IOSR Journal Of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 14, Issue 4 Ser. I (Jul. – Aug. 2022), PP 29-39
www.Iosrjournals.Org

Radio Refractivity Patterns Induced By 6-Hourly Mean Surface Relative Humidity Over Nigeria

Ajileye, O. O.
Centre for Atmospheric Research, National Space Research and Development Agency
Kogi State University Campus, Ayangba, Kogi State

Abstract

This study examined and compared20-year mean values of surface radio refractivity patterns at 6am, 12noon, 6 pm and 12 am local times in January (the peak of dry season)and July (peak of rainy season) over Nigeria using meteorological parameters from 112 gridded stations averaged over a period of 1979 – 1998 and 1999 – 2018 with a view to produce updated refractivity maps linked with surface meteorological patterns.The dataset of atmospheric temperature, T (K), atmospheric pressure, P (hPa), relative humidity, Rh (%) and rainfall, RR (mm/hour) were extracted using text import wizard and appropriate delimited options using ITU-R equations and averaged to deduce 20-years average of surface refractivity at 6am, 12noon, 6pm, and 12midnight in January and July for 40 years (1979 – 2018) in two steams of 20 years each.In January, 6-hourly variations of mean values of surface relative humidity over Nigeria for 40 years showed prevalence of drier climate; 6am is the worst scenario for radio propagation with 21.81 N-Units mean surface radio refractivity reduction while 6pm is relatively the best with 13.01 N-Units reduction. In July, 6-hourly variations of mean surface relative humidity over Nigeria showed an incidence of drizzlier climate; mean surface relative humidity significantly increased most especially at 6pm; 12noon is the worst radio propagation scenario while 6am is comparatively fair.

***Keywords**: meteorological parameters, diurnal variations, surface radio refractivity, refractivity map,*

Date of Submission: 25-07-2022 Date of Acceptance: 08-08-2022

I. Introduction

Variations in atmospheric temperature, pressure and humidity as well as clouds and rain, influence the way in which radio waves propagate from one point to another in the troposphere. This region exercises a considerable influence on radio waves at frequencies beyond 30MHz, though this effect becomes significant only at frequencies greater than 100MHz especially in the lower atmosphere [8].Nigeria has a tropical climate that varies from one part of the country to another; semi-arid in the far north and progressively rainier towards the south. The weather condition can be generally characterized into wet season, from April to October; dry season, from November to March in the north and wet season, from March to October; dry season, from November to February in the south.

The dry season in Nigeria, which reaches its peak in January, is a period of little cloud cover in the southern part of Nigeria to virtually no cloud cover in the northern part of Nigeria. Temperatures vary remarkably depending on the climatic zones. The northern regions are much drier in nature in comparison to the southern parts. The weather could be extreme in the deserts of the Sahara. The rest of the year is hot and dry with temperatures rising as high as 40°C [9]. In the south, the increase in temperature is limited, both because of the proximity to the ocean and because the rain starts earlier. From June to September, the air is humid and the sky is usually cloudy throughout the country; temperatures are uniform, and are everywhere between 28 and 30 °C; the daytime temperatures are lower than in harmattan, but relative humidity is higher. The monthly mean temperature is usually high between November and March while the rainfall and the corresponding relative humidity (RH) are high between June and September of each year with the exception of a slight reduction in RH (rainfall) during August.Variations in the temperature and RH are observed to be influenced by changes in the rainfall patterns [14].

Since the concentration of the constituents of the atmosphere depends on geographical location, environment and weather conditions, the study of radio wave propagation in this region is of utmost interest. The characteristics behavior of electromagnetic wave propagation is dependent on surface refractivity of the earth’s atmosphere and consequently on other physical parameters such as; pressure, temperature, and water content which vary in time and space randomly [13]. Radio waves propagating through the troposphere experience path bending due to inhomogeneous spatial distribution of the refractive index of air which causes adverse effects such as multipath fading and interference. These effects significantly impair radio communication, aero-space, environmental monitoring, disaster forecasting and so on.

Among all forms of obtainable precipitations, rainfall is of most dominance as it has an increasingly important attenuation effect on radio waves [17]. When an electromagnetic wave passes through a rain particle, the wave becomes attenuated. This attenuation may be caused by absorption, in which the raindrop, acting as a poor dielectric, absorbs power from the radio wave and dissipates the power by heat loss or by scattering. The scattering disperses the signal, while absorption causes the resonance of the waves with individual molecules of water [12]. Absorption increases the molecular energy, corresponding to a slight increase in temperature and results in an equivalent loss of signal energy. In strong precipitation phenomena, in addition to the signal being attenuated, the system noise temperature is increased and the polarization is changed.

Various studies by researchers on variation of refractivity in Nigeria showed that refractivity values are normally high during the rainy season and low in the dry season [18, 2, 1, 7, and 6]. [11], reported that radio refractivity gradient is more sensitive to relative humidity gradient during warm season in some selected locations. They established that relative humidity has a more significant influence on the radar ray path calculation than temperature. [7], examined the atmospheric refractivity over Abuja, Nigeria, and found out that relative humidity and pressure as well as temperature have greater influence during wet season while temperature has great influence on refractivity during dry and wet seasons. [4,5], studied surface refractivity and refractivity gradients at North Central, Nigeria and ascertained that it is not only the evaporation gradient and surface relative humidity that affects surface radio refractivity, but a combination of vegetation distribution properties and topographical features. They also observed that surface refractivity gradient varied at the rate of 7.87 N-Units/km and reduced with increasing altitude in their region of study.

[7], reported that the refractivity value over Nigeria increases from about 270N-units north to about 390N-units in the south. The variation of refractivity from northern Nigeria to southern Nigeria has a maximum of about 120N-units. The seasonal variation of refractivity over the north has a maximum of 90N-units while the maximum difference in the south is 65N-units.[3], estimated the monthly variation of surface refractivity for different climatic zones across West Africa using satellite dataset spanning 22 years (1983 - 2005). The maximum of 326 N-Units and 300 N-Units were recorded in April while the minimum of 300 N-Units and 261 N-Units were recorded in January for zones lower latitudes less than 5 and 10^0N respectively. They reported Surface refractivity values to be generally low during the dry months and high during the wet months. Surface refractivity was observed to have higher values at 2 m than 10 m. Maximum values of 332 N-Units and 336 N-Units were recorded in June and July for climatic zones within latitudes 15 and 20^0N while minimum of 272 N-Units and 269 N-Units were recorded in December and January respectively. [16], studied the regional implication of tropospheric surface refractivity on radio propagation using Nigeria as a case study, and discovered thatthe refractive index of the atmosphere varies not only with the altitude but also with the regions. It was also shown that the refractivity at the coastal region comprises of both hydrostatic and non-hydrostatic components of refractivity which is traceable to the characteristic heavy contents of humidity in the region which varies with the time of the day (sunrise effects) [19].

