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# Modelling and Application of Vertical Refractivity Profile for Cross River State

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**Abstract:** In this paper six months data on primary radioclimatic parameters obtained using Radiosunde lunched by Nigerian Meteorological Agency (NIMET) in Cross River state, Nigeria is used to model the vertical radio refractivity profile. Cross River state is located at 4°57'North in latitude and 8°19'East. For each of the six months, cubic trendline equation is developed to predict the refractivity in the lower atmosphere (where height < 150 m above sea level). The cubic trendline equation can enable the determination of refractivity at any height less than 150m and also point refractivity gradient which requires the refractivity at 0 m and at 65 m above sea level. Sample point refractivity gradient for the month of January was used to demonstrate the application of the vertical refractivity profile models. From the result, the point refractivity gradient of Cross River state is 124.278 N-units in January.

**Keywords:** Radio Refractivity, Refractivity Profile, Refractivity Gradient, Point Refractivity Gradient, Refractivity Index

## 1. Introduction

Among other parameters, radio refractive index is a very important parameter in planning of wireless communication links. The ratio of the radio wave propagation velocity in free space to its velocity in a specified medium is referred to as radio refractive index [1]. Variations in the value of radio refractive index can cause the path of propagating radio wave to bend either towards the earth or away from the earth. Near the earth surface, the value of radio refractive index is equal to approximately 1.0003 at standard atmosphere conditions [1]. However, anomalous radiowave propagation is observed due to deviation and variations in atmospheric condition from the standard atmosphere conditions. Such anomalies are incident with some meteorological conditions (inversion of temperature, high evaporation and humidity, passing of the cold air over the warm surface and conversely) [3].

Generally, atmospheric radio refractive index depends on the following primary radioclimatic parameters, namely; atmospheric pressure, humidity, air temperature, and water vapour pressure. Additionally, atmospheric pressure, humidity and air temperature vary with height above the ground surface. Little changes in any of the primary radioclimatic parameters can have significant influence on radiowave propagation [4]. In a well–mixed atmosphere, pressure, temperature and humidity decrease exponentially as a function of height *h* [5]. The value of radio refractive index is very close to unit and the changes in this value are very small in time and space. With the aim of making them more visible, the term refractivity, *N*, is used [1- 8].

The vertical profiles of refractive index values in the first 1 km interval above ground are important for the estimation of super–refraction and ducting phenomena and their effects on radar observations and VHF field strength at points beyond the horizon [9]. The vertical gradient of the refractive index is responsible for bending of propagation direction of the electromagnetic wave [12]. If it is negative, the signal bends downward.

It was mentioned in [9], that standard or normal propagation conditions of the radar beam (i.e. vertical refractivity gradients around -40 $km^{-1}$ for the first kilometer above sea level) are considered to be the most representative. Accordingly, studies on vertical profiles of the refractive index have been presented in several studies in different parts of the globe [2], [11-16]. The main goals of this paper is to develop model that can effectively define the variation of radio refractivity with height above ground for a location in Cross River state based on radiosunde meteorological data obtained in Cross River state.

# 2. Methodology

### *2.1. Study Area*

The study area for this work is a location in Cross River state in the South South region of Nigeria. Cross River state is located at 4°57'North in latitude and 8°19'East in longitude. The southern part of Nigeria experiences heavy and abundant rainfall. The storms are usually conventional in nature due to the regions proximity to the equatorial belt. The annual rainfall received in this region is very high, usually above the 2000mm (78.7in) rainfall totals applicable to tropical rainforest climate worldwide.

### *2.2. Data*

In this paper, Radiosunde data from Nigerian Meteorological Agency (NIMET) for Cross River state is used. Six (6) months data for the year 2013 is used. The data contains the monthly data of temperature, pressure and relative humidity for various altitudes above sea level for the first 6 months in the year 2013.

### *2.3. Determination of Atmospheric Radio Refractivity*

Atmospheric radio refractivity is estimated from the Radiosunde data. The data used are the primary clear-air radioclimatic parameters, namely; temperature, pressure and relative humidity. The refractivity is computed according to the ITU-R P.453-9 model given as [19-23]:

$$N = N_{dry} + N_{wet} = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) \quad (1)$$

The dry term of the radio refractivity is given as [22-24];

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

The wet term of the radio refractivity is given as [22-24];

$$N_{wet} = \frac{77.6}{T}\left(4810\frac{e}{T}\right) = 3.73256(10^5)\frac{e}{T^2} \quad (3)$$

Where T is the atmospheric temperature in kelvin, P is the total atmospheric pressure in hpa and e is the water vapour pressure in hpa. The water vapour pressure is determined with the expression [2], [19-22], [26]:

$$e = \frac{6.112H}{100}\exp\left(\frac{17.5t}{t+240.9}\right) \quad (4)$$

where H is the relative humidity and t is the atmospheric temperature in Kelvin

### *2.4. Determination of Radio Refractivity Gradient and Point Refractivity Gradient*

Radio refractivity gradient is expressed as a function of height as follows [19-22]:

$$\frac{dN}{dh} = \frac{N2-N1}{h2-h1} \quad (5)$$

where N1 and N2 are the refractivity at heights h1 and h2 respectively.

