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Full Length Research Paper

Regional evidence of climate change in Nigeria

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Most available data on climate change are mainly global whereas the effects are more at regional levels. It is on this premise that this study investigated the regional evidences of climate change using Nigeria as a case study. Mean annual air temperature from 30 synoptic stations between 1901 and 2005 were collected from the Nigerian Meteorological Agency, Lagos and Meteorological Department in some Airports. The data were divided into three climatic periods namely 1901-1935, 1936-1970 and 1971-2005 for the purpose of comparison. Time series, correlation, least square range test, ANOVA and isotherm maps were some statistical tools used to analyze the data. The results show that air temperature is steadily increasing especially from the 1970s. Between 1901 - 1935 and 1936 - 1970 climatic periods, temperature anomalies were below the 1970 - 2005 normal, but 22 years (63%) out of the 35 years were above the normal between 1971 and 2005. The temperature anomalies shows that climate change signal is stronger as from the 1970s.The rate of temperature increase is higher in the semi-arid region than the coastal areas of Nigeria. The current available pieces of evidence show that Nigeria, like most parts of the world, is experiencing the basic features of climate change.

Key words: Climate change, global warming, Nigeria, climate change signal and temperature.

INTRODUCTION

IPCC (2007) Fourth Assessment Report (AR4) gave the most acceptable definition of climate change, which states that "climate change is a change in the state of the climate that can be identified (eg. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period typically decades or longer". Climate change is different from the generally known terms like climatic fluctuations or climatic variability. Climate fluctuation or variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc) of the climate on all spatial and temporal scales beyond that of individual weather events. Like climate change, variability may be due to; natural internal processes within the climate system (internal variability), or variations in natural or anthropogenic external forces (external variability). The most crucial things about the concept of climate change is not only the time periods involved but also the degree of variability that the change is subjected to as well as the duration and impact of such variability on man and the ecosystem.

The causes of climate change are both natural and anthropogenic as conceptualised in Figure 1. As shown in Figure 1, climate change is caused by either natural or/and anthropogenic factors. Researchers have shown that for the past few decades, anthropogenic factors likes urbanization, deforestation, population explosion, Industrialization and the release of greenhouse gases are the major contributing factors to the depletion of the ozone layer and its associated global warming and climate change (Buba, 2004; Porbeni, 2004; DeWeerdt, 2007; Odjugo, 2007). There have been growing awareness that the earth's climate is changing at an alarming rate and the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) affirms that climate change is no longer in doubt but is now unequivocally apparent based on evidence from scientific observations of increases in global average air and ocean temperatures (IPCC, 2007). Although extreme violent weather has occurred throughout history, recent upsurge in climate related hazards is confirming the argument for global warming and climate change (McGuire et al., 2002; Odjugo and Ikhuoria, 2003; Nwafor, 2006). The evolving climate change coupled with increasing temperature has been observed to plunge some localities into experiencing extreme weather conditions (Olaniran,

