RADIOBRIGHTNESS VALIDATION ON DIFFERENT SPATIAL SCALES DURING THE SMOS VALIDATION CAMPAIGN 2010 IN THE RUR CATCHMENT, GERMANY

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ABSTRACT

ESA´s Soil Moisture and Ocean Salinity (SMOS) mission has been launched in November 2009 and delivers now brightness temperature and soil moisture products over terrestrial areas on a regular three day basis. In 2010 several airborne campaigns were conducted to validate the SMOS products with microwave emission radiometers at L-band (1.4 GHz). In this paper we present the activities performed in the Rur and Erft catchment, which is situated in the very west of Germany close to the borders to Belgium and The Netherlands. Measurements of the L-band sensors EMIRAD and HUT-2D on board a Skyvan aircraft as well as ground-based mobile measurements with the JÜLBARA radiometer mounted on a truck are analyzed in a qualitative comparison for different crop stands. These data can be used for validation of the SMOS sensor by giving valuable information about parameters for the radiative transfer modeling.

***Index Terms*—** SMOS Validation, soil moisture, brightness temperature, radiometer,

1. INTRODUCTION

The objectives of Soil Moisture and Ocean Salinity (SMOS) mission are to provide soil moisture and ocean salinity observations for weather forecasting, climate monitoring, and the global freshwater cycle. Since November 2009, when the satellite was successfully launched, its instrument MIRAS (Microwave Imaging Radiometer by Aperture Synthesis) produces two-dimensional brightness temperature images of the Earth surface at a frequency of 1.4 GHz (L-band).

The brightness temperature signal as well as the radiative transfer into soil moisture is influenced by other biophysical and geophysical variables like soil surface roughness and vegetation optical depth. In addition, surface soil water content is highly variable in space and time. Therefore, to ensure that data derived from SMOS are closely related to real soil moisture conditions and to estimate the accuracy of the spaceborne measurements validation activities are needed. In the past, several campaigns have been conducted in order to rehearse the validation concepts, instruments and algorithms (e.g. [1-4]). For a direct comparison with SMOS products, in 2010 validation campaigns have been conducted in several regions of the world.

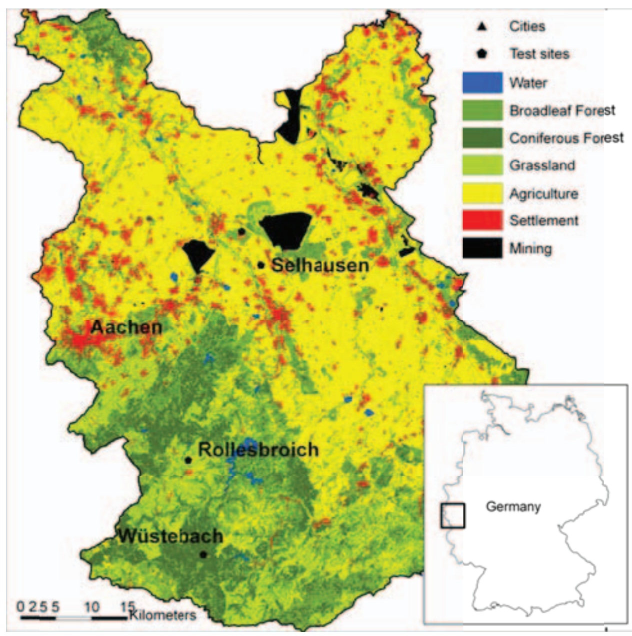

Fig. 1: The Rur and Erft catchments.

In this paper we present the SMOS validation activities in the Rur and Erft catchment (REC) [5], which is located in the Belgian-Dutch-German border region close to the cities of Aachen and Cologne (Fig. 1). A Short SC-7 Skyvan aircraft has been instrumented with the EMIRAD radiometer of the Technical University of Denmark and the

HUT-2D radiometer of the Aalto University. The aircraft flights were aligned with SMOS morning overpasses during ascending orbits between May and June 2010. At the same time we recorded the soil moisture and soil temperature in situ at specific sites. In addition, we mounted the L-band radiometer JÜLBARA on a truck in order to measure brightness temperatures 3 m above the soil surface. By this mobile setup we were able to investigate differences in brightness temperatures above the main crops in the Rur and Erft catchment. This approach is the first step to validate the global scale SMOS remote sensing products on a regional and a point scale.

