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EFFECT OF MAGNETIC CLOUD ON COSMIC RAY INTENSITY AND GEOMAGNETIC FIELD IN ASSOCIATION WITH CORONAL MASS EJECTION AND INTERPLANETARY SHOCKS

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ABSTRACT

The relationship between magnetic cloud and Coronal Mass Ejection is a part of research in this field. The view that all ICMEs would originate as flux ropes while only one-third of CMEs show clear magnetic cloud signatures. Magnetic clouds shows smoothed rotation of magnetic field. 106 Magnetic clouds were observed out of which 38 events are associated with CME and IP, 48 events are associated with CMEs and 36 with GMSs during the period of 1995 -2007. Influence of these magnetic clouds alone, with CME, with CME and IP shocks and GMSs on the intensity of cosmic rays has been examined. The result of our study signifies that CME and IP shocks associated magnetic clouds remarkably produces large Forbush type decrease in cosmic ray intensity. It begins before onset time of magnetic cloud. Only CME associated shows lower variation in Cosmic Ray intensity than that of associated with CME and IP shocks while without any association produce least variation. Simultaneously higher geomagnetic activity observed. A plot is formed between average arrival hour time difference of geomagnetic storm and CME and number of days in respective year. We find that the arrival hour difference is maximum during maxima of solar cycle. A frequency histogram is plotted for finding probability of occurrence of geomagnetic storm for only magnetic cloud events or in association with CME, IP or both. We find that most of the geomagnetic storms are occurred for magnetic cloud events which are in association with both IP and CME.

KEYWORDS : Magnetic Cloud, Cosmic Ray Intensity, Coronal Mass Ejection, Interplanetary Shock

Magnetic cloud is a term that was first introduced by Burlaga which has intense southward magnetic field within or around various large interplanetary structures (Tsurutani et al., 1999). It significantly interacts with Earth's magnetic field. As an observer passes through magnetic cloud, observes a smooth rotation in direction of magnetic field with lower than average proton temperature. These structures are like huge magnetosphere moving out from the Sun (Burlaga et al., 1990) often at a speed slightly faster than the speed of the solar wind ahead of them at least at 1AU with magnetic flux rope signatures.

Subsequent analysis of solar wind data from various spacecraft near Earth and in the outer heliosphere revealed that magnetic clouds are common phenomenon in solar wind. Magnetic clouds that strike the Earth may cause intense geomagnetic storms. The search for the solar origin of the magnetic clouds brought up a close association of magnetic clouds with CME and erupting prominences (disappearing filament). Interplanetary shocks can arise from a variety of solar sources (Borini et al., 1982).

Close to the Sun a typical CME consists of the following substructures (i) a bright frontal structure which could be an expanding coronal arcade or coronal material swept up by the moving structures (ii) a dark coronal cavity (iii) an erupting prominence core consisting of cold and partially ionized material (iv) an arcade formed beneath the erupting prominence & (v) a shock wave ahead of the CME if the latter travels faster than the local characteristic speeds.

In the present study we have considered the events of interplanetary shocks and CMEs in association with magnetic cloud events to show their individual and combined effects on short term basis for the period of 1995-2007. Also geomagnetic storm associated magnetic cloud events are studied. Arrival time difference of CME and GMS is taken into consideration. We have used chree analysis of super epoch method to derive the effect of magnetic cloud on cosmic ray intensity variation and geomagnetic indices.

Data and Method of Analysis

In Our Study Sources of Data Are

1. Coronal mass ejection data from website (http://cdaw.gsfc.nasa.gov/CME_list/)
2. Magnetic Cloud data for solar cycle 23 from WIND-MFI website.nasa.gov/mfi/mag-cloud_publ.html.106

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events of magnetic clouds are taken for the period of 1995 to 2007.

3. Cosmic ray hourly values for Oulu neutron monitor (Lat.65.050N, Long.25.470E and Rigidity≥0.8GV) from website of cosmic ray intensity http://cr0.izmiran.rssi.ru/oulu/main.htm.
4. Geomagnetic indices data from website http://nsdc.gsfc.nasa.gov/omniweb.

