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Incorporating rainfall uncertainty in a SWAT model: the river Zenne basin (Belgium) case study

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The European Union Water Framework Directive (EU-WFD) called its member countries to achieve a good ecological status for all inland and coastal water bodies by 2015. According to recent studies, the river Zenne (Belgium) is far from this objective. Therefore, an interuniversity and multidisciplinary project “Towards a Good Ecological Status in the river Zenne (GESZ)” was launched to evaluate the effects of wastewater management plans on the river. In this project, different models have been developed and integrated using the Open Modelling Interface (OpenMI). The hydrologic, semi-distributed Soil and Water Assessment Tool (SWAT) is hereby used as one of the model components in the integrated modelling chain in order to model the upland catchment processes. The assessment of the uncertainty of SWAT is an essential aspect of the decision making process, in order to design robust management strategies that take the predicted uncertainties into account. Model uncertainty stems from the uncertainties on the model parameters, the input data (e.g, rainfall), the calibration data (e.g., stream flows) and on the model structure itself. The objective of this paper is to assess the first three sources of uncertainty in a SWAT model of the river Zenne basin.

For the assessment of rainfall measurement uncertainty, first, we identified independent rainfall periods, based on the daily precipitation and stream flow observations and using the Water Engineering Time Series PROcessing tool (WETSPRO). Secondly, we assigned a rainfall multiplier parameter for each of the independent rainfall periods, which serves as a multiplicative input error corruption. Finally, we treated these multipliers as latent parameters in the model optimization and uncertainty analysis (UA). For parameter uncertainty assessment, due to the high number of parameters of the SWAT model, first, we screened out its most sensitive parameters using the Latin Hypercube One-factor-At-a-Time (LH-OAT) technique. Subsequently, we only considered the most sensitive parameters for parameter optimization and UA. To explicitly account for the stream flow uncertainty, we assumed that the stream flow measurement error increases linearly with the stream flow value. To assess the uncertainty and infer posterior distributions of the parameters, we used a Markov Chain Monte Carlo (MCMC) sampler – differential evolution adaptive metropolis (DREAM) that uses sampling from an archive of past states to generate candidate points in each individual chain.

It is shown that the marginal posterior distributions of the rainfall multipliers vary widely between individual events, as a consequence of rainfall measurement errors and the spatial variability of the rain. Only few of the rainfall events are well defined. The marginal posterior distributions of the SWAT model parameter values are well defined and identified by DREAM, within their prior ranges. The posterior distributions of output uncertainty parameter values also show that the stream flow data is highly uncertain. The approach of using rainfall multipliers to treat rainfall uncertainty for a complex model has an impact on the model parameter marginal posterior distributions and on the model results

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