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CHANGES OF RAINFALL IN THE FUTURE OVER BANGLADESH SIMULATED BY A HIGH RESOLUTION REGIONAL CLIMATE MODEL CONSIDERING THE RCP SCENARIOS

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ABSTRACT

Research related to the changes of rainfall events due to global warming is considered to be one of the challenging fields of research throughout the globe. Extreme rainfall events are responsible for the occurrence of floods and water logging in low-lying areas. On the other hand, lack of rainfall events is a major cause of agricultural droughts and deficiency in water management systems. Bangladesh is one of the countries of the world most vulnerable to natural disasters such as floods, cyclones and storm surges as well as climate change due to its least capacity to adapt these problems. Thus, assessment of change in variability of rainfall and their patterns are very important for the agriculture as well as the economy of the country. To analyze the future changes of rainfall patterns, the Fifth Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC) suggests a new set of emission scenarios which is known as "Representative Concentration Pathways (RCPs)". Climate data used in the study are from the global climate model ECHAM5 developed by the EC-Earth consortium. These global data were downscaled dynamically for the period of 1951 to 2100. Three emission scenarios were used namely RCP2.6, RCP4.5 and RCP8.6. Simulation were made over the large CORDEX domain with spatial resolution of 50km. Downscaled data are used in this study to evaluate precipitation change for the three future time slices: from 2011 to 2040 as the early-21st century, from 2041 to 2070 as the mid-21st century and from 2071 to 2100 as the end of the 21st century with respect to base line (from 1971 to 2000). Possible changes of rainfall events over Bangladesh in the future are presented both in temporally and spatially. Based on the analysis of all the RCP scenarios, significant increase of rainfall has been observed in the pre-monsoon season than that of any other seasons of the year. Climate predictions using the RCP scenarios for the historical periods have less bias than the earlier scenarios used in the Fourth Assessment Report (e.g., A1B, A2, B1 and B2).

Keywords: Climate change, CIMP5, CORDEX, IPCC, RCP Scenarios, rainfall extreme

INTRODUCTION

The observed warming of the world over the past century has produced a significant impact on society, economy, environment and the ecosystems. According to IPCC (2007), the world population will become much more vulnerable due to the climatic changes resulted from continuous global warming. The ongoing climate change and its consequent negative impacts of the future, have been taken increased attention by the researchers and policy makers around the globe. Due to high population density and geographic location, the climate vulnerable country like Bangladesh is also facing many challenges and difficulties to address the issue. Being a monsoon-dominated country, precipitation plays an important role on the country'seconomy as its livelihood is mainly depend on the agriculture and ecosystems services. Thus, any change in the pattern of precipitation cycle will surely affect the economic, society and livelihood of the people. Shahid (2010b, 2011) has already

found that the annual and pre-monsoon precipitation has increased and provided some negative impacts on the socioeconomic state of the country. Several other literaturesalso showed concern for the current and upcoming danger related to the change in precipitation patterns over this region under prevailing climate change(Ali, 1999; Haque et al., 2012; Islam and Hasan, 2012; Murshed et al., 2011; Shahid, 2010a).However, all of these studies usedthe 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 over this region using the new sets of RCP scenarios.

