Journal of Physical Science and Environmental Studies
Vol. 3 (1), pp. 8-17, January, 2017
ISSN 2467-8775
Full Length Research Paper
http://pearlresearchjournals.org/journals/jpses/index.html

On the Analysis of the Changes in the Temperatures over Abuja, Nigeria

Ikenna C. Orisakwe[1*], Okey K. Nwofor[2], Clement C. Njoku and Ugochukwu O. Ezedigboh

Accepted 30 January, 2017

[1]Nigerian Meteorological Agency, Abuja, Nigeria.
[2]Atmospheric Science Group, Imo State University Owerri, Nigeria.

ABSTRACT

The obvious deviation of the air temperatures from its long term mean is a clear indication of the reality of climate change. This research paper examines the seasonal and inter-seasonal trends in the maximum, minimum and mean temperatures over Abuja (9.07ºN; 7.6ºE), Nigeria, and spanning over three decades. Daily temperature data (from 1983 to 2014) obtained from the archives of the Nigerian Meteorological Agency (NiMet) was used for this study. To obtain our results, we employed two statistical tools vis-à-vis Arithmetic Mean and Trend Analysis (using simple linear regression analysis). The results show a downward trend in the average maximum temperature in the last two decades (1993-2013) and an upward trend in the average minimum and mean temperatures over Abuja. From this study, it is established that global warming has started happening in Abuja, Nigeria. Therefore, we recommend that further studies be carried out to discover the particular kind(s) of greenhouse gases (GHGs) responsible for this observed warming.

Keywords: Temperature, Abuja, Trend, Variability, Analysis.

*Corresponding author. E-mail: ikennacorisakwe@gmail.com. Tel: +234 (0) 7038190831.

INTRODUCTION

It is a known fact that changes in our climate are taking place very sensibly (Ahrens, 2006) and so far nothing has suggested that it will not continue to change till further notice. These changes have resulted in the phenomenon of global warming. It is clear that one of the ways to understand the degree of these changes is to study the effect which is global warming. But then to quantify the degree of warming arising from these changes in our climate, one has to study the changes in the global temperature which is the fundamental factor. According to Amadi et al., (2014), one of the most commonly used parameters that indicate climate change is the surface temperature. Temperature has always been defined as the quantity that tells us the degree of hotness or coldness of a "body". Hence, in order to ascertain the impacts of climate change over Abuja, Nigeria, the study of the changes in the degree of hotness or coldness of this city is one of the surest means to do so. Also pointed out in Audu (2012), one of the climate variables mostly affected by global warming, climate variability and climate change is temperature.

Globally, the surface temperature of the earth has increased by 0.74 $\pm$ 0.18ºC during the last 100 years ending in 2005 (IPCC, 2007); but this value has been discovered to be varying from one place to another. For instance, the mean annual temperature of Bangladesh increased by 0.31ºC between 1895 – 1980 (Mehrotra and Mehrotra, 1995), while the mean annual maximum temperature has been projected to increase by 0.4ºC and 0.73ºC in the years 2050 and 2100 respectively (Karmaker and Shrestha, 2000). More recently, in order to understand the pattern of change of temperature of Dhaka, the capital of Bangladesh (Mohiuddin et al., 2014) the average monthly maximum temperature was observed to be showing a negative (decreasing) trend but though statistically less significant, while the average monthly minimum temperature shows a trend of 6.8ºC increase per 100years period. Interestingly, in India though most of the

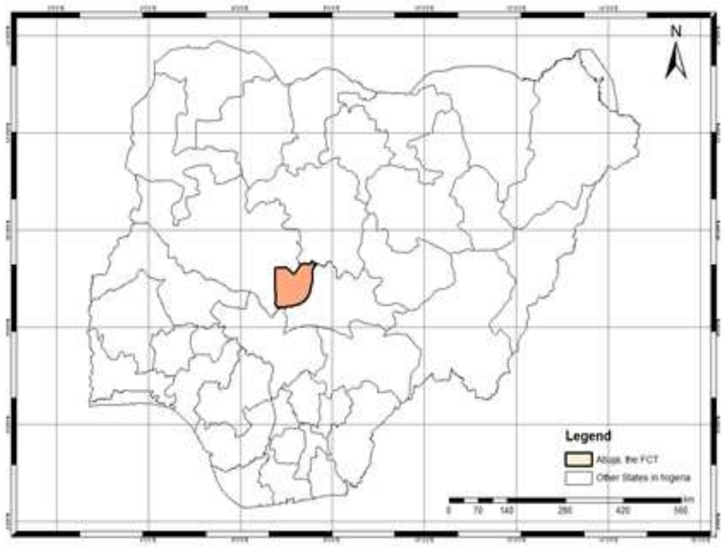

Figure 1: Map of Nigeria showing the location of Abuja, the federal capital territory.

cities investigated had rising trends, there were records of cities with falling trends in the maximum temperature (Jain and Kumar, 2012).

Amadi et al., (2014) in a study of the trends and variations of monthly mean, minimum and maximum temperatures over some selected cities in Nigeria did not include Abuja, the nation's capital city. This study revealed that Nigeria is experiencing a rise in air surface temperature for the period 1950 – 2012. Other studies carried out to investigate the trends and variations in the temperature over Nigeria were done over Ibadan, Nigeria (See Ogolo and Adeyemi 2009; Jackson et al., 2012), over Lokoja (Audu, 2012) and over Katsina (Adakayi, 2009). Over Ibadan, the surface temperatures have been observed to be on the increase though with a revelation that the increase in maximum temperatures was not statistically significant (Jackson et al., 2012; Ogolo and Adeyemi, 2009). This implies that the reported increase in temperature was due to the minimum temperature that was on the increase. Also in their studies over Nigeria, (Audu *et al*., 2004) observed that from 1971 - 2010, temperature increased by $0.34^{o}C$ while the average minimum temperature increased by $3^{o}C$ per decade, while Adakayi, (2009) observed an increase in the minimum temperature over Katsina while in Bello, (2010), some of the stations studied recorded $0.2\text{-}0.3^{o}C$ per decade.

