Meteorological Comfort Indices to Assess Extreme Warmness in Southwest, Nigeria.

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***Abstract*--2015, 2016 and 2017 have been confirmed the three warmest years on record and the degree of warming during these three years has been exceptional. Extremes of heat and cold environmental conditions have been known to be very detrimental to the health and comfort of humans. The severity of these adverse effects is often local and varies from one place to another though they are happening on a global scale therefore Temperature variation, Heat Index (HI) temperature and Dew Point Temperature (DPT) (Meteorological comfort indices) were used to assess the effect of this condition in southwest, Nigeria. Air temperature and Humidity data were collected from meteorological stations situated in the southwestern states selected for study and was processed using the rule of Thumb for DPT calculations as expressed by Lawrence (2005) and Steadman (1979) formula simplified by Rothfusz' model (1990) for HI temperature. The data analysis was done using Microsoft Excel Package and Statistical Package for the Social Sciences (SPSS), the following results were obtained: Elevation may affect temperature yet during extreme warmness other factors can have a greater influence on temperature and meteorological comfort indices used to assess extreme warmness in southwest Nigeria from this study showed greater impacts thus: Heat Index Temperature has highest values in Lagos State, while Dew Point Temperature have highest values in Ogun state. None of these extreme warmness measuring variables seem to be solely in favour of state Location in terms of coordinates and elevation; this suggests more anthropogenic influence forming the characteristics of the states to geographic locations of the states however, between the start year of extreme warmness (2015) and 2017, HI temperature showed a significant increase while average DPT did not really change during the period of extreme warmness.**

***Index Terms*—Dew point temperature; Extreme warmness; Heat Index; Warmest years.**

I. INTRODUCTION

When weather elements are warmer than normal, they have direct impacts on our lives [2]. This condition is usually called Extreme warmness. The frequency, intensity, severity and duration of most of these extreme events [11] threaten the health of man and animals during and after the event. Though they happen on a global scale, however their impacts are often local and vary from one place to another[3]. Some meteorological elements considered during warmness are air temperature and humidity among others. Although human tolerance to humidity variations is much greater than tolerance to temperature variations, humidity control is also important because it can retard human heat loss by evaporative cooling (sweating and respiration). However, the combination of air temperature and relative humidity accounts for heat stress and dew point temperature, these have been expressed in the heat index or apparent temperature concept, developed by R. G. Steadman in 1979 and the rule of Thumb expression by M.G Lawrence in 2005 for dew point temperature. These meteorological comfort indices (Heat index and Dew point temperatures) can be used to describe and classify both comfort and discomfort levels in humans for necessary actions when cautioned.

II. RELATED WORKS

A. Extreme Weather and Effects

Extreme weather events is said to be one of the visible impacts of climate change and climate variability. However, some other studies have it that anthropogenic activities globally have a major contribution to climate extremes in terms of frequency and intensity variations [9][10]. At its occurrence, it has a direct impact on the environment (humans, plants and animals) globally or locally affecting every individual's performance, attitude and overall health [4][6].

B. Thermal climate and extreme temperature in Nigeria

However in Nigeria, [5] studied the spatial and temporal (1951–2009, 1951–1980, 1981–2009, decadal, seasonal and monthly averages) variations in the thermal climate of Nigeria, in terms of the temperature, relative humidity, effective temperature (ET), Temperature–humidity index (THI) and relative strain index (RSI). Results from their study revealed that elevation; the movement of the Inter Tropical Discontinuity and urbanization affect thermal comfort in Nigeria. They concluded that thermal stress has increased in Nigeria from 2000 at most stations, especially in the south and north-western regions. Also, [1] revealed that global warming increases the occurrence of extreme temperature and heat wave events in Nigeria; it also enhances the frequency of the extreme rainfall events in the south and southeast and reduces the annual rainfall over the northeast.

