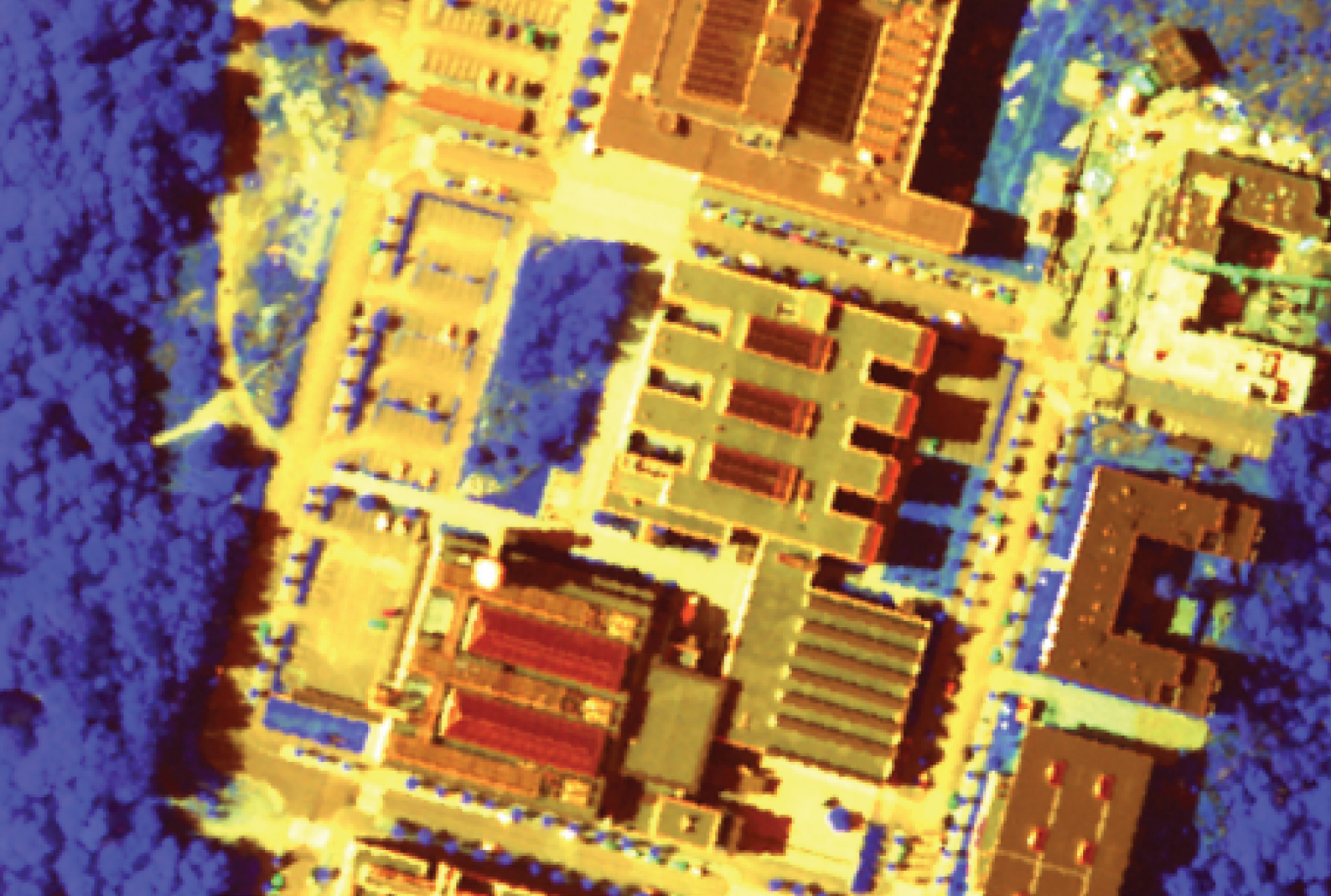




DEPARTMENT OF GEOSCIENCES AND GEOGRAPHY C7

Finnish Remote Sensing Days 2012: book of abstracts

MATTI MÖTTUS (EDITOR)



UNIVERSITY OF HELSINKI
FACULTY OF SCIENCE

Finnish Remote Sensing Days 2012: book of abstracts

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Remote Sensing Club of Finland is an informal body bringing together actors from both academic and commercial arenas. The position of the chair rotates among members. One of the most visible tasks of the Club is arranging yearly Remote Sensing Days. The event is hosted by the organization of the chair of the steering group. Thus, in 2012, Remote Sensing Days were held on the Kumpula campus of the University of Helsinki (shown in false color on the back and front covers of this book as recorded by airborne AISA Eagle imaging spectrometer in 2011).

The goal of the meeting is to facilitate nationwide exchange of information and ideas. Remote Sensing Days allow to obtain a quick overview of the diverse remote sensing activities currently underway in Finland. However, the most important goal of the event is to bring together the community involved in remote sensing research and development scattered among the many research institutions, universities, and private companies.

This book is a collection of the abstracts of the presentations given at the 2012 Finnish Remote Sensing Days held in the Linus Torvalds Auditorium in the Exactum building on October 25–26. It is a snapshot of remote sensing research in Finland in 2012 and, hopefully, helps the reader to recollect the presentations given at the meeting and to find new contacts in the Finnish remote sensing community.

Members of the organizing committee for the 2012 Finnish Remote Sensing Days – and also the steering group of the Remote Sensing Club of Finland in 2012 – were

Matti Möttus (chair, University of Helsinki)

Alfred Colpaert (University of Eastern Finland)

Jaan Praks (Aalto University)

Kari Luojus (FMI)

Kirsikka Heinilä (SYKE)

Matias Takala (FMI)

Miia Salminen (SYKE)

Mika Karjalainen (FGI)

Robin Berglund (VTT)

Timo Kumpula (University of Eastern Finland)

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Finnish Remote Sensing Days 2012. Program

Thursday, 25 October

Plenary Session

Chair: Matti Mõttus

09:00 Welcome

09:05 Jouni Pulliainen: Sodankylä satellite data centre: an initiative to establish real-time satellite data-aided services in Finland 33

09:30 Tuomas Häme: The Sentinels will make a difference in remote sensing services

09:55 Erkki Kyrölä: Studying atmospheric composition by satellite measurements 34

10:20 Pauli Stigell: Finnish Earth Observation in European programmes 35

10:45 Coffee break

Remote Sensing of Snow and Ice

Chair: Kari Luojus

11:00 Kari Luojus: Overview of snow remote sensing R&D at FMI & SYKE – work towards NRT & long term snow cover data records 36

11:20 Marko Mäkynen: Sea ice remote sensing R&D at Finnish Meteorological Institute 37

11:40 Juha Karvonen: Sea Ice concentration retrieval based on dual-polarized C-Band SAR 38

12:00 Robin Berglund: ICEMAR – a System for sea ice information delivery 39

12:20 Tuomo Smolander: Detection of soil moisture and soil freeze using microwave radars 40

12:40 Lunch

Remote Sensing of Forests: General

Chair: Mika Karjalainen

13:30 Timo Vesala (invited presentation): From flux and concentration observations to greenhouse gas sinks and sources

14:00 Heikki Astola: EUFODOS – European forest downstream services improved information on forest structure and damage – project presentation 41

14:20 Paras Pant: Spectral characteristics of hyperspectral and multispectral sensors for area based tree species classification.....	42
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Poster Bazaar

Chair: Kirsikka Heinilä

15:30 Coffee break. Posters on display

Krista Alikas: A robust Kd(490) algorithm for remote sensing of optically complex waters	13
Lea Hallik: Vegetation indices detecting the effect of climate change on vegetation	14
Henna-Reetta Hannula: automatization of a spectroradiometer measurement system for satellite image validation.....	15
Pekka Hurskainen: Application of open-source GIS and live GPS tracking for land use / land cover field data collection in Kilimanjaro, Tanzania	16
Iolanda Ialongo: Characterization of OMI tropospheric NO ₂ over the Baltic sea area.....	17
Jere Kaivosoja: UASI Potato Monitoring flight campaign preliminary results.....	18
Rigel Kivi: Atmospheric composition measurements in northern Finland and comparison with space borne observations	19
Lauri Korhonen: Modeling lidar-derived boreal forest crown cover with SPOT 4 HRVIR data	20
Andres Kuusk: Reference panel for remote sensing studies at Järvelja, Estonia	21
Petr Lukeš: biomass and species composition are tightly related to forest albedo in the boreal zone	22
Rami Piironen: Hyperspectral remote sensing in Taita Hills Kenya	23
Eetu Puttonen: Ground point labeling in a terrestrial laser scanning configuration with utilization of scanner-centered coordinate system	24
Svetlana Saarela: Model-assisted estimation of growing stock in a two-phase sampling survey utilizing ALS sample and wall-to-wall satellite optical data	25
Tuure Takala: Canopy shadow fraction estimation from AISA Eagle using spectral unmixing	26
Tuomas Tikka: Aalto-2 – An atmospheric nanosatellite	27
Harold Weepener: Forecasting outbreaks of the brown locust using rainfall estimates, NOAA images and SPOT Vegetation images	28
Xiaochen Zou: Using digital camera for measuring leaf inclination angle in crops	29
Commercial presenter: Specim OY	

Remote Sensing of Forests and Land Cover Change

Chair: Mika Karjalainen

16:15 Urmas Peterson: cross-border comparison of forest area changes caused by clear-cutting and afforestation of abandoned agricultural land using snow covered satellite imagery in northeastern Europe	43
16:35 Timo Pitkänen: Tracing variations of deciduous component over grassland–forest continuum by subpixel classification.....	44
16:55 Niina Käyhkö: Consequences of land cover transitions on the sustainability of coral rag forests in Zanzibar, Tanzania	45

17:15 Laura Sirro: Forest crown cover estimation in northern boreal and temperate European forest	46
17:35 Timo Kumpula: Detecting landuse and landcover changes in reindeer pastures using multi-source remote sensing and GIS data.....	47
18:00 Sauna at FMI	

Friday, 26 October

New Technologies in Remote Sensing

Chair: Heikki Saari

09:45 Antti Näsilä: Aalto-1 spectral imager: Design and mission	48
10:05 Maria Gritsevich: A pioneer European airborne-based observation campaign of a meteor shower	49
10:25 Lingli Zhu: Using mobile laser scanning and UAV for 3D city models	50
10:45 Eija Honkavaara: 3D hyperspectral reflectance signatures by light-weight UAVs for the monitoring and measuring the environment.....	51
11:05 Heikki Saari: UASI Summer 2012 UAV flight campaign results for forest and agriculture.....	52
11:25 Coffee break	

Remote Sensing of Forests: New Methods and Algorithms

Chair: Ilkka Korpela

11:50 Matthieu Molinier: Social Forest Planning project: summary of results 2010–2012	53
12:10 Paula Litkey: Automatic detection of storm damages in forests using airborne stereoscopic images	54
12:30 Jan Pisek: Estimating leaf inclination and G-function from leveled digital camera photography for broadleaf tree and shrub species in Kaisaniemi and Kumpula botanical gardens, Helsinki.....	55
12:50 Lunch	

Remote sensing of forests: forest structure and composition

Chair: Eija Honkavaara

13:40 Caner Demirpolat: Assessment of boreal forest cover properties from interferometric TanDEM-X data	56
14:00 Joel Kuusk: BRF of forests.....	57
14:20 Ilkka Korpela: Directional reflectance signatures in aerial images – an aid to tree species classification?.....	58

14:40 Wrap-up

Poster Presentations

A robust $K_d(490)$ algorithm for remote sensing of optically complex waters

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We developed and compared different empirical and semi-analytical algorithms for optically complex waters to retrieve the diffuse attenuation coefficient of downwelling irradiance ($K_d(490)$) and tested them against an independent data set, in order to ultimately suggest a robust algorithm that is valid for optically complex water bodies with high concentrations of CDOM.

