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Sediment dynamics and hydrodynamics during low river discharge conditions in the Nha Trang Bay, Vietnam

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SZCZUCIŃSKI, WITOLD; JAGODZIŃSKI, ROBERT; NGUYEN TRUNG THANH; KUBICKI, ADAM & STATTEGGER, KARL, 2005: Sediment dynamics and hydrodynamics during low river discharge conditions in Nha Trang Bay, Vietnam. (Sedynamik und hydrodynamik während niedrigwasser Perioden in Nha Trang Bay, Vietnam).- Meyniana, **57**:117-132, 8 fig., 1 tab., Kiel.

SE Asia is one of the most important sources of particulate matter transported to the ocean. However, the discharge is seasonal due to the monsoonal climate. The results of our investigation on sedimentation and water circulation in the Nha Trang Bay (Vietnam) during a period of lowest river discharge and neap tide are presented. The major hydrological factors are thermal stratification of the water column and its thorough mixing during short periods of local winds. The Cai River water influence as the major freshwater source is limited to less than 2.8 km from its mouth. Suspended particulate matter concentrations are very low between 0.03-4.3 mg dm^{-3}, only one sample reached 8.9 mg dm^{-3}. Downward particulate matter flux determined with sediment traps at a station 2.8 km off the river mouth is very low: 0.77 g m^{-2} day^{-1} at 2 m water depth and 5.36 g m^{-2} day^{-1} at 12 m water depth, about 3 m above the bottom. The bottom sediments in the Nha Trang Bay are composed mainly of sands. Along with sediment trap results, it shows that no significant accumulation occurs in the dry season. It is thus evident that fine material, which is expected to be deposited on the bay bottom during the rainy season, as observed in satellite images, must have been reentrained and advected further offshore.

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Zusammenfassung

Der saisonale monsungesteuerte Sedimenteintrag aus Flüssen in Südost-Asien ist für den globalen Sedimenttransport in den Weltozean von großer Bedeutung. Als Fallstudie wurden Zirkulation und Sedimentation in der Bucht von Nha Trang, Süd-Vietnam unter den Randbedingungen geringen Flusseintrags und geringer Gezeiteneinwirkung untersucht. Die wichtigsten hydrologischen Faktoren sind die thermisch bedingte Schichtung des Wasserkörpers und kurze Perioden der Durchmischung ausgelöst durch Wind/Wellentätigkeit. Süßwasser aus dem Cai-Fluss, dem einzigen größeren Zufluss in die Bucht von Nha Trang, lässt sich bis zu einer Entfernung von 2.8 km von der Flussmündung nachweisen. Die Konzentrationen der Suspensionsfracht sind sehr niedrig und liegen zwischen 0.03 und 4.3 mg dm^{-3}, in einer Probe wurden 8.9 mg dm^{-3} gemessen. Der vertikale Flux gemessen in iener Sedimentfalle 2.8 km von der Flussmündung entfernt beträgt 0.77 g m^{-2} Tag^{-1} in 2 m Wassertiefe und 5.36 g m^{-2} Tag^{-1} in 12 m Wassertiefe bzw. 3 m über Grund. Die Oberfächensedimente in der Bucht von Nha Trang bestehen überwiegend aus Sand. Während der Trockenzeit wird kaum Sediment akkumuliert. Große Mengen von siltig/tonigen Sedimenten, die während der Regenzeit eingetragen und abgelagert werden, wie aus Satellitenbildern hervorgeht, werden danach resuspendiert und weiter seewärts in den offenen Ozean transportiert.

Introduction

About 70-80 % of the world's sediment flux from lands to oceans is contributed by rivers in monsoonal Asia and Oceania (MILLIMAN & MEADE 1983). A substantial fraction of this load is derived from small, mountainous river systems (MILLIMAN & SYVITSKI 1992). Being dominated by monsoon climate, the SE Asian rivers have large seasonal variations in discharge: often with more than 90 % of all waters discharged during wet season (VAN MAREN & HOEKSTRA 2004). Specific monsoon related circulation and episodic sediment and freshwater influx, imply that the sedimentary processes on the Asian shelves may be different from those operating in other tropical regions (NITTROUER et al. 1995).

