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Some climatological characteristics of the changing pattern of temperature in Bangladesh – A diagnostic approach

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सार – बंगलादेश मौसम विज्ञान विभाग (BMD) से 60 वर्षों की अवधि (1949-2008) के 17 केंद्रों के अधिकतम और न्यूनतम तापमानों के जलवायविक आँकड़े प्राप्त किए गए। बंगलादेश में तापमान के परिवर्तनशील पैटर्न की जाँच की गई। माध्य मासिक न्यूनतम, माध्य मासिक अधिकतम और माध्य मासिक तापमान, माध्य मासिक आयाम के वार्षिक परिवर्तिता और स्थानिक वितरण के परिवर्तनशील पैटर्न के कुछ लक्षणों को बताया गया है। मानक विचलन, विचरण गुणांक, माध्य मासिक अधिकतम और मासिक न्यूनतम तापमानों के मध्य अनुपात जैसे तापमान के परिवर्तनशील पैटर्न के अभिलक्षणों का अध्ययन किया गया है। वर्ष 1949-2008 के लिए विभिन्न स्टेशनों में तापमान के प्रवाह, माध्य वार्षिक तापमान और माध्य दशक विचलनों की आवर्तिता पर विचार - विमर्श किया गया। ढाका के लिए माध्य वार्षिक तापमान की सम्पूर्ण वक्रता तैयार कर बताई गई। ढाका सहित सइलहेट, चिटगाँव, खुलना और रंगपुर स्टेशनों के लिए जनवरी, अप्रैल, जुलाई और अक्तूबर के माध्य मासिक तापमान के लिए समाश्रयण विश्लेषण किए गए। कुछ रैखीय सहसंबंध समीकरणों के परिणाम निकाले गए। इस जाँच में बंगलादेश में तापमान के परिवर्तनशील पैटर्न के सिनाप्टिक कारणों को स्पष्ट करने का प्रयास (यथासंभव) किया गया।

ABSTRACT. Based on climatological data of maximum and minimum temperatures of seventeen stations for a period of 60 years (1949 - 2008), obtained from Bangladesh Meteorological Department (BMD), the changing pattern of temperature in Bangladesh has been investigated. Some characteristics of annual variation and spatial distribution of mean monthly minimum, mean monthly maximum and mean monthly temperature, annual variation and spatial distribution of mean monthly amplitude of temperature have been explained. The characteristics of changing pattern of temperature such as standard deviation, coefficient of variation, ratio between mean monthly maximum and mean monthly minimum temperatures have been studied. The run of the temperature in different stations for the years 1949-2008, the periodicity of mean annual temperature and mean decade deviations have been discussed. The integral curve of mean annual temperature for Dhaka has been prepared and explained. Regression analysis for mean monthly temperature of January, April, July and October for the stations Sylhet, Chittagong, Khulna and Rangpur with Dhaka have been analyzed. Some linear correlation equations have been deduced. In the investigation, attempts (as far as possible) have been made to explain the synoptic cause of the changing pattern of temperature in Bangladesh.

Key words – National economy, Growth of vegetation, Rational agriculture planning, Aforestation, Mesoscale climate, Mean temperature, Standard deviation, Coefficient of variation, Correlation characteristics, Ratio between maximum and minimum temperature probability, Run, Periodicity, Decade deviation.

1. Introduction

Bangladesh is mainly a densely populated agricultural country. It is situated partly in the tropics and partly in the sub tropics (in between 20° 34′ N and 26° 33′ N correspondingly to 88° 01′ E to 92° 41′ E) maximum extension is about 440 km in E - W direction and 760 km in NNW - SSE direction. (Chowdhury *et al*., 2003)

The production of various crops in Bangladesh depends on different parameters of weather and climate. Temperature is an important parameter playing a vital role on the growth and production of vegetation. The study of the climatological changing pattern of temperature may be useful in defining rational economic plan of this country. Such a study may also be useful in health science, in construction engineering, in aforestation, in tourism, in environmental protection, in pisciculture, in water management planning etc.

Earlier Nandi (1982), studied some basic characteristics of temperature of air for a series of data for 27 years. A detailed study with a longer series is obviously expected for a good diagnosis of surface temperature. Present study is based on the data mainly for about 60 years of length (1949-2008).

It is assumed that the climate of the globe is changing. There are different hypotheses regarding this. It is forwarded by a group of scientists that the surface temperature is increasing. Most of the meteorologists work on the global change of mean sea level temperature. But the changing pattern of temperature in a mesoscale area is to be studied for a better application in the national economic policy. Being guided by these considerations, an attempt has been made to investigate the climatological changing pattern of surface temperature of air in Bangladesh.

2. Data

Climatological data obtained from Bangladesh Meteorological Department for seventeen stations with the maximum length of 60 years (1949-2008) have been used in the present investigation. In the present work, the climatological parameters like maximum temperature and minimum temperature of individual stations have been utilized (Bangladesh Meteorological Department, 2009).

3. Method of investigation

Standard statistical and synoptic methods have been used to study the changing pattern of surface temperature of Bangladesh. In the process, mean monthly temperature, standard deviation, coefficient of variation, correlation coefficient, regression equation, ratio of temperatures (maximum and minimum), probability, run, decade deviation and integral curves have been studied by using literature sources (Alisov *et al*., 1940; Chromov *et al*., 1974; Conrad & Pollak, 1950; Gulinova, 1974; Kelchevskaia, 1971; Kobisheba *et al*., 1978).

The climatological parameters in this research paper have been formulated in the following way:

(*i*) Daily minimum temperature, it is the lowest temperature of everyday of a particular month.

(*ii*) Mean monthly minimum temperature of a particular year. It is defined as the mean of daily minimum temperatures of a particular month, *i.e*.,

$$\bar{t}_{i\min} = \frac{\sum_{i=1}^{n} \text{daily minimum temperature of a particular month}}{n} \tag{1}$$

where *n* is the number of days of the month.

(*iii*) Daily maximum temperature is defined as the highest temperature of a particular day of a particular month.

(*iv*) Mean monthly maximum temperature of a particular year: It is defined as the mean of the daily maximum temperature for a particular month, *i.e*.,

$$\bar{t}_{i\max} = \frac{\sum_{i=1}^{n} \text{daily maximum temperature of a particular month}}{n} \tag{2}$$

where, *n* is the number of days of the month.

(*v*) Mean monthly minimum temperature (for the whole of the series), *i.e*.,

$$\bar{t}_{\min} = \frac{\sum_{i=1}^{n_1} \bar{t}_{i\min}}{n_1} \tag{3}$$

where n_1 is the number of year of the series.

(*vi*) Mean monthly maximum temperature (for the whole of the series), *i.e*.,

$$\bar{t}_{\max} = \frac{\sum_{i=1}^{n_1} \bar{t}_{i\max}}{n_1} \tag{4}$$

where, n_1 is the number of year of the series.

(*vii*) Mean monthly temperature

$$\bar{t} = \frac{\bar{t}_{\min} + \bar{t}_{\max}}{2} \tag{5}$$

(*viii*) Amplitude of the temperature:

(a) *Diurnal amplitude* : It is the difference between the highest and lowest temperatures of a particular day.

(b) *Mean monthly amplitude* : It is the difference of mean monthly maximum and monthly minimum temperature.

(c) *Annual amplitude* : It is the difference of the mean monthly temperatures with the highest and lowest values in the annual variation.

(*ix*) Standard deviation:

$$\sigma_t = \sqrt{\frac{\sum_{i=1}^{n} \left(t_i - \bar{t}\right)^2}{n_1}} \tag{6}$$

where, t_i is the temperature of the defined month for the i_{th} year,

$\bar{t}$ is the mean temperature of that month for the series with n_1 number of observations.

(*x*) Coefficient of variation (C.V.) %

$$\text{C.V. } (\%) = \frac{\sigma_t}{\bar{t}} \times 100 \tag{7}$$

(*xi*) Correlation coefficient: It is defined for a pair of stations. At first scatter diagram was drawn to find out the pattern of relation between the two stations. In case of liner relation the coefficient of correlation has been obtained by the formula.

$$r = \frac{\sum_{i=1}^{n} \left(t_{x_i} - \bar{t}_x\right)\left(t_{y_i} - \bar{t}_y\right)}{\sqrt{\sum_{i=1}^{n} \left(t_{x_i} - \bar{t}_x\right)^2 \sqrt{\left(t_{y_i} - \bar{t}_y\right)^2}}} \tag{8}$$

where, t_{xi} and t_{yi} are the monthly temperatures of the i_{th} years of the related stations and $\bar{t}_x$ and $\bar{t}_y$ - Monthly mean temperatures of the mentioned stations.

