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Latitudinal Distribution of Solar Flares and Their Association with Coronal Mass Ejections

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Abstract Major solar flare events have been utilised to study the latitudinal frequency distribution of solar flares in northern and southern hemispheres for the period of 1986 to 2003. A statistical analysis has been performed to obtain the correlation between Coronal Mass Ejections (CMEs) and Forbush decrease (Fds) of cosmic ray intensity. Almost the same flares distribution in both hemispheres is found in association with CMEs. In a further analysis, it is noted that a larger number of CME-associated solar flares located in the northern hemisphere are found to be more effective in producing Forbush decreases.

Key words: Solar flares – coronal mass ejections – Forbush decrease

1 INTRODUCTION

It has long been recognized that several sporadic cosmic ray intensity variations such as the well-known Forbush decreases, transient decreases, and ground level enhancements have their common source of origin at the sun. Solar flares with their release of vast amounts of matter and radiation in a short-time, are of importance to solar physics as well as to the study of cosmic ray modulation. Earlier observations of solar flares indicated that their occurrence is not uniform in the northern and southern hemispheres (Rusin et al. 1979; Badruddin et al. 1983). Their distribution on the sun and their association with various geomagnetic and cosmic ray decreases have been studied by several authors (Hatton 1980; Garde et al. 1983; Shrivastava 2003). The flares ejecta show proportional characteristics over long distances in the interplanetary space, so the flares are expected to be good events for the study of cosmic ray time variation. Recently it has been reported that CMEs, not solar flares alone, may produce modulation in cosmic ray intensity (Shrivastava 2003b). In this paper, we derive the latitude distribution of solar flares. in solar latitude and study any association between the flares and CMEs on one hand and sporadic variation of cosmic ray intensity.

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2 DATA AND METHOD OF ANALYSIS

For the purpose of this study, we have selected most of the solar flares during the interval 1996 to 2003 with optical importance ≥ 1. The selection was made from the routine list of published in Solar Geophysical Data. Only those major solar flares have been considered, which are found to be associated in time either with CMEs alone or with both CMEs and Forbush decreases (Fds). An Fd is considered to associated with a flare if it occurs between +1 to 3.5 days after. CMEs are considered as associated with solar flares if within a the ± 1 day window. It is expected that the event near the earth will occur with certain delay compared to the time of the flare due to the finite time taken by the solar wind and the associated magnetic field to propagate to the earth neighbourhood.

Table 1 shows the different solar and cosmic ray parameters in the period from 1996 to May, 2003. We have, in total, 852 solar flares, 458 CMEs and 66 Fds in the period considered. Of the 852 solar flares 452 are associated with CMEs.

Table 1

Year	1996	1997	1998	1999	2000	2001	2002	2003	Total
Total No. of solar flares	11	20	108	163	179	165	136	70	852
Total No. of CMEs									
—Halo	0	5	10	23	56	46	21	3	164
—Partial Halo	0	8	12	37	51	21	2	0	131
—Bright Loop	0	7	8	15	49	54	25	5	163
—Total	0	20	30	75	156	121	48	8	458
Solar Flare + Halo CME	0	1	13	28	64	48	21	7	182
Solar Flare + Partial Halo	0	4	12	43	52	20	5	0	136
Solar Flare + Bright Loop	0	3	4	16	46	39	23	3	134
Total no. of soalr flares associated with CMEs	0	8	29	87	162	107	49	10	452
Total No. of Fds	0	6	12	7	14	13	10	4	66
Total No. of Solar Flares associated with Fd and Halo CME	0	1	3	1	19	14	3	3	44
Total No. of solar flares associated with Partial Halo CME and Fd	0	1	3	1	10	4	0	0	19
Total No. of Flares associated with Bright Loop CMEs and Fds	0	1	0	1	8	4	1	0	15

3 RESULTS AND DISCUSSION

Solar active regions have been identified by location of major solar flares. Cosmic ray intensity monitored at neutron monitor energies has been found to vary with an 11 year cycle (Shrivastava et al. 1993; Singh et al. 1999). This solar modulation takes place as galactic cosmic rays pass

through the region around the sun. Recently, Shrivastava (2003a) reported that the flares occurring between 15° to 30° North and beween 0° to 30° East are more effective in producing Fd events. In the present analysis, we use a slightly different approach from the earlier authors (Garde et al. 1983; Shrivastava et al. 2003a).

