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Meteorological Impacts of Sea Surface Temperature Variations Along Coastline of Karachi

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Abstract

Variability of sea surface temperature (SST) is important as the duration and intensity of SST provide the basis for studies related to climatic change scenario. In the present study, monthly datasets of Sea Surface Temperature (SST) relation to Wind Speed, Temperature and Sea Level Pressure (SLP) for the period of six years are used for the period 2004-2009. The SST data is obtained from Moderate Resolution Imaging Spectroradiometer (MODIS). We selected an area for latitude (24°-25° N) and longitude (66.6°-67.5° E) as a reference point to show the variations of SST along coastline of Karachi located in north Arabian sea and its relation to meteorological parameters Wind Speed, Temperature, SLP. Meteorological parameters datasets are obtained from weather Underground Karachi Airport Station. The trend analysis of monthly mean SST shows that SST variations dominated in summer especially in the month of June in. SST is related to Wind Speed, there is positive correlation between SST and wind speed. Generally wind Speed is higher in summer and lower in winter along the coastline of Karachi. SST and air Temperature has shown positive correlation over the coastline of Karachi. The correlation between SST and Sea level pressure negative in the study area.

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Meteorological impacts results heavy precipitation, tropical cyclone, sea level rise and flood in coastline of Karachi.

Keywords: SST, Wind Speed, Air Temperature, MODIS (Moderate Resolution Imaging Spectroradiometer), tropical cyclone, heavy precipitation.

Introduction

In this study an attempt has been made to estimate SST ,Wind Speed, Air Temperature, Sea level pressure (SLP) trends and SST relation to meteorological parameters (Wind Speed, Air Temperature, Sea level pressure) using data obtained from MODIS and Karachi Air Port Metrological station to characterize the Meterological impacts of SST variations along Karachi coastline from the period 2004-2009.SST plays an important role in controlling the ocean's heat content and regulating climate (Bo QU et. al.,2012).SST variations controls meteorological and oceanographic processes such as monsoon depressions and subsequent floods, large-scale sea level fluctuations and formation of tropical cyclones. The expected rise in SST of about 0.2 ℃ to 2.5 ℃ (IPCC, 2008), may cause sea level rise and other natural disasters such as increase in storm frequency and intensity (Singh and Khan, 1999, Khan et al., 2002, Khan et al., 2008).

The temperature of the oceans has a marked influence on the heating and moisture content of the atmosphere. Moreover, scientists have shown that global climate change has impact on local coastal and urban climate (Hussain et al., 2012). Arabian Sea water temperature data sets near Karachi coast reveal increasing trend (Hussain et al., 2010, Hussain et al.,2012).The higher rate of increment of SST in Karachi coastline may be attributed to rapid industrialization Pollution and increase in Air temperature (khan et al., 2008). Researches have also shown that with increase of SST the Wind Speed is also increasing over sea surface (Hussain et al., 2012).

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This communication attempts to investigate Meteorological Impacts along coastline of Karachi by changing pattern of SST and relation to metrological parameters data taken from MODIS and Karachi Airport station.

Instrumentation

In the present study, monthly datasets of SST, Wind Speed, Temperature and SLP for the period of six years are used from 2004-2009. The SST data is obtained from MODIS. Wind Speed, Temperature, SLP datasets are obtained from weather underground Karachi Airport Station.

Site Description

Pakistan has a coastline of about 990 km and roughly divided into two main sections the Sindh coast and the Baluchistan coast. The Sindh coast is roughly 320 km located in the south-eastern part of the country between the Indian border along Sir Creek on the east, while the Baluchistan coast is 670 km at south-western part of the country and borders with Iran near Jiwani in the west (UNEP, 1996). We selected Karachi coast an area for latitude (24°-25° N) and longitude (66.6°-67.5° E). Fig.1 shows Karachi coastline location (khan et al., 2008)

