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Spatio–Temporal Characterization of Land Surface Air Temperature Anomaly over Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author OOA designed the research proposal, author ABR directed the research work. Authors OOA and SSA carried out the analysis and interpretation of the results. Author SSA edited the paper. All authors read and approved the final manuscript.

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ABSTRACT

In this study, seventeen gridded stations across the latitude over Nigeria were selected with a view to determine and characterize land surface air temperature anomaly for both minimum and maximum values. The study intends to present graphic illustrations of spatial and temporal variations of land surface air temperature anomaly within a period 2008 – 2013.
Long-term averages of minimum and maximum land surface air temperatures were obtained from National Aeronautic and Space Administration satellite meteorological dataset (1983 – 2007). Also, monthly and annual averages of land surface air temperatures were obtained from tutiempo.net to compute monthly anomaly, annual anomaly and percentage departure of minimum and maximum land surface air temperatures within a period of 2008 – 2013.
The results showed that Jos had consistently experienced -10.8 and -4 percent decrease in minimum and maximum LSAT anomaly for the period under review. The implication is that Jos is getting colder than usual. The minimum LSAT anomaly declined by -2.8 percent in Lagos. Other stations across Nigeria showed a considerable percentage increase in minimum LSAT anomaly led by Yola (19.5%), Sokoto (18%) and Katsina (15.5%). Inland stations had percentage increase of minimum LSAT anomaly ranging between 5.8% and 10% except in Osogbo where the percentage

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increase was 1.8%. Osogbo is a less populated capital city of Osun state with active agricultural activities as heat sink. Percentage increase of minimum LSAT anomaly was not significant in Nigerian coastal areas most especially at Port Harcourt (0.5%).
The spatial distribution of maximum LSAT anomaly across Nigerian latitudinal belt, unlike minimum LSAT anomaly, reduced in trend except in Lagos, Makurdi, Abuja, Bida, Minna and Kano. The minimum and maximum anomaly for maximum LSAT was observed at Jos and Makurdi respectively. There are 2 stations to be watched in terms of getting colder in the years to ahead namely Jos and Osogbo while Makurdi and Yola are gradually becoming hotspots.

Keywords: Land surface air temperature; temperature anomaly; minimum and maximum temperature; latitudinal belt.

1. INTRODUCTION

Land Surface Temperature (LST) is defined as the temperature of the interface between the earth's surface and its atmosphere and thus it is a critical variable to understand land-atmosphere interactions and a key parameter in meteorological and hydrological studies, which involve energy fluxes [1]. Land surface air temperature (LSAT) is the temperature of the air near the earth´s surface which is routinely measured at 1.5 to 2 m by common meteorological stations distributed across a territory.

When researching global climate changes and temperature data, temperature anomaly is often mentioned. This is the difference between the long-term average temperature (sometimes called a reference value) and the temperature that is actually occurring. In other words, the long-term average temperature is one that would be expected; the anomaly is the difference between what is expected and what is happening.

A positive anomaly means that the temperature was warmer than normal; a negative anomaly indicates that the temperature was cooler than normal. Anomaly values are often preferred in temperature variability studies because actual temperature measurements are often difficult to gather. Some areas in the world have few temperature measurement stations (for example, remote jungles and deserts), and temperatures must be estimated over large regions. Using anomalies, the departure from an "average," allows more accurate descriptions over larger areas than actual temperatures and provides a frame of reference that allows easier analysis.

In this study, seventeen gridded stations across the latitude over Nigeria were selected with a view to determine and characterize land surface air temperature anomaly for both minimum and maximum values. The study presented graphic illustrations of spatial and temporal variations of land surface air temperature anomaly within a period 2008 – 2013. Long-term averages of minimum and maximum land surface air temperatures were obtained from National Aeronautic and Space Administration satellite meteorological dataset (1983 – 2007). Also, monthly and annual averages of land surface air temperatures were obtained from tutiempo.net to compute monthly anomaly, annual anomaly and percentage departure of minimum and maximum land surface air temperatures within a period of 2008 – 2013.

