



Assessment of Better Prediction of Seasonal Rainfall by Climate Predictability Tool Using Global Sea Surface Temperature in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MZH and MNIM designed the study, performed the mathematical and statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAKA and SK managed the analyses of the study. Author MD helped me by data of sea surface temperature (SST) and CPT software. Authors MMR and MAH managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to determine better prediction result of seasonal rainfall. To evaluate the better prediction of seasonal rainfall of rainy season (15 June-15 August) by Climate Predictability Tools (CPT) in the context of using sea surface temperature (SST) of starting month of rainy season

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compare to using SST of one month before the rainy season. The study was carried out at the South Asian Association for Regional Cooperation Meteorological Research Centre, Dhaka; Bangladesh between January and December, 2010. A correlation between rainfall at Rangpur, Dhaka, Barisal and Sylhet and global SST of different areas of the world was studied by using the both data of 1975- 2008 years with the help of the CPT to find more positive correlated SST with observed rainfall and use as predictor for giving the prediction of the year 2009. The statistical method applied using CPT which is canonical correlation analysis. Using SST of one month before rainy season as predictor, the positive deviation of predicted rainfall from observed rainfall was 1.34 mm/day at Sylhet and 0.9 mm/day at Dhaka. The negative deviation of mean rainfall was 1.16 mm/day at Rangpur and 1.10 mm/day at Barisal. Again, using of starting one month SST of rainy season as predictor, positive deviation of predicted rainfall from observed rainfall was 4.03 mm/day at Sylhet. The positive deviation of daily mean rainfall was found 6.58 mm/day at Dhaka and 6.23 mm/day over southern Bangladesh. The study reveals that SST of one month before rainy season was better predictor than SST of starting month of rainy season.

Keywords: Climate predictability tools; rainfall, prediction; season; sea surface temperature.

1. INTRODUCTION

Climate is the statistics of weather over long periods of time up to 30 years. The use of seasonal climate prediction has been essential in present time due to climate change. As Climate prediction shows the future atmosphere state for a given location which is the application of science and technology to predict. Weather data predictions are made by collecting quantitative weather data about the current state of the atmosphere at a given place. Bangladesh is a typical country of the most vulnerable countries to Natural Disasters in the world, in the context of Physical, Social as well as Economic conditions [1]. Now Bangladesh is expected to be highly affected for any global climate change because of its geographical location, low-lying landscape, population density, poverty, illiteracy, etc. So climate prediction has been necessary for this country. In the present study prediction of seasonal rainfall is assessed based on anomalies in rainfall in four Divisions, namely Rangpur, Dhaka, Barisal and Sylhet weather stations to cover whole Bangladesh considering the data from 1975 to 2008 period. This prediction will help policy makers, planners and stakeholders of the vulnerable sectors such as agriculture, food security and water resources to take decision for minimizing the losses due to weather hazards.

Seasonal climate prediction is potentially very useful for planning agricultural activities. So seasonal climate prediction is getting higher demand as policy makers, planners and stakeholders of the vulnerable sectors such as agriculture, food security and water resources are making plan to minimize the losses due to weather hazards. The India Meteorological

Department had started prediction of monsoon rainfall based on the Himalayan snow cover in 1877. Blandford [2] developed an operational monsoon rainfall forecast for India and Burma. Many researchers [3,4] developed a sixteen parameter power regression model and it had been operational for forecasting monsoon rainfall over India till 2002. As the model was not able to predict the all-India drought in 2002, [5] introduced a new ten parameter model for forecasting monsoon rainfall over India. Further improved version of eight parameter model was introduced by Rajeevan et al. [6] and it is being operational since then. Monsoon rainfall forecasts are issued in two stages in April (with six parameters) and updated in June with all eight parameters. Most of the models that were used to forecast Indian summer monsoon rainfall (ISMR) come under empirical modeling approach. Gadgil et al. [7] developed a general overview of forecasting models for Indian monsoon rainfall. Excellent reviews of the empirical models used to predict ISMR are presented in some studies [8,9]. In this study, we have considered Artificial Neural Networks (ANNs) as the forecasting tool. The ANNs have been used in various fields for predicting and forecasting complex nonlinear time series, including the forecast of Indian monsoon rainfall. The neural network technique is able to learn the dynamics within the time series data [10]. In the past, ANNs have been successfully used to predict Indian monsoon rainfall [11,12,13,14]. Goswami [11] used the time series approach, in which previous values from the time series were used to predict future values. Venkatesan et al. [12] has used neural network technique to predict monsoon rainfall of India using few predictors and compared the results with linear regression techniques, showing that the model based on