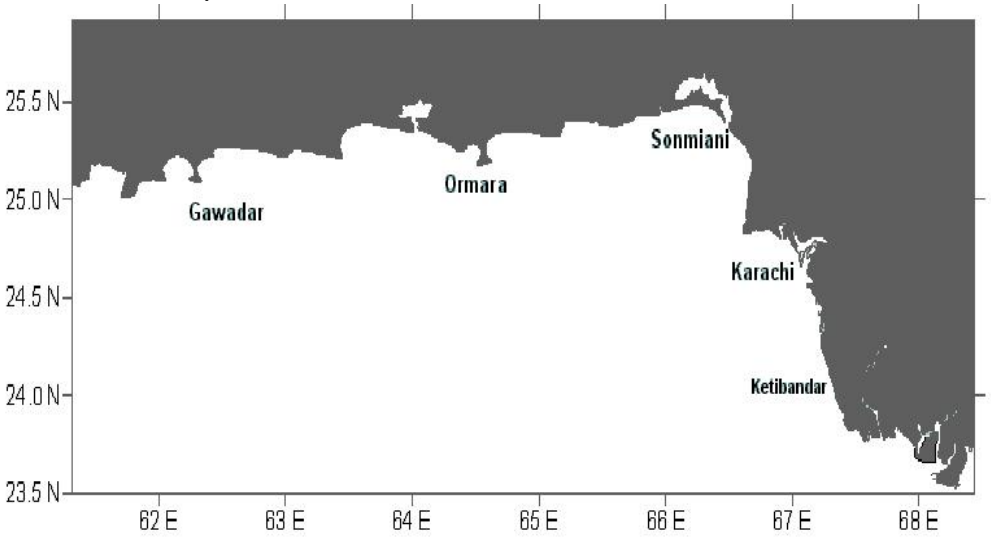

Fig.1: Area under study and location of coastal station along Pakistan coastline. **(khan et al., 2008)**

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MODIS

The MODIS instruments onboard National Aeronautics and Space Administration (NASA)'s Terra and Aqua satellites launched December 1999 and May 2002, respectively have 36 spectral channels providing information on atmospheric, terrestrial, and oceanic conditions. They are useful for collecting large statistics on the impacts that aerosols have on clouds. They are also very useful in detailed studies of their local, regional, and global distributions, and their temporal dynamics, as well as for radiative forcing calculations. Aerosol retrieval is different over land (Kaufman et al., 1997) from over the oceans (Tanre et al., 1997), with MODIS aerosol retrievals over land not expected to be as accurate as over the oceans. The percentage error is thus consistently smaller over the oceans than it is over land (Remer et al., 2005).

The MODIS provides observations at moderate spatial (250–1 km) and temporal (1–2 days) resolutions over different portions of the electromagnetic spectrum. MODIS allow scientists the opportunity to study many of the Earth's terrestrial and oceanic characteristics such as ocean pollution, changes in landscape, amount of bound carbon, and others with a single instrument (Alam et al., 2014).

MODIS add a significant new capability for investigating the 70% of the earth's surface that is covered by oceans, in addition to contributing to the continuation of a decadal scale time series necessary for climate change assessment in the oceans. Sensor capabilities of particular importance for improving the accuracy of ocean products include high stability for narrower spectral bands, improved onboard radiometric calibration and stability monitoring, and improved science data product algorithms. MODIS data are expected to make significant, new contributions to the enhanced understanding of the oceans' role in understanding climate change are discussed (Esaias et al., 1998).

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Results and Discussion

Relationship between Sea Surface Temperature and Wind Speed

Sea surface temperature (SST) plays an important role in controlling the ocean's heat and regulation of climate (Harris et al., 1994). SST influence weather and climate (Kawal, 2007).Wind speed, or wind velocity, is a fundamental atmospheric rate. Wind speed affects weather forecasting, aircraft and maritime operations, construction projects, growth and metabolism rate of many plant species, and countless other implications (Hogan, 2010). From Table .1 we see that SST and wind speed has shown positive correlation over the coastline of study area. The positive correlation between SST and wind speed implies that an increase of SST would lead to increase of wind speed.

However some researches shows the correlation between SST and wind speed is negative which suggest that high wind speed is related with low SST over the Arabian Sea (Shukla et al., 1977; Hurrell, 1995; Jerkness, 1964; Hugon, 2009).

