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COAST
JOURNAL OF THE SCHOOL OF SCIENCE
Volume 3, Issue 2. November, 2021 ISSN: 2714-3716
Coast, J. Sch. Sci. 3 (2): 652- 664

F2 IONOSPHERIC EFFECT ON INTENSE GEOMAGNETIC STORM ASSOCIATED WITH DIFFERENT DRIVERS: MAGNETIC CLOUD AND COMPLEX EJECTA.

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Abstract
The F2-region response to the intense geomagnetic storm was studied using six (6) ionospheric stations ranging from high to low latitude. The onset of the geomagnetic storms is used in the method of classification of variation of electron density. The increases or decreases of maximum electron density (NmF2) in the storm onset were classified into four types: positive or negative storm phase, positive storm followed by negative storm and negative storm followed by positive storm. The criterion used enables us to properly identify whether or not plasma is redistributed owing to sunrise effects during the storm onset occurrences. The storm onset was chosen around 0000 hrs universal time (UT) which corresponds with local time (LT) of American sector between (4-8 p.m.). The result obtained shows geomagnetic storms with nighttime storm onset in all seasons are generally dominant to negative ionospheric storm while geomagnetic storm with daytime storm onset in all seasons to positive storm.
Keywords: F2-region, Geomagnetic storm, Ionospheric effect, Storm onset, Sunrise effect, Negative storm effect and Positive storm effect.

Introduction

In the previous study (Bakare and Chukwuma 2010), the relationship between Disturbance Storm Time (Dst) and solar wind conditions during the intense geomagnetic storm was examined. It was deduced that though both classes of drivers can cause intense geomagnetic storm, however, the magnetic cloud is more geoeffective than complex ejecta. In this regard, this study seeks to show the degree of deviation of the interplanetary causes based on the nature of ionospheric response between the two classes of drivers of geomagnetic storms.

The geomagnetic storms were primarily associated with two classes of drivers, the fast magnetic cloud whose interplanetary characteristic are identified by its enhanced magnetic field strengths, a large and smooth rotation of the magnetic field vector over a period of order 1day (at 1AU) and low proton temperature and plasma beta typically 0.1 (Burlaga1981) and fast complex ejecta that have a variety of signatures and forms.

Danilov (2001) regarded the F2 region response to a geomagnetic storm as a rather complicated event that consists of the positive and negative phases, which have very complicated spatial and temporal behaviour. The work revealed that the principal features of the positive and negative phase distribution and variable have been explained on the basis of the principal concepts during a geomagnetic disturbance as an input of energy into the polar ionosphere, which change thermosphere parameters, such as composition, temperature and circulation in the F2 region. The circulation spreads the heated gas to the lower latitude.

In this paper, the study seek to present the storm time variation of positive and negative ionospheric storm conditions during the intense geomagnetic storm (Dst ≤ -100nT, Gonzalez et.al, 1994) for a period of solar cycle 23. The nature of ionospheric response between the two classes of geomagnetic storm drivers was also presented.

Materials and Method.

Ionospheric Data used.

The hourly values of the low latitude magnetic index (Dst) data were obtained from National Space Science Data Centre's NSSDC OMNIWeb Service (http://nssdc.gsfc.nasa.gov/omniweb). Most of the magnetic clouds were obtained from the wind magnetic field investigation (MFI) (http://lepmfi.gsfc.nasa.gov/mfi/mag_cloud_pub1.html).

The ionospheric data used in this study consists of foF2 obtained from some of the National Geophysical Data Center's Space Physics Interactive Data Resource (SPIDR), a network of ionosonde stations located in the American sector: Boulder, Wallop Island, Point Arguello, Dyess, Eglin AFB, and Puerto Rico. The characteristics of the stations are listed in Table 1. However, the F2 region response to geomagnetic storms is most conveniently described in terms of D(foF2) that is the normalized deviations of the critical frequency foF2 (Chukwuma 2003):

$$D(f_0F2) = \frac{f_0F2 - (f_0F2)ave}{(f_0F2)ave} \quad (1)$$

Hence, the data analysis consisted of D(foF2) of respective hourly values of foF2 of each storm under consideration. The reference for each hour is the average value of foF2 for the hour calculated from the five quiet days preceding or exceeding the storm. The criterion for chosen references day is the values of Dst ≥ -25nT.The use of D(foF2) rather than foF2 provides a first-order correction for temporal, seasonal and solar cycle variations so that geomagnetic storm effects can better be identified. To study the storm time variation of positive and negative effects of ionospheric storm during intense geomagnetic storm, the ionospheric parameters from 1996 - 2006 were examined. The corresponding response of the ionosphere has been measured by the D(foF2) index. For the period between 1996 – 2006 the study focus on average six (6) ionospheric stations during each storm were studied and further classified the geomagnetic storms into four types: positive storm phase, negative storm phase, positive storm followed by negative storm and negative storm followed by positive storm according to the increase or decrease of the F layer electron density (NmF2) in their storm onset.

