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Time Series Analysis and Forecasting of Average Monthly Temperature Levels in Jos, Nigeria

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Abstract: **Temperature is an essential weather component because of its tremendous impact on humans and the environment. As a result, one of the widely researched parts of global climate change study is temperature forecasting. This study examines the monthly average temperature levels for year 2008 to 2020 in Jos, Nigeria. A preliminary check on the time series plot of the data showed that the series was not stationary. The classical Box and Jenkins Time Series methodology with its indicative ACF and PACF identification guide was employed. The ARIMA (3, 1, 3) model was found to be adequate for the series and the monthly forecast from 2021 to 2024 showcased relatively stable temperature values within these years.. In the end, it was recommended that studying and carefully applying ARIMA models could help scientists and decision-makers in formulating effective policies for flood prediction, urban planning, and environmental management.**

Keywords: **Box-Jenkins, Temperature, Time Series, ARIMA, Forecasting, Autoregressive.**

I. INTRODUCTION

The earth's climate system and its changes control life on earth and substantially influence society and the economy. Today, the entire global community suffers from unfriendly climatic conditions, the gradual disappearance of rain forests in the tropics, the loss of plant and animal species, changes in rainfall patterns, and global warming resulting from climate change. Climate change has the potential to affect all natural systems, thereby becoming a threat to human development and survival socially, politically, and economically [1].

Temperature variations play a major role in climate variability, as such the need to continue to monitor the trends of temperature even in locations where a pattern has been established is necessary. Temperature is the degree of hotness or coldness of an object.

Jos is a city located in Plateau State of Nigeria, and it is known for its cool, temperate climate. The city is situated at an altitude of over 1,200 meters above sea level, which contributes to its cool and moderate temperature. The temperature levels in Jos can vary throughout the year, with temperatures ranging from 20 to 25 degrees Celsius. The city is in a region that experiences two main seasons, the dry and the rainy season. During the dry season, which typically lasts from November to February, temperatures tend to be lower and more stable. On the other hand, during the rainy season, which lasts from March to October, temperatures can become more unpredictable, with occasional spikes in temperature due to increased humidity levels. The temperature levels in Jos have significant impacts on the local economy and the lives of its residents. For example, the cool climate attracts tourists, who flock to the city for its pleasant weather, scenic views, and cultural attractions. Additionally, the temperate climate is beneficial for the growth of various crops, such as maize, beans, and vegetables, which are widely cultivated in the region. Temperature is a crucial climatic factor that has significant implications for various aspects of life, including human health, agriculture, and ecosystem dynamics. The city of Jos in

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Nigeria experiences a wide range of temperature levels throughout the year, which can have significant impacts on the local community. Therefore an analysis of the time series of the average monthly temperature levels in Jos is a powerful tool for understanding the dynamics of temperature levels in the city.

Time series is a sequence of data points ordered in time intervals, where each data point represents a measurement or observation at a specific time. A time series analysis involves analyzing the patterns, trends, and behaviour of the data over time. According to Box and Jenkins [2], time series can be defined as "a set of observations arranged in chronological order, and it is usually assumed that each observation represents a realization of a stochastic process with certain stationary properties, including independence between observations and a constant mean and variance over time."

There is a considerable amount of literature on time series analysis of temperature levels by various researchers. A time series analysis of temperature and rainfall levels was undertaken by [3]. Their research analyzed and modelled the seasonal autoregressive integrated moving average (SARIMA) of Annual Minimum, Maximum Temperature and Rainfall in Ijebu ode, Nigeria as a case study with annual time series of the variables ranging from 1989 to 2018. Their study proposed that seasonal ARIMA $(4,1,1)(1,1,1)_{12}$ and ARIMA $(1,1,1)(1,1,1)_{12}$ models for maximum temperature and minimum temperature respectively be adopted using the information selection criterion. The result of the forecast models shows that there is a tendency for an increasing pattern of annual rainfall and temperature over the forecast period from year 2019 to year 2028. Furthermore, [4] explored long term trends in ambient temperature for Akure, Nigeria using the ARIMA time series methodology. Their results show that SARIMA $(0,0,1)(2,1,2)_{12}$ and SARIMA $(2,0,2)(0,1,2)_{12}$ models best describe the monthly maximum temperature and minimum temperature series for Akure in 1981 to 2010. Other references for time series modelling of temperature levels can be found in [5]–[7]. In this study, the focus is on building a time series model for forecasting average monthly temperature in Jos, Nigeria.

