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Solar Activity and Dynamics of Particles in the Ionosphere

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Abstract

*The study of midlatitude ionospheric storm dynamic, low latitude irregularities and equatorial region have shown that the midlatitude is much more dynamics than earlier predicted. It was found that strong enhancement of electron density that occurred in midlatitude at midday, could also favour the local **E X B** instability that is driven by thermospheric wind. Hence, the high effect of ionospheric disturbances was recorded at the midlatitudes, which was attributed to increase in solar activities. On the other hand, minor storm effect was observed in the equatorial region. It was then concluded that very strong storm effects recorded in the multitudes could be responsible for its being conspicuously very dynamic.*

***Key words**: Electrojet, dynamics, ionosphere, thermospheric wind, electron density.*

1. Introduction

Coronal Mass Ejections (CMEs) have been attributed to one of the major solar sources of geomagnetic disturbances. They could equally occur as a result of an increase in the velocity and concentration of the solar wind. This results in ejection of small concentration of more energetic protons and electrons that behave as independent charged particles rather than plasma. As the protons or the particles reach the vicinity of the earth they produce (i) Sudden ionospheric disturbances (SID), (ii) Ionospheric storm (IS) (iii) Magnetic Storms (Ratcliffe, 1972). The current in the ionosphere consists of the polar current, ionsopheric dynamo current, ring current, the Sq current etc.

At the dip equator, the midday eastward polarization field generated by global scale dynamo action gives rise to a downward Hall current (Okeke et al., 2000; Kikuchi, 2002). A strong vertical polarization field is set up which opposes the downward flow of current due to the presence of non-conducting boundaries. The field in turn gives rise to the intense Hall current which is the equatorial electrojet (EEJ).

In the magnetosphere the dominant dynamic process is the streaming of solar plasma coming outward from the sun. Studies on geomagnetic activities reveal that geomagnetic disturbances tend to occur when the Interplanetary Magnetic Field (IMF) is directed southward (Burch 1972, 1973).

Akasofu *et al.*, (1969) found that ground magnetic perturbations during substorm are consistent with a three dimensional current systems which include the west-ward electrojet and magnetic aligned current. Fairfield et al (1998) found a connective plasma flow towards the earth. Pulkinent et al. (1998) discovered that the first event took place during persistently southward interplanetary magnetic field (IMF).

Sizora, (1995) showed that counter electrojet caused by IMF occurs under magnetoperturbed conditions when component B_z of the IMF turns from the South direction to the north. Kuznetsov *et al.*, (1995) found that features of the equatorial ionsopheric electrojet were responsible for the peaks of intensity of electrons with Ee ~ 30keV. Yizengaw *et al.* (2005) showed that minor storm effects occurred in the equatorial region. Danilov *et al.* (2001) found that in the F_2 layer the midlatitude effect is basically an ionsopheric response to storm – induced charges in the neutral atmosphere. Okeke (1998) showed that the energetic electron fluxes suddenly increased just before onset, and repeatedly peaked for a few hours. This paper is aimed at studying storm effects in midlatitude as well as in equatorial latitudes using H variations, in order to ascertain their contribution to the dynamics of particles in the ionosphere.

Sources of data

ɔries of large geomagnetic storms across many :ars associated with Dst values of -300nT and ss have been selected for this study. The data ˌed in the study was obtained from the World ata Center for Geomagnetism in Kyoto, Japan. ıe data consisted of hourly values of Dst index certain days of some months, which cover a ɔriod of 44 years starting from 1957 to 2001.

Also, the data set consists of H hourly ılues of two Japanese observatories, one Indian ɔservatory and one from the Euro-African observatories. The equatorial stations are PON, KTM (Japanese), and the midlatitude stations are the JAIP and TAM of Indian and Euro African observatories respectively, (Table 1). The geomagnetic data used in this study are accessed from the World Data Centre (WDC) Kyoto, Japan and also from the Space Physics Interactive Data Resource Centre (SPIDR), Boulder, USA. The storm data were also accessed from the USA database. Furthermore, the CME data were obtained from NASA's CDAW data center.

