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Reducing the uncertainty of time-varying hydrological model parameters using spatial coherence within a hierarchical Bayesian framework

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Hydrological processes are considered non-stationary under the influences of climate change and human activities. This non-stationarity highlights the need to adopt time-varying parameters in hydrological models. Most existing literature quantifies time-varying parameters by incorporating real observations of only one basin into a hydrological model, which are limited in their information on catchment characteristics and climatic factors, to constrain time-varying parameters, and thus models are difficult to apply for hydrological predictions outside the calibration periods. This paper formulated the time-varying parameters for a lumped hydrological model as explicit functions of physically-based covariates that captured the catchment characteristics and used a hierarchical Bayesian framework to incorporate the similarity of adjacent basins to reduce the uncertainty of the assumed functions of time-varying parameters. Four modeling scenarios were developed to explore the spatial coherence between different characteristics of adjacent basins. Five criteria were adopted to evaluate the performance of assumed functional forms. Four spatially adjacent catchments in central United States were selected as case studies to examine the validity of the proposed method. Results showed that (1) the proposed method succeeded in reducing the uncertainty of time-varying parameters, and (2) the seasonality of the catchment storage was more coherent between adjacent basins, indicated by the largest increase in model prediction performance (i.e., 9%). This study improved our understanding of the spatial coherence of time-varying parameters, which will help improve hydrological predictions in the future.