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AVERAGE CHARACTERISTICS OF FORBUSH DECREASES OF GALACTIC COSMIC RAY INTENSITY VARIATION

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ABSTRACT

Forbush decrease (Fd) event in cosmic rays shows a sudden decrease in count rates of neutrons followed by gradual recovery, typically lasting for several days. In this study we have shorted out 54 events of Forbush decrease from the listings of hourly plots of cosmic ray intensity for the period of 1996 to 2007. The occurrence of forbush decrease is found to be higher during high solar activity period. The correlation between magnitudes of cosmic ray Forbush decreases and magnitude of geomagnetic storms are found positive and high for solar cycle 23.CME speed show normal correlation with Fd magnitudes. Large amount of Fds are associated with CMEs and M-Class solar flares.

KEY WORDS: Cosmic rays, Forbush decrease, geomagnetic storms

Forbush decrease (Fds) is a transient and rapid decrease in the observed galactic cosmic ray intensity followed by a gradual recovery typically lasting several days (Forbush ,1938; Lockwood ,1971). Forbush decreases occur when the sun releases an exceptionally large burst of matter and magnetic disturbance (magnetic cloud). The disturbance sweeps away some of the cosmic ray energetic particles in its path and prevents many cosmic ray particles from entering the atmosphere. Various theories and models have been proposed by many investigators to explain Forbush decreases (Fds). Some of the models are based on enhanced drift while others are concentrated on diffusion of scattering models both drift and scattering mechanisms suggest that the magnitude of Forbush minimum is proportional to the magnetic field strength and irregularities in the associated interplanetary disturbances (Barnden, 1973). The two step Forbush decreases are caused by the combination of shocks and CMEs, the first step is connected to the turbulent structure behind the shocks, and the second step is connected to the enhanced magnetic field and loop-like field configuration of the CMEs (Cane, 2000). The component related to the shocks shows a gradual decreases and slow recovery while the ejecta component starts, with the ejecta arrival and the effects of superposition shocks and CMEs lead to the rather complex structure in the intensity profile of Fds. It is well known that coronal mass ejection events produce major disturbances in solar wind and interplanetary magnetic field. It has now been proved by the recent studies of Forbush decreases with coronal mass ejections and the interplanetary shocks, magnetic clouds, ejecta which are interplanetary manifestations of coronal mass ejections that the Forbush decreases are strongly associated with CMEs (Cane, 2000; Shrivastava and Singh, 2008). Zhang and Burlaga (1988) concluded that relatively large decreases in cosmic ray intensity is associated with magnetic clouds that are preceded by a shock, whereas only a small decreases in cosmic ray intensity is associated with magnetic clouds that are not preceded by shock. Badruddin (2002) has reported that abrupt onset of decrease in intensity starts upon the arrival of certain shocks and decreases continue till the passage of post shock turbulent sheath. He has further determined that turbulent shocks are much more

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effective in producing Forbush decreases than non-turbulent shocks. He reported that halo CMEs are more effective transient modulator of cosmic ray intensity than other CMEs, and produces significant Forbush decreases. Cane et al., (1996) have studied Forbush decreases for 30 years period with coronal mass ejection and found that 86% FDs are associated with CMEs and interplanetary shocks that they generate. They have further concluded that depth of the Forbush decreases is dependent on the Helios longitude of the active region which ejected the associated CMEs. Cane et al., (1997) have inferred that the short term cosmic ray decreases are strongly associated with ejecta and shocks. They have reported that 88% short term cosmic ray decreases are associated with ejecta and 70% of these are associated with shocks. According to Cane (2000) CMEs are plasma eruptions from the solar atmospheres involving previously closed field region, which are expelled into the interplanetary medium. The ICMEs (interplanetary CME), termed as "ejecta", may may generate shocks. When earth enters such a "shocks followed by ejecta" combination, the first step in the classical Forbush decrease is due to entry in the shocks. A majority (>80 %) of short term cosmic ray decrease (FDs) >4% are of the two step (shocks and ejecta) type(Cane, 1996).Thus both the shocks and CMEs are responsible for Forbush decreases (FDs). Kane (2010) studied that all interplanetary disturbances having shocks and directed towards the earth are geoeffective, giving at least a storm sudden commencement (ssc) and giving Dst depressions in a wide range -10 to -500 nT. Gupta (2010) have investigated the solar sources and features of interplanetary structures associated with big geomagnetic storms(GS)and large Forbush decrease (FD) events. They have concluded that shock-associated CMEs can produce both large FDs and big GS. FDs and GS are likely to be closely correlated partially due to their common causes from solar and interplanetary disturbances. However, the magnitude, durations and time profiles of both phenomenon (FD and GS) are related to the interplanetary structures and their associated feathers. Both increase with increasing interplanetary magnetic field and solar wind velocity. Recently, Shrivastava et al. 2011 have reported that major solar flares occurring in western hemisphere of sun in association with halo coronal mass ejection produce large number of FD events.

