Kuwait J.Sci., Vol.50, No.(1B),January.2023,pp(1-14)

Forecasting seasonal mean temperature over Rangpur, Bangladesh

Zakaria Hossain

Dept. of Mathematics, Bangladesh University, Dhaka-1207, Bangladesh

Corresponding author: zakariaru001@gmail.com

Abstract

The study was conducted by Climate Predictability Tools (CPT) to forecast (short-range forecast) the seasonal mean temperature over Rangpur for six Bengali seasons in Bangladesh. In this study, the sea surface temperature (SST) for the period of 1975 to the previous month of each season of 2008 was used as the predictor. This study also evaluated the difference between forecasted seasonal mean temperature and observed seasonal mean temperature for six seasons. To find the SST that is similar to the temperature in Rangpur, a correlation between the temperature of Rangpur and the sea surface temperature of various parts of the earth was performed through CPT using both data of 1975- 2008 years. The obtained SST through correlation that is more or less similar to the temperature in Rangpur was used as a predictor to forecast seasonal mean temperature of the year 2009. Statistical and mathematical methods were applied by CPT in this research which included canonical correlation analysis, covariance matrix, and eigenvalues equations.The study found that the forecasted seasonal mean temperature was higher in rainy and winter seasons than the temperature observed and was lower in summer, autumn, late autumn, and spring season than the observed temperature at Rangpur. The maximum overestimated temperature was found to be 0.52°C/day in winter and the maximum underestimated temperature was found to be 0.54°C/day in autumn. On the other hand, the minimum overestimated temperature was found during the rainy season having the value of 0.34°C/day and the minimum underestimated temperature was obtained during the summer season having the value of 0.25°C/day, which was the best-forecasted temperature.

Therefore, the forecasted values of temperature in the summer and rainy seasons were found closer to the observed temperature during 2009. So, it can be said that it is possible to obtain good forecasting of temperature through CPT.

Keywords: Air temperature; climate predictability tool; forecasting; seasons of Bangladesh; sea surface temperature.

1. Introduction

The climate change process, in particular the change of temperature is a vital issue in the world at present. The pattern of temperature and rainfall is getting changed due to global climate change which is also getting seen in Bangladesh at present. The report of the Intergovernmental Panel on Climate Change revealed the amount of global climate change was between 0.3 to 0.6 degrees Celsius from 1900 to 1995 (IPCC, 2001). It is extensively believed that Bangladesh will be more severely affected than developing countries in the world's tropics because of its disadvantageous geographic location as well as climate changes. (Machiwal & Jha, 2006; Shamsnia *et al.,* 2011). On the other hand, the temperature has been identified as one of the main factors of climate change in the last two decades (Oyamakin, *et al.,* 2010) and The Reinsurance industry revealed that the number of climate-related disasters significantly increased in the 1930s (Cheema *et al.,* 2011). That's why the climate forecast has been essential to protect the agricultural sector of Rangpur in Bangladesh at present. So that, three to six months before a perfect climate forecast, probable growers and others in the agricultural sector may decide to abate the unexpected impact. So some forecasting-related studies were completed for this study. Such as Khan *et al.* (2020) applied a Long Short-Term Memory (LSTM) model in their study to predict monthly temperatures and precipitation by analyzing weather data of Bangladesh from 1901-2015. The LSTM model has shown -0.38 degree centigrade mean error in the case of predicting month-based temperatures of 2 years and -17.64 mm in the case of rainfall predicting. This prophecy model can help understand the changing pattern of weather in addition to studying Bangladesh's seasonal diseases whose prevalence depends on regional temperature and/or rainfall.

Karna *et al.* (2021) conducted a study and used in their study Statistical Linear Regression and Linear Regression including elastic nets and hyper parameters, and it is stated in the outcomes of the analysis that the regression based highest temperature long-term prediction models provide more accuracy with the RMSE (root mean square error) and MAE (mean absolute error). According to both Hydrology and Meteorology Department (HM D), only 284 weather centers are currently operating in Nepal. Though empirical predicting models are extensively analyzed as well as evaluated, the performance of these models is seen to vary following local climate and geographical location (Fan *et al*., 2018). Using Cluster Analysis (CA) and Principal Component Analysis (PCA)), the selected stations were clustered in well-defined groupings, and afterward one individual NN (neural network) was used in every group of stations. On the other hand, another NN (neural network) model was also created to measure the accuracy of the model proposed and was used in all the stations. Statistical outcomes exhibited that the 1st model generated better-predicted outcomes than the 2nd model (Arab Amiri *et al*., 2018). Portugal's annual temperatures were predicted using the autoregressive model, and research has shown that annual temperatures change from decade to decade. In other words, it was found fluctuations in the annual and decade temperature (Leite & Peixoto, 1996).

