SATELLITE DERIVED SEASONAL PATTERNS OF SEA SURFACE TEMPERATURE NEAR PAKISTANI COAST

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ABSTRACT

Measuring sea surface temperature (SST) trends and variability are the great importance to understand ecological changes and climate conditions. This study aims to observe SST through remote sensing data and translate to statistical information to produce seasonal and composite results. Moderate Resolution Imaging Spectro-radiometer (MODIS) satellite sensor monthly data sets of SST product are used from January 2017 to December 2019. From each monthly SST of raster mean values have been used. Monthly, seasonally and inter-annually SST distribution have been analyzed. Results show that SST has bimodal seasonal trends and near shoreline comparative cooler area is observed. Finally, data sets utilized for mapping and identify patterns. Subsequently, knowing this SST of this region could be useful in ecological and climate studies.

Keywords: Ocean remote sensing, SST, Arabian Sea, SST in Pakistan, Remote sensing of SST

INTRODUCTION

Ocean conditions and hydroclimate variability could be assessed with long term SST data (Ljungqvist *et al.,* 2016; Klein *et al.,* 2018; Elepathage and Tang, 2020). Ocean related information has significant role for the prediction of climate and its variation. SST also acts as an indicator of monitoring and observation of marine calamities. There are many factors that have influence on the SST (Sarkar *et al.,* 2019).

Remote sensing Earlier in the late 1980s, satellite data with infrared bands are providing SST data (Kilpatrick *et al.,* 2015). Since then Satellite images are useful for temporal and spatial assessment of SST. MODIS terra in 1999 and MODIS Aqua satellites in 2002 were launches by National Aeronautics and Space Administration (NASA). SST data from MODIS subsequently then provides a continually time series data with global coverage with many temporal resolutions (Rao *et al.,* 2006).

Now from the last 40 years scientists have observed great advancement in satellite remote sensing and systems to store, scrutinize analyze the data (Prabhakara *et al.*, 1974; Zhu *et al.*, 2018). Now global networks with buoy measurements, satellite data, and shore station data combine effect and record data. Remote sensing has great advantages including regional level mapping with temporal coverage. Also, with GIS and allied sciences, it makes superb tools for scientific measurement and modeling the data. The world is observing many phenomena though these geoinformatics that were not possible before (Joseph *et al.,* 2019; Muhammad et al, 2016).

For SST measurement, multispectral thermal and infra-red (IR) measurements from space through satellites are using emitted radiances at more than one wavelength. These wavelengths are also called bands or channels i.e. mid-wave (3–6 µm) and thermal IR regions of the electromagnetic spectrum (Brown *et al.*, 1999). For reducing and minimize the noise effects of gases and particles in the atmosphere (H_2O and CO_2), the readings of these wavelengths converted Brightness Temperature (T_b) from radiance values. Later atmospheric correction is being utilized for an accurate assessment. In the case of MODIS data, SST provides in product form (Davies, 2004; Wan and Li, 2008; Topouzelis *et al.,* 2015; Koner and Harris, 2016; Gladkova *et al.*, 2016, Merchant *et* al., 2019).

This sea region is important because of commercial sea routes. However, that makes some environmental issues like oil spill, pollution and sedimentation. The main purpose of the present study is to assess SST data pattern and temporal distributions in the study area by MODIS remote sensing data for the period 2017 to 2019.

METHODOLOGY

The study area is comprising of 61–69°E, 23-26°N. This geographical location of the northern Arabian Sea is shared by coastal lands of Pakistan, Iran western part of India, and the eastern coast of Oman (Figure 1). Numerous species of different biodiversity are found in this region. (Turner *et al.*, 2012; Raitsos, *et al.,* 2013).