DATA AND ANALYSIS

In this investigation hourly count rate of cosmic ray, recorded by Oulu neutron monitor [situated in Northern Finland (65.05ºN, 25.47ºE)] for solar cycle 23 (1996-2007) has been used to determine Forbush decreases (FDs). In this work we have selected only those Fds, which have decrease greater than 4%. For interplanetary parameters Omni web data site is used. Data of CMEs derived by CME catalog SOHO LASCO observations (daw.gsfc.nasa.gov/cme-list). Solar flare data have been taken from Solar Geophysical data book (NOAA/NESDIS/NGDC-STP, Boulder).

RESULTS AND DISCUSSION

We have observed 54 Forbush decrease (magnitude ≥ 4.0%) during the period of 1996-2007, which cover the solar cycle 23. FDs with magnitude in between 4 to 6 % are found to be more frequency of occurrence. In our analysis, 80% Fd events are found in range of 1 to 3 days main phase duration. On the other hand recovery duration is found in between the range of 3 to 8 days. We have plotted the number of Fd events for the years of 1986 to 2007 along with yearly mean values of sunspot numbers. It can be seen from the fig. (1) that Fd become in high frequency as sunspot increases. And less number of Fds is found during low solar activity period. Further we have extended our analysis to derive the relationship of Fd magnitude with magnetic storms magnitudes. Magnetic storm is an event in geomagnetic activity which shows a large decrease in geomagnetic field of earth. Similar to Forbush decreases, solar and interplanetary disturbances are the causes of geomagnetic storms. Fig. (2) Shows the correlation between FDs magnitude and magnitudes of geomagnetic storms for the period of 1996 to 2007. Scatter plot shows a positive and high correlation (0.554) between these two cosmic ray forbush decreases and geomagnetic storms. Recently, coronal mass ejections are found to be one of the main factor in short-term cosmic ray intensity variation (Jothe et al., 2010; Shrivastava et al., 2011). To associate the CMEs with

Fd events ,we have taken the CME speeds for the period of 1996 to 2007 and correlated these with Fd magnitudes as shown in Fig. (3). A normal correlation with correlation coefficient 0.25 is found. It indicates a possible influence of CMEs on cosmic ray forbush decreases. Fig. (4) shows that 75% Forbush decrease are found to be associated with solar flares and out of these 34% majority of Fd events are associated with M-class solar flares. Fig. (5) Shows the combine effect of CMEs (full halo & partial halo) and solar flares on cosmic ray intensity. It is found that 20 flares are associated with 25 full halo CMEs and 05 flares are associated with 08 partial halo CMEs out of 54 FDs (≥4%). These results suggest that the Forbush decreases of higher magnitudes may be produced by turbulence in interplanetary medium by solar and interplanetary process.

It is proposed that short term cosmic ray decreases are due to perturbations in the interplanetary medium caused by shock waves. It is also believed that at the time of an explosive solar flare, gas is ejected from the flaring region of the Sun in the form of a plasma cloud and when the plasma cloud arrives at the Earth it produces the decrease in cosmic ray intensity. A simultaneous occurrence of multiple CMEs will also produce a strong shock front or magnetic field discontinuity and will provide the mechanism for the initial reduction of the cosmic ray intensity at the earth.