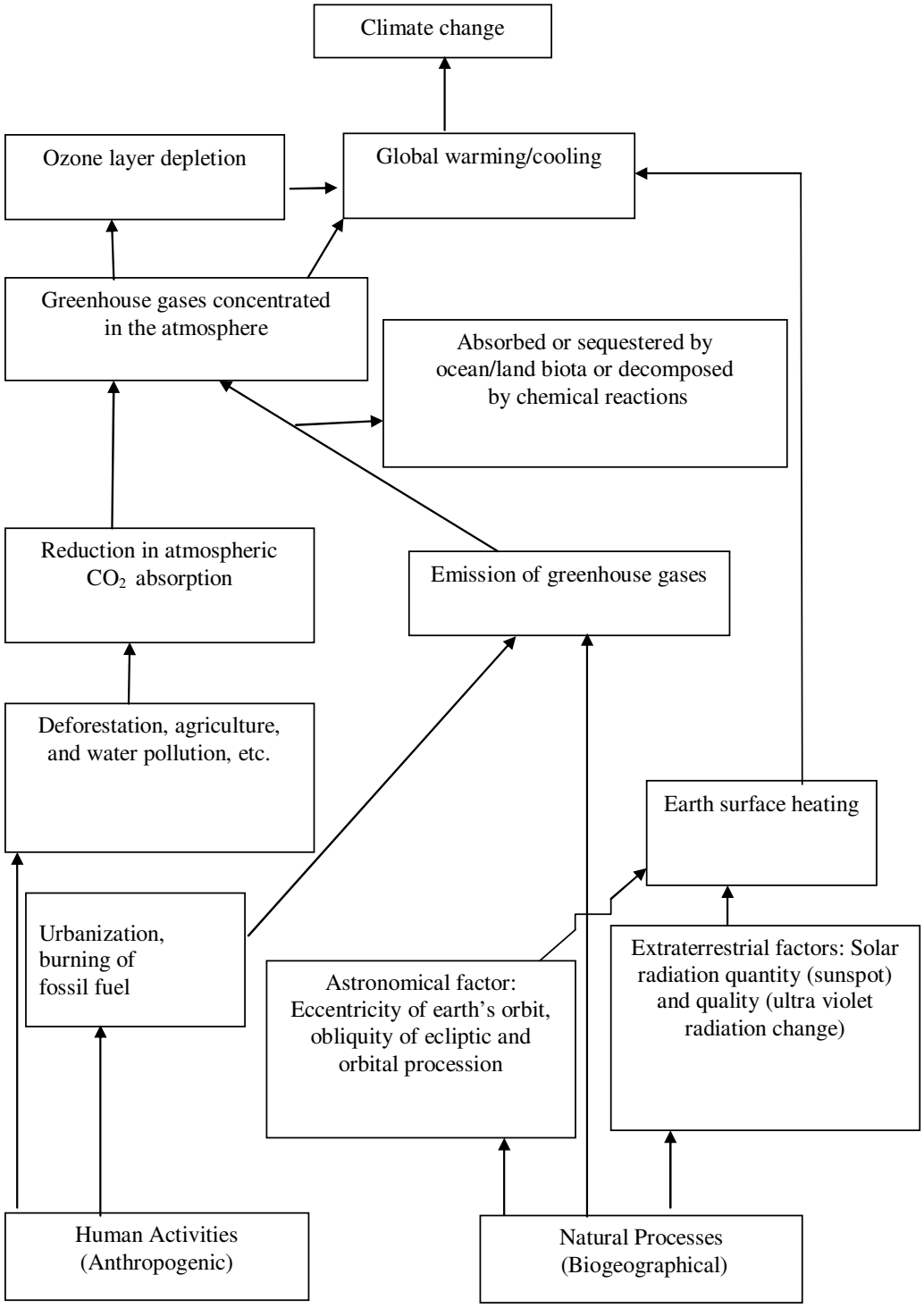

Figure 1. Causal factors of climate change.
Source: Odjugo (2010).

2002; Ayoade, 2003; Odjugo, 2005). The on-going climate change and its associated global warming are expected to cause distinctive climate patterns in different climatic zones, which will impact negatively on the ecosystem (Mshelia, 2005; Hengeveld et al., 2005; Ayuba, et al., 2007). That is why Ojo (1991) and Clerk (2002)

advised that weather and climate should not be taken for granted in the pursuit of technological development, exploration and processing of environmental resources.

Available evidences show that climate change will be global, likewise its impacts, but the biting effects will be felt more by the developing countries especially those in Africa due to their low level of coping capabilities (Mshelia, 2005; Nwafor, 2007; Jagtap, 2007). Nigeria is one of such developing countries. Researchers have shown that Nigeria is already being plagued with diverse ecological problems, which have been directly linked to the on-going climate change (Adebayo, 1998; Odjugo and Ikhuoria, 2003; NEST, 2003; Chindu and Nyelong, 2005; Odjugo, 2005; Adefolalu et al., 2007; Ikhile, 2007). These studies focused more on climatic impacts. Studies that address climate trends in Nigeria cover either short period or small area (Afiesimama, 1999; Anyadike 1992a; 1992b; Clerk 2002; Nkeiruka and Apagu, 2005; Olaniran 2002; Odjugo, 2005; Nnodu et al., 2007), whereas Singer and Avery (2007) revealed that it takes at least a century of weather data to evaluate climate trend for a reasonable conclusion to be drawn. There is therefore the need to examine the climatic pattern of Nigeria over a long time as also suggested by Nwafor (2006) so as to capture the long term changes in the climate of Nigeria. It is on this premise that this study examined the climatic pattern of Nigeria between 1901 and 2005 (105 years), using temperature data. Based on these data, the question as to whether there are enough changes in the spatio-temporal pattern of temperature over Nigeria to support the concept of regional climate change is answered.

