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RESEARCH ARTICLE

MONTHLY AIR TEMPERATURE VARIABILITY IN ILORIN AND LAGOS, NIGERIA

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ABSTRACT

Temperature is an important climatologically variable that cause global warming. The strategic location of Ilorin and Lagos calls for examining the variability of monthly air temperature in these cities. Seasonal means model was used to determine the variability of monthly air temperature. The seasonal pattern of the series follows a cosine function with variable amplitude; hence cosine trend model was fitted while least square method was used to estimate the parameters. The fitted models were used to forecast monthly temperature in the two cities. Linear trend model was fitted to Ilorin and Lagos forecast to know the direction of future monthly temperature. Seasonal means model revealed variability in the monthly temperature especially in Ilorin in the month of January where 37^0C was recorded and the direction of future monthly temperature was upward, an indication of global warming. Measures for global warming are suggested such as proper town planning and tree planting among others.

KEYWORDS: Temperature, Seasonal mean model, Global warming, Cosine trend model, Forecast

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INTRODUCTION

Temperature is described as how hot, warm or cold a place is at a particular time (Bello, 2010). Over the years, temperature in the globe is not static; there has been a steady rise in temperature across the universe (Audu*et al*., 2004). The steady rise in temperature across the globe is the cause of global warming.

Global warming is the gradual, but continuous increase in temperature of an area over time. It is caused by natural systems and human activities (IPCC, 2007). Human activities are the most

critical which result from various activities aimed at making life more comfortable such as industrialization, intensive and extensive farming, use of generating sets and urbanization among others. These activities tend to build up greenhouse gases thereby leading to greenhouse effect that causes global warming (Marc, 2015). Climate change over the last century is a subject of great topical interest. This problem worries the scientific community, as it could have a major impact on natural and social systems at local, regional and national scales. (Parker and Moberg, 2001) and (Jones *et al*., 1999) agreed that there has been a large-scale warming of the Earth's surface over the last hundred years or so. This warming up of the Earth during the 20th century brought with it a decrease in the area of the world affected by exceptionally cool temperatures, and, to a lesser extent, an increase in the area affected by exceptionally warm temperatures (Jones *et al*., 1999).

Some analyses of long time-series of temperatures on a hemispheric and global scale (IPCC, 2001) have indicated a warming rate of 0.3-0.6 since the mid-19th century, due to either anthropogenic causes (IPCC, 2001) or astronomic causes (Soon *et al*., 1998). A broad consensus of scientists has concluded that, the earth's surface air temperature increased by about 0.6 during the 20th century, that most of the warming during the latter half of the century is attributable to human emissions of greenhouse gases, and that temperature increases were greatest during the 1990s (IPCC, 2001). Numerous other factors such as variations in solar radiation and pollutant aerosols also contribute to climate change (Brasseur and Rockner, 2005).

The IPCC panel further concluded that global temperature increases are likely to persist in the 21st century and will probably be accompanied by changes in precipitation and runoff amounts. Future climate change is more difficult to predict with great certainty at the regional scale due to spatial resolution limitations of current climate models. In recent time, the concept of global warming has gained a universal discourse because of its high incidences of hydro meteorological hazards such as erosion, landslide and flooding (Audu *et al*., 2010). Nigeria is already facing the realities of these hazards especially flooding which is now an annual event especially in Jos Plateau, Ibadan, Sokoto, Abuja, Ilorin, Lokoja and Lagos among others. Temperature is so important because it influences health, agriculture, evaporation, transport, rainfall and human comfort among others**.** These were observed by various authors such as (Fayeye, 2010) and (Adesina *et al*., 2010). Physiological temperature is put at 36.7ºC or 37ºC (Nieuwolt, 1977) and (Ayoade, 1988) when this amount is exceeded; heat stress begins for instance heat waves, which is a threat to people's health.

Study Area

Ilorin, the capital city of Kwara State, Nigeria is located on latitude $8^0 24'$N and $8^0 36'$N and longitude $4^0 10'$E and $4^0 36'$E with an area of about $100km^2$ (Kwara State Diary, 1997). It is situated at a strategic point between the densely populated southwestern and the sparsely populated middle belt of Nigeria. Ilorin is located in traditional zone between the deciduous woodland of the

south and dry savannah of North of Nigeria (Jimoh, 2003). The climate of Ilorin is characterized by both wet and dry seasons.

