VARIABILITY OF RELATIVE HUMIDITY AND AIR TEMPERATURE IN KANO AND PORT HARCOURT, NIGERIA

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I. O. Agada[1], P. O. Agada[2] and G. T. Fila[1]

[1]Department of Physics, University of Agriculture, Makurdi, PMB 2373, Benue State, Nigeria

[2]Department of Mathematics/Statistics/Computer Science, University of Agriculture, Makurdi, Benue State, Nigeria

*Correspondingauthor:gadexx@yahoo.com

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Abstract: This work examines the year to year and month to month variability of relative humidity and air temperature in Kano and Port-Harcourt, Nigeria. Thirty-four (34) years data of relative humidity and air temperature were sourced from the archives of the International Institute of Tropical Agriculture (IITA) Ibadan, Oyo State, Nigeria. A descriptive statistic such as the mean and its 95% confidence interval were determined for each climatic parameter. For each station, the 95% confidence interval for the monthly mean of each parameter shows with 95% certainty that the mean lies in the established interval. The One-way Analysis of Variance (ANOVA) was employed in checking whether the variability in the climatic parameters is affected by season. This was done by comparing the monthly mean of each parameter for each station. The comparison revealed a significant difference in the means ($p<0.05$) for each parameter in each station showing a seasonal effect. Using graphical method, the study revealed a year to year and a month to month variability in the climatic parameters. The year to year and month to month variability pattern of relative humidity and air temperature is the same in Port Harcourt showing a direct relationship between the two parameters. In Kano, the pattern shows that when air temperature is increasing, relative humidity is decreasing and vice versa showing an inverse relationship. Since saturation vapour pressure relates inversely to relative humidity, then it can be inferred that the Claussius-Clapeyron equation establishes an inverse theoretical relationship between relative humidity and air temperature. It was established in this work that the equation confirms this relationship for the city of Kano but negates it for the city of Port Harcourt. Why is this so? The researchers were able to harness the climatic features of each city in answering this question. They finalized that the climatic features of a place as it affect relative humidity and air temperature determines whether the place upholds the established behavior of the Claussius-Clapeyron Equation or not.

Keywords: Air temperature, climate variability, relative humidity

Introduction

The manner in which climate fluctuates yearly, above or below a long-term average (mean) value is referred to as climate variability while climate change is a long-term continuous change, either increasing or decreasing from the mean value. Climate change is gradual and difficult to detect without a long term data (30 years and above), unlike climate variability which is year-to-year variability from the mean value. Climate variability has great effect on the economy, future generations, the societies, biological community and agriculture (Capparelli*et al*., 2015). Since this work analysis the year to year and month to month variability of relative humidity and air temperature in the cities of Kano and Port Harcourt, Nigeria, it can be seen to have analyzed the climate variability of these two cities.

Climate parameters such as air temperature and relative humidity are affected by global warming resulting to variability in the weather patterns. Studies have shown that human activities such as production of cements, burning of fossil fuel and cutting down of trees have resulted to the increase in greenhouse gases causing global warming (Neftel*et al*., 1985; Weiss, 1981; Machida *et al*., 1995; Berner*et al*., 1980; Adekola, 2014; Francey and Farquhar, 1982; Steele *et al*., 1996; Tubiello, 2012). The increase in these major greenhouse gases (carbon dioxide, methane, nitrous oxide, and fluorinated gases) has led to the increase in global air temperature (Bakri and Abou-Shleel, 2013; Groisman*et al*., 2004; Minia, 2008; Callendar, 1938; Easterling*et al*., 2007; Cincoe*t al*., 2014; Poulter*et al*., 2013; Mangodo*et al*., 2014). A work of this nature, which analyses the variability in the weather pattern of Kano and Port Harcourt cities of Nigeria is therefore not out of place as the results can be used in the weather and climate assessment of the two cities.

