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# CLIMATIC CONDITION OF THE NORTHWESTERN PART OF BANGLADESH

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**ABSTRACT**

*The 3-hourly surface synoptic dry bulb temperature (DBT), wet bulb temperature (WBT), daily maximum temperature, minimum temperature and rainfall data of five stations under Rajshahi and Rangpur divisions over Bangladesh during 1965–2014 have been considered for this study. The synoptic hours that considered for this study are 0000, 0300, 0600, 0900, 1200, 1500, 1800 and 2100 UTC for DBT and WBT. The study includes different seasonal and annual trends of average DBT, WBT, maximum temperature, minimum temperatures and rainfall of the northwestern part of Bangladesh. The study also identifies the day of maximum and minimum temperature and in which the maximum amount of rainfall occurred. The maximum rate of increase of DBT is observed at Rangpur (0.038$^o$C/year) in the monsoon season with the coefficient of determination 0.17 at 99.5% significant level. It is observed that the trends of average WBT and minimum temperature at all the stations in all seasons and annually are increased with the exception of Rangpur and Rajshahi for WBT and minimum temperature respectively in winter where it has a decreasing trend. The trend of annual rainfall is decreasing at all the stations but Rangpur over the region. The annual trend of maximum temperature is increasing at Rajshahi, Ishurdi and Bogra, and decreasing at Rangpur and Dinajpur.*

**Keywords:** *Rainfall, DBT, WBT, Maximum temperature, Minimum temperature.*

## 1. INTRODUCTION

South Asia is well known as a summer monsoon region (Normand, 1953, Jagannathan, 1960; Thapliyal and Kulshreshtha, 1992; Hastenrath, 1995; Kumar *et al.,* 1995; Rajeevan, 2001; Gadgil *et al.,* 2005) and Bangladesh is a heavy rainfall area in it. According to the Third Assessment Report of IPCC, South Asia is the most vulnerable region of the world to climate change impacts (McCarthy *et al*., 2001) and according to fifth Assessment Report of IPCC climate has started changing. Geographically, Bangladesh is a narrow flat low land, the Bay of Bengal is located in the south and the highly elevated Himalayas and Tibetan Plateau are situated in the north. These geographical features are very favorable for development of convection. The water vapor transported by the monsoon winds from the Bay of Bengal and highly elevated regions in the north causes development of heavy convection in Bangladesh.

Climate is not an invariant. It is ever changing in great or less degree (Krishnamurthy *et al*., 2009; Allan, 2011). In all parts of the world it differs from year to year, decade to decade and also from country to country. Several studies (Wang *et al*., 2009; Qian *et al*., 2010; Qian *et al*., 2011) have reported a weakening Asian winter monsoon in recent decades. The regular seasonal heating and cooling in different years is interfered by different amount of heat and moisture transported by winds (Allan and Soden, 2008) and ocean currents (Yan *et al*., 2002).

Local and regional climate are influenced by both large-scale atmospheric circulation and surface features (Kidson, 1994, Reza *et al.,* 2004). As spatial distributions of surface characteristics are relatively stable, it is expected that the large-scale climate play an important role in causing changes in local climate. Studies of local climate change are often linked to variations in the atmospheric circulation (Yarnal, 1984). Over the last one hundred years (1906-2005) the average temperature of the earth has increased by 0.74$^o$C (Trenberth *et al.,* 2007). Despite the recent strides towards achieving sustainable development, Bangladesh's potential to sustain its development is faced with significant challenges posed by climate change.

