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RESPONSE OF LOW LATITUDE IONOSPHERE TO THE INTENSE GEOMAGNETIC STORM OF THE HIGH SOLAR ACTIVITY PERIOD OF 23RD SOLAR CYCLE

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ABSTRACT

In the present work, we investigatedthe response of critical frequency of f2 layer for the low latitude station Darwin (131^0 E, 12^0 S) during the intense geomagnetic storms occurred during year 2000.For this we selected four severe geomagnetic storms. The behavioral change in foF2 with the z component of interplanetary magnetic field, geomagnetic index DsT and Kp is compared. In most of the cases positive phase is observed during magnetic disturbances. However, during prominent disturbances, the negative phase also be observed.

Keywords: Critical frequency of F layer, solar cycle, interplanetary magnetic field, Dst, Kp index, Geomagnetic storm.

I. INTRODUCTION

Geomagnetic storms are created when the Earth's Magnetic field captures ionized particles carried by the solar wind due to coronal mass ejections or coronal holes at the sun. Reconnection process occurs if the arriving solar wind plasma has southward field. The changes in terrestrial ring current are responsible for global decrease in the Earth's surface magnetic field. Disturbances in the Earth's magnetosphere have immense contribution to the structure and dynamics of the ionosphere. In response to the geomagnetic disturbances, the concentration of the ionosphere often changes drastically and such changes are called ionospheric storms. The magnitude of ionosperic storms vary from storm to storm, even when the magnitudes of the magnetospheric disturbances are similar. During geomagnetic storms, both increases and decreases of ionization are observed which are termed as positive and negative ionospheric storms respectively.The propagation of negative and positive ionospheric storms is strongly determined by the thermospheric disturbance gravity waves (Liu et al. 2010). According to

Kane (2005), positive storm effects are a result of downwelling of neutral atomic oxygen and uplifting of the F-layer due to winds. Both of these rely on large scale changes in the thermospheric circulation caused by heating in the auroral zone. The storm negative phase in foF2 and total electron content (TEC) occurs in a composition disturbance zone which reaches lower latitudes in summer than in winter, and has a preference for the night and morning sectors due to the local time variation of neutral winds. The reaction of the ionosphere as seen at different ionospheric stations may be quite different during the same storm period depending on the station coordinates, local time effects, and some other parameters (Danilov 2001, Akala et al. 2010, Vijaya et al. 2011, Adebesin et al. 2013). At low latitude and equatorial zone, E × B drifts are affected by prompt penetration of magnetospheric convection electric fields, as well as by long-lived dynamo electric fields from the disturbance neutral winds and storm-related changes in ionospheric conductivity (Fejer 1997). In addition, changes in the neutral composition alter the balance between production and loss in the plasma and this affects the peak density of the ionosphere. An increase in the percentage of molecular neutrals, as would be the case if the thermosphere were heated, would lead to depletion in the ionospheric density (Davis et al. 1997). (During periods of enhanced geomagnetic activity low latitude ionospheric plasma densities, electric fields and currents undergo strong perturbations. Magnetic disturbances at the day side dip equator are often caused by dayside penetration of the convection electric field and correlated with disturbances at high latitudes (Kikuchi et al., 1996; 2000a). The direct penetration of the high latitude electric field to lower latitudes, and the disturbance dynamo, both play a significant role in restructuring the storm time equatorial ionosphere and thermosphere. The response of equatorial electric fields and currents to geomagnetic disturbances has been examined in detail in a large number of case by case and statistical studies and Empirical models of storm time equatorial zonal electric field. (Fejer and Scherliess, 1997; Richmond, 1995).

The purpose of this paper is to examine the behavior of the ionosphere over the low latitude Australian region during the four storms which occurred during high solar activity period 2000 of 23^{rd} solar cycle on 11 Feb 2000, 23 May 2000, 11August 2000 and 6 November 2000.

II.DATA AND METHOD OF ANALYSIS

In the present work, we have analyzed the ionospheric response features during four magnetic storm events occurred during 2000 of 23rd solar cycle.Our main aim is to analyze the behavioral change in the critical frequency of F2 layer during geomagnetic storm period. The ionospheric data used in this study consists of hourly values of the criticalfrequency of the F2 layer obtained from low latitude Australian ionosonde station at Darwin (12ºS, 131ºE). These data were collected from Data Research (SPIDR) website at http://spidr.ngdc.noaa.gov/.ic. The geomagnetic index and solar wind data in this study constituted of hourly values of the magnetic index Dst, Kp index and interplanetary magnetic field component Bz. These data were obtained from National Space Science Centre's NSSDC OMNI Web services(http://nssdc.gsfc.nasa.gov/omniweb).

