Results (modifications)

It is well known that the upwelling along the west coast of India is influenced by local winds as well as remotely forcing (Yu et al., 1991; McCreary et al., 1993; Shankar and Shetye, 1997; Shankar et al., 2002). A modelling study by Suresh et al. (2016) has shown that winds near Sri Lanka drive 60% of seasonal sea level of Indian west coast where as the contribution from Bay of Bengal wind forcing is only 20%. They also pointed out that sea level signals forced by the winds near Sri Lanka extend westward into the eastern Arabian Sea with more than 50% contribution in the Lakshadweep high/low region. Negative seasonal sea level anomaly and associated thermocline shoaling in the southeastern Arabian Sea (Lakshdweep low region) during the summer monsoon brings nutrients near the surface causes phytoplankton bloom, and thus influences the food chain with a direct impact on the local fisheries (Madhupratap et al., 2001). A recent study by Suresh et al. (2018) showed that during positive IOD events downwelling Kelvin waves induce a positive sea level anomaly and a deep thermocline along the west coast of India very quickly (within days) during fall. Also, the equatorial easterlies force upwelling Kelvin waves that travel through the Bay of Bengal coastal waveguide to the west coast of India very slowly finally resulting in negative sea level anomaly in winter. The sea level anomaly along the west coast thus shifts from positive in fall to negative in winter during positive IOD events. Our results have shown that chlorophyll concentration is low along the south west coast of India during positive IOD years when compared to neutral and negative IOD years (Fig. 1) due to the presence of these downwelling Kelvin waves during Sep-Nov when IOD strength is at its peak. The maximum difference in chlorophyll concentration during a positive IOD year as against neutral/negative IOD year is seen from the tip of the subcontinent to below 12°N. This is in accordance with the findings of Suresh et al., (2018) who have shown that the equatorial easterly wind-stress anomalies during a positive IOD extend off the equator to approximately 10°N.

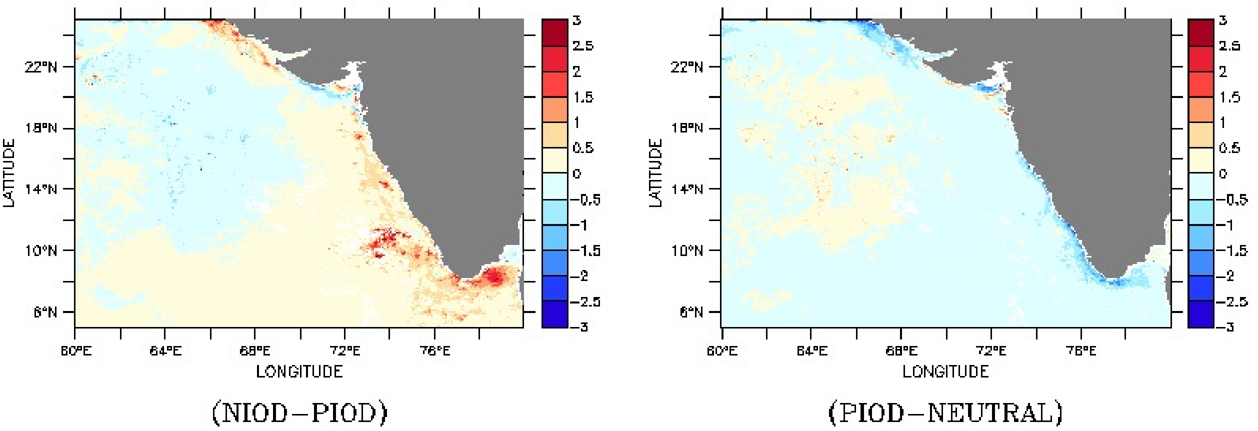

Fig .1 The difference in chlorophyll concentration in mg m^{-3} for the Sep-Nov months during (left) NIOD and PIOD years and (right) PIOD and neutral IOD years