II. DATA AND METHODOLOGY

A. Temperature Dataset

The data set used in this research was obtained from the Nigeria Meteorological Agency at the Jos Airport. The data consists of monthly average temperature measurements from 2008 to 2019. The descriptive statistics for the data is displayed in Table 1. We observe that the year 2010 has the highest average annual temperature levels of 22.4 ^oC while 2014 has the lowest average annual temperature levels of 21.45 ^oC. Furthermore, the lowest monthly temperature levels of 17.70 ^oC is in 2015 while the highest monthly temperature of 25.6 ^oC is in 2010. It is also noted that the highest and lowest average monthly temperature observations are in April and December respectively.

TABLE I: Yearly and Monthly Descriptive Statistics for Temperature Data

Year	Mean	Minimum	Maximum	Month	Mean	Minimum	Maximum
2008	21.99	19.90	25.35	January	20.34	18.65	23.55
2009	21.77	19.60	24	February	22.65	20.8	23.6
2010	22.43	19.40	25.62	March	24.31	22.05	25.9
2011	21.8	18.80	25.2	April	24.60	23.5	25.6
2012	21.97	19.15	24.2	May	23.31	22.4	24.35
2013	21.87	17.50	25.9	June	21.94	21.4	22.4
2014	21.45	19.65	24.2	July	20.87	20.2	21.4
2015	21.74	17.70	24.35	August	20.50	19.65	21.2
2016	22.14	19.10	25.60	September	21.38	20.7	22.1
2017	21.97	20.50	25.3	October	22.05	21.3	23.05
2018	21.69	18.65	24.5	November	20.83	19.8	22.7
2019	21.75	19.40	24.6	December	19.65	17.5	22.75
2020	21.70	19.10	25.15				

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B. The ARIMA Model

ARIMA is an abbreviation for Auto-Regressive Integrated Moving Average. It is a classical time series model which can be written in general form as

$$y_t = \mu + \alpha_1 y_{t-1} + \ldots + \alpha_p y_{t-p} + \varepsilon_t - \delta_1 \varepsilon_{t-1} + \ldots - \delta_q \varepsilon_{t-q} \qquad (0.1)$$

at time $t = 1, 2, ..., n$, where ε_{t-j} $(j = 0, 1, ..., q)$ are the lagged forecast errors. The $p + q + 1$ unknown parameters $\mu, \alpha_1, \ldots, \alpha_p$ and $\delta_1, \ldots, \delta_q$ are determined by minimizing the squared residuals. In the first part of the right hand side of (1.1), the dependent variable y_t is predicted, based on its values at earlier time periods. This is the autoregressive (AR) part of equation (1.1). In the second part, the dependent variable y also depends on the values of the residuals at earlier time periods, which may regard as prior random shocks. This is the moving average (MA) part of the equation. It is the task of the researcher analyzing a given time series, to find the relevant parameters of the ARIMA (p, d, q) model with p the number of autoregressive terms, d the number of non seasonal differences and q the number of lagged forecast errors in the prediction equation.

The Box-Jenkins methodology consists of consecutive steps that should be followed when building an ARIMA model [8]. These steps include ensuring stationarity, model identification, parameter estimation and model checking. Finally, goodness of fit among competing models will be determined by the Bayesian Information Criterion (BIC) [9].