MATERIALS AND METHODS

Mean monthly and annual air temperatures data from 30 synoptic stations (Figure 5) between 1901 and 2005 in Nigeria were collected from the Nigerian Meteorological Station, Lagos and Meteorological Department in some Airports. Although there are more than 30 meteorological stations in Nigeria, the study was limited to 30 stations because of consistency in available temperature data since the establishment of the stations. Moreover the selected stations are true representative of the various climatic belts of Nigeria. Temperature data was used in this study because Afiesimama et al (1999) show that this climatic element actually determines the prospects as well as the ecological and socio-economic problems of Nigeria. The research covers a period of 105 years (1901-2005). With 105 years, three climatic periods of 35 years each can be studied and this will provide a better platform to investigate the changes within the climatic periods. The three climatic periods are 1901 - 1935, 1936 - 1970, and 1971 - 2005; and this classification is to ease comparison of temperature trend and pattern between the periods. The mean annual temperature data were used to construct the isothermal maps of Nigeria for the three climatic periods. These were constructed using the Microsoft Power Point Software.

With these maps, the analysis of the spatial pattern of temperature changes in Nigeria was carried out. The temporal climatic changes over the years were examined by employing the time series. Standardized anomalies were computed and plotted to show yearly departures of the climatic element using the 1971 to 2005 normal. This normal was employed because clear climate change signals are present globally after 1970 (IPCC, 2007). The relationship in temperatures between the climatic periods was evaluated with the aid of correlation while the Least Square Range (LSR) test was used to determine which climatic period is actually different from the other. ANOVA was employed to show whether the differences in temperatures within the periods are statistically significant.

RESULTS AND DISCUSSION

Air temperature

Both temporal and spatial variations were observed in the air temperature distribution. The temporal air temperature trend has remained generally on the increase since 1901 (Figure 2). The increase was gradual between 1901 and the mid 1940s. A slight drop in temperature was experienced between the late 1940's and early 1950s. Thereafter, the gradual increase continued until the late 1960s. A sharp rise in air temperature became evident as from the early 1970s, which continued till 2005 (Figure 2). The sharp rise in temperature observed in Nigeria since the early 1970s is in agreement with the global trend (IPCC (2007). Ayoade (2003) also records a slight drop in air temperatures within the late 1940s and early 1950s in Nigeria.

The mean air temperature for the study period (1901 - 2005) is 26.7°C. In the 1901 - 1935 climatic periods, the mean air temperature was 26.0°C. By 1936 – 1970, the air temperature slightly increased to 26.5°C, while it rose to 27.8 in 1971 - 2005. The decadal variation as shown in Figure 3 is in support of Figure 2 that reveals a gradual temperature rise between 1901-1960 decades and sharp rise between 1971-2005 decades. This implies that temperature increase between 1901-1935 and 1936 - 1970 was only 0.5°C, while it was 1.3°C between 1935-1970 and 1971-2005. Within the study period 1901 - 2005 (105 years), temperature increase in Nigeria was 1.7°C. Global temperatures on the earth's surface have increased by 0.4 - 0.8°C with a mean of 0.74°C since record started in 1860 and it is projected to increase between 1.6°C (Low), 2.5°C (middle) and 4.5°C (high) by the year 2100 (IPCC, 2007; Spore, 2008). Cueto et al. (2009) recorded 0.66°C decadal temperature increase in some China urban areas. A sharp increase in temperature between 1971 and 2005 could be linked to the effect of climate change and its associated global warming earlier reported (Mabo, 2006; Ikhile, 2007). The difference in temperature between 1901-1935 and 1936-1970 (r = 0.24) is statistically the same while that of 1901-1935 and 1971-2005 (r = 0.37) and 1936-1970 and 1971-2005 (r = 0. 46) are statistically significant at p = 0.05 and p = 0.01 levels respectively (Table 1). Applying the least square range (LSR) test shows that at p = 0.05, the 1971-2005 climatic period is statistically different from 1901-1935

