1 Hydro-sediment model

FVCOM is a three-dimensional coastal ocean model that utilizes an unstructured, finite-element grid. The unstructured grid employed by FVCOM is particularly well-suited to HZB due to its complex shoreline geometry and multiple islands [49]. The model resolves the three-dimensional momentum and conservation equations in integral form by calculating fluxes between non-overlapping horizontal triangular control volumes. A σ-stretched coordinate system is applied in the vertical direction to better presenting the irregular bottom topography. The σ-coordinate transformation is defined as

$$\sigma = \frac{z-\zeta}{H+\zeta} = \frac{z-\zeta}{D} \tag{S1}$$

where σ varies from −1 at the bottom to 0 at the surface. The total water-column depth is $D = H + \zeta$, where H is the depth to mean surface level and ζ the height of the free surface.

The control equations are as follows:

$$\frac{\partial \xi}{\partial t} + \frac{\partial uD}{\partial x} + \frac{\partial vD}{\partial y} + \frac{\partial \omega}{\partial \sigma} = 0 \tag{S2}$$

$$\begin{aligned} &\frac{\partial uD}{\partial t} + \frac{\partial u^2 D}{\partial x} + \frac{\partial uvD}{\partial y} + \frac{\partial u\omega}{\partial \sigma} - fvD \\ &= -gD\frac{\partial \xi}{\partial x} - \frac{gD}{\rho_0}\left[\frac{\partial}{\partial x}\left(D\int_\sigma^0 \rho d\sigma'\right) + \sigma\rho\frac{\partial D}{\partial x}\right] + \frac{1}{D}\frac{\partial}{\partial \sigma}\left(K_m\frac{\partial u}{\partial \sigma}\right) + DF_x \end{aligned} \tag{S3}$$

$$\begin{aligned} &\frac{\partial vD}{\partial t} + \frac{\partial v^2 D}{\partial y} + \frac{\partial uvD}{\partial x} + \frac{\partial v\omega}{\partial \sigma} + fuD \\ &= -gD\frac{\partial \xi}{\partial y} - \frac{gD}{\rho_0}\left[\frac{\partial}{\partial y}\left(D\int_\sigma^0 \rho d\sigma'\right) + \sigma\rho\frac{\partial D}{\partial y}\right] + \frac{1}{D}\frac{\partial}{\partial \sigma}\left(K_m\frac{\partial v}{\partial \sigma}\right) + DF_y \end{aligned} \tag{S4}$$

$$\frac{\partial TD}{\partial t} + \frac{\partial STD}{\partial x} + \frac{\partial STD}{\partial y} + \frac{\partial T\omega}{\partial \sigma} = \frac{1}{D}\frac{\partial}{\partial \sigma}\left(K_h\frac{\partial T}{\partial \sigma}\right) + D\hat{H} + DF_T \tag{S5}$$

$$\frac{\partial SD}{\partial t} + \frac{\partial SuD}{\partial x} + \frac{\partial SvD}{\partial y} + \frac{\partial S\omega}{\partial \sigma} = \frac{1}{D}\frac{\partial}{\partial \sigma}\left(K_h\frac{\partial S}{\partial \sigma}\right) + DF_s \tag{S6}$$

$$\rho = \rho(T, S, p) \tag{S7}$$

where x, y, and σ are the eastward, northward, and vertical coordinates, respectively; u,

v, and w are the corresponding velocity components. T is the potential temperature, S the salinity, ρ the density and f the Coriolis parameter. K_m and K_h are the vertical eddy viscosity and thermal vertical eddy diffusion coefficients, respectively. Fu, Fv, F_w, F_T, and F_S represent the horizontal and vertical momentum, thermal, and salt diffusion terms, respectively. The Smagorinsky turbulence model is applied to the horizontal turbulence closure scheme [50], and the Mellor and Yamada level 2.5 turbulence closure scheme is adopted as the default for vertical viscosity [51].

