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Effects of Variations in Meteorological Parameters of Atmospheric Pressure, Relative Humidity and Temperature on Radio Refractivity in Calabar

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Abstract: *Effects of variations in meteorological parameters of Atmospheric Pressure, Relative Humidity and Temperature on radio refractivity in Calabar have been investigated. The data on Temperature, Relative Humidity and Atmospheric Pressure obtained from the Nigeria Metrological Agency (NIMET) was analysed for twelve months in year 2016. The relationships between the given meteorological parameters are easily obtained from plots of refractivity N against P, H and $\frac{1}{T}$ as independent variables. Statistical correlation of the calculated refractivity values and all three meteorological parameters was done, which yielded 0.71 as correlation coefficient for Refractivity and Relative Humidity, -0.16 for Refractivity and Atmospheric Pressure, and -0.17 for Refractivity and Temperature with the relevant plots, these clearly shows that of all the three met. parameters, Relative Humidity contributes most to variation in Refractivity.*

Keywords: *Atmospheric Pressure, Relative Humidity, Temperature, Radio Refractivity, Atmosphere, Troposphere*

I. Introduction

The troposphere is the lower region of the Atmosphere and it extends from the earth's surface to an altitude of about 6 km at the poles and up to 18 km at the equator. The basic parameters that describe the
tropospheric medium are atmospheric pressure, temperature and relative humidity. All propagating radio waves are affected by these physical properties of the atmosphere; they can be reflected, refracted, scattered, and absorbed by different atmospheric constituents (Ali *et al.*, 2012).A measure of the extent to which a medium will deviate a radio wave entering its surface is referred to as its refractivity. This is greatly affected by fluctuations in these atmospheric parameters, essentially at the troposphere. It is important to know that the effects of varying conditions in radio propagation have many practical applications such as frequencies selection for international shortwave broadcasting, designing of reliable mobile telephone systems, radio navigation, and operation of radar systems.

Calabar, located on Latitude 4º57'06"N and longitude 8º19'19"E at an elevation of 42m above sea level in the southern region of Nigeria, experiences a rare type of climate called the tropical monsoon. It experiences precipitations almost throughout the whole year except in the core months of the short dry seasons (Edet *et al., 2017).*

II. THEORY OF REFRACTIVITY

A useful variable for modeling the variation of refractive index in the atmosphere is its refractivity, N which is defined as (Agbo *et al*, 2013):

$$N = (n - 1) \times 10^6 \tag{1}$$

where n is the refractive index of the atmosphere.

Refractivity and the meteorological parameters of atmospheric pressure, temperature, vapor pressure are related by:

$$N = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) = 77.6\frac{P}{T} + \left(3.732 \times 10^5 \frac{e}{T^2}\right) \tag{2}$$

where;

P: Atmospheric Pressure(hPa)

e: Water vapour pressure(hPa)
T: Absolute temperature(K)
Refractivity of the lower atmosphere (troposphere) is divided into two components of the dry and the wet. The dry term contributes a greater percentage, about 70% to the total value of the refractivity in the atmosphere. The dry term is proportional to the density of the gas molecules in the atmosphere and changes with their distribution. The dry term of refractivity, which is fairly stable, can be modeled with an accuracy of about 20% using surface measurements of pressure, P (hpa) and temperature, T (Kelvin) according to:

$$N_{dry} = 77.6\frac{P}{T} \quad (3)$$

Conversely, the wet term contributes the major variation of refractivity in the atmosphere. The Wet term is due to the polar nature of the water molecules and is given by:

$$N_{wet} = 3.732 \times 10^5 \frac{e}{T^2} \quad (4)$$

III. METHODOLOGY

The data on Temperature, Relative Humidity and Atmospheric Pressure obtained from the Nigeria Metrological Agency(NIMET) is analysed for twelve months in year 2016.The temperature averages are obtained from averaging the average daily temperatures, according to(Edet *et al.,*2017);

$$T_{avg} = \frac{T_{min}+T_{max}}{2} \quad (5)$$

T_{avg} = Average daily temperature in degree celcius
T_{min} = Minimum daily temperature in degree celcius.
T_{max} = Maximum daily temperature in degree celcius.