The western margin of South China Sea includes a narrow Vietnam shelf, which is an important regional sediment depocenter (SCHIMANSKI & STATTEGGER 2005). In a transect located offshore Nha Trang town, the middle and outer part of the shelf is composed of muddy, siliciclastic, sediments forming a clinoform. They accumulated during the last century with maximum rates of 0.14 to 0.58 g cm^{-2} y^{-1} (SZCZUCIŃSKI & STATTEGGER 2001). The sedimentary structures and radionuclide profiles of these sediments suggest that they are transported seaward in seasonal pulses – possibly in fluid mud form. Despite the geochemistry and mineralogy of the sediments indicating their local provenance (SZCZUCIŃSKI & STATTEGGER 2001; SCHIMANSKI 2002; JAGODZIŃSKI 2004), their direct source, way of transport and driving factors remain unknown. Previous studies in Nha Trang Bay indicated that the major part of its bottom is covered with sand (DOUGLAS & NORDSTROM 1973; TRINH PHUNG et al. 1979). Finer sediments are documented only from areas in the vicinity of the river mouth. It was found that significant portion of the fine sediments is transported southwards with a wave induced longshore current (TRINH PHUNG et al. 1979; BUI HONG LONG & LE DINH MAU 2000; NGUYEN TAC AN et al. 2000). However, hydrographical data shows that a portion of river delivered suspended load is also transported eastward (NGUYEN BA XUAN 1998; NGUYEN BA XUAN & TONG PHUC HOANG SON 2000). It is possible that sedimentation takes place in the bay only seasonally, and the entire deposited material is resuspended and subsequently transported offshore. In such a situation, the Nha Trang Bay would serve as a repository for muddy sediments finally deposited on the middle, outer shelf or passed by to the continental slope region. Such a role of inner shelf as a repository was recently documented from the narrow northern California shelf (CROCKETT & NITTROUER 2004).

To resolve the above stated problems, a study on sediment dynamics and hydrodynamics in the Nha Trang Bay was conducted. The present study is focussed on determination of the sedimentation processes and their rates during period with the lowest river discharge (beginning of May 2005) at the end of dry season, and with the lowest impact of tides and waves (neap tide and calm wind conditions). So the quantitative results may be treated as representative for a lower boundary energy conditions for further considerations. A simultaneous analysis of several important factors: tides, waves, currents, water masses properties, their stratification and mixing, suspended particulate matter concentration and their changes in tidal cycle, modern surface, as well as, subsurface sediments and vertical particulate matter flux measured with sediment traps give a chance to understand better driving factors and to quantify influence of dominating sedimentation processes in such a setting. The problem of quantitative particulate matter fluxes in the bay and suspended sediment dynamics have not been addressed in the previous studies from this region. High resolution salinity and temperature surveys have not yet been published.

The main aim of the survey was to determine physical constrains, style and rates of modern estuarine sedimentation and sediment transport during dry season, on example of the Nha Trang Bay.

Study area

Nha Trang Bay is located on the western coast of Vietnam (fig. 1). It forms a shallow embayment 10 to 30 m deep, which is open to the east. The surrounding of the bay is characterised by mountainous relief. Most of the coastline in this region is rocky, sandy beach dominates the western coastline of the bay. The area has a distinct monsoon climate. The maximum of rainfall (up to 400 mm per month) is from September to December during wet season maximum, from February to May the maximum of dry season occur (LE PHUOC TRINH et al. 1979). The average precipitation in Nha Trang is 1359 mm per year and even few times more in the surrounding mountains (NGUYEN BA XUAN 1998). The major supply of freshwater and suspended load to the bay is transported through Song Cai River. The river is 75 km long and drains an area of about 2000 km^2, reaching altitude of 1475 m above the mean sea level. Its fresh water discharge during the dry season is 5.6 m^3s^{-1} and in wet season 78.1 m^3 s^{-1} on an average (NGUYEN BA XUAN 1998). In rainy season, the suspended particulate matter concentration in river waters near the river mouth is 7.9 – 21.2 10^{-3} kg m^3 (NGUYEN BA XUAN 1998). The Nha Trang Bay is characterised by diurnal tidal regime with a tidal range from about 40 cm during neap tide to more than 2 m during spring tides (MARINE HYDROMETEOROLOGICAL CENTRE HANOI 2004).