Numerous papers have been written on climate variability and its impacts on temperature, rainfall, agriculture, land-use and the economy over Nigeria (Olaniran and Summer, 1989; Ekpo, 1991; Odjugo and Al Isi, 2003; Adefolalu, 2007; Odekunle, 2007; Adesina, 2010; Fayeye, 2010; Odjugo, 2010; Ekpoh and Nsa, 2011); but none to the best of the authors' knowledge has been written with a focus on the variability in the temperature of Abuja. In response to calls for further investigation into the temperatures trends of other regions in Nigeria (Jackson et al., 2012), this study aims at establishing the seasonal and inter-seasonal trends in the maximum, minimum and mean temperatures over Abuja Nigeria.

The importance of this study cannot be over-emphasized as changes in temperature can have great impacts on a whole lot of spheres of our life from energy supply, water supply, flood and drought, thermal comfort, work output and especially agriculture, through rainfall (Arora *et al*., 2005). Since majority of the agricultural practices in Abuja are rain-fed and over 70% of the rainfall comes from convective systems (Omotosho, 1985 and Orisakwe, 2015). Over time, increase in low-level water vapour have been observed to be a constant response to low-level warming (changes in temperature; see Held & Soden, 2006) But a combination of this low-level warming and low-level water vapour can lead to enhanced buoyant energy needed by thunderstorms updrafts (Trapp et al., 2009) which determines the intensity of the thunderstorms. Furthermore, one of the three factors that strongly influence the organization of cumulus clouds into severe thunderstorms is temperature,the rest are moisture and wind. All these points go ahead to buttress the importance of this study on the changes in temperatures and how the study will assist many in making informed policies as regards weather. It will also go a long way towards boosting our understanding of the trends and variability on the temperatures over Abuja Nigeria, thus forming a basis for further studies on their implications on different sectors of the economy.

Abuja, the capital territory of the federal republic of Nigeria, is located within $9.07^{o}N$ and $7.6^{o}E$ occupying 1769sqkm (Figure 1). It is surrounded by Kaduna, Kogi, Nasarawa and Niger states to the north, south, east and west respectively with a population of about 776,298 (Census, 2006). The city of Abuja experiences double of thunderstorm (Ochei et al., 2015). The weather is

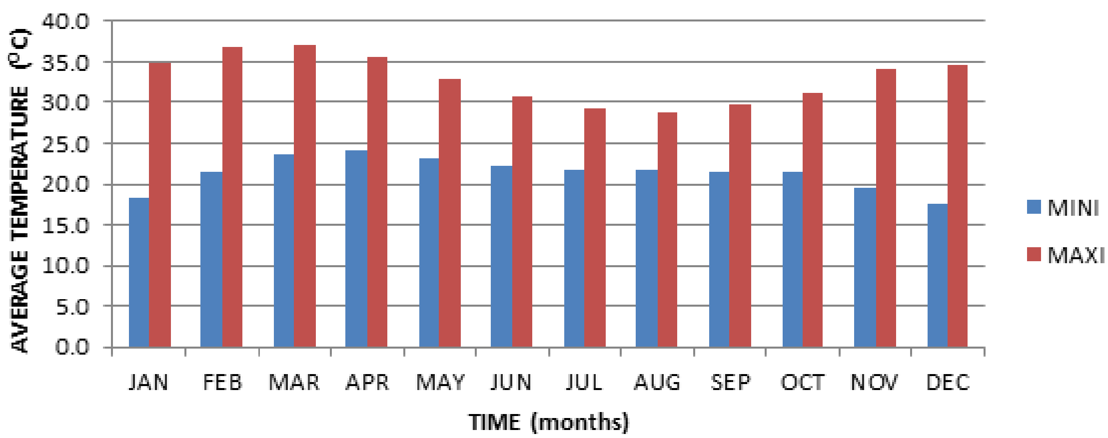

Figure 2. Average monthly maximum and minimum temperatures from 1983 to 2014.

determined by many factors among which are orography and the interplay between the two major air-masses, viz: the tropical continental (cT) air-mass and the tropical maritime (mT) air-mass. The tropical continental air-mass is often dry, cold and dusty because it is of Saharan origin while the tropical maritime air-mass is usually warm and moist simply because it originates from the Atlantic Ocean (Ologunorisa and Tersoo, 2006; Akinsanola and Ogunjobi, 2014; Akinyemi, 2011; Ekpoh, 2011; Odekunle, 2004). As a result of the differences in the characteristics of these two air-masses, there are seasonal differences in the temperatures over Abuja. This depends largely on the prevailing air-mass at any given season of the year.

DATA AND METHODOLOGY

Daily temperature data spanning a period of 31years (1983 to 2014) obtained from the archives of the Nigerian Meteorological Agency (NiMet), Abuja was used for this study.

Firstly, the arithmetic means of the daily maximum temperature and minimum temperature were calculated to obtain the monthly means, while the diurnal temperature range was computed by subtracting the averages of the daily minimum temperature from that of the Maximum temperature.

