VARIATION IN SEA SURFACE TEMPERATURE FOR COASTAL WATERS OF GULF OF MANNER, INDIA

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Abstract:

Sea surface temperature (SST) is primary factor for understanding, quantifying and predicting the marine resources and important parameter in earth science model. The variability of SST in the coastal water increasing gradually over the recent years, which subsequently affects the marine habitats as well as the human beings located over the coastal zone. Gulf of Manner (GOM) is one of the coastal zone with marine national park receives several rivers covered with almost 21 small islands, pearl banks, coral reefs, and high variety of plants and animals. In this study, MODerate-resolution Imaging Spectroradiometer (MODIS) satellite images were used to understand the long term changes and spatial variation of SST over theGulf of Manner (GOM) located in the south-eastern part of India. To achieve the goal, satellite data from 2000-2020 over the GOM were used to understand the SST variations. This analysis helps to predict the potential fishing zone and primary productivity. This SST analysis over the coastal environments regionally provides solution for several challenges in management and utilisation of coastal resources.

Keywords: Sea surface temperature (SST), Satellite Remote Sensing, Gulf of Manner, India

1. Introduction:

Sea surface temperature is the major interface between the overlying atmosphere and the ocean, which controls the heat and gases exchange between the atmosphere and the ocean. SST is primary indicator to understand the realistic changes of climate, due to the ocean waters.The natural causes and anthropogenic activities are the reason for thechanges in SST in overpopulated coastal areas(Lima & Wethey, 2012). This fluctuation in SST directly affects the quality of the natural products, livelihoods, coastal protection and biodiversity by affecting the health of coral, seagrasses, sea ice, and habitats. Especially, the corals can be degraded heavily or dies due to the fluctuation of sea surface temperature (Claar et al., 2018). The Intergovernmental Panel on Climate Change (IPCC) assessment report (Bindoff et al., 2019) predicted, the rise in SST (0.2 C to 2.5 C) subsequently affects in a major sea level rise, that is a severe cause of impact in worldwide coastal ecosystem.

Mapping the spatial and temporal SST is important for the prediction, forecasting models(Robinson et al., 2012). SST parameter in ocean is required to measure at the depth from the surface 1 mm to 20 m.SST is obtained through satellite infrared (IR) radiometers, microwave radiometers, drifting buoys, and ships of opportunity. Earlier, most of the measurements were done with shipboard measurements. Nowadays, various satellite SST measurements has been available from 1981 and provides a sustained operational stream of global SST data. The SST as a function of depth in the ocean is measured from space is based on the frequency (IR measure a depth of 20 micrometres and microwave measure a depth of a few millimetres) of the satellite instruments. This global SST data improves the modern observing system and provides better forecasting models(O'Carroll et al., 2019). Still, the availability of the SST data were limited for scientific and near real time applications, which affects inaccuracies in the ocean models and data assimilation models.In other hand, quality of satellite based high resolution spatial SST products were growing and its requirements get increasing day by day for various assimilation and forecasting models.

Wentz et al. (2000) derived the SST from satellite measurements from Advanced Very High Resolution Radiometer (AVHRR) sensors launched with National Oceanographic and Atmospheric Administration (NOAA) satellites. This provides spatially high resolution dataset of SST measured in the infrared bands. The SST measurements is very difficult during the presence of cloud, which is one of the major limitation of the AVHRR sensor. This difficulty can be overcomes by microwave radiometer, but it suffered from poor calibration system during 1980s and 1990s (Wentz et al. 2000). The above problems were solved in 1997, after launching in the Tropical Rainfall Measuring Mission (TRMM) satellite (Halpern et al. 2001). The TRMM Microwave Imager (TMI) measures radiation emitted by the ocean-atmosphere system. This TMI is the first satellite sensor capable of estimating the SST in the presence of clouds. Along with SST, TMI can be also measure oxygen, water vapor, and clouds. Several studies analysed the SST using the TMI dataset (Chelton et al. 2001; Vecchi and Harrison 2002).

The MODerate-resolution Imaging Spectroradiometer (MODIS) satellite with Aqua and Terra sensor launched in 1999 and 2002 respectively, were measures SST at <1 mm. SSTs observed from the MODIS provides long time spans with large spatial coverage for near real-time (NRT) application.Here, the SST is derived from the brightness temperature, which is obtained from water surface radiance at different bands. Several regional algorithm (Wang and Deng, 2017) and global algorithm (Hasoda, 2011) were developed for the estimation of SST from MODIS satellite dataset.In this study, the temporal and spatial distribution of SST are analysed for the Gulf of Manner, India using the MODIS dataset. The details of the SST data are discussed in section.2; description about the study area and importance of SST over the study area are described in section.3; spatial and temporal variability of SST are explained in section.4; and finally conclusion is in section.5.

