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Technical Note

Hydrodynamic evolutions at the Yangtze Estuary from 1998 to 2009

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ABSTRACT

Over the past decade, the Yangtze Estuary has witnessed an unprecedented scale of human interventions and modifications through extensively varied resource utilizations. During the processes, mankind has obtained various resources and benefits via the "golden waterway", such as navigation channel, harbor, shipping industry, shoreline, reclaimed land, freshwater and fishery resource. At the same time, the estuary and coast have also experienced a series of gradual changes in characteristics, such as sedimentation, erosion, sand hungry, water pollution, intertidal area loss, self-purification capacity decrease, and biological reduction. With the help of measurement data and numerical modeling, this study analyzed the response and feedback mechanisms between hydrodynamic evolutions and morphological processes in the Yangtze Estuary from 1998 to 2009. The results of this study indicate the following. (i) The water level along the main outlet of the Yangtze Estuary increased from 1998 to 2009. This increase was induced by the variation of the whole river regime (including natural geomorphodynamic process and local topography feedbacks from extreme metrological events and human activities). (ii) The decrease of the flow partition ratio at the 3rd bifurcation is directly induced by the Deepwater Navigational Channel (DNC) project and the corresponding morphological changes in the North Passage. (iii) The estuarine environmental gradients (salinity and suspended sediment concentration) were compressed, and the fresh-salt gradient became steeper. This has the indirect effect of backfilling in the waterway, i.e., strengthening the stratification effect near the ETM area and enhancing the tendency of up-estuary sediment transport. The results of this study give insights into explaining other phenomena such as deposition in the middle reach of the DNC, bathymetry evolutions, variations in vertical velocity and sediment concentration profiles, waterway backfilling and delta reclamation.

1. Introduction

The Yangtze River (or Changjiang River) is the longest river in China and Asia, and the third-longest in the world, after the Nile in Africa and the Amazon in American. The Yangtze is historically, culturally, and economically important to China. The River is approximately 6300 km long and flows eastwards from its source in the Qinghai Province into the East China Sea at Shanghai [1–3]. The Yangtze Estuary (Fig. 1) is first divided by the Chongming Island into the North Branch and the South Branch (1st bifurcation). The South Branch is subdivided again into the North Channel and the South Channel (2nd bifurcation), and lastly the South Channel is further subdivided into the North Passage and the South Passage (3rd bifurcation). The Yangtze Estuary, a semi-enclosed coastal environment, is a free connection point for the river and the open sea, where salt and fresh waters meet and mix, and marine tides and riverine currents interact in the same location.

With the economic development along the eastern coastal line of China, especially in the Yangtze Delta area, sailing traffic has increased exponentially. To solve this problem, constructing a fairway, together with dredging strategies, to allow a deeper navigation channel is necessary. As a result, the conveyance of the channel will be enhanced and it will be able to meet the demand for more water depth. The Regulation Project of the Yangtze Estuary Deepwater Navigational Channel (DNC Project) was launched in 1998. The waterway depth was planed to be developed in three phases (see Fig. 2) from 8.5 m in 2002 (Phase I), to 10 m in 2005 (Phase II) and to 12.5 m in 2010 (Phase III). The basic characteristic of these phases is the flow guidance contraptions becoming longer and narrower; as a result the resistance of the path from the river to the sea is likely to increase irreversibly. Further, it should be noted that the result is enhanced due to both adjustment of the entire river regime and regional sea level rise.

To evaluate the natural and anthropogenic influences on the Yangtze Estuary over the last 12 years (1998–2009), the basic hydrodynamic parameters such as water level, tidal range, velocity,

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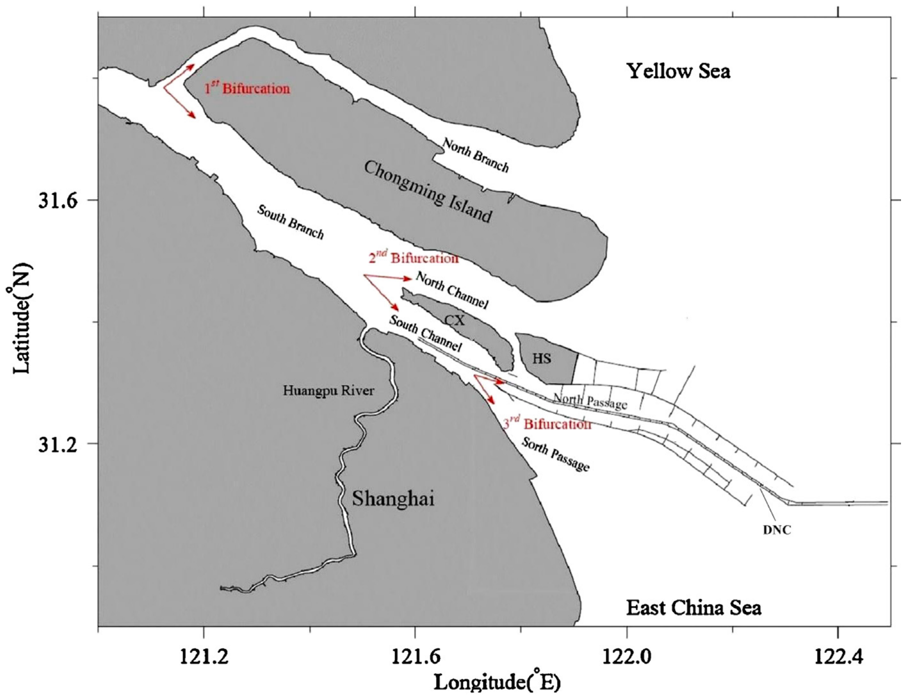

