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Meteorological parameter anomalies and anomalous radio propagation over Nigeria

I. Emmanuel†, K. D. Adedayo,B. Adeyemi, O. S. Ojo

Department of Physics, Federal University of Technology, Akure, Nigeria.

†Corresponding Author's Email: iemmanuel@futa.edu.ng

Abstract: Distribution and variation of anomalous radio propagation, temperature and relative humidity anomalies were obtained and analyzed using six years (2010-2015) Era interim data. Seasonal spatial distribution of refractivity gradient and its components were analyzed. The result showed that about 90% of wet component contributed to the variation of refractivity gradient. Highest range of refractivity gradients and its wet components were obtained during the wet season. The result of correlation between ducting occurrence and temperature showed strong negative correlation except in Lagos where positive correlation of 3% was observed. However, positive correlation which ranges between 39% and 70% exist between duct occurrence and relative humidity except in Lagos in Nigeria. Refractivity gradients, relative humidity anomaly and temperature experience a monthly variation. These variations can be attributed to the seasonal movement of inter-tropical discontinuity (ITD) across Nigeria.

Keywords: anomalous, anomaly, correlation, ITD

1. INTRODUCTION

Atmospheric parameters and its constituents cause radio wave propagated through it to reflect, refract, scatter, and be absorbed by different atmospheric constituents. These effects however depend mainly upon the frequency, the power of the signal and on the state of the troposphere through which the radio wave propagates [1]. The atmosphere over the earth is a dynamic medium, its properties varying with temperature, pressure and humidity [2 - 3]. Variability of tropospheric characteristic has noticeable significance on radio communications, aerospace, environmental monitoring and disaster forecasting. For instance, fading on communication link which results in decrease of signal power levels in receiver are caused by worse propagation conditions [4]. Performance and reliability of the radio link determines the quality of propagation of radio waves between the transmitter and the receiver. Normally, radio planning engineers need data of measured signal strength for radio link design [5]. Consequently, a radio propagation model which is the variation of radio refractive index in the troposphere is required for the evaluation and determination of signal strength variations that occur at any locations of interest over different times of the year. It was observed that sometimes microwave systems could become unavailable due to seasonal variation of refractive index [6]. Therefore, the accurate knowledge of radio refractive index of the lower atmosphere is important in the planning and design of terrestrial radio links for communication networks, radar and propagation applications [7 – 8]. Previous works on radio wave propagation in Nigeria have established seasonal variation of radio refractivity, occurrence of ducting, super refractivity and sub refractivity in some locations [5, 9]. Emmanuel *et al.*, [10] investigated and showed the occurrence of ducting phenomenon across Nigeria. The present study is concerned with investigating anomalous radio propagation and meteorological anomaly over Nigeria. Anomalous radio propagation can be classified into three, which are super refractivity, sub refractivity and ducting. Under sub refractive condition, refractivity gradient varies between positive values and -39 N-units/km. When the refractivity gradient varies from –41 to –157 N-units/km, super refraction is experienced in the troposphere and the radio waves will refract downwards at a rate greater than the standard value (-40 N-units/km) but less than the curvature of the earth. Ducting occurs when the refractivity gradient is less than – 157 N-units/km. During this condition, radar microwaves may be trapped and can travel within the duct layers like waveguide. This may lead to signal enhancement near and beyond radio horizon [11].

Table 1: Refractivity conditions

Atmospheric Condition	G (*N-units/km*)
Trapping or Ducting	< -157
Super refractive	-41 to -157
Normal	*-40*
Sub refractive	> 0

2. DATA SOURCE

Meteorological data of temperature and relative humidity used in this work were obtained from the archive of Era interim at European Centre for Medium Range Weather Forecast (ECMWF). Era interim is a global atmospheric analysis and built upon a consistent assimilation of an extensive set of observations distributed worldwide satellite remote sensing, in situ, radio sounding and profilers [12]. Cycle 31r2 of ECMWF's Integrated Forecast System (IFS) model was used for the ERA-Interim product.

