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The Effect of Magnetic Storm of May 2010 on the F2 Layer over the Ilorin Ionosphere

Benjamin JOSHUA [1], Jacob O ADENIYI [2], Isaac A ADIMULA [2], Mustapha ABBAS [1], Shola J ADEBIYI [2]

ABSTRACT [ENGLISH/ANGLAIS]

The effect of magnetic storm of May 2 to 3, 2010 and that of May 29 to 30, 2010 on the F2-layer at Ilorin (Lat. 8:53°N, Long. 4.5°E.) was observed. An increase of about 65% in NmF2 was observed during the sudden commencement storm and 58% increase in the NmF2 was observed during the geomagnetic storm of May 29, 2010, when compared with the quiet day variations; we also observe an increase of about 28% in the hmF2 during the sudden commencement and also a decrease of 16% during the storm of May 29, 2010. All these features observed during the geomagnetic storm and quiet days have been explained in this study in terms of movement of ionization caused by the cross field of the electric field (E) and the earth's magnetic field B. It was also observed that the minimum value of DH field (at Ilorin, MAGDAS) during the magnetic storm days fairly corresponds to the Dst index (WDC Kyoto).

Keywords: Magnetic storm; F2 layer; Ilorin; Ionosphere

RÉSUMÉ [FRANÇAIS/FRENCH]

L'effet de l'orage magnétique du 2 au 3 mai 2010 et celle de mai 29 au 30, 2010 sur la couche F2-à Ilorin (Lat. 08:53 ° N, long. 4,5 ° E.) a été observée. Une augmentation d'environ 65% en NmF2 a été observée lors de la tempête le début soudain et augmentation de 58% dans le NmF2 a été observée lors de la tempête géomagnétique du 29 mai 2010, en comparaison avec les variations journée tranquille, nous observons également une augmentation d'environ 28 % dans le cours hmF2 le début soudain et aussi une diminution de 16% pendant la tempête du 29 mai 2010. Toutes ces caractéristiques observées lors de la tempête géomagnétique et des jours tranquilles ont été expliquées dans cette étude en termes de mouvement de l'ionisation provoquée par le champ transversale du champ électrique (E) et B. le champ magnétique terrestre On a également observé que la valeur minimale du champ de DH (à Ilorin, MAGDAS) pendant les jours de tempête magnétique correspond assez à l'indice Dst (WDC de Kyoto).

Mots-clés: Tempête magnétique; F2 couche; Ilorin; Ionosphère

Affiliations:

[1] Physics Department, Kebbi State University of Science and Technology Aliero, PMB 1144, Aliero, Kebbi State, NIGERIA

[2] University of Ilorin, PMB 1515, Ilorin, NIGERIA

Email Address for Correspondence/ Adresse de courriel pour la correspondance: wisdomworld04@yahoo.com

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INTRODUCTION

Storm days are considered as days for which the magnetic index has values of Dst ≤ -50, Ap > 26 and Kp ≥ 5 [1, 2]. In this work the month of May, 2010 was considered and all the storm events for which sufficient magnetic and critical frequency (foF2) data were available were selected and this covers the period of April 30, 2010 to May 6, 2010 and May 27, 2010 to June 2, 2010 when the storms occurred. The storm days and the quiet days of the month of May were selected using the hourly equatorial Dst values (real time) supplied monthly by the World Data Center (WDC) for Geomagnetism, Kyoto. Figure 1, shows the description of the storm events and the quiet days for the month of May, 2010. The storm events were considered in three main phases, namely, the initial phase, the main phase and the recovery phases. Although it is sometimes difficult to identify the beginning of the recovery phase [1], therefore we shall consider the main phase and the recovery phase together. Two moderate storms (i.e. storms with Dst < -50 to Dst < - 100) occurred in the month of May, 2010. One of them is a sudden commencement storm with its initial phase on the May 2, 2010 and the main and recovery phases extends to May 4, 2010 (with Dst range of Dst < -50 to -67nT). The second storm has its initial and main phases on May 29 to 30, 2010 and early part of the recovery phase on May 30, 2010 which extended to June 2, 2010 (with Dst range of Dst < -50 to -85nT).

The sudden commencement of May 2, 2010 can be attributed to the sudden increase of dynamic pressure on the magnetosphere, by the plasma ejected from the sun after solar flares or by corona mass ejection [2]. The initial phase is due to the continued solar wind pressure until interplanetary magnetic field lines merge with magnetospheric field lines and the solar plasma makes entry to the earth's magnetic lines of force and gets trapped in the earth's magnetic field lines and oscillates between high latitudes simultaneously drifting normal to the magnetic field lines [3].

