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Forecasting of Maximum and Minimum Temperature in the Cox's Bazar Region of Bangladesh based on Time Series Analysis

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Abstract: *This paper analyses monthly maximum and minimum temperatures from the Cox's Bazar and Teknaf area situated in the eastern coast of Bay of Bengal and south-eastern side of Bangladesh. Maximum and minimum temperature data obtained from Bangladesh Meteorological Department (BMD) in Bangladesh for a period of 69 years from 1948-2017 at Cox's Bazar station and data from 1977-2017 at Teknaf station, was investigated for the time series analysis and forecasting. Here ARIMA (Auto Regressive Integrated Moving Average) models have been set-up and used to carry out long-term predictions (9 years) of monthly maximum and minimum temperatures in the Cox's Bazar and Teknaf area of Bangladesh. The Box-Jenkins methodology, stationary, ARIMA models for the maximum and minimum temperatures have been used for the study. The ACF, PACF autocorrelation plots, the most appropriate orders of the ARIMA models are determined and evaluated using the AIC-criterion. Using these ARIMA-models forecast of the temperatures at the two stations. From the forecast result, it is found that the maximum and minimum temperature is increasing in trend which is very alarming for this coastal area of Bangladesh.*

Keywords: *ARIMA Models, Time Series Analysis, Minimum Temperatures, Maximum Temperature, Forecast¸ Cox's Bazar*

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I. Introduction

Climate change is for many countries in the world one of the biggest environmental threats to food production, water availability, forest biodiversity and livelihoods [1]. Moreover, it is widely believed that developing countries in tropical regions of the world, e.g. Bangladesh, will be impacted more severely than developed ones [2], [3]. Climate Change is not predictable. By using different climate model calculations, scientist can state that the earth's climate is unstable and the human beings have played an important role on this change. The main impacts of the increase in Greenhouse gases on the environment is the global warming (absorption of the solar radiation increases)[4]. Approximately one third of incoming solar radiation is reflected back to the atmosphere and the remainder is absorbed by the earth. A positive radiative force tends to warm the surface; but negative one tends to cool the surface [5]. In order to observe this radiation change throughout the years, meteorological air temperatures are studied and this information forms the basis of different scenarios for climate change. Earth's climate is changing. This means that regional climate is also changing. Understanding the nature and scale of possible climate changes in south-eastern Bangladesh is of importance to the policy makers and people who are working there as it gives them a chance to be prepared for better mitigation and adaptation measures.

In fact, according to data from the reinsurance industry, the number of climate-related disasters has increased significantly the 1970's [6]. A number of classical time series studies have been conducted in recent years to assess the nature of the climate change [1],[3], as it has occurred over the world as well as in Bangladesh [6] in the recent past and as it will more in likely do so in the future.

The objective of this work is to study the meteorological air temperatures in Cox's Bazar and Teknaf area see how the regional temperature is changing in this south-eastern part of Bangladesh. 9 years of forecasting of maximum and minimum temperature can be given using statistical model for this region of Bangladesh. With this study, the cooling and warming trends of the regional sides over the country will be determined.

II. Material And Methods

In order to forecasting the maximum and minimum temperature of the Cox's Bazar region of Bangladesh, time series analysis of temperature data at Cox's Bazar station (69 years) and Teknaf station (40 years) taken to build ARIMA models (a) to verify the selected ARIMA models, and (b) to carry out long-term prediction for the temperatures at these stations. Studies related with the determination of variations, trends and/or fluctuations of air temperatures in Bangladesh are very few. To identify a perfect ARIMA model for a particular time series, Box and

Jenkins [7] proposed a methodology that consists of four phases, namely, i) model identification; ii) estimation of the model parameters; iii) diagnostic checking for the identified model appropriateness and iv) application of the final model, i.e. forecasting. Further details on the various procedures involved in these four steps are provided in [7], [8]. Time series plots, stationary or non-stationary time series, tests for stationarity, procedure for fitting a model and procedure white noise checking will be discussed elaborately in this paper.

2.1. Graphical analysis

The first step in the analysis of any time series is to plot the data. Such a plot gives an initial clue about the likely nature of the time series or shows an upward or downward trend, seasonal or cyclical variations etc. This suggests that the time series is not stationary. Such an intuitive feel is starting point of more formal test of stationarity.

2.2. Box-Jenkins Method

The influential work of Box-Jenkins [9] shifted professional attention away from the stationary serially correlated deviations from deterministic trend paradigm toward the ARIMA (p, d, q) paradigm. It is popular because it can handle any series, stationary or not with or without seasonal elements. The basic steps in the Box-Jenkins methodology consist of the following five steps-

Identification of appropriate model: Once we have used the differencing procedure to get a stationary time series, we examine the correlogram to decide on the appropriate orders of the AR and MA components. The correlogram of a MA process is zero after a point, that of a AR process declined geometrically. The correlogram of $ARMA$ process show different patterns (but all dampers after a while). Based on these, one arrives at a tentative $ARMA$ model. This step involves more of a judgment procedure than the use of any clear-cut rules.

