Original Research Article

Temperature extremes over selected Stations in Nigeria.

Eresanya, E.O.[1*], Ajayi, V.O. [2], Daramola, M.T.[3], Balogun, R. [4],

Department of Meteorology and Climate Change, Federal University of Technology, P.M.B 704, Akure, Nigeria
(+2347038874476, eresanyaemmanuel44@gmail.com)

This work was carried out in collaboration between all authors. Author A (EOE) designed the study, performed the statistical analysis,wrote the protocol, Author B (VOA) wrote the first draft of the manuscript. Author C (DMT) managed the analyses of the study. Author D (BR) managed the literature searches. All authors read and approved the final manuscript

ABSTRACT

This research aims to determine the temperature extremes for Ikeja (Lagos), Osogbo (Osun) and Maiduguri (Borno), Nigeria, West Africa using Statistica analytical tool. Thirty (30) years daily maximum and minimum temperature data for Lagos, Osogbo and Maiduguri used for this study were collected from Nigeria Meteorological Agency (NIMET), Oshodi, Nigeria. Analysis of extreme temperature trend indicated that in Ikeja the percentage occurrence of warm days (TX90P) in which the maximum temperature is above 34^{0}C (90th percentile value) is increasing and the percentage occurrence of cold days (TX10P) in which the maximum temperature is below 28^{0}C [10thpercentile value] is decreasing, in Osogbo the percentage occurrence of warm days (TX90P) in which the maximum temperature is above 35^{0}C [90th percentile value) is increasing at a slower rate whereas the percentage occurrence of cold days (TX10P, number of days) in which the maximum temperature is below 27^{0}C [10th percentile value] is constant while in Maiduguri the percentage occurrence of warm days (TX90P, number of days) in which the maximum temperature is above 41^{0}C [90th percentile value] is constant whereas the percentage occurrence of cold days (TX10P, number of days) in which the maximum temperature is below 30^{0}C [10th percentile value] is slightly increasing. Percentage of warm days indicate constant value at around 13-15% during the three (3) decades under investigation across the study areas while day time cooling increases slightly by 2% in Ikeja, 1% in Osogbo and 3% in Maiduguri significant level and Cold night decrease at 1% in Ikeja and remain constant in Osogbo but decrease by 5% in Maiduguri significant level.

Keywords: [Extreme values, Temperature and Percentile}

1. INTRODUCTION

Extreme temperature events cause destruction of properties, injuries, loss of lives and threaten the existence of some species. Observed global averaged warming and projected future warming over Central Africa have direct implications on the occurrence of extreme weather and climate events; as it is unlikely that the mean climate could warm without altering climatic extremes. Extreme events drive changes in natural and human systems much more than average climate [1-6]. Yet quantifiable information describing how weather and climate extremes are changing over Africa has, until now, been unavailable. In preparation for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report [7] a major effort was undertaken to analyze how extreme events' patterns are changing and affecting the world [8]. This included intensive international collaboration on data exchange and analysis, and, where data were not available, holding regional climate change workshops to generate information on extremes [9-14]. However, neither of these efforts was able to provide information for the whole of Africa. Hence this research seeks to determine the temperature extremes over Ikeja (Lagos), Osogbo (Osun) and Maiduguri (Borno) in Western and Northern Nigeria respectively.

2. MATERIAL AND METHODS

Thirty (30) years daily maximum and minimum temperature data (1971 – 2000) for Lagos, Osogbo and Maiduguri were used for this study. The data were obtained from the data archive of the Nigeria Meteorological Agency (NIMET), Oshodi, Nigeria. Lagos is a coastal area with average annual rainfall and temperature of 1693mm and 27°C. Osogbo is in the rainforest area with annual average rainfall and temperature of 1241mm and 26.1°C. Maiduguri is Savannah area with annual average rainfall and temperature of 613mm and 25.8°C. Monthly, seasonal and annual mean of minimum and maximum temperature was calculated using,

$$\bar{X} = \frac{\sum X}{N} \text{ .... (1)}$$

Where $\bar{X}$ = is mean (monthly, seasonal and annual as the case may be, X = Months of the year (1, 2 , … 12), N = Number of year(s)

Daily maximum and minimum temperature data were analyzed to compute the 10th and 90th percentile values in order to define a threshold for minimum and maximum temperature. Values less than the 10th and greater than the 90th percentile were extracted and counted for each day per annum and repeated for each year over the 30 years period. The values were then standardized to account for missing data. Plots to show the 30 years variability of the extremes for each of the parameter were generated. The data is set to between the range; ≥ 90th percentile values for the maximum temperature and ≤10th Percentile values for the minimum temperature. Table 1 below shows the 90th percentile and 10th percentile for both maximum and minimum temperature for the three stations within the years of consideration.

