easily removed from the system and provides an aerosol sample for confirmation testing.

Since UV fluorescence sensors are not capable of distinguishing naturally-occurring ambient bioaerosols from bio-threat aerosols, a second type of sensor is needed to confirm or rule out the presence of an actual bio-threat aerosol. To complete this test, the aerosol sample is extracted from the collection impeller disk into a buffered saline solution. Two primary detection methods exist for confirmation testing. Polymerase Chain Reaction (PCR) is used to identify if certain nucleic acid sequences associated with the threat organisms are present or alternatively, immunoassay test can target specific proteins associated with bio-threats. These technologies can be completed in less than 30 minutes.

A system-level false alarm is generated only when the UV florescence sensor has alarmed, a sample has been collected, and the second orthogonal test has resulted in a false positive. This two-tiered detection methodology has two desired characteristics: a fast-response warning capability and a low system false alarm rate. Operating experience with a two-tiered sensor network deployed in a commercial office building will be described.

6398-19, Session 4

Microfluidics-based integrated airborne pathogen detection systems

M. A. Northrup, Microfluidic Systems Inc. (USA)

Microfludic Systems Inc. (MFSI) is developing two kinds of optically-based, automated bio-aeorosol pathogen detection systems based on microfluidic circuits. The first is a detect-to-treat system, call the BioAgent Networked Detector (BAND) and the second is a detect-to-warn system called Instantaneous BioAerosol Detection System or (IBADS). Both of these systems are funded by the US Department of Homeland Security's HSARPA program, contain overlapping technologies, but provide for very different scenario protections against air-borne biological threats. The BAND system consists of a high volume air collector, automated sample processing and detection microfluidics and runs completely autonomously for weeks to months. It performs both flow-through immunoassays for toxins and end-point optical fluorescent measurements of polymerase chain reaction assays for nucleic acids (bacteria and viruses). The IBADS uses very rapid, high through-put, microfluidics-based immunoassays with in-situ optical fluorescence detection. MFSI is focused specifically on the confirmatory assay portion of the IBADS system, but is working closely with a collaborator on integrating the detection system into the trigger and collector to form a complete IBADS system for deployment.

The BAND system has been shown to perform a variety of autonomous assays with very high sensitivity within the time frame required for a detect-to-treat requirement. The MFSI BAND System, along with specific pathogen detection results will be presented. The MFSI IBADS confirmatory device (BioCADS) , along with results from its integration with the trigger will also be presented including 5-minute, high sensitivity, confirmatory pathogen detection results.

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6398-20, Session 4

Real-time detection of aerolsolized biological threat agents

A. Castro, Los Alamos National Lab. (USA)

No abstract available

6398-21, Session 4

Stroboscopic technique for measurement of fluorescence lifetimes of bacteria, fungi, and biological interferents

M. Wlodarski, M. Kwasny, K. Kopczynski, Military Univ. of Technology (Poland)

This work describes possibility of identification of various bacterial species and their discrimination from other biological materials by measuring fluorescence lifetimes. Methods of fluorescence lifetimes measurements are more and more often used for identification of bacterial species. Two most common techniques - time-correlated single photon counting (TC-SPC) and phase modulation need long time for measurement. Due to stroboscopic optical boxcar technique, real-time measurements results are obtained (10 seconds or shorter measurement time). So, this technique can be used in the systems of biological agent detection. Stroboscopic technique is based on amplification gating of PMT. Electric pulse is injected into a delay line connecting the photocathode and dynodes of a photomultiplier tube. Traveling pulse creates transient potential difference between dynodes resulting in significant amplification over a short period of time. Control of a delay between electric pulse and excitation source flash allows the intensity of fluorescence to be measured as a function of time. The measurements were made with EasyLife LS system from Photon Technology International. LEDs were used as excitation sources. Measurements were made for two excitation wavelengths: 280 nm and 340 nm. Fluorescence lifetimes were determined for bacterial spores and vegetative form, fungi and fungal spores, plant spores and pollens.

6398-29, Session 4

Rapid agent aerosol detector breadboard

W. D. Herzog, J. D. Hybl, D. Tardiff, P. C. Patel, R. H. Hoffeld, S. M. Tysk, W. F. DiNatale, A. Norige, G. Molnar, A. Sanchez-Rubio, MIT Lincoln Lab. (USA); V. Sivaprakasam, A. L. Huston, J. D. Eversole, Naval Research Lab. (USA)

The Rapid Agent Aerosol Detector (RAAD) Breadboard is a biological and chemical aerosol sensor that measures elastic scattering, dual UV-wavelength excited, multi-channel, detected fluorescence, and laser-induced breakdown spectra (LIBS) of single aerosol particles. We will present aspects of the instrument design and analysis of the performance of the combination of these technologies for aerosol discrimination.

6398-40, Session 4

A self-contained native fluorescence detector for measurement of organic molecules and chemicals of life

A. I. Tsapin, Jet Propulsion Lab. (USA); W. F. Hug, Photon Systems, Inc. (USA); R. Bhartia, Jet Propulsion Lab. (USA); R. D. Reid, Photon Systems, Inc. (USA)

We are developing a submersible deep ultraviolet laser induced native fluorescence (UVLINF) instrument to detect and identify trace levels of chemicals of life and other organic chemicals in subglacial lake environments in Antarctica. The instrument wills also measure and log temperature, pressure and conductivity of the ambient water environment. The instrument is solar-blind and can operate up to depths of few hundred meters. This instrument is intended to replace or supplement present measurement methods. The proposed concept uses a 224.3nm laser to excite and measure fluorescence in multiple UV and visible wavebands as a function of depth in a body of water. These fluorescence measurements can then be interpreted to classify organic material discovered during submersion of the instrument. The fluorescence instrument has the advantage that very sensitive measurements can be made in microseconds so that vertical profiling of a body of water can be done rapidly. The instrument also can be used for fast analysis of water quality from different sources.

6398-22, Session 5

Detection of infectious agents by xMAP multiplexed suspension array technology

S. A. Dunbar, Luminex Corp. (USA)

The Luminex xMAP(tm) system couples bioassays with advanced digital signal processing and proprietary identification techniques to perform multi-analyte testing of up to 100 features in real time. The general configuration of an xMAP assay can be described as a suspension array where specific capture moieties are covalently coupled to the surfaces of internally dyed microspheres. Fluorescent dyes contained within the microspheres provide unique spectral characteristics allowing each microsphere set to be distinguished from all others in the multiplex. The target is labeled for fluorescent detection. Examples will be presented describing rapid, multiplexed protein and nucleic acid analyses for infectious agents that demonstrate the utility of the platform. Benefits of the system include speed, economy, flexibility, and advanced capabilities. The potential for simultaneous detection of tens, hundreds, and even thousands of protein and nucleic acid targets provides for simultaneous, rapid, sensitive, and specific molecular analyses.

6398-23, Session 5

Development of an integrated detection and identification system for airborne biological agents

M. B. Tabacco, Smiths Detection (USA); J. Lewington, Smiths Detection (United Kingdom)

Smiths Detection is developing sensors and integrated instruments for rapid detection and identification of airborne biological agents. A biosensor array has been developed that provides real-time detection and classification of microorganisms based on molecular recognition and fluorescence spectroscopy. The biosensors for classification are being integrated with an identification instrument that is based on a novel approach combining surface plasmon resonance and light scattering. This device continuously monitors for up to 20 biological agents and provide identification in 15 minutes or less. Integration of these instruments provides for continuous air sampling and 24/7 detection and identification.

6398-24, Session 5

Novel device for multiplexed microsphere-based biological threat detection

A. R. Schilffarth, W. Deicher, Luminex Corp. (USA)

Multiplex analysis and flexibility are two of the most sought after features in biological threat detection. Multiplexed orthogonal markers enhance sensitivity and specificity, and flexibility allows a sensor to avoid obsolescence by adapting to emerging threats. Both multiplexing and flexibility are inherent to Luminex Corporation's xMAP microsphere platform. A novel device tailored for flexible biological threat detection utilizing xMAP technology is discussed in this paper.

6398-25, Session 5

UV imaging of biochips: limitations of contrast

J. Reverchon, C. Meyer, S. Cassette, Thales Research & Technology (France)

Ultraviolet microscopy is a bright field technique that uses short wavelengths to yield higher resolution than a conventional light microscope. The absorption of proteins at 280nm and DNA at 260nm gives additional contrast without staining. Combined with modern video equipment, these two facts render UV imaging a useful tool in live cell imaging - building on one hundred years of experience. Nevertheless, dissemination of UV imaging is still low due to the expensive material required, and the need of monochromator for wavelengths selection. On the contrary the new AlGaN based imagery is intrinsically very sensitive to ultraviolet and prevent the use of a spectroscope. It allows UV imaging at extremely low flux minimising damage for biological samples. In the frame of biological threat, security systems require label free biochips for rapid detection. SPR imaging is such a method proposed for antibody / antigen recognition but the optical set-up based on reflection requires a large optical path, and detection is only efficient as long as the biological compounds are close to the chip surface. In case of cells or bacteria whose typical dimensions are larger, ultraviolet imaging is a compact and suitable method to increase contrast. We present here DNA and protein

chips imaging obtained with a AlGaN based camera. When using a reflecting chip (metal or dielectric mirror), absorption gives a contrast even for short DNA of 100bp. Diffusion is another source for contrast in case of absorbing slides or in case of proteins. Finally, we compare sensitivity to other classical biological detection.

6398-26, Session 6

Micromachined chemiluminescent system for improvised explosives device detection

Y. S. Park, D. P. Neikirk, E. V. Anslyn, The Univ. of Texas at Austin (USA)

Under the recent US Office of Naval Research University Affiliated Research Center (UARC) Counter IED Basic Research Program we have begun a number of activities that we hope will enhance future ability to detect the presence of improvised explosives devices (IEDs). In this talk we will present work on the development of a microfluidic system for a new point chemical sensor that would allow the rapid, accurate, and specific detection of vapors emitted by explosive materials. We have already extensively tested a micromachined platform with external optical excitation and detection. To confine chemically derivatized microbeads we use “micro test-tubes” fabricated using a combination of bulk and surface micromachining. Our new chemical approach is to create a receptor with high affinity and selectivity to nitro-explosives. A series of chemiluminescent molecular signaling systems are proposed that are specifically directed toward detection of TNT, PETN, RDX, HMX, and CL-20. These will be used in a new micromachined platform that integrates photodetectors directly into a micromachined micro-fluidic bead platform for detection of the chemiluminescent signals. By integrating photodetectors into the sidewalls of our chemical sensor array, in immediate proximity to the sensing beads, we can eliminate all external optics currently required for optical signal collection. This should allow a more compact and robust system to be constructed by integrating photodetection and fluidics into a single chip-based platform.

6398-27, Session 6

QC-LPAS: demonstration of a multichannel photoacoustic laser spectrometer in the long-wave infrared based on quantum cascade lasers and quartz tuning forks

M. D. Wojcik, Pacific Northwest National Lab. (USA)

We demonstrate the performance of a novel mid-infrared photoacoustic laser absorbance spectrometer for gas-phase species using an amplitude modulated (AM) quantum cascade (QC) laser and a quartz tuning fork microphone. Photoacoustic signal was generated by focusing the output of a Fabry-Perot QC laser operating at 8.41 μm between the legs of a quartz tuning fork which served as a transducer for the transient acoustic pressure wave. This spectrometer was calibrated using Freon-134a by performing a simultaneous absorption measurement using a 30 cm absorption cell. The NEAS of this instrument was determined to be 2 x 10-8 W cm-1 Hz-1/2.

6398-28, Session 6

Performance of the FIRST: a long-wave infrared hyperspectral imaging sensor

M. Chamberland, V. Farley, A. J. Villemaire, A. Vallières, Telops, Inc. (Canada); J. Legault, Telops USA, Inc. (USA)

Emerging applications in Defense and Security require sensors with state-of-the-art sensitivity and capabilities. Among these sensors, the imaging spectrometer is an instrument yielding a large amount of rich information about the measured scene. Standoff detection, identification and quantification of chemicals in the gaseous state are fundamental needs in several fields of applications. Imaging spectrometers have unmatched capabilities to meet the requirements of these applications.

Telops has developed the FIRST, a LWIR hyperspectral imager. The FIRST is based on FTIR technology to yield high spectral resolution and to enable high accuracy radiometric calibration. The FIRST, a man portable sensor, provides datacubes of up to 320x256 pixels at 0.35mrad spatial resolution over the 8-12 μm spectral range at spectral resolutions of up to 0.25cm-1. The FIRST has been used in several field measurements, including demonstration of standoff chemical agent detection. One key feature of the FIRST is its ability to give calibrated measurements. The quality of the calibrated measurements will be presented in this paper. Sensitivity, spectral resolution and radiometric stability as obtained during field and laboratory measurements will be presented. Finally, movies of chemical releases detected with the FIRST will be shown.

6398-30, Session 6

The problem’s solving of optical-acoustic spectroscopy with means of net modeling

A. Erofeev, Consultant (USA)

The molecular CO2 turnable lasers, fitting out of high-frequency dressing down represent particular interest for gas analysis’s portable systems. They possess high output power at rather simplicity of design. Last developments in area of turnable lasers have opened an opportunity of radiation’s frequency agility (it takes some milliseconds) for any chosen wave’s length generation, on the base of the set, including more than hundred of spectral lines in the range of 9-11 microns. It also allows to generate the radiation simultaneously at different wave’s lengths, Such technical future trends have demanded the new approaches to develop the gaz analysis system’s software. Today, neural network are the principal instruments to construct the effective and flexible informational models of engineering systems.

The author is discussed the neural net method of model’s construction, applied in complex system, with reference to analysis’s task as well as the monitoring of chemical-gas medium.

It proposed to use CO2 laser, equipped with radiation’s frequency agility, and to entrust the neural network with the processing function of data’s receiving and their analysis.

The task’s decision in view of modeling is considered in the area of neural net informational technology of construction, applying for hybrid neural structure and containing Kokhonen clustered map and persepton network, trained according to the algorithm of back-propagation and “Neural gas”. Neural technology is revealed in the area of partial propriety of task, the decision of which is given with high level of accuracy. Substantially, the neural network differs with high stability to disturbances and functional high speed.

The application of turnable frequency lasers, coupled with modern microprocessor control system, methods of digital data’s gathering and processing in the sight will allow to create new generation of intellectual gaz-analytical systems. It can be supposed, that given development makes to improve the quality of gaz mixture’s analysis, including the finding of unknown impurities.

6398-44, Session 6

In-depth study of aerosol conditions in a public facility

K. Creek, P. Gray, N. Doggett, Los Alamos National Lab. (USA)

Los Alamos National Laboratory is conducting a project funded by the Department of Homeland Security through the Technical Support Working Group. The goal of this project is to enhance and complement development of detection and analysis protocols by providing essential information on the background microbial populations in public settings. As part of this project, an extensive 24/7 sampling campaign was conducted in a major metropolitan airport. Over the period of a week, environmental conditions were monitored employing fluorescence based bio-aerosol triggers, particle counters and sizers, and other standard sampling methods commonly used in environmental analysis of air quality. In addition to these standard methods of analysis, methods where utilized to provide for a more in depth understanding of the bio-triggers response to typical air contaminants present in public facilities. These higher resolution methods and analysis included viable culturable bacteria, total bacteria, total pollen and fungi, electron microscopy for particle shape and elemental analysis, fiber count, elemental metal scan, and micro-array analysis for biological diversity. In addition, a time and motion study complimented the sampling efforts to characterize activities at particular times. The results of this study give an in-depth view of the difficulties associated with unattended deployment of existing bio-sensors, and clear insight into approaches where they can be appropriately deployed and improved. The data on the 24/7 sampling campaign will be presented in summary form.

6398-31, Session 8

Device challenges for C/B detection

M. Wraback, Army Research Lab. (USA)

No abstract available

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6398-32, Session 8

III-nitride based deep-ultraviolet light sources

R. Gaska, Sensor Electronic Technology, Inc. (USA)

Wide band gap III-Nitride semiconductors with direct energy gap, chemical inertness, large current carrying capability and high thermal conductivity are ideally suited for fabrication of deep ultraviolet light emitters for next generation of portable, low-cost, virtually maintenance-free sensors of biological agents.

Sensor Electronic Technology, Inc. has developed technology and demonstrated AlInGaN-based DUV Light Emitting Diodes (DUV LEDs) with peak emission in the wavelength range from 247 nm to 365 nm. To date the highest output power was achieved for 280nm -285 nm DUV LEDs. In CW operation mode these devices can deliver up to 2.5 mW \@ 20 mA current. In the pulsed regime 200 mW power was demonstrated at 2 A current. CW power at 20 mA current for DUV LEDs emitting at wavelength as short as 247 nm was in sub-milliwatt range. The characteristic switching time of these devices is of the order of few nanoseconds which allows to modulate them up to 300 MHz frequency. Measurements of optical noise in DUV LEDs demonstrated record low noise performance compared to other light sources, especially at low frequencies below 10 Hz.

Multi-chip lamps with up to 48 DUV LEDs have been developed for high power applications. The lamps with peak emission at 280 nm demonstrated CW powers in excess of 10 mW \@ 200 mA current. Multi-chip, multi-wavelength lamps with up to 8 different wavelengths enabled us to cover the spectral range from 250 nm to 365 nm. Independent control of each wavelength allows for optimization of spectral power distribution in DUV spectral range.

We will also present the latest data on the development of DUV LED and UV-transparent optical fiber combination with light coupling efficiency close to 10% in sub-300 nm wavelength range.

6398-33, Session 8

Optimization of a UV light-emitting diode based fluorescence-phase sensor

A. Zukauskas, N. Kurilcik, P. Vitta, S. Jursenas, E. Bakiene, Vilnius Univ. (Lithuania); R. Gaska, Sensor Electronic Technology, Inc. (USA)

Due to an increased threat of attacks using biological warfare agents there is a need for portable, real-time optical detect-to-warn sensors of hazardous biological agents with a reliable discrimination capability. To increase the discrimination ability we propose a fluorescence sensor based on a phase shift between the high-frequency modulated excitation and fluorescence directly related to the characteristic fluorescence lifetime of biofluorophores. UV light-emitting diodes (LEDs) emitting in the range from 255 nm to 375 nm were used in the study and the fluorescence phase shift was measured as a function of modulation frequency and emission wavelength in B. globigii spores and common interferents. The excitation part of the sensor was optimized by using a single deep-UV LED modulated at a 70 MHz frequency. The registration part was minimized to two photodetectors each used for the measurements of the fluorescence phase shift and intensity in a particular spectral region. A high discrimination of B. globigii against common interferents was achieved in the three-dimensional space of fingerprint parameters, namely, the fluorescence phase shift in the near-UV region (protein fluorescence), the fluorescence phase shift in the blue region (coenzyme fluorescence) and the ratio of fluorescence intensities in the two regions.

