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DIURNAL AND SEASONAL VARIATION OF SURFACE REFRACTIVITY OVER NIGERIA

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Abstract—The diurnal and seasonal variation of surface refractivity over Nigeria was studied using four years in-situ meteorological data from eight location over Nigeria. At all the stations studied, it was observed that the diurnal refractivity variation was caused majorly by the dry term in the rainy season and the wet term is the major cause of refractivity variation in dry season except Sokoto and Jos. In Sokoto the result was found to be opposite and it is attributed to the fact that in dry season the humidity is almost close to zero while in rainy season the pressure seems to be almost constant but the temperature fluctuates rapidly and consequently the humidity. The variation pattern in Jos is as observed because of the altitude (~ 1000 m above sea level). At this altitude pressure variation seems to be insignificant. The result also show that the surface refractivity generally have higher value during rainy season than dry season at all location studied. The result also show that the value of surface refractivity increases from arid region in the north to the coastal area in south. The result also show that the diurnal refractivity variation is basically a function of local meteorology and while seasonal variation is caused follows the climatic condition.

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1. INTRODUCTION

The refractive index of the troposphere is an important factor in predicting performance of terrestrial radio links. Refractive index variations of the atmosphere affect radio frequencies above 30 MHz, although these effects become significant only at frequencies greater than about 100 MHz especially in the lower atmosphere. The radio refractive index n of the troposphere deviates slightly from unity due to the polarisability of the constituent molecules by the incident electromagnetic field, and the quantum mechanical resonances at certain frequency bands. While molecular polarisability is independent of frequency up to millimeter waves, molecular resonance is totally frequency dependent, and n tends to be dispersive above ~ 50 GHz [1].

Radio refractivity N is a measure of deviation of refractive index n of air from unity which is scaled-up in parts per million to obtain more amenable figures. Thus, N is a dimensionless quantity defined as measured in N units [2].

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

N depends on meteorological parameters of pressure P (hPa), temperature T (K) and water vapour pressure e (hPa), as given by the relation [2, 3]:

$$N = \frac{77.6P}{T} + 3 \times 10^5 \frac{e}{T^2} \tag{2}$$

The vapour pressure is also related to the relative humidity H (%) [2]:

$$e = \frac{He_s}{100} \tag{3}$$

e_s is the maximum (or saturated) vapour pressure at the given air temperature t °C, and may be obtained from:

$$e_s = 6.11 \exp\left[\frac{17.502t}{(t + 240.97)}\right] \tag{4}$$

Generally P and e decrease rapidly with height while T decreases slowly with height [2].

Horizontal variation of refractive index is generally negligible in the lower troposphere compared to the large-scale vertical variation which has a median gradient of about -40 N/km near the surface in midlatitude and most temperate regions [4]. However, significant deviations can arise from local or mesoscale meteorological factors, especially in the tropics [5]. This horizontal variation of refractive index is very significant over Nigeria because of the significant change in climatic condition from the coastal region in the extreme south to the semi-arid region in the extreme North.

Change in refractive index with height causes radiowaves to curve downwards, and to a degree which depends on the vertical refractivity gradient. Refractive bending causes extension of the radio horizon beyond the optical horizon. Surface radio refractivity N_s is known to have high correlation with radio field strength values [5, 6] while the surface refractivity gradient which depends on N_s determines the refractivity condition of the atmosphere which may result in a normal, sub-refractive, super-refractive or ducting layer, each of which has important influences on propagation of VHF, UHF and microwaves in the atmosphere. Under normal atmospheric conditions the refractive index of air decreases uniformly with height, and the surface value N_s is known to have a good positive correlation with the parameter ΔN representing the refractivity gradient in the first 1 kilometer above the surface. Lane and Bean [7] obtained correlation coefficient of 0.70 between VHF field strength and N_s and 0.71 between VHF field strength and ΔN. Other parameters also proposed for predicting or interpreting radio data include the equivalent gradient G_e [8], and the potential refractive index K [9]; while Saxton [10] highlighted the relative merits of the parameters. However, N_s is commonly used because of the relative ease in obtaining the related surface parameters of temperature, pressure and relative humidity from many widely separated stations. Bean and Thayer [11] showed that elevation angle errors and range errors can also be predicted from N_s values.

Thus, good knowledge of N_s as well as the diurnal and seasonal variability is particularly useful in planning terrestrial radio links. Earlier efforts in this regard with respect to Nigerian stations could not explore the diurnal trend due to paucity of data. Owolabi and Williams [12] showed that N_s in Minna has an annual range of 300–375 N-units while the seasonal trend showed that N_s rises from February to April, is steady between April and September and decreases from October to a minimum in February. The study by Kolawole [13] revealed that reduced-to-sea-level surface refractivity N_o in Nigeria varies from about 390 in the coastal areas of South to about 280 in the northern parts of the country. This is in agreement with Adebanjo [14] but slightly differs from Owolabi and Williams [12] due to the elevation dependence of N_s. Oyedum and Gambo [15] obtained similar results and a correlation coefficient of 0.73 between N_s and transhorizon VHF field strength values in Northern Nigeria; Oyedum [16] showed that based on N_s variability, substantial climate-related differences exist between the seasonal variability of VHF field strength and radio horizon distance in two Nigerian stations of Lagos (06° 35′N, 03° 20′E) on the Atlantic coast and Kano (12° 03′N, 06° 42′E) in sub-Sahara Northern Nigeria. Oyedum et al. [18] showed that reduced-to-sea-level refractivity in Minna (09° 37′N, 06° 32′E) has considerable diurnal and seasonal tendencies: Maximum values occur in the night while minimum values occur towards local evening; and a seasonal trend of higher values in rainy season and lower values in dry season. This seasonal trend is in agreement with other reports on Nigerian stations, including more recent efforts such as Adeyemi [17] or Titus and Ajewole [18].

In this work we investigate the diurnal and seasonal variation of surface refractivity over Nigeria using four years meteorological data from eight locations (Nsukka (Enugu), Akure, Jos, PortHarcourt, Makurdi, Minna, Sokoto and Lagos) to cover all the climatic regions in Nigeria (Figure 1). The improvement of this work on previous work is that for the first time local meteorological data are employed unlike the previous studies were the data employed assume a generalization base on regional climatic classification. This work will therefore reveal effect of local meteorology as well as regional climate.

