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STUDY ON THE TRENDS OF RAINFALL AND DIFFERENT TEMPERATURES DURING THE SOUTHWEST MONSOON SEASON IN BANGLADESH

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ABSTRACT

Attempts have been made to carry out the study on the trends in rainfall and different temperatures during the monsoon season in Bangladesh using the data for the period 1981-2010 at 34 stations. The study reveals that during the ongoing phases of southwest monsoon, there exists the negative trends of rainfall over the southern part of Bangladesh except in September when the negative trend of rainfall is in the northern part having the maximum negative trend in the northwest. It is found that the positive trend of dry-bulb temperature exists over the western and northeastern parts of Bangladesh and relatively negative trend of dry-bulb temperature is found over the eastern and southeastern parts of the country. The higher increasing trend in minimum temperature is found over the northern part of Bangladesh during the southwest monsoon season. The trends in country-averaged minimum temperature over Bangladesh in June, July, August and September, are positive i.e. increasing. The increasing rates of average minimum temperature are +0.013˚C/year, +0.022˚C/year, +0.016˚C/year and +0.014˚C/year in June, July, August and September respectively. The trends in July and August are statistically significant at 95% level of significance. The maximum temperature has increasing trends at most of the places in Bangladesh during the southwest monsoon season. The maximum increasing trend is 0.094˚C/year at Syedpur in September and maximum decreasing rate is -0.01˚C/year at Srimangal in June. The rates of increasing trend of country-averaged maximum temperature are +0.033˚C/year, +0.036˚C/year, +0.038˚C/year and +0.036˚C/year in June, July, August and September respectively. The trends in the months of July, August and September are statistically significant at 100% level. The trend in country-averaged seasonal maximum temperature over Bangladesh has also increasing trend at a rate of +0.036˚C/year, which is also statistically significant at 100% level. The correlation between country-averaged mean monthly rainfall and country-averaged mean monthly different temperatures have also been studied; the monthly coefficients are found statistically significant.

Keywords: *Trend, southwest monsoon, trend equation, rainfall, dry-bulb temperature, maximum and minimum temperatures*

1. INTRODUCTION

Bangladesh is one of the most climate-vulnerable countries in the world, and is expected to become even more so as a result of climate change. Climate change and variability have already had an impact on the lives and livelihoods of people living in coastal areas and in arid and semi-arid regions of Bangladesh. Floods, tropical cyclones, storm surges and droughts are becoming more frequent and will be more severe in the coming years and decades (BCCSAP, 2009). A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes. As well, weather or climate events, even if not extreme in a statistical sense, can still lead to extreme conditions or impacts, either by crossing a critical threshold in a social, ecological, or physical system, or by occurring simultaneously with other events(IPCC, 2012) These changes are threatening the significant achievements. In the future, Bangladesh may get warmer and wetter. For the IPCC (1990) "Business as usual" emissions scenario, Bangladesh is projected to be 0.5 to 2°C warmer than today by the year 2030, based on a range of global climate model results. Rainfall is more difficult to predict. However, climate models generally agree that regional monsoon rainfall should increase in warmer world. The best estimate is a 10 to 15 percent increase in average monsoon rainfall by the year 2030, although the uncertainties are very large. Little can be said specifically regarding future changes in the frequency and intensity of cyclones in the Bay of Bengal (Ahmad *et al*., 1994). The global average precipitation is projected to increase, but both increases and decreases are expected at the regional and continental scales (Dore, 2005). Higher or lower rainfall or changes in its spatial and seasonal distribution would influence the spatial and temporal distribution of runoff, soil moisture and groundwater reserves, and would affect the frequency of droughts and floods. Further, temporal change in precipitation distribution will affect cropping patterns and productivity.

A number of studies on climate change and its variability in Bangladesh have already been made by various scientists and organizations. Ahmed and Alam (1999) made a study on the development of climate change Scenarios with General Circulation Models. In this study, the vulnerability to climate change for different sectors was assessed based on climate scenarios for two projection years 2030 and 2075. These climate

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scenarios were developed by using General Circulation Models. t was inferred from the GCM output that moderate changes regarding climate parameters would take place for the projection year 2030, while for the projection year 2075 severe changes would occur. Karmakar and Shrestha (2000) studied the recent climatic changes in Bangladesh by using the surface climatological data on monthly and annual mean maximum temperature, minimum temperature and monthly and annual rainfall for the period 1961-90. According to the study, the annual mean maximum temperature over Bangladesh has significant decreasing trend up to 1975 and very significant increasing trend after 1975. The overall trend of annual mean maximum temperature for the period 1961-90 is of increasing order, which is statistically significant. The study also reveals that the annual mean temperature over Bangladesh has a slight increasing trend during the whole period 1961-90. In case of rainfall, it has been found that the seasonal rainfall over Bangladesh has increasing trends during all the seasons except the post-monsoon season when it shows a decreasing trend. Rimi *et al*. (2009) made a study on the trend analysis of climate change and investigation on its probable impacts on rice production at Satkhira, Bangladesh. Statistical analysis of the recent trend of climate change and prediction of future climate change scenarios have been made with Global Climate Models (GCMs) and most importantly investigation on the impacts of climate change on rice production over Satkhira district, which is in the southwestern coastal zone of Bangladesh. There was a statistically non-significant increasing trend of annual maximum and minimum temperature and annual total rainfall through the period of 1950-2006. The trend analysis of seasonal rainfall for the period 1981-2006 has revealed that the seasonal normal rainfall pattern has been altered from the last two decades. Some forms of climate extreme events have been on the rise over the last few decades (Banholzer *et al*., 2014).

According to Intergovernmental Panel on Climate Change (IPCC), about one-sixth of the total population of the world lives in the regions which shall be affected by a decrease in melting water. The warmer climate will likely cause more heat waves, more violent rainfall and also amplification in the severity of hailstorms and thunderstorms (Shahzad, 2015). Bhatla *et al.* (2016) made an analysis of rainfall pattern and extreme events during southwest monsoon season over Varanasi during 1971-2010. Their results show that cumulative rainfall during 1971-2010 is overall decreasing in monsoon season as well as in all the months June, July, August and September. In general, the observed rainfall events in all categories (Non rainy day, 0-2.4 mm; Category I, 2.5-64.4; Category II, 64.5 to 124.4; Category III, 124.5 mm or more) have a decreasing trend in all the months and monsoon season over the entire period of study. Korade and Dhorde (2016) studied the trends in surface temperature variability over Mumbai and Ratnagiri cities of coastal Maharashtra, India. According to them, increasing trends were observed over both the stations, with high rate of increase in maximum temperature than the minimum temperatures statistically significant at 95% confidence level. Mumbai experienced significant warming with higher rates than Ratnagiri. Warm extremes have also increased significantly over Mumbai. Ratnagiri showed decrease in hot days during monsoon and hot nights during remaining seasons significant in summer.

As Bangladesh is one of the most climate-vulnerable countries in the world in terms of monsoon temperature, rainfall, floods, heavy rainfall, erratic rainfall, etc., it essential to study the trend in rainfall and temperature during the southwest monsoon season in Bangladesh. The present study has been undertaken to study the climate change and its trends in Bangladesh with the recent data of Bangladesh Meteorological Department (BMD) during the monsoon season of period 1981-2010.

2. DATA AND METHODOLOGY

Rainfall, dry-bulb temperature, maximum and minimum temperatures for the southwest monsoon season (June-September) during the period 1981-2010 at 34 stations (Figure 1) of BMD have been collected and utilized in the present study. The monthly mean data of Chittagong station for the years 2003 to 2007 are absent. For this reason the same year's data of the nearest station like Ambagan (Ctg.) are taken.

