National Workshop

on

Oceanographic Features of the Indian Coastal Waters

6-7 Oct 2005

Theme

Coastal Ocean Observations & Modeling

Naval Physical & Oceanographic Laboratory,
Min. of Defence, DRDO,
Thrikkakara PO, Kochi-682021

Synoptic analysis of chlorophyll_a, suspended sediment and coloured dissolved organic matter during non-monsoon period in Mandovi Zuari estuarine system of Goa, India, through IRS P4 Ocean Colour Monitor

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Abstract

Simultaneous acquisition of water samples, radiance and irradiance measurements were carried out from 40 stations in the Mandovi Zuari estuarine system during February to May 2002. From the samples collected, both inherent and apparent optical properties (IOP and AOP) such as absorption coefficient "a", upwelling diffuse attenuation coefficient "k_u" and subsurface reflectance "R" were derived. Using these optical properties, radiative transfer at each water column was examined. On the basis of the radiative transfer outcome, band-ratio algorithms were derived for three optically active substances (OAS), chlorophyll_a, suspended sediment and coloured dissolved organic matter (CDOM). For chlorophyll_a the band-ratio algorithm is 670/555 nm, sediment it is 490/670 nm while for CDOM it is 412/670 nm. These algorithms were applied to Ocean Colour Monitor (OCM), flown on Indian Remote Sensing Satellite (IRS) Polar Satellite Launch Vehicle (P4), scenes (digital data), to synoptically analyze the constituents.

1. Introduction

Estuarine environment is characterized by dynamic water bodies of different temporal changes that occur due to hourly (tide) to seasonal variations (river discharge). This spatial heterogeneity of the water column is further augmented by change in the depth and width of the estuary. To monitor such changes of varying time scales due to tidal advection, dispersion and resuspension in an estuarine environment, synoptic analysis is imperative. This could be accomplished through optical remote sensing.

The general estuarine dynamics is exemplified by the need for better understanding of mechanism that control the water quality of the area of study, Mandovi Zuari estuarine system. The system is under strong anthropogenic influence due to transportation of iron ore, as a part of mining industry, through these estuaries. Hence the seepage of iron ore from the barges, carrying ore, completely alters the water quality and the photic zone. This is being augmented by the sediment flux from mining dumpsites through seasonal rain. Therefore an attempt was made to retrieve ocean colour components from the estuarine system through optical remote sensing, as this may be a valuable tool for monitoring the long term ecological consequences due to anthropogenic activities in the estuarine system.

2. Method

The waters in the estuarine system being highly optically complex, retrieval of chlorophyll_a, suspended sediment and CDOM through OCM is possible only by applying site specific algorithms developed through the analysis of hyperspectral water leaving radiance in the optical range (400 nm 700 nm) of Electromagnetic radiation (EMR). The hyperspectral water leaving radiance could be generated either using an in-water radiometer having hyperspectral bands or through radiative transfer analysis at different stations. In the present case the second approach was adopted. To carry out the radiative transfer analysis, the inherent optical properties (IOP) and apparent optical properties (AOP) of each water column represented by different stations were generated through water sample analysis. Details are given in Menon (2004) and Menon et.al (2005)

The procedure in identifying the wavelengths to develop band ratio algorithm to retrieve OAS from OCM are given below. The first step was to select a station with minimum concentration of OAS so that spectral radiance leaving from this station could be the base line spectrum. Hence water leaving radiance corresponding to station 7 sampled on 13th May 2002 was taken as baseline spectrum. Subsequently water leaving radiances were computed for different concentrations of chlorophyll_a within the acceptable range prevailing in the estuarine system (Mandovi and Zuari) during pre-monsoon season. While doing this it was assumed that concentration of sediment and CDOM (a_y 440) were not varying. Then each hyperspectral radiance was divided by the base line spectrum. This has resulted in the identification of wavelength having the least and maximum absorption by chlorophyll_a in the optical spectrum. Similarly by assuming chlorophyll_a and a_y (440) constant, hyperspectral radiances were computed for different concentrations of sediment prevailing in the estuarine system during pre-monsoon. Then each hyperspectral radiance was divided by the baseline spectrum to identify wavelengths having differential absorption characteristics due to change in sediment concentrations. The same procedure was repeated in the case of a_y (440). Thus the analysis revealed that wavelengths suitable to retrieve chlorophyll_a are 555 nm and 670 nm, for sediment 490 nm and 670 nm while for CODM 412 nm and 670 nm respectively. The band ratio algorithms are shown in Fig. 2. The respective algorithms are

