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RESEARCH ARTICLE

Comparison and Validation of Top Of Atmosphere (TOA) Radiance of Oceansat-2 OCM Sensor

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ABSTRACT

This study involves comparison and validation of Top Of Atmosphere (TOA) radiance of OCEANSAT-2,OCM sensor derived from 6S radiative transfer model with insitu TOA. The 6S is to derive total radiance (Lt), by applying suitable atmospheric corrections, to remove the errors occurs due to gaseous absorption and molecular & aerosols scattering effects suggested by (T.Suresh, 2006). The in-situ measurements were taken coastal water off Goa, (15° 25 N and 73° 43 E). The in-situ instrument called hyperspectral Radiometer is used to measure the geophysical parameters which proves an significant improvement for comparison with derived OCM2 ocean color data products, (e.g., pigments, suspended sediments, CDOM, chlorophyll etc). The TOA radiances for all bands determined using 6S are found to be well correlated with the TOA radiances extracted from the L1B_GAC data of OCM2 are described in the following graphs. The total radiance (Lt) derived from OCM-2 is found to be under estimated and overestimated for particular spectral bands. Such small differences are in the first two wavelength bands, especially 412 nm and 443nm, occur quite often and are reasonable, are shown in the perspective graphs. Statistics analysis of Coefficient of Determination (R^2) and Root Mean Square Error (RMSE) provides numerical analysis, perform a graphical criteria such as an indication on the non-linear behavior of the fit. The RMSE value obtained from the sampling points are 17.96, 11.10, and 9.20 respectively. Similarly a R^2 value obtained from the sampling points are 0.883, 0.875, and 0.849 respectively. Thus TOA is made for comparison and validate for chlorophyll estimation. Due to the small number of data points the significance of the comparison with the in-situ data is limited. Nevertheless, the validation of OCM2 data is clearly positive. Thus the data analyses in this study provide an important baseline for optical information of the coastal waters off the Goa.

INTRODUCTION

Oceanic water have been commonly classified as case I (Deep sea) and case II waters (Coastal) by (Morel and Prieur, 1977; Gordon and Morel, 1983). We are concern towards case II (Coastal) water off Goa which is the place surrounded by many islands. So far case II water often not accurate, due to poor performance of standard algorithm. In order to rectify these changes, the bio-optical algorithm gets performed under simulation technique using an empirical formula. This phenomenon is carried out to validate the TOA of Oceansat 2 OCM satellite sensor (Here after it is called OCM 2). The water leaving radiance plays an important role in the ocean color remote sensing, as the spectral values of the water leaving radiance of the ocean provide information about the constituents of the water column [T Suresh, 2006]. In this study the bio-physical and in situ hyperspectral (Satlantic) optical data were measured, in the coastal water off Goa, (15° 25 N and 73° 43 E).

MATERIAL AND METHODS

The In-situ data used for the 6S simulation of the satellite signals from the solar spectrum are water leaving radiance (Lw), is derived from Satlantic Hyperspectral Radiometer (HyperOCR). The field measurements were taken in Coastal water off Goa (15° 25 N and 73° 43 E). The water leaving radiance values are obtained from processing the radiometer data by using the proprietary software Prosoft 7.7. The average of the wind for the period 1000 to 1400 hrs local time provides the wind speed, wind direction and salinity from CTD are casts at the NIO, Goa. All data were mostly collected around noon time to secure a high sun zenith angle and when the ship was stationary to avoid white caps in the sensors' fields of view. To derive OCM2_GAC data, the image analysis software, SeaDAS version6.1 (developed in-house module by National Institute of Oceanography (NIO), Goa is used.

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Study Area

The study area involves Coastal water off Goa having a latitude and longitude of (15° 25 N and 73° 43 E).