[10], studied the diurnal and seasonal variation of surface radio refractivity in Mowe south west of Nigeria and observed that surface radio refractivity varies diurnally from 00:00 to 23:59 hrs local time. The diurnal variation of refractivity is a function of local meteorology [7].[15], studied the diurnal variation of surface refractivity in the North central and showed that refractivity values are high during the early morning and night hours and decreased rapidly during the afternoon hours. [8], investigated how the variations of atmospheric pressure, temperature and relative humidity affect the refractive index in the lower atmosphere of some selected locations in Nigeria. Their results show that average hourly variations of surface radio refractivity in dry season is majorly driven by the wet component (humidity) at Lagos, Port-Harcourt and Yola stations, while the dry component (pressure) is the major driving force for the variations at Anyigba during the same season. Surface refractivity tends to be high in the morning as well as late in the evening and low in the day time. They attributed this to the response of the earth to solar insolation which is the major force behind the weather condition observed. The diurnal variation of refractivity depends on local meteorology as dictated by the topography. The refractivity values computed for the locations under study increases from about 242 N-units at Anyigba northern Nigeria to 384 N-units at Lagos southern Nigeria.

[6], studied the monthly and seasonal variation of surface refractivity and water vapour density using thirty-nine years meteorological data for forty-eight stations in Nigeria. The results show that the value of surface refractivity and water vapour density varies from about 263 N-units and 3 g/m3 in arid region of Nigeria (North East) to about 393 N-units and 23 g/m3 in the coastal area of Nigeria (South West) respectively.Ajileye

2016 studied the monthly and annual variations of surface refractivity gradient (SRG) over West Africa for different climatic zones. The results showed that precipitation varies directly with SRG and the intensity of rainfall across West Africa remains the strong determining factor of SRG spatial and temporal distributions for the different climatic zones. It was also found that the annual SRG for the four climatic zones ranges from 18 N-Units/km to 57 N-Units/km within the period of 1983-2005.

This study investigates and compares20-year mean of surface radio refractivity patterns at 6am, 12noon, 6pm and 12 am local times in January (the peak of dry season)and July (peak of rainy season) over Nigeria using meteorological parameters from 112 gridded stations averaged over a period of 1979 – 1998 and 1999 – 2018 with a view to produce updated refractivity maps linked with surface meteorological patterns. This is expected to be a useful tool for planning and evaluation of line of sight communications in Nigeria.

II. Theoretical Background

The atmospheric radio refractive index, n, can be computed by the following formula [20]:

$$\mathrm{n} = 1 + \mathrm{N} \times 10^{6} \qquad 1$$

where the radio refractivity, N, is [20]:

$$\mathrm{N} = 77.6\frac{\mathrm{P_d}}{\mathrm{T}} + 72\frac{\mathrm{e}}{\mathrm{T}} + 3.75 \times \frac{\mathrm{e}}{\mathrm{T}^2} \text{ (N-units)} \qquad 2$$

The dry term of the radio refractivity,$\mathrm{N_{dry}}$, is:

$$\mathrm{N_d} = 77.6\,\frac{\mathrm{P_d}}{\mathrm{T}} \qquad 3$$

and the wet term of the radio refractivity,$\mathrm{N_{wet}}$, is:

$$\mathrm{N_{wet}} = 72\frac{\mathrm{e}}{\mathrm{T}} + 3.75 \times 10^{5}\,\frac{\mathrm{e}}{\mathrm{T}^2} \qquad 4$$

where:

P_d: dry atmospheric pressure (hPa)
P: total atmospheric pressure (hPa)
e: water vapour pressure (hPa)
T: absolute temperature (K)

and

$$\mathrm{P} = \mathrm{P_d} + \mathrm{e} \qquad 5$$

Since$\mathrm{P_d} = \mathrm{P} - \mathrm{e}$, equation (2) can be written as [20]:

$$\mathrm{N} = 77.6\frac{\mathrm{P}}{\mathrm{T}} - 5.6\frac{\mathrm{e}}{\mathrm{T}} + 3.75 \times 10^{5}\,\frac{\mathrm{e}}{\mathrm{T}^2} \qquad 6$$

Equation (6) may be approximated with reduced accuracy as:

$$\mathrm{N} = \frac{77.6}{\mathrm{T}}\left(\mathrm{P} + 4810\frac{\mathrm{e}}{\mathrm{T}}\right) \qquad 7$$

Equation (7) yields values of N within 0.02% f the value obtained from equation (2) for the temperature range from -50^0C to +40^0C. The relationship between water vapour pressure e and relative humidity H is given by:

$$\mathrm{e} = \frac{\mathrm{H}\,.\mathrm{e_s}}{100} \qquad 8$$

with [20]:

$$\mathrm{e_s} = \mathrm{EF}\,.\,\mathrm{a}.\exp\left[\frac{\left(\mathrm{b} - \frac{\mathrm{t}}{\mathrm{d}}\right).\mathrm{t}}{\mathrm{t}+\mathrm{c}}\right] \qquad 9$$

and [20]:

$$\mathrm{EF_{water}} = 1 + 10^{-4}[7.2 + \mathrm{P}\,.\,(0.032 + 5.9\,.\,10^{-6}\,.\,\mathrm{t}^2)] \qquad 10$$

$$\mathrm{EF_{ice}} = 1 + 10^{-4}[2.2 + \mathrm{P}\,.\,(0.0383 + 6.4\,.\,10^{-6}\,.\,\mathrm{t}^2)] \qquad 11$$

where:

t: temperature (^{0}C)
P: total atmospheric pressure (hPa)
H: relative humidity (%)
e: saturation vapour pressure (hPa) at the temperature t (^{0}C) and the coefficients a, b, c, and d are:

For water:	For ice:
$a = 6.1121$	$a = 6.1115$
$b = 18.678$	$b = 23.036$
$c = 257.14$	$c = 279.82$
$d = 234.5$	$d = 333.7$
(valid between -40^0 to $+50^0$)	(valid between -80^0 to 0^0)

III. Climate of the Study Area

In this study, the diurnal variation of meteorological parameters during the dry season over Nigeria as it affects surface refractivity is the major focus. Nigeria is located in the West African region between the latitudes of 4°N and 14°N and the longitudes of 2°E and 15°E and has a total area of approximately 925796 km^2 (as shown in figure 1). As in most of West Africa, Nigeria's climate is characterized by strong latitudinal zones, becoming progressively drier as one moves north from the coast. Rainfall is the key climatic variable, and there is a marked alternation of wet and dry seasons in most areas. Two air masses control rainfall--moist northward-moving maritime air coming from the Atlantic Ocean and dry continental air coming south from the African landmass.

Topographic relief plays a significant role in local climate only around the Jos Plateau and along the eastern border highlands.There are two major climatic regions in Nigeria: the Nigerian Sahel and Guinea Coast.In the Guinea Coast region, temperatures rarely exceed 32°C, but the humidity is very high and the nights are warm; whereas, in the Nigerian Sahel, midday temperatures rise above 36°C in summer, but with relatively cool nights, with the minimum temperature dropping as low as 19°C during the dry season.

