Transportation of Huanghe River-Discharged-Suspended Sediments in Nearshore of Huanghe River Delta in Conditions of Different Estuary Channels

X. H. Xue, G . S. Li, and L. Y. Yuan

Abstract

Periodical estuary-channel diversion, which intensely affects the coastal environment near Huanghe River Delta (HRD), is an important character of Huanghe River. To understand the differences in Huanghe river-suspended sediments (HRSS) transport in the nearshore of HRD under different estuary-channel conditions, Transportations of HRSS in conditions of two estuary channels were compared by numerical simulations. Results showed that longshore-transport pathways of HRSS, and thus the primarily HRSS-influenced coastal waters, were extremely varied in two estuary-channel conditions, that the dispersion area and distance of HRSS in condition of Diaokou Channel was larger and longer than that in condition of Qingshuigou Channel, and that HRSS transported from estuary to outer offshore was stronger in condition of Diaokou Channel than that in condition of Qingshuigou Channel. HRSS transport along longshore-transport pathways was also stronger in condition of Diaokou Channel than that in condition of Qingshuigou Channel.

Keywords

Estuary channel diversion • Sediment transport • The Huanghe River • The Bohai Sea

1 Introduction

Channel change is an important aspect of geomorphologic evolution in large alluvial rivers (Thad et al. 2004). The estuary channel of Huanghe River has experienced 50 times of shift ever since it re-entered the Bohai Sea in 1855 (Pang and Si 1979). Researchers has pointed out that the service life of every estuary channel of Huanghe River is limited (Wang et al. 2001), and that large-scale shift is unavoidable in the long term(Li et al. 2007). Frequent and large-scale shifts of estuary channel can deeply affects the coastal environment along Huanghe River Delta (HRD). One important factor is variation in the transport of Huanghe River-suspended sediment (HRSS) under conditions of different estuary channels. Although some studies have noted these problems, a clear knowledge on them, such as changes in transport direction, transport pathways, dispersion range and transport capacity, is unavailable.

The differences of hydrodynamics at different estuary and adjacent nearshore (Li 1990; Xue et al. 2011) make it possible for HRSS transport to be varied if estuary channel is changed (Ren & Shi 1991; Ren 2006). Studies in many fields, such as erosion and deposition (Li et al. 2002; Zhao 2006), remote sensing images (Huang et al. 2005), suspended materials content (Yang et al. 1991) and distribution of Huanghe River-diluted water (Shen and Le 1993), have also indentified those variations. But a detailed description on them is still needed.

Taking two typical estuary channels (Diaokou Channel and Qingshuigou Channel, which respectively entered the Bohai Sea at the north and the west of HRD) in their early

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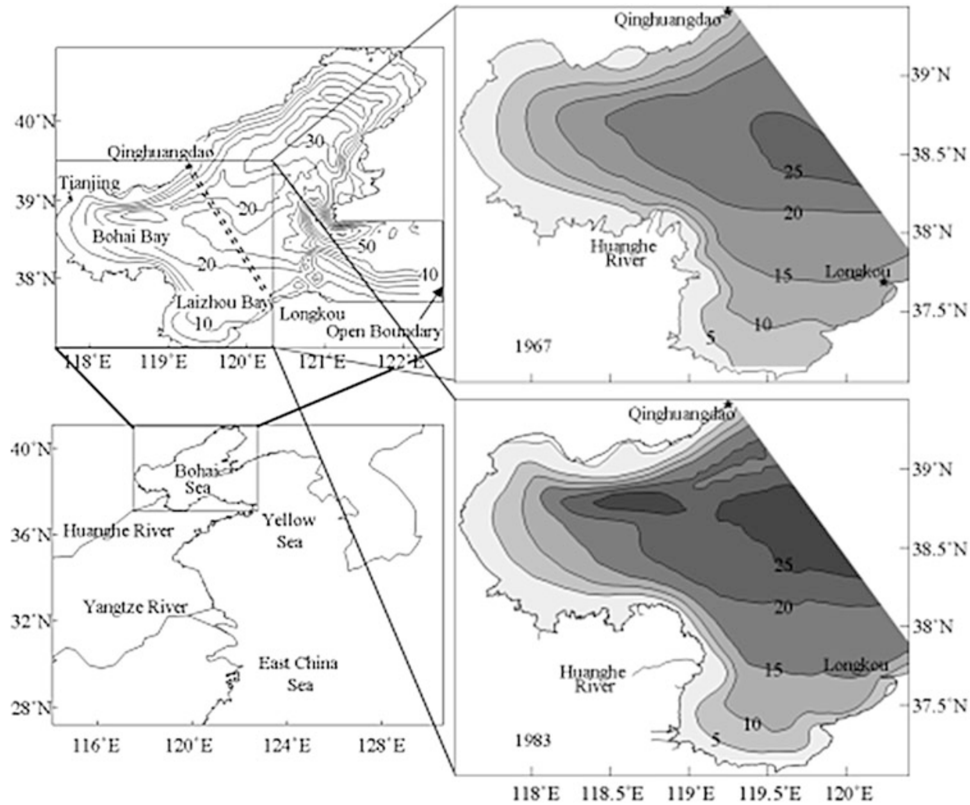

