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A Framework for Enhancing Seasonal Hydrological Forecasting in the Jucar River Basin (Spain)

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Seasonal hydrological forecasts are of critical importance for the effective management of water resources, particularly in complex and vulnerable basins such as the Mediterranean area which have both a deficitary water regimen and a high anthropogenic pressure. Nevertheless, inaccuracies in meteorological inputs can propagate through hydrological models, amplifying uncertainties in flow predictions. It is imperative to rectify these forecasts, whether meteorological or hydrological, to enhance prediction reliability and provide robust data for informed decision-making. This study proposes an advanced framework for seasonal hydrological forecasting that integrates raw and corrected weather forecasts with distributed hydrological modeling and sophisticated post-processing techniques to enhance flow prediction accuracy in the Júcar River in Spain as a representative case study of the Mediterranean area.

The catchment hydrological model was implemented using the model TETIS v9.1 wich was calibrated and validated using observed records from 1981 to 2019 at seven control points. To do this, a split sample test was conducted using the period 2009–2019 for calibration, and the rest of the time series for validation (1981–2008). The process involved refining parameter maps to ensure good or acceptable performance at all control points. Meteorological data were sourced from the W5E5 dataset, downscaled to a 0.09° resolution using ERA5-Land. This improved the spatial and temporal resolution of the hydrological model. Once we have established an acceptable hydrological model,, the seasonal forecast hindcasts were evaluated using meteorological inputs from global forecasting systems, including ECMWF-SEAS5, CMCC_SPSv35, DWD_GCFS21, and MeteoFrance System8. To address uncertainties in the meteorological forecasts and their propagation to hydrological outputs, two complementary correction strategies were implemented. First, artificial intelligence(fuzzy logic) was applied to correct meteorological inputs before integration into the hydrological model, assuming errors originate solely from meteorological data and treating the hydrological model as a “perfect” simulator. Second, a hydrological error model was developed to identify and adjust discrepancies between simulated and observed flows, addressing systematic biases and errors in the hydrological simulation.

The results demonstrated that forecasts based on corrected meteorological inputs exhibited significant accuracy improvements compared to those using unprocessed inputs. The hydrological

error model further enhanced prediction reliability by mitigating systematic biases. These findings underscore the effectiveness of combining meteorological forecasts with AI-driven corrections to address uncertainties, thereby improving the robustness of seasonal hydrological predictions. This study highlights the potential for integrating advanced correction techniques into seasonal hydrological forecasting frameworks, offering a replicable methodology for other basins with similar complexities. The proposed framework enhances both the reliability and applicability of forecasts, ensuring their relevance for effective decision-making in complex hydrological systems as the Mediterranean area. The improved accuracy of these forecasts provides a sound scientific support for adaptive water resource management, particularly in the face of increasing climatic variability and environmental changes.

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