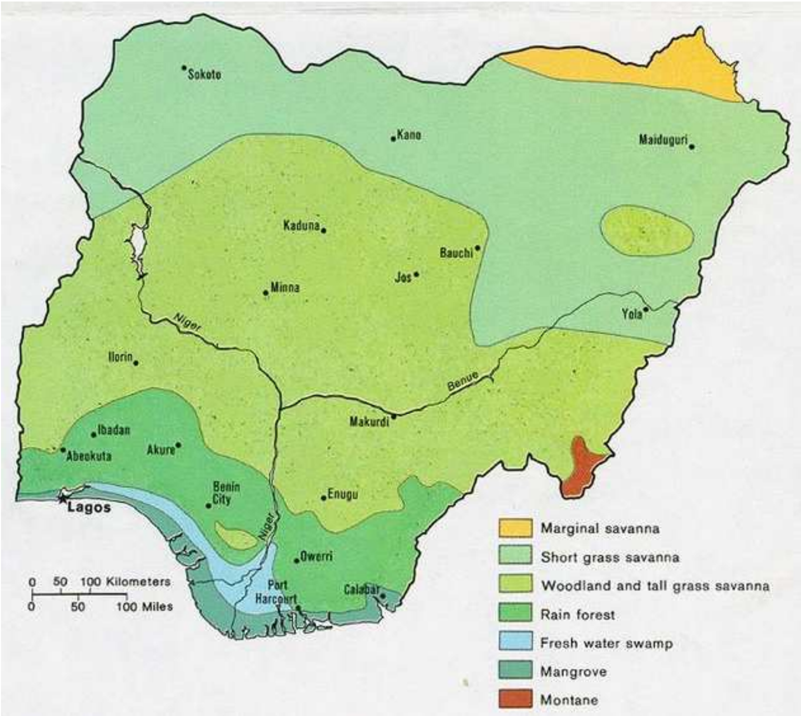


Figure 1. Vegetation map of Nigeria showing study area.

2. CLIMATIC CHARACTERISTICS OF NIGERIA

Nigeria is located between latitude 4°N and 14°N and longitude 2°E and 15°E respectively. The total area of 923,768 square kilometre falls within the **latitude and longitude of Nigeria**. The **country** is located within the Equator and the Tropic of Cancer. The **latitude of Nigeria** falls within the tropical zone but the climatic conditions are not entirely tropical in nature. The climatic condition varies in most parts of the country, in the north the climatic condition is arid and to the south there is an equatorial type of climate. The weather condition can be generally characterised into wet season, from April to October and dry season, from November to march in most part of the country.

The sites for this work was chosen to cover all the climatic region from the coastal region in the south to the arid region in the north (Figure 1)

3. INSTRUMENTATION AND DATA HANDLING

Four years data (2007–2010) from each of the eight locations under study was employed in this work. Two types of weather stations were employed for data collection. The first instrument for the measurement is the Davis 6162 Wireless Vantage Pro2 equipped with the integrated sensor Suite (ISS), a solar panel (with an alternative battery source) and the wireless console. The ISSs are positioned at the ground level for continuous measurement of the surface weather parameters: atmospheric pressure, temperature and relative humidity. The data is then transmitted by wireless radio to the data logger attached to the console/receiver located on the ground from which the data are then copied to the computer. The instrument has integration time of 30 minutes. This type of weather station was employed at Nsukka, Sokoto, Minna and Akure.

The second type of instrument is the Campbell automatic weather station with telemetry capability. This station have discreet sensors with capability of sending all the data to a single server. The integration time of this instrument is 5 minutes. This type of weather station was employed at Jos, Lagos, PortHarcourt and Makurdi.

To be able to combine data from these two types of weather station, the stations were first synchronised to ensure same level of sensitivity. This synchronisation was achieved by comparing the data from the two stations place side by side in the same location with data collected from other hand held instruments.

The data collected from these two instrument were then averaged over each hour to give twenty four data point representing diurnal variation for each month. Each month is further averaged to give a data point for each month and the seasonal variation for each year. The corresponding months for each year of the two years under study were then averaged to give the seasonal variation for the period under study.

4. RESULTS AND DISCUSSION

The diurnal and seasonal variation of refractivity over the study areas is depicted in Figure 2(a) to Figure 9(b).

The diurnal variation of surface refractivity at Akure in the dry season is shown in Figure 2(a). The refractivity shows a high value of about 360N-units to about 365 N-units during the early hours of the day and late in the evening. The value of refractivity start dropping about noon and reach a minimum of about 340 N-units around 17:00 hr local time. This variation was attributed to the response of the earth to solar insolation which is the major forcing behind the weather condition observed. The solar insolation caused the temperature to be high and humidity to be low during the day. The result shows that the refractivity over Akure for dry season is as a result of variation in the wet term of the refractivity. This result is in agreement with previous studies [19].

The variation of refractivity over Akure for rainy season is shown in Figure 2(b). The refractivity drop to a first minimum of about 368 N-units around 5:00 hr local time. It gradually increased to maximum of about 375 N-units around 10:00 hr local time. It decrease from then to another minimum of about 366 N-units around 16:00hr local time before increasing for the rest of the day. The pattern of refractivity variation observed here is different from what is described in the literature. To understand the reason for this pattern of variation, a profile of temperature, humidity and pressure was plotted (Figures 2(c), 2(d) and 2(e)). While the diurnal variation of temperature and humidity showed the expected pattern, the pressure variation showed a pattern that is synchronous with refractivity variation. It is therefore deduced that the pressure (dry term) is the major driver of the refractivity variation over Akure in the rainy season. This shows that while the wet term drive the refractivity variation in dry season, the dry component is the major driver in rainy season.

It should however be noted that diurnal variation of refractivity in the dry season over Akure (about 30 N-units) is more pronounce than the refractivity variation in the rainy season (about 8 N-units).