Fig. 1 Study area and its subaqueous landform

serving periods as an example, this paper compared HRSS transport in the nearshore of HRD by two numerical comparative tests.

2 Methods and Model Validation

2.1 Method

Two comparative numerical tests, in accordance with the boundary conditions of Diaokou Channel and Qingshuigou Channel, were designed: (1) as to coastline and coastal subaqueous landform (Fig. 1), the 1:50,000 topographic map in 1967 was used for condition of Diaokou Channel (test A), and water-depth data surveyed in 1983 was used for condition of Qingshuigou Channel (test B); (2) the location of river mouth in test A and B were respectively set at Diaokou (118.81°E, 38.15°N) and Qingshuigou (119.09°E, 37.74°N); (3) other model conditions and parameters were the same and detailed in the following section.

2.2 Data and Model Settings

Based on the Coastal Ocean Model with Sediment Transport (ECOMSED) model (Blumberg and Mellor 1987), test A and B for the simulation of hydrodynamics field and sediment transport were run. Study area in this paper is the nearshore along HRD (Fig. 1). But the modeling area contained the entire Bohai Sea, and the open boundary was set at the Bohai Strait to avoid the bad effect of imprecise water-level, velocity and temperature at open boundary on sediment transport.

Boundary and initial conditions for numerical calculation were achieved as follows: (1)sea surface forcing fields 1982–1984, including wind and heat flux, were got from NCEP/NCAR Reanalysis2 dataset (NOAA/OAR/ESRLPSD 2008); (2) the runoff and sediment load measured at Lijin Hydrometric Station (118°18′E, 37°31’N) during 1982–1984 was used as the Huanghe River flow and sediments delivered into the Bohai Sea, and the raw sediment data was amended by multiplying 70 %; (3) salt and temperature conditions were achieved from the “Marine Atlas of Bohai Sea, Yellow Sea and East China Sea” (Editorial Board for Marine Atlas 1993); (4) water level at open boundary was calculated from tidal parameters of 6 tidal components, including S_2, M_2, N_2, K_1, P_1 and O_1.

By using researches in study area (Lü et al. 2003; Gu et al. 2005) for reference and by adjustment calculation, parameters of bottom friction coefficient, horizontal mixing coefficient, vertical mixing coefficient and bottom roughness were respectively set to 0.0036, 0.1, 0.000001 and

