ATMOSPHERIC RADIO REFRACTIVITY AND WATER VAPOUR DENSITY AT OSHODI AND KANO, NIGERIA.

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Abstract: Some statistical analyses have been carried out on radiosonde data on atmospheric humidity taken during the period 1990-1993 at two meteorological stations, Oshodi (6° 32'N, 3° 21E) and Kano (12° 5N, 8° 52E) in Nigeria. Monthly means and standard deviations of columnar radio refractivity N and columnar water vapour density ρ have been obtained for the atmospheric columns, 0-3km, 0-10km, and 3-10km. It is found that the correlation coefficient between the monthly means of N and ρ is higher than 0.9 in most of the cases. Consequently, equations of regression have been obtained by means of which measurements of columnar water vapour density ρ can be used to estimate N over Oshodi, and Kano. For instance, line of regression of N upon ρ for Oshodi at the 0-3km atmospheric column is $N = (4.93 \pm 0.75)\rho + 254.15 \pm 11.26$.

Keywords: atmospheric humidity, columnar radio refractivity

1. INTRODUCTION

The troposphere is the lowest part of the Earths atmosphere extending from the ground level to an altitude of about 9km at the earth's poles and 17km at the equator. The tropopause is the upper boundary of the troposphere, above which the temperature increases slightly with height. The percentage composition of the principal gases does not change with altitude except that of water vapour. The permanent dipole moment of the molecules of water vapour causes it to be a very significant contributor to the variability of the atmospheric refractive index. The proportion by volume, of the water vapour, in the air at the ground level on the average varies from less than 0.001% in the arctic to more than 6% in the tropics [1]. This proportion decreases rapidly with height and is highly dependent on local air temperature.

The atmospheric refractive index is an important factor in the propagation of radio waves in the very high frequency (VHF) and higher frequency (HF) bands. The path and general characteristics of the signals are very much tied to the refractive conditions of the troposphere. These refractivity conditions give rise to signal propagation mechanism such as scattering, partial and specular reflections as well as ducting [2].

Nig. J. Pure Appl. Phys. (2005) Vol. 4 pp 11-15. Printed in Nigeria, ISSN 1596-0862. E-mail: njpapfuta@yahoo.com. For rights of reproduction and web access, contact African Journals Online, UK, www.inasp.ajol/journals/njpap

Depending on the prevailing mechanism, possible effects range from abrupt break in existing radio links to extension of signals beyond the normal radio horizon. Although trans horizon propagation can provide useful signals, it is also a potential source of adverse interference on co-channel circuits even at distances well beyond the radio horizon [3]. Nigeria's telecommunication network relies largely on VHF, UHF and microwave line of sight terrestrial paths, many of which are relay links. Fading resulting from atmospheric refraction has been observed on these paths, particularly during the dry harmattan season between December and March. High refraction and ducting is common in the West African zone. Oyedum, [4], Owolabi, [5] have also reported strong transhorizon VHF/UHF signals at various distances and locations within and around Nigeria.

This paper describes the analysis of two atmospheric parameters, radio refractivity N and atmospheric water vapour density ρ over two radiosonde stations. The two stations are in Nigeria. They are Oshodi (Lagos), a coastal tropical station and Kano (in northern Nigeria), an inland tropical station. The aim is to find for each station the relationship between N and ρ for three atmospheric columns, namely those between the surface and the 3km level (0 – 3km), between the surface and 10km and the upper column between 3km and 10km. An attempt is made to determine the seasonal variations of their surface values (N_s and ρ_s) and also to compare the values of these parameters for the two stations over the same periods of time.

2. DATA AND DATA ANALYSIS

2.1. Radio Refractive index (n)

The atmospheric radio refractive index, n, is very close to unity (typically 1.00035); hence it is more convenient to talk of the refractivity, N given by [6], [7]

$N=(n-1)*10^6=77.6/T\ (p+4810e/T)$......(1)

where p = atmospheric pressure (mb), e = water vapour pressure, and T = absolute temperature (K)

2.2. Water Vapour Density (ρ)

The dependence of ρ on temperature and relative humidity is very important in the tropics. The relationship between water vapour density, ρ (g/m^3), water vapour pressure e(mb) and temperature T(K) is given by [8]; [1]

$\rho = 216.7e/T$. ....(2)

The radiosonde observations for the years 1990 – 1993 were used for the refractivity and water vapour density computations for the stations. It should be noted that the surface parameters of refractivity and water vapour density are referred to, in this work, as surface refractivity N_s and ρ_s respectively. The standard layers defined by Aro [9] have been useful in the computation of the columnar values of the parameters involved in this study. The layers are: 0-3km, the lower layer, 3-10km, the upper atmospheric layer, and 0-10km, the total atmospheric column.

