ACTIVE AND PASSIVE AIRBORNE MICROWAVE REMOTE SENSING FOR SOIL MOISTURE RETRIEVAL IN THE RUR CATCHMENT, GERMANY

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ABSTRACT

The objective of the NASA Soil Moisture Active & Passive (SMAP) mission is to provide global measurements of soil moisture by fused active and passive L-band microwave measurements. With an airborne campaign conducted in the Rur catchment, Germany, in 2012, an active and passive L-band microwave data set is generated. The passive Polarimetric L-band Multi-beam Radiometer (PLMR2) and the active L-band system DLR F-SAR were installed on the DLR Dornier DO 228 aircraft. Despite of the differences between the airborne and the future spaceborne sensors, the data set will serve as a test bed for the analysis of existing and development of enhanced future active/passive data fusion techniques. Moreover, the derivation of (vegetation) parameters for the fusion approaches is planned.

Index Terms— SMAP, soil moisture, PLMR2, F-SAR, radar, radiometer, data fusion

1. INTRODUCTION

The objective of the NASA Soil Moisture Active & Passive (SMAP) mission is to provide global measurements of soil moisture and its freeze/thaw state. These measurements will be used to enhance the understanding of processes that link the water, energy and carbon cycles, and to extend the capabilities of weather and climate prediction models. The SMAP launch is currently planned for 2014-2015 [1]. The SMAP measurement approach is to integrate a L-band radar and a L-band radiometer into a single observation system combining the relative strengths of active and passive remote sensing for enhanced soil moisture mapping. The radar and radiometer measurements can be effectively combined to derive soil moisture maps with a similar accuracy like radiometer-only retrievals, but with a higher spatial resolution (even radar resolution under some conditions). The SMAP mission requirements include simultaneous L-band brightness temperature and backscatter data products, with a three-day (or better) global revisit at spatial resolutions of about 40 and 3 km, respectively. The combined radar-radiometer-based soil moisture product is generated at an intermediate resolution of about 9-km. Aircraft instruments will be a key part of the SMAP validation program. Therefore, several airborne active and passive microwave campaigns are conducted in the Terrestrial Environmental Observatories (TERENO) test sites [2]. Here, we present the activities in the Rur catchment in Germany, where the passive L-band system Polarimetric L-band Multi-beam Radiometer (PLMR2) and the active L-band system DLR F-SAR were flown. The flights covered the full heterogeneity of the area under investigation, i.e. all types of land cover and research sites. These data are used as a test bed for the analysis of existing and development of new active-passive fusion techniques. A synergistic use of the two signals can help to decouple soil moisture effects from the effects of vegetation (or roughness) better than in the case of a single instrument.

2. VALIDATION SITES

The test region encompasses the catchment basin of the river Rur, which is located in the Belgian-Dutch-German border region near the city of Aachen [3, 4]. The site can be separated into two main regions: (i) the southern part covers the bedrock of the Eifel Mountains, with a high long-term annual precipitation of 850 - 1300 mm; and (ii) 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 (Figure 1). Multiple sensor systems have been installed in the Rur catchment, e.g. wireless soil moisture sensor networks [5] and Cosmic Ray Probes. In addition, further manual measurements were conducted during the campaign, e.g. soil moisture, soil temperature, leaf area index, vegetation
water content. Four intensive test sites have been selected which are namely Selhausen (agriculture), Merzenhausen (agriculture), Rollesbroich (grassland) and Wüstebach (forest). All test sites are equipped with soil moisture sensor networks, meteorological weather stations and other relevant instrumentation. The flight sections (blue boxes in Figure 1) covered all intensive test sites and the heterogeneity of the Rur catchment. Based on these installations, the Rur catchment has already served as a validation site for the Soil Moisture and Ocean Salinity (SMOS) Mission [6] and was officially selected for SMAP validation.

Figure 1: The Rur catchment (red). Blue boxes refer to the flight sections, yellow lines indicate borders to Belgium and The Netherlands.