C. ARIMA Model Fit to the Data

A preliminary check of the time series plot of the data is displayed in Fig 1. From Fig 1 below, the time series plot shows that the data is not stationary. Hence, we make the data stationary by differencing the data.

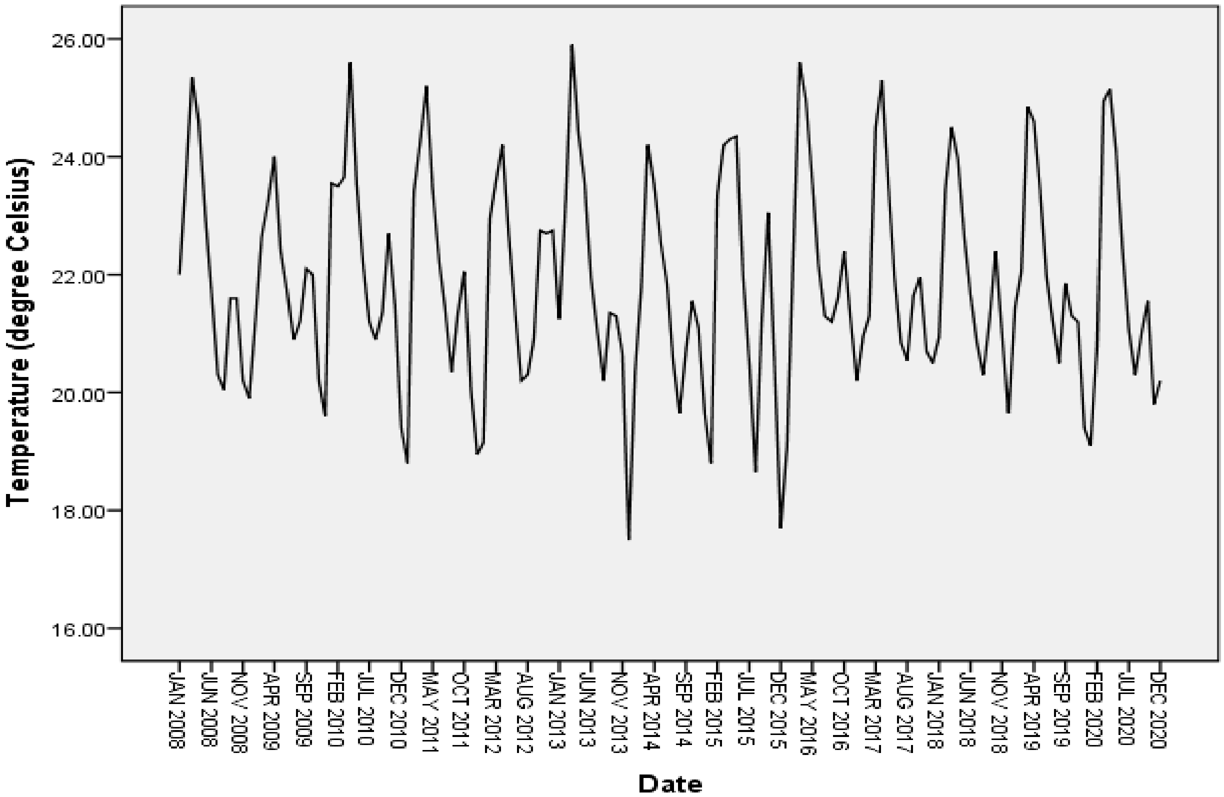

Fig 1: Time series plot for the monthly average temperature levels from January 2008 to December 2020.

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Fig 2 shows the first difference in temperature levels. The plot shows that the series is now stationary. For the purpose of model identification, the autocorrelation function (ACF) and PACF plots are displayed in Fig 3.