To eliminate the solar activity effect on foF2 first we calculate the average value of foF2 for all five quiet days occurred in the month in which storms are occurred. After that we calculate the standard deviation of foF2 for each hours with the help of following equation.

$D (f_oF2) = (f_oF2_{obs} - f_oF2_Q)/f_oF2_Q \times 100\%$

The D (foF2) variation is described in terms of percentage change in amplitude of critical frequency foF2 from the reference.

$f_oF2_Q$is average value of observed foF2 for all five quiet days observed in the month in which storm was occurred.

The storms are classified with negative intensity of Dst index. Magnetic storms are grouped into two classes: moderate (-50 nT ≤Dst ≤ -100 nT) and intense (-100 nT≤ Dst ≤-200 nT).

Table1

Selected magnetic storm events for the year 2000 for this study.

Month	Dates	SSC	Dst(minimm)
February	**10-14**	**23.58 UT (11Feb)**	**-133**
May	**21-25**	**17.02UT (23May)**	**-147**
August	**9-13**	**18.46UT (11Aug)**	**-235**
November	**4-8**	**9.47 UT (6 Nov)**	**-152**

Magnetic Storm of February 10-14, 2000

This is an intense storm in which minimum value of Dst-133 nT reached .The sudden storm commencement (SSC) occurred around 23.58 UT on Febuary11.The change in foF2 values of Darwin station from Feb 10 to 14, 2000 are shown in the first graph, the Bz values for the corresponding period are shown in second graph, the Dst values are shown in the thirdgraph and last graph shows Kp index in Figure 1.It is noticed from the figure that the fluctuations observed in the Bz follow the variation pattern of Dst. When there is maximum southward turning of Bz shown ingraphi.e. When it reaches to -16.4 nT around 10.00 hrs. UT on 12 Feb just after 1 hour of it, maximum negative excursion of Dst -133 nT is observed on 12feb around 11.00hrs. UT. At the same time Kp index also reached its maximum value 7. Again on same day on 11 Feb the small negative polarity changes in

Bz around 3.00 hrs. UT was followed with the little drop in Dst index at that particular time during the recovery phase. The figure shows a delayed negative phase effect in foF2 which is obtained after 6 hrs the Dst value reaches its minimum value during recovery phase and 17 hrs after SSC.The deviation of foF2 is showing a negative deviation of ~62% around 17 hrs. UT on 12 Feb. However a positive deviation of ~101% is obtained around 7 hrsUT during the main phase of storm i.e. 7 hours after SSC.

Magnetic storm of May 21-25, 2000

Deviation of foF2, values of Dst, Bz and Kp index during an intense magnetic storm event of May 21-26, 2000 is shown in figure 2. This storm had a minimum Dst excursion of -147 nT. The change in foF2 values of Darwin station from May 21 to 25, 2000 are shown in the first graph, the Bz values for the corresponding period are shown in second graph,the Dst values are shown in the third graphwhereaslast graph shows Kp index in Figure 2.The sudden storm commencement (SSC) occurred around 17.02 hrs. UT on 23 May. The figure shows the maximum southward turning of Bz which reaches its maximum negative value of -19.2 nT around 2.00 hrs. UT on 24 may. During the same time Kp index also reaches its maximum value 10, After 6 hrs.of maximum southward turning of Bz the maximum negative excursion of Dst -147 n T is observed on May 24 around 8.00 hrs. UT. After 19 hrsof minimum negative excursion of Dst a very large positive deviation of~165% is observed on May 25 around 3hrs UT.

