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Study of coronal mass ejections in relation with geomagnetic activity and cosmic rays

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Abstract

Coronal mass ejections (CMEs) represent large scale changes in the solar corona as up to 10^{12} kg of matter is expelled into space. Such a huge amount of energy (10^{25} J) propagates into interplanetary medium and produces significant perturbation of the density and magnetic structure of solar wind. In this work, we have studied the relation of Coronal mass ejection with geomagnetic activity and cosmic rays for the period of 1988 to 1993. It is investigated that the coronal mass ejections in association with B-type solar flare might be the reason for the enhancement of geomagnetic field variation. Further analysis of CMEs indicate its better role in cosmic ray modulation.

1. Introduction :

Coronal mass ejections (CMEs) from the sun are now considered to be an important aspect of the physics of the corona. CMEs have considerable importance towards our understanding of the heliospheric disturbances because of the evolved amount of mass and energy injected into interplanetary medium. CMEs has gained a new prospective in recent years with the addition of out of ecliptic observations from by predominantly quiet conditions, a number of CME events have been observed (Gosling, 1996). In a number of recent studies, CME is investigated as primary cause of geomagnetic activity. In a study Kudela *et al.* (1995) report that cosmic ray "fluctuations" are almost uncorrelated with concurrent Dst values, but are well correlated with Dst 30 hour later. Recently, Biber and Evanson (1997) reported a close relationship between the occurrence of CMEs and disturbed geomagnetic condition of earth. Cane *et al.* (1996) reported a significantly relationship between CMEs and cosmic ray variations. In this work, we have studied the effect of CMEs events with geomagnetic field variation on short-term basis. Studies have been further extended to investigate such effects also on cosmic rays for the period of 1988 to 93, almost high solar activity period of solar cycle 22.

2. Method of Analysis :

In this work, the chree analysis method of superposed epoch to determine the average behaviour of cosmic ray intensity and geomagnetic activity has been adopted. Zero days are taken as starting days of events. Coronal mass ejections (CMEs) events having duration more than 5 days have been sorted out from solar geophysical data book. Daily values of Oulu (0.78 cm) neutron monitor data have been taken for analysis.

3. Result and Discussion :

A attractive scenario was proposed in the late seventies that a CME is the part of corona expelled out by the energy of the associated flare (Dryer and Wu, 1985). Early concept on the solar origin of geomagnetic storm led to the suggestion that a flare might send off a blast wave into interplanetary space to disturb the earths magnetosphere (Huandhausen, 1972). After the discovery of CMEs, it was natural to suggest the CME might be blast wave in the above scenario. I this work, we have done chree analysis of superposed epoch to determine the effects of coronal mass ejections on geomagnetic activity in association of solar flares and without solar flare association. Figure 1 shows the results of chree analysis of superposed epoch to show the CMEs effect on geomagnetic field for number of events (noted in paranthesis). Daily values of Ap - index has been taken as geomagnetic disturb index. Zero day correspond to starting