MATERIALS AND METHODS

The per second data for the month of May, 2010 was collected from the University of Ilorin Magnetic data acquisition (MAGDAS) Station, a program read_1S was used to run the data through Mat Lab software, after which the raw data for each day (i.e. 86400 seconds/24 hours) was transferred to Microsoft Excel work sheet from where the 86400 second data was converted to 24 hours data using the relationship*:*

Average (A1:A3600), Average (A3601:A7200), etc

For each hour of the day respectively; giving rise to hourly values of the horizontal component of the magnetic field H.

The standard archiving output (SAO) format was also collected from the University of Ilorin Digisonde between April 30, 2010 to May 7, 2010 and also May 27, 2010 to June 2, 2010, the various hourly values of foF2 and hmF2 were obtained from the standard archiving output (SAO) format of the University of Ilorin Digisonde-4. Using the scaled ionospheric characteristics chart, the various values of foF2 and hmF2 were obtained from the SAO Format, after which the NmF2 values were obtained from the values of foF2, using the relationship:

$$NmF2 = (foF2)^2 \div 80.5$$

These values were used to plot the diurnal variation of NmF2 and hmF2**,** as shown in figures 4 and 5.

RESULTS AND DISCUSSION

The values of DH were also calculated for the month of May, this was done by subtracting the hourly values of H for the quiet day from the hourly values of H at any hour on storm day for the same local time and a plot of Dst and DH was made (Figure 2.) to enable us compare the WDC Dst real time values and that of DH obtained at the University of Ilorin MAGDAS station. The following observations were made:

- The two storms were observed on the same days (i.e. May 2 to 3, 2010 and May 29 to 30, 2010), which also commenced at about the same period.
- The recovery days and time were also observed to be similar.
- The trough of the sudden commencement of May 2 to 3, 2010 was observed to have a peak value of -53nT on DH plot, and a peak value of -64nT on the Dst real time index (Figure 2)
- The storm event of May 29 to 30, 2010 has a trough with a peak value of -85nT on the Dst real time index and -115nT on the DH plot (figure 2)
- All the storms fall within the range of -50nT to -85nT on the Dst real time index (figure 2), and within the range of -50nT to -115nT on the DH plot of the University of Ilorin MAGDAS station. A difference of about -32nT at peak values.

These differences can be attributed to the fact that the Dst index is an average result of four MAGDAS station or observatories on the equatorial plane, which was collected and processed by the world data center located at Kyoto, Japan.

It was also observed that the DH value at the University of Ilorin MAGDAS station started decreasing at 1400hr for the sudden commencement storm of 2nd May, 2010 and reach a minimum value around 1700 hr, while during the storm of 29th May, 2010, DH value started decreasing at 0000 hr, it reaches its minimum value at 1400 hr. these storm time variations are the same with that of the Dst real Time index, although the values are different, but the timing is the same.

Quite Days NmF2 Result (Day Time)

Considering figure 3, the electron density (NmF2) increases from sunrise at about 0600hr reaching a peak at 1000-1100LT after which a minimum day time decrease was observed at 1300hr (after attaining a pre-noon peak at about 1100hr) and later rises at 1400hr reaching another peak at 1700hr, just before sunset, after this, a consistent decrease in NmF2 was observed. For the quiet day's it was observed that the pre-noon peak (which is about 898.6x10^3 e/cm^3), is higher than the post-noon peak (which is about 863.6x10^3 e/cm^3).

Quite Days NmF2 Result (at Night)

A sharp drop in electron density (NmF2) was observed (figure 3) immediately after the post-noon peak, which continues after sunset at about 1800-1900LT, through the night. A night time peaks was observed around 400hr (with a value of about 268x10^3 e/cm^3), while a pre-sunrise minimum was observed at 0500hr (with a value of about 58.96x10^3 e/cm^3)

Quiet Day's hmF2 Result

The various results for the height of the peak electron density (hmF2) compared with that of NmF2 are shown in figures 4 and 5 For the two periods of study, the magnitude of the hmF2 for the quiet days rises within the interval of 0600 to 1000 LT, and between 1100 to 1400 LT, a much smaller range of variation is observed in the increase of hmF2, and after this time the magnitude of hmF2 decreases and reaches a minimum value at the interval of 1700 to 1800 LT with a post-sunset peak occurring at 1900 to 2000 LT, and a pre-sunrise minimum observed within the interval of 0500 to 0700 LT.

