Characteristics of Sea Surface Temperature of the Arabian Sea Coast of Pakistan and Impact of Tropical Cyclones on SST

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Abstract

Many studies were carried out to explain the behavior and impact of global sea surface temperatures for many climatic parameters. These studies were particular for specific regions or the whole globe but very rare work is available on sea surface temperatures of the Arabian Sea belt of Pakistan. Therefore, the preliminary information about the behavior of the sea surface temperatures of the Arabian Sea in relation to Pakistan covering the area between 8° N to 30° N latitude and 45° E to 78° E longitude is discussed here. Satellite based Sea Surface Temperature data taken from Advance Very High Resolution Radiometry (AVHRR) instrument on board of the National Oceanic and Atmospheric Administration (NOAA) polar satellite covering the period from January 1982 to December 2010 was examined for the purpose. Its variations, yearly and monthly trends are analyzed so as the work may provide a base for further studies on sea surface temperatures. Moreover SST's trend during and before the occurrence of tropical cyclone is also discussed to see the impacts of cyclogenesis on SST. Some warm pools were observed during the years and a cooling effect originates after cyclonic activities.

Introduction

With changing climate of globe, Pakistan remained much vulnerable during recent decades. To minimize the damage as a result of climatic changes, appropriate prediction and forecasting is extremely necessary and is a dire need to save the economic turmoil. For proper estimation and anticipation of future climate, many parameters and variables are accounted for. Among them sea surface temperatures play an important role in designing future weather system. Sea Surface Temperature and wind fields are two important parameters that influence the genesis of tropical (TCs) and cyclones hurricanes (Gray et al., 1992).

Similarly, the variations of latent heat fluxes created due to the changes in SST and tropical cyclones evaluate the atmospheric-ocean interactions and its function in climatic change. This latent heat flux intensity is large in the Arabian Sea and Bay of Bengal because of high surface temperatures which results in more evaporation.

The history of the Arabian Sea as weather cradle is quite complicated. Indian Ocean is the only ocean which has no means to transport the tropical warming to north through conveyor belts. Westerly systems and diffused depressions are accentuated and intermittently moisture flux is provided from Indian Ocean to give more severe precipitation over the northern regions of Pakistan (Shamshad, 1988). Mid tropospheric cyclones (MTC) play eccentric role in persistent weather occurrences over southeast coastal belt of Pakistan and western Ghat of India. MTC don't move as do the Bay of Bengal depressions (Sarfaraz, 2007). So both the Indian Ocean wings; BoB and Arabian Sea contributes to the weather activities over Pakistan. The Tropical Cyclones originating from or accentuated in Arabian Sea are the main source of weather activities over the costal belt. The behavior of the cyclones is the function of temperature fluctuations in the sea. So to understand the SST is the main indicator of whether cyclogenesis or pre–existing system fecundity. Normally the cyclones in the Arabian Sea move to northeast near the shore. Some of the cyclones demonstrated supernatural behavior during previous decade (Fagan, 2009).

Water vapor plays a decisive role in transfer of radiation and latent heat in atmosphere and its fluctuations are closely dependant on sea surface temperatures (Stephens, 1990). High temperature over

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the sea surface would enhance the water vapour concentration in the region increasing precipitation possibility. Latent heat release in the process warms the atmosphere but clouds formed in this process allows infrared radiations to leave the atmosphere thus prevent the atmosphere from further warming during warm SSTs (Wu. and Netwell, 1997). These water vapors along with latent heat would become the cause of cyclones and hurricanes over the surface. So sea surface temperatures are involved in the cause of tropical cyclonic activity and this temperature should be more than 26.5 °C for at least up to 50 meter depth of sea in addition to the five other conditions necessary for the buildup of cyclone (Gray, 1992). But SST only needs to cross a threshold so that a cyclonic activity might start provided that other conditions are also being met. Therefore SST is not an overriding factor in intensifying tropical cyclones but just need to cross the threshold (Evan, 1993) and (Michaels et al., 2006). After the changes in atmospheric temperature during cyclonic activity temperature of the sea surface drops down. Joseph et al. 2010 also observed a drop in sea surface temperature along the track of cyclone. Variations in solar cycles and changes in clouds cover are also responsible for bringing variations in SSTs. The temperature of the surface of oceans exhibits periodicity. These variations are induced by seasonal heating or cooling with varying intensity from year to year (Eber, 1971). Similarly some areas over water surfaces remain warm for larger extent due to availability of chlorophyll and salinity.