Table 1. The 90th percentile and 10th percentile for both Maximum and Minimum Temperature

STATIONS	90TH PERCENTILE (T-MAX(≥) (° C)	10TH PERCENTILE (T-MAX(≤) (° C)	90TH PERCENTILE (T-MIN(≥) (° C)	10TH PERCENTILE (T-MIN(≤) (° C)
IKEJA	34	28	26	21
MAIDUGURI	41	30	26	13
OSOGBO	35	27	24	18

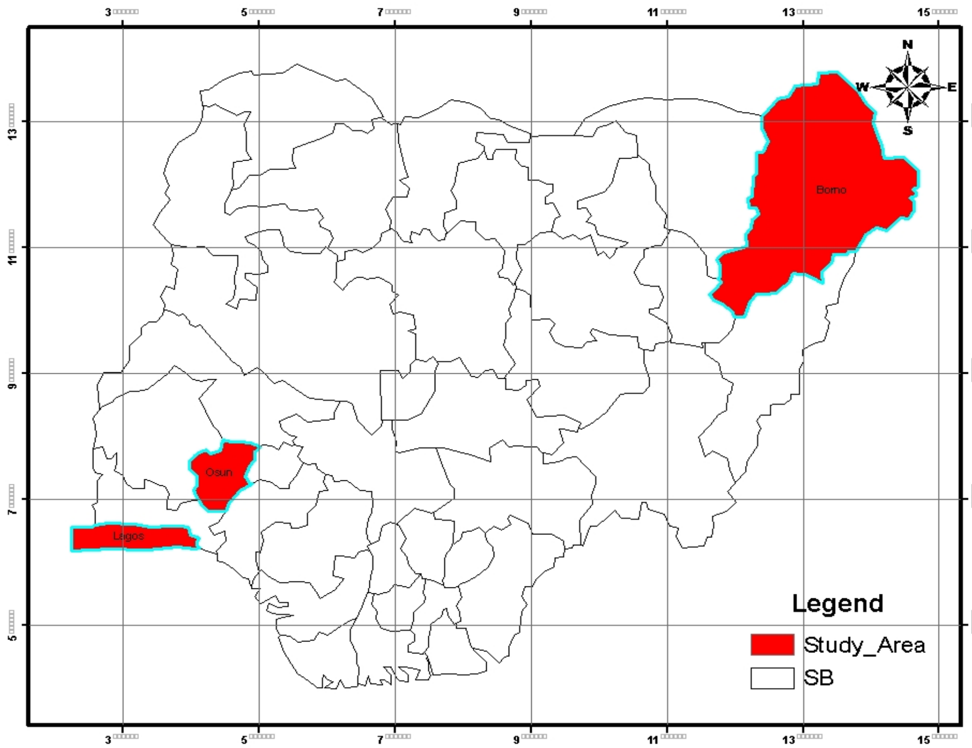

Figure 1: Map of Nigeria showing the study area.

3. RESULTS AND DISCUSSION

3.1 PERCENTILE-BASED TEMPERATURE INDICES

Figure 2 shows the annual trends in temperature extremes between 1971 and 2000 for the percentile-based temperature indices in Ikeja. Figure 2a indicate that the percentage occurrence of warm days (TX90P, number of days; in percentage) in which the maximum temperature is above 34^{0}C (90th percentile value) is increasing over the years while the percentage occurrence of cold days (TX10P, number of days [in %] in which the maximum temperature is below 28^{0}C [10th percentile value]) is decreasing over the station (Ikeja) as shown in Figure 2b. Percentage of day time warming indicates that values rise from around 11% to about 16% on the average over the three (3) decades under investigation whereas day time cooling is decreasing on the average around 11%. Another significant observation for Ikeja, representing rainforest zone, was that of a tendency towards night time warming as indicated, in Figure 2d, by a decrease in TN10P (percentage or proportion of days with minimum temperature below 21^{0}C [10th percentile value] and an increase in TN90P (proportion or percentage of days with minimum temperature above 26^{0}C [90th percentile value], that is an increase in the pattern of warm nights) as shown in Figure 2c. Basically, night time warming could be as a result of congestion of residents not allowing the easy passage of Outgoing Long wave Radiation (OLR). Generally, Ikeja is a place with strong tendency for day time warming and night time warming.