RESULTS AND DISCUSSION

Introduction of magnetic cloud with interplanetary shock provided another factor effecting cosmic ray intensity in space weather. Magnetic clouds are often associated with interplanetary shocks but not always show such association (Zhang and Burlaga 1998). Such association is observed only if magnetic cloud travels faster than the ambient solar wind (Gopalswamy et al.,1998) .All these phenomena are well known for affecting the cosmic ray particles on short-term basis (Kaushik & Shrivastava 2000).The main phase of cosmic ray intensity decrease is produced by the turbulent sheath between the interplanetary shock and the magnetic clouds. Sun related activity plays an important role in producing several electric and magnetic processes, which in turn also affects the magnetic field of Earth. Interplanetary magnetic field is known as one of the main factor in interplanetary space, which produces modulation in galactic cosmic rays as well as disturbances in earth southward component of IMF Bz and their fluctuations have been reported to be the most important parameters affecting the geomagnetic field variation. (Gopalswamy et al., 1998) find that the eruptive prominence core of the CME observed near the Sun may not directly become a magnetic cloud as suggested by authors and that it might instead become the "pressure pulse" following the magnetic cloud. (Webb et al., 2000) found that halo CMEs that were Earthward directed were associated with shocks, magnetic clouds and moderate geomagnetic storms at Earth 3-5 days later, and imply that MCs like structures are general characteristics of CMEs. (Shrivastava 2011) studied the effect of MC on CRI for the period of 1996-2006.He found that MCs without any association does not trigger CR decreases and found higher geomagnetic activity during passage of shock. (Echer 2013) studied the properties of magnetic clouds their geo-effectiveness and associated cosmic ray decreases during the rising phase of solar cycle 24 and the results are in agreement with the previous findings. A new parameter of geomagnetic storm is included.

Using chree analysis super epoch method relationship between cosmic ray intensity and magnetic cloud is determined. We have taken 106 magnetic cloud events between 1995 to 2007.We have divided these events into four categories as magnetic cloud associated with GMS, CME, IP shocks, and both CME and IP shocks. Out of

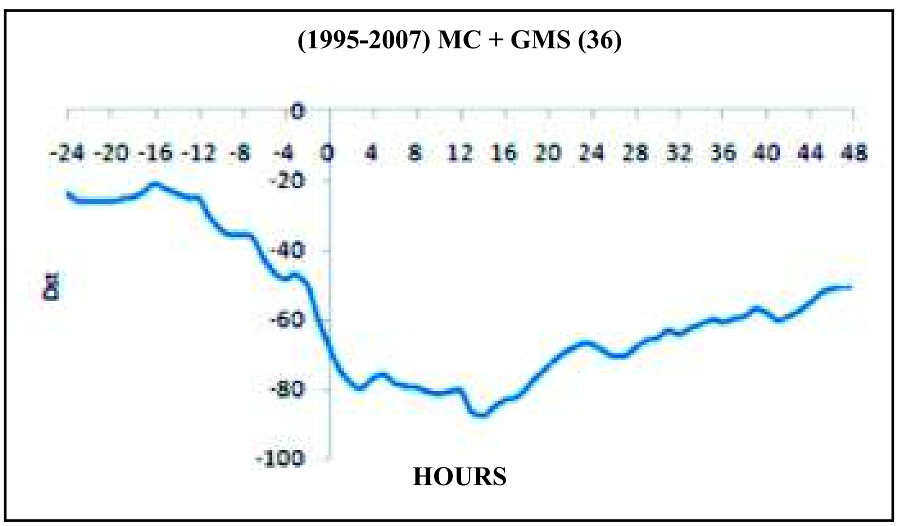

Figure 1 : Shows Variation of Dst Index for Magnetic Cloud Events Associated with Geomagnetic Storms. Zero Epoch Hour Corresponds To the Onset Hour of Magnetic Cloud.

