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Forecasting Monthly Average Temperature of Some Selected Stations from the Northern Part of Bangladesh by ARIMA Model

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ABSTRACT

The global temperature is increasing day by day. It is mostly because of the Greenhouse effect, using fossil fuels and others. It is potentially impacting on human population and another organism of the environment. The environment of Bangladesh, as well as the climatic conditions all over the world, are wildly affected due to increasing temperature. This paper attempts to identify the most appropriate Time Series model for the monthly average temperature of the selected places and make forecasting with this model. For this study, the monthly average temperature data is collected between the period from January 1972 and December 2017 for Rangpur, Rajshahi and Bogra station. However, for the Dinajpur the study period is January 1981 to December 2017 since the previous data are unavailability. The final model is selected by using well-established model selection criteria like AIC, BIC, MASE, RMSE and so on. We have found the seasonal ARIMA model like $ARIMA(4,0,3)(0,1,2)_{12}$, $ARIMA(5,0,4)(0,1,2)_{12}$, $ARIMA(2,0,1)(0,1,2)_{12}$ *and* $ARIMA(5,0,3)(0,1,2)_{12}$ *for Rangpur, Rajshahi, Dinajpur and Bogra stations respectively give the best fit. It is assumed that our forecasted monthly average temperature data can help the meteorologist and the decisionmakers to establish strategies, priorities and proper use of natural components.*

Keywords: Temperature; Box-Jenkin's Methodology; Model Selection; Bangladesh.

Mathematics Subject Classification: 97K80, 62-07, 37M10, 62M10

Journal of Economic Literature (JEL) Classification : C51, C52, C53, C54

1. INTRODUCTION

Bangladesh is a temperate country having a total area of about 1,47,570 square kilometers, has a subtropical humid climate characterized by wide seasonal variations. It is located between 20° to 26° North and 88° to 92° East. There are six seasons in Bangladesh which are Summer, Rainy season, Autumn, Late-autumn, Winter and Spring. However, four different seasons are familiar in Bangladesh from the climate change of view namely dry winter season (December-February), pre-monsoon season (March-May), rainy monsoon season (June-September) and post-monsoon autumn season (October-November) (Islam 2007). Moreover, the temperature of Bangladesh usually remains very high in the monsoon period and low in the winter but in other seasons, temperature observed as not so high nor so low. However, the yearly average temperature of Bangladesh will be increased by 0.6

to 1.4°C by 2050 and also the monthly average temperature is continuing to increase steadily every month (Rajib, et al., 2011). The production of agricultural materials depends not solitarily on the irrigation, humidity, rainfall, fertilizer or others but also on an appropriate temperature. In addition, the temperature has also a significant impact on the human being and other organisms of our environment. Therefore, increasing temperature will increase the evapotranspiration and create some disasters such as loss of water from soil and resultantly reduced crop yield, higher microbial concentration and growth rate in the surface water and so on. Shamim-Ul-Hasan and Rahman (2013) show that the monthly average temperature has an upward trend and increasing at a rate of 0.80C per 100 years. They also found that temperature has been increased largely over the period 1990-2010 (last 21years) than the period 1948-2010 (last 63 years).

Kaushik and Singh (2008) show that the SARIMA model provides reliable as well as satisfactory predictions for both rainfall and temperature. Afrifa-Yamoah (2015) used the ARIMA model for forecasting the monthly mean surface temperature of Brong Ahafo, Ghana. Khajavi et al. (2012) modeled the temperature of the Caspian southern coasts by seasonal ARIMA model. Eni and Adeyeye (2015) used a SARIMA model for forecasting the rainfall in Warri Town of Nigeria. Also, Abdul-Aziz et al. (2013) used a SARIMA model in order to forecast the rainfall pattern in Ghana. Nury et al. (2013) set-up the ARIMA models in order to carry out short-term predictions of monthly maximum and minimum temperatures in the Moulvibazar and Sylhet districts of Bangladesh. Both Hossain (2016) and Hossain et al. (2016) used a seasonal ARIMA model to forecast the humidity of some selected stations of Bangladesh. Sultana and Hasan (2015) used Seasonal ARIMA model for forecasting the maximum as well as minimum temperature in the Coastal Area of Bay of Bengal. Monday and Nengak (2017) fit seasonal autoregressive and integrated moving average (SARIMA) models for temperature and rainfall forecasting in Nigeria.

