



Assessing the difference between in-situ measurement and remote sensing data of chlorophyll a concentration and TSM in the mangrove waters of West Bengal, India

Chumki Chowdhury*

Department of Botany, Jangipur College, Jangipur, Murshidabad, West Bengal, India

Abstract

A comparative study was conducted between in-situ spectrophotometric analysis of concentration of chlorophyll a and remote sensing data to understand the conflict of data interpretation in two methods. Total Suspended Matter (TSM) was another selected parameter for water quality assessment in coastal and estuarine region which influence the Chlorophyll a concentration indirectly, henceforth was considered to be compared in the same way. *In-situ* concentrations and remote sensing data varied greatly in the mangrove waters in Indian Sunderban due to different causes. Limited sample size and lack of continuous sampling in in-situ study might be an important cause for the mismatch of data while high surface turbidity might prevent the sensor or board the satellite from working efficiently. To use both the method simultaneously, the algorithms are needed to be improved along with betterment in the sampling process and analysis in *in-situ* methods.

Keywords: Chlorophyll a, TSM, Remote Sensing, Coastal waters, Mangrove, Indian Sunderban

Introduction

Indian Sunderban is well known for its dynamic and unique ecosystem, and composed of community of estuaries, tidal inlets, river streams, and islands. The Sunderban ecosystem is one of the most vulnerable with respect to climate change. The nutrients from mangrove litter and freshwater river discharge enriches the ecosystem. Mangrove is one of the biggest protecting system of east coast of West Bengal and gives sustainability of this ecosystem ensuring livelihood of many people living in surrounding areas. So, it is important to monitor the ecosystem regularly. Chlorophyll content and total suspended matter (TSM) are two indicators of the health of estuarine and coastal environments for guiding environmental management decisions, and evaluating climate change impacts (Chowdhury *et al*, 2024)^[3]. Water quality monitoring in the stations with dense vegetation is sometimes difficult due to cost factor. Therefore, there should be an alternative way to estimate the water quality with a smaller number of stations. Chlorophyll-a (Chl-a), nutrient, and Total Suspended Matter (TSM) are the Optically Active Substances (OAS) in the ocean water column (Parida *et al*, 2019)^[6]. Anthropogenic activities in coastal waters may change the concentration of chlorophyll -a, Total suspended matter (TSM) and can degrade the water quality. Excess nutrient may cause algal blooms and increased suspended matter in water.

The biological processes in the coastal seas are mainly controlled by the phytoplankton-tiny microalgal community which is responsible for primary production in water. Chl-a is the dominant light harvesting pigment in phytoplankton and widely considered as proxy of phytoplankton biomass. TSM/TSS mainly represents the inorganic suspended material such as silt, decaying plant part, animal debris, and waste in the water column and is a main OAS due to role in light attenuation. TSM concentration is another considerable parameter to evaluate the water transparency hence light attenuation in water column. As researches and sampling are limited to a specific area and time, we can use Remote Sensing that is very helpful tools so combination of the in-situ and Remote Sensing data can be helpful to get a good result. Remote sensing data is a large-scale observation and processed with high quality sensor. This study investigated

the chlorophyll a and TSM concentration in some selected stations in coastal waters of West Bengal.

Methods

Chlorophyll a was measured in the laboratory by spectrophotometric method. Total suspended solid in the water were measured by deducting the dry weight of filter paper with TSM from wet weight of filter paper containing TSM. Chlorophyll a concentration was expressed in mg/m³ and TSM was measured in mg/l. Statistical analyses were done by using Minitab software.

Remote sensing process: Data were downloaded from Copernicus Open Access Hub to conduct this study. The Copernicus Open Access Hub which previously known as 'Sentinels Scientific Data Hub' that provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products (Fernández *et al*, 2022)^[2], starting from the In-Orbit Commissioning Review (IOCR). The Sentinel-3 is an Earth observation-heavy satellite series developed by the European Space Agency as part of the Copernicus Programmed (Apicella *et al*, 2022)^[1]. It currently consists of 2 satellites: Sentinel 3A and Sentinel-3B. Sentinel-3 products are distributed in the Sentinel-Standard Archive Format for Europe (SAFE) format, including image data in NetCDF4 format and metadata in xml format. The main objective of the Sentinel-3 mission is to measure sea surface topography, sea and land surface temperature, and ocean and land surface color with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. The Sentinel-3 Mission Guide provides a high-level description of the mission objectives, satellite description and ground segment. It also covers an introduction to heritage missions, thematic areas and services, orbit characteristics and coverage, instrument payloads and data products. ESA and EUMETSAT jointly operate the Sentinel-3 mission to deliver operational ocean and land observation services.