Thus analyzing various aspects of behavior of sea surface temperatures may help us in proper and precise prediction. Earth's climatic system could be studied more accurately by having full knowledge of Sea Surface Temperature. It is the most important field in climatic system modeling. Therefore, SSTs and its yearly and monthly trends over the Arabian Sea are analyzed and discussed in this study. Behavior of SST after cyclonic activity is also taken into account.

Brief History of Tropical Cyclones in Arabian Sea

Tropical cyclones developing in Arabian Sea or accentuation of deep depression from Bay of Bengal mostly affect Oman, the western Indian Peninsula and coastal areas of Pakistan under the influence of north-easterlies. The deadliest storm surge of Arabian sea was Great Bombay Cyclone, took place in 1882 causing 100,000 causalities. It is one of ten deadliest tropical cyclones of the known history of the world (Yusuf et al., 2008). Till 2006 most of the researchers believed cyclogenesis took place in pre and post monsoon season in north Indian Ocean. Unusual development of two tropical cyclones Gonu and Yemyen in the month of June, 2007 remained alarming of more warming of Arabian sea than Bay of Bengal (Haider et al., 2007). Gonu after recurring from landfall in Oman, intensified in to a powerful super cyclonic with strong winds (260 Km/hr) made it strongest tropical cyclone of documented super cyclones in the Arabian Sea (NOAA, 2007).

Data and Methodology

The basic data set used in this study is obtained from biased-corrected satellite based Advanced Very High Resolution Radiometry (AVHRR) instrument sensor mounted on the National Oceanic and Atmospheric Administration (NOAA) polar satellites. The data sets are produced on a 0.25° grid at the NOAA's National Climatic Data Center (NCDC) as described by Reynolds (et al. 2007) and datasets for the period from January 1982 to December 2010 are used. These datasets are extracted in excel form at 0.25 degree resolution, covering area between 8° N to 30° N latitude and 45° E to 78° E longitude, by Pakistan Meteorological Department using GrADS. The study area is subdivided into two zones deep sea zone (latitude 10° N to 21° N and longitude 57° E to 72° E) and coastal zone (latitude 21° N to 26° N to longitude 57° E to 71° E) on the basis of variations in temperatures. The images to study the variations in temperature during cyclone days are extracted using GrADS and analyzed. Monthly and yearly average graphs of the two regions are examined and variations in temperature are inspected. Two Cyclonic activities viz: Gonu (June 1-7, 2007) and Phet (May 30 to June 7, 2010) are also discussed in terms of temperature variations during both mesoscale activities.

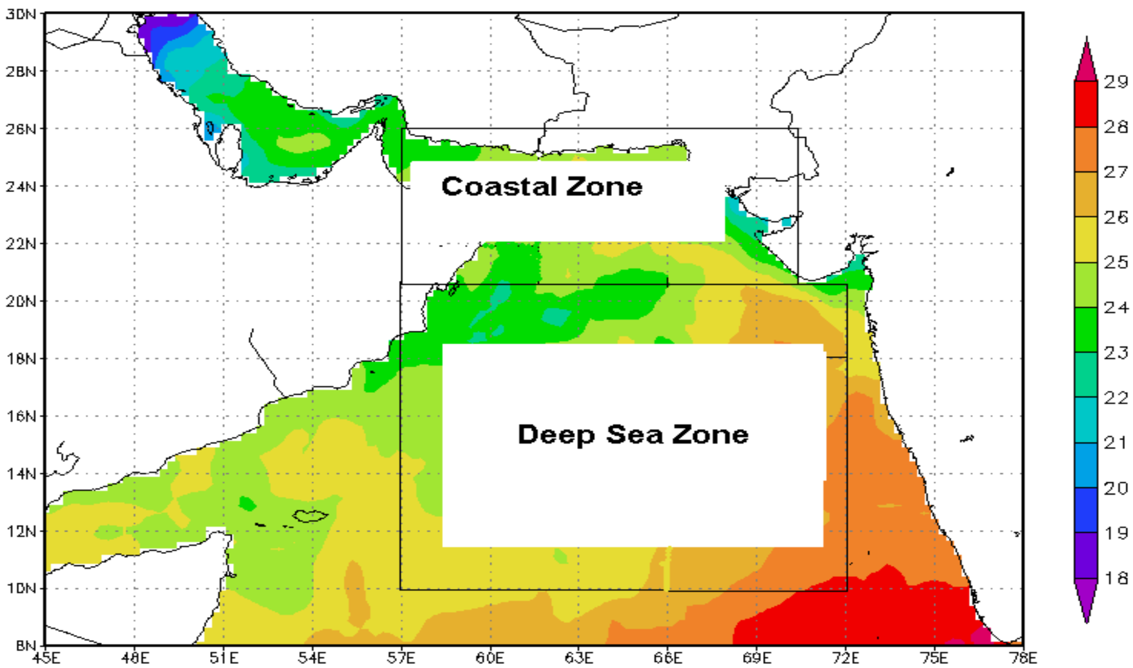
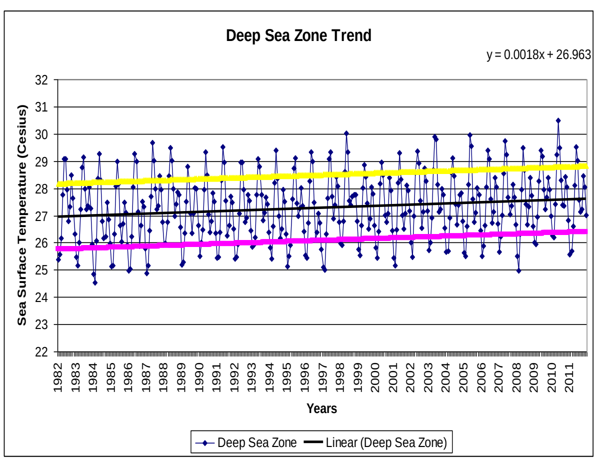


