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Parameter sensitivity estimation: The different information in derivative- and variance-based methods

Juliane Mai, Matthias Cuntz, and Luis Samaniego
Helmholtz Centre UFZ Leipzig, Dept. Comp. Hydrosystems, Germany (juliane.mai@ufz.de)

Parameter sensitivity is of high interest during development and application of complex models. Sensitivity information can, for example, be used to improve the efficiency of model calibration by discarding insensitive parameters or it can be employed to detect weaknesses in model formulation and structure. A variety of methods are available for global sensitivity analysis of mathematical models. They can broadly be divided into derivative-based and variance-based approaches.
In this study one derivative-based and one variance-based technique is applied to a distributed hydrologic model at the mesoscale (mHM) with 52 parameters. Sensitivity indeces are estimated using eleven year daily runoff simulations within a German river catchment. Both methods yield time dependent sensitivity measures which are combined to a single global index per parameter.
The two methods applied yield two distinctly different sets of sensitive parameters. The derivative-based technique selects parameters determining the largest output flux, which is evapotranspiration. The variance-based method, in contrast, prioritizes infiltration and soil water recession parameters, which are on the one hand empirical process descriptions with the least physical basis in the model and are on the other hand largely unknown and therefore have a large range.
Variance-based approaches depend on the given parameter ranges. We therefore hypothesize that an estimation of more precise parameter ranges, for example via a Monte Carlo Markov Chain sampling with respect to an optimal parameter set of a catchment, and subsequent application of the variance-based sensitivity method will lead to balanced importances of evapotranspiration, infiltration and recession parameters. This will dissent from the common assumption that only runoff generation parameters are important in calibration of hydrologic models.
These results lead to the conclusion that derivative-based sensitivity methods highlight key processes for output fluxes whereas variance-based techniques emphasize uncertain processes or process descriptions in the model.