2.1 Data analysis

Refractivity was calculated using [13 – 14]

$$N_i = \frac{77.6P}{T} + \frac{3.73\times10^5 e}{T^2} \quad (1)$$

where P (hPa) is the atmospheric pressure, T (K) is the temperature, e (hPa) is water vapour and i=0, 1,2…. is an integer representing atmospheric altitude. Water vapour, e is obtained using [10]

$$\boldsymbol{e_i} = \frac{\mathbf{6.1121}\boldsymbol{H_i}}{\mathbf{100}} \boldsymbol{exp}\,\frac{\mathbf{17.502}\boldsymbol{t_i}}{\boldsymbol{t_i}\mathbf{+240.97}} \quad (2)$$

where H (%) is relative humidity and t is temperature in degree Celsius. Refractivity gradient, G, is calculated from [10]

Table 1: Correlation of Ducting and Meteorological Parameters

		Temperature	Relative Humidity
Akure	Duct	-88.9	56.3
	No Duct	-77.0	89.1
Lagos	Duct	3.7	-36.3
	No Duct	-73.2	63.0
Jos	Duct	-73.4	65.0
	No Duct	-18.4	82.0
Maiduguri	Duct	-83.9	38.9
	No Duct	-0.6	73.3
Enugu	Duct	-37.0	71.2
	No Duct	-72.4	77.0
Ilorin	Duct	-48.0	63.3
	No Duct	-51.9	77.6
Kaduna	Duct	-76.9	61.2
	No Duct	-13.8	36.7
Kano	Duct	-83.6	53.7
	No Duct	-9.6	72.4
Oyo	Duct	-16.7	60.8
	No Duct	-69.3	77.0
Sokoto	Duct	-73.8	60.0
	No Duct	-21.5	64.8
Yobe	Duct	-84.2	55.0
	No Duct	9.0	70.6

$$G = \frac{N_s - N_i}{h_s - h_i} \quad (3)$$

where h_s and h_i represent surface height and altitude height respectively. The refractivity conditions, which determine anomalous propagation, are shown in Table 1.

3 RESULT AND DISCUSSION

3.1 Anomalous propagation and its component

Figure 1-4 shows the seasonal spatial distribution of radio refractivity gradient and its components (wet and dry) for January (peak of dry season), April (onset of wet season), September (peak of wet season) and November (onset of dry season) respectively. In all the observed seasons, refractivity gradient, G and its wet component, WG, follow similar trend distribution. During this period, WG component oscillate between -85 N-units/km and -255 N-units/km, G fluctuates between -115 N-units/km and -285 N-units/km. On the other hand, the dry component, DG varies between -22 N-units/km and -38 N-units/km. Super refractive and ducting conditions were prevalent during this period (see Figure 1). In April, onset of wet season, G, WG and DG varies between -70 and -370 N-units/km, -20 and -340 N-units/km , and -24 and -40 N-units/km respectively (see Figure 2). The range of variation between peak of dry season and onset of wet season is about 50 % for both WG and G, while the variation of DG is constant. At the peak of the wet season and in the month September, G, WG, and DG, ranges between -20 N-units/km and -320 Nunits/km, -20 N-units/km and -320 N-units/km and -25 N-units/km and -39 Nunits/km respectively, with no significant variation in their ranges between onset of wet season. However, values of WG, G, and DG ranges between -60 N-units/km and -290 N-units/km, -95 N-units/km and -315 N-units/km and -23 N-units/km and -39 N-units/km respectively. It is obvious that the magnitudes of radio refractivity gradient are influenced by wet component [13 – 15].

3.2 Correlation of ducting and meteorological parameters

Table 2 represents the correlation between ducting, no ducting occurrence and meteorological parameters (temperature and relative humidity). In all the 10 observed locations in Nigeria, negative but strong correlation exists between ducting and temperature except in Lagos, where positive correlation of 3.7% was found.

