

Change in Temperature over Bangladesh Associated with Degrees of Global Warming

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ABSTRACT

The aim of investigation of the research work is to study the temperature trend in Bangladesh. Long term changes of surface air temperature over Bangladesh have been studied using the available historical data collected by the Bangladesh Meteorological Department (BMD). Maximum, minimum and mean monthly temperature data of last sixty-three years (1948-2010) collected from 35 stations of BMD located all over the Bangladesh have been used in this study. It has been found that monthly maximum temperature shows a positive trend of increase at a rate of 0.5°C per 100 year. The maximum increase occurred during November at a rate of 2.05°C per 100 year. However, monthly minimum temperature shows more statistically significant trend of increase at a rate of 1.40°C per 100 year. The maximum increase occurred during February at a rate of 2.73°C per 100 year. Monthly mean temperature shows a positive trend of increase at a rate of 0.8°C per 100 year. It is clear found that monthly minimum temperature has been increased significantly during the winter season (October to February) over the last sixty-three years. This study also reveals that temperature has been increase predominantly over the last 21 years (1990-2010) than last 63 years (1948-2010). Bangladesh should also prepare adaptation policies to minimize the adverse effects of climate change. Vulnerabilities assessment, disaster management, enhanced structure design, institutional reform and anti extreme climate engineering are some feasible adaptation policies in Bangladesh due to increasing temperature.

Keywords: Global warming, Bangladesh, temperature, significant trend, climate change

1 INTRODUCTION

Global warming becomes one of the most important environmental problems in the 21st century and the impacts of global warming are worldwide (Chan 2006) and Bangladesh is the one of most vulnerable country in the world (Richard 2012). Global warming is mainly caused by the increase of green house gases of the atmosphere

(Houghton 2002). The assumption that increased greenhouse gas concentrations may lead to a rise in global temperatures first emerged in the 1960s (Peterson et al. 2008). The great majority of climate scientists now agree that the evidence for anthropogenic global warming is strong (Rosenberg et al. 2010). Predictions of average temperature changes and the economic costs of climate change are uncertain, but generally bleak: for increases of 5–6 °C, which is a “Production as Usual” scenario, the predicted economic loss is 5–10 % of global GDP (Stern 2007). In Earth’s past there have been significant periods of global warming and cooling, with average global temperatures from some era higher than current temperatures (Zachos et al. 2001). Intergovernmental Panel on climate Change (IPCC) has reported in their fourth assessment report that global surface temperature increased 0.74 ± 0.18 °C during the 100 years ending in 2005 (IPCC 2007). It is also noted by IPCC (2007) that the rise of mean annual temperature will be 3.3 °C per century. In the past, a number of studies have been carried out on trend of climate change in climatic parameters over Bangladesh. The pointed out that temperature trends has been changed (Chowdhury and Debsharma 1992; Mia 2003; Islam 2007). The reported mean annual temperature of Bangladesh has increased during the period of 1895-1980 at 0.31°C over the past two decades (Parthasarathy et al. 1987; Divya and Mehritra 1995). Using the 1961-1990 data for Bangladesh projected that annual mean maximum temperature will increase to 0.4°C and 0.73°C by the year of 2050 and 2100 respectively (Karmakar and Shrestha 2000). In this context, it is essential to quantify changes of temperature in recent years based on the historical data. This paper is going to study conducted on the long term changes of near surface air temperature of Bangladesh using data from historic period up to recent year and what government of Bangladesh should do due to climate change. This study represents both an extension of (Chowdhury and Debsharma 1992) and a continuation of (Islam 2008) with implications and policy framework. Where (Islam 2008) important questions such as implications, mitigation policy and adaptation to climate change remain unanswered.

2 DATA SET

The results of our study are expected to be different from (Islam 2008) if we adopt data for a longer time period. The present investigation will use approximately 63 years of temperature data is provided by the BMD. Maximum, minimum and average daily temperature data of last sixty-three years (1948-2010) has been collected from 35 stations of BMD located all over the Bangladesh have been used in this study . Fig. 1 shows location of the BMD stations over Bangladesh. These stations are mainly located at the city center of an urban district. Trend analysis has been conducted on monthly average data for all the stations. Monthly average value for both last 63 years and last 21 years (1990-2010) has been studied.