Figure 1: Area of study with identification of zone

Results and Discussion

The average monthly temperature of the two zones describes that there are more variations in temperature in coastal zone as compared to that of deep sea zone (Figure 2). These fluctuations might be due to presence of more salinity along the coastal belt. The temperature fluctuations in deep sea and coastal zones remain in between 25.5 °C to 29 °C and 24.5 °C to 29.5 °C respectively. It is clearly observed that there is very rare increase in the temperatures of both zones as compared to the global temperature fluctuations. Temperature in coastal zone increases at high rate than that of deep sea, however, deep sea is more warmer than coastal area belt as depicted from the monthly average and yearly average graphs of



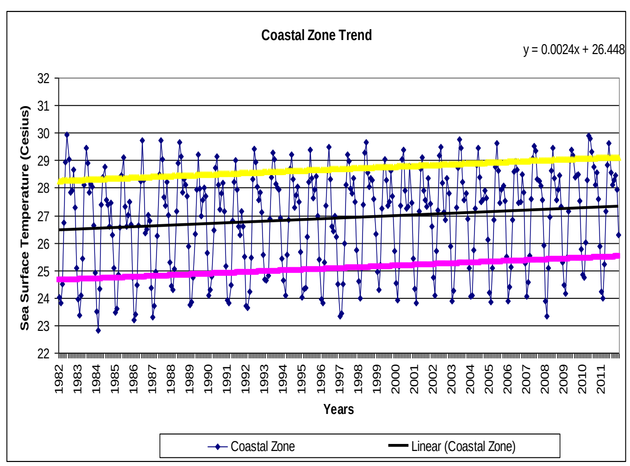


Figure 2: Average temperatures in deep sea zone and coastal zone for the last 30 years showing a slight increase in SST.

both zones (Figure 2 and 3). The rate of temperature increase in deep sea and coastal zone is 0.65 and 0.86 respectively during the period of study. However this increase is also followed by spells of cooling in between the years. The significant cooling effect has also been noticed between the two warming characteristics of sea surface temperatures during 1910-1940 and 1975 onwards (Moron, 1998). A cooling effect is noticed in deep sea zone during 1982 to 1990 whereas a minor cooling effect is observed in coastal zone in the start of study period despite gradual increase over the years. Monthly graphs are also analyzed which reveal that year to year temperature behavior is more or less equivalent. Figure 4 shows monthly average of 30 years temperature trends over the two zones of study.

