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Tracking the critical offshore conditions leading to marine inundation via active learning of full-process based models

Jeremy Rohmer, Deborah Idier, Thomas Bulteau, and François Paris
BRGM, Natural Risks, Orléans, France (j.rohmer@brgm.fr)

From a risk management perspective, it can be of high interest to identify the critical set of offshore conditions that lead to inundation on key assets for the studied territory (e.g., assembly points, evacuation routes, hospitals, etc.). This inverse approach of risk assessment (Idier et al., NHESS, 2013) can be of primary importance either for the estimation of the coastal flood hazard return period or for constraining the early warning networks based on hydro-meteorological forecast or observations. However, full-process based models for coastal flooding simulation have very large computational time cost (typically of several hours), which often limits the analysis to a few scenarios. Recently, it has been shown that meta-modelling approaches can efficiently handle this difficulty (e.g., Rohmer & Idier, NHESS, 2012).

Yet, the full-process based models are expected to present strong non-linearities (non-regularities) or shocks (discontinuities), i.e. dynamics controlled by thresholds. For instance, in case of coastal defense, the dynamics is characterized first by a linear behavior of the waterline position (increase with increasing offshore conditions), as long as there is no overtopping, and then by a very strong increase (as soon as the offshore conditions are energetic enough to lead to wave overtopping, and then overflow). Such behavior might make the training phase of the meta-model very tedious.

In the present study, we propose to explore the feasibility of active learning techniques, aka semi-supervised machine learning, to track the set of critical conditions with a reduced number of long-running simulations. The basic idea relies on identifying the simulation scenarios which should both reduce the meta-model error and improve the prediction of the critical contour of interest. To overcome the afore-described difficulty related to non-regularity, we rely on Support Vector Machines, which have shown very high performance for structural reliability assessment. The developments are done on a cross-shore case, using the process-based SWASH model. The related computational time is 10 hours for a single run. The dynamic forcing conditions are parametrized by several factors (storm surge S, significant wave height Hs, dephasing between tide and surge, etc.). In particular, we validated the approach with respect to a reference set of 400 long-running simulations in the domain of (S ; Hs). Our tests showed that the tracking of the critical contour can be achieved with a reasonable number of long-running simulations of a few tens.