Trends of the parameters have been determined. The statistical significance of the trends has been studied with the help of F-distribution test according to the formula:

$$F = \frac{R^2(n-k)}{(k-1)(1-R^2)}$$

Where n is the number of pairs of data, (n-k) is the degrees of freedom and R^2 is the co-efficient of determination.

From the daily rainfall and temperature data, mean monthly and seasonal rainfall and temperatures have been computed for stations under study. These values of rainfall and temperatures for 34 stations are averaged to obtain country-averaged rainfall and temperatures and correlation among them has been studied.

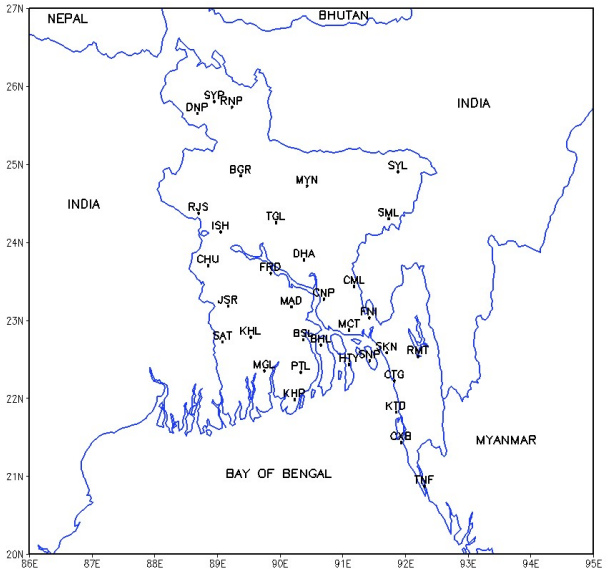

Figure 1: Location of meteorological stations of BMD

3. RESULTS AND DISCUSSION

The trends in monthly and seasonal rainfall, dry-bulb temperature, maximum and minimum temperatures for the southwest monsoon season (June-September) have been computed using the data for the period 1981-2010 and both the temporal and spatial distributions of the trends are studied over Bangladesh, The results are presented in the following sub-sections.

3.1 Trends in monthly and monsoon rainfall in Bangladesh

The trends in monthly rainfall in June through September at each station have been computed and are distributed spatially over Bangladesh. Besides, rainfalls of 34 stations are average to obtain country-averaged rainfall and their temporal variations have been studied for the months of June through September.

3.1.1 Spatial distribution of the trends in monthly monsoon rainfall over Bangladesh

The rainfall has increasing trends at 20 stations out of 34 stations in June. The maximum increasing trend is +7.252 mm/year at Dinajpur and the maximum decreasing rate is -11.44 mm/year at Kutubdia. In July, rainfall has increasing trends at 19 stations and decreasing trends at 15 stations, having maximum increasing trend of 15.58 mm /year at Hatiya and the maximum decreasing rate of -12.44 mm /year at M. Court. In August, the situation is different in that the rainfall has decreasing trends at 26 stations out of 34 stations, the maximum increasing trend being +3.749 mm /year at Kutubdia and maximum decreasing rate is -15.4 mm/year at M. Court. In September, rainfall has increasing trends at 20 stations. The maximum increasing trend is +8.663 mm /year at Hatiya and the maximum decreasing rate is -18.45 mm /year at Syedpur.

Therefore, it is clear that the rainfall has increasing trends at most of the places in Bangladesh during the southwest monsoon season except August when there is decreasing trends in rainfall in most places. The maximum increasing trend is +15.58 mm/year at Hatiya in the month of July and maximum decreasing rate is -18.45 mm /year at Syedpur in the month of September.

The spatial distributions of the trends in rainfall over Bangladesh during the monsoon months are given in Figures 2(a-d). In the month of June, the trend in rainfall is positive i.e. increasing in the northern part and Chittagong Hill Tracts-Comilla region of Bangladesh, the maximum increasing trend is in the northwest. In this month, there is decreasing trend in rainfall over the belts of Faridpur-Madaripur, central south and southeastern parts of Bangladesh (Figure 2a). In July, the rainfall has increasing trend over the central-southwestern part Bangladesh and decreasing trends are seen in the northern and southeastern parts. Maximum increasing trends exist over Hatiya and adjoining area (Figure 2b). In the month of August, the rainfall has decreasing trends in most of the places in Bangladesh. There is a narrow belt of increasing rainfall trends over Dhaka-Tangail-Bogura-Rangpur-Syedpur region in August and the rainfall has also increasing trend in Cox's Bazaar region. Maximum decreasing trend of -15.4 mm /year exists at M. Court (Figure 2c). The rainfall has increasing trends over central and southern Bangladesh in the month of September having maximum increasing trends over south-southwestern part and decreasing trends in the northern part of the country with the overall range of -18.45

mm/year at Syedpur to +8.6 mm /year at Hatiya (Figure 2d). In June, rainfall has positive i.e. increasing trend in the northern part and Chittagong Hill Tracts-Comilla region of Bangladesh. In July, the rainfall has increasing trend over the central-southwestern part Bangladesh and decreasing trends are seen in the northern and southeastern parts. A narrow belt of increasing rainfall trends exists over Dhaka-Tangail-Bogura-Rangpur-Syedpur region in August, while increasing trend is found over south-southwestern part of Bangladesh. The highest positive trend of rainfall is +15.58 mm/year at Hatiya in the month of July and highest negative trend of rainfall is -18.45 mm/year at Syedpur in the month of September.

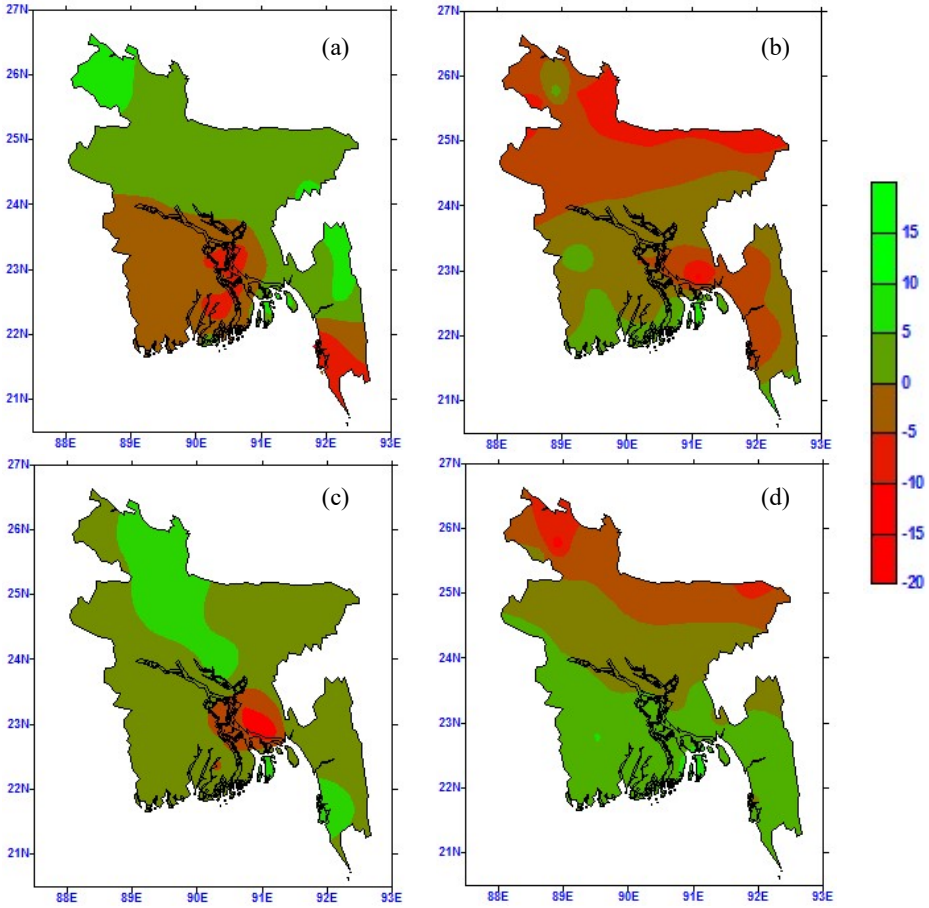

Figure 2: Spatial distribution of the trends in monthly rainfall of (a) June, (b) July, (c) August and (d) September over Bangladesh during the southwest monsoon season of 1981-2010

From the above discussion, it appears that during the ongoing phases of southwest monsoon, there exists the negative trends of rainfall over the southern part of Bangladesh except in September when the negative trend of rainfall is in the northern part having the maximum negative trend in northwest. There are no definite areas of positive or negative trends in rainfall over the country during the monsoon season; the areas vary from one month to another. In July and September, the rainfall has a definite decreasing trend in northern Bangladesh [Figure 2 (b, d)]. This negative trend in rainfall may be due to the variability of the monsoon axis especially due to the existence of the monsoon axis more southward as compared to its mean position (Karmakar, 2006).

