A COMPARATIVE ANALYSIS OF CMIP3 AND CMIP5 CLIMATE PROJECTIONS OVER BANGLADESH

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ABSTRACT

Bangladesh is one of the most climate vulnerable countries of the world. In recent years, climate change studies over the country getting more attention by the researchers and policy makers at the national and international levels. A considerable amount of climate change studies over the country use climate models to estimate future projections and uncertainties. However, most of them used the set of climate models under SRES emission scenariosprescribed in the fourth assessment reports (AR4) of Inter-governmental Panel for Climate Change (IPCC) which are commonly known as CMIP3(The Coupled Model Intercomparison Project phase 3) climate models. In the latest fifth assessment report (AR5) of IPCC, the Coupled Model Intercomparison Project Phase 5 (CMIP5) has documented a new set of climate models based on CIMP3 models to capture future uncertainty with a more accurate understanding.CIMP5 models under the Representative Concentration Pathways (RCPs) scenarios took considerable attentionin recent years to the scientists due to their wider range of future projections with more representative climate processes. CMIP5 and CMIP3 climate projections can be used as a unified projection for the future decision makingfor any nation. Therefore, anassessment can be done to understand the inter-variability of these two sets of projections over Bangladesh In this context, We have focused to conduct comparative analysison three widely used climate variables, namely, temperature maximum, temperature minimum and precipitation. Sixteen multi-ensemble downscaled climate projections derived from the HadCM3 global model are considered as regional CMIP3 data sets. The dynamic downscaling was conducted using regional climate model 'PRECIS' developed by MetOffice, UK. Similarly, dynamically downscaled climate projections from EC-EARTH and MPI global model under three RCP scenarios are consider as regional CMIP5 data sets. The selected variables over Bangladesh has been extracted from all of these regional data and a relative assessment has been made in the study. The spreading of the future projections of temperature are

wider in CIMP5 than CMIP3 over the land areas of Bangladesh. Precipiation shows lesser variability in CMIP5 climte projections.

Keywords:*Climate Change, CMIP3,CMIP5, RCP scenarios, Regional Climate Model.*

1. INTRODUCTION

During the twentieth century, the global surface temperature has risen by 0.74 ± 0.84°C and the warming trend accelerated in the last 50 years (IPCC, 2007). Bangladesh, a densely populated country of South Asia, is already experiencing the adverse impacts of global warming due to climate change. As, the country is already fraught with many problems such as high population density, food security, human health, poverty and so on, adverse impacts of changing climate will aggravate these problems(Ali, 1999). Moreover, the country experiences disasters such as tropical cyclones, storm surges, coastal erosion, floods, and droughts causing heavy loss of lives and property and staking developmental activities. Studies show that changing climate will increase the frequency and intensity of these natural calamities, which will hamper the future developments of the country(Brouwer et al., 2007; Cannon, 2002; Shahid, 2011). Therefore, there is a strong need to produce useful climate change projections for the future development initiatives and adaptation planning of the country.