Among the methods employed in this study was the statistical trend analysis, obtained using the simple linear regression analysis using the following equations;

$$y = bx + c \qquad 1$$

$$b = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sum(x_i - \bar{x})^2} \qquad 2$$

where y is the temperature, b is the linear trend of the temperature per time, x is the time (year) and c is the intercept of the line. x_i is the independent variable representing the year, y_i is the dependent variable representing temperature for the years, $\bar{x}$ and $\bar{y}$ are the averages of the variables (i.e. year and temperature) this method has been widely used (Mohiuddin et al., 2014; Arora et al., 2005; Kruger and Shongue, 2004; Mote, 2003).

However, in order to ascertain the degree of significance of the observed trend, the coefficient of correlation R^2 was used to test for significance. R-square tells one how much of the change in the dependent variable can be explained by the independent variable. The value of R^2 varies from 0 – 1, hence, any array of variable with R^2 less than 0.5 implies that the trend is statistically insignificant but when the value of R^2 is greater than or equal to 0.5, the trend could be said to be statistically significant. The formula for R^2 is given as in equation (3);

$$R^2 = \frac{[\sum(x_i - \bar{x})(y_i - \bar{y})]^2}{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2} \qquad 3$$

RESULTS AND DISCUSSIONS

Figure 2 shows the plot of the average maximum and minimum temperatures over Abuja, Nigeria from 1983 to 2014. The average maximum temperature was observed to be low in the months of July, August and September which are the months with the deepest monsoonal flow (Odekunle, 2004; Omogbai, 2010; Adejuwon, 2012; Bibi et al., 2014; Budnuka, 2015). Also, other factors responsible include more rainfall events which tend to reduce the daytime (maximum) temperatures and cloud cover which attenuates the intensity of solar radiation reaching the earth surface. The maximum temperature was also observed to be high in the months of February, March and April. These are the pre-monsoon seasons, during which the effects of the cold tropical continental (cT) air-mass has weakened, leaving the atmosphere dry and warm. These months (February, March and April) witness few or no

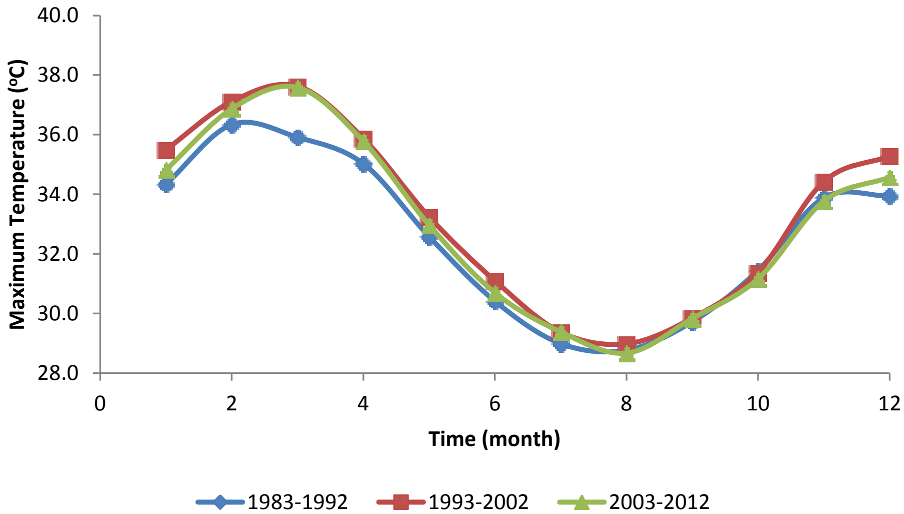

Figure 3. Seasonal variations of the maximum temperatures for the three decades; 1983 to 1992, 1993 to 2002, 2003 to 2012.

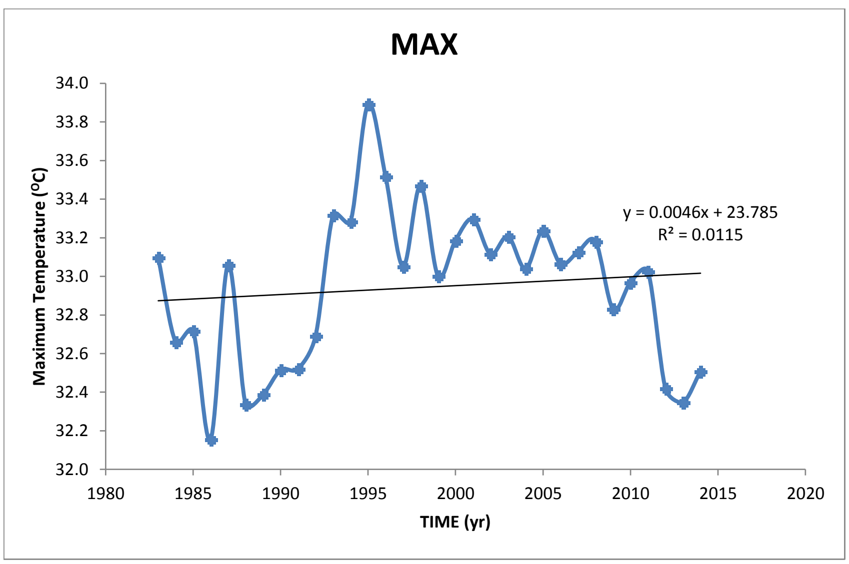

Figure 4a. Inter-seasonal variations of the average maximum temperature for 31 years (1983 to 2014).

cloud cover and no dust in suspension which would have attenuated the insolation, hence, the occurrence of high temperature. Also, the lowest maximum temperature occurred in August while the highest average maximum temperature was recorded in the month of March.

The highest minimum temperature value was recorded in April while the lowest average minimum temperature was recorded in December. These imply that the warmest and coolest months in the city of Abuja are March and December respectively.

