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Comparison of RegCM3 simulated meteorological parameters in Bangladesh: Part I-preliminary result for rainfall

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ABSTRACT

A Regional Climate Model of version 3 (RegCM3) is employed for the study of meteorological parameters in Bangladesh. To adopt the RegCM3 for this region comparison of model outputs with surface observational data is essential. In this connection, this paper represents the comparison of model rainfall with surface observational data of 29 stations throughout the country collected by the Bangladesh Meteorological Department (BMD). RegCM3 is run at 0.54° × 0.54° horizontal grid resolution in two parameterizations: Grell scheme with Arakawa-Schubert (GAS) and Fritch-Chappell (GFC) assumptions. GAS run used Lateral Boundary Conditions (LBCs) data for 1995-2000 whereas GFC run used LBC data for 1991, 1994, 1996 and 1999. For the entire rainy season (March-November), model estimates about 101% of the surface rain for GFC option whereas model overestimates in pre-monsoon and underestimates in monsoon periods. The GFC option is found better than the GAS option in estimating rainfall by the model.

1. INTRODUCTION

Bangladesh is a small country with a size of about 147340 km^2 situated between the foothills of the Himalayans to the North and the Bay of Bengal to the South. The big landmass of India is located to the west of the country. The country is at the eastern end of

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the great Indo-Gangetic plain also called "Lower Gangetic Bengal" and it is a flat alluvial plain. Bangladesh is a land of rivers. The major rivers are the Meghna, the Padma and the Brahmaputura. The rivers and their tributaries and distributaries drain a vast area of the sub-continent of India, the Himalayan Mountains and the Southern part of Tibetan Plateau. These unique geographic features produce distinct climate characteristics over South Asia. Observational analyses indicate that the Tibetan Plateau creates vigorous dynamic and thermal forcing [1] causing substantial atmospheric response that result in several unique climate features [2]. In this region the monsoon climate substantially controls the life style of the peoples, especially under the social and economical conditions of agriculture dependent countries like Bangladesh. The simulation of weather parameters appears to be necessary due to the fact that there is a lack of observational data, while the demand for climate forecasting to facilitate planning is increasing in the wake of climate change. Among the weather parameters, rainfall is the most important one that causes huge damages by severe weather events like thunderstorms, floods and cyclones. The seasonal mean monsoon behavior requires that the effects of the slowly varying components of the climate system be correctly simulated. Seasonal variations in observed precipitation over the South Asia region as a consequence of summer monsoon activity are poorly simulated by most of the models [3].

Advances are limited by the lack of data in this region and an inability to identify the fundamental processes that create the variability. Satellite estimates indicate that the northern Bay of Bengal receives the largest mean precipitation in south Asia during the summer monsoon. The similar indication is reported by Islam and Uyeda [4] from their analysis of TRMM (tropical rainfall measuring mission) 3B42RT products datasets for the years 2002-2004. The development mechanism of summer monsoon convection, which is one of the key points to understand the water cycle as well as the global circulation of the atmosphere, is also an important issue to discuss. Using the predicted range of precipitation it may possible to do future planning for agriculture, water management and infrastructure development of the country. In this direction, selection and adaptation of a regional climate model is very essential for the rainfall study in Bangladesh. Considering the above, the seasonal and annual variability of precipitation has been studied for the region in and around Bangladesh and model simulated rainfall is compared with the available surface rainfall over Bangladesh.

2. DATA USED AND PROCEDURE

The monthly and seasonal variability of rainfall in Bangladesh has been studied using monthly and seasonal precipitation collected from 29 stations throughout the country (Fig. 1). The surface observational data were taken from the Bangladesh Meteorological Department (BMD). A Regional Climate Model (RegCM3) developed by ICTP, Trieste, Italy [5,6] has been used for simulation of different meteorological parameters like rainfall, temperature, pressure, humidity, wind field, radiation, soil moisture, surface runoff, cloud fraction etc. In this analysis, the model simulated rainfall is compared with the observed data for 6 years from 1995 to 2000 in Grell scheme with Arakawa-Schubert (GAS) assumption and for 1991, 1994, 1996, 1999 in Grell scheme with Fritsch-Chappell (GFC) assumption [7].