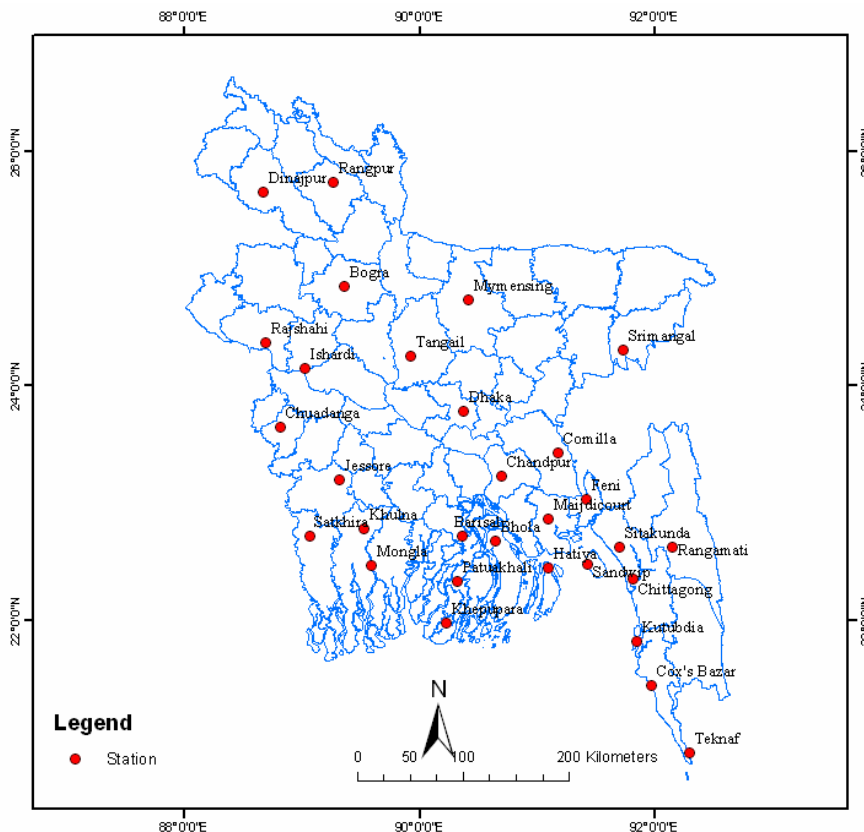


Fig. 1 Thirty five ground base measuring stations of Bangladesh Meteorological Department. Source (Islam 2008)

3 METHODOLOGY

Regression equation were formed in the form

$$y = mx + b \tag{1}$$

Where ‘m’ is the slope of the trend line and ‘b’ is the intercept of trend line with y-axis

$$m = \frac{\sum x_i y_i - \sum x_i \sum y_i}{\sum x^2 - \sum x_i \sum x_i} \tag{2}$$

$$b = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2} \tag{3}$$

Where, x_i is the independent variable, \bar{x} is the average of the independent variable, y_i is the dependable variable and \bar{y} is the average of dependable variable. Coefficient of determination, R-square (R^2) of the trend vary between 0 and 1. It can be found by using the following formula

$$R^2 = 1 - \frac{SS_{err}}{SS_{total}} \quad (4)$$

Correlation coefficient

$$r = \frac{[\sum (x_i - \bar{x})(y_i - \bar{y})]}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (5)$$

Long-term trend analyses were carried out for key meteorological parameters that might be influenced by global warming. There are many statistical methods for calculating trends, including parametric methods such as regression and t-test (e.g. Easterling et al. 1997; Karl et al. 1993) and non-parametric methods such as Mann-Kendall test (e.g. Qian and Giorgi, 2000; Quereda Sala et al. 2000). This study adopted the most commonly employed regression method and t-test (Easterling et al. 1997), a paper in IPCC (2001), and also (Karl et al. 1993). The long-term trend could then be inferred from the slopes of these straight lines. Two tailed t-test was applied to test the statistical significance of the trends at 5% significance level.

The test statistics t for testing the null hypothesis H0: trend = 0 against the alternative hypothesis H1: trend ≠ 0, is given by:

$$t = r \sqrt{\frac{n-2}{1-r^2}} \quad (6)$$

Where r is the correlation coefficient and follows a t distribution with n-2 degrees of freedom.

