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Using hyper-resolution land surface modeling for downscaling of remotely sensed soil moisture

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Soil moisture plays an essential role in controlling the exchanges of water, energy, and carbon at the land-atmosphere interface, with implications for hydrology and water management. Microwave-based satellite remote sensing offers unique opportunities for the large-scale monitoring of soil moisture at frequent temporal intervals. However, a major limitation is the coarse spatial resolution of remotely sensed soil moisture data caused by the large footprint of space-borne microwave radiometers. This leads to an inability to capture the fine-scale variability and the signature of extreme events, and constrain remote sensing product applications for water management at regional and local scales, such as for irrigation and flood prediction.

In this study, we assess the potential of using hyper-resolution land surface modeling to downscale remotely sensed soil moisture. Specifically, we introduce a tau-omega brightness temperature forward model into HydroBlocks land surface model (LSM) to explore its relationships with the Soil Moisture Active Passive (SMAP) retrieved brightness temperature. HydroBlocks explicitly solves the field-scale spatial heterogeneity of land surface processes through interacting hydrologic response units (HRUs) and represents human activities such as irrigation and groundwater pumping. The high-resolution estimates of top 5-cm soil moisture, soil surface temperature, and canopy temperature allow for brightness temperature estimations at the finest scale of 30-m spatial resolution. The HydroBlocks simulated brightness temperature is then bias corrected using SMAP, and the tau-omega algorithm is inverted to retrieve the SMAP corrected downscaled soil moisture.

This approach is demonstrated using HydroBlocks simulations (3-hourly, 30-m spatial resolution for 30 years) over the Little River Watershed (Georgia, USA), which consider natural and irrigated water managed conditions. In both scenarios, the downscaled moisture is subsequently evaluated against in situ soil moisture sites. Results show the reduction in soil moisture simulated bias, as well as the ability to present the field-scale spatial distribution of soil moisture under natural and managed conditions. Downscaling soil moisture using a hyper-resolution LSM improved not only the soil moisture estimations at the validation sites but also showed potential to provide reliable information at relevant decision-making scales.