6th International Workshop on Retrieval of Bio- & Geo-physical Parameters from SAR Data for Land Applications

Tuesday 17 November 2015 - Thursday 19 November 2015

Harwell, UK

Programme

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Tuesday 17 November 2015

Welcome & Registration - (09:20-09:50)

time	title
09:40	**Welcome & Logistics** *Presenter: Mr. ROMMEN, Björn (ESA)*

Opening Session - (09:50-10:50)

time	title
09:50	**Presentation I - Opening Session** "UK Space Agency Earth Observation- who are we and where are we going?" by Beth Greenaway, Head of Earth Observation, UK Space Agency
10:10	**Presentation II - Opening Session** "ESA Earth Observation Radar Missions" by Malcolm Davidson, ESA/ESTEC
10:30	**Presentation III - Opening Session** *Presenter: Prof. QUEGAN, shaun quegan (University of Sheffield)* "Why do we make use of SAR data so difficult?"

Coffee break - (10:50-11:10)

I - General Land-Use and Classification - (11:10-15:10)

time title

11:10 **Multi-temporal Sentinel-1 SAR data processing for thematic applications over land**

Presenter: Dr. WEGMULLER, Urs (Gamma Remote Sensing AG)

The Sentinel-1 SARs are designed to achieve global coverage with short repeat intervals. Using a constellation of two satellites and operating these in a special ScanSAR mode permits providing excellent multi-temporal data. Therefore, multi-temporal processing techniques are becoming very relevant. In our processing and retrieval concept we are using a two stage approach. The first stage deals with elements as calibration, co-registration, filtering, coherence estimation, estimation of multi-temporal signatures and geocoding. As a result standardized multi-temporal signatures are derived which are then used as input to the second stage, the retrieval algorithms.

In our work presented we focus on the first stage considering specifically Sentinel-1 IWS data. For applications based on SAR backscatter speckle reduction is one important aspect of the processing. We use a multi-image filtering approach (Wegmüller et al., 2013) that builds upon multi-image filtering methodologies proposed by Quegan et al. 2001, and structural spatial filtering proposed by Lee et al., 1999. In the multi-image filtering, an assumption used is that the spatial patterns remain unchanged over time. This is often almost perfectly the case for agricultural fields, built up structures as houses, roads, power lines, dams and alike also meet this criteria. As a consequence, the filter performs well over these targets with a significant increase of the Equivalent Number of Looks (ENL) over homogeneous areas such as fields while maintaining individual scatterers and field boundaries sharp. The filtering methodology is described and results generated using substantial multi-temporal Sentinel-1 stacks are discussed.

Speckle filtering is also relevant in the estimation of multi-temporal parameters as the temporal variability of the backscattering. Over land Sentinel-1 acquires data most of the time in dual polarization mode. As a consequence cross-polarization backscattering and combined parameters as the cross- to like-polarization ratio are available. Furthermore, Sentinel-1 coherence is estimated at both like and cross-polarization.

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Lee J-S., M.R. Grunes, and G. de Grandi, Polarimetric SAR Speckle Filtering and Its Implication for Classificantion, IEEE TGRS, Vol.. 37, No. 5, pp. 2363-2373, 1999.

Quegan and Yu, Filtering of multichannel SAR images, IEEE Trans Geosci. and Remote Sensing, vol. 39, no. 11, 2001.

Wegmüller, U., M. Santoro, and C. Werner, "Multi-temporal SAR data filtering for land applications," ESA Living Planet Symp., Edinburgh, UK, 9-13 Sep., SP-722, 2013.

11:30 **Multitemporal Sentinel-1 Backscatter Composite Products**

Presenter: Dr. SMALL, David (University of Zurich)

Modern SAR sensors are increasingly offering wide swaths, enabling shorter revisit intervals than were hitherto possible. The new open data policy of Sentinel-1 enables the development of higher level products, built on a foundation of level 1 SAR imagery that meets a high standard of geometric and radiometric calibration. We systematically process slant or ground range Sentinel-1 data to terrain-flattened gamma nought backscatter. After terrain-geocoding, multiple observations are then integrated into a single composite in map geometry.

Although composite products are ubiquitous in the optical remote sensing community (e.g. MODIS), no composite SAR backscatter products have yet seen similar widespread use. In the same way that optical composites are useful to avoid single-scene obstructions such as cloud cover, composite SAR products can help to avoid terrain-induced local resolution variations, providing full coverage backscatter information that can help expedite multitemporal analysis across wide regions. The composite products we propose exhibit improved spatial resolution (in comparison to any single acquisition-based product), as well as lower noise and backscatter stability. In addition, backscatter variability measures can be easily added as auxiliary channels.

We demonstrate a new type of SAR backscatter product based on robust radiometrically terrain corrected backscatter images. We show results from the first year of calibrated Sentinel-1 data, covering the whole of the European Alps. The composite backscatter product type can be generated first at medium resolution (e.g. 100m), with a ramp up to higher resolutions possible as higher resolution DHMs become available together with improved network bandwidth and computing resources.

The products could see application in all of the listed the fields, including

- snow cover mapping
- hydrology
- agriculture
- general land-use and classification.

11:50 **Spatially Variant Methods for Improved SAR Coherence**

Presenter: Dr. ANDRE, Daniel (Cranfield University, DAC)

Synthetic Aperture Radar (SAR) interferometry and Coherent Change Detection (CCD), both monostatic and bistatic, depend on high coherence between repeat pass SAR images pairs. In principle these approaches allow a sensitive change detection for example due to ground subsidence or due to vehicle tracks, both applications having clear civilian and military benefits.

However there is usually a difference in the radar collection geometry for the SAR image pair, which can lead to incoherence between SAR image pairs. When sensing flat terrain in a SAR-far-field regime, the incoherence due to collection geometry difference can be removed through a conventional global spatial frequency trimming process. However, it has been found that when the terrain either contains non-flat topography or is in a SAR-near-field regime, the optimal trimming process is substantially more involved, so much so that a per-pixel SAR bistatic back-projection imaging algorithm has been developed: Spatially Variant Incoherence Trimming (SVIT). The case where satellite illumination is collected bistatically via a ground based receiver would count as a SAR-near-field scenario.

The SVIT algorithm removes incoherent energy from the bistatic interferometric SAR image pair on a per-pixel basis according to the local radar geometry and topography, leaving a higher coherence SAR image pair as is evidenced by CCD products. In order to validate the approach, change detection measurements were conducted with GB-SAR, a Cranfield University ground-based radar system.

However, it is additionally noted that variation in bistatic Radar Cross-Section (RCS) from the ground is a factor that can lead to a loss of coherence between bistatic SAR collections. It is analytically shown that to improve SAR image coherence, bistatic polarimetric effects should be taken into account as they can lead to a significant change in RCS as a function of the changing bistatic geometry. Bistatic scattering in different polarimetric basis are calculated for a representative example scatterer over a full bistatic hemisphere of scattering geometries, indicating the receiver polarization necessary for maximising bistatic RCS and coherence.

The results indicate that for diffuse specular scattering ground, the bistatic polarimetric scattering response varies in a well-defined way, so that it is possible to develop an extension to previous spatially variant coherence improvement techniques, varying the bistatic polarization decomposition in a spatially variant manner to increase SAR coherence over the scene.

In order to accomplish this in the mountainous or SAR-near-field scenario, within the bistatic back projection image formation algorithm the appropriate bistatic polarimetric decomposition should be chosen for each radar pulse in the SAR aperture and for each SAR pixel: Spatially Variant Polarimetry (SVP). In general the appropriate basis will be different for the two SAR collections for which one wishes to improve coherence. For the flat ground and SAR-far-field scenario, the optimal approach reduces to a simpler approach of enhancement by adding linear combinations of polarimetrically decomposed whole SAR images.