(*xii*) Regression equation: In case of linear correlation, the equation is;

$$t_y = \bar{t}_y + \frac{\sigma_{ty}}{\sigma_{tx}}\left(t_x - \bar{t}_x\right) \tag{9}$$

where, σ_{ty} and σ_{tx} are the standard deviations of the monthly temperature for the stations *y* and *x* respectively.

(*xiii*) Ratio of the temperature (R_t)

$$R_t\,\% = \frac{\text{Mean monthly maximum temperature of a station}}{\text{Mean monthly minimum temperature of a station}} \times 100 \tag{10}$$

(*xiv*) Probability of monthly temperature

$$P(\%) = \frac{m}{n} \times 100 \tag{11}$$

where, *m* - no. of frequency of temperature of different intervals.

n - total number of cases.

This formula is used for the preparation of integral curves.

(*xv*) Mean decade deviation:

$$\Delta = \frac{\sum_{i=1}^{10} \left(\bar{t}_{idecade} - \bar{t}\right)}{10} \tag{12}$$

where, $\bar{t}_{idecade}$ - mean annual temperature for i_{th} decade for a particular station:

$\bar{t}$ - mean annual temperature for the whole of the series of that station.

i = 1, 2, 3, …., 6 for this research work. Decades are defined as:

1st decade = 1949-1958

2nd decade = 1959-1968 etc.

4. Results and discussion

4.1. *Mean monthly minimum temperature in Bangladesh*

The mean of daily minimum temperatures (°C) of a month is called mean monthly minimum temperature. Some characteristics of mean monthly minimum temperature of air in Bangladesh may be obtained in Table 1.

4.1.1. *Annual variation of mean monthly minimum temperature in Bangladesh*

Based on the mean monthly minimum temperature of air for different stations of Bangladesh, the annual variation curves have been prepared. The results are the following :

The lowest values of the minimum temperatures in all of the stations have been observed either in December or in January (12.5 °C in Dhaka and 10.4 °C in Dinajpur). It is due to the dominancy of the periphery of the Asiatic Anticyclone in Bangladesh and due to the minimum value of the radiation budget. The values rise from February having the highest values in the months of July or August. The highest values are due to the warm air mass carried in Bangladesh by many centered thermal (heat lows) depressions in addition to increased value of net solar radiation of the earth surface (Mobassher, 1991; Mobassher *et al*., 1992) With the introduction of the north-eastern monsoon (winter monsoon) from October, the frequency of periphery of Asiatic anticyclone begins to increase (Mobassher, 1981). Also net radiation begins to fall down. These two factors mainly cause the lowering of minimum temperature.

TABLE 1

Mean monthly minimum, mean monthly maximum, mean monthly amplitude, annual mean and monthly average surface temperature (°C) of air in different stations of Bangladesh

Station	Parameter	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual mean
Cox's Bazar	Mean monthly max	26.7	27.9	30	32.2	32.8	30.7	30.1	30.3	31.1	31.3	30	27.5	26
	Mean monthly min	14.9	16.9	20.7	23.9	25.1	25.2	25.1	25	25	24.2	20.9	16.5	
	Monthly average	20.8	22.4	25.4	28.1	28	27.9	27.6	27.6	28	27.8	25.5	22	8.2
	Mean monthly amplitude	11.8	11	9.3	8.3	7.7	5.5	5	5.3	6.1	7.1	9.1	11	
Chittagong	Mean monthly max	26	28.1	30.7	31.9	32.3	31.4	30.8	31	31.5	31.3	29.7	26.7	25.8
	Mean monthly min	13.8	16.1	20.4	23.5	24.5	25.2	25.2	25.1	25.1	24	20.1	21.6	
	Monthly average	19.9	22.1	25.5	27.7	28.6	28.3	28	28.1	28.3	27.6	24.9	20.9	8.7
	Mean monthly amplitude	12.2	12	10.3	8.4	7.5	6.2	5.6	5.9	6.4	7.3	9.6	11.6	
Rangamati	Mean monthly max	26.1	29	32.5	33.3	33.1	31.6	31.1	31.5	32	31.6	29.4	26.7	26
	Mean monthly min	13.8	15.7	19.8	23	24.2	25	24.9	24.9	24.9	23.8	20	15.7	
	Monthly average	20	22.3	26.1	28.2	28.6	28.3	28	28.2	28.4	27.7	24.7	21.2	8.6
	Mean monthly amplitude	12.3	13.3	12.7	10.3	8.9	6.6	6.2	6.6	7.1	7.8	9.4	11	
Barisal	Mean monthly max	25.6	28.4	32.2	33.6	33.2	31.7	30.9	31.1	31.4	31.5	29.4	26.4	25.9
	Mean monthly min	12.3	15.2	20.5	23.9	25	25.7	25.6	25.8	25.5	23.9	18.8	13.9	
	Monthly average	18.9	21.8	26.4	28.7	29.1	28.7	28.2	28.5	28.5	27.7	24.1	20.2	10.2
	Mean monthly amplitude	13.3	13.2	11.7	9.7	8.2	6	5.3	5.3	5.9	7.6	10.6	12.5	
Khulna	Mean monthly max	25.7	28.9	32.9	34.6	34.5	32.8	31.7	31.9	32.1	31.9	29.7	26.7	26.4
	Mean monthly min	12.9	15.8	20.6	24.1	25.4	26.2	26.1	26.3	25.9	24.1	19.5	14.4	
	Monthly average	19.3	22.3	26.7	29.4	30	29.5	28.9	29.1	24	28	24.6	20.5	10.7
	Mean monthly amplitude	12.8	13.1	12.3	10.5	9.1	6.6	5.6	5.6	6.2	7.8	10.2	12.3	
M. Court	Mean monthly max	25.3	27.9	31.3	32.7	32.6	31.1	30.4	30.8	31	31.1	28.9	26.2	25.8
	Mean monthly min	13.4	15.9	19.9	23.5	24.9	25.6	25.6	25.6	25.5	24.4	19.4	15.5	
	Monthly average	19.3	21.9	25.6	28.1	28.8	28.3	28	28.2	28.3	27.8	24.4	20.8	9.5
	Mean monthly amplitude	11.9	12	11.4	9.2	7.7	5.5	4.8	5.2	5.5	6.7	9	10.7	
Jessore	Mean monthly max	25.7	28.8	33.2	35.3	34.9	33.2	32	32.2	32.6	32	29.7	26.6	26.1
	Mean monthly min	11.1	14.2	19.4	23.6	25.1	25.8	25.9	25.9	25.5	23.2	17.7	12.4	
	Monthly average	18.4	21.5	26.3	29.4	30	29.5	29	29.1	28.3	27.6	23.7	19.5	11.6
	Mean monthly amplitude	14.6	14.6	13.8	11.7	9.8	7.4	6.1	6.3	7.1	8.8	12	14.2	
Comilla	Mean monthly max	25.4	27.8	31.2	32.7	32.6	31.4	31	31.6	31.7	31.4	29.3	26.6	25.6
	Mean monthly min	12.1	15.1	19.7	22.8	24.3	25.3	25.4	25.4	25.2	23.5	18.5	13.6	
	Monthly average	18.5	21.4	25.5	27.8	28.5	28.4	28.2	28.5	28.5	27.5	23.9	20.1	9.7
	Mean monthly amplitude	13.3	12.7	11.5	9.9	8.3	6.1	5.6	6.2	6.5	7.9	10.8	13	
Faridpur	Mean monthly max	24.2	27.7	32.1	33.9	33.1	32.1	31.2	31.3	31.5	31	28.4	25.3	25.6
	Mean monthly min	11.9	14.6	19.2	23	24.3	25.5	25.6	26.1	25.8	23.9	18.8	13.7	
	Monthly average	18.1	21.1	25.7	28.5	28.7	28.8	28.4	28.7	28.6	27.4	23.6	19.5	10.7
	Mean monthly amplitude	12.3	13.1	12.9	10.9	8.8	6.8	5.6	5.2	5.7	7.1	9.6	11.6	
Dhaka	Mean monthly max	25.2	28.3	32.5	33.8	33	31.9	31.4	31.6	31.7	31.7	29.3	26.3	26.2
	Mean monthly min	12.5	15.5	20.1	23.7	24.7	25.9	26.2	26.2	25.8	23.7	18.7	14	
	Monthly average	18.8	21.9	26.4	28.7	28.9	28.9	28.8	28.9	28.8	27.7	24	22.1	10.1
	Mean monthly amplitude	12.7	12.8	12.4	10.1	8.3	6	5.2	5.4	5.9	8	10.6	12.3	
Ishurdi	Mean monthly max	24.3	27.8	32.6	34.7	36.6	33	32	32.2	32.2	31.4	29.4	25.8	25.6
	Mean monthly min	10.2	12.9	17.8	24.3	24.4	25.7	25.9	26	25.6	22.9	17.5	12.1	
	Monthly average	17.3	20.4	25.2	29.5	29.5	29.3	29.1	29.1	28.9	27.2	23.4	19	12.2
	Mean monthly amplitude	14.1	14.9	14.8	10.4	10.2	7.3	6.3	6.2	5.8	8.5	11.7	13.7	
Rajshahi	Mean monthly max	24.4	27.9	33.1	35.6	34.9	33.4	32.2	32.5	32.4	31.5	29.3	25.7	25.8
	Mean monthly min	11	13.3	18	22.9	24.4	25.8	26	26.1	25.7	23.2	17.8	12.8	
	Monthly average	17.7	20.6	25.5	29.2	29.7	29.6	29.1	29.3	29	27.4	23.5	19.3	12
	Mean monthly amplitude	13.4	14.6	15.1	12.7	10.5	7.6	6.2	6.4	6.7	8.3	11.5	12.9	
Mymensingh	Mean monthly max	24.7	27.2	31.1	32.2	31.8	31.4	31.2	31.4	31.3	31.1	29.1	26.2	25.3
	Mean monthly min	11.8	14.2	18.5	22.2	23.7	25.4	25.9	26.1	25.5	23.4	18.3	13.7	
	Monthly average	18.2	20.7	24.8	27.2	27.7	28.4	28.5	28.8	28.4	27.3	23.7	19.9	10.6
	Mean monthly amplitude	12.9	13	12.6	10	8.1	6	5.3	5.3	5.8	7.7	10.8	12.5	
Sylhet	Mean monthly max	25.2	27.6	30.6	31.1	30.7	30.9	31.2	31.7	31.6	30.9	29.2	26.5	25
	Mean monthly min	12.6	14.5	18.3	21.1	22.8	24.5	25.1	25.2	24.6	22.7	18.3	14.3	
	Monthly average	18.9	21.1	24.5	26.1	26.7	27.7	28.1	28.8	28.1	26.8	23.7	20.4	9.5
	Mean monthly amplitude	12.6	13.1	12.3	10	7.9	6.4	6.1	6.5	7	8.2	10.9	12.2	
Bogra	Mean monthly max	24.8	27.7	32	33.8	33.1	32.4	31.8	32.1	32	31.4	29.6	26.4	25.7
	Mean monthly min	11.7	14	18.4	22.7	24	25.7	26.1	26.3	25.7	23.2	18.1	13.6	
	Monthly average	18.2	20.9	25.2	28.2	28.6	29	28.9	29.2	28.8	27.3	23.9	20	11
	Mean monthly amplitude	13.1	13.7	13.6	11.1	9.1	6.7	5.7	5.8	6.3	8.2	11.5	12.8	
Dinajpur	Mean monthly max	23.9	27.1	31.4	32.6	32.7	32.4	31.8	32.2	31.8	31.1	28.9	25.7	24.9
	Mean monthly min	10.4	12.7	16.9	21	23.3	25.1	25.7	26	25.3	22.3	16.3	11.9	
	Monthly average	17.1	19.9	24.1	26.8	28	28.8	28.8	29.1	28.6	26.7	22.6	18.8	12
	Mean monthly amplitude	13.5	14.4	14.5	11.6	9.4	7.3	6.1	6.2	6.5	8.8	12.6	13.8	
Rangpur	Mean monthly max	23.7	26.5	30.6	32.2	31.8	31.9	31.8	32.2	31.7	30.8	28.4	25.2	24.8
	Mean monthly min	10.6	12.8	16.7	20.5	22.9	24.9	25.8	26.3	25.3	22.4	17.2	12.7	
	Monthly average	17.2	19.7	23.7	26.3	27.3	28.4	28.8	29.3	28.5	26.6	22.8	19	12.1
	Mean monthly amplitude	13.1	13.7	13.9	11.7	8.9	7	6	5.9	6.4	8.4	11.2	12.5	