2. LITERATURE REVIEW

The continued buildup of greenhouse gases may force any number of changes to the climate system including the highly-popularized prediction for an increase in mean global temperatures. However, changes in temperature variability are also important in determining the future temperature distributions. While the newer numerical models of climate predict less warming with realistic greenhouse changes than do earlier versions, predictions of temperature variability remain inconsistent [2].

Empirical studies of observed temperature variability are no more conclusive. Parker et al. [3] examined the long temperature record from central England and found no evidence of increased variance in recent decades. Parker et al. [4] compared inter-annual seasonal temperature anomalies from the 1954–1973 periods to the 1974–1993 periods for most of the globe [5]. They found a small increase in variability overall with an especially large increase in central North America.

In a study carried out by Akinsanola and Ogunjobi [6] across Nigeria covering a period of

1971 - 2000, temperature was observed to increase southward during the months of January to March with temperature ranging from 21.1°C to 30°C. However there is a little variation in air temperature in the month of April with corresponding increase northward in May and June only. Also generally observed is a northward increase in temperature extending from July to September before a reverse in trend in the month of October (i.e. decreasing southward). It was observed that air temperature values were generally lower in the Northern part of Nigeria during dry season when compared with the wet season. This implied that temperature variation was higher over northern part of the country than over the southern part. This could be attributed to the equator ward incursion of mid-latitude systems (with alternating cool and warm air masses) which has greater influence on temperature variation over the northern part than over the southern part of Nigeria [7]. Secondly, the influence of the tropical maritime air mass from Gulf of Guinea moderates temperature fluctuations along the coast.

The results of standardized decadal analysis of temperature anomalies showed that in the first decade of 1971-1980 the whole country has negative anomalies. However in the second decade, stations like Jos, Maiduguri, Ikeja, Oshodi and Warri were cooler than normal with corresponding negative anomalies while Nguru, Calabar and Benin show positive anomalies. The third decade of 1991-2000, station such as Yelwa, Osogbo, Ikeja, Nguru all has negative anomalies while larger part of the country shows positive anomalies.

Related studies in Nigeria have similarly shown different periods of warming and cooling phases over the last century. Oguntunde et al. [8] showed the decadal trend of air temperature over Nigeria. During the first decade of 1971 to 1980 Yola, Bauchi, Jos, Kaduna, Zaria, Gusau, Sokoto, Nguru, Calabar, Warri, Benin and Ondo experiences decreasing trend in air temperature with values ranging from -0.04 to -0.07°C/decade while Lokoja, Minna, Lagos and Ibadan showed increasing trends of about 0.05 to 0.08°C/decade. In the second decade of 1981 to 1990, the areas that experiences increase in temperature trend extended to Zaria, Warri, Nguru, Kaduna and Gusau, while Bida and Jos showed decreasing trends. During the third decade of 1991 to 2000, only Ibadan, Ikeja and Oshodi showed decreasing trend while Nguru, Zaria and Bida increased with high values of about 0.2°C/decade. Result further showed that the entire country experiences increasing trend in air temperature of about 0.036°C except for Jos which shows a decrease in trend of about -0.02°C while Nguru, Yelwa and Enugu are just normal.

The findings was in agreement with the work of [9,8] which reported separately that spatial and temporal variations in temperatures were noticed in Nigeria where air temperature has been on the increase gradually since 1901 and with significant increase from 1970. In coastal region of Nigeria, it was observed that between 1971-1987, negative anomaly of air temperature were more prominent than positive anomaly but a change was noted from 1998 when temperature began to change to positive anomaly and these prolong well into 1990s. Result further showed that the changes were significant at 95% and 99% confidence level. In the tropical rainforest, there were more years of negative temperature anomalies within the periods of study while between 1971 and 1982, temperature was on the decrease. However starting from 1983, it was observed that there was more positive anomaly with only few years of negative anomalies within the same period in the guinea savannah. This observed pattern is similar to that of coastal areas which shows that temperature has been on the increase since 80's.

