TKK Radio Science and Engineering Publications

Espoo, March 2010

REPORT R13

NORDIC REMOTE SENSING DAYS 2009

Book of Abstracts

Editors: Jaan Praks, Mika Karjalainen, Jarkko Koskinen, Anne Leskinen, Kari Luojus, Eija Parmes, Yrjö Sucksdorff, Matias Takala, Markus Törmä

TEKNILLINEN KORKEAKOULU
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TECHNISCHE UNIVERSITÄT HELSINKI
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Nordic remote sensing co-operation

The Finnish Remote Sensing Club organized the annual remote sensing days in October, 2009, with a special theme of *Strengthening the Nordic Dimension*. Nearly 200 remote sensing specialists from all Nordic countries and Estonia gathered together at the Finnish Meteorological Institute, Kumpula, Helsinki.

In the plenary session, the keynote speakers from Sweden, Norway, Estonia and Finland resumed their latest earth observation activities and during nine thematic sessions latest advances in science and applications were presented. It became obvious that Nordic countries have strong traditions and knowledge in the area of remote sensing applications. Not to mention that Norway and Sweden have an advantage of having a space centre and satellite receiving stations.

Related to the theme of the days, thematic workshops were organized at the end of the first day. The current topics were *The Baltic Sea and water quality, Climate change, Boreal land cover and vegetation* and *Nordic co-operation in international programmes*. The results of the discussions were presented on the next day. Every workshop team emphasized the significance of Nordic cooperation and hoped for shared preparations of proposals for the European Union (EU) and European Space Agency (ESA) meetings. A longer summary of the workshops results are given in the chapter Workshop recommendations.

The atmosphere of the days was enthusiastic and it was decided that this kind of meeting of Nordic remote sensing community will be organized every second year by one of the Nordic countries. In the year 2011 the host will be Sweden. Meanwhile, the ESA Living Planet Symposium will be held in Bergen Norway from 28 June to 2 July 2010 http://www.esa.int/LivingPlanet2010/. All remote sensing specialists are most welcome to attend.

For additional information of the Finnish Remote Sensing Club and remote sensing days, please, check http://www.kaukokartoituskerho.fi/2009

Eija Parmes, Chairman of Finnish Remote Sensing Club (2010)
Anne Leskinen
Jarkko Koskinen, Chairman of Finnish Remote Sensing Club (2009)

Helsinki, November 1, 2009

Workshop recommendations

The Nordic Remote Sensing Days' participants were divided into four workshop groups in order to concretize the need of cooperation. The topics for the workshops were:*Baltic Sea and water quality, Climate change, Boreal land cover and vegetation* and *Nordic co-operation in international programmes*.

The goal of the workshops was to identify the current status of the Nordic remote sensing cooperation and to provide new ideas on how to promote it further. In order to facilitate and frame the discussion, each workshop was given seed questions concerning co-operation in existing programmes, operational networks and ESA/EU projects.

Each workshop team presented their comments, concerns and innovative ideas on the subjects in the workshop summary session. Brief summary of the workshop outcome is presented below.

The *Baltic Sea and water quality* workshop listed quite a few existing programmes, where collaboration is possible: NordForsk / NordAquaRS network, Marie Curie/EU, InterReg Central Baltic/EU, and Weather radar co-operation NORDRAD/Norway, Sweden, Finland, Estonia; extending to Latvia, Belarus and Poland. More ideas for cooperation in hydrology was calibration and validation activities for satellite instrument characterization and algorithm performance analysis, interdisciplinary seminars thematically related to earth observation covering several topics, visits to laboratories etc. facilities to complete studies, and to exchange views and data (technical aspects).

Cooperation in *Climate change*, especially concerning Nordic areas was appreciated by all participants. This could be realized by common participation to ESA and EU FP-7 programmes. Suggested co-operation could be established through the development of Nordic satellite CAL-VAL site infrastructure for climate change research of arctic and boreal areas, researcher exchange, and free time series datasets for wider use and to find ways to promote the use of remote sensing data for climate models.

The *Boreal land cover and vegetation* workshop noted that co-operation between Finnish and Estonian researchers is active but interaction between Finnish and other Nordic teams should be improved. More common projects is recommended. Common data portals like Swedish SACCESS promote open data policy and research co-operation.

Discussion for *Nordic cooperation in international programmes* will continue by organizing Nordic earth observation-days at bi-annual basis, next time 2011 in Sweden. Additionally, Nordic EO Delegates will meet once a year in order to discuss cooperation programatics, aiming to formulate common strategy for cooperation and information distribution. Promotion of an open and free data policy in GMES and data availability from Nordic areas, and cooperation in common (Nordic) priority areas, was suggested. Co-operation between research teams, cooperative funding from national programmes and special interest cryosphere and marine applications were suggested.

In conclusion, the results of the four workshops were similar. The continuation of the Nordic Earth Observation Days was recommended, meetings and negotiations of common opinions with Nordic EO delegates concerning EU/ESA programmes and joint proposals were considered important for future promotion. Open and free data policy, data availability and common applications in Nordic areas were suggested to promote the co-operation. Researcher and student exchange was regarded important as well as a common internet portal or web ring for Nordic remote sensing communities.

Program committee

Jarkko Koskinen, Chairman, Finnish Meteorological Institute (FMI)
Mika Karjalainen, Finnish Geodetic Institute (FGI)
Anne Leskinen, Pöyry Ltd
Kari Luojus, Finnish Meteorological Institute (FMI)
Eija Parmes, Technical Research Center of Finland (VTT)
Jaan Praks, Helsinki University of Technology (TKK)
Yrjö Sucksdorff, Finnish Environment Institute (SYKE)
Matias Takala, Finnish Meteorological Institute (FMI)
Markus Törmä, Finnish Environment Institute (SYKE)

Nordic Remote Sensing Days

22–23 October 2009

Finnish Meteorological Institute, Dynamicum

Helsinki, Finland

Sponsored by

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Nordic Remote Sensing Days

22–23 October 2009

Finnish Meteorological Institute, Dynamicum
Helsinki, Finland

Program

Thursday, 22 October 2009

08:30	Registration	
09:00	Opening and plenary session	
11:05	Poster session part I and refreshments	
11:20	Land applications	/ Water quality
13:20	Lunch	
14:20	Snow and ice	/ Instruments
15:40	Poster session part II and refreshments	
16:00	Snow and ice	/ UAV
17:00	Thematic workshops	
18:30	Social event	

Friday, 23 October 2009

09:00	Atmosphere	/ Commercial applications
10:20	Refreshments	
10:40	Atmosphere	/ Forest
12:40	Lunch	
13:40	Wrapping up the workshops	
15:00	End of seminar	

Poster session
Thursday, 22 October 2009

Land applications *Chair: P. Härmä*
Thursday, 22 October 2009, 11:20–13:15

Water quality *Chair: S. Koponen*
Thursday, 22 October 2009, 11:20–13:15

Snow and ice *Chair: J. Pulliainen*
Thursday, 22 October 2009, 14:20–16:55

Instruments *Chair: J. Heilimo*
Thursday, 22 October 2009, 14:20–15:35

UAV *Chair: H. Saari*
Thursday, 22 October 2009, 16:00–16:55

Atmosphere *Chair: J. Tamminen*
Friday, 23 October 2009, 9:00 – 12:20

Commercial applications *Chair: E. Parmes*
Friday, 23 October 2009, 9:00 – 10:20

Forest *Chair: T. Häme*
Friday, 23 October 2009, 10:40 – 20:45

Plenary session

Extending and strengthening of national remote sensing activities in the Nordic region via international networks

Anu Reinart [1] and Susanne Kratzer[2]

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Over the recent years, there have been many new developments in the Estonian space research & technology community. Based on the earlier achievements in Earth Observation, in collaboration with public authorities, a new generation of scientists has started several activities to link national interest in this field to the international space community. Complementary for long-lasting personal research contacts, two large capacity building projects have been funded by the European Community. At national scale, basic principles of the Estonian Space policy are formulated and Estonia is in the process to become a member of the European Space Agency in the near further. International collaboration has been one of the most important and effective factor to fuel new research ideas and business perspectives in the field which include remote sensing. In this talk we present an overview of two big international remote sensing networks in the Nordic region - the Estonian EstSpace program, as well as the Nordic Network for Aquatic Remote Sensing (NordAquaRemS).

The FP7 Regpot project "Expose the Capacity of Estonian Space Research and Technology through High Quality Partnership in Europe" (EstSpacE, 2008 March -2011 Feb, led by Dr. A. Reinart) is centered around Tartu Observatory. The main objective of the project is to create the necessary conditions for utilizing the existing and emerging research potential of Estonian scientific institutes in the field of space research and increase the level of international cooperation, furthermore to support closer cooperation with the European Space Agency and facilitating the participation of Estonian scientists in the activities of the FP7. More information is available in website www.estspace.ee.

The Nordic Network for Aquatic Remote Sensing (NordAquaRemS) /NordAquaRemS has recently been funded by NordForsk (October 2008 to October 2011, les by Associate Prof. S. Kratzer, Stockholm University). The network consists of ca. 50 researchers and PhD students from the Nordic and Baltic Sea region. The main focus is to improve Nordic collaboration as well as PhD training in aquatic remote sensing. Because of the geographical location, Nordic countries have a great challenge in the application of aquatic remote sensing; the use of standard processing of satellite data and global algorithms is inadequate (global products from NASA and ESA). Development of region-specific processing and algorithms is required (both for water and atmosphere). The planned events are listed on http://nordaquarems.org/events

Poster session

Marine Target Detection in Single and Dual Channel SAR Images

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Synthetic Aperture Radar (SAR) data for target detection are used today in operational maritime surveillance services in several countries and the European Union. However, further research is still needed to be able to fully exploit the information available from current and future SAR missions. The launch of new advanced SAR sensors (e.g. like RADARSAT-2) enables us to use single, dual and full polarimetry in automatic algorithms for target detection. Detecting targets (e.g. ship and icebergs) within SAR images can be made more reliable if several polarizations are combined with appropriate radar incidence angles during acquisition.

The capabilities of the SAR instrument in application to marine target detection and classification has been extensively documented, and operational services has to a certain extent been implemented, most often in a semi-supervised mode requiring a trained operator to quality assure and modify the output of an automatic detection algorithm. In this study we aim to improve the robustness of existing automatic algorithms, which will yield a better starting point for implementation of operational services. We focus on marine target detection in the High North, where we are not only interested in vessel detection, but also in detection of icebergs and discrimination of vessels and icebergs. As both shipping routes and exploration and production of oil and gas are moving towards higher latitudes, this aspect of marine target detection will be very important to support both environmental and economical interests as well as health and security.

It is a problem in operational systems that the specified false alarm ratio is not met in practice because the data do not fit the assumed model under varying conditions. Our goal is to obtain improved statistical data models for single, dual and full polarimetric SAR data over sea that will contribute to robust target detection under various acquisition parameters (incidence angle and polarization) and sea states. We will here present results based on single and dual polarized SAR products.

Remote sensing of vegetation based on canopy spectral invariants

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The concept of *canopy spectral invariants* states that simple algebraic combinations of leaf and canopy spectral transmittance and reflectance become wavelength independent and determine a small set of canopy structure specific variables. This set of structural variables specify the spectral response of a vegetation canopy to the incident solar radiation and allow for a simple and accurate parameterization of the partitioning of the incoming radiation into canopy transmission, reflection and absorption at any wavelength in the solar spectrum [1].

The theoretical basis and applicability of the *recollision probability* for use in physically based optical remote sensing of vegetation was investigated in the SPRINTER project. The recollision probability (p) is one of the canopy spectral invariants, and can be defined as the probability that a photon after being scattered from a leaf (needle) in the canopy will interact within the canopy again. The beauty of this parameter lies in that, knowing p, the canopy scattering coefficient (*albedo*) at any wavelength can be expressed as a simple function of the leaf (needle) albedo at the same wavelength. Parameter p depends on the structure of the canopy at a variety of scales and a main goal of the project was to derive specific relationships between p and basic structural characteristics of forests, including the leaf area index (LAI) [2]. Furthermore, as p only allows prediction of total canopy scattering, methods to divide the scattered radiation into reflected and transmitted fluxes were developed [3].

Results from the SPRINTER project provide an effective tool for incorporating the effect of canopy structure at different hierarchical levels in forest reflectance models and, conversely, for extracting canopy structural characteristics from the remotely sensed multispectral signal when leaf albedo is known.

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Airborne small-footprint discrete-return LiDAR data in the assessment of boreal mire surface patterns, vegetation, and habitats

Korpela Ilkka, Koskinen Markku, Vasander Harri, Holopainen Markus, Minkkinen Kari

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Boreal mires cover high diversity in species and habitats, many of which are endangered. A need for accurate and cost-efficient vegetation mapping and monitoring of habitats exists in mire conservation, restoration and peatland forestry. LiDAR is excellent new tool for probing the geometry of vegetation and terrain. Modern systems measure the backscattered signal accurately and provide radiometric information. Experiments were carried out in a complex minerotrophic−ombrotrophic eccentric raised bog in southern Finland (61°47'N, 24.18'E). First, we tested LiDAR for the modeling of mire surface patterns and the detection of hummocks and hollows. Secondly, the response of different mire vegetation samples in LiDAR intensity was examined. Thirdly, we tested area-based geometric and radiometric features in supervised classification (RF, *c*-SVM, k-NN) of mire habitats to discover the meaningful LiDAR variables. The vertical accuracy of LiDAR in mire surface modeling was high: 0.05−0.10 m. A binary hummock-hollow model that was estimated from a LiDAR-based elevation model matched flawlessly in aerial images and had moderate explanatory power in habitat classification trials. The intensity of LiDAR in open-mire vegetation was mainly influenced by the surface moisture, and separation of vegetation classes spanning from ombrotrophic to mesotrophic vegetation proved to be difficult. Area-based features that characterize the height distribution of LiDAR points in the canopy were the strongest explanatory variables in the classification of 21 diverse mire site types. Actual qualifying differences in the ground flora were unattainable in the LiDAR data, which resulted in inferior accuracy in the characterization of ecohydrological conditions and nutrient level of open mires and sparsely forested wet sites. Mire habitat classification accuracy with LiDAR surpassed earlier results with optical data. The results suggested that LiDAR constitutes an efficient aid for monitoring applications. We propose the co-use of images and LiDAR for enhanced mapping of open mires and tree species. *In situ* calibration and validation procedures are required until invariant geometric and radiometric features are discovered.

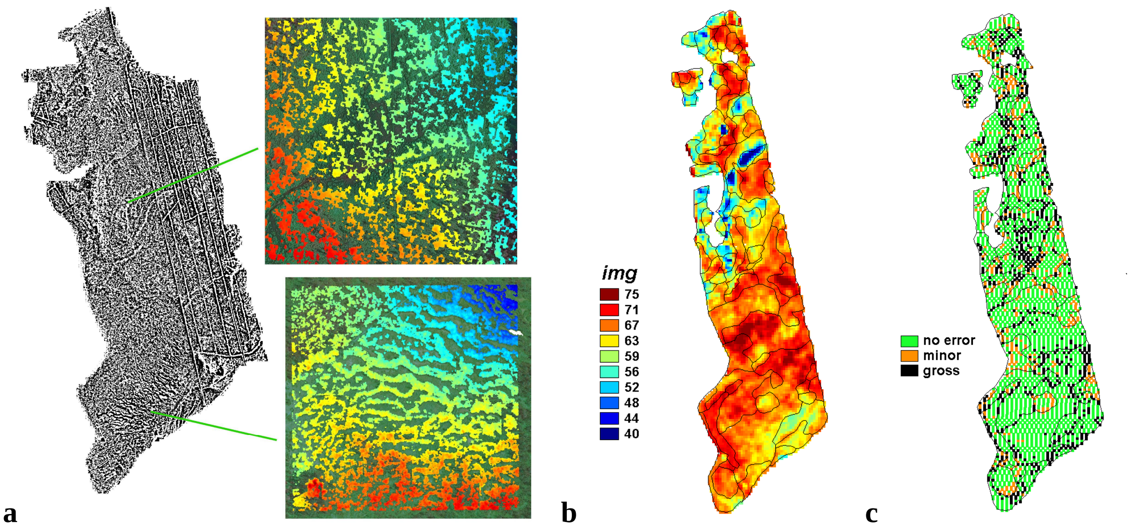

Fig. 1. (a) Binary hummock-hollow model of the 118-ha mire. (b) Intensity map for near-ground returns in 69-ha pristine mire. (c) Traffic-light-results of site type classification in a 10-m grid.