Estimation of the model: The next step is the estimation of the tentative $ARMA$ model identified in step-2. The estimation of AR model is straight forward. We estimate then by OLS by minimizing the error sum of squares $\sum Z_t^2$. In case of MA models, Box-Jenkins suggested a grid-search procedure. In this procedure we compute $\hat{Z}_t$ by successive substitution for each value of the MA parameters and choose the set of values of the parameters that minimizes the error sum of squares $\sum \hat{Z}_t^2$. For $ARMA$ models, both the AR and MA parts are to be estimated with the procedure discussed above.

Diagnostic Checking: When an $AR, MA, ARMA$ has been fitted to a given time series, it is an advisable to check that the model does really given an adequate description of the date. There are two criteria after used that reflect the closeness of fir and the number of parameters estimated. One is the Akaike information criterion (AIC) and the other is Schewatz Bayesian information criterion (BIC). If s is the total number of parameters estimated

$$ACI(s) = n\log\hat{\sigma}^2 + 2s$$

$$and \qquad BIC(s) = n\log\hat{\sigma}^2 + s\log n$$

Here n is the sample size. If $RSS = \sum \hat{Z}_t^2$ is the residual sum squares, then

$$\hat{\sigma}^2 = \frac{RSS}{n-p}$$

If we are considering several $ARMA$ models we choose the one with the lowest AIC of BIC. The two criteria can lead to different conclusions.

Forecasting: Suppose that we have estimated the model with n observations, we want to forecast Y_{n+k}. This is called a k-periods ahead forecast. First we need to write out the expression for Y_{n+k} and then replace all future values Y_{n+k} $(0 < j < k)$ by their factors and Z_{n+j} $(j > 0)$ by zero (since the expected value is zero). We also replace all Z_{n-j} $(j \geq 0)$ by the predicted residuals.

2.3. ARIMA model

The acronym ARIMA stands for 'autoregressive integrated moving average' and they are sometimes also called Box-Jenkins models [10]. An autoregressive model of order p is conventionally classified as AR (p) and a moving average model with q terms is known as MA (q). A combined model that contains p AR-terms and q MA-terms is called an ARMA (p, q) model [7]. To make a generally non-stationary time-series stationary time-shifted (by d-lags, whereby in most cases d=1) differences are computed before further processing. Such a model is then classified as ARIMA (p, d, q), where the symbol "I" signifies "integrated".

Assuming that the original data Xt has been made stationary by taking d nonseasonal differences (whereby in most cases d=1), an ARMA (p, q) model for this new, stationary time series Yt is as follows:

The time series $\{y_t\}$ is an ARMA(p,q) process if it stationary and satisfies for every t,

$$y_t - \Phi_1 y_{t-1} - \ldots\ldots\ldots - \Phi_p y_{t-p} = z_t + \theta_1 z_{t-1} + \theta_2 z_{t-2} + \ldots\ldots\ldots + \theta_q z_{t-q}$$

$$or, \mathrm{y_t} - \sum_{i=1}^{p} \Phi_i z_{t-i} = \mathrm{z_t} + \sum_{i=1}^{q} \theta_i z_{t-i}$$

Where, $\{z_t\} \sim \mathrm{WN}(0, \sigma^2)$ and the polynomials $\left(1 - \Phi_1 z - \ldots\ldots\ldots - \Phi_p z^p\right)and\left(1 + \theta_1 z + \ldots\ldots\ldots + \theta_q z^q\right)$ have no common factors.

2.4. Study Area: The study is only based on meteorological data for a Cox's Bazar district comprising Cox's Bazar Sadar Upazila and Teknaf Upazila. The Cox's Bazar station is situated in Cox's Bazar Upazila and Teknaf station situated in Teknaf Upazila of Cox's Bazar District of south-eastern side of Bangladesh (Map-1). The temperature data of station Cox's Bazar covers a period of 69 years, from 1948 to 2017 and station Teknaf covers a period of 40 years, from 1977 to 2017.

Map no 1. Study area showing the station in Cox's Bazar & Teknaf Upazila of Cox's Bazar District of Bangladesh.

2.5. Data Collection and Preliminary Analysis: Monthly maximum and minimum temperature data of Cox's Bazar from 1948 to 2017 and Teknaf from 1977 to 2017 was obtained from the Bangladesh Meteorological Department (BMD) which is the principal organization gathering meteorological data in Bangladesh. Data was analyzed used some statistical software's which will make our work easier, such as Microsoft Excel and R.

III. Results and Discussion

Our data is the temperature of Cox's Bazar station and Teknaf station. At first we have to check the non-stationarity of the data. Then we have to fit an appropriate model. After that we will check whether the errors are white noise or not. Then we will predict the temperature for the future time. The next step in the Box and Jenkins methodology [9] consists then in the determination of the orders p and q in ARMA(p,q) model. This is done by examination of the partial autocorrelation plot and the partial autocorrelation plot of the time series, respectively. ACF- and PACF- autocorrelation plots of the maximum and minimum temperatures and ACF, PACF residual plot of Cox's Bazar and Teknaf after differencing are shown in this section and given an indication of the significant orders p and q to be used in model-setup. As prescribed by Box-Jenkins methodology, the identified ARIMA model must be diagnostically checked for its appropriateness, by looking at the ACF residuals. These are shown for the monthly maximum, minimum temperatures at Cox's Bazar and Teknaf station.

