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Climate Change between Extreme and Moderate Temperature Area in Bangladesh: A Comparative Study

J. M. Adeeb Salman Chowdhury^{1*}, Md. Touhidul Islam¹, Md. Kamruzzaman², Md. Abdul Khalek³ and M. Sayedur Rahman³

¹ Department of Statistics, Comilla University, Comilla

² Institute of Bangladesh Studies, University of Rajshahi, Bangladesh

³Department of Statistics, University of Rajshahi, Bangladesh

*Correspondence should be addressed to J.M. Adeeb Salaman Chowdhury (Email: adeeb_cu@yahoo.com)

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Abstract

Worldwide, climate change is one of the major challenging issues. Bangladesh is potentially one of the most vulnerable countries that will be affected by this. Temperature rising or global warming is considered as the key drivers of climate change. The objective of this study was to investigate comparative change in temperature between two regions; one with extreme temperature and another with moderate. Ishwardi (one sub-district under Pabna district) and Cox's Bazar district were considered as the extreme temperature and moderate temperature regions respectively. Data on average temperature on these two regions for 52 years (from 1962 to 2013) were collected from Bangladesh Meteorological Department (BMD). Some basic statistical analysis and hence trend analysis were performed on various criteria of the temperatures of both areas for comparison. Results shows that temperatures of Ishwardi has consistently been extreme in both summer and winter seasons, while Cox's Bazar has favorable or moderate temperature. We also found that temperature of these two regions have risen from lowest increment 0.49°C to highest increment 2.58°C. The lowest temperature ever recorded on Ishwardi was 3.5°C and the highest was 37.5°C, while the figures in Cox's Bazar were 9.7°C and 37.5°C respectively. Comparing these two stations, average value of temperature of west region is greater than south east region but Rainfall and humidity has less influence on west region than south east.

Keywords: Climate Change, Temperature, Extreme, Moderate, Trend Analysis, Bangladesh

AMS Classification: 91G70.

1. Introduction

Climate is literally the statistics of weather over long periods of time. It is measured by involving the patterns of variation in various climate elements such as temperature, relative humidity, wind speed, atmospheric pressure, precipitation and other meteorological variables in a given region over long periods of time. The climate of Bangladesh is characterized by high temperature, heavy rainfall, often excessive humidity and other seasonal variations. Bangladesh has a moist, warm and tropical climate. Monsoon, partly by pre-monsoon and post-monsoon circulations primarily influence her climate. The south-west monsoon creates over the Indian Ocean and carries hot, soggy, and unstable air. With some inter-annual variations in dates, the monsoon begins during the first week of June and ends in the first week of October. The easterly trade winds provide warm and relatively drier circulation besides monsoon in Bangladesh. Climate change is a change in weather patterns for a very long period of time considering decades to millions of years of time with respect to statistical distributions. Hence climate change may refer to a change in the context of long term average weather conditions. Many reasons have been identified for climate change. Mainly it is caused by multiple factors such as biotic processes, variation in solar radiation that reaches on earth, movement of tectonic plates and volcanic eruptions. Global warming which is caused by humans and others living being on the planet have been identified as the primary cause of ongoing climate change.

In Bangladesh many studies have done by the researchers about climate and temperature changes. Everyone has individually done something of their own with different region and on different goal. Rajib & Rahman (2012) inferred that the dry season months like December or January might have a greater amount of temperature change (around 5 °C in 2071-2100, 0.5 °C per decade from 2011 onwards) with respect to 1971-2000, compared to the monsoon season months like July (around 3 °C in 2071–2100). They concluded that average annual temperature rise of 4°C by the year 2100. Islam (2009) has found that daily maximum temperature shows a positive trend of increase at a rate of 0.621 \pm 0.491 °C per 100 year. The maximum increase occurred during November at a rate of 2.7 0C per 100 year. However, daily minimum temperature shows more significant trend of increase at a rate of $1.536 \pm 0.461^{\circ}$ C per 100 year. His study also revealed that temperature has been increase mainly over the last 30 years (1978-2007) than last 60 years (1948-2007). Rakib (2013) said Bangladesh has warmed up during the last 18 years; annual temperature has increased by 0.4-0.6°C during the period 1981-2010. Particularly annual average warming happened as the result of monsoon and pre-monsoon warming. Nury et al. (2013) forecasted maximum and minimum temperatures one month ahead for years 2010