Temperatures throughout Nigeria are generally high; diurnal variations are more pronounced than seasonal ones. Highest temperatures occur during the dry season; rains moderate afternoon highs during the wet season. Although average temperatures vary little from coastal to inland areas, inland areas, especially in the northeast, have greater extremes. There, temperatures reach as high as 44° C before the onset of the rains or drop as low as 6° C during an intrusion of cool air from the north from December to February.

IV. Data Source and Analysis

Surface meteorological data from 112 gridded locations (100 km by 100 km) across Nigeria were used in this study. The data spanned two periods of 20 years each (1979 – 1998 and 1999 – 2018) for January as a suitable representation of dry season scenario over Nigeria. The meteorological which include temperature, atmospheric pressure and relative humidity were obtained from Modern-Era Retrospective analysis for Research and Application (MERRA - 2).

MERRA, like other current re-analyses, makes extensive use of satellite radiance information, including data from hyper-spectral instruments such as the Atmospheric Infrared Sounder (AIRS) on Aqua. The assimilation of radiance data requires a forward radiative transfer model as the observation operator, to calculate the model-equivalent radiances, and the corresponding Jacobian to calculate the influences in model space of the radiance increments calculated from the analysis. For this, the GSI is coupled to the Community Radiative Transfer Model [21].

The GEOS-5 atmospheric general circulation model (AGCM) used for MERRA is based on finite-volume dynamics [22] found to be effective for transport in the stratosphere (e.g., [23]. It includes moist physics with prognostic clouds [24], a modified version of the Relaxed Arakawa-Schubert convective scheme described by [25], the shortwave radiation scheme of [26], and the long-wave radiation scheme of [27]. Two atmospheric boundary-layer turbulent mixing schemes are used. The [28] scheme is used in stable situations with no planetary boundary layer (PBL) clouds, while the [29] scheme is used for unstable or cloud-topped PBLs. GEOS-5 incorporates both an orographic gravity wave drag scheme based on [30], and a scheme for nonorographic waves based on [31]. The land surface is modeled with the Catchment Land Surface Model [32]. The grid used for MERRA is ½° latitude × 2/3° longitude with 72 vertical levels, from the surface to 0.01 hPa.

The meteorological data for 112 locations defined by latitude and longitude grids over Nigeria, as shown in figure 1, were downloaded for two periods of 20 years, 1979 – 1998 and 1999 – 2018. The data was obtained for 6am, 12noon, 6pm and 12 am Nigerian time for 30th day of January through the entire period as a suitable representation of dry season. The dataset of atmospheric temperature, T (K), atmospheric pressure, P (hPa), relative humidity, Rh (%) and rainfall, RR (mm/hour) were extracted using text import wizard and appropriate delimited options to prepare excel spreadsheet format for data manipulations. A 6 – hourly surface radio refractivity (N) was computed from a set of T, Rh and P for the periods of 1979 – 1998 and 1999 – 2018 using ITU-R equations 2 – 11and averaged to deduce 20-years average of surface refractivity at 6am, 12noon, 6pm, and 12midnight in January for 40 years (1979 – 2018) in two steams of 20 years each. Surface refractivity values were interpolated using ArcGIS produce contour patterns over entire Nigeria. The contours were overlaid on rasterized distributions of relative humidity to deduce the influence of surface relative humidity on diurnal variations of surface refractivity with a view to establish degree of correlations. The values of surface refractivity motivatedby patterns of meteorological parameters during the period of 1979 – 1998 were compared with values obtained in the period of 1999 – 2018.

V. 6-Hourly Mean Variation of Relative Humidity and Radio Refractivity in January over Nigeria

The results of 6-hourly mean variation of relative humidity and surfaceradio refractivity in January for 40 years were partitioned in two periods; the maps for 1979 – 1998 over Nigeria are presented in figure 1 while the maps for January 1999 – 2018 are presented in figure 2. In January over Nigeria, cool dry dusty North-Eastern trade wind with low relative humidity and high air temperature dominated the region. Rear and scattered rainfall with poor visibility prevail in the atmosphere. The season is characterized with longer night time and relative shorter day. Relative humidity changes near the surface have more than twice the impact on refractivity as temperature changes as a results of high variability of humidity in dry months and partly due to the inherent sensitivity of refractivity to relative humidity in the additional wet term.Increase in relative humidity significantly influenced the values of surface radio refractivity in January across Nigeria.

In figure 1, at 6am, results show that there is a general significant reduction in mean relative humidity over the past 40 years with consequential decrease in surface radio refractivity across Nigeria. On comparing results in 1979 – 1998 period with 1999 – 2018, Northern Nigeria experienced reduction in surface relative humidity by 9% with corresponding reduction in surface refractivity by 9.05 N-Units. Southern Nigeria experienced reduction in surface relative humidity by 21% with equivalent reduction in surface refractivity by 34.05 N-Units. Nigeria experienced reduction in mean surface relative humidity at 6am by 15% while surface refractivity reduced by 21.81 N-Units. In 1979 – 1998 period, the 20-year mean value of surface relative humidity was 60.00% which had significantly reduced to 44.93% in 1999 – 2018. Surface refractivity within these periods were also influenced accordingly, 20-year mean value was 325.57 N-Units in 1979 – 1998 and 303.57 N-Units in 1999 – 2018. In Northern Nigeria, mean surface relative humidity decreased from 31.57 % in 1979 – 1998 period to 22.91 % in 1999 – 2018 while surface radio refractivity declined from 287.26 N-Units to 279.06 N-Units respectively. In Southern Nigeria, mean surface relative humidity dropped from 87.94 % in 1979 – 1998 period to 66.19 % in 1999 – 2018 while mean surface radio refractivity plunged from 362.53 % to 327.59 N-Units similarly.

At 12 noon over Nigeria in figures 1 and 2, a decline in 20-year mean surface relative humidity and surface radio refractivitycontinued by 9.19% and 19.37 N-Units respectively. Generally from 1979 - 2018, mean of surface relative humidity decreased by 2.21 % and 16.18 % in Northern and Southern Nigeria while surface radio refractivity dropped by 4.72 and 34.02 N-Units in turn. The 20-year mean value of surface relative humidity was 29.66 % in 1979 – 1998 and 20.46 % in 1999 – 2018 while 20-year mean value of surface radio refractivity was 304.32 N-Units in 1979 – 1998 and 284.95 N-Units in 1999 – 2018 over Nigeria. In Northern Nigeria, mean surface relative humidity reduced from 11.7 % in 1979 – 1998 to9.32 % in 1999 – 2018 while surface radio refractivity dropped from 269.07 N-Units to 263.99 N-Units respectively. In Southern Nigeria, mean surface relative humidity decreased from 47 % in 1979 – 1998 to 31.21 % in 1999 – 2018 while mean surface radio refractivity plummeted from 339.57 % to 305.17 N-Units correspondingly.

