Nordic Network on

Physically-based remote sensing of forests

[PHYSENSE]

Workshop
September 25, 2007
Tartu, Estonia

PHYSENSE is a Nordic network which focuses on the development, validation and application of physically based approaches in the interpretation of remotely sensed data of forest ecosystems.

***PHYSENSE** is a Nordic network of research groups (est. 2007) which focuses on the development, validation and application of physically-based approaches in the interpretation of remotely sensed data of forest ecosystems.*

Creating a synoptic view of global and regional ecological systems and environmental trends requires extensive geographical data sets which are difficult to collect with field measurements. Remotely sensed data provide the only cost-effective technique for the data collection. The data are used to characterize various ecological variables that are applicable in monitoring, for example, changes in land and vegetation cover, land use, vegetation structure, phenological cycles, natural disasters or biodiversity of habitats. In addition, remotely sensed data are continuous, verifiable (for other parties) and comparable over different countries and years.

During the past decade, along with the rapid technological and methodological development of satellite derived products, a range of new possibilities has risen in global monitoring and assessment of forest and vegetation status from remotely sensed data with physically-based image interpretation techniques.

The physically-based approach formulates mathematically the transfer of solar radiation in vegetation canopies using reflectance models which relate the spectral signature of the vegetation to a set of vegetation parameters. Physical models also play a key role in the design of new earth observation missions and instruments as well as techniques to utilize satellite images in estimating ecosystem balances at regional and global scales. In addition to obtaining biophysical parameters, physically-based reflectance models are also needed for instance in calibrating and correcting radiometric problems present in remotely sensed data.

Seminar program

Venue: Oxford Hall, Hotel London, Rüütli 9, Tartu.

Opening session

09.15 - 09.30	Miina Rautiainen	Welcome, PHYSENSE background
09.30 - 10.00	Key note: Tiit Nilson	The role of reflectance models in forest remote sensing
10.00-10.30	*Coffee break*	

Session 1: Reflectance measurements and their applications

Chair: Mait Lang

10.30-11.00	Key note: Jouni Peltoniemi	Measurement and modelling of reflectance of forest understorey and bare land objects
11.00-11.20	Pille Mänd	Responses of reflectance indices to experimental warming and drought at European shrublands
11.20-11.40	Per Schubert	The applicability of a light use efficiency (LUE) model for an ombrotrophic bog in southern Sweden
11.40-12.00	Juha Suomalainen	Polarization in forest understorey multiangular reflectance - first results from our summer 2007 campaigns
12.00-12.20	Joel Kuusk	Airborne measurements of forest reflectance at Järvselja, Estonia
12.20-14.00	*Lunch (Ülikooli kohvik)*	

Session 2: Forest reflectance models

Chair: Lauri Korhonen

14.00-14.30	Key note: Matti Mõttus	Photon recollision probability and canopy reflectance
14.30-14.50	Mait Lang	Järvselja test site for RAdiation transfer Model Intercomparison
14.50-15.10	Miina Rautiainen	Multiangular reflectance properties of a hemiboreal forest: an analysis using CHRIS PROBA data
15.10-15.40	*Coffee break*	

Session 3: Forest inventory parameters

Chair: Matti Mõttus

15.40-16.00	Lauri Korhonen	Estimation of forest canopy cover in the Finnish NFI
16.00-16.20	Jaan Praks	Forest Height Estimation with Polarimetric Interferometric Synthetic Aperture Radar
16.20-16.30	Matti Mõttus	Closing words

19.30 --- *Dinner (Wilde Irish Pub)*

Session 1: Reflectance measurements and their applications

Measurement and modelling of reflectance by forest understorey and bare land objects.

Jouni Peltoniemi, Juha Suomalainen, Eetu Puttonen
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We have developed a mobile measurement facility for anisotropic reflectance measurements in high spectral resolution. We have measured reflection properties (BRF) of over 100 samples. We have observed that reflection properties of typical forest land surfaces vary in very large range (up to and over a factor of 100). We have verified that spatial variations even among same type of vegetation can be well over 20%, diurnal variations of the same order, seasonal variation often over a factor of 10. We have advanced in physical modeling of snow and soil using ray tracing techniques, and will present some new results with comparison to measurement data. We will discuss about the challenges our results set for forest remote sensing, modeling and new measurements.

Responses of reflectance indices to experimental warming and drought at European shrublands.

