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Stepwise improvement of hydrological model concepts using satellite based evaporation and total water storage estimations

Petra Hulsman, Hubert Savenije, and Markus Hrachowitz
Delft University of Technology, Delft, Netherlands (p.hulsman@tudelft.nl)

Traditionally, rainfall runoff models are calibrated on discharge observed at the basin outlet. This may result in accurate flow predictions, but not necessarily correctly represent internal processes in space and time; especially in poorly gauged regions where limited ground observations are available. More and more satellite observations become available which can be valuable for model development and calibration to improve the representation of internal processes in space and time. In this study, satellite based evaporation and total water storage observations were used to improve, in a stepwise analysis, the structure of a hydrological model and the selection of feasible parameter sets. For this purpose, a semi-distributed rainfall runoff model, accounting for sub-grid process heterogeneity, was developed for the poorly-gauged Luangwa River basin in Zambia. As benchmark, this model was calibrated with respect to observed discharge. Then, the model was modified by (1) including upwelling groundwater in low-elevation parts of the landscape close to the river, depending on the water availability in the (un-) saturated zone and (2) adjusting the spatial representation of the groundwater. Next, each model was calibrated to all variables simultaneously with respect to discharge, evaporation and total water storage. In the benchmark case, calibrated on discharge only, the model reproduced the discharge well, but failed to provide an adequate spatiotemporal representation of evaporation and total water storage, especially in wetland dominated areas. Overall model performance improved most when including upwelling groundwater as a function of the saturated zone and when calibrating on all variables (discharge, evaporation and total storage) simultaneously. Hence including satellite based data on evaporation and total water storage improved model structure development and identifying feasible parameter sets.