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# STUDY OF THE GEOMAGNETIC STORM OF OCTOBER 29, 1973

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## ABSTRACT

Due to the absence of data for solar wind plasma parameters during the October 29, 1973 geomagnetic storm, the auroral electrojet (AE) index was employed for the study of the ionospheric response to the storm. The available interplanetary magnetic field component, $B_z$, and the low latitude magnetic index, $D_{st}$, showed that the storm was moderate ($D_{st}$ = -64nT, $B_z$ = -5.8nT). The analysis from the disturbances in ionospheric foF2 from October 29-31, 1973 showed predominantly an enhancement (positive storm) at the mid and low latitude stations. In between the time of storm (i.e. 14:00UT on 29 and 05:00UT on 30 October), the upper latitudes also showed some degree of enhancement. This paper concluded that the reason for this positive ionospheric storm across all latitudes could be injection of energy because of significant increase in the AE index, which caused an uplift of the ionospheric layers to higher altitudes, where the recombination rate was small. In addition, the paper attempted to confirm the argument that, moderate magnetic storms are capable of generating ionospheric storms, which are of comparable magnitude with those resulting from intense geomagnetic storms.

**Keywords:** Geomagnetic storm, moderate storm, solar wind, AE index, ionospheric storm

## INTRODUCTION

According to Danilov (2001), the F2 region response to a geomagnetic storm usually called a ionospheric storm is a rather complicated event. It consists of the so-called positive and negative phases, which have very complicated spatial and temporal behaviors. The principal features of the positive and negative phase distribution and variables have been explained on the basis of the principal concepts that during a geomagnetic disturbance there is an input of energy into the polar ionosphere, which changes thermosphere parameters, such as composition, temperature and circulation. Composition changes directly influence the electron concentration in the F2 region. The circulation spreads the heated gas to lower latitude. The conflict between the storm-induced circulation and the regular one determines the spatial distribution of the negative and positive phases in various seasons.

The primary physical process of solar wind energy transfer to the magnetosphere during the main phase of major magnetic storms is believed to be magnetic reconnection (Gonzalez and Tsurutani, 1987). According to Tsurutani *et al.* (1988) and Gonzalez *et al.* (1989), coronal mass ejections (CMES) are transient phenomena that involve the expulsion of significant amount of plasma and magnetic flux from the sun into interplanetary space, on a timescale between a few minutes and several hours. It is generally accepted that the fast interplanetary manifestations of coronal mass ejections (ICMES) are the major solar drivers of space weather, including large, non-recurrent geomagnetic storms and solar energetic particle events. The orientation of the interplanetary magnetic field (IMF) carried by the solar wind is also a very important factor.

According to Gonzalez and Tsurutani (1987), the IMF structures leading to intense magnetic storms have an intense and long duration southward component. Such a configuration tends to increase the coupling between the solar wind and the magnetosphere, with the result that relatively more solar wind energy can then enter the magnetosphere. Hence, geomagnetic storms and the associated ionospheric effects are the results of the interaction between solar wind and the magnetosphere through the coupling link: solar coronal hole-solar wind-magnetosphere-ionosphere.

According to Chukwuma (2003) and references therein, one way of getting large $D_{st}$ events is to have two-step storm main phases, with the second enhancement of the $D_{st}$ index closely following the first one. Such events are quite common and are caused by two IMF southward field of approximately equal strength. This could also be viewed as two moderate magnetic storms with the base of the second well below that of the first. The October 29, 1973 storm can be viewed as a two-step storm, because the main phase of the storm developed in two consecutive steps.

Due to the absence of data for solar wind plasma parameters during this October 29, 1973 geomagnetic storm, the auroral electrojet (AE) index was employed to study the cause of the response of the ionosphere to this storm. Furthermore, the paper looked into the possible outcomes of the injection of energy as measured by the AE index across all latitudes. In addition, the paper attempted to verify the argument of Chukwuma and Lawal (2007) that moderate magnetic storms are capable of generating ionospheric storms, which are of comparable magnitude with those resulting from intense geomagnetic storms.

In this work, we present the analysis of the foF2 data during the October 29 storm in the East Asian Sector.

