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On the coexistence of ionospheric positive and negative storm phases during January – December, 2000 geomagnetic activities at East Asian Sector

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ABSTRACT

In this paper, the analyses of the peak monthly geomagnetic storms observed between January – December 2000 had been presented. This study is based on data from a network of ionosondes stations located within the East Asian latitudinal sector of 40–65°N. It was found that the effects of ionization depletion at an F2 layer maximum observed at all stations during some of the events are as a result of rapid heating of the polar atmosphere during energy income from the magnetosphere. On the contrary, the positivestorm phases observed can be attributed partly to an eastward electric field, which will movethe mid-latitude ionospheric F region plasma to higheraltitudes with lower recombination, resulting in increases of the electron density. It is therefore suggested that this action may be responsible for the observed long-duration positive storm for the 12th February 2000 and 5th October 2000 geomagnetic activities. On the geoeffectiveness of the F2 Ionosphere with Interplanetary and Solar wind parameters,the correlation percentage between the F2 critical frequency deviation D(foF2) and IMF Bz are higher at most ionosonde stations than between D(foF2) and Dst. In relation to the flow speed V, all the stations had a good correlation (>58%) except at Petropavlovsk.The average correlation percentage for the F2 ionosphere against the Dst, flow speed V and Bz are 40.5, 60.3 and 46.4 respectively. This suggests that the plasma flow speed is the most geoeffective parameter with the F2 ionosphere; irrespective of the latitudinal position (low latitude is not considered here).For D(foF2)versus $(V\ x\ Bz) = E$*,the high latitude station of Salekhard had the highest correlation percentage (71.4%), followed by Magadan (60.4%), Tashkent (42.3%), Novosibirk (10%), and Petropavlovsk (negligible). From these, the following were deduced: (i) the increase in percentage correlation of* $(V\ x\ Bz) = E$*against D(foF2) is directly proportional to the increase in the latitudinal position of each station (ii) the stations with more occurrences of electron density enhancement are those whose altitudes are greater than 100m. (iii) an average value of 37.5% correlation for* $(V\ x\ Bz) = E$ *versus D(foF2) showed that V is more geoeffective, if it were to be Bz, the % value would have been ≥50%.*

Keywords: magnetosphere, electric field, critical frequency deviation, ionization, ionosphere, mid –latitude.

INTRODUCTION

Some excellent works on ionospheric storms has beenpublished during the past four decades. It has beendifficult or impossible to develop any unique theory thatcan explain the ionospheric responses at all latitudes for storms in general. Electrodynamic drifts, meridionalwinds, rapid changes in atmospheric heating andthermal expansion etc., have been invoked and suggested by many researchers.However, ionospheric storms represent large global disturbances in the F region electron density in response to geomagnetic storms. Positive and negative storm phases

are used to describe increases and decreases in the ionospheric electron density during storms. Positive storm phases occur more frequently in winter, and negative storm phases often occur in summer [1].So far mid- and low-latitude F2-layer storm effects have been studied more extensivelythan high-latitude ones. This is partly due to thedifficulties with ground-based ionosonde observationsduring geomagnetically disturbed periods. In addition,the high-latitude F2 region is very variable, being stronglyinfluenced by magnetospheric processes; in particular,substantial electric fields are usually present duringgeomagnetic storms. These electric fields and the corresponding horizontal plasma drifts can stronglyperturb the electron density distribution at F2-layerheights. Neutral composition and temperature changesare the other source of negative F2-layer storm effects.

Hence the aim of the present work is to study the physicalmechanism and to estimate the contribution of variousprocesses that affects theionospheric F2 layer (using the critical frequency foF2), during the peak storm activities (in each month of the year 2000) at 5 general ionospheric stations in the East Asian geomagnetic zone.

2.0 Data, Methodology and Plots

The OMNI data base is a convenient and widely used source for studying intense magnetic storms: see the http://nssdc.gsfc.nasa.gov/omniweb/ow/html Web site. For the purpose of this paper, twelve (12) storm events occurring in the year 2000 are being understudied. The 12 storms are the peak geomagnetic activity occurring in each month of the year 2000 (see Table I). All are intense, except for the one of January 23 (for the month of Jan.), June 26 (for Jun.) and December 23 (for Dec.).According to [2], intense storms are those with peak of Dst of -100 nT or less, moderate storms fall between -50 and -100 nT, and weak storms are those between -30 and -50 nT. However, the interplanetary, geomagnetic and solar wind parameters data used are the plasma proton density, the solar wind flow speed V(km/s), the average magnetic field B (nT), the IMF Bz (nT), the plasma temperature T (K), the low latitude magnetic index Dst (nT), plasma beta and the electric field (mV/m). All are from the OMNI database and mostly from the IMP 8 Spacecraft. Highlighted in Table I are the peak storm events and days for each month, with corresponding values of flow speed, IMF Bz (in GSM) and occurrence time at minimum peak Dst value. Five (5) out of this twelve (12) geomagnetic activities are discussed in the next section. This are February 11-14 (fig. 1), August 11-14 (fig. 3), September 16-19 (fig. 5), October 4-7 (fig. 7) and July 14-17 (fig. 9), all in the year 2000. 3 of these are part of the 9 great geomagnetic storms that occurred during the Solar cycle 23 (i.e between 1996 and 2006).Year 2000 also falls between the period of rise and maximum of Solar cycle 23 [3].

Table I: Maximum Geomagnetic activity days for each of the months in the year 2000 with corresponding peak Dst and time, flow speed, and IMF Bz (in GSM).

Storm Date	Month	Peak Dst	V (km/s)	Bz	Peak Dst time
Jan. 23, 2000	Jan.	-97	360	-14.1	00.00
Feb. 12, 2000	Feb	-133	568	-1.4	11.00
Mar. 31, 2000	Mar	-60	396	-4.9	11.00
Apr. 7, 2000	Apr	-288	571	-4.7	00.00
May. 24, 2000	May	-147	642	-7.1	08.00
Jun. 26, 2000	Jun	-76	540	-7.8	17.00
Jul. 15, 2000	Jul	-301	1030	-3.7	00.00
Aug. 12, 2000	Aug	-235	613	-13.9	09.00
Sept. 17, 2000	Sep	-201	794	-5.8	23.00
Oct. 5, 2000	Oct	-182	523	-10.4	13.00
Nov. 6, 2000	Nov	-159	570	5.3	21.00
Dec. 23, 2000	Dec	-62	323	-12.7	04.00

On the other hand, the Ionospheric data used consists of hourly values of the F layer critical frequency foF2 obtained from some of the National Geophysical Data Center's in Space Physics Interactive Data Research (SPIDR) network of ionosonde stations located in the East Asian sector (predominantly Russia region). See Table II. The F layer critical frequency foF2 is used because of its direct relationship with the F layer peak electron density NmF2 (which

is a measure of positive or negative storm effects through its significant increases or decreases about the mean position respectively). i.e

$$foF2(Hz) = 9.0x\sqrt{NmF2}(m^{-3}) \quad (i)$$

For the purpose of these work, we concentrate only on the high and mid-latitude stations.The High latitude ones are Salekhard (66.59^0N) and Magadan (60.20^0N), while the mid-latitude stations are Petropavlovsk (52.97^0N), Tashkent (41.16^0N) and Novosibirsk (55.04^0N).It is important to note that paucity of data at most stations during the days under investigation restricted the choice of ionosonde stations. Moreover, the criterion used in selecting the stations is such that storm variations represented real changes in electron density and not simply redistribution of the existing plasma. However, the F2 region response to a geomagnetic storm is most conveniently described in terms of the normalized deviations of the critical frequency foF2 from the reference, D(foF2) [4], where

$$D(foF2) = \frac{foF2-(foF2)_{aver.}}{(foF2)_{aver}} \quad (ii)$$

Table II: List of Ionosonde Stations in the East Asian Sector

Station	Code	Altitude (m)	Geographic cord. Lat. (°N)	Geographic cord. Long. (°E)	Diff. between LST and UT (hrs.)
Petropavlovsk	PK553	50	52.97	158.45	+12
Tashkent	TQ241	480	41.16	69.13	+5
Salekhard	SD266	66	66.59	66.61	+5
Novosibirsk	NS355	111	55.04	82.55	+7
Magadan	MG560	610	60.21	151.03	+11

Hence the data under analysis consists of D(foF2) of respective hourly values of foF2 of February 12-16 (figure 2), August 12-16 (figure 4), September 17-21 (figure6), October 5-9 (figure 8) and July 15-19 (figure 10), all in the year 2000. The reference for each hour (for each storm event) is the average value of foF2 for that hour calculated from the five quiet days preceding the storm.Furthermore, the use of D(foF2), the normalized deviations of the critical frequency rather than the critical frequency foF2 itself provides a first-order correction for temporal, seasonal and solar cycle variations, so that geomagnetic storm effects are better identified. Note that in analyzing D(foF2) variations for ionospheric storms, positive and negative storms are defined by changes in amplitude, [5] postulated that the maximum absolute value of D(foF2), of more than 10% are regarded as intense activities.

3.0 February 12, 2000 Storm

3.1 Interplanetary and Geomagnetic Observations

In Figure 1 are the response plots of the geomagnetic, interplanetary and solar wind parameters for the storm of February 12, 2000. According to [6], the principal defining property of a magnetic storm is the creation of an enhanced ring current, formed by ions (notably by protons and oxygen ions) and electrons in the 10-300 keV energy range, located between 2 to 7 $R_E$and producing a magnetic field disturbance which, at the equator, is opposite in direction to the Earth's dipole field, thereby causing a diamagnetic decrease in the Earth's magnetic field measured at near-equatorial magnetic stations as low- latitude magnetic index, Dst.

From panel a of Figure 1, showing the average interplanetary magnetic field B, the IMF Bz (in GSM) and the plasma proton density, it was observed that both B and plasma protondensity followed the same pattern. It should be noted that both variables began to drop southwardly at the instance the Dst (panel c) began its main activity dropping to its peak minimum value of -133 nT on Feb. 12 around 1100UT. This is indicated by the vertical line that drops through the whole figure. It is well established that the Bz component of the IMF exerts the most important influence on the magnetoshere and high-latitude ionosphere, as it controls the fraction of the energy in the solar wind which is extracted by the magnetosphere. Furthermore, when Bz is strongly negative, magnetic reconnection between the IMF and the geomagnetic field produces open fields which allowed for mass, energy and momentum to be transferred from the solar wind to the Earth's magnetosphere. Here the IMF Bz experiences a sinusoidal wave-

like pattern until around 1800UT ofFebruary 11 when it turns totally southward, after it had experienced a shock in the interplanetary medium, obtaining its peak minimum value of -14.1 nT.Note also the increase in the solar plasma flow speed (panel c) to a value of 568 km/s within the same period, as well as the increase in the plasma proton density.It should be noted also that the relatively slow rising stream above 400km/s indicate the arrival of shocks [7]. According to [8] and [9], intense magnetic storms occur when the solar flow speed is substantially higher than the average speed of 400km/s.

