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Assessing hydrological model structures and parameterizations via catchment mixture modeling

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An accepted means of representing 'structural' uncertainty in rainfall runoff models is to pool results from multiple model outputs. In a Bayesian paradigm this approach is known as Bayesian Model Averaging, and arises out of the traditional Bayesian approach for comparing model performance under uncertainty. The approach provides an appealing alternative to more traditional methods of model aggregation as it allows realistic assessment of predictive uncertainty, but suffers from the drawback that that the overall model framework is fixed. Models are weighted based on their determined overall ability but are not judged in regards to their performance at different periods in the catchments response. Using a fixed model (or ensemble) with a rigid model structure like this can lead to significant bias in the modeled hydrograph.

In this study we present an alternative where the catchment can be modeled as existing under a number of discrete states. The states are represented by individual model structures which are chosen in a probabilistic manner based on selected catchment indicators. Each model then allows representation of alternative dominant processes, the relevance of these changing with time based on the catchment indicators used. The approach allows aggregation of alternative model structures or alternative model parameterizations.

This framework, known as a Hierarchical Mixture of Experts (HME), can have two major functions. It can act as a powerful multi-model predictive tool where simulation is extended beyond the calibration period. It also offers a basis for model development and building based on interpretation of the final model architecture in calibration. An

innovation of the HME framework is that it provides a way of assessing the components of our existing models to see the conditions under which alternative models or parameterizations best describe observable hydrological processes.

We present applications of the approach in the context of several parsimonious lumped and distributed catchment models. Specification of the model framework via a Bayesian algorithm allows assessment of the predictive uncertainty associated with the model outputs. The algorithmic and computational challenges of the approach for applied hydrological modeling are critically assessed. We then compare the predictive performance of several observed and simulated catchment indicators for aggregating the models in an application of the popular distributed model Topmodel. The framework is assessed via three catchments in different continental, geographic and climatic settings, with results showing that the approach provides a good improvement in predictive performance using catchment indicators that reflect the most dynamic runoff producing mechanism.