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Study of Interplanetary Magnetic Field and Solar Wind Parameters Associated with Geomagnetic Storm During Solar Cycle 24

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Abstract

We have studied about geospheric environment which has caused by the interplanetary magnetic field (IMF) and solar wind plasma parameter during the period of 2018 to 2019. In this solar cycle (SC) 24 geomagnetic storms index range Dst ≤ -90nT respectively data collect during the period, we have found 27 geomagnetic storms data. Coronal mass ejection (CME) associated with frequency of geomagnetic storms rate are 74% there the Halo CME and Partial Halo CME association rate 65% and 35% determined. Analysis of X-ray solar flare (SF) associated with majority of geomagnetic storms are 69.23% respectively, there linked solar flare (SF) classified X-class, M-Class, C-Class and B-Class relative association rate 20%, 40%, 30% and 10% determined. We have examined positive co-relation with co-relation coefficient 0.509 between magnitude of geomagnetic storms and The peak value of IMF, 0.495 between magnitude of geomagnetic storms and the magnitude of IMF, 0.22 between the magnitude of geomagnetic storms and the peak value of solar wind plasma speed (SWPS), 0.298 between the magnitude of geomagnetic storms and the magnitude of solar wind plasma speed (SWPS), 0.619 between the magnitude of geomagnetic storms and the peak value of flow pressure, 0.58 between the magnitude of geomagnetic storms and the magnitude of flow pressure, 0.402 between the magnitude of geomagnetic storms and the peak value of solar wind proton density (SWPD), 0.275 between the magnitude of geomagnetic storms and the magnitude of solar wind proton density (SWPD). We have examined this statistical relation and concluded that the Earth's magnetosphere disturbance is caused by the coronal mass ejection, X-ray solar flare, interplanetary magnetic field, and solar wind plasma parameter.

1. Introduction

Geomagnetic phenomena relate to solar processes is that the sun is the source of energy for geomagnetic phenomena, and the solar wind (SW) transfers energy to the Earth's magnetosphere (McPherron, R. L. 2005). The SW energy enters the magnetosphere only when the interplanetary magnetic field (IMF) has a significant component parallel to the terrestrial magnetic dipole, i.e. It contains mention of the IMFBz component, which is generally negative (pointing southward). Energy builds up in the magnetosphere when the pace of energy input exceeds the rate of its quasi-stationary dissipation. When it reaches and surpasses a certain threshold, any minor disruption within or outside the magnetosphere can cause this energy to be released (Borovsky, J. E. et. al. 2018) . This can be seen as a magnetospheric disturbance, which is characterized by the reconnection of magnetic field lines, the global reorganization of current systems in the magnetosphere, and the heating or acceleration of plasma (Hesse, M. et.al. 2020). Given that the field is located in the ecliptic plane, quasi-stationary SW typically lacks extended stretches of southern IMF components (Kivelson, M. G. et.al. 2014)(Nakariakov, V. M. et.al. 2016). Interplanetary shocks (IS), magnetic clouds (MC), areas of compression at the transition between slow and rapid streams (known as co-rotating interaction regions, or CIR), along with other significant disturbances can occasionally propagate in the SW. Either they have a significant southbound IMF Bz component, or they alter the environment so that it can remain in the SW for a duration of many hours. Most of the X and M-class X-ray solar flare related intense geomagnetic storms (82.45%) have found to be associated with halo and partial halo coronal mass ejection. Coronal mass ejection, solar radio bursts and associated disturbances in solar wind plasma parameters are mainly responsible to generate X and M-class X-ray solar flare related intense geomagnetic storms (Verma, P. L.) (GOUR, P. S. et.al. 2012).
The lowest solar minima occur during solar cycle 23 and 2, whereas the longest solar minima, known as a “deep minimum” occur during solar cycle 14 and 15 (Usoskin, I. G. et.al. 2003). coprisin between the characteristic solar parameters of high-speed solar wind streams in the present solar cycle with those of precious solar cycle to understand the dependance of their long term’s variation on the cycle phase (Manoharan, P. K. 2012) (Hathaway, D. H. 2015). The fact that the solar wind-magneto sphere coupling was weaker in cycle 24 than in cycle 23 is due to a less active Sun (Tsurutani, B. T. 2000). Geomagnetic activities in cycle 24 showed two peak characteristics caused by CME’s that identified to be associated with high seed solar wind from coronal holes (Richardson, I. G. 2000) (Watari, S. 2017). During rising phase of solar cycle 24 super intense storms rates are only comparable to or below the minimum rates observed in previous cycle. In the ascending phase of Sunspots cycle 24 ICME activity were reduced in comparison of rising phase of solar cycle 23 (Soni, S. L. et.al. 2018). In this article we study Sun and their associated parameter during the solar cycle 24 period of 2008 to 2019. Taking geomagnetic storms magnitude dst index ≤ -90nT and create relation between different solar wind parameter.

