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Intense Geomagnetic Storms and Variation in Solar wind parameters

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Abstract:*The extravagant solar wind magnetospheric energy coupling process results in geomagnetic disturbances. An electro dynamical coupling of solar wind plasma and magnetosphere initiated by the magnetic reconnection is leading to geomagnetic disturbances. The infrequent coronal mass ejections and interplanetary coronal mass ejections being the foremost framework, are flowing during solar maximum. The occurrence of coronal holes is more general around the descending solar cycle phases. Around the solar maximum the CHs emerge as black patches and are constricted to solar poles but as they grow in size, proceed to the equatorial regions around the declining phase. We have considered three geomagnetic storms in the present study. To elucidate these events, we have discussed the interplanetary solar wind data and geomagnetic indices. The cross-correlation technique has been used to expound the satellite data and Dst parameters (-100 nT to above). The Bz values are about -20 nT -50nT and -20 nT and the Dst values are -250 nT, -400 nT and -300 nT depicting highly intense storms. The cc among these parameters reveals that interplanetary magnetic field Bz is the leading cause of geomagnetic storms.*

Key Words: *Geomagnetic storms; Solar wind; Cross correlation analysis.*

1. INTRODUCTION:

Solar wind is a continuous stream of charged subatomic particles ejected by the sun. It flows at a speed of 400 km/s at a temperature of 1 million degrees (Celsius). Nearly hundred tons of solar wind is released daily from the sun in the form of kinetic energy and electrical energy. This energy infiltrates into the magnetosphere of our earth and this gets heated. These energies also produce turbulence to the geomagnetic activity thus giving rise to geomagnetic storms , sub-storms and aurora (Chapman, Bartels, 1992, Gonzalez et al., 1994) after infiltrating into the magnetosphere. The interaction of solar wind with the earth's magnetic field produces interim disturbances (Dungey, 1961). The increase in solar wind pressure squeezes first of all the earth's magnetosphere. The amount of energy becomes greater due to which there is an increase in plasma level in magnetosphere and also increase movement of electric current in magnetosphere by the interaction of earth's magnetic field and solar wind field (Dungey; Gonzalez et al., 1994). On the basis of Dst value, the geomagnetic storms have been categorized into four types as: weak(-30 nT to -50 nT); intense 9-100 nT to -250 nT) and severe (-250 nT and above) (Gonzalez et al; 1994. The health related problems, satellite disruptions and variations in weather are some issues created by geomagnetic activity. The disturbance to magnetosphere by solar wind gives rise to auroras and the paths of the charged particles in both solar wind and magnetosphere plasma precipitate them in the upper atmosphere and drop their energy there. The natural phenomenon taking place within the magnetically heated outer atmospheres in the sun are known as solar phenomenon including solar wind, energy bursts (Camp; Tung, 2007). The source of these phenomenon is a helical dynamo near the center of the sun's mass producing powerful magnetic fields and a disorderly dynamo close to the surface creates smaller magnetic field variation (Kivelson, Russel, 1995). The solar maxima and minima are the periods falling under solar activity. In the 11 year sunspot cycle, solar minimum is the least activity period where sunspot and solar flare activity declines rather is absent for many days. After the six months of true occurrence of solar minima, this minima is recognized by describing a smoothed average over 12 months of sunspot activity. The greatest activity period of the same sunspot cycle is called solar maximum. During this period, huge number of sunspots are observed and the irradiance output of the sun develops by about 0.07% affecting directly the planet's global climate (Burlagu, 1995; Harvey et al., 2000). The geomagnetic indices help to measure the GMSs occurring for short-time periods. The magnetic field near the earth's surface was observed to vary in wide ranges due to solar wind interaction with earth's magnetosphere and coupling between magnetosphere and ionosphere (Dungey, 1961;

Gonzalez et al; 1994). Usually Dst and AE are used to measure the strength of magnetic field (Sugiura, 1964; Rostoker, 1972). The Dst index is used to record the global magnetic storm level. This is done by taking the mean of H from mid-latitudes and equatorial magnetogram around the globe. The negative value of Dst indicates a storm in progress due to the storm time ring current proceding around the earth from east to west in equatorial plane. Dst values are directly related to sunspot activity. The approximate values of Dst are +100 to -600 nT. The cause for +ve value of Dst is due to squeezing of magnetosphere when the solar wind pressure increases. Auroral electrojet is the electric current moving around D and E region of ionosphere and auroral electrojet index measures the global auroral zone magnetic activity (Rostoker, 1972; Kivelson; Russel, 1995). We choose one minute datasets of H-component from auroral zone observatories situated around the globe to constrict auroral electrojet. We plot the constricted values as function of UT. AU and AL indicate upper and lower amplitudes for maximum disturbance produced by eastward electrojet current in the afternoon sector and AL stands for the maximum disturbance created by westward electrojet current in morning and midnight sectors. Their difference AU-AL yields AE index and (AU+AL)/2 yields AO ndex. In short AE represents AU, AL, AE and AO.

