National Seminar on Climate Change Impact and Adaptation

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Changes of Seasonal Temperature Extremes in Future over Bangladesh using Projections by a Regional Climate Model

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ABSTRACT: Temperature is one of the key factors of climate change around the world. Being vulnerable to climate change, Bangladesh will experience special and seasonal differences in change of temperature in the upcoming years. General Circulation Model (GCM) is used for predicting future climate change in coarse resolution. On the other hand, a regional climate model (RCM) is a dynamic downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). GCMs are typically run with horizontal scales > 250km whereas regional models can resolve features down to 50km or less. The paper discusses on change of future special and seasonal temperature using a regional climate model, PRECIS developed by Met office, UK. The SRES A1B scenario is used as a storyline of projection which is balanced in terms of future emissions. Experiment was conducted over a domain with a size of 88 × 88 pixels with a horizontal resolution of 50km. The mean annual increase of maximum temperature over Bangladesh will be 3.11°C and 4.77°C for the period 2050s (2041 to 2070) and 2080s(2071 to 2100) as compared to the baseline period (1971 to 2000), respectively. But during summer season the increase of maximum temperature will be 2.71°C and 4.4°C respectively for those two future periods as compared to the baseline period. The extents of hot days will be increased from summer to spring and late spring. Winter will be much warmer from current days as maximum temperature will increased up to 3.12°C and 4.9°C for those two future periods from baseline period. It will result a significant change in yield of winter crops like potato and wheat. Spatial distribution maps were generated for the country considering future climate. Summer will much hotter in North-West part of the country, results an increase of temperature of about 3.01°C in 2050's period and 4.91°C in 2080's period. On the other hand, in this region, mean temperature of winter will also increase which will reduce the coldness. It has observed that the diurnal range of temperature will decrease during winter season in future years.

Keywords: *Extreme Indices, GCM, Met office, PRECIS, Projections, Regional Climate Model, Seasonality*.

1. Introduction

According to the fourth IPCC report, with constant increase of concentration of green house gases, the average global temperature will increase through 2100 (IPCC, 2007). Bangladesh is likely to be one of the most vulnerable countries of the world in the event of climate change. A suite of climate change indices derived from daily temperature has made the most up-to-date and comprehensive global picture of extremity of climate change worldwide. The identification and trend analysis of these extremities of temperature has done over whole world in coarse resolution with GCM result (*Alexander et al., 2006*). Different fine resolution analysis using climate extremes have been done for different region of the world (*Thomas et al, 1996; Vincent et al., 2005*). Determination of temperature extreme in fine scale considering seasonal variability is essential for observing future climate. However, no study has been reported for Bangladesh on determining extreme temperature indices using finer resolution climate change projections and focusing seasonal changes of temperature indices.

Adaptation to change will require high-quality climate change information, often with a lot of spatial detail. Global climate models predict large-scale changes in climate but are not yet capable of providing the fine-

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scale information, about areas such as mountains and inland water basins, or representing high-resolution climate phenomena, all of which are needed for some adaptation planning. PRECIS is a Regional climate model which can generate high resolution data from later boundary GCM (global climate model) data. By simulating different scenarios, it can also project future climate in regional scale. An optimum domain of simulation has been selected from the domain size experiment by *Islam et al. (2011*). The validation of the model has been made for the selected domain and found PRECIS is able to capture the seasonal and temporal variability of the climate over this region. In this study, experiments have been conducted on the selected domain with the SRES A1B scenario. The scenario A1B is the most suitable scenarios in considering optimistic future condition in context of Bangladesh as it is the balanced scenario of IPCC. Using daily time series data from the experiments, temperature indices have been analyzed. Finally, seasonal variation of the change of the indices has been determined.

2. Data and Methods

2.1. *Regional climate model data:*

PRECIS (Providing Regional Climate for Impact Studies) is a regional climate model developed by Met office, UK. The PRECIS RCM is based on the atmospheric component of the HadCM3 climate model (Gordon et al., 2000). The selected domain was set over the South Asia with a grid of 88×88 pixels with a horizontal resolution of 50km each (Figure 1). PRECIS experiments have been conducted by Institute of Water and Flood Management (IWFM), BUET using boundary data of a high resolution GCM called "HadCM3". The "HadCM3" was an atmospheric coupled model, which's data set were provided by Met office, UK. PRECIS can generate a number of diagnostic variables consisting temperature, precipitation, relative humidity, wind components, soil moisture, potential evapotranspitation, solar radiation, mean sea level pressure, geopotential heights etc. Among these variables, daily maximum temperature, minimum temperature and precipitation data are selected for further analysis. Data for each grid point over Bangladesh have been extracted from the PRECIS experiments.