Our analysis has shown that the trend of the chlorophyll concentration in the CEAS is negative and statistically significant ($p < 0.05$) (Fig. 2 and Fig. 3). This is can be attributed to the increase in the SSTs resulting in enhanced stratification and reduction in nutrient exchange through vertical mixing (Behrenfeld et al., 2006, Capotondi et al., 2012). The chlorophyll trends may also be skewed due to the negative IOD of 2016, which is the strongest negative IOD recorded since 1980 (Lu et al., 2018). The SSTs have increased by 0.57 ºC (0.46 ºC) during the 38 year period 1981 to 2018 in the eastern (western) Arabian Sea area (Fig. 4 and Fig. 5). In the SEAS, the regions away from the coast shows negative chlorophyll trends whereas regions very close to the close to the coast show positive chlorophyll trends. But there is no significant trend in the chlorophyll concentration in SEAS area as a whole ($p = 0.996$). It is also interesting to note that within the SEAS area, SST warming trend is lower close to the coast where the chlorophyll trend is positive. Prakash et al. (2012) had shown that there is no significant trend in the chlorophyll in a small area off the south west coast of India covered by the area SEAS of our analysis. The increase in surface chlorophyll concentration very close to the coast is due to the increased wind stress over this region. In addition to the reduced positive trend of SSTs close to the south west coast of India (east of 70°E (Fig. 4), several modelling studies have shown that the withdrawal of the Indian summer monsoon season is getting delayed in a warming environment (eg: Jayasankar et al., 2015), resulting in increased upwelling favorable conditions during Sep-

Nov months.

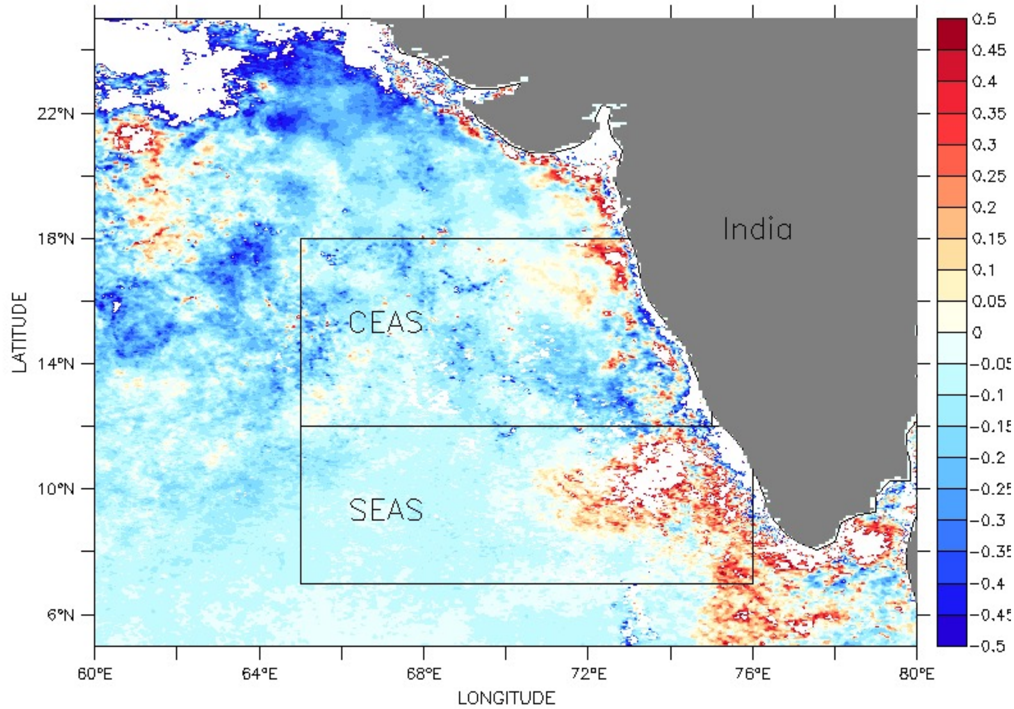

Fig. 2 Chlorophyll trend in mg m^{-3} for the Sep-Nov months durring the period 1981-2018. area 1 (65° E-75° E 12° N-18° N) represents the central eastern Arabian Sea (CEAS), area 2 (65° E-76° E, 7° N-12° N) represents the south eastern Arabian Sea (SEAS).