2. Data Reduction and Analysis

In this research geomagnetic storm hourly data of Dst index ≤ -90nT, interplanetary magnetic fields (IMF) and southward component of interplanetary magnetic fields (IMF B_Z), solar wind plasma parameter, such that solar wind plasma velocity, solar wind density, solar wind pressure this various parameter has been examine for the period of August 2008 to December 2019. Determine data of geomagnetic storms, solar wind plasma parameter (speed, pressure, density) and interplanetary magnetic field (IMF) has been taken from Omni web data (http://omniweb.gsfc.nasa.gov/form/dxi.html).
Coronal mass ejection (CMEs) and solar flare (SF) data have been taken from SOHO-large angle spectrometric coronograph (SOHO/LASCO) (https://cdaw.gsfc.nasa.gav/CME-list/) and extreme ultraviolet imaging telescope (SOHO/EIT) are used.

Table 1: Solar wind and geomagnetic activity parameter

S. No.	Geomagnetic Storms					IMF		SW Speed		SW Proton Density	
	Onset Time			Peak Value	Magnitude	Peak Value	Magnitude	Peak Value	Magnitude	Peak Value	Magnitude
	Date	Day	Hour								
1	05-08-2011	217	20	-115	-116	29.4	25.2	611	262	26.8	24.5
2	26-09-2011	269	15	-118	-125	34.2	27	686	342	27	17.6
3	24-10-2011	297	22	-147	-125	24	21.1	508	196	27.9	14
4	08-03-2012	68	14	-145	-129	23.1	14.9	587	211	16	6.6
5	23-04-2012	114	18	-120	-110	15.5	11.6	389	80	23.5	18.3
6	15-07-2012	197	2	-139	-127	27.3	23.4	655	326	20.7	17.1
7	30-09-2012	274	15	-122	-111	21	18.4	411	116	32.2	24.2
8	07-10-2012	281	13	-109	-108	16.3	8.9	371	18	10.5	3.9

9	13-11-2012	318	18	-108	-106	22.8	18.6	455	126	NA	NA
10	17-03-2013	76	7	-132	-127	17.8	11.9	712	240	14	10
11	01-06-2013	152	1	-124	-127	19.6	17.8	683	338	39	36.6
12	28-06-2013	179	3	-102	-98	12.5	10.4	425	35	27.3	25.1
13	18-02-2014	49	14	-119	-118	18.6	13.9	409	20	11.4	9.8
14	17-03-2015	76	7	-234	-216	31.5	25.6	614	252	33.7	19.3
15	22-06-2015	173	18	-198	-196	37.7	35.9	742	397	40.4	25.9
16	31-03-1900	237	2	-103	-91	16.3	12.5	NA	NA	23.6	21.4
17	08-09-2015	251	20	-105	-98	21.3	14.7	NA	NA	19.4	13.5
18	07-10-2015	280	2	-130	-147	20.4	16.3	462	55	26.2	21.7
19	20-12-2015	354	4	-166	-163	19.5	16.3	495	107	62.7	58.1
20	31-12-2015	365	12	-116	-104	16.9	13.3	465	104	25.5	17.1
21	20-01-2016	20	5	-101	-97	19.2	11.2	371	29	26.3	6.6
22	06-03-2016	66	16	-99	-101	20.1	16.6	542	176	32	22.1
23	08-05-2016	129	1	-95	-92	16.3	9.9	655	127	19.6	14.3
24	13-10-2016	287	7	-110	-92	24.1	20.3	439	59	30.5	25.1
25	27-05-2017	147	22	-125	-140	22.8	20	401	93	62.1	57.1
26	07-09-2017	250	22	-122	-94	27.3	24.9	817	406	NA	NA
27	25-08-2018	237	18	-175	-167	18.2	12.4	444	93	23.2	14.9

Table no. 2 Solar and geomagnetic activity parameter

S. No.	Geomagnetic Storms					Flow Pressure		CME		Solar Flare
	Onset Time			Peak Value	Magnitude	Peak Value	Magnitude	Type	Speed	
	Date	Day	Hour							
1	05-08-2011	217	20	-115	-116	20.85	20.34	Partial Halo	712	M
2	26-09-2011	269	15	-118	-125	14.15	11.72	Halo	2254	X
3	24-10-2011	297	22	-147	-125	15.29	11.7	Halo	1174	M
4	08-03-2012	68	14	-145	-129	14.13	6.63	Halo	2684	X
5	23-04-2012	114	18	-120	-110	11.25	10.32	Partial Halo	660	C
6	15-07-2012	197	2	-139	-127	14.38	13.66	Halo	2265	X
7	30-09-2012	274	15	-122	-111	6.22	4.79	Halo	1319	C
8	07-10-2012	281	13	-109	-108	1.92	0.55	Partial Halo	885	B
9	13-11-2012	318	18	-108	-106	NA	NA	Partial Halo	1039	M
10	17-03-2013	76	7	-132	-127	12.24	10.5	Halo	1247	M
11	01-06-2013	152	1	-124	-127	11.69	11.15	Partial Halo	419	C
12	28-06-2013	179	3	-102	-98	9.42	8.79	Halo	349	C
13	18-02-2014	49	14	-119	-118	3.38	2.85	Partial Halo	362	C
14	17-03-2015	76	7	-234	-216	18.24	14.34	Halo	719	M
15	22-06-2015	173	18	-198	-196	37.89	29.69	Halo	1477	M
16	31-03-1900	237	2	-103	-91	1.69	0.56	Halo	547	M
17	08-09-2015	251	20	-105	-98	9.64	5.84	Partial Halo	651	B
18	07-10-2015	280	2	-130	-147	7.94	6.56	NA	NA	NA
19	20-12-2015	354	4	-166	-163	21.86	20.53	Halo	579	C
20	31-12-2015	365	12	-116	-104	10.35	8.3	Halo	1243	M

