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Characteristic association of geomagnetic storms and forbush decreases

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Abstract

An attempt has been made to associate the characteristics of major geomagnetic storms and forbush decreases at 1 AU between 1999 and 2009. Most probable value for the Onset time difference is found between -1 to + 5 hours. It was also observed that majority of geomagnetic storms lag Forbush decreases only few geomagnetic storms lead Forbush decreases. 48.9% geomagnetic storms are found in the range of 0 to 10 hours, so that most probable value of main phase duration is 0 to 10 hours and recovery of geomagnetic storms are much faster than forbush decreases.

Keywords: Geometric, Storms, Forbush

Introduction

The geomagnetic storm is in short a sequence of varying magnetospheric response to the varying conditions in the interplanetary space, which are caused by a solar storm. A well-developed geomagnetic storm comprises of different phases as S.S.C. (sudden storm commencement) and/or S.I. (sudden impulses), initial phase, main phase and recovery phase. Forbush decreases are large sudden asymmetrical depression observed in the cosmic radiation at the earth lasting several days. Forbush decreases in cosmic ray intensity have been observed to propagate outward in the ecliptic plane at the speed of solar wind about 400-500 Km/Sec. During this period the geomagnetic field is usually disturbed, many a times starting with a storm sudden commencement which is followed by a depression in its horizontal component in the equatorial region, studies of forbush decrease and geomanetic storms make it possible to consider that these effects are associated with transient of a shockwave generated after solar chromospheric flare.

Forbush decrease in the vicinity of 1 AU generally consist of two components or steps[1-4]. Observationally, the first step is related to the shock arrival at the Earth. The second step is connected to the entry of the observer into a region of enhanced field magnitude and a loop like field configuration. Iucci *et al.,* discussed the different longitudinal variations of the two steps and the correlation of their amplitudes with interplanetary parameters[5]. The relations between cosmic ray decrease and various types of interplanetary disturbances have partly led to conflicting results. Lockwood *et al.,* discussed Forbush decrease associated with shocks and magnetic clouds and concluded that magnetic clouds are not very effective in producing the maximum depression of a Forbush decrease[6]. It was found that the minimum depression is observed in many cases only after the arrival of the magnetic cloud[3,7].

Data analysis

We have classified major geomagnetic storms and Forbush decreases for the year 1999 to 2009. The selection criteria for major geomagnetic storm is Dst value greater than 60Y and for Forbush decreases it must be greater than or equal to 3 percent. To know the correlation between the frequency of occurrence with different phases of geomagnetic storms and Forbush decreases viz. Onset phase, main phase and recovery phase. We have classified geomagnetic storms which are associated with forbush decreases. For onset time phase, the time of occurrence of geomagnetic storms and forbush decreases have been noted and then time difference between them has been calculated in hours. Similarly for main phase duration and recovery duration of both type of events have been calculated in hours with respect to frequency of occurrence. In figure 1 the onset time difference of geomagnetic storms and forbush decreases was plotted with respect to frequency of occurrence.

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It is clear from the graph that most probable value for the said difference is in between-1 to + 5 hours. We observed that majority of geomagnetic storms lag Forbush decreases only few geomagnetic storms lead Forbush decreases

For main phase duration, all the events have been classified in the range of 0-5, 5-10, 10-15, -------, 45-50 and more than 50 (keeping in mind the frequency of occurrence) then percentage have been calculated. Figure 2 shows the correlation between the frequency of occurrence in percent and main phase duration of geomagnetic storms. 48.9% geomagnetic storms are found in the range of 0 to 10 hours, so the most probable value of main phase duration is 0 to 10 hours. Similarly, frequency histogram is plotted for the main phase duration of Forbush decreases with respect to frequency of occurrence (in percent). We found most probable value of main phase duration is in between 5 to 30 hours (Fig. 3).

The recovery phase is duration between the maximum decrease point to the end of the event, but the end of the event has been considered as the time when Dst value reaches some constant level for few days provided that no other event is seen at the recovery time. We have sorted out the recovery duration of geomagnetic storms and Forbush decreases in the interval of 0-10, 10-20......90-100 and greater than 100 and frequency histogram is plotted with respect to frequency of occurrence in percent (Figure. 4 and 5). The ratio of recovery duration of both the events varied greatly. From Fig. 4 and Fig. 5 it is clear that the recovery of geomagnetic storm is faster than the recovery of Forbush decreases.