In relation to the development of a country, climate plays a very important role and can be considered as a natural resource, which makes it essential to understand and explore its various components. Ara *et al.* (2005) studied on surface air temperature and found increasing rate 0.017$^o$C/year over Sylhet division. Islam (2009) worked with model simulated temperature and rainfall and estimated increasing trend in rainfall. Alam *et al.* (2010) worked on DBT, WBT and rainfall over southwestern part of Bangladesh and found increasing trend of seasonal rainfall at Jessore, Khepupara, Khulna and Satkhira in Khulna division. The motivation of the present study is to investigate the changes in the different meteorological parameters such as Dry Bulb Temperature (DBT), Wet Bulb Temperature (WBT), Maximum Temperature (MaxT), Minimum Temperature (MinT) and Rainfall of five meteorological stations of the northwestern part of Bangladesh under Rajshahi and Rangpur Divisions.

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## 2. DATA AND METHODOLOGY

The 3-hourly (0000, 0300, 0600, 0900, 1200, 1500, 1800, 2100 UTC) surface synoptic data of DBT and WBT and daily maximum temperature, minimum temperature and rainfall of five stations over Rajshahi and Rangpur divisions during 1965-2014 have been collected from the Climate Division of Bangladesh Meteorology Department (BMD). The stations are Dinajpur, Rangpur, Bogra, Rajshahi and Ishurdi (Fig. 1). It is important to note that some data were not available in some stations in some years. These data have been considered as missing and have not been used for statistical computations.

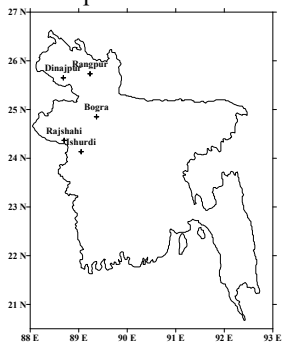


**Figure 1:** The locations of five meteorological stations of the northwestern part of Bangladesh.

3-hourly DBT and WBT data have been used to obtain daily, monthly, seasonal and annual mean values. For the other parameters the daily data have been used to compute the same. The December of previous year is added with January and February of the following year for winter. Linear regression equations are fitted for different seasonal and annual data to study the linear trends along with coefficient of determination (square of the coefficient of correlation, $r^2$). Student t-test has been done for all cases to study the statistical significance of the trends. The study also includes identification of extreme values of all the above mentioned parameters.

## 3. RESULTS AND DISCUSSIONS

We have analyzed the maximum temperature, minimum temperature, dry bulb temperature, wet bulb temperature and rainfall data of different meteorological stations (Dinajpur, Rangpur, Bogra, Rajshahi and Ishurdi) of the northwestern part of Bangladesh. We have presented the monthly mean values of all analyzed meteorological parameters in Fig. 2 and seasonal as well as annual mean values in Fig. 3. We have determined different seasonal and annual trends, the coefficient of determination and the statistical level of significance of all these parameters and presented in Table 1-5. The extreme values of all of the above mentioned parameters of different stations are tabulated in table 6.

### 3.1 Dry Bulb Temperature

The average DBT of winter has decreased in all stations except Rangpur (Table 1). In the pre-monsoon season the average DBT has increased at Bogra and Rangpur and decreased at Ishurdi, Rajshahi and Dinajpur and the decrease is maximum at Dinajpur (-0.039$^o$C/year). The corresponding time variant coefficient of determination has been found 0.213 with 99.5% level of significance (Table 2). In monsoon season the average DBT has increased all over the region (Table 3) and the increase has maximum at Rangpur (0.038$^o$C/year) with the coefficient of determination (0.17) at 99.5% significant level. In the post monsoon season the trend of average DBT has increased at Bogra and Rangpur and decreased at Ishurdi, Rajshahi and Dinajpur (Table 4). The trend of annual average DBT has decreased at Ishurdi, Dinajpur and Rajshahi and increased at Bogra and Rangpur stations (Table 5). In April, May and June, the maximum DBT has found at Rajshahi and minimum at Rangpur (Fig. 2a). It has been observed that the Rangpur station has the lowest DBT in all seasons (Fig. 3a).