and 2011 for Sylhet using ARIMA model (1,1,1) (1,1,1) and (1,1,1) (0,1,1) respectively and for Moulvibazar using ARIMA (1,1,0) (1,1,1) and ARIMA (0,1,1) (1,1,1). Basak et al. (2013) have found that the trend of variation of yearly average maximum temperature is increasing at a rate of 0.0186° C per year, whereas the rate was 0.0152° C per year for yearly average minimum temperature. Monthly average maximum temperature analysis also showed increasing trend for all months other than January and April. Karmakar & Shrestha (2000) have projected that by the year of 2050 and 2100, the annual mean maximum temperature of Bangladesh is going to increase into 0.4° C and 0.73° C respectively using data from 1961-1990.

This study is conducted to find the various issues of temperatures in Bangladesh. Our core objective of the study is to find out the nature of temperature in Bangladesh. To get this, we are going to compare extreme and moderate temperature and hence observe and find the situation. This will be helping us in finding out the trend of changes in temperature in different region which is one of our core objectives. This research is also aimed to find out the impact of others weather elements such as rainfall and humidity over temperature and vice versa.

2. Climate Zone in Bangladesh

Bangladesh is located in the subtropical monsoon region. It can be divided into seven climatic regions (Figure-1) on the basis of climate condition. (1) South-Eastern Zone, (2) North-Eastern Zone, (3) Northern Part of the Northern Region, (4) North-Western, (5) Western Zone, (6) South-Western Zone and (7) Southcentral zone. The temperature of south-eastern zone goes rarely over a mean of 32°C and below a mean of 13°C. Rainfall is heavy and usually it is over 2540 mm. Like South eastern zone, the mean maximum temperature of north eastern zone is rarely above 32°C and mean minimum is 10°C and below. This is the cloudiest part of Bangladesh and in winter fog s very common and rain is appreciable. Northern part of the northern Region has mean maximum temperature above 32°C while it is below 10°C in winter. The summer is very dry but the rainy season is very wet with 2000 to 3000 mm of rainfall. North-Western zone is similar to northern part of the northern region except that the rainfall is lower. Thus this area is almost drier. Western Zone is the driest area in Bangladesh. Rainfall here is below 1,500 mm and humidity in summer is less than 50%. In summer, it is the hottest and driest with mean summer maximum temperature over 35°C. South-Western region is less hot than western region. Rainfall is between 1500 mm to 1800 mm. Dew-fall is heavier than western zone and mean summer maximum temperature is below 35°C. Temperature of southcentral zone is less than of west but somewhat more than south-east zone. Rainfall here is abundant being over 1900 mm.

3. Data and Methods

3.1 Data Source

This study has been conducted over secondary data. Climate data (Temperature, Rainfall and Humidity) have been collected from Bangladesh Metrological Department (BMD). We have used data for 52 years from 1962 to 2013. For temperature, we have used –Long term average maximum temperature, Long term average minimum temperature, Extreme maximum temperature, Extreme minimum temperature, Year-wise monthly average maximum temperature, Year-wise monthly average minimum temperature. For Rainfall and Relative humidity –Long term average rainfall, Long term average relative humidity



Figure 1: Climate Zone of Bangladesh

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3.2 Study Area

Selection of areas for study was one of the toughest choices as they are meant to represent the whole country. Analysis on monthly long term average maximum and minimum temperature was performed to get the extreme and moderate temperature area. In average maximum temperature analysis, "Ishwardi" station was found to have 35.8°C of average maximum temperature while its nearest maximum temperature was recorded on Rajshahi with 35.7°C. In case of average minimum temperature, "Srimangal" station has the lowest temperature with 9.1°C and Ishwardi has 2nd lowest with 10.2°C. So for extreme temperature we have chosen Ishwardi station which is located on the west region and also by the side of north east region.



