Forecasting and Modelling the Impact of Air Temperature on Global Warming: Karachi as a Case Study

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ABSTRACT: The world has been experienced extreme global warming and climate changes and reason to increase temperature, rising sea level, droughts, and flooding. The transportation and construction activities in Karachi affected the Green House Gases (GHG) mostly and carbon dioxide (CO2) emission. The novelty of this paper to study the impact the temperature over time and forecast the maximum and minimum Karachi temperature, in this regard 60 years mean monthly maximum and minimum air temperature of Karachi ranging from 1961 to 2020 data under consideration. The minimum and maximum Karachi monthly average air temperatures are stationary. ARMA (p, q) model technique applied to evaluate forecasting and modelling the behaviour of Karachi maximum and minimum air temperature using Pakistan Metrological Department (PMD) data. The adequacy of model describes via least values Akaike information criterion (AIC), Bayesian Schwarz information criterion (SIC) and Hannan Quinn information criterion (HIC). Durbin- Watson (DW) test is also applied. DW values (< 2) shows that all month's average maximum and minimum Karachi air temperature are strongly correlated. Diagnostic checking tests like Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Theil's U-Statistics are used to predict minimum and maximum Karachi monthly average air temperatures. Theil's U-Statistics values of each month lie near to zero in the results which are showed that the air temperature is strongly correlated to previously observed values. This study is very helpful to observe the impact of air temperature on the global warming.

Keyword: ARMA (p, q) model, air temperature, Root Mean Square Error, Skewness, Kurtosis.

1. INTRODUCTION

Global warming threatens our environment and human health. It also causes high temperatures, rising sea levels, droughts, and floods. There are a variety of features that contribute but the work of transportation and travel during the construction process contributes to the high GHG in the big city of Karachi (Sagheb et al. 2011). The United Nations (UN) Office for Disaster Risk Reduction (UNDRR) between 2000 and 2019, heatwave accounted for 13% of all catastrophic deaths (91pc) worldwide. In addition, United Nations (UN) experts have warned Karachi to prepare for extraordinary temperatures as global temperatures rise by 1.1 ℃ and will continue to cause such disasters (Dawn News. 2020). Historically, rising temperatures could have a direct impact on agriculture, the sea, and the prevalence of extreme weather. In the last few years especially from 2015 to 2020 the city of Karachi has experienced some very bad weather. Usually, May to June should be the hottest months before the onset of heavy rains in Karachi. Rays of solar radiation in the heat of the Day rise to 40 to 42 ℃ in parts of Sindh, including Karachi. According to the German clock, the German think tank in its current global climate risk report ranked Pakistan 05th in the list of the top 10 countries most affected by climate change (https://reliefweb.int/report/pakistan/impact-climate-change-karachi-may-be-one-pakistan-s-biggest-threats. 2021). Karachi may be one of the most affected cities in Pakistan due to climate change. This large city cannot withstand the effects of global warming. There are several factors that contribute to global warming and CO2 emissions. However, construction work accounts for about 39% of all carbon emissions in the world (https://www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published (2021). with the building performance of the building as a necessary accounting strength of about 28%. While 11% CO2 is emitted from the construction process, the logistics / production process, the life process and the demolition process.

In the middle of the airflow process it emits high temperatures and particles that increase global warming. Similarly, land transport does the same, releasing gases such as hydrocarbon, carbon dioxide, sulfur oxides, nitrogen, and black carbon etc. into the environment causing higher temperatures. CO2 is the only emissions from the construction and manufacturing industry with a total percentage of petrol consumption in Pakistan at 23.84 per cent from 2014 which was significantly higher than 43 years. Concrete, on the other hand, is the most common building material in Pakistan, known as the largest CO2 emitters that produce hazardous waste to the environment during processes related to its production, construction, acece maintenance and demolition (https://dunyanews.tv/en/Pakistan/595585-Hottest-day-history-Karachi-breaks-74-yr-old-record-44-degree. 2021). Factors contributing to Karachi climate change can vary so it is difficult to measure them until all of them have been raised. A few decades ago, Karachi experienced the unexpected and minimal impact of air temperature as presented in Table 1.

SN	Month	Year	Record Break	Max Temperature ℃	Year	Min Temperature ℃
1.	January	1965		32.80	1934	00.00
2.	February	2016		36.50	1950	03.30
3.	March	2010		42.20	1979	07.00
4.	April	1947 \ 2021	72 years	44.40	1967	12.20
5.	May	1938		47.80	1989	17.70
6.	June	1979		47.00	1997	22.30
7.	July	1958		42.00	1984	20.00
8.	August	1964		41.70	1994	18.00
9.	September	1951		42.80	1949	10.00
10.	October	1994		43.30	1938	06.10
11.	November	2011		38.50	1986	01.30
12.	December	1938		35.50	1934	00.00

Table 1: Recorded Maximum and Minimum Air Temperature Karachi.

On March 11, 2020, the World Health Organization (WHO) announced that the COVID-19 pandemic, which survived the Chain, spread to Europe, the United States, and other parts of Asia (Arsalan. 2020). Outcome of Covid 19: The good COVID 19 has caused great damage to all developed and developing countries causing serious health problems and shutting down many industries due to tight operating procedures (SOPs). China has experienced a sharp decline in economic activity and CO2 emissions due to key adherence especially in Wuhan and Nanjing (Forster. 2020; Bauwen. 2020). On the other hand, the epidemic has dramatic effects on the environment. As the virus spreads around the world many countries have shut down their passengers to limit air and land travel. Daily activity in the country, province or city center has shown a significant reduction in CO2 (Zhang et al. 2020). Only in Pakistan's air transport system causes 40% CO2 emissions (Le Quéré 2020).

During the epidemic the construction and construction activities have been halted but the question is how much of these activities are causing global warming in the capital city of Karachi. Large, transport offices were closed during the closure as most of the staff worked at home. Energy consumption would not be as high as the energy required for cooling and the light structure was not high during closing. Thus, 60 years means total air temperature and a minimum of a month in Karachi from 1961 to 2020 data is used to predict temperature over time. Low and low temperature data were observed for the predicted city temperature. The effect of heat during the epidemic was compared using Pakistan Metrological data where the activity of the transport and construction sector was limited during the closure compared to other years. Low and high temperature data are observed, compared, and analyzed by urban temperatures.