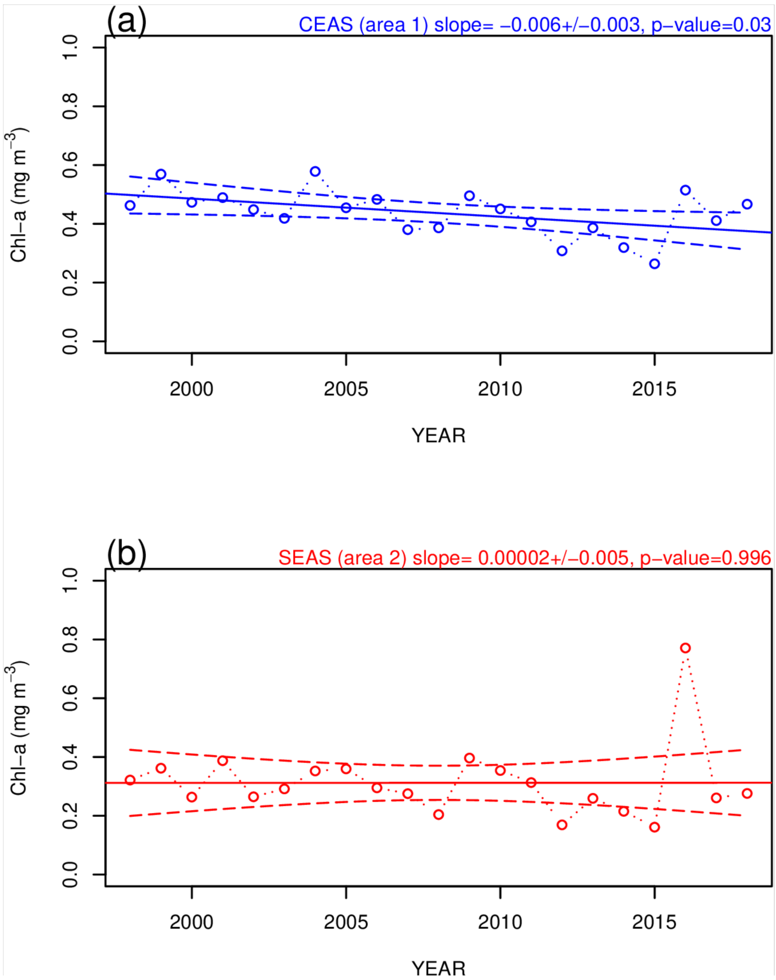

Fig. 3 a) The surface chlorophyll trend in mg m^{-3} in the eastern Arabian Sea area (65E-75E, 8N-18N) and b) chlorophyll trend in mg m^{-3} in the western Arabian Sea (55E-65E, 8N-18N) during the study period 1981-2018.