Two-way coupling is applied between the sediment model and FVCOM, thereby allowing the sediment to influence water density and, consequently, water circulation. This study focuses on fine sediment in a macro-tidal, high-turbid estuarine environment. The suspended sediment model utilizes a concentration-based approach, governed by the following evolution equation [52,53]:

$$\frac{\partial C}{\partial t}+\frac{\partial (uC)}{\partial x}+\frac{\partial (vC)}{\partial y}+\frac{\partial [(w-w_s)C]}{\partial z}=\frac{\partial}{\partial x}(A_H\frac{\partial C}{\partial x})+\frac{\partial}{\partial y}(A_H\frac{\partial C}{\partial y})+\frac{\partial}{\partial z}(K_h\frac{\partial C}{\partial z}) \tag{S8}$$

where x, y, and z represent the east, north, and vertical coordinates, respectively, while u, v, and w denote the corresponding velocity components. w_s represents the settling velocity of the sediment, and C represents the SSC by volume. A_h refers to the thermal horizontal eddy diffusion coefficient, and K_h is the vertical eddy diffusivity used for suspended sediment in the momentum equation.

The continuous exchange of sediment at the bottom between the seabed and the water column occurs through erosion and deposition, which is influenced by temporal and spatial variability in shear stress. The boundary conditions of the surface and bottom suspended sediment fluxes are defined as:

$$K_h\frac{\partial C}{\partial z}=0, z=\zeta; K_h\frac{\partial C}{\partial z}=E-D, z=-H \tag{S9}$$

where, E represents the suspended sediment flux resulting from erosion, and D represents the flux of sediment deposited at the seabed.

The sediment erosion flux (E) on the seabed is calculated based on van Prooijen's method [54]:

$$E=\begin{cases}0,\tau_b<0.52\tau_{ce}\\ E_0(1-P_b)(\frac{\tau_b}{\tau_{ce}}-1),\tau_b>1.70\tau_{ce}\\ E_0(1-P_b)\left[-0.144(\frac{\tau_b}{\tau_{ce}})^3+0.904(\frac{\tau_b}{\tau_{ce}})^2-0.823\frac{\tau_b}{\tau_{ce}}+0.204\right],\\ 0.52\tau_{ce}<\tau_b\le 1.70\tau_{ce}\end{cases} \tag{S10}$$

here, E_0 represents the erosion coefficient, P_b denotes the porosity, and τ_{ce} represents the critical erosion stress. The bottom stress, denoted as τ_b, is calculated as follows:

$$\tau_b=\rho C_d|U_b|U_b \tag{S11}$$

here U_b is the bottom current, ρ the water density, and C_d the bottom drag coefficient.

The deposited sediment flux (D) on the seabed is calculated as:

$$D=C_b w_b \tag{S12}$$

where C_b is the SSC at the bottom level and w_b the settling velocity of the suspended sediment at the bottom level.

Considering the high turbidity characteristics of Hangzhou Bay, the model allows the SSC to influence the water density, and the equations proposed by Hansen and Rarrary are used to calculate the seawater density ρ_w under the influence of salinity, and the equations proposed by Winterwerp are used to calculate the seawater density ρ when the influence of sediment is considered [55,56]:

$$\rho=\rho_w+\left(1-\frac{\rho_w}{\rho_s}\right)C,\quad \rho_w=\rho_f\left(1+\beta S\right) \tag{S13}$$

where ρ_f is the freshwater density, which is taken as 1000 kg/m^3 in this paper. ρ_w is the seawater density without considering the water-sediment density coupling, ρ_s is the sediment density, C is the sediment concentration, β is the coefficient of salinity expansion, which is taken as 7.8×10^{-4} psu^{-1}, and S is the salinity [57].

The bottom drag coefficient (C_d) in a sediment-laden bottom boundary layer is given by [58,59]:

$$C_d = \frac{k^2}{\left(1 + A_1 R_f\right)^2 \left[\ln\left(\frac{h}{z_0} + 1\right) - 1\right]^2} \tag{S14}$$

where k = 0.4 is the von Karman constant, h is the depth of water and z_0 is the bottom roughness parameter. The effect of stratification is considered by a stability function, $1 + A_1 R_f$, where A_1 is an empirical constant and R_f is the Richardson number. Adams and Weatherly determined A_1=5.5 for a sediment-laden oceanic bottom boundary layer [60].

