



International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

www.iasir.net

Study of the Geoeffectiveness of Halo CMEs in different phases of solar activity cycle 23

Brijesh K. Mishra¹, Pankaj K. Shrivastava² and R.K. Tiwari³

^{1,2} Department of Physics, Govt. P.G. Science College, Rewa, (M. P.), 486001, INDIA;

³ Department of Physics, Govt. New Science College, Rewa, (M.P.), 486001, INDIA;

Abstract: Based on SOHO/LASCO catalogue and solar geophysical data, we studied the geoeffectiveness, solar source and flare association of a set of 397 halo CMEs during the period of 1996 to 2008. We find that Disk halos are followed by strong storms, limb halos are followed by moderately storms and backside halos are about near to moderate storms. The Frontside halos (Disk +F-limb) are most geoeffective (~71%). Intense storms are occurred in maximum phase of solar cycle and the few are occurred in declining phase. Most intense storms occur, when there are successive CMEs and occurred near the disk center towards western hemisphere. The Limb halos are faster than the Disk halos and Backside halos.

I. INTRODUCTION

Coronal mass ejections (CMEs), are the most stunning activities of the solar corona in which large-scale expulsion of plasma are seen as bright arcs in coronagraph images. CMEs appear to surround the occulting disk of the observing white light coronagraphs in the sky plane projection and expand rapidly are known as Halo CMEs [1] which may be Backside or Frontside. If the site of eruption (known as the solar source) can be identified on the visible disk of Halo CMEs then they are said to be Frontside halo CMEs, while those occurring on the invisible side of the sun are known as Backside halo CMEs and they propagate in the anti earthward direction [2]. In observational point of view halo CMEs are classified as full (type F), Asymmetric (type A) and partial (type P) halos [3]. For F and A-type halos the apparent (sky plane) width is 360 deg., while P-type halos have a width ≥ 120 deg. F and A-type halos are also simply referred to as Halo CMEs. Extensive observations from the Solar and Heliospheric Observatory (SOHO) mission's Large Angle and Spectrometric Coronagraphs (LASCO) have shown that the full halos constitute ~ 3.6% of all CMEs, while CMEs with width $\geq 120^\circ$ account for ~11% [4]. Frontside halo CMEs are further divided into Disk halos and Limb halos. Halos with their sources within ± 45 deg of the central meridian (longitudinal distance from the disk centre ≤ 45 deg.) are known as Disk halos while those with a central meridian distance beyond ± 45 deg and up to ± 90 deg are known as Limb halos.

There have been many researchers [5], [6] who have studied on the geoeffectiveness of halo CMEs using different samples. They found that ~75% of the front side halos produced significant geomagnetic storms. Almost all the Frontside halos were geoeffective during solar minimum while fewer were geoeffective during solar maximum with an overall geoeffectiveness rate of ~64% for halos detected up to the solar maximum in 2000. Characteristic features of geomagnetic storms and their long term relationship with solar activity cycle is studied [7]. They found that occurrence of moderate, major and severe categories of magnetic storms vary according to 11-year solar cycle. Gopalswamy et al. [2] analyzed 378 halos for the period of 1996-2005 and concluded that ~71% of Frontside halos are geoeffective. Zhao and Webb [6] and Gopalswamy [2],[11] used the same criteria of halo CMEs (width =360deg) and found similar geoeffectiveness rates, while Kim et al. [8] and Yermolaev and Yermolaev [9] defined their halos as CMEs with width ≥ 120 deg. and reported the lower geoeffectiveness rate. Shrivastava and Jaiswal [10] concluded that the CME occurrence rate is minimum during low solar activity and maximum during high solar activity of solar cycle 23. In this work, we have derived a significant relationship between CME Speed and geoeffectiveness for the extended period of 1996 to 2008, which cover whole period of solar cycle 23.

II. DATA ANALYSIS

We used all the 397 halo CMEs data observed by SOHO/LASCO from 1996 to 2008 taken from the SOHO/LASCO Halo CME catalog (http://cdaw.gsfc.nasa.gov/CME_list). We have sorted the following subsets of Halo CMEs: Disk halos, F-limb halos, B-limb halos and Backside halos. We have found 180 disk halos, 68 F-limb halos, 80 B-limb halos and remaining 69 backside halos out of 397 halo CMEs obtained from the LASCO halo CME catalog. It is further selected the Frontside halos made up of combination of Disk halos and Limb halos. We have also referred the Fully Backside halos as the combination of B-limb halos and Backside halos. Thus we have sorted 248 halo CMEs as Frontside halos and 149 as fully Backside halos.