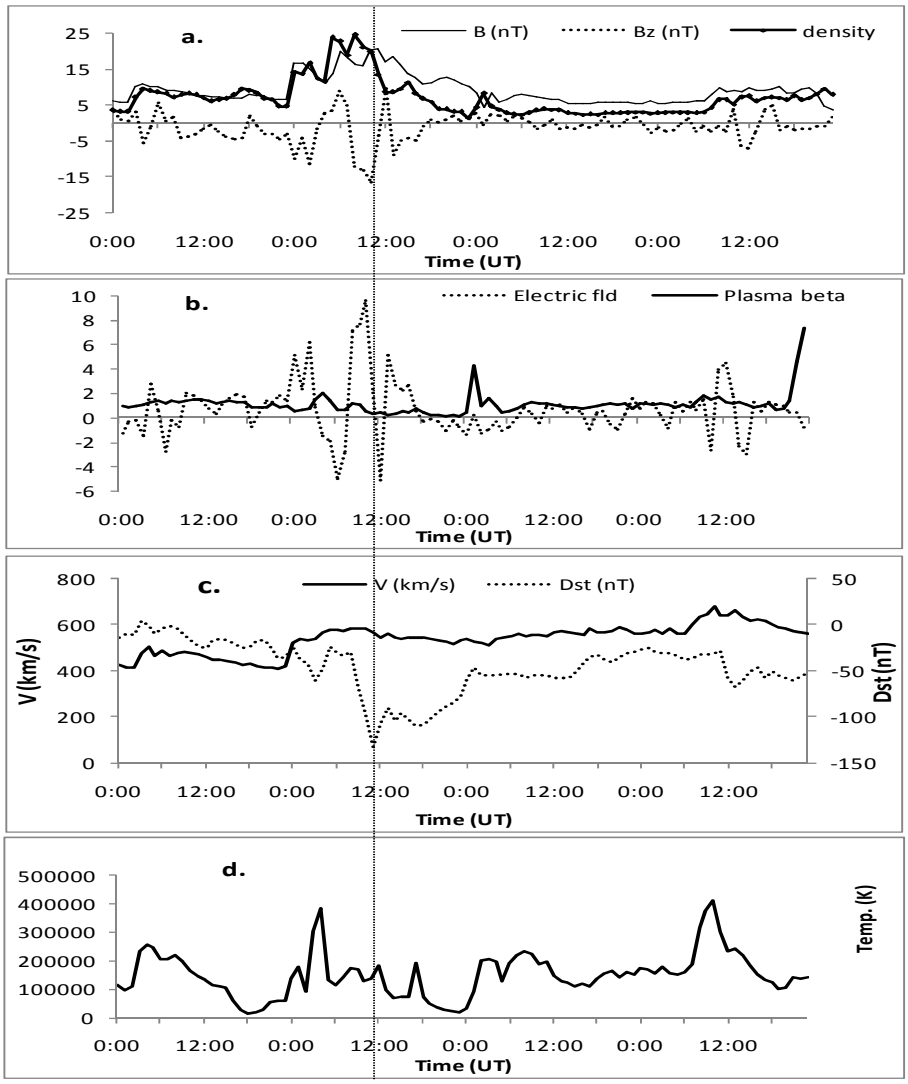

Figure 1: Response plots of the geomagnetic, interplanetary and solar wind parameters for the storm of February 12, 2000 spanning Feb 11-14, 2000

It was also observed that before the actual storm event, the Dst variations indicate that weak storm dominated throughout most of the period 0000UT on Feb. 11 to 0000UT on Feb 12; at which time the Bz orientation is northward. On the temperature panel (panel d), it was observed that immediately after the shock was experienced in the interplanetary medium as indicated on the Dst plot, the plasma temperature abruptly rose to a value of about 380000K around 0600UT on Feb 11.The structure of this geomagnetic storm event is further made clearer by the plasma beta (panel c). The plasma beta plot shows a relatively low value between 1200UT through 2300UT on Feb. 12. Given this low values which is coincident with low plasma temperature, and an enhanced plasma flow speed, the profile of the plasma beta appears to present a criterion for magnetic clouds. Hence, it can be stated that the storm is

generated by shocks from magnetic cloud origin which is characterized by low beta plasma, high IMF magnitude and large scale coherent field rotations often including large and steady north-south components. However, in due course, it was discovered that the north-south component of the interplanetary magnetic field regulated the growth of the ring current.

Regarding the electric field, the primary causes of geomagnetic storm at the Earth, according to [2], are strong dawn-to-dusk electric fields associated with the passage of southward magnetic fields Bs past the Earth for a sufficiently long interval of time. It was observed from the figure (panel b) that the electric field rose to a value of 8.00 mV/m at the instance the Bz turns southward. It has been proposed by [10] that when the IMF turns southward and remains stably southward for several hours, the dayside eastward ionospheric electric field is enhanced throughout the entire interval of southward IMF, and that a similar enhancement of the westward ionospheric electric field is observed when the IMF turns northward and remains stably northward. In this case, the ionospheric electric field enhancement lasts for longer than 1 hour without significant decay, so it is termed the long-duration enhancement of the ionosphericelectric field.

3.2 Ionospheric Response

Moreover, the ionospheric observations to the storm of February 12, 2000 are shown in Figure 2, and it spans 12- 16 February. From the figure, it was observed that generally for all the stations, it was more of an enhancement in the foF2 ionosphere (i.e positive phase storm), but more pronounced at the high latitude stations of Magadan and Salekhard, as well as at Petropalvosk. It is well established that the Bz component of the IMF is the most important influence on the magnetoshere and high and mid-latitude ionosphere as it controls the fraction of the energy in the solar wind which is extracted by the magnetosphere. Therefore, the positive storm experienced at the high and mid latitude stations after storm commencement appear to be caused by the short duration southward turning of Bz giving $\delta Bz =$-14 nT between 0600UT and 1100UT on February 12. It thus appear that this southward turning with $\delta Bz =$-14 nT may have been accompanied by an increase in solar wind dynamic pressure which led to an enhanced coupling between the solar wind and the terrestrial magnetosphere that significantly increased the geoeffectiveness of the solar wind [11].According to [12], although negative IMF is important in enabling the extraction of solar wind energy and thus driving global ionosphere/thermosphere disturbances, the solar wind energy density must be high for coherent changes to be seen at mid-latitudes. [13]recently found that variations in mid-latitude ionosphere are well correlated with variations in IMF.

From the figure (i.e figure 2), the significant increases of the mid-latitude ionosphericF region electron density experienced over Petropavlovsk, Tasshkent and Novosibirsk started to occur at 1200 UT on 12 February2000, almost immediately after the SSC (as indicated on the Dst plot in figure 1), and lasted formore than 7 hours during the daytime. This case may beclassified as a long-duration positive storm phase. Observe also that thereafter the F2 region experiences a short term depletion level to about 10% in all the stations for just about 5 hours, before they began to pick up again. It was further shown that all the ionospheric stations experiences depletion in the F2 layer at the exact time the Dst recorded its minimum peak value (i.e 1100UT on February 12).One striking feature is the electron density depletion recorded at all stations around 0600UT of each day between 12-16 February.

4.0 August 12, 2000 Storm

4.1 Interplanetary, Geomagnetic and Ionospheric Observations

The Interplanetary and Geomagnetic observations to the storm of 12th August 2000 are presented in Figure 3, spanning August 11-14.

From the first panel (i.e., panel a) of the figure showing the respective plots of B, Bz and proton density, it was observed that the average magnetic field B attained its peak value of 33.6 nT around 0900UT on August 12. This coincides with the peak depression value on the IMF Bz plot to a value of -28.7 nT, as well as the minimum peak value on the Dst plot (panel c). Note also that the Bz orientation was mostly southward throughout the whole of August 11 through 1700UT of August 12. However, as the storm began to recover, the Bz turned northward and maintain this posture till the 2300UT of August 14. The instance the Bz abruptly turned northward to a value of 10.7 nT, which also corresponds to the Dst value of -24 nT around 0000UT on August 11 marked the onset of the SSC during which little energy was entering the magnetosphere, regardless of the speed and number density of particles in the solar wind. More importantly, it was discovered that SSC is not a necessary condition for a storm to occur,

and hence the initial phase is not an essential feature [14]. It is thus evident, that the most essential feature of a storm is the significant development of a ring current and its subsequent decay.

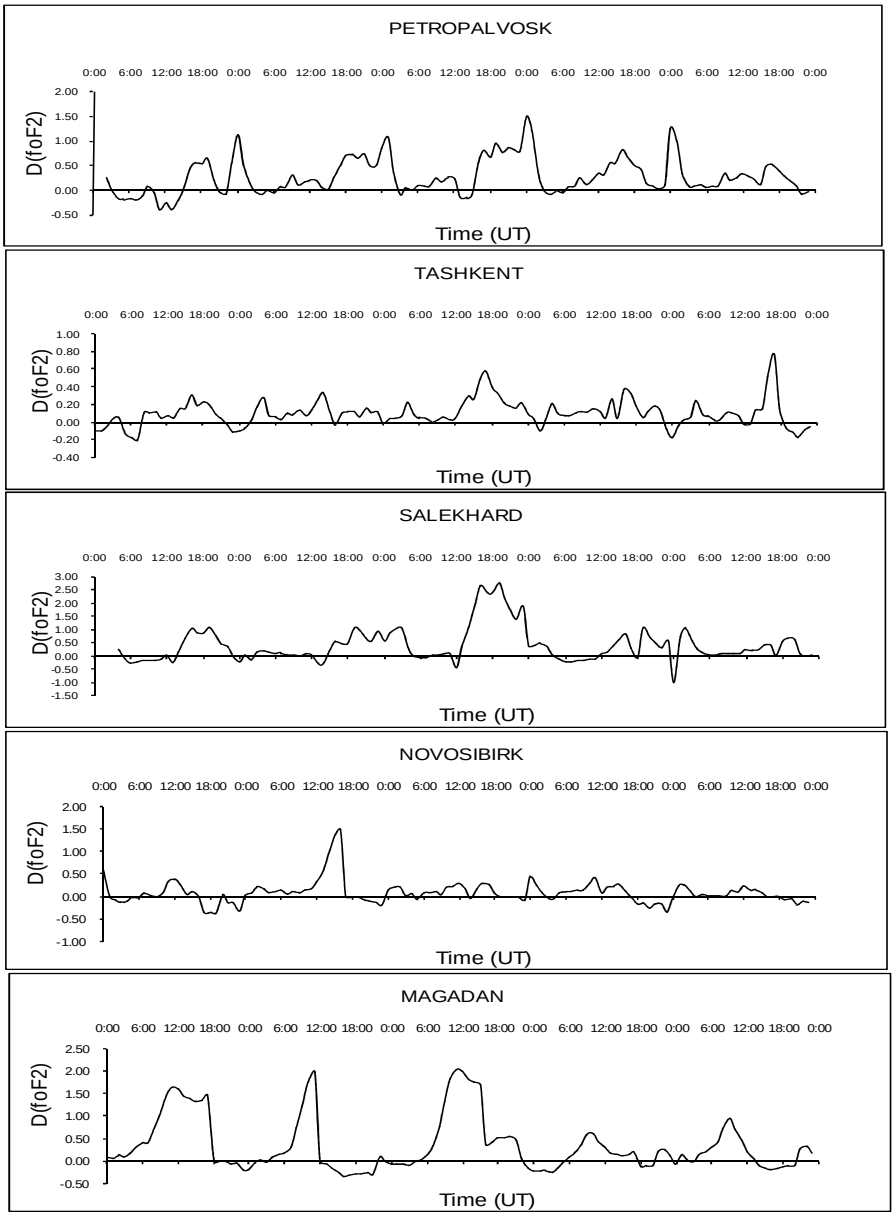

Figure 2: The Ionospheric observations of the storm of February 12, 2000

From panel c of the figure, showing the plots of the flow speed, it was shown that the flow speed suddenly rose from 515km/s around 1900UT on August 11 to 613 km/s of the same day, and thereafter to 644 km/s around 0500UT. It has been agreed that the power required to build up the storm time ring current and to supply the dissipation associated with various auroral and ionospheric manifestations of storms and substorms must be extracted ultimately from the kinetic energy of solar wind flow. Therefore, the observed increase in the flow speed value just immediately after SSC can be attributed to the conversion of the solar wind which is initially in electromagnetic form to mechanical energy of particle motion (either flow or thermal); whereas the energy supplied by the solar wind is initially all in mechanical form. According to [15],energy flow from the solar wind to the magnetosphere and ionosphere must therefore proceed in two steps: mechanical energy from the solar wind is converted to

electromagnetic energy (and can be viewed as stored in the magnetic field primarily of the magnetotail) and this electromagnetic energy is converted to mechanical energy of particles in the plasma sheet, ring current, and ionosphere. Thus, the observed higher plasma proton density and higher flow speed combine to form a much larger solar wind ram pressure.Moreover, the 11 August 2000 event thus indicates thatthe magnetosphere is much more sensitive to solar winddynamic pressure variations when the IMF is stronglysouthward than when it is weakly southward.

