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Solar Latitudinal Distribution of Solar Flares around the Sun and Their Association with Forbush Decreases during the Period of 1986 to 2003

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Abstract

Solar flare events of high importance were utilised to study solar latitudinal frequency distribution of the solar flares in northern and southern hemisphere for the solar cycle 22 to recent solar cycle 23. A statistical analysis was performed to obtain their relationship with sudden storm commencement (SSCs) and Forbush decrease events (Fd) of cosmic ray intensity. An 11-year cyclic variation pattern was seen in occurrence of number of events for solar flares, SSCs and Fds. It was noted that number of solar flares (Fd associated) occurred in southern hemisphere was larger as compared to that in northern hemisphere for the solar cycle 22. Situation reversed, as we associated SSCs and Fds. Northern hemisphere was found more active for the solar cycle 23.

Keywords: Solar flares; Cosmic rays; Forbush decrease

1. Introduction

It has been known that several sporadic cosmic ray intensity variations such as Forbush decreases, transient decreases and Ground level enhancements have their common source of origin at the sun. Solar flares are considered one of the major factors in solar physics as they release vast amount of matter and radiation in short-interval. Earlier observations of solar flares indicate that their occurrence in northern and southern hemisphere is not uniform [2,8]. Distribution of solar flares around the sun and their association with various geomagnetic and cosmic ray decreases have been studied time to time by several workers [4,6,10]. The solar flare ejecta do have proportional characteristics over long distances in the interplanetary space and expected to be a better solar event for the cosmic ray time variation studies. In this paper, we derived the helio-latitudinal frequency distribution of major solar flares on solar disk for the recent solar cycles 22 and 23. The association between solar flares and SSCs and also one of the sporadic variation of cosmic ray intensity (Fds) were studied. Forbush decrease is a sporadic variation in cosmic ray intensity where the sudden decrease is followed by a slow recovery typically lasting for several days.

2. Data and Method of Analysis

In this study, we have selected all the major solar flare events which have optical importance $\geq$ 1, for the period of 1986 to 2003. Selection was made from the

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list of routinely published solar flares in the Solar Geophysical Data book. Only those major solar flares were considered, showing a time association with Fds or with both the Fds and SSCs events. To relate these solar flares with the occurrence of SSCs/Fds possible time lags of +1 to 3.5 days have been considered. Due to the 27-day rotation of sun, it is expected that the event near earth will occur with certain delay compared to the time of the solar flare. This is due to finite time taken by the solar wind and the associated magnetic field to propagate near earth.

3. Results and Discussion

Solar active regions were identified by location of major solar flares. The cosmic ray intensity monitored at neutron monitor energies showed an eleven year cycle variation pattern [9,11]. This solar modulation takes place as galactic cosmic rays propagate through the region around the sun. Recently, Shrivastava [10] has reported that the flares occur in zones between 15° North to 30° North and 0° East to 30° East are more effective in producing Fd events in cosmic ray intensity. In this analysis, we have an approach slightly different from that used by earlier reports [4,10].

Figure 1 shows the yearly mean values of sunspot numbers along with number of events of solar flares, SSCs and Fds for the period of 1986 to 2003. One can clearly observe 11-year cyclic variation in all these four factors representing the solar, geomagnetic and cosmic ray indices. Minimum values concede on minimum solar activity as on 1986 and 1996. Higher values are evident during the period of 1989 to 1991, with a small decrease in 1990, which also represent a mix polarity year. On the other hand during the maximum phase of solar cycle 23, small decreases are seen only for SSCs and Fds in the year 1999. To derive the relationship of occurrence of solar flares with Fd events, first of all we considered only those solar flares associated with the Fds. We identified 326 and 127 solar flares which were found to be associated with Fds for the solar cycle 22 and 23, respectively. Figure 2 shows the solar latitudinal frequency distribution on the solar disk of solar flares associated with Fds during the period of 1986 to February 1996, which represents whole solar cycle 22. The flare location was summed up over 10° helio-latitudinal interval. It is noted from Figure 2 that the number of flares occurred in the southern hemisphere is significantly larger as compared to that in the northern hemisphere. It indicates that the majority of flares occurred in southern hemisphere are more active in producing Fd events in cosmic ray intensity. Observation of larger number of solar flares in southern hemisphere is probably associated with the preponderance of the sunspot numbers in that hemisphere. It has been reported earlier that the solar activity could be more in one or the other hemisphere depending upon the phase of the 22-year magnetic cycle [5]. Similar analysis is extended for the period of March 1996 to 2003, which cover the ascending and high phases of solar cycle 23. One may see from Figure 3 that the situation is reversed for solar cycle 23 and larger number of flares is seen on northern hemisphere. For the further analysis, we considered only those events associated with SSCs and Fds. 173 and 69 events of solar flares were identified in this category for the solar cycle 22 and 23, respectively.

