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The impact of typhoon Morakot on the modern sedimentary environment of the mud deposition center off the Zhejiang–Fujian coast, China

Yunhai Li [a,*], Aijun Wang [a], Lei Qiao [b,c], Jianyong Fang [a,d], Jian Chen [a]

[a] Third Institute of Oceanography, State Oceanic Administration, Xiamen 361005, China
[b] Department of Earth and Atmospheric Sciences, Saint Louis University, St. Louis, MO 63103, USA
[c] Center for Environmental Sciences, Saint Louis University, St. Louis, MO 63103, USA
[d] State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China

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ABSTRACT

Typhoon Morakot, which first made landfall in central Taiwan on Aug. 7th and then in Fujian on Aug. 9th after crossing through the Taiwan Strait was the strongest typhoon to impact the East China Sea (ECS) in 2009. Two surveys were conducted, respectively on Aug. 1st and Aug. 12th, in the mud deposition center off the Zhejiang–Fujian coast to study the impacts of the typhoon on the marine environment and sediment transport. Continuous in-situ hydrographic data (water temperature, salinity, depth and turbidity) were recorded at 29 stations during the first survey and 23 stations during the second survey. The water and surface sediment samples were collected at the same time.

A comparison of the measurements from the two surveys shows that significant variations in temperature, salinity and turbidity distributions occurred in the water column. The upper water layer was well-mixed after the passage of Morakot. The water temperature and salinity dropped approximately 0.2–1.4 °C and 0.3–3.3 psu, respectively, while the water turbidity increased from less than 1 FTU to 1–30 FTU. In the bottom layer, the temperature increased approximately 2.5–4.0 °C, and the salinity dropped approximately 0.2–0.6 psu due to the water mixing. The water turbidities generally increased to greater than 50 FTU (greater than 150 FTU in some locations), which were several times to more than tenfold greater than those in the first survey, which were generally between 10 and 60 FTU. The thermocline, which existed at a depth of approximately 10 m during the first survey, disappeared after the typhoon. A halocline appeared at approximately 10 m depth in the near-shore area due to abundant fresh water supply, whereas the salinity was generally homogeneous during the first survey. Concurrently, the relatively warm and fresh water extended downward to the whole medial water layer due to the water mixing. The turbidity and volume of the bottom turbid layer was greatly increased at the second survey compared with the first survey. The intrusion of the low-temperature and high-salinity deep water (below 50 m depth) was significantly reduced at the same time.

1. Introduction

The passage of a typhoon may, on a short time scale, considerably alter the seawater column structures (Price, 1981; Dickey et al., 1998; Souza et al., 2001; Lin et al., 2003; Deng et al., 2010), sediment transport and deposition (Rejmánek et al., 1988; Chang et al., 2001; Allison et al., 2005; Milliman and Kao, 2005; Sheremet et al., 2005; Wren and Leonard, 2005; Milliman et al., 2007; Silverberg et al., 2007), marine biogeochemical processes (Davis and Yan, 2004; Walker et al., 2005; Goñi et al., 2006; Mead and Goñi, 2006; Zheng and Tang, 2007; Huang et al., 2011) in the affected marine area. Due to the insufficient ability to forecast typhoon events and the shipboard operation difficulties under severe weather conditions, studies on typhoon impacts by observations have far lagged behind the normal marine processes observations and studies (Shiah et al., 2000; Wren and Leonard, 2005). With improvements in instrumentation and technology (e.g., remote sensing technology, long-term records from profiling floats, and numeric model methods), many studies have been initiated and conducted to measure the variations of water structure, sediment transport and deposition, biogeochemical processes during the typhoons since 1980s. During a typhoon, the strong cyclonic wind stress accelerates the air-sea heat exchange and the mixing within the water column, which strengthens the upwelling (downwelling) of deep (surface) water and significantly alter the water structures (Lin et al., 2003; Rao et al., 2010). Meanwhile, heavy precipitation dilutes the ocean surface water and, as a result, the salinity structure is changed

* Corresponding author: Tel./fax: +86 592 2195056.
E-mail address: liyunhai1980@gmail.com (Y. Li).

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(Li et al., 2007). The increases of water mixing and particles supply might also alter the distributions of nutrients and marine organisms during typhoon process (Babin et al., 2004; Goñi et al., 2006; Mead and Goñi, 2006; Zheng et al., 2010).

The East China Sea (ECS), with huge terrigenous particles supply from Mainland China (mainly from Yangtze (Changjiang) River) and complex ocean circulations, was a natural laboratory to study modern sedimentary processes. According to historical weather records, on average, 4 typhoons impact the ECS shelf annually (Su, 2005), which might have significantly impact on modern sedimentary processes. Studies on shelf sediment dynamic processes caused by tropic cyclones are helpful in understanding the fate of the shelf sediment and its components such as pollutants, chlorophylls and organic debris in terms of the transportation to the adjacent deep waters and related ecological issues (Shiah et al., 2000; Chang et al., 2001; Wren and Leonard, 2005; Goñi et al., 2006; Bian et al., 2010). However, intensive fishery and navigation regulations impede ocean buoy deployment and real-time shipboard measurement activities on the ECS shelf so that a paucity of data has been obtained so far, and improvements in data acquisition and typhoon impact studies are still urgently needed (Wang et al., 2009; Bian et al., 2010).

In this study, the effects of Typhoon Morakot on the water structure and sediment distribution were studied and discussed using the data collected during two shipboard surveys in the mud deposition center off the Zhejiang–Fujian coast on the ECS inner shelf. To our knowledge, it is almost the first time to have such valuable data set to reveal the sedimentary environment changes due to huge typhoon impact in this widely-interested area, which would be very important for further studies related to sediment transportation and deposition across the ESC shelf.

