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Flexible modeling frameworks to replace small ensembles of hydrological models and move toward large ensembles?

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Climate change impacts on hydrological processes are typically assessed using small ensembles of hydrological models. That is, a handful of hydrological models are typically driven by a larger number of climate models. Such a setup has several limitations. Because the number of hydrological models is small, only a small proportion of the model space is sampled, likely leading to an underestimation of the uncertainties in the projections. Further, sampling is arbitrary: although hydrological models should be selected to provide a representative sample of existing models (in terms of complexity and governing hypotheses), they are instead usually selected based on legacy reasons. Furthermore, running several hydrological models currently constitutes a practical challenge because each model must be setup and calibrated individually. Finally, and probably most importantly, the differences between the projected impacts cannot be directly related to differences between hydrological models, because the models are different in almost every possible aspect. We are hence in a situation in which different hydrological models deliver different projections, but for reasons that are mostly unclear, and in which the uncertainty in the projections is probably underestimated.

To overcome these limitations, we are experimenting with the flexible modeling framework FUSE (Framework for Understanding Model Errors). FUSE enables to construct conceptual models piece by piece (in a "pick and mix" approach), so it can be used to generate a large number of models that mimic existing models and/or models that differ from other models in single targeted respect (e.g. how baseflow is generated). FUSE hence allows for controlled modeling experiments, and for a more systematic and exhaustive sampling of the model space. Here we explore climate change impacts over the contiguous USA on a 12km grid using two groups of three models: the first group involves the commonly used models VIC, PRMS and HEC-HMS and the second group three models generated using FUSE. All models are driven by CMIP5 model runs bias-corrected and downscaled. We explore whether the range of outcomes projected by the first group can be captured by the second group, i.e. whether a flexible modeling framework like FUSE can replace a small ensemble of hydrological models typically used for impact modeling. We envision that flexible modeling frameworks will allow us to provide more reliable and more tractable estimates of the uncertainty in hydrological projections, and to progressively move toward large ensembles of hydrological models.