SEASONAL VARIATION OF SURFACE REFRACTIVITY AND ITS DISTINCT COMPONENTS IN ILORIN, KWARA STATE, NIGERIA.

[1]Otto, M. S., [1]Abimbola, O. J., [1]Sanderson, E., [1]Bello, A. A., [2]Falaiye, O. A. and [3]Abe, A. O.
* [1]Department of Physics, Federal University of Lafia,
[2]Department of Physics, University of Ilorin, Nigeria
[3]Physics Department, Federal University of Kashere, Gombe.
Correspondence: o.muhammed@science.fulafia.edu.ng +2348037928630.

ABSTRACT

This work investigated both wet and dry component of seasonal variations in the tropospheric surface refractivity of Ilorin, Kwara State, Nigeria in order to understand the tropospheric propagation of radio-waves based on its weather parameters. Utilizing the meteorological data acquired from the Nigerian Meteorological Agency, Ilorin, the seasonal surface refractivity for both dry (November to March) and rainy (April to October) seasons for the years 2000 to 2002 were calculated via averaging the seasonal values i.e., dry (November to March) and rainy (April to October) of relative humidity, temperature and pressure individually then inputting into the refractivity formula. The result shows the comparison between the 3years span that the maximum surface refractivity (126.85 N-units, 190.50 N-units and 135.24 N-units) respectively during the rainy season (that is, April to October) as compared to the maximum surface refractivity (126.22 N-units, 116.49 N-units and 118.77 N-units) respectively during the dry season (that is, November to March) therefore showing a variation between tropospheric surface refractivity in rainy season (April-October), which is higher than in dry season (November-March) mainly due to enormous water content in the atmosphere (troposphere) during the month of April to October. Also, both the dry component (N_{dry}) and wet component of surface refractivity (N_{wet}) for the months of April to October are more than that of of November to March due to high moisture content for the stipulated 3 years period and thereby the wet component (N_{wet}) of the surface refractivity has higher values in both seasons than the dry component (N_{dry}) of the surface refractivity.

Keywords: Atmosphere, Troposphere, Atmospheric parameters, Refractivity, Propagation.

INTRODUCTION

The ratio of the propagation speed of radio energy in a vacuum to the speed in a specified medium is known as radio refractive index, *n* (Hughes, 1998). In the troposphere, the changes in the refractive index of air are used to determine the propagation of radio-wave and there is difficulty to study the variation of refractive index of the atmosphere because it is so small and close to unity (Bean *et al*., 1959). When the variation of refractive index in the atmosphere was modeled, a more convenient variable to use is the refractivity (Thayer, 1974). Refractivity *N* is a dimensionless quantity which as the measure of deviation of refractive index, *n* of air from unity which is scaled-up in parts per million to obtain more amenable figures and measured in N-units (Freeman, 2007)

$$N = (n - 1) \times 10^6 \qquad (1)$$

The surface refractivity *N* of the atmosphere depends on meteorological parameters' variation (atmospheric pressure, water vapour pressure, air temperature and relative humidity) which depend on the height at a point above the ground surface and also seasonal changes (Bean, 1966). Since pressure, temperature and relative humidity exponentially decrease with altitude therefore, the value of *N* varies with altitude resulting to a significant influence on radio waves propagation because radio signals can be refracted over whole signal path (Priestley *et al*., 1985).

Meteorological parameters and Refractivity are related by (Willoughby *et al*., 2002):

$$N = \frac{77.6}{T}\left(P + 4.810\frac{e}{T}\right) = 77.6\frac{P}{T} + \left(3.732 \times 10^5 \frac{e}{T^2}\right) \qquad (2)$$

Refractivity of the troposphere (lower atmosphere) is divided into dry and wet compositions. In the atmosphere, the dry term is proportional to the gas molecules' density and varies with their distribution gives rise to a greater percentage i.e., 70% to the total value of the atmospheric refractivity (Bean *et al*., 1959). The dry term of refractivity can be modeled with accuracy about 20% even if it is fairly stable using surface measurements of temperature, *T*(*K*) and pressure, *P*(*hpa*) respectively (Agbo *et al*., 2013):

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

Conversely, the polar nature of the water molecules makes the wet term responsible for the major variation of refractivity in the atmosphere and is given by (Agbo *et al*., 2013):

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

Saturated vapor pressure, e_s and water vapor pressure, *e* can be computed with the equations below (Ukhurebor *et al*., 2017).