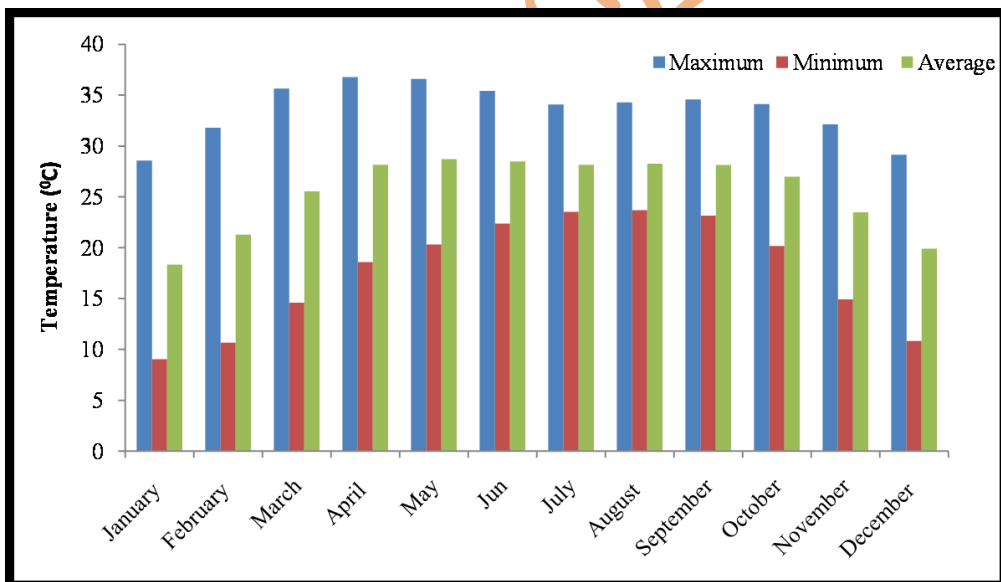
4 RESULTS AND DISCUSSION

4.1 MONTHLY MAXIMUM, MINIMUM AND MEAN TEMPERATURE

The monthly maximum, minimum and mean temperature of the country has been determined using historic available data from the meteorological stations of Bangladesh which shows in table (1). Fig.2 shows month-wise distribution of the average of maximum, minimum and mean temperature. Data within last 63 years period (1948-2010) from all the 35 stations of BMD is used to determine mean monthly temperature over Bangladesh. Monthly maximum data has shown its peak at 36.78 °C during April. However, Monthly minimum data has shown the highest rise of temperature of 23.67 °C during August. Moreover, monthly mean temperature has shown the highest rise of temperature of 28.71 °C during May.

Table 1: The average of monthly maximum, minimum and mean temperature of 35 stations of the country from (1948-2010)

Average	Maximum	Minimum	Mean
(1948-2010)			
January	28.56	9.06	18.34
February	31.80	10.65	21.27
March	35.64	14.60	25.55
April	36.79	18.59	28.16
May	36.59	20.31	28.71
Jun	35.44	22.37	28.48
July	34.09	23.53	28.15
August	34.31	23.68	28.26
September	34.57	23.17	28.12
October	34.14	20.18	26.97
November	32.13	14.91	23.50
December	29.14	10.82	19.89
Yearly	37.67	8.79	25.43

**Fig. 2** Bar diagram of monthly average of maximum, minimum and mean temperature (°C) during the last sixty-three years period (1948-2010)

5 TRENDS OF MONTHLY (FROM AVERAGE OF DAILY) MAXIMUM, MINIMUM AND MEAN TEMPERATURE

In this study, trends of monthly (from average of daily) temperature data for all the 35 stations of BMD have been analyzed during the period 1948-2010. Monthly maximum temperature data have shown an increasing trend of 0.50 °C per 100 years Fig.3 (a). On the

other hand, monthly minimum temperature data have exhibited more statistically significant trend of $1.40\text{ }^{\circ}\text{C}$ per 100 years and shown in Fig.4 (a). Also, monthly mean temperature have increased with a rate of $0.8\text{ }^{\circ}\text{C}$ per 100 years.

It has also evident from these plots that the rate of change has more accelerated in the last 21 years. Therefore, data of monthly (from average of daily) temperature of last 21 years (1990-2010) have been also studied for trend analysis. Monthly maximum, minimum and mean temperature have shown positive increase with a rate of $4.5\text{ }^{\circ}\text{C}$, $2.9\text{ }^{\circ}\text{C}$ and $2.1\text{ }^{\circ}\text{C}$ per 100 years and shown in Figures 3(b), 4(b) and 4(b) respectively. It has clearly found that maximum temperature has been increased dramatically over the last 21 years period.