Pille Mänd[1], Olevi Kull[1], Lea Hallik[1], Claus Beier[2], Bridget Emmett[2], Edith Kovács-Láng[2], Josep Peñuelas[2], Giuseppe Scarascia-Mugnozza[2], Albert Tietema[2]

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We examined plant response to warming and drought at shrubland ecosystems of six European sites (UK, Denmark, Netherlands, Hungary, Spain, Italy). We used ground based canopy reflectance measurements in visible/near-infra-red wavebands for evaluation of the method to use in early detection in canopy composition and structure with possible implication in remote sensing technology. Reflectance index NDVI revealed expected relationship with green biomass data (obtained from point quadrat measurements) with strong tendency to saturate at high biomass conditions. Differences in reflectance indices between treatments were considerably smaller than differences between sites. Cross-sites comparison showed that in general effect of warming treatment was positive on NDVI, whereas drought treatment had negative effect. Green biomass data showed similar trends. Reflectance index PRI had no tendency to saturate at high biomass values suggesting that this parameter works better than NDVI in high biomass conditions. PRI showed a good agreement with leaf-level photochemical efficiency measurements. Plot level PRI measurements suggested that photochemical efficiency of plants was mainly influenced by the warming treatment. Reflectance proves to be a useful means for detecting changes in vegetation while reflectance is easier to measure and has better averaging ability than direct measurements of biomass or physiological status of vegetation.

The applicability of a light use efficiency (LUE) model for an ombrotrophic bog in southern Sweden.

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Studies on the applicability of using remote sensing data as input to a light use efficiency (LUE) model for estimation of carbon exchange have shown positive results for closed forest stands. To extend already established relationships to other vegetation types, studies are needed in different kinds of sparse forest stands and open landscapes. In this study, measurements of reflectance, photosynthetic photon flux density (PPFD), and carbon flux are made at Fäjemyren, an ombrotrophic bog located in the southern part of Sweden. Ground based radiometric reflectance measurements of spectral signatures in the wavelength interval from blue to near infrared (NIR) are made together with chamber measurements of carbon fluxes at sixteen sample points approximately every three weeks from March to October 2007. The sixteen sample points are divided into groups of four where one is the control group and the other three are fertilized with nitrogen, phosphorous and nitrogen/phosphorous respectively. Closely located to these sampling points, there is an eddy flux tower providing incoming and reflected PPFD, and carbon flux data. Reflectance and PPFD data will be used to study the potential of different vegetation indices (VI) to estimate fraction of photosynthetically active radiation (FAPAR). Since the reflectance measurements are made in narrow bands, reflectance data can be used to calculate the photochemical reflectance index (PRI). To study the potential for PRI to estimate LUE, LUE will be calculated from absorbed PPFD and flux data. Reflectance and flux data will also be used to study the potential for different VI:s to differentiate between the four fertilization groups.

Polarization in forest understorey multiangular reflectance - first results from our summer 2007 campaigns.

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Finnish Geodetic Institute Field Goniospectrometer (FIGIFIGO) is an highly automated portable instrument for multi-angular reflectance measurements. It can be used in definition of sample's bidirectional reflectance factor (BRF) either at field using sunlight or in laboratory using artificial illumination. The samples must be at diameter between 5 and 100 cm. The spectral range is from 350 to 2500 nm. During the last few years FIGIFIGO has been successfully used at multiple field campaigns with the samples mostly concentrating on forest understorey and snow. The latest technical development in FIGIFIGO is an ability to make polarized measurements allowing also the degree of polarization in BRF to be analyzed. During the summer 2007 we (will) have measured polarized BRF of multiple forest understorey samples. The results of these first-of-a-kind measurements will be presented and their significance will be discussed.

Airborne measurements of forest reflectance at Järvselja, Estonia.

Joel Kuusk
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The presentation gives an overview of the airborne spectrometer system built at the Tartu Observatory. On July 26, 2006, several stands at VALERI test site at Järvselja, Estonia were measured. The results of these measurements as well as preliminary results of measurements carried out at summer 2007 (if there will be any) will be presented. The spectrometer is based on a 256-channel NIR enhanced miniature spectrometer module MMS-1 by Carl Zeiss Jena GmbH. It's spectral range is 300-1140 nm. The spectrometer system comprises web camera and GPS receiver for position tracking. For 2007 summer's measurements attitude and heading reference system and angular distribution measuring system were added. The angular distribution measuring system is based on 256-channel linear array together with band-pass filter (lambda = 660 nm, delta = 10 nm) and wide angle lens (140 deg). On July 10, 2005, a CHRIS image of the Järvselja test site was acquired. Reflectance spectra of several homogeneous stands in the CHRIS scene were compared to airborne measured data. Altogether 615 recorded spectra over 197 CHRIS pixels over 23 homogeneous stands were used for calculation of correction factors for the CHRIS calibration coefficients. The footprint of the airborne spectrometer's field-of-view from the height 100 m is 9.5 m^2, thus the total area of airborne measurements involved in the comparison was equal to the area of 20 CHRIS pixels.

Session 2: Forest reflectance models

Photon recollision probability and canopy reflectance.

