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Research Advances

Dynamics of Bottom Boundary Layers in the Yellow River Subaqueous Delta Based on Long-Term In-Situ Observations

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Objective

In geo-marine science, the generalized bottom boundary layer (BBL) represents a layer between sediments and seawater. The BBL plays an important role in geological, geobiochemical, geophysical and geotechnical research because it is the connection region of hydrosphere, geosphere and biosphere. Most previous studies on BBL focus on the theory and experiment due to the difficulty in in-situ observation. Besides, the existing observation data are mainly about the parameters of seawater and rarely involve sediments. The Yellow River is considered to be the second largest river in the world in terms of sediment load, and the dynamics of BBL in its subaqueous delta are complex and important. This work conducted long-term in-situ observations in order to provide first-hand data of BBL in the Yellow River subaqueous delta, not only about seawater but also sediments. We briefly introduce the observation and aims to reveal the complex dynamics of BBL, such as sediment erosion, deposition, resuspension, transport, and seabed deformation.

Methods

The modified submarine in-situ tripod is the hardcore in the observation system. The submarine in-situ tripod is 1 m high and the length of each side is 2 m. With modularization installation, the submarine in-situ tripod can be assembled and dismantled on site easily. By this integrated instrument, the time series of various parameters of BBL can be measured. Especially, the water-sediment interface and salinity profile can be determined by self-developed multi-electrode resistivity probe.

Apart from the integrated submarine in-situ tripod, the shape acceleration array (SAA) is another important instrument. The 4-meter-long SAA was vertically lowered into the sediment to measure the seabed deformation during our observation. The submarine in-situ tripod and the shape acceleration array were deployed on December 9th, 2014 and recovered on April 22nd, 2015.

Before and after the observation, the side-scan sonar, sub-bottom profiler, dual-frequency sounder were used to obtain the seabed topography and stratigraphy. The self-developed offshore cone penetration test (CPT) instrument was employed to measure the sediment strength. Sediment trap and suspension profiler (ASM-IV) were also used in this observation.

Results

The time series of the waves (wave height and wave period), tides, currents (velocity and direction), temperature, conductivity, dissolved oxygen, chlorophyll, turbidity, salinity profile, pore water pressure, seabed elevation and water-sediment interface were obtained during the 4-month-long observation. Besides, the seafloor topography, seabed stratigraphy and sediment strength were measured before and after the observation. Some of the observation results can be seen in Fig. 1, such as water depth, temperature, elevation and seabed deformation.

We found the superposed sawtooth model of suspended sediment concentration influenced by waves and currents. The sharp rise in turbidity (near 800 NTU) is attributed to the episodic high waves, and the quotidian currents are responsible for the periodic fluctuation in turbidity (Fig. 1). The calculated shear stress can explain why episodic waves account for big sawtooth and currents are responsible for the small sawtooth. It is because there is a linear correlation between the suspended sediment concentration and turbidity. Therefore, the suspended sediment concentration also witnesses a similar phenomenon, namely, superposed sawtooth model.

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The maximum horizontal seabed displacement of 13 mm during the observation was captured by the shape acceleration array (SAA) on February 8th, 2015 (Fig. 1). This kind of seabed displacement can be regarded as creep deformation. The significant wave height of 3.3 m and current velocity of more than 1 m/s were recorded while the creep deformation occurred. Though the fast slides were not captured in this observation, the creep deformation was also an important process for submarine mass movements.

Conclusions

The 4-month-long observation may make it one of the longest observations of BBL in the Yellow River subaqueous delta. We found the superposed sawtooth model of suspended sediment concentration deranged by waves and currents. Further, creep deformation was captured during high waves, which may make it the first successful trial in monitoring seabed deformation in China and one of the very few in the world.

The dynamics of BBL in Yellow River subaqueous delta are complex and the long-term in-situ observations may offer an effective tool for discovering it.

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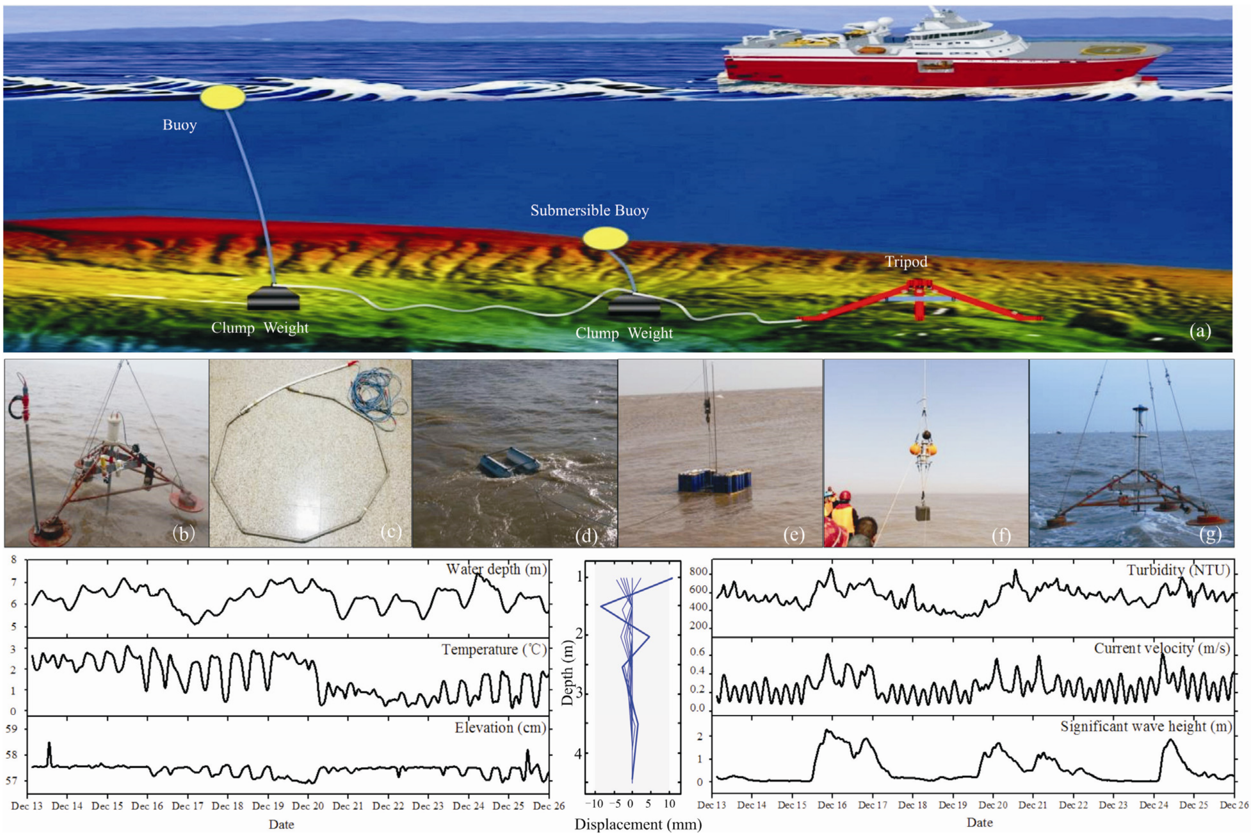

Fig. 1. Observations of BBL in the Yellow River subaqueous delta.
(a), Schematic diagram of in-situ observation layout of the submarine in-situ tripod; (b), Integrated submarine in-situ tripod; (c), Shape acceleration array; (d), Sub-bottom profiler; (e), Offshore cone penetration test equipment; (f), Sediment trap; (g), Suspension profile.