12:10	**Sensitivity of earth surface Ka radar backscatter to bio-geophysical parameters: a model based study** *Presenter: Prof. PIERDICCA, Nazzareno (Sapienza University of Rome)* Ka-band RADAR frequency range has not yet been used for Synthetic Aperture Radar (SAR) from space so far, but this technology may lead to important applications for the next generation of SAR space sensors. First of all the small wavelength makes small baseline suitable for interferometric applications, thus enabling a relatively simple implementation of single pass interferometry from a spaceborne platform. However, a better knowledge is required on backscatter at Ka-band in order to assess the realistic performance of a spaceborne SAR for the envisaged applications. The research presented in this paper was supported by an ESA project (Ka-band SAR backscatter analysis in support of future applications) aimed at investigating the wave interaction at Ka-band for a widely varying range of targets, both natural and manmade. The main objective was to establish a reference for the range of sigma nought expected from the earth surface and its variability as function of incidence angle and target conditions, to be used for system performance assessment and design. An additional outcome of the project was a better understanding on the sensitivity of Ka sigma nought to surface parameters as compared to other frequency bands. In particular, it was investigated the radar response of bare soil, crops, forests, sea surface and snow covered soil. The investigation was based both on the analysis of experimental data and on the exploitation of electromagnetic scattering models. Actually the available experimental data are quite scarce and in some cases not consistent, so that the electromagnetic models revealed themselves essential to enlarge the range of conditions (e.g., incidence angle and range of target bio-geophysical parameters) to be investigated. In the presentation the results of the models are showed and critically compared to the available data. The model outputs are then presented to assess the sensitivity to the target parameters of Ka backscatter in comparison to other radar frequency bands currently exploited from space for different applications. Namely, modelling of Ka backscatter of bare soil is discussed and the limitation of state of art asymptotic solutions demonstrated. The sensitivity to soil parameters was finally showed using a semi-empirical model. As for vegetated target both crops, shrubs and few types of forests were considered. A solution of the Radiative Transfer Equation was used to investigate the polarimetric response of those targets, their range of sigma nought at Ka band, and the sensitivity to vegetation type and biomass. As for the seas surface, backscatter is manly determined by Bragg scattering at the higher frequency range of the capillary wave spectrum, thus echibiting some modelling challenges and some differences with respect to the commonly used frequency band for sea applications (e.g., C and Ku).
12:30	Lunch break
14:00	**Land Applications from High Resolution, X-band, Airborne SAR** *Presenter: Ms. MUIRHEAD, Fiona (University of Edinburgh)* High resolution (<1m, single look images), X-band airborne synthetic aperture radar (SAR) imagery was collected for sites of environmental interest in Scotland. The SAR system utilised was Selex ES's novel, compact, low-cost airborne experimental platform. Its size, power consumption and lightweight build allow it to be placed on helicopters, fixed wing aircrafts and UAVs; making techniques such as SAR interferometry (InSAR) and coherent change detection (CCD) more widely available for civilian environmental applications. InSAR requires an extremely stable platform and is usually placed on a fixed wing aircraft, such as DLR's E-SAR or a satellite, such as the new Tandem-X satellite, to overcome this issue. We show that InSAR can even be carried out from helicopter data, making the technique more accessible. The inertial measurement unit (IMU) is local to the radar allowing for the accurate motion compensation required to robustly carry out repeat pass InSAR. The use of airborne platforms, as opposed to satellites, for environmental monitoring allows for rapid deployment times to sites of interest and multiple viewing angles to help overcome issues caused by shadowing in final DEMs. A high resolution airborne system could complement a global coverage satellite system by analysing results from a smaller localised area. The data was collected over a two day period in September 2014 for multiple sites of interest in Scotland with the system placed on a Twin Squirrel helicopter and overall 2000 spotlight SAR images were gathered. Up to seven repeat passes with differing flight paths were collected for some sites and multiple areas were imaged from different viewing angles. CCD results and digital elevation models (DEMs) for the sites collected can be used for many environmental applications. One example is for site management by the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS). The Scottish Environmental Protection Agency (SEPA) are interested in DEMs of sites for landslide and flood risk management. The data collection also covers sites for many more applications such as coastal erosion, forestry monitoring, subsidence detection and monitoring areas where mining activities take place. Figure 1 shows Selex ES's experimental SAR system placed on the Twin Squirrel helicopter. Figure 2 shows an example of an interferogram produced from two repeat pass images over a site with steep terrain. Figure 3 (a) and (b) show images of a field taken from two passes and (c) shows the CCD result between these two passes. It is clear that the field has been ploughed between revisits. This result shows the effectiveness of the small changes that can be detected using high resolution SAR images. This research is a collaboration between Selex ES, the Schools of Geoscience and Engineering at the University of Edinburgh and the Knowledge Transfer Partnership (KTP).
14:20	**Vegetation classification in the floodplains based on the MetaSensing airborne PolSAR-L and InSAR-X** *Presenter: Dr. CORUCCI, Linda (MetaSensing BV)* Floodplain vegetation classification is an important issue in the Netherlands since the country is highly vulnerable to flooding. The resistance force exerted by vegetation on water flowing over or through it alters the water flow velocity, thus, it is important to classify and monitor the vegetation in such sensitive areas. Currently, this is done by means of aerial photography interpretation with field control. However, such method results to be very time consuming. Moreover, it does not allow for the discrimination of the vegetation underneath canopy. In order to answer the need for an efficient means of classifying and monitoring the vegetation present in the Dutch floodplains, MetaSensing performed test flights with their airborne fully polarimetric L and X band SAR systems over selected areas in the Netherlands. In addition, ground truth surveys have been conducted to validate the outcome of the classification. The L band polarimetric SAR data allowed for distinguishing between most of the vegetation classes of interest. This was achieved by means of a classification algorithm based on an eigenvalue/eigenvector decomposition of the coherency matrix. However, by comparing the results of the classification with the ground truth, it was found that some misclassification happened in areas covered by vegetation types of different heights (such as tall shrubs and forest). The use of a different frequency band, specifically X-band, was attempted and a fully polarimetric X-band SAR system was flown over the same areas. However, the analysis of the X band data did not add useful information to the L band classified data. Since the main responsible for the misclassification resulted to be the missing information about the height of the vegetation, an additional flight with an X-band interferometric SAR system was performed, in order to obtain a Digital Surface Model (DSM) of the areas of interest. By fusing the L-band classification with DSM it was possible to distinguish the vegetation types basing on their height, thus, it was possible to correctly label those classes which were previously misclassified.
14:40	**Round Table on General Land-Use and Classification**

Coffee break - (15:10-15:30)

II - Soil and Hydrology - (15:30-17:00)

time	title
15:30	**A Multitemporal soil moisture retrieval algorithm applied to L-band radar data** *Presenter: Prof. PIERDICCA, Nazzareno (Sapienza, University of Rome)* Remote sensing represents a very useful tool to monitor volumetric Soil Moisture Content (SMC) at different temporal and spatial scale. Indeed, such measures present a direct sensitivity to SMC at microwave bands, where the soil electrical permittivity is influenced by the water content. However, the radar return is sensitive not only to soil moisture, but also to surface roughness and, in presence of vegetation, to biomass and other vegetation parameters, so that the retrieval process is quite challenging. Synthetic Aperture Radar (SAR) systems are characterized by high spatial resolution, so that detailed soil moisture maps can be obtained. Nowadays, frequent coverage of SAR images are becoming feasible thanks to the launch of the ESA Sentinel 1 A and B satellites (C-band). The NASA Soil Moisture Active and Passive (SMAP) satellite (L-Band) was also conceived for this purpose, although unfortunately the radar failed after a short period of operation and only low resolution soil moisture map are produced from SMAP radiometer. In this work, we test a multitemporal algorithm (MLTA) to retrieve soil moisture from L-band data, such as those produced by SMAP; the multitemporal algorithm has been originally developed for the 2-polarization radar images produced by Sentinel-1 at C-band1. The software has been updated to accommodate SMAP radar images, which are collected at L-Band and three polarizations (HH-VV and HV) within short revisit time. Such type of algorithm may deliver frequent and more accurate soil moisture maps mitigating the problems due to the roughness and vegetation changes, which can be assumed to occur at longer temporal scale respect to the changes of soil moisture. A dense time series of radar backscatter measurements are integrated within a multitemporal inversion scheme based on the Bayesian Maximum A Priori (MAP) criterion in order to invert a forward backscattering model, which relates the backscattering coefficient to the bare soil parameters (not only soil moisture, but also soil roughness) and includes also the contribution from vegetation. A segmentation of the SMAP coverage has been carried out in order to minimize the revisit time of each area along the SMAP orbit precise cycle, by exploiting the superimposition of the radar field of view for different tracks. Moreover, it is analysed how working with the SMAP L1C sigma nought product at full resolution (1 km) may improve the estimates of soil moisture with respect to using the 3-km resolution sigma nought. The data provided by the calibration and validation (CAL/VAL) campaign SMAP Validation Experiment 012 (SMAPVEX012) has been used to update the forward model for bare soil scattering at L-band with respect to the Oh and Sarabandi2 model previously used at C Band and, in a second step, to tune simple vegetation scattering models. SMAPVEX012 consists of in situ soil moisture and vegetation parameters measurements coincidently to L Band images collected by the UAVSAR sensor over several agricultural regions located South of Winnipeg, Manitoba (Canada), which includes a range of crop types, some permanent grasslands, wetlands and mixed forest cover. The results of the inversion algorithm applied to the SMAPVEX012 data are presented and compared to ground truth, thus summarizing strength and weakness of the approach. [1] N. Pierdicca, L. Pulvirenti, G. Pace: A Prototype Software Package to Retrieve Soil Moisture from Sentinel 1 Data by Using a Bayesian Multitemporal Algorithm. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 7, no. 1, pp., 153-166, Jan. 2014. [2] Y. Oh, K. Sarabandi, F. T. Ulaby: Semi-empiricalmodel of the ensemble-averaged differential Mueller matrix for microwave backscattering from bare soil surfaces. IEEE Trans. Geosci. Remote Sens., vol. 40, 1348–1355, 2002.

15:50 **Initial Results on Soil Moisture Retrieval from Sentinel-1 Data**

Presenter: Dr. MATTIA, Francesco (CNR-ISSIA)

The objective of this paper is to report on a first assessment of superficial soil moisture (SSM) products retrieved from Sentinel-1A (S-1A) data. The SSM retrieval is obtained by applying the SMOSAR algorithm [1-2], which has been devised to exploit the advanced observational capabilities of S-1 mission, particularly its frequent revisit (i.e. exact revisit with 1 satellite of 12 days & 6 days with 2 satellites). The algorithm inverts the temporal changes of radar backscatter rather than the “single-date” backscatter values, as it was usually performed on SAR data acquired by past spaceborne systems, whose revisit was too long to enable an effective time series approach. The rationale of SMOSAR is that temporal changes of surface parameters influencing the radar backscatter, apart from SSM, (e.g. soil roughness, canopy structure, vegetation water content, etc.) usually take place at longer temporal scales than SSM changes (excluding cultivation practices). Therefore, SAR time series with a sufficiently short repeat cycle are expected to track changes in SSM only, since other parameters affecting radar backscatter can be considered constant. In SMOSAR this approximation is made and this implies that the retrieval approach is extremely simplified and fast with respect to approaches based on the cumbersome inversion of scattering models depending on a large number of surface parameters. SMOSAR can be applied to bare and vegetated surfaces dominated by surface scattering as, for instance, cereal crops. This means that beforehand retrieval a masking process, obscuring those areas dominated by volume scattering, is required.

