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Association between the HCMEs and major SEP events for Solar cycle 23 & Effect of Halo Coronal Mass Ejection on Cosmic Ray Intensity and Disturbance Storm-Time index

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Abstract
The aim of this paper is to study the Association between the HCMEs and major SEP events for Solar cycle 23 and effect of halo coronal mass ejections (CME) on cosmic ray intensity (CRI)and disturbance storm-time (Dst) index for the ascending phase of solar cycle 24. A Chree analysis by the superposed epoch method has been done for the study. From the present analysis, we have During our study we have found that most of the SEP events have shown strong relationship with HCMEs rather than other CMEs we also found that the maximum decreases in CRI and Dst index takes place withinfive days after the onset of halo CMEs. Also, solar flare associated halo CMEs are found to be most effective in producing maximum decreases in CRI and Dst index in comparison to non- flare associated halo CMEs.
Keywords: *Coronal mass ejection, Cosmic rays, Disturbance storm-time index, interplanetary medium, Solar flare*

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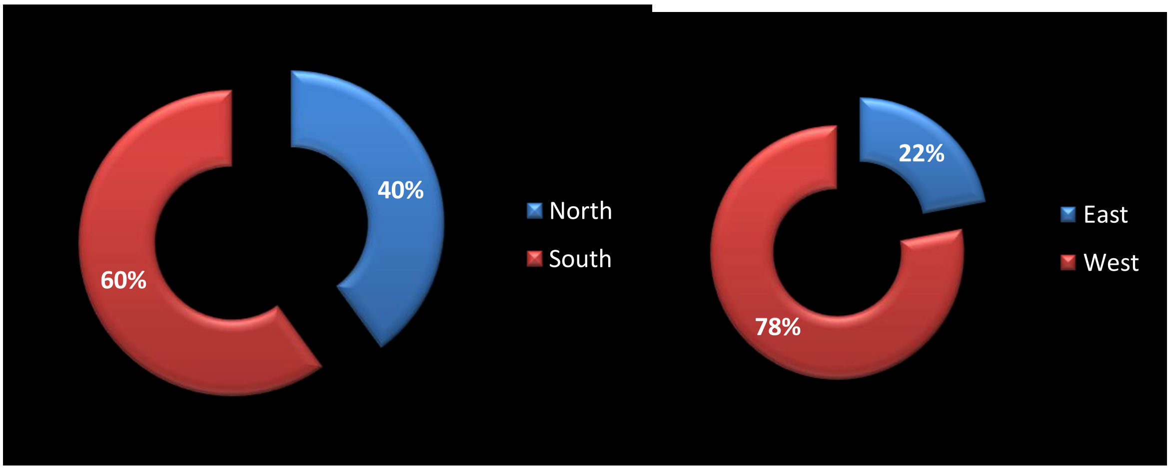
I. Data and Method

For the present study, we have used Chree analysis by the superposed epoch method. The onset days of halo CMEs with speed $\geq$ 500 km-s^{-1} is taken as zero days for the analysis. The halo CME data are taken from the SOHO/LASCO halo CME catalogue from ttp://cdaw.gsfc.nasa.gov/CME_list/halo/halo.html for the period 2009 - 2015 (ascending phase of solar cycle 24). The pressure-corrected daily mean data of CRI are taken from the Moscow Neutron Monitor Station (r0.izmiran.rssi.ru/mosc/main.htm . The daily mean values of the disturbance storm-time index (Dst index) are taken from the Omniweb data center(mniweb.gsfc.nasa.gov/form/dx1.html) . For our study we have collected the data of SEP events from the website http://cdaw.gsfc.nasa.gov/CME _ list/sepe/ while the data of HCMEs is collected from the website http://cdaw.gsfc.nasa.gov/CMElist/halo/ halo.html.

II. Results and Discussion

During our study we have found that most of the SEP events have shown strong relationship with HCMEs rather than other CMEs. The high energy of HCMEs that can create large acceleration in the charged particles may be the reason for this kind of behavior. From (Fig.1(a)) it can be clearly seen that about 78% of the events are associated with those flares whose origination is from the western hemisphere of the Sun while 22% are those whose origination is from the eastern hemisphere of the sun. From these observations we can clearly conclude that western hemisphere is effectively associated with the origination of large solar flare associated SEP events. In the similar way when we have studied the latitudinal behavior of these SEP events we have found that the southern (60%) hemisphere is more dominant in the perspective of the occurrence of HCMES associated solar flares SEP events in comparison to the northern hemisphere(40%)(Fig. 1 (b)). For the deep analysis we have divided the HCMEs associated solar flares in three classes namely:- X- class solar flare, M- class solar flare and C- class solar flare. Our analysis showed that around 50% of the SEP events are those which are associated with the X class this may be due to its high energy and intense nature while a very few events are found to be associated with the C class i.e. around 10%(Fig. 2).



