9B.5

ANOMALIES IN METEROLOGICAL FIELDS OVER NORTHERN ASIA AND IT'S IMPACT ON HURRICANE GONU

Mostafa El Rafy* and Yehia Hafez

University of cairo, Giza, Egypt

ABSTARCT

On June of year 2007, three tropical Indian storms had been recorded. One of those is a supper cyclonic storm ,hurricane Gonu, with maximum surface wind more than 140 Knots had been observed during the period 2-7 June, 2007. The present paper investigates the anomalies in the meteorological fields over northern Asia and its impacts on hurricane Gonu. Daily NCEP/NCAR reanalysis data composites for different meteorological elements over Asia for June 2007 has been used through this study. In addition to that, satellite image for hurricane Gonu has been used. These datasets have been analyzed using anomalies methodology. The results revealed that there existed outstanding anomalies in the meteorological fields distribution which persisted over northern Asia from 1 to 7 June 2007. Also, a weakling of westerlies air current aloft existed over the central region of northern Asia. The unusual winds caused by the weaklings of pressure system over central Asia transfer the cyclone Gonu to become hurricane over the Arabian Sea through a short period of time. In addition, analysis of the 10- day mean anomaly of the geopotential height at 500 mb for the northern Asia for June 2007 revealed that there is outstanding negative anomalies more than -100 m over central Asia simultaneously with positive anomalies more than + 100 m over eastern part of Asia existed only during the first 10 days of June 2007.

1. INTRODUCTION

The North Indian Ocean NIO (Bay of Bengal and Arabian Sea) cyclone season of 2007 was distinct event in the annual cycle of tropical cyclone formation. The NIO cyclone season has no official bounds, but cyclones tend to form between April and December, with peaks in May and November. India Meteorological Department IMD is the official Regional Specialized Meteorological Centre RSMC in this basin. Meanwhile, the Joint Typhoon Warning Center JTWC releases unofficial advisories. Based on the JTWC analysis, tropical cyclone activity in the NIO basin was well above normal during June, 2007, with three tropical cyclones of gale intensity, and one reaching hurricane intensity. This storm of hurricane intensity was Super Cyclonic Storm Gonu, which became the most intense tropical cyclone ever tracked in the Arabian Sea. The peak of the maximum sustained winds MSW estimates for this cyclone were 140 knots and 130 knots from JTWC and IMD, respectively. There have been three previous tropical cyclones in the North Indian Ocean basin for which JTWC's peak MSW estimate reached 140 knot, but none higher. All these cases occurred in the Bay of Bengal: Typhoon Gay (32W) in November, 1989; Tropical Cyclone 02B in April, 1991; and Tropical Cyclone 05B in October, 1999. The hurricane Gonu is considered as a rare Cyclone brushes Arabian Peninsula. It is the most powerful cyclone ever to threaten the Arabian Peninsula since record keeping began back in 1945. While tropical cyclones occasionally form in the Arabian Sea, they rarely exceed tropical storm intensity. In 2006, Tropical Storm Mukda was the only tropical system to form in the region and it remained well out to sea before dissipating.

Cyclonic Storm Gonu led to the worst natural disaster on record in Oman, with total rainfall reached 610 mm near the coast. Particularly, in Muscat, winds reached 54 knots, leaving the capital city without power. The cyclone killed 49 persons with an additional 27 reported missing. Over 20,000 people were adversely affected by Cyclone Gonu, and damage in the country was about 4 billion $ Dollars. In the United Arab Emirates, large waves led to flooding in the coastal city of Fujairah, forcing roads to be closed and traffic diverted causing severe damage to the port. In Iran Gonu dropped moderate to heavy rainfall, including 74 mm in the city of Chabahar, where winds reached 60 knots. A storm tide of 2 meters was reported in some locations. In addition to that, the cyclone was responsible for 23 deaths and caused damage about 216 million $ Dollars.

Fluctuations in tropical cyclone activity are of obvious importance to society, especially as populations of afflicted areas increase. In general, there are several recent literatures challenge the tropical storm intensity, activity and disasters (e.g. Shapiro and Goldenberg, (1998); Emanuel, (2005); Webster et al., (2005);

* Corresponding author address: Mostafa El Rafy, Univ. of Cairo, Dept. of Astronomy & Meteorology, Giza, Egypt 12613; e-mail: elrafy@yahoo.com

Klotzbach, (2006); Michaels (2006)). Whereas, Emanuel (2005) defined an index of the potential destructiveness of hurricanes based on the total dissipation of power, integrated over the lifetime of the cyclone, and showed that this index had increased markedly since the mid-1970s. This trend is due to both longer storm lifetimes and greater storm intensities. Also, he found that the record of net hurricane power dissipation is highly correlated with tropical sea surface temperature SST, reflecting well-documented climate signals, including multi-decadal oscillations in the North Atlantic and North Pacific, and global Warming. Webster et al (2005) analyzed category 4-5 hurricanes (MSW >115 knots) for all tropical cyclone basins over the past 30 years and found that their numbers had nearly doubled between an earlier (1975-1989) and a more recent (1990-2004) 15-year period. Klotzbach (2006) investigated worldwide tropical cyclone frequency and intensity to determined trends in activity over the period 1986-2005 during which there had been an approximate 0.2-0.4 C warming of SSTs. Michaels (2006) found a significant relationship between overall sea surface temperature SST and tropical cyclone intensity in the Atlantic basin, the relationship is much less clear in the upper range of SST normally associated with these storms. More Recently Hafez, (2008) Study the hurricane Katrina and he found that the blocking systems over the northern hemisphere impacts on the track and activity of the hurricane Katrina. The present work aims to investigate the impacts of the anomalies in the meteorological fields over northern Asia on hurricane Gonu.

2. DATA AND METHODOLOGY

The daily data of meteorological parameters and satellite image for hurricane Gonu through the period 1-7 June 2007 has been used through the present study. These data sets obtained from the Indian Meteorological Department (http://www.imd.ernet.in) and the Joint Typhoon Warning Center JTWC (https://metocph .nmci.navy.mil/jtwc.html) .In addition to that, The daily NCEP/NCAR reanalysis data composites for the meteorological elements (MSL pressure, surface temperature, Sea surface temperature, zonal and meridonal wind, precipitation rate, and geopotential height, and air temperature at 500 mb level) over the domain of study (0º N – 60º N) latitudes and (35º E – 145º E) longitude for the period from 21 May 2007 to 20 June 2007 (Kalnay, et al., (1996) has been used through this study. This data sets obtained from the NOAA – CIRES, Climate Diagnostics Centre (CDC) through the Web Site (http://www.cdc.noaa.gov /composites). In the present work, these datasets have been analyzed using of anomalies methodology and linear correlation coefficient techniques, Spiegel (1961).

