

Geomagnetic Storms Related with Partial Halo Coronal Mass Ejections and Their Relation with Solar and Solar Wind Parameters During Ascending Phase of Solar Cycle 25



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Abstract

We have analyzed geomagnetic storms (GMs) associated with partial halo coronal mass ejections, observed during the period of ascending phase of solar cycle 25 with solar and solar wind parameters X-ray solar flares (SFs) and disturbances in solar wind plasma parameters, interplanetary magnetic fields (IMFB), southward component of interplanetary magnetic fields (IMFBz), solar wind plasma velocity (SWPV), solar wind plasma temperature (SWPT) and solar wind plasma pressure (SWPP). We have observed that all the P-CMEs related geomagnetic storms are associated with X-ray solar flares (SFs) of different categories. Positive correlation with correlation coefficient 0.27 has been found between magnitude of P-CMEs related geomagnetic storms and speed of associated partial halo CMEs. Further all the P-CMEs related geomagnetic storms (GMs) are associated with disturbances in solar wind plasma parameters. Large positive correlation with correlation coefficient 0.73 has been found between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of associated disturbances in IMFB, 0.85 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of associated disturbances in IMFBz. Further we have obtained positive correlation with correlation coefficient 0.50 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of disturbances in SWPT, 0.40 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of disturbances in SWPV and 0.76 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of disturbances in SWPP. We have concluded that partial halo coronal mass ejections (CMEs) associated with hard X-ray solar flares and disturbances in solar wind plasma parameters are responsible to generate geomagnetic storms (GMs).

1. Introduction

Due to the dynamic nature of its atmosphere, which affects the distribution and properties of plasma around the Earth, the Sun is the primary cause of space weather. Consequently, a geomagnetic storm may occur due to a change in the Earth's magnetosphere's configuration. Together with corotating interaction regions (CIRs) in interplanetary space, where the fast wind compresses the slow solar wind, coronal mass ejections (CMEs), the most significant of several phenomena in the Sun's atmosphere, are the primary causes of geomagnetic storms (27; 23). Initiating storms is a common feature of these events. The Earth's magnetic field weakens during the day and then re-connects due to the interplanetary magnetic field's (IMF) southward orientation (7; 25; 26). As a result, energy and particles enter the geomagnetic field. According to (22), this circumstance leads to the start of a number of chain events that travel from the Sun through the geomagnetic field, the atmospheric layers, and finally the ground surface. In addition to the quantity of dense particles, the second common characteristic is that when the structures of geomagnetic drivers are analyzed, they are typically at high speeds (>350 km/s) (10; 24; 14). Storms caused by coronal mass ejection are typified by abrupt increases in proton density (N_{sw}), solar wind speed (V_{sw}), and southward B_z , frequently accompanied by a shock (15). In contrast, CIR-driven storms are marked by fluctuating increases in V_{sw} , decreases in the N_{sw} , and fluctuations in the IMF (20; 21). (6) Reviewed the differences between storm-driven CMEs and storm-driven CIRs, which are influenced mainly by the solar wind, and looked at how their signatures differ. The intensity of the resulting geomagnetic storm is dependent on the quantity of energized particles in the magnetic field (3; 11; 1; 9). As a result, the southward-directed magnetic field (B_z), solar wind or CME parameters, and ionosphere particles all contribute significantly to the formation of a geomagnetic storm (3; 5; 11; 1; 9; 29; 4; 17). Interestingly, the CME assumes this role during the solar maximum (2; 8; 28), while the solar wind becomes the primary driver of a geomagnetic disturbance during the solar minimum (19; 18). The energetic particles and magnetic fields carried by a high-speed streamer from a coronal hole or a specially directed CME travel towards Earth. The interaction between the fast flow and the ambient solar wind can enhance the wind's density, temperature, and magnetic field, forming an interplanetary shock (IPS) before it reaches Earth. The IPS may produce a geomagnetic storm when it reaches the Earth's vicinity (12; 13; 16). In order to determine whether there is a connection between partial halo coronal mass ejection-related geomagnetic storms and solar wind plasma disturbances, we have examined partial halo coronal mass ejection-related geomagnetic storms with solar flares and solar wind plasma disturbances during the rising phase of solar cycle 25.