Method of Selection of Events.

Table 2 summarizes statistical study for the classification of intense geomagnetic storm versus the two types of main drivers. It is important to note that 83 intense geomagnetic storms were analyzed; however, we selected one event in each of the two types of drivers to identify the structure of positive and / or negative storm effects were selected and these selections were based on the result of space constraints. Out of 83 intense geomagnetic storms studied during the solar cycle 23, 43 geomagnetic storms (~51.8%) are caused by magnetic cloud. The relationship between Dst

- Bs during magnetic cloud revealed that the overall correlation coefficient is 0.90. Furthermore, 40 geomagnetic storms (~48.2%) were caused by the fast complex ejecta. The fast complex ejecta had less overall correlation between Dst–Bs as the overall correlation is 0.64.

Results and Discussion

Interplanetary and geomagnetic observation of April 12-16, 2006 showing magnetic cloud as main driver.

Figure 1 shows the interplanetary and geomagnetic observations during the period 12-16 April 2006. The storms are summarized using the low latitude index Dst, interplanetary magnetic field Bz, solar wind flow speed, ion number density, electric field, proton temperature and plasma beta.

Dst variation shows a monotonic decrease of Dst minimum in the main phase having a minimum peak (-111nT) at 0900 hrs UT on 14 April, 2006. Vieira *et al.* (2001) had classified geomagnetic storms with Dst below -100 nT as intensed geomagnetic storms. It may be noted that the storm main phase (storm onset) occurs in near coincidences with the sharp southward turning of Interplanetary Magnetic Field (IMF) at the magnetic cloud boundary. The storm main phase development is rapid and the decrease is monotonic. There are numerous mechanisms that can lead to southward components fields in the sheath (Tsurutani et. al., 1992). Among them are shocked southward fields, shocked heliospheric current sheet, turbulence, waves or discontinuities.

The Bz plot shows that until ~ 0000 hrs UT on 13 April there was no definite trend in Bz variations. At ~ 0000 hrs UT on April 13 in that year, there came a sharp southward turning of Bz, Bz reached a value of -13.4 nT at 0400 hrs UT and attained a peak value of -14.2 nT at 0800 hrs UT indicating that IMF has experienced about four hours southward components. It is important to note that the southward turning of Bz at ~ 0400 hrs UT appears to have triggered the depression of Dst beginning from 0100 hrs UT.

The flow speed plot shows a moderate stream throughout 12 April. The stream attained a minimum value of 382 km s^{-1} at 1800 hrs UT on the same day. Thereafter, there is an enhancement in the speed stream which reached a peak value of 676 km s^{-1}on 1400 hrs UT on 15 April. It may be noted that during 14-15 April, the solar wind attained the 500 km s^{-1} which is greater than 350 km s^{-1} the criterion of fast solar wind.

The proton number density plot shows increment from 0900 hrs UT on 13 April. The proton number density attained a peak value of 17.7 cm^{-3}at 1400 hrs UT. The large increase in the proton number density during this period signifies the arrival of a shock in the interplanetary medium (Strickland et al., 2001). The enhanced solar wind density at 1400 hrs UT drove the plasma sheet density leading to the injection of the ring current and this caused sharp depression in Dst in the interval between 0000 and 0900 hrs UT on 14 April. This implies that the plasma sheet density is found to correlate well with high solar wind density (Borovsky et al., 1998). It has been shown that the solar wind density drives plasma sheet density with the source of ring current particles being the plasma sheet (Borovsky et al., (1998).

The electric field began a gradual increase and reached a value of 7.14 mV m^{-1} at 0400 hrs UT. Four hours later, it attained its peak value of 7.30 mV m^{-1} at 0800 hrs UT. These electric field conditions which gave Bz>10nT are indicative of intense geomagnetic storm (Chukwuma 2007).

The structure of geomagnetic storm of 14 April is clearer by the proton temperature and plasma beta. The plasma beta plot shows a value of 0.07 at 1700 hrs UT on 13 April, which increased to 0.12 at 0800 hrs UT on 14 April. For the same time, the plasma temperature was after the arrival of the shock, decreased precipitously to a low temperature of ~ 1166.0^{0}K at 1700 hrs UT on 13 April. It transpired from the low plasma beta and proton temperature value that the shock followed ejecta which were a magnetic cloud (Dal Lago et al., 2004)..

Interplanetary and geomagnetic observation of August22-26, 2005 showing Complex ejecta as main driver.

Complex ejecta events driving a Reversed Pressure Wave (RPW) observed on August 24, 2005, are shown in Figure 2. The first thick vertical line indicates the shock position and the complex ejecta are in the interval between the two vertical dotted lines where maximum and minimum speeds in the stream are represented. It is shown from top to bottom; the Dst index, the magnetic field component (Bz) in GSM, flow speed, proton density, electric field, proton temperature and plasma beta.