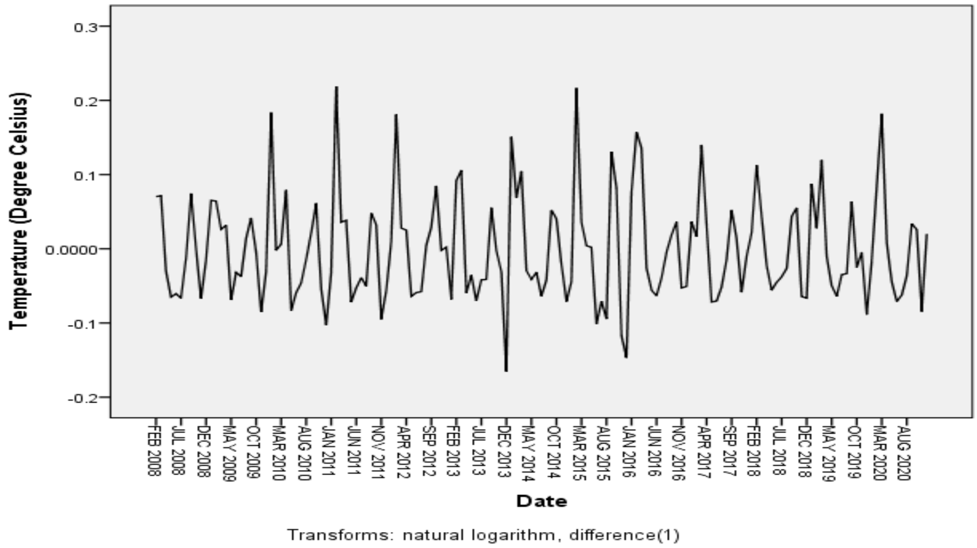

Fig 2: Time series plot for temperature levels after differencing once.

