RADIO REFRACTIVITY GRADIENT OVER NIGERIA USING CM-SAF SATELLITE RETRIEVED DATA

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INTRODUCTION

What is radio refractivity gradient?

- One major constituent of the atmosphere that plays a significant role in hydrological cycle and energy balance of the earth atmosphere is water vapour.
- Water vapour molecules possess permanent dipole moment making it a significant contributor to atmospheric radio refractive index variability.

INTRODUCTION CONT'D

- The troposphere has a dielectric constant and hence a refractive index 'n' (Ajayi, 1989, Adeyemi, 2004).
- n = c/v where c = vel of light in vacuum, and v = velocity of light in air.
- The radio refractive index n is slightly greater than unity, and gradually decreases to unity with increase in altitude.

INTRODUCTION CONT'D

- At the earth surface, n is between 1.000250 and 1.000400.
- For easy handling, the radio refractivity N was defined by Smith and Weintraub (1953) as

$$N = (n-1) \times 10^6$$

- This now makes N to vary between 250 and 400.
- N is important to radio wave propagation in the VHF and HF bands.

INTRODUCTION CONT'D

- N decreases with height as temperature and water vapour do.
- Hence lapse rate of refractivity dN/dh (refractivity gradient).
- The curvature of ray path in the troposphere is governed by the value of refractivity gradient (Ajayi, 1989).
- Possible effects range from abrupt break in existing radio links to extension of signal beyond normal radio horizon (Oyedum and Gambo, 1994).

LITERATURE REVIEW

Many researchers have worked on the refractivity and refractivity gradient distributions across the globe:

- Pickard and Stetson (1950) established that correlation exists between transmission loss and N at the earth surface;
- Babalola (1999) established that surface refractivity Ns and dN/dh are well correlated in the African region;
- Blanchard and Sizun (1998) have shown that field strength and dN/dh are fairly correlated most especially in April;

LITERATURE REVIEW (CONT'D)

- Kolawole (1981) studied the vertical distribution of N over Nigeria using radiosonde data;
- Adeyemi and Rabiu,2002; Adeyemi and Adedayo, 2002; Gombev, 1998 have carried out various studies on the vertical profile of refractivity, to provide adequate explanation for the various propagation mechanisms in their regions;
- Adediji and Ajewole (2008) studied the vertical profile of dN/dh at Akure using an in-situ meteorological data

LITERATURE REVIEW (CONT'D)

- Ayantunji et al, (2011) investigated the diurnal and seasonal variations of N over Nigeria using in-situ measurement from 8 stations;
- Statistical consideration of the structure of N over Akure was carried out by Falodun (2007); and
- Variation of N with height up to 1.2km above ground over Lithuanian has also been investigated by Valma et. al., (2011).

MOTIVATION

The availability of layered satellite data (CM-SAF retrieved data) to cushion the effect of dearth of upper air data in Nigeria has been the motivation behind this work. Many researches have been conducted on radio refractive gradient in Nigeria, but with minimal coverage (maximum of three stations). With CM-SAF data, this has been investigated over 26 stations.

OBJECTIVES

Objectives are to:

- Observe the variations in radio refractive gradient over Nigeria;
- Observe the latitudinal distributions of anomalous radio propagation parameters over Nigeria; and
- Deduce correlation between surface refractivity Ns and dN/dh for all the stations and compare it with the existing ones.

DATA AND DATA ANALYSIS TECHNIQUE

- The source of meteorological data used for our analyses is the Department of Satellite Application Facility on Climate Monitoring (CM-SAF), DWD Germany.
- The CMSAF operationally applies the international ATOVS processing package (IAPP) to retrieve humidity and temperature from ATOVS observations onboard NOAA - 15, - 16 and -18 satellites.

