

Sediment dispersal during NE monsoon over northern Bay of Bengal: Preliminary results using IRS-P4 OCM data

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Abstract

False Color Composite (FCC) from the sequential satellite images of Indian Remote Sensing Satellite IRS-P4 OCM (bands around 443, 555, and 845 nm) together with sea truth data acquisition at 42 stations along the Orissa coast have been used to reconstruct the sediment dispersal patterns in the northern Bay of Bengal during the NE monsoon. Our preliminary results suggest a south-southwesterly dispersal of the fluvial plumes of Ganga-Brahmaputra along the coast during October 1999 through January 2000. The suspended sediment load is observed to be higher in November. An increased discharge off the mouth of Ganga-Brahmaputra feeds the coastal sediment plumes off coastal waters of Orissa, and these sediments are transported for long distance in a short span of one week along the coast. These results demonstrate a teleconnection between enhanced discharge of Ganga-Brahmaputra and coastal turbidity. Higher influx of suspended load off the Sand Head feeds the coastal plumes, which move into the shallow coastal waters. These sediments appear to sink along the coastal stretches of southern Orissa and Northern A.P.

We have also observed development of offshore curl in the deeper waters. This curl enhances with an increase in the width and augmentation of suspended loads in the Ganga-Brahmaputra plumes, and dies down rapidly. From the images of 10-12 November 1999, it is also apparent that the plumes of high concentration act as feeder and contribute towards the generation of this feature. From these preliminary results, it is tentatively deduced that the suspended sediment discharge of the Ganga-Brahmaputra system continues to influence the coastal processes with much higher temporal and spatial variability along and across the continental margin.

1. Introduction

The Bay of Bengal is one of the largest fresh water and sediment input sites of the World Ocean (Emmel and Curray, 1984). The annual fresh water discharge of the bay exceeds $1.5 \times 10^{12} \text{ m}^3$, which reduces mean salinity by about 7‰ in the northernmost bay (Laviolette 1967). The main contribution into the bay is through the Himalayan rivers, the Ganga & the Brahmaputra. The peninsular Indian rivers, the Mahanadi, the Godavari, and the Krishna also contribute the sediments to the bay.

The circulation in the bay is very complex, with large-scale spatial and seasonal variations associated with the NE & SW monsoons. Poleward currents with a 40 km wide upwelling zone along the central east coasts of India are reported during the SW monsoon (Shetye et al., 1991). Upwelling is completely absent and a reversal in the current direction (i.e., equatorward) occurs during the NE monsoon. These currents are remotely controlled and are found to be related with other hydro-meteorological phenomena (Shetye et al., 1993). A high fresh water discharge from the Himalayan rivers associated with the SW monsoon, and by some of the Peninsular rivers during the NE monsoon

carrying the nutrients and other land discharges will have great influence on the ocean processes such as upwelling, productivity and sediment flux etc., which are least understood in the bay. The influences of seasonal fluvial discharge on the bay circulation and sediment dispersal processes are needed to be fully understood since there is a long distance dispersal of these sediments by low salinity the Bay of Bengal waters into the Arabian Sea (Chauhan and Gujar, 1996). In this paper we present our preliminary results for the dispersal patterns in the northern Bay of Bengal during NE monsoon, derived from the sequential analysis of images and sea truth data.

2. Methodology

The IRS-P4 OCM sequential images (path 10, row 13 and path 10, row 14) during October 1999 - January 2000 have been analyzed to determine the dispersal pattern of sediments in the study area. The available algorithms to retrieve suspended sediment concentration were utilized for the preparation of False Color Composite (FCC) using bands around 443, 555, and 845 nm. The observed variations in the contents of the suspended sediments, retrieved from the imagery and

compared with in situ measurements at 42 stations, show that the patterns in FCC can broadly be used for qualitative reconstruction. This paper encompasses the results of sequential analysis of IRS-P4 OCM FCC data during October 1999 - January 2000.