In this study, S-1A and ground data collected over the Apulian Tavoliere (southern Italy) from October 2014-onward are analyzed. The Apulian Tavoliere is the second largest plain in Italy and a crucial agricultural area, particularly for the durum wheat production. The site is in the Mediterranean semi-arid climatic zone and presents important challenges for the water management. A network of more than 40 agrometeorological stations is distributed across the plain and a high resolution X-band meteorological radar with a coverage radius of 30 km and spatial resolution of 60 m covers approximately a quarter of the area. A focus area of approximately 2x3 km2 is almost completely managed by three agricultural research Institutes, which conduct intensive crop and soil monitoring activities, with a particular emphasis on cereal crops. In this focus area, a hydrologic network, composed of 11 ground stations continuously recording soil moisture and soil temperature (at 0.025, 0.1, 0.2 and 0.4 m depths) at an average spacing of approximately 500 m has recently been set up [3].

The assessment of S-1A SSM products includes i) a comparison between SSM data retrieved and observed by the hydrologic network over almost a one-year period and ii) an analysis of SSM spatial patterns observed at regional scale over single-date and seasonal-averaged SSM maps. In addition, the error structure of SSM estimates derived from SMOSAR is discussed.

References

[1] A. Balenzano, F. Mattia, G. Satalino, M. Davidson, “Dense temporal series of C-and L-band SAR data for soil moisture retrieval over agricultural crops,” IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. vol. 4, no. 2, pp. 439-450, 2011.

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[3] A. Balenzano et al, "A ground network for SAR-derived soil moisture product calibration, validation and exploitation in Southern Italy," Proc. of Geosci. and Remote Sens. Symp. (IGARSS), pp. 3382-3385, 2014.

16:10 **Detection of water bodies at global scale with Envisat ASAR: lessons learnt and recent achievements**

Presenter: Dr. SANTORO, Maurizio (GAMMA Remote Sensing)

The availability of global datasets of synthetic aperture radar (SAR) data has boosted the development of algorithms in several thematic applications requiring large-scale classifications or quantitative mapping. From the Envisat mission (2002-2012), a decade of observations of the radar backscattered intensity acquired by the Advanced SAR (ASAR) sensor is available, with a spatial resolution between 30 m and 1,000 m. While the high resolution modes of ASAR were used for local studies, the coarse resolution modes were used more systematically to cover large areas. As a result, the archives of ASAR data are dense but are not spatially uniform. Availability of a large number of observations of the C-band SAR backscatter has been demonstrated to be beneficial to improve the performance of forest biomass retrieval, soil moisture estimation and wetlands detection (Pathe et al., 2009; Santoro et al., 2011; Bartsch et al., 2012). In such examples, estimates or classifications are derived from individual images and eventually combined to improve the original values. Multi-temporal metrics are another way to profit from the availability of multi-temporal observations either because the noise is reduced compared to the original data (Bartsch et al., 2008) or such metrics are better related to specific properties of a land cover class or land surface parameter (Quegan et al., 2000; Thiel et al., 2009).

With respect to the detection of open water bodies, we have reported on the reliability of the backscatter temporal variability and the minimum backscatter used as input in a rather straightforward approach based upon a number of thresholding rules (Santoro et al., 2014). When applied on a global scale to six years of observations by Envisat ASAR from the Wide Swath Mode, the thresholding rules were challenged by the heterogeneity of the Earth's landscape. The metrics were found to be similar for water bodies and specific surface types (e.g., sandy desert and snow fields) or events (snow melt, increased soil moisture) (Santoro et al., submitted). Recently, we integrated data from the Image Mode, Wide Swath and Global Monitoring archives over all land surfaces (Antarctica excluded) into a single database of SAR backscattering coefficients to allow an improved understanding of C-band time series of observations and develop further methods for improved characterization of parameters of the carbon and water cycle. With respect to the detection of water bodies, we are currently investigating the parameters of a linear model relating the SAR backscatter observations to the corresponding local incidence angle as additional parameter to discriminate water from other land surfaces.

In this presentation, we shall review observations of the SAR backscatter by Envisat ASAR and related metrics with the aim of a full characterization of water bodies with respect to other land surfaces. These investigations are possible thanks to the unique dataset of ASAR backscatter observations, which are publically available via the Grid Processing On Demand (G-POD) platform for the time period 2005-2012. In this presentation, we shall also present data products obtained by applying straightforward classification algorithms (threshold, classification tree) to the ASAR data, portraying the spatial distributions of water bodies at global scale.

References

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16:30 **Round Table on Soil & Hydrology**

Ice Breaker - (17:15-19:00)

Wednesday 18 November 2015

III - Ice & Snow - (09:20-12:50)

time	title
09:20	**Very High Resolution Imaging of the Vertical Structure of Snowpack and Sea Ice** *Presenter: Dr. TEBALDINI, Stefano (Politecnico di Milano)* Characterisation of snow and ice plays a pivotal role in understanding and monitoring changes in the global climate and ecosystem. Monitoring inland snowpack properties is a most important issue for the management of water resources, especially in the present context of climate change. The properties of sea ice and its snow cover control the amount of solar radiation reflected to the atmosphere, absorbed within snow and ice, and transmitted into the ocean beneath the ice. In this paper we present scientific investigations of both ice and snow based on high resolution Synthetic Aperture Radar (SAR) Tomography (TomoSAR). TomoSAR has been largely considered in recent years for forestry applications as it entails a fundamental advantage over traditional (i.e.: 2D) SAR imaging, namely the possibility to see the vertical structure of the imaged volume, to be afterwards employed as a robust basis for validation and development of physical models. The instrumentation to be employed for this scope is the Ground-Based Synthetic Aperture Radar (GB-SAR) developed by the SAPHIR team at IETR, University of Rennes I, hereinafter referred to as IETR GB-SAR. Such a system can be operated at frequency bands ranging from C-Band to Ka-Band. The system is able to form a 2D aperture by moving transmitting and receiving antennas along a rail that can be vertically displaced, achieving a vertical resolution of few centimeters. Data are presented from the ESA campaign AlpSAR, in the Austrian Alps, dedicated to snowpack investigations, and from surveys carried out over Kattfjord, Tromsø, Norway, where sea ice was the focus of the analysis. For both snowpack and sea ice the images produced by the GBSAR revealed a multi-layered structure. In many cases the backscattered from the bottom layers was observed to dominate the one from the surface and near subsurface by over 20 dB. This result was found to be largely independent of the incidence angle. GBSAR images also turned out to provide sensitivity to propagation velocity within the snowpack, as revealed by the apparent depth variation with respect to the incidence angle. This effect was used to assess propagation velocity according to a simple model based on Snell law.
09:40	**Three Dimensional Imaging of the Internal Structure of an Alpine Glacier** *Presenter: Dr. TEBALDINI, Stefano (Politecnico di Milano)* The main objective of the AlpTomoSAR experiment was then to assess the added value of L-Band TomoSAR for glacier and icecap applications, by discussing: o The level of analogy/complementarity/synergy of TomoSAR w.r.t. Nadir looking systems. o The added value w.r.t. single baseline inversion. o The information content of SAOCOM-CS TomoSAR over glaciers, icecaps and ice sheets. The campaign has encompassed coincident in-situ data, GPR, and SAR surveys, gathered in about two weeks from the end of February to the beginning of March 2014. Field works have also included deployment, maintenance, and dismantlement of 8 corner reflectors. SAR data were acquired by repeatedly flying over the Mittelbergferner along an oval-like racetrack configuration, so as to illuminate the scene from two opposite view points. The analysis of TomoSAR cubes immediately shows the complexity of the glacier sub-surface scattering. Most areas are characterized by surface scattering in proximity of the Lidar surface, plus a complex pattern of in-depth volumetric scattering beneath. A significant backscatter signal is observed in the top 10 to 20 m. In other areas, instead, a gap on the order of 10-20 m is observed between surface and in-depth scattering. These results show that modelling scattering from the ice layer in terms of an exponential decay due to uniform wave extinction is definitely insufficient for characterizing glaciers. The availability of a dense in-situ information allowed to further analyse TomoSAR cubes, and associate the observed features with physical interpretation. Corner reflectors, deployed on the snow surface, were observed in TomoSAR cubes to float about 2-3 m above surface scattering. This observation implies that the observed surface in TomoSAR cubes corresponds to the snow/glacier ice interface, whereas the winter snow volume does not appear to contribute to the signal. This result is also consistent with field measurements of the winter snowpack depth. Various subsurface features observed in GPR transects at 600 MHz and 200 MHz can be clearly identified in TomoSAR sections as like firn bodies, crevasses, and even the bedrock down to 50 m below the ice surface. Accordingly, the AlpTomoSAR experiment has provided evidence that, for a temperate glacier, L-Band waves can penetrate down to tens of meters, and that Tomographic SAR imaging can successfully be employed to derive information on the subsurface structure which is in well agreement with low frequency GPR profiles.

10:00 **A volume detector to identify icebergs in satellite radar imagery**

Presenter: Dr. MARINO, Armando (The Open University)

SAR is very valuable for monitoring icebergs due to its capability to acquire images with almost any weather condition and without solar illumination. In SAR images, icebergs are often visible as bright regions or points (depending on iceberg size and image resolution). This work is focused on the detection of smaller icebergs or thick/deformed blocks of sea ice embedded in thinner sea ice. The detection of icebergs of several km size is routinely done, however, there are still issues in identifying bergy smaller than a few hundred meters, especially when embedded in sea ice. In fact, in some situations sea ice can appear very bright defeating detectors based on image intensity. The use of polarization is expected to improve the detection capability of the system. The aim of this work is to propose a novel detector based on dual-polarimetric detected images (i.e. only intensity) to improve the detection of small icebergs embedded in sea ice.