Magnetic storm of August 9- 13, 2000

A super magnetic storm event of August 9-13 is illustrated in Figure 3. This storm had a minimum Dst excursion of -235 nT. It shows index of ionospheric disturbances in foF2, the Dst index,the Bzvalues and Kp index for the corresponding period for the duration of August 9-13, 2000 from top to bottom. The first sudden storm commencement (SSC) occurred around 5.00hrs UT on August 10. The second SSC occurred around 18. 46 hrs UT on August 11.The first fall in Dst occurred on August 11 with Dst values dropping to -106 nT at 6.00.hrs UT. Simultaneously fluctuations in the Bz were obtained. A positive deviations in the foF2 values ~179% &~184% are observed around 5.00hrs UT on August 10 and 6.00 hrs UT on August 11.The second fall in Dst values dropping to -235 nT is obtained on August 12 around 9.00 hrs UT. During the same time, just before 1 hour of it, there is maximum southward turning of BZ of about -28.7 nT.During the same time Kp index also reaches its maximum valueof 8.A very large increase (positive) in foF2 values ~197% was obtained on November 13 around 6.00 hrs UT after 21 hrs of maximum Dst decrease.

Magnetic storm of November4-8, 2000

An intense magnetic storm event of November 4-8, 2000 is illustrated in Figure 4. The change in foF2 values of Darwin station from of November 4-8, 2000, are shown in the first graph, the Bz values for the corresponding period are shown in the second graph, the Dst values are shown in the third graphwhereaslast graph shows Kp index in Figure 4. The storm was intense with sudden storm commencement time occurred around 9.47 hrs UT on November 6.The figure shows southward turning of value the z component of interplanetary magnetic field and a maximum negative value of -12.7nT was reached around 23.00 hrs UT on November 6 .Before 2 hours of southward turning of Bz the minimum negative excursion of Dst-159 nT is observed on November 6 around 21 hrs UT.Kp index also reaches its maximum value of 7 just before 1 hour of minimum negative excursion of Dst. The deviation of foF2 shows fluctuations and it reaches to the maximum positive value of~ 45% around 10.00.hrs UT on November 5.Again on November 6 around 21.00 hrs UT foF2 deviate positively and reaches to value ~29% during main phase of storm occurred around 9.47hrs UT on November 6.Afterwards during recovery phase of storm there is negative deviation of foF2 of ~46% around 15.00hrs UT on Nov 7