In the first approach, developed by [1], revisited by [2], $K_d(490)$ was estimated from the empirical relation between $K_d(490)$ and the ratio of remote-sensing reflectances at two wavelengths within the visible spectrum. Due to MERIS characteristics, several bands in the longer wavelengths (560, 620, 660, 710 nm) were available to retrieve better reference conditions over CDOM dominated coastal waters. Various sets of band ratios were tested to achieve the best estimate for $K_d(490)$ where reflectance data was retrieved either using MERIS standard algorithms (MEGS) or an alternative processor for atmospheric correction and water quality parameters (FUB WeW). In the second approach, $K_d(490)$ was expressed as a function of inherent optical properties (IOP) after the algorithms by [3] and [4]. The IOPs needed as an input for these algorithms were retrieved from MERIS level 2 products (algal_2, total_susp and yellow_subs) or taken from the literature.

We compared the MERIS derived $K_d(490)$ values by various algorithms with values measured in optically complex coastal waters in the Baltic Sea which showed relatively good estimates in case of both methods. The results indicate that for empirical algorithm, the RMS (%) decreases and the coefficients of determination (R^2) increases while using the longer wavelengths in the visible spectrum for the reference band. We found that the best estimates were retrieved by using the ratio of MERIS bands $R_{rs}(490)/R_{rs}(710)$, which provides a promising approach (RMS 14%, $R^2=0.98$, $N=14$) for estimating $K_d(490)$ over wide range of values ($0.2 - 2.5\text{m}^{-1}$).

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Vegetation indices detecting the effect of climate change on vegetation

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"INCREASE" infrastructure (funded by EU 7th Framework Programme) is designed for studying long-term effects of climate change on shrubland vegetation by field experiments. Climate manipulation techniques involve experimental drought and warming treatments in field conditions using sensor-controlled curtains. Plastic curtains controlled by rain sensor are used for extended summer drought, and night-time warming is achieved by covering the vegetation with IR-reflective curtains at night (controlled by a light sensor).

We conducted reflectance measurements in Porto Conte experimental site (Italy) during April 2011 and in Mols site (Denmark) in August 2011. Canopy level reflectance was measured from nadir at 1 m height above the canopy with Field Portable Spectroradiometer SVC HR-1024 using fiber optics (FoV 8 deg.).

Majority of vegetation indices we tested were capable to detect differences between treatments at canopy scale. Vegetation on control plots appeared less stressed than in drought and warming treatment plots by Photochemical Reflectance Index (PRI). Plant Senescing Reflectance Index (PSRI) also suggested that carotenoids to chlorophyll ratio was lower on control plots than treatment plots. Drought treatment plots had lower Anthocyanin Reflectance Index (ARI) and higher Normalized Difference Nitrogen Index (NDNI) values.

Automatization of a Spectroradiometer Measurement System for Satellite Image Validation

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Accurate measurement data is vital to understand and assess the state and changes in the environment. Spectroscopy, mainly made by satellite instruments, is a well established field of research acquiring knowledge of spectral reflectance of Earth's surface utilized in several environmental applications. However, the validation of satellite data for accurate research purposes is hampered due to atmospheric and vegetation effects, coarse image resolution, and the lack of regionally extensive *in situ* measurements. This is especially true in remote polar regions.

In project NorSEN (Nordkalotten Satellite Evaluation co-operation Network) an Analytical Spectral Devices (ASD) Field Spec Pro JR spectroradiometer was mounted on a 30-meter-high mast in Sodankylä northern Finland in 2006 [1]. Mast data is providing additional information to reduce the gap between remotely sensed and ground based measurements. The measurement lens installed at the end of a turning pole enables spectral measurements between 350–2500 nm from two different locations – a forest and a forest opening.

Measurement system has suffered several long measurement breaks due to device flaws and till now the measurement procedure has been very complicated. During summer 2012 the system has been automatized by Veli-Pekka Halme and measurements can now be executed by using a single computer and a scheduled script. At the moment, spectral measurements are executed automatically every half an hour between 6–12 UTC. Measurements will be used to validate satellite data retrieval algorithms and e.g. in snow research. Every component of the measurement equipment is controlled via its own Python module which hides the technical details of the communication. Thus, the end user will be able to write a new client software without a need to know, how the devices are controlled. Measurements are taken during months with high enough solar elevation angle. To avoid problems introduced by low temperatures, high winds, and clouds, weather thresholds are set. Nevertheless, the upcoming winter will test the tolerance of the automatization in extreme conditions, and the work to develop a system to gain high-quality and homogenous spectral data will be continued.

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Application of Open-Source GIS and live GPS tracking for land use / land cover field data collection in Kilimanjaro, Tanzania

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One of the key outputs of CHIESA project (*Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa*) is the production of accurate and up-to-date land use / land cover (LU/LC) maps of the project's study areas. These maps will be used as inputs for modeling various ecosystem services, SWAT analysis, as well as to detect historical and model future LU/LC changes.

In April 2012, researchers from University of Helsinki and Clark University conducted field work in the Southern slopes and surrounding plains of Kilimanjaro, where one of the research transects is situated. The purpose of the trip was to collect ground control points for satellite image (SPOT5) orthorectification and training areas for LU/LC classifications. GPS receivers were used for real-time navigation, collection of waypoints and tracks, and taking geotagged photographs. The satellite images were roughly georeferenced with old topographic maps before the field work.

Traditionally *in situ* data collection for LU/LC mapping has been done with either a combination of printed maps, satellite images and a hand-held GPS. Alternatively a more sophisticated solution combines handheld data collector integrated with a GPS, and propriety GIS software.

The first solution is simple and robust, and works in most situations, but the drawbacks are the difficulties of positioning and orienteering with the paper prints, and being limited to the fixed scale. Making remarks on the prints is also cumbersome. The second solution is more user-friendly and effective, but the equipment and propriety software licenses are expensive and out of reach for many researchers in the developing world.

A good compromise between the two solutions was tested and found to be very cost-effective for this study case: A normal hand-held GPS was connected with an USB cable to a PC laptop, which was running QuantumGIS free/open source GIS software. With the help of live tracking integrated in the software, the car's location on the satellite image could be seen and training areas could be digitized from the satellite image straight away. Geotagged photographs taken from different LU/LC types served as an additional reference.

Collection of ground control points was also made very easy with this setup: it could be easily verified from the satellite image, if a particular road crossing was clearly visible in the image, and had remained the same since the image was taken.

Because the study area was well covered with an extensive road network, the laptop stayed inside the car at all times, and training area sampling was stratified close to the roads. The downside of this particular setup is that it is not very portable. However, it would be possible to connect the GPS to a lightweight tablet running Android OS with QuantumGIS.

We believe the above field data collection method works well especially in developing countries, and it is very cost-effective since no expensive equipment or software is needed.

Characterization of OMI tropospheric NO₂ over the Baltic sea area

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The tropospheric NO₂ monitoring at high latitudes using satellite data is challenging because of the reduced light hours in winter and the snow-covered surface, which make the retrieval complex. The tropospheric NO₂ content over land is mainly due to anthropogenic emissions (urban or industrial areas), while ship emissions constitute the main source in the marine boundary layer. This work presents a characterization of the tropospheric NO₂ distribution in the Baltic Sea and its coastal area during summer months, using OMI (Ozone Monitoring Instrument) NO₂ data. The role of the transport by the wind, in both marine and urban boundary layer, is illustrated using ECMWF wind information. The results show that the NO₂ spatial distribution is mainly determined by the contribution of strong westerlies winds, which dominate the wind patterns during summer, especially over open sea areas.

Fig.1 shows the seasonal NO₂ emissions (left panel) from maritime traffic as derived from STEAM model (Ship Traffic Emission Assessment Model), based on the messages provided by the Automatic Identification System (AIS), which enable the positioning of ships with high spatio-temporal resolution. The emission data are compared with the tropospheric NO₂ columns (Fig.1 - central panel) during July-August 2006-2011. NO_x emission data (Fig.1 - left panel) show that the ship emission sources are mostly located along one main shipping lane along the direction from SW to NE, with some secondary branches. The time series of both NO_x emissions and OMI NO₂ tropospheric columns are shown in the right panel in Fig.1. The time series follows a similar behaviour, both showing a decrease in year 2009 which corresponds to the economical crisis.

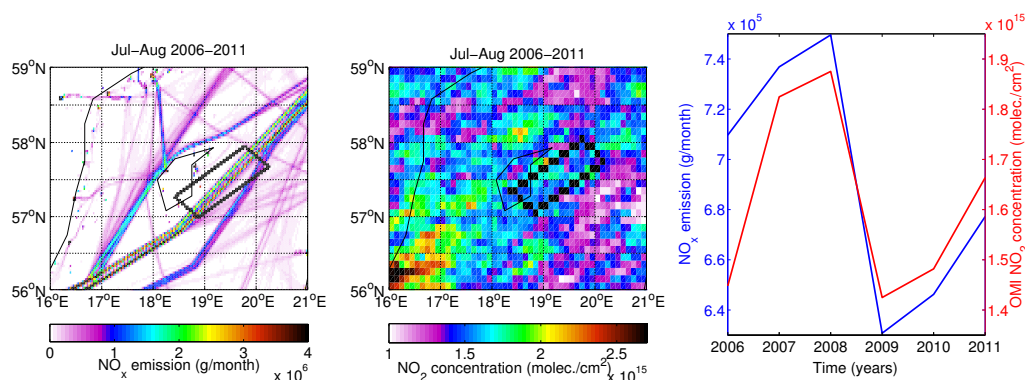


Figure 1: Comparison between STEAM NO_x emissions and OMI NO₂ tropospheric columns during the period 2006-2011. Left panel: July-August cumulative NO_x emissions from STEAM model; central panel: July-August mean NO₂ concentrations from OMI; right panel: time series of both NO_x emissions and NO₂ columns as derived from the mean value within the black boxes in the left and central panel, respectively.

UASI Potato Monitoring flight campaign preliminary results

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It is foreseen that using UAV Hyperspectral imaging new tools to reduce the environmental impact of potato cultivation can be developed. This would offer potato sector more options to reduce the number of sprays, and/or the dosage, while ensuring crop health. With the aid of Hyperspectral imaging novel approaches could be developed for monitoring the plant health and these new data sets could be used in the operational decision support system (DSS) to minimize the number and amount of chemical dosages in potato cultivation. UASI project funded by Tekes, the Finnish Funding Agency for Technology and Innovation, aims to develop technologies for the Unmanned Systems based services. As part of the agriculture application evaluation the UAV imaging of the test plots of Potato Research Institute were performed in July and in August with the UASI 2012 hyperspectral imager prototype.

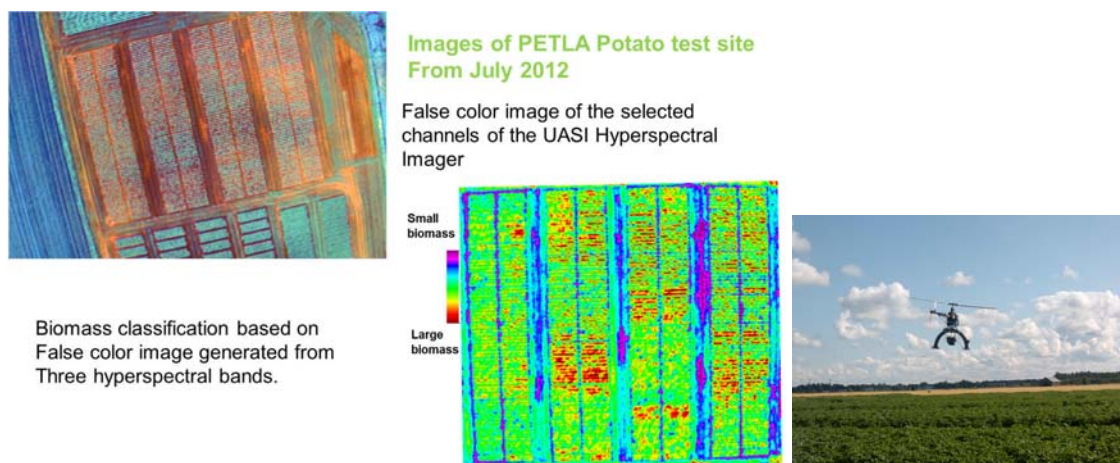


Figure 1. Preliminary result of the biomass determination of the PETLA Potato test filed in Ylistaro based on three Hyperspectral wavelength band images recorded on 12.7.2012.

