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A Synthetic 1D Data Assimilation Experiment for SMOS Radiative Transfer Parameter Estimation

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MIRAS, the radiometer system onboard SMOS, records brightness temperatures (Tb), which cannot be implemented into the relevant models such as climate models directly. Therefore, ESA provides operational routines to calculate the SMOS level-2 product soil moisture from the radiometer raw Tb. This SMOS Level-2 Processor contains the radiative transfer model L-MEB (L-band Microwave model of the Biosphere), which describes the emission and scattering of the surface, vegetation, and atmosphere at 1.4GHz. But, the radiative transfer from measured Tb into soil moisture is influenced by biophysical and geophysical variables such as soil surface roughness and vegetation opacity, which are parameterized in a general way. The optimization of L-MEB for different surfaces has been addressed by numerous studies over the last decade, most of them based on the analysis of ground-based and airborne L-band data. Nevertheless, knowledge is still rather limited for global applications as well as for the temporal variability covering the phenological stages of plant communities. Moreover, most studies focused on specific regions for a limited time period and neglecting global and temporal variability. As already stated soil surface roughness and vegetation opacity are important drivers in radiative transfer, but the parameters needed for modeling approaches cannot be easily measured at the scale of SMOS observation. The absolute values of these parameters for different land surfaces are uncertain, and the degree of this uncertainty is unknown as well. Recent studies found that SMOS overestimates the Tb. This can be related to the impact of small radio frequency interferences (RFI), which cannot be easily filtered with methods like the Kurtosis approach. This leads to an underestimation of soil moisture, which affects the accuracy of the radiative transfer parameter estimation.

In this paper, we present a method to enhance the accuracy of the SMOS soil moisture product by parameter estimation using a data assimilation technique (Sampling Importance Resampling Particle Filter – SIR-PF) with in situ soil moisture observations. Therefore, we performed a synthetic study to analyze the ability of the system to track the temporal evolution of parameters such as vegetation opacity and soil surface roughness. The advantage of performing a synthetic study is that the true system is exactly known, and is therefore not prone to model inaccuracies or measurement errors. To generate a soil moisture and soil temperature reference the hydrological model HYDRUS-1D was used. Based on the generated soil moisture contents and temperature values, the L-MEB forward model was run and perturbed according to the measurement accuracy of MIRAS to simulate the SMOS Tb observations. L-MEB was integrated into a data assimilation framework using the SIR-PF, which is able to concurrently update L-MEB states and parameters. In addition, we investigate the ability of the proposed approach to account for the SMOS observation bias by introducing a bias factor in L-MEB. The overall advantage of the proposed sequential approach is its ability to be integrated into the operational near real time processing of the Level-2 product.

The objectives of this study are: (i) to retrieve radiative transfer parameters and their temporal changes and (ii) to account for a bias in SMOS measurements.