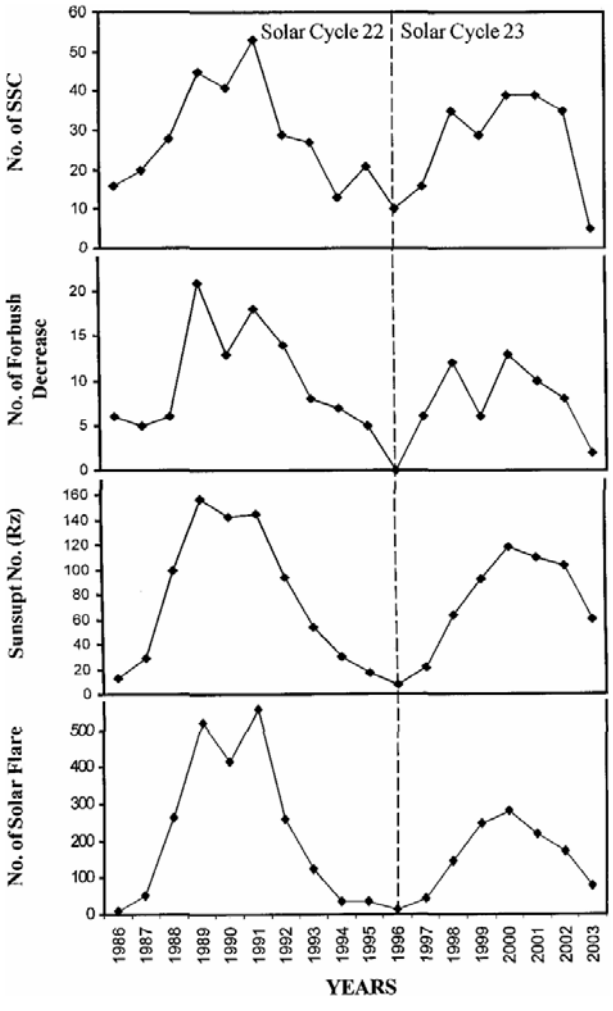

Figure 1. Yearly mean values of sunspot numbers are plotted along with number of solar flares, SSCs and Forbush decrease events for the period of 1986 to 2003.

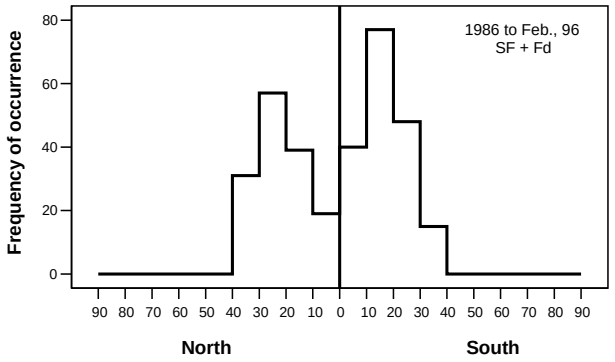

Figure 2. Shows the frequency of occurrence of solar flares with helio-latitude in interval of 10° for the year 1986 to February, 1996. A group of 326 solar flares is in association with Fd events.

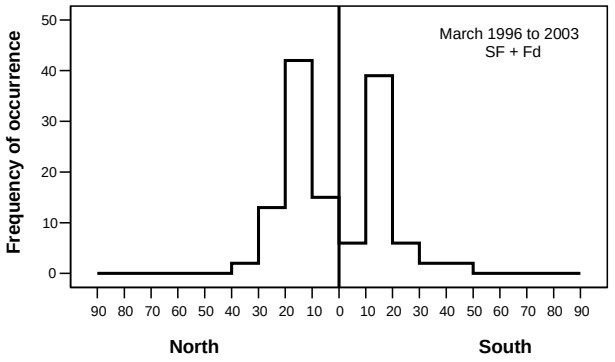

Figure 3. Shows the helio-latitudinal distribution of 127 solar flares for the period of March, 1996 to 2003.

The helio-latitudinal distribution of these 173 and 69 solar flares are plotted in Figures 4 and 5, respectively. It is concluded from the Figure 4 that the frequency distribution pattern is almost similar in both the hemisphere northern and southern. We observed that larger numbers of flares have been occurred in northern hemisphere in comparison to southern hemisphere for the period of 1986 to February 1996. We observed almost similar result for the extended period of March 1996 to 2003 as shown in Figure 5. In this way we can infer that the majority of solar flares occurred in northern hemisphere of sun are more active in producing both the SSCs and Fd events. Forbush decrease in cosmic ray intensity has generally been explained as due to the shielding of cosmic ray particles by the shock fronts produced by an intense solar flare [3]. These shock fronts on interaction with earth magnetosphere produce geomagnetic field variation and SSC. The onset of Fds are generally coincident with the time of occurrence of SSC [1]. Nishida [7] has reported quantitative relationship between Fds and passage of shock fronts followed by disturbance represented by enhanced solar wind velocity and reduced field align diffusion coefficients.

