THE INFLUENCE OF SEA SURFACE TEMPERATURE ON TROPICAL CYCLONE FORMED IN THE BAY OF BENGAL

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ABSTRACT

The influence of Sea Surface Temperature (SST) on tropical cyclone formed in the Bay of Bengal was examined, using 314 months (November 1981–December 2007) of National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation version 2 weekly mean SST data. The study area was from 5.5 21.5ºN to 80.5 95.5°E; with a total 272 grid points at 1º × 1º grid spans were found. The formation of depression was dominated during the monsoon period whereas the formation of very severe cyclonic storms (VSCS) was dominated during pre-monsoon and post-monsoon periods. The SST shows positive trend whereas occurrence number of tropical disturbance shows negative trend. The SST variation shows two peaks, one major peak in May and another peak in October. Total numbers of disturbance were 164 out of which 56 % were converted into cyclone. The disturbances which formed in the area-3 (7.5ºN ≤ latitude < 13.5ºN) had maximum probability to convert into VSCS. Within area-3 the average temporal SST remains nearly constant and value was about 28.70ºC. The study revealed that the intensity of cyclone has a step-like, rather than continuous relationship with SST.

Keywords: Cyclone; SST; Bay of Bengal

INTRODUCTION

Tropical Cyclone (TC) genesis is one of the few atmospheric processes that are poorly understood. The climatological conditions under which tropical cyclones occur have now been well established over decades of research. The importance of monsoon circulations in determining tropical cyclone characteristics is related to the six primary environmental factors defined by Gray (1968, 1975) to be favorable for tropical cyclone formation. These include (i) large values of low-level cyclonic relative vorticity, (ii) a location that is at least a few degrees pole-ward of the equator, (iii) weak vertical wind shear, (iv) large values of relative humidity in the lower and middle troposphere, (v) conditional instability throughout a deep tropospheric layer, and (vi) sea surface temperature (SST) above 26ºC. The existence of such conditions is common in the tropics. Several recent publications [Emanuel (1987, 2000, 2005)] have shown that the intensity of TC is linked with rising SST. All these research have fueled the debate on whether warming environment is causing an increase in intensity of TC.

It is well established that SST>26°C is a requirement for TC formation in the current climate [Palmen (1948)]. Webster et al. (2005) found an increase trend in tropical cyclone number, duration and intensity with increasing SST in North Indian Ocean basin.

Mark and Adam (2008) used a statistical model to disentangle the two main hurricane predictions SST and near surface trade wind speed. These two variables together explain about 80% of the variance observed in tropical Atlantic hurricane activity between 1965 and 2005. Their result indicates that 0.5°C increase of SST in August – September SST, an average 40% increase in hurricane activity, a measure including both number and severity of storms. Their study showed that if the SST increases by 2°C by 2100 AD, maximum wind speeds of hurricanes could increase by 63%, with damage from hurricanes rising in proportion to the cube of the wind speed. This is because the warm ocean water provides sensible heat and water vapor that fuels the intense convection of a hurricane, and assists the conversion of a depression to a cyclone.

Research has been done on the frequency of cyclones as well as intensity with SST of different oceans, such as Atlantic Ocean, Indian Ocean, North Indian Ocean etc. But the relationship between the SST of the Bay of Bengal and cyclone that hits around the coastal region of Bangladesh is poorly investigated.