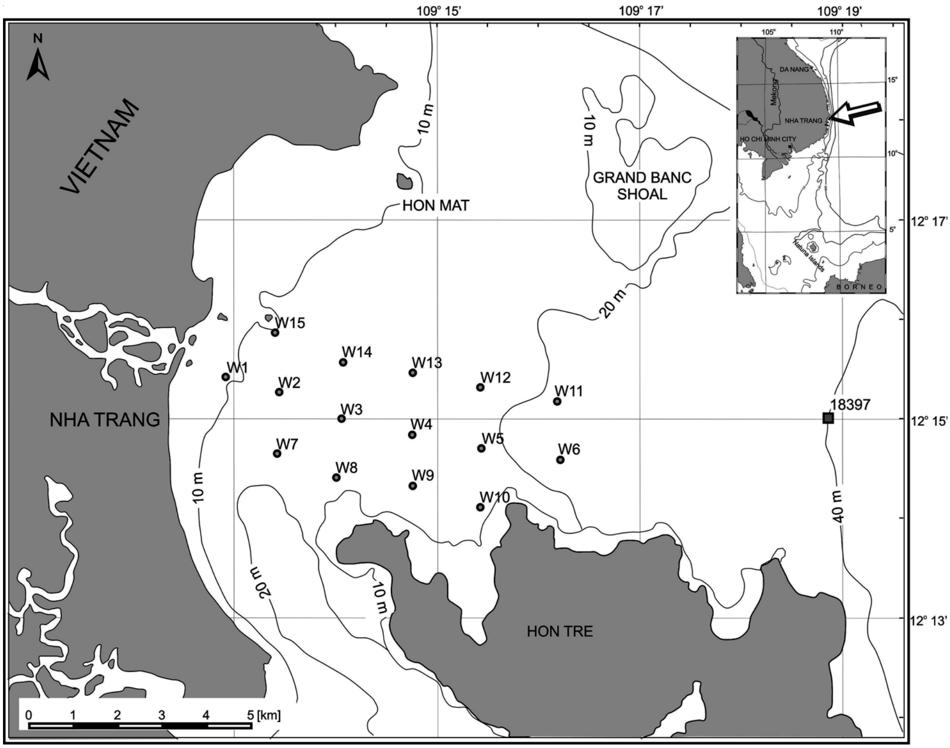

Fig. 1: Nha Trang Bay with positions of stations (W1- W15). Inset shows Nha Trang in the western part of South China Sea. Station 18397 is the most onshore station from the previous shelf sediment study (SZCZUCIŃSKI & STATTEGGER 2001).

Methods

Surveys were conducted in May 2005, with research vessel NCB 95 from Institute of Oceanography in Nha Trang. Measurements were conducted at 15 selected work stations (fig. 1, tab. 1). Water salinity and temperature were measured with the CTD-Log by Driesen & Kern GmbH. Water samples were collected with the 5l Niskin water sampler. To obtain suspended particulate matter (SPM) concentrations, water samples were filtered on pre-weighted paper filters, rinsed with distillated water and dried. Sediment traps were constructed from plastic cylinders 1 m long and have 10.56 cm inner diameter, closed on one end with a plastic cap. The trap geometry and deployment (fig. 2) follows recommendation of ZAJACZKOWSKI (2002). At station W2, W4 and W6, sediment traps were deployed at the beginning of the survey in a similar manner (fig. 2). Two traps were located at 2 m water depth (open top of sediment trap) and two traps at about 2 –3 m above the sea bottom. The trap geometry (open diameter to trap length ratio) was 1:9.5. It guaranties that no resuspension of the trapped sediment occurs. The traps exposure time was 70 hours. Unfortunately, the traps at stations W4 and W6 were lost, probably due to fishing activity. The wave, winds and currents were noted during all the measurements descriptively. Two drifter experiments were conducted on W2 station during calm and wavy conditions respectively. The drift of the buoys was measured for 5 m distance at least three times. The bottom sediments were sampled with a grab sampler and described in detail after recovery. Grain size, sorting, colour, structures, existence of flocks or aggregates and major components were noted for the surface (uppermost 5 mm) and subsurface segments.

Tab. 1: List of the investigated survey stations with types of measurements and their number (in parentheses).

Station	**Latitude N**	**Longitude E**	**Water depth [m]**	**Activities**			
				Grab sample	Sediment traps	Water sampling	CTD
W1	12º 15.412	109º 12.502	9.5	v			v (2)
W2	12º 15.257	109º 13.138	15	v	v (3)	v (23)	v(38)
W3	12º 15.008	109º 13.859	16	v			v(1)
W4	12º 14.839	109º 14.712	16	v	v [lost]		v(3)
W5	12º 14.704	109º 15.539	20	v			v(1)
W6	12º 14.583	109º 16.468	22.5	v	v [lost]	v (10)	v(6)
W7	12º 14.644	109º 13.124	15	v			v(1)
W8	12º 14.402	109º 13.825	15	v			v(1)
W9	12º 14.318	109º 14.735	16	v			v(1)
W10	12º 14.115	109º 15.521	14	v			v(1)
W11	12º 15.856	109º 13.084	15	v			v(1)
W12	12º 15.564	109º 13.903	15	v			v(1)
W13	12º 15.462	109º 14.714	16	v			v(1)
W14	12º 15.306	109º 15.51	18	v			v(1)
W15	12º 15.168	109º 16.429	21	v			v(1)

Two Landsat scenes were analysed for SPM and chlorophyll distribution. The Landsat Thematic Mapper (TM) from June 1989 was taken during the ebb phase of spring tide, and can be considered as characteristic for the beginning of the rainy season. The Enhanced Thematic Mapper (ETM) scene from January 2002 describes the situation of the flood phase of the spring tide during the dry season. For the study two algorithms were used. One of them was created for estimation of chlorophyll-a input of river Delaware into Delaware Bay in the United States, where most of the bay is shallower than 20 metres (KEINER & YAN 1998).

Chlorophyll [ìg l^{-1}] = 51.728 + 2.569 * TM1 – 33.462 * TM1/TM3 Eq. 1

The second algorithm was created by BABAN (1993) for estimation of suspended solids concentration for the Yare River mouth in Norfolk Broads, UK.

Suspended solids [mg l^{-1}] = -427 + 7,01 * TM1 Eq. 2

The same algorithms applied for both scenes allowed the spatial comparison of chlorophyll and SPM concentration in Nha Trang Bay.