At 6 pm over Nigeria in figures 1 and 2, a general reduction in 20-year mean surface relative humidity and surface radio refractivity was sustained by 5.56 % and 13.01 N-Units respectively. The mean surface relative humidity decreased by 0.1 % and 11.03 % in Northern and Southern Nigeria while mean surface radio refractivity dropped by 1.97 and 24.06 N-Units in turn. The 20-year mean value of surface relative humidity was 39.12 % in 1979 – 1998 and 33.56 % in 1999 – 2018 while the 20-year mean value of surface radio refractivity was 312.47 N-Units in 1979 – 1998 and 299.45 N-Units in 1999 – 2018. In Northern Nigeria, mean surface relative humidity increased slightly from 17.49 % in 1979 – 1998 to 17.78 % in 1999 – 2018 while mean surface radio refractivity decreased from 277.22 N-Units to 275.25 N-Units respectively. In Southern Nigeria, mean surface relative humidity decreased from 59.99 % in 1979 – 1998 to 49.33 % in 1999 – 2018 while mean surface radio refractivity fell from 347.72 % to 323.66 N-Units consistently.

At 12 am over Nigeria in figures 1 and 2, a general decline in 20-year mean surface relative humidity and surface radio refractivity was unrelenting by 12.87 % and 20.84 N-Units respectively. The mean value of surface relative humidity decreased by 2.83 % and 22.92 % in Northern and Southern Nigeria while mean surface radio refractivity dropped by 4.15 and 37.33 N-Units corresponding in 40 years (1979 – 2018). The 20-year mean value of surface relative humidity was 50.38 % in 1979 – 1998 and 37.19 % in 1999 – 2018 while the 20-year mean value of surface radio refractivity was 318.79 N-Units in 1979 – 1998 and 297.95 N-Units in 1999 – 2018. In Northern Nigeria, mean surface relative humidity decreased from 23.35 % in 1979 – 1998 to 20.52 % in 1999 – 2018 while mean surface radio refractivity decreased from 281.15 N-Units to 277 N-Units respectively. In Southern Nigeria, mean surface relative humidity reduced from 76.78 % in 1979 – 1998 to 53.86 % in 1999 – 2018 while mean surface radio refractivity dropped from 356.43 % to 318.9 N-Units respectively.

InNorthern Nigeria over the period of 40 years, considerable reduction in mean surface relative humidity had occurred most specially between 12am and 6am in the month of January. The variations had led to significant departure of the mean values of surface radio refractivity by >4 N-Units. In January over Northern Nigeria, 6am had worst scenarios of mean value variation while 6pm has a moderate variation over the period of 40 years. Worst scenario of reduction in mean surface relative humidity was observed at 12am in the south resulting in the highest decrease in surface radio refractivity. The extent of reduction in the south was more pronounced than that of north which indicates more surface moisture in the south than north in the dry season. In January, radio propagation is less susceptible to attenuation at 6pm across Nigeria due to moderate surface radio refractivity as a result of least mean surface relative humidity variation while 6am in the north and 12am in the south would require adequate transmission planning.

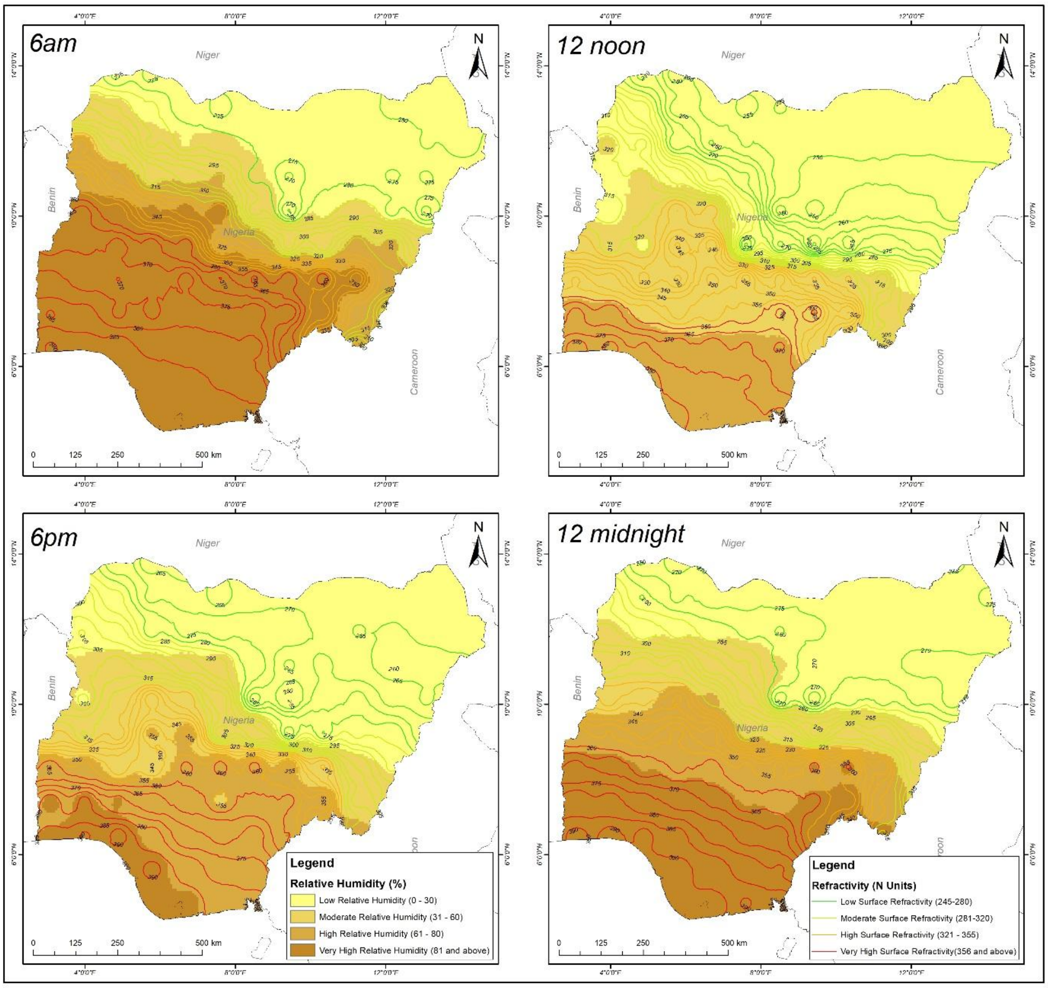

Figure 1: A 20-Year Mean Relative Humidity and Radio Refractivity Patterns for January (1979 – 1998)

