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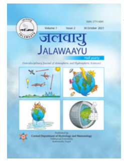

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Research Article

Simulation of Rainfall over Bangladesh Using Regional Climate Model (RegCM4.7)

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Abstract: Regional climate model is a scientific tool to monitor present climate change and to provide reliable estimation of future climate projection. In this study, the Regional Climate Model version 4.7 (RegCM4.7) developed by International Centre for Theoretical Physics (ICTP) has been adopted to simulate rainfall scenario of Bangladesh. The study examines model performance of rainfall simulation through the period of 1991-2018 with ERA-Interim75 data of 75 km horizontal resolution as lateral boundaries, downscaled at 25km resolution using the mixed convective precipitation scheme; MIT-Emanuel scheme over land and Grell scheme with Fritsch-Chappell closure over ocean. The simulated rainfall has been compared both at spatial and temporal scales (monthly, seasonal and annual) with observed data collected from Bangladesh Meteorological Department (BMD) and Climate Research Unit (CRU). Simulated annual rainfall showed that the model overestimated in most of the years. Overestimation has been observed in the monsoon and underestimation in pre-

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monsoon and post-monsoon seasons. Spatial distribution of simulated rainfall depicts overestimation in the southeast coastal region and underestimation in the northwest and northeast border regions of Bangladesh. Better estimation of rainfall has been found in the central and eastern parts of the country. The simulated annual rainfall has been validated through the Linear Scaling bias correction method for the years of 2016, 2017, and 2018 considering the rainfall of 1991-2015 as reference. The bias correction with linear scaling method gives fairly satisfactory results and it can be considered in the future projection of rainfall over Bangladesh.

1. Introduction

Climate change is one of the greatest threats that is facing our world today in the 21st century. Understanding and prediction of climate change is now a major issue because of its adverse effects on the environment and society. Several climatic models which are known as Global Climate Model or Global Circulation Model (GCM) have been developed to simulate and predict climate parameters over the decades. These models are based on complex mathematical relationships between the major climate system components like atmosphere, land surface, ocean, and sea ice. Thus, GCM is developed based on global patterns in the atmosphere and ocean. Though the coupled Atmospheric-Ocean Global Circulation Model (AOGCM) predicts the future changes of climatic parameters, but are not able to resolve regional features such as topography, land use patterns, and cloud features due to coarse horizontal resolution (Almazrouri, 2012; Sigdel and Ma, 2016). To attain the information of regional climate change several regional climate models (RCMs) have been utilized to downscale the coarser-resolution model outputs to a higher resolution considering the land cover and topography of that region. In the dynamic downscaling process, information about climate change at a higher resolution for a particular region can be derived using RCM by employing GCM data or Reanalysis data as lateral boundary conditions.

Bangladesh is one of the most vulnerable countries in the world which is susceptible to the impacts of climate change because of its geographic location and low-lying topography (Fahad *et al.*, 2018). Rainfall is one of the major climatic features that have a strong influence on the socio-economic activity of the country as its economy is highly dependent on agriculture and rainfall is a major triggering factor in agriculture. Global climate change is changing the rainfall pattern arguably in different regions at different scales. To assess climate change, specifically the rainfall over Bangladesh, it is required to execute climate models at a regional level. There are few RCMs that have been utilized to examine over the Bangladesh domain. But in this study, the Regional Climate Model (version 4.7) developed by the International Centre for Theoretical Physics (ICTP), defined as RegCM4.7 has been adopted. This model has been examined widely over the South Asian CORDEX (Coordinated Regional Downscaling Experiment) domain to predict climate change (Gu *et al.*, 2012; Almazroui, 2012; 2016; Park *et al.*, 2013; Hassan *et al.*, 2014; 2015; Bhatla *et al.*, 2016; Ngo-Duc *et al.*, 2017; Sanjay *et al.*, 2017; Kumar & Dimri, 2020) for different regions. Almazroui (2012) examined the performance of the ICTP regional climate model (RegCM4; Giorgi et al., 2012) over the Arabian Peninsula (0-45° N, 15-75° E) using ECHAM5 and ERA40 data as lateral boundaries and proposed the use of the model for this domain for better outcomes.

Bal and Mitra (2019) simulated summer monsoon climate over Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) countries using RegCM4.3 with ERA-Interim boundary forcing. Hassan et al. (2014) experimented with RegCM4.3 by using ECHAM5 and ERA40 (2.5° resolution) data as lateral boundaries simulating at 50 km horizontal resolution and found better results for temperature but underestimation in Bay of Bangle and refers to different parameterization schemes over this region for rainfall prediction. Raju et al. (2015) investigated the performance of four convective schemes on simulating summer monsoon features over the South Asian CORDEX domain using RegCM4.3 where the mixed convection scheme (MIT-Emanuel over land and Grell over ocean) results better than the others. Over Bangladesh, very few experiments have done using RegCM for rainfall projection. Rahman et al. (2012) used RegCM3 to make a projection of rainfall and temperature for 2050 and 2060 over Bangladesh at 50 km resolution with Grell scheme as convective precipitation parameterization scheme which results in higher estimation of rainfall over the country. The study results with overestimation in some seasons. The previous studies found anomalies in simulated rainfall over Bangladesh which might be reduced by using different convective schemes. To estimate rainfall over the region with higher resolution (at 25km) the RegCM4.7 has been employed in this study using mixed convective schemes. In these contexts, the primary objective defined in this study is to examine the model performance by analyzing simulated monthly, seasonal and annual rainfall over Bangladesh. The secondary objective of the study is to validate the simulated rainfall with observation using bias correction.