The global temperature is increasing day by day. It is mainly due to the Greenhouse effect, using fossil fuels and others. It is potentially impacting on human population and another organism of the environment. Besides, the water level of the sea will increase, the ice of the top of the mountain and polar region will meltdown, and different natural calamities such as drought, heavy rainfall, cyclone, tornado, etc. will be held. The environment of Bangladesh, as well as the climatic conditions all over the world, are wildly affected due to increasing temperature. The Time Series Analysis such as randomness, unit root, fitting model, and prediction, etc. of the temperature can help the meteorologist for making an appropriate decision about atmosphere, and it will help to reduce the bad impact of various natural calamities. Thus, this paper firstly, checks the stationarity, seasonal effect of temperature of Rangpur, Rajshahi, Dinajpur and Bogra station. Finally, identify the most appropriate model for the selected places and make forecasting with this model.

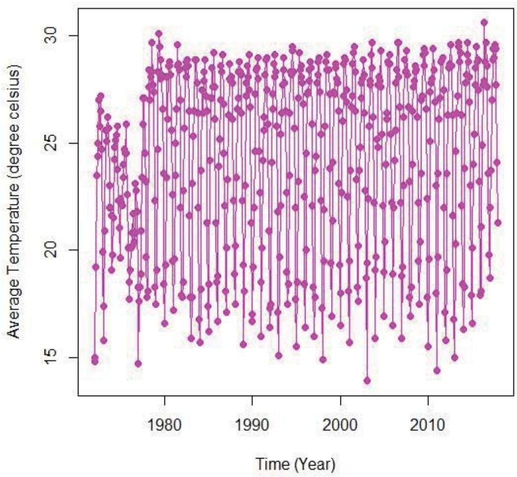
2. METHODOLOGY

This study considers the secondary dataset of monthly average temperature and considers the period of January 1972 to December 2017 for Rangpur, Rajshahi and Bogra station. However, for the Dinajpur the study period is January 1981 to December 2017 due to unavailability of the previous data. The necessary data were collected from the Bangladesh Meteorological Department and a website http://en.tutiempo.net/climate/bangladesh.html. The statistical software R (version 3.4.3) is used to analyze the data. Here, Time Series plot, ADF and KPSS test is employed to test the stationarity of the data set. The seasonal ARIMA model is selected by the method developed by Box-Jenkins (1970).

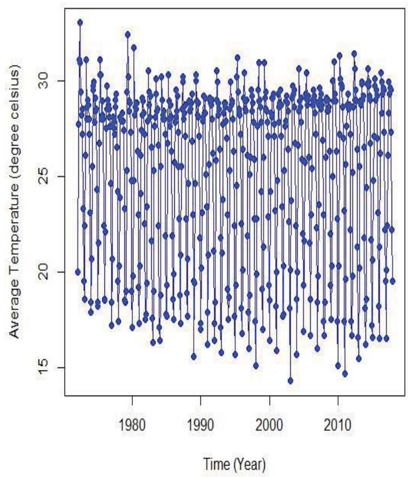
However, the final model is selected by using well-established model selection criteria like AIC, BIC, MASE, RMSE and so on. Furthermore, the normality and autocorrelation are checked by the Box-Ljung test (Ljung and Box 1978) and Jarque–Bera test (Jarque and Bera 1987) respectively.

