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Transferability of monthly water balance models under changing climate conditions in an arid catchment

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Assessment of climate change impact on water resources is often based on hydrologic projections developed using monthly water balance models (MWBMs) forced by climate projections. These models are calibrated against historical data but are expected to provide accurate flow simulations under changing climate conditions. However, an evaluation of these models' performance is needed to explore their applicability under changing climate conditions, assess uncertainties and eventually indicate model components that should be improved. This should be done in a comprehensive evaluation framework specifically tailored to evaluate applicability of MWBMs in changing climatic conditions.

In this study, we evaluated performance of four MWBMs (abcd, Budyko, GR2M and WASMOD) used for hydrologic simulations in the arid Wimmera River catchment in Australia. This catchment is selected as a challenge for model application because it was affected by the Millennium drought, characterised by a decrease in precipitation and a dramatic drop in runoff. The model evaluation within the proposed framework starts with dividing the complete record period into five non-overlapping sub-periods, calibration and cross-validation (i.e., transfers) of the models. The Kling-Gupta efficiency coefficient is used for the calibration in each sub-period. Consistency in model performance, parameter estimates and simulated water balance components across the sub-periods is analysed. Model performance is quantified with statistical performance measures and errors in hydrological signatures. Because the relatively short monthly hydrologic series can lead to biased numerical performance indicators, the framework also includes subjective assessment of model performance and transferability.

The results show that model transfer between climatically contrasted sub-periods affect all statistical measures of model performance and some hydrologic signatures: standard deviation of flows, high flow percentile and percentage of zero flows. While some signatures are reproduced well in all transfers (baseflow index, lag 1 and lag 12 autocorrelations), suggesting their low informativeness about MWBM performance, many signatures are consistently poorly reproduced,

even in the calibrations (seasonal distribution, most flow percentiles, streamflow elasticity). This means that good model performance in terms of statistical measures does not imply good performance in terms of hydrologic signatures, probably because the models are not conditioned to reproduce them. Generally, the greatest drop in performance of all the models is obtained in transfers to the driest period, although abcd and Budyko slightly outperformed GR2M and WASMOD. Subjective assessment of model performance largely corresponds to the numerical indicators.

Simulated water balance components, especially soil and groundwater storages and baseflow, significantly vary across the simulation periods. These results suggest that the model components and the parameters that control them are sensitive to the calibration period. Therefore, improved model conceptualisations (particularly partitioning of fast and slow runoff components) and enhanced calibration strategies that put more emphasis on parameters related to slow runoff are needed. More robust MWBM structures or calibration strategies should advance transferability of MWBMs, which is a prerequisite for effective water resources management under changing climate conditions.