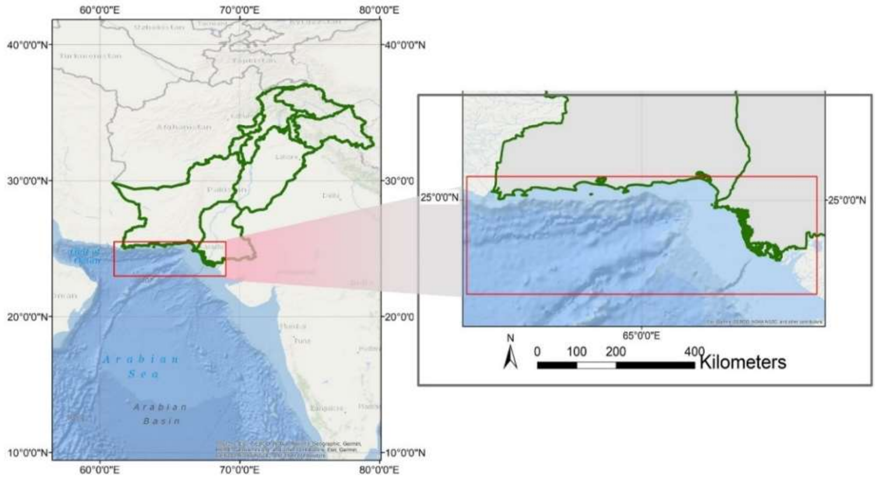

Figure 1: Study area out line along Pakistani coast

MODIS SST data

Remote sensing and GIS data sets along with numerous statistical techniques have made it possible to time series and periodic analysis. For mapping and monitoring globally many scientists are being used these satellite data. SST from MODIS now repossessing and storing in a product form with the help of computers and algorithms by different bands (Table1), several data sets in product form are available with different spatial and temporal coverage (Table 2) (Ackerman *et al.*, 1998; Kilpatrick *et al.*, 2015). MODIS high sensitivity bands are found near 4µm (20, 22, and 23) (defined as 1/L dL/dT where L is the radiance emitted by the ocean surface and T is temperature). These are located where the influence of the atmosphere on the top of the atmosphere (TOA) radiances is smaller and slightly less variable than in other spectral regions where the atmosphere is relatively transmissive. These observational MODIS data have 1 km of spatial resolution with a swath width of 2330 km. There are 36 spectral bands in MODIS Bands these includes bands at 4 µm and the split-window bands—11 and 12 µm—for SST retrievals The current algorithm for computing SST4 is shown below, and is also described by Kilpatrick (Kilpatrick *et* al. 2015).

From NASA GES DISC Giovanni platform, MODIS Monthly data sets of SST from January 2017 to December 2019 at 4 km resolution are acquired. MODIS Ocean data and MODIS products and their application are briefly discussed in the ATBD document. MODIS SST Algorithm develops the utilization of bands 22 and 23 at 3.959 and 4.050 um. The brightness temperatures are derived from the observed radiances to the final SST in product form (Devise, 2004). ArcGIS 10.3 and excel has been used for further analysis. These analyses include monthly data extraction, raster statistics, zonal mean, and finally layout developments. Excel has used for monthly data graphical presentation and finally time series tables of SST.

Table1: MODIS Bands			
Band	Wavelength (nm)	Resolution (m)	Primary Use
1	620–670	250	Land/Cloud/Aerosols Boundaries
2	841–876	250	
3	459–479	500	Land/Cloud/Aerosols Properties
4	545–565	500	
5	1230–1250	500	
6	1628–1652	500	
7	2105–2155	500	
8	405–420	1000	Ocean Color/ Phytoplankton/ Biogeochemistry
9	438–448	500	
10	483–493	1000	
11	526–536	1000	
12	546–556	1000	
13	662–672	1000	
14	673–683	1000	
15	743–753	1000	
16	862–877	1000	
17	890–920	1000	Atmospheric
18	931–941	1000	Water Vapor
19	915–965	1000	
20	3.660–3.840	1000	Surface/Cloud
21	3.929–3.989	1000	Temperature
22	3.929–3.989	1000	
23	4.020–4.080	1000	
24	4.433–4.498	1000	Atmospheric
25	4.482–4.549	1000	Temperature
26	1.360–1.390	1000	Cirrus Clouds
27	6.535–6.895	1000	Water Vapor
28	7.175–7.475	1000	
29	8.400–8.700	1000	Cloud Properties
30	9.580–9.880	1000	Ozone
31	10.780–11.280	1000	Surface/Cloud Temperature
32	11.770–12.270	1000	
33	13.185–13.485	1000	Cloud Top Altitude
34	13.485–13.785	1000	
35	13.785-14.085	1000	
36	14.085- 14.385	1000	

Table2: MODIS algorithm and SST Product
Inputs:
T3.9µm: brightness temperature at 3.959 µm, in °C
T4.0µm: brightness temperature at 4.050 µm, in °C
θ: sensor zenith angle
θ∗: sensor zenith angle made negative for pixels in the first half
mirror: mirror side number (0 or 1)
coefficients aj: algorithm coefficient sets for month of year and