3. RESULTS

3.1 STAGES AND DEVELOPMENT OF HURRICANE GONU

On June 1, 2007 hurricane Gonu developed from a persistent area of convection in the eastern Arabian Sea. Later on the day the system developed to became a depression, as classified by IMD (IMD, 2007). It tracked westward along the southwestern periphery of a mid-level ridge over southern India. Convection system continued to organize, and early on June 2 the JTWC classified it Tropical Cyclone 02A while it was located about 685 km southwest of Mumbai, India (JTWC, 2007). The storm steadily intensified; early on June 2 the IMD upgraded it to deep depression status and later in the day the IMD classified the system as Cyclonic Storm Gonu while it was located 760 km southwest of Mumbai, India. With a solid area of intense convection, it rapidly intensified to attain severe cyclonic status early on June 3, and with good outflow the JTWC upgraded it to the equivalent of a Category 1 tropical cyclone. Gonu rapidly deepened and developed a well-defined eye in the center of convection. Late on June 3, the IMD classified the storm as Very Severe Cyclonic Storm Gonu, upon which it became the most intense cyclone on record in the Arabian Sea. The IMD upgraded it to Super Cyclonic Storm Gonu late on June 4, with sustained winds reaching 240 km/h and an estimated pressure of 920 mbar. After maintaining peak winds for about 9 hours, the IMD downgraded Gonu to very severe cyclonic storm status early on June 5. Its eye became cloud-filled and ragged, and the cyclone gradually weakened as it continued tracking northwestward. On June 6, the cyclone turned to the north-northwest as an approaching shortwave trough created a weakness in the ridge, and later that day the JTWC downgraded Gonu to tropical storm status. The IMD followed suit by downgrading Gonu to severe cyclonic storm status and later to cyclonic storm status early on June 7.

Figure (1): Terra satellite image for Tropical Cyclone Gonu (02A) in the Arabian Sea on 5 June at 06:35 UTC.

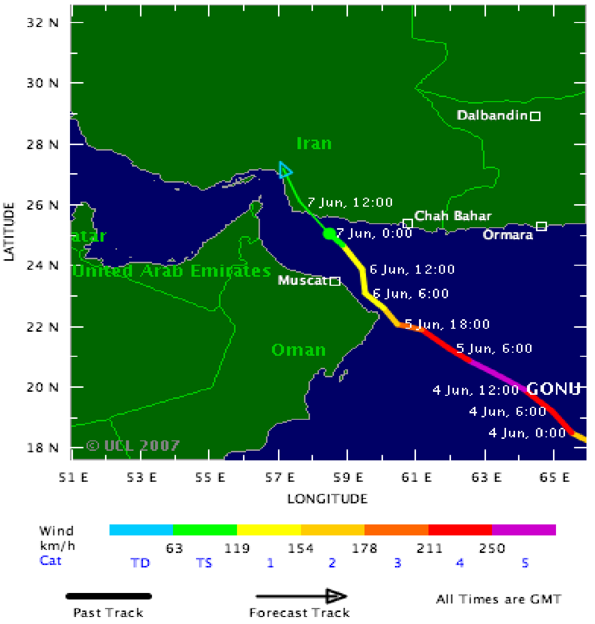


Figure (2): The track and category of hurricane Gonu (NASA).

3.2 ANOMALIES IN THE METEOROLOGICAL FIELDS OVER ASIA DURING LIFE TIME OF HURRICANE GONU

Analysis of the anomalies in daily MSL pressure during the period 1- 8 June 2007 indicate that negative values recorded over the Arabian Sea, with higher negative values during days of 3, 4, to 5 of June. The center highest negative anomalies in MSL pressure appeared following the track and development of Gonu through the period 1-5 June. Positive anomalies can be noticed to the north of the Indian continent on 4 June, to extend southwestward over northeastern Arabian Sea. This may indicate the decay stage of Guno. In addition to that, a significant negative values have been existed over central northern Asia, to extended southward mainly during 2- 5 June, see Figure (3). Those negative anomalies appeared as if they pulled the negative anomalies of the Arabian Sea northward. The distribution of Sea Surface Temperature (SST) anomalies indicate positive values over the Arabian Sea during the period of study with a center of higher positive values to the south of Arabian peninsula. The high positive values of SST anomalies become higher in magnitude and cover a larger area through the period of study until 6 June, with normal conditions (relatively cold SST) begin to appear in the eastern part of Arabian Sea along the west coast of India on 4 June, as shown in Figure (4). Surface zonal wind anomalies indicate positive values over the southern part of Arabian Sea, while negative values existed over the northern part on 2 and 3 June. The negative anomalies over the Arabian Sea associated with high positive anomalies over central and western parts of northern Asia on 4 and 5 June (see figure 5). In addition to that, anomalies of surface meridional wind have high negative values over the western part of Arabia Sea with positive values over the eastern part during the period of study. The values of both positive and negative anomalies persisted during the period of study until 6 June, with higher significant values on 3 and 4 June , as shown in Figure (6). According to the above stated analysis, in comparison with the life history of Guno, one may suggest that the existence of above normal SST (positive anomaly) with positive and negative anomalies in both zonal and meridional winds over the Arabian Sea are the most probable conditions affecting generation and development of hurricane Guno. Figure (7) shows daily mean anomalies in 500 mb level geopotential height for the period of study. The major significant features are as follows: A cell of negative anomalies can be noticed over the Arabian sea on 2 June, to cover a larger area and migrate northward through the period of study until 7 June. The track of the negative anomaly nearly coincides with the track of Gonu. A high significant positive anomalies can be observed over both of eastern and western parts of northern Asia, with a marked negative anomaly in between. Those negative anomalies in 500 mb geopotential height over central north Asia deepened to become higher in magnitude and shifted southward through the life time of Gonu until 7 June. Also, those negative anomalies of central northern Asia appeared as if it attracted the negative anomalies over the Arabian Sea. Daily mean anomalies of 500 mb level air temperature , as shown in Figure (8), shows similar distribution to that of geopotential height over northern Asia. It is clear that, over the Arabian Sea positive anomalies of air temperature can be noticed to become larger in magnitude and moved northward through the period of study. These positive anomalies appears as if it follows the track of hurricane Gonu. Figure (9) shows 10-day mean of both geopoential height and temperature at 500 mb level for three period (I) from 21 to 31 May 2007, (II) from 1 to 10 June 2007 and (III) from 11 to 20 June 2007. The three periods have been chosen to investigate the fluctuation of meteorological field distribution before, during and after the life time of hurricane Gonu. The major significant feature is the existence of positive anomalies in geopotential height(more than +100 m) over both western and eastern part of north Asia, with negative anomalies (less than –100 m) in between over central north Asia. During the life time of Gonu, period (II), the negative anomalies over north Asia became higher in magnitude and shifted southward, while the positive anomalies over the western north Asia weakened. The positive anomalies over eastern northern Asia intensified during the same period. Similar significant distributions can be noticed in the 500 mb temperature fields.

