Supporting Information for

River-enhanced non-linear overtide variations in river estuaries

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Section I. Supplementary Figures

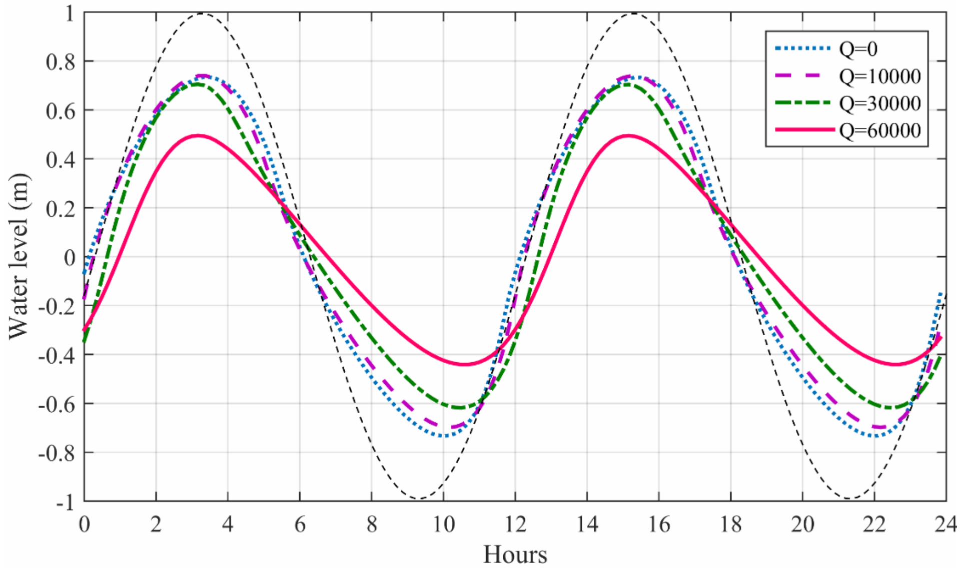

Figure S1. Time series of water level (mean water height filtered) at a location of km-400 in the four scenarios, compared to the undistorted wave at the estuary mouth, i.e., the thin dashed line. Q indicates river discharge.

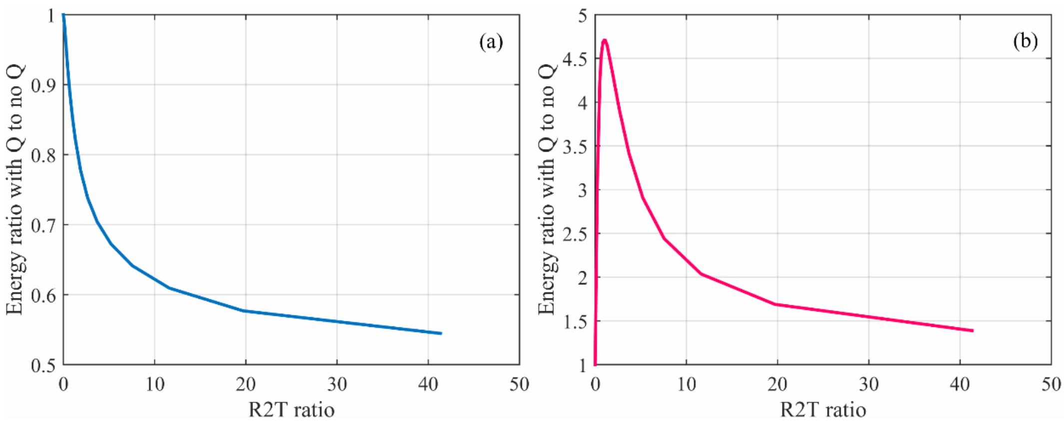

Figure S2. The ratio of the total energy of (a) M2 and (b) M4 tides integrated throughout estuary in the scenarios with river discharge to the case without river discharge as a function of the ratio of river discharge to tide-mean discharge (R2T ratio) on a linear x scale.

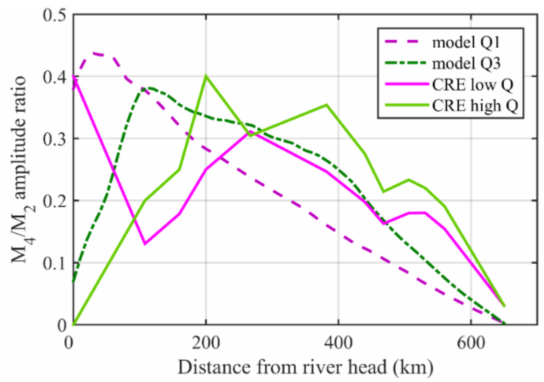

Figure S3. Comparison of modeled M_4 to M_2 amplitude ration in the convergent estuary with the data in the Changjiang River estuary (CRE).