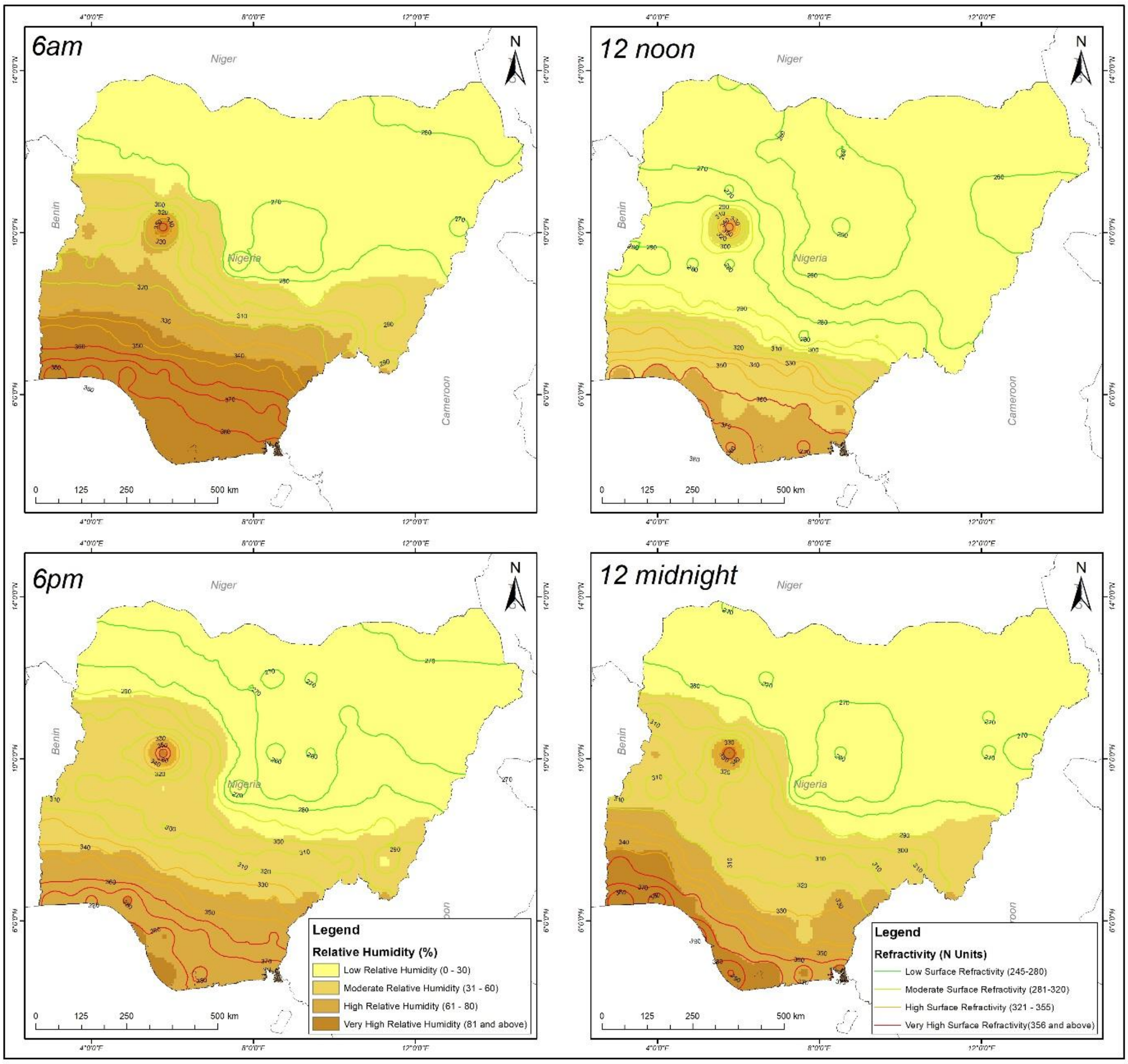

Figure 2: A 20-Year Mean Relative Humidity and Radio Refractivity Patterns for January (1999 – 2018)

VI. 6-Hourly Mean Variation of Relative Humidity and Radio Refractivity in July over Nigeria

The results of 6-hourly mean variation of relative humidity and surface radio refractivity in July for 40 years were partitioned in two periods; the maps for 1979 – 1998 over Nigeria are presented in figure 3 while the maps for January 1999 – 2018 are presented in figure 4. Over Nigeria, July is the peak of rainy season with maximum relative humidity and lowest temperature in the year. The monsoon wind dominated the region and heavy cloud cover in the sky scattering more incoming solar radiation back to space. It is characterized with longer day and shorter night.Of the three atmospheric variables that influence surface radio refractivity (temperature, moisture, and pressure), moisture – or more specifically, water vapor – has the greatest effect on refraction.Surface radio refractivity is a useful predictor of convective storms, through detection of convergence lines and the use of near-surface relative humidity diagnosis to improve stability assessment.

At 6am over Nigeria, results showed a general significant decrease in mean relative humidity over the past 40 years with consequential decrease in surface radio refractivity across Nigeria. On relating results in 1979 – 1998 period with 1999 – 2018, Nigeria had reduction in surface relative humidity by 1.24% and in surface radio refractivity by 0.44 N-Units. Southern Nigeria haddecrease in surface relative humidity by 0.01 % with equivalent reduction in surface refractivity by 0.69 N-Units. Northern Nigeria experienced reduction in mean surface relative humidity at 6am by 2.47 % while surface refractivity reduced by 0.20 N-Units. In 1979 – 1998 period, the 20-year mean value of surface relative humidity was 90.66% which had slightly increased to 91.9 % in 1999 – 2018. Surface refractivity within these periods were also influenced accordingly, 20-year mean value was 361.47 N-Units in 1979 – 1998 and 361.03 N-Units in 1999 – 2018. In Northern Nigeria, mean surface relative humidity improved from 87.21 % in 1979 – 1998 period to 89 % in 1999 – 2018 while mean surface radio refractivity had insignificant reduction from 358.59 N-Units to 358.39 N-Units. In Southern Nigeria, mean surface relative humidity had no significant change with 94.12 % in 1979 – 1998 period and 94 % in 1999 – 2018 while mean surface radio refractivity followed same trend with 364.35 % and 363.65 N-Units correspondingly.

At 12 noon over Nigeria, comparing results in figures 3 and 4, decrease in 20-year mean surface relative humidity and surface radio refractivity continued by 26.94 % and 8.83N-Units. Mean values of surface relative humidity decreased by 31.55 % and 22.33 % in Northern and Southern Nigeria while surface radio refractivity dropped by 13.34 and 4.32 N-Units in turn. The 20-year mean value of surface relative humidity was 91.9 % in 1979 – 1998 and 64.96 % in 1999 – 2018 while 20-year mean value of surface radio refractivity was 361.03 N-Units in 1979 – 1998 and 352.19 N-Units in 1999 – 2018 over Nigeria. In Northern Nigeria, mean surface relative humidity reduced from 89.68 % in 1979 – 1998 to 58.13 % in 1999 – 2018 while surface radio refractivity dropped from 358.39 N-Units to 345.05 N-Units respectively. In Southern Nigeria, mean surface relative humidity reduced from 94.13 % in 1979 – 1998 to 58.13 % in 1999 – 2018 while mean surface radio refractivity followed same trend from 363.66 % to 359.34 N-Units correspondingly.