2. Data, Model Setup, and Methodology

2.1. Data used in model simulation

RegCM4.7 model has been adopted over Bangladesh for this study. For simulation, three different types of data have been used, namely terrain (topography and land use), Sea Surface Temperature (SST), and Initial Condition and Boundary Conditions (ICBC). For terrain representation, Land Cover Characterization (GLCC) dataset and Global Multi-resolution Terrain Elevation Data (GMTED2010) have been employed. Both of the datasets are with 30 arc-seconds resolution. NOAA Optimum Interpolated Sea Surface Temperature (OISST) version 2 (V2) weekly mean temperature with 1°×1° resolution has been utilized. For initial and boundary conditions, ERA-Interim75 (EIN75) data from ECMWF with 0.75° horizontal resolution has been employed for simulation for the period of 1990-2018 with 6-hr interval. The output of the model has been obtained with 0.25° (25km) horizontal resolution.

2.2. Observed data

The observed rainfall data has been used to compare with the RegCM4.7 simulated rainfall, and to validate through bias correction. Observed rainfall datasets have been collected for the period 1991-2018 from two different sources. Daily observational data has been collected from 34 stations of the Bangladesh Meteorological Department (BMD) throughout the country (Figure 1). On the other hand, monthly gridded rainfall data has been collected from the Climatic Research Unit (CRU). The dataset is known as CRU Time Series data of version 4.03, defined afterward as CRU, which is produced by the Climatic Research Unit at the University of East Anglia, Norwich, England. The NetCDF format CRU data is having horizontal resolution of 0.5°×0.5° (~50 km).

BMD observed daily data from 34 stations are constructed to monthly, seasonal, and annual products for all the stations. As the rain gauge stations are scattered, observed rainfall of BMD has been interpolated into grided data by ordinary kriging interpolation method with linear semivariogram using ArcGIS. Then the interpolated rainfall with 0.023° grid resolution has been regridded into 25×25 km (~0.25°) horizontal resolution complying with the model grid resolution using Climate Data Operators (CDO) tool. CRU monthly mean data has also been regridded into 25 km horizontal resolution through CDO tool using bilinear method. Bilinear interpolation is used in many studies for remapping the grids with a similar spatial resolution (Kalognomou *et al*. 2013; Nikulin *et al.* 2012). Seasonal and annual rainfall of the same horizontal resolution has also been obtained from the monthly data.

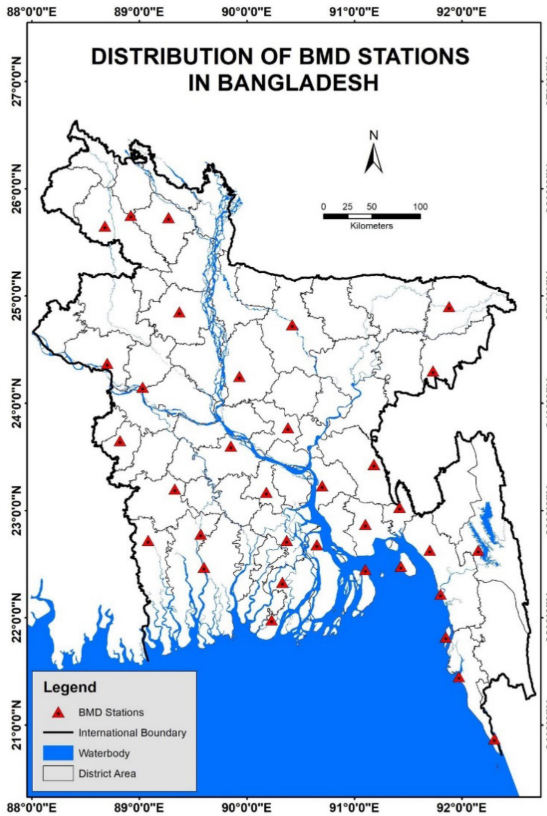

Figure 1. Location of 34 meteorological stations of BMD in Bangladesh. The triangle marks represent the geographical location of the stations.

2.3. Model setup

Complying with the modeling criteria simulated domain has been selected as 84.82°E to 96.18°E and 17.82°N to 29.18°N, where the region of interest (Bangladesh) lies within 88°E to 92.75°E and 20.5°N to 26.75°N (Figure 2). The horizontal resolution of 25 km has been considered for simulation by maintaining the appropriate downscaling ratio compared to the ICBC resolution of 75 km.

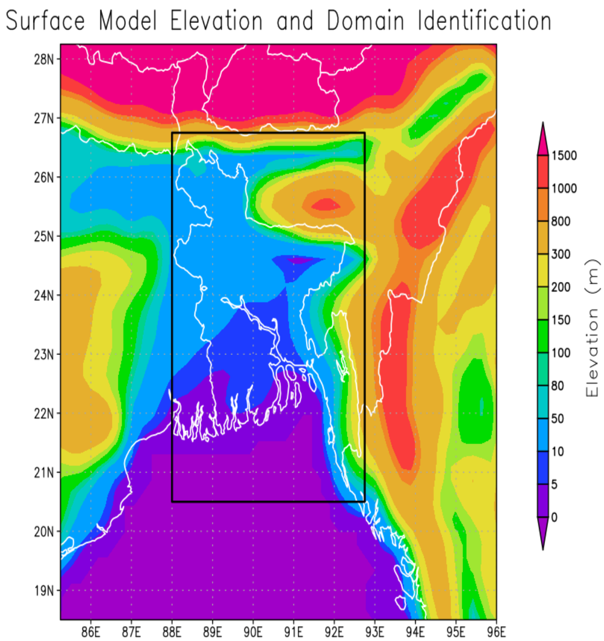

Figure 2. Model domain set-up for the study with topography in the background. The black box indicates the study region.