## MATERIALS AND METHODS

**Data and method of analysis:** The data used in this study consists of hourly values of foF2 obtained from some of the National Geophysical Data Centre's SPIDR (Space Physics Interactive Data Resource) global network of ionosonde stations. In order to solve the problem on nature of ionospheric response to October 29, 1973 storm, we have chosen to study the response in the East Asian Sector.

The stations were Yakutsk, Magadan, Khabarovsk, Wakkanai, Akita, Kokunbunji, Yamagawa, Okinawa and Manila. Table 1 listed the stations and their corresponding geographic coordinates. The stations were chosen with the criterion that storm sudden commencement did not coincide with sunrise at the stations. The criterion is important because the arrival of sunrise is manifested by rapid increase in electron temperatures and a less rapid increase in ion temperature at all altitudes. In a plasma that tends toward equilibrium, a sharp increase in particle temperatures results in a redistribution of the plasma (Soicher, 1972).

The present study is concerned with variations in foF2 due to the geomagnetic storm of October 29, 1973. However, the F2 region response to geomagnetic storms was most conveniently described in terms of $D_{foF2}$, that is, the normalized deviations of the critical frequency foF2 from the reference: (Chukwuma, 2003)

$$D_{foF2} = [foF2 - (foF2)_{ave}]/(foF2)_{ave}$$

Hence, the data that was analyzed consisted of respective hourly values of $D_{foF2}$ on October 29-31. The reference for each hour was the average value of foF2 for that hour calculated from the five quiet days, October 24–28, 1973, preceding the storm.

## RESULTS AND DISCUSSION

The results of the present study were shown in figures I and II. Figure I showed the auroral electrojet (AE) index, the interplanetary magnetic field component, $B_z$, and the low latitude magnetic index, $D_{st}$ for the period October 27-31, 1973. Storms can be classified as weak ($D_{st} > -50$ nT), moderate ($-50nT < D_{st} < -100nT$) and intense ($D_{st} < -100nT$) (Viera *et al.,* 2001). According to this classification, the $D_{st}$ plot for the period October 29-31 showed that the interval 0:00UT – 07:00UT, October 29 was largely quiet with $D_{st}$ fluctuating in the range $-20 > D_{st} > -35$. However, at about 10:00UT Dst began to depress steadily indicating a storm commencement, reaching a value of $D_{st} = -64nT$ at ~ 23:00UT. Thereafter, $D_{st}$ recovered gradually reaching a quiet values in the interval 03:00UT – 18:00UT on October 30.

The October 29, 1973 storm could be viewed as a two-step event. In the first step of the main phase, the $D_{st}$ reaches the peak value of -51nT at 10:00UT on October 29. With the sharp rotation of $B_z$ to northward there is a sharp partial $D_{st}$ recovery to the level of -38nT. The second step of the main phase is associated with the sharp southward turning of $B_z$ at 13:00 UT. Thereafter, $D_{st}$ and $B_z$ reach peak values of -64nT and -5.8nT respectively at 18:00UT on October 29. This is in accordance with the argument of Kamide *et al.* (1998) that two-step storm main phases, with the second enhancement of the $D_{st}$ index closely following the first one are quite common and are caused by two IMF southward fields of approximately equal strength; and that it could be viewed as two "moderate" magnetic storms, with the base of the second well below that of the first.

The third panel of figure I was the AE index for the period of October 29-31, 1973. The plot showed a low energy input fluctuating in the range 400-700nT between the interval 0:00UT and 07:00UT, October 29. However, the AE index increased sharply from ~ 400nT at 07:00UT on October 29, until it finally reached the highest peak of 1450nT at 09:00UT on the same day. Thereafter, it swung decreasingly to the steady level, when the storm was over on October 31 around 18:00UT. It is important to note that the AE index reached its peak as at the time the $D_{st}$

signaled a moderate storm (i.e. the time the first $D_{st}$ minimum was reached; -51nT). As a result, energy might have been injected into the polar cups thereby, causing an ionospheric storm.
Figure II shows $D_{foF2}$ vs UT throughout October 29–31, 1973 for the ionosonde stations listed in table 1.