2. Study Area:

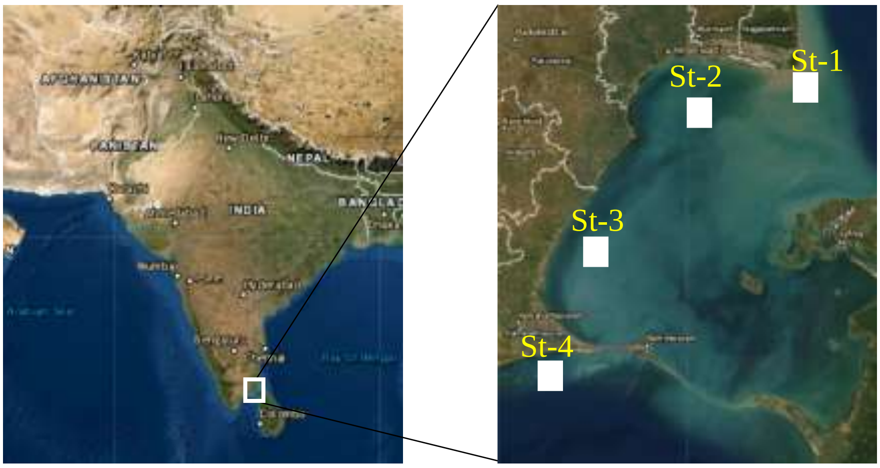

Fig.1. The schematic map shows the image of study area over the region of Gulf of Mannar, India used for the SST analysis in this study. (Source: https://earthexplorer.usgs.gov/).

Table.1. Details of the sites in the Gulf of Mannar (GOM) used for the analysis in this study

Stations	Lat	Lon
St-1	10.204	79.943
St-2	10.093	79.454
St-3	9.644	79.186
St-4	9.083	78.870

The GOM is located in between India (south east) and Sri Lanka (north west) is shown in fig. 1.The average depth in the GOM is relatively deep with average 100m over the length of 190km along the Indian coastline(Jyothibabu et al., 2014).The GOM is connected to the Bay of Bengal in the east and Arabian Sea through Indian Ocean in the west. The physical barriers such as Rameswaram Island of India, Ramsethu Bridge and Manner Island of Srilanka were restricts the movement of water between the Bay of Bengal and Arabian sea. The Northern part of the GOM is know as Palk Bay, which is dominated by suspended sediments. The visibility of underwater were studied over GOM were analysed through radiometric and photometric measurements (Sundarabalan et al., 2013). This Palk bay is shallow water region covered with seagrass at the bottom of the seabed(Rengarajan et al., 2010). The entire region between the GOM and Palk Bay are highly productive waters which are dominated with Chlorophyll.

3. Dataset:

MODIS Terra/Aqua are the ocean satellites launched by NASA in the year of 1999 and 2002 respectively, for ocean color mission, which are sun-synchronous satellites that passes the earth surface for every one or two days and scanning covers a swath width of 2330 km. The satellites are placed in the altitude of 705 km from the earth surface. MODIS Terra capture image in the morning (10.30 AM) by descending pass, and Aqua capture image in the afternoon (1.30 PM) by ascending pass. Both satellites acquire data in 36 spectral bands using visible and infrared radiometers ranging from 0.4-14.4 μm. The resolution of the captured images are 250m for two bands, 500m for five bands, and 1km for remaining 29 bands. The spectral bands of 11-12μm from thermal infrared region and 3.7-4 μmfrom mid-infrared region are used mainly for skin SST estimation at a depth of 10-20 μm using the technique developed by the NASA MODIS Science Team. The Ocean Biology Processing Group from NASA has derived the SST products are in variety of different temporal and spatial resolution format and updated in the website (https://oceancolor.gsfc.nasa.gov).