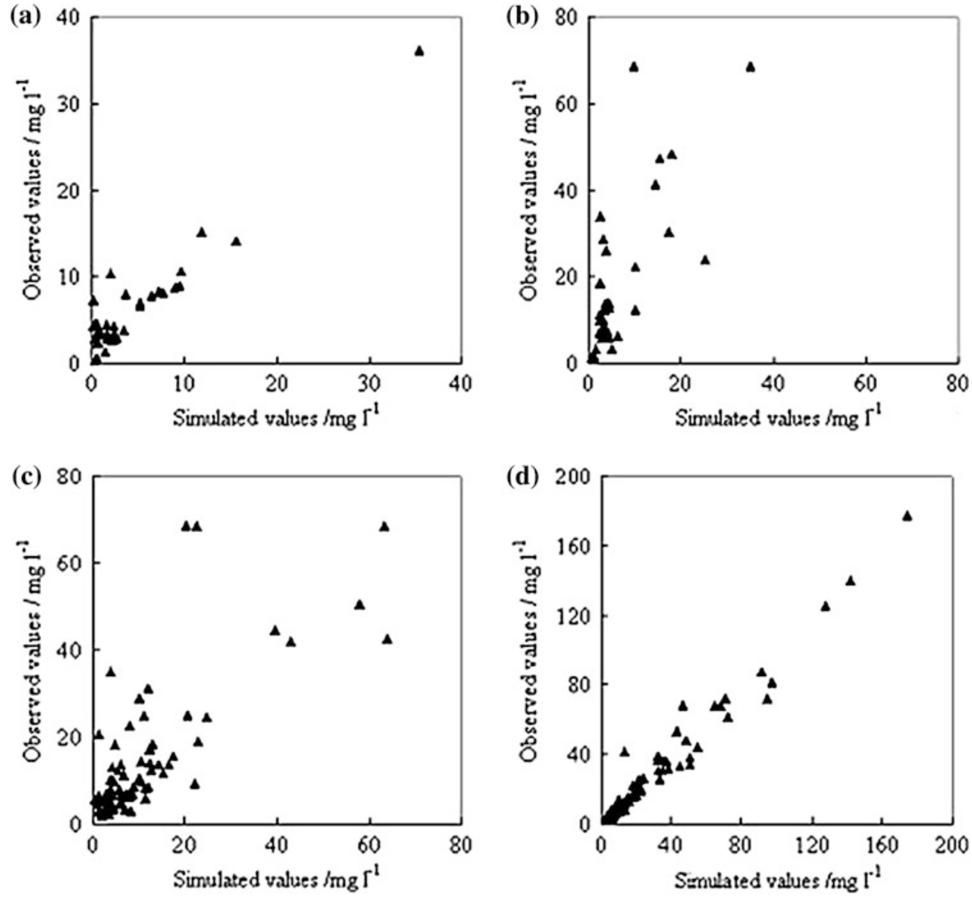

Fig. 2 Validation for sediment-concentration (a) at surface layer in Aug. and Sep., (b) at surface layer in Jan., (c) at middle layer, and (d) at bottom layer

0.0001 m. Reid and Bodine boundary condition was used as open boundary condition. Horizontal mixing process was calculated by Smagorinsky equation.

Parameters for the simulation of cohesive sediment flocculation and settling involving constants α, β, and minimum bottom shear stress $\tau_{b,\min}$ were respectively set to 2.42, 0.22 and 1 dynes cm^{-2}. In cohesive-sediment resuspension calculation, τ_c(critical shear stress for erosion) from first to the seventh layer were 1.1, 2.0, 3.0, 4.0, 5.0, 6.0 and 8.0 dynes cm^{-2}; the dry density of sediment bed was 1.1 g cm^{-3}; values of a_0, m *and* n were respectively 2.0, 0.5 and 2.0; bottom friction coefficient of cohesive sediment and bottom roughness were set to 0.0036 and 0.001 m.

2.3 Model Validation

Validation for tide and tidal current in modeling area has carried out in previous work (Li et al. 2005; Xue et al. 2011) which identified the effectiveness of numerical hydrodynamic model used in this paper.

Sediment data transformed from turbidity which was measured at 73 stations in the summer of 2000 and in the winter of 2001 was used for suspended sediment concentration (SSC) validation. Using conditions of runoff discharge, sediment, coastal landform and wind field during 1999-2001, a numerical test for sediment-validation was run. Fig. 2 shows that there is good agreement between the simulated and the observed values. For SSC at surface layer, the simulated results in August and September have good consistence with the observed (Fig. 2a), but have less consistence in January (Fig. 2b). Correlation coefficient for bottom layer (Fig. 2d) amounts to 98.8 % with $R^2 = 0.96$. Correlation coefficient for middle layer (Fig. 2c) is 76 % with $R^2 = 0.57$.

3 Results and Discussion

3.1 Comparisons on the Pathways and Ranges of HRSS-transport in the Nearshore of Huanghe River Delta

As shown in Fig. 3, HRSS mainly moves to the two sides of river mouth and then transport along the longshore of HRD in both estuary-channel conditions. Sediment transport at the direction of river discharge is weak and not far. There are two basic longshore-transport pathways in the two