neural network technique performed better. [13] has used hybrid principal component and Neural Network approach for long range forecast of the Indian summer monsoon rainfall. They observed improved accuracy in prediction. Sahai et al. [15] applied the ANN technique to five time series of June, July, August, September monthly and seasonal rainfall. For the next year the previous five years values from all the five time-series were used to train the ANN to predict rainfall. They found good performance in predicting rainfall. Other studies, using ANNs for summer monsoon rainfall forecasting over India include [14]. They identified the first empirical mode as a nonlinear part and the remaining as the linear part of the data. The nonlinear part was handled by ANN techniques, whereas the linear part was modeled through simple regression. They focus that their model can explain 75 to 80% of the inter-annual variability of eight regional rainfall series considered in their study. A study was conducted on high resolution mesoscale model (MM5) to view rainfall estimation over Bangladesh. The model was performed at two resolutions 45km and 15km for two durations (March 31 to April 5, 2002 and May 20 to 25, 2002). In both cases [16] has showed that MM5 model good capability to estimate rainfall over Bangladesh. Seasonal variation in reversal of winds is named as monsoon. Temperature gradient between the ocean and adjacent land is the main cause of this variation [17]. Weather Research and Forecast (WRF) model was used to gauge Lightning Potential Index (LPI) in another study. The potential in a convective thunderstorm is calculated by LPI for charge generation. Two heavy rainfall events having significant lightening activity for the study were simulated by WRF at different horizontal grid sizes. WRF was found reasonable after comparison of simulated and observed lightening [18]. Another study was created for the predictability of an extreme heat season precipitation event over central Texas on twenty nine Gregorian calendar months to 07 Gregorian calendar month 2002 using MM5. The event was explored through MM5 with numerous grid resolutions, initial and boundary conditions. The results showed that MM5 at high resolution convective resolving simulations do not produce the best simulations or forecast [19]. The SAARC Meteorological Research Centre (SMRC) has been using the Seoul National University coupled General Circulation Model (GCM) and Asia Pacific Climate Centre (APCC) Multi Model Ensemble (MME) products with statistical downscaling technique built in Climate

Predictability Tools (CPT) for making seasonal weather forecasts for Sri Lanka [20]. Rahman et al. [21] compared in their paper JJA of CPT mean rainfall and observed rainfall for all Bangladesh and they have shown that JJA of CPT rainfall is overestimated 0.47% and it is almost same with the observe value. They have also studied on twelve selected stations rainfall in the western, southwestern and southeastern parts of Bangladesh. Results reveal that forecasted rainfall of seven stations is overestimated and five stations are underestimated over Bangladesh. Kassa [22] predicted JJA seasonal rainfall using Canonical Correlation Analysis (CCA) by CPT. The CCA applied to predict seasonal rainfall over Ethiopia using world sea surface temperature (SST) as predictor data and historical monthly total Ethiopian rainfall as well as merged both satellite and rain gauge rainfall data predictand data, It is found that in general, ENSO is the main supply of predictive ability for Ethiopian seasonal rainfall. As a result, the rainfall predictability using CCA the forecast and the observed one are in agreement over much of the country however, some discrepancy over northwestern parts of the country. Manzano and Ines [23] studied on Predictability of May to August (MJJA) seasonal rainfall in Northern Philippines and found that the observed SST predictor yields the lowest climate change of 0.65 and Goodness Index (GI) of 0.55. On the other hand, Observed MJJA rainfall of Batac (324.80 mm) in 2014 was comparable with the forecasted rainfall of 325.53 mm, showing the remarkable ability of the model to predict MJJA rainfall for that year.

The research is a new field of study. Because the researcher reviewed more than 60 documents like books, journals, reports web pages and articles on relevant field. Some studies on temperature and rainfall were reported but not found any specific research on prediction of Bengali rainy seasonal rainfall in Bangladesh. Since Bangladesh is a country of six season. Agricultural crop Amon of Bangladesh depends on the rainfall of rainy season (June 15 to August 15). Now it is not raining timely in Bangladesh because of climate change. Climate change has important role on the changing pattern of seasons. So, rainfall prediction is very need in present time. This research study will fulfill this research gap.