III. RESULTS & DISCUSSION

In this paper we analyze the geoeffectiveness of 397 halo CMEs during the periods from 1996 to 2008. Several physical relationship have been investigated to select geoeffective CMEs such as CME angular width, CME location and speed, magnetic field orientation of a CME's source region and a CME earthward direction parameter. Figure 1 refers the CME speed distribution of different halos CMEs. The average (Avg.) values, median (Med) values and total no. of different CMEs are shown on their respective graphs. The F-limb halos (second panel from the bottom of figure 1) corresponds to the highest average and median speeds (~1529 km/s and 1475 km/s resp.) while the lowest average and median speeds (679 km/s and 586 km/s resp.) belongs to Backside halos (top panel of figure 1). It is obvious from the graphs that the CME speed distribution for the Disk halos (bottom panel of figure 1) and Backside halos are similar. Most of the geomagnetic storms events comprise between CME speeds 500 km/s to 2000 km/s for all the halos but the plots are slightly different for F-limb and B-limb halos. In F-limb and B-limb halos, most of the event comprise between CME speeds 1000 km/s to 3000 km/s. Thus it is noted that the Limb halos are faster than the Disk and Backside halos. For concise analysis, we draw the plots between CME Speed and Number of geoeffective events. Figure 2 shows different subgroups of halo CMEs while figure 3 shows combined effect of halo CMEs. Figure 2 depicts that at starting CME Speeds (<500 km/s), the number of GE events are very less but at speed 500 km/s the number of GE events are maximum for Disk halos and Backside halos. The scenario is different for Limb halos. The numbers of GE events are found maximum between speed 800 km/s to 1600 km/s for Limb halos. As CME Speed increases, the numbers of GE events decreases. The combined effects of halo subgroups are shown in figure 3. The Frontside (Disk + F-limb) halos and Fully Backside (B-limb + Backside) halos shows similar behavior but Limb (F-limb + B-limb) halos have different characteristics.

From the Table 1, it is clear that the large geomagnetic activity is related with Disk halo CMEs. About 76% Disk halo CMEs are geoeffective. Geomagnetic activity is found to be larger during the period of high solar activity i.e. most of the GE (geoeffective) halo CMEs are found in maximum phase of solar activity, but geoeffectiveness rate steadily increases from maximum to descending phase. About 76% of the Disk halos, 60% of the F-limb halos, 44% of the B-limb halos and 32% of the Backside halos are geoeffective. This indicates that the Backside halos are also geoeffective but has minimum geoeffectiveness rate. Most of the geoeffective halos are confined only to the maximum and descending phases. The Frontside halos are most geoeffective (about 71%), but about 38% of Fully Backside halos are geoeffective. Most of the geoeffective events of Halo CMEs are found between CME Location 0° to 30° i.e. near to disk center. Most of the intense storms are occurred towards western hemisphere.

CME location is also a parameter which can be deciding the geoeffectiveness of halo CMEs. It is an originating angle (measured in degree) of halo CMEs from the disk center towards east and west direction. The top panel of Figure 4 shows that the Disk halos originating towards western hemisphere are stills more geoeffective than eastern hemisphere. The number of geoeffective events is found to be greatest between CME Location 0° to 30°. Similar result is found for F-limb halos but with slighter geoeffectiveness. We obtained completely different result for Backside limb halos. The bottom panel of figure 4 illustrates that the halos originating towards eastern hemisphere are more geoeffective than western hemisphere.

The CME speed and the southward magnetic field determine the strength of the storm. The southward IMF in a CME arises from their flux-rope structure and in the sheath region due to field line draping around the flux rope and compression, whereas the sheath field is from the heliosphere. The CME speed depends on the active region free energy, modified by the interaction with solar wind. A larger fraction of the disk halos are geoeffective because there is a better chance of encountering southward field in ICMEs aimed at Earth than when they are at a large angle to the Sun-Earth line. The direction parameter could be used to trace the CME's propagating direction at least near the Sun. If a CME is directly propagating toward the Earth, the shape of the CME front edge should be nearly symmetric and the CME may trigger a geomagnetic storm. Otherwise CME may not drive a geomagnetic storm, if the shape should be quite asymmetric.