TOP OF ATMOSPHERE (TOA)

The bio-optical properties involve inherent optical properties and apparent optical properties which gives absorption and scattering coefficients and spectral response of Ocean water. The Top of atmosphere is an amount of light directly emits from sunlight and reaches the earth surface. It may depend on atmospheric corrections such as aerosols, water leaving radiance, absorption and back scattering coefficients. These can be defined by,

$$\rho_{\mathrm{TOA}}(\theta_s, \theta_v, \phi_s - \phi_v) = Tg(\theta_s, \theta_v)\left[\rho_{R+A} + T^{\downarrow}(\theta_s)T^{\uparrow}(\theta_v)\frac{\rho_s}{1 - S\rho_s}\right]$$

Table 1. OCEANSAT 2 – OCM channel characteristics

Band no	Wave length (nm)	*Typical Use*
1	402-422	Yellow substance & turbidity
2	433 – 453	Maximum Chlorophyll absorption
3	400 – 500	Chlorophyll absorption
4	500 – 520	Chlorophyll absorption
5	600 – 680	Suspended sediments
6	600 – 680	Secondary Chlorophyll absorption
7	745 – 785	Oxygen absorption
8	845 – 885	Aerosol optical thickness

The Total atmospheric radiance (TOA) is derived from OCM 2 involves water leaving radiance derived from the in-situ measurements and from OCM-2 as well. The earlier reports on bio optical algorithms said that under and over estimation of OCM-2 total radiances, speculated as arising from variable errors when correcting atmospheric effects in coastal regions [Antoine *et al.* (2008) Park *et al*. (2006), Bailey and Werdell (2006)]. These errors are produced most probably by gaseous absorption and through molecular aerosols and scattering effects from sea water constituents. In the current study optical data sets from boat cruise are taken into account and thus a large variance in top of atmosphere provinces is addressed.