### 3.2 Wet Bulb Temperature

The trend of average WBT has increased in all seasons and also annually in all the stations except Rangpur in winter (Table 1-5). The maximum rate of increase of average WBT is observed at Ishurdi and Bogra in the pre-monsoon season (Table 2) and the value is 0.044$^o$C/year with the coefficient of determination 0.553 and 0.603 respectively at 99.5% level of significance. Highest average WBT found in Rajshahi and lowest in Rangpur in months of May-September (Fig. 2b). In winter and post-monsoon Dinajpur has the lowest and Bogra has the highest average WBT. In pre-monsoon and monsoon Rajshahi has the highest average WBT (Fig. 3b).

**Table 1:** Winter trends, coefficients of determination and its statistical significant level of different parameters of five meteorological stations

| Parameters | Ishurdi | Rajshahi | Bogra | Rangpur | Dinajpur |
|---|---|---|---|---|---|
| DBT ( $^{o}$C/year) | -0.016 | -0.026 | -0.003 | 0.003 | -0.018 |
| $R^2$ = | 0.135 | 0.226 | 0.005 | 0.001 | 0.073 |
| Significant Level (%) | 99.5 | 99.5 | 60 | 55 | 95 |
| WBT ( $^{o}$C/year) | 0.018 | 0.001 | 0.025 | -0.002 | 0.011 |
| $R^2$ = | 0.156 | 0.001 | 0.265 | 0 | 0.057 |
| Significant Level (%) | 99.5 | 55 | 99.5 | 0 | 90 |
| MaxT ( $^{o}$C/year) | -0.012 | -0.019 | -0.019 | -0.031 | -0.038 |
| $R^2$ = | 0.058 | 0.135 | 0.130 | 0.155 | 0.284 |
| Significant Level (%) | 95 | 99.5 | 99 | 99.5 | 99.5 |
| MinT ( $^{o}$C/year) | 0.020 | -0.012 | 0.019 | 0.045 | 0.015 |
| $R^2$ = | 0.146 | 0.062 | 0.204 | 0.389 | 0.078 |
| Significant Level (%) | 99.5 | 95 | 99.5 | 99.5 | 95 |
| Rainfall (mm/year) | -0.455 | -0.326 | 0.003 | -0.016 | -0.078 |
| $R^2$ = | 0.038 | 0.025 | 0 | 0 | 0.002 |
| Significant Level (%) | 90 | 80 | <55 | 0 | 60 |

**Table 2:** Pre-monsoon trends, coefficients of determination and its statistical significant level of different parameters of five meteorological stations

| Parameters | Ishurdi | Rajshahi | Bogra | Rangpur | Dinajpur |
|---|---|---|---|---|---|
| DBT ( $^{o}$C/year) | -0.005 | -0.017 | 0.003 | 0.033 | -0.039 |
| $R^2$ = | 0.009 | 0.065 | 0.003 | 0.136 | 0.213 |
| Significant Level (%) | 70 | 95 | 60 | 99 | 99.5 |
| WBT ( $^{o}$C/year) | 0.044 | 0.032 | 0.044 | 0.041 | 0.039 |
| $R^2$ = | 0.553 | 0.330 | 0.603 | 0.428 | 0.343 |
| Significant Level (%) | 99.5 | 99.5 | 99.5 | 99.5 | 99.5 |
| MaxT ( $^{o}$C/year) | -0.003 | -0.005 | -0.019 | -0.038 | -0.024 |
| $R^2$ = | 0.002 | 0.004 | 0.063 | 0.173 | 0.078 |
| Significant Level (%) | 60 | 60 | 95 | 99.5 | 95 |
| MinT ( $^{o}$C/year) | 0.024 | 0.008 | 0.019 | 0.065 | 0.019 |
| $R^2$ = | 0.212 | 0.027 | 0.185 | 0.417 | 0.060 |
| Significant Level (%) | 99.5 | 90 | 99.5 | 99.5 | 90 |
| Rainfall (mm/year) | -2.628 | 0.183 | 0.518 | 1.134 | 0.528 |
| $R^2$ = | 0.058 | 0 | 0.003 | 0.010 | 0.003 |
| Significant Level (%) | 95 | 0 | 60 | 70 | 60 |