$$x = \frac{17.2694(T-273.15)}{T-35.85} \quad (5)$$

$$e_s = 6.11 \times \exp(x)(\text{mbars}) \quad (6)$$

$$e = \frac{RH}{100} e_s \quad (7)$$

where e_s is saturated vapor pressure in *millibars*, *e* is partial pressure of water vapor in *millibars*, *T* is absolute temperature in *Kelvin*, *P* is barometric pressure in *millibars*. Also, the rains and clouds have a greater influence on the radio waves propagation from point to point in the lower atmosphere precisely (Hall, 1979). These variables differ hourly, daily, daily hourly quartile and seasonally in the tropics, in order to construct a radio communication (terrestrial and satellite) system. Extensive contributions have been made towards the evolution of refractivity. Igwe *et al*., in 2009 made use of the University of Ilorin Atmospheric observatory to obtain data from the radiometric network of the Baseline Surface Radiation Network (BSRN) to compute the variations of radio refractive index monthly near the ground surface for five years (2000 – 2004) period over Ilorin (Igwe *et al*., 2009). Ali *et al*., in 2011 worked on variation of radio refractivity seasonally at 10 *km* atmospheric layer above ground over Minna (9° 37''N, 6° 30''E) and their result showed that the values of refractive index gradients computed for the atmosphere over Minna was super-refractive during the wet season and sub-refractive during the dry season of the year (Ali *et al*., 2011). The effect of diurnal variations in meteorological parameters on the tropospheric radio refractivity during dry and rainy seasons over Minna in 2008 was investigated and the result showed that the variations in meteorological parameters such as humidity and temperature in the lower troposphere was observed to cause the radio refractivity to vary at different times of the day and be more significant during the rainy season than the dry season (Okoro *et al*., 2012).

The radio refractivity from measurements of atmospheric parameters made in Akure, Nigeria (2007-2011) via weather stations (Davies 6162 wireless vantage Pro2 specs) at different altitude was analysed and discovered that at all levels, the most significant influence on radio refractivity is the water vapour pressure than any other parameters (Adediji *et al*., 2013).

For the disturbed and quiet days of the atmospheric refractivity at Abuja during (dry and rainy) seasons which were evaluated and deduced that the both disturbed and quiet days of refractivity variation during dry and rainy season over Abuja are governed by the changes of weather variables (Agbo *et al*., 2013).

Therefore, this work is aimed at investigating the seasonal surface refractivity variation of Ilorin, Kwara state, Nigeria and to determine the wet component N_{wet} and dry component N_{dry} of the surface refractivity for a period of 3years (2000 – 2002).

STUDY AREA

the research location of this work is Ilorin (longitude 4.542 *°E*, latitude 8.497 *°N* and altitude 303 *m*), the capital city of Kwara State of Nigeria with a population of about 777,667. It is classified as *Aw* on a Köppen climate classification and is located within a tropical savannah climate. The average climatic data for Ilorin is: temperature (32.5 *°C*), total annual rainfall (1,185 *mm*), average rainy days (88 *days*), and average relative humidity (51.1 %). The weather of Ilorin and its environ is divided into two, that is, the dry season which spans the months of November to March and the wet/rainy season which spans the months of April to October. Figure 1, shows the geographic location of Ilorin on the Nigeria map. The data used in this study were recorded in a period of three years, and provided by the Nigerian Meteorological Agency, (NIMET). The station uses dry bulb thermometer to measure temperature, barometer to measure atmospheric pressure and hygrometer to measure relative humidity.

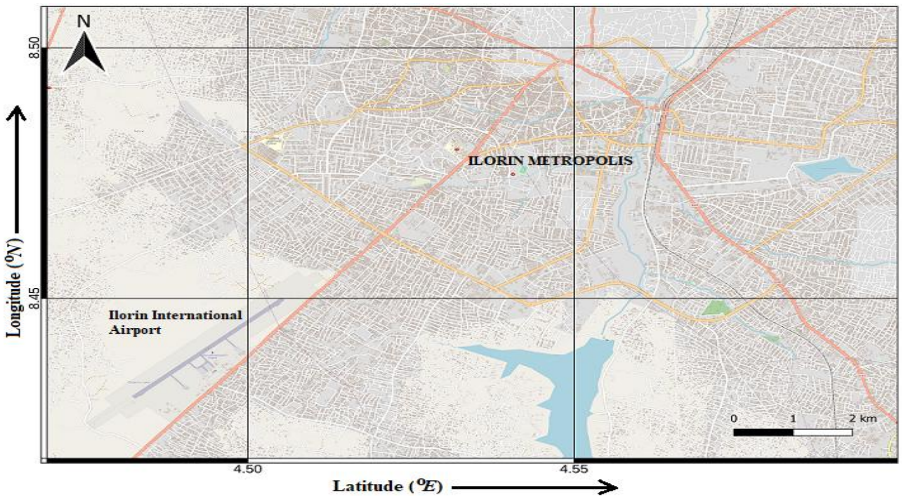

Figure 1: The Map of Ilorin showing the Ilorin Metropolis and Ilorin International Airport which is the location of NiMET station where data was collected.

METHODOLOGY

Weather data (pressure, temperature and relative humidity) from January 2000 to December 2002 were extracted from Nigeria Meteorological Agency (NiMET), Ilorin. All computations, Tables and graphs were executed with Microsoft Excel. The seasonal values of each of the meteorological parameters and the surface refractivity computation for three years (2000-2002) over Ilorin was done via the seasonal values of relative humidity, temperature and pressure respectively. In order to allow comparison between the variations (diurnal and seasonal) of surface refractivity, the graphs were plotted.

Determination of seasonal values of each of the Meteorological parameters:

The data of metrological parameters for four (4) consecutive months (November-February) for dry season and (June-September) for the raining season of each year were averaged to seasonally estimate the variation of the 3 meteorological parameters for the period under study.