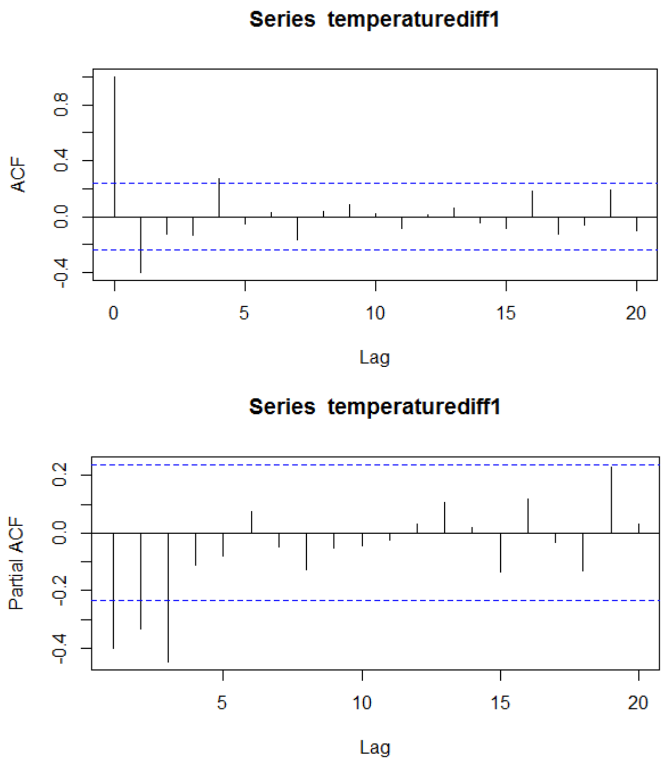
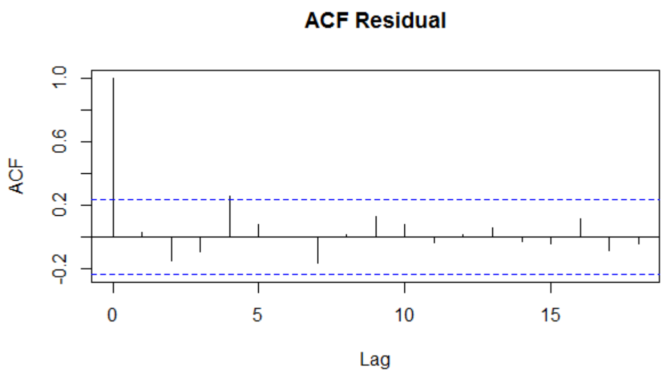


Figure no 1: ACF (top panel) and PACF (bottom panel) of monthly maximum temperatures at Cox's Bazar station after differencing.



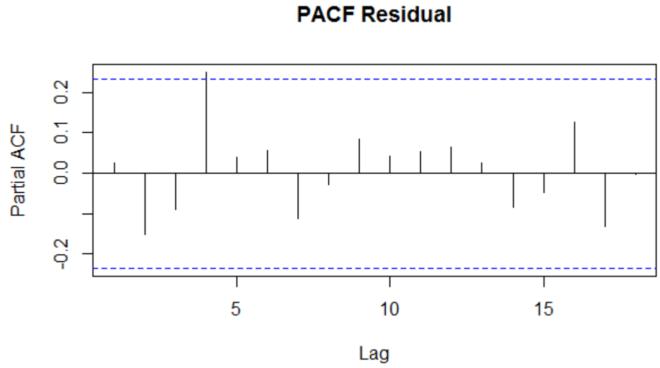


Figure no 2: ACF (top panel) and PACF (bottom panel) of residuals of monthly maximum temperature at Cox's Bazar station

Graph of the monthly maximum temperatures at Cox's Bazar station in figure-1 and figure-2. As the spikes at the different lags in the ACF and PACF plots in the figure-2 are within the statistical confidence bands, the ARIMA (0,1,1) model for this time series is adequate. Similarly good results have been obtained for the other time series analyzed.

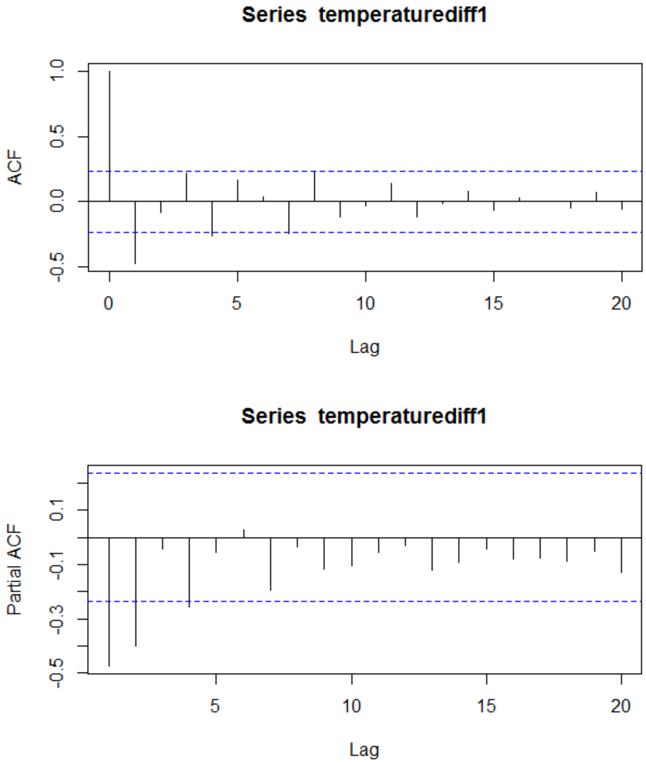


Figure no 3: ACF (top panel) and PACF (bottom panel) of monthly minimum temperatures at Cox's Bazar station after differencing.