### 3.3 Maximum Temperature

The maximum temperature has decreasing trend in winter and pre-monsoon over all the stations (Table 1 & 2). The maximum rate of decrease of maximum temperature as observed is -0.038$^{o}$C/year with the coefficient of determination 0.173 and 0.284 at 99.5% level of significance at Rangpur in pre-monsoon and at Dinajpur in winter season respectively. In monsoon and post-monsoon the trend of maximum temperature has increased all over the region (Table 3 & 4). The annual trend of maximum temperature has increased at Rajshahi, Bogra and Ishurdi and decreased at Rangpur and Dinajpur (Table 5).

The rate of increase is maximum at Ishurdi (0.010$^{o}$C/year) with the coefficient of determination 0.109 at 97.5% significant level and the decrease is maximum at Rangpur (–0.010$^{o}$C/year) with the coefficient of determination 0.057 at 90% level of significance. In the months of March-Jun lowest average MaxT found at Rangpur and highest found at Rajshahi (Fig. 2c). Rangpur has the lowest average MaxT in all four seasons (Fig. 3c).

**Table 3:** Monsoon trends, coefficients of determination and its statistical significant level of different parameters of five meteorological stations

| Parameters | Ishurdi | Rajshahi | Bogra | Rangpur | Dinajpur |
|---|---|---|---|---|---|
| DBT ( $^{o}$C/year) | 0.013 | 0.012 | 0.023 | 0.038 | 0.010 |
| $R^2$ = | 0.325 | 0.257 | 0.637 | 0.170 | 0.145 |
| Significant Level (%) | 99.5 | 99.5 | 99.5 | 99.5 | 99 |
| WBT ( $^{o}$C/year) | 0.019 | 0.018 | 0.017 | 0.036 | 0.017 |
| $R^2$ = | 0.521 | 0.635 | 0.65 | 0.184 | 0.186 |
| Significant Level (%) | 99.5 | 99.5 | 99.5 | 99.5 | 99.5 |
| MaxT ( $^{o}$C/year) | 0.029 | 0.035 | 0.037 | 0.008 | 0.023 |
| $R^2$ = | 0.500 | 0.500 | 0.664 | 0.058 | 0.257 |
| Significant Level (%) | 99.5 | 99.5 | 99.5 | 90 | 99.5 |
| MinT ( $^{o}$C/year) | 0.012 | 0.008 | 0.015 | 0.011 | 0.014 |
| $R^2$ = | 0.277 | 0.149 | 0.367 | 0.209 | 0.068 |
| Significant Level (%) | 99.5 | 99.5 | 99.5 | 99.5 | 95 |
| Rainfall (mm/year) | -6.900 | -5.582 | -3.342 | 2.156 | -2.791 |
| $R^2$ = | 0.082 | 0.09 | 0.021 | 0.005 | 0.009 |
| Significant Level (%) | 97.5 | 97.5 | 80 | 60 | 70 |

**Table 4:** Post-monsoon trends, coefficients of determination and its statistical significant level of different parameters of five meteorological stations

