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Coupled method for bed load transport in 1D open channels with arbitrary geometry

Sergio Martinez-Aranda, Javier Murillo, and Pilar García-Navarro
University of Zaragoza, LIFTEC-CSIC, Department of Science and Technology of Materials and Fluids, Spain

Riemann solver-based techniques have proved to be a successful tool to ensure well balanced solutions in the context of the shallow water equations, leading to a wide number of well-balanced numerical schemes based on the preservation of the motionless steady state in presence of irregular geometries [1]. The presence of source terms modifies the behavior of the solution and forces to use different weak or approximate solutions, even in cases of smooth variations of topography. Augmented Roe solvers, based on the upwind discretization of the source terms and the Roe solver defined for the homogeneous case, have demonstrated their efficiency to converge to the exact solution of the hydrodynamic system [2]. Moreover, when a morphodynamical component is added to account for the bed load transport process, a new coupled system of equations appears. The bed load transport is usually evaluated by the Exner continuity equation. However, the total bed load flux depends on the water discharge and the channel shape. Therefore, changes in the downstream geometry may affect the solid discharge through the channel.

In this work a new numerical finite volume scheme for the resulting morphodynamical system is developed for 1D open channels with arbitrary geometry. The Shallow Water and Exner equations can be rewritten as a non-conservative hyperbolic system with three moving waves and one contact wave to account for the source terms discretization [3]. Finding a linearized Jacobian matrix of the system can be a challenge if one considers arbitrary shape channels, even for the simplest solid transport models. Moreover, the bed deformation depends on the erosion-deposition mechanism considered to update the channel cross-section profile [4]. An augmented Roe solver (first order accurate in time and space) is proposed to overcome the solid transport flux variations caused by the channel geometry changes. The stability region is controlled by the proper reconstruction of the approximate solution, enforcing positive values for the intermediate states of the conserved variables. The transition between fixed-mobile bed conditions is also analyzed. Comparison of the numerical results for several analytical and experimental cases demonstrate the effectiveness, exact well-balanceness and accuracy of the scheme.

References

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