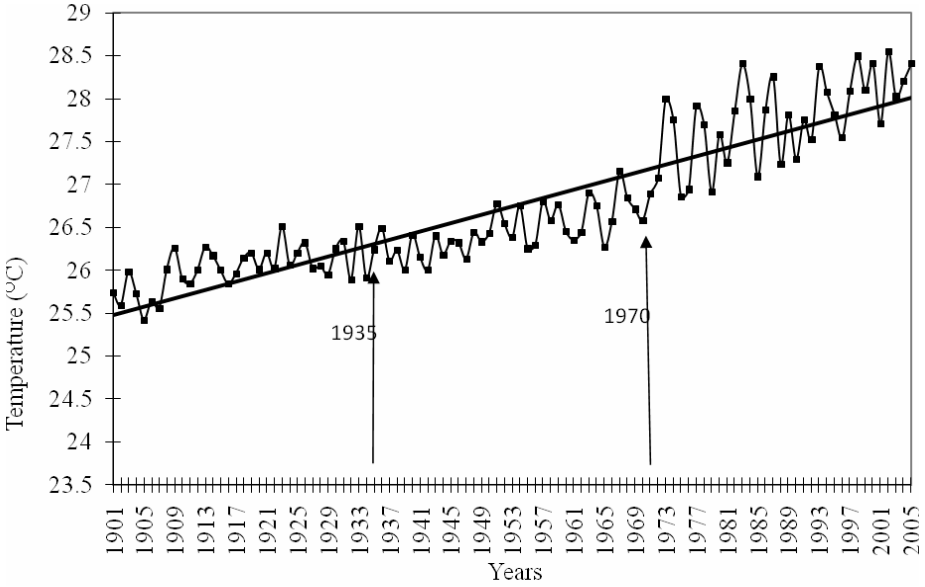

Figure 2. Air temperature distribution in Nigeria 1901-2005.

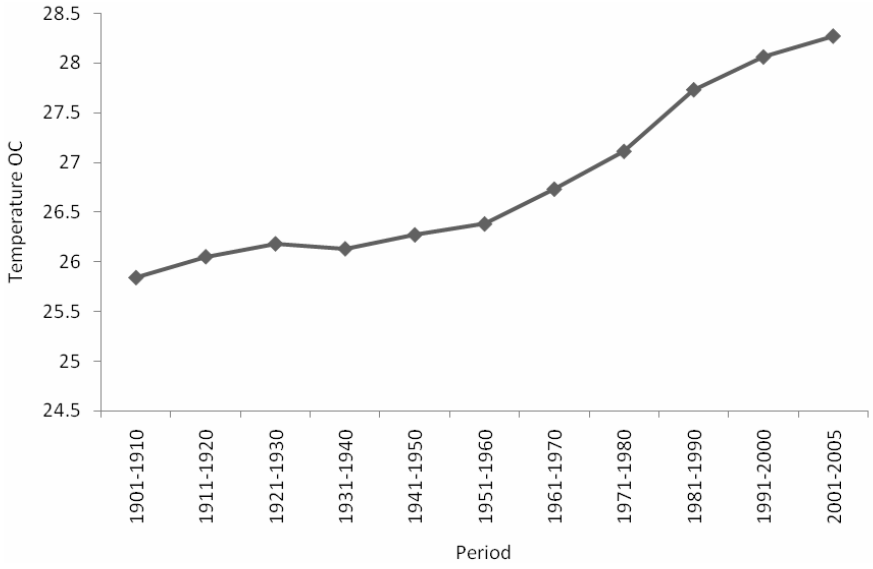

Figure 3. Decadal temperature variation in Nigeria between 1901-2005.

Table 1. Relationship in temperature variation between the three climatic periods.

	T1	T2	T3
T1	1.00		
T2	0.238	1.00	
T3	0.373*	0.463**	1.00

T=Temperature; 1=1901-1935; 2=1936-1970; 3=1971-2005 Climatic period
*Significant at $p = 0.05$; **Significant at $P = 0.01$