6398-34, Session 8

Deep-ultraviolet photodetectors grown by gas source molecular beam epitaxy on sapphire and AlGaN/sapphire substrates

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Optically-based chemical and biological sensors require optoelectronic devices with specific emission and detection wavelength ranges. Semiconductor optoelectronic devices applicable to this sensing are of particular interest due to their low power consumption, compact size, long lifetime, and low cost. We report the electrical and optical properties of deep UV p-i-n photodiodes (PDs) based on short period superlattices (SPSLs) of AlN/AlGaN. All device and test structures are grown by gas source molecular beam epitaxy with ammonia on sapphire and AlGaN/sapphire substrates. AlGaN/sapphire substrates were grown by stress controlled hydride vapor phase epitaxy (HVPE). The cutoff wavelength of PDs based on these SPSLs can be varied from 250 to 280 nm by changing the SPSL barrier/well thickness ratio. For mesa diodes with 150 μm diameter we obtain extremely low dark leakage current of ~ 3 pA/cm^2, and high zero-bias resistance of ~ 6 Å~ 10^14 Ω. A cutoff wavelength of 247 nm is obtained for these devices with four orders of magnitude rejection by 315 nm. We obtain a maximum responsivity of 60 mA/W. We will describe electrical and optical properties of PDs grown on different substrates. The efficacy of transparent HVPE templates for PD growth will be discussed. We describe the influence of n- and p-type dopant distribution, thickness of i- and p-type regions, the importance of barrier/well thickness fluctuations, and the quantum efficiency of the front and back illuminated PDs. Work at TTU is supported by the U.S. National Science Foundation (ECS-0323640) and the J. F Maddox Foundation.

6398-41, Session 8

Widely tunable pulsed UV source for laser-induced fluorescence of bioaerosols

G. Feugnet, A. Grisard, E. Lallier, Thales Research & Technology (France)

Fluorescence induced by ultraviolet laser light has shown a strong potential to help detect and identify hazardous bioaerosols. After several demonstrations limited to standard 266 nm or 355 nm sources, recent developments emphasized the advantages of tunable excitation or time-resolved experiments to increase discrimination capabilities. Taking advantage of the recent availability of frequency converting crystals with unprecedented efficiency, we present a three-stage laser design suited to the generation of 500 picoseconds pulses of several microjoules ruggedly tunable from 290 to 350 nm.

The first stage boosts the output of a commercial pre-amplified microchip actively Q-Switch laser up from 50μJ to 1 mJ at 1064 nm (1 kHz repetition rate) before frequency doubling in a KTP crystal with an efficiency around 40%. The second stage is based on Quasi-Phase Matched Optical Parametric Generation (OPG) in a periodically-poled lithium niobate (PPLN) crystal. Visible pulses from 580 to 700 nm are obtained by translating this multiple-grating crystal. The last stage involves a BBO crystal rotated to enable Second Harmonic Generation (SHG) or Sum Frequency Generation (SFG).

6398-42, Session 8

Novel multiwavelength UV laser development for biosensing applications

S. F. LeBoeuf, T. Tolliver, W. Huber, S. Tandon, J. Balch, GE Global Research (USA)

GE Global Research has developed multiwavelength electron-pumped UV

emitters using selectively grown submicron AlGaN pyramids. With wavelengths from 330-375 nm, these AlGaN nanocrystals have demonstrated evidence of stimulated emission via narrow bandwidths, superlinear “thresholding,” and narrow divergence angles (~30*). Optical models show that these 500-700 nm crystals contain resonant modes promoting resonant light extraction along the primary vertical axis of symmetry. High-Al AlGaN pyramids are generally of poorer optical quality than low-Al pyramids, but recent innovations in selective area epitaxy have extended high optical quality to 30% Al and potentially higher. Initial feasibility assessments shows that compact, 10-100 mW, multiwavelength UV laser arrays can be generated with 10% power conversion efficiency. However, thermal packaging and voltage multiplication must be incorporated into a small portable unit.

6398-35, Session 9

Confocal data acquisition for digital quantification using amplified single molecule detection

J. Melin, J. Jarvius, J. Göransson, J. Stenberg, F. K. Nikolajeff, M. Nilsson, Uppsala Univ. (Sweden)

Amplified single-molecule detection constitutes a scheme for biomolecule enumeration by transforming specific molecular recognition events at nanometer dimensions to optically detectable micrometer-sized DNA

macromolecules. Unlike traditional ensemble average measurements, our detection approach preserves the discrete nature of the molecular population, enabling multiplex detection and highly precise quantification of molecules over a wide dynamic range. The formation of one DNA circle as a result of recognition of one target is the first step in the digital signal transmission chain. This is achieved by a highly specific molecular probing reaction, employing so-called padlock probes. Padlock probes are linear synthetic DNA molecules that become circularized through enzymatic ligation upon identification of specific DNA targets. Subsequently, each circular DNA molecule is copied using rolling circle amplification (RCA), generating a large DNA macromolecule with the sequence complementary to the circle concatenated about 1000 times. A fluorescently labeled DNA oligonucleotide is hybridized to the repeated sequence of the RCA product generating a confined cluster of about 1000 fluorophores. These clusters are visible as bright objects with a diameter of approximately 1 μm when observed by fluorescence microscopy. The number of targets can thus be quantified by counting these objects. Throughout the signal transmission the discrete nature of the molecular population is preserved, enabling digital analysis. Object enumeration is achieved by pumping the liquid through a microchannel observed by linescanning confocal fluorescence microscopy across the channel. Using this setup the data contributing volume is defined by the confocal volume reducing variations induced by flow rate differences. We have characterized the data acquisition process by means of simulations and direct measurements. The method has also been applied for detection and quantification of the bacterial pathogen Vibrio cholerae with zeptomole sensitivity.

6398-36, Session 9

Optically based Grippe viruses detection based on liquid crystals

M. G. Tomilin, S.I. Vavilov State Optical Institute (Russia); S. C. Stafeev, St.-Petersburg State Univ. of Information Technologies, Mechanics and Optics (Russia); A. Stepanova, St. Petersburg R&D Institute of Grippe RAMS (Russia)

The problem of grippe viruses detecting is very important because of its possible dangerous epidemic and pandemia scale all around the world. There were developed some methods of grippe viruses detecting based on application of spectroscopic and fluorescence technique. All of them couldn't visualize directly the grippe virus modifications, need few days for examination and consist many steps of operation. To avoid the disadvantages the new contact technique with high spatial resolution based on nematic liquid crystals (NLC) application was suggested.

On glass plate the antibody-viruses sandwich was placed and coated with thin NLC layer of mixture MBBA:EBBA. In the case of antibody-viruses unconformity the complimentary reaction doesn't take place that may be directly observed through polarizing microscope. In the case of antibody-viruses conformity the complimentary reaction takes place that visualize quite different regular surface structure with crystal-like segments. The effective results were achieved in usage polyaniline (PA) layer that obtained a good adhesion of antibody material to the glass plate. In some cases the same results were obtained without PA layer. The LC vision technique based on NLCs has some advantages in comparison with technique based on lyotropic chromonic LCs that is expensive and cannot visualize directly the grippe virus modifications.

It is possible to conclude that new simple and expressive technique based on NLC application to grippe viruses detection is developed. It promises the possibility for direct observation of the surface structures in the case of virus' mutation, for example the bird's flue.

6398-38, Session 9

Monitoring the aggregation pathways of human transthyretin (TTR) and human carbonic anydrase II (HCA II) by time-resolved fluorescence

F. Stabo-Eeg, Norwegian Univ. of Science and Technology (Norway); K. Sörgjerd, Linköpings Univ. (USA); S. Moparthi, U. Carlsson, Linköpings Univ. (Sweden); P. Hammarström, Linköping Univ. (Sweden); M. Lindgren, Norges Teknisk-Naturvitenskapelige Univ. (Norway)

Amyloid diseases evolve from aggregation of proteins. Proteins aggregate due to misfolding of the protein structure. Disease prevention requires sophisticated but yet simple techniques to follow the complex properties of protein aggregation. One such useful technique is labeling one or more specific sites in the protein with fluorophores to follow relative internal movements of subunits and site specific packing of residues in the amyloid state. Conformational changes can then be monitored by time-resolved measurements of the fluorescence anisotropy or resonance energy transfer (RET). We have monitored kinetics of the misfolding process by anisotropy measurements on human transthyretin (TTR) labeled with the fluorophores 1,5-IAEDANS and pyrene-methyl-iodo-acetamide (PMIA). Anisotropy measurements of Human carbonic anhydrase II (HCAII) labeled with 6-IAF was also used for understanding aggregation and chaperone interactions. We show that it is possible to follow protein aggregation from initial "unfolded" to final amyloid fibre structures and that distances (30-60 Å) can be measured within protein molecules. By using images from our confocal microscope we can explore spectral change to various fluophores when bound to different aggregated proteins. Changes of the fluorescence due to different local environment can also be investigated.

6398-39, Session 9

Method for the recognition of maintenance of urine salts

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No abstract available

Conference 6399A: Advanced Free-Space Optical Communication Techniques and Applications III

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6399A-02, Session 1

Free-space optical nodes applicable to simultaneous ring and mesh networks

S. V. Kartalopoulos, Univ. of Oklahoma (USA)

The preferred method for ultra-high bandwidth in communications has been the optical. This is mainly due to the demand for more bandwidth, which the 1300-1650nm band of light offers in an optically transparent medium, air or fiber. Although fiber technology has been advanced to produce a wide range of fiber types to meet specific needs, fiber deployment requires long-term planning and installation that culminate to long delays till full service is established. There are applications that demand high-data rate connectivity urgently, either because of natural emergencies or because the private sector cannot wait for the long planning and deployment. Thus, an alternative communication method is free space optical. This method uses a laser beam that is directed from a building to another to establish full-duplex point-to-point high-data rate connectivity. However, this technology has been limited to a point-to-point topology. In this paper we present a free space optical node design deployeable in mesh and/or ring topology with full connectivity. We also discuss engineering aspects, traffic management, fault management and security issues.

6399A-03, Session 1

A distributed sensing system for detection of contaminants in the ocean

D. Kedar, S. Arnon, Ben-Gurion Univ. of the Negev (Israel)

A compact and mobile distributed sensing system which can monitor contaminant content in the ocean and initiate an alert system when high contaminant levels are detected would be useful in the surveillance of ports and harbors. Oceanic data acquisition takes many forms, but miniature and low cost platforms are not available for widespread monitoring and surveillance tasks. In this paper we present a novel sensing system, adapted from a similar concept designed for atmospheric probing and evaluate its feasibility in the ocean environment. Both the probing task itself and the data communication from the sensor nodes to the base station are based on free space optics. We also develop a probabilistic model of multi-access interference in a system using spectral diversity, which may be applicable in many distributed sensor multihop networks.

6399A-04, Session 1

Anticorrelation polarization dynamics in VCSELs

Y. Hong, K. A. Shore, Prifysgol Cymru Bangor (United Kingdom)

In this paper, we report an experimental study of the effect of optical feedback on the magnitude of polarization dynamics anticorrelation in VCSELs operating at a number of bias currents relative to the polarization switching current. The correlations are considered in the time domain and in the spectral domain. The dynamics of the slow fluctuations between the X- and Y-polarizations show strong anticorrelation, which is considered to be induced by gain competition between the X- and Y- polarizations. The fast dynamical fluctuations between X- and Y- polarization are poorly correlated which is conjectured as coherence collapse dynamics by optical feedback. For the unstable polarization dynamics of solitary VCSEL, weak optical feedback increases the polarization dynamics anticorrelation. For higher optical feedback, the magnitude of the anticorrelation decreases with increasing optical feedback ratio. For stable dynamics of solitary VCSEL subject to parallel polarization feedback, the anticorrelation between the X- and Y-polarizations is small within the experimentally accessible optical feedback range because the parallel polarization feedback has a weaker effect on the gain competition between X- and Y-polarizations. For polarization-preserved or orthogonally polarized feedback, weak optical feedback induces weak anticorrelation. With increased feedback, the magnitude of the anticorrelation increases sharply and then decreases with the feedback ratio.

6399A-30, Session 1

Preliminary analysis of IR free-space communications

A. Nedelcu, L. Morvan, M. Alouini, P. F. Bois, J. Pocholle, D. Dolfi, Thales Research & Technology (France); C. Faugeras, S. Laurent, C. Sirtori, Univ. Paris VII (France)

No abstract available

6399A-05, Session 2

Performance evaluation of an adaptive optics free-space laser communications system from simulation of beam propagation

A. Belmonte, A. Rodríguez, F. Dios, A. Comerón, Univ. Politècnica de Catalunya (Spain)

Free-space optics refers to the propagation of light through the atmosphere for at least some significant part of the communications channel. This can include terrestrial, terrestrial-satellite, terrestrial-aircraft, aircraft-aircraft, and the last mile of data transmission to link fiber optic trunks to end-user equipment. Free-space optical communications have distinct advantages over conventional RF and microwave systems by virtue of their high carrier frequencies that permit high modulation bandwidth, enhanced security, freedom from interference, and low powered. However, the turbulent atmosphere causes phase variations along the path that are manifested in intensity variations (scintillation) and high beam divergence. These variations are a noise source that reduces the ability of the receiver to determine the information contained in the modulation. For many years, the emphasis throughout this area has been on elucidating those implications of the atmospheric propagation problem that bear on the design and performance of optical communication systems. In this work, it is our intention to elucidate how the addition of adaptive optics to the transmitter or receiver can reduce the effects of atmospheric propagation and, in so doing, to quantify the improvement on the performance of optical communications systems regarding coherent detection. Adaptive optics offers the potential for overcoming these limitations by adaptive tracking of the beam and correction of atmospherically-induced aberrations. The adaptive optics (optical elements -typically mirrors -that can adapt their optical surface and performance to compensate for phase and poor optical quality of the light reflecting from them) technology to be considered in free-space coherent optical communications will be virtually identical to that of imaging adaptive optics.

6399A-06, Session 2

Effects of turbulence on a combined 1550-nm retro reflective and a low-intensity single-path 850-nm optical communication link

F. Kullander, P. Jonsson, L. Sjöqvist, Swedish Defence Research Agency (Sweden)

Atmospheric turbulence can significantly degrade the performance of free-space optical communication links. Beam wander, intensity scintillations, beam broadening and angle of arrival fluctuations give rise to signal fading with communication channel drop-outs. In this work the performance of the potentially beneficial combination of a retro reflective link operating at 1550 nm in conjunction with a low intensity link at 850 nm was studied. The potential application is a free-space tactical quantum key distribution link where the weak light beam in the quantum channel at 850 nm could be steered and controlled by the strong signal in the classical channel at 1550 nm. A dual-channel laser unit, with output beams at 850 and 1550 nm, was used to characterise turbulence effects along an atmospheric path close above ground. The low intensity channel at 850 nm was aligned with the 1550 nm beam and detected in a terminal in one end of the link. The 1550 nm beam was retro reflected from a corner cube and detected in both ends of the link. Effects of beam wander, angular fluctuations and intensity scintillations were studied experimentally at different turbulence strengths and weather conditions. The experimental results were compared with a numerical model based on phase screens.

Conference 6399A: Advanced Free-Space Optical Communication Techniques and Applications III

6399A-07, Session 2

Fade statistics for Gaussian beam waves in moderate-to-strong turbulence

F. E. Strömqvist Vetelino, C. Y. Young, L. C. Andrews, Univ. of Central Florida (USA)

The performance of lasercom systems operating in the atmosphere is reduced by optical turbulence, which causes irradiance fluctuations in the received signal. The result is a randomly fading signal. In this work, fade statistics obtained from simulated and experimental data were compared to theoretical predictions based on the lognormal and gamma-gamma distributions. The probability of fade, number of fades per second and the mean fade time were calculated from the irradiance fluctuations of a Gaussian beam wave propagating through the atmosphere on a horizontal path, near ground, in the moderate-to-strong turbulence regime. Irradiance data was collected simultaneously at three receiving apertures of different size. Atmospheric parameters were inferred from the measurements and used to reproduce the experimental data with numerical simulations and to calculate the parameters for the theoretical distributions.

6399A-08, Session 2

Optical communications with femtosecond lasers

D. R. Alexander, Univ. of Nebraska/Lincoln (USA)

Experimental work has been performed comparing the propagation of a 10 fs laser pulse at 800 nm through 4-5 micron aerosol particle cloud to the same laser operating in the cw mode and propagated through the same optical train. Results indicate that the 10 fs pulse propagates better through the aerosol clouds with less absorption. A discussion of the results will be presented as well as a discussion of what makes a fs pulse propagate better. Results of theoretical calculations on a fs (few cycles) pulse interacting with an aerosol particle will be presented. The results show that typical Mie scattering is modified by the transient nature of the scattering phenomena. Calcualtions show that difference are more prevelant as the pulse approaches a few cycles of light. For 100 fs laser pulses, there is practically no difference than that obtained for continous wave laser propagation.

6399A-09, Session 3

Freespace photonics and laser communications at U.S. Naval Research Laboratory

G. C. Gilbreath, Naval Research Lab. (USA)

In this paper, progress in experimentally validating atmospheric models for transmitting data over an infrared carrier over water and land will be presented. Progress in creation of hybrid infrared-radio frequency links will also be presented as well as the issues associated with such a configuration. Progress in small form-factor support electronics and device packaging will be described as well.

6399A-10, Session 3

Multiple quantum well surface normal modulators for free-space optical communication links

Q. Wang, B. Noharet, S. Junique, S. Almqvist, D. Ågren, D. Zhang, J. Y. Andersson, Acreo AB (Sweden)

Retro-communication by the joint use of light modulators and retro-reflecting devices has been proposed and demonstrated as a promising technique to further extend the use of free-space optical communication to mobile communication. Acreo has developed and demonstrated high-speed surface-normal GaAs-based and InP-based multiple quantum well (MQW) electroabsorption (EA) modulators and arrays operating at different near-infrared wavelengths for FSO link applications. Using InxGa1-xAs/AlGaAs MQW structures grown on GaAs substrate, the EA modulator operating wavelength can be widely tuned from 0.8 μm to 1.06 μm, while using InGaAs/InP, InGaAs/InAlAs ternary and InGaAsP and AlInGaAs quaternary MQWs grown on InP substrate the operating wavelength region around 1.55 can be accessed. In this paper we report on the structure and device design issues, trade-offs when GaAs-based or InP-based modulators are needed in the FSO links. In particular the material properties of GaAs-based and InP-based MQWs grown by different epitaxy growth technology, device yield, temperature stability and the device static and dynamic performance are compared in details.