Based on the available cumulus convective precipitation scheme with RegCM4.7 and previous studies over South Asia (Raju *et al.*, 2015), a mixed convection scheme has been employed which is the MIT-Emanuel scheme (Emanuel 1991, Emanuel and Živković-Rothman 1999) is used over land and the Grell scheme (Grell *et al.*, 1994) with Fritsch & Chappell (1980) closure is used over the ocean. The other physical parameterization schemes used in this study are the Biosphere-Atmosphere Transfer Scheme (BATS) land surface model (Dickinson et al., 1993) to describe the role of vegetation and interactive soil moisture in modifying the surface-atmosphere exchanges of momentum, energy, and water vapor and the Sub-grid Explicit Moisture (SUBEX) Scheme (Pal et al., 2000)) to process the large-scale (grid-resolvable scale) precipitation processes. The Zeng *et al.* (1998) has been used for ocean flux parameterization scheme. The model configuration regarding resolution, global datasets, and physical schemes employed for the study is listed in Table 1.

Table 1. RegCM4.7 model configuration for the study

Model Aspects	Selected schemes
Model domain	84.82°E to 96.18°E and 17.82°N to 29.78°N (Study region: 88°E to 92.75°E and 20.5°N to 26.75°N)
Dynamics	Hydrostatic
Resolution	25 km horizontal.
ICBC	ERA Interim 75 (EIN75)
SST	NOAA WK-OISST weekly optimal interpolation dataset
Planetary boundary layer	Modified Holtslag
Cumulus convection	MIT-Emanuel over land and Grell over ocean
Land surface	BATS
Ocean flux	Zeng
Moisture	SUBEX

2.4. Methodology

The simulated outputs have been obtained from 1990-2018 for rainfall climatology at 25 km resolution with a 6-hr temporal scale. The first year (1990) has been excluded as the spin-up year. Precipitation has been extracted from the outputs. To examine model performance and analyze rainfall with observed data, the simulated rainfall has been compared with observed datasets of BMD and CRU in both temporal (monthly, seasonal, and annual) and spatial scales. In temporal comparison, area average rainfall is obtained by considering the grid points inside Bangladesh. The grided observed data of BMD has obtained from the interpolation of 34 rain gauge stations data by Kriging method using ArcGIS. The grid points inside the country border of Bangladesh have been taken into account by masking out using MeteoInfo software. Model performance is also studied by computing certain statistical values such as mean bias, root mean square error (RMSE), and correlation coefficient considering the area average value of annual mean rainfall. These computations have been operated by the following equations,

$$Mean\ Bias = \frac{1}{n}\sum_{i=1}^{n}\left(M_i - O_i\right) \qquad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{1}^{n}\left(M_i - O_i\right)^2} \qquad (2)$$

$$Correlation\ Coefficient, r = \frac{\sum_{i=1}^{n}\left(O_i - \overline{O}\right)\left(M_i - \overline{M}\right)}{\sqrt{\sum_{i=1}^{n}\left(O_i - \overline{O}\right)^2}\sqrt{\sum_{i=1}^{n}\left(M_i - \overline{M}\right)^2}} \qquad (3)$$

Where M represents the simulated values and O represents the observed values.

Spatial distribution of rainfall attained from the simulated, BMD and CRU have been compared for the annual and seasonal rainfall climatology analysis over the region. Besides the comparison of spatial distribution, spatial bias has also been inspected for the study region. Annual mean bias and annual percent bias between simulated rainfall and observed rainfall have been calculated using GrADS. Percent bias has been calculated by the following equation:

$$Percent\ bias = \frac{(Model\ mean - Observed\ Mean)}{Observed\ mean} \times 100 \qquad (4)$$

Bias correction methods intend to add value to the simulated outputs by removing systematic biases so that they can be applied in climate change impact modeling (Mendez *et al*., 2020). There are several kinds of bias correction methods, such as Delta-Method, Linear Scaling, Power Transformation of Precipitation, Empirical Quantile Mapping, Gamma Quantile Mapping, etc. Boer and Faqih (2019) used the Linear Scaling method for statistical bias correction of RegCM4 rainfall data. In this study, the Linear Scaling method has been employed. This method objects to perfectly match the long-term monthly and annual mean of corrected values with those of observed values. Rainfall is typically adjusted with the multiplier factor obtained by the ratio of mean observed value with simulated mean value (Mendez *et al*., 2020). Bias corrected rainfall is obtained by using the following equation of the Linear Scaling method:

$$P_{ftr}^{BC}(t) = P_{ftr}(t) \times \left[\frac{\mu P_{obs}(t)}{\mu P_{ref}(t)} \right] \qquad (5)$$

Where,

P is precipitation,
ref is RegCM simulated time series during the reference period,
obs is the observational time series during the reference period,
frc is the future projection time series to be corrected,
BC is the final bias-corrected time series,
t is the time step and
μ is the long-term mean

The linear scaling bias correction method (*equation 5*) has been examined on the simulated rainfall of recent-past-period. Data ranging from 1991 to 2015, a 25-year time was used as observed climatology for bias correction validation. The correction factor has been obtained by the ratio of observed BMD mean annual rainfall and simulated mean annual rainfall averaged for the referenced period (1991-2015) at each grid. The simulated annual rainfall data of the years 2016, 2017, 2018 were bias-corrected through the correction method and compared with the available observed rainfall of BMD. In Figure 3, the steps of the methodology are given in a flowchart.