4. Methodology:

The MODIS Aqua/Terra level-1 images were processed for analysing the distribution of SST over the sea surface using the software platform developed by NASA Ocean Biology Processing Group (OBPG). The OBPG used the standard model for the Level-2 SST products using the Multi-Sensor L1/L2 platform, which is another module in same OPBGsoftware which utilized for the operation of MODIS ocean color product generation. The temperature estimated from the satellite measurements are known as brightness temperatures (BT). Due to the effect of atmospheric interference the satellite derived SST is not same as the SST measured at the sea surface. For this reason the atmospheric correction procedures were followed for the identification or removal of clouds and aerosols contribution in the satellite derived radiance. Also, the atmospheric windows at the wavelength range of $\lambda = 3.5–4.1$ μm and $\lambda = 9.5–12.5$ μm are the bands which provide more information for the correction procedure (McMillin, 1975). Although the two spectral channels provides BT, but the magnitudes of the retrievals are different based on the atmospheric transmissivity. The difference in BT is defined as the temperature drop of SST and other BT (McMillin, 1975; Barton, 1995), which provides the linearized relation in terms of multi-channel sea surface temperatureequation.The above equation is as follows:

$$SST = aT_i + \gamma(T_i - T_j) + c \qquad (1)$$

Here, γ is the coefficient of differential absorption, T_i and T_j are the BTs obtained from the two channels, and offset (c). For MODIS Aqua/Terra, have two bands in the transmission window, the robust algorithm has given as follows:

$$SST = a_0 + a_1 T_{3.95} + a_2(T_{3.95} - T_{4.05}) + a_3(\sec(\theta) - 1) \qquad (2)$$

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The coefficients used in equation (2)such as a_0, a_1, a_2, and $a_3$are obtained from Kilpatrick et al. 2015. The above method has been applied to the SST retrieval from the MODIS images and produces satellite-derived SSTs for the temporal and spatial analysis.

5. Results and Discussion:

Following section shows the analysis of skin SSTs derived from the TOA MODIS based on calibrated Brightness Temperatureover the coastal waters of Gulf of Mannar, India. This section includes the analysis of spatio-temporal distribution of SST product and next sub-section explains the time series analysis of SST product over the study area.

5.1. Spatio-temporal distribution of SST product:

The characteristics of the SST variation from MODIS images were analysed for understanding the spatial distribution of the SST over the coastal waters of GOM. The spatial data were analysed for all the months during 2020. This spatio temporal distribution of SST from the GOM is shown in fig. 2 which also describes the seasonal variation of SST over the study area. The changes in the spatio-temporal distribution SST were almost closely correlated with the local climate.

The SST product of the coastal water in GOM from the January were slightly higher than the open ocean (Indian Ocean and Bay of Bengal) during the winter. The values of SST ranges in coastal waters ranges from 16°C ~ 32°C. During February, the values are slightly increased with max(32°C) and min(25°C), which indicates the beginning of summer. In the month of March (34°C) and April (37°C), the SST show rise in the magnitude, that represents the peak summer season. After this peak summer, there is a slight fall in the SST values, during the month of May.

The monsoon or rainy season starts during the month of June. The values of SST become low at the June (29°C) and July (27°C), which explains the peak rainy season around the month of June and July. The values of SST become increases at the August (28°C) and September (29°C), that represents the less rainfall with moderate temperature around the month of August and September. The magnitude of SST distributed in mixed in coastal and open waters during the month of October (30°C), November (30°C) and December (32°C), this correlated clearly with the post-monsoon period from October to December.