Estimating Snow Cover Properties over Northern Hemisphere in a Period of 30 Years

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Snow is an important physical parameter in hydrology and climate research. The thickness of snowpack is related to the water discharge when the snow melts and related to the Earth's water cycle. Snow Water Equivalent (SWE) describes how much water will be released when snowpack melts. The knowledge of SWE together with exact snow clearance date is an important input for hydrological and climate models. For example, once the growing season begins after snow melt the amount of CO_2 changes in the atmosphere. Spaceborne microwave radiometers are well suited for monitoring SWE and snow melt in global scale since the globe can be mapped in continental scale twice a day and bad weather and night time do not interfere with the measurement.

The SWE algorithm [1] is based on assimilating ground-based observations of snow depth together with spaceborne microwave data. A time series from 1995-1997 and 2006-2008 have been produced covering Eurasia and North America and the results have been valified with ground truth data from Canada and Russia. The result show improvement in accuracy compared to present operative SWE products.

The snow clearance date algorithm [2] is based on time series analysis of brightness temperature channel differences. The algorithm has been validated using russian INTAS-SCCONE snow depth measurements. A time series of 30 years exists and the results have been compared to other sources of snow clearance dates showing good consistency. A comparison of the results with climate model ECHAM5 is ongoing.

This work aims at producing a combined, global snow product and a time series of 30 years estimating SWE, snow clearance date and snow status. Snow status means differentiation between wet and dry snow, for example. Land use issues need to be further investigated. Especially mountains pose a challenge when working with radiometer data. There can be some other local effects as well. According to the validation results these two algorithms are well suited for global monitoring of snow.

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Merging Flat/Forest and Mountainous Snow Products for Extended European Area

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In the frame of EUMETSAT Hydrology and Water Management Satellite Application Facilities (H-SAF) project, two different approaches have been developed for snow products. One is focused on flat/forested areas and has been developed by Finnish Meteorological Institute (FMI) (originally for EUMETSAT Land-SAF), and the other one by Turkish State Meteorological Service (TSMS) for mountainous areas. Snow cover over mountainous areas and over flat/forest areas show completely different physical properties, thus usage of two separate algorithms makes it possible to get better results. On the other hand, the Project Plan of H-SAF states that the users should be offered a unified snow products covering the H-SAF domain.

In this study we introduce a method for merging the two snow recognition products, and also discuss the first results from validation. The products have different projections and nearest neighbor approach was selected for data co-location. The main idea of the merging algorithm is to minimize projection errors and try to reflect the strengths of the two algorithms in the final merged product. A mask based on digital elevation model (DEM) was used to separate the mountainous pixels from flat/forested areas. The merging algorithm finds the exact location of the non-mountainous pixels using this mask. These values are then replaced with the values from the product for flat and forested areas.

The method was first tested for the daily products of November 2008. The merged products were visually compared against METEOSAT RGB images. The merged products were found noticeably better than the stand-alone products according to visual comparison. While comparing the products separately to the RGB composites, it came apparent that flat/forest product underestimates the snow on mountainous regions, and the product for mountainous regions misclassified pixels on non-mountainous areas. With the merging, most of these errors are removed.

Computational 3-D geometry of airborne laser scanning data in modeling tree crown architecture

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Tree crown parameters obtainable from aerial inventories are of great interest in the field of several different applications; for example, knowledge on species-specific allocation of foliage biomass among tree trunk could be utilized in estimating stem dimensions through allometric relationships. It is known that airborne laser scanner (ALS) systems provide detailed 3-D data on forest canopy but certain methodology is required for extracting the information from the point cloud.

Computational geometry is a branch of computer science that deals with the study of algorithms and data structures for solving problems stated in terms of basic geometrical objects, such as points, line segments and polygons. As major attention is paid to the computational efficiency of the algorithms, the use of these could be advantageous for dealing with high-density ALS point data.

Our recent research has focused on applying computational geometry of tree-level ALS point data for quantifying parameters of crown shape and structure. The obtained results show that computational volume and complexity characteristics are useful in predicting tree species [1] and estimating stem diameter [2]. Also, the appraisal of other tree crown characteristics, such as crown base height [3], seems feasible. The purpose of this presentation is to demonstrate our approach of applying these algorithms and data structures. The presentation is based on both recently completed [1,2,3] and ongoing research.

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Sodankylä-Pallas Testbed

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The Sodankylä-Pallas Testbed is located in the boreal forest/taiga zone of Northern Finland. The purpose of the Testbed is to serve as a calibration and validation site for satellite remote sensing observations and provide long-term continuous measurement data sets for the development and verification of data inversion algorithms. The Sodankylä-Pallas site is a typical representative of Eurasian taiga belt characterized by a mosaic of sparse conifer-dominated forests and open/forested bogs. The landscape is relatively flat or gently rolling although small mountain regions (fjells) are typical.

The available data sets range from point-wise monitoring observations to regionally distributed information. These include automatic weather station observations, atmospheric sounding observations, carbon flux monitoring and ozone column measurements. Specifically, snow cover measurement at the site include both automated measurements of snow depth and temperature at several sites, as well as manual snow observations of snow stratigraphy.

Recently, the Sodankylä-Pallas site has hosted several permanent and semi-permanent reference instruments for satellite observations. These include permanent multispectral observations of ground radiance, and several experimental campaigns using microwave instruments. As of 2009/2010, the site will have permanent multi-frequency (L- to W band) radiometer observation capability and act as part of e. g. ESA SMOS Validation and Calibration activities. The site will also host a series of experimental active (scatterometer) measurements related to development of active retrieval algorithms of snow cover for the ESA CoReH2O mission.

The available and future data sets are relevant for space-borne remote sensing instruments with a high or coarse spatial resolution, as well as for atmosphere or surface monitoring instruments. The available reference data also enables the analyses of mixed pixel effects that are highly relevant for the utilization of satellite observations with a coarse spatial resolution.

The Sodankylä-Pallas site is coordinated by the Arctic Research of the Finnish Meteorological Institute (FMI-ARC). Permanent activities of the site are also related e.g. to the Global Atmosphere Watch (GAW) network of WMO, and to the Long Term Ecological Research (LTER) activities coordinated in Finland by the Finnish Environment Institute (SYKE).

Phytoplankton biomass *versus* chlorophyll *a*: do they show the same water quality?

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The national water quality monitoring in the Lithuanian Baltic Sea waters has started fifty years ago. Recently, four seasonal surveys are performed annually in the four water bodies classified according to water quality bioindicators phytoplankton composition, biomass and chlorophyll *a*, concentration of nutrients, salinity range, types of bottom sediments and wave exposure: 1) sandy and 2) stony coastal waters: above 20 m depth; 3) plume of the Curonian Lagoon in the coastal waters: an nutrient enriched area with the annual average salinity below 5 psu;. 4) open Baltic Sea: below 20 m depth [1]. However, relationship between phytoplankton biomass and concentration of chlorophyll *a* has been poorly studied in the local scale of the Baltic Sea. In case of Lithuanian national coastal monitoring some differences were found in the results of assessment of ecological status using both indicators. Therefore it is important to evaluate the correlation between phytoplankton biomass and concentration of chlorophyll *a*, and to determine the factors that could influence the patterns of relationships among them.

The analysis was based on the data of the national Lithuanian monitoring in the Baltic Sea during 2001-2007. Detailed analysis of interactions between chlorophyll *a* and phytoplankton biomass were performed according to sampling site (transitional and coastal waters), time (seasonal and diurnal) and different algae groups (cyanobacteria, diatoms and dinoflagellates). Additionally three methods of investigation of microalgae productivity were compared: standard spectrophotometry [2] and fluorometry for chlorophyll *a*, and determination of phytoplankton biomass by the Utermöhl [3] inverted microscope method. Satellite-derived optical information maybe also applicable in the future for the classification of pelagic ecosystems and typology of water masses since it is expensive and time consuming using classical water sampling by ships. Analysis of calibration between composition of phytoplankton populations and simultaneously satellite-derived pictures should take the first steps. The relationship between composition of phytoplankton and proxy such as concentration of chlorophyll should be also tested in order to automate the monitoring of the water quality which is very variable in time.

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Seasonal Reflectance Courses of Hemiboreal Birch Forests

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[Poster presentation]

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Satellite remote sensing offers an efficient method for observing vegetation dynamics – MODIS, AVHRR and SPOT VEGETATION data sets have been used to monitor continental and global on-set dates of greening and forest phenology. However, seasonal forest reflectance variation has only preliminarily been linked to stand structure or changes in leaf spectra and biochemistry. The seasonal reflectance course of a boreal forest is a sum of the temporal reflectance cycles of both tree canopy and understory layers. In other words, changes in forest reflectance are explained by the seasonal evolution of biochemical composition and geometrical structure of plants, and monthly and diurnal trends in solar illumination.

Our poster presents a case study on the reflectance seasonality of hemiboreal birch stands in Estonia from budburst to initial senescence (Rautiainen et al. 2009a, Rautiainen et al. 2009b). We assembled a smoothed time series of 32 Landsat TM, ETM+ and SPOT HRVIR, HRV satellite images collected between April and September at approximately 10-day intervals covering the Järvselja Training and Experimental Forestry District. The objectives of our study were (1) to track the seasonal reflectance changes of mature hemiboreal birch stands, (2) to evaluate the main driving factors for the observed seasonal reflectance courses through radiative transfer modeling, and (3) to compare our local results to routinely produced MODIS LAI and phenology products.

The radiative transfer model was able to mimic the measured seasonal reflectance dynamics; only minor quantitative differences were noted between the simulated and empirical data sets. The seasonal reflectance courses were mainly governed by the phenological cycle of total stand leaf area, and marginally by changes in leaf chlorophyll and forest water contents. Our LAI estimates and the MODIS LAI product were fairly similar; the largest differences were observed in early spring and at midsummer. Senescence started systematically later in the MODIS data than in our simulations. MODIS products also indicated a longer plateau in the LAI values during midsummer than our simulations. Our results indicated that future work on detecting stand-level phenological phases from medium-resolution satellite images in the hemiboreal zone should focus on (1) quantifying the role of debris and forest floor water and snow on stand reflectance during the early phases of leaf development in the spring, and (2) better characterizing the highly variable surface roughness and seasonality of the abundant understory layer.

Keywords: boreal forest, phenology, reflectance modeling.

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Using SeaPRISM Instrument on the Helsinki Lighthouse Tower for Satellite Validation

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The importance of monitoring the water quality by remote sensing has grown due to algal blooms becoming more common and occurring every summer. However, in coastal areas atmospheric correction process appears challenging and bio-optical algorithms used to quantify the optically significant constituents from water leaving radiance are not well established.

An autonomous above-water system called SeaWiFS photometer Revision for Incident Surface Measurements (SeaPRISM) was installed on the Helsinki Lighthouse Tower in May 2006. [1] It is part of the Aerosol Robotic Network – Ocean Colour (AERONET-OC), system of globally distributed autonomous sun photometers that was designed for validation of remote sensing products. It measures normalized water leaving radiance L_{WN} at various center-wavelengths from 412 to 675 nm. These standardized measurements of radiance emerging from the sea water and the atmosphere can be used to support investigations of quality of remote sensing products. [2]

Satellite instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Medium Resolution Imaging Spectrometer (MERIS) are widely used for water quality monitoring on coastal areas with complex optical properties. They are measuring radiance emerging from the sea which can be used to determine the normalized water leaving radiance corrected from the atmospheric perturbations and variations of sun angle. This carries information on the various optically significant seawater constituents like phytoplankton, particulate and dissolved organic matter. By combining in situ water samples and radiance measurements of SeaPRISM and MODIS-sensor the accuracy of optical remote sensing products for the Gulf of Finland can be investigated and more reliable bio-optical algorithms can be created. [1]

Observations of L_{WN} are recorded in four summers (2006-2009) and a preliminary bio-optical algorithm is created. The study is made in co-operation with Joint Research Center (JRC) of European Commission.

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An improved approach for automatic detection of changes in buildings

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Automatic detection of buildings and changes in buildings from airborne laser scanner and image data for map updating has been studied. A new, improved method for change detection between an existing building map and building detection results has been developed. Corresponding building objects between the two datasets are found by analysing the overlaps of the buildings. Depending on the correspondences, change detection is carried out, and new, demolished and changed buildings are found. Detection of changed buildings is based on analysing overlap percentages or investigating the building detection results inside and outside buildings on the map by using buffers. Additional rules were developed to investigate tree cover or a digital surface model (DSM) in cases where misclassifications in the building detection stage are likely. The change detection method was evaluated by using suburban test areas covering 4.5 km^2. Reference results were created by applying the same method to two real building maps. Accuracy estimates for different change classes and building sizes are presented. For all buildings, the completeness and correctness were about 70%. Further tests on building detection with a classification tree based approach are also presented. The method was applied to a new dataset containing laser scanner data and an ortho image created from digital aerial images. The mean accuracy of buildings was 89% when compared with a building map, pixel by pixel. The use of the aerial imagery in addition to laser scanner data clearly improved the results. For details of the study, see [1].

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Validation of CHRIS/PROBA chlorophyll content map for Norway spruce forest stands using airborne imaging spectroscopy data of very high spatial resolution

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Chlorophyll a+b (C_{ab}), the green foliar pigments, are one of the most important organic molecules on Earth, as they directly participate on the processes of photosynthesis. They are able absorb the energy of incident solar radiation, which is then transformed into the organic bounds of carbohydrates. Norway spruce (*Picea Abies (L.) Karst.*) is one of the dominant tree species of boreal forest ecosystems of the northern hemisphere. The leaf chlorophyll content of spruce canopy varies per phenological phase and actual environmental stress load. Therefore, information on leaf chlorophyll content of canopy can be used as indicator of actual forest stand health state.

The state-of-the-art satellite sensors (e.g., imaging spectrometer CHRIS onboard of PROBA satellite platform – C/P) are able to provide, by means of the radiative transfer models' inversion, or an appropriate optical vegetation index, a map of C_{ab} content. Due to the low or medium spatial resolution and a wide swath (pixel size of 17m, swath of 13x13km in case of C/P) space borne sensors can cover larger areas than airborne imaging spectroradiometers (e.g. AISA Eagle – maximal pixel size of 5m with swath of 5km). However, the major drawback of a lower spatial resolution is thorough the problematic validation of the product uncertainty, e.g. accuracy of the retrieved C_{ab} maps. The broad pixel size introduces spectrally mixed per pixel information, which disables identification of individual tree crowns with pure foliage spectral information. Moreover, to conduct extensive ground (laboratory) chlorophyll measurements on statistically significant number of sample trees for satellite product validation is unfeasible. To overcome this drawback, we propose to use a combined validation scheme, where the satellite C_{ab} map (spatial resolution of 17m) is cross-validated with the airborne high-spatial resolution C_{ab} product (spatial resolution of 0.4m), which accuracy is know from comparison with ground/laboratory measurements. We are demonstrating this validation scheme within the case study over the spruce forest stands located at Bily Kriz test site (Moravian-Silesian Beskydy Mts., Czech Republic). The mutual spatial co-registration of both nadir satellite and airborne image data collected on the same day of September 14th, 2006 was performed via accurate geo-othorectification into the UTM34N-WGS84 projection. The average positional rectification error was 15m for C/P data and 1m for AISA Eagle image mosaic. The C_{ab} values of sunlit spruce crown parts of the areas corresponding with CHRIS/PROBA image pixels were aggregated and used as the C_{ab} 'ground truth' spatial reference. The first results showed quite close correlation between C/P and airborne C_{ab} products, with root mean square error – RMSE = 5.14 $\mu g/cm^2$ for immature and RMSE = 6.63 $\mu g/cm^2$for mature spruce stands.

Key words: satellite chlorophyll map, validation, Norway spruce, CHRIS/PROBA, AISA Eagle

Preference for poster presentation.

Atmospheric ozone and water vapor observations: remote sensing and in situ data comparisons

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Confidence in satellite remote sensing observations is based on independent validation measurements. In Sodankylä, northern Finland, we have performed a series of measurements by balloon borne instruments that have been timed to satellite overpasses. Here we first focus on the water vapor data in the lower stratosphere and upper troposphere, and secondly on the ozone data in the lower stratosphere. The data used in this study have been obtained by satellite borne remote sensing measurements and by balloon borne in situ instruments. The in situ ozone measurements were obtained by the electrochemical concentration cell ozonesondes. Accurate measurements of water vapor were made by research grade hygrometers. In addition we have flown the newest versions of operational radiosondes in the same payload with research instruments. This has provided an opportunity to characterize the accuracy of radiosonde humidity measurements in the troposphere.