The Dst plot indicates that, from 0000 hrs UT on August 22, 2005, the Dst values have been between -15nT and-18nT. However, beginning from 0000 hrs UT on Aug. 24, Dst was gradually increasing to a peak value of 32nT at 0600 hrs UT. Thereafter, a sharp turning of Dst, gradually fluctuates until it reaches a peak value of 3nT at 0800 hrs UT before it was depressed rather sharply to –216nT at 1100 hrs UT being the lowest value for the storm. Vieira et al. (2001) had classified as intense geomagnetic storms with Dst in the range: Dst ≤ -100nT.

The B_z plot shows that until about 0800 hrs UT on Aug.24, there was no definite trends in B_z variations. At 0800 hrs UT, there came a sharp southward turning of Bz till 1000hrsUT when it reaches a peak value of –38.3nT indicating that the IMF has experienced about 3 hours of southward component. It is important to note that the southward turning of Bz at ~0800hrsUT appears to have triggered the depression of Dst beginning from 0800 hrs UT.

Starting from 0000 hrs UT on Aug. 22, the flow speed of 517kms^{-1}decreases to 446 kms^{-1}at 1300 hrs UT, thereafter it increases upwardly to 553kms^{-1} at 2100 hrs UT on the same day. The stream got to a minimum value of 412kms^{-1} at 0000 hrs UT on Aug.24. Thereafter, there is an enhancement in the speed stream which got to a maximum peak value of 721km/s on 1300 hrs UT on Aug.24. It is worthy to note that in the period Aug.24-26, the solar wind attained the 500kms^{-1}, in which case it met the criterion of fast solar winds. However, it was pointed out that geomagnetic storms occurred at the solar wind speed shown in the plot.

The proton number density plot presents the proton density increasing from ~0500 hrs UT on Aug.24. The proton number density got to peak values of 30.3/cm^3, 32.2/cm^3,29.8/cm^3 and 26.9/cm^3 at 0800 hrs UT,1100 hrs UT,1300 hrs UT and 1500 hrs UT respectively. The large increase in the proton number density during this period signifies the arrival of a shock in the interplanetary medium (Strickland et. al., 2001).

The solar wind speed shows a low stream within the period of 0000 hrs UT on Aug.22 and 0500 hrs UT on Aug. 24. It therefore began its rise to a peak value ~720 km/s around 1300 hrs UT on Aug.24. Note that this rise corresponds to an increase in plasma temperature to a peak value of 2666957^{0}K at 1300 hrs UT as well as an enhancement in the plasma beta value 6.12 at 1300 hrs UT. It transpires from this high plasma beta and temperature values that the shock was followed by ejecta, which may not be a magnetic cloud type. Moreover, the electric field plots show that no activity was observed until 1000 hrs UT on Aug.24 when it began its activity reaching its first peak value of 23.86 mV/m. It therefore reduces shortly to a value less than 1mV/m, before it starts to rise again to a value of 8.7mV/m at 1200 hrs UT and then recovers again to a lowest value of -14.13mV/m at 1300 hrs UT on Aug. 24, 2005.

Results on Ionospheric Responses of the Storm

During geomagnetic storms, ionospheric F region plasma parameters experience disturbances and in response, the electron density is either significantly enhanced or depleted resulting in positive or negative ionospheric storm. 60% of magnetic storm driven by magnetic cloud was found to go through positive storm while 40% of magnetic storm driven by magnetic cloud was found to go through negative storm during the storm onset. Furthermore, 55% of magnetic storm driven by fast complex ejecta was found to go through positive storm while 45% of magnetic storm driven by fast complex ejecta was found to go through negative storm during their storm onset. The onset of the geomagnetic storm is used in the method of classification of proceeding negative and or positive storm phase. The criterion used enables us to properly identify whether or not plasma is redistributed owing to sunrise effects when the storm occurs. The storm onset was chosen around 0000 hrs universal time (UT) which corresponds with local time (LT) of American sector between 4 and 8 p.m.

Ionospheric response of April 12-16, 2006

The plots illustrating D(foF2) versus time hrs UT) during 14-16 April 2006 for American sector are depicted in Figure 3. The result shows that, following the storm commencement on 14 April, there is immediate effect on foF2 in the ionosphere at all stations which are preceded by positive storm. There is appearance of positive storm before the beginning of the geomagnetic disturbances in all stations. However, at 1000 hrs UT on 14 April, depletion of foF2 became obvious at all the stations irrespective of their latitude. On 15 April, a definite pattern began to emerge from available data with respect to 0000 hrs UT. As shown, all the station indicated on an average some degree of depression simultaneity in foF2.

The ionosphere at Boulder shows moderate positive storm that occurred during 0000-0400 hrs UT on 14 April. At 0500 hrs UT, the ionosphere showed a negative storm that lasted throughout 14 April with peak depletion values of 34, 25, 25 and 35% at 1000, 1800, 2300 and 0800 hrs UT, respectively. The foF2 recovered abruptly reaching a peak value of 67% at 1100 hrs UT on 15 April before sharp reduction to a negative phase storm almost throughout 16 April.