Section II. Method of bottom stress linearization and model results

The quadratic bottom stress is linearized based on the first order of the method according to the energy dissipation condition of Lorentz (1926), as applied by Zimmerman (1992) and Hibma et al. (2003), that reads:

$$r\frac{u}{h+\eta} \quad \text{where} \quad r = \frac{8u_m C_d}{3\pi}$$

and r is a linearized bottom stress coefficient, um is a characteristic velocity scale (i.e., cross-section averaged mean velocity), and C_d is a drag coefficient defined as g/C^2. In this formulation, the total linear friction over the tidal cycle is the same as that for quadratic friction (van Rijn, 2011). It is notable that the linearization of the bottom shear stress in the above equation is not the same as the iterative quasi-linearization in Dronkers (1964) and Godin (1991). This is because the characteristic velocity (u_m) can be obtained from a preliminary simulation using quadratic bottom stress so that bottom friction term can be solved without iteration.

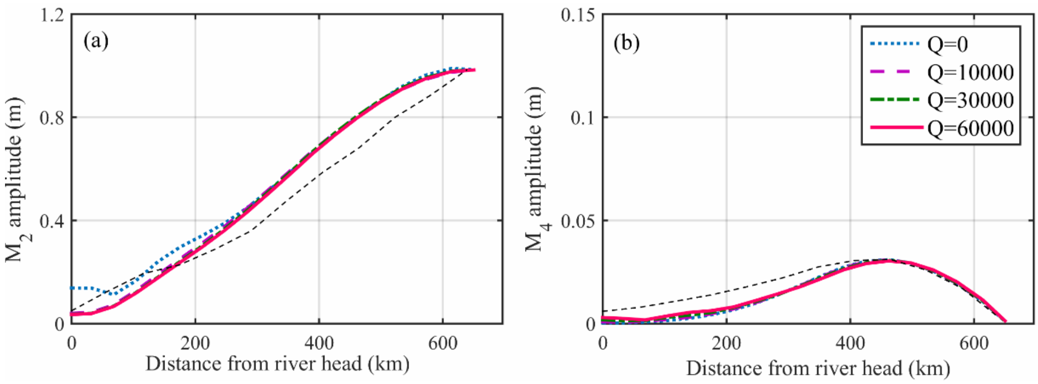

Figure S4. Longitudinal variations of (a) m2 and (b) M4 tidal amplitude under linear bottom shear stress in the rectangular estuary. The black dashed thin lines indicate the amplitudes under zero river discharge and quadratic shear stress.

Section III . Model results under time-varying river discharge

This part of the Supporting Information presents the model results in the scenarios under time-varying river discharges. The river discharge hydrograph is seen in Figure S5a. The schematized river discharge hydrograph includes both slow variations at the seasonal time scales and fast variations at the tidal time scales. The model produced tidal water levels are in Figure S5b. The non-stationary tidal water levels are analyzed in this case by NS_TIDE function developed by Matte et al. (2013), and the M2 and M4 amplitudes are resolved (Figure S6). The integrated M4 energy throughout the estuary is shown in Figure S7, which indicates similar results as that under constant river discharges, as regards that an intermediate river discharge induces maximal M4.