The diurnal variation of surface refractivity for rainy and dry season is depicted in Figures 3(a) and 3(b) respectively. Figure 3(a) shows that the refractivity is high (about 357 N-units to 360 N-units) in the early and late hours of the day. It gradually drops from 9:00 hr local time reach a minimum of about 344 N-units around 17:00 hr before gradually risen till the end of the day. This variation pattern is in line

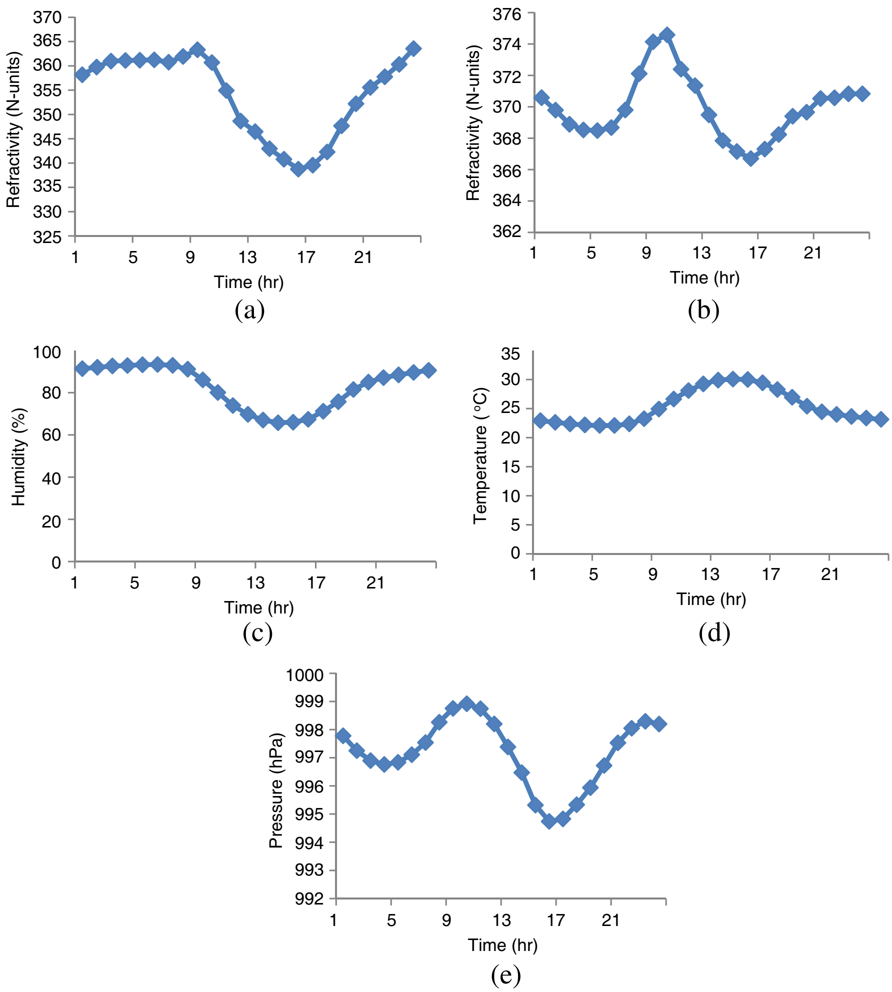


Figure 2. (a) Diurnal variation of refractivity over Akure for dry season. (b) Diurnal variation of surface refractivity over Akure for rainy season. (c) Diurnal variation of humidity over Akure for rainy season. (d) Diurnal variation of temperature over Akure for rainy season. (e) Diurnal variation of pressure over Akure for rainy season.

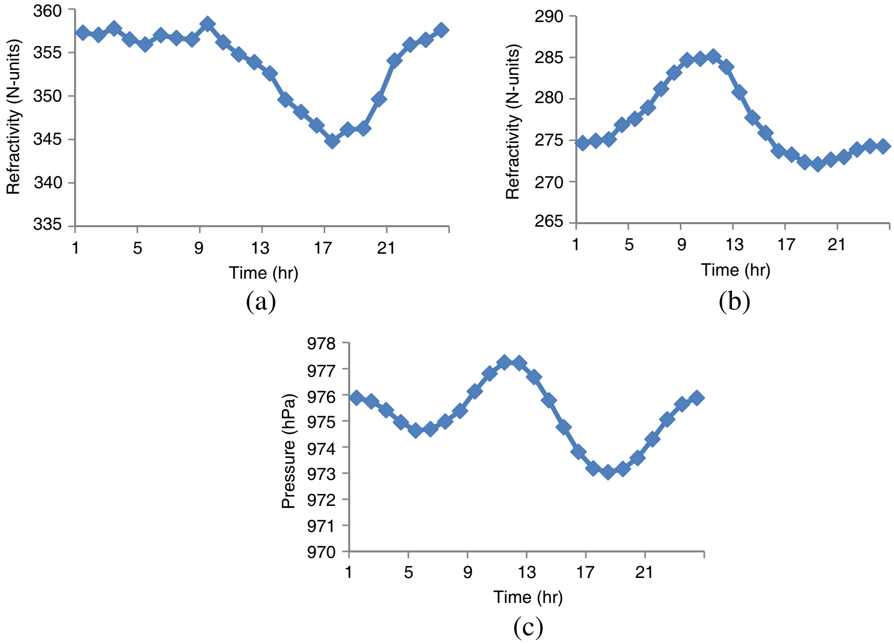


Figure 3. (a) Diurnal variation of surface refractivity over Sokoto for rainy season. (b) Diurnal variation of refractivity over Sokoto for dry season. (c) Diurnal variation of pressure over Sokoto for dry season.

with what is expected when the refractivity variation is been driven by the wet term (humidity) of tropospheric refractivity.

The diurnal variation of surface refractivity over Sokoto for dry season as shown in Figure 3(b) revealed high value during the day and low values in the morning and late in the evening. A maximum value of about 285 N-units was observed about noon over Sokoto in dry season. This result is contrary to what should be expected if the variation of refractivity is driven by the wet component. To show that the refractivity variation in this period over Sokoto is likely driven by the dry component a pressure profile was plotted in Figure 3(c). the pressure profile shows a synchronous pattern of variation with refractivity variation depicted in Figure 3(b). This confirm that while the refractivity variation over Sokoto is driven by the wet term in rainy season, the dry component is responsible for the variation in dry season. This result is contrary to what was observed in Akure earlier.

Figures 4(a) and 4(b) depicts the diurnal variation of surface refractivity over Minna for dry and rainy seasons respectively. While 4(a) showed a variation with high value during the early hours of

