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Impacts of climatic variables on cyclone in the coastal regions of Bangladesh

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Abstract

Geographical position of Bangladesh makes it vulnerable to several extreme weather events like cyclone in the southern part due to extreme climatological events. Therefore, in this study, we had mainly tried to study on the variations of temperature, relative humidity (RH) and sunshine hours (SH) in the coastal areas to find out its effect on the formation of cyclone. Data from 1975-2014 of these climatic variables was provided by the Bangladesh Meteorological Department (BMD) and analyzed with the statistical tool MS Excel 2010 as per objective of the study. Results showed that in the16 stations, temperature has shown homogenous trend where it has seen that in all the stations the T_{mean} and T_{max} were ranging from 18^0C to 30^0C and 28^0C to 42^0C respectively. In maximum stations, the T_{max} and extreme T_{mean} has found in the months of April and May which is a cyclone occurring month. Again RH_{max} has mostly found in the post monsoon season where RH_{mean} is ranging 84~88% mainly in the Khulna, Mongla, Khepupara and Barisal areas, may have profound influence on the formation of cyclone especially in this area. SH_{max} has found in the month April where the highest was about 12.08 hr. These higher amounts of temperature play profound influence in increasing temperature in the studied areas which have direct consequences on cyclone events. So, extreme temperature, RH and SH in these months may had profound influence on the formation of cyclone. These information could be very useful to the related scientists to study on several extreme weather events due to variation of temperature especially on cyclogenesis which are a most common devastating phenomenon for the coastal areas like Bangladesh.

Key words: Extreme weather, climatic variables, variation of temperature, cyclogenesis

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Introduction

Bangladesh is a low-lying country located in the deltaic plain of the Ganges, the Brahmaputra and the Meghna and densely populated. Its national economy strongly depends on agriculture and natural resources that are sensitive to climate change. The impact of higher temperature and more extreme weather events such as floods, cyclone, severe drought and sea level rise are already being felt in south Asia and will continue to intensify (Huq *et al.*, 1999; Ali, 1999). In this connection proper planning and analyses of climatic variations with their extreme events are essential to find out for this area. The southern region mainly known as a coastal region of Bangladesh experiences cyclone almost every year. As found from the statistics that, changes in temperature played a great role to cause such cyclone events in the southern coastal region. Cyclones originate from deep depression which is a consequence of high amount of temperature in the coastal region which is quite common in Bangladesh. They generally occur in early summer of the month from April-May or late rainy season from November-December (Choudhury, 1992; Wisner *et al.*, 2004; Ali,

1999; Paul, 2009; Farukh and Baten, 2015). For the formation of cyclone the effective temperature is about 27 to 29^{0}C which is responsible for category 1 to category 5 cyclone in the context of Bangladesh (Kumar *et al.*, 2011; Khan, 2012). So, it can be said that any temperature within or above of range would trigger the formation of a cyclone. Relative humidity (RH) is another important climatic factor and is also responsible for the formation of any kind of unsteady condition. Study on this parameter is also important because temperature and RH relates to each other (Lawrence, 2004; Skilling, 2009) and RH has a good influence on the formation of cyclone (Kaplan and DeMaria, 2003; Emanuel *et al*., 2004; Hendricks *et al*., 2010; Kaplan *et al*., 2010). Wu *et al*. (2012) showed that about 82% RH is responsible for the occurrence of North Atlantic Tropical cyclone. So, RH above this level is very much responsible for the formation of cyclone in the coastal region of Bangladesh. There are some indirect consequences of the Sunshine hours (SH) also, because SH have positive relationship with the temperature (Matuszko and Weglerczyk, 2014), and temperature has direct effect on the formation of cyclone. As a result, there is an increasing research interest in different parts of the world as well as in Bangladesh on extreme climatic parameters and their variations. Keeping these things in mind, the present study was therefore undertaken to find out the variability of temperature, RH and SH in terms of cyclone events in the coastal region of Bangladesh.

Materials and Methods

Study Area

The coastal area of Bangladesh surrounding the BB was selected as the study area. Satkhira, Khulna, Mongla, Khepupara, Barishal, Bhola, Patuakhali, Hatiya, Chandpur, Feni, Sandwip, Sitakunda, Chittagong, Kutubdia, Cox's Bazar and Teknaf was our study area.

Weather Data

In this study, daily weather data of temperature, sunshine hours (SH) and relative humidity (RH) were analyzed which were obtained from Bangladesh Meteorological Department, Agargaon, Dhaka, Bangladesh. The collected data were three hourly daily temperature (^{0}C), average air temperature (^{0}C), maximum air temperature (^{0}C), minimum air temperature (^{0}C), three hourly relative humidity (%) and sunshine hours (hr.). To compare the parameter, weather data from the indicated stations were carefully analyzed.

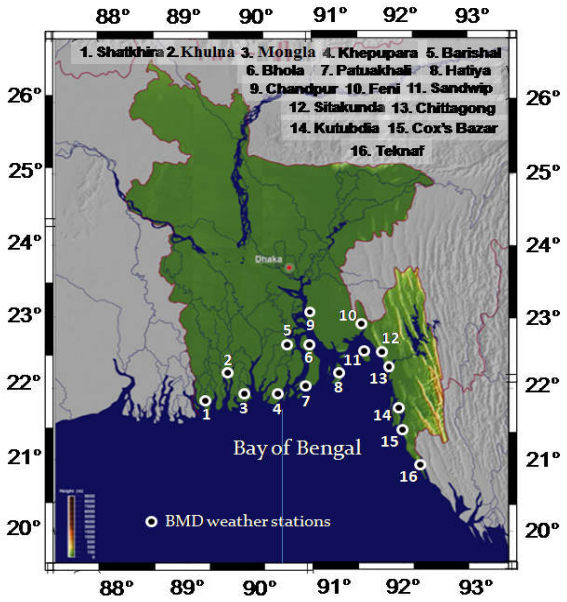


Figure 1. GIS plotting of 16 stations in southern coastal regions of Bangladesh

Data Processing and Analyses

All the collected data were then compiled, tabulated, and analyzed according to the objectives of the study. Daily average air temperature (^{0}C), maximum air temperature (^{0}C), minimum air temperature (^{0}C), three hourly relative humidity (%) and sunshine hours (hr.) were calculated using frequently used statistical software Minitab and MS Excel 2010 to analyze the variation and trend lines. The box plotting shows in the