Lagos is African second most populous city, which grew explosively, from 300,000 in 1950 to an expected 18 million by 2010, when it will be ranked as one of the world's ten largest cities. The metropolitan area, an estimated 1,000 square kilometers, is a group of islands surrounded by creeks and lagoons and bordered by the Atlantic Ocean. With a GDP triple that of any other West African country; Lagos is the commercial and industrial hub of Nigeria. Lagos is home to many industries and much large commercial infrastructure, and has greatly benefited from Nigeria natural resources of oil, natural gas, coal, fuel wood and water (UN Habitat, 2004). The climate of Lagos is affected by ocean and atmospheric interactions both within and outside its environment, in which the Inter Tropical Convergence Zone (ITCZ) plays a controlling factor. The climate of Lagos is also characterized by both wet and dry seasons.

In the light of the above, this study is sought to fit seasonal means model to examining the variability of monthly air temperature and global warming in the study areas and as well fit a cosine trend model to monthly air temperature series of Ilorin and Lagos. Forecast of monthly air temperature for the two cities would be studied based on the fitted cosine trend model.

MATERIALS AND METHODS

Seasonal Means Model

The time series data displays a very regular pattern called seasonality, seasonality for monthly value occurs when observations twelve months apart are related in some manner or another.

Consider now the model

$$Y_t = \mu_t + X_t \tag{1}$$

where E(X_t) = 0 for all t. The most general assumption for μ_t with monthly seasonal data is that there are 12 constant (parameters),β_1, β_2, ….. β_{12}. Giving the expected average temperature for each of the months we write

$$\mu_t = \begin{cases} \beta_1 & for,\ t = 1, 13, 25, \ldots \\ \beta_2 & for,\ t = 2, 14, 26, \ldots \\ \vdots & \vdots & \vdots \\ \beta_{12} & for,\ t = 12, 24, 36, \ldots \end{cases} \tag{2}$$

whereβ_1 = Jan, β_2= Feb, ……., β_{12}= Dec.

The resulting form of seasonal pattern follows a cosine function with variable amplitude.

Cosine Trend Model

Consider the process define as follows:

$$Y_t = \cos[2\pi(\frac{t}{12} + \emptyset)] \text{ for } t = 0, \pm1, \pm2, \ldots. \quad (3)$$

where$\emptyset$ is selected (once) from a uniform distribution on the interval from 0 to 1. A sample from such a process will appear highly deterministic since Y_t will repeat itself identically every 12 time units and look like a perfect (discrete time) cosine curve. However, its maximum will not occur at t = 0 but will be determined by the random phase$\emptyset$. The phase $\emptyset$ can be interpreted as the fraction of a complete cycle completed by time t = 0 still, the statistical properties of this process can be computed as follows:

$$E(Y_t) = E\{\cos[2\pi(\frac{t}{12} + \emptyset)]\} \quad (4)$$

Seasonal trends can be modeled economically with cosine curves that incorporate the smooth change expected from onetime period to the next while still preserving the seasonality, then we consider the cosine curve with equation

$$\mu_t = \beta cos(2\pi ft + \emptyset) \quad (5)$$

where$\beta(>0)$ is the amplitude, f is frequency, t is time and $\emptyset$ is the phase of the curve.

The equation above is inconvenient for estimation because the parameters β and $\emptyset$ could not be expressed linearly. Alternatively we use a trigonometric identity to re-parameterize equation (5) more conveniently as follows:

$$\beta cos(2\pi ft + \emptyset) = \beta_1 \cos(2\pi ft + \emptyset) + \beta_2 \sin(2\pi ft + \emptyset) \quad (6)$$

To estimate the parameters $\beta_1$and β_2 with regression technique, we simply use $cos(2\pi ft)$ and $sin(2\pi ft)$ as predictor variables.