The profiles are vertically integrated and averaged to provide temperature and humidity for 5 layers (i.e. 925 mbar, 775 mbar, 600 mbar, 400 mbar and 250 mbar). The data obtained for the period 2004-2007 were those used in evaluating refractivity for the twenty six stations, classified into four regions based on their climatic conditions as we have it in Olaniran and Sumner (1989) and Adedokun (1986) (See Fig 1)

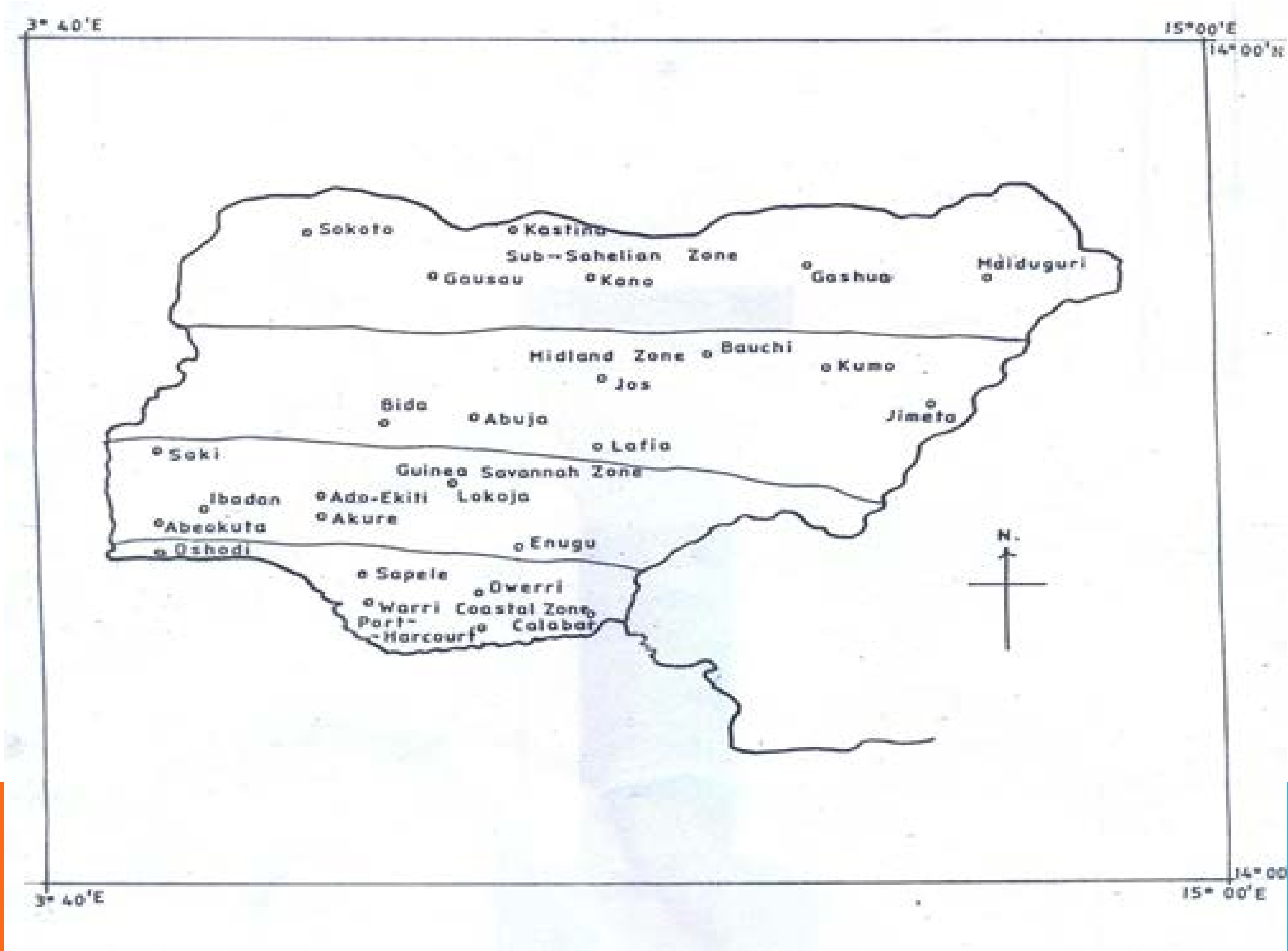


Fig 1: Nigeria map showing the stations and regions.