The flocculation process is considered using the method presented by Cao and Wang [44]:

$$w_s = w_{s0} \frac{1 + c_2 C^{m_2}}{1 + c_1 U^{m_1}} \times k_s \tag{S15}$$

where w_{s0} is the settling velocity for a single sediment particle calculated by the stokes equation of settling velocity. U is current, and c_1=0.06, c_2=4.60, m_1=0.75, m_2=0.90, k_s=1.30 are empirical parameters.

2 The suspended sediment flux mechanism decomposition method

By neglecting the turbulence term, we can decompose the instantaneous flow velocity U and the suspended sediment concentration C as follows:

$$\begin{cases} U = \bar{U} + U_v \\ C = \bar{C} + C_v \end{cases} \tag{S16}$$

where: $\bar{U}$ and $\bar{C}$ are the vertical averaged flow velocity and suspended sediment concentration, and U_v and C_v are the deviation terms of each layer's flow velocity and suspended sediment concentration relative to the vertical averaged value. $\bar{U}$, $\bar{C}$ can be further decomposed as:

$$\begin{cases} \bar{U} = \bar{U}_0 + \bar{U}_t \\ \bar{C} = \bar{C}_0 + \bar{C}_t \end{cases} \tag{S17}$$

where: $\bar{U}_0, \bar{C}_0$ are the time-averaged $\bar{U}, \bar{C}$. $\bar{U}_t, \bar{C}_t$ are the time-averaged vertical mean flow velocity and suspended sediment concentration at each moment relative to the $\bar{U}_0$, $\bar{C}_0$ deviation terms. Similarly, the instantaneous water depth h can be decomposed as:

$$h = h_0 + h_t \tag{S18}$$

where h_0 is the time-averaged water depth and h_t is the deviation term of water depth relative to h_0 at each moment. Then, the average single-width suspended sediment flux $\langle F \rangle$ of tidal cycle T can be decomposed as:

$$\begin{aligned} \langle F \rangle &= \frac{1}{T}\int_0^T\int_0^h ucdzdt = \frac{1}{T}\int_0^T\int_{-1}^0 hucd\sigma dt = h_0\bar{U}_0\bar{C}_0 + \bar{C}_0\left\langle h_t\bar{U}_t\right\rangle + \bar{U}_0\left\langle h_t\bar{C}_t\right\rangle + \\ & h_0\left\langle \bar{U}_t\bar{C}_t\right\rangle + \left\langle h_t\bar{U}_t\bar{C}_t\right\rangle + h_0\left\langle \overline{U_v C_v}\right\rangle + \left\langle h_t\overline{U_v C_v}\right\rangle = T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 \end{aligned} \tag{S19}$$

Physical meanings of different notations are listed in Table S2. This method is used to identify the different sediment-transport mechanisms in HZB.