figure expose the long term mean, mean+SD and mean-SD of temperature, RH and SH in these regions. The line through the box plot indicating the mean value of temperature, RH and SH. Upper portion of the box shows the mean+SD and the lower portion of the box shows the mean-SD value. The red, blue and red markers in the three types of graph represent the maximum temperature, RH and SH while the purple, green and blue markers represent the minimum temperature, RH and SH respectively in the definite area. In the results and discussion part few stations has discussed among the 16 stations based on mostly affected areas of cyclone from 1975-2014 showed in Table 1.

Table 1. List of Cyclone Events in Bangladesh from 1975-2014

Year	Date and Month	Affected Area	Nature of the phenomenon	Approximate loss
1975	May 9-12	Sunderban-Bhola-Chittagong coast	Severe cyclonic storm, w=110 km/h.	5 people killed
1976	October 19-20	Meghna estuary	Severe Cyclonic storm, w=105 km/h, tide plus surge at Companygonj was 3.5m.	Damage data not available
1977	May 9-12	Sunderban-chittagong coast (landfall at Sunderban)	Cyclonic storm, w=113 km/h, s=0.6m and t=0.7m.	Damage data not available
1978	September 30 to October 3	Sunderban khulna coast	Cyclonic storm, w=74 km/h.	Damage data not available
1983	15-Oct	Chittagong-Feni coast (landfall near Chittagong)	Severe Cyclonic storm, w=122 km/h.	43 persons were killed, 1000 fishermen missing and 20% aman crops destroyed
	November 9	Chittagong-Teknaf coast (landfall between Chittagong and Cox's Bazar)	Severe cyclonic storm, w=136 km/h	300 fishermen with 50 boats missing; 2000 houses,22 institutions destroyed
1985	May 24-25	Noakhali-Cox's Bazar coast (landfall at Sandwip)	Severe cyclonic storm, w=154 km/h	11,069 people killed, 94,379 houses damaged,64 km road and 390 km embankment damaged
1986	9-Nov	Barguna-Chittagong coast	Severe Cyclonic storm, w=110 km/h.	14 lives lost and huge damage to crops and properties
1988	29-Nov	Sunderban	Severe cyclonic storm, w=160 km/h	5,708 people killed and 6,000 missing; 65,000 cattle were lost
1990	October 7-8	Barguna-Noakhali coast	Cyclonic storm	150 fishermen with 16 mechanised boats missing
1991	29-Apr	Patuakhali-Cox's Bazar coast (landfall north of Chittagong)	Most severe cyclonic storm, w=235 km/h	145,000 people killed, 70,000 cattle killed, crops were damaged
	May 31 to June 2	Offshore islands and chars of Patuakhali, Barisal, Noakhali and Chittagong	Severe cyclonic storm, maximum w=110 km/hr	People killed, cattlehead perished, boats lost and standing crops destroyed.
1994	April 29 to May 3	Offshore island and chars of Cox's Bazar	Severe cyclonic storm with maximum wind speed of 210 km/hr	People killed about 400, cattle lost about 8,000
1995	November 21-25	Offshore island and chars of Cox's Bazar	Severe cyclonic storm with maximum wind speed of 210 km/hr	About 650 people killed, 17,000 cattlehead perished.

Table 1. List of Cyclone Events in Bangladesh from 1975-2014 (-Contd.-)

Year	Date and Month	Affected Area	Nature of the phenomenon	Approximate loss
1997	May 16-19	Offshore islands and chars of Chittagong, Cox's Bazar, Noakhali and Bhola	Severe cyclonic storm (hurricane) with a wind speed of 225 km/hr, storm surge of 3.05m	Only 126 people killed because of better disaster management measures taken by the government and the people.
	September 25-27	Offshore islands and chars of Chittagong, Cox's Bazar, Noakhali and Bhola	Severe cyclonic storm (hurricane) with a wind speed of 150 km/hr, storm surge of 1.83 to 3.05m.	Damage data not available
1998	May 16-20	Offshore islands and chars of Chittagong, Cox's Bazar and Noakhali	Severe cyclonic storm (hurricane) with a wind speed of 150 km/hr, storm surge of 1.83 to 2.44m.	Damage data not available
	November 19-22	Offshore islands and chars of Khulna, Barisal and Patuakhali	Cyclonic storm with maximum wind speed of 90 km/hr, storm surge of 1.22 to 2.44m.	Damage data not available
2007	May 14-15	south of Chittagong	Severe cyclone Akash struck with wind speeds up to 120 km/hour	14 people were killed and damages amounted to US$982 million.
	15-Nov	southern Bangladesh	Severe cyclone Sidr with wind speeds up to 260 km/hour	Causing over 3,500 deaths and severe damage.
2008	October 26-27	Bangladesh coast	Cyclone Rashmi with wind speeds up to 85 km/hour	15 people were killed and thousands of homes were also damaged.
2009	April 19-21	Bangladesh coast	Cyclone Bijli	not so severe damages were recorded except some houses and crop fields losses
	May 27-29	15 districts of south-western part of Bangladesh	Severe Cyclone Aila with wind speeds up to 120 km/hour	About 150 persons killed, 2 lac houses and 3 lac acres of cultivated land and crops losses.
2013	May 16-17	Chittagong	Cyclonic Storm Mahasen with wind speeds up to 85 km/hour	17 people died, and nearly 1.3 million were affected across the country. Losses to crops exceeded US$5.14 million.