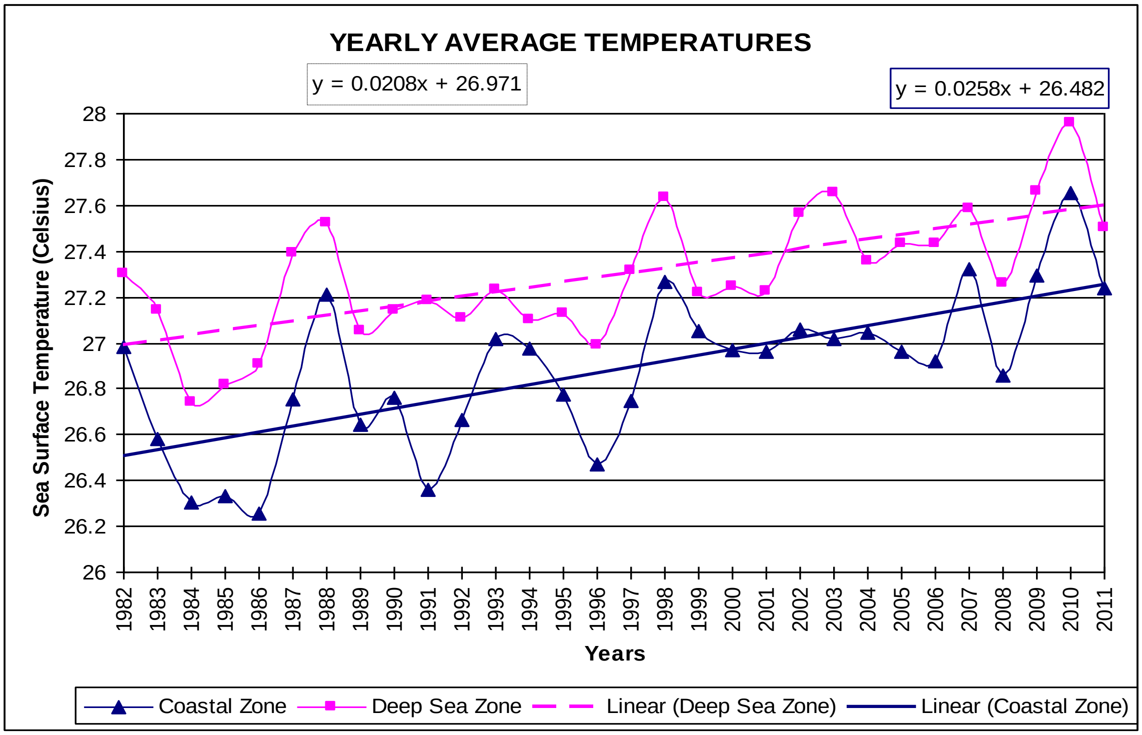


Figure 3: Average yearly temperatures in deep sea zone and coastal zone for the last 30 years showing a slight increase in SST.

Similarly if we see monthly average trend within a year it shows seasoned increase and decrease in accordance with the sun's location. The yearly graph depicts the temperature increases from 4 to 5 °C from January to May in deep sea zone, whereas this increase is seldom upto 10°C in coastal zone. It is worth mentioning that this uneven increase is synchronized in both zones in the start of the year. After remaining at around 30 °C during May and June, temperature falls during July and August and becomes comparable to those in January or February of deep sea zone (Figure-4). During this fall of temperature, both zones behave differently despite of their coordinated increase in the start of the year. There is more decrease in deep sea zone as compared to coastal zone. The coastal zone remain high with a small decrease of 2 °C compared to 4°C decrease of deep sea zone in the month of July and August. The deep sea zone behaves in somewhat different manner. It starts decreasing during June and attains its initial temperature of January in late August and in some early days of September. Thereafter it increases during September and October with 2 °C to 3 °C rise and finally both zones show downward trend from November onwards trying to sustain their positions of January temperatures. However, coastal zone decreases more rapidly despite of its gradual decrease during July and August. Temperature of both the zones remains same in the month of October as also shown in the monthly graph of October (Figure 5). Therefore the two transition phases of change in temperature occur in both zones i.e first temperature of coastal zone increases from deep sea zone during May and thereafter it decreases from deep sea in October but this decrease is gradual compared to increase in May and temperature of the both zones remain same in October. Hence both the zones maintain warm pools two times in a year during the months of May, June and October, November which would be one of the reasons of summer (monsoons) moisture flux over Pakistan and formation of tropical cyclones increases in these months.