3.1.2 Trends in country-averaged monsoon rainfall over Bangladesh

The temporal variations of country-averaged rainfall over Bangladesh for the monsoon months are shown in Figures 3(a-d). All the figures show inter-annual variations in rainfall. In June and August, the rainfall has decreasing trends at the rates of -0.612mm/year and -2.981mm/year respectively. In July and September, the trends of rainfall are positive i.e. increasing. The increasing rates of rainfall are +0.202 mm/year and +0.281 mm/year respectively. The trends of country-averaged rainfall are not statistically significant as the R^2 values are small. The seasonal rainfall over Bangladesh is shown in Figure 3(e). During 1981-2010, the seasonal rainfall during the monsoon season has inter-annual variation. It has decreasing trend and the rate of decreasing is -0.777 mm/year in Bangladesh.

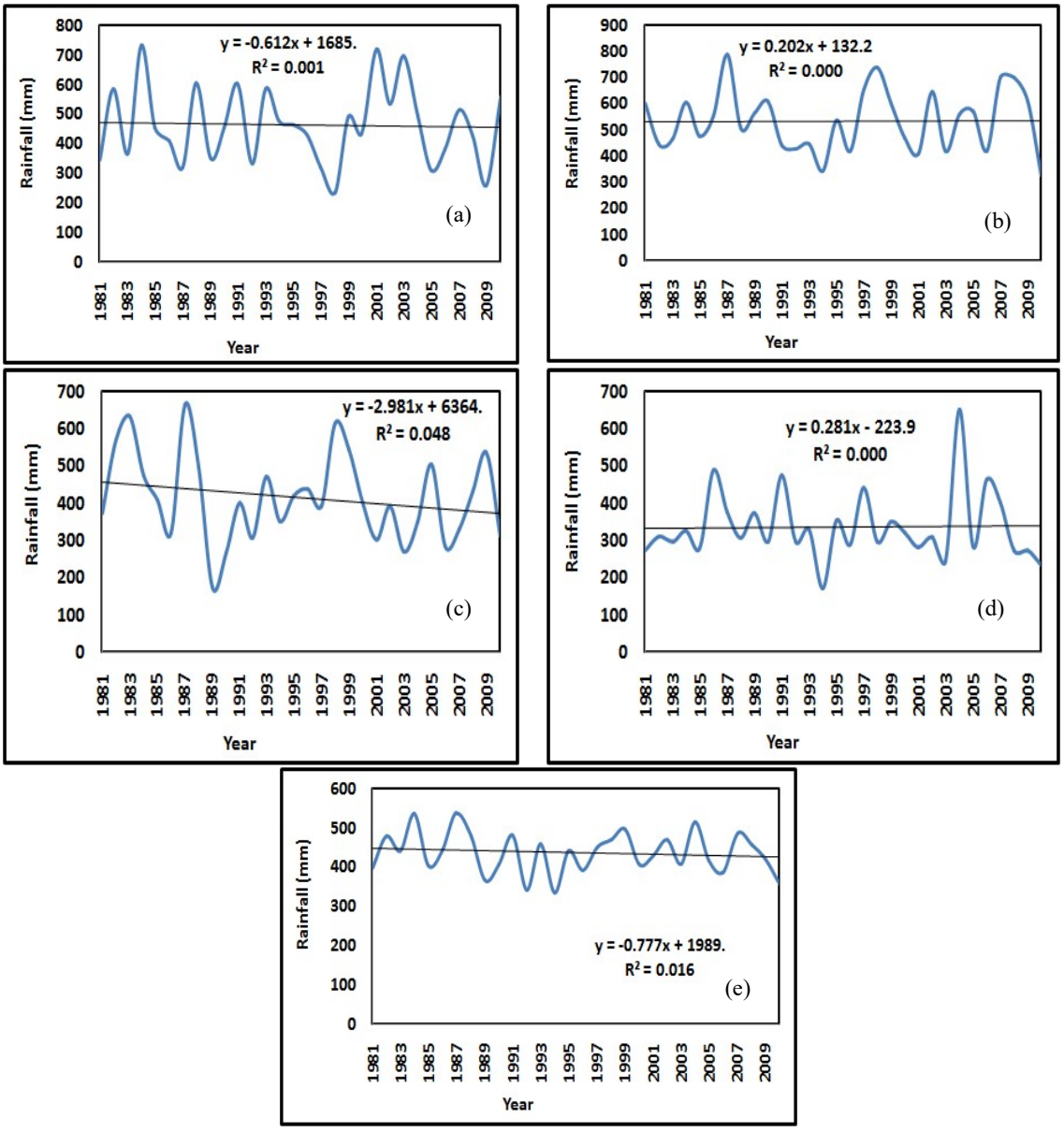

Figure 3: Temporal variation of country-averaged rainfall in (a) June, (b) July, (c) August, (d) September and (e) Monsoon season of 1981-2010 in Bangladesh

3.2 Trends in monthly monsoon dry-bulb temperature in Bangladesh

3.2.1 Spatial distribution of monthly mean monsoon dry-bulb temperature

The dry-bulb temperature has increasing trends at 25 stations out of 34 stations in June. The maximum increasing trend is 0.071ºC/year at Chuadanga and the maximum decreasing rate is -0.04ºC/year at Srimangal. In July, dry-bulb temperature has increasing trends at 28 stations and decreasing trends at 6 stations. The maximum increasing trend is 0.051ºC/year at Syedpur and the maximum decreasing rate is -0.019ºC/year at Madaripur. In August, it has increasing trends at 26 stations and decreasing trends at 8 stations, having maximum increasing trend is 0.027ºC/year at Sandwip and maximum decreasing rate is -0.015ºC/year at Sitakunda. In September, dry-bulb temperature has increasing trends at 27 stations. The maximum increasing trend is 0.09ºC/year at Syedpur and the maximum decreasing rate is -0.033ºC/year at Madaripur.

Therefore, it is clear that the dry-bulb temperature has increasing trends at most of the places in Bangladesh during the southwest monsoon season. The maximum increasing trend is 0.09ºC/year at Syedpur in the month of September and maximum decreasing rate is -0.04ºC/year at Srimangal in the month of June.

The spatial distributions of the trends in dry-bulb temperature over Bangladesh during the monsoon months are given in Figures 4(a-d). In the month of June, the trend of dry-bulb temperature is positive i.e. increasing in the western, southern and extreme southeastern parts of Bangladesh, the maximum increasing trend is in the west. In this month, there is decreasing trend in dry-bulb temperature over the belts of Rangpur-Mymensingh, Sylhet-Srimangal and Rangamati-Sitakunda (Figure 4a). There are also pockets of decreasing trends of dry-bulb temperature at Dinajpur, Satkhira and Madaripur. In July, the dry-bulb temperature has increasing trend over Bangladesh except a few pockets such as Srimangal, Madaripur, Mongla-Satkhira and Sitakunda-Teknaf where there are decreasing trends. Maximum increasing trends exist over northwestern and Sylhet regions (Figure 4b).

