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A Study on Variation of Temperature and Precipitation of Bangladesh

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Abstract: *Analysis of temperature data recorded at all 34 meteorological stations over Bangladesh show that in majority of these stations, the yearly average maximum and minimum temperatures show increasing trend during the period 1975-2005. Analysis of monthly average maximum temperature also show increasing trend for all months of the year except January; the increasing trend was particularly significant for the months of June to September. On an average, monthly-average maximum temperatures of each of these months have increased by about 1 °C during the 34 year period from 1975-2005. Monthly average minimum temperatures also show increasing trends for all months except January and November; average total increase in monthly average minimum temperature was about 0.65°C during the same period (i.e., 1975 to 2005). The magnitude of increase in monthly average maximum and minimum temperatures during the 34-year period from 1975 to 2005 is quite significant. Eighteen stations (out of 32) show increasing trend in number of "hot" days per year, while 13 stations (out of 31) show decreasing trend in the number of "cold" days per year; however, most of these trends are not statistically significant. Analysis of precipitation data during 1975-2005 show that for a large majority of stations, the total rainfall show increasing trend for monsoon (June to September) and post-monsoon (October to November) seasons, while decreasing trend is observed for the winter (December to February); pre-monsoon (March to May) rainfall did not show any significant change. In general, these trends are consistent with the general climate change predictions. These observations are particularly significant in the context of Bangladesh where agriculture is heavily dependent on temperature and rainfall.*

Keywords : *Temperature, precipitation, Bangladesh*

Introduction

Global climate has been changing due to natural forcings as well as anthropogenic activities, especially emissions of greenhouse gases and aerosols, and land use changes in recent decades.

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Note : Dr. A. M. Shadullah died on 14 September, 2010. May Allah grant eternal peace of the departed soul. It is noted that this paper was written while he was alive.

Observational evidences demonstrate that composition of global atmosphere is changing, e.g., increasing atmospheric concentrations of greenhouse gases, such as carbon-di-oxide (379 ppm recorded in 2005), methane (1774 ppb recorded in 2005) and nitrous oxide (319 ppb recorded in 2005) (IPCC, 2007). Observational evidences also suggest changes in earth's climate, e.g., recent recorded changes in temperature, precipitation, sea level, arctic ice temperature, mountain glacier and snow cover, and in some regions extreme events including heat waves, heavy precipitation events and droughts. Continuing emissions of greenhouse gases and other anthropogenic factors are likely to result in significant changes in mean climate and its intra-seasonal and inter-annual variability in the Asian region. Bangladesh, being in South Asia, is one of the most vulnerable countries regarding the impacts of climate change. Bangladesh is a part of humid tropics with Himalayas in the North and funnel shaped 710 km long coast touching the Bay of Bengal in the South. Bangladesh experiences severe flood, tornado, drought and catastrophic cyclones associated with severe storm surge on a regular basis. All these are temperature related phenomena, and are likely to experience significant changes (e.g., increased frequency and severity) as a result of climate change.

The Intergovernmental Panel on Climate Change, abbreviated as IPCC (2001) projected certain climate change events during the 21st century with significant confidence, which included higher maximum temperature and more hot days, higher minimum temperature and fewer cold days, increased heat index and more intense precipitation events. Also the recent 2009 conference included the 15th Conference of the Parties (COP 15) agreed with the IPCC to raise the voice on change of climate. However, a number of studies have been carried out on trends of change in climate parameters in the context of Bangladesh (Chowdhury and Debsarma, 1992; Warrick et al., 1994; Karmakar and Nessa, 1997; Karmakar and Shrestha, 2000; World Bank, 2000; Mia, 2003; Debsarma, 2003; Karmakar, 2003). Warrick et al. (1994), Karmakar and Shrestha (2000) and Debsarma (2003) provided assessment of changes in temperature and precipitation over Bangladesh, while Chowdhury and Debsarma (1992) and Mia (2003) reported changes in temperature based on analysis of historical data of some selected weather stations in Bangladesh. Karmakar and Nessa (1997) and Karmakar (2003) provided assessment of the effects of climate change on natural disasters. The present study provides an assessment of climate change and variability in Bangladesh based on analysis of historical data of temperature and rainfall

recorded at all 34 meteorological stations in Bangladesh. In particular assessments have been made of changes in maximum temperature, changes in minimum temperature, variations in number of hot days and cold days, and changes in precipitation pattern.