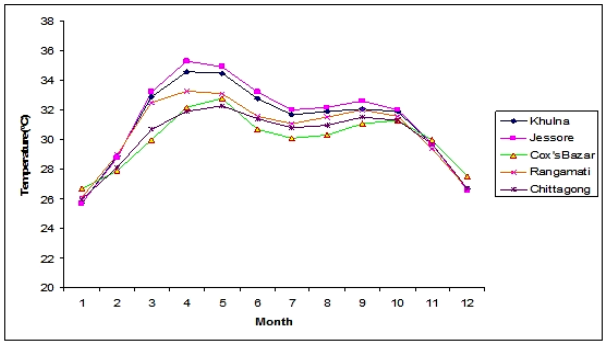

Fig. 1. Annual variation curve of mean monthly maximum temperature (°C)

Thus, the lowest value of minimum temperature in Bangladesh is observed in January or December by the influence of the periphery of Asiatic anticyclone and the lowest net solar radiation of the earth surface in Bangladesh. The highest value is observed in July or August by the dominancy of warm air mass of the Bay of Bengal by monsoon depression and increased value of net solar radiation. (Mobassher, 1991).

4.1.2. *Spatial distribution of mean monthly minimum temperature in Bangladesh*

Analysis shows that the mean monthly minimum temperature in January-February, December and June - September are quasi longitudinal, while the spatial distributions in the months of March - May and October - November are quasi latitudinal. From the analysis it is clear that the lowest values (24.5 °C in Sylhet, 10.4 °C in Dinajpur) are observed in the north and north-eastern part of Bangladesh.

4.2. *Mean monthly maximum temperature in Bangladesh*

Some characteristic of mean monthly maximum temperature of air in Bangladesh may be obtained in Table 1.

4.2.1. *Annual variation of mean monthly maximum temperature (ºC) in Bangladesh*

Annual variations of mean monthly maximum temperature in Bangladesh are double peaked. The lowest values (24.7 °C in Mymensingh, 25.7 °C in Jessore) are observed in January or December and the principal maximum (35.6 °C in Rajshahi, 33.8 °C in Dhaka) is observed mainly in April or May. The secondary minimum (30.4 °C in M. Court) is observed in July and the secondary maximum (32.1 °C in Bogra) is observed in August or in September (Fig. 1). The minimum of the maximum monthly temperature is due to the dominancy of the periphery of Asiatic anticyclone in Bangladesh and due to the lowest value of solar radiation of the earth surface. The principal maximum in April or May is due to the thermal depression and the highest value of the net solar radiation of earth surface (Mobassher, 1981; Mobassher, 1991; Mobassher *et al*., 1992). The secondary minimum is observed in July due to the frequent occurrence of rainfall by monsoon depression.

With the introduction of the north eastern monsoon the frequency of the Asiatic anticyclone begins to increase causing the fall of maximum monthly temperature and the decrease of net solar radiation of the earth.

4.2.2. *Spatial distribution of mean monthly maximum surface temperature (°C) in Bangladesh*

From the analysis it is clear that spatial distributions in January-February are quasi latitudinal, while the spatial distribution in the months of March-December are quasi longitudinal. The analysis also shows that in January-February highest values (26.1 °C in Rangamati) are observed in the south and south-eastern portion and in March-December, the highest values (34.9 °C in Rajshahi and Jessore) are observed in the western portion of Bangladesh. The lowest values (30.7 °C in Sylhet, 30.3 °C in Cox's Bazar) are observed in the north and north-eastern portion of the country.

4.3.M*onthly average temperature (ºC) in Bangladesh*

Some characteristics of monthly average temperature of air in Bangladesh may be obtained in Table 1. Analysis shows that the spatial distributions of monthly average temperature in January-March and October-December are quasi latitudinal, while the spatial distributions in the months of April-September are quasi longitudinal, It comes out that the lowest values (26.7 °C) are observed in the north-eastern part of Bangladesh. The values increase towards the south and the south-west portion of the country (28 °C in Khulna).

4.4. *Mean annual temperature (ºC) of air in Bangladesh*

The results may be obtained in Table 1. Analysis shows that the spatial distribution of mean annual temperature of air varies from 24.8 °C to 26.4 °C. The lowest temperature is observed in the northern portion of Bangladesh. The values increase from the northern to the southern part of the country. The isotherms are quasi-latitudinal. The maximum value of temperature is located in Khulna (26.4 °C).

