Microwave L-band dielectric constant and brightness temperature estimates of organic rich soils in the Boreal zone

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A database of microwave L-band dielectric constant and brightness temperature observations/estimates of organic-rich soils under natural vegetation in Northern Finland and Denmark

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Soil moisture is one of the main factors in the water, energy and carbon cycles, and thus, was selected as one of 13 Essential Climate Variables of the ESA's Climate Change Initiative. It constitutes a major uncertainty in climate and hydrological models, which are currently the best tools to simulate the ongoing human-induced climate changes. Hence, global soil moisture observations of good temporal resolution and quality are of high relevance. The ESA's Earth Explorer Soil Moisture and Ocean Salinity (SMOS) mission carries the first space-borne passive L-band microwave (1.4 GHz) radiometer on board, operating at the preferred frequency for soil moisture retrieval. It acquires global brightness temperature (TB) data every three days, from which surface soil moisture is retrieved, based on the inversion of the L-band Microwave Emission of the Biosphere (L-MEB) radiative transfer model. To account for the impact of roughness and vegetation, in L-MEB several land cover-dependent tuning parameters are implemented, which exclusively stem from study sites in the dry and temperate climate zones. Environmental conditions in the vast northern boreal zone are different. Prevailing land cover types include coniferous forest, heath- and wetlands with pronounced organic surface litter layers. The emission contributions of litter have been identified, but more knowledge is needed to take them into account in the modeling.

Due to currently above-average rising temperatures in the higher northern latitudes, a large amount of the important carbon sinks might be released, possibly causing a significant positive feedback on global warming. Thus, there is a strong need to monitor the hydrologic states and redistribution processes in these regions, rendering the exploration of SMOS data a high priority, especially given the hindered accessibility of these hostile environments. For these reasons, the research project SMOSHiLat has been evoked in the framework of ESA's Changing Earth Science Network. It's main objective is to improve our understanding of microwave L-band emissions from organic surface litter layers in boreal environments and thus, supporting the enhancement of SMOS soil moisture product quality over the higher northern latitudes. In a first step, a database is created from data collected at northern study sites, including (a) TBs of tower-based and airborne L-band radiometers, and (b) dielectric constant measurements of the organic substrate. Using this information, a soil surface emission model including the organic layer contribution will be developed and integrated in L-MEB for TB simulations over boreal environments. Finally, the new model will be tested in the SMOS soil moisture prototype retrieval algorithm in order to generate new soil moisture products. Focus is first put on unfrozen soil conditions. The newly gained knowledge will also be supportive for similar future space missions.

Two in this respect unexplored extensive data sets offer unique possibilities to work on the project objectives: (1) the Sodankylä-Pallas test site of the Finish Meteorological Institute (FMI) in Northern Finland, and (2) the SMOS validation site established in the framework of the Danish Hydrological Observatory and Exploratorium (HOBE) in the Skjern River Catchment in Denmark. At the Sodankylä site, profile soil moisture and soil temperature, including measurements in the organic litter, are available from several automatic stations under herbaceous vegetation and forest. Some of them are distributed around the footprint of the tower-based L-band radiometer ELBARA-II which has been acquiring data in a boreal forest clearing between fall 2009 and fall 2012. In October 2009 an airborne L-band radiometer campaign was flown (HUT-2D) including two flights with up to twenty overpasses of the ELBARA-site. During summer 2012 distributed soil moisture readings with hand-held sensors as well as soil and vegetation sample collection have been carried out around the automatic stations. The data set from the ‘HOBE site’ includes spatially distributed soil moisture measurements from hand-held sensors and samples of the organic litter as well as mineral soil layers from a heath and coniferous forest sampling patch, respectively. This data was taken concurrently with airborne L-band radiometer measurements (EMIRAD-2 and HUT-2D) on 3 days in spring 2010 around SMOS morning overpasses. Additionally, eight automatic profile network stations have been recording surface soil moisture and temperature under heath and coniferous forest since fall 2009 and summer 2010 in case of mineral and organic surface layers, respectively. Soil texture information is available for all these sites. Vegetation water content of the heathland was estimated at the beginning and end of the airborne campaign.

The dielectric constants of the organic material and the underlying mineral soil are quantified by two different approaches. First, the soil moisture sensors are calibrated for the organic substrate by means of the available samples. Based on this, sensor moisture readings are recalculated, whereupon the dielectric constant is modeled using this data as input to the Mironov dielectric model. Secondly, measurements of the dielectric properties from collected samples are carried out over a wide moisture range with two complementary methods: (1) a resonant cavity, measuring sample-induced changes of standing wave characteristics, and (2) a rectangular wave-guide, estimating the complex coefficients of transmission and reflection. The former method is more precise. However it is restricted to individual frequencies, while the wave-guide can measure over a wider range. Furthermore, the latter uses large enough samples to account for the material’s heterogeneity.

This conference contribution will present the above-mentioned dielectric constant and brightness temperature database. Comparison of EMIRAD-2, HUT-2D, ELBARA and SMOS brightness temperature estimations are illustrated. Likewise, comparisons of modeled and measured dielectric constant estimates are shown. An outlook on the subsequent work steps will be given.

Key words: ESA Programme: STSE, Soil Moisture

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