Applying equations (1) and (2), monthly mean values of atmospheric pressure temperature and relative humidity at different heights of the atmosphere at Oshodi (6° 32 N, 3° 21 E) and Kano (12° 5 N, 8° 52 E) in Nigeria by the Nigerian Meteorological Services (now Nigerian Meteorological Agency) are used to compute monthly mean values of atmospheric refractivity N and water vapour density ρ for the two stations and for the different atmospheric columns. Also the correlation coefficient and equations of regression between the monthly means of the columnar atmospheric refractivity and water vapour density were determined for the same period and for the two stations. For the purpose of obtaining a relation between radio refractivity and water vapour density, the periods have been combined into one 12- month period since data for some months in some of the years are not available.

3.RESULTS AND DISCUSSION.

3.*1. Surface radio refractivity (N_s) and water vapour density (ρ_s):*

Figs. 1and 2 show significant seasonal variations of the values of surface radio refractivity N_s and water vapour density (ρ_s) at the two stations respectively. N_s and ρ_s are highest in the months of April and November at Oshodi. Annual variations of N_s and ρ_s at Oshodi give rise to two peaks (primary and secondary) with a dip between them that corresponds well with the period of the little dry season in August. At Kano, the pattern is quite different. Values of N_s and ρ_s rise steadily from February to June. During the wet season months of June to September, values of N_s and ρ_s are highest and uniform with the complete absence of the August dip. This is due to the fact that during the month of August, the Inter tropical discontinuity (ITD) is at its northernmost limit and hence Kano will be at the peak of its rainy season. By October, when the dry harmattan season sets in, the N_s and ρ_s fall sharply reaching the lowest values around February. The sharp November rise observed here is not a common phenomenon. However, Kano is a sub sahellian station, whose atmospheric condition could be subjected to desert type vagaries in dew point temperature [10]. This may account for the sudden rise during this period. At Kano, greater variations of N_s and ρ_s occur in the dry season months of November to February, while Ikeja maintain higher, and almost uniform values during this period. The highest N_s and ρ_s values for Kano (373) and (19.5) respectively are clearly less than their corresponding values (387, and 23 respectively) at Oshodi. This can be attributed to the fact that Kano is at higher latitude than Oshodi. Higher latitudinal stations are characterized by lower humidity values.

3.2 Columnar N and ρ:

Tables 1 and 2 show the monthly means and standard deviations, SD of the columnar radio refractivity N and columnar water vapour density ρ for Oshodi and Kano respectively. The atmospheric columns considered are respectively 0-3km, 0-10km and 3-10km. It is found that N and ρ for the 0-3km atmospheric column have higher values than those of 0-10km and 3-10Km columns at Oshodi throughout the year. This is because there is high concentration of water vapour at the bottom level of the atmosphere than at higher levels, more so that Oshodi is a coastal station. This high concentration is caused by continuous evaporation from the ground surface into the layers of air nearest to the ground. In the higher layers 3-10km and above, accumulation of water vapour is prevented by

Table.1: Columnar water vapour density and columnar refractivity at Oshodi.