Evaluation of seasonal surface refractivity N_s:

The average values of the meteorological parameters were then used to analyze the seasonal surface refractivity, dry term of

RESULTS AND DISCUSSION

The results presented here show the variation plot of surface refractivity seasonally for 3years (2000-2002) using the meteorological data in Ilorin analysed via Microsoft excel package.

The result shows that surface refractivity is higher in rainy season than in dry season as shown in Fig.2. In rainy season, the seasonal surface refractivity and wet term of seasonal surface refractivity using equations 2, 3, and 4 respectively.

minimum and maximum refractivity are 112.34 N-units and 126.85 N-units respectively while, in dry season are 78.69 N-units and 126.22 N-units respectively. The outcome of high values is as a result of the increased relative humidity in rainy season than in dry season in the atmosphere.

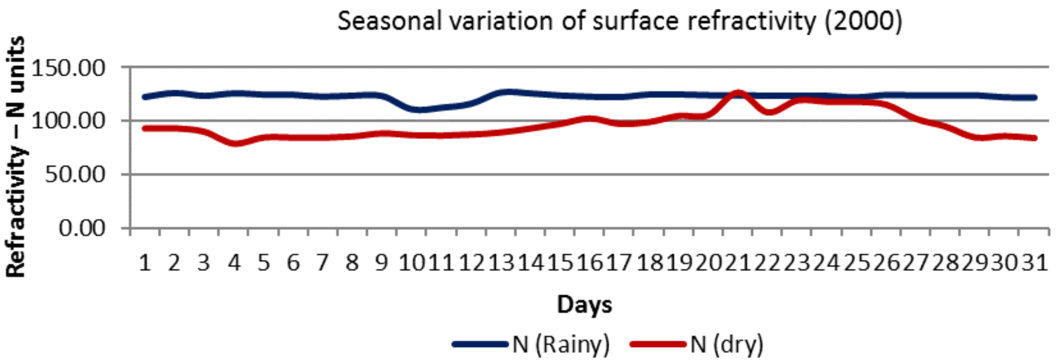

Figure 2: Surface refractivity plot for both dry & rainy season 2000.

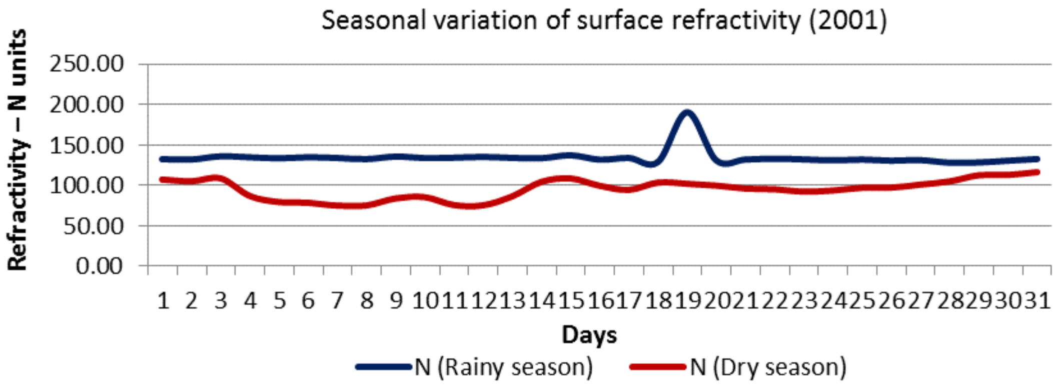

Figure 3: Surface refractivity plot for both dry & rainy season 2001.

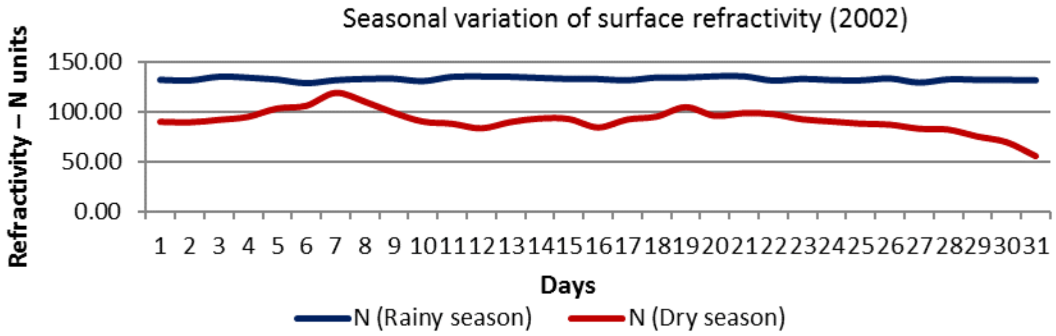

Figure 4: Surface refractivity plot for both dry & rainy season 2002.

In Figure 3, the result indicates that surface refractivity has high value in rainy season than in dry season as shown. In rainy season, the minimum and maximum refractivity are 127.84 N-units and 190.50 N-units respectively while, in dry season are 75.16 N-units and 116.49 N-units respectively. The result shows that higher surface refractivity in the rainy season compared to the dry season due to the high values in water content in the atmosphere as shown in Fig.4. In rainy season, the minimum and maximum refractivity are 128.56 N-units and 135.24 N-units respectively while, in dry season are 55.83 N-units and 118.77 N-units respectively. The plot in figure 2–4, shows that the surface refractivity from an averaged 4months period (November-February) is the dry season while (June-September) is the rainy season further proving that temperature is inversely related to relative humidity. Furthermore, the comparison between the 3years span shows the year 2001 has a very high surface refractivity (190.50 N-units) during the rainy season as compared to year 2002 (135.24 N-units) and year 2000 has the least surface refractivity (126.85 N-units) while during the dry season, year 2000 (126.22 N-units) has the highest surface refractivity followed by year 2002 (118.77 N-units) and year 2001 (116.49 N-units) with the least surface refractivity deducing the varying amount of water contents (moisture) in the atmosphere during those seasons.