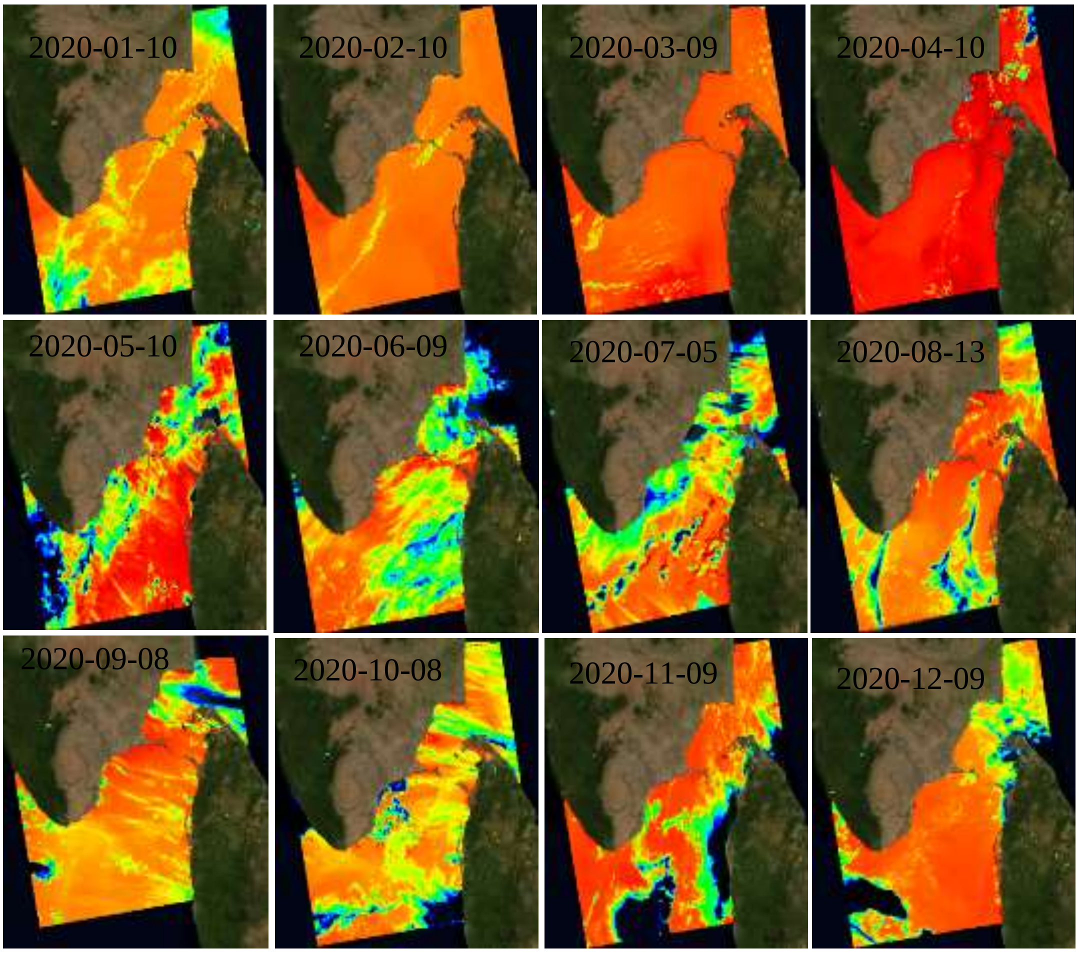

Figure 2.Collection of Level-2 MODIS-Aqua SST product for a single day image from each month over the year of 2020

As a result of the spatio-temporal distribution analysis, the maximum temperature was observed during the month of April and minimum temperature during the month of June for the year of 2020. This rise and fall in SST values are closely correlated with the local changes in the climate.

5.2. Time Series analysis of SST product:

The time series analysis used in this study are shown in Fig.3, which exhibit a seasonal pattern from the year of 2002-2020. Four stations (Table-1) are used for the temporal analysis over the GOM. Temporal variation of SST are observed for the Station-1 located in the coastal waters of off-Point Calimere. The SST range represents in the plot shows the minimum value as 21°C and maximum value as 40°C. Most of the SST values are higher than 35°C.

Variation in the magnitude of SST in the coastal water in GOM in Station-2 are analysed over the time period of 2002 to 2020. Like station-1, here also the SST range shows the minimum and maximum values as 21°C and as 40°C respectively. The frequencies of SST values are equally distributed from the maximum and minimum ranges. Station-3 is the site near the southern part of GOM covered mostly with stagnated water with shallow coastal water. As like other stations, here also the SST range shows the magnitude in the range of 21°C (minimum) and 40°C (maximum). Most of the SST values are higher than 35°C.

Station-4 is in the coastal waters of Indian ocean located in the south of GOM in which the depth is comparatively higher than the other stations 1-3. The temperature (21°C and 40°C) ranges in station-4 are similar to the other stations.This station is almost like an moderately turbid water with

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highly dominated by waves and current which is the reason maximum SST values towards the 35°C. This analysis shows that the major drift in temperatures between 21°C and 40°C occurs in coastal waters (Station-2&3) due to the primary productivity in the shallow waters of GOM. The drift is not observed much in the waters near to the moderately deep waters (in comparison with station-2&3) of GOM (Station-1&4).