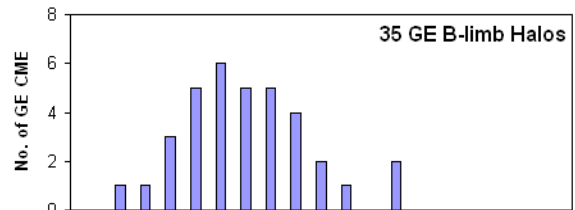
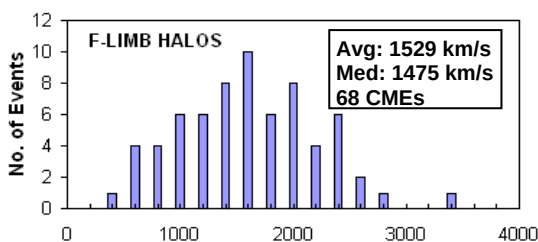
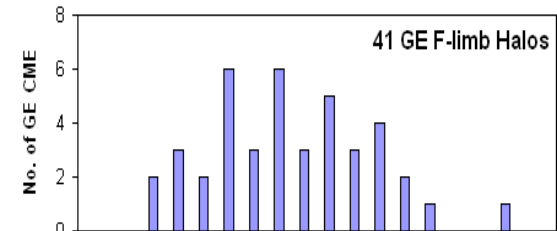
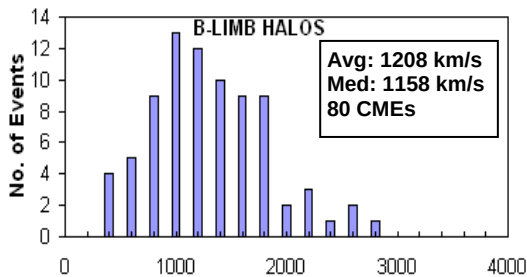
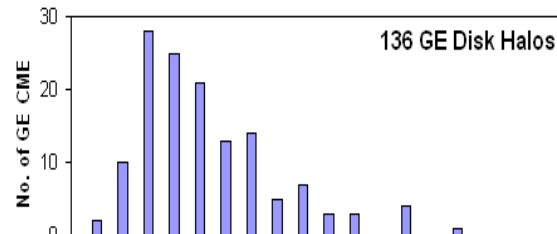
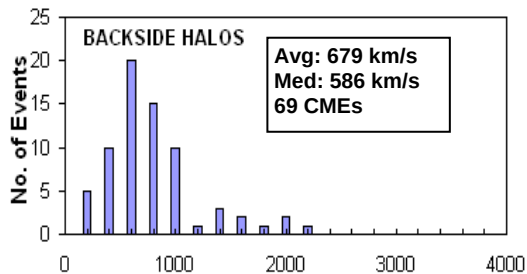
REFERENCES

- [1] R.A. Howard, D.J. Michels, N.R. Sheeley Jr., and M.J. Koomen, The observation of a coronal transient directed at earth, *Astrophys. J.*, 263, L101, 1982.
- [2] N. Gopalswamy, S. Yashiro and S. Akiyama, Geoeffectiveness of halo coronal mass ejections, *J. Geophys. Res.*, 112 A06112, doi: 10.1029/2006 JA 012149, 2007.
- [3] N. Gopalswamy, A. Lara, S. Yashiro, S. Nunes, and R.A. Howard, coronal mass ejection activity during solar cycle 23, *Proc. ICS 2003 Symp.*, Eur. Space Agency Spec. Publ., E SA-SP 535, p.403(2003a).
- [4] N. Gopalswamy, The Sun and the Heliosphere as an Integrated system, chap. 8, p. 201-252, edited by G. Poletto and S.T. Suess, Kluwer Acad., Boston, 2004.
- [5] O.C. St. Cyr et al., Properties of Coronal mass ejections: SOHO LASCO observations from January 1996 to June 1998, *J. Geophys. Res.*, 105, p.169, 2000.
- [6] X.P., Zhao, and D.F. Webb, Source regions and storm effectiveness of frontside full halo coronal mass ejections, *J. geophys. Res.*, 108 (A6), 1234, doi:10.1029/2002 JA009606, 2003.
- [7] M.M.S. Tiwari, and P.K., Shrivastava, Characteristic features of geomagnetic storms and their long term relationship with sunspot solar activity cycle, *Ultra Science.*, 16(3), p329-334, 2004.