Table 1.0: The observatory locations for this study

Name Code	Observatory	Geographic		Geomagnetic	
		Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)
PON	Pohnpei	7.00	158.83	0.99	229.19
KTM	Kiritimati	2.05	157.50W**	3.09	273.49
JAIP	JAIPUR	26.92	75.80	17.40	147.4
TAM	Tamanrasset	22.80	5.54	24.55	4.46

Table 2.0: CME Data for March 31, 2001

Date	**Time**	**Speed Km/s**
2001/03/31	04:06:08	479
2001/03/31	06:50:05	402
2001/03/31	07:27:22	310
2001/03/31	11:26:05	571
2001/03/31	19:50:07	550
2001/03/31	20:06:07	588

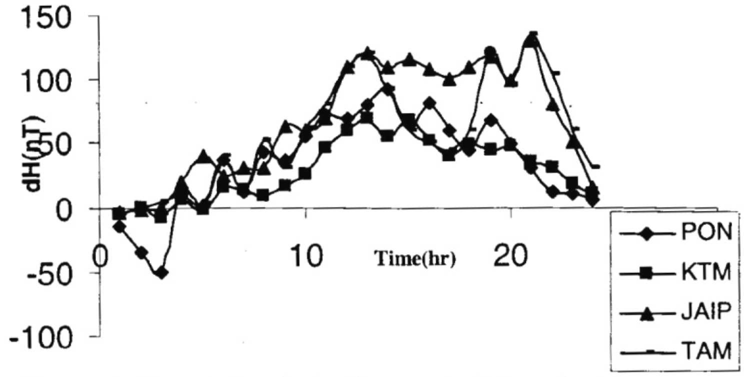

Figure 1:H variation in both equatorial and mid latitude stations pre-storm commencement in the year 2000.

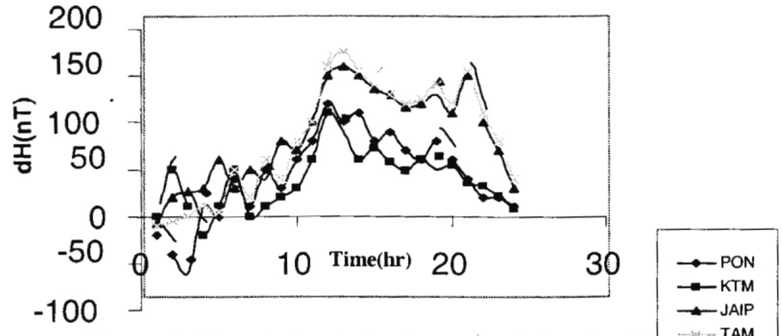

Figure 2: H variation in both equatorial and mid latitude stations at storm peak in the year 2000.

3. Data Analysis

The plots in Fig 1 depict the variations of H Components values for both equatorial electrojet (EEJ) stations and mid latitude stations – pre-storm commencement. The Fig 2 shows the plots of variations of H components during the storm peak time, for both EEJ and mid latitude stations. Part of the study focuses on investigation of severe geomagnetic storms occurring within a period of 44 years ranging from 1957 to 2001. The dataset consists of the hourly variation of Dst index for the eight selected days within the 44-year period.

Figures 3a to 3i show the variation of Dst versus time in hours for various years selected in the study. On the other hand, figure 3j depicts the overall plots of Dst index for the 24 hours of all eight days selected. However, geomagnetic storms occurring during this period are not limited to these. For instance, Yizengaw et al. (2002) worked on geomagnetic storm of September 22, 1999

