International Journal of Scientific Research in Physics and Applied Sciences
Research Paper
Vol.6, Issue.6, pp.94-103, December (2018)
E-ISSN: 2348-3423

Study the features of ICME/shock associated with Geomagnetic storms during ascending phase of solar cycle 23 and 24

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Available online at: www.isroset.org

Received: 09/Nov/2018, Accepted: 22/Dec/2018, Online: 31/Dec/2018

Abstract— In this presented work we study the characteristics, features and occurrence rates of Interplanetary Coronal Mass Ejections (ICMEs) and interplanetary shock during the rising phase of solar cycle 23 (January 1996–December 2000) and 24 (January 2008– December 2012). In particular, we give a detailed list of such events, in this given list, based on in situ observations, we consist a subsets of interplanetary shock, ICMEs and magnetic clouds corresponding with intense/ super-intense geomagnetic storms. Here we select total 67 geomagnetic storm events (50 events for solar cycle 23 and 17 events for solar cycle 24) which have Dst ≤ -75 nT. In our analysis we found that there were differences in the general properties of ICMEs between the SC 24 rising phase and same phase of the solar cycle 23. It is concluded that the geomagnetic storms during solar cycle 23 and 24 are such intense due to four major interplanetary structures (Interplanetary shock, ICMEs and magnetic clouds, southward component of IP magnetic field). On the comparison of solar cycle 23 and 24, we observed that the during the rise phase (first 5 years) of solar cycle 24, the Geomagnetic activity levels were lower than the comparable period of solar cycle 23 and ICME activities were less in the sunspot cycle 24 compared to cycle 23 during rising phase.

Keywords— *Coronal Mass Ejections, Interplanetary shock, ICME, Geomagnetic storms.*

I. INTRODUCTION

In our solar system, Coronal Mass ejection is one of the most energetic activity. It is now well established that the chain of events originating from the Sun and evolving into the flow of a geo-effective solar wind in interplanetary medium and near- Earth region are the cause of geomagnetic storms [1][2][3]. Depending on their origins, these type of geo-effective solar wind flows can be distinguish into two types, one of them is associated with Interplanetary coronal mass ejections (ICME). An ICME are conventionally known as magnetic cloud (MC) and/or ejecta. The second type of geo-effective solar wind flows is associated with fast solar wind from coronal holes [4][5]. To assess the magnetic storms, Disturbance storm time index (Dst) used for the geomagnetic activity measurement and it is affected by outputs of Sun. From last three decades, the relationship between CMEs and geomagnetic storms studied and observed by many researchers. Coronal mass ejections (CMEs) are obtained and identified in the observed images of the solar corona obtained by the Large Angle and Spectrometric Coronagraph (LASCO) onboard Solar and Heliospheric Observatory (SOHO) since 1996. As we know that, CMEs travel outward from the Sun into the interplanetary space, typically at an average speed of approximately ~450 kms^{-1}. But in interplanetary region it can be faster than ~3000 kms^{-1} or slow as ~100 kms^{-1}. Large sunspot active regions erupt fastest CMEs. These fastest CMEs powered by the photospheric strongest magnetic field concentrations [6][7]. These fast Earth directed CMEs can reach at 1 AU in ~15 - 18 hours after the launch from Sun surface and caused major disturbances on Earth's magnetosphere[8][9]. Several studies [10][11][12][13] have found that geomagnetic activities during the following solar cycle 23 was exceptionally low, and associated with unusual solar wind conditions, slow flow speed and in particular low magnetic field intensities on the comparison on just previous sunspot cycles. In this paper, we summarize the characteristics of geomagnetic activity and the interplanetary features during the first 5 years of solar cycle 24 and 23. Particularly, we point out that during the rise phase of cycle 24, geomagnetic activity continued to be at exceptionally low levels compared to similar intervals in solar cycles 23, and discuss the contributing factors.

Rest of the paper is organized as follows, Section I contains the introduction of solar eruption and their effect on earth's magnetic field, section II is Data Collection, in that section we provide the detail of data selection and sources. This is followed by detailed list of selected Geomagnetic storms along with their associated CMEs, IP-shcoks, ICMEs, Solar wind speed, southward component of interplanetary magnetic field and magnetic clouds (MCs) (Table 1 and Table 2). Section III is devoted to analyzing the data and comparison of solar cycle 24 and 23. This section is divided into parts, in first part we present the yearly distribution of geo-magnetic storms for both the cycles. In the second part, we identify the significance of south component of interplanetary magnetic field (Bz). Third part of section III is for identifying the significance of ICME/shock and geomagnetic activity. We present the rate of shock association with geomagnetic storm in Table 3 for both the sunspot cycle**.** Section IV concludes research work with future directions.