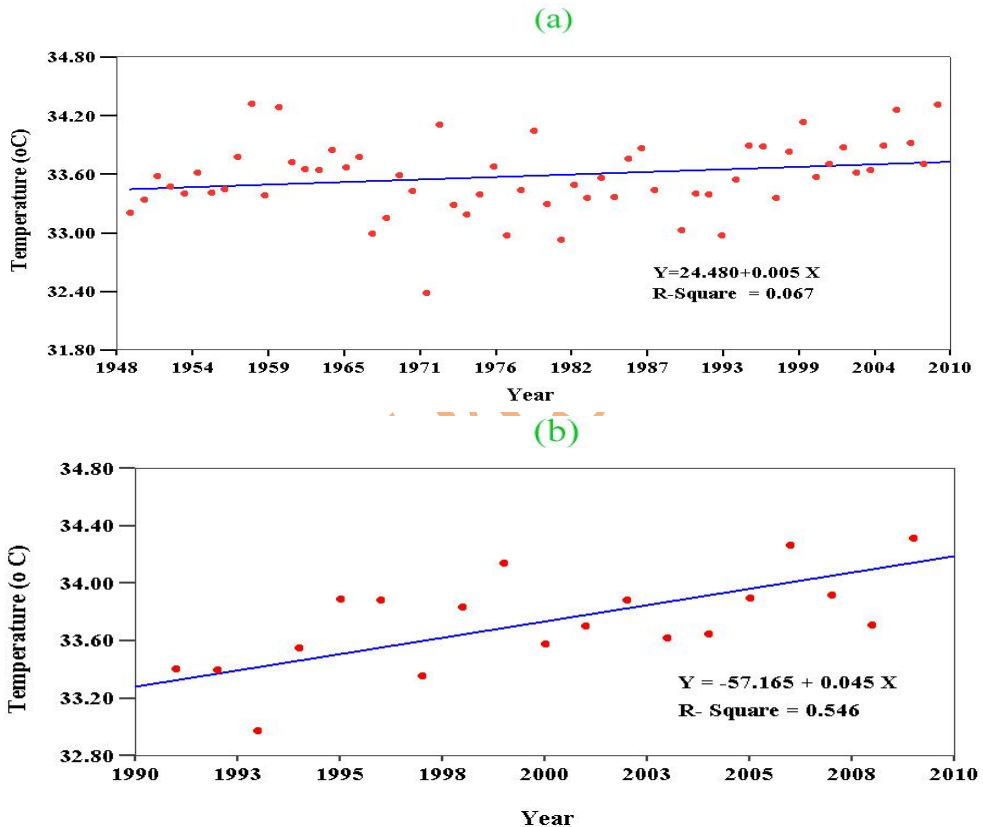


Fig. 3 Trend of monthly (a) maximum temperature of all the stations using the period of last 63 years data (1948-2010) where correlation coefficient $r = 0.26$. Trend of monthly (b) maximum temperature of all the stations using the period of last 21 years data (1990-2010) where correlation coefficient $r = 0.739$

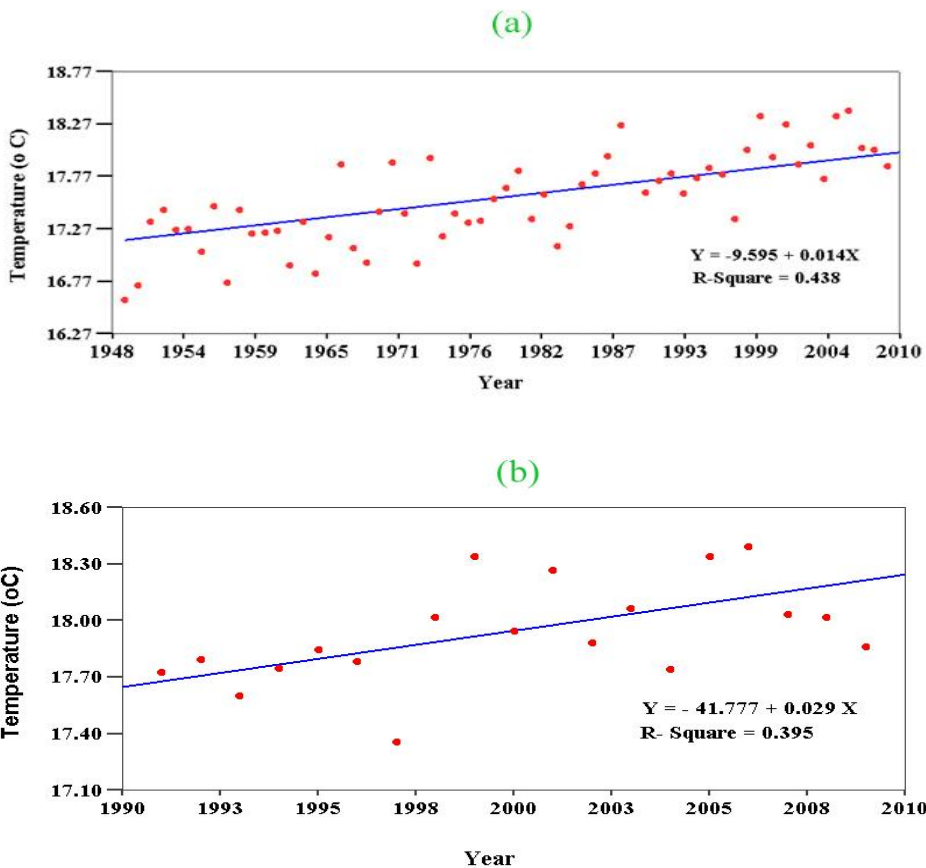
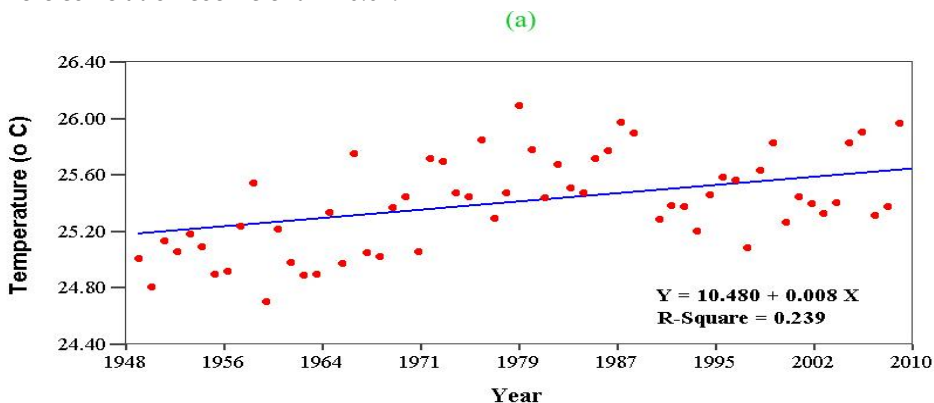


