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Mutual coupling of hydrologic and hydrodynamic models – a viable approach for improved large-scale inundation estimates?

Jannis Hoch (1,2), Hessel Winsemius (2), Ludovicus van Beek (1), Arjen Haag (2), Marc Bierkens (1,2)

(1) Department of Physical Geography, Utrecht University, Utrecht, Netherlands (j.m.hoch@uu.nl), (2) Deltares, Delft, Netherlands (jannis.hoch@deltares.nl)

Due to their increasing occurrence rate and associated economic costs, fluvial floods are large-scale and cross-border phenomena that need to be well understood. Sound information about temporal and spatial variations of flood hazard is essential for adequate flood risk management and climate change adaption measures. While progress has been made in assessments of flood hazard and risk on the global scale, studies to date have made compromises between spatial resolution on the one hand and local detail that influences their temporal characteristics (rate of rise, duration) on the other. Moreover, global models cannot realistically model flood wave propagation due to a lack of detail in channel and floodplain geometry, and the representation of hydrologic processes influencing the surface water balance such as open water evaporation from inundated water and re-infiltration of water in river banks.

To overcome these restrictions and to obtain a better understanding of flood propagation including its spatio-temporal variations at the large scale, yet at a sufficiently high resolution, the present study aims to develop a large-scale modeling tool by coupling the global hydrologic model PCR-GLOBWB and the recently developed hydrodynamic model DELFT3D-FM. The first computes surface water volumes which are routed by the latter, solving the full Saint-Venant equations. With DELFT3D FM being capable of representing the model domain as a flexible mesh, model accuracy is only improved at relevant locations (river and adjacent floodplain) and the computation time is not unnecessarily increased. This efficiency is very advantageous for large-scale modelling approaches. The model domain is thereby schematized by 2D floodplains, being derived from global data sets (HydroSHEDS and G3WBM, respectively).

Since a previous study with 1way-coupling showed good model performance (J.M. Hoch et al., in prep.), this approach was extended to 2way-coupling to fully represent evaporation, groundwater infiltration, and surface discharge in inundated areas, and to facilitate the mutual exchange of water between both models. It subsequently was tested and validated in both the Amazon and Niger River Basin to evaluate the model under disparate hydrologic conditions.

Model results were compared to model runs with the aforementioned 1way-coupling and observed discharge as well as flood extent observations based on satellite imagery. This exploratory set-up intends to detect possible strengths, weaknesses and opportunities of the coupled model. With the model set-up still being under active development, preliminary results indicate that model coupling contains a great potential for improved inundation modelling. By spatially distributing hydrology-based model forcing, water level dynamics in the Amazon Basin are for example more accurately represented in smaller channels than only for those forced by point measurements. Results furthermore imply that output quality is strongly linked to the general quality of hydrologic computations in a river basin, especially if evaporation and groundwater processes strongly impact the water balance on temporally inundated floodplains such as for instance in the Niger Basin.