A HYBRID APPROACH FOR CLIMATE CHANGE SCENARIO GENERATION FOR BANGLADESH USING GCM MODEL RESULTS

Nandan Mukherjee[1], Malik Fida Abdullah Khan[2], Bhuiya Md. Tamim Al Hossain[3], A K M Saiful Islam[4], Most. Nazneen Aktar[5], Shahriar Rahman[6]

[1] Center for Environmental and Geographic Information Services (CEGIS), Dhaka-1212, Bangladesh, e-mail: nmukherjee@cegisbd.com
[2]Center for Environmental and Geographic Information Services (CEGIS), Dhaka-1212, Bangladesh, e-mail: mkhan@cegisbd.com
[3]Center for Environmental and Geographic Information Services (CEGIS), Dhaka-1212, Bangladesh, e-mail: mkhan@cegisbd.com
[4]Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh, e-mail: akmsaifulislam@iwfm.buet.ac.bd
[5]Center for Environmental and Geographic Information Services (CEGIS), Dhaka-1212, Bangladesh, e-mail: gchdhury@cegisbd.com
[6]Center for Environmental and Geographic Information Services (CEGIS), Dhaka-1212, Bangladesh, e-mail: mkhan@cegisbd.com

ABSTRACT

In the 4th assessment report of IPCC, a total of 25 Atmospheric and Ocean Global Circulation Models, AOGCM have been used to project global average surface warming and sea level rise at the end of the year 2100. But the question is whether IPCC derived global and regional (South Asia) scenarios are adequate to represent the climatic condition of Bangladesh. Even in Bangladesh, within 350 km distance, annual precipitation in Sunamganj (Northeast region) is around two and half times than that of the annual precipitation of Chapainababganj (Northwest region) district. So generalizing the distribution of precipitation for overall South Asian region may not represent the climatic situations in Bangladesh. In this paper, a number of GCM models will be selected for generating climatic scenarios for Bangladesh. A sub-set of 8 GCMs was selected based on the models that best simulated the average rainfall during the main monsoon rainy season in Bangladesh (June to August to represent the monsoon), with around 8% increase in the rainfall and 1.6° C increase in the surface temperature.

Keywords: *AOGCM, GCM, climate change, downscaling, climate forcing*

1. INTRODUCTION

Climate is changing. So too are some of our preparedness to improve our resilience to cope with climate variability. The changes have raised concerns about how well we could cope in the future with accelerated climate change, concerns that are reflected in the UN Framework Convention on Climate Change (UNFCCC; http://www.unfccc.de), drafted at the Earth Summit in Rio in June 1992.

Globally, we have already experienced series of very warm years experienced globally during the past two decades, with 1998 being the single warmest year recorded globally using instrumental data and the unusual behaviour of the El Niño /Southern Oscillation (ENSO) over the decades (Trenberth and Hoar, 1996). Similarly, historical mean, maximum and minimum temperature in

Bangladesh is showing an increasing trend, where year 2006 is recorded as the warmest year in the history of time.

According to the Germanwatch Global Climate Risk Index, Bangladeshis the country which is most affected by extreme weather events from 1990 to 2008 (Harmeling, 2008). It has shown that the annual death toll induced by the climate induced disasters is around 8241 with death per 100,000 inhabitants is accounted as 6.27. Annual loss in the GDP worth around 2189 million US$ which is 1.81% of the total GDP contribution. The figures are alarming and needs immediate sensitization from the Government to the grass root level to be ready to adapt or mitigate with the climate induced disaster events. In this regard, the assessment of vulnerability and adaptation (V&A) need assessment is a daunting task. At present Bangladesh is on the way to prepare and submit the initial national communications to the UNFCCC Secretariat that may include V&A assessments of climate change. Now researchers are thriving to identify a reasonable range and character of anticipated future climate changes that may affect specifically Bangladesh as a whole. It is also important to identify critical thresholds of regional climate change beyond which the whole systems or sectors may collapse or become unable to function effectively. For all these reasons, national and regional V&A assessments not only need comprehensive information about present and recent climate variability (as it affects different sectors and population groups), but they also need robust descriptions of future regional climates at the finest possible spatial and temporal scales (Hulme, et al., 2000). Now the question is: how can such descriptions are achieved?