	Columnar water vapour density						Columnar radio refractivity					
Month	0-3km		3-10km		0-10km		0-3km		3-10km		0-10km	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
JAN	11.6	5.4	1.1	1.0	7.6	6.7	334	25.4	306	11.2	323	24.8
FEB	11.1	5.7	1.3	1.0	7.2	6.5	330	24.1	305	11.0	320	23.5
MAR	13.7	5.0	1.9	1.5	9.1	7.0	345	22.1	310	7.9	331	24.9
APR	14.3	5.5	1.9	1.5	9.6	7.5	349	24.3	310	8.1	334	27.3
MAY	14.5	4.7	2.3	1.7	9.8	7.0	351	20.7	313	6.4	336	25.0
JUN	12.9	4.2	2.0	1.5	8.7	6.3	345	18.4	312	7.5	332	22.0
JUL	13.6	3.9	2.4	1.8	9.3	6.4	350	17.0	315	6.8	337	22.2
AUG	13.1	4.4	1.8	1.5	8.7	6.5	344	17.7	311	8.7	332	22.0
SEP	13.1	4.4	2.0	1.6	8.9	6.5	346	19.5	312	8.0	333	22.9
OCT	14.0	5.0	2.0	1.6	9.4	7.1	349	22.2	312	7.5	335	25.4
NOV	13.5	5.1	1.8	1.5	9.0	7.0	346	22.8	311	9.1	333	25.5
DEC	11.6	5.4	1.1	1.0	7.6	6.7	334	25.0	306	11.2	323	24.8

Table.2: Columnar water vapour density and columnar refractivity at Kano

	Columnar water vapour density						Columnar radio refractivity					
Month	0-3km		3-10km		0-10km		0-3km		3-10km		0-10km	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
JAN	2.8	0.6	0.7	0.7	2.0	1.2	288	3.2	309	11.7	296	13.1
FEB	2.4	0.3	0.4	0.5	1.6	1.0	285	3.2	306	12.9	293	13.4
MAR	3.6	1.2	0.6	0.6	2.4	1.8	286	2.1	308	12.5	295	13.3
APR	5.0	2.1	0.8	0.7	3.3	2.7	293	6.0	308	11.2	299	11.4
MAY	8.3	3.4	0.9	1.0	5.4	4.5	311	12.0	309	10.2	310	11.4
JUN	12.4	4.7	3.3	4.0	8.7	6.3	340	20.9	319	9.1	331	19.9
JUL	12.0	4.3	1.4	1.1	7.8	6.2	338	18.9	313	8.2	328	19.9
AUG	12.6	4.5	1.8	1.5	8.3	6.4	342	20.2	315	7.2	331	21.1
SEP	11.5	4.6	1.5	1.2	7.3	6.1	335	19.7	314	7.9	326	19.0
OCT	6.5	2.8	0.7	0.8	4.2	3.6	303	9.5	308	11.7	305	10.7
NOV	12.2	4.3	1.7	1.4	8.0	6.2	339	18.7	315	6.6	330	19.3
DEC	2.7	0.8	0.4	0.3	1.8	1.3	285	2.5	306	15.0	294	14.1

Table 3: Correlation coefficient between N and ρ

	0-3km	3-10km	0-10km
Oshodi	0.901	0.946	0.907
Kano	0.873	0.652	0.911

Table 4: Line of regression of N upon ρ.

	SLOPE						INTERCEPT ON N-AXIS					
	0-3km		3-10km		0-10km		0-3km		3-10km		0-10km	
	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E
Oshodi	4.93	0.75	6.86	0.74	6.02	0.88	254.15	11.26	149.66	1.79	197.57	8.06
Kano	7.30	1.36	7.05	2.74	7.44	1.12	227.87	12.48	141.45	4.74	184.47	6.19

the effects of cloud formation and prevailing winds. The standard deviation, SD, for both parameters are high during the dry season months of October – April than in the peak rainy season months of May – September as can be seen in Table 1. Variability at 0-10km columns is higher than those of 0-3km and 3-10km columns. This may be because of the greater difference between the temperature at the surface and those of the 10km height since temperature decreases aloft within the troposphere. June / July seems to be the months of least variability in N and ρ. At Kano, during the dry season, (see Table 2), the upper atmospheric layer 3-10km has higher N than those of 0-10km and 0-3km respectively. This

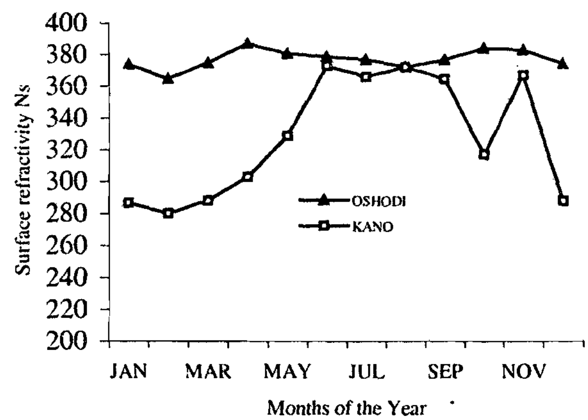

Fig. I Monthlly Variations of mean values of surface refractivity Ns at Oshodi and Kano.

