International Journal of Earth Sciences and Engineering
ISSN 0974-5904, Vol. 03, No. 06, December 2010, pp. 827-832

Spring Inter Monsoon Algal Blooms in the Eastern Arabian Sea: Shallow Marine Encounter off Karwar and Kumbla Coast using a Hyperspectral Radiometer

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Abstract: We encountered the presence of algal blooms in the shallow coastal waters; typical of case II conditions off Karwar (Karnataka) and Kumbla (Kerala), eastern Arabian Sea during the Inter Monsoon. The algal blooms are Trichodesmium species and appear in shades of brown strands and tufts representing T. Erythraeum. Sites of the algal blooms depict a high spectrophotometric surface chlorophyll-a value ranging from 32- 39 mgm^{-3} and sea surface area surrounding the bloom sites depict lower values of chlorophyll-a (1-3 mgm^{-3}). In-situ Hyperspectral radiometer measurements depict the existence of Chlorophyll Maxima at various depths (3.0-37.31 ug/l) representing the blooms along with their surface appearance. Contrary to the Karwar blooms that are dense, the blooms at Kumbla were dispersed and scantly distributed on the surface waters. Our sea-truth data on mean Sea Surface Temperature of Karwar (30.61 ^{0}C) that simulates the Kumbla (30.34^{0}C) scenario and the mean salinity of Kumbla was 35.86psu, and that of Karwar that is slightly elevated (35.40psu), suggests that SST and salinity probably do not either directly enhance or provide an environment for the deterioration of algal blooms.

Keywords: *Trichodesmium Bloom, Arabian Sea, Chlorophyll-a, Hyperspectral Radiometer, Deep Chlorophyll Maximum.*

Introduction:

Algal Blooms have been reported (Matondkar et al, 2006; Sarangi et al, 2001; Capone et al, 1997; Westberry et al, 2006; Subramaniam et al, 2002) from various oceanic settings and form extensive bloom scenarios in oligotrophic tropical and subtropical oceans. Genesis and occurrence of Algal Blooms are under intense observations in in situ conditions. The Arabian Sea is being tracked and monitored off the west coast of India by both sea-truth retrieval teams using in situ water samples and hyperspectral radiometers etc., and satellite oceanographic teams using various Ocean Color Monitoring satellites especially the Oceansat-I and more recently Oceansat-II. Trichodesmium species are widely spread as large dense patches in the Arabian Sea. They form extensive blooms in the oligotrophic tropical and subtropical oceans (Capone et al, 1997). Trichodesmium blooms are rare, occurring <5-10% of the time over most of the tropical and subtropical oceans for the time examined (1998 – 2003) (Westberry, 2006). Populations of Trichodesmium are generally found in stable, stratified waters; with low winds (Capone et al, 1997; Subramaniam et al, 2002; Villareal and Carpenter, 1989). Trichodesmium can grow fast or bloom and accumulate as dense, visible patches near the surface of the water (Sarangi et al, 2001). The colour of the bloom varies and has been described as red, brown, green,

yellow and silvery grey, depending on the age of the bloom and the concentration of Trichodesmium (Sarangi et al, 2001). King (1950) states that it is yellowish at the height of the bloom, becoming reddish brown when the peak of growth is passed. Here we report the encounter of algal blooms off Karwar and Kumbla in the eastern Arabian Sea along with sea-truth of the initiating stage of the bloom and the degrading stage of the bloom.

