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Advanced microwave forward model for the land surface data assimilation

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From local to global scales, microwave remote-sensing techniques can provide temporally and spatially highly resolved observations of land surface properties including soil moisture and temperature as well as the state of vegetation. These variables are critical for agricultural productivity and water resource management. Furthermore, having accurate information of these variables allows us to improve the performances of numerical weather forecasts and climate prediction models. However, it is challenging to translate a measured brightness temperature into the multiple land surface properties because of the inherent inversion problem. In this study, we introduce a novel forward model for microwave remote sensing to resolve this inversion problem and to close the gap between land surface modeling and observations. It is composed of the Noah-MP land surface model as well as new models for the dielectric mixing and the radiative transfer.

For developing a realistic forward operator, the land surface model must simulate soil and vegetation processes properly. The Noah-MP land surface model provides an excellent starting point because it contains already a sophisticated soil texture and land cover data set. Soil moisture transport is derived using the Richards equation in combination with a set of soil hydraulic parameters. Vegetation properties are considered using several photosynthesis models with different complexity. The energy balance is closed for the top soil and the vegetation layers. The energy flux becomes more realistic due to including not only the volumetric ratio of land surface properties but also their surface fraction as sub-grid scale information (semitile approach).

Dielectric constant is the fundamental link to quantify the land surface properties. Our physical based new dielectric-mixing model is superior to previous calibration and semi-empirical approaches. Furthermore, owing to the consideration of the oversaturated surface dielectric behaviour, a significant improvement by new approach would be expected in monitoring surface runoff and infiltration, managing and improving irrigation system, and mapping and predicting flood events. Finally, the novel dielectric-mixing model is able to successfully integrate the land surface model and the dielectric constant of microwave.

Radiative transfer is calculated for the bare soil and the vegetated components of the grid box using a two-stream radiative transfer model. These model characteristics provide all relevant information needed for a simulation of the microwave emission from the land surface with unprecedented realism.

Noah-MP is coupled with the Weather Research and Forecasting (WRF) model system. Also, the novel dielectric-mixing model physically links the Noah-MP land surface properties and the microwave effective dielectric constant. Finally, with the existing radiative transfer model the advanced forward model can assimilate microwave brightness temperature into a consistent land-surface-atmosphere system.

A case study will be provided to investigate how well the simulation of the forward model matches to the real world. L-band microwave remote-sensing measurements over the Schäfertal region in Germany have been used for this case study.