Results and Discussions

The statistics of the 9 stations and the ensemble means of the 16 stations has represented and discussed in this chapter. Temperature (^{0}C), RH (%) and SH (hr.) of the 9 stations have represented where the figures are drawn by using the raw data from the year of 1975 to 2014 and the discussion have made based on the two cyclone occurring period from March to June and from September to November (Farukh and Baten, 2015).

Satkhira

Mean air temperature (T_{mean}), maximum air temperature (T_{max}), minimum air temperature (T_{min}) and mean±SD of Satkhira from 1975 to 2014 is shown in Figure 2 (a). The extreme T_{max} of Satkhira is found in the month of May (38.10^{0}C) where the highest T_{mean} is 29.95^{0}C, both of which is in the cyclone occurring month May. The maximum temperature throughout the year ranges from 29^{0}C to 38^{0}C which is high enough to create unstable condition in the surrounding area. Mean RH (RH_{mean}), maximum RH (RH_{max}), minimum RH (RH_{min}) and mean±SD have shown in the Figure 2(b). The RH_{max} in Satkhira area is seen in August and September (99%) where their mean is around 86%. Again in April and May, the RH_{max} was 98% and the RH_{max} throughout the whole year ranged from 98-99% which indicated hot and humid situation on that

particular month. The higher RH also indicates higher temperature. Both of the parameters together may create any unsteady situation. Again, the highest RH range in this area indicates powerful signal of cyclogenesis. SH have shown the reverse trend compared to temperature and RH. The trend is shown in the Figure 2(c) where the highest period of SH (SH_{max}) in this region was in the month of April (11.30 hr.). From the figure, it is clearly seen that the maximum mean of SH (SH_{mean}) was in April which is more than 8.5 hours. The longest period of SH in April may have a strong influence in uprising of temperature which in consequence may form any cyclonic event in Satkhira region.

Khulna

For Khulna region, temperature (^{0}C) has shown in the Figure 2(d). From the figure, it has shown that temperature in this region in same trend like it was in Satkhira. Here, T_{max} is 37.56^{0}C that has found in the month of April and the highest mean value is about 29.5^{0}C which is in the month of May. These two months (April and May) indicated the T_{max} and highest mean value respectively are known as the cyclone occurring month. The T_{max} ranges throughout the year is about 29^{0}C to 37.5^{0}C which is very high amount and favorable for creating unstable disorder in the surrounding area which later may form deep depression and cause shattering cyclone. RH_{max}, RH_{min}, RH_{mean} and mean±SD of RH in Khulna area has shown in the Figure 2(e) where RH_{mean} in Khulna area is uppermost in the month of September pointing about 89% and the highest value throughout the year ranging from 98-99% and any area within this range indicated how hot and humid it was on that certain day. These high amounts of RH also indicate great amount of temperature on such day both of which may responsible for creating any unsteady situation which in later may cause some extreme events. The highest range in this area is a strong indicator for the formation of cyclone. The trend of SH in this region has shown in the Figure 2(f) where the SH_{max} in this region is in the month of April (12.08 hr.). The maximum mean has also found in the month of April pointing at 8.5 hr. This highest amount of SH also indicating higher amount of temperature in April at Khulna. This higher amount of temperature may create deep depression and form cyclonic activity in this area.

Mongla

Temperature in (^{0}C) has shown in the Figure 2(g) where extreme T_{max} has shown in the month of April which is about 37.62^{0}C and the highest of T_{mean} has found in the month of May (29.84^{0}C). From August to October, the T_{mean} is ranging from 27.5 to 28.5^{0}C where the T_{max} has found about 34.5^{0}C. Again the range of T_{max} throughout the year is about 29-38^{0}C. So, these maximum values indicating strong possibilities for unstable weather conditions in the studied area. Difference of maximum temperature from the mean is about 5-10^{0}C which sudden rise may cause any extreme weather events like cyclone in this area. RH_{max}, RH_{min}, RH_{mean} and mean±SD has shown in the Figure 2(h) where the RH_{max} in this region has shown in the month of September, November, January and March (99.92%). So, trend of RH of Mongla region is little bit different from the stations of Satkhira and Khulna. The highest RH_{mean} is about 89% in the month of September which indicated hot and humid circumstances in that specific month in Mongla. September is also known as the cyclonic month and this high amount of RH also may cause shaky condition in the specific area which may turn into deep depression later and ultimately forms cyclone.SH in this region has shown in the Figure 2(i). which shown that the SH_{max} in this region is in the month of May which is about 12.13 hr. From the figure, it has found that the maximum of SH_{mean} is in the month of April (8.75 hr.). This maximum of SH_{mean} in April and the SH_{max} in May in a day may have a strong influence in uprising of temperature which significantly may form any cyclonic event in Mongla region.