2. DATA SOURCES AND METHODOLOGY:

The data has been collected from the International Space Related Research Centers like OMNI (operating mission as nodes on the internet web system) (http://omniweb.gsfc.nasa.gov/ow.html). The omni system uses several ground and space based GPS and satellite for a very long period to carry out research. The three GMSs have been examined and the fluctuation of solar wind parameters during these GMSs at a specific time has been investigated. We used cross correlation between B_z (possible cause) with many solar wind parameters (outcome) utilizing data obtained through satellite. From this investigation, we obtained the degree of correlation and also depicts that how one time series lags another. This time lag provides the response time of the phenomenon and can deliver the clue of the mechanism happening in the energy transfer.

3. RESULTS AND DISCUSSION:

Event 1: The occurrence of GMSs in 24 November 2001

The OMNI data set for the period 24 november 2001 is depicted in figure 1. From the figure, the geomagnetic indices indicate highly intense values. The temperature(10e4k) during the main phase is approximately 190K, plasma speed (Vsw) approximately 1000 km/s, density D(n/cc) is around 50 n/cc. The value of B_z is about -20 nT , Dst shows the value of -250 nT and the value of AE is below 1800 nT. In this way the solar wind parameters, IMF and components manifests intense values. The ionospheric parameters exhibit variations due to energy input inside the magnetosphere and ionosphere during a geomagnetic disturbance e.g composition, temperature circulation (Gonzalez et al., 1994; Gonzalez et al., 1999).

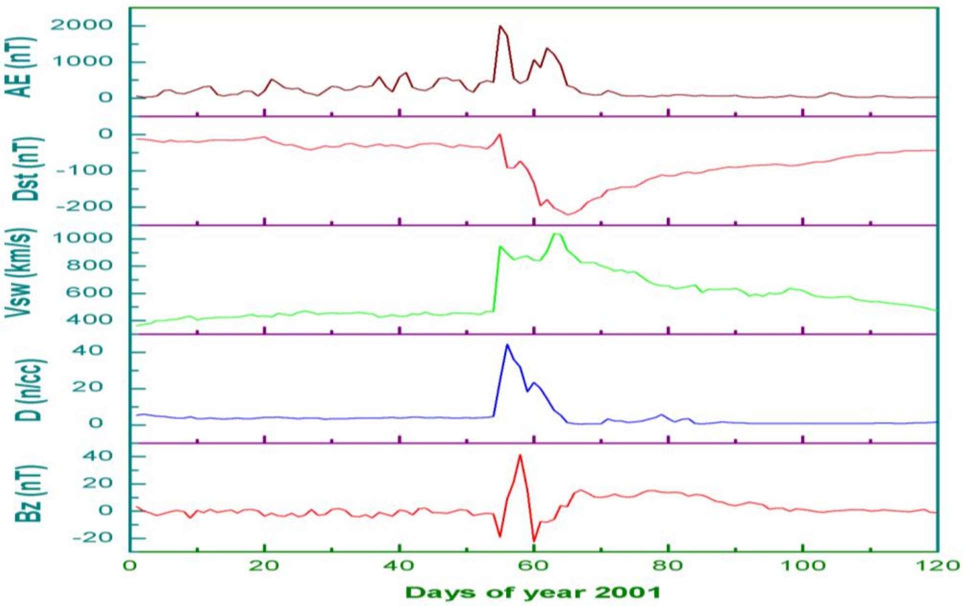

Figure 1 The panels in the given figure display the changes in (i) AE (nT), (ii) solar wind density (n/cc), (iii) solar wind velocity (Vsw), (iv) Z-component of magnetic field Bz (nT), (V) Dst (nT).

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Figure 1.1 exhibits the cross-correlation of Bz with Dst, Vsw, n(cc) and AE index for the period 24 november 2001. Time in minutes is represented by horizontal axis and cross-correlation coefficient is shown onvertical axis. The time scales of -150, 100, -50, 0, +50, +100, +150 have been designated along horizontal axis and the cross-correlation coefficient runs to its range in vertical axix. There is a positive correlation coefficient of about 0.4 between Bz and Vsw. Also Bz and n(cc) exhibit + correlation coefficient of about 0.5 at time lag of 25 minute while Bz and Dst bear a negative correlation coefficient of about 0.6 at time lag of 5 mintes; Bz with AE manifests a + correlation coefficient of about 0.55 at a time lag of 25 minutes.