II. Data collection

For this study include all the 17 geomagnetic storm events (DST index ≤-75 nT) for ascending phase of solar cycle 24 (period from 1996-2000) and 50 geomagnetic storm events (DST index ≤-75 nT) for ascending phase of solar cycle 23 (period from 2007-2012) (DST index) , which is shown in Table 1. To understanding the development of intense storms, total magnetic field and the southward component of the interplanetary magnetic field (IMF) values are important parameters, which obtained from the ACE data archive. From previous studies and observations, an intense geo-magnetic storm defining as the one whose value of Dst (Disturbance Storm-Time) index is less than -100 nT and associated with interplanetary structures involving long-duration (T > 3 hours) negative values of Bz and large intensity (BT > 10 nT). We further classify the storms as super-intense (DST ≤ -200 nT), intense (-200 nT ≤ DST ≤ -100 nT) and moderate (-100 nT ≤ DST ≤ -50 nT). The values of Dst indices were obtained from http://swdcwww.kugi.kyoto-u.ac.jpthe geomagnetic activity web page of the World Data Center, Japan. As we know that solar cycle 24 is less active comparted to previous cycles, and a large data set is required to understand the behavior of geomagnetic activity, so that we have chosen storms having Dst ≤-75 nT. Interplanetary coronal mass ejections (ICMEs) are the interplanetary manifestations of coronal mass ejections (CMEs) seen in light scattered from enhanced electron densities in the solar corona. Identification of Earth-affecting ICMEs were observed using in situ data obtained from the Advanced Composition Explorer [14]. The ACE a satellite placed at the L1 point near the Earth that observing both plasma properties in the solar wind and magnetic fields. The magnetic clouds are classic signature of an ICME [15], the MCs can be identified as depressed temperature and density and an incensement of magnetic field strength with a gradual transition between positive and negative in at least one component direction. This direction is indicating the flux rope magnetic field rotation around a central axis. The data (Such as date and time of occurrence; speed etc) for ICMEs and interplanetary shock are collected from the list of Richardson and Hilary Cane 'Near-Earth interplanetary coronal mass ejections since January 1996', which is available at http://www.srl.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm

Table 1 list of Geomagnetic storms (Dst ≤ -75 nT) corresponding associated interplanetary magnetic field index, IP shock event and ICME features for solar cycle 23.

	IP shock Date and Time (UT)	IP shock speed (km/s)	ICME Plasma/Field Start, End Y/M/D (UT)		ICME Speed (km/s)	Solar wind Speed (km/s)	Bz (nT)	MC	Dst (nT)	CME Date and Time	CME speed (km/s)
1	1997/01/10 0104	507	1997/01/10 0400	1997/01/11 0200	450	460	14	2	-78	1997/01/06 1510 H	136
2	1997/04/10 1745	552	1997/04/11 0600	1997/04/11 1900	460	470	20	2	-82	1997/04/07 1427 H	878
3	1997/04/21 0600		1997/04/21 1000	1997/04/23 0400	360	420	12	2	-107		
4	1997/05/15 0159	616	1997/05/15 0900	1997/05/16 0000	450	480	21	2	-115	1997/05/12 0530 H	464
5	1997/06/08 1636		1997/06/08 1800	1997/06/10 0000	380	400	12	2	-84		
6	1997/09/03 0800	405	1997/09/03 1300	1997/09/03 2100	410	430	14	1	-98	1997/08/30 0130 H	371
7	1997/10/01 0059	580	1997/10/01 1600	1997/10/02 2300	450	470	10	2	-98	1997/09/28 0108 H	359
8	1997/10/10 1612	430	1997/10/10 2200	1997/10/12 0000	400	450	12	2	-130	1997/10/06 1528	293
9	1997/11/06 2248	640	1997/11/07 0400	1997/11/09 1200	400	460	11	2	-110	1997/11/04 0610 H	785
10	1997/11/22 0949	640	1997/11/22 1900	1997/11/23 1400	510	520	17	2	-108	dg (1997/11/19 1700)	150
11	1997/12/30 0209	430	1997/12/30 1000	1997/12/31 1100	370	410	12	1	-77	1997/12/26 0231	197
12	1998/01/06 1416	480	1998/01/07 0100	1998/01/08 2200	400	410	16	2	-77	1998/01/02 2328 H	438
13	1998/01/06 1416	480	1998/01/07 0100	1998/01/08 2200	400	410	16	2	-77	1998/01/02 2328 H	438
14	1998/05/01 2156	780	1998/05/02 0500	1998/05/04 0200	520	650	11	2	-85	1998/04/29 1658 H	1374
15	1998/05/04 0215(A)	1150	1998/05/04 1000	1998/05/07 2300	550	830	10	0	-205	1998/05/02 1406 H(p)	938
16	1998/06/25 1636		1998/06/26 0400	1998/06/26 1900	470	490	11	0	-101		
17	1998/08/05 1300		1998/08/05 1300	1998/08/06 1200	360	390	8	1	-138	dg	
18	1998/08/26 0651	1260	1998/08/26 2200	1998/08/28 0000	650	860	14	0	-155	dg (1998/08/24 2200)	