21	20-01-2016	20	5	-101	-97	5.61	1.3	NA	NA	NA
22	06-03-2016	66	16	-99	-101	10.26	7.9	NA	NA	NA
23	08-05-2016	129	1	-95	-92	9.36	6.33	NA	NA	NA
24	13-10-2016	287	7	-110	-92	10.23	8.78	NA	NA	NA
25	27-05-2017	147	22	-125	-140	15.37	14.54	NA	NA	NA
26	07-09-2017	250	22	-122	-94	7.93	7.25	Halo	1571	X
27	25-08-2018	237	18	-175	-167	4.8	2.97	NA	NA	NA

3. Data Analysis and Result

3.1 Association with Coronal Mass Ejection and Geomagnetic Storms

We have examined geomagnetic storms linked to coronal mass ejection that were seen during solar cycle 24 in this section. There was a total of 27 geomagnetic storms Dst ≤ -90 nT recorded during solar cycle 24. Halo and partial halo Coronal mass ejection (CME) are shown to be linked to the majority of geomagnetic storms, 20 out of 27 (74%), Halo and partial halo CME association rates have been determined to be 65% and 35% respectively.

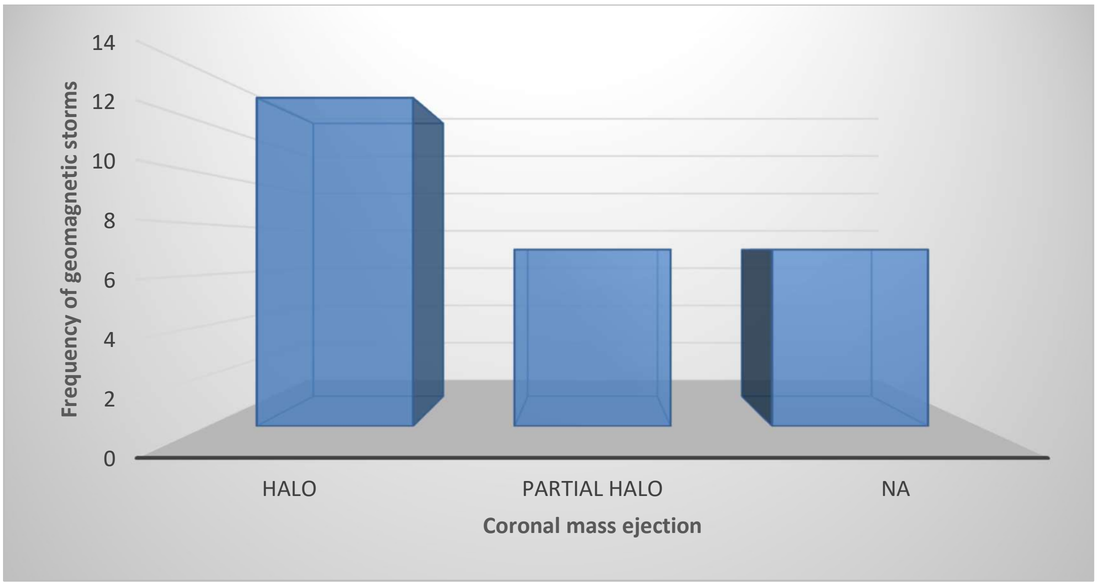

Fig.1 Bar diagram of coronal mass ejection and frequency of associated geomagnetic storms.

3.2 Analysis Geomagnetic Storm with X-Ray Solar Flare

Large amounts of solar plasma material are released from the sun into interplanetary space during solar flares, which are extreme solar occurrences that cause significant disruption to solar wind plasma and geomagnetic storms in geomagnetic fields. Numerous researchers have looked into geomagnetic storms that involve solar flares. This study examines geomagnetic storms using X-ray solar flares that were seen during solar cycle 24. 20 out of the 27 geomagnetic storms that we have identified (69.23%) are linked to X-ray solar flares of various classified types. X-Class, M-Class, C-Class and B-Class solar flares have relative association rates are 20%, 40%,30% and 10% respectively. Additionally, the great majority of geomagnetic storms are associated with solar flares.