3. RESULTS

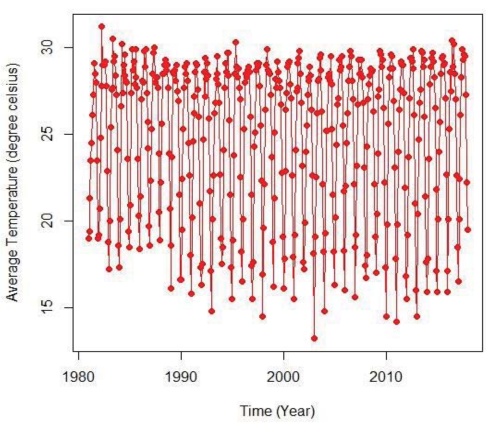
Firstly, in order to visualize the data, we use the Time Series plot and from the given plot we try to make the decision about the stationarity of the data set about the temperature for the selected stations in this paper. Figure 1 depicts the Time Series plot of the monthly average temperature of the selected four stations from the northern part of Bangladesh.



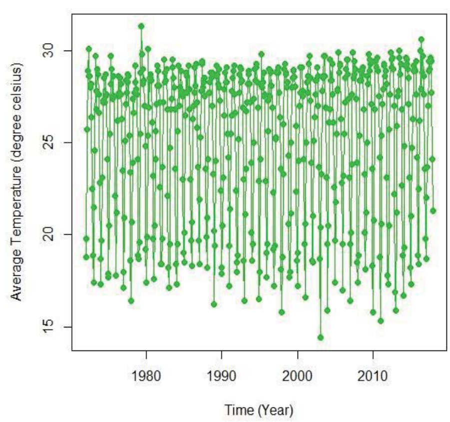
Rangpur



Rajshahi



(a) Dinajpur



(b) Bogra

Figure 1. Time Series plot of monthly average temperature for (a) Rangpur, (b) Rajshahi, (c) Dinajpur and (d) Bogra station.

From the Time Series plot, it can be seen that the random fluctuations in the Time Series are roughly constant in size over time. It indicates that the monthly average temperature of the selected four stations is stationary. However, the author thinks that graphical inspection is not enough to make a final conclusion. Hence, we use widely used the Augmented Dickey Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. The following Table 1 represents the results of these tests.

Table 1: Results of ADF and KPSS Tests

Stations	ADF Test			KPSS Test		
	Statistic	p-value	Decision	Statistic	p-value	Decision
Rangpur	7.7992	0.01	Stationary	0.45043	0.45043	Stationary
Rajshahi	8.1477	0.01	Stationary	0.023554	0.10	Stationary
Dinajpur	7.0464	0.01	Stationary	0.037024	0.10	Stationary
Bogra	8.2298	0.01	Stationary	0.06519	0.10	Stationary

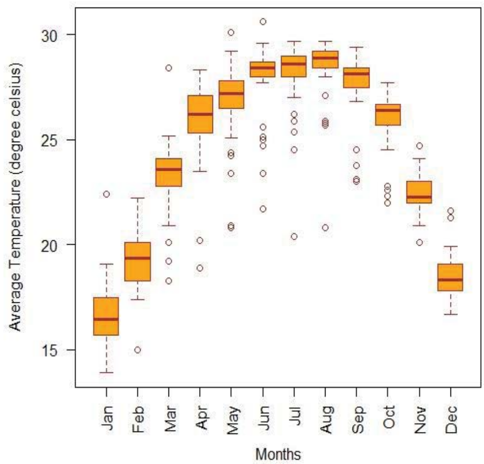
The p-value of Augmented Dickey-Fuller (ADF) test for all stations considered in this study is 0.01, which is smaller than 0.05. Therefore, the null hypothesis about non-stationary is rejected at 5% level of significance. Also, at 5% level of significance, the p-value of the KPSS test for all stations is greater than 0.05 which insist to make the same decision made by the ADF test. Thus, we may conclude that the monthly average temperature time series data of all stations considered in this study are stationary.

Now, we are interested in the seasonal effect on the monthly average temperature. The seasonal indices of the average monthly temperature of all stations considered in this study which are obtained by using the moving average method are shown in the following Table 2.

