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Representing Vegetation in Hydrological Modeling: Between process detail and structural uncertainty

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Vegetation strongly influences evapotranspiration, the largest water flux from land to atmosphere, and a key land-surface process, and thus plays a central role for capturing soil moisture and groundwater dynamics. As drought duration and magnitude increase, reliable high-resolution simulations of these variables become increasingly important for informed water resource management and sustainable allocation decisions. Yet, many hydrological models still have difficulty reproducing spatially distributed variables, in part due to epistemic uncertainty arising from model structural choices. Epistemic uncertainty is further amplified by calibration practices that rely solely on streamflow, an integration variable. This common practice disregards internal states and, consequently, the spatial variability of hydrological processes. Because vegetation modulates the variability of evapotranspiration and soil moisture, it is particularly relevant for local-scale uncertainty analyses. Although numerous studies examine individual aspects of vegetation–water interactions and their parameterization, it remains unclear which vegetation processes are essential to capture small-scale spatial variability and which may be redundant or even exacerbate overfitting, thereby increasing uncertainty.
In this study, we examine how different model structures influence simulated soil moisture and related water storage variables using the mesoscale Hydrological Model (mHM) [1]. To this end, we incorporate Leaf Area Index–based evaporation control, alternative root water uptake schemes, and additional land-cover types, representing three types of forest as well as pastures, savanna, wetlands. We construct model structure variants representing different combinations of these processes, including configurations in which individual processes are disabled. We then evaluate the skill of each model variant to reproduce not only the streamflow but also catchment wide total water storage and spatial distribution of soil moisture at a resolution of 1 km, which allows vegetation heterogeneity and its impact on evapotranspiration and soil moisture dynamics to be explicitly represented. The investigation provides an improved understanding of model structural uncertainty associated with vegetation, and assesses whether additional calibration on spatially distributed variables can compensate for structural shortcomings. This is achieved by comparing the traditional streamflow calibration with the actual evapotranspiration calibration using the spatial pattern efficiency metric (E_{SP}) defined by Dembélé et al. [2].
By identifying which vegetation processes meaningfully improve spatial predictions, this research

supports the development of more robust hydrological models for drought assessment and sustainable water management under increasing hydro-climatic stress.

References:

[1] L. Samaniego, R. Kumar, S. Attinger, Water Resources Research **2010**, 46.
[2] M. Dembélé, M. Hrachowitz, H. H. Savenije, G. Mariéthoz, B. Schaefli, Water resources research **2020**, 56, e2019WR026085.