2. Experimental Data

In this investigation partial halo coronal mass ejection related geomagnetic storms are analyzed with solar flares, disturbances in solar wind parameters interplanetary magnetic field (IMFB), southward component of interplanetary magnetic field (IMFB $_z$), solar wind plasma temperature (SWPT), solar wind plasma velocity (SWPV) and solar wind plasma pressure (SWPP) over the period of ascending phase of solar cycle 25. For this work the data of partial halo coronal mass ejections (P-CMEs) are taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. To determine disturbances in geomagnetic fields and solar wind plasma parameters, hourly data of Dst index and solar wind plasma velocity, pressure, temperature, interplanetary magnetic field, southward component of interplanetary magnetic fields are used and taken from omni web data (<http://omniweb.gsfc.nasa.gov/form/dxi.html>). The data of X ray solar flares and other solar data, solar geophysical data report U.S. Department of commerce, NOAA monthly issue and solar STP data (<http://www.ngdc.noaa.gov/stp/solar/solardataservices.html>) are used.

3. Data Analysis and Results

3.1 Association of P-CMEs Related Geomagnetic Storms with Speed of Partial Halo CMEs During Ascending Phase of solar Cycle 25

To see how magnitude of the P-CMEs related geomagnetic storms are correlated with speed of associated P-CMEs we have plotted a scatter diagram between magnitude of P-CMEs related geomagnetic storms and speed of associated CMEs and the resulting graph is shown in figure 1. Positive co-relation has been found between magnitude of P-CMEs related geomagnetic storms and Speed of CMEs events. Statistically calculated correlation co-efficient is 0.27 between these two events. From the figure 1 is clear that there is positive correlation between magnitude of P-CMEs related geomagnetic storms and Speed of P-CMEs events.

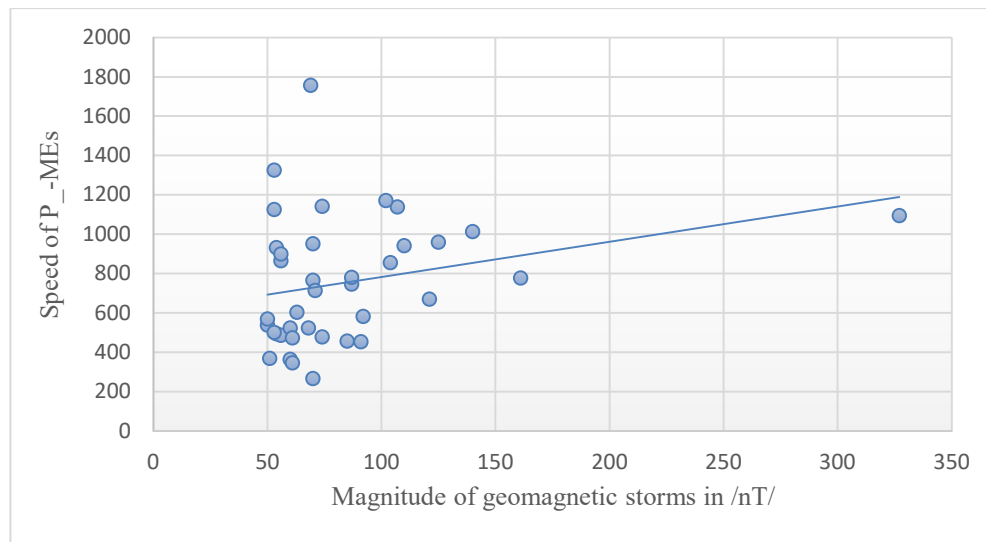


Fig.1 Shows scatter plot between magnitude of P-CMEs related geomagnetic storms and speed of associated P-CMEs during the period of ascending phase of solar cycle 25.

3.2 Analysis of P-CMEs Related Geomagnetic Storms with X-Ray Solar Flares During Ascending Phase of solar Cycle 25

Solar flares are drastic solar events in which vast solar plasma material is ejected from the sun into interplanetary states space and produces major disturbances solar wind plasma and geomagnetic storms in geomagnetic fields. Several investigators have studied geomagnetic storms with solar flares. In this study P-CMEs related geomagnetic storms are studied with X-ray solar flares observed during the period of ascending phase of solar cycle 25. We have determined 38 P-CMEs related geomagnetic storms and all are found to be associated with X-ray solar flares of different categories. The association rates of X-Class, M-Class, C-Class and B-Class and A-Class solar flares are 5.26%, 55.26%, 34.21%, 2.63 % and 2.63%, respectively. It is also observed that vast majority of the P-CMEs related geomagnetic storms are associated with M-Class solar flares.