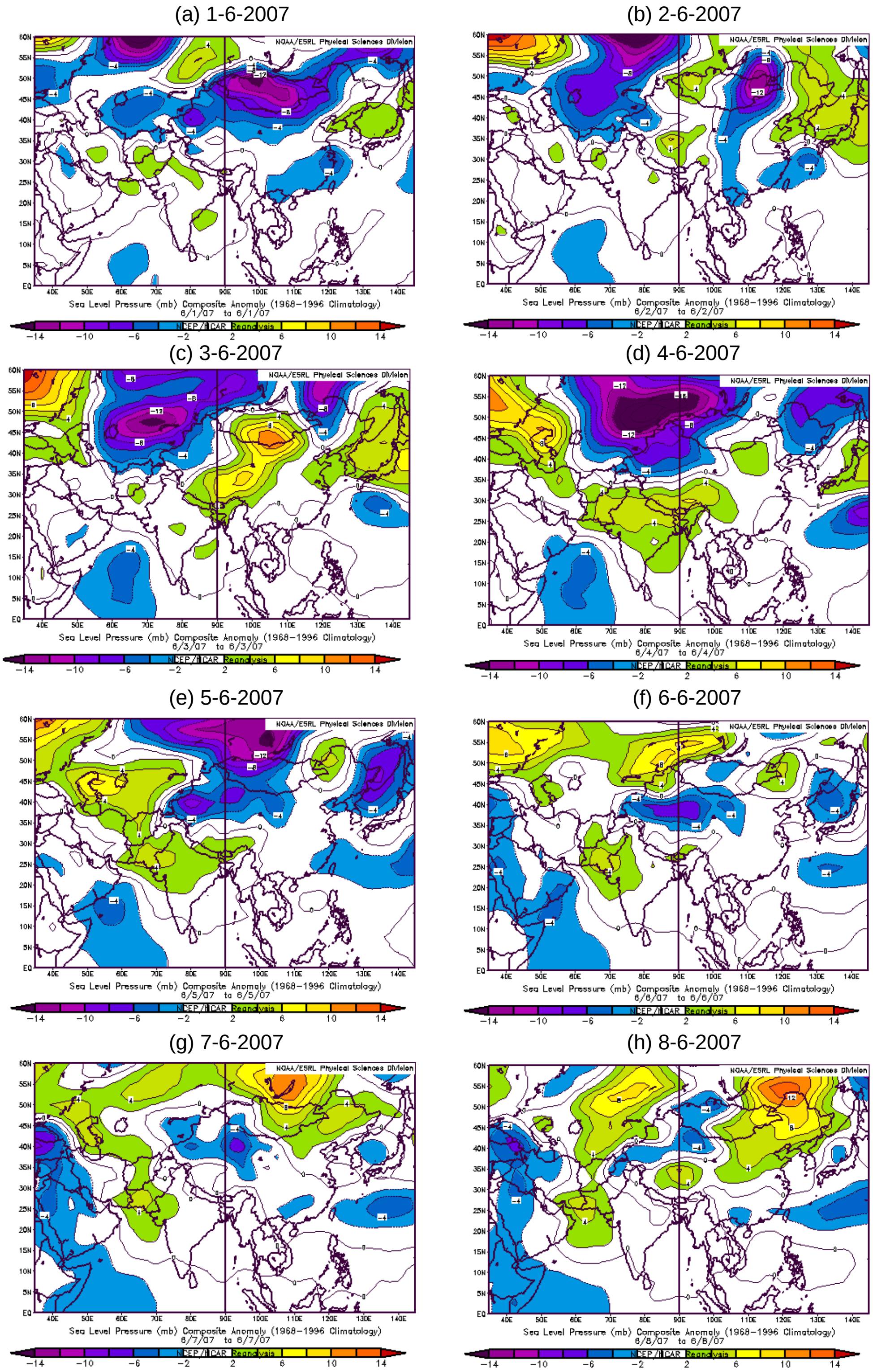


Figure 3: Daily mean composite anomaly of sea level pressure for the period from 1-6 to 8-6-2007.

