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Non-Hydrostatic Depth-Averaged Modeling of Free Surface Flow Driven Sediment Transport

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Many sediment transport problems in rivers occur for situations with a dynamic and complex free surface. An example is local scour around hydraulic structures, which can have threading effects on the stability and safety of infrastructure in and around rivers for more extreme discharges. For these types of situations, numerical simulations using computational fluid dynamics (CFD) software have always been performed at the limits of computer hardware. Accordingly, a lot of effort has been placed on the acceleration of CFD codes through efficient and especially parallelised solvers, mostly in contrast to two-dimensional wave models.
In the current paper, the two-dimensional flow model SFLOW solving the depth averaged Navier-Stokes equations is implemented in the open-source hydrodynamics model REEF3D. This model is equipped with cutting-edge solvers, which are parallelized following the domain decomposition strategy and scales extremely well on supercomputers. The newly implemented two-dimensional flow model makes use of all these high-performance capabilities enabling the calculation of flow on large domains using high-resolution meshes. Complex geometries are modeled with a ghost cell immersed boundary method. In addition to the hydrostatic part, the non-hydrostatic pressure is solved. This leads to a more realistic representation of the fluid flow and the free surface. Turbulence modeling is performed with depth-averaged two-equation RANS turbulence models. Based on the bed shear stress, bed load and suspended load transport formulations are implemented. The sediment continuity defect in the bed cells is converted into the rate of change of the vertical bed elevation. The resulting flow and sediment transport model delivers a relatively close representation of the hydrodynamic and morphologic physics, while at the same requiring considerably less computational power than full three-dimensional models. The model shows good performance for sediment transport in meandering open-channel flow.