DATA AND METHODS

In this study the tropical cyclone data during 1981-2007 have been taken from Bangladesh Meteorological Department (BMD) to assess the variability of tropical cyclone frequency. Initial location coordinates (latitude/longitude) for all the tropical disturbances developed in the Bay of Bengal during the above mentioned period are tabulated. The tropical disturbances are subdivided into tropical depression (D, wind speed = 41-50 km/h), deep depression (DD, wind speed = 51-61 km/h), cyclonic storm (CS, wind speed = 62-88 km/h), severe cyclonic storm (SCS, wind speed = 89-117 km/h), very severe cyclonic storm (VSCS, wind speed = 118-220 km/h) and supper cyclone (SC, wind speed > 220 km/h). The data of tropical disturbances as well as the SST are tabulated season wise, namely pre-monsoon (March, April and May), monsoon (June, July, August and September), post-monsoon (October and November) and winter (December, January and February). The weekly mean SST dataset are collected from the National Oceanic and Atmospheric Administration Climate Data Center. The study area have been taken from 5.5-21.5°N and 80.5-95.5°E; from that area at 1º interval of latitude and longitude total 272 observation grid points for SST are obtained. Spatial and temporal averages of the SST data are prepared. To find SST anomaly, long term spatio-temporal average SST has deducted from contemporaneous (during the formation of cyclone) SST. For analysis purpose the study area has been subdivided into 3 areas, namely, area-1 (17.5ºN ≤ latitude < 21.5ºN), area-2 (13.5ºN ≤ latitude < 17.5ºN) and area-3 (7.5ºN ≤ latitude < 13.5ºN).

RESULTS AND DISCUSSION

Table 1 shows the number of total seasonal disturbances formed during 1981-2007 and spatial average SST. From this table it is clear that the formation of VSCS was dominated during the pre-monsoon and post-monsoon periods. The formation of depression was dominated during the monsoon period. The SST was 28.85ºC (28.79ºC) with standard deviation 0.21ºC (0.22ºC) in the pre-monsoon (post-monsoon) period. The SST was the highest (lowest), 28.93ºC (27.17ºC) with standard deviation 0.26ºC (0.25ºC), in the monsoon (winter) season. During the monsoon period the number of total cyclones was 16, among them 13 were CS, 2 was SCS and 1 was VSCS.

Table 1. Various types of tropical disturbances formed during 1981-2007

Disturbances	Winter	Pre-monsoon	Monsoon	Post-Monsoon
D	0	6	28	12
DD	3	2	10	10
CS	5	3	13	17
SCS	4	5	2	12
VSCS	3	8	1	16
SC	0	1	0	1
SST (ºC)	27.17	28.85	28.93	28.79
Standard deviation of SST	0.25	0.21	0.26	0.22

Figure 1 shows the yearly occurrence number of disturbances and corresponding SST. The warmest year was 1998; in this year 6 disturbances were formed. In the coolest year, 1984, the formation of disturbances was 5 and the maximum frequency of cyclone was in the year of 1982. Figure 1 also shows that the yearly trend of SST was positive whereas trend the formation of tropical disturbance was negative. The minimum number of disturbance was found in the year of 2002.