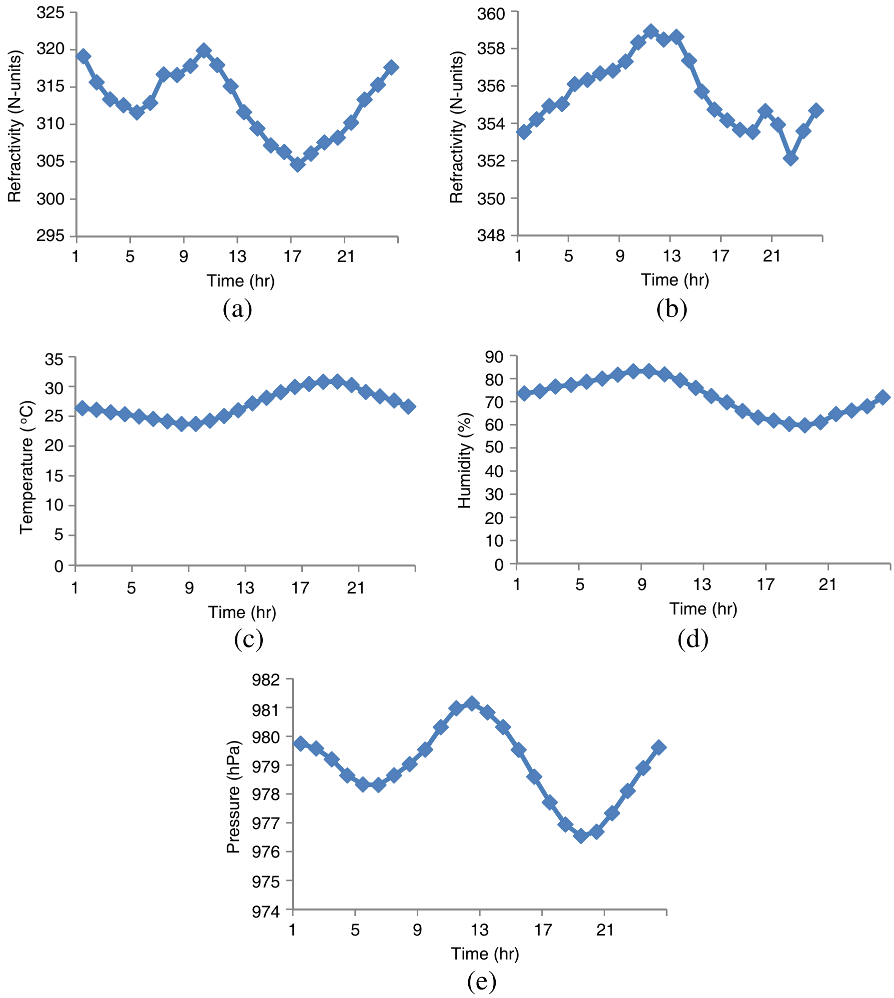


Figure 4. (a) Diurnal variation of surface refractivity over Minna for dry season. (b) Diurnal variation surface refractivity over Minna for rainy season. (c) Diurnal variation of temperature over Minna for rainy season. (d) Diurnal variation of humidity over Minna for rainy season. (e) Diurnal variation of pressure over Minna for rainy season.

the day which drops gradually from noon and reached a minimum of about 305 N-units around 17:00 hr local time for dry season, Figure 4(b) showed a variation that peaked to about 359 N-units at noon for rainy season. The variation in the dry season can be attributed to the influence of the wet term of refractivity which is mainly influence by the humidity. The variation in the rainy season can only be understood if the profile of temperature, humidity and pressure is plotted as shown in Figures 4(c), 4(d) and 4(e). Figures 4(c), and 4(d) showed the variation of temperature and humidity respectively. The temperature was lowest around 9:00 hr local time before gradually risen to maximum around 19:00 hr local time. The variation of humidity followed opposite trend as expected with highest value around 9:00 hr local time and 19:00 hr respectively. The pressure profile in Figure 4(e) showed maximums around noon and late around midnight and minimums around 6:00 hr and 19:00 hr local time. The combination of these three profiles can be used to explain the refractivity variation at Minna during the rainy season. While the maximum value of refractivity at noon can be attributed to maximum pressure at this time of the day (that is, the refractivity variation is driven by the dry term), the refractivity variation in the early hours and late hours of the day are driven by the combination of the wet and dry terms. This is evident in the gradual risen of refractivity from early morning to about 9:00 hr local time which is consistent with the humidity profile (wet term) with slight drop from 4:00 hr local time to 6:00 hr local time which is consistent with drop in pressure (dry term) and with lowest value of refractivity at around 19:00 hr local time and gradual rise till the end of the day which is consistent with both humidity (wet term) and pressure profile (dry term). In other word, the diurnal variation of refractivity over Minna for rainy season is as a result of the combination of both wet and dry terms.

The variation of refractivity over Nsukka for dry season as depicted in Figure 5(a) showed a pattern that is not consistent with any of the stations that had earlier been presented. This station showed a slightly high value at the beginning of the day that gradually dropped and reached a minimum of about 335 N-units around 5:00 hr local time. It then gradually increased with slight drop around noon and peaked to about 360 N-units around 21:00 hr local time. The humidity profile shown in Figure 4(b) also shows the same synchronous pattern of variation. Therefore, the refractivity variation over Nsukka for dry season can be said to be driven by the wet term.

The diurnal refractivity variation for rainy season over Nsukka as depicted in Figure 5(c) showed low value in the early hours of the day which gradually increased and reached maximum of about 372 N-units around 11:00 hr local time before gradually dropping to a minimum of about 366 N-units around 18:00 hr local time and rise till the end of the day. The consideration of the pressure profile as depicted in Figure 5(d) shows almost a synchronous pattern except slight differences at 2:00 hrs local, 10:00 hr local time and 16:00 hr local

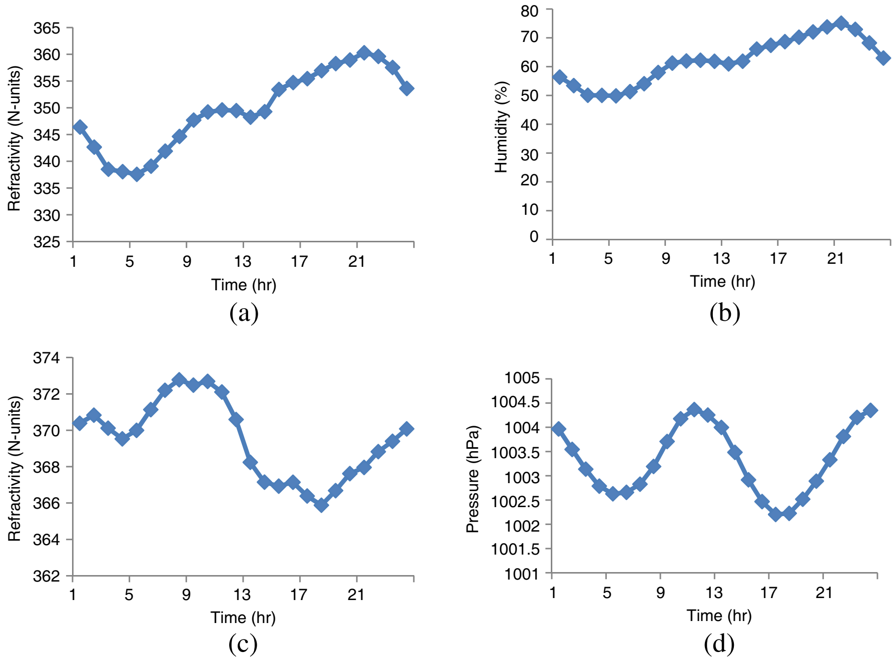


Figure 5. (a) Diurnal variation of surface refractivity over Nsukka for dry season. (b) Diurnal variation of surface refractivity over Nsukka for dry season. (c) Diurnal variation of surface refractivity over Nsukka for rainy season. (d) Diurnal variation of pressure over Nsukka for rainy season.

time. These discrepancies are attributed to the contribution of the humidity (wet term of refractivity). The refractivity variation over Nsukka for rainy season is therefore driven mainly by the combination of the dry and wet terms of refractivity.