| Parameters | Ishurdi | Rajshahi | Bogra | Rangpur | Dinajpur |
|---|---|---|---|---|---|
| DBT ( $^{o}$C/year) | -0.005 | -0.013 | 0.002 | 0.015 | -0.004 |
| $R^2$ = | 0.023 | 0.077 | 0 | 0.065 | 0.008 |
| Significant Level (%) | 80 | 95 | 0 | 95 | 70 |
| WBT ( $^{o}$C/year) | 0.010 | 0.004 | 0.015 | 0.006 | 0.014 |
| $R^2$ = | 0.060 | 0.009 | 0.132 | 0.012 | 0.116 |
| Significant Level (%) | 95 | 70 | 99 | 75 | 97.5 |
| MaxT ( $^{o}$C/year) | 0.021 | 0.014 | 0.036 | 0 | 0.010 |
| $R^2$ = | 0.245 | 0.124 | 0.417 | 0 | 0.047 |
| Significant Level (%) | 99.5 | 99 | 99.5 | 0 | 90 |
| MinT ( $^{o}$C/year) | 0.003 | -0.013 | 0.02 | 0.023 | 0.009 |
| $R^2$ = | 0.003 | 0.05 | 0.142 | 0.217 | 0.029 |
| Significant Level (%) | 60 | 90 | 99.5 | 99.5 | 80 |
| Rainfall (mm/year) | 0.521 | 0.358 | 1.032 | 2.713 | 2.070 |
| $R^2$ = | 0.004 | 0.004 | 0.019 | 0.083 | 0.035 |
| Significant Level (%) | 60 | 60 | 80 | 95 | 90 |

### 3.4 Minimum Temperature

The trend of minimum temperature has increased over all the stations except Rajshahi in winter and post-monsoon seasons (Table 1 & 4). In the pre-monsoon and monsoon seasons as well as annually all the stations are found to have an increasing trend (Table 2, 3 & 5). The maximum annual increasing trend (0.032$^{o}$C/year) has been found at Rangpur with coefficient of determination 0.589 at 99.5% significant level. In the winter months Dinajpur has the lowest average MinT and Bogra has the highest average MinT (Fig. 2d). In pre-monsoon Rangpur has the lowest average minimum temperature. However, in all seasons Bogra has the highest average minimum temperature (Fig. 3d).

### 3.5 Rainfall

The trend of rainfall in winter season has decreased at all the stations except Bogra (Table 1). The maximum rate of decrease is observed at Ishurdi (-0.455mm/year) with coefficient of determination 0.038 at 90% significant level. In the pre-monsoon season all the stations are found to have an increasing trend except Ishurdi (Table 2). In

monsoon season the trend of rainfall has decreased at all stations except Rangpur (Table 3). The rate of decrease is maximum at Ishurdi (-6.900mm/year) with coefficient of determination 0.082 at 97.5% significant level. In the post-monsoon season the rainfall has increasing trend all over the region (Table 4). The annual rainfall has decreasing trend over all the stations except Rangpur (Table 5). Minimum average rainfall has been found at Rajshahi (Fig. 2e) during April to July. It has been observed that Rangpur experienced highest amount of rain during pre-monsoon, monsoon and post-monsoon seasons (Fig. 3e). Annual rainfall also has been found maximum at Rangpur. In winter season Ishurdi got the highest amount of rainfall.

**Table 5:** Annual trends, coefficients of determination and statistical significant level of different parameters of five meteorological stations

| Parameters | Ishurdi | Rajshahi | Bogra | Rangpur | Dinajpur |
|---|---|---|---|---|---|
| DBT ( $^{o}$C/year) | -0.001 | -0.008 | 0.008 | 0.025 | -0.013 |
| $R^2$ = | 0.004 | 0.071 | 0.151 | 0.225 | 0.113 |
| Significant Level (%) | 60 | 95 | 99.5 | 99.5 | 97.5 |
| WBT ( $^{o}$C/year) | 0.023 | 0.016 | 0.026 | 0.025 | 0.021 |
| $R^2$ = | 0.522 | 0.337 | 0.643 | 0.398 | 0.333 |
| Significant Level (%) | 99.5 | 99.5 | 99.5 | 99.5 | 99.5 |
| MaxT ( $^{o}$C/year) | 0.010 | 0.006 | 0.007 | -0.010 | -0.003 |
| $R^2$ = | 0.109 | 0.056 | 0.062 | 0.057 | 0.012 |
| Significant Level (%) | 97.5 | 95 | 95 | 90 | 75 |
| MinT ( $^{o}$C/year) | 0.017 | 0 | 0.017 | 0.032 | 0.020 |
| $R^2$ = | 0.357 | 0 | 0.395 | 0.589 | 0.143 |
| Significant Level (%) | 99.5 | 0 | 99.5 | 99.5 | 99 |
| Rainfall (mm/year) | -9.250 | -4.765 | -1.573 | 5.761 | -1.984 |
| $R^2$ = | 0.090 | 0.047 | 0.003 | 0.027 | 0.003 |
| Significant Level (%) | 97.5 | 90 | 60 | 80 | 60 |

