**Paper ID: WRE-037**

**International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015)**
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# The Projection of Temperature and Precipitation over Bangladesh under RCP Scenarios using CMIP5 Multi-Model Ensemble

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**Abstract**

Temperature and precipitation extremes and their potential future changes are evaluated in an ensemble of 5th Phase Coupled Model Intercomparison Project (CMIP5) in the Intergovernmental Panel on Climate Change (IPCC) diagnostic exercise for the Fifth Assessment Report (AR5). The climate projections are examined for extremes temperature and precipitation over Bangladesh in the recent past (1971–2005) and for future (2020s, i.e. 2011-2040, 2050s, i.e. 2041-2070 and 2080s i.e. 2071-2100) considering the RCP 4.5 and RCP 8.5 representative concentrations pathway scenarios. Two regional climate models (RCM) i.e. SMHI-EC-Earth and MPI-MPI-ESM each of them having two scenarios in total of 4 datasets are used for analysis. The study manifests greater temperature extremes for RCP 8.5 than RCP 4.5 scenario. The warming tendency from 2011 to 2100 is 1.9°C per 100 years for RCP4.5, and 5.0°C per 100 years for RCP8.5 scenarios. Also among the two regional climate models, MPI-MPI-ESM output exhibits the highest (5.4°C) temperature increase whereas the SMHI-EC-Earth results showed the lowest (4.53°C) increase in temperature over Bangladesh. Based on the analysis of RCM models, significant increase of rainfall in the monsoon period about 3.7% and 8% has been observed, respectively. Changes in temperature and precipitation indices are most pronounced under RCP 8.5 scenario rather than RCP 4.5 scenario. The uncertainties in the projection are unavoidable, and further analyses are necessary to develop a better understanding of the future changes over the region.

**Keywords:** *Bangladesh, climate change, CIMP5, precipitation, RCP, temperature*

## 1. Introduction

Climate extremes are receiving increased attention, for the impacts of climate change are felt most intensely through changes in the extremes. Many studies reveal that temperature and precipitation variability is the vital aspect influencing on climatic variability and extremes. According to IPCC (2007), the world population will become much more vulnerable due to the climatic changes resulting from continuous global warming. Understanding the potential impacts of climate change is essential for informing both adaptation strategies and actions to avoid dangerous levels of climate change. According to Jones et al. [1], the rise of temperature is associated with the reduction of cold days and it is also accompanied by reduction of the areas of extreme cool temperatures and increase of the areas of extreme warm temperature. Yan et al. [2] revealed that the gradual lessening of the number of cold days in China over the 20th century.

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Similar warming trend over India is also demonstrated by Kumar et al. [3]. The international community identifies that Bangladesh, a south-Asian domain, ranks high in the list of most climate-vulnerable countries on earth. According SRES-A1B emissions scenario projected temperature increases over Bangladesh are in the region of 3 to 3.5 °C by 2100. Also, precipitation is projected to increase up to 20% in the north of the country with increases of 5-10% more typical through the rest of the country. Spatially non-uniform increasing trend in the extreme temperature over Bangladesh has been observed by Rajib et al. [4]. According to Shahid [5] annual and pre-monsoon precipitation has increased and provided some negative impacts on the socioeconomic state of the country. However, these previous studies are done either by PRECIS or by RegCM3 regional model which consist some biases in the control run simulation and are based on CMIP3 simulations. All of these studies used the SRES emission scenarios and predictions based on models developed before the Fourth Assessment Report. Therefore, it is necessary to undertake initiatives to identify possible changes of precipitation and temperature over this region using the new sets of RCP scenarios.

The new sets of climate model outputs become available for the IPCC Fifth Assessment Report (AR5) which are also known as the "CMIP5 multi model dataset" according to Stocker et al [6]. CIMP5 dataset comprise a new set of future climate scenarios, called Representative Concentration Pathways or RCP scenarios. Global Climate Models (GCMs) in CMIP5 are better in the sense that they represent more of the relevant climate processes in more detail than CMIP3 models. Moreover, they have a wider range of projections which will be very useful to capture wide range of model uncertainties as mentioned by Knutti et al. [7]. However, no study on the changes of precipitation over Bangladesh has been conducted using these new sets of CIMP5 Global Climate Model projections. Therefore, this study has taken a novel initiative to investigate the future changes of temperature and precipitation over Bangladesh using CIMP5 models projections. Global Climate Models of CIMP5 has provided results in a course scale grid with horizontal resolutions more than 100 km, which is not sufficient for the study of climate change for a small country like Bangladesh. Thus, GCM outputs are dynamically downscaled by Swedish Meteorological and Hydrological Institute (SMHI) and Max Plank Institute (MPI) to produce 50km fine scale climate change information over the South Asia region. Using these downscaled outputs, the future temperature and precipitation pattern of the country is investigated under new RCP scenarios. The changes of precipitation and temperature in the future are presented in both monthly and seasonal scales.

