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Morphology of the Quiet Equatorial Ionospheric F2 Layer During a Low Solar Activity

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Abstract

The latitudinal effect on the morphology of the F2 layer of the equatorial region during the quiet period at low solar activity was studied. Digisonde data for year 2010, a year of low solar activity from three equatorial stations in the African and Southern American sectors namely; Ilorin, Nigeria (8.5°N, 4.5°E, -2.96 dip) Fortaleza, Brazil (3°S, 38°W, -7.03dip) and Jicamarca, Peru (12°S, 76.8°W, 0.74 dip) were used for the study. It was observed that the variation of the electron density covers the height range from 100 km up to the F2 peak. The result obtained showed that the h_mF2 rises sharply within the time interval of 0600-1000 LT. It has a smaller range of variation between 1100-1400 LT and after 1400 LT, it begins to decrease and usually get to a minimum around 1700-1900 LT. The maximum day time peak varies from 300-319 km and that of the post-noon is about 312-417 km. The h_mF2 at Fortaleza was observed to show no prominent pre-noon peak, during the September equinox. Generally, the N_mF2 diurnal variations are similar to those of h_mF2 and the general departure of the F2-layer from the simple Chapman layer from the height of 190-230 km were observed from the three stations studied. It was observed that the results from Ilorin and Jicamarca are similar and that of Fortaleza are different from those of other two stations. The peculiarity at Fortaleza is attributed to its closeness to the crest of the equatorial anomaly than the other two stations; these variations observed may be due to effect of the latitudinal differences.

Keywords

Latitude, Morphology, F2 Layer and Quiet Ionosphere

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1. Introduction

The ionospheric electron density (N_mF2) was expected to vary from a maximum at the equator to a minimum at high latitudes because of the impact of the solar radiation over the equator. Investigations have shown that there is a large structure within trough around the equator, crest $\pm 15^o$ magnetic latitude [1-2]. The incident solar radiation is greatest around the mid day maximizing the production of electrons, this suggest that the peak value of N_mF2 of the equatorial ionosphere should be observed during this time. Electron production at the mid day is indeed at a maximum, other dynamic processes such as action of winds and electric current have been found to contribute to variations in the N_mF2 of the F2 layer [3]. F2 layer of the equatorial region has been described as being different from other region due to its uniqueness of the pre and post noon peaks, the effect of the fountain effects on the region [4-9].

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Most of the studies of the morphology of the equatorial bottom-side ionosphere are usually based on peak ionospheric parameters; studies using the electron profiles are quite few. Various authors have studied the equatorial F2 ionospheric layer [10-14] which are either in the low or high latitudes, with very few studies being done on the equatorial region. Available studies on morphology of F2 layer are on its response during disturbed time [8, 15-18].

Studies on quiet time condition on N_mF2 deviations in the daytime F2 region have been analyzed [19-21] with most of these studies on variability and disturbed days. [22-23] have also contributed to the meteorological effects in the F2 region.

We are yet to know if any author has studied the latitudinal effect on the morphology of the F2 region on N_mF2 profile of the African sector and Southern American sector as a result of which an attempt is made in this work. The scarcity of the work may be due to the acute shortage of digisonde sounders for continuous ionospheric studies in the African sector.

2. Data and Method

The digisonde portable sounder (DPS-4) data from three equatorial stations namely; Ilorin, Nigeria (8.5°N, 4.5°E, -2.96 dip), Fortaleza, Brazil (3°S, 38°W, -7.03dip), and Jicamarca, Peru (12°S, 76.8°W, 0.74dip) were used for this study and the data source is in table 1. Hourly data obtained from a DPS-4 located at Ilorin in the form of Standard Archive Output (SAO) files for the year 2010, a year of low solar activity were used. The DPS at Ilorin and Jicamarca are capable of collecting forty-five ionospheric parameters that describe the condition of the ionosphere at a particular point in time for a routine measurement. The instrument is usually set to take measurement at fifteen minutes interval, except for that of Fortaleza, which was set to take the reading at a time interval of ten minutes. All the data from the stations were analyzed using individual local time.