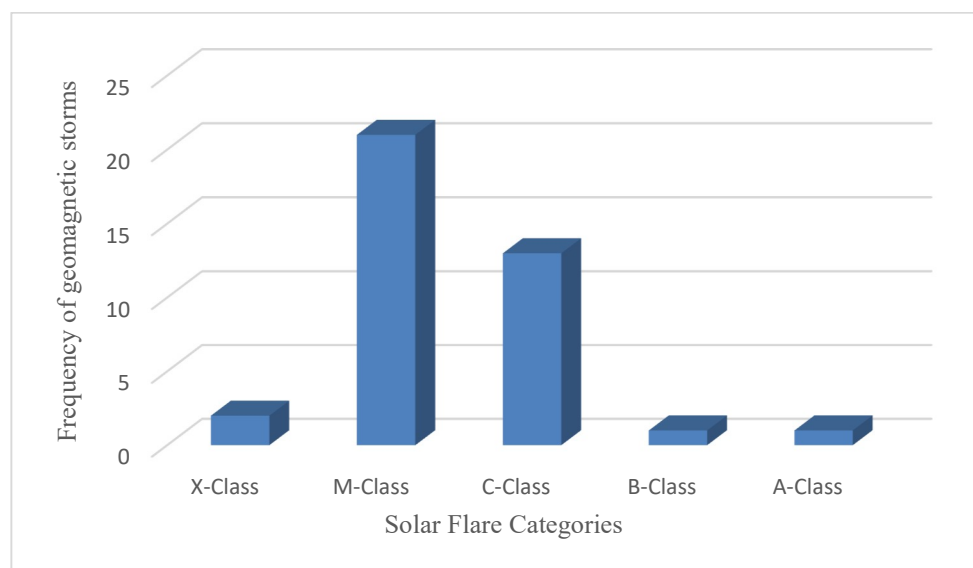
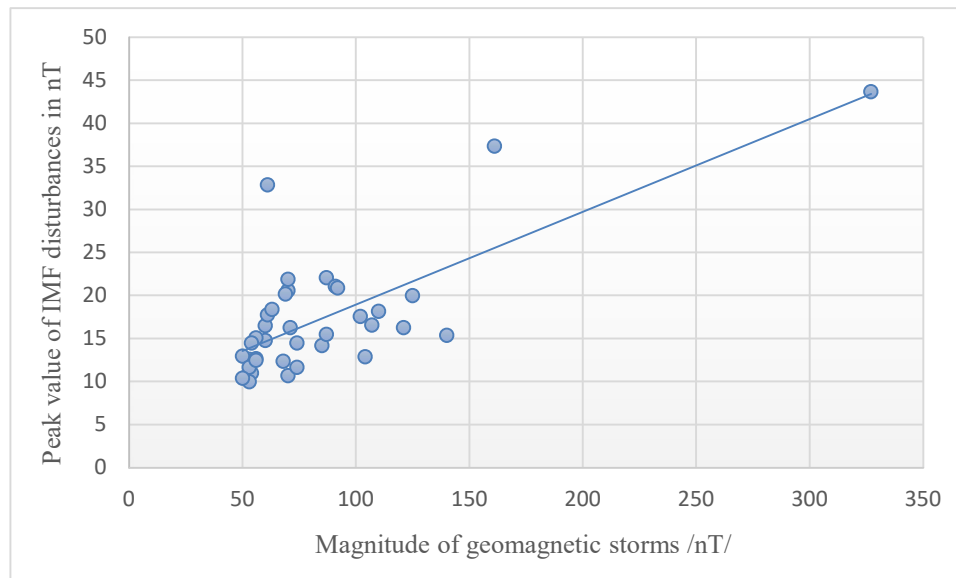


Fig.2 Shows bar diagram of types of solar flares and frequency of associated P-CMEs related geomagnetic storms during the ascending phase of solar cycle 25.