According to the Claussius-Clapeyron equation, saturation vapor pressure increases exponentially with temperature.The maximum amount of water vapour that the air can hold depends on the air temperature (Murry, 2012). Warm air is capable of holding more water vapour than cold air. Relative humidity and dew point temperature are the two major quantities used to describe the abundance of water vapor. The ratio of the amount of water vapor in the air to the amount of water vapor the air can hold at a particular air temperature is referred to as Relative humidity. The air is saturated when relative humidity is 100%, which means it cannot hold any more moisture.Dew point temperature is the temperature where moisture begins to condense out of the air. It is important to mention that since saturation vapour pressure relates inversely to relative humidity, then it can be inferred that the Claussius-Clapeyron equation establishes an inverse theoretical relationship between relative humidity and air temperature. The dilemma of the researcher is whether this relationship is realistically true in all cases.

In areas like Kano and Port Harcourt, Nigeria, changes in air temperature and relative humidity could mean a lot. Kano which features a tropical savanna climate is typically very hot throughout the year. The city is experiencing weathering of vegetation due to desert encroachment, drying of water resources, extinction of species and increased cases of vector borne diseases (Jaiyeoba, 2002). While Port Harcourt as a coastal city is faced with flooding, rise in sea level, erosion and thermal discomfort (Chiadikobi*et al*., 2011). This work besides analyzing the variability in air temperature and relative humidity of the two cities, has been able to harness the climatic features of each city in resolving the aforementioned dilemma.

Materials and Methods

Source of data and method of analysis

The daily maximum Relative-Humidity and maximum air temperature data for Kano and Port Harcourt used in this work were sourced from the International Institutes of Tropical

Agriculture (IITA) Ibadan, Nigeria for the period of 34 years (1977-2010).

Confidence interval for mean

This is the process of obtaining an estimate of a parameter as an interval marked by a Lower bound (L) and an Upper bound (U) which are functions of the observed random variable. The probability that the interval encloses the parameter is given as 1-α and is called confidence coefficient, that is P (L ≤ θ ≤ U) = 1-α where θ is the parameter. The interval (L, U) is called 100 (1-α)% confidence interval, L is the lower confidence limit and U is the upper confidence limit. The practical interpretation of confidence interval is that, at a probability value equal to the confidence coefficient we expect the interval to enclose the true value of the parameter (Emaikwu, 2010). The 95% confidence intervals for the mean of the daily maximum Relative-Humidity and maximum air temperature data sets are shown for each city in Table 1.

One-way analysis of variance (ANOVA)

ANOVA is a parametric statistic which provides the opportunity to undertake a multi-group comparison of data set. The comparisons being made using ANOVA are 2-dimensional. The sources of variation as the basis for comparison recognize that difference exists between and within groups being compared. The second dimension has to do with the fact that the direction of difference establishes the homogeneity (closeness) of variance between and within groups. The F-statistic obtained is usually compared with the F-critical ratio as a basis for establishing the acceptance or rejection of the hypothesis stated. ANOVA involves the estimation of within group and between group variations in means of research groups being compared (Emaikwu, 2010). The One-way Analysis of Variance (ANOVA) was employed in checking whether the variability in the relative humidity and air temperature for each city is affected by season. This was done by comparing the monthly mean of each parameter for each city (Table 2).

Claussius-Clapeyron equation

The Claussius-Clapeyron equation established that the saturation vapour pressure increases exponentially with temperature. This is shown mathematically in equation 1 below.

$$\log_{10} p_\omega \cong 9.4041 - \frac{2354}{T} \qquad (1)$$

Where: p_ω is the saturation vapour pressure and T is the temperature.

Recall,

$$R_H = \frac{p}{p_w} \times 100\% \qquad (2)$$

Where: R_H is the relative humidity and p is the vapour pressure.

From (1) and (2) we have,

$$\log_{10} R_H \cong -(7.4041 - \frac{2354}{T}) + \log_{10} p \qquad (3)$$

This shows that relative humidity decreases exponentially with temperature (Murry, 2012).

Result and Discussion

In Fig. 1, the annual mean relative humidity is observed to have dropped from 1978-1983 after every two years. The scenario changed in 1984-1998 where relative humidity decreases after each year except in 1991 and 1996. The lowest annual mean relative humidity of 43.5% was observed in 2008 while 2005 recorded the highest value of relative humidity (60.1%). The annual mean air temperature decreased after every one year in 1977 to 1990 except 1979 and 1980. Between 1991 and 2010, there were annual mean temperature spikes in 1992, 1995, 1996 and 2004 with air temperatures of 37.2, 38.9, 39.09 and 39.06°C, respectively. The highest annual mean air temperature of 39.09°C was recorded in 1996 and lowest air temperature of 31.0°C was in 1986. While the year to year air temperature is increasing, relative humidity is decreasing and vice versa.