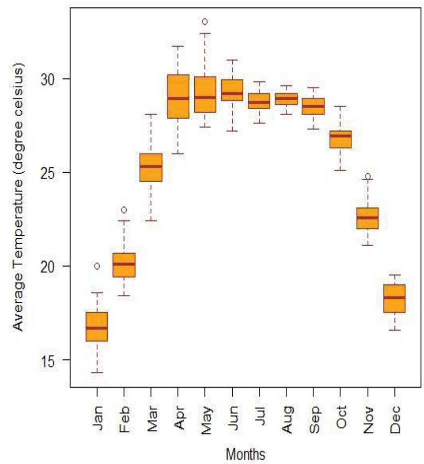
Table 2: Seasonal indices of monthly average temperature for Selected stations

Months	Seasonal indices			
	Rangpur	Rajshahi	Dinajpur	Bogra
January	92.31	91.46	91.33	92.26
February	95.06	94.86	94.86	95.72
March	99.10	99.92	99.45	99.89
April	101.66	103.67	102.36	102.79
May	102.69	103.91	103.32	102.99
June	103.78	104.03	104.21	103.61
July	103.93	103.45	104.00	103.50
August	104.18	103.59	104.28	103.63
September	103.42	103.20	103.52	103.07
October	101.70	101.51	101.76	101.39
November	98.05	97.41	97.64	97.69
December	94.12	92.98	93.27	93.47

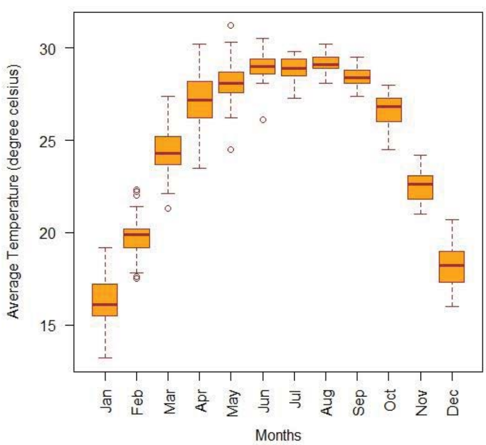
From the above table, it is evident that the entire seasonal indices are not equal or close to 100 for all the months. So, we may conclude that there is seasonal variation in the average monthly temperature data for Rangpur, Rajshahi, Dinajpur and Bogra stations. In addition, the multiple box plot used to identify the outliers as well as the shape of the distribution. The following figures presented in Figure 2 represent the box plot of the monthly average temperatures of the selected stations.