Table 1: *Correlation between Sea Surface Temperature and Metrological parameters*

YEAR	SST & Wind speed	SST & Temperature	SST & SLP
2004	0.50	0.89	-0.68
2005	0.456	0.91	-0.75
2006	0.43	0.84	-0.55
2007	0.58	0.90	-0.82
2008	0.52	0.83	-0.62
2009	0.77	0.93	-0.89

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From Table .1 correlation coefficient values of SST and Wind Speed for the year 2004-2009 are 0.50, 0.46, 0.43, 0.58, 0.52, 0.77 respectively while the correlation coefficient values of SST and Wind Speed over Arabian Sea find by (Shukla et al., 1977) are -0.23, -0.273 and -0.354. (Xie, 2004) showed that SST and Wind Speed are positive correlated over small scale region, the wind speed are locally higher over warm water and lower over cool water.

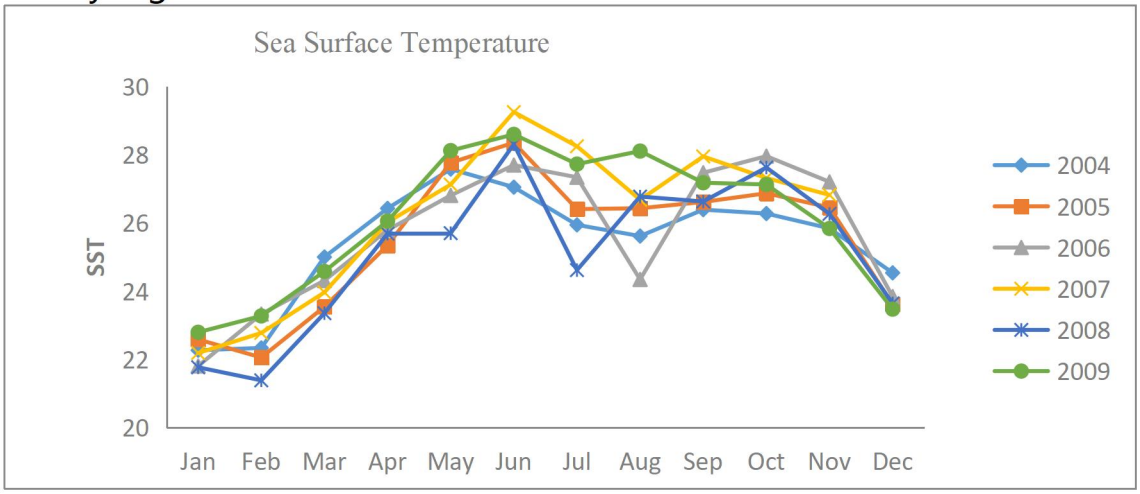

Fig .3: Sea Surface Temperature variations for the years 2004-2009

Fig.3 shows SST variation in Karachi coastline for the year 2004-2009.it can be observed from above figure that the average SST is high in month of june low SST month of Feburary.