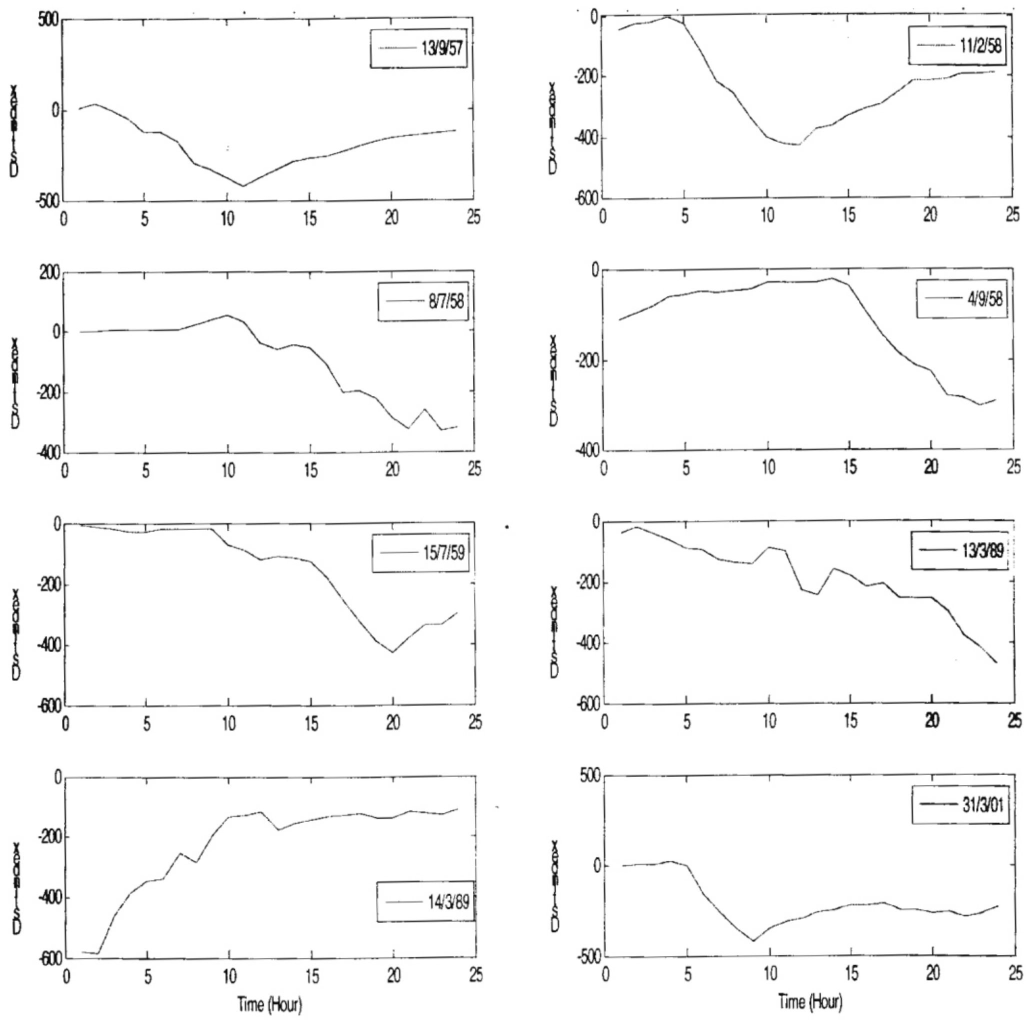

Fig 3j: Geomagnetic Storm for the Period under Study.

4. Discussion of Results

It is observed from the plots of figs. 1 and 2 that the ionsopheric response is more significantly noted at the mid latitude stations particularly during the storm peak time, this is true for the year understudy. On the other hand it is also observed that relatively, very minor storm effect occurred in the equatorial stations. These findings are in agreement with that of Yizengaw *et al.* (2005). This could be due to the fact that at the mid latitude there is strong ionsopheric response to storm-induced changes in the neutral atmosphere which are as a result of a strong Joule heating in the auroral thermosphere (Danilov, 2001). while at the lower heights (equatorial region) the role of ionization and photochemical processes increase due to shorter electron lifetimes. This explains why storm effect is very minor at EEJ regions. The response being significantly noted in the mid latitudes could be attributed to the peak in electron density at that level during the storm, hence higher or stronger solar activity.

Plots of figure 3a show that 1957 was a year of strong solar maximum, very strong, severe storm occurred on 4th, 12th, 22nd hour of the day, lasting for a short period.

From Figure 3b, geomagnetic disturbance with Dst magnitude that lies between $-589nT \leq$ Dst-317nT was found contrary to works of previous researchers (Egedal, 1947; Saka, *et al.* 1998, etc).

Figure 3j shows the overall plots of Dst index for the 24 hours of all 8 days. An exceptionally severe geomagnetic storm occurred on 0200 hours of March 14, 1989, with a Dst index of -589nT. Storms of almost equal magnitudes were recorded on July 15, 1959 at 2000hrs; February 11, 1958 at 1100hrs and 1200hrs, September 13, 1957 at 1100hrs and March 13, 2001 at 0900hrs, with Dst indices of -429 nT, -425 nT and -426 nT, -427nT, -420 and 418 nT respectively.

High Dst values (>-300nT) are recorded from 0800 hrs to 1300hrs on March 31, 2001, which is in agreement with increased speed (> 550 km/s) of Coronal Mass Ejection (CME) of same date and time frame as shown in Table 2.0. It is strikingly important to note that this results agrees with that of Crooker and McAllister (1997), Shinnichi and Takashi, 1998, the former noted that the strength of recurrent storms are controlled by transient CMEs. While the later found that a large number of geomagnetic disturbances (Dst, ≤-50nT) were dependent on CMEs. It is worthwhile to note that our result reconfirms these previous results; hence most geomagnetic disturbances depend on CMEs.

Out of the selected storms, 12 are of long duration which are associated with other dynamical phenomena. Prime cause of change in geomagnetic activity is increase in solar activity. At SSC the value of H is positively enhanced, which is observed mostly in midlatitude, this is attributed to the sudden increase in solar wind. It is suggested that equatorial electrojet effect is felt on SSC on the initial phase of storm.

5. Conclusion

The equatorial ionospheric electrojet effects on the dynamics of ionospheric particles are latitude and time dependent. The mid latitude is much more dynamic than equatorial region. This is attributed to the fact that the storm effect are felt more in the mid latitude, unlike the equatorial electrojet current that are strongly felt at the dip or very close to low latitudes.. Hence, storm contributions to this mid latitude enhance fast fluctuations and motions of particle in this region.

