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Study of Rainfall Distribution Pattern Changes and their Relationship with Atmospheric Parameters at Enugu and Kano States using Regression Model

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ABSTRACT
This study investigates rainfall distribution pattern changes and their relationship with atmospheric parameters (temperature, wind speed, relative humidity, atmospheric pressure and total cloud cover) at Enugu and Kano states in Nigeria. Rainfall describes the amount of water droplets that are descending onto the surface of the Earth inform of rain. It is a discontinuous quantity and an indispensible element in the hydrological cycle, which involves the cyclic movement of water from below, on and above the surface of the Earth. Daily rainfall and atmospheric parameters data records of the two locations were used for the analysis using regression model. Results indicated that there are robust relationships between rainfall and atmospheric parameters in the study areas. Though, a negative regression coefficient value for temperature was obtained at Enugu, the result showed that it has the greatest contribution to rainfall distribution pattern changes than the other atmospheric parameters in this study. On the other hand, the result showed that wind speed has the greatest contribution to rainfall distribution pattern changes at Kano than other atmospheric parameters in this present study. This present study suggests that there is evidence of differences in rainfall distribution pattern changes and their relationship with the atmospheric parameters in Enugu and Kano states. This implies that there were different levels of modification of rainfall distribution pattern changes at Enugu and Kano states by temperature, wind speed, relative humidity, atmospheric pressure and total cloud cover respectively, and their records may provide useful information that may be utilized to monitor rainfall related activities within a given geographical area.

Keywords:
Rainfall,
Distribution pattern,
Atmospheric parameters,
Regression model.

INTRODUCTION

Rainfall distribution patterns at Enugu and Kano in Nigeria over the surface of the earth have been under constant changes due to the Earth-atmosphere metamorphosis from one weather condition to another owing to the terrain, composition and interactions that exit in their environments. Nigeria, which has border with different geographical landscapes, has had different rainfall distribution, patterns over the years at different locations within the country and at different times (Okoro *et al.*, 2022). Surprisingly, two people residing in the same geographic location may sometimes experience varieties of rainfall distribution patterns over a given period of time because of the influence of atmospheric and environmental factors. The implication is that a certain droplet of rain falling from the lower atmosphere may be interfered with by the atmospheric or the environmental factors before reaching the surface of the earth, and the degree of the interference determines the nature of the rainfall distribution pattern that any given location or area may likely experience at a particular time.

Rainfall distribution pattern changes in Enugu and Kano are believed to have been caused by the contributions of atmospheric parameters interactions within the Earth-atmospheric environment. Often times in Enugu and Kano, people have been subjected to different levels of rainfall distribution hazards, ranging from flooding, water logging environment, erosion, destructions of goods and properties by unexpected and heavy rainfall distribution incidences that sometimes occur in the areas without prior notice. For instance, during heavy rainfall distribution, which may occur without fore warning, the storms drains accompanying the rainfall may become too heavy or being clustered with rubbles and therefore may result to overflow of the nearby roads and buildings. Low spots, such as underpasses, underground parking garages, basements, and low water crossings can become a danger zones for occupants of such people area. This has been attributed to lack of awareness of the time rainfall may possibly occur for people to get ready for it before hand in a particular location or area, especially during the rainy season due to lack of information on when rain may likely fall. Rainfall of course is a discontinuous parameter and therefore one might not say precisely when it will occur in a given location without prior information from a forecasting agency using rainfall forecasting instrument. However, experience shows that, the forecasting instrument is cost effective and so is being limited only to the forecasting agency. Based on the notions, this research work focused on the study of rainfall behavior in relation with the atmospheric parameters which are natural parameters that are readily available in the environment. This will make getting prior and prompt information concerning rainfall incidences at Enugu and Kano much easier. It will also help to fore tell the time rainfall is most likely to occur, based on the study of the nature of the atmospheric parameters, thereby expanding the horizon of the information concerning rainfall distribution within the locations for proper environmental monitoring.

Classification of Rainfall Distribution Patterns

No rainfall distribution pattern

This type of rainfall distribution pattern occurs when there is no trace of rainfall at a particular geographical location for a given instant. This may possibly be due to the inability of the convective air masses containing vapour (evaporating water) from the earth environment and ocean to form rain droplets at the atmosphere resulting from the overheating of the intriguing atmospheric environment by the solar radiation as well as other interactions in the Earth-atmosphere environments. The modifications of rain droplet forming processes in this case by radiation effects and other environmental factors in any location are relatively very intense that no rain droplet can be allowed to form within the atmospheric region.

Since rainfall depends on the sizes of the droplets formed and the gravitational force holding them together at the atmosphere, it therefore suggests that the capacity of rain forming droplets is totally negligible. Hence, they are not able to break out of the gravitational force holding them and thus result to no rainfall in such a location. This type of rainfall distribution patterns are majorly found at the desert areas and may be regarded as zero intensity rainfall. In such area, rainfall amount is zero, rainfall intensity is zero, period of rainfall is zero, seasonal distribution of rainfall is zero and frequency of rainfall is zero.