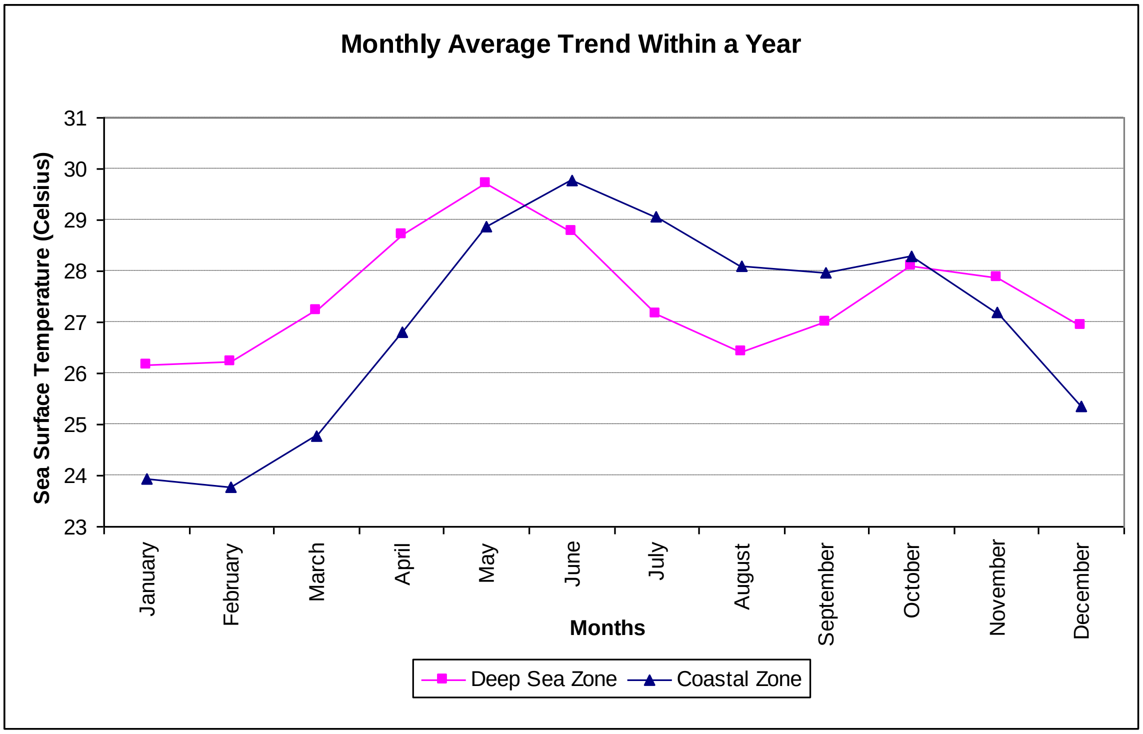
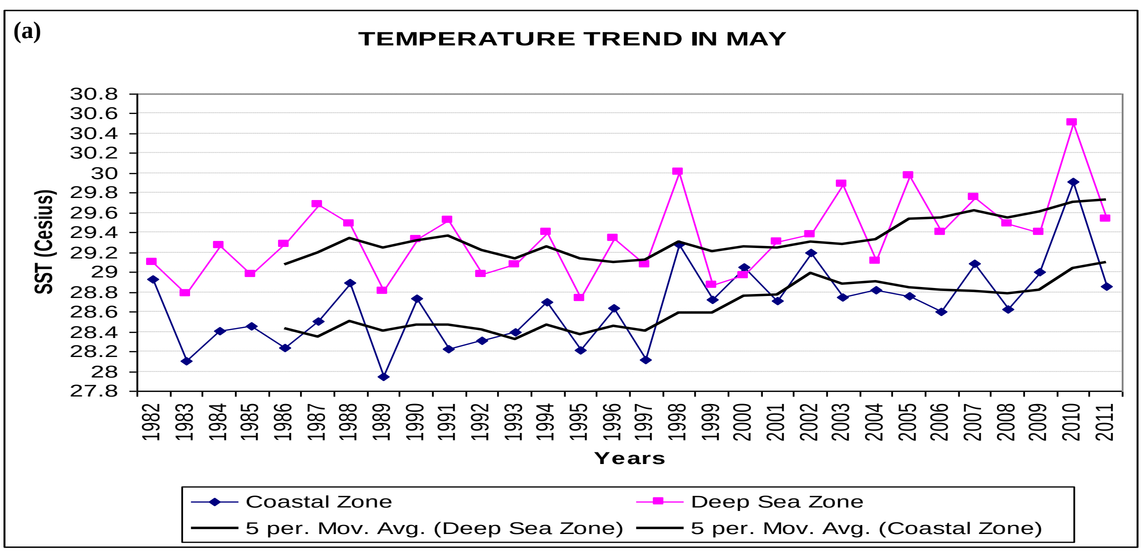


Figure 4: Average monthly temperature of 30 years in deep sea zone and coastal zone

Some of the warm zones are also defined by Babu et al., 2007 and Vinayachandran et al., 2007 in their respective studies. This warm temperature forms the basis for the occurrence of tropical cyclonic activity in the region. In the last two cyclones viz Gonu and Phet discussed in this study, the temperature of major area of sea was observed around 30 °C.

The warm areas created during the months of May, June, October and November are favourable for the formation of tropical cyclonic activity but there is no unusual change in SSTs before or during the outset of a cyclone. SSTs during cyclones monitored do not show any remarkable increase and other factors are to be taken into account for its prediction.



