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Joint inference of hydrological and error model parameters: problems and potential solutions

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Various studies have investigated the characteristics of errors in hydrological modelling, which are often correlated, heteroscedastic and non-normal. These studies contributed to improving our understanding of error sources and their effect on total output uncertainty. Despite these advancements, the joint inference of hydrological and error model parameters is still a challenging task with many pitfalls, especially when autocorrelation and heteroscedasticity are parameterized. This calls for additional in-depth analysis of the inference process of hydrological models in combination with error models that are able to describe the main statistical characteristics of the errors.

We present the theoretical framework of a new likelihood function to describe total output uncertainty of hydrological models considering heteroscedastic, correlated and non-normal errors. We assume that streamflow observations are realizations of a transformed, extended Ornstein-Uhlenbeck process such that (a) marginal distributions follow a user-specified distribution parameterized by the output of the deterministic hydrological model, and (b) autocorrelation is time-varying. Note that property (a) allows us to consider heavy tails and skewness and (b) a more realistic description of the changing characteristics of rainfall and dry weather periods. Most previous approaches were limited to normal innovations of (transformed) residuals and to a constant autocorrelation of the autoregressive process.

The performance of the developed likelihood function and its sensitivity to various assumptions are analysed and compared to well-known existing error models based on an hourly data set of the Maimai experimental headwater catchment in New Zealand. Problematic interactions between hydrological and error model parameters, especially on the rising limb of the hydrograph, are identified and discussed. Based thereon, we present methods to mitigate such interactions, which allowed us to reach a more stable joint inference of hydrological and error model parameters. If the presented approach can be successfully extended to other case studies and models, it could contribute to more reliable predictions of hydrological quantities and their associated total uncertainties.