Study Area and Methodology:

The study area represents the coastal waters off Karwar and Kumbla in the eastern Arabian Sea (Figure 1). The area is bounded by longitude 73º and 74ºE and latitude 14° and 12ºN. Two shore-normal transects with five stations each established using SimradNX40 GPS-Echosounder with a distance 5Kms between the station. Surface water Chl-a was determined spectrophotometrically (Fargion and Mueller 2000) and by deploying a Satlantic Hyperspectral radiometer (Dudeja et al, 2009) real time data on the depth, deep chlorophyll maximum, SST and Salinity. We present here data of parameters recorded by the Satlantic Hyperspectral radiometer and Chl-a determined spectrophotometrically (Table 1). The Karwar transect with 5 stations and varying depths from the shore has Satlantic Hyperspectral radiometer records of n=91; and Kumbla transect too with 5 stations has records of n=92. Spectrophotometric Chl-a data was determined (Table 1) for both the Transects (n=5/transect).

Results and Conclusion:

The concentration of sea surface chlorophyll at the bloom area in the Karwar transect is very high (32-39 mgm^{-3}). The area surrounding the bloom region shows a normal distribution of chlorophyll-a 1-2 mgm^{-3}. However, a high concentration of Deep Chlorophyll Maxima (DCM) is about 37.31 ug/l which is much higher than the surface concentration. The concentration of DCM at various depths ranging from 3-37 ug/l indicates that Trichodesmium species dominate at depths ranging from 8-31 mts. In the Kumbla transect, the concentration of surface chlorophyll range from 1-4 mgm^{-3} in the bloom area. The DCM concentrations show a high value of about 3-19 ug/l. with varying from 4-31 mts. The station depths in Karwar and Kumbla transects range from 8–40 mts that is typical of case II waters. We, thus provide sea-truth evidence of the occurrence of shallow marine blooms encountered at Karwar and Kumbla. The SST ranges from 30-31º C in the inter monsoon season when the Trichodesmium species bloomed in the Karwar region while the SST in the Kumbla transect was 29-30º C. Salinity was low <35 psu during the Trichodesmium bloom occurrence. Salinity was low <36 psu in both the transects thus suggesting that low salinity enhances the algal bloom and supports their growth in the shallow marine environment. Trichodesmium blooms are a common phenomenon in the spring inter monsoon season. The Trichodesmium blooms witnessed in the Karwar transect were in the initiating stage (Figure 2 & 3). These blooms appeared like sawdust floating on the surface. The Trichodesmium blooms encountered off Kumbla coast was in a degrading stage (Figure 4). The degrading part was visible in the crest of the wave (Figure 5). Here the bloom appears reddish in colour, which indicates that its peak growth stage has passed and is degrading (Figure 5).

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Table 1: *Deep Chlorophyll Maximum, Sea Surface Temperature and Salinity Data obtained from a Hyperspectral Radiometer Profile and Spectrophotometric Surface Chl-a Values.*

Transects	Latitude (Degrees)	Longitude (Degrees)	Distance from the Coast Km	Station Depth (mts)	DCM Depth (mts)	DCM (ug/l)	Surface CHL-a (mg/m^3)	SST (°C)	Salinity (psu)
KARWAR-01	N 14° 48' 98''	E 74° 05' 67''	5	10	8	37.3	1.78	31.07	33.72
KARWAR-02	N 14° 48' 98''	E 74° 02' 83''	10	16	10	12.9	1.9	30.29	35.56
KARWAR-03	N 14° 48' 98''	E 73° 58' 80''	15	24	11	6.83	32.33	30.3	35.86
KARWAR-04	N 14° 48' 98''	E 73° 55' 10''	20	32	25	3.53	32.91	30.82	35.92
KARWAR-05	N 14° 48' 94''	E 73° 51' 91''	25	39	31	8.54	38.52	30.57	35.94
KUMBLA-01	N 12° 36' 19''	E 74° 55' 36''	5	8	4	19.6	2.77	30.23	36.04
KUMBLA-02	N 12° 36' 19''	E 74° 52' 51''	10	15	8	11.5	1.44	29.69	35.86
KUMBLA-03	N 12° 36' 19''	E 74° 50' 30''	15	21	17	21.5	2.13	30.3	35.77
KUMBLA-04	N 12° 36' 19''	E 74° 47' 16''	20	29	19	2.65	4.24	30.64	35.66
KUMBLA-05	N 12° 36' 19''	E 74° 44' 27''	25	42	31	3.31	1.7	30.88	35.75