The calculated atmospheric surface refractivity values in year 2000 (January - December) ranging from 96.11 N-units to 122.62 N-units with an average value of 109.37 N-units. In terms of the pattern in which the surface refractivity varies, these calculated results are in agreement with results in (Falodun, 2006), (Adediji, 2013) and (Ukhurebor *et al*., 2018) but in terms of average values of surface refractivity, its result differs i.e., 369 N-units in Akure, Ondo State (Falodun, 2006), 366 N-units in Akure, Ondo State (Adediji, 2013) and 354.31 N-units in Auchi, Edo State (Ukhurebor *et al*., 2018).

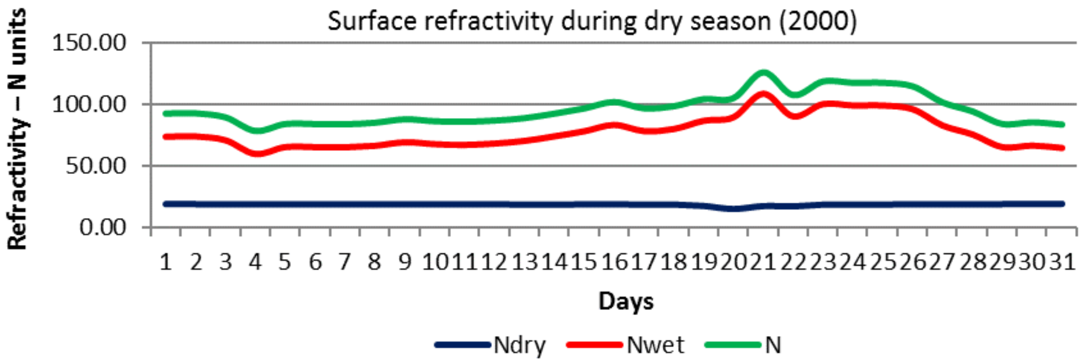

Figure 5: Surface refractivity plot for dry season 2000.

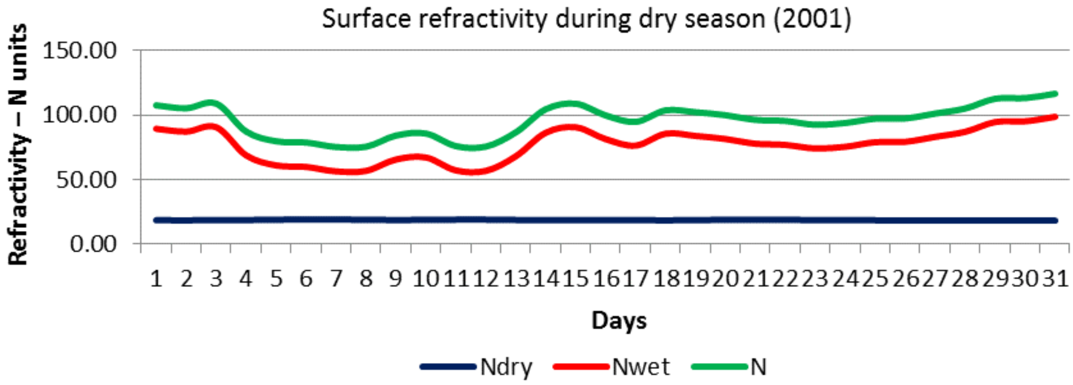

Figure 6: Surface refractivity plot for dry season 2001.

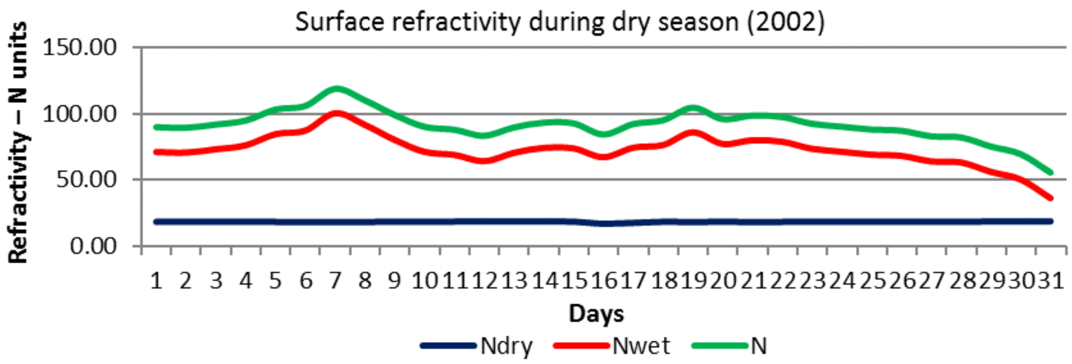

Figure 7: Surface refractivity plot for dry season 2002.