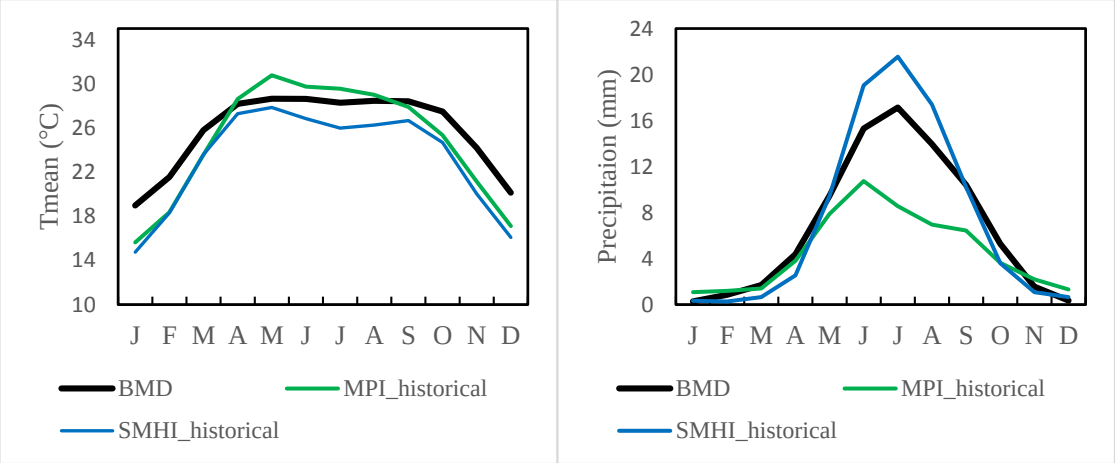
## 2. Data and Methodology

This study makes use of the regional climate model to generate temperature and precipitation for the historical (1971-2005) and future periods (2006-2100). EC-EARTH and MPI_ESM_LR are two global integrated climate models (GCM) developed by the EC-Earth consortium and Max Plank Institute (Germany) respectively. Fine scale (50km resolution) regional climate information was generated by driving RCM using the output of the two GCM as a lateral boundary condition. South Asian CORDEX domain was used as model domain for driving RCM model. The regional climate modelling experiments were carried out by SMHI and MPI model based on the three representative concentration pathways (RCPs) scenarios: RCP2.6, RCP4.5, and RCP8.5 scenarios. In contrast to the SRES greenhouse gas emission scenarios, the RCPs are the radiative forcing trajectories adapted by IPCC-AR5. Among the three RCPs, the extreme scenario RCP8.5 and the steady RCP4.5 are used for analysis. Four time slices are considered to represent the temperature and precipitation changes over Bangladesh. These time slices are baseline 1970s (1971-2000), early era 2010s (2011-2040), mid era 2040s (2041-2070), long term Era 2070s (2071-2100). Comparison of the simulated data with gage-base point observation has been made to assess the model performance in simulating past climatology. The observed rainfall and temperature data has been collected from Bangladesh Meteorological Department (BMD). The annual and seasonal changes of precipitation are assessed for the above

three selected time slices in the future.

**3. Results and Discussion:**

Fig. 1 demonstrates the ability of the RCMs to produce the past temperature and precipitation over the period 1971-2000. Both of the two RCMs shows an underestimation of average temperature for the period of October to March as shown in Fig. 1(a). MPI model overestimates the temperature during the summer season while the SMHI model shows underestimation. Also for the precipitation pattern shown in Fig. 1(b), both SMHI and MPI RCM have higher capability in capturing the pre monsoon and post monsoon rainfall. However, SMHI model overestimates the monsoon rainfall while the MPI model shows the opposite. A shift of monsoon rainfall towards the pre monsoon period is also observed in MPI model.




(a) (b)

Figure 1: Comparison of observed and regional climate model simulated rainfall and mean monthly temperature for the historical period (1971 - 2000).

