Meteorological Parameters Study and Temperature Forecasting in Selected Stations in Sub-Sahara Africa using MERRA-2 Data

F. O. Aweda[1*], S. J. Olufemi[1], J. O. Agbolade[2]

[1]Physics and Solar Energy Programme, College of Agriculture, Engineering, and Science, Bowen University, Iwo, Nigeria

[2]Electrical and Electronic Department, Federal Polytechnic, Ede, Nigeria

ABSTRACT: The study and forecast of climatic phenomena have progressed over time, but the huge knowledge with information gathered has aided in comprehending and anticipating weather changes. The goal of this research was to look at some specific meteorological characteristics and forecast air temperature over a number of stations in Osun State, Nigeria. Monthly rainfall, relative humidity, air temperature, air pressure, wind speed and direction for four stations were gathered from the HelioClim website archives and used in this study. For each variable, descriptive statistics were calculated. The normality of the data was determined using the Shapiro-Wilks test. The data was tested for stationarity using the Augmented Dickey Fuller (ADF) test, and different types of Autoregressive Integrated Moving Average (ARIMA) models were fitted. According to the statistics, the highest average temperature was observed in March ($T = 23.9^0C$). The months of June, July, August, and September had the highest mean relative humidity ($RH = 88.4\%$), pressure ($P = 987hPa$), wind speed ($WS = 1.8m/s$), wind direction ($WD = 225.1^0$), and rainfall ($RF = 413mm$). In January, the coefficient of variation (COV) for temperature was larger than in other months. In June, January, and December, relative humidity (RH), air pressure, rainfall, and wind speed and direction were all higher. The air temperature stationarity was tested using the Augmented Dickey Fuller (ADF) test, which revealed ($p>0.05$) but became stationary after the first difference ($p<0.05$). The temperature effect follows the same trend in ARIMA (1, 1, 1) forecasts for 2021 and 2022. As a result, air temperature modeling and forecasting are difficult tasks for any monthly time series. It is advised that all-time series models for any investigated location be considered, as well as meteorological conditions, in order to select the most appropriate model.

KEYWORDS: Atmospheric parameters, Climate change, Forecasting, MERRA-2, ARIMA, ADF.

[Received Oct. 9, 2021; Revised Feb. 8, 2022; Accepted Mar. 15, 2022] Print ISSN: 0189-9546 | Online ISSN: 2437-2110

I. INTRODUCTION

Surveillance and forecasting of weather phenomena have improved over the centuries; as a result, the immense knowledge and information gathered helps to comprehend and predict climate change, which has a huge impact on atmospheric parameters research all over the world. The soil-plant-atmosphere system is affected by the global warming process. Future weather patterns should be predicted, as should an increase in the frequency and magnitude of extreme occurrences (Lobell et al. 2012; Semenov and Shewry, 2011; Sillmann and Roeckner, 2008). According to Lobell et al. (2013), rising temperatures and restricted precipitation have contributed to the occurrence of droughts as a result of global warming, posing major concerns to food security. Even more importantly, climate change has a positive impact on people's life expectancy as well as their surroundings (Ukhurebor et al. 2017).

The posture, height, and proximity to water places are all affected by latitudinal influence. Solar irradiation has been found to be a significant factor in the study of weather adjustment, ecological effluence, vegetable production, food management, and hydrology (Pondyal et al. 2012). When developing a solar energy system, however (Aweda and Samson 2020), a detailed grasp of the accessibility of worldwide solar radiation around the area of concern is required (Prieto et al. 2009; Almorox 2011; Khatib and Elmenreich 2015). As a result, solar radiation capability plays an important role in anticipating atmospheric parameter variables (Poudyal et al. 2012; Hamrouni et al. 2008; Adhikari 2016; Aweda et al. 2021a; Aweda and Samson 2020).

Temperature is defined as the range of degrees of hotness and coolness of the body. This affects or controls other components such as dew point, relative humidity, air temperature, air vapours, and atmospheric air pressure, the situation observed has a wide range of measured variables for determining climate variation by affecting or controlling additional components of meteorological conditions (Geerts, 2003). The effects of drastic climate changes on physical surroundings and human infrastructure are widely acknowledged as being more important than typical standards. In the survey of weather conditions, climatic adaptability is also an important aspect for human consciousness (Rebetez 2001). It is a well-known fact that relative humidity and air

*Corresponding author: francisaweda@gmail.com

doi: http://dx.doi.org/10.4314/njtd.v19i1.9

temperature are frequently used in the same way as a pointer of humidity quantity in an environment's atmospheric condition (Lawrence 2005). Relative humidity, in reality, is still a sensitive limitation that affects the natural operation of electric appliances, metallic elements, agricultural products, and organic substances. It also assesses the critters' thermal discomfort (Eludoyin et al. 2014).

In comparison to the PV/T system, Mawoli et al. (2020) found that surface temperature whose cooling fluid was controlled by module surface and fluid temperatures had a lower temperature. In the study of atmospheric characteristics, it has been found that numerous factors such as dew point temperature, ambient temperature, and solar radiation energy combine to influence relative humidity (Chabane et al. 2018). According to research, relative humidity levels exceeding 80% produce pain due to the physical features of becoming liquid on the skin's nature (Tanabe and Kimura 1994); yet, a relative humidity level of 100% indicates humid conditions. As a result, at the condensation point, the partial diffusion gas pressure is equal to the unfinished vapor pressure (Tanabe and Kimura 1994).

Meteorologists choose precipitation point temperature over relative humidity as a sign of individual comfort (Gornicki et al. 2017) and use it to predict the rate of rainfall, ice, and smog formation, as well as the likelihood of storms (Yousif and Tahir 2013). However, if the dew point in the lower stratosphere is more than 60°C, violent rainstorms are possible (Ukhurebor et al. 2017). Around the world, several surveys of current temperature and solar radiation trends have been done. According to temperature investigations, other factors at local scales remain factors with significant longitudinal and earthly variation in climatic inclinations of the environment (Frimpong et al. 2014; Adhikari et al. 2013). Thereby, leading to countries ground-based weather stations which are few. In a related vein, research has shown that ground-based data can be a trustworthy and dependable source of atmospheric data for climate research. Authors such as Aweda and Samson (2020); Aweda et al. (2021a) predicted the future occurrence of temperature in Nigeria. The use of statistical tools or methodologies to forecast air temperature is critical in the prediction of environmental weather Murat et al. (2018). Time series forecasting approaches are based on the examination of historical data, according to various academics Murat et al. (2018). It has long been known that historical data patterns can be utilized to forecast future events.

According to the report, time series modeling utilizing autoregressive integrated moving-average (ARIMA) has aided in the data processing and predicting of future temperature occurrences. ARIMA models have been utilized for future prediction in a variety of fields, including science, engineering, medical, finance, economics, and business, according to literature. ARIMA models, on the other hand, have long been a key instrument in numerous aspects of metrological research and knowledge of air temperature (Murat et al 2018). The linear ARIMA model and the quadratic ARIMA model had the highest overall performance in creating short-term predictions of yearly absolute temperature in Libya, according to El-Mallah and Elsharkawy (2016). Balyani et al. (2014) applied the ARIMA model to Shiraz, Iran, during a 50-year period (1955-2005). ARIMA was chosen as the best model for temperature modeling. Furthermore, Anitha et al. (2014) forecast the monthly mean of India's maximum surface air temperature using the seasonal autoregressive integrated moving average (SARIMA) model.