During Geomagnetic Storm

During geomagnetic storms, the morphology of the NmF2 is a little bit different from that of the quiet days. In this study, the diurnal variation of the NmF2 during the magnetic storm is divided into three different intervals, namely: the build-up stage (0500 to 0900LT), the day-time stage (0900 to 1800LT) and the Night-time stage (1800 to 500LT). The magnetic storm disturbed days were compared with the quiet day's plots, from which the following observations were made. Considering figures 6 and 7 one can see that there is no any significant difference in the electron density (NmF2) during the build-up period. Variations were also observed during the day time intervals (i.e. 0900 to 1800LT) before sunset on storm days. There is a clear increase in the electron density (NmF2) within this period, higher peaks were observed during the day time on storm days of the period of study (i.e. figures 6 and 7). When compared with the quiet day variations, the storms had a significant effect on the electron density (NmF2) of the storm days. All the storms caused a significant increase in the electron density (NmF2) during the day time interval; this is because the storms within this period had their main phases during the day time interval (0900-1800) especially that of 29th and 30th of May, 2010 which commenced around 0700LT. Although that of 2nd May which is a sudden commencement began at about 1500LT, yet, an increase with a difference of about 643.4x10^3 e/cm^3 which is about 65% when compared with the quiet days was observed during the day time interval (figure 6), while an increase in NmF2 with a difference of about 464x10^3 e/cm^3 which is about 58% was observed in Figure 7.

Night Time Storm Effect

Figure 6, shows an increase in the electron density (NmF2) during the night. This is because the storm event of 2nd May, 2010 had its main phase and the early part of its recovery phase during the night time interval which extended to the 3rd of May, 2010.

hmF2 Result During Geomagnetic Storm

An increase in the magnitude of the post-sunset peaks of hmF2 with a difference of about 101km (i.e. 27%) was observed during the storm of June 2 to 3, 2010 which was a sudden commencement, this can be seen in figure 8, and a decrease of about 58km (which is about 16%) was observed, during the storm of May 29 to 30, 2010 (Figure 9).

DISCUSSION

The electron density of the ionospheric F-layer is produced by the photo-ionization and neutral composition during geomagnetic quiet days [4] however during geomagnetic storm days, ionospheric plasma parameters experiences disturbance and in response, the electron density will either experience a significant increase or decrease resulting into a positive or negative ionospheric storm respectively. It is known that at low solar activity, the peak electron density of the F2 layer of the ionosphere (NmF2) increases from sunrise (about 0600LT) and reaches a peak (a pre-noon peak) before midday at about 0900 to 1000LT. Within this period, there is a corresponding day time decrease, having a minimum peak around 1100-1200LT. A second peak (a post-noon peak) occurs after midday, just before sunset at around 1600-1700LT. at high solar activity the values of NmF2 are much higher than at low solar activity and their variations are similar to the observations for low solar activity [5]. This was confirmed in this work, however significant increases were observed during the storm days. This increases appeared in the following ways:

- The trough that usually appears on the normal day time NmF2, known as noon bite-out [6, 2] was replaced by a peak on storm days (Figure 6).
- When compared with the quiet days the noon bite appears to be filled up on storm days. The trough is not as deep as it was on the quiet days (figure 6 and 7).

- When the quiet day-time peak electron density (peak NmF2) was compared with that of the storm days, the increase in day time electron density (NmF2) of the storm days shows up as a higher peak. This can also be seen clearly in the result obtained in figure 6 and 7.

According to a similar researcher [7], the effect of magnetic storm and sub-storms on the low latitude, showed that the global system of currents and electric fields of ionospheric wind dynamo determine the geomagnetic quiet-time behavior of the low latitude ionospheric plasma. The features of the equatorial F2-layer in terms of movement of ionization, was linked to the cross fields of the electric field (E) and magnetic field (B) [1, 8, 9]. The earth's magnetic field (B) combines with the electric field (E) lines (which is about horizontal around the equatorial region) giving rise to the E X B force that acts on ionization on the vertical direction there-by creating disturbance in the ionospheric plasma which influences the vertical plasma drifts. The vertical drift is upwards when E is Eastward and downward when E is westward [5].

When the E X B force is upwards, the ionization in the ionospheric F-layer is caused to diffuse along the magnetic field lines in a particular direction (i.e. towards higher latitudes) on both sides of the equator. This takes place within the day time interval and it also account for the depletion of electron density around the equator. The direction of the electric field reverses at night and the E X B forces also reverses (i.e. is in the downward direction) thus, causing the F-layer of the ionosphere to be fed with electrons from altitudes above it [1]. A likely source of electrons from altitudes above the F2-layer is the protonosphere [10]