The proposed algorithm is based on dual-polarimetric detected images (i.e. only the intensity of the images is necessary, not the phase). The physical idea behind the algorithm is that icebergs or thick/deformed ice are supposed to have a stronger volume contribution compared to thin sea ice. Moreover, we are interested in detecting icebergs with a well-defined size. Two boxcar filters are applied over the entire HV and HH images, exploiting two different window sizes (a test and training window). The intensities obtained by these averaging are arranged in a compact mathematical expression:

$\Lambda = \frac{|\langle | HV |^2 \rangle_{test}-\langle | HV |^2 \rangle_{train}|}{\langle | HH |^2 \rangle_{train}}>T$

As mentioned previously, there is a specific size of the targets (icebergs or thick/deformed ice) that are able to trigger the detection. In order to change the dimension of the target of interest, the windows have to be modified. Clearly, we cannot be completely sure if the detected object is an iceberg or a block of thick/deformed ice, but they both may represent hazards for the navigation. Additionally, the proposed detector is more focused on relatively small bergs and it may be ineffective for large icebergs of several km. In such cases a more traditional methodology based on morphological characteristics of the target is suggested.

In order to test the detector, real Sentinel-1 dual-polarimetric images are exploited. The data were acquired in Greenland, near the basin of the Helheim glacier. The latter is one of the fastest calving glaciers. Moreover, the acquisitions were performed in cold seasons, where the sea is covered in sea ice.

Unfortunately, ground survey of the icebergs or thick/deformed ice is not available and we have to rely on visual inspection of the images. In particular, targets of interest were identified as bright regions in the HV channel that cast a shadow in the far range and a bright rim in the near range.

The proposed algorithm is able to detect icebergs of dimensions chosen by the selection of the averaging windows. Finally a comparison with algorithms using HV intensity alone shows that there is a much reduced number of false alarms.

10:20 **Modeling of Boreal Forest Canopy Effects in Satellite Snow Mapping**

Presenter: Mr. COHEN, Juval (Finnish Meteorological Institution)

Satellite based snow cover monitoring is typically performed using SAR, optical-, and passive microwave sensors. Effects of forest canopy on the observed signal need to be considered with all of these sensor types. Various models describing the interaction of electromagnetic radiation with the forest canopy have been developed, but in particular for radar backscattering, many of these are overly complex with high computational- and ancillary data requirements. For retrieval purposes, simple, invertible models are preferred.

This work aims at increasing the understanding of the effect of forest canopy on remote sensing observations of snow-covered terrain for both microwave and optical regimes, and at quantifying the capability of simple, zeroth-order models in simulating these effects. To achieve these goals, a spatial analysis of X to Ku band SAR, optical-, and multi-frequency passive microwave remote sensing data in the northern boreal forest region of Finland was performed. Model parameters for vegetation transmissivity as well as the properties of the underlying surface were optimized by utilizing LiDAR- and Landsat based simplified proxy parameters describing forest canopy closure and stem volume.

The results demonstrated that despite using these relatively simple proxies, a zeroth-order model can accurately estimate the scattering behavior of the SAR signal in the boreal forest biome, as well as passive microwave and optical signatures. The SAR model successfully estimated the median of the observations, but compared to optical and passive microwave, a large scatter of the observations was reflected by higher RMSE and lower correlation with the model. Due to both good estimation accuracy and simplicity, the presented models can be considered to be applicable in existing retrieval algorithms for seasonal snow, e.g. the estimation of snow-covered area from SAR observations. The results are relevant also concerning potential future missions for e.g. retrieval of SWE including concepts based on dual frequency SAR observations.

10:40 **Towards an automated method for detection and monitoring of avalanche debris using Synthetic Aperture Radar**

Presenter: Dr. VICKERS, Hannah (Northern Research Insitute)

Snow avalanches, both natural and human released, occur frequently throughout the winter season in the mountainous regions of Troms county in northern Norway. These avalanches can lead to road closures, community evacuations and fatalities. It is therefore desirable to develop a method by which snow avalanches can be actively mapped and monitored, especially in avalanche-prone areas that are not easily accessible for observation by human means. Avalanche debris can be observed over large spatial areas, independent of local weather and light conditions by synthetic aperture radar (SAR) satellites that can measure snow remotely. The recently launched Sentinel-1A satellite makes it possible to acquire SAR images within the entire county of Troms with updates as often as every 2-4 days. We have acquired and built up a database of Sentinel-1A images since the satellite became operational in September 2014. This database has allowed us to identify and monitor several key areas in Troms county where avalanches release frequently during the entire winter season. We have exploited the Sentinel-1A data to firstly show that Sentinel-1A images can be used to observe avalanche debris and secondly to develop an automated avalanche debris detection algorithm which makes use of change detection and object classification methods. In this work we give an overview of the method and present results of the automatic detection algorithm where we have applied it to selected areas in Troms county where repeated avalanche activity was observed throughout the winter season, including both wet and dry avalanche types. We evaluate the accuracy of the method by means of gathering incident reports, in-situ field measurements and high resolution SAR (RS-2 ultrafine) images. We show that the method delivers results that agree well with the supporting observations and could play an effective role in mapping avalanche-prone zones and routine monitoring of these areas within Troms county as well as other avalanche-prone regions that are observable by SAR. We also report on the outstanding challenges that must be overcome to fine-tune the current detection algorithm.

11:00	Coffee break
11:20	**Ku- and X-band Radar Backscatter and SWE – Observations in Different Snow Cover Regions** *Presenter: Mr. ROTT, Helmut (ENVEO IT)* Several field campaigns were conducted in recent years in order to advance the understanding of radar interaction with seasonal snow and to support Phase-A science activities for the ESA Earth Explorer candidate mission CoReH2O. Ku- and X-band backscatter data were acquired by ground-based scatterometer systems and the airborne SnowSAR sensor. The test sites cover tundra sites in Manitoba and the North West Territories, Canada, taiga snow near Sodankylä, northern Finland, and alpine and maritime snow in two different elevation zones of the Austrian Alps. These snow cover classes are characterized by distinct differences in snow depth, stratification and microstructure. Though the boundary conditions triggering the buildup and evolution of the snowpack are quite different in the various climate zones, similar problems arise for inverting the backscatter measurements in terms of snow water equivalent (SWE). A key issue is the separation of effects of evolving snow structure versus the signal arising from the accumulation of snow volume or mass. The snow packs in the various test sites are characterized by bottom layers with coarse grains, superimposed by layers with smaller grain size. Whereas in the tundra sites the temperature gradient metamorphism is the main mechanism for grain growth, it is melt metamorphism for the maritime snow type in the alpine valley Leutasch. In the high alpine site Rotmoos and the taiga site in Sodankylä transient melt events are common in the early snow season, causing the formation of a coarse grained bottom layer. The microstructure of this layer is later on modified through the formation of depth hoar. Snow accumulating on these layers has smaller grains, so that the scattering contribution of the bottom layer is important throughout the winter season. In the high alpine site the contributions of the rough ground/snow interface and of the coarse grained bottom layer dominate the backscatter signal throughout the winter season. Therefore the accumulating fine grained snow does not induce a significant change in backscatter, impeding distinct relations between sigma-0 and SWE both at X-band and Ku-band frequencies. Also in Sodankylä the X-band backscatter signal changes little during winter, whereas the Ku-band backscatter intensity increases. The firmness of the relation between Ku-band sigma-0 and SWE is quite different in the various winter seasons, where the history of snowfall and snow metamorphism seems to be a main factor. At the tundra site near Churchill, Manitoba, the Ku-band backscatter increases significantly during winter, though the maximum snow depth is rather modest. The rising backscatter intensity coincides with the growth of depth hoar, suggesting that depth hoar is a main factor for explaining the observed relationship between backscatter intensity and SWE. On the other hand, for the maritime snow in the alpine valley melt metamorphism is a dominating factor for evolution of the backscatter signal. During the AlpSAR field experiment 2012/13, we observed in January high backscatter coefficients both in X- and Ku-band after a major melt/freeze event. The accumulation of fine-grained snow later on did not cause any substantial change in the backscatter intensity. The observations in the different snow cover regions emphasize the importance of snow structure and metamorphic state for evaluating relations between backscatter intensity and SWE, as well as for explaining cases lacking such relations. Consequently, reliable methods for retrieval of SWE need to account for microstructure and layering of snow, taking into account the temporal evolution of snow state. Radar backscatter measurements by themselves are not sufficient for definite separation of the signal contributions induced by either snow mass or snow structure. Complementary information, supplied by snow process models driven by meteorological data, and possibly also complementary observations of snow properties by means of other remote sensing systems, are needed for supporting reliable SWE retrievals.
11:40	**Radar imagery to investigate dynamic changes in alpine snow** *Presenter: Dr. WIESMANN, Andreas (GAMMA Remote Sensing)* Remote sensing of snow with active and passive microwaves has a long tradition. Terrestrial instruments are used to investigate the interaction of snow with microwaves at selected locations, air- and space-borne sensors are used to image larger areas. While the terrestrial instruments are mobile and can be brought to selected test areas they are usually doing point measurements. Satellite based instruments on the other hand, have a given observation geometry and observation schedule. These constraints limit the potential to investigate dynamic processes in the snowpack spatially, especially of slopes. Terrestrial imaging radars such as the GPRI (GAMMA Portable Radar Interferometer), overcome some of these constraints due to their portability, operating range of several kilometers, image acquisition time of about 30 seconds and the possibility to do repeat acquisitions within minutes. In our presentation we discuss results of campaigns conducted with a Ku-band imaging radar at selected locations in the Swiss Alps covering dry and wet snow conditions. The investigation covers the analysis of backscatter information spatially and in time as well as the interferometric analysis of the corresponding time series. The interferometric processing allows to gather interferometric phase and coherence information. The coherence computed from shorter and longer image pairs allows to investigate the temporal decorrelation within the snowpack. The phase changes are related to atmospheric effects, changes in the snowpack and motion. The interferometric decorrelation is linked with changes in the snowpack structure. Consequently a drop in coherence is mainly an indicator for changes of the snowpack. They can be induced by short term effects like an avalanche release, or by slow restructuring such as snow metamorphism. If the correlation between two image acquisitions is high the interferometric phase can be interpreted. The phase reveals information about changes in the wave propagation to and from the target. Main contributions come from the displacement of the target area (e.g. speed and extent of creeping snow) along the line of sight, as well as changes in the atmospheric conditions. The results provide new and valuable information and methods for the snow research community, in particular for the research in snow mechanics and avalanche dynamics. A validation campaign proved the accuracy of the displacement measurement. But the findings together with results form other recent SnowScat campaigns are also relevant for future research in the interaction of electromagnetic waves with snow and dedicated campaign and mission planning. In an outlook we will discuss this aspect and outline next steps.