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Atmospheric composition measurements in northern Finland and comparison with space borne observations

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IASI instrument on board Metop-A satellite provides frequent measurements of greenhouse gases over the Arctic region. Metop-A is the first of the polar orbiting satellites by EUMETSAT. Currently IASI Level 2 processing includes water vapor, carbon monoxide, methane and other gases. Confidence in these remote sensing observations is largely based on ground based validation. For validation purposes we have used both remote sensing and in situ techniques. Accurate water vapor profiles were measured by a research grade cryogenic frost point hygrometer (CFH). The sonde launches were timed to Metop-A overpasses to minimize the time gap between CFH and IASI measurements. The CFH data were collected during various measurement campaigns since 2008. The greenhouse gas column measurements were made by a Fourier Transform Infrared (FTIR) spectrometer. The FTIR instrument in Sodankylä, Northern Finland is based on the Bruker HR125 spectrometer and it has been optimized for greenhouse gas measurements. The greenhouse gas measurements started in February 2009, thus we have more than 3 years of near simultaneous observations. The data from Sodankylä were recently re-processed using an improved retrieval.

Modeling lidar-derived boreal forest crown cover with SPOT 4 HRVIR data

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Forest crown cover (CC), defined as the proportion of forest floor covered by the vertical projection of the tree crowns, is a commonly used parameter in ecological modeling and it also forms the basis for the international definition of forest. Recent results indicate that airborne scanning lidars can produce accurate estimates for the CC. A simple fraction of lidar pulses that hit the canopy above a specific height limit will produce a level of precision that would otherwise require 30-60 minutes of field work per plot. However, the scan zenith angle must not be too far from vertical, because oblique pulses may overestimate CC as they have larger probability to hit the crowns from the side than the vertical ones.

Airborne lidar data could be too expensive for covering large areas, so in many cases the use of optical satellite images is more efficient. Two-level sampling schemes, where lidar data is combined with field measurements to provide reference data for satellite-based interpretation, are a cost-efficient method for large area inventories. In this study, we calculated the CC for 64 sample plots in Hyytiälä, Finland, directly from the lidar data obtained in July 2007. First echoes closer than 30 m to the plot center were included into the CC calculation. A SPOT 4 HRVIR image with 20 m pixel size was obtained in July 2008. After rectification and atmospheric correction, BRF values were calculated for the plots using average of the nine nearest pixels. Finally, the well known spectral vegetation indices NDVI, SR and RSR were calculated for each plot.

Crown cover was predicted by fitting different single predictor regressions. RSR, which utilizes also the short-wave infrared band in addition to the red and near-infrared bands, provided the smallest absolute standard error: 8.1%. This result was obtained by fitting an exponential curve through the origin using nonlinear regression. The best models obtained with NDVI and SR were clearly worse with standard errors of 13.7% and 15.1%, respectively. The results agree with an earlier study where RSR was found to predict the boreal forest leaf area index with higher precision than the other indices.

In conclusion, the result indicates that boreal forest crown cover can be estimated fairly reliably using a combination of airborne lidar data and medium resolution satellite images. A common situation in CC modeling is that imprecision of the field data weakens the model precision significantly. Our results show that this problem can be largely avoided by using lidar-derived CC instead of quickly made field observations.

Reference panel for remote sensing studies at Järvelja, Estonia

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A reference panel for the support of spectroscopic remote sensing measurements was built at Järvelja, Estonia, 58°16'5.98"N 27°18'15.43"E in 2010 (Fig.1). There is no natural surface in Estonia which is large and homogeneous and stable enough to serve as a reference for remote sensing spectroscopic measurements. The Järvelja reference is a 10 m x 10 m horizontal concrete panel which is protected from weather conditions by a removable roof.

The reflectance of the panel surface has been measured on a 1m grid with a field spectroradiometer in the spectral range of 350..2500 nm.



Figure 1: The perspective view of the Järvelja reference taken onboard an UAV

Biomass and Species Composition Are Tightly Related to Forest Albedo in the Boreal Zone

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Forests act as pools of carbon dioxide, thus mitigating global warming. On the other hand, some recent studies have demonstrated that the positive effect of forests in the boreal region on the mitigation of climate change can be canceled by the biophysical effects of low surface albedo and evapotranspiration [1]. The relationship between albedo and forest land is, however, complex and little is known about the driving factors of albedo in the boreal zone [2]. Using a radiative transfer model and an extensive forest inventory database, we simulated the albedo of forest stands of the most abundant tree species of Fennoscandia – Scots pine, Norway spruce and Silver birch, including both monospecific and mixed stands. The use of a physically-based radiative transfer model allowed us to uncouple the different factors driving the forest albedo. We analyzed separately how biomass, canopy cover, and species composition influence the shortwave albedo of a boreal forest. The albedos of monospecific forest stands differed significantly between species. The albedo generally decreased with increasing stand biomass. The sharpest decrease in albedo was observed at low biomass values (i.e. growth of a young stand), after which the albedo remained relative stable. Also, an increase in canopy cover was accompanied by a decrease in the albedo. Finally, a significant increase in the albedo of mixed spruce-birch stands was achieved already at a modest fraction of birch. Our results confirm that forest management practices have a significant influence on the albedo of the boreal biome.

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Hyperspectral remote sensing in Taita Hills, Kenya

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Taita Hills in southeastern Kenya is one of the target areas in CHIESA-project (Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa). Projects main donor is Ministry for Foreign Affairs of Finland. Project is divided in seven work packages and hyperspectral remote sensing campaign was made by work package 2. Aim of the campaign is to produce biogeophysical information of the target area for the use of other work packages and develop classification methods of hyperspectral datasets [1].

The area was divided in low, middle and high zone transects based on the elevation to get optimal spatial accuracy of 0.5 meters. Additional flights were flown above indigenous forest patches. Data was collected with SPECIM:s AISA Eagle VNIR sensor in spectral range of 400 – 1000 nm. Spectral range is divided to 64-channels with approximately 9.3 nm FWHM [2]. The flight campaign was successful and the data is now under preprocessing, which includes radiometric, geometric and atmospheric corrections. Georeferenced reflectance data will be classified to different land cover types and shared with other work packages. High spectral and spatial resolution makes it possible to identify single trees and analyze the turgidity etc. of the target. The first results are expected during the year 2013.

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Ground point labeling in a terrestrial laser scanning configuration with utilization of scanner-centered coordinate system

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Terrestrial laser scanning (TLS) has developed rapidly over the recent years allowing collection of high resolution geospatial data from close-range targets.

Close-range scanning means that the intrinsic point cloud densities vary significantly when compared to more established airborne laser scanning (ALS) data. Moreover, scanning distances and angles differ from airborne scanning. Scanner location within the target area also means that completely occluded viewing directions are probable. Also, the noise point number and distribution differ from those in ALS. Finally, spatial distribution of collected points is heavily concentrated around the immediate vicinity of the scanner. This can lead to excessively high point cloud densities that become detrimental for the point cloud processing.

Terrestrial point clouds are usually processed so that their spatial coordinates are first transformed into reference coordinates. Transformed point cloud information is then combined with point clouds measured in other scanings. Common ways to create a ground model over the whole combined data are a) laser point binning into a grid and then searching for the lowest bin heights, and b) creation of a Triangulated Irregular Network (TIN) from low points in the data. These approaches result in good quality ground models when distance variance of laser returns is relatively small compared to the scanning range, i.e. in ALS. However, in a terrestrial scanning configuration the point distance variance has the same scale as the scanning range. Moreover, a large number of noise points may occur below ground level in terrestrial scanning configurations. Presence of below-ground noise points complicates ground determination with binning and triangulation techniques.

This presentation introduces a novel approach for ground level determination in a terrestrial laser scanning geometry. The new technique uses scanning geometry information in ground level determination. The technique uses an assumption that high point density close to the scanner can be used for accurate initial ground level determination. When the point cloud is represented in scanner-centered coordinates, the ground level can be estimated with iterative binning. The iterative binning uses three preset parameters: bin width, rising angle, and layer height. The parameters prevent inclusion of extreme height changes in cases where height distributions of bin points change drastically.

The technique offers potential advantages over previous ground detection approaches in a terrestrial scanning geometry. Firstly, the ground detection algorithm allows pseudo/quasi-realtime data processing (ground classification can be performed during measurement or shortly after it, well before actual analysis). Secondly, the use of scanner-centered coordinates makes it straightforward to remove distant points and to decrease amount of noise coming behind partially penetrable targets. Thirdly, distance-dependent errors are easier to account for in scanner-centered coordinates. Finally, ground label information can be transferred directly to a reference coordinate system with proper indexing.

We present the working principles of the ground detection algorithm in this article, and test its performance in determining ground level in a forest site, which is scanned with a TLS setup.

Model-assisted estimation of growing stock in a three-phase sampling survey utilizing ALS sample and wall-to-wall satellite optical data. (Poster)

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Abstract

Airborne Laser Scanning (ALS) and satellite optical data for use in large-area forest inventories are evaluated with the intent to both increase the estimation accuracy and decrease costs. The aim of the study is to efficiently utilize both wall-to-wall satellite optical data combined with a sample of laser scanning data using model assisted sampling scheme for a growing stock variable. Variables derived from a Landsat 7 ETM+ satellite image are spectral values of bands 1,2,3,4,7. Data set on Kuortane area (30 000 ha) in Western Finland is being used with a sampling unit defined as a square plot with size 16m X 16m. Three ALS strips 1 070 m width and 14 km of length are located in 4 km apart from each other, covering approximately 25% of entire study area. Sample plots measured using a modification of the 10th National Forest Inventory measurement system, are used as field data. In two-phase sampling, the regression estimator is given by

$$\hat{t}_{diff} = \sum_U y_{1k}^\circ + \sum_{S_a} \frac{e_{1k} - e_k}{\pi_{ak}} + \sum_S \frac{e_k}{\pi_k^*},$$

where $\pi_k^* = \pi_{ak} * \pi_{k|S_a}$, $e_{1k} = y_k - y_{1k}^\circ$, $e_k = y_k - y_k^\circ$, and y_{1k}° and y_k° are proxy values for the element k from first and second phase respectively [1].

The approximate variance is given by

$$\hat{V}(\hat{t}_{\pi^*}) = \sum_S \sum \frac{\Delta_{akl}}{\pi_{kl}^*} \check{e}_{ak} \check{e}_{al} + \sum_S \sum \frac{\Delta_{kl|S_a}}{\pi_{kl|S_a}} \check{e}_k \check{e}_l,$$

where $\pi_{kl}^* = \pi_{akl} * \pi_{kl|S_a}$, $\check{e}_k = \sum_{k=1}^n \frac{\check{e}_{ak}}{\pi_{k|S_a}}$, $\check{e}_{ak} = \frac{e_k}{\pi_{ak}}$ and $\check{e}_l$ respectively for l sample size.

Specific features of the design are handled through the specific first and second order inclusion probabilities of pixels that the design leads to. Our results show that such sampling design utilizing fusion of ALS and optical satellite data tends to increase model-assisted estimation accuracy based on ALS data, which allows the potential to decrease costs on ALS.

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Canopy shadow fraction estimation from AISA Eagle using spectral unmixing

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In northern latitudes where the Sun remains in low elevations most of the year, forest canopies are affected by significant shadowing. Shadowed surfaces exhibit different spectral characteristics than directly sunlit surfaces due to multiple scattering in the atmosphere and inside the canopy itself. Accurate determination of forest productivity, biophysical variables and structural parameters often require that we use sunlit and shadowed canopy fractions separately in the calculations, as well as take the magnitudes of both direct and diffuse radiation into account. It is also essential to establish the magnitude of the shadowed background and separate it from other components. In case of remote sensing measurements of forest canopies, high spatial resolution is required for an accurate distinction between the shaded and sunlit surfaces.

Since the reflected light in the optical domain can be considered a linear combination of different radiation signals, radiometric measurements can be decomposed to sunlit canopy, sunlit background, shaded canopy and shaded background that are often referred to as scene components [1]. The fractions of sunlit and shaded canopy can be calculated once their spectral characteristics are known individually. By doing this, we will be able to retrieve the ratio of shadowed to total canopy area. This quantity known as canopy shadow fraction is in many ways required for reliable determination of various biophysical and ecological variables characterizing vegetation.