Optimization of continuous reflectance measurements in coastal waters

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The Baltic Sea is optically characterized by relatively clear waters rich in coloured dissolved organic matter (CDOM), seasonal phytoplankton blooms, and the influence of suspended sediments in near coastal areas and river plumes. Monitoring phytoplankton bloom development is of particular interest in terms of water quality and nutrient dynamics of this eutrophicated sea. Conventional monitoring is based on the analysis of phytoplankton by light microscopy, and automated transect monitoring of phytoplankton fluorescence from ships-of-opportunity e.g. within the Alg@line project.

We are currently investigating the potential for continuous reflectance measurements from ships of opportunity as a low cost, low-maintenance expansion of conventional water quality monitoring practises in the Baltic Sea, with special emphasis on the retrieval of phytoplankton biomass and related optical properties. Hyperspectral reflectance monitoring reveals the contribution of light absorbing and scattering substances to the upwelling light field, and provides a link between *in situ* measurements and basin scale (e.g., satellite imagery based) observations.

Avoiding low sun angles, sun glint, and removing the pollution of water leaving radiance by reflected skylight are prerequisite to succesful interpretation of *in situ* reflectance measurements. Data for fully overcast or fully clear skies and obtained under low wind pressure are then relatively easy to convert into a reflectance product. Data obtained under partly clouded skies, particularly in combination with non-flat seas, can normally not be used. Products of doubtful quality are, however, easily obtained even when following these restrictions. Using a large dataset of measurements obtained from the first auto-ranging shipborn reflectance sensor setup onboard R/V *Aranda*, we evaluate whether *in situ* water colour data can be improved using information contained in the transect data rather than strict point-by-point analysis. We also assess the added value of flowthrough instruments measuring absorption or fluorescence of optically active substances to restrict reflectance values in the blue and near-infrared parts of the spectrum.

Unsupervised Neural Network Classification of Boreal Mire Biotopes with Hyperspectral Airborne HyMap

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Spatial information on mire biot0pes would be an asset in inventorying mires for protection purposes and in monitoring changes in mire diversity caused by artificial regulation of mire hydrology, atmospheric deposition, and global change. We took a data-driven approach to explore the potential of airborne imaging spectroscopy data in determining plant communities of pristine treeless northern boreal mires in Finland (65˚57'N, 24˚29'E). It was hypothesized that plant species distribution and soil nutrient regimes are determining factors in spectral reflectance of mires, thus mires could be classified in several plant associations from medium resolution (5 m) imaging spectroscopic data. The objective was to discover the optimal ecological meaningful mire class number for our remotely sensed dataset. Minimum noise fraction transformation of geocoded and atmospherically corrected hyperspectral HyMap data (437-2485 nm) was subjected to non-metric multidimensional scaling (NMDS) and further classified with neural networks. The performance was tested against a field inventory of plant species, dielectric (ε) measurements of soil water content and electrical conductivity (σ) of soil nutrient regimes. NMDS ordination revealed nutrient-poor *Sphagnum fuscum* bogs with abundance of *Sphagnum fuscum*, *Rubus chamaemorus*, *Empetrum nigrum* and *Vaccinium uliginosum* to be associated with high NIR and NDVI, and spectrally deviate from nutrient-rich sedge fens with *Betula nana*, *Carex lasiocarpa*, *Carex* sp., litter and *Menyanthes trifoliata*. The NMDS also indicates that *Sphagnum angustifolium*, *S. lindenbergii* and *S. papillosum* dominated low sedge fens could be distinguished separately by spectral data. Classification to seven classes with Kohonen's self organizing maps (SOM) outperformed the fuzzy neural networks and *k*-means clustering producing the highest separability of classes in plant species coverages. The SOM classes were combined to produce a three class ('nutrient-poor *Sphagnum fuscum* bog', 'nutrient rich sedge fen' and 'nutrient-poor low sedge fen') thematic presentation of boreal mires. The study serves as a step towards an operational mire surface monitoring system based on imaging spectroscopic data which further improvement could be geared towards subpixel analysis and scale dependency of ecological classification detail in pixel based approaches.

IMAGING SPECTRAL SIGNATURE INSTRUMENT AIRBORNE CAMPAIGN

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The outcome of an ESA GSTP contract was an aircraft compatible breadboard of a programmable line imaging correlation spectrometer, named the Imaging Spectral Signature Instrument (ISSI)[1]. ISSI is implemented with a front objective, two spectrographs, a liquid crystal display (LCD) spatial light modulator (SLM) and a line sensor. A line imaged by the front objective is dispersed by the first spectrograph on the LCD. Any two dimensional transmission pattern can be programmed on the LCD. The modulated image is then re-gathered by the second spectrograph to a line on the CCD line detector.

The goal of the instrument is to find targets with an a priori known spectral signature from a more or less known background. A possible remote sensing application is to find oil spills mixed with ice from sea. The advantage of the ISSI concept is the hyperspectral strength augmented with real time results and the reduction of the data amount in all stages of the processing chain. The signal to noise ratio (SNR) is potentially better than for a conventional hyperspectral imager if the SLM function can be implemented with an efficient throughput. Using the programmable spatial light modulator ISSI performs a spectral correlation operation in real time and stores only the end result. ISSI approximates the spectral angle mapper (SAM) algorithm used in hyperspectral data processing. The breadboard has demonstrated that the operating principle works under laboratory conditions. The next step was to determine how well ISSI performs in remote sensing applications in the visible and near infrared domain with all the environmental uncertainties present.

Therefore in the present activity, potential applications were gathered and analyzed. Targets to determine the feasibility of detection were selected for a flight test campaign. Two flights with the ISSI instrument and an AisaEAGLE hyperspectral imager were performed over the cities of Lahti and Pori in September 2008. With this setup the ground was observed both with ISSI and the Eagle under the same environmental conditions. The target signatures were determined from a priori hyperspectral data and from the acquired Eagle data of the first flight. The source signatures are converted using atmospheric radiative transfer software and instrument calibration to the actual filter profile on the spatial light modulator. The aim is to assess the ISSI technical performance and compare the quality of the data extracted with the ISSI concept vs having the full hyperspectral data set available for hyperspectral processing.

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ESA GLOBSNOW – GLOBAL SNOW DATABASE FOR CLIMATE RESEARCH

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The European Space Agency (ESA) funded GlobSnow project aims at creating a global database of snow parameters for climate research purposes. The main objective is to create a fundamental climate data record (FCDR) concerning the essential climate variables (ECV) for snow. Two snow products will be created: one concerning the areal extent of snow (SE) the other measuring the snow water equivalent (SWE). Both products will include the actual observed satellite datasets (the FCDRs) and the geophysical parameters (the end products) derived from the satellite data along with accuracy information for the each snow parameter. The temporal span of the snow products will range between 15 to 30 years. A key improvement of the snow products, when compared with the currently available data sets, will be a thorough validation of their accuracy with respect to spatially and temporally extensive ground truth data sets.

In addition to the snow FCDRs and end-products, an operational near-real time (NRT) snow information service will be implemented. The service will provide daily snow maps for hydrological, meteorological, and climate research purposes. The snow products will be based on data acquired from active and passive, optical and microwave-based spaceborne sensors combined with ground-based weather station observations. The project was started in November 2008, and is being coordinated by the Finnish Meteorological Institute (FMI). Other project partners involved are NR (Norsk Regnesentral), ENVEO IT GmbH, GAMMA Remote Sensing AG, Finnish Environment Institute (SYKE) and ENVIRONMENT CANADA (EC).

The GlobSnow-project aims at creating temporally and spatially extensive snow products with well known accuracy characteristics. The snow products will be based on the state-of-the-art algorithms that are thoroughly validated using an extensive ground truth database gathered from Canada, Scandinavia, Russia and the Alps. The snow products will be generated on a daily, weekly and monthly basis for both SWE and weekly and monthly for SE. Both the historical data sets and the operational products will be made available through the GlobSnow web-based archive.

First algorithm evaluation results for both SWE and SE have been acquired and the selection of the GlobSnow algorithm for SWE has been made. For SE the decision is foreseen to be made during September 2009.

Additional information can be found on the GlobSnow-website: http://globsnow.fmi.fi

Land applications

Progress in the use of coarse-resolution satellite data for environmental monitoring, phenology and carbon

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The high frequency of observation from coarse-resolution sensors enables studies of dynamic vegetation variations. We have developed methodology and studied the use of vegetation indices from sensors like NOAA/AVHRR and Terra/MODIS. To generate smooth time-series from noisy input data we have developed curve-fitting methods implemented in the TIMESAT package [1]. We have furthermore tested how these data relate to variations in fractionally absorbed photosynthetically active radiation (fAPAR) [2]. This is one component in the computation of net primary production (NPP) together with variations in PAR flux [3] and the light use efficiency factor [4]. Based on data from carbon flux towers we are developing methods for computation of NPP and the net carbon balance for Nordic forests [5], wetlands [6], and for semi-arid areas [7]. The high time-resolution of the data enables their use for environmental monitoring. By integrating remotely sensed data with output from a mechanistic ecosystem model, the LPJ-GUESS, we have investigated the driving forces for the Sahelian drought [8]. This has enabled better understanding of the climate – human interaction in these ecosystems. A further area of research is the use of coarse-resolution data for phenology and phenology variations [9]. Of relevance to the Nordic countries is to investigate how visible phenological events in needle-leaf forests are in remote sensing data since temperature strongly regulates the biochemical processes that determine phenology. Also, disturbance of the phenological cycle due to insect attack is an important application field [10].

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Planning of a Large-scale Soil Moisture Network for the Validation of Remotely-sensed Surface Soil Moisture Data from the L-band Passive Microwave Radiometer SMOS: Skjern River Catchment, Western DK

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Hydrological models are important for the assessment of water resources especially under a changing climate. Currently however, problems exist with closure of the water balance at catchment scale – the scale on which sustainable water management strategies should be addressed. One of the major uncertainties is soil moisture, a key variable which is difficult to assess due to its pronounced scale-dependent spatial and temporal variability. Thus, there is an urgent need for the acquirement of global soil moisture data. The passive L-band microwave radiometer SMOS (foreseen launch in Nov. 2009) is promising to deliver continuous large-scale soil moisture data which, when downscaled and assimilated into hydrologic models, has the potential to ameliorate these models. However, the data first needs to be calibrated and validated and the planning of such activities is presently ongoing in all parts of the world. One such validation site is situated in the Skjern River Catchment in Western Denmark. Two interesting characteristics distinguish this area from other SMOS validation site – its short distance to the coast line in two directions and the very sandy soils. At present, the catchment is broadly investigated through the Danish Hydrological OBservatory and Exploratorium (HOBE). Within this project an airborne campaign with the passive L-band microwave radiometer EMIRAD is planned for spring 2010 to acquire soil moisture data at intermediate scale (ca. 500 – 1000 m spatial resolution) and support the SMOS validation activities. Furthermore, the installation of a soil moisture network designed to provide in-situ soil moisture data feasible for upscaling and comparison with SMOS soil moisture data at large scale is currently ongoing. The final network will consist of 3 individual measurement clusters of 10 data loggers holding 5 sensors each (Decagon ECH_2O), operating in wireless mode within an approximate extent of 6 km, respectively. Before the actual installation, thorough planning on suitable network locations has been conducted according to the following steps: (1) choice of one SMOS pixel to be validated (ca. 44 x 44 km), (2) detection of potential areas for the 3 network clusters within the selected SMOS pixel and (3) placement of the 10 loggers within each respective cluster. In planning steps (1) and (2) the SMOS measuring principle was taken into consideration, while in step (3) an analysis was carried out to locate the most representative combinations of predominant environmental conditions and their respective fractions within the selected SMOS pixel. Analyzed data included information on land use, top- and subsoil types, whereas topography in the area is homogeneously flat and thus assumed to be negligible. Combining these environmental parameters revealed a small number of new classes all together covering over 80 % of the selected SMOS pixel. The plan is now to distribute the available loggers of the network within these representative classes taking their individual fractions into account. In the following this theoretical analysis has to be checked in the field to decide on the final network locations. Furthermore, practical issues (installation permission, sensor removal during agricultural practice, etc.) need to be tackled. By considering the SMOS measuring principle and prevailing environmental conditions of the area already in the planning of the soil moisture network, we hope to be able to acquire valuable in-situ measurements fulfilling the requirements for feasible SMOS validation, and thus being a supporting step towards the urgently needed clarification of the behavior of soil moisture at catchment scale.

Measuring gap size distribution and beyond-shoot clumping at Järvselja RAMI (RAdiation transfer Model Intercomparison) test sites

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RAdiation transfer Model Intercomparison (RAMI) is an on-going mechanism to benchmark radiation transfer (RT) models used to simulate the transfer of radiation at or near the Earth's terrestrial surface, i.e. in plant canopies and over soil surfaces [1]. For the next (fourth) phase of intercomparisons, one of the goals is to investigate the potential of RT models to reproduce in situ measurements of transmitted light by various methods such as Tracing Radiation and Architecture of Canopies (TRAC) instrument or hemispherical photography.

Three sample plots in the Järvselja Training and Experimental Forestry District, Estonia, were preliminarily selected for a set of RAMI fourth phase experiments. In July 2009, TRAC measurements were acquired for 175 transects under various angular configurations at the three stands. Our findings include: 1) the gap size distribution and beyond-shoot clumping is very stable across the stands for the solar zenith angle range from 30 to 60 degrees. Beyond this range the changes of beyond-shoot clumping with solar zenith angle might differ from results of previous studies in northern ecosystems [2]; 2) the highest correlation between different ways of quantifying the beyond-shoot clumping was achieved for CC [3] and CLX [4] methods. The results are comparable with results of [5]; however, separate relationships need to be applied for coniferous and deciduous stands; 3) the illustration of the canopy structure effect on differences in measured clumping and gap size distribution with changing height.

The compiled data extend the original parameter dataset [6] to be used in the next phase of RAMI for different benchmark tests and reflectance modeling experiments, and contribute toward systematic validation efforts of radiative transfer models, operational algorithms, and field instruments, as promoted by the Comittee on Earth Observation Satellites (CEOS).

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geoland2 – Towards an Operational GMES Land Monitoring Core Service

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This presentation gives an overview of geoland2-project and SYKE's role in it. EU-funded geoland2-project intends to constitute a major step forward in the implementation of the GMES Land Monitoring Core Service (LMCS). The goal of geoland2 is to prepare, validate and demonstrate pre-operational service chains and products that will underpin the LMCS, and to propose and demonstrate a concrete functional organisation of the LMCS.

The architecture of geoland2 is made of two different layers, three Core Mapping Services (CMS) and seven Core Information Services (CIS). The CMS produce 'basic' land cover, land cover change, and land state products which are of broad generic use and can be directly used for deriving more elaborated products. The CMS products cover a wide variety of thematic content, spatial scales from local to global, and update frequency, from 1 day to several years. The CIS are a set of thematic elements that start from CMS products and other data sources to produce 'elaborated' information products addressing specific European policies.

The 3 Core Mapping Service tasks are:

- EUROLAND: At local scale, EUROLAND produces VHR Urban Atlas inventory and change on several tens of European cities. At continental scale, it produces over Europe and demonstration sites HR Land Cover inventory and change with 21 classes plus 4 Forest classes and Forest Density at 1-5 ha MMU.
- BioPar: BioPar produces in near real time and off-line a series of biogeophysical parameters describing the continental vegetation state, the radiation budget at the surface and the water cycle. The biogeophysical parameters are derived mostly with MR and LR data, at a global or continental scale; the time frequency of product update is on the order of 1 - 30 days.
- SATChMo: SATChMo operates at continental scale over Europe and Sub-Saharan Africa. It delivers: (i) a VHR/HR Area Frame Sampling over permanent samples representative for all European and African environmental / ecological conditions for annual statistics of land cover & land cover change; (ii) a complete MR continental coverage of seasonal and annual vegetation parameters to produce land cover change and agricultural land use. The time frequency of the product update is on the order of 3 - 12 months.

7 Core Information Services address important sectoral policies (Spatial Planning, Water, Agri-Environment, Forest, Land Carbon, Natural Resource Monitoring in Africa, Global CROP Monitoring) and show examples of GMES end-to-end services.