Fig. 5 – 7 shows that wet term N_{wet} contributes more to the surface refractivity N than the dry term N_{dry} due to the specific meteorological parameter (relative humidity). Also, the values of the dry term N_{dry} is approximately below 20 N-units for Fig. 5 – 10 which indicates low contribution to the Surface refractivity N compared to the values of wet term N_{wet} above 100 N-units approximately.

This is in accordance with Fig. 5 – 10 affirmed that the surface refractivity for seasons (both dry and rainy) varies with change in the amount of air's water content (i.e. relative humidity) as compared to its variation to other parameters used in the computation of both the N_{dry} and N_{wet} which shows in all the graph that N_{dry} is relatively constant in respect to time diurnally i.e. the values of N_{dry} are too close per day while N_{wet}

continuously varies in respect to time diurnally i.e. the values of N_{wet} are far apart per day. The result reaffirms to the fact that there is significant influence of air temperature on other weather variable like relative humidity and in agreement with (Ukhurebor, 2017).

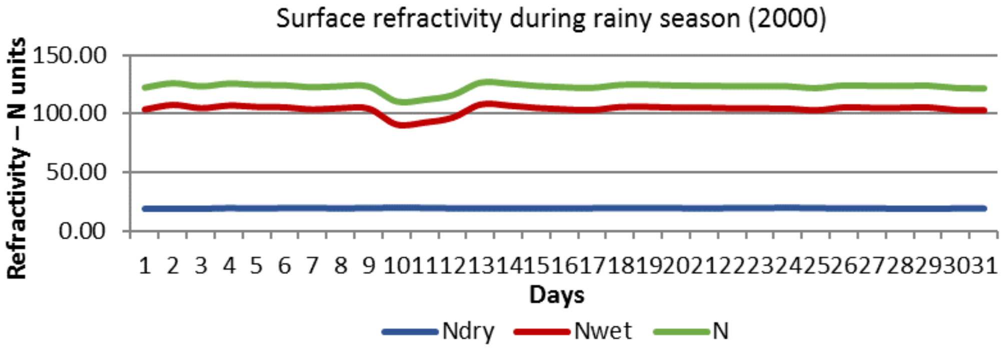

Figure 8: Surface refractivity plot for rainy season 2000.

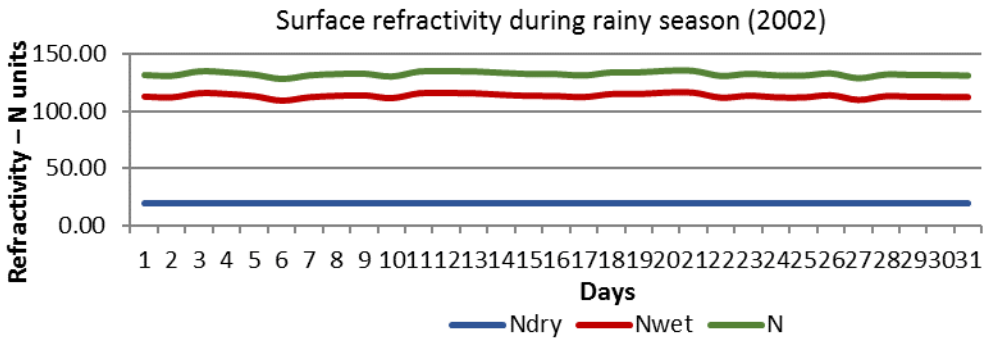

Figure 9: Surface refractivity plot for rainy season 2001.

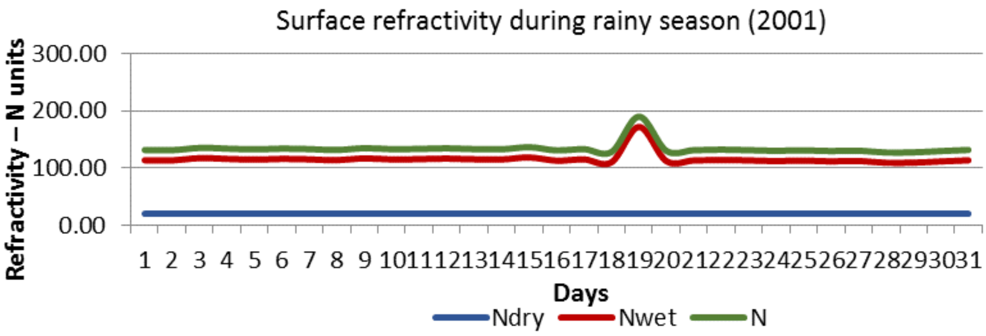

Figure 10: Surface refractivity plot for rainy season 2002.

