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What makes the tide at Qiangtangjiang Estuary unique? The coupling among the morphology, wave nonlinearity and civil engineering projects

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The Qiangtangjiang Estuary is characterized by owning one of world's three biggest tidal bores, and its unique Y-shaped and X-shaped tidal waves are still mysterious and important to understand the physics of natural tides. People usually attribute its uniqueness to its particular shape. It is externally wide and deep, while internally it is narrow and shallow, which shows a typical funnel-shaped delta. However, other than the morphology, why the Qiangtangjiang Estuary differs from others may be also related to the wave nonlinearity, southeast winds during summer, the changing water density and so on. Because of the complexity, few efforts exist to figure out why this funnel-shaped delta creates certain Y-shaped or X-shaped waves.

To explore the question, we narrow down factors and focus on quantifying the effects of the morphology, wave nonlinearity and recent civil engineering projects. We aim to analyze how much the three factors can affect water wave performance and whether Y-shaped or X-shaped waves can be generated without other factors. To meet our needs, we put the seabed displacement caused by 2011 Tohoku earthquake as the singular wave source term. Because it happened on March 11 when the tidal effect was relatively weak at the Qiangtangjiang Estuary and the local weather was calm, which enables us to neglect wind effect and reduce other uncertainties. During simulation, we slightly change the estuary geometry and regenerate the topography to match certain wave shapes. For accurately analyzing the impacts by strong nonlinear shallow water waves, we adopt the finite volume method coupled with WENO and high-order local time-stepping Runge-Kutta schemes. In terms of the influence of civil engineering projects, Dongjianzui Bending Shoal-cutting Project was recently built in the Qiantangjiang Estuary. To address this issue, we simulate virtual shoal-cutting projects in our models.

Model validations against cruises data and the numerical scenario experiments show how the three factors significantly influence the Qiangtangjiang Estuary. With slight change of the estuary shape or shoal-cutting projects, the wave propagation map differs and the Y-shaped and X-shaped waves disappear. The bores are shown to be closely related to topography and nonlinearity. Because after reducing the external depth of the Qiangtangjiang Estuary, the waves in the rear are hard to catch up with the waves ahead, and then bores can not be formed. The results show the Qiangtangjiang Estuary has made it unique under a very special condition, and it is fragile in front of the human interference. Recently, on the north side of the estuary, the coastal reclamation areas have been increasing and the river narrows, weakening the scouring force and causing deposition of sands brought by tides. In our model, changing the topography of the north side helps to predict the developments of degrading Qiangtangjiang Estuary.