academicJournals

Vol. 8(17), pp. 825-834, 9 May, 2013
DOI: 10.5897/IJPS2013.3852
ISSN 1992-1950 © 2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Regional variation of columnar refractivity with meteorological variables from climate monitoring satellite application facility (CM SAF) data over Nigeria

I. Emmanuel*, B. Adeyemi and K. D. Adedayo

Department of Physics, Federal University of Technology, P. M. B. 704, Akure, Ondo State, Nigeria.

Accepted 19 April, 2013

Data from satellite application facility on climate monitoring (CM SAF) have been used to estimate and study seasonal variation of columnar refractivity in relation with relative humidity and temperature for twenty six stations categorized into four climatic regions (coastal, Guinea savannah, midland and sub Sahel regions) over Nigeria. Mean, standard error, maximum, minimum values and ranges of these variables were also determined for different regions at each atmospheric level. The results have revealed that the monthly variation of refractivity along side with meteorological factors (relative humidity and temperature) from one region to another over Nigeria are influenced by seasonal variation, geographical location and environmental situation of each region. It is also noticed that the range of relative humidity and temperature are wider in the northern part (56.19 and 72.51% and 5.64 and 5.90 K respectively) compared to the southern part (17.85 and 25.27% and 3.19 and 5.44 K respectively) of the country. This effect was observed in the variation of refractivity also. Effect of inter tropical discontinuity (ITD) was recorded in the southern variation of relative humidity and refractivity.

Key words: Columnar, refractivity, meteorological, variation.

INTRODUCTION

The structure of the radio refractive index, *n*, at the lower part of the atmosphere is a very important parameter in the planning of the communication links. It is defined as a ratio of the radio wave propagation velocity in free space to its velocity in a specified medium (Freeman, 2007). Radio–wave propagation is determined by changes in the refractive index of air in the troposphere (Adediji and Ajewole, 2008). Changes in the value of the radio refractive index in the troposphere can curve the path of the propagating radio wave. The atmosphere radio refractive index depends on air temperature, humidity, atmospheric pressure and water vapour pressure. Even small changes in any of these variables can make a significant influence on radio-wave propagation, because radio signals can be refracted over the whole signal path (Priestley and Hill, 1985).

The refractive index is responsible for bending of propagation direction of the electromagnetic wave (Guanjun and Shukai, 2000). Previously worked with Adeyemi and Emmanuel (2011) and Adeyemi (2006) showed that seasonal variation affects radio refractivity in Nigeria. Earlier research work carried out on refractivity in Nigeria was based on radiosonde data (Willoughby et al., 2002) for view available locations and data logger data (Adediji and Ajewole, 2008). This research work covers all the geographical areas/zones in Nigeria.

*Corresponding author. E-mail: engineerisrael@yahoo.com. Tel: +2347033860655.

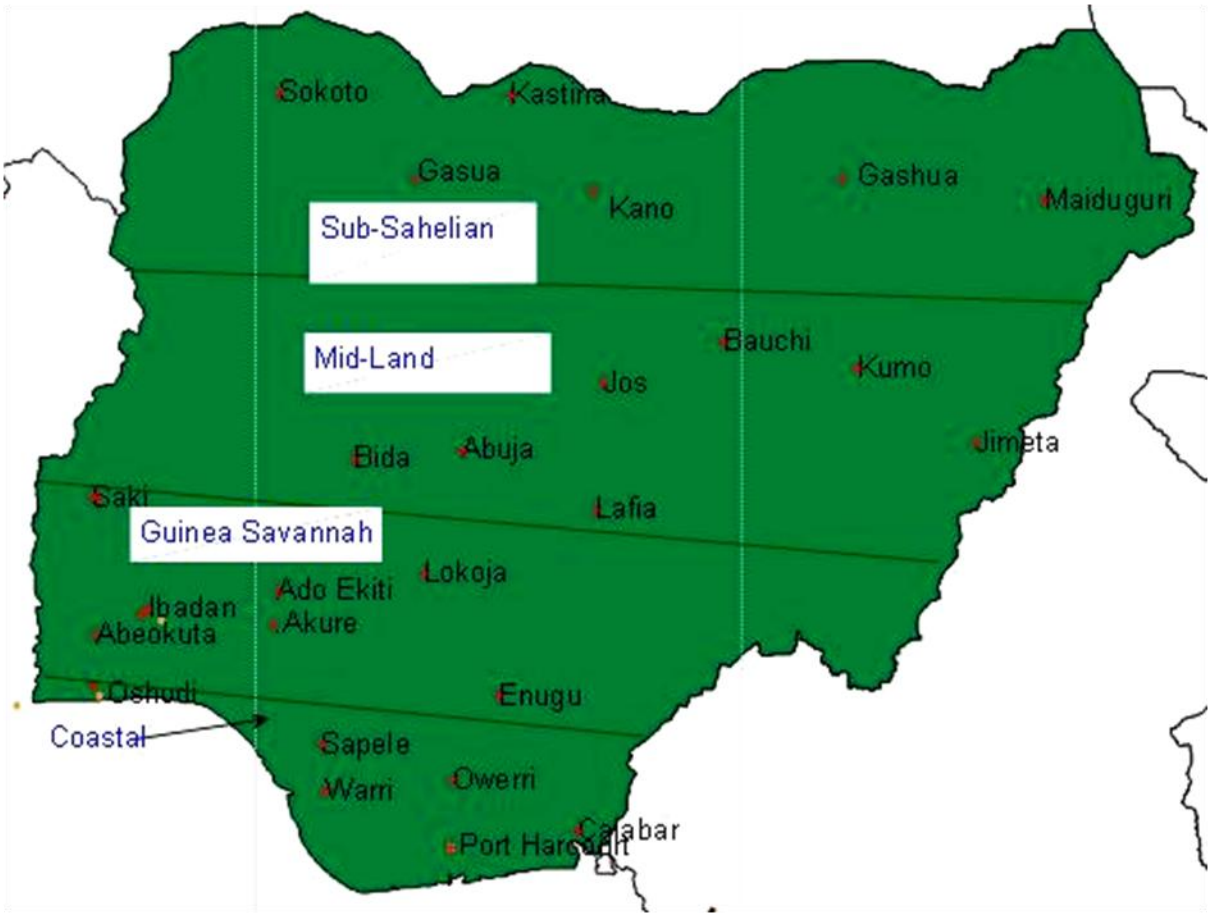

Figure 1. Map of Nigeria showing study locations.