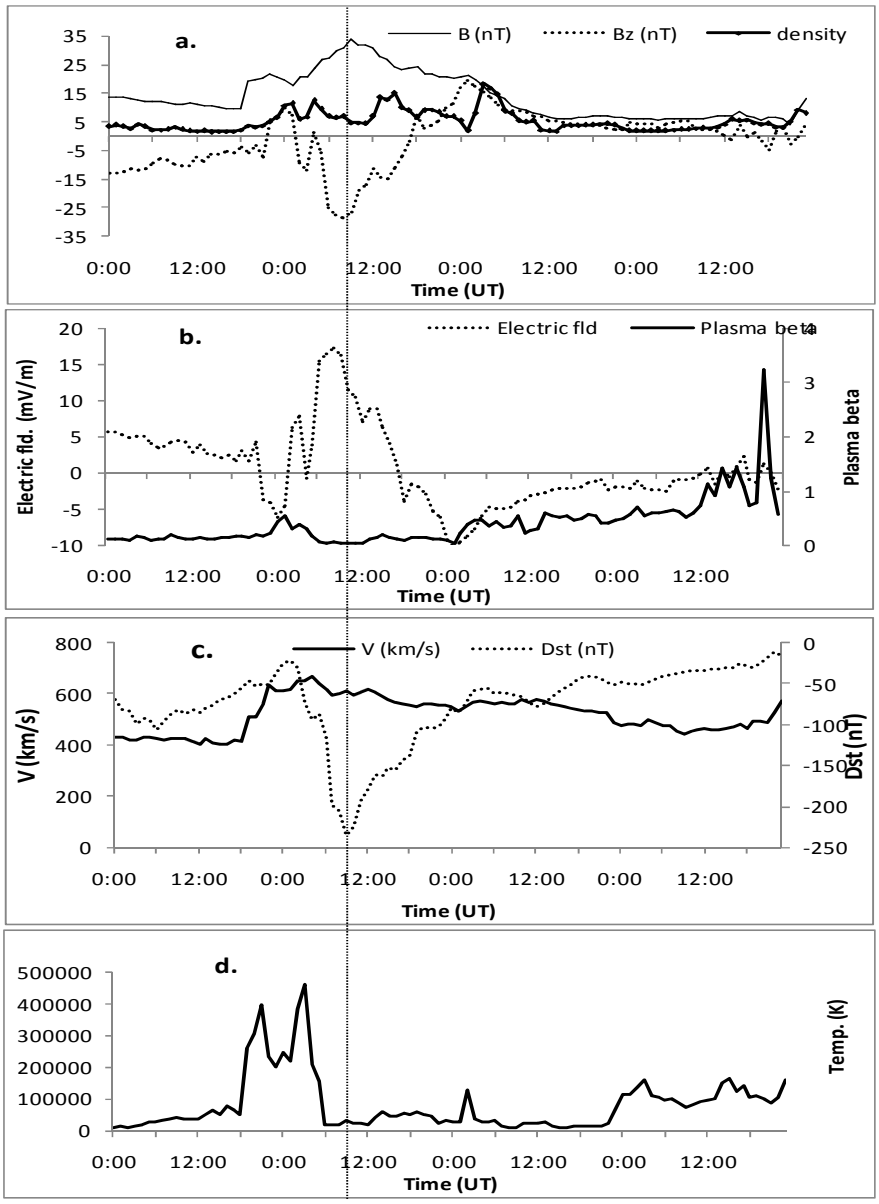

Figure 3: Response plots of the geomagnetic, interplanetary and solar wind parameters for the storm of August 11-14, 2000

Given the low values of plasma beta (panel b) and temperature (in panel d) which is coincident with an enhanced plasma flow speed between 1100UT and 2300UT on August 12, the profile of the plasma beta appears to present a criterion for magnetic clouds. Hence, it can be stated that the storm of August 12, 2000 is generated by shocks from magnetic cloud origin which is characterized by low beta plasma, high IMF magnitude and large scale coherent field rotations often including large and steady north-south components. Given the variations of the solar wind parameters

under investigation, it is safe to suggest that the same magnetospheric process played the leading role in the enhancement in the ring current

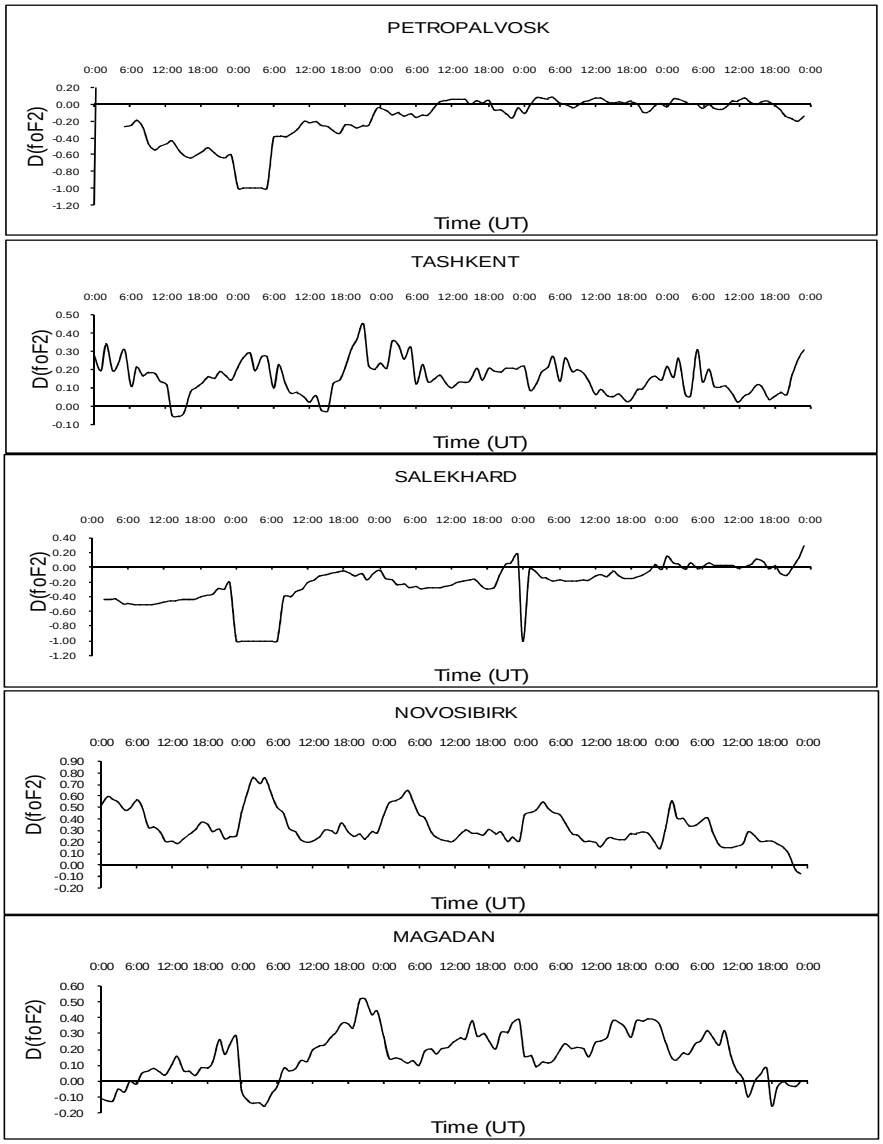

Figure 4: The Ionospheric observations of the storm of August 12-16, 2000

Moreover, according to [16] magnetic clouds that are geoeffective have a southward and then northward (or vice versa) magnetic field directional variation. When the magnetic cloud has a very high velocity, it compresses the plasma ahead of it and forms a "collissionless" shock. Behind this shock is a sheath, which contains heated plasma and compressed magnetic fields. These intense sheath magnetic fields in turn, can also cause magnetic storms. Regarding the ionospheric response (i.e Figure 4), [5] had suggested that the response of the ionospheric F2 region to magnetospheric disturbances is different from that of the lower ionosphere. The difference is due to the differences in physical mechanisims responsible for the changes of the electron concentration (e). While in the E and D regions the primary reason of the (e) changes is the variation of the ionization rate because of corpuscular intrusions, there is no considerable change of the ionizing source intensity in the F2 region during geomagnetic disturbances. From the figure (i.e figure 4), spanning August 12-14, 2000, it was observed from the D(foF2) plot that there is a decrease in the ionospheric foF2 at Petropalvosk and the high latitude station of Salekhard. However, there is an enhancement (i.e positive storm) at Tashkent, Novosibirk and Magadan. From the Bz plot in Figure 3

(panel a), a change in Bz of δBz = -16.8 nT was observed between 0300UT and 0800UT on August 12 which appear to coincide with increases in both plasma density and flow speed. This change in Bz could lead to the explanation of ionospheric responses observed at some stations hours after it occurred. This is because [12] have shown that a southward turning with a change in Bz of δBz = -11.5nT results in foF2 showing a marked decrease in amplitude, reaching a minimum value few hours after the southward turning. Hence, the positive storm experienced at Tashkent, Novosibirk and Magadanafter storm commencement appear to be caused by the short duration southward turning of Bz giving δBz = -16.8 nTbetween 0300UT and 0800UT on August 12.

[15]had proposed that changes in the large-scale electric field during magnetic storms, both substorm related and directly driven by the solar wind, can trap particles well inside geosynchronous orbit. Recent satellites observations in the inner magnetosphere have shown, however, that the abundance of ionospheric ions (particularly O^+) is high and is highly correlated with substorm activity. This O^- dominance coupled with the fact that a significant fraction of H^+ is also ionospheric in origin, suggests that the cause of the intense ring current during great storms is the enhanced outflow of ionospheric ions.

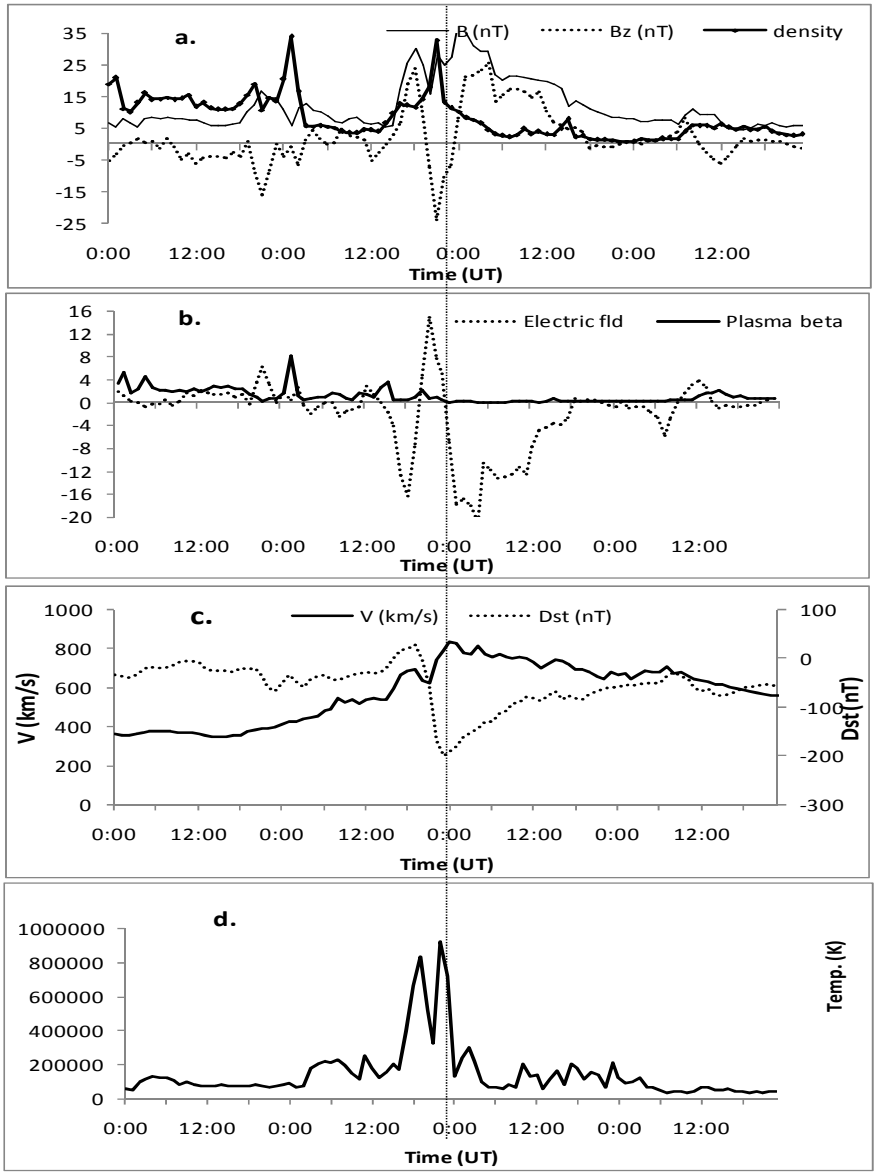

Figure 5: Response plots of the geomagnetic, interplanetary and solar wind parameters for the storm of September 17, spanning 16-19, 2000