1. Chlorophyll_a = $5.5931 R_1^{0.615}$

   Where $R_1 = L_w 670 / L_w 555$

2. $a_y(440) = 2.9393 R_2^{-2.2486}$

   Where $R_2 = L_w 412 / L_w 670$

3. Suspended sediment = $17.11 R_3^{-0.3596}$

   Where $R_3 = L_w 490 / L_w 670$

4. Results and discussion

Using the algorithms developed, four satellite scenes (satellite data) were processed. These were 8th January 2003, 14th January 2003, 14th February 2002 (Fig. 3), and 24th May 2003. These scenes were chosen to show the ability of the algorithms in retrieving OAS during different hydrodynamics of the estuary prevailing in different non-monsoon periods. The studies on the hydrography and circulation made by Murthy and Das (1972), Verma et al. (1975), Qasim and Sengupta (1981) revealed that estuaries behaved like a mixed one / homogeneous during pre monsoon, partially mixed during post monsoon and salt wedge type during monsoon. Hence they were tidally dominated during pre-monsoon, tide and fresh water influx control them during monsoon and post-monsoon seasons. Therefore January data were chosen as a representative of the estuarine water quality during the final stages of post-monsoon, February to represent the initial stages of pre-monsoon and May the final stages of pre-monsoon season. Another reason for choosing these scenes were to show the ability of the algorithms in retrieving OAS during non-monsoon seasons of any year in addition to the period of in-situ observations used for algorithm development. In general the OCM derived products and in-situ observations are in good agreement and are in the same range . A graphical representation of validation is given in Fig. 4. Though good correlation was observed for all the constituents, an offset was seen in the case of chlorophyll_a and sediment. The offset was on the axis where satellite derived values were taken. For validation, all the available data (chlorophyll_a and sediment) published so far from the area were considered. As some of the data were from the midstream of the estuary, where the width of the estuary was less than 1 km (the resolution of the sensor is 360 X 250 m), selecting corresponding pixel of the in-situ observation from OCM imagery would result in an erroneous value as the water leaving radiance would be entangled by the radiance from land. Therefore to correlate those in-situ data, pixels were not considered corresponding to the station positions rather from the adjacent area where the width of the estuary is around 1 km (three times the resolution of the sensor) or more. This resulted in the offset. As there were no published data on CDOM from the area, these values were derived during separate field surveys. Hence no offset was seen in this case. In the paper, the imagery corresponding to 14th Feb 2002 is presented.

Acknowledgment

The first author HBM is thankful to Indian Space Research Organization (ISRO), Bangalore for the project sanctioned "algorithm development" under the national programme IRS P4 OCM. He is also thankful to ISRO for the grant-in-aid project sanctioned to set up a Remote Sensing Laboratory in the University.

References

Menon, H. B. 2004. Calibration of an optical equation to analyze the atmospheric turbidity and water quality of an estuarine environment. Photonirvachak, Journal of Indian Society of Remote Sensing, 32, 287 - 300.

Menon, H.B., Lotliker, A., Nayak, S.R. 2005. Pre-monsoon bio-optical properties in estuarine, coastal and Lakshadweep waters. Estuarine, Coastal and Shelf Science, 63, 211-223

Murthy, C. S., Das, P. K. 1972. Pre monsoon tidal flow characteristics of Mandovi estuary. Indian Journal of Marine Science, 1, 220 225.

Qasim, S. Z., Sen Gupta, R. 1981. Environmental Characteristics of the Mandovi Zuari Estuarine system of Goa. Estuarine, Coastal and Shelf Science, 13, 557 578.

Verma, K. K., Rao, L. V. G., Cherian, T. 1975. Temporal and spatial variations in hydrographic conditions of Mandovi estuary. Indian Journal of Marine Science, 4, 11 17.

Legends to figure

Fig 1. Study area showing the different station positions (stn1 stn 10). Dotted lines indicate depth contours.

Fig 2. Correlation between

a) Chlorophyll_a concentration and the ratio of water leaving radiance at 670 (L_w670) and 555 nm (L_w555) bands.

b) Sediment concentration and the ratio of water leaving radiance at 490 (L_w 490) and 670 nm (L_w 670) bands.

c) Absorption coefficient due to CDOM at 440 nm (a_y(440)) and the ratio of water leaving radiance at 412 (L_w

412) and 555 nm (L_w 555) bands.