Fig. 4 Trend of monthly (a) minimum temperature of all the stations using the period of last 63 years data (1948-2010) where correlation coefficient $r = 0.66$. Trend of monthly (b) minimum temperature of all the stations using the period of last 21 years data (1990-2010) where correlation coefficient $r = 0.629$



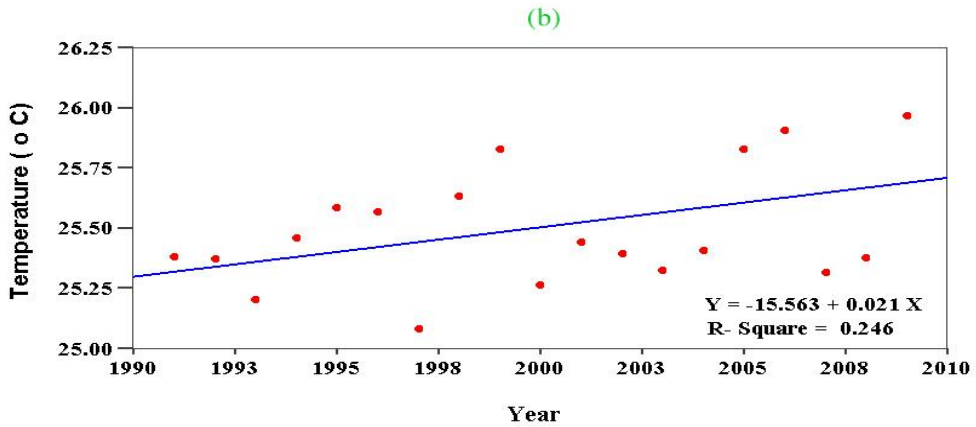


Fig. 5 Trend of monthly (a) mean temperature of all the stations using the period of last 63 years data (1948-2010) where correlation coefficient $r = 0.49$. Trend of monthly (b) mean temperature of all the stations using the period of last 21 years data (1990-2010) where correlation coefficient $r = 0.496$

6 STATION-WISE (SEVEN DIVISION) TRENDS OF MONTHLY AVERAGE MAXIMUM, MINIMUM AND MEAN TEMPERATURE

Trends of monthly average maximum, minimum and mean temperature have been analyzed for each station of BMD. The trend analysis is presented in below figures. Available years of data and beginning year of each data set are also presented for each station. Trend of mean temperature vary from -0.2 to 1.1 $^{\circ}\text{C}$ per 100 years among seven stations. At Dhaka, trend of mean temperature is the highest among the seven stations with a value of 1.1 $^{\circ}\text{C}$ per 100 year. Coefficient of determination, R^2 of the trend analysis of monthly mean temperature varies from 0.006 in Khulna to 0.242 in Dhaka among seven stations. R^2 Value less than 0.5 has found in many stations which represents poor statistical significance trend.

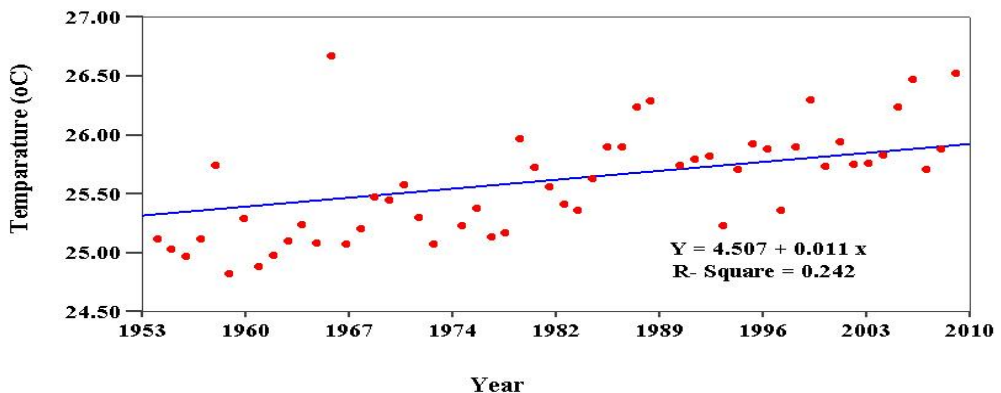


Fig. 6 Trend of the monthly mean temperature of Dhaka (1953-2010) where correlation coefficient $r = 0.505$

