Uncertainty analysis of a lumped physically based numerical model of dam breaching

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Failures of dams and dikes often lead to devastating consequences in protected areas. Overtopping is, by far, the most frequent cause of failure. Numerical models are crucial tools to assess risk and guide emergency plans.

Numerous sources of uncertainty exist when running a numerical model. Sensitivity analysis methods have been developed to probe relationships between uncertainties in input variables and the uncertainties they induce in output variables. Among them, variance-based methods allow input uncertainties or subsets of input uncertainties to be ranked according to the significance of their contribution to the induced uncertainty in the outputs. The use of significance descriptors, also called, sensitivity indices, is widely adopted. The significance descriptor of a given input subset quantifies the portion of the global output uncertainty caused by the uncertainty in this subset. It allows the relative significance of input variables to be assessed and the most critical ones to be identified.

We applied an uncertainty analysis using significance descriptors to our implementation of the lumped fully coupled hydro-morphodynamic model developed by Wu (2013, 2016). We computed significance descriptors for three main outputs of the numerical model, namely, the maximum breach discharge ($Q_{b,peak}$), the related elapsed time since the beginning of the experiment (t_{peak}), and a characteristic time related to the width of the breach hydrograph peak (t^*). We ran the model based on configurations corresponding to laboratory experiments led by Frank (2016) and a field-scale test performed during the IMPACT project (2005).

Preliminary results suggest that the amplitude of the impact of input uncertainties varies according to the embankment configuration. In all configurations corresponding to laboratory tests, uncertainty in parameters related to Manning's coefficient was most significant in inducing uncertainty in the outputs of interest. Uncertainty in the sediment adaptation length was also a significant contributor in most of these configurations. At laboratory scale, the influence of uncertainty in the breach weir efficiency increased significantly when the system was purely driven by an initial reservoir volume, i.e., when no inflow discharge was injected. In this configuration, the variability of t_{peak} was also highly dependent on the dike height uncertainty. Rather surprisingly, uncertainty in parameters related to sediment transport capacity was never critical. At field scale, the impact of uncertainties in physical parameters rose notably due to larger inaccuracies in field measurements.