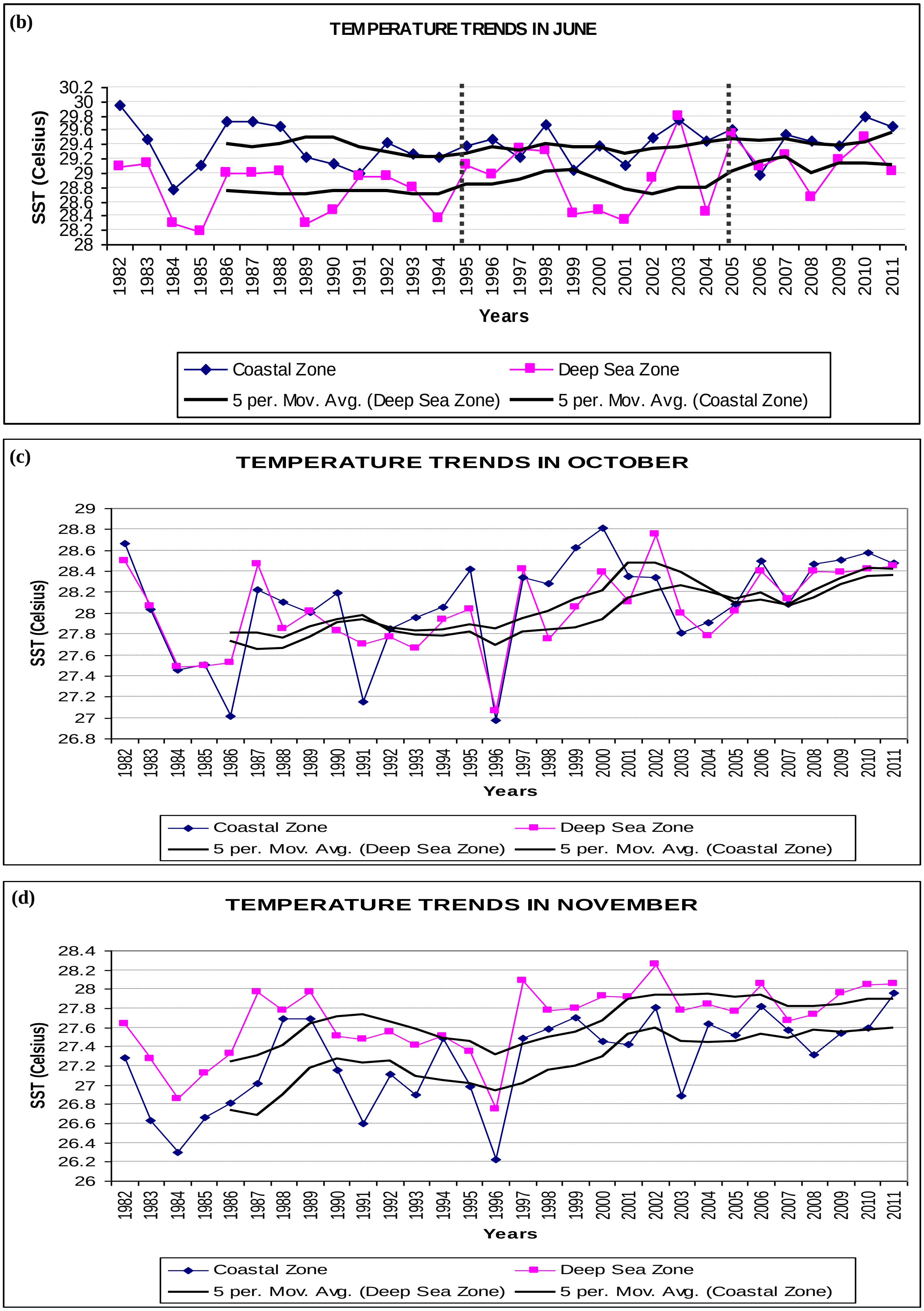


Figure 5: (a-d) Average Sea Surface Temperature trends for the warm months of May, June, October and November in the deep sea and coastal zone area. SSTs in these months remain high compared to other months of the year and are favourable for the formation of Tropical cyclones.

Linear trends of averaged SST for both zones show that there is no remarkable increase during the two cyclones under study viz: Gonu formed from June 1st to 7th, 2007, and Phet from May 31st to June 7th, 2010. SSTs during June 2010 are higher from that of June 2007 and therefore temperatures along the track of Phet remained higher (~1 °C) than observed during Gonu (Figure 5b). But temperature in the area where Gonu originates was observed as compared to the adjoining areas but no such trend appears during Phet. However, there was no rise in temperature in the area where cyclone converts from depression to a severe and a very severe cyclone on June 3, 2007 and temperature remains around 29 °C which was above 30.5 °C in the start of the activity (Figure 6). Similarly on 2nd and 3rd June, 2010 when Phet converts into severe and very severe cyclone, temperature of its track was not showing any unusual trend during or before the activity (Figure 7). In both activities, examination of temperature along the track of cyclone portrays decrease in that area despite of the fact that other areas have still high temperatures. In Figures 6 and 7 temperature of the area from where cyclone Gonu and Phet passed decreased after its passage is shown. So SST alone is not much adequate in predicting cyclonic activity as high temperatures do not sustain during strong cyclone but they are having temperature of 27 °C or more.