Using the seasonal ARIMA model Nury *et al*. (2013) forecasted the minimum and maximum temperatures of Moulvibazar and Sylhet districts and it suggested that this method would work better to forecast the time series data. A significant relationship between mortality and temperature was found in several cities around the world, where the direct temperature is responsible for maximum deaths for example the reason for cardio-respiratory disease may be the temperature rising of human body or vessels' weak functioning to transfer blood and nutrients in the human body (Kalkstein, 1991; Martens, 1998). Using artificial neural networks Jain (2003) conducted research on weather data, especially temperature for forecasting the next one to twelve hours in South Georgia. Rehman & Mohandas (2008) exhibits in their research that the neural network can predict Saudi Arabia's solar radiation by temperature and relative humidity from 1999 to 2000. A flexible and powerful tool was developed by researchers (Sharma & Bose, 2014) as an intelligent method for seeking ways to forecast weather parameters beyond the general method. ANN (Artificial neural network) is one of the intelligent methods capable of calculating logical functions and arithmetic. Forecasting of temperature is very important in agriculture and other sectors because Bangladesh is a major agricultural country. The output of this research will help the Agricultural Officials and National planners to take possible mitigation measures for protecting the crops from the adverse consequences of global climate change. The necessity of simulating or forecasting climate parameters in recent decades has become much more important because of climate change and global warming. So this study forecasted Rangpur temperature for six seasons in Bangladesh using the CPT model. Because Bangladesh is a country with six seasons (BBS, 2020).

This is a new field of study. Although some studies have been reported on temperature and rainfall, no specific study has been found on the forecast of seasonal temperature for Bengali seasons in Bangladesh. So, this study will fill up the research gap. Thus, to achieve the goal, the objectives are : (i) To forecast the seasonal mean temperature of six Bengali seasons: summer (14 April to 14 June), rainy season (15 June to 15 August), autumn (16 August to 15 October), late-autumn (16 October to 14 December), winter (15 December to 12 February), and spring (13 February to 13 April), by CPT using sea surface temperature for the period of 1975 to till the previous month of each season of 2008 as the predictor and (ii) To determine the differences between temperatures forecasted by CPT and observed temperatures.

2. Data and methods

2.1 Study area

Rangpur is 29 meters above sea level and located in a geographic position between 25°18' and 25°57' N latitudes and between 88°56' and 89°32' E longitudes. Rangpur lies in the northwestern part of Bangladesh. Rangpur district (Figure 1), covering a place of about 2,401 km². There are five major rivers in the Rangpur region–Dharla, Teesta, Brahmaputra, Dudhkumar, and Saniajan flow over the danger level because of the onrush of water from upstream and heavy rain. Geologically, the study area lies in the north-northwestern part of the Bengal Basin. The composition of the soil is predominantly Teesta River basin's alluvial soil which is 80%, and the residual is barind soil. The climate of Rangpur is categorized as temperate and warm. In accordance with Köppen and Geiger, this climate is classified as Cwa **(**Monsoon-influenced humid subtropical climate). There exists a humid subtropical climate at Rangpur. The temperature range is 32ºC to 11ºC. In winter, the night temperature can drop below 11.7 degrees Celsius whereas, the daytime temperature is around 23.6 degrees Celsius. Annual averages rainfall is 2931 mm**;** almost all of them fall from June to September, although there is very little rainfall from November to March, but a small amount of rainfall due to western disturbances coming from the Mediterranean Sea. Snow and frost have never been recorded in Rangpur. Around 2802.78 hours of sunshine are counted in Rangpur throughout the year. On average there are 92.24 hours of sunshine per month. The month of maximum relative humidity is September (86.88%).The month of minimum relative humidity is March (50.41 %). Jun of the year is the windiest month in Rangpur with an average speed of 12.6 kilometers per hour. December of the year is the quietest month in Rangpur with an average speed of 6.0 kilometers per hour (Rangpur climate, 2021).