The daily variations in the metrological parameters are evaluated, starting from the partial pressure of water (e) in air

$$e = \frac{e_{sH}}{100} , \quad (6)$$

where
H: Relative Humidity
e_s : saturated vapour pressure; e_s is calculated using Clausius-clapeyron relation :

$$e_s = 6.11\, exp\left(\frac{17.26(T-273.16)}{T-35.87}\right) \quad (7)$$

T: Temperature in Kelvin.
The radio refractivity for each day within the month is then calculated using equation (2).
Transformation of equation (2) yields, with H given by equation (6).

$$N = (\,3.732 \times 10^5)\frac{e_s H}{100T^2} + \frac{77.6}{T}P \quad (8)$$

The relationship between the given meteorological parameters are easily obtained from plots of refractivity N against P,H and $\frac{1}{T}$ as independent variables.
Statistical correlation was performed on the calculated refractivity and all three meteorological parameters using equation;

$$Correl(x, y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} , \quad (9)$$

which gives us the best fits for the plotted values.

IV. RESULTS

The correlation coefficient is found to be 0.71 for Refractivity and Relative Humidity, -0.16 for Refractivity and Atmospheric Pressure, and -0.17 for Refractivity and Temperature. The plots of refractivity against the given met. parameters are shown in Fig's. 1, 2 and 3 .the expected scatter of refractivity values in the respective cases is evident. This is what necessitated the correlation approach that yielded the best fits indicated in each of the graphs.

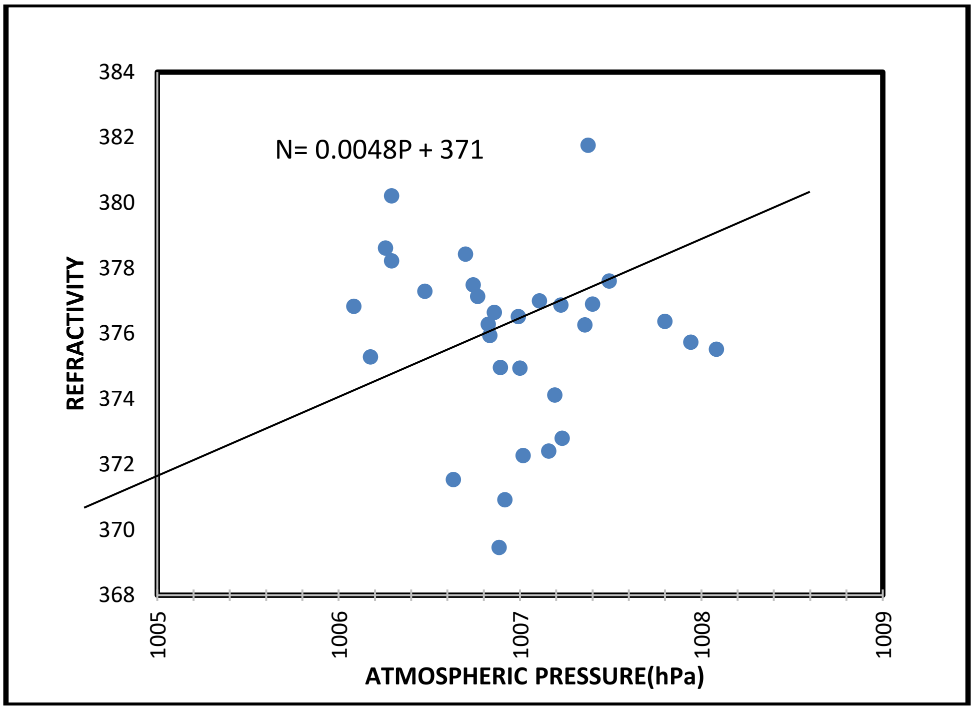

Figure 1; Refractivity Vs Atmospheric Pressure(1hPa=100Pa)

