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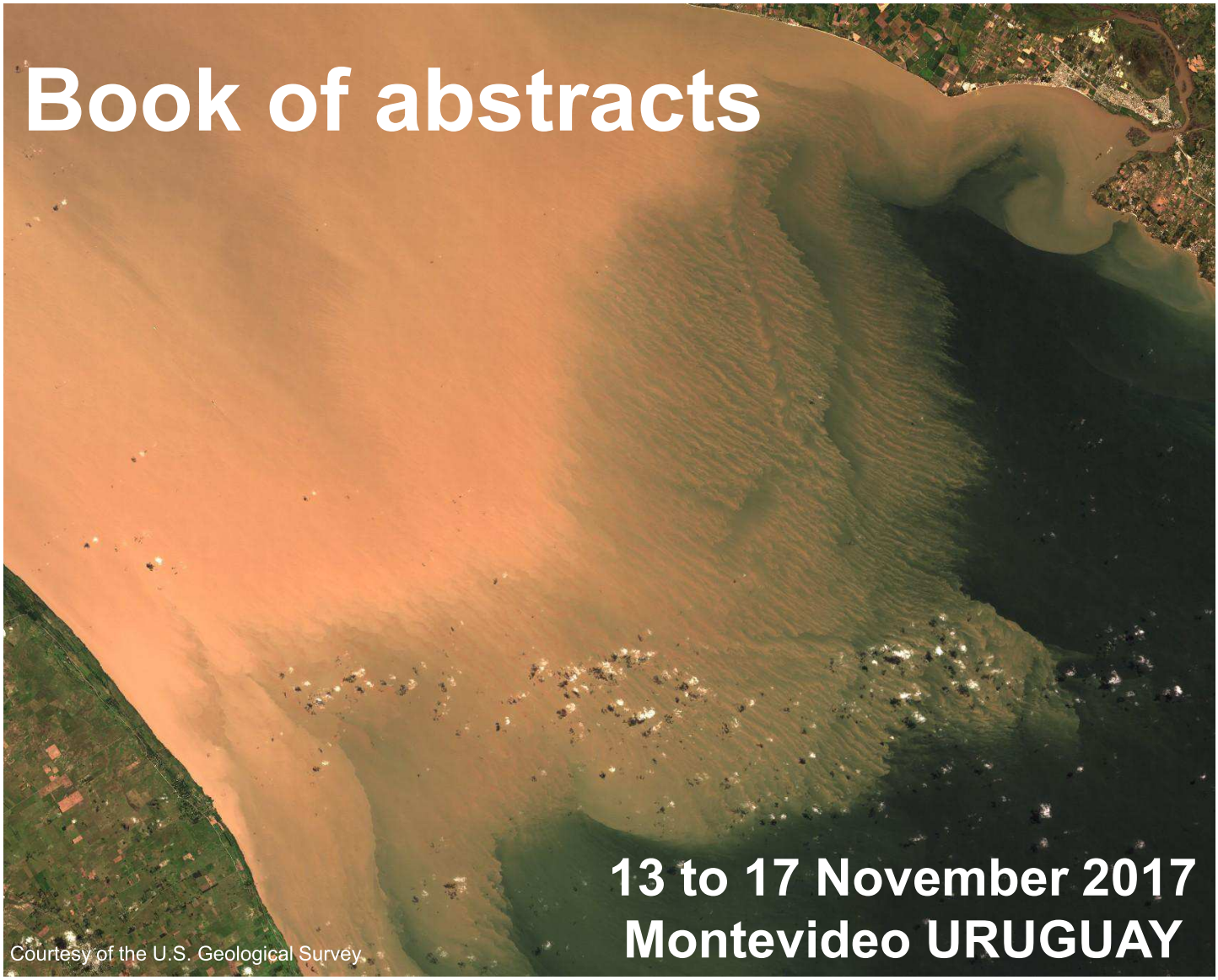

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Estuarine morphodynamic adaptation to sediment supply and human activities: a case study of turbidity maximum

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Abstract

Estuarine morphodynamics undergo significant changes due to declined sediment supply from river, rising sea-level, and human interferences (Syvitski and Saito, 2007; Syvitski et al., 2009). The Yangtze Estuary is such a case whose decadal morphodynamic evolution was broadly examined. It was documented that the subaqueous delta shifted from deposition to erosion since the early 2000s due to sediment supply reduction after the Three Gorges Dam (Yang et al., 2015) while some others reported that the estuary mouth bar area sustains accretion until 2010 (Luan et al., 2016; Zhu et al., 2016). The mouth bar area of the Yangtze Estuary is where the turbidity maximum exists. To clarify the morphodynamic changes therein, we examine the two large scale shoals, i.e. the Hengsha flat and the Jiuduan shoal, based on bathymetric data between 1958 and 2016 and satellite images since 1985.

Bathymetric data were digitized and converted to the same datum-the Theoretically Lowest Water Level (TLWL). Note that the landward part of the Hengsha flat was embanked since 2003 and the super-tidal flats of the Jiuduan shoal were vegetated (Fig. 1), thus bathymetric monitoring and data are lacking in these two regions. Satellite images of the mouth bar area from Landsat are also collected to identify the boundary between bare flat and saltmarsh. The Normalized Difference Vegetation Index (NDVI) can reflect the green vegetation, specifically, positive NDVIs indicate intertidal forested wetlands and intertidal marshes with vegetation. In this study, a threshold of 0.1 (NDVI>0.1) is chosen to calculate the vegetated area in each image to differentiate between vegetation and non-vegetation.