Low rainfall distribution pattern

This pattern of rainfall distribution occurs when rain droplets freed from the gravitation force binding them and descending the lower atmosphere to the surface of the earth encounter numerous obstacles either at the atmosphere or at the earth environment making them to drastically reduce in their size and intensity leading to low rainfall amount on the earth's surface. Low rainfall distribution pattern may be less than the rate of 1.0 - 2.5 mm/hour in diameter for a particular rainfall event in a specified area. Low rainfall distribution pattern may be characterized with non-extreme intensity (Naveau, Raphael, Pierre and Alexis, 2016). In this case, rain rate will be low, the intensity will be low, their potential and kinetic energies will be low and the duration of fall will increase. This type of rainfall distribution pattern is capable of penetrating the soil surface but cannot easily cause soil erosion and flooding.

Moderate rainfall distribution pattern

In this case, rainfall distribution pattern rate is within the range of 2.5-6.0 mm/hour for a particular geographical location. The modifications of rain droplet forming processes by radiation effects and other earth-atmospheric factors are relatively moderate and thus do not greatly alter the sizes of the droplets descending the surface of the Earth from the lower atmosphere. During the incident of moderate rainfall distribution pattern, rain droplets are clearly separated and can easily be viewed. The patterns in most cases always last for a long period of time and can accumulate into ponds and can easily flow through the gutters and water pathways. When lasted for a very long period can cause a moderate to heavy flooding and erosion.

Heavy rainfall distribution pattern

Rainfall distribution pattern here apparently falls in heavy sheets which are accompanied by hazy spray that can be visible over hard surfaces. Gutters, pathways and pipeline are mostly congested due to the gravity and the intensity of the down fall. The modifications of rain droplet forming processes by radiation effects, and other earth-atmospheric factors are invariably negligible and thus do not have a direct impacts on the sizes, gravity and intensity of the droplets descending the surface of the Earth from the lower atmosphere. Rainfall rate in this case is far greater than 6mm/hour. Heavy rainfall distribution pattern may possibly last for a few durations at most, but in most cases can generate hazardous flood that can invariably cause a lot of destruction to the natural environment. Obviously, some factors such as topography of the location in which the rain falls on, the amount of debris or sediments being moved by the water waves, as well as the vulnerability of the location to the pathway of the flood are most likely to affect the resultant effects of this type of rainfall.

As stated by Coles *et al.*, (2003); Embrechts *et al.*, (1997), employing basic univariate extreme value theory (EVT), the probability that large rainfall amounts distribution exceeding a well-chosen high threshold value u are larger than x can be approximated by a Generalized Pareto (GP) tail defined as:

$$GP = \overline{H}_{\xi}\left(\frac{x-u}{\sigma}\right) \quad (1)$$

where the survival function $\overline{H}_{\xi}$ is equivalent to

$$\overline{H}_{\xi}(x) = \begin{cases} (1+\xi)^{-1/\xi}, & \text{if } \xi \neq 0 \\ \exp(-x), & \text{if } \xi = 0 \end{cases} \quad (2)$$

If a_+ = max (a,0), then the scalar $\sigma > 0$ represents the scalar parameter. The shape ξ describes the Generalized Pareto tail behavior. Thus, when ξ assumes negative value, the upper tail assumes bounded form. If ξ is zero, that represents the exponential distribution, where all the existing moments are finite. If ξ is positive, the tail is unbounded but higher moments eventually become infinite. These three cases are termed short-tailed, light-tailed and heavy tailed respectively (Naveau, Raphael, Pierre and Alexis, 2016; *Katz et al.*, 2002). In this perspective, heavy rainfall distribution is perceived to have either exponential tail ($\xi = 0$) or heavy tails (($\xi > 0$).

MATERIALS AND METHODS

Study Area

The study was carried out at two separate areas - Enugu and Kano states. Enugu state is a state in the south eastern part of Nigeria, located at the foot of the Udi Plateau with the degrees, minutes, seconds (DMS) latitude of 6° 27' 35.8704" N and degrees, minutes, seconds (DMS) longitude of 7° 32' 56.2164" E respectively. The state share common boundary with Abia state and Imo state in the southern flank, Ebonyi state in the eastern flank, Benue state in the northeastern flank, Kogi state in the north western flank and Anambra state in the western flank. The climate in the state is tropical in nature and it is marked with two main weather conditions-the dry and the wet weather conditions. In the dry weather condition, there are more sunny days then rainy days while in the wet weather condition, there are more rainy days than sunny days. Average temperature at Enugu lies between 65°F and 85°F for rainy periods and dry periods respectively and it varies considerably at different parts of the state. If moisture content in the atmosphere remains constant while temperature increases, relative humidity will invariably decreases sorely due to the dependence of partial pressure of water on temperature increase (Lee 1998; Lin and Chen 2005; Kumar, 2006). The relative humidity at Enugu is quite higher in the dry weather conditions than in the wet weather conditions due to the heating of the intervening environment from solar radiation which causes rise in temperature and consequent increase in the rate of water vapour escaping into the atmosphere. Similarly, Enugu state is marked with a seasonal cloud cover changes with more significant sky coverage during the rainy weather conditions than during the dry weather conditions for a specific year.

