THE VARIABILITY OF THE HISTORICAL AND FUTURE TEMPERATURE IN BANGLADESH

ABSTRACT

**Aims:** To discern how the historical temperature varied over the time period from 1975 to 2014 and what kind of temperature profile Bangladesh may prevail in the future.

**Study design:** This study was designed to reveal how the monthly mean of the daily average, monthly mean of daily maximum and monthly mean of the daily minimum temperature of all divisions covering all hydrological units of Bangladesh changed historically. It is also designed to forecast the all type of temperatures from up to 2050 using Box Jenkin’s algorithm in IBM SPSS.

**Place and Duration of Study:** This study was conducted within the time period from December 2015 to December 2016 under the Department of Civil Engineering, Dhaka University of Engineering & Technology, Gazipur, Bangladesh.

**Methodology:** At first the daily average, daily minimum and daily maximum temperature for the time period 1975 to 2014 of 13 stations, covering all hydrological units of Bangladesh, were converted into monthly mean and then graphs of individual months were plotted and analyzed afterwards. To infer the historical temperature variations clearly over the entire time period, histogram of the decadal averages of each type of temperature of the individual months were also plotted. Finally, the monthly records were forecasted up to 2050 by a time series model using Box Jenkin’s algorithm in IBM SPSS.

**Results:** Based on the historical and projected temperature, this study revealed that winter became colder especially in January and the summer got hotter over the time which may continue in future. By 2050 the maximum temperature may rise by 1.50±0.3°C in summer, average temperature may rise by 1.0±0.3°C and minimum temperature may vary by -0.8±0.3°C in winter.

**Conclusion:** This study concludes that winter may get colder in the northern part as well as some southern part of Bangladesh and reverse may suit for the summer where January and April would be the coldest and the hottest months respectively in future. By the year 2050, the average temperature may rise by 1.0±0.3°C and the maximum temperature may lead to 1.50±0.3°C, whereas the minimum temperature may vary from -0.8°C to 0.2°C. Overall, Bangladesh would experience a comparatively warmer weather in the coming decades.

**Keywords:** Mean, Maximum, Minimum, Temperature, IBM SPSS, ARIMA and projection

1. INTRODUCTION

Climate change and global warming are major concerns across the world as the mean surface temperature is soaring up day by day. According to Inter-governmental Panel on Climate Change (IPCC), the global surface temperature increase by the end of the 21st century is likely to exceed 1.5°C relative to the 1850 to 1900 period for most scenarios, and is likely to exceed 2.0°C for many scenarios [1]. World Bank report argued that Bangladesh is the most vulnerable country in the south Asia by the expected 2°C rise in World’s average temperature in next decades [2] and due to its geographical location this country will also be affected in many ways [3]–[5]. By this time Bangladesh has already been experienced many climatic extremes such as droughts, floods, cyclones and salinity intrusions [6]. Though Bangladesh is a small country, it has different hydrological and meteorological characters of its different parts that show the temporal and spatial variations. In summer the temperature varies from 30°C to 40°C and in winter temperature falls to 10°C and sometimes even get lower [7].

Bangladesh mainly depends on agriculture for her economy as agriculture is the mainstay of
Bangladesh’s economy. Agriculture comprises about 15% of the country’s GDP and 60% of the total labor force. Temperature is one of the most important climatic parameters, that is greatly related with the agriculture of Bangladesh. High temperature has already affected this country in many ways [8] and it will keep affecting significantly the Bangladesh agriculture especially crop production [9]–[12], human health [13]–[15] and also other related fields.

Every crop has specific temperature range for their vegetative and reproductive growth and the production faces constraints when the temperature falls below or exceeds the range. Higher temperature may affect the production of rice, wheat, tomato seriously [16]–[18] and it has negative effects on the soil organic also. In case of human health, both low and high temperatures affect in different dimensions. For instance, low temperature causes infant mortality in rural areas [19] and high temperature causes infectious diseases [20]. To take the preventive and curative measures of the adverse effects on human health and agriculture due to temperature variations, now it has become a great question that what will be the temperature profile of Bangladesh in the future? In this regard, forecasting of temperature may play a very important role in adapting the crop production and cropping pattern with the temperature variations and also to take the preventive and curative measure for human health.

