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Differences between CME associated and CH associated RED events during 2005

Radharani Alyana[1*], Girija Rajaram[1], Jatin Rathod[1],
A. Chandrasekhar Reddy[1], D. S. Misra[1], C. G. Patil[2] and M. Y. S. Prasad[3]
[1]*CSRE, IIT-B, Powai, Mumbai 400 076, India*
[2]*MCF-ISRO, PB #66, Hassan, Karnataka State 573201, India*
[3]*SITAA-SAC, ISRO. Ahmedabad, Gujarat State 380015, India*

Abstract. As part of study of RED (Relativistic Electron Dropout) events at Geostationary orbit, we have classified them on the basis of their solar causes. We find that the solar causes associated with RED events are Interplanetary (IP) Shocks, Coronal Mass Ejection (CME), Flares, Magnetic Clouds and Corotating Interaction Regions (CIR) followed by Coronal Hole (CH) stream. Here we have taken CME and CH associated RED events during 2005. We have studied Interplanetary parameters (IP) (i.e. solar wind Velocity (Vsw), solar wind Ion density (Nsw), solar wind dynamic pressure (P_{sw}), total Interplanetary magnetic field B along with its north-south component, Bz), Radiation belt (RB) parameters at geostationary orbit (i.e. electron flux >2 MeV, Hp component (i.e. the component of magnetic field parallel to the spin axis of the satellite) and dayside magnetopause distance (MP)) and the geomagnetic indices (i.e. Dst and Kp) and Cosmic Ray Neutron Monitor (CRNM) count. The parameters which show significant differences between CME and CH events are Vsw, Psw, B, Bz, Dst and Kp, with Vsw and Dst showing the largest differences. As typical examples, in the case of the CME of 22 January, 2005, Vsw touches over 975 km s^{-1} and Dst is Sudden Storm Commencement (SSC) type with minimum Dst being -110 nT . In the case of the CH of 05 April, Vsw is only 650 km s^{-1} and Dst is of Gradual Commencement (GC) type with minimum Dst of -80 nT. In this paper we present differences observed in the above mentioned parameters for several RED events associated with CME and CH during 2005.

Keywords : Sun : coronal holes – CME – solar-terrestrial relations

*e-mail: radha_alyana@rediffmail.com

1. Introduction

The Relativistic Electron Dropout (RED) at geostationary orbit is mainly caused by solar disturbances which enter into geomagnetosphere and cause rapid decreases in electron flux at geostationary orbit (Lee et al. 2006). The solar causes which are responsible for decrease in relativistic electrons are Interplanetary Shocks (IPS), Coronal Mass Ejection (CME), Coronal Hole (CH) mostly followed by CIRs, Flares, Magnetic Clouds (basically a subset of Interplanetray CME) (Burlaga et al. 1991; Echer et al. 2006; Kim et al. 2006; Gopalswamy et al. 2005). CIRs are created from the interaction of the fast solar wind stream from CH with the slow wind stream from heliospheric neutral sheet in IP space (Smith & Wolfe 1976). Here CIR is included in CH. Mostly geoeffective storms are driven by CMEs and CH (Gonzalez et al. 1999; Kamide et al. 1998). In this paper we are presenting the RED events associated with CME and CH during 2005. The events and parameters under consideration are listed in Table 1(a) and 1(b) and Table 2 respectively. There is a major difference seen in the values and gradient of change of values for almost all the parameters (Borovsky & Denton, 2006). But the results were most clear in case of solar wind velocity (Vsw), solar wind dynamic pressure (Psw), total interplanetary magnetic field B and its north-south component, Bz and the geomagnetic index Dst.