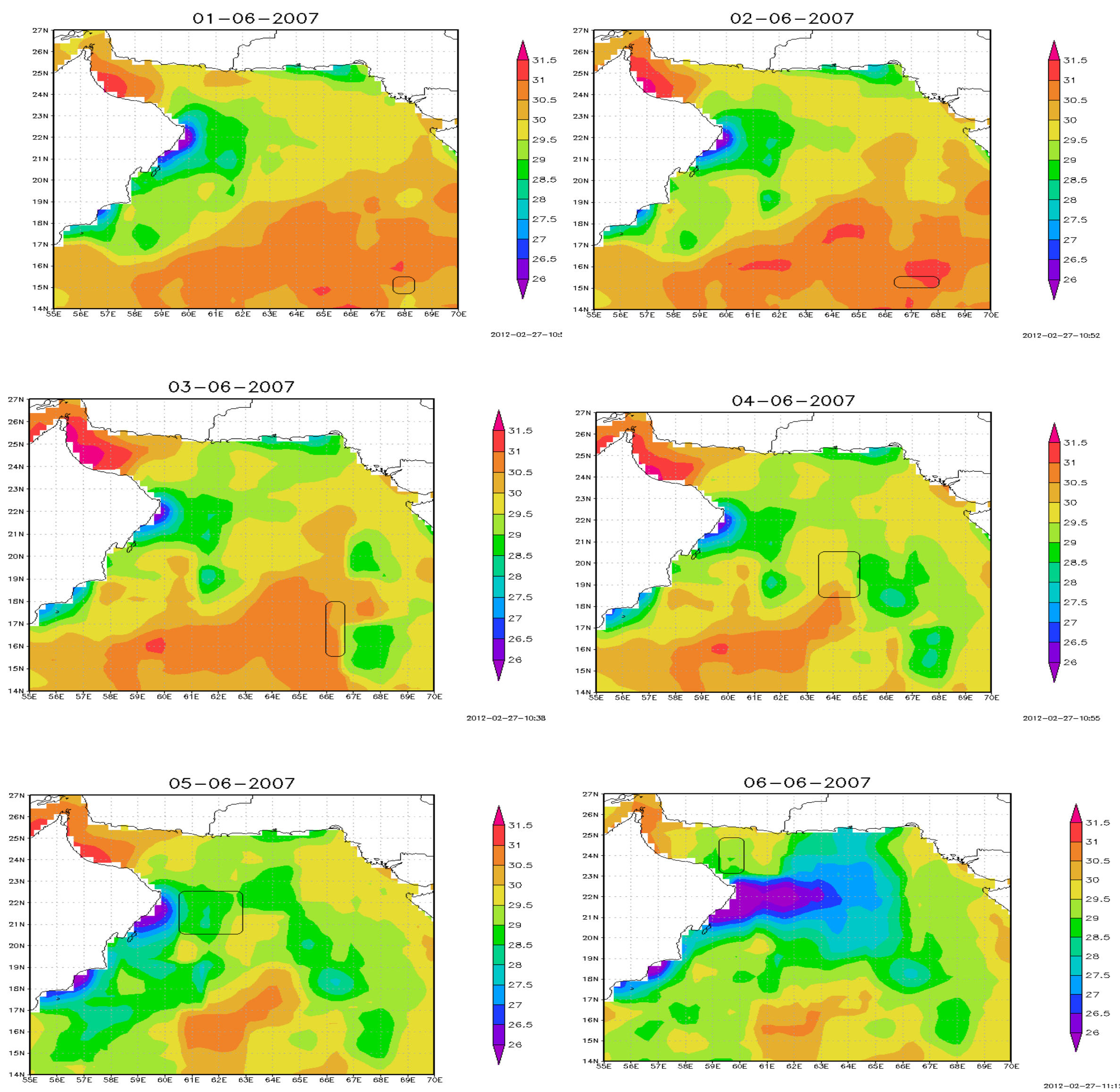


Figure 6: Temperature of sea surface during tropical cyclone Gonu; the circles show a decrease in temperature and path of cyclone in respective days.