Kano state is one of the states in the northern part of Nigeria. The state has common boundary with Bauchi state in the southeastern flank, Kaduna state in the southwestern flank, Jigawa state in the northeastern flank and Katsina state in the northwestern flank of the state. The climate in Kano state is Sahelian in nature and it is marked with two major weather conditions – dry and wet weather conditions. While the wet weather condition is characterized by rainy days, the dry weather condition is characterized by sunny days and dominates greater parts of the days within a given year. The state has the degrees, minutes and seconds (DMS) latitude of 12° 0' 0.0000" N and the degrees, minutes and seconds (DMS) longitude of 8° 31' 0.0012" E respectively. The average temperature at Kano state lies between 53°F and 102°F for minimum and maximum temperature in a given year and varies considerably at different parts of the state. Relative humidity in the state varies according to the weather condition and it is quite higher during dry weather conditions than wet weather conditions. In the same way, there is continuous variation in cloud cover at Kano state which is sorely dependent on the weather condition at a given instance within the year.

Data Source

The daily data of 2013 for Enugu and Kano used in this work is made up of satellite (Reanalysis-Interim) dataset that is comprised of rainfall recorded data and atmospheric parameters recorded data that were obtained from The European Centre for Medium-Range Weather Forecasting (ECMWF) and is jointly handled by National Center for Atmospheric Research data support division. This dataset is available for download on a daily and monthly temporal resolution at ECMWF public datasets web interface (http://apps.ecmwf.int/datasets/data/). The choice of the data source for the locations in this study is because of the availability of dataset for both rainfall and atmospheric parameters needed to carry out the work for the year of our interest.

Application Packages

Ferret-PMEL software, Panoply software, Excel spreadsheet package and Minitab 19 statistical software package were used for data extraction, conversion and analysis.

Data Extraction and Conversion

The daily dataset of all the parameters used for computation and analysis in this work were extracted from the selected locations in Nigeria for the time of our research. Meanwhile, since rainfall is a discontinuous parameter, thus, daily rainfall values used in our study oscillate between 0.1 and 120 mm. However, the numerical downscaling method of data extraction was employed using the Ferret-PMEL software on the Linux Operating system to download the datasets via http://apps.ecmwf.int/datasets/data/. The downloaded datasets were initially saved in NetcDF file format using the Panoply and the ferret software packages which were sourced from the National Aronautic and Space Administration Goddard Institute for Space Studies (NASAGISS) via https://www.giss.nasa.gov/tools/panoply/and the National Oceanic Atmospheric Administration (NOAA) via https://ferret.pmel.noaa.gov/Ferret/respectively. The dataset was thereafter converted into .txt format using Excel spreadsheet application package. In the process of data extraction, the available gridded point locations of the study area were established and then used as the available resources for which the atmospheric datasets were generated.

Modelling Technique

Regression modelling technique was used to investigate rainfall distribution patterns changes and their relationship with the atmospheric parameters for the year of study. The model is divided into simple and multiple linear regressions. Simple linear regression differs from multiple linear regressions because the former has only one predictor while the later has two or more predictors. Only simple linear regression was used in this work to investigate the association between one dependent variable and one independent variable by fitting the data set into a linear equation. Linear regression equation was employed to verify if there is any correlation between rainfall distribution and the atmospheric parameters in each of the locations.

For this model, the proposition applied was that for "each" or "all" of the atmospheric parameter(s), if the coefficient of the regression equation of their association with rainfall represents zero, it shows insignificant relationship between rainfall and the atmospheric parameter(s). But, if for "each" or "all" of the atmospheric parameter(s), the coefficient of the regression equation of their association with rainfall is not equal to zero, it indicates that there is a relationship between rainfall and the atmospheric parameters. In this case, a significance level of $\alpha = 0.05$ was chosen and stands for a 5% risk of concluding that an association exists when there is no actual of the parameters. Thus, if p-value obtained is less than or equal to the significance level (P-value $\leq \alpha$), then the association was regarded as being statistically significant and suggests a close relationship between rainfall and atmospheric parameters. Else, they are not statistically significant and suggest no close relationship.