2. Objectives and methodology

For the present work we have taken four CME associated and four CH associated RED events in 2005. The events are listed in Table 1(a) and 1(b). In this work we have studied IP parameters (i.e. solar wind Velocity (Vsw), solar wind Ion density (Nsw), solar wind dynamic pressure (P_{dsw}), total Interplanetary magnetic field B along with its north-south component, Bz), RB parameters at geostationary orbit (i.e. electron flux >2MeV, Hp component (i.e. the component of magnetic field parallel to the spin axis of the satellite) and dayside magnetopause distance (MP)) and the geomagnetic indices (i.e. Dst, Kp and CRNM count). The data is taken from ACE and SOHO satellites. The data for all the parameters is hourly data. In some events data is missing (may be due to instrument saturation) for some time intervals. So in some plots there is lack of continuity of the graph. The absolute values of all the parameters are taken for comparison except for dayside magnetopause distance. In case of magnetopause distance, the values are normalized with respect to 10 R_E. CRNM counts are taken from Beijing station (www.spidr.ngdc.noaa.gov). The values are taken for ±5 days from zero time i.e. the time of relativistic electron dropout. In the present paper only some parameters are discussed. The results are shown in Table 2. The position of Coronal Holes can be seen from the images given in www.spaceweather.com

Events of study in 2005

CME associated:

Table 1. (**a**) List of CME associated RED events during 2005.

Date of RED	Time of RED (UT)	Solar origin	SEP event
22 January	02:15	Sunspot 720 N12W58	Present
15 May	23:05	Sunspot 759 N12E12	Present
24 August	21:35	Sunspot 798 S13W65	Present
09 September	22:00	Sunspot 808 S09E67	Present

CH associated:

Table 1. (**b**) List of CH associated RED events during 2005.

Date of RED	Time of RED (UT)	SEP event
25 March	03:25	Absent
05 April	02:30	Absent
05 June	06:25	Absent
21 July	06:05	Absent

3. Results

Figs 1 and 2 show typical example of the variations of the IP, RB and Ground parameters mentioned in section 2 for a CME event and a CH event. RED occurs along with increase in Psw, southward turning of Bz and decrease of Dst (Green 2004) which is clear from both the figures. It can be seen that there is a sharp variation in all the parameters near to ZERO time during CME event (Fig. 1). All the parameters touch very high values compared to the previous quiet time values. Dst is SSC type as it generally happens in case of CMEs (Tsurutani 2000). Dst drops to around −265 nT indicating it is a severe storm (Gonzalez et al. 1994). On the other hand CH events are more diffused type (Fig. 2). Except Vsw, no other parameter has a large change in its magnitude when compared to the quiet time values. Dst is GC type with minimum Dst touching −80 nT. Except some parameters, there is a vast change in the behaviour of IP, RB and ground parameters associated with CME and CH, during RED time. Some of the results are summarized in Table 2.

Some major points to be noted are:

Table 2. List of parameters discussed in this paper.

Parameters	CME event	CH event
Vsw	• Always >700 km s^{-1} (Fig. 3) • The rise of Vsw during RED time is sharp and reaches peak within a day	• Less than 700 km s^{-1} (Fig. 4) • The rise of Vsw is not at all sharp and it reaches maximum in about a day or two
Psw	• Both the rise and drop during RED time are sharp and the peak Psw value exceeds the normal time value by a factor of 10 or so. (Fig. 5)	• Neither the rise nor the drop during RED time are sharp
	• Psw is always >20 nPa, except for 9th September case	• Psw mostly remains in the vicinity of normal value (Fig. 6) • Psw is always ≪20 nPa.
Bz	• There is a clear sharp and sudden change in Bz from +ve to −ve and base to +ve	• There is no clear sharp and sudden change in Bz from +ve to −ve or vice-versa
	• The gradient in change of Bz is high, ≥20 nT, except fpr 9th September case. (Fig. 7)	• The change is completely diffused type (Fig. 8)
Ne	• No major difference between the two types of events (Fig. 9)	• No major difference between the two types of events (Fig. 10)
Dst	• Dst is Sudden Storm Commencement (SSC) type for all the events (Fig. 11) • Dst drops to <−100 nT in all the cases • 9th September is an exception	• Dst is a Gradual Commencement (GC) type (Fig. 12) • Dst drops to maxiumu of −85 nT
Solar Proton Events	• All the events are associated with Solar Proton Events	• None of the events are associated with SEP events

(1) Vsw is always high in both the cases. But the rise and drop is very high and sharp in all CME events, which is not seen in CH events.

