Inferring reservoir filling strategies under limited data availability using hydrological modelling and Earth observation: the case of the Grand Ethiopian Renaissance Dam (GERD)

Awad Mohammed Ali$^{1,2}$, Lieke Melsen$^1$, and Ryan Teuling$^1$

$^1$Hydrology and Quantitative Water Management Group, Wageningen University, Wageningen, Netherlands
(awad.negmeldinawad.mohammedali@wur.nl; lieke.melsen@wur.nl; ryan.teuling@wur.nl)
$^2$Water Research Center, Faculty of Engineering, University of Khartoum, Khartoum, Sudan

The filling of the Grand Ethiopian Renaissance Dam (GERD) started in 2020, posing additional challenges for downstream water management in Sudan, which is already struggling to cope with the effects of climate change. This is also the case for many transboundary rivers that observe a lack of cooperation and transparency during the filling and operation of new dams. Without information about water supply from neighbouring countries, it is risky to manage downstream dams as usual and operation information is needed to apply modifications. This study aims to test the applicability of using lumped hydrological modelling coupled with remote sensing data in retrieving reservoir filling strategies in regions with limited data availability. Firstly, five rainfall products (namely; ARC2, CHIRPS, ERA5, GPCC, and PERSIANN-CDR) were evaluated against historical measured rainfall at ten stations. Secondly, to account for input uncertainty, the best three performing rainfall products were forced in the conceptual hydrological model HBV-light with potential evapotranspiration and temperature data from ERA5. The model was calibrated during the period 2006 - 2019 and validated during the period 1991 - 1996. Thirdly, the parameter sets that obtained very good performance (NSE > 0.75) were utilized to predict the inflow of GERD during the operation period (2020 - 2022). Then, from the water balance of GERD, the daily storage was estimated and compared with the storage derived from Landsat observations to evaluate the performance of the selected rainfall products. Finally, three years of GERD filling strategies were retrieved using the best-performing simulation of CHIRPS with RMSE of 1.7 billion cubic meters (BCM) and NSE of 0.77 when compared with Landsat-derived reservoir storage. It was found that GERD stored 14% of the monthly inflow of July 2020, 41% of July 2021, and 37% and 32% of July and August 2022, respectively. Annually, GERD retained 5.2% and 7.4% of the annual inflow in the first two filling phases and between 12.9% and 13.7% in the third phase. The results also revealed that the retrieval of filling strategies is more influenced by input uncertainty than parameter uncertainty. The retrieved daily change in GERD storage with the measured outflow to Sudan allowed further interpretation of the downstream impacts of GERD. The findings of this study provide systematic steps to retrieve filling strategies for data-scarce regions, which can serve as a base for future development in the field. Locally, the analysis contributes significantly to the future water management of the Roseires and Sennar dams in Sudan.