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Adaptive moving finite volume scheme for flood inundation modeling under dry and complex topography

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To assess and alleviate the risk of flood inundation on local scale, the use of numerical models with high accuracy, spatial resolution, and efficiency is crucial for the reliability of the solutions to provide the forecasts and early-warnings of flood inundation at large or meso-scales. Different with traditional numerical models on fixed meshes, an adaptive moving finite volume scheme on moving meshes is proposed for flood inundation modeling under dry and complex topography, this scheme aims to improve the predictive accuracy, spatial resolution, and computational efficiency as well as the satisfaction of well-balanced positivity preserving properties. The crucial feature of our scheme is to move fixed number of unstructured triangular meshes adaptively for approximating the time-variant patterns of flow variables and then to update flow variables through PDEs discretization on new meshes. At each time step of simulation, this scheme consists of three parts, giving in time n for instance: (1) adaptive mesh movement equation for adapting vertex from $\mathbf{x}_{ij}(n, v)$ to $\mathbf{x}_{ij}(n,v+1)$ where v is the iteration step, this equation can be transferred as Euler-Lagrange ones$\tilde{\nabla}\cdot(\omega\tilde{\nabla}\mathrm{x}) = 0$, in which the monitor function ω is determined by the solution and the gradient of solution; (2) geometrical conservative interpolation for remapping flow variables from $\mathbf{U}_i(n, v)$ to $\mathbf{U}_i(n,v+1)$, when $||\mathbf{x}_{ij}(n,v+1)-\mathbf{x}_{ij}(n, v)|| \leq 10^{-6}$ or v=5, then set $\mathbf{x}_{ij}(n, +\infty)$:= $\mathbf{x}_{ij}(n,v+1)$ and $\mathbf{U}_j(n, +\infty)$:= $\mathbf{U}_j(n,v+1)$, and (3) HLL-based PDEs discretization for updating flow variables from $\mathbf{U}_i(n,+\infty)$ to $\mathbf{U}_i(n+1,0)$, the treatments of bed slope source terms and wet-dry interface are based on second-order reconstruction of Audusse et al., (2004) and Audusse and Bristeau (2005). Two analytical and two experimental test cases were performed to verify the advantages of the proposed scheme over non-adaptive methods. The results revealed two attractive features: (i) this scheme could achieve high-accuracy and high-resolution shock-capturing of dam-break inundation over dry and complex topography with computational cost as lower as possible; (ii) this scheme could improve the capability of SWEs to handle non-hydrostatic pressure problem by achieving streamwise meshes parallel with the spatial distribution of time-variant streamlines. Therefore, adaptive moving finite volume scheme on unstructured triangular meshes could be one of efficient and reliable choices for simulating complex flow in flood inundation over dry and irregular topography.