The vertical refractivity gradient in the lowest 100 meters of the troposphere above the ground is an important parameter to estimate propagation effects such as ducting, surface reflection, effective earth radius factor and multipath fading on terrestrial line-of-sight links [21]. The point refractivity, dN1 is obtained from two refractivity values, Ns, (surface refractivity), and N1 (refractivity within 100 m height above the ground) [21]. In most cases, dN1 is the point refractivity gradient in the lowest 65 m of the atmosphere not exceeded for 1% of an average year [22-24]. The dN1 value is obtained using Eq 6, where N1 is calculated considering the h1 value nearest to 65 m height, so that 60 m < h1 < 70 m [21], [24-26].

$$dN1 = \frac{Ns-N1}{hs-h1} \quad (6)$$

The effective earth radius factor (k-factor) is also determined from the value of refractivity gradient as follows [21], [25-27];

$$k = \left[1 + \frac{\left(\frac{dN}{dh}\right)}{157}\right]^{-1} \quad (7)$$

The Geoclimatic factor, K (for quick planning) can be determined based on the procedure given in ITU-R. P 530-14 where dN 1 is the point refractivity gradient in the lowest 100 m of the atmosphere not exceeded for 1% of an average year considered in this work as [21], [28]:

$$k = 10^{-4.2-0029dN1} \quad (8)$$

Vertical refractive profile model can be developed from the available data to facilitate the estimation of the vertical profile of refractivity and hence the vertical profile of refractivity gradient. In this work, a cubic regression model is fitted to the vertical refractivity profile data for Cross River state. The cubic model is then used to estimate the refractivity at any height within the lower atmosphere.

# 3. Results and Discussion

The Radiosunde data for Cross River state for the months of January to June 2013 are presented in Table 1. From the data in Table 1 and the Radiosunde data for the other months, the temperature and pressure drop with height. However, the relative humidity do not have any specific linear relationship with height.

***Table 1.*** *The Radiosunde Data For Cross River state For The Months Of January and February 2013.*

| **JANUARY** | | | | **February** | | | |
|---|---|---|---|---|---|---|---|
| **P[hPa]** | **T[C]** | **H[%]** | **Altitude[m]** | **P[hPa]** | **T[C]** | **H[%]** | **Altitude[m]** |
| 1013.1 | 31.5 | 66 | 0 | 1014.2 | 31.9 | 58 | 0 |
| 1006.7 | 30.3 | 84 | 44.3 | 1009 | 30.2 | 61 | 47.7 |
| 994.2 | 28.9 | 75.3 | 169.6 | 998.8 | 29.2 | 66.4 | 138.3 |
| 921.8 | 22.7 | 83.2 | 837.3 | 940.9 | 24.1 | 79.9 | 667.1 |

| JANUARY | | | | February | | | |
|---|---|---|---|---|---|---|---|
| P[hPa] | T[C] | H[%] | Altitude[m] | P[hPa] | T[C] | H[%] | Altitude[m] |
| 836.6 | 18.4 | 76.1 | 1683.9 | 854.5 | 21.5 | 30.4 | 1507.2 |
| 753.5 | 13.1 | 77.7 | 2575.8 | 777.8 | 15.5 | 35.6 | 2315.8 |
| 686.6 | 9.7 | 51.2 | 3355.4 | 710.1 | 10.1 | 39.3 | 3082.1 |
| 615.5 | 3.9 | 55 | 4259.4 | 647.8 | 6.7 | 56.1 | 3845.2 |
| 545.8 | -2.5 | 37 | 5225.4 | 589.8 | 1.1 | 45.3 | 4609.8 |
| 489.9 | -5.1 | 23.9 | 6081.9 | 534.8 | -2.2 | 29.2 | 5396.6 |
| 440.9 | -11.6 | 24.2 | 6902.6 | 482.8 | -6.4 | 22.4 | 6207.5 |
| 393.2 | -16.4 | 23.4 | 7777.6 | 436 | -12.7 | 23 | 6998.6 |
| 351.7 | -21.1 | 18.8 | 8612.8 | 392.4 | -16.4 | 18.3 | 7799.7 |
| 312.5 | -29 | 22 | 9477.7 | 350.5 | -22.1 | 16.1 | 8645 |
| 274.8 | -37.7 | 35.4 | 10382.8 | 312.4 | -29.9 | 15.8 | 9480.9 |
| 239.8 | -45.4 | 32.7 | 11310.5 | 277.5 | -37.7 | 16.4 | 10317.1 |
| 207.7 | -51.7 | 22.8 | 12257.7 | 243.3 | -45.6 | 16.7 | 11208.1 |
| 180.7 | -59.4 | 26 | 13151.1 | 210.9 | -52.2 | 16.6 | 12155.6 |
| 156.3 | -66.1 | 22.2 | 14053.9 | 181.6 | -60.2 | 16 | 13108.2 |
| 135.5 | -72.7 | 23 | 14908.4 | 154.7 | -68.8 | 14.9 | 14095.5 |
| 120.9 | -76.1 | 25.1 | 15575.4 | 137.5 | -73.7 | 15.1 | 14804.6 |