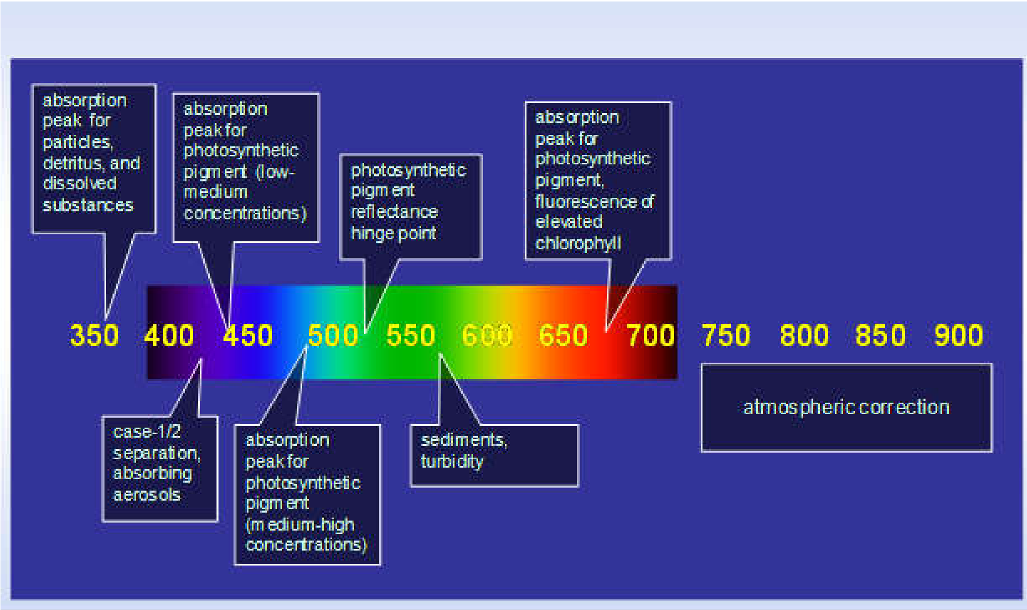


Fig.1. Spectral Characteristics of oceanic water

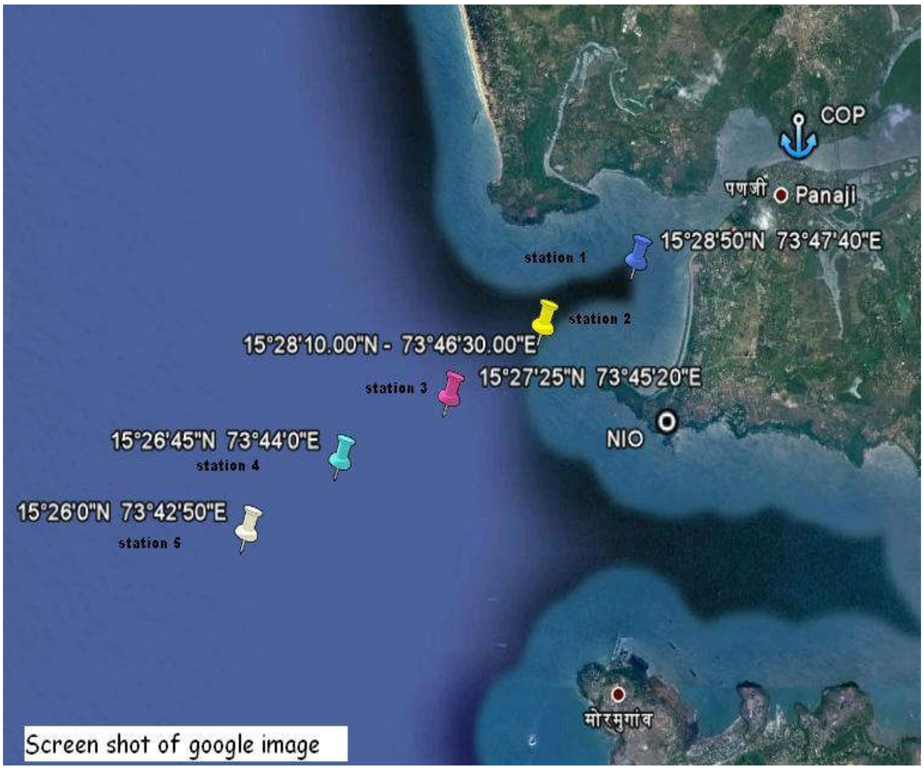


Fig. 2.1 Study area

Such provinces can be defined by comparing the optical data products.

Table 2. Data used in 6S to Estimate the Total radiance

6S_Input Parameters	Data Obtained from
Solar zenith angle	OCM_L2_GAC
Solar azimuth angle	OCM_L2_GAC
Sensor zenith angle	OCM_L2_GAC
Sensor azimuth angle	OCM_L2_GAC
Aerosol optical thickness(AOT)	sun photometer
Wind speed(Ws)	NIO
Wind direction(Wd)	NIO
Salinity(Sal)	YSI-CTD
Chlorophyll-a(Chl)	OCM_L2_ GAC & Measured
Lw - Band 412	OCM_L2_GAC & Measured
Lw - Band 443	OCM_L2_GAC & Measured
Lw - Band 490	OCM_L2_GAC & Measured
Lw - Band 510	OCM_L2_GAC & Measured
Lw - Band 555	OCM_L2_GAC & Measured
Lw - Band 620	OCM_L2_GAC & Measured
Lt - Band 412	OCM_L2_GAC
Lt - Band 443	OCM_L2_GAC
Lt - Band 490	OCM_L2_GAC
Lt - Band 510	OCM_L2_GAC
Lt - Band 555	OCM_L2_GAC
Lt - Band 620	OCM_L2_GAC

SEADAS WITH OCM

To derive OCM2_GAC data, the image analysis software, SeaDAS version6.1 (developed in-house module by National Institute of Oceanography (NIO), Goa is used. The SeaWiFS Data Analysis System (SeaDAS) is a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.The primary functionalities of Seadas6.1 is to process OCM2_GAC data from L1B data to L2 data products. SeaDAS6.1 is currently available for Linux platform, and also runs with VM-ware virtual appliance on Windows platform. The Ocean Color Monitor (OCM) provides radiance measurements in eight visible and near-infrared bands with higher spatial resolution.