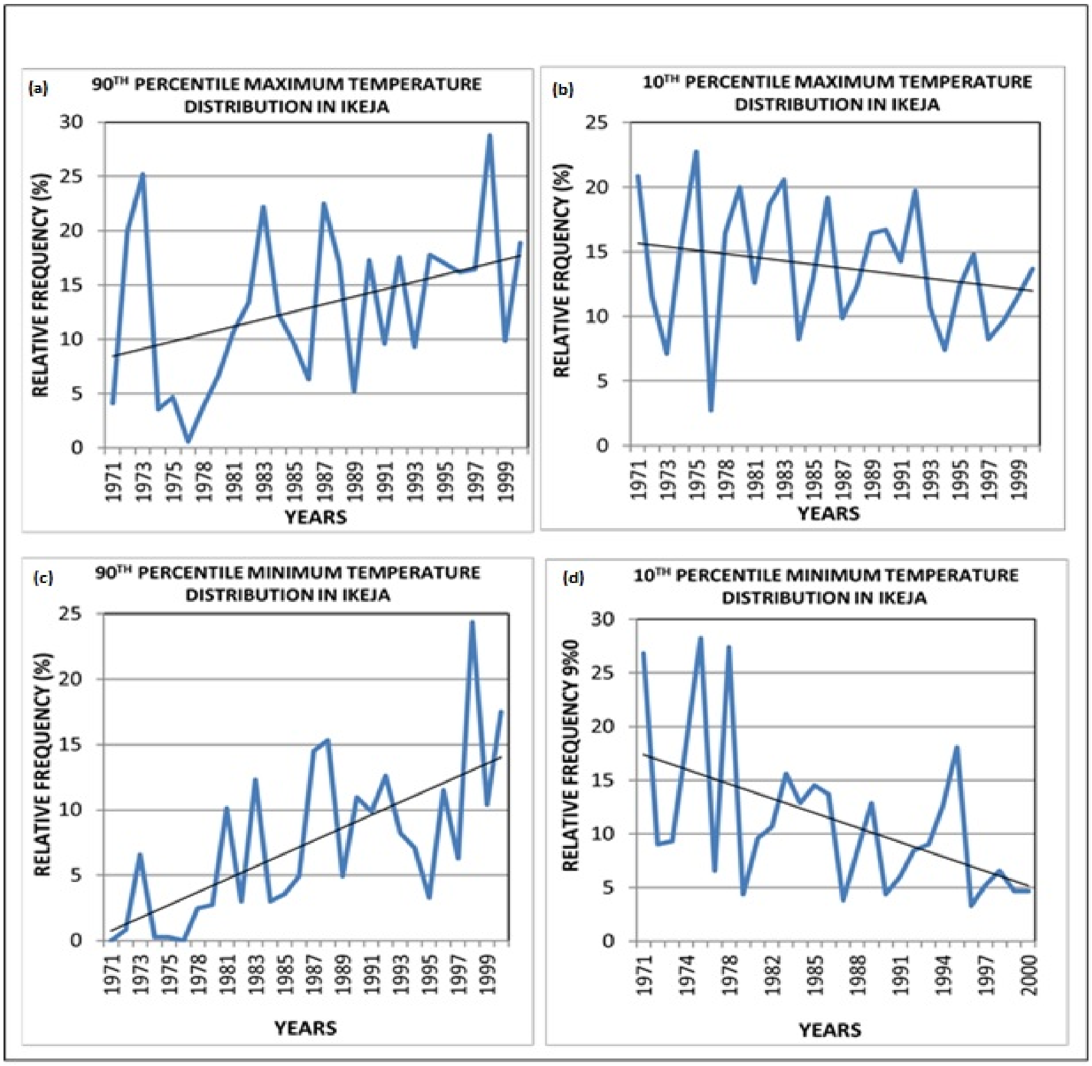

Fig 2. Temperature Extreme in Ikeja

Figure 3 shows the annual trends in temperature extremes between 1971 and 2000 for the percentile-based temperature indices in Osogbo. Figure 3a showed that the percentage occurrence of warm days (TX90P, number of days [in percentage] in which the maximum temperature is above 35^0C [90^{th} percentile value]) is increasing over the years but at a slower rate (when compared to Ikeja) whereas the percentage occurrence of cold days (TX10P, number of days [in %] in which the maximum temperature is below 27^0C [10^{th} percentile value]) is constant on the average over Osogbo as shown in Figure 3b. Percentage of day time warming indicates that values rise from around 10% to about 14% on the average over the three (3) decades under investigation whereas day time cooling is on the average around 10%. This indicates that Osogbo had been experiencing day time warming over the years but at a slight increase because the frequency of occurrence of day time cooling is relatively constant. Considering night time cooling/warming for the same station, results from Figures 3c, d showed that percentage of occurrence of warm nights (TN90P, number of days [in percentage] in which the minimum temperature is above 26^0C [90^{th} percentile value]) decreases slightly over the years whereas the proportion of cold nights (TN10P, number of days [in percentage] in which the minimum temperature is below 13^0C [10^{th} percentile value]) increases over the years. These generally indicate night time cooling (since night time warming is declining and night time cooling is on the increase) during the three (3) decades under investigation. Thus when compared with Ikeja (in which day and night are warming using threshold values for maximum and minimum temperatures respectively), Osogbo is slightly warming during the day and generally cooling during the nights in the past three (3) decades