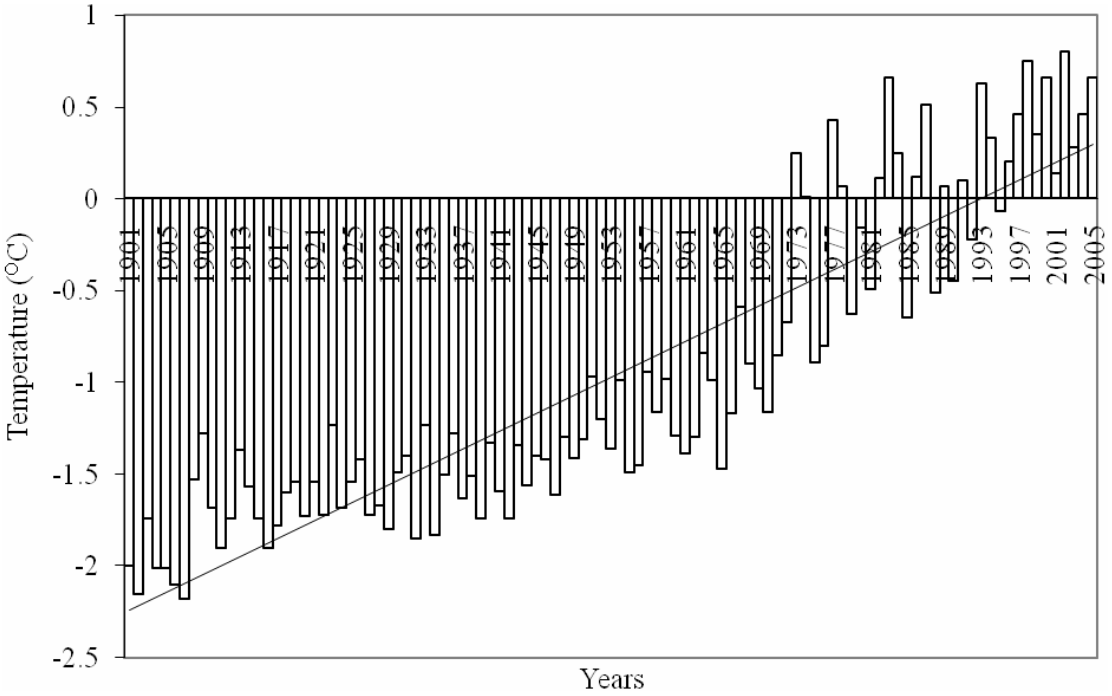

Figure 4. Air temperature anomalies in Nigeria using the 1971-2005 normal.

(3.26) and 1936-1971 (2.98) while 1901-1935 and 1936-1970 (1.63) is statistically the same. The computed *F*-value of 3.11 is lower than the critical value of 3.28 at $p = 0.05$. This clearly indicates that although there is an increasing air temperature in Nigeria between the three climatic periods, such temperature rise is not statistically significant. Although the temperature increase within the study period is statistically the same, the upward trend especially since the 1970s is a worrisome evidence of regional warming. This combined with the decreasing rainfall in Nigeria (Odjugo, 2005; 2009) is a pointer to increasing aridity in Nigeria.

The air temperature anomalies relative to 1970-2005 normal also support the increasing temperature trend, which was more from the early 1970s (Figure 4). Between 1901 -1935 and 1936 - 1970 climatic periods, temperatures were below the 1970-2005 normal, but 22 years (63%) out of the 35 years were above the normal between 1971 and 2005 (Figure 4). The temperature anomalies actually confirm the facts that global warming is unequivocal (IPCC, 2007) and climate change signal is stronger as from the 1970s. The spatial temperature variation in Nigeria is shown in Figure 5 a-c. Air temperature varied between 25.5°C in Port Harcourt and 28.2°C in Nguru (1901 - 1935) (Figure 5a). By 1936 - 1970, Port Harcourt recorded air temperature of 25.8°C while Nguru had 29.1°C (Figure 5b). This again increased to 30.2°C in Nguru and 26.7°C in Port Harcourt during the 1971 - 2005 climatic periods (Figure 5c). This implies that Port Harcourt, one of the Coastal cities, experienced temperature increase of 1.2°C within the study period (1901 – 2005) while Nguru, a semi-arid city of Nigeria, recorded 2°C temperature rise within the same period. As shown in Figure 5c, the least temperature was recorded on the Mambilla Plateau, followed by Obudu hills and Jos Plateau. Gembu on the Mambilla Plateau had a mean annual air temperature of 21.1°C, Obudu (on Obudu hills) and Jos (on Jos Plateau) had 21.6 and 22.5 °C respectively during 1971-2005 climatic period. This negates the earlier claims before climatic records started at Mambilla Plateau and Obudu hills that Jos Plateau is the coolest spot in Nigeria. In support of this fact, Adebayo and Umar (2005) reported mean annual temperatures of 17.5 and 18°C at Dorofi and Nguroje respectively, all on the Mambilla Plateau. These three highlands (Obudu hills, Mambilla and Jos Plateaux) experience a semi-temperate climatic condition.