The atmospheric refractive index was computed using Oyedun and Gambo (1994) and Adeyewa, 1995)

$$n = 1 + \left(N \times 10^{-6}\right) \qquad \textbf{1}$$

where: N = radio refractivity given as

$$N = (n-1) \times 10^{6} \qquad 2$$

$$N = (n-1) \times 10^{6} = \frac{77.6}{T}\left[P + \frac{4810e}{T}\right] \qquad 3$$

where: P = atmospheric pressure (hpa), e = water vapour pressure (hpa) and T = absolute temperature (K)

and $$\frac{dN}{dh} = \frac{N_2 - N_1}{h_2 - h_1}$$

Where N_1, N_2 h_1 and h_2 are the refractivities and heights at the different pressure levels dN/dh is refractivity gradient.

The radio beam leaving the transmitter at the earth surface describes a curved path.

There are 3 different forms of atmospheric refraction: They are Negative refraction, zero refraction and positive refraction.

Negative refraction: $dN/dh > 0$ and radius of curvature R of ray is negative i.e. it curves upward.

Zero refraction: $dN/dh = 0$ and R is infinite i.e ray is rectilinear.

Positive refraction: $dN/dh < 0$ and R is positive i.e. ray path is towards the earth.

Positive refraction has been classified into:

Standard: dN/dh = -40N/km

Sub-refraction: dN/dh > -40N/km

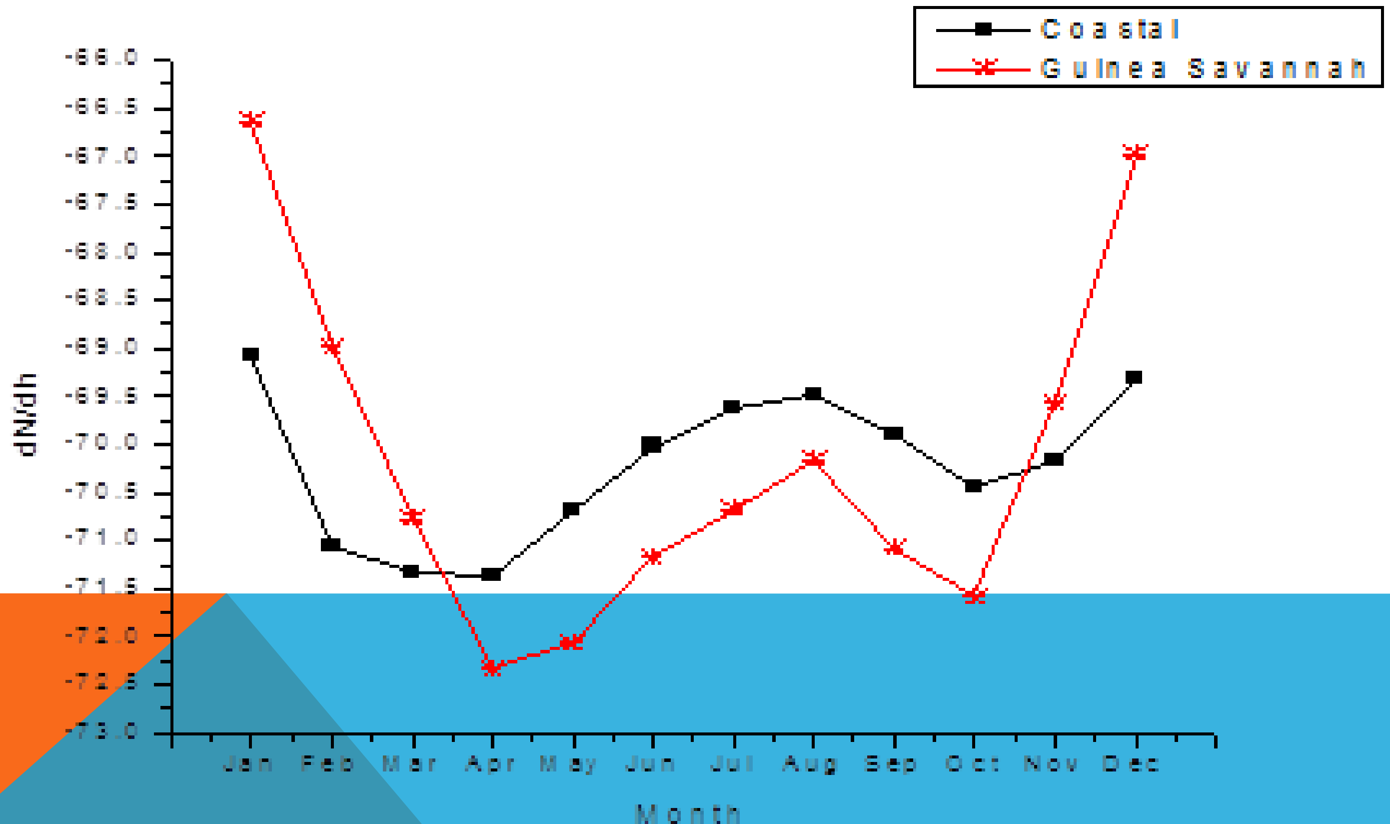
Super-refraction: -157< dN/dh < -40

Ducting: dN/dh < -157N/km

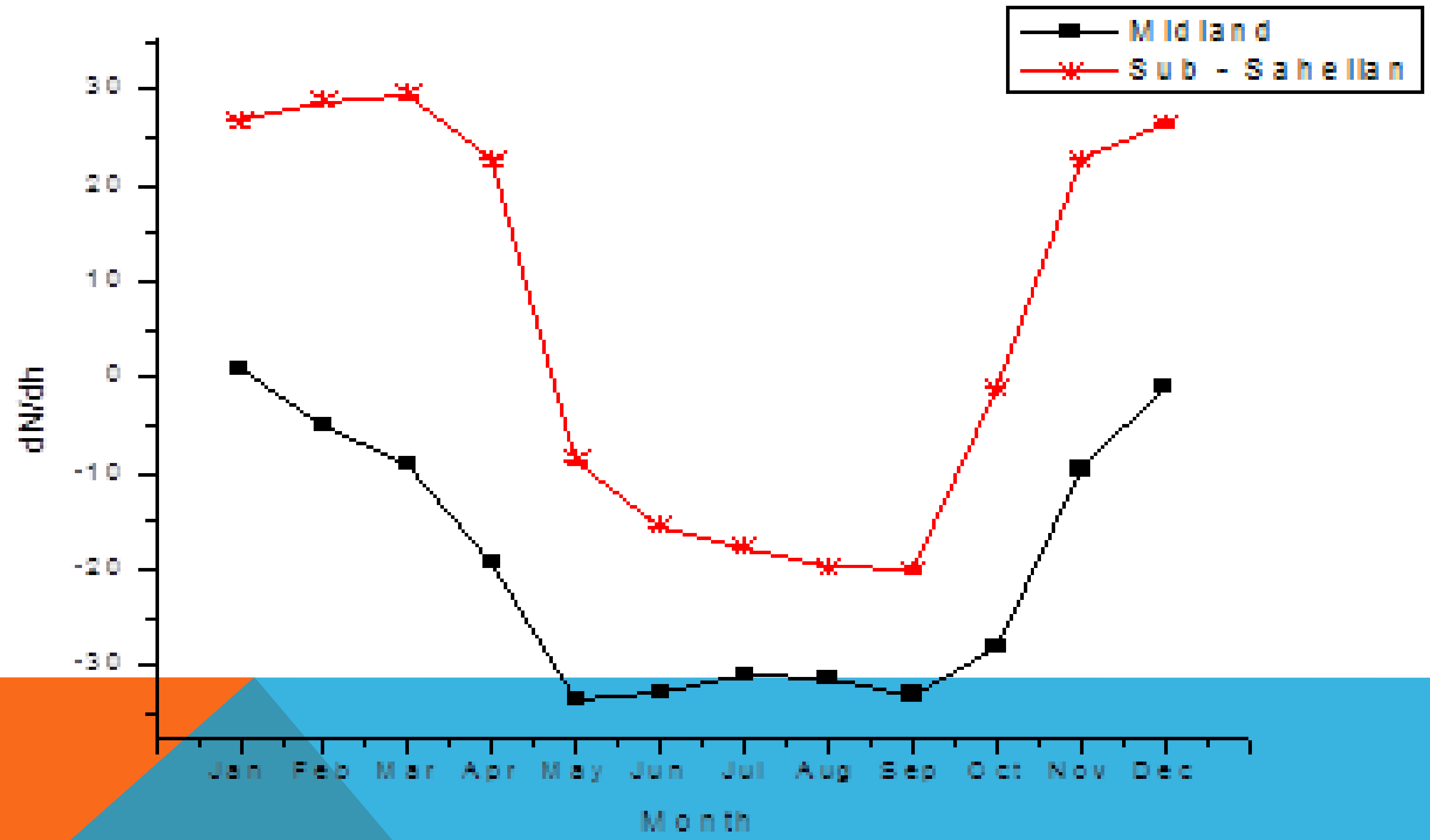
Critical: dN/dh = - 157 N/km

RESULTS AND DISCUSSION

Seasonal variations



Seasonal Variation cont'd



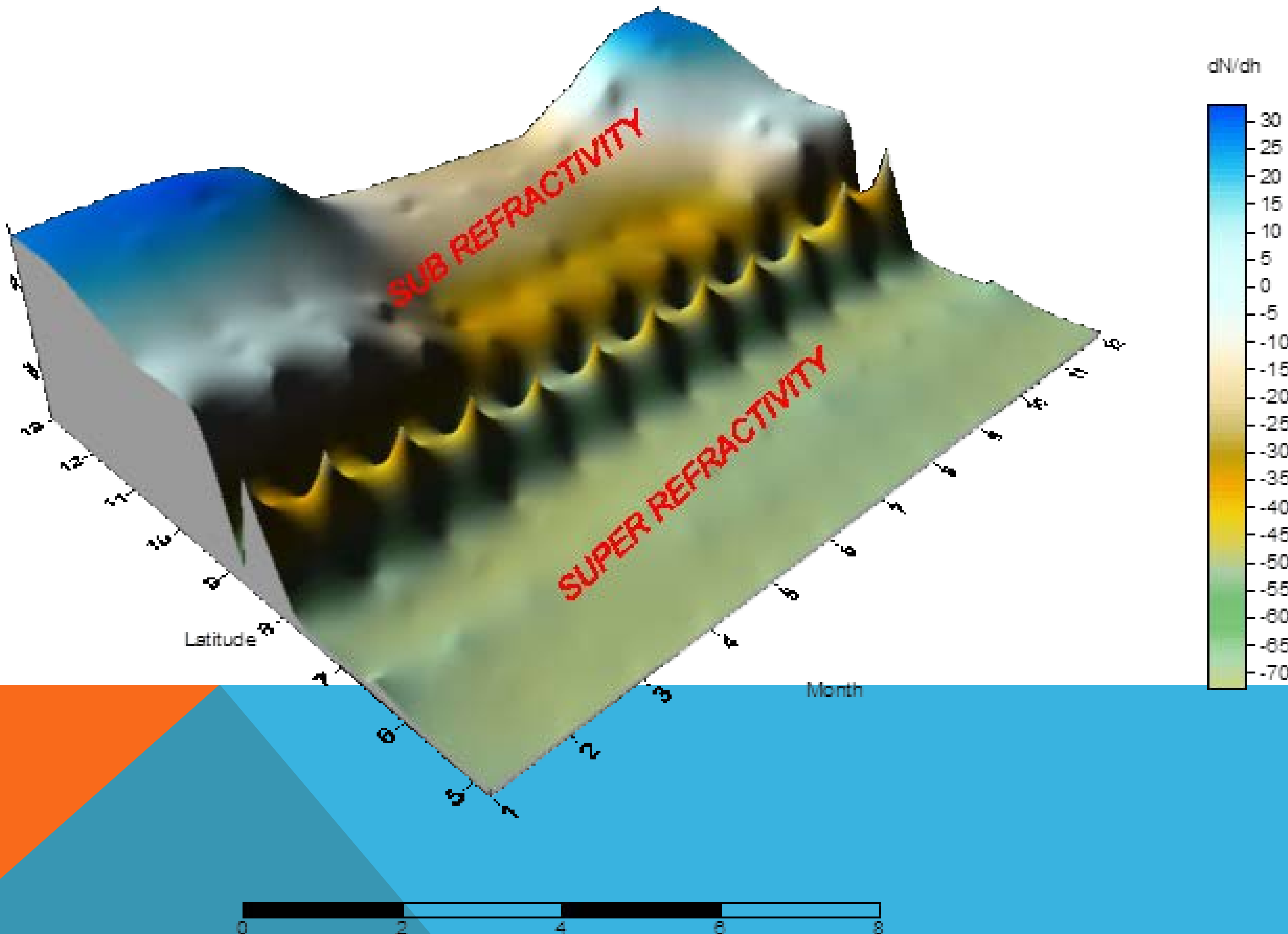
- Gradients are particularly high and steeper with high variability in the dry season months of November to March as well as in April, the onset of the rainy season at all the regions.

