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FULL LENGTH ARTICLE

Delineating the relationship between chromophoric dissolved organic matter (CDOM) variability and biogeochemical parameters in a shallow continental shelf

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Abstract Absorption coefficient of chromophoric dissolved organic matter (CDOM) at 440 nm [a_{CDOM} (440)], sea surface salinity (SSS), total suspended matter (TSM) and chlorophyll-*a* (chl-*a*) were measured during October, 2014 to March, 2015 in the shallow continental shelf waters of the Hugli Estuary, adjacent to West Bengal coast, India. The primary objective of the study was to characterize the relationship between a_{CDOM} (440) and the above mentioned biogeochemical parameters. Upon analyzing the results, we observed that SSS portrayed the best possible relation with a_{CDOM} (440) followed by TSM. Chl-*a* did not exhibit any statistically significant relationship with a_{CDOM} (440). TSM showed a positive linear relationship with a_{CDOM} (440) ($R^2 = 0.75$) but the relationship did not work at all for the lower end members of TSM values. SSS and a_{CDOM} (440) showed a strong negative relationship throughout the entire data range ($R^2 = 0.96$). In the lower SSS ranges, the relationship showed maximum goodness of fit ($R^2 = 0.99$). Though the goodness of fit between SSS and a_{CDOM} (440) decreased for the higher SSS end members, the relationship was statistically significant all through.

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Introduction

A fraction of Dissolve organic matter (DOM) which exhibits strong absorption of short wavelength radiation and imparts a color to the natural water is termed as chromophoric dissolved organic matter (CDOM) (Coble, 2007). CDOM is found in all natural waters, i.e. marine and fresh water (Kirk, 1994). Generally, CDOM comprises a varying mixture of aliphatic and aromatic polymers that are originated from the degradation of terrestrial and aquatic plant matter (Moran et al., 1999; Raymond and Bauer, 2000).

Marine waters are broadly classified into two categories: Case-I and Case-II (Mobley, 1994). In Case-I waters, remotely sensed ocean color data are principally dependent on the inherent optical properties of the surface water, which in turn, is mostly controlled by phytoplankton, i.e. chlorophyll-*a* (chl-*a*) concentration (Ishizaka et al., 2007). However, in Case-II waters, apart from phytoplankton, the optical properties are determined by a variety of other features like total suspended matter (TSM), CDOM and so forth (Branco and Kremer, 2005; Tan et al., 2007). CDOM in Case-II waters poses a problem for accurate chl-*a* estimation by means of ocean color sensor, since it influences the aquatic light (short wavelength) absorption (Matsuoka et al., 2007). Hence for proper estimation of chl-*a* from the space (especially in Case-II waters), intensive quantification and compensation of CDOM (Siegel et al., 2005) is required.

The regional assessment of CDOM has gained momentum in recent days mainly in order to correctly analyze the chl-*a* from remotely sensed data in local scale. In order to address this issue, assessment of CDOM should be downscaled to regional level to account all the possible criteria that are leading to the overestimation of chl-*a*.

Keeping in view the importance of CDOM measurement discussed so far, several studies have been conducted throughout the globe by means of *in-situ* sampling (Kowalczuk et al., 2006; Nelson et al., 2004; Sasaki et al., 2008; Takao et al., 2014). In this regard, it is also worth mentioning that *in-situ* CDOM estimation is more hectic and tricky compared to other hydrological parameters like chl-*a*, TSS and sea surface salinity (SSS) (Kishino et al., 2005). So, it is convenient to develop an empirical relationship (if found to exist) between CDOM and any other biogeochemical parameters (which is comparatively easier to measure than *in-situ* CDOM measurement) like SSS, chl-*a* and TSM for monitoring large scale spatio-temporal CDOM dynamics.

With regard to the above mentioned problem, the present study has been framed in the shallow continental shelf waters situated in the northern part of Bay of Bengal. In this study, we hypothesized that a relationship between the absorption coefficient of CDOM at 440 nm [a_{CDOM} (440)] with each or any of the parameters like SSS, chl-*a* and TSM exists in this region. The absorption coefficient of CDOM was deliberately chosen for 440 nm since this wavelength lies close to the major absorption band of chlorophyll-*a*, hence measurement of CDOM at 440 nm can be potentially used directly in remote sensing applications. The first and foremost objective of the present study was to examine and analyze the temporal (monthly) variability of a_{CDOM} (440), SSS, chl-*a* and TSM throughout the study period by means of *in-situ* sampling. The second most objective (in accordance with the proposed hypothesis) was to delineate the inter-relationship between a_{CDOM} (440) and the other three parameters.

Materials and methods

Study site

This study has been carried out in the shallow continental shelf waters situated in the northern part of the Bay of Bengal adjoining the coastline of the state of West Bengal, India (Fig. 1). This area receives a huge amount of freshwater discharge from the perennial River Hugli (a distributary of River Ganga) flowing by the megacities of Kolkata and Howrah. Moreover, in the north it is bounded by the world's largest single stretch of mangrove forest, i.e. the Sundarban mangrove ecosystem. Due to a perennial sediment load from the river networks, this region has an extremely shallow and distally elongated continental shelf (Akhand et al., 2013). This region experiences a semidiurnal tide of meso-macro tidal nature (2.5–7 m) and mean current velocities range from 108 cm s^{-1} to 117 cm s^{-1} during high and low tide respectively (De et al., 2011). It is worth to mention, that this study area experiences a steady cloud cover all through the year. Another unique aspect is the variance of SSS exhibited by this region due to the mixing of an enormous freshwater discharge with the typical offshore waters. Even in the post-monsoon season, SSS varied between ~18 and ~26 ppt in this region (Das et al., 2015).

The present survey has been conducted at a station (21° 25′ 30″ N; 88° 15′ 30″ E) ~ 17 km from the shoreline in the shallow continental shelf waters (< 10 m bathymetry) throughout the study period. All the cruises were begun from Frasargunje Fishing Harbour (Lat. 21° 34′ 45″ N; Long. 88° 15′ 05″ E).

Plan of sampling

During the present study period (October, 2014 – March, 2015) a total of twelve (12) sampling surveys were carried out. Two (02) surveys were conducted in each month and three (03) samples were taken in each survey. The entire sampling was accomplished in the daytime during high tide only. In order to provide the immediate ambience a minimum time to attain the equilibrium, the engine was stopped for 15 min before each sampling. Seawater samples were collected using a Niskin sampler (General Oceanics, Inc.) from the water surface (0.25 m below the air–water interface). SSS was analyzed immediately onboard. Samples were transferred into pre-rinsed containers from the Niskin sampler for TSM analysis. For chl-*a* estimation, water samples were filtered through GF/F (Whatman, 47 mm diameter) filter paper onboard and the filter papers were kept in the liquid nitrogen cylinder until analyzed in the laboratory. CDOM samples are taken according to Sasaki et al. (2005).

Analytical protocol

SSS was measured using a Multikit (WTW Multi 340 i Set; Merck, Germany) fitted with the probe WTW Tetracon 325. *In-situ* chl-*a* was measured by means of standard spectrophotometric methods using Shimadzu UV–Visible 1600