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Flexible modeling frameworks for controlled hydrological experiments

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Climate change impacts on hydrological processes are commonly assessed using a handful of off-the-shelf hydrological models. The small number of hydrological models means that only a small proportion of the model space is sampled, potentially leading to an underestimation of the projections uncertainty. Further, sampling is often arbitrary, as hydrological models should be selected to provide a representative sample of existing models (e.g. in terms of complexity, realism and sensitivity to climate change), but in practice their selection is often driven by legacy reasons. Furthermore, running more than a handful of hydrological models currently constitutes a practical challenge because each model must be setup individually. Finally, and probably most importantly, the differences between the projected impacts cannot be directly related to differences between hydrological models, because off-the-shelf models can be different in almost every possible way (i.e. they do not enable controlled experiments).

To overcome these limitations, we are experimenting with a new version of the flexible modeling framework FUSE (Framework for Understanding Model Errors), which enables catchment-scale to continental-scale modeling. FUSE allows us to construct conceptual models piece by piece, and thereby to generate a large number of models, which mimic existing models or differ from other models in single targeted respect. This presentation will focus on the regionalization of FUSE and its use for hydrological projections. We regionalized FUSE using hundreds of catchments from the CAMELS (Catchment Attributes and MEteorology for Large-sample Studies) data set. Each catchment was calibrated, resulting in a large pool of parameter sets. We optimized the transfer of these parameter sets to ungauged locations by leveraging the diversity of CAMELS catchment attributes and by comparing different definitions of hydrological similarity. Regionalized FUSE matches or exceeds the performance of conceptual models commonly used for impact assessments. We used this automated parameter estimation scheme to setup a several FUSE model structures and to produce hydrological projections over the contiguous USA using downscaled CMIP5 climate projections. The projected changes in discharge, soil moisture, snow water equivalent and evapotranspiration are consistent with those from other models, but are more tractable. We argue that flexible modeling frameworks like FUSE enable a more controlled, systematic and exhaustive exploration of climate change impacts than small ensembles of off-the-shelf models.