However, based on both historical and projected consequences of the incremental temperature, many researchers from in and outside of Bangladesh tried to explore how the historical temperature varied over time and what would be the future temperature scenario in Bangladesh. Depending on the research extent, methodology and used tools, different researchers came up with different outcomes. Some of the outcomes were consistent with each other while some of which did not. For instance, in Cox’s Bazar and Sylhet, the maximum temperature has increased significantly by 0.021°C per year and in case of minimum temperature the highest increase was found in Dhaka by 0.049°C followed by Cox’s Bazar (0.038°C per year) whereas significant decrease has been observed in Rajshahi by 0.047°C per year [21]. Based on monthly maximum temperature data during 1948 to 2010, Rahman (2013) pointed out a positive trend at a rate of 0.50°C per 100 year. The maximum increase occurred during November at a rate of 2.05°C per 100 year. In the other research Rahman & Lateh (2015) observed that in the northern, northwestern, northeastern, central and central southern parts of Bangladesh, the highest upward trend in minimum temperature ranged 0.80–2.4 °C was observed while greatest warming in the maximum temperature ranged of 1.20–2.48 °C was found in the southern, southeastern and northeastern parts during 1971–2010. Based on the data availability and the research interests, researchers studied on different kinds of temporal, spatial and seasonal variations. Some researchers also analyzed the temperature variations in the divisional areas and some specific districts or specific hydrological units only. For instance, Mohiuddin et al. (2014) studied only on the Dhaka city and found that minimum average monthly temperature increased significantly and the most significant changes occurred in winter (December-February) where highest increase observed by 13.6°C in December over the period of 100 years. On the contrary Basak et al. (2013) worked on almost all available stations (34 stations) across the country and found that yearly average maximum temperature was increasing at a rate of 0.0186°C per year, whereas the rate was 0.0152°C per year for yearly average minimum temperature. The authors also suggested that monthly average maximum temperature showed an increasing trend for all months except January and a very significant increase was in April. The monthly average minimum temperature also showed the increasing trends for all months except January and November [25]. From the above discussion it becomes very clear that most of the researchers worked on the trend analysis of the historical temperatures but very limited research works were carried out to explore the future temperature scenarios of Bangladesh. On the contrary, some people worked only on the average or maximum or only on the minimum temperatures but studies on all type of temperatures together and their future forecasting are very rare. For this reason this study aimed to explore the future maximum, minimum and average temperatures scenario of Bangladesh based on its historical records using a time series model in SPSS by Box-Jenkin’s method. To forecast the future temperature, a model must need the historical records which actuated this research to observe the historical variations in the maximum, minimum and average temperatures of different regions of Bangladesh.
2. METHODOLOGY

Daily average, daily minimum and daily maximum temperature of 35 stations across the country were collected from the Bangladesh Metrological Department (BMD). All the temperature records were for the time period from 1975 to 2014. Based on the hydrological regions (Figure 1) 13 stations were selected which cover all hydrological regions as well as all divisions of Bangladesh. At first daily temperatures of the selected stations were converted to monthly average of daily average, monthly average of the daily minimum and monthly average of the daily maximum and plotted against time of individual months afterwards.

For example, for the month January, the monthly average of the daily averages temperatures were plotted for the time period from 1975 to 2014. Then the monthly average of the daily minimum and the daily maximum temperature of the same month for the same time period were plotted. Likewise, the graphs of the monthly average of the daily averages, daily minimum and daily maximum temperatures were plotted for the months February to December for the same time period. After plotting these graphs, this study faced difficulties to provide the precise results as the all temperatures, either average or minimum or maximum, fluctuated enormously through the entire time period. To infer the historical temperature variations clearly over the entire time period, histogram of the decadal averages of the each type of temperatures of the individual months were also plotted.