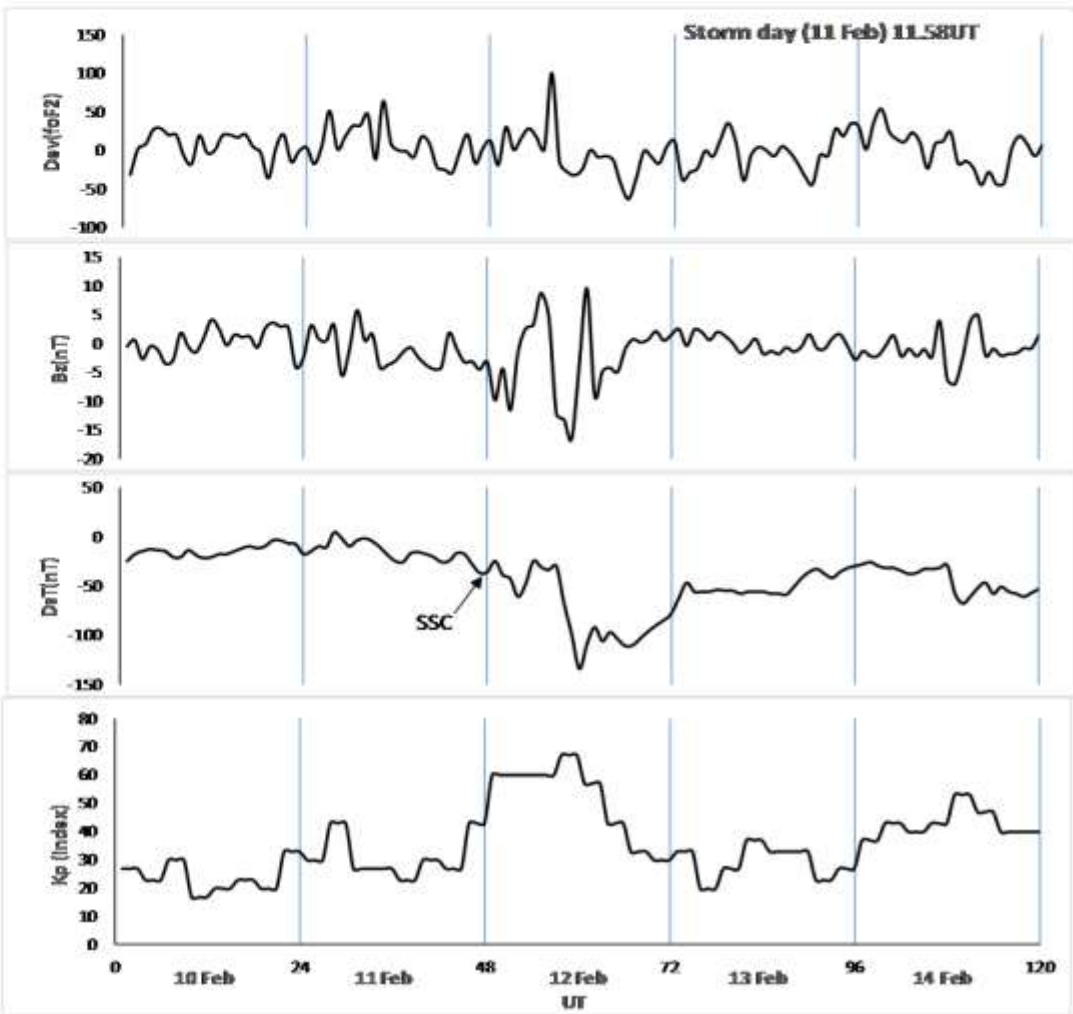

Figure 1 First graph shows the percentage deviation of foF2, second graph shows the variation of Bz component of IMF,third graph shows the variation of Dst index and the last graph shows the variation of Kp index from Feb 10-14, 2000