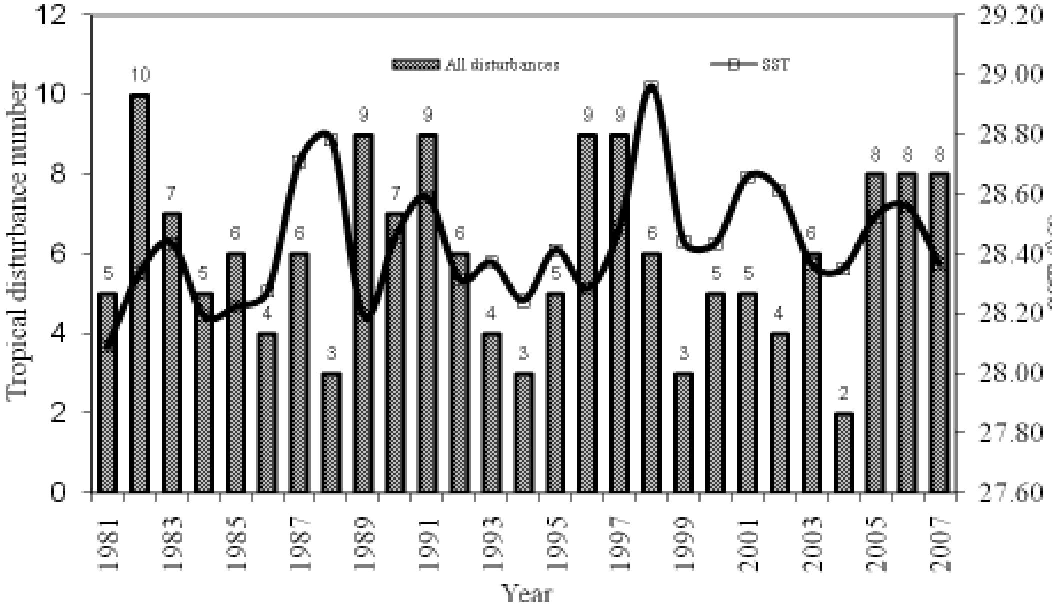

Figure 1. Yearly occurrence number of tropical disturbances and SST during the period 1981-2007

Figure 2 shows the monthly variation of average SST and frequency of tropical disturbances. From this figure it clear that the SST was the lowest in January and highest in May. The SST showed two peaks, one major peak in May and another minor peak in October. Within the study period the total number of formation of disturbance (including depression, deep depression, cyclonic storm, severe cyclonic storm, very severe cyclonic storm and super cyclone) were 164 as shown in Figure 2, 56% (91 out of 164) of them were cyclone. Maximum occurrence number (13) of VSCS and SC was in the month of November, whereas the most active month for the formation of SCS was in October. Maximum number (12) of CS was formed in the month of November. In the month of October maximum number (9) of DD was also formed. The most active months for the formation of D were in August and October and the number was 10.

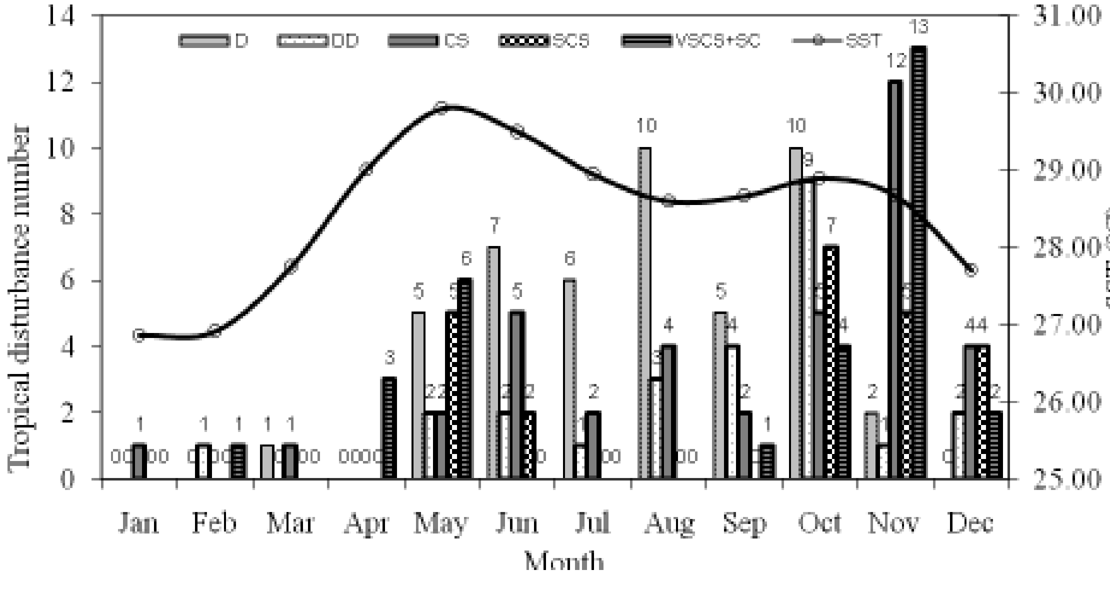

Figure 2. Monthly variation of SST and frequency of disturbance

In the lower latitudinal area-3 (7.5ºN ≤ latitude < 13.5ºN) 72% (21 out of 29) VSCS were found (Figure 3). On the other hand 13% (6 out of 46) depressions were formed within the same region. The disturbances which were formed within the area-3 had much probability to convert into VSCS. Above the area-3, 87% (40 out of 46) depressions were formed. The disturbances which were formed above the area-3 had less probability to convert into VSCS.