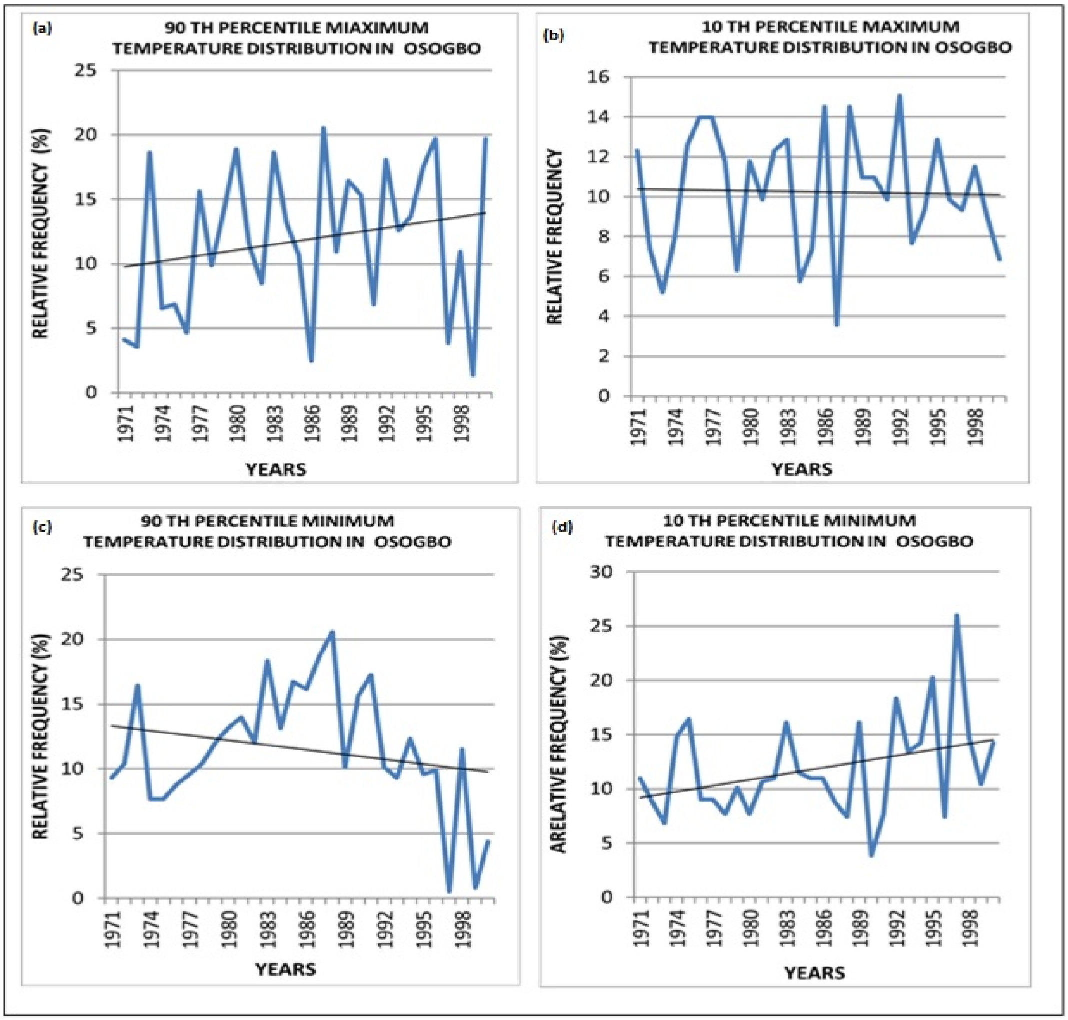

Fig 3. Temperature Extreme in Osogbo

Figure 4 shows the annual trends in temperature extremes between 1971 and 2000 for the percentile-based temperature indices in Maiduguri. Figure 4a showed that the percentage occurrence of warm days (TX90P, number of days [in percentage] in which the maximum temperature is above 41[90th percentile value]) is constant over the years whereas the percentage occurrence of cold days (TX10P, number of days [in %] in which the maximum temperature is below 30^{0}C [10th percentile value]) is slightly increasing as shown by the trend line in figure 4b. Percentage of warm days indicated that values is constant at around 13% during the three (3) decades under investigation whereas day time cooling increases slightly between 11% and 13%. Thus, because the percentage of cold days increases over the years, the tendency is that Maiduguri had experience day time cooling over the years but at a slight increase because the frequency of occurrence of day time warming is relatively constant. Considering night time cooling/warming for the same station, results from Figures 4c, d showed that percentage of occurrence of warm nights (TN90P, number of days [in percentage] in which the minimum temperature is above 24^{0}C [90th percentile value]) increases over the years whereas the proportion of cold nights (TN10P, number of days [in percentage] in which the minimum temperature is below 18^{0}C [10th percentile value]) increases over the years in Maiduguri. Both the night time cooling and night time warming are increasing at the same proportion