Temperature anomaly was observed to be on the decrease in both Sudan and Sahel savannah of Nigeria from 1971-1982, but changed suddenly to increasing temperature anomalies from 1983-2000 with about three years of negative anomalies period occurring within this period. The changes are significant at 95% and 99% confidence level. Odjugo and Ikhuoria (2003), Adefolalu (2007), reported that the increasing temperature in the semi-arid region of Sokoto, Katsina, Kano, Nguru and Maiduguri may be attributed to increasing evapotranspiration, drought and desertification in Nigeria.

3. METHODS OF ANALYSIS

Nigeria lies between 4°N and 14°N latitude and longitude 4°E to 14°E as shown in Fig. 1 It is bounded on the north by the Republic of Niger, on the east by Cameroon and on the west by Benin Republic while the southern boundary is Gulf of Guinea which is an arm of the Atlantic Ocean. The Nigerian climate is characterized by the interplay between the dry north-easterly and the moist south-westerly winds. The main ecological zones are the tropical rainforest along the coast, savannah in the middle belt and semi-arid zones in the northern fringes. The coastal area – in the Mangrove Rain Forest, five stations were selected namely, Port-Harcourt (PH), Calabar (CA), Enugu (EN), Lagos (LG), and Benin (BE). Seven inland stations – in the Tropical Rain Forest were selected namely, Makurdi (MK), Osogbo (SG), Abuja (AJ), Bida (BI), Yola (YO), Minna (MN), and Jos (JS). There were five stations in the up north – in the Sudan Sahel - namely, Kaduna (KD), Maiduguri (MD), Kano (KN), Katsina (KT), and Sokoto (SK).

Satellite-based monthly-averaged land surface air temperature (maximum, minimum and mean values) data within a period of 1983 – 2007 were extracted from the archive of National Aeronautic and Space Administration satellite meteorological dataset to compute reference values. Also, annual averages of land surface air temperatures were obtained from tutiempo.net to compute actual value within a period of 2008 – 2013.

The central idea behind anomaly construction is to split the data into two parts: data with expected behavior – which is represented by 25-year mean, and data that shows the variability from the expected, which is generally used for understanding climate variability phenomenon [10]. For a given location i, its anomaly times series f_0 is constructed from the raw time series f_i by removing a base vector b_i from it [11].

For a given location i, its anomaly in time series f' is calculated using the mean measure. In this measure, the long-time monthly mean values are considered as the base b_i and the recent measurements are classified as raw data [12]. Anomaly is therefore estimated using:

$$f' = f_i - b_i \qquad (1.0)$$

where,

f' = anomaly in time series
f_i = raw data (recent dataset)
b_i = base data (long-time average)

A simple measure of computing the base b_i is by taking the mean of all data (f_i) present for location i. However the sample mean would not be a good measure as the earth science data is associated with a large amount of seasonality. In order to account for this the base b_i is computed by taking a monthly mean for each month separately.

Mean value of monthly LSAT for a period of 1983 – 2007 for 17 stations across Nigeria was estimated and stored as base data while the mean monthly value of LSAT for each year within the period of 2008 – 2013 was also estimated