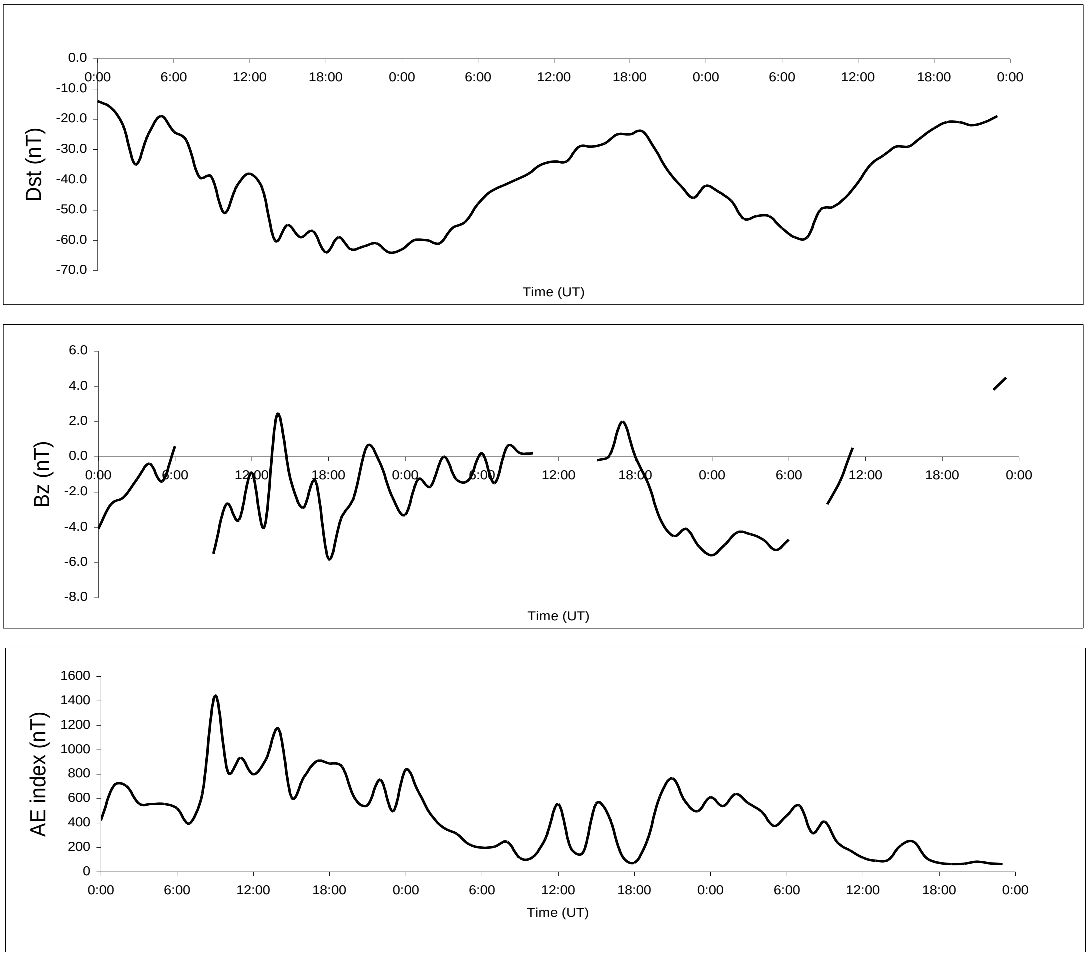

Fig. I: One-hour averages of the $D_{st}$, $B_z$ and AE index versus Time (in UT) for October 29-31, 1973.