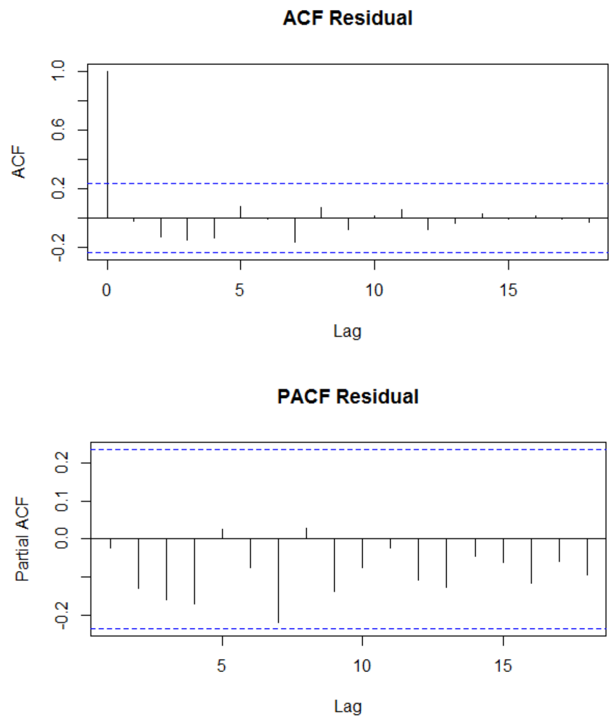


Figure no 4: ACF (top panel) and PACF (bottom panel) residuals of monthly minimum temperatures at Cox's Bazar station.

Graph of the monthly minimum temperatures at Cox's Bazar station in figure-3 and figure- 4. As the spikes at the different lags in the ACF and PACF plots in the figure-4 are within the statistical confidence bands, the ARIMA (2,1,0) model for this time series is adequate. Similarly good results have been obtained for the other time series analyzed.

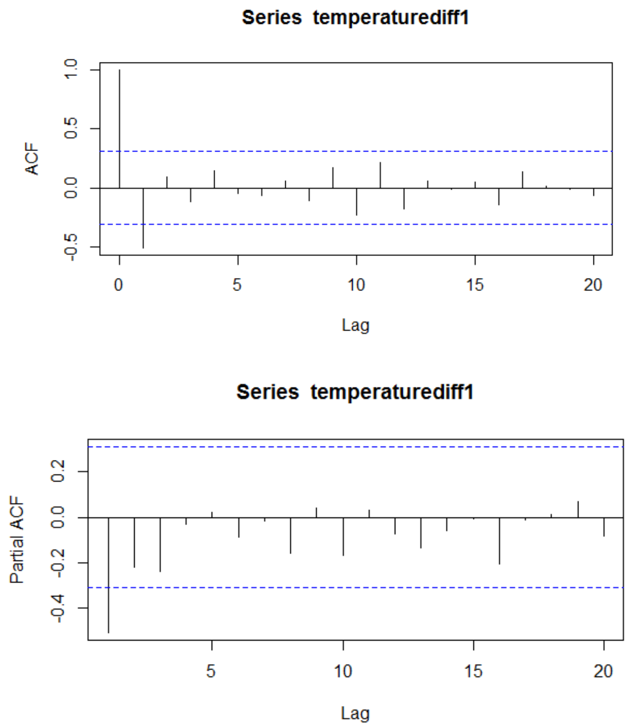


Figure no 5: ACF (top panel) and PACF (bottom panel) of monthly maximum temperatures at Teknaf station after differencing.

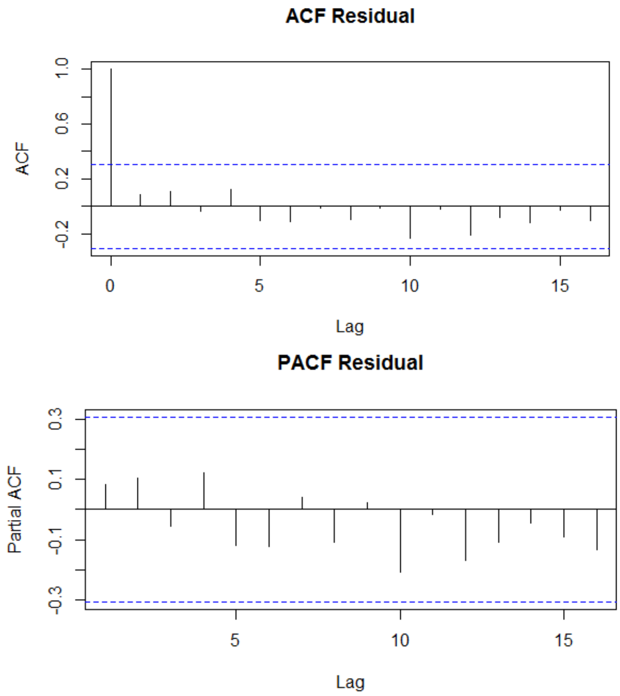


Figure no 6: ACF (top panel) and PACF (bottom panel) residual of monthly maximum temperature at Teknaf station

Graph of the monthly maximum temperatures at Teknaf station in figure-5 and figure-6. As the spikes at the different lags in the ACF and PACF plots in the figure-6 are within the statistical confidence bands, the ARIMA (0,0,0) model for this time series is adequate. Similarly good results have been obtained for the other time series analyzed.