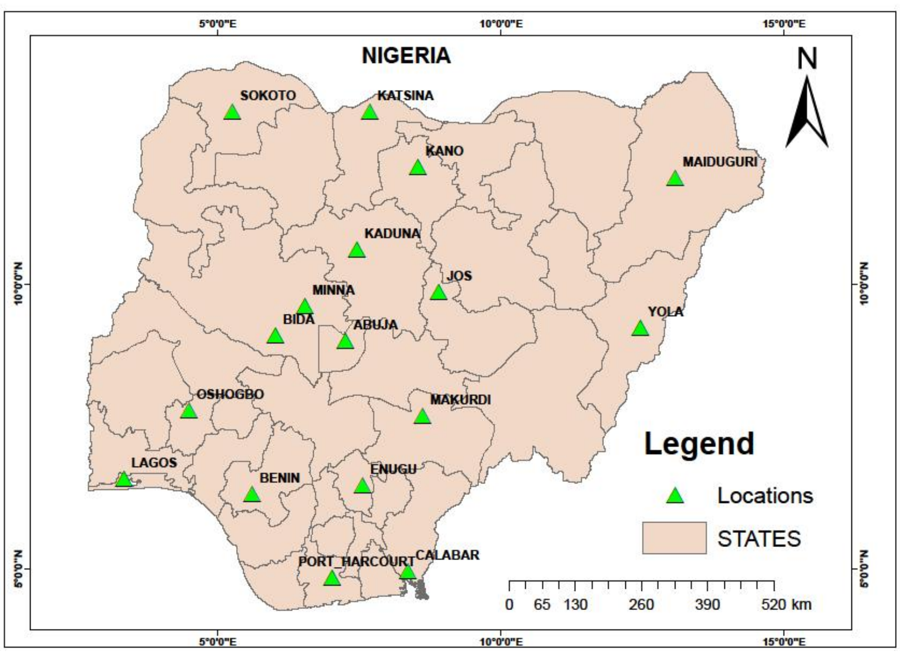

Fig. 1. Map of Nigeria showing 17 selected locations across different climatic zones

and stored as raw data with a view to calculate monthly LSAT anomaly using equation 1.0. All the calculations were carried out in Microsoft EXCEL spreadsheet. Percentage departure of minimum and maximum values of LSAT anomaly was computed to determine the extent of coolness or warmness in recent years covering 2008 - 2013. The results of minimum and maximum monthly values were plotted to show the spatial distribution of LSAT anomaly across latitudinal belt of Nigeria.

4. RESULTS AND DISCUSSION

4.1 Temporal Variation of Minimum and Maximum LSAT Anomaly across Nigeria

Temporal variations of minimum and maximum LSAT anomaly across Nigeria for the months January – April are shown in Fig. 2 May – August are shown in Fig. 3 while September – December are shown in Fig. 4.

In Fig. 2, land surface air temperature anomalies had high positive values in Yola, Makurdi and Maiduguri. Variation between minimum and maximum LSAT anomalies in Jos tends towards zero while other northern stations were closer in range compared with states in the south. The results showed that the anomalies were positive in almost all the stations for maximum LSAT anomaly values. Similarly, most of the stations had positive anomalies in minimum LSAT up to 10 – 16 stations. The months of January – April (2008 – 2013) were generally warmer on the average of 4°C for minimum LSAT and average of 3°C for maximum LST except in Jos.

Generally, in Fig. 3, more than 12 stations across Nigeria were warmer than expected showing positive anomalies in both minimum and maximum air temperatures except in Port Harcourt, Lagos and Jos. Abnormal upsurge in minimum and maximum air temperatures anomalies were observed at Makurdi while the characteristic of negative anomaly in both minimum and maximum temperatures was prevalent at Jos. Range of variation between minimum and maximum LSAT anomalies reduced significantly at stations in the northern stations of Yola, Minna, Jos, Kaduna, Katsina and Sokoto. There is an average range of 3.8°C between lowest and highest LSAT anomalies at the southern stations except in July and August when it was reduced to about 0.5^0C across Nigeria.

The observed trend of temperature anomalies at Jos for September to December (2008 – 2013) were consistent with what was noticed in the previous months. The upsurge in temperature anomaly was evident in Makurdi except in December. Range of variation between lowest and highest LSAT anomalies continued to reduce across northern stations. Lagos, Makurdi and Katsina had a very significant increase within a range of 3 - 6°C.

The results in Figs. 2 - 4 were consistent with Nigerian Meteorological Agency (NIMET) report within the period showing that increase in maximum temperatures was observed during the hot season (February and March) in the south and (March and April) in the north. Temperature ranged between 30.1°C – 40.0°C and maximum temperature gradually increased inland from the coastal areas, with the exception of Jos and its environs [13].