***Table 2.*** *Vertical Profile Of Refractivity in Cross River state For The Month of January.*

| Altitude[m] | DRY N | WET N | N | Altitude[m] | DRY N | WET N | N |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 8543.186 | 8543.186 | 7777.6 | 2036.241 | 476.1707 | 2512.411 |
| 379.8 | 85.13137 | 10725.07 | 10810.2 | 8203.8 | 2131.999 | 505.6543 | 2637.653 |
| 837.3 | 182.4101 | 14544.05 | 14726.46 | 8612.8 | 2290.45 | 331.2809 | 2621.731 |
| 1268.8 | 281.9556 | 10828.85 | 11110.81 | 9042.9 | 2402.359 | 317.6978 | 2720.057 |
| 1683.9 | 374.3072 | 10284.67 | 10658.98 | 9477.7 | 2493.117 | 350.9344 | 2844.051 |
| 2142.7 | 472.0997 | 10887.21 | 11359.31 | 9929.4 | 2562.426 | 444.9995 | 3007.425 |
| 2575.8 | 569.9518 | 9809.42 | 10379.37 | 10382.8 | 2612.533 | 614.2013 | 3226.735 |
| 2973.8 | 661.792 | 8709.949 | 9371.741 | 10833.7 | 2704.939 | 645.6168 | 3350.556 |
| 3355.4 | 803.1432 | 3164.098 | 3967.241 | 11310.5 | 2871.098 | 469.3247 | 3340.423 |
| 3772.4 | 875.4134 | 4594.783 | 5470.196 | 11796.2 | 2980.74 | 467.7199 | 3448.459 |
| 4259.4 | 1007.712 | 3333.483 | 4341.195 | 12257.7 | 3215.678 | 243.549 | 3459.227 |
| 4741.6 | 1153.443 | 2126.025 | 3279.467 | 12735.1 | 3330.784 | 237.5091 | 3568.294 |
| 5225.4 | 1308.036 | 1318.034 | 2626.07 | 13151.1 | 3413.128 | 251.1782 | 3664.306 |
| 5658.4 | 1398.827 | 1501.264 | 2900.091 | 13597 | 3573.069 | 192.0944 | 3765.163 |
| 6081.9 | 1589.611 | 609.3547 | 2198.965 | 14053.9 | 3694.386 | 177.4353 | 3871.821 |
| 6496.2 | 1709.99 | 516.3322 | 2226.322 | 14472 | 3795.293 | 171.8879 | 3967.181 |
| 6902.6 | 1802.294 | 557.2475 | 2359.541 | 14908.4 | 3908.418 | 160.6065 | 4069.025 |
| 7329.8 | 1939.947 | 424.4377 | 2364.385 | 15347.2 | 4009.908 | 157.1864 | 4167.095 |
| 7777.6 | 2036.241 | 476.1707 | 2512.411 | 15575.4 | 4054.515 | 160.2759 | 4214.791 |

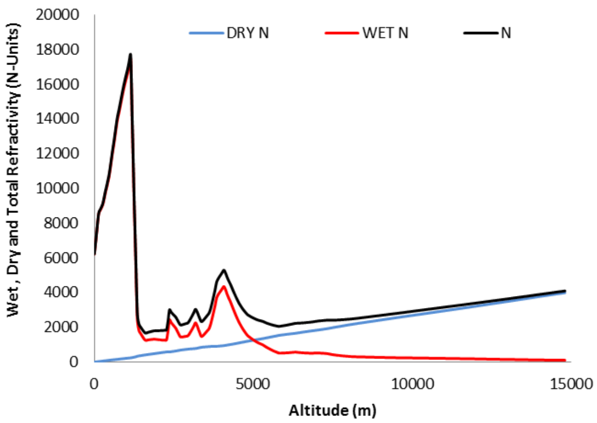


***Figure 1.*** *Vertical Profile Of Refractivity in Cross River state For The Month of January.*

The refractivity profile for the months of January to June are given in Tables 2 to Table 7. For each of the months, the vertical profile graph and the corresponding cubic regression model are given.