Methods

Data collection and data range

In this study, data on temperature and rainfall of all 34 weather stations in Bangladesh were collected from the Bangladesh Meteorological Department (BMD). Temperatures data included daily, monthly average and annual mean maximum and minimum temperatures for the period January 1948 through December 2005, and daily precipitation data for the same period. However, data for the 30-year period from 1975 to 2005 have been used in the present study, because data for the period 1948-1975 were not considered reliable.

Maximum Temperature and Hot Days

Monthly-average maximum temperature data for the period January 1975 to December 2005 have been used to assess the changes in maximum temperature. These data were used to assess trend in yearly-average maximum temperature (calculated from monthly average values) as well as trends in monthly-average maximum temperature. These trends were assessed for each of the 34 stations. In each case, only linear trend was assessed for the period 1975-2005 and the nature (increasing or decreasing) and significance of trend was estimated from the R^2 value of the fit.

For assessment of trend of hot days, the 85th Percentile average daily temperature for the period 1975-2005 has been taken as the cut-off point between "regular" and "hot" days. This value was found to be 29.3 °C, and the days exceeding this temperature were taken as "hot" days. Number of hot days was then calculated for each year for the period 1975-2005 for each weather station.

Minimum Temperatures and Cold Days

Monthly average minimum temperature data have been used to assess the changes in minimum temperature. From the monthly average, the yearly average temperature was computed. Trends of both yearly-average minimum temperature and monthly-average minimum temperature have been assessed. For assessment of variation in number of cold days, the 15th Percentile

average daily temperature for the period 1975-2005 has been taken as the cut-off point between "regular" and "cold" days. This value was found to be 20.1 °C and the days having temperature below this value were taken as "cold" days. Number of cold days was then calculated for each year for the period 1975-2005, and the nature and significant of the trend of cold days was estimated as described above.

Changes in Precipitation Pattern

In this study, changes in rainfall pattern have been assessed by analyzing changes in total rainfall during four seasons, i.e., pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February) for the period 1975 to 2005; analysis was made separately for each weather station. Analysis of "intense precipitation events" could not be made from the available data on precipitation.

Results and Discussion

Yearly Average Temperature and Hot-Cold Days

The trend of variation of yearly average maximum temperature was analyzed for each of the 34 stations and the results are summarized in Table 1. Table 1 shows that in 28 out of 34 stations, yearly average maximum temperatures show increasing trend. Out of these 28 stations, the increasing trends in 15 stations are significant at 99% confidence level; on the other hand, decreasing trend observed for the 6 stations which are statistically significant. Figure 1 shows variation of annual average maximum temperature for Comilla station during 1975-2005. Table 1 also shows that among the 34 stations, 27 showed increasing trend in yearly average minimum temperature; whereas increasing trend in 14 stations are significant at 95% confidence level or higher.

Table 1. Changes in annual average temperature, hot and cold days

Climate Change Phenomena (annual)	No. of Weather Station	No. of Station showing increasing trend	No. of Station showing decreasing Trend	Increasing Trend (No. of Station)			Decreasing Trend (No. of Station)		
				95% LOS	99% LOS	NS	95% LOS	99% LOS	NS
Maximum Temperature	34	28	6	1	15	12	0	0	6
Minimum Temperature	34	27	7	4	10	13	2	1	4
Hot Days	32	18	14	3	2	13	2	3	8
Cold Days	31	18	13	3	8	7	1	1	11

LOS: Level of Significance; NS: Not Significant

Among the 32 stations (for which data were available), 18 showed increasing trend in number of "hot" days per year; however, in only 5 stations these trends are significant at 95% confidence level or higher. On the other hand, 14 stations showed decreasing trend in number of "hot" days. Yearly number of cold days during 1975-2005 showed increasing trend for 18 out of 31 stations; tends in 11 being significant at 95% confidence level or higher. On the other hand, decreasing trend was observed for 13 stations; however, none except 2 are statistically significant. Figure 2 shows annual variation of number of cold days for Dhaka.