In Figure 3, it can be seen that the 1993-2002 decade has the highest average maximum temperature followed by 2003-2012 and then 1983-1992. This implies that the 2003-2012 decade was cooler than the preceding decade (1993-2002). Also observed are the significant differences in the temperature values noticeable in the months of January, February, March, November and December.

Figure 4 is the trend analysis of the average monthly maximum temperatures for; (a) the entire period under review from 1983-2014 (31yrs), (b) the first decade under review - 1983-1992, (c) the second decade under study-1993-2002, (d) the third decade of 2003-2012.

Figure 4 (a) gives the trend analysis for the entire 30 year period. It simply shows an increasing trend with prospects

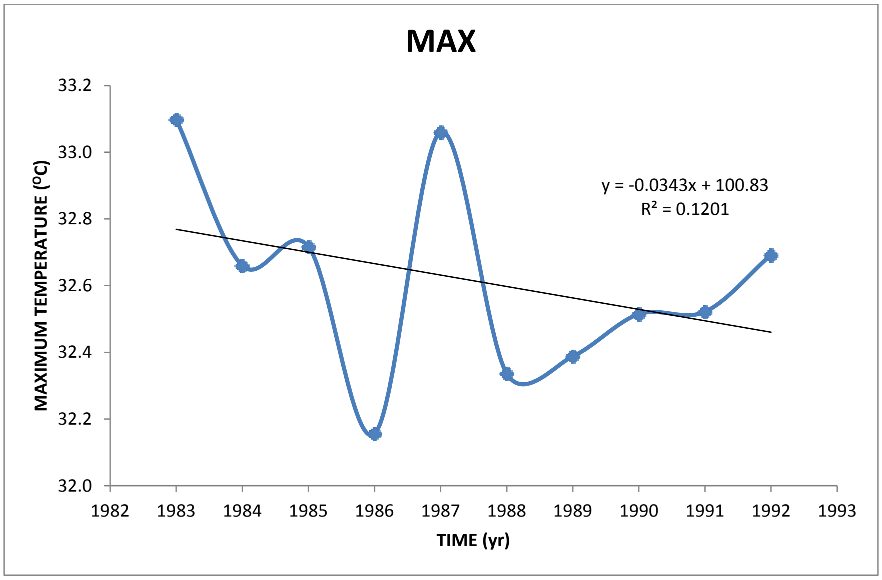

Figure 4b. Inter-seasonal variations of the average maximum temperature for the first decade (1983 to 2014).

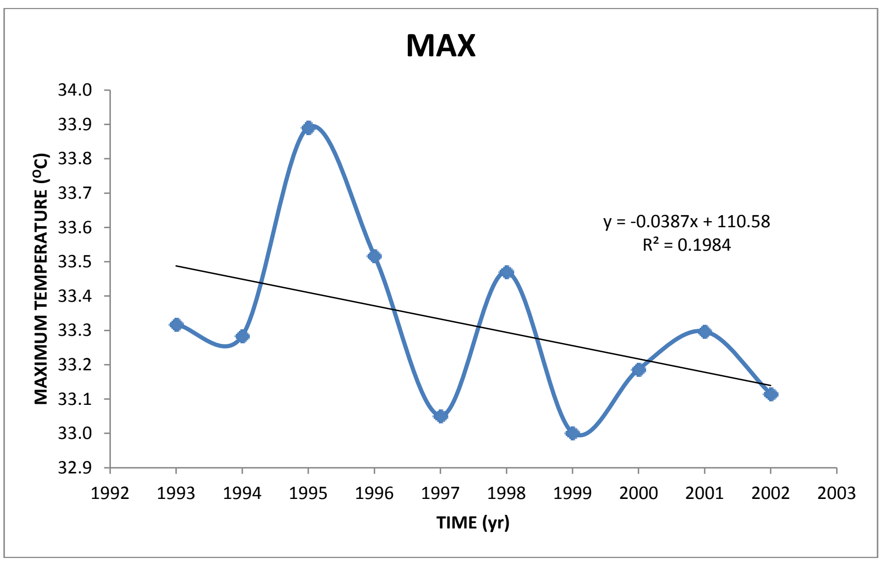

Figure 4c. Inter-seasonal variations of the average maximum temperature for the second (1993 to 2002).

of further increase by 0.46°C in the next 100-year period. However, since the coefficient of determination (R^2) is very low, it implies a very weak statistical significance of the trend. Further look at the graph (Figure 4a) shows a negative (decreasing) trend from 1995-2015 spanning two decades and a 7-year period in-between when there was a sudden rise in the maximum temperature at a rate of 0.21°C per year (Figure 4e), the highest before the beginning of the gradual downward trend. Since the majority i.e. two out of the three decades recorded downward trend, it is ideal to adjudge the maximum temperature as having recorded a decrease in value in the last 30-year period. Also it can be seen from the Figure (4a) that the lowest and the highest average maximum temperature for the period under review in Abuja occurred in the years 1986 and 1995 respectively.