SYKE is participating SATChMo CMS, following tasks:

- AFS: Interpretation of VHR-images (Kompsat-2 15 x 15 km2, about 35 sites, mostly twice during project) in Nordic and Baltic countries and change detection.
- MR-products: Monitoring of vegetation phenology and crop growing conditions.

Production of CORINE land cover 2006 and land cover changes between 2000-2006 in Finland

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The European Comission introduced the CORINE programme in 1985 in order to gather information relating to the environment for the European Inion. CORINE land cover (CLC) classification is produced using satellite images and visual interpretation.

In Finland, CLC has been made differently in order to produce more detailed land cover information for national use at the same time. Finnish CORINE 2000 was based on automated interpretation of satellite data and data integration with existing digital map data. LANDSAT 7 ETM satellite data received 1999-2002 was used (IMAGE2000).

The same process is repeated with CORINE 2006 project where CORINE 2000 data is updated and land cover changes detected. The update iscompleted using a new coverage of satellite images received 2005-2008 (=IMAGE2006). Finnish IMAGE2006 consists of 80 IRS P6 Liss and 51 Spot 4/5 images. There are two image coverages; one summer coverage (47 + 35) and another spring/autumn coverage (33+16). Clouds and their shadows were interpreted visually and masked out. Atmospheric correction was done using ATCOR2 of Erdas Imagine. The aim of atmospheric correction was to remove the effects of atmospheric disturbances and make the corrected images as similar as possible with IMAGE2000 mosaics.

Following map databases were used in the production of land cover 2006: SLICES land use element, Topographic database, Building and Dwelling Register 2006 and environmental registers. Estimation of tree variables was made using field sample plots measured in National Forest Inventory #10 during 2004-2007. The employed method is the same which is applied in the operative multisource forest inventory of Finland (kNN prediction). Also manual and semi-automatic interpretation of satellite images were used (for.ex. harbors, airports, peat-production areas etc). All collected and produced land cover data layers are processed into same 25 m grid and combined together according to priority list, which is based on the accuracy and importance of data.

Land cover changes between 2000 and 2006 were retrieved by comparing two data sets: 1) change areas detected using image-to-image comparison and 2) changes detected by direct comparison of thematic land cover classifications year 2000 and 2006.

The outputs are IMAGE2006 satellite images and mosaics, CORINE 2006 land cover classification and changes between 2000-2006. These will be produces in different spatial resolutions: raster data with spatial resolution of satellite images and European LC and LC changes with MMU of 25 and 5 hectares. European vector data sets are produced using automated generalization procedures from raster data.

The technical team of European CLC project validate land cover change database qualitatively. An independent validation will be tendered out by EEA in the end of project (2010).

Soil Moisture Retrieval in Boreal Forests with HUT-2D Synthetic Aperture Radiometer

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L-band radiometry is a promising technology for measuring soil surface moisture [2, 3, 4, 5]. Soil Moisture and Ocean Salinity (SMOS), scheduled for launch in 2009, is the European Space Agency's Earth Explorer satellite for global monitoring of soil moisture, and also sea surface salinity. It utilizes a single instrument: Microwave Imaging Radiometer by Aperture Synthesis (MIRAS), which is a passive instrument operating at a frequency of 1.4 GHz and using interferometry for producing two-dimensional brightness temperature images. [1]

Because the spatial resolution of the MIRAS is 30-50 km [1], each pixel covers several different land usage classes and vegetation types. L-band radiometry is preferred over higher-frequency sensors because of its relatively low sensitivity to vegetation [2, 3, 4, 5]. However, the effects of vegetation are still significant [6]. In the boreal zone forests and bogs are the dominant vegetation conditions, and knowing their emissivity properties is imperative to succesful global measurements of soil moisture.

HUT-2D is an airborne interferometric radiometer designed, manufactured and tested by Helsinki University of Technology and completed in spring 2006 [7]. The major technical characteristics of HUT-2D are similar to those of MIRAS and it can thus be used to collect datasets similar to SMOS products.

In 2007 the HUT-2D was used to collect a dataset including measurements over forested soils. These measurements were used to examine the retrieval of soil surface moisture in varying vegetation conditions. Where vegetation cover was abundant and polymorphic, reliable estimation of vegetation parameters proved problematic, but the results indicated, that succesful retrieval of soil parameters is still possible.

This paper describes the measurements carried out over forested areas during the measurement campaign of August 2007 in Finland with HUT-2D and the corresponding ground measurements. A method to model the above surface layer is examined. The accuracy of the measurements and the retrieval process s assessed and applicability of HUT-2D for retrieval purposes is discussed.

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Water quality

Testing of MERIS Boreal and Eutrophic Lake Processors at Lake Säkylän Pyhäjärvi, Finland

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Two new lake water quality processors were released in July 2008 for the Envisat/MERIS instrument after the ESA project "Development of MERIS Lake Water Algorithms" was concluded [1]. The processors are included in the BEAM software package and they convert the TOA radiances measured by MERIS into products that include water quality parameters (chl a, TSM, and CDOM), atmospheric parameters, and atmospherically corrected water leaving reflectances. The processors use neural networks and are based on the architecture of the C2R processor developed by Roland Doerffer [2]. The bio optical models used in the development of the neural networks were parameterized using in situ data from Finnish (Boreal lakes processor) and Spanish (Eutrophic lakes processor) lakes.

A measurement raft was installed in Lake Säkylän Pyhäjärvi on May 18, 2009 (TEKES project Catchlake 2 [3]). The sensors at the raft measure water quality parameters (e.g. turbidity and chlorophyll a) and weather parameters.

We have processed time series of satellite images from summer 2009 with the Lakes processors and compared the results with in situ data from the raft. The total suspended matter (TSM) concentrations estimated from satellite data agree well with in situ turbidity. For chl a, a correction factor was necessary, but after the correction the agreement between in situ and satellite data was good.

The results also indicate the potential problems when time series of water quality data are compared.

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Two decades of change in emergent macrophyte expansion in two large shallow northern temperate lakes on a retrospective series of satellite images

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Many large lakes in northern Europe have undergone an improvement of conditions after the decrease of agricultural land use intensity during the last two to three decades. However, recent habitat and lake level studies have demonstrated continuously increasing shore overgrowth by aquatic macrophytes, mostly by common reed, despite the favorable development in water quality. Consequently there is a growing interest in the factors that control macrophyte development and the changing extent of the macrophyte patches in large lakes. With inadequate retrospective field data the actual long-term changes of emergent macrophyte communities in large lakes is difficult to evaluate. Retrospective satellite images make it possible to go back in time even though no field data are available.

We made use of the more than 20-year archive of medium resolution Landsat TM and ETM+ data supplemented by SPOT and Aster satellite images to examine the change in coastal vegetation of two large shallow lakes Lake Peipsi (3550 square kilometers), the fourth largest in Europe and Lake Võrtsjärv (270 square kilometers), the second largest lake in the Baltic countries. We addressed the following questions. Is there a measurable change in the cover of emergent macrophytes that could be consistently monitored with medium spatial resolution satellite images? What are the main driving factors of the horizontal extension of emergent macrophyte vegetation in such large shallow lake environment? What are the main patterns of change of the width of the reed belt along the shore reaches of a large shallow lake?

The reflectance characteristics of aquatic macrophytes as well as density are known to alter seasonally. Satellite images used were acquired between the middle of July and the beginning of September, corresponding to the period of maximum aquatic macrophyte vegetation abundance. A classification into two categories: aquatic macrophyte vegetation and open water or lake bottom was performed. We used Normalized Difference Vegetation Index (NDVI) to decrease the dependence of the signatures of macrophyte patches on water or lake bottom background signals. Visual aerial photograph interpretation results and ground-based GPS-measurements were used to estimate the accuracy of emergent macrophyte patch boundary delineation. Multivariate linear modeling analysis was used to test the driving factors of horizontal expansion of coastal reed belt. In the model we included the soil, landscape and lake morphometric factors that on prior published knowledge could affect the emergent aquatic vegetation in large shallow northern temperate lakes.

The satellite images revealed the dynamic changes in the coastal reed areas within the last 22 years. Results of the mixed model analysis show that the horizontal extension of the reed belt has large interregional variation that is affected by large and small inflows and by anthropogenic activities.

Water Quality Service for Lakes

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Lake water quality can be monitored with several methods: traditional, automated or remote. Actors in the public or private monitoring are usually specialized in certain methods. Therefore additive information and enhanced accuracy that can be gained with the joint use of various methods are often not utilized. This project aims to develop an operations model for an environmental monitoring service that combines the functionality of public and private sector, and on the other hand, several monitoring data sources, including remote sensing. General goal is to generate operations model than can be copied to other monitoring regimes in Finland. This model provides business opportunities for private sector as a service provider, as an end user or as a data provider. At the same time it allows standardized organization of local environmental data which is highly valuable for research organizations. Project demonstrates a water quality service for lakes that offers both chargeable and free of charge environmental information for local end users. The commercial side of the service provides water quality information which is specifically tailored to users' needs. The public side of the service publishes general environmental information and encourages citizens to participate with discussion forums and 'blogs'. The technical solutions in this project are developed on the co-operation between University of Helsinki, Finnish Environmental Institute, University of Jyväskylä and Helsinki University of Technology. Technical goal is to build a local database and generate processing tools that are found useful both in the private and public sector. The project develops also the idea of clustered and interoperable network of local databases. After an end user questionnaire survey, a common data base for several environmental data sources including automated measuring stations, remote sensing and traditional measurements is built. All data is tagged with XML-based metadata. Automated interpretation, combination and forecast tools that use this data bank are then developed, as well as automated methods that transfer the information in standardized form to the service provider. Furthermore, the project develops a cheap 'laymans' device for measuring water quality, which is based on the cameras in mobile phones. This opens new business possibilities for e.g. mobile service solutions that are emphasized in the service development of the project. Project is included in the Water Programme by TEKES (the Finnish Funding Agency for Technology and Innovation). It is also supported and/or participated by following organizations/companies: Vesijärvi foundation, Nab Labs Oy, EHP-tekniikka OY, Avenla Oy, Länsi-Uudenmaan Vesi ja Ympäristö Ry, Luode Consulting Oy and Labyrintti Media Oy.

Comparison of different MERIS Case II processors for the water quality estimation on the coastal waters of Finland

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Three different MERIS Case II water processors [1,2,3] of the BEAM software were evaluated on the coastal waters of Finland. Boreal, Case II Regional and Eutrophic processors have been developed for different types of coastal or inland (Case II) waters. Chlorophyll-a (chl-a), total suspended matter (TSM), absorption of colored dissolved organic matter (a_{CDOM}(443)) and attenuation depth ($Z90_{max}$) products of BEAM processors were compared with in situ data. In addition, also algorithms based on reflectances, absorption of pigments (a_{pig}), total absorption (a_{tot}) and scattering of TSM (b_{TSM}) from different BEAM processors were compared against field measurements. The in situ data consisted of intensive monitoring station data of the Finnish environmental administration during years 2006-2008 and data from specific campaign days with flow-through system of Luode Consulting Oy. Also the processors were compared to the operationally used method developed at the Finnish Environment Institute. SeaPrism data from Helsinki Lighthouse were used to compare reflectances from different atmospheric correction processors.

The preliminary comparison shows that BEAM lakes processor Boreal lakes is able to estimate the TSM with R^2 0.7 and RMSE 0.82 FNU at the coast of Finland. C2R processor proved to be the best for chl-a concentration. However, the accuracy of the chl-a estimations was lower with all processors (R^2 ranged from 0.6 to 0.32 and RMSE from 1.7 to 12 µg/l). Especially on the spring bloom season the chl-a products need further development. Z90max product of BEAM BOREAL processor can be used for Secchi disk depth estimation with reasonable accuracy (R^2 0.51).

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Variability in the inherent and apparent optical properties of the Baltic Sea and consequences for ocean colour algorithm development

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The main components that affect the ocean colour in Case 2 (including Baltic Sea) waters are chromophoric dissolved organic matter (CDOM), phytoplankton, and non-pigmented particulate matter (e.g. sediments and detrital material). Their contributions to absorption and backscattering vary independently of each other. Development of ocean colour algorithms for Baltic waters is demanding task, involving knowledge of (1) variations in the concentrations of optically active in-water constituents, (2) variations in their inherent optical properties (IOPs), and (3) their interrelations to apparent optical properties (AOPs) that determine ocean colour. Further complications arise from atmospheric disturbances. In this presentation we summarize our recent studies of IOPs and AOPs of the Baltic Sea.

Spatial and seasonal variation of absorption properties of CDOM were studied in different sub-basins of the Baltic Sea. CDOM absorption $a_{CDOM}(375)$ ranged from 0.75 to 11.2 m^{-1} and the slope of CDOM absorption $S_{CDOM}(350\text{-}600)$ varied within a narrow range from 0.0175 to 0.0239 nm^{-1}. Clear non-linear relationship, characterized by hyperbolic function, was observed between $a_{CDOM}(375)$ and $S_{CDOM}(350\text{-}600)$. DOC specific CDOM absorption coefficient, $a_{CDOM}(375)^*$ varied from 1.43 to 9.08 nM^{-1} m^{-1}. Significant linear relationship was observed between $a_{CDOM}(375)^*$ and S_{CDOM}. Parameters and relationships for CDOM presented in this study provide useful information for variable ecological, bio-optical and remote sensing applications used throughout the whole Baltic Sea.

For natural samples, nonlinear relationships have been presented between Chl*a* concentration and Chl*a*- specific phytoplankton spectral absorption $a_{ph}^*(\lambda)$, suggesting that package effect varies predictably with Chl*a* concentration. For the pooled data of our studies in the Baltic Sea, it is clear that variability in this relationship is large. In the northern Gulf of Finland, seasonality in the phytoplankton spectral absorption and in the package effect was related to physical forcing of the water column and phytoplankton community succession. Mixing depth and abundance of picophytoplankton, together explained 87% and 82% of the variability in $a_{ph}^*(676)$ and $a_{ph}(437) : a_{ph}(676)$, respectively. Also water temperature was closely related to Chl*a* specific absorption coefficient.

A SeaWiFS Photometer Revision for Incident Surface Measurements (SeaPRISM) has been installed on the Helsinki Light House Tower in the Gulf of Finland, Baltic Sea, to determine normalised water leaving radiances $L_{WN}(\lambda)$ at centre-wavelengths of interest for ocean colour applications. A first analysis of MODIS and SeaPRISM $L_{WN}(\lambda)$ match-ups indicates an underestimate of 63 and 20% for MODIS $L_{WN}(\lambda)$ at 412 and 667 nm, respectively. By contrast, average differences are within ±5% at 443, 488 and 551 nm.

Our results will support development of optical instruments and algorithms for multivariate retrieval of optically active in-water constituents from ocean colour data in the Baltic Sea.

Secchi 3000: New Approach to Water Quality Measurement Instruments and Systems Integration with Remote Sensing

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Remote sensing of water quality is based on multi- or hyperspectral visible and near infrared low-to-medium resolution observations of water surface reflectance. Reflectance is an apparent optical property, which in addition to the water quality is dependent on sun direction and other variable properties of the observational setup. In model-based approaches, either implicitly or explicitly, the satellite observations are first converted to inherent optical properties such as spectrally resolved absorption and scattering of the observed water. Then, either implicitly or explicitly, these optical properties are converted to estimate laboratory of in-situ measurable estimates of for example phytoplankton chlorophyll concentration by using specific inherent optical properties. These link changes in optical properties to changes in concentrations, and often they are accurately applicable merely to specific types of water with characteristic types of phytoplankton and other substances, and observed in specific seasons. However, the laboratory and other in-situ measurements have their inherent errors, which often are correlated with, for example, phytoplankton types of the measured sample. Spatial variation of water quality and differences of scale of the measured target water volumes in both horizontal and vertical direction make it difficult to integrate these measurements in order to assess the true ecological state of the observed water body. Sparse locations of observations and technical difficulties in obtaining in situ water samples or automated measurements on the other hand invite to attempt combining this source of data to the spatial coverage provided by remote sensing.