Climate predictions are called warning of future weather situation which is important because

they are used to protect life and property. Prediction of rainfall is immensely important to agriculture, and therefore, to traders within commodity markets. The people use climate prediction to determine what to wear on given day. Since outdoor activities are severely curtailed by heavy rain. So rainfall prediction is very need to plan activities ahead and survive. In 2014, the US spent \$5.1 billion on weather prediction. Seasonal climate predictions provide gesture of the weather conditions that helps us to take advance decision in many areas. Climate predictions may help to get indications of the expected level of temperatures, precipitation, wind, humidity and sunshine. This information will be useful to industries that are exposed to direct or indirect impacts of weather events. Three-six months ahead of time perfect predictions of climate can potentially allow farmers and others in agriculture to make decisions to reduce unexpected impacts or take advantage of expected favorable climate. However, potential benefits of climate predictions vary considerably because of many physical, biological, social and political factors [24]. For example, in a study of the value of seasonal predictions in corn production in the Corn Belt of U.S.A. [25], it was found that consumers were the vivid winners and producers were the losers over the entire 10 years of the study. Therefore, the specific objectives of this study are:

- i. To predict seasonal rainfall of rainy season by CPT using global SST of starting month of rainy season considering the range from 1975 to 2008 periods,
- ii. To predict seasonal rainfall of rainy season by CPT using global SST of one month before rainy season considering the range from 1975 to 2008 periods, and
- iii. To evaluate the better prediction of seasonal rainfall of rainy season by CPT in the context of using SST of starting month of rainy season compare to using SST of one month before rainy season.

2. MATERIALS AND METHODS

Data sources and collection technique: The MME global product of APCC data (sea surface temperature) was used as predictors for the CPT to predict seasonal rainfall for Bengali rainy season in Bangladesh. The APCC data was taken through International Centre for Theoretical Physics, DODS server. After downloading data from this site, binary data is transformed into ASCII format using a FOTRAN code. Station data means observed daily rainfall data of Rangpur, Dhaka, Barisal, and Sylhet of Bangladesh was collected from the Bangladesh Meteorological Department (BMD) and processed to obtain JJA seasonal rainfall as the predictands for the CPT. All-Bangladesh and station-wise aerial precipitation was calculated for rainy season and transformed into a format (text), which suits for the CPT software. The location of stations was shown in (Fig. 1)

Sampling design: The data of observed rainfall and sea surface temperature were considered from 1975 to 2008 periods. Since the period 1975 to 2008 focus the climatologically period. So this period is considered.

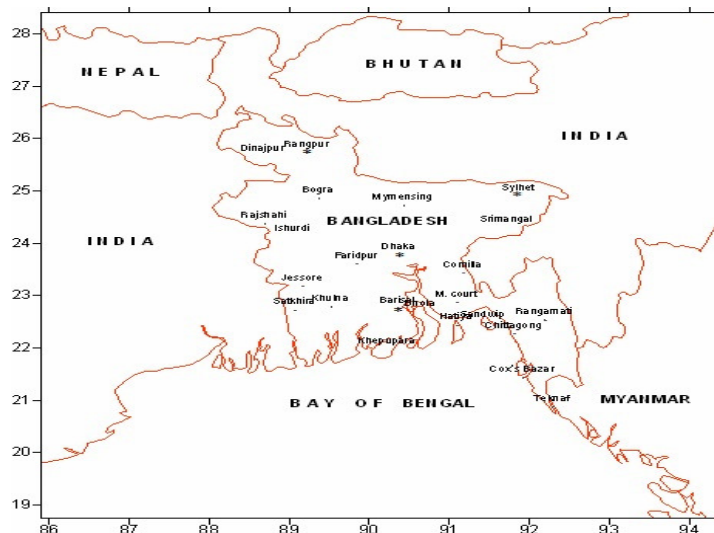


Fig. 1. The location of study area which are denoted by star (*) symbol

Variables selection: Observed rainfall is considered as predictand. On the other hand sea surface temperature is considered as predictor.

Statistical tools: Principal Component Regression (PCR) and CCA are the two methods were used in CPT. The brief description of PCR and CCA are given below:

In statistics, the PCR is a regression analysis technique that is based on principal component analysis. Typically, it considers regressing the outcome (also known as the response or the dependent variable) on a set of covariates (also known as predictors, or explanatory variables, or independent variables) based on a standard linear regression model, but uses PCA for estimating the unknown regression coefficients in the model.

The CCA is a way of making sense of cross covariance matrices; it is a method for exploring the relationships between two multivariate sets of variable (vectors), all measured on the same individual. One approach to studying relationship between the two sets of variables is to use CCA which describes the relationship between the first set of variables and the second set of variables. A typical use for canonical correlation in experimental context is to take two sets of variables and see what is common amongst the two sets. If we have two vectors $X = (X_1, \dots, X_n)$ and $Y = (Y_1, \dots, Y_m)$ of random variables, and there are correlations among the variables, then canonical-correlation analysis will find linear combinations of the X_i and Y_j which have maximum correlation with each other.

Analytical software: The CPT has been used in this study as statistical software. The CPT was initially designed for using in prediction development by national meteorological services, especially in Africa, to simplify the production of seasonal climate predictions. It can be used in any region, and for diagnostic research as well as prediction. It can be used to perform CCA or PCR on any pair of data sets, for any application.

