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An efficient multi-metric framework for the calibration of hydrological models with signature metrics

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Hydrological models are commonly applied for discharge prediction. To achieve reliable reproductions of the discharge and of the hydrological processes for different research questions, a calibration procedure providing reasonable model results is required. Automatic model calibrations of complex hydrological models usually require a large number of model runs. Thus, there is the need to reduce the high computational demand and to increase the information about model reliability in the same model framework that is applied for the automatic model calibration.
The calibration of hydrological models is often focused directly or indirectly on special discharge phases (e.g. extreme high flow or extreme low flow) by accepting less satisfying performance of other discharge phases. In this way, the best model calibration runs are selected according to the specific research questions. However, the efficiency of automatic calibration can be increased if the same set of model calibrations can be used for different research questions without recalibration. This is achieved by integrating a flexible evaluation of different discharge phases which depends on the aim of discharge prediction.
Our study presents an efficient multi-metric framework that is able to integrate different phases of the hydrograph with corresponding efficiency criteria. The evaluation framework integrates statistical performance metrics for the evaluation of discharge and signature metrics which are focused on the reproduction of segments of the flow duration curve (FDC).

In order to consider a fairly balanced evaluation between high and low flow phases, we divided the flow duration curve into segments of high, medium and low flow phases, and additionally into very high and very low flow phases. By integrating all the different segments of the FDC, we make sure that low and high flows are reproduced simultaneously without neglecting a satisfying reproduction of the other phases of the hydrograph. In this way, we identify calibration runs that are able to capture the whole hydrograph and are consequently able to predict discharge for the whole range of discharge magnitude. To achieve a flexible evaluation of the calibration, the relevance of each efficiency criteria can be emphasized according to the specific research question. For this, thresholds for the statistical performance metrics and signature metrics can be defined to focus on satisfying performance of extreme flows.

On the one hand, the results highlight the relevance of the signature metrics of the FDC for studies that require a satisfying discharge reproduction for the whole hydrograph. On the other hand, the application of the multi-metric framework shows the possibility to emphasise the relevance of extreme flows for specific research questions with thresholds for the corresponding statistical performance metrics. Consequently, the presented evaluation method leads to an improved and efficient selection of good calibration runs out of the set of model runs in dependence of multiple research questions.