Projection of a large dam's reservoir on the local climate

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ABSTRACT

The Upper Blue Nile Basin (UBNB) contributes approximately 60% of the Nile River's annual flow. The Grand Ethiopian Renaissance Dam (GERD) has been constructed at the UBNB outlet, raising a question about its climatic impact. The Regional Climate Model System (RegCM5) is applied over the UBNB domain at 10 km resolution, driven by ERA5 reanalysis data (2000–2009), to assess the local climate effects of land use change due to the GERD reservoir. The non-hydrostatic MOLOCH dynamical core is employed to better resolve mesoscale atmospheric processes over the complex topography of the basin. A baseline simulation representing pre-GERD status is developed and evaluated, showing acceptable dry bias in precipitation of around –21%. A second simulation incorporates the GERD reservoir by altering the land surface characteristics from land to inland water. The results indicate spatiotemporal changes in the precipitation pattern associated with the existence of the GERD reservoir in some regions in the basin domain during its relevant main rain seasons. During the February-May (FMAM) season, the short rain season over the UBNB, slight increases in daily precipitation of up to 2 mm d^{-1} are simulated over parts of the basin, while decreases of up to 4 mm d^{-1} occur in the southern parts of the broader domain. In June-September (JJAS), there are widespread increases in daily precipitation in the northern regions, westward across South Sudan and the Democratic Republic of the Congo, reaching up to approximately 10 mm d^{-1}. In contrast, reductions in precipitation are simulated during the October-January (ONDJ) season over the southern and southwestern regions of the domain, especially across Uganda and Kenya. Seasonal total precipitation exhibits a strong dependence on the rainfall regime, with cumulative increases of up to about 1400 mm during JJAS and reductions of up to approximately 800 mm during ONDJ. A comparison with observed precipitation anomaly patterns during recent years shows consistent spatial rainfall changes over the UBNB domain during FMAM and JJAS, supporting the simulated response. Overall, the results highlight the role of large reservoirs in changing the land-atmosphere interactions and emphasize the importance of incorporating hydro-climatic modeling approaches in dam planning and operation, with implications for regional water policy and climate resilience in the Nile Basin.

Keywords: Upper Blue Nile; GERD; RegCM5; Land use; Local climate.