- [8] R.S., Kim, K.S. Cho, Y.J. Moon, Y.H. Kim, Y.Yi. M.Dryer, S.C. Bany and Y.D. Park, Forecast evaluation of the coronal mass ejection (CME) geoeffectiveness using halo CMEs from 1997 to 2003, J. Geophys. Res. 110 A11104, doi: 10. 1029/2005 Jao11218, 2005.
- [9] Yu. I., Yermolaev., and M.Yu. Yermolaev, Statistical Relationship between solar, interplanetary, and geomagnetic disturbances, 1976-2000:3 cosmic Res, 41, p.539, 2003.
- [10] P.K., Shrivastava, and A. Jaiswal, A study of relationship among coronal mass ejections, Geomagnetic activity and cosmic ray modulation proceedings of the 31st ICRC, LODZ, p.1-2, 2009.
- [11] N. Gopalswamy, Halo coronal mass ejections and geomagnetic storms, Earth planet space lett. 61, p. 595-597, 2009.

Table 1 : No. of geoeffective halo CMEs in solar cycle 23

Phase	GE Halos	NGE Halos	Total
<u>Disk Halos</u>			
Ascending	19 (79%)	5 (21%)	24
Maximum	72 (70%)	31 (30%)	103
Descending	45 (85%)	8 (15%)	53
<u>F-limb Halos</u>			
Ascending	2 (33%)	4 (67%)	6
Maximum	13 (45%)	16 (55%)	29
Descending	26 (79%)	7 (21%)	33
<u>B-limb Halos</u>			
Ascending	2 (40%)	3 (60%)	5
Maximum	10 (27%)	27 (73%)	37
Descending	23 (60%)	15 (40%)	38
<u>Backside Halos</u>			
Ascending	2 (15%)	11 (85%)	13
Maximum	15 (45%)	18 (55%)	33
Descending	5 (22%)	18 (78%)	23
<u>Frontside [Disk + F-limb] Halos</u>			
Ascending	21 (70%)	9 (30%)	30
Maximum	85 (64%)	47 (36%)	132
Descending	71 (84%)	15 (16%)	86
<u>Fully Backside [B-limb + Backside] Halos</u>			
Ascending	4 (22%)	14 (78%)	18
Maximum	25 (36%)	45 (64%)	70
Descending	28 (46%)	33 (54%)	6



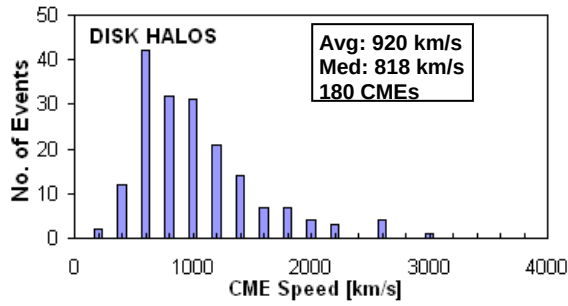


Figure 1 : The speed distributions of various halo CMEs: Disk halos, F-limb halos, B-limb halos, and Backside halos.

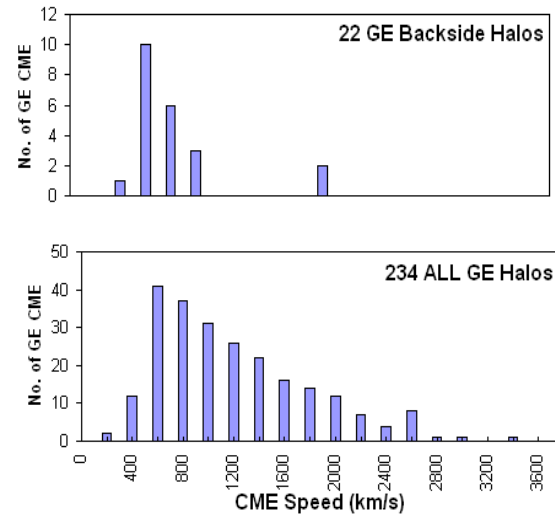


Figure 2. The speed distributions for the various GE halo CMEs: Disk halos, F-limb halos, B-limb halos, and Backside halos.