Nigeria lies wholly within the tropical zone, there are wide climatic variations in different areas of the country. Southern Nigeria is characterized by long rainy season starting in March and it lasts until the end of July, with a peak period in June over most parts of southern Nigeria. A short dry season is experienced in August for 3 to 4 weeks (Adeyemi and Aro, 2004). However, the real dry period known as the "August break" is generally observed in the last two weeks of August in most parts of southern Nigeria. This is followed by brief wet season from early September to Mid-October, with a peak period at the end of September. The long dry season period starts from late October and last to early March with peak dry conditions between early December and late February. This period witnesses the prevailing influences of the dry and dusty northeast winds, as well as the 'Harmattan' conditions.

The climatic conditions in the northern part of Nigeria exhibit only two different seasons, namely, a short wet season and a prolonged dry season. The main goal of this paper is to estimate refractivity and study its seasonal variation along side with the temperature and relative humidity at three different atmospheric levels (column) over Nigeria using satellite retrieved data.

DATA ANALYSIS TECHNIQUES

Atmospheric data used in this analysis were obtained from the Department of Satellite Application Facility on Climate Monitoring (CM-SAF), DWD Germany. The CMSAF focuses on the atmospheric part of the Essential Climatic Variables defined within the framework of the Global Climate Observing System (GCOS). The CMSAF operationally applies the international ATOVS processing package (IAPP) to retrieve humidity and temperature from ATOVS observations on-board NOAA - 15, 16 and 18 satellites. The profiles are vertically integrated and averaged to provide temperature and humidity for 5 layers (that is, 925, 775, 600, 400 and 250 mbar). The data used were obtained between the period of 2004 to 2006 for twenty six stations, classified into four climatic regions based in Nigeria (Figure 1), (Olaniran and Sumner, 1989). These regions are:

(i) Coastal region, ((Lat 4.0° to 6.5°, Lon 3.7° to 7.1°) dominated by tropical maritime (mT) air for most of the year;
(ii) Guinea savannah region, (Lat 6.6° to 7.8°, Lon 3.9° to 7.5°), where mT air dominates for about 7 months and tropical continental (cT) air for the remaining 5 months;
(iii) Midland, (Lat 8.0° to 10.8°, Lon 3.9° to 9.8°), which is predominantly highland, where the cT air mass dominates, but