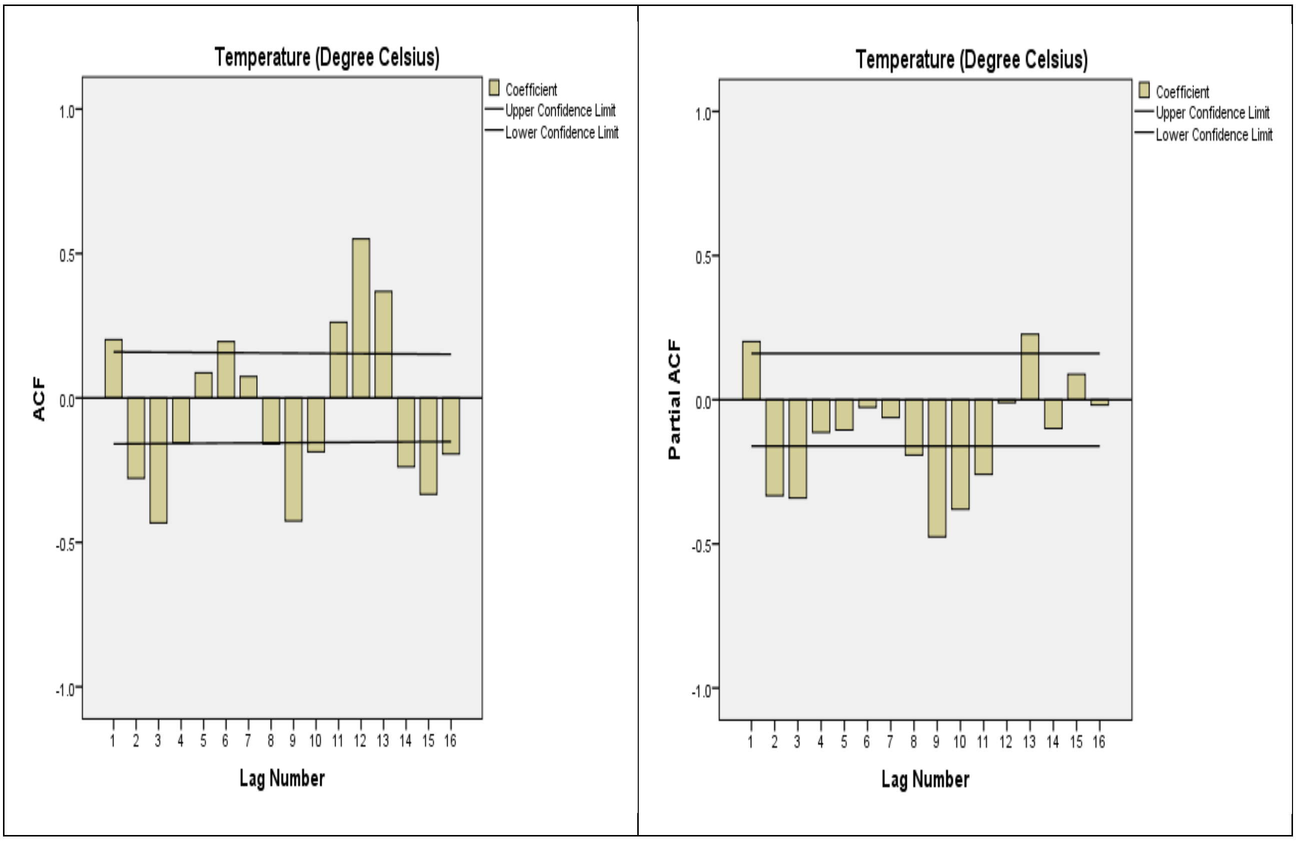

Fig 3: ACF and PACF plots for the differenced time series

The left and right panels of Figure 3 shows the ACF and PACF of the differenced temperatures levels respectively. The ACF plot shows a significant spike on the order of three. This indicates the moving average part can be represented by an order of three. The PACF plot shows a significant spike in the third order. This indicates the autoregressive part can be represented by an order of three.

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Some error metrics and measures of model fit are displayed in Table 2. It is noted that the Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and BIC are lower for the ARIMA (3,1,3) model compared to the ARIMA (3,1,4) model. This implies the ARIMA (3,1,3) model could be selected as the best fit for the Jos temperature data.

TABLE 2: Error Metrics and Measures of Model Fit for the ARIMA models

Model	RMSE	MAE	Stationary R^2	BIC
ARIMA (3,1,3)	1.219	0.912	0.392	0.624
ARIMA (3,1,4)	1.225	0.904	0.389	0.666

Model adequacy is further confirmed by checking the residuals. In Fig 4 below, the ACF and PACF plots of the residuals are displayed. Observe that the spikes at the ACF (left panel) and the PACF (right panel) up to lag 24 are within the 95% statistical confidence bounds respectively. This suggests that the ARIMA (3,1,3) model is adequate for the average temperature time series dataset. The results obtained from the ACF and PACF of Fig 3 is supported by the residual series plotted in Fig 4 as the values centres randomly around the zero value.