2. EXPERIMENTAL DETAIL

The most well-inserted forms of ARMA (p, q) are selected by the Akaike data (AIC) data, the Bayesian Schwarz information (SIC) and the Hannan Quinn information system (HIC). The predictive test for each of the Karachi models above and the minimum air temperature each month will be determined by diagnostic test tests such as Root Mean Squared (RMSE) error, Mean Absolute Error (MAE), Mean Absolute Percentage (MAPE) error and Theil's U-Statistics. High probability estimates mean that the ARMA model (p, q) is being studied. The Statistical EViews version 9.0 software is used for the analysis and calculation of ARMA (p, q) model and relevant graphs.

BASIC EQUATIONS OF STATISTICAL ANALYSIS

This section consists of short statistical analysis.

DIAGNOSTIC TEST

The selection of the most suitable models was evaluated by the Akaike information system (AIC), the Bayesian Schwarz information system (SIC) and the Hannan Quinn information system (HIC). The Durbin-Watson test also confirms the most suitable model. Guessing on Karachi's highest temperature model and Karachi's low temperature model is confirmed based on Root mean (RMSE) square error, Mean Absolute Error (MAE), Mean Absolute Percentage (MAPE) error and Theil's Statistics. The highest point of these words is given within the following.

AKAIKE EVIDENCE MEASURE: The AIC test was accessible by Hirotogu Akaike in 1973 (Hassan et al. 2001). It is the interruption of the utmost probability attitude the range standard is mortaring the minimum quantity worth of AIC.

$$AIC = -2Log(likelihood) + 2X \qquad (1)$$

Where X is that the perfect limit numbers. The probabilities are that a ration of the suitable model. Minimum values exhibition the finest trim.

SCHWARZ CRITERION: The SIC test is rummage-sale to select the leading suitable model among finite models. The suitable model trusts on the littlest amount value of SIC. Schwarz criterion (SIC) was presented by Gideon E. Schwarz. It is carefully linked to the AIC.

$$SIC = -2\ln(\text{Likelihood}) + (X + X\ln(N)) \quad (2)$$

Where X is that the model parameter numbers. N exhibits the quantity of observations.

Hannan-Quinn criterion: The HIC is that the criterion for model selection. This test is an alternate to AIC and SIC.

$$HQC = -2\,\text{Log}(\text{Likelihood}) + 2\,(X + X\ln(N)) \quad (3)$$

Where X is that the model parameter numbers. N exhibits the number of observations.

Durbin-Watson Test: The DW statistics might be a test for measuring the linear association between the adjacent residual from a regression model. The hypothesis of Durbin- Watson statistics is $\tau = 0$ is that the specification.

$$V_t = \tau\, V_{t-1} + \epsilon_t \quad (4)$$

Durbin-Watson (DW) Satisfaction 2 shows no serial overlap. If the Durbin-Watson (DW) is less than 2 indicates that combination and as a result the distance from 2 to 4 indicates that negative combination. Series is highly connected when values are close to zero.

Mean Absolute Error: The mean absolute error is stated as a mathematically formed.

$$MAE = \frac{1}{n}\sum_{t=1}^{n}|\rho_t| \quad (5)$$

Where is that number of views. The Mean Absolute Error (MAE) error is fully applicable to the deviation of the predicted values from the actual ones. It is also called the mean deviation between Mean Absolute (MAD). It denotes the magnitude of the total error created by the prediction. MAE does not eliminate the effect of positive and negative errors. MAE does not define error indicators. It should be as small as possible to predict permanently. MAE depends on the conversion of information and thus the size of the scale. The worst weather error does not exist with MAE (Akaike 1987; Adhikari et ai. 2021).

Mean Absolute Percentage Error (MAPE): The Mean Absolute Percentage Error (MAPE) is defined as

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{\rho_t}{X_t}\right| \times 100 \qquad (6)$$

Mean Absolute Percentage (MAPE) error provides the total daily error value. It is independent of the scale of the scale. MAPE does not track error correction. Serious deviations are not punished by MAPE. At this rate, distinctly signed errors do not irritate MAPE [1-13-14]. This means that due to the benefits of freedom and comment on the share error rate (MAPE), one of the most widely used measures of predictive accuracy. While independent of measurement but it is full of data conversion (Jenkins et al. 1970).

Root Mean Squared Error (RMSE): The root mean squared error (RMSE) is defined as

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\rho_t^2} \qquad (7)$$

RMSE calculates the average square deviation of the predicted values. Signed optional errors are not equal. RMSE provides an overview of the error that occurred during the forecast. By using precision measures, small and progressive errors, such as 0.1 RMSE and 1% MAPE, can often be detected. In RMSE, a full forecasting error is sickened by each major error. For example, the biggest mistake is much longer than the small mistakes. It does not indicate general error correction. RMSE is underperformed with information modification and rate conversion. RMSE can be a reliable measure of the general forecast error (Akaike 1987).

Theil's U-Statistics (U): Theil's U-Statistics is defined as

$$U = \frac{\sqrt{\frac{1}{n}\sum_{t=1}^{n}\epsilon_t^2}}{\sqrt{\frac{1}{n}\sum_{t=1}^{n}{f_t}^2}\sqrt{\frac{1}{n}\sum_{t=1}^{n}{Y_t}^2}} \qquad 0 \le U \le 1 \qquad (8)$$

Where f_t represent the forecasted value and Y_t shows that the actual value. U is the normalized measure of the total forecast error. U is equal to 0 exhibits the perfect fit.

Tests for Normality

Typical tests are performed to test whether the target data is usually distributed or not. These tests are supported by a two-step numerical analysis, condition appearance and additional kurtosis. Info sets are usually distributed when those steps are close to zero. The adoption of the Jurque-Bera test also focuses on inclination and kurtosis. Therefore, the standardized test consists of looking at the skewness and kurtosis on which Jurque-Bera tests rely.

Trend: Skewness determines the degree of asymmetry of information.

$$\text{Skewness} = \frac{\sum_{i=1}^{n}(Y_i - \bar{Y})^3}{(n-1)R^3} \qquad (9)$$

When Y¯means the mean and R that the difference and n that the value of the values (Christian and Jean-Michel 2004). Doubts of standard distribution. If the information is transmitted normally, then the folly suggests that the following data are equal. If the information is usually distributed when the distribution is consistent (the amount of skewness can be zero). Distribution is well removed, if it is greater than zero and badly shaken if it is zero.

Kurtosis: The Kurtosis measures the degree of peakness of the data. Kurtosis has been calculated as

$$\text{Kurtosis} = \frac{\sum_{i=1}^{n}(Y_i - \bar{Y})^4}{(n-1)R^4} \qquad (10)$$

Where Y¯is that the mean, R is that the variance and n is that the number of values of the statistical data. Kurtosis of an expected distribution is termed mesokurtic if it is up to 3. Whereas it is leptokurtic if the value is bigger than 3. It is Platykurtic if the worth is also a smaller amount than 3.