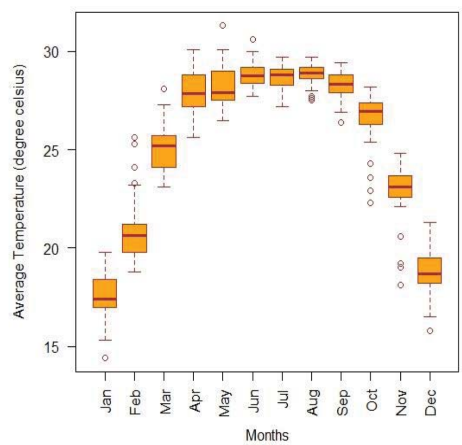
(a) Rangpur



(b) Rajshahi



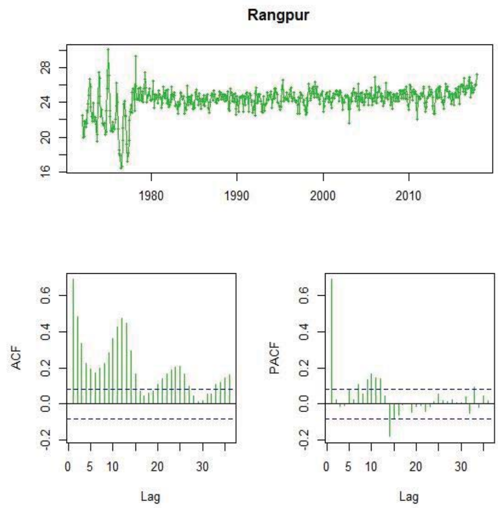
(c) Dinajpur



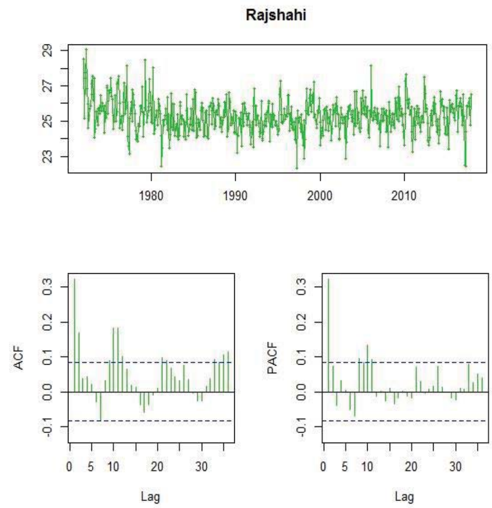
(d) Bogra

Figure 2. Box plot of monthly average temperature for (a) Rangpur, (b) Rajshahi, (c) Dinajpur and (d) Bogra station.

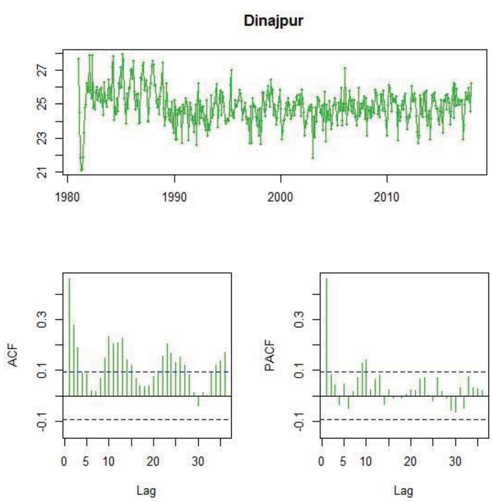
It is observed that in the case of Rangpur a lot of outlier presents for all months. Comparatively, a small number of outliers observed in Rajshahi and Dinajpur. However, in the case of Bogra, some outliers present in the average temperature of February, October and November. The figure also shows that there is a seasonal effect on the average temperature. Since it is observed that there are some seasonal variations so that we have to adjust the seasonal effect before selecting the model for forecasting. The time series plot along with ACF and PACF of the adjusted monthly average temperature for all the selected stations are given below (Figure 3).



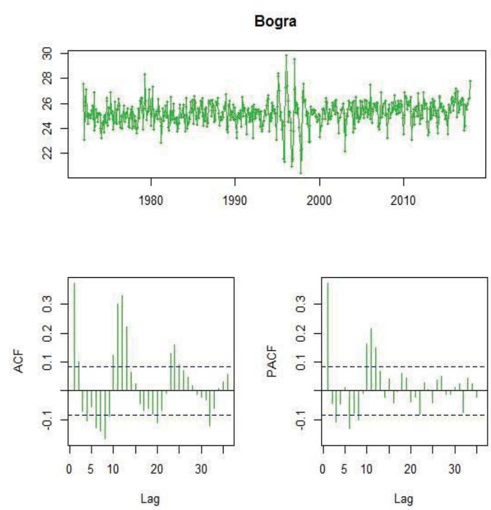
(a) Rangpur



(b) Rajshahi



(c) Dinajpur



(d) Bogra

Figure 3. Time Series Plot, ACF and PACF of seasonally adjusted monthly average temperature of (a) Rangpur, (b) Rajshahi, (c) Dinajpur and (d) Bogra station.

It can be seen that the seasonal variation has been removed from the seasonally adjusted time series. It is also observed that there is no significant trend of the seasonally adjusted data. The seasonally adjusted time series now just contains the irregular component. From the ACF and PACF, we identify the tentative models for the selected stations (Figure 3). We also identify the appropriate model by using several model selection criteria, for instance, AIC, AICC, BIC, RMSE, etc. The lower value of these model selection criteria indicates the better model. We arbitrarily change the value of the parameters of the model and record the values of the model selection criteria in each time. Among the fitted models, we select the most appropriate model. The values of the model selection criteria for the selected model given in Table 3.