The main instruments of the Sentinel-3 mission are Ocean and Land Color Instrument (OLCI), Sea and Land Surface Temperature Radiometer (SLSTR), SAR Radar Altimeter (SRAL), Microwave Radiometer (MWR) and Precise Orbit

Determination (POD) instruments. Data Product defines all data products available per instrument, such as the OLCI, SLSTR, Synergy, and Altimetry data products. The Sentinel-3A mission for 2024 was used to conduct the study. The sensor we have taken is OLCI (The Ocean and Land Color Instrument) and the processing level 1, and the data type is EFR (Earth Observation Full Resolution). Full resolution (300m) of Sentinel 3A were downloaded from the Copernicus Open Access Hub. The OLCI sensor onboard has a diverse set of 21 bands spanning a wavelength range of 400 to 1020 nm. The Sentinel-3 OLCI, is equipped with a sensor similar to its predecessor, the Medium Resolution Imaging Spectrometer (MERIS) on ENVISAT. The OLCI sensor has the capability to check the bio-optical properties in coastal and inland regions around the world. The OLCI bands are significant improvement over the MERIS as specifically designed to enhance the quality of ocean color remote sensing measurements. The sensor covers a swath of 1270 km and tilted at an angle opposite to the sun's direction to avoid the impact of solar glare. For the study, OLCI images from 2024 (January-June) were downloaded and analyzed. For the analysis, SNAP software was used. SNAP stands for Sentinels Application Platform and is a common software architecture on which a collection of free open-source toolboxes for the scientific exploitation of Earth Observation missions is available. The SNAP architecture is ideal for Earth Observation processing and analysis due to the following technological innovations, Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management, and a Graph Processing Framework. Using the Snap Software, the images were corrected for atmospheric effects. The Case-2 Regional/Coast Color (C2RCC) processor was utilized for atmospheric correction and deriving the inherent optical properties (IOP). The C2RCC processor is a processing chain that helps to recover water quality parameter like Chlorophyll-a (Chl-a) and Total Suspended Matter (TSM) (Shampa *et al.*, 2024)^[5]. For data processing, first product was downloaded from the file and then opened the RGB image by selecting the bands (8,6,4 respectively).

Then we selected the data to get the first subset product (Raster>Subset), and then we got the second subset by selecting Optical>Thematic Water Processing>C2RCC>OLCI. Then we selected second subset product to reproject by following steps Raster>Geometric>Reproject, and then selected UTM/WGS 84 20 (Automatic) from the reprojection parameter. After getting the third subset we exported the data as Geo tiff file after subsetting it again by selecting Band Subset (conc>con_chl). For TSM, same procedure was applied except the band selecting Band subset (conc<con_TSM). Thus, we got the final processed data through these processes. Then we composed our location map in ArcGIS software. In ArcGIS, using the 'extract multi values' tool, we extracted the Chl-a and TSM values. The attribute table for this layer was exported to excel sheet for further statistical analyses.

Result

In present study, the spectrophotometric analysis revealed that Chl *a* content in coastal waters ranged from 1.96-20.30 mg.m⁻³. In January, there was a significant rise in chlorophyll concentration at Station 1. It was low at all station in May and June. The lowest (1.96 mg m⁻³) concentration of chlorophyll was observed at Station 5 in June. In six months (January –June, 2024) the highest chlorophyll concentration was observed in January for all stations. The March and May had registered low chlorophyll content, as compared to the other months. From the satellite generated data, it was observed that Station 8 (22.4 mg m⁻³) had documented the high concentration of chlorophyll in June, and Station 9 (0.11 mg m⁻³) documented the lowest. For the month of March, Station 2 had the lowest (5.63 mg m⁻³) concentration and station 9 had the highest (25.36 mg m⁻³) concentration (Fig-1). The TSM value had ranged between 14.10-61.79 mg. L⁻¹ among the stations in study period. The highest value recorded from the station 2 and lowest at station 9. January had shown the lowest concentration of TSM which had gradually increased as the months progressed (Fig-2).