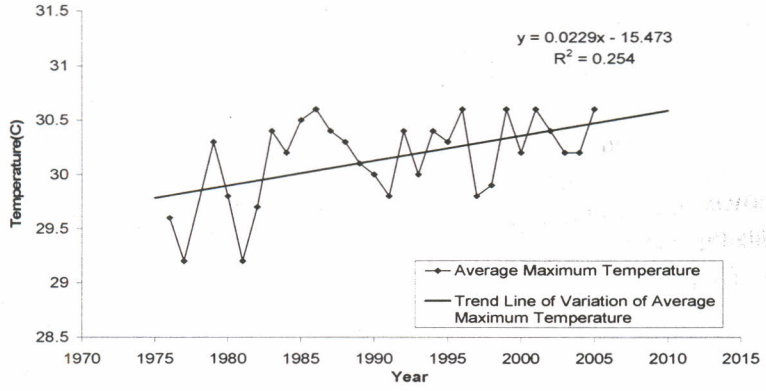

Figure 1. Changes in annual average maximum temperature for the Comilla weather station

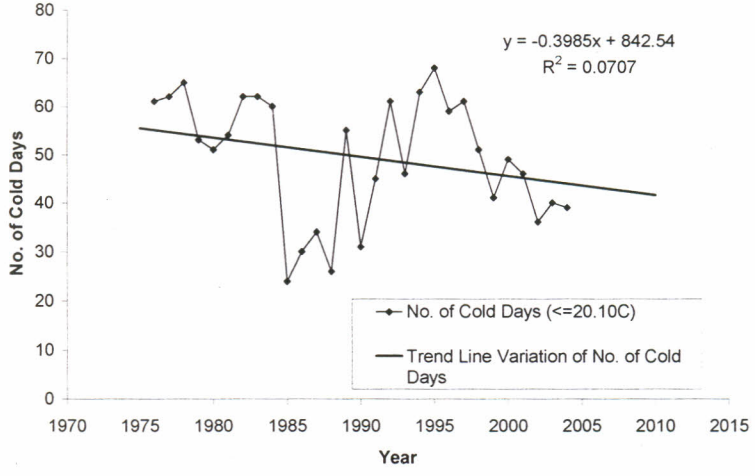

Figure 2. Yearly variation in number of cold days for Dhaka weather station during 1975-2005

Trend of Monthly Average Maximum and Minimum Temperature

The trend of variation of monthly average maximum temperature was analyzed for 34 weather stations. Figure 3 shows monthly average maximum temperature for the month of February for Barisal weather station during 1975-2005. Table 2 shows summary of analysis of monthly average maximum temperature for 34 weather stations. It shows that except for January, March and April, monthly average maximum temperature shows increasing trend for majority of the meteorological stations. Increasing trend was particularly not significant for the months between June to September. All 34 stations showed increasing trend for monthly average maximum temperature for the months of July and August, while all but one station showed increasing trend for the months of June and September. Only for January, more stations (25 out of 34) showed decreasing trend for monthly average maximum temperature.

Calculated (from trend lines) changes in monthly average maximum temperature showed an increase in temperature during 1975-2005 for all months except January. Significant increase during this 30-year period was observed for the months of April to September and also for February and December; average increase in temperature for each of these months being about 1 °C for the 30-year period. Figure 4 shows total changes in monthly

average maximum temperature (average of 34 stations) during the 30-year period from 1975 to 2005.

