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Remote sensing for monitoring of land surface hydrology at high latitudes within the framework of the ESA DUE Permafrost and STSE ALANIS-Methane projects

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ALANIS Methane is a research project to produce and use a suite of relevant earth observation (EO) derived information to validate and improve one of the next generation land-surface models and thus reduce current uncertainties in wetland-related CH4 emissions. It is part of ESA's Support to Science Element Program.

The focus on the remote sensing side of the project is the development of new and/or improved wetland maps, and snowmelt and frozen ground information. **Wetland dynamics are investigated on regional to local scale over Northern Eurasia for the years 2007 and 2008.** Algorithm development is carried out over three selected test regions in a first step. They cover the lower and middle Ob basin (West Siberian Lowlands) and parts of the Lena basin (see Figure 1).

Wetland dynamics play an important role for methane release in high latitudes. Global wetland databases lack information on seasonal dynamics. Long term variations in inundation can be capture with coarse resolution passive microwave data (SSMI, [1]). Such data can be used to improve methane modelling, but uncertainties are large in areas with lower water fraction [2]. Coarse to medium resolution satellite products which are used for landcover maps (such as from Meris, 300m) show in general low accuracy in high latitude environments, since e.g. tundra ponds are mostly below the resolution of the satellite data [3].

Synthetic aperture radars (SARs) operating in ScanSAR mode (e.g. ENVISAT ASAR Wide Swath, 150m) have shown to be applicable for efficient and accurate water bodies mapping at high latitudes. ScanSAR data are therefore used for the development of a local scale wetland dynamics product within the ALANIS methane project. Besides wetland dynamics, information includes **surface wetness and status regarding frozen or thawed condition** [7,8]. Land surface hydrology and permafrost conditions need to be considered for land ecosystem-atmosphere modeling at high latitudes. The suitability of active microwave data to help validate or constrain relevant models is investigated within the European Space Agency funded projects STSE ALANIS-Methane and DUE Permafrost.

Challenges for the derivation of near surface soil moisture in high latitudes are [9]:
- frozen/snow covered ground conditions,
- landscape heterogeneity,
- seasonal variation in landcover type (water – non water),
- scarcity of ground data
- and issues related to the overlaying vegetation such as moss cover.

These issues are also addressed within the two projects. Validation activities of coarse satellite surface wetness products (~25km) are presented below. Issues regarding monitoring of inundation with ScanSAR data are addressed.

Detection of open water surfaces

The European ENVISAT carries an advanced SAR (ASAR) which provides C-band data in ScanSAR mode. These data can be used for update of inundation status with 150m spatial resolution at frequent intervals (several times per month depending on actual acquisitions). This complements regional to global wetland datasets with coarser scale (~25km).

The algorithms are implemented with the use of the SAR Geophysical Retrieval Toolbox (SGRT) developed by the Vienna University of Technology [6], and the Next ESA SAR Toolbox (NEST), which is developed by ESA. The NEST software features processing in the polar stereographic map projection, which is crucial for high latitude satellite data processing over large regions.

A limiting factor for using C-band data for inundation mapping is the impact of weather conditions. Due to its wavelength, the system records signals of surface water waves caused by wind and rain. Therefore data selection of calm weather conditions is crucial for classification accuracy, as figure 2 shows.

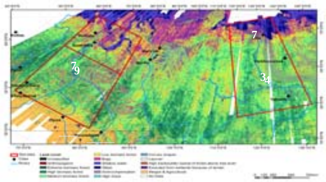

Figure 1: Overview of initial test sites of ALANIS-methane. Background: GBFM land cover map [4]

Longer wavelength SAR (L-band from ALOS PALSAR) is used to assess the impact of weather conditions and also the delectability for non-open inundation (in forests etc.). As expected, specular reflection (low backscatter over water bodies) corresponds to similar areas over tundra but differences are large over partly forested area.

Weather impact

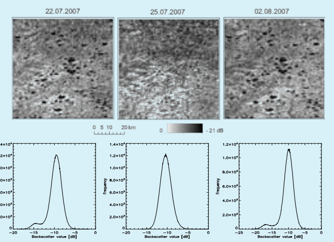

Figure 2: Backscatter time series showing loss of bimodal distribution over tundra: top normalized backscatter images, bottom: histograms of backscatter distribution [dB]. All images cover an identical area. 60% of acquisitions of Western Siberia are impacted by this phenomenon. Source [5].

Validation - examples

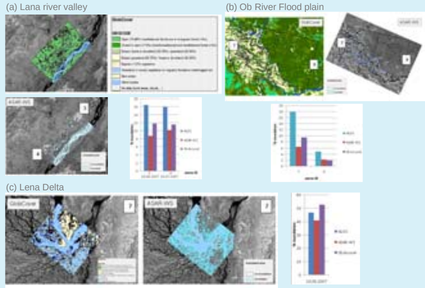

Figure 3: Comparison of land cover (GlobCover, ESA, 300m, static 2009; classes water and regularly flooded combined in graphs), ASAR-WS open water classification on days without weather impact and water fraction derived from ALOS PALSAR Fine Beam water classifications (25m resolution, L-band, same day acquisitions; JAXA PI No 91): a) Lena River valley, b) Ob river floodplain, and c) Lena Delta (EASE grid polar stereographic projection). For location see Figure 1.

Results - example

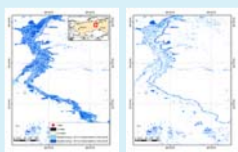

Figure 4: 10 day aggregated mosaics of open water surfaces derived from ENVISAT ASAR WS

Conclusions

Sampling intervals of ASAR are irregular and weather conditions can impede the retrieval what needs to be taken into account for the algorithm implementation. Verification does rely mostly on higher resolution satellite data with special emphasis on L-band SAR in order to identify the uncertainties when using C-band with respect to emerging vegetation and weather. C-band monitoring however could be used in combination with other sensors to separate open inundation from flooding below vegetation on a regular basis (10 days intervals – Figure 4).