(2) Psw, B Bz show a sudden rise and drop in the variation and the rate of rise or drop is also very high in case of CME events.

(3) It is understood that the magnitude of flux density of relativistic electrons is less during CME than CH (Borovsky et al, 2006) and the recovery and enhancement of the relativistic electrons are much faster and stronger in CH events than that of CME events (Miyoshi & Kataoka, 2005) and (Kataoka & Miyoshi 2006). But in our present study no clear difference is seen between CME events and CH events in relativistic Ne variation either during RED time or after the rise.

(4) Dst is always SSC type with values touching −100 nT (Kamide et al. 1998). But there is a lack of sudden commencement in CH events and rarely the values comes down to −100 nT (Tsurutani et al. 1995). The recovery time is more for CH associated RED events (Tsurutani et al. 2006).

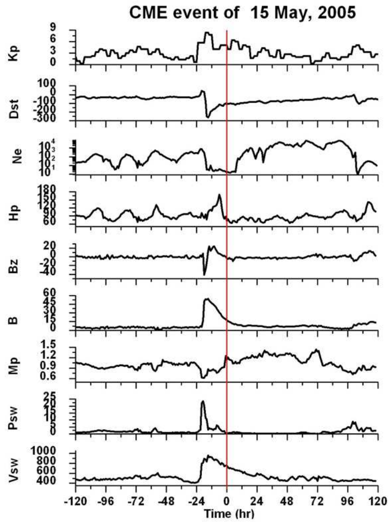

Figure 1. A typical example of variation in parameters in a CME associated RED event. Note the sharp change in all the parameters almost coincide with each other.

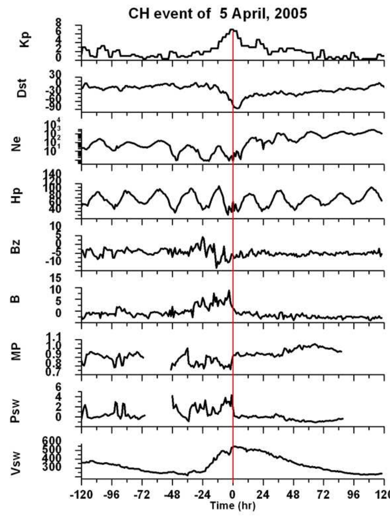

Figure 2. A typical example of variation in parameters in a CH associated RED event. Note the changes in the parameters are more diffused type.

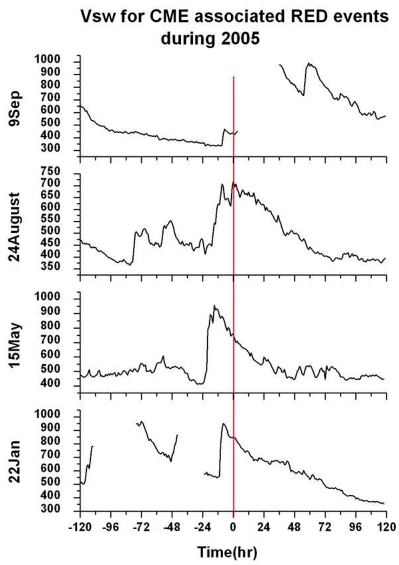

Figure 3. Variation of Vsw for the CME associated event. There is a sharp rise in Vsw and the value >700 km s^{-1}.