Maps of Bangladesh

Fig. 1. Study Area (Rangpur District)

2.2 Data collection

Sea surface temperature (The multimodel ensemble global product of APCC data) was considered as a predictor to forecast seasonal mean temperature (Basnayake *et al.,* 2010) for the six Bengali seasons in Bangladesh in this study. This data was obtained from the DODS server of ICTP (International Center for Theoretical Physics). The data downloading from the mentioned site was binary data that is converted to the ASCII format by FORTRAN code next. Daily observed temperature data of Rangpur station in Bangladesh was taken up from Bangladesh Meteorological Department. This observed data was processed to get the seasonal mean temperature as the predictands for the CPT. The temperature at Rangpur station was calculated for six Bengali seasons and converted to a format (text) suitable for the CPT software.

2.3. Methods

In this study statistical and mathematical methods were applied by CPT which included canonical correlation analysis, covariance matrix and eigenvalues equations. Canonical correlation analysis is used to find two sets of basis vectors which are one for u and the other for v, as a result onto these basis vectors the correlations between the estimates of the variables are reciprocally maximal. There is such a case where solely one pair basis vectors is required, as for instance, the ones related with maximal canonical correlation: considering $u = u^T \hat{z}_u$ and $v = v^T \hat{z}_v$ as linear combinations for two variables respectively. It's meaning that the maximal function is

$$\rho = \frac{E[uv]}{\sqrt{E[u^2]E[v^2]}}$$
$$= \frac{E[\hat{z}_u{}^T uv^T \hat{z}_v]}{\sqrt{E[\hat{z}_u{}^T uu^T \hat{z}_u]E[z_v{}^T vv^T \hat{z}_v]}}$$
$$= \frac{z_u{}^T C_{uv} z_v}{\sqrt{z_u{}^T C_{uu} z_u z_v{}^T C_{vv} z_v}} \tag{1}$$

The largest of ρ in respect of z_u and z_v is highest canonical correlation. The posterior canonical correlations are not correlated on account of various solutions, i.e.

$$\begin{cases} E[u_i u_j] = E[z_{ui}{}^T uu^T zuj] = z_{ui}{}^T C_{uu} z_{uj} = 0 \\ E[v_i v_j] = E[z_{vj}{}^T yy^T z_{yj}] = z_{vi}{}^T C_{vv} z_{vj} = 0 \\ E[u_i v_j] = E[z_{ui}{}^T xy^T z_{yj}] = z_{ui}{}^T C_{uv} z_{vj} = 0 \end{cases} \quad \text{for } i \neq j. \tag{2}$$

Calculating canonical correlations: Consider u and v are two variables with zero mean. The total covariance matrix

$$C = \begin{bmatrix} C_u & C_{uv} \\ C_{vu} & C_{vv} \end{bmatrix} = E\left[\begin{pmatrix} u \\ v \end{pmatrix} \begin{pmatrix} u \\ v \end{pmatrix}^T \right] \tag{3}$$

For u and v the within-sets covariance matrix are C_{uu} and C_{vv} respectively, and $C_{uv} = C^T{}_{vu}$ is the covariance matrix between-sets. Between u and v we can get canonical correlations by solving the eigenvalues equations

$$\begin{cases} C^{-1}{}_{uu} C_{uv} C^{-1}{}_{vv} C_{vu} \hat{z}_u = \rho^2 \hat{z}_u \\ C^{-1}{}_{vv} C_{vu} C^{-1}{}_{uu} C_{uv} \hat{z}_v = \rho^2 \hat{z}_v \end{cases} \tag{4}$$

Where ρ^2 indicate eigenvalues, which are squared canonical correlations. On the other hand, $\hat{z}_u$ and $\hat{z}_v$ indicate eigenvectors which are normalized canonical correlation of basis vectors. Non zero solutions of these equations are limited to the lowest dimensionality of u and v. E.g. if 8 and 5 are the dimension of u and v respectively, the highest number of canonical correlations will be 5.Only one among the eigenvalue equations needs to be resolved because the solutions are related by

$$\begin{cases} C_{uv} \hat{z}_v = \rho \lambda_u C_{uu} \hat{z}_u \\ C_{vu} \hat{z}_u = \rho \lambda_v C_{vv} \hat{z}_v \end{cases} \tag{5}$$

$$\text{Where } \lambda_u = \lambda_v^{-1} = \sqrt{\frac{\hat{z}_v{}^T C_{vv} \hat{z}_v}{\hat{z}_u{}^T C_{uu} \hat{z}_u}} \tag{6}$$

2.4 Climate predictability tool as software

The Climate predictability Tool was used as mathematical software for forecasting seasonal mean temperature using sea-surface temperatures as predictors and observed temperatures as predictands. It can be used in any area for diagnostic research and forecasting. In this study canonical correlation analysis on a pair of data sets was performed by CPT.