**Table 6:** Extreme values of different meteorological parameters of different stations over North Bengal

| | Rangpur | Dinajpur | Bogra | Rajshahi | Ishurdi |
|---|---|---|---|---|---|
| Highest DBT (DD/MM/YY) | **43.2**$^{o}$C 29/05/79 at 0900UTC | **42.3**$^{o}$C 29&30/03/70 at 0900UTC | **43.4**$^{o}$C 03/04/69 at 0900UTC | **43.3**$^{o}$C, 27/05/68; 17&18/05/72; 04/06/79; 23&24/04/80 at 0900UTC | **43.9**$^{o}$C 18/05/72 at 0900UTC |
| Highest WBT (DD/MM/YY) | **33.3**$^{o}$C 29&30/04/73 at 0600UTC | **38.0**$^{o}$C 22/07/12 at 1200UTC | **34.8**$^{o}$C 11/10/13 at 1200UTC | **35.5**$^{o}$C 21/04/79 at 0900UTC | **41.6**$^{o}$C 31/03/65 at 0000UTC |
| Highest Maximum Temperature | **42.8**$^{o}$C 02/05/66 | **43.3**$^{o}$C 29&30/03/70 | **44.0**$^{o}$C 21/04/89 | **45.1**$^{o}$C 19/05/72 | **44.0**$^{o}$C 13/05/70 |
| Lowest Minimum Temperature | **3.5**$^{o}$C 10/01/13 | **3.2**$^{o}$C 09/01/13 | **4.9**$^{o}$C 02/01/83 | **3.4**$^{o}$C 23/01/03 | **3.8**$^{o}$C 03/02/68 |
| Highest amount of rain in a day | **290** mm 28/07/79 and 16/06/84 | **508** mm 28/09/96 | **279** mm 23/06/88 | **247** mm 21/06/04 | **351** mm 10/07/76 |

### 3.6 Extreme Values

The lowest minimum temperature has been found at Rajshahi as 3.4$^{o}$C on 23/01/2003, at Dinajpur as 3.2$^{o}$C on 09/01/2013, at Rangpur as 3.5$^{o}$C on 10/01/2013, at Bogra as 4.9$^{o}$C on 02/01/1983 and at Ishurdi as 3.8$^{o}$C on 03/02/1968 (Table 6). The highest maximum temperature is observed at Rajshahi as 45.1$^{o}$C on 19/05/1972, Dinajpur as 43.3$^{o}$C on 29-30/03/1970, Rangpur as 42.8$^{o}$C on 02/05/1966, Bogra as 44.0$^{o}$C on 21/04/1989 and Ishurdi as 44.0$^{o}$C on 13/05/1970. The highest DBT of 43.3$^{o}$C at Rajshahi is observed at 0900 UTC on 27/05/1968, 17-18/05/1972, 04/06/1979, 23-24/04/1980. The highest DBT is observed at Dinajpur as 42.3$^{o}$C at