Figure 6(a) shows the diurnal variation of refractivity over Makurdi for dry season. This profile shows a gradual increase from early hours of the day and a peak of about 330 N-units around 10:00 hr local time and gradually decrease to minimum of about 305 N-units around 17:00 hr local time before risen to the end of the day. This variation pattern synchronised with humidity profile presented in Figure 6(b). This shows that the diurnal variation of refractivity for dry season over Makurdi is driven by the wet term of refractivity.

The diurnal variation of refractivity over Makurdi for rainy season is depicted in Figure 6(c). The refractivity peaked to about 369 N-units around noon and gradually dropped to a minimum of 362 N-units around 17:00 hr local time. It slightly rises to another small peak of

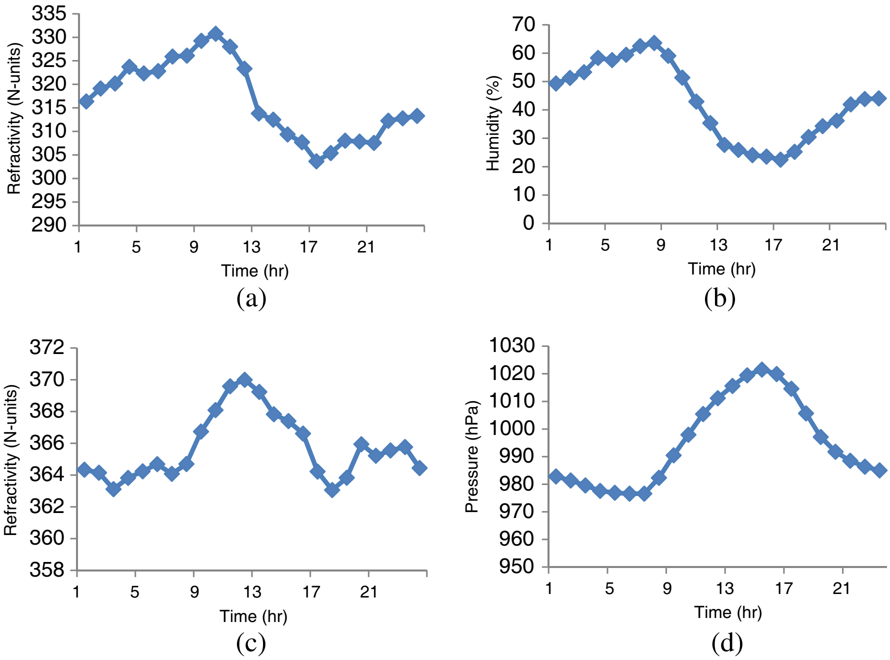


Figure 6. (a) Diurnal variation of surface refractivity over Makurdi for dry season. (b) Diurnal variation of humidity over Makurdi for dry season. (c) Diurnal variation of surface refractivity over Makurdi for rainy season. (d) Diurnal variation of pressure over Makurdi for rainy season.

about 364 N-units around 20:00 hr local time and the dropped again for the rest of the day. While the peak at noon can be explained by the pressure profile shown in Figure 6(d), the variation in the early hours of the day cannot be explained by this profile and it is therefore attributed to the contribution of the wet term. The diurnal variation of refractivity over Makurdi in rainy season is therefore due to the contribution of the both the wet and dry terms of the refractivity.

The diurnal variation of refractivity for rainy and dry seasons over Jos is depicted in Figures 7(a) and 7(b) respectively. The two profiles show low values in the day and high values in the morning and evening. The highest value for rainy season is about 322 N-units and the lowest value is 300 N-units while the highest value for dry season is about 270 N-units and the lowest value is about 255 N-units. The diurnal variation of refractivity over Jos showed a consistency with what is expected of humidity variation and therefore it is attributed to the wet term for both seasons.

The diurnal variation of refractivity over Port-Harcourt for dry and rainy season is depicted in Figures 8(a) and 8(b) respectively. Figure 8(a) showed that the refractivity value is high in the early morning and late in the evening with maximum value of about 365 N-units and low during the day with minimum value of about 320 N-units between the 14:00 hr and the 15:00 hr local time. This is agreement with what is expected when the refractivity variation is been driven by the wet term.

The variation in Figure 8(b) shows a sudden in just pre-noon and sudden drop post-noon. The maximum value of about 378 N-units was observed around noon. This maximum at noon can be explained as a result of the contribution of the dry term of refractivity and the variation during the remaining period and the sudden rise and fall at

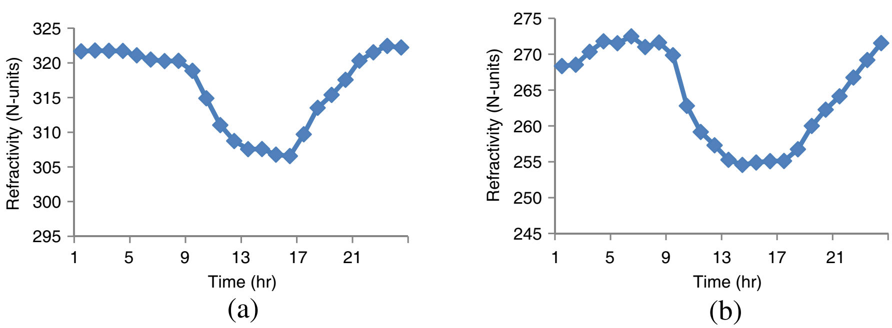


Figure 7. (a) Diurnal variation of surface refractivity over Jos for rainy season. (b) Diurnal variation of surface refractivity over Jos for dry season.