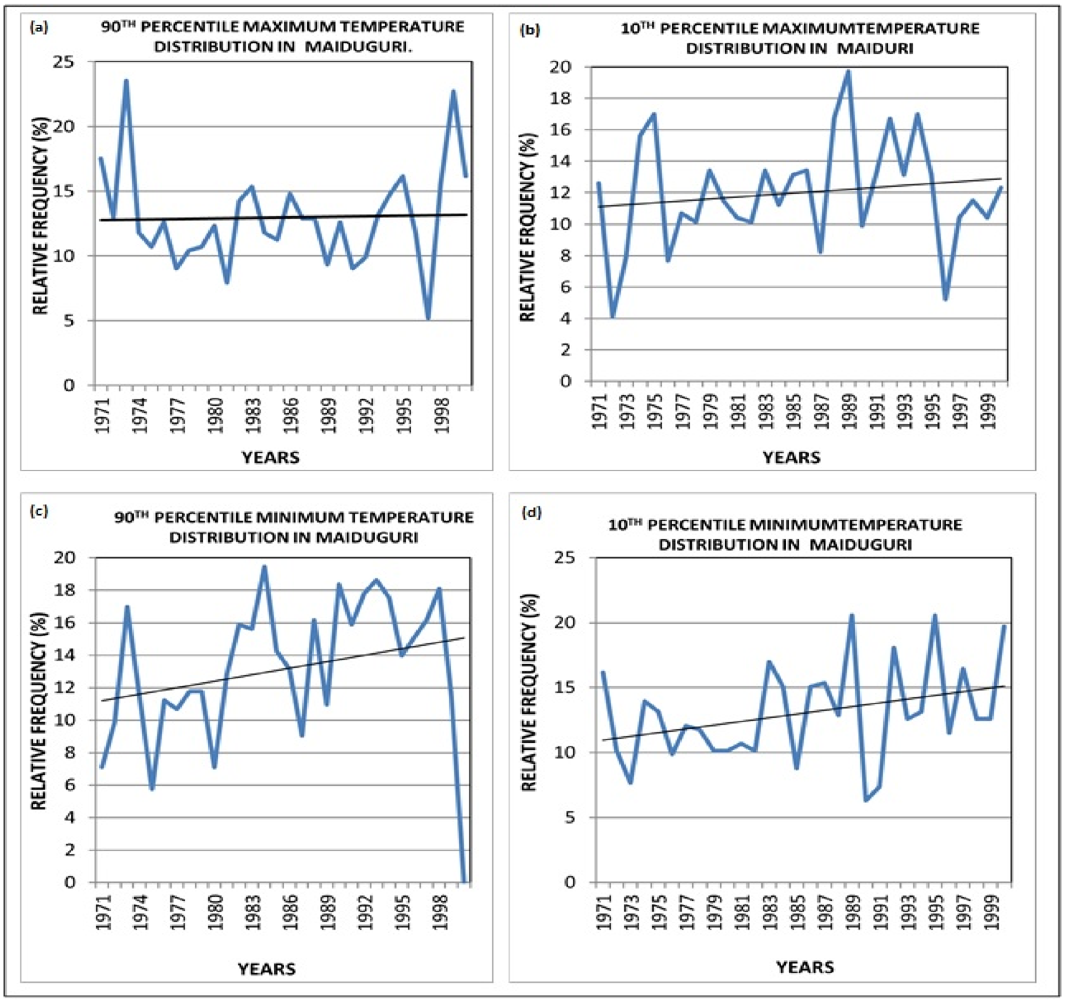

Fig 4. Temperature Extreme in Maiduguri

3.2 DECADAL DISTRIBUTIONS OF TEMPERATURE EXTREMES

Figure 5 shows the decadal distribution of maximum and minimum temperature in Ikeja between 1971 and 2000. Figure 5a and 5b showed that the decadal percentage occurrence of warm days (TX90P, number of days [in percentage] in which the maximum temperature is above 34^{0}C [90th percentile value]) is increasing over the years in Ikeja whereas the decadal percentage occurrence of cold days Figure 4c and 5d (TX10P, number of days [in percentage] in which the maximum temperature is below 28^0C [10^{th} percentile value]) is decreasing as shown by a forward shift (marked reduction) in the occurrence of cold daytime temperatures over the research period, particularly for the most recent decades Figure 5c and 5d. There is also a marked increase in the occurrence of warm nighttime temperatures during the last decades, again with strongest change in the last few decades (Figure 5d). The coldest minimum temperature (TNn) the coldest maximum temperature (TXn) have decreased over the decades while the warmest minimum temperature (TNx),) and the hottest maximum temperature (TXx) have increased but the difference between the decades is clearly shown by Figure 5c and d. The decadal occurrence of cold spells significantly decreased (Figure 4c and 4d) while the annual occurrence of warm spells significantly increased (Figure 5a and 5b). However, the trend in warm spells is greater in magnitude and is related to a dramatic rise in this index since the early 1990s.

