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Hydraulic model evaluation for large-scale flood risk assessments

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For a nationwide flood risk assessment in Germany a complete model chain, from rainfall-runoff to damage evaluation is being set up. Therefore continuous unsteady simulations of inundation depth and extent for all large catchments are required. Until today, hydraulic simulations at this scale are rarely carried out, due to the CPU demanding character of the models. Hence, less demanding, simplified hydraulic models are needed. From the range of existing methods, two fast storage cell models were evaluated to find an appropriate method for this large scale application. The performance of the Dynamic Rapid Flood Spreading Model (Dynamic RFSM) and a 2D storage cell model based on regular raster were compared. Simulations with the fully dynamic shallow water software InfoWorks RS 2D (MWH Soft) served as a benchmark. The raster-based storage cell model uses the inertial formulation of the shallow water equations. The Dynamic RFSM, developed at HR Wallingford in 2009, is based on irregular shaped computational elements. These - so called - impact zones are delineated around depressions in the topography in a pre-processing stage. The discharge between impact zones is calculated with the weir formula. The time-step is constant and fixed by the user. The hydraulic models were successfully applied to a test area having a very flat topography adjacent to the river Elbe with an approximate size of 600 km^2. A dike breach was enforced, at one point of the test reach. The total simulation period was 22 days.

To investigate the impact of the grid resolution on run time and model performance, the two dimensional simulation with the raster model was carried out several times with different grids. The best combination of low error and acceptable run time was found for a raster resolution of 100 m. The run time was about 3 hours on a single core processor. A root mean square error (RMSE) of the inundation depth of 0.21 m and a flood area index of 87 % were achieved. The Dynamic RFSM was not tested against the grid resolution as the impact zones size and number does not depend directly on the grid size. The model runs with the Dynamic RFSM were repeated several times to find an appropriate time step size. The best results were achieved with a time step of 60 s. The result of this analysis was a slight underestimation of the flood extent, likely to be due to the very large impact zones delineated in this flat test area. Like the raster-model, the run time was around 3 hours. The RMSE of inundation depth was slightly lower with a value of 0.18 m, but the flood area index was lower with 78 %. In this case study, the raster-based storage cell model performs a bit better than the dynamic RFSM. This could be explained by (i) the too coarse spatial resolution given by the impact zones in areas where the depressions extend over very large surfaces, and (ii) a better representation of inundation dynamics in the raster-based model thanks to the additional term included in the momentum equation by the inertial formulation.