Evaluation of parameter interaction effect of the hydrological models using the sparse polynomial chaos (SPC) method

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Abstract

Sensitivity analysis (SA) is an important tool for evaluating parametric uncertainty of a dynamical model. There exists a plethora of SA methods which are very effective in assessing the main effect of model parameters. However, most of the commonly available SA methods cannot reliably compute the second order effect, i.e. the interaction effect. Even though the classical Sobol? type methods that use Monte Carlo simulation can evaluate the interaction effect, the result is either inaccurate or requires an extraordinary number of model runs to obtain a reasonable estimate. In this study we evaluate the sparse polynomial chaos (SPC) method as a reasonable way to estimate the interaction effect. This method, along with the classical Sobol? method and two meta-model based Sobol? methods (Gaussian process regression and Polynomial chaos Kriging), is first evaluated on two mathematical test problems, whose theoretical interaction effects are known. Then we evaluate how reliable those methods can compute the interaction effects of the Hydrologiska Byrns Vattenbalansavdelning (HBV-SASK) hydrological model with 10 tunable model parameters and the Sacramento Soil Moisture Accounting (SAC-SMA) model, an operational model used by US National Weather Service with 13 tunable model parameters. Our results show that the SPC method needs about 300 samples (30 times the parameter dimension) and 910 samples (70 times the parameter dimension) to evaluate the interaction effects of the HBV-SASK and SAC-SMA models, respectively. Compared with the classical Sobol? method and the metamodel-based Sobol? method, the effectiveness and efficiency of SPC method in calculating interaction effects are proved. This is significant for hydrology simulations and parameters optimization, with much potential to improve the understanding of complex model interaction behavior and decrease model uncertainty.