EGU22-4372, updated on 09 Aug 2022
https://doi.org/10.5194/egusphere-egu22-4372
EGU General Assembly 2022

Multivariate evaluation of four high-resolution hydrological models at global scale

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Global hydrological models (GHMs) are a fundamental component of the Earth System Modeling initiative that aims to realize a Digital Twin in the next five to ten years [1]. Recent model evaluations of the state-of-the-art global hydrological models [2,3], however, indicate that existing models have several deficiencies that lead to poor model efficiencies of key terrestrial environmental variables such as runoff, evapotranspiration, and soil moisture, among others.

In this study, we evaluate four hydrological models: JULES, HTESSEL, mHM, and PCR-GLOBWB. These models are part of the modelling chain of the Copernicus Climate Change Service project ULYSSES [4], which aims to deliver global operational hydrological forecasts at a spatial resolution of 0.1°. The operational service started in July 2020 and the data will be provided every month through the Copernicus Data Store.

The initial conditions of the GHMs for the hindcast skill assessment are obtained with the ERA5-land reanalysis [5]. This global dataset provides meteorological forcings (e.g., precipitation and temperature) since 1950 with daily time steps. For this reason, historical simulations of streamflow, obtained with these GHMs from 1981 until 2020 will be cross-evaluated against observed streamflow provided by 2850 GRDC gauging stations. Simulations of evapotranspiration and terrestrial water storage anomalies were evaluated against GRACE and FLUXNET datasets, respectively.

During the model calibration phase, models were evaluated in a stratified sample of size 120 basins (i.e., considering hydroclimatic regions and locations around the world). The results of the evaluation indicate that the median value of the Nash-Sutcliffe efficiency obtained with daily streamflow for these models varies from 0.20 to 0.50. The mean Kling-Gupta efficiency (KGE) metric ranges from 0.45 to 0.63. The maximum KGE value corresponds to the mHM model, while the other models are clustered around 0.45.

This result alone is quite promising considering the results presented in Beck et al. [2]. One reason for these good results is the relation between the standardization of the input data sets and the common routing model (mRM [6]) with a very detailed river network [7]. The considerable

difference in performance between mHM and the other GHMs can be attributed to the parameterization of the models and model structure. mHM is the only GHM that employs the MPR technique [8] and includes fast and slow interflow components. Evaluation metrics obtained with the ILAMB [8] tool indicate that all models have exhibited satisfactory efficiencies (> 0.5 variable score) for monthly climatologies of latent heat, evapotranspiration and runoff. mHM, JULES, and PCR-GLOBWB, perform relatively well, representing the terrestrial water storage anomaly, although any of these models have explicit a detailed representation of the groundwater aquifers.

In this presentation, specific results of the model cross-validation, per geographic region will be presented. Finally, recommendations for further GHM model improvement will be discussed.

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