From the data in Table 2, the vertical profile of refractivity for January in Cross River state is given as;

$$N(h) = 0.0118(h^3) - 3.7778(h^2) + 319.98(h) + 8543.2 \quad (9)$$

From the vertical refractivity profile, the point refractivity gradient can be computed. Point refractivity gradient is computed with refractivity at the height of 0 m and 65 m as follows:

$dN1 = \frac{N(h2) - N(h1)}{h2 - h1} = \frac{N(65) - N(0)}{65 - 0}$. For example, for the month of January, dN1 is given as;

$$N(h) = 0.0118(h^3) - 3.7778(h^2) + 319.98(h) + 8543.2$$

$$N(65) = 0.0118(65^3) - 3.7778(65^2) + 319.98(65) + 8543.2 = 16621.27$$

$$N(0) = 8866.548$$

$$dN1 = \frac{16621.27 - 8866.548}{65 - 0} = 124.278$$

$$= 124.278$$

***Table 3.*** *Vertical Profile Of Refractivity in Cross River state For The Month of February.*

| Altitude[m] | DRY N | WET N | N | Altitude[m] | DRY N | WET N | N |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 6219.819 | 6219.819 | 872.1 | 189.1947 | 15264.73 | 15453.92 |
| 47.7 | 11.0824 | 6988.034 | 6999.116 | 925.3 | 200.1206 | 15743.43 | 15943.55 |
| 91.6 | 21.09246 | 7831.152 | 7852.245 | 981.5 | 211.6854 | 16177.78 | 16389.47 |
| 138.3 | 31.62074 | 8553.71 | 8585.331 | 1037.8 | 223.2694 | 16566.35 | 16789.62 |
| 185.1 | 42.23393 | 8743.167 | 8785.401 | 1090.3 | 233.9156 | 17022.36 | 17256.27 |
| 228.8 | 52.11294 | 8901.335 | 8953.448 | 1142.1 | 244.4207 | 17431.04 | 17675.46 |
| 271 | 61.59813 | 9098.544 | 9160.142 | 1193.3 | 260.4784 | 13645.24 | 13905.72 |
| 308.1 | 69.8264 | 9406.613 | 9476.439 | 1246.7 | 279.9303 | 9527.636 | 9807.566 |
| 348.6 | 78.75214 | 9759.805 | 9838.557 | 1300.3 | 302.5586 | 5940.863 | 6243.421 |
| 391.4 | 88.16441 | 10085.25 | 10173.41 | 1353.7 | 335.6138 | 2422.074 | 2757.688 |
| 431.8 | 96.98315 | 10418.6 | 10515.58 | 1404.9 | 354.9992 | 1813.411 | 2168.41 |
| 473.6 | 106.0339 | 10797.23 | 10903.27 | 1454.8 | 369.7756 | 1649.001 | 2018.776 |
| 519.9 | 115.8651 | 11386.04 | 11501.91 | 1507.2 | 385.4935 | 1490.129 | 1875.623 |
| 567.6 | 125.917 | 11995.09 | 12121.01 | 1559.3 | 401.3323 | 1344.545 | 1745.877 |
| 616.5 | 136.181 | 12583.6 | 12719.78 | 1610.5 | 416.3051 | 1249.777 | 1666.082 |
| 667.1 | 146.6902 | 13239.68 | 13386.37 | 1661.1 | 428.9563 | 1262.02 | 1690.976 |
| 718.3 | 157.2801 | 13872.7 | 14029.98 | 1711.8 | 441.4612 | 1280.894 | 1722.355 |
| 770.1 | 168.1006 | 14326.04 | 14494.14 | 1765.6 | 454.8823 | 1293.084 | 1747.966 |
| 820.8 | 178.6149 | 14791.08 | 14969.69 | 1817.4 | 467.762 | 1305.293 | 1773.055 |