To forecast the future temperature up to 2050, a time series model was developed in IBM-SPSS using Box-Jenkins algorithm. SPSS stands for Statistical Package for Social Science (SPSS) which is a data mining and text analytics software available from IBM. It is usually used to build predictive models and conduct other analytic tasks like manipulation and managing data, calculating a wide variety of statistics and analyses with simple instructions. It has a visual interface which allows users to leverage statistical and data mining algorithms without programming.

Table 1: Study area with corresponding hydrological region and number.

<table>
<thead>
<tr>
<th>Station</th>
<th>Hydrological Regions (no.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dhaka</td>
<td>North central (3)</td>
</tr>
<tr>
<td>Mymensing</td>
<td>North East (2)</td>
</tr>
<tr>
<td>Rajshahi</td>
<td>North West (4)</td>
</tr>
<tr>
<td>Bogra</td>
<td>North West (4)</td>
</tr>
<tr>
<td>Rangpur</td>
<td>North West (4)</td>
</tr>
<tr>
<td>Chittagong</td>
<td>Eastern Hill (7)</td>
</tr>
<tr>
<td>Comilla</td>
<td>South East (6)</td>
</tr>
<tr>
<td>Cox’s Bazar</td>
<td>Eastern Hill (7)</td>
</tr>
<tr>
<td>Barisal</td>
<td>South Central (5)</td>
</tr>
<tr>
<td>Khepupara</td>
<td>South Central (5)</td>
</tr>
<tr>
<td>Khulna</td>
<td>South West (1)</td>
</tr>
<tr>
<td>Jessore</td>
<td>South West (1)</td>
</tr>
<tr>
<td>Sylhet</td>
<td>South Central (2)</td>
</tr>
</tbody>
</table>

Figure 1: Hydrological regions of Bangladesh (Source, Alam 2015)

Figure 2: Auto Correlation Factor and Partial Auto Correlation Factor
This study used a time series model in IBM SPSS as the performance and validity of the model for forecasting was justified and recommended by many researchers [27]–[29]. However, to identify the appropriate model type that fits with the historical data, residual Auto Correlation Function (ACF) and Residual Partial Auto Correlation Function (PACF) with maximum number of lags 24 and 95% confidence interval were plotted at first (Figure 2). The graphs of ACF and PACF were used as an indicator of consistency of the data. If all the spikes (Figure 2) lied within the upper and lower boundary limits then the data were considered as consistent otherwise inconsistent. Both the consistent and inconsistent data were examined in this study but handled in different ways.

For the forecasting process, at first the temperatures of each month from 1975 to 2014 (for instance, monthly average temperature of January from 1975 to 2014) were incorporated in the data view of IBM SPSS and then the temperature data were defined from the data define option. In case of consistent data, at first Expert Modeler was chosen from the analyze option and for each execution of the model some statistical parameters; stationary $R^2$, $R^2$, Root Mean Square Error (RMSE) and normalized Bayesian information criterion (BIC), of the model were chosen to plot. When the model was run, it showed both graphical and numerical forecasted values and the forecasted values were saved along with other model statistical parameters. Expert Modeler usually gives the best model option for the incorporated data. In the second step, the model was run with Exponential Smoothing option which has three criteria; i.e. Holt’s Linear Test, Brown Linear Test and Damped Linear Test. Exponential Smoothing with these entire three criteria were executed sequentially. In all cases the model statistics; stationary $R^2$, $R^2$, root mean square error (RMSE) and normalized Bayesian information Criterion (BIC) were compared. From the Expert Modeler, Exponential Smoothing with Holt’s Linear, Exponential Smoothing with Brown Linear, and Exponential Smoothing with Damped Linear test, the best time series model was chosen based on maximum $R^2$, minimum RMSE and minimum normalized BIC values. Then forecasted temperatures of that best model were taken and exported to Microsoft excel.