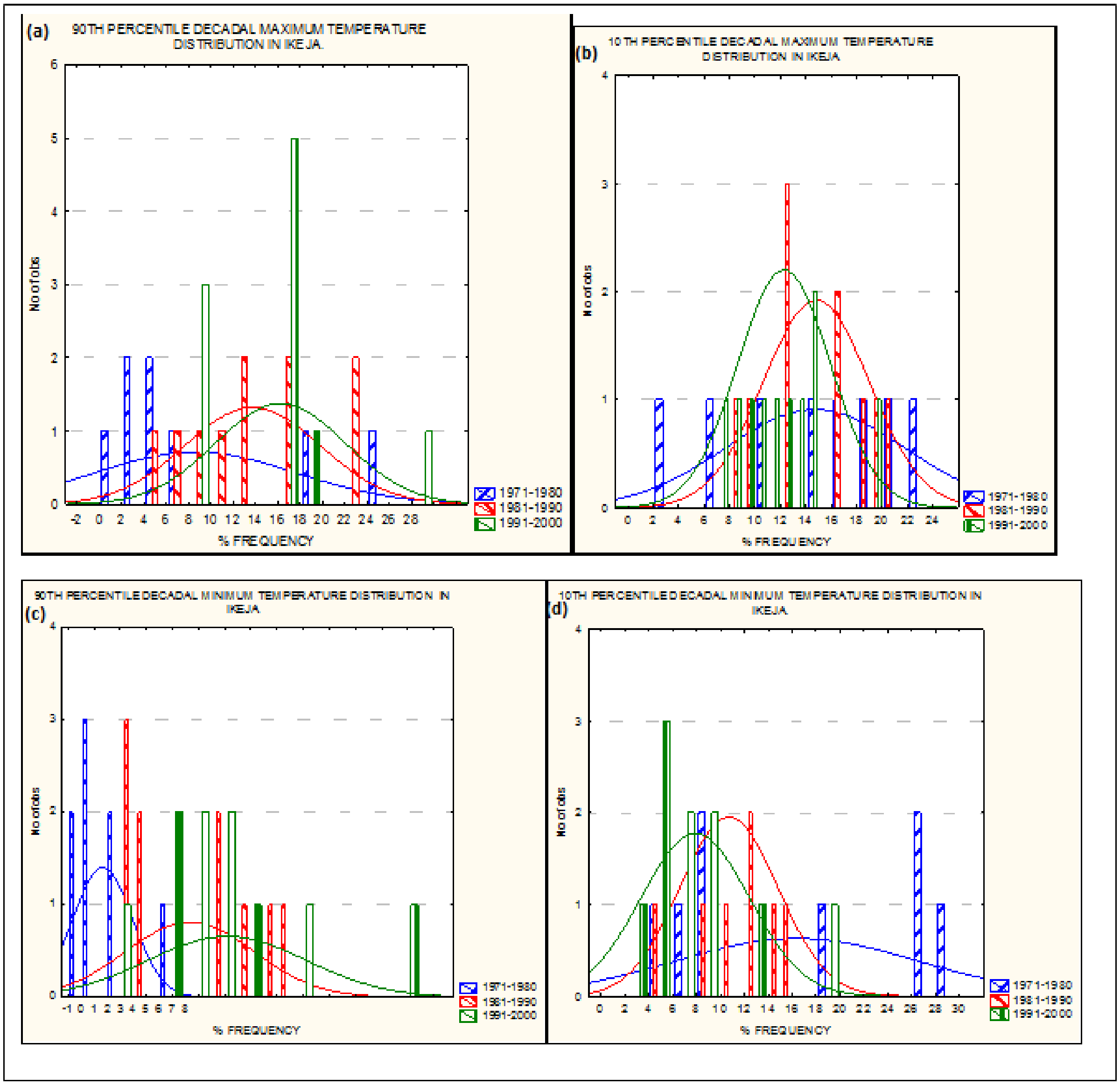

Fig 5. Decadal Minimum and Maximum Temperature Distribution in Ikeja

Figure 6 shows a decadal maximum and minimum temperature distribution in Osogbo between 1971 and 2000. Figure 6 a,b showed that the decadal percentage occurrence of warm days (TX90P, number of days [in percentage] in which the maximum temperature is above 35 ^{0}C [90th percentile value]) is increasing over the years whereas the decadal percentage occurrence of cold days Figure 5b (TX10P, number of days [in %] in which the maximum temperature is below 27^{0}C [10th percentile value]) is slightly increasing as shown by a forward shift (marked reduction) in the occurrence of warm daytime temperatures over the 1971–2000, particularly for the most recent decades Figure 5c. There is also a marked increase in the occurrence of warm nighttime temperatures during the last decades, again with strongest change in the last few decades (Figure 6d). The coldest minimum temperature (TNn), the warmest minimum temperature (TNx), the coldest maximum temperature (TXn) and the hottest maximum temperature (TXx) have also increased but the difference between the decades is clearly shown by Figure 6c and 6d. The decadal occurrence of cold spells significantly decreased (Figure 6c and 6d) while the annual occurrence of warm spells significantly increased (Figure 5a and 5b). However, the trend in warm spells is greater in magnitude and is related to a dramatic rise in this index since the early 1990s.