Climate models are one of the most widely used to tools for developing projections of climate change in the future. Global climate models under the Coupled Model Inter-comparison Project 3 (CMIP3) commonly known as 'CMIP3' climate models were prescribed in Intergovernmental Panel on Climate Change (IPCC) fourth Assessment reports (AR4). To evaluate future projections of these models, Special report on emissions scenarios (SRES) of AR4 identified a set of future climate emission pathway based on the different soci-economic development assumptions(IPCC, 2000). Using these SRES-based emission scenarios and climate projections from CMIP3, future climate change and its impacts on society and ecosystems were characterized in the AR4. In the past, climate projections for Bangladesh have relied on the CMIP3 models. For instance, Hasan et al. (2013b) using CMIP3 multi-model data, provided projections of surface temperature and rainfall over the country for the period 1971–2100. Several other studies also used CMIP3 for the impact studies of climate change over the region (Hasan et al., 2013a; Islam and Hasan, 2012; Nowreen et al., 2014; Rajib et al., 2010; Rajib et al., 2011b). IPCC published the SRES scenarios in 2000 and the underlying economic and policy assumptions were originally developed in 1997. However, a set of new-emission scenarios termed as representative concentration pathways (RCPs) has been adopted in the latest IPCC fifth assessment report(Van Vuuren et al., 2011). There are four RCP scenarios, which are based on greenhouse gas concentration trajectories instead of emission pathway. The RCP scenarios are RCP2.6, RCP4.5, RCP6.0 and RCP8.5. These scenarios are formulated such that they represent the full range of stabilization, mitigation and baseline emission scenarios. In the AR5, RCP-based climate projections become available from a number of climate models under the Coupled Model Inter-comparison Project 5 (CMIP5)(IPCC, 2013). In comparison to CMIP3, CMIP5 model can capture more of relevant physical processes of the earth in much detail(Knutti and Sedláček, 2013). Though global projection of CMIP3 and CMIP5 are much similar to each other, regional discrepancy has been observed between two sets of model projections(Wang et al., 2014). Therefore, comparative assessment of future projections is required at regional scale. In this context, as Bangladesh is vulnerable under the impact of ongoing climate change, such analysis needs to be done for more confident climate information. This study has attempted to assess this issue.

The climate projections from both CIMP5 and CMIP3 models are derived from global circulation models (GCMs). Though GCMs have provided good representations of the planetary-scale features, regional study requires high-resolution information typically 50km or more. In this context, the high-resolution regional climate models (RCMs) provide an opportunity to dynamically downscale GCM projections to superimpose the regional details of specific regions of interest. Therefore, RCMs derived climate projections are demanded for the climate change study over Bangladesh and proven to be effective in future decision making of the country. Nowreen et al. (2014) simulated the regional climate of Bangladesh by a high-resolution regional climate model known as 'Providing Regional Climate for Impact Studies (PRECIS)'. They have been downscaled global climate data from the Hadley Centre's Coupled Model (HadCM3) – one of the models among the CMIP3 experiment, using PRECIS to assess future precipitation extremes over Hoar area of Bangladesh. Hasan et al. (2013b) also used multi-ensemble climate projection for the future rainfall and temperature of the country. Future flow assessment has also been done using PRECIS derived climate projection data (Rajib et al., 2011a). However, none of the studies used the latest CMIP5 climate projections over Bangladesh, even with the GCMs derived data. Therefore, an analysis has been carried out in current study to evaluate a group of CMIP5 models projections in terms of mean climate, as a basis for the country. To have more reliable projections than GCMs, downscaled CMIP5 data by RCMs are also used. A comparison has been made between the multi-model ensemble of CMIP3 with that of CMIP5, as well as the change in the spread between the models are discussed in the study.

2. DATA AND METHODOLOGY

For comparative analysis, dynamically downscaled data from both CMIP3 and CMIP5 models are used in this study. Bangladesh University of Engineering and Technology and Met Office, UK conducted a collaborative research to generate high resolution (25 km) climate change information using PRECIS model. The simulations were based on the 17-member of perturbed physics ensemble (PPE) produced under the quantifying uncertainty in model predictions (QUMP) project of the Hadley Centre, Met Office, UK. All simulations are conducted over a large Indian Domain extending from 58°E to 116°E and 0°N to 41°N. These downscaled QUMP projections were considered as the representative of CMIP3 models as they cover the whole range of future projections from IPCC 4th assessment report. They are also proven competent in capturing the climatology of Bangladesh (Hasan et al., 2013c). Therefore, all the seventeen QUMP data sets are used as a CMIP3 data in the present study. These projections have spatial resolution of 25km by 25km and projected for the period of 1971-2100. On the other hand, regionally downscaled data from two GCMs of AR5are considered as CMIP5 data in this study. Swedish Meteorological Hydrological Institute (SMHI) has simulated all the available RCP scenarios over the large South Asian Cordex domain (Figure 1). They have dynamically downscaled EC-Earth global GCM data to 50km by 50km grid resolution. The regional model named Rossby Centre Regional Climate Model (RCA4) has been applied to downscale the GCM projections over the South Asian region. Projections of RCP2.6, RCP4.5 and RCP8.5 scenarios for the period of 1951-2100 are used in this study. Another, GCM data known as MPI-ESM have downscaled over the South Asian Cordex domain by the Max Planck Institute for Meteorology (MPI-M). The institute has conducted the dynamic downscaling by the regional climate model called "The Regional MOdel (REMO)". The downscaling practice has also been conducted for three RCP scenarios and historical run prescribed by AR5. The spatial resolution of downscaled product is 50km by 50km. Projections from the EC-EARTH and MPI-ESM model downscaled by RCA4 and REMO model respectively, are selected for analyzing the CMIP5 model result over Bangladesh.