6399A-11, Session 3

Improved robustness and capacity in MRR optical communication links

J. G. J. Rantakokko, Swedish Defence Research Agency (Sweden)

In this paper we will discuss the use of different techniques for improving the robustness and capacity of modulated retro-reflective (MRR) free-space optical communication links, e.g. error-correcting codes, link adaptation, high-level modulation schemes and space diversity techniques. Also, we will apply some of these techniques on channel data that has been collected in recent field trials, in order to demonstrate, through simulations, the potential gains that can be achieved. Finally, a brief comparison with competing radio techniques will be given.

MRR free-space optical communications has several desirable features which make it an interesting technique for use in future military and civilian communication systems. The main advantages with MRR techniques are the potential for achieving high-capacity secure communications with low weight, low energy consumption, and with a small form-factor. Also, it enables the use of free-space optical communications in mobile scenarios. These features makes MRR communication systems extremely suitable when e.g. transferring sensor data from UAV's, sensor networks or various marine platforms.

All free-space optical communication systems experience a heavily weather-dependent attenuation. Furthermore, turbulence causes beam broadening and wandering, as well as scintillations. The weather-dependent attenuation causes large but fairly slow changes in the signal-to-noise-ratio (SNR) in the receiver, while turbulence causes fast SNR fluctuations (i.e. fading). The channel characteristics are more similar to that of radio systems compared to fiber optic communications. Hence, by adopting techniques that has been used in radio communication systems it should be possible to achieve a more robust system, as well as a higher capacity (user data rate). Techniques of interest include e.g. error-correcting coding and adaptive coding and modulation.

Recent field trials have shown that MRR optical communications is a potentially feasible technique for applications that requires high-capacity; with Multiple Quantum Well (MQW) modulators capacities over 10 Mbit/s has been demonstrated. However, current experimental systems normally use binary modulation (on-off keeying) and the capacity is then limited by the modulation speed of the retro-reflector. Instead, by employing a higher-level modulation scheme the capacity can be increased substantially.

6399A-12, Session 3

Mid-infrared diode lasers for free-space optical communications

M. Yin, T. Krier, S. Krier, R. Jones, P. Carrington, Lancaster Univ. (United Kingdom)

There is increasing interest in the development of mid-infrared diode laser sources for free space optical communications mainly because of reduced atmospheric interference and higher security associated with operation in the spectral range near 3.8 μm. Several different device designs have been used to access the 3-4 μm spectral range but many of these rely on very complex structures comprising many ultra-thin layers and are difficult to manufacture. In this work we report on a simpler approach based on a specially optimised type-I InAsSb/InAsSbP double heterostructure ridge laser grown by liquid phase epitaxy (LPE). To remove residual impurities and reduce Shockley-Read recombination, the active region was purified using a Gd gettering technique. In addition free carrier absorption loss was minimised by the introduction of two undoped quaternary layers either side of the active region. These layers helped alleviate inter-diffusion of phosphorus and zinc dopants towards the active region during growth and also provided increased optical confinement. The non-radiative Auger resonance (CHSH) is detuned in InAs0.97Sb0.03 and since Gd gettering minimises residual carrier concentration and threshold current, Auger recombination is reduced and laser performance was improved. These diode lasers operate readily in pulsed mode at elevated temperatures and emit near 3.45 μm at 170 K with a threshold current density as low as 96 A/cm2 at 85 K. The peak wavelength of spontaneous emission is 3.69μm at room temperature.

Conference 6399A: Advanced Free-Space Optical Communication Techniques and Applications III

6399A-13, Session 4

Free-space secure key exchange from 1 m to 1000 km

J. G. Rarity, M. S. Godfrey, A. M. Lynch, J. L. Duligall, Univ. of Bristol (United Kingdom)

Coding data bits in the phase or polarisation state of light allows us to exploit the wave particle duality for novel communication protocols. Using this principle the first practical quantum communication systems have been built. These are the fibre and free-space quantum cryptography apparatus used for secure exchange of keys. To date free space key exchange has aimed at long range with 23km range achieved and future experiments aiming to extend this range to 1000km exchanging keys with low earth orbit satellites. At the other end of the spectrum we are developing low cost hand held systems. These systems could be an effective way for the user to generate a store of secrets shared with a central repository. These secrets can then be used up to protect a wide variety of sensitive classical communications. Examples include on-line PIN protection for consumer transactions and password protection in secure access schemes.

6399A-14, Session 4

Single-photon correlations for secure communication

D. Ljunggren, M. Tengner, S. Sauge, J. Waldebäck, A. Karlsson, Kungliga Tekniska Högskolan (Sweden)

Quantum cryptography can be sorted into two main categories. One that uses a single photonic qubit to create correlated information between a sender and receiver, and a second that uses the inherent nonclassical correlation between two entangled photonic qubits. Both categories require single photons to be precisely generated and efficiently coupled into single-mode fibers, for the preparation and long-distance transmission of qubits.

One promising way to produce single photons consists of conditioning the existence of one photon on the detection of another using photon-pairs emitted from a nonlinear crystal by spontaneous parametric downconversion. Here, we report experimental results of a so-called heralded single-photon source based on a quasi-phase-matched crystal material. The heralding photon has a wavelength of 810 nm chosen to efficiently exploit the available Si-based single-photon detectors, and the heralded single photon has a wavelength of 1550 nm to exploit the minimum transmission loss of telecommunucation fibers. By subselecting detection events we can change the photon number distribution and launch single photons characterized by sub-Poission statistics instead of multiphotons characterized by the original Poission statistics. We include a qualitative analysis of the single- and multiphoton probabilities, photon rates, and coupling efficiencies achievable.

When using two crystals, one can also create entangled photons-pairs. We choose to encode the sender station photon in polarization and the receiver station photon in time, as time-coding suitably avoids polarization dispersion of optical fibers making longer transmission distances possible. We present a scheme for quantum cryptography based on this idea, and analyse the quality of the source in terms of entanglement visibility and violation of the Bell-inequalities.

6399A-15, Session 4

Free-space quantum key distribution over 144 km

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A secure distribution of keys is essential for secure communication across the globe. A global quantum key distribution system could be accomplished by free space systems connecting satellites and ground stations. Several implementations of free space QKD systems exist achieving distances on the order of ten kilometers. We report on the progress of a free space QKD experiment on the Canary Islands over a distance of 144 km, which is a further step towards satellite based systems. In order to reduce atmospherical fluctuations both transmitter and receiver unit were placed 2400 m above sea level. The transmitter unit including a 15 cm diameter telescope was located on mount Roque de los Muchachos on La Palma. On Tenerife the OGS, developed for optical communication to and from satellites, was used as the recieving telescope. Thanks to a actively controlled tracking system the transmission loss of that link was stable with an attenuation between 25 dB and 35 dB over several minutes depending on weather conditions. This attenuation is sufficient to perform the BB84 protocol to generate secur cryptographic keys between sender and receiver. As this attenuation is also expected for downlinks from low earth orbit (LEO) satellites to ground stations, our experiment thus deemonstrates the feasibility for space-based secure communication accross the globe.

6399A-16, Session 4

Security aspects of the authentication used in quantum key growing

J. Cederlöf, J. Larsson, Linköpings Univ. (Sweden)

Quantum Key Growing (QKG), often called Quantum Cryptography or Quantum

Key Distribution, uses properties of quantum mechanical systems to share a secret key between two sites. It has attracted a lot of interest because the security is based on laws of nature rather than computational complexity as is usually the case for key-sharing systems. A vital but sometimes neglected part of the method is unconditionally secure message authentication. This paper examines security aspects of the authentication used in QKG, especially the fact that the authenticating key is partially known to the attacker. It is well known that the present QKG protocols prohibit the eavesdropper from decoding messages that are encrypted with the partially known shared key. Here we show that the authentication step of the protocols is more sensitive, which implies that the eavesdropper can remain undetected but still have a substantial probability of breaking the authentication. A simple solution to this problem is provided which mitigates the security implications of this finding. It is of course important to implement this or an equivalent extra security measure in any QKG system built.

6399A-17, Poster Session

Analysis and comparison of various free-space optical receiver configurations

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The paper deals with the analysis of receivers for free-space optical communication systems. The performance of high impedance (HZ) and transimpedance (TZ) configurations of front-end amplifiers in combination with an avalanche photodiode (APD) and a PIN photodiode are compared. The formula for optical receiver sensitivity in dependence on bit error ratio and data rate is re-stated.

The theoretical sensitivity analysis of optical fiber receivers has been presented in many previous works. But free-space optical systems make somewhat different demands on the receivers. One of them is relatively larger active area of photodiode which is necessary for the optimal coupling to the receiver lens. The relatively large active area causes large junction capacitance decreasing bandwidth and increasing preamplifier noise as well as photodiode dark current and consequently photodiode shot noise. These effects decrease receiver sensitivity, dynamic range and allowable bit rate.

The dark current depends also on the photodiode type (PIN, APD) and used technology and material (Si, GaAs, Ge). Therefore the receivers working at the wavelength of 850 nm using silicon photodiodes and receivers working at the wavelength of 1500 nm using GaAs and germanium photodiodes have different performance. Similarly bipolar and FET transistors used in the HZ and TZ preamplifiers do not provide the same resulting receiver sensitivity and bandwidth due to their unequal noise and frequency characteristics. Next demand made on the free-space optical receiver is high dynamic range necessary for limitation of the influence of variable attenuation in the atmosphere. It can be partially improved by incorporating the avalanche gain in an AGC feedback control loop.

The comparisons of various optical receiver configurations are based on many simulations and graphical results.

Conference 6399A: Advanced Free-Space Optical Communication Techniques and Applications III

6399A-18, Poster Session

Free-space quantum cryptography for metropolitan areas

M. Fürst, Ludwig-Maximilians-Univ. München (Germany); T. Schmitt-Manderbach, Ludwig-Maximilians-Univ. München (Germany) and MPQ Garching (Germany); H. Weier, I. Ordavo, Ludwig-Maximilians-Univ. München (Germany); H. Weinfurter, Ludwig-Maximilians-Univ. München (Germany) and MPQ Garching (Germany)

Quantum key distribution (QKD) in combination with the one-time-pad algorithm allows provably secure communication as opposed to classical asymmetric techniques. Different implementations of QKD systems promise the realisation of quantum cryptography based metropolitan networks within the next few years. We report on the progress of our 500 m urban link experiment. Both transmitter and receiver unit are located on rooftops of University buildings. Qubits are encoded into four nonorthogonal polarisation states of attenuated pulses emitted from four laser diodes. The free space link provides the quantum channel while a public internet connection serves as the classical channel. Secure key was generated by an implementation of data-processing software for key destillation, error correction and privacy amplification. Due to a completely automated alignment system the experiment runs over more than 12 hours during night without human interaction. An average sifted key rate of of 50 kbits/s with a QBER between 3% and 5% by employing the BB84 protocol led to about 30 kbit/s secure key rate. Our compact stand-alone system shows the feasibility of an advanced quantum key distribution system which can operate fully independent of fiber networks.

Conference 6399B: Photonic Components and Architectures for Microwave Systems and Displays II

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6399B-19, Session 5

A novel pulse source for low jitter optical sampling: a rugged alternative to mode-locked lasers

G. J. McDonald, QinetiQ Ltd. (United Kingdom); A. J. Seeds, Univ. College London (United Kingdom)

A novel low jitter optical pulse source for applications including optical sampling has been modelled and experimentally verified using commercially available photonic components. Dispersion and non-linear fibre effects were utilised to compress a periodic optical waveform to generate pulses of the order of 10-15 picoseconds, via soliton-effect compression. Modelling of variable dispersion fibre indicates that future work will enable pulse compression to sub-picosecond durations. Attractive features of this new pulse source include electronically tuneable repetition rates over a continuous range at frequencies above ~1.5 GHz, ultra-short pulse duration (10-15 ps now, 100's fs planned), and low timing jitter as consistently measured by both harmonic analysis and single-sideband (SSB) phase noise measurements. In addition, the system is inherently robust to thermal effects unlike some low jitter pulse source alternatives, and does not require precise optical alignment. Timing jitter analysis reveals that the optical pulse timing jitter is currently limited by the mid-range specification microwave source used to create the initial periodic waveform. In order to overcome stimulated Brillouin scattering at high launch powers into the compression fibre, phase modulation was applied to the pulse train, and the timing jitter implications of this are discussed. It is believed that this is the first time that detailed timing jitter analysis has been performed on a soliton-effect compression scheme.

6399B-20, Session 5

High-power and very-low-noise operation at 1.3 and 1.55-μm with quantum dot and quantum dash Fabry Perot lasers for microwave links

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We investigate the suitability of new devices called quantum dot and quantum dash lasers operating at 1.3 and 1.55μm respectively for low noise operation. Under CW operation we have obtained both high power associated with an ultra low relative intensity noise (RIN) in the L to Ku band. The latter feature is crucial in microwave systems since directly related to carrier to noise ratio (CNR).

For 1.3 μm wavelength range the device design based on dots in a well (DWELL) structures were grown using a solid source molecular beam epitaxy (MBE) system on GaAs substrates. In order to attain 1.55 μm emission the quantum dash Fabry Perot laser structures were achieved with a gas source MBE system on (100) InP substrates. In both cases the index guiding is provided by a narrow ridge waveguide, no coating was applied.

Under CW operation, 3 mm long devices with the DWELL structure have shown threshold currents of 20 mA and slope efficiency around 0.20 W/A. The optical power reaches 80 mW/facet. The RIN spectrum is nearly flat at -158 dB/Hz ± 2 dB/Hz between 0.1-10 GHz.

For the quantum dash lasers the cavity length was optimized around 900 μm. These lasers have demonstrated at 30 mW/facet, 15°C a very low RIN around -160 dB/Hz ± 2 dB/Hz within 50 MHz to 18 GHz without 1/f like behaviour. Furthermore, The ageing tests performed on these devices during 3000 hours have revealed no performance degradation in terms of resonance frequency and noise levels

6399B-21, Session 5

Time-domain comprehensive simulation of vertical external cavity semiconductor lasers

M. Kolesik, The Univ. of Arizona (USA); A. R. Zakharian, College of Optical Sciences/The Univ. of Arizona (USA); J. Hader, The Univ. of Arizona (USA); J. V. Moloney, College of Optical Sciences/The Univ. of Arizona (USA)

Vertical External Cavity Semiconductor Lasers (VECSL) represent a relatively new type of semiconductor based lasers. Similarly to the well-known Vertical Cavity Semiconductor Lasers (VCSL), the active structures in VECSLs are grown on semiconductor chips with laser emission directed perpendicularly to the growth. However, unlike in a VCSL, a VECSEL's active chip only contains a single Bragg reflector, while the output coupler mirror is external, with the laser cavity a few tens of centimeters long. The two-dimensional nature of the active medium results in favorable heat management, while the large-volume external cavity promotes a clean single-mode operation and thus high brightness. Consequently, it is expected that VECSEL output power can be scaled into hundreds of Watts for a single chip and into the KW region for multiple chips. This contribution describes our theoretical and experimental efforts to understand and build VECSEL lasers. The emphasis is on the power-scaling in VECSL lasers which still presents some problematic issues. Here, computer simulations can provide valuable insights. We describe our comprehensive VECSL simulation technologies which we use to study various aspects of power-scaling in these devices. These include the first-principle calculations of optical properties of the semiconductor active structure, simulation of the laser light dynamics in time-domain, and detailed simulation of thermal management. As an illustration, we show how Amplified Spontaneous Emission (ASE), and diffraction losses due to the active chip imperfections affect the performance in high-power devices. Conclusions are drawn that will be useful in designing wide pump-spot, high-power VECSEL devices.

6399B-22, Session 5

High crosstalk InP digital optical switch

M. Zegaoui, J. Harari, D. Lauvernier, D. Decoster, J. Chazelas, Univ. des Sciences et Technologies de Lille (France)

Electro-optic switches are basic bricks for the synthesis of large bandwidth, high dynamic, true time delays optically controlled microwave antennas [1]. But for this application, the switching time must be short (some ns) with no added noise. This is why we designed, fabricated and characterized integrated optical switches on InP substrate based on carrier-induced effects. Here we demonstrate that a 72dB microwave crosstalk (more than 36dB on the optical signal) can be achieved with a suitable designed InP DOS, keeping low consumption (60mA) and short response time (3ns). To reach such a goal :

-Carrier-induced effects were deeply experimentally analysed to define an InP/InGaAsP/InP heterostructure with high index change (\>5.10-3) [2] at 1.55μm wavelength when injecting a current.

-The light propagation was properly simulated by Beam Propagation Method to carefully design the electrodes.

In this talk, we will emphasis the way we followed to reach these state of the art electro-optic switches.

[1] S. Tonda-Goldstein, D. Dolfi, A. Monsterleet, S. Formont, J. Chazelas, J.P. Huignard

"Optical signal processing in Radar systems."

Microwave Theory and Techniques, Vol.54, (2), Feb. 2006, pp. 847-853.

[2] M. Zegaoui, D Decoster, J. Harari, JP Vilcot, F Mollot, V. Magnin, J. Chazelas.

"Comparaison between carried-induced optical index, loss variations and carrier life-time in GaInAsP/InP heterostructures for 1.55μm DOS application."

Electronics Letters, Vol.41 (10), May 2005, pp.613-614.

6399B-24, Session 5

A transient waveform digitiser for wideband signal capture

G. J. McDonald, R. A. Wilson, J. Olliero, M. J. Cooper, QinetiQ Ltd. (United Kingdom)

An opto-electronic transient waveform digitiser is detailed which combines the massive bandwidth of commercially available optical components

with the high resolution sampling capabilities of state-of-the-art electronic analogue to digital converters (ADCs). Fundamental to the realisation of sample rates beyond what is currently capable with all-electronic ADCs has been the development of a temperature stabilised fibre delay structure and associated optical phase locked loop. Together these generate multiple replicas of short incoming pulses, which are then digitised using the Vernier sampling technique. The successful temperature stabilisation of the optical sub-components now offers the potential for an environmentally rugged fibre based system, with small system footprint, and low power requirements through the use of a single electronic ADC and compact diode laser technology. System modelling indicates that the fibre delay line architecture performance could currently support extremely high sample rates, with the total system sample rate scaling directly with future ADC improvements.

6399B-25, Session 5

Interferoceiver and processing of transient RF signals

M. Li, Consultant (USA)

Transient phenomena contain rich intrinsic features as shown in the famous Edgerton's photo of a bullet piercing through an apple with the help of a stroboscope. Although a photo is able to freeze transient phenomena, it still lacks the ability to reveal intrinsic micro motions of constituents. The advancement of optical fibers has changed the above scenario. An RF transient signal and its reference can be fed into optical fiber recirculation loops, which are able to regenerate numerous replicas of these signals. The micro motions captured by the transient signal can then be deciphered through the repeated analysis of its replicas.

A new instrument which is capable of accomplishing the above has been referred to as an interferoceiver. It will have a broad impact on radar technology as well as on remote sensing and passive identification. The present talk will discuss its capabilities and experimental results.