Fig. 1. General layout of the Deepwater Navigational Channel (DNC). The length of the DNC is ∼90 km and the elevation of the channel is maintained at 12.5 m by daily dredging (the elevations, heights and bathymetry in this paper are referred to the Lowest Astronomical Tide). CX and HS are two fixed boundary islands, Changxing Island and Hengsha Island.

salinity, tidal prism, ebb dominance, bifurcation ratio, and suspended sediment concentration (SSC) are chosen to illustrate the spatiotemporal hydrodynamic evolutions along the main outlet, which is the main watercourse of the Yangtze Estuary (shown by bold green lines, see Fig. 3).

2. Methods

2.1. Measurement analysis

Because of the mushrooming of sailing traffic in the Yangtze Estuary at the end of the last century, comprehensive and high-quality measurements and in situ field survey data can be collected, including basic hydrodynamic and bathymetric data. The positions of these measurement stations are shown in Fig. 3, and the specified information about these measurements is shown in Table 1.

As can be observed from Table 1, these measurements cannot be utilized for comparison, because the different meteorological conditions and the boundary conditions clearly vary. Despite this, some general and basic information can be obtained from Fig. 4 as follows.

(1) Although some measured data are unavailable (see Tables 2 and 3 for data availability), the general trend observed from Fig. 4a and b is that the higher high water level (HHWL) and lower low water level (LLWL) during the spring tide period increase by 0.4–1.2 m. However, the average annual sea level rise in this region is only 1–1.5 mm [4], which means that the changes in HHWL and LLWL are not mainly attributed to the global sea level rise. The variation tendency of the HHWL and LLWL is clearly an overall change, which means that the variation is not primarily induced by regional engineering works. The overall water level rise in the entire Yangtze Estuary area should be triggered by the variation in the whole river regime.

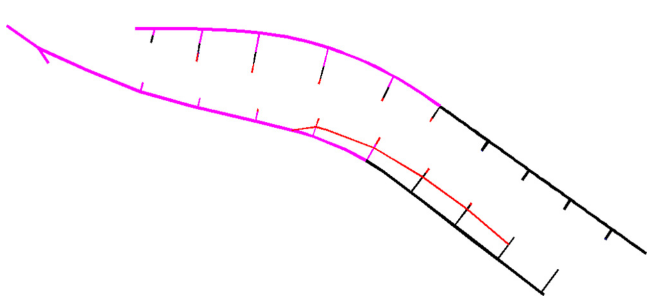

Fig. 2. The engineering progress of the DNC project (the pink lines indicate the Phase I of DNC project, the black lines indicate the extended engineering works of Phase II, and the red lines are the deployment of Phase III). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

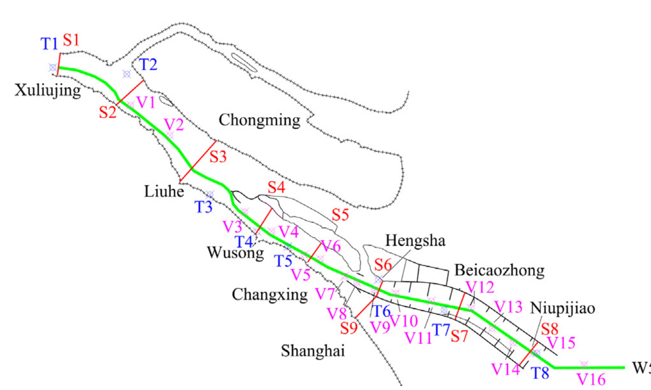

Fig. 3. Deployment of the measurements (the blue points (T1–T8) are the tidal water level gauges; the pink points (V1–V16) are the anchor stations for velocity, SSC and salinity; the green bold line is the main outlet of the Yangtze Estuary; the red lines (S1–S9) across the river are the cross-section for calculating the tidal prism only in modeling). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)