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Study of Geomagnetic Storms During Maxima of Solar Cycle 24

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Abstract:- **Modern society depends on a variety of technologies that are susceptible to the extremes of space weather-severe disturbances of the upper atmosphere and of the near- Earth region that are driven by the magnetic activity of the Sun. Coronal Mass Ejections are typically reached on Earth from one to five days after the eruption from the Sun. We have studied geomagnetic storms (DST ≤ - 100nT) observed during solar cycle 24 associated with halo and partial halo coronal mass ejections. The occurrence of total number of halo (H) and Partial halo (PH) CMEs are 469 and 158 during the maxima time period (2013-2014) and also 2015 of solar cycle 24.**

Keywords- Geomagnetic Field Disturbances, Coronal Mass Ejections (CMEs), Disturbance Storm Time (Dst), Bz, SW.

1. INTRODUCTION

Coronal mass ejections rising from the solar limb have been observed directly and routinely with white light coronagraphs since the yearly 1970s, the ability to detect those directed at Earth is a recent development. Spacecraft Coronagraphs show that typical CME consists of a bright leading edge of gas forming a loop or, more probably, a bubble in the corona ahead of a dark cavity. To determine the processes involved in mass ejection it is important to consider the pre-existing conditions and address whether there are locations from which mass ejections are more likely to arise. It is observationally difficult to correlate CMEs, which are most visible when close to the limb, with direct observations of the photospheric magnetic fields and associated structures immediately prior to eruption as such observations are often hard to obtain at the limb. The coronal mass ejections are closely related to the other form of solar activity which we see on the sun. In qualitative terms, the rate of mass ejections varies throughout the 11-year solar cycle, the same way as other indicators of the solar activity [1]. Solar activity comprising sunspots and other phenomena is strongly related to disturbances in the Earth’s magnetic field and it gives rise to various effects in the Earth’s upper atmosphere ([2-4]).The interplanetary causes of intense storms (Dst ≤-100 nT) during solar cycle 23 has been investigated by many author ([5-7]). A CME produces disturbances in the solar wind preceded by a shock wave. Interplanetary space probes encountering such disturbance have recoded increased wind speeds and densities, and a rapidly varying magnetic field. When these interplanetary disturbances reach to the Earth, they give rise to geomagnetic storms. Their frequency varies with the sunspot cycle. At solar minimum about one CME in a week, rising to an average of two or three per day at solar maximum. Coronal mass ejections can be geoeffective, in the sense that they can cause geomagnetic storms, because they can bring to Earth strong southward fields at the dayside boundary of the magnetosphere, as a consequence allow solar wind energy, momentum, and mass access to the magnetosphere ([8],[9],[10]). The speed of CME determines geoeffectiveness [11]. Speed is a factor in the solar wind electric field, which controls the merging rate at the boundary of the magnetosphere, but its overall contribution to storm strength as an electric field factor is not large because speed varies much than the other controlling parameter, the strength of the southward magnetic field. CME which are faster than the ambient solar wind are more geoeffective because they compress any southward fields in the vicinity of their leading edges [12]. CMEs are responsible for the most geoeffective solar wind disturbances. The geoeffectiveness of CMEs and further information regarding CMEs can be found in literature ([13-18]). The solar wind also carries with it the magnetic field of the Sun. This field will have either a North or South orientation. If the solar wind has energetic bursts, contracting and expanding the magnetosphere, or if the solar wind takes a southward polarization, geomagnetic storms can be expected. The southward field causes magnetic reconnection of the dayside magnetopause, rapidly injecting magnetic and particle energy into the Earth's magnetosphere. During a geomagnetic storm, the ionosphere's F2 layer will become unstable, fragment, and may even disappear. In the northern and southern pole regions of the Earth, auroras are observable in the sky. Several authors have studied the geoeffectiveness of magnetic clouds for longer time intervals ([19], [16], [7]).

2. DATA SELECTION

Here, we have analyzed in detail all those large geomagnetic storms Dst decreases of less than -100 nT and are observed during the period 2008-2015. If the magnitude of storm (Dst value) recurs for several consecutive days/hours, then the last day/hour is taken as the storms day. A set of five large geomagnetic storms associated with Dst≤-100 nT are presented. We have analyzed the association of storms with CMEs. Here, we have considered hourly averaged data. The hourly values of geomagnetic index have been obtained from Solar Geophysical Data (Prompt/ Comprehensive report) of U.S. Department of Commerce, NOAA and Omni web data. We present some of the recently interplanetary structures associated with large storms, mainly for solar cycle 24. The data of coronal mass ejections (CMEs) have been taken from SOHO - large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. To determine interplanetary magnetic field Omni web data system has been used, these data has also been taken online from Omni web data explorer (http//omniweb.gsfc. nasa.gov/form/dxi.html).