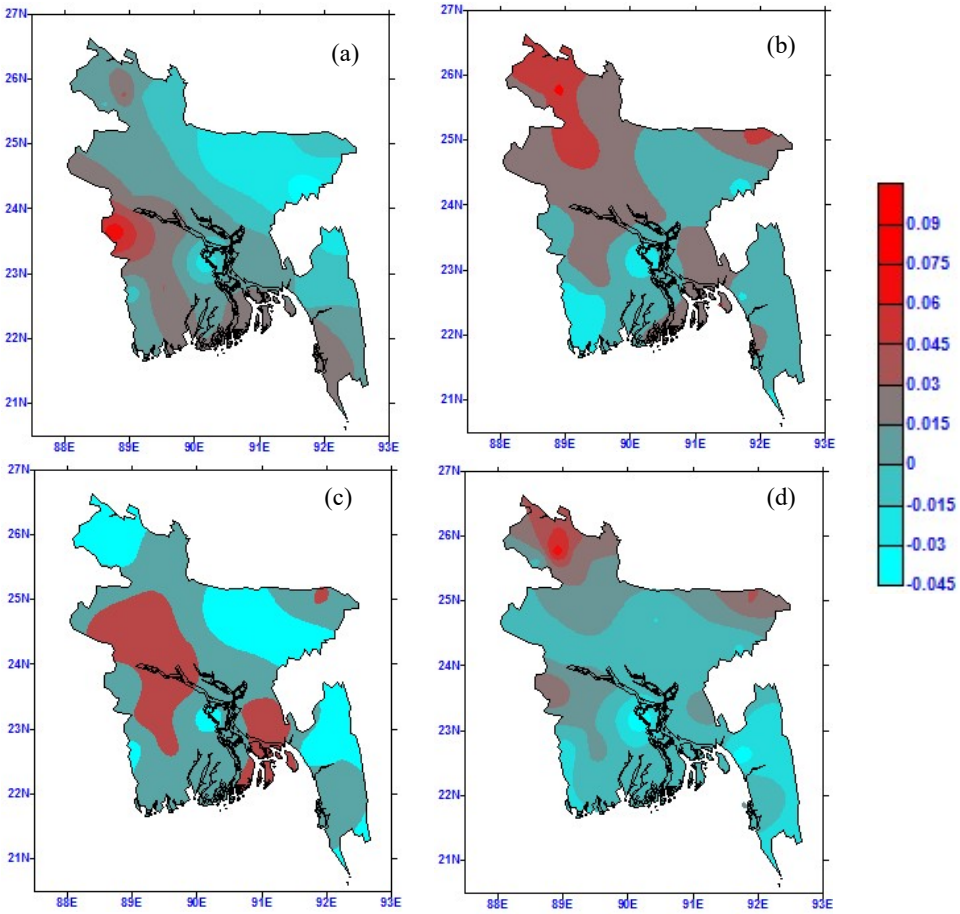

Figure 4: Spatial distribution of the trends in monthly dry-bulb temperature of (a) June, (b) July, (c) August and (d) September over Bangladesh during the southwest monsoon season of 1981-2010

For the month of August, the trend of dry-bulb temperature is positive in western part of Bangladesh except extreme northwest and Satkhira regions where the trend is decreasing. The trend is also negative i.e. decreasing over Mymensingh-Srimangal and Sitakunda-Teknaf regions (Figure 4c). In September, the dry-bulb temperature has the positive trends at most places over Bangladesh and the trends range from -0.033˚C/year to 0.09˚C/year. In this month, the lower or negative trends of dry-bulb temperature exist over middle, southwestern and southeastern parts of the country. But the maximum negative trend of dry-bulb temperature exists over Madaripur region. The area of highest positive trend of dry-bulb temperature is over Syedpur extending towards the south (Figure 4d). From the above discussion, it may be concluded that during the ongoing phases of southwest monsoon, the positive trend of dry-bulb temperature exists over the western and northeastern parts of Bangladesh and relatively negative trend of dry-bulb temperature is found over the eastern and southeastern part of the country. The highest positive and negative trends of dry-bulb temperature exist over Syedpur and Srimangal respectively.

3.2.2 Trend in average dry-bulb temperature in monsoon season over Bangladesh

The temporal variations of the country-averaged dry-bulb temperature over Bangladesh are shown in Figures 5(a-d). In June, July, August and September the trends of dry-bulb temperature are positive i.e. dry-bulb temperature has increasing trends. The increasing rates of temperature are +0.007˚C/year, +0.015˚C/year,

+0.01˚C/year and +0.007˚C/year in June, July, August and September respectively, showing the maximum positive trend in July. The seasonal trend of average dry-bulb temperature during the monsoon season over Bangladesh is shown in Figure 5(e). During 1981-2010, the seasonal dry-bulb temperature has increasing trend and the rate is +0.01˚C/year.

