Temporal changes in sediment distribution observed in MODIS images

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Abstract: Changes in spatial distribution of suspended sediment discharged from large rivers could be the result of short-term seasonal changes, inland environmental changes or re-suspension of bottom sediment by strong tidal currents. The time scales for these processes are different – the latter shorter than the former two. MODIS images collected between September 2004 and September 2005 are used to study the temporal variations in sediment distribution at the mouths of the Ayeyawady River and Gulf of Martaban, as well as, off the Mekong River Delta. Relatively cloudless images could be acquired almost daily during the dry season from December to February. The tidal influence on the sediment distribution can be clearly observed during this period – the largest areas of turbidity are observed during spring tides and the smallest areas during neap tides. These two regions are almost daily obscured by clouds from May to August. Nevertheless, seasonal variations due to the two monsoons can be discerned after eliminating tidal influence by selecting images acquired only during spring or only during neap tides.

.**Keywords:** suspended sediment, MODIS, coastal waters

1. Introduction

Large spatial extent of suspended sediment can often be seen in satellite images of two regions in South East Asia: the Gulf of Martaban and the waters off the Mekong River Delta. This is not too surprising considering that these two areas are where the large rivers (Ayeyarwady- Salween-Sittang and Mekong) discharge into the coastal seas. The aerial extents of these river plumes and their temporal variation have not been well studied except case studies done in the Gulf of Martaban [1]. Given the large spatial extent of the Gulf of Martaban (400 x 300 km) and the area needed to study the waters off the Mekong River Delta (400 x 70 km), it is difficult to make regular and comprehensive observations using data from high resolution earth observation satellites such as SPOT and Landsat. On the other hand, while the AVHRR does have a wide swath of 2300 km, its spatial resolution is rather coarse (1.1 km at nadir) for observing coastal waters.

The Moderate Resolution Spectroradiometer (MODIS) on board the Terra and Aqua satellites acquire data over wide swaths of 2300 km across track at spatial resolution ranging from 250 m to 1 km at nadir. The revisit time is one to two days. This allows almost daily observations of a given area of interest, especially of offshore suspended sediment.

2. Methods

CRISP operates a MODIS direct broadcast receiving station that receives data from the Terra and Aqua satellites daily. The downlinked data are processed to Level 1 using NASA/GSFC geo-registration and calibration algorithm for MODIS. Focusing on the two regions of interest, we processed the blue, green, red and near-infrared bands (bands 4,3,1 and 2, respectively) and mapped them to geographical latitude and longitude coordinates at intervals of 0.005 degrees.

Corrections were made for ozone absorption and Rayleigh scattering reflectance. The reflectance data are collected daily between September 2004 and September 2005. The images that are cloud obscured are discarded. Using the freely available software for tidal predictions, XTide [2], we attempt to correlate the observed turbidity fronts with the tides at stations in the vicinity.

3. Results and Discussion

3.1 Mouths of the Ayeyarwady River and the Gulf of Martaban

Ramaswamy et al 2004 [1] observed that in the central portion of the Gulf of Martaban, the turbidity front oscillates in phase with the spring-neap tide. Our observations concur with theirs. Fig.1 shows a typical reflectance image of the area from a cloud-free acquisition showing an area with high turbidity during spring tide while Fig. 2 shows a typical reflectance of the area during neap tide, when the central high turbidity area is very much reduced.