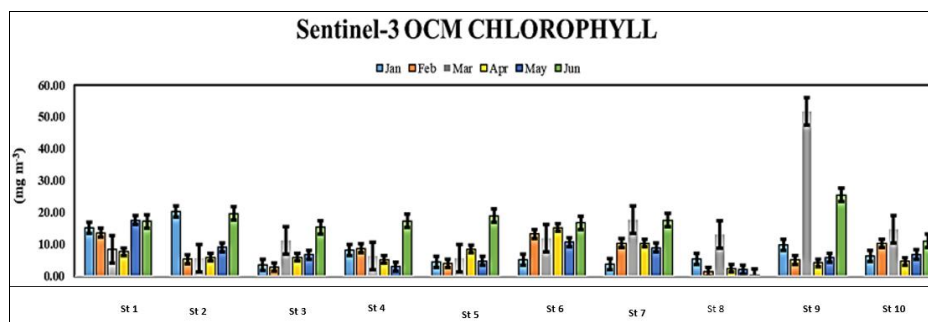


Fig 1: Chlorophyll Concentration data in different stations measured from satellite

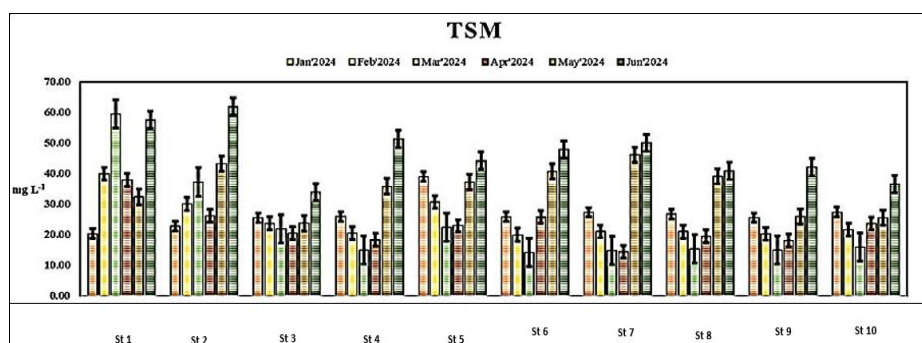


Fig 2: TSM Concentration data in different stations measured from satellite

Discussion

Concentration of Chl *a* was relatively higher in January. During post-monsoon, the North West Coast of Bay of Bengal witnessed a seasonal phytoplankton bloom with a more or less consistent pattern annually. The bloom and after bloom events contributed in chlorophyll a and TSM concentration respectively. The satellite generated data (Fig-1) of Chl *a* had a contradictory pattern with what was observed in-situ as the lowest Chlorophyll *a* value was observed in a month using OCM which was the highest in in-situ analysis. ANOVA between chlorophyll a concentration obtained from both laboratory analysis and satellite data, gave support for the anomaly. ANOVA for TSM concentration followed the same pattern. This anomaly could be attributed to the presence of high surface turbidity preventing the sensor or board the satellite from working efficiently, or the time at which the satellite swath was captured could not be practically corroborated with traversing in the selected study sites within the time frame of the orbital passing by of the satellite which meant the actual tidal regime must have shifted multiple times in comparison to the swath, which renders the verification impossible to the coincide

and support each other, based on the limited resources and dearth in synchrony.

The relationship between phytoplankton biomass and pigment content varies widely with light acclimation and nutrient status, while the fluorescence yield also varies with the physiological condition of the phytoplankton and with the type of plankton present. In both laboratory studies and in the field, researchers have observed a daily rhythm of fluorescence that is not correlated with diel changes in the concentration of chlorophyll-a during periods of high irradiance fluorescence tends to be lower than it is at night (Kampel *et al*, 2022).