In the 4th assessment report of IPCC, a total of 25 Atmospheric and Ocean Global Circulation Models, AOGCM have been used to project global average surface warming and sea level rise at the end of the year 2100. Increase in the global temperature is anticipated to be remaining in the range of 1.1°C to 6.4°C and projected increase in the global sea level rise is predicted in the range of 0.18m to 0.59m for different emission scenarios. It has also been projected for South Asia that the dry seasonal precipitation during the winter season will be decreased by 16%, followed by increase in the pre-monsoon and monsoon seasonal precipitation by 31% and 26% respectively for A1FI scenarios (IPCC, 2007). But the question is whether IPCC derived global and regional (South Asia) scenarios are adequate to represent the climatic condition of Bangladesh. Even in Bangladesh, within 350 km distance, annual precipitation in Sunamganj (Northeast region) is around two and half times than that of the annual precipitation of Chapainababganj (Northwest region) district. So generalizing the distribution of precipitation for overall South Asian region may not represent the climatic situations in Bangladesh.

But major problem lies with the spatial scale of prediction: GCM models usually better represent the global climatology, but at local scales, the results are too disperse to represent relatively small geographic coverage like Bangladesh. Moreover, there are uncertainties involved in each of the main stages required to provide climate change scenarios for assessing the impacts of climate change. Although, not all the aspects of these uncertainties can be quantified yet, but inherent uncertainties in the key assumptions of the IPCC SRES Scenarios can be examined by making climatic projections for a range of the available SRES scenarios. Moreover, incomplete understanding or imperfect representation of processes in the climate models can be minimized using projections from a range of GCMs (Jones et al., 2004). But not all the GCM models represent Bangladesh properly or create artificial bias while generating the local climatic scenarios.

In this regard, this study aims at selecting the best GCM models through which most rationale climate change scenario for Bangladesh can be constructed.

2. OBJECTIVE AND RESEARCH QUESTIONS

The main objective of this paper is to generate climate change scenarios especially for Bangladesh using the "best fit" GCM model results.
Two research questions are answered from this study: how well does a model or group of GCM models reproduce the present and historical climate, and what will be the climate change scenario for Bangladesh?

3. APPROACH AND METHODOLOGY

Projections of climatic changes for the twenty-first century at the broad regional, or sub continental, spatial scale (106–107 km2) are based on transient simulations with coupled atmosphere–ocean general circulation models (AOGCMs) including relevant anthropogenic forcing, for example, due to greenhouse gases (GHG) and atmospheric aerosols (e.g., Kattenberg et al. 1996). To date, such projections have been characterized by a low level of confidence and a high level of uncertainty deriving from different sources (Visser et al. 2000): estimates of future anthropogenic forcing, the response of a climate model to a given forcing, the natural variability of the climate system.
Quantifying uncertainties in the projection of future climate scenarios used for impact assessments has been identified as a critical research need both in the climate and impacts research communities (e.g., Carter et al. 1999), and has inspired a recent flurry of research (e.g., Katz 2001).
One of the primary factors of uncertainty is that different AOGCMs can simulate quite different regional changes even under the same anthropogenic forcing scenario (e.g., Kittel et al. 1998) and it is very difficult to ascertain which of the different AOGCMs are most reliable. Therefore, a comprehensive assessment of regional change projections needs to be based on the collective information from the ensemble of AOGCM simulations.
Understanding the principle, the first research question is answered through comparison of annual, seasonal and monthly means over the same historical period. For second research question, IPCC recommended four statistical indices are used here for examining each of the GCM model's performance: pattern correlation (r), root-mean-square error (RMSE), bias (B) and a bias – corrected RMSE. Based on the four tests, each of the GCM models is ranked from high to low for each of the test and a combined ranking from best to worst facilitate the GCM model selection procedure. Finally, from the selected best-suited GCM model results, local level climatic scenarios are generated through averaging the results from the group of selected GCM ensembles. The skill of a multi-model ensemble average consistently outperforms any individual model result (Gleckler et al., 2008 and Pierce et al., 2009). Normalized averaging approach for multi-model ensemble results is used which was introduced by Santer et al. (1990). Giorgi and Mearns (2002) proposed a weighting scheme based on skill and convergence criteria.
MAGICC tools developed in the Climatic Research Unit in the 1980 gives several statistics for choosing GCMs both unweighted and cosine weighted. Wigley et al. (2008) suggests using cosine weighted statistics. Among the available statistics, pattern correlation (r), root-mean-square error (RMSE), bias (B), and bias-corrected RMSE (RMSE-corr) has been used for evaluating the individual skills of models. Using these statistics, all the models have been first ranked based on skill criteria.
Two integrated tools are used for generating the climate scenario for Bangladesh: MAGICC and SCENGEN. MAGICC - Model for the Assessment of Greenhouse-gas Induced Climate Change – is a set of linked simple models that, collectively, fall in the genre of a Simple Climate Model as defined by Harvey et al. (1997). MAGICC is not a GCM, but it uses a series of reduced-form models to emulate the behavior of fully three-dimensional, dynamic GCMs. MAGICC calculates the annual-mean global surface air temperature and global-mean sea-level implications of

