Catchment processes modelling, including the assessment of different sources of uncertainty, using the SWAT model: the river Zenne (Belgium) case study

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Abstract:

The awareness of water quality issues and the environmental policy has gained increased importance in recent years. For example, in 2000 the European Union has launched the Water Framework Directive (EU-WFD), calling its countries to achieve a good ecological status for all inland and coastal water bodies by 2015 through integrated river basin management.

The river Zenne (Belgium) is far from this objective, as the river acquires high loads of organic pollutants and nutrients. Therefore, a multidisciplinary project "Towards a Good Ecological Status in the river Zenne (GESZ)" was launched to evaluate the effects of the wastewater management plans on the river. In the framework of 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 (water quantity, water quality, soil erosion and sediment transport). The assessment of the uncertainty of SWAT is also 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 objectives of this study are: 1) to develop, calibrate and validate the SWAT model for predicting daily stream flow, sediment concentrations and water quality variables for the upstream part of Zenne basin; 2) to perform a model parameter sensitivity analysis; 3) to assess the sources of uncertainty in a SWAT model of the river, and 4) to analyse the impact of climate change on stream flow and water quality variables.

We built-up the SWAT model for the period 1985-2008, based on geo-spatial and hydro-meteorological data. For the uncertainty analysis, we explicitly accounted for the uncertainties on the input (e.g, rainfall), on the most sensitive SWAT parameters and on the stream flow measurement. For the assessment of the rainfall uncertainty, we identified independent rainfall periods, based on the daily precipitation and stream flow observations, using the Water Engineering Time Series PROcessing tool (WETSPRO). We assigned a rainfall multiplier parameter for each of the independent rainfall period, which serves as a multiplicative input error corruption. To assess the uncertainty and infer posterior distributions of all 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.

The SWAT model results for the upland catchment processes match the observations with a reasonably accuracy. We found that different calibration strategies significantly affect the optimized SWAT parameter values and the model results. The approach of using rainfall multipliers to treat rainfall uncertainty for a complex environmental model such as SWAT is feasible and has an impact on the model parameter marginal posterior distributions and on the

model results. It is also shown that the marginal posterior distributions of the rainfall multipliers vary widely between individual events, as a consequence of rainfall measurement uncertainties and the spatial variability of the rain. The posterior distributions of the model parameters are well defined by DREAM. Finally, it is shown that multi-site calibration is very important for catchments with a high spatial variability like the river Zenne.