C. Heat Index as a determinant of human comfort

Different researchers and authors have presented "Heat Index" in various forms which at large have same meaning. [8] defined heat index as an accurate measure of how hot it

Published on February 26, 2019.
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DOI: http://dx.doi.org/10.24018/ejers.2019.4.2.1139

really feels, when the effects of humidity are added to high temperature and the combination of air temperature with relative humidity to determine an apparent temperature or what the air "feels like" to the average person for the various combinations of air temperature and relative humidity was the submission of [2] and National Weather Service (NWS) as heat index and that it has important considerations for the human body's comfort. [7] in a biometeorology study of climate and heat-related morbidity in Phoenix from 2001 to 2006 discovered that the greatest incidence of heat-related medical dispatches occurred during times of elevated human comfort indices (combined temperature and relative humidity) among other periods.

Dew point as extreme weather indicator

The dew point temperature, which provides a measure of the actual amount of water vapor in the air, is the temperature to which the air must be cooled in order for that air to be saturated is useful for a number of reasons; it helps meteorologists predict temperature lows in a weather forecast, a very high dew point can indicate severe weather which means air is unstable and that thunderstorms may develop, it is also a reflection of humidity and can be used to measure how weather conditions affect people differently.

Dew point temperature (td) helps to have a better direct indicator of expected comfort levels. Reference [13] noted that air with td > 20°C is generally considered uncomfortable, and air with td > 24°C is perceived as "sticky," almost regardless of the actual dry-bulb temperature, t.

III. MATERIALS AND METHODS

Air temperature and Relative humidity data were collected while Heat Index Temperature and Dew point Temperature were computed for southwest states, Nigeria for (2015-2017) - three confirmed warmest years on record [12]. Three states were selected for this study namely: Lagos, Ogun and Osun states. Air temperature and relative humidity data were collected from meteorological stations domicile in these states. Average monthly temperature and humidity values were collected from Nigerian Meteorological Agency (NIMET), DAVIS Weather station at Covenant University, Otta and daily temperature and humidity data from meteorological station of Obafemi Awolowo University, Ile-Ife for Lagos, Ogun and Osun states respectively.

Meteorological comfort indices (heat index and dew point temperature) were computed using temperature and humidity values adopting existing formula.

For Heat Index, Steadman (1979) formula comprising a group of parameters' calculations that were considerably simplified by Rothfusz' model (1990), using a multiple regression analysis assuming several fixed magnitudes to some parameters like vapour pressure or dimensions of a human skin surface or clothing cover or clothing resistance to heat transfer or activity, etc. was adopted.

$$\text{Heat Index} = -42.379 + 2.04901523T + 10.14333127R - 0.22475541TR - 6.83783 \times 10^{-3}T^2 - 5.481717 \times 10^{-2}R^2 + 1.22874 \times 10^{-3}T^2R + 8.5282 \times 10^{-4}TR^2 - 1.99 \times 10^{-6}T^2R^2$$

(Rothfusz regression equation),

where T is air temperature and R is relative humidity, expressed on degree Celsius (^{0}C).

While the rule of Thumb as expressed by M. G Lawrence of 2005 for dew point temperature was adopted for calculating dew point temperature for the period of study.

$$Td = T - \left({}^{(100 - RH)}/_{5}\right)$$

where Td is dew point temperature, T is air temperature and RH is relative humidity.

Geographic and periodic effect of extreme warmness on other determinants (heat index and dew point) were qualitatively analyzed comparing means (one- way ANOVA) of the Statistical Package for the Social Sciences (SPSS) with patterns clearly displayed using Microsoft excel package.

IV. RESULTS

Table 1: 2015-2017 Average Annual Temperature (AAT) for Lagos, Ogun and Osun states in Degree Celsius.

Year	Lag AAT	Lag. Diff.	Ogun AAT	Ogun Diff.	Osun AAT	Osun Diff.	Total AAT	Diff
2015	27.71		26.65		26.58		26.98	
		0.46		0.39		0.54		0.46
2016	28.17		27.05		27.11		27.44	
		-0.38		-0.11		0.82		0.12
2017	27.79		26.94		27.94		27.56	
		1.01		-0.33				
State Aver.	27.89		26.88		27.21			

The study revealed that 2017 was the warmest year among the three years under investigation in Southwest Nigeria with an average air temperature of 27.56^{0}C from Table 1.