emissions scenarios for greenhouse gases and sulphur dioxide (Raper et al., 1996). We have chosen different emission scenarios, and also altered a number of model parameters to explore uncertainty.

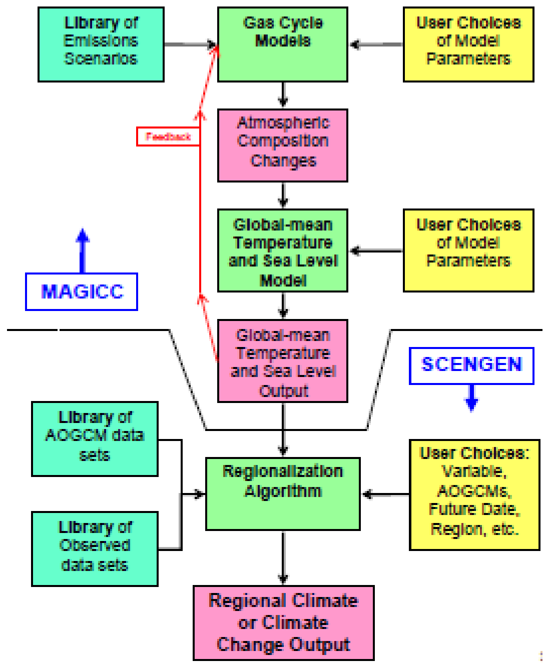

Figure 1: MAGICC and SCENGEN farmework for cliamte scenario generation

Flowchart of the climate change modeling and scenario generation procedure is elaborated in figure 1. The combination of the simple climate model called MAGICC and the climate scenario database called SCENGEN forms the scenario generator. SCENGEN – a global and regional SCENario GENerator – is not a climate model; rather it is a simple database that contains the results of a large number of GCM experiments, as well as an observed global and four regional climate data sets. These various data fields are manipulated by SCENGEN, using the information about the rate and magnitude of global warming supplied by MAGICC and directed by the customized choice of important climate scenario characteristics.

3.1 Assessment of GHG concentration using MAGICC

Modeling for the assessment of green-house gas induced climate change comprises of three sequential steps:

- Selection of emission scenarios
- Selection of model parameters
- Selection of time frame for projection

Under the emission scenarios, two emission scenarios are needed to be selected: reference scenario and the policy scenario, although they may well both be non-policy or policy scenarios. Out of the different SRES scenario (IPCC Special Report on Emission Scenarios; Nakicinovic et al., 2000) two different SRES scenarios named A2-AIM and B1-AIM has been selected for their relevance with South Asia and to get the range of uncertainty (maximum and minimum) in projection.

Under the model parameters, different options are exercised related to the forcing controls of the carbon cycle model, carbon cycle model feedbacks and aerosol facings. Moreover, various sensitivity options are also elaborated like equilibrium co_2 doubling temperature change, variability of thermohaline circulation, rate of vertical diffusion and rate of ice melting is also given as model input to incorporate the effect of relative climate sensitivity.
Output parameters option controls the period of analysis and time-step interval for output.
In a nutshell the following input has been given as input to the MAGICC interface:

Table 1: Parameter values used in running MAGICC/ SCENGEN

Parameter	**Value used**
Emission scenarios	A2-AIM and B1-AIM
Carbon Cycle Model	Mid
Carbon Cycle Climate Feedback	Yes
Aerosol forcing	Mid
Climate Sensitivity (T2x)	3°C
Thermohaline Circulation	variable
Vertical diffusion	2.3 cm2/s
Ice melt	Mid
Reference year for climate model output	1990
First year for climate model output	1990
Last year for climate model output	2100
Scaling technique (SCENGEN)	Linear
Smoothing (SCENGEN)	No

