SMOS CALIBRATION AND VALIDATION ACTIVITIES WITH AIRBORNE INTERFEROMETRIC RADIOMETER HUT-2D DURING SPRING 2010

J. Kainulainen[(1)], *K. Rautiainen*[(1)], *P. Sievinen*[(1)], *J. Seppänen*[(1)], *E. Rouhe*[(1)], *M. Hallikainen*[(1)] , *J. Dall'Amico*[(2)], *F. Schlenz*[(2)], *A. Loew*[(3)], *S. Bircher*[(4)] , *C. Montzka*[(5)]

[(1)] Helsinki University of Technology, Department of Radio Science and Engineering, Espoo, Finland

[(2)] University of Munich, Department of Geography, Munich, Germany

[(3)] Max-Planck-Institute for Meteorology, Land in the Earth System, Hamburg, Germany

[(4)] Technical University of Denmark, DTU Space, Microwaves and Remote Sensing

[(5)] Research Centre Juelich, Institute of Chemistry and Dynamics of the Geosphere, Agrosphere Institute (ICG 4), Juelich, Germany

1. INTRODUCTION

The goal of the ESA SMOS (Soil Moisture and Ocean Salinity) mission is to provide accurate global soil moisture and ocean salinity data on a regular basis. The satellite was successfully launched in November 2009 and its only instrument is the MIRAS (Microwave Imaging Radiometer by Aperture Synthesis) sensor. It operates at a frequency of 1.4 GHz (L-band) and employs interferometry to produce two-dimensional brightness temperature images of the Earth with a spatial resolution of 30 to 50 km. These images are transformed into soil moisture and ocean salinity maps using recently developed algorithms. [1]

In order to support the SMOS mission, an airborne 1.4 GHz interferometric radiometer HUT-2D has been developed, constructed and tested by the Helsinki University of Technology. The HUT-2D sensor is accommodated onboard the University's remote sensing aircraft. The main technical parameters of HUT-2D are similar to those of MIRAS; hence, HUT-2D can be used to produce multi-angular data sets needed for the development and validation of SMOS algorithms. [2]

Since 2006 HUT-2D radiometer has participated in various measurement campaigns to obtain L-band datasets mainly for soil moisture and ocean salinity retrieval studies. Data sets for soil moisture retrieval have been collected over test sites with various land-cover conditions ranging from bare and crop-covered agricultural fields to boreal forests and bogs. Data sets for sea salinity studies have been collected over the Baltic Sea and various test sites in the coastal area of southern Finland.

An intense campaign with the HUT-2D radiometer system is planned to be carried out in the frame of SMOS calibration and validation activities in the spring of 2010. This campaign consists of multiple measurements of several soil moisture test areas in Denmark and Central and Southern Germany, all recognized as main soil moisture calibration and validation sites for SMOS. In this paper we describe the main characteristics of the data sets acquired with the HUT-2D instrument over these test sites, as well as discuss the performance of the instrument and the technology concept.

2. HUT-2D INSTRUMENT

The HUT-2D instrument is described in detail in [2]. In short, it employs 36 receivers in a two-dimensional U-shaped configuration over a 7 MHz frequency band centered at 1.4135 GHz. It utilizes the same fundamentals of interferometry and aperture synthesis as the SMOS payload does, and the main technical solutions, such as calibration techniques, are common for the two instruments.

HUT-2D is capable in measurements of two polarizations by switching between two orthogonally aligned antenna feeds in the receivers' front ends. Angular resolution provided by the aperture synthesis is approximately 7 degrees, and the size of two-dimensional brightness temperatures images, each produced in 250 milliseconds, is 7 times 7 pixels. From a typical flight altitude, e.g. 2000 meters, this makes the projection of the acquired image to cover a square with a side of 2300 meters.

3. VALIDATION AREAS

This soil moisture calibration and validation activity consists of measurements of three river catchment areas described shortly in the following.

The Upper Danube catchment, a temperate agricultural area situated mostly in Southern Germany, is one of two major SMOS validation test sites in Europe covering 77.000 km^2. Its main part is situated in the alpine foreland with heterogeneous land cover and large natural gradients from the Alps northwards. The best soil moisture retrieval performance is expected in the smaller catchment of the river Vils, situated in the Northeast of the city of Munich. No open water bodies or large urban areas considerably affect the passive microwave signal in that area. The terrain as well as the soil is fairly homogeneous.

The second test site encompasses the catchment basins of the rivers Rur and Erft, which are located in the Belgian-Dutch-German border region near the city of Aachen. The site can be separated into two main regions. The southern part covers the bedrock of the Eifel mountains, with a high long-term annual precipitation of 850 - 1300 mm. This region consists of Devonian and Carboniferous sedimentary rocks with low permeability and small groundwater storage volumes, causing water runoff primarily linked to the fissure system. The northern region is characterized by soils evolved from loess, which accumulated on Tertiary and Quaternary depositions of the Rivers Rhine and Meuse. It has a relatively low annual precipitation of 650 – 850 mm. In accordance with this hydrogeological and climatic division, the land use types are clearly distinguishable. Forest and grassland characterize the south, whereas in the north fertile agricultural land predominates. Multiple sensor systems have been installed in the Rur catchment aiming to create observation platforms for long-term statistical time series of system variables for the analysis and prognosis of global climate change consequences using integrated model systems, which will be used to derive efficient prevention, mitigation and adaptation strategies.

The third test site is situated within the Skjern river catchment in Western Denmark (ca. 2500 km2) at short distance to the coast line. The climate in the area is temperate-maritime with annual precipitation of around 800 - 900 mm. The largest fraction of the catchment consists of low-relief alluvial plains with sandy sediments, while the very eastern areas are covered by more loamy soils on calcareous tills of hilly appearance. In poorly drained basins, organic deposits are found. The predominant soil type is podsol. The major part of the land is under intensive agricultural practice. Intermixed with farm land, patches of forest plantations (mostly spruce), grassland, heath, shrub and wetlands are encountered. The area is sparsely populated with scattered farms and single villages. Within the catchment an area corresponding to SMOS ground resolution (~44 km diameter circle) is chosen to be validated by means of (1)

measurements of a soil moisture network with 30 stations distributed throughout the area, and (2) the airborne campaign with concurrent snapshot ground measurements in three selected patches of differing land cover.

4. RESEARCH AND EXPECTED RESULTS

In this paper we present the main properties of the brightness temperature datasets acquired with the HUT-2D instrument over the three test areas. This is done from the instrument performance point of view, so that the results can be used in the on-going and forth-coming soil moisture retrieval development activities carried out in several European scientific institutes, e.g. [3]

The analysis of the performance parameters consists of assessment of instrument stability, radiometric resolution, and accuracy. We discuss and compare the concluded performance with the requirements given for soil moisture retrieval, with the performance of the SMOS payload, and with the expected performance from the novel technology. In the presentation, we also discuss the most evident correlations between the radiometric measurements obtained very recently (May-June 2010) and the geophysical parameters measured at the test sites.

5. REFERENCES

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