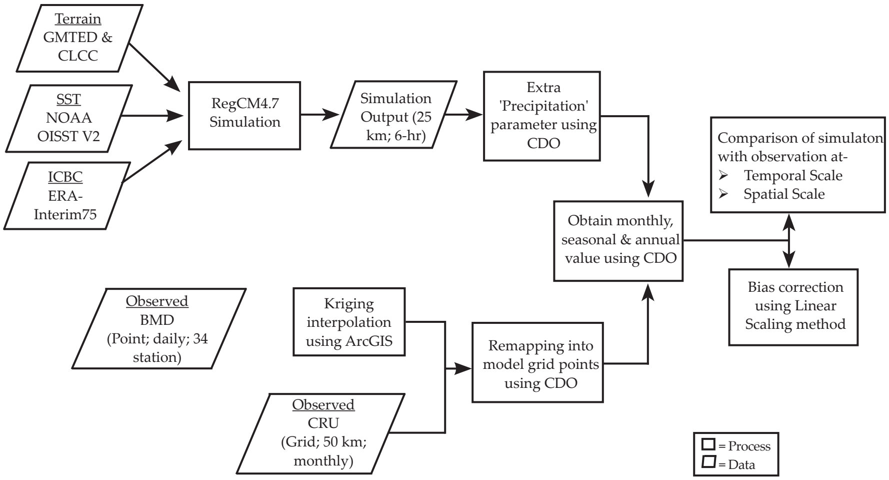

Figure 3. Flowchart of the steps and processes of methodology.

3. Results and Discussions

3.1. Rainfall Climatology Analysis

3.1.1. Annual rainfall pattern

The climatology of rainfall is analyzed in temporal (annual, seasonal, and monthly) and spatial (annual and seasonal) scales. The area average simulated annual rainfall overestimates in most of the years whereas, in the years 1993, 1997, 1999, 2005 model slightly underestimates comparing BMD and CRU rainfalls (Figure 4). The highest amount of BMD rainfall (2865 mm) in 2017 is also captured by the model though it is overestimated (2971 mm). The trend line of simulated rainfall indicates the increasing pattern of annual rainfall.

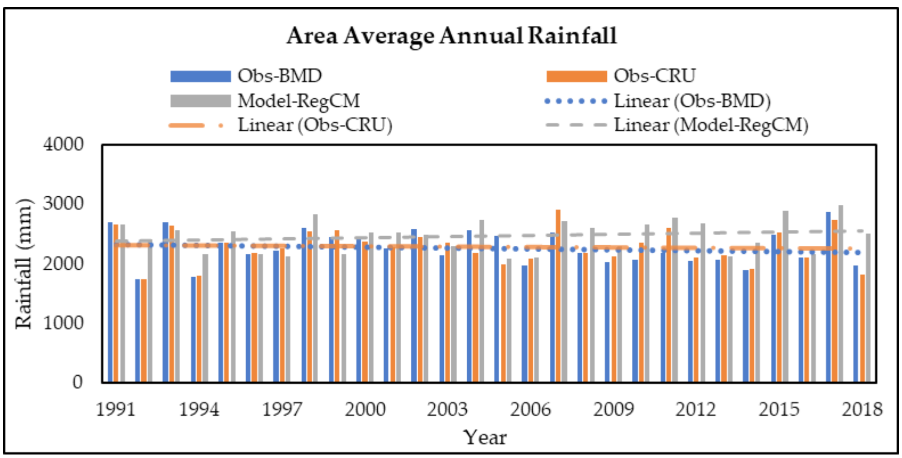

Figure 4. Time series of annual rainfall over Bangladesh for, BMD, CRU, and RegCM4.7.

The spatial distribution of annual and seasonal mean rainfall is obtained by averaging for the period 1991-2018. The spatial distribution of simulation shows extreme rainfall in the south-eastern part comprising the hilly region of Chittagong, alongside the coastal shoreline (Figure 5a). Another extreme region is found at Cherrapunji of Meghalaya, India which is the highest rainfall region in the world with higher topography, located just at the north of the northeastern part (Sylhet) of Bangladesh (Figure 5a). As it is situated beyond the country boundary and usually BMD has no observational data for that region, it couldn't be captured (Figure 5b). In the comparison of simulated rainfall with CRU observed rainfall (Figure 5c), the Cherrapunji region shows as a high rainfall zone but not as much as the model. Besides, CRU has no observed data for the ocean. Rather than these two regions (Chittagong and Cherrapunji), the model generates almost closer rainfall with both BMD and CRU observed data. The lower rainfall is observed in the western region of the country which is fairly similar to the observational data.

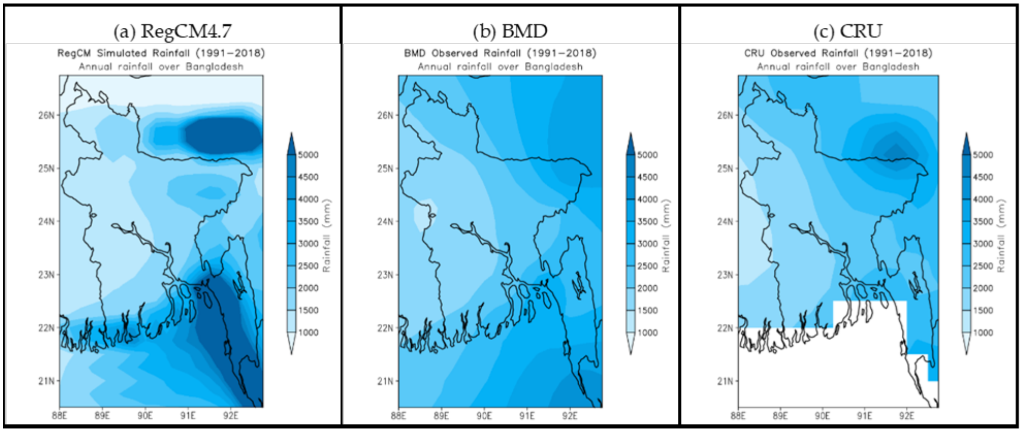

Figure 5. Spatial distribution of annual mean rainfall for (a) RegCM4.7, (b) BMD, and (c) CRU, averaged for the period 1991-2018 and unit is mm/year.