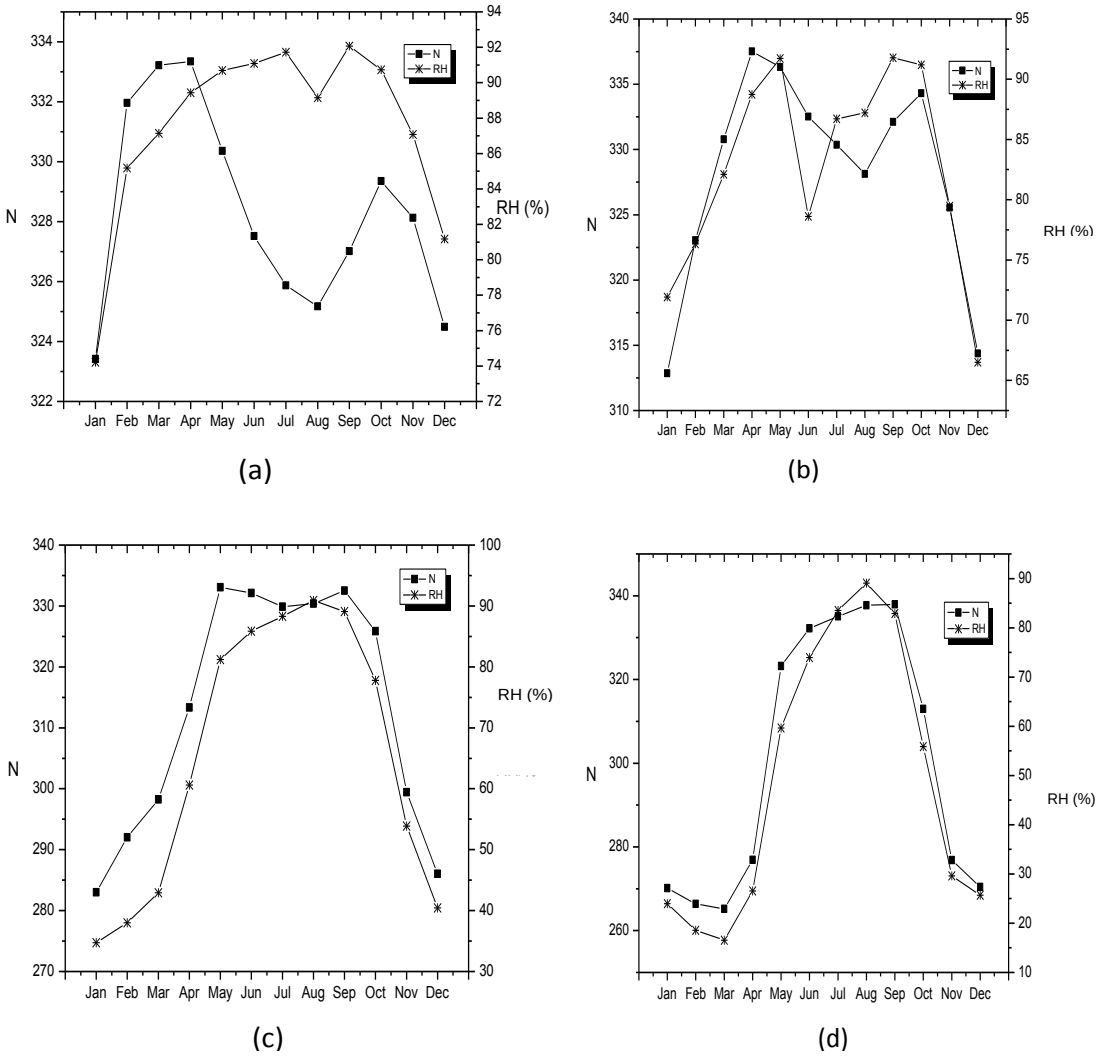

Figure 2. Monthly variation of Refractivity and Relative Humidity at Low Level in (a) Coastal (b) Guinea savannah (c) Midland and (d) Sub sahel regions.

where the topography effectively extended the length of the humid period, due to localized convection and orographic effects (Olaniran, 1983b; Adeyemi, 2004);
(iv) Sahelian region, (Lat 11.0° to 13.0°, Lon 3.7° to 13.333°), where the cT air mass predominates, and mT air mass invades for only 3 to 5 months at most (Olaniran, 1983b; Adeyemi, 2004).

Refractivity value, N, is deducted from the atmospheric data, using equation below.

$$N = (n-1)\times 10^{6} = \frac{77.6}{T}\left[P + \frac{4810\, e}{T}\right] \quad (1)$$

Where: P = Atmospheric pressure (hpa), e = Water vapour pressure (hpa) and T = absolute temperature (K), (Oyedum and Gambo, 1994).

$$e = \frac{He_s}{100} \quad (2)$$

Relative humidity (RH), temperature and refractivity were further grouped into three different atmospheric levels (columns), such as, between surface and 925 mbar have been labeled as low level; between 775 and 600 mbar as mid level and between 400 and 250 mbar as upper level.

RESULTS AND DISCUSSION

Monthly variations of relative humidity and radio refractivity

Figures 2 to 5 show the monthly variation of refractivity, N and relative humidity, RH at different atmospheric levels over Nigeria. From Figure 2a, RH increases with increase N, from January to April in coastal region at low level. A little dip is noticed in August both in RH and N, though that of N is conspicuous. The values of RH were high