Also, the results of the analysis (from satellite dataset) validated the report from in-situ measurements of monthly minimum temperature across the country during the cold season (most especially in January 2010 - 2012) which showed that low minimum temperatures, between 10.0 - 14.0°C, were recorded in the northeast, Kano, Katsina and the areas around Jos in the central region. The remaining parts of the north experienced seasonal minimum temperatures between 14.0°C - 18.0°C while cold season minimum temperatures ranged between 18.0 – 22.0°C over the north central and the south except at the coastal cities which experienced the highest temperatures range of 22.0°C – 24.0°C. This may as a result of presence of cool laden air of north-easterly trade wind across the region, coupled with the incursion of Sahara surface dust which tends to scatter the incoming solar radiation back to space during the period.

4.2 Percentage Departure of Minimum and Maximum LSAT Anomaly across Nigeria

Percentage departures of minimum and maximum LSAT anomalies across Nigeria (2008 – 2013) are shown in Fig. 5. The results showed that Jos had consistently experienced -10.8 and -4 percent decrease in minimum and maximum LSAT anomalies respectively for the period under review. The implication is that Jos is getting colder than usual. The minimum LSAT anomaly declined by -2.8 percent in Lagos. Other stations across Nigeria showed a considerable

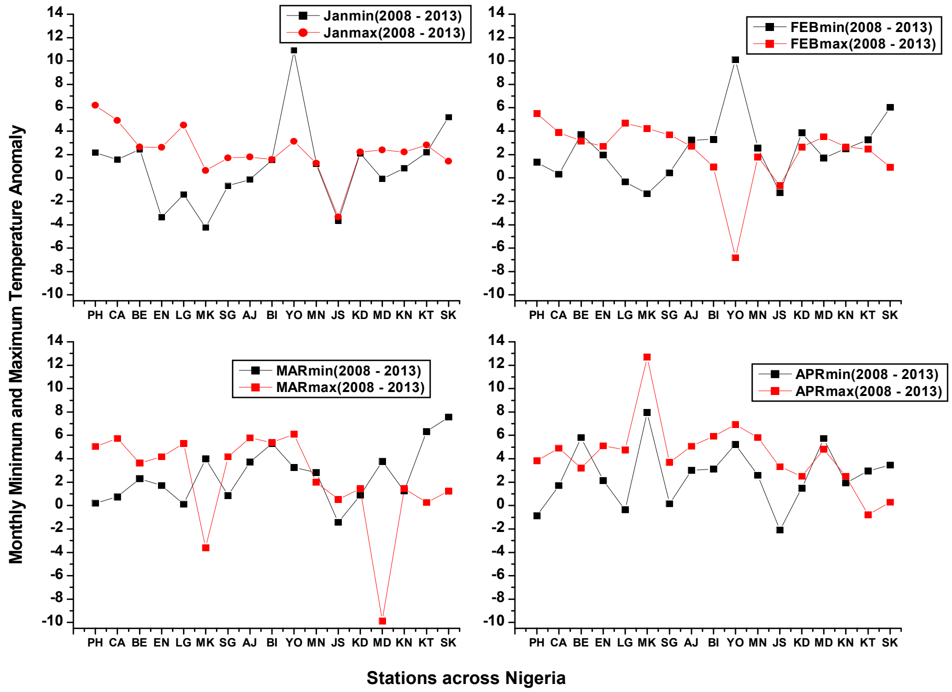

Fig. 2. Temporal variation of minimum and maximum LSAT anomaly across Nigeria for January – April (2008 – 2013)