4.5. *Mean monthly amplitude of temperature (°C) in Bangladesh*

The results are shown in Table 1.

4.5.1. *Annual variation of mean monthly amplitude of temperature (°C) in Bangladesh*

Analysis shows that the highest values (14.5 °C in Dinajpur, 12.8 °C in Dhaka) of mean monthly amplitude of temperature are observed in January, February, March or December. The values fall very sharply attaining minimum values (5.6 °C in Comilla, Chittagong) in the months of July, August (Fig. 2). After this the values rise very sharply attaining the maximum value as described earlier. The highest values of mean month amplitude are managed by the fluctuation of remote periphery of Asiatic anticyclone. The lowest values of the amplitude are observed due to the dominancy of monsoon depressions in Bangladesh and its surrounding areas.

4.5.2. *Spatial distribution of mean monthly amplitude of temperature (°C) in Bangladesh*

The spatial distributions of mean monthly amplitude of temperature in Bangladesh are quasi longitudinal in different months. From the analysis it is clear that the highest values are observed in the western portion (14.6 °C in Jessore in January) and the lowest values (5.5 °C in M. Court and Cox's Bazar in June) are observed in the eastern portion of Bangladesh. The values rise from the west to the eastern of the country.

4.6. *Spatial distribution of mean annual amplitude of temperature (°C) in Bangladesh*

Analysis shows that spatial distribution of mean annual amplitude of air temperature in Bangladesh varies from 8.2 °C (Cox's Bazar) to 12.2 °C (Ishurdi). The lowest amplitudes are observed in the eastern portion of Bangladesh. The highest value (12.2 °C) is observed in Rajshahi. The values decrease towards the eastern portion of the country. The isoamplitudes are quasi longitudinal.

4.7. *Standard deviation of mean monthly minimum temperature (°C) of air in Bangladesh*

The results are shown in Table 2.

4.7.1. *Annual variation of S.D. of mean monthly minimum temperature (°C) of air in Bangladesh*

Analysis shows that the annual variation pattern varies from station to station. However, double peaked variations are dominant (in 10 stations) (Fig. 3).

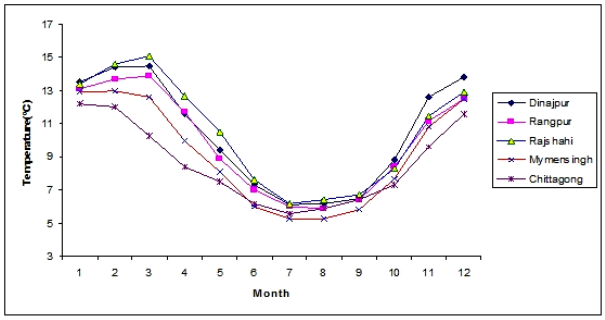

Fig. 2. Annual variation of mean monthly amplitude of temperature (°C)

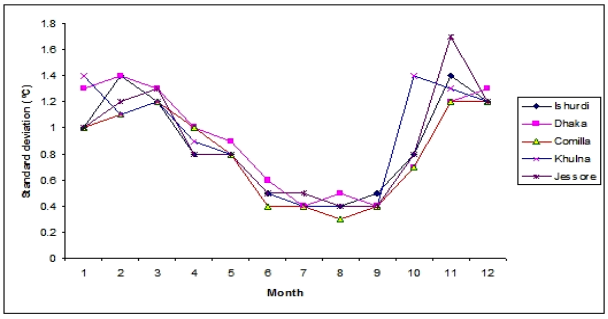

Fig. 3. Annual variation curve of S. D. of mean monthly minimum temperature (°C)

4.7.2. *Spatial distribution of S. D. of mean monthly minimum temperature of air (°C) in Bangladesh*

Analysis shows that the S. D. values of mean minimum temperature are quasi latitudinal in the months of March-April, June-July and October-December and quasi longitudinal in these months January-February, May and August to September. The highest values are observed either in the north-west portion (In March 1.9 °C in Dinajpur, In April 2.1 °C in Rangpur) or in the south-west portion(In October 1.4 °C in Khulna) when the isotherms are quasi latitudinal. When the isotherm are longitudinal, the highest values are observed either in eastern portion (in January 1.6 °C in Rangamati) or in the north-west portion (in May 1.6 °C in Rangpur).

4.8. *S. D. of mean monthly maximum temperature of air (°C) in Bangladesh*

The results are shown in Table 2.

4.8.1. *Annual variation of S. D. of mean monthly maximum temperature of air (°C) in Bangladesh*

Analysis shows that the highest values (1.2 °C in Chittagong in February, 1.5 °C in Dhaka in March) are mainly observed in the months of February or March or

TABLE 2

Standard deviation of mean monthly maximum, mean monthly minimum and mean monthly temperature of air (°C) in different stations of Bangladesh in different months

Station	Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Cox's Bazar	Mean monthly max	0.9	0.8	1.2	1.1	0.6	0.9	0.9	0.9	0.9	1	1.1	1
	Mean monthly min	0.9	1.1	1	0.9	0.8	0.6	0.4	0.5	0.4	0.6	1.3	1
	Mean monthly	5.9	5.5	4.7	4.2	3.9	2.8	2.5	2.6	3.1	3.6	4.6	5.5
Chittagong	Mean monthly max	0.8	1.2	1	0.9	0.6	0.8	0.7	0.7	0.6	0.8	0.9	1
	Mean monthly min	0.8	0.9	1	0.9	0.8	0.6	0.6	0.4	0.4	0.5	1.3	0.8
	Mean monthly	6.1	6	5.1	4.2	3.7	3.1	2.8	3	3.2	3.7	4.8	5.8
Rangamati	Mean monthly max	1	1.5	1.4	1.4	1.2	0.9	0.8	0.9	0.8	0.7	0.9	0.9
	Mean monthly min	1.6	1.6	1.6	1.2	1.1	0.8	0.6	0.5	0.5	0.9	1.6	1.6
	Mean monthly	6.2	6.7	6.4	5.2	4.5	3.3	3.1	3.3	3.6	3.9	4.7	5.5
Barisal	Mean monthly max	0.9	1.2	1.1	1	0.8	0.8	0.6	0.6	0.6	0.7	0.8	0.7
	Mean monthly min	1.2	1.9	1.3	1	0.9	0.5	0.4	0.4	0.5	0.7	1	1.1
	Mean monthly	6.6	6.6	5.9	4.9	4.1	3	2.6	2.6	3	3.8	5.3	6.3
Khulna	Mean monthly max	0.9	1.3	1.2	1.2	0.9	0.8	0.7	0.7	0.7	0.7	0.7	0.8
	Mean monthly min	1.4	1.1	1.2	0.9	0.8	0.5	0.4	0.4	0.4	1.4	1.3	1.2
	Mean monthly	6.4	6.5	6.2	5.3	4.6	3.3	2.8	2.8	3.1	3.9	5.1	6.2
M. Court	Mean monthly max	0.8	1.2	1	1	1	1.1	0.7	0.8	0.8	0.8	0.9	0.7
	Mean monthly min	1	1.4	1.5	0.9	0.7	0.6	0.5	0.5	0.4	0.6	1.5	1.2
	Mean monthly	6	6	5.7	4.6	3.9	2.8	2.5	2.6	2.8	3.3	4.5	5.4
Jessore	Mean monthly max	1	1.3	1.2	1.6	1.2	1.1	0.7	0.8	0.7	0.9	1	0.9
	Mean monthly min	1	1.2	1.3	0.8	0.8	0.5	0.5	0.4	0.4	0.8	1.7	1.2
	Mean monthly	7.3	7.3	6.9	5.8	4.9	3.7	3.1	3.2	3.5	4.4	6	7.1
Comilla	Mean monthly max	1	1.2	1.3	1.1	1	0.9	0.7	0.7	0.7	0.7	0.9	1
	Mean monthly min	1	1.1	1.2	1	0.8	0.4	0.4	0.3	0.4	0.7	1.2	1.2
	Mean monthly	6.7	6.3	5.7	4.9	4.1	3.1	2.8	3.1	3.2	3.9	5.4	6.5
Faridpur	Mean monthly max	1	1.5	1.3	1.6	1.9	0.9	0.7	0.8	0.7	0.9	1.2	1.3
	Mean monthly min	1	1.3	1.4	0.9	0.8	0.7	1.1	0.6	0.7	0.7	1.2	1.2
	Mean monthly	6.1	6.6	6.4	5.5	4.4	3.3	2.8	2.6	2.8	3.6	4.8	5.8
Dhaka	Mean monthly max	1	1.4	1.3	1.5	1.1	0.9	0.6	0.8	0.7	0.7	0.8	0.9
	Mean monthly min	1.3	1.4	1.3	1	0.9	0.6	0.4	0.5	0.4	0.7	1.2	1.3
	Mean monthly	6.3	6.4	6.2	5	4.1	3	2.6	2.7	2.9	4	5.3	6
Ishurdi	Mean monthly max	1	1.4	1.5	1.6	1.4	1	0.6	0.7	0.6	0.9	0.7	0.9
	Mean monthly min	1	1.4	1.2	0.8	0.8	0.5	0.4	0.4	0.5	0.8	1.4	1.2
	Mean monthly	7.1	7.4	7.4	5.2	5.1	3.6	3.1	3.1	3.3	4.2	5.9	6.8
Rajshahi	Mean monthly max	1	1.4	1.5	1.5	1.5	1.2	0.6	0.7	0.8	0.8	0.6	0.7
	Mean monthly min	1.1	1.1	1.1	1.1	0.9	0.6	0.4	0.4	0.5	0.9	1.1	1
	Mean monthly	6.7	7.3	7.6	6.4	5.3	3.8	3.1	3.2	3.4	4.2	5.8	6.5
Mymensingh	Mean monthly max	1	1.3	1.2	1.5	1.3	0.6	0.6	1	1	1	0.7	0.8
	Mean monthly min	1	1.4	1.2	1	1	0.6	0.5	0.5	0.6	0.9	1	0.9
	Mean monthly	6.5	6.5	6.3	5	4	3	2.6	2.7	2.9	3.9	5.4	6.3
Sylhet	Mean monthly max	1.3	1.5	1.3	1.6	1.3	1.1	1	1	1	0.9	0.8	0.9
	Mean monthly min	0.9	1.2	1	0.9	0.8	0.5	0.5	0.5	0.7	0.9	1	0.9
	Mean monthly	6.3	6.5	6.1	5	4	3.2	3	3.2	3.5	4.1	5.5	6.1
Bogra	Mean monthly max	1.2	1.2	1.5	1.6	1.5	0.9	0.7	0.8	0.7	0.9	1	1
	Mean monthly min	0.8	1.2	1.1	1	0.8	0.5	0.5	0.4	0.5	0.8	1.1	0.8
	Mean monthly	6.6	6.9	6.8	5.6	4.5	3.3	2.9	2.9	3.2	4.1	5.8	6.4
Dinajpur	Mean monthly max	1.6	1.6	1.6	1.7	1.7	1	0.8	0.9	0.8	0.9	0.7	1
	Mean monthly min	0.9	1.3	1.9	1.4	1.4	1.5	1.2	0.6	0.6	1	1.2	1.2
	Mean monthly	6.8	7.2	7.3	5.8	4.7	3.7	3.1	3.1	3.3	4.4	6.3	6.9
Rangpur	Mean monthly max	1.2	1.4	1.3	1.9	1.2	0.8	0.8	0.7	0.9	0.8	0.9	1
	Mean monthly min	1	1.4	1.6	2.1	1.6	1.5	0.8	0.4	0.8	0.9	1	1.1
	Mean monthly	6.5	6.9	7	5.9	4.4	3.5	3	3	3.2	4.2	5.6	6.3