The corresponding data used in the analysis for Fortaleza and Jicamarca were obtained online from the Centre for Atmospheric Research, University of Massachusetts, Lowell, United States of America http://giro.uml.edu/didbase/scaled.php. Good and scalable ionogram files were carefully chosen and days of intense storms were avoided, since the study is about the quiet days. The data is carefully chosen to avoid non-scalable ionogram and edited. The edited SAO file of same hour is copied into a separate file. The edited data is then stored in a separate file and run through a computer programme CARP (Calculated Average Representative Profile). The CARP helps to calculate the average profile of the input data for any given month. The ionograms used for the study and the data for the quiet day were manually scaled using the ARTIST program, (NHPC) to verify the automatic scaled data. The output from the SAO files was run using CARP program to obtain the average profile for a particular month. The Truth table, computer software from the NHPC programme was then run to generate the electron density profiles at a height interval of 10 km [24-25]. The average of each of the three months (November, December and January) was used to represent December Solstice; (February, March and April) March equinox; (May, June and July) June Solstice; and (August, September and October) September Equinox.

3. Results and Discussion

The Peak Height of Ionization (h_mF2)

The results obtained showed (figures 1 and 2) that the h_mF2 rises sharply within the time interval 0600-1000 LT. It has a smaller range of variation between 1100-1400 LT. After 1400 LT, it begins to decrease and get to a minimum at 1700 LT. The maximum day time peak varies from 300-391 km and that of the night around 312-417 km. These characteristics are generally observed during all seasons at the three stations studied. The highest value of h_mF2 was observed at Jicamarca during the equinox months, which is in fair agreement with results from previous studies [4, 11] that the highest value of h_mF2 should be observed during the equinox months. The variation in h_mF2 at Ilorin and Jicamarca (figure 1 (a & c) is similar and has values greater at the equinoxes than the solstice months for all the three stations. At Ilorin and Jicamarca, two distinct day peaks were observed on the h_mF2, one before noon and the other afternoon. The post-noon peak is generally higher than the pre-noon ones. The h_mF2 (figure 1b) at Fortaleza shows no prominent pre-noon peak.

During the March equinox, Figure 1(a-c) there is a steady rise in the h_mF2 from 0600-1000 LT till when the pre-noon peak was observed. The pre-noon peak at Jicamarca was observed earlier at about 10000 LT, while those of other stations were observed around 1100 LT. The highest value of h_mF2 was observed at Ilorin with a numerical value of 357 km. The post-noon peak of the h_mF2 was observed early at about 1900 LT, with that of Jicamarca having the highest value of 390 km at 2000 LT.

The observation during the September equinox is as shown in figure 1 (d-f). The h_mF2 pre-noon peak at Ilorin was first observed at 1000 LT with those of Jicamarca and Fortaleza coming around 1100 LT. The h_mF2 at Fortaleza has the highest value of 391 km.

At the June solstice (figure 2 (a-c), no distinct pre-noon peaks was observed at Ilorin and Fortaleza while the pre-noon peak was observed at 1100 LT at Jicamarca. During the

December solstice, (figure 2 (d-f) distinct pre-noon peaks was observed at all the three stations with that of Fortaleza coming around 1000 LT. The highest post-noon peak was observed at Fortaleza at around 2000 LT at 417 km.

The variation in the values of h_mF2 is observed to be higher during the equinox months than those of the solstice months. This may be due to the position of the sun during the equinox period, although other factors such as meridional wind and plasma transport may be responsible for the difference.

The Peak Electron Density (N_mF2)

The observation at Fortaleza station is similar to that of Ilorin station. The variations of h_mF2 with N_mF2 are as illustrated in figures 1 & 2. During the March equinox and the December solstices, the values of the post-noon peaks are higher than those of the pre-noon peaks, while at the September equinox and the June solstice the reverse is the case. The pre-noon peak in N_mF2 was observed at 0900 LT, with the midday bite-out between 1200-1300 LT and the peak height of ionization at 1100 LT, during the March equinox. No distinct pre-noon peak was observed at the September equinox. Also, it was observed that both the N_mF2 and h_mF2 peak around same time interval during this period. The observation at Fortaleza during the Solstice months is similar to that of the Equinox months; expect that, no distinct peak is observed during this period.