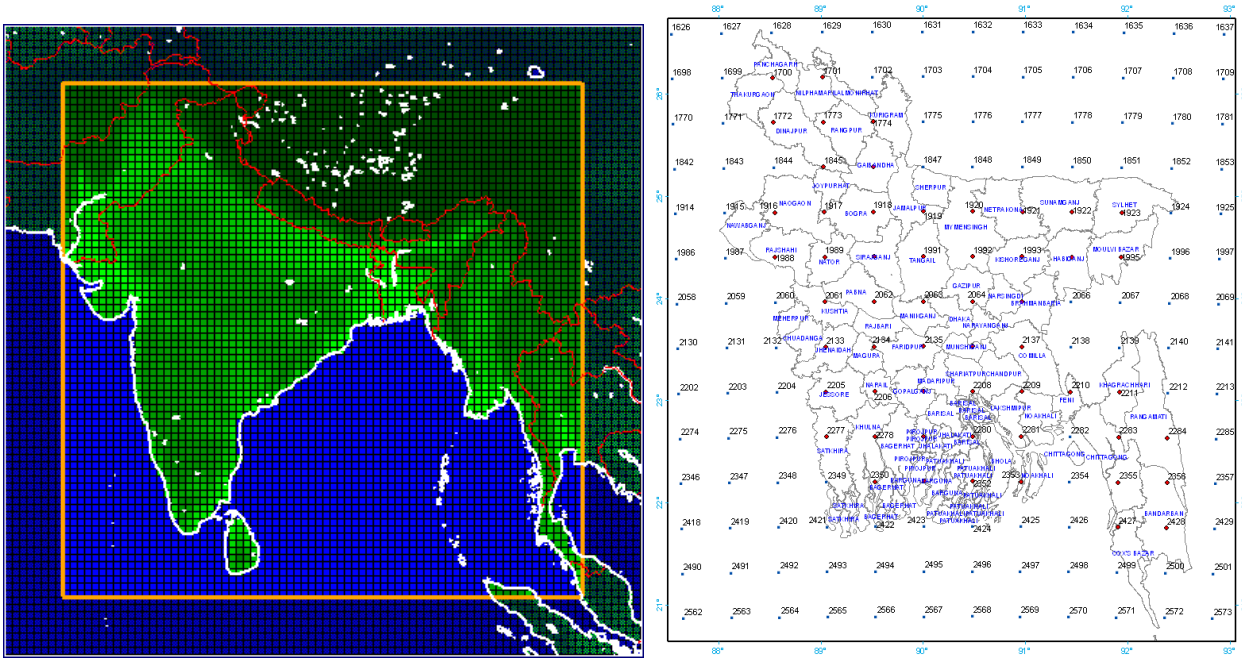

Figure 1 PRECIS domain over south Asia (left) and 55-grid points over Bangladesh (right)

2.2. *Methodology:*

The joint expert team on climate change Detection, Monitoring and Indices (ETCCDMI) developed a standard of extreme indices of climatic parameter. They has developed a software called "RClimdex" to measure these climatic indices easily (available at http://cccma.seos.uvic.ca/ETCCDMI/). Precipitation, maximum temperature and minimum temperature value obtained from PRECIS experiments, have been used as input parameters in the software. Temperature extreme indices as listed in the Table 1 were calculated for each of the grids points inside side Bangladesh using RClimdex. Indices have been further classified into four seasons: winter (December to February), summer (March to May), rainy (June to September) and late-autumn (October to November).