Evidence of climate change in Nigeria

Ahmad and Ahmed (2000), IPCC (2001), NEST (2003) and Hengeveld et al. (2005) provided indicators that one could use to assess the evidence of climate change in a region. These include increasing temperature, increasing evapotranspiration, decreasing rainfall amount in the continental interiors, increasing rainfall in the coastal areas, increasing disruption in climate patterns and

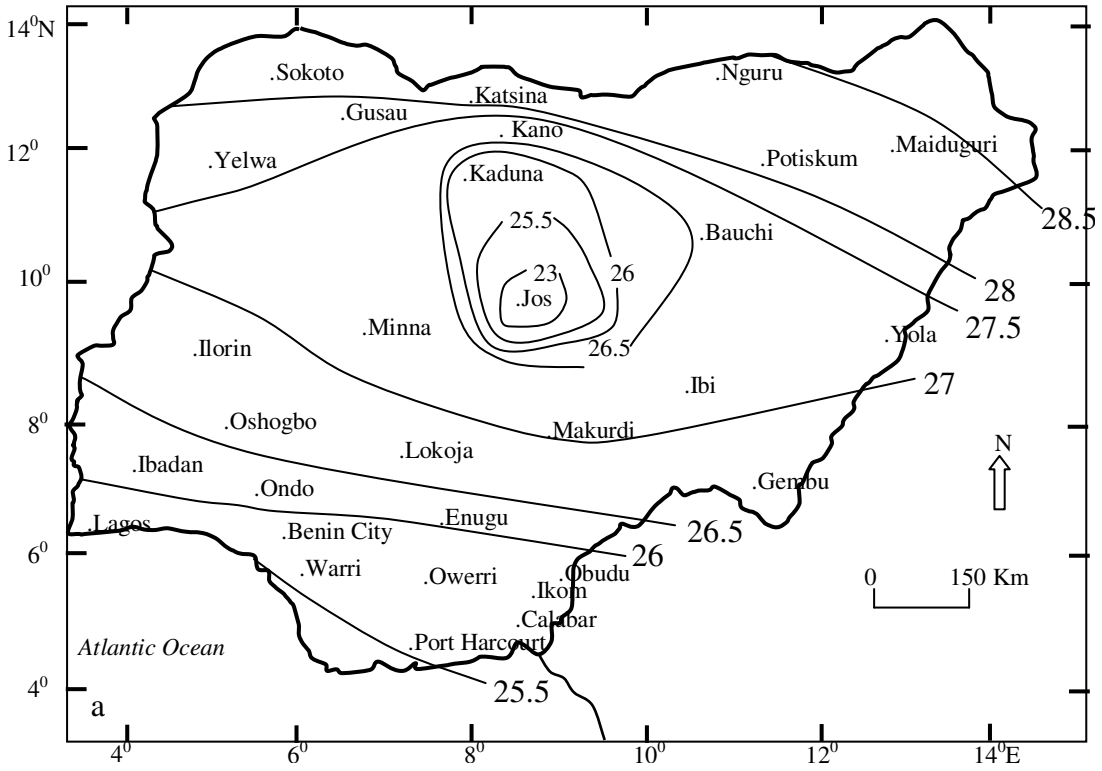

Figure 5a. Spatial pattern of mean air temperature in Nigeria (1901-1935).