The D(foF2) plot for Dyess appear to show positive ionospheric response to the magnetospheric processes during the period 0000-5000 hrs UT. The ionosphere registered a negative storm with 16% depletion which lasted until 38% depletion at 1000 hrs UT being the peak electron density. The ionospheric gradual increase to a positive phase storm at 1500 hrs UT on same day before foF2 began to decrease rapidly leading to an intense negative storm at 1800 hrs UT on 14 April with 14% depletion of foF2. D(foF2) started to recover gradually before steeply decreased to 28% at 2300 hrs UT on 14 April. D(foF2) started to recover again before it sharply decreases to 31% at 1000 hrs UT on 15 April.

The D(foF2) variation for Eglin AFB showed strong ionospheric F2 region response to the ionospheric processes during the period 0000-0400 hrs UT on 14 April. At 0500 hrs UT, the station recorded a major negative storm with 44% depletion at 0900 hrs UT which was followed by a positive storm at 1500 hrs UT. Commencing from 2000 hrs UT on 14 April, foF2 started decreasing sharply reaching 35% depletion at 0000 hrs UT and 44% at 0800 hrs UT which lasted until 1200 hrs UT on 15 April indicating the commencement of an intense storm. Beginning at 1200hrs UT, the foF2 started to recover gradually until it reached peak at 26% at 2000 hrs UT on 15 April before it gradually decreased.

The D(foF2) plot for Puerto Rico shows a positive ionospheric response during the period 0000-0500 hrs UT on 14 April. Thereafter, foF2 started to decrease and lead to negative phase at 0600 hrs UT. The foF2 recovered to a positive storm at 0900 hrs UT on the same day. The D(foF2) plot shows that the ionosphere at Puerto Rico is characterized by positive storm during the period under investigation. The D(foF2) variation further shows negative phase at 1000 and 1700 hrs UT with 21 and 12% depletion, respectively on 14 April.

Ionospheric responseof August 22-26, 2005

Fig.4 illustrates D(foF2) versus UT for 24-26 August, 2005 for American sector. As shown, following the storm commencement there is immediate effect on foF2 in the ionosphere at all stations which is preceded by negative storm. D(foF2) for Point Arguello shows a negative storm that started to develop between 0000 hrs UT on 24 August, the ionosphere at this stations immediately show a positive storm with peak values at 1500 and 1900 hrs UT. However, beginning at 2300 hrs UT on same day foF2 decreased sharply reaching a minimum value of 2% from the reference level at 0000 hrs UT. The D(foF2) variation shows foF2 recovering to 17% increase at 0700 hrs UT. But following a sharp increase in the proton density at 1300 hrs UT, foF2 began to decrease again reaching 10% depletion at 1400 hrs UT on 25 August.foF2 recovered to 34% at 1600 hrs UT on 25 August but thereafter, started decreasing again and reached 3% at 1800 hrs UT on same day before reaching peak depletion of 4% at 0200 and 10% hrs UT on 26 August.

The ionosphere at Dyess shows a negative storm that started to develop at 0000 hrs UT on 24 August. The situation was followed by a positive storm reaching peak value of 19% and 26% at 1200 and 2000 hrs UT, respectively. D(foF2) started to decrease rather sluggishly reaching 13% depletion at 0500 hrs UT indicating the commencement of an intense storm. Thereafter, foF2 recovered to a positive storm at 0800 hrs UT and lasted till 0000 hrs UT on 25 August. Commencing from 0000 hrs UT on same day, foF2 started to decrease but recovered abruptly only to depress sharply at 0300 hrs UT to reach 4% depletion at 0500 hrs UT. By 0600 hrs UT, foF2 had recovered to a weak positive storm.

D(foF2) at Boulder shows that there is a strong negative storm that started to develop at 0000 hr UT on 24 August. The situation followed by a positive storm reaching a peak value of 38% and 40% at 1500 and 2000 hrs UT respectively before steeply decreasing to 16% at 2200 hrs UT which lasted for about 12 h before reaching the peak depletion of 5% at 1100 hrs UT on 25 August. The D(foF2) variation shows foF2 recovering to 37% increase at 1500 hrs UT on 25 August before gradual decrease to 2% at 0200 hrs UT which lasted until 0400 hrs UT and gradually recovered again.

D(foF2) at Eglin AFB shows that there is a strong negative storm that started to develop at 0000 hr UT on 24 August. The ionosphere immediately at this station shows a positive storm that almost lasted for about 24 hours before decreasing abruptly at about 0400 hrs UT on 25 August. Thereafter, foF2 steeply recovered to a positive storm at 0900hrs which also lasted for more than 24 hrs.