Some regular structure in the interplanetary field is required for the propagation of energetic solar flare particles and to provide the magnitude of the initial intensity reduced observed given the measured magnitudes of the magnetic irregularities. A large solar flare occurs on the surface of the sun, provides the most favorable condition for the occurrence of a large Fd. About 24-72 h later from a large solar flare a Forbush decrease was observed in cosmic ray intensity data at neutron monitor energies. This proceeded about several hours by a sudden commencement of geomagnetic storms (SSC). The SSC marks the arrival of the shock front of the enhanced solar wind. This shock front, or magnetic field discontinuity provides the mechanism for the initial reduction of the cosmic ray intensity of the earth. For such a tangential discontinuity the balance equation in three dimensions can be written [12].

$$d / dr\ (4\pi\ r^3\ e) = 4\ \pi\ r^2\ (\rho_0\ V_{0d} - {}_eV_d) \qquad (1)$$

where ρ is the particle density inside and ρ_0 the density outside. V_d and V_{0d} are the particle drift velocities in the two regions respectively. For a maximum rate of decrease, put de / dt = 0, then

$$\frac{\rho}{\rho_0} \sqcup \frac{V_{0d}}{V_d} = \frac{\Delta B_0 / B_0}{\Delta B / B} = \frac{\Delta B_0}{\Delta B} \qquad (2)$$

neglecting the shuck-front velocity relative to the particle drift velocity and putting $B_0 \sim B$. From satellite data on the interplanetary field a gradient $\Delta B_0 / \Delta B \sim 0.3$ is reasonable [12]. Such a tangential discontinuity produces a massive decrease in the cosmic radiation behind the front.

4. Conclusions

1. 11-year periodicity is observed for occurrence of solar flares, Forbush decrease events and SSCs similar to sunspot solar activity cycle.

2. Majority of solar flares occurring in southern hemisphere are found to be associated with Fd events for the solar cycle 22. In contrary slightly larger number of solar flares are seen in northern hemisphere for the solar cycle 23.

3. Almost equal number of solar flares are found in northern and southern hemisphere in the case of solar flares associated with SSC and Fd for the solar cycle 22.

4. Majority of solar flares occur in northern hemisphere are found to be associated with both the SSCs and Fd events during solar cycle 23.

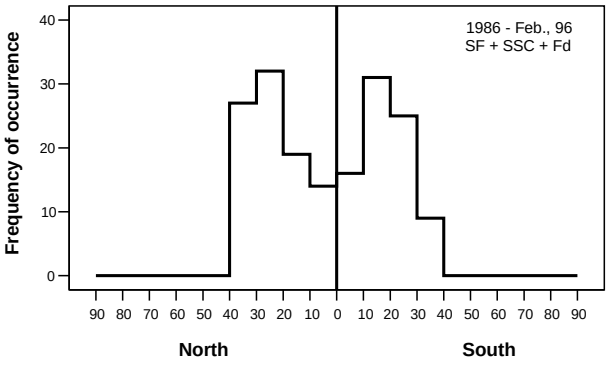

Figure 4. Shows the frequency of occurrence of solar flares with helio-latitudinal in interval of 10° for the year 1986 to February 1996. A group of 173 solar flares is in association with SSC and Fd events.

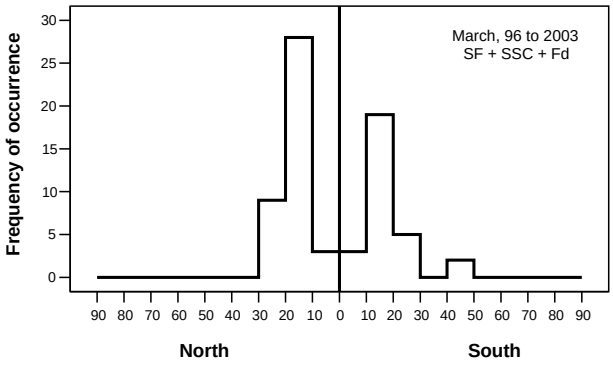

Figure 5. Shows the frequency of occurrence of solar flares with helio latitude in interval of 10° for the year March 1996 to 2003. A group of 69 solar flares is in time association with SSC and Fd events.

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