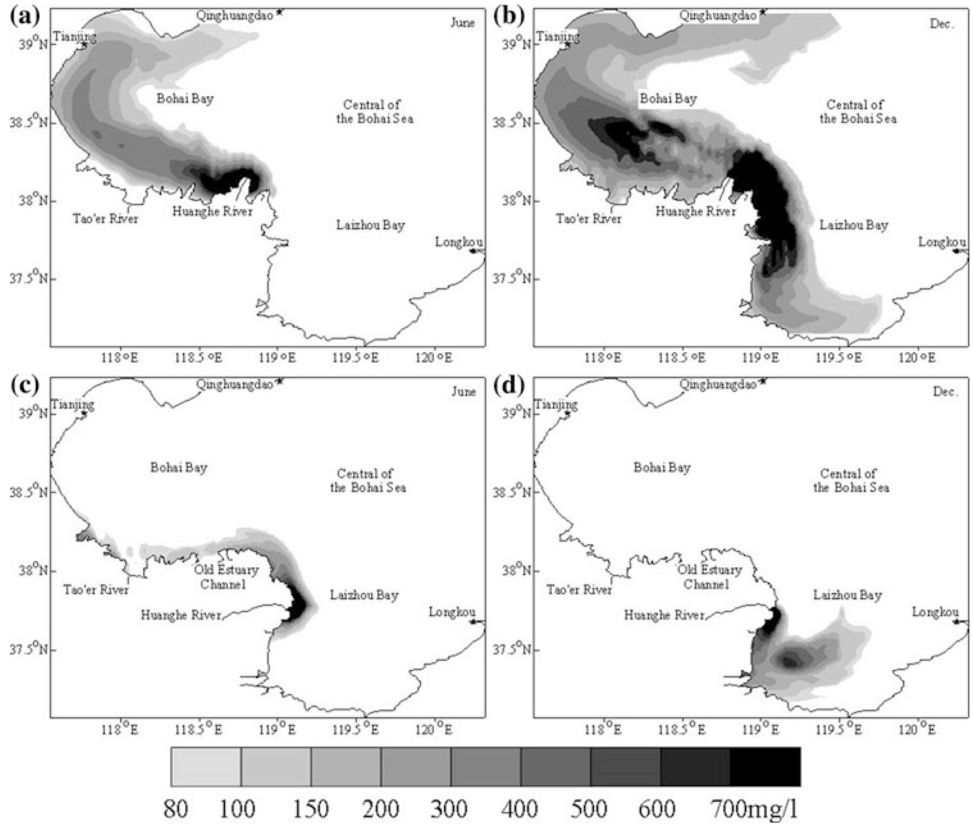

Fig. 3 Sediment distribution at middle layer of study area under condition of Diaokou Channel (a ∼ b) and Qingshuigou Channel (c ∼ d)

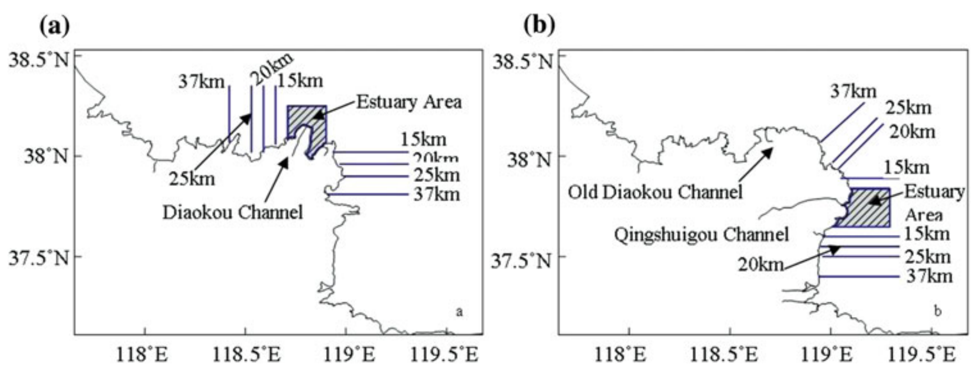

Fig. 4 Sections for the comparison of HRSS-transport capacity (a) in condition of Diaokou Channel and (b) in condition of Qingshuigou Channel

different conditions, respectively. Change of the location of river mouth leads to large difference in transport pathway and transport distance, which results in variation of HRSS-affected zone.

In condition of Diaokou Channel, HRSS moves to the west side of river mouth and then transports along south shore of Bohai Bay in summer (Fig. 3a), that is the longshore transport pathway along Bohai Bay (LTPBB). By another longshore transport pathway along west shore of Laizhou Bay (LTPWLB), HRSS moves to the east side of river mouth and then transports southward along the west shore of Laizhou Bay in winter (Fig. 3b).