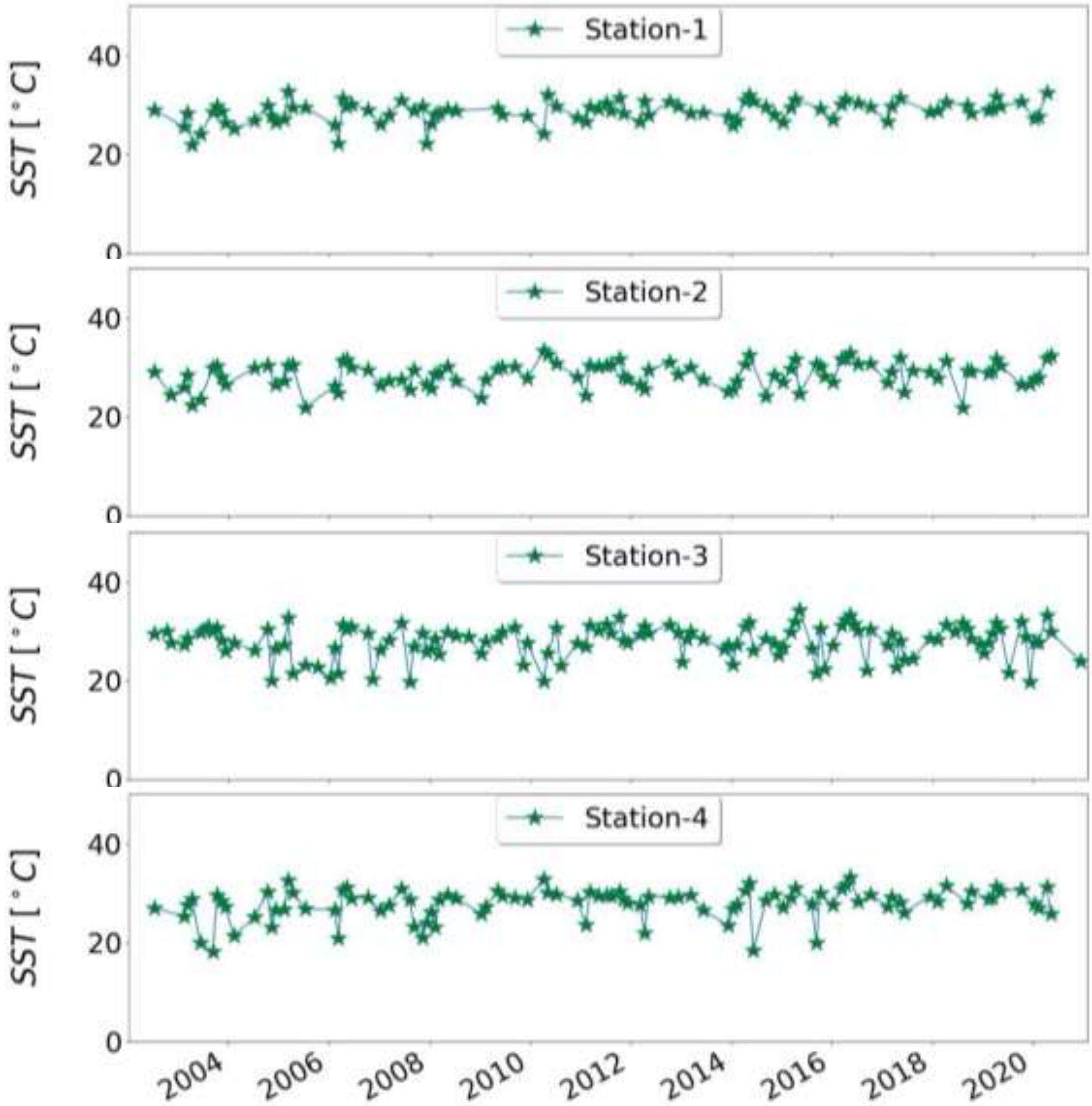

Fig. 3. Time series plots of SST product derived from MODIS satellite images from the year of 2002 to 2020 for the four stations (Table-1) of coastal waters over the Gulf of Mannar, India.

6. Conclusion:

The Gulf of Manner is a shallow coastal water which are connected with the features of Bay of Bengal and Indian ocean which experience different weather conditions. The SST trends also varies with respect to the weather conditions. This study used the MODIS satellite images available NASA ocean color websitefor the spatial and temporal analysis of SST. The spatio-temporal analysis of SST over the GOM showed that the SST images are closely correlated with the local seasonal changes. The long term time series analysis of SST also shows that it varies with climate changes. From this analysis, we recommend the MODIS images are highly used for the SST analysis over the coastal

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waters for understanding the different environmental condition. This study will be useful for the oceanographic and remote sensing community for the study of climate changes.