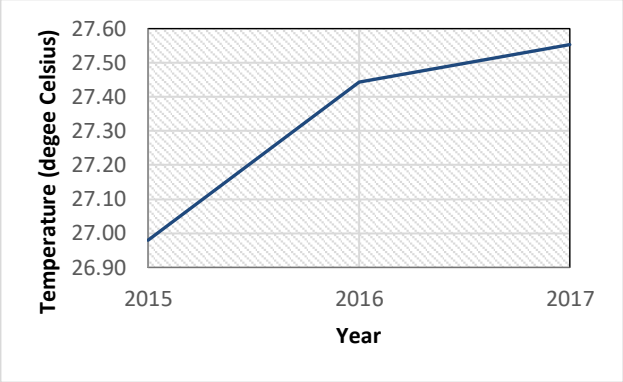

Fig. 1: Annual Temperature variation in Southwest-Nigeria

The pattern of the average annual temperature in southwest Nigeria (figure 1) revealed a continuous rise of temperature from 2015 to 2017.

Considering the average annual temperature with respect to state locations, figure 2 showed that the pattern of annual temperature is not consistent with state locations. This could also mean that, in southwest Nigeria, other factors contribute more to rise in temperature than state coordinates and altitude. Though other studies have revealed that latitude and

DOI: http://dx.doi.org/10.24018/ejers.2019.4.2.1139

elevation influence temperature pattern and that temperature increases with elevation within the troposphere yet this study has agreed with these when comparing Ogun and Osun states. Lagos on the other hand with the lowest elevation maintained the highest temperatures among the three states under investigation and a sharp decrease in AAT with a high temperature difference of 1.01^{0}C from Ogun state which is next in altitude. This therefore suggests that though elevation may affect temperature yet other factors can have a greater influence on temperature pattern.

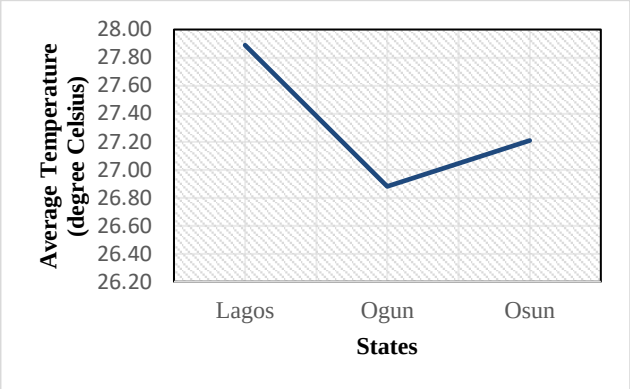

Fig. 2: Average Temperature variation in Southwestern states-Nigeria

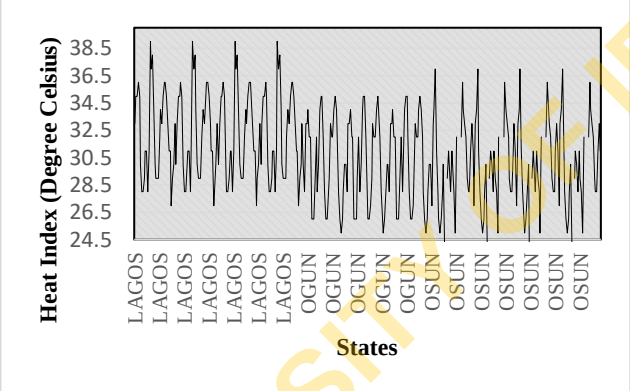

Fig. 3: Lagos, Ogun and Osun Heat Index pattern (progressive view)

Table 2: Heat Index ANOVA for Lagos, Ogun and Osun States

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.524	2	8.762	19.506	.000
Within Groups	169.347	377	.449		
Total	186.871	379			

The study reveals that there is statistically significant difference in southwest states with location descriptions: Lagos (3^{0}24^{l}E, 6^{0}27^{l}N, 0m), Ogun (3^{0}34^{l}E, 7^{0}00^{l}N, 77m) and Osun states (4^{0}30^{l}E, 7^{0}30^{l}N, 320m) and Heat Index temperature and in pattern (figure 3) in Table 2, p value of 0.000 implies that HI temperature is influenced by these states described with their geographical positions.