In general a simple linear regression can be described with a linear regression equation given as:

$$y = \beta + \alpha x \quad (3)$$

where

y denotes the dependent variable (response)

x denotes the independent variables (predictors)

β denotes the intercept indicating the value of y when all the predictors are equal to zero

αdenotes the coefficients of predictors which reflect the contributions of each independent variable in predicting the dependent variable

However, two major terms; R-square (R^2) and R-square predicted (R^2 predicted**)** associated with simple linear regression analysis based on Cohen (1992) classification in conjunction with the p-value as well as the regression equation were employed for the interpretation of the results. Pareto chart of the standardized effect, normal probability and residual plots were equally employed for result interpretation.

RESULTS AND DISCUSSIONS

Tables 1 and 2 represent the simple linear regression equation of rainfall distribution patterns and their relationship with atmospheric parameters at Enugu and Kano states.

Fig. 1a-e and fig. 2a-e below, show the simple linear regression analysis of rainfall distribution patterns and their relationship with the atmospheric parameters at Enugu and Kano states in 2013.

Fig. 3 represents the Pareto chart of the standardized effect between rainfall and atmospheric parameters at Enugu state. Fig. 4 represents the normal probability plot at Enugu state. Fig. 5: Plot of residual against observation order at Enugu state

Fig. 6 represents the Pareto chart of the standardized effect between rainfall and atmospheric parameters at Kano state. Fig. 7 represents the normal probability plot at Kano state. Fig. 8 represents plot of residual against observation order at Kano state

Interpretation of Regression Analysis

Table 1: Linear regression equation of rainfall distribution patterns and their relationship with atmospheric parameters at Enugu

Atmospheric parameter	Simple linear regression equation
Temperature	Rainfall (mm) = 20.98 - 0.5326 Temp. (^{O}C)
Atm. Pressure	Rainfall (mm) = - 428.0 + 0.004370 Atm. Press (Pa)
Relative humidity	Rainfall (mm) = - 0.979 + 0.06709 RH (Percent)
Wind speed	Rainfall (mm) = 1.530 + 1.649 Wind speed (m/s)
Total cloud cover	Rainfall (mm) = 0.318 + 5.079 TCC (0-1)

Table 2: Linear regression equation of rainfall distribution patterns and their relationship with atmospheric parameters at Kano

Atmospheric parameter	Simple linear regression equation
Temperature	Rainfall (mm) = - 4.697 + 0.3182 Temp. (^{o}C)
Atm. Pressure	Rainfall (mm) = 770.3 - 0.007962 Atm. Press (Pa)
Wind speed	Rainfall (mm) = 11.21 - 2.152 Wind speed (m/s)
Relative humidity	Rainfall (mm) = 6.059 + 0.00180 RH (Percent)
Total cloud cover	Rainfall (mm) = 6.065 + 0.1982 TCC (0-1)

From tables 1 and 2, it was clearly observed that none of the values of coefficient of the associations between rainfall and atmospheric parameters at Enugu and Kano in 2013 is equal to zero and therefore suggest significant or close relationship between them. This obviously means that there is a certain significant relationship between rainfall distribution patterns and the atmospheric parameters at Enugu and Kano states for the period of study. Thus, the differences in rainfall distribution patterns that are most often witnessed at the study areas may be connected to the changes in the values of temperature and other atmospheric parameters used in this study. However, it was noticed that temperature has negative value of the regression equation coefficient while atm. pressure, and the rest of the atmospheric parameters used in the study have positive values of the regression equation coefficient in relation with rainfall distribution patterns in Enugu for the period of study. This means that, a unit rise in temperature at Enugu may result to a consequent decrease in mean value of rainfall distribution patterns while a unit rise in atm. pressure, relative humidity, wind speed and total cloud cover may lead to a resultant increase in the mean value of rainfall distribution patterns.

Similarly, in Kano, the value of the regression equation coefficient obtained for rainfall distribution patterns and their relationship with temperature, relative humidity and total cloud cover were positive while for atm. pressure and wind speed the values of the regression equation coefficients obtained were negative. This suggests that a unit increase in the values of temperature, relative humidity and total cloud cover in Kano, can invariably cause a consequent increase in rainfall distribution patterns while a unit increase in the values of atm. pressure and wind speed is capable of causing a consequent decrease in the amount of rainfall distribution patterns in the area.

From fig. 1a-e, it was observed that the values of significant level (α) for rainfall distribution patterns and their relationship with temperature, atm. pressure, wind speed, relative humidity and total cloud cover obtained are 0.000, 0.015, 0.000, 0.000 and 0.000 respectively. The values of R^2 and R^2 adjusted for rainfall distribution patterns and their relationship with temperature, pressure, wind speed, relative humidity and total cloud cover obtained at Enugu are 8.3 %, 1.6 %, 3.7 %, 3.3 %, 5.1 % and 8.0 %, 1.4 %, 3.4 %, 3.1 %, 4.9 % respectively.