3.2 Climate change scenario generation using SCENGEN

SCENGEN constructs a range of geographically-explicit climate change scenarios for the world by exploiting the results from MAGICC and a set of GCM experiments, and combining these with observed global and regional climate data sets. SCENGEN contains a set of greenhouse gas induced patterns of regional climate change obtained from 20 different GCM experiments. Since the GCM experiments report results on different spatial grids, all GCM data were interpolated onto a common 2.5° latitude/longitude grid before inserting into SCENGEN.
A geographically-explicit climate change scenario is constructed by selecting a future time interval, by selecting one or more of the greenhouse gas-induced GCM climate change patterns and, optionally, by selecting the regional aerosol patterns. Pattern-scaling methods are employed to create the climate change fields at 2.5º resolution which can then be added to an observed 1961-90 baseline climate data set to obtain actual climate scenario values for the future time period in question.

3.3 Selection of the best fit GCMs

Among the available statistics, pattern correlation (r), root-mean-square error (RMSE), bias (B), and bias-corrected RMSE (RMSE-corr) has been used for evaluating the individual skills of models. Using these statistics, all the models have been first ranked based on skill criteria. Among the best nine models three are flux adjusted which gives them an advantage in a model validation exercise. Flux adjustment is not thought to be an issue for future climate change projections (Gregory and Mitchell, 1997). However, if a flux adjusted model validates well against present climate, this may not be a good indicator of model quality. In order to address this issue the convergence criteria is taken into consideration. Based on convergence criteria one model has been rejected and finally eight models have been selected.

4. RESULTS AND DISCUSSION

4.1 Selection of best fit GCM models

Out of the 20 GCM models, a total of nine models have been primarily selected based on skill criteria (see table 2). Three of them are flux adjusted and gives an advantage in a model validation exercise. Flux adjustment is not thought to be an issue for future climate change projections (Gregory and Mitchell, 1997). However, if a flux adjusted model validates well against present climate, this may not be a good indicator of model quality. In order to address this issue the convergence criteria is taken into consideration. Based on convergence criteria one model has been rejected and finally eight models have been selected. The selected models are CGCM 3.1 (T47), CCSM 3.0, CSIRO-Mk3.0, GFDL-CM 2.0 and 2.1, INM CM-3.0, MIROC 3.2 (medres) and UKMO-HadCM3.

Table 2: Ranking of different GCM models based on skill criteria

Rank	**Score**	**Flux Adjusted or not**	**Model**	**Pattern correlation**		**RMSE (mm/day)**		**Bias (mm/day)**		**RMSE-corr (mm/day)**	
				world	BD	world	BD	world	BD	world	BD
1	5	Yes	CCCMA-31	0.89	0.18	0.95	2.04	-0.01	-1.75	0.95	1.04
1	5	Yes	ECHO---G	0.91	0.72	0.86	2.33	0.128	-2.25	0.85	0.61
3	4	No	CSIRO-30	0.81	0.41	1.21	2.07	-0.16	-1.91	1.2	0.8
3	4	No	GFDLCM20	0.87	0.14	1.10	2.48	0.091	-2.3	1.1	0.93
3	4	No	UKHADCM3	0.86	-0.20	1.26	1.62	0.23	-1.29	1.24	0.99
6	3	No	CCSM—30	0.80	0.49	1.33	1.91	0.16	-1.52	1.32	1.17
6	3	No	MIROCMED	0.83	-0.80	1.16	2.33	0.035	-0.68	1.16	2.23
8	2	No	GFDLCM21	0.86	-0.69	1.15	2.30	0.215	-1.57	1.13	1.67
8	2	Yes	INMCM-30	0.70	0.89	1.61	1.47	0.116	-1.42	1.6	0.4
10	1	No	IPSL_CM4	0.81	0.85	1.27	2.94	-0.09	-2.91	1.27	0.45
10	1	Yes	MRI-232A	0.89	-0.83	0.97	3.36	-0.08	-3.03	0.96	1.44
12	0	No	BCCRBCM2	0.79	0.37	1.31	1.71	0.307	-1.37	1.28	1.02
13	-1	No	CNRM-CM3	0.77	0.40	1.44	1.95	0.54	-1.71	1.33	0.93
13	-1	No	MIROC-HI	0.80	-0.63	1.34	2.11	0.281	-0.44	1.31	2.06
15	-3	No	FGOALS1G	0.82	-0.85	1.23	3.32	0.307	-3.06	1.19	1.29
16	-4	No	NCARPCM1	0.67	0.46	1.72	2.34	0.343	-1.59	1.68	1.71
17	-5	No	UKHADGEM	0.80	-0.57	1.61	3.37	0.385	1.385	1.57	3.07
17	-5	No	MPIECH-5	0.81	-0.78	1.35	3.13	0.247	-1.55	1.33	2.71
19	-7	No	GISS—EH	0.73	-0.24	1.51	7.38	0.34	5.393	1.47	5.04
19	-7	No	GISS—ER	0.77	0.28	1.43	4.09	0.297	2.667	1.4	3.1