12:00	**Snow Retrieval Algorithm for Sentinel-1 Interferometric Wide-Swath Mode Data** *Presenter: Dr. NAGLER, Thomas (ENVEO IT GmbH)* The Sentinel-1 satellites of the European Copernicus Programme, equipped with a C-band SAR sensor, are providing improved, long-term observation capabilities for important bio- and geo-physical parameters of the Earth system. We developed, implemented and tested a procedure for retrieving maps of snowmelt area. The retrieval algorithm uses a similar change detection method as applied for snow mapping with SAR data of ERS and Envisat. We use Level 1 (swath based) single look complex (SLC) SAR products acquired in Interferometric Wide swath (IW) mode in dual (VV, VH) polarization. The IW mode is the nominal operation mode over land surfaces, with 250 km swath width and 5 m x 20 m nominal ground resolution. The reduced backscattering coefficient of snowmelt areas is detected by computing the ratio of backscatter intensity of the SAR image with melting snow versus reference images from the same satellite track acquired under snow-free conditions. As first processing step multi-channel speckle filters are applied to the precisely co-registered snow image and reference images. The ratio of the snow image versus the reference image in the VV and VH channels is combined to obtain an optimum feature space for snow segmentation. Terrain corrected geocoding and segmentation is performed for the combined ratio image, using precise orbit data and a DEM. Post-processing employs a land cover map in order to exclude water surfaces and dense forests. We generated a sequence of snowmelt area maps with 100 m spatial resolution for April to June 2015 covering the whole Alpine area, and maps with 50 m resolution for regional studies. For quality assessment we compare the S1 snow maps with snow extent derived from Landsat images and from high resolution TerraSAR-X images. The snow maps of the different sensors show good overall agreement. Along the snow boundaries there are some differences between SAR and optical sensor products, with a trend for underestimation of snow extent by SAR in particular in areas of broken snow cover due to high backscatter signals of snow-free patches. The combination of co- and cross-polarization data in the snow retrieval procedure yields improvements over single channel data. Differences in angular dependence of backscatter in the two channels are exploited to improve the backscatter contrast between snow-covered and snow-free surfaces over a wide range of local incidence angles. The retrieval algorithm enables the regular operational production of high resolution snow maps over extended areas. Sentinel-1 IW mode data provide complete repeat coverage in mid latitudes within 6 days with a single satellite, and within 3 days with the two satellite constellation, being an excellent basis for matching the snow mapping requirements in many fields of application.
12:20	**Round Table on Ice & Snow**

Lunch break - (12:50-14:00)

IV - Agriculture - (14:00-16:30)

time title

14:00 **Physical interpretation of the Polarimetric SAR changes observed over agricultural time series**

Presenter: Dr. ALONSO-GONZALEZ, Alberto (DLR)

In recent years, the presence of space-borne SAR systems has empowered the construction of dense time series datasets, containing SAR images of the same scene at different time instants. The importance of these datasets lies in that they contain information not only about the scene itself but also about its temporal evolution. Moreover, this is a growing trend which is expected to continue in the near future, since most of the current and planned SAR missions are focused on the construction of time series, as the ESA Sentinel-1 or the DLR TerraSAR-X, TanDEM-X and the future TanDEM-L.

This work is focused on the analysis of the temporal evolution of different agricultural fields and crop types by means of polarimetric time series datasets. The Binary Partition Tree (BPT) [1] is employed in order to improve the analysis of PolSAR time series. The BPT may be considered as a hierarchical region-based and multi-scale data representation. This technique has already been extended to process PolSAR [2][3] and hyperspectral data [4], demonstrating its ability to detect the homogeneous regions of the scene while also preserving the contours and the small details of the data. The BPT has also been extended to process SAR time series, as described in [5]. In the context of agricultural monitoring, the BPT is particularly useful, as it allows a precise characterization of the polarimetric signature of individual fields and crop types and its temporal evolution. In [6] a polarimetric change analysis has been proposed in order to give information not only about the amount of change, but also about the type of change. It decomposes the observed changes in the polarimetric space, giving information of the changes for different polarization states, being able to separate different behaviors.

A more detailed analysis of these time series datasets is proposed, with special attention to the characterization of the temporal evolution of the scene. The polarimetric change analysis technique described in [6] will be applied. In this work, the focus will be put in the physical interpretation of these changes, trying to link some physical properties of the target with the observed changes. Due to the multidimensional nature of the polarimetric data, the technique is able to detect different changes at distinct polarization states. This will help in the understanding of the physical changes and their relation with the polarimetric target response.

The method will be applied to the AgriSAR 2006 campaign and also the Wallerfing 2014 campaign, consisting of a set of E-SAR and F-SAR acquisitions over agricultural fields and an extensive collection of in-situ ground measurements. Moreover, in these datasets different types of data are available for exploration. This includes multi-frequency acquisitions at X-, C- and L-band, and interferometric data with different spatial and temporal baselines that cover different stages of the phenological cycle from April to August. All this information will be exploited in order to explore and interpret the polarimetric changes observed among these data. Additionally, the ground truth information and measurements will be used in order to analyse, interpret and verify the obtained results. Particular attention will be taken to the final land applications that may take profit of the proposed processing as, for instance, crop identification and monitoring, change detection and characterization or bio/geophysical parameter retrieval.

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14:20	**Field Measurements in Support of the ESA SWINTOL Project** *Presenter: Dr. MORRISON, Keith (Cranfield University)* At high spatial resolution (<1m) and/or for short wavelengths (i.e. < 3cm) there is a gap in our understanding of the interaction of a radar wave with natural targets over a SAR scene. This information is needed to look to and assess the next generation of EO satellites. Extant scattering models lack either the ability to incorporate the required SAR parameters or are not applicable at high frequencies. Hence there is a need to define a physically robust wave interaction approach that takes into account all the specificities of high resolution / short wavelength SAR imaging. The ESA project SAR Wave INteraction for Natural Targets Over Land (SWINTOL) is designed to address these deficiencies through a combined modelling and experimental study. Fieldwork was undertaken by Cranfield University to provide the data necessary for model validation and development. SAR and tomographic profiling (TP) imagery were taken of a barley crop over the growing season with Cranfield's portable outdoor Ground-Based SAR (GB-SAR) system. It comprises a trailer-mounted cherry picker which can provide measurements up to a height of 9m. Wide-area ~30m x 30m SAR images were captured of the scene from full height, in combination with lower height TP measurements. TP is a scheme for providing a detailed map of the vertical backscatter pattern through a crop canopy along a narrow transect directly beneath the along-track direction, whilst side-looking SAR imagery captures coarser sigma-nought measurements. Fully-polarimetric imagery was obtained across overlapping 6.5GHz bandwidths over the X- and Ku-band frequency range 8-20GHz. Such high bandwidths provide resolutions in the slant range direction at the wavelength scale. With comparable resolutions in the cross-range directions (there are two within a crop canopy volume) in the TP images, it gives the opportunity to see detail at the plant component level. Measurements were made on seven separate dates between 15 April and 31 July. The former corresponded to emergence of the crop, whilst the latter immediately followed harvesting of the crop. Surface roughness characterisation of the soil was made at the start of the season using a 3D optical stereoscopic system. Full bio-geophysical characterisation of the crop and soil was made on each date; a representative square metre of crop was fully described for 3D structure, biomass, and water distribution, along with soil moisture across the scene. The presentation will detail the measurements made and provide examples of TP and SAR imagery, and provide an comparative assessment of the results in terms of understanding the backscatter in relation to biophysical and radar parameters.
14:40	**UK National Crop Mapping using Sentinel-1** *Presenter: WOODING, Mike (Remote Sensing Applications Consultants Ltd)* RSAC and CEH are working on an InnovateUK supported project called Land Cover Plus which is aimed at producing an annual crop map of the UK based on the use of Sentinel-1 SAR data, as an add-on layer to the National Land Cover Map. The ESA AgriSAR 2009 programme demonstrated the potential of C-band SAR data for crop mapping using time series Radarsat data for test sites in The Netherlands, Canada and Spain. This has been taken forward in the UK using a time series of Radarsat images from 2014. Changes in the backscatter of different crop types through the growing season were investigated using a large ground data set collected in 3 test areas, and a crop classification technique developed based on matching temporal backscatter profiles. All the main arable crops are able to be separated including wheat, barley, oilseed rape, potatoes, sugar beet and field beans, but it is not possible to distinguish between different vegetable crops. Crop classification accuracies of around 90% have been obtained for all test areas. A large programme is being carried out in 2015 processing Sentinel-1 data for the whole of the UK. Measurements are being taken from a time series of 15-20 dates, and ground data have been collected for a full range of crops over the whole of the UK. The UK National Crop Map is expected be available for release at the time of the workshop in November 2015.