19	1998/09/24 2345	1020	1998/09/25 0600	1998/09/26 1600	640	820	13	2	-207	dg (1998/09/23 0700)	
20	1998/10/18 1952	510	1998/10/19 0400	1998/10/20 0700	390	430	18	2	-112	1998/10/15 1004 H	262
21	1998/11/07 0815	570	1998/11/07 2200	1998/11/09 0100	450	530	15	1	-81	1998/11/04 0754 H	523
22	1998/11/08 0451	740	1998/11/09 0100	1998/11/11 0100	450	640	12	2	-149	1998/11/05 2044 H	1118
23	1998/11/13 0143	520	1998/11/13 0200	1998/11/14 1200	390	400	17	2H	-131	1998/11/09 1818	325
24	1999/01/13 1054	dg	1999/01/13 1500	1999/01/13 2300	420	430	18	0	-112	dg	
25	1999/02/18 0246	870	1999/02/18 1000	1999/02/20 1700	540	680	9	2	-123	dg (1999/02/16 0312)	
26	1999/03/10 0130		1999/03/10 1700	1999/03/12 0200	410	460	7	0	-81		
27	1999/04/16 1125	520	1999/04/16 1800	1999/04/17 1900	410	460	18	2	-91	1999/04/13 0330 H	291
28	1999/09/22 1222	770	1999/09/22 1900	1999/09/24 0300	530	600	11	0	-173	1999/09/20 0606 H	604
29	1999/10/21 0225	561	1999/10/21 0800	1999/10/22 0700	480	550	20	0	-237	1999/10/18 0006 H	247
30	1999/11/13 1200		1999/11/13 2000	1999/11/15 0000	440	480	7	2H	-106	dg	
31	1999/12/12 1551		1999/12/12 1900	1999/12/13 1600	520	700	12	0	-85	dg	
32	2000/01/22 0023(A)	530	2000/01/22 1700	2000/01/23 0200	380	400	16	1	-97	2000/01/18 1754 H	739
33	2000/02/11 2352	915	2000/02/12 1200	2000/02/13 0000	540	590	13	2	-133	2000/02/10 0230 H	944
34	2000/04/06 1639	860	2000/04/07 0600	2000/04/08 0600	560	620	6	1	-288	2000/04/04 1632 H	1188
35	2000/05/16 2300	500	2000/05/16 2300	2000/05/17 0700	550	580	9	1	-92	2000/05/13 1226	666
36	2000/05/23 2342(W)	650	2000/05/24 1200	2000/05/27 1000	530	690	5	1	-147	2000/05/21 0726	629
37	2000/06/08 0910	1007	2000/06/08 1200	2000/06/10 1700	610	770	11	0	-90	2000/06/06 1554 H	1119
38	2000/06/26 0000		2000/06/26 1000	2000/06/27 0000	520	560	10	0	-76		
39	2000/07/15 1437	1500	2000/07/15 1900	2000/07/17 0800	740	1040	20	2	-301	2000/07/14 1054 H	1674
40	2000/07/19 1527		2000/07/20 0100	2000/07/21 0800	530	630	8	0	-93	2000/07/17 0854?	788
41	2000/08/10 0501	530	2000/08/10 1900	2000/08/11 2100	430	480	12	2H	-106	2000/08/06 2230	597
42	2000/08/11 1845	830	2000/08/12 0500	2000/08/13 2200	580	670	18	2	-235	2000/08/09 1630 H	702
43	2000/09/17 1657(A)		2000/09/17 2100	2000/09/21 0000	600	840	10	2	-201	2000/09/15/16 (p)	633
44	2000/10/03 0054		2000/10/03 1000	2000/10/05 0300	400	460	14	2	-143		
45	2000/10/05 0326	756	2000/10/05 1300	2000/10/07 1100	450	530	6	1	-182	2000/10/02 2026 H	569
46	2000/10/12 2228	590	2000/10/13 1600	2000/10/14 1700	400	460	12	2	-107	2000/10/09 2350 H	506
47	2000/10/28 0954	565	2000/10/28 2100	2000/10/29 2200	380	420	14	2	-127	2000/10/25 0826 H	770
48	2000/11/06 0948	660	2000/11/06 1700	2000/11/08 0300	510	610	20	2	-159	2000/11/3 1826 H	291
49	2000/11/26 1158		2000/11/27 0800	2000/11/28 0300	560	630	10	0	-80	2000/11/24 (p)	1289
50	2000/11/28 0530	720	2000/11/28 1100	2000/11/29 2200	540	580	9	1	-119	2000/11/25/26 (p)	675

Table 2 list of Geomagnetic storms (Dst ≤ -75 nT) corresponding associated interplanetary magnetic field index, IP shock event and ICME features for solar cycle 24.