3. Results and discussion

3.1 Forecasting of seasonal mean temperature

CPT was employed to forecast seasonal mean temperature for six Bengali seasons over Rangpur and the sea surface temperature (SST) for the period of 1975 to till the previous month of each season of 2008 was used as the predictor. In this study, some skill scores exempli gratia Hit Score (HS), Mean Absolute Error (MAE), Bias, and Root Mean Square Error (RMSE) were calculated to understand the exactness of forecasting results. RMSE is the metering of the distinction between the value observed and the value calculated by the CPT which helped to determine accuracy. Bias is an estimation of the value produced by the model compared to the observed value and it can be anyone positive or negative depending on the value produced by the model. The Hit Score is taken into consideration as the value of percentage (%) of the proportion of value calculated by the CPT model with the accurate value of observed data. Hence, if the forecasted value would be the same as the observed value, the Hit score should have been 100%. MAE is a type of measure by which we can easily understand how much the forecasted value is closer to the actual value.

3.2 Forecasting of seasonal mean temperature over Rangpur for six Bengali seasons in Bangladesh using sea surface temperature for the period of 1975 to till the previous month of each season of 2008 as the predictor.

To find the sea surface temperature (SST) that is similar to the temperature in Rangpur, a correlation between the temperature of Rangpur and the sea surface temperature of various parts of the earth was performed with the help of the CPT using both data from 1975- 2008 years. The obtained SST that is more or less similar to the temperature in Rangpur through correlation was used as the predictor to forecast the seasonal mean temperature of the year 2009. The maximal goodness index in this study was found by altering the X domain for Cross-Validated window. On the other hand, SST was obtained by using the correlation method of Pearson's and Spearman. Besides this was obtained the value of Pearson correlation coefficients and Spearman correlation coefficients along with the value of the forecasted seasonal mean temperature of six Bengali seasons for the year 2009. In Table 1, the obtained outcomes are presented.

Table 1. The obtained outcomes of correlation coefficients, GI, CVW, and forecasted temperature in various x-domains during the period 1975-2008 using sea surface temperature for the period of 1975 to till the previous month of each season of 2008 as the predictor.

		GI		CVW	Correlation coefficients		Forecasted temperature
seasons	*x*-domain	Pearson	Spearman		Pearson	Spearman	(º C/day) in 2009
Summer	2S-8N 2-48E	0.274	0.974	27	0.274	0.483	27.76
Rainy season	8S-8N 2-35E	-0.434	0.984	5	-0.434	-0.408	28.54
Autumn	44S-19N 4-50E	-0.312	0.992	11	-0.312	-0.25	28.06
Late Autumn	40S-20N 10-200E	0.258	0.998	1	0.25	0.357	22.45
Winter	10S-60N 10-80E	-0.311	0.994	5	-0.311	-0.288	16.8
Spring	12S-30N 2-58E	0.279	0.992	25	0.28	0.331	23.23

The following (Figures 2-7) showing X Domain of SST for six seasons in Bangladesh.

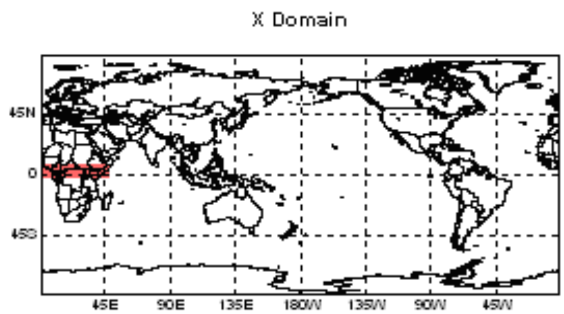

Fig.2. X Domain of global sea surface temperature in the summer for forecasting of temperature over Rangpur

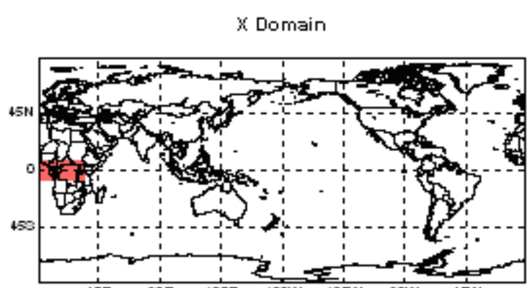

Fig. 3. X Domain of global sea surface temperature in the rainy season for forecasting of temperature over Rangpur.

