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Sediment dynamics in an offshore tidal channel in the southern Yellow Sea

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Abstract

The geomorphology of the southern Yellow Sea (SYS) is characterized by offshore radial sand ridges (RSR). An offshore tidal channel (KSY Channel) is located perpendicular to the coast, comprised of a main and a tributary channel separated by a submarine sand ridge (KSY Sand Ridge) extending seaward. In order to investigate the interactions among water flow, sediment transport, and topography, current velocity and suspended sediment concentration (SSC) were observed at 11 anchor stations along KSY Channel in RSR during a spring tide cycle. High resolution bottom topography was also surveyed. Residual currents and tidally averaged suspended sediment fluxes were calculated and analyzed by using the decomposition method. Results suggested that the water currents became stronger landward but with asymmetrical current speed and temporal duration of flood and ebb tides. Residual currents showed landward water transport in the nearshore channel and a clockwise circulation around the KSY Sand Ridge. Tidally-averaged SSC also increased landward along the channel. The main mechanisms controlling SSC variations were resuspension and horizontal advection, with spatial and temporal variations in the channel, which also contributed to sediment redistribution between channels and sand ridges. Residual flow transport and the tidal pumping effect dominated the suspended sediment flux in the KSY Channel. The KSY Sand Ridge had a potential southward migration due to the interaction between water flow, sediment transport, and topography.

Key Words: Tidal channel, Sand ridge, Suspended sediment concentration, Flux decomposition, Southern Yellow Sea

1 Introduction

Sand ridges are important submarine geomorphologic features in continental shelves and coastal regions. They mainly appear in estuaries, headlands, beaches, and open shelves. Under certain conditions, such as sufficient sediment supply, appropriate water depth and strong current speed, a sand ridge will change dynamically (Dyer and Huntley, 1999). When more than one sand ridge appears in vicinity, the system is formed with alternating sand ridges and tidal channels, such as in southern North Sea and northeast US Atlantic shelf.

Many theories have been proposed to explain the evolution mechanisms of sand ridges. Off (1963) and Houbolt (1968) noted the effect of helical flows produced by tidal flow on linear sand ridge. Caston (1981) and Berné (1994) considered sand ridges on open shelf as remnant of sand deposit being reshaped by tidal currents and storms. Based on stability analysis, Huthnance (1982a, b) concluded that sand ridge was formed due to the interaction between hydrodynamics and seabed morphology. His work was extended by Hulscher (1996) and Besio (2006) with more complex numerical models and supported by Pan (2007) with field measurement. However, most of the sand ridges investigated above were located paralleled to shoreline and under relatively simple pattern of sediment supply and tidal hydrodynamics. As a necessary supplement for sand ridge study, an offshore tidal channel-sand ridge system (TCSRS) perpendicular to coast in the southern Yellow Sea was examined in the present study.

The geomorphology of southern Yellow Sea (SYS) is characterized by large offshore radial sand ridges (RSR, Fig. 1a). Historically the old Yellow River had entered the SYS between 1128 and 1855 AD, providing plentiful sediment for

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shaping and developing RSR (Zhang, 1984). The ancient delta of Yangtze River laid material foundation for RSR, and the estuary migrated southward to the present location in thousands of years (Yang et al., 1983). The sediment discharged into the Yellow Sea from modern Yangtze River was still an additional source (Wang et al., 1998).

In addition to the complicated sediment sources, RSR is subjected to strong tidal currents in radial pattern and the interaction between hydrodynamics and topography has been an on-going subject with extensive debate (Li et al., 1979; Huang et al., 1987; Zhang et al., 1998; Zhu et al., 1998; Xing et al., 2012). Recent studies have mostly focused on the geomorphological change and channel sediment dynamics. Hou et al. (2006) and Chen et al. (2012) acquired erosion/deposition pattern of southern channels in RSR over the past decades. Wu et al. (2006) and Liu et al. (2011) concluded that tidal advection was the major factor controlling the suspended sediment transport in Xiyang Tidal Channel.

In this study, an offshore tidal channel, Kushuiyang Tidal Channel (KSY Channel), together with the submarine sand ridge (KSY Sand Ridge) inside, is chosen as the research area (Fig. 1b). During a spring tidal cycle, data were obtained from 11 anchor stations (Fig. 1b) along this channel from the coastal radial center to the open sea. The main purpose of the study is to explore the mechanism controlling SSC variations and sediment transport patterns in RSR, and TCSRS behavior responses to regional sediment dynamics.

