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Study of large solar flares in association with halo Coronal Mass Ejections and their helio–longitudinal association with Forbush decreases of cosmic rays

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Major solar flare events (Importance ≥ 1) and also associated with halo Coronal Mass Ejections (CMEs) have been taken to study their solar helio–longitudinal distribution around the sun for the period of 1996 to 2003. Analysis indicates that ~ 57% of this halo CME associated solar flares occur in the western hemisphere and ~ 43% flares occur in the eastern hemisphere. Analysis has been extended to observe the influence of major solar flares in association with halo CMEs on Forbush decreases of cosmic rays. It is found that larger numbers of halo CME associated major solar flares located in western hemisphere are found to be more effective in producing Forbush decreases.

1. Introduction

Occurrence of a solar flare on the surface of the sun is considered one of the major solar event and an impulsive astronomical phenomenon which releases vast amount of matter and radiation in short–interval. Earlier observations of solar flares indicate that their occurrence in eastern and western hemisphere is not uniform [1]. A number of research workers have studied the distribution of solar flares around the sun and their associated effects on cosmic ray modulation as well as geomagnetic field variations [2-3]. Cane et al. [4] have studied and reported the combined effect of solar flares and CMEs for producing short–term decreases in cosmic ray intensity. Recently, it has been reported that CMEs not solar flares alone may produce short–term decreases in cosmic ray intensity [5].

In this work an attempt has been done to study the helio–longitudinal frequency distribute of major solar flares in association with halo CMEs. Our aim of this study is also to identify the active longitudes for the period of 1996–2002, particularly effective for sporadic changes in CR intensity. Existence of active longitudes on the sun is well known. Bai [6] analyzed the spatial distribution of major solar flares and found active longitude zone, where the rate of occurrence of flares is much higher than elsewhere. A combined association of halo CMEs and major solar flares with Forbush decreases are studied for the recent solar cycle 23.

2. Discussion

For the purpose of this study we have selected the events of major solar flares for the period of 1996 to 2003 which have optical importance ≥ 1. Selection is made from the list of routinely published solar flares in solar geophysical data book. Only those major solar flares have been considered which are found time association with halo CMEs alone or with both the halo CMEs and Forbush decreases (Fds) events. The cosmic ray hourly intensity pots of Kiel (cut off rigidity 2.32 GV) have been used to select Fd events. Fd events having maximum decrease ≥ 4% have been taken for present study. A total 66 events of Fds have been identified during this period. To relate these solar flares with the occurrence of Fds possible time lags of + 1 to + 3.5

days have been considered. CMEs are considered as association with solar flare with ± 1 day window. Halo CME events have been taken from the internet website http://lasco6.nascom.nosa.gov/pub/losco/status/lasco_cme_list_1998. These events of halo CMEs are detected in white light observations of LASCO coronagraphs. Different combination of solar flares with CMEs, SSCs and Fds for the period of 1996 to 2003 and their helio–longitudinal distribution are given in table 1.

Table 1. East–West distribution of solar flares in different categories.

Combinations (1996–2003)	East	West	Total	Percent		$A=2\frac{(E-W)}{E+W}$
				East	West	
SF + Halo CME	79	103	182	43.41%	56.59%	-0.26
SF + Halo CME + Fd	06	38	44	13.63%	86.36%	-1.45
SF + Fd	30	79	109	27.52%	72.47%	-0.89
SF + SSC + Fd	17	52	69	24.63%	75.36%	-1.01

Figure 1, shows the solar longitudinal frequency distribution of major solar flares on the solar disk, which are also associated with Halo CMEs, for the period of 1996 to 2003. The flare locations have been summed up over 10º helio–longitudinal interval. It is noted that almost equal number of solar flares occurred in both the eastern and western hemisphere. However, slight larger numbers of flares are found in western hemisphere. Further, we have included the events of Fds in our study the investigate their association with solar flares, halo CMEs and also with SSCs. Helio–longitudinal distribution of solar flares associated with halo CMEs and also with Fds are plotted in Figure 2. It is seen from Figure 2 that large number of flare occurred in western hemisphere in comparison to that in the eastern hemisphere. In this way it can be inferred that the majority of solar flares occur in western hemisphere of sun, in association with CMEs are found to be more effective in producing Forbush decrease events of cosmic rays. The SSC associated solar flares are also found most effective in western hemisphere for producing Fds as given in Table 1. We have further derived the east–west asymmetry. Significant asymmetries are observed for all the solar flare combination. This asymmetry is mainly due to asymmetrical distribution of solar flares. Result obtained in this analysis contradicts with earlier findings of Jain et al. [7], in which effective helio–longitudinal region is found to be in between 60º East to 30º West of the solar disk.

Forbush decrease in cosmic ray intensity has generally been explained due to the shielding of cosmic ray particles by shock fronts produced by an intense flare [8]. Parker [9] proposed the shock wave production of a magnetic link or blast wave as a mechanism to reduce the cosmic ray intensity at earth during Forbush decreases. As a result of high coronal temperature the only way to dissipate coronal energy is by continuous outflow of solar material. However, following a large solar flare event when the coronal temperature increases vary rapidly in a short term, there is a sudden outward explosion of the corona. The resulting sudden injection of the fast wind pushes the slower, steady wind forwarded into a blast wave with a shock front. Those energetic solar flares, which are capable of producing sudden storm commencements, are known as geo–effective solar flares. More recently, it has been investigated that the SSC occurs within 3 to 4 days after the onset of a halo CME event [10]. It is now suggested that solar flare does not produce CME but nevertheless is a useful diagnostic for determining the longitude on the sun of which the CMEs and interplanetary shocks causing the occurrence of Forbush decreases in cosmic rays [11]. Fds are caused by CMEs and their associated interplanetary shocks, which can be associated with solar flares. CMEs associated with large solar flares usually have large speed (About 1000 kms^{-1} in some cases). In front of such a high-speed mass ejection a strong shock wave must develop. It has been suggested that type of a shock waves play an important role in modulation by acting a barrier to propagating cosmic ray particles.