At 6 pm over Nigeria in figures 3 and 4, a slight departure from general reduction trend in 40-year mean surface relative humidity and surface radio refractivity was observed with increase of 3.12 % and 0.21 N-Units respectively. The mean surface relative humidity increased by 7.84 % in Northern Nigeria while 1.59 % reduction was observed in Southern Nigeria. Mean surface radio refractivity also increased by 3.79 N-Units and reduced by 3.38 N-Units in north and south in turn. The 20-year mean value of surface relative humidity was 76.31 % in 1979 – 1998 and 79.43 % in 1999 – 2018 while the 20-year mean value of surface radio refractivity was 360.28 N-Units in 1979 – 1998 and 360.49 N-Units in 1999 – 2018. In Northern Nigeria, mean surface relative humidity increased from 64.92 % in 1979 – 1998 to 72.77 % in 1999 – 2018 while mean surface radio refractivity also increased from 350.09 N-Units to 353.88 N-Units respectively. In Southern Nigeria, mean surface relative humidity decreased slightly from 87.69 % in 1979 – 1998 to 86.09 % in 1999 – 2018 while mean surface radio refractivity dropped from 370.47 % to 367.09 N-Units consistently.

At 12 am over Nigeria in figures 3 and 4, an increase in mean surface relative humidity by 2.66 % and a reduction in mean surface radio refractivity by 0.99 N-Units over a period of 40 years wereobserved. The mean value of surface relative humidity increased by 6.18 % in the north and reduced by 0.8 % in the south. Consequently, mean surface radio refractivity increased by 2.14 N-Units in the north and reduced by 4.13 N-Units in the south. The 20-year mean value of surface relative humidity was 86.25 % in 1979 – 1998 and 88.94 % in 1999 – 2018 while the 20-year mean value of surface radio refractivity was 361.35 N-Units in 1979 – 1998 and 360.36 N-Units in 1999 – 2018. In Northern Nigeria, mean surface relative humidity increased from 78.61 % in 1979 – 1998 to 84.8 % in 1999 – 2018 while mean surface radio refractivity slightly increased from 354.67 N-Units to 356.81 N-Units respectively. In Southern Nigeria, mean surface relative humidity reduced slightly from 93.89 % in 1979 – 1998 to 93.08 % in 1999 – 2018 while mean surface radio refractivity decreased from 368.04 % to 363.91 N-Units respectively.

In the north over the period covering 1979 - 2018, variation of mean surface relative humidity had become unpredictable as increase and decrease scenarios were observed in the month of July, a typical wet season. North significantly experienced increase in mean surface relative humidity most especially at 6pm and 12am. It should be recalled that July coincides with peak of rainy season when the inter-tropical discontinuity is at the northernmost location with torrential downpour. North experienced the widest range of diurnal variation in surface relative humidity in the wet season which resulted in the lowest (at 6am) and highest (at 12noon) mean surface radio refractivity. In July over Northern Nigeria, 12noon had worst scenarios of mean value variation while 6am has a moderate variation over the period of 40 years. Worst scenario of reduction in mean surface relative humidity was observed at 12noon in the south resulting in the highest decrease in surface radio refractivity. The extent of reduction in the south was less pronounced than that of north. In July, radio propagation is less susceptible to attenuation at 6am across Nigeria due to moderate surface radio refractivity as a result of least mean surface relative humidity variation while 12noon, both in the north and south, requires special planning.

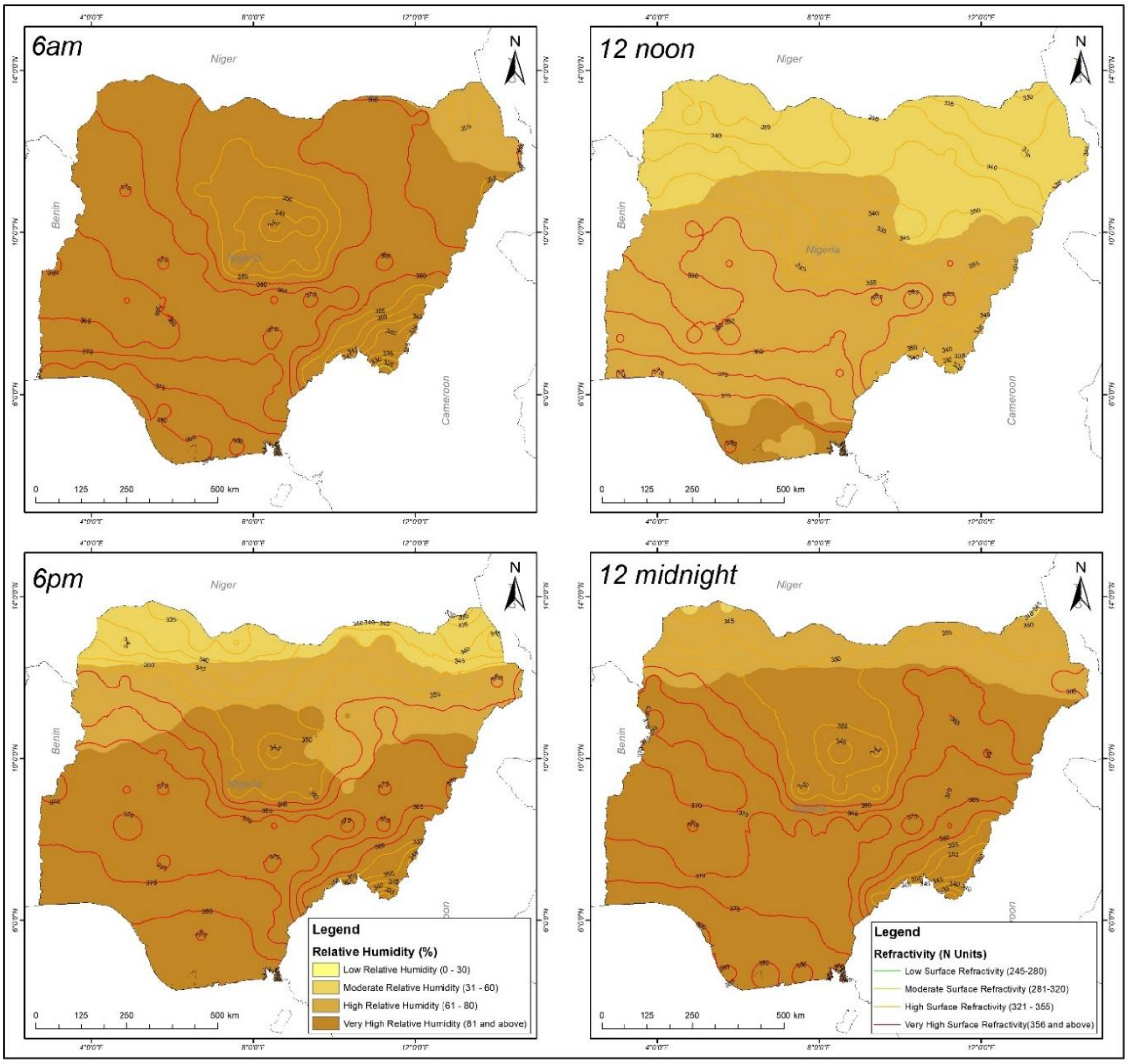

Figure 3: A 20-Year Mean Relative Humidity and Radio Refractivity Patterns for July (1979 – 1998)