The observation at Jicamarca station is similar to that of Ilorin, except in the values of both h_mF2 and N_mF2 post-noon peaks greater that those observed at the pre-noon peaks in the solstices and equinoxes months; as illustrated in figures 1 and 2 (a-f). A distinct midday bite-out was usually observed between 1100-1300 LT at all the seasons including Jicamarca station. During the March and September equinoxes, N_mF2 and h_mF2 peak at 1000 LT, while the post-noon peaks were observed at 2100 and 1800 LT for N_mF2 and 1900 and 2000 LT for h_mF2 respectively. This is shown in figures 2 (c & f).

Figures 2 (a-f), show the observations during the solstice months. The pre-noon peaks were observed at 0900 and 1000 LT, with a sharp midday bite-out between 1200-1300 LT and the h_mF2 peaks between 10000-1100 LT. It was also observed that the values of the post-noon peaks are higher than those of the pre-noon peaks.

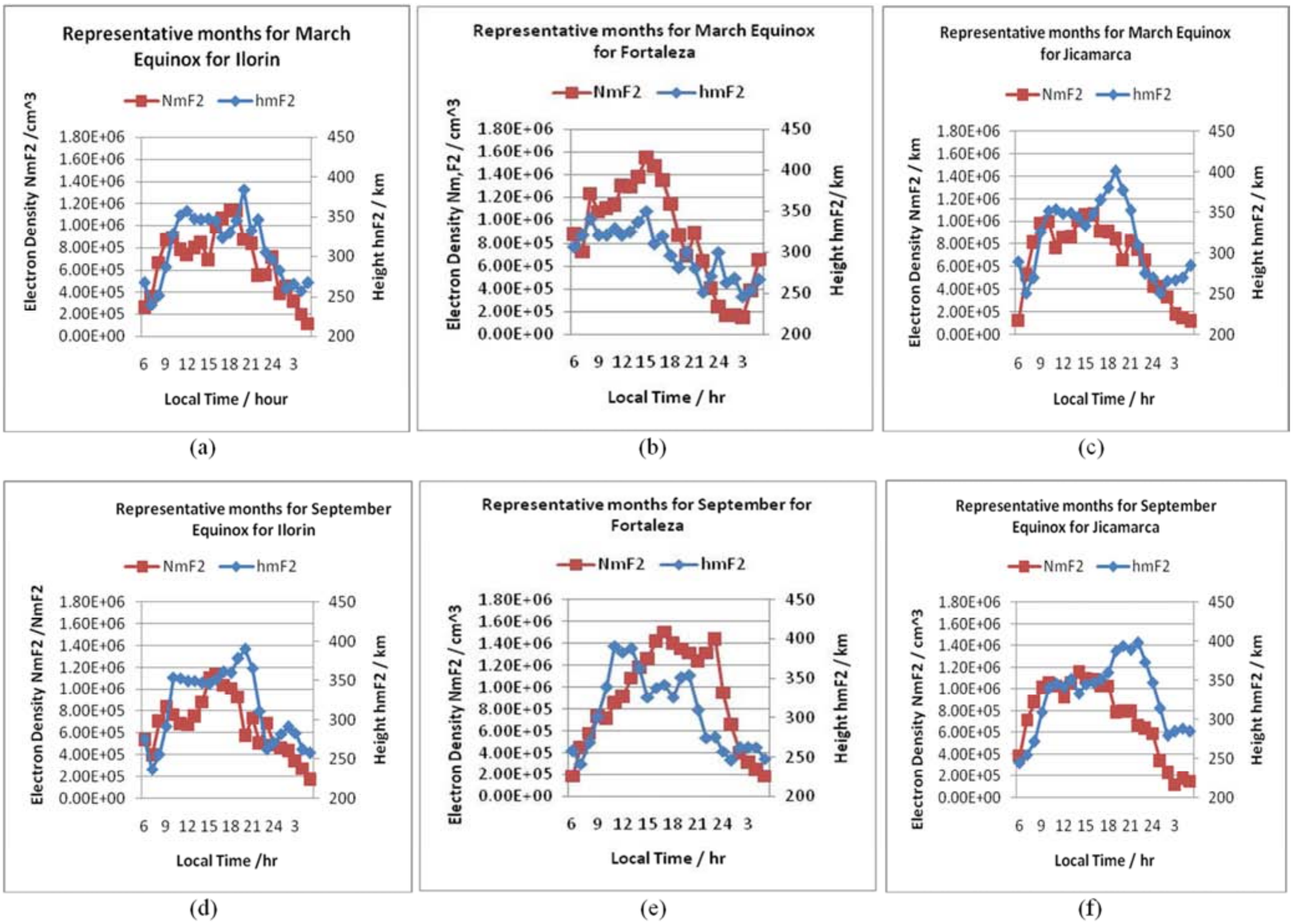

Figure 1. Average Plot for March and September Equinox (a) Ilorin(b) Fortaleza(c) Jicamarca.