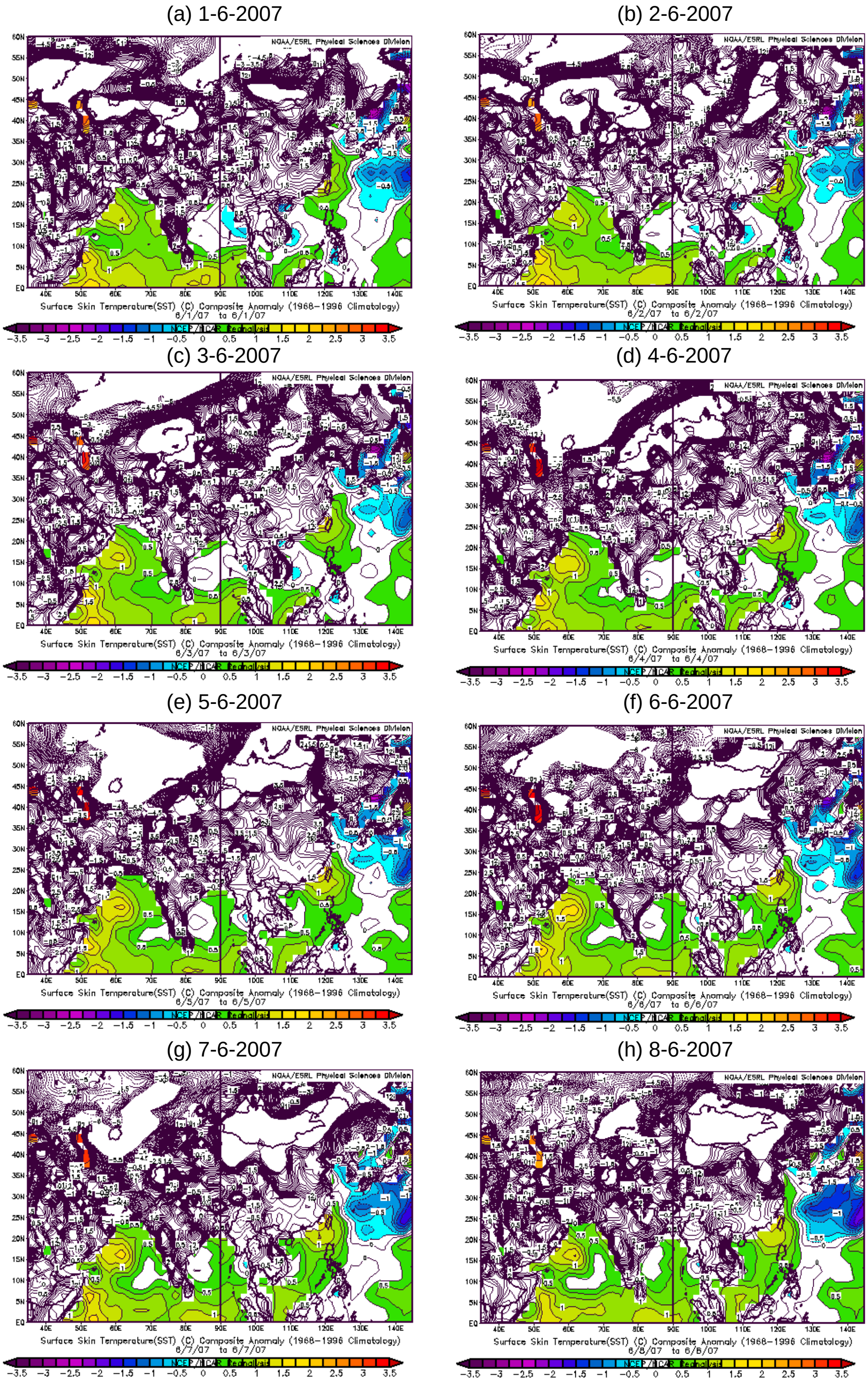


Figure 4 : Daily mean composite anomaly of sea surface temperature SST for theperiod from 1-6 to 8-6-2007.

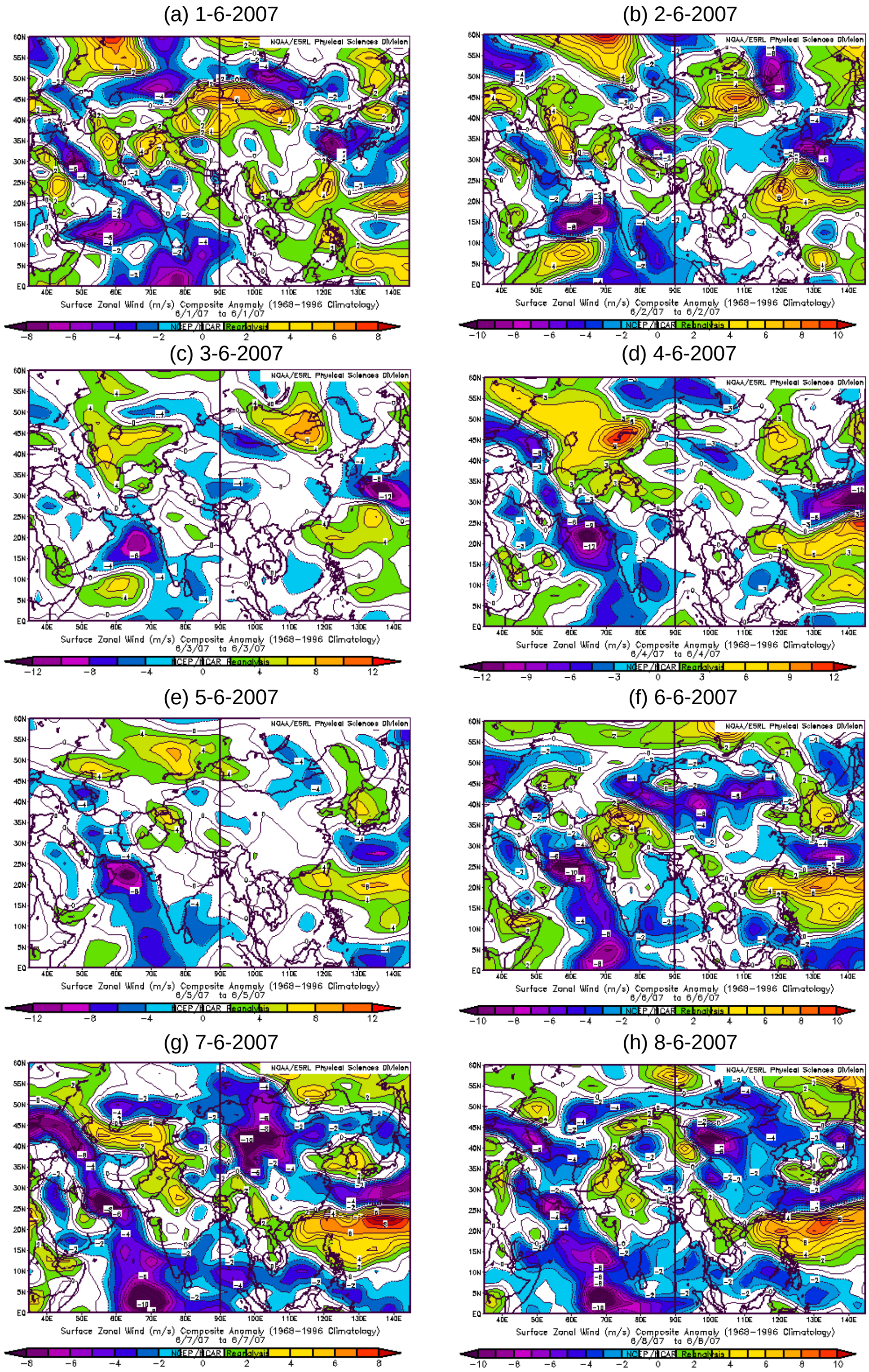


Figure 5: Daily mean composite anomaly of surface zonal wind m/s for the period from 1-6 to 8-6-2007.