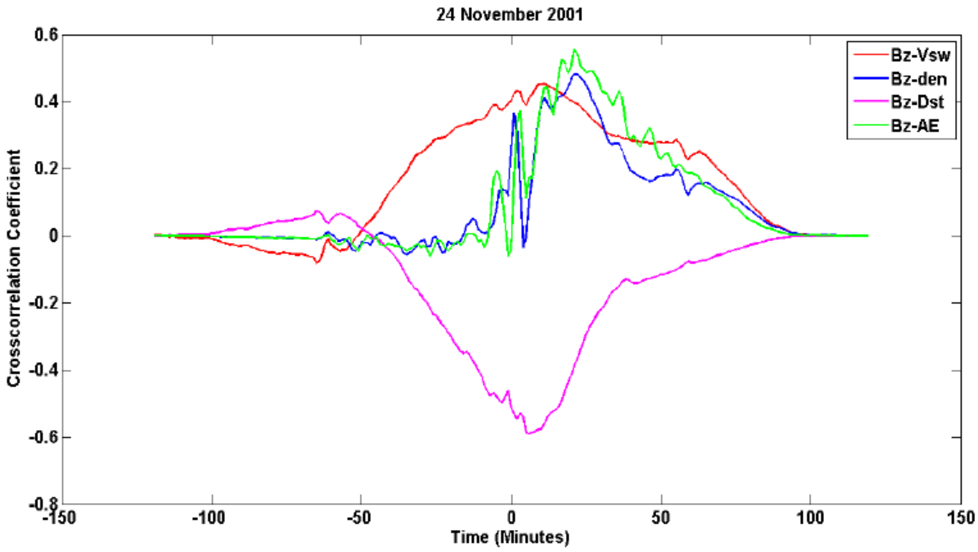

Figure 1.1 It represents the cross-correlation between Bz (nT) against solar wind velocity, density, Dst and AE.

Event 2: The occurrence of GMS on 31 March 2001

Figure 2 manifests the OMNI data sets during 31 march 2001. It reveals that the geomagnetic indices have intense values. For the period of main phase, the temperature T (10e4k) is approximately 70K, plasma speed (Vsw) is around 850 (km/s) , density D(n/cc)about 40n/cc. The Bz valueis -50 nT, Dst value -400 nT and AE value is below 1500 nT. Hence the solar wind parameters, interplanetary magnetic field components reveal intense values (Adhikari, 2015).

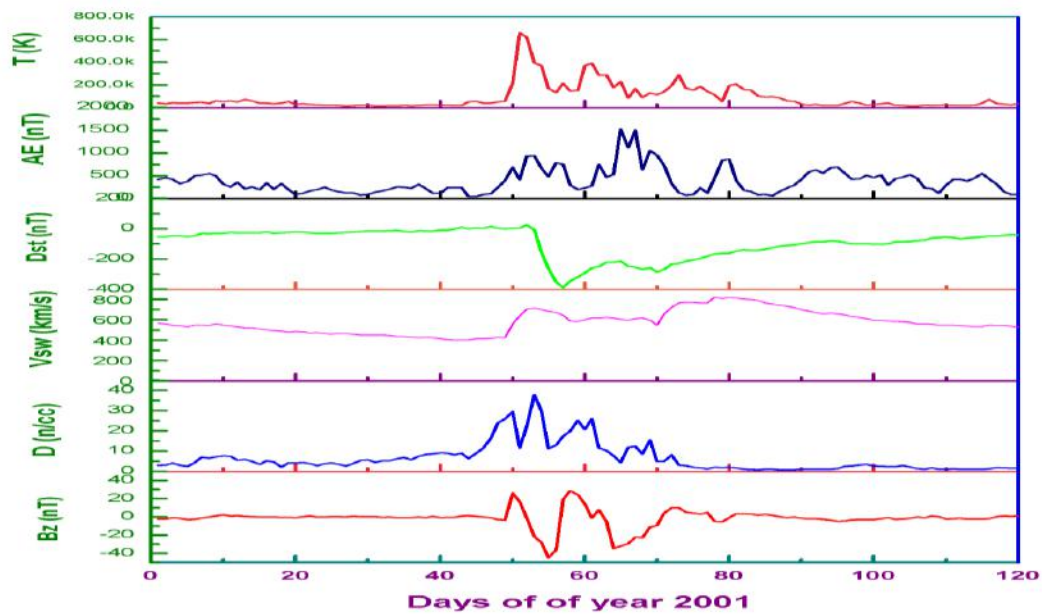

Figure 2 Variations in D (n/cc), Vsw (km/s) AE (nT), T (K), Bz (nT), and Dst (nT) indices with time (hrs) during 31 March, 2001.