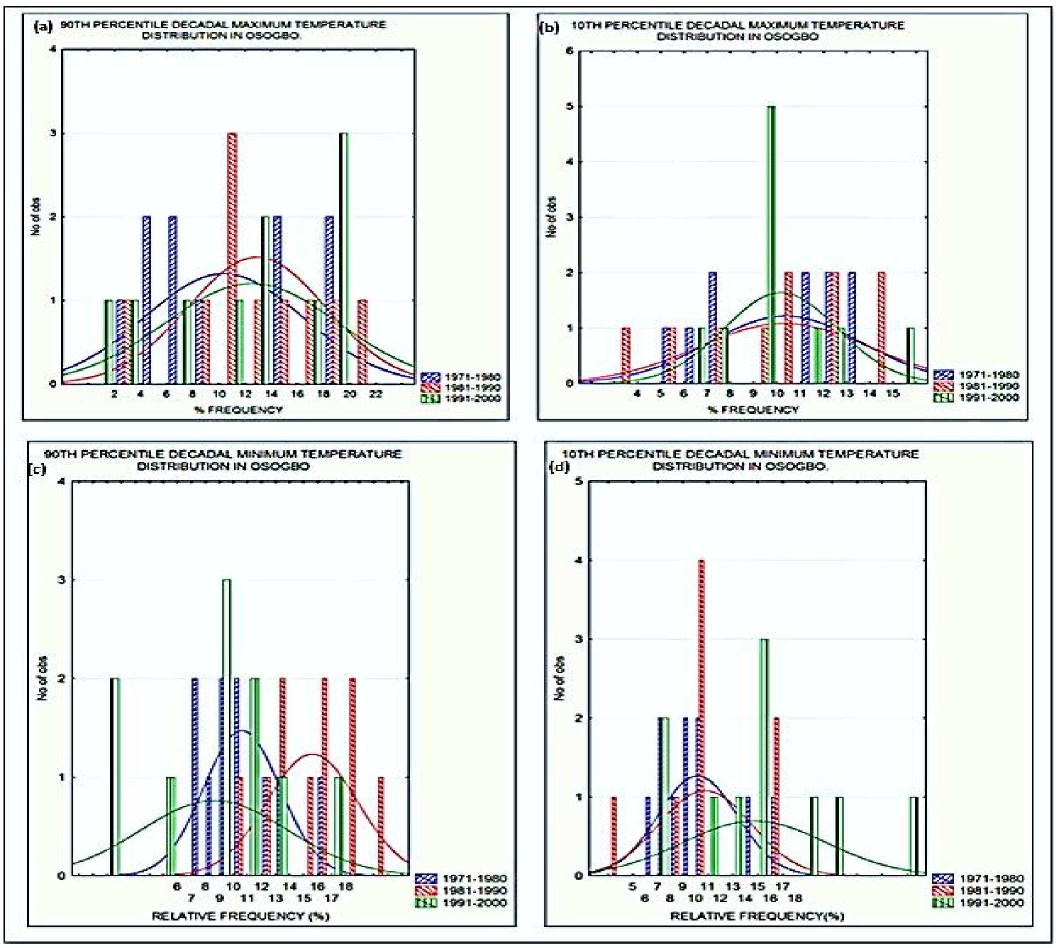

Fig 6. Decadal Minimum and Maximum Temperature Distribution in Osogbo

Figure 7 shows a decadal maximum and minimum temperature distribution in Maiduguri between 1971 and 2000. Figure 7a and 6b showed that the decadal percentage occurrence of warm days (TX90P, number of days [in %] in which the maximum temperature is above 410C [90th percentile value]) is increasing (on the average) over the years in Maiduguri whereas the decadal percentage occurrence of cold days Figure 6b (TX10P, number of days [in percentage] in which the maximum temperature is below 30C [10th percentile value]) is decreasing on the average as shown by a forward shift (marked reduction) in the occurrence of cold daytime temperatures over the 1971–2000, particularly for the most recent decades Figure 7c and 7d. There is also a marked increase in the occurrence of warm night time temperatures during the last decades, again with strongest change in the last few decades (Figure 7d). The coldest minimum temperature (TNn) the coldest maximum temperature (TXn) have decreased over the decades while the warmest minimum temperature (TNx),) and the hottest maximum temperature (TXx) have increased but the difference between the decades is clearly shown by Figure 6c and 6d. The decadal occurrence of cold spells significantly decreased (Figure 7c and 7d) while the annual occurrence of warm spells significantly increased (Figure 7a and 7b). However, the trend in warm spells is greater in magnitude and is related to a dramatic rise in this index since the early 1990s.