3. RESULTS

An attempt was made to generate seasonal climate prediction, in particular seasonal daily mean rainfall at Rangpur, Dhaka, Barisal, and Sylhet, using statistical downscaling tool developed by the International Research Institute of University of Columbia, USA. This tool known as CPT is a powerful statistical downscale tool that provides user friendly interface to downscale

GCM field variables (as predictors) using station level rainfall (as predictands). This tool is much popular in Climate Outlook forums in African countries for making Climate Outlook as it requires less computer power. Dynamical models are also used to downscale these GCM field variables to finer grid. However, for simulating seasonal scales weather, as far as the predictions skill concerns dynamical models are far behind due to poor resolving lower boundary forcing of the model.

Seasonal prediction of rainfall

CPT was employed for predicting rainy seasonal rainfall over Rangpur, Dhaka, Barisal and Sylhet using SST of one month before rainy season and SST of starting one month of rainy season as predictor for comparing the prediction result of rainy seasonal rainfall. In order to understand the accuracy of predictions, some skill scores such as root mean square error (RMSE), Hit Score (HS), bias and mean absolute error (MAE) were calculated. The RMSE is the measure of difference between observed value and the value being predicted or estimated by the model. Bias was a measurement or estimate of model value relative to a given actual observed value. It could be negative or positive depending on model produced value. The HS is defined as percentage value of the ratio of model predicted value to the observed value. Hence, if the model prediction would be perfect, HS should be 100%. The MAE is a quantity used to measure how close predictions or predictions are to the observed values. It is the average of the absolute errors.

Seasonal prediction of rainfall over four stations using SST of one month before the rainy season as predictor

The correlation between rainfall of Bengali rainy seasons at Rangpur, Dhaka, Barisal and Sylhet and SST of different areas of the world was studied by using the data of the period between 1975 and 2008 with the help of the CPT to find more positive correlated SST with rainfall of Bengali rainy seasons at Rangpur, Dhaka, Barisal and Sylhet and use obtaining more positive correlated SST as predictor. In this case maximum GI was obtained by changing the x domain for SST and Cross-validated window (CVW) using both the Pearson's and Spearman processes, and the correlation coefficients and predicted value of seasonal rainfall for the year 2009 was obtained. The results are presented in Table 1.

Table 1. The results of GI, CVW, and correlation coefficients and predicted rainfall in the different x-domain during 1975-2008 using SST of one month before the rainy season as a predictor

Stations	x-domain	GI			Correlation coefficients		Predicted rainfall (mm/day) in 2009
		Pearson's	Spearman	CVW	Pearson's	Spearman	
Rangpur	8S-18N 2-58E	0.267	0.825	29	0.268	0.319	12.12
Dhaka	18S-8N 21-58E	0.351	0.953	31	0.351**	0.115	12.77
Barisal	15S-17N 22-49E	0.214	0.765	31	0.215	0.162	12.91
Sylhet	2S-36N 2-124E	0.536	0.994	21	0.536***	0.511***	16.72

Note: *** and ** mean significant at 0.1% and 1% levels, respectively

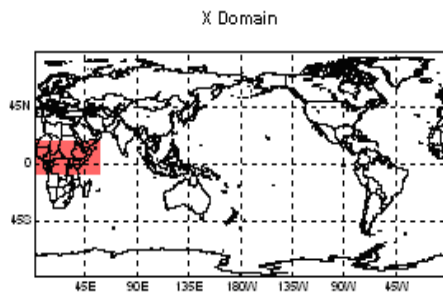


Fig. 2. x-domain of SST during rainy season for prediction of rainfall at Rangpur

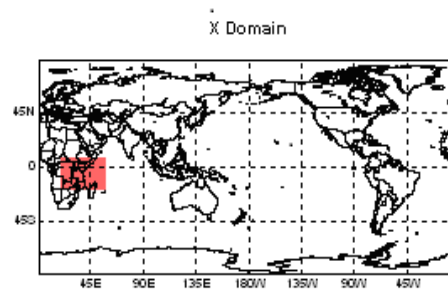


Fig. 3. x-domain of SST during rainy season for prediction of rainfall at Dhaka

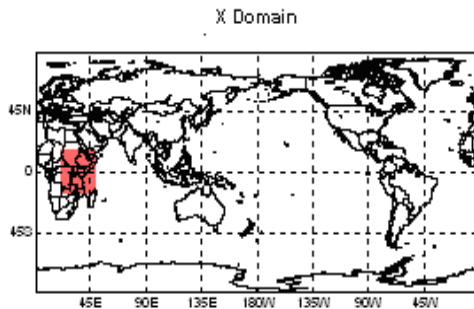


Fig. 4. x-domain of SST during rainy season for prediction of rainfall at Barisal