Figures 4(b, c and d) show a segmentation of the 30-year period of the study into three decades; 1983-1992 (Figure 4b), 1993-2002 (Figure 4c) and 2003-2012 (Figure 4d). They all indicate decades of negative (decreasing) average maximum temperatures at the rates of 0.03°C, 0.04°C and 0.06°C per year respectively. They have coefficients of determinants of 0.12, 0.20 and 0.49 respectively, indicating that the average maximum

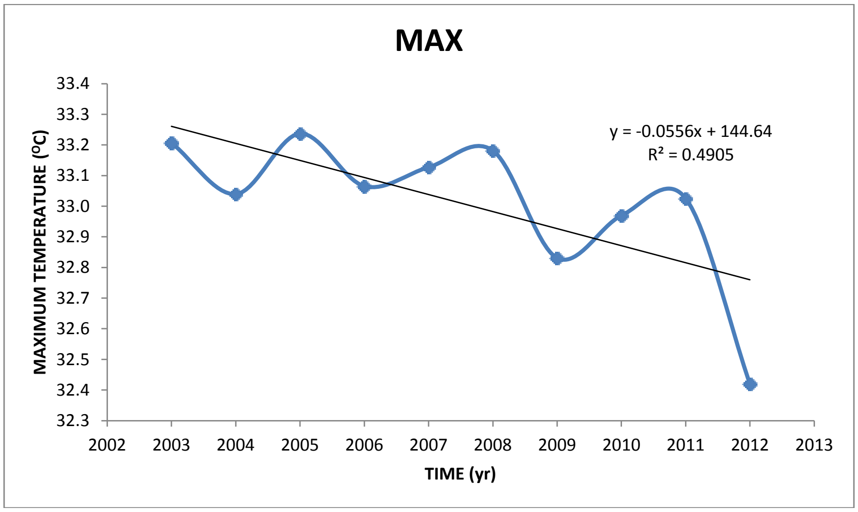

Figure 4d. Inter-seasonal variations of the average maximum temperature from 1983 to 2014.

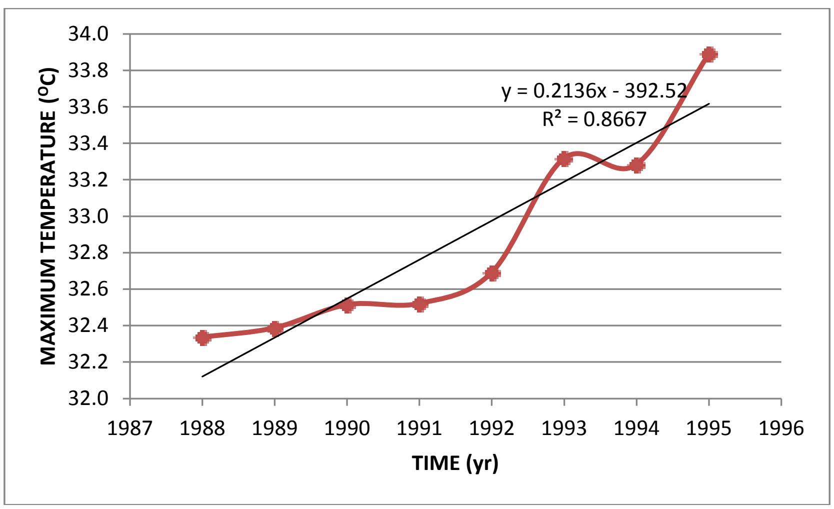

Figure 4e. Inter-seasonal variations of the average maximum temperature from 1988 to 1995.

temperatures have been decreasing over Abuja at the rate of 0.06°C per year in the last decade ending 2012. This is not out place as there are reports that some cities in India have falling trends in maximum temperatures (Jain and Kumar, 2012).

In order to understand the rates at which there were a rise and a continuous fall in the average maximum temperature between 1988 and 1995 and 1995 and 2014, Figures 4(e and f) were introduced. Figure (4e) shows that the average maximum temperature was increasing at the rate of 0.21°C per year with R^2 of 0.87 which is very significant. However if this rate is sustained, in the next 100 year period, the temperature over Abuja would have risen by 21°C per 100-year period. This was why the trend analysis of the 30-year period could not show the decreasing trend in the maximum temperatures. Figure (4f) on the other hand, indicates a negative (decreasing) trend in maximum temperature at the rate of 0.05°C per year with a significant R^2 value of about 0.65. This implies that if this negative trend is sustained, the maximum temperature would have fallen by 5.0°C in the next 100-year period. The observed negative trend is in line with the observations of Jain and Kumar, (2012).

Figure 5(a) shows the analysis of the average minimum temperatures with an increasing (positive) trend which has increased at the rate of 0.04°C per year period in the last three (3) decades ending in 2012, though with R^2 of about 0.35 which is statistically less significant. This indicates that not all the solar radiations reaching the earth's surface escapes back into space, hence keeping the night time temperature higher than normal. The chart (Figure 5a) also shows that the lowest and the highest average minimum

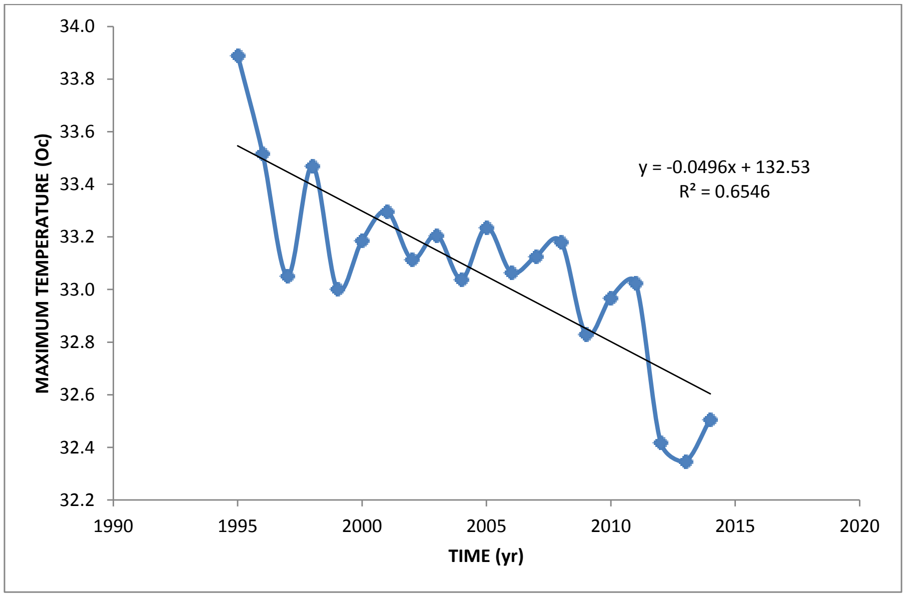

Figure 4f. Inter-seasonal variations of the average maximum temperature from 1995 to 2014.