Three meteorological variables namely, temperature maximum, temperature minimum and precipitation are chosen to compare CMIP3 and CMIP5 model projections. Assessment has been made for three periods, i.e. short (2011-2040), medium (2041-2070) and long term (2071-2100) in respect to baseline (1971-2000) period. All these analysis has been done over the 17 QUMP projections as CMIP3, EC-EARTH projections as CMIP5 and MPI projections as CMIP5 data for the selected three meteorological variables.

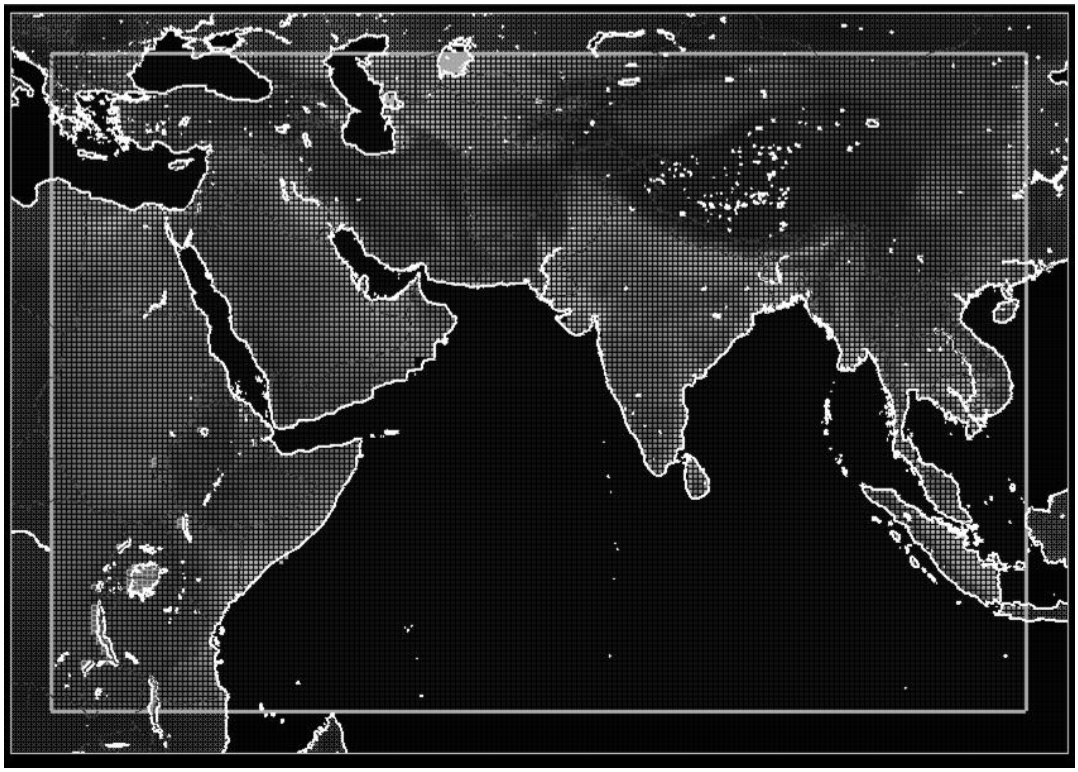

Figure 1: South Asian CORDEX Domain

3. RESULT

In has been observed that, there are some systematic biases in CMIP3 and CMIP5 model projections with respect to observational data. Using absolute value for the future projections would be erroneous. Therefore, anomalies of meteorological variables for the model projections are evaluated to nullify the biases. Figure 2& 3 shows the anomalies of maximum and minimum temperature in respect to baseline period (1971-2000) for all the CMIP3and CMIP5 climate projections over Bangladesh. Both sets predict a consistent warming trend over the country in short-, mid- as well as long-term scenarios. As expected in each of the three time slices RCP2.6 generally experiences the least warming, whereas RCP8.5 is associated with the highest warming, with RCP4.5 and RCP6.0 representing the moderate warming scenarios. Nevertheless, for both maximum and minimum temperature, the CMIP5 projections show much wider spread than the CMIP3 projections. Between the two CMIP5 models, MPI projections are warmer than the EC-Earth projections.

