Time Series Analyses of Active Microwave Satellite Data for Monitoring of Hydrology at High Latitudes

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Introduction

Microwaves can penetrate cloud cover and are independent from daylight conditions. Active systems onboard satellites provide coarse (scatterometer) to medium resolution data (ScanSAR and SAR). An increase of spatial resolution always goes along with reduced revisit intervals. In general, satellites with microwave sensors are polar-orbiting platforms. This means that data coverage increases at higher latitudes due to overlapping footprints and swaths, respectively. Scatterometer can provide here several measurements per day, and medium resolution ScanSAR, up to daily acquisitions.

The backscatter intensity depends on the used wavelength, polarization, incidence angle, and surface conditions (Henderson & Lewis 1998). The latter include dielectric properties and surface structure. Even surfaces such as lakes produce low backscatter compared to forests, where multiple scattering causes higher signal returns. Microwaves have a high application potential in hydrology, since dielectric properties are related to water content. Time series can be used to monitor soil moisture, snowmelt, and inundation. This extended abstract gives an overview of some available datasets and application examples in permafrost areas. Additional information can be found on http://www.ipf.tuwien.ac.at/radar/.

Near-Surface Soil Moisture

The ERS1 and ERS2 C-band scatterometer have been proven useful for derivation of relative soil moisture (Wagner et al. 1999, Wagner et al. 2007). Such data are available globally with 50km resolution since 1992. The long dataset allows the determination of deviations and thus anomalies. Continuation is ensured due to the launch of Metop in October 2006. The new ASCAT instrument on Metop provides even shorter revisit intervals and increased spatial resolution (25 km; Bartalis et al. 2007).

The near-surface soil moisture can be determined by time series analysis (Wagner et al. 2003). A dry and wet reference is identified for each grid point and each single measurement scaled between these limits. This results in a relative measure of near-surface soil moisture. By application of a simple infiltration model, profile soil moisture is derived (Wagner et al. 1999). The latter is referred to as Soil Water Index (SWI) and is available globally as 25 km grid cells in 10-day intervals (Wagner et al. 2007). The observed near-surface soil moisture variations are related to river discharge (Scipal et al. 2005). Although snowmelt is more important for the magnitude of discharge in high latitudes, a close relationship to soil moisture can be observed during the summer (Bartsch et al. 2007b).

The European satellite ENVISAT has a C-band SAR instrument onboard. This Advanced SAR (ASAR) provides higher resolution data (image mode) as well as medium resolution ScanSAR (Wide Swath and Global Mode). The latter has a wider swath (405 km) than high-resolution modes, which allows coverage of larger regions and provides shorter revisit intervals (with varying incidence angles). Therefore, a similar time series analysis, as developed for scatterometer data, can be applied to ScanSAR data for extraction of near-surface relative soil moisture. This has successfully been carried out for Southern Africa (Bartsch et al. 2007c) and Oklahoma (Pathe et al. 2007). It could be transferred to high latitudes where ENVISAT ASAR Gobal Mode (1km) data provide up to daily measurements (Bartsch et al. in press a). Such medium resolution ScanSAR data can also be used to derive spatial scaling properties, which allow an interpretation of coarse-resolution soil moisture from scatterometer (25 km) at local scale (1 km) (Wagner et al. 2008). Other new microwave sensors, such as the ALOS PALSAR (L-band, 12.5 m in fine beam mode), provide increased spatial and nevertheless low temporal resolution, but have potential for soil moisture retrieval (Bartsch et al. 2007d).

Snowmelt

C-Band (~5.6 cm) as well as K_u-band (~2.1 cm) radars are suitable for snowmelt detection. Changes in the snowpack, however, have a stronger impact on backscatter at shorter wavelengths. The SeaWinds Quikscat is a K_u-band scatterometer, which provides measurements with 25 km resolution since 1999. Re-gridded datasets are available with up to 5 km resolution (Long & Hicks 2005). The first entire snowmelt period on the Northern Hemisphere is covered in 2000. Large changes in backscatter between morning and evening acquisitions are characteristic for the snowmelt period, when freezing takes place overnight and thawing of the surface during the day. A change from volume to surface scattering occurs in case of melting. This may cause changes up to 6 dB (Kimball et al. 2004). When significant changes due to freeze/thaw cycling cease, closed snow cover also disappears (Bartsch et al. 2007a). For the identification of melt days over permanently snow- or ice-covered ground, only evening measurements are considered (Ashcraft & Long 2006). Diurnal differences (Bartsch et al. 2007a) on the other hand are calculated for the delimitation of the final spring snowmelt period. The exact day of year of beginning and end of freeze/thaw cycling can be clearly determined with consideration of long-term noise. Such an approach allows not only the monitoring of disappearance of snow. Areas which undergo thaw at a certain day can be identified as well. The QuikScat-derived thaw patterns relate to spring river discharge in high latitudes (Bartsch et al. 2007b).

Lakes and Wetlands

Due to the backscatter properties of open water (even surface), lakes can be easily identified with active microwave data. Although wind may increase the surface roughness, lakes can be identified based on time series (Bartsch et al. 2007e, Bartsch et al. in press b). Due to the wider swath and thus increased spatial and temporal coverage of ScanSARs, large regions can be processed. For example, ENVISAT ASAR Wide Swath data with 150 m resolution provide considerably more detailed information in tundra regions than land cover products from MODIS (500 m; Bartsch et al. in press b). The spatial distribution of lakes larger than 2 ha can be used for the determination of tundra wetland extent and also estimation of methane emissions.

Peatlands are characterized by high soil moisture conditions. They can be identified due to the sensitivity of microwaves to moisture/dielectric properties (Bartsch et al. 2007e). ENVISAT ASAR Wide Swath (150 m) as well as Global Mode (1km) time series are suitable for mapping of large regions such as the West Siberian Lowlands (Bartsch et al. in press b).

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