Based on our hyperspectral AISA Eagle II measurements of Hyytiälä forest stands, we will review the methodology for decomposing spectral measurements into four scene components and calculation of canopy shadow fraction. We will focus on spectral mixture analysis, which has previously been successfully used by [1], [2]. Validation work will be conducted later.

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Aalto-2 – An Atmospheric Nanosatellite

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Aalto-2 is an atmospheric nanosatellite designed to be part of the QB50 international satellite network project. The satellite is being built under the coordination of the Department of Radio Science and Engineering of Aalto University School of Electrical Engineering and is funded by the Finnish Funding Agency for Technology and Innovation (TEKES). It is designed to be a two-unit (2U) CubeSat, and it will be mostly built in-house by students of the university.

QB50 will be a network of 50 CubeSats in a ‘string-of-pearls’ configuration, launched to a circular low Earth orbit at 320 km altitude [1]. The satellites will carry standardized sensors for multi-point, in-situ, long-duration measurements in the largely unexplored lower thermosphere and ionosphere. Due to atmospheric drag, the satellites will decay to lower orbits allowing exploration of lower altitudes. The constellation is planned to be launched in 2015 and the lifetime of individual satellites is estimated to be about three months.

The main goal of the Aalto-2 project is to advance space technology education and cooperation in Finland, and help carry out the QB50 scientific mission [2]. The Aalto-2 satellite will be fitted with the QB50 sensor kit and the design of the rest of the satellite is based on the heritage received from the Aalto-1 project. Additional payloads are also planned: A highly miniaturized radiation detector to continue the measurements started with Aalto-1 and a small lightning sensor to demonstrate lightning detection feasibility from small satellites. The preliminary subsystem configuration is presented in Fig.1.

Apart from the QB50 scientific experiment, a formation flight experiment is proposed with the Tartu University ESTELLE satellite [2]. This allows reference measurements for the QB50 scientific measurements as well as the cold gas propulsion experiment of the ESTELLE satellite. An inter-satellite link is planned to be established with VHF/UHF radios.

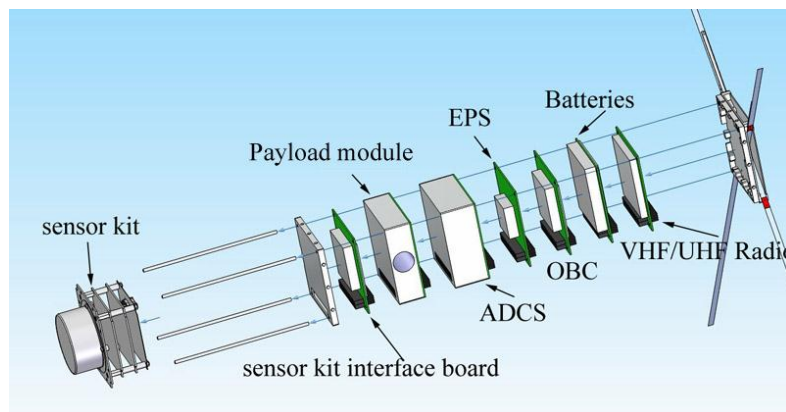


Figure 1: Overview of the Aalto-2 system (10*10*22.7 cm).

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Forecasting Outbreaks of the Brown Locust Using Rainfall Estimates, NOAA Images and SPOT Vegetation Images

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Previous research into modelling outbreaks of the Brown Locust (*Locustana pardalina*) was conducted by the Agricultural Research Council (ARC) and Greenwich University from July 2000 to July 2003. The aim of this study is to present a clear outline of the model to define whether there will be a large outbreak or a plague and to benchmark the outcome of the model against additional actual reports.

The Brown Locust is endemic to the semi-arid Karoo areas of South Africa and southern Namibia, and population fluctuations are closely related to climatic and habitat variability. The high outbreak frequency zones of the Brown Locust in South Africa were first defined in 1937 by Faure and Marais and subsequently confirmed by Lea in 1958 [1]. Due to a significant westward shift in the eastern boundary between 1937/1958 and 2001, the area was redefined by Kieser in 2001. Brown locust feeds mainly on grasses and staple foods (maize, wheat) and have the potential to devastate agriculture throughout Southern Africa.

Rainfall estimate surfaces and vegetation condition surfaces are used to predict locust outbreaks in a long-term (18 month) scenario. The Normalized Difference Vegetation Index (NDVI), calculated from NOAA and SPOT Vegetation images, is used for vegetation condition. The model is based on four conditions that have to be true in order to have a large outbreak or plague.

Condition 1

If the quantity of vegetation was sufficient in the late summer, two years earlier, then there will be a plague condition.

Condition 2

If the winter rain two years earlier is too high, then no plague will develop.

Condition 3

If sufficient rain is received in the early summer of the current season AND there were plague conditions before, then a plague condition will develop.

Condition 4

If sufficient rain is received in the late summer of the current season then a plague will develop.

The model gave a correct forecast for 13 of the 15 years from 1992 to 2006.

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Using digital camera for measuring leaf inclination angle in crops

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Leaf angle distribution (LAD) is a key parameter for simulating radiation transmission through a vegetation canopy and for characterizing canopy structure. It plays an important role in controlling energy and mass exchange in ecosystems [1]. In most studies, however, LAD is assumed to be spherical as the actual LAD is difficult to estimate. Recently, a simple and reliable method to measure LAD based on digital photography was developed and validated for various broadleaf tree species [2, 3]. The canopy structure and leaf shape for many common agricultural crops differ significantly from that of broadleaves. The performance of this promising LAD measurement method in crops has not been investigated yet. Thus, we present here our results on applying the digital camera LAD measurement protocol in an agricultural field in Viikki, Helsinki.

Nikon D1x camera on a tripod was used for taking photographs. The camera was levelled using a bubble level in the flash shoe of the camera. Seven species were measured. Five to six photographs were taken for each species with a distance about 1 m between crop and camera lens. To record the shape of the leaves, we scanned 20 fresh leaves of each species in the field using a portable document scanner. We also recorded the LAI and average leaf angle using the LAI-2000 plant canopy analyser. Leaves oriented approximately perpendicular to the viewing direction were selected from the photographs and the angles were estimated by angle measurement tool in ImageJ software. For straight and flat leaves, angles could be measured directly. However, the long, narrow and curved leaves angles could be only for leaf sections. Later, the leaf angle distributions for these species were reconstructed using the measured leaf shapes.

After the data processing, leaf inclination angle distribution functions were built for all species. The photographically determined LADs were compared with those determined from LAI-2000 measurements. Finally, the functions were used in radiative transfer simulations of Viikki test fields and the modelled canopy reflectance factors were compared with those measured using an ASD Handheld field spectroradiometer and an airborne AISA imaging spectrometer in 2011.

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Oral Presentations

Sodankylä Satellite Data Centre: An Initiative to Establish Real-Time Satellite Data-Aided Services in Finland

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The overall objective of the initiative is to establish basis for the development of sustainable Finnish satellite data-aided monitoring and forecasting services. The work is primarily performed by Finnish research institutes (Finnish Meteorological Institute (FMI) together with other relevant organizations). However, the aim is to outline, develop, promote and demonstrate services that are also linked (a) to co-operation with the Finnish industry and (b) to commercial end-use applications (public-private partnership). A special focus is in applications related to security (marine, terrestrial and aviation). The activity is also directly linked to the international co-operation within the fields of space and Arctic activities. This includes the contribution of Finland to the European Space Agency (ESA) and the EUMETSAT, as well as bi-lateral initiatives of co-operation.

The development work is largely based on the investments that the Finnish Meteorological Institute (FMI) carried out during the years 2009-2012 to establish the national Satellite Service Centre at Sodankylä. The total level of infrastructure investments was 6 M€. A major part of the investment was the procurement of new 7.3 meter X-band high-capacity satellite receiving antenna and the construction of the data processing and product archiving/delivery facility. With satellite receiving station FMI enhances the satellite reception activities at Sodankylä and targets to increase the user base of satellite products in Finland. Also participation to international satellite missions as a ground station facility and remote sensing instrument calibration and validation reference site is important part of future plans

Utilization of satellite imagery and data has not developed in Finland according to the possibilities available. Possibly on for that has been the availability, difficulty of access and/or price of the data. The goal here is the increase the utilization of the satellite imagery and data in its own operations and in Finnish society in general. With its new satellite reception station, FMI can provide the **right** satellite products to end-users **in time** and **reliably**. Currently Sodankylä Satellite Data Centre receives data from several spacecrafts: EOS-Aura, EOS-Terra, Suomi NPP, FengYun-3. Activities starting during 2013 include COSMO-SkyMed SAR-data reception, data processing and data retail.

Studying atmospheric composition by satellite measurements

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Satellite measurements are essential for monitoring changes in the distribution of ozone and other trace gases in the troposphere, stratosphere and mesosphere. Both the natural variation and anthropogenic change of trace gases are strongly dependent on altitude and latitude. The best global measurements of these changes can be obtained from space using limb viewing instruments. In this presentation we focus on ESA's GOMOS instrument and Canadian OSIRIS instrument. Finnish scientists and industry have participated for preparation and operations of both these instruments.

OSIRIS (Optical Spectrograph and Infrared Imager System) is one of the two instruments on board the Swedish Odin satellite, launched in February 2001. The spectrograph part of the instrument measures limb-scattered solar light (radiance) in the wavelength region of 280–800 nm with around 1 nm spectral resolution. Odin scans toward the Earth's limb from 7 to 110 km through a controlled nodding motion. The effective Field of View (FOV) is 1–2 km. In turn, the FOV is sampled discretely with 1–3 km vertical spacing. OSIRIS is the first dedicated satellite instrument to measure continuously the vertical composition of the atmosphere using the limb scatter technique and by recording the full spectrum from UV to visible wavelengths with a good spectral resolution.

GOMOS (Global Ozone Monitoring by Occultation of Stars) on board ESA's ENVISAT satellite measures attenuation of stellar light in occultation geometry. Daytime measurements also record scattered solar light from the atmosphere in the same way as OSIRIS. The wavelength regions are the ultraviolet-visible band 248–690 nm and two infrared bands at 755–774 nm and at 926–954 nm. From UV-Visible and IR spectra the vertical profiles of O₃, NO₂, NO₃, H₂O, O₂ and aerosols can be retrieved. In addition there are two 1 kHz photometers at blue 473–527 nm and red 646–698 nm wavelengths. Photometer data are used to correct spectrometer measurements for scintillations and to retrieve high resolution temperature profiles as well as gravity wave and turbulence parameters. Measurements cover altitude region 5–150 km. Atmospherically valid data are obtained in 15–100 km. GOMOS measured nearly one million ozone profiles during its ten years of operation 2002–2012.

Finnish Earth Observation in European programmes

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Finland started to use aerial photography early. The use of the Finnish air force aircraft fostered many natural resources measurements in Finland especially from the 1950's to the 1970's. In the 1970's satellite data was becoming to be utilised. Meteorology with its European and global connections was the first Finnish user but research on the use of satellite images on forestry soon followed. The advent of the SAR radar satellite was helping factor in a country where the weather is always cloudy.

In the 1980's Finland joined EUMETSAT and European Space Agency, which lead to a more coordinated national effort to develop satellite remote sensing both in spacecraft instrumentation development and in applications research.

ESA's ENVISAT and its French-Finnish GOMOS instrument and NASA's Dutch-Finnish OMI instrument were - and still are - major efforts in measuring and studying atmospheric ozone. ESA's SMOS satellite in especially measuring soil moisture and the onset of freezing and thawing of the ground has shown the value of collaboration of satellite, in situ and aircraft measurements. Finland has had a role in all ESA's Earth Observation satellites that have been developed during Finland's participation in ESA. ESA's programmes have also been an important forum for research and to some extent business development in EO applications.

ESA's ministerial meeting in November 2012 will define the volume of ESA's Earth Observation programmes for next several years. The European economy may lead into decisions where programmes shrink in size. However, ESA plans to hold its following ministerial meeting in two years when global economy is likely to be in a growing mode again.