Spatial annual mean bias (Figure 6a) and annual percent bias (Figure 6b) of simulated rainfall with respect to BMD represent that the southern coastal region in Bangladesh has around 50-75% positive bias and around 100% in the Chittagong coast and hills, indicates an overestimation of the model. On the other hand, in some parts of the northwest and northeast border regions of Bangladesh model shows negative biases whereas the rest of the country is found with minor negative biases. Figures 6c and 6d indicate the annual mean bias and the percent bias of the simulated rainfall with respect to CRU respectively. In comparison with CRU rainfall, the model shows overestimation in the coastal shoreline and Chittagong hilly regions located in the south and southeastern parts of the country. On the other hand, underestimation founds in the northeast and northwest border regions of the country. The simulated rainfall has negative biases (-10% to -25%) with the observed rainfall in the other parts of the country that contains smooth topography.

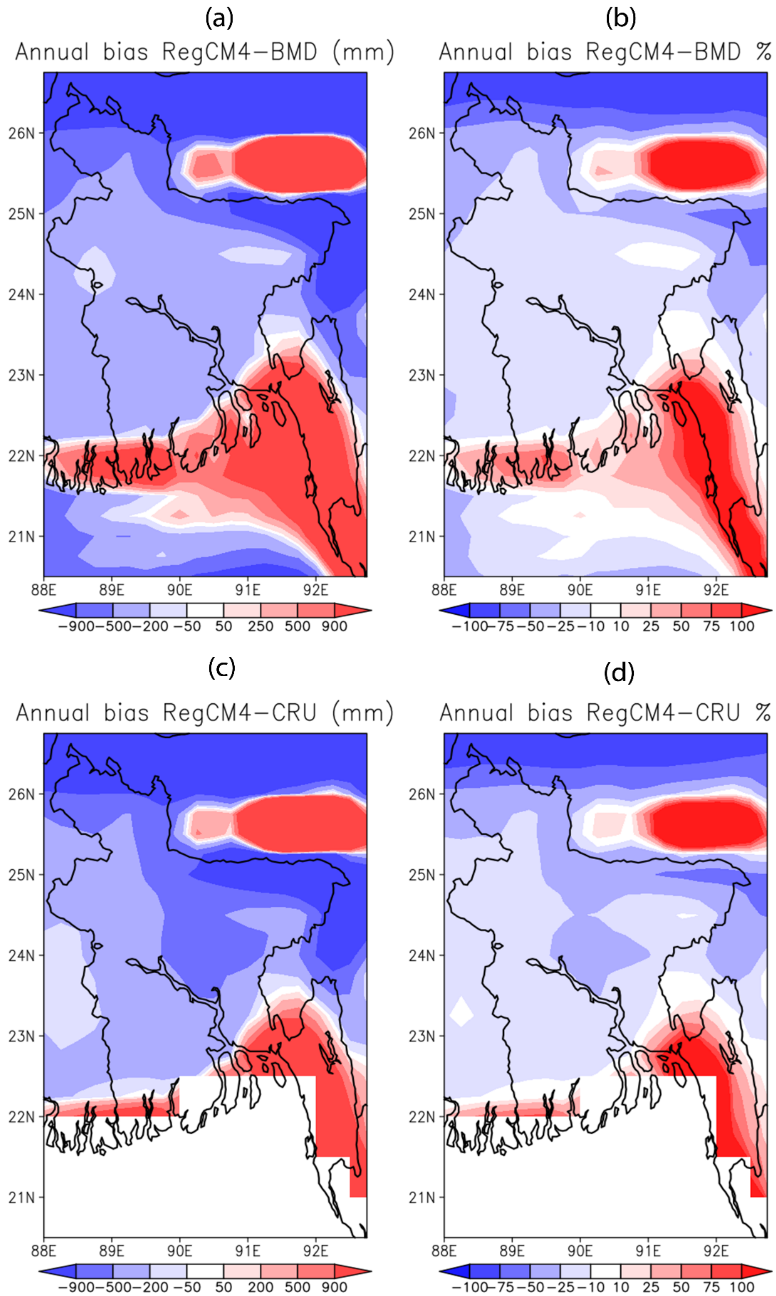

Figure 6. Spatial difference (mm) and percent bias (%) of RegCM4.7 simulated annual mean rainfall with respect to BMD (a,b) and CRU(c,d) for the period 1991-2018.

Table 2. Mean bias, RMSE, and correlation coefficient of area average annual mean rainfall for RegCM4.7 model simulation with respect to BMD and CRU averaged for the period 1991-2018.

	Model - BMD	Model - CRU
Mean Bias	202.1	185.6
Correlation Coefficient	0.52	0.56
RMSE	337.93	320.38

The statistical analysis i.e., mean bias, correlation coefficient, and root mean square error (RMSE) of the annual rainfall of the period 1991-2018 quantifies the differences between simulation and observation (Table 2). The mean bias of the model annual rainfall with respect to BMD and CRU is about 202.1 mm and 185.6 mm with 337.9 and 320.3 RMSE respectively. It can therefore be concluded that the model gives an overestimation for the overall area with both of the observed datasets. Correlation coefficients represent the moderate correlation between simulation and observations. Positive mean biases were also found in Rahman *et al.* (2012).