(a) **(b)**

Fig. 1 : Distribution of SEP events with HCMEs associated (a) latitudinal and (b) longitudinal solar flares.

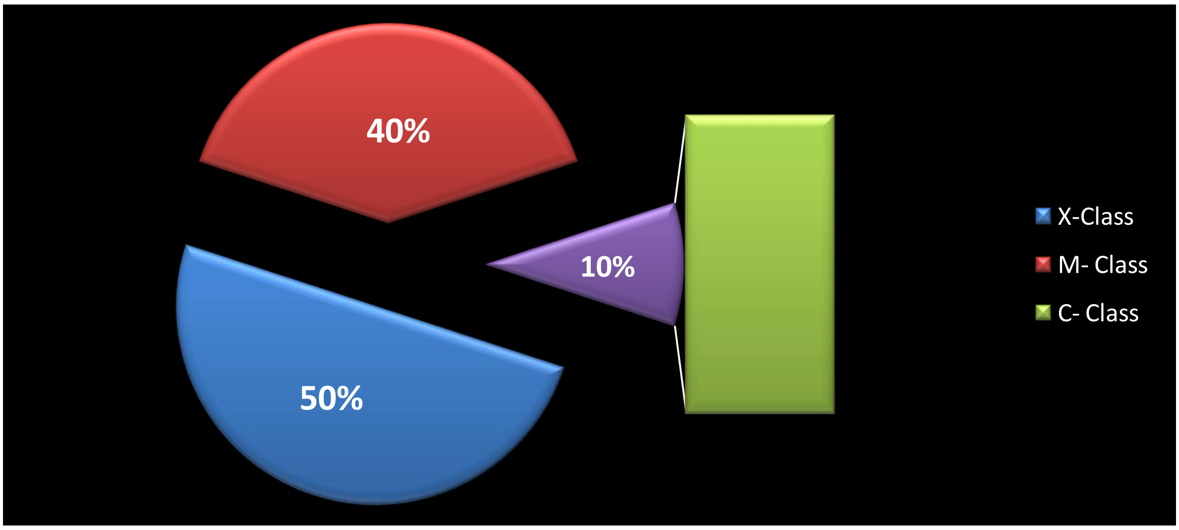


Fig.2: Association of SEP events with the X, M and C class solar flares.

Further, as it is well known that not all the halo CMEs are associated with solar flares, so their effect on CRI should be different. We have divided halo CMEs in two categories: i) flare associated halo CMEs and ii) non-flare associated halo CMEs. The variations of CRI and Dst index under the influence of flare associated halo CMEs and non-flare associated halo CMEs are shown in fig.3 and 4 respectively. It is clear from the figures that the flare associated halo CMEs produces maximum decreases in CRI and Dst index in comparison to non-flare associated halo CMEs. This may be due to the fact that halo CMEs in association with flares become more energetic and magnetized which may cause larger disturbances in interplanetary medium and hence, results more decreases in CRI and Dst index. These decreases in CRI and Dst index, due to the flare associated halo CMEs are found to be four and three days after the onset of the event,

