Geophysical Research Abstracts
Vol. 18, EGU2016-5701-3, 2016
EGU General Assembly 2016

Uncertainty quantification for a hydro-morphodynamic model of river Rhine

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Although numerical modelling is state of the art and has been very helpful in River engineering for a long time, it should not be neglected, that uncertainties are unavoidable in numerical modelling. Uncertainties arise from deficient descriptions of the physical processes and from the imprecision of model parameters such as roughness coefficients or sediment grain sizes. Model input parameters are uncertain due to measurement errors, natural variability or unsatisfactory parametrization. The propagation of uncertainties in the input data through simulations might have serious influence on the simulation results. Therefore, it is necessary to quantify the contributions of input uncertainties to the model results in order to appraise their reliability. Uncertainty analysis can help finding the input parameters that cause the larges output uncertainty, and can identify the most uncertain locations and the most uncertain time periods in hydro-mophodynamic model predictions. The Monte Carlo method (MC), the traditional approach for uncertainty analysis, requires a huge computational effort with thousands of simulations. However, for high-resolution numerical hydro-morphodynamic models, each simulation may take hours or days. This implies that the MC method is obviously impossible in river engineering practice. Therefore, other advanced uncertainty quantification methods should be investigated and applied for complex hydro-morphodynamic models.

In this study, five methods have been used and compared for uncertainty analysis of numerical simulations: (1) the Monte Carlo method (MC), (2) the First-Order Second Moment method based on numerical differentiation (FOSM/ND) and (3) based on algorithmic differentiation (FOSM/AD), and higher-order expansion methods such as (4) Taylor series expansion and (5) Polynomial Chaos Expansion (PCE). The latter two have been included in order to capture the effects of strong non-linearity in hydro-morphodynamic process during uncertainty analysis better than with FOSM-type methods. All methods have been applied to a laboratory experiment in steady state and in transient state to verify the performance of FOSM method. The uncertainty analysis is carried out on a hydro-morphodynamic model of river Rhine to define confidence intervals of river bed evolution during an artificial flood event and to detect the most sensitive parameters which contribute most to the change of the river bed. The study presents the benefit of uncertainty analysis with suitable methods to enhance the reliability of sediment transport models in river engineering practice.