Journal of Asian Earth Sciences 79 (2014) 509–519

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Review

Suspended sediment dynamics during the inter-monsoon season in the subaqueous Mekong Delta and adjacent shelf, southern Vietnam

Daniel Unverricht [a,*], Thanh Cong Nguyen [a,d], Christoph Heinrich [a], Witold Szczuciński [b], Niko Lahajnar [c], Karl Stattegger [a]

[a] Institute of Geosciences, Department of Sedimentology, Christian-Albrechts-University of Kiel, Germany
[b] Institute of Geology, Adam Mickiewicz University, Poznań, Poland
[c] Institute for Biogeochemistry and Marine Chemistry, University of Hamburg, Germany
[d] Department of Oceanology, Meteorology and Hydrology, University of Sciences, Ho Chi Minh City, Vietnam

ARTICLE INFO

Article history:
Available online 5 November 2012

Keywords:
Mekong
Suspended sediment
Sediment resuspension
Tide
Coastal zone
Continental shelf
LISST

ABSTRACT

Land–ocean interactions in the coastal zone are severely influenced by tidal processes. In regions of high sediment discharge like the Mekong River Delta in southern Vietnam, these processes are even more significant. Three cruises in 2006, 2007 and 2008 were carried out to investigate the sediment suspension and their spatial distribution. Additionally, we investigated the influence of the tidal currents in relation to the suspended sediment. Therefore, all cruises took place during the inter-monsoon season between March and May where wave and wind influences are not dominant in contrast to the summer monsoon (May to early October) and winter monsoon season (November to early March).

Suspended sediment concentrations (SSCs) in the particle-size range between 2.5 and 500 μm were measured with an LISST-instrument (Laser In Situ Scattering and Transmissiometry). Current velocities and directions were recorded with an Acoustic Doppler Current Profiler (ADCP). Additionally, data of different tidal gauge stations in the Mekong River Delta were correlated and compared to the mixed semi-diurnal–diurnal tidal cycle.

Our results show significant areas of SSCs greater than 25 μl/l in the Mekong River branches and its subaqueous delta during the inter-monsoon season. 20% of all measured SSCs in the subaqueous Mekong Delta exceed 100 μl/l. Highest concentrations occur close to the seabed. SSCs decrease at the transition to the open shelf. The shelf region contains only low suspension loads, especially on the south-eastern shelf (99% of all samples <25 μl/l). However, in the southern shelf region around Ca Mau Cape the suspension load is also higher (>25 μl/l) close to the seabed in water depths of 20–25 m.

Two surveys lasting 25 h each were performed on mooring stations in 12 m (Mooring 1) and 26 m (Mooring 2) water depth and located 3.2 km apart on the subaqueous delta slope.

Similar patterns of SSC over time show that concentrations of suspension load correlate with the tidal current velocities. High tidal current velocities of up to 0.6 m/s near the sea bottom generate increasing SSCs of more than 25 μl/l in the water column. Additionally a significant trend of decreasing SSC from the near-seabed to the upper part of the water column can be observed. In terms of sediment transport the ebb phase dominates the tidal cycle by its higher tidal current velocities but the flood phase has the longer duration. The switch of the tidal current direction from ebb to flood phase occurs rapidly against which the change from flood to ebb phase requires up to 3 h. This leads to an asymmetry of the tidal ellipses and may cause a net-sediment transport from the shelf into the subaqueous Mekong Delta.

In the subaqueous Mekong Delta and adjacent shelf, seven transects show similar patterns of SSCs dependent to the tidal phase. A hypopycnal sediment plume from the subaqueous Mekong Delta into the shelf region was not observed. Our results imply that resuspension by tidal currents dominates the sediment transport in the subaqueous Mekong Delta and adjacent shelf regions during the inter-monsoon season.

* Corresponding author. Address. University of Kiel, Institute of Geosciences – Sedimentology, Coastal and Continental Shelf Research, Otto-Hahn-Platz 1, 24118 Kiel, Germany. Tel.: +49 4318803469; fax: +49 4318804376.

E-mail address: unverricht@gpi.uni-kiel.de (D. Unverricht).

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http://dx.doi.org/10.1016/j.jseaes.2012.10.008

Contents

1. Introduction

Sediment delivery via rivers into the global oceans is one of the most important impacts in land–ocean interaction. The Sediment transport from the distributaries to the inner shelf passes many different stages (Wright and Nittrouer, 1995). In dependence on the prevailing environmental processes like waves, tides and wind induced currents the sediment will be net-transported in cross- or alongshore direction until its final deposition (Orton and Reading, 1993; Walsh and Nittrouer, 2009).