Table 3: Values of Different Model Selection Criteria

Station	Rangpur	Rajshahi	Dinajpur	Bogra
AIC	1978.24	1966	1569.81	1891.69
AICc	1978.73	1966.68	1570.06	1892.27
BIC	2025.69	2022.08	1598.48	1943.45
ME	0.08142504	0.09425061	0.01329689	0.05232771
RMSE	1.022023	0.8765198	0.901646	0.9258464
MAE	0.7474002	0.6651271	0.6781141	0.6934215
MPE	0.1327264	0.5609857	0.1900777	0.0407145
MAPE	3.260319	2.781263	2.930398	2.927114
MASE	0.3532792	0.2843835	0.2938517	0.3210177

The maximum likelihood estimates of the parameter for different stations considered in this study are presented in the following Table 4. The values in parenthesis indicate the standard error of the parameters.

Table 4: Estimates of the Parameters of the Selected Model for Different Stations

Rangpur Station $ARIMA(4,0,3)(0,1,2)_{12}$

ar1	ar2	ar3	ar4	ma1	ma2	ma3	sma1	sma2	Intercept
0.443 (0.084)	0.035 (0.09)	0.473 (0.05)	-0.68 (0.049)	0.452 (0.073)	0.250 (0.05)	-0.593 (0.042)	0.537 (0.047)	0.302 (0.04)	24.284 (0.165)

Rajshahi Station $ARIMA(5,0,4)(0,1,2)_{12}$

ar1	ar2	ar3	ar4	ar5	ma1	ma2	ma3	ma4	sma1	sma2	Intercept
0.276 (0.3)	0.112 (0.17)	0.402 (0.06)	-0.554 (0.14)	-0.16 (0.21)	0.49 (0.3)	0.119 (0.07)	-0.751 (0.05)	-0.255 (0.23)	0.529 (0.05)	0.368 (0.04)	25.294 (0.07)

Dinajpur Station $ARIMA(2,0,1)(0,1,2)_{12}$

ar1	ar2	ma1	sma1	sma2	Intercept
1.5895 (0.0269)	-0.8535 (0.0259)	-0.7773 (0.0289)	0.4384 (0.0503)	0.3585 (0.0423)	24.8903 (0.0987)

Bogra Station $ARIMA(5,0,3)(0,1,2)_{12}$

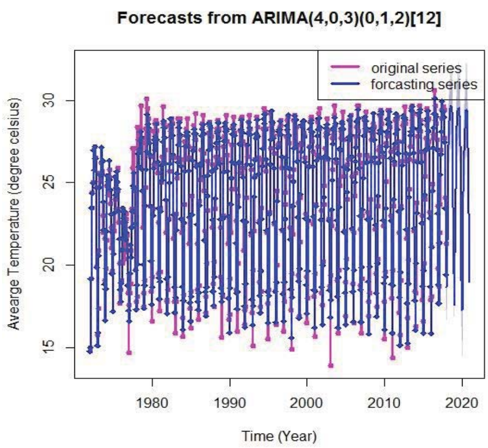
ar1	ar2	ar3	ar4	ar5	ma1	ma2	ma3	sma1	sma2	Intercept
0.428 (0.09)	0.054 (0.08)	0.425 (0.05)	-0.698 (0.077)	-0.015 (0.052)	0.232 (0.075)	0.025 (0.048)	-0.794 (0.035)	0.577 (0.047)	0.376 (0.039)	25.234 (0.062)

In order to forecast the future value by a model, it is needed to check the accuracy of the model. The accuracy of a model is done by justifying the statistical properties of the error of the fitted model. We check the normality and autocorrelation of the error of the fitted model. Moreover, the Ljung-Box test is used to check the autocorrelation and Jarque-Bera test is used to check the normality assumption of the error of the fitted model. The values of the test statistic for the fitted model of different locations are presented in Table 5.