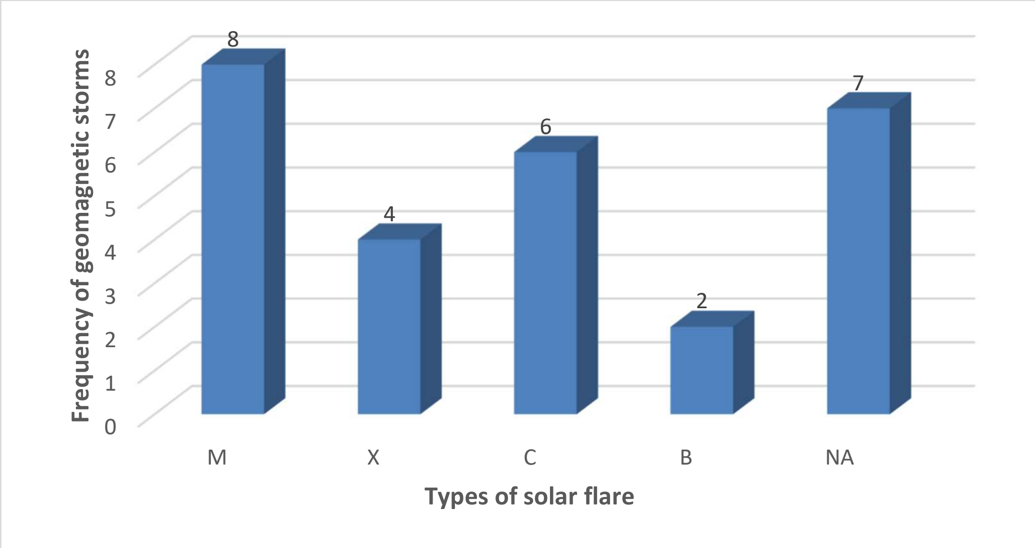

Fig.2 Bar diagram of geomagnetic storms and solar flare.

3.3 Correlation Between Magnitude Geomagnetic Storms and Disturbance of Interplanetary Magnetic Field (IMF)

From the data analysis is given in the IMF list table on geomagnetic storms and related to it. It has been found that most of the geomagnetic storms have been associated with the disturbances in the IMF have 27 geomagnetic in our list out of which 27 are associated with jump in interplanetary magnetic field.

Figure-3 to study the statistical behavior of geomagnetic storms and the peak value of associated IMF events and the higher intensity but they are associated with IMF events a scatter plot has been platted between geomagnetic storms and peak value of associated IMF event and the resulting plot show in figure 1. We have found some geomagnetic storms, which have higher magnitude but they are associated with such IMF events which have lower values of peak IMF and vice versa. Magnitude of geomagnetic storms and peak value of IMF of associated JIMF events between positive correlation has been found these statistically calculated co-relation coefficient between two events is 0.50945.

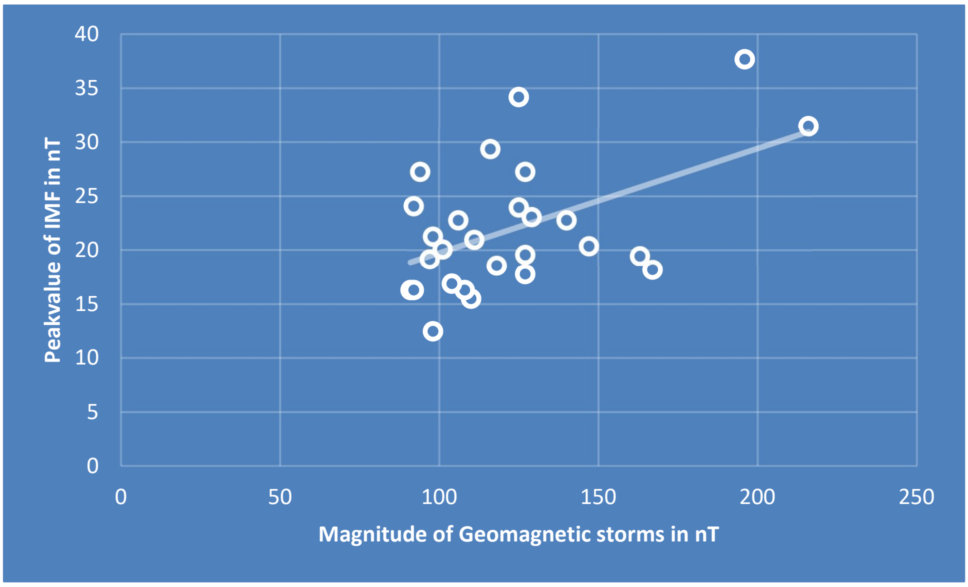

Fig.3 The scatter plot between the magnitude of geomagnetic storms and peak value of Interplanetary magnetic field (IMF).

To study another statistically behavior of geomagnetic storms and magnitude of jump of associated JIMF events a scatter plot has been platted between magnitude of geomagnetic storms and magnitude of Jump of associated JIMF events and resulting plot is shown in figure 4. In this figure most of the geomagnetic storms having higher magnitude are associated with such JIMF events which have relatively higher magnitude but these two events do not have any fixed. We have found some geomagnetic storms which have higher magnitude they are associated with such JIMF events which have lower magnitude of IMF and vice versa. The magnitude of associated JIMF events. Statistically calculated correlation coefficient found between these two events are 0.49512.

