Adapting hydrological model structure to catchment characteristics: A large-sample experiment

Nans Addor (1), Martyn P. Clark (1), and Bart Nijssen (2)

(1) Research Applications Laboratory, National Center for Atmospheric Research, Boulder, USA (naddor@ucar.edu), (2) Department of Civil and Environmental Engineering, University of Washington, Seattle, USA

Current hydrological modeling frameworks do not offer a clear way to systematically investigate the relationship between model complexity and model fidelity. The characterization of this relationship has so far relied on comparisons of different modules within the same model or comparisons of entirely different models. This lack of granularity in the differences between the model constructs makes it difficult to pinpoint model features that contribute to good simulations and means that the number of models or modeling hypotheses evaluated is usually small. Here we use flexible modeling frameworks to comprehensively and systematically compare modeling alternatives across the continuum of model complexity. A key goal is to explore which model structures are most adequate for catchments in different hydroclimatic conditions.

Starting from conceptual models based on the Framework for Understanding Structural Errors (FUSE), we progressively increase model complexity by replacing conceptual formulations by physically explicit ones (process complexity) and by refining model spatial resolution (spatial complexity) using the newly developed Structure for Unifying Multiple Modeling Alternatives (SUMMA). To investigate how to best reflect catchment characteristics using model structure, we rely on a recently released data set of 671 catchments in the continuous United States. Instead of running hydrological simulations in every catchment, we use clustering techniques to define catchment clusters, run hydrological simulations for representative members of each cluster, develop hypotheses (e.g., when specific process representations have useful explanatory power) and test these hypotheses using other members of the cluster. We thus refine our catchment clustering based on insights into dominant hydrological processes gained from our modeling approach. With this large-sample experiment, we seek to uncover trade-offs between realism and practicality, and formulate general recommendations on model structures based on catchment characteristics.