15:00	**Agricultural Crop Structure by Means of Multi-Baseline Pol-InSAR and SAR Tomography** *Presenter: Ms. JOERG, Hannah (German Aerospace Center, ETH Zurich)* Multi-parameter synthetic aperture radar (SAR) acquisitions can be employed for the quantitative estimation of biophysical parameters of agricultural vegetation (e.g. crop height and canopy structure). Polarimetric SAR Interferometry (Pol-InSAR) [1], by exploiting the variation of the interferometric coherence with polarisation, presents a valuable support to the extraction of crop parameters from SAR data. The estimation of these parameters is achieved via the inversion of electromagnetic scattering models relating the Pol-InSAR complex coherences to the physical properties of the agricultural scenario. The Random Volume over Ground (RVoG) scattering model, widely used for the inversion of forest height, assumes a 2-layer structure consisting of a cloud of particles with no preferred orientation (volume layer) on top of an impenetrable ground. Based on this simplified formulation, the scattering from the ground is polarisation-dependent, whereas the propagation through the volume is independent of polarisation [1]. However, orientation effects present inside the agricultural vegetation require to consider a polarisation dependency also for the volume layer. Hence, a generalisation of the RVoG model, the Oriented Volume over Ground (OVoG) model, has been developed. In this case, the volume particles have a non-uniform orientation distribution: as a result, the effective medium is not isotropic and the propagation constants vary with polarisation [2]. Due to the increased number of unknown parameters when compared to the RVoG case, the inversion of the OVoG model requires fully-polarimetric radar measurements from at least two spatial baselines [2, 3]. (Polarimetric) tomographic SAR techniques, as an extension of the Pol-InSAR principle, enable the analysis of the profile of the backscattered power along height and hence the 3-D characterization of the scattering mechanisms occurring in vegetated fields. SAR Tomography can help to interpret and separate ground and volume scattering signatures in an unambiguous and non-model based way yielding estimates of the scattering parameters, such as for instance, scattering phase centres, the ground-to-volume ratio as well as the multi-baseline volume coherences for every polarisation [4]. In this work, crop parameters such as vegetation height, extinction coefficients and ground-to-volume ratios are estimated by using both a Pol-InSAR OVoG inversion scheme [3] and a more generalised tomographic approach. The investigation is carried out on a data set of fully-polarimetric multi-baseline SAR acquisitions at X-, C- and L-band, acquired by DLR's airborne sensor F-SAR in 2014. These measurements have been collected from May to August over an agricultural area in Germany, covering different stages of the plant growth cycle. A comparison of the results from Pol-InSAR and SAR Tomography is then performed to ascertain the potential and the limitations of these two techniques over different crop types and sensor frequencies. This comparison provides a big potential in fostering the understanding of the physical scattering behavior of agricultural crops and the implications for model based inversion, as for instance the benefit from particular a priori knowledge. [1] K.P. Papathanassiou, and S.R. Cloude, "Single-baseline polarimetric SAR interferometry", IEEE Transactions on Geoscience and Remote Sensing, vol. 39, no. 11, pp. 2352-2363, Nov. 2001. [2] J.D. Ballester-Berman, J.M. Lopez-Sanchez, and J. Fortuny-Guasch, "Retrieval of biophysical parameters of agricultural crops using polarimetric SAR interferometry", IEEE Transactions on Geoscience and Remote Sensing, vol. 43, no. 4, pp. 683-694, Apr. 2005. [3] M.Pichierri, I. Hajnsek, and K.P. Papathanassiou, "A multi-baseline Pol-InSAR inversion scheme for crop parameter estimation at different frequencies," IEEE Transactions on Geoscience and Remote Sensing (submitted). [4] H. Joerg, M. Pardini, I. Hajnsek, "Spatial and temporal characterization of agricultural crop volumes by means of polarimetric SAR Tomography", in Geoscience and Remote Sensing Symposium (IGARSS), 2015 IEEE International, IEEE, 2015.
15:20	Coffee break
15:40	**Intelligent Farming with Sentinel 1** *Presenters: Mr. WICKS, Dan (Satellite Applications Catapult), Dr. MINCHELLA, Andrea (Satellite Applications Catapult)* For the purpose of agricultural monitoring, the study of vegetation phenology by means of remote sensing has been largely addressed by the analysis of temporal variations in vegetation indices acquired by optical sensors. To date, the use of radar sensors has been explored in the literature but is less developed for operational agricultural monitoring activities. Many theoretical and experimental studies have demonstrated the sensitivity of microwave backscattering to vegetation, which can be linked to parameters such as biomass and crop type. However, due to the costs associated with data and the infrequency of data acquisition, there is huge failure to commercially exploit this technology for agricultural applications. ESA's Sentinel 1 mission offers the ideal platform to support application development, with focus on reliability, operational stability, global coverage, quick data delivery and of course zero cost. Work has been conducted to explore the potential of Sentinel 1 data for the retrieval of information on the phenology of cereal and oilseed crops. Specific activities have included analysis of SAR backscatter coefficients and the exploitation of polarimetry and interferometry techniques, correlating these observables to extensive ground truth data collected from 24 fields in South-West England. A total of 36 images across different tracks were considered from April to September and all processing was carried out using the open-source ESA Sentinel-1 and PolSARpro toolboxes. Analysis of the spatial variation in the SAR derived observables has demonstrated positive relationships with significant growth stages that farmers rely on identifying for accurate chemical application.
16:00	**Round Table on Agriculture**

V - Forestry - (16:30-18:00)

time title

16:30 **AfriSAR, a P-Band Ariborne SAR campaign over Gabon**

Presenter: Mrs. DUBOIS-FERNANDEZ, Pascale (ONERA)

The first part of the AfriSAR campaign was conducted over sites in Gabon in July 2015 with the ONERA airborne system SETHI and the second part will be performed with the DLR airborne system F-SAR in February 2016. The main objective of this campaign is to collect data to support the development of the Earth Explorer candidate mission, Biomass. The following specific scientific questions still need to be addressed and the data collection strategy was constructed accordingly:
-Verify the BIOMASS geophysical inversion method over an african tropical forest, - extend the coverage in the 100t-300t/ha biomass range,
-assess the P-Band SAR for deforestation and degradation, - map a large reference area, - assess the impact of seasonal changes on the inversion schemes.

This contribution will describe the selected test sites, followed by a summary on the radar instruments. The set of flight lines designed to optimize the coverage and the test cases within the constraints associated with the flight regulation over Gabon will then be detailed with flight geometry and radar modes.

The data acquired in July is being processed at ONERA. First results will be presented.

16:50 **The Potential of TanDEM-X InSAR Coherence for Mapping Tropical Forest Structure: A Case Study in East Kalimantan**

Presenter: Ms. DE GRANDI, Elsa Carla (University of Edinburgh)

Forest disturbance due to fire and subsequent regeneration are important processes particularly in South East Asia. Forests damaged by fire are still valuable in terms of conservation due to their ability to recover, sequester carbon and restore ecosystem services and should therefore be monitored. Sungai Wain Protected Forest (SWPF) located near the city of Balikpapan, East Kalimantan was affected by fires driven by El Nino Southern Oscillation (ENSO) in 1998 which led to the degradation of a previously undisturbed *Dipterocarpaceae* forest. With the frequency and magnitude of ENSO events likely to increase in the future it is important to monitor forest regeneration after fire in the long term with Remote Sensing being a particularly valuable option. Spaceborne Interferometric Synthetic Aperture Radar (InSAR) offers an alternative to optical sensors in tropical areas where cloud cover and haze is frequent and hampers the retrieval of meaningful information. In particular, the TanDEM-X missions offers the opportunity to acquire data in interferometric mode thanks to two satellites closely orbiting in a double helix formation with minimization of temporal baseline and at high spatial resolution (approximately 2 m ground resolution at 41° incidence angle in StripMap single polarisation) compared to previous satellite missions. Typically temporal decorrelation has severely limited the ability to use coherence to monitor forests. The unprecedented provision of TanDEM-X coherence through simultaneous capture, thus without the limitation of temporal decorrelation, solves this problem. The aim is to assess the sensitivity of TanDEM-X coherence to horizontal vegetation structure (canopy cover) and vertical structure (vegetation height) these being derived from a high resolution airborne LiDAR (1 m resolution). Tests were done on 150 plots (35 x 35 m) located in secondary forest and agriculture, with mean canopy cover of 73% and height between 0.4 to 36.4 m (mean 14.7 m). Results indicate a negative linear relationship between TanDEM-X coherence and canopy cover (R2=0.64) (n= 150). This suggests that coherence is sensitive to the spatial distribution of scattering volume which causes decorrelation proportional to canopy cover. However, it was found that for fully regenerated secondary Dipterocarp forest with high canopy cover coherence ranges between 0.4 and 0.8 resulting in high scatter for high canopy cover. This was further investigated by assessing whether topography played a role in lowering coherence. No correlation between slope and coherence was found. Another possible cause for low coherence could be due to layover. Hoekman and Varekamp (2001) suggest that a high height difference between the forest components (presence of tall emergent trees) results in lowered coherence due to geometric decorrelation. Moreover, relationship between the vertical structure component (vegetation height derived from a LiDAR Canopy Height Model- CHM) was also tested resulting in a good correlation with coherence (R2=0.68) while, a weaker relationship was found with LiDAR CHM mode (R2=0.63) and, lower still with the distribution of standard deviation (R2=0.5): but some of these independent correlations offer possibilities for better mapping of canopy cover. These results offer a promising potential for the use of coherence for detecting forest structural parameters such canopy cover and forest height.