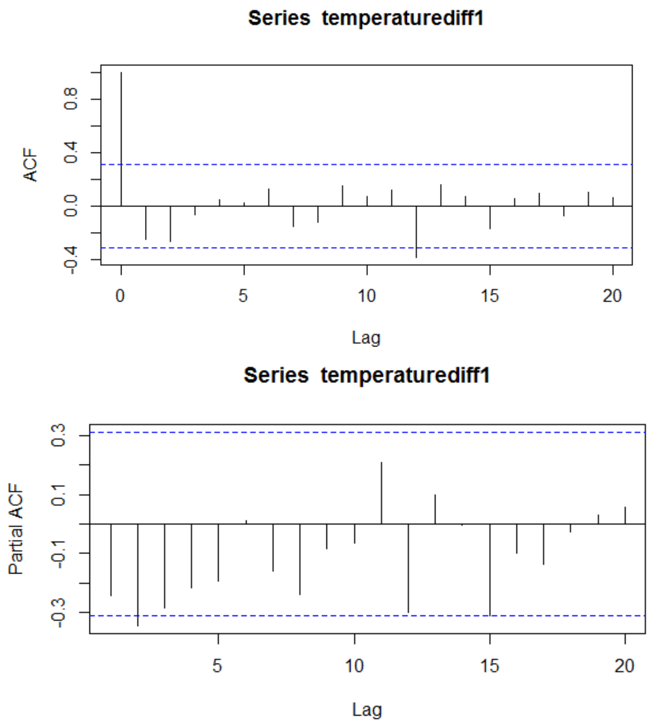


Figure no 7: ACF (top panel) and PACF (bottom panel) of monthly minimum temperatures at Teknaf station after differencing

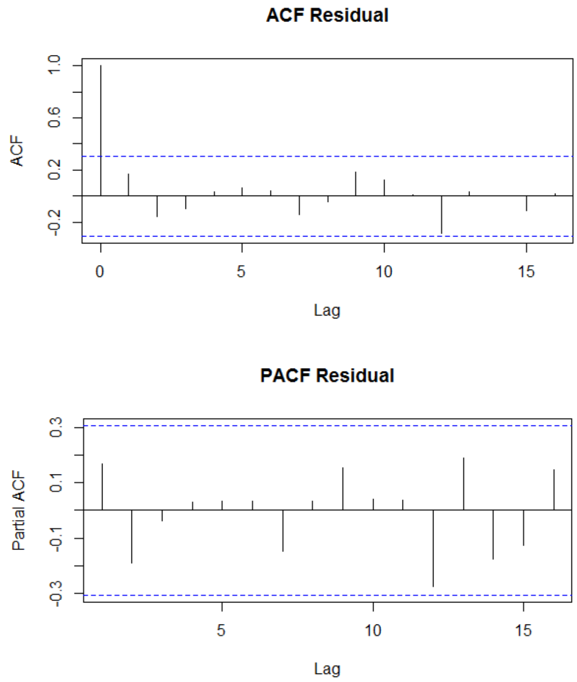


Figure no 8: ACF (top panel) and PACF (bottom panel) residual of monthly minimum temperature at Teknaf station

Graph of the monthly minimum temperatures at Teknaf station in figure-7 and figure-8. As the spikes at the different lags in the ACF and PACF plots in the figure-8 are within the statistical confidence bands, the ARIMA (0,0,0) model for this time series is adequate. Similarly good results have been obtained for the other time series analyzed.

Once the most appropriate order of the ARMA- or ARIMA model is specified, the AR- and MA- coefficients are estimated. The goodness of the best models is evaluated using the AIC (Akaike Information Criterion).

Table no 1: lists the ARIMA models obtained for the maximum and minimum temperatures time series at Cox's Bazar and Teknaf stations, together with their corresponding AIC –values

Variable	Station Name	Best ARIMA Model	AIC
Max. Temp.	Cox's Bazar	(0,1,1) with drift	204.83
Min. Temp.	Cox's Bazar	(2,1,0) with drift	206.59
Max. Temp.	Teknaf	(0,0,0) with non-zero mean	133.64
Min. Temp.	Teknaf	(0,0,0) with non-zero mean	108.99

At this point we have to perform diagnostic checking for the fitted model. Now from the analysis using R software (version R-2.14.1), we find the diagnostic checking plot, which is given below:

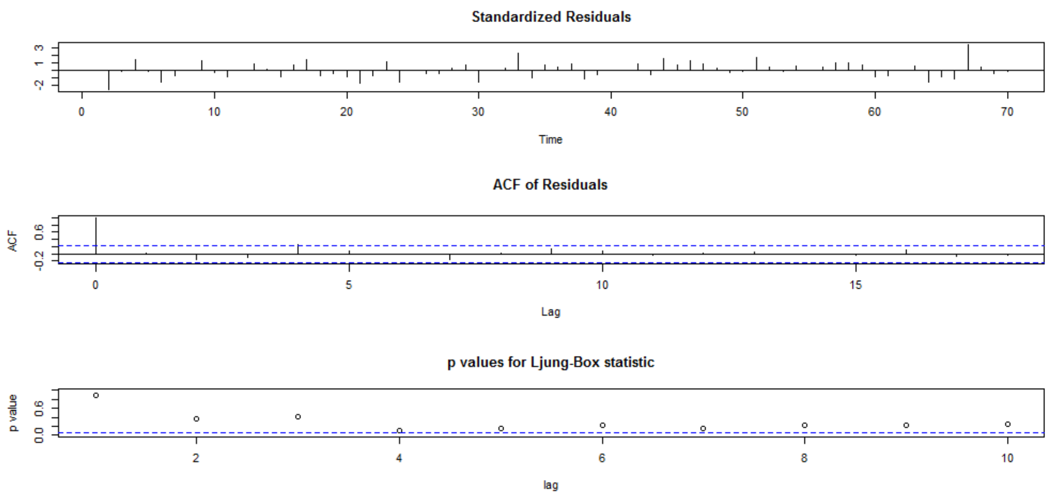


Figure no 9: Diagnostic checking the fitted model of Cox's Bazar maximum temperature data

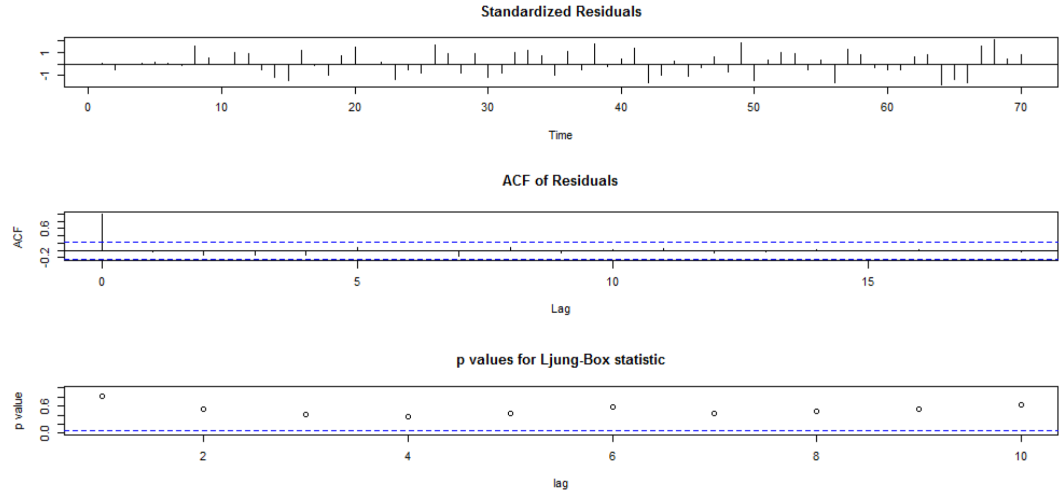


Figure no 10: Diagnostic checking the fitted model of Cox's Bazar minimum temperature data

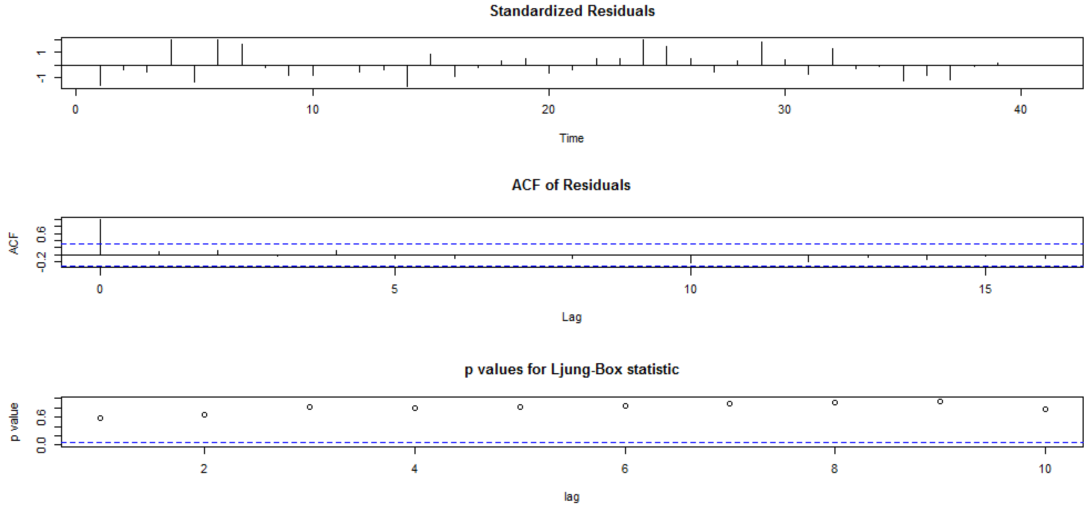


Figure no 11: Diagnostic checking the fitted model of Teknaf maximum temperature data