Fig.1. Shows the yearly frequency of occurrence of Fd events along with Yearly mean values of sunspot numbers

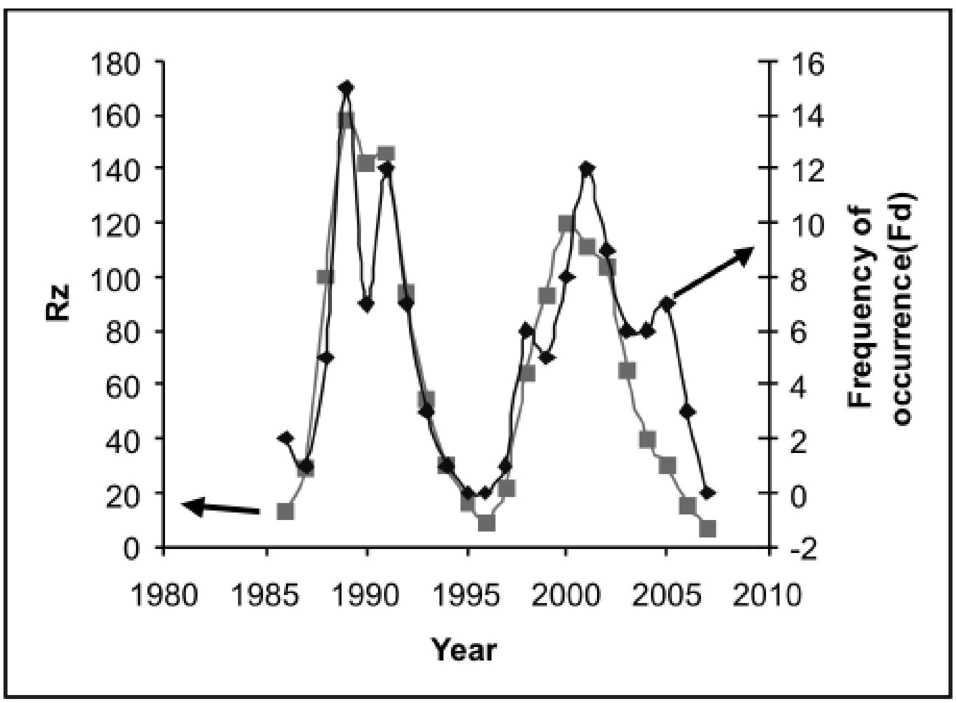


Fig. 2 : Association of magnitude of FDs magnitude with mag.storms magnitude

