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Disentangling uncertainties in distributed hydrological modeling

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The quantification of uncertainty in hydrologic modeling is a difficult task, as it arises from a combination of physical measurement errors, errors due to different temporal and spatial scales, and errors in the mathematical description of hydrologic processes. In this work we present an efficient tool to explicitly quantify, by means of sequentially assimilating data, the principal sources of uncertainty in hydrologic models, namely parameter, precipitation, potential evapotranspiration, and structural model uncertainty. Sequential data assimilation is performed using a particle filter that combines stochastic universal resampling and kernel smoothing with local shrinkage to improve its performance in comparison to traditional basic importance sampling filters. Precipitation, potential evapotranspiration, and structural model uncertainty are introduced into the assimilation process using multiplicative error models. To illustrate the approach the particle filter is applied to a large-scale distributed hydrological model of the Rhine river. Posterior diagnostic of the model performance and the underlying statistical assumptions of residual errors demonstrate that the posterior distributions can be considered as reliable. Posterior distributions of the precipitation, potential evapotranspiration, and structural model multipliers are used to identify whether a systematic bias for the two input variables as well as for structural model error exists. Furthermore, the distributions illustrate that uncertainty from those sources can be reduced significantly in comparison to the prior assumptions and that they can potentially provide hints about the principal deficiencies of the hydrologic model. An evaluation of the predictive capabilities of the hydrologic model illustrates that considering parameter, precipitation, potential evapotranspiration, and structural model uncertainty appears to be sufficient to characterize the principal sources of error and that the herein presented approach provides a valuable tool to characterize uncertainties in hydrologic models.