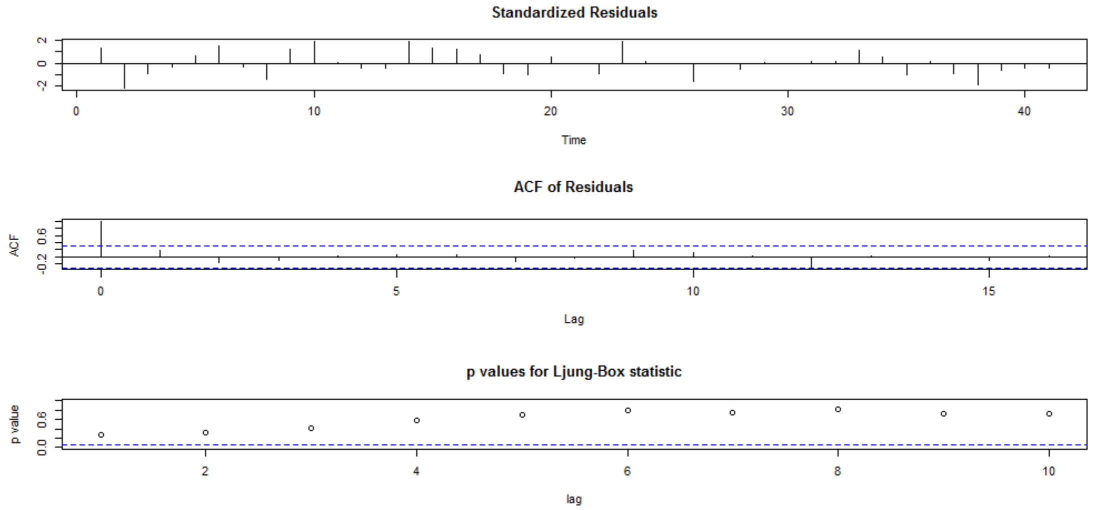


Figure no 12: Diagnostic checking the fitted model of Teknaf minimum temperature data

From those plots shown in figure-9 to figure-12, we can see that the plot of the standardized residual and the ACF plots are correctly specified. From the plot of p-value we can see that all p-values are above the level of significance. So, we can interpret that the residual is white noise; hence the model is also correctly estimated and ACF of the residuals shows no significant autocorrelations.

Table no 2: For white noise checking we also can perform Box-Ljung test

Variable	Station Name	P value	Null hypothesis	Comments
Max. Temp.	Cox's Bazar	0.6401>0.05	Accepted	Errors are white noise; hence the model is correctly estimated.
Min. Temp.	Cox's Bazar	0.9773>0.05	Accepted	Errors are white noise; hence the model is correctly estimated.
Max. Temp.	Teknaf	0.8806>0.05	Accepted	Errors are white noise; hence the model is correctly estimated.
Min. Temp.	Teknaf	0.785>0.05	Accepted	Errors are white noise; hence the model is correctly estimated.

The p-values for the Box-Ljung test all are well above 0.05, indicating "non-significance." we can go ahead and calculate the forecast.

The ultimate goal of ARIMA modeling is then the forecasting of the time series for one or more future time steps ahead [10] using ARIMA equation with the coefficients determined and values of the time series from previous years.

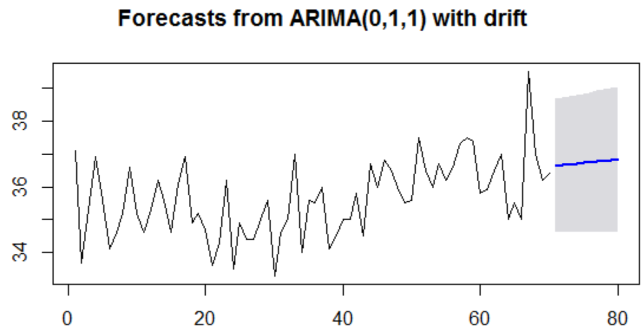


Figure no 13: Forecasting plot of maximum temperature at Cox's Bazar station for the years 2019-2027 (9 years) using forecast

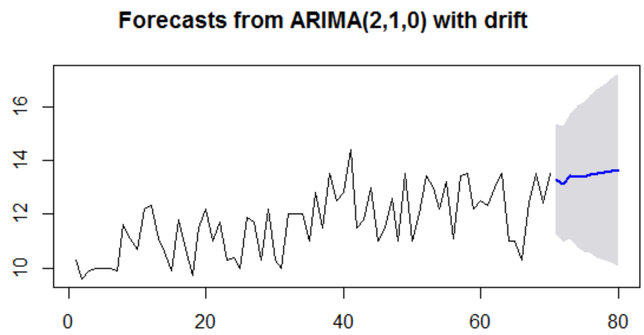


Figure no 14: Forecasting plot of minimum temperature at Cox's Bazar station for the years 2019-2027 (9 years) using forecast