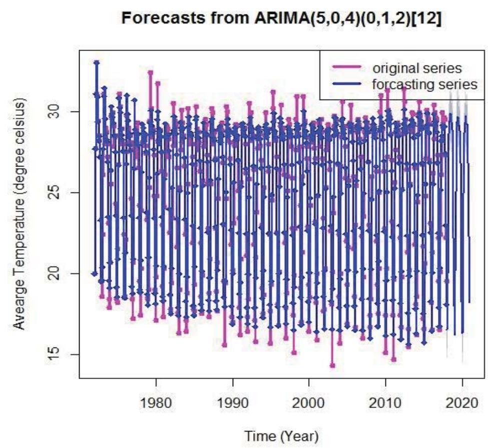
Table 5: Value of Test Statistic

Station	Ljung-Box		Jarque-Bera	
	Test Statistic	P value	Test Statistic	P value
Rangpur	16.563	0.1668	1811.8	<0.001
Rajshahi	12.622	0.3971	32.309	<0.001
Dinajpur	19.714	0.0727	28.038	<0.001
Bogra	35.496	0.0004	103.43	<0.001

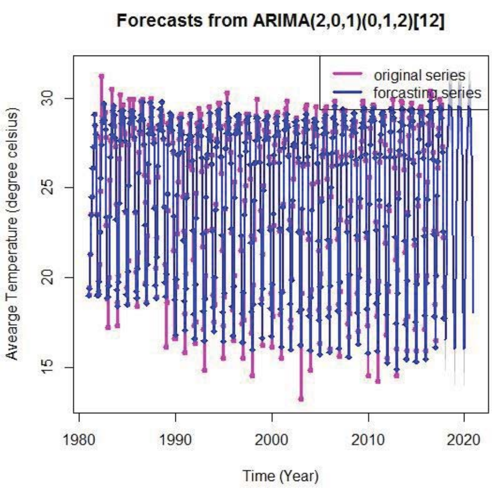
From Table 5, it is observed that the errors of the fitted model are normally distributed at a 5 percent level of significance for all stations considered in this study. Also, there is no autocorrelation among the residuals of the fitted model for Bogra. However, for Rangpur, Rajshahi and Dinajpur the errors are auto-correlated. The graphical comparison of the observed and predicted value is given in the following figure (Figure 4) of all stations considered in this study. It is observed that the forecasted series (blue-color) fluctuated from the original series (pink-color) with a very small amount which shows the fitted series has the same manner of the original series for all stations considered in this study (Figure 4). Therefore, the forecasted series is really a better representation of the original monthly average temperature series of the selected stations from the northern part of Bangladesh.



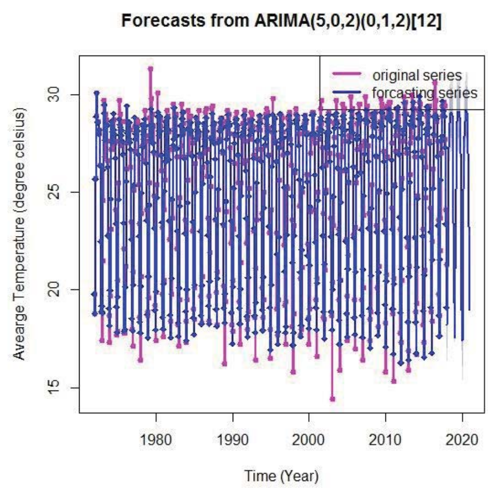
(a) Rangpur



(b) Rajshahi



(c) Dinajpur



(d) Bogra

Figure 4. Comparison of monthly average temperature of (a) Rangpur, (b) Rajshahi, (c) Dinajpur and (d) Bogra station.

The following Table (Table 6) represent the forecasted value of the monthly average temperature up to December 2020 for the selected stations namely Rangpur, Rajshahi, Dinajpur and Bogra.