Since the E X B force has a significant influence on the quiet day variation of the F2-layer of the ionosphere as explained above, therefore, a disturbance in the ionospheric electric field can cause a significant change in the electric field which will produce a storm effect on the electron density of the F2-layer (NmF2). An increase in the day-time electric field can lead to an increase in theE X B force, which will result in the increase drift of ionization away from the equatorial F2-layer. Short period fluctuations in H field at equatorial stations are known to occur during magnetic storms. These effects are often related to the directional changes in the Bz component of the interplanetary magnetic field [11]. A decrease in the H field during magnetic storms would indicate a reduction in the eastward electric field during the day and suggest an enhancement of the westward electric field at night [12]. This will result into a decrease in the drift of ionization away from the equatorial F2-layer during the day and an increase in the drift of electrons toward the layer at night [1].This explains the increase observed in the electron density of the F2-layer (NmF2) during the geomagnetic storm days as shown in figure 6 and 7, for both day and night. During the main phase and the early part of the recovery phase of the magnetic storms. The decrease observed during geomagnetic storms may be due to large energy input into the ionosphere during such storms. The energy input result in increase in the electron temperature during magnetic storms which in turn leads to an increase in recombination, thereby causing an increase in loss rate [1]

Figure 1: This figure shows hourly Equatorial Dst (real time) plots for May 1 to 31, 2010, World Data Center (WDC) for Geomagnetism, Kyoto

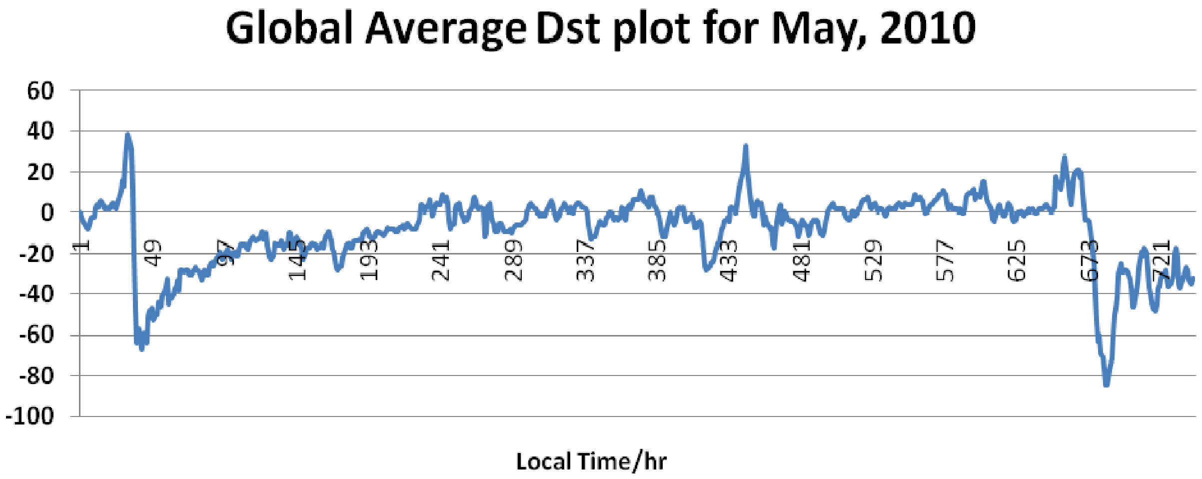

Figure 2: This figure shows comparison between the WDC Dst real time index (thick spectrum) and DH values obtained from the University of Ilorin MAGDAS station (Faint spectrum)

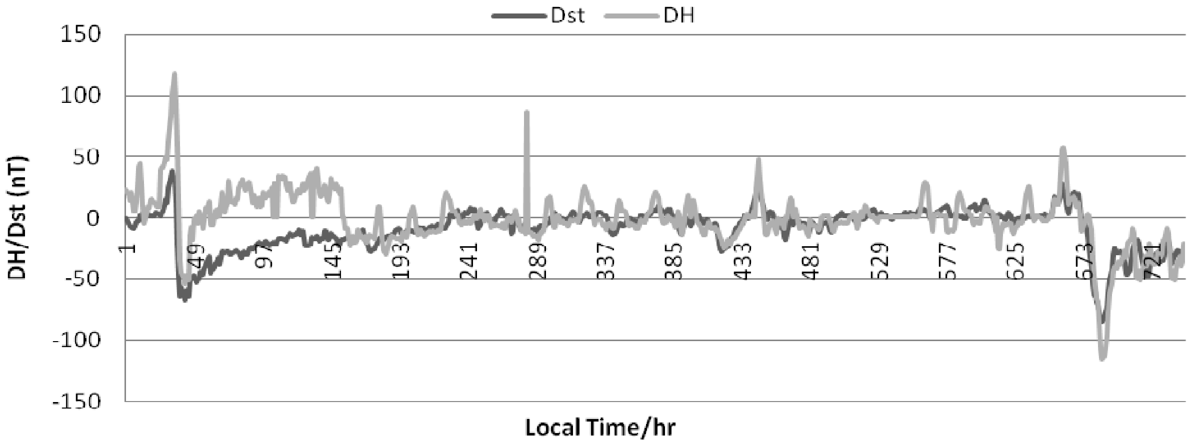

Figure 3: This figure shows average Quiet day plot of electron density (NmF2) for May, 2010