106 events associated with magnetic cloud,36 events are associated with geomagnetic storms, 38 events are associated with CME and IP shocks and 48 events are associated with CME only.

Figure 1 shows the variation of Dst index for events of magnetic cloud associated with geomagnetic storms where zero hour corresponds to the onset hour of magnetic cloud.

Figure 2 Depicts year-wise variation of number of events and average arrival hour time difference of CME and GMS which are associated with magnetic cloud events.

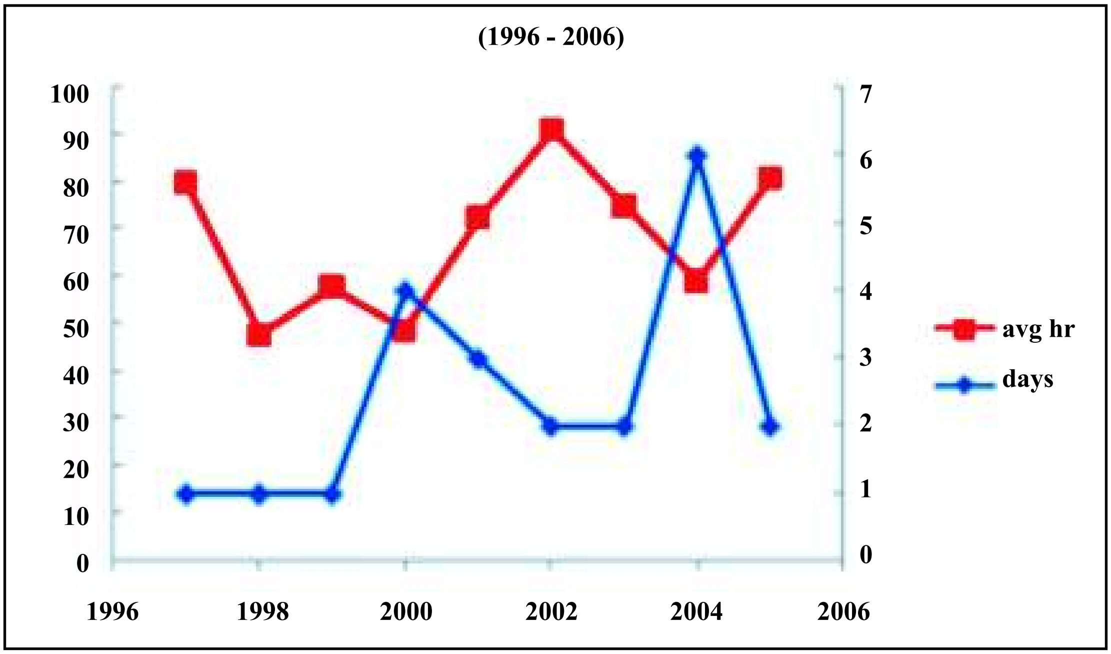

Figure 2 : Shows Variation of Average Arrival Time Difference of Onset Time of CME and Geomagnetic Storm with Number of Days for Possessing This Difference in the Respective Year.