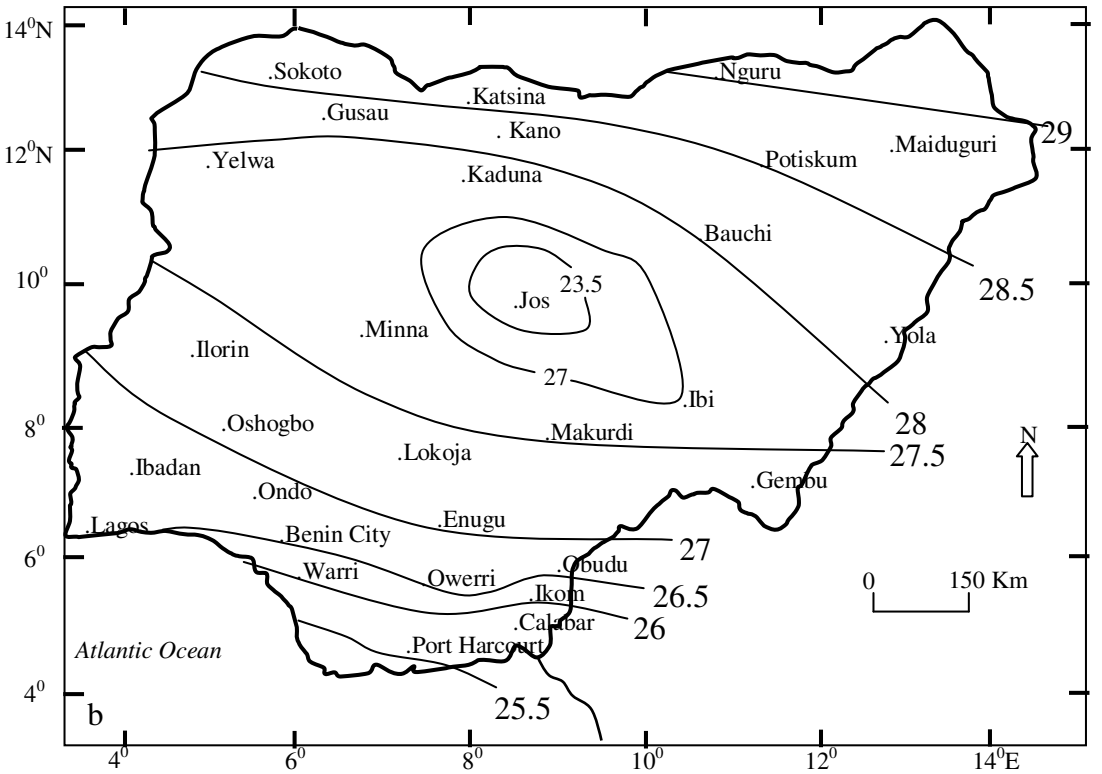

Figure 5b. Spatial pattern of mean air temperature in Nigeria (1936-1970).

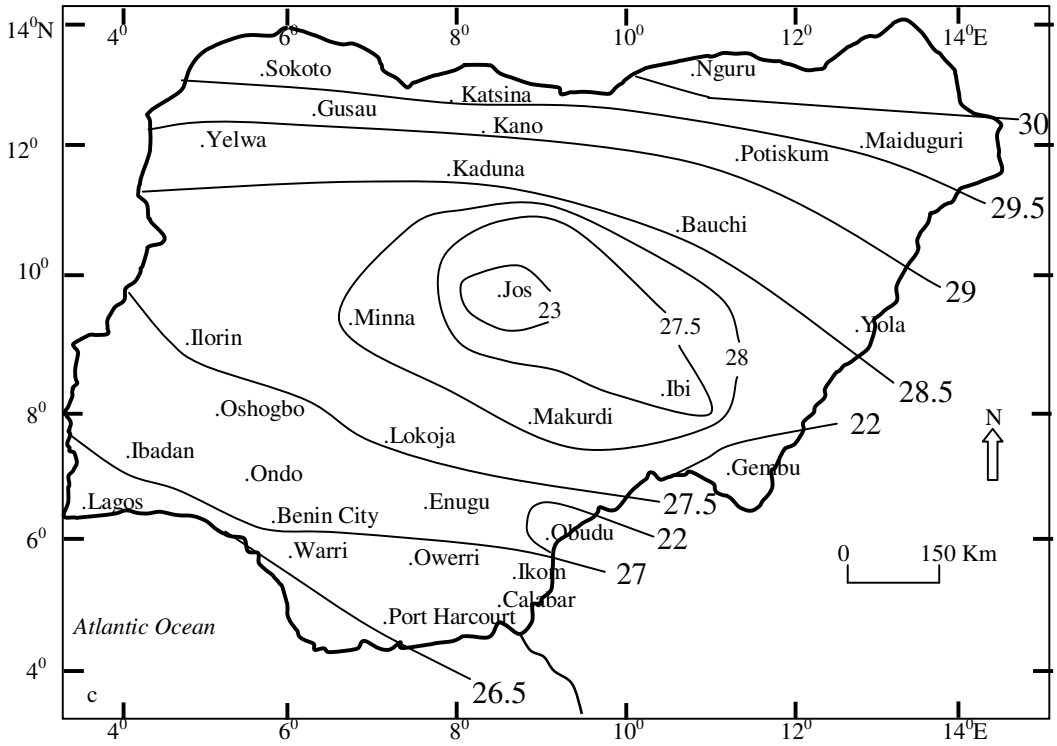

Figure 5c. Spatial pattern of mean air temperature in Nigeria (1971-2005).

increasing frequency and intensity of unusual or extreme weather related events such as; thunderstorms, lightning, landslides, floods, droughts, bush fires, unpredictable rainfall patterns, sea level rise, increase desertification and land degradation, drying up of rivers and lakes and constant loss of forest cover and biodiversity.