2. SITE CHARACTERIZATION

The test region encompasses the catchment basins of the river Rur and the river Erft [6, 7]. 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. The northern region is characterized by soils evolved from loess and 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 within the infrastructure measure Terrestrial Environmental Observatories (TERENO), a long-term aimed research program with a close cooperation between several facilities of the German Helmholtz-Gemeinschaft [8]. The SMOS validation activity is based on data recorded on three TERENO test sites in the Rur catchment. Here we focus on the site Selhausen (50°52'13"N 6°27'03"E). It is an arable site which covers an area of approximately 34 ha and represents an intensively used agricultural area, where the main crops were sugar beet, wheat, maize, rape and grass. In selected fields cultivated with the mentioned crops data loggers were installed in order to measure soil moisture and soil temperature.

3. L-BAND SENSORS

The microwave sensors used during the SMOS validation campaign from 11.5.2010 to 27.6.2010 (DoY 131 – DoY 178) are all working in 1.4 GHz frequency of L-band. SMOS payload is the 2-D interferometric radiometer MIRAS, which exploits the interferometry principle by way of 69 receivers. The technique is based on cross-correlation of observations from all possible combinations of receiver pairs. A two-dimensional 'measurement image' is taken every 1.2 seconds in 30 km to more than 50 km ground resolution, 0.8 to 3 K radiometric sensitivity, and one to three days for temporal sampling.

SMOS provides spaceborne brightness temperature observations, where HUT-2D [9] and EMIRAD [10] provide airborne measurements onboard the Skyvan aircraft [4]. To cover all test sites it flew in an altitude of 1650 m a. s. l. The JÜLBARA radiometer [11] was mounted on a truck in order to mobile record the ground-based emissivity over different crops at the agricultural test site Selhausen.

4. RESULTS AND DISCUSSION

The airborne and ground-based radiometer data are compared to SMOS data. In Fig. 2 the 1st Stokes of the airborne radiometer EMIRAD of 27th of March 2010 (DoY 178) is presented. The 1st Stokes is the sum of the vertical and horizontal brightness temperatures and represents the total power in the field, which makes it unaffected by Faraday rotation. As expected, open waters bodies such as lakes can be clearly identified by very low intensities. Additionally, moisture conditions in most parts of the south region are reflected by relatively low intensities, whereas more dry soil conditions in the north part are indicated by relatively high intensities.

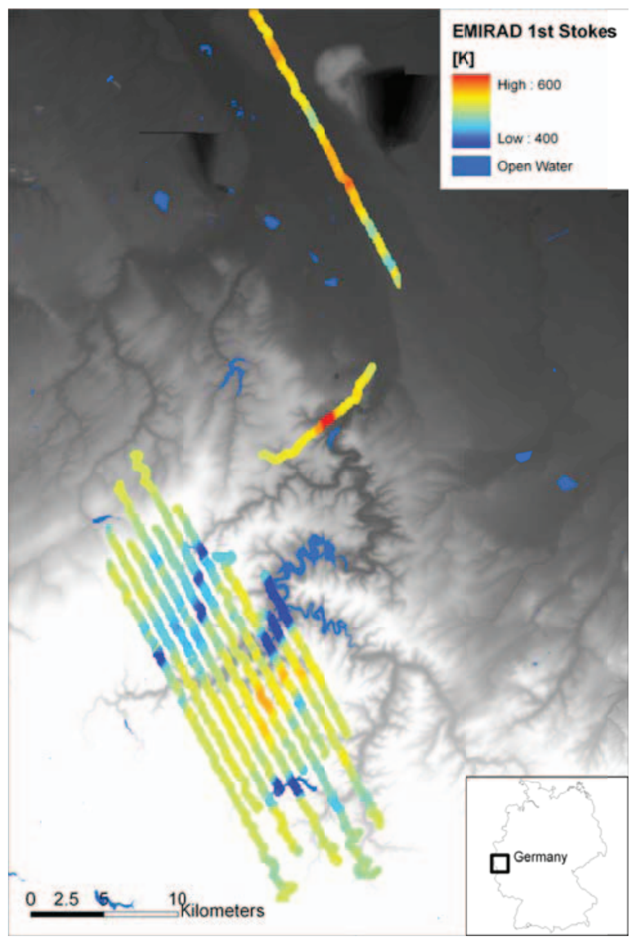

Fig. 2: 1st Stokes of EMIRAD for the 27th June 2010 (DoY 178). The background shows the elevation of the terrain.