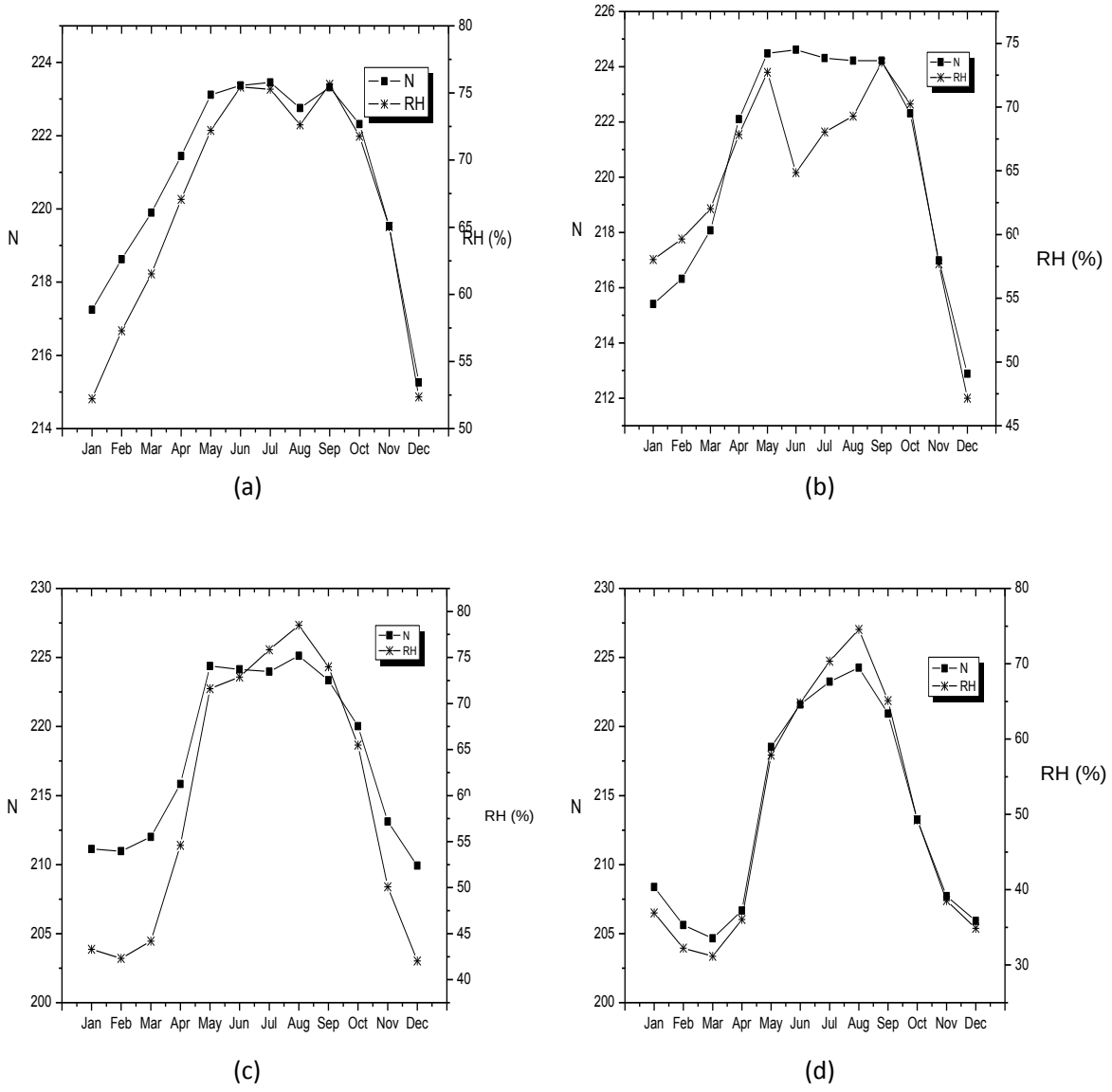

Figure 3. Monthly variation of Refractivity and Relative Humidity at Mid Level in (a) Coastal (b) Guinea savannah (c) Midland and (d) Sub sahel regions.

during the rainy season with an average value of 150% and low during the dry season with an average value of 144.97%, likewise N with average values of 328.4 and 327.2 during the rainy and dry season respectively. The variation of RH and N in the Guinea savannah region, (Figure 2b) is similar to that of the coastal region. It rises from January and reaches its peak in May. Two peaks with a dip in between were noticed here. One in May and the second in September/October. The value of RH was also higher during the rainy season and low during the dry season with average values 87.99 and 75.26% respectively. The dip in between the peaks was noticed between June to August. The average values of N during the dry and rainy seasons are 324.9 and 324.7 respectively. The variation of RH and N at midland and sub Sahel regions are similar. RH and N have the same pattern; they were high during the rainy months of May – September and low in the dry months of October to April in both regions (Figure 2c and d). At midland, their average values of RH during these periods are 69.50 and 56.92%, respectively and for N is 329.3 and 291.5 respectively; at sub Sahel region, it is 67.36 and 22.87%, respectively, while that of N are 321.9 and 269.4, respectively.

At mid level, (Figure 3), in coastal and guinea savannah regions, the monthly variation of RH and N follow the same pattern. Both RH and N have two peaks in these regions, these peaks were noticed in June/July

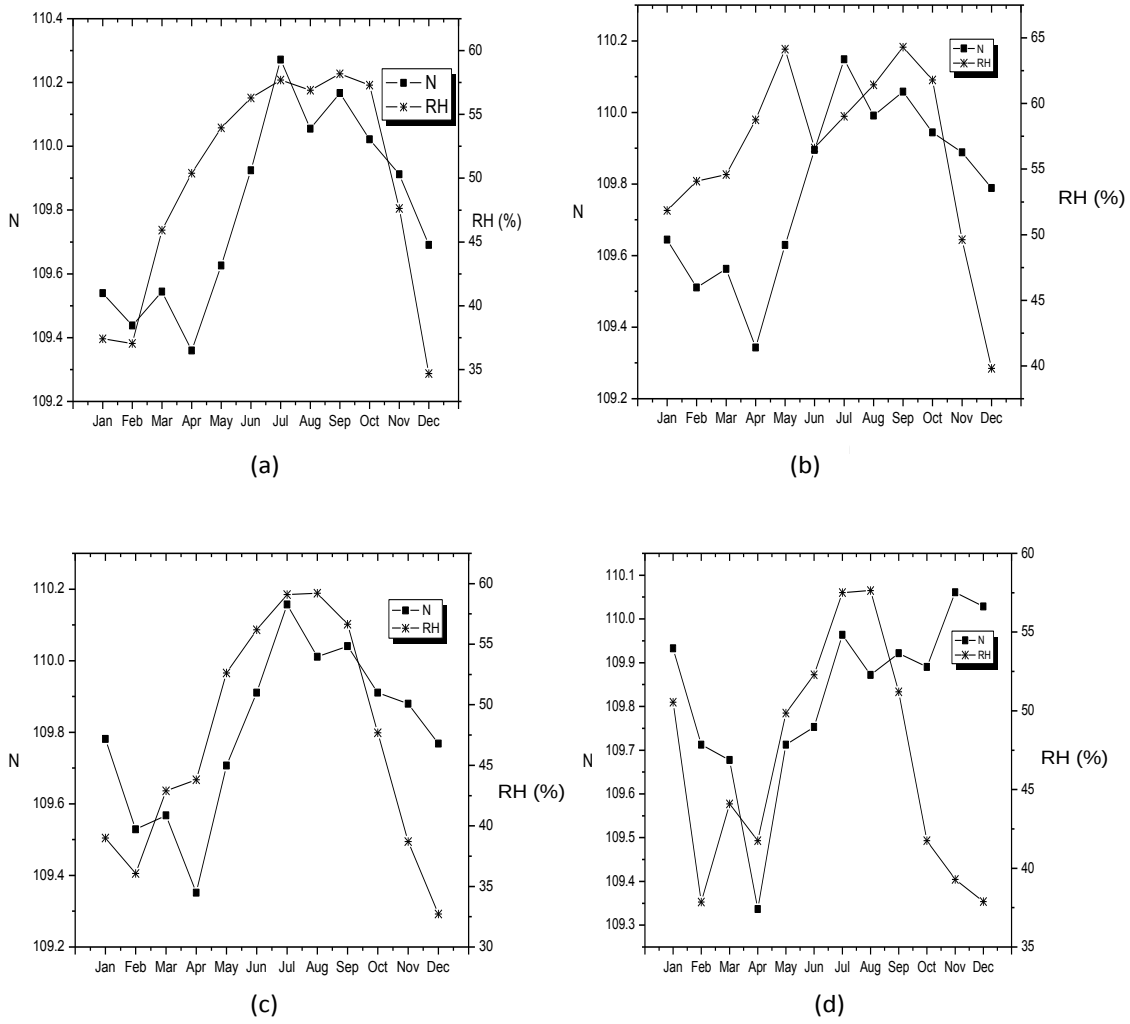

Figure 4. Monthly variation of Refractivity and Relative Humidity at Upper Level in (a) Coastal (b) Guinea savannah (c) Midland and (d) Sub sahel regions.