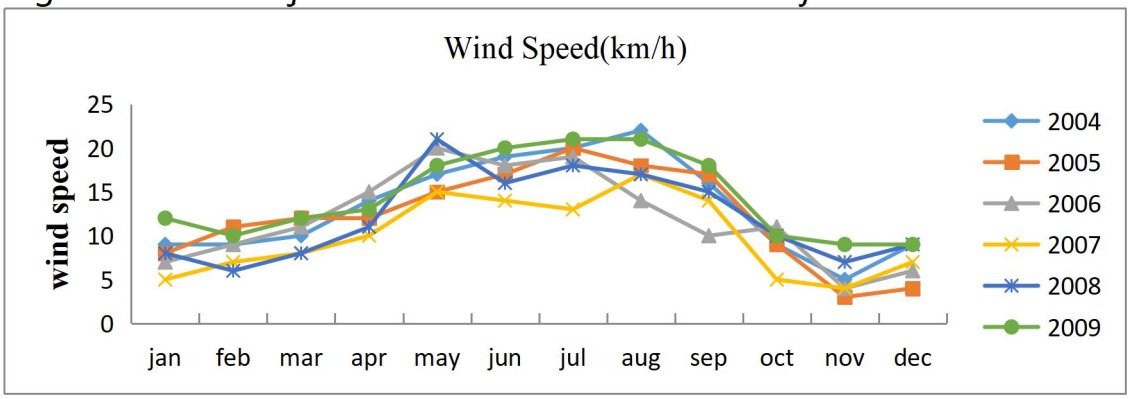

Fig.4: Variation of wind speed from year 2004-2009

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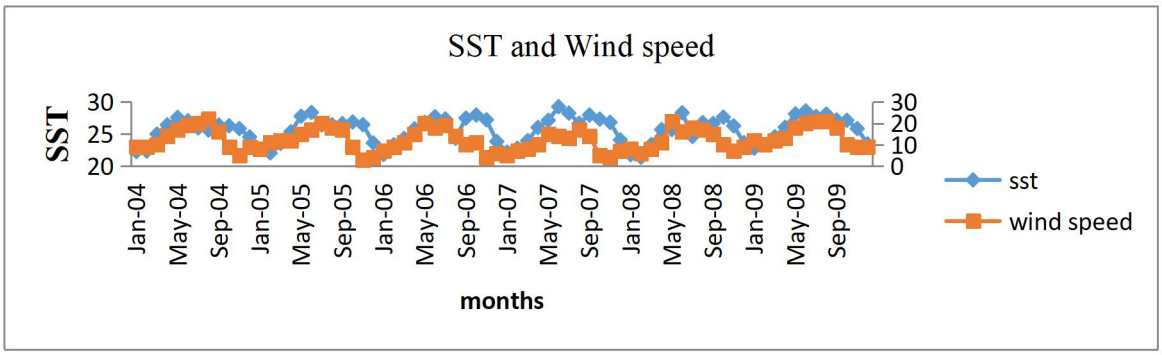

Fig .5: Sea Surface Temperature vs Wind Speed

Fig.4 and Fig.5 shows wind speed variation and SST verses Wind speed for the period 2004-2009 respectively. This can be observed from above Figures the Highest peaks of SST and wind speed occurs in summer. Thus in summer higher the SST results heavy storms, increase evaporation, heavy precipitation in the region.

Relationship between Sea Surface Temperature and Air Temperature

Air Temperature is the Temperature of atmosphere that represent the average kinetic energy of molecular motion in small region. The air temperature at Karachi city and its adjoining coastal belt are generally warmer throughout the year. From the Fig .6 the average annual range of temperature is about 17℃ to 32℃. The average annual air temperature during winter months are 18℃ to 24℃. The average annual temperature during summer months are 28℃ to 31℃.There is always an exchange of energy between the ocean and atmosphere by different mechanism. It implies that SST plays, significant role in climate control (Haroon et al., 2012).the SST in coastal water of Karachi is increasing at higher rate (SMRC, 2004).

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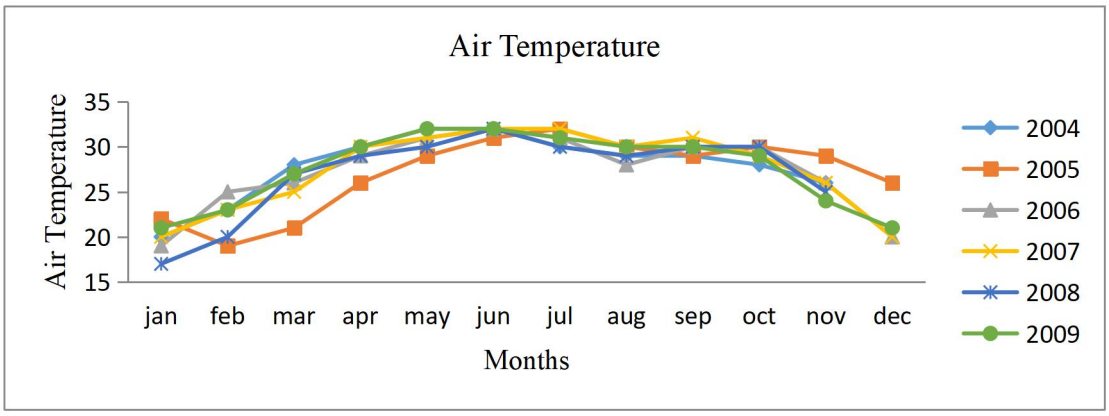

Fig .6: Variation of Air Temperature from year 2004-2009

From Fig.6 we can observe that average air temperature is high in summer i.e in months of May ,June and July. From Fig.6 it can also be observe that highest air temperature is in June 2009.