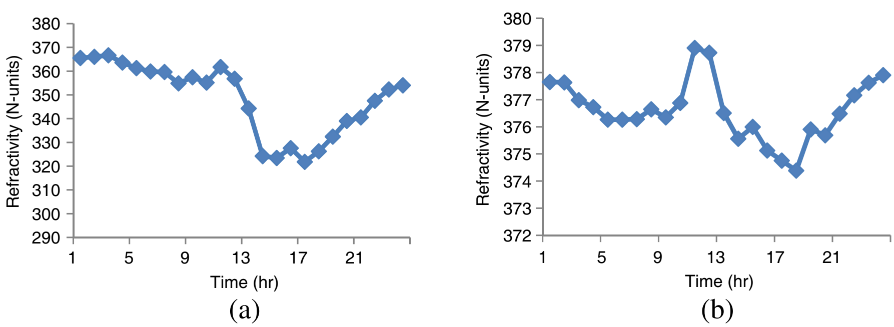


Figure 8. (a) Diurnal variation of surface refractivity over Port-Harcourt for dry season. (b) Diurnal variation of surface refractivity over Port-Harcourt for rainy season.

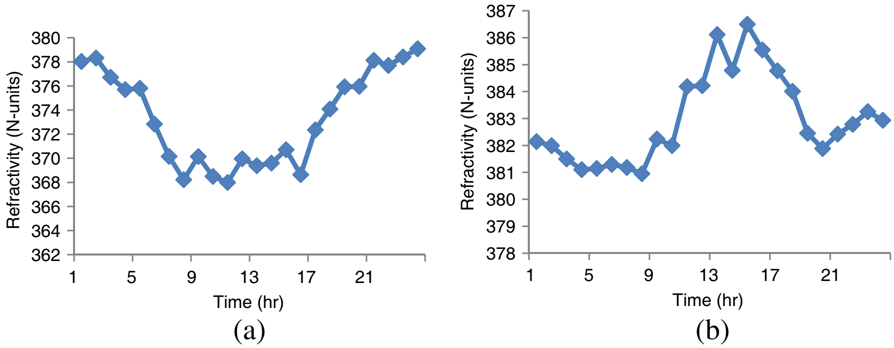


Figure 9. (a) Diurnal variation of surface refractivity over Lagos for dry season. (b) Diurnal Variation of surface refractivity over Lagos for rainy season.

noon is attributed to the contribution of the wet component.

The diurnal variation of refractivity over Lagos for dry season as shown in Figure 9(a) shows strong dependence on the wet term of refractivity with high values in the morning and late in the evening and low values in the day time. The highest value is about 380 N-units and the lowest value is about 368 N-units at 9:00 hr, 12:00 hr and 17:00 hr.

The diurnal variation of refractivity over Lagos for rainy season as shown in Figure 9(b) shows a maximum in the afternoon with a sudden rise and sudden drop just before noon and just after noon. The maximum value is about 387 N-unit which occur between the 13:00 hr local time and 15:00 hr local time. The peak value at this period is attributed to the pressure variation (dry term) while the variation during the rest of the day and the sudden rise and sudden drop pre-noon and post-noon is attributed to the contribution of the wet term. In other word, the diurnal variation of refractivity over Lagos during rainy season is as a result of the contribution of both the dry and wet terms.

Figure 10 to Figure 17 depict the seasonal variation of refractivity for the study areas for the period under investigation. It is observed from the results that there is seasonal variation of refractivity at all the stations. This result agree with the work of Owolabi and Williams [12] and Oyedum and Gambo [15]. The results also showed an increase in the value of refractivity from minimum value of about 270 N-units at Sokoto station (Figure 13) to maximum value of about 390 N-units at Lagos station (Figure 17). This result agrees with work of Kolawole (1980) [13].

Figure 10 is the seasonal variation of refractivity over Nsukka for

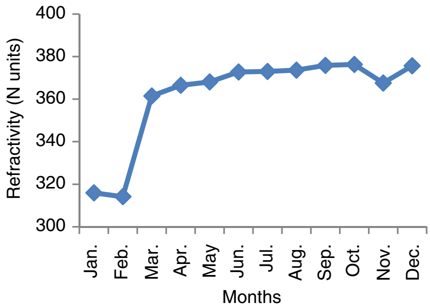


Figure 10. Seasonal refractivity variation over Nsukka.

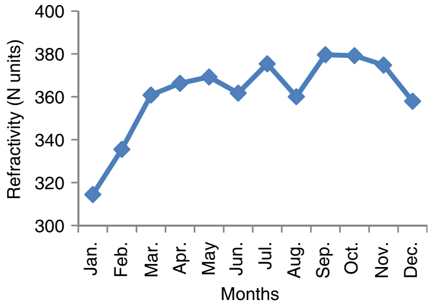


Figure 11. Seasonal variation of refractivity over Akure.

2008 to 2009. The refractivity at Nsukka showed gradual increase from a minimum of about 315 N-units for February until it climaxed at about 380 N-units for the month of October. There is slight drop for the month of November before reaching another peak of about 375 N-units in December. This pattern of variation can be attributed to rain pattern in Nsukka over the period under study where it usually rain till December with a little break from mid-November to about early December and rained throughout December before the unset of dry season between January and February.

The variation of refractivity over Akure as depicted in Figure 11 also show a seasonal variability with gradual increase from minimum of about 315 N-units in January and maximum of about 380 N-units in September. The refractivity over Nsukka showed slight drop in June and August. The drop in August can be attributed to August break while that of June can be attributed to slight rain cessation from late May to early June.

Seasonal variation of refractivity over Minna, Makurdi and Jos is depicted in Figures 12, 14 and 15. These three stations fall within the same geographical and climatic region (North Central Nigeria/Guinea Savannah). The variation in these three stations follows the same pattern with almost constant value in the months of May to October which coincided with rainy season. The maximum value of refractivity was observed in August for the three stations. The minimum value was recorded in February at Minna and Jos while the Minimum value was recorded in December at Makurdi. The observation of Maximum in December at Makurdi in contrast to other two stations within the same climatic region can probably be attributed to the presence of river Benue in Makurdi. When the Harmattan wind climaxed in February more water vapour is blown from river Benue thereby increasing the

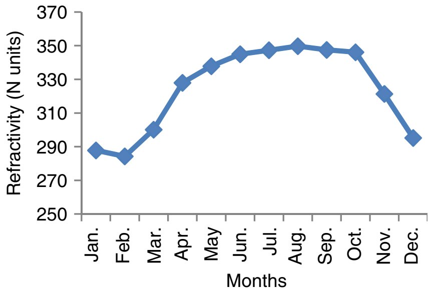


Figure 12. Seasonal variation of refractivity over Minna.

