EGU23-11245, updated on 15 Apr 2024
https://doi.org/10.5194/egusphere-egu23-11245
EGU General Assembly 2023

Multi-variable Pareto optimal calibration of the global hydrological model WaterGAP for 1500 major drainage basins around the globe

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Global hydrological models (GHM) are indispensable tools for understanding hydrological dynamics in natural settings as well as for analysing complex hydrological human-nature systems in critical regions of the globe and for supporting sustainable management policies in current context and future climate change scenarios. However, GHMs suffer from high predictive uncertainties which stem from input data and climate forcing uncertainties, incomplete knowledge about hydrological processes and their imprecise mathematical description, unknown initial and boundary conditions, and uncertain parameters. Reduction of these uncertainty by model calibration has almost never been performed globally for any GHM due to the high number of parameters in these models, the limited availability of observations of critical hydrological variables at a scale suitable for these models, and the high computational complexity and demand of model calibration. To address these issues, we have developed and employed a parallel and scalable multi-criterial Pareto optimal calibration framework to estimate parameters of the state-of-the-art global hydrological model WaterGAP for 1509 drainage basins with available streamflow observations. Model calibration was done against gauge-based observations of streamflow (Q) and terrestrial water storage anomalies of GRACE/GRACE-FO (TWSA). The influential parameters of each basin were identified prior to calibration by a multi-variable sensitivity analysis for the variables Q, TWSA, and percentage snow cover in the case of basins with relevant snow accumulation. We expect that our study will advance methodologies for sensitivity and calibration analyses of GHMs.