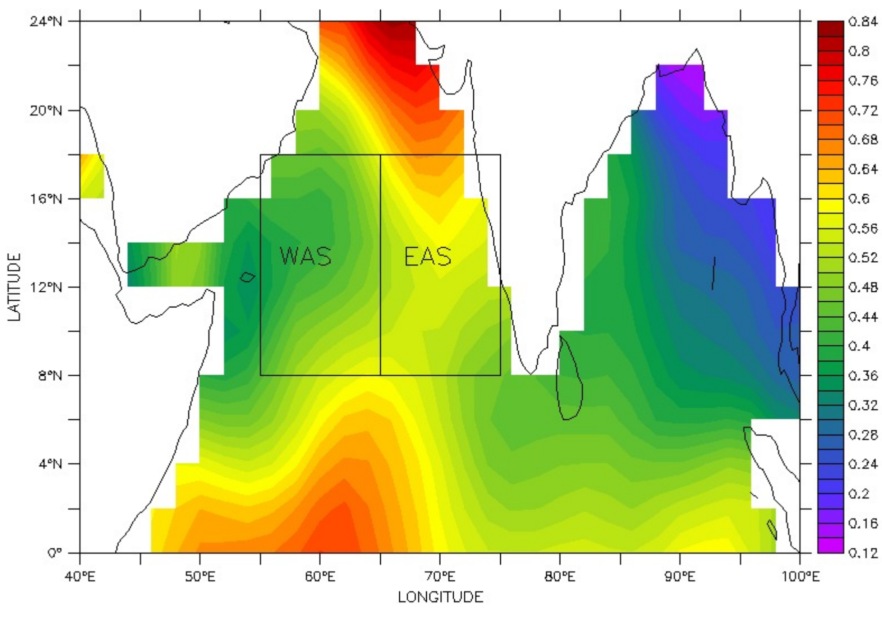

Fig. 4 The map of tropical Indian Ocean highlighting the study area. WAS represents the western Arabian Sea (55° E–75° E , 8° N–18° N, EAS represents the eastern Arabian Sea (65° E–75° E, 8°

N–18° N). The annual SST trend (°C) during the period 1981 to 2018 is also shown in the image.

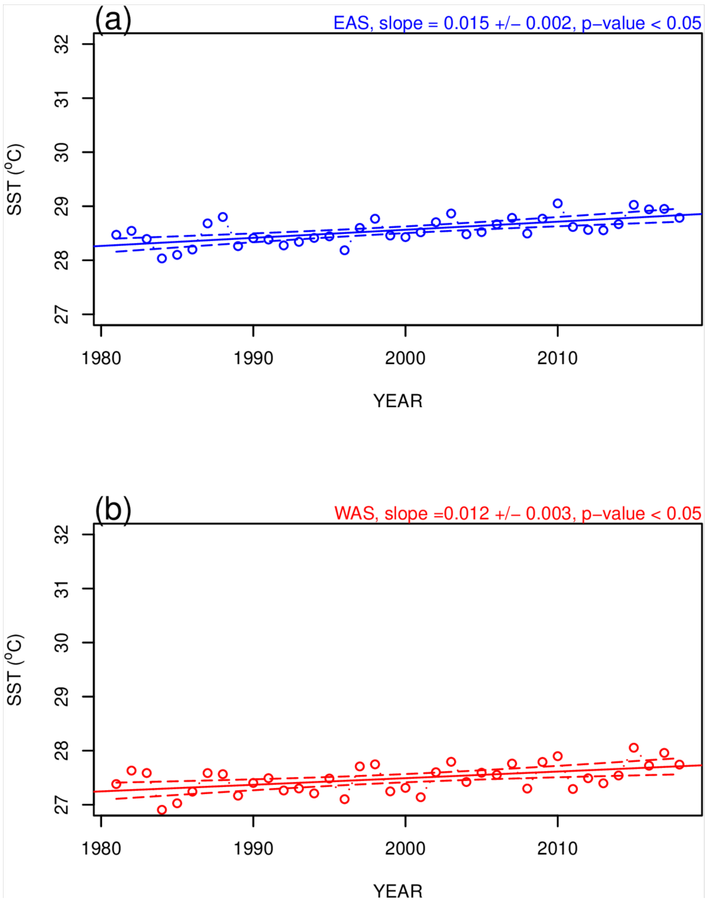

Fig. 5 a) The SST trend in the eastern Arabian Sea area (65E-75E, 8N-18N) and b) SST trend in the western Arabian Sea (55E-65E, 8N-18N) during the study period 1981-2018.

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