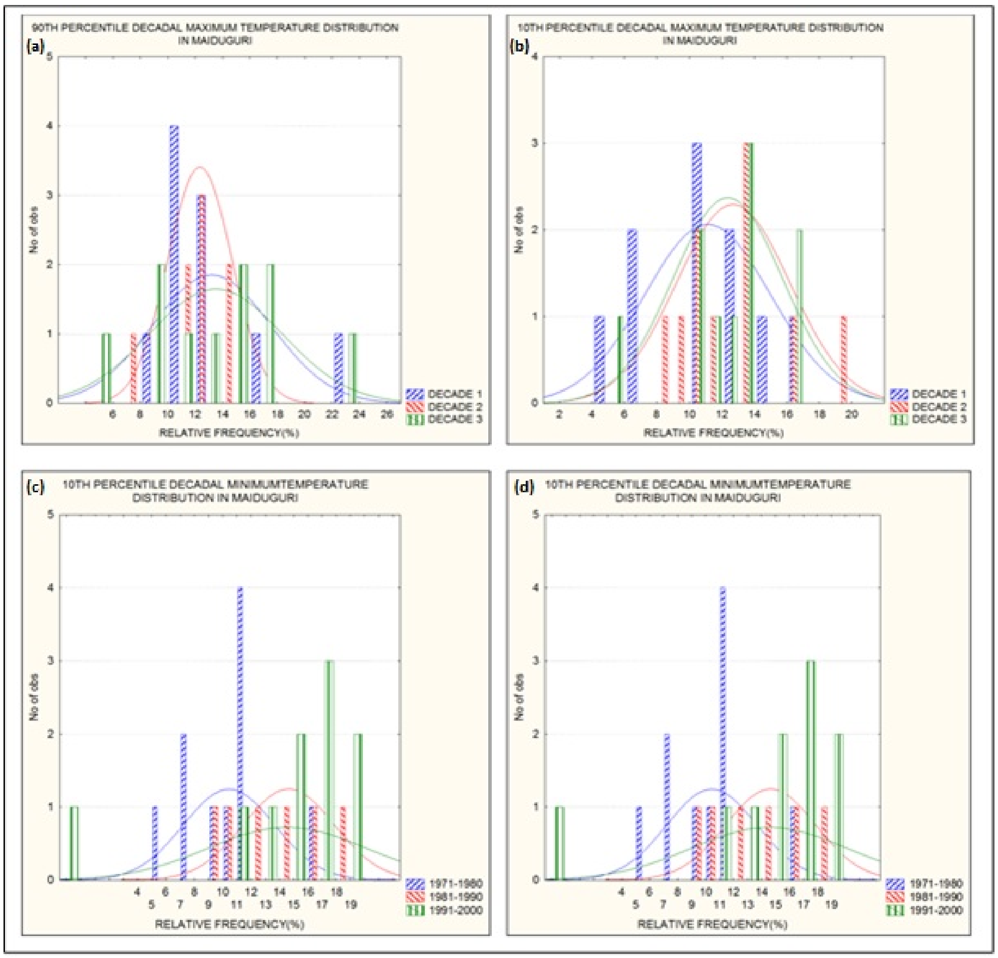

Fig 7. Decadal Minimum and Maximum Temperature Distribution in Maiduguri

4. Conclusion

This study has provided valuable insights about maximum and minimum temperature over Ikeja (Lagos), Osogbo (Osun) and Maiduguri (Borno), Nigeria, West Africa. It reveals that there is significant increase in warm time hour over the year and a decrease in the cold time hour. The increase in the warm time hour may be attributed to increase in carbon dioxide and other greenhouse gases resulting from human activities. The increase in anthropogenic activities causes a radiative heating that traps solar energy in the atmosphere that would otherwise be dissipated back into the space. The increase in the warm and cold time hour is more pronounced in the latter decades in recent years.

REFERENCES

1. Peterson TC, Manton MJ. Monitoring changes in climate extremes: A tale of international collaboration, Bull. Am. Meteoro. Soc., 2008; 89:1266–1271.
2. Manton MJ, Della-Marta PM, Haylock MR, Hennessy KJ, Nicholls N, Chambers LE, Collins DA, Daw G, Finet A, Gunawan D, Inape K, Isobe H, Kestin TS, Lefale P, Leyu CH, Lwin T, Maitrepierre L, Ouprasitwong N, Page CM, Pahalad J, Plummer N, Salinger MJ, Suppiah R, Tran VL, Trewin B, Tibig I, Yee D. Trends in extreme daily rainfall and temperature in Southeast Asia and the South Pacific: 1961–1998, Int. J. Climatol., 2001; 21(3): 269-284.
3. Folland CK, Karl TR, Christy JR, Clarke RA, Gruza GV, Jouzel J, Mann ME, Oerlemans J, Salinger MJ, Wang SW. Observed climate variability and change in: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.
4. Aguilar E. et al. Changes in precipitation and temperature extremes in Central America and northern South America, 1961 – 2003, J. Geophys. Res. 2005;110, D23107, doi:10.1029/2005JD006119.
5. Vincent LA, Peterson TC, Barros VR, Marino MB, Rusticucci M, Carrasco G, Ramirez E, Alves LM, Ambrizzi T, Berlato MA, Grimm AM, Marengo JA, Molion L, Moncunill DF, Rebello E, Anunciação YMT, Quintana J, Santos JL, Baez J, Coronel G, Garcia J, Trebejo I, Bidegain M, Haylock MR, Karoly D. Observed trends in indices of daily temperature extremes in South America 1960–2000, J. Clim. 2005;18: 5011–5023.
6. Trenbeth, K.E.; Fasullo, J.T.; Shepherd, T.G. Attribution of climate extreme events. *Nat. Clim. Change* 2015, *5*, 725–730.
7. IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
8. Francis, J.A.; Vavrus, S.J. Evidence linking Arctic Amplification to extreme weather in mid-latitudes. *Geophys. Res. Lett.* 2012, *39*, L06801.
9. Alexander L V, Zhang X, Peterson TC, Caesar J, Gleason B, Klein Tank AMG, Haylock M, Collins D, Trewin B, Rahimzadeh F, Tagipour A, Rupa Kumar K, Revadekar J, Griffiths G, Vincent L, Stephenson DB, Burn J, Aguilar E, Brunet M, Taylor M, New M, Zhai P, Rusticucci M, Vazquez-Aguirre JL. Global observed changes in daily climate extremes of temperature and precipitation, J.Geophys.Res. 2006;111(D5).
10. Kivinen, S.; Rasmus, S. Observed cold season changes in a Fennoscandian fell area over the past three decades. *Ambio* 2015, *44*, 214–225.
11. Donat, M.G.; Alexander, L.V.; Yang, H.; Durre, I.; Vose, R.; Dunn, R.J.; Willett, K.M.; Aguilar, E.; Brunet, M.;Caesar, J.; et al. Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset. *J. Geophys. Res. Atmos.* 2013, *118*, 2098–2118.
12. Wang, X.L.; Feng, Y.; Vincent, L.A. Observed changes in one-in-20 year extremes of Canadian surface air temperatures. *Atmos.-Ocean* 2014, *52*, 222–231.
13. Beniston, M. Ratios of record high to record low temperatures in Europe exhibit sharp increases since 2000 despite a slowdown in the rise of mean temperatures. *Clim. Change* 2015, *129*, 225–237.
14. Ruosteenoja, K.; Jylhä, K.; Kämäräinen, M. Climate projections for Finland under the RCP forcing scenarios. *Geophysica* 2016, *51*, 17–50.