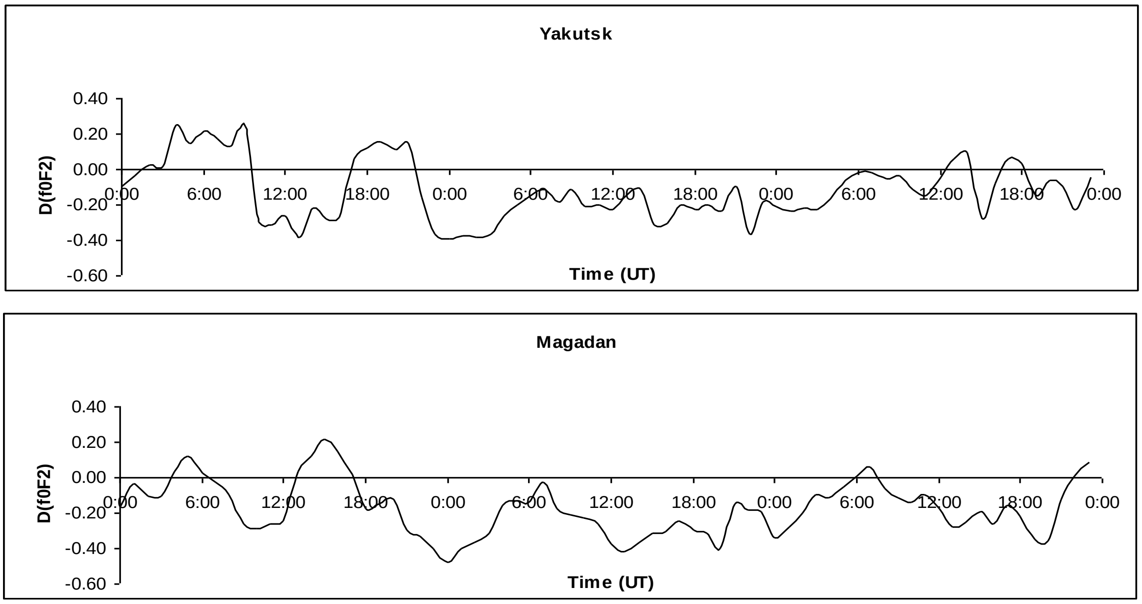

Fig. IIa: Variation in $D_{foF2}$ at the upper latitude stations of East Asian Sector during October 29-31, 1973

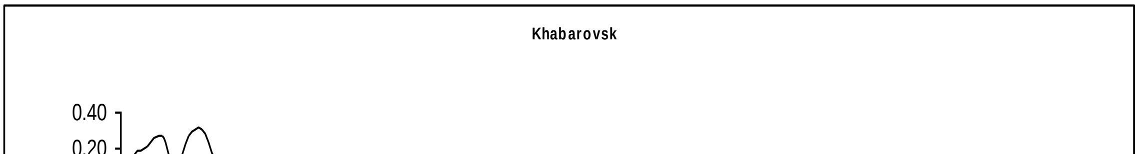

Fig. IIb: Variation in $D_{foF2}$ at the middle latitude stations of East Asian Sector during October 29-31, 1973

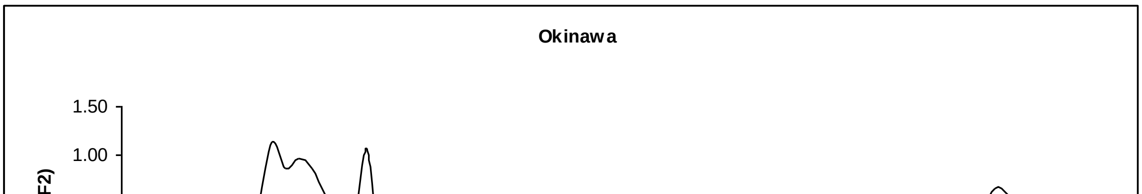

Fig. IIc: Variation in $D_{foF2}$ at the lower latitude stations of East Asian Sector during October 29-31, 1973

Table 1: Ionosonde stations

| Stations | Geographic co-ordinates | | Difference between Lst and UT (in hours) |
|---|---|---|---|
| | $\phi$ | $\lambda$ | |
| Yakutsk | 62.00$^0$N | 129.60$^0$E | + 9 |
| Magadan | 60.00$^0$N | 151.00$^0$E | +10 |
| Khabarovsk | 48.50$^0$N | 135.10$^0$E | + 9 |
| Wakkanai | 45.40$^0$N | 141.70$^0$E | + 9 |
| Akita | 39.70$^0$N | 140.10$^0$E | + 9 |
| Kokunbunji | 35.70$^0$N | 139.50$^0$E | + 9 |
| Yamagawa | 31.20$^0$N | 130.60$^0$E | + 9 |
| Okinawa | 26.30$^0$N | 127.30$^0$E | + 8 |
| Manila | 14.70$^0$N | 121.10$^0$E | + 8 |

