

Abstract

The Congo River Basin (CRB) is among the largest and most hydrologically complex basins in the world, yet sparse rainfall and discharge observations constrain robust assessments of basin-scale water balance and hydrological responses to environmental change. In the absence of adequate in-situ data, global gridded precipitation products provide an essential alternative for hydrological modelling. This study improves rainfall-runoff simulation in the CRB by optimizing the GW-Pitman model and evaluating its sensitivity to two widely used precipitation datasets: Climate Research Unit Time Series (CRU TS) and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). The GW-Pitman was selected for its ability to represent key hydrological processes such as forest canopy interception, soil moisture and groundwater stores, infiltration and runoff yield. Precipitation datasets were evaluated against 8 meteorological stations, and streamflow from 26 gauging stations distributed across the major hydrological units of the Congo Basin. Parameter optimization combined expert-guided range definition with a two-step Monte Carlo uncertainty framework to identify behavioural parameter sets. Calibration windows were aligned with rainfall data availability, using CRU TS for historical simulations prior to 1981 and CHIRPS for the post-1981 period. Both precipitation products successfully reproduced the seasonal rainfall regime of the basin, although notable spatial contrasts emerge. CRU TS provides smoother long-term variability that supports stable historical reconstructions, while CHIRPS better resolves spatial rainfall gradients and improves runoff simulations in medium-sized and upstream sub-catchments. Model performance is generally highest in large basins, where spatial aggregation dampens precipitation uncertainty. CHIRPS-driven simulations tend to underestimate discharge magnitudes, although both forcings reproduce seasonal timing, peak-flow behaviour, and flow-duration characteristics with reasonable skill. This study provides a framework for future work to explicitly incorporate wetland, peatland, and lake processes to better represent storage dynamics and lateral exchanges in the areas such as the Cuvette Centrale, thereby supporting improved assessments of hydrological connectivity and water-carbon interactions across the CRB.