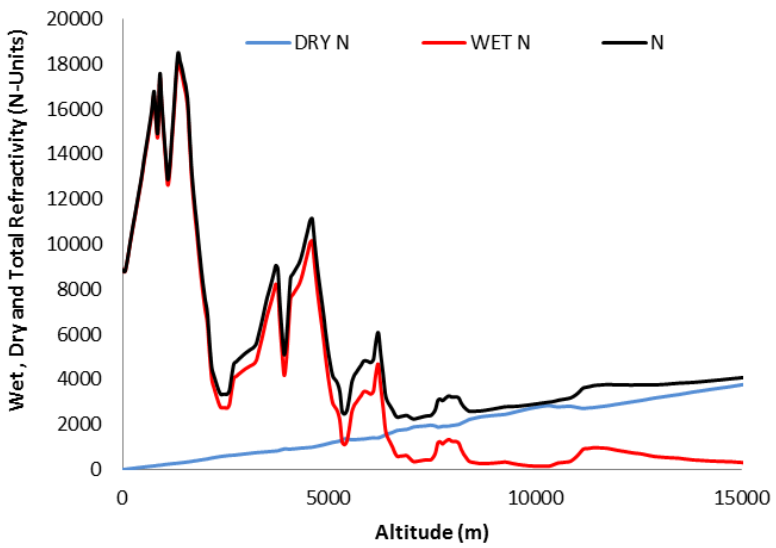


***Figure 2.*** *Vertical Profile Of Refractivity in Cross River state For The Month of February.*

***Table 4.*** *Vertical Profile Of Refractivity in Cross River state For The Month of March.*

| Altitude[m] | DRY N | WET N | N | Altitude[m] | DRY N | WET N | N |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 8866.548 | 8866.548 | 8206.5 | 2055.598 | 887.5794 | 2943.178 |
| 359.9 | 80.04655 | 11859.72 | 11939.77 | 8677.4 | 2339.702 | 261.8139 | 2601.516 |
| 806.1 | 174.7789 | 15447.24 | 15622.02 | 9144.9 | 2428.625 | 315.0359 | 2743.661 |
| 1191.9 | 258.8621 | 14485.17 | 14744.03 | 9635.6 | 2610.763 | 211.6411 | 2822.404 |
| 1582.7 | 339.8382 | 15891.69 | 16231.53 | 10111.1 | 2790.261 | 145.1396 | 2935.4 |
| 2000.7 | 456.4961 | 7084.798 | 7541.294 | 10556.2 | 2779.644 | 296.2106 | 3075.855 |
| 2428.5 | 591.6848 | 2748.216 | 3339.9 | 11042.4 | 2747.324 | 660.187 | 3407.511 |
| 2860.7 | 672.4942 | 4304.809 | 4977.303 | 11514.2 | 2775.713 | 971.1672 | 3746.88 |
| 3293.2 | 760.3461 | 5209.482 | 5969.828 | 11981.1 | 2899.075 | 858.6756 | 3757.751 |
| 3711.9 | 823.9229 | 8233.292 | 9057.215 | 12430 | 3028.471 | 726.7623 | 3755.233 |
| 4121.4 | 915.6045 | 7748.797 | 8664.401 | 12890.1 | 3174.458 | 579.4312 | 3753.889 |
| 4542.6 | 983.8285 | 10066.87 | 11050.7 | 13362.4 | 3299.148 | 518.1093 | 3817.257 |
| 4978.6 | 1151.533 | 4138.031 | 5289.564 | 13854.3 | 3448.023 | 425.502 | 3873.525 |
| 5431.8 | 1362.339 | 1247.411 | 2609.75 | 14327.1 | 3578.317 | 373.5873 | 3951.904 |
| 5899.2 | 1371.003 | 3457.958 | 4828.961 | 14861.8 | 3719.044 | 331.7016 | 4050.746 |
| 6369.2 | 1547.432 | 1762.376 | 3309.809 | 15377.7 | 3876.899 | 271.9793 | 4148.878 |
| 6826.4 | 1772.26 | 615.4629 | 2387.723 | 15812.4 | 3964.595 | 273.9333 | 4238.529 |
| 7293.7 | 1933.03 | 417.1733 | 2350.203 | 16032.2 | 4051.119 | 234.6989 | 4285.818 |
| 7752.5 | 1917.126 | 1140.44 | 3057.565 | 55.8 | 12.73928 | 8780.174 | 8792.913 |