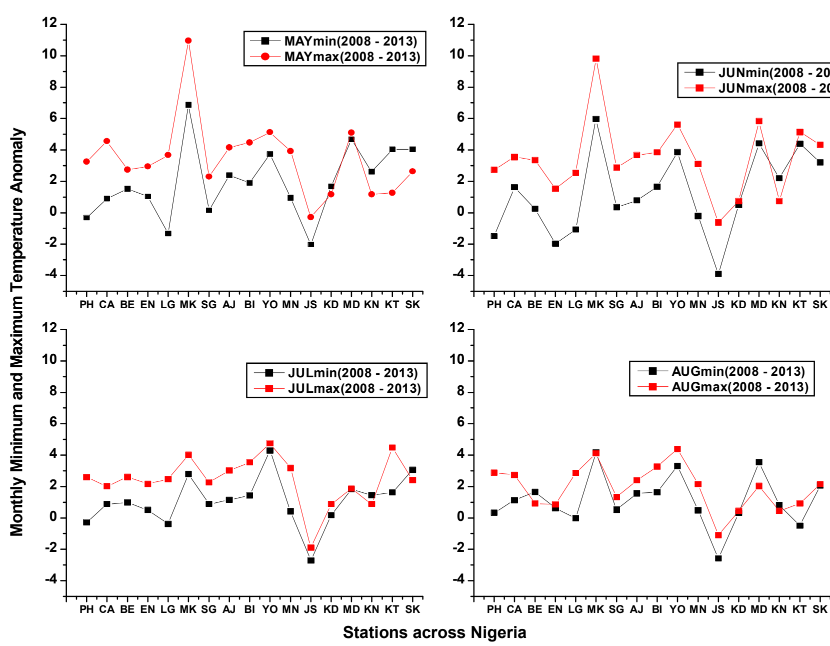

Fig. 3. Temporal variation of minimum and maximum LSAT anomaly across Nigeria for May – August (2008 – 2013)

percentage increase in minimum LSAT anomaly led by Yola (19.5%), Sokoto (18%) and Katsina (15.5%). Inland stations had percentage increase of minimum LSAT anomaly ranging between 5.8% and 10% except in Osogbo where the percentage increase was 1.8%. Osogbo is a less populated capital city of Osun state with surrounding active agricultural activities as heat sink. Percentage increase of minimum LSAT anomaly was not significant in Nigerian coastal areas most especially at Port Harcourt (0.5%).

Percentage increase in maximum LSAT anomaly was led by Makurdi and coastal stations namely Lagos, Calabar and Port Harcourt with more than 14% increase. Enugu had the least percentage increase of maximum LSAT anomaly of 1.7%. Other inland stations were relatively high ranging between 7.5% and 11%. Stations in the up north were relatively low in percentage maximum LSAT anomaly ranging between 3% and 8%.

The results were consistent with [13] in-situ measurement which reported that maximum LSAT showed that the period was warmer than normal in the northern parts of the country with maximum temperature departures ranging from 0.5 - 2.5°C. Normal temperature conditions were reported at the southern and central parts of the country in the year, except for Makurdi and Bida where maximum temperatures were extremely higher than normal maximum temperatures.

The demarcation line between the above normal temperature in the northern part of the country and normal temperature in the south always follows the Inter Tropical Discontinuity (ITD), which tends to be around the areas that mostly receive solar radiation. ITD keeps warm light air to the north and monsoon cool heavy air to the south. It moves to the highest latitude in August and least latitude in January.

4.3 Spatial Distribution of Minimum and Maximum LSAT Anomaly across Nigeria

Spatial distributions of minimum and maximum LSAT anomalies across 17 selected stations across Nigerian latitudinal belt are shown in Fig. 6. The spatial distribution indicated that minimum LSAT anomaly were increasingly positive across Nigeria latitudinal except in stations like Lagos (due to coastal influence), Osogbo (extremely low industrial activities and surrounding agrarian dominated communities) and Jos (influenced by extremely undulating terrain and high altitude). The extremely negative and positive anomalies for minimum LSAT were observed at Jos and Yola respectively.

