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Method-independent, Computationally Frugal Convergence Testing for Sensitivity Analysis Techniques

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The increasing complexity and runtime of environmental models lead to the current situation that the calibration of all model parameters or the estimation of all of their uncertainty is often computationally infeasible. Hence, techniques to determine the sensitivity of model parameters are used to identify most important parameters or model processes. All subsequent model calibrations or uncertainty estimation procedures focus then only on these subsets of parameters and are hence less computational demanding.

While the examination of the convergence of calibration and uncertainty methods is state-of-the-art, the convergence of the sensitivity methods is usually not checked. If any, bootstrapping of the sensitivity results is used to determine the reliability of the estimated indexes. Bootstrapping, however, might as well become computationally expensive in case of large model outputs and a high number of bootstraps.

We, therefore, present a Model Variable Augmentation (MVA) approach to check the convergence of sensitivity indexes without performing any additional model run. This technique is method- and model-independent. It can be applied either during the sensitivity analysis (SA) or afterwards. The latter case enables the checking of already processed sensitivity indexes.

To demonstrate the method independency of the convergence testing method, we applied it to three widely used, global SA methods: the screening method known as Morris method or Elementary Effects (Morris 1991, Campolongo et al., 2000), the variance-based Sobol' method (Solbol' 1993, Saltelli et al. 2010) and a derivative-based method known as Parameter Importance index (Goehler et al. 2013). The new convergence testing method is first scrutinized using 12 analytical benchmark functions (Cuntz & Mai et al. 2015) where the true indexes of aforementioned three methods are known. This proof of principle shows that the method reliably determines the uncertainty of the SA results when different budgets are used for the SA. Subsequently, we focus on the model-independency by testing the frugal method using the hydrologic model mHM (www.ufz.de/mhm) with about 50 model parameters.

The results show that the new frugal method is able to test the convergence and therefore the reliability of SA results in an efficient way. The appealing feature of this new technique is the necessity of no further model evaluation and therefore enables checking of already processed (and published) sensitivity results. This is one step towards reliable and transferable, published sensitivity results.