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A Comprehensive Hydrologic Model Evaluation based on Multitemporal Model Performance

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Hydrologic models have to be calibrated prior to their application. However, there are numerous parameter sets that perform equally well in the calibration period (equifinality), and model performance commonly decreases outside the calibration period (problem of model transferability in time). An analysis of consistency in model performance is proposed to distinguish plausible models among numerous equally well performing ones. Model efficiency is evaluated over various subperiods, rather than represented by a single performance measure calculated over the entire simulation period. Plausible models yield consistent (minimum variance) efficiency, while high variation in efficiency across the subperiods indicates model overfit. Considerations of consistency could mitigate equifinality and enable detection of the models that perform satisfactorily under various changing conditions.

In this research, a multitemporal model evaluation is conducted; namely, model efficiency is estimated over subperiods of increasing length included within the calibration period, and each subperiod of a specific length starts one water year after the previous one. Model performance is quantified in terms of the Kling-Gupta efficiency measure (KGE), and bias in runoff volume as an additional performance measure.

The 3DNet-Catch model is employed for simulations in the Toplica catchment in Serbia. A semi-lumped model setup is applied; the catchment is divided into nine elevation zones, all of which are assigned a single parameter set, while meteorological forcing is adjusted for each zone to account for the change in elevation. The available record period (1980-2013) is divided into the calibration-wet period (1997-2013), and the evaluation-dry period (1981-1997). The periods are selected to provide assessment of model applicability for simulations under changing conditions, since numerous hydrologic projections under climate change for Serbia suggest decrease in precipitation and runoff.

For this analysis, 20000 parameter sets are sampled from their uniform prior distributions, and two groups comprising 100 parameters sets each are formed. The first group (G1) is composed of the parameters sets that result in the highest KGE value over the entire calibration period. The second group (G2) includes sets with the highest mean and minimum KGE variance across all 1- through 15-year long periods within the calibration one.

Only 27 parameter sets are common to both groups. The median KGE over the calibration period amounts to 0.74(G1) and 0.66(G2), while in the evaluation period these values decrease to 0.50(G1) and 0.54(G2). The KGE averaged over all subperiods is 0.67(G1) and 0.66(G2) in the calibration period, and 0.45(G1) and 0.51(G2) in the evaluation one. G2 yields smaller variance in KGE over both periods. The median bias in runoff volume amounts to 1%(G1) and 11.5%(G2) in the calibration period, and 24.6%(G1) and 14%(G2) over the evaluation one. Additionally, G2 encompasses more observations than the G1 ensemble in both periods. Overall, G2 yields relatively consistent performance, while a drop of G1 efficiency outside the calibration period is pronounced.

Consistency in model performance can be used as an additional criterion for model/parameter selection, which is easily applicable to any model or with any calibration approach.