[Note: Models ranked from 1-8 are primarily selected as best fit models, but ECHO-G model shows poor performance in convergence and hence rejected. Selected models are shown in green shed with model in the yellow shedding is rejected for poor convergence score]

4.2 Climate change scenario for Bangladesh

Table 3 presents the annual average changes predicted for 2030s and 2050s. Figure 3 illustrates annual average temperature and precipitation over Bangladesh for 2050s. Table 3 shows that temperature will increase 1.6°C by 2050s while precipitation will increase by 8%.

Table-3: Annual average changes in temperature and precipitation

Emission Scenario	Temperature (Change in °C)		Precipitation (Percentage change)	
	2030s	2050s	2030s	2050s
A2	0. 73	1.32	4.9	8.1
B1	0.78	1.62	6.3	8.4

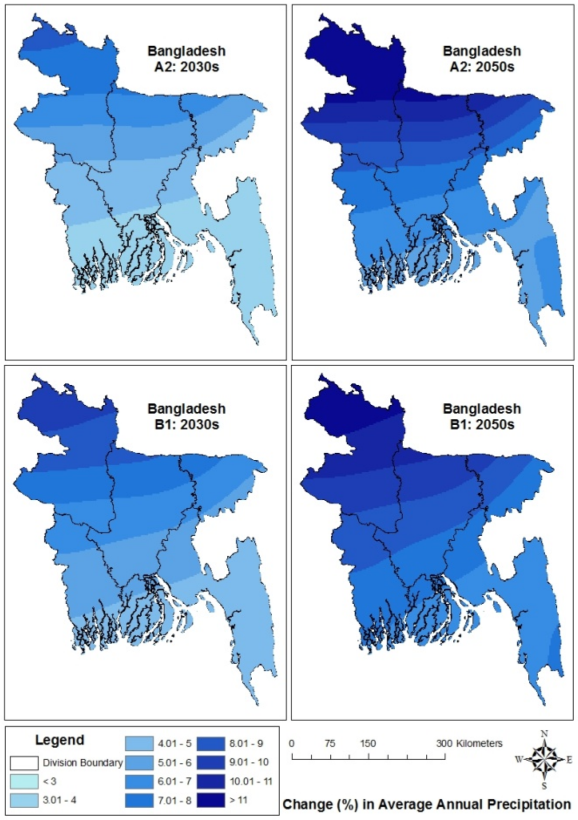

Figure 2: Mean annual precipitation pattern all over Bangladesh in 2030s and 2050s for A2 and B1 mission scenarios