3. ACTIVE AND PASSIVE L-BAND SENSORS

Airborne microwave instruments are especially useful in studies requiring the mapping of large areas with high spatial resolution as well as more control over the frequency and timing of coverage. In the past years, several campaigns were conducted by flying simultaneously with active and passive microwave sensors in the Rur catchment. The novelty of the activities in 2012 is that both active and passive sensors were installed on a single platform. Since the F-SAR is operated onboard the DLR Dornier DO 228 aircraft, the PLMR2 was mounted in the P-band antenna shielding of the same aircraft. Moreover, a broad band thermal infrared camera was installed, and the option to install a hyperspectral system in addition is still given. In 2012, one flight with the hyperspectral HySpex sensor installed on a Cessna aircraft was conducted in order to characterize the vegetation conditions. In the following we provide a brief description of the airborne sensors PLMR2 and F-SAR [8].

3.1. Polarimetric L-band Multibeam Radiometer (PLMR2)

The passive microwave instrument used was the Polarimetric L-band Multi-beam Radiometer (PLMR2) of the Research Centre Jülich, Institute of Bio- and Geosciences: Agrosphere (IBG-3). This system is referred to as PLMR2 and is to a certain extent identical to the PLMR of Monash University, Australia [9]. The PLMR2 enables medium-resolution mapping of near-surface soil moisture and land surface salinity, providing unprecedented details on characteristics critical to our understanding and management of the environment [10]. It measured both V and H polarized TB at incidence angles +/-8°, +/-22° and +/-38° across-track. In the normal pushbroom configuration the 3dB beamwidth is 17° along-track and 14° across-track resulting in an overall 90° across track field of view. The instrument has a frequency band of 1401 – 1425 MHz and a band width of 24MHz, with an accuracy better than 1K for an integration time of 0.5s.

3.2. DLR F-SAR

The Synthetic Aperture Radar (SAR) system DLR F-SAR is able to operate fully polarimetric in five frequency bands, X-, C-, S-, L- and P-band, hence it covers a range of wavelengths from 3 to 85 cm. F-SAR offers high operational flexibility and full polarimetric capability in all frequencies. In addition, the X- and S-bands provide a single-pass polarimetric interferometry capability. Additionally, repeat-pass Pol-InSAR as standard measurement mode can be used to ensure baseline flexibility in all bands. The instrument has a band width of 150MHz around the frequency of 1325 MHz. The final product has a spatial resolution of 1.5m x 0.4m [11]. The DLR F-SAR L-band system has also been established in preparation for the possible future spaceborne L-band mission Tandem-L proposed for launch in 2017 [12].
For regular Earth observation purposes the radar covers an off-nadir angle range of 25° to 55°. Since PLMR2 is installed with only one outer beam within this range (centred at 38°), overlapping measurements can be performed in repeat-pass only.

4. ACTIVE/PASSIVE MICROWAVE FUSION

Despite the differences between the airborne and the future spaceborne sensors (especially in case of the radar systems and the conically scanning reflector antenna architecture of SMAP), the data set will serve as a test bed for the analysis of existing and the development of enhanced future active/passive data fusion techniques and in particular the scaling can be studied with the present setup. The capability of the algorithm proposed by Das et al. [13] has been demonstrated by implementing the approach using the airborne Passive and Active L-band System (PALS) instrument data set from Soil Moisture Experiments 2002 (SMEX02) and a four-month synthetic data set in an Observation System Simulation Experiment (OSSE) framework. The results indicate that the algorithm has the potential to obtain better soil-moisture accuracy at a high resolution and show an improvement in root-mean-square error.

The parameter \( \beta(C) \) will be estimated by time-series regression. Here, a major assumption is introduced, which allows the development of a robust algorithm, but at the cost of increased error due to land-cover heterogeneity. It is assumed that significant variations in relevant parameters on the medium scale related to vegetation type, vegetation cover, and surface roughness are homogeneous within the coarse scale.

We use the L-MEB model [14] for soil moisture retrieval from the radiometer. The radar backscatter data residuals are used for spatial disaggregation of the retrieved soil moisture map. We estimate disaggregation parameters for different regional vegetation characteristics on the coarse scale (\( \beta(C) \)). Moreover, we analyze the ability of an approach to estimate medium scale parameters (\( \beta(M) \)).

5. OUTLOOK

After successful campaigns in the recent years, more airborne active and passive microwave remote sensing activities are planned in the future. The generated data sets can serve as test beds not only for SMAP active/passive fusion algorithms, but also for the validation of further soil moisture downscaling methods.

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7. REFERENCES