In figure IIa, the high latitude stations of the East Asian Sector, there was an alternating positive and negative ionospheric storm before storm commencement at Yakutsk (62.0$^0$N) and Magadan (60.0$^0$N). However, following the storm commencement at ~ 17:00UT on October 29, a depletion of foF2 gradually developed at Magadan, while there was an enhancement of foF2 at Yakutsk. Nevertheless, starting from about 21:00UT on this day, a rapid and definitive decrease in foF2 occured at these stations. Figure IIa also appeared to indicate that the two high latitude stations recorded predominantly a depletion of foF2 throughout October 30 and 31. The peak depletions at Yakutsk were 38% at 13:00UT, 39% at 0:00UT and 27% at 15:00UT for each of the three days (October 29-31) respectively, while at Magadan, 40% at 23:00UT, 48% at 0:00UT and 36% at 20:00UT were respectively observed.

Figure IIb showed the middle latitude stations of the East Asian Sector. The $D_{foF2}$ plots showed an existing positive ionospheric storm preceding the storm commencement at Khabarovsk (48.5$^0$N), Wakkanai (45.4$^0$N), Akita (39.7$^0$N), Kokubunji (35.7$^0$N), and Yamagawa (31.2$^0$N).

Figure IIb also indicated that with the exception of the lowest of the mid- latitude stations (i.e. Yamagawa), which recorded positive ionospheric storm, all the other middle latitude stations recorded a sharp depletion of foF2 at 18:00 UT and is coincident with the values of $D_{st}$ and $B_z$. Note the alternating enhancement and depletion of fof2 throughout October 30 and 31. However, this event was more of negative ionospheric storm for the first two stations nearest to the high latitude, while there was a positive predominance for the other three stations nearest to the lower latitude. Generally, figure IIb appeared to indicate that the middle latitude stations recorded predominantly an enhancement of foF2. The peak depletions recorded at these stations were shown in table 2.

Table 2: The peak depletions recorded at these stations

| Station/Day | October 29 | October 30 | October 31 |
|---|---|---|---|
| Khabarovsk | 32% at 20:00UT | 43% at 21:00UT | 22% at 21:00UT |
| Wakannai | 46% at 21:00UT | 31% at 21:00UT | 22% at 18:00UT |
| Akita | 19% at 20:00UT | 21% at 21:00UT | 18% at 09:00UT |
| Kokubunji | 35% at 21:00UT | 14% at 22:00UT | 14% at 10:00UT |
| Yamagawa | 1% at 19:00UT | 18% at 21:00UT | 23% at 10:00UT |

In figure IIc, that is, the lower latitude stations of the East Asian Sector, there was no immediate effect on foF2 in the ionosphere above Okinawa (26.3$^0$N) and Manila (14.7$^0$N) following the arrival of the shock in the interplanetary medium. However, starting from 9:00UT and about 13:00UT on October 29 at Okinawa and Manila respectively, there was predominant positive ionospheric storm for most of the storm period at these stations. However, the ionospheres at these stations were characterized by intermittent negative storm. Surprisingly, of this intermittent negative storm, the lower latitude of Manila produced an ionospheric storm (44% at 03:00UT on October 31), which was of the order of an intense ionosperic storm and also of about the magnitude produced by the upper latitude stations.

Figure II appears to show that during the October 29 storm the depletion of foF2 was restricted to the high latitudes. It is important to note that the depletion (negative storm) diminished in amplitude towards the lower latitude (Danilov, 2001). Furthermore, the F2 region global structure response lacked simultaneity just like the intense storm of October 20–21, 1989 but unlike the very intense storm of March 13–14, 1989 in which the depletion of foF2 was extended to a latitude as low as 12:4$^0$N, and at the same time globally (Chukwuma, 2003).

## CONCLUSION

This study concludes that the reason for the positive ionospheric storm across all latitudes could be due to injection of energy as a result of significant increase in the AE index, which causes an uplift of the ionospheric layers to higher altitudes, where the recombination rate is small. It also confirms the work of Chukwuma and Lawal (2007) that there is need to research moderate storms seeing that it can cause such a great intense ionospheric storm comparable to that of intense geomagnetic storms, contrary to the notion that intense storms are more likely to have negative effects on satellite navigation, communication and power system.

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