Validation of Satellite and In-Situ Measurement of Variability of Surface Refractivity with Air Temperature over Nigeria.

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ABSTRACT

The atmosphere's composition greatly affects the electromagnetic waves which propagate through it. This is as a result in the fluctuations of the meteorological parameters (temperature, pressure and relative humidity) which in turn affect the atmospheric radio refractive index that depends on the meteorological parameters. In this study, the results of the variation of surface refractivity Ns with air temperature Ts were derived from the computation of surface refractivity through the measurement of meteorological parameters across six locations (Akure, Abuja, Jos, Makurdi, Port-Harcourt and Minna) in Nigeria are presented. Five years (Jan., 2006 – Dec., 2010) data of both satellite and in-situ measurement data as provided by Davies 6162 vantage pro 2 wireless stations (TRODAN) and a year satellite data NCEP-NCAR was used to validate. Results showed that the average value of Ns for Jos, Minna, Makurdi, Akure, Port-Harcourt, and Abuja is 260.93, 270.56, 275.04, 275.53, 277.91 and 268.29 N-units respectively. The average value of Ts is 297.60, 299.83, 300.60, 298.62, 297.99 and 299.16 K for respective locations. Results also showed that the Surface refractivity was higher during the wet season and low during the dry season. It was shown that, as the surface refractivity increases, so the Air temperature reduces.

Keywords: Surface refractivity, Air temperature, Communication, Meteorological parameters, Pressure, Relative humidity.

1.0 INTRODUCTION

The propagation of electromagnetic waves in the atmosphere (mainly the troposphere) is greatly affected by the composition of the atmosphere [1]. This is due to the fluctuations of atmospheric parameters like temperature, pressure and relative humidity primarily at the troposphere which is normally referred to as “the lower” part of the earth. Troposphere extends from the earth surface to an altitude of about 10 km at the earth poles and 17 km at the equator [2]. These fluctuations of the atmospheric parameters cause the refractive index of the air in this layer to vary from one point to the other. Refractivity is responsible for various phenomena in the wave propagation such as ducting and scintillation, [3] refraction and fading of electromagnetic waves.

A radio waves propagating through the earth atmosphere will 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 effect significantly impair radio communication, aero-space, environmental monitoring, disaster forecasting. Change of 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 [4]. This region exerts a considerable influence on radio waves at frequencies above 30MHz, although this effect became significant only at frequencies greater than 100MHz especially in the lower atmosphere [1]. Radio waves propagate through the atmosphere in wireless communication. They are affected by variability in radio refractivity which leads to a decrease in their rate of propagation which eventually cause propagation delay or attenuation in the troposphere. The atmospheric radio refractive index depends on air temperature, relative humidity, water vapour pressure and atmospheric pressure. In determining the coverage and quality of UHF, VHF and SHF signals, radio refractive index is an important parameter [5]. However, radio refractivity contributes to the determination of distance travel by radio signal within the visible/radio horizon [6].

Several works carried by many researchers showed that the refractivity fluctuation in the lower atmosphere (troposphere) is a function of atmospheric parameters. [7], studied variation of tropospheric refractivity at Nsukka in South Eastern Nigeria. [8], studied diurnal and seasonal variation of surface refractivity over Nigeria. [9], in his work stated that even small changes of temperature, humidity and partial water vapor pressure lead to changes in the atmospheric refractive index. [10], studied the Variability of Microwave Radio Refractivity and Field Strength over Some Selected Locations in Nigeria, [11] reported that seasonal variation of refractivity gradient could cause microwave systems unavailability. [12] studied the effect of variation of meteorological parameters on the tropospheric radio refractivity for Minna, Nigeria. [13], studied a test of the relationship between refractivity and radio signal propagation for dry particulate. [14] studied the variation of surface refractivity with air temperature over Savanah and Coastal zones of Nigeria. [15], computed radio refractivity index in the lowest 100 m layer of the troposphere in Akure, South–western Nigeria.

