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How robust is rainfall-runoff modelling performance in a changing climate?

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State-of-the-art climate models are trained with historical observations to adjust parameters in order to yield optimal model performance. While the models are used for future climate projections, it remains unclear how model performance changes outside the climate range for which the models are trained. Here, we investigate the robustness of model performance in transient climate conditions for the example of rainfall-runoff models, which are the primary tools to explore the impacts of climate change on runoff, hydrological processes, and associated water resources. In particular, we consider three different types of rainfall-runoff models to represent various model structures and complexities: physical (Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg, JSBACH), conceptual (Simple Water Balance Model, SWBM), and statistical (Long Short-Term Memory, LSTM). Using runoff data from >400 near-natural catchments located across Europe, we calibrate the models for each catchment in particularly dry years, and assess their performance in the remaining wetter years. The same is done vice versa, i.e. calibration during the wettest years, and evaluation in the other years. Results show a general model performance loss, which generally increases the more conditions deviate from the training climate. The performance of the statistical model deteriorates slightly faster than that of the conceptual model, even though both models produce good simulations (close agreement with observed runoff) over calibration periods. The findings from the study provide a first indication of the reliability of models to accurately simulate potentially changed future climate conditions.