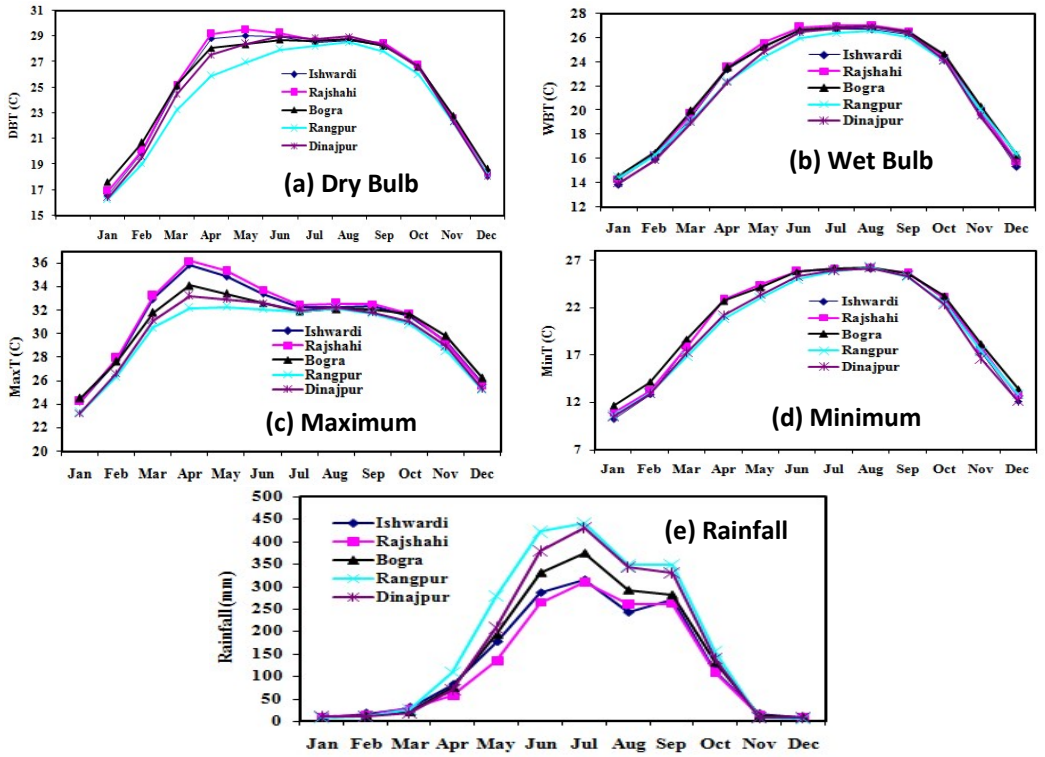


**Figure 2:** Monthly average a) dry bulb temperature (°C), b) wet bulb temperature (°C), c) maximum temperature (°C), d) minimum temperature (°C) and e) rainfall (mm) of different stations over northern part of Bangladesh.