Figure 1 shows the solar latitude frequency distribution of flares associated with Halo CMEs during the period of 1996 to May 2003. The flare locations are taken over 10° intervals. It is noted that the number of flares occurred in both the northern and southern hemisphere are active in producing Forbush decrease events in cosmic ray intensity. Figure 2 shows the solar flares associated with partial Halo CMEs during the period of 1996 to 2003.

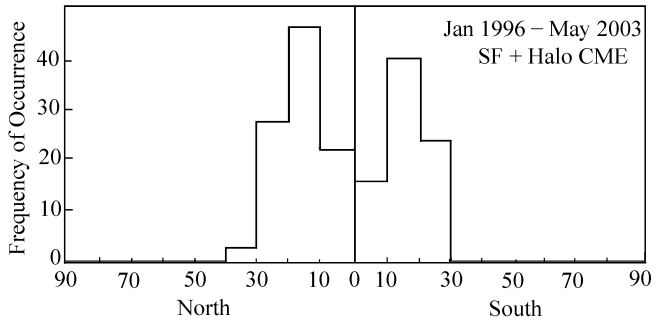

Fig. 1 Frequency of occurrence of solar flares with helio-latitude in internal of 10° for the period of 1996 to May, 2003. The group of 182 solar flares is in association with halo CMEs.

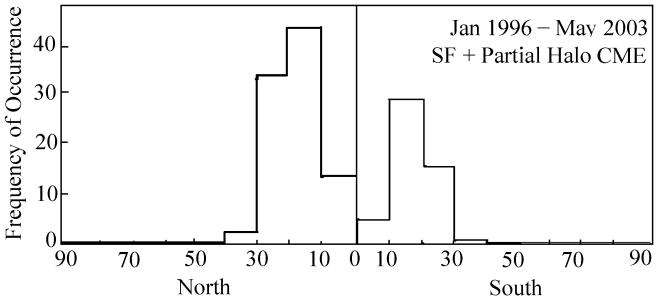

Fig. 2 Same as Fig. 1, but for the group of 136 solar flares in association with partial halo CMEs.

Similarly Fig. 3 shows the solar flares associated with bright loop CMEs during the period of 1996 to 2003. We have almost similar results in Figs. 1, 2 and 3, from which we can infer that a large number of solar flares are in association with CMEs that occur in the zone between 10° North and 30° South. Further we have extended our analysis to observe the influence of solar flares in association with CMEs on Fds for the entire period under study. During this time there were 66 Fds in cosmic ray intensity. Out of these 66 Fds, 44 are associated with solar flares and halo CMEs.

Figure 4 shows the distribution of flares associated with Halo CMEs and Fds. Similarly Figs. 5 and 6 show the distribution of flares associated with partial Halo CMEs and Bright Loop CMEs along with Fds. It can be seen from Fig. 4 that a large number of the flares occurred in the northern hemisphere than in the southern hemisphere. A similar difference can be seen in Figs. 5 and 6.

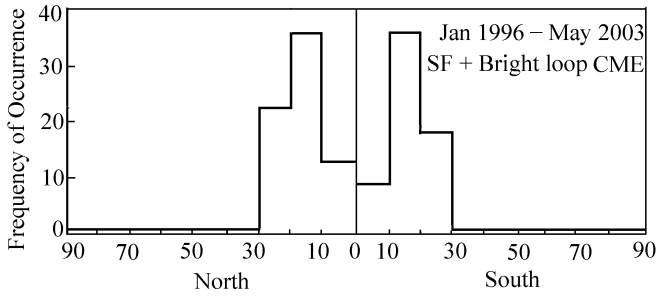

Fig. 3 Same as Fig. 1 but for the group of 134 solar flares in association with Bright Loop CMEs.