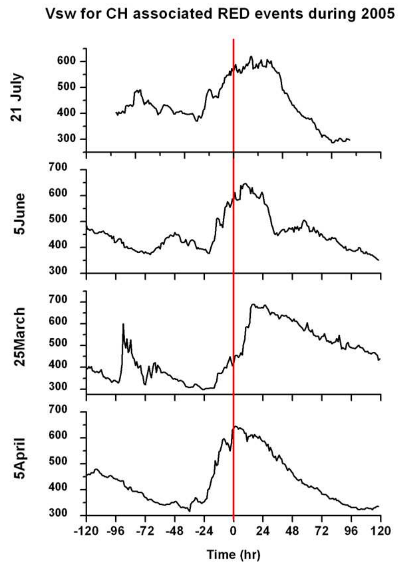

Figure 4. Variation of Vsw for the CH associated event. The rise is not sharp and the values never exceeded 700 km s^{-1}.

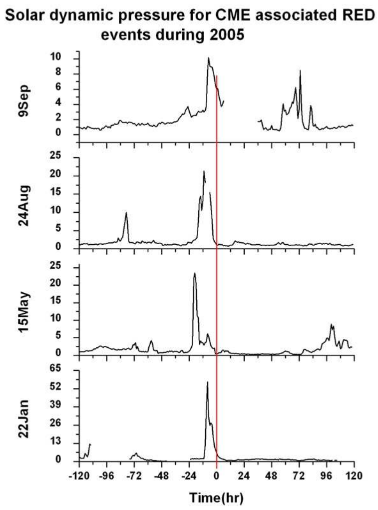

Figure 5. The variation of Psw (dynamic) for CME associated events. Note there is a sharp rise and drop and the rate of rise is in order of 10.

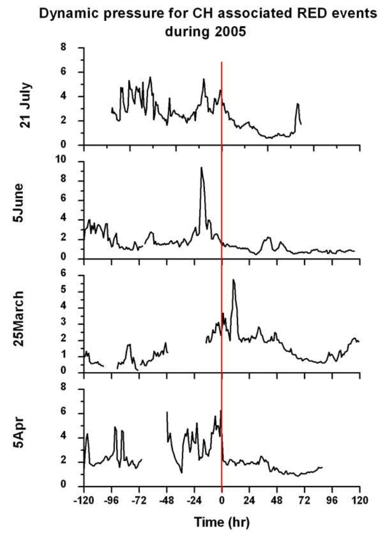

Figure 6. The Variation of Psw (dynamic) for CH associated events. Note there is neither sharp rise nor drop.

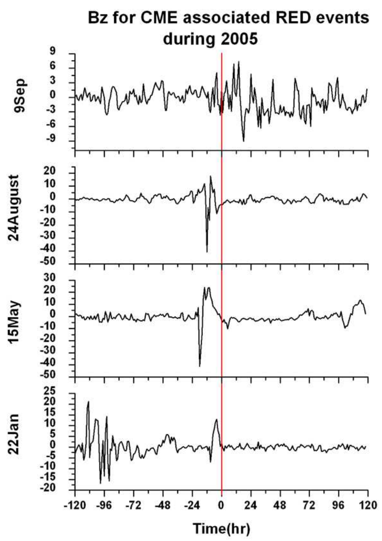

Figure 7. The variation of Bz component for CME events. There is a sharp change in Bz component from north to south and vice versa and the magnitude of variation also is high.

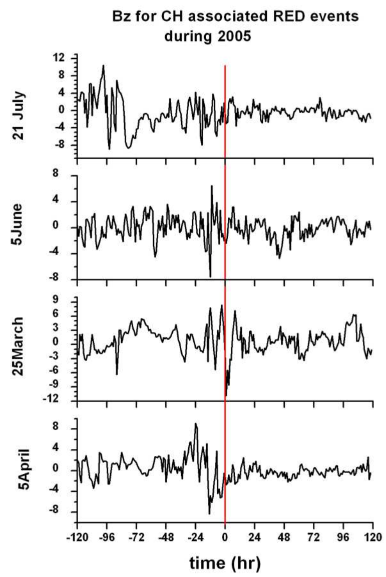

Figure 8. The variation of Bz component for CH events. There is no drastic change in the variation of Bz. But it continuously oscillates between north and south.