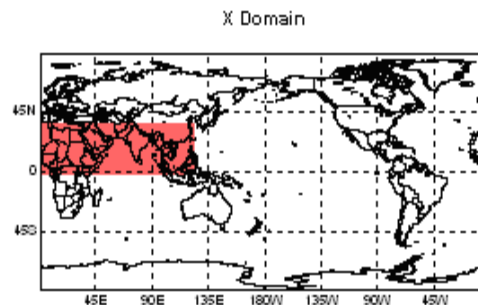


Fig. 5. x-domain of SST during rainy season for prediction of rainfall at Sylhet

The x-domains of the sea surface temperature for different stations are shown in (Figs. 2-5).

It is seen in Table 1 and Figs. 2-5 that maximum GI could not be obtained for the same x domain. The x-domain differed from one station to another for getting maximum GI as well as maximum correlation coefficient. Table 1 shows that the correlation coefficients were positive in both the Pearson's and Spearman processes in the seasons. The correlation coefficients were

found significant at different levels. The predicted values of rainfall during 2009 were found closer to the observed rainfall. So, it could be said that a good prediction of rainfall was obtained by using CPT. The skill scores of seasonal rainfall prediction over the four stations using SST of one month before rainy season as predictor are shown in Table 2.

It is seen from Table 2 that the RMSE were reasonably very lower (1.11) at Sylhet and big

Table 2. Skill scores of seasonal rainfall (rainy season) forecast over four stations SST as a predictor

Stations	RMSE (mm/day)	HS (%)	Bias	MAE (mm/day)
Rangpur	5.81	35.29	0.82	4.28
Dhaka	3.01	38.24	-0.67	2.35
Barisal	6.72	32.35	-0.42	5.14
Sylhet	1.11	44.12	-0.17	0.76

(6.72) at Barisal. The MAE was lower at Sylhet and relatively higher in other stations. But the bias was very low only at Sylhet. The HS ranged from 32.35 to 44.12 which were relatively lower. Because of the lower HS the predicted seasonal rainfall was not as closer to the observed rainfall as could be seen from the (Figs. 6-9). But the predicted and observed rainfall shows almost the same patterns of variation which is very encouraging.

Seasonal prediction of rainfall over the four stations using SST of starting month of the rainy season as predictor

The correlation between rainfall of rainy season for four stations of Bangladesh and global SST of

different areas of the world was studied by using the data of the period between 1975 and 2008 with the help of the CPT to find more positive correlated SST with rainfall of Bengali rainy seasons at Rangpur, Dhaka, Barisal and Sylhet and use obtaining more positive correlated SST as predictor. In this case also maximum GI was obtained by changing the x domain for SST and CVW using both the Pearson's and Spearman processes, and the correlation coefficients and predicted value of seasonal rainfall during rainy season for the year 2009 was found. These results are presented in Table 3.

The x-domains of the sea surface temperature for rainy season of different stations are shown in (Figs. 10-11).

Table 3. The results of GI, CVW, correlation coefficients, and predicted rainfall in the different x-domain during 975-2008 using SST of starting month of the rainy season as a predictor

Stations	x-domain	GI		CVW	Correlation coefficients		Predicted rainfall (mm/day) in 2009
		Pearson's	Spearman		Pearson's	Spearman	
Rangpur	17S-37N 4-53E	0.287	0.950	13	0.2712*	0.2234*	6.02
Dhaka	13S-41N 6-53E	0.296	0.946	13	0.2339*	0.1914	7.09
Barisal	13S-41N 6-53E	0.296	0.946	13	0.2958**	0.2285*	5.58
Sylhet	13S-41N 6-53E	0.296	0.946	13	0.3547**	0.2717*	14.03