So it is found that the formation of VSCS was higher in area-3 where the SST was higher and the formation of VSCS decreased along the direction of higher latitude where the SST comparatively lower.

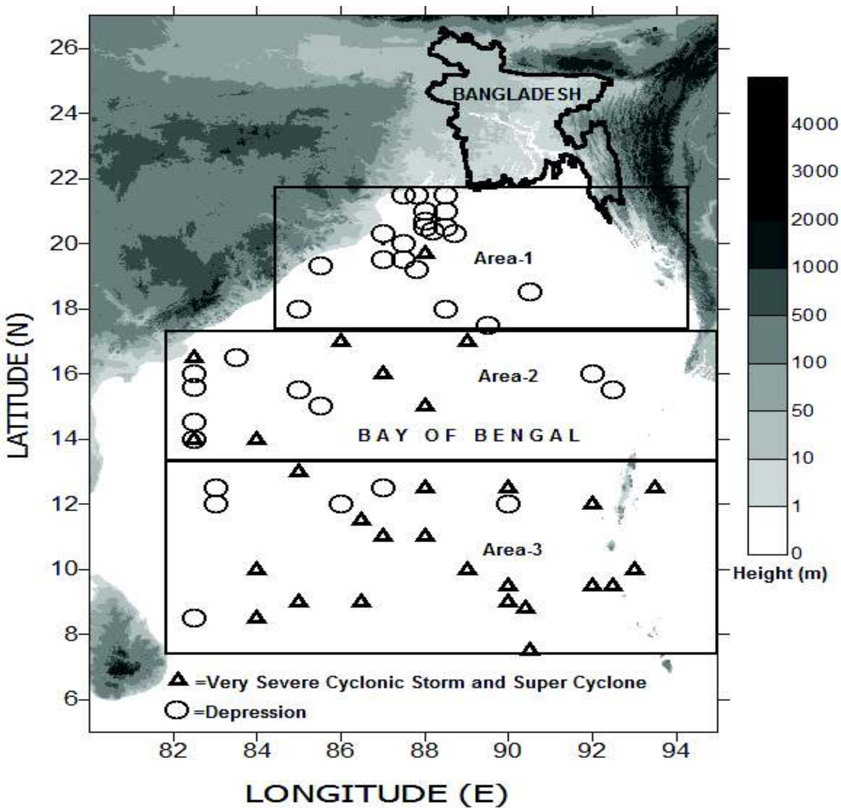

Figure 3. Initial location of very severe cyclonic storm (triangle) and depression (circle). Gray shade indicates the topography in meter

Figure 4 shows the changing behavior of SST with respect to latitude. It illustrated that from higher to lower latitude, which is toward the direction of the equator, the SST increased. Within area-3 the average temporal SST remains nearly constant around the value of 28.70ºC during the study period. It is found that (Figure 3) there was no formation of VSCS and SC before 7.5ºN latitude; even though the SST was higher but may be due to the lack of Coriolis force there was no VSCS and SC. Moreover it is found that 45% (13 out of 29) VSCS and SC formed within 7.5-10.5ºN of area-3 and only 2% (1 out of 46) depressions formed in this region. After 12.5ºN, the decreasing trend of SST was higher with respect to the higher value of latitude. Within area-2 there were 24% (7 out of 29) VSCS and SC and the percentage of formation of depressions were 22% (10 out of 46). Within area-1 only one VSCS (3%) was formed, on the other hand the formations of depression were 61% (28 out of 46). Hence area-1 with average temporal SST 27.75ºC was favorable for the formation of depressions and the formation of VSCS and SC within the area-3 around the average temporal SST 28.70ºC was favorable.