Secchi3000 arises from the need of increasing the applicability of integrated in situ measurements to be co-used with remote sensing, both in measurement data quantity and conceptual quality. Secchi3000 is based on an idea of using digital cameras viewing simultaneously different a priori known surfaces through different depths of water layers. The traditional Secchi disc depth is a measurement of depth at which a white disc disappears or re-emerges from/to sight above water surface. By using digital images these estimations can be automated, and specifically by using mobile phone cameras, information can be easily transported. We will investigate if colors and patterns visible in the image can be used for estimating absorption, scattering and, based on wavelength channel ratios, water quality, in parallel with similar data derived from remote sensing. Aside of the camera, the device could be remarkably inexpensive and easy to use, thus having potential for mass distribution and provision of extensive amounts of in situ data. Research and development activities on the Secchi3000 related techniques (innovated by Timo Pyhälahti) are on-going in SYKE and TKK.

Water Insight [1] WISP-3 hand-held spectrometer is able to derive water quality estimates from close range, but without physical contact, by measuring downwelling irradiance and radiance from two directions and applying relevant models and algorithms – which relate to those used for remote sensing and Secchi3000 data. This kind of close sensing device used with less expensive, potentially less accurate but more spatially abundant Secchi3000 observations could be an important part of the on-ground segment of EO based integrated monitoring system.

[1] http://www.waterinsight.nl/

Snow and ice

Development of remote sensing of cryosphreric processes: The ESA CoReH2O and its relation to other satellite missions

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The development and activities related to the planned ESA CoreH2O mission are described. This space-borne dual-frequency SAR mission is aimed for the improved monitoring of snow water equivalent, in order to investigate snow processes for hydrology, climate research and meteorology. CoReH2O is aimed to provide reliable information on snow cover with a spatial resolution of around 100 m, which is a totally new feature. The mission is one of the candidates for the next ESA Earth Explorer satellite.

Simulating GPM DPR snowfall observations by using combined weather radar and CloudSat measurements

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Global Precipitation Measurement (GPM) is a NASA Earth observation satellite mission planned for launch in 2013. The goal of the mission is to characterize the role of precipitation in the Earth's water cycle. The Dual-frequency Precipitation Radar (DPR) is one of main instruments of GPM, and will be used to characterize the three dimensional structure of precipitation. DPR will operate at K_u- and K_a-bands.

One of the biggest uncertainties in GPM retrieval algorithms is how the algorithms will work in cases of shallow light precipitation that are common in northern latitudes. Unfortunately, K_u/K_a-band radar observations are not readily available to study the performance of the algorithms in those cases. To augment the lack of observations, we have developed a procedure that can be used to simulate the output of the GPM K_u/K_a radar in realistic snowfall scenarios. The inputs of the simulation are coinciding CloudSat W-band radar and C-band weather radar observations.

As a starting point of the study, we have simulated the dependence of the Dual-frequency ratio (DFR) at the GPM frequencies from the C/W-band DFR. For these simulations a wide range of input parameters, such as particle size distributions, snow density, etc. were used. Our simulations, performed with Mie scattering, indicate that the K_u/K_a-band dual frequency ratio can be simulated with good accuracy from the C/W-band DFR. This implies that the GPM snowfall measurements can be simulated from combined data obtained from ground-based and space-based radars.

The results of simulations were applied to coinciding University of Helsinki C-band weather radar and CloudSat snowfall measurements, to generate synthetic GPM observations. To collect these observations, University of Helsinki (UH) was carrying dedicated sector volume scans along CloudSat track. The measurements were synchronized with CloudSat overpasses to achieve minimal spatial and temporal differences in observations.

Finnish Meteorological Institute and the University of Helsinki are in cooperation with the National Aeronautics and Space Administration (NASA) to organize a test measurement campaign in preparation for GPM. The campaign is scheduled to take place in southern Finland in the Autumn of 2010 and will involve *in situ* observations as well as remote measurements by ground-based, airborne and spaceborne radars. Included in the data sources are a NASA aircraft, the C-band radar operated by UH in Helsinki, and the CloudSat CPR W-band radar. During this campaign, the proposed procedure will be subjected to further evaluation.

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Applications for laser scanning based methods for seasonal snow cover monitoring

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We review the feasibility of applications for laser scanning methods for seasonal snow cover monitoring developed at the Finnish Geodetic Institute. A laser scanner provides geometric and radiometric information that can be used for example to monitor snow cover depth, to define snow surface structure and as validation method for fractional snow cover mapping [1]. We have made stationary and mobile field measurements during SNORTEX (Snow Reflectance and Transition Experiment) campaign using two different terrestrial laser scanners and digital NIR-camera. The first results point out that a terrestrial laser scanner data provides detailed information on, e.g., the snow cover structure and roughness. Using mobile platform these data could be collected and used in, e.g., validation of satellite based snow cover products in cost-effective manner.

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Figure 1: Mobile snow cover mapping

Snow remote sensing at Finnish Environment Institute

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Remote sensing of snow has a long tradition at SYKE. Snow covered area (SCA) products have been produced since 2001 using AVHRR and later MODIS data [1]. The original coverage of Finland has been enlarged to contain also the Baltic countries. The SCA values are used by the WSFS (Watershed Forecasting System) to forecast the discharge of rivers during snow melt.

SCA has also been estimated from RADARSAT-1 data to complement the optical products using the method developed at Helsinki University of Technology. Recently, during spring 2009 snow water equivalent (SWE) products have been produced from AMSR-E microwave radiometer data together with weather station measurements [2].

Recent and on-going projects include GlobSnow, PolarView, SnowCarbo, and FloodFore, which are briefly described hereafter.

In Globsnow project (http://globsnow.fmi.fi) under ESA DUE program, SYKE contributes to development, validation and implementation of Snow extent mapping procedure employing optical sensors ERS/ATSR-2 and ENVISAT/AATSR, mainly concerning the boreal forest and tundra areas in Northern hemisphere. The result from processing (accomplished by Norwegian computer center eventually) will be 15 years harmonized data set showing the inter-annual and intra-annual evolution in snow extent.

PolarView (http://www.polarview.org) is an earth observation project, which has been running since 2005. Within the project an algorithm, developed at SYKE [1], has been implemented to a monitoring service of the fraction of snow covered area (SCA) in 5km x 5km grid covering most of the Baltic Sea drainage area.

SnowCarbo (http://snowcarbo.fmi.fi) is an EU Life+ project. The aim of the project is to develop a method for spatial carbon balance mapping by combining bio-physical modeling of terrestrial carbon exchange and remote sensing techniques providing input for the models. Special emphasis is given to the influence of seasonal snow cover on carbon exchange.

FloodFore (http://floodfore.fmi.fi) project develops an information system and techniques for improving flood forecasting by applying satellite observations, weather radars, and in situ measurements from automatic monitoring stations. The following physical characteristics relevant to flooding are included: SWE, amount and intensity of precipitation, SCA, soil moisture and soil frost. The project demonstrates the feasibility of the use of multisource information in a pilot experiment for Finnish Lapland using the hydrological forecasting system of SYKE. Using the new system, performance of hydrological model forecasts should improve.

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On retrieving sea ice thickness using SAR and MODIS data

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In this presentation we will discuss under which sea ice and weather conditions we can hope to obtain meaningful information about the ice thickness using SAR and thermal infrared (TIR) data. The radar response at C-band from first-year sea ice (FYI) is dominated by the surface scattering. For multi-year ice and practically saline free ice, like the fast ice areas in the Baltic Sea, the volume scattering is of significance due to the larger penetration depth of the radar signal and the greater porosity of ice. The snow layer affects the radar response when it is moist. Hence, we will restrict our attention in (FYI) drift ice areas under cold weather conditions.

We will base our discussion on the analysis results obtained using the CryoSat Cal/Val campaign data which took place in March 2005 in the Baltic Sea. Airborne laser scanner (ALS) measurements were conducted in the campaign. Later 3-D ice surface topography along transects with a total length about 150 km, width 300 m and a resolution of 3 m^2 was constructed from this data set. It was then compared to the nearly co-incident ENVISAT ASAR images. The analysis results showed that the mean backscatter coefficient ($\sigma°$) increases almost linearly when the fraction of deformed ice grows inside the analysis window (300 m by 300 m). A statistical model was established to predict the ice freeboard (h_f) on the basis of $\sigma°$, the dominant thickness of the parent ice sheet for the deformed ice and the magnitude of the incidence angle. h_f can be converted to ice thickness. For this limited data set the model yielded good results. The uncertainty of the estimates was quantified using the predictive distributions (a Bayesian approach). The obtained results implicate that one can expect reasonable ice thickness class estimates if the large scale ice surface roughness is strongly correlated with the ice thickness. Another requirement is that we through thermodynamic modeling or in situ-data can estimate the thickness of thermodynamically grown ice. In the clear sky conditions this is possibly also using the TIR channels of MODIS [1]. From the TIR channels one obtains the ice surface temperature which is used to calculate the ice surface heat budget, one also needs at least the modeled air temperatures and wind speeds (e.g. HIRLAM or ECMWF). The resulting ice thickness estimate is called the thermal ice thickness and the algorithm gives the correct order of ice thickness classes up to 1 m (a saturation thickness).

The determination of the dominant local level ice thickness is, however, problematic due the different resolution of MODIS (1 km) and ENVISAT ASAR data (30-100 m). The complicating factor is that usually the TIR pixels cover as well level ice as deformed ice areas with varying spatial extent. The ice surface temperature for these ice categories differ significantly from each other. We will outline a strategy to overcome this restriction. We will also discuss application of our sea ice thickness estimation method to Arctic Seas (e.g. Kara Sea).

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Sea Ice SAR Data and Segmentwise Edge Features

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Sea ice types in SAR images are best described by the edges present in the images. The type and amount of edges give us information on the ice types, in addition to backscattering statistics. Here we present a classification scheme for sea ice SAR data, based on edge detection and edge-based features.

We first perform a speckle filtering, which is based on a simplified version of an anisotropic diffusion filtering. Then an intensity-based segmentation is applied in full image resolution (high resolution segmentation). Also lower resolution segmentations are produced. Two lower resolutions are used, we here call them the medium and the low resolutions, respectively. The two lower resolution segmentations are derived from the high-resolution segmentation by iteratively joining smaller segments to their neighboring larger segments. The condition for joining segments is based on a (dynamic) threshold for the contrast at the segment edge. This approach is different from the generally used down-sampling approach (multi-resolution pyramid), which leads to blurring of the segment boundaries at the lower resolutions.

Some segments in the full-resolution are actually small ice features or small uniform ice field details, the medium and low resolutions are more suitable for statistical classification of the segments. The classification resolution depends on the size of the elementary features. Three resolutions are necessary: the high resolution includes small ice details or features as single segments in addition to larger uniform ice segments, in the lower resolutions these small features are incorporated as parts of the segments, i.e. are features describing the segment contents. The medium resolution can be used for statistical classification based on pixel-wise edge features, and the low resolution can be used for classification based on larger-scale segment (edge) features (areal ice statistics).

The edges are located using the Canny edge detection algorithm.The edges can be divided into structured edges and random, structureless edges. Also the corner points detected by the Harris corner detection algorithm are used as pixel-wise elementary features. The amounts of corners and structured vs structureless edges given information of the local ice structure. Also the local amount of detected edges gives information on the local ice deformation. We also show that open water areas can be located based on these edge features.

The segment shape also gives information on the segment, e.g. ice floes typically can have polygonal or round shape, and ice ridges and cracks or leads typically are narrow but long segments, often they are not straight lines, however. The segment shape can be described by shape features based on the segment edges. The segment shape features in our approach are computed from the ordered edge points sampled along the edge. Then the object shape can roughly be characterized by the polygon defined by the sampled set of the edge points and multiple useful features based on this representation can be computed for the ice type classification.

We have collected C-band SAR data, both Radarsat and Envisat ASAR data over the Baltic Sea and also over the Arctic Sea areas for our studies. The data are Radarsat ScanSAR wide mode data and Envisat ASAR wide swath mode data. These data have a resolution of about 100 m and each image covers an area of about 500 km wide, thus suitable for operational sea ice monitoring. We show classification results over the Baltic Sea and over Kara sea, using our data sets, and compare the results with ice analyst interpretations.

ShipSensorNet – using ships as sensors in winter navigation

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Information about prevailing ice and weather conditions is important for all operations in ice-infested sea areas. Frequent observations about the ice field are valuable to enhance and update the latest view based on satellite imagery and model results.

In the ShipSensorNet project a prototype system of using ships and coastal stations as a sensor network was designed and tests conducted during the winters 2008 and 2009. The system collects automatically near real-time information about the ice field, processes, analyzes and combines the information with other data sources on server-side, and delivers enhanced information back to ships and other users, like ice services and maritime authorities (Figure 1). The collected information includes ship performance observations and terrestrial marine radar images. Ships going in ice are affected by the resistance of the ice field, so their performance, i.e. the speed vs. used machine power, can be used as an indicator of ice resistance. On the other hand, radars on board and on coastal stations provide an additional source of information to derive ice field properties.

The radar image collection prototype system was tested at the Raahe coastal station in 2008 and on board rv Aranda and the icebreaker OTSO in 2009. Different visualization techniques were tried during the project. Algorithms to build larger mosaics from the limited area radar images were also implemented. An important processing element was to derive ice drift from a sequence of radar images.

The experiences of the prototype system give valuable information about the possibilities to acquire real-time information about the ice field in areas with frequent ship traffic and how to use this information in ice routing.

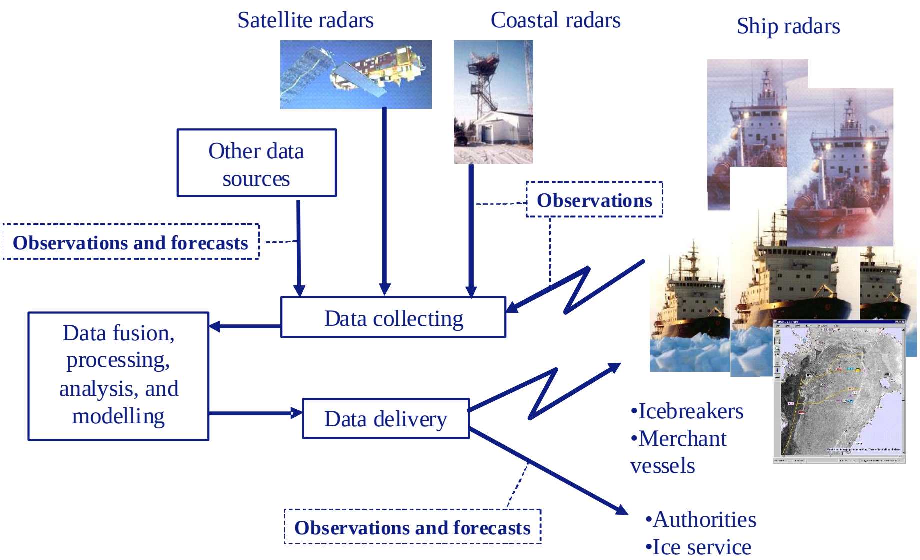

Figure 1. The concept of ships as a sensor network to observe ice field properties.

Instruments

L-band Imaging Radiometry with Airborne HUT-2D Interferometer – From the Performance to Remote Sensing Applications

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Airborne radiometer system HUT-2D, operated by Helsinki University of Finland (TKK), stands for a new technology in the field of remote sensing. Applying the novel principles of interferometry and aperture synthesis, the instrument is capable in multi-angular airborne measurements at L-band, 1.41 GHz to be exact [1]. The most important environmental parameters desired from the measurements of this low frequency band are soil moisture and ocean salinity, both essential to climatology.

After finalization of instrument's construction and functional tests in 2007, HUT-2D has participated in several soil moisture and ocean salinity measurement campaigns. The instrument performance has given valuable new information on the new technology it stands for [2], [3]. HUT-2D resembles European Space Agency's (ESA) Soil Moisture and Ocean Salinity (SMOS) mission payload. ESA has been an important subscriber of instrument's measurements, as well as co-operator in the development and design of the instrument and its test campaigns.

Measurements of soil moisture and ocean salinity require progressive radiometric performance from the system measuring them. On a conceptual level, aperture synthesis radiometer provides improved angular resolution and simultaneous multi-angular measuring capability with the cost of system complexity, and especially, decreased sensitivity and radiometric resolution. In fact, applicability of the technology on the demanding retrieval of the climatologic parameters hasn't been well demonstrated. One purpose of HUT-2D is to consolidate this retrieval, and the related algorithms.

In this paper, we present the general characteristics of the HUT-2D instrument and introduce the scientific test campaigns, in which the instrument has participated. We present the recently updated radiometric performance characteristics of the system, assessing instruments sensitivity, resolution, accuracy and stability. We analyze the instrument performance from the remote sensing applications point of view, and propose guidelines in the planning of future measurement campaigns with the instrument.