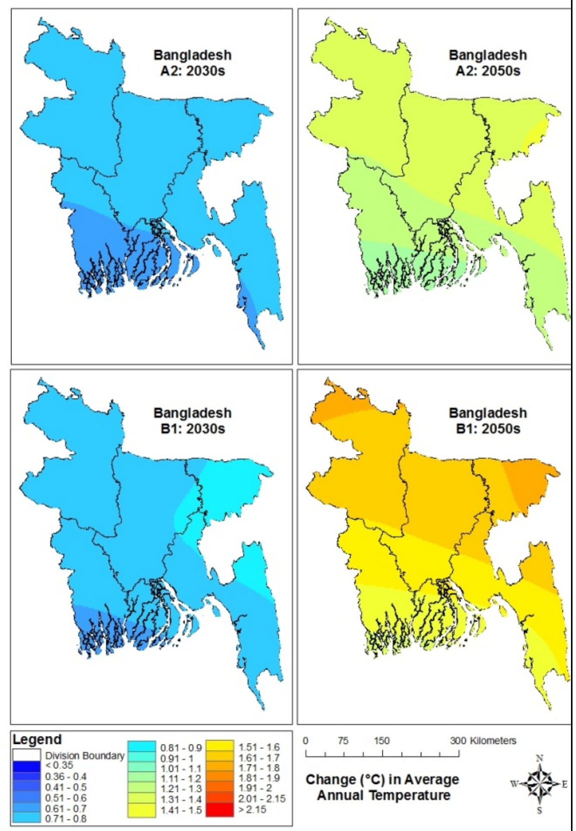

Figure 3: Mean annual temperature pattern all over Bangladesh in 2030s and 2050s for A2 and B1 mission scenarios

Other than this, division wise percent change in temperature and precipitation pattern from the base is also analysed which is given in the annex. It is found that maximum increase in the precipitation is observed during the pre-monsoon season (MAM) for A2 scenario when maximum precipitation is reported to be increase in Dhaka division by around 52% and 70% during the 2030s and 2050s. In the coastal regional division Khulna, increase in minimum and mean precipitation is also found to be increased by 24%, 30% and 32%, 40% respectively over the same periods. In terms of temperature change, it is found that the minimum temperature will increase in all the divisions specially in Rajshahi during the winter season under the A2 scenario. The increase in the temperature will be minimum in Khulna during the monsoon months (JJAs) .

5. CONCLUSION

In this study, a total of eight GCM models have been selected as "best suited", based on skill and convergence criteria for representing the climate change scenario of Bangladesh. The models are: CCCMA-31, CSIRO-30, GFDLCM20, UKHADCM3, CCSM-30, MIROCMED, GFDLCM21 and INMCM-30.

Ensemble of selected GCM models show that by 2050, temperature will increase 1.6°C by 2050s while precipitation will increase by 8%. But GSM Model results are coarse and are unable to catch the local scale variation in the climatology. In this regard, regional climate model driven scenario should be constructed for spatial and temporal planning of adaptation and mitigation.

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APPENDIX 1:

A2	Annual	Precipitation (Percent Change)					Annual	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	2.07	3.15	6.04	3.63	5.35	10.03	0.65	0.70	0.78	1.14	1.23	1.40
CHITTAGONG	2.51	3.79	5.03	4.42	6.35	8.28	0.62	0.73	0.78	1.08	1.29	1.40
DHAKA	3.34	4.72	9.21	5.50	7.77	14.70	0.69	0.75	0.82	1.24	1.35	1.53
KHULNA	2.97	4.47	5.63	5.16	7.51	9.34	0.60	0.68	0.72	1.06	1.21	1.30
RAJSHAHI	4.16	6.55	9.14	6.91	10.62	14.59	0.69	0.76	0.84	1.25	1.39	1.55
SYLHET	4.21	5.07	5.81	6.93	8.35	9.57	0.72	0.74	0.75	1.29	1.33	1.35
National	3.34	4.92	7.30	5.62	8.10	11.81	0.66	0.73	0.80	1.18	1.32	1.45
A2	DJF	Precipitation (Percent Change)					DJF	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	-35.99	-32.26	-29.73	-46.11	-42.40	-39.23	0.88	1.03	1.24	1.47	1.72	2.08
CHITTAGONG	-40.42	-29.32	-21.52	-55.11	-39.09	-29.34	0.86	1.12	1.29	1.44	1.87	2.15
DHAKA	-34.17	-26.92	-14.62	-46.59	-36.86	-20.16	1.14	1.19	1.41	1.93	2.00	2.39
KHULNA	-32.41	-28.73	-25.42	-44.71	-39.12	-33.65	0.88	1.09	1.22	1.48	1.83	2.06
RAJSHAHI	-27.38	-19.96	-12.54	-37.76	-27.88	-17.84	1.14	1.25	1.38	1.93	2.14	2.40
SYLHET	-56.70	-43.70	-32.50	-77.32	-59.59	-44.31	1.11	1.14	1.17	1.85	1.90	1.96
National	-35.64	-27.68	-19.54	-48.63	-37.67	-26.68	1.03	1.16	1.32	1.73	1.96	2.24
A2	MAM	Precipitation (Percent Change)					MAM	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	11.91	15.78	35.36	16.28	21.74	47.60	0.72	0.76	0.82	1.31	1.37	1.49
CHITTAGONG	13.40	15.20	19.57	18.53	20.93	26.75	0.70	0.77	0.81	1.24	1.39	1.48
DHAKA	13.22	25.36	51.74	18.08	34.43	69.65	0.69	0.77	0.82	1.27	1.42	1.61
KHULNA	24.01	30.01	36.88	32.09	40.30	49.30	0.68	0.72	0.74	1.21	1.31	1.37
RAJSHAHI	16.38	28.20	43.92	22.45	38.25	59.12	0.70	0.77	0.86	1.29	1.47	1.69
SYLHET	20.38	24.81	28.26	27.86	33.91	38.64	0.72	0.75	0.77	1.33	1.38	1.42
National	16.20	24.00	37.58	22.10	32.61	50.68	0.70	0.76	0.81	1.27	1.41	1.54
A2	JJA	Precipitation (Percent Change)					JJA	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max