The monthly mean of maximum surface air temperature in India showed a trend, according to their findings. Muhammet (2012) also used the ARIMA method to forecast temperature and precipitation in Afyonkarahisar Province, Turkey, until 2025, and found that the quadratic and linear trend models predicted an increase in temperature. Finally, Khedhiri (2014) investigated the statistical properties of historical temperature data in Canada from 1913 to 2013 and developed a seasonal ARIMA model for the series in order to forecast future temperatures. In Umuahia, Akpanta et al. (2015) used the SARIMA frequency modeling approach to analyze monthly rainfall data. Using the SARIMA models, Afrifa-Yamoah (2016) projected monthly rainfall in many regions in Ghana. Yusof and Kane (2012) created SARIMA models of the weekly and monthly rainfall time series of two selected weather stations in Malaysia, and Dabral and Murry built SARIMA models of the weekly and monthly rainfall time series of two selected weather stations in India (2017).

For yearly and monthly agrometeorological time series, the ARIMA models indicated above offer good post-sample forecasting ability (Murat et al. 2018). Fitting regression models (RM) to time series with trend and seasonality components is another method for forecasting meteorological time series (Murat et al. 2018). The RM models are based on linear modeling at their core but they also allow for the addition of characteristics such as trend and season to the data (Murat et al. 2018). The cost of some meteorological data in the Nigerian Meteorological Agency's (NiMet) archive, on the other hand, motivated the collection of satellite data.

II. MATERIALS AND METHODS

A. *Data Collection*

Monthly rainfall, air pressure, air temperature, relative humidity, wind speed and direction for four stations were obtained from the HelioClim-1 (www.soda-pro.com) archives using the Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) method to investigate climate data (Gelaro et al. 2017). On the 5th of March, 2021 HelioClim-1 data was accessed. According to the paper, data for eleven (11) years spanning 2010 to 2020 was acquired as a monthly average for January to December of each year in comma-separated value (CSV) format (Aweda et al. 2020). The coordinates for the station used are Ife (7.4905° N, 4.5521° E), Iwo (7.6292° N, 4.1872° E), Ilesha (7.6395° N, 4.7588° E) and Oshogbo (7.7827° N, 4.5418° E).

B. *Statistical Analysis*

For each variable, descriptive statistics were calculated (mean and coefficient of variation). The Shapiro-Wilks test was used to examine the normality of the data. The bivariate relationship between the metrological variables was examined using Spearman rank correlation and for the purpose of forecasting temperature, the Autoregressive Integrated Moving Average (ARIMA) was used and the order of differencing was determined after subjecting the data to Augmented- Dickey Fuller (ADF) test. The tentative ARIMA model was diagnosed using Ljung Box test, with a p-value greater than 0.05 indicating a good fit. To enhance data analysis, the Statistical Package for Social Sciences (SPSS version 20.0) and Econometric View version 7.0 were used.

III. RESULTS AND DISCUSSION

Table 1 displays monthly rainfall, air pressure, air temperature, relative humidity, wind speed, and direction in Ife. The coefficient of variation (COV) recorded for temperature in January was larger than that of other months, while it was higher in January and December for rainfall, air pressure, RH, wind speed and direction. Although the highest mean rainfall, air pressure, RH, and wind speed - direction in Ife were discovered in June and July respectively, the highest mean rainfall, air pressure, RH, and wind speed - direction were found in August and September.

In Ilesha, Table 2 shows monthly variations in rainfall, air pressure, air temperature, relative humidity, wind speed, and direction. The coefficient of variation (COV) recorded for temperature in January was larger than that of other months, whereas it was higher in January, January, December, December, December, and December receptively for rainfall, air pressure, RH, wind speed and direction. Although the maximum mean rainfall, air pressure, RH, and wind speed - direction in Ilesha were achieved in July, July, August, and September, respectively, the average temperature in March was higher than other months.

In Iwo, Table 3 shows monthly variations in rainfall, air pressure, air temperature, relative humidity, wind speed, and direction. The coefficient of variation (COV) recorded for temperature in January was larger than that of other months, while it was higher in January, December, December, December, and December receptively for rainfall, air pressure, RH, wind speed and direction. The average temperature in March was higher than in other months, despite the fact that Ife had the highest mean rainfall, air pressure, relative humidity, wind speed, and direction. It was collected for Iwo in the months of July, August, July, and September, respectively.

In Osogbo, Table 4 shows monthly variations in rainfall, air pressure, air temperature, relative humidity, wind speed, and wind direction. The coefficient of variation (COV) for temperature in January was larger than in other months, although rainfall, air temperature, relative humidity, wind speed and direction in Ife were higher in February, December, December, December, and December, respectively. Although the maximum mean rainfall, air pressure, RH, wind speed and direction in Osogbo were achieved in July, July, August, and September, respectively, the average temperature in March was higher than other months. Figures 2(A-F) demonstrate the fluctuation in rainfall, air pressure, air temperature, relative humidity, wind speed, and direction over the months at the four stations in Southwest. The graphs show that these variables follow the same trend in each of the municipalities.

The results of the monthly variation of air temperature, relative humidity, pressure, wind speed, wind direction and rainfall for the stations considered as shown in Figure 1 revealed that the average variation of parameters for the eleven years across all the stations has a sinusoidal waveform for temperature $T = 26^0C$, with the highest value in March indicating the hottest month across the ten years and then maintaining an average values up until the month of May. It was observed that there was a steady decrease from April to August, which has the lowest temperature value of about $T = 23.81^0C$, indicating the coldest month of the year, and then continued to rise through September to October, reaching its second peak in November at an average of $T = 25.18^0C$, forming a sinusoidal wave pattern as temperature rises and falls during the study period.

In another vein, the average temperature change between January and March was around2^0C, which isn't much when compared to other geographical places where the temperature difference is around 10^0C (Geerts 2002, Eludoyin et al. 2014, Frimpong et al. 2014, Gornicki et al 2017). Furthermore, air temperature and relative humidity are two distinct environmental factors, with the air temperature(24.15^0C) having a significant impact on relative humidity (87.23%). Other meteorological phenomena such as rain, wind speed, and an overcast day can also impact relative humidity, as seen in Figure 1. The average RH was lower in January (marking the driest month of the year, "Harmattan"), but it quickly rose to its maximum value in July (87.51%), the coolest month of the year. As a result, over the course of ten years, a parabola has formed.

During the wet season, RH became virtually constant. In September, the maximum average percentage of RH was around 87.51 %. Following that, a declining trend was noted, with the second-lowest value of 68.28 % in December. Harmattan is responsible for the low relative humidity and air temperature between November and March.

Rainfall was quite low in January, at 20.11 mm, and the RH was similarly low, at 65.59 %, with a temperature of 24.29^0C, indicating one of Nigeria's significant seasonal differences. From January through July, however, the amount of rain fell continuously. Temperatures soared from January to March, peaked in March, and then progressively fell until July, when they reached an average of 23.81^0C. RH progressively climbed and maintained an average saturation of 87 %, showing that the meteorological parameters in Nigeria were changing and seasonal variations. Figure 2(c) shows that the average pressure in January was 972.03 hPa, dropping to 970.92 hPa in February, a difference of around 1.1 hPa across all stations. The atmospheric pressure began to rise steadily in March and peaked in July, at the same time as the temperature dropped to its lowest point.