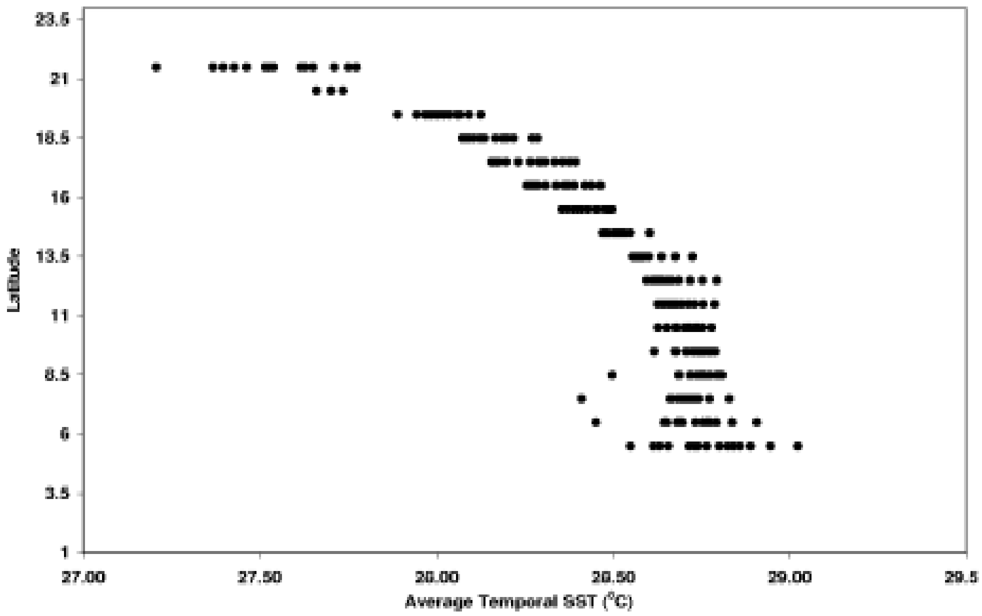

Figure 4. Variation of average temporal SST with respect to the latitude

From Table 2 it is clear that the formation of VSCS and SCS started after 27.0°C and increased with SST. The formation of SCS and VSCS decreased for SST from 29.0°C to 29.9°C after that increased with SST. So it revealed that the intensity of cyclone has a step-like, rather than continuous relationship with SST [Patrick et al. (2006)].

Table 2. Comparison among the number of various types of cyclones at 1^0C temperature bins with the total number of weeks remaining within that temperature bin

Temperature bin(^{0}C)	No. of total week	CS	% of CS	SCS	% of SCS	VSCS	% of VSCS
26.0-27.9	166	0	0.0	0	0.0	0	0.0
27.0-28.9	237	2	1.5	1	1	2	1.9
28.0-29.9	540	19	7.5	12	4.8	12	4.3
29.0-30.9	375	12	5.3	4	1.6	8	4.7
30.0-30.9	47	5	11.9	6	31.9	8	36.7

SUMMARY

In this study the relation between SST and tropical cyclone formed in the Bay of Bengal was examined. Depressions are dominated during the monsoon period whereas VSCSs are dominated during the pre-monsoon and post-monsoon periods. The maximum occurrence frequency of cyclone was found in the year 1982. The SST was lowest in the January and highest in May. The SST showed two peaks, one major peak in May and another minor peak in October. The formation of VSCS was 72% in the lower latitudinal area-3 (7.5ºN ≤ latitude < 13.5ºN). The disturbances which were formed above the area-3 had less probability to convert into VSCS. The formation of VSCS and SCS started after 27.0°C and increased with SST. The formation of SCS and VSCS decreased for SST from 29.0°C to 29.9°C after that increased with SST. So this study revealed that the intensity of cyclone has a step-like, rather than continuous relationship with SST.

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