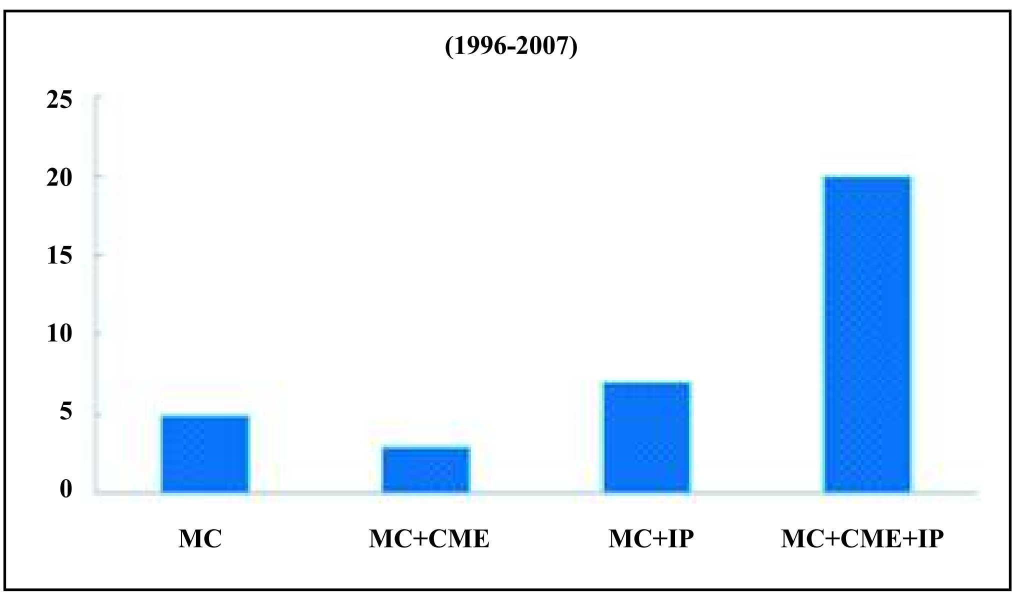

Figure 3 : Shows Frequency of Occurrence of Geomagnetic Storms as a Result of MC Alone or in Association With CME, IP or Both.

