2D multi-layer hydrodynamic and sediment transport modelling in a tidal estuary

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This study developed a multi-layer hydrodynamic and sediment transport model for simulating tides and the estuarine flows. The flow circulation in an estuary shows complicated mixing and stratification patterns due to the combined effects from currents and tides. This kind of issues becomes more important in Taiwan in line with the more and more frequent sediment flushing operation which led to high sediment concentration flow at the estuary. In some applications, three-dimensional (3D) models solving full Navier-Stokes equations were used. However, the extremely high computational cost, especially for the large-scale environmental problems, is always a serious concern. In the past years, continuous efforts have been devoted to the development of efficient quasi-three-dimensional models under hydrostatic and Boussinesq assumptions. Following the same state-of-the-art modelling strategy, this study develops a multi-layer shallow-water and sediment transport model with finite volume method. In this model, a terrain following coordinate with high local resolution is used to vertically divide the computational domain into multiple layers to better addressing bottom topography and velocity profile. Our model is rigorously validated against several benchmark cases including wind-driven circulation, subcritical flow over a hump, tidal wave propagation, and sediment transport. The grid convergence test and accuracy both are in good agreement with analytical solutions. Subsequently, the model is applied to investigate the estuary dynamics and sediment transport under different conditions, e.g., flow discharges, bottom slopes, wind shears and tidal variations. Overall, the results show a relationship between flow conditions and sediment transport. Later, some scenarios for various upstream inflow and sediment concentration will be examined to assess the reservoir operation rules.

Keywords: shallow water, sediment transport, multi-layer, hydrostatic, Boussinesq Assumption, a finite volume characteristics (FVC) method