Jurque-Bera Statistics Test (JBS): The JBS is recognized with the normality of the information with skewness is adequate zero and excess kurtosis is additionally up to zero. Jurque-Bera test is defined as follows.

$$\text{Jurque-Bera test} = \frac{n(Skewness)^2}{6} + \frac{n(Kurtosis-3)^2}{24} \qquad (11)$$

Jurque-Bera test statistics are rated as a double distribution of Chi by two degrees of freedom. The null hypothesis (Ho) can be a traditional distribution with zero skewness and excessive kurtosis (similar to kurtosis is 3). Another hypothesis (HA) of the data provided is not uncommon for distribution.

ARMA Model

In stochastic process, Autoregressive process AR (p) can be stated by a weighted sum of its previous value and a white noise. The generalized Autoregressive process AR (p) of lag p as follow

$$Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \epsilon_t \qquad (12)$$

Here ϵ_t white sound with mean E (ϵ_t) = 0, variance Var (ϵ_t) = σ^2 and Cov (ϵ_{t-s}, ϵ_t) = 0, if s ≠ 0. For every t, suppose that τ_t independent with Y_{t-1}, Y_{t-2},… .. τ_t not compatible with each Y_s s <t. Reversal of AR (p) models of previous data set values. While the MA model (q) is related to error words as descriptive variants [17]. The standard procedure for mediating MA (q) of lag q follows.

$$Y_t = \epsilon_t + \beta_1 \epsilon_{t-1} + \beta_2 \epsilon_{t-2} + \ldots + \beta_q \epsilon_{t-q} \qquad (13)$$

The process Y_t is defined by the ARMA Process.

$$Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \epsilon_t + \beta_1 \epsilon_{t-1} + \beta_2 \epsilon_{t-2} + \ldots + \beta_q \epsilon_{t-q} \quad (14)$$

With ϵ_t is an uncorrelated process with mean zero. The prediction of ARMA (p, q) process shows the decay to be sinusoidally and exponentially to zero.

Unit Root Test

The random walk model is expressed as

$$Z_t = \rho Z_{t-1} + u_t \qquad -1 \le \rho \le 1 \quad (15)$$

When Zt is the value of a time series and ut represents the error of white noise while ρ is the corresponding value. Equation (15) is used to reverse Zt to the reverse value Zt-1 ratio of the root test unit. If the expected value ρ is equal to 1 series following the unit root test and the non-existent hypothesis is rejected [18]. Changing the equation by taking out Zt-1 on both sides

$$Z_t - Z_{t-1} = \rho Z_{t-1} - Z_{t-1} + u_t$$

$$Z_t - Z_{t-1} = Z_{t-1}(\rho - 1) + u_t$$

$$\Delta Z_t = \phi Z_{t-1} + u_t \quad (16)$$

Where Δ and ϕ represent the operation of the first difference. The null hypothesis ($\phi = 0$) for time series (non-stationary condition) follows the unit root test (da Silva Lopes 2006).

Augmented Dickey Fuller (ADF) tests are used to solve autocorrelation problems. This test is performed incrementally by three figures, dependent variable (Δ Zt) additional values remaining

and Yt represents random movement with

$$\Delta Z_t = \gamma 1 + \gamma_{2t} + \phi Z_{t-1} + u_t \quad (17)$$

Where γ_{2t} and $\gamma 1$represents the intercept and trend respectively.

The following equation

$$\Delta Z_t = \phi Z_{t-1} + u_t \quad (18)$$

shows neither intercept nor trend.

And the equation

$$\Delta Z_t = \gamma 1 + \phi\, Z_{t-1} + u_t \qquad (19)$$

Shows the intercept ($\gamma 1$) only (Kwiatkowski *et al.*, 1992; McCarthy, 2015).

For the null hypothesis H_0: If the variables have a unit root (non-stationary data) then H_0 is rejected when p-value is less than 5% or the critical value of the absolute value of Augmented Dickey Fuller (ADF) test is greater the values at 1% and 5% significance level.

3. RESULTS AND DISCUSSION

This study focused to estimate modelling and forecasting the future Karachi maximum and minimum air temperatures with Box-Jenkins ARMA (p, q) models. In this regard, mean monthly Karachi maximum and minimum air temperatures ranging from 1961 to 2020 data are used. Each cycle consists of each monthly average (1961-2020) data are used.

S.N	Months	Mean	Median	Std. D	Skewness	Kurtosis	Jur-Bera
1	January (1961-2020)	26.158	26.15	1.0980	-0.2963	3.3833	1.2454
2	February (1961-2020)	28.190	28.400	1.46098	-0.14951	2.508887	0.826514
3	March (1961-2020)	32.0767	31.7000	1.42963	0.55635	2.87566	3.133914
4	April (1961-2020)	34.63833	34.80000	1.200295	-0.464940	2.614918	2.532411
5	May (1961-2020)	35.45833	35.50000	0.906528	0.471162	4.305775	6.482564
6	June (1961-2020)	35.24000	35.20000	0.842957	0.356270	3.181870	1.351978
7	July (1961-2020)	33.3800	33.50000	0.791437	-0.575589	3.162964	3.379425
8	August (1961-2020)	32.0633	32.05000	0.776556	-0.014867	2.232942	1.473155
9	September (1961-2020)	32.94467	32.89000	1.097074	0.717705	3.494313	5.761874
10	October (1961-2020)	35.07667	35.10000	1.148524	-0.372990	2.535301	1.931081
11	November (1961-2020)	32.2667	32.50000	0.955567	-0.397746	2.213957	3.126680
12	December (1961-2020)	27.93500	28.10000	1.210662	-0.113984	3.123287	0.167924

Table 2: Descriptive Statistics for Karachi Maximum Average Monthly Air Temperatures (1961-2020)

Table 2 demonstrates the descriptive statistics of mean monthly Karachi maximum air temperatures ranging from 1961 to 2020 which is consists of each month (1961-2020). Mean, median, standard deviation, skewness, kurtosis and Jurque-Bera test have been calculated of each cycle. January has mean ± standard deviation with 26.158± 1.0980. February has 28.190± 1.46098. March has 32.0767± 1.42963. April has 34.63833± 1.200295. May has 35.45833± 0.906528. June has 35.2400 ± 0.842927. July has 33.38000 ± 0.791437. August has 32.0633± 0.776556. September has 32.94467± 1.097074. October has 35.07667± 1.148524. November has 32.2667± 0.95559. December has 27.93500±1.210662. Most of the months show negative skewness which represent that the risk of left tail events and unpredictable. March, May, June, and September indicate positive skewness. Whereas different months shows maximum air temperature have different kurtosis behaviour. Some months shows platykurtic which represents that flat tail (peakness) and remaining months evaluate leptokurtic (heavy tail). In Jurque-Bera test, maximum air temperature of each month (1961-2020) represent that rejected the null hypothesis (normally distributed by any mean and variance).