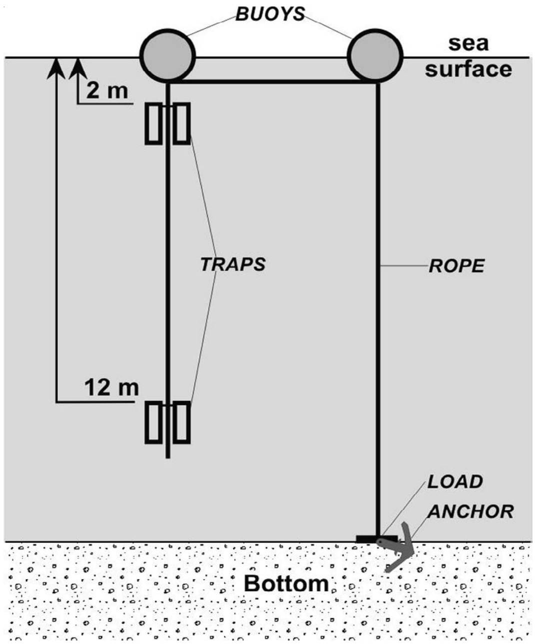

Fig. 2: Scheme of sediment trap deployment, example W2 station.

Results

Wave, wind, current and tidal conditions

The survey was conducted during neap tide with maximum tidal amplitude of 0.6 m (fig. 3). Both- CTD and water sampling were performed during different stages of the tides to estimate their influence on water circulation and suspended particulate matter (SPM) distribution.

Wave and wind conditions were strongly related. Winds from S and SSE dominate. However, during the most of the time, they were very weak or absent. Southern winds started to blow daily in the early afternoon between 13:30 and 15:30 hrs with speeds up to several m s^{-1}. In the early morning, western winds were observed. However, due to the shorter fetch length, the resulting waves were smaller. The highest waves reaching up to 40 cm were observed during maximum southern winds. The noted wave heights are presented in fig. 3.

Surface sea currents were found to be relatively strong at several locations. They were observed continuously at the W2 station. They were flowing dominantly northwards, but during western winds and low tide, they were eastward directed, and in periods of quiescence, they were absent. Thus, the currents appear to be mainly wind generated. The measurements (with drifters) of surface current velocities at the W2 station during relatively calm conditions with slight southern wind revealed an average speed of 0.2 m s^{-1}, and during stronger winds up to 0.83 m s^{-1}.

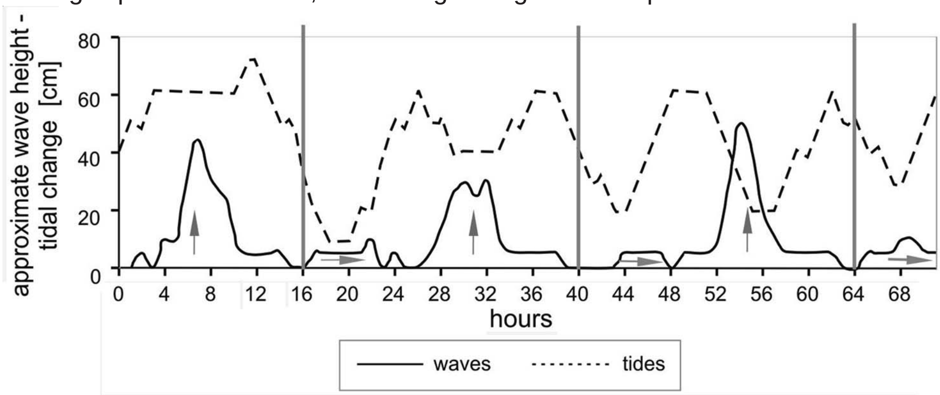

Fig. 3: Tidal cycle and wave heights at W2 station from 08:00 hrs on 4th May to 07:00 hrs on 7th May 2005. Based on tide tables of Marine Hydromet. Centre Hanoi 2004. The most marked phenomena is enhanced wave height in early afternoons related to southern winds (vertical arrows), and smaller waves due to western winds (horizontal arrows) in the very early mornings. The vertical lines mark midnights.

Water salinity and temperature

Water properties (temperature, salinity, density) were measured frequently on station W2 to obtain their temporal changes (fig. 4), as well as in three transects perpendicular to the coast (fig. 1, fig. 5) to reveal spatial variations. The recorded water temperatures mainly range from 24° to 28 °C with maximum and minimum values at 22.1° and 28.3 °C, respectively. Warmer waters are always in the upper part of water column (fig. 5). The salinity is generally in range of 31.2 to 33 [psu]. Wider range of salinity values is found in the upper water column. At water depths below 8 m, the variations are much smaller. Vertical profiles are of different shapes, in some cases the near-surface waters are the most saline, in others the least saline (fig. 5). Salinity minimum was observed usually at depths between 5 and 8 m. Vertical salinity changes are, however, very small. Except for one measurement, all the profiles revealed variations within the range of 1 and sometimes even within 0.2 [psu].