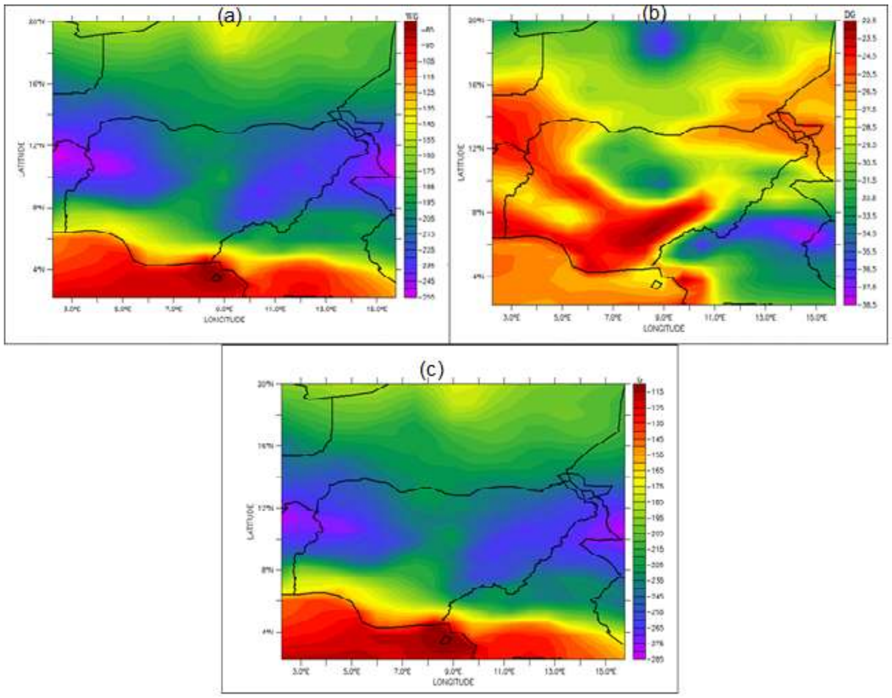

Fig. 1. Spatial distribution of (a) wet ducting component (b) dry ducting component (c) ducting in January

