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Uncertainty of a hydrological climate change impact assessment - Is it really all about climate uncertainty?

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Climate change impact assessments have become more and more popular in hydrology since the middle 1980's with another boost after the publication of the IPCC AR4 report. During hundreds of impact studies a quasi-standard methodology emerged, which is mainly shaped by the growing public demand for predicting how water resources management or flood protection should change in the close future.

The "standard" workflow considers future climate under a specific IPCC emission scenario simulated by global circulation models (GCMs), possibly downscaled by a regional climate model (RCM) and/or a stochastic weather generator. The output from the climate models is typically corrected for bias before feeding it into a calibrated hydrological model, which is run on the past and future meteorological data to analyse the impacts of climate change on the hydrological indicators of interest.

The impact predictions are as uncertain as any forecast that tries to describe the behaviour of an extremely complex system decades into the future. Future climate predictions are uncertain due to the scenario uncertainty and the GCM model uncertainty that is obvious on finer resolution than continental scale. Like in any hierarchical model system, uncertainty propagates through the descendant components. Downscaling increases uncertainty with the deficiencies of RCMs and/or weather generators. Bias correction adds a strong deterministic shift to the input data. Finally the predictive uncertainty of the hydrological model ends the cascade that leads to the total uncertainty of the hydrological impact assessment.

There is an emerging consensus between many studies on the relative importance of the different uncertainty sources. The prevailing perception is that GCM uncertainty dominates hydrological impact studies. There are only few studies, which found that the predictive uncertainty of hydrological models can be in the same range or even larger than climatic uncertainty.

We carried out a climate change impact assessment and estimated the relative importance of the uncertainty sources. The study was performed on 2 small catchments in the Swiss Plateau with a lumped conceptual rainfall runoff model. In the climatic part we applied the standard ensemble approach to quantify uncertainty but in hydrology we used formal Bayesian uncertainty assessment method with 2 different likelihood functions. One was a time-series error model that was able to deal with the complicated statistical properties of hydrological model residuals. The second was a likelihood function for the flow quantiles directly. Due to the better data coverage and smaller hydrological complexity in one of our test catchments we had better performance from the hydrological model and thus could observe that the relative importance of different uncertainty sources varied between sites, boundary conditions and flow indicators. The uncertainty of future climate was important, but not dominant. The deficiencies of the hydrological model were on the same scale, especially for the sites and flow components where model performance for the past observations was further from optimal (Nash-Sutcliffe index = 0.5 – 0.7). The overall uncertainty of predictions was well beyond the expected change signal even for the best performing site and flow indicator.