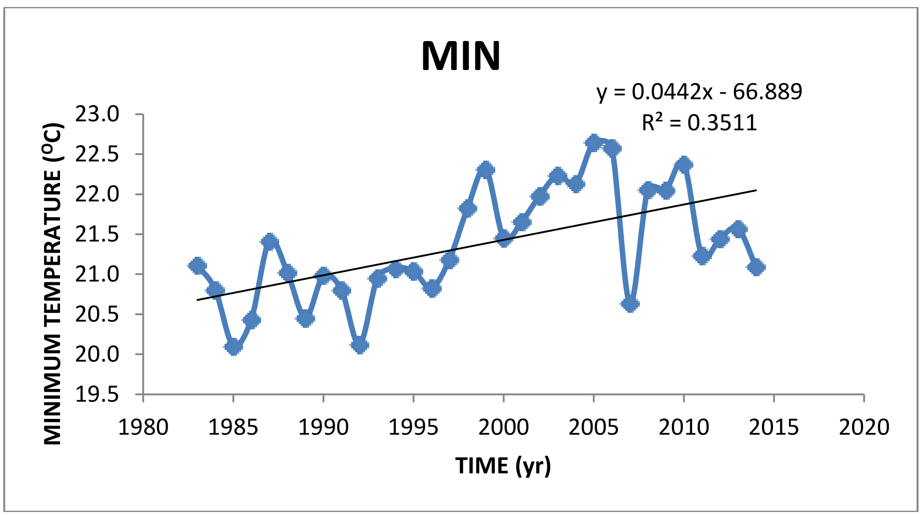

Figure 5a. Inter-seasonal trend of the average minimum temperature from 1983 to 2014.

temperatures for the period in consideration occurred in the years 1985 and 2005 respectively. But comparing the three decades, Figure 5(b) shows that the third decade (2003-2012) recorded the highest average minimum temperatures in 91.6% of the months, followed by the second decade (1993-2002) with about 8.3% of the months, while the first decade 1983-1992 remained low throughout the period (1983-2012). It can also be seen that the average minimum temperature has one peak in April and one low in December. Similar trend was observed over Ibadan (Ogolo and Adeyemi, 2009; Jackson et al., 2012).

In Figure 6, the trend for the mean temperature was 0.02°C per year period, with the lowest mean temperature occurring in 1985 while the highest mean temperature occurred in the year 2005. Generally, the mean temperature over Abuja could be said to be increasing during the period in review.

CONCLUSION

It has just been discovered that while the average maximum temperature was decreasing, the average minimum temperature was increasing. This can only happen when there is in the atmosphere a layer of air that tends to reduce the intensity of the incoming Solar radiation reaching the earth surface and also prevents the long wave solar radiation from leaving the earth surface;

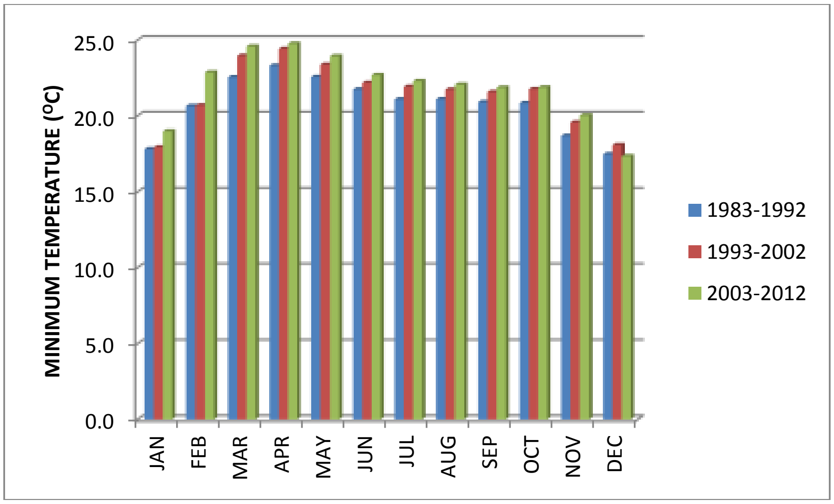

Figure 5b. The seasonal variations in the average minimum temperatures for the three separate decades; 1983 to 1992, 1993 to 2002 and 2003 to 2012.

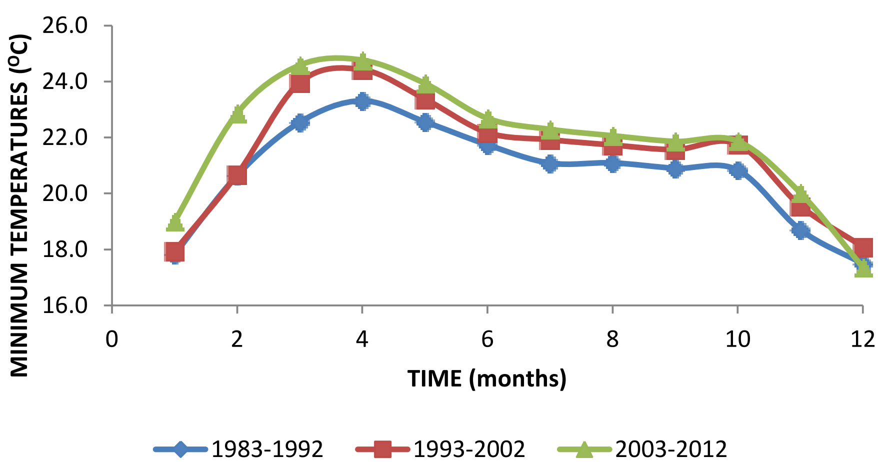

Figure 5c. The trend in the seasonal variation of the minimum temperature over Abuja.