3. RESULTS AND DISCUSSION

Magnetic field was pointing substantially southward, thus causing the Dst to fall up to –137 nT. During the event, three halo CMEs and two partial halo CMEs have been observed by the LASCO instrument with a speed of 593, 1005, 570 km/s and 441, 270 km/s respectively. Probes encountering such disturbances have recorded increased solar wind speeds, densities and rapidly varying magnetic field. When these interplanetary disturbances reach the Earth, they give rise to geomagnetic storms. The decrease in the equatorial magnetic field strength, measured by the Dst index, is directly related to the total kinetic energy of the ring current particles; thus the Dst index is a good measure of the energetic of the magnetic storm. The Dst index itself is influenced by the interplanetary parameters. A superposed epoch analysis shows a decrease in the rate of development of Dst index with substorm occurrence, contrary to the view that substorm contribute to the build-up of the ring current as measured by Dst index [20]. Here we have analyzed five geomagnetic storms as follows: August 03-09 (year 2011) Geomagnetic Storm Figure1 is a composition of solar–interplanetary and geomagnetic observations from the 3rd to 9th of August 2011. Variation of magnetic field and plasma parameters observed by ACE, together with the Dst index. Interplanetary and geomagnetic parameters are presented. Soon after the shock "S" the Z component of magnetic field turns southward and is intensified because of a compression of sheaths region, remaining like that for approximately 18 hours, making the Dst index to fall to – 113 nT. The total average magnetic field jumps across the shock from 7 to 29 nT, southern component Bz rapidly jumps from -16 to 13nT and solar wind proton density jumps across the shock from 9 to 21 N/cm3. During the event, three halo CMEs and three partial halo CMEs have been observed by the LASCO instrument with a speed of 610, 1315, 1610 km/s and 338, 1343, 1070 km/s respectively.

August 03-09 (year 2011) Geomagnetic Storm

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4. CONCLUSION

The 5 geomagnetic storms considered in this paper, indicate various solar and interplanetary characteristics and their corresponding geomagnetic effects. For each event, peak Dst values as well as date and time of their occurrences has been analyzed. Dst decreases with increasing magnetopause shielding currents, a measure of magnetospheric compression produced by an increase in solar wind density. A fast solar wind speed and a strong southward component of the magnetic field are particularly effective in producing geomagnetic storms. It is observed only when the magnetic field of the near-Earth interplanetary medium focus the Earth has a strong southward component. A good relationship is obtained between Dst and the product B x V. In contrast, the CMEs maximum speed index provides information about energy of solar events, not just the frequency of solar magnetic activity. The interplanetary manifestations of CMEs can result in extensive transient disturbances that, when directed Earthward, can cause major geomagnetic storms at Earth. The physical link between CMEs and geomagnetism present a new meaningful index to describe solar geoeffectiveness. These results are in agreement with those anticipated in the earlier work ([21-22]). These quantitative relationships are invaluable for modeling studies and space weather phenomena.

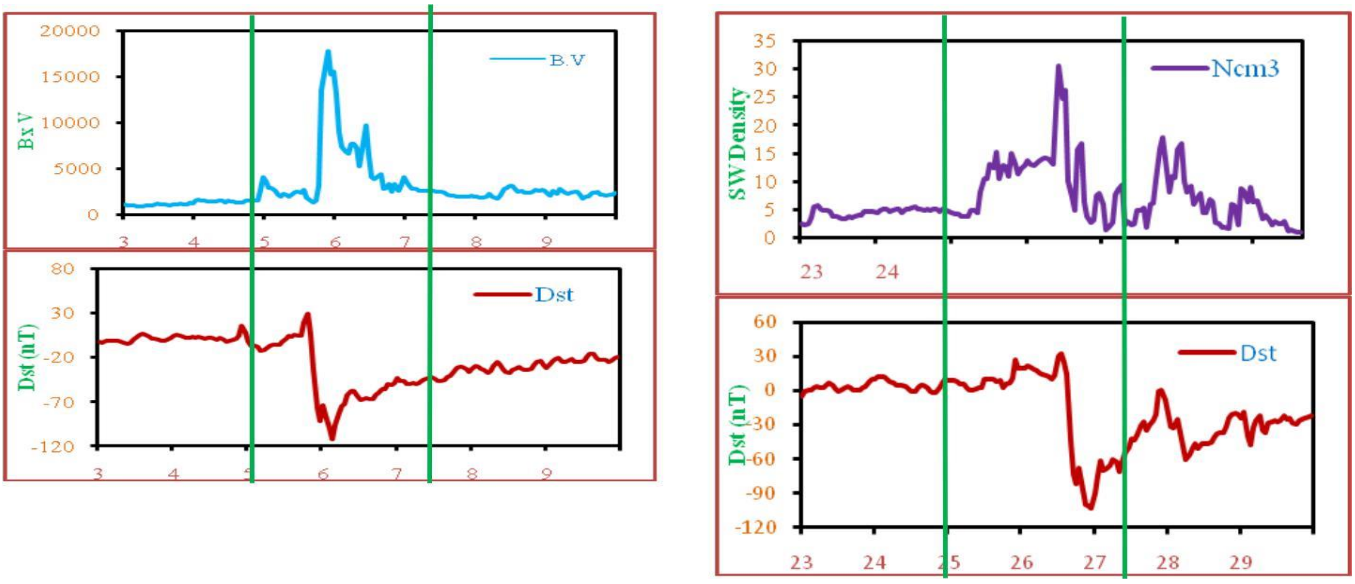

Fig.1 shows the association of geomagnetic storm with interplanetary magnetic field B x V, solar wind speed and Dst observed during 03-09 Aug. 2011.

