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Constraining the hydrological model mHM using satellite retrieved soil moisture and streamflow data

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Hydrological models are usually calibrated against observed streamflow at the catchment outlet and thus they are conditioned by an integral catchment signal. Rakovec et al. 2016 (JHM) recently demonstrated that constraining model parameters against river discharge is a necessary, but not a sufficient condition. Such a procedure ensures the fulfillment of the catchment's water balance but can lead to high predictive uncertainties of model internal states, like soil moisture, or a lack in spatial representativeness of the model. However, some hydrologic applications, as e.g. soil drought monitoring and prediction, rely on these information.

Within this study we propose a framework in which the mesoscale Hydrologic Model (mHM) is calibrated with soil moisture retrievals from various sources. The aim is to condition the model on soil moisture (SM), while preserving good performance in streamflow estimation. We identify the most appropriate objective functions by conducting synthetic experiments. The hydrological model is constrained using either satellite retrieved soil moisture as or a combination of streamflow and soil moisture observations. The model is implemented on the native scale of the observations, e.g., 25 km in case of the satellite retrieved ESA-CCI soil moisture. The study is conducted in three distinct European basins (upper Sava, Neckar, and upper Guadalquivir basin) ranging from snow domination to semi arid climatic conditions.

Results obtained with the synthetic experiment indicate that objective functions focusing on the temporal dynamics of SM are preferable to objective functions based on spatial patterns or catchment average. Conditioning the hydrological model with satellite soil moisture alone yields Nash-Sutcliffe Efficiencies (NSE) for streamflow ranging between 0.1 and 0.3, whereas the coefficient of correlation between modeled and satellite retrieved soil moisture exceeds 0.7. Improvements in discharge estimation are achieved by consecutively adding streamflow observations as calibration criteria which lead to NSEs exceeding 0.6. In comparison calibrations using streamflow data alone exceed an NSE of 0.8.