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ESTCube Mission — Testing the Electric Sail with the First Estonian Satellite

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The ESTCube project [1] is a joint effort of the University of Tartu, the Tallinn University of Technology, and the Estonian Flight Academy. The project was initiated in Tartu. The goal of the project is to launch Estonia's first satellite, ESTCube-1, into orbit by the year 2012. The project team consists mainly of students of the aforementioned institutes, but students from the University of Surrey (UK), the International Space University (FR), and the Aachen University of Applied Sciences (DE) are taking or have taken part in the project.

ESTCube-1 will be based on the Cubesat standard [2]. The standard was primarily designed to serve the needs of the student satellite teams. The basic Cubesat, or the single Cubesat, is a cube with the dimensions $10\times10\times10$ cm^3. Its mass must not exceed 1 kg.

Unlike most student satellite projects, the ESTCube mission has quite ambitious scientific goals. ESTCube-1 will perform the first in-orbit test for the Electric Sail concept. The electric sail is a novel spacecraft propulsion method, which was invented and is currently being developed at the Finnish Meteorological Institute (FMI) [3, 4]. The electric sail consists of thin, conductive tethers, which are held at a high positive potential. The sail gets its thrust from the charged plasma flow of the solar wind. ESTCube-1 will contain one such tether, the length of which in this test mission will be approximately 10 meters. The primary objective of the mission is to test the deployment of the tether. The principle of the deployment is similar to that of the actual spacecraft; the satellite will spin around its axis and the tether is deployed with the help of the centrifugal force. The secondary objective is to measure the electric sail force as the satellite and the deployed tether move through the ionosphere plasma. The satellite also has an on-board camera. The main task of the camera is to photograph the deployment. Once this has been successfully done, the satellite will be oriented to enable the camera to take pictures of the Earth.

The subsystems of the satellite include the structure, attitude control, power system, thermal control, communications (including space and ground segments), command and data handling, and the payload. The design of each subsystem is handled by a dedicated team of students. The design and manufacture of the tether payload is handled by an international team, coordinated by FMI. The team includes members from FMI, the University of Helsinki, the University of Jyväskylä, and the German Aerospace Center (DLR). In addition, the project includes working groups for the issues of space environment and project management.

Currently the project has gone through phases 0 (mission analysis) and A (feasibility study). Phase B (preliminary definition) started in October 2009. The first hardware tests of the space segment have been scheduled to commence during 2009. The ground segment (the ground station used for communications) is nearly completed. The launch has been scheduled to 2011 and the mission is expected to reach its end by the end of 2012.

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Enhancing Satellite Data Reception Capabilities in FMI Arctic Research Centre at Sodankylä

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Finnish Meteorological Institutes's Arctic Research Centre (FMI-ARC) own and operates satellite receiving station in its Sodankylä facilities. With the current 2.4 meter antenna FMI receives the direct data downlink from NASA's EOS Aura and EOS Terra, and EOS Aqua spacecrafts. EOS Aura spacecraft has OMI instrument on board measuring atmospheric ozone column. The OMI data is downlinked to Sodankylä simultaneously as it is measured for Very-Fast-Delivery (VFD) data products of ozone content above Finland and northern Europe. Direct downlink of MODIS data from EOS Terra and EOS Aqua is also received and data is distributed to scientific users in Finland.

With the current antenna, it is possible to receive the downlink from two spacecrafts without conflict. With some re-scheduling, the capability can be increased to accommodate third spacecraft. However, the data rate of the current system is limited and the satellite data dumb, cannot be received. In order to enhance its reception capability, FMI has initiated a development project to procure, install and test a new ~7-meter satellite reception antenna and relevant receiver hardware to enable the reception and data processing of the data dump from various satellites.

The new satellite receiving station and data processing facilities will facilitate the development of independent environment observation system that enables Finland to prepare for natural disasters as well as weather and climate induced emergencies more efficiently. Potential applications and uses of the system are for example: flood detection, ice monitoring in the Baltic Sea, forest fire detection, oil-spill monitoring, and snow cover analysis and various other remote sensing applications.

With current antenna and facilities, FMI has already extensive co-operation with NASA, ESA, EUMETSAT and KNMI. With the new antenna and the infrastructure, it will be possible to receive and to process data from several new space missions. Concrete co-operation plans already exists with current partners, as well as new partners like China and Canada. The new antenna also opens the possibility for FMI to provide satellite data reception and data processing services to various parties both domestically and internationally.

The Finnish and international calibration/validation activities of high-resolution Earth remote sensing instruments

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Modern imaging techniques enable accurate assessment and monitoring of geometric and radiometric properties of the Earth surface. Important high-resolution sensors include the high-resolution multi-spectral satellite sensors (e.g. Ikonos and GeoEye), large-format airborne photogrammetric multi-spectral sensors (e.g. DMC from Intergraph and ADS40 from Leica Geosystems), medium-format photogrammetric multi-spectral sensors (e.g. DSS from Trimble), and hyper-spectral imaging systems (e.g. AISA from Specim).

Imaging sensors and systems should be radiometrically and geometrically calibrated, characterized and validated, in order to make reliable quantitative interpretations from the images and to make monitoring and change detections from imagery collected at different times and with different sensors. A feasible approach for the operational sensor/system validation is to utilize permanent test fields. Objectives of this presentation are to present the current activities of the Finnish Geodetic Institute (FGI) as well as international activities in the field on calibration, characterization and standardization of passive, high-resolution Earth remote sensing systems, to the Nordic remote sensing community.

FGI has a long tradition in building and maintaining test fields for radiometry and geometry; the most extensive achievement of the FGI is the world famous, permanent photogrammetric test field in Sjökulla, which has been in operation since 1994 [1]. Current important activities of the FGI include vicarious calibration/validation studies of various sensors and material studies of reflectance targets; FGI is also considering of constructing a new test field for high-resolution remote sensing instruments and participating international activities in this field. Important international calibration/validation activities include the work by the European digital aerial camera certification (EuroDAC) group established by the European Organization for Spatial Data Research (EuroSDR) [2], the International Society for Photogrammetry and Remote Sensing (ISPRS) [3], the Committee on Earth Observation Satellites (CEOS) [4, 5], the European Fleet for Airborne Research (EUFAR) [6], and the International Organization for Standardization (ISO) [7, 8].

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UAV

MD4-200 Unmanned Aerial Vehicle and Retrieval of Bidirectional Reflectance Factor from Aerial Photographs

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Unmanned aerial vehicles (UAV) offer numerous new appealing possibilities for remote sensing applications, when compared to conventional manned aerial vehicles. By deploying UAV based instruments during field campaigns the operators can more freely choose optimal timing and location for the remote sensing measurement, the legislation and regulations for operating an UAV are not as strict as for larger aerial vehicles, and the costs for single flight are minimal.

The possibilities of a highly automated UAV, model md4-200 by Microdrones Gmbh, Germany, have been researched at Finnish Geodetic Institute. The model is capable of carrying 200-300 grams of payload, depending on wind conditions; it has a sophisticated flight controller, capable of conducting pre-programmed aerial photography missions; and has an onboard inertial measurement unit with a data logger. Currently the onboard instrumentation is limited to a small digital camera, Ricoh GR Digital II.

The UAV equipped with the camera has been used during several research expeditions in conjunction with other instrumentation, including Finnish Geodetic Institute Field Goniospectrometer (FIGIFIGO) and several airborne instruments. The current UAV setup is developed for taking multiangular reflectance measurements from large (some meters) samples of ground surface. After rigorous calibration the data measured using the UAV setup has been found to correlate strongly with a similar sample measured with FIGIFIGO (Fig. 1).

In this presentation some preliminary data from Snortex 2009 (FMI-ARC, Sodankylä, Finland) field campaign will be presented. Also during this presentation the technical aspects of the UAV will be demonstrated.

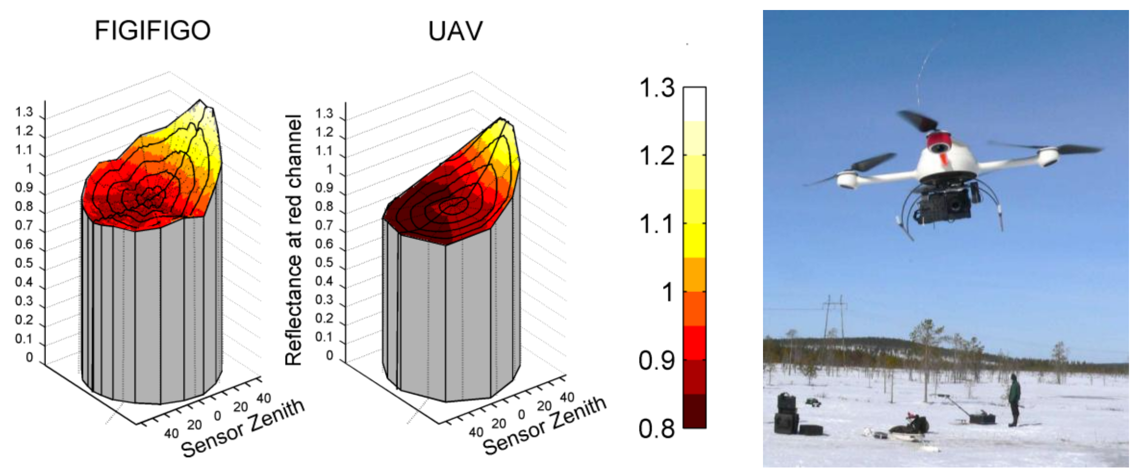

Fig. 1, Left and middle: Bidirectional reflectance factor of smooth snow measured simultaneously with FIGIFIGO and the digital camera of the UAV during Snortex 2009. Both measurements show similar increased reflectance in forward direction. Right: A picture of the md4-200.

New Hyperspectral Imager for Light Weight UAVs – First test flight results

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VTT Technical Research Centre of Finland has earlier developed hyperspectral push broom imaging technologies based on Prism-Grating-Prism components or on aberration corrected holographic gratings. In many applications however it would be beneficial to produce 2D spatial images with a single exposure at a few selected wavelength bands instead of 1D spatial and all spectral band images like in push broom instruments. Lately, VTT has developed a new concept based on the Piezo actuated Fabry-Perot Interferometer to enable recording of 2D spatial images at the selected wavelength bands simultaneously and to reduce the size of the hyperspectral spectrometer to be compatible with light weight UAV platforms. In our spectrometer the multiple orders of the Fabry-Perot Interferometer are used at the same time matched to the sensitivities of the image sensor channels. For example in a Bayer pattern RGB sensor or in a three CCD videocamera based on a wavelength separation prism there are different types of pixels for three wavelength channels. We have built prototypes of the new spectrograph fitting inside of a 30 mm cube and with a mass less than 50 g. The operational wavelength range of built prototypes can be tuned in the range 400 – 1100 nm and spectral resolution is in the range 5 – 10 nm @ FWHM. Presently the spatial resolution is 480 x 750 pixels but it can be increased simply by changing the image sensor. The hyperspectral imager records simultaneously a 2D image of the scenery at three narrow wavelength bands determined by the selected three orders of the Fabry-Perot Interferometer which depend on the air gap between the mirrors of the Fabry-Perot Cavity. The air gap value is determined using a capacitive measurement and changed under closed loop control with three Piezo actuators. The effective aperture the Fabry-Perot interferometer is 7 mm in diameter and the air gap can be controlled in the range 0.8 – 3.5 µm enabling the use of the wide range of interferometer orders. The new hyperspectral imager prototype will be used on UAV test flights in September 2009 in co-operation with the Mekrijärvi Research Station of University of Joensuu, Pieneering Oy and Flemish Institute for Technological Research (VITO). The results of these trials will be presented at the conference.

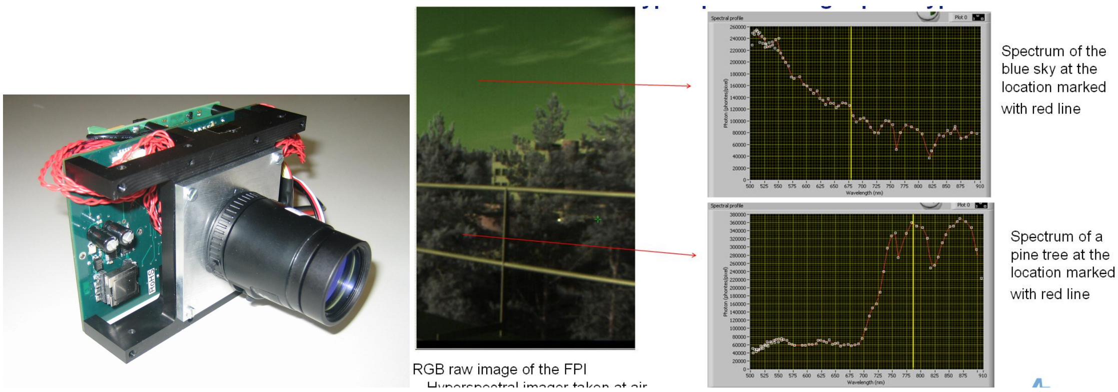

Figure 1. A photograph of the new UAV compatible Hyperspectral Imager prototype with a mass of 350 g. An example of a hyperspectral data cube recorded from laboratory window is shown on the right. The spectra of a blue sky and a pine tree are plotted.

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Automatic georeferencing of a UAV carried small format camera

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A fundamental task in any Earth remote sensing application is the georeferencing of the imagery. In this presentation, we establish a georeferencing approach developed for the Finnish Geodetic Institute's (FGI) UAV-imaging system consisting of a quadrocopter type Microdrone md4-200 UAV and a Ricoh GR Digital II low-cost RGB compact camera. The use of different types of unmanned airborne vehicle (UAV) based airborne imaging systems are rapidly increasing in various applications. The characteristics to the FGI's system is high flexibility; it can be operated from different flying heights (1-100 m), with various flying speeds (also in stop-and-go mode), in different orientations (nadir and oblique imagery), in different temperatures (summer to winter), and in different conditions. Because of the flexibility, the system is usable in a wide variety of applications, e.g. snow monitoring, building modelling, forestry, agriculture and bidirectional reflectance factor measurement.

The georeferencing process has been realized in the FGI's photogrammetric software environment. The backbone of the environment is the BAE Systems Socet Set software, which has been extended with various commercial and in-house developed components. The steps of the georeferencing process are: 1) determination of approximate orientations, 2) refinement of the approximate orientations using automatic tie point measurement and self-calibrating bundle block adjustment, 3) measurement of an object surface model and 4) production of georeferenced image products, such as orthophotos, photorealistic surface models, and stereo models (Figure 1).

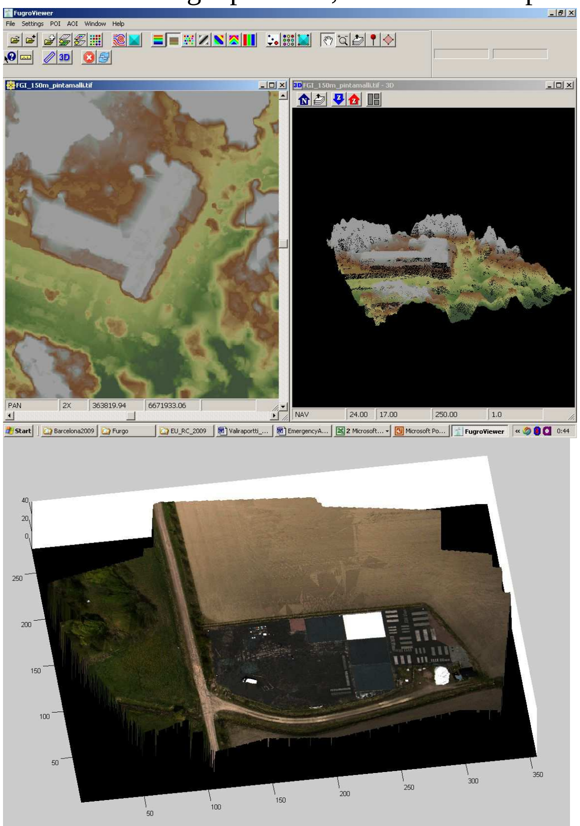

Figure 1. a) A 3D surface model of the FGI main building produced from Microdrone/Ricoh imagery using photogrammetric techniques. b) A photorealistic surface model from the Sjökulla test field.