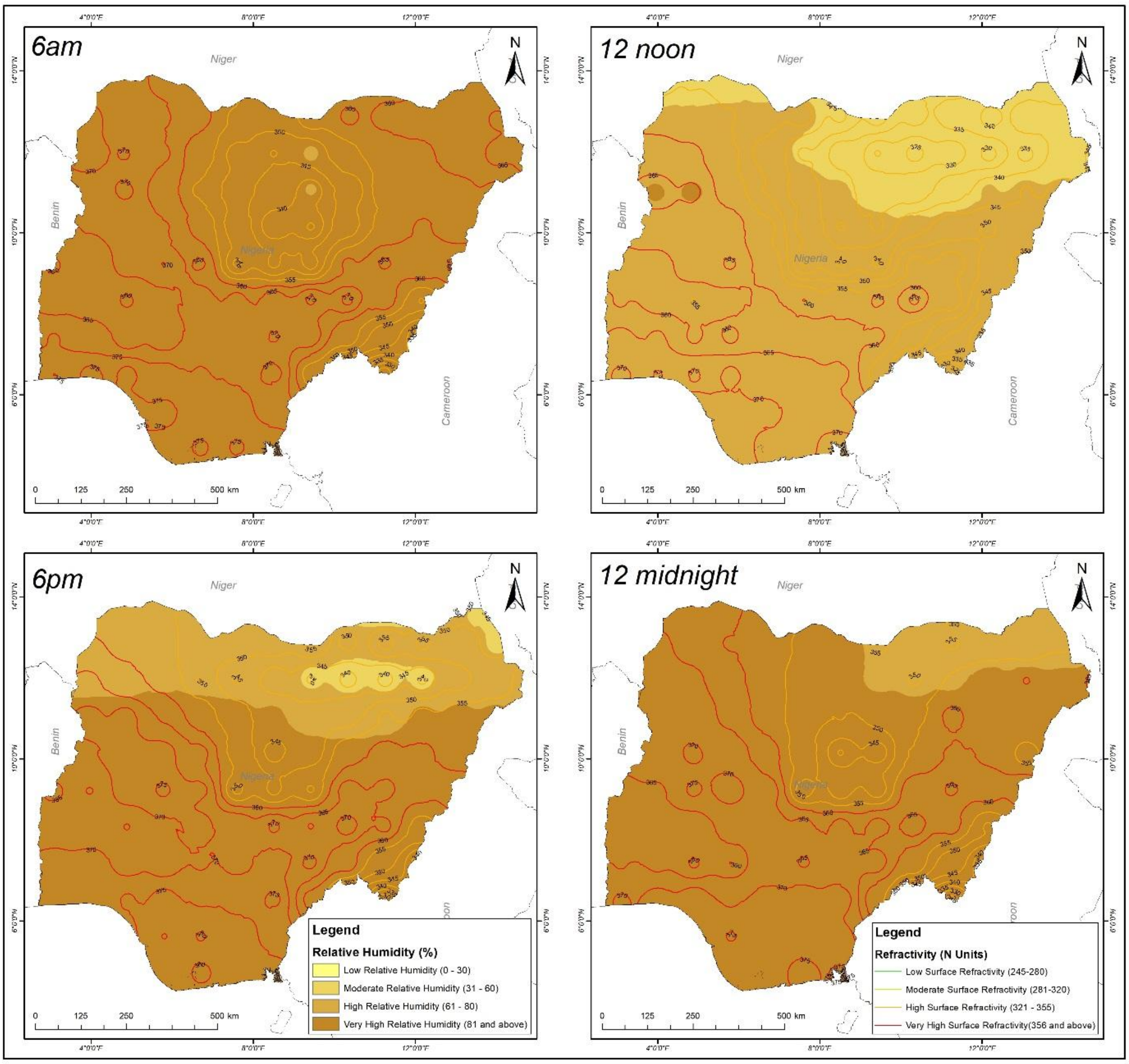

Figure 4: A 20-Year Mean Relative Humidity and Radio Refractivity Patterns for July (1999 – 2018)

VII. CONCLUSION

Mean variation in values of surface relative humidity and surface radio refractivity in 1979 – 1998 were compared with 1999 – 2018 in January (peak of dry season) and July (peak of wet season) over Nigeria. urface radio refractivity was greatly influenced by variations in relative humidity in the dry season much more than wet season. This clearly indicates that cloud cover and attendant minimal diurnal temperature difference played key role in mean values of surface radio refractivity fluctuations most especiaSlly in Southern Nigeria. This region experienced continuous reduction in mean surface radio refractivity irrespective of increase or decrease in mean relative humidity values.

In January, 6-hourly variations of mean values of surface relative humidity over Nigeria for 40 years showed prevalence of drier climate; 6am is the worst scenario for radio propagation with 21.81 N-Units mean surface radio refractivity reduction while 6pm is relatively the best with 13.01 N-Units reduction. In July, 6-hourly variations of mean surface relative humidity over Nigeria showed a incidence of drizzlier climate; mean surface relative humidity significantly increased most especially at 6pm; 12noon is the worst radio propagation scenario while 6am is comparatively fair.

REFERENCES

[1]. Adediji A. T., Ajewole M. (2008). Vertical profile of radio refractivity gradient in Akure Southwest Nigeria. Prog. Electromagn. Res. 14:157-168

[2]. Adeyemi B. (2004). Tropospheric radio refractivity over three Radiosonde Stations in Nigeria, Ife. J. Sci. 6(2):167-176.

[3]. Ajileye O. O., Jegede O. O., Ayoola M. A., Eguaroje O. E. and Mohammed S. O. (2014). Variations of Surface Refractivity for Different Climatic Zones across West Africa. International Journal of Scientific and Engineering Research, Vol. 5, Issue 3 (USA) pp 521 – 530

[4]. Ajileye O. O. (2016). Dependence of Surface Refractivity Gradient Variation on Precipitation in the Tropical West Africa. IOSR Journal of Applied Physics, Volume 8, Issue 3 Ver. III, PP 57-65.

[5]. Ajileye O. O., Kolawole I. S., Ogbole J. O., Alaga A. T., Halilu A. S. and Mohammed S. O. (2016). Influence of Topography on Surface Radio Refractivity Patterns over North Central, Nigeria. Physical Science International Journal, 11(3): 1-12, DOI: 10.9734/PSIJ/2016/27436.