Output: SST Data in °C		
Generic Algorithm: $SST4=aij0+aij1*T3.9\mu m+aij2(T3.9\mu m-T4.0\mu m)+aij3(sec\vartheta-1))+aij4(mirror)+aij5(\vartheta*)+aij6(\vartheta 2)$		
MODIS Data in Products:	**Level 2**	**Level 3**
Spatial Resolution	1km resolution (Swath 2030km X 1354 Km)	Global Products Level 3 data with 4km, 36km and 1 degree
Temporal Resolution:	5 minute granule;	daily, 8 day week, monthly, yearly

RESULTS AND DISCUSSION

In this study we evaluated monthly data for the years 2017, 2018, and 2019 (table 3). Secondly, we make a graph for this data that shows two peaks or alternative patterns of SST (figure 2). The values of SST remain high first during April, May, and June then the second peak during September and October. However, during July and August overall SST decline in these months. Time series analysis also was done to make a graph of all data from January 2017 to December 2019. Similar results as two trends intra-annual and rising trend inter-annually are observed (figure 3). Figure 4 shows the zonal mean of SST of monthly 4 km [MODIS-Aqua) during 2017-01-01 -2019-01-12 Region 61E, 23N, 69E, 26N. The SST values in the region 23 to 25-degree latitude are placed 26 to 27 °C. Besides, in the region 25 and higher degree latitude the SST value getting higher 27 to 34 °C (figure 4).

Figure 5 explains the seasonal variation of SST in the study area (a) Dec to Feb (b) March to May (c) June to August (d) September to November from 2017 to 2019. Whereas figure 6 describes the overall or composite data of SST, which shows comparatively low temperature near the coastline, and gradually on the rise with distance. Figure 7 describes two classifications of SST one is less than 27 °C near the shore that makes buffer exactly with the coastal line, the other one is higher than 27 °C gradually increasing especially the western part of the study area. These results are useful since surface Temperature (SST) the key oceanographic parameters. In this study we have done three years analysis these types of studies can be useful for understanding the seasonal, inter annual and changes.

These observations can be useful for assessment of environment and ecological changes. Many studies already been done regarding global warming in Arabian Sea and neighboring regions (Khan *et al.*, 2015; Qazi, 2016). There are many explanations for SST variation one of the prominent reasons is monsoon annual cycle within that the wind systems entirely reverse its direction (Terray *et al.*, 2003). Overall, it has a great impact on seasonal temperature (Sarangi and Devi, 2017). Also, the coastal and local breeze at a smaller scale. However, impacts from north Indian Ocean circulation that varies within seasons also affect by the remarkable Somali Current (Joseph *et al.*, 2019; Smith *et al.*, 2019).

Table 3: MODIS derived mean monthly SST

	2017	**2018**	**2019**	**Monthly SST Average**
Jan	25.80	25.35	25.55	25.56
Feb	25.75	25.69	25.20	25.55
Mar	26.65	27.04	26.04	26.58
Apr	27.74	28.82	28.39	28.32
May	29.48	29.46	29.13	29.36
Jun	29.11	28.67	29.61	29.13
Jul	27.10	27.13	28.11	27.45
Aug	27.08	25.70	27.30	26.70
Sep	28.12	27.49	28.11	27.91
Oct	28.84	29.27	29.41	29.17
Nov	27.83	28.57	27.84	28.08
Dec	25.87	26.88	26.76	26.50
Yearly SST Average	27.45	27.51	27.62	