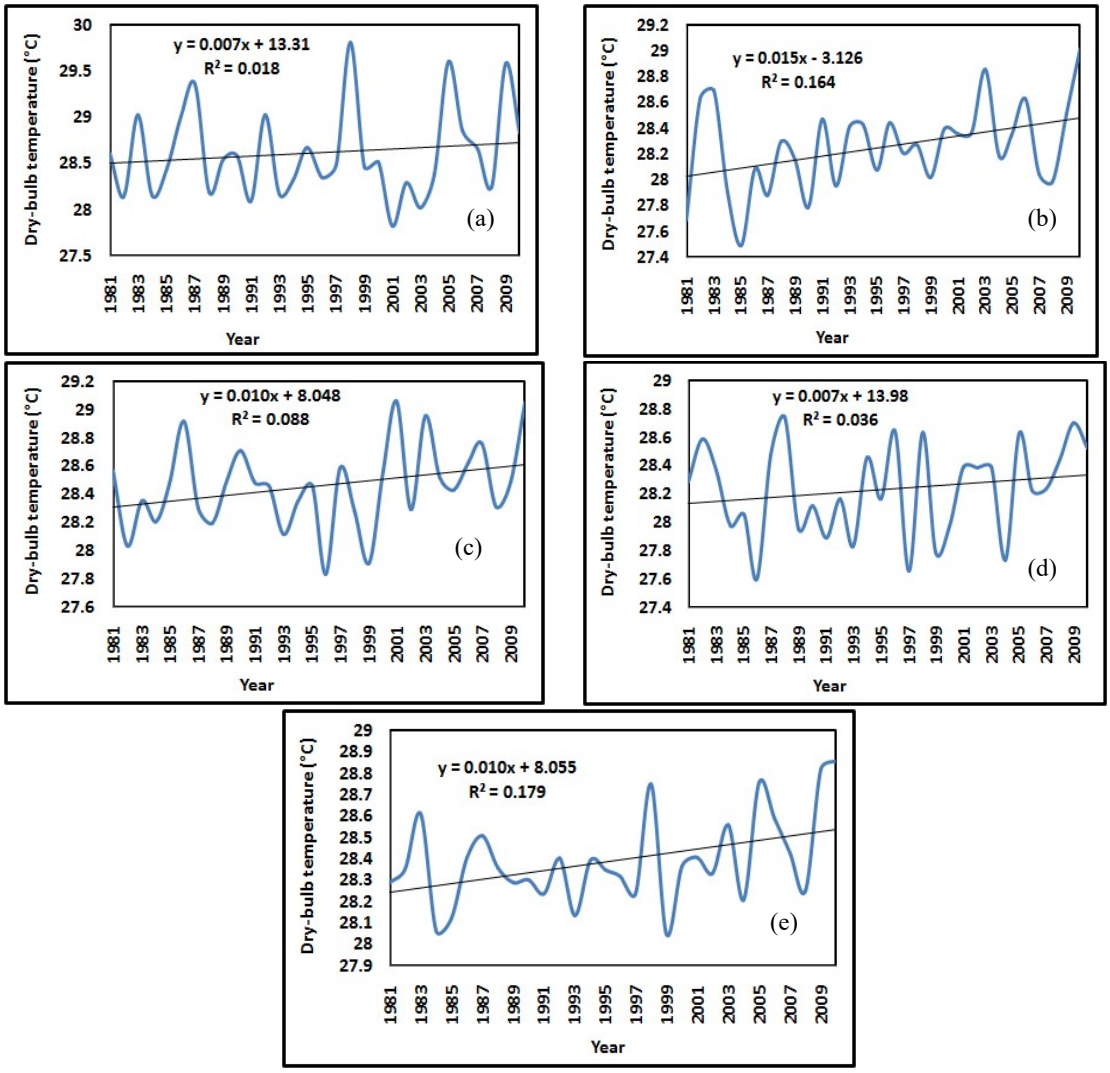

Figure 5: Temporal variation of country-averaged dry-bulb temperature in (a) June, (b) July, (c) August, (d) September and (e) Monsoon season of 1981-2010 in Bangladesh

3.3 Trends in monthly average minimum temperature in monsoon season in Bangladesh

3.3.1 Spatial distribution of the trends in monthly mean minimum temperature during the monsoon season in Bangladesh

The monthly mean minimum temperature has increasing trends at 26 stations out of 34 stations and decreasing trends in 8 stations in June. The maximum increasing trend is 0.071˚C/year at Dinajpur and the maximum decreasing rate is -0.012˚C/year at Srimangal. In July, minimum temperature has also increasing trends at 32 stations and decreasing trends at 2 stations, having maximum increasing trend of 0.081˚C/year at Dinajpur and maximum decreasing rate of -0.017˚C/year at Sandwip. While in August, it has increasing trends at 32 stations and decreasing trends at 2 stations, having maximum increasing trend of +0.044˚C/year at Madaripur and maximum decreasing rate of -0.028˚C/year at Sandwip. Monthly mean minimum temperature has increasing trends at 29 stations and decreasing trends at 5 stations in September. The maximum increasing trend is +0.054˚C/year at Sylhet and the maximum decreasing rate is -0.035˚C/year at Sandwip.

Therefore, it is clear that the minimum temperature has increasing trends at most of the places in Bangladesh in all the months during the southwest monsoon season. The maximum increasing trend is +0.081˚C/year at Dinajpur in July and maximum decreasing rate is -0.035˚C/year at Sandwip in September.

The spatial distributions of the trends in monthly mean minimum temperature over Bangladesh during the monsoon months are given in Figures 6(a-d). In June, the trend in mean minimum temperature is positive i.e. increasing in the western and southern parts of Bangladesh, the maximum increasing trend is in the northwest. In this month, there is decreasing trend in minimum temperature over the belts of Sandwip, Sitakunda and the region of Dhaka-Srimangal-Mymensingh-Rangpur-Syedpur (Figure 6a). In July, the minimum temperature has increasing trend all over Bangladesh except Sandwip and Dhaka where the trend is negative and zero respectively. Maximum increasing trends in minimum temperature exist over Dinajpur (Figure 6b).

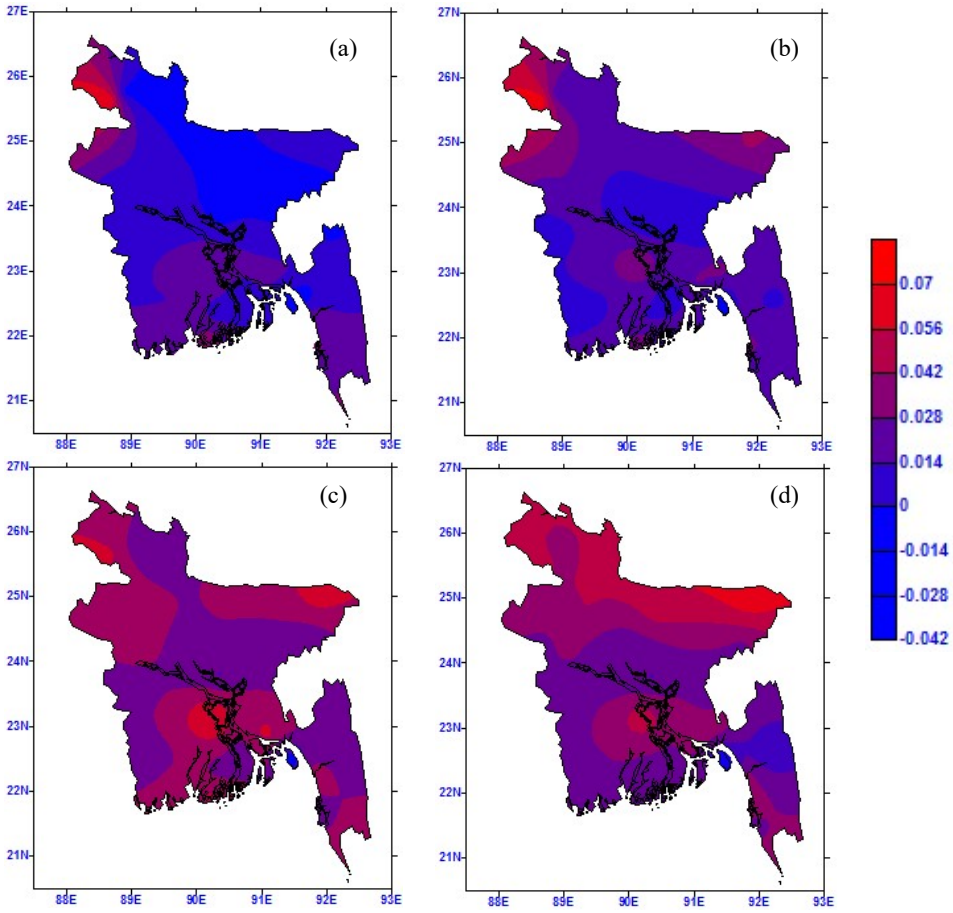

Figure 6: Spatial distribution of the trends in monthly minimum temperature of (a) June, (b) July, (c) August and (d) September over Bangladesh during the southwest monsoon season

In the month of August, the trend of minimum temperature is positive almost over Bangladesh except Dhaka and Sandwip where there are slight negative trends. Maximum increasing trend of +0.044˚C/year is found at Madaripur (Figure 6c). In this month, the positive trends are higher over northwestern, northeastern and Madaripur-Barisal-Chandpur region. The mean minimum temperature has increasing trend over Bangladesh except Dhaka and Rangamati-Sandwip-Sitakunda region in September ranging from -0.035˚C/year at Sandwip to +0.054˚C/year at Sylhet. The increasing trend is higher in northern part of the country (Figure 6d). The spatial distribution of the trends in monthly mean minimum temperature reveals that the higher increasing trend in minimum temperature is found over the northern part of Bangladesh during the southwest monsoon season.

3.3.2 Trend in country-averaged minimum temperature during the monsoon season in Bangladesh

The trends in country-averaged minimum temperature over Bangladesh are shown in Figures 7(a-d) for the months of June through September respectively. In June, July, August and September, the trends of minimum temperature are positive i.e. increasing. The increasing rates of average minimum temperature are

+0.013˚C/year, +0.022˚C/year, +0.016˚C/year and +0.014˚C/year in June, July, August and September respectively. The trends in July and August are statistically significant at 95% level of significance.