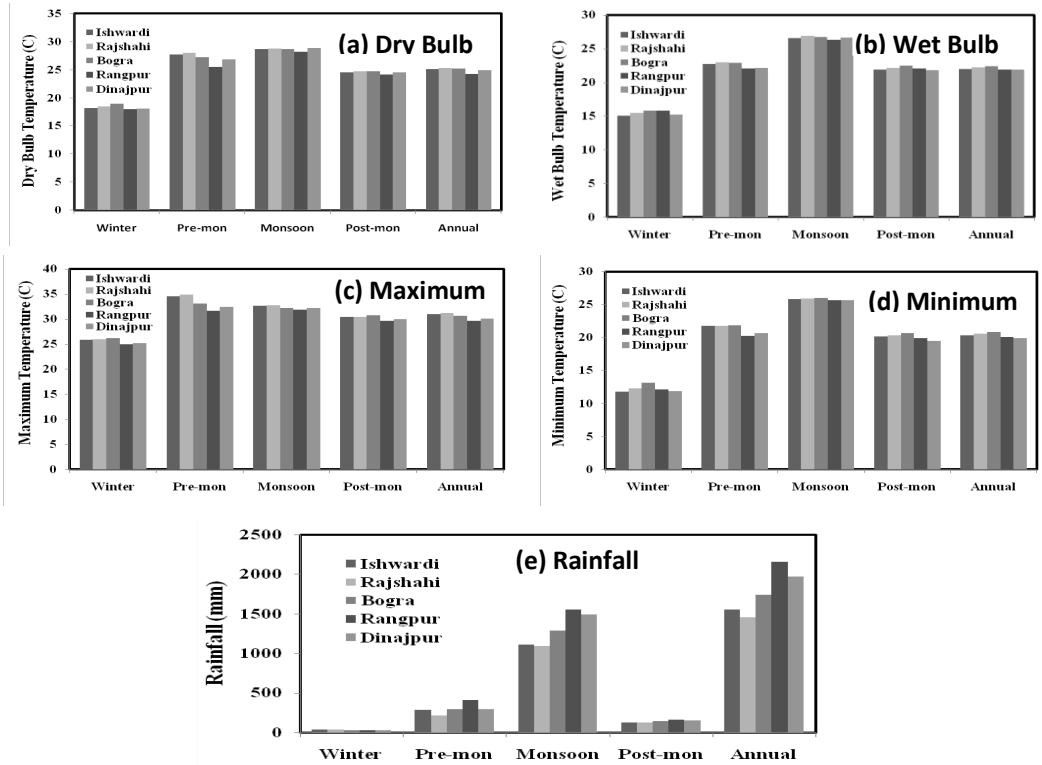


**Figure 3:** Average a) dry bulb temperature (°C), b) wet bulb temperature (°C), c) maximum temperature (°C), d) minimum temperature (°C) and e) rainfall (mm) of five stations.

0900 UTC on 29-30/03/1970, at Rangpur as 43.2°C at 0900 UTC on 29/05/1979, at Bogra as 43.4°C at 0900 UTC on 03/04/1969 and at Ishurdi as 43.9°C at 0900 UTC on 18/05/1972. The highest WBT is observed at Rajshahi as 35.5°C at 0900 UTC on 21/04/1979, at Dinajpur as 38.0°C at 1200 UTC on 22/07/2012, at Rangpur as 33.3°C at 0600 UTC on 29-30/04/1973, at Bogra as 34.8°C at 1200 UTC on 11/10/2013 and at Ishurdi as 41.6°C at 0000 UTC on 31/03/1965. The highest amount of rain is observed in a day at Rajshahi as 247mm on 21/06/2004, at Dinajpur as 508mm on 28/09/1996, at Rangpur as 290mm on 28/07/1979 and 16/06/1984 at Bogra as 279mm on 23/06/1988 and at Ishurdi as 351mm on 10/07/1976.

## 4. CONCLUSIONS

i) The maximum rate of increase of DBT is observed at Rangpur in the monsoon season and the value is 0.038°C/year with the coefficient of determination 0.170 at 99.5% significant level.

ii) The trends of average WBT in all the seasons and annually in all stations over the region have increased except at Rangpur in winter.

iii) The observed trend of annual maximum temperature has increased at Rajshahi, Ishurdi and Bogra, whereas it has decreased at Rangpur and Dinajpur. The maximum rate of decrease of maximum temperature -0.038°C/year with the coefficient of determination 0.173 and 0.284 at 99.5% level of significance is observed at Rangpur in pre-monsoon and at Dinajpur in winter respectively. The maximum rate of increase is observed at Bogra (0.037°C/year) with the coefficient of determination 0.664 at 99.5% level of significance in the monsoon season.

iv) The observed trend of minimum temperature has increased all over the region in all seasons and annually except at Rajshahi in winter and post-monsoon seasons, where it has decreased.

v) The trend of annual rainfall has decreased at all the stations except at Rangpur. The rate of maximum decrease is found at Ishurdi (-9.250mm/year) and that of increase at Rangpur (5.761mm/year) with the coefficient of determination 0.090 and 0.027 at 97.5% and 80% level of significance respectively.

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