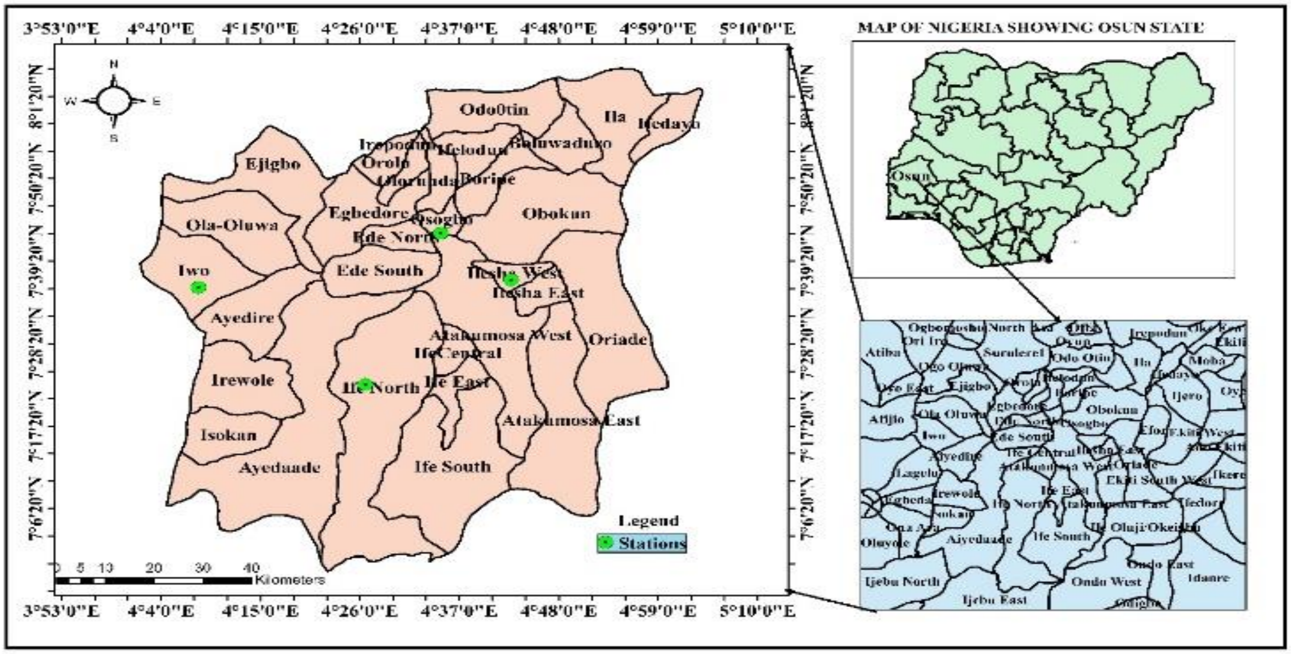


Figure 1: Map of Osun State showing the stations for the data collection.

Table 1: Descriptive statistics for the parameters in Ile- Ife

Month	Temperature		Relative humidity		Pressure		Wind speed		Wind direction		Rainfall	
	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)
Jan.	24.29	3.03	69.92	8.44	978.47	0.08	0.67	52.06	140.88	52.04	24.16	65.50
Feb.	25.82	2.17	75.99	8.09	977.37	0.06	1.19	39.93	208.24	21.64	55.89	51.68
Mar.	26.30	1.59	81.57	2.76	977.43	0.05	1.82	12.91	223.71	1.89	105.20	30.39
Apr.	26.09	1.41	84.68	1.18	977.56	0.06	1.86	9.24	219.97	1.67	134.03	29.96
May	25.59	1.09	87.56	0.64	978.67	0.06	1.71	9.11	218.48	1.53	215.89	23.66
Jun.	24.81	0.96	88.38	0.59	980.06	0.04	1.83	9.56	224.13	1.42	271.55	18.50
Jul.	24.17	1.13	88.38	0.69	980.33	0.06	2.13	6.70	228.11	1.39	359.23	16.85
Aug.	23.95	1.26	87.78	1.03	980.19	0.04	2.21	6.22	225.10	1.33	315.81	27.31
Sep.	24.39	0.69	88.34	0.70	979.69	0.05	1.58	8.06	218.96	1.49	413.14	24.05
Oct.	24.98	1.14	87.32	1.23	978.65	0.05	1.07	10.74	207.83	3.38	272.50	30.15
Nov.	25.32	1.25	82.67	2.39	977.98	0.05	0.63	43.49	209.09	19.46	77.09	25.15
Dec.	24.27	2.76	72.00	8.01	978.45	0.08	0.60	80.43	104.98	69.34	19.88	88.63

COV- Coefficient of variation (%)

Table 2: Descriptive statistics for the parameters in Ilesha

Month	Temperature		Relative humidity		Pressure		Wind speed		Wind direction		Rainfall	
	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)
Jan.	24.30	3.25	65.60	10.22	972.03	0.08	0.77	53.32	141.53	54.87	20.11	67.75
Feb.	25.88	2.81	72.03	9.74	970.92	0.06	1.33	43.85	209.39	22.63	48.49	54.83
Mar.	26.40	1.78	78.25	3.99	970.96	0.05	2.12	14.15	224.82	1.88	92.36	34.26
Apr.	26.14	1.54	81.97	1.91	971.09	0.06	2.23	10.02	221.68	1.57	122.56	33.36
May	25.54	1.13	85.88	0.90	972.21	0.06	2.01	10.46	219.88	1.37	199.61	22.43
Jun.	24.73	0.99	87.11	0.88	973.57	0.04	2.11	9.92	225.18	1.47	251.31	17.26
Jul.	24.06	1.19	87.52	0.92	973.79	0.06	2.41	7.60	230.23	1.38	350.75	15.25
Aug.	23.81	1.24	87.19	1.03	973.64	0.04	2.50	7.44	227.78	1.36	321.63	26.93
Sep.	24.24	0.74	87.52	0.78	973.19	0.05	1.70	8.94	220.17	1.61	397.70	25.26
Oct.	24.84	1.19	86.09	1.56	972.19	0.05	1.11	13.64	206.24	4.37	247.01	33.46
Nov.	25.18	1.22	80.18	2.92	971.54	0.05	0.64	52.86	206.72	21.52	61.50	28.16
Dec.	24.17	2.54	68.27	9.50	972.02	0.08	0.71	83.26	104.66	72.70	15.07	94.17

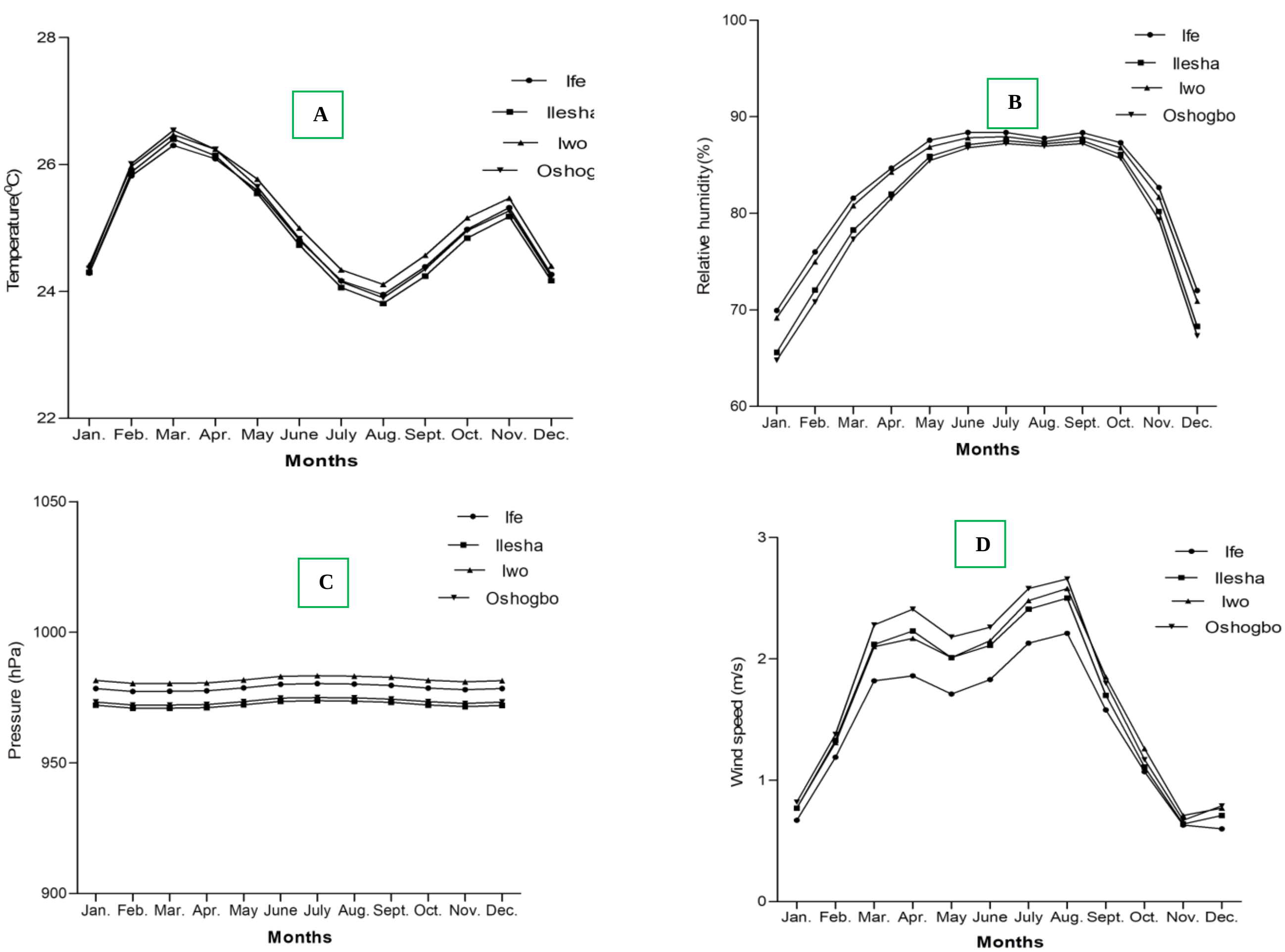
COV- Coefficient of variation (%)

