Supporting Information for

Human Activities Caused Hypoxia Expansion in a Large Eutrophic Estuary: Non-negligible Role of Riverine Suspended Sediments

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1.1 Physical model

The physical model is a 1D-3D coupled model that integrates the Pearl River network (1D) and the PRE (3D) into an overall modelling system. This model was firstly developed by Hu and Li (2009) to study the nutrient flux budgets for the river network and the estuary (Fig. 1a), and was further utilized to investigate hypoxia dynamics (Huang et al., 2019; Wang et al., 2017; Wang et al., 2018; Zhang et al., 2022) and sediment-water nutrient exchanges (Liu et al., 2016) in the PRE.

The 1D component for the Pearl River network adopts a Preissmann implicit scheme and an iterative approach to solves the Saint-Venant equations of water mass and momentum conservation. A salinity transport module was also incorporated. The river network was discretized into 299 reaches and 1726 computational cross sections, with five upstream boundaries (including the Gaoyao, Shijiao, Boluo, Laoyagang, and Shizui hydrological stations). The Gaoyao, Shijiao, and Boluo sites were forced by real-time river discharge data, while the Laoyagang and Shizui sites were forced by real-time water level data. The riverine salinity at the upstream boundaries was set to zero. The initial conditions of water levels and salinity in the 1D model domain were set to zero.

The 3D component, covering the PRE and its adjacent shelf regions, is based on the Estuaries and Coastal Ocean Model (ECOM, (Blumberg, 2002)). It adopts Smagorinsky type formula (Smagorinsky, 1963) to calculate the horizontal mixing and utilizes the level-2.5 turbulent closure scheme developed by Mellor and Yamada (1982) to parameterize vertical viscosity and diffusivity. It has 183×186 horizontal grid cells with adaptive horizontal resolution that gradually decreases from ~400 m in the estuary to ~3 km over the shelf. In addition, it has 16 terrain-following vertical layers with refined resolution near the surface and bottom. Along the three open boundaries at the east, west, and the south, the tide forcing in the form of water levels was obtained from

Oregon State University Tidal Data Inversion Software (OTIS). Observed temperature and salinity profiles were spatial-uniformly applied at the three open boundaries (Hu and Li, 2009). The atmospheric conditions (e.g., wind speed, wind direction, and solar radiation) were interpolated onto the model grid, forced by the six-hourly reanalysis product of ERA-Interim (http://www.ecmwf.int/en/research/climate-reanalysis/era-interim). The initial temperature and salinity conditions were spatial-uniformly set to 20 °C and 34.5 PSU, respectively.

The exchange of water mass between the 1D and the 3D model domains is coupled at the eight river outlets. Briefly, at each time step, the 3D model utilizes the simulated discharge obtained from the 1D model as the river boundary forcing and the 3D model sends simulated water levels to the 1D model as the downstream boundary forcing for the next time step. The detailed description of the methodology and setting of the coupled 1D-3D physical model can be found in Hu and Li (2009).

1.2 Suspended sediment module

The transport and fate of sediments in the PRE were simulated by a cohesive sediment module incorporated within the ECOM (Blumberg, 2002). This module shares the same model grid and computational framework as the hydrodynamics module. It simulates the sediment dynamics including sediment transport, deposition, and resuspension. The governing equation of suspended sediments in the water column is formulated as follows:

$$\frac{\partial C}{\partial t} = -\left(U\frac{\partial C}{\partial x} + V\frac{\partial C}{\partial y} + (W - W_s)\frac{\partial C}{\partial z}\right) + \frac{\partial}{\partial x}\left(A_H\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(A_H\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_H\frac{\partial C}{\partial z}\right) \quad \text{(s1)}$$

where C is the suspended sediment concentration (SSC, mg/L); U, V and W are the water velocity components in the x, y and z directions (m/s), respectively; W_s is the sinking rate of the suspended sediments (m/s); A_H is the horizontal diffusion coefficient; K_H is the vertical diffusion coefficient.

Detailed governing equations including boundary conditions treatment, bottom shear stress parameterization, resuspension and deposition characterization can be found in Blumberg (2002). The riverine inputs of suspended sediments at the eight river outlets were prescribed based on observations. The open boundary and initial conditions of SSC were set to zeros.

Table S1. Data source of long-term water quality changes in the Pearl River Estuary (PRE).

Data	Year	Source
Bottom DO	1985-2013	This study (can also found in Hu et al. (2021)). (2021))
Bottom DO	2014	Su et al. (2017)
Bottom DO	2015&2017	Li et al. (2021)
Bottom DO	1990-2017	Environmental Protection Department of Hong Kong
Riverine DIN, DIP, DO	1990-2017	This study
Riverine SSC	1990-2017	China River Sediment Bulletin

Note: DO (dissolved oxygen); dissolved inorganic nitrogen (DIN); dissolved inorganic phosphorus (DIP); suspended sediment concentration (SSC).

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