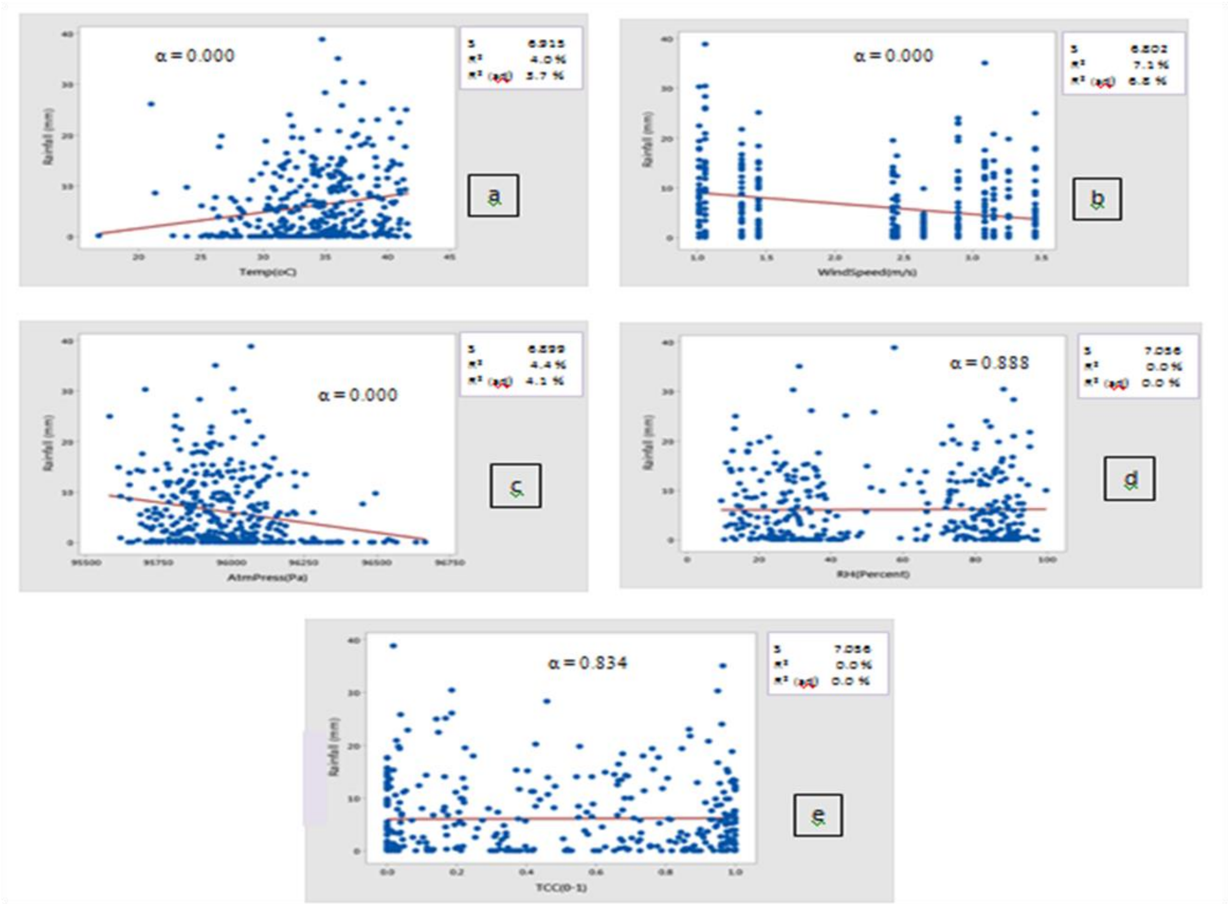

Figure 1: Linear regression analysis of rainfall distribution patterns and their relationship with (a) Temperature (T) (b) Wind speed (WS) (c) atm. pressure (P) (d) Relative humidity (RH) (e) Total cloud cover (TCC) at Enugu in 2013.

Supposedly, the significant level (α) of 0.000 < the proposed significant level (α) of 0.05 obtained for temperature, wind speed, relative humidity and total cloud cover respectively indicated strong correlation with rainfall distribution patterns in Enugu, unlike 0.015>0.05 significant level obtained for atm. pressure that indicates weak correlation. This suggests that temperature, wind speed, relative humidity and total cloud cover have greater effects on rainfall distribution patterns at Enugu than atm. pressure and therefore may be used as a yardstick for the monitoring or predicting of rainfall distribution patterns in the area. The results are further supported by the values of R^2 and R^2 (adj.) obtained which absolutely showed that temperature, wind speed, relative humidity and total cloud cover have greater percentage of the values of R^2 and R^2 (adj.) than atm. pressure. Thus, may offer better interpretations to rainfall distribution pattern changes in the area.