Table 3: Descriptive statistics for the parameters in Iwo

Month	Temperature		Relative humidity		Pressure		Wind speed		Wind direction		Rainfall	
	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)
Jan.	24.42	3.29	69.16	8.45	981.52	0.08	0.77	56.79	130.28	53.54	20.78	66.68
Feb.	25.97	2.07	74.99	8.31	980.40	0.06	1.31	41.14	199.52	22.14	50.16	51.88
Mar.	26.47	1.70	80.80	3.02	980.44	0.05	2.10	13.70	218.87	1.98	93.05	30.48
Apr.	26.24	1.39	84.25	1.07	980.58	0.06	2.17	9.01	216.29	1.69	122.39	30.40
May	25.77	1.11	86.87	0.82	981.70	0.06	2.01	9.34	215.28	1.63	202.54	28.02
Jun.	25.00	0.93	87.82	0.65	983.10	0.04	2.15	9.65	221.38	1.14	251.70	19.74
Jul.	24.34	1.11	87.94	0.72	983.37	0.06	2.48	6.60	224.64	1.40	349.74	20.03
Aug.	24.11	1.33	87.43	1.05	983.23	0.04	2.58	6.77	221.17	1.21	293.56	28.77
Sep.	24.57	0.71	87.92	0.79	982.73	0.05	1.85	7.93	215.66	1.47	419.96	29.71
Oct.	25.16	1.13	86.80	1.45	981.68	0.05	1.26	10.90	205.34	3.23	272.96	32.92
Nov.	25.47	1.24	81.69	2.54	981.02	0.05	0.71	45.61	202.43	19.56	67.76	26.37
Dec.	24.40	2.95	70.90	7.56	981.51	0.09	0.77	75.97	92.30	64.62	16.62	88.72

Table 4: Descriptive statistics for the parameters in Oshogbo

Month	Temperature		Relative humidity		Pressure		Wind speed		Wind direction		Rainfall	
	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)	Mean	COV (%)
Jan.	24.36	3.46	64.78	10.40	973.29	0.08	0.82	56.69	136.58	57.71	17.94	69.21
Feb.	26.01	2.88	70.80	10.45	972.15	0.06	1.38	45.97	205.71	23.07	44.24	55.97
Mar.	26.54	1.92	77.31	4.41	972.18	0.05	2.28	14.78	222.68	1.76	84.71	36.17
Apr.	26.24	1.51	81.53	1.86	972.31	0.06	2.41	10.00	220.31	1.47	116.19	34.71
May	25.65	1.14	85.44	0.97	973.43	0.06	2.18	10.75	218.55	1.32	192.87	24.51
Jun.	24.83	0.98	86.78	0.89	974.80	0.04	2.26	9.98	223.73	1.24	241.07	16.84
Jul.	24.15	1.17	87.23	0.97	975.04	0.06	2.58	7.65	228.48	1.33	345.39	17.31
Aug.	23.90	1.26	86.94	1.10	974.89	0.04	2.66	8.00	225.97	1.23	306.61	27.44
Sep.	24.35	0.75	87.23	0.81	974.42	0.05	1.80	9.00	218.46	1.56	403.64	29.56
Oct.	24.96	1.21	85.67	1.77	973.42	0.05	1.17	14.05	204.79	4.45	249.01	34.59
Nov.	25.27	1.19	79.32	3.03	972.78	0.05	0.67	55.76	203.04	22.15	55.71	29.44
Dec.	24.23	2.70	67.30	9.16	973.28	0.09	0.79	81.48	112.52	87.25	12.90	94.09



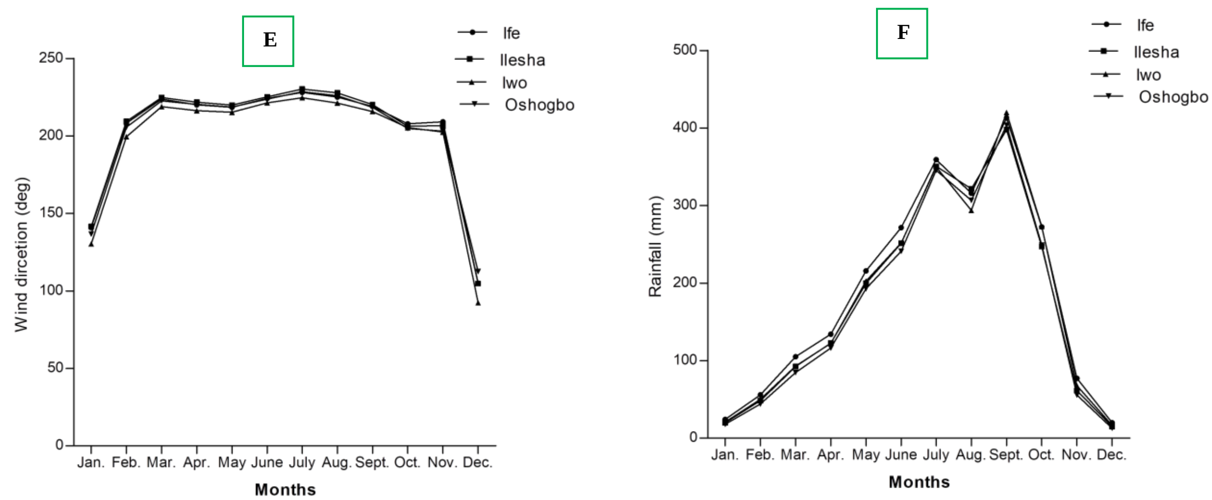


Figure 2: The monthly average of the atmospheric parameters for the locations.

The air pressure decreased progressively, reaching its lowest point in November before rebounding in December. In November, though, the temperature reached its second-highest level.

As a result, we can establish a relationship between temperature and atmospheric pressure, with the atmospheric pressure being lower at higher temperatures and vice versa in Figure 2(C). The graph of atmospheric temperature, on the other hand, is in Sine shape. Figure 2A also shows a sine graph, with pressure leading temperature by 90^0 or temperature lagging pressure by 90^0. It may be deduced that the previous month's pressure can be used to easily anticipate the temperature for the following month. As a result, a substantial link between temperature and air pressure is implied.