In 1995 Finland joined European Union. European Commission's Framework Programmes in research have been valuable for Finnish EO community at least since "FP5". The current seventh programme is ends with the call with a deadline of 21 November 2012. Finnish research teams have fared well in the previous calls in GMES, Global Monitoring of Environment and Security. A Finnish company is building major parts of SAR radars for Sentinel 1 satellite that is commonly developed by ESA and European Union, and for similar satellites for Germany and Spain. Finnish researchers are participating in GMES projects on water, ice, snow, climate, atmosphere, and leading a project on forests and deforestation.

During the period 2014-2020 European Union's space programmes will change remarkably. The overall volume of EU's space activities can increase to 2 billion euro annually, whereas ESA's budget is 3.7 billion euro. GMES is likely to become a large independent EU programme with a budget of 5.8 billion euro for seven years. The 8th Framework Programme has been given the name "Horizon 2020" – its Space programme will have a budget of order for 1.7 billion euro. Its contents is still to be defined.

The many European level changes in space programmes' goals, funding and contents are threats and opportunities for Finnish Earth Observation.

On national level the Finnish space strategy for years 2013-2020 is being currently defined.

OBSERVATIONAL ASSESSMENT OF SNOW ACCUMULATION ON NORTHERN HEMISPHERE IN CMIP5 CLIMATE MODEL SIMULATIONS AND GLOBSNOW SATELLITE-BASED DATA RECORD

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ABSTRACT

The European Space Agency (ESA) GlobSnow project has produced a daily hemisphere-scale satellite-based snow water equivalent (SWE) data record spanning more than 30-years. The GlobSnow SWE record, based on methodology by Pulliainen [1] utilizes a data-assimilation based approach for the estimation of SWE which was shown to be superior to the approaches depending solely on satellite-based data [2]. The GlobSnow SWE data record is based on the time-series of measurements by two different space-borne passive radiometers (SMMR and SSM/I) measuring in the microwave region, spanning from 1979 to present day. The sensors utilized provide data at K- and Ka-bands (19 GHz and 37 GHz respectively) at a spatial resolution of approximately 25 km. The GlobSnow SWE data record is available through the GlobSnow web-pages (www.globsnow.info).

The GlobSnow satellite-based dataset is inter-compared with climate model simulations from the CMIP5 archive. The objective of this work is to investigate the performance of the CMIP5 models in capturing the evolution of hemispheric scale snow conditions for the period of 1980 to 2010. The climate model simulations on snow cover extent, snow depth and snow water equivalent are evaluated against the GlobSnow SWE record and other existing independent ground-based reference data. The eventual goal is to assess the performance of the CMIP5 models to simulate snow conditions for the time-period that is covered by satellite-based observations.

The results obtained so far indicate a clear decreasing trend in total hemispherical snow mass for the period of 1980 to 2010 in the remote-sensing based data record. The inter-comparison of satellite-based record and climate model simulations show notable differences in capturing the evolution of Hemispherical scale snow conditions. Similar trends of decreasing snow cover are also seen in the investigated CMIP5 models, although there are notable differences between the various climate models. Some of the models capture the overall hemispherical snow mass more accurately than others. In general the winter months (December, January and February) seem to be rather well captured, while the spring season, (March, April and May) appears more challenging for the climate models.

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Sea ice remote sensing R&D at Finnish Meteorological Institute

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The presence of sea ice has large practical and economical importance in several countries and regions in the world. Satellite based timely information on sea ice condition and its variability is essential for all operations in ice-covered areas. In the Baltic Sea ice information is mainly needed for ship navigation and planning of icebreaker operations, but in the Arctic marginal seas like Barents and Kara Seas also for off-shore operations and fishery. Sea ice information is also input data for numerical weather prediction models and it can be assimilated to sea ice models for better short-term prediction of ice conditions.

As a part of Marine Research Unit the Ice Research Group conducts research and development of sea ice products based on satellite data and sea ice models. The main target area has been the Baltic Sea where satellite data in ice monitoring and R&D has been operational since 1978, and SAR data since 1992. In recent years we have also developed sea ice products for the Barents and Kara Seas based on earlier Baltic Sea products and also on some new methods. The main source for the sea ice products are SAR images due to their fine resolution (10-100 m) and independence of cloud cover. Other satellite data utilized includes radiometer and optical data.

Here we give overview of the current operational sea ice products: e.g. Baltic Sea level ice thickness chart and ice drift chart showing also convergence/divergence ice zones, delivered through Polar View (ESA) and MyOcean (EC) project web-portals, and some products under development, e.g. sea ice thickness chart for the Barents and Kara Seas based on a sea ice thermodynamic model and multisensor satellite data, see Fig. 1. The sea ice products are derived with automatic algorithms incorporating statistical relationships between sea ice characteristics and satellite signatures, modelled sea ice parameters, image processing and pattern recognition.

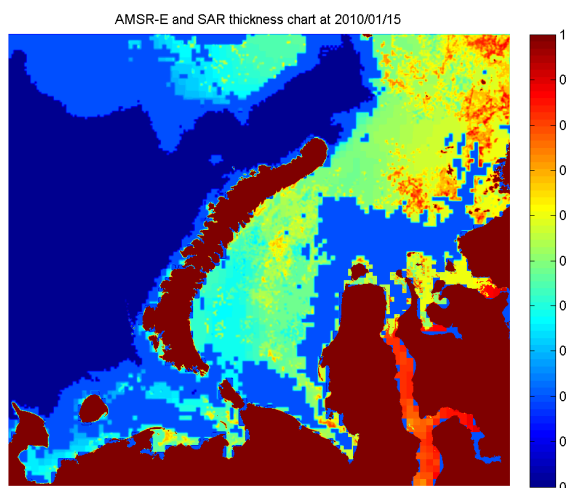


Fig. 1. Sea ice thickness chart on 15 Jan 2010 based on ENVISAT ASAR WSM, AMSR-E and a sea ice thermodynamic model data. The chart covers part of the Barents and Kara Seas. Each grid cell represents the mean thickness over the cell. The grid size is 1x1 km. The ice thickness range is from 0 to 1 m.

Sea Ice Concentration Retrieval Based on Dual-Polarized C-Band SAR

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Ice concentration is defined as the proportion of the ice covered area over a given area. High-resolution ice concentration information are required for navigation, validating ice models and data assimilation. The currently available operational ice concentration products are based on microwave radiometer data and their typical resolution is several kilometers. For example University of Bremen delivers operational (global) ice concentration products based on AMSR-E and SSMI/S data using an algorithm called the ASI algorithm [1]. However, also data from SAR instruments cover large sea and ocean areas with a much higher precision than that of the radiometer data, and they are not very efficiently utilized in operational monitoring of the ice concentration yet. In [2] we have shown that the local autocorrelation can be used to distinguish between open water and sea ice for HH-polarized C-band data. Recently we have also studied the estimation of the ice concentration based on the C-band SAR HH-channel autocorrelation distributions [3]. In this presentation we also include the cross-polarized (HV) channel, and study whether the concentration estimates can significantly be improved by including the cross-polarized channel. In this experiment we use the HH-channel concentration estimate of [3] as a starting point. Then we additionally include two features based on the HV-channel: the HV channel backscattering coefficient σ_{HV}^0 , and the polarization ratio $P = (\sigma_{HH}^0 - \sigma_{HV}^0) / (\sigma_{HH}^0 + \sigma_{HV}^0)$. The HH-channel estimate and the two new features with the incidence angle value are used as inputs of a multi-layer perceptron (MLP) neural network with the error backpropagation training algorithm. The incidence angle is used as one input to avoid the explicit modelling of the incidence angle dependence of σ_{HV}^0 . The new concentration estimates are computed for the same data set as used in [3], and the performances of the single-polarization and dual-polarization algorithms can thus directly be compared. The data set consists of 31 dual-polarized wide swath mode Radarsat-2 images over the Baltic Sea, acquired during the first half of March 2011. The data set includes both dry snow cover and wet snow cover cases. The reference data used in training and testing of the algorithm are the ice concentrations of the gridded Finnish Ice Service ice charts. We also make a comparison with the ASI algorithm concentrations over the Baltic Sea area.

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ICEMAR – a System for Sea Ice Information Delivery

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The sea ice in the Arctic seems to be diminishing at an accelerating pace. This opens up opportunities for transportation in the Arctic area. Still the conditions are extreme and a prerequisite for safe shipping is the availability of good forecasts of the sea- and ice state. There are many national ice services providing ice information, but delivering this information to ships in the Arctic area is challenging and often requires polling of many sources, which is cumbersome and time consuming.

In ICEMAR, a project funded by the European Commission, a consortium consisting of system providers, a satellite service provider, ice chart producers and maritime educators, a system is built that acts as an automated ordering and delivery portal for sea ice information for on board use. Project coordinator of the consortium is Kongsberg Satellite Services (KSAT) in Norway.

The ICEMAR User sets up a profile defining area of interest, products of interest and on board display and communications capabilities. This information is then utilized by a server acting as the common hub that gathers products (ice charts, satellite images and iceberg information) from different producers in real time. Based on the user specific profile parameters enhanced with information about the current position of the ship, the ICEMAR server selects, converts and subsets the products to be delivered to the user over existing telecommunications channels.

VTT develops the on board part of the system, the so called ICEMAR Manager (IMM), which communicates with the ICEMAR server using XML based messages. On reception of the ordered products the IMM automatically decompresses the packages and puts the products in a predefined folder for export to an on board viewing application such as ViewIce or as an additional layer to an ECDIS system.

The system will be piloted on some ships in the Arctic area. The main trial period will be after May 2013. Trials will also be performed in the Baltic Sea in the ice season of 2013.

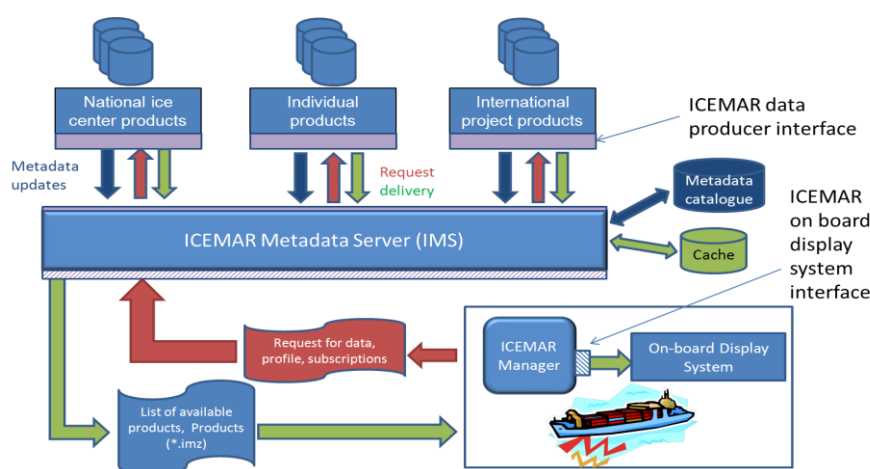


Fig 1. The ICEMAR system

Detection of Soil Moisture and Soil Freeze Using Microwave Radars

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A method for detection of soil moisture and soil freeze using microwave radar measurements is presented. The detection is based on an inversion method presented by Pulliainen et al. in [1]. It employs a semiempirical backscattering model that describes the dependence of radar backscattering of forest as a function of stem volume, soil moisture, vegetation canopy moisture, surface roughness and incidence angle. The backscattering model was developed using C- and X-band airborne HUTSCAT scatterometer data. The backscattering of soil is determined using model presented in [2]. The inversion is made using a constrained least-squares algorithm.

The method gives an estimate of soil moisture. It can be used to detect soil freeze by determining a threshold value below which the soil is considered to be frozen. This method can be used with both low resolution scatterometer measurements and higher resolution SAR-radars. We are applying it to space borne ASCAT and ASAR instruments. The main validation site is FMI Sodankylä-Pallas supersite.