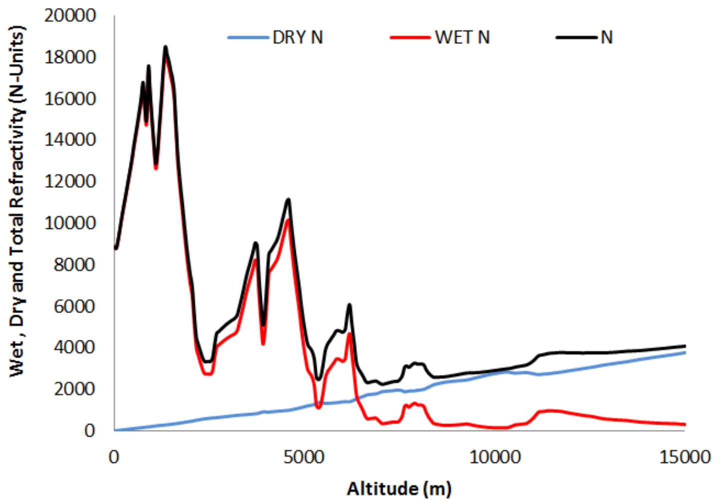


***Figure 3.*** *Vertical Profile Of Refractivity in Cross River state For The Month of March.*

***Table 5.*** *Vertical Profile Of Refractivity in Cross River state For The Month of April.*

| Altitude[m] | DRY N | WET N | N | Altitude[m] | DRY N | WET N | N |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 8866.548 | 8866.548 | 8206.5 | 2055.598 | 887.5794 | 2943.178 |
| 359.9 | 80.04655 | 11859.72 | 11939.77 | 8677.4 | 2339.702 | 261.8139 | 2601.516 |
| 806.1 | 174.7789 | 15447.24 | 15622.02 | 9144.9 | 2428.625 | 315.0359 | 2743.661 |
| 1191.9 | 258.8621 | 14485.17 | 14744.03 | 9635.6 | 2610.763 | 211.6411 | 2822.404 |
| 1582.7 | 339.8382 | 15891.69 | 16231.53 | 10111.1 | 2790.261 | 145.1396 | 2935.4 |
| 2000.7 | 456.4961 | 7084.798 | 7541.294 | 10556.2 | 2779.644 | 296.2106 | 3075.855 |
| 2428.5 | 591.6848 | 2748.216 | 3339.9 | 11042.4 | 2747.324 | 660.187 | 3407.511 |
| 2860.7 | 672.4942 | 4304.809 | 4977.303 | 11514.2 | 2775.713 | 971.1672 | 3746.88 |
| 3293.2 | 760.3461 | 5209.482 | 5969.828 | 11981.1 | 2899.075 | 858.6756 | 3757.751 |
| 3711.9 | 823.9229 | 8233.292 | 9057.215 | 12430 | 3028.471 | 726.7623 | 3755.233 |
| 4121.4 | 915.6045 | 7748.797 | 8664.401 | 12890.1 | 3174.458 | 579.4312 | 3753.889 |
| 4542.6 | 983.8285 | 10066.87 | 11050.7 | 13362.4 | 3299.148 | 518.1093 | 3817.257 |
| 4978.6 | 1151.533 | 4138.031 | 5289.564 | 13854.3 | 3448.023 | 425.502 | 3873.525 |
| 5431.8 | 1362.339 | 1247.411 | 2609.75 | 14327.1 | 3578.317 | 373.5873 | 3951.904 |
| 5899.2 | 1371.003 | 3457.958 | 4828.961 | 14861.8 | 3719.044 | 331.7016 | 4050.746 |
| 6369.2 | 1547.432 | 1762.376 | 3309.809 | 15377.7 | 3876.899 | 271.9793 | 4148.878 |
| 6826.4 | 1772.26 | 615.4629 | 2387.723 | 15812.4 | 3964.595 | 273.9333 | 4238.529 |
| 7293.7 | 1933.03 | 417.1733 | 2350.203 | 16032.2 | 4051.119 | 234.6989 | 4285.818 |

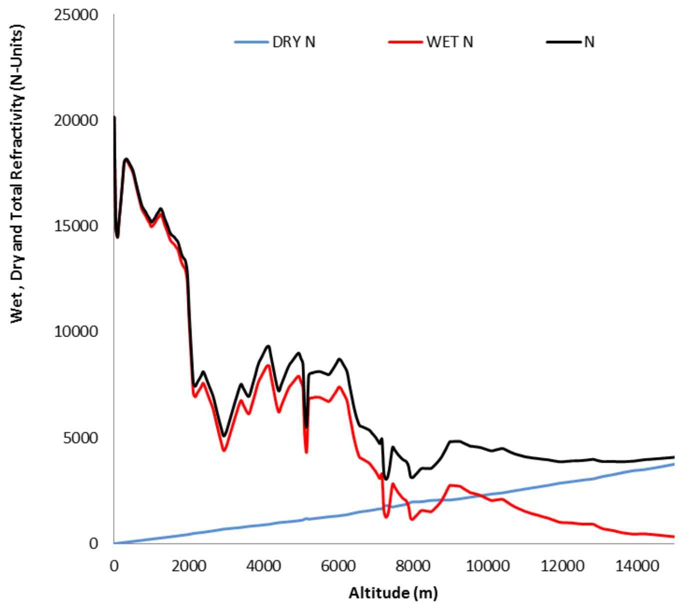


***Figure 4.*** *Vertical Profile Of Refractivity in Cross River state For The Month of April.*

***Table 6.*** *Vertical Profile Of Refractivity in Cross River state For The Month of MAY.*

| Altitude[m] | DRY N | WET N | N | Altitude[m] | DRY N | WET N | N |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 25936.03 | 25936.03 | 5815.1 | 1236.984 | 10670.82 | 11907.81 |
| 327.1 | 70.23509 | 18375.18 | 18445.42 | 6066.3 | 1296.818 | 9748.188 | 11045.01 |
| 727.8 | 169.7544 | 6136.614 | 6306.368 | 6274.4 | 1344.267 | 9244.398 | 10588.67 |
| 1180.2 | 284.6861 | 3668.027 | 3952.713 | 6521.7 | 1397.636 | 8929.239 | 10326.87 |
| 1532.9 | 369.3047 | 3584.856 | 3954.161 | 6778 | 1460.63 | 8087.626 | 9548.256 |
| 1861.2 | 443.851 | 3981.409 | 4425.26 | 7031.8 | 1520.389 | 7519.533 | 9039.922 |
| 2245.9 | 521.3337 | 5503.09 | 6024.423 | 7266.7 | 1572.054 | 7242.271 | 8814.326 |
| 2579.1 | 590.5523 | 6341.279 | 6931.831 | 7581.4 | 1646.101 | 6650.847 | 8296.948 |
| 2948 | 659.6448 | 8170.46 | 8830.105 | 7988.9 | 1742.869 | 5947.759 | 7690.628 |
| 3331.7 | 738.0529 | 8860.635 | 9598.688 | 8377.3 | 1833.79 | 5417.5 | 7251.29 |
| 3681.6 | 808.868 | 9405.121 | 10213.99 | 8690.2 | 1913.62 | 4822.581 | 6736.201 |
| 4035.7 | 874.7774 | 10634.54 | 11509.32 | 9051.1 | 2017.132 | 3955.602 | 5972.734 |
| 4331.1 | 932.2978 | 11146.71 | 12079.01 | 9355.5 | 2119.669 | 3072.852 | 5192.521 |
| 4676.1 | 991.9775 | 12707.04 | 13699.02 | 9694.5 | 2191.358 | 3020.705 | 5212.063 |
| 4965.5 | 1050.498 | 12657.03 | 13707.53 | 10082.4 | 2275.725 | 2914.84 | 5190.565 |
| 5196.1 | 1101.687 | 11989.53 | 13091.21 | 10408.1 | 2364.369 | 2562.849 | 4927.218 |
| 5395.7 | 1147.455 | 11287.27 | 12434.73 | 10715.7 | 2434.958 | 2442.694 | 4877.652 |
| 5574.7 | 1185.846 | 10998.64 | 12184.48 | 11087.1 | 2520.091 | 2305.84 | 4825.93 |

