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Temporal and spatial changes in coastline movement of the Yangtze delta during 1974–2010

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ABSTRACT

The evolution of the Yangtze delta, where the largest economic zone (e.g. Shanghai) in China is located, directly affects the regional economic development and ecoenvironment. The mean high tide lines as the coastline delineated from multi-temporal remote sensing data of Landsat during 1974–2010 at intervals of about 8 years were used to examine the shoreline progradation and recession of the Yangtze delta in the past four decades. Our results show that significant parts of the shoreline in the Yangtze delta in the past four decades and particularly after the operation of the Three Gorges Reservoir (TGR), the world's largest hydropower project ever built, experienced continual progradation despite a substantial decrease in the Yangtze sediment input. During 1974–2010, the area of the Yangtze subaerial delta increased by 667 km^2 with a net progradation rate of 18.5 km^2/yr, and the maximum progradation occurred at the eastern parts of Chongming Island and Nanhui bank, where the coastline advanced seaward about 8 and 6 km, respectively, with mean net progradation rates of 0.22 and 0.17 km/yr, respectively. An important (probably dominant) reason for the Yangtze shoreline progradation despite markedly decreased riverine sediment supply is coastal engineering, such as sea reclamation works, filling project, and wharf constructions.

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1. Introduction

The river delta among the areas where land–ocean interactions occur is one of the most sensitive to the fluvial and oceanic changes. In a short-term period (e.g. a few years to several decades) with a relatively high sea level during the Holocene, the fluvial process is often dominant. The worldwide river sediment supply to the oceans has been strongly affected by human activities (Nilsson et al., 2005; Syvitski et al., 2005). The decreased riverine sediment discharges due to human interference with emphasis on dam constructions are the main cause for observed deltaic degradation processes worldwide (Stanley and Warne, 1993; Syvitski et al., 2009), such as the Nile (Stanley, 1988; Fanos, 1995; Frihy and Dewidar, 2003), the Mississippi (Kesel, 2003), the Ebro (Guillén and Palanques, 1997; Sanchez-Arcilla et al., 1998), and the Yellow (Chu et al., 2006, 2009).

The Yangtze is the third largest in length, fifth largest in water discharge, and forth largest in sediment load in the world (Eisma, 1998) at natural state. The Yangtze inputs to the sea are closely related to the geomorphology and eco-environment of the estuary, coastal oceans, and even the continental shelf areas (Milliman et al., 1985; Saito et al., 2001; Li et al., 2003; Shi, 2004; Liu et al., 2007; Shi et al., 2010). For instance, the Zhoushan fishing ground located SE of the Yangtze estuary, which is the largest fishery in China, is mainly cultivated by the Yangtze inputs. Besides, the Yangtze delta economic zone including Shanghai city with a 2% of land area is raising about 11% of entire population and creating 22% of GDP in China (Zhang, 2009).

Rapidly changing coastlines in many areas of the world such as the Nile Delta and the Yellow River Delta are always a hot concern (e.g., Blodget et al., 1991; White and Asmar, 1999; Dias et al., 2000; Chu et al., 2006). There are many literatures around the Yangtze delta evolution with different or combined materials and methods such as topographic data (e.g., Chen et al., 1985; Shen, 2001; Fan et al., 2006; Huo et al., 2010; Yang et al., 2011), sedimentary records from surface sediment and borehole cores (e.g., Chen et al., 2000; Hori et al., 2002; Zhao et al., 2008), and numerical, empirical, and conceptual simulations (e.g., Xin and Xie, 2006; Gao, 2007). However, few literatures have been published to study the evolution of the entire subaerial delta in the past several decades and particularly after the operation of the Three Gorges Reservoir (TGR) in 2003, which is the world's largest hydropower project ever built. The repetitive acquisition and synoptic capabilities of remote sensing systems can be exploited to provide timely broader scale spatial data for coastal geographical information systems (GIS). As a result, satellite imagery is especially useful for study

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in areas that contain rapidly changing landforms. The first aim of this paper is to examine temporal and spatial changes in coastline movement of the Yangtze estuary in the past four decades, and the second is to discuss the causes for the Yangtze coastline changes.