Table 1 List of Indices used in the study

Index	Description	Definition
DTR	Diurnal temperature range in ºC	Monthly mean difference between TX and TN
TXx	Maximum Daily maximum Temperature in ºC	Monthly maximum value of daily maximum temperature
TNx	Maximum Daily Minimum Temperature in ºC	Monthly maximum value of daily minimum temperature
TXn	Minimum Daily Maximum Temperature in ºC	Monthly minimum value of daily maximum temp temperature
TNn	Minimum Daily Minimum Temperature in ºC	Monthly minimum value of daily minimum temperature
TMAXmean	Maximum Daily Mean Temperature in ºC	Monthly maximum value of daily mean temperature
TMINmean	Minimum Daily Mean Temperature in ºC	Monthly minimum value of daily mean temperature
SU25	Number of summer days	Annual count when TX(daily maximum)>25ºC
TR20	Number of Tropical nights	Annual count when TN(daily minimum)>20ºC

3. Results and Discussions

3.1. Seasonal variability

Daily maximum temperature and minimum temperature have been analyzed for a 30 year mean period from 1961-1990 as baseline period and three future so called time slices of 2020s (2011-2040), 2050s (2041-2070) and 2080s (2071-2100). Table 2 presents statistics of the mean changes of daily maximum and minimum temperature over Bangladesh for baseline and three future time slices. It has been found that summer of future time slices will more hot compare to other seasons. It will have a temperature rise of 4.32 ºC for 2080s compared to the baseline period. This rise of temperature can lead to more health related problems (heat stroke) in the country. Considering standard deviations of the maximum temperature, variability of maximum temperature will be increased during monsoon season at the end of 21st century. That will make sudden rise of hot day temperature in monsoon season along with high humidity in the air. In context of minimum temperature, coldness of the winter season will be gradually decreased in future. However, the annual variability of minimum temperature will be higher than maximum temperature.

Table 2 Characteristics of simulated seasonal and annual mean temperature for Bangladesh using SRES A1B scenarios as simulated by of PRECIS

	Mean of Max. Temperature (ºC)					Standard dev. of Max. Temperature (ºC)				
	DJF	MAM	JJAS	ON	Annual	DJF	MAM	JJAS	ON	Annual
1980s	23.23	35.01	32.18	27.28	29.86	3.42	4.21	2.72	3.14	5.64
2020s	24.75	36.17	33.24	28.82	31.14	3.54	4.36	2.86	3.61	5.62
2050s	26.67	37.70	34.67	31.10	32.86	3.34	4.24	3.61	3.30	5.51
2080s	28.61	39.33	35.98	32.41	34.43	3.63	4.33	4.00	3.16	5.55
	Mean of Min. Temperature (ºC)					Standard dev. of Min. Temperature (ºC)				
1980s	9.68	24.36	25.84	17.87	20.15	3.99	3.87	1.19	4.45	7.39
2020s	11.77	25.77	26.98	19.85	21.74	4.10	3.63	1.18	4.56	7.06
2050s	13.62	27.25	28.12	21.59	23.24	4.13	3.44	1.66	4.20	6.70
2080s	15.25	28.64	29.22	23.07	24.64	3.88	3.24	1.79	4.12	6.58

3.2. Annual Cycles

Constantly increase of temperature has been found through the annual cycle based on month maximum and minimum temperature over Bangaldesh (Figure 1). Though there is a month by month variation of the increase of temperature, the pattern of increase is steady throughout the end of the 21st century. Maximum temperature of the summer season will increse the most comapre to the other seasons of the year. During winter season, minum temperature will be rised prodimanantly than other seasons of the year. Rise of the minumum temperature in winter will effect the yield of cold loving crops (e.g. wheat, potatao etc.). On the other hand, winter will not be very cold although variability of maximum and minimum temperature will be increased.