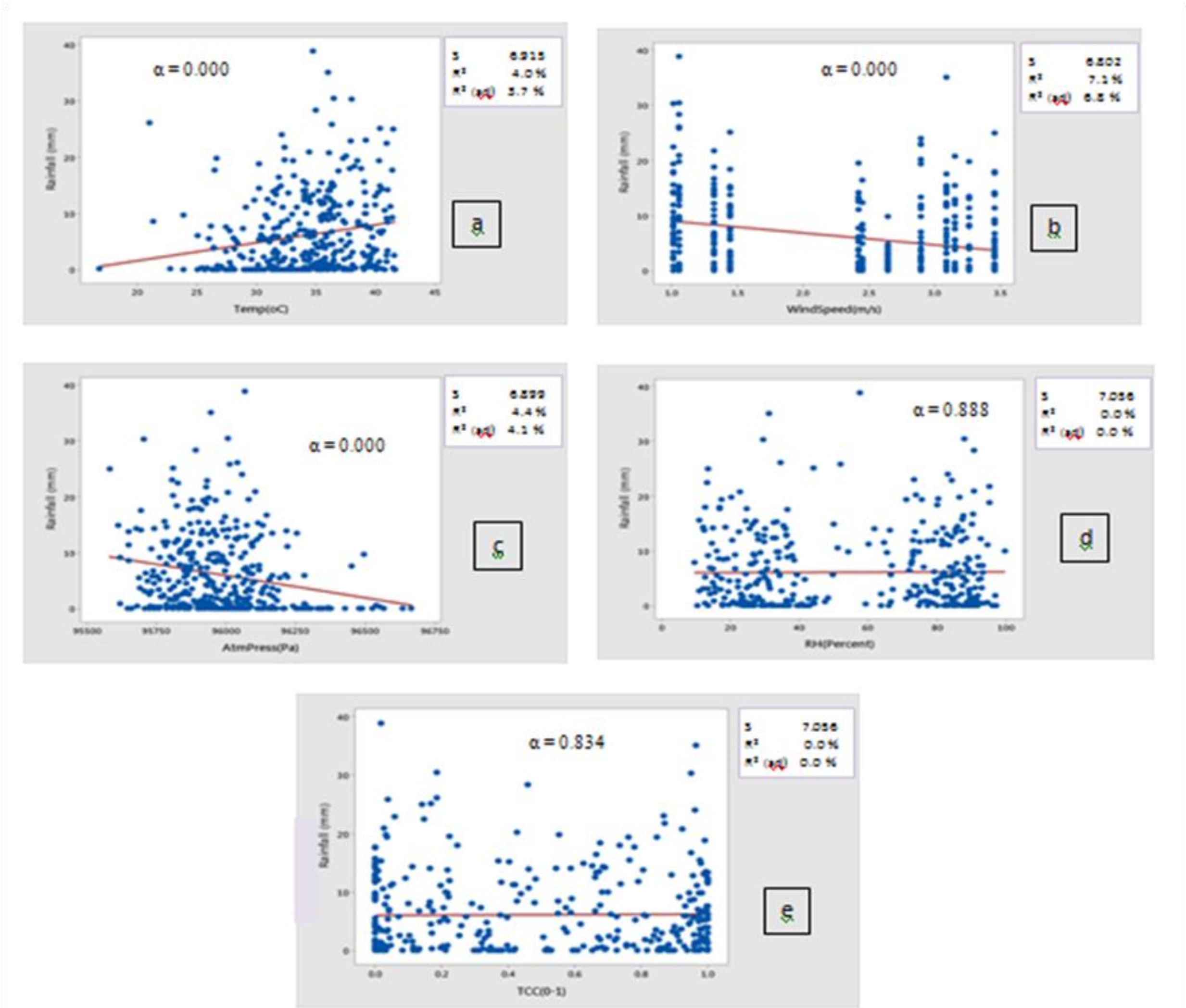

Figure 2: Linear regression analysis of rainfall distribution patterns and their relationship with (a) Temp. (T) (b) Wind speed (WS) (c) pressure (P) (d) Relative humidity (RH) (e) Total cloud cover (TCC) at Kano in 2013.

From fig. 2a-e, it was observed that the values of significant level (α) for rainfall distribution patterns and their relationship with temperature, pressure, wind speed, relative humidity and total cloud cover obtained were 0.000, 0.000, 0.000, 0.888 and 0.834 respectively. The values of R^2 and R^2 adjusted for rainfall distribution patterns and their relationship with temperature, pressure, wind speed, relative humidity and total cloud cover obtained were 4.0 %, 4.4 %, 7.1 %, 0.0 %, 0.0 %, and 3.7 %,, 4.1 %, 6.8 %, 0.0 %, 0.0 %, respectively at Kano. Evidently, the manifestation of the α values of temperature, atm. pressure and wind speed as 0.000 each which are less than the 0.05 significant level, is a good standing point which proved that atmospheric parameters (temperature, atm. pressure and wind speed) are significantly related to rainfall distribution patterns in Kano while the reverse is the case in terms of other atmospheric parameters (relative humidity and total cloud cover), which have α values of 0.888 and 0.834 respectively greater than the 0.05 significant level. Obviously, in this perspective, it suggests that temperature, atm. pressure and wind speed have more robust effect on rainfall distribution patterns at Kano than relative humidity and total cloud cover and therefore may be used as a measure in monitoring rainfall incidences within the area.