S.N	Months	Mean	Median	Std. D	Skewness	Kurtosis	Jur-Bera
1	January (1961-2020)	11.200	11.2000	1.5821	0.010721	2.430687	0.811443
2	February (1961-2020)	13.7350	13.8000	1.828014	0.153141	3.377305	0.590420
3	March (1961-2020)	18.4867	49.5500	1.295686	0.103063	2.903723	0.129393
4	April (1961-2020)	22.9967	22.9500	1.365801	-0.402918	3.243466	1.771616
5	May (1961-2020)	26.4367	26.40000	0.990115	-0.309804	2.428584	1.776079
6	June (1961-2020)	28.2300	28.20000	0.616249	0.108956	3.630071	1.111188
7	July (1961-2020)	27.60500	27.60000	0.629077	-0.570490	3.905819	5.305862
8	August (1961-2020)	26.30833	26.45000	1.106727	-3.223907	18.80637	728.5388
9	September (1961-2020)	25.58333	25.55000	0.821360	-0.054398	2.702505	0.250850
10	October (1961-2020)	21.98000	22.2000	1.833104	-0.253617	2.902498	0.680750
11	November (1961-2020)	16.84667	16.80000	1.898391	0.358797	3.502721	1.919176
12	December (1961-2020)	12.43500	12.60000	1.497209	0.048388	2.782486	0.141695

Table 3: Descriptive Statistics for Karachi Minimum Average Monthly Air Temperatures (1961-2020)

Table 3 depict that the descriptive statistics of mean monthly Karachi minimum air temperatures ranging from 1961 to 2020 which is consists of each month (1961-2020). January has 11.2± 1.5821. February has 13.7350± 1.828014. March has 18.4867± 1.295686. April has 22.9967± 1.365801. May has 26.4367± 0.990115. June has 28.2300 ± 0.616249. July has 27.60500 ± 0.629077. August has 26.30833± 1.106727. September has 25.58333± 0.821360. October has 21.98000±1.833104. November has 16.84667±1.898391. December has 12.43500±1.497209. Most of the months show positive skewness (right tail). Different months have different kurtosis behaviour. Some months shows leptokurtic (heavy tail) which represents the strong correlation among pervious values, and rest of months evaluate platykurtic which represents that flat tail (peakness). In Jurque-Bera test, minimum air temperature of each month (1961-2020) represents that the null hypothesis (normally distributed by any mean and variance) is rejected. The ARMA model is a tool for analysis and calculating of the fundamental structures or getting the predictions of future values in time series. The appropriate models for Karachi maximum and minimum air temperatures are selected based on Durbin-Watson statistics test. The Durbin- Watson (DW) approach to zero is describe the series are positively correlated. The value 2 shows that the series has no correlation. If DW is ranged between 2 and 4 indicates negative correlation. Least square estimation is used to estimate ARMA process. The coefficient of determination R2 range scale indicated value (from 0 to 1), a large value of R2 shows that models reveal a closer fit to the time series data.

Months	ARMA (p, q)	R^2	ADJ R^2	SE Reg	Log Likelihood	AIC	SIC	HQC	DWS
Jan	ARMA (8, 8)	0.001	-0.0525	1.1264	-90.2394	3.1413	3.2809	3.1959	1.70008
Feb	ARMA (5, 5)	0.112	0.0641	1.4134	-106.1251	3.6708	3.81046	3.72545	1.905304
Mar	ARMA (5, 8)	0.1822	0.1384	1.32703	-100.6119	3.48706	3.62669	3.54168	1.953579
Apr	ARMA (3, 3)	0.0591	0.0087	1.19504	-94.11827	3.27061	3.41023	3.32522	1.878168
May	ARMA (4, 4)	0.0579	0.0075	0.90314	-78.26200	2.74207	2.88169	2.79668	2.023145
June	ARMA (2, 1)	0.3691	0.3353	0.68724	-60.92862	2.16429	2.30391	2.21890	1.958390
July	ARMA (1, 5)	0.1048	0.05686	0.76860	-67.38142	2.37938	2.51900	2.43400	1.956939
Aug	ARMA (3, 3)	0.0429	-0.0083	0.77979	-68.25707	2.40857	2.54819	2.46318	1.736523
Sep	ARMA (9, 7)	0.1090	0.06130	1.06292	-87.21517	3.04051	3.18013	3.09512	1.545102
Oct	ARMA (1, 1)	0.1159	0.06858	1.108444	-89.42402	3.11413	3.25376	3.16875	1.975780
Nov	ARMA (2, 2)	0.0988	0.05051	0.93112	-79.08439	2.76948	2.90910	2.82409	1.157654
Dec	ARMA (3, 3)	0.0770	0.02753	1.19388	-93.93413	3.26447	3.40409	3.31909	1.308388

Table 4: Diagnostic test of ARMA (p, q) for Karachi Maximum Average Monthly Air Temperatures (1961-2020)

Table 4 depicts the appropriate model for each months of Karachi maximum air temperatures (1961-2020). Least square estimation is used to estimate ARMA (p, q) model. Adequacy of the models is checked by AIC, SIC, HQC and Maximum log likelihood tests. The criteria of choose most appropriate model is less values of AIC, SIC, HQC and DW value is less than 2. According to Durbin- Watson (DW) test and AIC, SIC and HQC represent that April, August and December follow the best fitted model, are ARMA (3, 3). January shows most appropriate model is ARMA (8, 8). February indicate ARMA (5, 5) is best fitted model. March explore ARMA (5, 8) is appropriate model. May shows most appropriate model is ARMA (4, 4). June explore ARMA (2, 1) is best fitted model. July has ARMA (1, 4) is appropriate model. September indicate ARMA (9, 7) is best fitted model. October explore ARMA (1, 1) is appropriate model and November shows most appropriate model is ARMA (2, 2).