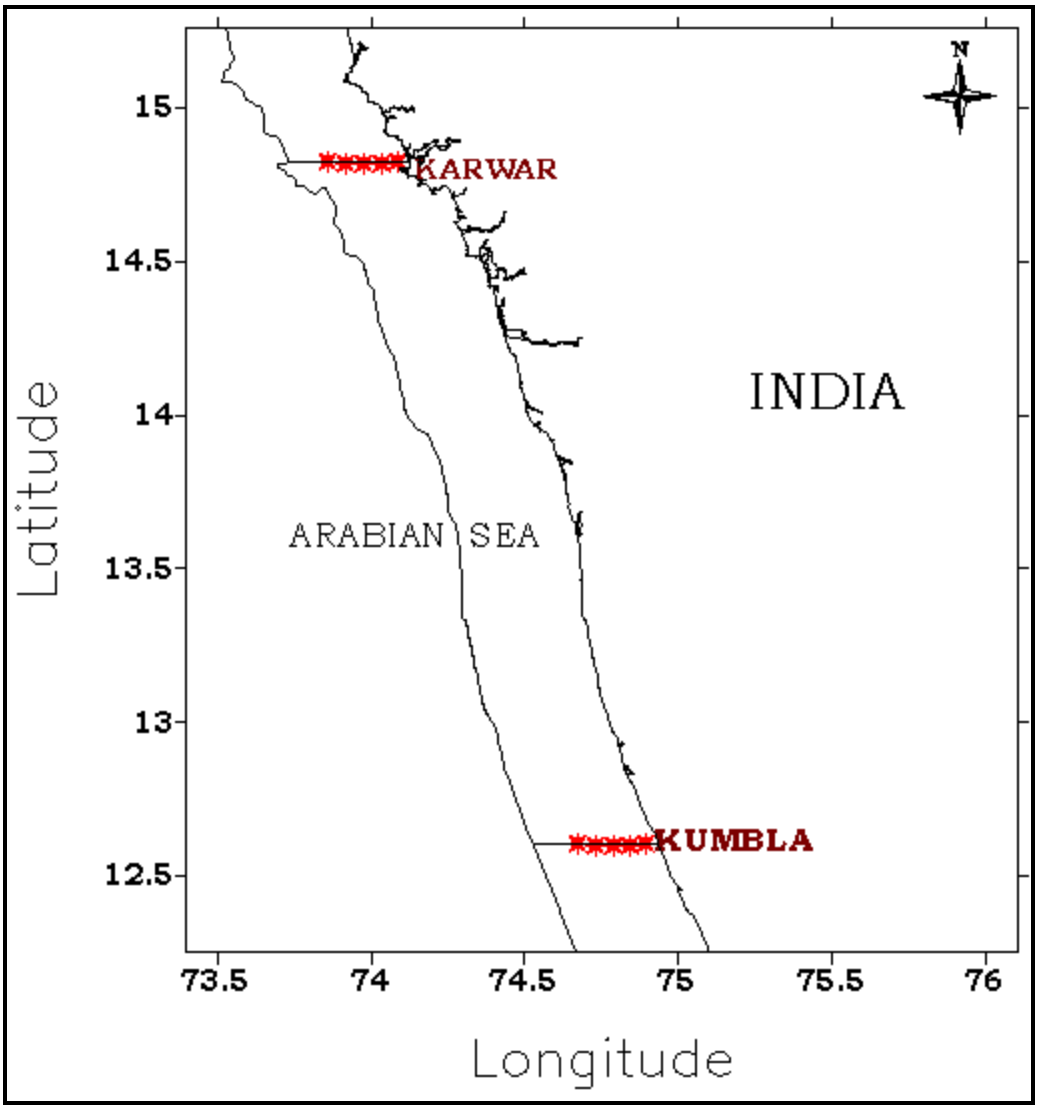

Figure 1: *Location of Transects where the T. Erythraeum were Encountered.*

Figure 2: *Initiating Stages of T. Erythraeum Bloom as off Karwar. Note the Yellowish Brown Color and Linear Strands.*