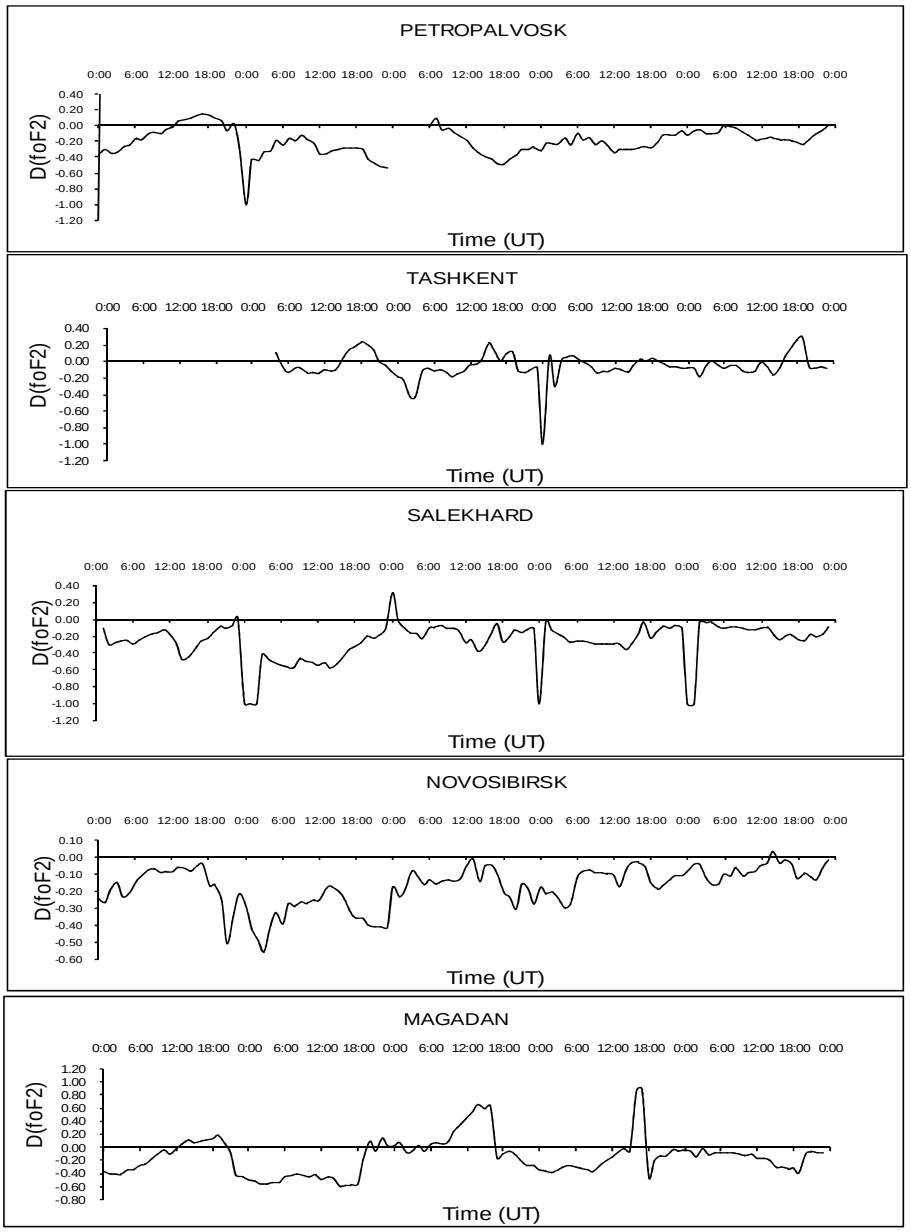

Figure 6: The Ionospheric observations for September 17-21, 2000

5.0 Solar, IMF Activity and Ionospheric Observations to the September 17, 2000 Storm

The solar and interplanetary magnetic field activities and the Ionospheric observations to the storm of September 17, 2000 storm are presented in figure 5 and figure 6 respectively. According to [17], while investigating the roles of interplanetary and geomagnetic parameters in the generation of 'intense'(-250nT ≤ peak Dst< -100nT) and 'very intense' (peak Dst< -250nT)magnetic storms, it was revealed that the interplanetary magnetic field Bz plays a prominent role alongside Dst in the generation of intense storms. Moreover, the interplanetary electric field (-V x Bz) associated with high speed streams and the solar wind density Np, (which is a function of the solar wind ram pressure) also plays an important role in the ring current intensification. He went further to propose that in regards to the geoeffectiveness of the flow speed V, the Bs and Bs interval (B_T) with the average magnetic field B, it was observed that generally for all the storms, the flow speed is the most correlated, showing a correlation coefficient of 50.9% with B,Furthermore, the result shows that 'very intense' storms whose main feature is a plasma flow speed greater than 550 km/s has a negligible correlation between the flow speed and the magnetic field B; whereas,

'intense' storms have a 58.7% correlation between the two parameters. [17] finally argued that all 'very intense' storms are likely to have a plasma flow speed greater than 550 km/s within the storm interval, but not all flow speed greater than 550 km/s are 'very intense' storms. The last assertion is true for the storm of September 17, 2000. From Figure 5, the Dst plot (in panel c) revealed the minimum peak value for these storm event (i.e., -201 nT), and the corresponding flow speed value (same panel c) revealed 794 km/s. The high value recorded by the average magnetic field B (panel a) together with the increment in the flow speed V value (27.5 nT) around 2300UT of September 17 also points to the fact there is a good correlation between the two parameters, especially when it satisfies the 'intense' storms condition.

It must be noted that the plasma temperature (panel d of figure 5) showed a tremendous increase to a value of 920518 K, at the instance of the minimum peak value of the Dst around 2300UT of September 17; which also heralded the high flow speed rate, as well as a southward turning of the electric field (Figure 5- panel b) and low plasma beta.Note also that the temperature was initially minima between 0000UT of September 16 and 1300UT of September 17. All these appear to indicate that the storm is as a result of interplanetary ejecta of the magnetic cloud type [18].

It has been said that the dominant solar/coronal events that occur near the maximum sunspot phase of the solar cycle are impulsive ejecta, often referred to as coronal mass ejections (CMEs). These events have different speeds, but the ones that are most effective in creating magnetic storms are fast events, with speeds exceeding the ambient wind speed by the magnetosonic wave speed, thus forming a fast forward shock. As a fast plasma and field structure propagates from the sun through interplanetary space, it sweeps up and compresses the slower plasma and field ahead thus creating a 'sheath' between the shock and the interplanetary manifestation of the ejecta. This condition holds for the storm of September 17, 2000. It can therefore be said that the sheath created is as a result of the Bz southward orientation around 1700UT on September 18, few hours to the storms main phase. This is because if an intense storm (like the one under investigation here), has a long-duration southward field intervals in either the sheaths or the ejecta itself, a main phase may follow. It is also important to note that in several occasions; more than one interplanetary structure can be associated with the origin of intense storms, which are complex in nature. These complex structures have been studied by different scientists e.g. [8]. Also, most of these reported complex structures involve a fast forward shock followed by a magnetic cloud, and usually another high speed stream is found in the magnetic cloud [19].

In a work by [20], while studying the variation between Dst and IMF Bz during 'intense' and 'very intense' geomagnetic storms, it was observed that 'very intense' storms are more likely to experience shock in the interplanetary magnetic field region faster than 'intense storms with a flow speed >400 km/s. It was also observed that 'intense storms recover faster than the 'very intense ones.

Regarding the Ionospheric observations (as indicated in Figure 6), it was observed from the D(foF2) thata depletion at an F2 layer maximum (negative ionospheric storm) was predominant at all the five ionospheric stations of Petropalvosk, Tashkent, Salekhard, Novosibirsk and Magadan. However, it is pertinent to state that there was a transient positive phase storm at Magadan between 0900UT and 1400UT on September 19. This could be as a result of composition changes, which directly influence the electron concentration in the F2 region. However, the circulation may spread the heated gas to lower latitudes, which may eventually result in the observed general negative storm.

It could also be explained on the bases of [5] conclusion, that during geomagnetic disturbances, a large amount of energy is deposited into the thermosphere at high latitudes that leads first of all, to an increase of the neutral gas temperature (depletion on the atoms-to-molecules ratio). Both factors may contribute to a decrease of the electron concentration (the negative phase of an ionospheric storm) in the high latitude ionosphere. The energy deposit thereafter produces a strong enough storm-induced circulations which is directed equatorward and may coincide or conflict with the quite-time circulation. Accordingly, the gas with depleted $[O]/[N_2]$ is brought far the latitude in order for the negative storm to spread equatorward. Observe that at all the stations (except Tashkent, that is short of data) recorded their main electron concentration depletion between the hours of 2100UT of September 17 and 0300UT of September 18.

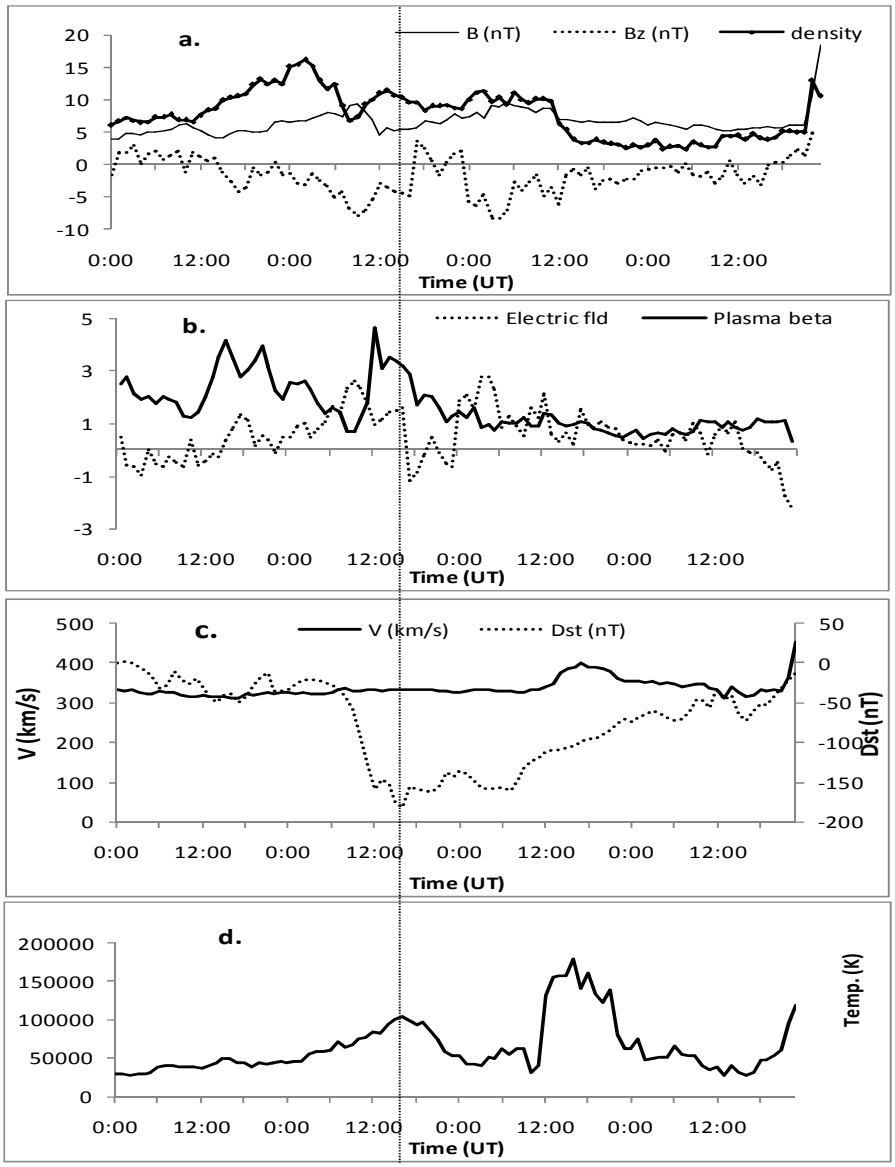

Figure 7: Response plots of the geomagnetic, interplanetary and solar wind parameters for the storm of October 5, 2000, spanning October4-7.