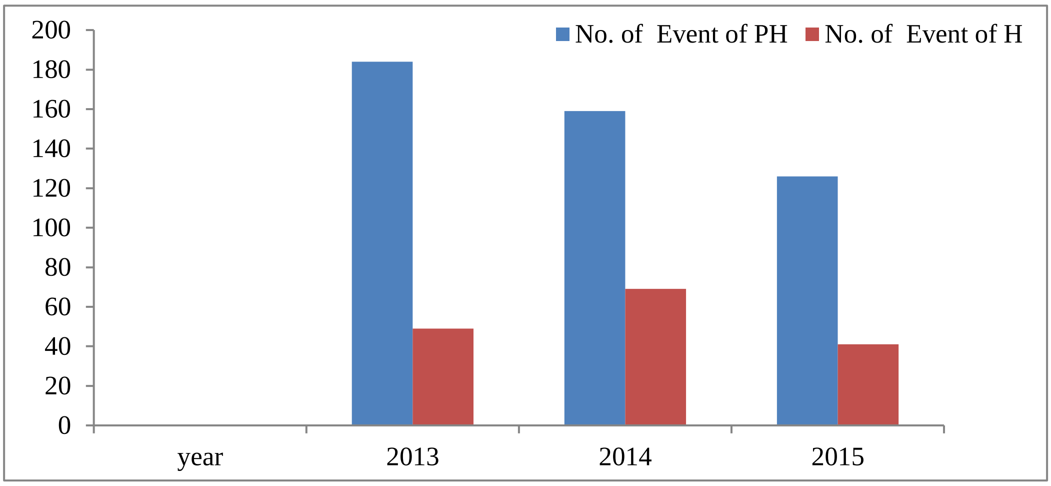

Fig.2 shows the occurrence of Partial Halo (PH) and Halo (H) CMEs during year 2013, 2014 &2015

TABLE I. CHARACTERISTIC FEATURES OF LARGE GEOMAGNETIC STORMS OCCURRED DURING MAXIMA OF SOLAR CYCLE 24

Sr. No.	**Date of maximum decreases in Dst value**	**Magnitude of storm ≤-100 (nT)**	**Date and time of CMEs**	**Speed Of CMEs (km/s)**	**Solar wind velocity (km/s)**	**Bz-component of IMF (nT)**	**Angular Width (d)**	**Types of CMEs**
1.	06 Aug. 2011	-113	03/08/2011(14:00:07)	610	355	-0.7	360	H
			04/08/2011(04:12:05)	1315	341	0.2	360	H
			04/08/2011(06:24:06)	338	350	2.9	123	PH
			08/08/2011(18:12:07)	1343	358	-1.8	237	PH
			09/08/2011(03:48:05)	1146	417	-2.9	141	PH
			09/08/2011(08:12:06)	1419	423	1.6	369	H
2.	26 Sept. 2011	-103	24/09/2011(09:48:06)	1936	336	-0.7	360	PH
			24/09/2011(12:48:07)	1915	348	0.9	360	H
			24/09/2011(19:36:06)	972	335	-2.1	360	H

			25/09/2011(00:24:07)	557	330	-0.4	132	PH
			25/09/2011(05:12:05)	788	308	-1.7	193	PH
			25/09/2011(07:36:05)	641	313	-1.1	157	PH
3.	25 Oct. 2011	-123	22/10/2011(02:25:53)	593	320	-1.0	360	H
			22/10/2011(10:24:05)	1005	313	-0.1	360	H
			23/10/2011(23:48:07)	441	314	-1.7	148	PH
			26/10/2011(10:00:05)	270	400	2.1	158	PH
			27/10/2011(12:00:06)	570	421	-0.9	360	H
4.	9 March 2012	-133	07/03/2012(00:24:06)	2684	375	0.7	360	H
			08/03/2012(17:47:13)	591	683	0.3	161	PH
			09/03/2012(04:26:09)	950	683	-14.2	360	H
			09/03/2012(08:29:52)	336	713	-12.1	204	PH
			10/03/2012(16:24:05)	423	503	-2.7	127	PH
			10/03/2012(18:12:06)	1379	481	-3.0	360	H
			12/03/2012(01:25:50)	638	424	-3.5	122	PH
5.	25 April 2012	-107	23/04/2012(18:24:05)	528	309	-3.5	360	H
			24/04/2012(08:12:05)	443	373	7.5	190	P H
			24/04/2012(09:12:08)	521	379	7.9	131	PH
			24/04/2012(11:36:07)	433	383	7.4	140	PH
			24/04/2012(16:12:05)	547	390	-3.5	168	P H
			27/04/2012(16:24:06)	681	585	0.8	360	H

H- halo CMEs and PH- partial halo CMEs**.**

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