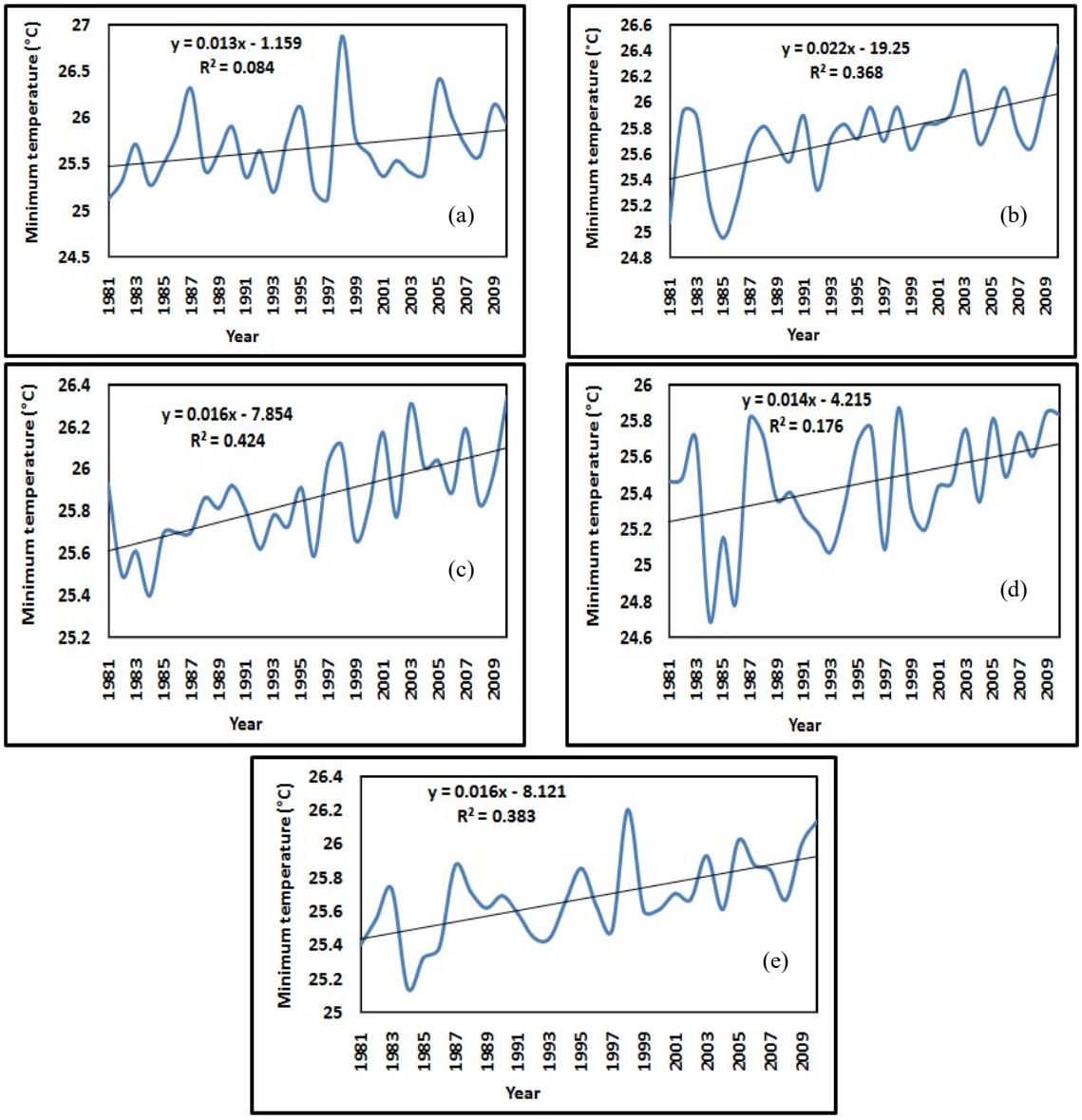

Figure 7: Temporal variation of country-averaged minimum temperature in (a) June, (b) July, (c) August, (d) September and (e) Monsoon season of 1981-2010 in Bangladesh

3.4 Trends in monthly average maximum temperature in monsoon season in Bangladesh

3.4.1 Spatial distribution of the trends in monthly mean maximum temperature during the monsoon season in Bangladesh

The maximum temperature has increasing trends at 32 stations out of 34 stations in June. The maximum increasing trend is 0.078˚C/year at Cox's Bazaar and the maximum decreasing rate is -0.01˚C/year at Srimangal. In July, maximum temperature has also increasing trends at all the stations. The maximum increasing trend is 0.07˚C/year at M. Court and the minimum increasing trend is 0˚C/year at Madaripur. In August, it has increasing trends at all the stations, having maximum increasing trend of 0.08˚C/year at M. Court and minimum increasing trend of 0.006˚C/year at Chittagong. While in September, maximum temperature has increasing trends at 33 stations. The maximum increasing trend is found to be 0.094˚C/year at Syedpur and the maximum decreasing rate is -0.0009°C/year at Bhola.

The spatial distributions of the trends in maximum temperature over Bangladesh during the monsoon months are given in Figure 8(a-d). In the month of June, the trend in maximum temperature is positive i.e. increasing over Bangladesh except Rangpur and Srimangal, the maximum increasing trend is in the southeastern part and secondary maximum in Jessore region (Figure 8a). In July, the maximum temperature has increasing trend all over Bangladesh. Maximum increasing trend exists over the region starting from M. Court to Cox's Bazar (Figure 8b). Secondary maximum trends in monthly mean maximum temperature are found over Sylhet, Tangail-Dinajpur regions. For the month of August, all the trends are positive in maximum temperature. Relatively maximum increasing trend in mean maximum temperature is found over from M. Court towards southeastern part of Bangladesh (Figure 8c). In this month, secondary maximum positive area is found over Tangail and adjoining area. Figure 8(d) shows the spatial distribution of the trends in mean maximum temperature in September, having the maximum positive area over Syedpur-Dinajpur-Tangail region and secondary positive area over Sylhet and southern regions.

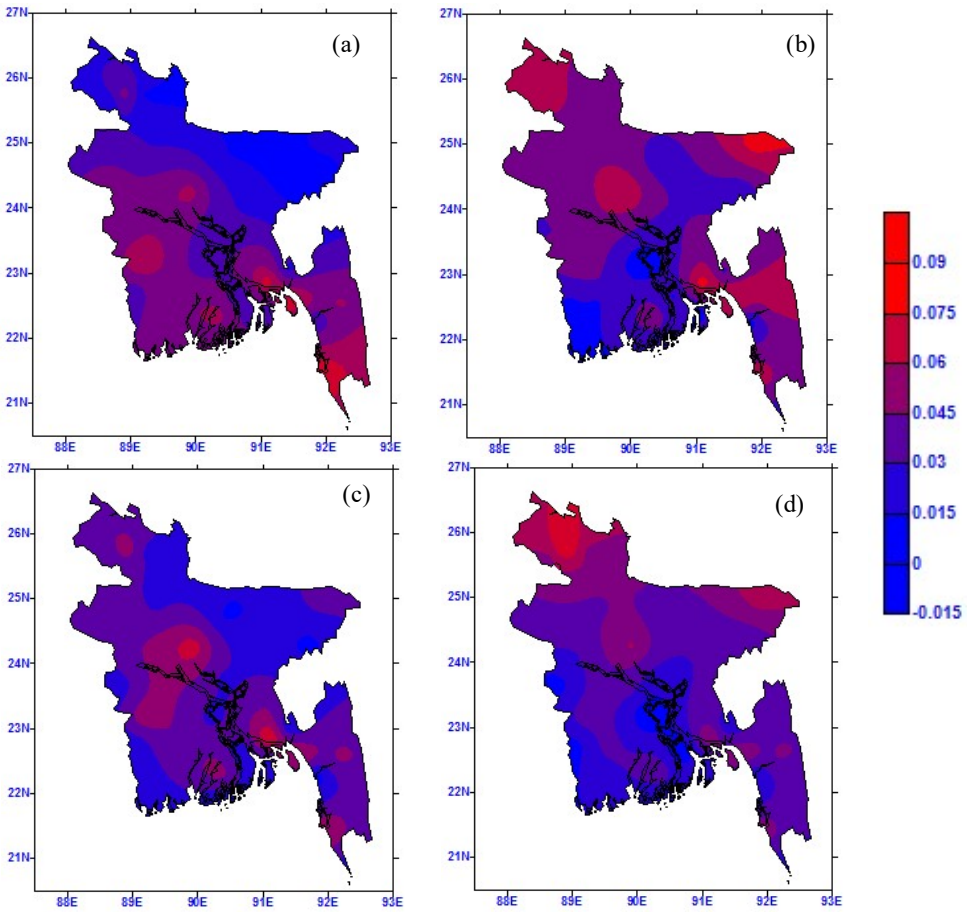

Figure 8: Spatial distributions of the trends in monthly maximum temperature over Bangladesh during the southwest monsoon season: (a) June, (b) July, (c) August and (d) September