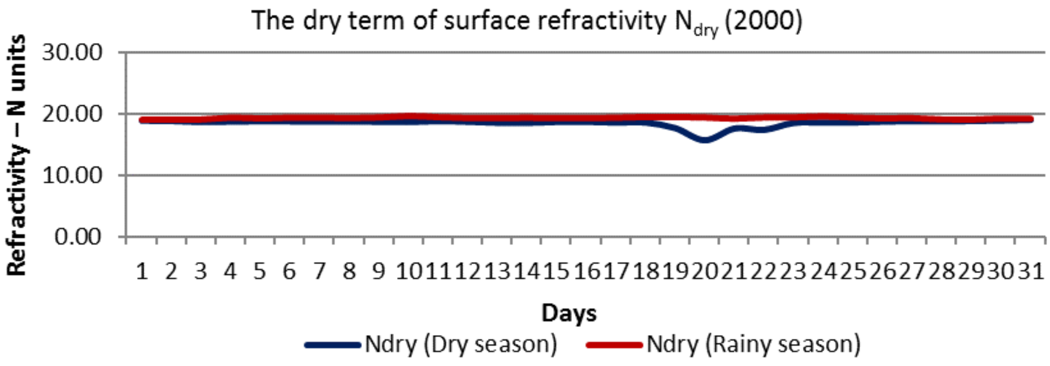

Figure 11: Dry component N_{dry} of surface refractivity plot for dry & rainy season 2000.

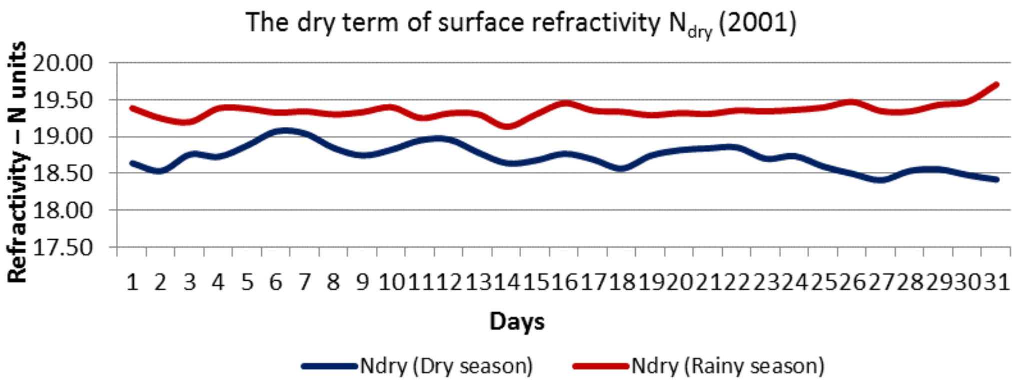

Figure 12: Dry component N_{dry} of surface refractivity plot for dry & rainy season 2001.

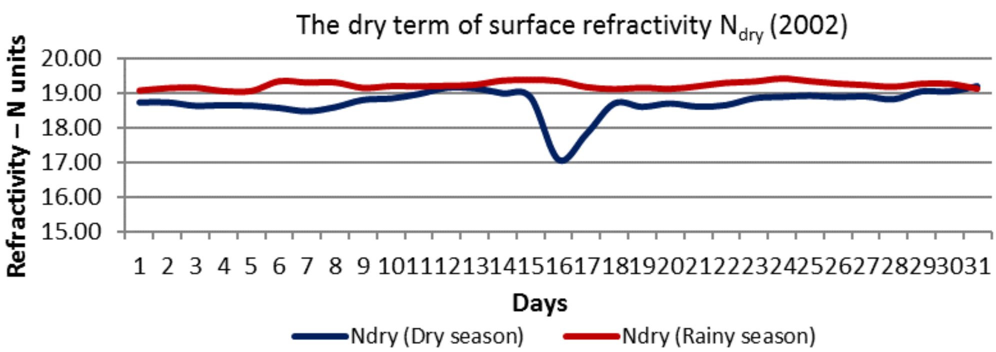

Figure 13: Dry component N_{dry} of surface refractivity plot for dry & rainy season 2002.

Figures 11 - 13 reaffirm the variation within the dry term of surface refractivity, N_{dry} for the (dry and rainy) season, which deduces that the rainy season N_{dry} exceeds that of the dry season within the stipulated 3 years period.

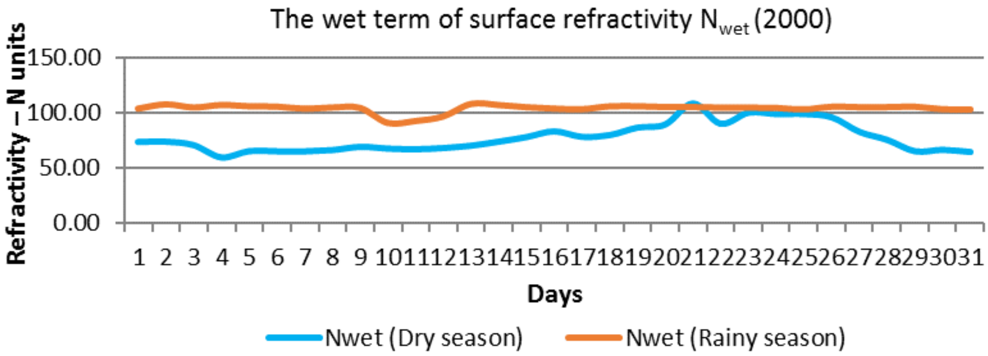

Figure 14: Wet component N_{wet} of surface refractivity plot for dry & rainy season 2000.