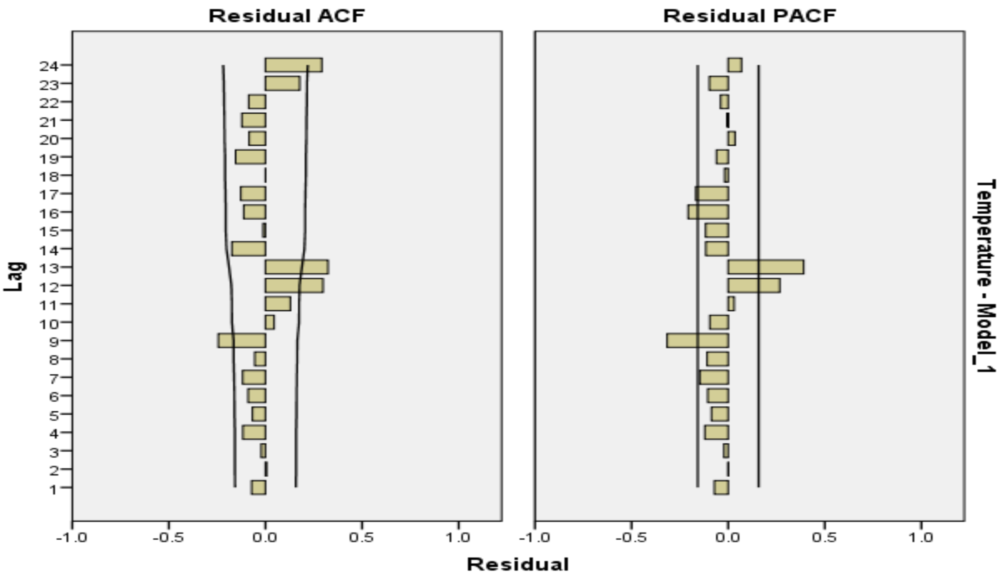

Fig 4: ACF and PACF plot for the residual series.

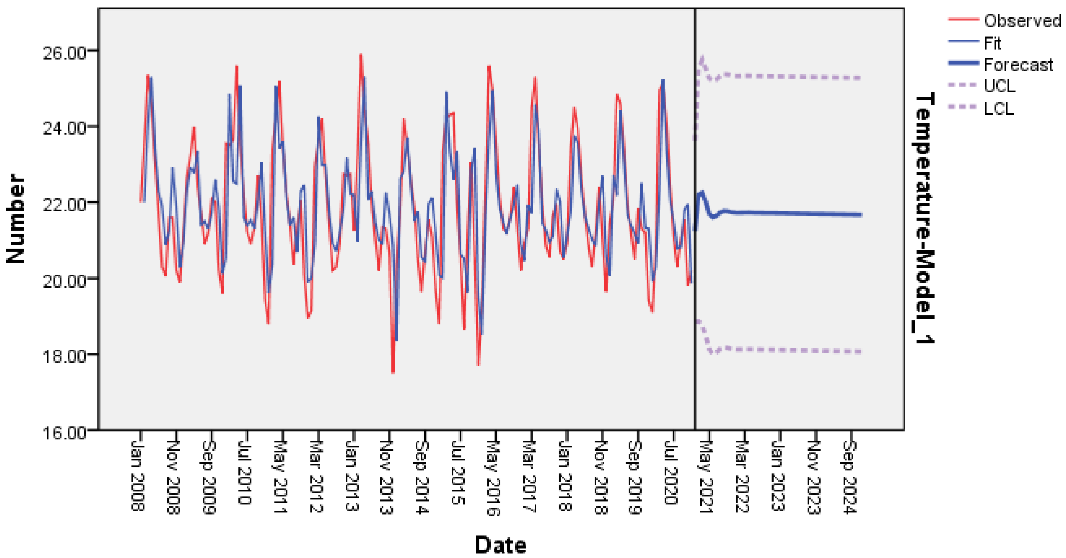

Fig 5: Original Plot with four Years Forecasts at 95% Confidence Interval

A final and another useful step in the Box and Jenkins approach is the application of the identified model in forecasting one or more future time steps ahead. Using the identified model's parameters, Fig 5 shows the one-month-ahead predictions with their 95% confidence limits for the monthly maximum and minimum temperatures for the next four years (2021 – 2024). The years 2008- 2020 were used to verify the predictability of the model as exhibited in Fig 5.

III. CONCLUSION

In this study, the Box-Jenkins approach for model identification, estimation and forecasting has been useful in identifying the most suitable time series model for the temperature data. The findings from this study indicate that employing ARIMA modelling, specifically ARIMA (3,1,3), for forecasting monthly average temperature levels in Jos can offer valuable assistance to scientists and decision-makers in formulating effective policies for flood prediction, urban planning, and environmental management. This forecast serves as a reliable tool for enhancing water management practices. Given the dynamic factors of climate change and population growth in Jos, Nigeria, the outcomes of this research can significantly contribute to comprehending the influences on current water management practices, policies, agricultural conditions, and flood control in the region.

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