Note: ** and * mean significant at 5% and 10% levels, respectively

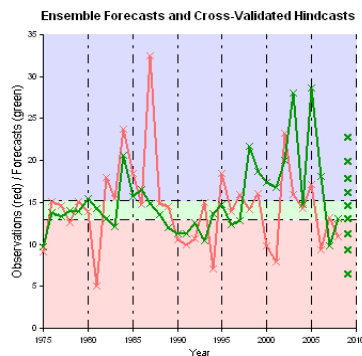


Fig. 6. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Rangpur

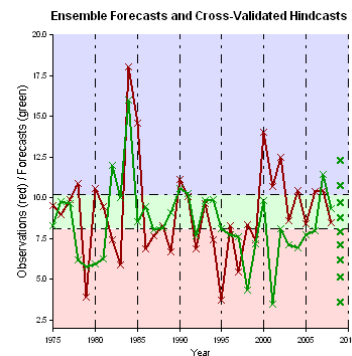


Fig. 7. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Dhaka

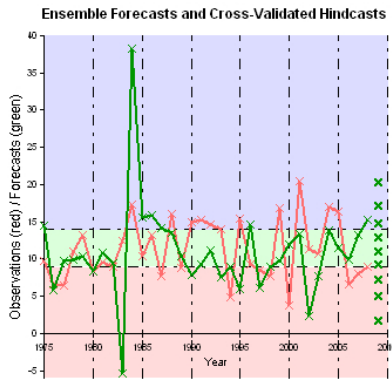


Fig. 8. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Barisal

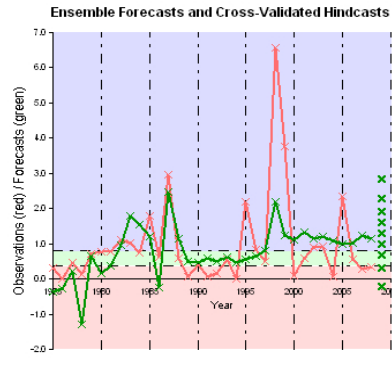


Fig. 9. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Sylhet

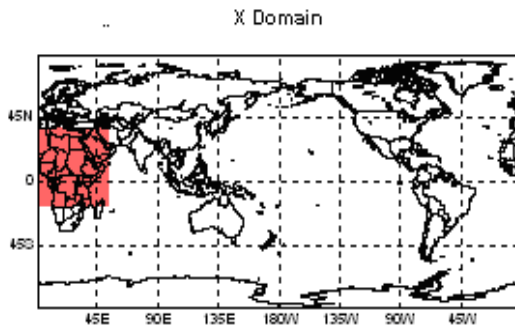


Fig. 10. x-domain of SST during rainy season for prediction of rainfall at Rangpur

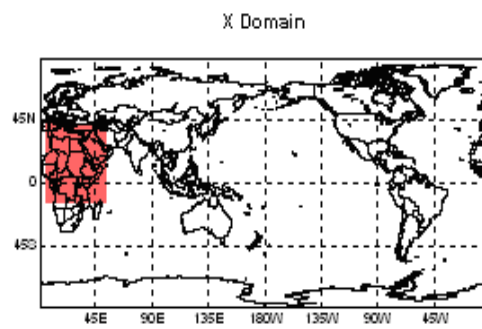


Fig. 11. x-domain of SST during rainy season for prediction of rainfall at Dhaka, Barisal, and Sylhet

Table 4. Skill scores of seasonal rainfall (rainy season) forecast at the four stations using SST as a predictor

Stations	RMSE (mm/day)	HS (%)	Bias	MAE (mm/day)
Rangpur	2.78	23.53	0.01	2.18
Dhaka	3.57	50.00	-0.05	2.73
Barisal	2.35	41.18	-0.03	1.92
Sylhet	3.95	52.94	-0.01	3.02

Table 5. Observed rainfall and predicted rainfall by CPT using SST of one month before the rainy season as a predictor in 2009

Stations	Observed rainfall (mm/day)	Predicted rainfall (mm/day)	Deviation
Rangpur	10.96	12.12	-1.16
Dhaka	13.67	12.77	0.9
Barisal	11.81	12.91	-1.10
Sylhet	18.06	16.72	1.34

Table 6. Observed rainfall and predicted rainfall by CPT using SST of starting one month of the rainy season as a predictor in 2009

Stations	Observed rainfall (mm/day)	Predicted rainfall (mm/day)	Deviation
Rangpur	10.96	6.02	4.94
Dhaka	13.67	7.09	6.58
Barisal	11.81	5.58	6.23
Sylhet	18.06	14.03	4.03