6399B-26, Poster Session

Development of all-around 360 degree display that can be viewed from any direction

T. Nishida, K. Sakamoto, Shimane Univ. (Japan)

This paper describes 360 degree viewing display system that can be viewed from any direction (ie, the display has a 360-degree viewing angle). The authors have ever researched 3D display systems using the polarized glasses and liquid crystal shutter glasses, image splitter such as the parallax barrier or lenticular screen and holographic optical elements. However conventional monitor display is viewed from one direction, that is, the display has narrow viewing angle and observers cannot view the screen from the opposite side. Hence we developed tabletop display system for collaborative tasks cooperated by two users. This tabletop display can provide different images to different users surrounding the system utilizing the image splitting technologies for displaying stereoscopic 3D image. But screens on the monitor cannot be viewed correctly by all users from any direction. Thus, conventional display systems enable users not to do collaborative tasks on the round table.

In this paper, we describe the 360 degree viewing display. This newly developed 360 degree viewing system has a liquid crystal display screen and 360 degree rotating table by motor. The principle is very simple. The screen of monitor rotates at a uniform speed. Then the observer can view the monitor screen at any position surrounding the round table. But the solid of revolution is formed when the image screen is rotated. Hence the angle of view is controlled by the slit or the optical element in order that the screen faces an observer and he can view only 2D image on screen without 3D solid image.

Prototype display has commercial 5.4 inch LCD display. The 360 degree turn table is made using an electric drill. The drill is operated at 700 rpm. The result of test running is very good. The rotating LCD panel enables users to be viewed from any direction. Moreover 360 degree viewing 3D display can be build. Because the LCD panel is very thin and prototype system has only single side displaying plane, one side can also display stereoscopic image for left eye and the other side for right eye.

6399B-27, Poster Session

Full-screen high-resolution stereoscopic 3D display using LCD and EL panels

M. Yoshigi, K. Sakamoto, Shimane Univ. (Japan)

Many methods of the 3-D display have proposed, for example, a stereoscopic 3D, the super multi-view, the depth fused display(DFD) and holography. But the 2-views stereoscopic 3D display is described here. 2-views stereoscopic 3D displays need an image separator such as polarizing glasses, lenticular lens, a parallax barrier and so on. Especially, the parallax barrier 3D display has superior characteristics, such as having a planar screen and a thin panel. Moreover, the observers could see glasses-free 3D images. However, a conventional parallax barrier display system has disadvantages such that horizontal resolution is reduced by half because each eye only sees half the pixels. The purpose of this paper is to solve this problem. The newly developed 3D display has two image plane (LCD panels and/or EL devices) in order to reconstruct left and right stereoscopic viewing full images. A polarizer slit separates left and right images the same as parallax barrier. The advantage of this parallax polarizer barrier is that the resolution of the presented parallax images is much greater than that of a conventional display.

The parallax barrier can separate the stereoscopic image into the images for left and right eyes. A linear polarizer selectively blocks the ray or passes, for example, only the incident light that is vibrating parallel to the polarization direction is allowed to pass. Therefore, parallax polarizer barrier, which is horizontally oriented, works as the conventional slit for vertically oriented light wave, for instance. But the different polarization direction, i.e., horizontal polarization, is passed through this slit. Then twice resolution 2-views stereoscopic 3D display can be build using the orthogonal polarized two image planes for displaying left and right images.

In this paper, we describe a method to generate orthogonal polarized parallax images and a thin stereoscopic 3D display with a polarized parallax barrier. This compact display has liquid crystal display(LCD) panels and/or Electoro Luminescence(EL) devices to present stereo views and control polarization. It has twice the 3D image resolution, because the image plane can multiplex images with horizontal and vertical polarization to display stereo views.

6399B-28, Poster Session

Multiview 3D display using parallax barrier combined with polarizer

K. Sakamoto, T. Morii, Shimane Univ. (Japan)

A 3D display system is useful technology for virtual reality, mixed reality and augmented reality. We have researched spatial imaging and interaction system. We have ever proposed 3D displays using the slit as a parallax barrier, the lenticular screen and the holographic optical elements(HOEs) for displaying active image.

A display system requiring no special glasses is useful for 3D images. The parallax barrier display system has superior characteristics, such as having a planar screen and a thin panel. In this paper, we describe a newly developed, 4-views display using the parallax barrier with a polarzer.

The parallax barrier display system has superior characteristics, such as requiring no special glasses and having a planar screen and a thin panel. We have ever researched 2-views stereoscopic 3D display systems. These systems can be extended to 4-views or more. However conventional multi-view parallax barrier display system has disadvantages such that the resolution of each of the stereo images is reduced only in the horizontal dimension. To solve this problem, we propose two techniques (or solutions) using a polarizer for development of the 4-views 3D display.

One of the solutions is to arrange the viewing points of parallax images arbitrarily using the special backlight. The other method is to combine a polarizer slit and cylindrical lenses. A linear polarizer selectively blocks the ray or passes, for example, only the incident light that is vibrating parallel to the polarization direction is allowed to pass. Hence the polarizer controls the parallax ray through the slit aperture one bye one. Then the pixels of 4-views stereoscopic images are aligned in not only horizontal direction but also vertical. As a result, both 4-views 3D display can avoid the horizontal resolution problem of conventional system because the image resolution of each view is reduced both horizontally and vertically.

6399B-29, Poster Session

High-power laser diodes safety operation area

P. D. Yankov, D. Todorov, B. Georgiev, E. Saramov, Technical Univ. of Sofia (Bulgaria)

An research set up is designed for elaboration the optical safety operation area (OSOAR) of laser diodes under pulsed operation. The data allows to predict the maximum pulsed current and lifetime of the diode.

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6400-01, Session 1

Femtosecond laser microfabrication of 3D structures in Foturan glass

Y. Cheng, Univ. of Missouri/Rolla (USA) and The Institute of Physical and Chemical Research (Japan); K. Sugioka, K. Midorikawa, The Institute of Physical and Chemical Research (Japan); Z. Xu, Shanghai Institute of Optics and Fine Mechanics (China)

Nowadays, photonics is playing an ever-increasing role in the chemical and biological sensing and analysis. The trend of miniaturization in optically based biosensors demands the integration of microoptical and microfluidic components in a microchip with true 3D configurations. Traditionally, since the techniques for fabricating microoptical and microfluidic elements are not compatible, the optical and the fluidic elements must be first separately fabricated, and then assembled onto a same chip. The alignment between the microoptical and microfluidic components requires micron-scale precision. To overcome this difficulty, we developed a novel microfabrication technique using a single exposure step to form 3D hollow structures buried in a photosensitive glass - Foturan. The technique is based on femtosecond laser direct writing followed by post-baking and successive chemical etching, completely eliminating the procedures like alignment, fixation, stacking, and bonding that are inherent in traditional 3D microprocessing techniques. Using this technique, 3D microfluidic structures, such as microchannels, microchambers, and microvalves, were first fabricated inside the Foturan glass with a fabrication precision of ~10 microns. Since this is a non-ablative processing, the fabricated internal surface is smooth and free of debris and cracks. The smooth surface can thus be used to build a series of optical components, including micromirror, microbeam splitter, microoptical lens, and freestanding fibers. We also examined the optical properties of these structures. Finally, we describe the integration of the microoptical and microfluidic structures into one glass chip using the single-exposure-step processing. Functional devices including microfluidic dye lasers and biosensors for photoabsorption spectroscopic application were fabricated and demonstrated.

6400-02, Session 1

Microfluidic sorting system based on optical waveguide integration created by femtosecond laser micromachining

J. A. Squier, R. Applegate, Colorado School of Mines (USA); T. Vestad, J. S. Oakey, MetaFluidics, Inc. (USA); D. W. M. Marr, Colorado School of Mines (USA); P. Bado, Translume Inc. (USA)

Effective methods for manipulating. isolating and sorting cells and particles are essential for the development of microfluidic-based life science research and diagnostic platforms. We demonstrate an integrated optical platform for cell and particle sorting in microfluidic structures. Fluorescent-dyed particles are excited using an integrated optical waveguide network (created by femtosecond lasers) within microchannels. A diode bar optical trapping scheme guides the particles across the waveguide/micro-channel structures and selectively sorts particles based upon their fluorescent signature. This integrated detection and separation minimizes the optical and feedback complexity commonly associated with extant platforms.

6400-03, Session 1

Femtosecond laser micromachining: applications in photonic device fabrication and laser joining

W. Watanabe, National Institute of Advanced Industrial Science and Technology (Japan) and Osaka Univ. (Japan); J. Nishii, National Institute of Advanced Industrial Science and Technology (Japan)

When femtosecond laser pulses are tightly focused into a transparent material, the intensity in the focal volume is high enough to induce permanent structural modifications. Using these permanent structural modifications, one can micromachine structures inside the bulk of a transparent material in three-dimensions. I present the fabrication of photonic devices in transparent materials, including waveguides, couplers, diffractive lenses, and microfluidic channels in silica glass and PMMA. Applications of femtosecond laser micromachining include the joining of glass substrates by localized melting and resolidification.

6400-04, Session 1

Monolithic multifunctional integration in fused silica using femtosecond laser: a technology platform for all-optical microsystems

Y. Bellouard, Technische Univ. Eindhoven (Netherlands)

At energy level below the ablation threshold, femtosecond-laser irradiation of Fused Silica (a-SiO2) can induce significant changes in the material properties: refractive index and chemical etching susceptibility are both significantly locally increased. By scanning a femtosecond laser beam over the substrate volume, one can create three-dimensional patterns with tailored material properties. Using this method, optical component like waveguides can be embedded in three-dimensional parts with various functionalities like for instance fluidic channels or micro-mechanical elements.

In this paper, we show that femtosecond laser irradiation applied on Fused Silica (a-SiO2) defines a novel technology platform for highly integrated all-optical microsystems. Instead of combining materials to achieve particular functions - like it is commonly done, this technology utilizes a single piece of material the properties of which are locally tailored by applying femtosecond laser irradiation.

This leads to new micro-systems design paradigms that we propose to illustrate in this paper with a few examples of both passive and active micro-devices.

6400-05, Session 2

Three-dimensional laser microfabrication

S. Juodkazis, H. Misawa, Hokkaido Univ. (Japan)

Three - dimensional (3D) laser micro-structuring of resists, polymers, glasses, and crystals is demonstrated by the direct laser writing and holographic recording. 3D photonic crystal templates with a stopband at a shorter than 1 micrometer wavelength have been achieved in resist. The achievable resolution limits of femtosecond 3D laser micro-fabrication are discussed.

The light - matter interaction of a tightly-focused femtosecond pulse with dielectric is described. The void formation is demonstrated inside silica glass and crystalline sapphire by a single pulse exposure. Altered chemical properties of shock-affected regions inside silica glass and sapphire were revealed by wet etching of “shocked” regions in aqueous solution of hydrofluoric acid. The maximum wet etching selectivity defined as a ratio of the etched-out length to the width of channel in silica glass, quartz, and sapphire were approximately 100, 500, and \> 1000, respectively. Potential of the fabricated 3D patterns in photonics, microfluidics, and sensor applications is discussed.

6400-06, Session 2

Transversal waveguides with symmetric cross sections generated at large depths (\>7-mm) in SiO2 with femtosecond laser pulses

V. Diez-Blanco, J. Siegel, J. Solis, Consejo Superior de Investigaciones Científicas (Spain)

Although the use of femtosecond laser pulses has been widely proved to be a very suitable technique to generate microstructures, particularly waveguides, inside glasses there still remains a range of open questions. One of these aspects concerns optimum energy deposition to generate a maximally localized refractive index increase inducing neither material damage nor uncontrollable nonlinear propagation. Previous works have shown that, at energies low enough to neglect the effect of nonlinear propagation phenomena such as critical self-focusing, spherical aberration due to air-glass interface turns to be a determining factor with regard to the shape and size of the modified zones. As a consequence of the air-medium refractive index mismatch, the depth of focus becomes dramatically longer with increasing depths meaning both a drop on deposited power densities and the formation of elongated regions of increased refractive index. In principle, low numerical aperture lenses reduce the effect of spherical aberration and thus potentially enable

processing at large depths. However, these lenses inherently have long depths of focus which will eventually lead to elliptical modified regions. This effect can be compensated by means of astigmatically shaped beams, as firstly demonstrated by Cerullo and coworkers, who obtained waveguides with circular cross sections very close to the material surface.

In this work, we show that waveguides with symmetric cross sections can be generated in SiO2 at large depths (\>7 mm) using a combination of a low numerical aperture (NA=0.26) focusing lens and an astigmatically shaped 100 fs-laser beam at 800 nm and 1 kHz repetition rate, working in the linear propagation regime. The guiding structures were produced translating the sample perpendicularly to the incident beam at 100 micron/s. Circular guided modes of 25 microns width were obtained.

6400-07, Session 2

Holey fibre delivered radiation for laser curing and trimming of direct write components

T. Delmonte, S. Raja, G. Simpson, J. McDonald, E. J. O'Driscoll, BAE Systems plc (United Kingdom); J. C. Flanagan, J. R. Hayes, M. N. Petrovich, V. Finazzi, F. Polletti, D. J. Richardson, Univ. of Southampton (United Kingdom); D. P. Hand, Heriot Watt Univ. (United Kingdom)

In this paper we demonstrate how Holey Fibre (HF) technology can positively impact the field of materials processing and fabrication, specifically Direct Write (DW). DW is the out-of-vacuum, large scale, patterned deposition of functional materials on conformal surfaces. DW processes are of interest in a wide range of applications sectors, including defence and security, where the capability of fabricating devices directly onto structural parts and assemblies is of great interest.

Current DW techniques involve a post-deposition thermal processing stage, whereby the entire structure is enclosed in an oven in order to cure the inks and pastes written onto the surface. This limits the size of the workpiece and the range of substrate materials that can be used, since many materials in real applications cannot withstand the processing temperatures required. Selectively laser curing the ink would allow the ink to be brought up to the required temperature without heating the surrounding substrate material. In addition the ability to trim components would allow miniature circuits to be written and devices to be tuned by changing the capacitance or resistance.

HF technology enables in-situ curing and trimming of direct write components using the same rig and length of fibre. HF's with mode areas in excess of 450μm2 can be routinely fabricated allowing high power transmission whilst retaining the high beam quality of the radiation source.

We will present results of curing and trimming trials which demonstrate that HF's provide a distinct advantage over standard multimode fibres by allowing both curing and machining to be achieved through a single delivery fibre.

6400-08, Session 2

Nonlinear laser-induced damage and absorptance effects in dielectric coatings by using ultrashort pulses

K. Starke, M. Jupé, H. Mädebach, M. Lappschies, D. Ristau, A. Ostendorf, Laser Zentrum Hannover e.V. (Germany)

The power handling capability of optical components is still one of the most important limitations for the further improvement of ultra-short pulse lasers in respect of average power and pulse energy. Laser-induced damage of functional dielectric coatings on laser crystals, pockels cells, out-coupling polarizers and compressor gratings is severely inhibiting the wide dispersion of ultrashort pulse laser systems especially in industrial production environments. Since the underlying physical causes for laser-induced damage with ultrashort pulses are distinctly differing from those in the nanosecond time scale, novel approaches must be found for an unambiguous improvement in damage resistance of optical coatings.

In previous investigations, the band-gap of the coating material and the maximum field strength in the layer stack were identified as most important influences on the laser-induced damage with ultrashort pulses. Furthermore, a significant nonlinear increase of absorptance in dielectric coatings was found to be strongly related to the band-gap of the material. These effects were traced back to the multi-photon and avalanche-ionization as driving mechanisms for producing a critical conduction band population. In the current investigations, numerous model layer systems were investigated concerning laser-induced damage and nonlinear absorptance. Adapting the ion beam sputtering coating process for achieving co-deposition of high and low index materials, coatings with continuously tunable refractive indices were produced. The results of the experiments exhibit a strong correlation of the damage threshold to the controllable shifting band-gaps of the coating materials.

6400-09, Session 2

Femtosecond-laser writing of 3D photonic crystals in polymer

M. Gu, Swinburne Univ. of Technology (Australia)

Three-dimensional (3-D) photonic crystals hold a key to the successful development of all-optical devices. Photonic crystals with bandgaps in the infrared or the visible spectral region are a challenge for micro-fabrication, as they require a highly correlated arrangement of structural elements at a size of only a few hundred nanometers. The most common ways to generate them are the use of semiconductor technology or the self-organization of colloidal particles. The ability to generate voids inside transparent materials using femtosecond pulsed laser light has provided a useful tool for fabricating 3-D photonic crystals. The physical mechanism for this process is the micro-explosion under multi-photon absorption. Here we present a novel approach to generate submicron-size voids and void channel-based 3-D photonic crystals by direct femtosecond-laser writing into a solid polymer material. This method is a one-step approach and results in photonic crystals with a high degree of perfection. 3-D photonic crystals with woodpile, face-centred-cubic, body-centred-cubic. and diamond lattice structures have been successfully produced, exhibiting a near-infrared transmission suppression of 70-90%. The tunability and the defect generation in these photonic crystals will be discussed.

6400-10, Session 3

Rewritable nanogratings in fused silica by focused femtosecond laser for secure data storage application

R. S. Taylor, C. Hnatovsky, E. S. Simova, J. Liu, D. M. Rayner, P. B. Corkum, National Research Council Canada (Canada)

Applications in the area of secure data storage will be discussed. Periodic nanogratings written inside fused silica using a focused femtosecond laser beam can be erased and replaced with new gratings whose orientation is determined by the polarization of the femtosecond laser overwrite beam. The nanoplane gratings are created by means of a nanoplasmonic self-replication mechanism. The orientation of the grating planes is perpendicular to the laser polarization direction and control of this orientation has led to polarization selective etching of fused silica. Grating structures have also been observed at the fixed focus of a femtosecond laser beam. In this work we use a femtosecond laser beam from a regeneratively amplified Ti:Sapphire laser tightly focused deep inside high optical grade fused silica to make volume nanogratings. We show that these gratings are very robust and are present after heating the sample above 1000 deg C. We also show that it is possible to rewrite these gratings with a second set of gratings with an orientation perpendicular to the polarization direction of the rewrite laser beam. High contrast reading of the grating voxels will also be demonstrated using polarization optics. The ability to write and rewrite volume nanogratings is important for archival 3-D data storage applications where a low power linearly polarized "read" beam can be used to give a high signal-to-noise signature from the grating voxel. The use of the femtosecond laser beam to switch the orientation of the grating planes provides an exciting rewriting capability, for example, to correct errors.

