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Regionally tuned algorithm to study the seasonal variation of suspended sediment concentration using IRS-P4 Ocean Colour Monitor data

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Abstract Satellite data product validation and algorithm development activities both require the substantial accumulation of high-quality *in situ* observations. Data were acquired from Ocean Colour Monitor (OCM) and *in situ* observations for tuning of Tassan's algorithm (Tassan, 1994) to retrieve the suspended sediment concentration (SSC) in the coastal waters off southern Karnataka, India. Tassan's algorithm has been modified regionally by adopting statistical/graphical criteria to characterize the spatial and seasonal distribution of SSC. A concurrent and collocated datasets ($n = 120$) of *in situ* SSC and OCM based remote sensing reflectance [Rrs(λ) in bands 490, 555 and 670 nm] were regressed. The linear fit yielded regionally tuned new coefficients which were replaced in place of Tassan's global coefficients. The tuned algorithm was shown to retrieve SSC with range of 1.1–37.12 mg/l, which means it can be used for coastal waters. Since *in situ* samples were collected within the continental margin (average depth of ~20 m), we retain the global SSC algorithm (Tassan, 1994) approach for deeper bathymetric values (> 50 m depth) where we have no *in situ* measurements. Comparative analysis indicated statistically significant relationship ($R^2 = 0.99$; $n = 45$; $p < 0.05$ at 95% confidence level) between *in situ* SSC and regionally tuned algorithm based SSC, with bias of 0.36 mg/l and root mean square (RMS) difference of 0.73 mg/l. This result clearly demonstrated the improvement of SSC measurement from OCM using

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regionally tuned Tassan's algorithm (RMS = 0.73 mg/l) over the globally coefficient based Tassan's algorithm (RMS = 16.1 mg/l).

The tuned regional algorithm was used to estimate SSC in 2004, 2005 and 2007 which shows the concentration varied from 1.13 to 28.1 mg/l in 2004, 1.84 to 23.12 mg/l in 2005 and 2 to 27.85 mg/l in 2007. Graphical and statistical methods using analysis of variance (ANOVA) have shown significant seasonal variability and inter-station spatial variability in SSC. Peak concentrations were recorded in the post-monsoon followed by the pre-monsoon period. The wind, wave and current pattern associated with southwest monsoon possibly controls the seasonal distribution, while nearshore turbulence and littoral transport influence the spatial distribution. This paper clearly demonstrated the potential application of regionally tuned algorithm for SSC mapping to study the spatial and seasonal pattern in shallow water off southern Karnataka.

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1. Introduction

Oceans occupy about 70% of the Earth's surface, which play an important role in the climatic conditions of the adjacent land regions. Coastal areas are important ecological zones, because more than 50% of the world's population lives within 60 km of coasts. Moreover, 90% of the world's fish catch comes from coastal and shelf sea (Pernetta and Milliman, 1995). Coastal areas are potential zones of marine resources for a country like India which has approximately 7500 km of coastline. Oceanic water circulation dynamics along the coast are important in understanding the numerous physical, chemical and biological processes in operation nearshore (Clark, 1995; Tang et al., 2002). The study of suspended sediment is of ecological interest as sediment comprises various inorganic and organic substrates and becomes the main substratum for biogeochemical processes. It also affects the penetration of light, transport of nutrients, shoreline morphology and other coastal processes.

The colour of seawater depends on the relative concentrations of optically active water-column constituents, including phytoplankton pigments, non-algal particulate and dissolved organic carbon, and water molecules themselves (Morel and Prieur, 1977). Coastal waters (Case 2) are characterized by relatively high phytoplankton, suspended sediment concentrations (SSC) and yellow substances as compared to open oceanic environment (Case 1). Generally, the optical properties of suspended sediment are highly nonlinear with many factors such as particles size, shape and colour influencing the optical properties of suspended sediment (Pak et al., 1970; Baker and Lavelle, 1984; Stumpf and Pennock, 1989; Kirk, 1994; Sydor and Arnone, 1997). As a result, the use of colour-ratio bio-optical algorithms to estimate the coastal water constituents from remotely sensed ocean colour data is often difficult owing to its optically complex nature induced by river influx and local geological phenomena (Gordon et al., 1980; Kishino et al., 1998; O'Reilly et al., 1998). In addition, the bottom reflectance often contributes significantly to observed remote sensing reflectance in shallow bathymetric region (IOCCG, 2000). Several researchers have attempted to measure the SSC in the coastal waters based on understanding of the reflection, absorption and scattering of light by water and its constituents (Klemas et al., 1974; Gordon and Morel, 1983; Tassan and Strum, 1986; Ritchie et al., 1990; Hooker et al., 1992; Forster et al., 1993; Tassan, 1994; Chauhan et al., 1996; Allee and Johnson, 1999; Thiemann and Kaufmann, 2000; Green and Sosik, 2004; Matsumura et al., 2004; Siripong et al., 2004; Kishino et al., 2005; Pradhan et al., 2005).

In this paper, we have attempted to develop a site-specific algorithm after modifying the global suspended sediment algorithm (Tassan, 1994) in Case 2 waters off southern Karnataka using Indian Remote Sensing Satellite (IRS)-P4 Ocean Colour Monitor (OCM) data. Since *in situ* samples were collected in different seasons during 2001–2003, within the continental margin (average depth of ~20 m), we retain the global suspended sediment algorithm (Tassan, 1994) approach for deeper bathymetric values (> 50 m depth) where we have no *in situ* measurements. Further, regionally algorithm based SSC maps were generated during 2004, 2005 and 2007, to study the seasonal variability.

2. Area of study

The study area – off Dakshina Kannada and Udupi districts of Karnataka State, India – extends for about a length of 100 km and lies between 12°45′–13°45′ N latitudes and 74°15′–75°15′ E longitudes (Fig. 1). It trends in NNW–SSE direction and is bordered by Western Ghats in the east and Arabian Sea in the west. The coastline of the area is characterized by typical open, shallow water, high energy coastal ecosystem with long sandy shore of moderate gradient. Ten major river systems draining the area from south to north are: Netravati, Gurpur, Pavanje, Mulki, Udyavara, Swarna, Sita, Haladi, Chakra and Kollur. All of them are originated in the Western Ghats and debouch into the Arabian Sea (Fig. 1).

The area is characterized by heavy precipitation due to the influence of Western Ghats, receives an average annual rainfall of ~3900 mm, of which about 80% is received during the southwest monsoon (June–September) and the rest during the post-monsoon (October–December) and pre-monsoon (April–May). Post-monsoon is the northeast monsoon period but is not prominent like southwest monsoon and ends in the early December with less than 10% contribution to the annual rainfall. January–March (winter–summer transition) period is characterized by fair-weather and calm sea conditions with gradual increase in temperature. The temperature ranges from 24 to 28 °C during July–December and 29 to 33 °C during

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