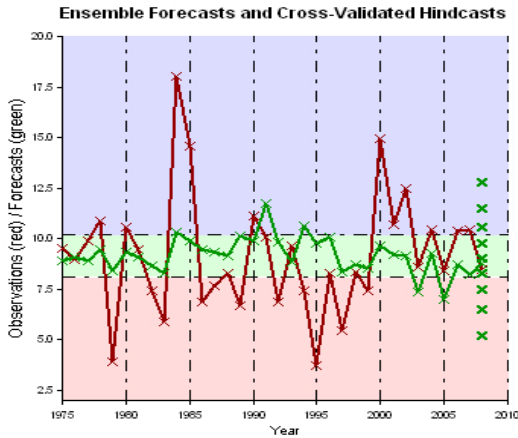


Fig. 12. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Rangpur

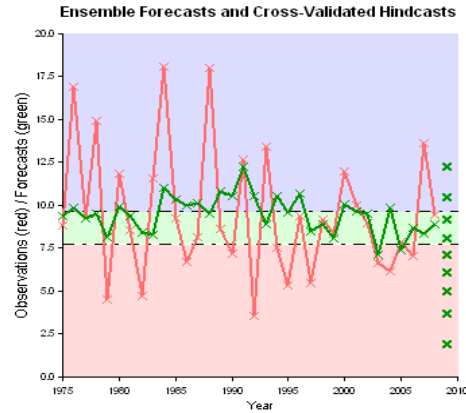


Fig. 13. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Dhaka

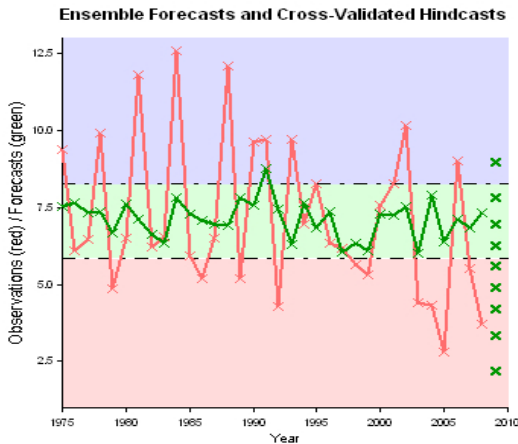


Fig. 14. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Barisal

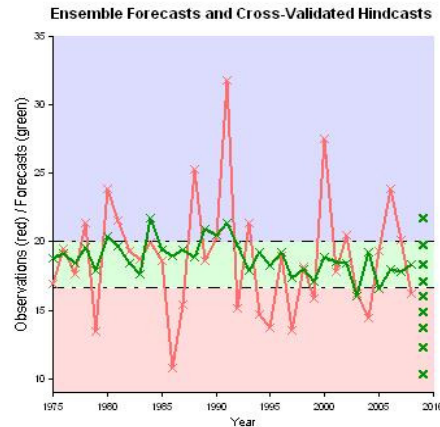


Fig. 15. Ensemble prediction of rainfall and Cross-Validated Hindcasts for rainy season at Sylhet

From Table 3 and the Figs. 10-11 it is seen that the maximum GI could not be found for the same x-domain. The x-domain differed from one station to another in order to get maximum GI and maximum correlation coefficients. The table shows that the correlation coefficient was positive in both the Pearson's and Spearman processes and significant at 5% and 10% level. The predicted value of rainfall during 2009 was

not found closer to the observed rainfall. The skill scores of seasonal rainfall (rainy season) prediction over the four stations using SST of starting month of rainy season as predictor are shown in Table 4.

It is seen in Table 4 that the RMSE was small at Barisal and higher at Sylhet. The MAE was lower at Barisal and relatively higher at Sylhet. But the

bias was very low at all stations. The HS ranges from 23.53 to 52.94 which was not relatively higher. Because of the lower HS the predicted seasonal rainfall was not so closer to the observed rainfall which could be seen from the Figs. 12-15. The figures show almost similar patterns of variation between the predicted and observed rainfall.

4. DISCUSSION

The CPT was found to determine underestimated rainfall at Dhaka and Sylhet, and overestimated rainfall at Rangpur and Barisal during the rainy season. The maximum positive deviation of mean rainfall was 1.34 mm/day at Sylhet. On the other hand, the minimum positive deviation of mean rainfall was 0.9 mm/day at Dhaka. Besides, the maximum negative deviation of mean rainfall of 1.16 mm/day at Rangpur and minimum negative deviation of mean rainfall of 1.10 mm/day at Barisal was obtained during rainy season. The observed and predicted values of daily mean rainfall are shown in Table 5. [21] observed that CPT generated forecast (JJA) rainfall for all Bangladesh 0.08 mm/day is overestimated and also taken individual selected twelve stations in which seven stations rainfall forecast is overestimated namely Faridpur (5.42 mm/day), Jessore (3.67 mm/day), Khulna(0.05 mm/day), Rajshahi (1.54 mm/day), Barisal(1.34 mm/day), Comilla (4.67 mm/day), and Rangamati (1.60 mm/day) and five stations are underestimated over Bangladesh specifically Bogra (1.34 mm/day), Teknaf (3.54 mm/day), Chittagong (6.11 mm/day), Sandwip (3.54mm/day) and Dinajpur (0.31mm/day) which is located western, southwestern and southeastern parts of Bangladesh. Basnayake and Nesssa [26] found that JJA (June, July, August) rainfall for the whole Bangladesh was quite accurate. Forecast for individual stations are also accurate over the high and low rainfall areas of the country during summer-monsoon season (June, July, August, and September). Sandwip, Rangamati, Teknaf, Chittagong, Cox's Bazar and Patuakhali stations are good examples for high rainfall regions whereas Rajshahi and Dinajpur are example for low rainfall stations. This study also found that the predicted values of rainfall during 2009 were closer (not accurate) to the observed rainfall over low and high rainfall regions of Bangladesh. The slight difference results may be occurred due to lower rainfall received at Rangpur and Barisal and higher rainfall received at Dhaka and Sylhet during rainy season. Basnayake et al. [20] found