and September with the dip in the coastal region; and May and September in guinea savannah with dip in June are extending into August here (Figure 3a-b). Here the values of RH and N were high during the rainy season and low during the dry season (Table 1). Also variation at midland and sub Sahel regions follows the same pattern both in RH and N. Here RH and N rise at the same time and attain their peak at the same time. The values were high during the rainy and low during the dry seasons (Table 1). At the upper level (Figure 4) the monthly variation of RH was different from that of N in all the regions. The variations are summarized in Table 1.

Monthly variations of temperature and radio refractivity

Figures 5 to 7 show the monthly variation of temperature, T (in Kelvin) along side with radio refractivity for the three atmospheric levels (low level, mid level and upper level). At low level, the average values of T, were higher during the dry months of November – March with an average value of 292.18 K, and slightly dropped till it gets to minimum values in the months of July/August with an average value of 289.50 K in the coastal region. The average value during the rainy months here is 290.47 K. In Guinea savannah, variation of T follows the same pattern as that of coastal regions. The values were higher during the dry season and low during the rainy season. Their values during these periods are 293.60 and 291.49 K. The dip is noticed in August with an average value of 289.84 K. In midland region, T gradually increases from January and attain its maximum in March/April. The value suddenly drops to minimum values in August with a value of 291.14 K and partially rises again. Its average values during the rainy and dry season are 292.26 and 294.39 K

Table 1. Analysis result of relative humidity over Nigeria.

Region	Low level					Mid level					Upper level				
	Mean RH	Max RH (%)	Min RH (%)	ΔRH (%)	SE	Mean RH	Max RH (%)	Min RH (%)	ΔRH (%)	SE	Mean RH	Max RH (%)	Min RH (%)	ΔRH (%)	SE
Coastal	87.47	92.07	74.22	17.85	1.51	66.54	75.65	52.22	23.43	2.54	66.54	58.17	34.69	23.48	2.55
Guinea savannah	82.69	91.77	66.5	25.27	2.39	64.26	79.5	47.16	32.34	2.21	64.26	64.28	39.81	24.47	2.02
Midland	65.31	90.91	34.72	56.19	6.47	59.57	78.49	42.02	36.47	4.27	59.57	59.21	42.02	17.19	2.74
Sub sahel	48.82	89.08	16.57	72.51	8.15	49.32	74.56	31.15	43.41	4.70	49.32	57.63	37.84	19.79	2.09

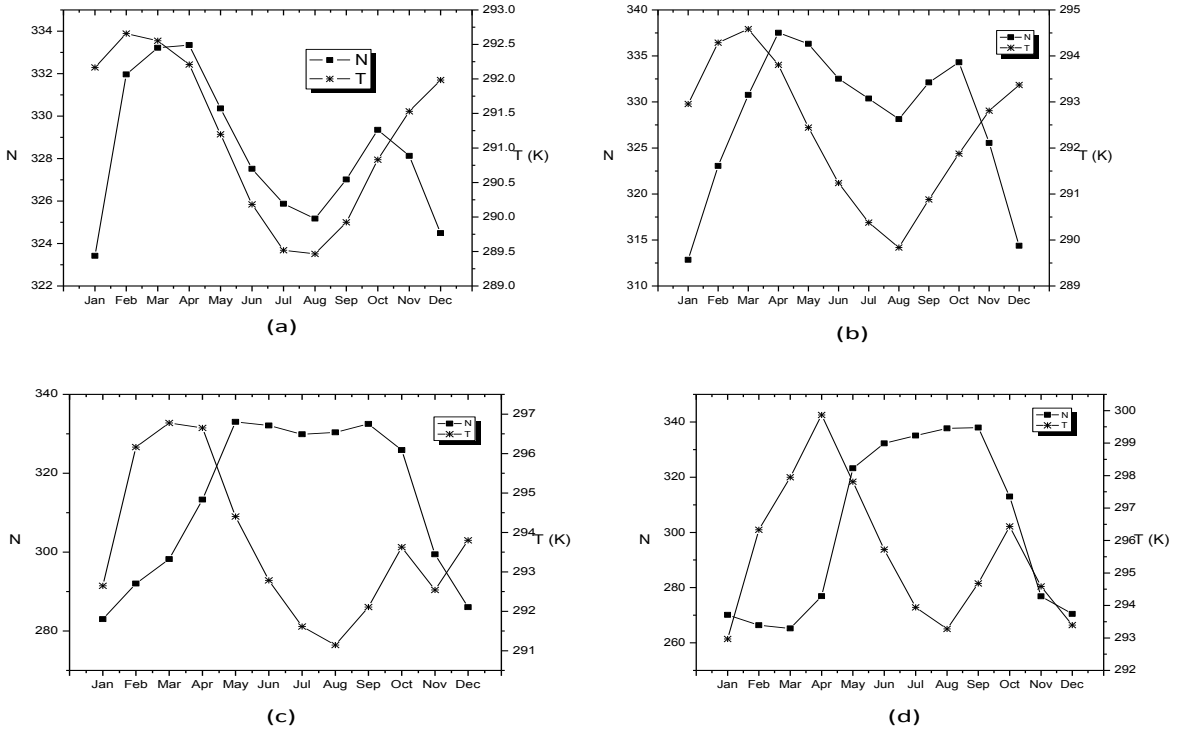

Figure 5. Monthly variation of Refractivity and Temperature at Low Level in (a) Coastal (b) Guinea savannah (c) Midland and (d) Sub sahel regions.