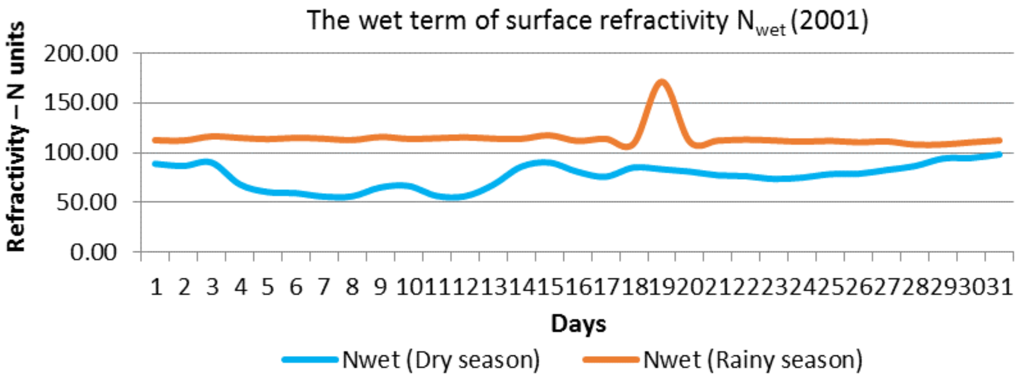

Figure 15: Wet component N_{wet} of surface refractivity plot for dry & rainy season 2001.

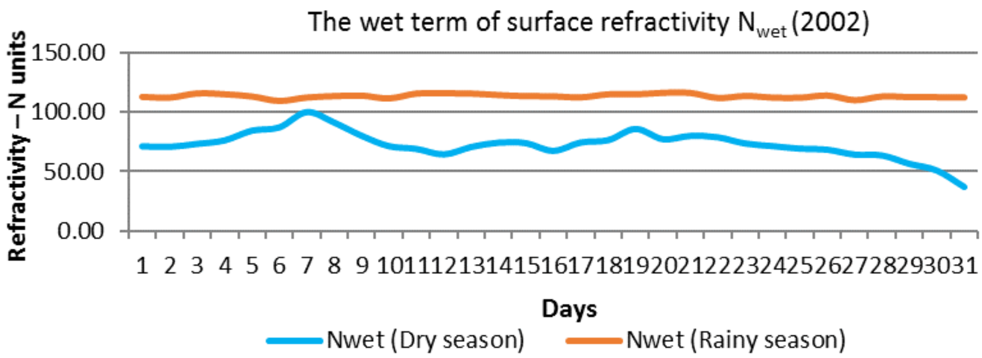

Figure 16: Wet component N_{wet} of surface refractivity plot for dry & rainy season 2002.

The variation within the wet component of surface refractivity, N_{wet}, for both the dry and rainy seasons is reaffirmed in Figures 14 - 16, implying that the N_{wet} for the rainy season exceeds the dry season during the stipulated three-year period due to high moisture content. Figures 17 and 18 reaffirm the variation within the wet component of surface refractivity, N_{wet}, for both the dry and rainy seasons over a three-year period, demonstrating that the N_{wet} for the dry season fluctuates more than the rainy season, which fluctuates less due to the varying moisture content in the dry season versus a fairly uniform/constant moisture content in the rainy season.

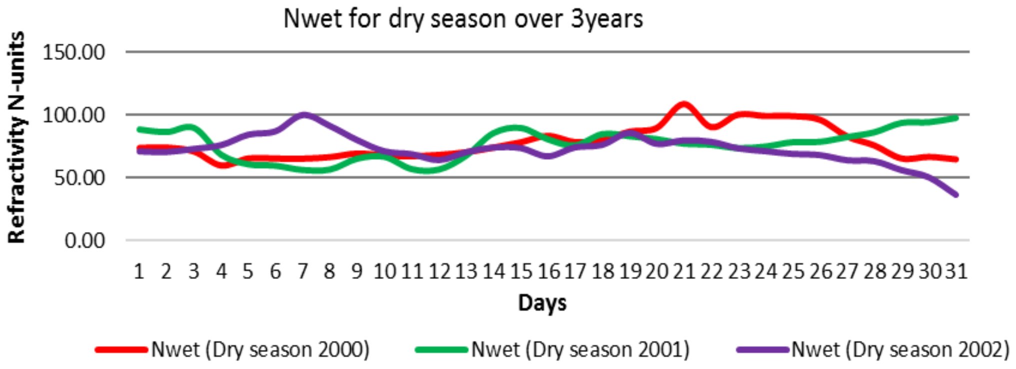

Figure 17: Wet component N_{wet} of surface refractivity for dry season over 3years (2000-2002).