D(foF2) at Wallop Island shows that there is a strong negative storm that started to develop at 0000 hr UT on 24 August. The situation was followed by a positive storm reaching a peak value of 38%, 34%, 36% and 35% at 1100, 1700, 2000 and 2300 hrs UT respectively. The D(foF2) decreasing again and reached 2% at 0200hrs UT on 25 August before gradual recovered to positive storm reaching the peak values of 43% and 44% at about 1100 and 2200 hrs UT respectively. On 26 August at about 0100hrs UT foF2 decrease to a weak storm that almost lasted throughout that day.

Implication of Ionospheric Response of the Storm

The ionospheric response of American sector of the year under consideration can be summarize using a superimpose plot as shown in Fig. 5. The result reveal some degree of simultaneous intense enhancement of foF2 at all latitudes at 0000 -0500 hrs UT on 14 April suggest that during the intense geomagnetic storm, the foF2 enhancement at all stations may not be mainly due to changes in neutral composition resulting from neutral wind produced predominantly in the region of Joule heating in the aurora zone. From the result obtained, it can be deduced that in the American sector, the local time extended to night. For instance, the storm of April 14, 2006 became intense at 0900UT. Puerto rico, a low latitude station experienced enhancement during the storm as expected since there is no sunrise effect. Also it could be added that at American sector where there is no sunrise effect due to local time, the response of the ionosphere agree with Danilov 2001 that the so called negative and positive phase have very complicated spatial and temporal behavior.

The superimposed variation in D(foF2) for August 24-26, 2005 are shown in Figure 4. There is appearance of negative storm during the pre-storm phase of the geomagnetic disturbances in all stations, at about 0000 to 0900 hrs UT on 24 August shows a definite pattern from the available data as presented, all the stations indicated on the average some degree of simultaneity in the depletion of foF2. foF2 appears to be reduced by ~40% from the reference level before midday, and thereafter foF2 started recovering from ~0000 hrs UT and continued throughout August 25, 2005.

The negative storm at mid and low latitude stations appear to be caused by southward turning of Bz at 0800 hrs UT which got to a change in Bz of $\delta Bz = -38.3nT$ at 1000 hrs UT on August 24 .Davies et al (1997) have shown that southward turning with a change in Bz of $\delta Bz > 11.5nT$ results in foF2 showing a marked decrease, reaching a minimum value of about 20hours after the southward turning and is assumed as an indicator that energy is deposited at high latitudes which leads to ionospheric disturbances. Composition changes, particularly the increase of neutral molecular densities are known as the main cause of negative storm phases (prölss, 1987). Indeed, a high correlation between the region of enhanced molecular species in the neutral gas and the decrease of NmF2 has been shown by Fuller-Rowell et. al.,(1997) base on numerical simulation of an idealized geomagnetic storm.

The ionospheric effects are classified into four main group based on the variations of increase or decrease in D(foF2). They are ionospheric storms with daytime storm onset are said to produce positive storm denoted by P while ionospheric storms with nighttime storm onset are said to produce negative storm denoted by N. ionospheric storms with daytime storm onset that produce positive storm followed by negative storm denoted by PN while ionospheric storms with nighttime storm onset that produce negative storm

followed by positive storm denoted by NP.
462 occurrences during onsets period are classified into four main group based on the variations of increase or decrease in D(foF2) of which 254 occurrences show ionospheric effect for storm onset of ionospheric storms occur during the daytime while 208 occurrences show ionospheric effect for storm onset of ionospheric storms occur during the nighttime. Table 3 list the number of different types of ionospheric effect that occurred during the day and nighttime storm onset of ionospheric storms. The number of positive storms occurrence during the daytime is twice that of nighttime. Similarly, the number of occurrence of negative storm during the nighttime is twice that of daytime as shown in Table 3. The statistics of ionospheric effects seems to show that during the storm onset of ionospheric storm, positive storm phase often occur during the daytime while negative storm phase are more prevalent during the nighttime.

Table 1 — List of ionosonde stations

American Sector	Station Code	Geographic Coordinates		Geomagnetic Coordinates		**Difference between LST & UT (hrs)**
		Φ	λ	**Φ**	λ	
Boulder	BC840	40.0^0 N	254.7^0 E	48.9^0 N	318.2^0 E	-7
Wallop Island	WP937	37.9^0 N	284.5^0 E	49.8^0 N	352.7^{0}E	-5
Point Arguello	PA836	35.6^0 N	239.4^0 E	42.3^0 N	302.4^0 E	-8
Dyess	DS932	32.4^0 N	260.3^0 E	41.9^0 N	328.8^0 E	-7
Eglin AFB	EG931	30.4^0 N	273.8^0 E	40.8^0 N	343.7^0 E	-6
Puerto Rico	PR118	18.5^0 N	292.5^0 E	29.8^0 N	3.51^0 E	-4

Table 2: Storm phases versus two classes of drivers

Features	Classes of Drivers’	
	Magnetic clo	Complex ejecta
Correlation coeffici	0.90	0.64
% of occurrences	51.8%	48.2%
Positive storm pha	60%	55%
Negative storm pha	40%	45%