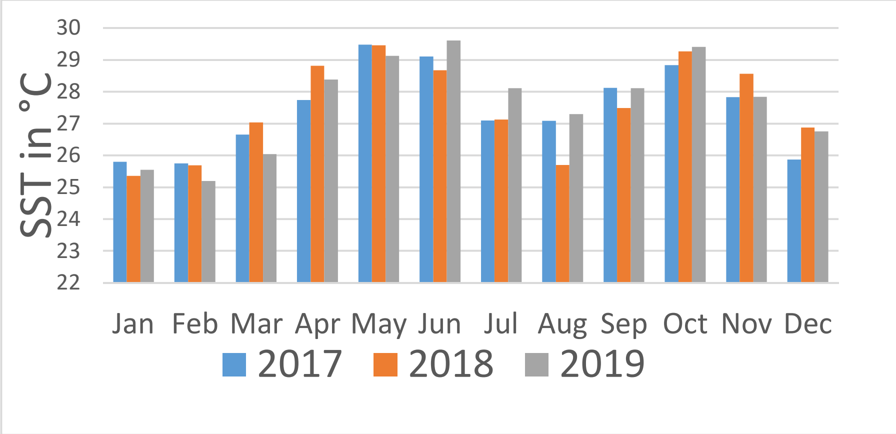

Figure 2: Monthly SST data

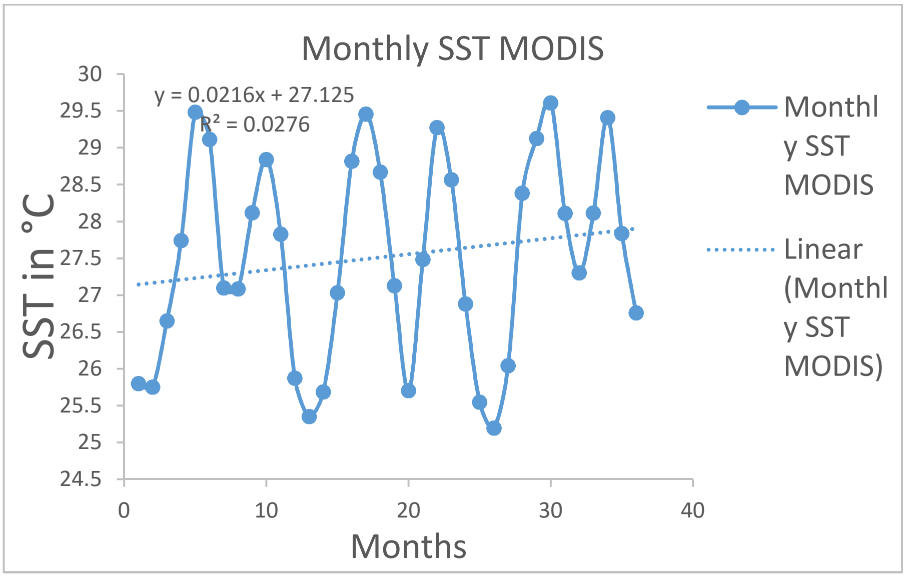

Figure 3: Time series data of SST

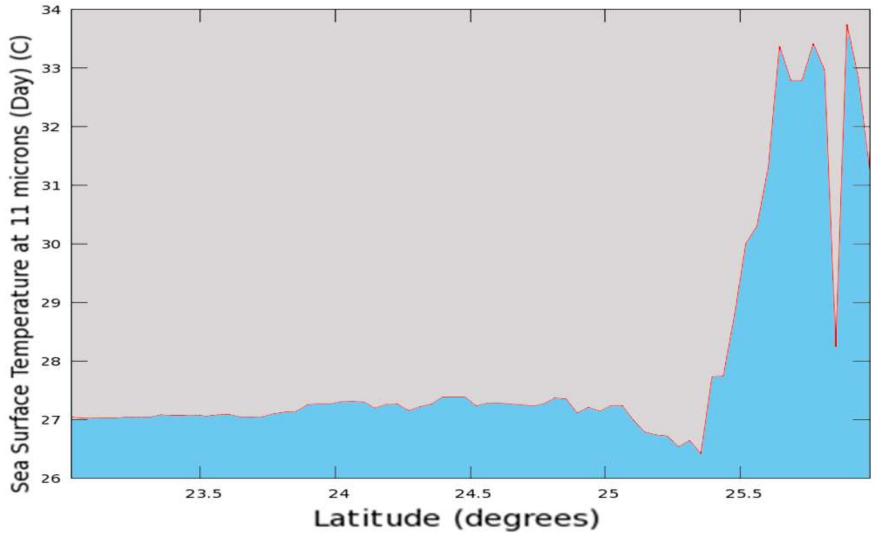

Figure 4: Zonal Mean of Sea Surface Temperature

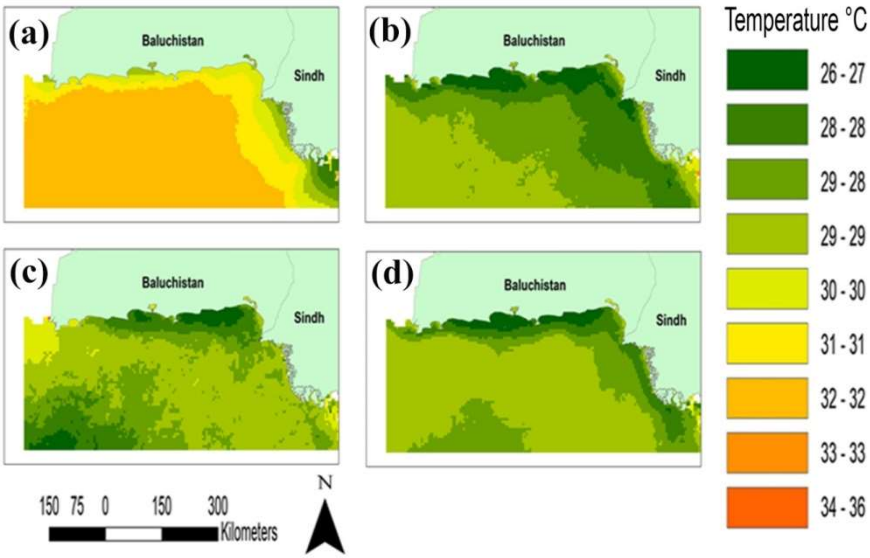

Figure 5: Seasonal variation of SST in the study area (a)Dec to Feb (b) March to May (c)June to August (d) September to November during 2017 to 2019.

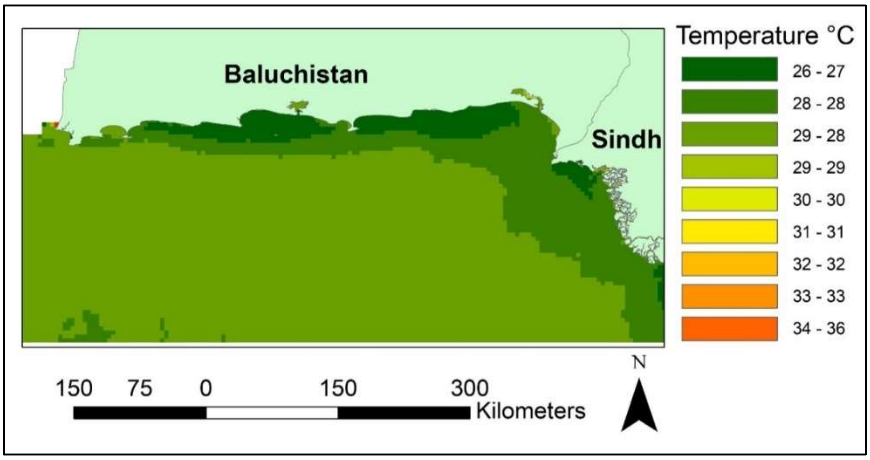

Figure 6: Composite data of 3 years of SST of the study area