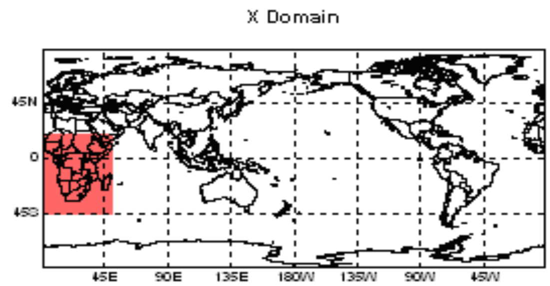

Fig. 4. X Domain of global sea surface temperature in the autumn for forecasting of temperature over Rangpur

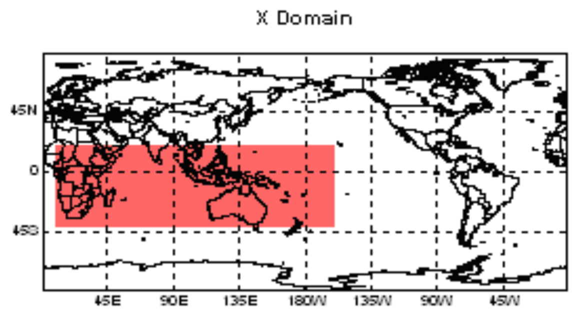

Fig. 5. X Domain of global sea surface Temperature in late autumn for forecasting of temperature over Rangpur

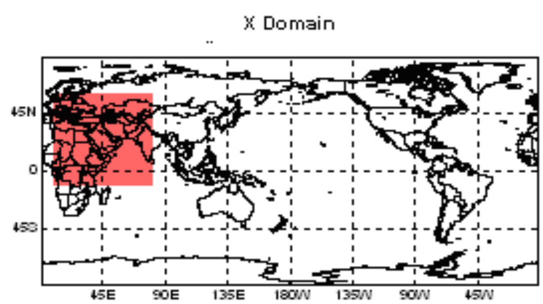

Fig. 6. X Domain of global sea surface temperature in the winter season for forecasting of temperature over Rangpur

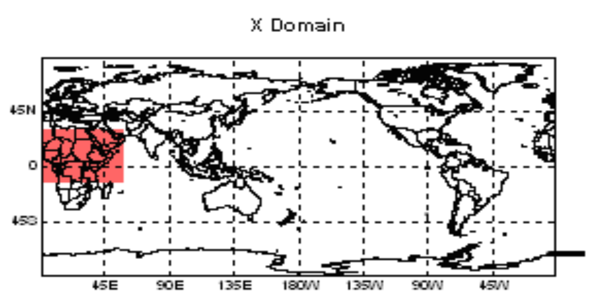

Fig.7. X Domain of global sea surface temperature in the spring season for forecasting of temperature over Rangpur

From Table 1 and (Figures 2-7) it is said that maximal goodness index (GI) was not found for all x domain. This means that a different x-domain was found for one season to another season in case of getting maximum correlation coefficient and maximum GI. From Table 1 the positive correlation coefficients were obtained only in summer, late autumn, and spring seasons for the both Pearson and Spearman processes. The value of the forecasted temperature for the year 2009 was found to be nearby to the observed temperature, shown in Table 3. In Table 2, the skill scores for forecasting seasonal mean temperature over Rangpur are presented.

Table 2. Efficiency scores of forecasting seasonal temperature over Rangpur

Name of Seasons	RMSE (°C/day)	HS (%)	Bias	MAE (°C/day)
Summer	2.24	58.82	0.31	1.28
Rainy season	1.73	35.29	0.00	0.93
Autumn	1.26	29.41	-0.05	0.74
Late autumn	0.65	52.94	-0.01	0.47
Winter	1.09	38.24	-0.05	0.78
Spring	1.24	52.94	0.19	0.82

From the above Table 2, it is seen that the values of root mean square error (RMSE) were logically less in all the seasons except summer. The mean absolute errors (MAE) were lower in the rainy season, autumn, late autumn, winter, and spring and relatively higher in the summer season only. On the other hand, the bias was very lower in the rainy season, autumn, late autumn and winter than in summer and spring. The range of hit scores was 29.41 to 58.82 which is relatively lower. The forecasted temperatures were not near to the observed temperature as much could be seen in Figures 8 to 13. It may be occurred because of a lower hit score (HS). But the figures for actual and forecasted temperature exhibit more or less equivalent patterns of variation which is very much encouraging. It is seen that the values of root mean square error (RMSE) were logically less.

