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Comparison of three different methods for global sensitivity analysis - application to a complex environmental model

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Complex environmental models which are able to consider the dynamic interactions between plants, soils and the environment are suitable tools to predict the impact of climate variability and climate change on the water budget of small catchments. Unfortunately increases the number of potential calibration parameters with increasing complexity of these models. Methods of global sensitivity analysis (GSA) are considered as helpful tools to identify the sensitive and therefore relevant model parameters which need to be considered in the optimization process.

To assess the efficiency of these approaches, three different methods for GSA of model parameters, namely: (1) Mutual Entropy (ME), (2) Regional Sensitivity Analysis and (3) enhanced Fourier Amplitude Sensitivity Test (eFAST) have been tested and compared using the complex environmental model SWAP. The model was set up to simulate the water budget and soil water dynamics of a small experimental catchment in the Ore Mountains, Germany. Discharge and soil water content time series established the data basis for the sensitivity analysis. All three methods have been applied to investigate the sensitivity of the model parameters regarding the different data types, different model efficiency measures and different time resolutions for the calculation of the efficiency measures.

The results indicate that GSA methods from which only the first order sensitivities, this means the sole influence of a specific parameter on the model output, can be obtained (ME & RSA) are unsuitable for complex environmental models. They identified less than 20% of the model parameters to be sensitive, while almost 80% of the model parameters were identified as sensitive on the basis of the total sensitivity index calculated by the eFAST method. Possible reasons for the failure of the first-order methods are the strong interactions of the parameters and the non-linear behavior of the model. A second important result of this study is that different parameters are identified by the GSA methods for different efficiency measures, which supports the hypotheses that different efficiency measures assess different aspects of the behavior of the system under study. Another important role plays the time resolution of the sensitivity analysis. The calculation of weekly, rather than yearly or overall sensitivity indices provides the most information about the model system and its parameters, because the sensitivity of most model parameters is limited to particular system states, such as snowmelt, precipitation events or prolonged dry periods.

However, a subsequent optimisation analysis of the different sensitive parameter sets of the model using an evolutionary multiobjective optimization procedure revealed that the smallest uncertainties and best performances were obtained by simultaneous calibration of all 60 model parameters instead of using the reduced parameter sets.