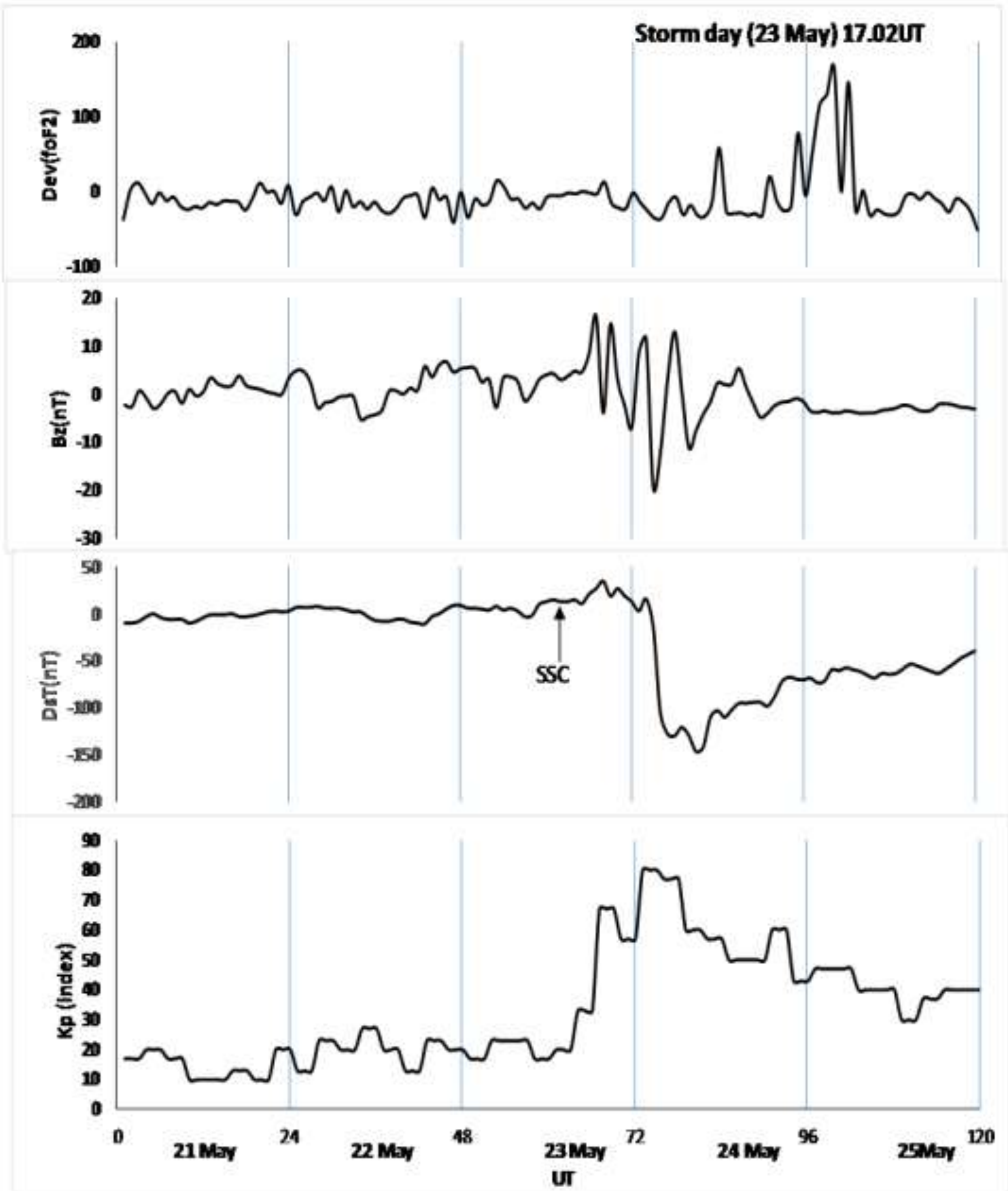

Figure 2: First graph shows the percentage deviation of foF2, second graph shows the variation of Bz component of IMF, third graph shows the variation of Dst index and the last graph shows the variation of Kp index from May 21-25, 2000

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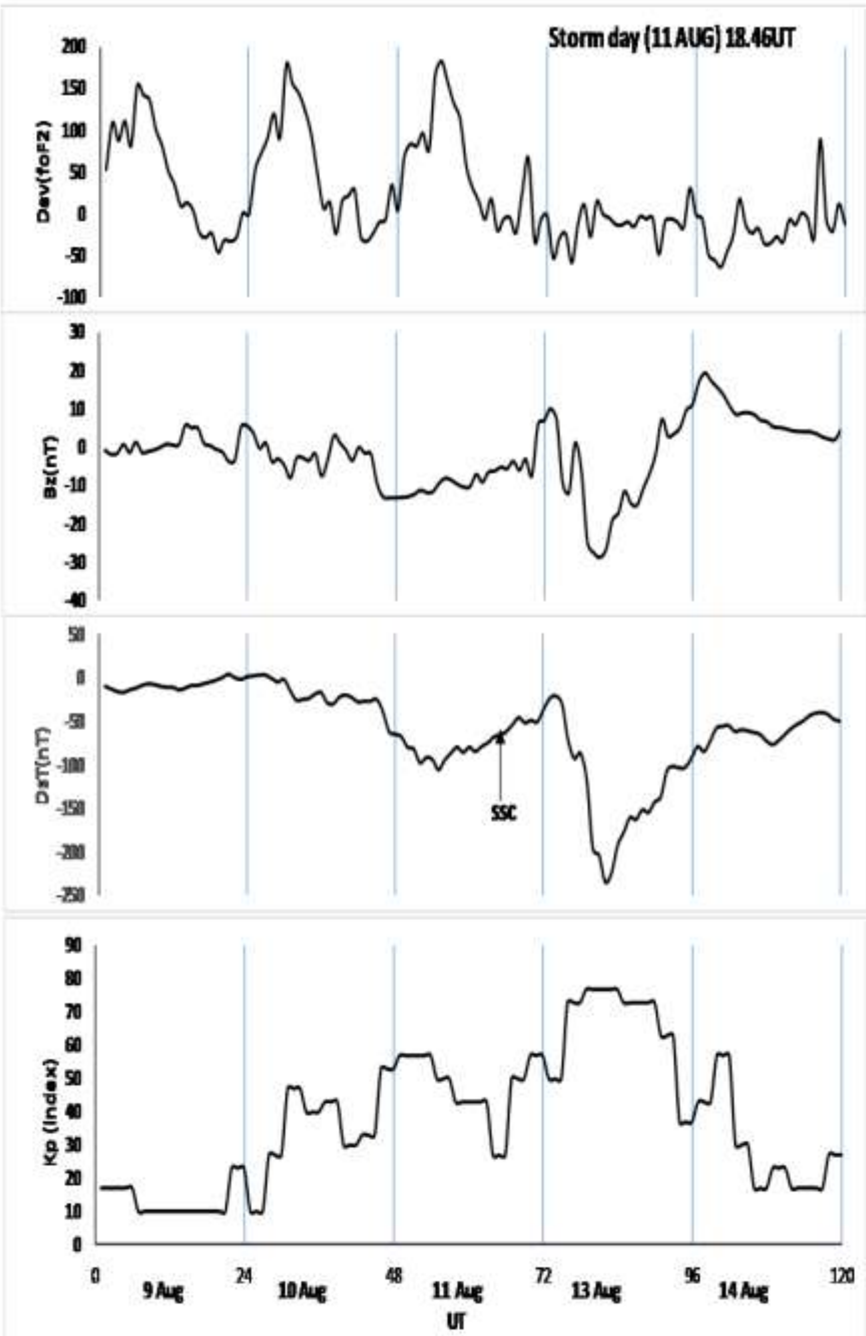