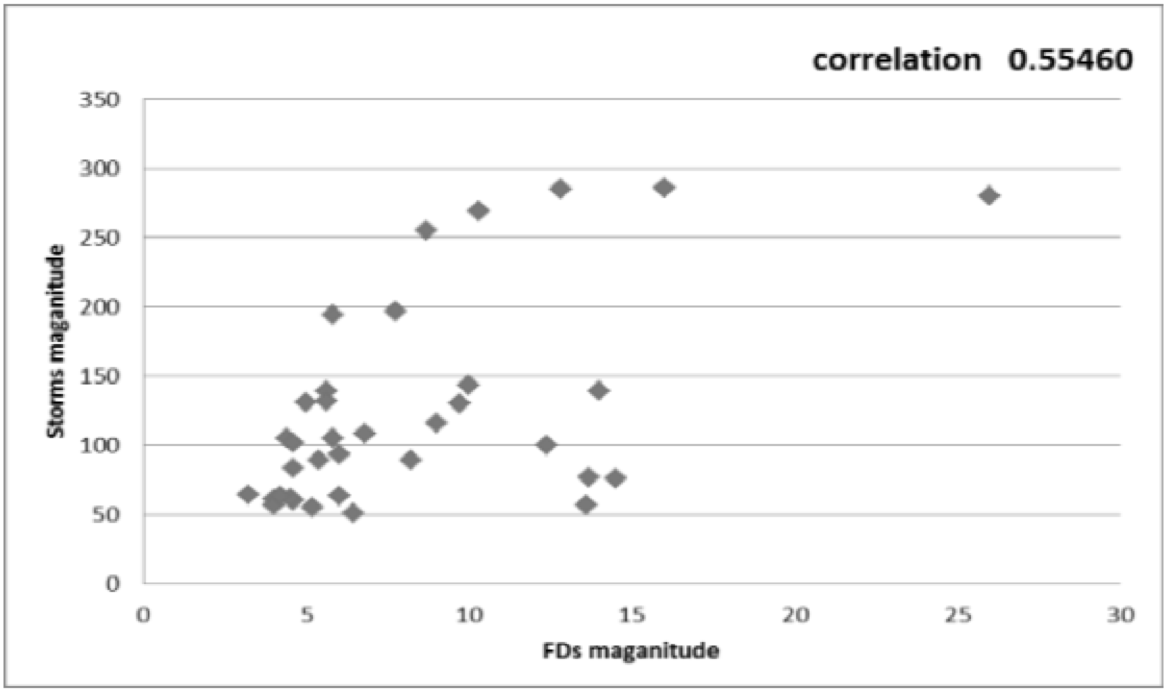


Fig. 3 : Association of FDs magnitude with CMEs speed

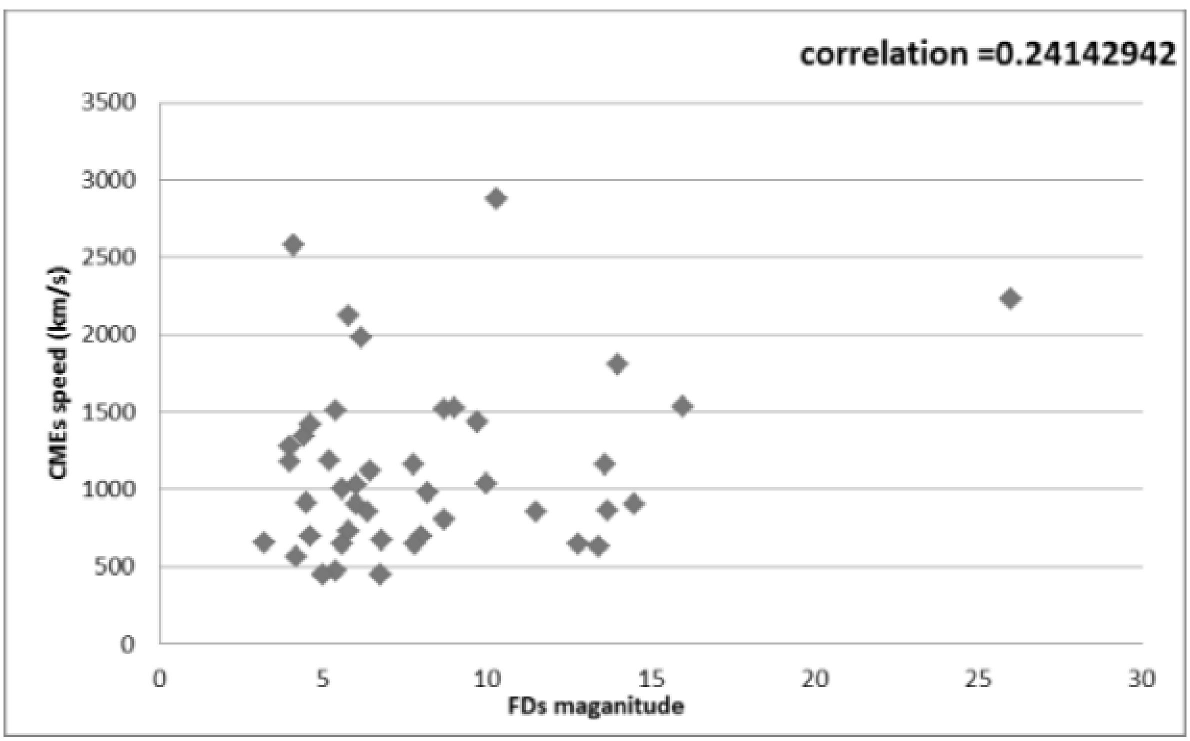


Fig. 4 : Association of types of Fd associated solar flares in its three categories