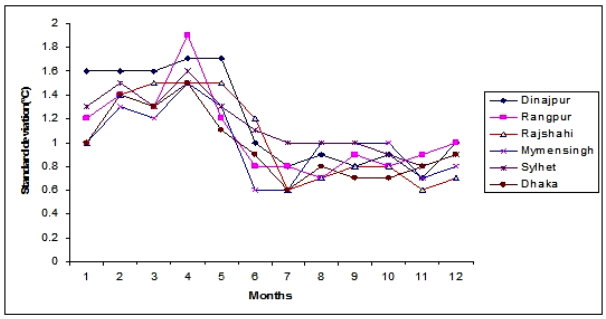

Fig. 4. Annual variation of S. D. of mean monthly maximum temperature of air (°C) in Bangladesh

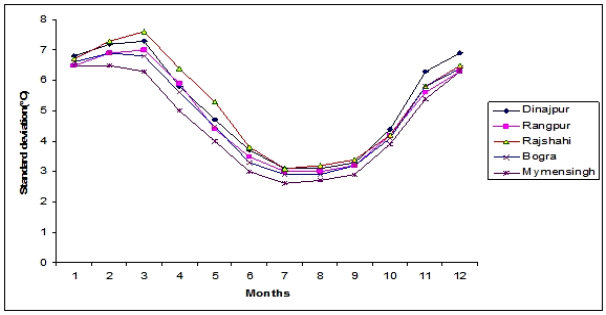

Fig. 5. Annual variation of S. D. of mean monthly temperature of air (°C) in Bangladesh

April, while the lowest values are observed in the months of July or August (0.6 °C in Dhaka in July, 0.7 °C in Rangpur in August) or September. The annual variation curves of mean monthly maximum temperature are single peaked (Comilla, Khulna), double peaked (Cox'sBazar), triple peaked (Dinajpur, Rangpur, Rajshahi, Mymensingh, Sylhet, Ishurdi, Dhaka, Rangamati, Chittagong) or tetra peaked (Faridpur, M. Court, Jessore, Barisal). Single peaked are observed in the months of February or March, double peaked are observed in April, August or November, triple peaked are observed in February, March, April, May, June, September, October. Tetra peaked are observed in February, April, May, June, August, November or December (Fig. 4).

4.8.2. *Spatial distribution of standard deviation (S. D.) of mean monthly maximum temperature of air (°C) in Bangladesh*

From the analysis it is clear that the spatial distributions of S. D. of mean monthly maximum temperature of air are quasi latitudinal in the months of January-May and December, while the spatial distributions are quasi longitudinal in the months of June-November. The highest values (in January 1.6 °C in Dinajpur, in April 1.9 °C in Rangpur) are observed in the northern portion and the lowest values (in March 1 °C in M.court and Chittagong) are observed in the southern portion of the country in the months of January-May. The value rises towards the north. In the months of June-November, the highest values are observed in the western portion (in June 1.2 °C in Rajshahi) or in the north eastern portion (in July 1 °C in Sylhet) or in the south-eastern portion (in November 1.1 °C in Cox's Bazar) of Bangladesh.

4.9. *S. D. of mean monthly temperature (°C) in Bangladesh*

The results are shown in Table 2.

4.9.1. *Annual variation of S. D. of mean monthly temperature of air (°C) in Bangladesh*

Analysis shows that the variation pattern is not regular the highest values are observed mainly in January, February, March or December (6.7 °C in Comilla in January, 6.4 °C in Dhaka in February, 7.6 °C in Rajshahi in March), while the lowest values (2.6 °C in Mymensingh in July, 2.6 °C in Faridpur in August) are observed mainly in July or August. The values fall sharply from March upto the lowest value in July or August. After that the values rise sharply attaining the highest values. The rising and falling pattern are almost same (Fig. 5). The highest values may be due to the fluctuation of the remote periphery of Asiatic anticyclone. The lowest values are observed due to dominance of monsoon depressions and its surrounding areas (Mobassher, 1991).

4.9.2. *Spatial distribution of S. D. of mean monthly temperature of air (°C) in Bangladesh*

Analysis shows that the spatial distributions of S. D. of mean monthly temperature are quasi longitudinal in the months of January-December. The highest values (in May 5.3 °C in Rajshahi) of S. D. of mean monthly temperature are observed in the western portion of Bangladesh. The lowest values are located in the east and in the south portion (in June 2.8 °C in M. Court and Cox's Bazar) of the country. The value rises from east to the west.

4.10. *Coefficient of Variation of mean monthly temperature of air (%) in Bangladesh*

The results are shown in Table 3.