2. Data and method

Multi-temporal remote sensing data of Landsat MSS, TM and ETM from 1974 to 2010 at intervals of about 8 years were used in this study with GIS techniques to examine coastline movement. The selected satellite imagery before 1982 are MSS data, between 1989 and 2001 are TM data, and since 2002 are ETM data. The spatial resolutions of ETM, TM and MSS data are 30 m for the two former and 80 m for the latter, respectively. One full MSS (path 127, row 38 34—Worldwide Reference System), TM (path 118, row 38), or ETM (path 118, row 38) scene can cover most sections of the Yangtze subaerial delta. Besides, the uninterrupted monthly records of the TGR sedimentation, and water discharge and suspended sediment load of the Yangtze measured at Datong gauging station (its location is shown in Fig. 1) during 1953–2009 were also collected from the Yangtze Water Resources Commission and could permit accurate estimates of the Yangtze sediment discharge. Datong station is located downstream of 94% of the drainage area and at the tidal limit of the river mouth. This station is the last main station and serves as the controlling station for the measurements of the Yangtze discharges entering the estuary.

The Landsat images were registered to geographical coordinates using a second order polynomial to transform the line and column locations of pixels to their latitude and longitude locations. The root mean square error of the transformation was not permitted to exceed 0.5 pixel. The mean high tide line as the coastline was delineated manually by the same person at the same scale from the combined pseudo-color imagery according to the knowledge about the morphological features, vegetation and sediment characteristics (color, sediment type and water content) of the estuary. If the seawall along the coast existed, the seawall was regarded as the coastline. Standard GIS measurement tools (MapInfo) enable precise calculation of changes (progradation or recession) in distance and area when asynchronous coastlines are digitally overlaid, registered and compared to the initial 1974 shoreline.

Given the Changzhi Project for soil and water conservation, which launched in 1988 in the upper-middle Yangtze reaches and contributed to reduce sediment load, we calculated the water and sediment discharges into the estuary for three time periods, two (1953–1987 and 1988–2002) before and one (2003–2009) after the TGR operation. The Yangtze inputs entering the estuary after the TGR operation were compared with those during the two time periods before the TGR operation. This method is

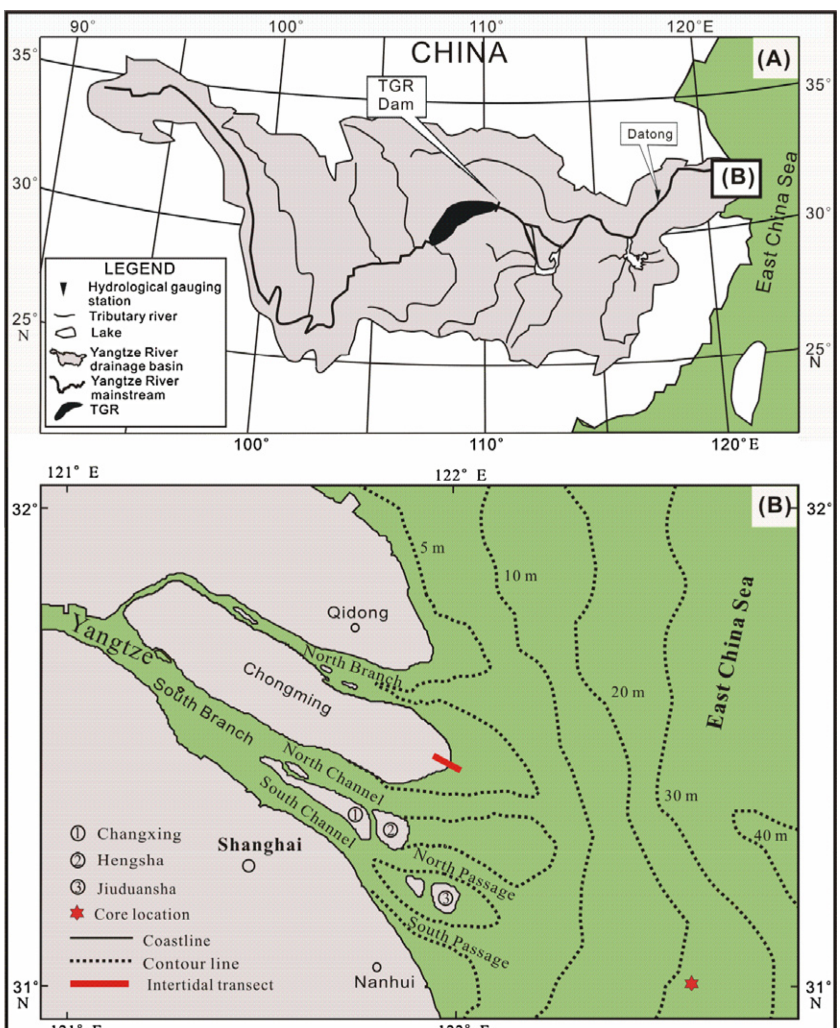

Fig. 1. Location map of the Three Gorges Reservoir (TGR), Datong gauging station and the Yangtze estuary. Bathymetric contours are in meters. The coastline is got from Landsat remote sensing image acquired in 2010.

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