[16], also measured meteorological parameters of temperature, pressure and relative humidity at five different height levels beginning from the ground surface and at intervals 50 m to a height of 200 m in Akure (7.15 °N, 5.12°E). This work presents the result of validation of satellite and in – situ measurement of surface refractivity with air temperature over six locations Akure ((7.15°N, 5.12°E), Abuja (7.10°N, 9.25°E), Jos (9.50°N, 8.50°E), Ma kurdi (7.30°N, 8.53°E), Port-Harcourt (4.20°N, 7.00°E), and Minna (7.73°N, 8.54°E)) in Nigeria.

2.0 MATERIALS AND METHODS

Five years (2006-2010) meteorological variables (pressure, temperature and relative humidity) were obtained from the archived data of Akure (7.15°N, 5.12°E), Abuja (7.10°N, 9.25°E), Jos (9.50°N, 8.50°E), Makurdi (7.30°N, 8.53°E), Port-Harcourt (4.20°N, 7.00°E) and Minna (7.73°N, 8.54°E). Each of the locations is equipped with complete wireless weather equipment as provided by Tropospheric Data Acquisition Network (TRODAN). The radio refractivity, N is related to radio refractive index and from the data collected, radio refracti-vity and field strength are computed [10] as;

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

where T (K) is the air temperature, P (hPa) is air pressure and e (hPa) is water vapour pressure. Equation (1) consists of two terms: the dry term and the wet term.

$$N_{dry} = \frac{77.6\, p}{T} \quad (2)$$

$$N_{wet} = \frac{3.73 \times 10^5}{T^2} e \quad (3)$$

the dry term contributes about 70% to the total value of refractivity while the wet term is mainly responsible for its variability [17]. The water vapor e can be determined by equation (4) [18].

$$e = \frac{RH \times e_s}{100} \quad (4)$$

es is the saturation vapour pressure determined by Clausius Clapeyron equation according to [20] is given as:

$$e_s = 0.661121 e^{\left[\frac{17.502 \times t}{t + 240.97}\right]} \quad (5)$$

where t is the air temperature in degree Celsius (℃). Equation (1) may be employed for the propagation of radio frequencies up to 100GHz.

3.0 RESULTS AND DISCUSSION

3.1 Diurnal variation of surface refractivity and air temperature

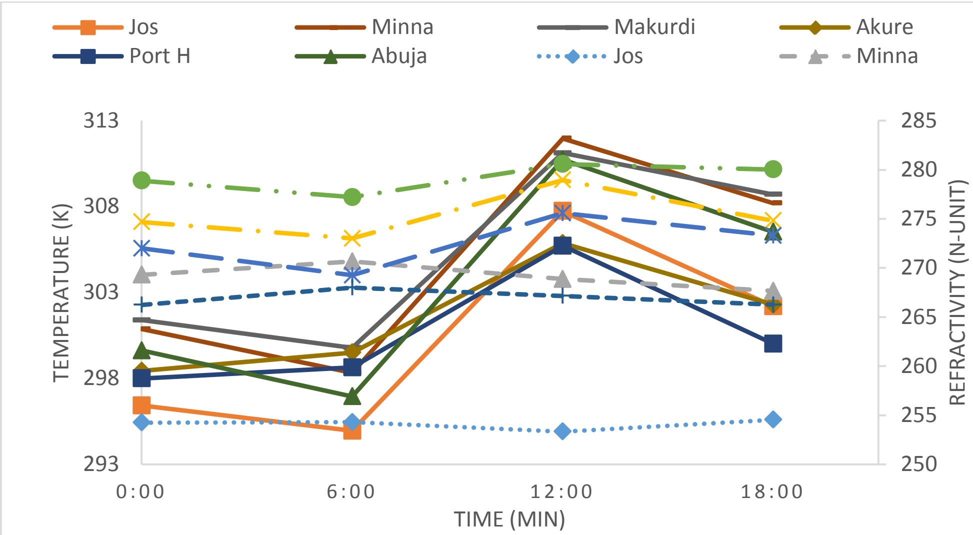

Figure 1: Diurnal of variation of surface refractivity and air temperature of a typical day (March 5th), 2010 over the locations.