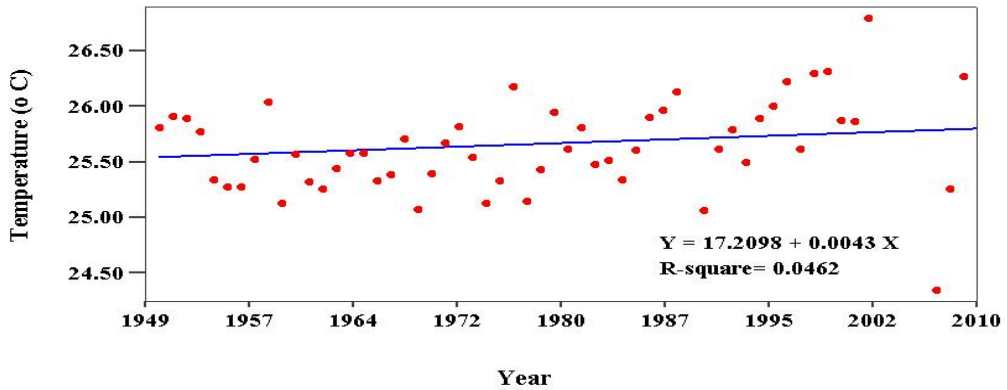


Fig. 7 Trend of the monthly mean temperature of Chittagong (1949-2010) where correlation coefficient $r = 0.304$

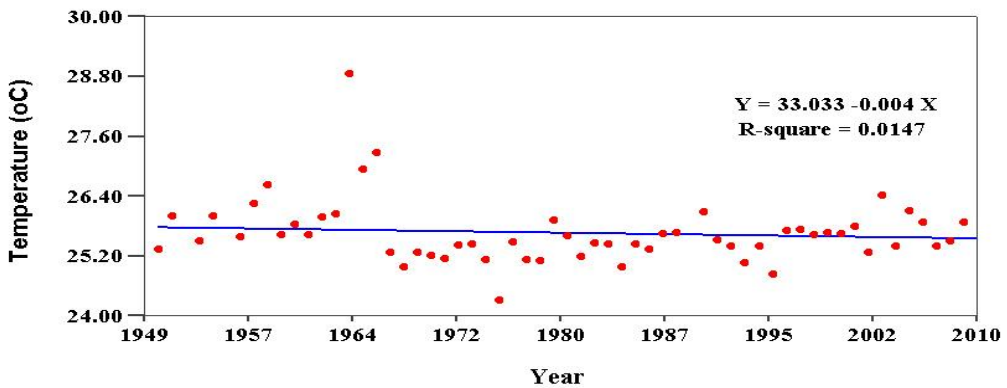


Fig. 8 Trend of the monthly mean temperature of Barisal (1949-2010) where correlation coefficient $r = -0.193$

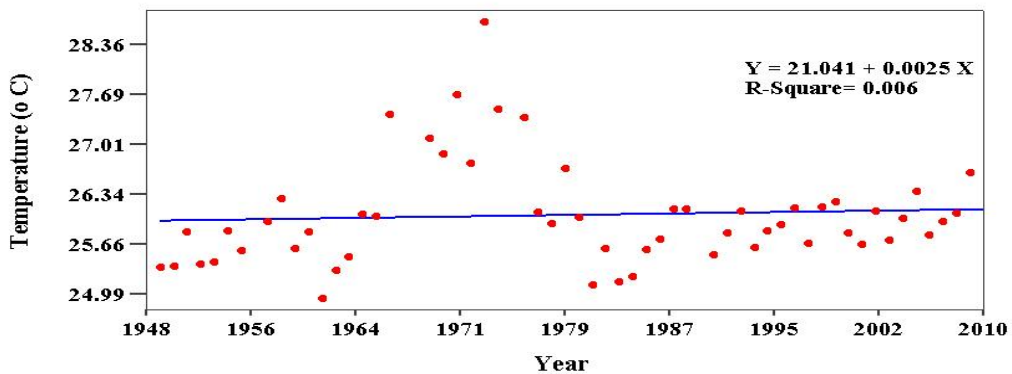


Fig. 9 Trend of the monthly mean temperature of Khulna (1948-2010) where correlation coefficient $r = 0.070$

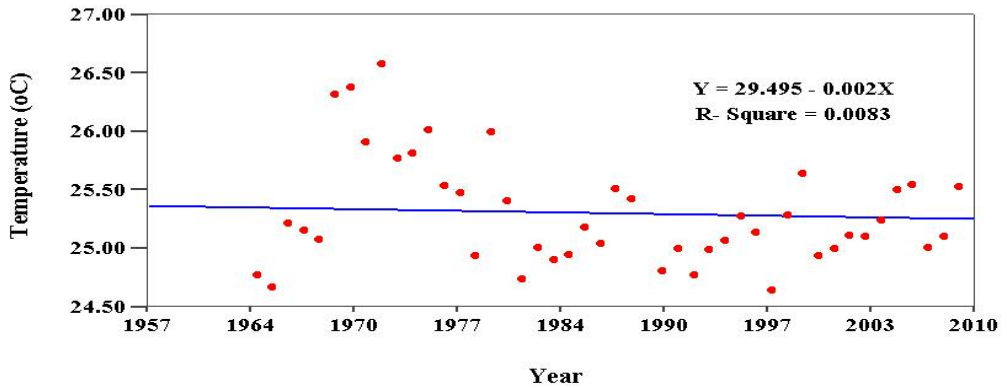


Fig.10 Trend line of the monthly mean temperature of Rajshahi (1957-2010) where correlation coefficient $r = -0.038$