Fig 3. Synoptic distribution of a) chlorophyll_a, b) suspended sediment and c) a_y440 on 14th February 2002

Fig 4. Correlation between satellite derived and in-situ values of

a) chlorophyll

b) suspended sediment

c) absorption due to CDOM at 440 nm

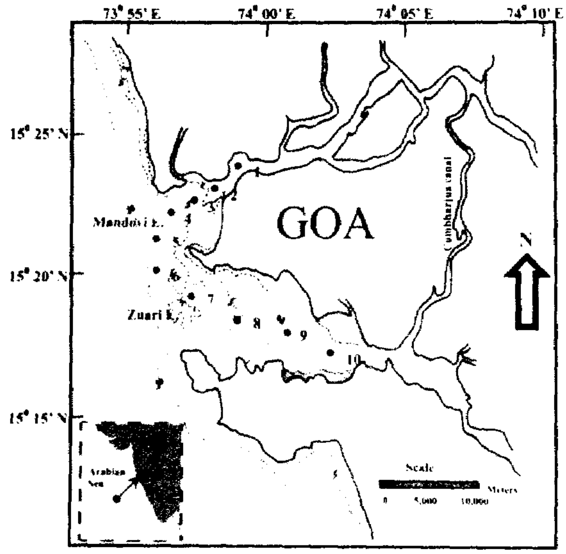

Fig. 1

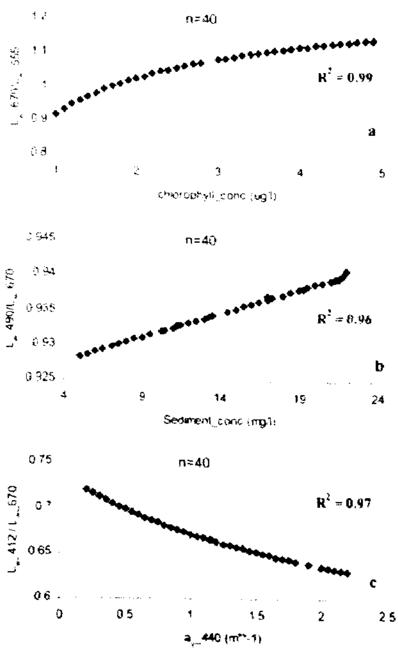

Fig. 2

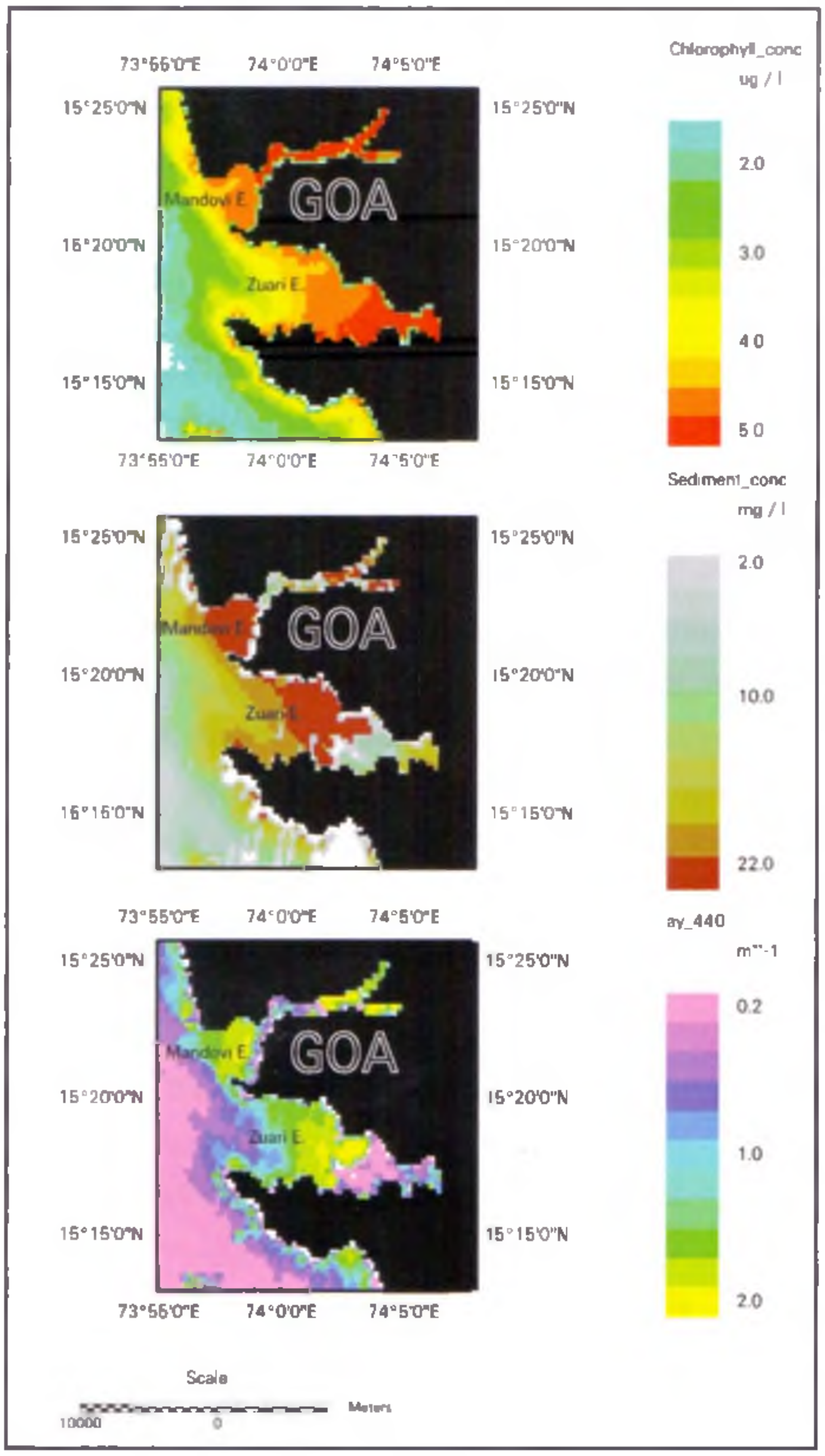
Chlorophyll_conc
ug / l
2.0
3.0
4.0
5.0
Sediment_conc
mg / l
2.0
10.0
22.0
ay_440
0.2
1.0
2.0
GOA
Mandovi E.
Zuari E.
73°55'0"E
74°0'0"E
74°5'0"E
15°25'0"N
15°20'0"N
15°15'0"N
Scale
10000
0
Meters

