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1D flow simulation with irregular cross-sections using the pre-balanced shallow water equations

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With the possible climate change and increased pace of urbanization in the century, urban flooding has caused more and more attentions nowadays. Shallow water equations are widely used to reproduce the flow hydrodynamics of flooding around the urban areas, which have been proved a powerful tool for flood risk assessment and evacuation management, like river flow or flowing at drainage networks with irregular cross-sections at 1D scale. Over the last two decades, Godunov-type schemes have became popular for its robustness treating complex flow phenomenons. When tacking complex topography in the framework of Godunov-type scheme, sourer term needs to be treated property to preserve steady state, that flux gradient and sourer term are balanced. Capart et al. (2003) reconstructed the momentum flux by considering the balance of hydrostatic pressure with the approximated water surface level, which has the ability to tackle the irregular and non-prismatic channel flow with complex topography. This approximation is exact for two cases: 1) rectangular and prismatic channel; 2) water surface is horizontal. However, for other cases, approximation is employed to achieve the hydrostatic equilibrium, which has reduced the accuracy of the numerical solution and increased the complexity for the model implementation.

In this work, we present a new well-balanced numerical scheme for simulating 1D frictional shallow water flow with irregular cross-sections over complex topography involving wetting and drying. The proposed scheme solves, in a finite volume Godunov-type framework, a set of pre-balanced shallow water equations derived by considering pressure balancing (Liang and Marche, 2009). HLL approximated Riemann solver is adopted for the flux calculation at the cell interface. Non-negative reconstruction of Riemann state (Audusse et al., 2004) and local bed modification (Liang, 2010) produce stable and well-balanced solutions to shallow water flow hydrodynamics. Bed slope source term can be approximated using central difference and no special treatment is needed for wet and dry bed. The friction source term is discretized using a splitting implicit scheme and limiting value of friction force is used to ensure stability for the dry bottom (Liang and Marche, 2009). The new numerical scheme is validated against two theoretical benchmark tests and then compared with the validated shallow water model with circular and trapezoid cross-sections over complex topography involving wetting and drying. This method is also possible to reproduce the mixed flow in the conduit or for the flow with non-prismatic channel like river flow in the near future.

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