Over an 11-year period, the average wind speed for the month of January was 76 m/s; it grew rapidly to reach its first peak in April to about 2.23 m/s; conversely, it declined significantly in June and July. In August, however, wind speeds peaked at 2.49 m/s. In November, the wind speed reaches its lowest point (0.64 m/s). The second lowest value for average wind direction was 1.4 m/s in January.

The temperature then remained constant at 20.00 and peaked at 23.60 in July; on the other hand, the temperature dropped to its lowest point in July, and the average humidity for the time also peaked in July. As a result, because relative humidity and wind direction are both parabolas, they have a lot in common. In December, the average monthly wind direction dropped to roughly 14.70 (suggesting the lowest degree change). This, in turn, was the largest degree difference (approximately 250) between July and December, showing a significant change in wind direction during that time.

The normality of the data was tested using Shapiro- Wilk's test to determine whether the relationship between the variables will be determined using either parametric or non-parametric correlation methods. The result, as shown in Table 5, reveals that RH, pressure, wind speed, and rainfall reported p-values. In all towns, the only temperature was determined to follow a normal distribution ($p>0.05$). Because most of the variables do not have a normal distribution, the bivariate relationship between them was investigated using Spearman ranks correlation, the findings of which can be found in Table 6.

The results in Table 6 show that relative humidity, pressure, and rainfall have a significant negative connection with temperature ($p<0.05$) in all towns, implying that when the temperature rises, relative humidity, pressure, and rainfall decrease significantly ($p>0.05$). However, regression was used to explore the effect of air temperature on rainfall, air temperature, relative humidity, wind speed and direction, and the results are shown in Table 7 which follow what was reported by Aweda et al. (2021b).

Results of coefficient of determination (r^2) reveal that all in location, temperature accounted for more variation in pressure than other meteorological parameters. Temperature was found to significantly predict rainfall in all locations with r^2 of 11.1% in Ife, 14.7% in Ilesha, 9.9% in Iwo and 13.7% in Oshogbo while for wind speed, r^2 were very low in all study which implies that temperature is not a significant predictor of wind speed. For wind direction, result yielded r^2 of 11.4%, 10.0%, 9.9% and 9.9% in Ife, Ilesha, Iwo and Oshogbo respectively and these were all significant ($p<0.05$) meaning that temperature significantly predict wind direction in the study areas.

The regression shows that air temperature has a substantial negative effect on relative humidity and rainfall in Ife, Ilesha, Iwo, and Oshogbo. This means that the air temperature rises in all of the towns, while relative humidity and rainfall decline dramatically. The data also demonstrates that air temperature has a significant positive effect on wind direction ($p>0.05$), implying that when air temperature rises, wind direction rises

Table 5: Summary of the Shapiro- Wilk's test for the normality of the data

	Ife		Ilesha		Iwo		Oshogbo	
Variables	TS	P-value	TS	P-value	TS	P-value	TS	P-value
Temp.	0.993	0.749	0.982	0.085	0.994	0.891	.9806	0.183
RH	0.805	0.000**	0.829	0.000**	0.815	0.000**	0.837	0.000**
Pressure	0.973	0.009**	0.975	0.017*	0.973	0.010*	0.975	0.017*
Wind speed	0.930	0.000**	0.926	0.000**	0.932	0.000**	0.927	0.000**
Wind speed	0.550	0.000**	0.578	0.000**	0.563	0.000**	0.611	0.000**
Rainfall	0.934	0.000**	0.926	0.000**	0.924	0.000**	0.919	0.000**

TS- Test statistics,*not normally distributed at 5% (p<0.05), **not normally distributed at 1% (p<0.01).

Table 6: Correlation between the parameters in each of the locations

	Variables	1	2	3	4	5	6
Ife	1. Temp.	1.					
	2. RH	-.281**	1				
	3. Pressure	-.685**	.595**	1.			
	4. Wind speed	-.094	.590**	.399**	1		
	5. Wind direction	.022	.384**	.194*	.560**	1	
	6. Rainfall	-.284**	.912**	.613**	.619**	.353**	1
Ilesha	1. Temp.	1					
	2. RH	-.347**	1				
	3. Pressure	-.685**	.614**	1			
	4. Wind Speed	-.041	.545**	.344**	1		
	5.Wind direction	-.002	.376**	.199*	.511**	1	
	6. Rainfall	-.305**	.931**	.615**	.581**	.347**	1
Iwo	1. Temp.	1					
	2. RH	-.276**	1				
	3. Pressure	-.686**	.588**	1			
	4. Wind speed	-.103	.603**	.407**	1		
	5.Wind direction	-.034	.548**	.280**	.648**	1	
	6. Rainfall	-.264**	.924**	.592**	.598**	.473**	1
	1. Temp.	1					
	2. RH	-.343**	1				
Oshogbo	3. Pressure	-.689**	.610**	1			
	4. Wind speed	-.034	.537**	.329**	1		
	5. Wind speed	-.032	.447**	.246**	.555**	1	
	6. Rainfall	-.294**	.931**	.603**	.558**	.402**	1

**Correlation is significant at 1% (p<0.01), *Correlation is significant at 5% (p<0.05)

as well. The influence of air temperature on wind speed was not stationary (p>0.05).

In time series model fitting, stationarity is crucial. The air temperature stationarity was tested using the Augmented Dickey Fuller (ADF) test, and the results are shown in Table 8. The findings show that air temperature in all of the towns studied was not stable at the baseline (p>0.05), but became stationary after first differencing (p>0.05).

The data was fitted using various time series models, and the results of model selection are shown in Table 9. All of the tentative models had a Ljung-Box P-value larger than 0.05, indicating that they were all well-fitting. The best model was chosen from among the competing models based on R^2 and Root Mean Square Error (RMSE), with the model with the highest R^2 and lowest RMSE being declared the best. The results show that ARIMA (1,1,1) (1,1,1)12 had the highest R^2 and lowest RMSE in all of the towns studied, indicating that it is the best of the competing models. Table 10 shows the model parameter estimates for each of the four towns.

Table 10 shows that the Moving-average (MA) 1 terms were significant (p>0.05) in all locations, whereas the Auto regression (AR) 1 terms were not significant in all locations, indicating that while previous day air temperature has a positive effect on current-day air temperature, the effect is not significant. The ARIMA (1,1,1) (1,1,1)12 was used to forecast monthly air temperature for 2021 and 2022 after the model passed the model fitting test. Tables 11, 12, 13 and 14 provide expected air temperature values together with their Lower Confidence Limit (LCL) and Upper Confidence Limit (UCL). Figures 3(A-D) depicts the temperature effect forecasts for 2021 and 2022 for each location (A – Ife, B – Ilesha, C – Iwo, D – Osogbo). It was discovered that all of the stations follow the same pattern, indicating that the temperature is sinusoidal, and that the temperature pattern for the coming year will be lowest in August and highest in March.