Figure 2: BMD weather station of Bangladesh with study area

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In choice of moderate area for study, we have studied both long term average maximum and long term average minimum temperature. "Cox's Bazar" station has the highest value in the long term average minimum temperature record and 3rd lowest value in the long term average maximum with 14.9°C and 32.4°C respectively. No other station has shown that much effectiveness on the selection of moderate area. Cox's Bazar is located on the south east region. Thus Ishwardi station is chosen for extreme and Cox's Bazar is for moderate area.

Simple calculation of univariate and bivariate with graphical analysis is performed on data. To find different value of temperature changes, regression and time series trend analysis is performed on some cases.

Time series Regression model, also referred as trend line were formed in the form

$$y_t = a + bx_t$$

Where b is the slope coefficient and a is the intercept of the trend line.

$$b = \frac{\sum (x_t - \bar{x})(y_t - \bar{y})}{\sum (x_t - \bar{x})^2}$$

And coefficient of determination R-Squared (R^2) of the trend, varies between 0 to 1 can be formulated as

$$R^2 = 1 - \frac{SS_{err}}{SS_{total}}$$

Microsoft Excel and R was use for data analysis. BMD station map was created with Tableau.

4. Results and Discussions

4.1 Analysis of Temperature of Ishwardi Station



Figure 3: Bar diagram showing extreme maximum and minimum temperature of Ishwardi



Figure 4: Curve of long term average maximum and minimum temperature of Ishwardi

4.1.1 All Time Extreme Temperature

For all-time extreme maximum temperature record, maximum temperature in summer was recorder 44°C while in winter maximum temperature was recorded 31.8°C. Mean extreme maximum temperature is found to be 39.18 °C. Meanwhile in extreme minimum temperature record it is found that the least temperature recorded in Ishwardi was 3.5 °C and 20.5°C was recorded as the minimum temperature on summer. Mean extreme minimum temperature was found to be 11.27°C (Figure 3). For record, in 1997 4.8°C temperature was recorded on August which is rare in the history.

4.1.2 Long Term Average Temperature

Long term average maximum summer temperature of Ishwardi is 35.8°C and in winter average maximum temperature is 24.3°C. Mean of the average maximum temperature is 31°C. In long term average minimum temperature, the meanest temperature in winter is 10.2°C and in summer the average minimum temperature

is 26.1°C. Mean for long term average minimum temperature is 20.33°C. Average maximum temperature is high on the month of April and lay down on the month of December-January. Similarly for the average minimum, lowest temperatures are in December-January. Unlike average maximum temperature, average minimum temperature is high during the months of July-August (Figure 4).

After the whole analysis of behavior of temperature over Ishwardi station, we have come to find that the temperature rises very high during May-June and they lay down to very low during December-January. However, it also shows a big difference between minimum and maximum temperature.



4.2 Analysis of Temperature of Cox's Bazar Station

Figure 5: Bar diagram of extreme maximum and minimum temperature of Cox's Bazar

Figure 6: Curve of long term average maximum and minimum temperature of Cox's Bazar

4.2.1 All Time Extreme Temperature

In extreme maximum temperature record, 37.5°C was found to be the maximum summer temperature and 33°C was found to be the maximum temperature in winter of Cox's Bazar. Mean of the extreme maximum temperature is 36.075°C. In Extreme minimum temperature record of Cox's Bazar, we can see that in winter extreme minimum temperature was 9.7°C and in summer the extreme minimum temperature was 21.2°C. Mean of the extreme minimum temperature is

14.47°C. For extreme maximum temperature, March, April and May have the maximum value. But in case of extreme minimum temperature, September has the highest value (Figure 5).