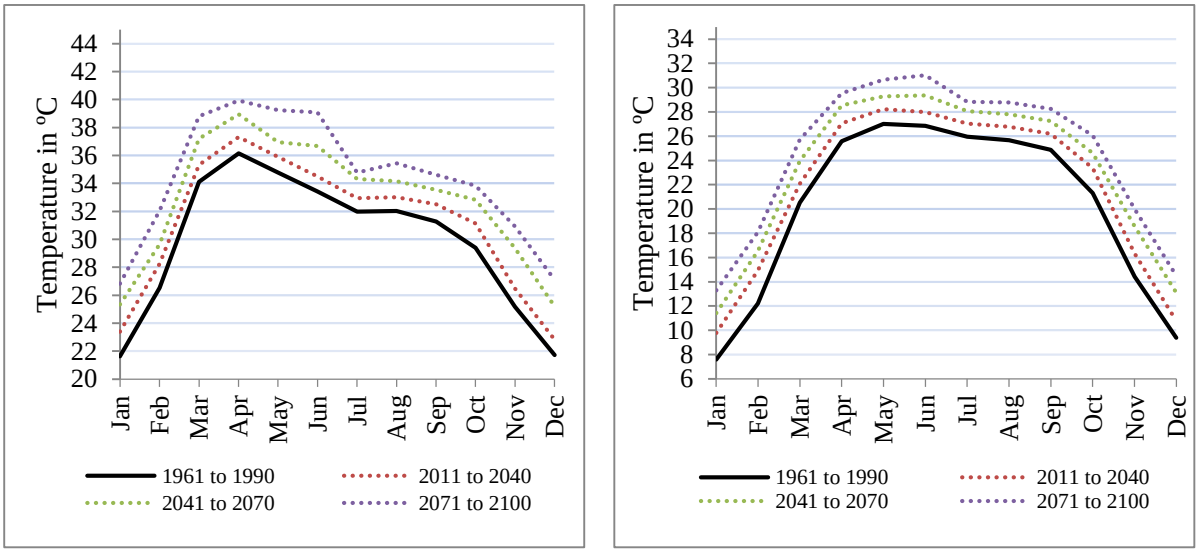

Figure 1 Annual cycle of daily maximum temperature (left) and minimum temperature (right) over Bangladesh for baseline period and three future time slices.

3.3. Extreme Weather Events

Changes of extreme weather events can provide idea about the possible changes required for the adaptation and mitigation measures. A total of nine extreme indicators have been determined by analysis daily time series data from the regional climate model for the baseline and three future time slices. Seasonal changes of the extreme weather events has been quantified and presented spatially for Bangladesh.

3.3.1 Spatial Patterns

Spatial patterns of changes of number of summer days (temperature>25ºC) and tropical nights for three future time slices from baseline period have been shown in Figure 2. In the north part of Bangladesh, especially in the Kurigram and Nilphamari, the change of numbers of summer days is less comparative to that of the south part of the country. But for Panchagar district, though summer days will increase less, number of tropical nights will be rapidly increased in future periods. This means, in that region, temperature will not drop so much and result a constant hot weather for a long period of a day. In the north of Netrokona district, number of warm nights will experience an increasing trend in future periods. This trend is much more prominent than the other part of the country. In the northwest side of the country, the area can have up to 88 days or more numbers of tropical nights. Changes of summer days and tropical nights will not be very significant for the north central parts of the country. So temperature difference of two portions may form air depression result some thunderstorm in the area.

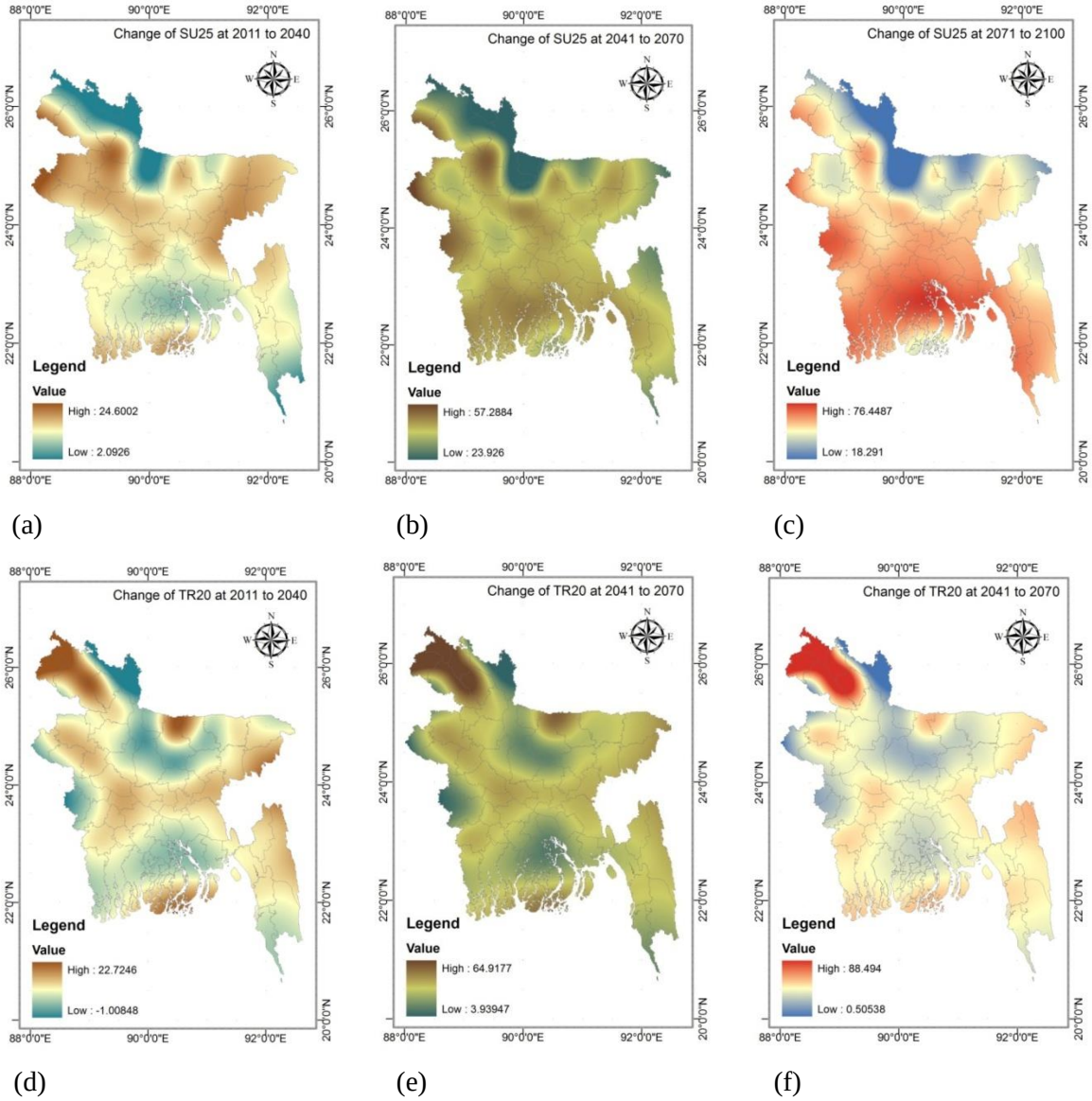

Figure 2 Spatial patterns of changes in annual numbers of summer days, SU25 (top) and tropical nights, TR20 (bottom) for 2020s, 2050s and 2080s minus baseline, respectively (left to right).

Maximum daily temperature and minimum daily temperature are important parameters for the yield of

different kinds of crops production of Bangladesh. Change of maximum temperature in any seasons may result reduction of crop production. For day time, temperature change can be high as 4 ºC to 5 ºC during the summer season. So high temperature will cause mango or other fruit rip earlier, resulting less amount and quality of production. Similarly, minimum temperature change can also result less amount of yield in any season especially for the cold loving crops. Changes of spatial patterns of the one day maximum and minimum temperature for three future time slices from baseline period have been shown in Figure 3 and Figure 4, respectively. It has been found that single day maximum temperature will increase more in the south parts of the country than north in future periods. On the other hand, 1-day minimum temperate shows opposite trend. Extremes of minimum temperature in the north and central parts will increase more than south parts of the country in future.

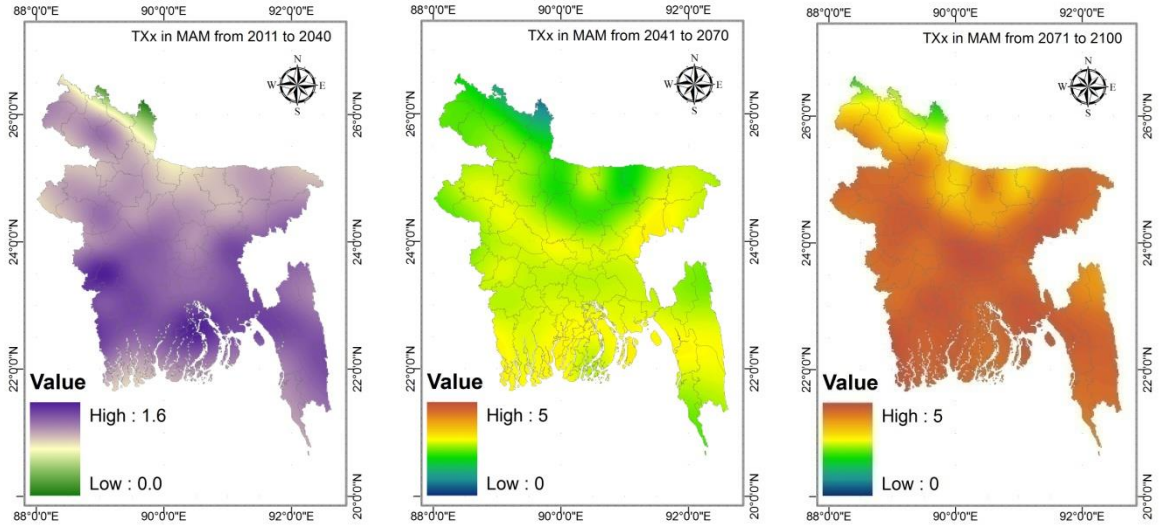

Figure 3 Spatial distribution of changes of the TXx (1-day maximum temperature in ºC) over Bangladesh for 2020s, 2050s and 2080s minus baseline, respectively (left to right).

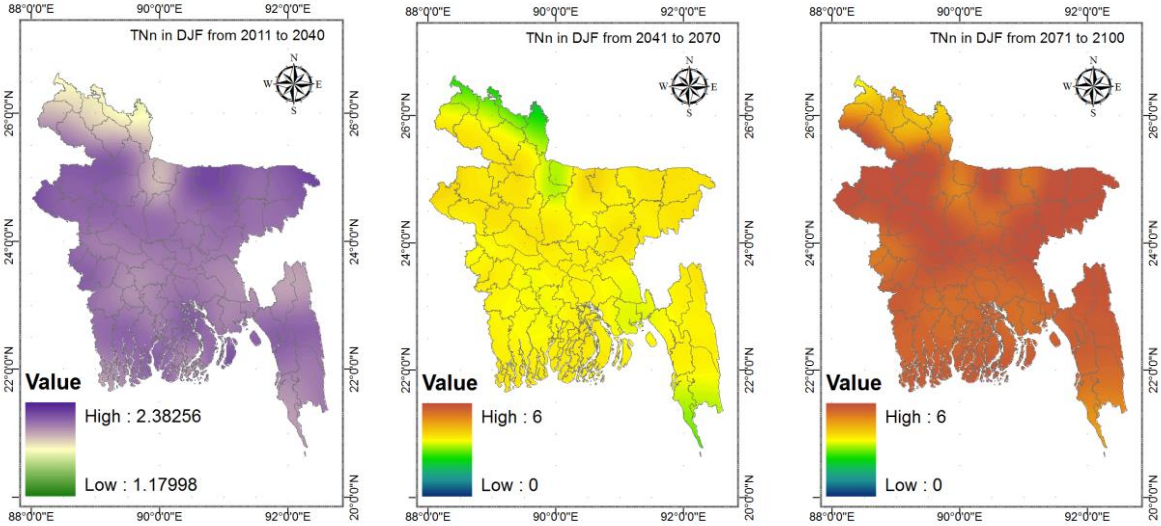

Figure 4 Spatial distribution of changes of the TNn (1-day minimum temperature in ºC) over Bangladesh for 2020s, 2050s and 2080s minus baseline, respectively (left to right).

3.1.3 Seasonal Changes

Changes of maximum and minimum temperature for each season have been examined for future periods. Figure 5 shows seasonal bar charts of the changes maximum and minimum temperature over Bangladesh for three future periods from baseline period. It has been found that during late autumn (post-monsoon) season, increase of daily maximum temperature will be the highest for all future periods. On the other hand, during summer season, change will be about 2.8ºC increase for 2050's and about 4.5ºC increase for 2080's. During winter season, changes of maximum temperature are about 3.2ºC and 5ºC for 2050s and 2080s, respectively. However, change of minimum temperature will be highest during the winter season which is about 3.7ºC increase for 2050s and 5.5ºC increase for 2080s.

Trends of annual maximum and minimum temperature have been determined for Bangladesh (Figure 5). The annual maximum temperature will rise at a rate of 0.046ºC per year whereas minimum temperature will rise at a rate of 0.051ºC. The rise of minimum temperate is higher than maximum temperature which will impact various sectors (agriculture, fisheries, livestock, health, water resources, energy etc.) of the country in future.

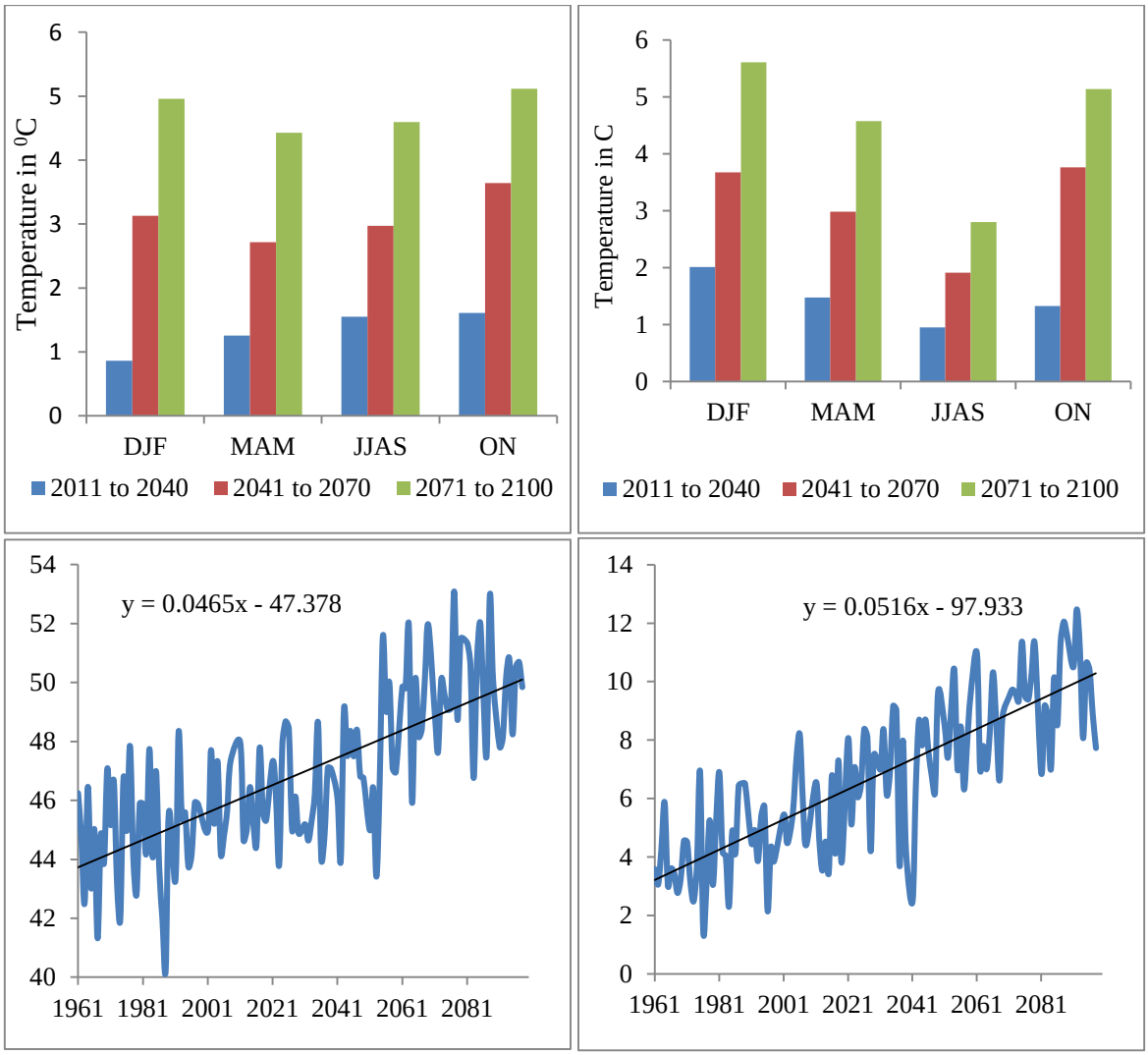

Figure 5 Season wise changes of daily maximum and minimum temperature over Bangladesh for three future periods from baseline period, respectively (top; left to right). Trends of the yearly maximum and minimum temperature over Bangladesh, respectively (bottom; left to right).

3.1.3 Diurnal Changes

Changes of diurnal temperature ranges have been quantified for each season for three future periods from baseline period. Figure 6 shows changes of diurnal ranges during four seasons over Bangladesh. It has been found that diurnal ranges will increase in the monsoon and post monsoon season whereas it will decrease in the winter and summer season. However, there is no significant trend found in the mean annual diurnal temperature range in future.

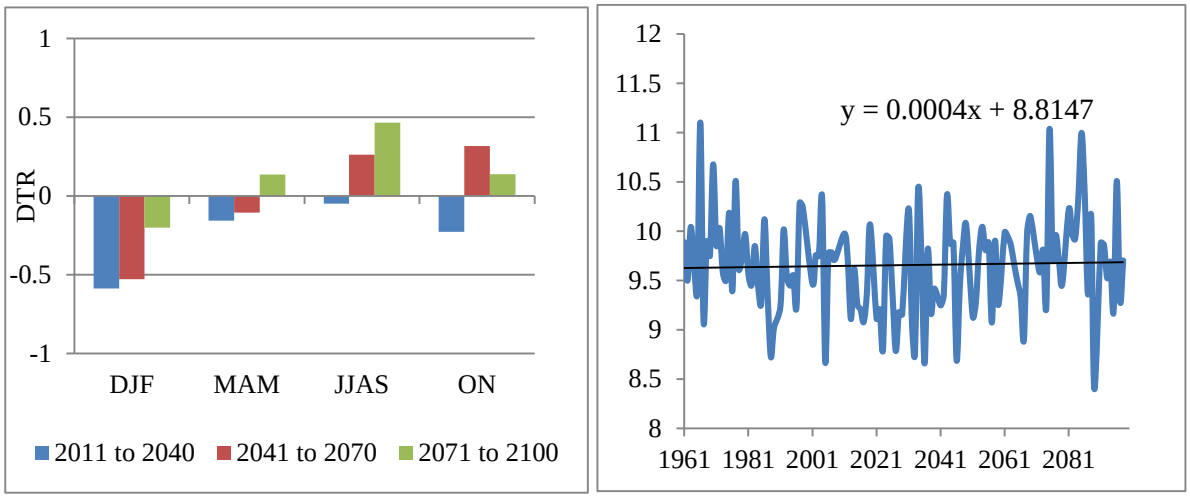

Figure 6 Season-wise changes of diurnal temperature range during four seasons for three future periods from the baseline period (left). Trends of mean annual diurnal temperature range over Bangladesh (right).

4. Conclusion

This study focuses on revealing the changes of extreme temperature considering regional scale plausible changes of future climate. A number of major conclusions can be within the limited scope of this study-

- Monthly maximum and minimum temperature will rise throughout the end of the 21st though it varies month by month. Maximum temperature will rise more predominantly in summer whereas minimum temperature will rise mostly in winter.
- In the context of maximum temperature, summer of future time slices will more hot (about rise of 4.32 ºC for 2080s from the baseline period) compare to other seasons. This will possibly put stress on human health, effect on crop production, create imbalance to the ecosystem and increase energy demand of the country.
- It has also found that tropical nights will be increasing more rapidly than summer days.
- In context of minimum temperature, coldness of the winter season will be gradually decreased in future.
- Change of minimum temperature will be highest during the winter season. This will reduce yield of the cold loving crops (e.g. wheat, potato, etc.)
- Diurnal temperature of range of monsoon will be increased where as that of winter period will be reduced.

Acknowledgement

The authors would like to acknowledge the Hadley Centre, Met Office, UK, for providing PRECIS software and lateral boundary data of the GCM (HadCM3).

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