With these statistically significant values between Lagos with Ogun and Osun states revealed by Tukey HSD multiple comparisons of heat index among states, it may be said that Heat Index values are affected by southwest states locations. This therefore suggest that, during these years of extreme warmness, average HI values of Lagos, Ogun and Osun (32.22^{0}C, 30.17^{0}C and 29.97^{0}C) in southwest Nigeria decreased with state coordinates and altitudes. The difference in their mean values is not consistently statistically significant meaning that decrease in HI with state location is not entirely due to the states geographical location in terms of coordinates and altitude but other qualities or characteristics of the states has a greater effect on the HI values.

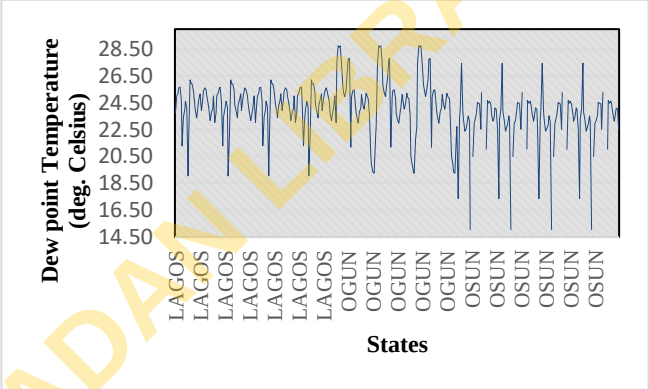

Fig. 4: Lagos, Ogun and Osun State Dew point Temperature Pattern (progressive view)

Table 3: Dew Point ANOVA for Lagos, Ogun and Osun States

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.758	2	6.879	13.480	.000
Within Groups	192.389	377	.510		
Total	206.147	379			

The study also reveals a statistically significant difference in southwest states with location descriptions: Lagos (3^{0}24^{l}E, 6^{0}27^{l}N, 0m), Ogun (3^{0}34^{l}E, 7^{0}00^{l}N, 77m) and Osun states (4^{0}30^{l}E, 7^{0}30^{l}N, 320m) and Dew Point temperature in pattern (figure 4) and in Table 3, p value of 0.000 implies that dew point temperature is influenced by these states described with their geographical positions.

With these significant values between Lagos, Ogun and Osun states revealed by Tukey HSD multiple comparisons of heat index among states, it may be said that southwest states locations can affect the dew point temperature values. This therefore suggest that, during these years of extreme warmness, the difference in the DPT values of Osun compared with other southwest states is not largely due to the states geographical location in terms of coordinates and altitude but other qualities or characteristics of the states also has a greater effect on the DPT values.

DOI: http://dx.doi.org/10.24018/ejers.2019.4.2.1139

V. CONCLUSION

Extreme warmness was assessed in Southwest Nigeria from 2015 to 2017 using the following indices: Temperature variation, Heat index temperature and Dew point temperature. Three states were carefully selected in Southwest Nigeria- Lagos, Ogun and Osun. Meteorology data used (air temperature and Humidity) were collected from meteorological stations in the states selected for study. The data collected was processed using the rule of Thumb as expressed by Lawrence in 2005 for DPT calculations and Steadman (1979) formula simplified by Rothfusz' model (1990) for HI. The data analysis was done using Microsoft Excel Package and Statistical Package for the Social Sciences (SPSS), the following results were obtained: Elevation may affect temperature yet during extreme warmness other factors can have a greater influence on temperature, meteorological comfort indices used to assess extreme warmness in southwest Nigeria from this study showed greater impacts thus: Heat Index Temperature has highest values in Lagos State, while Dew Point Temperature have highest values in Ogun state. None of these extreme warmness measuring variables seem to be solely in favour of state Location in terms of coordinates and elevation; this suggests more anthropogenic influence forming the characteristics of the states to geographic locations of the states which is in line with the suggestion of [9] and [10] however, between the start year of extreme warmness (2015) and 2017, HI temperature showed a significant increase while average DPT did not really change during the period of extreme warmness. However, Lagos state maintained the highest air temperature during the extreme warmness years and Heat Index decreased with state geographical location in southwest Nigeria during period of extreme warmness.

ACKNOWLEDGMENT

The authors would like to appreciate Tertiary Education Trust Fund (TETFUND) for approving and sponsoring this research work.

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