6400-11, Session 3

Limits of ultrafast nanomachining: bubble dynamics and acoustics

A. J. Hunt, K. Ke, S. Lee, Univ. of Michigan (USA)

Damage produced by optical breakdown becomes very precise for pulse durations less than a picosecond. This precision is particularly evident near the critical breakdown threshold intensity, thus enabling the application of optics at critical intensity (OCI) for reproducible laser machining of sub-diffraction limit features on surfaces. Although the physics of optical breakdown are central to establishing this precision, and thus the limits of micro or nanomachining, in practice machining is often limited by a less subtle difficulty: the ultimate destination of ablated materials. Ablated materials may be redeposited at or near the site of breadown, creating unintended structures or debris at the machining site. We have investigated using unusual long-lived bubbles that are produced

during machining as a mechanism to extrude fluid entrained debris. During higher-energy microscale machining, bubbles can diminish the accuracy due to unintended damage associated with there violent collapse, but we find a low energy regime exists in which highly damped and surprising long-lived microbubbles gently extrude debris. Machining efficiency is strongly influenced by the bubble dynamics, and is inhibited when bubbles become immobilized in acoustic nodes created during the machining process.

6400-12, Session 3

Femtosecond laser nanoprocessing using near-infrared nanojoule pulses at MHz repetition frequency

K. König, R. LeHarzic, H. Schuck, D. Sauer, T. Velten, Fraunhofer-Institut für Biomedizinische Technik (Germany)

We report on nanostructuring of biological as well as non-biological materials including biofilms, DNA, silicon wafers, polymers, metal films, metallic nanoparticles and photoresists. Using 80/90 MHz near-infrared pulses between 730 and 960 nm. We were able to laser-induce sub-100 nm features which corresponds to sizes of 1 order below the diffraction limited laser spot size. We present applications for stem cell research and nanofabrication.

6400-16, Session 4

New Yb-doped crystals for high-power and ultrashort lasers

F. P. Druon, J. Boudeile, Y. Zaouter, M. Hanna, F. Balembois, P. M. Georges, Univ. Paris-Sud II (France); J. Petit, P. Goldner, B. Viana, École Nationale Supérieure de Chimie de Paris (France)

In the field of femtosecond lasers, an intense interest has been shown for ytterbium-doped laser-crystals. These crystals are now well-known to be particularly suitable for very efficient, directly-diode-pumped, solid state femtosecond oscillators. However, it has been shown that the spectral properties of the Yb3+ dopant strongly depend on the matrix host and a lot of works have been done to find the “ideal” matrix allowing both ultra-short-pulsed and high-power lasers. Firstly, in order to take advantage of the very high-power laser diodes available to pump Yb-doped materials, ideal crystals need to be able to hold high power pumping; so high thermal conductivity is required (\>5W/m/K, typically). Secondly, to generate very short pulses (<100 fs) ideal crystals have to demonstrate very broad and smooth spectra. Among the numerous Yb-doped crystals already studied, many failed with one of these two contradictory criteria (contradictory because broad spectra are often synonymous of high disorder in the host lattice and the good thermal conductivity requires an ordered matrix to allow good propagation of phonons). In this paper, we are relating the performance of a new Yb-doped crystal: Yb:CaGdAlO4 (Yb:CALGO) and how it takes place in this quest of “ideal” crystal. Actually, this very new crystal allowed, to our best knowledge, the shorter pulses ever produced with an Yb-doped crystal with the production of 47 fs pulses. Moreover, compared to other crystals allowing the production of sub-100 fs pulses such as Yb:GdCOB, Yb:BOYS and Yb:KGW, the atypical CALGO shows a thermal conductivity of 6.5W/m/K.

6400-17, Session 4

High-energy diode-pumped femtosecond oscillator with up to 1-μJ pulse energy at 9-MHz pulse repetition rate

C. Honninger, E. Mottay, Amplitude Systemes (France)

High energy femtosecond oscillators at high pulse repetition rate have a great potential for many applications such as micro- and nano-machining and structuring, waveguide writing in dielectric media, or nonlinear frequency conversion. Up to now most femtosecond oscillators operating at pulse repetition rates higher than 1 MHz were limited at pulse energies far below the microjoule level.

We demonstrate a directly diode-pumped Yb:KYW laser oscillator delivering pulse energies up to 1 μJ and pulse durations down to 430 fs, thus pulse peak powers exceeding the MW level. The pulse repetition rate is 9 MHz and the average power is on the 10-W-level. The laser setup is compact and fits in a 60 x 40 cm footprint.

We externally compressed the pulse duration of this laser down to about 60fs by focusing the laser into a large mode area micro-structured fiber followed by a compressor module containing a pair of parallel aligned dispersive mirrors. The good coupling efficiency and the high-reflecting dispersive mirrors resulted in an overall compressor transmission of 80%. For a maximum injected pulse energy of 0.53 μJ we obtained up to 0.42 μJ pulse energy after the compressor which corresponds to a peak power of 7 MW.

6400-18, Session 4

Canadian TeraWatt portable laser

M. Chateauneuf, J. Dubois, Defence Research and Development Canada (Canada)

Defence Research & Development Canada (DRDC) has recently acquired a Terawatt laser system mounted in a portable container. The compact laser system stands on a 1.25m x 2.5m optical table. The pulse energy at the output of the compressor is higher than 250mJ and the pulse width output beam lower than 50 fs resulting in a peak power greater than 5TW. Although the laser system is portable which allows its deployment for test fields on multi-kilometer military ranges, a special building will be constructed to efficiently use its capabilities. While the container will seat inside a garage, it will be possible to steer the laser beam toward a well confined 250m exterior range, or toward a class 100 000 laboratory. This laboratory will be designed to work either on the laser beam or to generate THz waves from the femtosecond laser beam.

Preliminary work with the facility will be reported putting emphasis on the spatial beam shaping using a phase mask. This binary mask, designed using a custom optimization simulated annealing algorithm, is used to transform the top hat beam into any shape desired. The objective is to spatially control the filamentation pattern of the TW beam.

A description of the portable laser system will be presented at the conference as well as more details and results on the filamentation control pattern using the phase mask.

6400-19, Session 4

Femtosecond-laser-encoded distributed-feedback color center laser in lithium fluoride single crystal

K. Kawamura, Tokyo Institute of Technology (Japan); T. Kurobori, Kanazawa Univ. (Japan); M. Hirano, H. Hosono, Tokyo Institute of Technology (Japan)

Lithium fluoride (LiF) offers good physical and chemical properties and high photothermal stability of the laser active color center. For these reason, it has been used for room temperature color center laser. Especially, F2 and F3+ centers in LiF are very promising candidates for the visible laser action. However, high-energy deposition techniques such as electron beams and X-ray irradiation have been generally needed for producing the color centers because of its large energy optical bandgap (~14 eV). Here we report that an active optical device and a distributed-feedback (DFB) color-center laser were fabricated by the holographic encoding method using an infrared fs laser.

The femtosecond laser pulses were focused on the surface and inside of LiF plates. As a result, formation of F, F2, F3+ and F2+ color centers was observed by optical transmission measurements. Estimated concentration of the F2 color center was 2*10^18 cm-3. Then, we fabricated DFB F2 color center laser using the microgratings. Microgratings 40 micrometers in diameter were written continuously in a 5-mm line at a depth of ~ 100 micrometers by the holographic encoding method using an infrared fs laser. As we aimed at lasing from F2-center, the line-spacing of the grating was designed to be 510 nm, which line spacing corresponds to the theoretically expected DFB oscillation wavelength of 710 nm. Much narrowed, intense emission is clearly observed at 707 nm from the grating line. The line width is less than the resolution of our measurement system (1 nm).

6400-13, Session 5

Applications of adaptive optics correction procedures

T. Wilson, Univ. of Oxford (United Kingdom)

The ability to focus light to a diffraction limited spot within a material is a very general one with applications in many branches of optics. As disparate examples one may cite microscopy where resolution and contrast are often compromised when focussing deep within the specimen due to aberrations introduced by the specimen itself. Another example might be the case of three dimensional optical data recording where data is often written deep within a high refractive index material using an air objective via a non-linear process such as two-photon absorption. In

this case a finely focussed spot is crucial and aberration correction is essential.

In general an adaptive optics system requires the design of a wavefront sensor to measure the aberration to be corrected together with an appropriate correction element to introduce the necessary conjugate phase front into the optical system. We will describe a number of approaches to wavefront sensing and correction techniques including modal wavefront sensing. Examples taken from a number of fields will be presented.

6400-14, Session 5

Parallel drilling of inkjet nozzle plate using a picosecond laser and a diffractive optical beam splitter

X. Liu, Panasonic Technologies Co. (USA)

We describe, to the best of our knowledge, the first commercial mass production application of ultrafast laser micromachining. A picosecond regenerative amplifier with a pulse width of 20ps and a pulse energy of 1mJ is used to drill precisely shaped holes in stainless steel plate for high-speed, industrial color inkjet nozzle plate production. A high-efficiency diffractive optical element (DOE) beam is used to generate the entire nozzle pattern in the stainless steel plate for high throughput drilling to make the process commercially economical. The drilling system will be described and performance results presented.

6400-15, Session 5

Programmable focal spot shaping of amplified femtosecond laser pulses and their application to micromachining

N. Huot, N. Sanner, E. Audouard, Univ. Jean Monnet Saint-Etienne (France)

The use of ultra-short pulses has opened a number of industrial and scientific perspectives. In particular, for the micro/nano structuring of materials, it is possible to exceed the ablation threshold of all types of materials. The nature of the laser-matter interaction in the ultra-fast regime is fundamentally different from an interaction with longer pulses .As a result, the machining is very accurate with a reduced thermal affected zone. A consequence of the weak extension of surrounding damages is that the shape of the processed area is very close to the intensity distribution in the focal spot. This has motivated some efforts in the field of femtosecond laser beam shaping.

Active phase filtering using adaptive optics methods appears to be an attractive solution which provides both custom beam shaping with one single device together with a real-time control of the result. A non-pixelated liquid-crystal light valve is used as the phase-front modulator. We describe active wavefront correction of high repetition rate amplified femtosecond laser thanks to an adaptive optics loop. Residual wavefront distorsions are decreased down to * /15 peak-valley and * /100 rms. Such a nearly-diffraction limited beam is applied to two kinds of ultra-fast processes: micromachining of metals and optical waveguide photowriting. Moreover, beam patterning in the focal plane is also presented. Theoretical calculations of the required phase modulation are proposed, and experimental shapes are obtained, like square and circular top-hats, as well as triangle or doughnut shapes. Such a promising versatile femtosecond laser tool is used to perform direct marking of complex shapes.

Scientific and industrial perspectives of this device will be discussed.

6400-20, Session 6

Breakdown of envelope approximations and third-harmonic generation in femtosecond pulses propagating in gases

M. Kolesik, The Univ. of Arizona (USA); E. M. Wright, J. V. Moloney, College of Optical Sciences/The Univ. of Arizona (USA)

Third-harmonic (TH) generation using femtosecond pulses in gases has been studied for more than a decade. This interest has been motivated by both the potential for applications, such as in remote sensing, and in high-frequency pulse sources, as well as by the need to understand the underlying physics. This contribution reports on numerical simulations of third-harmonic and supercontinuum generation for femtosecond pulses propagating in air.

We present the first self-consistent model including both supercontinuum (SC) and TH radiation effects into simulation of femtosecond pulse propagation in air. In all previous works a two-envelope approximation has been utilized, one envelope being associated with the SC centered around the fundamental, and the other centered around the TH. Though in certain limited situations such an approximation can work well, it is difficult to justify in general and, strictly speaking, ill defined. Our approach works with the total real optical field, and thus eliminates envelope-based approximations completely. We demonstrate that our model provides results in good agreement with femtosecond experiments in air.

We use our simulation results to elucidate the physics that governs TH generation in air using femtosecond pulses, in particular the relation between TH and SC radiation. For this we utilize the simulated far-field spectra, in conjunction with an effective three-wave mixing approach, to present an intuitive explanation of the structure and generation mechanism of the SC and TH light. In the process, we improve and correct some interpretations of these processes published previously in the literature.

6400-21, Session 6

Propagation of high-intensity laser pulses in the atmosphere

N. Lascoux, R. Ackermann, E. Salmon, J. Kasparian, P. Béjot, Univ. Claude Bernard Lyon 1 (France); J. Extermann, L. Bonacina, J. Wolf, Univ. de Genève (Switzerland); K. Stelmaszczyk, P. Rohwetter, S. Li, A. Lindinger, L. Woste, Freie Univ. Berlin (Germany); N. Blanchot, O. Bonville, A. C. L. Boscheron, P. Canal, M. Castaldi, O. Hartmann, C. Lepage, L. Marmande, E. Mazataud, G. Mennerat, L. Patissou, D. Raffestin, CEA Cesta (France); S. Champeaux, L. Bergé, C. Guet, Commissariat a l'Energie Atomique (France)

We report on experiments conducted to better understand high intensity laser's propagation in the atmosphere. Such lasers generate self guided filaments due to a dynamic balance between Kerr effect and plasma generation. The properties of the filaments (broad spectrum, intensity (1014W/cm2), length of tens to hundreds of meters...) generated by table-top lasers are now well-known; but for higher intensity lasers, in the multijoule range, a lot of work remains to do in order to be able to control the characteristics of the filaments and use them for applications like LIDAR or lightning guiding.

Our first series of experiments were performed on the Alisé laser facility which delivers pulses of 25J, 600fs, 45TW. We characterized the influence of energy, chirp and focus of the pulses on the generation of filaments. Even at these extreme powers, the laser can propagate in the atmosphere without collapsing on itself shortly after the laser exit. The results were quite encouraging as we could report on the first (25J, 45TW) LIDAR system giving signal up to 15km in the atmosphere.

In our second series of experiments, we optimized, for the first time, the generation of filaments by our Teramobile laser thanks to a pulse shaper controlled by a genetic algorithm. We clearly observed the convergence of the genetic algorithm. Optimizing LIDAR signals at different wavelengths and the plasma density yielded different optimal shapes allowing us to distinguish the physical mechanisms involved in these processes.

6400-23, Session 6

Femtosecond pump-probe depletion to sort biological from background urban particles

V. M. Boutou, L. Guyon, C. Bonnet, Univ. Claude Bernard Lyon 1 (France); M. Roth, H. Rabitz, Princeton Univ. (USA); F. Courvoisier, J. Wolf, Univ. de Genève (Switzerland)

A major drawback for detecting and identifying bioaerosols using laser induced fluorescence (LIF) is the presence of organic particles (Diesel particles, soot,..) in the air, which exhibit very similar fluorescence signatures. The physical origin of this interference is the excitation in the UV of similar excited states (pi-electrons from benzenic rings) in amino acids (e.g. Tryptophan) and in PAHs. To help the diagnostic, we present a new femtosecond pump-probe depletion (PPD) concept, based on the time-resolved observation of the competition between excited state absorption (ESA) into a higher lying autoionizing excited state and fluorescence into the ground state. This approach makes use of two physical processes beyond that available in the usual fluorescence spectrum: (1) the dynamics in the intermediate pumped state and (2) the coupling efficiency to a higher lying autoionizing excited state. A fluorescence depletion induced by the probe pulse is observed in Tryptophan containing solutions but not for naphthalene. The PPD

excitation is so robust that a similar quenching is observed for live bacteria (E. coli, B. Subtilis) in contrast with diesel fuel. PPD works also for biomolecules such as flavins if the excitation is set to 400 nm. The interaction of water molecules with the chromophores is suspected to reduce their ionization potential and therefore facilitate the depletion. This allows for the increase by a factor x20 the ability to discriminate bacteria from background organic particles. Further attempts to improve the diagnostic sensitivity for one micro-organism among others by shaping the excitation pulses are in progress.

6400-24, Poster Session

Cross-correlation technique for determination of temporal profile of terahertz pulses

D. L. Hovhannisyan, Yerevan State Univ. (Armenia)

We propose a new single-shot cross-correlation method for determination of the time profile of an terahertz pulses. As an optical laser pulse modulated by the electric field of the terahertz pulse in an electro-optical (EO) crystal, it is proposed to use a non-uniform pulse modulated both in time and in space. In the proposed technique the measurement of the time profile is realized during a single laser shot. In this case, as a result of electro-optical modulation of a non-uniform femtosecond pulse, the information on the time profile of the terahertz pulse is contained in only the spatially shifted spectral components of the modulated pulse. The time sweep in the output of nonlinear crystal BBO with a thickness of 3 mm along the X-axis amounts to 4.79 fs/μm. Time resolution of the proposed method is determined by the value of the spatial resolution of the detector and, in particular, at the spatial resolution of the detector equal to 5 μm the time resolution amounts to 24 fs. The linear dispersion coefficient along the X-axis in the output of the non-linear crystal amounts to 0.034 nm/μm. The spectral resolution is in this case 0.17 nm at the spatial resolution of the detector equal to 5 μm.

6400-25, Poster Session

Computational modeling of near-infrared radiation generation by femtosecond laser pulse of a few optical cycles

D. L. Hovhannisyan, Yerevan State Univ. (Armenia)

In this paper, we study the generation of near infrared radiation in (1 - 3.5) mkm wavelength range by extraordinary linearly polarized laser pulse of a few optical cycles propagated in the direction normal to the optical axis of a nonlinear uniaxial crystal of 3m symmetry group.

6401-18, Poster Session

Enhanced luminescence from InAs/GaAs quantum dots

P. O. Holtz, Linköpings Univ. (Sweden)

Single quantum dots (QDs), based on the InAs/GaAs material system have been characterized by micro-photoluminescence (* PL). The self-organized quantum dots studied are fabricated by the Stransky-Krastanov method, taking advantage of the strain caused by the lattice mismatch between InAs and GaAs. Well-defined narrow excitonic features from individual QDs are monitored in the * PL spectra, upon single or dual tunable laser excitation. The charge state of the quantum dot is revealed from these excitonic lines in the * PL spectra. However, by tuning the laser excitation energy, it is demonstrated that the charge state of the dot can be altered: The distribution of neutral and charged excitons is demonstrated to be extremely sensitive on the laser energy. In addition, with an additional infrared laser, striking changes are induced in the * PL spectra. The results achieved demonstrate the existence of two well-defined excitation energy regions for the main laser, in which the presence of the infrared laser will decrease or increase, respectively, the integrated dot * PL intensity. For excitation above the critical threshold energy of the main laser, the addition of the infrared laser will induce a considerable increase, by up to a factor 5, in the QD emission intensity. At laser excitation below the threshold energy, on the other hand, the QD emission intensity will decrease. This fact is due to reduced carrier capture efficiency into the dot as determined by the internal electric field driven carrier transport. In order to get further insight into the carrier capture process due to the electric field in the vicinity of the QD, the dots have also been subjected to an external electric field

In most optical experiments with QDs, electrically injected or photoexcited carriers are primarily created somewhere in the sample outside the QDs, e.g. in the barriers or in the wetting layer. Consequently, excited carriers undergo a transport in the wetting layer and/or barriers prior to the capture into the QDs. This circumstance highlights the crucial role of the carrier transport and capture processes into the dot for the performance and operation of the dot based devices such as QD lasers, QD infrared detectors and QD memory devices. This transport effect on the optical response of the quantum dots has been investigated by subjecting the carriers to an external electric field in * PL measurements. This external field is formed by application of a lateral field between two top contacts. It is demonstrated that the QD PL signal intensity could be increased several times (\>5 times) by optimizing the magnitude of this external field.