4.10.1. *Annual variation of C. V. of mean monthly temperature of air (%) in Bangladesh*

Analysis shows that the highest values of annual variation of C.V. of mean monthly temperature are mainly observed in January (39.8% in Dinajpur, 33.7% in Dhaka) and the lowest values are mainly observed in July (9.1% in Dhaka) or August (10.2% in Rangpur). The values fall

TABLE 3

Coefficient of variation of mean monthly temperature of air (%) in different stations of Bangladesh

Station	Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Cox's Bazar	Mean monthly max	3.3	3	3.9	3.3	1.8	2.9	2.8	3.1	2.8	3.2	3.6	3.6
	Mean monthly min	6.2	6.7	5	3.7	3	2.3	1.6	2	1.4	2.3	6	6.3
	Mean monthly	28.9	24.6	18.4	14.7	13.3	9.9	9.1	9.6	11	12.8	17.9	25.1
Chittagong	Mean monthly max	3.1	4.1	3.2	2.7	2	2.7	2.2	2.3	2	2.6	3.2	3.9
	Mean monthly min	5.7	5.8	4.7	3.9	3.4	2.2	2.2	1.6	1.4	2.3	6.6	5.6
	Mean monthly	30.5	27.1	20.1	15.2	13.1	10.9	9.9	10.5	11.4	13.2	19.2	27.8
Rangamati	Mean monthly max	3.8	5.2	4.1	4.3	3.6	2.8	2.6	3	2.6	2.1	3	3.4
	Mean monthly min	11.7	9.9	8.1	5.4	4.5	3	2.2	2	2.2	3.7	8	10
	Mean monthly	31	29.9	24.4	18.3	15.5	11.7	11	11.7	12.5	14.1	18.9	25.8
Barisal	Mean monthly max	3.4	4.1	3.3	2.9	2.3	2.6	1.8	1.9	1.9	2.2	2.8	2.8
	Mean monthly min	9.5	12.4	6.5	4.1	3.4	2	1.7	1.4	1.8	3	5.3	8.2
	Mean monthly	35	30.3	22.3	16.9	14.1	10.6	9.3	9.2	10.5	13.7	22	31.2
Khulna	Mean monthly max	3.4	4.6	3.6	3.4	2.7	2.5	2.3	2.2	2.2	2.2	2.9	3.1
	Mean monthly min	10.6	7.2	5.9	3.6	3.1	2	1.6	1.4	1.4	5.6	6.6	8.1
	Mean monthly	33.1	29.1	23.1	17.9	15.2	11.3	9.7	9.6	10.7	14	20.8	30
M. Court	Mean monthly max	3.1	4.4	3	3.2	3	3.5	2.4	2.6	2.6	2.7	3.2	2.7
	Mean monthly min	7.5	9.1	7.6	3.9	2.9	2.5	1.8	1.8	1.6	2.6	7.3	7.7
	Mean monthly	30.8	27.5	22.2	16.4	13.5	9.7	8.8	9.2	9.8	12	18.4	25.7
Jessore	Mean monthly max	3.8	4.6	3.7	4.6	3.5	3.3	2.2	2.4	2.2	2.9	3.4	3.3
	Mean monthly min	9.3	8.7	6.5	3.4	3.2	2	1.8	1.4	1.4	3.5	9.5	7.7
	Mean monthly	39.8	34.1	26.4	19.8	16.4	12.4	10.5	10.9	12.2	15.9	25.4	36.3
Comilla	Mean monthly max	3.9	4.1	4	3.4	3	2.7	2.4	2.3	2.3	2.2	3	3.6
	Mean monthly min	8.1	7.3	5.9	4.2	3.3	1.7	1.5	1.3	1.6	3	6.3	8.9
	Mean monthly	35.5	29.5	22.5	17.7	14.6	10.8	9.9	10.9	11.4	14.3	22.5	32.5
Faridpur	Mean monthly max	4.3	5.5	3.9	4.6	3.6	2.9	2.3	2.7	2.1	3.1	4.1	5
	Mean monthly min	8	8.7	7	4.1	3.3	2.7	4.2	2.4	2.6	3	6.5	8.4
	Mean monthly	33.9	31	25.1	19.2	15.4	11.5	9.9	9.1	9.9	13	20.5	29.7
Dhaka	Mean monthly max	4	5.1	3.9	4.5	3.5	2.9	2	2.4	2.3	2.3	2.8	3.4
	Mean monthly min	10.3	8.7	6.6	4.2	3.5	2.2	1.5	1.8	1.7	3.1	6.6	9.6
	Mean monthly	33.7	29.3	23.3	17.6	14.3	10.3	9.1	9.2	10.2	14.5	22	27.3
Ishurdi	Mean monthly max	4	5.2	4.5	4.6	4.1	3.1	1.8	2.1	1.9	2.8	2.4	3.3
	Mean monthly min	9.5	10.5	7	3.3	3.3	1.9	1.5	1.5	1.8	3.7	8	9.8
	Mean monthly	40.9	36.5	29.4	17.6	17.4	12.3	10.8	10.6	11.6	12.6	25.1	36
Rajshahi	Mean monthly max	4.3	4.9	4.6	4.1	4.4	3.6	2	2.3	2.5	2.5	2.1	2.8
	Mean monthly min	9.7	7.9	6.1	4.7	3.9	2.2	1.6	1.6	1.8	4.1	6.3	8
	Mean monthly	37.9	35.5	29.7	21.7	17.9	12.9	10.6	10.9	11.6	15.2	24.5	33.7
Mymensingh	Mean monthly max	4.2	4.8	4	4.5	4.1	2	1.9	3.1	3.3	3.3	2.2	3.2
	Mean monthly min	8.6	9.6	6.5	4.3	4.1	2.4	1.7	1.9	2.2	4	5.7	6.4
	Mean monthly	35.6	31.2	25.5	18.4	14.7	10.5	9.2	9.4	10.2	14.2	22.7	31.4
Sylhet	Mean monthly max	5.1	5.6	4.2	5.1	4.3	3.6	3.1	3.3	3.2	3	2.6	3.3
	Mean monthly min	6.8	8.3	5.3	4	3.5	2.1	2	2	2.8	3.8	5.6	6.9
	Mean monthly	33.5	31.1	25.1	19.2	14.9	11.5	10.8	11.4	12.5	15.4	23.1	30
Bogra	Mean monthly max	4.7	4.5	4.7	4.7	4.5	2.8	2.2	2.5	2.3	2.9	3.3	3.8
	Mean monthly min	7	8.7	6	4.4	3.1	1.8	1.7	1.4	1.9	3.4	6	6.1
	Mean monthly	36.1	32.9	27	19.7	15.8	11.5	9.9	9.9	11	15.1	24.2	32.2
Dinajpur	Mean monthly max	6.6	5.9	5.2	5.2	5	3.1	2.4	2.7	2.6	2.9	2.3	3.9
	Mean monthly min	9.1	10.4	11.3	6.7	6.1	6	4.8	2.1	2.2	4.4	7.2	10.3
	Mean monthly	39.8	36.4	30.1	21.8	16.8	14.4	10.6	10.5	11.5	16.6	27.7	36.6
Rangpur	Mean monthly max	5.1	5.3	4.1	6	3.8	2.6	2.5	2.3	2.7	2.7	3.2	4
	Mean monthly min	9.3	10.9	9.3	10.2	7	6	3.2	1.6	3.1	3.8	6.1	8.2
	Mean monthly	38	34.9	29.5	22.3	16.2	12.4	10.4	10.2	11.3	15.8	24.6	32.9

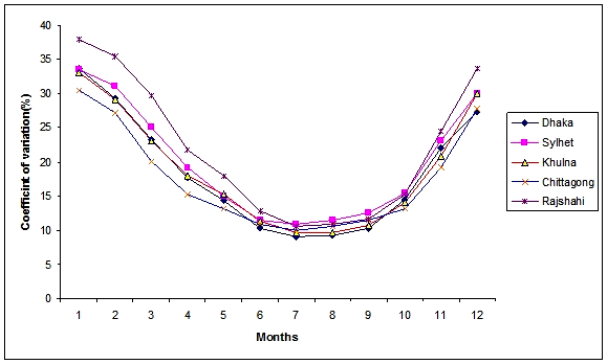

Fig. 6. Annual variation of C. V. of mean monthly temperature of air (%)

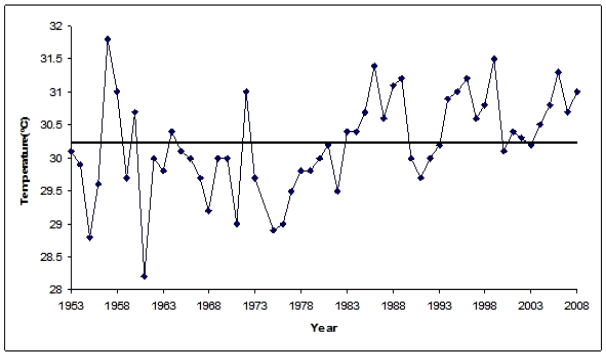

Fig. 7. Run of mean annual temperature (°C) in Dhaka

sharply upto the lowest value and then the values raise very sharply upto highest values as described. The rising and falling patterns are almost the same (Fig. 6).