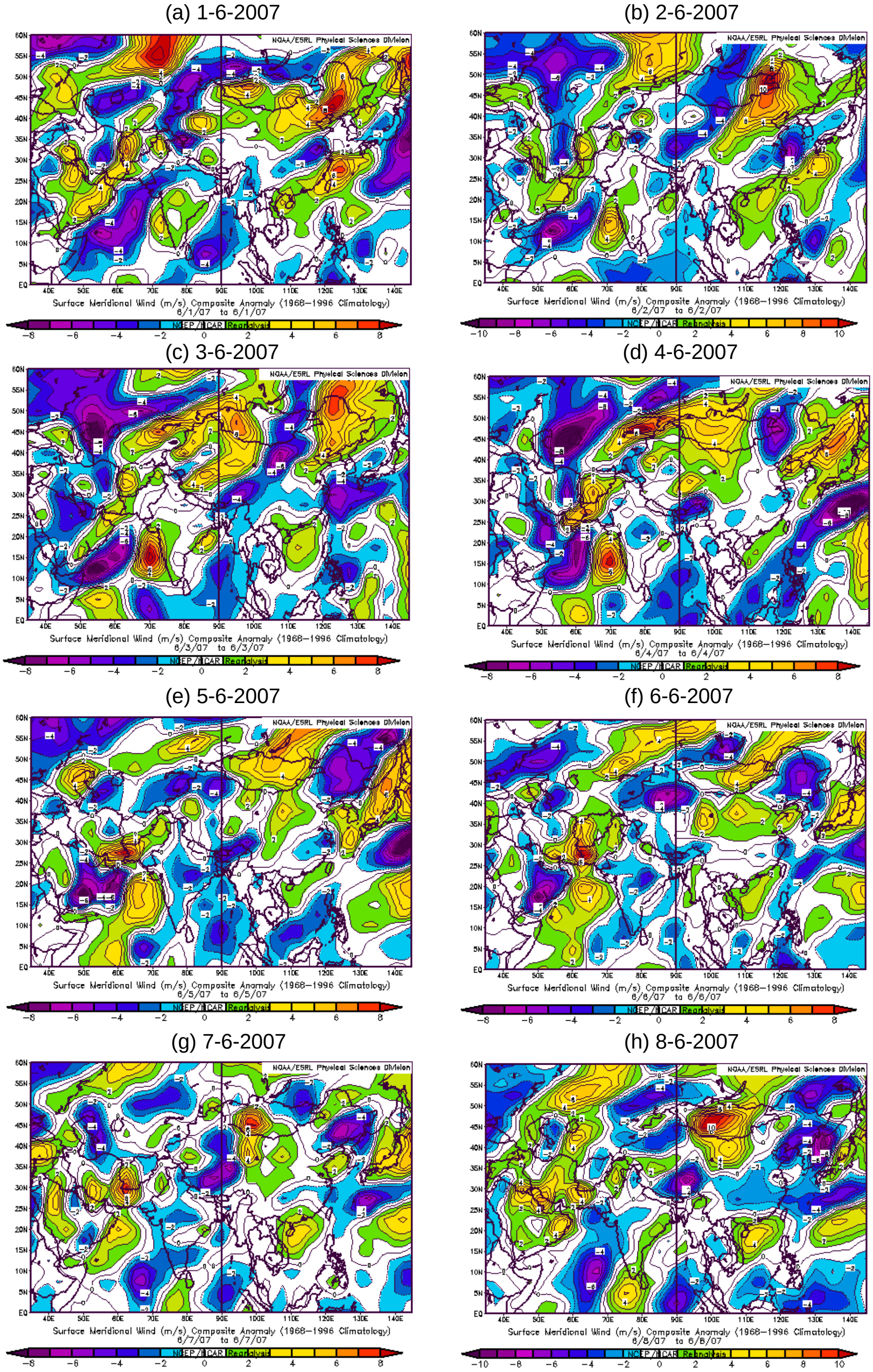


Figure 6 : Daily mean composite anomaly of surface meridional wind m/s for the period from 1-6 to 8-6-2007.