The water column is partly stratified, with a well established stratification during long part of the night and in the morning (fig. 4). In the afternoon, complete mixing was observed. Due to small variations in salinity, the water stratification is mainly controlled by changes in water temperature (fig. 4). The mixing seems to be not related to tidal action but to waves. Each full mixing occurred within 1 hour after the period of stronger winds and waves, and was not related to tidal phase.

The lateral changes between stations are very small and show the same trends, with only minor changes in values (fig. 5).

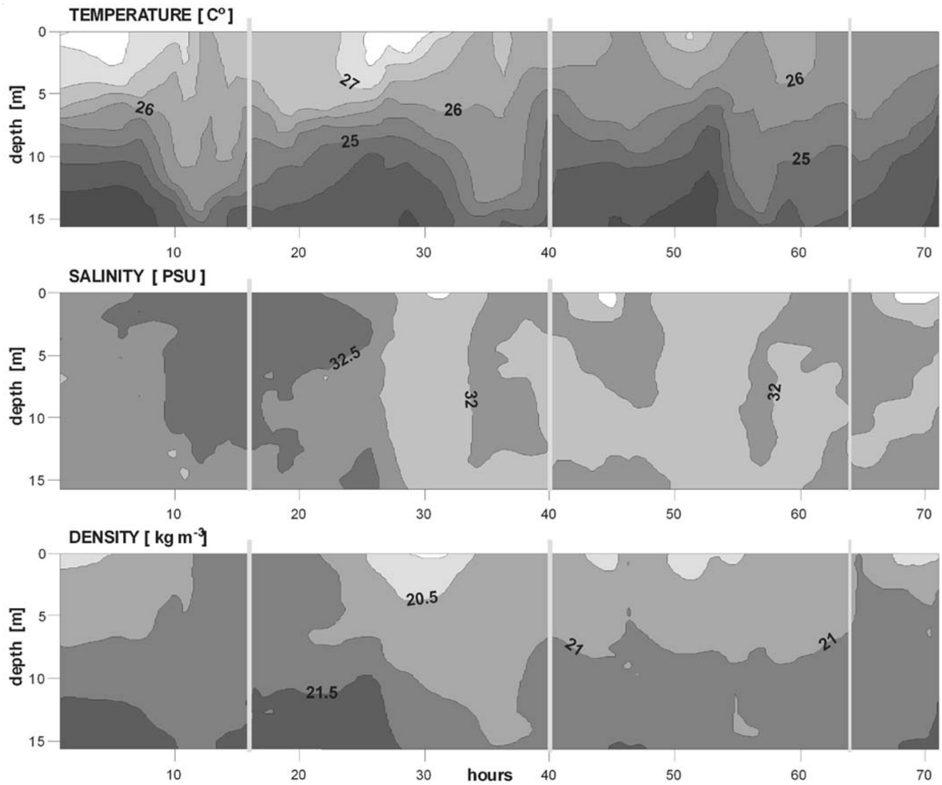

Fig. 4: Temporal changes in temperature, water salinity and density measured at W2 station, based on 38 CTD measurements from 08:00 hrs on 4th May to 07:00 hrs on 7th May 2005. The isolines are every 0.5 value. The vertical lines mark midnights.

SPM concentration

Suspended particulate matter (SPM) concentrations are found to be very low, in particular in the uppermost part of the water column. The observed values range between 0.03 and 4.3 mg dm^{-3}. Only in one sample, the SPM concentration reached 8.9 mg dm^{-3}. Fig. 6 presents concentrations of SPM at W2 station and W6 during low and high tide, as well as during calm and wavy conditions. During low tides, the SPM values were slightly elevated. The maximum values were recorded during wavy conditions in low tide. However, the differences are very small.

Downward particulate matter flux

The downward particulate matter flux measured with sediment traps on W2 station is generally small. It is found that much more particulate matter was deposited in the lower traps at 12 m depth, about 2-3 m above the sea bottom, than in the upper 2 m below sea surface. The vertical particulate matter flux in the upper traps was 0.77 g m^{-2} d^{-1}, and in the lower traps were 5.09 and 5.64 g m^{-2} d^{-1} (average 5.36).

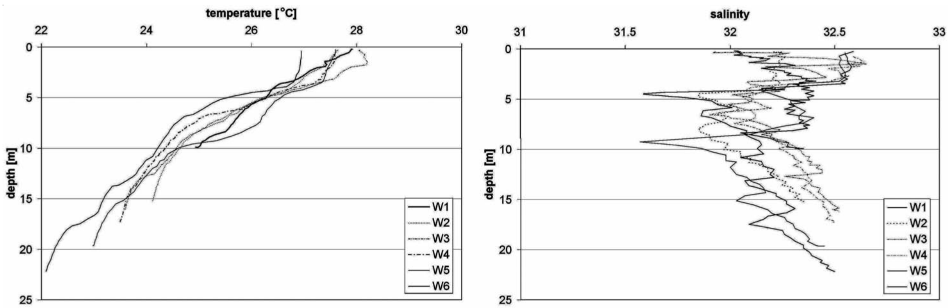

Fig. 5: Salinity [psu] and temperature changes in profiles W1- W6 during high tide calm conditions.

