Latitudinal Variation of F2 Region Response to Geomagnetic Storms over the Longitudinal Range 140–151

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Abstract—*In order to study the effect of effect of geomagnetic storms on the ionosphere, ionosonde data for stations in the latitudinal range 30°N to 30°S and longitudinal range (142.3 to 152.4) were taken. The effect of geomagnetic storms on the F2 region was studied by calculating the deviation ∆foF2 of foF2 during 40 geomagnetic storms, ranging from moderate (Dst<-50nt) to very intense (Dst<-200nt) of the 21st solar cycle. The features exhibited by positive and negative phases were essentially different. The storm time ∆foF2 clearly exhibited a latitudinal variation and this variation were found to be coupled with the seasonal variation. As for the variation with storm intensity, though ∆foF2 was found to vary even between two storms of almost equal intensity, the amplitude of a positive or negative phase, |∆foF2max| showed a distinct upper limit for each intensity category of storms.*

1. INTRODUCTION

Magnetosphere-ionosphere coupling refers to the processes which interconnect the lower-altitude, solar-produced ionospheric plasma with the energized plasmas and mechanisms of the high-altitude magnetosphere [1,5]. The phenomenon of Magnetospheric-Ionospheric coupling has eluded physicists for several decades and a lot of study has been going on in this field revealing rather interesting and sometimes contradictory facts. The study of ionospheric parameters during storm-time, when the effect of the coupling is much pronounced, can reveal a lot of facts about the process of Magnetospheric-Ionospheric coupling. Among the various ionospheric parameters, foF2, the F2 layer critical frequency is an important one as it is related to the F2 layer peak electron density NmF2 by the relation,

$$NmF2 = 1.24(foF2)^2 \times 10^{10} \text{el. m}^{-3}$$

Thus the response of foF2 to geomagnetic storms has been extensively studied. Contrary to the lower ionosphere (post-storm effects, auroral absorption, polar cap absorption (PCA)) where all disturbances are actually an increase of electron concentration above some quiet -time background level, the F2-layer response to a geomagnetic disturbance (so called ionospheric storm) consists of effects of both signs. Both depletion and an increase of the electron concentration relative to a background level are observed during geomagnetic storms and are called “positive” and “negative” phases of the storm, respectively [2,4].

2. AIM AND OBJECTIVE

Study of individual storm effect in details is more basic in nature and aims at revealing the inherent physical processes at work in Magnetospheric-Ionospheric coupling [9,10]. Nevertheless, the study of an extensive database of storms is bound to be useful as the global distribution of ionospheric storm effects is also rather complicated and differs considerably from one storm to another. In this study we have chosen a total of 40 storms with a view to revealing certain common characteristics, if any, of the latitudinal variation of foF2 response which would contribute better to predicting the foF2 response to a geomagnetic storm. In addition to the latitudinal variation, we have also studied the seasonal variation as well as the variation with storm intensity of the foF2 response to geomagnetic storms. In particular we wish to study the effect of geomagnetic storms on the anomaly region.

3. DATA AND METHODOLOGY

All the geomagnetic storms occurring in the solar cycle 21 were identified by examining the Dst index. These storms were then classified into storms of different categories according to intensity (Table 1). From these storms, 40 storms were selected for study and were classified into three groups according to season as: Summer storms, Winter storms and Equinoctial storms (Table 2(a), 2(b) and 2(c)). Here the Summer and Winter seasons refer to seasons in the Northern hemisphere.

The hourly Dst index for a period of 7 days (±3days from Dst minimum) was noted for each of the 40 selected storm so as to include the whole period from storm commencement to recovery. The minimum value of Dst, the time of storm commencement (day-time or night-time) and Dst minimum, were noted (Table 2).

Ionosonde data for stations in the latitudinal range 60°N to 60°S for the longitudinal ranges (142.3 to 152.4) were taken. The stations were chosen so as to lie within a small longitudinal range so that the maximum local time variation was 40 minutes To study the effect of a particular storm on foF2, the hourly foF2 values for the same period as the Dst data were noted for all the eight stations. To do away with temporal, seasonal and solar cycle variations in the foF2 data, the ΔfoF2 were calculated by subtracting the average value of foF2 of seven days from the foF2 of a particular hour on a particular day.

$$\Delta foF2 = foF2 - (foF2)_{mean}.$$

Simultaneous plots of ΔfoF2 and Dst were obtained for all the storms against time (in hours). The $\Delta foF2_{max}$ during the storm main phase was noted down in. The storms under study were chosen from both the declining and rising phase of solar cycle 21.

