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Multi-criterial calibration of WGHM in the Ganges-Brahmaputra basin

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The transboundary river basin Ganges-Brahmaputra (GB) of over 1.7 million km2 in size is home of estimated over 600 million inhabitants, distributed between India, China, Nepal, Bangladesh and Bhutan. Understanding hydrological dynamics in this region is of immense importance for water management and supply. Global-scale hydrological models like the WaterGAP Global Hydrological Model (WGHM) provide a means of analyzing hydrological processes and the water cycle dynamics in such a complex river basin towards water availability assessment at a regional scale. However, huge uncertainty of large-scale hydrological models hinders their reliable application. A Pareto-based optimization concept for more than one calibration variable can be used to reduce the model uncertainty and equifinality through model calibration prior to any model application. Here, we calibrated the 12 and 11 most sensitive parameters of WGHM for the Ganges and Brahmaputra, respectively. The sensitive parameters were identified using Morris's Elementary Effect Test (EET) method for each basin. The model was calibrated against four observations – in situ river discharge (Q), satellite-derived evapotranspiration (ET), surface water storage variations (SWSV) from multi-satellite observations and GRACE-based total storage variations (TWSV). As calibration objective for each observable the Kling-Gupta Efficiency of basin-scale monthly averages was used. The Pareto frontier of the objectives was approximated using the Multi-Objective Evolutionary Algorithm Borg-MOEA. Borg-MOEA performed well in estimating Pareto optimal model parameters as well as identifying the trade-offs among objectives. Good model performance for the calibrated variables usually was at the expense of simulation performance for the other variables that were not included in calibration. The largest trade-off was observed between river discharge (Q) and surface water storage variations (SWSV) which suggests that constraining the model only with discharge observations results in inappropriate simulations of SWSV. We observed poor performance of WGHM to generate accurate SWS in fast responding basin like Ganges especially during heavy rainfall in monsoon. In general, however, any additional observation considered during calibration helped to better represent the hydrological dynamics, with good performance for all considered performance criteria.