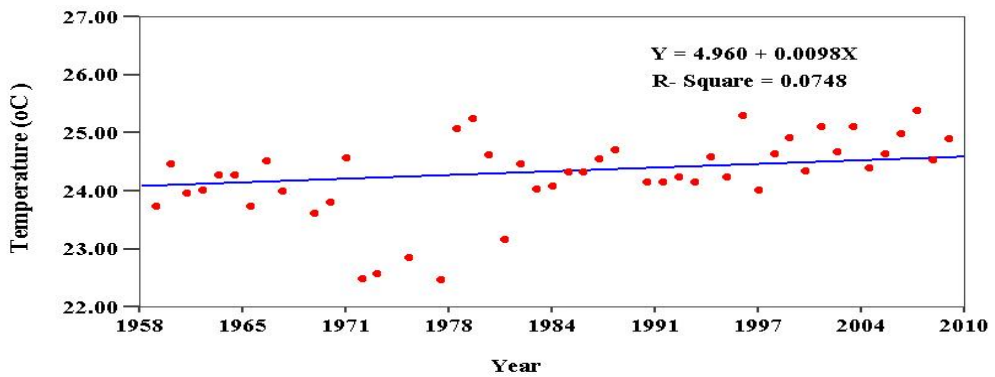


Fig. 11 Trend line of the monthly mean temperature of Rangpur (1958-2010) where correlation coefficient $r = -0.072$

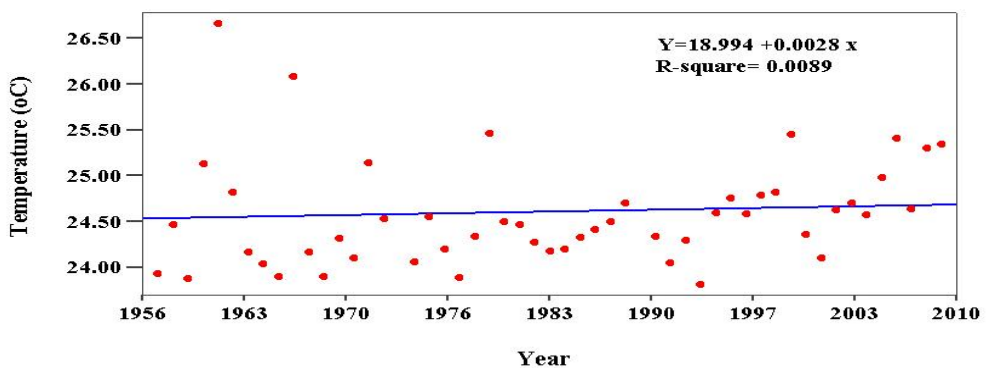


Fig. 12 Trend line of the monthly mean temperature of Sylhet (1956-2010) where correlation coefficient $r = 0.090$

7 MONTHLY TRENDS OF DAILY MAXIMUM, MINIMUM AND MEAN TEMPERATURE

Monthly average rate of change of temperature during last 63 years (1948-2010) has been studied. Table 2 shows a summary of trends $^{\circ}\text{C}$ monthly maximum, minimum and mean temperature over Bangladesh for each month. Coefficient of determination, R^2 of the trends are also presented in Table 2. Monthly maximum data exhibits trends from -0.21°C per 100 years during May to 2.05°C per 100 years during November. On the other hand, the maximum trend of monthly minimum temperature is 2.73°C per 100 years in February. The minimum trend of monthly minimum temperature is 0.5°C per 100 years in September. However, the maximum and minimum values of trends of monthly mean temperature have found as is 2.68°C per 100 years in December and is -0.26°C per 100 years in May respectively. It can be clearly found that monthly minimum temperature has been increased significantly during the winter season (October to February) over the last 63 years. Trends of monthly maximum, minimum and mean temperature over the last 21 years (1990-2010) have also determined and presented in Table 3. The maximum trend of monthly maximum temperature is found as 2.22°C per 100 years in January and minimum trend is found as 8.95°C per 100 years in February. Similar results can be found for monthly minimum and mean temperature. The highest value of trends of monthly minimum and mean temperature are found as 10.97 and 3.95°C per 100 years in April and March respectively.

Table 2: Monthly average trends and R^2 value of monthly maximum, minimum and mean temperature during last 63 year period (1948-2010)

Month	Average of 63 year period (1948-2010)					
	Max	R^2	Min	R^2	Mean	R^2
January	0.0051	0.0269	0.0113	0.0704	0.0043	0.0109
February	0.0069	0.0307	0.0273	0.1910	0.0134	0.0908
March	-0.0111	0.0526	0.0266	0.1922	0.0063	0.0255
April	-0.0150	0.0592	0.0160	0.0959	-0.0041	0.0094
May	-0.0021	0.0019	0.0091	0.0576	-0.0026	0.0056
June	0.0094	0.0525	0.0076	0.0760	0.0066	0.0786
July	0.0080	0.0635	0.0107	0.1767	0.0072	0.1465
August	0.0176	0.2697	0.0105	0.1586	0.0085	0.2226
September	0.0093	0.1286	0.0050	0.0502	0.0054	0.0972
October	0.0150	0.2472	0.0067	0.0234	0.0052	0.0461
November	0.0205	0.3003	0.0161	0.0809	0.0173	0.1642
December	0.0086	0.0617	0.0199	0.1814	0.0268	0.4069
Average	0.006		0.0139		0.0079	

Table 3: Monthly average trends and R^2 value of monthly maximum, minimum and mean temperature during last 21 year period (1990-2010).