6401-19, Poster Session

Two-photon absorption and luminescence of some novel thiophenyl Pt(II)-ethynyl derivatives

E. Glimsdal, Norges Teknisk-Naturvitenskapelige Univ. (Norway); M. Carlsson, B. Eliasson, Umeå Univ. (Sweden); M. Lindgren, Norges Teknisk-Naturvitenskapelige Univ. (Norway)

The multi-photon absorption and optical power limiting (OPL) properties of two new thiophenyl-containing bis(ethynylaryl)bis(tributylphosphine) platinum(II) complexes (ATP1, ATP2) were studied. Thiophene units were introduced into the structure as an attempt to enhance the OPL properties. The two compounds have the thiophene rings either close to the Pt-atom (ATP1) or at the terminal ends. The measurement results were compared with those of Pt1 capped with a 2,2-bis(methylol)propionic acid (bis-MPA) dendrimer (Pt1-G1). Just as Pt1-G1, both thiophenyl derivatives showed large intersystem crossing capabilities and triplet phosphorescence, thus have potential of enhancing the nonlinear absorption and specifically the OPL properties.

The two-photon absorption cross section of ATP1 and ATP2 was found to be in the same order of magnitude as for the Pt1-G1 case i.e., between 10-20 GM, but slightly larger for ATP1 than for ATP2. The fluorescence decay time of all compounds was found to be very short (sub nanosecond) with quantum yields approximately 0.0045, 0.0007 and 0.0011 for ATP1, ATP2 and Pt1-G1, respectively. The multi-photon induced phosphorescence was reduced with decreased prf showing a population dependence of the triplet state with pulse repetition frequency, correlating with the relatively long phosphorescence decay lifetime around 200us.

6401-20, Poster Session

Theory of singlet oxygen emission photosensitized by porphyrins

B. F. Minaev, Norges Teknisk-Naturvitenskapelige Univ. (Norway)

For most sensitizers the role of the singlet excited state quenching by oxygen molecule is limited to enhancement of the triplet state quantum yield; thus the main path of the singlet oxygen sensitization is the energy transfer from the triplet T1 state. The ration of the a/b singlet oxygen production is significantly larger than that expected from the electronic exchange energy transfer mechanism of Dexter-type. The presented theory includes account of spin-orbit and charge-transfer interactions; exchange coupling is also included by direct quantum chemical calculation of the dipole transition moments. Correlation between the enhancement of the a-X transition in oxygen with the T1 state quenching is proposed.

6401-21, Poster Session

Microwave properties of thermochromic metal oxide surfaces

J. Ousback, H. M. Kariis, Swedish Defence Research Agency (Sweden)

Microwave properties of thermochromic metal oxide surfaces

Thermochromic metal oxides with a Mott transition, such as vanadium dioxide, exhibit an extensive alteration in their infrared reflectivity when heated above the transition temperature. For VO2 the reflectivity increases as the material becomes more metal-like above the transition temperature at 68 °C.

For protection against multiple sensors, it is interesting to study the signature properties of a material in several wavelength ranges. The microwave properties of VO2 as a function of temperature have been investigated here.

Measurements were made with an automated network analyzer combined with an electrical heating unit. Reflection properties of VO2 in the microwave region were determined.

Above the transition temperature, an increase in the reflection of the surface was observed. The VO2 became more metal-like in the whole measured microwave frequency range, as in the infrared region.

It is concluded that VO2 not only can be used to adapt the thermal emissivity of a surface but also to control the microwave reflectivity. Possible military applications are switchable radoms, frequency selective surfaces and heat protection for antenna apertures.

6401-22, Poster Session

Method for the recognition of maintenance of urine salts

I. H. Yarynovska, A. I. Bilyi, R. O. Bilyy, O. Bordun, Ivan Franko National Univ. of L'viv (Ukraine)

Up to this time systematic optic-luminescent researches of urine were conducted as a rule only by the methods of hesitating spectroscopy, such as infra-red absorption and combination dispersion of light. The given methods allow systematizing composition of pathological components in urine. The diagnostic tests of determination of their maintenance were developed on the methods of molecular spectroscopy. Tools for their registration were created. Systematic opto-luminescent researches of urine in the ultraviolet and visible region of spectrum are practically absent.

The special interest in researches of luminescent properties of urine is conditioned by the last achievements of molecular biology, which testify that in difficult biological molecules it is possible to select structural nanoobjects - domains, molecules-proteins, for which the luminescence conditioned by the transfer of charge is observed. Confirmative changes of such molecules are caused by the row of factors of external and internal nature and lead to the changes of their spectral properties. Creation of biological nanosensore for control of maintenance of pathological component for the human organism on the given principle is possible.

The spectrums of luminescence of urine excited by nitric laser (337,1 nm) and photo excitation in the interval of lengths of waves 250 - 550 nm at a temperature 85 and 300 K and the influence of different origin salts were researched. Emission was observed in a spectral interval 400 - 800 nm.

Its intensity depends on temperature and type of excitation. It was noticed that presence in urine of salts of oxalate, urate and phosphate compositions results in the change of maximum of emission spectrums in the long-wave region of spectrum and falling of emission intensity. The mathematical curriculum of emission spectrums of dry tailings of urine on rectangular components allowed selecting a row the component, the quantity of which that their intensity depends to the type of salt and type of excitation accordingly. In work the possible machineries of the changes looked after in the emission spectrums of dry tailings of urine are considered. The model of recombination processes which describe the luminescent processes looked after is offered.

6401-23, Poster Session

High signal-to-noise ratio quantum well bolometer materials

S. G. E. Wissmar, L. Höglund, J. Y. Andersson, C. Vieider, S. Savage, P. Ericsson, Acreo AB (Sweden)

Novel single crystalline high-performance temperature sensing materials (quantum well structures) have been developed for the manufacturing of uncooled infrared bolometers. SiGe/Si and AlGaAs/GaAs quantum wells are grown epitaxially on standard Si and GaAs substrates, respectively. The former use holes as charge carriers utilizing the discontinuities in the valence band structure, whereas the latter operate in the same manner with electrons in the conduction band. By optimizing parameters such as the barrier height (by variation of the germanium/aluminium content, respectively) and the fermi level Ef (by variation of the quantum well width and doping level) these materials provide the potential to engineer layer structures with an outstanding signal to noise ratio. This implies a very high temperature coefficient of resistance, TCR, as compared with conventional thin film materials such as vanadium oxide and amorphous silicon. In addition, the high quality crystalline material promises very low 1/f-noise characteristics and well defined and uniform material properties.

A comparison between the two (SiGe/Si and AlGaAs/GaAs) quantum well structures and their fundamental theoretical limits are discussed and compared to experimental results. A TCR of 3.3%/K and 4.4%/K were obtained for SiGe/Si and AlGaAs/GaAs, respectively. The noise level for both materials is several orders of magnitude lower than of a-Si and VOx.

These uncooled thermistor materials can be hybridized with read out circuits by using conventional flip-chip assembly or wafer level adhesion bonding. The increased performance obtained can either be exploited for increasing the imaging system performance, i. e. obtaining a low NETD, or to reduce the vacuum packaging requirements for low cost applications (e.g. automotive).

6401-24, Poster Session

Gradient optics of dielectric nanofilms (stand-by oral presentation)

A. B. Shvartsburg, Russian Academy of Sciences (Russia)

The unusual reflection - refraction properties of gradient nanofilms and perspectives of their using for design of new classes of miniaturized optoelectronic devices are considered.

The physical fundamentals of these devices are based on the dispersive properties of heterogeneous dielectric films with some special profiles of refractive index n, distributed across the film:

a. Non - local, heterogeneity - induced dispersion, determined by technologically controlled shape and spatial scales of profile n(z). Having nothing in common with usual material dispersion, this non - local effect results in formation of both normal and abnormal dispersion of the film, the host material being the same, and, respectively, in drastic changes of film's optical properties.

b. Some concave profiles of n(z) provide the cut-off frequency of the film, located in the visible and near IR ranges.

Unlike the traditional tunneling regimes, the effects in question arise in a medium with negative gradient of dielectric susceptibility meanwhile the susceptibility itself remains positive. This peculiarity is shown to provide a multitude of applications, connected with non- attenuative narrow - banded tunneling (100% transfer of energy or information) through the gradient layer.

c. For each spectral range the choose of material and n(z) profile can be optimized on such a way, that the effects of non - local dispersion under discussion would be located in the fixed spectral band, far from the absorption bands of the material.

Using of these phenomena opens the possibilities to design the series of miniaturized (film thickness/wavelength < 0.1) devices in optoelectronics and photonics, in particular:

1. Narrow-banded frequency filters, polarizers and phase shifters, operating at large angles of incidence;

2. Broadband antireflection coatings, effective reflectors and frequency - selective interfaces;

3. Delay lines, using surface waves, whose spectra are governed by shape and thickness of the subsurface profiles of n.

6401-01, Session 1

Materials R&D as enablers for quantum leaps in photonics device development and performance

L. Thylén, Kungliga Tekniska Högskolan (Sweden)

No abstract available

6401-02, Session 1

Organic components for optical devices: fabrication and characterization

A. F. Fort, J. Bombenger, S. Klein, A. Barsella, L. Mager, D. Gindre, K. D. Dorkenoo, Institut de Physique et Chimie des Matériaux de Strasbourg (France)

We report on photopolymers doped with non-linear optical (NLO) molecules as key materials in the elaboration of organic NLO devices. We have developed different techniques for the fabrication and imaging of optical components using one and two photon absorption for the polymerization of functionalized polymers.

The mastering of the refractive index distribution through one photon absorption polymerization has been used to fabricate self written photopolymeric waveguides by a solitonic propagation of an actinic beam inside the bulk of a resin. The spatial photo-patterning of the quadratic non linear optical properties of doped photopolymers has also been performed by a direct laser writing enabling the fabrication of stable optical structures.

Using another approach, we have taken advantage of the high spatial selectivity of the two-photon absorption procedure for the design of controlled polymerized pathways. By using a two-photon confocal microscopy technique with a femtosecond laser source to activate the polymerization, we demonstrate how it is possible to create optical circuits in the bulk of doped photopolymers. Specific techniques of imaging such polymeric micro-structures have been developed, trough second harmonic generation and two-photon induced fluorescence detection. Finally, a 3D storage system, which encodes bit data in the local orientation of chromophores by spatially-selective photopolymerization will be presented.

6401-03, Session 1

Multiphysics modeling of optical materials

H. Ågren, Kungliga Tekniska Högskolan (Sweden)

In this talk I will describe applications in materials science of modelling of multi-photon processes in particular and of non-linear optical effects in general. The project is rooted in that novel compounds featuring large multiphoton absorption cross sections are of great interest due to many attractive applications exploiting high order non-linearity of media's response to exciting light. These include, for example, ultrahigh-resolution biological imaging using multiphoton confocal microscopy, high-efficiency upconverted lasing for infra-red to visible upconversion, and optical power limiting, where the range of radiation amenable to effective suppression can be extended to the infra-red region. Our applications have been carried out in collaborations that involve design by theoretical modelling, synthesis and characterization. The research has mostly addressed organic and organometallic compounds, but has recently also been extended to the design of multiphoton quantum dots. These offer the combined advantage of brilliance and photo-resistance of normal quantum dots with the 3-dimensional confocality and penetration of multiphoton excitation, something that can have a broad ramification on fluorescence based experiments in biology.

I will highlight the use of multiscale/multiphysics approaches combining quantum mechanics with wave mechanics on one hand and quantum mechanics with molecular dynamics simulations on the other. The first

type of combined approach addresses pulse propagation in non-linear media and allows to estimate the optical transmission from cross sections of multi-photon absorption processes and from considerations of propagation effects, saturation and pulse effects. It is shown that in the non-linear regime it is often necessary to account simultaneously for coherent one-step and incoherent step-wise multi-photon absorption, as well as for off-resonant excitations even when resonance conditions prevail. The other type of combined approach, quantum mechanics with molecular dynamics, allows to study temperature and pressure effects and also cooperative effects, like pooling, aggregation and loading, on the macroscopic outcome of the non-linear effect. Numerical illustrations are given for some studied dipolar and octupolar chromophores hosted by polymer matrices.

6401-04, Session 1

DFT study of excited states and phosphorescence of platinum(II) acetylides

B. F. Minaev, Norges Teknisk-Naturvitenskapelige Univ. (Norway); E. Jansson, Kungliga Tekniska Högskolan (Sweden); M. Lindgren, Norges Teknisk-Naturvitenskapelige Univ. (Norway)

Optical power-limiting (OPL) devices can protect visible sensors (eyes, for example) against possibly damaging laser light and need to have a spectral response in the range 400-700 nm. Optically nonlinear materials are important to achieve the OPL function and particularly Pt-based organic complexes have been proven useful for such applications. Here, the nonlinear process is dominated by excited state absorption of triplet states. We present theoretical DFT results of a series of Pt-acetylides in terms of ground and excited state geometries, vibronic activity, spin-orbit coupling (SOC) and compare with results of spectrally and time-resolved luminescence measurements. Besides the delocalized $\pi\pi^*$ singlet and triplet states, which determine strong visible absorption and phosphorescence, respectively, there are dark $\sigma\pi^*$ states of charge-transfer type, which provide strong SOC at the platinum 5d-shell and effective spin conversion. Our DFT results indicate that there is a spontaneous broken symmetry in the first excited triplet state.

6401-05, Session 2

Lessons from biology: sensing, locomotion, and catalysis

M. O. Stone, Air Force Research Lab. (USA)

No abstract available

6401-06, Session 2

Optical properties of deoxyribonucleic acid (DNA) polymer host

A. Samoc, M. J. Samoc, The Australian National Univ. (Australia); J. G. Grote, Air Force Research Lab. (USA); A. Miniewicz, Politechnika Wroclawska (Poland); B. Luther-Davies, The Australian National Univ. (Australia)

Recently, DNA polymer has been found to be a promising material for applications in photonics due to its unique double-helix, chiral secondary structure and the ability to act as a host for photochromic, fluorescent, and nonlinear optical (NLO) chromophores. Physical and optical properties of DNA can be remarkably modified with an alteration of the nucleic acid counter-ions. A novel exciting photonic material was fabricated out of marine, salmon-based DNA by complexing it with a surfactant, cetyltrimethyl-ammonium (CTMA) chloride. In DNA-CTMA the sodium ions of the native DNA are replaced with cetyltrimethyl-ammonium ions.

We have been interested in optical properties of double-stranded DNA, as well as DNA-CTMA, because they might have a capability to induce orientation of the chromophores needed in photonic applications. We identified optical parameters, which are fundamental for understanding properties of waveguides and NLO structures containing DNA-based photonic materials.

We determined optical properties of DNA and DNA-CTMA polymers in solutions and films. We measured refractive indices in the direction parallel and perpendicular to the surface plane of the films. They show a large anisotropy in orientation of DNA molecules in films. Optical properties of DNA films are sensitive to the film fabrication and environmental conditions influencing the structure. Prism coupling measurements showed nearly isotropic refractive indices (no birefringence) and a lack of the preferential alignment of DNA-CTMA molecules in films unlike that observed in DNA films.

The Z-scan technique using femtosecond pulsed laser system was employed to determine the NLO properties of DNA in solutions in the 530-1300 nm wavelength range.

6401-07, Session 2

Bio-organic light-emitting diodes based on deoxyribonucleic acid biopolymer electron blocking layer

J. G. Grote, Air Force Research Lab. (USA)

Enhanced electroluminescent efficiency using a deoxyribonucleic acid (DNA) biopolymer-based material as an electron blocking layer (EBL) has been achieved for both green and blue emitting organic light emitting diodes (OLEDs). The resulting green and blue bio organic LED's, or BioLEDs, achieved a maximum luminous efficiency of 8.2 and 0.8 cd/A, respectively. These BioLED devices were as much as 10X more efficient, 30X brighter and had 3X longer lifetimes than their non-DNA biopolymer OLED counterparts.

6401-08, Session 2

Development and performance of an all-DNA-based electro-optic waveguide modulator

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Marine-based deoxyribonucleic acid (DNA), purified from waste products of the Japanese fishing industry, has recently become a new material of interest in photonics applications. The water soluble DNA is precipitated with a surfactant complex, cetyltrimethl-ammonium chloride (CTMA), to form a water insoluble complex, DNA-CTMA, for application as a nonlinear optical material. In order to fabricate an all-DNA-based waveguide, it is necessary to crosslink the DNA-CTMA films. Crosslinking makes the films resistant to their initial solvent; this permits spin-coating of successive DNA-CTMA layers without solvent damage. A chromophore dye is added to the core layer to allow for an electro-optic coefficient to be induced through contact poling. Through contact poling, an electro-optic (EO) coefficient comparable to that in other polymers was demonstrated in crosslinked DNA-CTMA films with the chromophore dye Disperse Red 1. This EO effect allowed for the creation of the first all-DNA-based EO waveguide modulator. The performance of the modulator will be discussed.

6401-09, Session 3

Quantum dots-in-a-well infrared photodetectors for long-wavelength infrared detection

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Vertical InAs/In0.15Ga0.85As/GaAs dots-in-a-well (DWELL) quantum dot infrared photodetectors (QDIPs) have been developed to detect infrared radiation in the long wavelength infrared (LWIR, 8-12μm) region. In DWELL structures intersubband transitions occur in the conduction band between the quantum dot (QD) and the quantum well (QW). Compared to conventional QDIPs, this opens new possibilities to tune the detection wavelength window, partly by varying the QD energy levels and partly by adjusting the width and composition of the QW.

The performance of the DWELL QDIPs has been evaluated regarding responsivity and dark current for temperatures between 20K and 120K. At temperatures below 100K the photocurrent spectrum is dominated by the LWIR peak, with a peak wavelength at 8.5μm and a FWHM (full-width-half-maximum) of 1μm. This peak corresponds to a transition from the QD ground state to a QW excited state. At an operating temperature of 65K, the peak responsivity is 30mA/W at an applied bias of 4V and the dark current is 1.21E-5A/cm2. At temperatures above 100K a mid wavelength infrared (MWIR, 3-5μm) peak is dominant, with a peak wavelength of 4.9μm and a FWHM of 1.6μm. The MWIR peak corresponds to a transition from the QD ground state to the GaAs barrier.

A comparison between DWELL QDIPs and state-of-the-art quantum well infrared photodetectors (QWIPs) will be presented. Methods how to increase the responsivity of the QDIP through optical coupling and how

to decrease the dark current through design of the DWELL structure will be discussed.