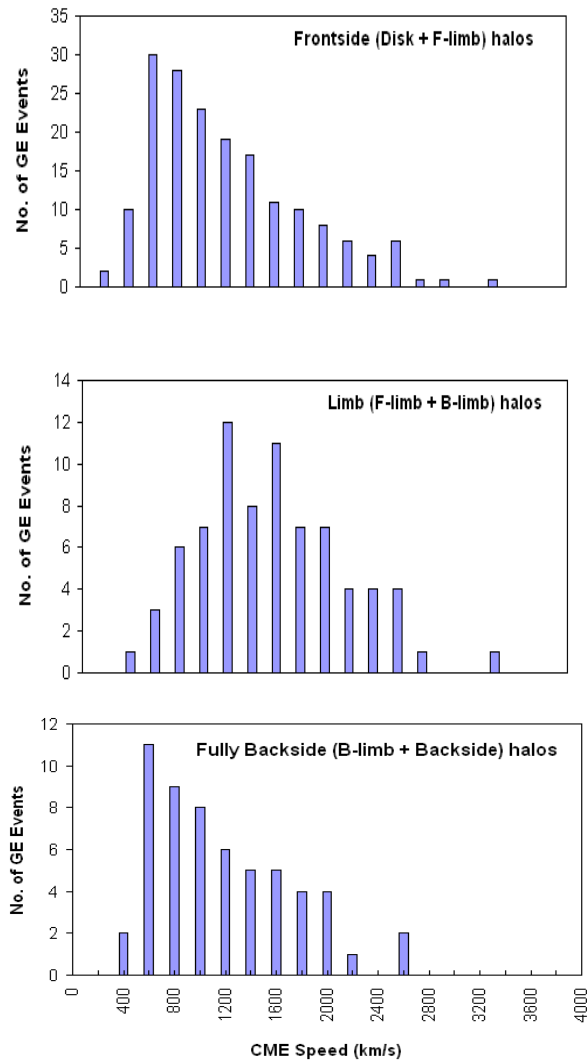


Figure 3. The speed distributions for the various combined GE halo CMEs: Frontside halos, Limb halos, halos, and Backside halos.

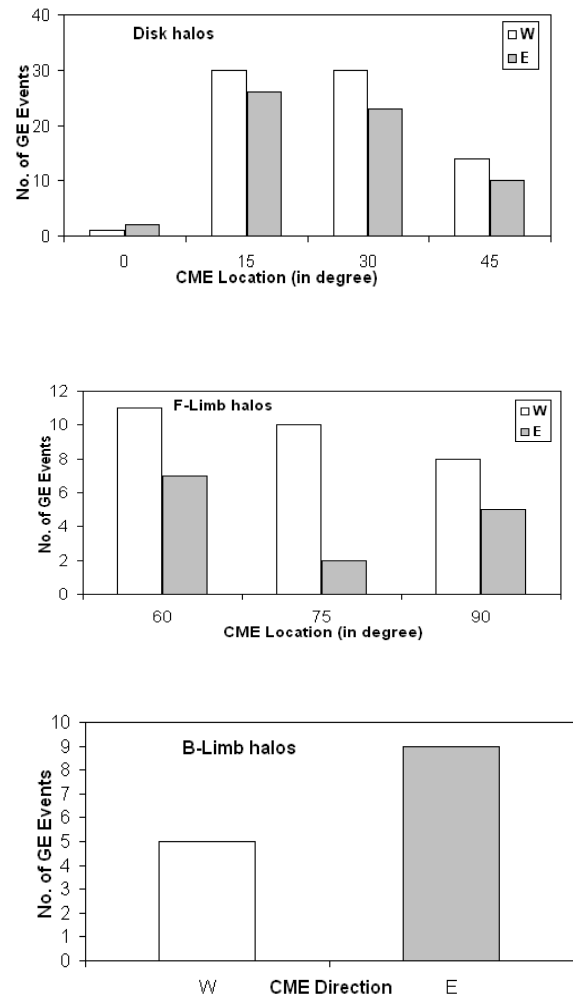


Figure 4: Distribution of GE halo events with CME Location for Disk halos, F-limb halos, and B-limb halos.