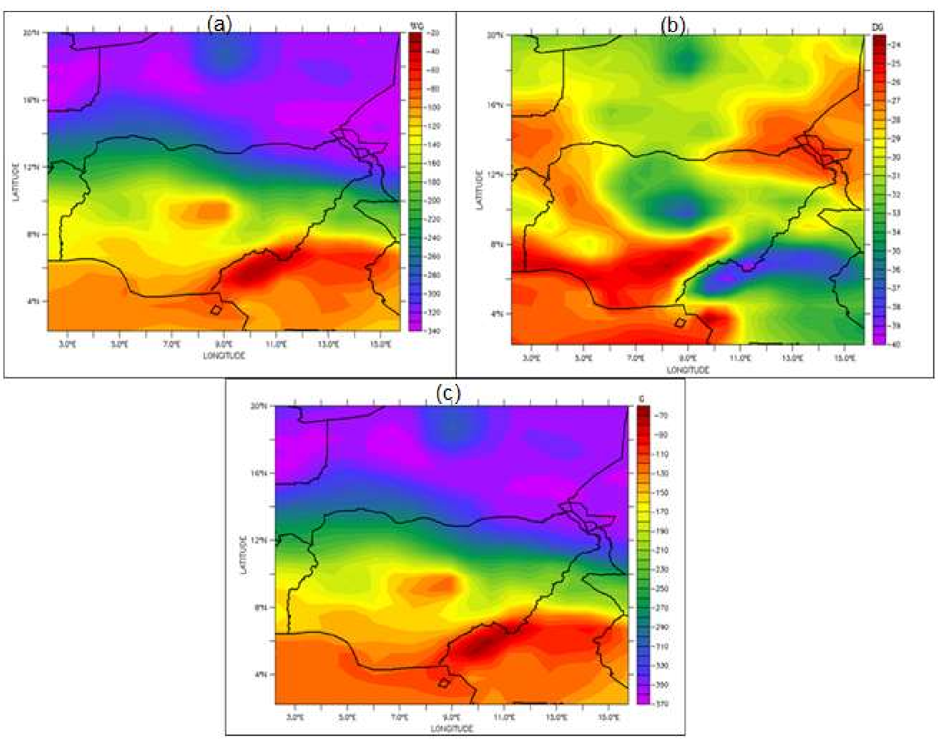

Fig. 2. Spatial distribution of (a) wet ducting component (b) dry ducting component (c) ducting in April

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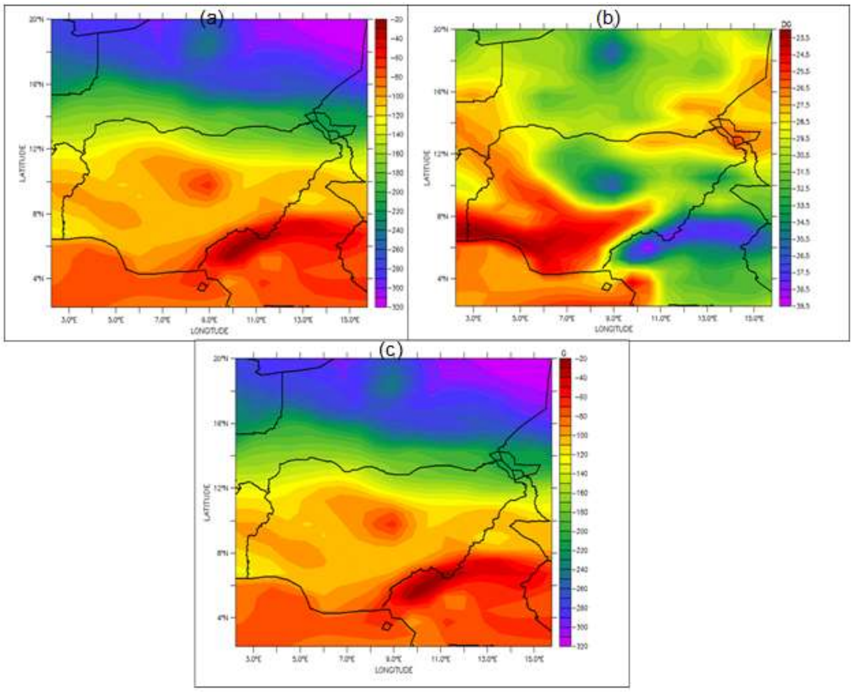

Fig. 3. Spatial distribution of (a) wet ducting component (b) dry ducting component (c) ducting in September