Changes of the mean annual temperature from the historical period (1971-2000) till 2100 is shown in the Figure 2. Between the two RCM models, results from MPI model exhibit greater temperature extremes for the future period (2011-2100) as shown in Figure 2. Also among two RCP scenarios, projections based on the RCP8.5 scenarios showed greater temperature extremes over Bangladesh. The maximum average temperature using the SMHI and MPI models are 1.67°C and 3°C under RCP4.5 scenario and 2.7°C and 5.4°C under RCP8.5 scenario. Slow increase of temperature up to year 2050 is observed for both RCP4.5 and RCP8.5 scenarios whereas accelerated warming trend is observed for RCP8.5 scenario for both of the RCM models. Compared to the total set of Representative Concentration Pathways (RCPs), RCP8.5 thus corresponds to the pathway with the highest greenhouse gas emissions.

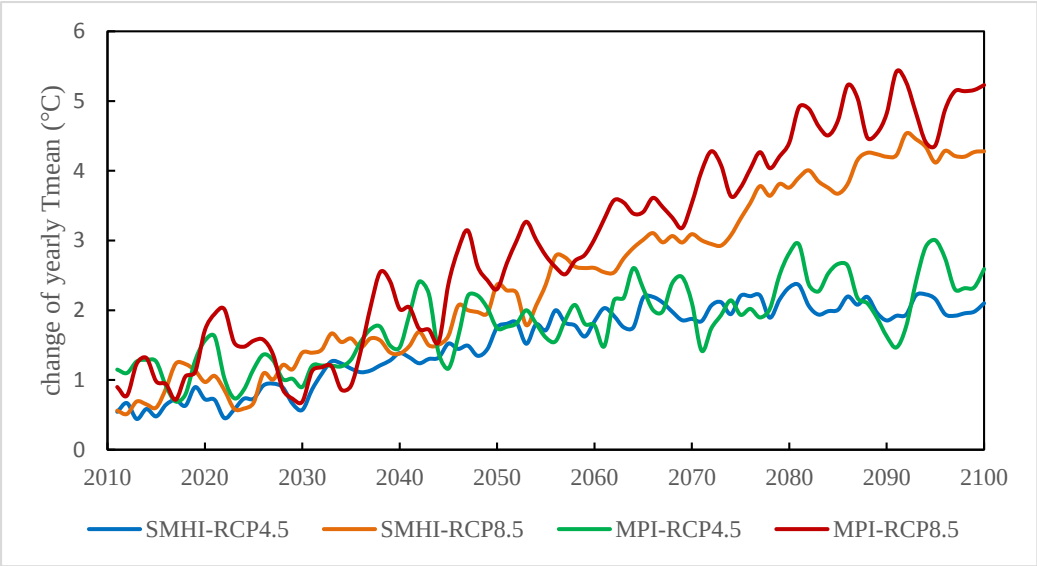



Figure 2: Projected mean annual temperature over Bangladesh under different RCP scenarios.