- They tend to be slightly lower in the wet season months of May to September with less variability. This may be due to the fact that the period is characterized by intense rainfall, which keeps the atmosphere in constant supply of water vapour.

- During the dry season, the atmosphere tend towards being sub-refractive; while the rainy season period is characterized by super-refractive conditions at both the coastal and guinea savannah regions. Generally speaking super refractivity is prevalent here.

- At both the midland and sub-sahelian regions, the atmosphere is sub-refractive.

Latitudinal Distributions:



- Figure above shows that between latitude 4° and 8° N, consisting of the coastal and guinea savannah regions, the atmosphere is super refractive while between latitudes 8° and 13° N, consisting of both the midland and sub-sahelian regions, the atmosphere is sub-refractive.

- Ducting phenomenon is totally absent in all the regions.

CORRELATION BETWEEN REFRACTIVITY GRADIENT& N_S

Table III: Values of constants A and β in the expression for the stations

	$\Delta N_L = A\exp(\beta N_s)$			$\Delta N_m = A\exp(\beta N_s)$			$\Delta N_u = A\exp(\beta N_s)$		
Location	A	B	CD/%	A	B	CD/%	A	B	CD/%
Oshodi	23.89746	0.002877	99.99506	7.923481	0.004782	60.94923	0.604103	0.003936	99.90211
Sapele	24.01499	0.002863	99.99554	5.882928	0.005589	69.65335	0.610047	0.003906	99.8245
Warri	24.22931	0.00284	99.99842	3.581408	0.006896	70.0105	0.606542	0.003922	99.67109
Owerri	24.20004	0.002843	99.99754	8.588717	0.004561	55.64549	0.621802	0.003846	99.62419
Calaba	24.20069	0.002843	99.99648	5.258138	0.005861	66.93731	0.619006	0.00386	99.52197
PortHarcourt	23.85546	0.002882	99.99855	3.404099	0.007042	60.11398	0.591946	0.003996	98.8944
Saki	23.78653	0.002888	99.98183	9.558394	0.004287	89.93878	0.62421	0.003833	99.95275
Ibadan	24.13162	0.00285	99.9915	12.10287	0.003676	72.75383	0.637627	0.003767	99.95964
Abeokuta	24.24181	0.002838	99.9902	9.232563	0.004399	68.01554	0.63352	0.003787	99.95782
Ado Ekiti	23.83061	0.002883	99.99138	11.65277	0.003758	88.48349	0.628435	0.003813	99.94019
Akure	24.12833	0.002851	99.99254	11.8448	0.003733	56.36354	0.633734	0.003787	99.92848
Enugu	23.0941	0.002968	99.97881	7.750559	0.004807	95.91126	0.597531	0.003966	99.93948
Lokoja	23.20583	0.002955	99.98208	7.127966	0.005048	92.50254	0.605749	0.003926	99.92054
Jos	0.000236	0.033429	83.83189	2.17547	0.008253	98.90764	0.40624	0.004865	99.78639
Bauchi	0.000926	0.029834	79.56428	1.871236	0.008746	98.68747	0.38047	0.004995	99.8363
Kumo	0.00063	0.030566	64.90532	1.962544	0.008567	99.0798	0.393817	0.004921	99.83962
Abuja	6.64E-05	0.037275	88.89275	2.860044	0.007487	97.88058	0.454835	0.004653	99.7847