Table 7: Summary regression result of the effect of air temperature on RH, Pressure, wind speed, wind direction and rainfall

	Variables	B	SE	t-calc.	P-value	r^2	Regression equation
Ife	RH	0.299	0.711	0.420	0.675	0.01	RH = 75.417+0.299*T
	Pressure	-0.855	0.090	-9.484	0.000**	0.409	P = 1001.118-0.855*T
	Wind speed	-0.004	0.062	-0.065	0.951	0.00003	WS = 1.552-0.004*T
	Wind direction	19.188	4.684	4.096	0.000**	0.114	WD = -277.190+19.188*T
	Rainfall	-53.961	4.684	4.096	0.000**	0.111	R = 1537.608-53.961*T
Ilesha	RH	-0.703	0.776	-0.905	0.367	0.006	RH = 98.164-0.703*T
	Pressure	-0.781	0.081	-9.602	0.000**	0.415	P = 991.739-0.781*T
	Wind speed	0.031	0.068	0.460	0.647	0.002	WS = 0.855+0.031*T
	Wind direction	17.171	4.518	3.800	0.000**	0.100	WD = -225.082+17.171*T
	Rainfall	-56.733	11.977	-4.737	0.000**	0.147	R = 1592.380-56.733*T
Iwo	RH	0.421	0.717	0.587	0.558	0.003	RH = 71.624+0.421*T
	Pressure	-0.849	0.090	-9.466	0.000**	0.408	P = 1003.139-0.849*T
	Wind speed	-0.017	0.071	-0.240	0.811	0.0004	WS = 2.111-0.017*T
	Wind direction	20.211	4.624	4.371	0.000**	0.128	WD = -311.580+20.211*T
	Rainfall	-50.942	13.493	-3.776	0.000**	0.099	R = 1461.813-50.942*T
	RH	-0.740	0.782	-0.946	0.346	0.007	RH = 98.547-0.740*T
	Pressure	-0.769	0.079	-9.676	0.000**	0.419	P =992.755-0.769*T
Oshogbo	Wind speed	0.035	0.072	0.484	0.629	0.002	WS = 0.876+0.035*T
	Wind direction	17.265	4.575	3.773	0.000**	0.099	WD = -230.558+17.265*T
	Rainfall	-54.019	11.904	-4.538	0.000**	0.137	R = 1525.116-54.019*T

**Correlation is significant at 1% ($p<0.01$), *Correlation is significant at 5% ($p<0.05$), β = regression coefficient, S.E= standard error.

Table 8: Augmented Dickey Fuller (ADF) Test for stationarity of air temperature data.

		ADF test statistic	P-value	Remarks
Ife	At level	-1.614901	0.4719	Not stationary
	After first differencing	-12.29508	0.0000	Stationary after first differencing
Ilesha	At level	-1.416542	0.5721	Not stationary
	After first differencing	-12.23224	0.0000	Stationary after first differencing
Iwo	At level	-1.690970	0.4333	Not stationary
	After first differencing	-11.77257	0.0000	Stationary after first differencing
Oshogbo	At level	-1.479372	0.5408	Not stationary
	After first differencing	-11.90984	0.0000	Stationary after first differencing

Table 9: Model selection criteria for air temperature data.

	Models	R^2	RMSE	Ljung- Box P-value
Ife	ARIMA (1,1,1) $(1,1,1)_{12}$	0.746	0.4460	0.750
	ARIMA (1,1,0) $(1,1,1)_{12}$	0.687	0.4920	0.205
	ARIMA (0,1,1) $(1,1,1)_{12}$	0.742	0.448	0.764
Ilesha	ARIMA (1,1,1) $(1,1,1)_{12}$	0.763	0.462	0.6770
	ARIMA (1,1,0) $(1,1,1)_{12}$	0.720	0.501	0.274
	ARIMA (0,1,1) $(1,1,1)_{12}$	0.755	0.469	0.7610
Iwo	ARIMA (1,1,1) $(1,1,1)_{12}$	0.734	0.462	0.851
	ARIMA (1,1,0) $(1,1,1)_{12}$	0.678	0.506	0.275
	ARIMA (0,1,1) $(1,1,1)_{12}$	0.728	0.465	0.865
Oshogbo	ARIMA (1,1,1) $(1,1,1)_{12}$	0.754	0.482	0.771
	ARIMA (1,1,0) $(1,1,1)_{12}$	0.715	0.517	0.351
	ARIMA (0,1,1) $(1,1,1)_{12}$	0.746	0.488	0.851

R^2= Coefficient of Determination

Table 10: Estimate of the best time series model among the competing models.

	Models	Parameters	Estimate	SE	t-value	P-value
Ife	ARIMA (1,1,1) $(1,1,1)_{12}$	Constant	.002	.002	.945	.346
		AR 1	.143	.130	1.096	.275
		MA 1	.837	.080	10.406	.000**
		Seasonal AR1	-.128	.136	-.937	.351
		Seasonal MA1	.970	1.043	.929	.355
Ilesha	ARIMA (1,1,1) $(1,1,1)_{12}$	Constant	.002	.003	.764	.447
		AR 1	.205	.137	1.499	.137
		MA 1	.826	.087	9.523	.000**
		Seasonal AR1	-.100	.144	-.697	.487
		Seasonal MA1	.990	3.499	.283	.778
Iwo	ARIMA (1,1,1) $(1,1,1)_{12}$	Constant	.002	.002	.979	.330
		AR 1	.164	.132	1.245	.216
		MA 1	.835	.082	10.166	.000**
		Seasonal AR1	-.171	.129	-1.328	0.187
		Seasonal MA1	.999	55.761	.018	0.986
Oshogbo	ARIMA (1,1,1) $(1,1,1)_{12}$	Constant	.002	.003	.803	.424
		AR 1	.210	.137	1.538	.127
		MA 1	.827	.086	9.588	.000**
		Seasonal AR1	-.071	.146	-.488	.626
		Seasonal MA1	.964	.955	1.009	.315

Table 11: Forecast air temperature for 2021 and 2022 in Ife.

	2021			2022		
	Forecast	UCL	LCL	Forecast	UCL	LCL
Jan.	24.74	25.56	23.92	24.64	25.64	23.64
Feb.	26.14	27.00	25.28	26.20	27.21	25.18
Mar.	26.53	27.40	25.65	26.69	27.72	25.67
Apr.	26.36	27.25	25.47	26.50	27.53	25.46
May	25.83	26.73	24.93	26.01	27.06	24.97
Jun.	25.12	26.04	24.20	25.25	26.31	24.20
Jul.	24.53	25.46	23.60	24.63	25.69	23.57
Aug.	24.33	25.27	23.39	24.41	25.49	23.34
Sep.	24.77	25.72	23.81	24.88	25.96	23.79
Oct.	25.32	26.29	24.35	25.49	26.58	24.39
Nov.	25.68	26.66	24.70	25.84	26.94	24.74
Dec.	24.54	25.53	23.55	24.82	25.93	23.71

Table 12: Forecast air temperature for 2021 and 2022 in Ilesha.

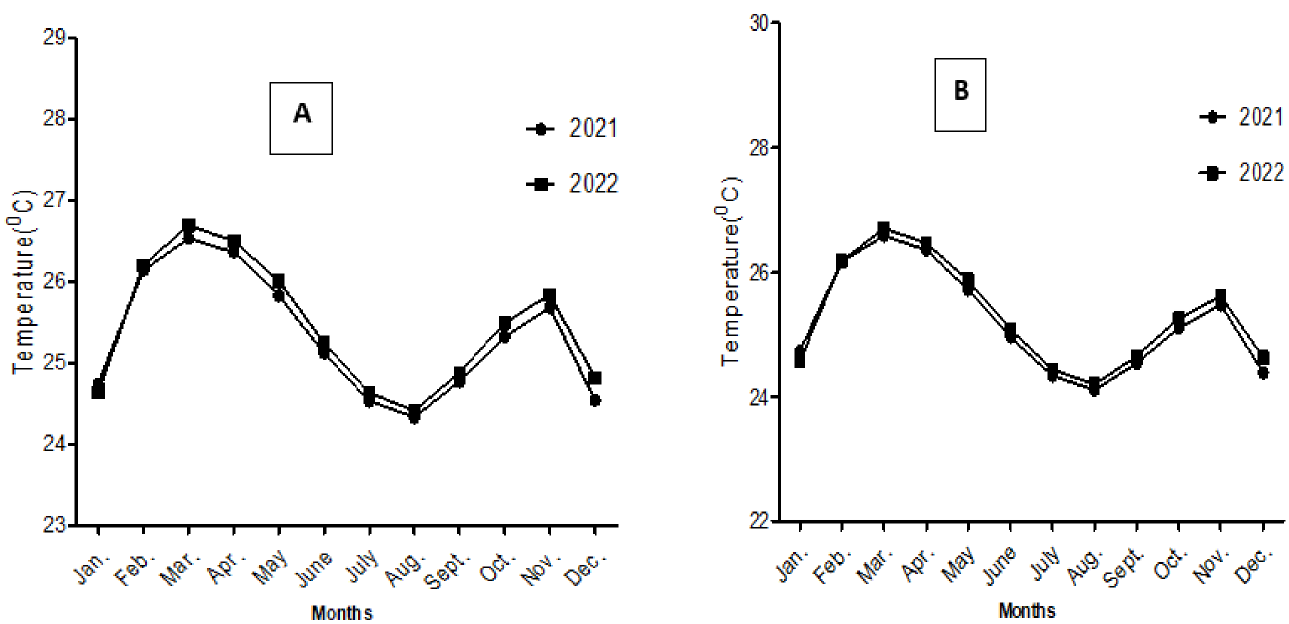
	2021			2022		
	Forecast	UCL	LCL	Forecast	UCL	LCL
Jan.	24.73	25.58	23.87	24.57	25.68	23.46
Feb.	26.17	27.09	25.26	26.18	27.30	25.06
Mar.	26.59	27.53	25.65	26.71	27.85	25.58
Apr.	26.36	27.31	25.40	26.47	27.62	25.32
May	25.72	26.69	24.74	25.88	27.05	24.72
Jun.	24.96	25.95	23.97	25.09	26.27	23.91
Jul.	24.34	25.35	23.33	24.44	25.63	23.24
Aug.	24.11	25.13	23.08	24.20	25.41	22.99
Sep.	24.54	25.58	23.49	24.65	25.87	23.43
Oct.	25.11	26.17	24.05	25.26	26.50	24.03
Nov.	25.48	26.55	24.40	25.62	26.86	24.37
Dec.	24.39	25.49	23.30	24.63	25.89	23.37

