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Climate change impacts on Three Gorges reservoir impoundment and hydropower generation

Hongmei Xu (1), Pengcheng Qin (2), Min Liu (2), Liangmin Du (2), Chan Xiao (1), and Lüliu Liu (1)

(1) National Climate Center,CMA, Beijing, China (xuhm@cma.gov.cn), (2) Wuhan Regional Climate Centre, Hubei Meteorology Bureau, Wuhan, China

Climate change is expected to alter regional hydrological regimes and consequently affect the operation and performance of hydraulic infrastructure such as reservoirs and hydropower facilities. Using a top-down modelling approach, this study examines the impacts of climate change on the performance of the Three Gorges Reservoir (TGR), which is the largest hydropower project in the world. Climate scenarios are firstly derived for a baseline period (1986-2005) from five General Circulation Models (GCMs) and for two future time horizons (2046-2065 and 2080-2099) under three Representative Concentration Pathways (RCP2.6, RCP4.5 and RCP8.5), and used as forcing input to the Soil and Water Assessment Tool (SWAT). The simulated discharge based on SWAT is subsequently regulated by an empirical model to obtain reservoir inflow to the TGR. Finally, a detailed daily simulation of reservoir operation is conducted on the TGR inflow and linked to a hydropower model. Based on the ensemble simulation output, groups of metrics for natural streamflow, reservoir impoundment, and hydropower generation are derived and further analyzed. The results show that the mean annual streamflow and the extreme high and low flows are generally projected to increase in 2046-2065 and 2080-2099, with the most significant increase occurring in spring and autumn. As a result, the average initial time reaching the normal storage level of the TGR will advance generally by 2.0-4.7d in 2046-2065 and by 2.6-8.4d in 2080-2099, the fully filled rate will decrease by 0.7-6.7% in 2046-2065, but increase by 3.3-7.3% in 2080-2099, the mean fill level will decrease by 0.2-0.6m in 2046-2065 and by 0.1-0.2m in 2080-2099. The projected annual average power production will increase by 2.0-2.3% in 2046-2065 and by 5.2-8.1% in 2080-2099, with the increase mainly occurring in the spring before flood season and the early autumn during the end of flood season. However, the inter-annual variation of power generation is significantly increased, especially in the dry season. The reservoir performance is highly sensitive to the seasonal distribution and extreme streamflow. Due to the general increase of simulated streamflow in the flood season and the simulated increase of flood frequency in the future, the amount of abandoned water increases, as a result the utilization rate of water resources decreases. In addition, since the projected shortage period for water storage as well as the dry season in the unfilled years will become more extreme, the average storage level and the assurance rate of power generation will decrease, which results in decreased operation efficiency of the reservoir and reduced stability of power supply. Due to the decreased utilization rate of water resources under projected extreme streamflow, the response of TGR power generation to climate change is reshaped into a non-linear pattern. These findings indicate the complexity of hydropower management and production under future climate change scenarios, and call for the introduction of detailed regulating models for impact assessment study, and adaptive adjustment of the reservoir management to combat climate change.