4.10.2. *Spatial distribution of C.V. of mean monthly temperature of air (%) in Bangladesh*

It is found that spatial distributions of C. V. of mean monthly temperatures are quasi-longitudinal in the months of January-December. The highest values (In February 36.5% in Ishurdi, in June 14.4% Dinajpur) are observed in the west and in the north-western portion of Bangladesh. The lowest values (in March 18.4% in Coxs Bazar) are located in the east and south-eastern portion of the country. The values rise from the south-eastern portion to the west and the north-western part of Bangladesh.

5. Run of mean annual temperature (°C) in Bangladesh for the years 1949-2008

The run of mean annual temperature has been studied by graphical method. The results may be shown in Fig. 7.

TABLE 4

The highest and the lowest value of mean annual temperature (°C) in Bangladesh from 1949 to 2008

Station	Highest value in (°C) (Year)	Lowest value in (°C) (Year)
Cox's Bazar	28 (1988)	24.4 (1955)
Chittagong	27.6 (1958)	22.7 (1949)
Rangamati	27.3 (1966)	24.7 (1993)
Barisal	28 (1970)	23.7 (1971)
Khulna	27.6 (1966)	24.4 (1982)
M.Court	27.9 (2005)	24(1981)
Jessore	27.5 (1961,1975)	23.7 (2000)
Comilla	26.9 (1953)	23.8 (1995)
Faridpur	26.6 (2006)	23.2 (1971)
Dhaka	27.1 (1957,1986)	23.6 (1955)
Ishurdi	26.4 (1968,2006)	24.2 (1964)
Rajshahi	27 (1979)	23.4 (1993)
Mymensingh	27.2 (1964)	23.7 (1968, 1991)
Sylhet	27(1967)	24.2 (1964)
Bogra	26.8 (1983)	23.6 (1969)
Dinajpur	26.4 (1972)	22.9 (1961)
Rangpur	27.3 (1962)	22.6 (1969, 1981)

5.1. *The highest and the lowest value of mean annual temperature (°C) in Bangladesh from 1949 to 2008*

The highest and lowest values of mean annual temperature for different stations of Bangladesh may be found in Table 4.

Analysis shows that the height of the mean of the annual temperature has been observed in Cox's Bazar in 1988 and in Barisal in 1970, which is 28 °C, the lowest temperature has been observed in Rangpur in 1969 and in 1988 which is 22.6 °C.

5.2. *Periodicity of temperature (°C) in Bangladesh*

The periodicity of temperature (°C) has been studied by the construction of periodigrams for the annual temperature. The mean of the periods may be obtained in Table 5. It varies from 3.3 (Comilla & Jessore) to 5.9 (Faridpur) years.

5.3. *Mean decade deviation of temperature (°C) in different decades from 1949 to 2008 in Bangladesh*

The data used in this investigation have been divided into the following decades

1949 - 1958 (1st decade), 1959 - 1968 (2nd decade), 1969 - 1978 (3rd decade), 1979 - 1988 (4th decade), 1989 - 1998 (5th decade), 1999 - 2008 (6th decade).

TABLE 5

The Mean of the period for individual waves of periodigram (By graphical method)

Station	Mean period (year)
Cox's Bazar	4
Chittagong	4.1
Rangamati	5.7
Barisal	2.8
Khulna	6
M.Court	4
Jessore	3.3
Comilla	3.3
Faridpur	5.9
Dhaka	4.8
Ishurdi	3.5
Rajshahi	4.1
Mymensingh	4.1
Sylhet	3.4
Bogra	4.8
Dinajpur	4.8
Rangpur	4.4

The results are shown in the Table 6.

The spatial distributions for the deviation of annual sum of temperature from the mean have been analyzed in the following way;

First decade (1949-1958)

Analysis reveals that except in comilla (+0.1 °C), Khulna (+0.1 °C) and Barisal (+0.1 °C), the whole of the country experiences negative deviation of temperature. Highest negative deviation has been observed in Bogra (-1.6 °C) and the lowest of it in Sylhet (-0.1 °C) and Chittagong (-0.1 °C).

Second decade (1959-1968)

In the second decade, the distribution is almost analogous to that of the first one. It is clear that except in Dinajpur (+0.2 °C), Rangpur (+0.2 °C), Mymensingh (+0.4 ºC), Sylhet (+0.3 ºC) and Rangamati (+0.3 °C), the whole of Bangladesh experiences negative deviation of temperature from the normal.

Third decade (1969-1978)

In this decade the whole country experiences negative deviation of temperature except in Dinajpur (+0.2 °C), Sylhet (+0.1 °C), Khulna (+0.2 °C), Rangamati (+0.2 °C) and Jessore (+0.1 °C). It is almost analogous to the second decade.

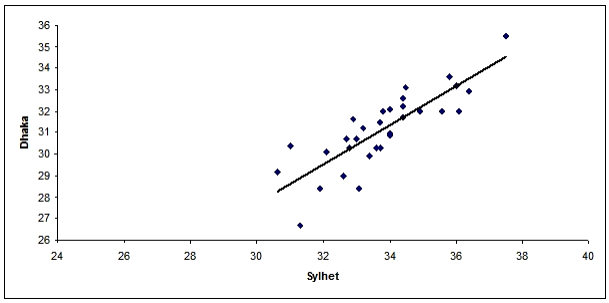

Fig. 8. Scatter diagram of mean monthly temperature °C of Dhaka and Sylhet for April

Fourth decade (1979- 1988)

In fourth decade except, in Rajshahi (+0.1 °C), Bogra (+0.2 °C), Mymensingh (+0.2 °C), Dhaka (+0.1 °C), Comilla (+0.1 °C) and Chittagong (+0.1 °C), the rest of the country experience negative deviation of temperature.

Fifth decade (1989-1998)

In this decade the distribution is almost analogous to that of the fourth decade. The analysis shows that except in Dinajpur (+0.1 °C), Rangpur (+0.1 °C), Bogra (+0.3 °C), Dhaka (+0.2 °C), M. Court (+0.3 °C), CoxsBazar (+0.3 °C) Chittagong (+0.2 °C) and Faridpur (+0.3 °C), the whole country experiences negative deviation of temperature.

Sixth decade (1999-2008)

In this decade positive deviation of temperature is dominant all over the country. The highest value of positive deviation of temperature is observed in Faridpur (+0.8 °C) and the lowest value is observed in Mymensingh (+0.1 °C).

From the above analysis it is clear that from the first to the fifth decades (*i.e*., from 1949 to 1999), the whole of the country experiences negative deviation of mean annual temperature from the normal, while in the sixth decade, the positive deviation of the mean annual temperature dominates all over the country.

5.4. *Correlation characteristics of temperature between selected stations*

For the purpose scatter diagrams have been prepared (Fig. 8). Analysis shows that the relation is linear.

Dhaka – Sylhet

Correlation coefficient of mean temperature between Dhaka and Sylhet varies from 0.37 to 0.72.

TABLE 6

Mean decade deviation of mean annual temperature (°C) in different stations of Bangladesh

Station	First Decade (1949-1958)	Second Decade (1959-1968)	Third Decade (1969-1978)	Forth Decade (1979-1988)	Fifth Decade (1989-1998)	Sixth Decade (1999-2008)
Cox's Bazar	-0.5	-0.4	-0.5	-0.1	+0.3	+0.7
Chittagong	-0.1	-0.5	-0.2	+0.1	+0.2	+0.4
Rangamati	-0.7	+0.3	+0.2	-0.1	-0.2	+0.2
Barisal	+0.1	-0.1	-0.2	-0.3	-0.1	+0.3
Khulna	+0.1	-0.3	+0.2	-0.3	-0.2	+0.4
M. Court	-0.6	-0.1	-0.8	-0.4	+0.3	+0.7
Jessore	-0.3	-0.2	+0.1	-0.2	-0.1	+0.3
Comilla	+0.1	-0.2	0	+0.1	-0.3	+0.2
Faridpur	-0.3	-0.4	-0.7	-0.1	+0.3	+0.8
Dhaka	-0.5	-0.3	-0.2	+0.1	+0.2	+0.4
Ishurdi	N.A	-0.2	-0.4	-0.3	-0.2	+0.4
Rajshahi	N.A	-0.5	-0.2	+0.1	-0.3	+0.4
Mymensingh	-0.2	+0.4	-0.9	+0.2	-0.3	+0.1
Sylhet	-0.1	+0.2	+0.2	-0.4	-0.2	+0.3
Bogra	-1.6	-0.6	-0.6	+0.2	+0.3	+0.5
Dinajpur	-0.5	+0.2	+0.2	-0.3	+0.1	+0.4
Rangpur	N.A	+0.2	-1.1	-0.4	+0.1	+0.3

N.B. + indicates positive deviation of annual temperature from the mean (normal for the whole of the series).
– indicates the negative deviation from the mean (normal for the whole of the series).
N.A. - Data not available

The regression equations in this case are :

$$y_I = 8.35 + 0.566x_I \qquad r = 0.61$$
$$y_{IV} = 6.44 + 0.85x_{IV} \qquad r = 0.72$$
$$y_{VII} = 17.1 + 0.41x_{VII} \qquad r = 0.37$$
$$y_X = 15.86 + 0.44x_X \qquad r = 0.59$$

(y = temperature in Dhaka in °C, x = temperature in Sylhet in °C).