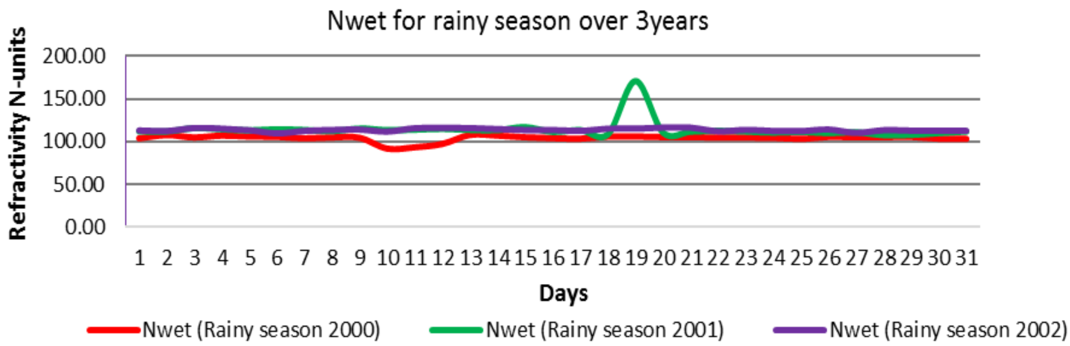

Figure 18: Wet component N_{wet} of surface refractivity for rainy season over 3 years (2000-2002).

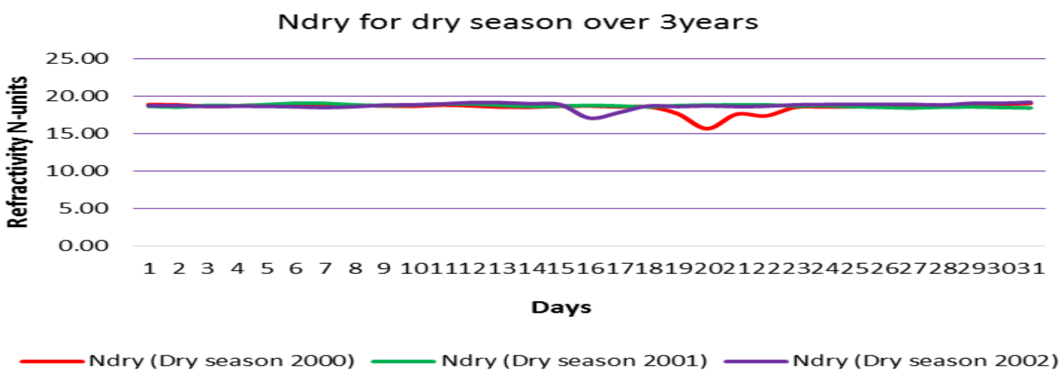

Figure 19: Dry component N_{dry} of surface refractivity for dry season over 3years (2000-2002).

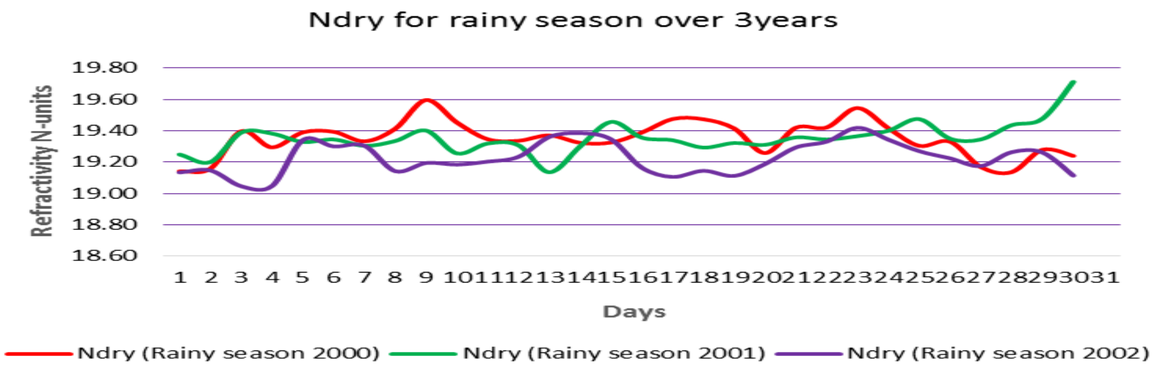

Figure 20: Dry component N_{dry} of surface refractivity for rainy season over 3 years (2000-2002).

The variation within the dry term of surface refractivity, N_{dry}, for both the dry and rainy seasons during the stipulated 3-*year* period is confirmed by Figures 19 - 20, indicating that the rainy season N_{dry} fluctuates more than the dry season, whose fluctuation is fairly minimal due to the varying temperature in the rainy season versus a fairly uniform/constant temperature in the dry season.

Finally, Figures 17 - 20 show that the wet term of surface refractivity, N_{wet}, for both the dry and rainy seasons during the stipulated 3-*year* period is influenced by both moisture content (relative humidity) and temperature but not atmospheric pressure, whereas the dry term of surface refractivity, N_{dry}, is influenced by both atmospheric pressure and temperature but not moisture content (relative humidity).

CONCLUSION

The seasonal surface refractivity variation and its distinct components were studied in Ilorin, Kwara state, Nigeria; the results revealed that the meteorological components of radio refractivity (e.g., pressure, temperature, and relative humidity) have a significant impact on the seasonal propagation of electromagnetic waves and thus terrestrial radio communications. According to the findings of this study, relative humidity (atmospheric moisture content) has the greatest influence on the value of radio refractivity when compared to atmospheric temperature and pressure. The atmospheric relative humidity determines whether an electromagnetic wave is reflected, refracted, ducted, or simply travels in a straight line into space. Furthermore, the seasonal variation in weather was discovered to be significant during rainy season (June-September) than during the dry season (November-February) whereby surface refractivity was at its maximum.

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