In case of inconsistent data, The Box-Jenkins algorithm to modeling Auto Regression Incorporated Model Analysis (ARIMA) was chosen rather than the Expert Modeler or Exponential Smoothing. ARIMA models describe the current behavior of the variables in terms of linear relationships with their past values. ARIMA model can be decomposed into two parts. First, it has an integrated (I) component (d) which represents the order of differentiating to be performed on the series to attain stationary. The second component of an ARIMA consists of an ARMA model for the series rendered stationary through differentiation. The ARMA component is further divided into AR and MA components. The Auto Regressive (AR) components capture the correlation between the current values of the time series and some of its past values. For example, AR (1) means that the current observation is correlated with its immediate past values at a time. The moving Average (MA) component represents the duration of the influence of a random shocks. For example, MA (1) means that a shock on the value of the series at time $t$ is correlated with the shock at time $t = 1$. The Auto Correlation Functions (ACF) and Partial Auto Correlation Functions (PACF) are used to estimate the values of $p$ and $q$. The models were run several times on trial and error basis using different $p$, $d$, and $q$ values until the spikes reach the boundary limits which indicates the data are stationary (Figure 3).

![Figure 3: ACF and PACF after becoming the data stationary.](image)

In the ARIMA model $p$ means the number of autoregressive orders in the model. Autoregressive
orders specify which previous values from the series are used to predict the current values. For example, an autoregressive order of 2 specifies that the value of the series two time periods in the past be used to predict the current value. In this case a higher value of \( p \) was preferred. The parameter \( d \) refers the order of differencing applied to the series before estimating models. Differencing is necessary when trends are present (series with trends are typically non-stationary and ARIMA modeling assumes stationarity) and is used to remove their effect. The order of differencing corresponds to the degree of series trend–first-order differencing accounts for linear trends, second-order differencing accounts for quadratic trends, and so on. The last parameter \( q \) refers the number of moving average orders in the model. Moving average orders specify how deviations from the series mean for previous values are used to predict the current values. For example, moving-average orders of 1 and 2 specify that deviations from the mean value of the series from each of the last two time periods be considered when predicting the current values of the series. Pure mathematical form of ARIMA model can be written as follows:

\[
W_t = \mu + \frac{\theta(B)}{\phi(B)} \alpha_t \quad \text{Where,} \\
\begin{align*}
t & \text{is the index time} \\
W & \text{is the response series } Y_t \text{ or a difference of the response series} \\
\mu & \text{is the mean term} \\
B & \text{is the backshift operator that is;} \\
BX_t & = X_{t-1} \\
\phi(B) & \text{is the autoregressive operator, represented as a polynomial in the back shift operator:} \\
\phi(B) & = 1 - \phi_1B \ldots - \phi_pB^p \\
\theta(B) & \text{is the moving-average operator, represented as a polynomial in the back shift operator:} \\
\theta(B) & = 1 - \theta_1B \ldots - \theta_pB^p \\
\alpha_t & \text{is the independent disturbance, also called the random error.}
\end{align*}
\]

Finally the forecasted monthly mean of daily averages, monthly mean of daily minimum and monthly mean of daily maximum temperatures from all the best models were saved and exported to Microsoft Excel. The graphs of the individual temperature types and individual months were plotted and analyzed afterwards which are shown in the results and discussions.