Months	ARMA (p, q)	R^2	ADJ R^2	SE Reg	Log Likelihood	AIC	SIC	HQC	DWS
Jan	ARMA (3, 3)	0.1119	0.06431	1.5304	-108.9463	3.76487	3.90450	3.81949	1.803513

Feb	ARMA (2, 2)	0.2605	0.22088	1.61135	-112.2341	3.87447	4.01109	3.92908	1.539951
Mar	ARMA (1, 1)	0.4600	0.43108	0.97729	-82.20201	2.87734	3.01302	2.92802	1.981122
Apr	ARMA (2, 3)	0.2792	0.24060	1.190209	-93.84288	3.26143	3.40105	3.31604	1.756209
May	ARMA (2, 2)	0.2693	0.23019	0.86871	-75.16614	2.63887	2.77849	2.69239	1.779427
June	ARMA (2, 2)	0.1996	0.15675	0.565895	-49.50644	1.78355	1.92317	1.83816	1.850507
July	ARMA (1, 1)	0.0481	-0.0029	0.62999	-55.43766	1.98125	2.12088	2.03587	1.887623
Aug	ARMA (1, 1)	0.0484	-0.0025	1.10813	-89.37702	3.11257	3.25219	3.16718	1.884068
Sep	ARMA (1, 1)	0.1744	0.13022	0.766019	-67.30791	2.37693	2.51655	2.43155	1.859151
Oct	ARMA (9, 6)	0.2070	0.16453	1.675530	-115.2324	3.97441	4.11404	4.02903	1.652979
Nov	ARMA (1, 1)	0.1058	0.05791	1.842605	-119.8714	4.12905	4.26867	4.18366	1.881639
Dec	ARMA (2, 2)	0.2433	0.20276	1.33683	-100.9122	3.49708	3.63670	3.55169	1.747414

Table 5: Diagnostic test of ARMA (p, q) for Karachi Minimum Average Monthly Air Temperatures (1961-2020)

Table 5 describe that the appropriate model for each months of Karachi minimum air temperatures (1961-2020). Most of the months indicate that the most appropriate model is ARMA (1, 1). Remaining months explore the best fitted model is ARAM (2, 2). Whereas the forecasting evolution of each month maximum Karachi air temperature is analysis in the view of diagnostic checking by Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and U tests in Table 6.

Months	Cycles	ARMA (p, q)	RMSE	MAE	MAPE	Theil's U-Statistics
Jan	1	ARMA (8, 8)	0.95995	0.749935	2.849781	0.018317
Feb	2	ARMA (3, 1)	1.415891	1.169637	4.182772	0.025097
Mar	3	ARMA (5, 8)	1.429994	1.190426	3.688714	0.022271
Apr	4	ARMA (3, 3)	1.170910	0.931425	2.705899	0.016881
May	5	ARMA (4, 4)	0.906172	0.707484	1.990004	0.012772
June	6	ARMA (2, 1)	0.810055	0.649168	1.837062	0.011490
July	7	ARMA (1, 5)	0.790753	0.613130	1.849194	0.011843
Aug	8	ARMA (3, 3)	0.787744	0.651390	2.033833	0.012279
Sep	9	ARMA (9, 7)	1.098765	0.813010	2.427218	0.016658
Oct	10	ARMA (1, 1)	1.129824	0.910085	2.607623	0.016096
Nov	11	ARMA (2, 2)	0.903958	0.768850	2.374901	0.014040
Dec	12	ARMA (3, 3)	1.188373	0.945916	3.387101	0.021281

Table 6: Forecast Evolution for Karachi Maximum Average Monthly Air Temperatures (1961-2020)

MAE is least among MAE, RMSE, and MAPE of all the months. According to RMSE shows that August has least value with 0.787744. MAE shows July has least value with 0.613130 and MAPE represent that June has least value (1.837062). Theil's U-Statistics is also applied evolution of forecasting of each month Karachi maximum air temperature. According to Theil's U-Statistics is equal to 0 exhibits the perfect fit. Each month has Theil's U-Statistics value near to zero which is shows that month air temperature is correlated to previous one. Theil's U-Statistics explain that October has ARMA (1, 1) is best fitted model with 0.016096 value.

Months	Cycles	ARMA (p, q)	RMSE	MAE	MAPE	Theil's U-Statistics
Jan	1	ARMA (3, 3)	1.551177	1.291205	11.80153	0.068907
Feb	2	ARMA (2, 2)	1.819293	1.389515	10.49024	0.065791

Mar	3	ARMA (1, 1)	1.26921	0.992359	5.431667	0.034235
Apr	4	ARMA (2, 3)	1.334917	1.065271	4.798778	0.029021
May	5	ARMA (2, 2)	0.958591	0.790791	2.992003	0.018156
June	6	ARMA (2, 2)	0.591310	0.432525	1.524124	0.010490
July	7	ARMA (1, 1)	0.626952	0.477938	1.741525	0.011350
Aug	8	ARMA (1, 1)	1.105409	0.685987	2.735701	0.021002
Sep	9	ARMA (1, 1)	0.833460	0.682373	2.679016	0.016266
Oct	10	ARMA (9, 6)	1.800607	1.437522	6.519923	0.027820
Nov	11	ARMA (1, 1)	1.839092	1.479105	8.807034	0.054524
Dec	12	ARMA (2, 2)	1.422629	1.130309	9.069072	0.053590

Table 7: Forecast Evolution for Karachi Minimum Average Monthly Air Temperatures (1961-2020)

Table 7 also shows the forecasted evolution of Karachi minimum air temperature of each month analysis and ARMA (p, q) equation in the view of diagnostic checking. MAE is least among MAE, RMSE, and MAPE of all the months. The smallest values of MAE, RMSE, MAPE and Theil's U-Statistics exist for the June, which is 0.432525, 0.591310, 1.524124 and 0.010490 respectively. Tables 8 and 9 shows that maximum and minimum mean monthly Karachi air temperature stationary nature and unit root test rejected. The reason to reject H_0 is p-value is less than 5% or the critical value of the absolute value of Augmented Dickey Fuller (ADF) test is greater than that at 1% and 5% significance level. Figure (1-6) shows actual vales of maximum and minimum Karachi air temperature.