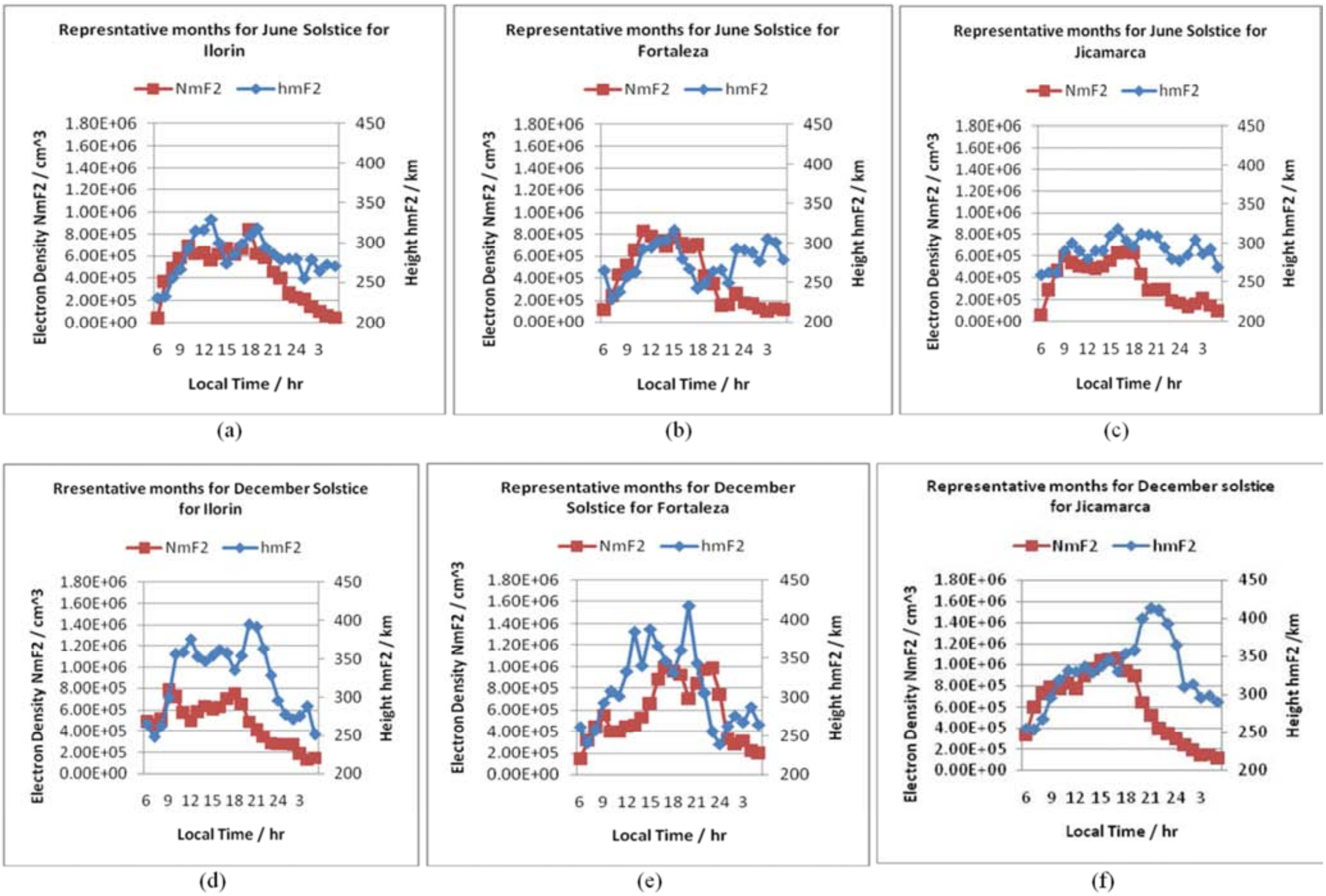

Figure 2. Average Plot for June and December Solstice (a) Ilorin(b) Fortaleza(c) Jicamarca.

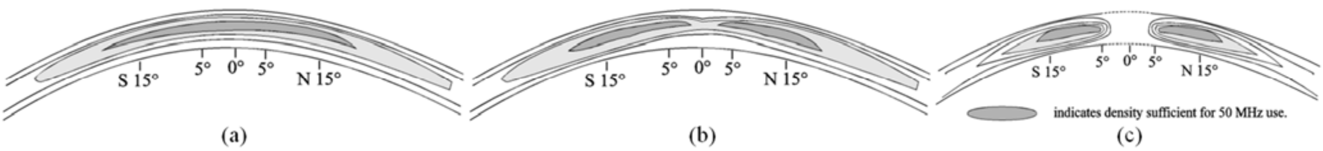

Figure 3. Typical ionization of the F region (a) Before noon (b) At noon(c) After noon (Adeniyi, et. al, 2012).

