Catchment-scale connection between vegetation accessible storage and satellite-derived Soil Water Index

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Estimates of water volumes stored in the root-zone of vegetation are a key element controlling the hydrological response of a catchment. Remotely-sensed soil moisture products are available globally. However, they are representative of the upper-most few centimeters of the soil. For reliable runoff predictions, we are interested in root-zone soil moisture estimates as they regulate the partitioning of precipitation to drainage and evaporation. The Soil Water Index approximates root-zone soil moisture from near-surface soil moisture and requires a single parameter representing the characteristic time length $T$ of temporal soil moisture variability. Climate and soil properties are typically assumed to influence estimates of $T$, however, no clear quantitative link has yet been established and often a standard value of 20 days is assumed. In this study, we hypothesize that optimal $T$ values are linked to the accumulated difference between precipitation (water supply) and evaporation (atmospheric water demand) during dry periods with return periods of 20 years, and, thus, to catchment-scale vegetation-accessible water storage capacities. We identify the optimal values of $T$ that provide an adequate match between estimated SWI from several satellite-based near-surface soil moisture products (derived from AMSR2, SMAP and Sentinel-1) and modeled time series of root-zone soil moisture from a calibrated process-based model in 16 contrasting catchments of the Meuse river basin. We found that optimal values of $T$ vary between 1 and 98 days with a median of 17 days across the studied catchments and soil moisture products. We furthermore show that $T$, which was previously known to increase with increasing depth of the soil layer, is positively and strongly related with catchment-scale root-zone water storage capacity, estimated based on long-term water balance data. This is useful to generate estimates of root-zone soil moisture from satellite-based surface soil moisture, as they are a key control of the response of hydrological systems.