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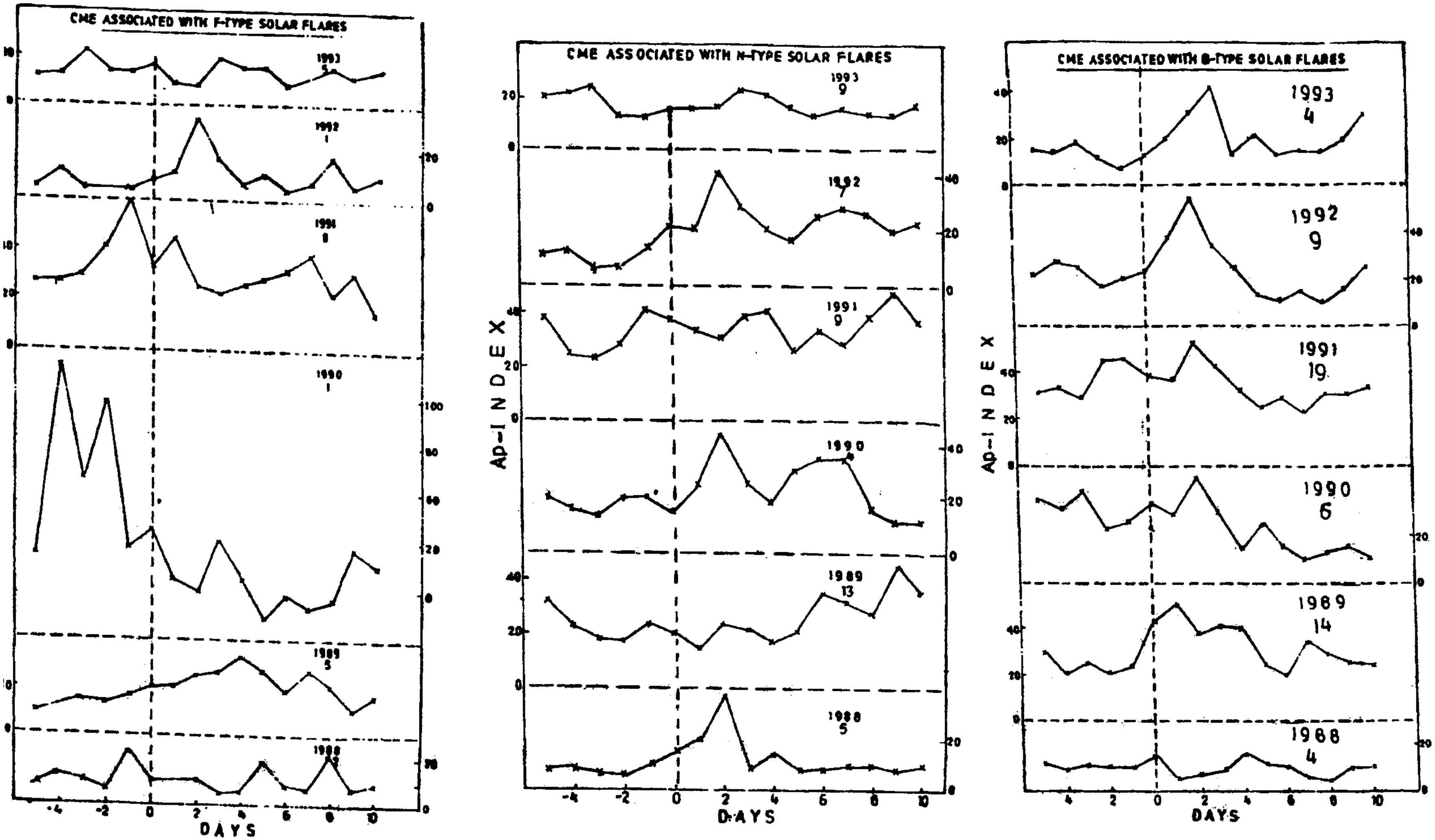

Fig 1: The results of chree analysis for -5 to 10 days with respect to zero epoch Days. The variation of mean Ap values are shown in the figure. CME Events associated with F, N, and B type solar flares are considered Zero day correspond to the starting day of occurrence of CME events.

day of coronal mass ejections. Result of this analysis generally indicates increase in geomagnetic activity during the period of CMEs. Further to observe the influence of solar flares in geomagnetic field variation in association with CMEs, we have separated all the CMEs events into three categories (1) associated with F type solar flares (ii) associated with N type solar flares, (iii) associated with B type solar flares. Results of chree analysis for –5 to 10 days have been plotted for these three categories separately. During each year from 1988 to 1993. Significant increases in geomagnetic field are noticed for B type solar flare. A slight increase in Ap values for N type solar flares are seen. It is difficult to draw any conclusion for F type solar flares. Finally, it can be inferred that the CMEs associated with B-type solar flares are more effective in producing disturbances on geomagnetic activity. Further we have studied the possible relationship between cosmic ray variation with CME events. We have selected 144 CME events for this period. Out of 144 CME events 66 are associated with high speed solar wind streams and same number of events are associated with cosmic ray decreases. Solar wind streams play important role in cosmic ray modulation. In precious studies, solar wind streams with solar flare origin are found to be one of the responsible factor in cosmic ray transient decreases (Shrivastava and Shukla, 1994, Shrivastava, 1997). It is well known that solar flares are also produce decreases in cosmic ray intensity, hence it is necessary to study the effect of CMEs (free from solar flares association) are also found responsible in cosmic ray decreases. Thus our result suggest that the CMEs are also found one of responsible factor in cosmic ray decreases. The reason of such a decreases is that CMEs in general accompanied by enhanced in agnetic field in turn responsible for modulation in cosmic rays.