Bangladesh precipitation projections of CMIP3 models have larger uncertainties as evident from the large spread of the precipitation change projections in Figure 4, which ranges from –5% to 30% towards the end of the century. Such a large uncertainty range in precipitation projections is also supported with a range of ~ -20% to 10% in the CMIP5 projections over the country. However, MPI projections show large disagreement with EC-EARTH projections where MPI suggest a decrease of rainfall to contrary to EC-EARTH as well as CMIP3 projections.

Changes in mean state of climate over Bangladesh are also calculated in Table 1 for both CMIP3 and CMIP5 models. Based on CMIP5 models projects, it is observed that Bangladesh annual precipitation will rise 4.4%,4.9%, and 11.9% for RCP2.6, RCP4.5and RCP8.5 respectively, by 2100 compared to the 1971–2000 baseline in EC Earth model. The annual mean temperature increases by 1.4–4.1°C by 2050s under different RCP scenarios and by about 2.3–6.4°C by 2080s, relative to the base period.

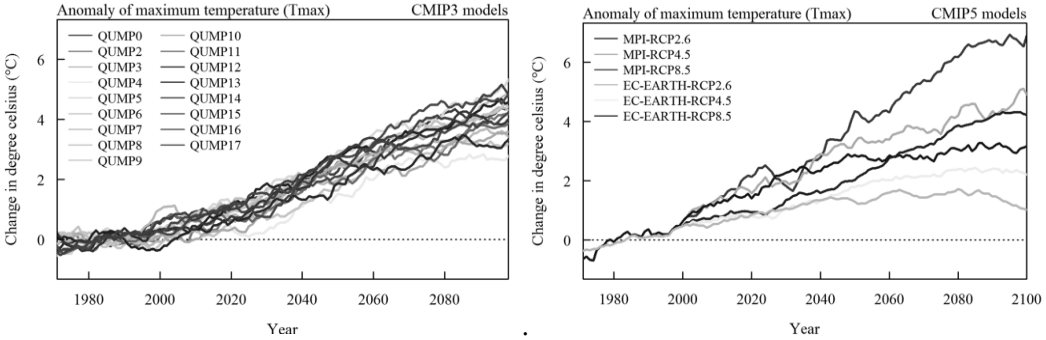

Figure 2: Anomaly of maximum temperature over Bangladesh for CMIP3 (left) and CMIP5 (right) model projections.

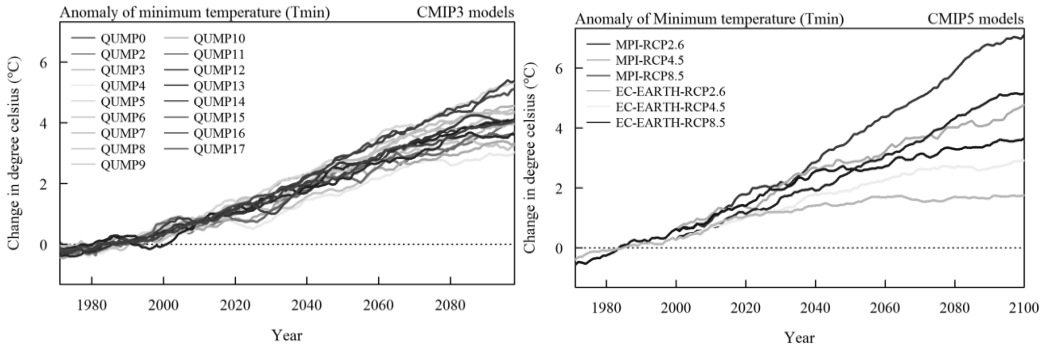

Figure 3: Anomaly of minimum temperature over Bangladesh for CMIP3 (left) and CMIP5 (right) model projections.

