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AI-based ensemble flood forecasts and its implementation in multi-objective robust optimization operation for reservoir flood control

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Providing reservoirs with accurate forecasts is crucial for effective real-time flood control. This research focuses on the key role of forecasts in real-time flood management for reservoirs. A new approach was developed in this study, integrating a forecast-driven methodology to handle uncertainty in reservoir flood control operations. This involves a novel hybrid of two post-processing techniques: the Cloud model and error-based copula functions, together termed as the stochastic errors-based Cloud (SE-Cloud). Additionally, a multi-objective robust optimization model (MRO) was proposed, encompassing risk, resilience, and vulnerability, to address flood control challenges using ensemble forecasts. For comparative purposes, a two-objective stochastic optimization model (TSO) was also created, aiming to reduce both the highest expected reservoir level and peak discharge. The proposed methodology was applied to the Lishimen reservoir in the Shifeng River subbasin, China, aiming to comprehensively verify the relationships among deterministic forecasts, ensemble forecasts, and flood control performance. The main findings of this study are: (1) The SE-Cloud model was proved to be more efficient in predicting peak flow events and in representing uncertainties in forecasts, with an improvement in hypervolume values ranging from 13.14% to 39.65% over the Cloud model. (2) The MRO strategy resulted in a higher inflow release compared to the TSO, leading to a 0.05m reduction in the anticipated highest water level and a 4.29% increase in peak discharge. (3) With the resilience value downstream remaining constant, it was suggested that increasing upstream vulnerability by using the MRO strategy would not lead to a decrease in resilience. The findings highlight the potential of AI-based ensemble forecasts in augmenting flood control robustness.