6S ALGORITHM

6SV1.1- Simulation-Second Simulation of Satellite Signal in the Solar Spectrum Vector Version-1 The 6S is a Radiative Transfer code predicts the satellite Signals from **0.25** to **4.0** micron, the main atmospheric effects such as, Gaseous absorption by water vapour, CO_2, O_2, Ozone, and Scattering by molecules and Aerosols are considered [T.Suresh,(2006)]. It requires, input parameters namely, wind speed, wind direction, salinity, azimuth and zenith angles for both solar as well as sensor, aerosol optical thickness (AOT), chlorophyll, water leaving radiance (Lw), total radiance(Lt) has to derived from in-situ data and from OCM2 data as well.

The 6S acquires following features

- The 6S code is a basic RT code used for calculation of MODIS atmospheric correction algorithm.
- To run OCM-2 data the Radiative Transfer code is modified by generating empirical models
- Since OCM-2 data having spectral characteristics has been changed in Band 6&7 will give optimal result when compared to OCM1.
- Then the extracted actual Total radiance (Lt) value from OCM-2 and Lt value measured from 6S, is made for comparison. Though water leaving radiance Lw is used as input in 6S to examine the exact measurement of Lt
- These relationships now are used to calibrate satellite sensor with similar bands, by calculating the TOA radiance from 6S and satellite sensor as well.
- The Validation is mainly to compare the total radiance (Lt) from OCM-2 and the total radiance (Lt) derived from 6S made same, which is to estimate the chlorophyll.

METHODOLOGY

The RMSE analysis provides useful information of the accuracy between model and *in-situ* data. The RMSE statistics for the comparison of the two algorithms was generated using the following formula.

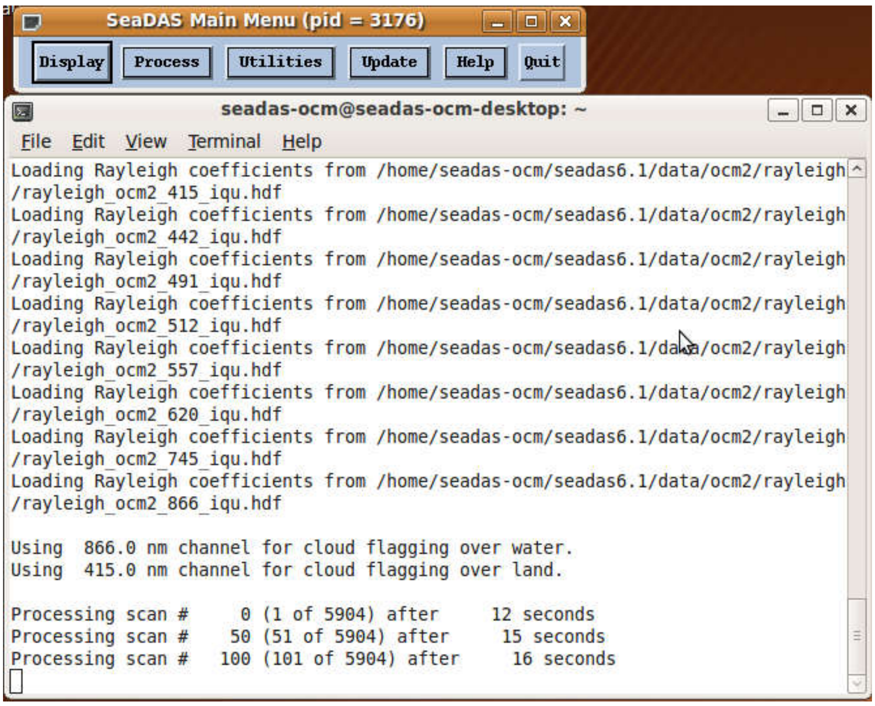


Fig. 2.2. Screen SHOT of data processing in SeaDAS 6.1

$$RMSE = \sqrt{\frac{N\sum(\log(C_{i\ \mathrm{mod}\ ...}) - \log(C_{i\ \mathrm{means}})^2}{n}}$$

Where C*i is* chlorophyll-a concentration for a point / station i, and n is the total no of stations in the data set. The performances of the algorithms were evaluated on the basis of a standard evaluation criterion suggested by (Chauhan *et.al* 2002), (P. V. Nagamani 2007), Madhavan (2012) which states that Coefficient of Determination (R^2) should be more than 0.80 and RMSE error should be less than 0.185.

