26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Climate change dominates recent increase in streamflow in the Yellow River Basin

Zhen Huang [a], **Congcong Li** [a], **and Yongqiang Zhang** [a]

[a] *Key Laboratory of Water Cycle and Related Land Surace Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China*
Email: huangz.19b@igsnrr.ac.cn

Abstract: Since the operation of the Xiaolangdi Reservoir in 2002, the lower reaches of the Yellow River Basin (YRB) have no longer experienced flow interruptions, and the previously declining streamflow trend has been reversed. However, most previous hydrological modeling studies either focused on the source region of the YRB—where human activities are limited but climate change sensitivity is high—or investigated the combined effects of climate change and human activities on the water cycle. This has left a substantial knowledge gap regarding the physical mechanisms driving recent hydrological changes and the relative contributions of climate change versus human interventions.

To address this gap, we employed an enhanced wflow_hbv model that integrates modules for reservoir regulation, human water consumption, and inter-basin water diversion. The model was validated against monthly streamflow and reservoir storage observations, and scenario experiments were conducted to disentangle the impacts of climate change and individual human activities on streamflow increases across subbasins. The main findings are: (1) Model performance was satisfactory, with Nash-Sutcliffe Efficiency (NSE) values ranging from 0.61 to 0.88 across nine hydrological stations and Percent Bias (PBIAS) values within 10% at eight stations (17% at Hejin). (2) The baseline scenario (S0) successfully reproduced the observed increasing streamflow trend (2002–2022), ranging from 0.76 $m^3\ s^{-1}$ at Hejin to 22.23 $m^3\ s^{-1}$ at Sanmenxia. Substantial deviations from S0 were detected at Tangnaihai, Toudaoguai, Hejin, and Lijin stations. (3) Climate change was identified as the dominant driver of streamflow increases in eight out of nine subbasins, while reservoir regulation exerted the primary influence in the SZS - TDG subbasin (Figure 1, the subbasins are designated by the initials of the corresponding inlet and outlet hydrological stations).

Uncertainty analysis highlighted that data quality remains a key limitation. To mitigate this, we used the CHM-PRE precipitation dataset, which accounts for topographic effects and has been validated against multiple stations, and further constrained the model with streamflow and reservoir storage data. Reservoir storage uncertainties were partly reduced using four years of monitoring data (2019 - 2022), though longer records are needed. Structural uncertainties were addressed by incorporating new modules for reservoir operation, irrigation (estimated using the validated PML-V2 model), and sectoral water use based on official statistics.

This study provides new insights into the distinct and combined effects of climate change, reservoir regulation, water consumption, and inter-basin diversion on streamflow increases in the YRB. The enhanced model offers a solid foundation for sustainable water resource management and can be readily integrated with sub-seasonal to seasonal forecasting products to support future flood and drought prediction. Adaptive measures—such as optimized reservoir operation, improved irrigation efficiency, and coordinated water allocation—are crucial to reducing climate risks and ensuring long-term water security in the basin.

Keywords: *Streamflow increases; Hydrological processes; Driver; Yellow River Basin*

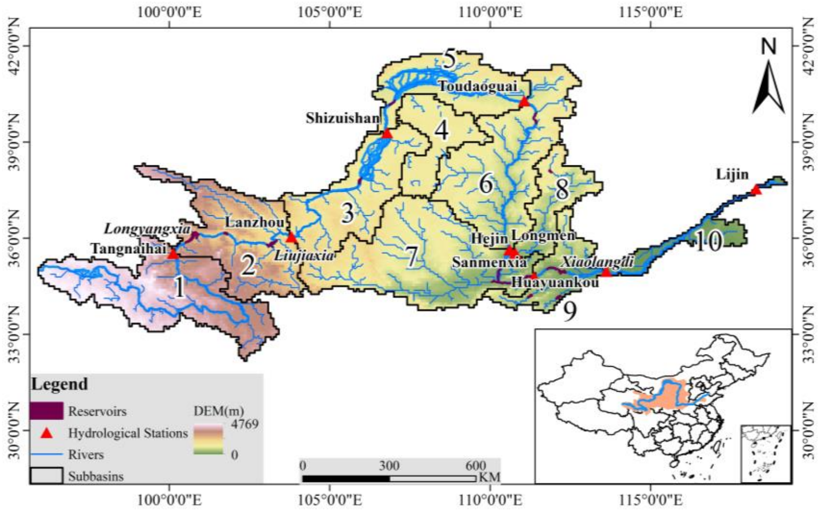

Figure 1. Geographical location of the Yellow River Basin and map of major large reservoirs (italic, note that Sanmenxia Reservoir and hydrological station locations overlap), mainstream hydrological stations and 10 subbasins (Subbasin 4 is endorheic and others are exorheic)