Table: 3 Ionospheric storms for storm onset of geomagnetic storms during the day and nighttime

Features of ionospheric storms	Numbers of occurrences during the daytime	Numbers of occurrences during the nighttime
P-Storm	148	61
PN-Storm	28	8
N-Storm	60	123
NP-Storm	8	16

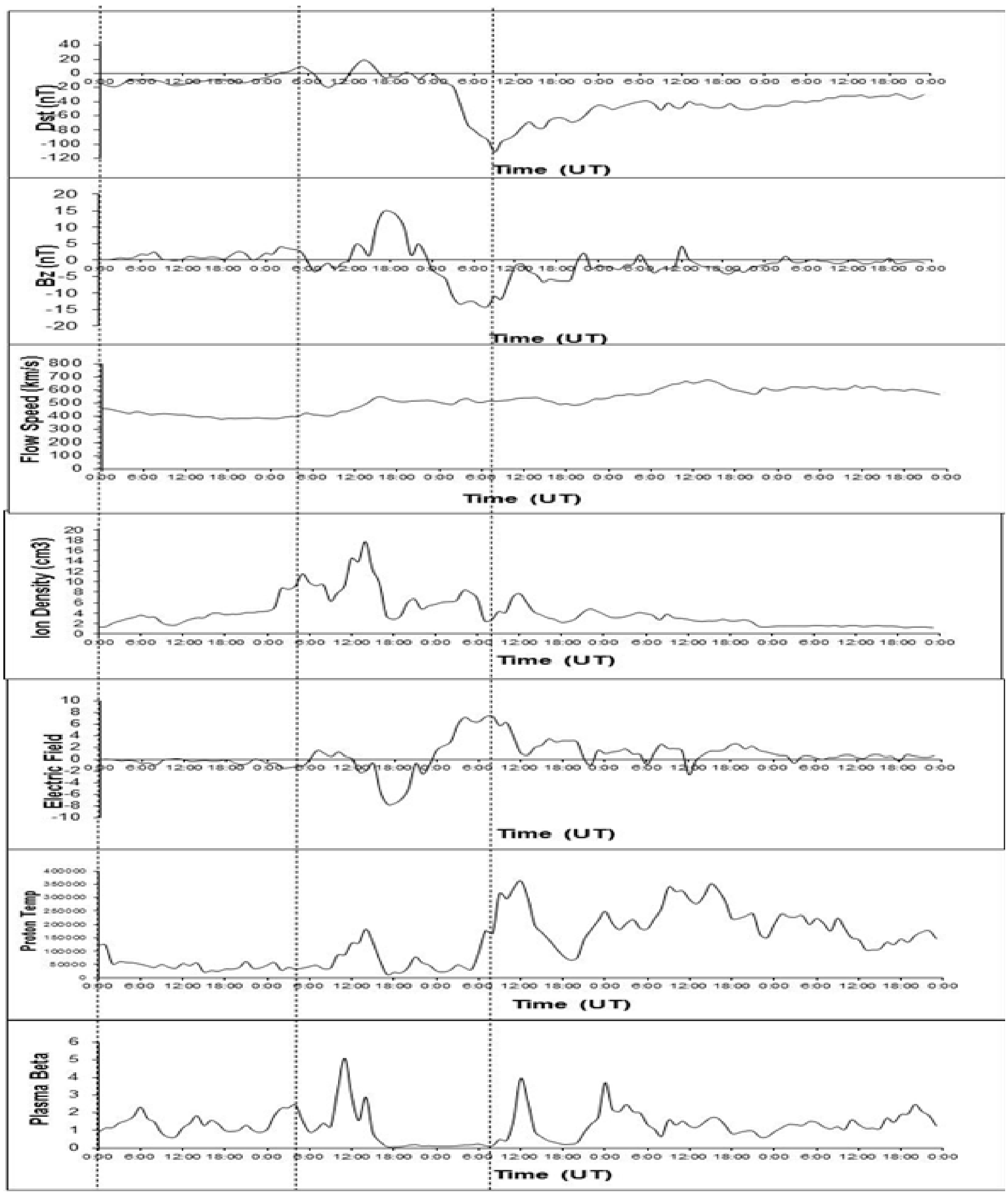

Figure 1: Composition of interplanetary and geomagnetic observations for April 12-16, 2006