Matti Mõttus
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To be applicable to a wide variety of biomes, algorithms for predicting remotely sensed signatures of forests have to rely on physically-based principles. These physically-based models are able to calculate the angular distribution of reflected intensity for any reasonable set of illumination conditions. Recently, parameterizations for physically-based models based on the photon recollision probability p have been developed to relate canopy absorption and scattering. Recollision probability is defined as the probability that a photon, once scattered, will interact with the canopy again. It can be considered wavelength-independent and, thus, it connects canopy reflectance at different wavelengths in the visible and near-infrared spectral regions. The applicability of p has been tested using radiative transfer models, analytical methods and radiation measurements. However, its applicability, both theoretically and practically, is restricted by a number of simplifying assumptions. The first and most evident of these is the assumption of p remaining constant in successive interactions. Also, calculations containing only the photon recollision probability cannot provide any information on the angular distribution of scattered radiation needed to compare directional measurements with modeling results. In turn, this lack of angular information leads directly to the problem of partitioning the incident flux into the fractions reflected and transmitted by a canopy layer.

Järvselja test site for RAdiation transfer Model Intercomparison.

Mait Lang
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Since 1999 there has been three benchmarking phases in the RAdiation Model Intercomparison study (RAMI, http://rami-benchmark.jrc.it/HTML/Home.php). In all of these three simulated canopy strucure was used for model input. Next phase of RAMI will use the data of real forests located in Järvselja Experimental Forest District, Estonia. The test sites are a Norway spruce stand Scots pine stand and Silver birch dominated deciduous stand - each in size of 1 hectare. The presentation will give an overview of the methodology and some problems that are faced when compiling detailed database of forest structure and reflectance measurements for forest canopy reflectance modeling.

Multiangular reflectance properties of a hemiboreal forest: an analysis using CHRIS PROBA data.

Miina Rautiainen[1,2], Mait Lang[1], Matti Mõttus[1,2], Andres Kuusk[1], Tiit Nilson[1], Joel Kuusk[1], Tõnu Lükk[1]

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Forest types differ in their spectral anisotropy patterns mainly due to species-specific geometrical structure, spatial arrangement of canopies and subsequent shadow patterns. We examine the multiangular reflectance properties of typical hemiboreal forests during summer time using three simultaneous CHRIS PROBA (mode 3) scenes and stand inventory data from the Järvselja Training and Experimental Forestry District in southeastern Estonia. We investigated the magnitude and reasons for the differences in the anisotropy patterns of deciduous and coniferous stands at three viewing nadir angles. A forest reflectance model (FRT) was used as a tool to provide a theoretical basis to the discussion, and to estimate the directional contribution of scattering from crowns and ground to total stand reflectance for the two forest types. The FRT model simulated successfully the HDRF curves of the study stands to match those obtained from the CHRIS image, yet it produced a smaller and less wavelength-dependent angular reflectance effect than was observed in the satellite image. The main results of this study provide new information for separating the spectral contribution of the forest floor (or understory layer) from the tree canopy layer: (1) the red edge domain was identified to have the largest contribution from forest understory, and (2) the more oblique the viewing angle, the smaller the contribution from the understory. In addition, coniferous stands were observed to have a specific angular effect at the red and red edge domain, possibly as a result of the hierarchical structure and arrangement of coniferous canopies.

Session 3: Forest inventory parameters

Estimation of forest canopy cover in the Finnish NFI.

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Forest canopy cover is one of the parameters required by physical reflectance models to describe the reflectance of a forest stand. In the Finnish national forest inventory (NFI), canopy cover is estimated in each sample plot along with numerous other forest characteristics, which makes NFI data the only source of geographically extensive canopy cover information in Finland. The problem with this data is that until 2007, the percent cover has been estimated by eyesight

without proper training of the observers. In spring 2007 all the NFI group leaders participated training, in which they could train their eye by estimating the canopy cover in 7-8 previously measured plots. The results of the training period indicate that there is considerable variation in the estimates between the different observers, and that many of the observers underestimated the cover significantly. As an alternative to the ocular estimation, a specific canopy cover model based on hundred sample plots data was used to predict the cover in each plot. The model used information on the plot basal area by species, mean height and site fertility to give a prediction of canopy cover. The model obtained RMSEs of 8.3%, 6.7%, and 16.2% in Tammela, Joensuu, and Rovaniemi test sites, whereas the average RMSEs of the observers were 9.9%, 7.1%, and 7.9%, respectively. The results indicate that in Southern Finland many of the group leaders were not able to achieve as good estimation accuracy as the model did. However, when the ocular estimations were averaged with the model predictions, the results improved considerably, except in Rovaniemi where the model designed for Southern Finland was seriously biased. This way the average RMSEs in Tammela and Joensuu decreased to 5.3% and 5.4%. Even better results might be obtained by calculating error distributions of the model and each observer, and combining the estimates with Bayesian statistics.

