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Calibrating robust conceptual hydrological models for future extremes

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Abstract: Calibrating conceptual rainfall-runoff models to predict a catchment's response to extreme rainfall events is a significant challenge, especially when historical data is limited and the event exceeds recorded extremes. This challenge is amplified in non-stationary environments where the frequency and intensity of extreme rainfall and floods are increasing. Traditional parameter estimation methods thus may not adequately capture the behaviour of extreme events. To address this, we propose an Adaptive Markov Chain Monte Carlo (MCMC) algorithm that incorporates a model robustness-likelihood function, a novel approach in the context of hydrologic parameter sampling. Our two-stage sampling method first uses an automated scheme to identify the posterior distribution of parameter sets, then in the second stage, we sample robust parameter sets from this posterior using a likelihood function based on hypothetical (design) storm events. We demonstrate this approach using the GR4H model applied to a catchment in Victoria, Australia. The robust parameter sets selected through this process exhibit reduced variability across simulations, providing more reliable predictions for extreme events not observed in historical data. This methodology increases confidence in simulating hydrologic responses to unprecedented events. While use is made of probabilistic design storms in defining the robust parameter space, this rationale can be extended to incorporate other alternatives including site analogues, future climates or paleo reconstructions across the broad realm of hydrological applications.

Keywords: *Hydrological modelling, calibration, robust, non-stationarity*