The TSM consists of phytoplankton cells as well as other clastic and non-clastic particles which contributed to the ultimate suspended particulate load within the water column. It is quite understandable that the TSM pattern (Fig.2) was observed to be quite similar to the Chlorophyll *a* curve. The OCM value for TSM (Fig.4) also has registered a specifically contradictory pattern to what was observed in-situ, the explanation of which has already been stated in case of Chl *a*. Limited sample size and lack of continuous sampling in laboratory analysis might be an important cause for the mismatch of data with the satellite obtained data.

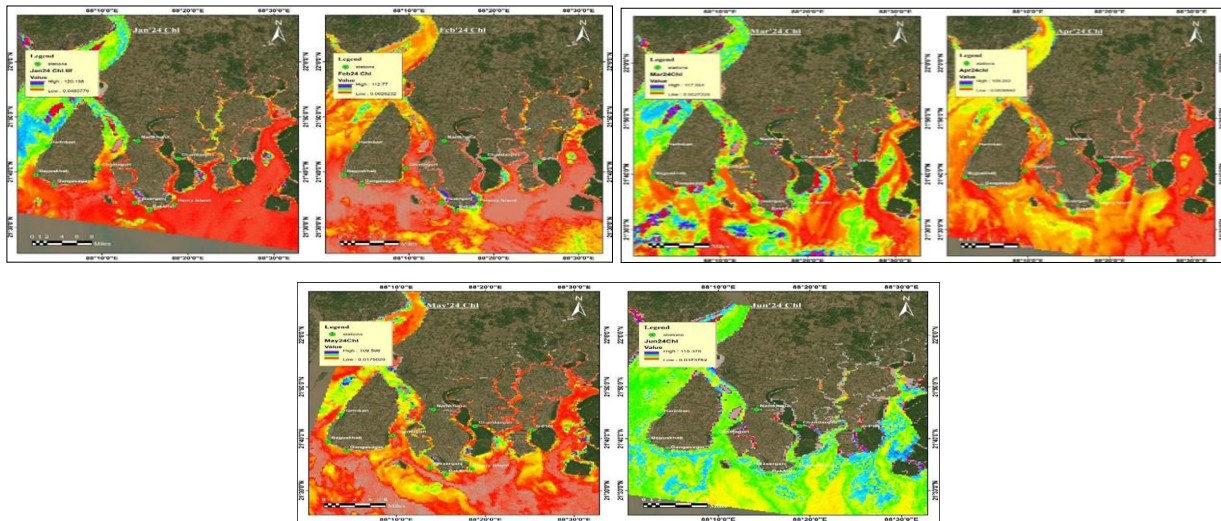


Fig 3: Mapping of Chlorophyll a concentration from OLCI image in different study stations (station 1: Harinbari, station 2: Beguakhali, station 3: Ganga Sagar, station 4: Chemaguri, station 5: Namkhana, station 6: Fresarganj, station 7: Bakkhali, station 8: Henry Island, station 9: Chandanpiri, station 10: Bonny Camp)