Figure 1 showed the diurnal variation of surface refractivity and temperature over the locations from 2006-2010. It was observed that between 00:00 -06:00 local time (LT), there was a decrease in the values of temperature and an increase was observed in the values of refractivity. However, between 06:00 -12:00 LT, the value of temperature was increased to its maximum at exactly 12:00 h while refractivity reduced to its barest minimum value at the same LT. The reverse was the case between 12:00 -18:00 LT. This occurrence may be due to change in local meteorology and solar irradiance.

3.2.1 **Seasonal Variation of surface refractivity and air temperature.**

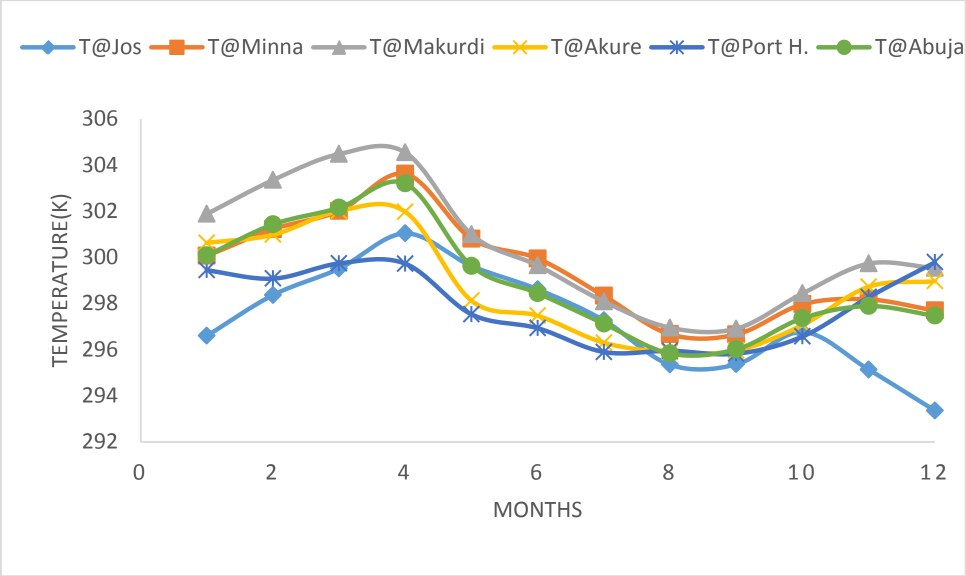

Figure 2: Seasonal Variation of air temperature over the locations.

It is seen from figure 2 that the values of temperature were increased from January to April and decreased between May and October and increased again between the months of October to December. Generally, the values of temperature were very high during the dry season months, January, February, March, November and December and low during the wet season months May, June July, August and September. This reduction may be attributed to the occurrence of high humidity and water vapour in the troposphere.

3.2.2 **Seasonal Variation of Surface refractivity over the locations.**

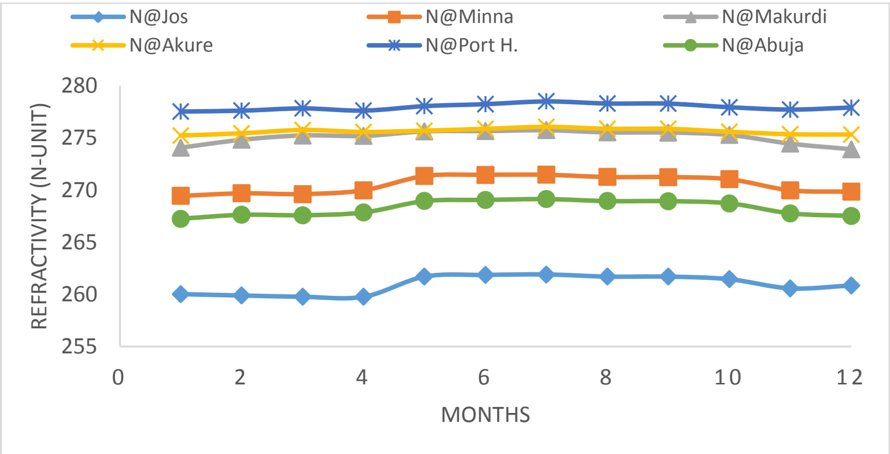

Figure 3: Seasonal Variation of surface refractivity over the locations.