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EUFODOS - European Forest Downstream Services Improved Information on Forest Structure and Damage - Project presentation

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Forests play a key role in the European economy and environment. This role incorporates ecological as well as economic functions which can be affected by the occurrence of insect infestations, storms or windfall events. Local or regional authorities thus require detailed information on the degradation status of their forests to be able to take appropriate countermeasures against forest damage and to ensure sustainable forest management. The EUFODOS project will use state-of-the-art satellite and laser scanning technology to provide forest authorities with cost-effective, timely and comprehensive information on forest structure and damage. EUFODOS is carried out within the GMES programme and is scheduled to run from January 2011 to the end of 2013.

The main goals

The European Earth Observation Programme GMES provides data useful in tackling a range of issues including climate change and citizens' security. The purpose of GMES is to deliver information which corresponds to user needs. The Forest Downstream Services (FDS) to be developed within EUFODOS include in particular the assessment of forest damage and the measurement of functional parameters for commercial and protective forests. For example the latter has an important function to maintain the safety of settlements and infrastructure in alpine areas. The assigned monitoring services, urgently required by regional European forest authorities, will be developed to an operational level by a consortium of research organisations and commercial service providers from Austria, Germany, Finland, Italy, Bulgaria and Poland.

The benefits

The use of space- and air-borne sensor platforms allows data to be acquired at short time intervals and in a cost effective way. The Forest Downstream Services will thus provide fast and reliable information for effective damage assessment and sustainable forest management on a regional scale.

The data can be utilized by users in a wide range of applications:

- Effective damage assessment and countermeasures: identification of damaged areas – due to storm, fire or insect infestations – in order to enable proper countermeasures, compensation payments and reforestation planning
- Sustainable management of protective forests: targeted management of protective forests in order to maintain and enhance their protective function against natural hazards
- Sustainable management of commercial forests: wood procurement planning and strategic investment planning for commercial forests
- Reporting: revision of forest maps and inventories, compilation of regular reports and annual statistics (e.g. changes in forested area), establishment of forest damage information systems

EUFODOS involves an extensive user community well connected to other related GMES User Groups. This construction will facilitate the roll-out of the services and will create a strong socio-economic benefit.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 262786.

Spectral Characteristics of Hyperspectral and Multispectral Sensors for Area Based Tree Species Classification

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Area based tree species classification using spectral characteristics of hyperspectral (HS) sensor and the simulated spectral characteristics of four band *Vexcel UltraCam-D* (UCD) and *UltraCam-X* (UCX) multispectral sensors was studied. Airborne hyperspectral images of the tree canopy were acquired in Hyytiälä forest [1] using SPECIM, AisaEAGLE line scanning hyperspectral camera. The flight campaign was organized on July 22, 2011 from 6:44 to 7:38 GMT. HS images with 64 spectral bands were acquired in the wavelength region 400 nm to 1000 nm using spectral sampling of 9.3 nm. The pixel size at ground was approximately 0.5 m. The camera field of view (FOV) was 35.8°. The forest was imaged in nine strips. Strips were radiometrically calibrated to radiance and geometrically rectified into WGS84 UTM zone 35 projected coordinate system [2]. In total, 577 forest plots (each plot has single species) of three tree species (254 pines, 177 spruces and 146 birches) visible in HS image strips were identified by an expert using previously acquired LiDAR and other aerial images. For each plot 21 × 21 pixels window (10.5m² area) was extracted from HS image, the mean spectrum was calculated and used as a feature in classification process. The quadratic discriminant analysis (QDA) was used as the classifier. To measure the classification performance of the sensors the classification rate (CR) and the kappa value (KA) were calculated. Leave-One-Out classification results for spectral characteristics of HS sensor and the simulate spectral characteristics of UCD, UCX sensors (for the 577 plots extracted from 9 strips) are shown in Table.1. There are no significant differences in the classification results between the UCD and UCX sensors both were around 89.5% and kappa 0.84. The HS sensor gives the best classification accuracy (98.4%). With HS sensor, there is around 16% increment in pine class and 5% in spruce class. These high classification accuracies are partly due to limited view-illumination geometries and short measurement time intervals between the strips.

Table 1: Leave-One-Out classification results for the simulate spectral characteristics of UCD, UCX sensors and spectral characteristics of HS sensor for the 577 plots extracted from 9 strips.

Sensor	Total		Pine	Spruce	Birch
	CR [%]	KA	CR [%]	CR [%]	CR [%]
UCD	89.4	0.84	83.1	89.8	100.0
UCX	89.6	0.84	83.5	89.8	100.0
HS	98.4	0.98	100.0	94.9	100.0

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Cross-Border Comparison of Forest Area Changes Caused by Clear-Cutting and Afforestation of Abandoned Agricultural Land Using Snow Covered Satellite Imagery in northeastern Europe

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Boreal and northern temperate forests cover substantial parts of European land area. These forests are subjected to several kinds of tree removal disturbances, dominated by clear-cut logging. There is a need for quick and cost-efficient remote sensing methods to provide an independent means of detecting disturbances and recording the history of disturbances both at regional, national as well as at European level.

The forests at northern latitudes are characterized by winters in which snow cover remains for some months of the year. Winter images are particularly suitable for change detection, while snow provides a uniformly bright background that accentuates tree crowns and their shadows and provides remarkable conditions for separating forested from non-forested areas. Winter images are particularly appropriate for monitoring gradual changes on lands that were formerly in agricultural use, that have been abandoned and are in places growing into forests.

We highlight a methodological approach of remote sensing based mapping of forest patches, forest disturbances and regrowth of forests on formerly non-forested land in the Baltic and Russian regions. Satellite imagery used are multi-temporal winter imagery, obtained from medium spatial resolution satellite scanners onboard Landsat and SPOT and from scanner Aster together with more high resolution Quickbird images. The mapping examples cover the areas in Eastern Europe in Estonia, Latvia and western parts of Russia. The time period covered is from 1987 to 2011.

Results show that a very simple approach using winter images is useful in mapping forest patches, canopy removal disturbances in forests and appearance of new forest patches within the context of agricultural lands in the situation of abandonment of agricultural land. We conclude that the use of snow-covered satellite images for forest change detection can be very efficient alternative to the use of summer images.

Tracing variations of deciduous component over grassland–forest continuum by subpixel classification

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Land cover classifications based on satellite imagery has traditionally paid little attention to fragmented and complex components of the landscape, such as grasslands and deciduous forests. They are typically treated as spectral noise between more robust and major classes and as such they are obliterated from the final classification through post-classification procedures. However, the deciduous component, including deciduous forests, wooded grasslands and spontaneous deciduous forests succession on former grasslands, is generally pinpointed as the main carrier of biodiversity in the rural landscape [1][2] and must therefore be treated in any future satellite based environmental monitoring process.

In this paper, we test the possibilities of using mid-resolution satellite imagery (Landsat TM and SPOT) in the detection and quantification of transitional deciduous component. As the component is highly heterogeneous in terms of spectral characteristics, we have selected a hybrid classification which combines supervised and spectral unmixing approaches, assisted by high precision acquisition of training data from CIR aerial photographs. The rationale behind the procedure is to narrow down the complexity of the target and utilize the advantages of different classification methods thus gaining a reliable estimate of the deciduous characterization of grassland–forest continuum. As a result, a three-level product including pure grassland component, pure deciduous forest component and mixed transitional component with further categorization is presented. Furthermore, landscape ecological consequences of the classification as well as its relation to land use history are discussed.

Preliminary results indicate that as expected, detection of pure components is fairly straightforward compared to the classification of the mixed component. Spectral unmixing approach offers a promising way of making detailed observations on fractional elements and has previously been tested *e.g.* to detect urban mixed vegetation [3] and cypress canopies [4], but workflow also includes the specification of multitudinous parameters which make the results prone to unintentional misinterpretations. However, if accomplished carefully and subjected to detailed verification, results may be highly applicable for detection and stratification of transitional deciduous component in a way significant for landscape ecological approaches.

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Consequences of land cover transitions on the sustainability of coral rag forests in Zanzibar, Tanzania

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Forests are complex socio-ecological systems, which are overused especially in the tropical regions. It has been estimated that about 6 million hectares of primary forest is lost globally each year due to agriculture, logging and other human activities [1]. For many decades, governments and global community have tried to tackle the issue of forest deterioration, but the mechanisms leading into forest degradation relate to complex dynamics of physical, social, economic and cultural factors [2]. At local scales, these changes relate closely to values and preferences set on different land use strategies and materialise as various temporary and permanent land use and land cover transitions [3]. At broader scales, land cover transitions are manifestations of the overall land use developments and changes in biophysical and socio-economic factors [4]. We have studied land cover and land use transitions in a tropical island of Zanzibar at local and regional scales using contemporary and historical remote sensing data over the last 50 years. We used spatio-temporal change trajectory analysis [5] on a set of consecutive aerial images (1953-1978-1989-2005) at local scales and post-classification change detection techniques on Landsat TM (2009) and SPOT XS (1996) images at regional scale to detect major land cover and forest transitions. The outcomes of regional level change detection were linked to biophysical factors through regression analyses to explain happened and to predict future changes [4]. Our results show that Zanzibar is deforesting with annual pace of 0.8–1.1%, but within the rural land use regimes significant part of the changes are temporary and forest have capacity to re-establish at local scales. Rates and causes of deforestation seem to differ between the eastern coral rag and the western deep soil areas. At landscape scale, recent deforestation concentrates to the vicinity of the coastline, roads and Zanzibar Town, where also the future risk of deforestation is highest. Deforestation is a direct result of agricultural and urban expansion, but shifting cultivation, fuel wood collection, logging, grazing and extraction of coral cause more subtle forest degradation. Detecting changes at multiple spatial and temporal scales shows the complexity of land cover transitions where forest losses are simultaneously coupled with forest gains and where forests are not simply lost but experience different level of degradation. Since we used two different classification schemes at regional scale, we were able to establish range of deforestation rates rather than one single figure.

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Forest crown cover estimation in northern boreal and temperate European forest

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Forest crown cover that is defined as the percentage of the forest area covered by vertically projected tree crowns is a versatile indicator of forest's structure and condition. The most used definitions of forested areas are based on crown cover percentage. Crown cover reflects forest's productivity and carbon assimilation. Decrease of crown cover may indicate forest degradation.

While it is laborious and expensive to assess crown cover on ground, earth observation provides a cost efficient alternative for the fieldwork. For independent accuracy assessment of the crown cover estimates, reference data can be collected by visual interpretation of very high resolution optical earth observation data with a reasonable effort.

A method for forest crown cover estimation using high resolution optical earth observation data was developed and tested at four study sites in Europe. Crown cover was estimated using the probability estimation method of VTT and Image2006 data. The accuracy of the crown cover predictions was assessed using reference data that were collected by visual interpretation of very high resolution aerial and space borne imagery.

The average crown cover values in the reference data varied from 17 % to 86 % and in the predictions from 18 % to 80 %. The absolute root mean square error of the crown cover predictions varied between 14 % and 33 %. The results of the study showed that it is possible to map forest crown cover with twenty to thirty meter spatial resolution optical earth observation data using the single pixel values. However, understanding the variable results at different sites requires further investigation. To support this, a more comprehensive set of validation data is being collected and analyzed.

The study was part of Geoland2 project that has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 218795. This presentation is based on the conference paper that was given in Sentinel-2 Preparatory Symposium in April 2012.

Detecting landuse and landcover changes in reindeer pastures using multi-source remote sensing and GIS data

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We are investigating land use and land cover changes and their effects on reindeer husbandry in the Lappi reindeer herding district in eastern Lapland over the past six decades. Forestry, hydropower construction, tourism, nature conservation, and recently mining are major drivers of land use/cover changes in the research area. There have been conflicts between other land use forms and reindeer husbandry because of resource utilization for different purposes and subsequent adverse effects on each other. A series of Landsat MSS, TM and ETM+ images (1972, 1987, 1993 2005, 2011) and Corona images (1977) were used to detect land cover changes in a study area of 4553 km². More detailed analyses of land cover changes were carried out in three locations within the study area using a series of aerial photography from late 1950's to 2000's. Information on forest logging history were gained from Forest Government (Metsähallitus) logging plans (1950's) and follow up maps. This data was transformed into GIS database. Information of reindeer herding system and its changes in the study region were derived from old maps and interviews with reindeer herders.

