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Towards a reliable decomposition of uncertainty in hydrologic modeling using independent data analysis: Characterizing rainfall errors using conditional simulation

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Calibration and prediction in conceptual rainfall-runoff (CRR) modelling is affected by the sampling and measurement uncertainty in the observed input/output data and by the structural error of the model conceptualisation. The Bayesian Total Error Analysis methodology (BATEA) provides the opportunity to directly and comprehensively address these sources of uncertainty. BATEA is based on Bayesian hierarchical methods and uses explicit error models for input/output data and structural errors. However, previous studies demonstrated that simultaneous inference on forcing (e.g. rainfall) and structural errors requires strong prior knowledge of the error mechanisms (e.g., statistical properties of rainfall errors).

This paper investigates methods to derive informative prior knowledge on data (input/output) errors. A geostatistical approach is used to estimate the sampling error made in approximating the areal rainfall by averaging point-values from a raingauge network. The geostatistical model generates an ensemble of rainfall fields conditioned on gauged values (conditional simulation). This ensemble is treated as a distribution of the “true” areal rainfall over the catchment and used as a prior in the BATEA framework. Prior knowledge on runoff errors is derived from a statistical analysis of the gaugings used to derive the rating curve.

A comparative case study is then carried out, by comparing several inference schemes (full BATEA, ignoring input errors, ignoring structural errors, ignoring both input/structural errors). Results show that: (i) the inclusion of prior knowledge on rainfall accuracy allows simultaneous estimation of input and structural errors, whereas in the absence of such information the inference is ill-posed; (ii) accounting for all sources of errors leads to a more reliable estimation of predictive uncertainty. These findings demonstrate the key role played by priors on data (rainfall/runoff) accuracy, since they control the well-posedness of the inference and allow decomposing predictive uncertainty into its contributing sources. This paves the way for a meaningful analysis of structural errors affecting hydrologic models, thus enabling meaningful model comparison and improvement.