Null Hypothesis H_0: January Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-6.459141	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: February Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-7.694832	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: March Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*

Augmented Dickey Fuller (ADF) test		-7.300308	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: April Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-7.387534	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: May Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-8.014637	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: June Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-2.378506	0.0000
Test Critical vales	1% level	-3.548208	
	5% level	-2.912631	
	10% level	-2.594027	

Null Hypothesis H_0: July Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-5.638010	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: August Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*

Augmented Dickey Fuller (ADF) test		-6.839803	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: September Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-5.898242	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: October Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-5.834399	0.0000
Test Critical vales	1% level	-3.598208	
	5% level	-2.912631	
	10% level	-2.594027	

Null Hypothesis H_0: November Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-4.469369	0.0000
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Null Hypothesis H_0: December Karachi Maximum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-5.027488	0.0001
Test Critical vales	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

Table 8: Karachi Maximum Average Monthly Air Temperatures (1961-2020) Augmented Dickey Fuller (ADF) test (stationary)

Null Hypothesis H_0: January Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-13.82118	0.0000
Test Critical vales	1% level	-3.548208	
	5% level	-2.912631	
	10% level	-2.594027	

Null Hypothesis H_0: February Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-13.94044	0.0000
Test Critical vales	1% level	-3.548208	
	5% level	-2.912631	
	10% level	-2.594027	

Null Hypothesis H_0: March Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-6.254207	0.0000
Test Critical vales	1% level	-3.560019	
	5% level	-2.917650	
	10% level	-2.596689	

Null Hypothesis H_0: April Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-9.31552	0.0000
Test Critical vales	1% level	-3.550396	
	5% level	-2.913549	
	10% level	-2.594521	

Null Hypothesis H_0: May Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-8.862812	0.0000
Test Critical vales	1% level	-3.550396	
	5% level	-2.913549	
	10% level	-2.594521	

Null Hypothesis H_0: June Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-7.087532	0.0000
Test Critical vales	1% level	-3.555023	
	5% level	-2.915522	
	10% level	-2.595565	

Null Hypothesis H_0: July Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-8.008315	0.0000
Test Critical vales	1% level	-3.555023	
	5% level	-2.915522	
	10% level	-2.595565	

Null Hypothesis H_0: August Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-8.658552	0.0000
Test Critical vales	1% level	-3.550396	
	5% level	-2.913549	
	10% level	-2.594521	

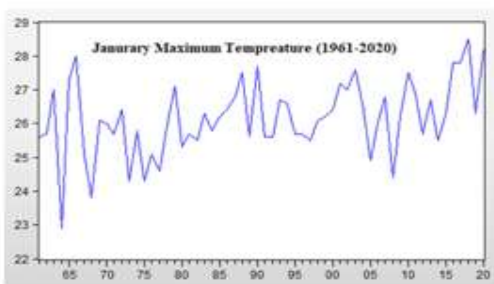
Null Hypothesis H_0: September Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-6.847970	0.0000
Test Critical vales	1% level	-3.555023	
	5% level	-2.915522	
	10% level	-2.595565	

Null Hypothesis H_0: October Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-6.847970	0.0000
Test Critical vales	1% level	3.550396	
	5% level	-2.913549	
	10% level	-2.594521	

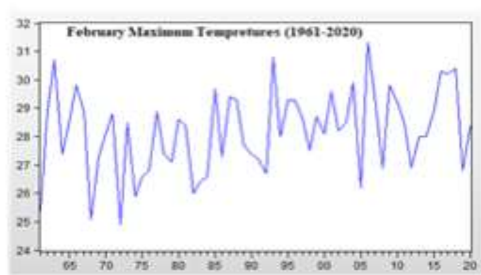
Null Hypothesis H_0: November Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-12.84336	0.0000
Test Critical vales	1% level	-3.548208	
	5% level	-2.912631	
	10% level	-2.594027	

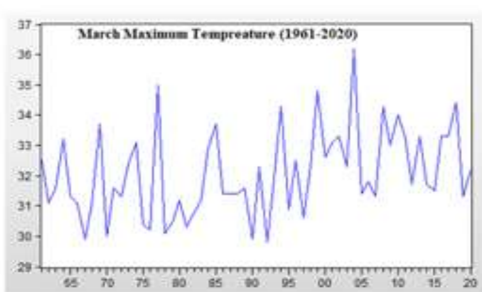
Null Hypothesis H_0: December Karachi Minimum Average Monthly Air Temperatures (1961-2020) has a unit root			
		t-statistics	prob*
Augmented Dickey Fuller (ADF) test		-9.623561	0.0001
Test Critical vales	1% level	-3.550396	
	5% level	-2.913549	
	10% level	-2.594521	

Table 9: Karachi Minimum Average Monthly Air Temperatures (1961-2020) Augmented Dickey Fuller (ADF) test (stationary).

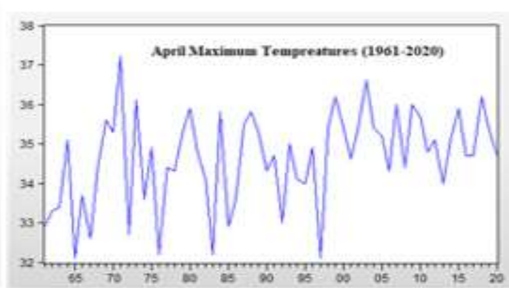


1(a) January Maximum Temperature (1961-2020)


1(b) February Maximum Temperature (1961-2020)

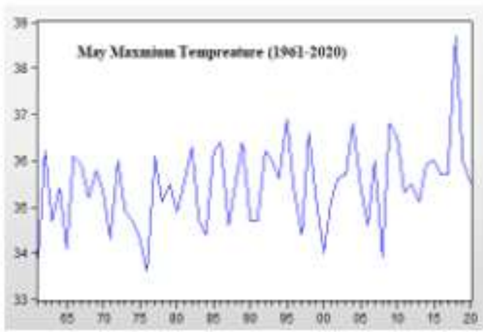


1(c) March Maximum Temperature (1961-2020)

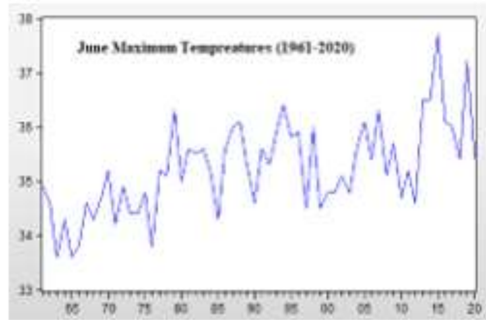


1(d) April Maximum Temperature (1961-2020)

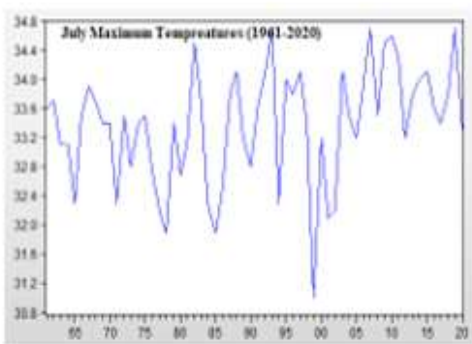
Figure 1: Karachi Maximum Air Temperature January-April (1961-2020)