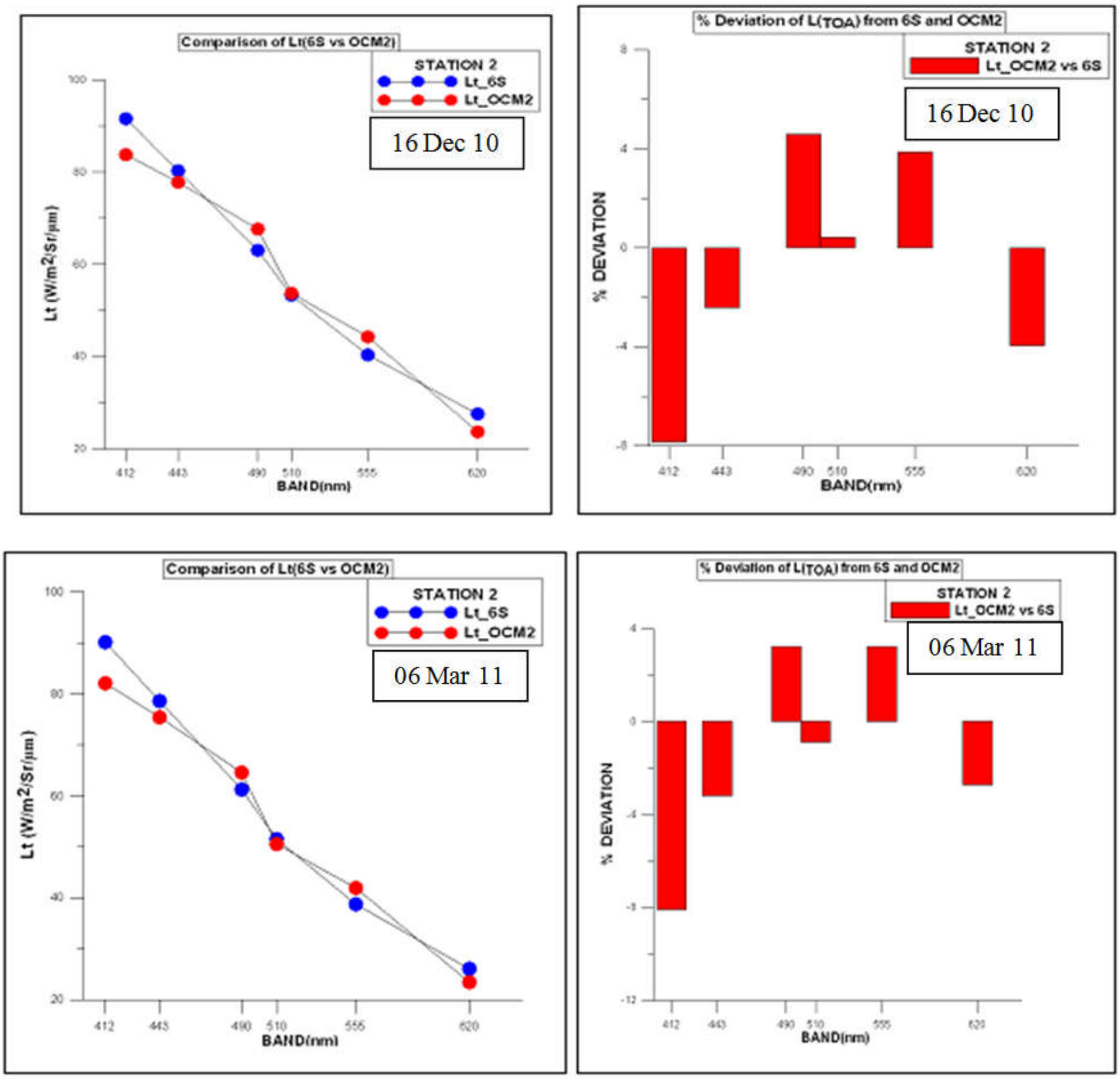
RESULTS

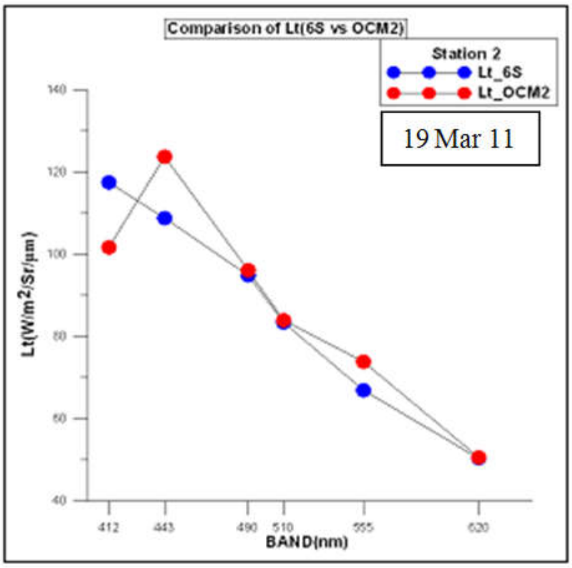
The In-situ instruments such as Hyperspectral Radiometer, Microptops Sun Photometer were used to measure the geophysical parameters such as Total radiance, water leaving radiance, aerosol optical thickness (AOT). In which the In-situ dataset was collected for the period of 8 sampling days. These output values are made for comparison of TOA from 6S and from Oceansat 2, OCM derived. The RMSE values obtained from the sampling points (16.Dec.10, 11.Mar.2011, 19.Mar.2011) were such as 17.96, 11.10, and 9.20 respectively.

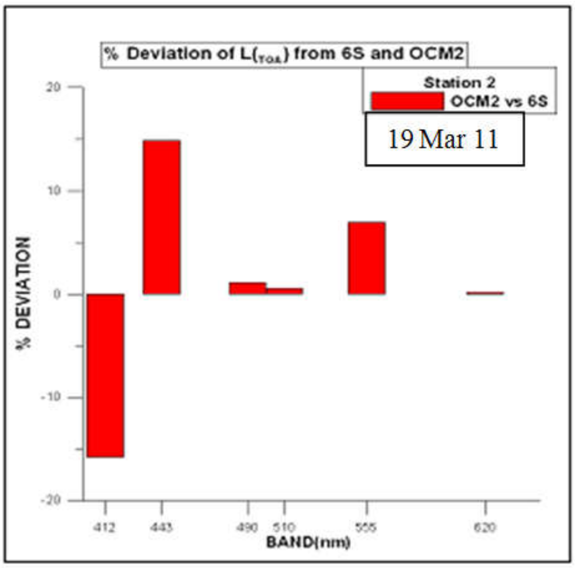
Table 3.

16.12.2010			06.03.2011			19.03.2011		
BAND	6S_Lt	OCM2_Lt	BAND	6S_Lt	OCM2_Lt	BAND	6S_Lt	OCM2_Lt
1	99.285	101.83	1	110.008	101.9989	1	117.501	101.7489
2	88.64	121.17	2	100.567	123.2544	2	108.895	123.7656
3	71.999	91.9	3	85.537	94.0172	3	94.975	96.0587
4	60.761	76.54	4	74.101	80.524	4	83.403	83.9546
5	45.629	59.68	5	58.113	64.5717	5	67.007	73.1017
6	31.094	36.58	6	42.267	39.8921	6	50.42	50.5949
RMSE	17.96			11.10			9.20	
R^2	0.883			0.875			0.849	

Table 4 showing comparison graph (6S vs OCM2) and its percentage deviation







Similarly a R^2 value obtained from the sampling points (16.Dec.10, 11.Mar.2011, 19.Mar.2011) were such as 0.883, 0.875, and 0.849 respectively. The results shows that, TOA derived from 6S and OCM 2 dataset is well correlated with middle wavelength bands than the shorter wavelength bands. The corresponding comparison graph and its percentage of deviation is shown below in the following Figures. The Estimation of chlorophyll from (Oceansat-2_OCM_GAC satellite dataset) shown in the Fig 3.2, 3.3, 3.4 respectively.