The cosine model is expressed as

$$\mu_t = \beta_0 + \beta_1 cos(2\pi ft) + \beta_2 sin(2\pi ft) \quad (7)$$

Forecast

The main purpose of modeling a time series is to make forecasts. The basic idea behind self-projecting time series forecasting models is to find the mathematical formula that will approximately generate historical patterns in a time series. After fitting an adequate model to the

set of data, we are now in a position to use this model to forecast future observations that are optimal in the sense of the minimum mean square error. Base on the available history of the series up to time t namelyY_1, Y_2, ……., Y_{t-1}, Y_t we would like to forecast the value of $Y_{t+\gamma}$that will occur γ time units into the future. We call time t the forecast origin and γ the lead time for the forecast, and denote the forecast itself as $\hat{Y}_{t(\gamma)}$. The minimum mean square error forecast is given by

$$\hat{Y}_{t(\gamma)} = E\,(Y_{t+\gamma}|Y_1, Y_2, \ldots\ldots, Y_t) \quad (8)$$

Trend Fitting for the Forecast

Trend is the tendency of the series to increase or decrease over a long period. It can be defined as the systematic change in the mean with time. It shows the direction in which the graph of the series appears to be going over a long period of time or interval of time. Trend may be linear, exponential or any other function. For the purpose of this study, linear trend model would be fitted which is expressed as

$$\hat{Y}_t = a + bt \quad (9)$$

Where t = 1, 2, 3… n. The parameters is estimated using least square method

RESULTS

The monthly data used was collected from Nigerian Meteorological Agency (NIMET), Oshodi, Lagos State, Nigeria. The study covers a range of twenty years from 1994 to 2013.

Seasonal Means Model

Table 1: Results for the Seasonal Means Model for Lagos

Months	Estimate of β's	Standard Error	t-value	Probability
January	33.8500	0.4826	72.19	<2e-14
February	25.4100	0.7611	54.19	<1e-18
March	24.0650	0.6523	51.32	<1e-17
Apr	20.0250	0.6404	42.70	<1e-15
May	16.5000	0.3903	35.19	<1e-12
June	15.1850	0.1994	32.38	<1e-11
July	15.1400	0.2377	32.29	<1e-11
August	15.8000	0.3348	33.70	<1e-11
September	16.5550	0.3647	35.30	<1e-12
October	17.8900	0.2685	38.15	<1e-13
November	25.6350	0.4984	54.67	<1e-18
December	34.1100	0.4202	72.74	<2e-15

Table 2: Results for the Seasonal Means Model (Ilorin)

Parameters	Estimate of β's	Standard Error	t-value	Probability
January	37.0750	0.2738	137.5	<3e-16
February	35.5200	0.3547	131.8	<3e-10
March	33.6050	0.3084	124.7	<2e-14
Apr	32.5550	0.3170	120.8	<2e-12
May	31.3500	0.2966	116.3	<2e-11
June	29.5750	0.2127	109.7	<2e-08
July	30.2350	0.2133	112.2	<2e-10
August	30.4000	0.1955	112.8	<2e-10
September	32.2300	0.2432	119.6	<2e-12
October	32.9550	0.2196	122.2	<2e-12
November	34.2650	0.2884	127.1	<2e-14
December	34.7400	0.2610	128.9	<2e-14

The seasonal means model in Tables 1 and 2 showed the means and variation for monthly air temperature of Ilorin and Lagos. The month with higher mean have more variability than the one with lower mean, here only the January mean for Ilorin is above the physiological temperature of 36.7^0C - 37^0C which is an indication of global warming.

Cosine Trend Model

Table 3: Cosine Trend Model for Temperature Series for Lagos

Coefficient	Estimate of β's	Standard Error	t-value	Probability
Intercept	21.6804	0.2129	101.837	>2e-16
Cos(2πt)	8.6241	0.3011	28.644	>2e-15
Sin(2πt)	-0.6550	0.3011	-2.175	0.0306

The cosine model $\mu_t=\beta_0+\beta_1 cos(2\pi t)+\beta_2 sin(2\pi t)$ becomes $\mu_t = 21.6804 + (8.6241)cos(2\pi t)$ - $(0.6550)\ sin(2\pi t)$. The model is significant and fits the data quite well (Table 3), therefore the model could be used to predict future values for monthly air temperature of Lagos.