References:

1. P. SHANMUGAM: A New Bio-optical Algorithm for the Remote Sensing of Algal Blooms in Complex Ocean Waters. J Geophys Res Oceans, 116 (4), 1-12 (2011). https://doi.org/10.1029/2010JC006796.
2. J. FENG, J. M. DURANT, L. C. STIGE et al.: Contrasting Correlation Patterns between Environmental Factors and Chlorophyll Levels in the Global Ocean. Global Biogeochem Cycles, 29 (12), 2095 (2015). https://doi.org/10.1002/2015GB005216.
3. T. PLATT, S. SATHYENDRANATH: Ecological Indicators for the Pelagic Zone of the Ocean from Remote Sensing. Remote Sens Environ, 112, 3426 (2008). https://doi.org/10. 1016/j.rse.2007.10.016.
4. C. LAUFKÖTTER, M. VOGT, N. GRUBER et al.: Projected Decreases in Future Marine Export Production: the Role of the Carbon Flux through the Upper Ocean Ecosystem. Biogeosci, 13, 4023 (2016). https://doi.org/10.5194/bg-13-4023- 2016.
5. T. PLATT, G. N. WHITE III, L. ZHAI, S. SATHYENDRANATH, S. ROY: The Phenology of Phytoplankton Blooms: Ecosystem Indicators from Remote Sensing. Ecol Model, 220, 3057 (2009). https://doi.org/10.1016/j.ecolmodel.2008.11.022.
6. SUNDARABALAN, BALASUBRAMANIAN, SHANMUGAM, P., & AHN, Y. H.: Modeling the underwater light field fluctuations in coastal oceanic waters: Validation with experimental data. Ocean Science Journal. https://doi.org/10.1007/s12601-016-0007-y
7. M. THOLKAPIYAN, A.MOHAN, VIJAYAN.D.S: A survey of recent studies on chlorophyll variation in Indian coastal waters, IOP Conf. Series: Materials Science and Engineering 993 (2020) 012041, 1-6.
8. GOPALAKRISHNAN, R., MOHAN, A., SANKAR, L. P., & VIJAYAN, D. S. (2020). Characterisation On Toughness Property Of Self-Compacting Fibre Reinforced Concrete. In Journal of Environmental Protection and Ecology (Vol. 21, Issue 6, pp. 2153–2163).
9. MOHAN, A., TABISH HAYAT, M.: Characterization of mechanical properties by preferential supplant of cement with GGBS and silica fume in concrete, Materials Today: Proceedings, 2020, 43, pp. 1179–1189.
10. DHARMAR, S., GOPALAKRISHNAN, R., MOHAN, A.: Environmental effect of denitrification of structural glass by coating TiO2, Materials Today: Proceedings, 2020, 45, pp. 6454–6458
11. PRABHA, S.L., SURENDAR, M., NEELAMEGAM, M.: Experimental investigation of eco-friendly mortar using industrial wastes ,Journal of Green Engineering, 2019, 9(4), pp. 626–637.

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 12, Iss 02, 2023

12. O'REILLY, J. E., & WERDELL, P. J. :Chlorophyll algorithms for ocean colour sensors - OC4, OC5 & OC6. Remote Sensing of Environment, 229, 32–47. https://doi.org/10.1016/j.rse.2019.04.021(2019).
13. PLATT, T., FUENTES-YACO, C., FRANK, K.T:. Spring algal bloom and larval fish survival. Nature 423, 398–399. https://doi.org/10.1038/423398a(2003)
14. SIMON, A., & SHANMUGAM, P: An Algorithm for Classification of Algal Blooms Using MODIS-Aqua Data in Oceanic Waters around India. 1, 35–51. https://doi.org/10.4236/ars.2012.12004(2012).
15. SUNDARABALAN, B., & SHANMUGAM, P.: Modelling of underwater light fields in turbid and eutrophic waters: Application and validation with experimental data. Ocean Science. https://doi.org/10.5194/os-11-33-2015(2015).
16. THOLKAPIYAN, M., SHANMUGAM, P. CHAUHAN, P AND SURESH, T: "Derivation of Calibration Coefficients for OCM-2 Sensor for Coastal Waters", Journal of Remote Sensing and GIS 1, 1-7(2014).