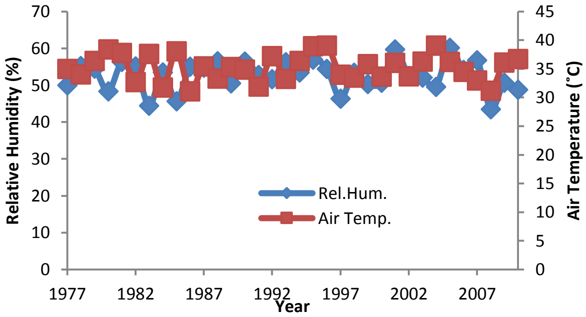

Fig. 1: Annual variability of relative humidity and air temperature in Kano metropolis

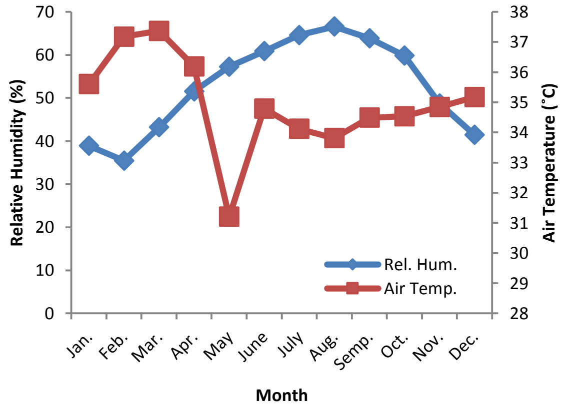

Fig. 2: Monthly variability of relative humidity and air temperature in Kano metropolis

In Fig. 2, the mean monthly relative humidity is observed to increase from the month of March to August and decreased from September to February rapidly while the monthly mean air temperature increased from September to March and decrease from April to August except that there was a sharp decrease in the month of May with air temperature of 31.2°C. The peak monthly mean relative humidity of 66.5% was observed in the month of August and the lowest mean monthly relative humidity of 35.4% was recorded in February. The highest temperature of 37.3°C was recorded in March while the lowest monthly mean air temperature of 31.2°C was recorded in the month of May. Also when the monthly mean relative humidity is increasing, monthly mean air temperature is decreasing and vice versa.

Port-Harcourt experienced high annual mean relative humidity in the 34 years considered in this study compared to Kano. The annual mean relative humidity has shown a sudden increase (high spikes) in 1982, 1993 and 2004. While the annual mean air temperature has high spikes in 1987, 1998 and 2009. The year to year variability pattern of relative humidity and air temperature is the same as shown in Fig. 3.The result of the monthly mean relative humidity and air temperature presented in Fig 4, reveal an increasing trend from the month of June to October and a decreasing trend from month of November to May. The month to month variability pattern of relative humidity and air temperature is also the same as shown in Fig. 4.

The 95% confidence interval allows us to estimate a range of values that contain the actual true value of the monthly mean of relative humidity and air temperature. The interval estimate gives the precision or the accuracy of an estimate in a probability sense. The narrow the interval the more precise is the estimate. The 95% confidence interval for the monthly mean of each parameter shows with 95% certainty that the mean lies in the established interval Table 1. The result of the One-way Analysis of Variance (ANOVA) presented in Table 2, indicates a significant difference in the monthly means of relative humidity and air temperature ($p< 0.05$). This explains the existence of a month to month variability in each climatic parameter confirming the influence of seasonal effect. This also indicates the existence of significant climate variability in Port Harcourt and Kano, Nigeria.