17:10 **FoRAsT – Measuring Forest Degradation by Radar Remote Sensing**

Presenter: Mr. VACCARI, Simone (LTS International Ltd.)

Forest degradation is an important source of emissions of carbon dioxide, a greenhouse gas. In many African woodland countries, degradation is a more substantial source of carbon dioxide emissions than deforestation, but degradation cannot be accurately measured using optical remote sensed data such as Landsat. LTS International and the University of Edinburgh have developed FoRAsT (Forest Radar Assessment Tool), an innovative new tool for detecting and measuring forest degradation using radar technology. Radar systems are well suited for assessing aboveground biomass because they are sensitive to woody biomass but not to canopy foliage. Radar can also be used day or night, under any weather conditions.
FoRAsT makes use of the Phased Array L-band Synthetic Aperture RADAR (PALSAR) instrument, which is part of Japan’s Advanced Land Observing Satellite (ALOS). ALOS PALSAR data has been successfully used worldwide to quantify forest aboveground biomass, with especial focus in African woodlands due to its compatibility with the biomass range of up to a maximum of around 300 Mg ha-1, after which the sensor saturates. Up to this level, FoRAsT can estimate forest aboveground biomass with an averaged RMSE of 62 Mg ha-1. The first ALOS mission (ALOS-1) ended in early 2011, whereas the second ALOS mission (ALOS-2) was successfully launched in May 2014 and data was made available from November 2014.
LTS applied the FoRAsT in two different international development projects. In the first project, biomass change in the Sierra Leone/Guinea border region was assessed as part of a USAID and USFS/IP funded climate change mitigation pilot Sustainable & Thriving Environments for West African Regional Development (STEWARD) project. Over 90% of the biomass lost resulted from degradation. These data are being used by the STEWARD project to inform land use decisions and contribute to on-going forest monitoring. LTS also produced a biomass change assessment for priority catchments of the Shire river basin in Malawi as part of an integrated land use management project for the Government of Malawi. Production of biomass maps for 2007 and 2010 enabled the project team to show the spatial pattern of forest degradation over that period. This information is now being used by the Government of Malawi to target interventions in support of sustainable land use management.
The application of FoRAsT, developed with ALOS-1 data, generated promising results in African woodlands in regards to forest aboveground biomass assessment. In order to guarantee application longevity and consistence of the tool, FoRAsT is currently under development to allow simultaneous implementation of ALOS-2 data (from 2014) and ALOS-1 data (timeframe 2007 – 2010). This will allow bridging the gap between 2010 and 2014 in which there were no L-band radar satellites orbiting around the Earth, making it possible to extend forest monitoring assessment in woodland ecosystems of the last decade.

17:30 **SAR for REDD+**

Presenter: Dr. HAARPAINTNER, Jörg (Norut - Northern Research Institute)

The overall goal of the ESA funded DUE Innovator III project “SAR for REDD” is to provide satellite synthetic aperture radar (SAR) pre-processing and analyzing capabilities and tools for operational tropical forest monitoring to REDD countries and primarily in Africa.

The UN initiative Reducing Emissions from Deforestation and Forest Degradation, including conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+), is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. A necessity to implement REDD+ is the development of consistent and accurate monitoring, reporting and verification (MRV) systems based on both remote sensing and in-situ measurements.

As persistent cloud cover in the humid tropics prevent reliable observations at any time with optical satellite sensors, cloud-penetrating SAR imagery has proven to be a useful tool for interoperability and/or to complement optical satellite forest monitoring systems. For forest applications, L-band SAR is generally better suited than C- or X-band since its signal penetrates deeper into the forest canopy and thus, also provides more information on biomass. However, with the launch of Sentinel-1A in 2014, ESA’s C-band SAR has evolved from a research purpose to a fully operational satellite with higher coverage and revisit frequencies to establish denser time-series, increased radiometric accuracy and free data policy.

SAR pre-processing and analysis has not been at the reach for everybody and there is still a strong need for technical and human capacity in developing countries for this sensor type to be fully used. Since the 1990, Norut has developed automatic SAR pre-processing and analysis tools and set up operational SAR-based monitoring system for several environmental monitoring projects.

In this project, Norut will therefore not only provide already processed remote sensing products in the form of radiometric calibrated and geo-referenced SAR images and mosaics, forest/non-forest maps and forest change maps for specific periods, but also provide necessary easy-to-use tools for SAR pre-processing, mosaicking, temporal averaging and classification. The system will be able to process the main historical and current SAR sensors: ERS-1&2 SAR, Envisat ASAR, ALOS Palsar (1&2), Radarsat-2 and Sentinel-1. This will give REDD countries the possibility to process and analyze historical and future SAR imagery and implement SAR into their operational forest monitoring systems to improve their monitoring, reporting and verification of REDD activities.

The pilot focus region is the Mai-Ndombe district in the Democratic Republic of Congo and the service user is the Observatoir Satellitale des Forêts d’Afrique Centrale (OSFAC), a Congolese NGO, who support the management of natural resources with satellite based products and advises governmental institutions of several Congo Basin countries. OSFAC has been a close collaborator and already a user in the EU FP7 project ReCover where Norut has developped SAR based forest products based on Envisat ASAR and ALOS PALSAR.

Thursday 19 November 2015

V - Forestry: Continuation - (09:30-12:30)

time	title
09:30	**Potentials of SAOCOM-CS Tomography for Boreal Forest Biomass Retrieval** *Presenter: Dr. TEBALDINI, Stefano (PoliMi)* This paper concerns the evaluation of the performance of the future SACOOM-CS spaceborne mission for the characterization of boreal forests. This assessment is based on estimates and indicators obtained from airborne tomographic acquisitions led during the BioSAR 2 campaign. A comparison is led between results obtained from original high-quality measurements to those derived from degraded data sets, resulting from the transformation of the airborne signal according to the SAOCOM-CS mission specifications. Apart from obvious changes between airborne and spaceborne configurations, particular features are accounted for in this study: • Unlike classical tomogarphic sensors, SAOCOM-CS will not acquire N SLC 2-D data sets, but instead (N-1) pairs of interferometric images with a low level of correlation between every two pairs. This aspect needs to be handled by a specific tomographic focusing scheme • The reduced range resolution in a spaceborne configuration deteriorates the spatial resolution of the retrieved results and affects tomographic performance through the range decorrelation effect. • Compared to airborne measurements, spaceborne acquisitions are affected by lower SNR figures as well as by potential temporal decorrelation between the acquisitions The influence of each of these factors on the estimation performance is first tested individually and is then assessed globally. Forest biomass retrieval was based on two key observables that can be easily computed from tomographic products: • the total integrated volumetric backscatter from 10m above the ground and up. • average scatterer height, computed as the mean of the height above ground weighted by the returned intensity for each voxel. As a result, simulated SAOCOM-CS tomographic data have been observed to produce biomass retrievals from boreal forest matching or surpassing those obtained from L-band ESAR full resolution backscatter images.
09:50	**SAR Tomography for Forest Structure Classification and Monitoring: Actual Status and Perspectives** *Presenter: Dr. PARDINI, Matteo (German Aerospace Center (DLR))* Microwaves can propagate through vegetation layers, allowing the radar signal to interact with the different physical forest structure elements. Exploiting this property, SAR Tomography techniques provide a 3D profile of the backscattered radar power providing a proxy to the physical forest structure. This capability has been demonstrated by means of several (long wavelength) airborne campaigns, which have triggered the development of a new generation of forest structure monitoring applications by means of SAR remote sensing. At the same time, the progress in SAR technology makes possible the implementation and operation of a new generation of spaceborne SAR configurations able to realize these applications on a global scale with a high spatial and temporal resolution. The objective of this work is to present the status and to address potentials and challenges related to applications of SAR Tomography for 3D forest structure characterization and monitoring. A number of issues will be addressed, in particular: 1. the performance of several reflectivity estimators (model-based and not) with respect to acquisition configuration (e.g. geometry and number of baselines, availability of multiple polarization channels, frequency, etc.), and different seasonal and environmental conditions (leaves on/off, dry/wet acquisition days, etc.); 2. the interpretation of the reflectivity profiles, by means of a comparison with ground measurements, lidar profiles and forest simulations. In this, a key role is played by the variability of the profiles with seasons and environmental conditions; 3. the possibility and the methodologies to distinguish between different physical forest structure types by using the reflectivity profiles. In the presentation, several experimental results will be presented. Airborne (L-band polarimetric repeat-pass interferometric) SAR data will be used. Data have been collected under different environmental and seasonal conditions systematically over a period of 12 years (2003-2015) over the Traunstein test site by means of the DLR's airborne platforms E-SAR and F-SAR. Traunstein is a heterogeneous temperate forest located in southern Germany, with a wide range of stand compositions, stand heights (from 10 to 40m) and stand biomass (mean biomass level of 200 Mg/ha and stands up to 500 Mg/ha). Radar results have been validated by means of extensive ground measurements and lidar profiles.