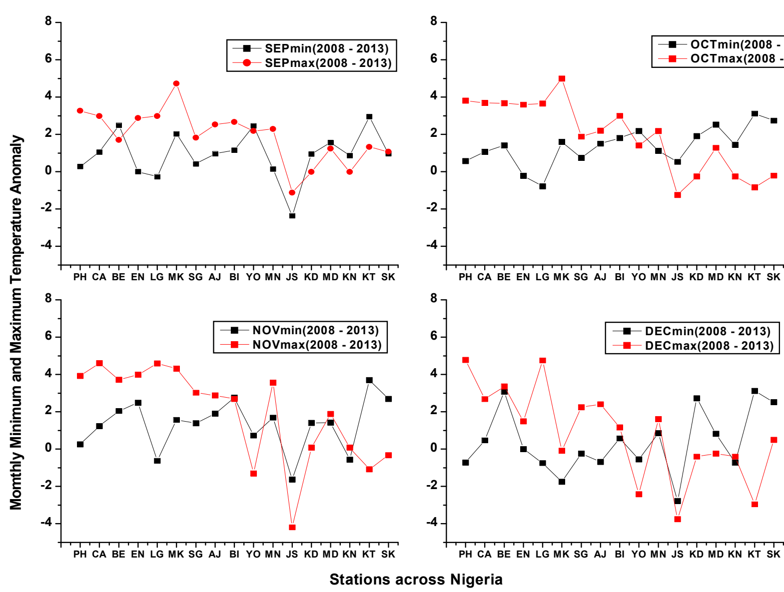

Fig. 4. Temporal variation of minimum and maximum LSAT anomaly across Nigeria for September – December (2008 – 2013)

The spatial distribution of maximum LSAT anomaly across Nigerian latitudinal belt, unlike minimum LSAT anomaly, reduced in trend except in Lagos, Makurdi, Abuja, Bida, Minna and Kano. The lowest and highest anomaly for maximum LSAT was observed at Jos and Makurdi respectively. There are two stations to be watched in terms of getting colder in the years ahead namely Jos and Osogbo while Makurdi and Yola are gradually becoming hotspots.

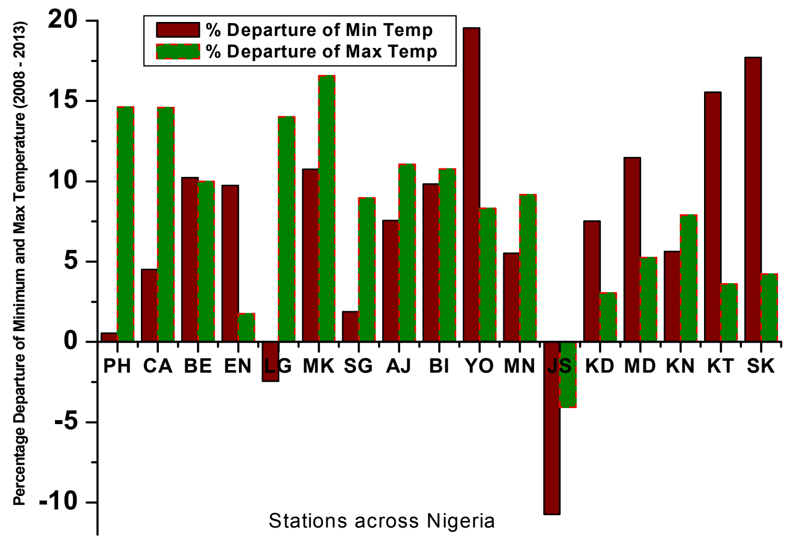

Fig. 5. Percentage departure of minimum and maximum LST anomaly across Nigeria (2008 – 2013)