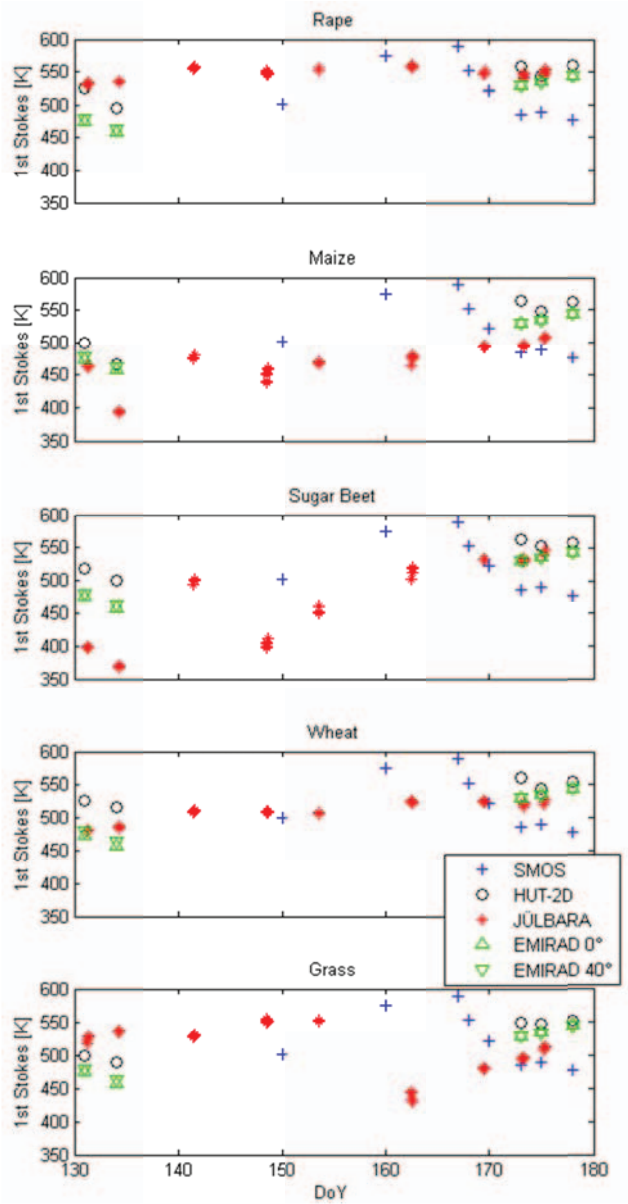

Fig. 3: Qualitative comparison of different radiometer records during the campaign period for the Selhausen site. SMOS observation from DoY 152, 155 and 165 have 1st Stokes of >600 K are not presented here.

In Fig. 3 a qualitative comparison of emission intensities measured by EMIRAD, HUT-2D and JÜLBARA radiometers is presented for different crop types showing the trends of all radiometers in 1st Stokes development over time. Although the radiometers have different footprint sizes and therefore are not directly comparable, this comparison is useful to indicate the quality of the data sets. The JÜLBARA data represents the 1st Stokes of specific crops, whereas the airborne radiometer footprints observe areas which can be affected by more than one crop type simultaneously. Due to the high spatial resolution of the HUT-2D data (<150 m), the crop types can be clearly distinguished, whereas the lower resolution of the EMIRAD data (<1500 m) precludes the differentiation of crop types. Therefore, EMIRAD data presented in Fig. 3 are the same for all crops. It shows that lower 1st Stokes during the wet conditions in May as well as higher 1st Stokes during to the dry conditions in June were consistently observed by all instruments. Also the vegetation effects on the 1st Stokes are clearly visible, especially for the ground-based measurements. For instance the grass plot was mown on DoY 156 resulting in a significant lower emission as measured by the JÜLBARA instrument on DoY 162. However, since only one part of the grass plot was cut and according to growing grass until the next flight on DoY 173, this effect is not visible in the airborne measurements.