6.0 October 5, 2000 Storm

6.1 Interplanetary, Geomagnetic and Ionospheric Observations

The Interplanetary and geomagnetic observations are shown in figure 7 spanning October 4-7. From the Dst plot (panel c), the Dst got to its first minimum peak value of -182nT at 1600UT on October 5. It could therefore be argue that the solar wind became geoeffectivea day before the storm day. According to [15], if a new major particle injection occurs, it leads to a further development of the ring current with Dst index decreasing. It should also be noted that the increases in both plasma density (panela)and flow speed around this period are indicative of arrival of a shock in the interplanetary medium. It was also observed that the solar wind speed increased towards the storm day, far above a value of 350km/s. [21] had proposed earlier that moderate or strong storms occurred only when solar wind speed was above ~350km/s. The plot thereafter shows the arrival of another shock in the interplanetary medium making the Dst, (which originally is setting up to recover) to reach its second minimum value of -157nT at ~0500UT on October 6. According to [22], a major storm occurs when the IMF experiences more than three hours

and more than 10n T southward component. This is further indicated by the first decrease in Dst at 1600UT of October 5. Therefore, the Dst plot presents a double step main phase event taking over 24 hours to develop.

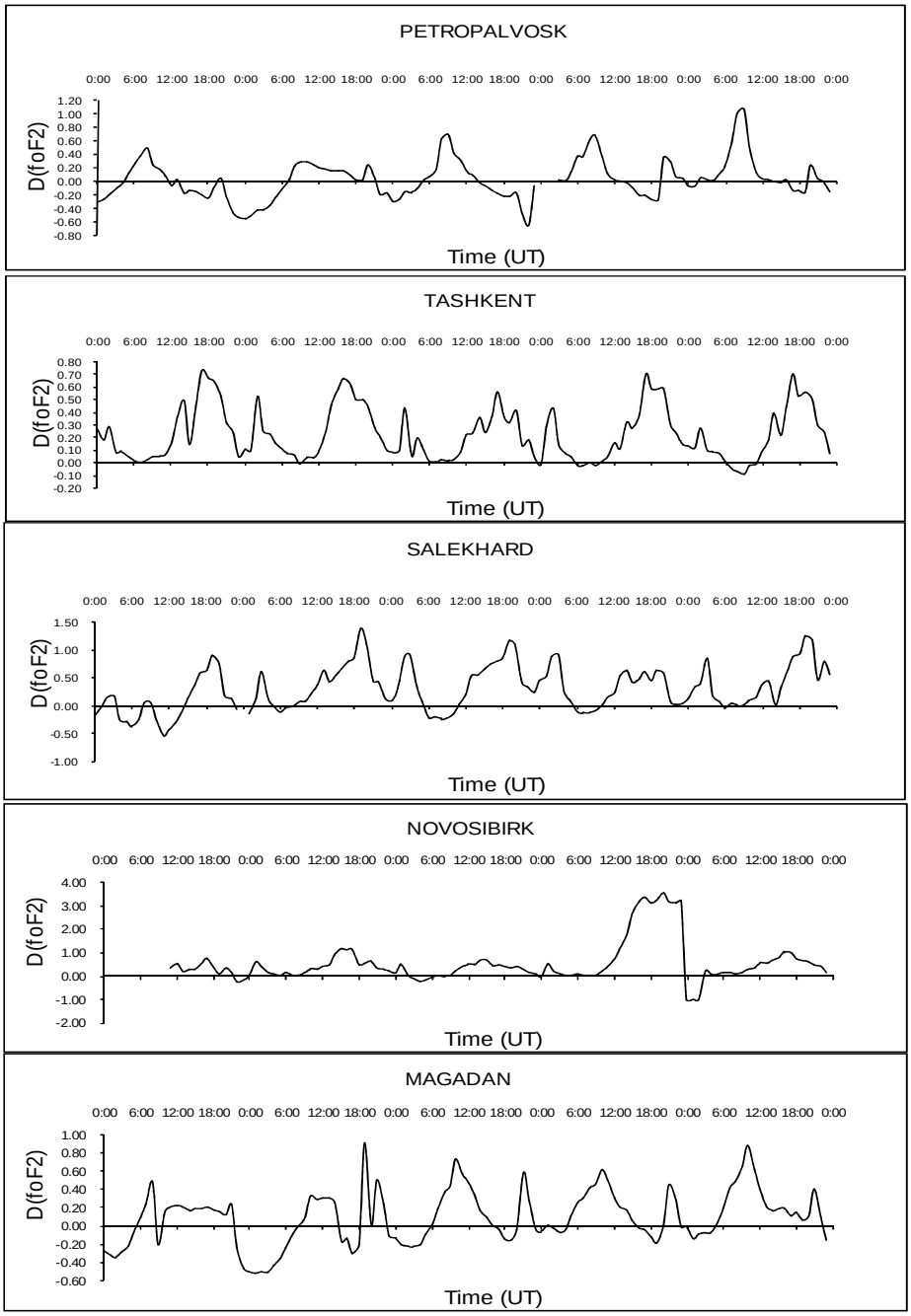

Figure 8: The Ionospheric observations for October 5-9, 2000

The first step of the main phase with Dst -182 nT starts at 2100UT on October 4. Also, the second step is associated with the sharp southward turning of Bz at 0000UT on October 6, reaching a value of -5.7 nT (see panel a of figure 7). Also, after Bz had reached its peak value of -8.3 nT around 0400UT October 6, it began rotating towards the north direction, whereas this decrease in the intensity of the southward component of the IMF is followed by a recovery in Dst. The long duration of Bz in the southward direction for over 12 hours is an indication that the storm

event is intense in nature. According to [5], the IMF structures leading to intense magnetic storms have intense (>10nT) and long duration (>3hr) southward component.

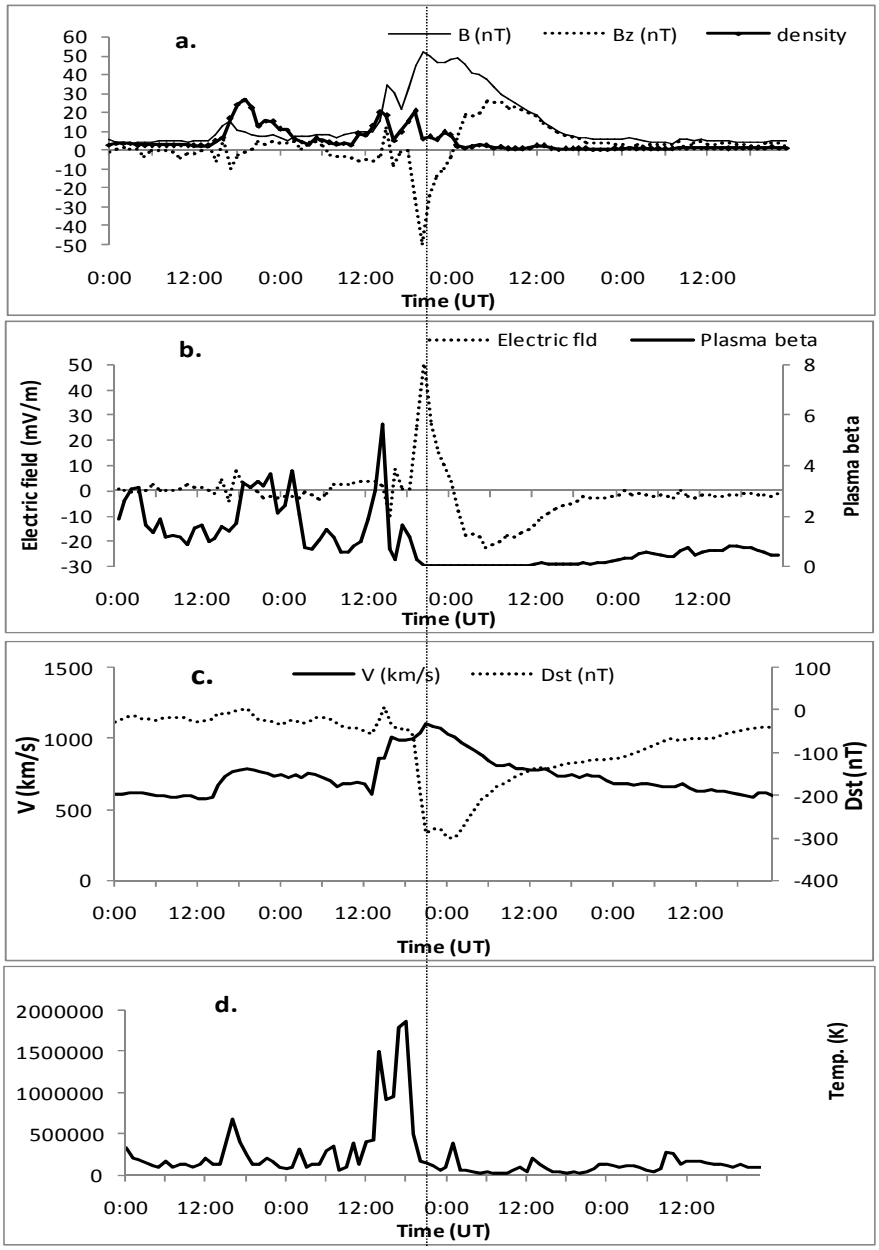

Figure 9: Response plots of the geomagnetic, interplanetary and solar wind parameters for the storm of July 15, 2000, spanning July 14-17, 2000

The Dst profile for this storm event also appears to present a Type 2 intense geomagnetic storm. However, a Type 2 storm must satisfy the following two conditions [15]: (i) the first decrease in Dst should partly subside before the second decrease follows sometime later. If M represents the magnitude of the first Dst decrease, while R quantifies Dst recovery, then M > R >0 nT.Furthermore, R/M < 0.9. (ii) The two peaks in Dst must be separated by more than 3 hours i.e. T + T1 > 3 hours. Here, T is the duration of recovery for the first storm, while T1 is the duration of the main phase of the second storm. Presently with the Dst plot here, M = 182nT, R = 138nT, this implies that M > R > 0nT and R/M (138/182 = 0.76) < 0.9. Also, T + T1 = 14 hours (between 1500UT of October 5 and 0500UT of

October 6). Therefore, ΔT = T + T1 = 14 hours > 3 hours. These results confirm that the intense storm of October 5 is a Type 2 storm.Moreover, the structure of the geomagnetic storm of October 5, 2000 is illustrated further by the, plasma beta, electric field and plasma temperature. It was observed that there is a high value of plasma beta and plasma temperature on October 5. Hence, it can be inferred from this that the shock was followed by ejecta which was not a magnetic cloud type [3].

Illustrated in Figure 8 are the ionospheric responses to the October 5, 2000 storm. The figure depicts more of a positive phase storm at the high latitude stations ofSalekhard and Magadan, as well as the mid-latituude stations of Tashkent, Novosibirk and Petropalvosk. However, there is a preceeding negative phase storm observed at the two high latitude stations of Salekhard and Magadan, as well as at Petropalvosk between 0000UT and 0600UT of October 5, as well as between 0000UT and 0600UT of October 6.