Regional Climate Models (RCMs) using the boundary data of GlobalClimate Models (GCMs) developed under CMIP3 and CMIP5 initiativesare capable of realistically simulating many aspects of the climate and the primary tools for developing projections of future climate change. However, only a few studies have taken over Bangladesh to examine the future climate change based on simulations of the fine scale regional climatemodels.Results obtained from the analysis of climate projections from RCMs provided some valuable information onthe probable future precipitation of the country. From the multi-model ensemble of 17 CMIP3 model simulations, Hasan et al. (2013b) found that the pre-monsoon precipitation is more likely to increase about 15% during 21st century. Nowreen et al. (2014)showed that high intensity precipitation will be less frequent in the north-eastern part of the country in the future. Other similar studies also indicated that the annual precipitation over Bangladesh will be increased in future years(Islam and Hasan, 2012; Islam et al., 2008; Rahman et al., 2012; Rajib et al., 2011). As climate extremes are more sensitive to the global climate change, changes of various indicators of precipitation extremes have also assessed. Based on the multi-ensemble regional climate modelling results, Hasan et al. (2013a) documented a decrease of consecutive rainy days with an increase in intensity of precipitation. However, these previous studiesare done either by PRECIS or by RegCM3 regional model which consist some biases in the control run simulation and are based on CMIP3 simulations(Rahman et al., 2012).But, 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"(Stocker et al., 2013). CIMP5 dataset comprise a new set future climate scenarios, called Representative Concentration Pathways or RCP scenarios. Global Climate Models (GCMs) in CMIP5 arebetter in the sense that they represent more of the relevant climate processesin 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 (Knutti and Sedláček, 2013). 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 been taken an novel initiative to investigate the changes of 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 asmall country like Bangladesh. Thus, GCM outputare dynamically downscalledby a Swedish Meteorological and Hydrological Institute (SMHI)regional climate model (RCM) to produce 50km fine scale climate change information over the South Asia region.Figure 1(a) shows the domain of the regional climate modelling experiments. Using these downscaled outputs, the future precipitation pattern of the country is investigated under new RCP scenarios. The changes of precipitation in the futureare presented in both monthly and seasonal scales.

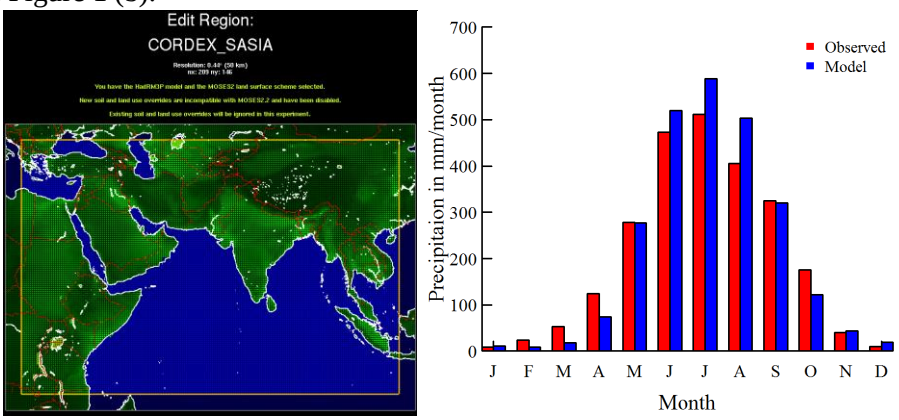
METHODOLOGY

In this study, EARTH climate model wasemployedto generate precipitation for the historical (1971-2005) and future periods (2005-2100). EC-EARTH model is a global integrated climate model developed by the EC-Earth consortium and also one of the models of CMIP5. The model has various usability in atmospheric and geographic research(Weaver et al., 2001).Fine scale regional climate information was generated by driving RCM using the output of EC-EARTH GCM as a lateral boundary condition. South Asian CORDEX domain was used as model domain for driving RCM model as shown in Figure 1(a). The regional climate modelling experiments werecarried out by SMHI 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

radiativeforcing trajectories adapted by AR5. The scenarios can reflect various possiblecombinations of economic, technological, demographic,policy developments and are not associated with predefined storylines(Van Vuuren et al., 2007).The fine scale (50km)climate projectionsare used which are generated by the EC-EARTH CIMP5 climate model consideringthe three RCP scenarios. Four time slices areconsider to represent the precipitation changes over Bangladesh. Thesetime slices are baseline (1971-2000), early era (2011-2040), mid era (2041-2070), long term era (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 data has been collected from Bangladesh Meteorological Department (BMD). The annual and seasonal changes of precipitation are assessed for the above three selectedtimeslicesin the future. Results also presented as spatial distribution over the whole country to determine the spatial patterns of the future precipitation.

RESULT AND DISCUSSION

A comparison on the mean month precipitation generatedby the model and observation are made and shown in the Figure 1 (b).



