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Improving probabilistic prediction of daily streamflow by identifying Pareto optimal approaches for modelling heteroscedastic residual errors

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This study provides guidance to hydrological researchers which enables them to provide probabilistic predictions of daily streamflow with the best reliability and precision for different catchment types (e.g. high/low degree of ephemerality). Reliable and precise probabilistic prediction of daily catchment-scale streamflow requires statistical characterization of residual errors of hydrological models. It is commonly known that hydrological model residual errors are heteroscedastic, i.e. there is a pattern of larger errors in higher streamflow predictions. Although multiple approaches exist for representing this heteroscedasticity, few studies have undertaken a comprehensive evaluation and comparison of these approaches. This study fills this research gap by evaluating 8 common residual error schemes, including standard and weighted least squares, the Box-Cox transformation (with fixed and calibrated power parameter, lambda) and the log-sinh transformation. Case studies include 17 perennial and 6 ephemeral catchments in Australia and USA, and two lumped hydrological models. We find the choice of heteroscedastic error modelling approach significantly impacts on predictive performance, though no single scheme simultaneously optimizes all performance metrics. The set of Pareto optimal schemes, reflecting performance trade-offs, comprises Box-Cox schemes with lambda of 0.2 and 0.5, and the log scheme (lambda=0, perennial catchments only). These schemes significantly outperform even the average-performing remaining schemes (e.g., across ephemeral catchments, median precision tightens from 105% to 40% of observed streamflow, and median biases decrease from 25% to 4%). Theoretical interpretations of empirical results highlight the importance of capturing the skew/kurtosis of raw residuals and reproducing zero flows. Recommendations for researchers and practitioners seeking robust residual error schemes for practical work are provided.