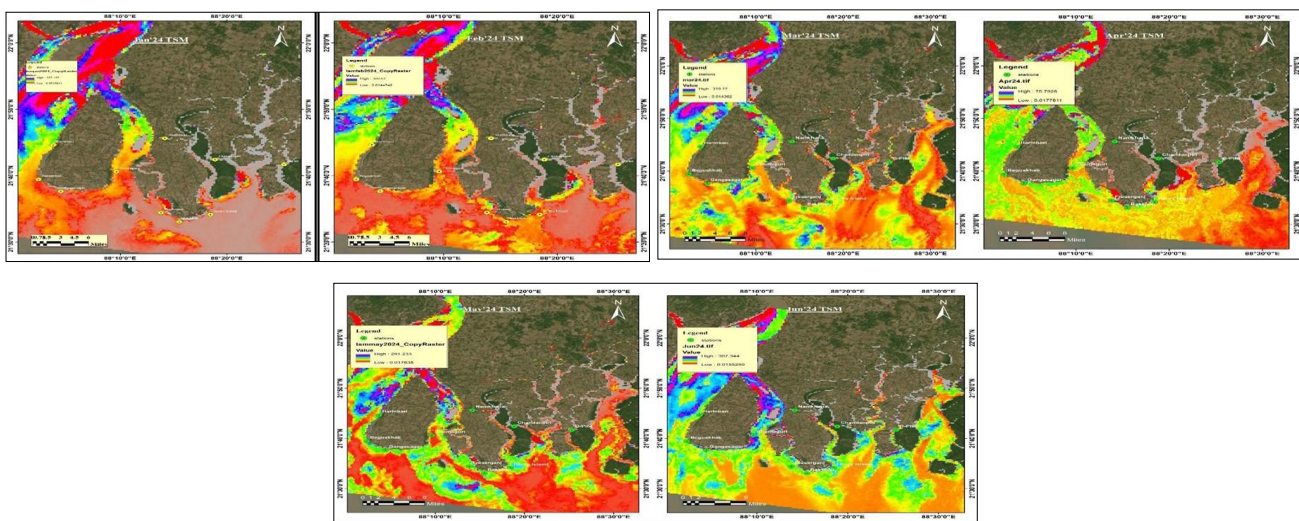


Fig 4: Mapping of Total Suspended Matter from OLCI image in different study stations (station 1: Harinbari, station 2: Beguakhali, station 3: Ganga Sagar, station 4: Chemaguri, station 5: Namkhana, station 6: Fresarganj, station 7: Bakkhali, station 8: Henry Island, station 9: Chandanpiri, station 10: Bonny Camp)

Conclusion

The present study reports an analysis of satellite data (Chlorophyll a, TSM) in an ecologically dynamic coastal site along east coast of India. January had higher amounts of chlorophyll-a (Chl a) than previous months. The satellite-generated data, revealed a contradicting pattern, with the lowest Chl a value noted during a month that also had the greatest in-situ value. This mismatch may be caused by timing problems between satellite swaths and in-situ sampling, which would make synchronization challenging, or by excessive surface turbidity impairing the satellite sensor's performance. Phytoplankton cells and other particles make up total suspended matter (TSM), which adds to the suspended particulate burden in the water column. The TSM pattern was very similar to the Chl a curve. Because of the transient nature of the tide and the resuspension of silt, stations such as station 1 and station 2 which are two coastal stations demonstrated minimal seasonality influence. This suggests the necessity for long-term investigations to understand the trends. Like the Chl a data, the OCM value for TSM showed a pattern that was in conflict with the in-situ observations. The shortcomings of satellite data were not addressed by the small sample size and short research length, highlighting the difficulties in coordinating satellite and in-situ measurements for environmental monitoring.

References

1. Apicella L, Martino MD, Quarati A. Copernicus user uptake: From data to applications. *International Journal of Geo-Information*,2022;11(2):121.
2. Fernández M, Peter H, Arnold D, Duan B, Simons W, Wermuth M, *et al.* Copernicus Sentinel-1 POD reprocessing campaign. *Advances in Space Research*,2022;70(2):249–267.
3. Chowdhury M, Caballero I, de la Calle I, Laiz I. Chlorophyll-a and suspended matter variability in a data-scarce coastal-estuarine ecosystem. *Estuarine, Coastal and Shelf Science*,2024;309(1):108973.
4. Kampel M, Lorenzetti JA, Bentz CM, Nunes RA, Paranhos R, Rudorff FM, *et al.* Simultaneous measurements of chlorophyll concentration by lidar, fluorometry, above-water radiometry, and ocean color MODIS images in the southwestern Atlantic. *Sensors*,2009;9:528–541.
5. Shampa MTA, Ahmed K, Chowdhury KMA, Islam A, Hasan M, Rahman MS, *et al.* Spatial and seasonal variability of chlorophyll-a, total suspended matter, and colored dissolved organic matter in the Sundarban mangrove forest using earth observation and field data. *Heliyon*,2024;2(10):38789.
6. Parida C, Baliarsingh SK, Lotliker AA, Dash M, Srichandan S, Sahu KC. Seasonal variation in optically active substances at a coastal site along western Bay of Bengal. *SN Applied Sciences*,2019;1:1–8.