that the forecasted June-July-August seasonal mean-rainfall is slightly overestimated especially over the individual districts, except Kandy and Nuwara Eliya, due to fairly higher rainfall received during the southwest monsoon in 2008 in Sri Lanka. This study also found that the predicted June-July-August (rainy season) seasonal mean-rainfall is slightly overestimated especially over the individual stations. Manzano and Ines [23] studied on Predictability of MJJA Seasonal Rainfall in Northern Philippines and found that the observed MJJA rainfall of Batac (324.80 mm) in 2014 was comparable with the forecasted rainfall of 325.53 mm, showing the remarkable ability of the model to predict MJJA rainfall for that year. This study also found a remarkable ability of the model to predict rainy seasonal rainfall for the year 2009. This work follows on the above mentioned previous studies on Ethiopian seasonal rainfall prediction, using a software/Graphics package called the CPT. The statistical method applied using CPT is, CCA. In the CCA, precursor tropical and extra tropical SSTs are used as predictor fields, and observed station rainfall data is used as predictand in an attempt to define the sources of predictive skill in the inter annual variability of rainfall over Ethiopia. The ultimate goal is to develop the best possible statistical seasonal forecast models for use in real-time rainfall forecasting, both Belg and Kiremt seasons.

Predicted value of seasonal daily mean rainfall was found lower than the observed seasonal daily mean rainfall during rainy season at Rangpur, Dhaka, Barisal, and Sylhet. The deviation of predicted rainfall from observed rainfall was minimum positive at Sylhet having the minimum value of 4.03 mm/day, but the maximum positive deviation of daily mean rainfall was found in middle part of Bangladesh having the value of 6.58 mm/day at Dhaka. Nearest value of maximum positive deviation of mean rainfall was 6.23 mm/day over southern Bangladesh. The observed and predicted values of rainfall are shown in Table 6.

Valli et al. [27] studied on prediction of rainfall. This prediction of rainfall for the year 2011 to 2015 is done by using the Climate Predictability Tool for the Karimnagar and Prakasam districts of India. The results indicated the values of prediction of rainfall for Karimnagar for the years 2006, 2007, 2008 and 2011. The prediction was fairly consistent showing an error within the

range of $\pm 5\%$. Prakasam showed highly erratic values between the forecasted and predicted and actual data which was not more similar to this study due to atmospheric disturbance and study location. Kassa [22] predicted JJA seasonal rainfall over Ethiopia. As a result, the rainfall predictability using CCA the forecast and the observed one are in agreement over much of the country however, some discrepancy over northwestern parts of the country. This study also found some discrepancy between observed and predicted rainfall over the study area.

5. LIMITATIONS OF THE STUDY

The study was conducted within Dhaka, Sylhet, Rangpur and Barisal Division. On the other hand, only one season has been predicted within six Bengali seasons namely Summer, Rainy season, Autumn, Late autumn, Winter and Spring. Due to budget, time and lab facilities constraints, the study couldn't predict rainfall of the other seasons and other stations.

6. CONCLUSION

Underestimated rainfall at Dhaka and Sylhet, and overestimated rainfall at Rangpur and Barisal was found by CPT. The maximum positive deviation of mean rainfall was 1.34 mm/day at Sylhet, on the other hand, the maximum negative deviation of mean rainfall was determined 1.16 mm/day at Rangpur. Using SST of starting month of rainy season, predicted value of seasonal daily mean rainfall during rainy season was found lower than observed daily mean rainfall at Rangpur, Dhaka, Barisal and Sylhet. The deviation of predicted rainfall from observed rainfall was minimum but positive at Sylhet with value of 4.03 mm/day, but the maximum positive deviation of daily mean rainfall was found in the middle part of Bangladesh having the value of 6.58 mm/day at Dhaka. The study also reveals that SST of starting month of Rainy season was not good predictor but SST of one month before of Rainy season is suitable for CPT. So, it is said that CPT has shown some skills in prediction of rainy season rainfall at some selected division in Bangladesh. Develop climate-prediction system for reducing natural hazards. Reduce percentage of error in climate-prediction system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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