	IP shock Date and Time (UT)	IP shock speed (km/s)	ICME Plasma/Field Start, End Y/M/D (UT)		ICME Speed (km/s)	Solar wind Speed (km/s)	B (nT)	MC	Dst (nT)	CME Date and Time	CME speed (km/s)
1	2009/07/20 1400	300	2009/07/21 0100	2009/07/22 0400	330	350	8	1	-83	2009/07/15 0430 W	
2	2010/04/05 0826	910	2010/04/05 1200	2010/04/06 1400	640	790	9	2	-81	2010/04/03 1033 HW	668
3	2010/05/28 0258	500	2010/05/28 1900	2010/05/29 1700	360	390	14	2	-80	2010/05/24 1406	427
4	2011/05/28 0100	450	2011/05/28 0500	2011/05/28 2100	510	540	11	2	-80	2011 05/25, 0420 W	379
5	2011/08/05 1751	1100	2011/08/06 2200	2011/08/07 2200	540	610	4	1	-115	2011/08/04 0412 H	1315
6	2011/09/09 1242	680	2011/09/10 0300	2011/09/10 1500	470	530	14	2	-75	2011/09/06 2305	575
7	2011/09/26 1234	870	2011/09/26 2000	2011/09/28 1500	580	700	7	0	-118	2011/09/24 1248	1915
8	2011/10/24 1831	630	2011/10/24 2200	2011/10/25 1600	460	510	21	2	-147	2011/10/22 0005 W	593
9	2012/03/08 1103	1220	2012/03/09 0300	2012/03/11 0700	550	890	7	1	-145	2012/03/07 0024 H	2684
10	2012/03/15 1306	960	2012/03/15 1700	2012/03/16 1000	680	760	9	1	-88	2012/03/13 1736 H	1884
11	2012/04/23 0320	...	2012/04/23 1700	2012/04/24 0500	370	390	13	2	-120		
12	2012/06/16 2019	770	2012/06/16 2300	2012/06/17 1200	440	510	28	2	-86	2012/06/14 1412 HW	987
13	2012/07/08 0800	480	2012/07/09 0000	2012/07/09 1400	410	450	12	2	-78	2012/07/04 1724 H	662
14	2012/07/14 1809	850	2012/07/15 0600	2012/07/17 0500	490	670	16	2	-139	2012/07/12 1648 H	885
15	2012/09/30 2305	590	2012/10/01 0000	2012/10/02 0000	370	410	14	2	-122	2012/09/28 0000 H	947
16	2012/10/08 0516	560?	2012/10/08 1800	2012/10/09 1200	390	420	16	2	-107	2012/10/05 0248?	612
17	2012/10/12 1900	...	2012/10/12 2200	2012/10/13 1000	490	530	11	2	-90		

In this given table the first and second column shows the time and date respectively of peak of geomagnetic storms.

Column third consist the value of Dst in nT. For Interplanetary magnetic field, here we are taking southward component Bz with time.

We collect the data of interplanetary shock features (forward and reversed shock) we calculate the speed of IP shock we follows

$$V_{sh} = (n_2 v_2 - n_1 v_1)/(n_2 - n_1)$$

Where v and n denote the flow speed and density of the solar plasma and the subscripts 1 and 2 represent the pre-shock and post-shock solar wind properties.

For interplanetary CMEs we took out the duration and mean solar wind speed in the ICME.

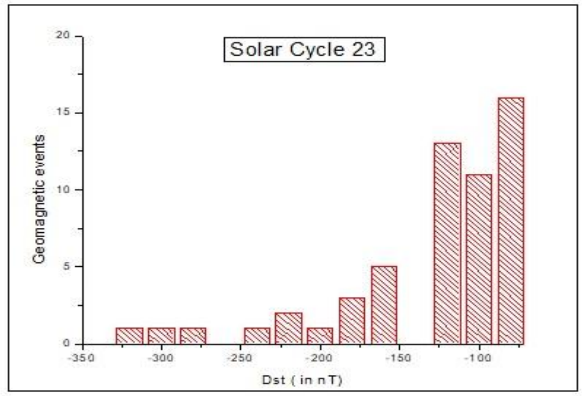
MC is magnetic cloud: the 0,1 and 2 identify the different states of MC. Where 0 is for when the magnetic field shows small evidence of rotation; when a more subjective assessment suggests evidence of a relatively organized field rotation within the ICME, but a magnetic cloud has not been reported, then MC identified as 1; and 2, the ICME has been reported as a magnetic cloud which can be modeled by a force-free flux rope.

III. RESULTS AND DISCUSSION

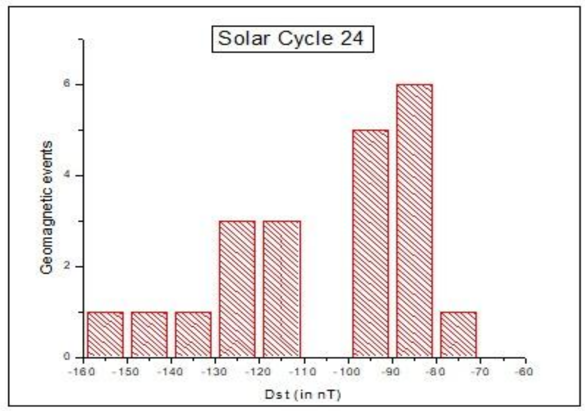
Statistical investigation of the solar wind features of reported geomagnetic storms that occurred during the rising phase of solar cycle 23 and 24. The investigation further indicates that most of four interplanetary features: Interplanetary shock, solar wind velocity, southward component of interplanetary magnetic field, magnetic cloud can be used as a significant predictor in forecasting of space weather. It is also important to understand the interplanetary consequences of geo-effective CMEs for predicting the magnitude and the onset time of geomagnetic storms. In the recent past decades several studies have been undertaken to understand the interplanetary causes of major geomagnetic storms [16][17][18][19][20][21]. In this following section we discuss the characteristics of the interplanetary sources of major geo-magnetic storms that occurred during 1996–2000 (ascending phase of SC-23) and 2008-2012 (ascending phase of SC-24). We attempt to relate these characteristics to their solar origins.