Table 4: Cosine Trend Model for Temperature Series (Ilorin)

Coefficient	Estimate of β's	Standard Error	t-value	Probability
Intercept	32.8754	0.0841	39.0911	>2e-16
Cos(2πt)	2.9820	0.1189	25.0730	>2e-13
Sin(2πt)	-0.2927	0.1189	-2.461	0.0146

The cosine model $\mu_t=\beta_0+\beta_1 cos(2\pi t)+\beta_2 sin(2\pi t)$ becomes $\mu_t = 32.8754 + (2.9820)cos(2\pi t)$ - $(0.2927)\ sin(2\pi t)$.The model is significant and fits the data quite well (Table 4), therefore the model could be used to predict the future values for monthly air temperature of Ilorin.

Table 5: Monthly Air Temperature Forecast for Lagos City

	Jan	Feb	Marc	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	26.2	26.1	26.1	26.0	25.1	25.8	25.8	25.7	25.6	25.6	25.5	25.4
2015	25.3	25.3	25.2	25.1	25.1	25.0	24.9	24.8	24.8	24.7	24.6	24.5
2016	24.5	24.4	24.3	24.3	24.2	24.1	24.0	23.9	23.9	23.8	23.7	23.6
2017	23.6	24.7	24.7	24.6	24.5	24.4	24.4	24.3	24.2	24.1	24.1	24.0
2018	22.6	22.5	22.5s	22.4	22.3	22.2	22.2	22.1	22.0	21.9	21.8	21.8

Table 5, showed the monthly air temperature forecast for Lagos using the result obtained from cosine trend model in Table 3.

Table 6: Monthly Air Temperature Forecast for Ilorin

	Jan	Feb	Marc	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	34.4	34.4	34.3	34.3	34.3	34.3	34.2	34.2	34.2	34.6	34.1	34.1
2015	34.8	34.1	34.0	34.3	34.0	34.0	34.2	33.9	33.9	34.1	33.8	33.8
2016	33.8	33.8	33.7	34.0	33.7	33.7	33.9	33.6	33.6	33.8	33.5	33.5
2017	33.5	33.4	33.4	33.4	33.4	33.3	33.3	33.3	33.2	33.2	33.2	33.2
2018	33.1	33.1	33.1	33.1	33.0	33.0	34.0	32.9	32.9	32.9	32.9	32.8

Table 6, showed the monthly air temperature forecast for Lagos using the result obtained from cosine trend model in Table 4.

Linear Trend Model fitted for Lagos and Ilorin Forecast

Lagos forecast trend model is given as Y_t= 21.6804 + 8.6241(t) while Ilorin forecast trend model is Y_t = 32.8754 + 2.9820(t)

Table 7: Trend Values for Lagos Forecast

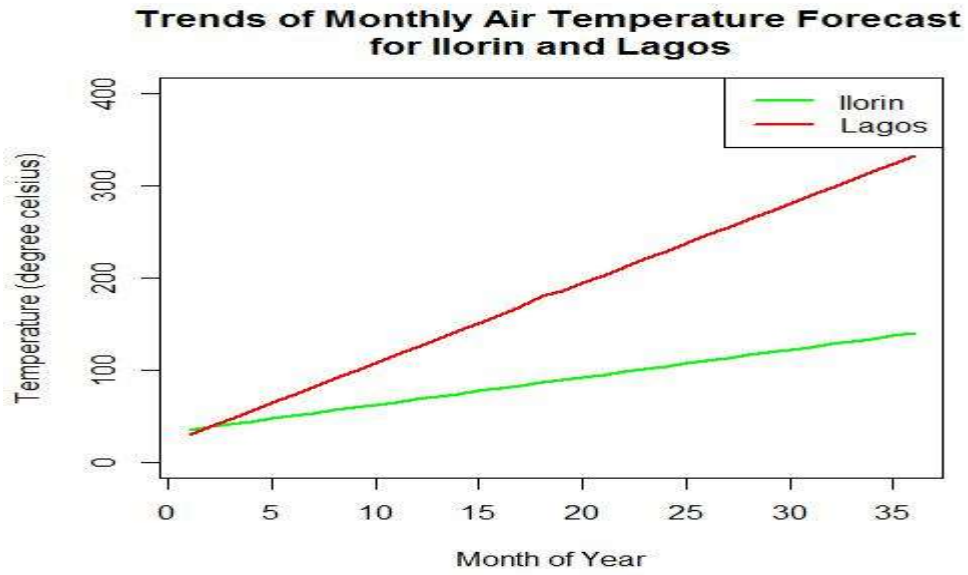
	Jan	Feb	Marc	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	30.31	38.93	47.55	56.18	64.80	73.43	82.05	90.67	99.30	107.9	116.6	125.2
2015	133.8	142.4	151.1	159.7	168.3	179.9	185.5	194.2	202.8	211.4	220.1	228.7
2016	237.3	245.9	254.5	263.2	271.8	280.4	289.1	297.7	306.3	314.9	323.5	332.2