The results highlight various changes in land cover/use resulting from clear-cutting, road construction, use of herbicides and the construction of artificial lakes. The area of young forests had significantly increased in the landscape. Old forests were mainly found in protected areas (national and nature parks, wilderness areas). Further, the density of the road network had noticeably increased as a result of the construction of forestry roads and tourism. From the reindeer husbandry viewpoint the number and the extent of disturbances in the landscape have increased during the past decades. Forestry has mainly negative effects on reindeer husbandry through the reduced amount of ground-growing and arboreal lichens. Artificial lakes have reduced the area of suitable pastures and disturbed pasture rotation system. Further, increased tourism in the vicinity of Saariselkä skiing resort park have disturbed reindeer herding in fjell areas. Cumulative impacts of land use and land cover changes are reflected to the spatio-temporal land use of reindeer husbandry as reindeer herding system tries to adapt to new conditions and shrinking pasture land

Aalto-1 Spectral Imager: Design and Mission

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The Aalto-1 Spectral Imager (AaSI) is a miniaturized spectral imager capable of recording images at 20+ selectable wavelength bands between 500 and 900 nanometers.

VTT has developed tunable Fabry-Pérot interferometer (FPI) modules based on piezo or electrostatic actuation. A spectral imager can be built by combining this kind of a tunable FPI and an RGB CMOS or CCD sensor. AaSI will have an RGB CMOS sensor consisting of 1024x1024 pixels, which allows the minimum ground pixel size of ca. 100 meters. These technologies enable extremely lightweight spectrometers and spectral imagers (< 500 g) which are suitable for small unmanned aerial vehicles and different space applications.

AaSI will be developed as a part of the ESA activity “MEMS Fabry-Perot interferometer technology for miniaturized hyperspectral imagers and microspectrometers”, which has started in autumn 2012. This project will perform space qualification testing (vibration, thermal and thermal vacuum) for piezo-actuated and MEMS FPI's. The spectral, radiometric and spatial performance of the instrument will be tested on the Aalto-1 nanosatellite mission. As Aalto-1 will have limited downlink capacity, the amount of measured spectral bands has been reduced. However, the instrument itself can measure 60+ spectral bands, and this feature may still be tested during the mission. In-orbit spectral calibration is planned to be done by using known bright spectral features (e.g. Sahara) and measuring the spectrum around strong absorption peaks (e.g. O₂ absorption at 750-760 nm). AaSI will also include a normal RGB camera (ca. 1000 x 1000 pixels) with wider field of view. The images taken by this camera will be used as a georeference for the spectral images.

The main advantages of the AaSI concept are the small size and the spectral programmability, which provides flexibility and reduced data rate when the application is well defined. A successful space qualification and orbit demonstration will enable more advanced instruments based on piezo and MEMS Fabry-Pérot interferometer technologies.

Main specifications for AaSI:

- Across the flight FOV: 10° (105 km swath width at 600 km altitude)
- Along the flight FOV: 10°
- Spectral image size: 512 x 512 pixels (2x2 binning)
- Wavelength range: 500 – 900 nm
- Spectral resolution: 10 – 30 nm (FWHM)
- SNR (20 ms & 20 nm FWHM): > 50 (0.3 albedo near Finland in June)
- Amount of spectral bands: > 20
- Volume: 90 x 96 x 48mm³
- Mass: 500 g

A Pioneer European Airborne-Based Observation Campaign of a Meteor Shower

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We provide overview and preliminary results of the successful international airborne-based observation campaign held on October 8, 2011. During the campaign the team had two research-dedicated aircrafts, Safire (CNRS) and Falcon 20E (DLR), flying in tandem over Scandinavia (mainly Finland), equipped with wide and narrow field of view cameras and other instrumentation. The goal of the project was to record and analyze exceptional outburst of the Draconids meteor shower predicted for 2011 [1, 2]. This was the first time when such a campaign was organized in Europe by European organizations. Remote sensing of meteors can be used to measure their parent comet's main element composition, grain size distribution of its component dust particles, bulk and grain density - parameters that cannot be obtained in other way. The Earth's passage through a recently ejected comet dust trail, from the width, peak time and strength of the shower, also provides insight into where along the comet orbit this dust was ejected, the speed of ejection, and the past orbit of the comet. Thus the recorded outburst of Draconids was our first opportunity to field modern observing techniques to study the dust particles of comet 21P/Giacobini-Zinner. It was also the only opportunity in coming decades since there will be no showers of such high activity expected until at least 2050 [2]. The comet was passed and studied by the NASA's International Comet Explorer (ICE) spacecraft in 1985 (it was also first historical comet flyby). Here we present the first results obtained in frame of the project, in particular we provide pre-atmospheric particles mass and other parameters obtained by method developed in [3] and its further extension [4]. Along with a number of ground based observations, the Draconids are found to be a small particles with initial mass in the order of 0.01 g, exceptionally fragile, disintegrating at high altitudes and not penetrating deep into the Earth's atmosphere and they may therefore represent the most primitive, loosely packed material in the Solar System. Ejected particles survive in the comet's dust stream for thousands of years. As former part of a comet, this matter is among the most pristine material known, and therefore is of extreme value to increase our knowledge of the physical and chemical conditions in the early Solar System.

The presentation will include introductory part and thus we will keep it understandable and interesting almost for everyone.

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Using mobile laser scanning and UAV for 3D city models

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3D city model has been paid high attention for recent ten years, especially when many new applications e.g. location-based services, navigation, tourism, urban planning, require advanced visualization from the real scene. According to CityGML standard, the levels of detail (LoD) of the models are grouped to five categories. The detail definitions can be found from www.citygml.org. However, usually we also refer to two groups according to the distance and height from the target objects: models for fly-through views and models for walk-through views. Models for fly-through view can be regarded as an overview of the scene, the distance between the view point and the target is usually further than 100 m and the height is beyond the height of the objects. As regards with walk-through view, the distance can vary usually from half meter to one hundred meters. Models for walk-through view offer a sense that you were walking in the real scene. Therefore model reconstruction for walk-through view requires higher visual quality than for fly-through view since small errors or distortions or the rough surfaces can be clearly presented in front of you. The level of detail for walk-through view models can be referred to LoD 4 and LoD 5 according to CityGML standard.

As the sensor technology development, the increasing availability in multiple data sources acquired by different sensor platforms has provided the great advantages for detailed model achievement. This paper proposes the use of both MLS data and UAV images for 3D model reconstruction. Mobile laser scanning (MLS) has been commercialized for almost ten years. Since then due to the disadvantage in one-side (without backside information) data collection, it results in the limitation of applications. However the rise of the unmanned aerial vehicle (UAV) offers an alternative complementary for the disadvantages of MLS. As we know that 3D city models are reconstructed, the information from both building facades and roofs is needed. MLS can provide high resolution point clouds in building facades, whereas UAV images can offer detailed information in building roofs. The data fusion of MLS and UAV images can generate a complete high resolution 3D model for walk-through views. Methods are performed by four steps: i) Building facades are extracted from MLS data; ii) UAV images are referenced to MLS and extract building roof information from UAV images; iii) Data fusion of building facades building roofs; iv) Complete building model generation. By the above four steps, the desired models are achieved and the results are analyzed.

3D hyperspectral reflectance signatures by light-weight UAVs for the monitoring and measuring the environment

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Light-weight UAV imaging techniques have developed rapidly. Currently, the UAV based methods are efficient in measurement projects covering small areas, typically less than 1 km². There are many potential applications for this novel data due to the increasing need of accurate environmental information.

One of the challenging parts of the UAV image data utilization is to process the data so that reliable information of the object geometry and radiometry is obtained. The FGI has been developing processing methods for UAV imagery to provide accurate 3D hyperspectral information [1,2]. The steps in the rigorous processing include radiometric and geometric sensor calibration, controlled flight campaign, georeferencing by self-calibrating bundle block adjustment technology, point cloud generation using novel dense matching technologies and finally a radiometric adjustment and reflectance transformation. This processing provides 3D hyperspectral reflectance point clouds, digital surface models and hyperspectral image mosaics, with a high geometric and radiometric accuracy, and high spatial resolution. These can be utilized in various environmental remote sensing applications, such as precision agriculture, water monitoring, forest damage detection and environmental impact assessment.

The approach has been demonstrated by using low-cost consumer cameras as well as with the novel Fabry-Perot hyperspectral imager (FPI) developed by the VTT Technical Research Center [3]. The FPI technology provides a new concept for environmental measurement, by providing hyperspectral data cubes in a frame image format. Frame images are suitable for providing 3D object information and for stereoscopic interpretation.

In the presentation we will present our approach and results concerning accurate environmental measurements by the novel UAV technology.

More details about our recent activities are given in the Internet:

<http://www.fgi.fi/fgi/research/researchgroups/spectrophotogrammetry>

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UASI Summer 2012 UAV flight campaign results for forest and agriculture applications

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Innovative and compact system consisting of CIR (Color Infrared) and hyperspectral imagers integrated into a very light UAS (unmanned aerial system) with modern classification algorithms provides significantly improved ways for remote sensing for forest and agriculture applications. Tekes, the Finnish Funding Agency for Technology and Innovation, has granted a funding for this large cooperation research project of four research institutes and several companies. The project is coordinated by University of Jyväskylä. The objective of the project is to be able to evaluate forest and agriculture biomass changes. The project started in 2011 and several flight campaigns were carried out in summer 2011. The new Hyperspectral imager prototype was designed and built for the summer 2012 flight campaigns based on the analysis of the 2011 imaging data. The UASI 2012 imaging system consisted of the 4 Mpix CIR camera and hyperspectral imager with spatial resolution of either 2048 x 1296 or 1024 x 648 pixels in the wavelength range 500 – 900 nm at a resolution of 10...30 nm @ FWHM. In 2012 the Hyperspectral imager and CIR camera were flown together. The UASI system has been tried in summer 2012 in Southern Finland for the forest and agricultural areas. The design and calibration of the hyperspectral imager will be shortly explained. The test UASI 2012 flight campaigns on forest and crop fields and their preliminary results are also presented.



Figure 1. Infotron IT-180 UAV helicopter with both the CIR camera and Hyperspectral imager payload and flight configuration of UASI 2012 hyperspectral Imager.

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Social Forest Planning project : summary of results 2010-2012

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The overall objective of the Social Forest Planning project is to develop and demonstrate a novel system for forest management planning and updating of present plans. The system combines images from cellular phones with remote sensing data to predict forest variables. The variables are input to a Planner Engine that outputs forest resources information for every forest stand and feeds them into a Geographical Information System (GIS). The GPS location tag in the images makes it possible to use them easily as in-situ reference data. The main technical development goal of Social Forest is to develop automatic and interactive methods for the cell phone image analysis. The automatic methods were presented in Remote Sensing Days 2010 [2], and interactive delineation of tree stems for computing basal area in Remote Sensing Days 2011 [3]. This paper gives an overview of results of the whole processing chain, including :

- methods for automatic and interactive tree stem detection from the cell phone images
- methods for the transmission and archiving of the cell phone images through the internet
- methods for the processing and analysis of UAV images
- use of the cell phone-based data as reference to UAV and satellite image analysis to predict the forest variable values wall-to-wall
- system introducing the stand-wise predictions of forest variables and the cell phone plot data into the Planner Engine that outputs the forest management plan.

Latest results include stand-wise predictions of forest variables from satellite and cell-phone images and analyzed cell-phone images as a reference data.

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Automatic detection of storm damages in forests using airborne stereoscopic images

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Risks of storms causing damages in forests are increasing due to the climate change. Fast and reliable detection of fallen trees, assessment of their amount and their efficient collection are of great importance for the economical and environmental reasons.

In Finland, the Ministry of Agriculture and Forestry defined a strategy for the fast detection of storm damages. Airborne photogrammetry was selected as the basic remote sensing method, and the image collection flights should be carried out immediately after the storm.

Visual storm damage detection and delineation from images can be a slow and error prone process. It is expected that the methods based on comparisons of digital surface models (DSMs) collected before and after storm could be efficient for automating the storm damage detection. This is a potential approach with airborne images as well, because the novel dense matching methods have provided promising results in DSM generation (Honkavaara et al., 2012).