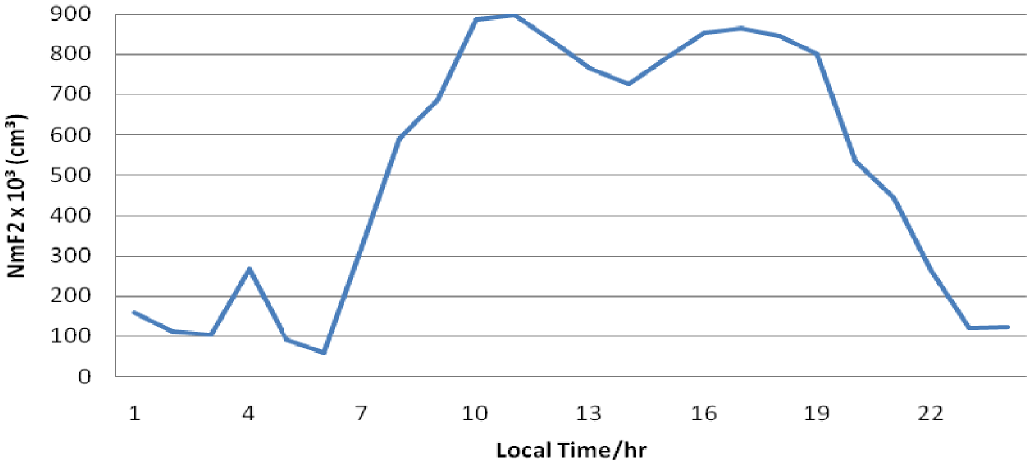

Figure 4: This figure shows Diurnal variation of NmF2 and hmF2 of April 30, 2010 to May 7, 2010

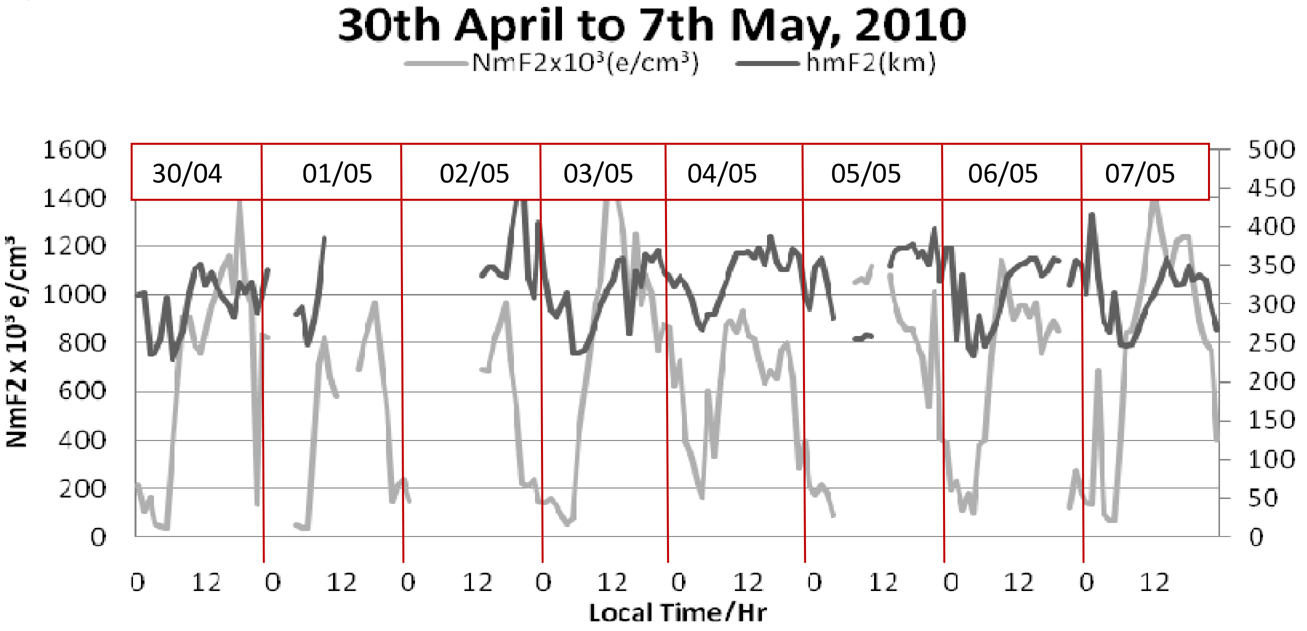

Figure 5: This figure shows Diurnal variation of NmF2 and hmF2 of May 27, 2010 to June 2, 2010