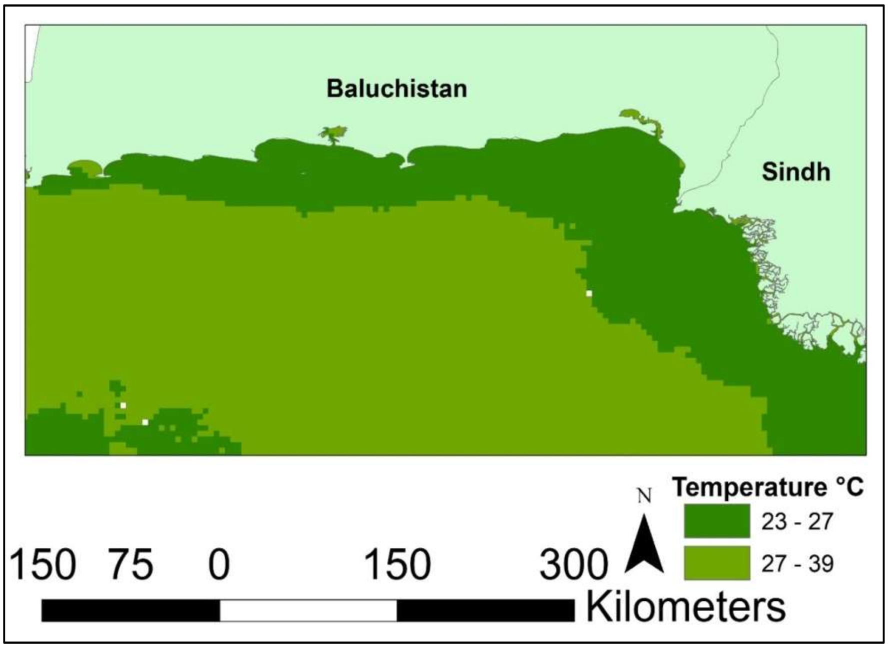

Figure 7 : Conditional demonstration of composite SST data

CONCLUSION

This study displays the advantages of remote sensing at regional scale. MODIS derived data sets have been utilized for mapping and identify patterns of SST near Pakistani coast line. SST mean monthly values shows bimodal (two peaks) seasonal pattern and over all rising trends. Long term SST study could be useful for future climate conditions and their management.

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