Khepupara

T_{mean}, T_{max}, T_{min} and mean±SD of temperature has shown in the Figure 2(j). In this area, T_{max} has shown in

the month of April (35.08^{0}C) and the range of T_{max} in this area throughout the year is about 29 to 35^{0}C where the highest T_{mean} is about 30^{0}C which is in the month of May. The high amount of temperature in the pre-monsoon period (April and May) indicating unstable condition at the surrounding area. Again the difference between the highest temperature and the higher mean value is about 5-8^{0}C which also indicating the strong positive signals of increasing temperature. The trend of RH in Khepupara area has shown in the Figure 2(k) where RH_{max}, RH_{min}, RH_{mean} and mean±SD have represented. July has represented the highest RH_{mean} (88.56%). In fact, from June to October the RH_{mean} is more than 85%. These highest RH_{mean} in the area indicated hot and humid conditions in that specific months in Khepupara. September and October is also known as the cyclonic month and the high amount of RH showed in the figure also may cause insecure disorder in the specific area which in later may form deep depression and ultimately forms cyclone. The trend of SH (hr.) in this location has shown in the Figure 2(l). The SH_{max} in this location is in the period of April (11.68 hr.) and the highest SH_{mean} is about 8 hours which has also found in the month of April. The longest period of SH in this area indicating also higher amount of temperature in April at Khepupara. This higher amount of temperature may form also cyclonic activity in that area.