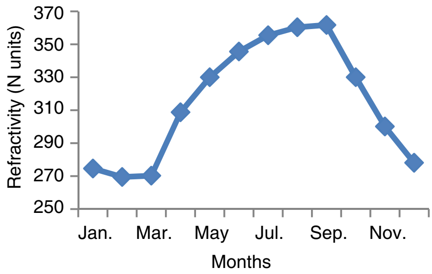


Figure 13. Seasonal variation of refractivity over Sokoto.

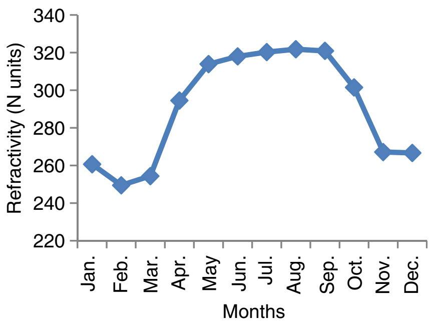


Figure 14. Seasonal variation of refractivity at Jos.

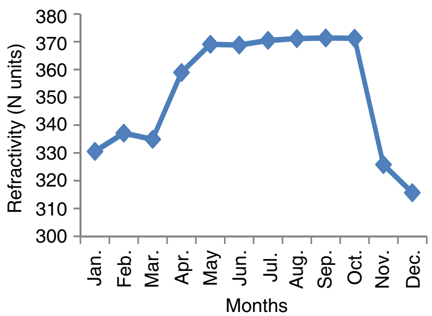


Figure 15. Seasonal variation of refractivity over Markurdi.

humidity over Makurdi and consequently the refractivity. This can also explain the drop for the month of March when the Harmattan wind has subsided and the rain is yet to commence. This observation further proves the need for local study of this phenomenon. The value of refractivity at Minna station increased from a minimum of about 280 N-units in February to a Maximum 350 N-units in August. The value of refractivity at Makurdi station increased from minimum of about 315 N-units in December to about 370 N-units in August. The refractivity at Jos station increased from 250 N-units in February to about 320 N-units in August. The low value of refractivity over Jos is attributed to high altitude. The pressure in Jos is low because of the high altitude and since the pressure is directly proportional to the dry component of the refractivity, the overall value of refractivity is affected.

The variation of refractivity over Sokoto is depicted in Figure 13. The value of refractivity shows a minimum of about 270 N-units in

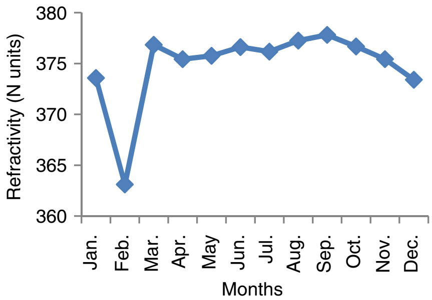


Figure 16. Seasonal variation of refractivity over Port-Harcourt.

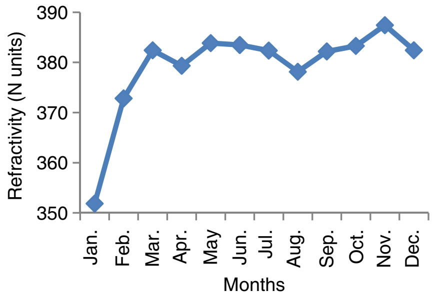
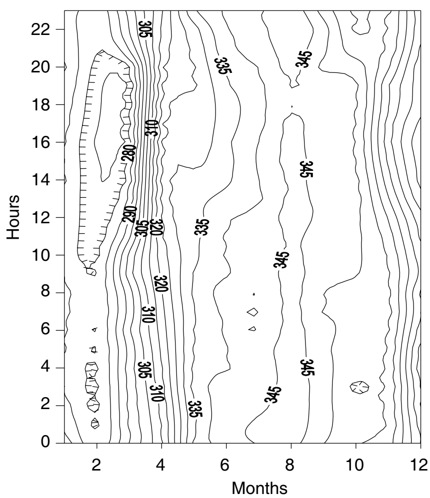


Figure 17. Seasonal refractivity variation over Lagos.

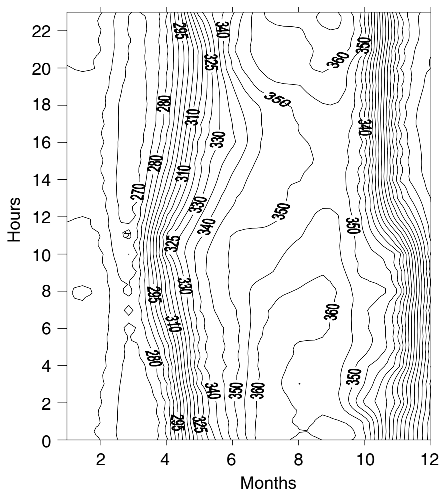
March and maximum of about 360 N-units in August. The pattern of variation in Sokoto is different from that of other Northern stations such as Minna, Makurdi and Jos with a very steep rise and fall because of rainfall pattern and shorter period of rainfall in Sokoto. Sokoto is located in North-Eastern Nigeria and within Sahel Savannah. The value of refractivity at Sokoto in the rainy season is however found to be higher than that of Minna during the peak period because the rainfall at Sokoto is usually heavy within the short rainy season.

Figures 16 and 17 depict the refractivity variation for Port-Harcourt and Lagos respectively. These stations are located along the coastal area. The refractivity variation in these stations is more erratic when compared to the previous stations considered because of the influence of the Atlantic Ocean. The value of refractivity in these stations is also high when compared with other stations due to the same reason. The value of refractivity in Port-Harcourt from about 365 N-units in February to about 378 N-units in September while that of Lagos increased from about 350 N-units in January to about 390 N-units in December.