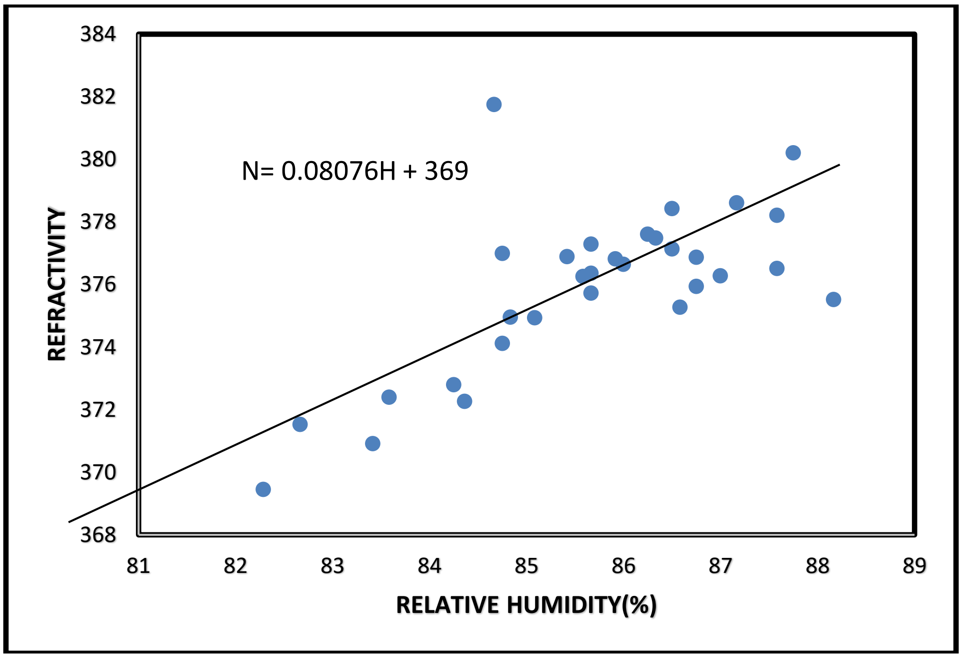

Figure 2; Refractivity Vs Relative Humidity (%)

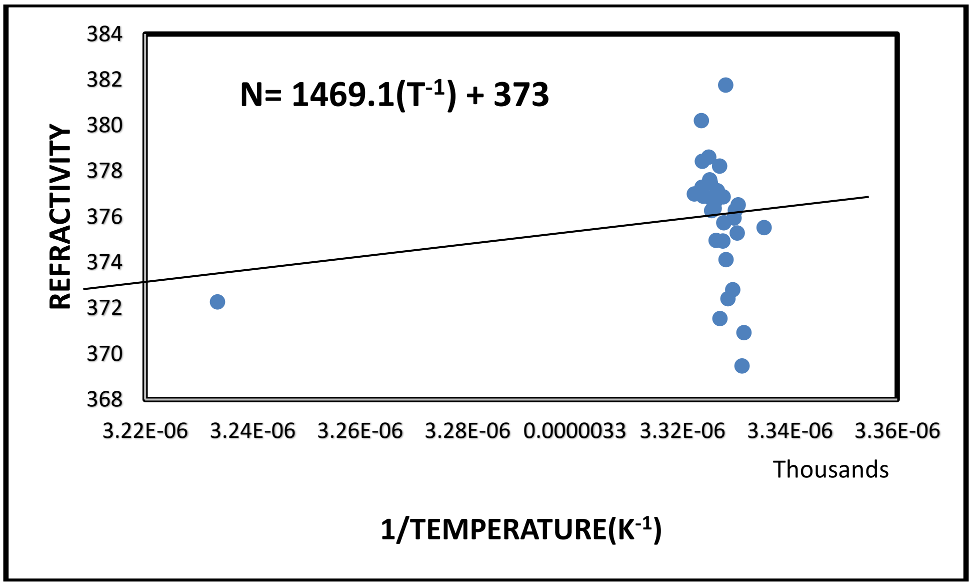

Figure 3; Refractivity Vs $\left(\frac{1}{Temperature}\right)(K^{-1})$

V. DISCUSSIONS

Fig.1 clearly shows a positive correlation which here confirms a linear relationship between refractivity in Calabar and Atmospheric Pressure during the period under investigation. The second graph also shows a linear relationship but with a negative statistical correlation. On the other hand, Fig.3 does not indicate any direct dependence of refractivity on temperature. Equation (8) already indicates an inverse relationship

The value of the refractivity N indicated at $\frac{1}{T} = 0.00323$ or T= 36^{0}C can be ignored as this temperature hardly obtains in Calabar. The value of N cluster between $\frac{1}{T}$= 0.00332 and 0.00334 which translates to the temperature range of about 28^{0}C and 26^{0}C. This is the normal temperature range in Calabar throughout the year.

VI. CONCLUSION

Our conclusion here is that the radio refractivity in Calabar is more affected by relative humidity than by the other two parameters . And humidity is a function of water vapour content of the atmosphere as clearly indicated in equation (6).

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