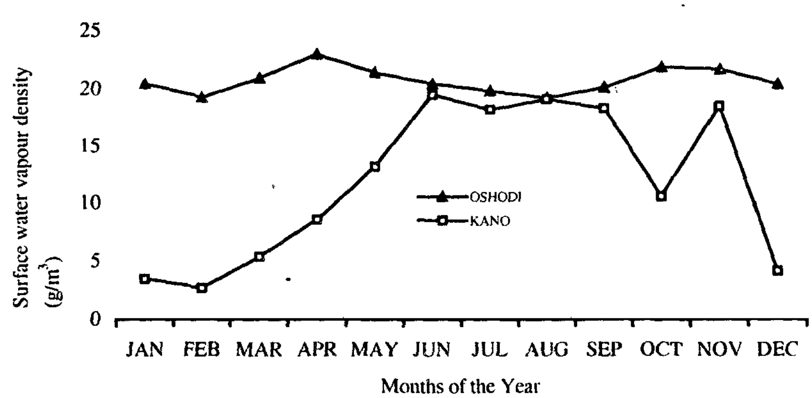

Fig.2. Monthly Variations of mean values of surface water vapour density (r).

may be explained from the temperature behaviour of the lower atmosphere. The temperature excursion of air into the troposphere decreases with height with increasing distance from the ground [11]. Hence low temperature in the upper atmospheric layer 3-10km permits higher values of ρ in this layer thereby resulting in higher value of N in the upper atmosphere. During the rainy season, the reverse case persists. The observation relates well with that of Oshodi (see Table 1) where 0-3km columns has higher values of N than the upper column 3-10km.

3.3 Correlation between columnar radio refractivity and water vapour density.

The correlation coefficients between the monthly means of radio refractivity of columns, N and water vapour density of column ρ have been calculated and the equations of regression N upon ρ have also been obtained. For each station, N at different atmospheric columns has been correlated with values of ρ for the same column. The results are shown in Table 3. The mean slopes and intercepts determining the lines of regression are shown in Table 4. Also shown are the standard errors, SE, of the mean slope and of the intercept. For each line of regression, the standard errors indicate the accuracy of the coefficients [9], the coefficients being the slope and the intercept of the line on the N-axis. Hence the standard errors will determine the accuracy of the value of N when calculated by substituting a measured value of ρ into the particular regression equation. For example, by taking the values of the coefficients and their standard-errors from Table 4, for columnar water vapour density at

Oshodi, the regression equation giving the columnar radio refractivity, N, for 0-3km column is

$$N=(4.93 \pm 0.75)\rho + (254.15 \pm 11.26)\ldots \quad (3)$$

The corresponding equation of regression for Kano is

$$N = (7.30 \pm 1.36)\rho + (227.87 \pm 12.48)\ldots \quad (4)$$

This regression equation should be useful in Nigeria since there are sparse network of radiosonde stations. Upper-air data are scarcely available in Nigeria, and where available, they are always incomplete.

5. CONCLUSIONS

Clearly, only limited conclusions can be reliably drawn from statistics for only one 12-month period; however some patterns of variation in the atmospheric radio meteorological parameters have emerged. Radio refractivity and water vapour density in both the lower and higher columns of the first 10km of the atmosphere over Oshodi and Kano have been found to be considerably different temporally and spatially. The surface values N_s and ρ_s follow closely the season at each station. Values are higher at Oshodi than Kano throughout the year. This is because Oshodi is a coastal station. In almost all the cases investigated, there has been high correlation between N (columnar radio refractivity) and ρ (columnar water vapour density), permitting the computation of equations of regression. It is therefore here suggested that equations of regression, shown in data form in Table 4, can be used to estimate to within 10% the columnar radio refractivity.

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