4. RESULT AND DISCUSSION

Of the 40 storms selected, the foF2 corresponding to 35 storms showed a distinct modification at most of the stations during the storm main phase. The following storms are presented as these are typical representatives of other storms for the same season:

i. 11-01-76 (-156nt)
ii. 19-12-80 (-240nt)
iii. 06-03 -76 (-226nt)
iv. 05-03-81(-215nt) 0
v. 6-09-82 (-289nt)
vi. 28-08-78(-226nt)

The storms exhibited the following features:

Negative phase

It was seen that the negative effect appeared to occur simultaneously at all the latitudes under study for most of the storms depicting the negative effect. This must be due to the fact that the velocity of the negative phase equatorward "drift" is, according to various estimates, about 50–300 ms^{-1} [4] and thus could not be detected for most of storms and they seemed to appear simultaneously at all the latitudes. (Fig. 1)

Positive phase

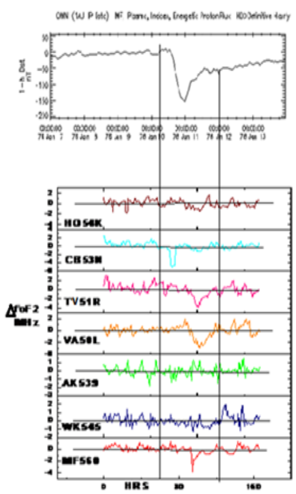
The features depicted by the positive deviations were different from that depicted by the negative ones. At higher latitudes the positive deviations reached a peak and then come down, but at lower latitudes the case was slightly different. The plateau has the greatest width and smallest height at the equatorial station . This is probably because the storm-induced circulation brings down the gas with the depleted $[O]/[N_2]$ ratio which tends to reduce electron concentration in the F2 peak (Fig. 2)

Positive and negative phase

A combination of positive and negative phases were seen in case of equinoctial storms on 05-03-1981 (-215nT) (Figure 5.5) and on 6-09-1982 (-289nT) where the ΔfoF2 increased to a maximum forming a positive phase and then decreases to form a negative phase (Fig. 3)

Dead zones in the middle of storm

In summer the quiet-time and storm-induced circulations coincide (both are equator-ward) [6,7,8]. In this case the upward vertical drift increases, and a positive phase is expected. However, it is not always the case because the storm-induced circulation brings the gas with the depleted $[O]/[N_2]$ ratio, and this tends to reduce electron concentration in the F2 peak. The rivalling of the two factors sometimes gives rise to the positive and negative phases at the same point of time and neutralises thus each other. (Fig. 4)



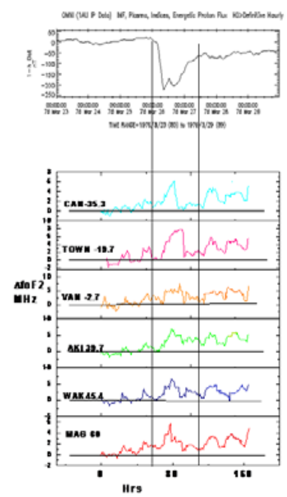
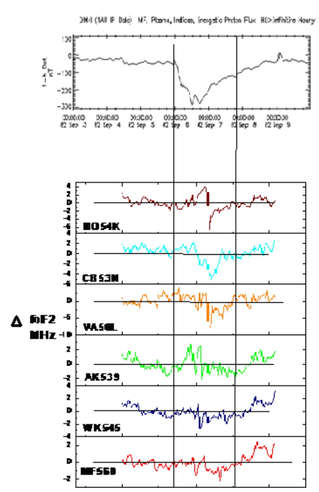


Fig. 1: Negative phase **Fig. 2: Positive phase**



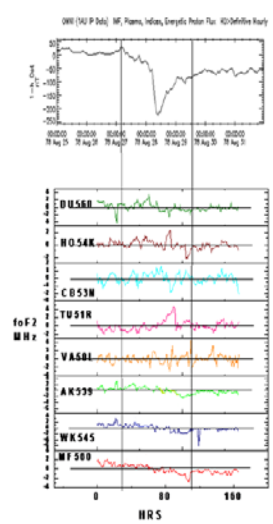


Fig. 3: Positive and negative phase **Fig. 4: Dead-zone**

5. CONCLUSION

This study of foF2 response to 40 distinct geomagnetic storms has revealed certain new features in addition to confirming some earlier results. The foF2 configuration was found to be modified during the main phase for each storm at almost every station. This modification was found to start at a time almost coinciding with the storm commencement pointing to the fact that the process of M-I coupling is very strong. The foF2 variation was found to recover the original (quiet-time) profile during storm recovery period itself. The modification in foF2 during storm-time i.e., ΔfoF2 differed greatly from one storm to the other, both in magnitude and direction

6. ACKNOWLEDGEMENTS

The authors thank WDC-C2, Kyoto for the Dst data which were supplied, by the World Data Centre C1 for Solar Terrestrial Physics at RAL. We thank national geophysical centre's SPIDR (http://spidr.ngdc.noaa.gov) for the hourly values of ionosonde foF2 data.

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