1. Yearly distribution of Geomagnetic storms

Figure 1 (a) & (b) shows the occurrence of geo magnetic storm (Dst -Disturbance storm time index) during the first 5 years of cycles 23 and 24 respectively; Dst is available since 1957; ‘‘Intense’’ storm specified by Dst ≤ -100 nT and ‘‘super intense’’ storm identified by Dst ≤ -200 nT [22]. By the inspection of Figure clarify that severe storms were present during the rising phase of each cycle except for SC 24, and the occurrence of intense and super intense geo-magnetic storms was also reduced in SC 24.The yearly distribution of reported storms events with Dst values as seen in the histograms for solar cycle 23 and 24 of Figure 1 (a) and (b), As we know that, Solar cycles are followed dual–peak distribution[23], on that the first peak appeared at solar maximum and the next peak at the early part of the declining phase after the solar maximum. Here in this paper we are only focus on the ascending phase of solar cycle 23 and 24.

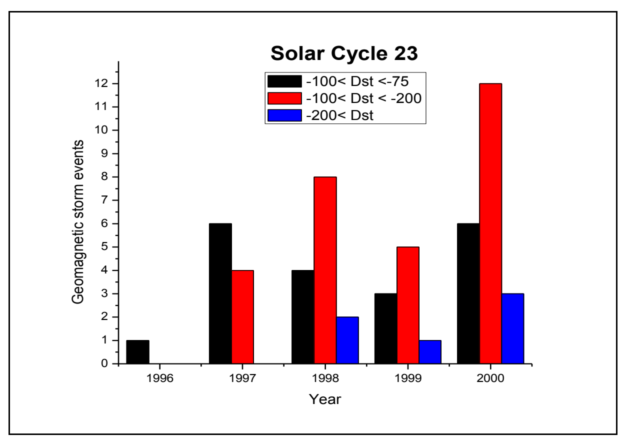


(a)

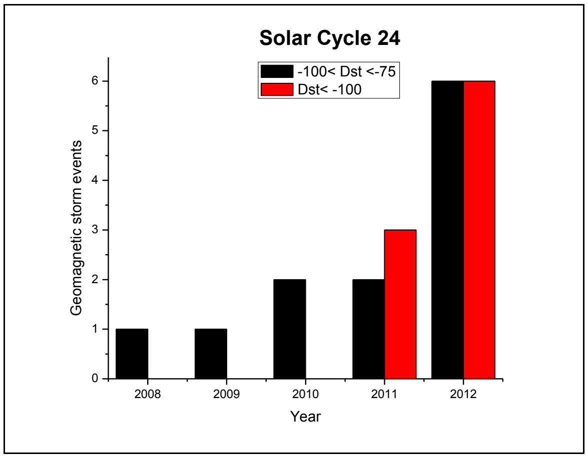


(b)

Figure 1: *(a) Shows the geomagnetic storm event distribution during sunspot cycle 24.*
(b) Shows the geomagnetic storm event distribution during sunspot cycle 23.



(a)



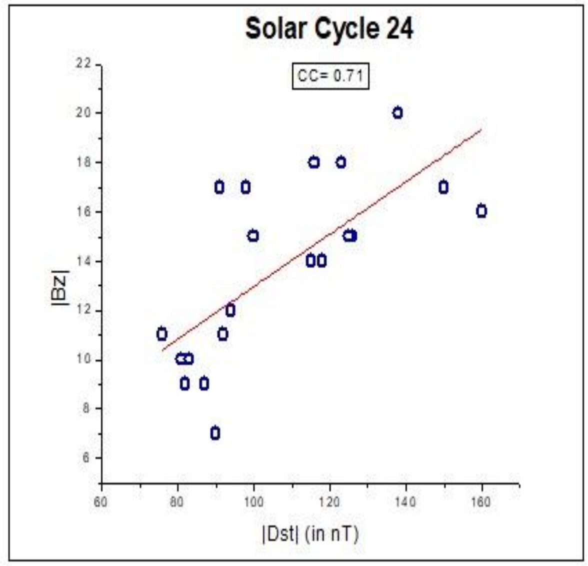
(b)

Figure 2: *(a) & (b) shows the yearly distribution of geomagnetic storms with their Dst value for solar cycle 23 and 24 respectively.*

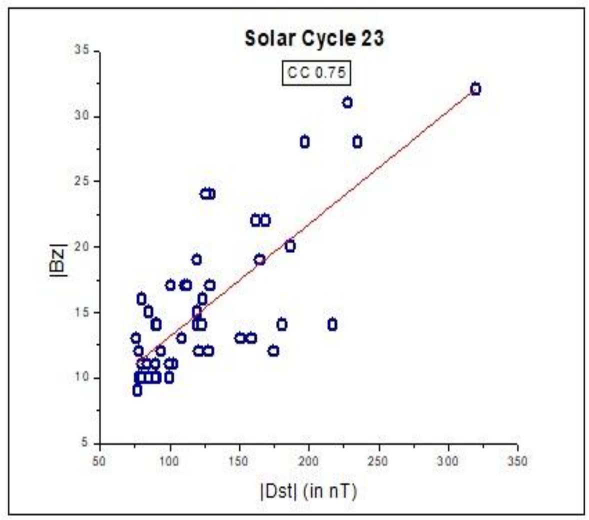
2. Significance of Bz in Geomagnetic Activity:

When the solar wind come towards the Earth, the magnetic reconnection between the Interplanetary magnetic field and the Earth's magnetic field is primary physical mechanism for energy transfer from the solar wind to the Earth's magnetosphere. The strength and efficiency of this process mainly depends on the strength of the southward component of interplanetary magnetic field (B_z). The geo-effective solar wind is usually a period of prolonged and enhanced southward directed magnetic field (B_s) that allows efficient solar wind energy transport into the Earth's magnetosphere (Dungey et al 1961). This enhanced B_s field could be embedded within any part (front or rear) of ICMEs, SHs, and CIRs [24][25].

