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Efficient downscaling of coarse grid hydrodynamic model simulations

Guy J.-P. Schumann and Konstantinos M. Andreadis
JPL - Caltech, Jet Propulsion Laboratory, Pasadena, United States (guy.j.schumann@jpl.nasa.gov)

Hydrodynamic modelling is now moving to increasing spatial coverage while trying to preserve simulation accuracies at computationally efficient coarse grids (100 m to several km). Apart from trying to balance physical complexity with computational efficiency, one of the major challenges is also to retain fine spatial resolutions at large scales wherever possible in order to still retrieve meaningful information from models or indeed observations, such as identifying individual assets at risk from flooding for instance. Since it is currently rather impractical to model hydrodynamics across areas larger than a couple of thousand km2 at a fine spatial resolution (finer than 100 m), this paper proposes a method to downscale coarse model simulations (model grid size of 100 m to several km) to a fine spatial resolution. The method is mass conservative and uses a hydraulic 1D approach within the channel and a pseudo region-growing algorithm on the floodplain. Comparison to a high resolution reference model over a domain size much larger than those traditionally modelled showed that downscaling a 600 m grid resolution hydrodynamic LISFLOOD-FP model to 30 m leads to average accuracies greater than 30 cm in water depth and above 90% in inundation area for a high accuracy digital elevation model (DEM). When employing a SRTM DEM accuracies were still between 0.5 m and 1.5 m for water depth but agreements in inundated area were much lower than 90%. We also analyzed floodplain depth-volume relationships within a coarse model grid cell for DEMs of different spatial resolutions and for regions that show significant differences we suggest simulating dynamics with a nested high resolution 2D model. In a hypothetical test case we illustrate that for simulating the world's major rivers and their floodplains at a resolution of 90 m, even a speed-efficient model could take over 3 years to simulate inundation patterns at that resolution for a 1-year hydrograph. However, it is expected that the proposed downscaling method could be used to downscale LISFLOOD-FP model simulations run at a 3 km resolution with reasonably similar accuracies and at only a fraction of the computational time required by the 90 m model.