The particulate matter was found to be mainly in form of flocks, probably bounded with organic matter.

Bottom sediments

Surface sediments (0-0.5 cm layer) are dominated by the sand fraction (fig. 7). Aggregates of fine material, which are bounded probably by organic matter are observed very often on the surface as flocks – similar material up to 2 cm in size is found in the sediment traps. In many cases, the surface sediments are also enriched in small admixtures of fines, and in small organisms. Except at the W1 location, which is dominated by mud, the remaining locations are composed of sand: fine sand at the W2 station, medium, and medium to coarse sand further offshore. At the most distal stations, the surface sediments are classified as silty sand. Surface sediments are characterized by poor sorting, which is an effect of mixing of sands and fine material, and are usually dark, olive gray, dark brown and green. Relatively few carbonate organic fragments were found in these samples.

Subsurface sediments (0.5 to about 5 cm layer) are also dominated by the sand fraction, except for sediments from W1 station, which are muds. In general, an offshore coarsening trend is observed from mud, fine silt to medium sand. On the locations close to the Hon Tre Island, the trend is relatively modified and coarse sands are found close to caps and fine sands in a bay. The sediments are usually very well sorted. In places, some intercalations of more silty sand similar to that found on the contemporary surface, are observed. Among the components of the sand fraction, the lithoclasts dominate. Carbonate fragments of shells and skeletons of organisms are of secondary significance.

Analysis of satellite images

Satellite scenes are commonly used for the water-quality studies as long as they register the wavelengths of sunlight efficiently penetrating the water. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) scanners have four spectral bands useful for water surface and water column studies, and reasonable resolution of the pixel (30 m x 30 m). This allow successful presentations of spatial

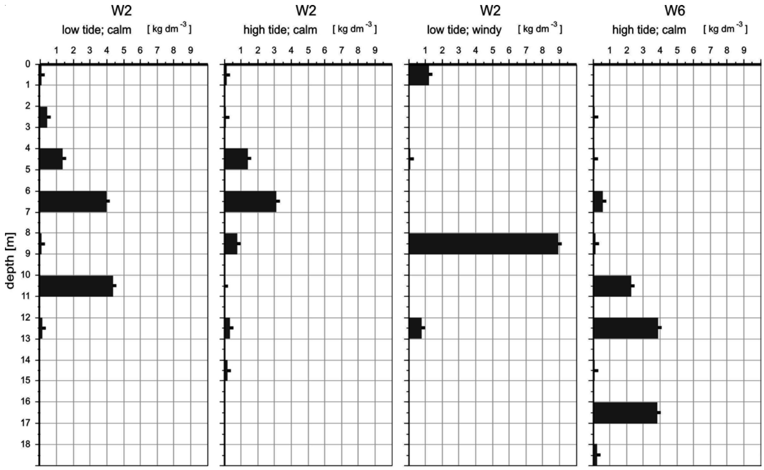

Fig. 6: Suspended particulate matter concentration [mg dm^{-3}] distribution at W2 and W6 stations in different tidal stages and wave conditions.

distribution of suspended matter over large water bodies (ROUSE & COLEMAN 1976; BAGHERI & DIOS 1990; BABAN, 1993, 1995; LAVERY et al. 1993; KEINER & YAN 1998: HELLWEGER et al. 2004).

The amount of SPM in coastal waters is affected by several factors such as sediment input influenced by river discharge, sea-bottom relief, or tidal and wind regime affecting local hydrodynamics. Due to such a complexity, it is necessary to create unique algorithms for a particular bay, which are based on *in situ* measure-ments of the water quality. The data should be collected during all characteristic periods in which SPM distribution is expected to be changed. For the Nha Trang Bay, the periods of particular interest would be the middle of the rainy and dry seasons connected with high and low discharges of Song Cai River, spring and neap tide, flood and ebb phase of the tide. Additional difficulty is that *in situ* measurements should be performed at the same time, when the satellite scanner is recording the area. Due to the lack of such data, we focussed in this study on showing the possibilities of riverine sediment-rich plume extension and discharge direction, than on finding exact values of SPM for the entire bay.