We find a correlation coefficient of 0.71 for solar cycle 24 and 0.75 for solar cycle 23, between the maximum southward component of the interplanetary magnetic field, i.e., B_z and the D_{st} values. This high correlation implies that the accurate predictions of geo-effectiveness of interplanetary magnetic field, it is necessary to know the configuration of it at the time of arrival at 1 AU. By understanding and analysis of interplanetary magnetic fields we can avoid the false alarms of magnetic storms. Notably, the variation in the southward component of interplanetary magnetic field ($B_{z)}$ plays a crucial role in determining the amount of solar wind energy, this energy is transferred to the Earth's magnetosphere. The high correlation coefficient between the $|B_z|$ and |Dst| suggests that $|B_z|$ are the reliable predictor for the geomagnetic storm intensity.



(a)

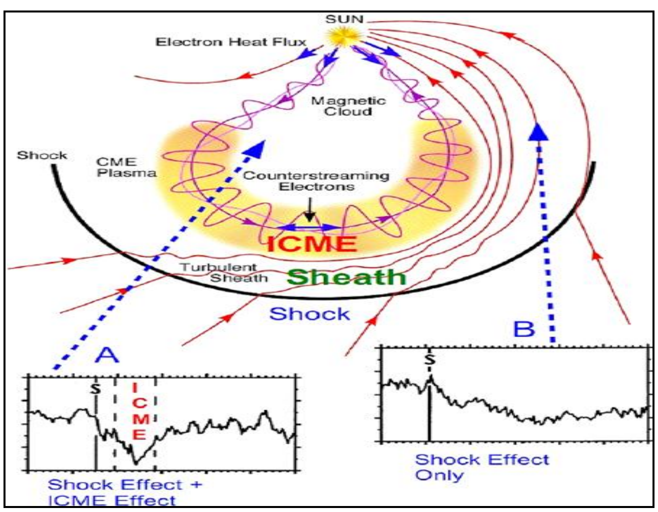


(b)

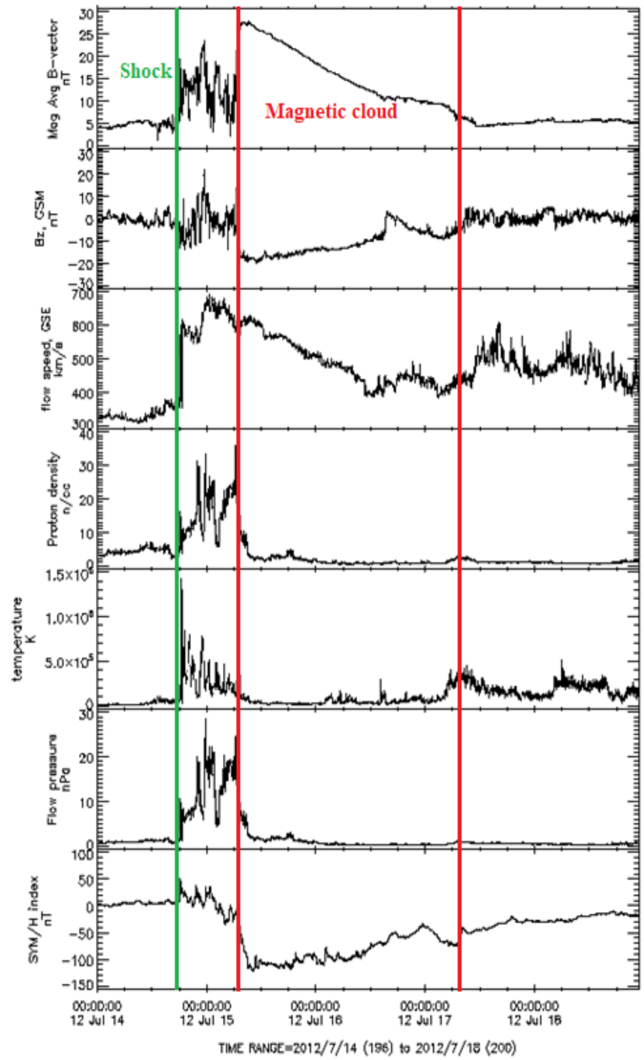
Figure 3. *(a)Correlation between |Bz| and |Dst| index for the chosen geo-effective events for solar cycle 24. (b) Correlation between |Bz| and |Dst| index for the chosen geo-effective events for solar cycle 23.*

