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Boreal Soil Measurements Using L-band Radiometers, SMOS and ELBARA-II

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Finnish Meteorological Institute (FMI), Arctic Research (ARC) has established a continuously observed test area to Northern Finland, Sodankylä. This Intensive Observation Area (IOA) has at the moment three measurement towers and an instrument arsenal consisting of radiometer, scatterometer and spectrometer systems. Observations are backed up with extensive automatic and manual in-situ measurements. The soil on IOA is a typical boreal mineral soil composed mostly of sand and silt.

This study concentrates on passive L-band measurements and their feasibility on monitoring boreal soil processes, emphasising on soil freezing and thawing cycles. We use both tower-based data from ELBARA-II radiometer and space borne data from SMOS (Soil Moisture and Ocean Salinity) mission. ELBARA-II is a dual polarized elevation scanning radiometer at 1.4 GHz frequency manufactured by GAMMA Remote Sensing, Switzerland and owned by ESA. FMI has operated it continuously in Sodankylä since October 2009. The SMOS mission payload instrument MIRAS is the first space borne remote sensing imaging radiometer based on aperture synthesis, launched on November 2009. For our study we have established a larger test area of size 150 km x 150 km in Northern Finland. The area includes Sodankylä IOA. Land cover, forest biomass and stem volume information on the area is available at 25 m x 25 m resolution. For further processing we have interpolated the SMOS data to 50 km x 50 km grid, thus obtaining 9 cells in our larger test area.

FMI-ARC test areas in Northern Finland are excellent for space borne instrument calibration and validation activities thanks to the extensive automatic and manual in-situ observations. For this study automatic measurements of snow depth, snow water equivalent and snow temperature, soil moisture and temperature and air temperature are used. As a reference, manually gathered parameters are snow density and depth, snow water equivalent, snow temperature, snow layer composition and snow grain size. Additionally, soil frost data has been recorded from the frost tubes three times per month from three different locations, open area, typical coniferous forest on mineral soil and bog.

We will present the ELBARA-II results through its' first one and half years in Sodankylä together with SMOS measurements at Northern Finland. The analysis of ELBARA-II measurements concentrate on combining the brightness temperature measurements with soil properties models to understand the soil freezing and thawing processes. The main interest in SMOS data is on feasibility of its use for detecting soil frost and how to use it for monitoring the soil freezing and thawing cycles. The challenge for SMOS data usage is the relatively coarse geometrical resolution.

The first results show a good correlation between soil frost depth and L-band radiometer brightness temperatures to certain frost depth. When the soil is frozen up to 30 cm depth, the brightness temperature signature begins to saturate. The soil dielectric constant decreases with soil freezing and thus the brightness temperature increases. Another very interesting phenomenon was observed during the snow melt-off on spring 2010. Rapid snow melting resulted on soil top layer thawing. Both ELBARA-II and SMOS had a brightness temperature minimum exactly at the same time as the in-situ observations indicate the snow melt-off.

Our results show that L-band radiometry has a clear potential for monitoring boreal/sub-arctic terrestrial regions, even using instruments with a coarse spatial resolution, such as SMOS. Potential applications for the monitoring of cryospheric processes are soil freezing and depth of soil frost during early winter, snow melting processes especially daily snow freeze-melt cycles, and the detection of snow clearance, which is related to the melt of the seasonal soil frost.