4.2.2 Long Term Average Temperature

For long term average maximum temperature of Cox's Bazar, the average maximum temperature is 32.4° C and in winter average maximum temperature is 26.7° C. The range is very thin; 5.7° C. Mean of long term average maximum temperature is 30.12° C. Observing long term average minimum temperature of Cox's Bazar, we have found that the lowest average temperature is 14.9° C and in summer the average minimum temperature is 25.2° C. Like maximum temperature, its range is also small, 10.3° C. Mean of the average minimum temperature is 21.93° C.

In conclusion of Cox's Bazars station's temperature, the difference between highest and lowest temperature is not that much (Figure 6). In summer (May-June), it has lower temperature and in winter (December-January) it has more temperature than any other region.

4.3 Comparison of Two Stations: Average Temperature

Statistics	Ishwardi Average (Min + Max) Temp	Cox's Bazar Average (Min + Max) Temp
Maximum	29.6	28.8
Minimum	17.2	20.8
Range	12.4	8
Mean	25.65	26.017
Median	28.05	27.55
Mode	29.1	27.9

Table 1: Average (minimum + maximum) Temperature

For Ishwardi, average maximum temperature in summer is 29.6°C and in winter is 17.2°C. Mean is 25.65°C. On the other hand, Cox's Bazar has 28.8°C of maximum temperature on summer and 20.8°C on winter. Mean temperature is 26.02°C.

Unlike extreme temperature and average (maximum or minimum) temperature, these average (max+ min) values of two stations shows a very little difference between these two stations. Difference of mean temperature is 0.37° C between

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these two stations. This happens because of taking both maximum and minimum temperature for consideration. Although Ishwardi station has extreme maximum and minimum temperature and Cox's Bazar has moderate both maximum and minimum temperature, but in case of average (maximum + minimum) both comes in neighborhood of each other.



Figure 7: Line chart for average (min + max) temperature of two stations

Here in the (Figure 7), Ishwardi station has lowest temperature on January and has some peak during April-May. But in case of Cox's Bazar station, the lowest average is higher than Ishwardi during December-January (winter) and the highest average temperature is lower than Ishwardi during summer.

4.4 Comparison of Two Stations: Rainfall and Humidity

Climate parameters are often related to each other. Changing on weather does not depend on only one particular parameter but to the relationship and fluctuations of all the parameters. To know about temperature changes we may need to observe the behavior of rainfall and relative humidity.



Figure 8: Bar diagram for average rainfall (mm)

Figure 9: Bar diagram for average Relative humidity (%)

Mean of the long term average rainfall of Ishwardi station is 128.54 millimeter. June-July is the rainiest season of the year and maximum rainfall recorded for a month is 310.63 millimeter. In case of Cox's Bazar, mean of the average rainfall is 305.81 millimeter and highest rainfall recorded here is 956.83 millimeter in July. But during the winter season (December-January) rainfall is same on the two areas. Although Cox's Bazar has the record of average maximum rainfall in a month, but in the month of January it has less average rainfall record than Ishwardi. So it is clear that average rainfall during summer of Cox's Bazar is greater than Ishwardi. But in winter both areas are dry.

Relative humidity is measured in percentage. Comparing long term average relative humidity of Ishwardi and Cox's Bazar it is found that average humidity of Cox's Bazar is more than the average humidity of Ishwardi. But in winter (December-January), Cox's Bazar has less than Ishwardi. Just like we have found previously about average (max+min) temperature of Ishwardi being greater during

summer and is lesser during winter, here is the opposite of this situation. Here, relative humidity is lesser in the summer and greater in the winter.

This may implies that the area with more rainfall and humidity has less temperature and area with less rainfall and humidity has more temperature.