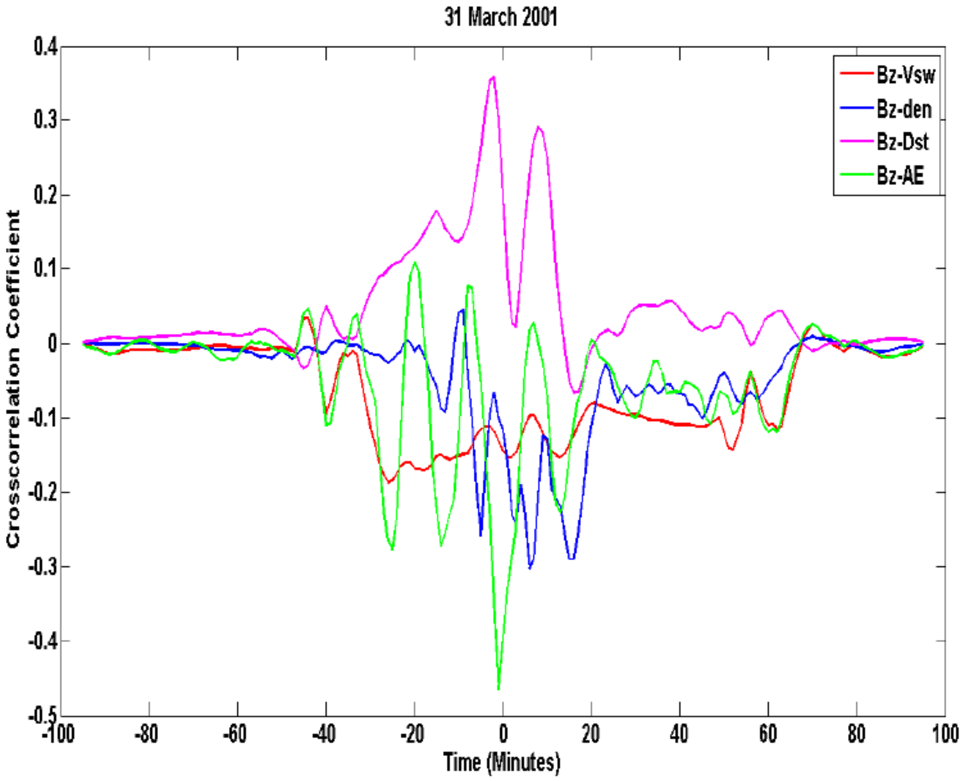

Figure 2.1 It shows the cross-correlation of Bz with Vsw, density, Dst and AE.

The plot 2.1 exhibits the cross-correlation of Bz with Vsw, D(n/cc), Dst and AE index during 31 March 2001. The time (in minutes) is represented on horizontal line and the vertical line represents the correlation coefficient. From this figure it is clear that only Bz-AE exhibits correlation of about 0.5 at zero time lag.

Event 3: The occurrence of GMS in April 11, 2001

In this event, the below figure reveals the data taken from the OMNI web on 11 April 2001. The diagram shows the geomagntic indices having intense values. The value of temperature T(10e4K) is around 70 K, Vsw is 800 km/s, density D(n/cc) is about 25 (n/cc). The Bz has its value -20 nT, Dst value is about -300 nT and AE index bears a value below 1750 nT.