3. RESULTS AND DISCUSSION

From the historical average temperature, this study revealed that the average temperature declined in winter and spiked in the summer which is an indication of cold winter and hot summer in the future. However, among the all stations Dhaka (Figures 4-7), Chittagong, Sylhet and Cox’s Bazar showed an exceptional case where temperatures were never went below but in both winter and summer the temperature increased significantly which is consistence with reference [30]. In winter, the magnitude of the historical minimum temperature decreased by 0.3℃ to 1.6℃ from 1975 to 2014 where the maximum decreasing rate was observed in January (Figures 8-11). On the contrary, in summer the extent of the maximum temperature increased by 0.5℃ to 3.0℃ throughout the total time period where the maximum increasing rate was observed in April (Figures 8-11). The projected temperature shows that the maximum temperature may increase up to 1.50℃±0.3℃ from 2015 to 2050 and minimum may vary by −0.8±0.3℃. The summarized results of all stations are shown in the Table 2 (ANNEX).
Figure 4: Decadal average of the monthly average temperature in Dhaka

Figure 5: Average temperature variations in Dhaka

Figure 6: Decadal averages of the monthly minimum temperature in Dhaka
Figure 7: Decadal averages of the monthly maximum temperature in Dhaka

![Bar chart showing monthly maximum temperatures in Dhaka from 1975-2014.]

Figure 8: Decadal average of the monthly mean temperature in Rajshahi

![Bar chart showing monthly mean temperatures in Rajshahi from 1975-2014.]

Figure 9: Mean temperature variations in Rajshahi

![Line graph showing monthly temperature variations in Rajshahi from 1975 to 2045.]
Dhaka and Chittagong are considered as the mega cities of Bangladesh. The concentrations of Green House Gases (GHGs) in the atmosphere and humidity have direct influence on the increase in temperature. But in these two mega cities, there may have some other reasons behind the local temperature rise in addition to these two factors. For example, heat emissions from the industries, vehicles and also a very dense population may contribute greatly to the temperature rise. In this sense, Sylhet and Cox's Bazar were supposed to show different trends as they are not like Dhaka and Chittagong. However, this study did not deal with the causes of temperature rise but worked only on the statistical analysis and finally projected up to 2050.

This study used the temperature data from 1975 to 2014 and observed yearly variations of the individual months. For example, the variations of the maximum, minimum and average temperatures of the month January throughout the total time period. But from the yearly variations of the individual months, it is really difficult to assess the trends as the magnitude of the temperature fluctuated a lot through the entire time period. For this reason this study mainly focused on the decadal variations which made the things easy to assess the variations of individual months. Based on this observation, this study suggests that the highest increase in the maximum and average temperature was observed in April and maximum temperature increased during summer and also in winter except the month of January which is consistent with the observation of Rahman 2013 and Basak et al. 2013. However, among the thirteen stations Dhaka, Chittagong, Sylhet and Cox's Bazar showed different trends unlike the others.

The forecasted temperatures showed almost similar trends like their respective historical temperatures. It is obvious that each model's output depends on its input and gives the output based on it. As ARIMA is a time series model, its forecasting process will be based on its historical input. This is why the forecasted temperature showed almost similar trends like the trends of their historical temperatures. But this study found a bit different forecasting values than the other studies. For instance, Rahman & Lateh (2015) found that by 2020 the maximum temperature will rise by 1.0℃ whereas this study found maximum temperature may lead to 1.80±0.3℃ by 2050. This study also found that an average temperature may vary by −0.8 ± 0.3℃ which is positively consistent with the trend of the reference [25] but not with the numerical figures exactly. However, the forecasted values also depend on model type used and their forecasting process. This study used Box-Jenkin's algorithm using IBM-SPSS which is based on the historical data only. But temperature variations mainly rely on some environmental and climatological factors which are not taken into consideration in this study.

It is worth noting that the forecasting of temperature is kind of prediction which may be or may not turnout exact in the future. But if the existing state contains business as usual then the forecasted results may come true over time.
4. CONCLUSION

Based on the historical and forecasted temperatures, this study concludes that winter may get colder and reverse may happen for the summer where January and April would be the coldest and the hottest months respectively in the future. By the year 2050, the average temperature may rise by $1.0 \pm 0.3^\circ C$ and the maximum temperature may go up to $1.50 \pm 0.3^\circ C$, whereas the minimum temperature may vary from $-0.8^\circ C$ to $0.2^\circ C$.