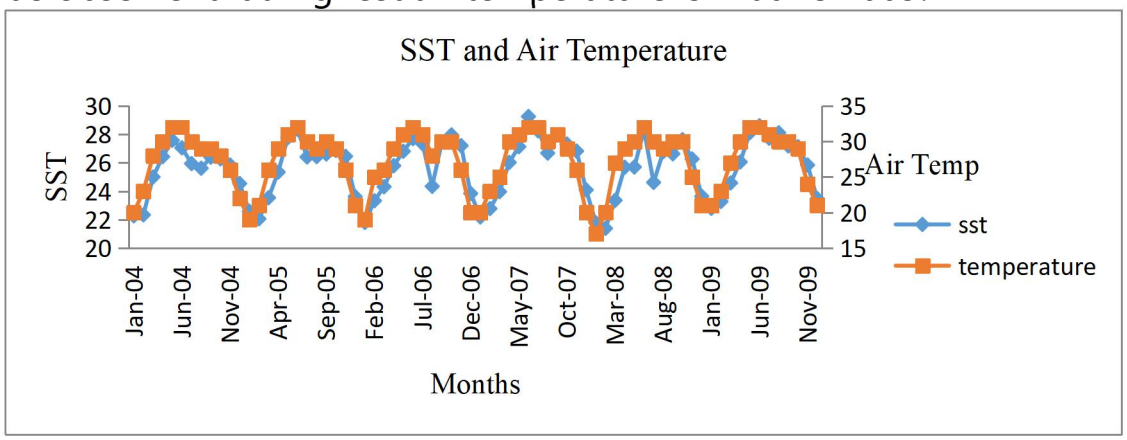

Fig .7: Variations of SST and Air Temperature from year 2004-2009

Fig. 7 shows the direct relationship between SST and Air Temperature.

From the Table .1 we see that SST and Air temperature shows positive correlation in Karachi coastline. The higher correlation value is 0.93 in the year 2009 indicating higher thermal communication at the interface. The correlation value I find 0.93 between SST and Air temperature is strong than the correlation value 0.70 find by (Jaswal et al., 2012). So Warmer the air temperature and SST increase evaporation, heavy precipitation in coastline of Karachi.

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Relationship between Sea Surface Temperature and Sea Level Pressure

Sea Level Pressure is atmospheric pressure at sea level. The pressure is more at the surface of the earth as compared to altitude because of the masses present in the atmosphere that have greater mass on earth as compared to height.