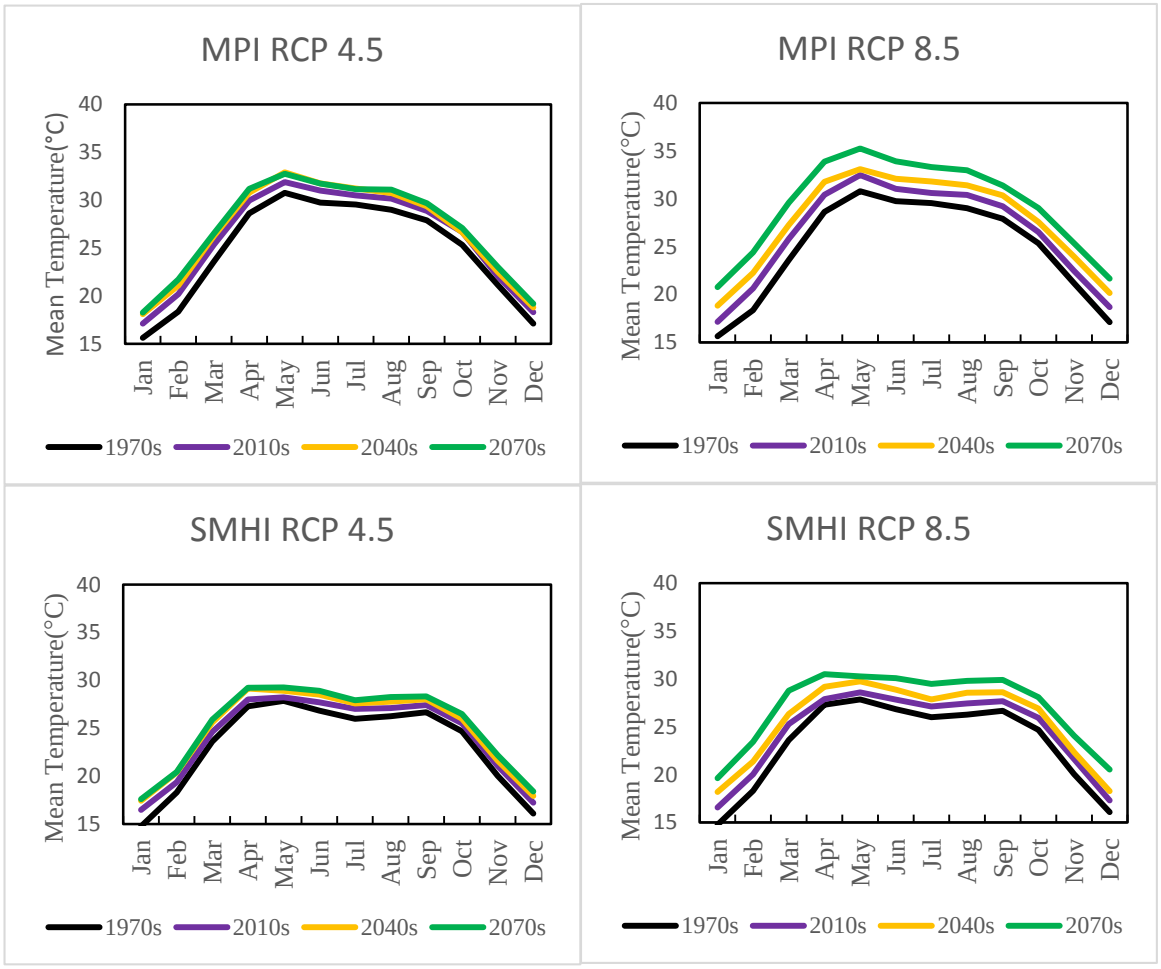



Figure 3: Annual cycles of mean temperature simulated by RCM models for 1970s, 2010s, 2040s and 2070s over Bangladesh

As showed in Figure 3, slight increase of mean temperature in the annual cycle is observed in RCP4.5 scenario for both of the RCMs (i.e. MPI and SMHI). Significant increase of temperature (3°C) during April and May is observed in 2070s (i.e. 2070-2100) for MPI RCP8.5. Among SMHI and MPI model, MPI RCP8.5 scenario shows greater temperature extreme (35.24°C) in the annual cycle than in SMHI model. Both of the SMHI RCP scenarios (i.e. RCP4.5 and RCP8.5) exhibits two peaks in the annual cycle. From the Figure 3 it is evident that temperature will increase up to 3°C during pre-monsoon and post monsoon period in the upcoming future according to SMHI RCP8.5 model. Decrease in temperature up to 2°C during the month of June, July and August is observed in SMHI RCP8.5 scenario. On the other hand, the MPI model shows only one peak in the annual cycle and no decrease in temperature during the months JJA.