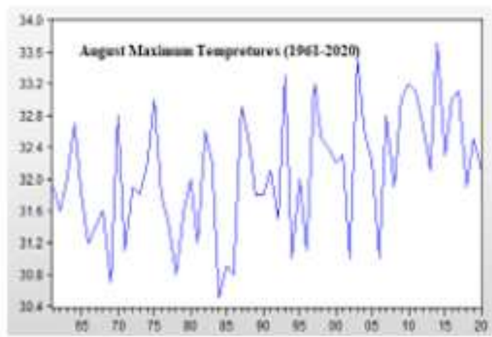
2(a) May Maximum Temperature (1961-2020)



2 (b) June Maximum Temperature (1961-2020)

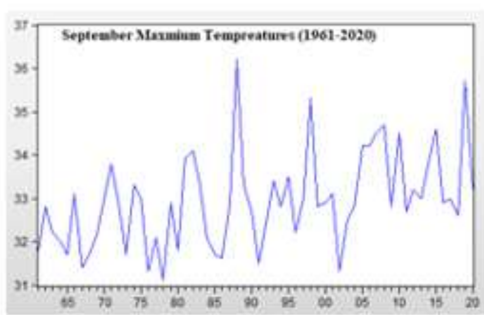


2 (c) July Maximum Temperature (1961-2020)

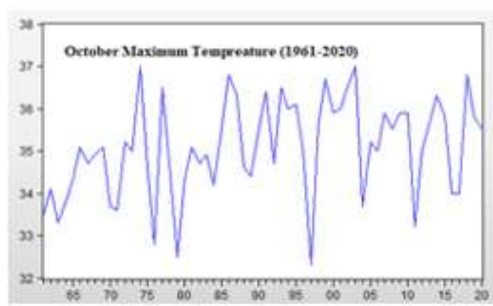


2 (d) August Maximum Temperature (1961-2020)

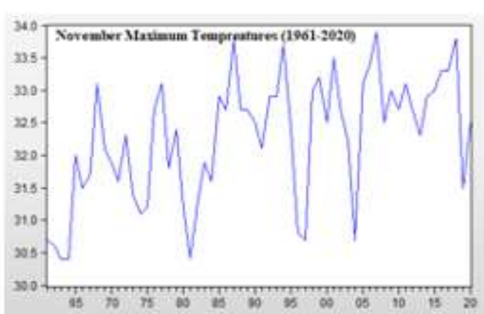
Figure 2: Karachi Maximum Air Temperature May-August (1961-2020)



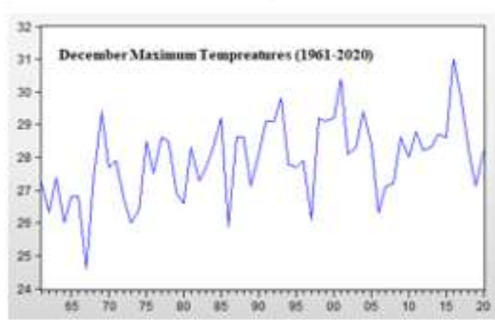
3(a) September Maximum Temperature (1961-2020)



3 (b) October Maximum Temperature (1961-2020)

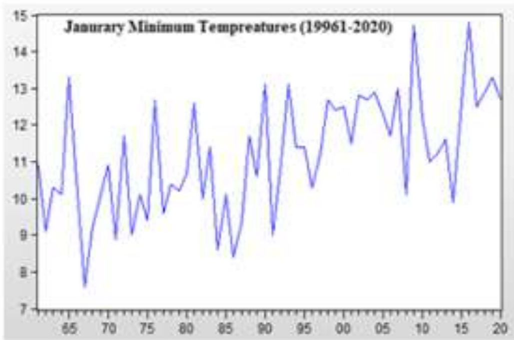


3 (c) November Maximum Temperature (1961-2020)

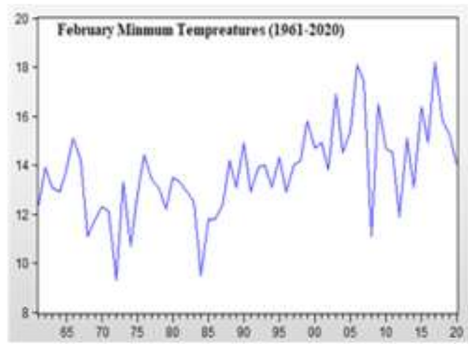


3 (d) December Maximum Temperature (1961-2020)

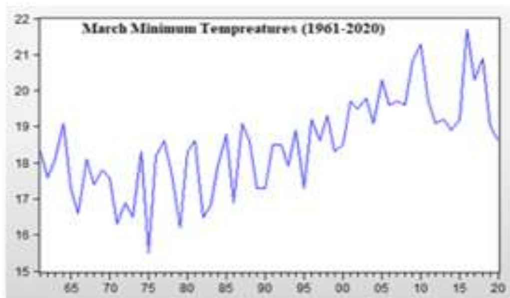
Figure 3: Karachi Maximum Temperature September-December (1961-2020)



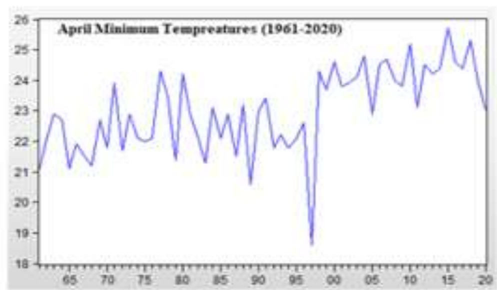
4 (a) January Minimum Temperature (1961-2020)



4(b) February Minimum Temperature (1961-2020)

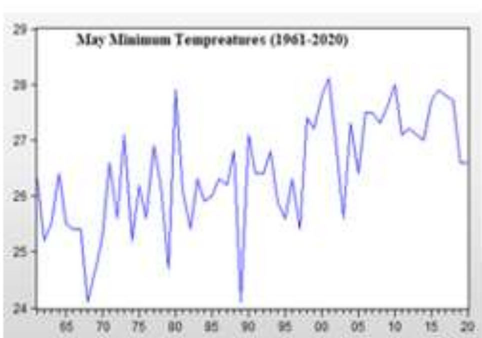


4(c) March Minimum Temperature (1961-2020)

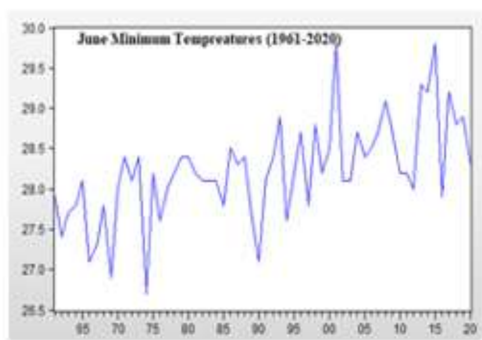


4(d) April Minimum Temperature (1961-2020)