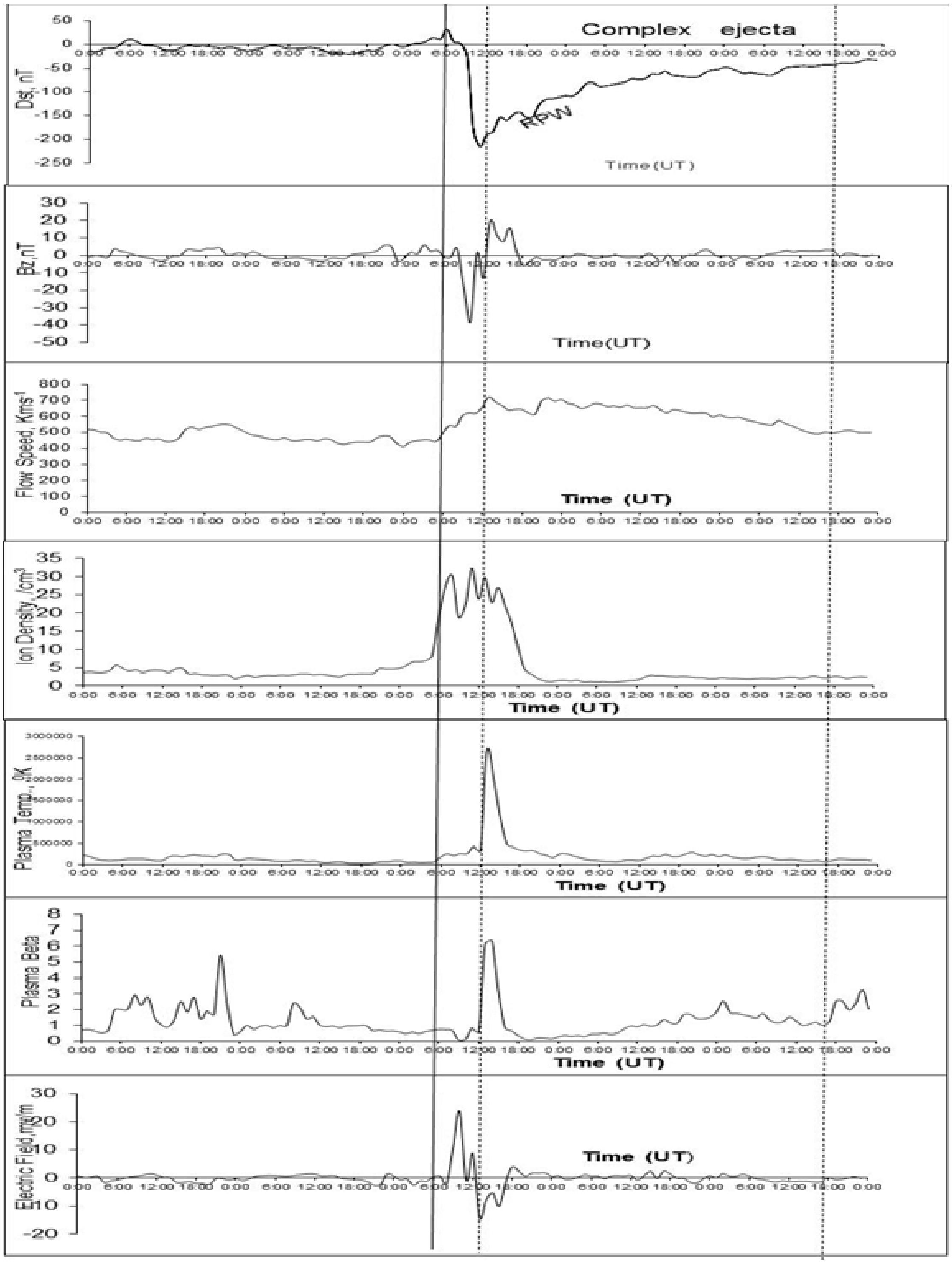

Figure 2: Composition of interplanetary and geomagnetic observations for August 22-26, 2005