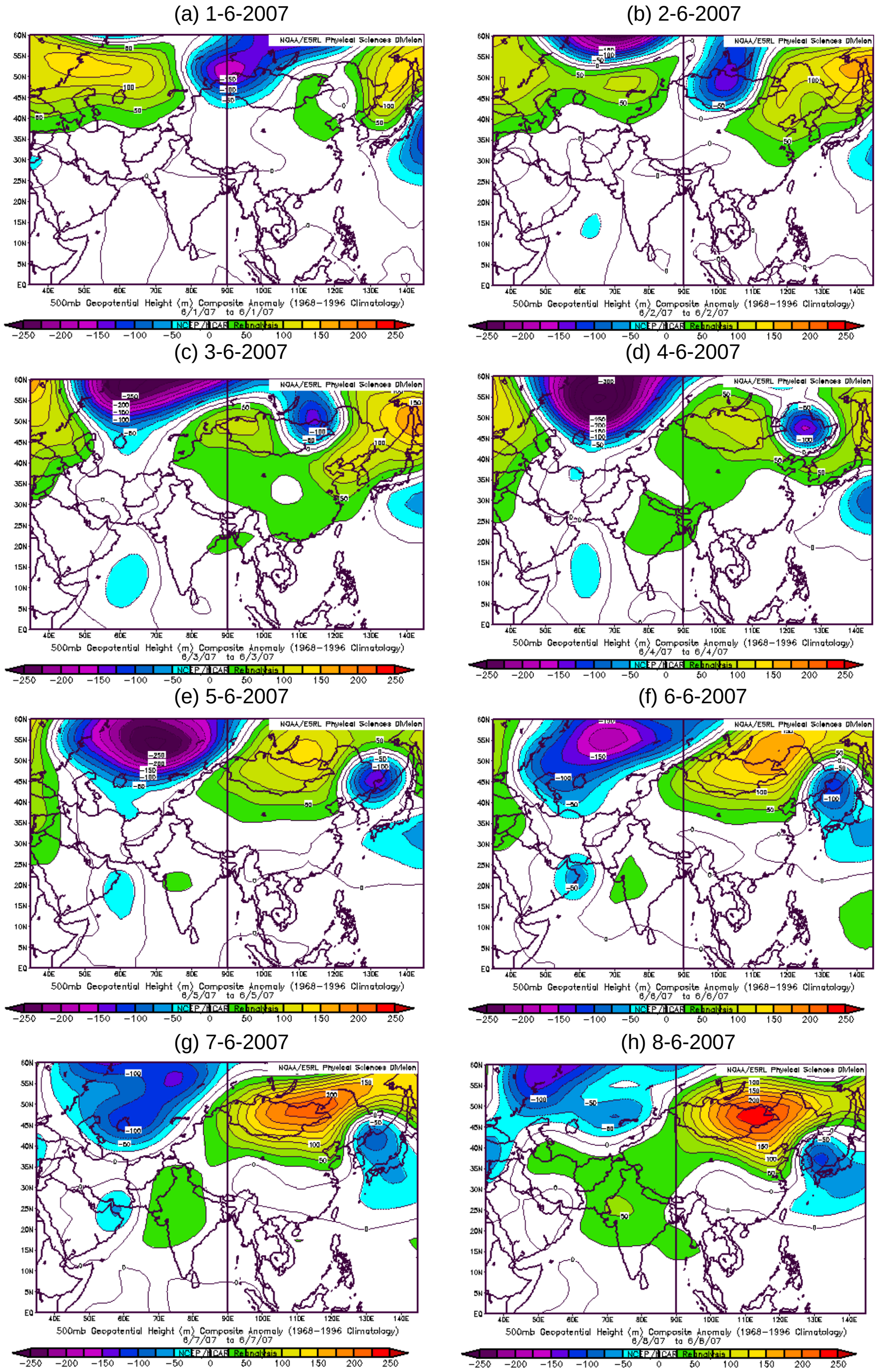


Figure 7: Daily mean composite anomaly of 500 mb geopotential height for the period from 1-6 to 8-6-2007.

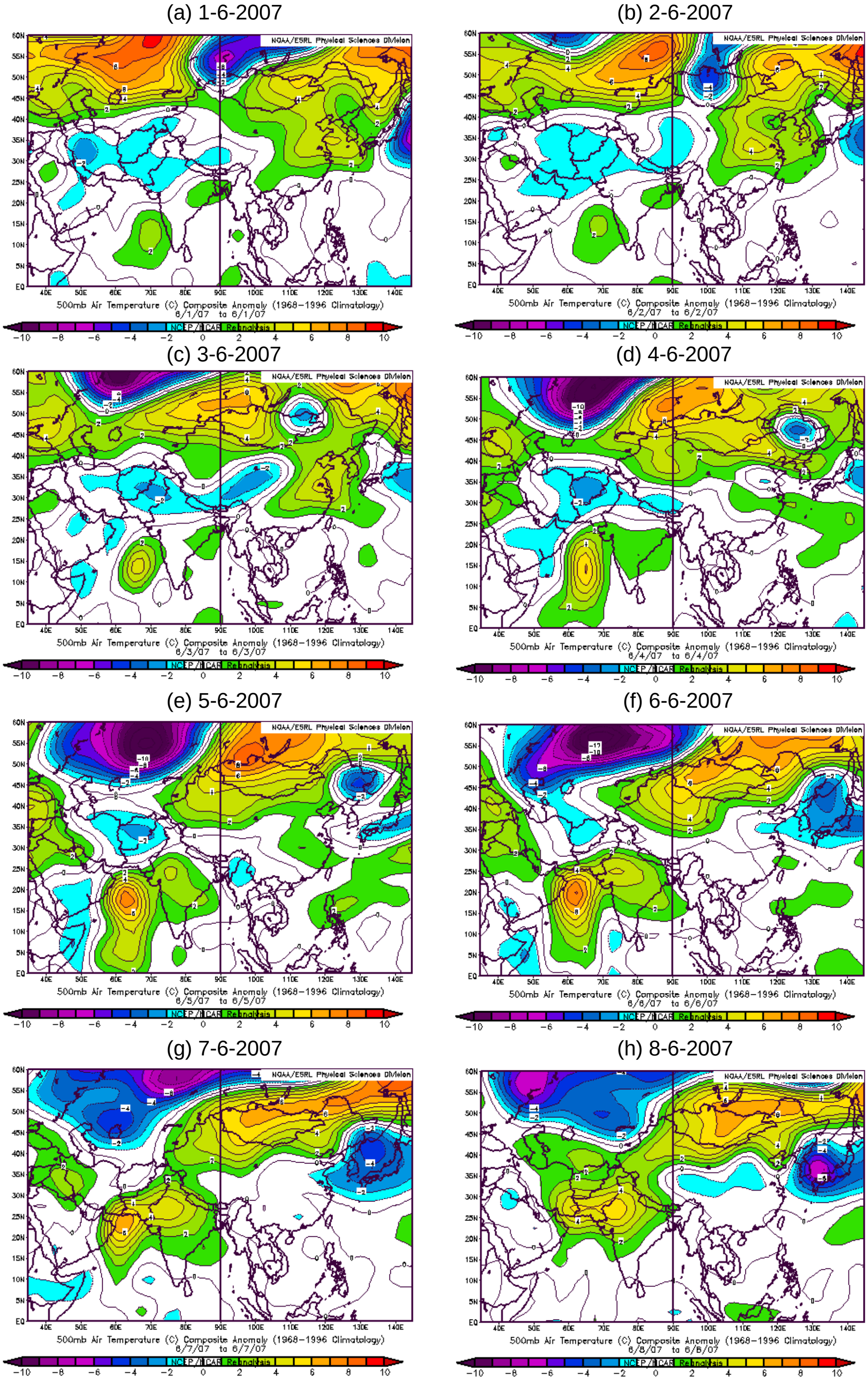
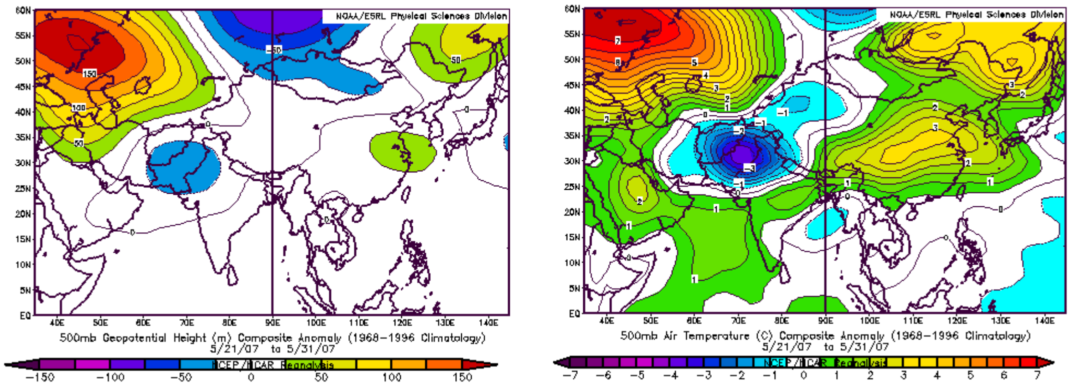