2. Background

2.1. Study area and surveys

The mud deposition center off the Zhejiang–Fujian coast acts as a sink for Yangtze (Changjiang) River particles and accounts for the primary mud deposits on the ECS inner shelf (Fig. 1a) (Hu and Yang, 2001; Liu et al., 2006a, 2006b, 2007; Xu et al., 2011). Sedimentary processes, controlled by material supply and marine hydrodynamics, vary seasonally in the mud deposition center (Liu et al., 2006a, 2006b; Xu et al., 2011). The circulation system in the mud deposition center includes the coastal current, which flows northward in summer and southward in winter due to monsoons and has a relatively low temperature, low salinity and high turbidity, and the Taiwan Warm Current (TWC), which perennially flows northward and has a high temperature, high salinity and low turbidity (Su, 2005). The particles discharged from the Yangtze (Changjiang) River are obstructed by the northward monsoon and the marine circulations and are generally rapidly deposited in the estuary in the summer (Hu and Yang, 2001; Liu et al., 2006a, 2006b; Xu et al., 2011). The deposited sediments can be resuspended by extreme storms and transported southward again along the coast in the winter (Liu et al., 2006a, 2006b). The sediment transport and deposition along the ECS coast mainly occurs in the winter and forms the thickened Zhejiang–Fujian Mud Wedge (Liu et al., 2006a, 2006b; Xu et al., 2011). According to long-term records, on average, 4 typhoons pass over the ECS shelf annually (Su, 2005), which significantly impact the modern sedimentary environment.

Two surveys were conducted on the mud deposition center off the Zhejiang–Fujian coast in ECS inner shelf (Fig. 1b). The first one was conducted on Aug. 1st, 2009, followed by a second survey conducted on Aug. 12th, 2009, 2.5 days after Typhoon Morakot making landfall in Fujian on Aug. 9th, 2009. The first survey lasting from Aug. 1st to 3rd measured at 29 stations with 5 sections from south to north. During the first survey, the weather was calm with south wind speed less than 10.7 m/s, and wave height less than 1.6 m (data from Ocean Monitoring and Forecasting Center of Zhejiang Province, www.zjhy.net.cn). The second survey lasting

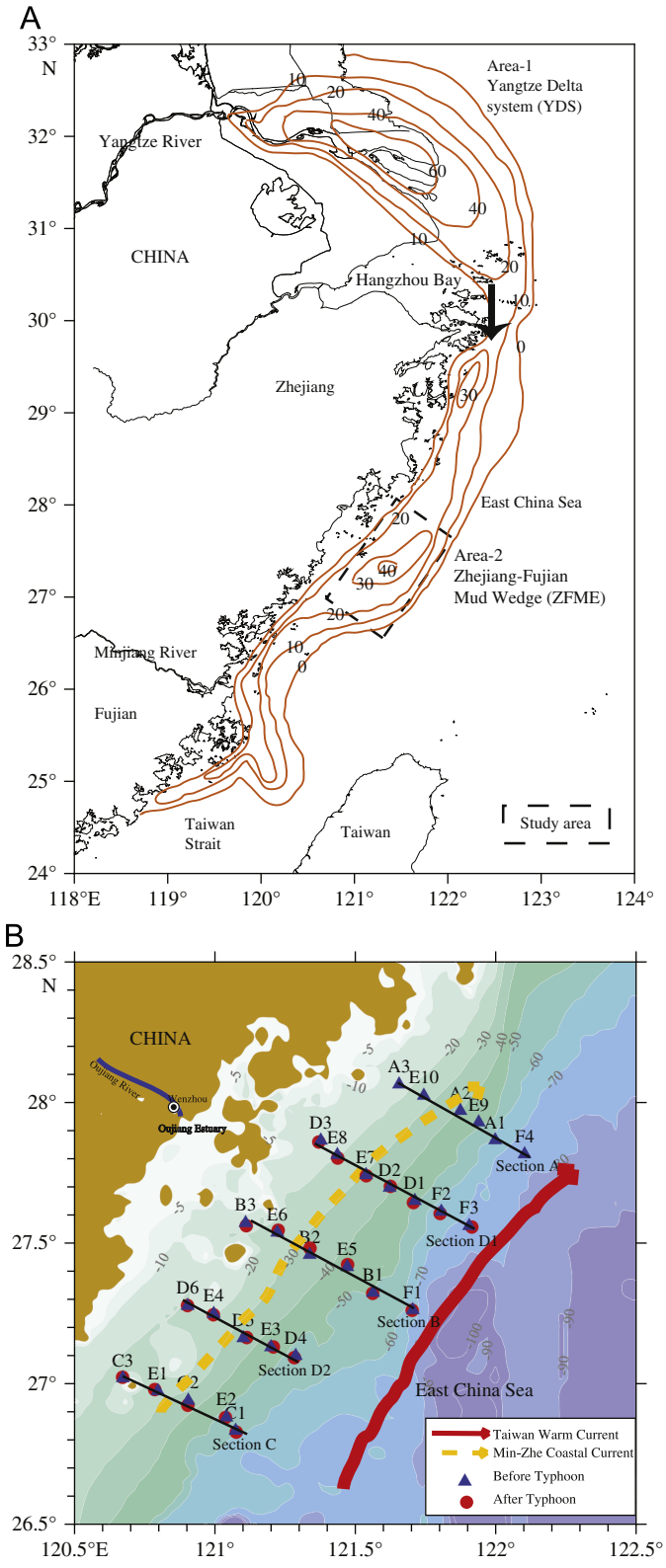

Fig. 1. (a) An isopach map (in meters) of the Yangtze-derived sediment deposited over the last 7000 yr on the inner shelf of the ECS (after Liu et al., 2006) and (b) station locations and survey sections.