One of the challenges in the process is the great variability of the input data. Characteristic to the storm damage detection process is that storms can occur at any season, which also influences the properties of the input data. Also low solar altitudes at autumn-winter periods can be challenging, because the low amount of light and shadows can deteriorate quality of image matching. Furthermore, the camera properties can cause variability on the data. (Honkavaara et al., 2012)

The objectives of this investigation were to develop an automated method for storm damage detection and to investigate its performance in detection of storm damages in wintry images collected using a high performance photogrammetric mapping camera.

Serious winter storms took place in Finland in 26.12.2011 and 27.12.2011. Photogrammetric imagery were collected in less than two weeks time after the storms. Data were collected over an area of 1620 km² from a flying altitude of 5400 m, which provided a ground sample distance of 0.3 m. The national laser scanning data was used to create the before-storm DSM. After-storm DSM was computed using automatic image matching provided by the Socet Set NGATE software.

The DSM extraction by image matching was successful in wintry imagery. Visual inspection of the storm damage detection results indicated that the automatic method correctly found changed areas.

In the future we will carry out further studies on the performance of the method, including influences of atmospheric conditions, season, sensor and image matching algorithm.

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Estimating leaf inclination and G-function from leveled digital camera photography for broadleaf tree and shrub species in Kaisaniemi and Kumpula botanical gardens, Helsinki

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Directional distribution of leaves is one primary parameter for determining the radiation transmission through the canopy. When inverting canopy transmittance measurements for estimating the leaf area index (LAI) or foliage clumping, incorrect assumptions on leaf angles may lead to considerable errors. Often spherical distribution of leaf normals is assumed, i.e. leaf normals are assumed to have no preferred direction in situations where no measurement data are available.

Here we examined if a spherical leaf angle distribution and the resulting isotropic G-function ($G \equiv 0.5$) is indeed a valid assumption for temperate and boreal tree and shrub species. Leaf angle distributions were measured for 62 deciduous broadleaf species in Kaisaniemi and Kumpula botanical gardens in Helsinki in August 2012. The studied species are commonly found in temperate and boreal ecoclimatic regions. The leaf inclination angles were obtained by sampling the complete vertical extent of trees and shrubs using a recently introduced technique based on digital photography [1,2]. It is found a spherical leaf angle distribution is not a valid assumption for both tree and shrub species in temperate and boreal ecoclimatic regions.

Given the influence of leaf angle distribution on inverting clumping, LAI estimates and other parameters from canopy transmittance measurements or reflectances obtained from remote sensing, it is recommended to use planophile or plagiophile leaf angle distribution as more appropriate for modeling radiation transmission in temperate and boreal ecoclimatic regions when no actual leaf inclination angle measurements are available.

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Assessment of Boreal Forest Cover Properties from Interferometric TanDEM-X Data

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Recently launched TanDEM-X mission offers new interesting possibilities for interferometric analysis of terrain and evaluation of vertical structure of forest canopy. Location of interferometric Scattering Phase Center (SPC) inside the forest canopy (and canopy penetration depth) can be effectively used to characterize and monitor boreal forests with Synthetic Aperture Radar interferometry (InSAR). Seasonal, monthly or even shorter term variations in these InSAR-derived parameters can provide distinctive information specific to the different tree structure and species that can be useful for their discrimination.

In this study, 5 sets of dual-polarimetric (HH/VV) TanDEM-X coregistered single-look slant-range complex products were processed. The imagery was acquired primarily during autumn 2011 over Kirkkonummi region near Helsinki, Finland. For each interferometric pair, the Canopy Height Models (CHM) were derived from the interferometric coherence phase. As the reference and auxiliary data CHM and Digital Terrain Model (DTM) measured by LIDAR were used. Using the land cover CLC2006 data, temporal variations in average SPC heights and penetration depths were mapped with respect to coniferous, deciduous and mixed forest classes. For all classes, the SPC heights relative to the treetop were found to be decreasing from early September until late October. As expected, mean penetration depths were found to be increasing in this time interval. The biggest temporal variations were observed for deciduous forest, while mixed forest and coniferous forest were found to be less affected. HH-pol signals were found to have higher penetration depths and lower relative SPC heights than VV-pol signals for all acquisitions. Also, temporal variations in parameters of interest were higher for HH-pol data. Some of the aforementioned dependencies are shown in Figures 1 and 2.

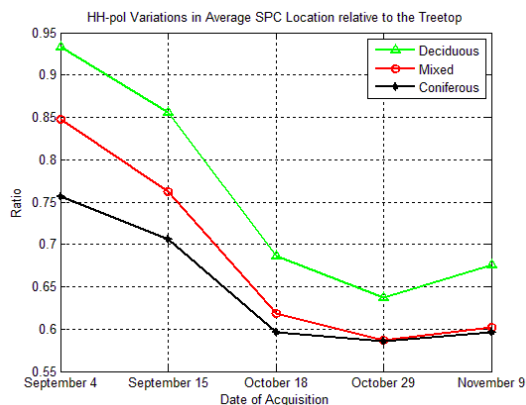


Fig 1. HH-pol variation of average SPC location

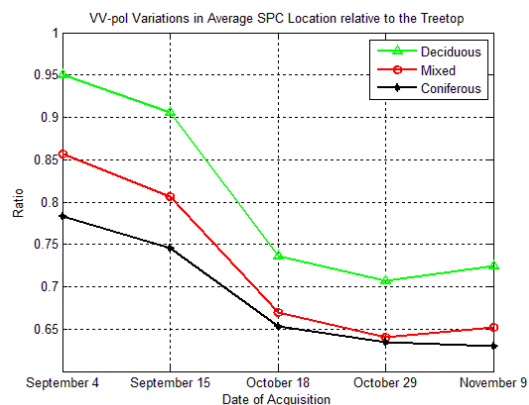


Fig 2. VV-pol variation of average SPC location

BRF of forests**Andres Kuusk** ⁽¹⁾**Joel Kuusk** ⁽¹⁾**Mait Lang** ⁽¹⁾ ⁽²⁾⁽¹⁾ **Tartu Observatory**
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For the study of forest reflectance a special airborne spectrometer system UAVSpec3 [1] was designed and built at Tartu Observatory. UAVSpec3 is an autonomous spectrometer system which does not need operator's intervention during measurement. Its main components are a spectrometer module which measures VNIR reflectance in the nadir direction and a bidirectional reflectance factor (BRF) sensor which records angular distribution of reflectance in one narrow spectral band on a transect along the flight path.

Angular distribution of hemispherical-directional reflectance of forests at Järvselja test-site in South-East Estonia has been measured in flight campaigns in July-August of 2007-2011. The BRF sensor measures the angular distribution of reflectance at the azimuth angle determined by the flight direction. The red filter (660 nm) was used in 2007, 2008, 2010, and 2011. In 2009 the NIR filter (850 nm) was used. As the share of diffuse incident radiation is small at these wavelengths, the measured reflectance distribution is almost BRF.

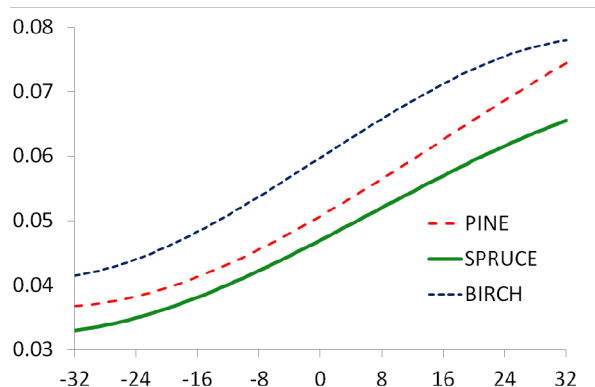
The BRF of three stands at Järvselja which are described in the Järvselja data-base [2] has been measured several times and at various azimuths.

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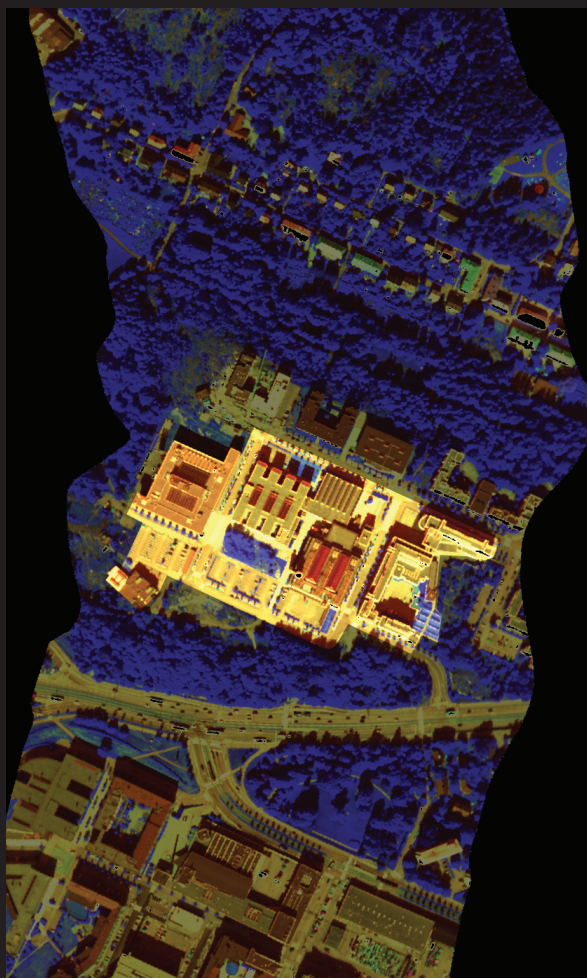
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Directional reflectance signatures in aerial images - an aid to tree species classification?Ilkka Korpela⁽¹⁾, Anne Seppänen⁽²⁾, Lauri Mehtätalo⁽²⁾, Lauri Markelin⁽³⁾, Annika Kangas⁽¹⁾⁽¹⁾Department of Forest Sciences, University of Helsinki⁽²⁾Faculty of Science and Forestry, University of Eastern Finland⁽³⁾Finnish Geodetic Institute**Keywords:** Individual tree, BRDF, Mixed-effects modeling, Monte-Carlo simulation, Scandinavia

Tree species identification is a bottleneck in remote sensing of Scandinavian boreal forests. Airborne LiDAR gives acceptable estimates of the total growing stock, while species-specific estimates remain less accurate. Aerial images are widely used as an alleviating data source. Image observations include directional effects from trees and the atmosphere, which has traditionally been considered a nuisance. We estimated species-, band-, and illumination-specific anisotropy models to assist tree species classification in real and simulated image data. Multispectral Leica ADS40 line-sensor data from Finland (62°N, 24°E) were analyzed using mixed-effects modeling. This allowed the division of the reflectance variation between directional anisotropy, tree and image effect, and the residual. The anisotropy models and the covariance structures were then utilized in a Monte-Carlo simulation, which aimed at quantifying the gain from directional signatures under different assumptions for reflectance calibration accuracy. A simple classifier employing Mahalanobis distance was implemented to classify the multiangular directional signatures. In real data, directional signatures suffered from reflectance calibration inaccuracy, and no gain was obtained in classification performance compared to averaged spectral features and discriminant analysis. Simulations however implied that directional signatures comprise an improvement provided that the reflectance calibration is accurate. The gain from using the directional signatures was however low, less than 5% in overall classification accuracy. The optimal selection of the flying direction with respect to the solar azimuth was influenced by the classification strategy. Species classification accuracy of dominant—co-dominant Scots pine, Norway spruce and birch seems to saturate at 85–90% even in multiangular data owing to the strong within-species variation and correlation of the spectra in individual trees. These factors relate to the inherent structural variation in trees and constitute a natural upper bound.



An example (1-dimensional cut) of anisotropy models (reflectance) for GRN band and direct illumination along the solar principal plane (−32° to +32°). The relative brightness of pine varies and the classifier considers these between species differences.



Finnish Remote Sensing Days is an annual event organized by the Remote Sensing Club of Finland, an informal body bringing together actors in the field of remote sensing. In 2012, Remote Sensing Days were held on the Kumpula campus of the University of Helsinki on October 25–26. This book is a collection of the abstracts of the 43 presentations given during the two exciting days.

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