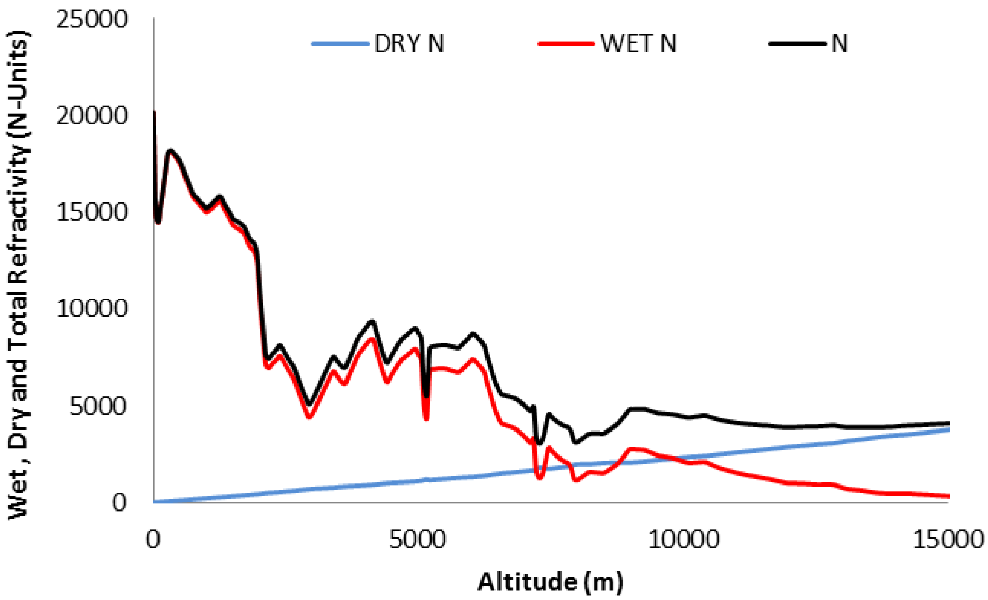


***Figure 5.*** *Vertical Profile Of Refractivity in Cross River state For The Month of MAY.*

***Table 7.*** *Vertical Profile Of Refractivity in Cross River state For The Month of JUNE.*

| Altitude[m] | DRY N | WET N | N | Altitude[m] | DRY N | WET N | N |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 20152.33 | 20152.33 | 7513.6 | 1752.496 | 2680.209 | 4432.705 |
| 322.1 | 69.2573 | 18113.62 | 18182.87 | 7942.2 | 1953.454 | 1205.77 | 3159.224 |
| 729.8 | 158.0588 | 15859.56 | 16017.62 | 8371.5 | 2016.227 | 1537.915 | 3554.142 |
| 1144.1 | 247.5109 | 15327.99 | 15575.5 | 8830.5 | 2061.513 | 2221.241 | 4282.753 |
| 1549.4 | 335.9414 | 14233.4 | 14569.34 | 9274.5 | 2123.639 | 2704.851 | 4828.489 |
| 1962.5 | 428.9859 | 12282.36 | 12711.34 | 9707.9 | 2237.401 | 2337.478 | 4574.879 |
| 2382.1 | 538.9241 | 7586.51 | 8125.435 | 10183.6 | 2358.243 | 2053.051 | 4411.294 |
| 2816.9 | 654.0737 | 5123.662 | 5777.736 | 10669.8 | 2481.944 | 1804.027 | 4285.971 |
| 3243.5 | 741.3714 | 5994.732 | 6736.104 | 11169.9 | 2629.009 | 1431.765 | 4060.774 |
| 3668.9 | 830.7751 | 6435.975 | 7266.75 | 11673.7 | 2771.968 | 1178.136 | 3950.104 |
| 4091.7 | 903.574 | 8394.844 | 9298.418 | 12151.5 | 2907.667 | 986.2806 | 3893.948 |
| 4519.2 | 1011.8 | 6701.963 | 7713.763 | 12617.2 | 3017.241 | 926.1821 | 3943.423 |
| 4953.1 | 1089.766 | 7903.042 | 8992.808 | 13064.1 | 3163.102 | 725.2619 | 3888.364 |
| 5365.2 | 1188.184 | 6917.829 | 8106.013 | 13489.7 | 3307.427 | 566.5055 | 3873.933 |
| 5802 | 1280.897 | 6809.362 | 8090.259 | 13930.5 | 3452.593 | 451.2737 | 3903.866 |
| 6246.6 | 1374.748 | 6691.792 | 8066.54 | 14362.7 | 3547.249 | 442.9597 | 3990.208 |
| 6688.9 | 1527.092 | 3965.352 | 5492.445 | 14828 | 3693.909 | 361.3788 | 4055.288 |
| 7120.9 | 1649.991 | 3083.517 | 4733.507 | 15334 | 3822.417 | 328.6654 | 4151.082 |