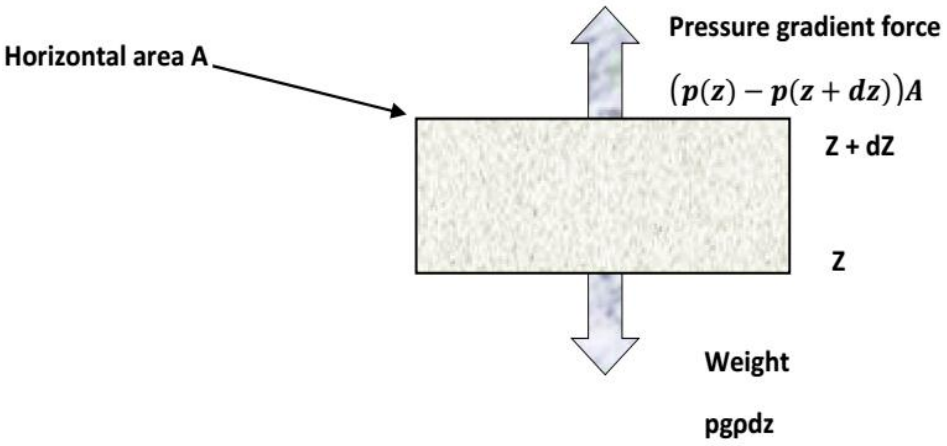

Fig. 2: Vertical forces acting on an elementary slab of atmosphere

From hydrostatic Equation we know that rate of change pressure depends on gravity and density of particles in air. Consider an elementary slab of atmosphere (thickness dz, horizontal area A) at altitude z. The atmosphere exerts an upward pressure force P(z)A on the bottom of the slab and a downward pressure force P(z + dz)A on the top of the slab. The net force, (P(z)-P(z+dz))A, is called the pressure gradient force. Since P (z) > P (z+dz), the pressure gradient force is directed upwards. For the slab to be in equilibrium, its weight must balance the pressure gradient force Fig.2 shows forces acting on an elementary slab of atmosphere

$$\frac{p(z+dz)-p(z)}{dz=-\rho g} \quad (1).$$

The left hand side is dP/dz by definition

$$dp/dz = -\rho g \qquad (2)$$

Equation (2) shows rate of change of pressure with height depends on gravity and particles density.

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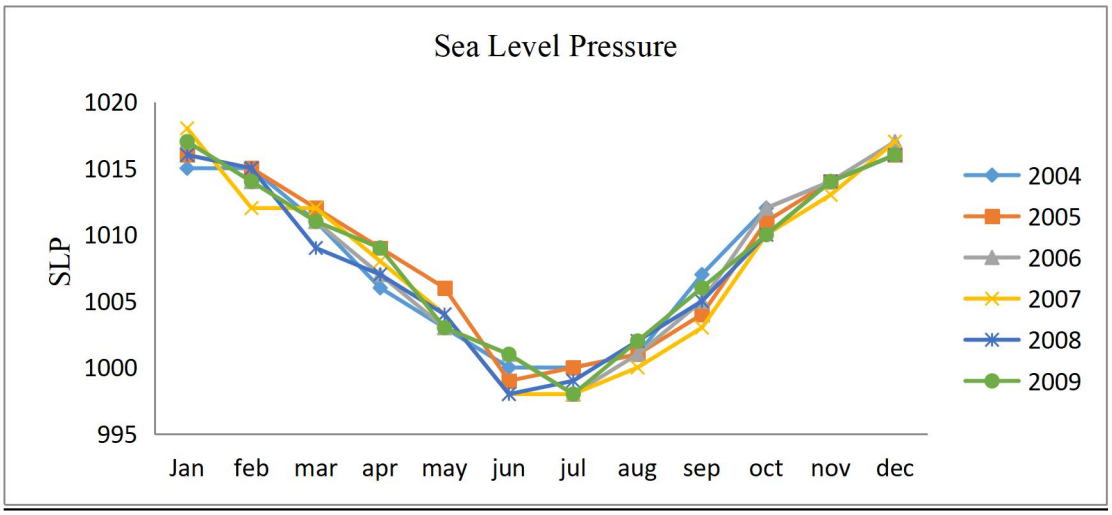

Fig .8: Variation of SLP from year 2004-2009

From Fig. 8 we see that the pressure is maximum in winter that is month of January and February the maximum. Monthly average pressure range is from 1012 – 1018 hpa in winter, while in summer the pressure is minimum especially in month of June and July minimum pressure range is 998 – 1001 hpa.