Forest Height Estimation with Polarimetric Interferometric Synthetic Aperture Radar.

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Rapidly developing synthetic aperture radar (SAR) instrumentation and measurement methodology have opened new prospects for vegetation remote sensing. One of the new interesting techniques is polarimetric SAR interferometry which in combination with scattering model shows the possibility for forest height estimation from interferometric SAR image pairs. This is an interesting prospect for new SAR satellites, ALOS PALSAR, TerraSAR-X and Radarsat-2. In this presentation, we give brief overview of SAR polarimetric interferometry, vegetation induced coherence modeling width Random Volume over Ground model and inversion of the model for forest parameters. Our study and prestentation is based mostly on FINSAR campaign results. The FINSAR campaign was carried out to validate forest height retrieval algorithm by using polarimetric interferometry for boreal forest. The campaign was a co-operation project between Helsinki University of Technology (TKK) and German Aerospace Centre (DLR) and the measurements were carried out in autumn 2003 in Finland. In the campaign airborne polarimetric L-band (1.3 GHz) and X-band (9.6 GHz) polarimetric radar E-SAR and helicopter-borne C-band (5.4 GHz) and X-band (9.8 GHz) profiling scatterometer HUTSCAT were operated over a forest test site. Tree height estimates were calculated by various means and compared with each other and with ground measurements. The results of the campaign were encouraging; the forest height could be retrieved from L-band and X-band coherence images. Additionally, the extinction coefficient of the forest on X-band could be retrieved by combining E-SAR and HUTSCAT measurements. The study showed that a good agreement exists between the forest height estimates derived by RVoG model inversion using E-SAR measurement and forest height estimates derived from HUTSCAT scattering profiles. Interpretation of E-SAR tree heights on HUTSCAT profiles showed, that agreement between HUTSCAT and E-SAR derived height estimates is very good for some areas. Also restricted single polarization based inversion based of X-band measurement performed surprisingly well. Our results show, that new SAR satellites like ALOS PALSAR and Tandem-X have potential for forest height measurement by means of polarimetric interferometry. However, the temporal decorrelation between ALOS PALSAR image pairs complicates significantly forest height estimation and short wavelength of X-band radar limits its ability to estimate tree height to mostly sparse forests, like the boreal forest.

A new network in Nordic forest research:

Physically-based Remote Sensing of Forests (PHYSENSE)

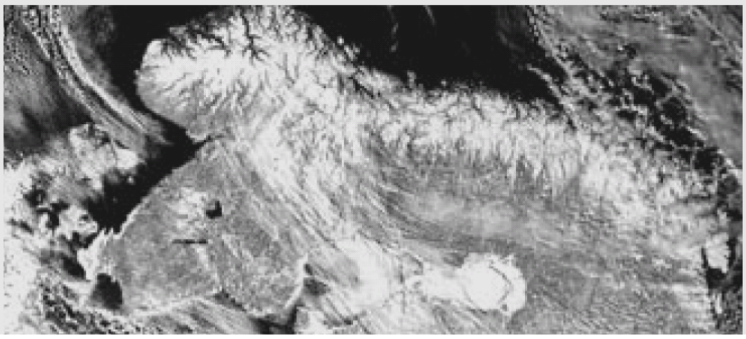
A new Nordic forest remote sensing network, PHYSENSE, was established in January 2007 with support from SNS.

A distinctive feature of the network is that its founder members are young postdoctoral researchers and PhD students who wish to exchange knowledge and know-how, and to increase collaboration between research groups in the Nordic and Baltic countries.

PHYSENSE focuses on the theoretical aspects of remote sensing – the development, validation and application of physically-based approaches in the interpretation of remotely sensed data from forest ecosystems.

The network will hold its inaugural seminar in autumn 2007 in Tartu, Estonia.

Winter in Scandinavia from the satellite Envisat. Copyright: ESA



Background

Understanding environmental trends in forest ecosystems requires extensive geographical data sets, which are difficult to collect by means of field measurements.

Remotely sensed data provide the only cost-effective option and are used to characterize many ecological variables for monitoring, such as changes in land use, vegetation cover and structure.

During the past decade there have been rapid technological and methodological advances in the acquisition and use of satellite-derived data. Thus, a range of new possibilities has opened up for global and regional monitoring and assessment of forest and vegetation status using remotely sensed data and physically-based image interpretation techniques.

In physically-based approaches, radiation patterns in forest canopies are mathematically interpreted, using reflectance models that relate the spectral signature of the forest to a set of forest structural parameters. Physical reflectance models play a key role in the design of new earth observation missions and satellite instruments. They are also used for estimating ecosystem balances and biophysical variables at regional and global scales. In addition, physical reflectance models are needed, for example, in calibrating and correcting radiometric problems associated with aerial and satellite images.

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