(*I*, *IV*, *VII* and *X* stand for January, April, July and October respectively).

Dhaka (y) – Chittagong (x)

In Dhaka and Chittagong correlation coefficient varies from 0.50 to 0.85.

The regression equations in this case are

$$y_I = -2.8 + 1.09x_I \qquad r = 0.76$$
$$y_{IV} = 5.0 + 1.2x_{IV} \qquad r = 0.85$$
$$y_{VII} = 3.85 + 0.89x_{VII} \qquad r = 0.50$$
$$y_X = 6.75 + 0.75x_X \qquad r = 0.70$$

(y = temperature in Dhaka in °C, x = temperature in Chittagong in °C).

Dhaka (y) – Rangpur (x)

Correlation coefficients at Dhaka and Rangpur varies from 0.46 – 0.80.

$$y_I = 16.0 + 0.17x_I \qquad r = 0.46$$
$$y_{IV} = 6.12 + 0.85x_{IV} \qquad r = 0.80$$
$$y_{VII} = 15.56 + 0.47x_{VII} \qquad r = 0.57$$
$$y_X = 15.48 + 0.46x_X \qquad r = 0.48$$

(y = temperature in Dhaka in °C, x = temperature in Rangpur in °C).

Dhaka (y) – Khulna (x)

The values of correlation coefficient in Dhaka and Khulna vary from 0.21 to 0.92.

The regression equations in this case are –

$$y_I = 14.69 + 0.22x_I \qquad r = 0.21$$

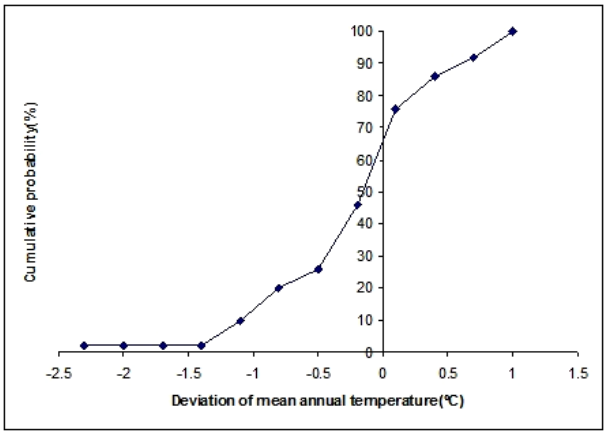

Fig. 9. Integral curve of mean annual temperature (°C) for Dhaka

$$y_{IV} = -6.41 + 1.19x_{IV} \qquad r = 0.92$$
$$y_{VII} = 18.30 + 0.36x_{VII} \qquad r = 0.26$$
$$y_X = 11.88 + 0.56x_X \qquad r = 0.58$$

(y = temperature in Dhaka in °C, x = temperature in Khulna in °C).

5.5. *Probability of mean annual temperature in Dhaka: Integral curve*

The Integral curve is shown in Fig. 9.

Analysis shows that the fluctuation of mean annual temperature in Dhaka -2.1 °C to +1.5 °C for the whole of the series. Deviation in the limit from -2.1 °C to -1.2 °C is about 2%. In the interval of -0.1 °C to -0.3 °C the cumulative probability is about 25%. At the point of normal *i.e*., 0 deviation is about 45%.

6. Conclusion

The following conclusions have been drawn.

(*i*) In the annual variation of mean monthly minimum temperature in Bangladesh, the lowest values (12.5 °C in Dhaka, 10.4 °C in Dinajpur) are observed in January/December by the influence of the periphery of Asiatic anticyclone and the lowest solar radiation of the earth surface. The highest values (26.3 °C in Bogra, 25.8 °C in Barisal) are observed in July/August by the dominancy of warm air mass of the Bay of Bengal by monsoon depression and increased value of net solar radiation.

(*ii*) The spatial distribution of mean monthly minimum temperature in January-February, June-September and December are quasi longitudinal, while the spatial distributions in the months of March-May and October to November are quasi latitudinal. The lowest values (24.5 °C in Sylhet, 10.4 °C in Dinajpur) are observed in the northern portion and the highest values (20.7 °C in Coxs Bazar) are located in the south-eastern portion of Bangladesh.

(*iii*) Annual variations of mean monthly maximum temperature in Bangladesh are double peaked. The lowest values (24.7 °C in Mymensingh, 25.7 °C in Jessore) are observed in January/December and the principal maximum (35.6 °C in Rajshahi, 33.8 °C in Dhaka) is observed mainly in April/May. The secondary minimum (30.1 °C in M. Court) is observed in July and the secondary maximum (32.1 °C in Bogra) is observed in August/September.

(*iv*) From the analysis of mean monthly maximum temperature, it is found that spatial distribution in January-February are quasi-latitudinal, while in the months of March- December are quasi longitudinal.

(*v*) The spatial distributions of monthly average temperature in January- March and October-December are quasi-latitudinal and in the months of April- September are quasi- longitudinal. The highest values (26.7 ºC in Sylhet) are located in the north-eastern part and the lowest values (28 °C in Khulna) are observed in the south-western portion of Bangladesh.

(*vi*) From the analysis of annual variation of mean monthly amplitude, it is clear that the highest values (14.5 °C in Dinajpur, 12.8 °C in Dhaka) are observed in January- March or December and the lowest values are observed in the months of July or August (5.6 °C in Comilla, Chittagong). The highest values are observed due to the dominancy of the remote periphery of Asiatic anticyclone in January. The lowest values are observed due to the frequent occurrence of monsoon depression in July August in Bangladesh and its surrounding areas.

(*vii*) Mean annual amplitude varies from 8.2 °C (Cox's Bazar) to 12.2 °C (Ishurdi). Mean amplitude of the annual temperature decreases from the west to east.

(*viii*) In the annual variation of S. D. of mean monthly minimum temperature, the highest values are mainly observed in January-March and the lowest values are observed mainly in July- September. The annual variation curves of S. D. of mean monthly minimum temperature are single, double or triple peaked.

(*ix*) The spatial distribution of S. D. of the mean monthly temperature are quasi longitudinal throughout the year. The values rise from the east to the west.

(*x*) From the analysis of annual variation of C. V. of mean monthly minimum temperature, it is clear that the highest values are observed mainly in January or February and the lowest values are observed mainly in July or August. The annual variation curves are single, double or triple peaked. The spatial distributions of C. V. are quasi longitudinal throughout the year. The values decrease from the west to the east.

(*xi*) From the analysis of run of the temperature for different stations of Bangladesh for the years 1949-2008, the highest value has been observed to be 28 °C in Barisal in 1970 and in Coxs Bazar in 1988, while the lowest value of it is 22.6 °C in Rangpur in 1969 and 1981.

(*xii*) The periodicity of the mean annual temperature (by graphical method) varies from 3.3 to 5.9 years in Bangladesh.

(*xiii*) Analysis of the mean decade deviation of the annual temperature shows that the mean decade deviation values from the mean anual for the first - fifth decades (1949-1999) are mostly negative, while in the sixth decade (1999-2008) it is positive informing that the mean annual temperature is rising up in Bangladesh, i.e. the climate of Bangladesh is warming up.

(*xiv*) From the analysis of integral curve for Dhaka it has been observed that in the point of normal, the cumulative probability is 45% and in the positive deviation interval it is 40% to 100%, *i.e.*, the positive deviation of temperature in Dhaka is dominant.

(*xv*) The analysis reveals that the correlation characteristics of mean monthly temperature shows the stability at Dhaka and other selected stations (Chittagong, Rangpur, Sylhet, Khulna) for the selected months (January, April, July, October). The correlation co-efficient varies from 0.37 to 0.72 with Sylhet, from 0.50 to 0.85 with Chittagong, from 0.21 to 0.92 with Khulna and from 0.46 to 0.80 with Rangpur. Analysis shows that the relation is linear.

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