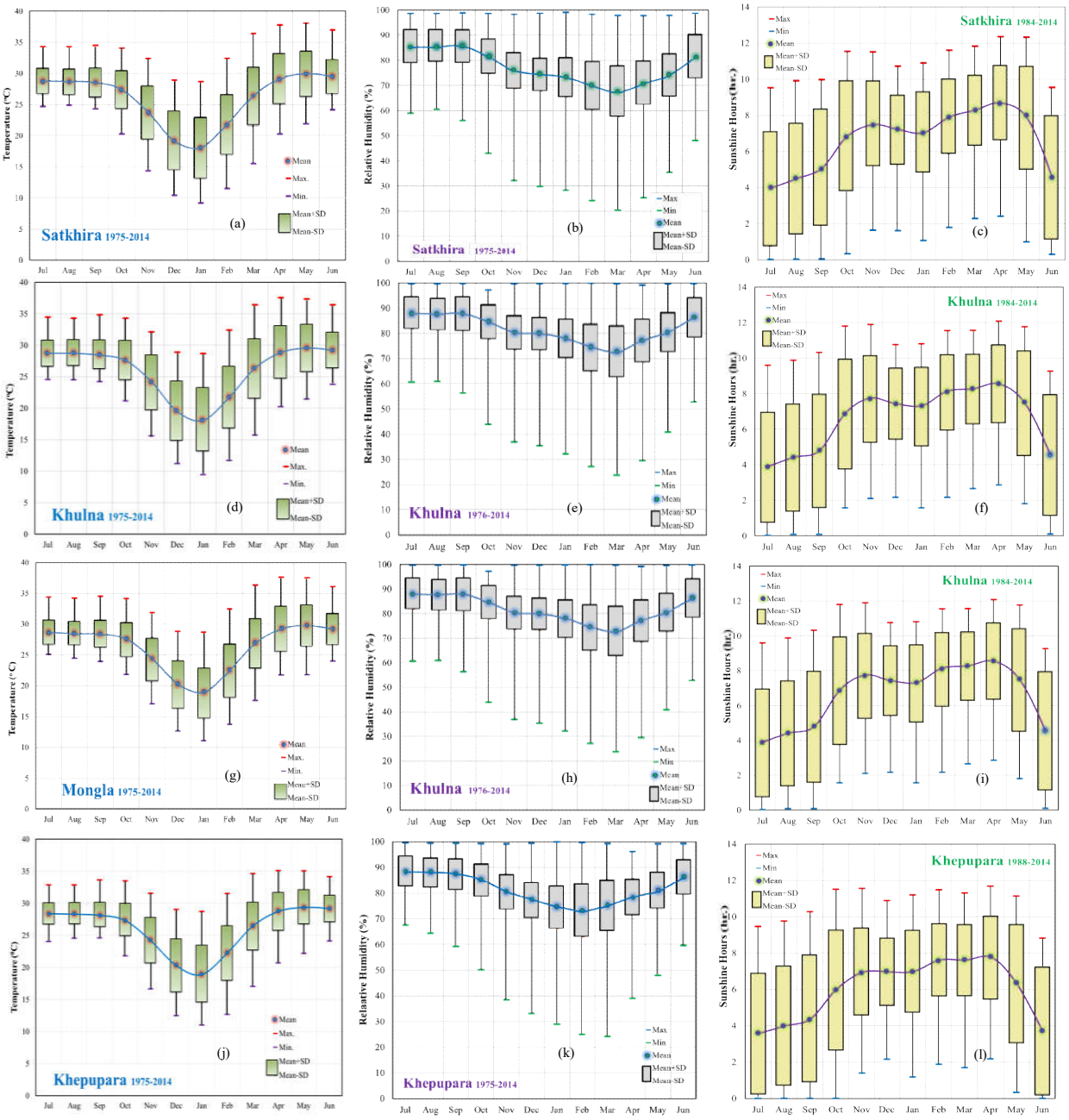
Bhola

The T_{max} of Bhola in the Figure 2(m). has shown in the month of May (35.10^{0}C) and the T_{max} in this area is ranging from 28-35^{0}C throughout the year. The T_{mean} in this area throughout the year is ranging from 18-28.5^{0}C where the maximum T_{mean} is about 28.5^{0}C is in the month of May. So, the T_{max} in this area has strong influence in creating unstable condition and also shows powerful indication for the formation of cyclone by creating low atmospheric pressure in the adjacent area. The abrupt 7-10^{0}C difference of the temperature between the maximum range and the mean value are strong indication of changing temperature in the area in such a day where the condition of the environment may become unstable. RH of Bhola has given in the Figure 2(n). July has represented the RH_{max} (99.97%) where the RH_{mean} is about 91%. This highest mean value in the area indicated hot and humid circumstances in that specific month in Bhola. In both cyclone occurring months, the RH_{mean} is comparatively low and is not in at that level of forming cyclone though the maximum range is high enough in almost every month. The high amount of RH also may cause unstable condition in the specific area which in later may form deep depression and ultimately forms cyclone.SH of Bhola have given in the Figure 2(o). The SH_{max} is 11.37 hr. has found in the month of April and the highest SH_{mean} is about 7 hours also found in the month of April. This highest level of SH also indicating higher amount of temperature in April at Bhola which may induce atmospheric low pressure in the area and may form cyclonic activity.

Patuakhali

T_{mean},T_{max}, T_{min} and mean±SD of temperature have shown in the Figure 2(p). The T_{max} in this area is in the month of April (35.96^{0}C) and the T_{mean} is ranging throughout the year from 19-29^{0}C where the maximum T_{mean} has found in the month of May which is a cyclone occurring month. Again, the T_{max} in this region is ranging from 28-36^{0}C throughout the year which is too high for creating any unstable condition on that day in the area. Again temperature above 28^{0}C is vulnerable for occurring cyclone in the coastal region of Bangladesh in the cyclone occurring months. So, here the maximum temperature showing in the graph mainly in the two period of cyclone occurring months are strong enough to create any unstable condition which in later may generate deep depression in the surrounding area and as subsequent, cyclonic storm may form. RH from 1975-2014 of Patuakhali area has shown in the Figure 2(q). Like the other one, RH_{max}, RH_{min}, RH_{mean} and mean±SD of RH also has shown here where July has represented the highest RH_{mean} pointing at 91%. This highest mean value in the area

indicated hot and humid circumstances in that specific month in Patuakhali. The high amount of RH also may cause insecure condition in the specific area which in later may form low atmospheric arc and ultimately forms cyclone. The Figure 2(r) has shown the SH for the area of Patuakhali where SH_{max}, SH_{min}, SH_{mean} and mean±SD have shown in the figure. The SH_{max} has shown in the month of April (11.13 hr.) and the the maximum SH_{mean} is in the month of March which is more than 7 hours. The maximum of SH_{mean} and the SH_{max} in the months of March and April may have a strong effect in uprising of temperature which in concern may form any cyclonic event in Patuakhali region.



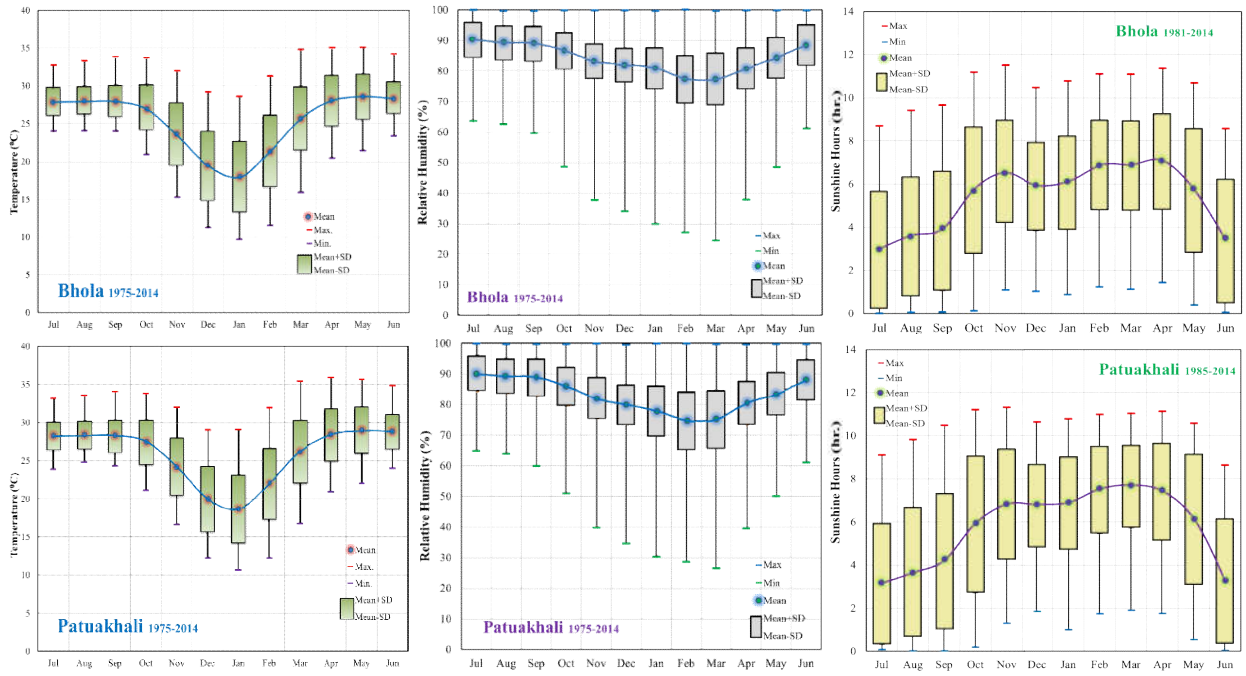


Figure 2. Temperature (^{0}C), RH (%) and SH (hr.) with maximum, minimum, mean and mean±SD of Satkhira, Khulna, Mongla, Khepupara, Bhola and Patuakhali.

