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Evaluating model performance: a non-parametric variant of the Kling-Gupta efficiency

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Multi-objective calibration is a well-established approach for defining runoff model parameters. Evaluating multiple aspects of the simulated runoff response is expected to increase the plausibility and thus the robustness of model parameters. The Kling-Gupta efficiency (KGE) integrates the timing (Pearson correlation coefficient), variability (standard deviation) and magnitude (mean) of a catchment's runoff response and has become a popular objective function among hydrologists. The calculation of KGE is based on the assumptions of data linearity and normality, as well as the absence of outliers. However, these assumptions are often violated when working with real data. We therefore propose a modified version of the KGE that relaxes the strong assumptions by introducing the Spearman rank correlation and the mean absolute error of the flow-duration curve as alternative components for the Pearson correlation coefficient and the standard deviation. We tested the proposed modification using the bucket type HBV runoff model and simulating runoff for 100 catchments spread across different hydroclimates of the United States. Model simulations were evaluated in an independent ten year time period based on six commonly used statistical metrics focusing on different flow magnitudes and five signatures representing major catchment functions. The modification of KGE resulted in comparable or higher model performance with respect to mean and low flow metrics compared to the original formulation of KGE. In contrast, model efficiency for high flow metrics sensitive to timing was deteriorated when calibrating the model on the modified version of KGE. Importantly, the introduction of the flow-duration curve was generally crucial for the positive effect on the model efficiency, whereas the use of the Spearman rank correlation had a more varied effect on the results. Our modelling results encourage the use of the proposed KGE modification which represents realistic characteristics of observed runoff data.