It is also shown from figure 3 that the value of refractivity depicted seasonal variation with high value during the rainy season and low value during the dry season. This result is in agreement with the result by [10], [8], and [5]. It is also showed that the surface refractivity has high value at the coastal areas compared with the inland areas. This is due to the influence of the Atlantic Ocean on the coastal areas. This result supports the work of [20].

3.3. **Annual variation of Air temperature.**

Table 1: Annual variation of Air temperature

Stations	**2006 T (k)**	**2007 T (k)**	**2008 T (k)**	**2009 T(k)**	**2010 T (k)**
Jos	297.247	297.256	297.880	297.728	297.893
Minna	299.430	299.532	300.328	299.923	299.925
Makurdi	300.378	300.244	300.998	300.419	300.941
Akure	298.673	298.256	298.789	298.444	298.958
Port-Harcourt.	297.894	297.864	298.063	297.743	298.380
Abuja	298.884	298.824	299.581	299.150	299.381

Table 1 showed the annual variation of Air temperature over the locations for the period of the study. It was observed from the table that the average values of air temperature over the locations, Jos, Minna, Markurdi, Akure Port-Harcourt and Abuja are 297, 300, 300.06, 299, 298 and 299.2 k respectively. Jos which is located in the northern part of Nigeria is expected to have high temperature but recorded the least value of average temperature. This may be due to the altitude which is approximately 1217 m above sea level. At this altitude there is a decrease of about 5-6℃ in temperature.

3.4 **Comparison between the Refractivity values using TRODAN (tr) and Satellite (st)**

Table 2: Comparison between the Refractivity (Ns) values using TRODAN (tr) and Satellite (st)

Months	Ns (tr)	Ns (st)
Jan	383.17	274.72
Feb	379	275.43
March	373.68	275.36
April	375.34	275.35
May	375.49	275.58
June	374.86	275.91
July	372.9	275.94
Aug.	348.91	275.7
Sept	348.46	275.8
Oct	349.05	275.57
Nov.	348.67	275.36
Dec.	348.23	275.1

Table 3: Correlation analysis between Surface radio refractivity and the Surface air temperature

Stations	Correlation value
Jos	- 0.0047
Minna	- 0.1611
Makurdi	- 0.2900
Akure	- 0.6569
Port- Harcourt.	- 0.8570
Abuja	- 0.3907

It is observed from Table 2 that the refractivity values obtained using TRODAN are higher than those obtained through the satellite. The difference in their refractivity values may be due to vegetation, topography, residential and industrial activities. The average values of the Ns (tr) and Ns (st) are 364.81 and 275.48 N-units. Analyzing the correlation (Table 2) and observation from fig. 2 shown that the radio refractivity rises in value during the fall in the value of the air temperature, and moreover the correlation never affirms causality

4.0 CONCLUSION

Five-year (Jan. 2006-Dec. 2010) archived data and Satellite data of atmospheric variables: temperature, pressure and relative humidity obtained for Abuja, Akure, Jos, , Markurdi, Minna and Port-Harcourt locations were employed in this study. The data were used to compute the surface radio refractivity. However, some of the main findings in the study are as follows: The surface refractivity were high at the early hours of day and very low between the hours of 12:00 LT and 16:00 LT and also high at late night in all the locations for this study. Seasonal surface refractivity shows a seasonal variation with high values in the wet season months and low values in the dry season months over Nigeria. The value of temperature was increased to its maximum at exactly 12:00 h. The mean surface refractivity value was highest in Port-Harcourt and lowest in Jos also the average values of the Ns (tr) and Ns (st) are 364.81 and 275.48 N-units respectively. The difference in the values of the surface refractivity over Nigeria is attributed to the meteorological influence of the semi-permanent climatological features, such as ITD, Sub-Tropical High Pressure (STHP) and associated monsoonal flow pattern. The variability of radio refractivity with air temperature showed an inverse law relationship.

REFERENCE

1. Korak shaha, P.N. (2003). The physics of the earth and its atmosphere, John and sons Inc., New York, USA.

2. Hall M.P.M. (1979). "Effects of the Troposphere on Radio Communication" Institute of Electrical Engineers.

3. Martin Grabner, Vaclav kvicera, (2003). "Refractive index Measurement at TV-Tower Prague". J. Radio Engineering, vol. 12 no 1, Pp 5-7.