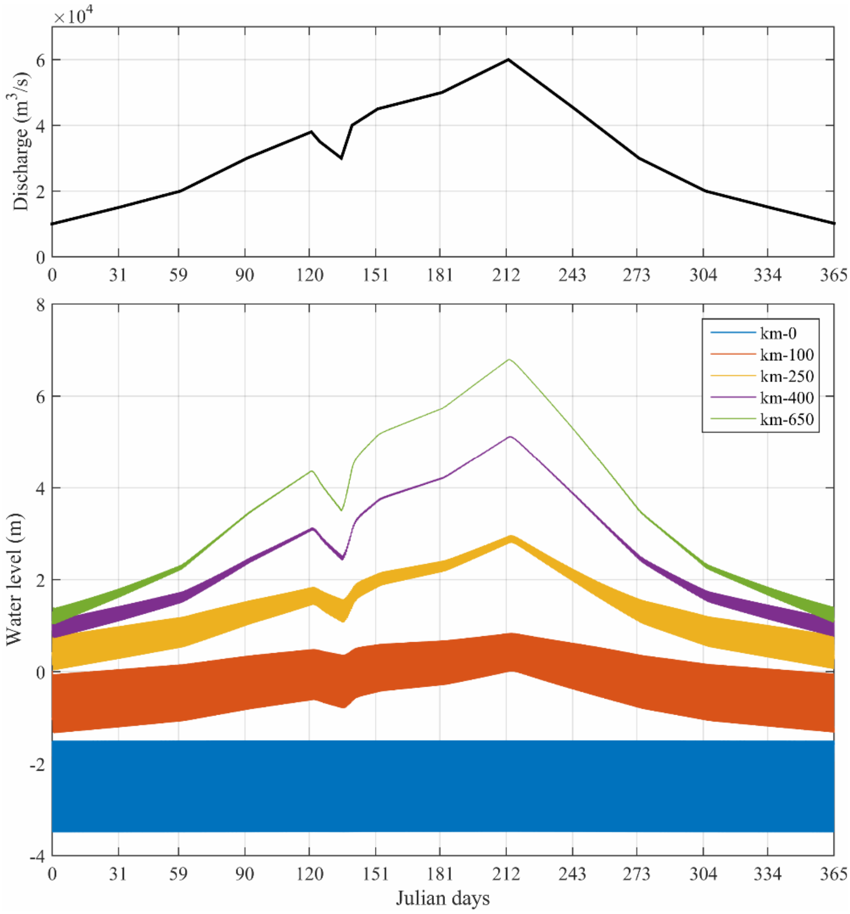

Figure S5. (a) River discharge hydrograph imposed, and (b) model produced tidal water level at five selected sites. The width of the color band indicate the tidal ranges.

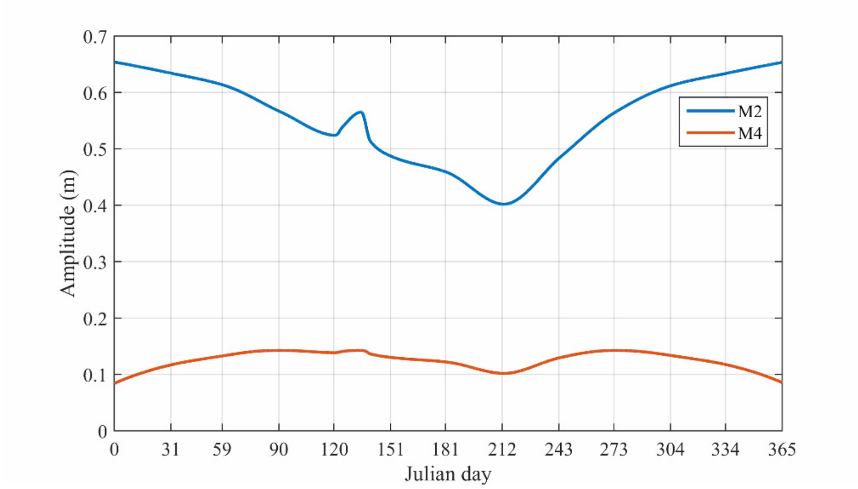

Figure S6. Temporal variations of M2 and M4 amplitude resolved by NS_TIDE function based on model reproduced tidal water levels at a selected site km-400.

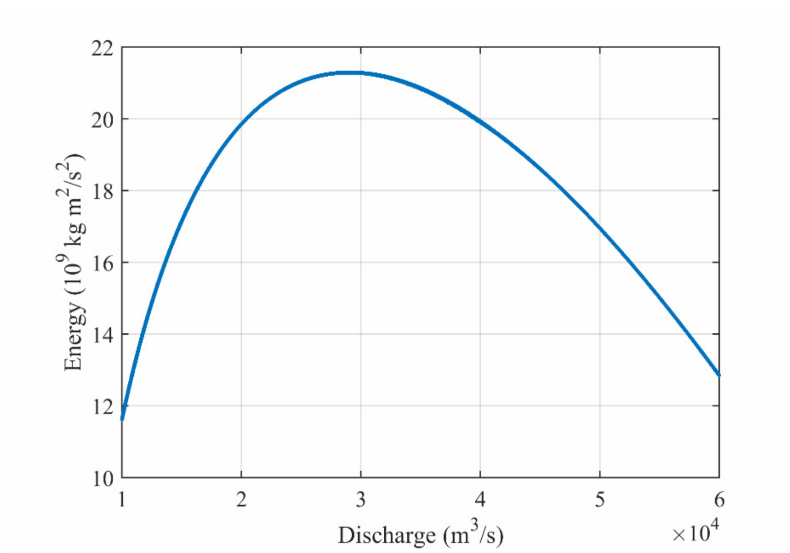

Figure S7. Variation of integrated M4 energy throughout the schematized estuary in the scenario under time-varying river discharges.