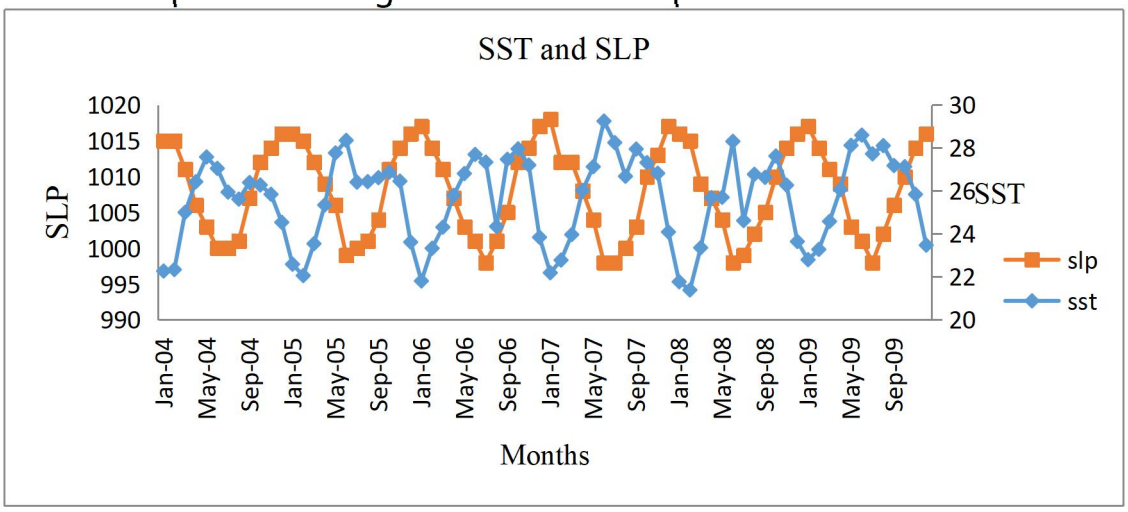

Fig .9: Variations of SST and SLP from year 2004-2009

From fig. 9 we observe low SST and high SLP in winter while in summer high SST and and low SLP. We find strongly negative correlation between SST and SLP. Correlation values are -0.68, -0.75, -0.55, -0.82, -0.62, -0.89 for the year 2004-2009 respectively as shown in table.1.

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The relationship indicates that warmer the SST lower the SLP, results heavy storm in coastline.

Conclusion

The purpose of the study was to examine the Meterological Impacts of SST variations along the coastline of Karachi. We had a unique data set of six years mean monthly observed SST, Wind Speed, Air Temperature and SLP. We computed the correlation coefficient values using observed time series data of SST, Wind Speed, Air Temperature and SLP.

It is found that Wind Speed is positively correlated with SST over Coastline of Karachi. The significant increase in correlation coefficient from year 2007-2009 results heavy storms, cyclones, hurricanes along coastline of Karachi.

The correlation between SST and Air Temperature found to be positive along coastline of Karachi. The positive correlation coefficient suggest increase evaporation rate which further results heavy precipitation in the region.

We also found the correlation between SST and SLP which is negative along coastline of Karachi, results heavy storms, cyclones, Sea level rise and floods in coastline.

From the above relationships we conclude that the Meterological Impacts of SST variations along coastline of Karachi are heavy precipitations, sea level rise, heavy storms, cyclones and floods.

References

A. Hussain and M. R. K. Ansari. (2012). Arabian Seawater Temperature Fluctuations in the Twentieth Century, Journal of Basic and Applied Sciences,8, 105-109.

Bjerknes, J. (1964). Atlantic air-sea interaction. Advances in Geophysics, 10, 1-82.

Bo QU, Albert J. GABRIC, Jing-nan ZHU, Dao-rong LIN, Feng QIAN, Min ZHAO. (2012). Correlation between Sea surface temperature and wind speed in Greenland Sea and their

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

relationships with NAO variability. Water science and engineering, 5(3), 304-315.

Esaias, W.E., Abbott, M.R., Barton, I., Brown, O.B., Campbell, J.W., Carder, K.L., Clark, D.K., Evans, R.H., Hoge, F.E., Gordon, H.R., Balch,W.M., Letelier, R., Minnett, P.J. (1998). An Overview of MODIS Capabilities for Ocean Science Observations. IEEE Transactions on geosciences and remote sensing, 36, 1250-1265.

Haroon, M.A., Afzal, M. (2012). Spatial and Temporal variability of Sea Surface Temperature of the Arabian Sea over the past 144 years. Pakistan journal of meteorology, 9.

Harris, A.R., Brown, S.J., Masons, I.M. (1994). The effect of wind speed on sea surface temperature retrieval from space. Geophysical Research Letters, 21, 1715-1718.