4. Bawa M; Ayantunji B.G, Mai-unguwa H, Galadanchi G.S.M and Shamsuddeen I.M, (2015). Study of Hourly Variations of Radio Refractivity Variations across Some Selected cities in Nigeria. IOSR Journal of Applied Physics, 7(6), 37-43, ISSN: 2278-4861.

5. Adediji, A. T, Ismail M. and Mandeep J. S. (2014). Performance Analysis of Microwave Radio Refractivity on Radio Field Strength and Radio Horizon Distance Over Akure, Nigeria, Wireless Personal Communications Vol.77, No.4.ISSN: 0929-6212.

6. Adediji, Adekunle Titus, Joseph Babatunde Dada, and Moses Oludare Ajewole. "Diurnal, Seasonal and Annual Variation of Microwave Radio Refractivity Gradient over Akure, South West Nigeria." Physical Science International Journal (2019): 1-11

7. Ekpe. O. E, G. A. Agbo., B.G. Ayantunji, N. Yusuf and A. C. Onugwu (2009). Variation of Tropospheric Surface Refractivity at Nsukka in South Eastern Nigeria, Nigerian Journal of Space Research, vol. 7, 5-10

8. Ayantunji, B. G., Okeke, P. N., & Urama, J. O. (2011). Diurnal and seasonal variation of surface refractivity over Nigeria. Progress in Electromagnetics Research, 30, 201-222.

9. Norland, R., 2006. Temporal variation of the refractive index in coastal waters. In: Radar Symposium, 2006. IRS 2006. International. IEEE, pp. 1–4.

10. Adediji A. T, Adebusola S.O and Ojo J.S, (2017). Variability of Microwave Radio Refractivity and Field Strength over Some Selected Locations in Nigeria. Physical Science International Journal 14(3): 1-11, ISSN: 2348-0130

11. Salema, C., (2003). Microwave Radio Link from Theory to Design (New Jersey, Wiley) New York.

12. Okoro O. N and. Agbo, G. A., (2012). The Effect of Variation of Meteorological Parameters on the Tropospheric Radio Refractivity for Minna. Global Journals Inc. (USA), Volume 12 Issue 2 pp 1

13. Famoriji J. O. and Oyeleye M. O., (2013). A test of the relationship between refractivity and radio signal Propagation for dry particulates. Research desk. Oct-Dec 2(4). 334-338. ISSN: 2319-7315

14. Ojo O.S, Adeyemi, W. A and Abioye I.O, (2015). Variation of surface refractivity with air temperature over savannah and coastal zones of Nigeria. Proceedings of National Conference of Engineering and Technology, 1, 144-147.

15. Falodun, S. E. and M. O. Ajewole, (2006). Radio refractive index in the lowest 100 m layer of the troposphere in Akure, South-western Journal of Atmospheric and Solar terrestrial Physics, Vol. 68,236-243.

16. Adediji, A. T, and Ajewole, M. O. (2008). Vertical profile of radio refractivity gradient in Akure South-West Nigeria. Progress in Electromagnetics Research C, 4, 157-168.

17. Babin, S.M., Young, G. S. and Carton, J. A. (1997). A new model of the oceanic evaporation duct. Journal of Applied Meteorology. 36, 193–204.

18. Fuwape, I. A, Ogunjo, S. T, Dada, J. B, Ashidi, G. A, Emmanuel I. (2016). Phase synchronization between tropospheric radio refractivity and rainfall amount in a tropical region. J Atmos Solar-Terrestrial Phys 149, 46–51

19. Safdar, A., Shahzad, A., Khurram, S., Shahid, A., & Rana, L. (2012). Statistical estimation of tropospheric radio refractivity derived from 10 years meteorological data. Journal of Atmospheric and Solar-Terrestrial Physics, 77, 96-103.

20. Dhein, N. R., Pontes, M. S., & da Silva Mello, L. A. R. (1993, March). Statistical behaviour of refractivity gradient in the tropics. In 1993 Eighth International Conference on Antennas and Propagation (pp. 340-343). IET.