Table 13: Forecast air temperature for 2021 and 2022 in Iwo.

	Forecast	UCL	LCL	Forecast	UCL	LCL
Jan.	24.98	25.83	24.13	24.80	25.85	23.75
Feb.	26.38	27.28	25.49	26.39	27.45	25.33
Mar.	26.75	27.66	25.83	26.93	28.00	25.85
Apr.	26.56	27.49	25.63	26.70	27.78	25.62
May	26.05	27.00	25.10	26.26	27.35	25.17
Jun.	25.36	26.32	24.40	25.49	26.60	24.39
Jul.	24.77	25.75	23.80	24.86	25.97	23.74
Aug.	24.56	25.55	23.57	24.63	25.75	23.51
Sep.	25.00	26.01	24.00	25.11	26.25	23.98
Oct.	25.56	26.58	24.54	25.73	26.87	24.59
Nov.	25.88	26.91	24.85	26.06	27.21	24.90
Dec.	24.67	25.72	23.63	25.02	26.18	23.86

Table 14: Forecast air temperature for 2021 and 2022 in Oshogbo.

	Forecast	UCL	LCL	Forecast	UCL	LCL
Jan.	24.79	25.68	23.89	24.67	25.84	23.50
Feb.	26.29	27.25	25.33	26.34	27.52	25.15
Mar.	26.75	27.74	25.77	26.89	28.10	25.69
Apr.	26.47	27.48	25.47	26.61	27.83	25.39
May	25.86	26.88	24.83	26.03	27.27	24.80
Jun.	25.09	26.13	24.04	25.24	26.49	23.99
Jul.	24.44	25.50	23.38	24.58	25.84	23.31
Aug.	24.20	25.28	23.12	24.33	25.61	23.05
Sep.	24.66	25.75	23.56	24.80	26.10	23.51
Oct.	25.26	26.37	24.14	25.43	26.74	24.12
Nov.	25.59	26.72	24.46	25.76	27.08	24.43
Dec.	24.51	25.66	23.36	24.75	26.09	23.41



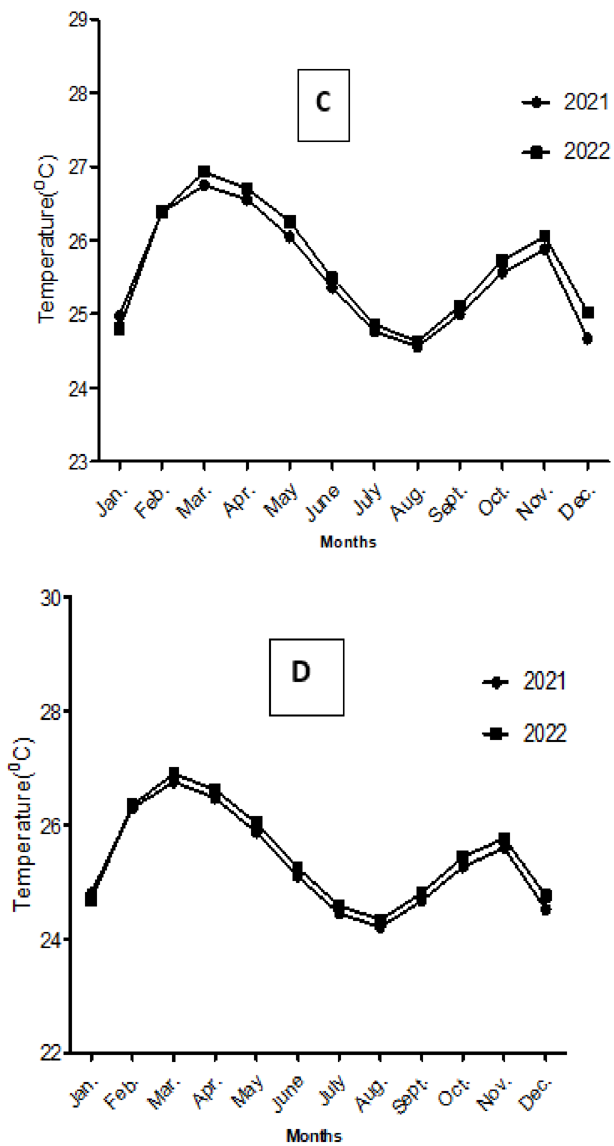


Figure 3: The forecast of the air temperature across all the locations considered.

IV. CONCLUSION

The change of air temperature, relative humidity, air pressure, wind speed, and direction follows the Gaussian distribution, which is governed by a sine function. Temperatures are high in February, March, and April, according to the monthly variation pattern of meteorological factors. Other metrics are substantially connected with air temperature, which has the highest value in Osogbo, according to the correlation matrix. Air temperature, RH, pressure, rainfall, wind speed, and direction. Air temperature, rainfall, relative humidity, air pressure, wind speed, and wind direction, on the other hand, vary sinusoidally across the study's years. Statistically, the coefficient of variation (COV) found for temperature, although the variance observed for rainfall, air temperature, RH, wind speed and direction across all sites was lower.

The average temperature in March was higher than in other months, but the maximum mean rainfall, air pressure, relative humidity, wind speed, and direction were recorded in July, August, and September, respectively. For any monthly time-series, however, air temperature modeling and forecasting are challenging to handle. In this work, we demonstrate that ARIMA models can successfully capture the course of air temperature in the examined stations by delivering the minimum forecast RMSE and can better forecast long seasonal time series with high frequency by delivering the minimum forecast RMSE.

It was demonstrated that, in reality, more than one measure should be used to obtain appropriate information on overall forecasting, and that the best statistical approach model can vary based on the data. The results then predicted the similar trend for temperature variation in the years 2021 and 2022 with a 98 % confidence level. It is recommended that all-time data for any studied location, as well as climatic characteristics, be considered while choosing the most appropriate model. More research on the specifics of air temperature forecasting, as well as research on meteorological characteristics, should be carried out across the country.

ACKNOWLEDGEMENT

The authors gratefully acknowledge HelioClim MERRA-2 for supplying the data for the study.