Hatiya

The T_{max} in this area is in the month of May pointing in the Figure 3(a) at 34.39^{0}C where the uppermost T_{mean} in this area is 28.71^{0}C also is in the month of May. The T_{max} is ranging from 28 to 35^{0}C throughout the year which is not comfortable at all and blamable for unsteady situation. Again the temperature above 28^{0}C is responsible for the formation of cyclone. So the maximum values in this area in the cyclonic period are too high and powerful components for the formation of cyclonic activity in the area. RH_{max}, RH_{min}, RH_{mean} and mean±SD of RH of Hatiya have shown in the Figure 3(b). Like some of other stations, Hatiya has also shown the Highest RH_{mean} value in the month of July which is about 89% and this highest mean value in the area indicated hot and humid circumstances in that specific month for Hatiya. This high amount of RH also may cause insecure condition in the specific area which in later may form deep depression and ultimately forms cyclone. The trend of SH in this part has shown in the Figure 3(c). The SH_{max} in this area is in the month of May (11.8 hr.) and the highest of SH_{mean} is more than 7 hours in the month of November. The SH_{max} which has found in the month of May indicating higher amount of temperature in May on such day at Hatiya. This higher amount of temperature may have profound influence to form cyclonic activity in that area.

Chittagong

T_{mean},T_{max}, T_{min} and mean±SD of temperature (^{0}C) has shown in the Figure 3(d). The T_{max} in this area is 34.33^{0}C (in May) and the highest of T_{mean} has found in the month of May (28.56^{0}C). In the post-monsoon season (August to October) the T_{mean} is in the range of 27.5 to 28.5^{0}C where the T_{max} has found about 33.5^{0}C. Again the range of T_{max} throughout the year is about 28-34^{0}C. These maximum values indicating strong possibilities for unstable weather conditions in the studied area. Again, sudden rise of temperature like this maximum values may cause deep depression and then may turn into cyclonic storm which may affect the

whole coastal areas of Bangladesh. RH for the Chittagong area has shown in the Figure 3(e). July has represented the highest RH_{mean} pointing about 86% here in Chittagong. This highest mean value in the area indicated hot and humid circumstances in that specific month in Chittagong. September is also known as the cyclonic month and the high amount of RH showed here also may cause insecure condition in the specific area which in later may form atmospheric low pressure and ultimately forms cyclone.SH for port City Chittagong has shown in the Figure 3(f). It is clearly seen that the maximum of SH_{mean} is in the month of March which is more than 8 hr. and the SH_{max} has found in the month of April (11.60 hr.). The maximum mean of SH and the sudden longest period of SH in a day of both March and April may have a strong effect in uprising of temperature which in concern may have strong influence to form cyclone in Chittagong region.