3.1.2 Seasonal rainfall pattern

In the case of seasons, the highest rainfall in Bangladesh is experienced in the monsoon that starts from June and extended up to September. The model captures the monsoon rainfall well but with an overestimated value (Figure 7). Model captures the pre-monsoon season rainfall reasonably.

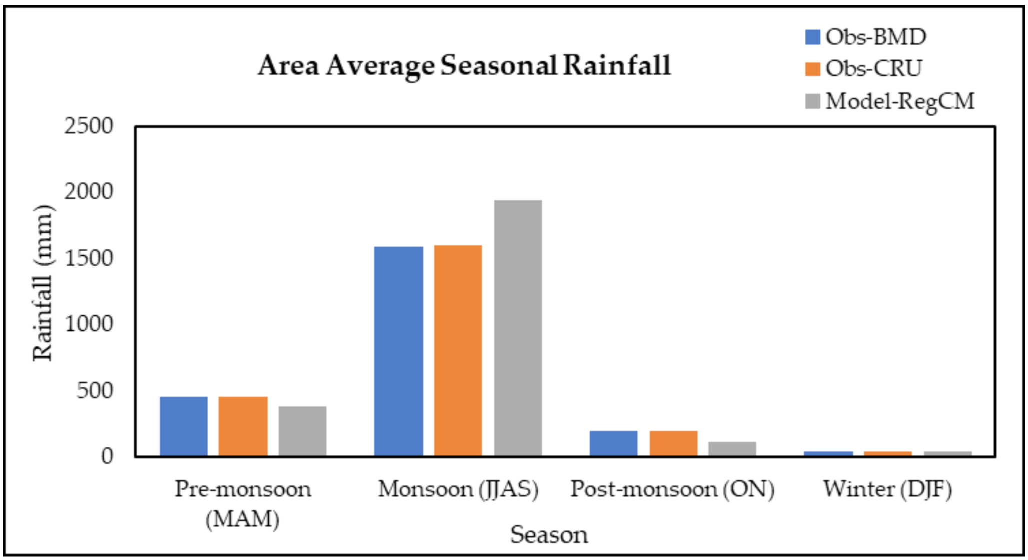

Figure 7. Average seasonal mean rainfall for BMD, CRU, and RegCM4.7 in Bangladesh.

In the comparison with CRU and BMD, the model gives overestimation for the monsoon season and underestimation in pre-monsoon and post-monsoon where fair estimation is found for winter. The overestimation has also been observed for monsoon when the RegCM3 experimented with ERA-40 data using the Grell scheme (with Fritch-Chappell closure) over Bangladesh (Rahman *et al.*, 2012).

Table 3. Mean bias of area average seasonal rainfall (mm) for the period 1991-2018 over Bangladesh.

Season	Model - BMD	Model - CRU
Pre-monsoon	-69.3	-69.3
Monsoon	352.9	341.6
Post-monsoon	-89.1	-90.7
Winter	1.5	4.0

Overestimations and underestimations are assessed by the mean bias of the simulated rainfall with respect to BMD and CRU are shown in Table 3. The positive values indicate the overestimation of simulated rainfall to the corresponding observed data and the negative values indicate the underestimation. Rahman *et al*, (2012) found overestimated rainfall in monsoon, pre-monsoon, and winter for RegCM3. RegCM4.7 performs better with the mixed scheme in winter and pre-monsoon rather than RegCM3 with Grell scheme over Bangladesh.

The spatial distribution of seasonal rainfall demonstrates that the model estimates high rainfall with more than 900 mm rainfall in the Chittagong coastal region for the pre-monsoon season (Figure 8a) which is observed by BMD and CRU with a comparatively lower value of near 500 mm (Figure 8b and 8c).

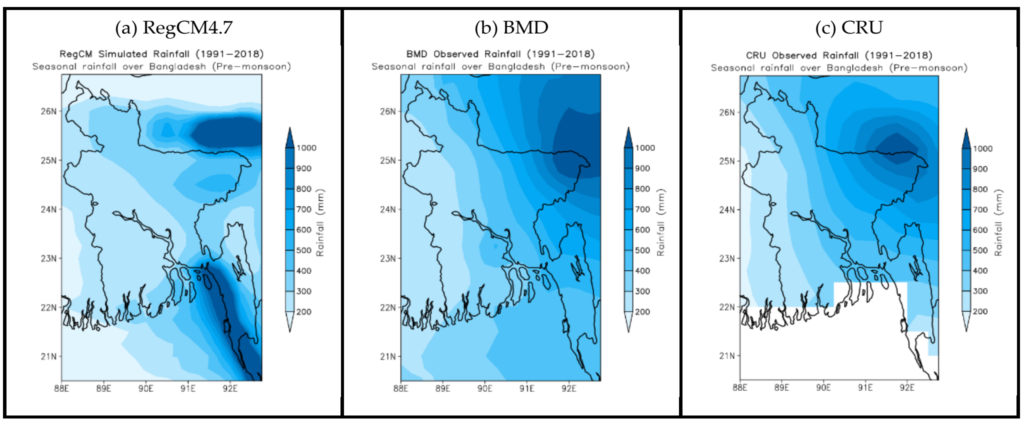

Figure 8. Pre-monsoon seasonal rainfall distribution of (a) RegCM4.7 model simulation, (b) BMD observation, and (c) CRU observation averaged for the period 1991-2018, unit of rainfall is millimeter.