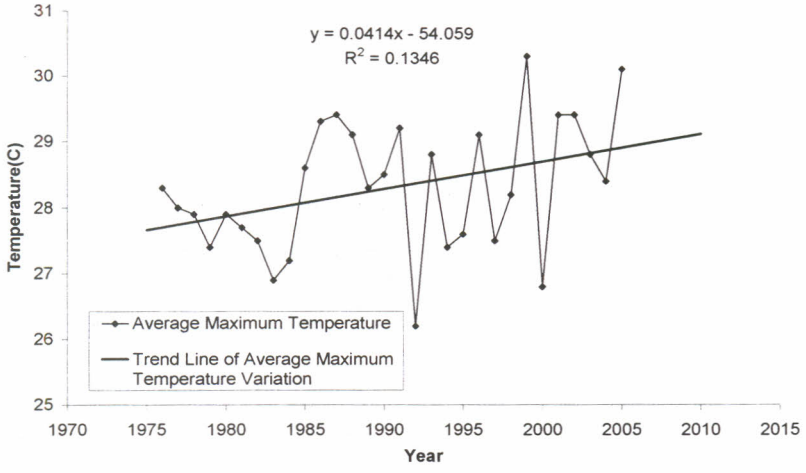

Figure 3. Variation of monthly-average maximum temperature for the month of February at Barisal weather station

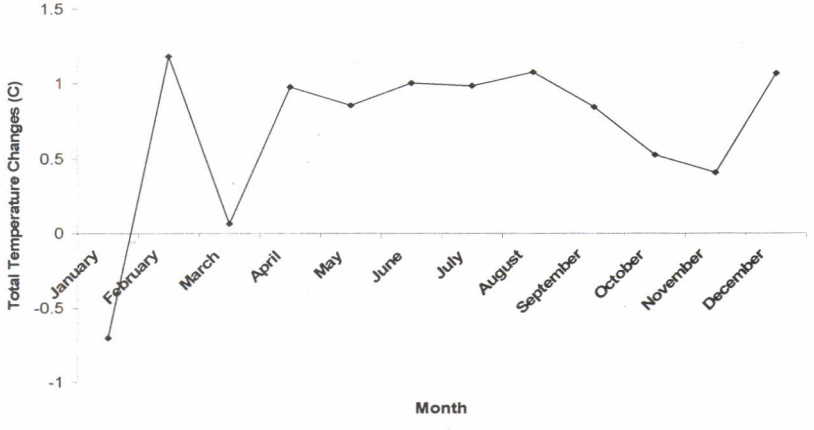

Figure 4. Total changes in monthly average maximum temperature during 1975-2005

Table 2. Changes in monthly-average maximum temperature during 1975-2005

Month	No. of Station showing increasing trend	No. of Station showing decreasing trend	Total Temp. change (°C) in 30 years from 1975 to 2005	Average Temp. changes per year °C /year	Increasing Trend (No. of Station)			Decreasing Trend (No. of Station)		
					95% LOS	99% LOS	NS	95% LOS	99% LOS	NS
January	9	25	-0.700	-0.023	3	0	6	8	3	14
February	32	2	1.182	0.039	5	3	24	1	0	1
March	17	17	0.064	0.002	1	1	15	1	1	15
April	17	17	0.975	0.032	7	1	9	2	0	15
May	32	2	0.852	0.028	5	2	25	0	0	2
June	33	1	1.002	0.033	6	7	20	0	0	1
July	34	0	0.983	0.032	8	18	8	0	0	0
August	34	0	1.075	0.035	7	19	8	0	0	0
September	33	1	0.842	0.028	2	15	16	0	0	1
October	24	10	0.524	0.017	1	7	16	0	0	10
November	23	11	0.406	0.013	5	4	14	1	0	10
December	32	2	1.065	0.035	1	13	18	0	0	2

LOS: Level of Significance; NS: Not Significant

Table 3 shows summary of analysis of monthly average minimum temperature for 34 weather stations during 1975-2005. Except for January and November, monthly average minimum temperature shows increasing trend for majority of the weather stations. The increasing trend was not significant especially for the months of February and April to August (Table 3). Calculated (from trend lines) total change during the 30-year period showed an increase in monthly average minimum temperature for all months of the year except January and November. For the 10 months (except January and November), average (i.e., average of 34 stations) total increase in monthly average minimum temperature was about 0.65 °C during the 30-year period, while for January and November, average decrease was about 0.2 °C during the same period. Figure 5 shows monthly average minimum temperature for Barisal weather station during 1975-2005. Figure 6 shows total changes in monthly average minimum temperature (average of 34 stations) during the 30-year period from 1975 to 2005.