Figure 3 First graph shows the percentage deviation of foF2, second graph shows the variation of Bz component of IMF,third graph shows the variation of Dst index and the last graph shows the variation of Kp index from Aug 9-13, 2000

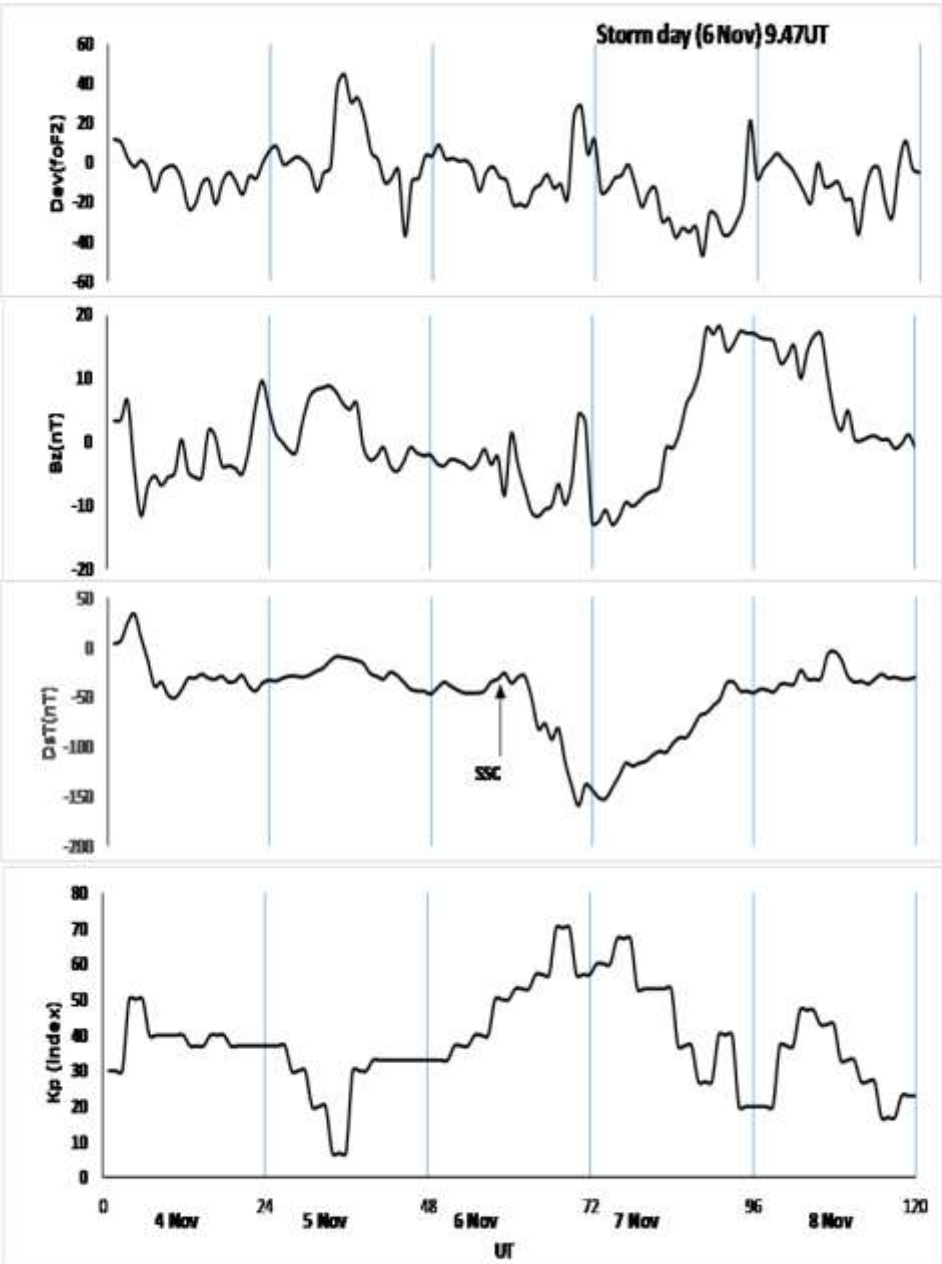

Figure 4 First graph shows the percentage deviation of foF2, second graph shows the variation of Bz component of IMF, third graph shows the variation of Dst index and the last graph shows the variation of Kp index from Nov4-8, 2000

III. DISCUSSION

D (f_oF2) and never becomes negative. Sometimes, there is existence of so called "dead zones" in which from the middle of a storm for several hours the deviation from the median does not exceed 10% [*Danilov and Belik*, 1991]. To understand the physical mechanisms operating in the thermosphere and ionosphere during a magnetic disturbance all of above these features are important It has been noticed that negative phases are almost always observed at high latitudes and more often than positive phases at middle latitudes, positive phases tend to occur at middle and low latitudes .In most cases the positive phase is observed at equatorial latitudes during magnetic disturbances [*Adeniyi*, 1986; *Mikhailov et al.*,1994]. However, during some disturbances, the negative phase may also be observed [*Adeniyi*, 1986; *Turunen and Rao*, 1980].

Several mechanisms are considered as a probable source of the ionospheric storm positive phase [e.g., *Danilov and Belik*,1991; *Prölss*, 1995]. In our study we have selected four storms of varying intensity of high solar activity period of 23rd solar cycle for the low latitude station Darwin. We have observed both increase and decrease in foF2 which represent positive and negative storm effect on foF2.The response of ionosphere to these storms are related to the changes in Dst index, Bzcomponent andKpindex.The principal physical mechanisms responsible for the formation of positive and negative phases are believed to be different. One of the reason of the negative phase is theequatorwardshift of ionosphere during the storm from auroral latitudes to middle latitudes. During this shift the maximum absolute value of *D* (f_oF2) decreases. According to*Seaton* [1956], it was believed that the heating of thermosphere during geomagnetic storm changes