Jimeta	0.000179	0.034518	90.47056	2.066125	0.008435	98.63342	0.401945	0.004894	99.81764
Bida	0.004154	0.025428	97.3095	3.623591	0.00682	97.2158	0.482429	0.004529	99.86141
Lafia	0.001968	0.027629	96.28282	3.174811	0.007202	97.35742	0.474244	0.004569	99.85446
Sokoto	1.56E+22	-0.10218	37.02184	0.958355	0.010733	98.37942	0.278085	0.005408	99.72637
Kastna	1.2E+24	-0.11801	38.66104	0.942005	0.010778	98.19142	0.269318	0.005445	99.74227
Gashua	1.15E+27	-0.14386	53.11947	0.853429	0.011096	98.66051	0.252568	0.005524	99.67825
Gusau	3.09E+19	-0.08163	41.27309	1.10902	0.010264	98.5503	0.300928	0.005315	99.81455
Kano	1.15E+24	-0.12114	41.24126	1.07631	0.010363	97.73216	0.281112	0.005404	99.80144
Maiduguri	1.39E+24	-0.12193	44.34879	1.11237	0.010278	97.88419	0.282377	0.005402	99.74819

- At the low – level, all coastal and guinea savannah stations display very good coefficient of determination (CD) (i.e. CD= 99.99%); the midland stations on the other hand displayed CD ranging between 64% and 97%, while the sub-sahelian stations displayed CD ranging between 37% and 53%. This shows that CD decreases from the coast inland. This is to be expected because of the high degree of relationship existing between humidity, air temperature and refractivity parameters.

- At the midlevel, we observed a reversal in the value of the CD where the coastal and guinea savannah regions displayed values ranging from 56% and 73%, midland and sub-sahelian regions, 92 -98%.
- The upper - level gave rise to very high CD of about 99% at all the stations.
- The constants A and β varies from station to station. The constant A in the southern stations (coastal and guinea savannah regions) has value ranging between 23 and 24 which is very close to that obtained by Willoughby et.al. (2002); where A = 22.05 was obtained for the coastal station of Oshodi. The low values of β in the order of 10^{-3} obtained here at the coastal and guinea savannah regions are also related to the values obtained by Kolawole and Owonubi (1982) and Willoughby et al. (2002) in their work.

CONCLUSSION

The CM-SAF data has proven to be a reliable replacement for radiosonde data in Nigeria. This is due to the fact that:

- The variations observed in refractivity gradient is in consonance with the ones observed by Adeyemi, 2004 (PhD work) using surface data and some empirical formulations.
- The values of A and β are also closely related to those obtained by Kolawole and Owonubi (1982) and Willoughby et al. (2002) using radiosonde data covering three stations.

- The anomalous propagation parametric values obtained in this work are useful tools in the prediction of radio propagation mechanism needed at the different climatic regions of Nigeria.

THANKS FOR LISTENING