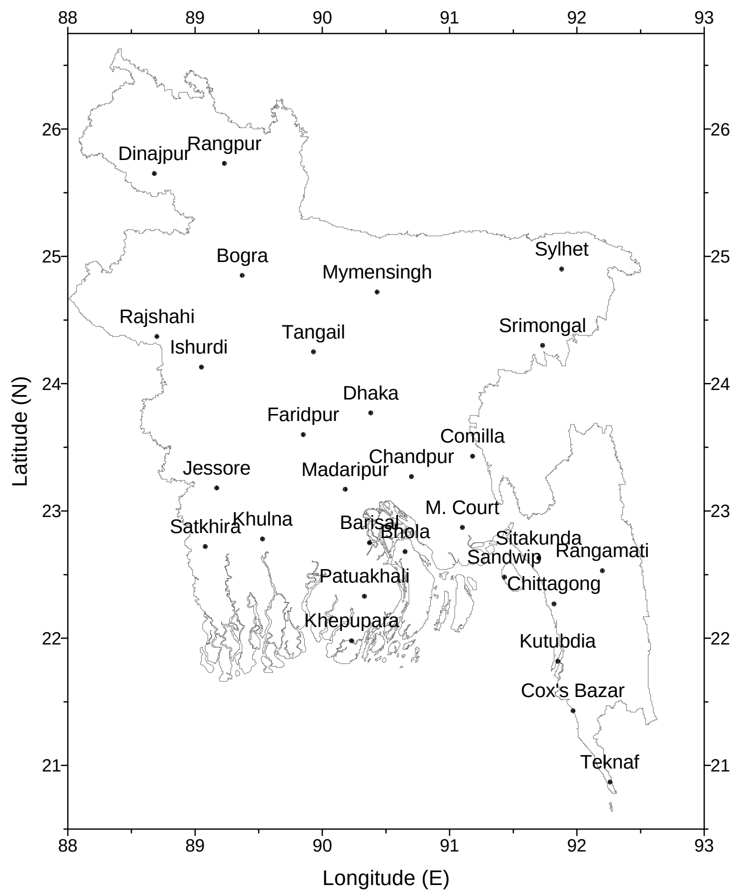
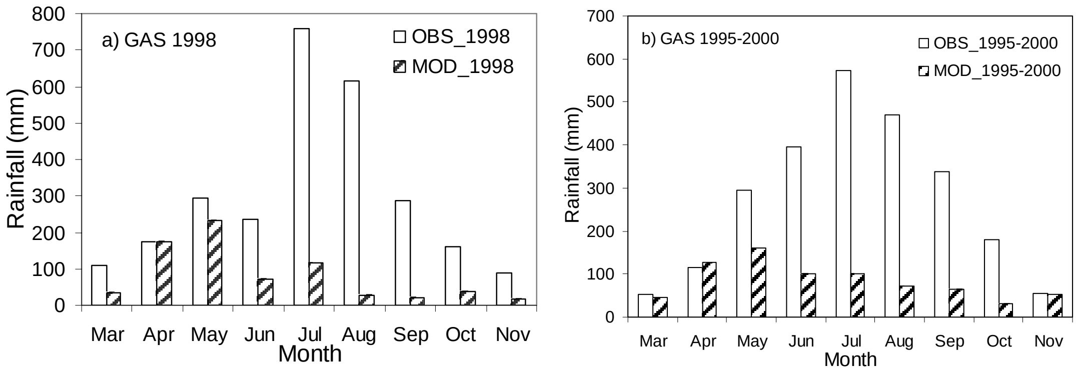


Fig. 1. Rain-gauge locations of Bangladesh Meteorological Department (BMD) throughout Bangladesh.