Fig. 3

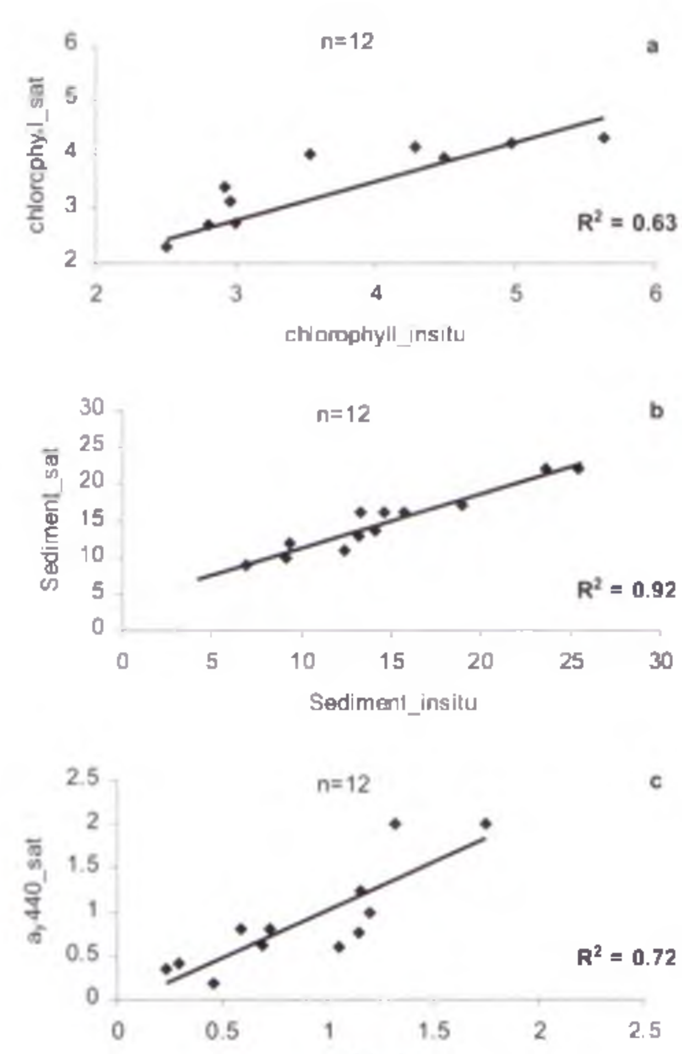
n=12
a
chlorophyll_sat
chlorophyll_insitu
R^2 = 0.63
n=12
b
Sediment_sat
Sediment_insitu
R^2 = 0.92
n=12
c
a_y440_sat
a_y440_insitu
R^2 = 0.72

Fig. 4