Comparison of fluvial dike breaching numerical modelling approaches

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ABSTRACT: Failures of fluvial dikes often lead to devastating consequences in floodplains. Overtopping is the most frequent cause of dike failure. Numerical models are instrumental tools to assess the consequences of failure and guide emergency plans. Multiple modelling strategies exist regarding dike morphology and flow descriptions but also the coupling between them. The coupling may be online, i.e., data are shared between modules during computation, or offline, i.e., the modules are run sequentially. The selected modelling strategy significantly influences the model accuracy and computational performance.

Full coupling between a spatially distributed sediment transport model of dike breaching and a hydrodynamic model is usually avoided. 2D models based on shallow-water equations can only represent horizontal surface erosion, although three-dimensional effects cannot be neglected. However, 3D models are computationally too demanding. Therefore, lumped models for dike breaching are often preferred. Here, we compare the accuracy and performance of two different modelling approaches against data from field experiments. The first modelling strategy consists in describing the flow and the morphologic evolution of the dike breach according to an in-house adapted version of the lumped model "DLBreach". In the second modelling approach, we use an online coupling of a 2D hydrodynamic model based on shallow-water equations (resolving the flow in the river and in the floodplain) with our adapted dike breaching model, whose goal is now limited to the description of the dike breach morphodynamics. In the latter case, we also compare results obtained when feeding the morphodynamic dike breaching module with various combinations of hydrodynamic variables computed by the 2D hydrodynamic module, i.e., water levels and velocity fields.

While being substantially quicker and providing reasonable results compared to experimental data, the modelling approach solely based on the lumped model for dike breaching shows a mismatch in the timing of the breach discharge as it is intrinsically not able to properly take into account the propagation of waves that may be created by the boundary conditions. Conversely, the modelling strategy based on the online coupling between the 2D hydrodynamic model and the lumped dike breaching module is expected to lead to more accurate results at the expense of an extensive computational cost. We aim for a holistic comparison of our modelling strategies to reveal the predictive capabilities of simplified modelling approaches for solving real-world dike-breaching and inundation problems.