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Quantifying uncertainties in streamflow predictions through signature based inference of hydrological model parameters

Fabrizio Fenicia (1), Peter Reichert (1), Dmitri Kavetski (2), and Calro Albert (1)

(1) EAWAG, SIAM, Dübendorf, Switzerland, (2) School of Civil, Environmental and Mining Engineering, University of Adelaide, Adelaide, Australia

The calibration of hydrological models based on signatures (e.g. Flow Duration Curves - FDCs) is often advocated as an alternative to model calibration based on the full time series of system responses (e.g. hydrographs).

Signature based calibration is motivated by various arguments. From a conceptual perspective, calibration on signatures is a way to filter out errors that are difficult to represent when calibrating on the full time series. Such errors may for example occur when observed and simulated hydrographs are shifted, either on the “time” axis (i.e. left or right), or on the “streamflow” axis (i.e. above or below). These shifts may be due to errors in the precipitation input (time or amount), and if not properly accounted in the likelihood function, may cause biased parameter estimates (e.g. estimated model parameters that do not reproduce the recession characteristics of a hydrograph).

From a practical perspective, signature based calibration is seen as a possible solution for making predictions in ungauged basins. Where streamflow data are not available, it may in fact be possible to reliably estimate streamflow signatures. Previous research has for example shown how FDCs can be reliably estimated at ungauged locations based on climatic and physiographic influence factors.

Typically, the goal of signature based calibration is not the prediction of the signatures themselves, but the prediction of the system responses. Ideally, the prediction of system responses should be accompanied by a reliable quantification of the associated uncertainties. Previous approaches for signature based calibration, however, do not allow reliable estimates of streamflow predictive distributions.

Here, we illustrate how the Bayesian approach can be employed to obtain reliable streamflow predictive distributions based on signatures. A case study is presented, where a hydrological model is calibrated on FDCs and additional signatures.

We propose an approach where the likelihood function for the signatures is derived from the likelihood for streamflow (rather than using an “ad-hoc” likelihood for the signatures as done in previous approaches). This likelihood is not easily tractable analytically and we therefore cannot apply “simple” MCMC methods. This numerical problem is solved using Approximate Bayesian Computation (ABC).

Our result indicate that the proposed approach is suitable for producing reliable streamflow predictive distributions based on calibration to signature data. Moreover, our results provide indications on which signatures are more appropriate to represent the information content of the hydrograph.