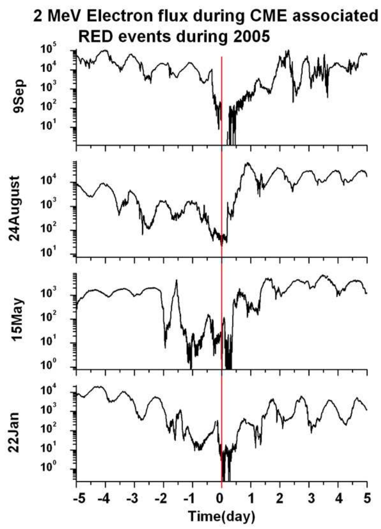

Figure 9. Relativistic electrons change during CME associated events.

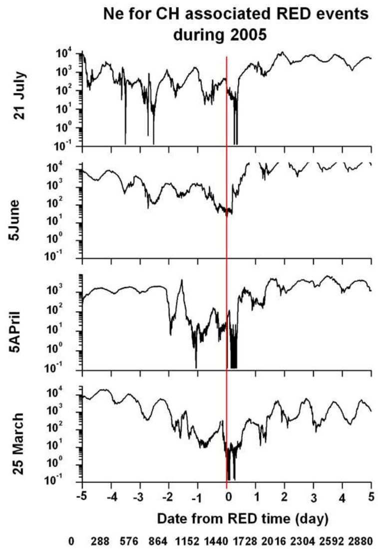

Figure 10. Relativistic electrons change during CH associated RED events.

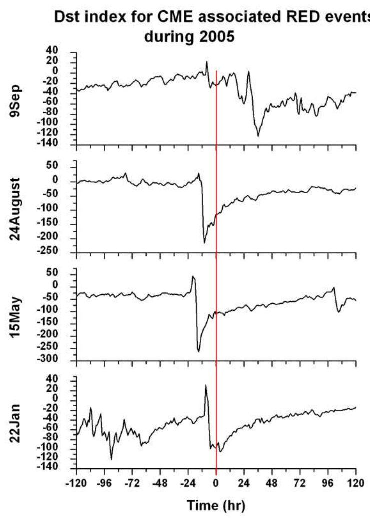

Figure 11. Plot of Dst index for CME associated events. It is clearly SSC type. And the Dst_{min} is <-100 nT (usually strong storms).

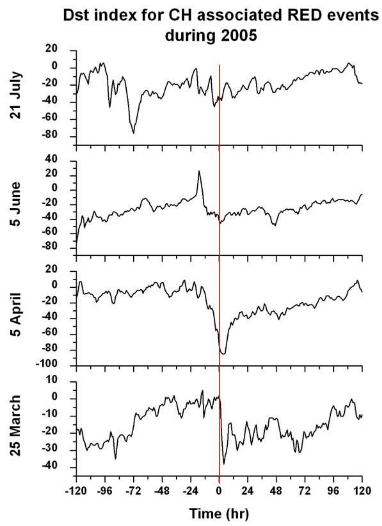

Figure 12. Plot of Dst index for CH associated events. It is mostly GC type and Dst_{min} never comes down to -100 nT (usually moderate storms).

4. Conclusions

The following conclusions can be drawn from the above plots:

- Vsw, Psw, Bz and Dst parameters show a clear difference between the two types of events.
- Peak in Vsw either coincides or occurs before RED time in case of CME associated events. But in case of CH associated events, peak Vsw happens after RED time or coincides with it.
- Bz changes sharply and drastically from positive to negative and vice versa during RED time in CME associated events allowing the particle flux to enter at a sudden into geospace. But in case of CH associated events, there is a smooth variation in Bz from positive to negative and vice versa allowing particles to continue entering into geomagnetosphere for long time.
- Not much difference is seen in behaviour of relativistic electrons in the two types of events. More cases have to be studied to see the differences.
- 9 September shows exception in the behaviour of almost all the parameters of its group.

Further work is being carried out on this event to understand why this is so.

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