Two Landsat scenes were chosen for the presentation of SPM distribution. The TM from June 1989 was taken during the ebb phase of spring tide and can be considered as characteristic for the beginning of the rainy season. The ETM scene from January 2002 shows the situation of the flood phase of spring tide during the dry season. Unfortunately, wind and waves data sets were not available, so there is no certainty if the SPM is affected only by standard hydrodynamics. The scene from 1989 is additionally affected by image artifact in a form of bending known as Memory Effect (VOGELMANN et al. 2001). For the study, two algorithms for chlorophyll (KEINER & YAN 1998) and SPM concentrations (BABAN 1993) were used. The same

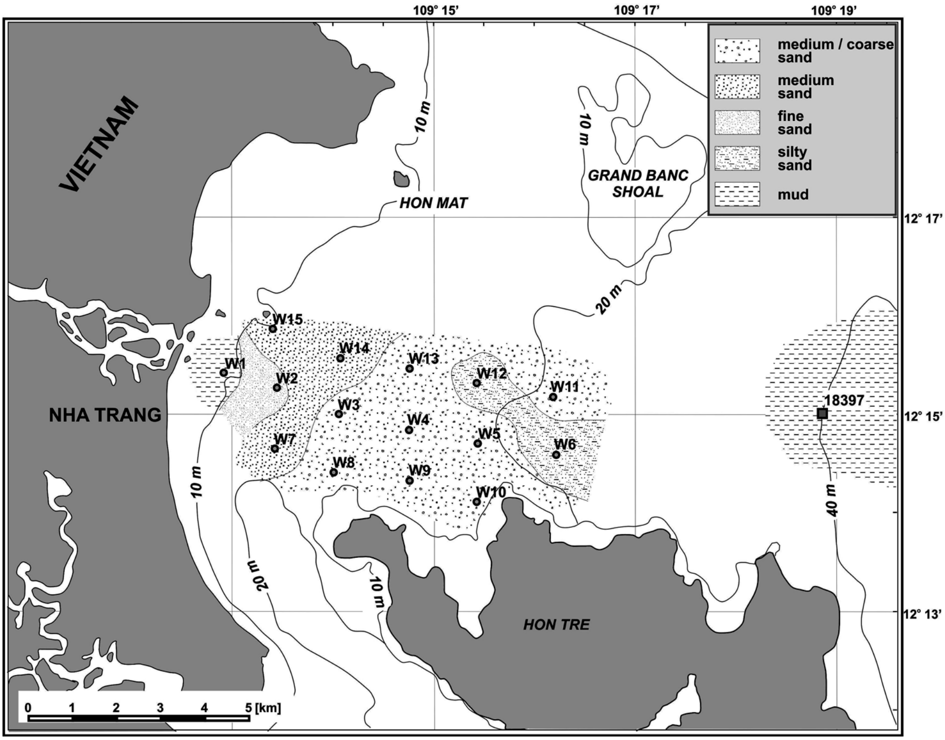

Fig. 7: Distribution map of surface sediments in Nha Trang Bay based on macroscopic determination of the surface (0 – 0.5 cm) bottom sediment layer. The furthermost offshore data is based on SZCZUCIŃSKI & STATTEGGER (2001).

algorithms applied for both scenes allowed the spatial comparison of SPM and chlorophyll concentration in the Nha Trang Bay (fig. 8). On 19th June 1989 during the ebb phase in wet season, the values of both suspended matter and chlorophyll are much higher in a zone extending 3 km from the shore. The highest chlorophyll concentrations are observed in the vicinity of Song Cai River mouth, and in front of Nha Trang town. Further to the south, another high concentration area exists in Cua Be River mouth (fig. 8a). The distribution of SPM in the bay is very similar, but higher concentration is observed in the embayment westwards from Hon Mat Island and over the Grand Banc Shoal in the northeastern part of the area (fig. 8c). On 14th January 2002 during flood phase of the dry season, high concentrations of chlorophyll are observed in the embayment northwards from the Song Cai River mouth. In front of the mouth, the plume of organic and non-organic matter does not reach 1 km offshore (fig. 8b, 8d). The distribution of SPM either seems to be affected by a long-shore current acting northwards, or it is pushed landwards by southeastern winds causing the Corner-Effect. During this time, fine sediment parti-cles cannot be transported offshore, but during the wet season, as observed in June 1989, it appears to be possible.

Discussion and conclusions

The present study supports earlier results (NGUYEN BA XUAN & TONG PHUC HOANG SON 2000) on the very limited influence of Cai River on Nha Trang Bay waters during the dry season. The water stratification was dominated by a weak, mainly temperature controlled gradient (fig. 4). Salinity variations were very small. Mixing of the entire water column occurred every day in consequence of short periods of local wind generated waves. Tidal component in water column mixing was very weak during the survey. However, it cannot be representative for the entire season since normally mixing rates are highest during spring tides and decrease towards neap tides together with decreasing of current velocities (SIMPSON et al. 1990). The water layers with the highest density gradients (usually 5 – 10 m) have also the highest SPM concentrations (up to 8.9 mg dm^{-3}). No significant spatial variations in water properties were found.

Such conditions with water mixing periods when surface currents reach more than 0.83 m s^{-1} are expected to cause resuspension of fine bottom sediments. These observations together with data from sediment traps with vertical particulate matter flux of 0.77 g m^{-2} day^{-1} at 2 m depth and 5.36 g m^{-2} day^{-1} just above the bottom, suggest that during such conditions, there is very little sedimentation of a river-delivered suspension. Most of the downward particulate matter flux is probably due to resuspension. Particulate matter both in suspension as well as in sediment traps was dominantly found in the form of flocks, probably tied by organic matter. The common existence of suspended particulate matter in the agglomerated form with organic detritus was also documented, for instance in the Mekong River mouth during high and low flow seasons (WOLANSKI et al. 1996, 1998).