3. Results and Discussions

From the sequential IRS-P4 OCM FCC imagery the monthly-generalized variations during October 1999–January 2000 are shown in the Fig. 1. During October 1999 the dispersal pattern is mostly southwestwards in the coastal waters (Fig. 1A). We document a reversal in the circulation pattern in early October, which mostly remains northerly during the SW monsoon (Shetye et al., 1991). An occurrence of high discharge of the suspended sediments (off the mouth of the Ganga-Brahmaputra), extending over 120 km offshore in the southern direction with a minor branch also moving alongshore has also been observed. The width of the coastal plume has been found to decrease away from the source, and is significantly reduced south of

the Chilika Lake. Therefore, the sediments discharged by the rivers Ganga-Brahmaputra disperse and deposit alongshore into the shallow coastal waters of Orissa. From these results, we also deduce that the fluvial discharge from the Ganga-Brahmaputra continues to be significant even after cessation of the SW monsoon.

During November, the NE monsoon sets in and there is high probability of the cyclonic storms in the northern Bay of Bengal (Chauhan, 1992, 1995). From the sequential analysis of the FCC, it is derived that the generalized pattern of the suspended sediments is similar to the ones observed in October (Fig. 1B). However, concentration of the suspended sediments in the deeper offshore waters is not so pronounced off the mouth of the Ganga-Brahmaputra. It is, therefore, inferred that upon the initiation of the NE monsoon, there is a reduction in the supply of fluvial sediments (from the Ganga-Brahmaputra source) into deeper, offshore regions of the bay. The patterns of the suspended sediments in the coastal region along the Orissa Coast are also different, and are marked with