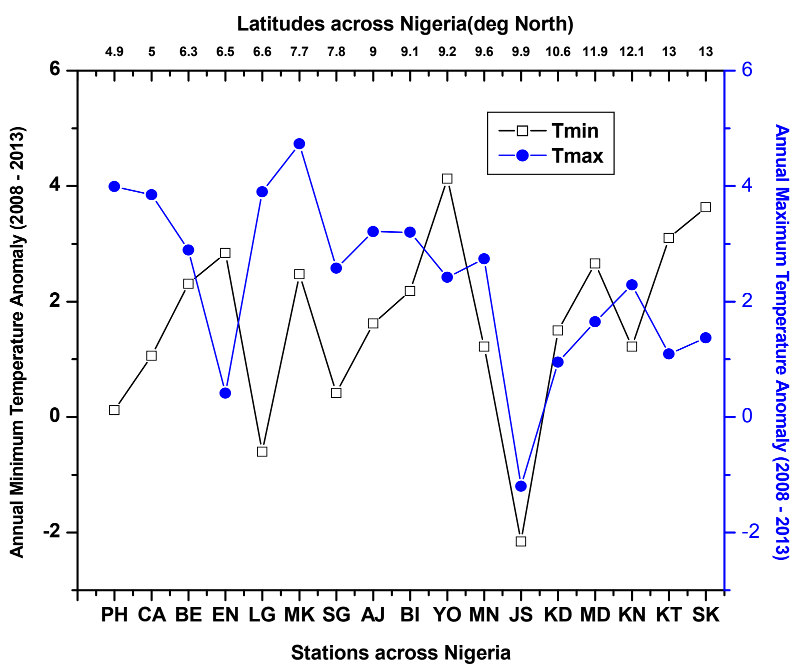

Fig. 6. Spatial distribution of minimum and maximum LST anomaly across Nigeria (2008 – 2013)

5. CONCLUSION

In this study, the findings showed that there is significant climate variation in four major locations, therefore; further intensive measurement of LSAT for more detailed analysis is required in stations namely Osogbo, Jos, Majurdi and Yola. The study confirms, to a large extent that there is climate variation which may result in climate change in few years' time.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Niclòs, Valiente JA, Barberà MJR, Estrela MJ, Galve JM, Caselles V. Preliminary results on the retreival of land surface temperature from MSG-SEVIRI data in Eastern Spain. Proceedings p.55, EUMETSAT Meteorological Satellite Conference, Bath, UK, 21-25 September. 2009;8.
2. Patrick JM, Robert CB, Russell SV, Paul CK. Analysis of trends in the variability of daily and monthly historical temperature measurements. Climate Research. 1998;10:27–33.
3. Parker DE, Legg TP, Folland CK. A new daily central England temperature series, 1772–1991. International Journal of Climatology. 1992;12:317–342.
4. Parker DE, Jones PD, Folland CK, Bevan A. Inter-decadal changes of surface temperature since the late nineteenth century. Journal of Geophysical Research. 1994;99:14373–14399.
5. Manley G. Central England temperatures. Monthly means 1659 to 1973. Quarterly Journal of Royal Meteorological Society. 1974;100:389–405.
6. Akinsanola AA, Ogunjobi KO. Analysis of rainfall and temperature variability over Nigeria Global Journal of HUMAN-SOCIAL SCIENCE: B Geography, Geo-Sciences, Environmental Disaster Management Vol. 14 Issue 3 Version 1.0. 2014.
7. Adefolalu DO. Climate change and economic sustainability in Nigeria, Paper presented at the International Conference on Climate Change and Economic Sustainability held at Nnamdi Azikiwe University, Enugu, Nigeria. 12-14 June. 2007;1-12.
8. Oguntunde PG, Abiodun BJ, Gunnar L. Spatial and temporal temperature trends in Nigeria, 1901–2000. Meteorology and Atmospheric Physics. 2012;118:95–105.
9. Odjugo PAO. General overview of climate change impacts in Nigeria. Journal of Human Ecology. 2010;29(1):47-55.
10. Kawale J, Steinbach M, Kumar V. Discovering dynamic dipoles in climate data: In SIAM Inter- national Conference on Data Mining, SDM, SIAM; 2011.
11. Kumar A, Jha BZhang Q, Bounoua L. A new methodology for estimating the unpredictable component of seasonal atmospheric variability. Journal of Climate. 2007;20(15):3888-3901
12. Wei L, Kumar N, Lolla V, Keogh E, Lonardi S, Ratanamahatana C. Assumption-free anomaly detection in time series. In Proceedings of the 17th International Conference on Scientific and Statistical Database Management. Lawrence Berkeley Laboratory. 2005;237–240.
13. Nigeria Climate Review Bulletin (2010 - 2012): Nigerian Meteorological Agency, Abuja, Nigeria, (NIMET 2010 – 2012).

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