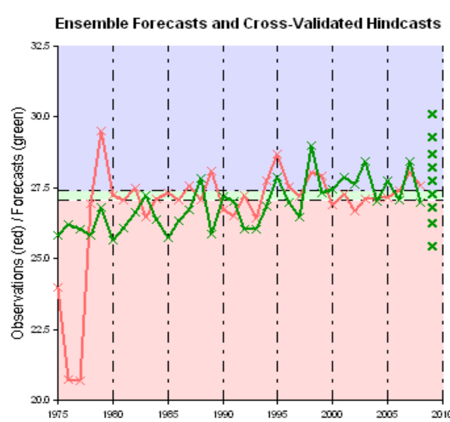

Fig. 8. Ensemble forecast temperature & Cross-Validated Hindcasts during summer over Rangpur.

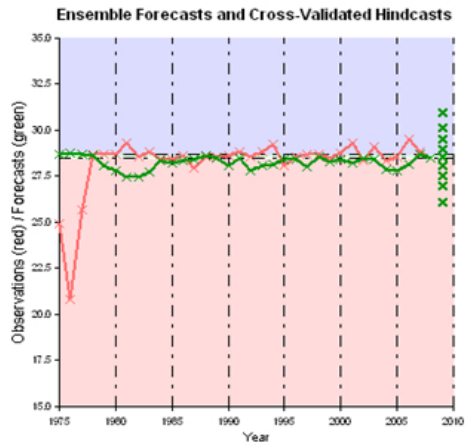

Fig. 9. Ensemble forecast temperature & Cross-Validated Hindcasts during the season of rainy over Rangpur.

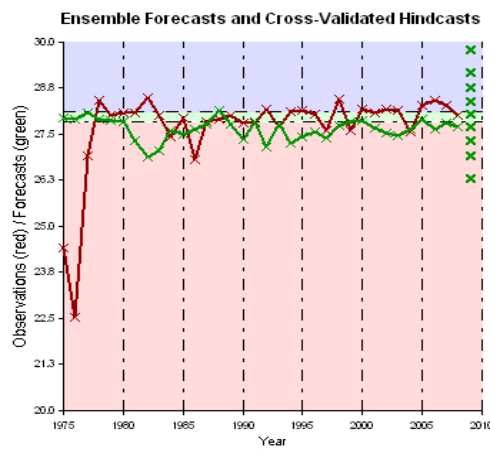

Fig. 10. Ensemble forecast temperature & Cross-Validated Hindcasts during autumn season over Rangpur.

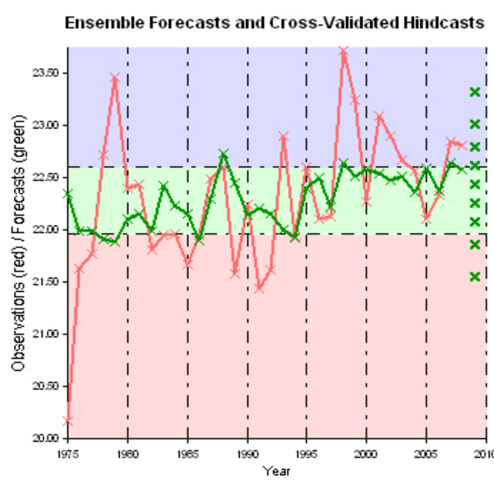

Fig. 11. Ensemble forecast temperature & Cross-Validated Hindcasts during late autumn over Rangpur.

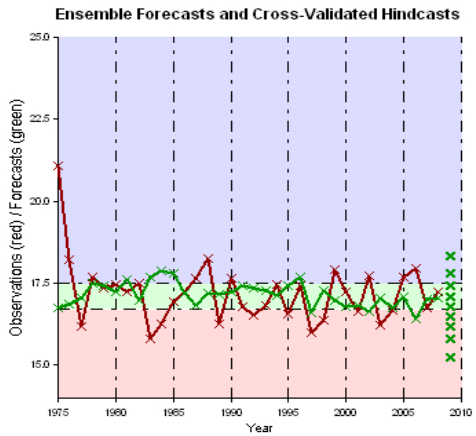

Fig. 12. Ensemble forecast temperature & Cross-Validated Hindcasts during winter over Rangpur.

