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Comparing the performance of different model structures with respect to different hydrological signatures

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Correctly representing the dominant flow generation processes in conceptual rainfall-runoff models is crucial for ensuring adequate predictive power of the models. Recent work showed that on the small scale uniqueness of place requires different model structures for different catchments and that different calibration strategies frequently result in a wide range of model parameter sets. In this study we investigate the following research questions: (1) What is the effect of different calibration objective functions on the model performance? (2) Can the difference in performance of specific objective functions be related to hydrological signatures and physical catchment characteristics.

Data from four experimental (approx. 1000 km^2) sub-catchments (Alzette, Kyll, Orne and Seille) of the Moselle were used in this study. Eleven conceptual model structures (HBV, GR4J and 9 SUPERFLEX (flexible) model structures) of varying level of complexity are applied on each of the four study catchments. Besides classical objective functions (eg. Nash-Sutcliffe efficiency), additional objective functions are defined based on several hydrological signatures, such as the flow duration curve, rising limb density and auto-correlation. A multi-objective optimization is performed on all the objective functions for each catchment and each model structure considered. The results of the multi-objective optimization are then compared using Principle Component Analysis in order to identify the causes for differences in performance in the objective functions and relate these to physical catchment characteristics such as elevation, shape of the catchment and the height distribution above the nearest drain within a catchment. If such relationships are found then they can help to a priori identify suitable model structures and hydrological signatures in a catchment, given its spatial scale and physical characteristics.