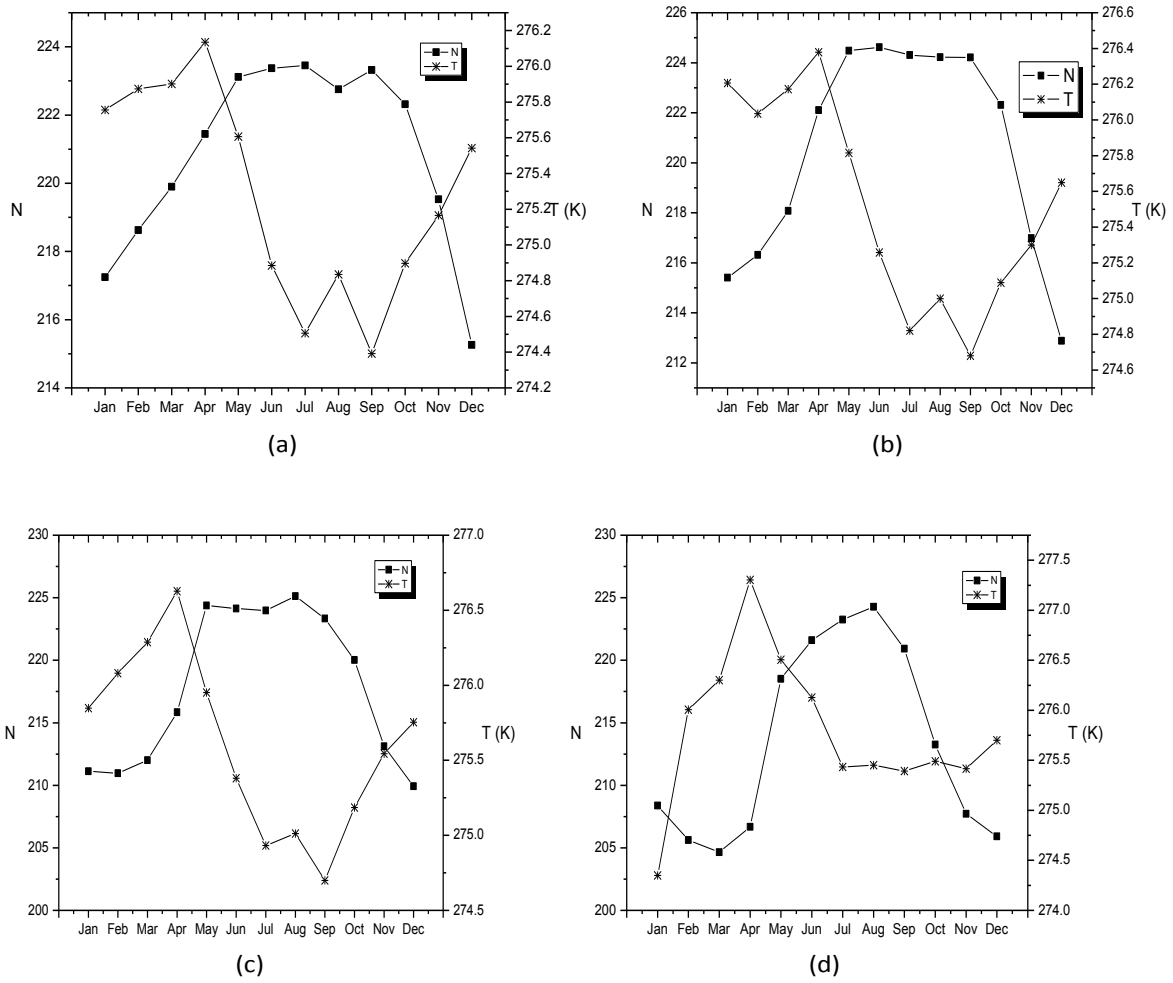

Figure 6. Monthly variation of Refractivity and Temperature at Mid Level in (a) Coastal (b) Guinea savannah (c) Midland and (d) Sub sahel regions.

respectively. The variation in the sub Sahel region is a little bit similar to that of midland region. Here two peaks are discernible; the major one in April with an average value of 299.87 K and minor in October with an average value of 296.43 K. The dip in between is noticed in August with an average value of 293.28 K. At mid level (Figure 6) monthly variations of T in coastal and Guinea savannah regions are similar. The variation does not have a particular pattern (Figure 6a and b). The behavior of T, at midland region is shown in Figure 6c. The values of T rise gradually from January to a peak in April and started descending until it reach its minimum in July. It partially rises in August and fall the remaining months of the year. In the sub Sahel region, the value of T is low in January, and it gradually rises to a maximum in April before it falls and reaches a minimum value in July. The value of T is almost constant for the remaining of the year. Figure 7a to d shows the monthly variation of T and N at the upper level, the behavior of T is almost the opposite of N in all the regions. This shows greater dependence of N on T at this level.