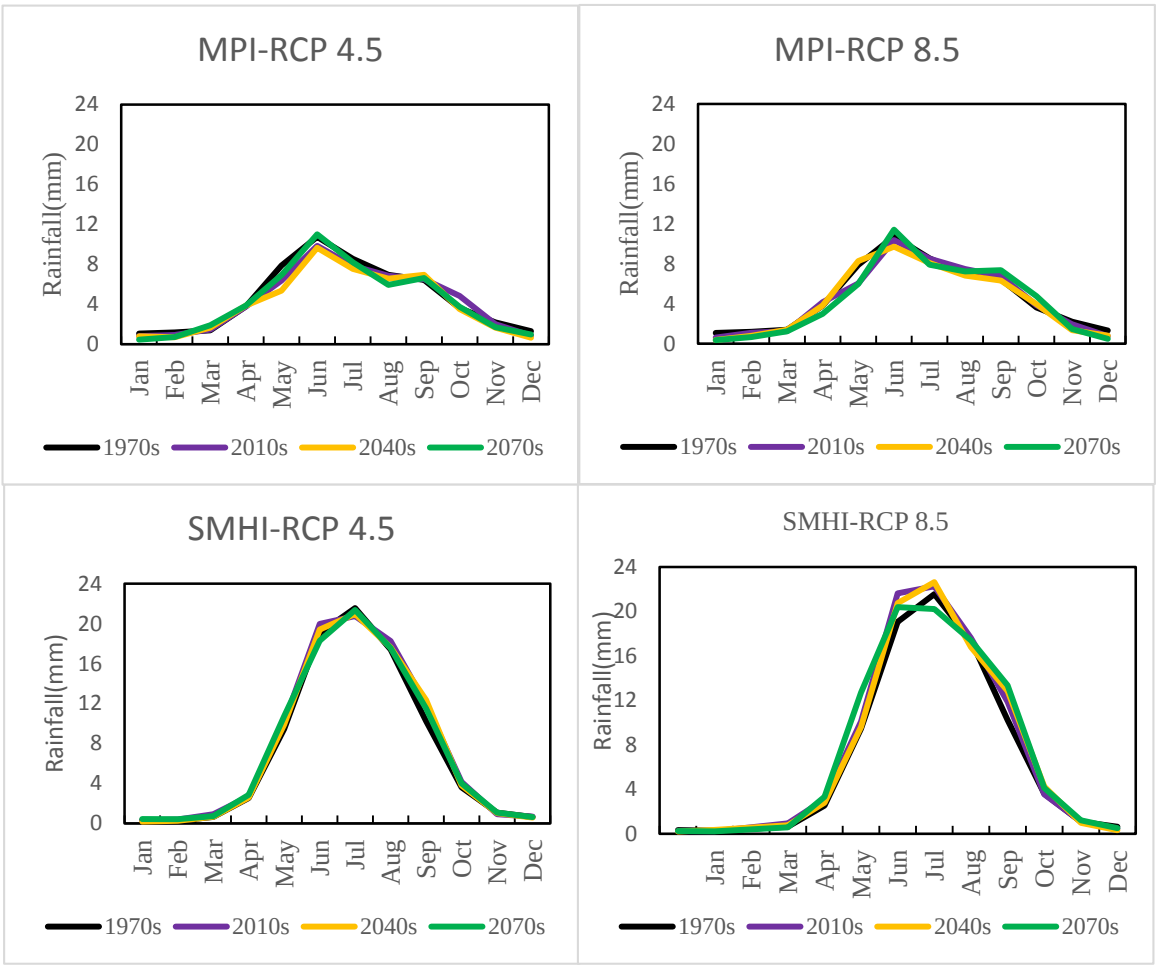



Figure 4: Annual cycles of average monthly rainfall simulated by RCM models for 1970s, 2010s, 2040s and 2070s over Bangladesh.

Significant increase in monsoon rainfall up to 10 mm in the SMHI model than MPI model is observed as shown in fig. 4. Also MPI model exhibits that rainfall will decrease up to 5mm in the upcoming future compared to the observed BMD rainfall. On the other hand, monsoon rainfall will increase by 5 mm in SMHI RCP4.5 and 7mm in RCP8.5 scenario in the future compared to the BMD observed rainfall. For both of the SMHI and MPI model shows that amount of monthly average rainfall will remain more or less same for the three time slices (i.e. 2010s, 2040s, and 2070s). A peak in rainfall cycle for September month is observed in the MPI RCP4.5 and RCP8.5 scenario. Although no significant change in rainfall in the pre and post monsoon period is observed in SMHI model, according to MPI model increase in rainfall in the pre monsoon period is observed as shown in Figure 4.

**4. Conclusion:** A comprehensive analysis has been done in the present paper to study in detail characteristic features of temperature and precipitation extremes and its seasonal behavior using the new RCP4.5 and RCP8.5 scenarios. Following are some noteworthy conclusions,

- High-resolution regional climate models SMHI and MPI showed good skill in representing the seasonal mean as well as some small-scale features of monsoon over Bangladesh.
- Towards the end of the 21$^{st}$ century (2071-2100) all RCP scenarios indicate a significant rise in the mean annual temperature (~5°C) over Bangladesh.
- The monsoon precipitation may increase varies from 10 to 20% over Bangladesh towards the 2070s relative to the observed precipitation corresponding to the 1970s.

- The analysis of temperature extremes indicates that both the daily maximum and minimum temperatures may be intense in the future under global warming conditions.

The scenarios presented in this article are indicative of the expected range of changes in the climate over Bangladesh. It must be noted that the quantitative estimates still have some uncertainties associated with them. In response to the temperature and precipitation extremes under different scenarios; it is important to make suitable adaptation and mitigation strategies in Bangladesh.

## 5. Acknowledgement

The research leading to these results has received funding from the European Union Seventh Framework Program FP7/2007-2013 under grant agreement no 603864.

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