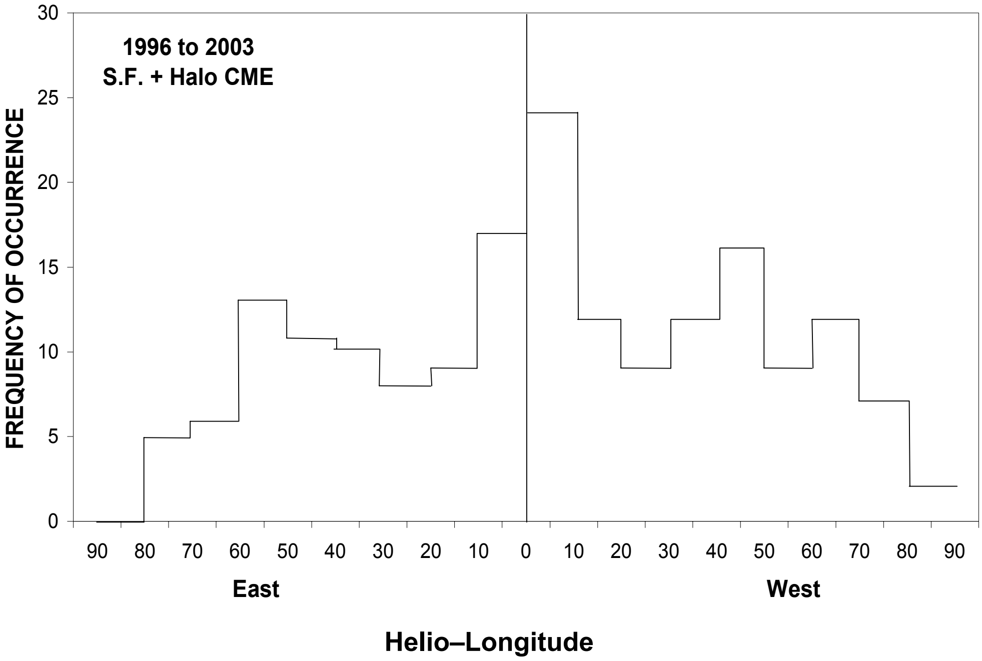

Figure 1. Shows the frequency of occurrence of solar flares with helio–longitude in interval of 10º for the period of 1996 to 2003. The group of 182 solar flares are in association with halo CMEs.

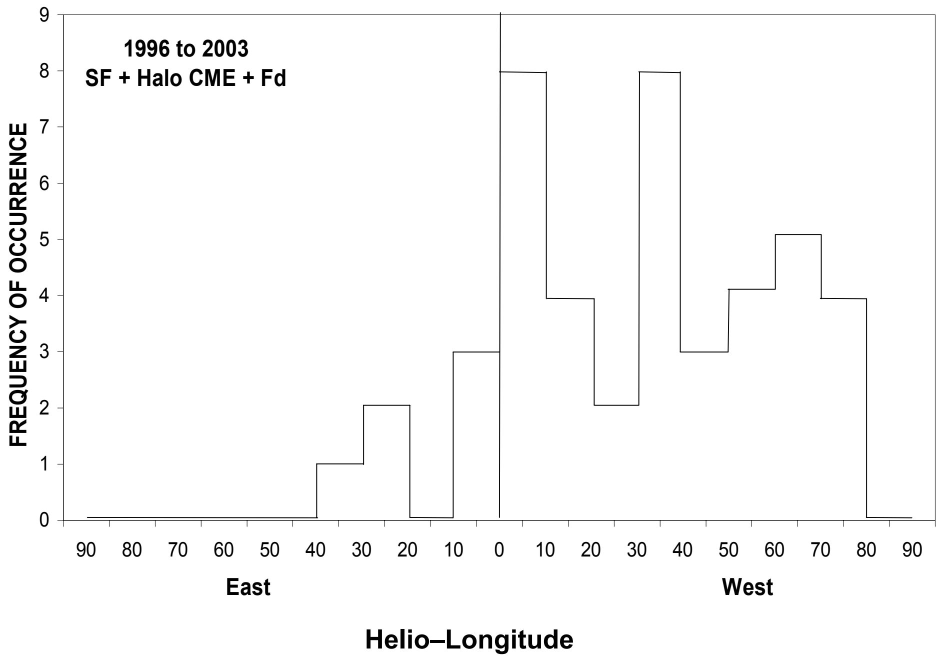

Figure 2. Shows the frequency of occurrence of solar flares with helio–longitude in interval of 10º for the period of 1996 to 2003. The group of 44 solar flares are in association with halo CMEs and Fds.

3. Conclusions

(i) Major solar flares in association with halo CMEs are found to be almost equally distributed all over the helio–longitude. However, slight larger numbers of solar flares are evident in western hemisphere.

(ii) Large number of solar flares in western hemisphere is found to be associated with Forbush decreases.

(iii) Solar flares in association with halo CMEs occurring in western hemisphere are found to be more effective in producing Forbush decreases than the flares, which occur in the eastern hemisphere.

(iv) Western hemisphere is also found effective in producing SSC and Fds for the ascending and high solar activity period of recent solar cycle 23.

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