6401-10, Session 3

Formation and properties of isoporous membranes composed of polymer semiconductors

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Conjugated polymers are an important class of materials because of their unique optical and electrical properties. The facile formation and photophysical characterization of functional, highly ordered isoporous films achieved by blending poly(9,9'-dihexylfluorene) (PDHF) with polystyrene grafted silica nanoparticles (Si-graft-PS) will be presented. It was found that the periodicity of the porous films was improved in the presence of Si-graft-PS, compared to the neat conjugated polymer. Photoluminescence spectra recorded on thin films of PDHF were investigated. Interestingly, the emission maxima of the isoporous films are red-shifted (up to 30 nm), with respect to films prepared by spin casting (420 nm) or drop casting (429 nm). This red-shift in emission is attributed to intermolecular interactions induced by PDHF-water interactions. These porous conjugated polymer films may find use in microelectronic and bio- and/or chemical sensor applications.

6401-11, Session 3

Photophysics of fullerene-containing nanostructures

N. V. Kamanina, S.I. Vavilov State Optical Institute (Russia)

No abstract available

6401-12, Session 4

Tuning of the optical limiting in the visible range by multiphoton absorption

J. Nicoud, L. Gehringer, P. Masson, Univ. Louis Pasteur (France); P. L. Baldeck, Y. Morel, Univ. Joseph Fourier (France)

Two-photon absorption (TPA) chromophores have received high interest over the past decade, owing to numerous potential applications in photonics. It has been observed by various groups that symmetrical one-dimensional (1D) conjugated molecular systems bearing two donor groups at each end in conjugation can display high non-linear absorption behaviour characterized by large two-photon absorption coefficients sigma2. When two conjugated systems bearing donor group(s) are linked at a central rigid core giving rise to the general structure D-π system-central rigid core-π system -D [D = donor group(s)], new types of chromophores are built that show also intense TPA.

We report here the syntheses and photonic characterizations of two series of chromophores built from biphenyl and fluorenyl aromatic central cores that are surrounded by two styrenyl moieties, giving rise to bis-stilbenyl chromophores. The donor alkoxy groups placed at each extremity have been chosen in order to keep a nearly complete transparency in the visible range. We have chosen alkoxy donors groups bearing long alkyl chains in order to get highly soluble chromophores in organic solvents. We have studied the influence of the number and the position of these alkoxy donor groups on the multiphoton absorption properties. By measuring the non-linear transmission of concentrated solutions a strong three-photon absorption has been evidenced in nearly all the visible range and in the nanosecond regime. The three-photon absorption coefficients alpha3 have all been determined. This property shows that the more performing chromophores can be used for optical limiting of nanosecond pulses in the visible range. The position and the number of the donor alkoxy chains give surprising results; we concluded that a tuning of the optical limiting properties is possible with this kind of multiphoton absorption chromophores.

6401-13, Session 4

Hybrid materials for optical limiting applications

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Optical limiting materials are developed for applications in protection of electro-optical sensors against laser aggressions. The molecular engineering for such devices is essentially based on the presence of extended π-conjugated systems along the molecule and the presence of electro-active groups. Insertion of a metal providing spin-orbit coupling is also an interesting parameter in order to improve the optical limiting properties. We have studied functionalised macrocycles (thiacalixarenes, thiacalixthianthrenes) and alkynylplatinum(II) derivatives for optical limiting applications. Thiacalixarenes can be selectively functionalised either on the upper or the lower rims, they can display extended π-systems depending on the type of substituting groups, and can provide spin-orbit coupling. Thianthrene derivatives have shown interesting and unique electronic and optical properties. Moreover, the presence of electron donating sulphur bridges in these macrocycle derivatives can play an important role regarding nonlinear optical properties. The macrocycles have also shown high stability upon heating, with decomposition temperatures in the range 210 - 420°C. Materials based on alkynyl platinum derivatives and macrocycles were prepared through the sol-gel process. The molecular species were grafted to the matrix in order to maximise the concentration and the stability of the final solid-state material. Broadband optical limiting performances in the visible wavelength region, for nanosecond laser pulses, were for example observed in the prepared materials.

6401-14, Session 4

Styrylpyridine derivatives as lego building blocks for electroluminescence and two-photon processes

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In the first part, we will describe a general approach for the synthesis of 6,6'-(disubstituted)-3,3'-bipyridine based chromophores. All these compounds exhibit a high electron affinity and are strongly fluorescent. As an application, blue-and green-emitting LEDs were fabricated.

In the second part, we will report on the design, synthesis, and structural as well nonlinear optical characterizations of a new class of disclike molecules based on tristyrylpyridine cores. Measurements of TPA using the two-photon fluorescence method in the fs regime indicate that these chromophores exhibit two-photon absorption. The results indicate that (i) a change of the substitution either of the electron-acceptor core or of the peripheral electron-donating groups, and (ii) of the number of branches influence significantly the TPA cross sections.

6401-15, Session 4

Molecular engineering for two-photon absorption

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Applications related to the two-photon absorption (TPA) process are now well-known and concerns different fields : 3D-fluorescence imaging, 3D optical data storage, 3D lithographic microfabrication, photodynamic cancer therapy, and optical limiting. Different approaches for the design of efficient TPA chromophores will be considered.

Oligomers of fluorene are of great interest for the design of molecules with enhanced TPA cross-sections in the visible. Their high TPA efficiency may be interpreted in terms of coherent coupling of transition dipole moments in oligomers. 2D and 3D dendrimeric polyfluorene derivatives will be also presented and their TPA properties will be interpreted using theoretical calculations.

TPA properties of long-lived luminescent rare-earth complexes will be also presented ; these properties arise from an efficient light harvesting process between the organic ligand and the metal;

Chromophores, with a high photochemical stability and interesting solubility and spectroscopic properties, have been designed for biological imaging.

6401-16, Session 4

Nonlinear optical properties of selected rotaxanes

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Nonlinear optical properties of rotaxanes were studied by the time resolved degenerate four wave mixing experiments. Experiments were done using different polarization configurations in order to check rotational contributions to cubic susceptibility arising from rotational movements of these molecules composed from mobile parts. The obtained results will be reviewed and discussed.

6401-17, Session 4

Triazole-containing platinum acetylides for optical power limiting in sensor protection

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The development of tunable lasers has increased and intensified the demand for sensor protection devices. Platinum(II) acetylides have proven to be efficient in optical power limiting (OPL) applications due to their nonlinear optical properties. Extended conjugation and incorporation of metals are common features that can enhance the OPL properties. However, there are also a number of other tools that may be employed to improve the limiting abilities of nonlinear optical chromophores, e.g. creation of a protective dendritic shell around the chromophore, increased branching, or introduction of triazoles in the chromophore structure.

Dendrimers have the ability to shield their inner parts from the surrounding leading to site isolation of the core. Dendrimers also give rise to an increased number of end-groups that can be easily modified for further reactions in order to prepare nano-hybrid materials or solid-state devices. Thus, the versatility of using dendritic substituents on chromophores will be demonstrated.

Triazoles can be easily prepared using 'Click'-chemistry and are so far rather unknown in OPL applications. Photo physical properties as well as theoretical calculations on triazole containing platinum(II) acetylides will be presented, focusing on the effects from the triazole units on the nonlinear optical properties.

Conference 6402: Optics and Photonics for Counter-Terrorism and Crime-Fighting

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6402-01, Session 1

Cognitive manoeuvre: getting inside the mindset of the terrorist and isurgents

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Understanding the intent of an adversary (such as terrorists), and influencing their actions, has long been recognised as a key aspect of planning military and civil policing operations. The military theatres in which we are operating challenge traditional kinetic-based approaches to delivering effects on the battlefield, especially when we are addressing counter-insurgency missions and the need to win the hearts and minds of the population.

In places such as Kosovo, Iraq and the deployment of NATO forces in Afghanistan our commanders are operating against a complex backdrop of ethnic, tribal, family, militia, criminal and religious tensions. To create the desired effects in these situations requires care on their part to get inside the mindset of individuals or groups (be they terrorists, political, militia, religious or criminal) and to try and understand their intent, objectives and crucially their timetable, however extreme.

This article introduces a five dimensional model, based upon research in the field of cognitive psychology that provides a start-point for representing what are often complex socio-cultural, economic and ideological interactions between potential and current adversaries that may contribute to the process outlined for the Comprehensive Approach. The five dimensions of the model are:

- The ideological background, values and beliefs that drive the individual being studied
- The influences brought to bear on the individual their closest advisors and family
- The personal goals of the individual - what are they trying to achieve and in what timeframe?
- The view of the world held by the individual - often described as the lens through which they see the world
- The personality profile of the individual, what are their character traits?

Populating the model requires a range of information that is fused across traditional and non-traditional defence and intelligence boundaries. One of these is access to open source intelligence information on the individual under study, looking at - for example - their public statements. Alongside this there is an important need for access to high quality human intelligence (HUMINT) and Signals Intelligence (SIGINT) that allows the development of the overall situation and how various actors are involved in making decisions.

Key to building this picture of the adversary's mindset is the collection and analysis of many forms of intelligence that profile his lifestyle and behaviour profile. Electro-optical sensor systems have a specific role to play in helping build up such a picture, using a variety of sources located on the ground, in the air and in space, to build up evidence of the adversary's behaviour profile. Analysis of this can be helpful in forecasting the extent and range of their future actions. This paper will examine the ways in which a model of the mindset of terrorists can be helpful in providing a framework for intelligence direction and collection, two vital parts of the intelligence cycle.

The model has been validated using a number of high profile subjects, such as former and current leaders of regimes and members of terrorist groups. In its current form it provides a visualisation of the cognitive dimension that will provide insights to civil and military commanders who need to adapt their campaign plans to achieve the desired effects as circumstances prevail in their theatres of operation.

6402-02, Session 1

International evaluation collaboration: developing and managing infrastructure for research and development programs

R. J. Bowers, J. Garofolo, National Institute of Standards and Technology (USA); D. E. Moellman, SRI International (USA)

Evaluation is a critical component of technology research and development - it provides the research sponsor with an important tool to gauge progress and understand the maturity of the technology. Evaluation also assists the researcher in understanding the strengths and weaknesses of his/her technology solution. Evaluation methodologies that support repeatable tests permit fast iterative research improvements.

From the perspective of the research sponsor, the authors believe these evaluations must be formal and rigorous. We identify four vital infrastructure components for effective evaluation: 1) clear unambiguous definitions of the evaluation tasks including permitted training resources, configuration settings, and contrastive test conditions; 2) test collections which are sufficiently broad and deep to address performance issues of interest; 3) ground truth annotations accurate enough to discern statistically significant differences in performance between evaluated systems and progress against particular goals; and 4) informative well-conceived metrics and software to implement them. Such an evaluation infrastructure can be of considerable cost to develop, apply and maintain. It must be carefully considered in the overall design of any research program. Therefore, it is essential to create infrastructures that can be shared across similar and complementary research programs. Such a collaborative approach increases critical mass both in the research and evaluation efforts, facilitates standardization of approaches, metrics and results; thus, it improves data sharing opportunities, which maximize comparability and reuse of all evaluation components.

This paper addresses program management practices the authors have evolved for developing and managing the technology evaluation process and the efforts to date to "socialize" this process among other organizations to develop an international community of interest collaboration.

6402-03, Session 2

Classification of human interaction from a distance using salient body behaviour modeling

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Understanding far and close proximity human-human interaction observed from a distance is a neccesary step towards automated suspicious or antisocial behaviour detection. Most previous work on human-human interaction has made the implicit assumption that interactions occur only at immediate spatial and temporal proximity between the subjects concerned. We propose a more realistic approach to human-human interaction classification in surveillance data where the subjects of interest tend to be represented by few pixels relative to the rest of the scene due to the distance between the camera and the physical scene, and interactions among subjects can occur between quite large distances both in space and possibly over time.

Our technique uses a spatial and temporal saliency measure to extract and select features using modifications to Kadir and Brady's scale saliency and Hung and Gong's temporal saliency algorithms respectively. From this, a hierarchical multi-scale model of a single person, his/her body pose and groups of people is formed. A person is represented by an elliptic blob where prominent blob-like parts are formed into a sub-ellipse configuration. Interactions are found by finding temporally correlated salient changes (we call events) in the probability distributions of features in the multi-scale configuration model.

In this paper we will show that pose or configuration based models of the human body can provide a very rich framework for modelling human-human interactive body behaviour from a distance when each part of the human body is only represented by a few pixels in image frames. The work is highly relevant to the development of automated systems for suspicious and antisocial behaviour detection and prevention.

6402-04, Session 2

Image fusion technology for security and surveillance applications

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Image fusion technology offers a range of potential benefits to the security

and surveillance community, including increased situational awareness and enhanced detection capabilities. With the addition of further processing and data fusion, functionality such as tracking and classification can also be added to a system, thereby increasing effectiveness and broadening applicability. This paper reports on how image fusion technology is being adapted from the military arena (in which it is generally found today) to provide a new and powerful asset in the fight against crime and terrorism. System issues, algorithms and practicalities are addressed before a number of case studies are presented which illustrate the use of image fusion in security and surveillance applications, including implementation of real-time hardware on a police helicopter.

6402-06, Session 2

Lip-reading enhancement for law enforcement

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Lip-reading is known to be a key emerging skill for law enforcement but there are very few skilled lip-readers and their accuracy has not been comprehensively tested so, currently, while the potential benefit is large, there a number of serious practical problems. We have investigated the possiblity of making this task more amenable to a wider range of operators by enhancing lip appearances using software techniques. Our approach fits active appearance models to the talkers and then modifies the eigenvalues to amplify the lip-motions. We have measured the word-error rates using a variety of test sequences and experienced, but non-expert, lip-readers. The results are mixed. We find that there appears to be the potential to improve the word error rate for non-experts but, for the method to improve the intelligibility there is need for more sophisticated tracking and visual modelling. Our technique also can act as an expression or visual gesture amplifier so has applications to animation and the presentation of information via avatars or synthetic humans.

6402-07, Session 2

Latest electro-optic and photonic devices for security and military applications

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Maturity of fiber optic, photonic, and electro-optic technologies has opened the doors for their applications in covert military communications, battlefield systems, night-vision sensors, perimeter security, space surveillance and host of other military systems. This paper summarizes performance capabilities of latest electro-optic components and photonic band gap devices, which have potential applications in security and defense systems. These devices are best suited for battlefield systems, space surveillance, covert communications, unmanned air vehicles (UAVs) and perimeter security. Performance parameters of fiber optic devices for both WDM and Dense-WDM (DWDM) communications systems are summarized with emphasis on dispersion-free instantaneous bandwidth, data rate, channel capacity and channel spacing. Critical performance parameters of Erbium-doped fiber amplifiers (EDFAs), praseodymium-doped fiber amplifiers (PDFAs), and optical hybrid amplifiers (OHAs) are discussed with emphasis on bandwidth, gain-flatness, and data handling capability. Note a PDFA offers wider bandwidth in the 1400-1550 nm spectral range and with drastic reduction in transmission losses. Requirements for fiber-optic ring lasers, optical switches, optical circulators, programmable delay lines and dispersion compensation devices are defined. Design parameters for fiber optic cables best suited for high power laser transmitters are summarized with emphasis on damage threshold capability, mechanical integrity and reliability under severe operating environments. Improved photonic and electro-optics devices are identified for deployment in IR missiles, heavy tanks, UAVs, and gun-ship helicopters. Performance capabilities of photonic and electro-optic devices and sensors such as CCD-based cameras, micro lasers, miniaturized IR imaging sensors, night-vision sensors, high speed IR-digital cameras, optical sights, laser range finders, image intensifiers, laser warning systems, photonic detectors and IR scanners are briefly summarized.

6402-08, Session 2

Countering laser pointer threats to road safety

S. A. Svensson, C. Lopes, S. Björkert, Swedish Defence Research Agency (Sweden)

At night a laser pointer is able to dazzle a driver more intensely than vehicles from the opposite direction with full headlights on. As a consequence of the availability of commercial laser pointers we can envision dazzled drivers resulting in hazardous traffic incidents. In fact several incidents of the kind have been reported. Most of them seem to be the result of pranks but in the hands of a criminal a laser pointer may pose a threat worth considering.

The exposure levels from laser pointers directed towards moving vehicles are not likely to cause any permanent loss of vision. The temporary effects however can be quite intimidating. Under most circumstances the driver will be likely to slow down or stop the vehicle until the dazzle is removed, but the risk of losing control of the vehicle cannot be ruled out. Two scenarios can be envisioned where these impacts would be attractive goals for a criminal:

1. Preventing police cars from pursuing criminal vehicles.
2. Stopping vehicles carrying valuable load.

The aiming accuracy of a good shooter is generally in the order of 1 mradian. To aim at a moving vehicle from another moving vehicle is a lot more demanding. The beam will be likely to flicker on the intended target at random intervals.

The paper will outline specifications which would be sufficient for a driver's protective device against dazzle from laser pointers. Several kinds of protective principles will be discussed like: fast shutters to eliminate flickering beams, sensor with large dynamic range, fixed line filters, adaptable line filters, and spatial light modulators.

Mechanical shutters/filter wheels, LCDs and other mainly active protection technologies will be described.

6402-09, Session 3

Optical network security: countermeasures in view of attacks

S. V. Kartalopoulos, Univ. of Oklahoma (USA)

The huge amount of traffic transportable by the next generation optical network is vulnerable to attacks, as is discerned from an alarmingly increase of incidents. The types of attack are expected to range from the typical eavesdropping and service denial to more sophisticated source mimicking. As a consequence, modern encrypted methods refuge to highly sophisticated methods that emanate from quantum mechanics, known as quantum cryptography. However, the sophistication and elegance of quantum-cryptography makes the assumption that the transmission medium and the components involved on the link are perfect and that the properties of photons and the signal intensity do not change during propagation over many kilometers. Therefore, a practical implementation of Q-C may exhibit its own vulnerabilities due non-linear interactions between photons and medium. Therefore, in addition to the sophistication of QKD and encryption algorithms, an additional function is needed that detects malicious intervention on the transmission link as well as a countermeasure strategy that outsmarts the attacker. In this paper, we consider a practical optical signal that consists of multiple photons, we consider a pragmatic medium with non-linearities, scattering and absorption centers. We describe a case of service denial with Q-C, a method by which an attack is detected, and we develop a countermeasure strategy outsmarting the attacker. Our method assumes that the data channel is encrypted using sophisticated algorithms.

6402-10, Session 3

Message extraction mechanism in optical chaos communications using injection-locked semiconductor lasers

A. Murakami, K. A. Shore, Prifysgol Cymru Bangor (United Kingdom)

In this paper, we employ a simple theory based on driven damped oscillators to clarify the physical basis for message extraction in optical chaos communications using injection-locked semiconductor lasers . The receiver laser is optically driven by injection from the transmitter laser. We have numerically investigated the response characteristics of the receiver when it is driven by periodic (message) and chaotic (carrier)

signals. It is thereby revealed that the response of the receiver laser in the two cases is quite different. For the periodic drive, the receiver exhibits a response depending on the signal frequency, while the chaotic drive provides a frequency-independent synchronous response to the receiver laser. Message extraction using chaos pass filtering (CPF) is also examined, and the validity of the theoretical explanation for the physical mechanism underlying CPF is thus verified.