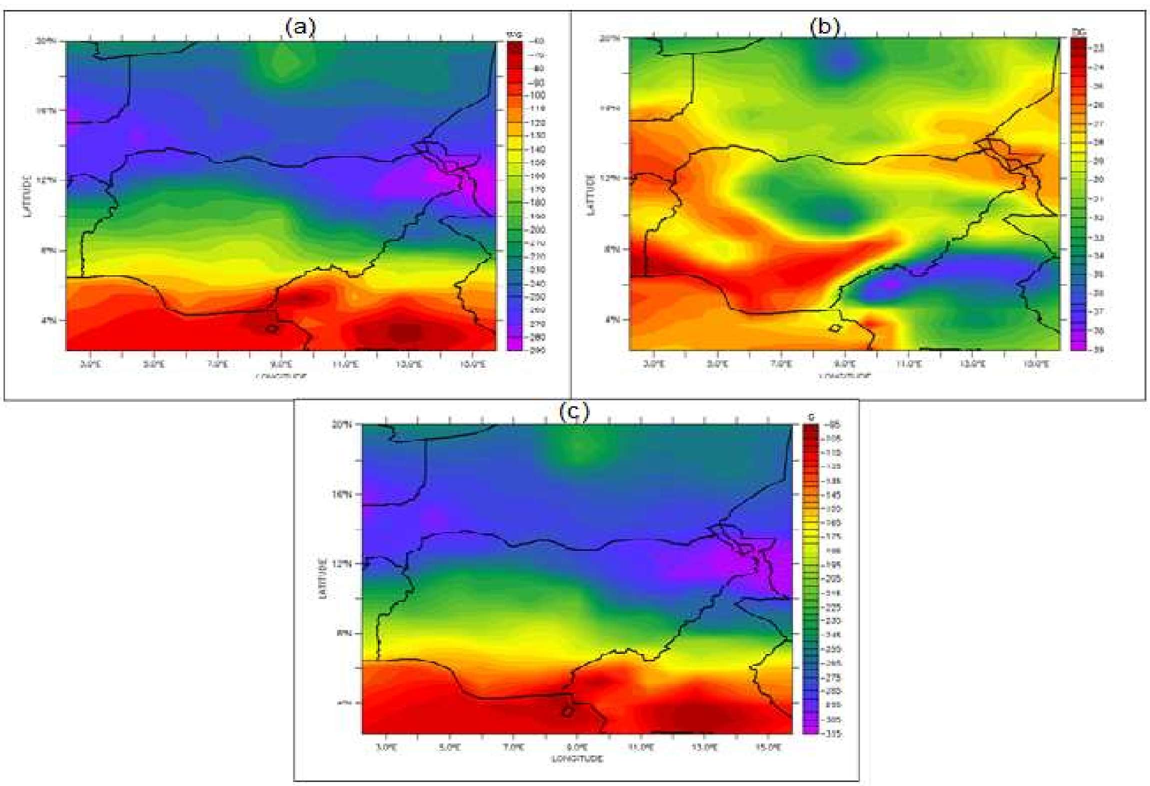

Fig. 4. Spatial distribution of (a) wet ducting component (b) dry ducting component (c) ducting in November

The highest correlation magnitude of -88.9% was observed in Akure while the lowest correlation of -37% was observed in Enugu. The implication of these is that ducting occurrence increases as surface temperature decreases. On the other hand, positive correlation exists between ducting and relative humidity except in Lagos, where -36% was observed. This may be attributed to the amount of water vapour in air at Lagos, which is almost high throughout the year. This shows that ducting occurrence increases with increase in relative humidity.

3.3 Radio refractivity gradient and meteorological anomaly

Figure 5 represents the seasonal variation of refractivity gradients and meteorological anomaly in ten locations across Nigeria. It was observed across the locations that seasonal variation of relative humidity anomaly (RH anomaly) and refractivity gradients follow similar trends. The values of G and RH anomaly were higher in the wet months than in the dry months. However, temperature anomaly (T anomaly) fluctuates in opposite direction to that of the gradient. RH anomalies reached their peaks of 0.99, 1.02 and 1.08 in September at Akure, Oyo and Ilorin with corresponding G values of -111 N-units/km, -126 N-units/km and -116 N-units/km respectively. In Lagos, RH anomaly reaches its maximum value of 1.10 with corresponding G value of -137 N-units/km in June (Figure 5). Minor dip of RH anomaly and G was observed in Lagos in August. However, T anomaly attained its minimum values of -1.67, -1.52, -1.69 and -1.59 in August at Lagos, Akure, Oyo and Ilorin respectively. In the northern parts of the country, RH anomaly attained its maximum height in August in all the locations with RH anomaly values ranging between 1.22 and 1.65. The corresponding values of G varied between -90 in Jos and -145 in Sokoto. A minimum value of T anomaly was also observed in August and it ranged between -1.27 and -1.63. The observed monthly variation of G, RH anomaly and T anomaly can be attributed to the migration of inter-tropical discontinuity (ITD) which is the interface between the tropical maritime (mT) air mass that emanates from the Southern belt and the tropical continental (cT) air mass originating from the high pressure belt north of the Tropic of Cancer [14 – 16].