the thermospheric composition and this causes negative phase. The electron concentration is directly proportional to the [O]/ [N_2] ratio at the *F*2 -layer maximum height [*Rishbeth and Barron*, 1960. The heating induces its own circulation, which at the *F*2 -layer heights tends to bring the air equator ward to lower latitudes [*Duncan*, 1969]. This leads to the drift of the negative phase to lower latitudes. The heated gas with depleted [O]/ [N_2] ratio has a higher temperature throughout the thermosphere. The increase of temperature increases the linear recombination coefficient at the F- region heights and thus there is further decrease of the electron concentration [*Mikhailov et al.*,1995]. Thus, the following two factors are responsible for the negative phase in the heated thermospheric gas: the depleted [O]/ [N_2] and the increased recombination due to increased temperature [*Mikhailov and Förster*,1997].

The morphology of the positive phase is more complicated [*Zevakina*, 1971]. Sometimes, the positive phases are observed several hours before the beginning of the magnetic disturbance, which is considered to be a reason of this particular ionosphericstorm [*Danilov and Belik*, 1991; *Szuszczewicz et al.*,1998]. Sometimes the entire storm consists of a single durable positive phaseThese are as follows: plasma fluxes from the plasmasphere, the *F*2 -layer uplifting due to vertical drift, and downwelling of the gas as a result of the storm-induced thermospheric circulationThe two principal mechanisms which causes the *F*2 -layer drift are: an increase of the electric fields of magnetospheric origin and the equatorward horizontal thermospheric circulation which lifts up the *F*2 -layer plasma along the inclined field lines. The question of penetration of strong electric fields into the *F* region from the magnetosphere is still open, and there is no proof that this mechanism contributes significantly to the *F*2 -

layer behavior during ionospheric storms at middle latitudes [*Prölss*, 1995]. Neither are there any indications to the role of plasma fluxes from the plasmasphere. As for the circulation-induced drift and thermospheric gasdownwelling, they are considered to participate essentially in a positive phase formation.

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