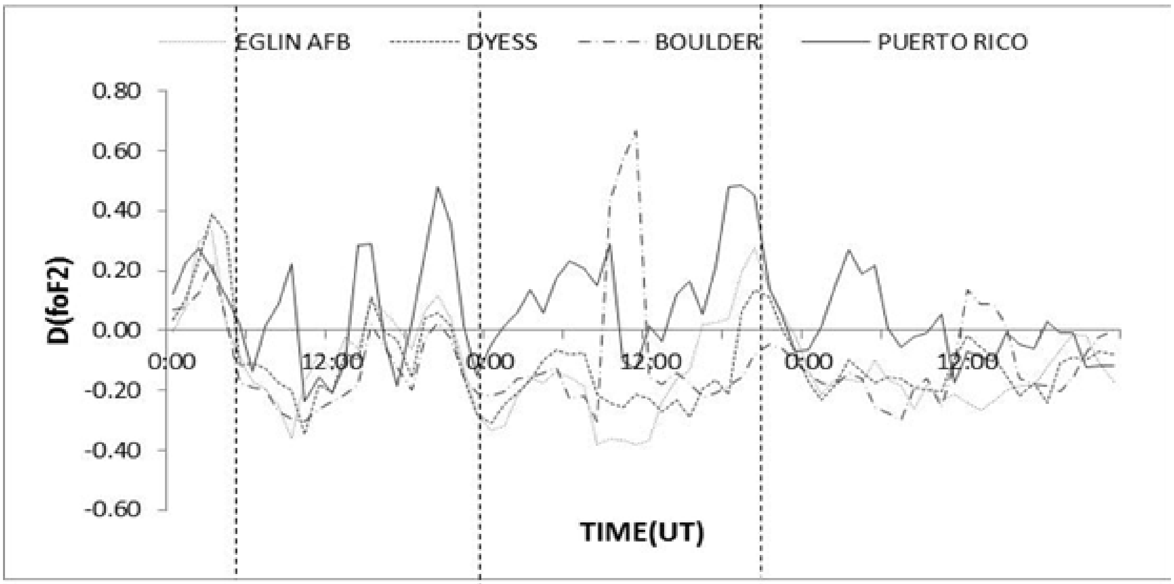

Figure 3: The superimposed variation in D(foF2) for April(14-16),2006.The horizontal dashed lines show the disturbed reference level.

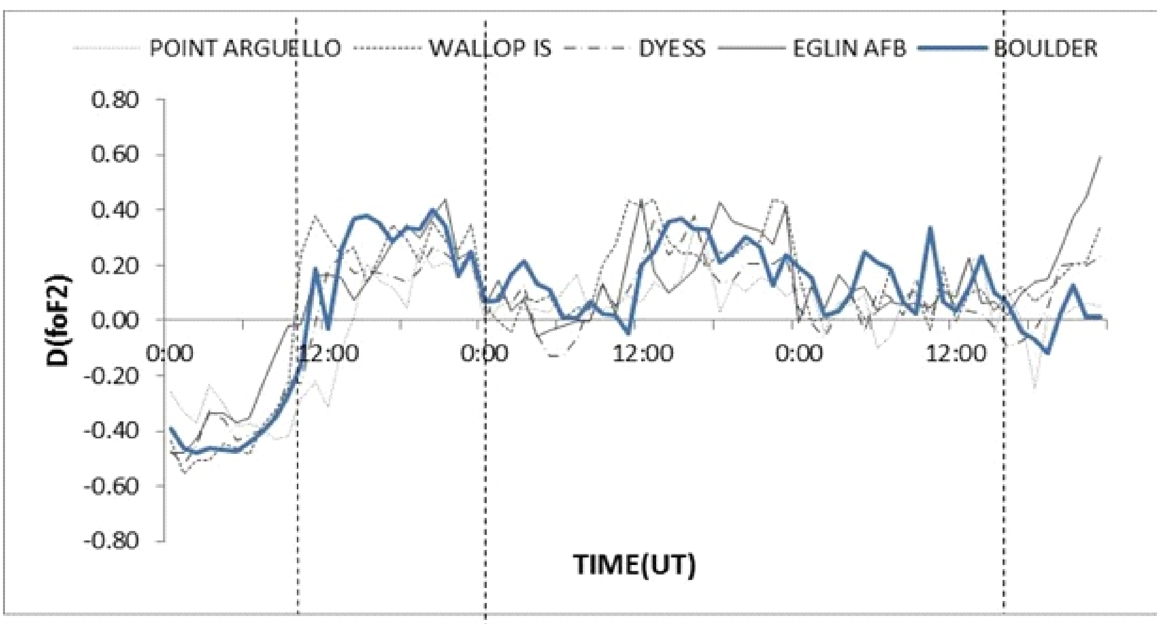

Figure 4: The superimposed variation in D(foF2) for August 24-26, 2005 The horizontal dashed lines show the disturbed reference level.

Conclusion

F2 ionospheric effects on intense geomagnetic storm associated with different drivers have been studied. Both classes of geomagnetic storm drivers are more dominant to positive storm phase than negative storm phase during the onset period of the geomagnetic storms occurrences.

The F2 region response to ionospheric storm is affected by the local time of the corresponding station. Depending on the local time of the station, there is tendency for plasma to be redistributed owing to sunrise effect when the storm occurs at mid-day. For instance, the storm of April 14, 2006 became intense at 0900 UT (5p.m.LT). . Puerto rico, a low latitude station experienced enhancement during the storm as expectedas seen in the D_{foF2} plot. A puzzling feature here is the greater depletion at the mid latitude stations Boulder compared to Dyess and Eglin AFB. One would have concluded that it still follows the normal trend as depletion is known to decrease down the latitudes (Danilov, 2001). This could be due to other anomalies such as sunrise effect which may be accounted for by increase in ionization.

Finally, geomagnetic storms with nighttime storm onset in all seasons are generally dominant to negative ionospheric storm than geomagnetic storm with daytime storm onset in all seasons to positive storm.

Acknowledgement

The daily values of ionosonde data for all stations were taken from the National Geophysical Centre's Space Physics Interactive Data Resource (SPIDR) (http//spidr.ngdc.noaa.gov) and from National Space Science Data Centre's (NSSDCs) OMNIweb service (http//nssdc.gsfc.nasa.gov/omni web) for which i am grateful

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