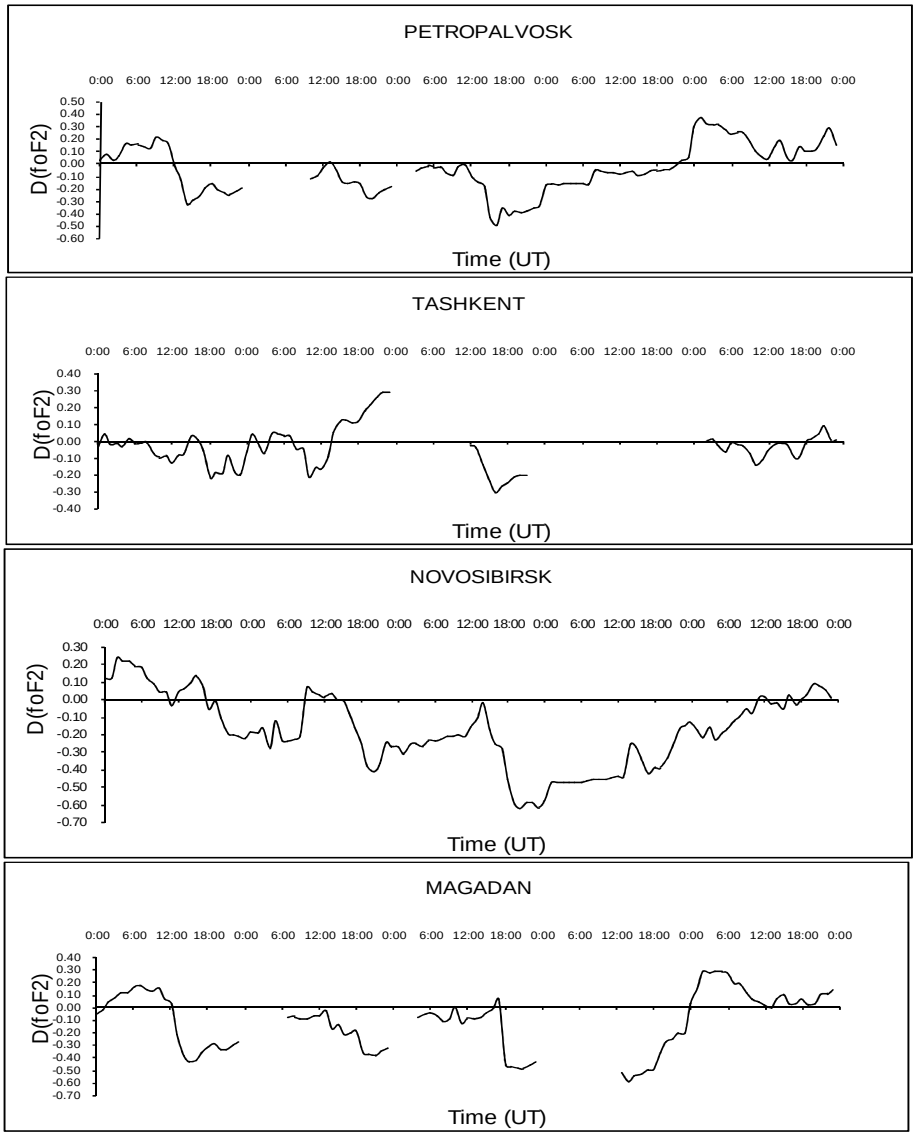

Figure 10: The Ionospheric observations for July 15-19, 2000

However, theobserved mid-latitude F2-layer positive storm effect in the `daytime' could be attributed to the vertical plasma drift increase, resulting from the interaction of background (poleward) and storm-induced (equatorward) thermospheric winds, but not to changes of (O) and (N_2) concentrations. This is because different longitudinal

sectors marked by the storm onset as `night-time' and `daytime' demonstrate different F2-layer positive stormmechanisms. Neutral composition changes in the `night-time' sector with increased (O) and (N_2) absolute concentrations, while (N_2/O)*storm*/(N_2/O)*quiet*\approx1 at F2-layer heights, are shown to contribute largely to the background N*m*F2 increase at lower latitudes lasting during daytime hours. Storm-induced surges of the equatorward wind give rise to an additional N*m*F2 increaseabove this background level.

7.0 Geomagnetic Storm of 15 July 2000

7.1 Solar and IMF Activity on 14-18 July

A major magnetic storm was observed on 15 July2000 with the Dst values down to -300 nT.The storm began around 1600 UT, 15 July 2000. The Dstreached its minimum value (-300 nT) around 2300 UT on the same day. Recovery of the storm took about 3 days. Figure 9 shows the response of Interplanetary, Geomagnetic and Solar wind parameters for July 14-18, 2000. This kind of event, according to [19] is known as the 'Bastilla event', in which case it consists of an interplanetary shock driven by a magnetic cloud, whose intense magnetic field rotates from south to north smoothly. While the Bz is pointing southward, it causes a very intense fall in the Dst value, reaching its minimum peak value of -301 nT. It should be noted that immediately after the shock, there was a sudden rise in the plasma temperature (panel d), plasma density (panel a), as well as an increase in the value of the flow speed to ~880 km/s. On July 14 the solar wind shows a fairly flat, although high, speed with a falling density and temperature.

On the 14th day, the plasma parameters stay fairly flat until about 1530 UT when there is a clear forward shock with a speed increase to over 700 km/s. This is followed by a sudden density increase and temperature decrease near 1700 UT. On the 15th, there is a declining speed until a large forward shock arrives near 1400 UT. This shock is clearly identified by the abrupt and strong speed increase from about 600 km/s to over 900 km/s. This shock has a strong density and stronger temperature enhancement. On the 16th day, the speed continues to be quite high, with an interesting and substantial decrease occurring at about 0140 UT and lasting until 0210 UT. During this decrease, the density also falls and the electric field increased. This storm is interplanetary ejecta of the magnetic cloud type [18], which could be as a result of possible association between CME and an interplanetary event. Associated with this flare was a full halo CME, observed by the LASCO instrument, with an expansion speed of 2177km/s.

7.2 Ionosphere Disturbances Following the Geomagnetic Storm on 15 July 2000

In Figure 10 is the Ionospheric response to the geomagnetic storm of 15 July 2000 From the ionospheric D(foF2) plot, it was observed that generally for all the stations under consideration,there is a decrease in the electron density (NmF2) at a maximum of the ionospheric F2 layer, thereby resulting in a negative phase storm. Note that the appearance of the short-lived positive storms (enhancement) at the high latitude station of Magadan between 0100UT and 0800UT 15th July and 2200UT 18th July till 0600UT 19th July up to 28% as well as the mid-latitude station of Tashkent between 1500UT and 2200UT on 16th July 2000 up to 29% could be as a result of energy being injected into the polar upper atmosphere as the solar wind become geoeffective; which in turn launches a traveling atmospheric disturbance (TAD) which propagates with high velocity [23] and the references therein. This TAD carries along equatorward- directed winds of moderate magnitude. At high latitudes, these meridional winds drive ionization up inclined magnetic field lines and cause uplifting of the F layer, leading to an increase in the ionization density.

The observed decrease in foF2 during the storm is related to the neutral composition disturbances. Heating at auroral and high latitudes causes expansion of the neutral atmosphere, and enhanced neutral winds carry disturbed composition. However, enhancement in the mean molecular mass in the neutral composition disturbance zone leads to an increase in the loss rate of ions, resulting in a decrease of the ionospheric plasma density and thus a negativestorm. [7] had shown that negative ionospheric storm effects are indeed correlated with the region of enhanced molecular mass.Observations have shown a general good correlation between (O/N_2) and negative ionospheric storms [24]. Numerical simulation outputs from global first principles models such as the Thermosphere Ionosphere General Circulation Model (TIGCM) [25] the Coupled Thermosphere Ionosphere Model (CTIM) (i.e [26]) have shown clear association of decreases in the mean molecular mass with increases in NmF2 during geomagnetic active periods. However, whether the compositional perturbation is fully responsible for the negative storm effects is still an open question. Some have suggested that perturbations in neutral gas composition are the main cause for negative ionospheric storms e.g.[27], while others have suggested that vibrationally excited N_2, as it can enhance the O+ recombination rate, may be important in explaining the negative storm effects [28].

On simultaneity, it was observed that between 1200UT and 1500UT 15th July, 1200UT and 1400UT 16th July, as well as 1200UT and 2300UT 17th July 2000, there are some degrees of simultaneity in the observed decrease in foF2 at all the stations. Note that lack of average hourly data marked the areas where there appear to be gap in the plots. Note also that no data was recorded at Salekhard withinthe plotted period.

8.0Morphology and Discussion

Now we consider the effects of ionization depletionat an F2 layer maximum (negative ionospheric storm)observed at all stations during the respective storms of 17thSeptember 2000 and15th July, 2000; as well as the ionospheric stations of Petropalvosk and Salekhard during the storm of 12th August, 2000. It was first suggested by [29] and the references therein, that neutral composition changes in the thermosphereas a main reason for the decrease in NmF2 duringnegative ionospheric storms. Later it became apparent thatphysical mechanisms are driving this decrease. Rapid heatingof the polar atmosphere during energy income fromthe magnetosphere generates a vertical ascent of the air(upwelling) through the surfaces of constant pressure. According to them, thisascent leads to a deviation from the diffusive equilibriumand to an increase in the mean molecular mass, that is, to adecrease in the ratio of the atomic oxygen density (O) to themolecular nitrogen (N_2) and molecular oxygen (O_2) densities.

Expansion of a heated region also leads to a formationof pressure gradients changing the thermospheric circulation.An increased equatorward wind however brings the air with a changedcomposition to the middle latitudes, increasing therethe mean molecular mass. Moreover, originating gradient winds usuallyplay a more important role at night because they are added tothe background wind in the global atmospheric circulation(day-night). The winds often have the form of waves ortraveling atmospheric disturbances (TADs), when the energycomes in the form of a single pulse. Atmospheric disturbancesare shown in the ionosphere in the form of traveling ionospheredisturbances (TIDs) registered in ionograms. As aresult, the atmospheric region with a changed compositionreaches mid-latitudes at night and then rotates together withthe Earth into the dawn sector. Since the photoionization rateis proportional to the O density, whereas the loss rate isproportional to the N_2 and O_2 densities, the increase in themean molecular mass leads to a decrease in the electrondensity (NmF2) at a maximum of the ionospheric F2 layer.The velocity of TAD motion considerably exceeds the windvelocity; therefore the TIDs caused by heating of the polaratmosphere are first registered at mid-latitude stations and arethen followed by an ionospheric storm.Hence, the reason for the observed negative ionospheric storm.The F peak electron density in the mid-latitude ionosphere may be reduced by a factor of 2–5 during negative storm phases.

However, positive storms have not been well understood.Increases in the ionospheric F region electron density during positive storms show different characteristics, and several mechanisms have been proposed to explain the observations. Positive storms may be classified into several categories, depending on duration, local time,and latitude[10]. It must be noted that the type of a frequently observed positive storm is the daytime short-duration increases in the mid-latitude ionospheric electron densityi.e the one experienced at the mid-latitude stations of Tashkent and Novosibirk between 0100UT and 0400UT 12th August during the storm of August 12, 2000 (figure 4); as well as the one at Petropalvosk and Magadan between 0800UT and 1000UT 15TH July during the storm of July 15, 2000(figure 10). However, short-durationincreases occur a few hours after a storm sudden commencement(SSC) or a substorm [30] and[31]. The simulationsof [10] and the references therein, show that atmospheric disturbances(large-scale gravity waves) are launched in theauroral zone during storms or substorms and travel to themid-latitude ionosphere. The traveling atmospheric disturbancesmove the F region ionization upward to higheraltitudes along the geomagnetic field lines, resulting inslower loss rates and higher electron densities.Note that the increases in the mid-latitude ionospheric Fregion electron density and total electron content (TEC)are often observed in local dusk sector during magneticstorms and termed dusk effect. This is because the uplifting of theF layer by an eastward electric field and convergence in theeast-west direction might be responsible for the dusk effect.

However, the resultant density enhancements at the equatorwardedge of the dusk-sector ionospheric trough were termedstorm-enhanced density (SED). [32]have compared measurementsof SED with the Millstone Hill radar, the globalGPS receiver network, and the DMSP satellites. They findthat the SED density enhancements in the dusk sector areassociated with the erosion of the outer plasmasphere bysubauroral polarization stream electric fields and that theSED plumes can map directly into the plasmaspheric tailobserved with the IMAGE spacecraft. Storm-time increases of the F region electron densityare observed also in the nightside (near midnight) mid-latitudeionosphere. It was proposed that downward plasmafluxes from the plasmasphere into the underlying ionospherecould cause significant enhancements in the Fregion electron density. [33] showed that a persistentelectric field can also cause

strong positive storm phasesnear midnight at middle latitudes.The F region electron density in the equatorial ionosphereand at the anomaly latitudes can be increased ordecreased during magnetic storms. Moreover, [34] found that increases in NmF2 over the equatorduring the main and first recovery phases of storms seemto be more common than decreases; the increases in NmF2were interpreted as the consequence of a downward motionof the F2 layer and reduced fountain effect caused by anenhanced westward electric field. Furthermore, [10] and the references therein showed that atomic oxygen concentration increases inthe equatorial thermosphere may be the main reason for apositive NmF2 storm effect. [35] while investigating the mid-latitude ionosphericelectric field and F region electron density during astorm, found a large increase of the electron densityover Arecibo and a significant decrease of the electrondensity over the equator and suggested that an enhancedeastward electric field caused the disturbances in the ionosphere.