Asian Mega-Deltas show similar alongshore ranging clinoforms (Liu et al., 2009). The sediment discharge, transport and deposition in these deltas are strongly influenced by the monsoon seasons (Wright et al., 1990; van Maren and Hoekstra, 2004). The sedimentation in the subaqueous Mekong delta is also linked to wave impact and wind induced currents driven by the monsoon climate (Tamura et al., 2010). The Sediment pattern associated with the subaqueous delta morphology illustrates, that there are processes with regional dependency (Unverricht et al., 2012, submitted for publication). However, many other factors influence sedimentation processes and shaping of subaqueous deltas (Vörösmarty et al., 2003; Syvitski and Saito, 2007).

Our cruises were carried out during the inter-monsoon season from March to May, where the monsoonal forces are low with less wind and wave activity. This situation gives an advantageous precondition to investigate possible influencing factors without monsoonal impact like tides. Tidal ranges of more than 3 m in the Mekong Delta region of the South China Sea affect the sediment transport and deposition due to its currents inside and outside the Mekong distributaries. Tidal induced sediment distributions can be observed also in other Asian Deltas like the Yellow and Yangtze River delta (Wright et al., 1990; Zhen Xia et al., 1998; Shi, 2010).

This article shows the spatial suspended sediment distribution during the inter-monsoon season in the subaqueous Mekong Delta and its adjacent shelf. In addition, our investigations improve the understanding of tidal influences concerning sediment transport and deposition in the subaqueous delta region.

2. Study area

The headwaters of the Mekong River are situated in the Tibetan Plateau. The river crosses six countries until it flows via eight distributaries into the southern South China Sea. The delta plain covers an area of 49,500 km^2 between Phnom Penh in the Cambodian lowlands and the southeast Vietnamese coast (Le et al., 2007).

The complex character of the tidal regime is dominated by the M2- and K1-tidal-constituents which extend from northeast to southwest in the South China Sea (Fang et al., 1999; Zu et al., 2008). A pronounced meso-tidal regime prevails in the South China Sea, while in the Gulf of Thailand a micro-tidal system occurs. In the South China Sea it leads to tidal ranges of 2.5–3.8 m in a semi-diurnal to mixed-tidal system (Nguyen et al., 2000). However, the Gulf of Thailand has diurnal tides with tidal ranges between 0.5 and 1.0 m. Tidal ellipses of the dominant tidal constituents with its according currents extend in the subaqueous Mekong Delta mainly in a shore-parallel direction (Hung and Dien, 2006; Zu et al., 2008).

The East Asian Monsoon causes strong seasonal climatic variations in the Mekong Delta (Hordoir et al., 2006; Mitsuguchi et al., 2008; Xue et al., 2011). In the winter monsoon season from November to early March winds are coming mainly from northeastern direction and during the summer monsoon south-western winds prevail (Fig. 1). Annual wind speed recorded from 1999 to 2008 (Fig. 1) by the Southern Regional Hydro-Meteorological Center (SRHMC, Vietnam) ranges at Vung Tau station from 7 to 9 m/s and in Bac Lieu from 6 to 8 m/s (1st and 3rd quartile). Under stormy condition wind speeds can reach 20–30 m/s (Institute of Strategy and Policy on natural resources and environment (ISPONRE), 2009). The maximum wind stress prevails along the south-eastern coast of Vietnam in both monsoon seasons.

The wave climate differs significantly between the annual seasons and the Mekong Delta subareas. In the river mouth region significant wave heights of more than 1 m can occur at the coastline in the whole year (Tamura et al., 2010). In Vin Tan (close to Bac Lieu), southwest of the Bassac distributary (Fig. 1) significant wave heights of 0.2–0.25 m (measured during 3.–5.10.2012) and up to 0.55 m (measured during 21.–28.01.2011) m respectively were measured 300 m far from the shoreline (Albers and Lieberman, 2011).

During the inter-monsoon season significant wave heights of 0.6 m are measured at the southern Mekong Delta shoreline near the Bo De estuary (Nguyen, 2012; unpublished PhD-thesis).

The water discharge of the Mekong River varies significantly with the particularly monsoon season. Between May and October (wet season) occur 85% (475 billion m^3) of the annual water discharge while only 15% (78.8 billion m^3) are discharged in the dry season (November to April) (Snidvongs and Teng, 2006; Le et al. 2007).

The water current system is also attributed to the East Asian Monsoon (Wendong et al., 1998). During the winter-monsoon season the western coastal currents has a south-western and during the summer monsoon season a north-eastern direction.