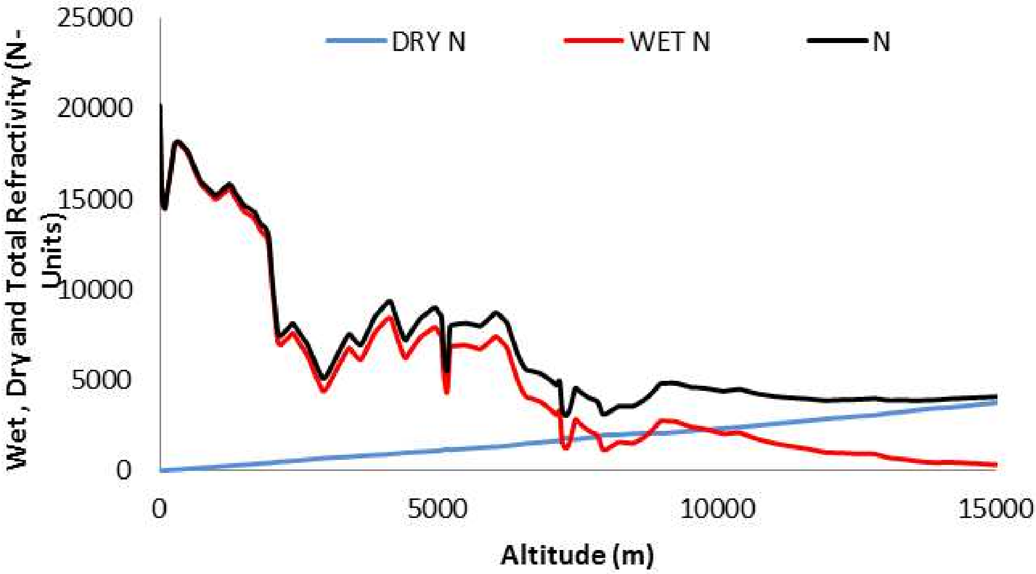


***Figure 6.*** *Vertical Profile Of Refractivity in Cross River state For The Month of June.*

The vertical refractivity profile for each of the six months is modeled using a cubic trendline model fitted to their graph and the models are as follows:

For The Month of February

$$N(h) = -0.0005\ (h^3) + 0.1094(h^2) + 12.355(h) + 6219.8 \quad (10)$$

N(65) = 7347.778; N(0) = 6219.8 and dN1 =17.3535

For The Month of March

$$N(h) = -0.00001\ (h^3) + 0.0117(h^2) + 5.6735\ (h) + 8866.5 \quad (11)$$

N(65) = 9281.964; N(0)= 8866.5 and dN1 =6.39175

For The Month of April

$$N(h) = 0.00001\ (h^3) + 0.0117(h^2) + 5.6735\ (h) + 8866.5 \quad (12)$$

For The Month of MAY

$$N(h) = 0.00003\ (h^3) + 0.0455(h^2) - 11.594\ (h) + 25936 \quad (13)$$

For The Month of June

$$N(h) = 0.000006\ (h^3) + 0.0026(h^2) - 5.6346\ (h) + 20152 \quad (14)$$

From the result in Table 2 to Table 7, it can be seen that the wet component of refractivity contributes the larger portion of the total refractivity. Also, the dry refractivity component increases linearly with height whereas the wet component of the refractivity do not have such linear relationship with height.

## 4. Conclusion

Model for the vertical profile of atmospheric radio refractivity is developed based on six months Raduiosunde data for Cross River state in the Southern region of Nigeria. Particularly, cubic trendline model is developed for each of the six months to predict the radio refractivity in the lower atmosphere ( height < 150 m above sea level). The model can be used to predict the refractivity at any height between 0 m and 150 m. Also, the model can enable the determination of point refractivity gradient which requires the refractivity at 0m and at 65 m above sea level. Other secondary radio climatic parameters such as effective earth radius factor and the geoclimatic factor can also be computed based on the values obtained from the models.

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