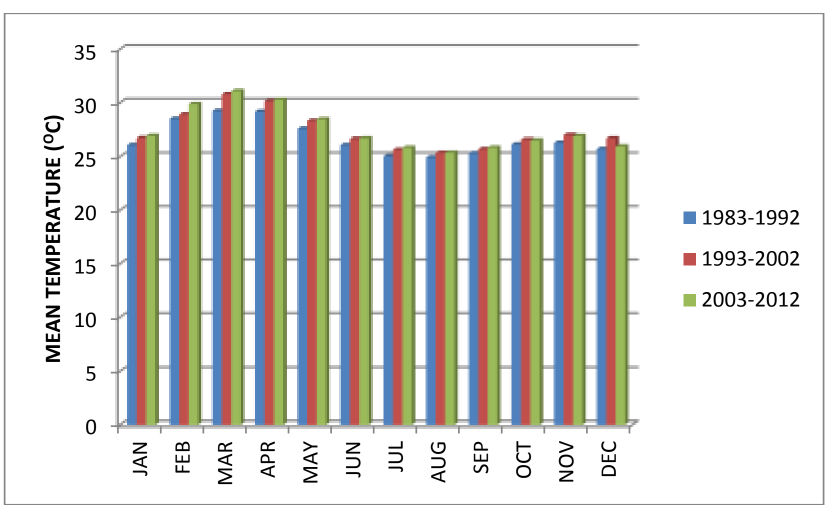

Figure 5d. The seasonal variation of the mean temperature for a 31 year period (1983 to 2014).

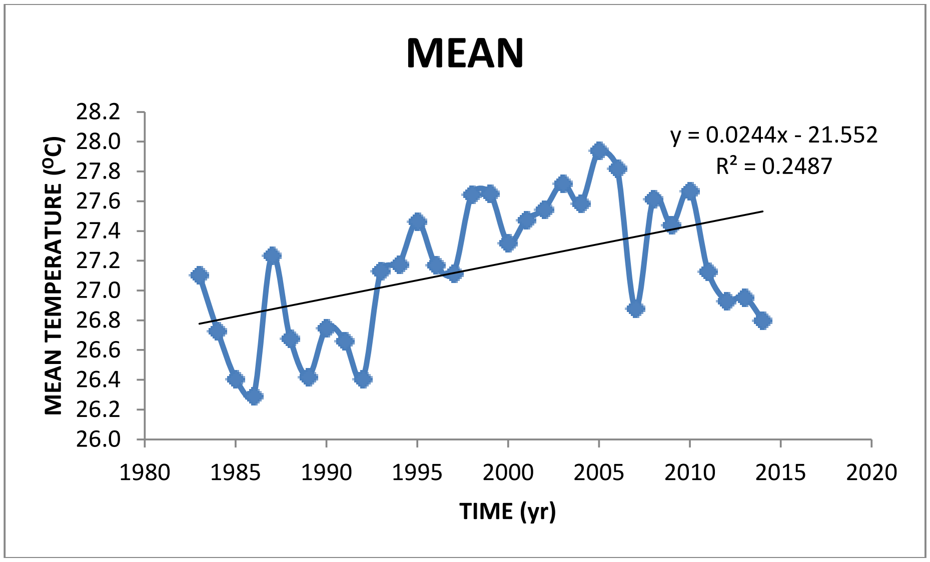

Figure 6. The inter-seasonal trend of the mean temperature over Abuja from 1983 to 2014.

trapping the heat (at night). Hence, reducing the average maximum temperature but increasing the average minimum temperature over Abuja. From this study, it is established that global warming has started happening in Abuja, Nigeria. Therefore, we recommend that further studies be carried out to discover the particular kind(s) of greenhouse gases (GHGs) responsible for this observed warming.

REFERENCES

Adefolalu DO (2007). Climate change and economic sustainability in Nigeria. Paper presented at the international conference on climate change and economic stability held at Nnamdi Azikiwe University, Awka, Nigeria. 12-14 June 2007 pp. 1-12.

Adejuwon JO (2012). Rainfall seasonality in Niger-Delta Belt, Nigeria. J. Geograph. Region. Plann. Vol. 5(2): 51-60.

Adesina BT, Omitonyi BO, Oguntuga OA, Oluyemi SO, Ajibade AO (2010). Climate Change Impacts on Livestock and Fisheries. J. Meteorol. Climate Sci., 8(2):121.

Ahrens CD (2006). Meteorology Today: An Introduction to Weather, Climate and the Environment, 8th Edition. Published by Brooks Cole.Canada.

Akinsanola AA, Ogunjobi KO (2014). Analysis of Rainfall and Temperature Variability over Nigeria. Global J. Human-Social Sci. (B)., 14(3):1-9.

Amadi SO, Udo SO and Ewona IO (2014). Trends and Variations of monthly mean, minimum and maximum temperatures data over Nigeria for the period 1950-2012. Int'l J. Pure and Appl. Phys., 2(4):1-27.