4.5 Trend Analysis of Monthly Average Maximum Temperature



Figure 10: Time Series plot with trend of Maximum Temperature of Ishwardi



Figure 12: Time Series plot with trend of Maximum Temperature of Cox's Bazar

Figure 11: Time Series plot with trend of Minimum Temperature of Ishwardi



Figure 13: Time Series plot with trend of Minimum Temperature of Cox's Bazar

Monthly Average Maximum Temperature of Ishwardi (Figure 10) shows an upward trend in the data series of monthly average maximum temperature of Ishwardi. The fitted trend model is $y_t = 30.76 + 0.00079 x_t$. According to this model, temperature rising rate of each month is 0.00079°C. For last 52 years, temperature has raised total 0.493°C for average maximum temperature of Ishwardi.

Monthly Average Minimum Temperature of Ishwardi (Figure 11) shows an upward trend in the data series with the model, $y_t = 19.82 + 0.00161x_t$. Hence the rising rate of average minimum temperature per month is 0.00161°C. Total increase is 1.0046°C.

Average maximum temperature of Cox's Bazar (Figure 12) has raised 0.004051° C per month. The model can be defined as, $y_t = 28.96 + 0.004051x_t$. A total of 2.528°C temperature has risen since 1962.

From the figure 13 (Monthly Average Minimum Temperature of Cox's Bazar) we can see that the series has an upward trend with increment of 0.001842°C per month. In that case a total temperature change for last 52 years is 1.149°C. The trend model can be defined as, $y_t = 21.47 + 0.001842x_t$.

4.6 Comparison of Changes in Temperature

Average maximum and minimum temperature for all station has risen 0.493°C to 2.528°C. The temperature for moderate tempered area has risen more than extreme area. Inspecting R^2 values, we can see all of our models are not significant. But it won't matter in this study because R^2 is calculated considering all the values including the extreme ones of summers and winters. As Ishwardi station has been chosen as extreme are and Cox's bazar as Moderate area of temperature, the values of R^2 are much less on Ishwardi's model and relatively greater in the model of Cox's Bazar.

	Average	Average	Average	Average
	Maximum	Minimum	Maximum	Minimum
	Temperature	Temperature	Temperature	Temperature
	of Ishwardi	of Ishwardi	of Cox's Bazar	of Cox's Bazar
Intercept	30.76	19.819	28.96	21.47
Increment	0.00079	0.00161	0.004051	0.001842

Table 2: Comparison of Temperature Criteria

Total Increment	0.493	1.0046	2.528	1.149
RSE	3.563	5.806	1.824	3.726
R^2	0.0016	0.00249	0.1384	0.0079

From this analysis it is clear that temperature rising is certain. But it increases very slowly in extreme areas and rapidly in moderate areas. That means overall temperature of Bangladesh will be rising on a great scale within next century. Moderate temperature area will be lost and all the country will be transformed into extreme temperature area.

5. Conclusions

Comparing extreme and moderate temperature region of Bangladesh, we have come to a clear consequence which indicates that there have been a slight changes on temperature in past 52 years. But this much changes of temperature have a major impact on climate change which cannot be ignored. Temperature of Ishwardi has been always on extreme position in both summer and winter meanwhile temperature of Cox's Bazar has been always favorable. Average Maximum Temperature and Average Minimum Temperature of Ishwardi have increased 0.493°C and 1.0046°C respectively. On the other hand Average Maximum Temperature and Average Minimum Temperature of Cox's Bazar have increased 2.528°C and 1.149°C. Hence Temperatures of these two regions have risen from lowest 0.49°C to highest 2.58°C. Rainfall and humidity effect temperature as well. Places with more rainfall and humidity have less temperature and with less rainfall more temperature. On the basis of our analysis we can conclude that within next century temperature will increase about 1-2 degree Celsius. Human life on earth will be more difficult to live on. Increment of surface temperature will make imbalance on biodiversity and nature. Bangladesh is on the crucial place of being victim of global warming. Country on the baseline of the ocean will go under water soon if we do not prevent or control global warming.

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