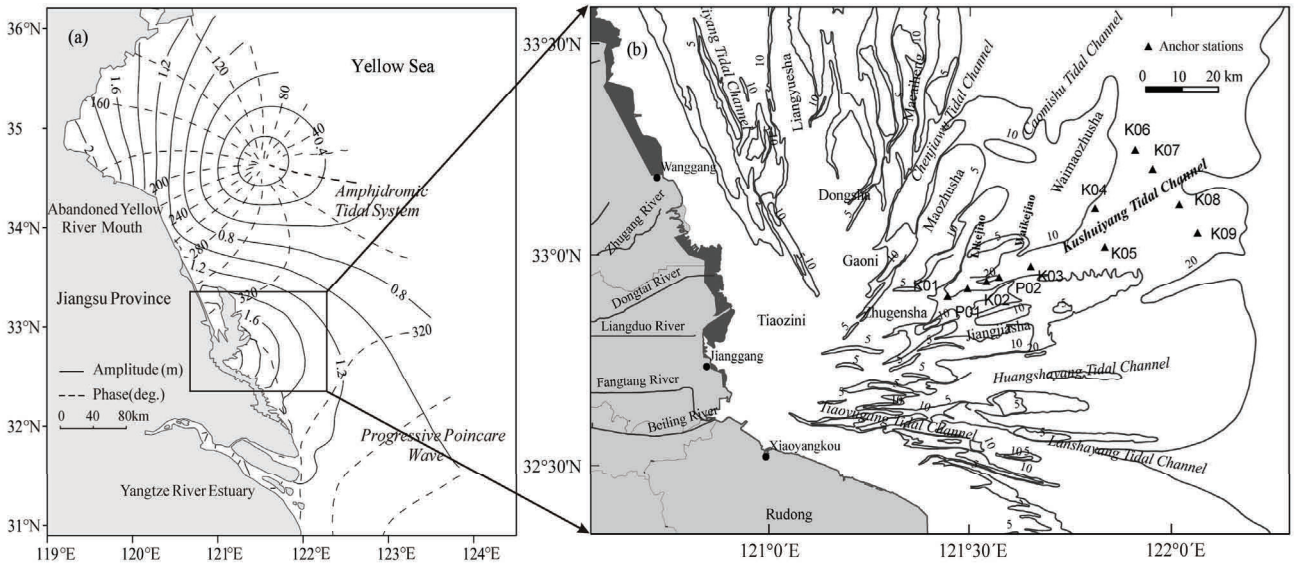

Fig. 1 Location of the study area showing (a) co-tidal and co-phase lines of the M2 tidal constituent in the SYS (revised from Xing et al., 2012), and (b) observation stations in the KSY Channel

2 Regional setting

As a sedimentary system, RSR has a length of approximately 200 km in north-south direction and a width of approximately 90 km in east-west direction, with water depth ranging from 0 to 25 m. For each sand ridge, the width generally ranged from hundreds of meters to several kilometers, with tens of kilometers in length, and it alternates with tidal channel radiating from the apex in Jianggang and Xiaoyangkou to the open sea (Fig. 1b). More than 2,000 km^2 of ridge areas are exposed above mean water level mostly distributed near radial centre. The sediment deposits of sand ridges mainly consist of well-sorted fine sand and silt.

The local tide is characterized by two large tidal wave systems, i.e. a progressive Poincaré wave from the East China Sea and an amphidromic system in the Yellow Sea (Fig. 1a) (Xing et al., 2012). This is a macro-tidal region dominated by semi-diurnal tide. Tidal range increases alongshore which can reach 7.0 m close to Jianggang (Fig. 1b). Model simulations revealed strong tidal currents with a radial pattern in the form of bi-directional current in northern RSR, and gradually changes into a rotary current with increasing ellipticity in southern part (Zhu et al., 1998). The suspended sediment concentration (SSC) showed seasonal differences normally ranging from 100 to 800 mg L^{-1} in the bottom water layer (Xing et al., 2010). Influenced by water movement, suspended sediment was exchanged between the Yellow Sea and East China Sea with seasonal variations (Pang et al., 2011). In Jiangsu coastal area, mean wind speed in summer is 2.8 m s^{-1}, mostly blowing from the southeast; the significant wave height is less than 1.0 m (He et al., 2010).

KSY Channel is located in the middle of RSR and directed perpendicular to the coast, having an average depth of 12-20 m below low water level. The widest section is about 10 km near the seaward entrance and the narrowest is in the landward end in width less than 5 km. The channel passes between the Waimaozhusha and Jiangjiasha sand ridges with more than 70 km in length. Some sand ridges above low water level, namely Zhugensha, Likejiao and Waikejiao spread in north of the western KSY Channel (Fig. 1b).