Also, geomagnetic disturbances with long duration are equally found to be very intense lying between (-589nT ≤ Dst ≤-317nT). Most of Dst values less or equal to -300nT are found to be due to CMEs. Large energy is deposited, particularly at the mid-latitudes, hence it is more dynamic than earlier predicted. Very high effect of ionospheric disturbances recorded at the mid latitudes is responsible for mid latitude being much more dynamic than earlier predicted.

References

Akasofu, S.I. and Meng. C.I. (1969): A Study of Polar and Magnetic Substorm, J.Geophys. Res., 74, 293-300.

Burch, J.L. (1972): Preconditions for the Triggering of Polar Magnetic Substorms by Storm Sudden Commencements, J. Geoph. Res, 97, 5629-5640.

Burch, J.L. (1973): Triggering of the Substorm Expansion Phase by Directional Discontinuities in the Interplanetary Magnetic Field, EOS Trans. AGU, 54, 413-424.

Crooker, N. U. and McAllister, A. H. (1997): Transients associated with recurrent storms, J. Geophys. Res.., 102, 14041-14047.

Danilov, A.D. and Lastovicka J. (2001): Effects of Geomagnetic Storms on the Ionosphere and Atmosphere. Int. J. of Geomagn and Herono. V2, 3. 11-17.

Egedal, J. (1947): The Magnetic Diurnal Variation of the Horizontal Force near the Magnetic Equator. J. Terr. Magn. Electr.52, 449-451.

Fairfield, D.H., Mukai, T., Lui, A.T.V., Catteh, C.A., Reeves, G.D. Nagai, T. Rosboker G, Singer, H.J., Kaiser, M.L., Kokubun, S. Lazarus, A.J. Epping, R.P. Nakamura, M., Steinberg J.T., Tsurunda, K. Williams, D.J. and Yamamoto, T. (1998): Geotail Observations of Substorm onset in the Inner Magnetotail .J. Geophys. Res. 102, 103-117.

Kikuchi T. (2002): Transmission Line Model for Ground Magnetic Disturbances. Journal of the Communications Research Laboratory. Vol 49, no. 3, pp 119 -138.

Kuznetsov, S.N. and Kudala, K. (1995): The Effect of the Equatorial Ionospheric Electrojet on the Dynamics of Trapped Particles in the Inner Radiation Belt. Geomagn. And Aerono. 35, 2, 167 – 170.

Okeke, F.N (1998): The Magnetospheric Substorm of 29 April 1997. Irish Astro. J. 26(1) 23-28.

Okeke F.N. and Hamano Y. (2000): Daily Variations of Geomagnetic HD and Z-Field at Equatorial latitudes. Earth Planet Space. Vol. 52, pp. 237 -243.

Pulkkinen, T.I, Baker, D.N., Frank, L.A. Signwarth, J.B. Opgeneorth, H.J. Greenwald, R., Friis-Chriskenen, E. Mukai, T., Nakamura, R., Singer H., Reeves, G.D. and Lesler M. (1998): Two substorms intensification compared: Onset, expansion and global consequences, J.Geophys. Res., 103, 15-27.

Ratcliffe, J.A. 1972. An Introduction to the Ionosphere and Magnetosphere: Cambridge University Press: 137-131.

Saka, O., Kitamura, T., Tachihara, H., Shinohar, M., Trivedi, N. B., Reeves, G. D and Hansen, T. L. (1998): Amplitude Modulation of the Equatorial Electrojet during a Magnetospheric Storm. Jour. Atmos. and Solar-Terr. Phy. 60, (11), 1129-1137.

Sizora, L.Z. (1995): Dynamics of Equatorial Counter Electrojet caused by Interplanetary Magnetic Field. Geomagn. and Aerono. 35, 1, 141 – 145.

Shinichi, W. and Takashi, W., (1998): The solar driver of geomagnetic disturbances during solar minimum. Geophys. Res. Lett. 25, (14) 2489-2492.

Yizengaw, E. Dyson, P.L. Essex, E.A. and Moldwin M.B. . (2005): Ionosphere dynamics over the Southern Hemisphere during the 31 March 2001 severe magnetic storm using multi instrument measurement dataAnnals Geophysicae 23, 707-72.

Yizengaw E. and Essex E.A. (2002). Use of GPS Signals to Study total electron content of the ionosphere during the geomagnetic storm on 22 September 1999. WARS02. Proceedings. Australian Academy of Science, pp. 1- 4. ISBN 0-9580476-0-X.