3. Significance of ICME/shock and Geomagnetic activity:

Interplanetary coronal mass ejections (ICMEs) are the interplanetary manifestations of coronal mass ejections (CMEs) seen in light scattered from enhanced electron densities in the solar corona. In situ data from the Advanced Composition Explorer (ACE: Stone et al., 1998) are using to identify the Earth-affecting ICMEs. In this instrument a satellite located near the Earth at the L1 point that is capable of observing both magnetic fields and plasma properties in the solar wind. ICME can be identified by examine the basic signature a magnetic cloud. A magnetic cloud consists of a depressed temperature and density and mostly an enchantment in magnetic field strength with a gradual transition between negative and positive in at least one component direction, which shows the rotation of the magnetic field of flux rope around central axis. The dropping of the temperature and density inside the flux rope lead to a less plasma pressure in the ICME than in the ambient solar wind. Furthermore, interplanetary shocks are often observed ahead of these features, identified by nearly instantaneous and sharp increases in magnetic field, density and temperature (Jackson, 1986). Zhang, Poomvises, and Richardson, 2008 has been studied that the sheath region of compressed solar wind plasma between the shock and the flux rope has been shown to contribute about 30% of the energy of a Earth's geomagnetic storm. In practice, observation shows that ideal signatures of ICMEs are presented by very few ICMEs. When the CMEs travels through interplanetary space, the interaction between two or more CMEs can lead to complex in situ signatures. These signatures are more difficult to predict, interpret, and may be more likely to lead to extreme space weather situations [26][27]. CMEs that are not pointed directly at Earth can also lead to in situ data that are not observed as a perfect magnetic cloud because the leg of the CME impacts the Earth [28][29].



(a)

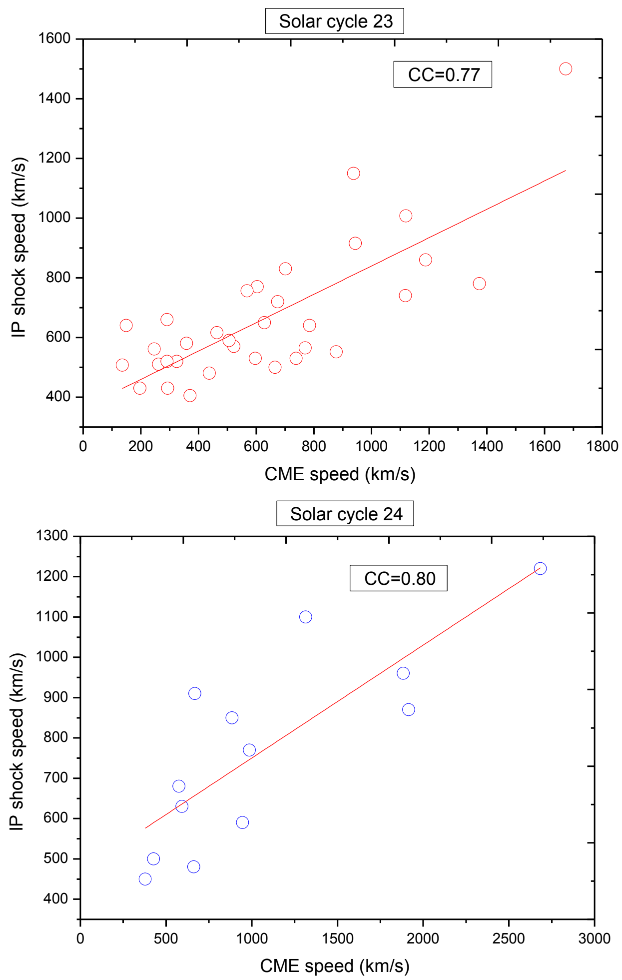


(b)

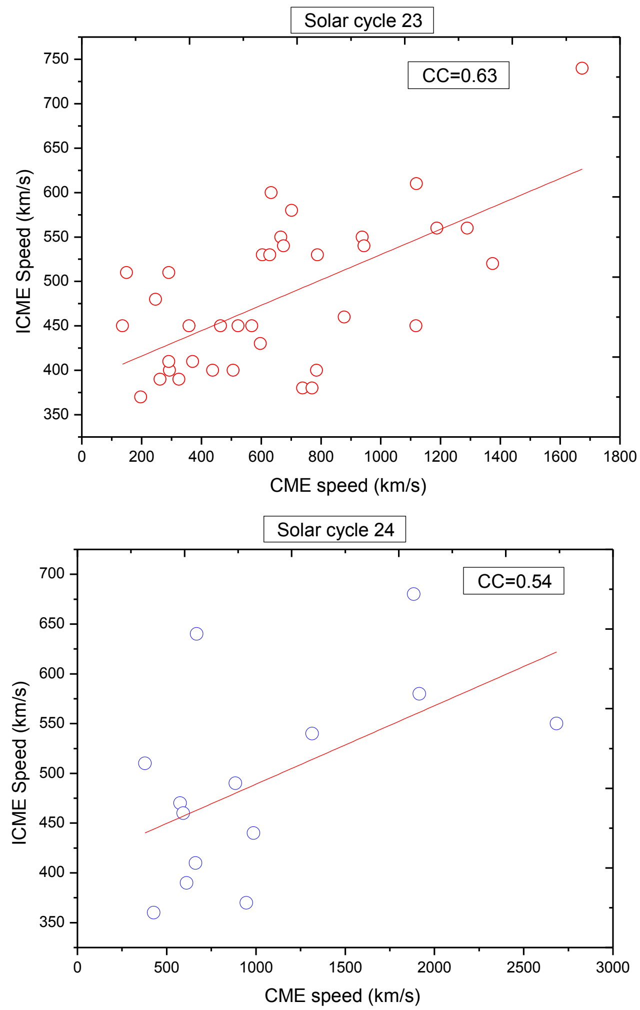
Figure 4: *(a) Shows the animated diagram of solar eruption, in this picture we can classified different parts of solar eruption and their effects and identification features at 1 AU (Source : Richardson 2013). (b) The Dst index, and solar wind magnetic field (in GSE coordinates) and plasma parameters, for the July 15, 2012, geomagnetic storm with minimum Dst = -133 nT, associated with passage of a magnetic cloud with a southward magnetic field ($B_z \leq 0$) indicating between red lines the Green line indicating the IP shock and red line are marked for showing arrival of ICME.*