Therefore, it is clear that the maximum temperature has increasing trends at most of the places in Bangladesh during the southwest monsoon season. The maximum increasing trend is 0.094˚C/year at Syedpur in the month of September and maximum decreasing rate is -0.01˚C/year at Srimangal in June. The maximum increasing trend in mean maximum temperature is found in the southeastern part in the month of June, M. Court to Cox's Bazaar in July and August while in September, the maximum positive area is found over Syedpur-Dinajpur-Tangail region.

3.4.2 Trend in country-averaged mean maximum temperature during the monsoon season in Bangladesh

The trends in monthly country-averaged maximum temperature over Bangladesh are shown in Figures 9(a-d). The country-averaged maximum temperature has increasing trends in all the months. The rates of increasing trend of country-averaged maximum temperature are +0.033˚C/year, +0.036˚C/year, +0.038˚C/year and +0.036˚C/year in June, July, August and September respectively. The trends in the months of July, August and September are statistically significant at 100% level. The trend in country-averaged seasonal maximum

temperature over Bangladesh is shown in Figure 9(e), which shows that the seasonal maximum temperature has positive trend and the rate is +0.036˚C/year, which is also statistically significant at 100% level.

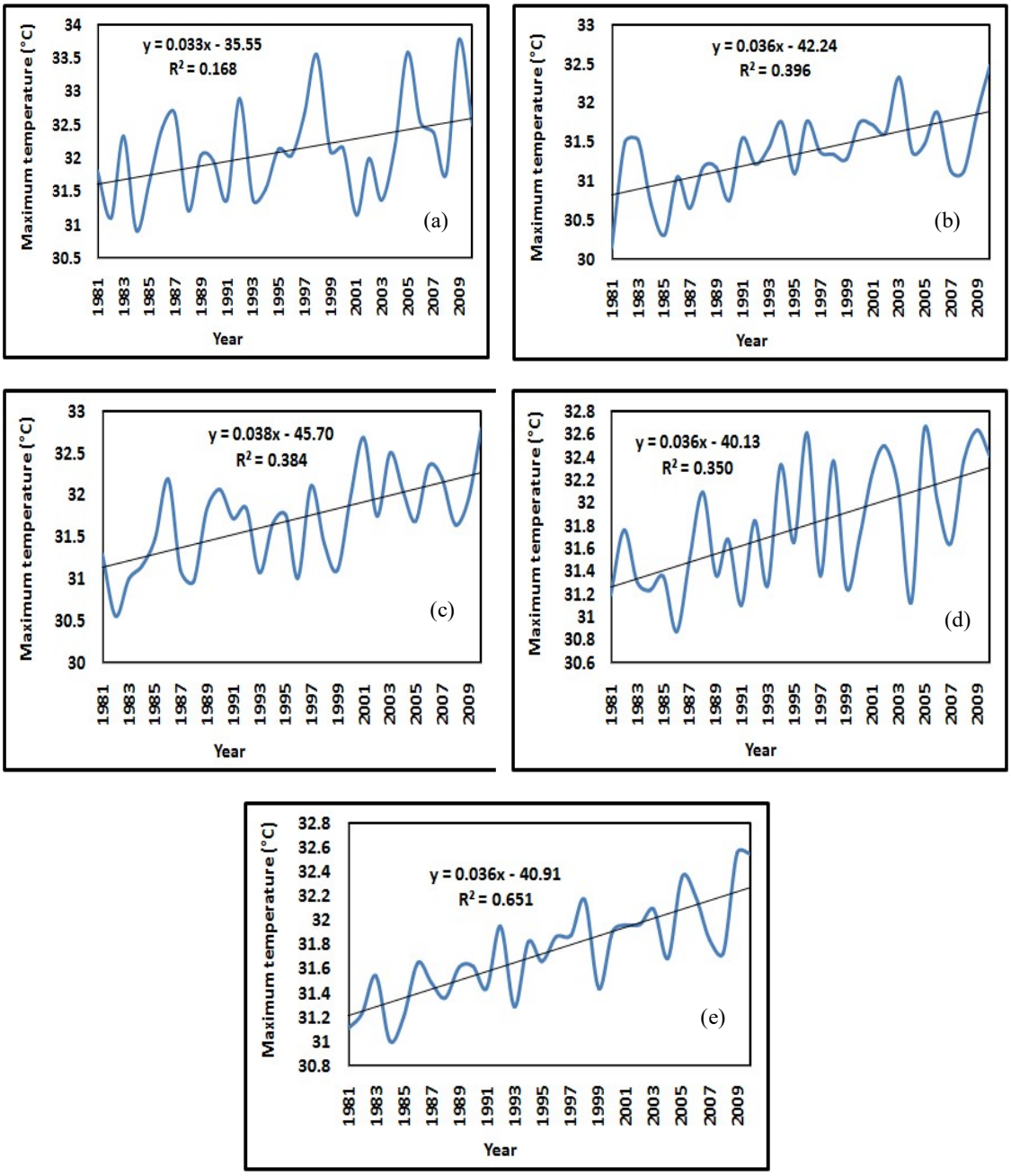

Figure 9: Temporal variation of country-averaged maximum temperature in (a) June, (b) July, (c) August, (d) September and (e) Monsoon Season of 1981-2010 in Bangladesh

3.5 Correlation of country-averaged monsoon rainfall with different country-averaged temperatures

The correlations of country-averaged monsoon mean monthly and seasonal rainfall with corresponding different temperatures such as dry-bulb, maximum, maximum and minimum temperatures have been studied. In this case, mean monthly and seasonal rainfall for 34 stations of Bangladesh have been averaged to get the country-averaged mean monthly and seasonal rainfall (here-in-after called country-averaged rainfall); similarly country-averaged mean monthly and seasonal temperatures are obtained and the correlation coefficients are obtained through scatter diagrams as shown in Figure 10 for the correlation of rainfall with dry-bulb temperature. The

correlation coefficients of country-averaged rainfall with country-averaged maximum and minimum temperatures are also calculated in the similar way. The results are given in Table 1.