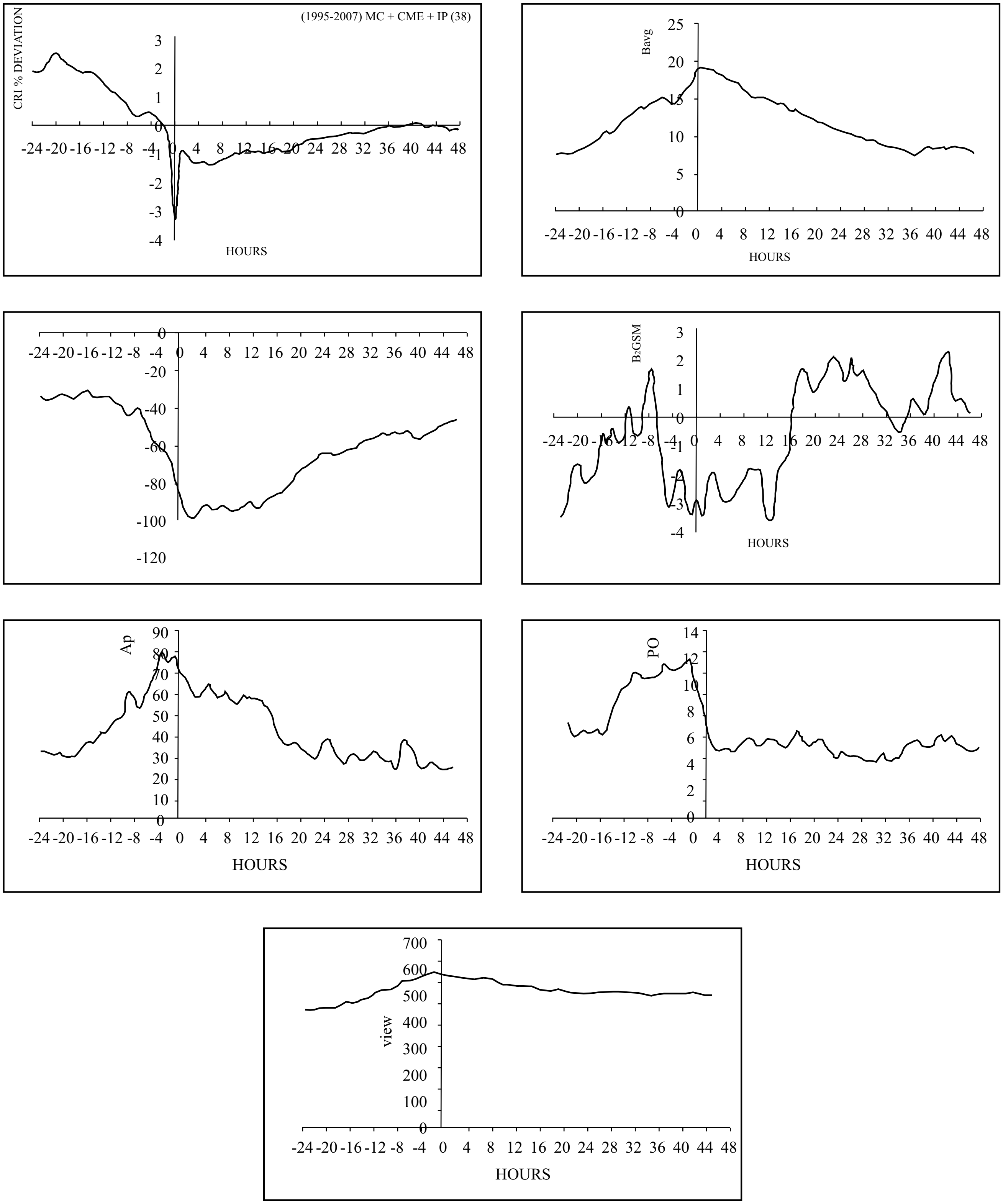

Figure 4 : Shows The Results of Chree Analysis For % Deviation of C Cosmi Ray Intensity of Oulu, Dst, Ap, Vsw, Bavg, Bzgsm, Proton Density, For Magnetic Cloud Events Associated With Cme and IP Shocks With Zero Epoch Hour Corresponds to the Hour of Magnetic Cloud Event