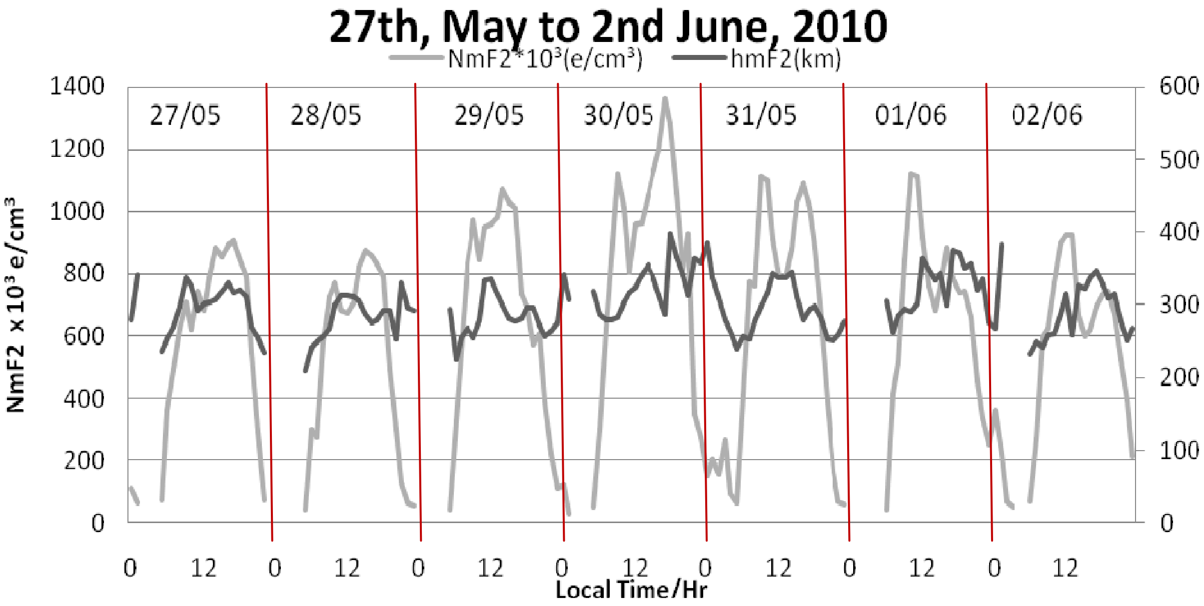

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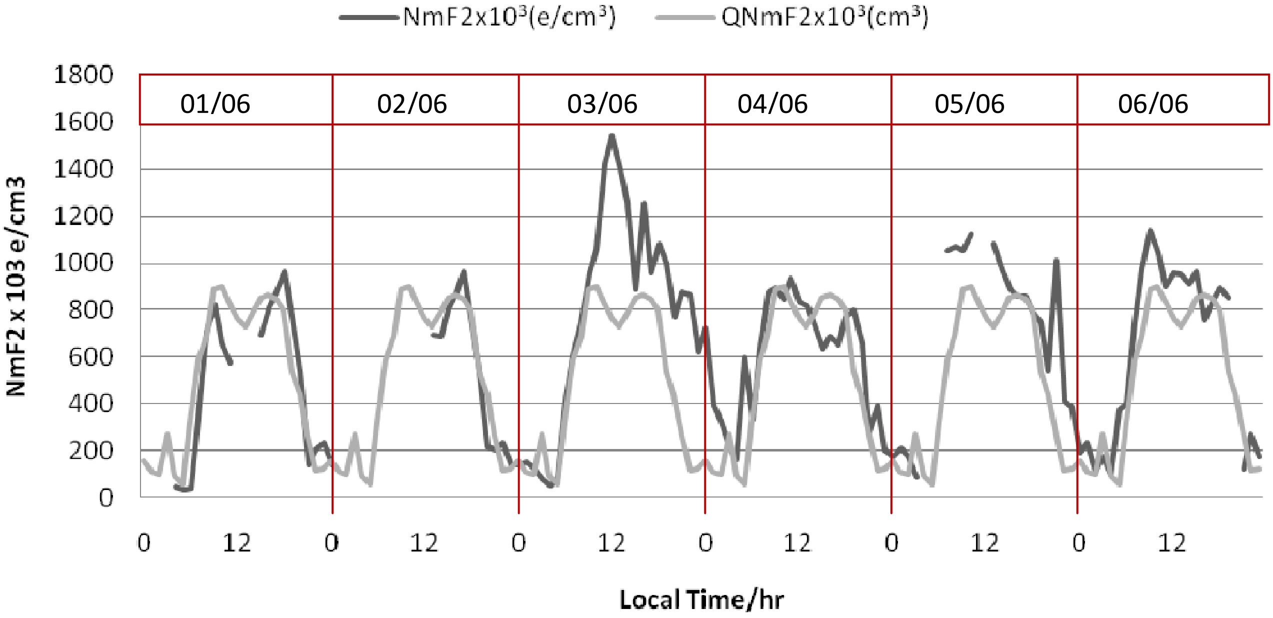
Figure 6: This figure shows average storm (thick spectrum) and quiet (faint spectrum) NmF2 of May 1 to 6, 2010