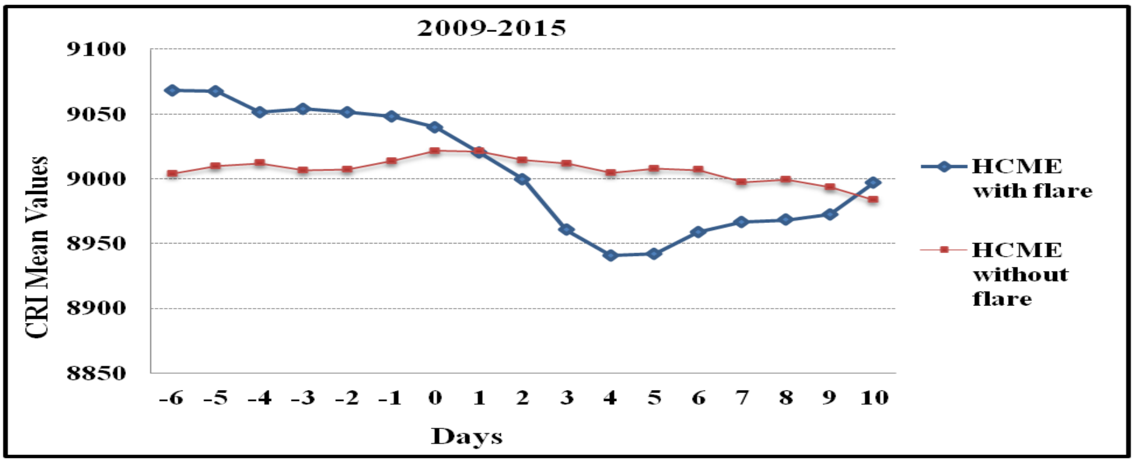


Fig.3: Variation of CRI under the influence of flare associated halo CME (HCME) and non-flare associated halo CME depicted by different symbols

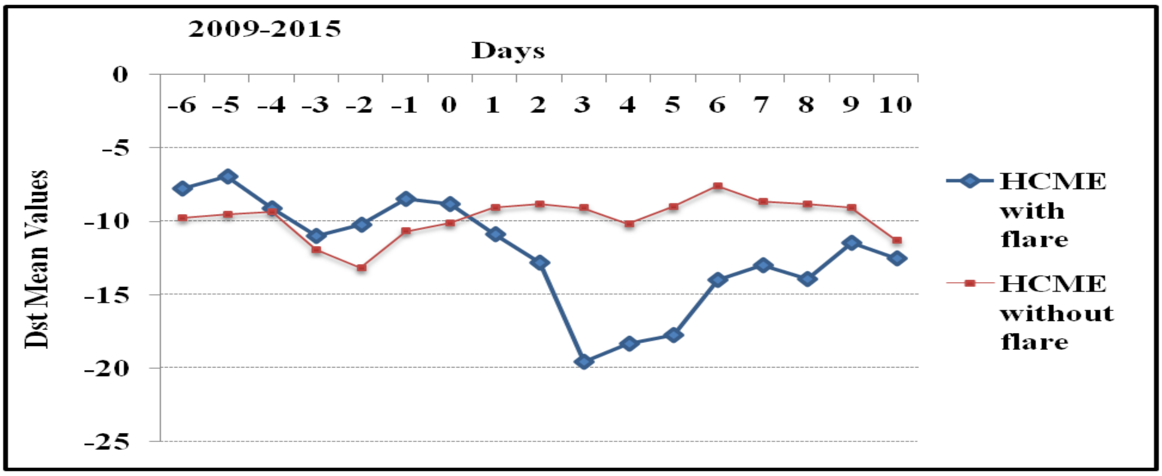


Fig.4: Variation of Dst index under the influence of flare associated halo CMEs (HCME) and non-flare associated halo CMEs depicted by different symbols.

Further we have divided the flare associated halo CME events with the class of solar flares and studied their effect on CRI and Dst index. The results are shown in fig.5 and 6. It is clear fromthe fig.4 that halo CMEs associated with X- class solar flare produces maximum decrease in CRI than the M and C-class flare associated halo CMEs. Since X-class solar flares are most energetic flares of the solar surface, so the halo CMEs becomes more energetic in association with X- classof solar flares. Hence, its effect on CRI is very high. However in case of Dst index, all the flare associated halo CMEs have almost similar effect. Although, decreases in CRI and Dst index have a common origin in interplanetary space but magnitude of both the decreases are not proportionalto each other. The Dst variations depends on the local characteristics of the solar wind flowing around the Earth's magnetosphere whereas CRI decreases depend on the condition of whole interplanetary space (Kane, 1977). The maximum decrease in Dst index is found to be three, fourand five days after the event due to M, X and C- class flare. This result of our study is in good agreement with the result of Prasad et al. (2013) who have suggested that the GSs occur within five days after the onset of event.