Arora M, Goel NK, Singh P (2005). Evaluation of temperature trends over India. Hydrological Sci. J.-des Sci. Hydrologiques, 50(1): 81-93.

Audu EB (2012). An Analytical View of Temperature in Lokoja, Kogi State Nigeria. Int'l. J. Sci. Tech., 2(2): 856-859.

Audu HO, Chukwu GO, Ogbonnaya N, Afuape SO (2004). Global Warming in Nigeria: Evidence in Southeastern Nigeria. A Conference paper delivered at the National Conference of the Nig. Met. Soc. (NMetS), Univ. of Agric., Abeokuta Nigeria. pp.4-6.

Bello NJ (2010). Climate Change: Implications for food Production and Security in Nigeria: In Climate Change Impacts and Adaptation: Developmental Issues. A Special Book on Climate Change. Nig. Met. Soc. (NMetS). p.4.

Bibi UM, Kaduk J, Balzter H (2014). Spatial-Temporal variation and Prediction of rainfall in Northeastern Nigeria. Climate(volume and page number)

Budnuka AC (2015). Statistical Analysis of seasonal temperature variation and Thunderstorm activities over Yola North-East Nigeria. Am. J. Educ. Res.,3(7): 873880.

Ekpoh IJ (2011). Extreme climatic variability in North-western Nigeria: an analysis of rainfall trends and patterns. J. of Geograph. Geol, 3(1) :51-62.

Ekpoh IM, Nsa E (2011). Extreme Climatic variability in North-western Nigeria:An analysis of rainfall trends and patterns. J. Geograph. Geol., 3(1): 51-62.

Feyeye TR (2010). Global warming and the challenges of sustainable livestock production in the sub-saharan Africa. Nigerian Meteorological Society Proceedings of the National Conf. on Climate change Impact and adaptation:Is Nigeria Ready? Nov. 1-4, 2010, Ilorin p. 50.

Held IM, Soden BJ (2006). Robust response of the hydrological cycle to global warming. J. Clim., 19:5686-5699.

IPCC (2007). Climate Change 2007: The Physical Science Basis: IPCC Working Group I, Fourth assessment Report: Summary for Policy makers.

Jackson OI, Isienyi NC, Osudiala CS, Odofin BJ, Adeyemi AA, Odeleye OA, Amoo VO (2012). Analysis of temperature trends of Ibadan, Nigeria over the period of 1965-2012. J. Forest. Res. Manag., 9: 61-72.

Karmaker S, Shrestha ML (2000) Recent Climate Change in Bangladesh, SMRC No. 4, SMRC Dhaka.

Kruger AC, Shongwe S (2004). Temperature trends in South Africa: 1960-2003. South Africa. Int. J. Climatol., 24, 1929-1945.

Mehrotra D, Mehrotra R (1995). Climate Change and hydrology with emphasis on the Indian Sub-continent. Hydrologic Sci. J. 40: 231-241.

Mohiuddin H, Bhuiya MR, Al Mamum MM (2014). An Analysis of the temperature Change of Dhaka City, proceedings of 5th International Conference on Environmental Aspects of Bangladesh (ICEAB), pp.46-48.

Mote PW (2003). Trends in temperature and precipitation in the pacific Northwest during the Twentieth century. University of Washington. Washington. North West Sci. 77(4): 271-282.

Ochei MC, Orisakwe IC, Oluleye A (2015). Spatial, Seasonal and Inter-seasonal variations of thunderstorm frequency over Nigeria. Afr. J. Environ. Sci. Technol., 9(12): 810-833.

Odekunle TO (2004). Rainfall and the length of growing season in

Nigeria. Int. J. Climatol., 24: 467-479
Odekunle TO (2004). Rainfall and the length of growing season in Nigeria. Int. J. Climatol., 24: 467- 479.
Odekunle TO (2007). Application of GIS to assess rainfall variability impacts on crop yield in Guinean Savanna part of Nigeria. Afr. J. Biotechnol., 6(18): 2100-2113.
Odjugo PA (2010). General overview of climate change impacts in Nigeria. J. Hum. Ecol., 29(1): 47-55
Odjugo PAO, Ikhuoria AI (2003). The impact of climate change and anthropogenic factors on desertification in the semi-arid region of Nigeria. Global J. Environ. Sci., 2(2): 118-126.
Ogolo EO, Adeyemi B (2009). Variations and trends of some meteorological parameters at Ibadan, Nigeria. The Pacific J. Sci. Technol., 10(2): 81-987.
Olaniran OJ, Summer GN (1989). A Study of Climate variability in Nigeria based on the onset, retreated and length of the rainy season. Int. Climatol., 9:253-269.
Ologunorisa TE, Tersoo T (2006). The changing rainfall pattern and its implication for flood frequency in Makurdi, Northern Nigeria. J. Appl. Sci. Environ. Mgt., 10(3): 97-102.
Omogbai BE (2010). An empirical prediction of seasonal rainfall in Nigeria. J. Hum. Ecol., 32(1): 23-27.
Omotosho JB (1985). The Separate contributions of Line Squalls, Thunderstorms and The Monsoon to the Total Rainfall in Nigeria. J. Climatol., 5:543-552.
Orisakwe IC (2015). Disaggregation and Quantification of Rainfall Associated with the Three Rainfall Producing Systems in Nigeria, Unpublished M.Tech Thesis, FUTA, Nigeria. p.47.
Trapp RJ, Diffenbaugh NS, Gluhovsky A (2009). Transient response of severe thunderstorm forcing to elevated greenhouse gas concentrations. Geophys. Res. Let., 36: 1-6.