Results and analysis

The characteristics of magnetic storms and Forbush decreases were not found correlated to each other. However, The time difference between the onset time of Geomagnetic storm and Forbush decrease is found less than 5 hours in most of the cases. In most of the cases main phase duration of Geomagnetic Storm is less than 10 hours. But Forbush decreases have main phase duration of five to thirty hours. Recovery of Geomagnetic storms are much faster than Forbush decreases; however, we found no quantitative relation between them.

The initial phase of the geomagnetic storm is the result of interaction between the past shock solar wind and the magnetosphere. The duration of main phase is highly variable and may persist from a few minutes to more than six hours or more. The H-component, in low and middle latitudes, increases by few gamma in few minutes. In the Polar Regions at about dipole latitude 80 degree in the sunlit sector, this phase is characterized by a large activity after the S.S.C. and convection of magnetospheric Plasma in the Polar Regions enhances considerably. The initial phase is followed by the main phase, which is characterized by a decrease of mean value of H, first below the high mean of the initial phase and than below the normal prestorm value. The value of H decreases by several hundred of gammas in a few hours. The main phase varies from 5 to 30 hours or even more. The main phase depression has two components, one is isotropic component Dst which is common for all longitudes and other is the D.S. component, which is local time dependent in fact during the main phase of geomagnetic storms, all or most of Dst (H) has been attributed to the growth of symmetrical ring current within the magnetosphere, and the field of this current is denoted by D.R. (D for disturbance, R for ring current). The case of the negative Dst during the geomagnetic storm has been ascribed to a westward ring current arching the Earth. The declination Dst (D), shows practically no storm time change and Dst (z) is much smaller than Dst (H) except in the polar cap where Z component shows a large positive change. Any change of external D R magnetic field induces electric current within the Earth. This induced current produces an additional field, and therefore on the surface of the earth, we observe the combination of the external and internal (induced) Dst and DS Fields. Main phase of a geomagnetic storm is followed by recovery phase during which the value of H comes back to its prestorm value in few tens of hours. During recovery the injection of particles into the ring current drops and decay rate exceeds the injection rate.

The first important parameter for defining the characteristics and its relationship with interplanetary medium is onset time. The features of the onset times may be completed by the strong special anisotropic that usually exists during the onset period. Sandstorm observed that early onset occurred almost always for stations whose asymptotic directions were towards the west of the earth sun line. The position and angular width of the early onset zone varied from event to event, whereas the time difference in the onset time in different events has been observed to range from two to four hours. The second but most important factor for characterizing the forbush decrease is main phase. In this phase the value of cosmic ray intensity dips considerably upto the level of 3% to 15% or more. The magnitude of forbush decrease varies within very wide limits from one event to another. The forbush decreases are found to occur with equal probability during all the solar cycles with slightly longer tendency during sunspot

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maxima but the magnitude of forbush decreases are found to be larger after sunspot maxima. Locwood[7] observed that magnitudes of forbush decrease depend upon the cut off rigidity and location at which the detector is situated. He found magnitude is nearly 2.0 to 2.5 times large at a station with vertical cut off rigidity 1 GV than at equatorial stations with cut off rigidity 15 GV. The last but not least phase is recovery phase in which the cosmic ray intensity reaches from its minimum value to some constant level for a few days. The recovery duration generally lasts for several days but in some cases where large forbush decrease occurs it may take several weeks. Webber[8] observed that exponential function

$$\mathbf{I=I_0 exp\ (-t/t_o)}$$

Satisfies in a smooth recovery where

I is difference between the pre-decrease and recovery phase intensity, $\mathbf{I_0}$ is the maximum aplitude of decrease, **t** is the time after the onset of the decrease, t0 is the characteristics time constant during the recovery period. Usually the recoveries of forbush decreases are very irregular and are very sensitive towards many other small transient variations. It has been found by number of authors that stations located at equatorial latitudes recover more quickly than others.

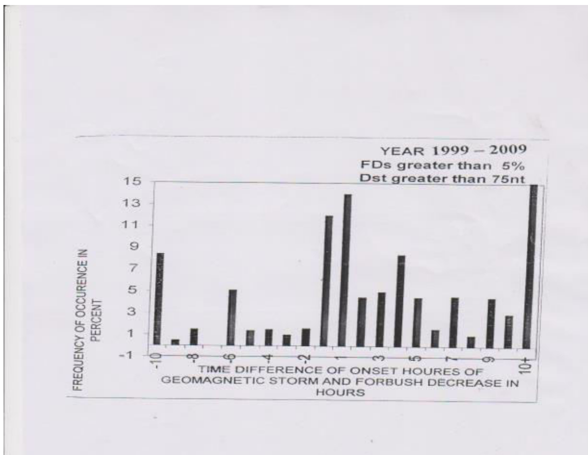

Fig. 1 shows frequency of occurence(in percent) for time difference between onset time of major geomagnetic storm and forbush decrease