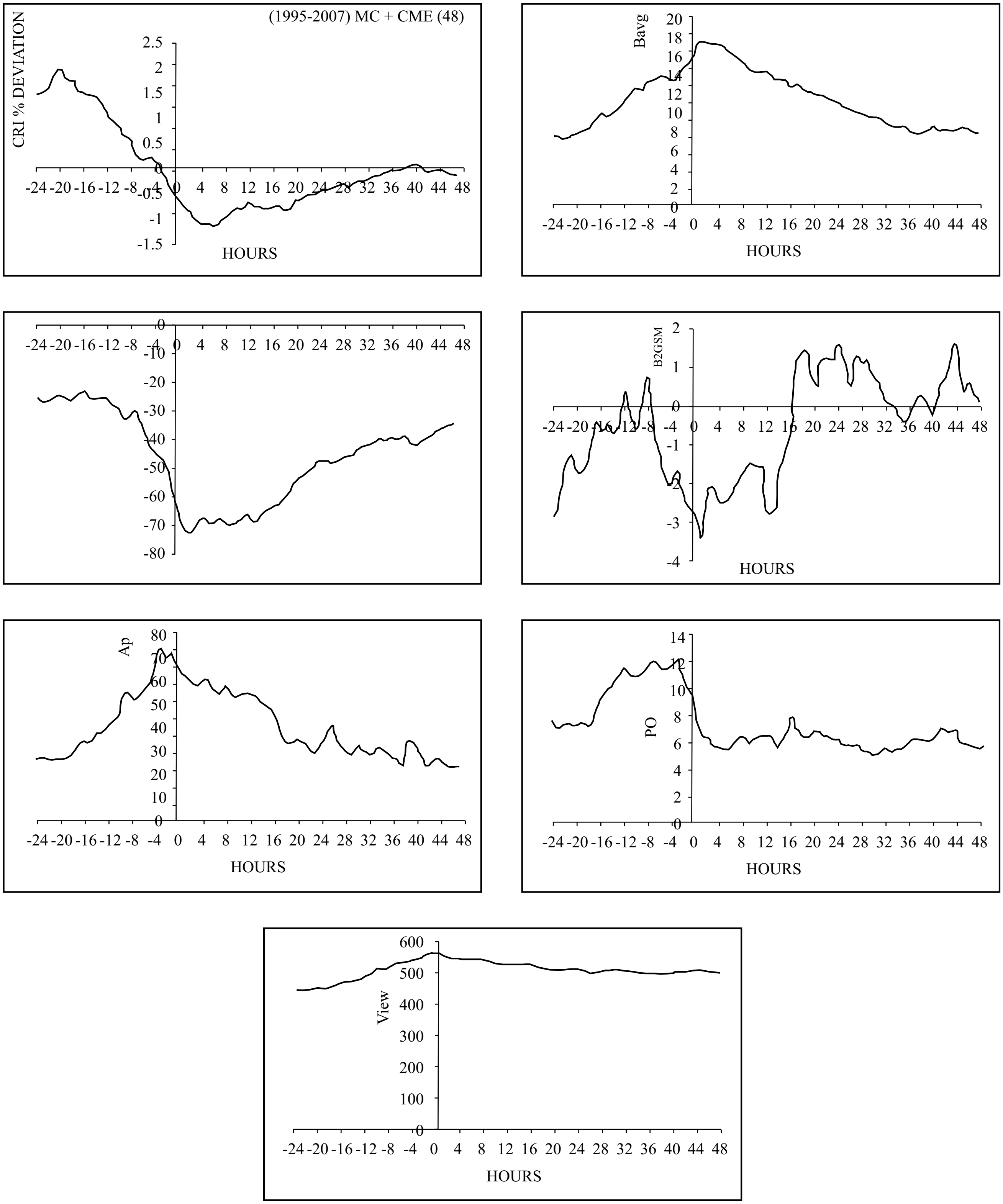

Figure 5 : Shows The Results of Chree Analysis for % Deviation of Cosmic Rays of Oulu, Dst, Ap, Vsw, Bavg, Bzgsm, Proton Density, for Magnetic Cloud Events Associated With Cme With Zero Epoch Hour Corresponds to the Onset Hour of Magnetic Cloud Event

