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On the information content of hydrological signatures and their relationship to catchment attributes

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Hydrological signatures, which are indices characterizing hydrologic behavior, are increasingly used for the evaluation, calibration and selection of hydrological models. Their key advantage is to provide more direct insights into specific hydrological processes than aggregated metrics (e.g., the Nash-Sutcliffe efficiency). A plethora of signatures now exists, which enable characterizing a variety of hydrograph features, but also makes the selection of signatures for new studies challenging. Here we propose that the selection of signatures should be based on their information content, which we estimated using several approaches, all leading to similar conclusions. To explore the relationship between hydrological signatures and the landscape, we extended a previously published data set of hydrometeorological time series for 671 catchments in the contiguous United States, by characterizing the climatic conditions, topography, soil, vegetation and stream network of each catchment. This new catchment attributes data set will soon be in open access, and we are looking forward to introducing it to the community.

We used this data set in a data-learning algorithm (random forests) to explore whether hydrological signatures could be inferred from catchment attributes alone. We find that some signatures can be predicted remarkably well by random forests and, interestingly, the same signatures are well captured when simulating discharge using a conceptual hydrological model. We discuss what this result reveals about our understanding of hydrological processes shaping hydrological signatures. We also identify which catchment attributes exert the strongest control on catchment behavior, in particular during extreme hydrological events. Overall, climatic attributes have the most significant influence, and strongly condition how well hydrological signatures can be predicted by random forests and simulated by the hydrological model. In contrast, soil characteristics at the catchment scale are not found to be significant predictors by random forests, which raises questions on how to best use soil data for hydrological modeling, for instance for parameter estimation. We finally demonstrate that signatures with high spatial variability are poorly captured by random forests and model simulations, which makes their regionalization delicate. We conclude with a ranking of signatures based on their information content, and propose that the signatures with high information content are best suited for model calibration, model selection and understanding hydrologic similarity.