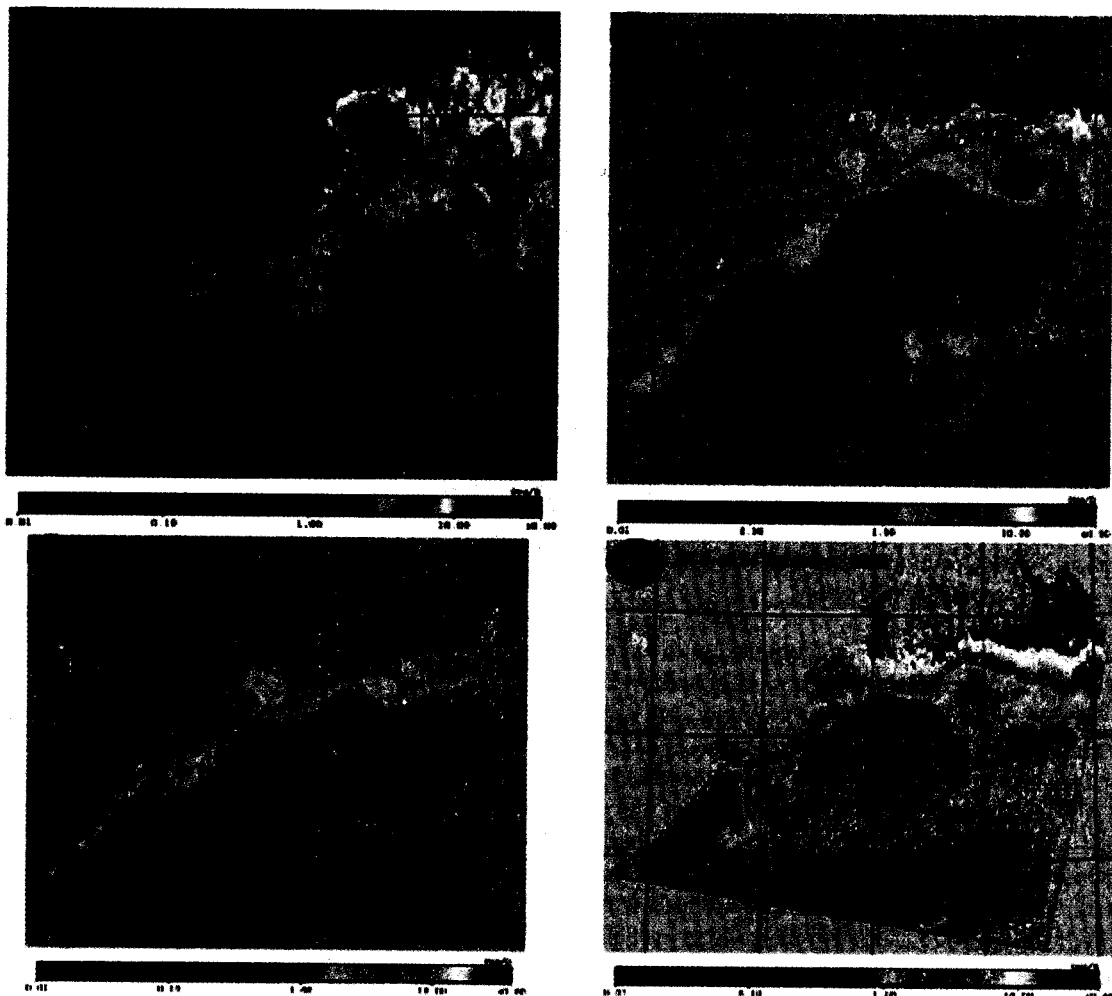


Fig. 1. False color composite of northern Bay of Bengal. Note formation of curl in November 1999 FCC.

reduced width of turbid waters in the coastal belt. In an enclosed bay like feature (located between Dhamara river in the south and Sand Head in the north) there is the least concentration of the suspended sediments, and therefore, this area appears to have least possibility for the deposition of fine terrigenous detritus discharged by either the Ganga-Brahmaputra or the Dhamara river. To confirm this hypothesis, we have determined mean grain size of 12 grab samples from this area. The grab sediment samples have mean grain size $M_z > 2 \phi$, with < 5 per cent of fine detritus (size $< 4 \mu\text{m}$). These results corroborate the inferences derived from the FCC that the area is rather unsuitable for the deposition of fine detritus.

From the sequential analysis of imagery of 8-14 November 1999 we have also archived short span temporal and spatial variation in the dispersal patterns of the suspended sediments. The imagery of 10 November 1999 shows turbid water extending farther southwards off the Sand Head. In subsequent imagery, we observed augmented turbid coastal waters in the areas around the river Dhamara extending farther along the Orissa Coast. We deduce strong teleconnection between the higher sediment discharge of the Ganga-Brahmaputra and occurrence of the plume of turbid water all along the Orissa Coast and further southwards. The subsequent image of 14 November 1999 suggest shifting and confinement of suspended sediments onshorewards. From the above results, it is apparent that increased discharge of the Ganga-Brahmaputra also feeds the coastal sediment plumes off Orissa and these sediments are transported for the long distances in a short span of one week. These results point to the fact that the short term augmented discharge of the Ganga-Brahmaputra moves alongshore and sink in the shallow coastal stretches rather rapidly off southern Orissa and Northern A.P.

An enhanced suspended plume of the Ganga-Brahmaputra (as seen the imageries of 12-14 November, 1999) also appears to have influences over the deeper waters. Off Sand-Head, with the influx of the sediments during the period of above observation, development of an offshore curl in the deeper waters has been observed (Fig 1B). The curl enhances with the increase in the width and concentration of the Ganga-Brahmaputra plumes (acting as feeder for the development of this feature), and then dies down rather rapidly when supply from the hinterland dwindles (Fig. 1C).

There is no significant change in the regional direction of the suspended sediment dispersal in December

1999, which by and large remains southerly to south-westerly (Fig. 1D). However, compared to November 1999 the turbid waters plume off the Sand Head flows farther offshore (for about 40 km). Off Chilika Lake, we have also observed a conspicuous feature extending for over 50 km (Fig. 1D). This feature depicts across shelf dispersal of sediments to the deeper offshore region, disrupting the southwesterly alongshore dispersal of the sediments contributed into this area from the Ganga-Brahmaputra source.

From these preliminary results, it is deduced that the suspended sediment discharge of the Ganga-Brahmaputra system influences the coastal processes with higher temporal and spatial variability along and across the continental margin of Orissa and Andhra Pradesh. The sequential analysis of higher resolution FCC (2 days repeatability) is expected to further document short-lived regional changes in the dispersal patterns in the bay to understand and identify the source to sink mechanism for the land released matter, here to before poorly understood in this area.

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