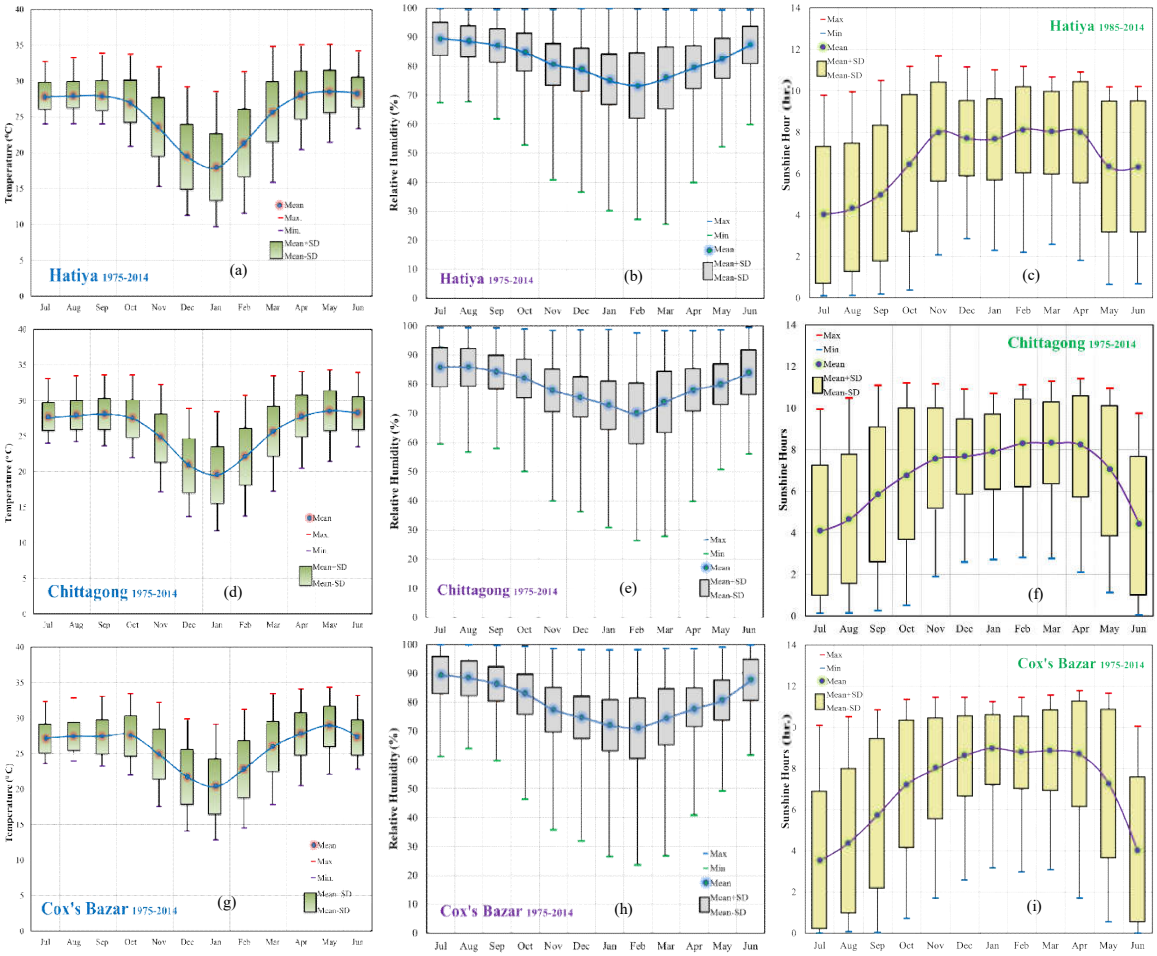


Figure 3. Temperature (^{0}C), RH (%) and SH (hr.) with maximum, minimum, mean and mean±SD of Hatiiya, Chittagong and Cox's Bazar.

Cox's Bazar

The temperature graph has shown in the Figure 3(g). The graph has shown little bit variations in this area than the other area. The T_{max} in this area is in the month of May which is 34.32^{0}C and the range of T_{max} in this area throughout the year is about 29 to 34.5^{0}C.The highest T_{mean} is about 29^{0}C which is in the month of May though in post monsoon cyclonic period

September and October, the T_{mean} is about 26-27^{0}C which is very much comfortable and is not suitable enough for creating any unsteady condition. The high amount of temperature in the pre-monsoon period (April and May) indicating unstable disorder at the surrounding area. The trend of RH of Cox's bazar has presented in the Figure 3(h) where it has shown that the RH_{max} in this area is in the month of July and August and the point is 99.95%. July has also presented the highest RH_{mean} where the RH_{mean} is about 89%. This highest mean value in the area showed warm and moist situations in that specific month in Cox's Bazar. This high amount of RH also may cause uncertain situation in the specific area which in later may form deep depression and ultimately forms cyclone.SH for Cox's Bazar area has displayed in the Figure 3(i). The SH_{max} in this area is in the month of April which is 11.78 hours This sudden longest period of SH in a day of April may have a strong effect in uprising of temperature on such day which in concern may form any cyclonic event in Cox's Bazar region.

Ensemble Means

The Figure 4 represents the comparison of mean values of temperature (^{0}C) of 16 coastal areas which have been studied here. The figure also represents the average value of temperature of 16 coastal regions of Bangladesh. From the illustration, it is understandably seen that except Satkhira, Khulna, Mongla, Cox's Bazar and Teknaf, the others 11 stations showed almost homogenous starting point from the month of July where the temperature was around 27.5^{0}C to 28.5^{0}C. Among the rests, Satkhira, Khulna and Mongla which have positioned at the last south-western part of Bangladesh and also covered by the Sunder ban have showed the similar starting point where the temperature is ranging from 28.74^{0}C to 28.84^{0}C. In fact, these three areas showed the uppermost T_{mean} in the coastal regions of Bangladesh. Cox's Bazar and Teknaf shows little bit lower temperature of the starting point than that of others areas. From July to August, all the stations with their total mean started to rise up indicates little bit rise of temperature in the coastal areas, except Satkhira, Mongla and Khepupara where the temperature is in decreasing trend though the temperature is still higher than the others for these three up to October. From August, the mean is started to fall and drops up to January though for Cox's Bazar and Teknaf, the perceptiveness is dissimilar. In Cox's Bazar, the trend has dropped with a good range in the months from September to October and then rise up again in late October, but from mid-October, the trend has started to fall. For Teknaf, the trend is uprising from its starting point to mid-October and then fall down to January.

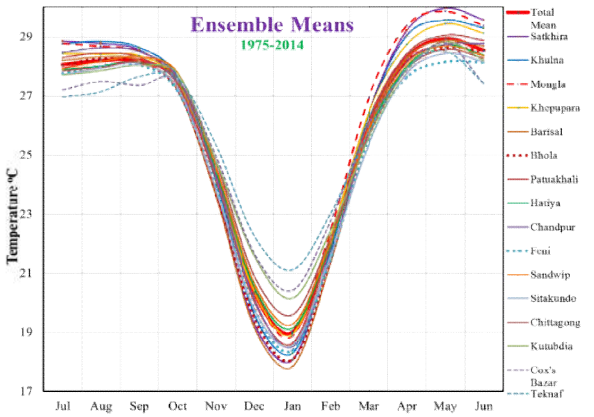


Figure 4. Ensemble means of 16 stations air temperature (^{0}C) from 1975-2014

So, variations of temperature in this area indicate unstable condition of that surrounding area. From the figure, it has seen that Satkhira, Khulna and Mongla shows relatively higher mean temperature in the month from July to October and from March to June. This situation strongly indicates the possibility of unsteadysituation in that area. Shamsad *et al*. (2012), Farukh and Baten (2015) reported that increase of 0.5^{0}C temperature from August to November may gear up an average of 40% cyclone activity. Now, if we compare the mean values of Satkhira, Khulna, and Mongla with the total mean value for the two cyclonic period, then we can see that the difference of mean of the areas with their total mean is about 0.5-1^{0}C which strongly indicating the possibility of creating

uncertaincircumstances. Ali (1999), Farukh and Baten (2015) again in their report stated that the months from March to June is second most vulnerable time for the formation of cyclone, because on an around 45% of cyclone from 1952-2010 has occurred in this time. The scenario in the figure for these months also showing the same indications. The southern-western zone mainly the Sunder ban area is more vulnerable due to its higher temperature scenario than the other stations.