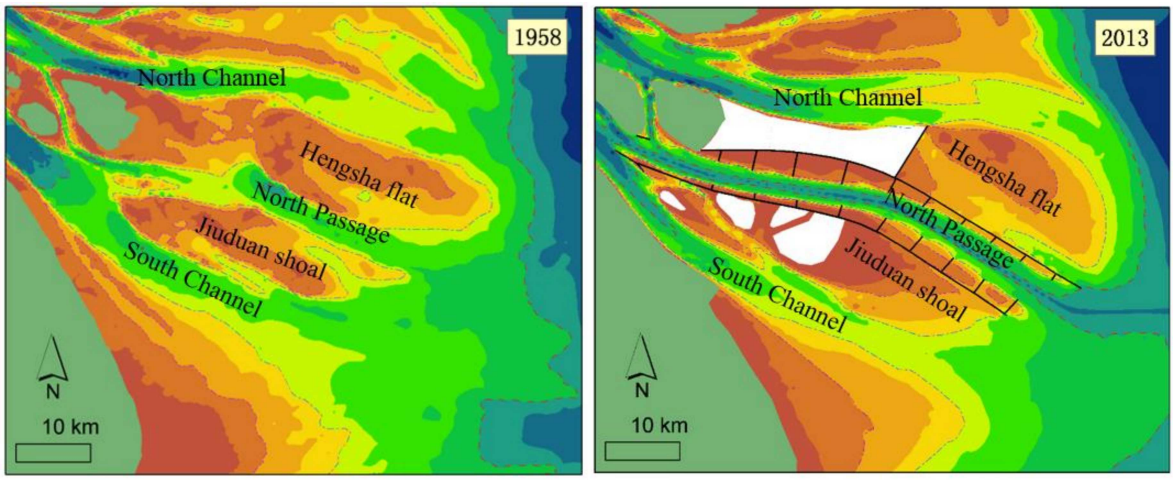

Fig. 1. Bathymetric changes with 2, 5, and 10m isobaths of the Jiuduan shoal and the Hengsha flat in 1958 and 2013. The white area was the reclaimed region in the landward part of the Hengsha flat and the vegetated super-tidal flats of the Jiuduan shoal.

We detect the morphodynamic changes of the two shoals in terms of deposition rate, hypsometry profile and saltmarsh area. Although the Hengsha flat and the Jiuduan shoal were continuously accreting prior 2010, the morphodynamic changes of these two shoals are both to a large extent influenced by human activities. In the pre-1997 period when local human activities are rare, the Jiuduan shoal accreted enormously since its isolation from the Hengsha flat while the Hengsha flat grew at a smaller rate. Since 1997, dredging and dumping activities and saltmarsh growth stimulate the growth of the Hengsha flat. However, dredging and dumping activities slow down the

development of the Jiuduan shoal and caused strong erosion in the region off the North Passage. In summary, it suggests a transition from natural morphodynamic evolution processes prior 1997 to afterwards human-driven morphodynamic adaptation.

Further, we found the accretion of the two shoals vanishes since 2010, even changes to slight erosion (Fig. 2). We argue that the upper 600-km long reaches and the region off the North Passage can supply sediment to the mouth bar area, contributing to the former accretion of the two shoals. In addition, the nearshore mud deposition belt should be taken as one of sediment sources (Liu et al., 2010). Since the erosion found off the North Passage is mainly caused by dredging activities in the North Passage, regional human activities are expected to slow down the response time of global changes. However, the reduced riverine sediment supply tends to slow down shoal accretion and initiate large scale erosion in the long term. As a result, erosion of the two shoals in recent decades is found in this study. From the evidence of erosion, we propose that the morphodynamic adaptations of the shoals lag behind the changes of the sediment load at a time scale of 10~100 years.

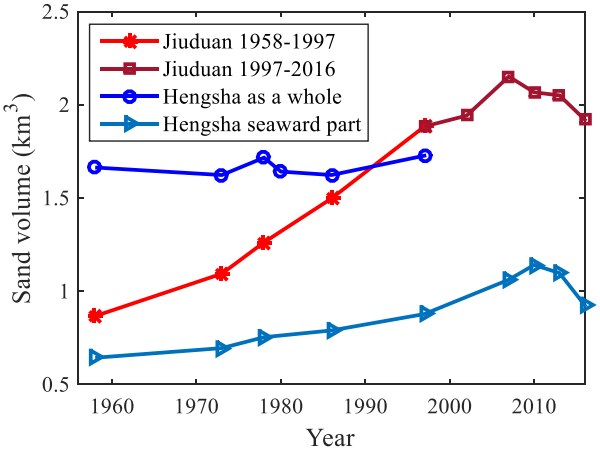

Fig. 2. Temporal sand volume (the sand volume of the flat with flat elevation <6 m) changes of the Jiuduan shoal and Hengsha flat between 1958 and 2016.

In conclusion, the two shoals in the mouth bar area of the Yangtze Estuary are influenced by complex forcing as well as strong human activities. This study deals with morphodynamic evolution of the two shoals in 60 years. The results are different from previous studies with near-instantaneous estuarine erosion. More specifically, morphology in the mouth bar area has >10 years response time for upstream sediment decline. Additionally, regional human activities play a role in buffering its response through sediment redistribution within the estuary. Such understanding of its natural behaviour and the response to human activities could also be used for research on turbidity maximum and practical projects in other highly-regulated estuaries.

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