10:10	**Radar backscatter of forests: Recent advances and application to the retrieval of forest biomass** *Presenter: Dr. LE TOAN, Thuy (CESBIO)* Assessing terrestrial ecosystems as carbon sources or sinks and predicting their changes under different scenarios of climate change requires accurate and repetitive estimates of forest biomass. For this purpose, the Biomass mission has been selected as the 7th ESA Earth Explorer mission, a P-band SAR satellite dedicated to global biomass measurements. During the preparation phase of Biomass, several airborne and ground based experiments have been conducted over boreal and tropical forest sites, to develop innovative measurement concept for biomass retrieval. Also in recent years, ALOS-PALSAR data have been made widely available by JAXA, leading to numerous studies using L-band SAR data to retrieve forest above ground biomass (AGB), although mostly limited to forest of low AGB, such as savannah woodland. The large datasets formed by both radar data and in situ data, and the analysis results provided by those recent studies has led to several findings in the last few years. Firstly, nearly continuous ground based backscatter measurements over a tropical forest have shown that the backscatter temporal variations, for example a clear diurnal cycle of the backscatter and its vertical distribution following variations in the tree functioning. This has an impact on the backscatter radiometric stability and the determination of the optimal time of the day for data acquisition. The backscatter 'saturation effect' has been revisited. At P-band, the increase of the backscatter has been observed for tropical forest AGB up to 500 t/ha, provided that the perturbing effect of topography is minimized. This has been done by properly taking into account both scattering mechanism and geometric effects, or discarded by isolating the backscatter of a tomographic layer the least affected by ground scattering. At L-band, for high AGB of dense forest canopy (AGB > 200 t/ha), a decrease of the backscatter with AGB due to the attenuation effect is observed. Most observations have been interpreted using an electromagnetic model which indicated the relevant scattering mechanisms involved in the SAR measurements. This paper will present these new findings and their integration in biomass retrieval methods.
10:30	Coffee break
10:50	**The role of optical and L-band SAR data in discriminating stages of tropical secondary forests** *Presenter: Dr. CARREIRAS, Joao (National Centre for Earth Observation (NCEO), University of Sheffield)* Land use and land cover change, particularly conversion from forest to non-forest, is the second largest source of greenhouse gases emissions. Global deforestation is mostly concentrated in the tropics, with severe consequences for carbon stocks depletion and major impacts on biodiversity, with most of the cleared land occupied with annual or perennial crops, plantations or cattle ranching. The Brazilian Amazon is one of the world's major deforestation hotspots, although deforestation rates reported by the Instituto Nacional de Pesquisas Espaciais (INPE) show a decreasing trend from its highest value in the mid-1990s (~30,000 sq km/yr) to a record low of ~4,500 sq km/yr in 2012. Abandoned croplands and pastures in tropical regions give rise to rapid establishment of secondary forests, with consequent carbon accumulation and potential restoration of biodiversity. However, the age, type and composition of these forests established on abandoned lands are a consequence of several factors, such as land use history, soil fertility, and distance to mature (primary) forests. Therefore, it is important to know the age and land use history of regrowth areas to better understand patterns of carbon accumulation and impacts on biodiversity. The land use history prior to land abandonment can be retrieved by analyzing time series of land cover maps derived from classification of high resolution optical data. This approach is nonetheless often hindered by cloud cover, leading to poor coverage by optical data. However, all-weather SAR data availability is increasing with consequent benefits for land use/land cover change monitoring over tropical regions. The objective of this study was to assess the capability of C- and L-band SAR data to discriminate and map the age of secondary forests across the Brazilian Amazon. Available 3-class (mature forest, non-forest, secondary forest) land cover maps over three selected sites of the Brazilian Amazon (Manaus: 1973-2011; Santarém: 1984-2010; Machadinho d'Oeste: 1984-2011) were used to generate maps of age of secondary forests (ASF) at any given year in those periods. ASF classes were defined as initial (≤ 5 years), intermediate (6-15 years) and advanced (≥ 16 years). Japan Aerospace Exploration Agency (JAXA) Advanced L-band Observation Satellite (ALOS) Phased Array L-band SAR (PALSAR) data acquired over those sites between 2007 and 2010 were processed and used to test its ability to discriminate stages of tropical secondary forests. Additionally, the current concurrent availability of both C-band (Sentinel-1A) and L-band (ALOS-2 PALSAR-2) data makes it possible to test the synergy of multi-frequency SAR data to improve the classification of stages of tropical secondary forests. Fitted models of the type I = a0 + a1 ln(ASF) (where I = HH or HV backscatter intensity in dB) were significant (α=0.05) at the site and time-step level (with the exception of those with HH polarization at Manaus in 2007 and 2009); model goodness of fit (R2) was low but better at the HV polarization, ranging from 0.02-0.04, 0.13-0.34 and 0.10-0.23 at Manaus, Santarém and Machadinho d'Oeste respectively. Models fitted with aggregated data at the site level were also significant (α=0.05) and with a better goodness of fit (R2), ranging from 0.28 to 0.43; however considerable inter-annual variability is noticeable. The analysis of variance and the Kruskal-Wallis rank sum test of the model relating ASF classes to L-band HH or HV backscatter intensity at the site scale showed that overall all models were significant (α=0.05). The exceptions are those with HH in 2009 and 2010 (Manaus), and with HH in 2007 (Santarém). Non-significant (α=0.05) pairwise combinations of ASF classes, according to Dunn's test are: i) Manaus, initial-intermediate; initial-advanced; ii) Santarém, intermediate-advanced. Data from aggregating all sites showed that according to the analysis of variance and the Kruskal-Wallis rank sum test all models were significant and only the combination initial-intermediate in 2007 was rejected as significant according to Dunn's test. L-band SAR data alone does not accurately discriminate the age and stages of tropical secondary forests in the Brazilian Amazon; however, better results were obtained when data from different sites were aggregated. The concurrent use of data acquired by L- and C-band SAR sensors may improve the discrimination of these forests; structural differences among different ages/stages of tropical secondary forests might be better captured with SAR data representing the interaction of radiation with different parts of the tree.

11:10	**Interest of Support Vector Regression (SVR) for Biomass retrieval from POLSAR data over Boreal Forests** *Presenter: Dr. FRISON, Pierre-Louis (Universite Paris-Est Marne-la-Vallée - MATIS - IGN / CESBIO)* SAR data are well suited for the retrieval of biomass from vegetated areas. In particular, the ability of low frequencies to deeply penetrate dense vegetation, allows P band radar data to retrieve high biomass levels that can be encountered over forests, where other frequencies show their limitations. Up to know many biomass retrieval methods are based on multi-linear regressions using the different polarized channel intensities acquired in HH, HV, and VV polarization. Such linear behaviour is not necessarily observed by the measured parameters with respect to biomass. The present study aims to assess the potential on Support Vector Regression (SVR) for biomass retrieval from polarimetric SAR data. Support Vector algorithms have been widely used especially for classification of remote sensing data. It is especially well suited to take into account multiple parameters, not necessarily homogeneous in a physical point of view. The SVR algorithm allows to better fit learning data, displaying linear behaviour or not. The polarimetric parameters consists in different parameters obtained from polarimetric decomposition algorithms (the entropy, anisotropy, Freeman parameters, degree of coherence between HH and VV polarizations,…) The method is assessed on SAR and in situ data collected in 2007 and 2008 over Remningstorp and Krycklan during the BioSAR-1 and BioSAR-2 campaigns. These two data set, collected over two different test sites, with different topographic environment, at different dates (March April and May 2007, and October 2008), allow to evaluate the robustness of the methods with respect to spatial and temporal variations. These results will be analysed in the frame of the 7th ESA Earth Explorer mission BIOMASS, for which the number of training plots is a critical point .
11:30	**Forest Above Ground Biomass Mapping in Biomass Mission Configuration : Applications to P-band TropiSAR data"** *Presenter: Dr. VILLARD, Ludovic (CESBIO)* To support the selection of Biomass as the 7th ESA Earth Explorer mission, an essential part of the work was to demonstrate that the Above Ground Biomass (AGB) of dense forests (above 300 t/ha) can be retrieved from P-band SAR data, given the importance of tropical forests in the carbon cycle. Using PolSAR data, the retrieval of AGB in tropical forest is a challenging task given the small sensitivity of the radar backscatter to forest biomass with respect to perturbing sources such as environmental effects or terrain topography. Besides, another challenging aspect of the future retrieval algorithm for a global mission like Biomass lies in its ability to deal with different forest types and natural land covers. Therefore, the mapping of forest Above Ground Biomass (AGB) is not only challenging over tropical dense forests, but also over complex natural landscapes characterized by their high spatial variability (heterogeneous areas, forest patches, clearings, borders...). The foreseen retrieval algorithms have therefore to be parametrized according to the various possible forest types at the global scale, assuming thereby an ad-hoc (adapted) classification prior to the inversion process. As a result, the attributes of the forest classes are more linked to the retrieval algorithm capability than to ecological characteristics. The retrieval algorithm is based on a Bayesian formulation of the estimated AGB, in which the Gaussian probability density functions are characterized by a mean value derived from the so-called analytical model (power law between a PolSAR indicator and AGB) and by a standard deviation derived by a perturbation model (resulting from electromagnetic simulations of the backscatter). Both analytical model and perturbation model are parametrised using the P-band observations and in-situ data on the forest test plots, but the parametrisation of the analytical model is based on a regression analysis, whereas the parametrisation of the perturbation model is based on its ability to reproduce the complex backscatter, from which the likelihood functions are computed. A general description of the retrieval algorithm will be first given in the paper, before going more into the details of the three main steps, considering 1/ the ad-hoc classification, 2/ the parametrisation of both analytical and perturbation models and 3/ the pixel-to-pixel inversion. To assess the performance of the proposed algorithm, the TropiSAR P-band data acquired over tropical forests in French Guiana will be used as demonstration case, considering however a limited number of forest classes, which could be further extended with the very recent data from AfriSAR ESA campaign.
11:50	**Round Table on Forestry**

<u>Lunch break</u> - (12:30-14:00)

<u>VI - Sessions summaries</u> - (14:00-15:30)

time	title
14:00	**Summary "General Land-Use and Classification"**
14:15	**Summary "Soil and Hydrology"**
14:30	**Summary "Ice & Snow"**
14:45	**Summary "Agriculture"**
15:00	**Summary "Forestry"**
15:15	**Workshop Conclusion & Recommendations**