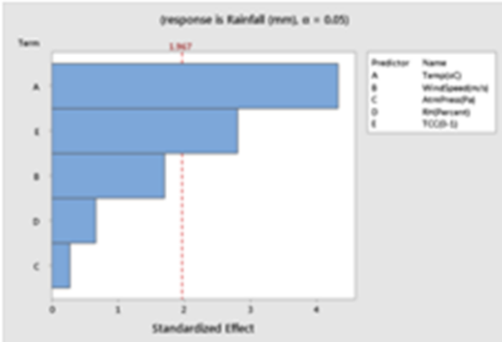

Figure 3: Pareto chart of the standardized effect at Enugu state

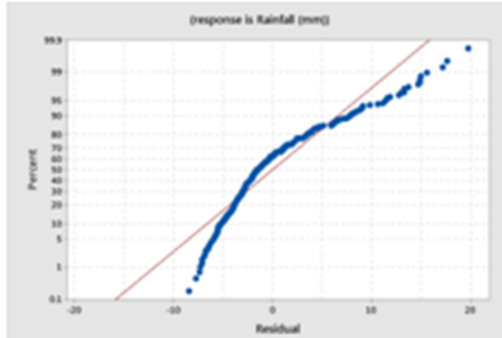

Figure 4: Normal probability plot at Enugu state

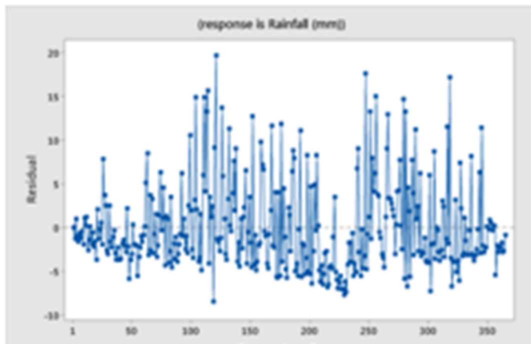

Figure 5: Plot of residual against observation order at Enugu State

Interpretation of Pareto Chart Standardized Effect, Normal Probability Plot and Residual Plot at Enugu and Kano

Pareto chart standardized effect

Fig. 3 and 6 showing the Pareto chart of the standardized effects at Enugu and Kano display the atmospheric parameters in this perspective that have the standardized effects beyond 95 % confidence level (i.e. beyond the line at 1.967). Following that, it is imperative to assert that temperature and total cloud cover are the most significant atmospheric parameters in relation with rainfall distribution patterns at Enugu (Fig. 3) for the period of study whereas wind speed and atmospheric pressure are the most significant atmospheric parameters in relation with rainfall distribution patterns at Kano (Fig. 6) for the period of study. Thus, in this contest, they are regarded as VITAL FEW atmospheric parameters that contribute up to 80% of the changes in rainfall distribution pattern in Enugu and Kano respectively. On the other hand, for the purpose of this study, wind speed, relative humidity and atmospheric pressure are the least significant atmospheric parameters in relation with rainfall distribution patterns in Enugu for the period of study while temperature, relative humidity and total cloud cover are the least significant atmospheric parameters in relation with rainfall distribution patterns in Kano. This implies that they contribute up to 20 % of the changes in rainfall distribution patterns in Enugu and they are termed USEFUL MANY (80/20 RULE).This may be connected to the difference in geographical location of Enugu and Kano states in the eastern and northern parts of Nigeria which are marked with two dissimilar weather conditions. The implication is that temperature and total cloud cover contribute greater percentage on rainfall distribution pattern changes in Enugu than wind speed, atmospheric pressure and relative humidity and should be given utmost preference in terms of hazard monitoring and control relating to rainfall distribution pattern changes within the area. In this regard, the moderate temperature experienced in the area may have necessitated evaporation of water vapour contained in the water holding surfaces in the area which may invariably increase the amount of cloud forming capacity in the atmosphere that may eventually being dislodged as rainfall inform of water droplets. This implies that increase in the rate of water vapour escaping on the surface of the Earth into the atmosphere sequel to rise in temperature may lead to consequent increase in cloud formation that may equally result to rainfall. Also from the figure, it is evidently seen that the descending order of the effects drifted from temperature as the highest to total atmospheric pressure as the lowest. On the other hand, wind speed and pressure have greater influence on rainfall distribution pattern changes than temperature, relative humidity and total cloud cover at Kano state. This may be connected to the location of Kano state within the Sahelian region dominated almost throughout the year with dry and hot air because of the intense solar radiation. Hence, since the environment is already being engulfed with dry and hot air (high temperature), increase in wind speed will consequently increase the pressure on the water containing surfaces which will ultimately hastens the escape of water vapour into the atmosphere to form cloud. Thus, wind speed and pressure are the main driving forces that have greatest contribution to rainfall distribution changes in the area.