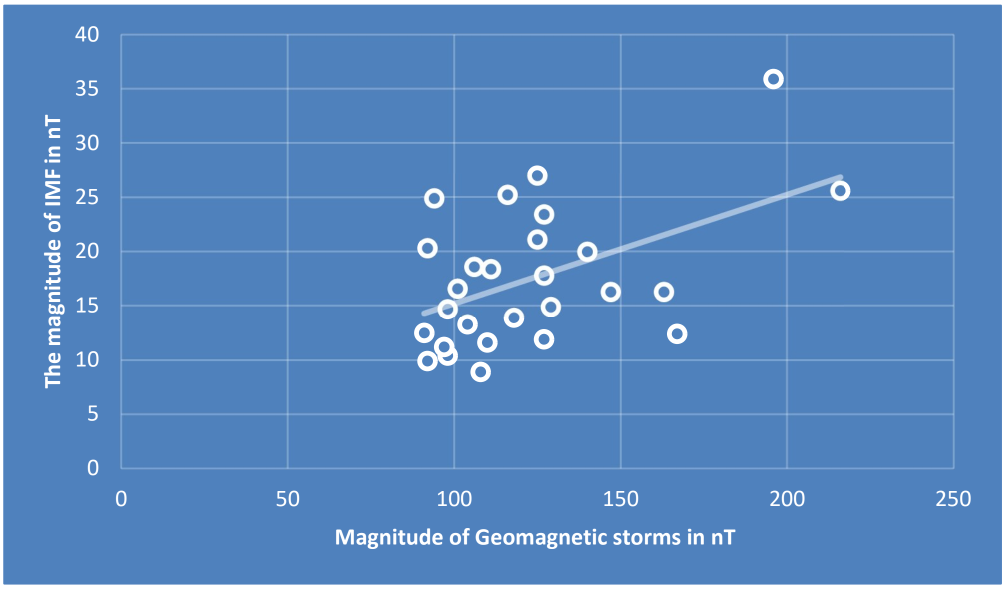

Fig.4 The scatter plot between the magnitude of geomagnetic storms and the magnitude of interplanetary magnetic field (IMF)

3.4 Statistical Relation Between Magnitude of Geomagnetic Storms and Solar Wind Plasma Speed

To know the statistical behavior of geomagnetic storms and peak value of associated JSW plasma speed events and the resulting plot is shown in figure 5. From the figure it is inferred that most of geomagnetic storms having higher magnitude are associated with such JSW plasma speed events which have relatively higher peak value of speed but these two events do not have any fixed proportion. We have found some geomagnetic storms which have lower values of peak JSWS events and vice versa. Positive correlation has been found between magnitude of geomagnetic storms and peak value of solar wind speed of associated JSWPS events. Statistically calculated correlation co-efficient is 0.22052 between these two events.

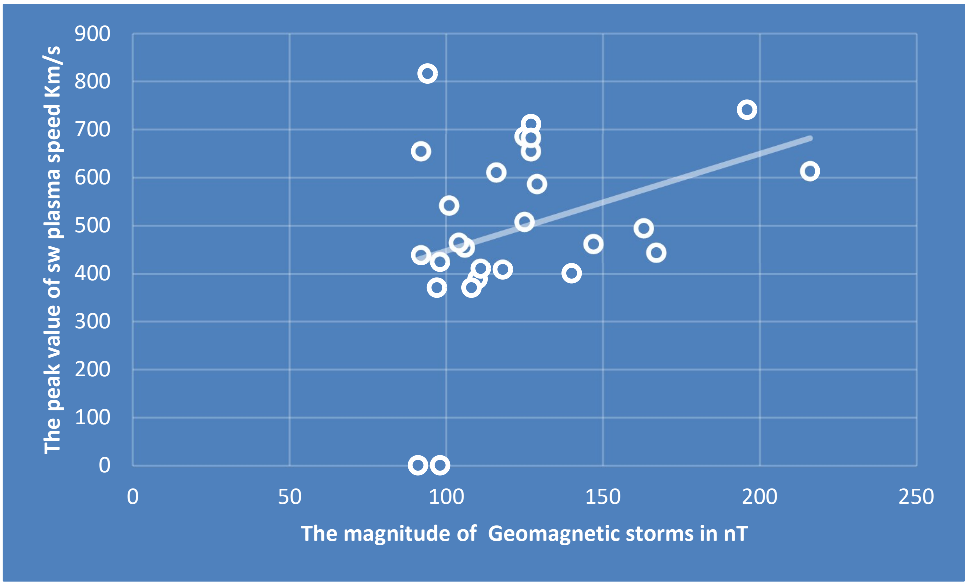

Fig.5 The scatter plot between the magnitude of geomagnetic storms and the peak value of solar wind plasma speed.

From the data analysis it is observed all geomagnetic storms are associated with disturbances in magnitude of speed. A scatter plot has been plotted between magnitude of geomagnetic storms and magnitude value of associated JSWS events and resulting plot is shown in figure 6. From the figure it is inferred that most of geomagnetic storms having higher magnitude are associated with such JSWS events which have relatively higher peak value of speed but these two events do not have any fixed proportion we have found some geomagnetic storms which have higher magnitude but they are associated with such JSWS events which have lower values of peak JSWS events and vice versa. Positive correlation has been found between magnitude of geomagnetic storms and peak value of speed of associated JSWS events statistically calculated correlation coefficient is 0.29835 between these two events.