Statistic variation of relative humidity, temperature and refractivity

Tables 1, 2 and 3 show the statistical analysis results of relative humidity, temperature and refractivity, respectively. The result includes mean value, maximum value (max), the minimum value (min), differences (∆RH) and standard error (SE) of the above parameters. Mean value of relative humidity is higher in the southern Nigeria (coastal and Guinea savannah regions) than the northern part (midland and sub Sahel regions) at low level and mid level (Table 1). Higher range of relative humidity (∆RH) is also recorded in the northern part. This may be attributed to high and low rainfall witness in the southern regions and Northern regions, respectively. This is in line with

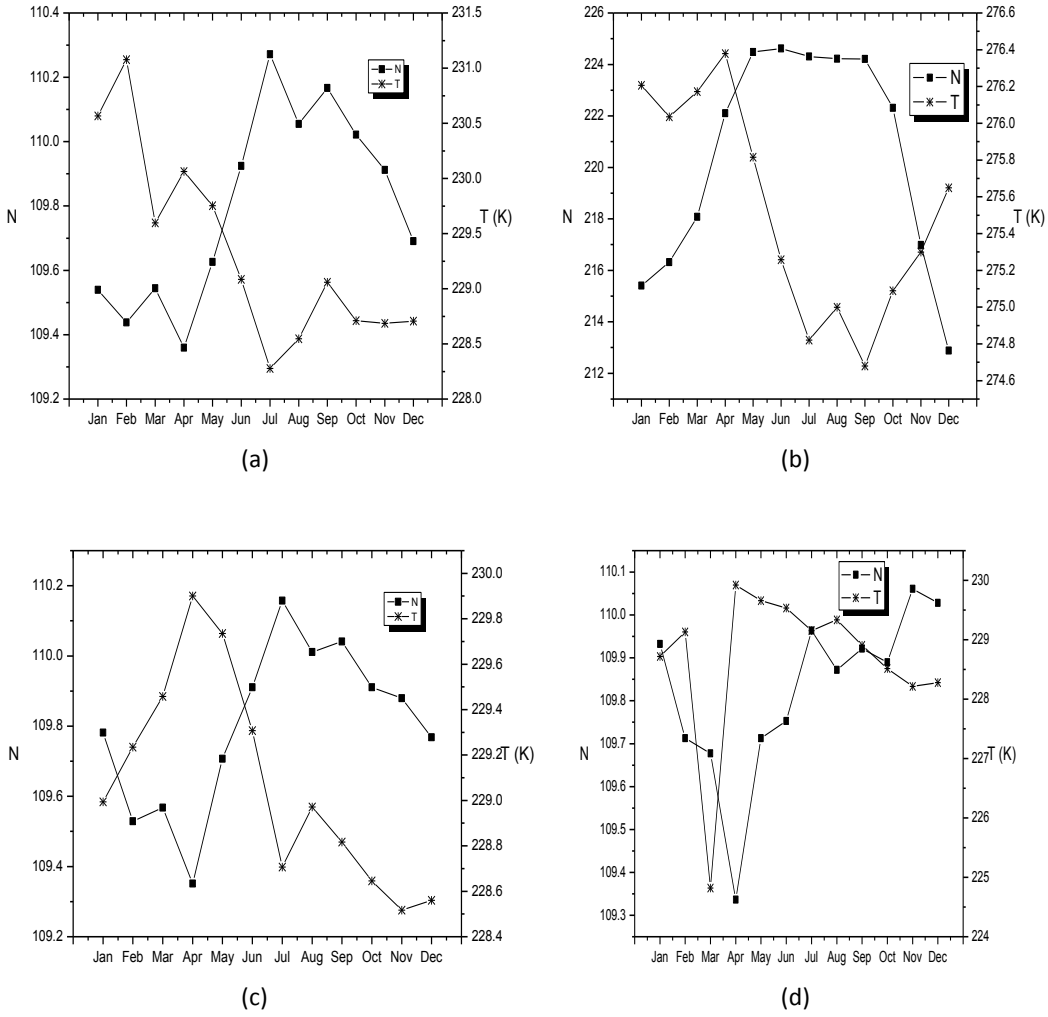

Figure 7. Monthly variation of Refractivity and Relative Temperature at Upper Level in (a) Coastal (b) Guinea savannah (c) Midland and (d) Sub Sahel regions.

finding of Olusina and Odumade (2012). Temperature values are higher in the northern regions than the southern regions (Table 2). From Table 3, high values in variation of refractivity were noticed in the northern regions.

Conclusion

Using satellite data from CM – SAF, it has been established that monthly variation of refractivity is majorly influenced by relative humidity and temperature which also vary geographically and seasonally. At low level and mid level, relative humidity and refractivity decreases northward while temperature increases northward. The dip noticed (in August) in monthly variation of relative humidity and refractivity in coastal and Guinea savannah regions at low level may be associated to the August break (a short period of dryness). This break (known as the intra-monsoonal period) is believed to be a consequence of several factors such as coastal upwelling and the northern advance of the subtropical high pressure systems of the southern Atlantic ocean or because of the circulation aloft which becomes divergent and subsident due to frequent occurrence of inversions and isothermals in the upper atmosphere along the coast when the weather zone – E makes its appearance a short way inland from the coast (Adedokun, 1986; Balogun and Adedokun, 1985; Balogun, 1981; Olaniran and Sumner, 1989; Trewartha, 1970). The values of relative humidity and refractivity are partially low during the dry season and high during the rainy season in southern regions and much lower in the dry month at northern regions.

There is a unique variation in the ranges of these parameters (relative humidity, temperature and refractivity) over the four regions in the country.

Table 2. Analysis result of temperature over Nigeria.