BARISAL	6.43	8.18	10.73	8.72	11.24	15.11	0.37	0.42	0.47	0.76	0.82	0.92
CHITTAGONG	8.06	10.01	12.46	11.26	13.91	17.54	0.38	0.44	0.47	0.73	0.85	0.92
DHAKA	7.09	8.97	11.91	9.98	12.58	17.96	0.37	0.44	0.50	0.76	0.88	1.01
KHULNA	7.13	8.73	12.89	9.76	11.76	16.91	0.32	0.36	0.38	0.67	0.74	0.78
RAJSHAHI	7.25	9.68	12.58	9.92	14.02	18.97	0.38	0.41	0.45	0.77	0.84	0.92
SYLHET	8.80	10.72	12.37	12.38	15.08	17.41	0.45	0.46	0.47	0.87	0.90	0.92
National	7.47	9.47	12.32	10.36	13.29	17.79	0.37	0.42	0.46	0.76	0.84	0.92
A2	SON	Precipitation (Percent Change)					SON	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	-7.58	-6.11	0.15	-8.50	-6.30	4.34	0.52	0.55	0.61	0.96	1.02	1.14
CHITTAGONG	-8.75	-6.74	-5.39	-9.81	-7.27	-5.65	0.49	0.58	0.62	0.91	1.06	1.14
DHAKA	-7.02	-3.88	5.05	-7.36	-2.80	10.16	0.56	0.60	0.70	1.01	1.10	1.28
KHULNA	-3.17	-0.87	0.14	-0.84	2.17	4.06	0.49	0.54	0.58	0.88	0.99	1.04
RAJSHAHI	0.11	2.46	5.24	3.27	6.62	10.53	0.56	0.64	0.71	1.02	1.16	1.31
SYLHET	-8.00	-7.03	-5.93	-8.39	-7.37	-6.22	0.57	0.59	0.60	1.06	1.09	1.10
National	-5.08	-2.81	0.88	-4.31	-1.18	4.16	0.54	0.59	0.65	0.98	1.09	1.20
B1	Annual	Precipitation (Percent Change)					Annual	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	2.97	4.29	8.01	4.51	6.10	10.92	0.69	0.74	0.83	1.38	1.49	1.69
CHITTAGONG	3.61	5.02	6.47	5.49	6.92	8.56	0.65	0.77	0.83	1.31	1.56	1.69
DHAKA	4.29	6.07	10.70	5.68	8.07	13.14	0.73	0.80	0.90	1.52	1.65	1.97
KHULNA	4.19	6.02	7.46	6.33	8.47	10.17	0.62	0.71	0.76	1.30	1.48	1.59
RAJSHAHI	5.52	8.02	10.62	7.52	10.30	13.04	0.73	0.82	0.91	1.53	1.75	2.00
SYLHET	5.41	6.52	7.47	7.16	8.63	9.89	0.77	0.79	0.80	1.55	1.60	1.63
National	4.49	6.30	8.87	6.29	8.41	11.29	0.70	0.78	0.86	1.44	1.62	1.82
B1	DJF	Precipitation (Percent Change)					DJF	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	-72.12	-63.13	-57.86	-73.89	-54.74	-46.07	1.02	1.17	1.40	1.68	1.93	2.28
CHITTAGONG	-80.58	-57.34	-42.90	-76.63	-51.36	-40.79	0.99	1.27	1.45	1.64	2.07	2.36
DHAKA	-70.73	-56.16	-34.03	-72.47	-54.88	-34.36	1.30	1.35	1.59	2.12	2.22	2.78
KHULNA	-73.68	-63.25	-52.05	-75.49	-62.71	-47.44	1.00	1.23	1.39	1.70	2.07	2.31
RAJSHAHI	-62.24	-47.72	-32.12	-63.77	-50.25	-35.00	1.30	1.44	1.62	2.16	2.47	2.83
SYLHET	-	-	-	-	-	-	1.25	1.28	1.32	2.03	2.08	2.15