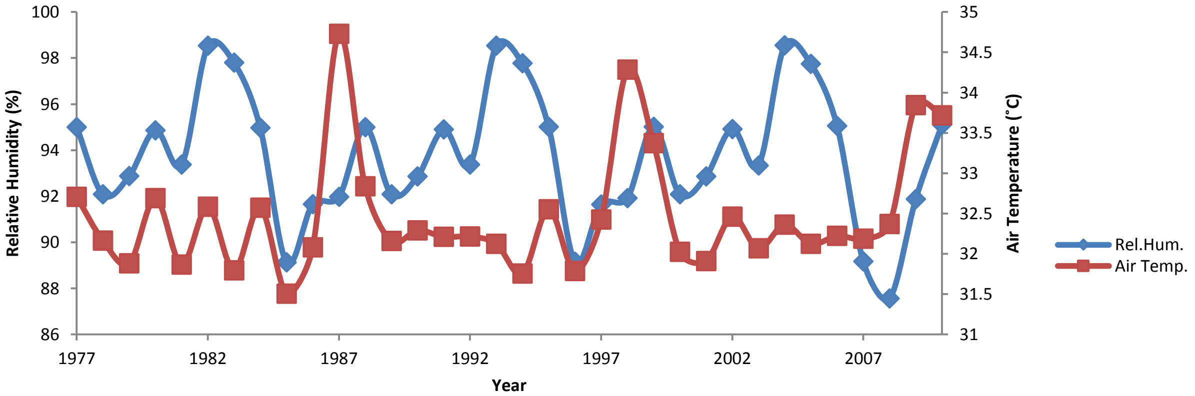

Fig. 3: Annual variability of relative humidity and air temperature in Port-Harcourt metropolis

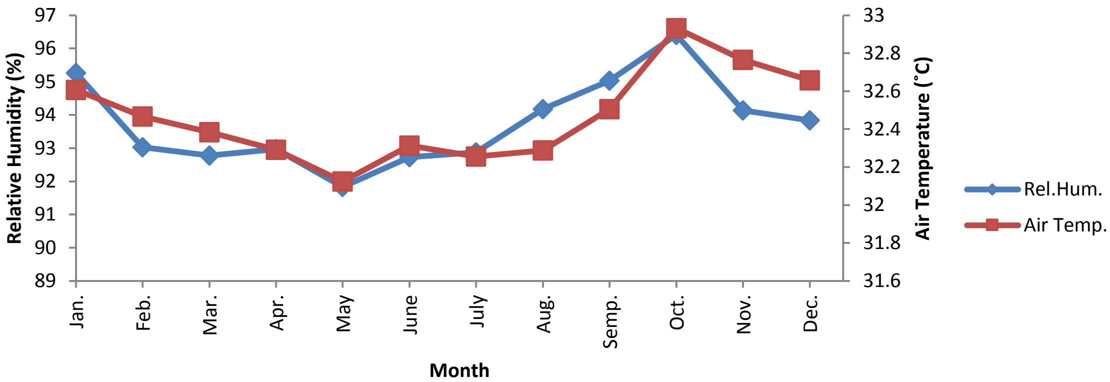

Fig. 4: Monthly variability of relative humidity and air temperature in Port Harcourt metropolis

Table 1: 95% confidence interval of monthly mean relative humidity and air temperature in Port Harcourt and Kano, Nigeria

Month	Port Harcourt				Kano			
	Relative Humidity		Air Temperature		Relative Humidity		Air Temperature	
	L.B.	U.B.	L.B	U.B.	L.B.	U.B.	L.B	U.B.
January	38.0378	39.7148	34.0917	34.9878	94.9905	95.5496	32.4608	32.7514
February	34.5609	36.1786	38.1245	39.5384	92.6016	93.4326	32.3146	32.6256
March	42.465	43.9093	38.3715	39.7264	92.355	93.1872	32.2323	32.5363
April	50.9192	52.1406	35.9086	36.4576	92.4524	93.477	32.1331	32.4408
May	56.6597	57.8494	36.4968	37.9507	91.1885	92.465	31.9757	32.2733
June	60.1933	61.4655	34.4268	35.112	92.3015	93.1502	32.1616	32.469
July	63.7887	65.339	35.1356	36.6238	92.2235	93.457	32.1096	32.4015
August	65.744	67.3415	32.4209	33.4378	93.674	94.6643	32.1406	32.4355
September	63.1639	64.503	34.109	34.885	94.744	95.3132	32.3515	32.6623
October	59.1779	60.3841	35.8536	37.3296	96.1096	96.6998	32.7845	33.078
November	48.0829	49.3363	34.5802	35.1122	93.5154	94.7336	32.6066	32.9207
December	40.7642	42.1113	36.3812	37.7958	93.2106	94.4657	32.5056	32.8099