Region	Low level					Mid level					Upper level				
	Mean	Max T (K)	Min T (K)	ΔT (K)	SE	Mean	Max T (K)	Min T (K)	ΔT (K)	SE	Mean	Max T (K)	Min T (K)	ΔT (K)	SE
Coastal	291.18	292.65	289.46	3.19	0.34	275.29	276.13	274.39	1.74	0.17	229.34	231.08	228.71	2.37	0.25
Guinea savannah	292.21	292.95	287.51	5.44	0.44	275.53	276.21	274.68	1.53	0.17	229.04	229.98	228.53	1.45	0.14
Midland	293.69	296.78	291.14	5.64	0.56	275.61	276.63	274.7	1.93	0.17	229.07	229.73	228.51	1.22	0.13
Sub Sahel	295.58	299.87	293.97	5.90	0.63	275.79	277.3	274.35	2.95	0.21	228.68	229.91	228.21	1.7	0.38

Table 3. Analysis result of refractivity over Nigeria.

Region	Low level					Mid level					Upper level				
	Mean N	Max N	Min N	ΔN	SE	Mean N	Max N	Min N	ΔN	SE	Mean N	Max N	Min N	ΔN	SE
Coastal	328.32	333.35	323.42	9.93	0.97	220.86	223.45	215.26	8.19	0.79	109.80	110.27	109.36	0.91	0.08
Guinea savannah	328.16	337.51	312.85	24.66	2.30	220.49	224.47	212.88	11.59	1.23	109.78	110.15	109.34	0.81	0.07
Midland	312.99	333.05	283.00	50.05	5.75	217.83	223.97	210.97	13.00	1.79	109.80	110.16	109.35	0.81	0.07
Sub Sahel	300.42	337.97	265.18	72.79	9.13	213.40	224.26	204.66	19.60	2.24	109.82	110.06	109.33	0.73	0.06

It was observed that the ranges of the parameters increases northward at low level and mid level. This may be associated with the seasonal variation in these regions. As the southern part (coastal and Guinea savannah regions) of the country is characterized with long rainy season and short dry season, whereas the northern part (midland and sub Sahel regions) is characterized with short rainy season and long dry season (Imo and Ekpenyong, 2011). The ranges of relative humidity at low level are 17.85, 25.27, 56.19 and 72.51% in coastal, Guinea savannah, midland and sub Sahel regions, respectively at low level. For the temperature at this level, the differences are 3.19, 5.44, 5.64 and 5.9 K, respectively. This may be accounted for the variation observed in refractivity at this level. From the foregoing, the behaviour of radio wave propagation will vary from one region to the other.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the officials and management of the Department of Climate Monitoring SAF, Deutscher Wetterdienst, Offenbach, Germany for providing the data. The efforts of Dr. Joerg Schulz, who incidentally was the host of the corresponding author during his visit to CM-SAF, and Mr. Markus Jonas in making sure that the data were available in ASCI format is also greatly appreciated.

REFERENCES

Adediji AT, Ajewole MO (2008). Vertical profile of radio refractivity gradient in Akure Southwest Nigeria. Progress Electromagn. Res. 14:157-168.

Adedokun JA (1986). On a relationship for estimating precipitable water vapour aloft from surface humidity over West-Africa. J. Climatol. 6:161-172.

Adeyemi B, Aro TO (2004). Variation in surface water vapour density over four Nigeria stations. Nig. J. Pure

Appl. Phys. 3:46-55.
Adeyemi B (2004). Tropospheric radio refractivity over three radiosonde stations in Nigeria. Ife J. Sci. 6(2):167-176.
Adeyemi B (2006). Surface water vapour density and tropospheric radio refractivity linkage over three stations in Nigeria. J. Atmos. Solar-Terr. Phys. 68:1105-1115.
Adeyemi B, Emmanuel I (2011). Monitoring tropospheric radio refractivity over Nigeria using CM – SAF data derived from NOAA 15, 16 and 18 satellites. Indian J. Radio Space Phys. 40:301-310.
Balogun EE, Adedokun JA (1986). Note and correspondence on the variations in precipitable water over some West African stations during the special observation period of WAMEX. Am. Meteorol. Soc. 1(14):772-775.
Freeman RL (2007). Radio system design for telecommunications, 3rd ed., Wiley–Interscience, New York.
Guanjun G, Shukai L (2000). Study on the vertical profile of refractive index in the troposphere. Int. J. Infrared Millimeter Waves. 21(7):1103-1112.
Imo JE, Ekpenyong N (2011). Extreme climatic variability in northwestern Nigeria: An analysis of rainfall trends and patterns. J. Geogr. Geol. 3(1):51-62.
Olaniran OJ, Sumner GN (1989). A study of climate variability in Nigeria based on the onset, retreat, and length of the rainy season. Int. J. Climatol. (UK). 9:253-269.
Olaniran OJ (1983b). The onset of rainfall and the start of the growing season in Nigeria. Niger. Geogr. J. 26.
Olusina JO, Odumade OM (2012). Modeling climatic variation parameters of Nigeria using the statistical downscaling approach. FIG working week 2012, knowing to manage the territory, protect the environment, evaluate the cultural heritage, Rome, Italy, pp. 6-10.
Oyedum OD, Gambo GK (1994). Surface radio refractivity in northern Nigeria." Nig. J. Phys. 6:36-41.
Priestley JT, Hill RJ (1985). Measuring high–frequency refractive index in the surface layer. J. Atmos. Oceanic Technol. 2(2):233-251.
Trewartha GT (1970). The Earth's Problem Climates. The University of Wisconsin Press. pp. 91-110.
Willoughby AA, Aro TO, Owolabi IE (2002). Sesasonal variations of radio refractivity gradient in Nigeria, J. Atmos. Solar-Terr. Phys. 64:417-425.