Another type of positive storms is the long-durationincrease in the F region electron density or TEC at middleand low latitudes. [36] found that positive regionsoccurred at lower magnetic latitudes in equatorial fronts ofspreading negative regions over a couple of days. Theysuggested that thermospheric disturbances originating in thepolar region spread equatorward with the progress ofstorms, creating positive phases in front of the spreadingdisturbances by the effect of wind and negative phases bythe effect of enhanced molecular composition

The possible mechanisms that may beresponsible for the observed long-duration positive storm at all the ionosphericstations from the D(foF2) plots during the 12th February 2000 (Figure 2) and at Tashkent, Salekhard and Novosibirk during the 5th October 2000 geomagnetic activities (Figure 8) can now be fully explained. Awidely accepted mechanism for daytime positive stormphases at mid-latitudes is equatorward wind disturbancesthat can uplift the F region plasma [30], [31] and [37]. In ourcase, the respective solar wind flow speed and the Electric field plots in figure 1 (storm of 12th February) and figure 7 (storm of 5th October 2000) measurements show that there was no large equatorward wind during thedaytime, so the electron density increases cannot be attributedto equatorward disturbance winds.

Another mechanismproposed by [10] and the references therein, is related to changes in the mean molecular mass.Enhanced heat inputs in the auroral zone during stormscause upwelling and drive equatorward winds that carryaway energy absorbed by the upwelling. This energy isreleased by the compressional heating due to downwellingat lower latitudes. The upwelling, equatorward winds, anddownwelling cause increases in the N_2/O ratio at highlatitudes and decreases in the N_2/O ratio at low latitudes.This shows that the positive phase thus observed may not be caused by adecrease in the N_2/O ratio for some reasons. One of the most striking reason is that if theenergy transfer is carried by equatorward neutral winds, itwill take several hours for disturbance winds originating inthe auroral zone to reach middle latitudes to cause thedecrease of the mean molecular mass. However, on the contrary, the observed positive phase started to occur just after theSSC, and any variations of molecular mass caused bystorm-associated winds at middle latitudes could not begenerated within such a short time.

However, the only process that can quickly propagate fromhigh to low latitudes without obvious delay according to [10]is the penetration ofelectric fields. [35] and [38] suggested that a storm-time enhanced eastwardelectric field uplifted the ionospheric plasma particles, causing a decrease of the electron density over the equatorand an increase of the electron density at the anomalylatitudes. An eastward electric field will movethe mid-latitude ionospheric F region plasma to higheraltitudes with lower recombination, resulting in increases of the electron density. It is therefore suggested that this action may be responsible for the observed long-duration positive storm for the 12th February 2000 and 5th October 2000 geomagnetic activities.

It has been shown that the fast solar wind ions in the magnetosheathhave limited entry into the magnetosphere andinstead tend to flow down the flanks of the magnetosphere.This leaves a slow solar wind component that is better ableto convect into the inner magnetosphere. These particlestrack the prevailing two-cell convection pattern. The particlesremain at low energies as they convect over the polarcap. When they reach the convection reversal region theyexperience strong heating as they head sunward. Some ofthe particles of the dawn side appear to cross to the duskside to produce the most energetic solar wind contributionto the symmetric ring current. The biggest loss of theseenergized particles occurs when they again reach the subsolarregion where they first enter. At this point the ionsappears to reenter the reconnection region and are eitheracceleration around the flanks via the low-latitude boundarylayer or back over the cap and into the mantle via newreconnected field lines. The issue of speed is also importantto the heavy ions within the solar wind, which show ahigher percentage of penetration into the inner magnetosphere than for the solar wind protons [39].

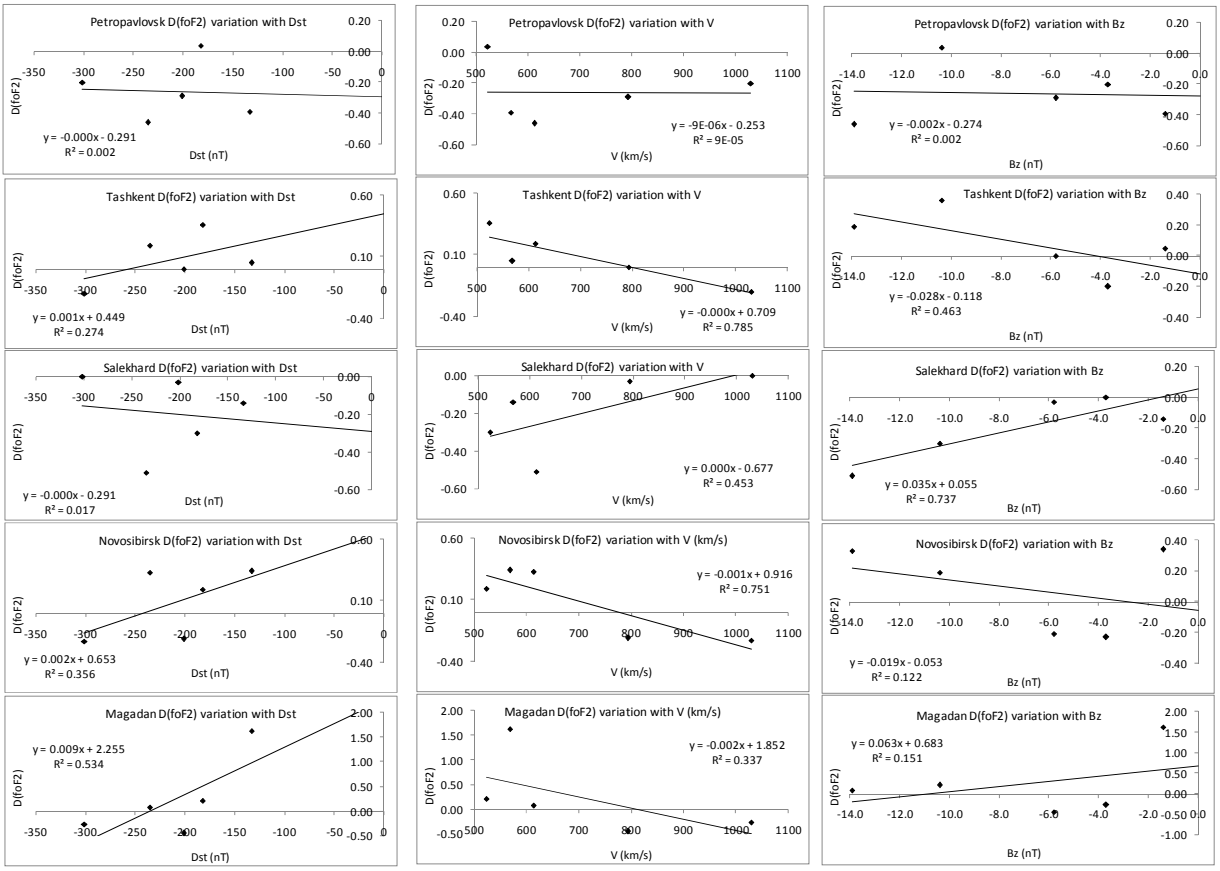

Figure 11: Showing the Regression plot for IonosphericD(foF2) variations with (a) Dst (left column), (b) with plasma flow speed V (middle column), and (c) with IMF Bz (right column) for each of the 5 ionospheric stations

9.0 Geoeffectiveness of Ionosphere with Interplanetary and Solar wind parameters.

Figure 11 showed the Regression plot for IonosphericD(foF2) variations with Dst, plasma flow speed V, and IMF Bz respectively for each of the 5 ionospheric stations; and is made clearer in Table III. Table III however, presents thedeviation of the ionospheric critical frequency D(foF2) variations for each of the 5 geomagnetic storm events at the 5 stations with corresponding values of Dst, flow speed and Bz, atDstminimum peak value. Moreover, presented in Table IV are the Correlation coefficients of D(foF2) variations during each of the 5 storm events against the Dst, V, Bz and (V x Bz) respectively; for each of the 5 stations.

Table III: Deviation of the ionospheric critical frequency D(foF2) variations for each of the 5 storm events for each of the 5 stations at peak Dst time, with corresponding values of Dst, flow speed and Bz

				Peak	Ionospheric stations D(foF2) variations				
Storm Date	**Peak Dst**	**V (km/s)**	**Bz**	**Dst time**	**Petropavlovsk**	**Tashkent**	**Salekhard**	**Novosibirsk**	**Magadan**
Feb. 12, 2000	-133	568	-1.4	11.00	-0.39	0.05	-0.14	0.34	1.63
Jul. 15, 2000	-301	1030	-3.7	23.00	-0.20	-0.20	0.00	-0.23	-0.27
Aug. 12, 2000	-235	613	-13.9	09.00	-0.46	0.19	-0.51	0.33	0.08
Sept. 17, 2000	-201	794	-5.8	23.00	-0.29	0.00	-0.03	-0.21	-0.45
Oct. 5, 2000	-182	523	-10.4	13.00	0.04	0.36	-0.30	0.19	0.21

It was observed from the Table (i.e Table IV) that with regards to the ionospheric response correlation with Dst, the high latitude station of Magadan recorded 73.2% , followed by Novosibirsk with 59.7 correlation percentage. The least was recorded at Salekhard (i.e 13%). In relation to the flow speed V, it was observed that all the stations had a

good correlation (above 58%) with the F2 ionosphere, with the exception of only Petropavlovsk that recorded a rather negligible correlation percentage. The correlation percentage between D(foF2) and IMF Bz however recorded 85.8% at Salekhard and 68.0% at Tasskent. Petropavlovsk recorded a negligible correlation percentage here as well. The calculated averaged value for each plotted variable (i.eDst, VandBz) is the sum total for each variable divided by 5 (i.e., number of stations). Note that the average correlation percentage for the F2 ionosphere against the Dst, flow speed V and Bz are 40.5, 60.3 and 46.4 respectively. The implication of these is that the plasma flow speed is suggested to be the most geoeffctive parameter with the F2 ionosphere, irrespective of the latitudinal position (This is yet to be established for low latitudes, as low latitude is not considered here).

Table IV: Correlation coefficient of D(foF2) variations during each of the 5 storm events versus Dst, V, Bz and (V x Bz) respectively; for each of the 5 stations. [The averaged is the mean correlation coefficient for each variable plotted against D(foF2)].

	Latitude Position	Altitude (m)	D(foF2) vs Dst	D(foF2) vs V	D(foF2) vs Bz	D(foF2) vs (VxBz) = E	No of +ve phase storm	No of -ve phase storm
Petropavlovsk	Middle	50	0.044	0.009	0.044	0.032	2	3
Tashkent	Middle	480	0.523	0.886	0.680	0.423	3	2
****Salekhard**	High	66	0.130	0.673	0.858	0.714	2	2
Novosibirsk	Middle	111	0.597	0.867	0.349	0.100	3	2
Magadan	High	610	0.731	0.581	0.389	0.604	3	2
**averaged*			*0.405*	*0.603*	*0.464*	*0.375*		

*** → no data available for this station during the July 15, 2000 storm*

It has been said that the solar wind is regarded as the driver for all forms of geomagnetic storms. However the relationship between solar wind induced dawn-dusk electric fields E and the flow speed is given by E= V x Bz (i.e., these electric fields are caused by a combination of solar wind velocity and southward IMF). Meanwhile, [40] had suggested that of these two parameters, the southward IMF is probably the more important because of its far greater variability. In spite of this (i.e., to show this validity), a correlation column was also created for V x Bz against the deviation of the F2 critical frequency D(foF2) for the 5 stations (see Table IV). From the Table it was observed that the high latitude station of Salekhard had the highest percentage correlation with 71.4%, followed by Magadan (60.4%), Tashkent (42.3%), Novosibirk (10%), and Petropavlovsk (negligible). From these, the following were deduced: (i) the increase in percentage correlation of V x Bz against D(foF2) is directly proportional to the increase in the latitudinal position of each station (i.e., the highest % is from the highest latitude station of Salekhard). (ii) the stations with more occurrences of electron density enhancemet (positive phase storms) are those whose altitudes are greater than 100m. (iii) an average value of 37.5% correlation for V x Bz versus D(foF2) showed that it is V that is more geoeffective, otherwise (i.e., if it were to be Bz), the percentage value would have been ≥50%.[33] hadshowed that a persistent electric field can cause strong positive storm phases near midnight at middle latitudes.