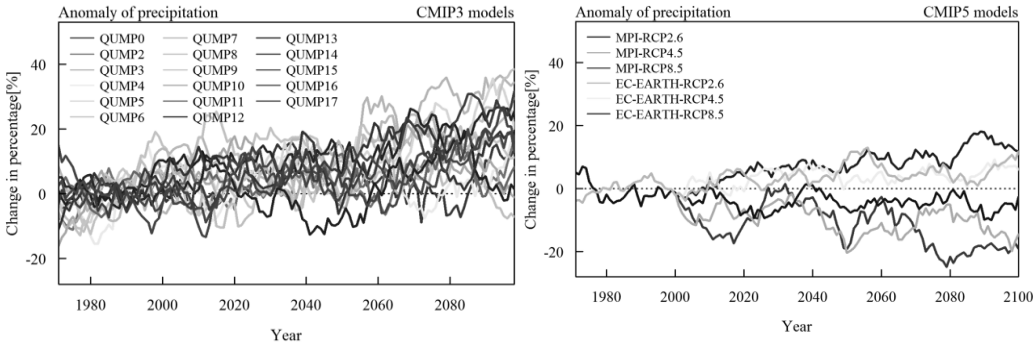

Figure 4: Anomaly of precipitation over Bangladesh for CMIP3 (left) and CMIP5 (right) model projections.

Table 1: Change of meteorological variables in CMIP3 and CMIP5 projections.

		CMIP3			CMIP5					
		QUMP 00 to 17			MPI			EC-EARTH		
		Min	Med*	Max	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Precipitation (%)	2020s	18.8	4.8	-2.4	-5.0	-5.3	-8.6	2.9	3.7	6.2
	2050s	17.8	7.4	-3.5	-3.9	-14.3	-9.2	6.9	3.8	8.9
	2080s	31.1	12.6	1.9	-4.6	-10.1	-19.3	4.9	4.4	11.9
Tmax (C)	2020s	0.5	1.1	1.5	1.9	1.9	2.2	1.0	0.9	1.2
	2050s	1.8	2.6	3.1	2.7	3.5	4.1	1.4	1.9	2.4
	2080s	2.7	3.8	4.5	3.0	4.2	6.4	1.5	2.3	3.9
Tmin(C)	2020s	0.8	1.3	1.6	1.8	1.8	1.9	1.1	1.2	1.4
	2050s	2.0	2.6	3.2	2.7	3.1	4.0	1.6	2.1	2.8
	2080s	2.8	3.8	4.7	3.4	4.1	6.3	1.7	2.7	4.6

***** Median value

4. CONCLUSION

Climate change is recognized as the biggest challenge for the developing country like Bangladesh. To understand the future climate state, assessment of both CMIP3 and CMIP5 projections are required. In this study a comparative assessment have done using these projections over the country. The following are some of the major conclusions based on the results of this study.

1. Future variability of temperature in climate projections has increased in new CMIP5 climate projections. However, considering new CMIP5 projections in decision based on specific scenarios will be more helpful for decision makers as they have comparatively better representation of earth's physical processes.
2. Spread of CMIP5 precipitation projections are smaller than CMIP3 climate projections.
3. Although MPI and EC-EARTH regional projections are quite similar for the temperature, the precipitation projections have large spread between the models over Bangladesh.

Climate change projections over Bangladesh are associated with a range of limitations and uncertainties in CMIP3 and CMIP5 models due to the model and scenario uncertainties. Therefore, a combined assessment of CMIP3 and CMIP5 models is required for the future development initiatives of the country.

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