While this study reveals that an indicator (increasing temperature) is already present in Nigeria, recent studies show evidence of those indicators not covered in this study (Chindo and Nyelong, 2005; Ikhile, 2007; Nwafor, 2007; Umoh, 2007). This study shows gradual increasing air temperatures between 1901 and 1970 and a higher increase since 1970. An increase of 1.7^{O}C in air temperature has been observed in Nigeria for the 105 years. The implication is that if the increase continues at this rate, by 2100, Nigeria will fall within the low or medium scenario of global warming of not less than 2.5°C. Should it continue at the 1971-2005 rate, Nigeria will then be placed among areas that will experience high scenario of 2.5 - 4.5°C. Another indicator is the increasing frequency and intensity of unusual or extreme weather related events such as erratic rainfall pattern, floods and sea level rise among others. Although these indicators are outside the scope of this study, recent researches confirm their existence in Nigeria (Odjugo, 2005; 2009; Molega, 2006; Nnodu et al., Umoh, 2007). Odjugo (2005; 2009) observe decline in rainfall amount in Nigeria. A further support of the evidence of climate change in Nigeria by the two studies is the increase in rainfall amount in the coastal areas since the 1970s, and a constant decline in rainfall amount and duration in the continental interiors of the semi-arid region of Nigeria. The increasing rainfall in the coastal cities may have partly be responsible for the increasing floods devastating the coastal cities of Warri, Lagos, Port Harcourt and Calabar as observed by (Ogundebi, 2004; Ikhile 2007; Nwafor, 2007; Umoh, 2007; Odjugo, 2010).

The increasing temperature and decreasing rainfall in the semi-arid region of Sokoto, Katsina, Kano, Nguru and Maiduguri may have resulted in the increasing evapotranspiration, drought and desertification in Nigeria as reported by (Odjugo and Ikhuoria 2003; Adefolalu, 2007). Constant loss of forest cover and biodiversity in Nigeria is linked to global warming and climate change (NEST, 2003; Ayuba et al., 2007). Available evidence also shows that climate change has impacted on agriculture and health in Nigeria (Mshelia, 2005; Adefolalu, 2007). The decreasing rainfall, increasing temperature and evapotranspiration have resulted in either reduction of water levels or total dry up of some rivers and lakes in Northern Nigeria, while lake Chad in Nigeria is reported to be shrinking in size at an alarming rate since the 1970s (Chindo and Nyelong, 2005; Odjugo, 2007). In the coastal region of Nigeria, sea level rise of 0.2 m and

incursion of salt water into the coastal plain for about 2016 - 3400 km^2 was reported (NEST, 2003; Nyelong, 2004; Nwafor, 2006). With these factors, one can say with a high level of confidence that this study with other related works cited have successfully revealed that Nigeria, like most parts of the world, is experiencing the basic features of climate change.

Conclusion

Spatial and temporal variations in temperatures were noticed. Air temperature has been on the increase gradually since 1901 but rapidly as from 1970. The air temperature patterns between 1901-1935 and 1936 - 1971 were almost the same but differ significantly from the 1971-2005 records. Between 1901-1935 and 1936-1970 climatic periods, temperatures were below the 1970-2005 normal, but 22 years (63%) out of the 35 years were above the normal between 1971 and 2005. The temperature anomalies show the facts that global warming is unequivocal and climate change signal is stronger as from the 1970s.

Within the 105 years, temperatures increased by 1.2°C in the coastal cities of the Niger Delta and 2°C in the northern extreme of Nigeria. A mean air temperature increase of 1.7°C was observed in Nigeria for the past 105 years. The lowest mean annual temperature was recorded on the Mambilla Plateau, followed by Obudu hills and the Jos Plateau as against the initial claims that Jos Plateau experiences the lowest temperatures in Nigeria. These plateaux and hills experience semi-temperate climatic condition. The current available evidences show that Nigeria, like most parts of the world, is experiencing the basic features of climate change.

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