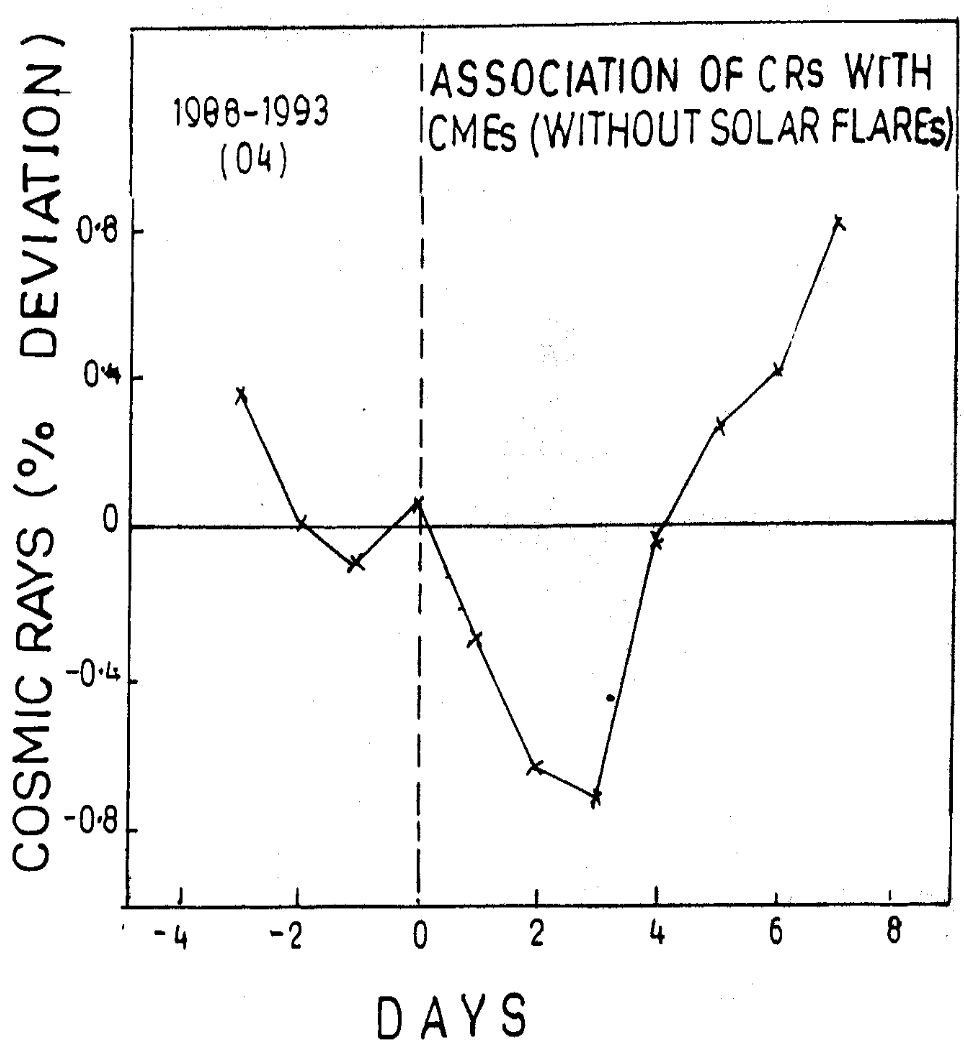

Fig 2: Shows the effects of CME events (without association of solar flares) on Cosmic ray intensity on short term basis.

Short term modulations are caused by interplanetary shocks which are driven by matter that is expelled from the sun during a reorganisation of the solar magnetic field i.e. CMEs. Most of CMEs are related with a specific solar flare and generate an interplanetary shock. The ejecta is known to be the driver of interplanetary shocks. This feature of importance for understanding the longitude effect of interplanetary shocks is the fact that the field lines of upstream solar wind get draped around the ejecta. Magnetic cloud is also investigated as a ejecta. These ejecta have a magnetic enhancement which shows a clear rotation in the field direction. Wibberenz *et al.* (1996) explained the mechanism of ejecta with the help of simple propagating diffusive barrier model to calculate the expected change in the radial diffusion coefficient to account for the size of decreases in cosmic ray by shock alone with the effect of the ejecta removed. Thus, coronal mass ejections and high speed solar wind streams have considerable influence on particle propagation and the interaction of these flows with quiet solar wind create regions of compressed, heated solar wind and shocks, which are responsible for the modulation of cosmic rays.

4. Conclusions :

(i) From this analysis, it is concluded that the CMEs in association with B-type solar flares might be the reason for the enhancement of geomagnetic activity.

(ii) CMEs associated with N-type or F-type solar flares produce comparatively slight lower increases in geomagnetic activity.

(iii) CMEs (with or without solar flare) play a crucial role in producing decreases in cosmic ray intensity on short-term basis.

(iv) 50% Forbush decreases in cosmic ray intensity are found in association with high speed solar wind streams and also with coral mass ejections.

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