References
[1] C. Prigent, F. Papa, F. Aires, W. B. Rossow, and E. Matthews. Global inundation dynamics inferred from multiple satellite observations, 1993–2000. Journal of Geophysical Research, 112:D12107, 2007.
[2] Bruno Ringeval, Nathalie de Noblet-Ducoudre, Philippe Ciais, Philippe Bousquet, Catherine Prigent, Fabrice Papa, and William B. Rossow. An attempt to quantify the impact of changes in wetland extent on methane emissions on the seasonal and interannual time scales. Global Biogeochemical Cycles, 24:GB2003, 2010.
[3] A. Bartsch, C. Pathe, W. Wagner, and K. Scipal. Detection of permanent open water surfaces in central Siberia with ENVISAT ASAR wide swath data with special emphasis on the estimation of methane fluxes from tundra wetlands. Hydrology Research, 39(2):89–100, 2008.
[4] Jan Kropacek and Gianfranco De Grandi. Wetlands mapping in siberia by classification of the GBFM radar mosaic using backscatter and terrain topographic features. In H. Lacoste, editor, Proc.'GlobWetland: Looking at Wetlands from Space', Frascati, Italy, 1920 October 2006.
[5] Bartsch, A., A. M. Trofaier, G. Hayman, D. Sabel, S. Schlaffer, D. Clark, and E. Blyth (2011): Detection of wetland dynamics with ENVISAT ASAR in support of methane modelling at high latitudes. Biogeosciences Discuss., 8, 1–28, 2011.
[6] Sabel, D., Bartalis, Z., Wagner, W., Doubkova, M., & Klein, J.-P. (accepted). Development of a Global Backscatter Model in support of the Sentinel-1 mission design. Remote Sensing of Environment(Sentinel Special Issue).

Surface wetness validation

Near Surface soil moisture can be derived e.g. from scatterometer (active microwave sensors). The algorithm by [10] is used for the DUE Permafrost project with Metop ASCAT data (2007 onwards, 25km resolution, C-band). The final products are masked for frozen ground conditions by application of a threshold-analysis method [7]. Validation at high latitudes is carried out by for example use of USDA-NRCS data over Alaska [11] and in-situ measurements in the Lena Delta, Russia by AWI [12].

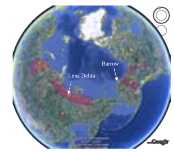

Figure 5: Extent of regional datasets and location presented soil moisture validation sites

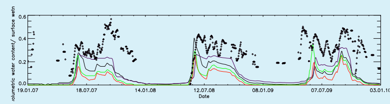

Figure 6: Comparison of Metop ASCAT surface wetness and USDA soil moisture measurements (5 cm depth) at site Barrow 1 (subsites : 1 – black, 2 –purple, 3-red, 4-green) : time series plot of weekly averages for ASCAT relative soil moisture scaled between 0 und 1 (diamonds), Volumentric water content values at USDA subsites (lines). (source [11])

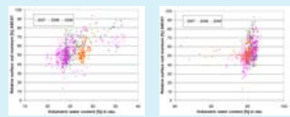

Figure 7: Volumetric water content (in %) from in-situ measurements of Samoylov Island (Lena River Delta, RU) and relative surface-wetness from Metop ASCAT (in %, 25 km resolution) for summers 2007, 2008 and 2009: left: slope of polygon, right: centre of polygon. (source [12])

Conclusions

In-situ soil moisture measurements at shallow depths reflect variations of satellite derived relative near surface soil moisture although the used sensor provides data at 25 km resolution. There are indications that this relationship is impacted by micro-topography and temporal offsets relate to snowmelt and active layer dynamics. These issues and relationships to other environmental parameters such as vegetation need to be further investigated.

References
[7] Naeimi, V., Paulik, C. Bartsch, A., Wagner, W., Kidd, R., Boike, J., K. Elger (accepted): ASCAT Surface State Flag (SSF): Extracting information on surface freeze/thaw conditions from backscatter data using an empirical threshold-analysis algorithm. IEEE Transactions on Geoscience and Remote Sensing
[8] S.-E. Park, Bartsch, A., D. Sabel, W. Wagner, V. Naeimi, Y., Yamaguchi (accepted): Monitoring Freeze/Thaw Cycles using ENVISAT ASAR Global Mode Remote Sensing of Environment.
[9] Bartsch, A., Sabel, D., Wagner, W. & S.E. Park (2011): Considerations for derivation and use of soil moisture data from active microwave satellites at high latitudes. Proceedings IGARSS 2011.
[10] Wagner, W., Noll, J., Borgeaud, M. & Rott, H. (1999): Monitoring soil moisture over the Canadian prairies with the ERS scatterometer. IEEE Transactions on Geoscience and Remote Sensing 37: 206–216
[11] Bartsch, A., Melzer, T., Elger, K., & B. Heim (submitted): Soil moisture from satellite data at high latitudes. TICOP proceedings.
[12] Heim, B., Bartsch, A., Elger, K., Lantuit, H., Boike, J. Muster, S., Langer, M., Duguay, C., Hachem, S., Soliman, A., Paulik, Chr., Strozzi, T., & Seifert, F.-M. (2011) ESA DUE Permafrost: an Earth Observation (eo) Permafrost Monitoring System. EARSeL eProceedings 10: 73-82.

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