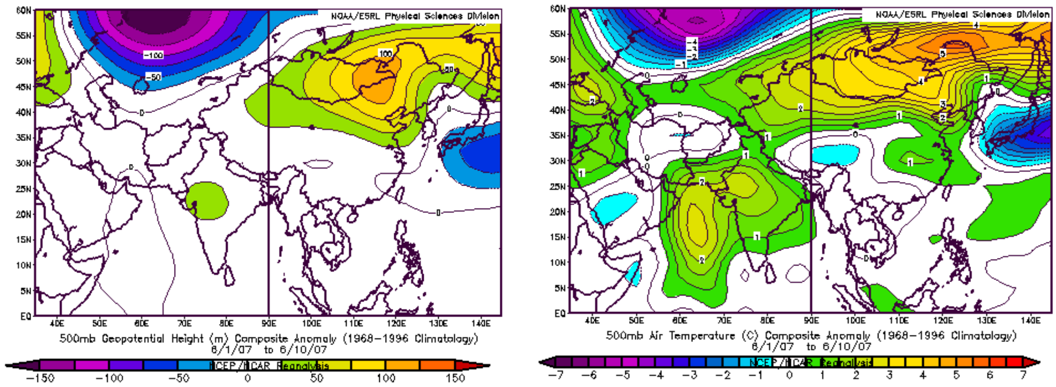
Figure 8 : Daily mean composite anomaly of 500 mb air temperature for the period from 1-6 to 8-6-2007.

(I) Geopotential height (II) Air temperature

(a) For the period from 21-5 to 31-5-2007



(b) For the period from 1-6 to 10-6-2007



(c) For the period from 11-6 to 20-6-2007

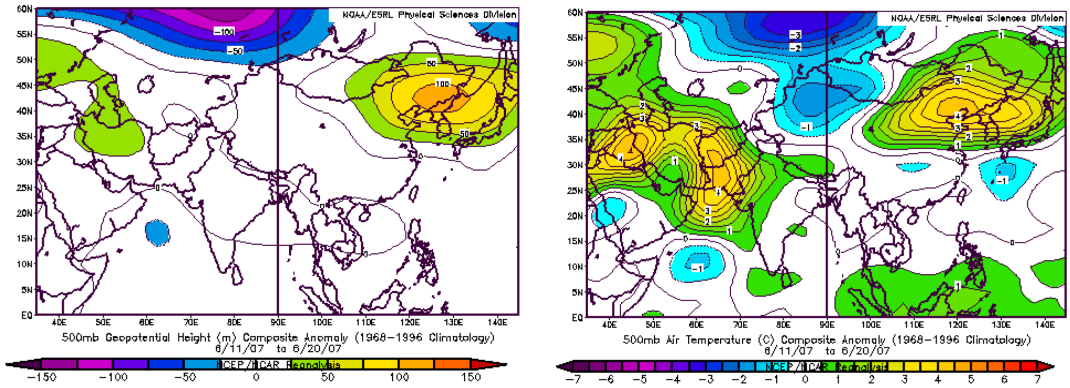


Figure 9: 10 days mean composite anomaly of 500 mb level (I) Geopotential height and (II) Air temperature for the periods (a) From 21-5 to 31-5-2007, (b) From 1-6 to 10-6-2007 and (c) From 11-6 to 20-6-2007.

Table 1: Illustrates the matrix correlation coefficient values of the anomalies of meteorological parameters on the northern Asia (western, central, eastern regions) and Arabian Sea region through the period of (1 –8 June 2007).

Arabian Sea Region / Northern Asia Regions	MSL pressure at northern part	MSL Pressure at southern part	Temperature at 500 mb level	Geopotential Height at 500 mb at northern part	Geopotential Height at 500 mb at southern part	Surface Zonal wind at northern part	Surface Zonal wind at southern part	Surface Meridonal wind at northern part	Surface Meridonal wind at southern part	Precipitation Rate
MSL Pressure at Western	-0.58	-0.60	0.43	-0.68	-0.59	-0.78	0.66	0.11	-0.11	0.71
MSL pressure at Central	0.61	0.11	0.07	0.57	-0.12	0.39	-0.72	-0.76	0.69	-0.09
MSL Pressure at Eastern	0.48	0.03	-0.03	0.08	0.14	0.27	-0.48	-0.56	0.46	0.04
Geopotential Height 500 mb at Western	-0.02	0.75	-0.55	0.26	0.25	0.62	-0.10	0.36	-0.42	-0.72
Geopotential Height 500 mb at Central	0.18	-0.67	0.58	-0.20	-0.27	-0.49	0.03	-0.57	0.59	0.66
Geopotential Height 500 mb at Eastern	0.21	0.78	-0.76	0.04	0.49	0.68	-0.24	0.00	-0.16	-0.74
Temperature at 500 mb Western	-0.08	0.74	-0.59	0.15	0.31	0.56	-0.01	0.45	-0.49	-0.73
Temperature at 500 mb Central	-0.28	-0.42	0.29	-0.52	-0.51	-0.62	0.46	-0.23	0.22	0.48
Temperature at 500 mb Eastern	-0.52	0.29	-0.46	0.01	0.41	0.17	0.43	0.68	-0.81	-0.42