Normal probability plot

In any given experimental study, the normality of an observed dataset can be compared by plotting normal probability of the residuals. This normal probability plot represents the graphical measure to check whether or not an observed datasets are approximately normally distributed (Pokhrel and Viraraghvan, 2006). If the points fall fairly close to the straight line on the plot the datasets are said to be normally distributed (Hasan *et al.*, 2009).

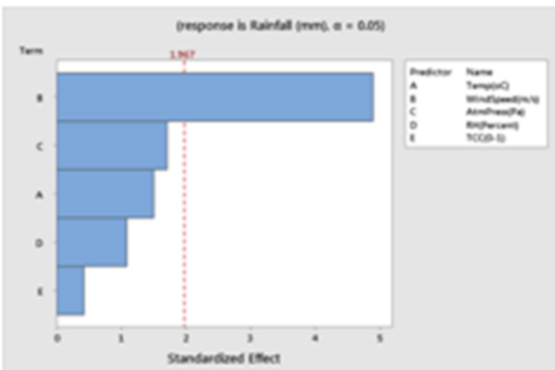

Figure 3: Pareto chart of the standardized effect at Kano

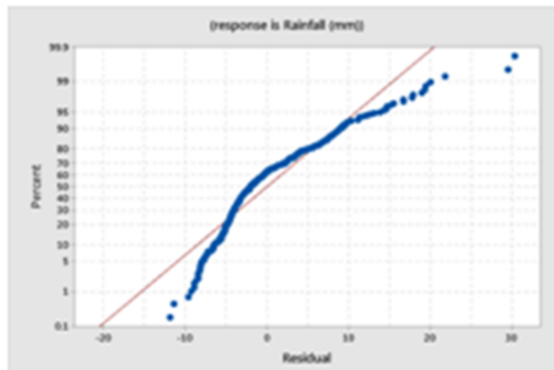

Figure 7: Normal probability plot at Kano

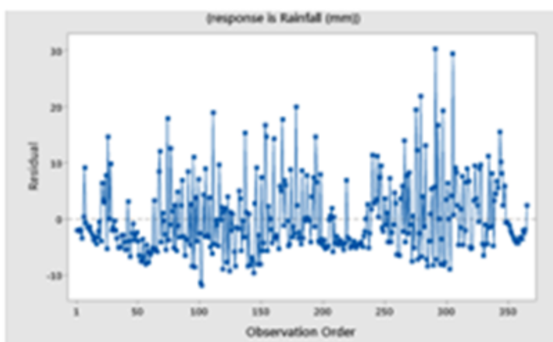

Figure 8: Plot of residual against observation order at Kano

Therefore, figs. 4 and 7 representing normal probability plots for Enugu and Kano showed that the data points on the plots were aligned fairly close to the straight line suggesting normality of the experimental datasets distribution for the two locations.

Residual Plot

The residual plot simply describes the difference between observed data and the predicted value from the regression analysis. In figs. 5 and 8, it is obvious that the residuals plots for Enugu and Kano, were normally distributed between –10 to +30 and –10 to +20 respectively with constant variance, mean zero and independently. This invariably shows the manifestation of variation in the contribution of the atmospheric parameters to rainfall distribution pattern changes due to the difference in geographical location of Enugu and Kano states.

CONCLUSION

In this study rainfall distribution pattern changes and their relationship with the atmospheric parameters (temperature, wind speed, relative humidity, atmospheric pressure and total cloud cover**)** was investigated in two different locations (Enugu and Kano states) in Nigeria. For each of the locations, the datasets were computed and compared using simple linear regression analysis. The results showed that there is evidence of close relationship between rainfall distribution pattern changes and atmospheric parameters in this study. Obviously, rainfall distribution pattern changes exhibited different model of interaction in the two locations with the atmospheric parameters. At Enugu, temperature has the greatest contribution to rainfall distribution pattern changes than other atmospheric parameters while at Kano, total cloud cover has the greatest manifestation to rainfall distribution pattern changes than other atmospheric parameters. This suggests that monitoring temperature, wind speed, relative humidity, atmospheric pressure and total cloud cover events can evidently help to determine rainfall distribution pattern changes for the two areas for the period of study which may be an anchor that will help to monitor rainfall related events for proper hazard control and management.

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DISCLOSURE OF CONFLICT OF INTEREST
The authors declare no conflict of interest.

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