In condition of Qingshuigou Channel, HRSS moves northeastward and then turns northwest in summer(Fig. 3c), that is, the longshore transport pathway at north of river mouth (LTPNRM). Partial HRSS can enter the Bohai Bay and move westward along the south shore of Bohai Bay. By another longshore transport pathway at south of river mouth (LTPSRM), HRSS moves to the south side of river mouth and transports southward along the west shore of Laizhou Bay. But after a non-far southward transport, sediments turn northeast.

The above transport patterns of HRSS shows that influence of HRSS on the Bohai Bay is much larger than that on the Laizhou Bay in condition of Diaokou Channel. Contrarily, HRSS, most of which disperses in the Laizhou Bay, has littler effect on the Laizhou Bay. In addition, the dispersion area of HRSS in condition of Diaokou Channel is much broader than that in condition of Qingshuigou Channel. But their differences in sediment offshore-dispersion distance are not obvious. Therefore, the longshore-transport distance of HRSS in condition of Diaokou Channel is much longer than that in condition of Qingshuigou Channel.

3.2 Comparisons on the Transport Capacities of HRSS in the Nearshore of Huanghe River Delta

To understand differences in HRSS transport capacity between conditions of two different estuary channels, their differences at estuary area and offshore along transport-pathway are separately discussed. Estuary area is defined by a section (20 km from river mouth) perpendicular to direction of run-off flowing and by two cross sections (10 km from river mouth) at two sides of river mouth (Fig. 4). To quantify the transport capacities along pathways, four cross sections which are respectively 15, 20, 25 and 37 km from river mouth are set(Fig. 4).

As to transport capacity in estuary area, HRSS transported out estuary area in condition of Diaokou Channel amounts to 35.2 % of sediment discharge, but it is only 14.7 % in condition of Qingshuigou Channel. In condition of Diaokou Channel, HRSS transported to west side of river mouth is much larger than that transported to east side of river mouth. In condition of Qingshuigou Channel, there is no evident difference between amounts of HRSS transported to south and north sides of river mouth.

As to transport capacities along longshore-transport pathways, the total transport capacity along two basic longshore-transport pathways in condition of Diaokou Channel is much stronger than that in condition of Qingshuigou Channel, but their difference decreases with increase of transport distance. In condition of Diaokou Channel, 74.7 % of HRSS that move out estuary are transported through the cross-section that is 15 km from river mouth, but it is only 50 % in condition of Qingshuigou Channel. HRSS transported through four sections that are separately 15, 20, 25 and 37 km from river mouth in condition of Diaokou Channel is respectively 2.7, 2.3, 2.3 and 1.7 times that in Qingshuigou Channel condition.

HRSS-transport along the Bohai Bay (LTPBB) plays a dominant role in condition of Diaokou Channel, transportation along west shore of Laizhou Bay (LTWLB) is much weaker. Amounts of HRSS transported through four cross-sections, which are set at pathway of LTPBB and are separately 15, 20, 25 and 37 km from river mouth, are 4.5, 3.9, 3.0 and 1.1 times that along LTWLB, respectively. In condition of Qingshuigou Channel, difference in the transport capacities between two basic pathways is much less.

4 Conclusions

Differences in the transportation of Huanghe River-suspended sediments discharged by different estuary channels are important for understanding influence of estuary-channel shift on coastal environment. Numerical simulation for Diaokou Channel and Qingshuigou Channel evidently revealed these differences in the transport pathway, dispersion range and transport capacity.

Transportation along south shore of Bohai Bay and transportation along west shore of Laizhou Bay are the two longshore-transport pathways of HRSS in condition of Diaokou Channel. Northward transport along west shore of Laizhou Bay and another pathway by which HRSS turns northeast after a non-far southward movement are the two longshore-transport pathways for condition of Qingshuigou Channel. Influence of HRSS on the Bohai Bay is larger than on the Laizhou Bay in condition of Diaokou Channel. Contrarily, influence of HRSS on the Laizhou Bay is primary in Qingshuigou condition. The dispersion area and transport distance of HRSS in condition of Diaokou Channel is much larger than that in condition of Qingshuigou Channel.HRSS transported from estuary to outer offshore in condition of Diaokou Channel is much more than that in condition of Qingshuigou Channel. The transport capacity along longshore-transport pathways in condition of Diaokou Channel is also stronger than that in condition of Qingshuigou Channel.

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