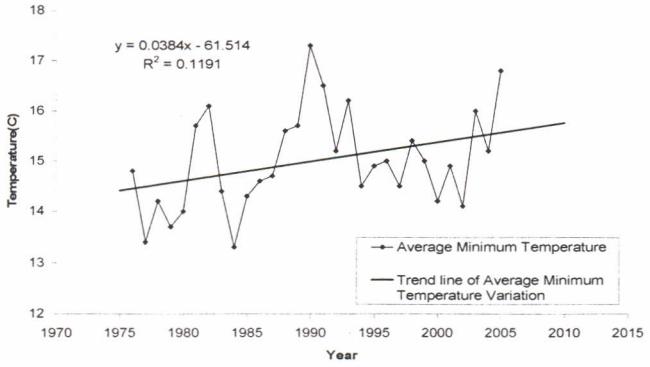

Figure 5. Variation of monthly-average maximum temperature for the month of February at Barisal weather station

Trend of Seasonal Rainfall

Table 4 shows variation in total amount of rainfall in 4 seasons for all 34 meteorological stations during 1975-2005. It shows that the observed trends are not statistically significant in most cases. Nevertheless, majority of stations showed increasing trend of rainfall during monsoon and post-monsoon seasons, while significant number of stations showed decreasing trend of total rainfall during winter. These results are consistent with the general climate change predictions that wet periods would become wetter and dry periods would become drier. Figure 7 and Figure 8 show variation in total rainfall in post-monsoon and winter season, respectively for Satkhira weather station during 1975-2005.

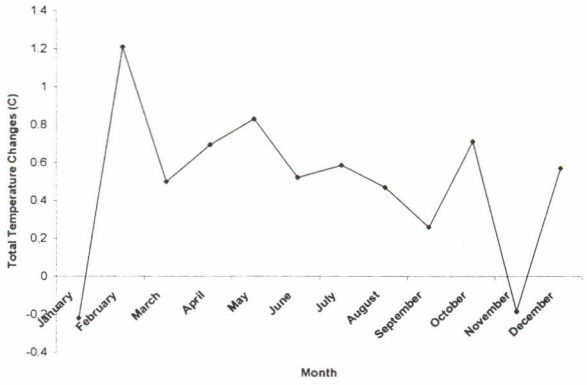

Figure 6. Total changes in monthly average minimum temperature during 1975-2005

Table 3. Changes in monthly-average minimum temperature during 1975-2005

Month	No. of Station showing increasing	No. of Station showing decreasing	Total Temp. change (°C) in 30 years from 1975 to 2005	Average Temp. changes per year °C /year	Increasing Trend (No. of Station)			Decreasing Trend (No. of Station)		
					95 % LOS	99 % LOS	NS	95 % LOS	99 % LOS	NS
January	16	18	-0.218	-0.007	1	3	12	2	4	12
February	29	5	1.210	0.040	6	9	14	0	1	4
March	24	10	0.500	0.016	5	2	17	1	1	8
April	28	6	0.695	0.023	4	0	24	0	0	6
May	29	5	0.831	0.027	9	3	17	0	0	5
June	31	3	0.522	0.017	3	4	24	1	0	2
July	30	4	0.586	0.019	6	8	16	0	0	4
August	28	6	0.468	0.015	6	8	14	0	0	6
September	22	12	0.258	0.008	1	6	15	0	1	11
October	30	4	0.712	0.023	3	8	19	1	0	3
Novem	14	20	-0.183	-0.006	1	1	12	0	2	18
December	26	8	0.571	0.019	7	5	14	1	2	5

LOS: Level of Significance; NS: Not Significant

Table 4. Changes in total amount of rainfall in 4 seasons during 1975-2005

Seasons	No. of Station showing increasing trend	No. of Station showing decreasing trend	Increasing Trend (No. of Station)				Decreasing Trend (No. of Station)			
			90 % LOS	95 % LOS	99 % LOS	NS	90 % LOS	95 % LOS	99 % LOS	NS
Winter (Dec. to Feb.)	16	18	2	1	1	12	0	2	2	14
Pre-monsoon (Mar. to May)	20	14	2	2	1	15	1	0	0	13
Monsoon (June to Sept.)	30	4	2	1	3	24	0	0	0	4
Post-monsoon (Oct.-Nov.)	32	2	2	3	4	23	0	0	0	2