	113.04	87.12	64.78	107.50	82.85	61.61						
National	-74.99	-58.40	-42.09	-74.78	-56.56	-40.90	1.17	1.32	1.50	1.94	2.20	2.55
B1	MAM	Precipitation (Percent Change)					MAM	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	10.01	13.09	27.67	4.56	6.41	8.19	0.83	0.88	0.97	1.56	1.70	1.93
CHITTAGONG	11.31	12.79	16.45	5.19	6.37	8.71	0.78	0.90	0.96	1.47	1.76	1.92
DHAKA	11.11	20.65	40.49	5.06	7.89	11.98	0.82	0.92	1.06	1.68	1.86	2.39
KHULNA	18.15	23.22	27.96	4.36	6.44	8.27	0.76	0.84	0.88	1.48	1.68	1.80
RAJSHAHI	13.96	22.92	34.37	4.58	7.55	10.19	0.83	0.96	1.12	1.70	2.07	2.49
SYLHET	17.13	20.85	23.75	7.80	9.49	10.82	0.86	0.90	0.92	1.71	1.79	1.84
National	13.39	19.52	29.68	5.09	7.34	9.97	0.81	0.91	1.01	1.61	1.85	2.15
B1	JJA	Precipitation (Percent Change)					JJA	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	8.35	10.87	15.96	7.28	9.83	15.01	0.23	0.32	0.36	0.96	1.00	1.11
CHITTAGONG	10.47	13.00	16.18	9.41	11.94	15.25	0.29	0.33	0.36	0.89	1.03	1.11
DHAKA	9.21	12.27	17.21	8.68	11.66	17.94	0.24	0.32	0.39	0.96	1.08	1.28
KHULNA	10.99	13.17	18.76	9.86	11.99	16.14	0.23	0.24	0.24	0.84	0.93	0.98
RAJSHAHI	11.16	13.86	16.96	10.49	14.34	18.95	0.24	0.26	0.29	0.97	1.07	1.18
SYLHET	11.43	13.92	16.07	10.77	13.11	15.14	0.34	0.35	0.36	1.06	1.09	1.11
National	10.41	13.05	16.97	9.60	12.51	16.96	0.26	0.30	0.33	0.94	1.04	1.15
B1	SON	Precipitation (Percent Change)					SON	Temperature (Change ºC)				
Scenario		2030			2050			2030			2050	
Division	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
BARISAL	-6.66	-5.27	0.57	-1.51	0.15	9.53	0.54	0.57	0.63	1.28	1.35	1.48
CHITTAGONG	-7.68	-5.81	-4.58	-1.74	-0.44	0.16	0.51	0.60	0.64	1.22	1.40	1.49
DHAKA	-5.97	-3.17	4.53	0.12	2.95	9.97	0.55	0.61	0.71	1.28	1.43	1.68
KHULNA	-2.61	-0.46	0.54	4.25	6.92	8.92	0.48	0.53	0.57	1.14	1.25	1.32
RAJSHAHI	0.43	2.39	4.69	7.17	8.68	10.33	0.55	0.64	0.73	1.29	1.46	1.65
SYLHET	-6.80	-5.98	-5.04	0.13	0.15	0.18	0.59	0.61	0.62	1.39	1.42	1.44
National	-4.29	-2.26	0.95	2.08	3.88	6.87	0.54	0.60	0.67	1.26	1.40	1.55