3. RESULTS AND DISCUSSION

3.1 Monthly rainfall patterns in Bangladesh

Monthly rainfall averaged from 29 stations over Bangladesh is shown in Fig. 2. As seen in Fig. 2(a), GAS option of model underestimates rainfall in 1998 for all months while in April 1998 both observed (OBS) and model (MOD) are almost closer: observed value is 175.7 mm and model value is 175.3 mm. When rainfall amounts are averaged for 6 years from 1995 to 2000 (Fig. 2(b)), the pattern is almost similar to the year of 1998 except model overestimated in April and measured nearly the same in November (Fig. 2(b)). Hence GAS option of RegCM3 underestimated in estimation of rainfall.



(a) (b)

Fig. 2. Monthly rainfall averaged from 29 stations over Bangladesh (a) observed (OBS) and model (MOD) in 1998 and (b) averages for six years from 1995 to 2000. Model output in GAS option is

Rainfall amounts estimated by model (GAS and GFC) and observation in different years is tabulated in Table 1. It is seen that GFC option overestimated rainfall in pre-monsoon (March, April and May) period and underestimated rainfall in monsoon (June, July, August and September) period. In post-monsoon period, GFC option underestimated rainfall about 26%, 64% and 77% in 1991, 1996 and 1999 respectively whereas it overestimated about 12% in 1996. As shown in Table 1, GAS option underestimated rainfall with a few exceptions. In March 1991 it overestimated by a small amount. Overall, GAS measured 58.14 mm whereas observed value is 37.68 mm.

Fig. 3 shows the monthly rainfall amounts estimated by the model with GAS and GFC options and observation averaged for 1991, 1994, 1996 and 1999 and from 29 stations over Bangladesh. Again it is seen that GFC option overestimated and underestimated rainfall in pre-monsoon (MAM) and monsoon (JJAS) periods respectively. The GAS option underestimated rainfall in all months except March.

Table 1. Monthly rainfall amount (mm) estimated by model (GAS and GFC) and observation in different months in 1991, 1994, 1996 and 1999. The symbol * represents missing data.

	1991			1994			1996			1999		
	OBS	GAS	GFC	OBS	GAS	GFC	OBS	GAS	GFC	OBS	GAS	GFC
MAR	37.68	58.14	137.67	116.35	119.53	137.43	51.73	83.19	66.14	*	*	*
APR	123.62	93.23	267.32	169.26	149.05	153.48	117.13	98.65	228.27	33.42	100.64	379.52
MAY	328.32	285.46	591.92	198.39	111.66	343.56	223.63	221.25	477.73	349.23	126.42	1084.13
JUN	612.48	202.14	403.15	489.87	80.40	459.41	437.07	158.15	576.70	478.35	62.85	407.28
JUL	450.61	85.99	363.24	356.00	102.38	398.16	418.63	102.12	289.82	591.16	72.52	343.39
AUG	411.97	138.73	314.99	364.97	124.98	381.71	445.80	102.12	368.01	530.58	75.93	220.65
SEP	459.48	115.14	228.79	175.23	64.91	236.36	287.30	45.79	165.34	353.58	37.93	95.28
OCT	265.45	20.67	140.70	92.77	37.39	95.50	290.43	17.12	82.65	271.03	28.24	42.92
NOV	32.32	16.39	77.91	8.13	36.15	124.73	14.27	17.46	25.21	6.93	59.77	19.66

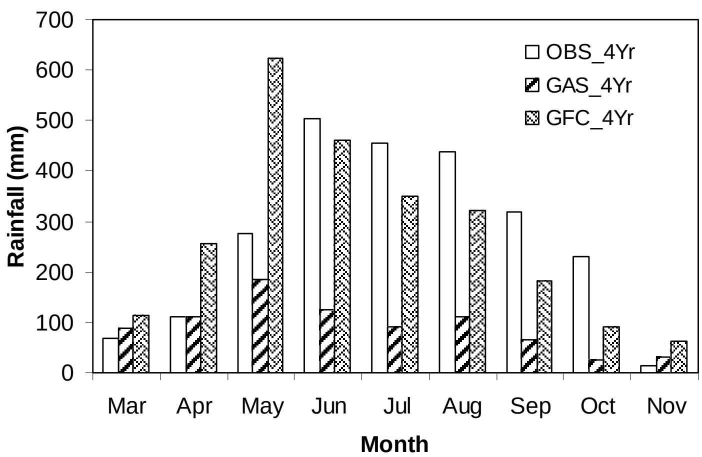


Fig. 3. Same as in Fig. 2 except averages for four years 1991, 1994, 1996 and 1999 for both GAS and GFC option.