Table 6: Forecasted Monthly Average Temperature for the Selected Stations

Month	Year	Rangpur	Rajshahi	Dinajpur	Bogra
Jan	2018	18.67	16.51	16.54	18.21
Feb	2018	21.51	19.97	20.12	21.21
Mar	2018	24.84	24.65	24.39	24.63
Apr	2018	27.30	28.61	27.24	27.28
May	2018	28.72	29.39	28.44	28.54
Jun	2018	29.50	29.87	29.60	29.02
Jul	2018	29.63	29.37	29.44	29.06
Aug	2018	29.65	29.35	29.54	29.10
Sep	2018	29.30	28.87	28.98	28.97
Oct	2018	27.41	26.69	26.89	27.09
Nov	2018	23.51	22.20	22.40	23.44
Dec	2018	19.49	18.02	18.03	19.34
Jan	2019	17.57	16.24	16.01	17.54
Feb	2019	20.76	20.17	19.91	21.05
Mar	2019	24.62	25.06	24.24	25.13
Apr	2019	27.09	28.78	27.16	27.77
May	2019	28.42	29.37	28.39	28.61
Jun	2019	29.38	29.68	29.57	29.16
Jul	2019	29.53	29.10	29.39	29.09
Aug	2019	29.53	29.16	29.50	29.07
Sep	2019	29.10	28.84	28.95	28.83
Oct	2019	27.24	26.81	26.86	27.00
Nov	2019	23.27	22.36	22.36	23.27
Dec	2019	19.06	18.26	18.04	18.97
Jan	2020	17.27	16.32	15.99	17.41
Feb	2020	20.55	20.13	19.88	21.06
Mar	2020	24.43	24.93	24.21	25.15
Apr	2020	26.95	28.65	27.13	27.84
May	2020	28.27	29.30	28.36	28.63
Jun	2020	29.26	29.69	29.54	29.20
Jul	2020	29.40	29.17	29.37	29.08
Aug	2020	29.43	29.24	29.48	29.10
Sep	2020	28.98	28.90	28.93	28.82
Oct	2020	27.15	26.82	26.84	27.02
Nov	2020	23.16	22.32	22.34	23.25
Dec	2020	18.98	18.21	18.01	18.98

4. DISCUSSION AND CONCLUSION

The main terget of this study was to identify the most suitable Time Series model which will be used for forecasting the monthly average temperature of Rangpur, Rajshahi, Bogra and Dinajpur stations in Bangladesh. Firstly, we make a Time Series plot of monthly average temperature data and we found that the monthly average temperature for Rangpur, Rajshahi, Dinajpur and Bogra stations seems to be stationary. Also, with the help of ADF and KPSS test, we may conclude that the Time Series data of the stations considered in this study are stationary. Now, we check the seasonal effect on the data set and the seasonal index as well as the Box plot suggest that seasonal variations are present in the series. So, it is necessary to adjust the seasonality for all the stations. After, adjusting the seasonal effect, we fit the tentative models and select the appropriate model with the help of model selection criteria like AIC, BIC, RMSE and so on. We have found the seasonal ARIMA model like $ARIMA(4,0,3)(0,1,2)_{12}$, $ARIMA(5,0,4)(0,1,2)_{12}$, $ARIMA(2,0,1)(0,1,2)_{12}$ and $ARIMA(5,0,3)(0,1,2)_{12}$ for Rangpur, Rajshahi, Dinajpur and Bogra stations respectively gives the best fit. Then we made a diagnostic check to examine that the model is either appropriate or not for forecasting. From the fitted models, the Box-Ljung test is employed to test the presence of autocorrelation and fond that there is no autocorrelation for Bogra station but a little evidence for non-zero autocorrelation for Rangpur, Rajshahi and Dinajpur stations. Again, for checking the normality assumption, we use Jarque-Berra test and it suggests that the residuals of all the fitted models follow normality assumption. Secondly, by comparing the fitted and actual values of temperature data using our selected model we found that forecasts are sufficiently accurate.

Finally, using the best fitted models, we forecast the monthly average temperature for the next 36 months for all the stations considered in this study. It is assumed that our forecasted monthly average temperature data can help the meteorologist and the decision makers to establish strategies, priorities and proper use of natural components.

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Conflict of Interest
The author declares no conflict of interest.

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