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Benchmarking three two-dimensional hydraulic models within a single code

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Two-dimensional flood inundation models are widely used tools for flood hazard mapping and an essential component of statutory flood risk management policy in many countries. However, there are numerous hydraulic model codes embodying a wide variety of numerical methods and processes representations. To help managers and modellers chose appropriate codes or classes of model it is imperative to understand the differences between them and quantify the magnitude of this differences in relation to factors such as spatial resolution and uncertainty in model parameters and/or forcing. A key method for resolving this problem is model benchmarking, where multiple codes are applied to the same set of problems. Whilst benchmarking tests are useful, it can often be difficult to obtain good experimental control as subtle differences in model implementation (e.g. spatial discretization, implementation of friction terms etc) may generate differences at least as large as those due to the differences between different physical representations or numerical techniques themselves.

In order to overcome this issue this research undertook a benchmarking exercise using three explicit two-dimensional hydraulic models with different physical representations developed within the same modelling framework. This approach provides substantially improved experimental control such that we can be sure that the differences between simulations are due to the physical representations and not any unstated ancillary choice. The three models are: a shallow water model LISFLOOD-Roe (an implementation of Roe's approximate Reimann solver), an approximate inertial wave model LISFLOOD-INT and an approximation of a diffusive wave (storage cell) model LISFLOOD-ATS. Simulations by the diffusive type model LISFLOOD-ATS were typically 1-3 orders of magnitude longer that the other models due to the relatively short time-step needed to maintain stability, whilst the inertia model LISFLOOD-INT was the quickest, being approximately 3 times faster than the shallow water model LISFLOOD-Roe because it required less computation per time-step.

The recent Environment Agency two-dimensional model benchmarking report provided a set of relevant scenarios to test, but also allowed for comparisons to be made with industry shallow water codes including TUFLOW, MIKEFLOOD, SOBEK and ISIS2D and industry diffusive codes JFLOW-GPU and FlowRoute. A total of six test cases were run including a test of flood spreading over perfectly flat topography, where the LISFLOOD-ATS and LISFLOOD-INT models were unable to simulate symmetry because of excess diagonal flow. This was likely to be due to the decoupling of flows in X and Y directions in these schemes, although a similar affect on irregular topographies was not identifiable. For a valley flooding following a dam break test at the 50 m resolution required by the EA study, simulations of velocity were surprisingly similar between the codes (typically within the spread of the simulations from the industry shallow water codes partially because modelers were able to chose how they sampled the topography to 50 m resolution) and as a percentage of magnitude similar to the depth differences. However, more pronounced differences emerged between LISFLOOD-ATS and the other two models at 10 m resolution, with LISFLOOD-ATS giving similar results at both resolutions. Simulations of velocity were surprisingly similar between the codes and as a percentage of magnitude similar to the depth differences. Decisions about how frequently to record velocity (e.g. every time step or at maximum depth) were shown to have greater impacts on hazards assessment than numerical scheme at many locations. Nevertheless, the use of the simplified model formulations should be justified through a need for simplicity or speed as the shallow water codes were applicable to a wider variety of tests (e.g. LISFLOOD-INT was often unstable when Manning's roughness was below 0.03).