Table 3: This list provided the Geomagnetic storm events during Solar cycle 23 and 24 and associated IP shock and ICME.

Solar Cycle	**Dst Event s**	**Association with IP shock**	**Association with ICME**
SC 23	50	Forward shock =74%; Reversed Shock =4%	78%
SC 24	17	Forward shock = 78%; Reversed shock = 14%	47%



(a)



(b)

Figure 5: *(a) Shows the scattered plot between IP shock speed and CME speed value with correlation coefficient 0.77 for SC 23 and 0.80 for solar cycle 24 (b) Shows the scattered plot between ICME speed and CME speed with correlation coefficient 0.63 for SC 23 and 0.54 for SC 24.*

As we can see from Figure 5 (a), where we compare the features of IP shock Speed and CME speed correlation for solar cycle 23 and 24. It has good correlation for both SC 23 (CC=0.77) and SC 24 (CC=0.80). And Figure (b) shows the scattered plot between ICME speed and CME speed with correlation coefficient 0.63 for SC 23 and 0.54 for SC 24. Our analysis (Table 3) shows that in solar cycle 23, there are 39 events associated with interplanetary shock and 75% of them are associated with Forward shock and only 4% geomagnetic storm events are associated with reversed shock. There are 78% (43 events) have association with interplanetary CMEs. While in rising phase of solar cycle 24 (from 2008 to 2012) we have 17 Geomagnetic events (Dst≤-75nT), there are 15 events associated with interplanetary shock and 76% (14 events) of them are associated with Forward shock and only 14% (3 events) geomagnetic storm events are associated with reversed shock. There are 47% (9 events) have association with interplanetary CMEs.

IV. CONCLUSION

In this presented work, we have done a statistical study of the occurrence rates and properties of ICMEs/IP shock with geomagnetic storms and their relation to the variations in the solar wind activity and magnetic field parameters during ascending phase of solar cycles 23 and 24. As previous studies shows that the SC 23 rising phase is different in many respects from the same phase of the previous sunspot cycle[30][31][32][33]. We have pointed out in this paper that there were differences in the general properties of ICME/IP shock between the rising phase of SC 24 and corresponding phase of the solar cycle 23.

1) We have prepared a comprehensive list of IP shock/ ICMEs for Dst ≤ -75 nT recorded at 1 AU during the period January 1996 through December 2000 (phase of SC-23) and January 2008 to December 2012 (ascending phase of SC-24). We find the following:
2) The geo-magnetic activities were lower during the ascending phase (first 5 years) of solar cycle 24 comparatively to corresponding duration of solar cycle 23.
3) During rising phase of solar cycle 24, Super-intense storm rates are only comparable to or below the minimum rates observed in previous cycle.
4) In the ascending phase of Sunspot cycle 24, ICME activity were reduced in comparison of rising phase of SC 23.
5) Based on the Richardson & Cane (updated -June 2018) catalog used in this study, ~20% fewer ICMEs passed Earth during the ascending of SC 24 compared to SC 23.
6) The mentioned in Table 2, that 90% and 78% of all reported geo-magnetic storms (Dst ≤ -75 nT) are associated with the IP shocks for solar cycle 24 and 23 respectively. This suggests that occurrence of major geo-magnetic storms are not always caused by strong IP shocks. In general, the absence of shock/ ICMEs would give rise to intense geomagnetic storms. These events may be the result of a combination of a fewer ICMEs with speeds exceeding average solar wind speeds (450 kms^{-1}) and lack of such structures with strong southward magnetic fields having Bz > 20 nT compared with cycle 23.

As mentioned in Table 1, it is important to mention that sometimes identification of magnetic clouds within ICMEs little difficult by following the methods suggested by [34][35]. However, this is a problem associated with a observation from single satellite that would be solved by multi- satellite observation in near future.

ACKNOWLEDGMENT

We are grateful to the Solar Geophysical Data team, WDC, Kyoto team, OMNI team for their open data policy. The CME catalogue we have used is generated and maintained by the Centre for Solar Physics and Space Weather, SOHO is a project of international cooperation between ESA and NASA. We are very thankful to Dr. Bhuwan Joshi, Associate Professor, Udaipur Solar Observatory, PRL, Ahmedabad for his great support to us.

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