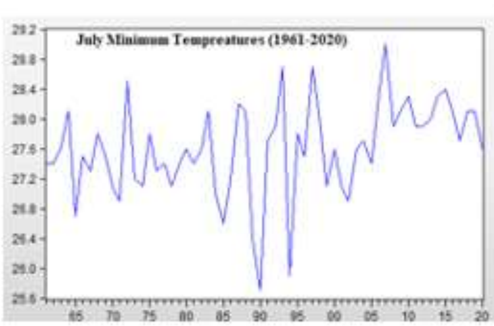
Figure 4: Karachi Minimum Temperature January-April (1961-2020)



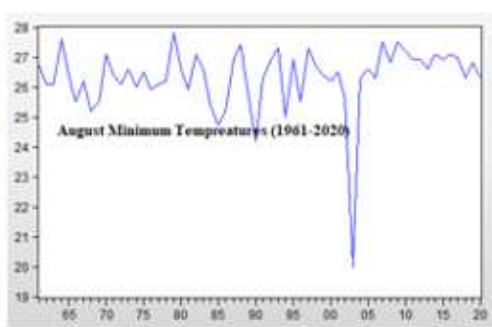
5(a) May Minimum Temperature (1961-2020)



5 (b) June Minimum Temperature (1961-2020)

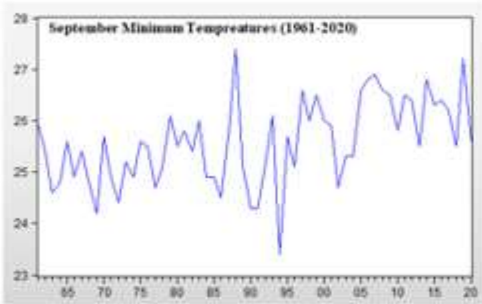


5(c) July Minimum Temperature (1961-2020)

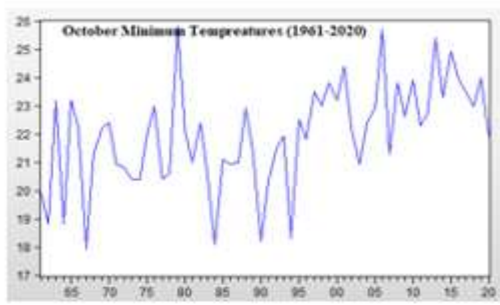


5 (d) August Minimum Temperature (1961-2020)

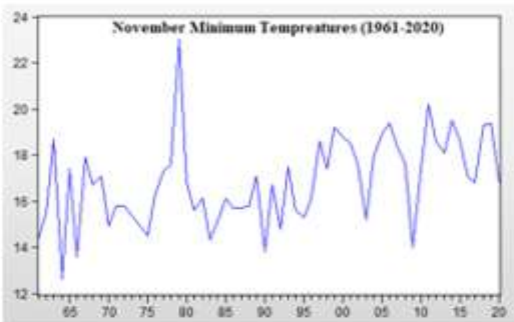
Figure 5: Karachi Minimum Air Temperature Ma y-August (1961-2020)



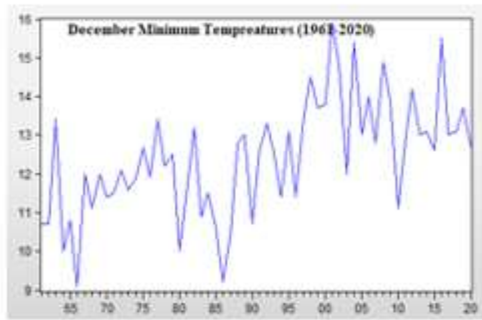
6(a) September Minimum Temperature (1961-2020)



6(b) October Minimum Temperature (1961-2020)



6 (c) November Minimum Temperature (1961-2020)



3(d) December Minimum Temperature (1961-2020)

Figure 6: Karachi Minimum Air Temperature September-December (1961-2020

4. CONCLUSIONS

Global warming and climate change describe to an increase in average global temperatures. Human activities and Natural events are main contributors to such increases in average global air temperatures. The change in climate is caused by increasing emissions of carbon dioxide from vehicles, factories, and power stations, will not affects only the sea and atmosphere but also will alter the Earth geology. Emissions of carbon dioxide due to our fossil energy usage will change the climate and the air temperature is estimated to increase by 2 to 6o Celsius within year 2100, which is a remarkable increase from our current average air temperature of 1.7o Celsius as predicted.

The novelty of this study is a preliminary experiment on know how to mean monthly Karachi maximum and minimum air temperature behave and climate change. ARMA (p, q) model used to modelling and forecasting the behaviour of Karachi maximum and minimum air temperature. In this regard, the data under consideration is that mean monthly maximum and minimum air temperature of Karachi ranging from 1961 to 2020 (each month wise). Descriptive studies of each month (1961-2020) are described. Finding the most appropriate models is depending on the least value of Akaike information criterion (AIC), Bayesian Schwarz information criterion (SIC) and Hannan Quinn information criterion (HIC). Durbin-Watson Test also apply for knowing most appropriate model. Root mean square error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Theil's U-Statistics are used to calculate the forecast accuracy of the best-fitted model of Karachi mean monthly maximum and minimum air temperature. Minimum air temperature, most of months follows the most appropriate model is ARMA (1, 1) and some months shows the best adequate model is ARMA (2, 2) process apart from January has the best fitted model is ARMA (3, 3), April shows the most fitted model is ARMA (2, 3) and October follows the most appropriate model is ARMA (9, 6). Although, in the maximum air temperature shows most of the months follows the most appropriate model is ARMA (3, 3) remaining months express the different ARMA (p, q) process is best. MAPE values is less as compared to other forecast evaluations like RMSE and MAE. Theil's U-Statistics also demonstrate for the maximum and minimum air temperature of each month. The Theil's U-Statistics values of each months lies approaches to zero shows that the air temperature is strongly correlated to previous one. With rising in the Earth's global mean air temperature i.e., global warming, the various effects on climate change pose risks that rises. It is also found that during Pandemic despite transportation and construction activities were discontinued the temperature difference was not affected much however air quality was improved. The unit root test is used for non-stationarity data. H_0 is rejected when p-value is less than 5% or the critical value of absolute value of Augmented Dickey Fuller (ADF) test is greater than at 1% and 5% significance level. This study analysed that mean monthly maximum and minimum Karachi air temperature are stationary.

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The datasets generated during the current study are not publicly available due to Pakistan meteorological department sells the said data but are available from the corresponding author on reasonable request.

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