6402-11, Session 4

Broadband terahertz spectroscopy for security applications

A. G. Davies, E. H. Linfield, A. D. Burnett, W. Fan, P. Upadhya, J. Cunningham, Univ. of Leeds (United Kingdom); T. Munshi, H. G. M. Edwards, J. Kendrick, Univ. of Bradford (United Kingdom)

We will review the use of terahertz frequency time-domain spectroscopy for the measurement of far-infrared vibrational modes of a range of illegal drugs and high explosives that are of interest to the forensic and security services, and outline what has been achieved by the international community to date. We will then discuss our own work in this field, using sub-20 femtosecond near-infrared laser pulses to generate terahertz radiation with bandwidths \> 8 THz. Absorption features have been measured as a function of temperature for a number of drugs-of-abuse and explosives, and the peak positions compared with simulations. These results confirm that absorption features are highly sensitive to the structure and spatial arrangement of the molecules. The use of high resolution low frequency Raman spectroscopy as a complementary analysis technique will be discussed, allowing better understanding of the low frequency inter- and intra-molecular vibrational modes of the molecules to be obtained.

6402-12, Session 4

Compact and coherent source of widely tunable THz radiation

T. J. Edwards, D. Walsh, D. J. M. Stothard, M. B. Spurr, Univ. of St. Andrews (United Kingdom); P. G. Browne, Macquarie Univ. (Australia); C. F. Rae, M. H. Dunn, Univ. of St. Andrews (United Kingdom)

The THz spectral region, lying between the microwave and the far infrared, is currently attracting widespread interest in relation to potential spectroscopic and imaging applications that span many areas of pure and applied science and technology, including: security, crime prevention and detection and medical. The development of practical sources of THz radiation, the lack of which has previously inhibited progress, is crucial to the realisation of these applications. We report the development of a novel source characterized by nanosecond pulsed THz output, with pulse energy of up to 20nJ at a repetition rate of 15Hz, and where the narrow bandwidth (<100GHz) radiation is continuously tunable over the spectral range 1.2-3.05THz (250-100μm) and is anticipated to have a spatial quality close to diffraction limited. . The source, based on the nonlinear process of parametric generation, has the novel feature of “intersecting cavities”, in which the nonlinear medium providing the parametric gain (magnesium oxide doped lithium niobate) is located both within the cavity of the pump laser (a miniature, Q-switched, diode-laser-pumped Nd:YAG laser) and simultaneously within the idler-wave cavity. In this way the high circulating field within the pump laser cavity is accessed, so reducing the power/energy requirement placed on this laser and hence leading to a compact, portable and affordable solution to practical THz sources. It is demonstrated that when operated at twice oscillation threshold the pump energy is efficiently down-converted to the nonlinearly generated signal/idler waves. Scaling to higher pulse energies and repetition rates (kHz) is considered together and acquired THz spectra presented.

6402-13, Session 4

Millimetre-wave and terahertz technology for the detection of concealed threats: a review

M. C. Kemp, Iconal Technology Ltd. (United Kingdom)

There has been intense interest in the use of millimetre wave and terahertz technology for the detection of concealed weapons, explosives and other threats. Electromagnetic waves at these frequencies are safe, penetrate barriers and have sufficiently short wavelengths to discriminate between objects. In addition, many solids including explosives have characteristic signatures at terahertz wavelengths which can be used to identify them. The paper will describe work by the author and other groups towards systems using both millimetre wave and terahertz. It will review the progress, challenges and future prospects for these technologies in checkpoint people screening, stand-off detection for IED’s and suicide bombers as well as more specialised screening tasks.

6402-14, Session 4

Through-the-wall high-resolution imaging of a human and experimental characterization of the transmission of wall materials

S. Nilsson, A. Jänis, Swedish Defence Research Agency (Sweden); M. Gustafsson, J. Kjellgren, A. Sume, Swedish Research Defence Agency (Sweden)

This paper describes the research efforts performed at the Swedish Defence Research Agency (FOI) concerning through-the-wall imaging as well as fundamental characterization of various wall materials. These activities are part of two FOI-projects concerning security sensors in the aspect of MOUT and Homeland Defence.

Through-the-wall high resolution imaging of a real human at 28-40 GHz has been performed at FOI. The UWB radar that was used is normally a member of the instrumentation of the FOI outdoor RCS test range Lilla Gåra. The armed test person was standing behind different kinds of walls. The radar images were generated by stepping the turntable in azimuth and elevation. The angular resolution in the near-field was improved by refocusing the parabolic antennas, which in combination with the large bandwidth (12 GHz) gave extremely high resolution radar images. A 3-D visualization of the person even exposed the handgun tucked into one hip pocket. A qualitative comparison between the experimental results and simulation results (physical optics-based method) will also be presented.

The second part of this paper describes results from activities at FOI concerning material characterization in the 2-110 GHz region. The transmission of building materials, packing materials and clothing materials has been experimentally determined. The wide-band measurements in free space is carried out with a scalar network analyzer. In this paper results from these characterizations will be presented. Furthermore, an experimental investigation will be reported of how the transmission properties for moisted materials change as a function of water content and frequency. We will also show experimental results of how the transmission properties of a pine panel is affected when the surface is coated with a thin surface layer of water.

6402-28, Session 4

Quantum Cascade Lasers (QCL) in homeland security applications

E. Normand, Cascade Technologies Ltd. (United Kingdom)

Following successfull use of Quantum Cascade Lasers (QCL) for trace gas detection in the continuous emission monitoring market, the core technology platform is now being developed towards homeland security applications.

This paper will highlight the potential of QCL based trace gas sensor for detecting vapours of explosives. Furthermore we will present results that let foresee the use of such technologies at addressing security gaps for protection against terrorism in infrastructures where high throughput screening of individuals or items is required. Preliminary measurements have shown that rapid identification, or fingerprinting, of explosive is achievable in 10ms at extrapolated sensitivities in the sub-part per billion range.

The experiments were carried out with support from the Home Office Scientific Development Branch (HOSDB) in the UK and were focused at selecting specific explosive compounds and identifying them using a novel sniffer platform system based on the use of quantum cascade lasers. Preliminary studies on the technology have indicated that direct fingerprinting (identification) of explosive compounds such as NG and tagging agents such as EGDN by sniffing surrounding ambient air is achievable. Furthermore these studies have also indicated that detection of such compounds on packaging used to ship the sealed compounds is possible, making this platform a strong contender for detection through cross contamination on material that have been in contact with each other. Additionally, it was also possible to identify breakdown products associated with sample material NG providing a further capability that could be exploited to enhance the detection and identification of explosive compounds.

Work will now be carried out at further validating these measurements with additional focus on detection limit, sampling methods and expending the explosive database.

6402-16, Session 5

Imaging techniques in digital forensic investigation: a study using neural networks

G. B. Williams, Univ. of East London (United Kingdom)

Imaging techniques have been applied to a number of applications, such as translation and classification problems in medicine and defence. This paper examines the application of imaging techniques in digital forensics investigation with particular emphasis on neural network. A review of applications of digital image processing is presented, whiles a Pedagogical analysis of computer forensics is also highlighted. A data set describing selected images in different forms are used in the simulation and experimentation.

The experimentation explores how traditional techniques such as infrared and ultra-violet imaging techniques compares to neural networks in the recovery of evidence on digital media as a counter measure to terrorism and cyber crime.

6402-17, Session 5

Raman and infrared techniques for fighting drug-related crime: a preliminary assessment

S. Valussi, M. Underhill, The Forensic Science Service (United Kingdom)

Forensic science is a vital component in the prevention, investigation and detection of crime and the administration of justice. The effective use of technological tools is fundamental to ensure more criminals are brought to justice in less time.

Drugs-related crime costs taxpayers millions of pounds every year and creates enormous fear in communities. A proof-of-concept hand-held Raman spectrometer and a commercial portable system based on Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-IR) have both been assessed for the rapid, “at scene” analysis of illicit drugs.

Data obtained are promising and demonstrate the potential advantages and limitations of the use of such systems in this field of operations.

6402-18, Session 5

Enhancing forensic science with spectroscopic imaging

S. G. Kazarian, C. Ricci, Imperial College London (United Kingdom)

This presentation will outline the research we are developing in the area of FTIR spectroscopic imaging with the focus on materials of forensic interest. FTIR spectroscopic imaging has recently emerged as a powerful tool for characterisation of heterogeneous materials. FTIR imaging relies on the ability of the military-developed infrared array detector to simultaneously measure spectra from thousands of different locations in a sample. Recently developed application of FTIR imaging using an ATR (Attenuated Total Reflection) mode has demonstrated the ability of this method to achieve spatial resolution beyond the diffraction limit of infrared light in air. Chemical visualisation with enhanced spatial resolution in micro-ATR mode broadens the range of materials studied with FTIR imaging with applications to pharmaceutical formulations or biological samples. Macro-ATR imaging has also been developed for chemical imaging analysis of large surface area samples and was applied to analyse the surface of human skin (e.g. finger), counterfeit tablets, textile materials (clothing), etc. This approach demonstrated the ability of this imaging method to detect trace materials attached to the surface of the skin. This may also prove as a valuable tool in detection of traces of explosives left on the surfaces of different materials. This FTIR imaging method is substantially superior to many of the other imaging methods due to inherent chemical specificity of infrared spectroscopy and fast acquisition times of this technique. Our data demonstrated that this methodology will provide the means to non-destructive detection method that could relate evidence to its source. This will be important in a wider crime prevention programme. In summary, intrinsic chemical specificity and enhanced visualising capability of FTIR spectroscopic imaging open a window of opportunities for counter-terrorism and crime-fighting, with applications ranging from analysis of trace evidence (e.g. in soil), tablets, drugs, fibres, tape explosives, biological samples to detection of gunshot residues and imaging of fingerprints.

6402-19, Session 5

New type counterfight laser marked label

P. D. Yankov, Sofia Univ. St. Kliment Ohridski (Bulgaria)

A widely used by the industry, laser marked label is used for vehicle identification against forgery. The label is constructed in a way that includes an organization scheme for identifying the crime chain, thus preventing situations and simplifying the investigation structure. The method may be used for labeling other documents and goods.

6402-20, Session 5

Distance detection using Raman scattering: a new tagging technology

W. E. Smith, A. McCabe, G. McNay, Univ. of Strathclyde (United Kingdom); N. C. Shand, B. E. Foulger, Defence Science and Technology Lab. (United Kingdom)

Surface enhanced resonance Raman scattering (SERRS) provides sensitivity to rival or surpass fluorescence. In addition, it produces a series of sharp peaks that act as a molecular fingerprint for the analyte. This advantage has enabled the construction of targets containing hidden codes which can be detected at a distance using a simple handheld Raman spectrometer. This technology has yet to be exploited but offers considerable potential for identification and detection of objects at distances between a metre and 20 metres. There is no need for spacial separation such as a bar code in order to read the tag, reading times currently are approximately one second at 1 metre. Current technology uses visible excitation at about the eye safe limit for lasers. . The coded tag materials have a lifetime of at least 6 months and in some circumstances it is predicted that the lifetime will be many years. In some formats, the tags will resist exposure to weather, sunlight etc.

6402-21, Session 6

Tackling field-portable Raman spectroscopy of real-World samples

N. C. Shand, Defence Science and Technology Lab. (United Kingdom)

A major challenge confronting first responders, customs authorities and other security-related organisations is the accurate, rapid, and safe identification of potentially hazardous chemicals outside a laboratory environment.

Currently, a range of hand portable Raman equipment is commercially available that is low cost and increasingly more sophisticated. Many systems are based on the 785 nm Stokes shifted Raman technique with many using dispersive grating spectrometers. This technique offers a broad range of capabilities including the ability to analyse illicit drugs, explosives and chemical weapons but still has some fundamental constraints. “Real world” samples such as those found at a crime scene often will not present themselves in the most accessible manner. Simple issues such as glass fluorescence can make an otherwise tractable sample impossible to analyse in-situ.

A new generation of portable Raman equipment is currently being developed to address these issues. Consideration is given to the use of longer wavelength for fluorescence reduction. Alternative optical designs are being tested to compensate for the signal reduction incurred by moving to longer wavelengths. Furthermore, the use of anti-Stokes spectroscopy is being considered as well as investigating the robustness and portability of traditional FT interferometer designs along with future advances in detector technology and ultra small spectrometers.

6402-22, Session 6

Identification of artificial fingerprints using optical coherence tomography technique

K. V. Larin, Y. Cheng, Univ. of Houston (USA)

Spoofing of biometric fingerprint devices is a common problem nowadays. Fingerprint gummies are frequently used to fake those machines. In this paper we present results of a pilot study on using Optical Coherence Tomography (OCT) technique to identify artificial material commonly used

for spoofing fingerprint devices. Gelatin, silicone, wax, and agar-based gummies were placed on a finger and analyzed using OCT technique. We were able to identify presence of the artificial materials at all times. The results of these studies suggest that OCT could be a powerful tool for accurate and sensitive identification of the fingerprint gummies made from different materials.

6402-23, Session 6

Multistream face recognition on dedicated mobile devices for crime fighting

S. A. Jassim, H. Sellahewa, Univ. of Buckingham (United Kingdom)

Automatic face recognition is a useful tool in the fight against crime and terrorism. Evolving technological developments in mobile communication devices used for multiple applications provides a new platform for active and passive surveillance. A dedicated mobile device that incorporates audio-visual sensors would not only complement existing networks of fixed surveillance devices (e.g. CCTV) but could also provide wide geographical coverage in almost any situation and anywhere. A small portion of a law enforcing agency biometric database can be downloaded temporarily onto such a device to consist of audio and/or visual data of a number of suspected/wanted or missing persons who are expected to be in a local geographical area. This will enable law-enforcing officers on the ground to instantly identify if a person is one of the people stored on the device. Biometric data on the device can be regularly updated which will reduce the number of faces an officer has to remember. The proposed dedicated device would act as an active/passive mobile surveillance unit which incorporate automatic identification. This paper is concerned with the feasibility of using wavelet-based face recognition schemes on such devices. The proposed schemes extend the recently developed for implementation on a currently available PDA. In particular we will investigate the use of a combination wavelet frequency channels for multi-stream face recognition. We shall present experimental results for a number of publicly available face databases including a new AV database of videos recorded on a PDA.

6402-24, Session 6

Full-field optical coherence tomography used for security and document identity

S. Chang, S. S. Sherif, C. Flueraru, National Research Council Canada (Canada)

The optical coherence tomography (OCT) is an emerging technology for high-resolution cross-sectional imaging of 3D structures. In the past years, OCT systems have been used mainly for medical, especially ophthalmological diagnostics. Concerning the nature of OCT system being capable to explore the internal features of an object, we apply the OCT technology to directly retrieve the 2D information pre-stored in a multiple-layer information carrier. The standard depth-resolution of an OCT system is at micrometer level. If a 20mm by 20mm sampling area with a 1024 x 1024 CCD array is used in the OCT system, an information carrier having a volume of 20mm x 20mm x 2mm could contain 100 Mega-pixel images. Because of its tiny size and large information volume, the information carrier, with its OCT retrieving system, will have potential applications in documents security and object identification. In addition, as the information carrier can be made by low-scattering transparent material, the signal/noise ratio will be improved dramatically. As a consequence, the specific hardware and complicated software can also be greatly simplified. Owing to non-scanning along X-Y axis, the full-field OCT could be the simplest and most economic imaging system for extracting information from such a multilayer information carrier. In this paper, deign and implementation of a full-field OCT system is described and the related algorithms are introduced. In our experiments, a four layers information carrier is used, which contains 4 layers of image pattern, two text images and two fingerprint images. The extracted tomography images of each layer are also provided.

6402-26, Poster Session

Optical visual cryptography based on the phase characteristics of spatial light modulator

S. Yi, Electronics and Telecommunications Research Institute (South Korea)

As a security controlling systems, thresholding scheme that allowed to access by agreement of members after spreading information to members are developing in order to protect important information. Visual cryptography, which is based on a thresholding scheme, using digital operation for the process of encryption, but decryption is implemented by visually without any operation. The application area of visual cryptography is restricted by the limit of expression caused by the using of binary input image and low resolution. Optical visual cryptography is an optical implementation of the visual cryptography. In optical visual cryptography, visual cryptography system which is special in “OR” operation can be applied BCGH to protect hologram information. This method can be achieved simply by replacing each cell of BCGH with pixel of visual cryptography then performs visual cryptography. Decryption and restored image by this method has high resolution compared with the decrypted image by established visual cryptography system. Nevertheless, it keeps the same contrast as visual cryptography. Regardless of many advantages, the optical visual cryptography can’t clearly recover encrypted text due to the white noise that is added during the encryption process. Mathematically, modular or “XOR” operation is used for general cryptography system. This is very effective to realized by using computer but very ineffective to realized by optical system.

In this paper, we suggest a new optical visual cryptography system using the phase characteristics of liquid crystal display (LCD) for solving these problems. As a spatial light modulator (SLM), LCD has the phase modulation ability that can perform the XOR operation for this. We can control the phase information of each LCD from the composition of several of them. Accordingly, the white noise can be removed and the decryption easily implemented with this optical system. As LCD can express all of their values (+1, 0, -1), if we combined an appropriate encryption algorithm with this, it’ll be very useful for the security system.

6402-27, Poster Session

FTIR spectroscopic imaging for the identification of concealed drugs residue particles and fingerprints

C. Ricci, S. G. Kazarian, A. K. L. Chan, Imperial College London (United Kingdom)

Conventional FTIR spectroscopy and microscopy has been widely used in forensic science. New opportunities exist to obtain rapid chemical images and to enhance the sensitivity of detection of trace materials using attenuated reflection infrared spectroscopy coupled with a focal-plane array (FPA) detector. In this work, the sensitivity of FTIR imaging using three different kinds of ATR crystals (Ge coupled with an infrared microscope, ZnSe and diamond) and resulting in three different optical arrangements for the detection of model drug particles is discussed. Model systems of ibuprofen and paracetamol particles having a size below 125, 90 and 32 micrometers have been prepared by sieving. The sensitivity level in the three different approaches has been compared and it has been found that both micro and macro-ATR imaging methods have proven to be a promising technique for the identification of concealed drug particles. To demonstrate the power and applicability of FTIR chemical imaging to forensic research, various examples are discussed. This includes investigation of the changes of chemical nature of latent fingerprint residue under controlled conditions of humidity and temperature through ATR-FTIR imaging. This study demonstrates the potential for visualizing the chemical changes of fingerprints by spectroscopic imaging.