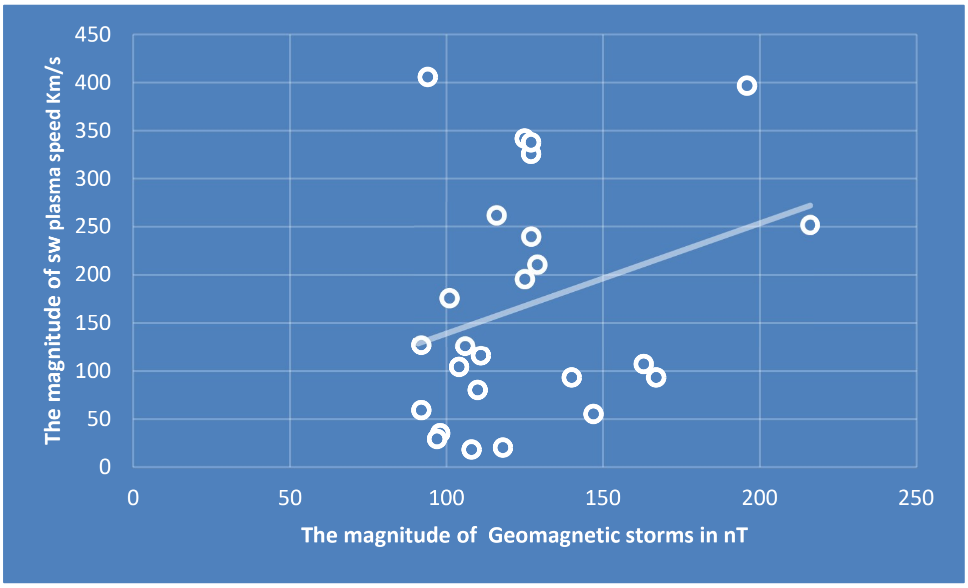

Fig.6 The scatter plot between the magnitude of geomagnetic storms and the magnitude of solar wind speed.

3.5 Correlation Between Magnitude of Geomagnetic Storms and Flow Pressure

To study the statistical behavior of geomagnetic storms and peak value of JSW flow pressure events a scatter plot has been plotted between magnitude of geomagnetic storms peak value of associated JSWP events and resulting plot is shown in figure 7. from the figure it is inferred that most of geomagnetic storms having higher magnitude are associated with such JSWP pressure events which have relatively higher peak value of pressure but these two events do not have any fixed proportion. We have found some geomagnetic storms which have magnitude but they are associated with such JSWP pressure events which have lower values of peak JSWP pressure events and vice versa.

Positive correlation has been found between magnitude of geomagnetic storms and peak value of flow pressure of associated JSWP events. Statistically calculated correlation coefficient is 0.61998 between these two events.

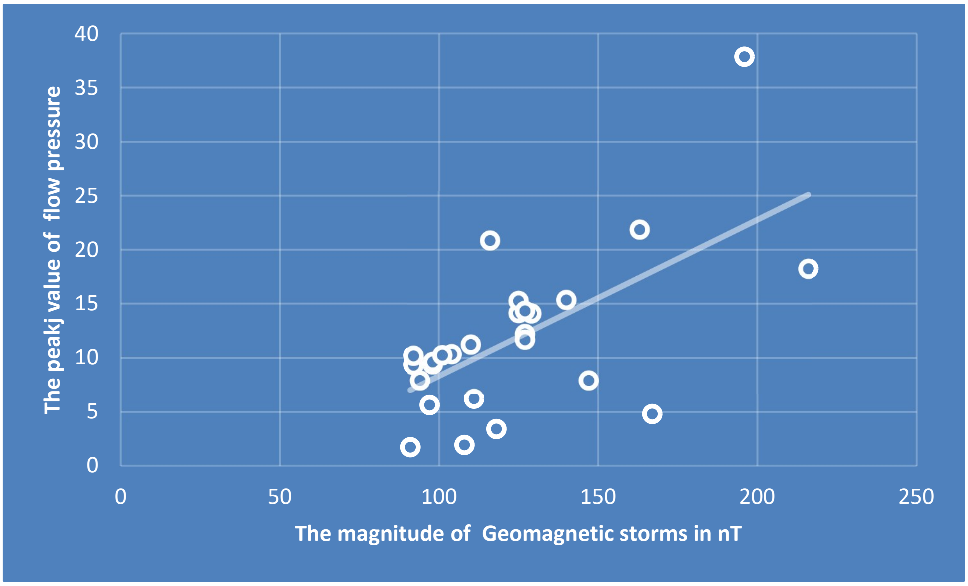

Fig.7 The scatter plot between the magnitude of geomagnetic storms and the peak value of flow pressure.