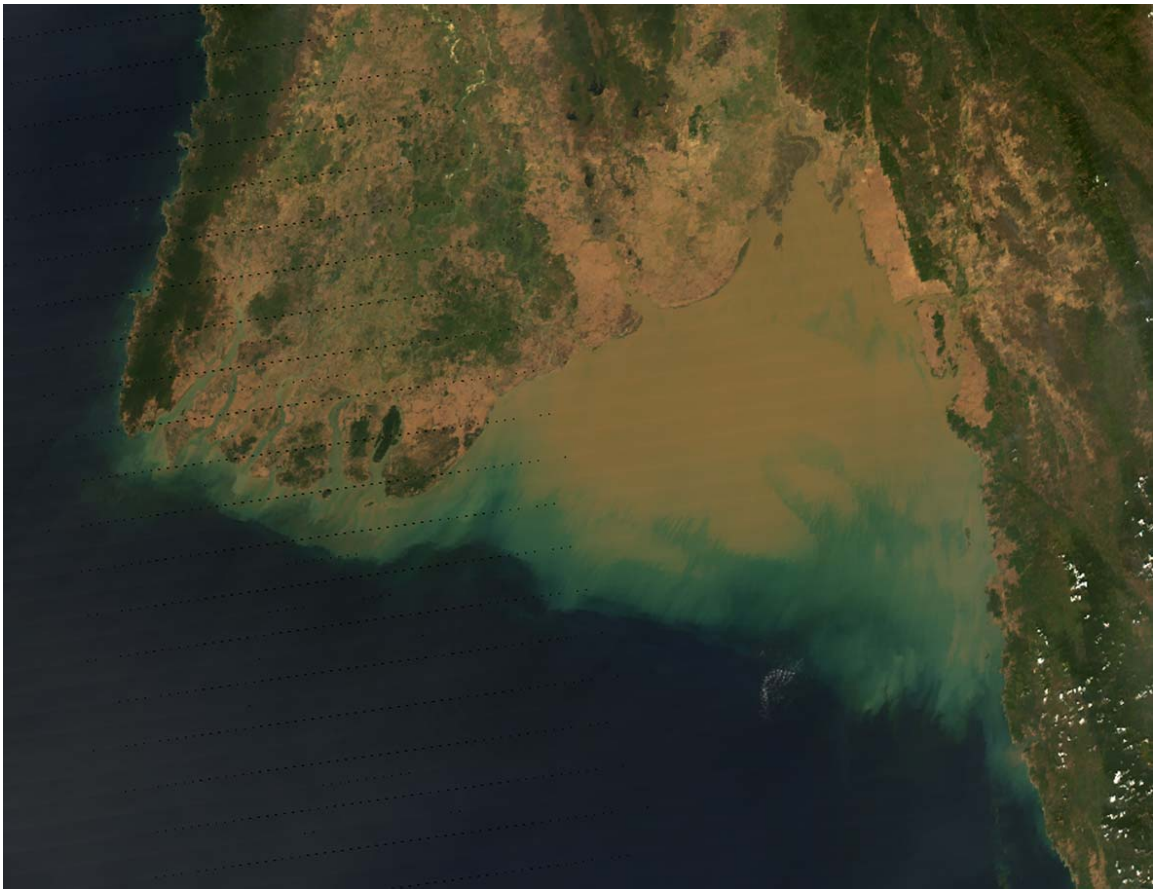

Fig. 1 MODIS reflectance image showing the turbid waters at the mouths of Ayeyarwady River and the Gulf of Martaban. This image was acquired by Aqua on Feb 8, 2005. The predicted tide at the mouth of Rangoon River is 4.4 m and the predicted tidal range for that day was about 5.0 m. As it was the new moon, the spring tide occurred on this day.

Fig. 2. Reflectance image from Aqua acquired on 2005 Feb 19 with a much reduced high turbidity area. The predicted tide level at Rangoon River mouth was 4.0 m and the tidal range for the day was 1.2 m.

3.2 Mekong River Delta

This region is frequently covered by clouds. However, when the clouds are thin, the sediment areas can be visually identified. So we only exclude the images which are completely obscured by thick clouds. Despite this, the available dataset is not as extensive as that for the Gulf of Martaban. The predicted tide levels are shown in Fig. 3 while a series of images of the area are shown in Fig. 4. The area of high turbidity off the Mekong River Delta can be seen to oscillate with the spring-neap tidal cycle.