(a) (b)

Figure 1: (a) South Asia CORDEX domain. .(b)Comparison of model generated precipitation with the observed precipitation for the historical time slices (1971-2005).

It has found that model is performing well in the spre-monsoon and post –monsoon seasons. It is also revealed that the model in general overestimate the observed precipitation throughout the monsoon. The values are significant during the peak rainfall months i.e. in July and August. The CIMP5 GCM showed better performance than the earlier CIMP3 models as studied by Hasan et al.(2013c) and Islam et al.(2008). While precipitation CMIP5 GCMs are overestimated the CMIP3 GCMsas the previous regional climate model simulations underestimated the monsoon rainfall of the country.

Figure 2shows the projected annual precipitation by the end of the 21st century under the RCP2.6, RCP4.5 and RCP8.5 scenario with respect to the present-day simulation (RCP Historical simulation). It is clear that the annual precipitation isprojected to increase in the whole of Bangladesh, with a largerincrease in RCP8.5 at the end of the century. Under RCP 2.6 and RCP 4.5, the annual precipitation over Bangladeshalso shows incremental trends.

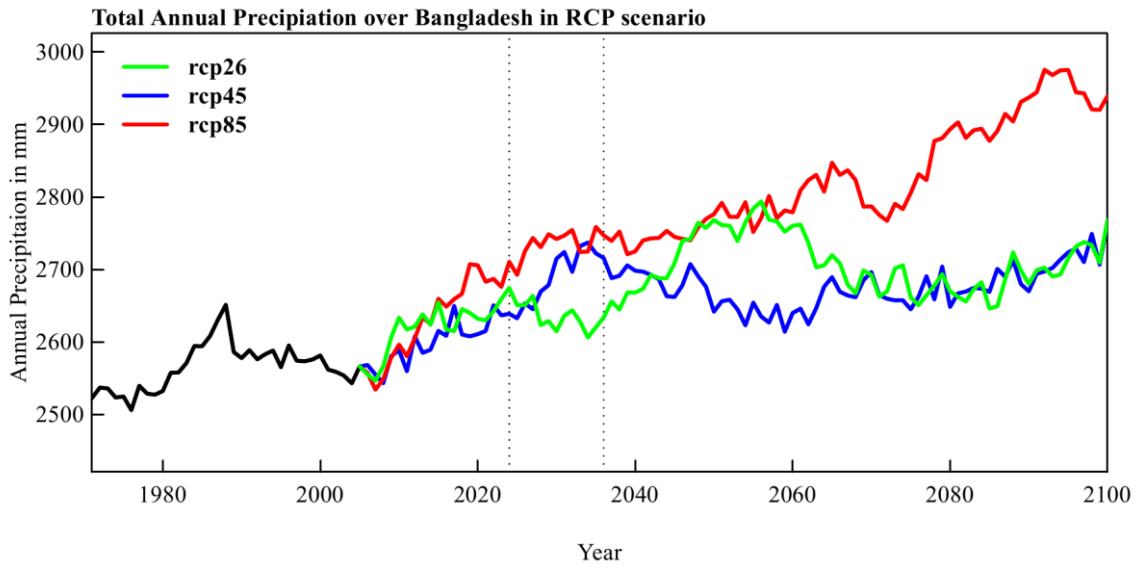


Figure 2: Annual precipitation over Bangladesh under RCP scenarios from 1970 to 2100.

Seasons plays a considerable role in the patterns of precipitation on which economy, development and culture of Bangladesh depends. Seasons in Bangladesh can be classified as Winter (December to February); Pre-monsoon (March to May); Monsoon (June to September) and Post-monsoon (October to November) from hydro-meteorological point of view. To understand the impacts of climate change on the seasonal precipitation pattern, this study made an attempt of using new RCP emission scenarios.Seasonal changes of precipitation for three future time slices are determined under the RCP 2.6, RCP 4.5 and RCP 8.5. A plot of the changes of seasonal precipitation over Bangladesh is shown in the Figure 3. The likely range of increase in the annual precipitation is projected to be 5%– 50% during pre-monsoon and 10% for both monsoon and post-monsoon seasons under the RCP8.5 scenarioin the 2080s era. However, upto 45% reduction of precipitation will be observed during winter in 2050s under the RCP 8.5 scenario. Other two RCP scenarios show higher spatial variability of precipitation comparing to that of the RCP 8.5 scenarios. On the other hand, change of monsoon precipitationis less comparing the other three seasons.