To study another statistical behavior of geomagnetic storms and magnitude of jump of associated JSWP pressure events a scatter plot has been plotted between magnitude of geomagnetic storms and magnitude of jump of associated JSWP pressure events and resulting plot is shown in figure 8. In this figure most of the geomagnetic storms having higher magnitude are associated with such JSWP events which have relatively higher magnitude but these two events do not have any fixed proportion. We have found some geomagnetic storms which have higher magnitude they are associated with such JSWP pressure events and vice versa. Positive correlation has been found between magnitude of geomagnetic storms and peak value of solar wind plasma pressure of associated JSWP events. Statistically calculated correlation coefficient is 0.58046 between these two events.

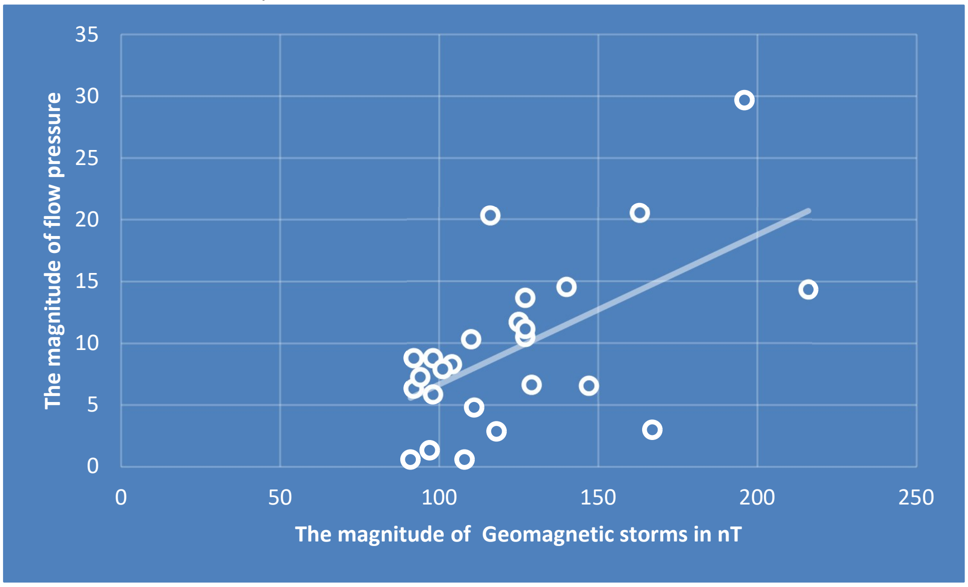

Fig.8 The scatter plot between the magnitude of geomagnetic storms and the magnitude of plasma flow pressure.

3.6 Statistical Correlation Between Magnitude of Geomagnetic Storms and Solar Wind Plasma Density

From the data analysis it is observed all geomagnetic storms are associated with disturbances in magnitude of density. A scatter plot has been plotted between magnitude value of associated jump solar wind plasma (JSWP) density events and resulting plot is shown in figure 9. From the figure it is inferred that most of geomagnetic storms having higher magnitude are associated with such JSWP density events which have relatively higher peak value of density but these two events do not have any fixed proportion we have found some geomagnetic storms which have higher magnitude but they are associated with such JSWP density events which have lower values of peak JSWP density events and vice versa. Positive correlation has been found between magnitude of geomagnetic storms and peak value of density of associated JSWP density events statistically calculated correlation coefficient is 0.40207 between these two events.

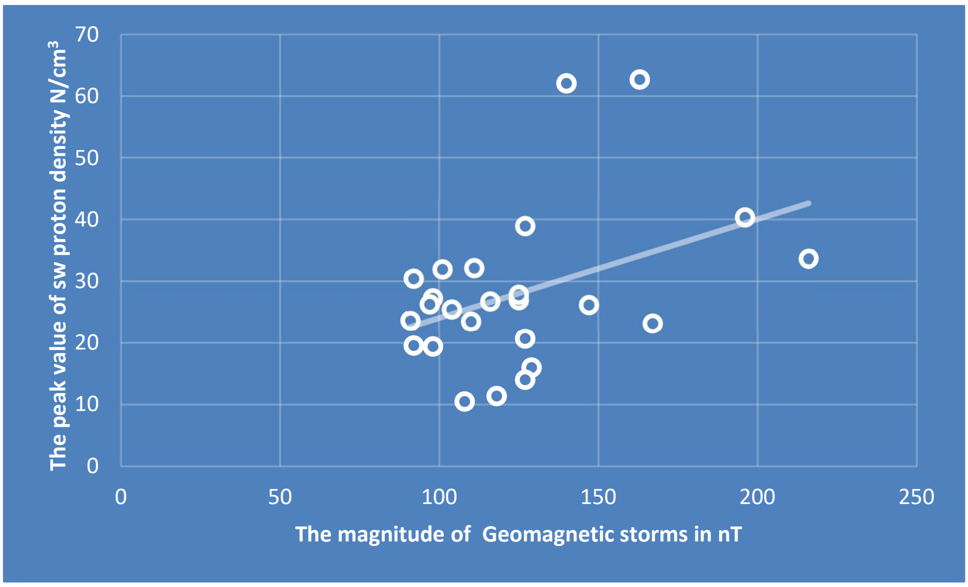

Fig.9 The scatter plot the magnitude of geomagnetic storms and peak value of plasma density.