The flow diagram shows the methods adopted for comparison of Total radiance (Lt),

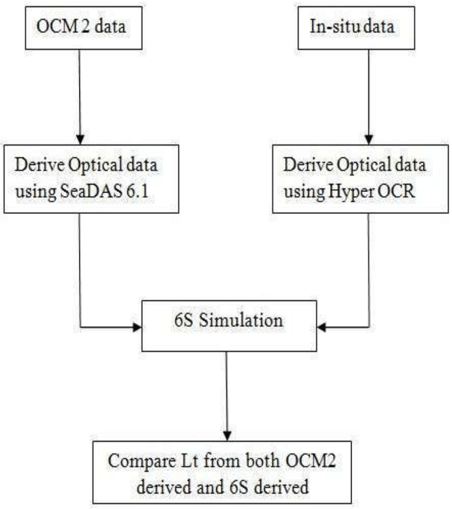


Fig. 2.4 Methodology chart

DISCUSSION

The 6SV1.1 an Radiative Transfer Model developed for atmospheric correction in MODIS data products and it effects on two processes namely absorption and scattering, Eric.F.Vermote (2006). In this study, the 6S algorithm is modified to derive Oceansat-2 OCM bands (built by Marine Instrumentation Division, National Institute of Oceanography, Goa). The linear relationship between the TOA radiance of all bands of OCM2 and derived TOA radiance value through 6S shows some relative changes. The TOA radiance derived from OCM2 are found to be overestimated and under estimated for particular spectral bands are due to atmospheric effects, that could be a failing while undergo atmospheric correction [Theis *et al*. (2008), Antoine *et al*. (2008), Bailey and Werdell (2006) and Park *et al*. (2006)]. A large noise in shorter wavelengths indicates errors by