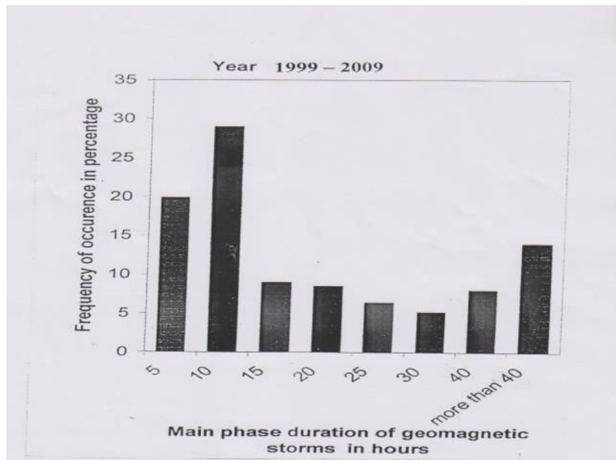

Fig. 2 Shows the main phase duration of geomagnetic storms in different time interval

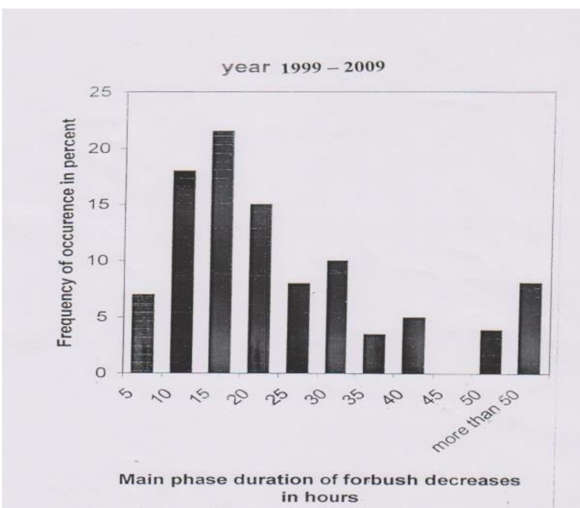

Fig. 3 Shows the main phase duration of forbush decreases during different time interval

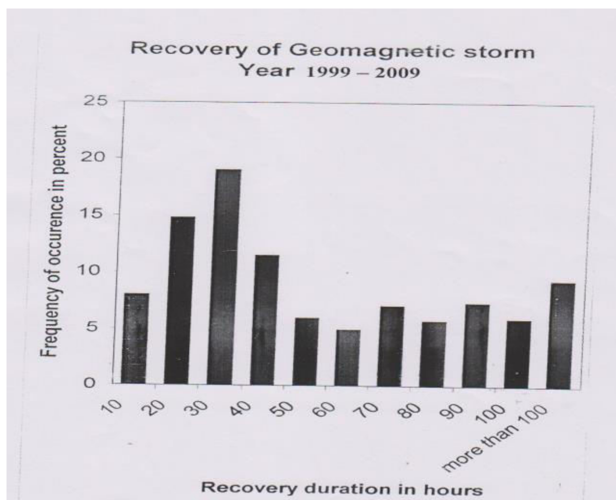

Fig. 4 Shows the recovery duration of geomagnetic storm in different time interval

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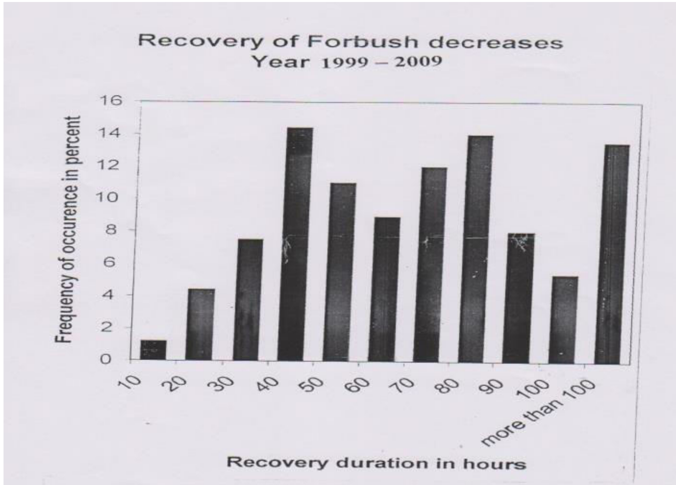

Fig 5 Shows the recovery duration of forbush decreases during different time interval

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