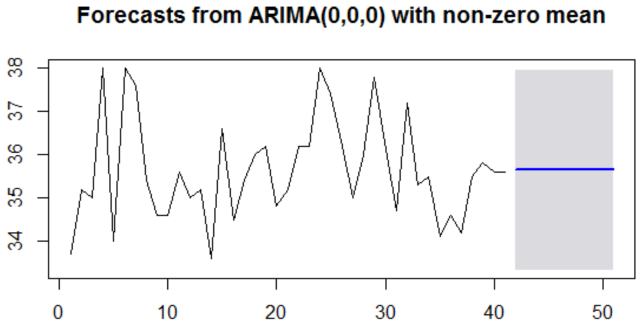


Figure no 15: Forecasting plot of maximum temperature at Teknaf station for the years 2019-2027 (9 years) using forecast

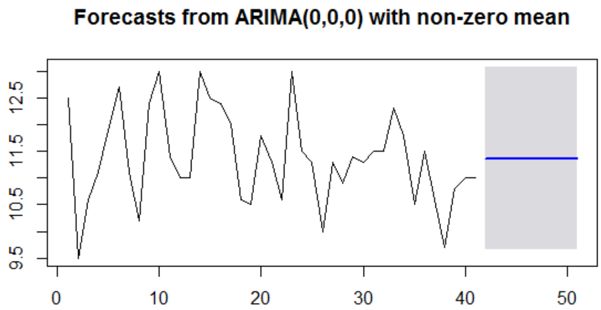


Figure no 16: Forecasting plot of minimum temperature at Teknaf station for the years 2019-2027 (9 years) using forecast

The forecasts are shown as a blue line in the figure-13 to figure-16 and the figures shows 9 years ahead predictions for the maximum, minimum temperatures for years 2019 to 2027 at Cox's Bazar and Teknaf station, respectively. From the visual inspection of these graphs one may note that the ARIMA-model is a valuable tool for long-term forecasting of the two meteorological variables maximum and minimum temperature.

By using this ARIMA (0,1,1) ,(2,1,0) and (0,0,0) model we can predict temperature for the future time. The predicted value of maximum temperature for 2019 to 2027 at Cox's Bazar are 36.66346, 36.68246, 36.70147, 36.72047, 36.73948, 36.75849, 36.77749, 36.79650, 36.81550 degree Celsius respectively will remain with a 95% prediction interval (34.60317, 38.72374), (34.60305, 38.76187), (34.60311, 38.79983), (34.60333, 38.83762), (34.60372, 38.87524), (34.60427, 38.91270), (34.60498, 38.95000), (34.60584, 38.98715), (34.60685, 39.02416) respectively in degree Celsius.

The predicted value of minimum temperature for 2019 to 2027 at Cox's Bazar are 13.09554, 13.40555, 13.37795, 13.36980, 13.48170, 13.50669, 13.54181, 13.60445 ,13.64493 degree Celsius respectively, will remain with a 95% prediction interval (10.93182,15.25926), (11.10461,15.70649), (10.75560,16.00030), (10.59402,16.14559), (10.54698,16.41642), (10.38590,16.62748), (10.27289,16.81072), (10.18932,17.01957), (10.08271, 17.20714) respectively in degree Celsius.

The predicted value of maximum temperature for 2019 to 2027 at Teknaf is 35.63902 degree Celsius will remain with a 95% prediction interval (33.3342, 37.94385) degree Celsius. The predicted value of minimum temperature for 2019 to 2027 at Teknaf is 11.36585 degree Celsius will remain with a 95% prediction interval (9.659606, 13.0721) in degree Celsius.

IV. Conclusions

The temperature time series for the two selected stations can be used for to build ARIMA models for the two temperature stations in the Cox's Bazar district, to verify the selected ARIMA models, and to carry out long-term prediction for the temperatures at these stations. Thus, the Box-Jenkins methodology can help decision makers to establish better strategies and to see that errors or residuals are White Noise, which was the main focus of this study to test the white noise property of the fitted time series model and predict upcoming weather changes approximately value which may have effects last, but not to the least, on the marine resource in the Cox's Bazar district. 9 years ahead predictions has been measured for the maximum and minimum temperatures for years 2019 to 2027 at Cox's Bazar and Teknaf station. For the maximum and minimum temperatures at Cox's Bazar station

ARIMA (0,1,1) with drift and (2,1,0) with drift respectively and AIC 204.83 and 206.59 are obtained, whereas the respective models for the Teknaf station are ARIMA (0,0,0) with non zero mean and (0,0,0) with non zero mean and AIC 133.64 and 108.99. The predicted value for maximum temperature will remain in the range 34.60305 to 39.02416(Degree Celsius) and minimum temperature will remain in the range 10.08271 to 17.20714 (Degree Celsius) in 2019-2027 for Cox's Bazar area where the predicted value of maximum temperature at Teknaf will remain in the range 33.3342 to 37.94385 (Degree Celsius) and minimum temperature will remain in the range 9.659606 to 13.0721 (Degree Celsius) in 2019-2017 periods.

The study area is unique and situated in the eastern coastal part of Bay of Bengal which very popular for tourism where longest unbroken sandy beach situated in this area. In case of temperature change related to the change in sea level in this area are very crucial matter needs to take concern by policy maker. Among the geographical regions, only Eastern Anatolia appears to show similar behavior to the global warming trends. All the coastal regions, however, are characterized by cooling trends.

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