Overall, Bangladesh is likely to experience a relatively warmer weather in years to come. However, using temperature records of all the available stations and improving forecasting techniques, the predictions can be made far more precisely.

REFERENCES

[19] M. Hashizume, Y. Wagatsuma, T. Hayashi,


### Table 2: Summary of the historical temperature of individual stations

<table>
<thead>
<tr>
<th>Stations</th>
<th>Average</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dhaka</td>
<td>Increased in all months</td>
<td>Increased in all months except January.</td>
<td>Increased in all months.</td>
</tr>
<tr>
<td>Chittagong</td>
<td>Increased in all month but almost remained</td>
<td>In all months increased in first three decades but decreased in the last decade.</td>
<td>Increased in all months.</td>
</tr>
<tr>
<td></td>
<td>same in January</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khulna</td>
<td>Remained almost the same in all months except</td>
<td>Increased in all months except January where a bit decreased.</td>
<td>Little increased in winter but almost remained the same in summer.</td>
</tr>
<tr>
<td></td>
<td>December where increased a little in the last decades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rajshahi</td>
<td>Significant decreased in winter and little</td>
<td>Decreased in January and little increase in summer and almost remained same in October, November and December</td>
<td>Little increase in summer except May. In winter only in January remained same but increased in December</td>
</tr>
<tr>
<td></td>
<td>increase in summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rangpur</td>
<td>Increased in all months except January where</td>
<td>Increased in all months except January where decreased in last three months. But in the last decade in the month of December otherwise increased in the first three decades.</td>
<td>Increased in all months except January, May and June where it remained the same only in December it decreased.</td>
</tr>
<tr>
<td></td>
<td>it decreased but remained almost the same in December.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bogra</td>
<td>Increased in all months except January and</td>
<td>Increased in all months except January and December.</td>
<td>Increased in all months except January and December.</td>
</tr>
<tr>
<td></td>
<td>December.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mymensing</td>
<td>Decreased in November, December, January and February. In other months it remained almost the same with little fluctuations.</td>
<td>Increased in all months except January, March and April.</td>
<td>Increased in all months throughout the total time period.</td>
</tr>
<tr>
<td>Jessore</td>
<td>A little decrease in December, January and</td>
<td>Increased in all months except January.</td>
<td>Increased in all months except December, January and February.</td>
</tr>
<tr>
<td></td>
<td>March otherwise increased but not significantly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sylhet</td>
<td>Increased in all months except January where little fluctuations observed.</td>
<td>Increased in all months throughout the total time period.</td>
<td>Increased in all months throughout the total time period.</td>
</tr>
<tr>
<td>Cox’s Bazar</td>
<td>Increased in all months throughout the total</td>
<td>Increased in all months throughout the total time period.</td>
<td>Increased in all months throughout the total time period.</td>
</tr>
<tr>
<td></td>
<td>time period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khepupara</td>
<td>Decreased in December, January and February. On the contrary, it remained the same in the other months.</td>
<td>Increased in all months throughout the total time period.</td>
<td>Decreased in November, December, January, February and March whereas in the other months a little increase was observed.</td>
</tr>
<tr>
<td>Barisal</td>
<td>Decreased only in January but increased in April, May and June whereas in others months it did not show any significant variation.</td>
<td>Increased in all months except January where decreased very little.</td>
<td>Increased in all months throughout the total period of time.</td>
</tr>
<tr>
<td>Comilla</td>
<td>Decreased only in January but in the other months it remained almost the same.</td>
<td>Decreased only in January but increased in the other months except December where it fluctuated.</td>
<td>Increased in all months except January where decreased very little.</td>
</tr>
</tbody>
</table>
MODEL VALIDATION

To validate the model this study used the average temperature of the month July of Dhaka station and found that at the beginning of the time period the model fit values were not so close to the observed values. But after certain years the fit values were adjusted with the observed values which is shown in Figure 11.

Figure 11: Model validation and forecasting