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A first computational framework for integrated hydrologic-hydrodynamic inundation modelling

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To provide detailed flood hazard and risk estimates for current and future conditions, advanced modelling approaches are required. Currently, many approaches are however built upon specific hydrologic or hydrodynamic model routines. By applying these routines in stand-alone mode important processes cannot accurately be described. For instance, global hydrologic models (GHM) run at coarse spatial resolution which does not identify locally relevant flood hazard information. Moreover, hydrologic models generally focus on correct computations of water balances, but employ less sophisticated routing schemes such as the kinematic wave approximation. Hydrodynamic models, on the other side, excel in the computations of open water flow dynamics, but are highly dependent on specific runoff or observed discharge for their input. In most cases hydrodynamic models are forced by applying discharge at the boundaries and thus cannot account for water sources within the model domain. Thus, discharge and inundation dynamics at reaches not fed by upstream boundaries cannot be modelled.

In a recent study, Hoch et al. (HESS, 2017) coupled the GHM PCR-GLOBWB with the hydrodynamic model Delft3D Flexible Mesh. A core element of this study was that both models were connected on a cell-by-cell basis which allows for direct hydrologic forcing within the hydrodynamic model domain. The means for such model coupling is the Basic Model Interface (BMI) which provides a set of functions to directly access model variables. Model results showed that discharge simulations can profit from model coupling as their accuracy is higher compared to stand-alone runs.

Model results of a coupled simulation clearly depend on the quality of the individual models. Depending on purpose, location or simply the models at hand, it would be worthwhile to allow a wider range of models to be coupled. As a first step, we present a framework which allows coupling of PCR-GLOBWB to both Delft3D Flexible Mesh and LISFLOOD-FP. The coupling framework consists of a main script and a set of functions performing the actual model coupling as well as data processing. All that is required therefore are model schematizations of the models involved for the domain of interest. It is noteworthy that no adaptions to already existing schematizations have to be made. Within the framework, it is possible to distribute input volume from PCR-GLOBWB over the 2D hydrodynamic grid (“2D option”), or if available, directly into the 1D channels (“1D option”). Besides, it is possible to input the water volumes into the hydrodynamic models either as fluxes or states. With PCR-GLOBWB being a global model, it is possible to apply the coupling scheme anywhere, which reduces the dependency of observation data for discharge boundaries. Reducing this dependency is of particular benefit for areas where only a limited number of accurate measurements are available.

First results of applying the coupling framework show that differences between both hydrodynamic models are mainly apparent in the timing of peak discharge when using the 1D option. Regarding inundation extent, applying LISFLOOD-FP with a regular grid outperforms the flexible mesh of Delft3D for those areas where a coarser spatial resolution is used in the flexible mesh. When using the 2D option, however, using Delft3D Flexible Mesh is more robust than LISFLOOD-FP due to the differences in the solver used in the models. With Delft3D Flexible Mesh solving the full Saint-Vernant equations, and LISFLOOD-FP solving the local inertial wave approximation which lacks the convective acceleration term, the framework hence allows for choosing the hydrodynamic parts based on the local characteristics of a chosen study area.