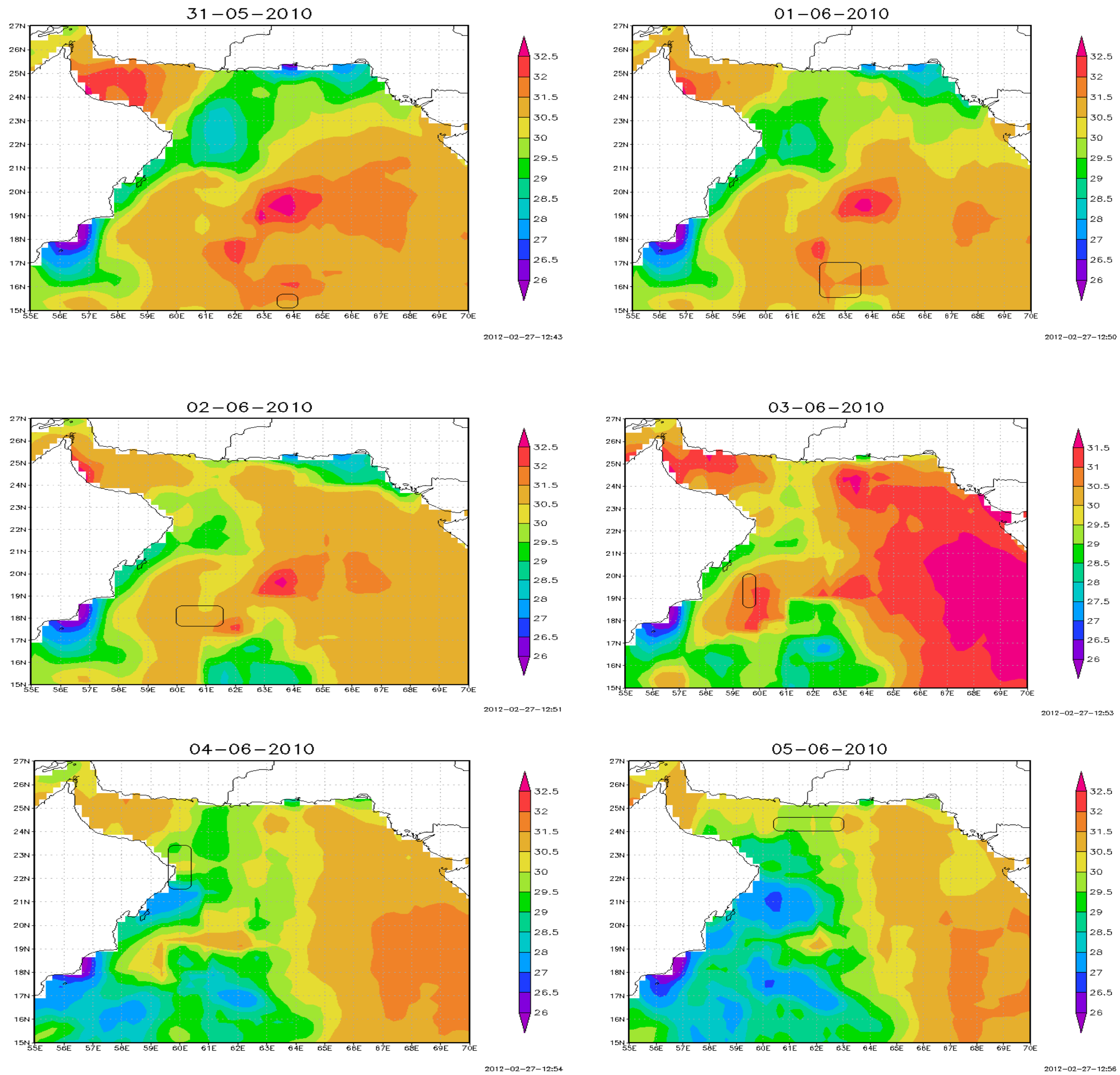


Figure 7: Temperature of sea surface during tropical cyclone Phet; the circles show a decrease in temperature and path of cyclone in respective days.

Conclusion

The above discussion is meant for the preliminary analysis of sea surface temperature of the Arabian Sea along Pakistan coast. Transfer of moisture is obvious from the behavior of sea surface temperatures during different months. High temperature during the months of May, June, October and November causes more transfer of moisture into the atmosphere and maintains warm pools in the Arabian Sea. Therefore these months are more suitable for the formation of tropical cyclones. Over the study period, an increase in SST has been observed. Sea Surface Temperature increases by 0.65 degree Celsius in the deep sea zone and 0.86 degree Celsius in coastal zone. Coastal zone shows more warming tendency as compared to deep sea region. No remarkable increase in SST has been observed during two cyclonic activities (Gonu and Phet). However SST remains around 30°C and after passage of a cyclone, decrease in SST is observed along the track.

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