In monsoon, heavy rainfall is evaluated (more than 3300 mm) in the south and southeast coastal areas as well as in the southeast coast adjoining hilly areas (Figure 9a), which is found relatively lower for BMD and CRU (Figure 9b and 9c). Monsoon rainfall, triggered by southwesterly flow over the Bay of Bengal, is captured by the model well for the other parts of the country. The maximum rainfall was also captured by RegCM4.3 driven with ERA40 (Hassan *et al.*, 2014). On the other hand, Bal and Mitra (2019) found underestimation of summer monsoon rainfall over Bangladesh using RegCM4.3 with ERA-Interim data and Grell scheme. The discrepancy between the result obtained from Bal and Mitra (2019) and this study might be attributed to different schemes i.e.; Grell scheme over land and ocean in Bal and Mitra (2019) where MIT-Emanuel over land and Grell scheme over ocean in this study.

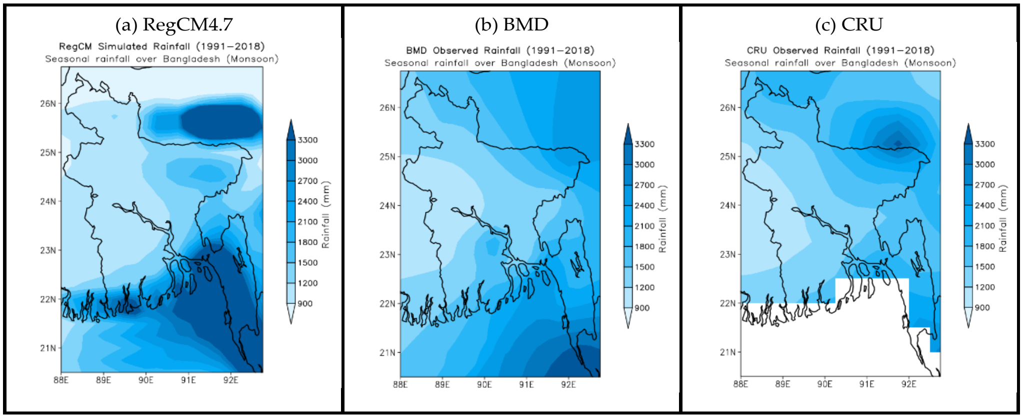

Figure 9. Monsoon seasonal rainfall distribution of (a) RegCM4.7 model simulation, (b) BMD observation, and (c) CRU observation averaged for the period 1991-2018, unit of rainfall is millimeter.

For post-monsoon, simulated rainfall in the south and the southeast region is found relatively similar to the observed BMD and CRU (Figure 10). In the rest of the country, the model estimates comparatively lower rainfall than observation.

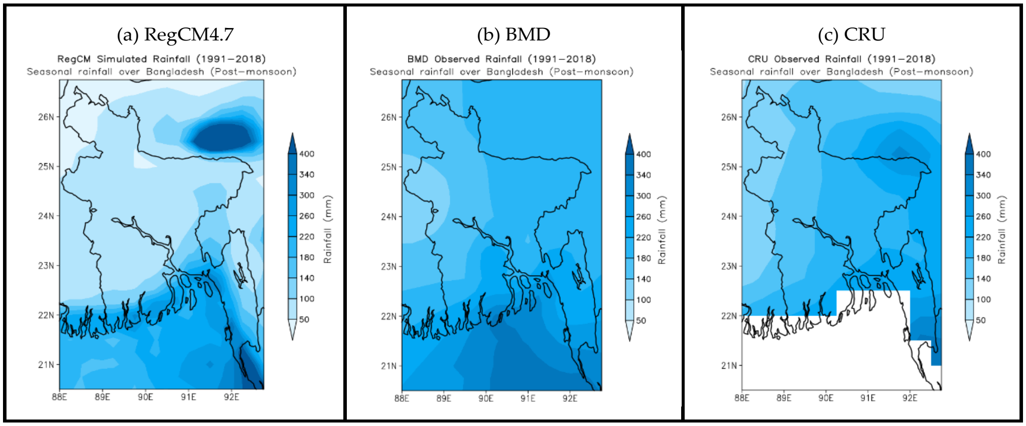

Figure 10. Post-monsoon seasonal rainfall distribution of (a) RegCM4.7 model simulation, (b) BMD observation, and (c) CRU observation averaged for the period 1991-2018, unit of rainfall is millimeter.

3.1.3. Monthly rainfall pattern

The area-averaged mean annual cycle of monthly rainfall is calculated over Bangladesh for the period 1991-2018 (Figure 11). The simulated monthly rainfall depicts positive biases in the months of June, July, August, and December. For the rest of the months, the model gives negative biases with respect to observed rainfall. In February, March, and September, the model estimates rainfall almost similar to BMD and CRU. Though there is a high positive bias, the model simulates the heavy rainfall months well along with the dry month. The mean bias value for the months is shown in Table 4. Higher positive mean biases are found in June and July whereas higher negative mean bias is in October. In contrast, Rahman *et al.* (2012) found significant positive bias during the onset phase of the monsoon with excess rainfall in the month of May and June. The discrepancy between (Rahman *et al.*, 2012) and this study might be due to different versions of RegCM, different boundary forcing datasets, and different schemes (Grell scheme over land and ocean where MIT-Emanuel over land and Grell over ocean).