4. CONCLUSION

Anomalous radio propagation and meteorological anomaly

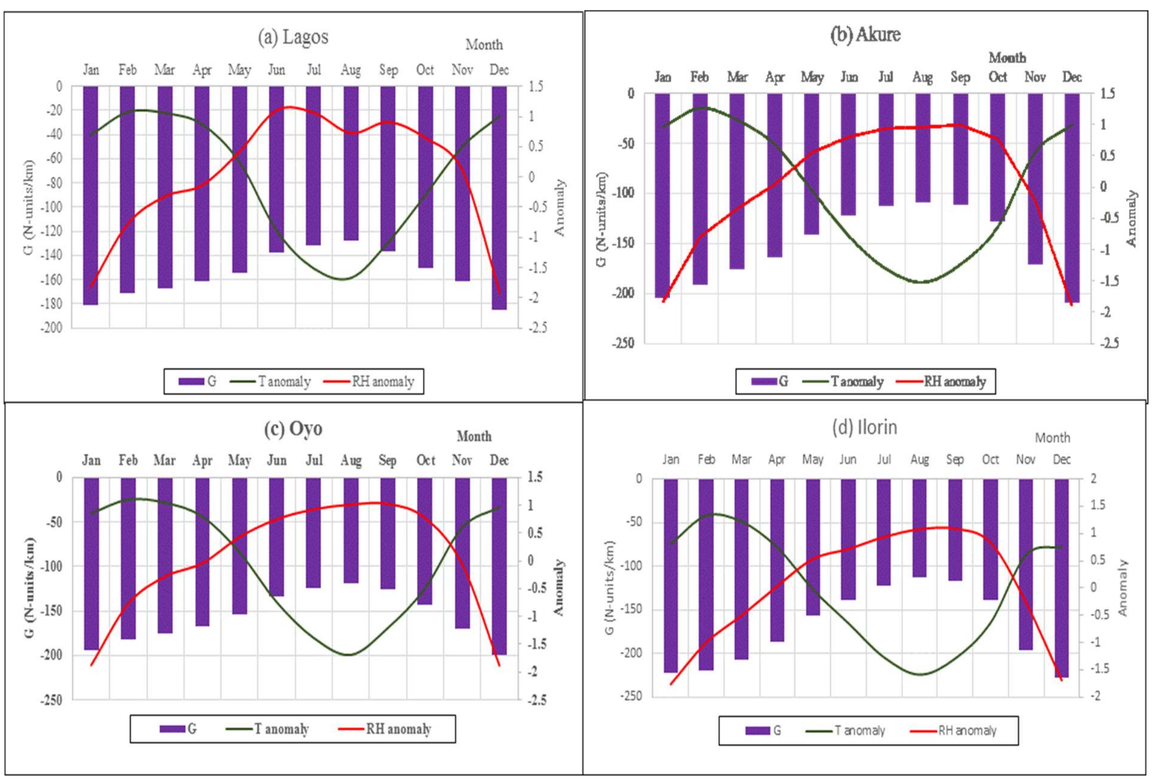

Fig. 5. Seasonal distribution of refractivity gradient and meteorological anomaly in (a) Lagos (b) Akure (c) Oyo and (d) Ilorin

