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Statistical Disaggregation of Coarse Soil Moisture Estimates Across Different Landscapes and Climatic Regions

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The accuracy of water and energy fluxes simulated by land surface models is strongly affected by availability and resolution of spatially distributed soil moisture fields. Currently, active and passive satellite-based remote sensors are able to provide reliable soil moisture estimates at a scale of the order of 10-50 km. The utility of satellite estimates for land-surface simulations can be significantly improved through the use of downscaling schemes, especially if these tools are applicable in a wide range of environmental conditions and climatic settings. In this study, we present results of calibration and validation of a statistical downscaling algorithm based on a multifractal model, in a broad range of soil texture, land cover and climate conditions. For this goal, we use 800-m aircraft-based soil moisture estimates collected in three field campaigns, including: SGP97, held in Oklahoma, in an area with temperate climate, gently rolling topography, pasture and agriculture land cover; SMEX02, focused on a flat, agricultural region with moderate to heavy water content in Iowa; and SMEX04, conducted in two semiarid areas with complex topography in Arizona and Sonora (Mexico). Calibration is conducted at each site according to the same approach: (i) several 25.6 x 25.6 km^2 coarse-scale domains (mimicking the satellite footprint) are selected in each study area; (ii) model parameters are estimated through multifractal analysis in the scale range 0.8-25.6 km, and (iii) empirical relations are found between model parameters and coarse-scale predictors. Results show that a regional calibration relation can be estimated at each site as a function of the spatial mean soil moisture and ancillary predictors accounting for topography, soil texture and land cover within each coarse domain. The use of the calibrated model allows the small-scale soil moisture distribution to be adequately reproduced in a broad range of environmental conditions. Model performances are instead limited in coarse domains containing anthropogenic land cover features that introduce heterogeneity in the soil moisture distribution. This work has a twofold aim. First, a robust and efficient downscaling tool is provided to enhance the utility of satellite soil moisture products in land-surface simulations and data assimilation schemes. Second, the calibration relations dependent on ancillary factors can be utilized to identify the physical controls that exert the major influence on soil moisture spatial variability in different climatic regions.