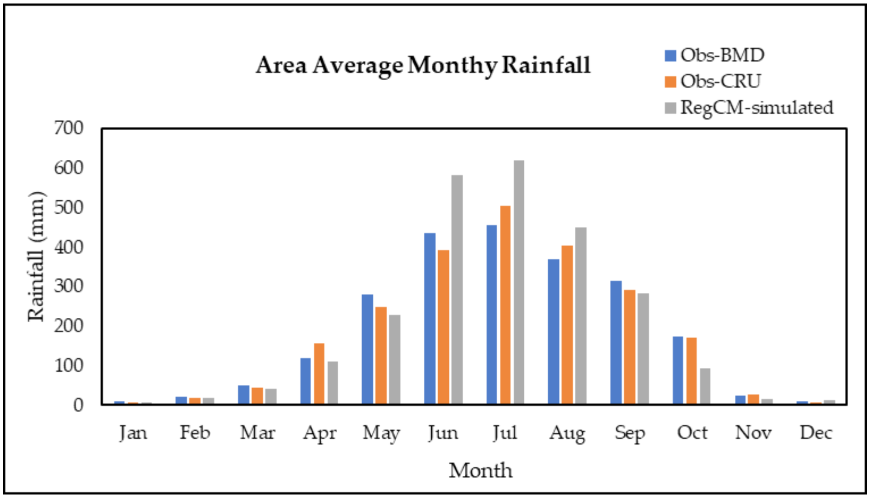

Figure 11. Average monthly mean rainfall for BMD, CRU, and RegCM4.7 in Bangladesh.

Table 4. Mean bias of simulated area-averaged rainfall with respect to BMD and CRU for Bangladesh.

Months	Area average mean bias (mm)	
	Model - BMD	Model - CRU
January	-1.2	-0.1
February	-1.2	-0.9
March	-7.3	-1.7
April	-8.7	-47.7
May	-52.8	-19.9
June	148.1	191.6
July	163.1	114.9
August	79.1	43.8
September	-30.3	-8.7
October	-80.4	-77.7
November	-8.8	-13.0
December	3.9	4.8

3.2. Bias Correction and Validation

For bias correction, the annual mean rainfall of the period ranging from 1991-2015 is considered as the reference period for validation. Using the linear scaling method (*Equation 5*), bias-corrected rainfall has been obtained for the years 2016, 2017, and 2018 which have compared with the observed rainfall of BMD of the corresponding years. The comparison is represented in Figure 12 including the simulated rainfall before bias correction for the respective years.

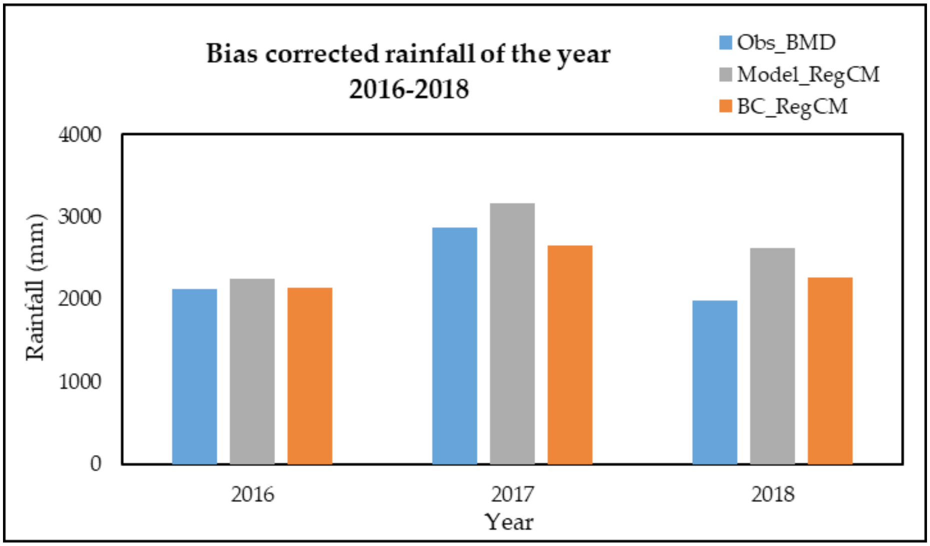

Figure 12. Bias corrected rainfall of model simulation compared with observed BMD rainfall and simulated rainfall before bias correction for the years 2016, 2017, and 2018.

Figure 12 demonstrates that the bias-corrected rainfalls are comparatively closer to the observed value. The annual rainfall of the model simulation for the year 2016 was 2254 mm which is bias-corrected and found rainfall of 2133 mm, which is much closer to the BMD observed rainfall of 2122 mm. Mean bias value is confined from 132 mm to 11 mm. Bias correction reduces the amounts of rainfall and makes it comparable to observation in 2017 and 2018. The RMSE is reduced from 1249, 2997, and 2210 to 417, 799, and 516 for the years 2016, 2017, and 2018 respectively whereas the correlation is also improved from moderate to high degree after bias correction.

4. Conclusion

The present study attempts to verify the downscaled rainfall for Bangladesh simulated through RegCM4.7 driven by EIN75 boundary forcings. The simulated rainfall is compared with observed rainfall of BMD and CRU at temporal and spatial scales. Temporal analysis is conducted for monthly, seasonal and annual, and spatial analysis is done for seasonal and annual.

The results show that the model overestimates annual rainfall in most of the years. But seasonal analysis depicts that model overestimates rainfall in the monsoon season and underestimates in the pre-monsoon and post-monsoon seasons. In the case of winter, model rainfall doesn't show any systematic biases. Overestimation is found in the southeast and northeast regions but potential underestimation is observed in the northwest region of the country on annual scale. In the central and eastern regions, model-generated rainfalls are quite similar to the observed rainfall with little negative biases. The model overestimates in the southeast part of Bangladesh in all the seasons, but underestimation is found in other regions with notable underestimation in the northwest and northeast parts in pre-monsoon, monsoon, and post-monsoon seasons.

Validation through the linear scaling method for the simulated rainfall is done for the years 2016, 2017, and 2018 considering the period 1991-2015 as the reference period, which gives a quite satisfactory result when compared to the observed rainfall of the corresponding years. There has ample scope to experiment with different schemes with different datasets to check the sensitivity of the model over the region as well as evaluate projections for future rainfall and climate change.

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