3.2 Spatial distribution of rainfall in Bangladesh

The spatial distribution of daily average rainfall (mm) obtained from observation (OBS) and model (GFC and GAS) is shown in Fig. 4. Daily average values are shown instead of monthly accumulated amounts to accommodate results from all three analyses in one figure. Rainfalls are averaged for the entire rainy season (March – November) and for 1991, 1994, 1996 and 1999. It is seen that GAS underestimates rainfall in all stations except in two northwestern stations Rangpur and Dinajpur. The underestimation ranges between -15.12 to -2.33 mm/day. On the other hand, GFC overestimates at 18 stations and underestimates at 11 stations. Underestimation ranges from -0.08 to -8.71 mm and overestimation ranges from 0.3 to 6.4 mm/day. It is also seen that underestimation by GFC occurs in the costal and wet region of the country whereas overestimation occurs in the dry regions. These results are consistent with the TRMM satellite 3B42 product analysis as described by Islam and Uyeda [8].

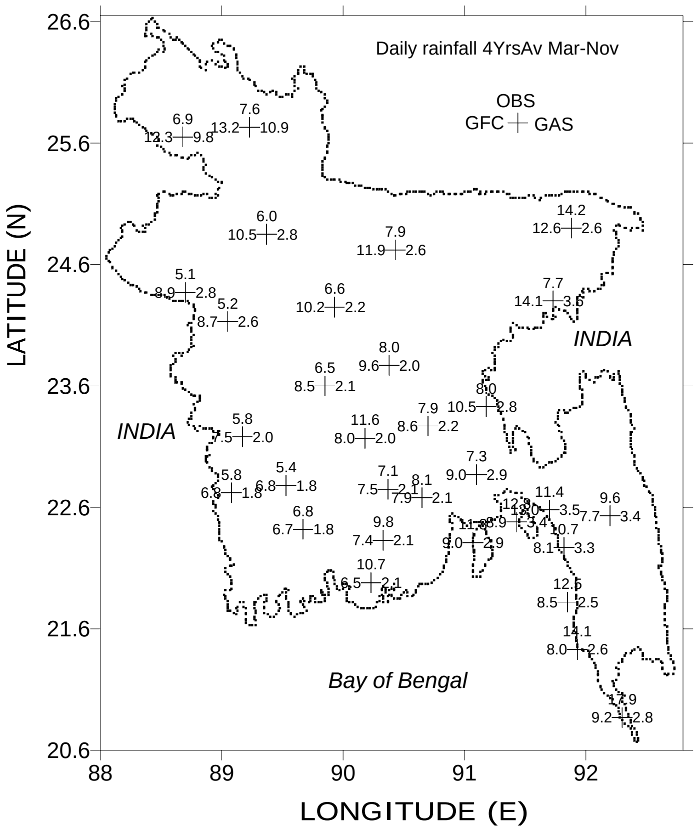


Fig. 4. Spatial distribution of daily rainfall obtained from observation (OBS) and model (GFC and GAS). The plus mark represents observation location. Number above, left and right of plus mark are OBS, GFC and GAS, respectively. Rainfalls are averaged from March to November for 1991, 1994, 1996 and 1999.

3.3 Simulation of seasonal rainfall in Bangladesh

Seasonal rainfall values obtained by observation and simulation are shown in Fig. 5. Rainfalls are averaged for the years of 1991, 1994, 1996 and 1999. It is very clear that in seasonal scale, GFC option overestimated rainfall in pre-monsoon. It underestimates in monsoon and post-monsoon periods. For GAS option, model underestimates for all periods. Interestingly, in rainy-period (March–November) i.e., in rainy scale GFC option estimated rainfall is very close to the observation whereas GAS option estimated almost one-third of the observed amount. The observed, GFC and GAS values are 2398.30, 2432.18 and 813.12 mm respectively. The overestimation during pre-monsoon and underestimation during monsoon periods by GFC option is consistent with the TRMM satellite estimation as described by Islam and Uyeda [9].