In general, the data recorded during the SMOS validation campaign in May and June 2010 can serve as a good reference for comparison with SMOS L1C data. But due radio frequency interferences (RFI) an in depth validation of spaceborne SMOS measurements is not straight forward. During this campaign in the REC, JÜLBARA detected no RFI and very few RFI have been detected by EMIRAD which have been removed from the data using the Kurtosis method [12]. The Kurtosis method indicated that RFI was not present in the SMOS data during the flight dates, but during several other dates of the investigated period. This is due to ESA activities for identifying and eliminating RFI sources. Here, ESA identified the radar system of the airport Braunschweig (Germany, 300 km distance to REC) as a RFI source which had been switched off for the flight dates only. But SMOS footprints in the REC are still affected by RFI disturbances which are far away from the area of investigation.

5. CONCLUSIONS

The airborne radiometers EMIRAD and HUT-2D as well as the ground-based radiometer JÜLBARA were used in order to generate a brightness temperature reference for the comparison with spaceborne SMOS L1C data.

In general, the 1st Stokes measurements of the ground-based and airborne radiometers show a good agreement. Also SMOS data have similar ranges during the flight dates, but the remaining investigation period strong RFI affected the measurements. Nevertheless, more efforts are needed in filtering the SMOS data from interferences also by focusing on improvements in RFI detection, flagging and mitigation approaches or in activities around the Earth Exploration Satellite Service to protect the L-band.

In order to generate a brightness temperature reference, which covers a large area for a longer period, modeling approaches are recommended. Hydrologic models calibrated with in situ measurements generate a soil moisture reference, and coupled radiative transfer models generate a time series of area-wide brightness temperatures to be compared with SMOS data [5]. Radiative transfer parameters can be calibrated by using the airborne data presented in this paper. With this approach a more detailed validation can be accomplished.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] J. T. Dall'Amico*, et al.*, "Airborne and Ground Campaigns in the Upper Danube Catchment: Data Sets for Calibration, Validation and Downscaling of SMOS Data," *IEEE Transactions on Geoscience and Remote Sensing, submitted,* 2011.

[2] S. Delwart*, et al.*, "SMOS validation and the COSMOS campaigns," *IEEE Transactions on Geoscience and Remote Sensing,* vol. 46, pp. 695-704, Mar 2008.

[3] A. Cano*, et al.*, "The SMOS Mediterranean Ecosystem L-Band characterisation EXperiment (MELBEX-I) over natural shrubs," *Remote Sensing of Environment,* vol. 114, pp. 844-853, Apr 15 2010.

[4] J. Kainulainen*, et al.*, "SMOS calibration and validation activities with airborne interferometric radiometer HUT-2D during spring 2010," in *Geoscience and Remote Sensing Symposium (IGARSS), 2010 IEEE International*, 2010, pp. 702-705.

[5] C. Montzka*, et al.*, "Brightness temperature validation at different scales during the SMOS Validation Campaign in the Rur and Erft catchments, Germany," *IEEE Transactions on Geoscience and Remote Sensing, submitted,* 2012.

[6] C. Montzka*, et al.*, "Modelling the water balance of a mesoscale catchment basin using remotely sensed land cover data," *Journal of Hydrology,* vol. 353, pp. 322-334, May 30 2008.

[7] C. Montzka*, et al.*, "Multispectral remotely sensed data in modelling the annual variability of nitrate concentrations in the leachate," *Environmental Modelling & Software,* vol. 23, pp. 1070-1081, Aug 2008.

[8] H. Bogena*, et al.*, "Towards a network of observatories in terrestrial environmental research," *Adv. Geosci.,* vol. 9, pp. 109-114, 09/26 2006.

[9] J. Kainulainen*, et al.*, "First 2-D interferometric radiometer Imaging of the earth from an aircraft," *IEEE Geoscience and Remote Sensing Letters,* vol. 4, pp. 241-245, Apr 2007.

[10] J. Rotbøll*, et al.*, "A novel L-band polarimetric radiometer featuring subharmonic sampling," *Radio Science,* vol. 38, pp. -, Mar 6 2003.

[11] F. Jonard*, et al.*, "Mapping field scale soil moisture with L-band radiometer and ground penetrating radar over bare soil," *IEEE Transactions on Geoscience and Remote Sensing, accepted for publication,* 2011.

[12] N. Skou*, et al.*, "L-Band RFI as Experienced During Airborne Campaigns in Preparation for SMOS," *IEEE Transactions on Geoscience and Remote Sensing,* vol. 48, pp. 1398-1407, Mar 2010.