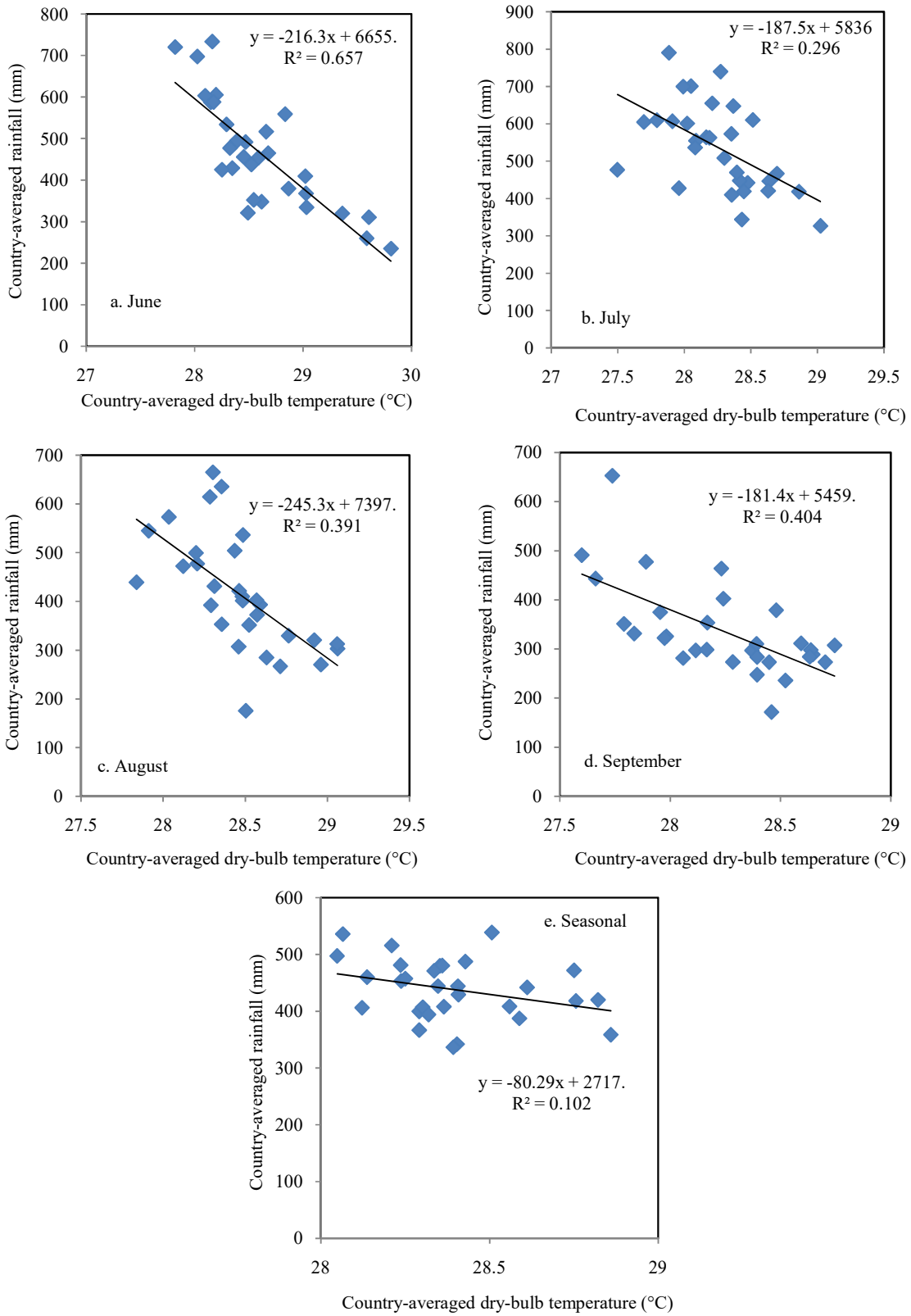

Figure 10: Scatter diagrams for the correlation of country-averaged rainfall with dry-bulb temperature during the monsoon season in Bangladesh

The significant test has been made with the help of Student-t Test:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Where r is the correlation coefficient and n is the length of the data.

The regression equations for monthly mean rainfall (R) obtained is given below:

Table 1: Regression equations for monthly mean rainfall

With dry-bulb temperature T_{db}	Maximum temperature T_{max}	Minimum temperature T_{min}
$R_{Jun} = -216.3T_{dbJun} + 6655.$	$R_{Jun} = -146.0T_{maxJun} + 5150.$	$R_{Jun} = -177.1T_{minJun} + 5013.$
$R_{Jul} = -187.5\ T_{dbJul} + 5836.$	$R_{Jul} = -120.8T_{maxJul} + 4325.$	$R_{Jul} = -105.6T_{minJul} + 3255.$
$R_{Aug} = -245.3\ T_{dbAug} + 7397.$	$R_{Aug} = -162.3T_{maxAug} + 5567.$	$R_{Aug} = -185.5T_{minAug} + 5212.$
$R_{Sep} = -181.4\ T_{dbSep} + 5459.$	$R_{Sep} = -98.84T_{maxsep} + 3478$	$R_{Sep} = -94.20T_{minSep} + 2735.$

Figure 10 shows that the country-averaged monthly and seasonal mean rainfall is negatively correlated with the country-averaged monthly and seasonal mean dry-bulb temperature during the monsoon season. Similar results are also obtained with country-averaged monthly and seasonal mean maximum temperature and minimum temperature (Table 2). Correlation coefficients of monthly rainfall with monthly dry-bulb and maximum temperatures are found to be statistically significant at 99% level of significance in June through September. Correlation coefficient of monthly rainfall with monthly minimum temperature in June is also significant at 99% level. Seasonal rainfall is less correlated with the seasonal mean temperatures (Table 2). The negative correlation of rainfall with different temperatures is for the obvious reason that when there is less rainfall there is higher temperatures and vice-versa.

Table 2: Correlation coefficients between the country-averaged rainfall and different temperatures during the monsoon season in Bangladesh

Correlation of country-averaged rainfall with Country-averaged	Correlation Coefficients				
	June	July	August	September	Seasonal
Dry-bulb temperature	-0.8109***	-0.54425***	-0.62544***	-0.63626***	-0.32004
Maximum temperature	-0.82055***	-0.54245***	-0.71763***	-0.58271***	-0.4275**
Minimum temperature	-0.54783***	-0.2936	-0.35627*	-0.31229	-0.12691

***Significant at 99%; **Significant at 95%; *Significant at 90%;

4. CONCLUSIONS

On the basis of the present study, following conclusions can be drawn:

i. The monthly rainfall has increasing trends at most of the places in Bangladesh during the southwest monsoon season except August when there is decreasing trends in rainfall most places. There exist negative trends of monthly rainfall over the southern part of Bangladesh during the monsoon season, except in September when there is negative trend of rainfall in the northern part with the maximum negative trend in northwest. There are no definite areas of positive or negative trends in rainfall over the country during the monsoon season; the areas vary from one month to another.

ii. During the ongoing phases of southwest monsoon, the positive trend of dry-bulb temperature exists over the western and northeastern parts of Bangladesh and relatively negative trend of dry-bulb temperature is found over the eastern and southeastern part of the country. The highest positive and negative trends of dry-bulb temperature exist over Syedpur and Srimangal respectively.

iii. The minimum temperature has increasing trends at most of the places in Bangladesh in all the months during the southwest monsoon season. The maximum increasing trend is +0.081˚C/year at Dinajpur in July and maximum decreasing rate is -0.035˚C/year at Sandwip in September. The higher increasing trend in minimum temperature is found over the northern part of Bangladesh during the southwest monsoon season.

iv. The maximum temperature has increasing trends at most of the places in Bangladesh during the southwest monsoon season. The maximum increasing trend is 0.094˚C/year at Syedpur in the month of September and maximum decreasing rate is -0.01˚C/year at Srimangal in June. The maximum increasing trend in mean maximum temperature is found in the southeastern part in the month of June,

M. Court to Cox's Bazar in July and August while in September, the maximum positive area is found over Syedpur-Dinajpur-Tangail region.

v. The country-averaged monthly and seasonal mean rainfall is negatively correlated with country-averaged monthly and seasonal mean dry-bulb, maximum and minimum temperatures during the monsoon season and the correlation coefficients are statistically significant in case of monthly mean rainfall mainly with dry-bulb and maximum temperatures in June through September

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