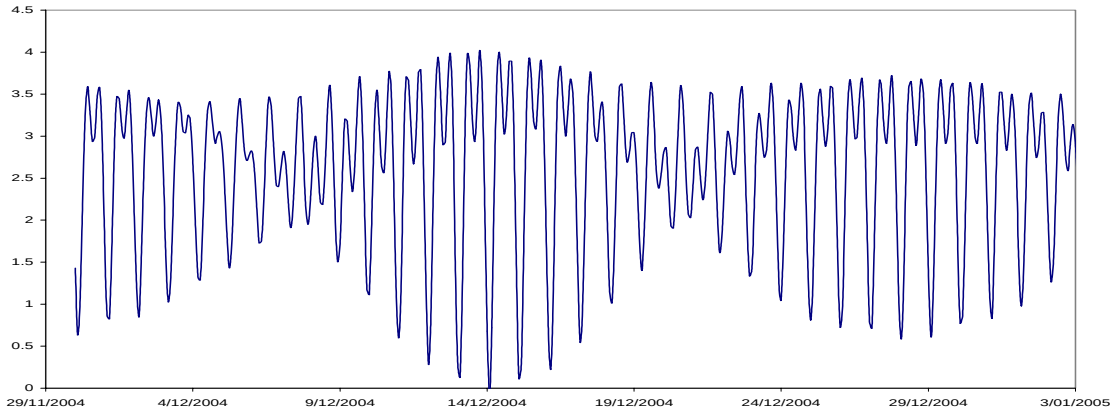

Fig. 3 Predicted tide levels at Vung Tau, Vietnam

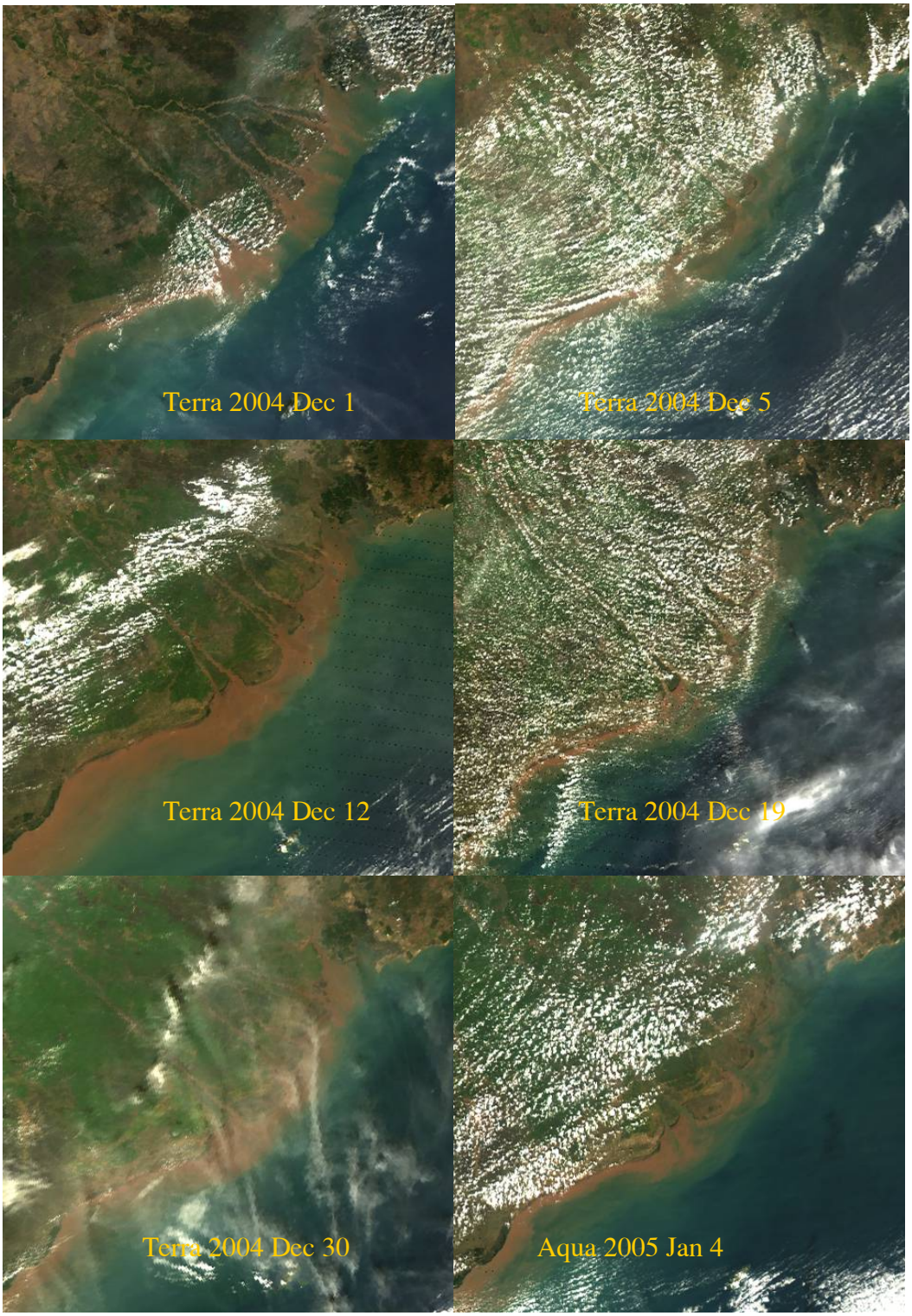

Fig. 4 Reflectance images showing the temporal variation in spatial extent of highly turbid waters off the Mekong River Delta, Dec 1, 2004 – Jan 4, 2005. Similar oscillations are observed in the months of January 2005 and February 2005. Data for the other months are limited because of thick cloud cover.

This area is strongly affected by the seasonal monsoons – the southwest monsoon between mid-May and end of September, and the northeast monsoon between December and February. In order to take into account the tidal effects, we compare images acquired approximately during the same phase of spring-neap tide cycle. Two sets of such images are shown in Fig. 5.