The increase observed in figure 8, was due to a sudden commencement that occurred on the 2nd of May 2010. It was observed that; sudden commencement storms are characterized by a sudden increase in H, which is usually accompanied by enhancement of the eastward electric field during the day time [13]. This increase in the day-time electric field implies an increase in EXB force, which will result in increased drift of ionization away from the equatorial F2 – layer [1].

CONCLUSION

In conclusion:

I. All the storms had their initial phases during the day time interval (i.e. 0900hr to 1800hr) one of which was a sudden commencement, figure 2.

II. For the quiet days, the NmF2 pre-noon peaks were higher than the post-noon peaks during the day figure 3, which can be attributed to the particular E X B drift pattern, this usually occurs when the upward E X B drift velocity is maintained for a longer period,. While a night time peak was observed around 400hr and a pre-sunrise minimum at 0500hr.

III. Higher peaks in electron density, NmF2 were observed during the day time on magnetic storm days when compared with the quiet day variations, Figures 6 and 7.

The altitude of hmF2 was about 473km that is a difference of 101km(27%) when compare to the quiet day hmF2 (which was about 371km), during the sudden commencement of May 2, 2010. Figure 8. This was due to the increase in the E X B force caused by the sudden commencement while a decrease of about 58km (which is about 16%) was observed, during the storm of May 29 to 30, 2010, figure 9.

Figure 7: This figure shows average storm (thick spectrum) and quiet (faint spectrum) NmF2 of May 27, 2010 to June 2, 2010

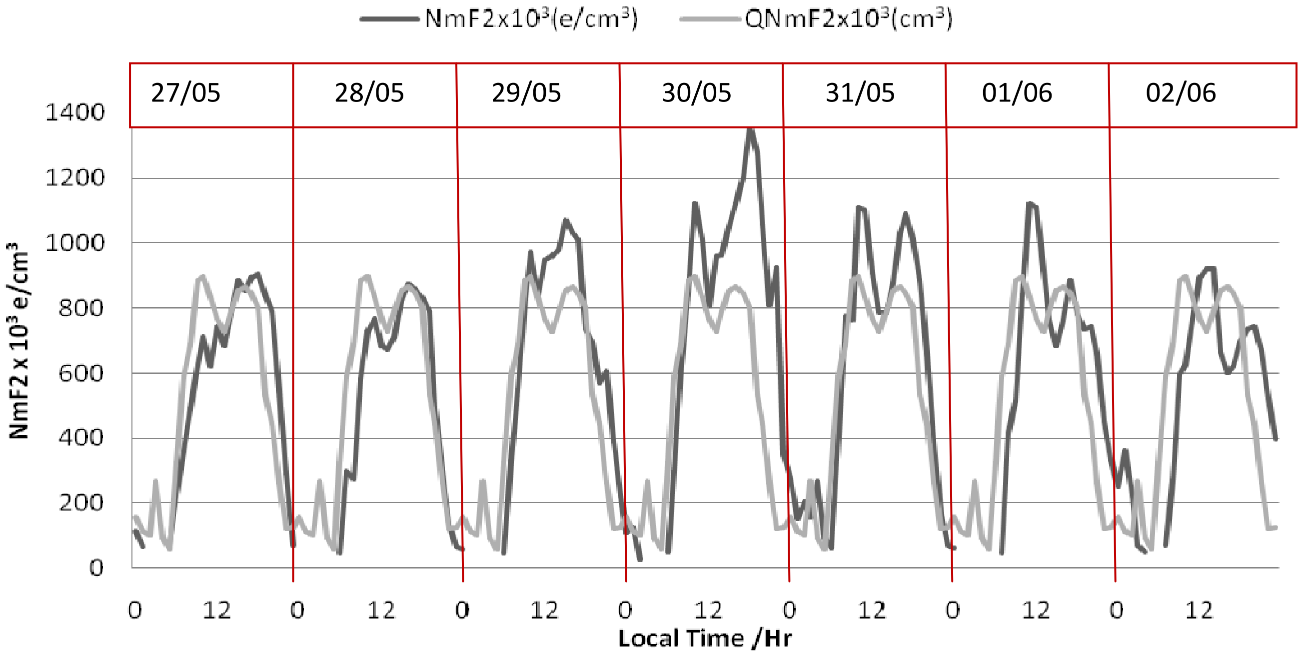


Figure 8: This figure shows average hmF2 for both storm (thick spectrum) and quiet (faint spectrum) days April 30, 2010 to May 7, 2010