L.B. = Lower Bound; U.B. = Upper Bound

Table 2: Monthly one way analysis of variance (ANOVA) of relative humidity and air temperature in Port Harcourt and Kano, Nigeria

Month	Port Harcourt						Kano					
	Relative Humidity			Air Temperature			Relative Humidity			Air Temperature		
	F-value	P-value	Rem.	F-value	P-Value	Rem.	F-value	P-value	Rem.	F-value	P-Value	Rem.
January	12.076	0	sig.	27.168	0	sig.	29.834	0	sig.	173.666	0	sig.
February	8.466	0	sig.	25.512	0	sig.	24.164	0	sig.	525.317	0	sig.
March	9.159	0	sig.	34.776	0	sig.	27.657	0	sig.	538.46	0	sig.
April	15.344	0	sig.	11.358	0	sig.	14.026	0	sig.	31.287	0	sig.
May	28.096	0	sig.	27.438	0	sig.	21.551	0	sig.	571.756	0	sig.
June	11.073	0	sig.	11.601	0	sig.	24.275	0	sig.	30.382	0	sig.
July	38.6	0	sig.	31.778	0	sig.	57.227	0	sig.	504.651	0	sig.
August	21.077	0	sig.	31.091	0	sig.	50.109	0	sig.	78.871	0	sig.
September	29.198	0	sig.	17.439	0	sig.	38.5	0	sig.	31.169	0	sig.
October	13.738	0	sig.	34.206	0	sig.	28.991	0	sig.	556.937	0	sig.
November	15.276	0	sig.	24.318	0	sig.	13.655	0	sig.	31.907	0	sig.
December	181.71	0	sig.	35.06	0	sig.	10.962	0	sig.	590.726	0	sig.

α=0.05; Rem. = Remark; Sig. = Significant

As earlier mentioned in this work, the Claussius-Clapeyron equation established that the saturation vapour pressure increases exponentially with temperature (equation 2). When transformed to reflect Relative humidity, it can be deduced that relative humidity decreases exponentially with temperature (equation 4). This relationship holds for Kano but does not hold for Port Harcourt. The reason for this is not farfetched. As earlier explained in this work, Kano features a tropical savanna rise in climate and it is typically very hot throughout the year. The city is experiencing weathering of vegetation due to desert encroachment, drying of water resources, extinction of species and increased cases of vector borne diseases. While Port Harcourt as a coastal city is faced with flooding, rise in sea level, erosion and thermal discomfort. The hot climate of Kano throughout the year as well the associated dryness is indicative of increasing air temperature and decreasing relative humidity. While the flooding, rise in sea level as well thermal discomfort in Port Harcourt is indicative of increasing relative humidity and high temperature. It therefore becomes clear that the climatic features of a place as it affect relative humidity and air temperature determines whether or not it upholds the established behavior of the Claussius-Clapeyron Equation.

Conclusion

The following conclusions were drawn from the study;

(i) For the city of Kano, Nigeria, while the year to year and month to month variability in air temperature is increasing, that of relative humidity is decreasing.

(ii) For the city of Port Harcourt, Nigeria, year to year and month to month variability pattern of relative humidity and air temperature is the same.

(iii) The annual mean relative humidity for the city of Port Harcourt, show sudden increase (high spikes) in the year 1982, 1993 and 2004. While the annual mean air temperature has high spikes in the year 1987, 1998 and 2009.

(iv) The 95% confidence interval for the monthly mean of each parameter shows with 95% certainty that the mean lies in the established interval and the closeness of the confidence limits in each month depicts less variability of relative humidity and air temperature within months.

(v) Seasonality is a significant cause in the variability of relative humidity and air temperature in cities of Kano and Port Harcourt.

(vi) The climatic features of a place as it affect relative humidity and air temperature determines whether or not it upholds the established behavior of the Claussius-Clapeyron Equation.

Recommendations

The study recommends that the findings of this study which includes among others; that the climatic features of a place as it affects relative humidity and temperature determines whether or not it upholds the established behavior of the Claussius-Clapeyron principle, be used by stakeholders in the weather and climate assessment of the city of Kano and Port Harcourt, Nigeria.

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