Evaluating WRF-Hydro model reliability for water resource assessment in a semi-arid catchment of Australia

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Abstract: Water is a primary resource for human and environmental persistence. The growing water demand, coupled with the impacts of climate change, has stressed the limited water resources, intensifying concerns for managing water resources sustainably. Quantitative assessment of spatial and temporal variability of available water in terms of runoff, soil moisture, and groundwater is the key input for formulating water management and sharing practices. However, due to the lack of resources and measuring techniques, quantification of available water is challenging, where Rainfall-Runoff (RR) models are the fundamental tools for such assessments. In general, RR models require meteorological data, hydrological data, and the physical characteristics of the catchment to simulate the historical variability of water resources and forecast future availability under a changing climate. Uncertainty in these input data can critically reduce the accuracy of the RR model simulation. Though hydrologic modelers utilise local and global data to develop and simulate the RR models with a considerable level of uncertainty. Therefore, this study focused on assessing the capability of the Weather Research and Forecasting Model Hydrological Modelling system (WRF-Hydro) to simulate streamflow and soil moisture dynamics in a semi-arid sub-catchment of the Murray-Darling Basin using exclusively global datasets.

The physically based distributed WRF-Hydro model coupled with Noah Multi-Parametrization (Noah-MP) Land Surface Model (LSM) was developed to represent the spatio-temporal variability of water in the Murrumbidgee catchment from water years 2017/18 to 2022/23. The model was configured with State Soil Geographic (STATSGO) soil data, Moderate Resolution Imaging Spectroradiometer (MODIS) International Geosphere-Biosphere Programme (IGBP) 20-category global land cover data, and HydroSHED Digital Elevation Model (DEM). Meteorological forcing was derived from Modern-Era Retrospective Analysis for Research and Applications (MERRA2) reanalysis data. Accuracy of the simulated daily streamflow and soil moisture at 4 depths was evaluated against observed streamflow at Hydrologic Reference Stations (HRS) and in-situ soil moisture measurements within the OzNet Hydrological Monitoring Network. The Nash-Sutcliffe efficiency (NSE) and Pearson's correlation coefficient (R-value) are utilised as the efficiency criteria.

Comparison of total hydrographs demonstrated a better match in daily streamflow during wet years from 2020/21 to 2021/22, while daily streamflow during the dry years was considerably underestimated. The NSE and R-value were 0.52 and 0.82, respectively. Simulated soil moisture also illustrated an acceptable agreement with point-scale in-situ soil moisture measurements over the period.

In light of these results, the WRF-Hydro model, configured with globally available datasets, is capable of simulating daily streamflow and soil moisture in the semi-arid Murrumbidgee catchment with an acceptable level of accuracy. The approach offers valuable insights for water resources assessment in regions lacking a comprehensive observational network.

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