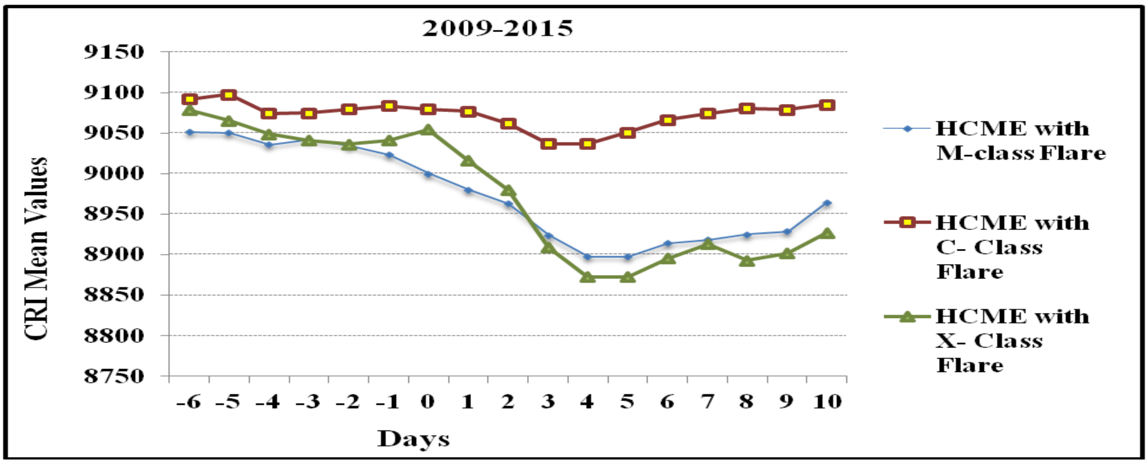


Fig.5: The variation of CRI under the influence of Halo CMEs associated with M, C and X-class solar flares is shown by different symbols.

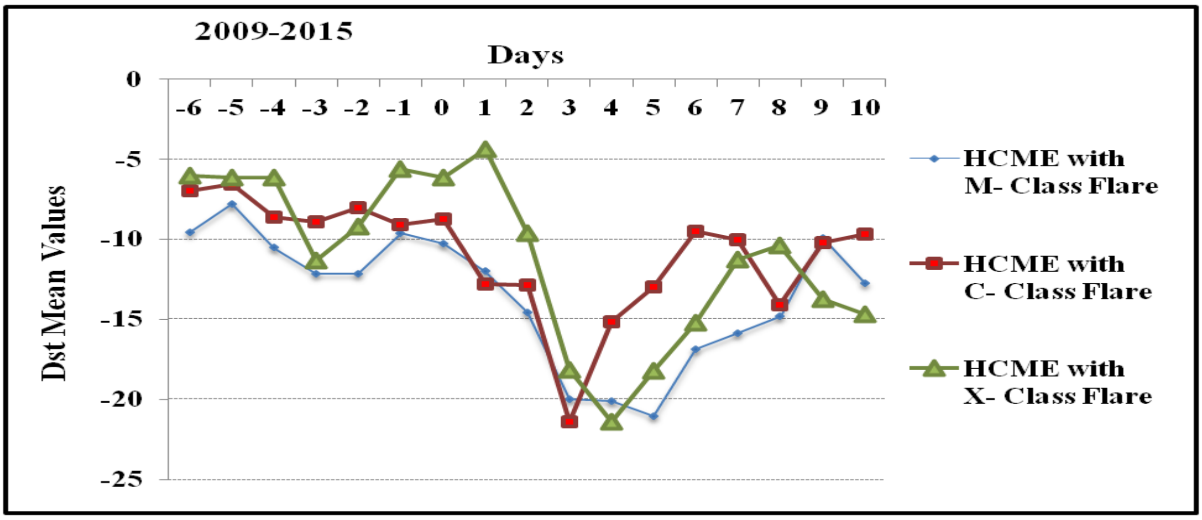


Fig.6: Variation of Dst index under the influence of Halo CMEs associated with M, C andX-class solar flares is shown by different symbols.

III. Results

A maximum decrease in CRI and Dst index is found within five days after the onset of halo CMEs.
Flare associated halo CMEs produces larger decreases in CRI and Dst index than that of without flare associated halo CMEs.
More decrease in CRI is found due to those halo CMEs which are associated with X-class solar flare.
Halo CMEs associated with X, M and C-class of solar flares has similar effect in Dst index
About 78% SEP events are linked with the western solar flares while around 22% are linked with the eastern one.
About 60% of SEPs that are associated with those HCMEs that are associated with solar flares occur in southern hemisphere while rest of the 40% occurs in northern hemisphere
Maximum SEP events (around 50%) are associated with X- class solar flares while 40% are associated with the M class and rest of the events (10%) are associated with the C class solar flares.
The X- class solar flares is about 4 times more powerful than M- class flare and these flares often associated with SEP and CMEs.
The X- class flare play a valuable role in forecasting SEP event.

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