There are system, object and condition dependent challenges in the georeferencing process, which required tailoring of standard commercial software environment. The system dependent challenges include the poor quality of the approximate orientation information and the large geometric distortions of the images. Examples of the object dependent challenges are the perspective problems with 3D objects and the poor texture in snow monitoring applications. The rapid orientation changes caused by gusts of wind and poor illumination are significant condition dependent challenges. The level of automation of the georeferencing process varies from completely automated to different levels of semi-automated, depending on the complexity of the task. High georeferencing accuracy can be obtained from the imagery.

ACKNOWLEDGEMENTS
We are grateful to Jouni Peltoniemi, Juha Suomalainen and Teemu Hakala, who have built the UAV-system and provided the imagery for this study. Ministry of Agriculture and Forestry of Finland is acknowledged for the financial support.

Atmosphere

Intercomparison of O3M SAF OUV and OMI/Aura OMUVBL3 Surface UV Products

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The offline surface UV product (OUV) of the Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M SAF) is produced operationally during 15-year EUMETSAT Polar System programme using the measurements of the three Metop satellites. UV product is based on the O3M SAF near real time total column ozone product derived from Metop/GOME-2 measurements. OUV is a global gridded (level-3) product. The diurnal cloud cycle needed in calculating the daily UV doses is sampled using Metop/AVHRR level 1b products in the morning side and NOAA/AVHRR level 1b products in the afternoon side. Included in the product are daily doses and maximum dose rates of integrated UV-B and UV-A radiation together with values obtained by different biological weighting functions.

Aura OMI Level-3 Global Gridded Surface UVB Irradiance product (OMUVBL3) is processed at Finnish Meteorological Institute. The input data for UV products is level-2 OMI total ozone product (OMTO3) derived from measurements from Ozone Monitoring Instrument (OMI) nadir viewing spectrometer. OMI is a contribution of the Netherland's Agency for Aerospace Programs (NIVR) in collaboration with FMI to the EOS Aura mission. OMUVBL3 is global surface UV product including local solar noon irradiances at 305, 310, 324 and 380 nm, as well as erythemally weighted irradiance. In addition, erythemally weighted daily surface UV dose is included.

In this presentation, we present the intercomparison results for these two products for the period of two years from June 2007 to June 2009. Erythemally weighted daily doses and daily maximum dose rates are compared. In addtion, differences in the products and contributions of different error sources to the product errors are discussed.

Retrieving ozone partial columns from HIRS measurements

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The High Resolution Infrared Radiation Sounder HIRS/4 is an atmospheric sounder for temperature and humidity profiles, surface temperature, cloud parameters and total ozone. HIRS/4 has 19 infrared channels (3.8-15 μm) and 1 visible channel. HIRS has been onboard NOAA satellites since 1979, and is also included in the payload of the two first Metop satellites of EUMETSAT. The HIRS instruments can, therefore, provide long time-series of ozone data.

This presentation will focus on the HIRS/4 that was launched onboard the Metop-A satellite in October 2006. Metop-A is the first of three satellites of the EUMETSAT Polar System (EPS). The current HIRS Total Ozone product algorithm of the Ozone and Atmospheric Chemistry Monitoring SAF (O3M SAF) developed by Meteo France is based on a regression method. Here we present a new version of the retrieval scheme for ozone partial column amounts. The HIRS 9.7 micron ozone absorption band is used in conjunction with other HIRS thermal infrared bands to obtain temperature, water vapour and ozone profiles. The partial column ozone is integrated from the profile data. The retrievals are based on the optimal estimation method [1] using the NWP SAF RTTOV 8.7 Radiative Transfer model and Met Office 1DVar code.

The first results using the optimal estimation method for retrieving ozone amount from HIRS radiances and comparison of retrieved ozone partial columns to ozone soundings and ECMWF ERA Interim ozone fields will be presented.

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Atmospheric remote sensing at FMI

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Finnish Meteorological institute has participated actively in several satellite instrument projects targeted for measuring atmospheric composition and dynamics in the middle atmosphere. During recent years also satellite remote sensing of air pollution and green house gases has become attractive. In this presentation we show highlights of GOMOS, OSIRIS, OMI and GOME-2 measurements and discuss FMI's plans for participating future satellite projects.

An Urban Morphological Database Created Using Remote Sensing for Modeling of Atmospheric Dispersion and Micro-Meteorology

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The transport of momentum, heat and pollutants over urban areas take place within an atmospheric boundary layer (ABL). The mixing properties of the ABL depend strongly on the ground-air interactions, and thus on the surface morphology. Computational Fluid Dynamics (CFD) models of various degrees of description of involved physical processes are used in studies of the ABL processes over urban areas.
In large-scale models the surface morphology is typically modeled by means of simple scalar measures of surface roughness. This is a highly simplified approach and cannot provide new insight into the details of the ground-air interactions processes taking place in the lowest part of urban ABL, the roughness layer. To understand these processes and to assess and further develop better simplified models for them, so called obstacle resolving numerical simulations are needed. This means that a morphology model of the urban area is required [1].
In this study a morphological database is created for the city of Paris, France, based mostly on remote sensed data. The database has two resolution levels and areas. A high resolution area is located in southern Paris in the vicinity of Place d'Itale and its area is 6x3 km^2. The coarse resolution area is the whole Paris inside beltway and its surroundings, an area of 13x10 km^2.
The database is created using Optical images, digital maps and SAR interferometry. The sources of optical images and digital maps are public internet map services e.g. Google Maps and Microsoft Virtual Earth. SAR images are obtained from ESA's Envisat ASAR instrument. Another public source for the morphological database was NASA's SRTM database.
The database consists of several layers. These layers hold information from streets and roads, parks and cemeteries, water bodies, buildings, trees, terrains digital elevation model as well as building height. The layer extraction and creation methods include supervised classification and interferometric coherence manipulation [2].

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Multiyear observations of the middle atmosphere by the GOMOS and OSIRIS instruments

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We present observations of the middle atmosphere from the OSIRIS/Odin and GOMOS/Envisat instruments. Both instruments measure the vertical structure of the atmosphere for chemical species such as O_3 and NO_2 and achieve global coverage. We have already obtained almost a decade of measurements and over one million atmospheric profiles.

GOMOS (Global Ozone Monitoring by Occultation of Stars) is a stellar occultation instrument with superior vertical resolution and high accuracy/precision during night observations. The stellar occultation method offers several advantages such as accurate pointing and self-calibration. The GOMOS inversion problem is also relatively straightforward to solve.

OSIRIS (Optical Spectrometer and Infrared Imaging System) measures limb scattered UV-visible sunlight during daytime and features good signal to noise ratio. On the other hand, the modelling of the multiple scattering of photons is a challenging task.

These two totally different measurement methods are able to provide e.g. highly consistent ozone measurements. Thus, the instruments may contribute to the long time series of high resolution ozone profile measurements started earlier, for example, with the SAGE instruments.

Classification of meteorological and non-meteorological targets with principal component analysis applying conventional and polarimetric measurements and their texture

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Classification of hydrometeor types based on measured conventional quantities (dBZ, V, W, SQI) and frequently available polarimetric quantities (ZDR, LDR, RHO, KDP or PHI) at each radar bin has been found to give useful information for the purposes of quantitative precipitation estimation (QPE). Even more significant seems to be the obvious ability of radars equipped with polarization diversity to diagnose and quantify specific precipitation types and phenomena (e.g. hail, melting snow, attenuation) and non-meteorological targets (e.g. birds, insects, sea clutter, external emitters). The type of scattering medium should be diagnosed by applying a probabilistic scheme for the purpose of quality control of hydrological radar products. A useful application of radars can also be the production of specific diagnostic of birds and insects, e.g., for the purposes of flight safety and preventive actions against immigration of pest insects. Thus detailed classification of non-meteorological targets is important but so far not much work has been devoted to it. It also appears that fuzzy single bin member functions are not necessarily sufficient for a detailed classification of radar targets even with the extended set of polarimetric quantities. We have extended the existing polarimetric fuzzy classification schemes in two aspects: (1) The number of target classes has been increased to several dozens. Examples of such fine-tuned classes are nocturnal songbird migration, arctic duck migration, anomalous sea clutter, daytime insect migration and melting convective snow. Frequency distributions of the quantities given above were calculated for each class. As is already known many of the polarimetric quantities exhibit quite different probability distributions (membership functions) when various target classes are compared. (2) In addition to single bin properties we also observe the texture of all the measured quantities in a small region surrounding each bin. A number of filters that quantify various textural properties of the local pixel neighborhood like graininess or presence of borders were designed and applied to a manually selected and classified set of radar observations. The resulting high-dimensional (up to 85) data set was studied with Principal Component Analysis (PCA) to identify a subset of dimensions with optimal resolving power for each class. The obtained PCA hyperellipsoids provide a natural metric for non-local class member functions. The selection of training areas from PPI and RHI images of a polarimetric C band radar has been performed by very experienced radar researchers and by applying external weather data. The classification used is conditional with respect to the signal processing applied in the sense that only bins with available dBZ data after Doppler filtering have been accepted as objects for classification. Unfortunately no validation results applying independent data sets are yet available while writing this but the results with dependent data are quite promising.

BALTRAD – an Advanced Weather Radar Network in the Baltic Sea Region

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BALTRAD is a three-year EU project developing a real-time radar network for the Baltic Sea Region. The project partnership constitutes national weather services in Finland and Denmark, with both weather and hydrological services in Sweden, Estonia, Latvia, Poland, and Belarus.

BALTRAD delivers value-added precipitation information to improve short term weather forecast. It provides a durable and sustainable element of regional infrastructure, attracting local and regional authorities to use the forecast to improve their services. BALTRAD represents the first dedicated international weather radar networking project funded with European money (INTERREG IV B, the Baltic Sea Region). However, the technical concept has already been proven once before, with the establishment of the NORDRAD network around 20 years ago.

The goal is to achieve a network where data is exchanged on equal terms and where each institute hosts a processing node. One of the key concepts is that the nodes are technically similar processing frameworks, hence supporting easy interchange of product generators ie. implementations of meteorological radar algorithms. In addition, each processing node can be configured according to local needs. The new network will increase current coverage, time and space resolution as well as support for data quality information and dual-polarization data.

The BALTRAD project was launched on 1 February 2009, and it will continue until 31 January 2012. The Swedish Meteorological and Hydrological Institute is leading the project. The Finnish Meteorological Institute is responsible for the product generation framework as well as for project communication.

Tracking of Thunderstorms through Weather Radar and Lightning Location Data

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Thunderstorms cause damage and economic losses throughout the world. As a local and rapidly changing phenomenon, forecasting of individual thunderstorms is difficult. For instance, conventional numerical weather prediction models are inefficient in this task. Therefore, doing spatially accurate short term prediction, i.e. *nowcasting*, of thunderstorms is important in the current weather forecasting.

Storms can be identified efficiently through spatially and temporally accurate remote sensing instruments, such as weather radar. Therefore, these data sources are frequently applied to the nowcasting of thunderstorms. For a human observer, following the movement and development of individual storms from weather radar images is usually not a difficult task. This, however, is not the case if the task is given to a computer.

A popular computer vision based approach to the nowcasting of thunderstorms is *object tracking*. The aim of the object tracking based nowcasting is to capture the trajectory of a storm, which can be applied to estimate velocity of the storm and consequently its movement.

In addition to the storm motion, the tracking approach is able to capture other essential parameters of individual thunderstorms. As an example, we may automatically estimate how much lightning a storm is producing or how intense it is with respect to different radar parameters. This is an important advantage over other computer vision based nowcasting techniques, which usually estimate the movement of the whole image pattern but are unable to analyze individual storms.

In here, a clustering-based object tracking method, which employs spatially and temporally accurate weather radar and lightning location data, is proposed for the nowcasting and monitoring of thunderstorms [1,2]. Since both weather radar and lightning data contain occasional errors, the fusion of these information types consolidates the tracking.

The method can be applied to several practical problems. Primarily, the automatic storm tracking and extrapolation facilitates human made monitoring and prediction of storms. Secondly, by means of the tracking method we can estimate life cycle phases of a storm and deduce if the storm is dissipating or intensifying. Furthermore, the method can be applied to the acquisition of extensive data sets, which can be utilized in the statistical analysis of thunderstorms.

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Quantifying gravity waves and turbulence in the stratosphere using satellite measurements of stellar scintillation

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Stellar scintillations observed through the Earth atmosphere are caused by air density irregularities generated mainly by internal gravity waves (GW) and turbulence. The strength of scintillation measurements is that they cover the transition between the saturated part of the gravity wave spectrum and isotropic turbulence. This allows visualization of gravity wave breaking and of resulting turbulence. We analyzed the scintillation measurements by GOMOS fast photometers on board the Envisat satellite in order to quantify GW and turbulence activity in the stratosphere.

The analysis is based on reconstruction of GW and turbulence spectra parameters by fitting the modeled scintillation spectra to the measured ones. We use a two-component spectral model of air density irregularities: the first component corresponds to the gravity wave spectrum, while the second one describes locally isotropic turbulence resulting from GW breaking and other instabilities. The retrieval of GW and turbulence spectra parameters - structure characteristics, inner and outer scales of the GW component - is based on the maximum likelihood method.

In this presentation, we show global distributions, seasonal and interannual variations of the GW and turbulence spectra parameters retrieved from GOMOS data in 2002-2005, for altitudes 30-50 km. In addition, we show global distributions of GW potential energy per unit mass and of turbulent structure characteristic C_T^2. In our presentation, we pay special attention to gravity wave breaking. Since other measurements at such small scales are very scarce in this altitude range, the obtained global distributions provide unique and complementary information about small-scale air density irregularities in the stratosphere.

Commercial applications

BlomURBEX – Blom's Unique Oblique Data Base

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Blom is one of Eurepe's largest aerial survey companies and providers of geospatial products, applications and services. Blom has offices in 12 European countries and operates 33 aeroplanes and 4 helicopters with more than 1 000 employees. Blom's business areas are aerial photography, laser scanning, mapping and modeling, Pictometry®- navigation- and database services.

Blom has captured Pictometry® oblique and ortho imagery over more than 1 000 biggest cities in Europe. The imagery covers more than 80 % of Europe's population. Capture started in 2006 and 2009 was the fourth year of operations. In Finland, Blom has captured Pictometry® data in more than 30 largest cities.

Blom has built a unique oblique image data base BlomURBEX. BlomURBEX is a European wide standard product being first of its kind in Europe, all objects viewed from five angles. Blom is also introducing 3D models into the database. BlomURBEX provides better information in terms of shape, texture, and height of the surrounding buildings as a service platform covering both consumer and professional applications in the following segments: navigation, geo search, emergency services and private & public GIS. BlomURBEX is accessible via internet.

Operationalisation of Hyperspectral Remote Sensing in Finland

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In Finland, hyperspectral Remote Sensing was one of Geological Survey of Finland's interests in the early 2000s, but later since then, its activities (that were usually related with mining applications) have been limited. In the Finnish Geodetic Institute, spectrometry has been and is being developed. VTT, Specim Oy and HUT have developed e.g. the AISA imaging spectrometers. Certain spaceborne acquisitions have been conducted. Nevertheless, there has been no stable domestic hyperspectral aerial service provider in Finland. There are recognised needs, and the hyperspectral application field as a whole has been a promising solution, but the practises have taken a long time to become operational.

Some challenges of hyperspectral imaging (HSI) are

- atmospheric corrections
- that good conditions and many ground references are needed
- that in Boreal areas, dense vegetation cover hinders from mapping the ground
- taking reflectance anisotropy (the BRDF effects) into account
- that processing of hypersectral imagery may be specific and time-consuming
- management of localised spectral libraries

For the summer of 2008, Pöyry Environment Oy organised a hyperspectral campaign where especially a large area in the Rauma–Pori region was acquired with a 2.5 m spatial resolution. The area is globally one of the biggest continuous hyperspectral areas acquired, and the data can be used as a source and reference for various studies.

The campaign has brought new logistical and technical experience. Using foreign operators is possible also for large projects (lasting longer than a few days for which the weather forecasts are reliable). Domestic service providers would be more flexible to mobilise, but this time they weren't able or willing to setup hyperspectral instruments expect for very large projects.

Hyperspectral applications that are suitable for the Boreal region should be recognised and further developed. There are promising ones e.g. in the fields of forest inventory, vegetation health, water quality, and mining. There is a need to demonstrate what information is possible to extract from hyperspectral imagery – which is more than from using traditional instruments and methods! Combining HSI with airborne laser mapping projects is possible, too.

