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Climatic and Physiographic Controls on Errors of Large-scale Hydrological Models

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The development of large-scale hydrological models (LHMs) has enabled the spatiotemporal quantification of water resources globally. However, numerous benchmarking efforts have demonstrated that the performance of LHMs is generally less than that of catchment-scale hydrological models. Here we present a statistical benchmarking approach to identify the relationship between climatic and physiographic settings and model errors. First, we calculated the bias between simulated runoff and observed streamflow, for five flow percentiles derived from long-term time series. For the bias calculation, we used the ensemble mean of daily simulated runoff (for 1979 to 2012 at 0.5°) from ten state-of-the-art LHMs driven by the same meteorological dataset and observed daily and monthly streamflow time series from 3653 stations worldwide. Second, we combined a clustering approach with a regression analysis and a Random Forest approach to link climatic and physiographic variables with the calculated biases. The use of clustering facilitated the distinction between forcing errors and structural model errors/parameterization errors. Our results show that biases caused by structural model errors/parameterization errors are linked to variables describing climate, soil, and geologic characteristics. These biases suggest that model errors originate from inadequacies of the corresponding model routines/parameterizations (e.g., storage). Overall, the presented analysis proved to be useful for advancing model development by identifying model deficiencies. This study emphasises the benefit of statistical approaches over traditional benchmarking efforts for obtaining further insight into the model errors.