As documented by the bottom sediment distribution, sands are the dominating sediment type in the Nha Trang Bay. Muds are found only in the part adjacent to the river mouth. This suggests that there is almost no sedimentation of fine terrigenous material during the dry season, but it also proves that Nha Trang Bay does not serve as a sediment trap for fine material delivered during the rainy season. An explanation given by TRINH PHUNG et al. (1979) and NGUYEN TAC AN et al. (2000) is that the dominating sediment transport direction during wet season is southwards, and the sediment load escapes the bay via passage between mainland and Hon Tre Island. However, hydrological studies (NGUYEN BA XUAN & TONG PHUC HOANG SON 2000) as well as satellite images (fig. 8) suggest that at least a portion of the Cai River sediment load is delivered to central part of Nha Trang Bay. This material must be redeposited more offshore or sediment transport is dominated by advection processes, rather by local resuspension, and deposition occurres more offshore. These conclusions support results of the studies on sedimentation on shelf offshore Nha Trang (SZCZUCIÑSKI & STATTEGGER 2001; SCHIMANSKI & STATTEGGER 2005), where significant modern fine sediment accumulation was observed. Sediments, which are probably partly delivered through Nha Trang Bay are caught in clastic clinoform composed of muddy deposits which extends from about 40 to 120 m water depth on the adjacent shelf.

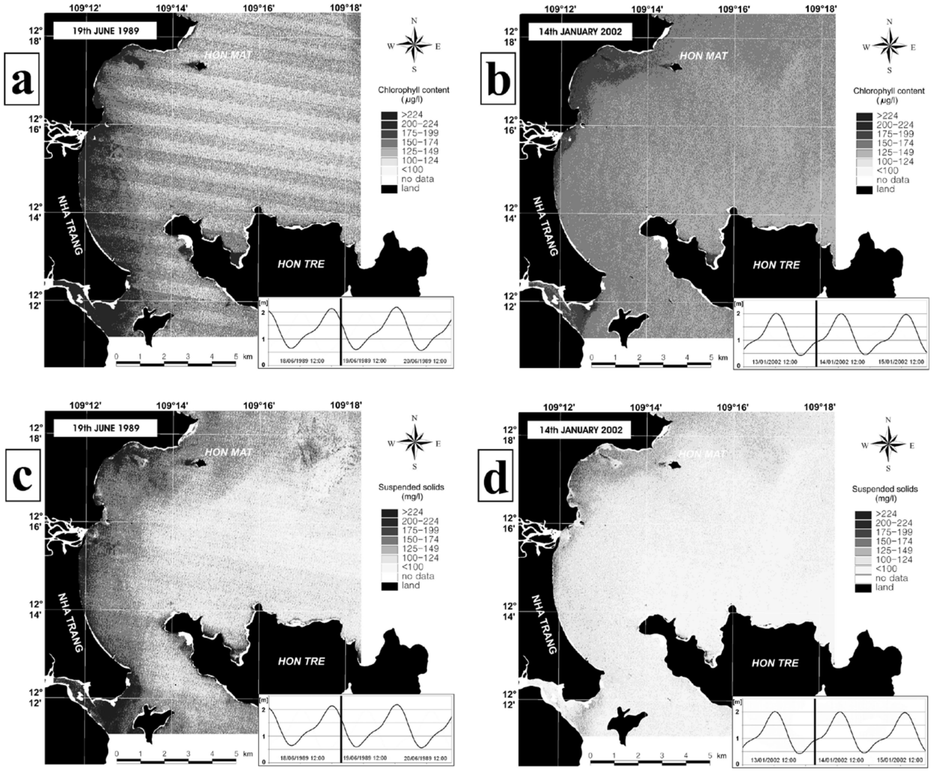

Fig. 8: Results of algorithms application for a), b) chlorophyll content from Equation 1 (KEINER & YAN, 1998) and c),d) suspended solids content from Equation 2 (BABAN, 1993) for two Landsat scenes. The water level is computed for the Nha Trang gauge station and the marker is showing the moment of satellite overpassing.

In conclusion, conditions during the dry season and neap tide are characterised by:

- minimal freshwater influence limited to less than 2.8 km from river mouth,
- weak, temperature-controlled water stratification,
- daily mixing due to local winds,
- very small SPM content < 10 mg dm^{-3},
- very small vertical particulate matter flux with maximum registered value of 5.36 g m^{-2} day^{-1} close to the bottom,
- bottom sediments composed of mainly of sands, which do not represent modern hydrodynamic conditions and,
- fine sediment delivered during wet season is not accumulated in the Nha Trang Bay, but is redeposited or advected further on the continental shelf.

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