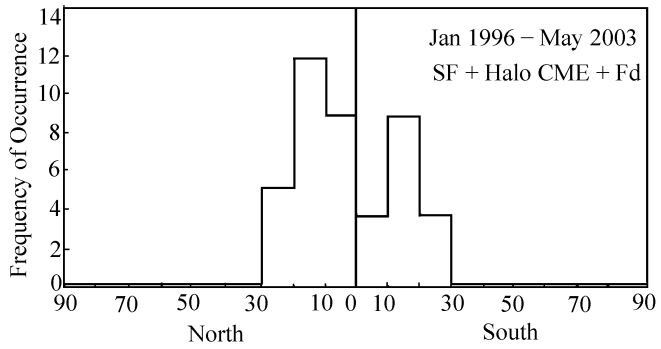

Fig. 4 Frequency of occurrence of solar flares with helio latitude in interval of 10° for the period of 1996 to May 2003. The group of 44 solar flares is in association with halo CME and Fds.

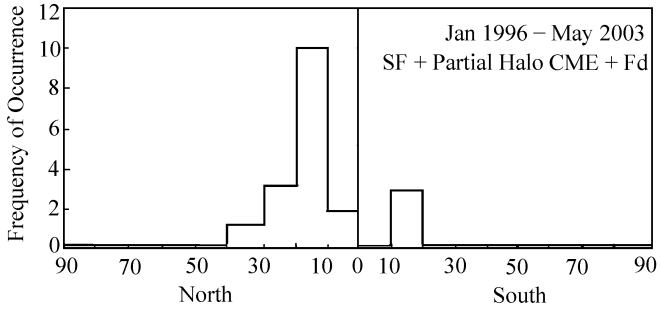

Fig. 5 Same as Fig. 4 but for group of 19 solar flares in associated with partial halo CME and Fds.

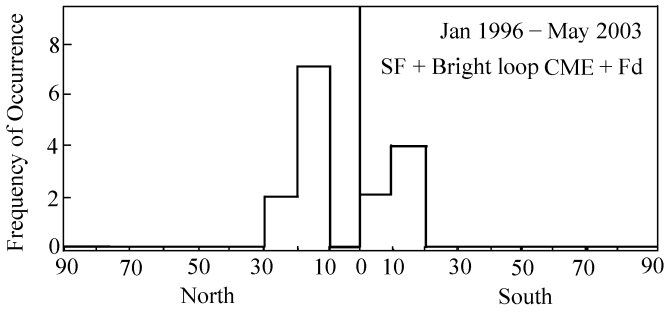

Fig. 6 Same as Fig. 4 but for group of 15 solar flares in associated with Bright Loop CME and Fds.

Therefore, we can infer that the majority of solar flares occurring in the northern hemisphere are more effective in producing Forbush decrease events. These events have generally been understood to be due to the shielding of cosmic ray particles by the shock fronts produced by an intense solar flare (Dryer 1974).

Nishida (1982) has reported a quantitative correlation between Fds and passage of shock fronts followed by disturbance represented by enhanced solar wind velocity and reduced field aligned diffusion coefficients. The number of events of different solar flares, CMEs, and Fds are given in Table 1.

4 CONCLUSIONS

1. Solar flares in association with CMEs are found to be equally distributed in the northern and southern hemispheres.
2. Solar flares in association with halo CME events are found to be responsible for producing Forbush decreases in cosmic ray intensity.
3. Solar flare in association with CMEs occurring in the northern hemisphere are found to be more effective in producing Forbush decrease events in cosmic ray intensity.

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