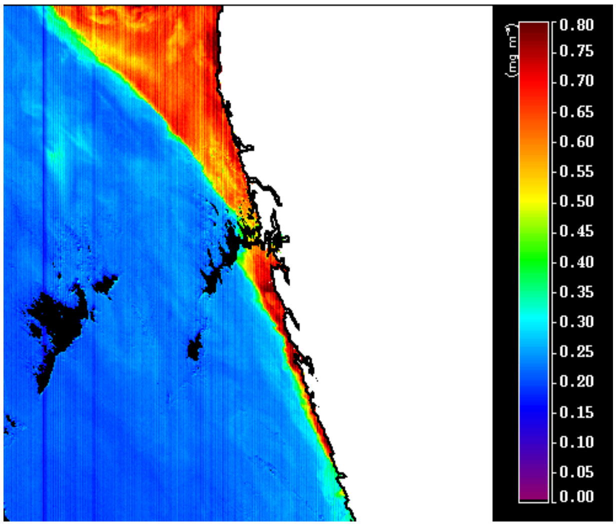


Fig 3.2: Chlorophyll a obtained from OCM2_**16 Dec_10**

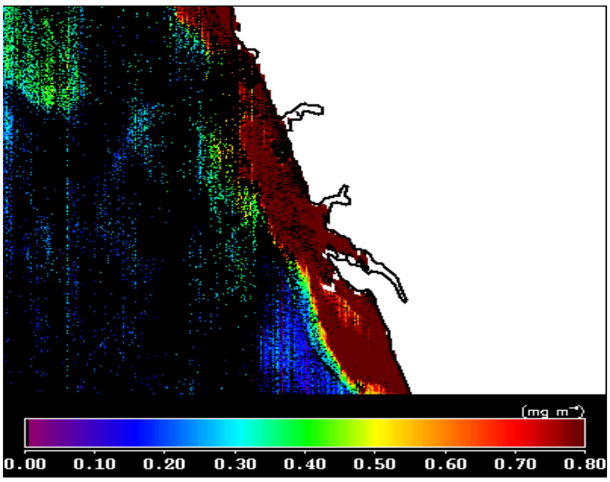


Fig 3.2: Chlorophyll a obtained from OCM2_**16 Dec_10**

atmospheric correction was already discussed by[Antoine *et al*. (2008)]. The atmospheric correction strongly relies on the correct assessment of absorbing aerosols in the atmosphere. An incorrect estimation of the aerosol amount and distribution will affect the retrieval of water leaving radiance.

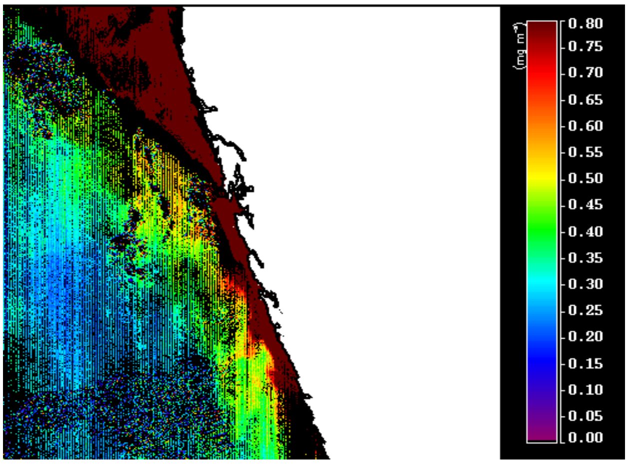


Fig 3.4: Chlorophyll a obtained from OCM2_**19 Mar_2011**

In this study, also discrepencies occured in the OCM2 datasets (16.Dec.10, 11. Mar. 2011, 19.Mar. 2011). This effect is more severe in the shorter wavelength bands than for larger wavelength bands. Such large differences in the first two wavelength bands, especially 412 nm and 443nm, due to the presence of sediment deposition the scattering occur quite often and are reasonable under this perspective. The cross calibration of SeaWiFS sensor and OCM sensor provides equivalent result of TOA radiance made comparison with 6S, results shows RMSE value of 0.28 and 0.26 respectively T.Suresh (2006). The TOA reflectance is less in shorter wavelength bands, because in the scattering light, the spectral characteristics is high at blue band and low at red band I.Ketut Swardika (2007). The middle spectral bands such as 490nm, 510nm and 555nm to improve the chlorophyll estimation, S.R. Nayak (2001) In this study, the TOA radiance is found well correlate in middle spectral bands such as 490nm and 510 nm, than the shorter wavelength bands is shown in comparison graph in Table 4 respectively. Thus the Top of Atmosphere radiance (TOA) is derived with a helps of other geo-physical parameters such as water leaving radiance, remote sensing reflectance, which improves better result for the chlorophyll absorption. The result obeys the following equation,

$$L_t = L_w + L_{\text{atmosphere (AOT)}}$$

Conclusions

The Oceansat 2 OCM sensor is the only ocean color satellite sensor with higher pixel resolution 1km is available for tremendous application in monitoring the optical properties. Simulation by radiative transfer model 6S, which has been used for validation of various satellite sensors and other applications, is used here to obtain the TOA radiance from the OCM2 sensor. The comparison of $L_{(TOA)}$ Top of Atmosphere is made for validation. The comparison provides an closer agreement between the spectral bands from the 6S derived and OCM2 derived for the satellite validation. Thus the data analyses in this study provide an important baseline for optical information of the coastal waters off the Goa. Due to the small number of data points the significance of the comparison with the in-situ data is limited. Nevertheless, the validation of OCM2 is clearly positive.

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