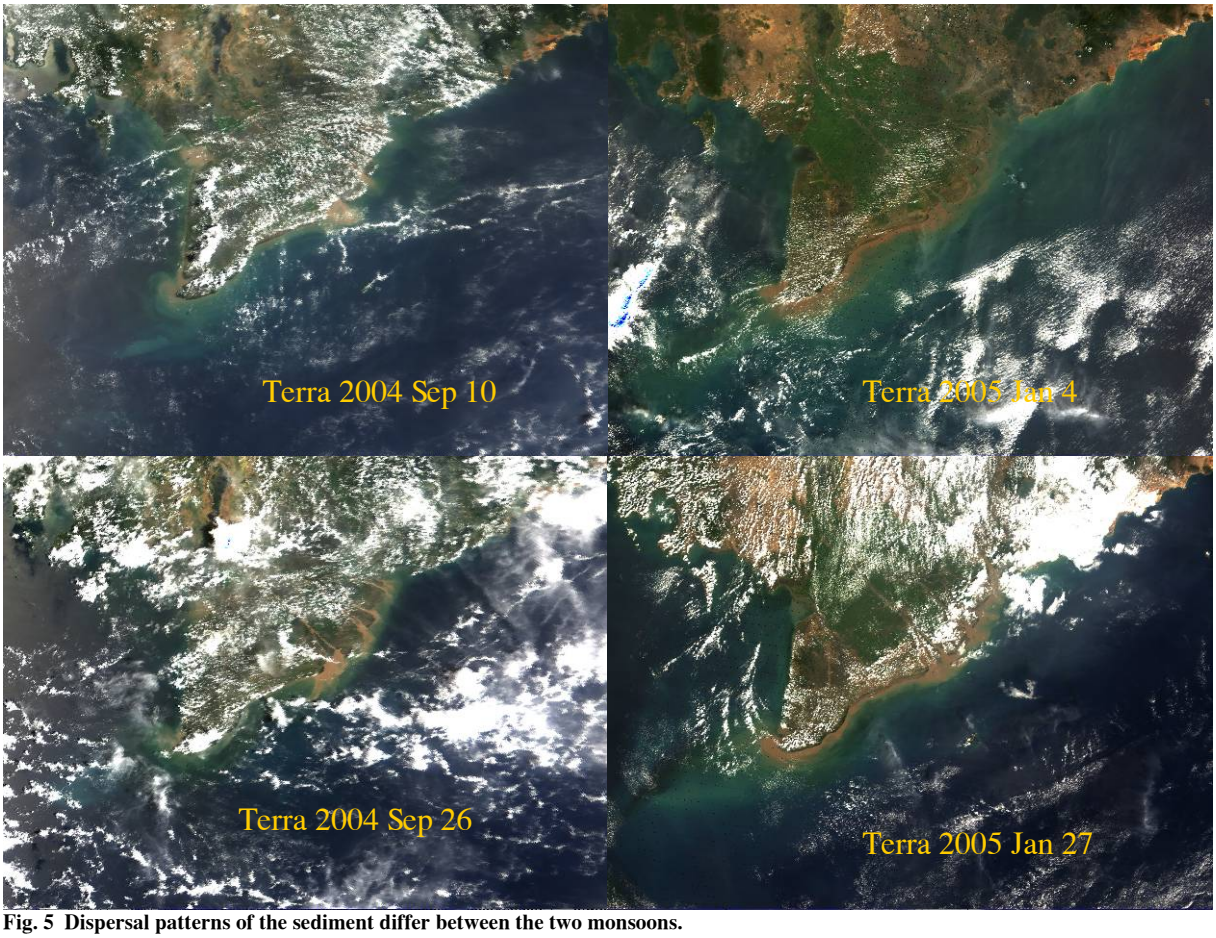

Fig. 5 Dispersal patterns of the sediment differ between the two monsoons.

4. Conclusion

MODIS images show clearly the tidal influence on suspended sediment distribution in the Gulf of Martaban and the waters off the Mekong River Delta. Evidence of the effects of the prevailing monsoon can also be observed.

References

[1] Ramaswamy, V., Rao, P.S., Rao, K.H., Thwin, Swe, Rao, N. Srinivasa and Raiker, V. (2004). Tidal influence on suspended sediment distribution and dispersal in the northern Andaman Sea and Gulf of Martaban. Marine Geology, 208, 33-42.

[2] XTide: Harmonic tide clock and tide predictor. Available at: http://www.flaterco.com/xtide/