Morphodynamic evolution of the mouth-bar area in the Yangtze Estuary, China: the potential impacts from tide, river, and seasonal wave climates

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The geomorphology of the Yangtze Estuary in the Changjiang River Delta in Eastern China has been the subject of extensive research. Most previous studies highlight the dominance of river-tidal interaction in controlling the morphological stability in the estuary. This study identified a tide-wave-dominated mouth-bar area, where about half of the river-borne material settles to the bed. This site is located just outside of Changjiang River mouth which is characterized by a moderate-irregular tidal regime, high turbidity and a significant degree of exposure to seasonally veering wind and waves. Coupled wave-current hydrodynamic modeling using TELEMAC and TOMAWAC and validated against observed data was performed. A combined Bottom Shear Stress (BSS) from river, tide and waves using numerical model output was studied in order to improve knowledge of their respective effect on the subaqueous delta evolution at different depths. The results suggest that:

(1) Under monsoon climate, the seasonal river runoff shows significant variance in intensity and seasonal wind-waves veered to a totally opposite direction. The model results show that river-tide interaction is dominant within the river mouth, while outside the mouth at the bar area (above -10 m) the runoff effect is weak and the wave and tide influences are relatively strong, even during the larger discharge experienced during the wet season. Tidal currents tend to produce the largest BSS over the lower, deeper part of the mouth-bar, whereas waves create the greatest BSS over the shallower shoals.

(2) The overall mouth-bar morphodynamics of the Yangtze Estuary is tidally dominated, however, seasonal BSS analysis revealed that asymmetry effects in both temporal and spatial dimensions, due to wave-current interaction, induced variations in sediment motion over the shallow shoals. Hence, from the perspective of potential sediment mobility, the shallow shoals of mouth-bar were wave dominated. Tidal effects in the deep channels and the lower parts of the shallow shoals were found to be ebb-dominant, but over the upper part of the shallow shoals flood dominance prevailed. Wave effects proved to be important to induce sediment mobility on shallow shoals, which changes between flood and ebb dominance varying seasonally in response to the changing wind-wave climate.

(3) BSS and its principal forcing processes varied spatially and temporally in the mouth-bar of Yangtze Estuary. Temporal tidal asymmetry maintains and deepens the channels, while the spatial tidal asymmetry reinforces the process of gradual growing of the shallow shoals. Wind-waves and river-tide currents combined to produce sediment mobility on shallow shoals throughout the entire year, the nature of which varies from winter to summer due to the seasonal monsoonal climate.

(4) Seasonal variation and the influence of wind-waves on tidal asymmetry, combined with river discharge has an important influence on the balance of mouth-bar morphology. The combined effect of wave-current interaction results in BSS asymmetry in both temporal and spatial dimensions. When seaward BSS asymmetry exceeds the effect of diffusion onto the shallow shoals, sediment transport will be in a seaward direction and this occurs during the winter months. This then reverses to a landward

direction under southeasterly summer wind-wave influence and is reinforced by the diffusion effect. As a result, the sedimentation at shallow shoals has a seasonal characteristic of "summer storing and winter erosion".

(5) The long-term development of the Yangtze Estuary and mouth-bar is most likely one of dynamic equilibrium, and has been shown to respond often quite dramatically to changes in natural and anthropic forcing. This study expands on this knowledge by presenting short to medium-scale results, which illustrate the importance of tides and seasonal wind-wave effects in balancing the movement of sediment on and around the mouth-bar. A full understanding of how the mouth-bar develops over a range of temporal scales is essential to better guide estuarine and coastal management and the possible influence on large scale intervention projects, such as the ongoing deep water project at North Passage and reclamations on the four shallow shoals.

Keywords: Bottom shear stress, wave-current interaction, mouth bar, estuary geomorphology, seasonal, Yangtze Estuary