Figure 3: *T. Erythraeum off Karwar. Note the Strands and Tufts of Bloom.*

Figure 4: *T. Erythraeum off Kumbla. Note the Reddish Tinge Indicative of the End of the Growth Stage.*

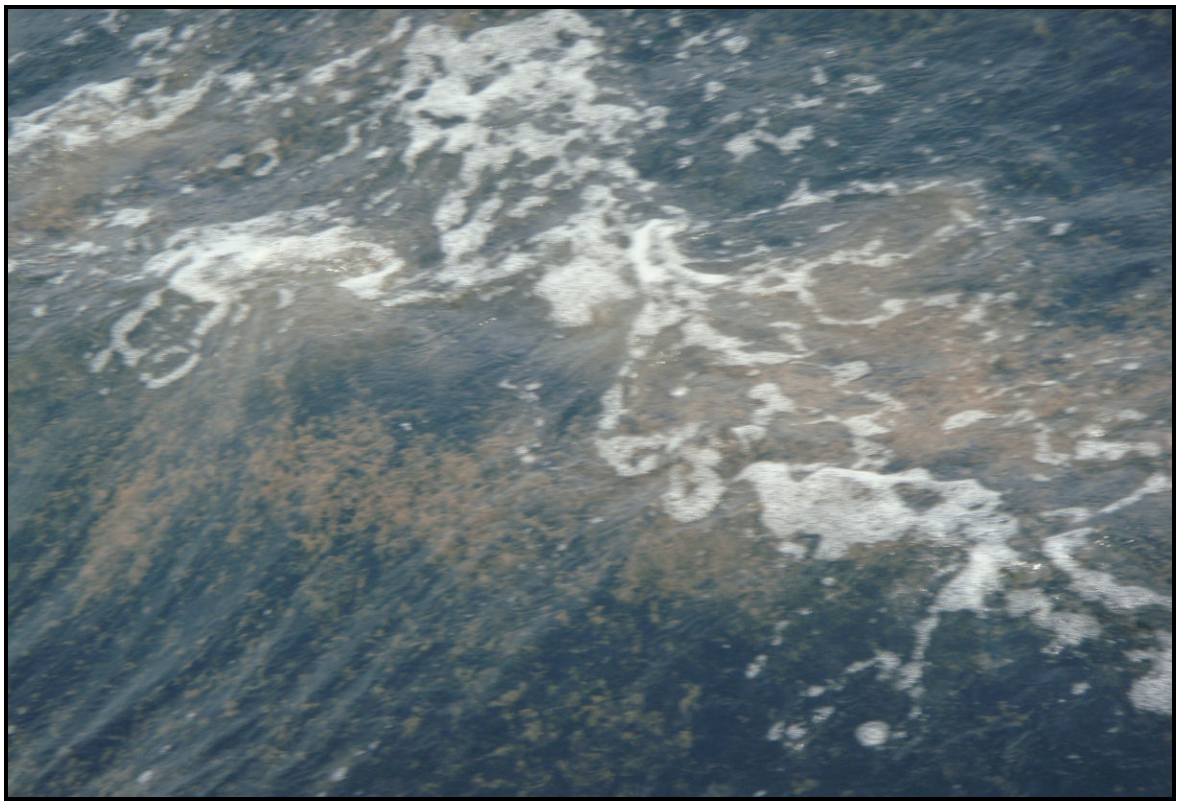

Figure 5: *T. Erythraeum off Kumbla. Note the Reddish Tinge and Dispersed Phase Suggestive of the End of the Growth Stage.*