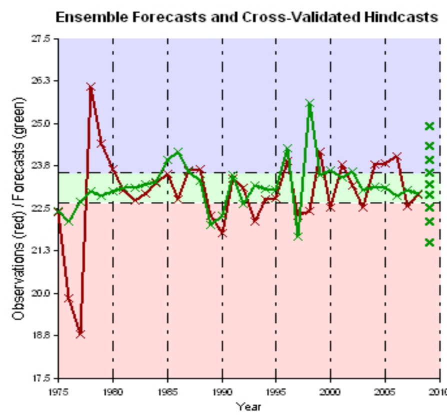

Fig.13. Ensemble forecast temperature & Cross-Validated Hindcasts during spring over Rangpur.

Table 3. Observed temperature, forecasted temperature and deviation of forecasted temperature from observed temperature of the year 2009.

Seasons	Observed temperature (° C/day)	Forecasted temperature (° C/day)	Deviation
Summer	28.01	27.76	0.25
Rainy-season	28.20	28.41	-0.21
Autumn	28.60	28.06	0.54
Late-autumn	22.85	22.45	0.40
Winter	16.28	16.80	-0.52
Spring	23.61	23.23	0.38

From Table 3, the value of the forecasted seasonal mean temperature was more as compared to the actual (observed) temperature during the rainy and winter seasons at Rangpur. Syeda (2012) found in his study a decreasing trend in temperature simulated by the ARIMA model over Rajshahi and Barisal and an increasing trend over other divisions of Bangladesh with Rangpur. On the other hand, the value of the forecasted seasonal mean temperature was low as compared to the actual temperature during summer, autumn, late autumn, and spring seasons at Rangpur. The annual average temperature of Dinajpur, Rajshahi, and Rangpur was decreased at the rate of 0.01180°C/year, 0.01340°C/year, and 0.02620°C/year respectively, which is reported by Ferdous & Baten (2011). The forecasted temperature deviation from the observed temperature was minimally positive that is 0.25°C/ day during the summer and maximally positive that is 0.54 °C/day during the autumn. On the other hand, the minimum negative value of -0.21°C/day during the rainy season and the maximum negative value of -0.52°C/day during the winter season was found at Rangpur. From above discussion it is seen overestimated forecasted temperature during some seasons and underestimated forecasted temperature during some seasons. It may be occurred due to variations of hit score (HS) or Goodness index (GI). However, it can be said that the Climate Predictability Tool (CPT) skillfully forecasted the seasonal mean temperature over Rangpur region. It can be undoubtedly said that forecasting temperature is one of the most important ways through which it is possible to enlarge both the quality and quantity of production in the agricultural sector having diminished temperature-related risk. As a result, the people of Rangpur will be able to recover in advanced social and economic management products in livestock and agriculture by using reliable and up-to-date seasonal temperature forecasts.

6. Conclusion

A seasonal climate forecast is very useful for agricultural activity planning due to climate change. So in this research, an attempt was made to forecast seasonal mean temperature for six Bengali seasons of Bangladesh in the year 2009 using Climate Predictability Tool (CPT). From this study, it was found that sea surface temperature for the period of 1975 to till the previous month of each season of 2008 was more or less appropriate for CPT as the predictor. So, it can be said without a doubt that CPT exhibited a lot of skill in the forecasting of seasonal mean temperature over the Rangpur division during some selected seasons: The Summer and Rainy seasons of Bangladesh. Finally, it can be concluded that Climate Predictability Tool (CPT) is a powerful model to forecast seasonal mean temperature.

ACKNOWLEDGEMENTS

This study was performed by CPT which was made by the International Research Institute at Columbia University in the United States. Support of Climate Predictability Tools (CPT) is gratefully acknowledged. The author greatly appreciates the support from Bangladesh Meteorological Department (BMD) and the International Center for Theoretical Physics, DODS server. On the other hand, the author is a lot grateful to the referees for their valuable advice.