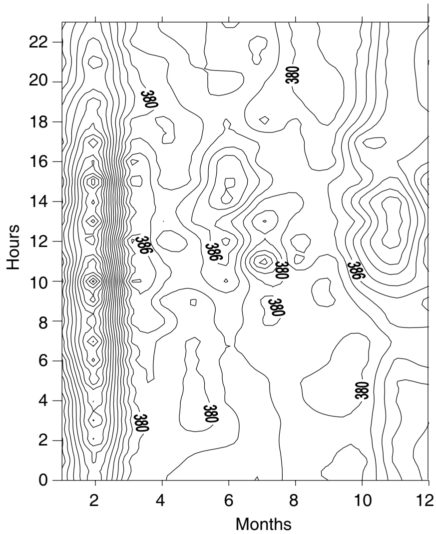
In General, for all the stations studied, the study of diurnal refractivity variation showed that the dry term is the major cause of refractivity variation in rainy season and the wet term is the major cause of refractivity variation in dry season except Sokoto and Jos. In Sokoto the result was found to be opposite and it is attributed to the fact that in dry season the humidity is almost close to zero while in rainy season the pressure seems to be almost constant but the temperature fluctuates rapidly and consequently the humidity. The variation pattern in Jos is as observed because of the altitude (~ 1000 m above sea level). At this altitude pressure variation seems to be insignificant. It is also shown the value of refractivity and consequently the refractive index showed seasonal variation with high value during rainy season and low value during dry season. This result is in agreement with the result obtained by Samson 1975 [20] which was produced as world atlas for refractivity variation. There result also show high value of refractivity at the coast compared with inland area. Dhein et al. in 1993 [21] also obtained the same result. However, none of these studies studied the diurnal variation based on different seasons. This result further emphasizes the need for local study of this



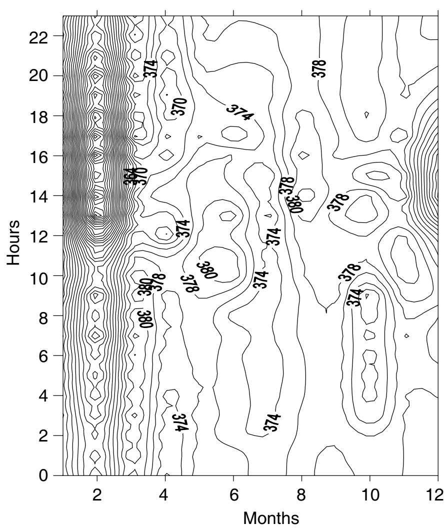
(a)



(b)



(c)



(d)

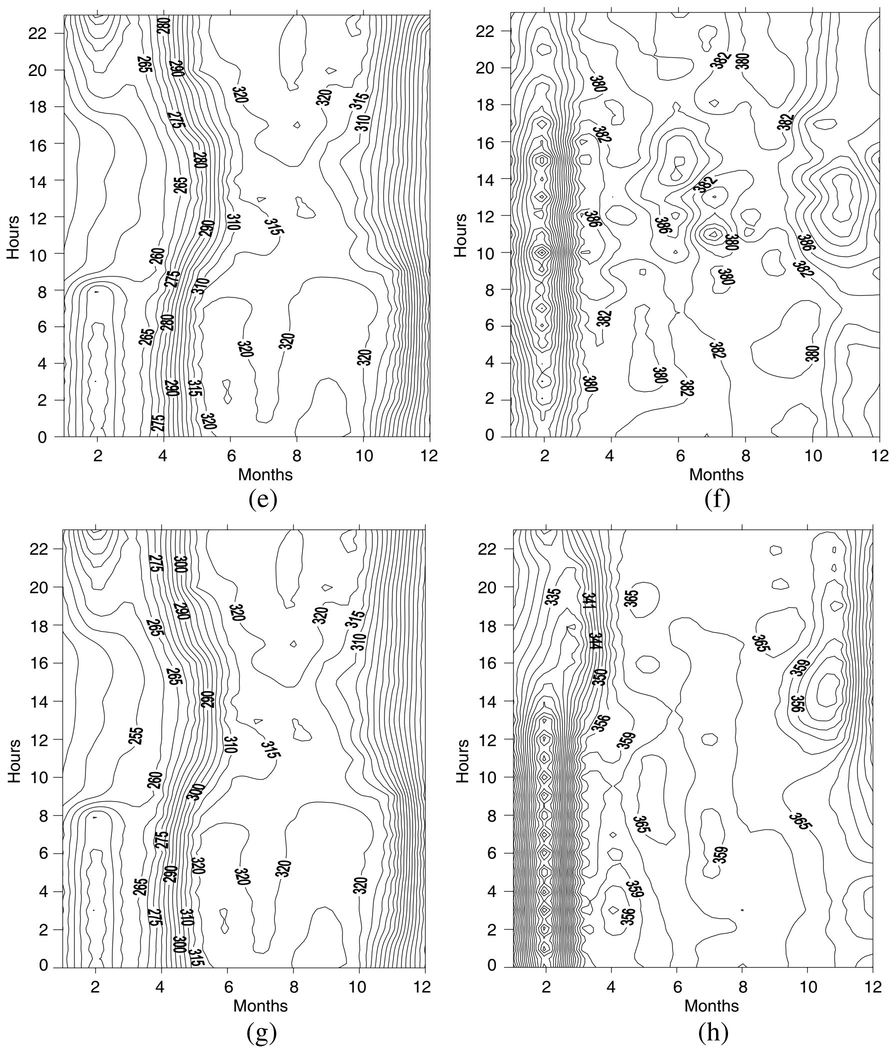


Figure 18. (a) Diurnal and seasonal variation surface refractivity over Sokoto. (b) Diurnal and seasonal variation of of surface refractivity over Minna. (c) Diurnal and seasonal variation of surface refractivity over Port-Harcourt. (d) Diurnal and seasonal variation of surface refractivity over Akure. (e) Diurnal and seasonal variation surface refractivity over Lagos. (f) Diurnal and seasonal variation of of surface refractivity over Jos. (g) Diurnal and seasonal variation of surface refractivity over Nsukka. (h) Diurnal and seasonal variation of surface refractivity over Makurdi.

phenomenon with in-situ data.

The contour maps in Figure 18(a) to Figure 18(h) present the summary of the seasonal and diurnal variation of surface refractivity over the stations under study. The results obtained from this study will be very useful in planning communication system in Nigeria especially at VHF, UHF and microwave frequencies since several studies has shown that there is a very high correlation between signal strength and surface refractivity.

5. CONCLUSION

In conclusion, the following results were deduced from this work:

(i) Refractivity value over Nigeria increases from about 270 N-units north to about 390 N-units in the south.

(ii) The diurnal variation seems to be mainly driven by the dry component in the rainy season and the wet component in the dry season.

(iii) Refractivity show a seasonal variation with high value in the rainy season and low value in the dry season.

(iv) The diurnal variation of refractivity is a function of local meteorology as observed from results obtained for all the study area while the seasonal variation is influenced by climate with exception of stations at Minna, Jos, and Makurdi where the influence of local topography is pronounce.

(v) The variation of refractivity from northern Nigeria to southern Nigeria have a maximum of about 120 N-units.

(vi) The seasonal variation of refractivity over the north has a maximum of 90 N-units at Sokoto while the maximum difference in the south is 65 N-units at Akure.

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