Abstract

Climate change alters the behaviour of the water cycle, which imposes an enormous threat to basin-scale water security in global river basins. A robust quantitative assessment of water security, that conceptually partition freshwater into blue and green water resources (BGW) has gained substantial attention for basin-scale water management. Although many water accounting tools (WATs) (viz. hydrological model and land surface model) are available to quantify BGW, the difference in inherent model structure can intricate this quantification. Moreover, such WATs also rely on model input datasets, as the input bias may propagate into the baseline and future BGW computation. Besides, the total BGW uncertainties are escalated further due to cascading of global circulation models (GCMs) when same WATs are employed for climate change impact studies in future time slices. Therefore, this thesis i) explores the impact of model structure on baseline dynamics of blue water flow (BWF) and green water flow (GWF) through a multi-model framework (viz., HYSIM, SWAT, JULES); ii) investigates the effect of baseline meteorological datasets [secondary precipitation datasets (SPDs)] on BWF and GWF dynamics through the proposed multi-model framework; iii) develops the GCMs multi-model ensemble machine learning (MME-ML) framework for future climate projection under CMIP6 climate change scenarios; iv) assesses the possible changes in future BWF and GWF dynamics adopting multi-model ensemble framework and quantifies the relative contribution of uncertainty in streamflow prediction by hydrologic and climate models which explored across Damodar River basin (DRB) in eastern India. The proposed multi-model framework identified the strength of individual models for BGW estimation by assessing the estimated hydrological fluxes from each model. Notably, although all three models performed satisfactorily in streamflow simulation, the robustness of JULES model was observed for actual evapotranspiration and soil moisture estimation. In addition, the SWAT and JULES models were also more capable of representing the spatial dynamics of BWF and GWF compared to HYSIM model across the DRB. Evaluating the SPDs as inputs, the multi-model framework also revealed the efficacy of APHRODITE, IMDAA, and WFDEI datasets in streamflow and BGW estimation. The proposed novel MME-ML approach helped to reduce the uncertainties associated with CMIP6 GCMs by robustly simulating the IMD-observed climate variables and the seasonal analysis of climate indices throughout the DRB. The future projections of BGW dynamics across DRB evinced that the south-west part of the DRB may witness hydrological drought conditions in dry season (Nov- May) due to the potential decline in precipitation (- 19% to -41%), BWF (-40% to -50%) and green water (-39% to -68%) for both SSP 245 and SSP 585 scenarios. Apart from the quantification of future BGW dynamics, the study also segregated the uncertainties in streamflow prediction, where more than 40% and 22% of total uncertainty were contributed from GCMs and model structure. Overall, this study can help hydrological modellers to quantify how model structure and model inputs could affect the hydrological fluxes computations and also the resulting error magnification when used for future climate change impact studies.

Keywords: Blue water flow; Green water flow; Multi-model framework; SPDs; CMIP6 GCMs; Multi-model ensemble; SSP scenario