[6]. Akinwumi S. A., Omotosho T. V., Willoughby A. A., Mandeep J. S., Abdullah M. (2015). Seasonal Variation of Surface Radio Refractivity and Water Vapour Density for 48 Stations in Nigeria, Proceeding of the 2015international conference on space science and communication (ICONSPACE), 10-12 August, 2015, Langkawi Malaysia.

[7]. Ayantunji B. G., Okeke P. N., and Urama J. O (2011). Diurnal and seasonal variation of surface refractivity over Nigeria, Progress in Electromagnetics Research B, Vol. 30, 201–222.

[8]. Bawa M., Ayantunji B.G., Mai-Unguwa H., Galadanchi G. S. M., Shamsuddeen I. M. (2015). Study of Average Hourly Variations of Radio Refractivity Variations across Some Selected Cities in Nigeria, Journal of Applied Physics (IOSR-JAP), Vol. 7, 37-43.

[9]. Ekpoh I. J., Nsa E. (2011). Extreme Climatic Variability in North-western Nigeria: An Analysis of Rainfall Trends and Patterns. J. Geogr. Geol. 3(1):51-62.

[10]. Falade J. A., Adesanya S. O., and Akinyemi G. A. (2014). Variability of Meteorological factors on surface refractivity index over Mowe, a coastal area in Nigeria, Indian Journal of Radio and Space Physics, Vol. 43, pp. 355-361.

[11]. Jidong G., Keit B., Ming X. (2008) Variation of Radio Refractivity with Respect to Relative humidity and Temperature and Influence on Radar Ray Path. Adv. Atmos. Sci. 25(6):1098-1106.

[12]. Karagianni, E.A., Mitropoulos, A.P., Drolias, N.G., Sarantopoulos, A. D., Charantonis, A. A., (2015). Radio Refractivity and Rain-Rate Estimations over Northwest Aegean Archipelagos for Electromagnetic Wave Attenuation Modelling.

[13]. Martin G., Vaclav K., (2011). Atmospheric Refraction and Propagation in Lower Troposphere, Electromagnetic Waves, VitaliyZhurbenko (Ed.). InTech 7:139-156.

[14]. Salau O. R., (2016). The Changes in Temperature and Relative Humidity in Lagos State, Nigeria,World Scientific News, WSN 49(2), 295-306.

[15]. Ogherohwo, E. P., Eggah. M.Y., Patience. R. P. (2014). Prognostication of Radio Refractivity in Transmission Link: Diurnal and Seasonal Variation of Surface Refractivity Over Jos-Plateau State, International Journal of Advanced Research in Physical Science (IJARPS) Vol 1, Issue 8, pp76-92.

[16]. OlorodeD. O. andAdeniji, M. A., (2013).Regional implication of tropospheric surface refractivity on radio propagation (A case study of Nigerian atmosphere), Advances in Applied Science Research, 4(4):346-349.

[17]. Sumit J. (2012). A review on rain attenuation of radio waves, JHPCSN: Volume 4, Number 1, pp. 59-64

[18]. Willoughby A, Aro T. O., Owolabi I. E. (2002). Seasonal variations of radio refractivity gradients in Nigeria, Journal of Atmospheric Science and Solar Terrestrial Physics, 64:417-425.

[19]. Zilinskas M, Tamosiunaite M, Tamosiuniene M, Valma E, Tamosiunas S (2012). Gradient of Radio Refractivity in Troposphere. Progress in Electromagnetics Research Symposium Proceedings, Moscow, Russia, pp. 603-607.

[20]. Radio Sector of International Telecommunication Union (ITU-R) (2017): The radio refractive index: its formula and refractivity data, P Series, Radio propagation. Recommendation ITU-R P.453-13. pp. 2 – 3.

[21]. Han, Y., P. van Delst, Q. Liu, F. Weng, B. Yan, R. Treadon and J. Derber, (2006): JCSDA Community Radiative Transfer Model (CRTM) - Version 1, NOAA Tech Report 122, pp. 33

[22]. Lin, S.J., (2004): A vertically Lagrangian finite-volume dynamical core for global models. Mon. Wea. Rev., 132, 2293-2307.

[23]. Pawson, S., I. Stajner, S. R. Kawa, H. Hayashi, W. Tan, J. E. Nielsen, Z. Zhu, L.-P. Chang, N. J. Livesey, (2007): Stratospheric Transport Using Six-Hour Averaged Winds from a Data Assimilation System. J. Geophys. Res., 112, D23103. DOI:10.1029/2006JD007673.

[24]. Bacmeister, J. T., M. J. Suarez, and F. R. Robertson, 2006: Rain re-evaporation, boundary-layer/convection interactions and Pacific rainfall patterns in an AGCM, J. Atmos. Sci., 63, 3383-3403.

[25]. Moorthi, S., and M. J. Suarez, 1992: Relaxed Arakawa-Schubert, A Parameterization of Moist Convection for General-Circulation Models. Mon. Wea. Rev. 120, 978-1002.

[26]. Chou, M.-D. and M. J. Suarez, 1999: A Solar Radiation Parameterization for Atmospheric Studies. NASA Technical Report Series on Global Modeling and Data Assimilation 104606, v15, 40pp.

[27]. Chou, M.-D., M. J. Suarez, X. Z. Liang, and M. M.-H. Yan, 2001: A Thermal Infrared Radiation Parameterization for Atmospheric Studies. NASA Technical Report Series on Global Modeling and Data Assimilation 104606, v19, 56pp.

[28]. Louis, J., M. Tiedtke, and J. Geleyn, 1982: A short history of the PBL parameterization at ECMWF. Proc. ECMWF Workshop on Planetary Boundary Layer Parameterization, Reading, United Kingdom, ECMWF, 59–80.

[29]. Lock, A. P., A. R. Brown, M. R. Bush, G. M. Martin, and R. N. B. Smith, 2000: A new boundary layer mixing scheme. Part I: Scheme description and single-column model tests. Mon. Wea. Rev., 138, 3187-3199.

[30]. McFarlane, N. A., 1987: The effect of orographically excited gravity wave drag on the general circulation of the lower stratosphere and troposphere. J. Atmos. Sci., 44, 1775-1800.

[31]. Garcia, R.R. and B.A. Boville, 1994: Downward control of the mean meridional circulation and temperature distribution of the polar winter stratosphere, J. Atmos. Sci., 51, 2238–2245.

[32]. Koster, R. D., M. J. Suárez, A. Ducharne, M. Stieglitz, and P. Kumar, 2000: A catchment-based approach to modeling land surface processes in a GCM, Part 1, Model Structure. J. Geophys. Res., 105, 24809-24822.

Ajileye, O. O.. “Radio Refractivity Patterns Induced By 6-Hourly Mean Surface Relative Humidity Over Nigeria.” *IOSR Journal of Applied Physics (IOSR-JAP)*, 14(4), 2022, pp. 29-39.