In Figure 5(a), the mean value of RH for 16 stations have represented from where the comparison of the stations is clearly seen along with their total mean value. The result is important as because temperature and RH relates to each other (Lawrence, 2004; Skilling, 2009) and the RH has a good influence on the formation of cyclone (Kaplan and DeMaria, 2003; Emanuel *et al*., 2004; Hendricks *et al*., 2010; Kaplan *et al*., 2010).

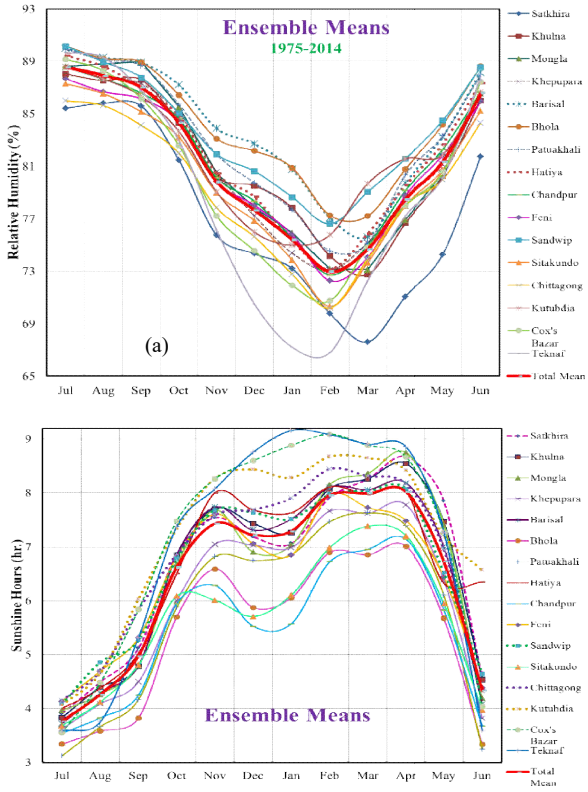


Figure 5. Ensemble means of 16 stations (a) RH (%) and (b) SH (hr.) from 1975-2014

From the figure it is clearly seen that all the stations show almost similar relationship at its starting point except Chittagong and Satkhira. These two stations show much lower RH than that of others in the month of July. From July to August, the entire trend is decreasing except Satkhira and Mongla and in the following months the entire trend follow similar characteristics except Khulna that showed different characteristics where RH was increasing like Satkhira and Mongla. Then for the preceding months, the mean value has started to fall and continued up to February-March. The maximum of total mean has found in the month of July (88%) which was much higher than the average value in July for whole Bangladesh, recorded 81.78% (BBS, 2009). In cyclone occurring months specially from August to October, the mean value of the coastal region is on around 84~88% and in May to June, the value is about 82-86% both of which indicate positive sign for the formation of cyclone as Wu *et al*. (2012) showed. In fact, Khulna, Mongla, Khepupara and Barisal area are mostly responsible for creating deep depression if the RH plays any role to the formation of cyclone, as the highest amount of RH has found in this area, though Satkhira showed the lowest amount of RH in these months. In fact, almost every station was not in homogenous trend and showed different characteristics which may have reduced the importance of RH to the formation of cyclone for the coastal areas of Bangladesh.Mean of SH for the 16 stations has been represented in the Figure 5(b). with their total mean which indicating the average mean of the coastal region. The starting point is almost same for all the 16 stations from the month of July ranging from 3.12 to 4.15 hours. Now from this month to November, the time period is increasing for all the 16 stations, except the Sitakundo. From November to April, the lines are not in homogenous trend and there are lots of ups and down in these months in the 16 stations. But from April, the lines have followed similar movement and decreased from this month up to June. SH have not direct effect on the formation of cyclone though there are some indirect consequences of the SH. Because SH

have positive relationship with the temperature (Matuszko and Weglerczyk, 2014) and temperature have direct effect on the formation of cyclone as it is stated earlier in the temperature part. From the figure, it is clearly seen that in the months of April, the average mean is maximum which indicating the higher amount of temperature in that period. This higher amount of temperature in the following month may cause unstable condition in the area which later may form the unwanted cyclonic events in that area.

Conclusion

In this study, we mainly tried to find out the temperature, RH and SH variations in the coastal area and also their possible effect for the formation of cyclone. Data of this climatic variable was provided by the Bangladesh Meteorological Department (BMD). Then these data were analyzed as per objectives of the study. Temperature in the 16 stations has shown homogenous trend where it has seen that in all the stations the T_{mean} is ranging from 18^0C to 30^0C in throughout the year where the T_{max} is ranging from 28^0C to 42^0C. In maximum stations, the T_{max} and extreme T_{mean} has found in the months of April and May which is a cyclone occurring month. So, extreme temperature in these months may have profound influence for the formation of cyclone. Again, among the coastal areas, Satkhira region has showed the highest T_{mean} which makes the area more vulnerable to the formation of cyclone. Again Cox's Bazar has showed increasing trend (different from others) in the month of October which may have influence on the formation of cyclone for this area. RH_{max} has mostly found in the post monsoon season may have profound influence on the formation of cyclone. Among the 16 stations, Khulna, Mongla, Khepupara and Barisal area are mostly responsible for creating deep depression if RH plays any role to the formation of cyclone, as the highest amount of RH has found in this area. SH_{max} has mostly found in the month April where the highest was about 12.08 hr. These higher amount of temperature play profound influence in increasing temperature in the studied areas which have direct consequences on cyclone events. So, these variations of temperature, RH and SH in these regions could be very useful to study on cyclone eventswhich are a most common phenomenon for the coastal area like Bangladesh.

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