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Understanding Spatio-Temporal Impact of Land-Surface Heterogeneity on Soil Moisture Retrieval and Validation of Remotely Sensed Soil Moisture Products

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This work serves to address the two-fold impact of land-surface heterogeneity on the soil moisture remote sensing community i.e. it 1) complicates the soil moisture retrieval process and 2) introduces uncertainty in validating remotely sensed soil moisture products using ground based data. In the retrieval algorithm for passive remote sensing, brightness temperature has been one key variable used to estimate soil moisture. However, the quantitative understanding of how brightness temperature evolves through space, time and hydroclimates is yet lacking. In this work, we attempt to develop an understanding of W's i.e. which (land surface variables), where (hydroclimates), what (support scale) and when (time) the sensitivity of brightness temperature varies with land surface variables. To this effect, a spatial global sensitivity analysis (GSA) to estimate sensitive variables of brightness temperature (H and V polarizations) at various support scales 800m, 1.6km, 3.2km, 6.4km, 12.8km, and 25.6km, 40km was employed. The effects of upscaling through various averaging techniques are also explored. It was found that the sensitivity of brightness temperature to spatial soil moisture decreases, whereas the sensitivity of scalar variables increase with increasing support scales. Also, the higher order interactions were significant in SMAPVEX12 and SMEX02 i.e. ∼18% and ∼10 % respectively, whereas SGP97 and SMEX04 show ∼1% and ∼5% interactions respectively between land surface variables. These interactions were also observed to decreases with increasing support scale. The second part of the study addresses the challenges in validation that arise as a result of scale discrepancy between footprint scale soil moisture and observed ground based data. The designed scheme generates the spatial variance structure of footprint scale moisture redistribution as a function of a scale appropriate dominant physical factor on which soil moisture redistribution depends. The scheme was developed for a variety of heterogeneous conditions found in 3 regions (Arizona, Iowa and Oklahoma) with different hydro-climates and 3 footprint scales (0.8 km, 1.6 km and 3.2 km). Results indicate that the spatial variance of moisture redistribution can be effectively modeled as a function of the most dominant physical control (minimum mean R2 = 0.8 and maximum mean RMSE = 0.119). In order to make the validation scheme potentially transferable to regions with heterogeneity that is different from the data used, the validation scheme was extended by exploiting the relationship between soil moisture, scale and land-surface heterogeneity through a conceptualized scale-wetness-heterogeneity (SWHET) cuboid. The SWHET cuboid is described by a wetness index, scale index and a newly defined heterogeneity index which can adequately quantify the land-surface heterogeneity across scales. The proposed SWHET cuboid can potentially serve as a look-up graph to model the spatial variance of footprint scale moisture redistribution as a function of the dominant physical controls and is being validated using SMOS data for the Winnipeg region in Canada.