Costs of hyperspectral acquisitions can be cut down for example by developing the workflows during projects, calibration, and by benefitting from the synergy of common campaigns. For 2010, another campaign is being planned and implemented depending on the interests and available budgets. Pöyry Environment follows the availablility of available operators, instruments and methodologies.

"KSAT's integrated services: Ground Station to End-user"

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Kongsberg Satellite Services AS (KSAT) is a commercial Norwegian enterprise, providing services based on data from polar orbiting satellites such as Telemetry, Tracking and Command (TT&C), Global data dump and Operational Earth Observation. The company currently operates four ground stations; the Tromsø Station at 69°N, Svalbard Satellite Station at 78°N, Grimstad (South Norway) at 58°N and TrollSat 72°S (Antarctica). These stations all have direct data capture systems that acquire the raw data from the satellite directly to disks. KSAT downloads data from more than 50 Earth Observation satellites.

KSAT provides operational satellite based near real-time services within the maritime sector, such as oil and vessel detection where information to customers is guaranteed to be within 30 to 60 minutes from data acquisition. KSAT has served European authorities with an operational oil spill detection service based on satellite SAR (Synthetic Aperture Radar) images since 1998. The overall aim of the service is to provide operational detection and early warning of possible oil spills and associated sources for regional environmental monitoring. A short delivery time is essential in order for the information to be useful in support to surveillance means (coastguard vessels and surveillance aircraft). Since 2006 KSAT has been leading a consortium supplying the CleanSeaNet service, an integrated multi-user service for oil spill detection, to the European Maritime Safety Agency (EMSA). Satellite based vessel detection and information from Automatic Identification System (AIS) are fully integrated into the service. The KSAT vessel detection service provides vessel positions detected in satellite images. The satellite based information is combined with other available vessel tracking systems (VTS, AIS, LRIT, VMS, etc), and the non-reporting vessels are highlighted. Such a system is proven powerful for fisheries monitoring and control purposes. KSAT is currently together with MDA Geospatial Services using the system to monitor the situation in the Gulf of Aden and Somali coastline in response to piracy issues.

KSAT also focuses on developing new services based on user requirements, e.g. real-time image access for navigation, snow cover mapping, detection and tracking of icebergs, customized multi-mission data acquisition and delivery. KSAT is currently implementing a service named DirectImage. This development is based upon direct requests from users of monitoring services for various applications that require data from several satellites in order to obtain required temporal coverage. The DirectImage service is a result of the fact that KSAT supports a very high number of medium and high resolution Earth Observation satellites including QuickBird, WorldView, GeoEye, RapidEye, Kompsat-2, Formosat-2, Envisat, Radarsat 1 and 2. These missions use KSAT and KSAT infrastructure to optimize global data acquisition with respect to data delivery timeliness and the use of on-board storage dump. By using the pole-to-pole infrastructure of KSAT, the on-board storage can quickly be acquired in order to free up space for new imagery. The Svalbard Ground Station has access to the satellites on every orbit and the Troll (Antarctica) Ground Station has access to the satellites on 12 of 14 orbits. In addition KSAT has invested in new technology to allow the users to view the images anywhere in the world, even on low bandwidths.

Green Net Finland and the possibilities for Finnish Cleantech companies

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Green Net Finland is a cleantech business network that brings together the expertise and resources of Finnish cleantech companies, scientific and educational institutions and public authorities. Our mission is to promote cleantech innovations and the growth of business, exports and expertise through public-private cooperation, networking and project development. Currently, our major thematical focus areas are environmental monitoring including remote sensing and clean energy, with a special focus on energy efficiency in urban environment. We believe in the growth of the Finnish cleantech business by combining the expertise in these sectors with the strong ICT cluster. In years 2007-2013, we are coordinating the work of the national Cleantech Cluster Programme in the Uusimaa Region as a national centre of expertise.

We are actively looking for co-operation with cleantech companies and research organizations all over the world. Furthermore, we can provide partner search and matchmaking services for foreign cleantech companies and research organizations interested in co-operation with the Finnish Cleantech Cluster. Green Net is aiming as one of its objectives to promote and help the small and medium size companies to grow in the remote sensing field by coordinating EU/ESA and national projects.

The biggest project currently coordinated by Green Net is the Innovation Pipeline project. Business from the Innovation Pipeline – Commercialization of Cleantech Innovations project was started in 2008. Now the ideas already accepted into the Innovation Pipeline are incubating into commercial products, and the inventors and companies behind these innovations have taken a big step towards international markets. Each idea will pass through the pipeline at individual speed. The three-year-long project coordinated by Green Net Finland may accept new promising ideas of environmental monitoring, remote sensing and energy and material efficiency during the entire project term, since it is possible to support dozens of different innovations in the project.

The project advances cleantech innovations by various stages which are the recognition and evaluation of innovations, product development, testing in Living Lab conditions and other testing environments as well as global commercialization. As a result of all this the project will establish an innovation system model. In addition the project will identify and solve the bottle necks related to the commercialization of innovations. The project is financed by the European Regional Development Fund (ERDF) through the Regional Council of Päijät-Häme and by a group of municipalities of Southern Finland.

Forest

Reflectance of forests: from shoots to global models

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The science of passive optical remote sensing of vegetation canopies aims to convert the multi- and hyperspectral images taken by a satellite- or airborne sensor into useful information on the amount and types of plants covering the underlying surface, their structural properties and, ultimately, biochemical composition and functioning. New instruments and algorithms are being developed constantly. As the reflectance signal of forests exhibit a strong and spatially varying effect of threedimensional canopy structure, modern methods of remotely estimating leaf area index, canopy cover and absorbed photosynthetically active radiation have come to rely on complex algorithms based on the physical processes of radiative transfer. Such physically-based canopy reflectance models are especially promising for the boreal region. The traditional approaches based on vegetation indices fail in vegetation canopies which have well-expressed multilevel structure. Some recent models implicitly include wavelength independent structural parameters, so-called 'spectral invariants'. They represent the eigenvalues of the underlying radiative transfer equation and relate canopy optical properties to leaf optical properties. Thus, they provide a powerful and innovative theoretical basis for developing canopy reflectance models, enabling to separate the effects of canopy structure and canopy biochemical composition. Knowing the empirical relationships between the invariants and different characteristics of canopy structure would allow more realistic, yet simple representations of the canopies. We present the results of the recent SPRINTER project (funded by the MASI program of TEKES and Academy of Finland) aimed at developing improved methodology for quantitative remote sensing of vegetation based on the concept of spectrally invariant parameters, and validating and applying the developed methodology on test sites in Finland and through international vegetation remote sensing networks.

Clearcut Detection between Aerial and Satellite Imagery Supporting Species-wise Forest Variable Estimates

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This study is part of the on-going NewForest project, whose objective is to develop remote sensing data analysis methods for producing species-wise forest variable estimates with accuracy that is adequate for operational forest inventory. Species-wise forest estimates relies on individual treetop locations detection from the remote sensing imagery. As ground data used for validation has been acquired at a different date as the satellite and aerial imagery, one of the first step was to identify clearcuts and thinning areas that occurred within the temporal span of all gathered data. This was done using image-based change detection.

The study area is located in Kuortane, central Finland (62°46'54"N, 23°27'49"E). Coniferous forest on mineral soil is the dominating forest type, second type being mixed forests on mineral soil. The image dataset include two sets of QuickBird images (Panchromatic at 0.6m resolution + Multispectral at 2.4m), and an aerial image at 0.5m resolution. The QuickBird images were obtained from database and dated of 07th September 2003, whereas the aerial image was acquired on 2006 by the University of Joensuu. In addition, records of clearcuts done in year 2007 in the study area was obtained from Metsäliitto and field inventory data from 2006 by the University of Joensuu. A field inventory trip was done in Kuortane in June 2009 to collect ground data. This field trip was customised for tree species classification from remote sensing images.

As preprocessing, the satellite and aerial images were co-registered one to another, using 25 ground control points and in-house rectification software InRec. The co-registration was carried out twice, by taking alternatively the satellite image or the aerial image as a reference, resulting in average RMS errors of 0.386 pixel and 1.076 pixel, respectively. These residual registration errors are compatible with high resolution change detection [2]. The size of co-registered and clipped images were 9429×11754 pixels when the aerial image was the reference, and 7858×9795 pixels when using the satellite image as a reference.

Standard change detection methods were used on the two sets of registered imagery. Baseline methods included pixel-to-pixel image difference and the use of AutoChange, a software developed at VTT for the detection of changes in forested areas [1]. A clearcut-specific change detection method was designed based on Support Vector Machines and post-classification change detection. Single-class SVM (1-SVM) was run separately on the aerial and satellite images to characterise forested areas, using a training/testing approach. The combination of classification maps obtained by changing the data source used in SVM training (satellite and aerial image, respectively) and the data source used in testing (aerial and satellite image, respectively) provided altogether a map of forested areas and of clearcuts. Thinnings detection was refined by comparison of treetop detection in aerial and satellite images.

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Edge proximity influence on radiance at forest edges on a very high resolution IKONOS winter satellite image

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In increasingly fragmented forest landscapes the influence of edges is significant. Edge effects usually consist of altered conditions of canopy openness and microclimatic conditions compared to the interior of the stand. Significant differences in tree growth, seedling establishment and ecosystem composition have been described associated with distance from stand edges. The forest edges have been treated as a function of distance from edge and the cardinal direction of the forest edge facing the open area.

The effect of forest stand edge on radiance patterns in the northern temperate forests in Estonia was studied. Radiance data were derived from very high resolution IKONOS satellite images. Our objective was to characterize the radiance contrast at the forest edges in the visible and near infrared IKONOS images. The magnitude of the effect of distance from edge was quantified as a radiance gradient that could range from steep and short (large magnitude, small distance) to shallow and long (small magnitude, large distance) in interaction with cardinal direction (solar illumination azimuth). We considered only anthropogenically created forest to non-forest edges whether maintained artificially or left for forest regeneration. Sampling consisted of transects perpendicular to well established forest edges. Forest to non-forest boundaries included in the analysis were those running more or less straight with apparently the same stands along the whole run of the transects. Forest stands more than 30 years of age were selected for this study to ensure that interior conditions of stand would be realistic for forest community. 350 edges were analyzed. Stand edges were sampled with block transects of pixel arrays parallel to the stand boundary running from 30 metres in the centre of each clearcut or open area and to 30 m deep into the forest.

The analyses of radiance contrast at non-forest to forest edges revealed the effects of stand parameters, time since edge creation (clearcut age) and azimuthal exposure on magnitude and distance of edge influence. The study points on the importance of considering specific edge effects and boundary area in landscape-scale estimations of forest change. The results are used in forest area change studies.

Peek under Forest Canopy with Polarimetric Coherence Tomography

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Polarimetric SAR interferometry (POLinSAR) [1] is a new branch of radar interferometry, which combines radar polarimetry and interferometry: it allows to locate scattering mechanisms as a function of height. Known applications of polarimetric interferometry are forest height estimation by Random Volume over Ground model (RVoG) inversion [2] and advanced 3D imaging techniques. New 3D techniques have been developied along with the multi baseline interferometric measurements. One of the simplest new 3D methods is Polarimetric Interferometric Tomography [3]. The method uses interferometric measurement of two or more baselines to estimate the shape of the scattering function inside the canopy. It approximates the vertical structure function of the canopy with Fourier-Legendre polynomial series. The approximation accuracy is dependent on the available amount of measurements, in this case interferometric baselines. The method utilizes also results achieved with the RVoG model for forest.

This project applies Polarimetric Coherence Tomography (PCT) to the FINSAR dataset and tries to clarify, under what conditions and how PCT can detect objects hidden under forest canopy. The airborne SAR measurement campaign FINSAR was arranged in autumn 2003 by Helsinki Technical University together with the Finnish Defense Forces and German DLR arranged. Among other experiments, an L-band multi-baseline fully polarimetric SAR image set was measured. The ground arrangements included three corner reflector assortments hidden in various types of forests. This part of the campaign was called FINSAR. This study attempts to reveal these corner reflectors by means of PCT.

Our study shows that, under certain conditions, objects under forest canopy are visible on the L-band interferometric tomograms. It has to be noted that in most cases when corner reflector could be certainly identified in a tomogram, the corner reflector was also visible in SAR amplitude and coherence images. However, this may not be the case when more baselines are used. At the moment there are some theoretical restrictions for the multi-baseline method and many practical shortages of the FINSAR dataset and, therefore, this claim could not be proved.

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Planning of Remote Sensing based National Forest Inventory: Comparison of alternative Materials and Data Sources in tropical area

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Reducing Emissions from Deforestation and forest Degradation (REDD) is a global commitment to mitigate carbon emissions and to compensate tropical forest countries for their efforts in achieving REDD targets. A central issue in setting up a workable REDD scheme is a balance between compensation and the cost and feasibility of accurately verifying the carbon stored. Estimating above ground carbon content in the tropical forests pose uncertainties due to the spatial coverage of the heterogeneity in forest and inherent difficulty of field based inventories.

Alternative data sources and materials were compared with two-phase sampling scheme in Lao PDR. The previous National Forest Inventory (1991-99) data and Land Use Maps (based on the SPOT satellite images) were used in describing and studying forest population. Information about spatial forest biomass variation and time studies of field work were used to determine suitable practice for field work. Alternative remote sensing materials were compared and respective need for field work was estimated for cost estimation using various R^2 assumptions in multiphase sampling approach. Modifications for ground truthing were proposed and cost of alternative remote sensing based REDD inventory systems were compared. According to current price assumptions, the most price efficient way is to use ALOS data, laser-scanning and field sample plots.

A concept for the monitoring of tropical forest

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A concept for the monitoring of tropical forest cover and biomass is presented with preliminary test results. The system combines wall-to-wall medium resolution satellite data, a sample of Very High Resolution (VHR) data, and ground plot data.

The target forest characteristics, land cover and biomass variables, are first estimated from the VHR images with the help of reference data. The maps produced are further used as reference to compute the estimates for wall-to-wall imagery.

The statistical sample of the VHR imagery together with *in-situ* measurements and the wall-to-wall estimates are finally used to compute the accuracy statistics for the inventory and possibly calibrate the wall-to-wall maps. In the model training stage the statistical representativeness does not have to be considered.

First results of the inventory concept are presented over province Savannakhet of 2.1 million ha in Lao PDR. The data applied are QuickBird and Kompsat-2 VHR imagery, AVNIR medium resolution optical imagery (10 m), and ALOS PalSAR imagery to augment wall-to-wall optical data in cloudy regions.

The study is conducted for the Ministry of Foreign Affairs of Finland and Indufor Oy as part of the ongoing project SUFORD (Sustainable Forestry for Rural Development). It will be completed by the end of October, 2009. Its predecessor activities are the GMES project Forest Monitoring in French Guiana and a proposal on a VHR resolution satellite to collect images on statistical sampling basis [1], [2].

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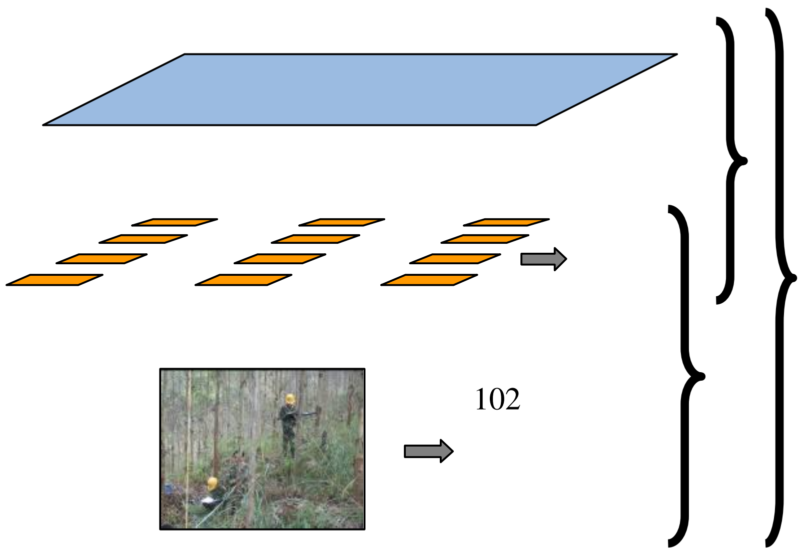

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