https://dx.doi.org/10.4314/njpap.v9i1.7

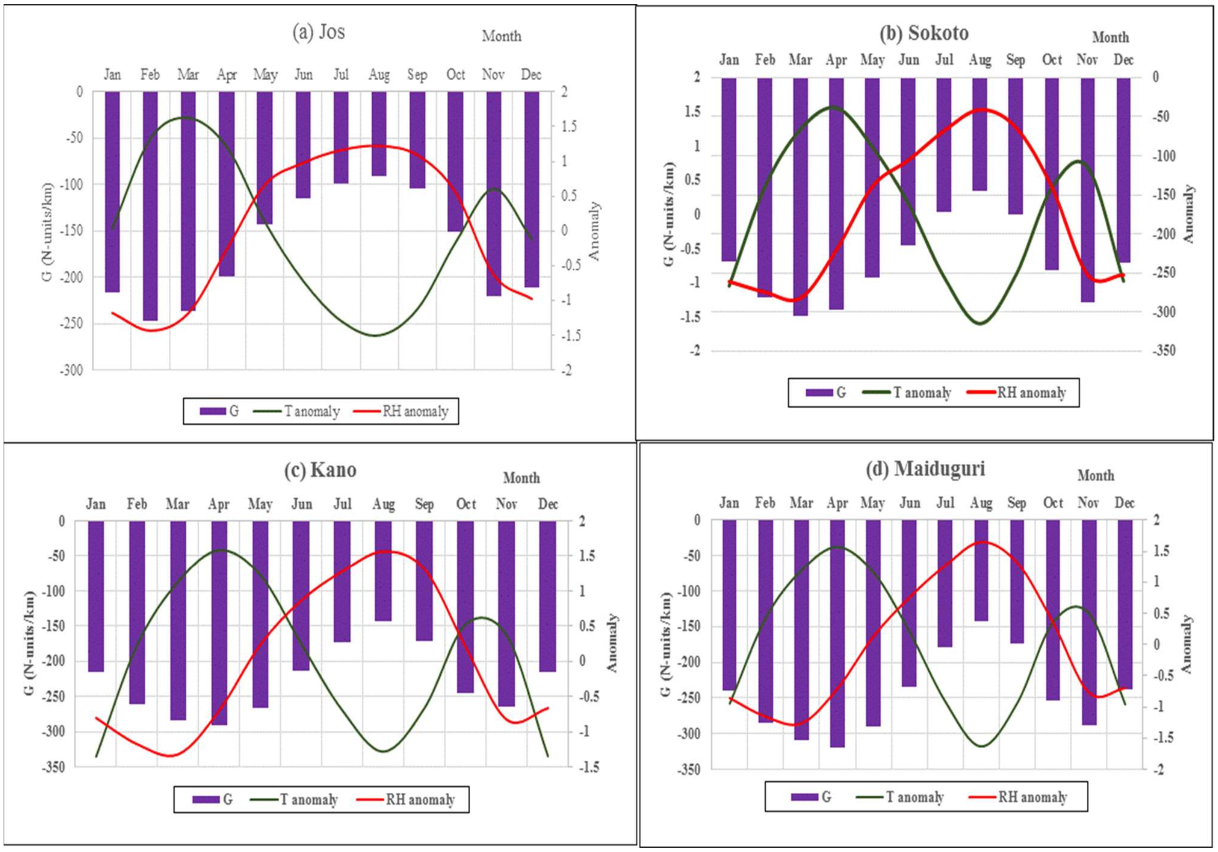

Fig. 6. Seasonal distribution of refractivity gradient and meteorological anomaly in (a) Oyo (b) Ilorin (c) Maiduguri and (d) Kano

were obtained and analysed using meteorological data obtained from Era-interim archive. Spatial distribution of duct and duct components (wet and dry) were plotted for peak of dry season (January), onset of wet season (April), peak of wet season (September) and onset of dry season (November) in Nigeria. The range of variation between the peak of dry season and onset of wet season is about 50% of wet component and refractivity gradient, while the dry component is less than 5%. Correlation of ducting and metrological parameter (temperature and relative humidity) were also analyzed for some selected location across Nigeria. Strong negative correlation exist between ducting occurrence and temperature except in Lagos where the correlation value is 3.7 %. Positive correlation which ranges between 39% and 70% existed between ducting and relative humidity. The monthly distribution of refractivity gradient and metrological anomaly were also examined for some location across Nigeria. These parameters experiences monthly variations with RH anomaly and G having similar trends.

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