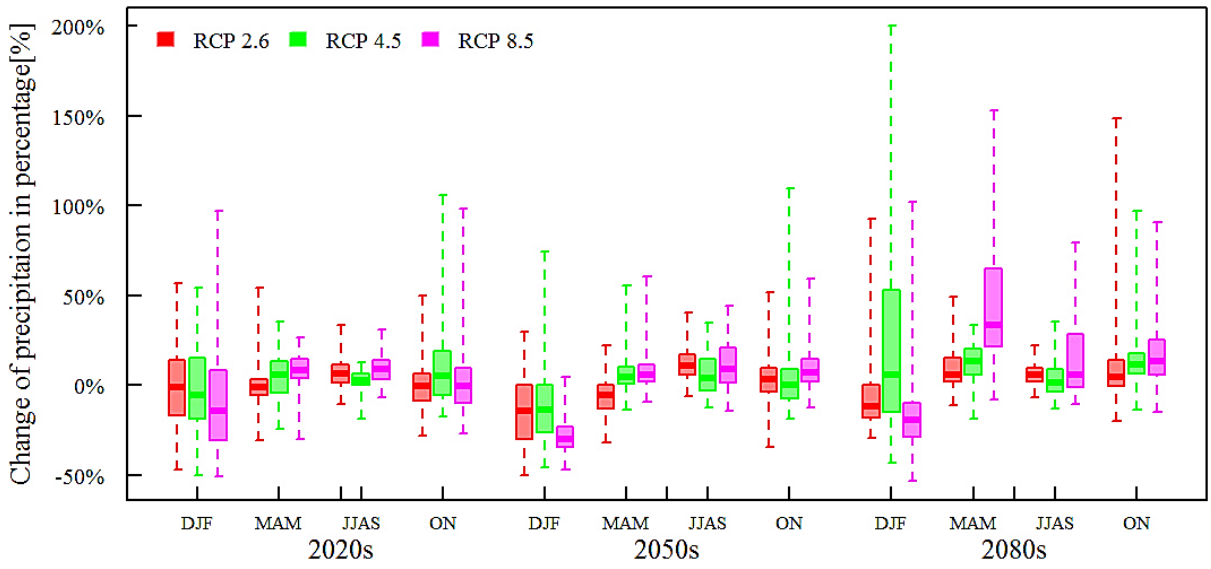


Figure 3: Change of Seasonal Precipitation under RCP scenarios over Bangladesh.

CONCLUSION

A study on the changes of precipitation over Bangladesh have been carried out consideringto determine the inter-annual and inter-seasonal variability. Regional precipitation predictions are generated using theEC-EARTH boundary data for the RCP emission scenarios. Analysisrevealed that regional climate model simulated by EC-EARTH boundary datacan able to reproduce Indian monsoon which was found challenging for the previous modelling studies. Global models forced by the new RCP scenarios showed a considerable improvement in capturingthe past climate of Bangladesh. Under the RCP8.5, the amount of precipitation is likely to be increased during pre-mosoonseasons at the end of century. In the future, precipitation will decrease almost all parts of the country during winter season. Under the RCP2.6 and RCP4.5 scenario, amount of precipitation will be increased during the early parts of the 21st century but became steady in the latter part the century. Climate predictions based on the new RCP scenarios showed improvement in capturing the present day climate. However, further analysis of thechanges of the extreme climate analysis is needed. Moreover, it is also felt that multi model climate predictions will be able to capture wide range of uncertainties of the changes of precipitations over this region.

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