The purpose of this correlative study is to determine the correlation between the magnitudes of geomagnetic storms and the peal value of disturbance in solar wind density events. To do this, we have plotted a scatter diagram between the two variables in figure 10. The figure makes it obvious that the majority of significant magnitude geomagnetic storms are associated with solar wind density disturbances with high peak values. A positive correlation has been identified between the intensity if geomagnetic storms and the values of fluctuation in solar wind density through solar cycle 24, represented by a correlation coefficient of 0.27531.

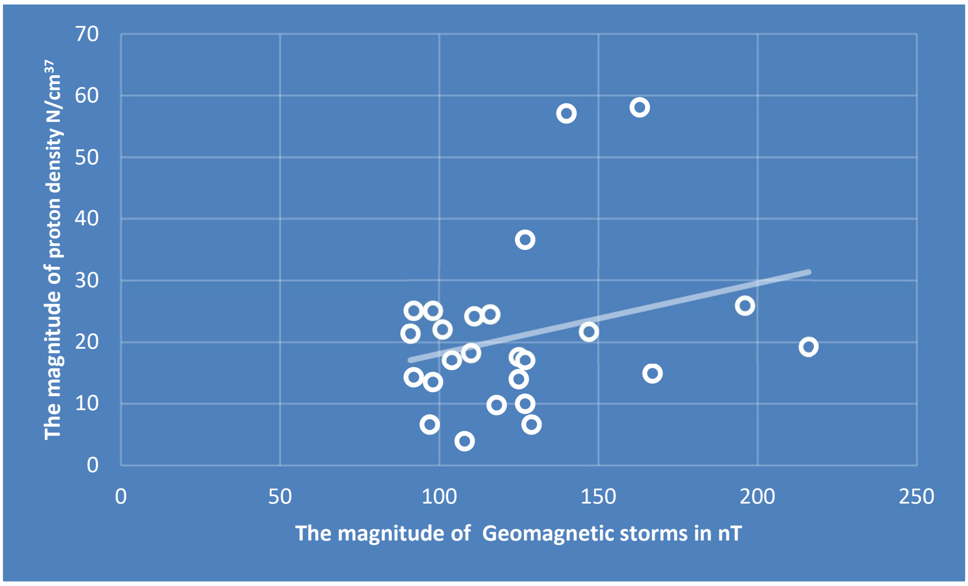

Fig.10 The scatter plot between the magnitude of geomagnetic storms and the magnitude of plasma density.

4. Results

1. Halo and partial halo coronal mass ejection (CMEs) and x-ray solar flares (SFs) of various types have been shown to be linked to the majority of geomagnetic storms.
2. The magnitude of geomagnetic storms and the peak value of IMFB have been found to positively correlate with a correlation coefficient of 0.50945.
   A significant positive correlation between the magnitude of related disturbances in IMFB and the magnitude of geomagnetic storms (GMs) has been discovered with a correlation coefficient of 0.49512.
3. There is a positive correlation between the peak value of disruption in solar wind speed and the magnitude of geomagnetic storms (GMs) with a correlation coefficient of 0.22052.
   Another positive correlation between the magnitude of geomagnetic storms and the magnitude of solar wind speed with a correlation coefficient of 0.29835.
4. A significant positive association between the peak value of related disturbance in flow pressure and the amplitude of geomagnetic storms (GMs) has been discovered with a correlation coefficient is 0.61998.
   A significant positive correlation between the magnitude of geomagnetic storms and the magnitude of flow pressure with a correlation coefficient is 0.58046.
5. There is a significant positive correlation coefficient between the peak value of SW plasma density and magnitude of geomagnetic storms (GMs) has been correlation coefficient is 0.40207.
   There is a positive correlation coefficient between the magnitude of SW plasma density and magnitude of geomagnetic storms (GMs) with a correlation coefficient is 0.27531.

5. Conclusion

We conclude that study during the solar cycle 24 Dst ≤ -90nT related 27 geomagnetic storms data collect statistical behavior found between coronal mass ejections (CMEs), solar flares (SFs), disturbances in solar wind plasma parameters, such as solar wind plasma speed, solar wind proton density, flow pressure and interplanetary magnetic fields (IMFs) are analyzed in relation to geomagnetic storms that were observed respectively.

1. CME association rate is 74% were halo CME is more than the partial halo CME their association rates are 65% and 35% respectively.
2. In X-ray solar flares M-class, X-class, and C-class are mostly associated with geomagnetic storms.
3. In SC 24 strongly positive co-relation found between IMF and geomagnetic storms. IMF mostly caused to generate geomagnetic storms and affect Erath environment.

4. SW parameters statistical relation found during SC 24, SW plasma speed and the magnitude of geomagnetic storms show weak positive co-relation, moderate positive co-relation between SW plasma density and maximum value of geomagnetic storms, strongly positive co-relation show between the magnitude of geomagnetic storms and low pressure.

Conflict of Interest

The authors state that there are no conflicts of interest related to this study.

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