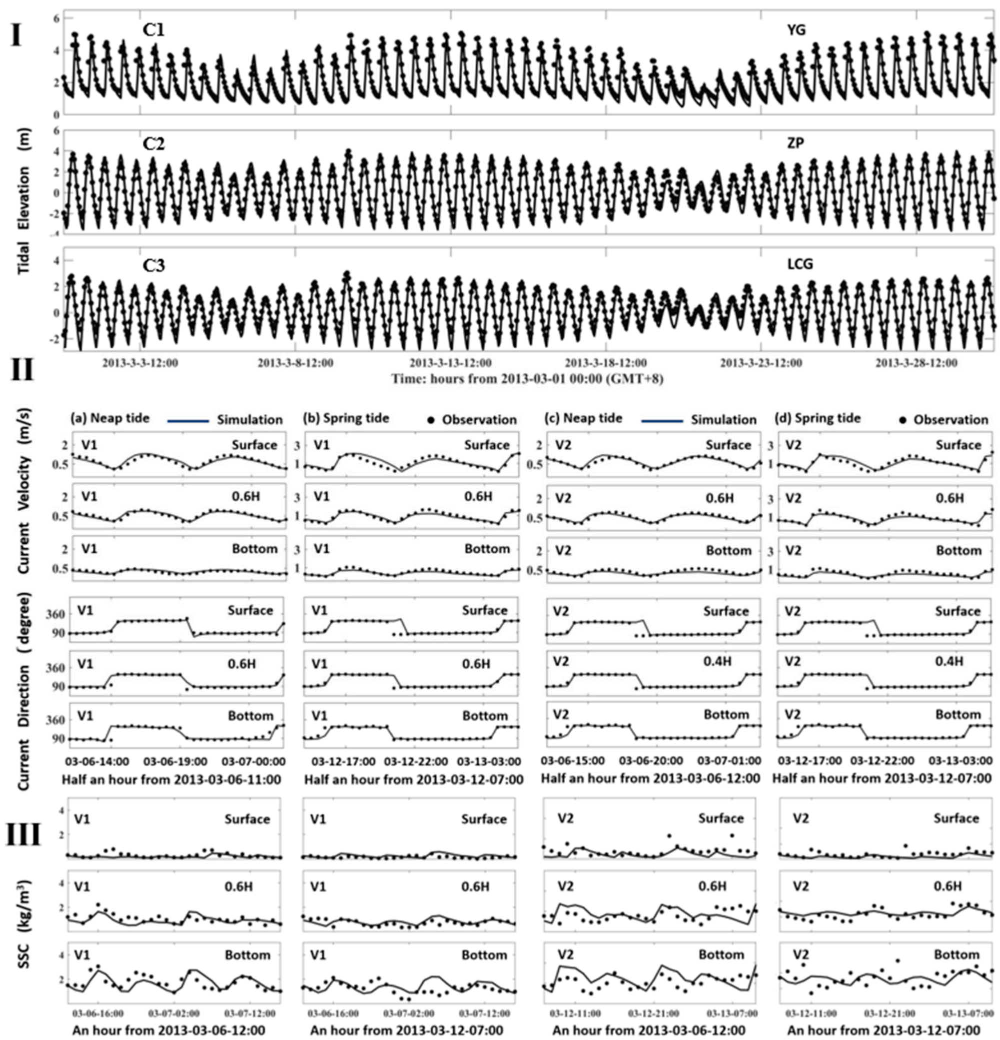

Figure S1. (**I**) Comparisons of the sea−surface levels at stations (**a**) C1, (**b**) C2, and (**c**)

C3. The dots indicate the field data. The solid lines indicate the model results. (**II**) Verification of the current velocities and directions at stations (**a**) V1 and (**c**) V2, respectively, during neap tides; (**b**,**d**) are the same as (**a**,**c**) except for spring tides. (**III**) Comparisons between the observed and modeled SSC at stations (**a**) V1 and (**c**) V2 during neap tides; (**b**,**d**) are the same as (**a**,**c**) except for spring tides.

Table S1. Error analysis between modeled and observed data.

	Station	**Time**	**WSS**	**CC**
Tidal elevation	C1	A month	0.841	0.761
	C2		0.980	0.971
	C3		0.973	0.972
Current speed	V1	Spring tides	0.918	0.886
		Neap tides	0.934	0.851
	V2	Spring tides	0.917	0.889
		Neap tides	0.908	0.879
Current direction	V1	Spring tides	0.956	0.886
		Neap tides	0.964	0.902
	V2	Spring tides	0.943	0.864
		Neap tides	0.948	0.876
SSC	V1	Spring tides	0.698	0.683
		Neap tides	0.512	0.501
	V2	Spring tides	0.692	0.691
		Neap tides	0.498	0.497

Table S2. Physical meanings of different notations [20].

Notation	Physical meaning
brackets	Tidally averaged value of a vertically integrated variable
overbars	Vertically averaged value
T_1	The flux due to the non-tidal drift, the Eulerian velocity
T_2	The flux due to Stokes drift
T_3	The correlation term between the tidal level and sediment concentration
T_4	The flux due to sediment resuspension and deposition
T_5	The correlation term between the tidal level, velocity, and sediment concentration
T_6	The flux due to vertical gravitational circulation
T_7	The changing forms of the vertical profiles of velocity and concentration in the tide