3.3 IMPACT OF ANOMALIES IN METEOROLOGICAL FIELDS OVER NORTHEN ASIA ONHURRICANE GONU

In the present study, it is liable that, northern Asia can be divided into the following three distinct regions: Whereas, Region (I) is the western region which represented by the boundaries (30º N –60º N) latitudes and (35º E –70º E) longitudes. Region (II), is the central region with boundaries of (30º N –60º N) latitudes and (70º E –110º E) longitudes. The third region, region (III), which occupy (30º N –60º N) latitudes and (110º E –145º E) longitudes. In addition to that, the Arabian Sea region (Gonu Region) has been divided into two regions, the first one is the northern part lies north of latitude 15º N , while the southern part lies to the south of 15º N. The linear correlation coefficient analysis according to Spiegel, (1961) has been used to study the relationship between the anomalies in the meteorological fields over northern Asia and hurricane Gonu. Table (1) illustrates the matrix correlation coefficient values of the anomalies of meteorological parameters over the northern Asia regions and Arabian Sea region through the period of (1–8 June 2007). Analysis of the correlation coefficient clarify that, there are several high significant values of correlations. Also, it is clear that there are high significant positive correlation values (0.75, 0.78, 0.74) between the mean sea level pressure over the Arabian Sea and the anomalies in geopotential height at 500 mb level in the western , eastern northern of Asia, and temperature at 500 mb over the western part of Asia respectively. In addition to that, there are four significant correlation coefficient values (0.71, -0.72, -0.74, -0.73) between the precipitation rate over the Arabian Sea (Gonu region) and mean sea level pressure over the western Asia, the anomalies in geopotential height at 500 mb level in the western , eastern northern Asia, and temperature at 500 mb over the western part of Asia, respectively. The anomalies in the upper air temperature at 500 mb over the Arabian Sea correlated to the anomalies in geopotential height at 500 mb level in the eastern northern Asia with a significant negative correlation value of -0.76. Also the anomalies in the surface zonal wind over the northern and southern parts of Arabian Sea had significant negative correlations (-0.78, -0.72) with the mean sea level pressure at the western and central regions of the northern Asia respectively. Anomalies in surface meridional wind over the northern and southern parts of Arabian Sea are highly correlated with mean sea level pressure over central Asia and temperature at 500 mb level over the eastern Asia with negative correlation coefficient values (-0.76, -0.81), respectively.

4- DISCUSSION AND CONCLUSION

The characteristics of hurricane Gonu that existed over the Arabian Sea through the period 1-7 June 2007 had been studied using of the available data recorded by IMD and JTWC. The anomalies in the meteorological fields over the north Asian region and Arabian Sea during that period had been analyzed too. The analysis revealed the following results: Existence of the above normal SST (positive anomaly) associated with positive and negative anomalies in both zonal and meridional wind components over the Arabian Sea are the most outstanding meteorological conditions affecting the generation and development of hurricane Gonu. Statistically, high significant correlations had been fund between the meteorological fields over the Arabian Sea and northern Asia regions. Whereas, there are high significant positive correlation values between the mean sea level pressure over the Arabian Sea and the geopotential height at 500 mb level over the western and eastern north of Asia. Moreover, surface zonal and meridonal wind components over the Arabian Sea are significantly correlated with the mean sea level pressure over the different regions of northern Asia. Generally, the abnormal fluctuations in surface pressure, and wind field components in the Arabian Sea during the period of Gonu are results of the south ward oscillation of subtropical weather regimes from over the northern Asia. One can conclude that the mid-latitude and tropics interaction may cause amplification of a tropical storm to become a super storm and controlled its track in the Arabian Sea.

ACKNOWLEDGEMENTS

The Authors would like to express they deep gratitude to the Indian Meteorological Department for supporting data of hurricane Gonu through its website (http://www.imd.ernet.in). And also, great thanks for Joint Typhoon Warning Center for supporting data used through this study. In addition to that, It is pleasure to us to present best thanks to the Earth System Research, the NOAA/ESRL Physical Sciences Division. Whereas, NCEP Reanalysis Derived datasets for the meteorological elements provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov.

REFERENCES

Emanuel, K. A., 2005: Increasing destructiveness of tropical cyclones over the past 30 years, Nature, 326, 686-688.

Hafez, Y. Y., 2008: The Role Played by Blocking over the Northern Hemisphere on hurricane Katrina. AMS, 88TH Annual Meeting, New Orleans, LA, USA, 20-24 January 2008, Tropical Meteorology Special Sympo-sium.

IMD, 2007: Monthly Global Tropical Cyclone Summary, June, 2007.

JTWC, 2007: Monthly Global Tropical Cyclone Summary, June, 2007.

Kalnay, E., et al., 1996: The NCEP/NCAR 40-year reanalysis project. Bull. Amer. Meteor. Soc., 77,437-470.

Klotztzbach, P. J., 2006: Trends in global tropical cyclone activity over the past twenty years (1986-2005). Geophys. Res. Lett., 33, L10805, doi: 10.1029/2006Gl0-25881.

Michaels, P. J., 2006: Sea- surface temperature and tropical cyclones in the Atlantic basin. Geophys. Res. Lett., 33, L09708, doi: 10.1029/2006Gl025757.

Shapiro, L., J., and S. B. Goldenberg, 1998:Atlantic sea surface temperatures and tropical cyclone formation. J. Clim., 11, 578-590.

Spiegel, M. R., 1961: Theory and Problems of Statistics, Schaum, 359 PP.

Webster, P. J., G. J. Holland, J. A. Curry, and H. R. Chang, 2005: Changes in tropical cyclone number, duration, and intensity in a warming environment, Science, 309, 1844.