References

Arab Amiri, M., Conoscenti, C. & Mesgari, M.S. (2018). Improving the accuracy of rainfall prediction using a regionalization approach and neural networks. Kuwait J. Sci. **45 (4):** 66 -75.

Basnayake, B.R.S.B., Nesssa, F.F. & Mannan, M.A. (2010). Seasonal weather forecasting in Bangladesh using Climate Predictability Tool (CPT). SMRC Report No. **34**: SAARC Meteorol. Res.Cen.(SMRC), Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics) (2020). Bangladesh Statistics 2020, Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, page 2.

Cheema, S.B., Rasul, G., Ali, G. & Kazmi, D.H. (2011). A comparison of minimum temperature trends with model projections. Pakistan Journal of Meteorology, **8**: 39-52.

Fan, J., Chen, B., Wu, L., Zhang, F., Lu, X. & Xiang, Y. (2018). Evaluation and development of temperature-based empirical models for estimating daily global solar radiation in humid regions. Energy,**144:** 903–914.

Ferdous, M.G. & Baten, M.A. (2011). Climatic Variables of 50 Years and their Trends over Rajshahi and Rangpur Division. Journal of Environmental Science and Natural Resources, **4**: 147-150.

Intergovernmental Panel on Climate Change (IPCC), (2001). Climate change 2001: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge, UK.

Jain, A. (2003). Predicting air temperature for frost warning using artificial neural network. A Thesis Submitted to the Graduate Faculty of the University of Georgia in Partial Fulfillment of the Requirements for the Degree Master of Science, Athens, Georgia, 92 pages.

Khan, M.M.R., Siddique, M.A.B., Sakib, S., Aziz, A., Tasawar, I.K. & Hossain, Z. (2020) Prediction of Temperature and Rainfall in Bangladesh using Long Short-Term Memory Recurrent Neural Networks. 4th International Symposium on Multidisciplinary Studies and Innovative Technologies, IEEE, TURKEY, 22-24.

Karna, N., Roy, P. C. & Shakya, S. (2021). Long Term Temperature Forecasting using Regression Model. International Journal of Advanced Engineering, **4(2):** 73-92.

Kalkstein, L.S. (1991). A new approach to evaluate the impact of climate on human mortality. Environmental Health Perspectives, **96**: 145–150.

Leite, S.M. & Peixoto, J.P. (1996). The autoregressive model of climatological time series: an application to the longest time series in Portugal. International Journal of Climatology, **16**: 1165-1173.

Martens, W.J.M. (1998). Climate change, thermal stress and mortality changes. Social science & medicine, **46:** 331–344.

Machiwal, D. & Jha, M.K. (2006). Time Series Analysis of Hydrologic Data for Water Resources Planning and Management: A Review. J. Hydrol. Hydromech., **54**: 237–257.

Nury, A.H., Koch, M. & Alam, M.J.B. (2013). Time Series Analysis and Forecasting of Temperatures in the Sylhet Division of Bangladesh. In: 4th International Conference on Environmental Aspects of Bangladesh (ICEAB), 65-68.

Oyamakin, O., Adebayo, J., Ayoola, F. J. & Oyeleye, B. (2010). Time Series Analysis of Rainfall and Temperature in South West Nigeria. The Pacific J. of Sci. and Techno., **11**: 552-564.

Rehman, S. & Mohandes, M. (2008). Artificial neural network estimation of global solar radiation using air temperature and relative humidity. Energy Policy, **36**: 571–576.

Rangpur climate (2021). Average Temperature, weather by month, Rangpur weather averages - Climate-Data.org. en.climate-data.org. Retrieved 1.

Sharma, A. & Bose, M. (2014). Rainfall prediction using k-NN based similarity measure. Recent advances in information technology, Advances in Intelligent Systems and Computing, **266**:125-132.

Syeda, J. A. (2012). Trend and Variability Analysis for Forecasting of Temperature in Bangladesh. Journal of Environmental Science and Natural Resources, **5**: 243-252.

Shamsnia, S.A., Shahidi, N., Liaghat, A., Sarraf, A. & Vahdat, S.F. (2011). Modeling Of Weather Parameters (Temperature, Rainfall and Humidity) Using Stochastic Methods. International Conference on Environment and Industrial Innovation IPCBEE, IACSIT Press, Singapore, **12**: 282-285.

Submitted: 13/02/2022
Revised: 10/05/2022
Accepted: 31/05/2022
DOI: 10.48129/kjs.18877