EGU24-4140, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-4140
EGU General Assembly 2024

Integrating Deterministic and Probabilistic Approaches for Improved Hydrological Predictions: Insights from Multi-model Assessment in the Great Lakes Watersheds

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The utilization of probabilistic streamflow predictions holds considerable value in the domains of predictive uncertainty estimation, hydrologic risk management, and decision support in water resources. Typically, the quantification of predictive uncertainty is formulated and evaluated using a solitary hydrological model, posing challenges in extrapolating findings to diverse model configurations. To address this limitation, this study examines variations in the performance ranking of various streamflow models through the application of a residual error model post-processing approach across multiple basins and models. The assessment encompasses 141 basins within the Great Lakes watershed, spanning the USA and Canada, and involves the evaluation of 13 diverse streamflow models using deterministic and probabilistic performance metrics. This investigation scrutinizes the interdependence between the quality of probabilistic streamflow estimation and the underlying model quality. The results underscore that the selection of a streamflow model significantly influences the robustness of probabilistic predictions. Notably, transitioning from deterministic to probabilistic predictions, facilitated by a post-processing approach, maintains the performance ranking consistency for the best and worst deterministic models. However, models of intermediate rank in deterministic evaluation exhibit inconsistent rankings when evaluated in probabilistic mode. Furthermore, the study reveals that post-processing residual errors of long short-term memory (LSTM) network models consistently outperform other models in both deterministic and probabilistic metrics. This research emphasizes the importance of integrating deterministic streamflow model predictions with residual error models to enhance the quality and utility of hydrological predictions. It elucidates the extent to which the efficacy of probabilistic predictions is contingent upon the sound performance of the underlying model and its potential to compensate for deficiencies in model performance. Ultimately, these findings underscore the significance of combining deterministic and probabilistic approaches for improving hydrological predictions, quantifying uncertainty, and supporting decision-making in operational water management.