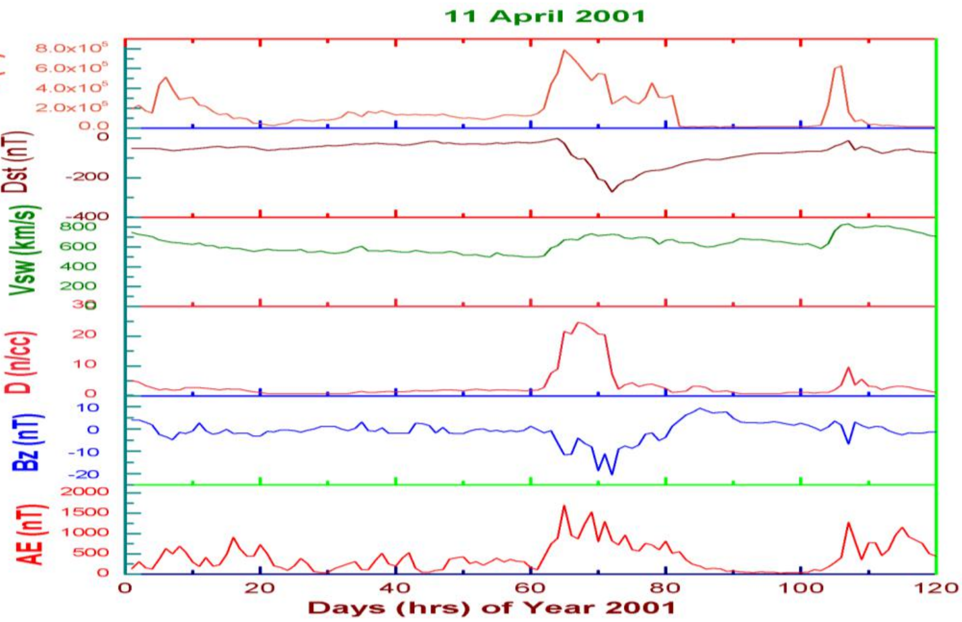

Fig 3 The above panel shows the variation of different parameters against time during the event 11 April 2001.

The cross-correlation observation of Bz with D(n/cc), Vsw, Dst and AE are depicted in figure 6 during the period 11 April 2001. Similarly as in the previous figure, the time scale is shown along horizontal axis. There is a positive correlation coefficient of approximately 0.8 between Bz and Vsw at time lag of zero, Bz and D also exhibit a positive correlation of about 0.7 at same time lag. Bz and Dst also reveal +ve correlation of about 0.8 at the same time lag while negative correlation coefficient of around 0.9 with zero time lag is exhibited by Bz and AE.

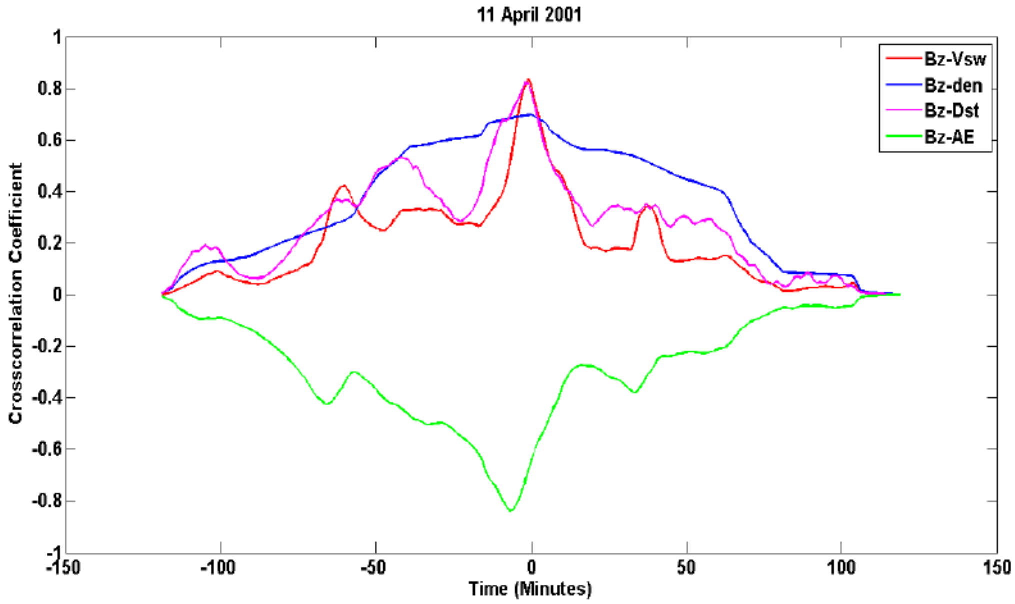

Fig. 3.1 Cross-correlation of Bz against Vsw, density, Dst and AE during 11 April 2001.

5. CONCLUSION:

To analyze the space weather, the geomagnetic storms have to be studied elaborately. The Bz component plays a key role to demonstrate the presence of geomagnetic storm. Various solar wind parameters and geomagnetic indices have been investigated and the cross-corelation technique of Bz- component with rest of the parameters has been taken into account. We have analyzed the change in various parameters during the GMSs. Three different cases have been sorted out yielding different results. The values of Bz were observed to be equal to -20 nT, -50 nT, and -20 nT in 1,2 and 3 events. Intense effect has been observed for the events 1, 2, and 3 (Gonzalez et al; 1994) with Bz values -20 nT , -50 nT, and -20 nT respectively. Also the correlation coefficient acquired from this research work clearly reveals that Bz is a main cause of geomagnetic disturbance.

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