Hogan, M. (2010). Abiotic factor. Encyclopedia of Earth. Edition Emily Monosson and C. Cleveland. National Council for Science and the Environment.

Huang, C., Qiao, F. (2009). The relationship between sea surface temperature anomaly and wind energy Input in the Pacific Ocean. Progress in Natural Science, 19(10), 1409-1412.

Hurrell, J. W. (1995). Decadal trends in the North Atlantic Oscillation, Regional temperatures and precipitation. Science, 269, 676-679.

IPCC. (2008). IPCC Fourth Assessment Report, Working Group I: Chapter 5. Maggie L. Walser and Stephen C. Nodvin (Topic Editors).

Jaswal, A.K., Singh, V., Bhambak, S.R. (2012). Relationship between sea surface temperature and surface air temperature over Arabian Sea, Bay of Bengal and Indian Ocean. Journal of Indian Geophysics, 16(2), 41-53.

Kaufman, Y.J., Tanre, D., Remer, L.A., Vermote, E.F., Chu, A., Holben, B.N. (1997). Operational remote sensing of tropospheric aerosol over land from EOS Moderate-resolution Imaging

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Spectroradiometer. Journal of Geophysics Research, 102, 17051–17067.

Kawal, Y., Wada, A. (2007). Diurnal sea surface temperature variation and its impact on the Atmosphere and ocean. Journal of oceanography, 63, 721-744.

Khan Alam, Rehana Khana, Thomas Blaschke, Azam Mukhtiar. (2014).Variability of aerosol optical depth and their impact on cloud properties in Pakistan. Journal of Atmospheric and Solar-Terrestrial Physics, 107, 104-112.

Khan, T.M.A, Khan, F.A, Jilani, R. (2008). Sea Surface Temperature variability along Pakistan coast and its relation to EL NIÑO-Southern Oscillation. Journal of Basic and Applied Sciences, 4, 67-72.

Khan, TMA, Razzaq, DA, Chaudhry, QZ, Quadir, DA, Kabir, A and Sarker, MA. (2002). Sea Level Variations and Geomorphological Changes In The Coastal Belt of Pakistan, Marine Geodesy, 25, 159-174.

M. A. Hussain and M. R. K. Ansari. (2010). Some Insights of Local and Global Temperatures Dynamics. Arabian Journal for Science and Engineering, 35, 103-113.

Muhammad Arif Hussain, Muhammad Jawed Iqbal, Safeeullah Soomro. (2012). Urban Wind Speed Analysis in Global Climate Change Perspective: Karachi as a Case Study .International Journal of Geosciences, 3, 1000-1009.

Remer, L.A., Kaufman, Y.J., Tanre´, D., Matto, S., Chu, D.A., Martins, J.V., Li, R.-R., Ichoku,C., levy, R.C., Kleidman, R.G., Eck, T.F., Vermote, E., Holben, B.N. (2005). The MODIS aerosol algorithm, products, and validation. Journal of Atmospheric Science, 62, 947–973.

Shukla, J., Misra, B. M. (1977). Relationships between sea surface temperature and wind speed over the Central Arabian Sea and monsoon rainfall over India. Monthly Weather Review, 105, 998-1002.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Singh, OP and Khan, TMA. (1999). Changes in the Frequencies of CyclonicStorms and Depressions over the Bay of Bengal and the Arabian Sea, SMRC No. 2, SAARC Meteorological Research CM.

SMRC. (2004). The status of climatic variations in Pakistan and its impact. Report-10, SAARC Metrological research Centre, Dhaka, Bangladesh, 225.

Tanre, D., Kaufman, Y.J., Herman, M., Mattoo, S. (1997). Remote sensing of aerosol properties over oceans using the MODIS/EOS spectral radiance. Journal of Geophysics Research Atmosphere, 102, 16971–16986.

UNEP. (1996). Fact sheet No.3, United Nations Environmental program, Nairobi, Kenya.

Xie, S. P. (2004). Satellite observations of cool ocean-atmosphere interaction. Bulletin of the American Meteorological Society, 85(2), 195-208.