CONCLUSION

The effects of ionization depletion at an F2 layer maximum observed at all stations during the respective storms of 17th September 2000 and15th July, 2000; as well as at Petropalvosk and Salekhard during the storm of 12th August, 2000, could be attributed to the rapid heating of the polar atmosphere during energy income from the magnetosphere, which generates a vertical ascent of the air (upwelling) through the surfaces of constant pressure. This ascent in turn leads to a deviation from the diffusive equilibrium and to an increase in the mean molecular mass, that is, to a decrease in the ratio of the atomic oxygen density (O) to the molecular nitrogen (N_2) and molecular oxygen (O_2) densities, which could be as a result of increased equatorward wind.

However, for positive storms,it must be noted that the type of a frequently observed positive storm is the daytime short-duration increases in the mid-latitude ionospheric electron densityi.e the one experienced at the mid-latitude stations of Tashkent and Novosibirk between 0100UT and 0400UT 12th August during the storm of August 12, 2000, as well as the one at Petropalvosk and Magadan between 0800UT and 1000UT 15th July during the storm of July 15, 2000. Meanwhile, the possible mechanisms that may beresponsible for the observed long-duration positive storm at all the ionospheric stations from the D(foF2) plots during the 12th February 2000 (Figure 2) and at Tashkent, Salekhard and Novosibirk during the 5th October 2000 geomagnetic activities (Figure 8) can be explained on the basis that the respective solar wind flow speed and the Electric field plots in figure 1 (storm of 12th February)

and figure 7 (storm of 5th October 2000) measurements show that there was no large equatorward wind during thedaytime, so the electron density increases cannot be attributedtoequatorward disturbance winds (as opposed to the general theory that a widely accepted mechanism for daytime positive stormphases at mid-latitudes is equatorward wind disturbancesthat can uplift the F region plasma [30] and [37].

A good reason for these is that if theenergy transfer is carried by equatorward neutral winds, itwill take several hours for disturbance winds originating inthe auroral zone to reach middle latitudes to cause thedecrease of the mean molecular mass. However, on the contrary, the observed positive phase started to occur just after theSSC, and any variations of molecular mass caused bystorm-associated winds at middle latitudes could not begenerated within such a short time. However, the only process that can quickly propagate fromhigh to low latitudes without obvious delay according to [10]is the penetration ofelectric fields. An eastward electric field will movethe mid-latitude ionospheric F region plasma to higheraltitudes with lower recombination, resulting in increases of the electron density. It is therefore suggested that this action may be responsible for the observed long-duration positive storm for the 12th February 2000 and 5th October 2000 geomagnetic activities.

On the geoeffectiveness of Ionosphere with Interplanetary and Solar wind parameters, it was observed that with regards to the ionospheric response correlation with Dst, the high latitude station of Magadan recorded 73.2% , followed by Novosibirsk with 59.7 correlation percentage. The least was recorded at Salekhard (i.e 13%). In relation to the flow speed V, it was observed that all the stations had a good correlation (above 58%) with the F2 ionosphere, with the exception of only Petropavlovsk that recorded a rather negligible correlation percentage. The correlation percentage between D(foF2) and IMF Bz however recorded 85.8% at Salekhard and 68.0% at Tasskent. Petropavlovsk recorded a negligible correlation percentage here as well.Note that the average correlation percentage for the F2 ionosphere against the Dst, flow speed V and Bz are 40.5, 60.3 and 46.4 respectively. The implication of these is that the plasma flow speed is suggested to be the most geoeffctive parameter with the F2 ionosphere, irrespective of the latitudinal position (This is yet to be established for low latitudes, as low latitude is not considered here).

On the relationship between solar wind induced dawn-dusk electric fields E and the flow speed which is given by E = V x Bz, a correlation column was created for V x Bz against the deviation of the F2 critical frequency D(foF2) for the 5 stations, it was however observed that the high latitude station of Salekhard had the highest percentage correlation with 71.4%, followed by Magadan (60.4%), Tashkent (42.3%), Novosibirk (10%), and Petropavlovsk (negligible). From these, the following were deduced: (i) the increase in percentage correlation of V x Bz against D(foF2) is directly proportional to the increase in the latitudinal position of each station (ii) the stations with more occurrences of electron density enhancemet (positive phase storms) are those whose altitudes are greater than 100m. (iii) an average value of 37.5% correlation for V x Bz versus D(foF2) showed that it is V that is more geoeffective, otherwise (i.e., if it were to be Bz), the percentage value would have been ≥50%.

Acknowledgement
The hourly interplanetary, geomagnetic and solar wind parameters used in this work were made possible by the data from the NSSDC's OMNI database (http://nssdc.gsfc.nasa.gov/omniweb), and also the daily values of ionosonde data for all stations were obtained from the National Geophysical Center's SPIDR (http://spidr.ngdc.noaa.gov) for which the author is grateful.

REFERENCES

[1] Rodger, A. S., G. L. Wrenn, and H. *J. Atmos. Terr. Phys*.,51, **1989,**851.
[2] Gonzalez W.D; Joselyn J.A; Kamide Y; Kroehl, H.W; Rostoker G; Tsurutani B.T; and Vasyliunas V.M *J. Geophys. Res*, 99, No. A4, **1994**, 5771-5792
[3] Dal lago, A., L. E. A. Vieira, E. Echer, W. D. Gonzalez, A. L. Clua de Gonzalez, F.L. Guarnieri, L. Balmaceda, J. Santos, M.R. da Silva, A. de Lucas, and N.J. Schuch. *BrazillianJournal of Physics*, 34 (4B), **2004**, 1542-1546.
[4] Chukwuma, V.U.*ActaGeophys. Pol*. 51,**2003**, 459-472.
[5] Danilov, A,D. *J. Atoms. Sol. Terre. Phys*. 63, **2001**, 431 - 440
[6] Buonsanto, M.J., and T.J. Fuller-Rowell. *Strides made in understanding space weather at Earth, EOS, Transactions, AGU*78, 1,**1997**, p.1.
[7] Strickland, D.J; Daniel, R.E; Craven, J.D. *J. Geophys. Res*., 106, **2001**, 21, 049.

[8] Gonzalez, W. D., A. L. Clua de Gonzalez, J. H. A. Sobral, Dal lago, L.E. Vieira. *Atmos. Terr. Phys*. 63, **2001**, 403 - 412.
[9] Gonzalez, W.D., B.T. Tsurutani, R.P. Lepping and R. Schwenn. *J. Amos. Sol. Terr. Phys*. 64,**2002**, 173 - 181.
[10] Huang Chao-Song, J. C. Foster, L. P. Goncharenko, P. J. Erickson, W. Rideout and A. J. *J. Geophys. Res*. 110, **2005**, A06303, doi:10.1029/2004JA010865.
[11] Chukwuma, V.U. *ActaGeod. Geoph. Hung*. 42(1), **2007**, 1-21.
[12] Davis, C.J., M.N. Wild, Lockwood and Y.K. Tulmay.*Ann. Geophys.*15, **1997**, 217-230
[13] Huang Chao-Song, J. C. Foster, and P. J. Erickson. *J. Geophys. Res*. 107, NO A8,**2002**, 1192
[14] Joselyn, J.A., and B.T. Tsurutani, *Eos Trans AGU*, 71, **1990**, 1808
[15] Kamide, Y., W.Baumjohann, I.A. Daglis, W.D. Gonzalez, M. Grande, J.A. Joselyn, R.L. McPheron, J.L. Philps, E.G.D. Reeves, G. Rostoker, A.S. Sharma, H.J. Singer. B.T. Tsurutani and Vasyliunas, *Geophys. Res.*103,**1998**, 17,705 -17,728.
[16] Tsurutani. B.T; Gonzalez, W.D; Lakhina, G.S; Alex, S. *J. geophys. Res*., 108 (A7), **2003**, 1268-1275.
[17] Adebesin, B.O. *Acta. Geod.Geoph.Hungarica*.43 [4], **2008,** 383-408. doi: 10.1556/A Geod.43.2008.4.2.
[18] Burlaga L.F., E. Sittler, F. Mariani, and R. Schwenn.*J. Geophys. Res*. 86, **1981**, 6673
[19] Dal lago, A., W. D. Gonzalez, A. L. Clua de Gonzalez and L. E. A. Vieira. *J. Atmos. Sol. Terre. Phys*. 63, **2001**, 451-455
[20] Adebesin, B.O. and Chukwuma, V.U. *ActaGeod. Geoph. Hung.*, 43,**2008**, 1-15
[21] Kane, R.P. *J. Geophys. Res*., 110, **2005**, A02213, doi: 10, 1029/2004JA010799.
[22] Gonzalez, W. and Tsurutani, B.T. *Planet, Space Sci*., 35, **1987**, 1101.
[23] Adebesin, B.Oand Bakare, N.O.*Nigerian Journal of Space Research*, 5,**2008**, 42-56 [ISSN: 0794-4489]
[24] Prolss, G. W., and J. D. Craven. *Adv. Space Res*., 22(1), **1998**, 129– 134.
[25] Burns A.G., T.L. Kileen, G.R. Carignan and R.G. Roble, *J. Geophys. Res*., 100,**1995**, 14,661-14,671
[26] Fuller-Rowell, T. J., M. V. Codrescu, H. Rishbeth, R. J. Moffett, and S.*J. Geophys. Res*., 101,**1986**, 2343.
[27] Pavlov, A. V., M. J. Buonsanto, A. C. Schlesier, and P. G. Richards. *J. Atmos. Sol. Terr. Phys.*,**1999**, 61, 263.
[28] Prolss, G. W., and S. *J. Geophys. Res.*, 107(A2), **2002**, 1016, doi:10.1029/2001JA900126.
[29] Gordienko G. I., V. V. Vodyannikov, and A. F. Yakovets. *J. Geophys. Res*110, **2005**, A09S35.
[30] Jakowski, N., S. Schluter, and E. Sardon.*J. Atmos. Terr. Phys*., 61,**1999**, 299.
[31] Prolss, G. W. *Ann. Geophys.*,11,**1993**, 1.
[32] Foster, J. C., P. J. Erickson, A. J. Coster, J. Goldstein, and F. J. Rich. *Geophys. Res. Lett.*, 29(13),**2002**, 1623, doi:10.1029/2002GL015067.
[33] Sojka, J. J., M. David, and R. W. Schunk.*J. Atmos. Sol. Terr. Phys*.,**2002**, 64, 687.
[34] Adeniyi, J. O. *J. Atmos.Terr. Phys*., 48, **1986**, 695.
[35] Foster, J. C., and F. J. Rich.*J. Geophys. Res*., 103,**1998**, 26,367.
[36] Tanaka, T. *J. Atmos. Terr. Phys*., 41,**1979**, 103.
[37] Lu, G., A. D. Richmond, R. G. Roble, and B. A. Emery. *J. Geophys. Res*., 106, **2001**, 24,493
[38] Foster, J. C., A. J. Coster, P. J. Erickson,W. Rideout, F. J. Rich, T. J.Immel, and B. R. Sandel. Redistribution of the stormtime ionosphere and the formation of the plasmaspheric bulge, *in Global Physics of the Coupled Inner Magnetosphere, AGU, Washington, D. C*, **2005**
[39] Winglee, R.M. *J. Geophys. Res*.,108, NO. A10, **2003,** 1385, doi:10.1029/2002JA009819
[40] Tsurutani, B.T; Gonzalez, W.D; Tang, F; Lee, Y.T and Okada, M. *Gephys. Res., lett*, 19.**1992**.