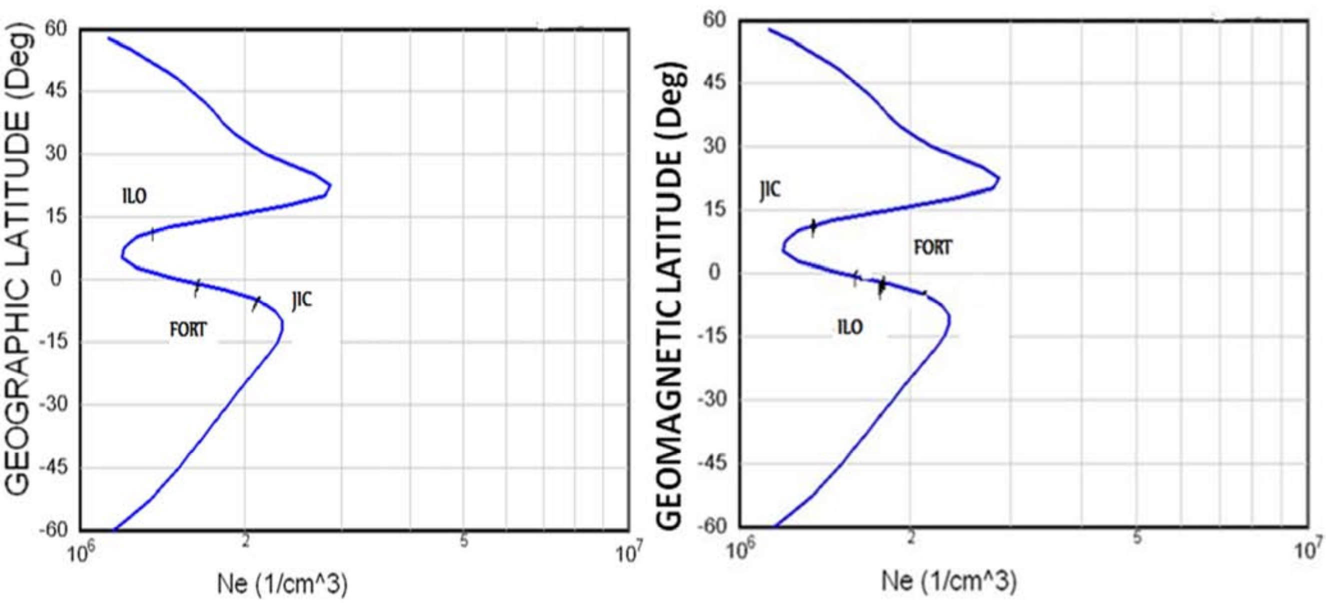

Figure 4. Equatorial Anomaly (Adeniyi, et. al, 2012).

Table 1. Data Source.

Geograhic Coordinate	Geomagnetic coordinate
Ilorin, Nigeria(8.5°N, 4.5°E)	(-1.82, 76.80, -2.96 dip)
Fortaleza, Brazil (3°S, 38°W)	(-3.64, 34.21,-7.03dip)
Jicamarca, Peru (12°S, 76.8°W)	(0.77, 354.33, 0.74dip)

At the low latitude, many special phenomena have been discussed [26-28] one of this special phenomenon is the Equatorial ionization anomaly (EIA). It is due to the horizontal orientation of geomagnetic field at the equator, at which the variation of the electron density exhibit an unexpected large structure around the equator, crests near $\pm 15^o$ magnetic latitudes and crest to trough ratio of about 1.6 in day time peak electron density [29]. The equatorial ionization of the F region is as illustrated in Figure 3 [24]. Figure 3a is a state of the equatorial ionosphere in the morning, when the neutral species has not been ionized. As the solar radiation begins to interact with the species of the ionosphere (O_2), around the noon time and figure 3b comes into play, which produces the first peak in the ionization of the species. Another peak is usually being oberved in the region, the post-noon peak is depicted in figure 3c.

[30] reported that in addition to diffusion of ionospheric species, upward $\overline{E} \times \overline{B}$ drift of plasma is important cause of the anomaly. Diffusion produces weak anomaly in the morning with the crest around $\pm 10^o$ magnetic equator due to large plasma pressure gradient between the equator and higher latitudes, and the anomaly becomes weaker with time and disappears before noon when the gradient pressure is smaller [31]. The EIA is formed mainly from the removal of plasma from around the equator by the upward $\overline{E} \times \overline{B}$ drift creating the trough and consequently the crest with small accumulation at the crests as long as the crests are at lower latitudes. The upward movement of the drift and other dynamics in the ionosphere may be the cause of the latitudunal effect on the morphology of F2 region in the equatorial layer. The peak of N_mF2 is seen to appears at different time interval at various latitude. Figure 4b, shows the geomagnetic latitude curves for Ilorin and Jicamarca, to be on the opposite sides of the curve, hence, a close resemblance of obervation in these stations. Fortaleza, observation is observed to be different due to its further distance of the station on the curve.

4. Conclusion

The main result of the morphology of the equatorial F2 layer is as stated:

(i) The layer has its peak electron density at the minimum height, when the sun is at its peak height in the sky and disappears at night

(ii) It was observed that the h_mF2 shows diurnal and seasonal variations, with two peaks: the pre-noon peak and the post-noon peak. The post-noon peaks are usually greater than, the pre-noon peaks.

(iii) The h_mF2 is usually found to be maximum when the midday bite-out is observed on the plots of N_mF2.

(iv) The N_mF2 is also characterized like the h_mF2; showing diurnal and seasonal variations with midday bite-out occurring between 1300-1400 LT. N_mF2 values at equinoxes are higher than those of the solstices.

In this study, it was observed that the results from Ilorin and Jicamarca are similar and that of Fortaleza are different from those of other two stations. The peculiarity at Fortaleza is attributed to its closeness to the crest of the equatorial anomaly than the other two stations (figure 4b).

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