Table 7, showed the trend values for Lagos forecast using the forecast trend model Y_t= 21.6804 + 8.6241(t)

Table `8: Trend Values for Ilorin Forecast

	Jan	Feb	Marc	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	35.86	38.84	41.82	44.80	47.79	50.77	53.75	56.73	59.71	62.70	65.68	68.66
2015	71.64	74.62	77.61	77.61	83.57	86.55	86.55	92.52	95.50	98.48	101.5	104.4
2016	107.4	110.4	113.4	113.4	119.4	122.3	125.3	128.3	131.3	134.3	137.3	140.2

Table 8, showed the trend values for Ilorin forecast using the forecast trend model Y_t = 32.8754 + 2.9820(t)



The above plot showed the linear trends of monthly air temperature forecast for Ilorin and Lagos with an upward movement.

DISCUSSION

According to the results and based on the number of years under consideration (20 years) which is sufficient enough to determine the temperature of any station, Lagos has a mean temperature below the physiological temperature of 36.7^0C-37^0C which indicates that human comfort in the Lagos city is still favourable. Ilorin also has mean temperatures below the physiological temperature of 36.7^0C-37^0C, except January with temperature above physiological temperature. The general rise in temperature is attributed to the exodus movement of people into the cities, Lagos and Ilorin has led to rapid urbanization, high population, massive construction of houses and roads, deforestation of gallery forest, numerous vehicular movement, use of generating sets and reduction in vegetal cover. Constructions lead to more bare spaces and increase the albedo leading to positive temperature changes since modern building materials like the aluminum roofing sheets are poor absorbers of heat, but rather heat reflectors. Also, farmlands were taken over by rapid urbanization hence reduction in vegetation cover (both natural and artificial) leading to increasing temperature. Again, vehicles and generating sets which are on the increase burn carbon which have two (2) main effects – smokes from them cause pollution and increases the ambient temperature and the carbon emitted increases the carbon layer in the lower atmosphere thereby leading to global warming. Several authors have pointed out that anthropogenic activities are the main causes of global warming, climate variability and climate change (Audu *et al*., 2004), (Audu *et al*., 2010), (Ayoade, 1988), (IPCC, 2001), (Marc, 2015) and

(Soon *et al*., 1998). Therefore, areas with low population, less affected by desertification, low or total absence of industrialization and other human activities have low vulnerability rate to global warming, climate variability and climate change.

Also, from the plot the upward movement of temperatures in the two cities is an indication of global warming in the future especially Ilorin that had steeper trend.

CONCLUSION

In conclusion, this study has shown that there is a steady rise in temperature in the study areas which is a sign of global warming in the study areas.

It is therefore suggested that tree planting campaign should be given an aggressive attention in order to curb excess carbon dioxide emission which can lead to an abnormal rise in temperature of the study areas. Again, there should be proper urban planning with the creation of green areas in and around the town to serve as carbon sink. Illegal structures, encroachments and alteration of the colonial town planning and master plan in the old Ilorin should be discouraged. Alternative power sources such as wind, solar and waste energies should be explored to replace the use of generating sets.

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