Month	Max	R^2	Min	R^2	Mean	R^2
January	0.0222	0.0904	0.0500	0.1318	-0.0188	0.0242
February	0.0895	0.1607	-0.0315	0.0237	0.0154	0.0099
March	0.0451	0.0736	0.0297	0.0247	0.0395	0.0591
April	0.0275	0.0248	0.1097	0.3433	0.0393	0.0673
May	0.0797	0.3639	0.0378	0.1000	0.0342	0.1260

June	0.0658	0.2949	0.0292	0.1406	0.0196	0.0559
July	0.0482	0.3558	0.0370	0.2200	0.0205	0.1764
August	0.0275	0.0808	0.0356	0.2938	0.0146	0.0993
September	0.0202	0.0458	0.0423	0.3730	0.0222	0.1783
October	0.0447	0.2668	0.0344	0.0347	0.0292	0.1368
November	0.0270	0.0520	0.0105	0.0043	0.0244	0.0577
December	0.0409	0.2103	-0.0269	0.0382	0.0071	0.0049
Average	0.0449		0.0298		0.0206	

Table 4: Change of trends ($^{\circ}\text{C}$ per 100 year) of monthly maximum, minimum and mean temperature over the last 21 years (1990-2010) than that of over last 63 year (1948-2010)

Month	Max	Min	Mean
January	1.71	3.87	-2.31
February	8.26	-5.88	0.2
March	5.62	0.31	3.32
April	4.25	9.37	4.34
May	8.18	2.87	3.68
June	5.64	2.16	1.3
July	4.02	2.63	1.33
August	0.99	2.51	0.61
September	1.09	3.73	1.68
October	2.97	2.77	2.4
November	0.65	-0.56	0.71
December	3.23	-4.68	-1.97
Average	3.88	1.59	1.27

Changes of trends of temperature within last 63 years and within last 21 years have been compared. A comparison of the trends of monthly maximum, minimum and mean temperature has been presented in Table 4. There has been a significant increase of the values of trends of daily maximum and mean temperature during summer season. On the other hand, over the last 21 years trends of monthly minimum and mean temperature has been diminished than that of last 63 years during winter season.

8 CONCLUSIONS

Monthly maximum, minimum and mean temperature shows a positive trend over Bangladesh. Increase of monthly maximum temperature is 0.60°C , monthly minimum temp is 1.39°C and monthly mean temperature is 0.79°C per 100 years. Maximum increase of monthly maximum temperature has occurred in November at 2.05°C and monthly minimum temperature has occurred in February at 2.73°C in 100 years. The highest increase of monthly maximum temperature has occurred as 1.1°C per 100 years at Dhaka and monthly minimum temperature has occurred as -0.2°C per 100 years at Rajshahi. It has clearly found that maximum temperature has been increased dramatically over the last 21

years period. Monthly maximum, minimum and mean temperature has shown positive increase with a rate of 4.49 °C, 2.98 °C and 2.06 °C per 100 years respectively during the period of last 21 years (1990-2010). Increase of winter temperature can reduce the environmental suitability for wheat, potato and other temperate crops grown in Rabi season. Implications for Agriculture and Fisheries; in Bangladesh, the largest demand for both surface and ground water is to support irrigation in the dry months. Changes in climate may affect irrigation requirements for all the three cropping seasons: Rabi, Kharif-I, Kharif-II. Increase in temperature will scale up irrigation demands by 200Mm³ for March alone. Currently, the irrigation and fisheries sectors compete for water. Since the solubility of oxygen in water decreases with higher temperature reported by Asian Development Bank (2004), it could be a problem for fisheries. If river flow is reduced during the dry season, this problem will be worse. Moreover, freshwater migratory fish hatchlings will face a survival problem in the southwestern part of Bangladesh because of increased salinity from sea level rise.

Mitigation Policy Framework; Bangladesh should adopt a number of policies where environment issues will address. Important policy documents throughout the analysis are:

1. Maintenance of the ecological balance and overall progress and development of the country through protection and improvement of the environment;
2. Protection of the country against natural disasters;
3. Identification and control of all types of activities related to pollution and degradation of environment;
4. Undertaking environmentally development programs in all sectors including agriculture, industry, health, energy, water, land, forest.

Vulnerabilities assessment, disaster management, enhanced structure design, institutional reform and anti extreme climate engineering are some feasible adaptation policies in Bangladesh. A complete climate policy should encompass both mitigation and adaptation to climate change due to global warming.

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