The impact of considering different sources of uncertainty on a SWAT model parameter distributions and model outputs: the River Zenne (Belgium) case study

Olkeba Tolessa Leta
*Vrije Universiteit Brussel, otolessa@vub.ac.be*

Jiri Nossent
*Vrije Universiteit Brussel*

Carlos Velez
*Vrije Universiteit Brussel*

Narayan Kumar Shrestha
*Vrije Universiteit Brussel*

Ann van Griensven
*Vrije Universiteit Brussel, UNESCO-IHE Institute for Water Education, Core of Hydrology and Water Resources*

*See next page for additional authors*

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Authors
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Olkeba Tolessa Leta\textsuperscript{a,}\textsuperscript{*}, Jiri Nossent\textsuperscript{a}, Carlos Velez\textsuperscript{a}, Narayan Kumar Shrestha\textsuperscript{a}, Ann van Griensven\textsuperscript{a,b}, Willy Bauwens \textsuperscript{a}.

\textsuperscript{a}Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium. 
\textsuperscript{b}UNESCO-IHE Institute for Water Education, Core of Hydrology and Water Resources, The Netherlands.

*Corresponding author. Tel.: +32 (0)2629 3027; fax: +32(0)2629 3022. E-mail: otolessa@vub.ac.be

EXTENDED ABSTRACT

Introduction: 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 (EU, 2000). However, 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 the framework of this project, different models have been developed and integrated using the Open Modelling Interface (OpenMI) (Gregersen et al., 2007). The hydrologic, physically-based, semi-distributed Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) 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 this hydrologic model is an essential part for decision making, in order to design robust management strategies that take the predicted uncertainties into account. Hereby, it needs to be considered that the model uncertainty does not only stem from the parameter uncertainty, but also from the uncertainty on the input data (e.g, rainfall), the uncertainty on the calibration data (e.g., stream flows) and the uncertainty on the model structure. These sources of uncertainty have already been considered and treated in the SWAT model of the River Zenne (Leta et al., 2013). The aim of this paper is to assess the impact of considering the different sources of uncertainty on the model parameter distributions and model outputs. For the assessment processes, we applied the differential evolution adaptive metropolis that uses sampling from the past states and snooker update to generate candidate points in each individual chain, (DREAM\textsuperscript{zs}) algorithm (Vrugt et al., 2009).

Materials and methods: Three sources of uncertainty (rainfall, model parameters and stream flow) have been explicitly accounted for in the SWAT model of the River Zenne. For the detailed information on how these uncertainties were treated in the SWAT model of the river, the reader is referred to Leta et al (2013). In this paper, we describe the development of four different scenarios (S1-S4) that differ in their underlying assumptions about the treatment of uncertainty, in order to assess the impact of considering different sources of uncertainty on the SWAT model parameter behavior and outputs. S1 only considers the uncertainty on the SWAT model parameters. S2 is similar to S1 but explicitly includes stream flow measurement uncertainty. S3 jointly considers model parameter and rainfall uncertainty. Finally, S4 simultaneously encompasses model parameter, stream flow measurement and rainfall uncertainties. For all the considered parameter inferences, we used a Markov Chain Monte Carlo (MCMC) sampler, the DREAM\textsuperscript{zs} (Vrugt et al., 2009). We assumed a uniform prior distribution for all the considered input factors, within the preselected minimum and maximum ranges. We performed the analyses by using the observed daily stream flows and daily rainfall data for the period 2000-2004.

Results and discussion: The marginal posterior distributions of the SWAT parameters for scenario S1 (based on a sample size of 15000 after model convergence) are presented in Fig. 1. The distributions of some parameters (e.g., Alph-Bf, CN2, ESCO and Gw-delay) are highly skewed and not well identified by the DREAM\textsuperscript{zs} within their prior ranges (Fig.1). Only a few parameters are well defined within their prior ranges. The highly skewed parameters, like Alpha-Bf, show high frequency values, either close to their upper or lower bounds, indicating such parameters are highly uncertain. However, when all uncertainty sources are explicitly treated (S4 scenario), the distributions of some parameters are changed from skewed to Gaussian while the other parameters remain the same (Fig. 2).
For example, the curve number (CN2) parameter values that previously showed a skewed distribution, becomes Gaussian. The remained skewed parameter values after S4 scenario may indicate a compensation for the unconsidered parameters. Additionally, considering the different sources of uncertainty impacts the inferred intervals and the dispersion of the parameter values (Fig. 2).

Closely looking at the CN2 values reveals that for S4, the parameter range is well identified and relatively covers small ranges. In general, considering the different uncertainty sources can potentially affect the inferred values and parameter distributions. Also, based on the parameter values posterior distribution, taking into account the different sources of uncertainty can substantially impact the simulated stream flows.

Conclusions: The input, parameter and output uncertainty components of the SWAT model are explicitly considered for the River Zenne (Belgium). Based on these uncertainty sources, we formulated four uncertainty scenarios and successfully assessed their impact on model parameters and results, using the DREAM(r) algorithm. We found that considering the different sources of uncertainty can potentially impact the parameter distribution as well as the inferred parameter values within the feasible ranges. Finally, it is shown that explicitly considering the different sources of uncertainty is very important to infer the feasible parameter ranges, as they compensate for the other sources of uncertainty.

References: