Generation of PRECIS scenarios for Bangladesh: Validation and Parameterization

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Climate Change Cell
Department of Environment

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Foreword

The impacts of global warming and climate change are worldwide. For Bangladesh they are most critical because of its geographical location, high population density, high levels of poverty, and the reliance of many livelihoods on climate-sensitive sectors, such as agriculture, fisheries.

To address current impacts and manage future risks of climate change and variability towards development of a climate resilient Bangladesh, the government has established the Climate Change Cell (CCC) in the Department of Environment (DoE) under the Comprehensive Disaster Management Programme (CDMP). Climate change research, covering modeling and adaptation is one of the major activities of the Cell.

CCC in association with its Technical Advisory Group (TAG) and other stakeholders identified a set of research activities related to climate change in Bangladesh through a number of consultations. The activities have been prioritized and a number of projects have been commissioned in last few years.

Bangladesh is prone to various natural hazards and calamities including seasonal flood, flash flood, storm, cyclone etc. It is predicted that impacts of climate change will increase the intensity, frequency and magnitude of hazards leading to more frequent disasters. Natural disaster can not be prevented or controlled but advance knowledge of its occurrence is very much important for national disaster planners. However, to understand impacts of climate change on occurrences of future disaster events and to treat risks originating from such events modeling exercises are being practiced worldwide to predict impacts of climate change. In Bangladesh, Climate modeling has been introduced very recently. Cell undertook several initiatives to provide model output of the impacts of climate change to the relevant institutions and stakeholder groups in Bangladesh.

The study developed climate change scenarios using PRECIS for Bangladesh. Rainfall and temperature scenarios have been generated for 2030-31, 2050-51 and 2070-71 using ECHAM4 SRES A2 Emission as model input. The study decisively disclosed that PRECIS is very much successful for seasonal forecasting of meteorological parameters like rainfall and temperature.

The study revealed that in Bangladesh dry season rainfall will remain closer to historical amount whereas pre-monsoon rainfall will be of mixed pattern. The monsoon and post-monsoon rainfall will increase in all years, however from 2051 and onwards monsoon rainfall will follow higher increasing trend. Regarding temperature, the study showed that average maximum temperature will increase in monsoon period and will decrease in other periods while monthly average minimum temperature will increase in all periods.

It is expected that the research will create a strong link between modeling community and other stakeholders to share research results and needs. However, this study only considers two climatic parameters as a start. Model run involving more climatic parameters and prediction for local level (upazila, union) need to be generated to provide policy makers and planners with appropriate tools to formulate viable adaptation policies, strategies and action plan.

Zafar Ahmed Khan, Ph.D
Director General
Department of Environment

Acronyms and Abbreviations

BD	Bangladesh
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering and Technology
DFID	Department for International Development
DJF	December, January, February
DoE	Department of Environment
IITM	Indian Institute of Tropical Meteorology
JJAS	June July August September
LBC	Lateral Boundary Condition
MAM	March, April, May
NE	North East
NW	North West
ON	October, November
PRECIS	Providing REgional Climates for Impact Studies
RCM	Regional Climate Model
SAARC	South Asian Association for Regional Cooperation
SE	South East
SMRC	SAARC Meteorological Research Centre
SPARRSO	Bangladesh Space Research and Remote Sensing Organization
SPSS	Statistical Package on Social Survey
SW	South West
UNDP	United Nations Development Programme

Table of Contents

List of Tables

List of Figures

The SRES A2 scenarios: The A2 scenarios are of a more divided world. The A2 family of scenarios is characterized by:

- *A world of independently operating, self-reliant nations.*
- *Continuously increasing population.*
- *Regionally oriented economic development.*
- *Slower and more fragmented technological changes and improvements to per capita income.*

Executive Summary

A regional climate modeling systems called PRECIS (Providing REgional Climates for Impacts Studies) is employed to generate projections for rainfall and temperature in 2030, 2031, 2050, 2051, 2070 and 2071 in Bangladesh using ECHAM4 SRES A2 emission scenarios as the model input. Projected annual average rainfall is obtained 6.93, 6.88, 6.84, 7.16, 7.17 and 7.33 mm/d in 2030, 2031, 2050, 2051, 2070 and 2071 respectively whereas the baseline period (1961-1990) rainfall is 6.78 mm/d (deviation from -2.18 to 1.92 mm/d). The important notice is that in Bangladesh, rainfall during monsoon and post-monsoon periods will increase whereas it will remain close to historical amount during dry season. Rainfall during pre-monsoon period will fluctuate in different years. Over the country, rainfall will increase about 4%, 2.3% and 6.7 % in 2030, 2050 and 2070 respectively with reference to the observed baseline period. Monthly average maximum temperature will change from -1.2 to 4.7 °C in 2030, from -1.2 to 2.5 °C in 2050 and from -1.2 to 3.0 °C in 2070. Maximum temperature will increase during monsoon period and it will decrease in other periods. On the other hand, monthly average minimum temperature will increase in all periods and vary from 0.3 to 2.4 °C in 2030, from 0.2 to 2.3 °C in 2050 and from -0.6 to 3.3 °C in 2070. Large increase of temperature is the clear indication of global warming.

Variation of rainfall and temperature (maximum and minimum) in a location over Bangladesh and in a particular month is quite large than the seasonal or annual average. For examples, at Kutubdia rainfall will increase about 26.47 mm/d in June 2030 and it will decrease about 6.58 mm/d in August 2030. Maximum temperature will increase about 5.97 °C at Bogra in June 2030 and it will decrease about 3.51 °C at Khepupara in October 2030. Minimum temperature will increase about 5.67 °C at Faridpur in July 2030 and it will decrease about 4.87 ^{0}C at Jessore in December 2050. The fact is that mean value for a period or in a domain differs from individual month and individual location. A brief summary for change of rainfall and temperatures in different regions of Bangladesh for 2030, 2050 and 2070 is given below.

		2030					2050					2070				
		DJF	MAM	JJAS	ON	Ann	DJF	MAM	JJAS	ON	Ann	DJF	MAM	JJAS	ON	Ann
Rainfall Change (%)	NE	-9.6	9.0	4.2	24.6	7.0	-6.1	-5.2	2.1	22.9	3.4	-1.3	6.4	-5.6	17.0	4.1
	SE	-5.3	3.3	-3.3	14.3	2.3	-6.8	0.5	2.8	11.3	1.9	2.7	6.9	7.7	10.9	7.1
	NW	-17.9	2.0	27.0	4.6	3.9	-0.2	-4.5	15.6	4.5	3.9	5.8	9.8	14.8	5.3	8.9
	SW	-3.6	-2.9	-5.5	19.8	2.0	-4.1	-6.3	-5.8	17.0	0.2	1.3	7.7	3.9	17.7	7.6
	BD	-8.7	4.1	3.8	16.6	4.0	-4.7	-3.5	3.0	14.5	2.3	1.8	7.4	4.6	13.2	6.7
Maximum Temperature Change (^{0}C)	NE	0.22	-0.05	-0.26	-0.33	-0.10	0.42	0.16	0.02	-0.21	0.12	0.48	0.15	-0.01	-0.33	0.10
	SE	0.10	0.56	0.70	-0.59	0.30	0.17	0.70	0.20	-0.47	0.21	0.32	0.68	0.60	-0.58	0.35
	NW	-0.31	0.03	0.16	-0.26	-0.06	-0.58	0.02	0.11	-0.13	-0.13	-0.75	-0.08	-0.04	-0.24	-0.26
	SW	-0.12	0.09	0.30	-0.90	-0.06	-0.23	0.21	0.07	-0.95	-0.14	-0.35	0.06	0.26	-0.85	-0.13
	BD	-0.03	0.16	0.23	-0.52	0.02	-0.05	0.27	0.10	-0.44	0.01	-0.08	0.20	0.20	-0.50	0.02
Minimum Temperature Change (^{0}C)	NE	0.20	0.69	0.48	0.13	0.40	0.02	0.79	0.53	0.32	0.43	-0.05	1.21	0.85	0.24	0.61
	SE	0.27	0.41	0.78	-0.46	0.35	0.18	0.40	0.80	0.17	0.44	0.02	0.78	1.60	0.13	0.76
	NW	0.06	0.42	0.69	0.20	0.38	-0.09	0.53	0.87	0.39	0.46	-0.13	0.75	1.29	0.30	0.64
	SW	0.01	0.40	0.62	0.33	0.36	-0.25	0.35	0.76	0.90	0.43	-0.59	0.71	1.45	0.29	0.56
	BD	0.13	0.48	0.64	0.05	0.37	-0.03	0.52	0.74	0.44	0.44	-0.19	0.86	1.30	0.24	0.64

To obtain the projected rainfall and temperature (maximum and minimum), firstly a Look-up table is prepared with reference to the observed data during baseline period 1961-1990. Using the prepared Look-up table PRECIS generated scenarios is validated for 1989, 1990, 2000 and 2001. This work revealed that use of Look-up table facilitates a lot for the validation of PRECIS outputs. Validation is found significant 99 % level for the mentioned years. In addition to this, validation is carried out for continuous 7 years from 2000 (2000-2006). It is found that PRECIS over-performed by only 4.471% in estimating rainfall over Bangladesh. This admirable performance of PRECIS encourages using it for projection of rainfall in Bangladesh. This work decisively disclosed that PRECIS is very much successful for seasonal forecasting of meteorological parameters like rainfall and temperature (maximum and minimum) in Bangladesh. Monthly projections are also considerable to use with a minor limitation. It is pointed out here that Look-up table facilitated to make useful PRECIS outputs in application purposes. Direct use of PRECIS outputs are not suggested without help from Look-up table.

1. Scope of the Work

Climate change is recognized as the greatest long-term threat to the World and particularly to the SAARC region. The economic impact of climate change, rising food prices and assessment of food security are key issues to discuss. It is accounted that in the SAARC countries 21% of world population resides on only 4% of the world's total physical area. In this connection proper planning and judicious management of water resources are essential for this region. Long-term planning is impossible without any idea of the climate change. Now-a-days regional climate models (RCMs) are becoming useful tools in generating future climate scenarios. The question is how to utilize the model generated scenarios for application purposes. It is well known that model outputs are not free from uncertainties. In spite of certain uncertainties, model outputs are only the candidates for planners in national interest because model is merely the tool that can provide some information beyond the real time. Therefore, preparation of Look-up Table for climatic parameters like rainfall and temperature (maximum and minimum) is considered. The Look-up Table will be very useful to validate model outputs and in utilizing the model generated future scenarios to the end users.

2. History of PRECIS in Bangladesh

Providing REgional Climates for Impacts Studies (PRECIS) is a regional climate modeling system developed by the Hadley Centre, UK. A training workshop on PRECIS was held on 21-24 July 2004 in Bhutan. Participants from BUET (Bangladesh University of Engineering & Technology) and SPARRSO (Space Research and Remote Sensing Organization) took part in the said workshop. After that a working group from Bangladesh took part in the informal workshop (24-28 February 2005) on PRECIS at IITM, Pune, India. In the working group participants are from BUET, BMD (Bangladesh Meteorological Department), SPARRSO and SMRC (SAARC Meteorological Research Center). There after PRECIS is installed in PC at BUET. The PC is provided by the Department of Environment (DoE), Ministry of Forest and Environment, the Peoples' Republic of Bangladesh with cooperation of UNDP and DFID. The Department of Physics, BUET updated PRECIS with its latest version 1.5.1 from Hadley Centre and working on it since 2005 besides other modeling activities.

3. Methods of Work

Taking the aim of preparation of Look-up Table in mind, data were gathered for rainfall, maximum and minimum temperature from PRECIS outputs and Bangladesh Meteorological Department observed data for the base line period of 1961-1990. Model outputs are 50 km ×50 km grided format whereas observed data are text format at 31 sites throughout Bangladesh. For the calibration of PRECIS outputs, required data for rainfall and temperature (maximum and minimum) are extracted at 31 observation sites. On the other hand, observed data are grided using Kriging method to compare areal averages for mentioned parameters with model data. Among them, best method is selected as described by Islam *et al*. (2008). Then calibration of PRECIS is completed using point-to-point method and Look-up Table is prepared for monthly, seasonal and annual values of rainfall, maximum and minimum

temperatures for the entire country using statistical technique. Regression analysis is performed using model and observed data at each station and every month. Regression slopes and constants are utilized in validation purposes.

In the next step PRECIS was run (50 km ×50 km resolution) for the year 2000-2006, 2030-2031, 2050-2051 and 2070-2071. Model run starts from December of the previous years in each slot. One may consider the one year spin-up time from the beginning of model run for the application purpose of model outputs. Using the prepared Look-up table, model generated parameters is validated for 1989, 1990, 2000, 2001 and 2000-2006. The level of significance is also tested for 1989, 1990, 2000 and 2001 using statistical method (SPSS). The calibration factor obtained through regression analysis is used for the estimation of parameters from PRECIS generated future scenarios. To understand PRECIS performance, the estimated rainfall for 2000-2006 is validated with rain-gauge rainfall. Finally projection of rainfall and temperature are obtained for the years 2030-2031, 2050-2051 and 2070-2071.

4. Results

4.0. Necessity of Look-Up Table:

The model simulated parameters like rainfall and temperature are not able to use directly in application purposes. The reason is that model generated parameters are not free from uncertainties. Even uncertainties are there, till to date, there are no alternatives to predict meteorological variables in advance without any help from model. It is to be remembering that meteorological parameters are complex and completely nature dependent. Till to date, there is no way to control the meteorological parameters. Therefore, climate models are used as one of the prediction tools considering the limitations. In Fig. 1 comparison of temperature obtained from observed data and model simulation is shown. Maximum temperature (Tmax) under-calculated from October to February but followed the historical annual cycle (upper panel). Overall, in annual scale Tmax was under-calculated about 1.35 °C by the model. On the other hand, Tmin calculated by the model was very close to observed value (lower panel). In annual scale model under-calculated Tmin by about 0.04 °C whereas Tmin was over-calculated from March to August.

Comparison of rainfall obtained from observed data and model simulation is shown in Fig. 2. There is a substantial difference between rainfall amounts obtained from both data sources in different months. It does not mean that we can not use model outputs because two different tools never can measure the same. From this point of view, we have to find the suitable way of utilizing simulated outputs and preparation of Look-up table is one of the techniques to make use of the model generated scenarios in application purposes throughout this research.

Not only in the measurement of accumulated value, can similar happen for spatial distribution of meteorological parameter like rainfall and temperature. Therefore, preparation of Look-up table for rainfall and temperature are very essential, which are obtained through this project. Figure 3 shows the distribution of daily observed rainfall for the monsoon (JJAS) period averaging from 1961-1990. It is obvious that rainfall amounts in NE and SE regions are large compared to western part of the country. In the same way the plot of PRECIS simulated rainfall for JJAS is shown in Fig. 4. It is seen that PRECIS simulates well the trend of rainfall: in the NE, SE and Southern parts of the country, although the simulated rainfall amounts are

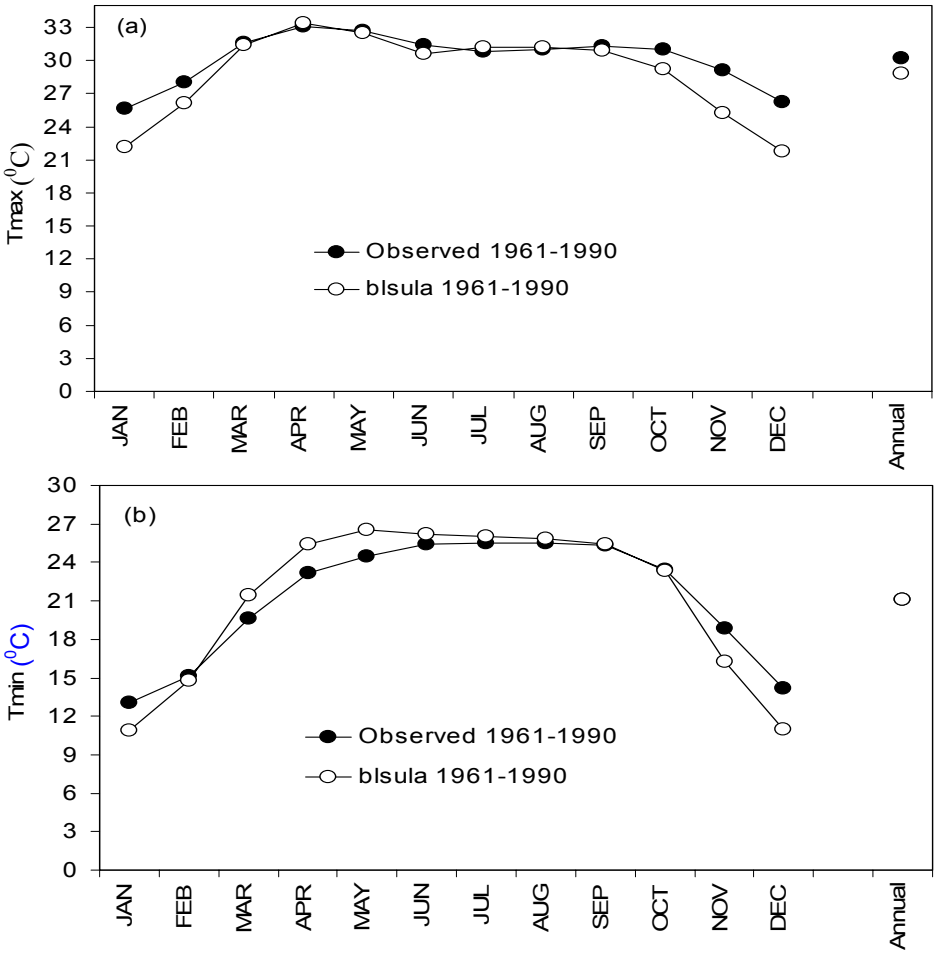


Figure 1: PRECIS simulated monthly (a) maximum temperature and (b) minimum temperature with observed data averages for 1961-1990 over the country.

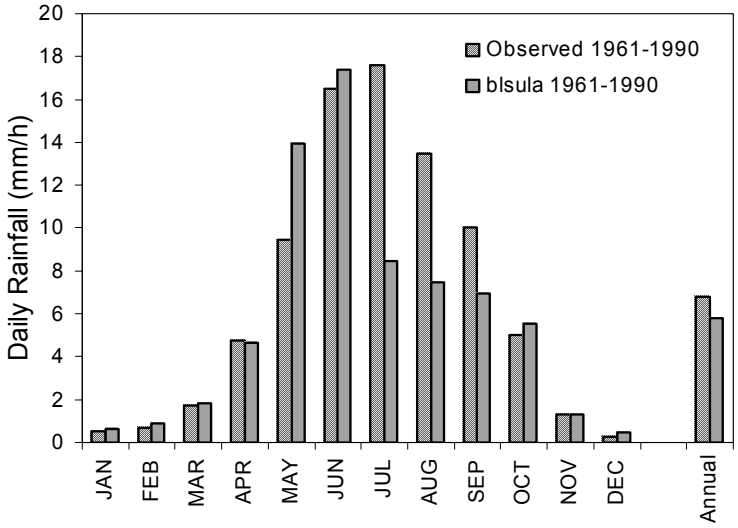


Figure 2: PRECIS simulated monthly rainfall with observed data averages for 1961-1990 over the country.

not same. The western part of the country is relatively dry, which simulated well by the model. The concern points are that, the distribution patterns are somehow similar but the

amounts are not same. As mentioned earlier, two different measurements never obtain same amounts. The proposed Look-up table can bridge the model and observed data. Therefore, preparation of Look-up table is very essential for the utilization of PRECIS scenarios. Hence, our final target of this study is to prepare a Look-up table and utilize it in projecting rainfall and temperature for Bangladesh.

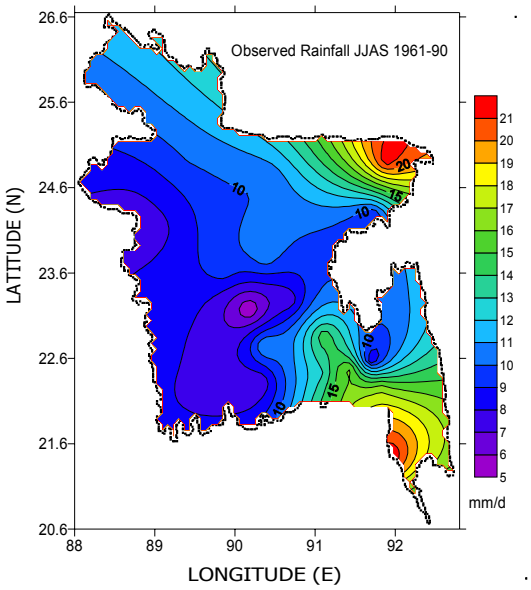


Figure 3: Spatial distribution of observed rainfall averages for 1961-1990.

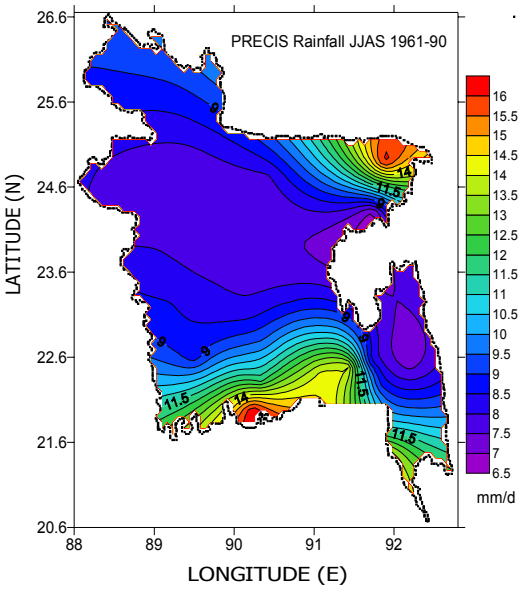


Figure 4: Spatial distribution of PRECIS simulated rainfall averages for 1961-1990.

4.1. Preparation of Look -Up Table:

This subsection describes the preparation of Look-up table for both rainfall and temperature (maximum and minimum).

4.1.1. Rainfall

Table 1 shows the daily rainfall amounts for corresponding months and seasons including annual average. The values are obtained averaging 1961 to 1990 for observed and model data. The value of K_{RF} called correction factor indicates the difference between rainfall measured by model outputs and observation. This means that there is a bias in simulation of rainfall that is defined by the correction factor. The positive correction factor means the model overestimated in simulation of rainfall and vice versa. Therefore, to obtain the real amount of rainfall this correction factor KRF is to be subtracted or added from the projected value depending on the location in the country. Consequently, rainfall scenarios may be utilized for rainfall projection RFprojection in Bangladesh using the equation (Islam et al., 2008) proposed below:

$$RF_{projection} = RF_{scenario} \pm C_{RF} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Table 1: Look-up Table for rainfall (mm/day) in Bangladesh.

	Obs. RF 1961-90	Model RF 1961-90	K_{RF}
DEC	0.26	0.46	0.20
JAN	0.51	0.62	0.11
FEB	0.67	0.87	0.19
MAR	1.74	1.84	0.10
APR	4.77	4.65	-0.11
MAY	9.43	13.95	4.52
JUN	16.49	17.39	0.90
JUL	17.62	8.44	-9.18
AUG	13.48	7.49	-5.98
SEP	10.03	6.97	-3.06
OCT	5.02	5.52	0.50
NOV	1.29	1.28	-0.01
DJF	0.48	0.65	0.17
MAM	5.31	6.81	1.50
JJAS	14.40	10.07	-4.33
ON	3.16	3.40	0.25
Annual	6.78	5.79	-0.99

4.1.2. Maximum Temperature:

In the same way of rainfall as explained in subsection 4.1.1, a Look-up for maximum temperature with correction factor is prepared for Bangladesh (Table 2). Monthly, seasonal and annual temperatures are determined from observed and model data with the correction factor K_{TX} for maximum temperature. Therefore, maximum temperature scenarios may be utilized to obtain projection of maximum temperature TXprojection in Bangladesh using the equation proposed below:

$$TX_{projection} = TX_{scenario} \pm K_{TX} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Table 2: Look-up Table for maximum temperature (^{0}C) in Bangladesh.

	Obs Tmax 1961-90	Model Tmax 1961-90	K_{TX}
DEC	26.24	21.77	-4.46
JAN	25.67	22.16	-3.51
FEB	28.07	26.19	-1.88
MAR	31.63	31.46	-0.16
APR	33.07	33.45	0.38
MAY	32.74	32.52	-0.22
JUN	31.43	30.60	-0.83
JUL	30.79	31.23	0.44
AUG	31.04	31.19	0.15
SEP	31.35	30.90	-0.45
OCT	31.03	29.27	-1.75
NOV	29.12	25.25	-3.86
DJF	26.66	23.37	-3.28
MAM	32.48	32.48	-0.00
JJAS	31.16	30.98	-0.17
ON	30.07	27.26	-2.81
Annual	30.18	28.84	-1.35

4.1.3. Minimum Temperature:

In the same way of maximum temperature correction factor, a Look-up for minimum temperature correction factor is prepared for Bangladesh (Table 3). Monthly, seasonal and annual temperatures are determined from observation and model simulation with the correction factor K_{TN} for minimum temperature. Therefore, minimum temperature scenarios may be utilized to obtain projection of minimum temperature $TN_{projection}$ in Bangladesh using the equation proposed below:

$$TN_{projection} = TX_{scenario} \pm K_{TN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Table 3: Look-up Table for minimum temperature (^{0}C) in Bangladesh.

	Obs Tmin 1961-90	**Model Tmin 1961-90**	K_{TN}
DEC	14.17	10.95	-3.21
JAN	13.04	10.86	-2.17
FEB	15.12	14.80	-0.32
MAR	19.64	21.45	1.82
APR	23.20	25.41	2.21
MAY	24.46	26.52	2.06
JUN	25.44	26.16	0.72
JUL	25.47	26.06	0.59
AUG	25.54	25.83	0.28
SEP	25.31	25.43	0.12
OCT	23.41	23.38	-0.03
NOV	18.84	16.28	-2.57
DJF	14.11	12.21	-1.90
MAM	22.44	24.46	2.03
JJAS	25.44	25.87	0.43
ON	21.13	19.83	-1.30
Annual	21.14	21.09	-0.04

4.2. Utilization of Look-Up Table

In subsection 4.1 the utilization of prepared Look-up table for the projected rainfall, maximum temperature and minimum temperature are outlined. The equations 1-3 are tested for validation of model outputs (not shown) and found not much suitable to project rainfall and temperature because the coefficients will remain constant over the future decades and deviation from baseline is too large. For the better utilization of future scenarios in application purposes, more scientific procedure is cited in this subsection 4.2.

4.2.1. Rainfall:

Statistically, regression procedure is utilized to calibrate one unknown parameter with reference to the known one. The general regression equation has the form y = c + mx, where the m and c represent for gradient/slope and constant respectively. For the estimation of rainfall from model generated future scenarios, the regression equation is proposed below:

$$\text{Estimated}_{RF} = c_{RF} + m_{RF}\,(\text{Scenario}_{RF}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where, $Estimated_{RF}$ is the rainfall to project, m_{RF} is the slope for rainfall, $Scenario_{RF}$ is the model generated scenarios and c_{RF} is a constant value for rainfall. Examples of m_{RF} and c_{RF} at different locations in Bangladesh for the month of July and averages for 1961-1990 are shown in Fig. 5. Allover the country, the m_{RF} and c_{RF} values in different months, seasons and annual scale are presented in Table 4. There is a clear variation in different places and in different seasons.

4.2.2. Maximum temperature:

The projection of maximum temperature is proposed below:

$$Estimated_{TX} = c_{TX} + m_{TX}\,(Scenario_{TX}) \quad \text{..... (5)}$$

Here the subscripts TX represents for maximum temperature. Figure 6 shows the same of Fig. 5 except for maximum temperature. The values for m_{TX} and c_{TX} are also shown in Table 4.

4.2.3. Minimum temperature:

The projection of minimum temperature is proposed below:

$$Estimated_{TN} = c_{TN} + m_{TN}\,(Scenario_{TN}) \quad \text{..... (6)}$$

Again the subscript TN represents for minimum temperature. In Fig. 7, the values of m_{TN} and c_{TN} for minimum temperature are shown similar to Fig. 6. For different months and seasons the values of m_{TN} and c_{TN} are also tabulated in Table 4.

Table 4. Look-up table for Rainfall and Temperature.

	Rainfall		Maximum Temperature		Minimum Temperature	
	m_{RF}	c_{RF}	m_{TX}	c_{TX}	m_{TN}	c_{TN}
JAN	0.05	0.47	-0.17	29.32	-0.16	14.93
FEB	-0.11	0.75	0.11	25.32	0.10	13.59
MAR	-0.10	1.86	-0.12	35.27	0.37	11.50
APR	0.30	3.50	0.01	32.40	-0.07	25.12
MAY	-0.03	9.67	0.21	25.26	0.19	19.41
JUN	-0.05	17.22	0.23	26.66	0.37	15.50
JUL	0.16	16.03	0.19	25.09	0.76	5.61
AUG	0.50	9.78	0.03	30.31	0.47	13.22
SEP	0.12	9.18	0.07	29.30	0.29	17.70
OCT	-0.24	6.10	-0.25	38.43	-0.08	25.40
NOV	0.13	1.11	0.07	27.38	0.23	14.79
DEC	0.10	0.22	0.06	24.85	-0.02	14.60
DJF	0.01	0.48	0.00	26.50	-0.03	14.37
MAM	0.06	5.01	0.03	30.97	0.16	18.68
JJAS	0.18	13.05	0.13	27.84	0.47	13.01
ON	-0.06	3.61	-0.09	32.90	0.08	20.09
Annual	0.07	6.32	0.04	29.13	0.20	15.95

Note: The value of slope (m) and constant (C) for Bangladesh averages from 26 stations throughout the country. The subscripts RF, TX and TN are for rainfall, maximum temperature and minimum temperature respectively.

Using Look-up table 4, estimated rainfall and temperature are obtained for the validation of model generated scenarios. Information gathered throughout validation is utilized in obtaining projected rainfall and temperature as discussed later.

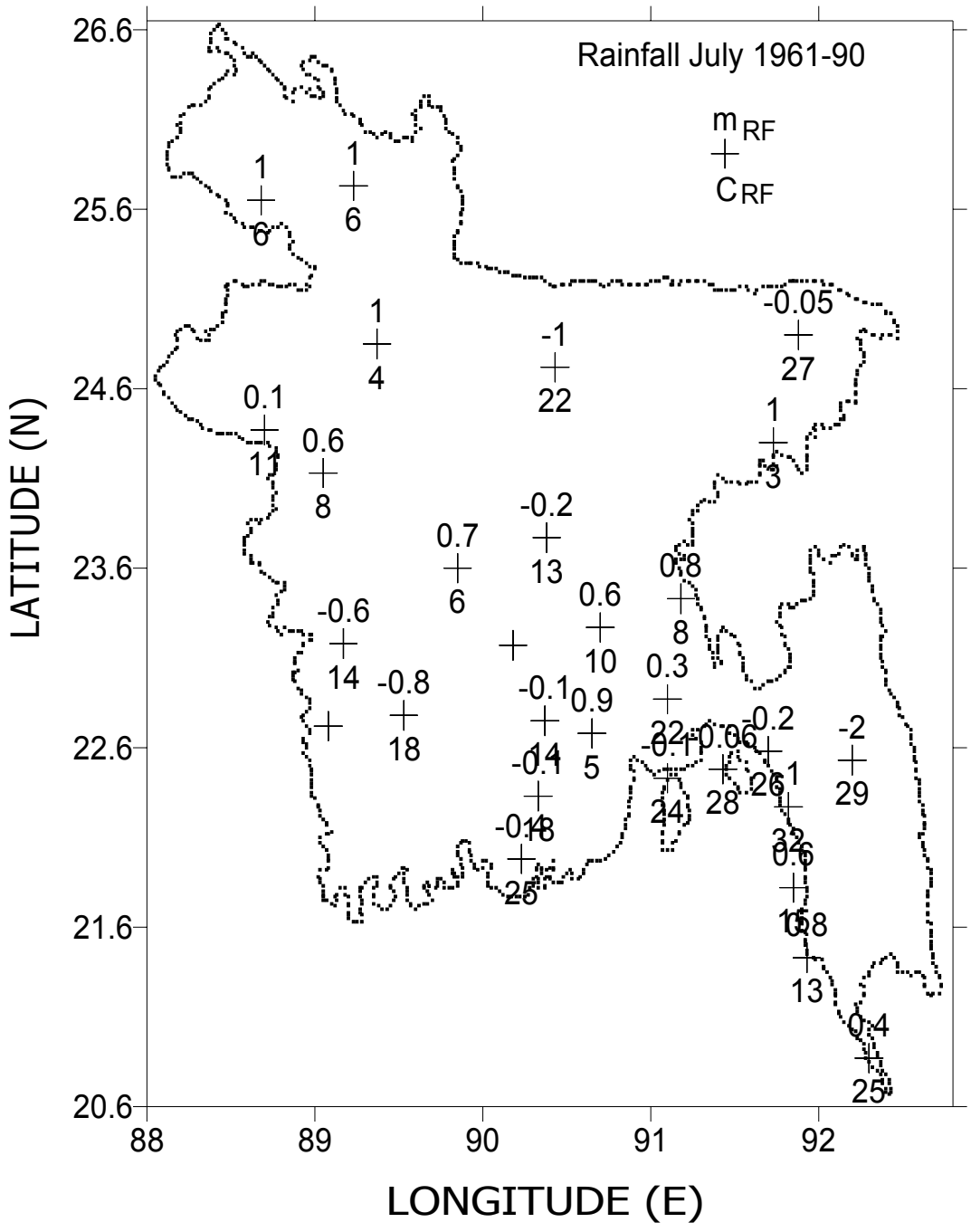


Figure 5: Examples of slope parameter and constant for rainfall at different stations over the country in July and averages for 1961 to 1990.

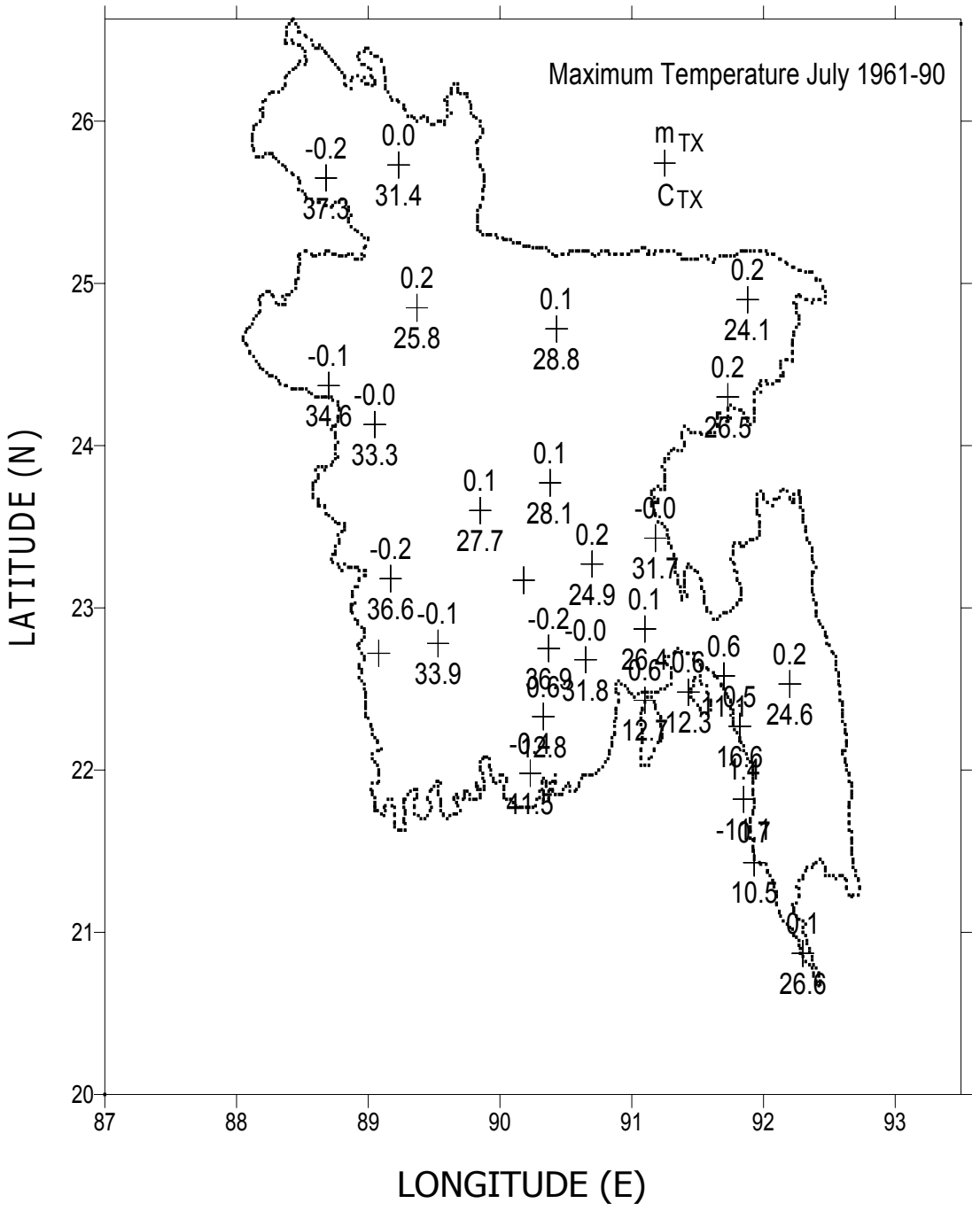


Figure 6: Examples of slope parameter and constant for maximum temperature at different stations over the country in July and averages for 1961 to 1990.

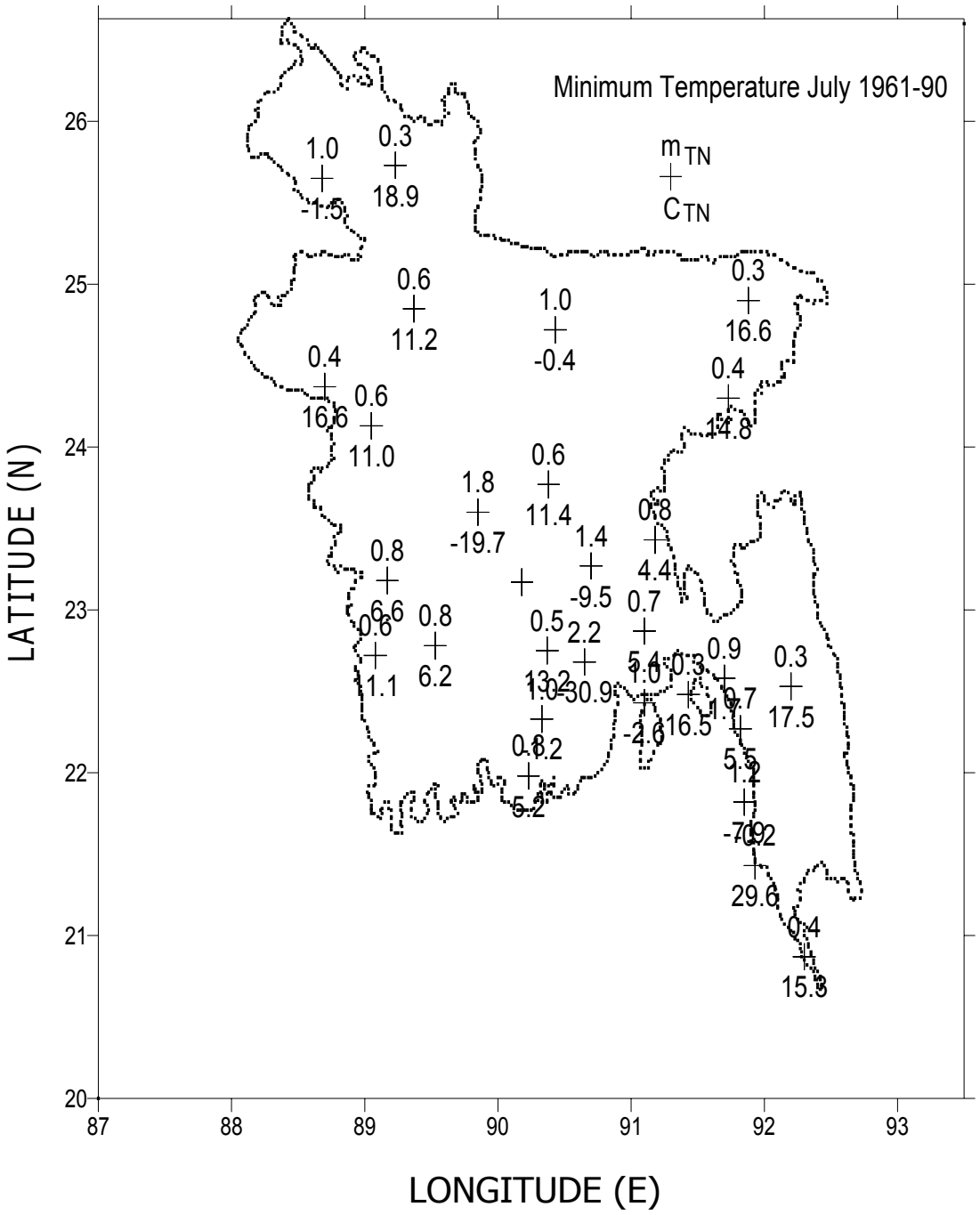


Figure 7: Examples of slope parameter and constant for minimum temperature at different stations over the country in July and averages for 1961 to 1990.

5. Model Validation

In order to use model generated scenarios for application purposes, model outputs have been validated with observed data. Otherwise, model outputs can not be utilized with confidence. Actually, validation provides the deviation of simulation with actual data obtained through observation. Validation of rainfall and temperature (maximum and minimum) for the year 1989, 1990, 2000, 2001 and 2000-2006 are discussed in this section.

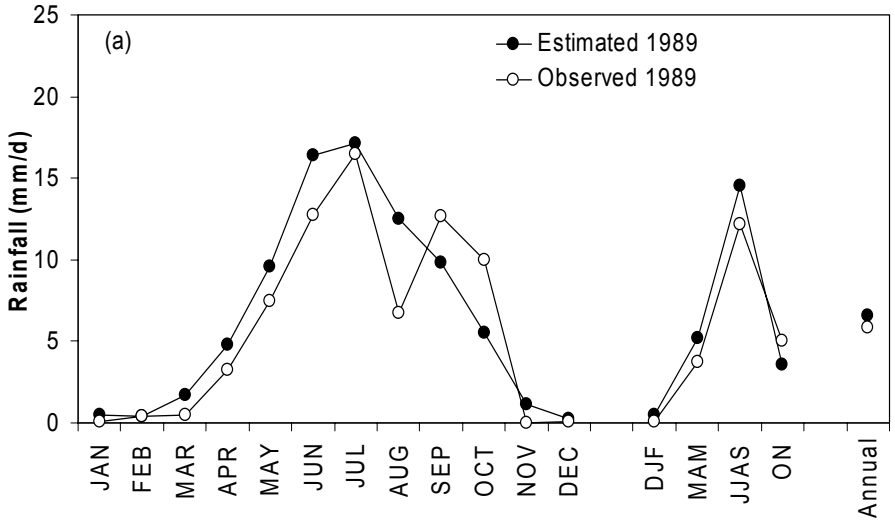
5.1. Validation for Rainfall:

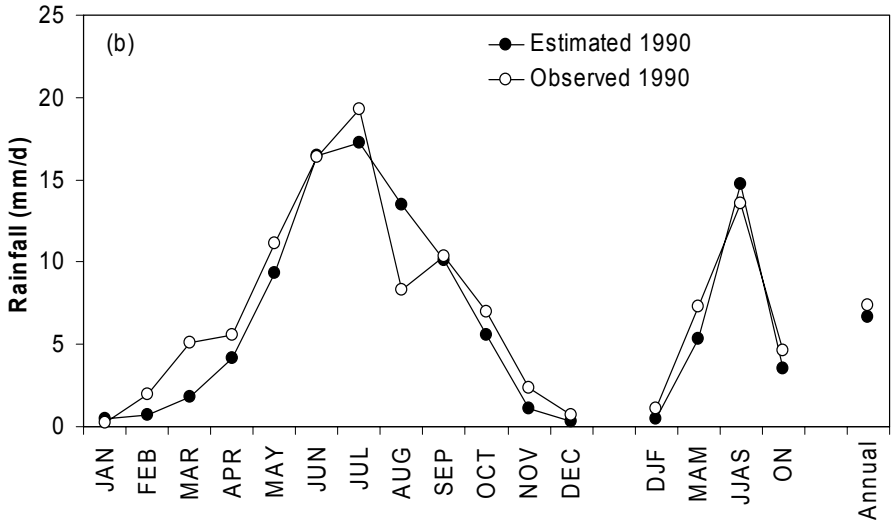
Observed rainfall in 1989, 1990, 2000 and 2001 is shown in Fig. 8 (a-d) with model simulated amounts and then estimated values. Estimated rainfall is obtained after using slope (m) and constant (c) with model generated scenarios. Almost for all years estimated rainfall lies close to the observed value with some exceptions. Seasonal values for estimated rainfall are very close to the observed one with a little deviation. Deviation is the difference between estimated and observed rainfall. In annual scale this deviation is very little and no deviation found in 2000. The deviation of rainfall in month to month is high and the deviation in annual scale and on an average for all years is about -0.18 %. This indicates that estimated rainfall from model simulation is underestimated in a very small order. The validation for 1989, 1990, 2000 and 2001 is found significant at 99 % level using SPSS package.

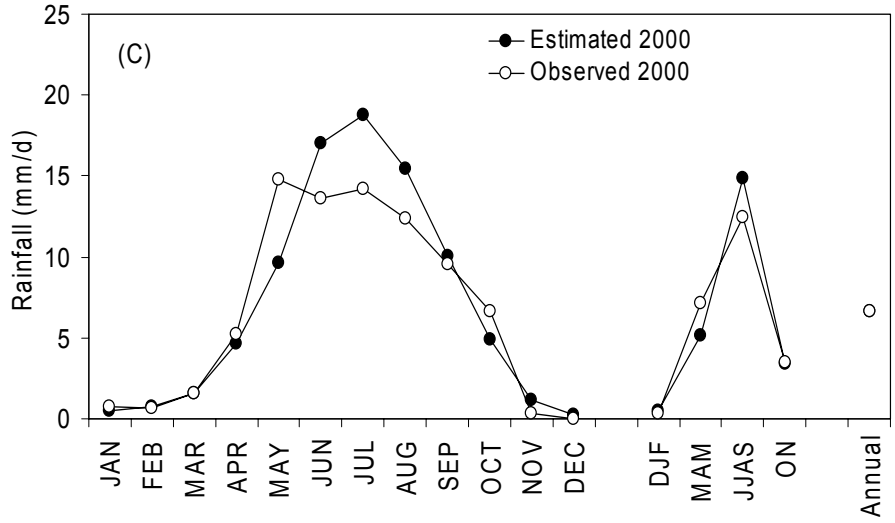
The PRECIS output for rainfall is again tested for continuous model run during 2000-2006. According to table 5, PRECIS overestimated 12.37%, 1.58%, 10.81%, 4.79 and 13.18% in 2000, 2002, 2003, 2005 and 2006 respectively. It underestimated 0.64% and 10.84% in 2001 and 2004 respectively. On an average, rainfall overestimated by PRECIS is 4.47% of rain-gauge amount. It seems that the PRECIS performance (estimated minus observed divided by observed and expressed in percentage) is quite reasonable because about 4.47% error may be considered in long-term forecasting using a climate model. Correlation coefficients are obtained from both model and rain-gauge rainfall in individual year and found that it lies within 0.87 to 0.97 which are quite significant. Inspection of annual cycle of estimated rainfall from PRECIS it is found that patterns are almost similar to historical observed data (not shown). Therefore, utilization of PRECIS outputs are suggested for obtaining rainfall projection in Bangladesh.

Table 5: Validation of PRECIS with model performance (for rainfall).

Year	Observed	Estimated	Model Performance	Correlation Coefficient
2000	6.64	7.46	12.37	0.91
2001	6.78	6.74	-0.64	0.90
2002	7.11	7.22	1.58	0.97
2003	6.19	6.86	10.81	0.87
2004	9.11	6.92	-10.84	0.90
2005	6.88	7.21	4.79	0.91
2006	6.01	6.80	13.18	0.89


(a)
Estimated 1989
Observed 1989
Rainfall (mm/d)
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
DJF
MAM
JJAS
ON
Annual


(b)
Estimated 1990
Observed 1990
Rainfall (mm/d)
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
DJF
MAM
JJAS
ON
Annual


(C)
Estimated 2000
Observed 2000
Rainfall (mm/d)
25
20
15
10
5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
DJF
MAM
JJAS
ON
Annual

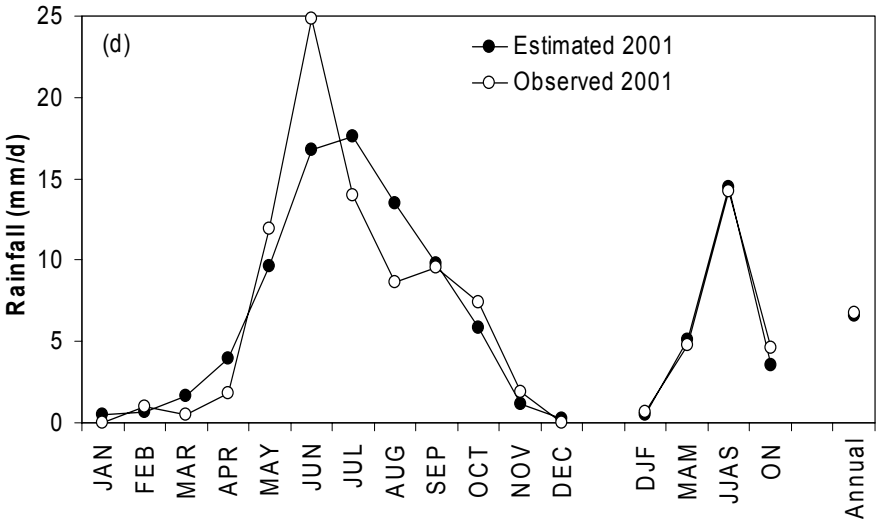
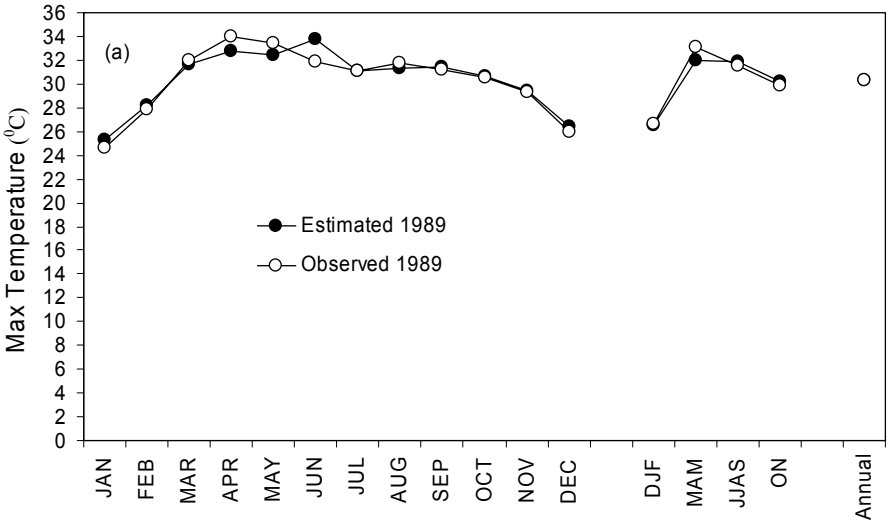


Figure 8: Observed and estimated rainfall (mm/d) for monthly, seasonal and annual scale in (a) 1989, (b) 1990, (c) 2000 and (d) 2001.

5.2. Validation for Maximum Temperature:

Observed maximum temperature (Tmax) in 1989, 1990, 2000 and 2001 is shown in Fig. 9 (a-d) with model simulated and then estimated Tmax. Estimated Tmax is obtained after using slope (m) and constant (c) with model generated outputs. Deviation is the difference between estimated and observed Tmax. It seems that deviation from month to month is high and the deviation in seasonal scale is small. Tmax overshoot in June in all years. In annual scale it is about 0.09 %, 1.14 %, 0.26 % and -1.2 % in 1989, 1990, 2000 and 2001 respectively. On an average for all years it is found 0.07 %. Therefore, estimated maximum temperature is over-calculated.



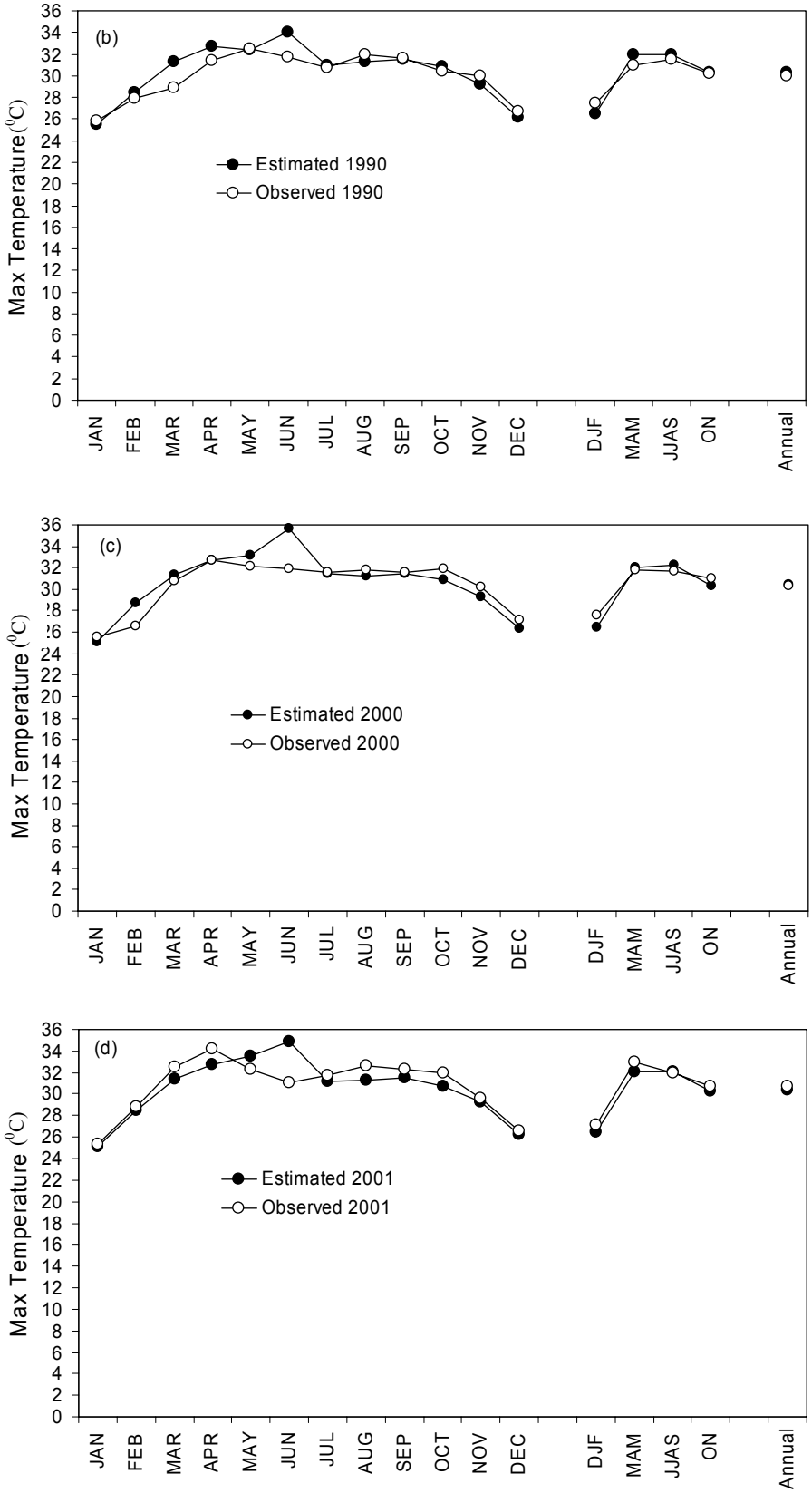
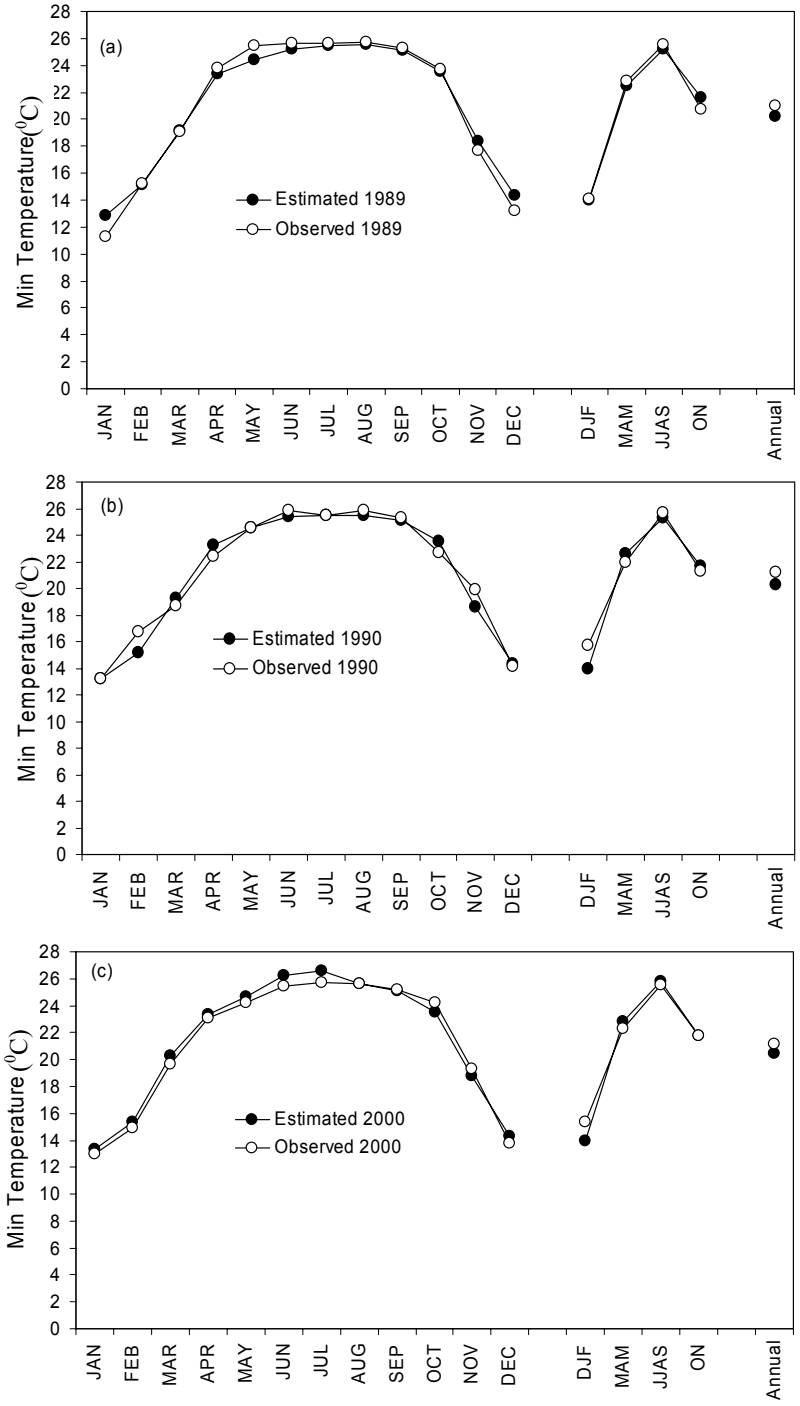


Figure 9: Observed and estimated monthly, seasonal and annual maximum temperature (a) 1989, (b) 1990, (c) 2000 and (d) 2001.

5.3. Validation for Minimum Temperature:

Observed minimum temperature (Tmin) in 1989, 1990, 2000 and 2001 is shown in Fig. 10 (a-d) with model simulated and then estimated Tmin. Estimated Tmin is obtained after using slope (m) and constant (c) with model generated scenarios. Deviation is the difference between expected and observed Tmin. It seems that deviation from month to month is high and it is small for seasonal scale. In annual scale this deviation is about -3.83 %, -4.61 %, -3.65 % and -3.90 % in 1989, 1990, 2000 and 2001 respectively. On an average for all years, it is about -4.0 %. This means that estimated minimum temperature is under calculated.



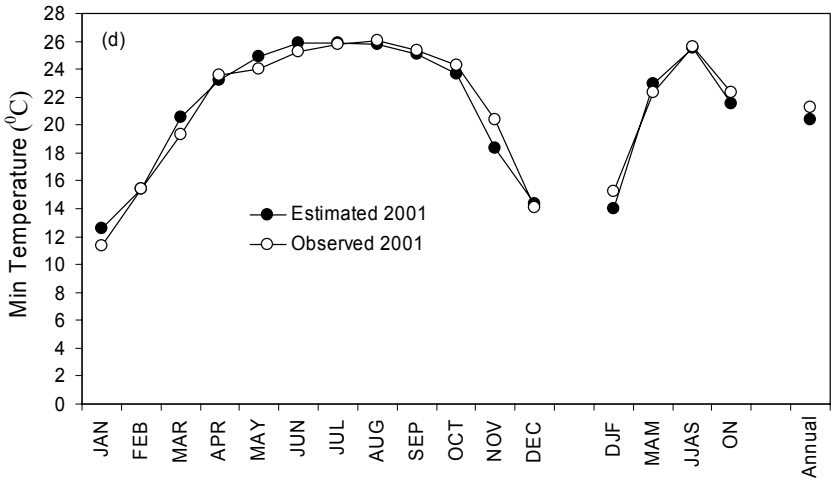


Figure 10: Observed and estimated monthly, seasonal and annual minimum temperature (a) in 1989, (b) in 1990, (c) in 2000 and (d) in 2001.

6. Model Generated Scenarios

6.1. Rainfall Scenarios:

The model generated scenarios for rainfall and temperature (maximum and minimum) generated by PRECIS version 1.5.1 are shown and discussed in this section.

Rainfall scenarios generated for 2030, 2050 and 2070 are shown in Fig. 11 (a-c). It seems that heavy rainfall is simulated in northeast parts of Bangladesh as expected. The rainfall in southern slope of Bhutan is also very intensive. These rainwater falls in Brahmaputra and Meghna basin is supposed to enter into Bangladesh through Brahmaputra/Jamuna and

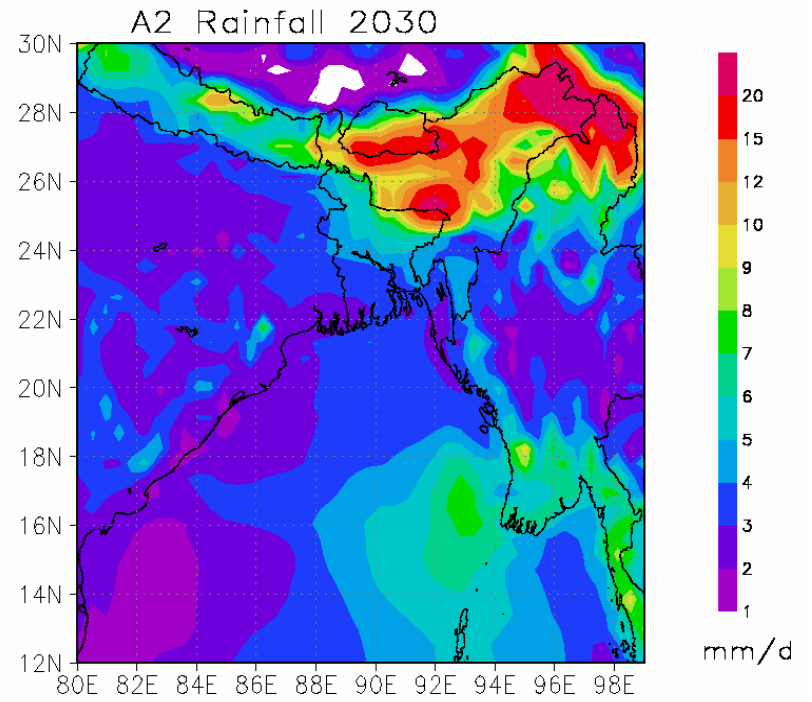


Figure 11 (a): A2 (SRES A2 Emission) rainfall scenarios generated by PRECIS in 2030.

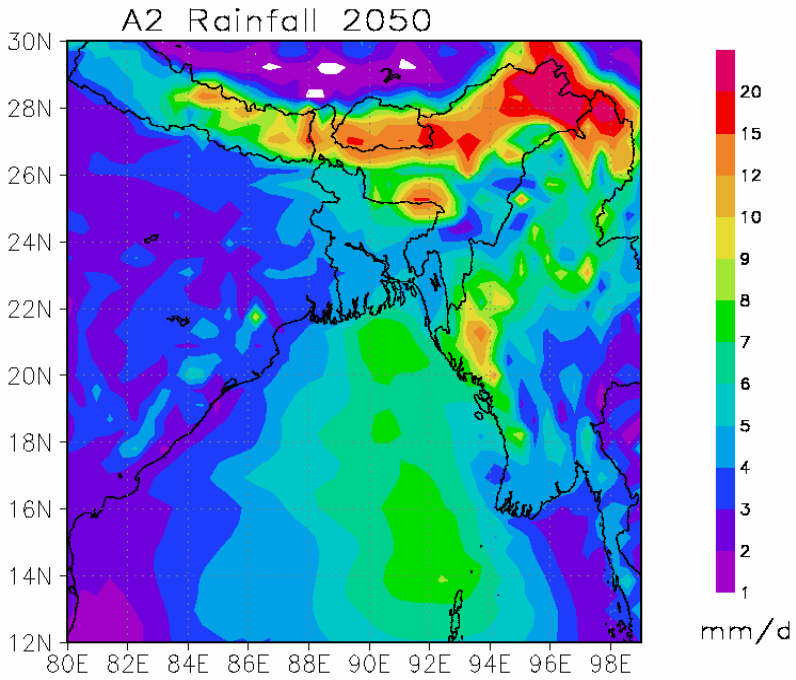


Figure 11 (b): A2 (SRES A2 Emission) rainfall scenarios generated by PRECIS in 2050.

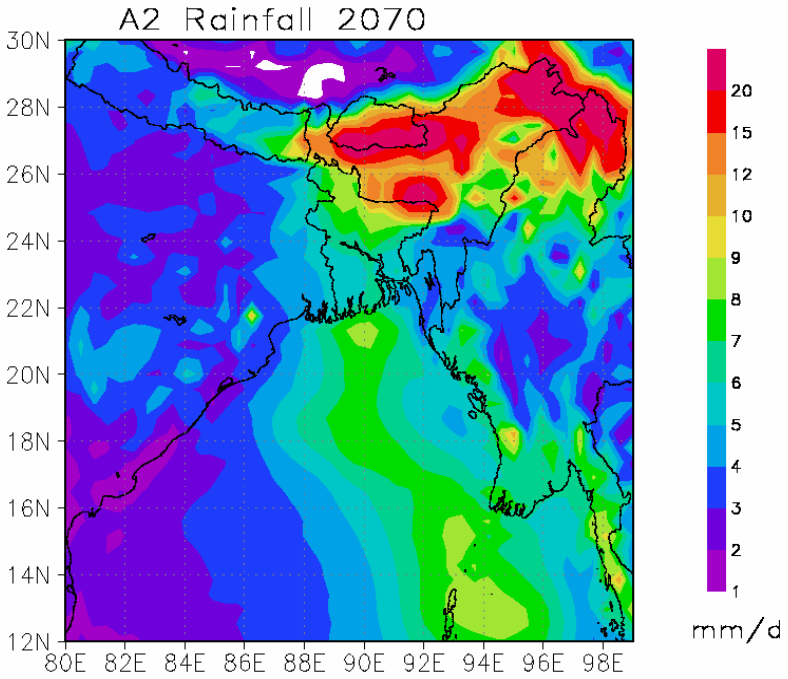


Figure 11 (c): A2 (SRES A2 Emission) rainfall scenarios generated by PRECIS in 2070.

Meghna rivers. Rainfall in Ganges basin is not much intense as seen in scenarios. Therefore, in Bangladesh flood in coming days may occur due to surplus rainwater in Brahmaputra and Meghna basin.

Monthly rainfall extracted and averages for 27 locations over Bangladesh corresponding to BMD rain-gauge locations are processed from model generated scenario (Fig. 12 (a)) for

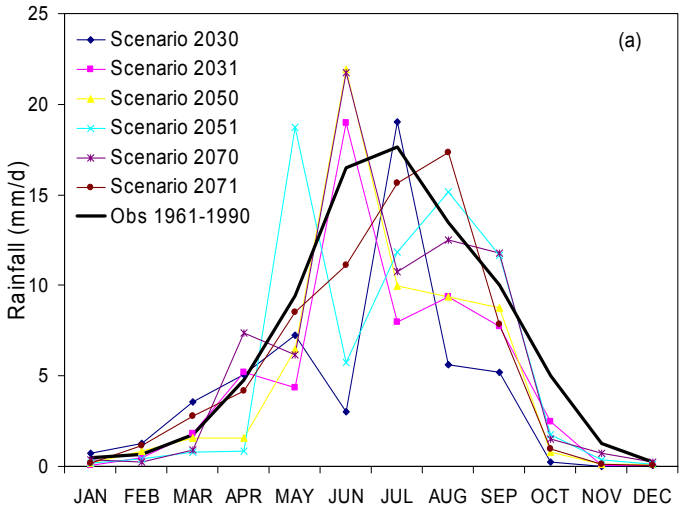


Figure 12 (a): Annual variation of rainfall (A2 scenarios)

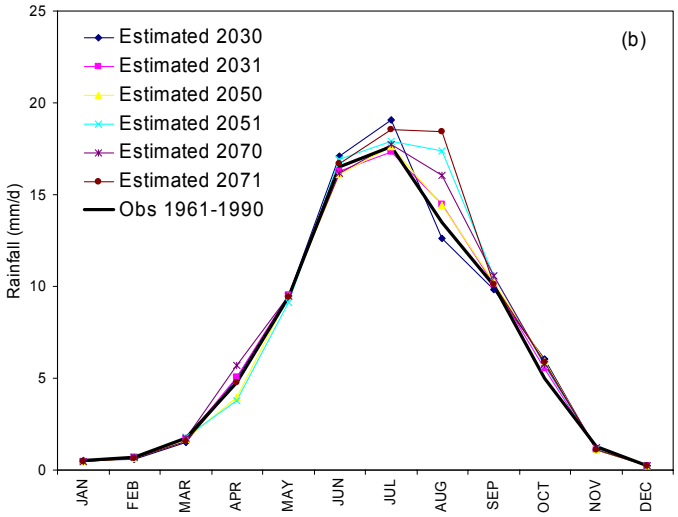


Figure 12 (b): Annual variation of estimated rainfall (A2 scenarios)

2030, 2031, 2050, 2051, 2070 and 2071. The slope and constant parameters from Look-up table 4 are used to obtain estimated rainfall as shown in Fig. 12 (b). For scenarios, the maximum peaks of rainfall are found either in May or June or July or August whereas the historical observed rainfall peak of Bangladesh is in July. The estimated rainfall (Fig. 12 b) matched well with observed amounts. Hence, figure 12 (b) shows the advantages in utilizing Look-up table prepared through the present study. This result is consistent with historical rainfall patterns in Bangladesh. The peak of maximum rainfall shifted in August in 2071. The shifting of rainfall peak also happens for historical amount if we examine year to year. However, surplus of rainfall is expected in August in all projected years except for 2030. It is obvious that without utilization of Look-up table the model outputs are not following the historical pattern. It is also worthy to say that within couple of decades rainfall pattern will not completely change from historical trend even climate change issue is there. Therefore, utilization of Look-up table is suitable one to make model outputs in an applicable format.

Monthly rainfall extracted and averages for 27 locations over Bangladesh corresponding to BMD rain-gauge locations are processed from model generated scenario (Fig. 12 (a)) for

2030, 2031, 2050, 2051, 2070 and 2071. The slope and constant parameters from Look-up table 4 are used to obtain estimated rainfall as shown in Fig. 12 (b). For scenarios, the maximum peaks of rainfall are found either in May or June or July or August whereas the historical observed rainfall peak of Bangladesh is in July. The estimated rainfall (Fig. 12 b) matched well with observed amounts. Hence, figure 12 (b) shows the advantages in utilizing Look-up table prepared through the present study. This result is consistent with historical rainfall patterns in Bangladesh. The peak of maximum rainfall shifted in August in 2071. The shifting of rainfall peak also happens for historical amount if we examine year to year. However, surplus of rainfall is expected in August in all projected years except for 2030. It is obvious that without utilization of Look-up table the model outputs are not following the historical pattern. It is also worthy to say that within couple of decades rainfall pattern will not completely change from historical trend even climate change issue is there. Therefore, utilization of Look-up table is suitable one to make model outputs in an applicable format.

6.2. Maximum Temperature Scenarios:

Scenarios of maximum temperature generated for 2030, 2050 and 2070 are shown in Fig. 13 (a-c). It seems that higher value of maximum temperature is simulated in western part of Bangladesh which is the dry zone of the country. Maximum temperature increases from 2030 to 2050 and from 2050 to 2070. This is the clear indication of global warming.

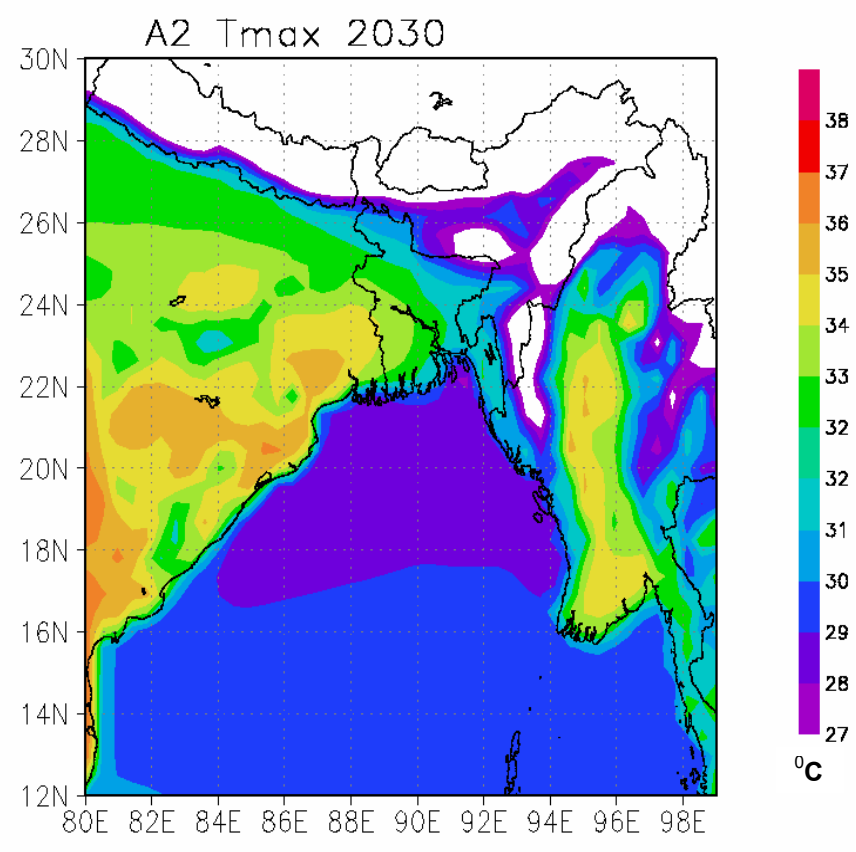


Figure 13 (a): Maximum temperature scenarios generated by PRECIS for 2030.

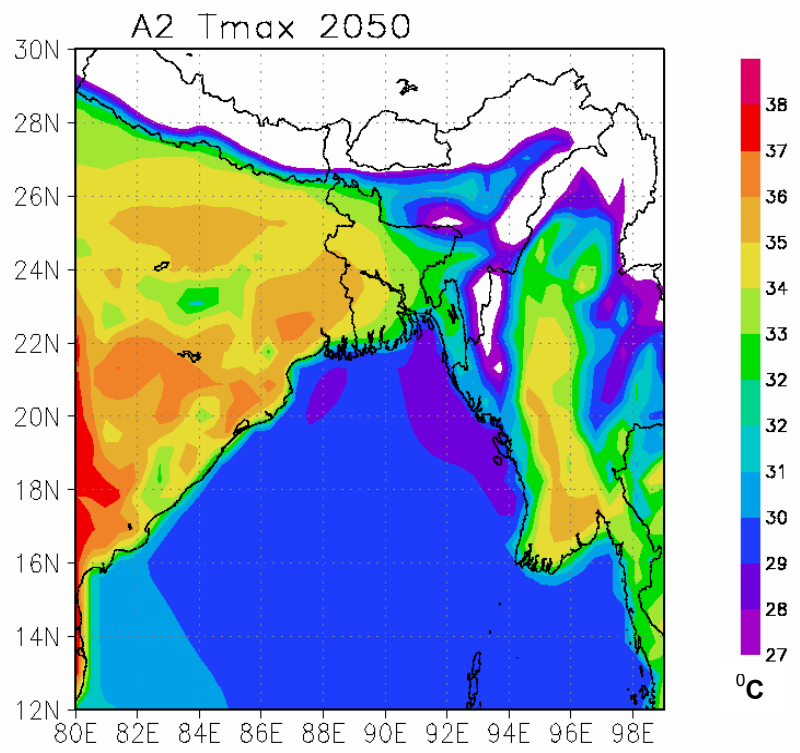


Figure 13 (b): Maximum temperature scenarios generated by PRECIS for 2050.

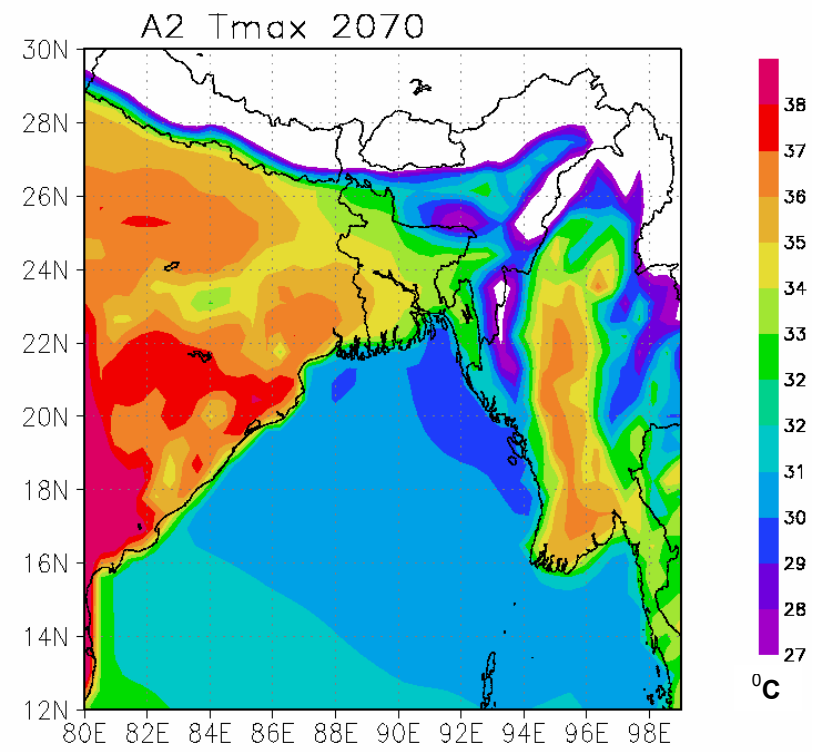


Figure 13 (c): Maximum temperature scenarios generated by PRECIS for 2070.

Annual cycle of maximum temperature extracted from scenarios of all analyzed years is sown in Fig. 14 (a). Almost in all months maximum temperature is higher than historical one as expected. In June 2030 the maximum temperature of scenario is about 9.66 °C higher compared to historical value. This seems unrealistic even global temperature is rising.

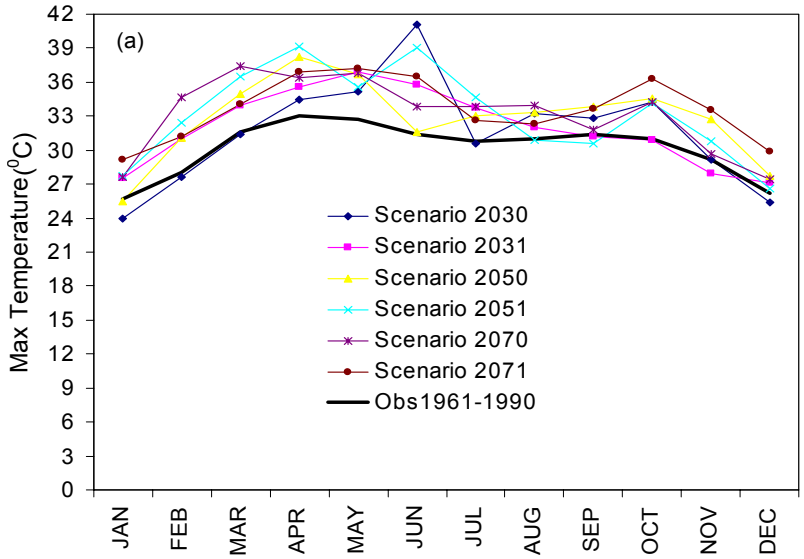


Figure 14 (a): Maximum temperature generated by PRECIS (A2 scenarios)

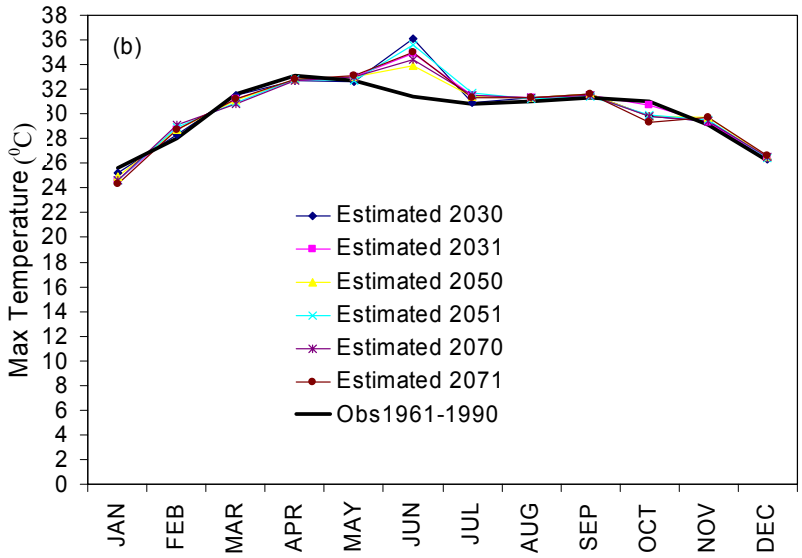


Figure 14 (b): Estimated maximum temperature generated by PRECIS (A2 scenarios)

The estimated maximum temperature almost follows the trend of historical data except under calculated in October and over calculated in June as shown in Fig 14 (b). In this status anomaly become lower compared to scenarios one.

6.3. Minimum Temperature Scenarios:

Scenarios of minimum temperature generated for 2030, 2050 and 2070 are shown in Fig. 15 (a-c). It seems that higher value of minimum temperature is simulated in 2030 in the southern part of Bangladesh which expanded to the inland in 2050 and 2070. Overall, minimum temperature increases from 2030 to 2050 and from 2050 to 2070. This is again a clear indication of global warming. One can calculate the increase of minimum temperature as shown in discussion section.

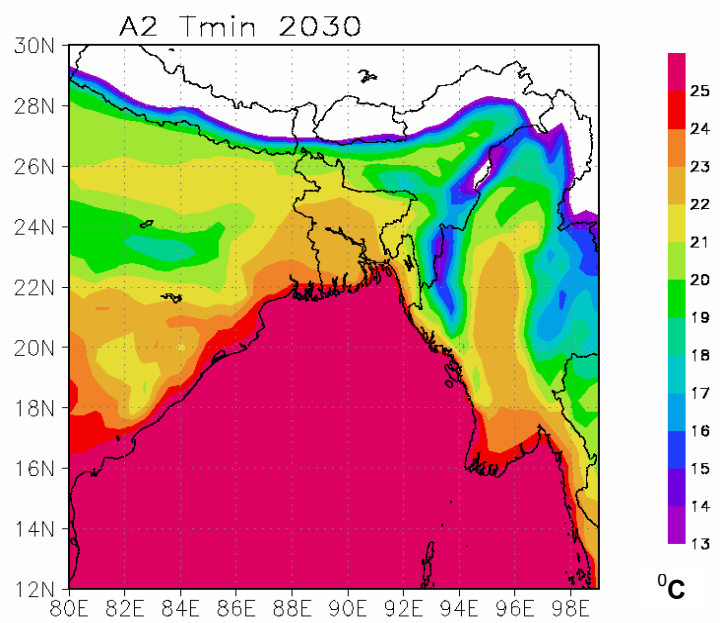


Figure 15 (a): Minimum temperature scenarios generated by PRECIS for 2030.

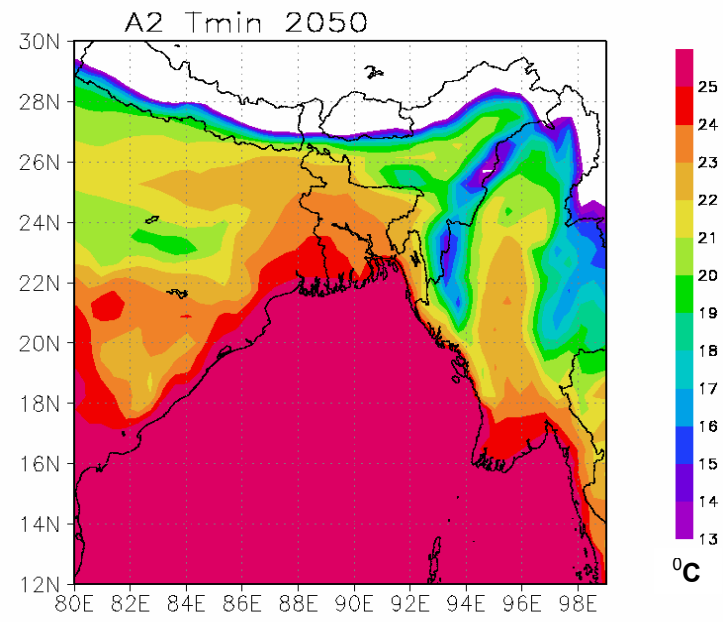


Figure 15 (b): Minimum temperature scenarios generated by PRECIS for 2050.

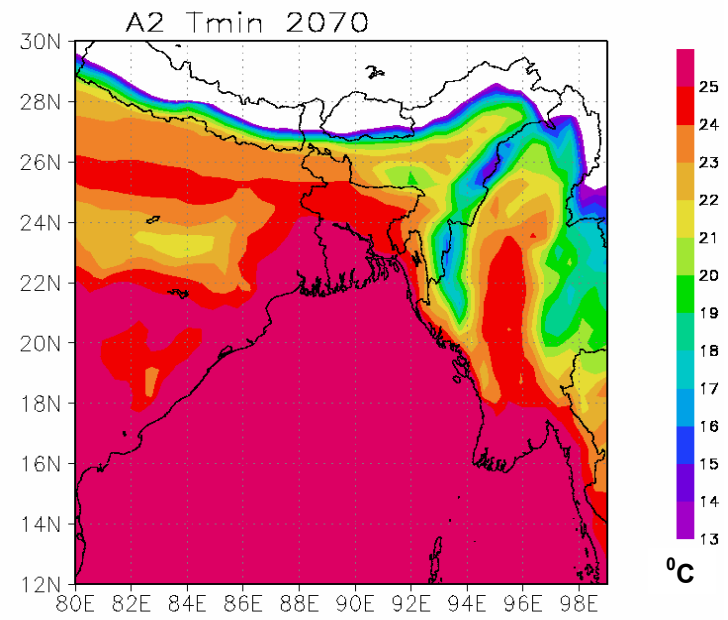


Figure 15 (c): Minimum temperature scenarios generated by PRECIS for 2070.

Annual cycle of minimum temperature in different analyzed years is sown in Fig. 16 (a-b). Almost in all years, a scenario of minimum temperature is higher compared to historical value without a few exceptions in November and December in 2030 and in November in 2031. The estimated minimum temperature almost follows the pattern of historical trend except over-calculated during monsoon months. It seems that difference in pre-monsoon and post-monsoon temperate are less significant compared to increase of monsoon temperate in coming days. The use of Look-up table makes the annual variation of estimated minimum temperature much smoother compared to model generated scenarios.

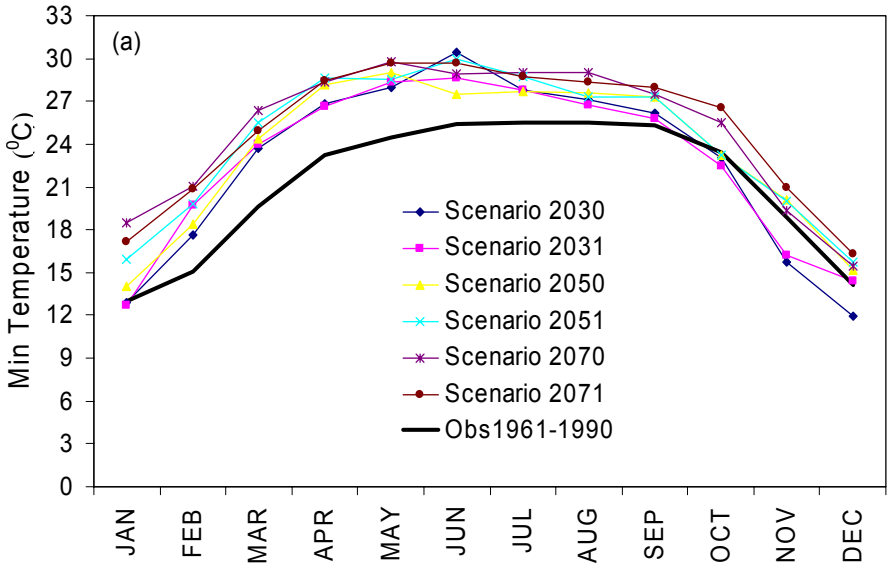


Figure 16 (a): Minimum temperature generated by PRECIS (A2 scenarios).

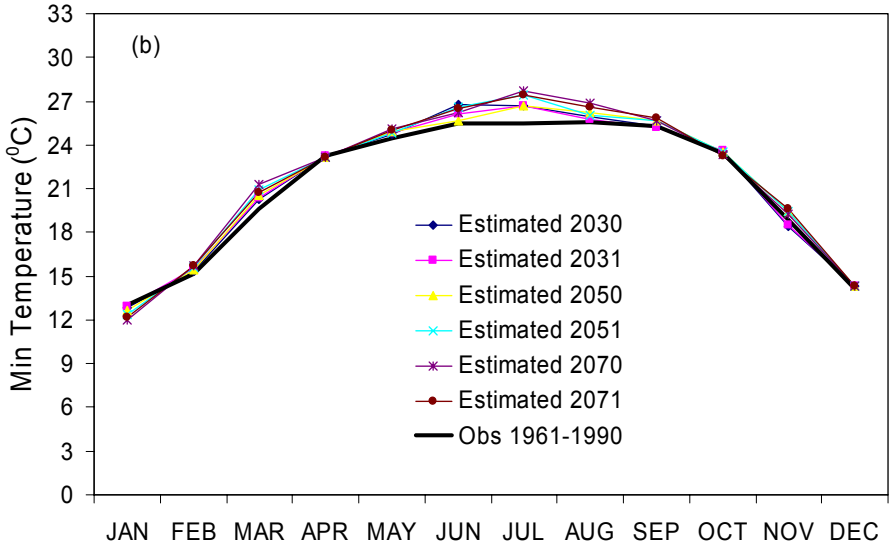


Figure 16 (b): Estimated minimum temperature generated by PRECIS (A2 scenarios).

7. Projected Rainfall and Temperature

7.1. Projected Rainfall:

Projected rainfall is obtained after using Look-up table or calibration factors with model generated scenarios. Monthly as well as seasonal and annual amounts (mm/d) of projected rainfall in different analyzed years are tabulated in table 6.

Table 6: Projected rainfall (mm/d) with observed amount.

	Rainfall (mm/d)						
	Observed	**Projected**					
	1961-1990	**2030**	**2031**	**2050**	**2051**	**2070**	**2071**
JAN	0.51	0.51	0.47	0.48	0.48	0.49	0.48
FEB	0.67	0.61	0.70	0.66	0.70	0.72	0.63
MAR	1.74	1.51	1.68	1.71	1.79	1.77	1.58
APR	4.77	5.04	5.07	3.98	3.77	5.72	4.76
MAY	9.43	9.47	9.56	9.49	9.12	9.50	9.43
JUN	16.49	17.10	16.30	16.15	16.96	16.16	16.69
JUL	17.62	19.11	17.34	17.65	17.95	17.78	18.57
AUG	13.48	12.62	14.48	14.47	17.40	16.06	18.47
SEP	10.03	9.82	10.13	10.25	10.60	10.61	10.14
OCT	5.02	6.06	5.52	5.92	5.69	5.75	5.88
NOV	1.29	1.11	1.12	1.13	1.16	1.20	1.13
DEC	0.26	0.23	0.23	0.23	0.23	0.25	0.23
DJF	0.48	0.45	0.47	0.46	0.47	0.49	0.44
MAM	5.31	5.34	5.44	5.06	4.89	5.67	5.26
JJAS	14.40	14.66	14.56	14.63	15.73	15.15	15.97
ON	3.16	3.58	3.32	3.52	3.42	3.48	3.50
Annual	6.78	6.93	6.88	6.84	7.16	7.17	7.33

Observed monthly rainfall averages from 1961 to 1990 are also shown for better understanding the surplus and deficit of rainfall in coming years. Rainfalls are averages from 27 BMD rain-gauge locations. Surplus or decrease of rainfall in a particular month in a year is the result of using dynamical climate model outputs and down scaling the model outputs. The down scaling using a statistical model might give the linear trend that is not suitable for a complicated meteorological parameter like rainfall.

For better comparison of surplus or deficit of projected rainfall with observed amount-monthly, seasonal and annual rainfall amounts are shown in Fig. 17 (a-b). Pre-monsoon rainfall is deficit in all analyzed years except for 2030, 2031 and 2070. The monsoon rainfall will increase in all years and from 2051 and onwards its surplus amount is large. It will remain almost same in 2030, 2031 and 2050. Importantly, large amount of rainfall is projected in August for all years except its deficit in 2030. One can calculate the projected amount of rainwater from the daily values.

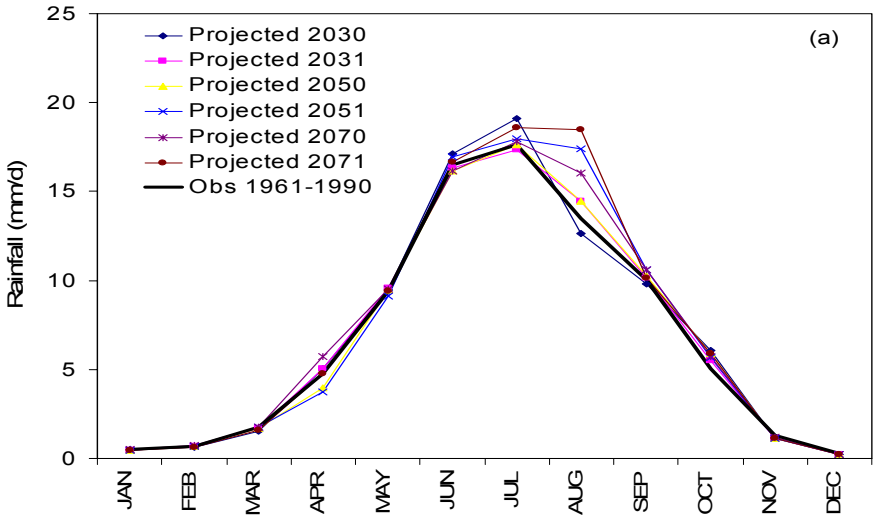


Figure 17 (a): Annual cycle of projected rainfall.

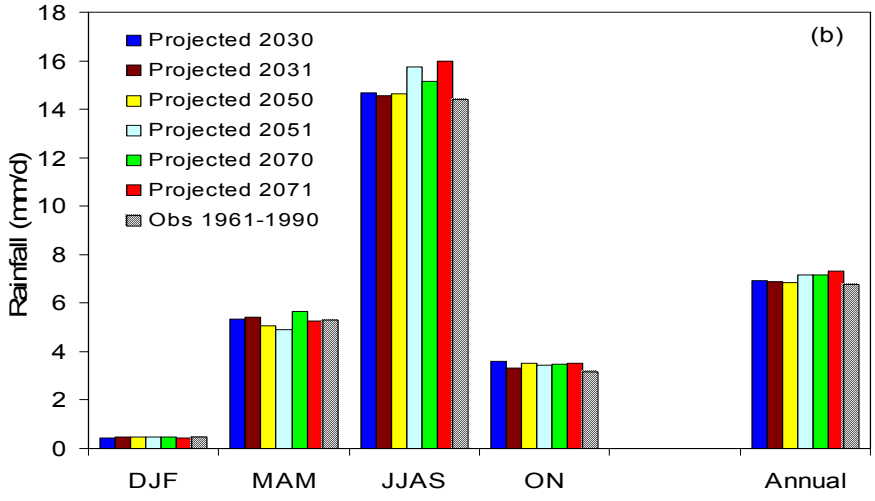


Figure 17 (b): Seasonal and annual amount (mm/d) of projected rainfall.

Projected rainfall will be surplus during monsoon and post-monsoon periods. It will remain almost same during pre-monsoon and dry periods. In annual scale, rainfalls will not much increase in 2030, 2031 and 2050 compared to 2051, 2070 and 2071. However, rainfall during dry and wet region might decrease and increase in trend respectively which are not analyzed in this report and may be done for detail clarification of regional variation/ distribution and trend analysis.

The deviation of seasonal and annual rainfall from the historical observed amount in analyzed year is tabulated in table 7. Surplus of rainfall is obvious during monsoon and post-monsoon periods. In means that flood frequency during monsoon and post-monsoon periods might increase in coming years. This information might be helpful for the nationwide agriculture and water management planning. There is a huge variation of rainfall from month to month. Monsoon and post-monsoon rainfall will increase a lot whereas pre-monsoon and dry period's rainfall will reduce.

Table 7: Deviation of seasonal and annual rainfall from the baseline period.

	Rainfall (mm/d)						
	Observed	**Deviation from Observed baseline**					
	1961-1990	**2030**	**2031**	**2050**	**2051**	**2070**	**2071**
JAN	0.51	0.00	-0.03	-0.03	-0.03	-0.02	-0.03
FEB	0.67	-0.06	0.02	-0.02	0.03	0.05	-0.05
MAR	1.74	-0.24	-0.06	-0.04	0.04	0.03	-0.16
APR	4.77	0.27	0.30	-0.79	-1.00	0.96	-0.01
MAY	9.43	0.04	0.12	0.06	-0.31	0.07	0.00
JUN	16.49	0.61	-0.19	-0.33	0.48	-0.32	0.21
JUL	17.62	1.49	-0.28	0.03	0.33	0.16	0.95
AUG	13.48	-0.86	1.00	0.99	3.93	2.59	5.00
SEP	10.03	-0.21	0.10	0.22	0.57	0.58	0.11
OCT	5.02	1.04	0.50	0.90	0.67	0.74	0.86
NOV	1.29	-0.18	-0.17	-0.16	-0.13	-0.09	-0.16
DEC	0.26	-0.03	-0.03	-0.03	-0.02	-0.01	-0.03
DJF	0.48	-0.03	-0.01	-0.02	-0.01	0.01	-0.04
MAM	5.31	0.02	0.12	-0.25	-0.42	0.35	-0.06
JJAS	14.40	0.26	0.16	0.23	1.33	0.75	1.56
ON	3.16	0.43	0.17	0.37	0.27	0.32	0.35
Annual	6.78	0.16	0.11	0.07	0.38	0.39	0.56

7.2. Projected Maximum Temperature:

Projected maximum temperature (Tmax) is obtained after using the slope and constant with model generated scenarios. Monthly, seasonal and annual values of projected Tmax in different analyzed years are tabulated in table 8. Observed monthly Tmax averages from 1961 to 1990 are also shown for better understanding of increase or decrease of Tmax in coming years. Tmax are averages from 27 BMD first class observation locations.

Table 8: Projected maximum temperature (^{o}C) with observed values.

	Maximum Temperature (^{o}C)						
	Observed	**Projected**					
	1961-1990	**2030**	**2031**	**2050**	**2051**	**2070**	**2071**
JAN	25.67	25.23	24.63	24.97	24.58	24.61	24.34
FEB	28.07	28.34	28.71	28.72	28.86	29.11	28.73
MAR	31.63	31.48	31.18	31.05	30.86	30.76	31.16
APR	33.07	32.72	32.73	32.76	32.77	32.74	32.75
MAY	32.74	32.63	32.98	32.95	32.72	32.97	33.05
JUN	31.43	36.09	34.87	33.90	35.61	34.42	35.02
JUL	30.79	30.87	31.47	31.35	31.65	31.50	31.27
AUG	31.04	31.29	31.25	31.29	31.22	31.31	31.26
SEP	31.35	31.57	31.46	31.64	31.42	31.50	31.63
OCT	31.03	29.85	30.69	29.78	29.86	29.85	29.33
NOV	29.12	29.40	29.32	29.65	29.51	29.43	29.71
DEC	26.24	26.35	26.46	26.49	26.43	26.47	26.62
DJF	26.66	26.64	26.60	26.73	26.62	26.73	26.56
MAM	32.48	32.27	32.30	32.25	32.12	32.16	32.32
JJAS	31.16	32.45	32.26	32.05	32.47	32.18	32.30
ON	30.07	29.62	30.00	29.72	29.69	29.64	29.52
Annual	30.18	30.48	30.48	30.38	30.46	30.39	30.41

The monthly, seasonal and annual variations of projected Tmax with historical observed values are shown in Fig. 18 (a-b). The increase trend of seasonal Tmax is higher in June for all years. Tmax will increase during monsoon period and decrease in October. Year to year variation of Tmax in June and October is significant. In annual scale, it will increase from historical value which indicates the presence of global warming.

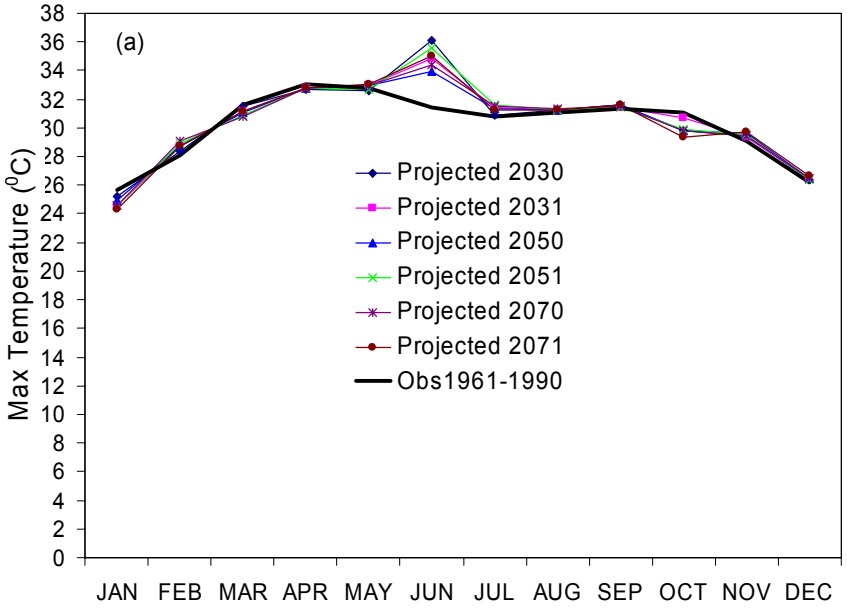


Figure 18 (a): Annual cycle of projected maximum temperature.

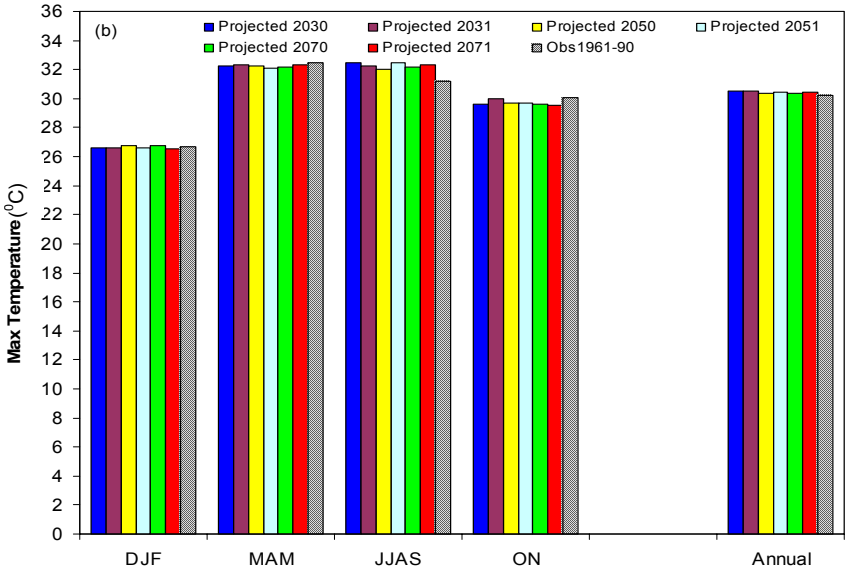


Figure 18 (b): Seasonal and annual value of projected maximum temperature.

The deviations of monthly, seasonal and annual Tmax from the historical observed value for analyzed years are presented in table 9. As mentioned earlier, Tmax has positive bias for monsoon period. In annual scale, Tmax will rise 0.30, 0.30, 0.20, 0.28, 0.21 and 0.22 °C in 2030, 2031, 2050, 2051, 2070 and 2071 respectively. This information might be helpful for the nationwide agriculture planning and impact studies due to global warming. The deviation of maximum temperature lies between -4.7 to 3.8 °C. Therefore, average annual temperature may not reflect the increase of temperature in a particular month. The deviation of maximum temperature in a particular place might also be important which is not studied in this project.

Table 9: Deviation of seasonal and annual maximum temperature from the baseline period.

	Maximum Temperature (°C)						
	Observed	**Deviation from Observed baseline**					
	1961-1990	**2030**	**2031**	**2050**	**2051**	**2070**	**2071**
JAN	25.67	-0.44	-1.04	-0.70	-1.08	-1.05	-1.32
FEB	28.07	0.27	0.64	0.65	0.79	1.05	0.66
MAR	31.63	-0.15	-0.45	-0.57	-0.76	-0.86	-0.47
APR	33.07	-0.35	-0.34	-0.31	-0.30	-0.33	-0.33
MAY	32.74	-0.11	0.24	0.21	-0.02	0.23	0.31
JUN	31.43	4.65	3.44	2.47	4.17	2.98	3.59
JUL	30.79	0.08	0.68	0.56	0.85	0.71	0.48
AUG	31.04	0.25	0.21	0.25	0.18	0.27	0.22
SEP	31.35	0.22	0.11	0.29	0.07	0.15	0.28
OCT	31.03	-1.18	-0.34	-1.25	-1.16	-1.18	-1.70
NOV	29.12	0.29	0.20	0.54	0.40	0.32	0.59
DEC	26.24	0.12	0.22	0.26	0.19	0.24	0.39
DJF	26.66	-0.02	-0.06	0.07	-0.03	0.08	-0.09
MAM	32.48	-0.20	-0.18	-0.23	-0.36	-0.32	-0.16
JJAS	31.16	1.30	1.11	0.89	1.32	1.03	1.14
ON	30.07	-0.45	-0.07	-0.36	-0.38	-0.43	-0.56
Annual	30.18	0.30	0.30	0.20	0.28	0.21	0.22

7.3. Projected Minimum Temperature:

Projected minimum temperature (Tmin) is obtained after using the slope and constant with model generated scenarios. Monthly, seasonal and annual values of projected Tmin in different analyzed years are tabulated in table 10. Observed monthly Tmin averages from 1961 to 1990 are also shown for better understanding of increase or decrease of Tmin in coming years. Tmin's are averages from 27 BMD first class observation locations.

Table 10: Projected minimum temperature (^{o}C) with observed values.

	Minimum Temperature (^{o}C)						
	Observed	**Projected**					
	1961-1990	**2030**	**2031**	**2050**	**2051**	**2070**	**2071**
JAN	13.04	13.38	13.41	13.19	12.88	12.45	12.68
FEB	15.12	15.97	16.18	16.04	16.19	16.32	16.30
MAR	19.64	21.07	21.20	21.34	21.77	22.10	21.55
APR	23.20	24.17	24.19	24.07	24.04	24.06	24.05
MAY	24.46	25.71	25.78	25.91	25.83	26.07	26.05
JUN	25.44	27.83	27.12	26.71	27.64	27.24	27.54
JUL	25.47	27.77	27.77	27.75	28.54	28.81	28.55
AUG	25.54	26.98	26.82	27.23	27.08	27.94	27.62
SEP	25.31	26.29	26.20	26.65	26.65	26.70	26.85
OCT	23.41	24.50	24.54	24.48	24.48	24.29	24.21
NOV	18.84	19.16	19.26	20.20	20.16	20.00	20.40
DEC	14.17	14.94	14.89	14.87	14.86	14.86	14.84
DJF	14.11	14.76	14.83	14.70	14.64	14.55	14.61
MAM	22.44	23.65	23.72	23.78	23.88	24.08	23.88
JJAS	25.44	27.22	26.98	27.09	27.48	27.67	27.64
ON	21.13	21.83	21.90	22.34	22.32	22.15	22.31
Annual	21.14	22.31	22.28	22.37	22.51	22.57	22.55

The monthly, seasonal and annual variations of projected Tmin with historical observed values are shown in Fig. 19 (a-b).

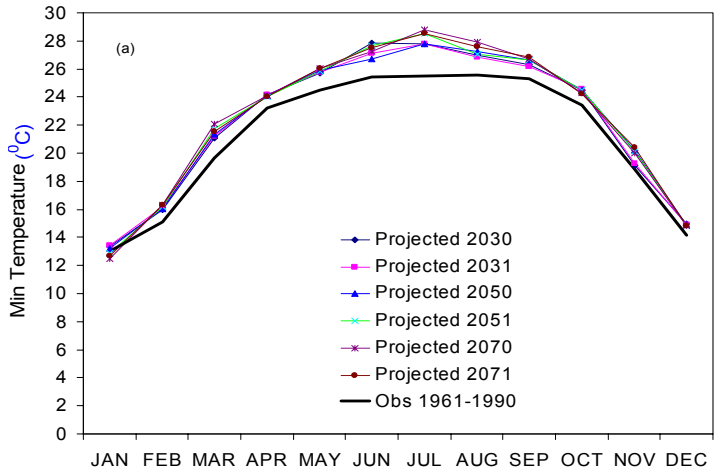


Figure 19 (a): Annual cycle of projected minimum temperature.

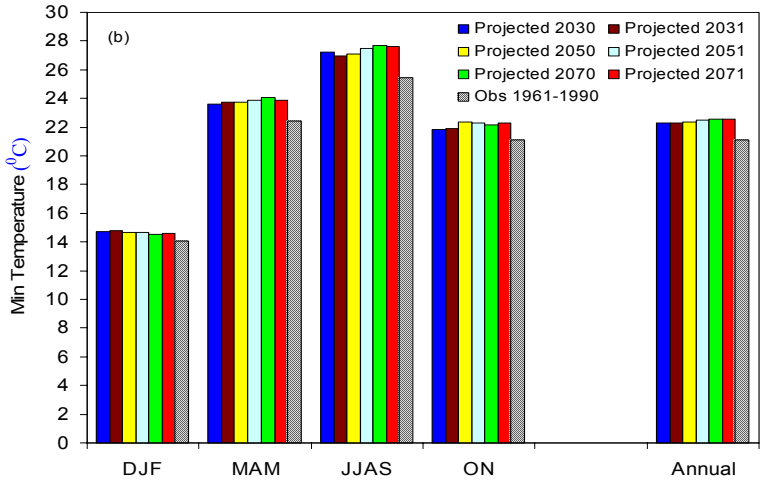


Figure 19 (b): Seasonal and annual value of projected minimum temperature.

Overall, Tmin over-calculated in all years. It over-calculated in other months. This also reflects seasonal average. In annual scale, it will increase in a high rate from historical one which clearly indicates the global warming.

The deviation of monthly, seasonal and annual Tmin from the historical observed value for analyzed years is tabulated in table 11.

Table 11: Deviation of seasonal and annual minimum temperature from the baseline period.

	Minimum Temperature (°C)						
	Observed	Deviation from Observed baseline					
	1961-1990	**2030**	**2031**	**2050**	**2051**	**2070**	**2071**
JAN	13.04	0.35	0.37	0.15	-0.16	-0.59	-0.36
FEB	15.12	0.85	1.06	0.92	1.08	1.21	1.18
MAR	19.64	1.43	1.56	1.70	2.13	2.46	1.92
APR	23.20	0.97	0.98	0.87	0.83	0.86	0.85
MAY	24.46	1.24	1.32	1.45	1.37	1.61	1.58
JUN	25.44	2.39	1.69	1.28	2.20	1.80	2.10
JUL	25.47	2.30	2.30	2.28	3.07	3.34	3.08
AUG	25.54	1.44	1.28	1.69	1.54	2.40	2.08
SEP	25.31	0.98	0.89	1.34	1.34	1.39	1.55
OCT	23.41	1.09	1.13	1.07	1.07	0.88	0.80
NOV	18.84	0.31	0.42	1.36	1.32	1.16	1.56
DEC	14.17	0.77	0.72	0.70	0.69	0.69	0.68
DJF	14.11	0.65	0.72	0.59	0.54	0.44	0.50
MAM	22.44	1.21	1.29	1.34	1.44	1.64	1.45
JJAS	25.44	1.78	1.54	1.65	2.04	2.23	2.20
ON	21.13	0.70	0.78	1.22	1.20	1.02	1.18
Annual	21.14	1.18	1.14	1.24	1.37	1.43	1.42

As mentioned earlier, Tmin has positive bias for monsoon, post-monsoon and dry month except for January in 2051, 2070 and 2071. In annual scale, Tmin will rise 1.18, 1.14, 1.24, 1.37, 1.43 and 1.42 °C in 2030, 2031, 2050, 2051, 2070 and 2071 respectively. This information might be helpful for the nationwide agriculture planning and impact studies due to climate change and global warming.

The deviation of minimum temperature lies between - 0.59 to 3.34 ^{0}C. Therefore, average annual temperature may not reflect the increase of temperature in a particular month. The deviation of minimum temperature in a particular place might also be important which is not studied in this project.

8. Discussion

The comparative statement of model generated scenarios and estimated values for rainfall and temperature in different years is shown in table 12. The scenarios are not directly useable in next steps. Estimated values are close to the observed one at least in seasonal and annual scale. Finally, estimated values are the candidates to use in planning purposes.

Table 12: Comparison of scenarios and projected rainfall and temperature.

Parameter	Year	2030	2031	2050	2051	2070	2071	Observ. 1961-1990
Rainfall (mm/d)	Scenarios	4.26	4.88	5.13	5.64	6.19	5.83	6.78
	Projected	6.92	6.87	6.83	7.14	7.16	7.32	
Tmax (°C)	Scenarios	31.60	31.96	32.78	33.18	33.13	33.61	30.18
	Projected	30.51	30.50	30.40	30.48	30.41	30.43	
Tmin (°C)	Scenarios	22.59	22.78	23.56	24.22	24.90	24.97	21.14
	Projected	21.46	21.42	21.51	21.64	21.70	21.69	

Note: Scenarios are without using Look-up table and projected rainfall is after using Look-up table.

Variation of rainfall and temperature (maximum and minimum) at a location over Bangladesh and in a particular month is quite large than the season or in annual average. In examples, at Kutubdia, rainfall will increase about 26.47 mm/d in June 2030 and it will decrease about 6.58 mm/d in August 2030. Maximum temperature will increase about 5.97 °C at Bogra in June 2030 and it will decrease about 3.51 °C at Khepupara in October 2030. Minimum temperature will increase about 5.67 °C at Faridpur in July 2030 and it will decrease about 4.87 °C at Jessore in December 2050. The fact is that average for a season or in a domain differs from individual month and individual location. To obtain regional averages we consider NE (90.4-92.5 °E; 23.5-26 °N), SE (90.4-92.5 °E; 20.8-23.5 °N), NW (88.5-90.4 °E; 23.5-26 °N)) and SW (88.5-90.4 °E; 20.8-23.5 °N) zones. Averages of all zones are termed as BD. The seasonal and annual values for each zone in 2030, 2050 and 2070 are tabulated in Table 13.

Table 13: Rainfall and temperature at different regions of Bangladesh in 2030, 2050 and 2070.

	Region	DJF	MAM	JJAS	ON	Annual
Year 2030						
Rainfall Change	NE	-9.60	9.00	4.20	24.60	7.00
	SE	-5.30	3.30	-3.30	14.30	2.30
	NW	-17.90	2.00	27.00	4.60	3.90
	SW	-3.60	-2.90	-5.50	19.80	2.00
	BD	-8.70	4.10	3.80	16.60	4.00
Maximum Temperature Change (^{o}C)	NE	0.22	-0.05	-0.26	-0.33	-0.10
	SE	0.10	0.56	0.70	-0.59	0.30
	NW	-0.31	0.03	0.16	-0.26	-0.06
	SW	-0.12	0.09	0.30	-0.90	-0.06
	BD	-0.03	0.16	0.23	-0.52	0.02
Minimum Temperature Change (^{o}C)	NE	0.20	0.69	0.48	0.13	0.40
	SE	0.27	0.41	0.78	-0.46	0.35
	NW	0.06	0.42	0.69	0.20	0.38
	SW	0.01	0.40	0.62	0.33	0.36
	BD	0.13	0.48	0.64	0.05	0.37
Year 2050						
Rainfall Change	NE	-6.10	-5.20	2.10	22.90	3.40
	SE	-6.80	0.50	2.80	11.30	1.90
	NW	-0.20	-4.50	15.60	4.50	3.90
	SW	-4.10	-6.30	-5.80	17.00	0.20
	BD	-4.70	-3.50	3.00	14.50	2.30
Maximum Temperature Change (^{o}C)	NE	0.42	0.16	0.02	-0.21	0.12
	SE	0.17	0.70	0.20	-0.47	0.21
	NW	-0.58	0.02	0.11	-0.13	-0.13
	SW	-0.23	0.21	0.07	-0.95	-0.14
	BD	-0.05	0.27	0.10	-0.44	0.01
Minimum Temperature Change (^{o}C)	NE	0.02	0.79	0.53	0.32	0.43
	SE	0.18	0.40	0.80	0.17	0.44
	NW	-0.09	0.53	0.87	0.39	0.46
	SW	-0.25	0.35	0.76	0.90	0.43
	BD	-0.03	0.52	0.74	0.44	0.44
Year 2070						
Rainfall Change	NE	-1.30	6.40	-5.60	17.00	4.10
	SE	2.70	6.90	7.70	10.90	7.10
	NW	5.80	9.80	14.80	5.30	8.90
	SW	1.30	7.70	3.90	17.70	7.60
	BD	1.80	7.40	4.60	13.20	6.70
Maximum Temperature Change (^{o}C)	NE	0.48	0.15	-0.01	-0.33	0.10
	SE	0.32	0.68	0.60	-0.58	0.35
	NW	-0.75	-0.08	-0.04	-0.24	-0.26
	SW	-0.35	0.06	0.26	-0.85	-0.13
	BD	-0.08	0.20	0.20	-0.50	0.02
Minimum Temperature Change (^{o}C)	NE	-0.05	1.21	0.85	0.24	0.61
	SE	0.02	0.78	1.60	0.13	0.76
	NW	-0.13	0.75	1.29	0.30	0.64
	SW	-0.59	0.71	1.45	0.29	0.56
	BD	-0.19	0.86	1.30	0.24	0.64

9. Conclusions

Look-up table is prepared for utilization of PRECIS outputs with reference to the observed data during 1961-1990 for rainfall and temperature (maximum and minimum). Using the Look-up table PRECIS generated scenarios is validated for 1989, 1990, 2000 and 2001. This work revealed satisfactory results for validation of PRECIS generated scenarios at 99% significance level. Then a validation is also completed for continuous 7 years from 2000 (2000-2006). Regression factors or correction factors are utilized in obtaining projected rainfall and temperature (maximum and minimum) for Bangladesh in 2030, 2031, 2050, 2051, 2070 and 2071. This work decisively disclosed the technique for seasonal forecasting meteorological parameters like rainfall and temperature in Bangladesh. However, high resolution model outputs and averages from a number of ensembles are suggested for better projection of any meteorological parameters in application purposes. The results obtained may be verified with other regional climate model outputs for better understanding the climate change impacts in Bangladesh. Till to-date, there is no simulation technique which can be used with 100 per cent accuracy. Therefore, this work strongly suggests applying the PRECIS outputs with proposed Look-up table as soon as possible and parallel consideration of other techniques. Otherwise, suitable time will never come when model can provide 100 per cent accuracy in simulating climatic parameters and nation will loose getting benefit from Science, especially from climate modeling systems.

Reference:

Islam M. Nazrul, M. Rafiuddin, A. U. Ahmed and R. K. Kolli, 2008: Calibration of PRECIS in employing future scenarios in Bangladesh. Int. J. Climatol., Wiley InterScience, 28: 617-628, DOI: 10.1002/joc.1559.

10. Appendix:

Appendix A: PRECIS generated Rainfall (mm/d) scenario in 2030.

	2030 m1	2030 m2	2030 m3	2030 m4	2030 m5	2030 m6	2030 m7	2030 m8	2030 m9	2030 m10	2030 m11	2030 m12
Barisal	0.25	0.90	1.24	2.55	2.89	2.52	18.39	5.67	4.81	0.19	0.00	0.03
Bhola	0.25	0.82	1.80	3.05	3.47	2.19	19.09	4.84	3.60	0.23	0.00	0.04
Bogra	1.16	2.61	4.06	4.41	10.57	4.23	20.95	6.90	8.87	0.15	0.00	0.06
Chandpur	0.39	0.97	1.66	3.21	4.54	2.37	17.40	4.32	4.80	0.19	0.00	0.02
Chittagong	0.31	0.51	1.67	4.49	5.96	1.56	15.43	3.00	0.76	0.06	0.02	0.10
Comilla	0.95	1.12	3.98	4.62	5.58	2.70	20.41	4.88	4.69	0.32	0.01	0.04
Coxbazar	0.39	0.37	0.80	4.03	3.83	1.32	11.20	1.00	0.39	0.22	0.03	0.07
Dhaka	2.11	1.62	3.52	4.85	9.57	3.00	21.98	5.99	9.34	0.23	0.02	0.03
Dinajpur	0.66	1.03	5.27	3.51	9.23	4.49	22.39	7.96	8.17	0.31	0.03	0.07
Faridpur	1.05	1.20	1.87	2.47	5.28	2.24	17.87	6.24	7.50	0.20	0.03	0.03
Feni	0.35	1.09	3.07	5.58	6.67	2.42	22.50	5.73	3.40	0.19	0.03	0.07
Hatiya	0.31	0.87	3.15	4.82	3.78	2.19	19.13	2.53	1.58	0.08	0.00	0.05
Ishurdi	1.58	3.77	2.08	1.77	5.00	2.96	18.53	6.65	8.66	0.08	0.03	0.02
Jessor	0.50	0.92	1.02	1.64	2.43	2.33	17.58	6.10	5.79	0.22	0.02	0.02
Khepupara	0.24	0.57	1.39	2.56	1.82	2.77	18.80	6.32	3.68	0.18	0.00	0.06
Khulna	0.29	0.84	0.66	1.17	1.45	2.39	16.94	6.90	5.03	0.23	0.00	0.02
Kutubdia	0.39	0.43	1.04	3.85	4.71	1.11	12.13	1.49	0.55	0.17	0.02	0.08
M'court	0.35	1.10	3.00	4.25	4.98	2.66	22.96	5.22	3.78	0.27	0.00	0.02
Madaripur	0.45	1.04	1.45	3.22	4.16	2.38	18.73	5.13	6.44	0.18	0.01	0.02
Mongla	0.29	0.84	0.66	1.17	1.45	2.39	16.94	6.90	5.03	0.23	0.00	0.02
Mymensing	1.10	1.21	10.27	13.08	19.44	5.10	23.03	5.44	7.92	0.28	0.03	0.07
Patuakhali	0.24	0.57	1.39	2.56	1.82	2.77	18.80	6.32	3.68	0.18	0.00	0.06
Rajshahi	1.48	4.94	2.36	2.40	6.35	3.16	18.66	7.21	8.63	0.04	0.01	0.03
Rangamati	0.45	0.82	1.26	2.86	5.56	2.34	11.47	5.11	2.84	0.29	0.01	0.03
Rangpur	0.65	0.80	8.08	5.79	13.07	5.77	21.50	7.53	8.96	0.38	0.04	0.09
Sandwip	0.32	0.93	3.24	8.03	5.65	2.02	19.12	3.18	1.64	0.12	0.01	0.10
Satkhira	0.38	1.13	0.73	1.06	1.05	2.42	15.98	8.19	4.70	0.27	0.01	0.02
Sitakunda	0.90	1.33	3.96	5.05	7.01	3.40	21.12	6.04	4.35	0.27	0.04	0.11
Srimongal	1.56	1.40	8.83	9.74	13.20	3.43	17.87	5.25	5.76	0.41	0.03	0.11
Syedpur	0.66	1.03	5.27	3.51	9.23	4.49	22.39	7.96	8.17	0.31	0.03	0.07
Sylhet	1.48	2.95	24.58	38.51	43.03	7.52	32.82	10.62	9.11	0.65	0.05	0.06
Tangail	1.53	2.49	3.59	4.70	10.29	3.91	19.11	5.38	8.77	0.19	0.02	0.05
Teknaf	0.21	0.33	0.80	3.55	5.79	2.14	16.95	3.87	0.69	0.30	0.02	0.03
Country	0.70	1.29	3.57	5.09	7.24	2.99	19.04	5.63	5.22	0.23	0.02	0.05
Normal	**0.51**	**0.66**	**1.74**	**4.70**	**9.32**	**16.48**	**17.39**	**13.39**	**10.01**	**4.96**	**1.28**	**0.25**

Appendix A continued.....

Appendix A: PRECIS generated Rainfall (mm/d) scenario in 2050.

	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12
Barisal	0.11	0.66	0.67	0.54	2.97	22.10	9.88	10.53	10.02	1.20	0.20	0.05
Bhola	0.13	0.86	1.19	0.61	3.10	26.15	10.07	10.71	10.70	0.85	0.12	0.06
Bogra	0.06	0.39	0.96	1.04	9.83	18.28	13.95	12.35	10.20	0.68	0.06	0.10
Chandpur	0.08	0.68	1.01	0.63	2.78	20.16	7.29	9.08	10.10	1.07	0.10	0.05
Chittagong	0.36	1.24	1.95	2.11	6.34	24.99	3.51	6.18	4.48	0.33	0.18	0.31
Comilla	0.08	0.76	1.42	0.93	3.06	18.90	7.86	10.04	10.56	0.99	0.09	0.05
Coxbazar	0.18	1.36	1.98	2.13	8.87	37.30	2.71	4.21	3.95	0.27	0.16	0.14
Dhaka	0.06	0.42	1.48	0.78	6.12	20.64	11.01	10.57	12.12	1.07	0.23	0.07
Dinajpur	0.06	0.34	0.55	1.39	8.45	17.78	15.93	11.86	10.83	0.63	0.00	0.04
Faridpur	0.06	0.32	0.94	0.63	4.15	17.73	11.00	8.93	8.80	0.83	0.18	0.07
Feni	0.16	1.12	1.92	1.21	5.00	22.92	7.55	10.33	9.25	1.06	0.15	0.08
Hatiya	0.26	1.35	1.74	1.41	4.11	27.89	4.89	7.63	9.18	0.35	0.04	0.09
Ishurdi	0.06	0.18	0.76	0.45	5.30	15.92	13.33	8.88	6.68	0.60	0.10	0.16
Jessor	0.07	0.27	0.55	0.52	3.42	16.51	12.22	7.66	5.40	1.16	0.13	0.11
Khepupara	0.11	0.63	0.64	0.40	3.00	27.99	11.20	12.14	9.27	0.72	0.19	0.05
Khulna	0.08	0.32	0.41	0.52	2.78	16.72	12.37	8.31	5.28	1.33	0.16	0.12
Kutubdia	0.32	1.27	2.04	1.97	6.94	29.33	2.61	4.37	3.62	0.31	0.23	0.30
M'court	0.11	1.17	1.60	0.79	3.19	23.77	8.28	10.79	10.94	0.98	0.05	0.04
Madaripur	0.08	0.58	0.91	0.63	2.92	19.48	8.96	9.48	10.68	1.24	0.20	0.06
Mongla	0.08	0.32	0.41	0.52	2.78	16.72	12.37	8.31	5.28	1.33	0.16	0.12
Mymensing	0.14	1.03	2.73	2.59	14.64	18.68	10.72	9.78	13.55	0.51	0.15	0.15
Patuakhali	0.11	0.63	0.64	0.40	3.00	27.99	11.20	12.14	9.27	0.72	0.19	0.05
Rajshahi	0.07	0.27	0.72	0.59	6.22	17.55	13.45	8.91	7.45	0.48	0.10	0.15
Rangamati	0.29	0.87	1.78	1.35	6.13	20.63	5.58	6.14	5.80	0.99	0.02	0.04
Rangpur	0.04	0.52	0.84	1.63	10.10	16.38	16.59	11.25	12.24	0.43	0.01	0.03
Sandwip	0.31	1.75	2.68	2.72	5.84	27.15	5.24	7.98	6.97	0.28	0.15	0.09
Satkhira	0.07	0.22	0.36	0.49	2.73	16.58	13.71	8.15	4.65	1.28	0.09	0.15
Sitakunda	0.14	0.88	1.57	1.28	4.82	19.15	7.50	9.97	10.99	1.44	0.17	0.08
Srimongal	0.09	1.18	2.56	2.08	8.19	15.44	8.54	8.84	10.62	0.75	0.15	0.11
Syedpur	0.06	0.34	0.55	1.39	8.45	17.78	15.93	11.86	10.83	0.63	0.00	0.04
Sylhet	1.28	4.60	12.43	15.59	28.45	17.26	15.53	12.40	14.43	1.20	0.68	0.22
Tangail	0.05	0.44	1.06	0.85	8.11	17.09	11.63	9.83	9.76	0.62	0.12	0.08
Teknaf	0.08	0.86	0.77	1.63	11.09	49.72	5.35	8.26	5.77	0.15	0.04	0.04
Country	0.16	0.84	1.57	1.57	6.45	21.90	9.94	9.33	8.78	0.80	0.14	0.10
Normal	**0.51**	**0.66**	**1.74**	**4.70**	**9.32**	**16.48**	**17.39**	**13.39**	**10.01**	**4.96**	**1.28**	**0.25**

Appendix A continued.....

Appendix A: PRECIS generated Rainfall (mm/d) scenario in 2070.

	2070 m1	2070 m2	2070 m3	2070 m4	2070 m5	2070 m6	2070 m7	2070 m8	2070 m9	2070 m10	2070 m11	2070 m12
Barisal	0.41	0.08	0.23	6.18	4.97	21.15	13.58	14.25	11.87	1.44	0.69	0.01
Bhola	0.32	0.12	0.19	5.56	4.30	20.79	13.20	13.86	11.92	1.34	0.69	0.01
Bogra	0.21	0.08	0.42	10.55	8.74	33.49	10.91	12.66	15.34	1.89	0.77	0.61
Chandpur	0.28	0.07	0.20	5.56	4.25	18.68	11.44	11.78	10.23	1.24	0.59	0.04
Chittagong	0.71	1.66	1.32	5.20	3.68	10.75	7.92	8.61	7.90	0.55	0.25	0.29
Comilla	0.28	0.09	0.28	5.20	4.66	20.19	10.14	13.84	10.35	1.47	0.55	0.20
Coxbazar	0.22	0.41	2.27	6.84	1.45	8.64	3.81	6.31	9.54	0.48	0.26	0.66
Dhaka	0.41	0.06	0.86	7.61	7.97	29.20	12.39	15.26	13.94	2.33	1.17	0.73
Dinajpur	0.12	0.02	0.34	9.89	9.02	33.56	11.32	12.41	13.82	2.22	0.45	0.03
Faridpur	0.32	0.07	0.59	5.78	5.02	19.27	10.85	12.98	12.86	1.98	1.31	0.35
Feni	0.18	0.12	0.63	5.17	4.59	19.72	10.47	13.19	10.56	1.12	0.38	0.09
Hatiya	0.28	0.30	0.55	7.97	2.70	18.84	8.94	9.40	10.90	0.51	0.34	0.02
Ishurdi	0.27	0.10	0.47	6.45	5.25	21.73	10.90	12.24	11.88	1.85	1.33	0.83
Jessor	0.33	0.11	0.42	5.21	3.98	17.35	11.87	12.33	11.80	1.97	1.15	0.17
Khepupara	0.37	0.10	0.16	6.06	3.60	22.99	14.54	13.79	13.16	0.89	1.13	0.01
Khulna	0.38	0.09	0.19	4.75	2.97	16.02	12.29	12.51	11.43	1.73	0.87	0.05
Kutubdia	0.65	1.45	1.72	5.47	2.34	8.31	4.75	6.29	8.12	0.50	0.26	0.50
M'court	0.26	0.14	0.20	5.67	4.09	22.46	12.52	14.66	11.96	1.32	0.51	0.03
Madaripur	0.45	0.06	0.32	6.18	4.76	20.52	12.87	13.11	11.86	1.77	0.84	0.06
Mongla	0.38	0.09	0.19	4.75	2.97	16.02	12.29	12.51	11.43	1.73	0.87	0.05
Mymensing	0.55	0.26	1.60	12.34	15.76	36.81	9.76	12.97	14.17	1.58	0.55	0.24
Patuakhali	0.37	0.10	0.16	6.06	3.60	22.99	14.54	13.79	13.16	0.89	1.13	0.01
Rajshahi	0.27	0.08	0.33	7.92	6.51	26.67	11.06	11.41	12.19	1.82	0.96	1.03
Rangamati	0.13	0.15	1.28	3.61	1.80	8.49	6.14	7.88	5.38	1.07	0.56	0.30
Rangpur	0.11	0.02	0.59	11.36	11.89	37.21	10.58	13.74	13.86	2.17	0.40	0.03
Sandwip	0.24	0.31	1.79	7.49	3.35	17.04	8.27	9.86	9.93	0.45	0.30	0.07
Satkhira	0.32	0.12	0.16	3.89	2.85	15.47	13.16	12.57	11.24	1.91	0.89	0.10
Sitakunda	0.26	0.08	0.55	4.76	5.24	17.41	9.73	12.65	10.36	1.48	0.47	0.23
Srimongal	0.56	0.07	1.16	9.35	7.94	20.41	9.29	13.92	10.11	1.72	0.77	0.49
Syedpur	0.12	0.02	0.34	9.89	9.02	33.56	11.32	12.41	13.82	2.22	0.45	0.03
Sylhet	2.32	1.57	8.43	28.35	34.12	37.40	16.40	20.71	14.48	3.22	1.33	0.26
Tangail	0.25	0.11	0.78	7.99	7.37	28.93	8.44	13.65	14.36	1.66	1.05	0.80
Teknaf	0.03	0.08	1.37	4.35	2.80	14.39	9.03	15.13	14.19	0.52	0.21	0.45
Country	0.37	0.25	0.91	7.38	6.17	21.71	10.75	12.51	11.76	1.49	0.71	0.27
Normal	**0.51**	**0.66**	**1.74**	**4.70**	**9.32**	**16.48**	**17.39**	**13.39**	**10.01**	**4.96**	**1.28**	**0.25**

Appendix B: PRECIS generated Maximum Temperature (^{o}C) scenario in 2030.

	2030 m1	2030 m2	2030 m3	2030 m4	2030 m5	2030 m6	2030 m7	2030 m8	2030 m9	2030 m10	2030 m11	2030 m12
Barisal	24.50	28.11	31.49	33.48	35.77	42.17	30.97	33.23	33.83	35.81	29.85	25.79
Bhola	24.29	27.82	30.69	32.04	34.05	39.72	30.63	32.71	33.23	35.20	30.00	25.64
Bogra	22.97	26.99	32.83	39.39	37.63	42.91	31.03	34.45	32.13	33.33	27.94	24.76
Chandpur	24.42	28.20	31.56	33.70	35.16	41.84	31.13	34.27	34.19	36.03	30.25	25.76
Chittagong	24.99	28.81	31.94	32.93	33.70	39.91	30.08	34.04	33.99	36.17	31.60	26.20
Comilla	24.07	27.92	30.75	32.83	34.03	41.89	30.49	34.29	34.08	35.59	29.87	25.51
Coxbazar	23.62	26.23	28.63	30.16	30.72	32.36	29.10	29.26	28.97	29.28	27.46	24.88
Dhaka	23.01	27.31	31.94	36.59	37.10	43.60	30.71	34.36	33.38	35.16	29.09	24.68
Dinajpur	23.64	27.75	31.15	36.02	33.17	40.09	30.93	33.87	31.09	31.67	27.28	25.16
Faridpur	23.78	28.07	33.71	38.62	39.51	45.03	31.60	34.54	34.05	35.39	28.93	25.12
Feni	24.87	28.25	30.50	31.64	32.47	40.99	29.60	33.70	33.97	35.82	30.50	26.03
Hatiya	23.52	26.50	29.10	30.49	31.46	35.05	29.61	30.88	30.79	31.77	28.31	24.91
Ishurdi	23.75	27.82	35.64	42.33	42.19	45.54	31.71	33.99	33.37	34.15	28.08	24.92
Jessor	24.36	28.55	34.69	39.31	40.98	45.89	32.08	33.75	34.24	35.35	28.56	25.34
Khepupara	24.59	27.96	30.88	32.36	35.01	40.66	30.89	32.48	33.37	35.53	30.06	25.91
Khulna	24.78	28.53	33.63	37.48	40.00	45.35	32.12	33.30	34.30	35.45	28.80	25.78
Kutubdia	24.09	27.35	30.33	31.61	32.28	36.06	29.69	31.72	31.34	32.63	29.34	25.33
M'court	24.54	28.08	30.63	31.93	33.33	40.50	30.24	33.88	34.10	35.92	30.26	25.82
Madaripur	24.22	28.06	32.18	35.06	36.56	43.26	31.21	34.03	34.03	35.70	29.62	25.52
Mongla	24.78	28.53	33.63	37.48	40.00	45.35	32.12	33.30	34.30	35.45	28.80	25.78
Mymensing	22.23	25.88	29.11	32.50	32.97	40.74	29.66	34.14	31.63	34.35	29.10	23.98
Patuakhali	24.59	27.96	30.88	32.36	35.01	40.66	30.89	32.48	33.37	35.53	30.06	25.91
Rajshahi	23.49	27.05	34.56	41.89	40.53	44.46	31.28	33.93	32.54	32.92	28.05	25.32
Rangamati	25.08	28.69	31.24	32.80	33.87	40.76	28.88	33.50	33.87	34.97	31.35	26.69
Rangpur	23.34	27.50	30.60	34.68	32.69	39.58	31.01	34.27	31.12	32.20	27.77	25.03
Sandwip	23.54	26.55	29.19	30.62	31.30	35.95	29.39	31.00	30.86	31.74	28.24	24.91
Satkhira	24.75	28.77	34.82	39.16	41.59	46.24	32.39	33.04	34.25	35.13	28.40	25.57
Sitakunda	24.13	27.82	30.11	31.75	32.45	41.28	29.38	33.66	33.31	35.01	29.74	25.46
Srimongal	23.22	27.12	30.03	32.23	32.81	41.89	30.18	34.45	32.82	35.38	30.23	25.23
Syedpur	23.64	27.75	31.15	36.02	33.17	40.09	30.93	33.87	31.09	31.67	27.28	25.16
Sylhet	21.95	24.76	26.59	28.00	29.13	37.79	28.19	31.77	29.70	32.53	29.66	24.60
Tangail	22.87	27.15	32.79	38.99	38.46	43.83	31.08	34.90	32.91	34.68	28.60	24.59
Teknaf	25.05	28.10	30.06	30.97	31.88	34.81	28.66	30.65	32.26	32.68	29.80	26.57
Country	23.96	27.63	31.43	34.47	35.18	41.10	30.54	33.27	32.80	34.25	29.18	25.39
Normal	**25.67**	**28.07**	**31.63**	**33.07**	**32.74**	**31.43**	**30.79**	**31.04**	**31.35**	**31.03**	**29.12**	**26.24**

Appendix B continued.....

Appendix B: PRECIS generated Maximum Temperature (^{o}C) scenario in 2050.

	2050 m1	2050 m2	2050 m3	2050 m4	2050 m5	2050 m6	2050 m7	2050 m8	2050 m9	2050 m10	2050 m11	2050 m12
Barisal	25.90	31.93	35.28	37.88	37.20	30.77	33.49	33.14	35.04	35.73	34.38	28.06
Bhola	25.47	30.48	33.78	36.16	35.87	30.54	33.04	32.45	34.00	34.96	33.20	27.80
Bogra	26.00	32.92	37.90	44.17	38.72	32.79	33.30	34.80	34.85	34.81	33.24	27.75
Chandpur	25.77	31.75	35.45	38.20	37.75	31.41	34.19	33.89	35.18	35.76	34.15	28.10
Chittagong	25.46	28.84	31.98	34.33	35.34	30.71	34.04	33.56	33.39	35.71	32.70	28.55
Comilla	25.44	30.84	35.09	37.63	37.76	31.97	34.33	34.01	34.21	35.02	32.62	27.66
Coxbazar	23.55	26.37	29.52	31.21	31.36	29.76	29.73	29.44	29.33	29.22	27.37	26.04
Dhaka	25.08	32.58	36.49	41.59	38.81	32.25	33.51	34.26	34.85	35.59	33.55	27.47
Dinajpur	26.00	32.54	38.25	42.14	36.37	33.02	32.46	34.37	33.68	33.35	32.52	27.76
Faridpur	25.88	33.93	37.54	42.52	40.10	32.31	33.96	34.56	35.69	36.12	34.94	27.85
Feni	25.79	29.48	33.50	35.44	36.06	30.74	34.14	33.29	33.68	34.90	32.33	28.22
Hatiya	24.15	27.72	31.33	32.98	33.01	30.12	31.18	30.92	31.17	31.58	29.41	26.35
Ishurdi	26.64	34.68	38.91	45.72	41.39	32.68	33.61	34.58	35.69	35.72	34.74	27.94
Jessor	26.35	34.51	37.96	42.33	40.44	32.39	33.70	34.12	35.73	36.16	35.48	27.78
Khepupara	25.94	31.02	33.80	36.12	35.98	30.50	32.90	32.51	34.31	35.59	33.89	28.02
Khulna	26.57	33.94	37.22	40.61	39.44	32.17	33.51	33.81	35.42	36.07	35.37	27.93
Kutubdia	24.24	27.41	30.51	32.72	33.31	30.23	31.83	31.60	31.37	32.44	29.83	27.05
M'court	25.64	30.32	34.13	36.17	36.79	30.99	33.99	33.55	34.13	35.25	33.06	28.00
Madaripur	25.75	32.64	36.13	39.58	38.50	31.41	33.86	33.88	35.33	35.72	34.56	27.93
Mongla	26.57	33.94	37.22	40.61	39.44	32.17	33.51	33.81	35.42	36.07	35.37	27.93
Mymensing	24.22	29.94	33.80	38.03	34.94	32.76	32.68	34.06	33.43	34.70	31.58	26.73
Patuakhali	25.94	31.02	33.80	36.12	35.98	30.50	32.90	32.51	34.31	35.59	33.89	28.02
Rajshahi	26.75	34.21	38.79	45.65	40.45	32.57	33.06	34.54	35.22	34.86	33.95	28.15
Rangamati	25.84	29.30	33.45	35.24	35.97	30.22	34.34	33.28	32.39	34.01	31.60	29.14
Rangpur	25.74	32.09	37.56	41.33	35.95	33.46	32.79	34.66	33.67	33.72	32.38	27.70
Sandwip	23.93	27.27	31.15	32.92	33.04	30.03	31.46	31.00	31.05	31.40	29.03	26.31
Satkhira	26.82	34.67	37.93	41.78	40.33	32.61	33.60	34.08	35.24	36.03	35.62	27.81
Sitakunda	25.43	29.59	33.95	36.21	36.16	31.53	33.75	33.28	33.11	34.16	31.61	27.56
Srimongal	24.99	30.19	34.16	37.05	35.58	33.53	33.80	34.56	33.50	34.64	31.86	27.60
Syedpur	26.00	32.54	38.25	42.14	36.37	33.02	32.46	34.37	33.68	33.35	32.52	27.76
Sylhet	23.01	26.63	29.84	31.36	30.79	32.10	30.89	32.47	31.09	31.77	29.52	27.24
Tangail	25.66	32.96	37.38	43.54	39.35	32.87	33.69	34.99	35.18	35.70	33.81	27.68
Teknaf	25.40	27.65	31.34	32.47	32.76	28.77	31.39	30.27	31.33	33.33	30.80	28.50
Country	25.51	31.09	34.95	38.24	36.71	31.60	33.06	33.35	33.81	34.52	32.75	27.71
Normal	**25.67**	**28.07**	**31.63**	**33.07**	**32.74**	**31.43**	**30.79**	**31.04**	**31.35**	**31.03**	**29.12**	**26.24**

Appendix B continued.....

Appendix B: PRECIS generated Maximum Temperature (^{o}C) scenario in 2070.

	2070 m1	2070 m2	2070 m3	2070 m4	2070 m5	2070 m6	2070 m7	2070 m8	2070 m9	2070 m10	2070 m11	2070 m12
Barisal	27.99	35.78	37.63	36.89	37.23	35.21	33.79	34.39	31.96	35.43	30.55	28.21
Bhola	27.46	34.29	36.08	35.98	36.21	34.16	33.48	33.73	31.53	34.75	30.16	27.83
Bogra	27.35	36.67	41.16	37.80	40.09	32.55	34.74	34.66	31.78	33.74	28.82	26.92
Chandpur	27.76	35.84	37.96	37.54	37.55	35.16	34.62	34.64	32.53	35.64	30.64	28.11
Chittagong	27.62	31.16	33.31	35.46	35.43	34.59	34.41	33.56	32.20	35.78	31.76	28.22
Comilla	27.38	34.89	37.97	37.31	36.67	34.77	34.67	34.63	32.39	35.59	30.15	27.55
Coxbazar	25.71	28.45	30.63	31.89	32.25	30.98	30.89	30.62	29.76	29.52	27.64	25.87
Dhaka	26.56	35.82	39.61	37.94	38.95	34.28	34.72	34.50	32.09	34.46	29.34	26.86
Dinajpur	28.37	36.81	40.36	34.77	35.45	30.68	34.45	34.55	31.01	33.38	28.54	27.06
Faridpur	27.84	37.40	40.78	38.75	40.33	35.70	34.84	34.92	32.63	34.81	29.75	27.43
Feni	28.15	33.87	35.44	36.33	35.22	34.44	34.16	34.06	32.01	35.68	30.74	28.06
Hatiya	26.21	30.99	32.98	33.68	33.37	32.09	32.06	32.06	30.47	31.74	28.37	26.12
Ishurdi	28.02	38.36	42.39	40.14	42.79	34.70	34.52	34.93	32.63	34.08	28.96	27.09
Jessor	28.83	37.92	41.20	39.00	40.70	36.45	34.33	35.08	32.90	34.95	30.06	27.84
Khepupara	27.99	34.25	36.01	35.75	36.44	34.39	33.34	34.34	31.60	35.26	30.45	28.19
Khulna	29.26	37.30	40.09	38.23	39.48	36.35	34.02	35.29	32.85	35.19	30.55	28.30
Kutubdia	26.38	29.40	31.84	33.59	33.96	32.70	32.70	32.19	30.97	32.64	29.56	26.80
M'court	27.73	34.52	36.66	36.71	35.95	34.32	34.17	34.19	32.13	35.63	30.56	27.99
Madaripur	27.77	36.58	38.93	37.78	38.25	35.70	34.36	34.60	32.32	35.26	30.31	27.91
Mongla	29.26	37.30	40.09	38.23	39.48	36.35	34.02	35.29	32.85	35.19	30.55	28.30
Mymensing	25.36	32.77	37.50	35.39	35.11	32.11	34.48	33.96	31.18	33.73	28.71	26.40
Patuakhali	27.99	34.25	36.01	35.75	36.44	34.39	33.34	34.34	31.60	35.26	30.45	28.19
Rajshahi	27.75	38.04	42.12	39.23	41.94	33.62	34.36	34.72	32.10	33.53	28.47	27.02
Rangamati	28.70	33.92	33.96	35.77	35.22	35.32	34.38	32.90	32.29	34.77	30.78	28.18
Rangpur	28.14	36.26	39.82	34.67	35.16	30.80	34.72	34.79	31.02	33.61	28.77	27.07
Sandwip	26.12	30.62	32.52	33.67	33.27	32.33	32.24	32.03	30.49	31.80	28.30	26.05
Satkhira	29.99	38.04	40.96	39.23	40.90	36.68	33.96	35.38	32.88	34.99	30.36	28.12
Sitakunda	27.65	33.88	36.43	36.65	35.57	34.36	34.00	34.13	31.76	35.21	29.91	27.33
Srimongal	26.80	33.92	37.72	36.39	35.66	34.03	35.00	34.87	32.27	34.82	29.45	27.09
Syedpur	28.37	36.81	40.36	34.77	35.45	30.68	34.45	34.55	31.01	33.38	28.54	27.06
Sylhet	25.01	30.55	32.60	32.46	31.60	30.99	32.84	32.15	29.90	32.26	27.45	26.18
Tangail	26.94	36.28	40.69	38.24	40.39	33.69	34.99	34.86	32.21	34.31	29.29	26.91
Teknaf	27.76	31.34	31.85	33.35	33.20	31.80	30.84	30.93	30.67	33.39	29.66	27.62
Country	27.58	34.68	37.38	36.34	36.84	33.83	33.88	33.99	31.76	34.24	29.62	27.39
Normal	**25.67**	**28.07**	**31.63**	**33.07**	**32.74**	**31.43**	**30.79**	**31.04**	**31.35**	**31.03**	**29.12**	**26.24**

Appendix C: PRECIS generated Minimum Temperature (^{o}C) scenario in 2030.

	2030	**2030**	**2030**	**2030**	**2030**	**2030**	**2030**	**2030**	**2030**	**2030**	**2030**	**2030**
	m1	**m2**	**m3**	**m4**	**m5**	**m6**	**m7**	**m8**	**m9**	**m10**	**m11**	**m12**
Barisal	12.85	18.22	24.01	27.25	28.43	30.51	27.97	26.88	25.89	24.02	15.68	10.91
Bhola	13.66	18.59	24.40	27.44	28.50	30.55	27.98	27.11	26.18	24.52	16.97	12.35
Bogra	11.88	16.00	23.59	26.86	27.92	31.53	27.89	27.49	26.35	20.99	13.56	11.26
Chandpur	12.27	17.80	23.98	27.33	28.29	30.56	28.04	27.14	26.31	23.87	15.86	10.75
Chittagong	10.97	17.05	22.43	26.53	27.97	30.35	27.62	27.24	26.59	24.96	17.63	11.66
Comilla	11.92	17.12	23.37	26.74	27.60	30.09	27.59	26.70	25.91	22.56	14.90	10.42
Coxbazar	19.92	22.99	26.38	28.61	29.37	30.55	28.24	27.99	27.21	26.78	24.23	21.37
Dhaka	12.29	17.24	23.77	27.09	28.02	30.79	27.94	27.15	26.36	22.88	15.30	11.09
Dinajpur	11.41	15.40	22.56	24.40	25.47	29.36	27.49	27.59	25.96	20.06	12.34	10.56
Faridpur	12.72	17.77	24.33	27.66	28.86	31.29	28.34	27.37	26.65	23.08	15.05	10.81
Feni	11.57	16.88	23.05	26.41	27.36	29.72	27.21	26.39	25.64	22.73	15.52	10.86
Hatiya	15.93	20.43	25.59	28.22	28.91	30.63	28.14	27.66	26.80	25.31	19.83	16.11
Ishurdi	12.44	16.76	24.12	27.75	29.50	32.27	28.34	27.32	26.73	21.81	14.30	11.39
Jessor	13.07	18.13	24.55	27.80	29.22	31.33	28.33	27.15	26.45	22.97	14.64	10.43
Khepupara	13.18	18.33	24.07	27.15	28.60	30.55	27.93	26.83	25.73	24.13	15.31	11.50
Khulna	13.51	18.73	24.62	27.77	29.13	31.13	28.24	27.08	26.21	23.08	14.64	10.65
Kutubdia	14.92	19.66	24.53	27.72	28.75	30.50	27.94	27.65	26.81	25.69	20.28	15.75
M'court	11.59	17.09	23.51	26.91	27.76	30.07	27.52	26.66	25.88	23.06	15.11	10.18
Madaripur	12.43	17.95	24.03	27.35	28.39	30.62	28.07	27.05	26.22	23.74	15.63	10.66
Mongla	13.51	18.73	24.62	27.77	29.13	31.13	28.24	27.08	26.21	23.08	14.64	10.65
Mymensing	12.54	16.63	22.61	25.88	26.77	29.82	27.20	26.99	25.76	21.83	15.43	11.77
Patuakhali	13.18	18.33	24.07	27.15	28.60	30.55	27.93	26.83	25.73	24.13	15.31	11.50
Rajshahi	11.93	16.02	23.66	27.34	28.96	32.13	28.14	27.28	26.49	20.93	13.83	11.81
Rangamati	11.14	16.13	21.13	25.03	26.32	29.07	26.49	25.76	24.98	22.33	16.14	11.81
Rangpur	11.42	15.35	22.52	24.60	25.56	29.06	27.52	27.70	25.93	20.30	12.63	10.76
Sandwip	15.39	19.94	25.21	27.91	28.66	30.33	27.76	27.35	26.55	24.89	19.51	15.77
Satkhira	13.68	18.65	24.69	27.84	29.40	31.55	28.37	27.05	26.32	22.91	14.49	10.74
Sitakunda	12.16	16.99	22.67	26.00	26.84	29.50	27.08	26.23	25.43	22.08	15.51	11.53
Srimongal	11.79	16.54	22.72	26.08	27.04	30.27	27.65	27.13	25.88	22.03	14.77	11.13
Syedpur	11.41	15.40	22.56	24.40	25.47	29.36	27.49	27.59	25.96	20.06	12.34	10.56
Sylhet	12.04	16.03	21.11	24.30	25.20	28.48	26.45	26.16	24.78	21.03	15.28	11.66
Tangail	12.25	16.77	23.84	27.31	28.37	31.54	28.05	27.52	26.58	21.91	14.20	10.98
Teknaf	14.20	18.11	22.58	26.26	27.45	29.11	26.75	26.34	26.06	25.30	20.04	15.23
Country	12.88	17.63	23.66	26.81	27.93	30.43	27.76	27.07	26.14	23.00	15.78	11.96
Normal	**13.07**	**15.11**	**19.61**	**23.17**	**24.44**	**25.41**	**25.46**	**25.53**	**25.29**	**23.40**	**18.86**	**14.20**

Appendix C continued.....

Appendix C: PRECIS generated Minimum Temperature (^{o}C) scenario in 2050.

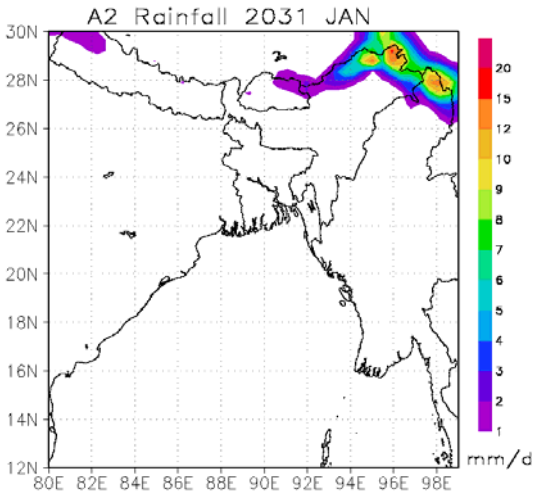
	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050
	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12
Barisal	14.10	19.05	24.40	28.29	29.46	27.58	27.68	27.45	27.20	24.03	21.34	15.22
Bhola	14.91	19.61	24.83	28.46	29.53	27.75	27.87	27.60	27.41	24.43	21.63	16.12
Bogra	12.62	16.10	24.24	28.88	29.05	27.76	27.89	27.94	27.79	22.05	18.56	13.52
Chandpur	13.81	18.77	24.58	28.40	29.59	27.55	27.91	27.64	27.50	23.66	20.98	14.98
Chittagong	13.47	18.11	23.83	27.28	28.76	27.24	27.93	27.69	27.50	23.95	19.14	14.31
Comilla	13.40	18.22	24.34	28.00	29.04	27.04	27.59	27.23	27.08	22.19	19.52	14.16
Coxbazar	20.30	23.40	27.02	29.42	29.94	28.77	28.50	28.29	28.05	26.68	24.32	22.35
Dhaka	13.29	17.62	24.41	28.58	29.17	27.43	27.81	27.64	27.50	22.96	19.81	14.62
Dinajpur	11.81	15.68	22.94	27.55	27.84	27.95	27.79	28.00	27.65	20.81	16.92	12.63
Faridpur	13.65	18.20	24.98	29.00	29.75	27.79	28.03	27.95	27.69	23.79	21.02	15.22
Feni	13.45	18.86	24.09	27.49	28.49	26.73	27.26	26.90	26.77	22.26	19.42	14.37
Hatiya	17.33	21.85	26.21	29.21	29.76	28.20	28.26	28.04	27.81	25.22	22.62	18.52
Ishurdi	13.46	16.91	25.06	29.68	29.83	27.98	27.94	28.03	27.81	23.31	20.33	14.91
Jessor	13.90	18.61	25.09	28.96	29.82	27.82	27.89	27.84	27.41	23.87	21.35	15.55
Khepupara	14.57	19.50	24.55	28.14	29.45	27.66	27.64	27.42	27.17	24.62	21.58	15.45
Khulna	14.61	19.47	25.13	28.71	29.73	27.83	27.84	27.76	27.25	24.00	21.73	15.97
Kutubdia	16.42	20.65	25.48	28.54	29.42	28.07	28.23	28.04	27.71	25.23	21.33	17.86
M'court	13.41	18.64	24.40	28.02	29.06	27.06	27.54	27.18	27.03	22.61	19.77	14.16
Madaripur	13.76	18.72	24.47	28.46	29.60	27.58	27.83	27.62	27.38	23.73	21.21	15.10
Mongla	14.61	19.47	25.13	28.71	29.73	27.83	27.84	27.76	27.25	24.00	21.73	15.97
Mymensing	12.96	16.18	22.84	27.50	27.75	26.99	27.44	27.44	27.10	22.01	18.31	14.00
Patuakhali	14.57	19.50	24.55	28.14	29.45	27.66	27.64	27.42	27.17	24.62	21.58	15.45
Rajshahi	13.24	16.69	24.79	29.42	29.63	27.90	27.83	27.94	27.79	22.37	19.41	14.40
Rangamati	12.90	16.89	22.14	25.66	27.53	25.88	26.53	26.26	26.15	21.45	17.62	14.59
Rangpur	11.75	15.36	22.92	27.55	27.71	27.93	27.89	28.08	27.67	20.88	16.84	12.58
Sandwip	16.76	21.67	26.09	28.85	29.35	27.95	27.97	27.75	27.53	24.65	21.79	17.96
Satkhira	14.69	19.26	25.30	28.90	29.66	27.92	27.86	27.77	27.26	24.01	21.79	16.33
Sitakunda	13.69	18.25	23.78	27.19	28.22	26.51	27.11	26.76	26.58	21.77	19.16	14.59
Srimongal	13.02	17.06	23.54	27.51	28.28	27.07	27.85	27.57	27.17	21.73	18.46	13.49
Syedpur	11.81	15.68	22.94	27.55	27.84	27.95	27.79	28.00	27.65	20.81	16.92	12.63
Sylhet	13.04	16.01	22.05	25.53	26.20	25.98	26.75	26.68	26.03	20.84	17.74	13.43
Tangail	12.91	16.65	24.64	29.16	29.32	27.71	27.99	27.97	27.81	22.77	19.45	14.26
Teknaf	15.15	19.00	23.79	27.19	28.14	27.27	27.26	26.79	26.89	24.72	21.37	17.47
Country	14.04	18.35	24.38	28.18	28.97	27.53	27.73	27.59	27.33	23.21	20.14	15.22
Normal	**13.07**	**15.11**	**19.61**	**23.17**	**24.44**	**25.41**	**25.46**	**25.53**	**25.29**	**23.40**	**18.86**	**14.20**

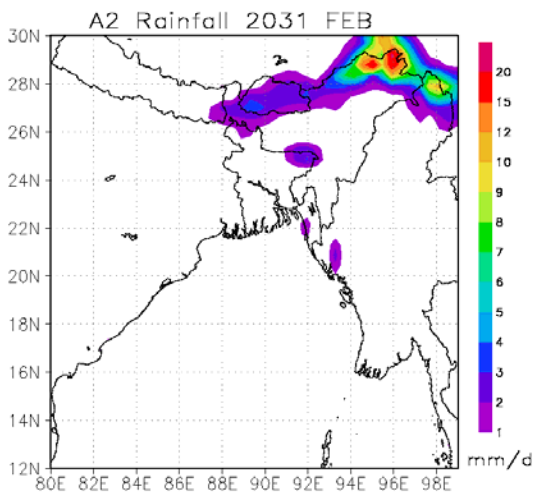
Appendix C continued.....

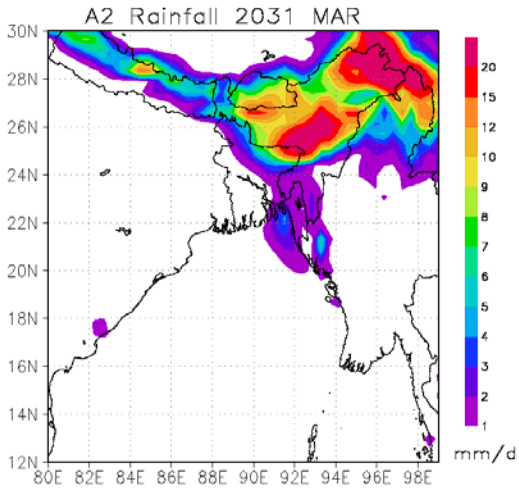
Appendix C: PRECIS generated Minimum Temperature (^{o}C) scenario in 2070.

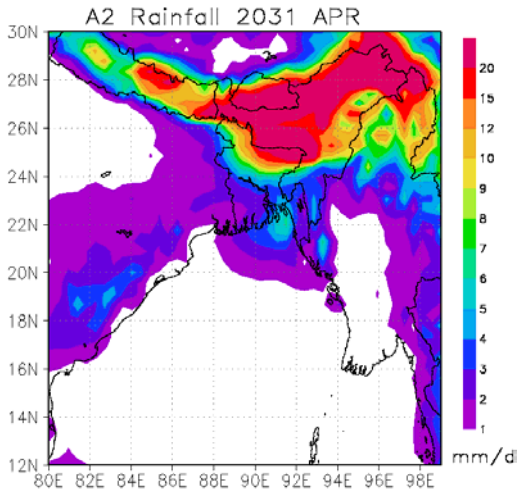
	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
	m1	**m2**	**m3**	**m4**	**m5**	**m6**	**m7**	**m8**	**m9**	**m10**	**m11**	**m12**
Barisal	19.49	21.41	26.77	28.31	30.10	29.40	28.99	28.97	27.46	26.22	19.31	15.10
Bhola	19.70	21.79	27.08	28.57	30.25	29.42	29.16	29.15	27.66	26.47	20.01	16.05
Bogra	17.24	20.24	25.54	28.76	30.25	28.39	29.22	29.31	27.66	24.51	18.31	14.44
Chandpur	18.70	21.13	26.93	28.44	30.24	29.39	29.16	29.05	27.58	26.21	19.04	14.86
Chittagong	16.94	20.04	25.57	28.03	29.70	29.13	29.22	29.22	27.64	26.52	20.13	14.99
Comilla	17.81	20.27	26.69	28.03	29.61	28.91	28.79	28.70	27.19	25.30	18.23	14.41
Coxbazar	22.79	25.31	28.69	30.10	31.05	29.89	29.93	29.81	28.71	27.42	25.13	22.95
Dhaka	18.35	20.51	26.41	28.44	30.01	29.10	29.13	28.95	27.53	25.31	18.65	14.65
Dinajpur	16.23	19.92	24.50	27.72	27.72	26.64	29.12	29.17	27.19	23.77	17.71	13.60
Faridpur	18.91	21.47	27.05	28.81	30.62	29.60	29.44	29.34	27.78	25.74	18.96	14.86
Feni	17.31	20.47	26.18	27.58	29.32	28.59	28.51	28.48	26.91	25.39	18.68	14.92
Hatiya	20.76	23.80	28.22	29.43	30.57	29.66	29.60	29.55	28.19	26.89	21.76	18.60
Ishurdi	18.12	21.34	26.28	29.07	31.11	29.46	29.37	29.47	27.87	25.33	18.69	14.99
Jessor	19.54	21.80	27.33	28.97	30.73	29.68	29.35	29.32	27.79	25.76	18.95	14.81
Khepupara	19.90	21.65	26.74	28.32	30.09	29.46	29.00	29.14	27.54	26.51	19.59	15.47
Khulna	20.46	22.17	27.55	28.99	30.61	29.71	29.33	29.33	27.86	25.88	19.26	15.15
Kutubdia	19.70	22.50	27.26	29.15	30.45	29.51	29.60	29.57	28.19	26.86	22.30	18.42
M'court	17.88	20.55	26.65	27.97	29.71	28.92	28.74	28.66	27.19	25.61	18.35	14.41
Madaripur	19.00	21.31	26.88	28.43	30.23	29.45	29.12	28.99	27.52	26.05	19.04	14.80
Mongla	20.46	22.17	27.55	28.99	30.61	29.71	29.33	29.33	27.86	25.88	19.26	15.15
Mymensing	17.49	18.86	24.56	27.55	28.79	27.96	28.78	28.64	27.02	24.44	18.57	15.26
Patuakhali	19.90	21.65	26.74	28.32	30.09	29.46	29.00	29.14	27.54	26.51	19.59	15.47
Rajshahi	17.50	21.08	25.98	28.94	30.93	28.99	29.23	29.37	27.75	24.75	18.23	14.78
Rangamati	15.95	19.25	24.33	26.34	28.21	28.28	27.96	27.69	26.26	24.56	18.21	14.41
Rangpur	16.15	19.58	24.46	27.75	27.73	26.76	29.21	29.21	27.17	23.80	17.75	13.64
Sandwip	20.18	23.46	27.95	29.17	30.33	29.34	29.38	29.32	27.90	26.57	21.45	18.23
Satkhira	20.54	22.43	27.58	29.23	30.79	29.76	29.30	29.38	27.94	25.85	19.27	15.19
Sitakunda	17.19	20.03	25.93	27.42	28.97	28.40	28.35	28.28	26.70	24.92	18.55	15.10
Srimongal	16.97	19.15	26.05	27.90	29.25	28.77	29.07	28.91	27.25	24.78	18.00	14.38
Syedpur	16.23	19.92	24.50	27.72	27.72	26.64	29.12	29.17	27.19	23.77	17.71	13.60
Sylhet	16.58	18.74	24.13	26.15	27.27	27.35	27.99	27.75	26.42	23.58	17.96	14.46
Tangail	18.07	20.40	25.93	28.83	30.40	29.13	29.36	29.37	27.76	24.97	18.70	14.61
Teknaf	17.84	20.64	25.54	27.61	29.16	28.55	28.27	28.51	27.30	26.58	21.70	18.19
Country	18.48	21.06	26.35	28.33	29.78	28.89	29.06	29.04	27.50	25.54	19.30	15.45
Normal	**13.07**	**15.11**	**19.61**	**23.17**	**24.44**	**25.41**	**25.46**	**25.53**	**25.29**	**23.40**	**18.86**	**14.20**

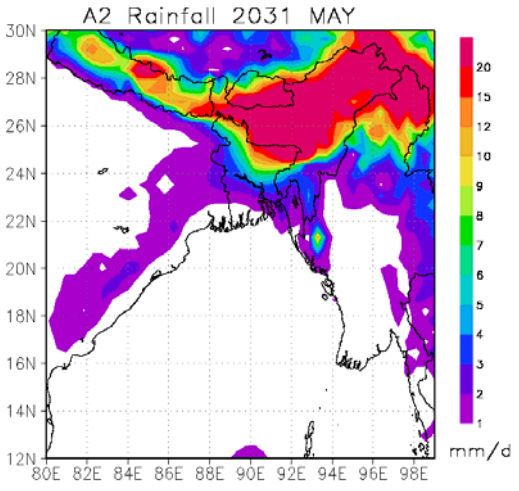
Appendix-D: Monthly Rainfall (mm/d) scenarios for 2031.

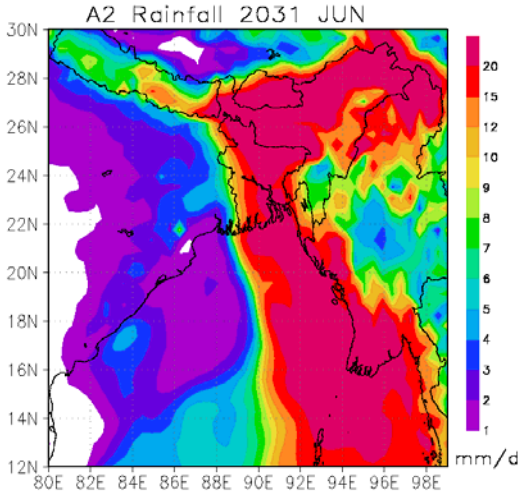


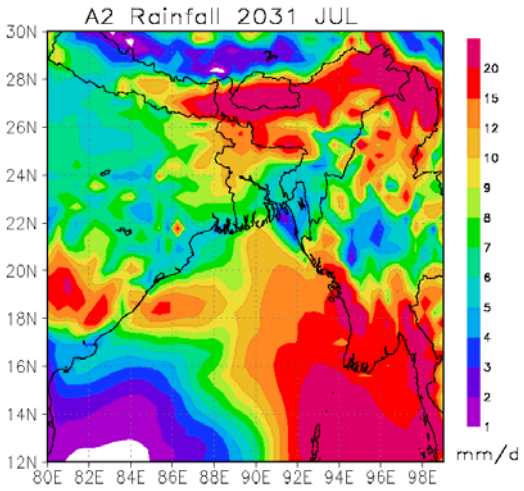


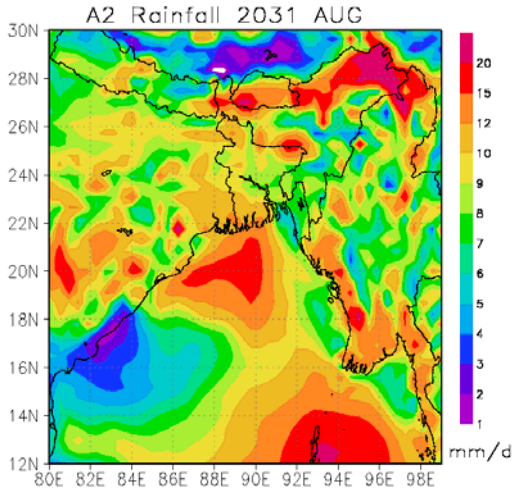


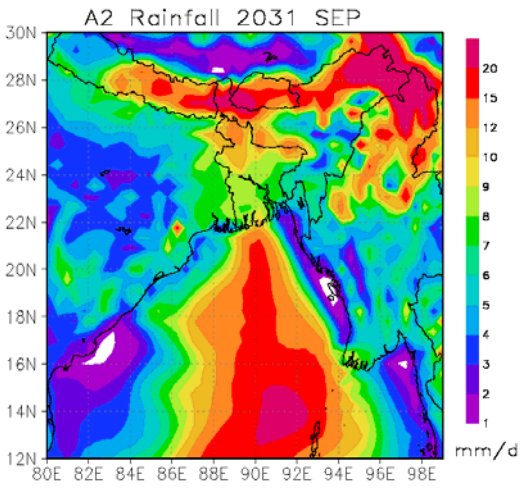


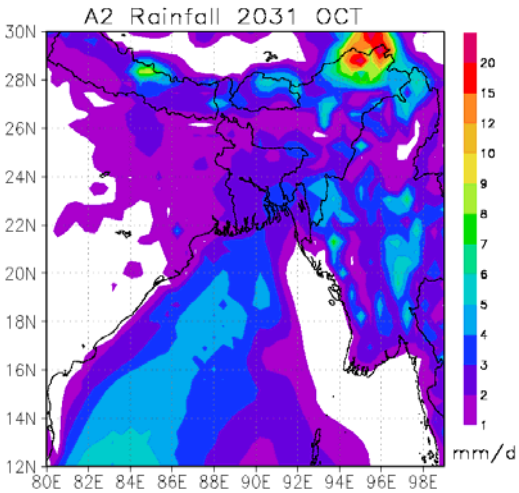


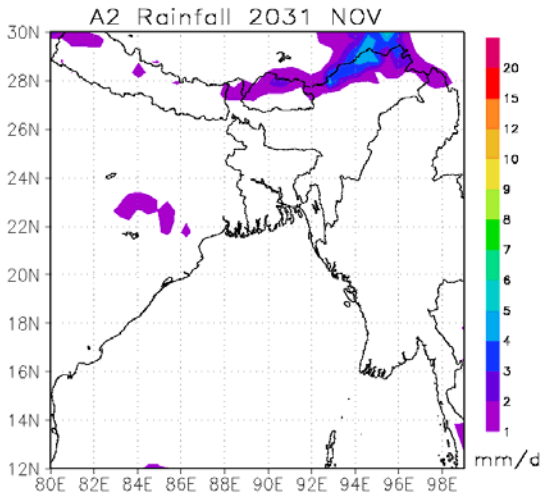


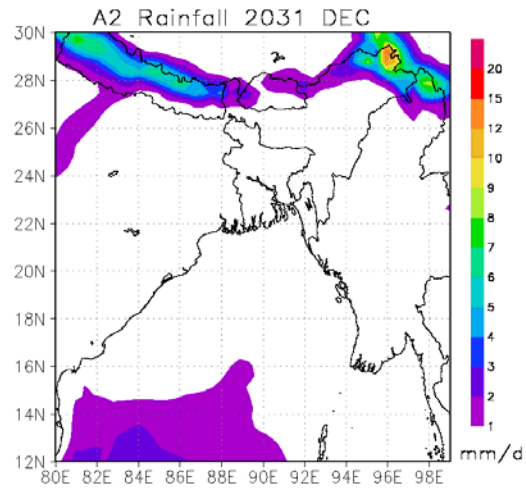

A2 Rainfall 2031 JUL
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
20
15
12
10
9
8
7
6
5
4
3
2
1
mm/d


A2 Rainfall 2031 AUG
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
20
15
12
10
9
8
7
6
5
4
3
2
1
mm/d

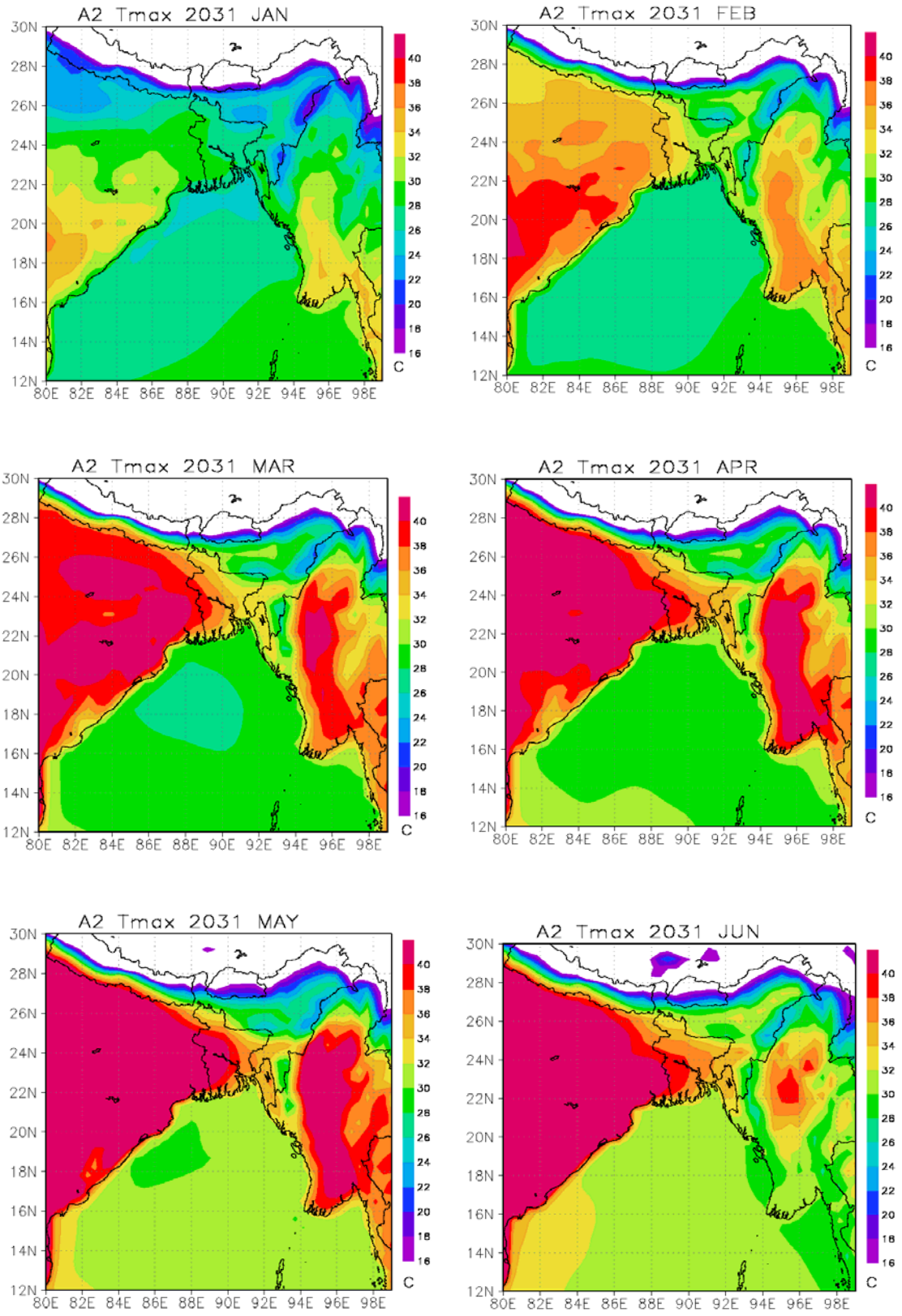

A2 Rainfall 2031 SEP
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
20
15
12
10
9
8
7
6
5
4
3
2
1
mm/d

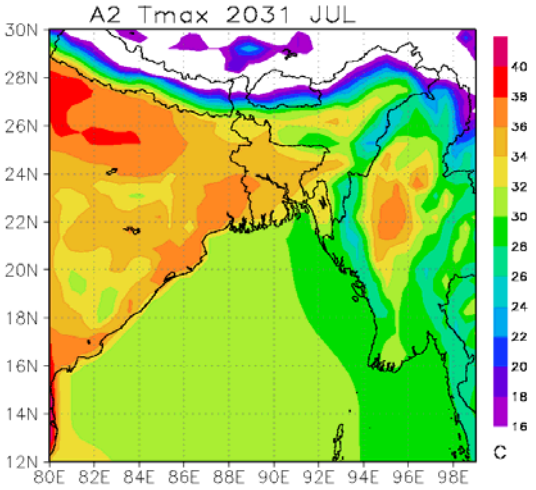

A2 Rainfall 2031 OCT
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
20
15
12
10
9
8
7
6
5
4
3
2
1
mm/d

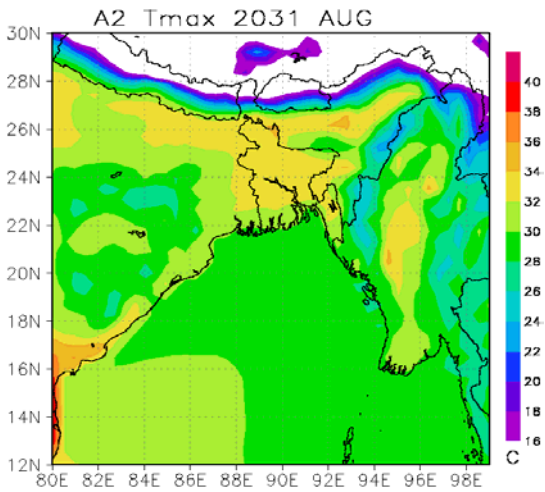

A2 Rainfall 2031 NOV
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
20
15
12
10
9
8
7
6
5
4
3
2
1
mm/d

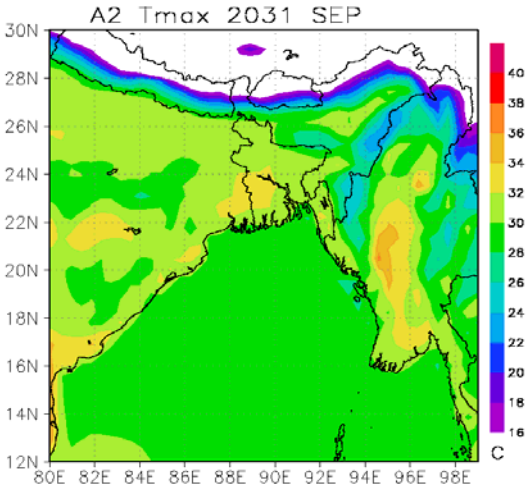

A2 Rainfall 2031 DEC
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
20
15
12
10
9
8
7
6
5
4
3
2
1
mm/d

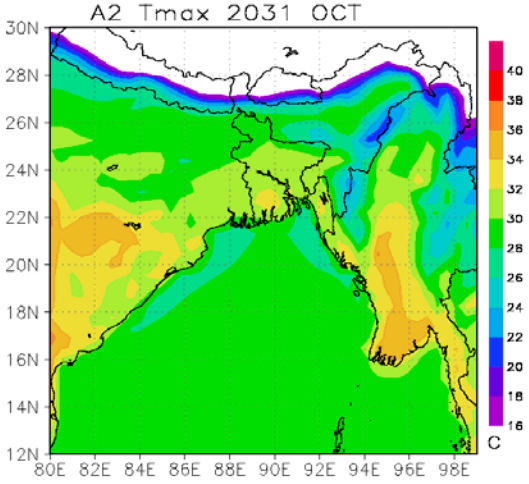
Appendix-E: Monthly Maximum Temperature (^{0}C) scenarios for 2031

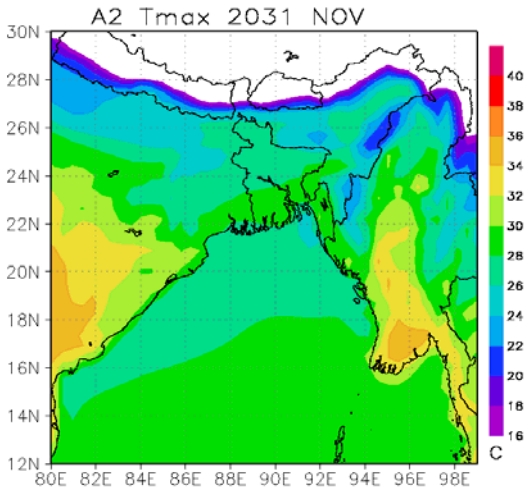


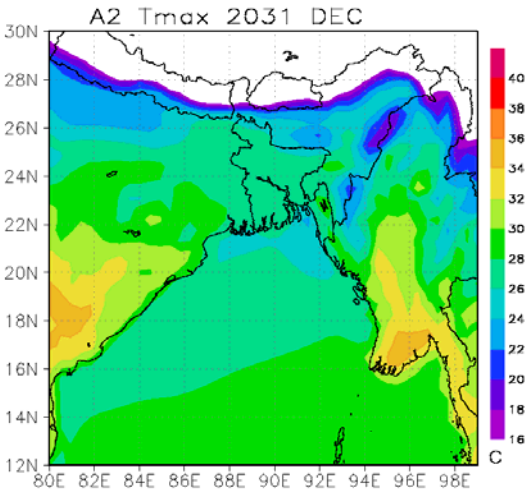

A2 Tmax 2031 JUL
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
40
38
36
34
32
30
28
26
24
22
20
18
16
C


A2 Tmax 2031 AUG
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
40
38
36
34
32
30
28
26
24
22
20
18
16
C


A2 Tmax 2031 SEP
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
40
38
36
34
32
30
28
26
24
22
20
18
16
C


A2 Tmax 2031 OCT
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
40
38
36
34
32
30
28
26
24
22
20
18
16
C


A2 Tmax 2031 NOV
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
40
38
36
34
32
30
28
26
24
22
20
18
16
C


A2 Tmax 2031 DEC
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
40
38
36
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28
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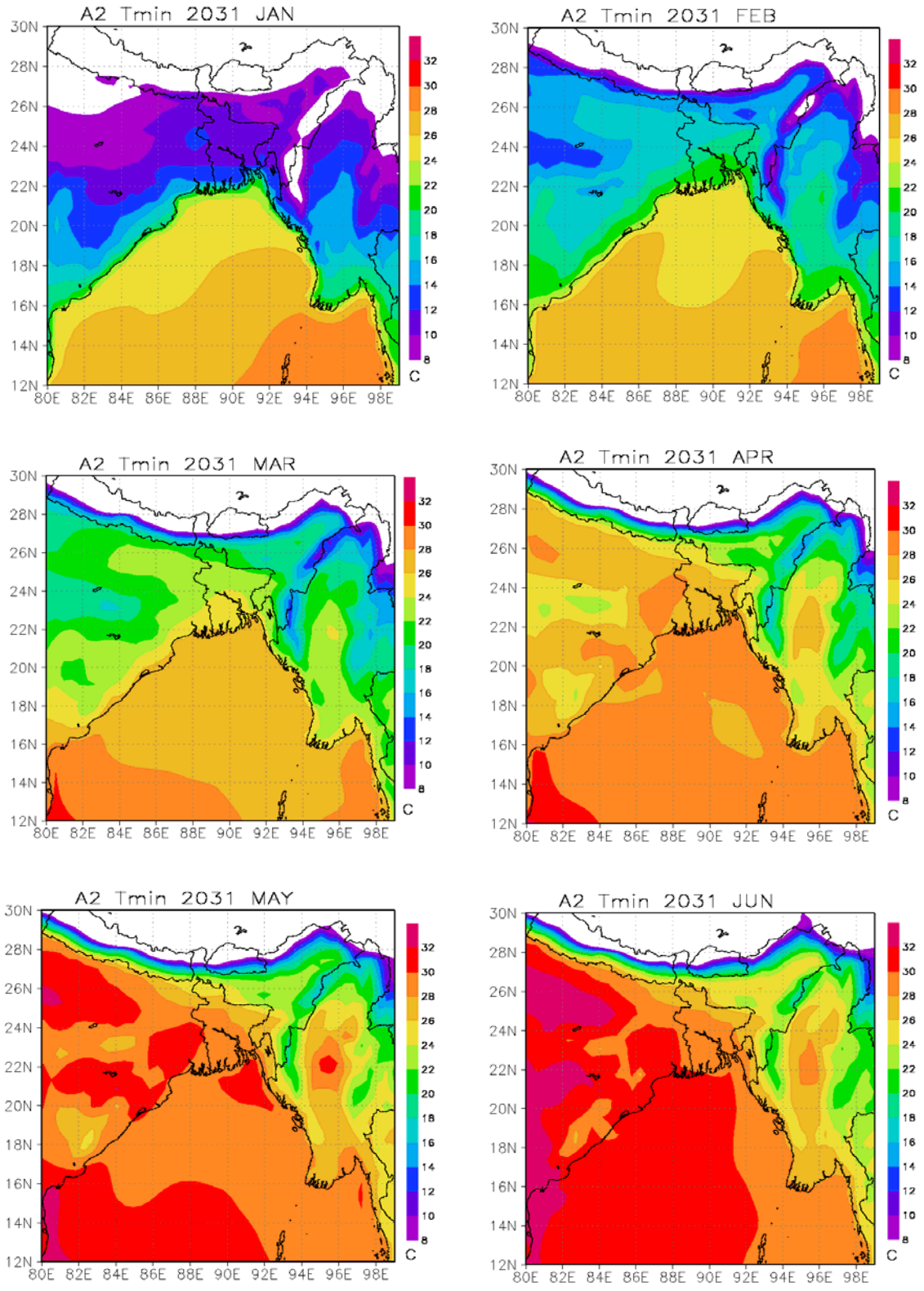
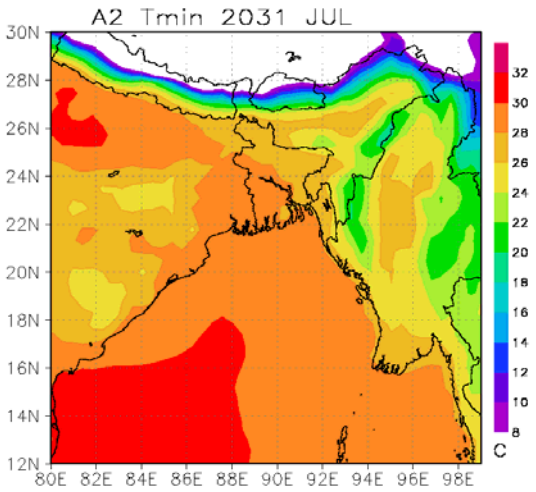
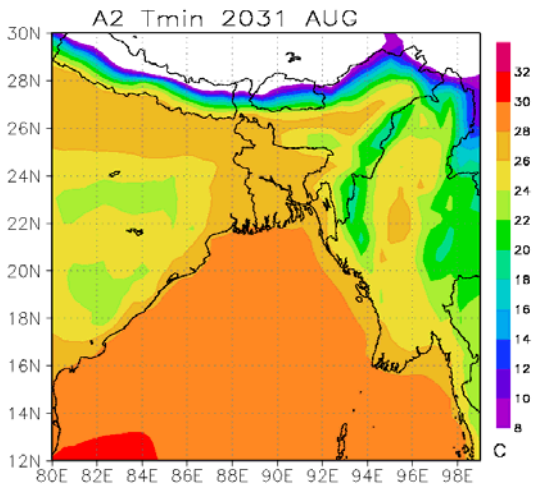
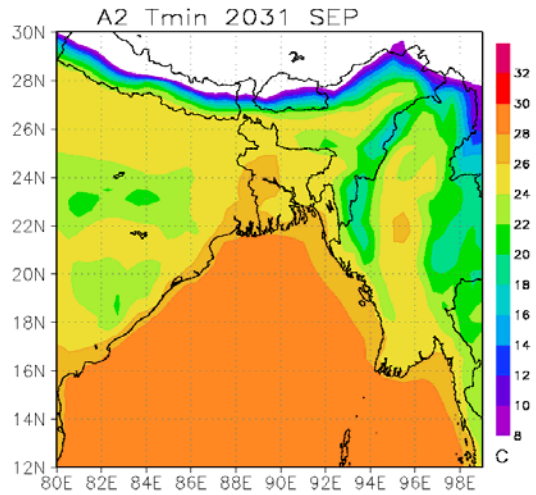
24
22
20
18
16
C

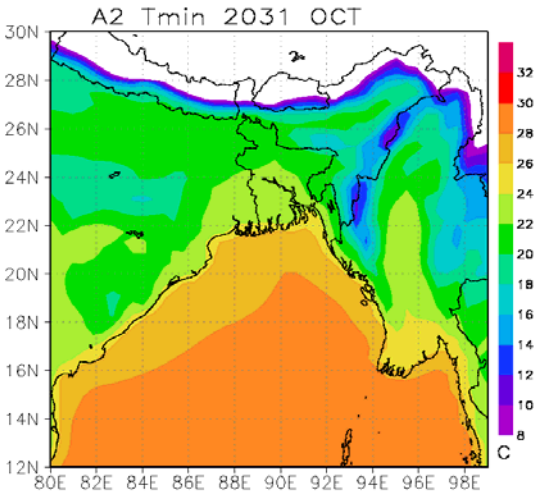
Appendix-F: Monthly Minimum Temperature (^{0}C) scenarios for 2031.

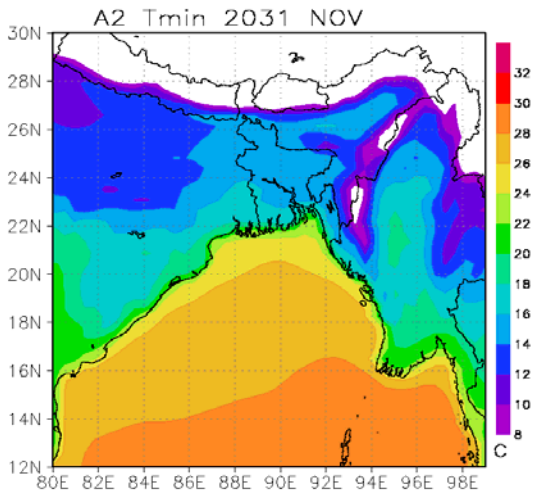


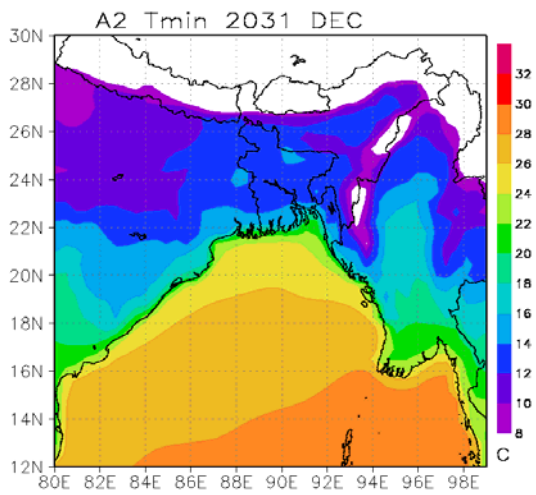

A2 Tmin 2031 JUL
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
32
30
28
26
24
22
20
18
16
14
12
10
8
C


A2 Tmin 2031 AUG
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
32
30
28
26
24
22
20
18
16
14
12
10
8
C

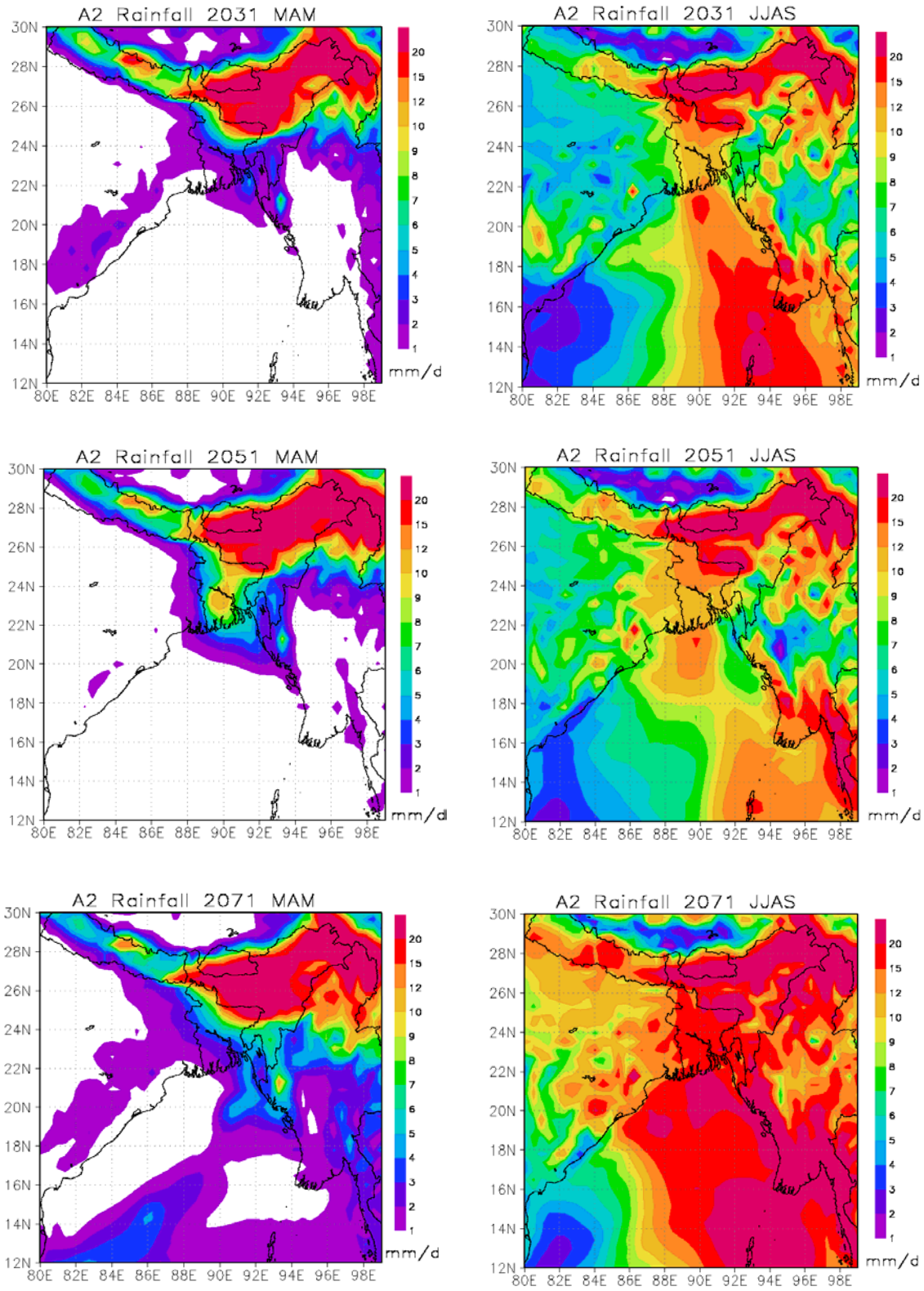

A2 Tmin 2031 SEP
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
32
30
28
26
24
22
20
18
16
14
12
10
8
C


A2 Tmin 2031 OCT
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
32
30
28
26
24
22
20
18
16
14
12
10
8
C

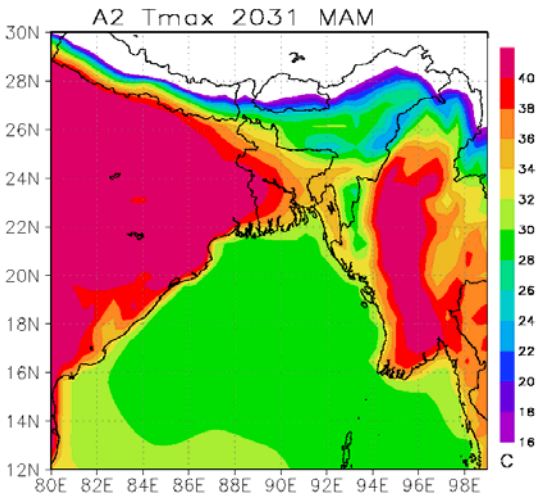

A2 Tmin 2031 NOV
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
32
30
28
26
24
22
20
18
16
14
12
10
8
C

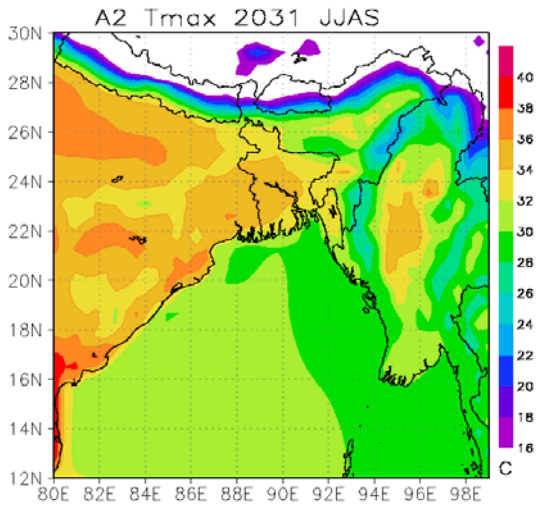

A2 Tmin 2031 DEC
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
80E 82E 84E 86E 88E 90E 92E 94E 96E 98E
32
30
28
26
24
22
20
18
16
14
12
10
8
C

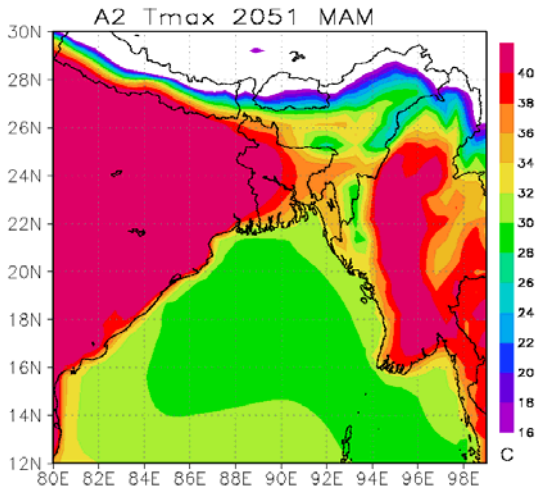
Appendix-G: Seasonal Rainfall (mm/d) scenarios for 2030, 2050 and 2070.

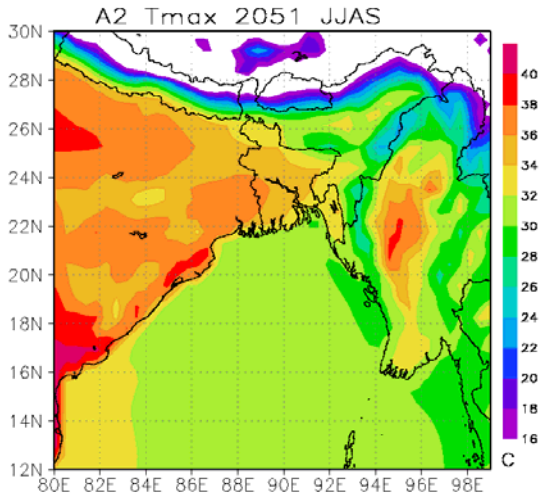


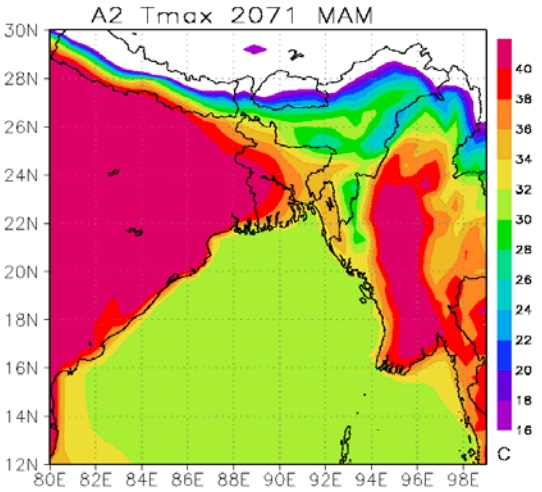
Appendix-H: Seasonal Tmax (^{0}C) scenarios for 2030, 2050 and 2070.

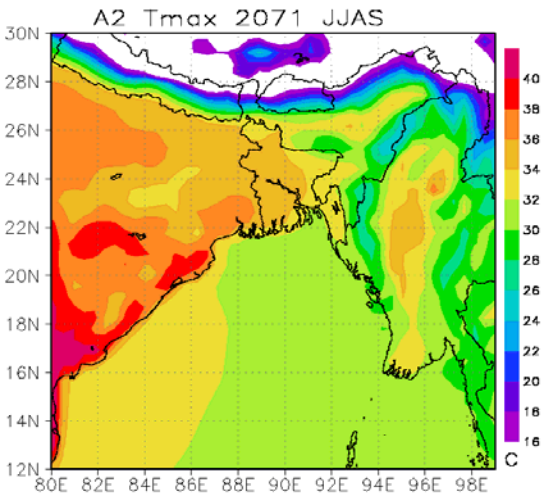




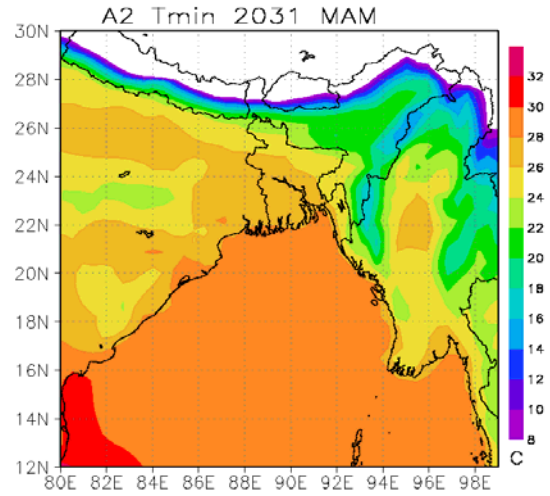


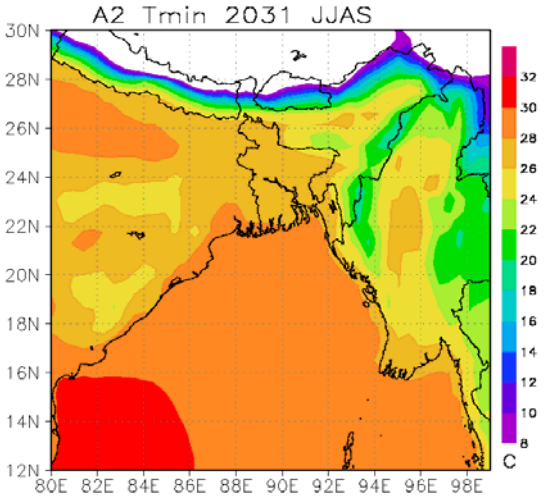


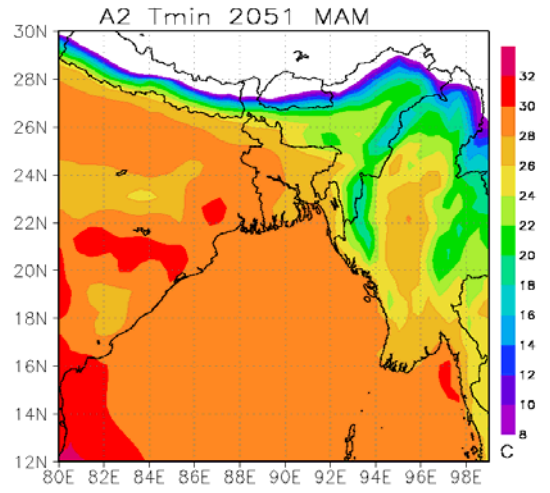


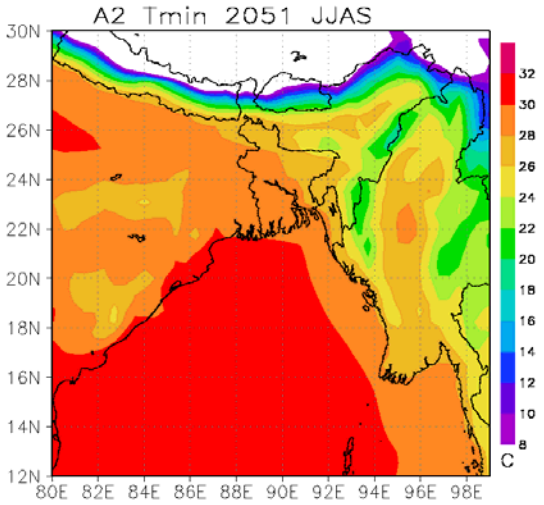


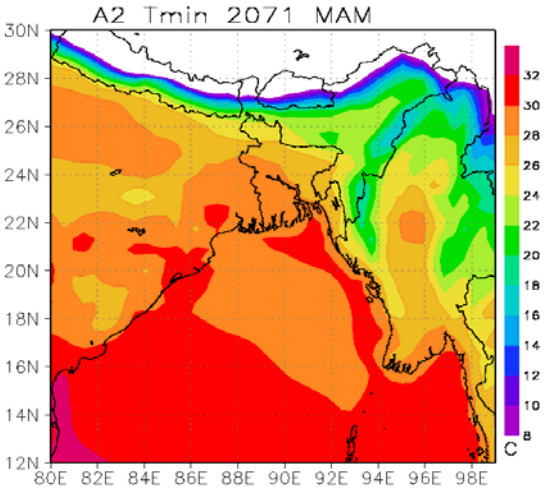
Appendix-I: Seasonal Tmin (^{0}C) scenarios for 2030, 2050 and 2070.

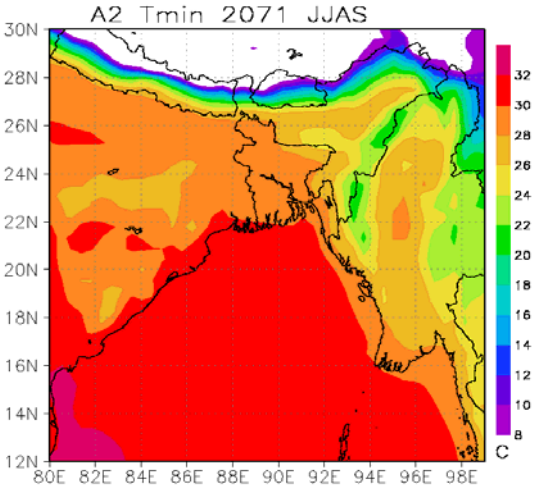












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Department of Environment
Ministry of Environment and Forests

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Comprehensive Disaster Management Programme (CDMP)
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