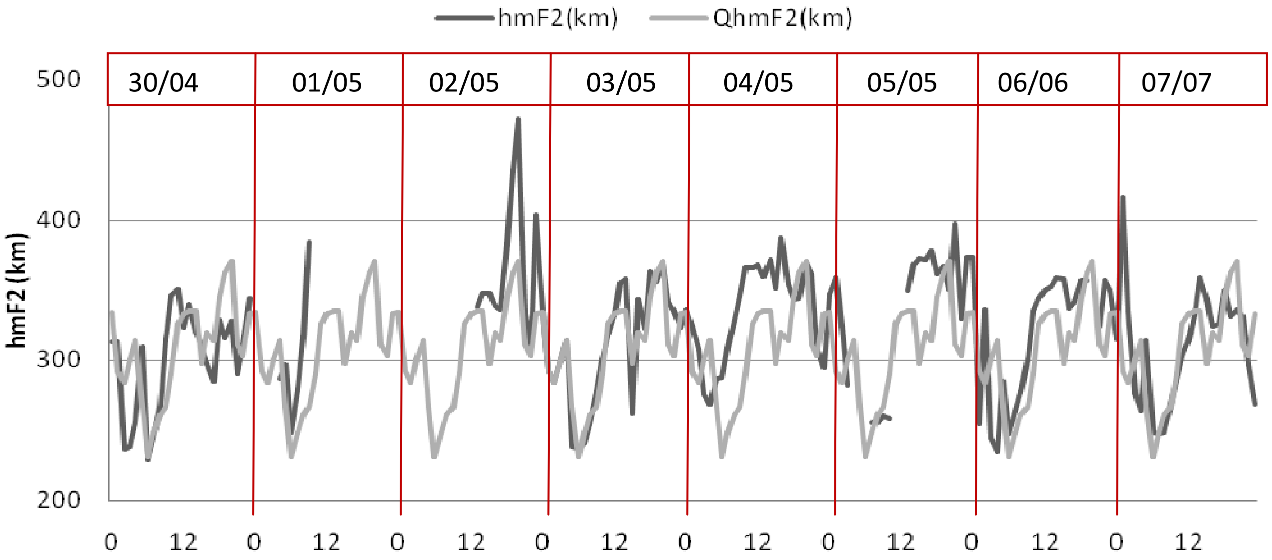
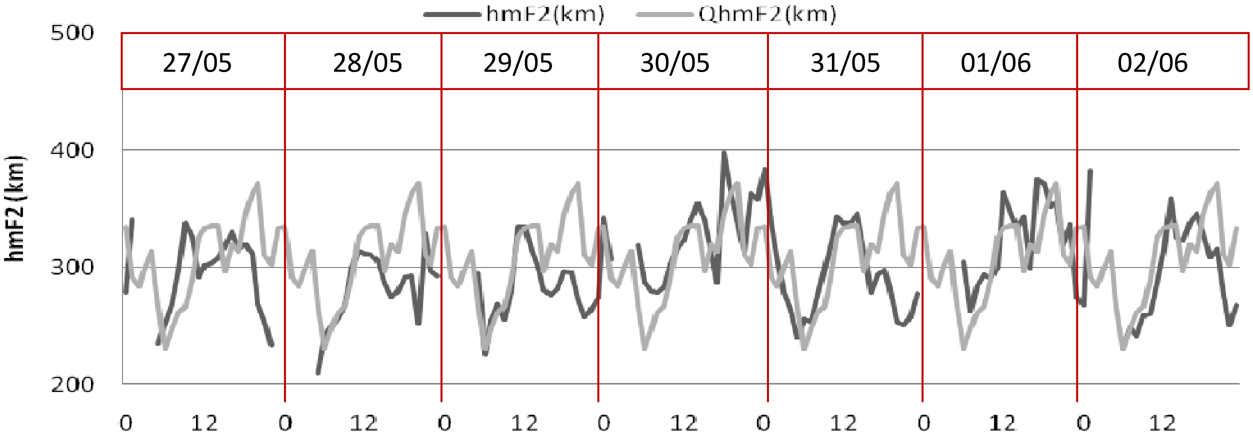


Figure 9: This figure shows average hmF2 for both storm (thick spectrum) and quiet (faint spectrum) days May 27, 2010 to June 2, 2010



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CONFLICT OF INTEREST

No conflict of interests was declared by authors.