REFERENCES

Adhikari, K. R.; B. K. Bhattarai and S. Gurung. (2013). Estimation of global solar radiation for four selected sites in Nepal using sunshine hour, temperature, and relative humidity. Journal of power and Energy Engineering, 1(3): 1-9.

Adhikari, S. (2016). Seasonal and Spatial variation of solar radiation in Nepal Himalayas. Journal of Hydrology and Meteorology, 8(1): 1 – 9.

Afrifa-Yamoah E.; I. Bashiru; I. Saeed and A. Karim. (2016). Sarima Modelling and Forecasting of Monthly Rainfall in the Brong Ahafo Region of Ghana. World Environment, 6(1): 1-9.

Almorox, J. (2011). Estimating global solar radiation from common meteorological data in Aranjuez, Spain. Turk Journal de physique, 35(1): 53 – 64.

Anitha, K.; N.K. Boiroju and P. R. Reddy. (2014). Forecasting of monthly mean of maximum surface air temperature in India. Int. J. Statistika Mathematika, 9(1): 14-19.

Aweda, F. O. and Samson, T. K. (2020). Modelling the Earth's Solar Irradiance across Selected Station in Sub-Sahara Region of Africa. Iranian (Iranica) Journal of Energy and Environment Journal, 11(3): 204-211.

Aweda, F. O.; J. A. Oyewole; J. B. Fashae and T. K. Samson. (2020). Variation of the Earth's Irradiance over selected Towns in Nigeria. Iranian (Iranica) Journal of Energy and Environment Journal, 11(4): 301 – 307.

Aweda, F. O.; S. Adebayo; T. K. Samson and I. A. Ojedokun, (2021a). Modelling Net Radiative Measurement of Meteorological Parameters Using MERRA-2 Data in Sub-

Sahara Africa Town. Iranian (Iranica) Journal of Energy and Environment Journal, 12(2): 173 – 180.

Aweda, F. O.; J. O. Agbolade; J.A. Oyewole and M. Sanni. (2021b). Seasonal Variation of Some Atmospheric Parameters in Fresh Water Swamp and Sudan Savanna areas of Nigeria. Nigerian Journal of Technology (NIJOTECH), 40(4): 740 –750.

Balyani, Y.; G.F. Niya and A. Bayaat. (2014). A study and prediction of annual temperature in Shiraz using ARIMA model. J. Geographic Space, 12(38): 127-144.

Chabane, F.; N. Moummia and A. Brima. (2018). Forecast of relationship between a relative humidity and a dew point temperature. Journal of power Technologies, 98(2): 183 – 187.

Gelaro, R.; W. McCarty; M. J. Suarez; R. Todling; A. Molod; L. Takacs; C. A. Randles; A. Darmenov; M. G. Bosilovich; R. Reichle; K. Wargan; L. Coy and B. Zhao. (2017). The Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2). Journal of Climate, 30(14): 5419 – 5454.

El-Mallah, E.S. and Elsharkawy S.G. (2016). Time-series modeling and short term prediction of annual temperature trend on Coast Libya using the Box-Jenkins ARIMA Model. Advances Res., 6(5): 1-11.

Eludoyin, O. M.; I. O. Adelekan; R. Webster and A. O. Eludoyin. (2014). Air temperature, relative humidity, climate regionalization and thermal comfort of Nigeria. International Journal of Climatology, 34(6): 2000 – 2018.

Frimpong, K.; J. Oosthizen and E. J. Van Etten. (2014). Recent trends in temperature and relative humidity in Bawku East, Northern Ghana. Journal of Geography and Geology, 6(2): 69 – 81.

Geerts, B. (2003). Empirical estimation of the monthly-mean daily temperature range. Theoretical and Applied Climatology, 74: 145 – 165.

Gornicki, K.; R. Winiczenko; A. Kaleta and A. Choinska. (2017). Evaluation of models for the dew point temperature determination. Technical Sciences, 20(3): 241 – 257.

Hamrouni, N.; M. Iraidi and M. Cherif. (2008). Solar radiation and ambient temperature effects on theperformances of a PV pumping system. Revue des Energies Renouvelables, 11(1): 95 – 106.

Khatib, T. and Elmenreich, W. (2015). A model for hourly solar radiation data generation from daily solar radiation data using a generalized regression artificial neural network. International Journal of Photoenergy, 13(1): 1-13.

Khedhiri, S. (2015). Forecasting temperature record in PEI, Canada. Letters in Spatial and Resource Sciences, 9: 43-55, doi 10.1007/s12076-014-0135-x

Lawrence, M. G. (2005). The relationship between relative humidity and dewpoint temperature in moist air: a simple conversion and applications. American Society, 86(2): 225 – 234.

Lobell, B.D.; A. Sibley and J. I. Ortiz-Monasterio. (2012). Extreme heat effects on wheat senescence in India. Nature Climate Change, 2: 186-189.

Lobell, D.B., G. I. Hammer; G. Mclean; C. Messina; M. J. Roberts and W. Schlenker. (2013). The critical role of extreme heat for maize production in the United States. Nature Climate Change, 3: 1-13.

Mawoli, M.; H. N. Yayha; B. G. Danshehu; M. L. Muhammad and A. S. Bature. (2020). Development and Performance Evaluation of Solar Photovoltaic Module's Surface-to-Rear Temperature Controlled Valve for Cooling Application. Nigerian Journal of Technological Development. 17(1): 20-27. doi: http://dx.doi.org/10.4314/njtd.v17i1.3

Muhammet B. (2012). The analyse of precipitation and temperature in Afyonkarahisar (Turkey) in respect of Box-Jenkins technique. J. Academic Social Sci. Studies, 5(8): 196-212

Murat, M; I. Malinowska; M. Gos and J. Krzyszczak. (2018). Forecasting daily meteorological time series using ARIMA and regression models. Int. Agrophys., 32: 253-264.

Poudyal, K. N.; B. K. Bhattarai; B. Sapkota, B. Kjeldstad. (2012). Solar radiation potential at four sites of Neptal. Journal of the Institute of Engineering. 8(3): 189 – 197.

Poudyal, K. N.; B. K. Bhattarai; B. Sapkota and B. Kjeldstad. (2012). Estimation of global solar radiation using clearness index and cloud transmittance factor at trans-Himalayan region in Nepal. Energy and power Engineering, 4(6): 415 – 421.

Prieto, J. I.; J. C. Martinez-Gacia and D. Garcia. (2009). Correlation between global solar irradiation and air temperature in Asturias, Spain. Solar Energy, 83(7): 1076 – 1085.

Rebetez, M. (2001). Changes in daily and nightly day – to – day temperature variability during the twentieth century for two stations in Switzerland. Theoretical and Applied Climatology, 69(1 - 2): 13-21.

Semenov M.A. and Shewry P.R. (2011). Modelling predicts that heat stress, not drought, will increase vulnerability of wheat in Europe. Scientific Reports, 1: 66.

Sillmann J. and Roeckner E. (2008). Indices for extreme events in projections of anthropogenic climate change. Climate Change, 86: 83-104.

Tanabe, S. I. and Kimura, K. I. (1994). Effect of air temperature, humidity, and movement on thermal comfortunder hot and humid conditions. Symposium, ASHRAE Transactions, 100(2): 953 – 969.

Ukhurebor, K. E.; I. C. Abiodun, F. Bakare. (2017). Relationship between relative humidity and dew point temperature in Benin City, Nigeria. Journal of Applied Sciences and Environmental Management. 21(5): 953 – 956.

Ukhurebor, K. E.; T. B. Batubo; I. C. Abiodun and E. Enoyeze. (2017). The influence of air temperature on the dew point temperature in Benin City, Nigeria. Journal of Applied Sciences and Environmental Management, 21(4): 657-660.

Yousif, T. A. and Tahir, M. H. (2013). The relationship between relative humidity and dew point temperature in Khartoum State, Sudan. Journal of Applied and Industrial Sciences, 1(5): 20 - 23.