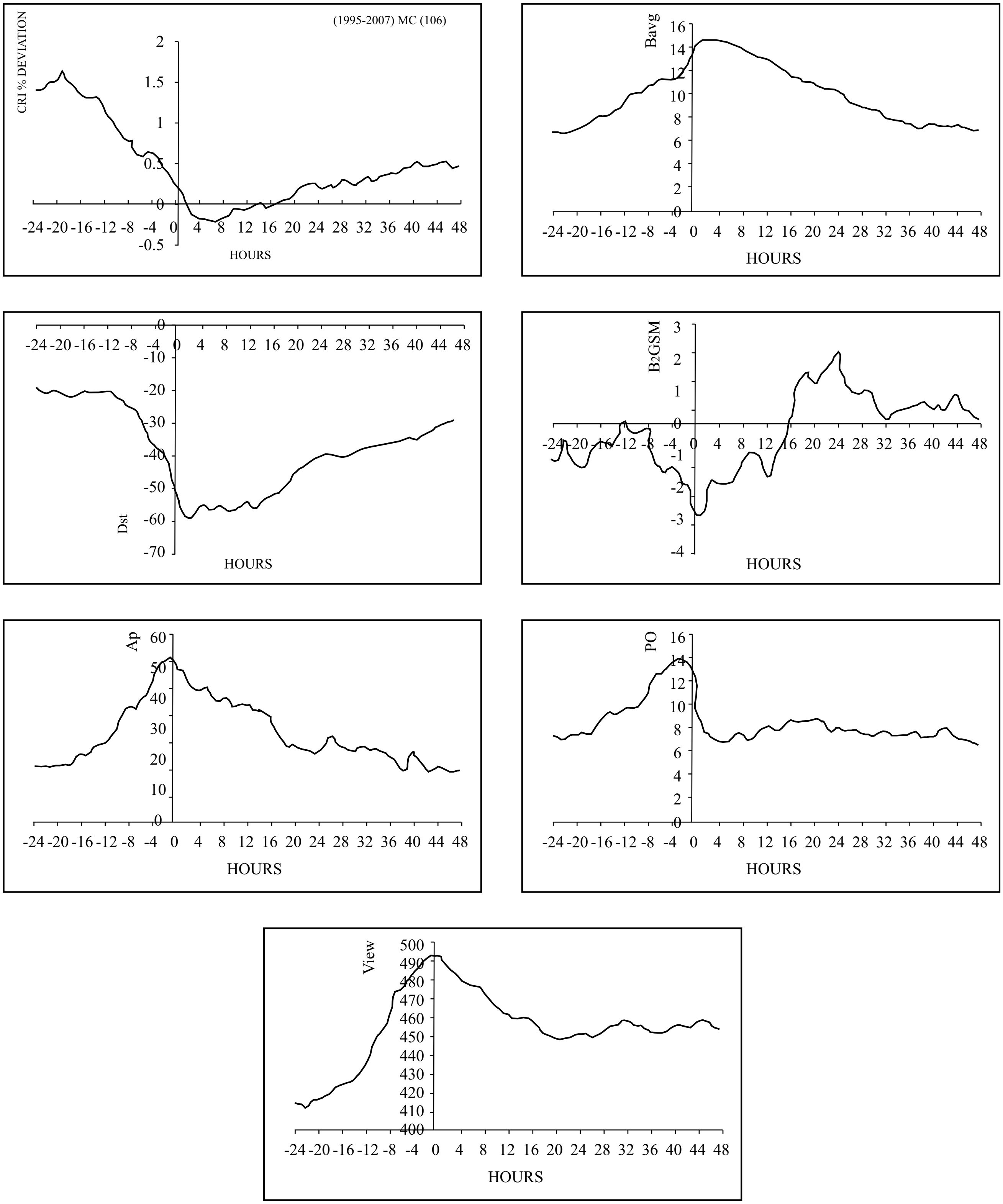

Figure 6 : Shows The Results of Chree Analysis for % Deviation of Cosmic Ray Intensity of Oulu, Dst, Ap, Vsw, Bavg, Bzgsm, Proton Density, for Magnetic Cloud Events With Zero Epoch Hour Corresponds to the Onset Hour of Magnetic Cloud Event

Figure 3 represents the frequency of occurrence of GMS for magnetic cloud events alone or in association with CME, IP or both.

Figure 4,5,6 depicts the variation of CRI % deviation for Oulu neutron monitor, Dst, Ap, IMF B (Bavg), IMF Bz (BzGSM) and Proton Density (PD) and solar wind velocity (Vsw) for magnetic cloud events associated with CME and IP shocks, magnetic cloud events associated with CME only and magnetic cloud events without any association. Zero hour is corresponding to the onset hour of magnetic cloud. The results of our analysis can be summarised as follows:

1. Variation of cosmic ray intensity is studied as % deviation value. We find that it smoothly varies for magnetic cloud events associated with CME and attains minimum value at +8hr. Steep variation is obtained at onset hour for magnetic cloud events in association with both CME and IP shocks with maximum depression say Forbush decrease. A smooth variation is obtained for magnetic cloud events only prior to maximum depression at +4hr. The maximum depression value -3.5.
2. Disturbance storm time index (Dst) shows steep variation at onset hour with smooth variation afterwards. It attains minimum value between +2hr to +16hr.The maximum depression value is 95nT.
3. Ap varies smoothly at onset hour with maximum value of 81nT at-3hr for magnetic cloud events associated with IP and CME.
4. Solar wind velocity (Vsw) and Bavg varies smoothly at onset with maximum value of 600 km/sec and maximum value of 19nT.
5. PD and BZGSM vary steeply at onset hour. PD has maximum value 14 N/cm3 prior to -1hr for MC events without any association which implies the fact of lower than normal proton temperature as characteristics of magnetic cloud while BZGSM has minimum value -3.5nT at ±2hr for MC+CME+IP events.
6. Average hr difference is maximum for maxima of solar cycle. Number of days corresponding to the average hr difference is maximum for the period ± 2 year of maxima of solar cycle i.e. 2002.
7. Average hr difference is inversely proportional for number of days i.e. when difference is maximum no. of days is minimum and vice versa.

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