LOS: Level of Significance; NS: Not Significant

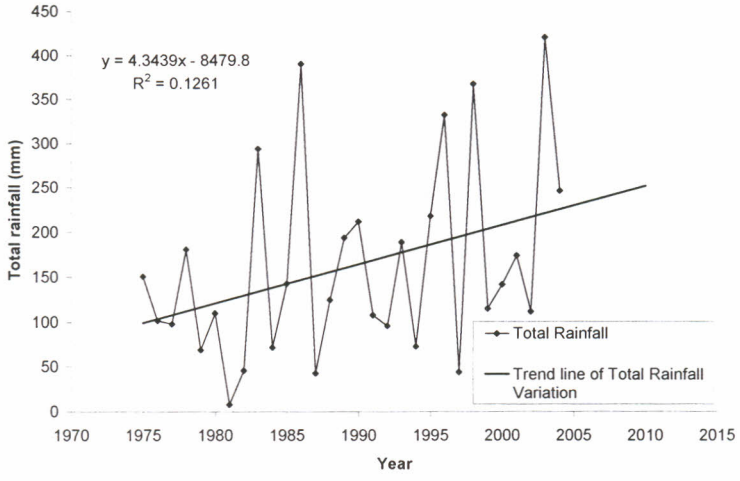

Figure 7. Variation in total rainfall during post-monsoon at Satkhira weather station

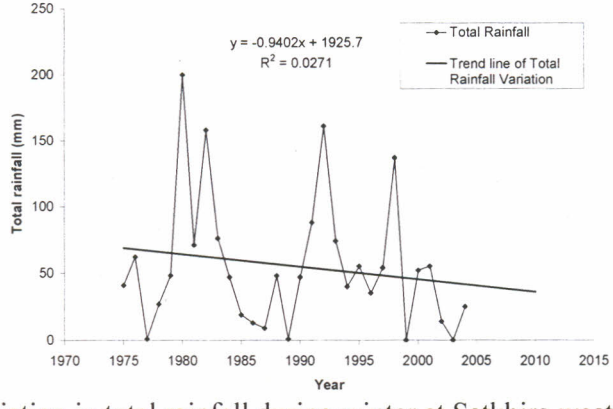

Figure 8. Variation in total rainfall during winter at Satkhira weather station

Conclusion

Temperature and precipitation data of all 34 meteorological stations of Bangladesh for the period 1975-2005 have been analyzed. Analysis of temperature data showed that at majority of these stations, the yearly average maximum and minimum temperatures have increasing trends. Analysis of monthly average maximum temperature also showed increasing trend for all months of the year except January; the increasing trend was particularly significant for the months of June to September. Calculated average increase

in temperature for these months was about 1 °C for the 30-year period from 1975 to 2005. Monthly average minimum temperatures also showed increasing trends for all months except January and November. Average increase in monthly average minimum temperature was about 0.65 °C, while for January and November, average decrease was about 0.2 °C during the same period (i.e., 1975 to 2005). The magnitude of increase in monthly average maximum and minimum temperatures during the 30-year period from 1975 to 2005 is quite significant. Eighteen stations (out of 32) showed increasing trend in number of "hot" days per year, while 13 stations (out of 31) showed decreasing trend in the number of "cold" days per year; however, most of these trends were not statistically significant. Analysis of precipitation data during 1975-2005 showed increasing trend of rainfall for majority of stations during monsoon and post-monsoon seasons, while decreasing trend of total rainfall during winter was found for significant number of weather stations; pre-monsoon (March-May) period did not show any significant change in total rainfall. In general, these trends are consistent with the general climate change predictions. The temperature and precipitation patterns are of great importance for an agro-based economy like Bangladesh. Therefore, it is necessary to regularly and systematically compile, monitor and analyze the relevant climatic parameters.

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