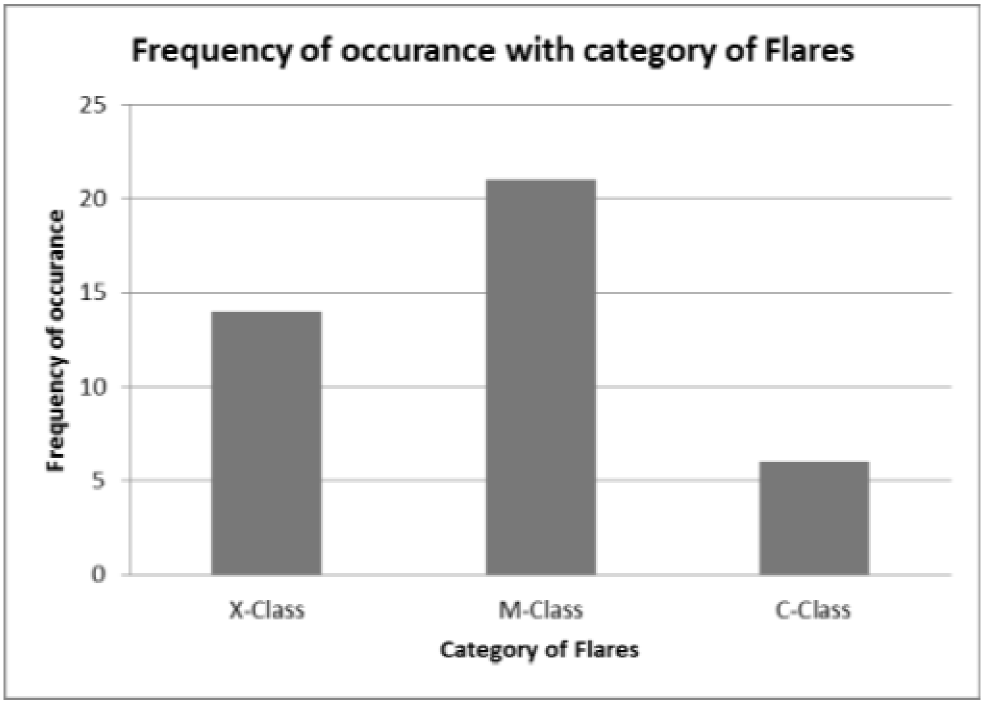
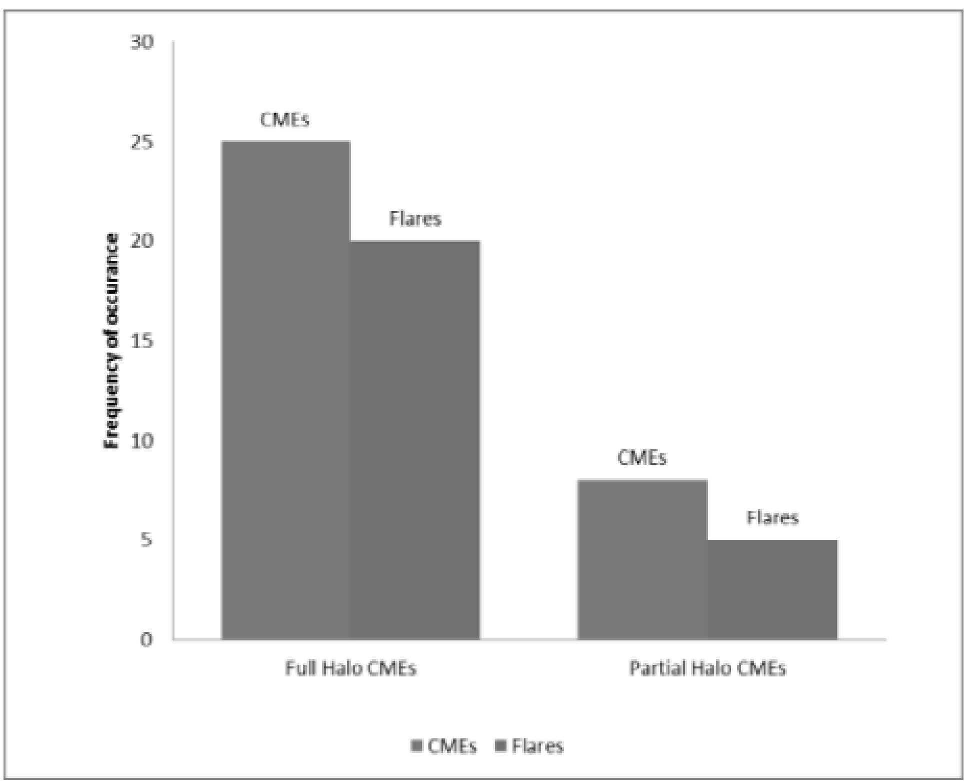


Fig. 5: Association of Full Halo CMEs and Partial Halo CMEs with flares on Cosmic ray decrease



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