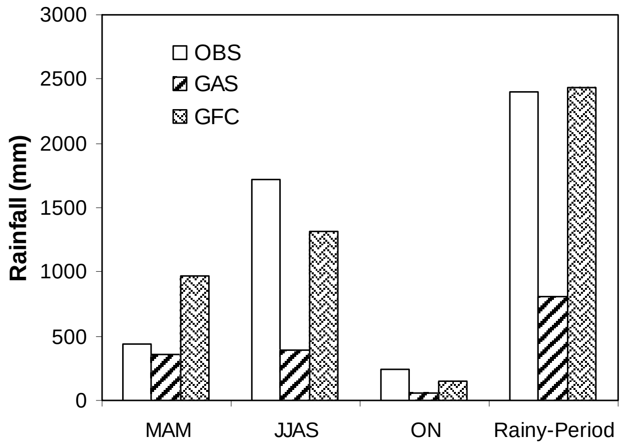


Fig. 5. Same as in Fig. 3 except for the seasonal rainfall amounts.

Table 2. Rainfall averaged for 1991, 1994, 1996 and 1999 and from 29 stations over Bangladesh. Bias is defined as model value minus observed value.

	Rainfall (mm)			Rainfall (%)	
	Observed	Bias(GAS)	Bias(GFC)	GAS	GFC
MAM	437.19	-75.39	529.61	82.76	221.14
JJAS	1715.77	-1322.75	-402.71	22.91	76.53
ON	245.33	-187.03	-93.01	23.76	62.09
Rainy-Period	2398.30	-1585.18	33.88	33.90	101.41

Seasonal observed rainfall and its bias (=model-observed) with percentages in GAS and GFC options are tabulated in Table 2. Rainfalls are averaged for 1991, 1994, 1996 and 1999 and from 29 stations over Bangladesh. It is seen that in seasonal scale, GFC option overestimates rainfall in pre-monsoon by about 121%. The underestimation of rainfall by GAS option in this period is about 17%. So, for the estimation of pre-monsoon rainfall, GAS option seems good. On the other hand, for monsoon period GFC option underestimated about 23%. In this period GAS option underestimated about 77%. Hence GFC option is better than GAS option for monsoon period. For the post-monsoon period, GFC option is better than the GAS option. However, for rainy-period, GFC estimated 101.41% out of 2398.30 mm observed rainfall. So, for annual scale (because only 2% rainfall occurred in winter period from December to February [10], it is concluded that GFC option is better than the GAS option. Therefore, rainfall estimation by model is found season dependent. Unfortunately, only one generic assumption has been coded in the model algorithm which is executed throughout the model run. Therefore, the model can not change closure assumption for different seasons during one run time, which is why the seasonal sensitivity of model generated outputs can only be obtained with relatively large uncertainty. However, in reality, the structure of convective systems in pre-monsoon, monsoon and post-monsoon periods are indeed different in and around Bangladesh [10]. The season dependent aspects are not yet included in the model physics even it is sensitive for simulating tropical rainfall. This work, therefore, suggests inclusion of season-specific closure assumptions in future version of the model.

4. CONCLUSIONS

Analyzing RegCM3 model outputs, it is found that GFC option is much better than GAS option in simulating rainfall in Bangladesh. In general, model overestimates and underestimates pre-monsoon and monsoon rainfall, respectively. For sub-annual scale (March-November) and averages from 4 years (1991, 1994, 1996 and 1999), it is found that estimated rainfall by GAS, GFC and observation is 813.12, 2432.18 and 2398.30 mm, respectively. Overall, GFC option is found better compared to GAS in estimating rainfall in Bangladesh. More research work is necessary on other model options and other parameters for long term data analysis. Once the option is settled then the RegCM3 outputs may be useful in rainfall forecasting purpose in Bangladesh.

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