3.3 Correlation Between Magnitude of P-CMEs Related Geomagnetic Storms and Peak Value of Interplanetary Magnetic Fields Disturbances During Ascending Phase of the Solar Cycle 25

We have performed correlative of magnitude of P-CMEs related geomagnetic storms and magnitude of associated disturbances in interplanetary magnetic fields to see that how the magnitudes of P-CMEs related geomagnetic storms are correlated with peak value of interplanetary magnetic fields disturbances events during the period of ascending phase of solar cycle 25. a scatter plot between the magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in interplanetary magnetic fields events in fig.3. It is clear from the figure 3. that most of the P-CMEs related geomagnetic storms which have large magnitude are

associated with such interplanetary magnetic fields disturbances events which have large peak values, but the magnitude of these two events do not have any fixed proportion, we have found some P-CMEs related geomagnetic storms which have large magnitude but they are associated with such interplanetary magnetic fields disturbances events which have small peak values and some P-CMEs related geomagnetic storms which have small magnitude but they are associated with such interplanetary magnetic fields disturbances events having large peak values. These results indicates that although these events do not have any quantitative relation but the P-CMEs related geomagnetic storms of higher magnitude are generally associated with such IMF disturbances events which have relatively higher peak values. Strong positive correlations with correlation coefficient 0.73 have been found between magnitude of P-CMEs related geomagnetic storms and peak value of IMF disturbances during ascending phase of solar cycle 25.



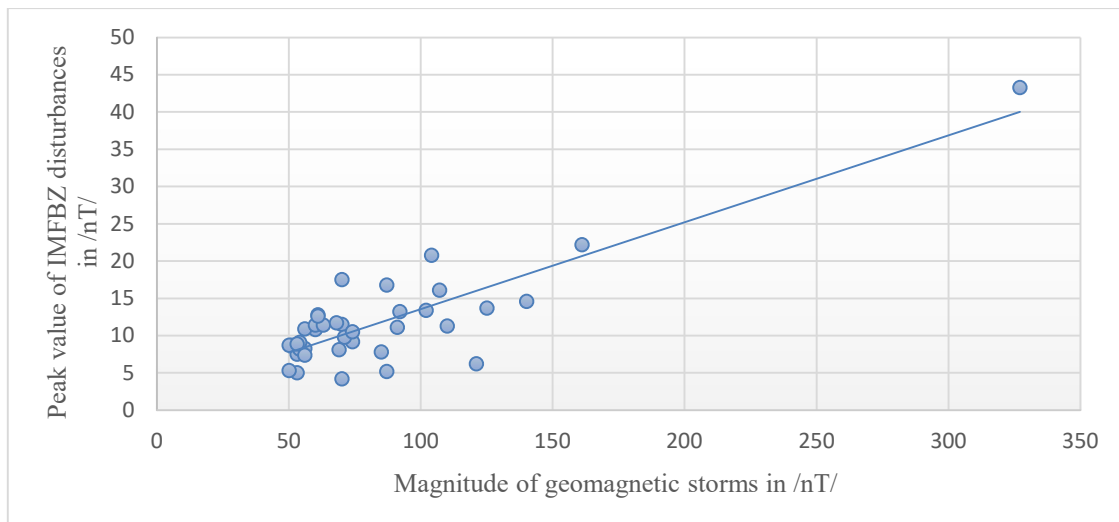


Fig.4 Shows scatter plot between magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in southward component of interplanetary magnetic fields (IMFBz) events during the period of ascending phase of solar cycle 25.

3.5 Correlation Between Magnitude of P-CMEs Related Geomagnetic Storms and Peak Value of Disturbances in Solar Wind Velocity During Ascending Phase of Solar Cycle 25

In this correlative study to see that how the magnitudes of P-CMEs related geomagnetic storms are correlated with peak value of disturbances in solar wind velocity events. We have plotted a scatter diagram between the magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind velocity events in fig.5. It is clear from the figure that most of the P-CMEs related geomagnetic storms which have large magnitude are associated with such disturbances in solar wind velocity events which have large peak values, but the magnitude of these two events do not have any fixed proportion, we have found some P-CMEs related geomagnetic storms which have large magnitude but they are associated with such disturbances in solar wind velocity events which have small peak values and some P-CMEs related geomagnetic storms which have small magnitude but they are associated with such solar wind velocity events having large peak values. These results indicates that although these events do not have any quantitative relation but the P-CMEs related geomagnetic storms of higher magnitude are generally associated with such disturbances in solar wind velocity events which have relatively higher peak values. Positive correlations with correlation coefficient 0.40 have been found between magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind velocity during ascending phase of solar cycle 25.

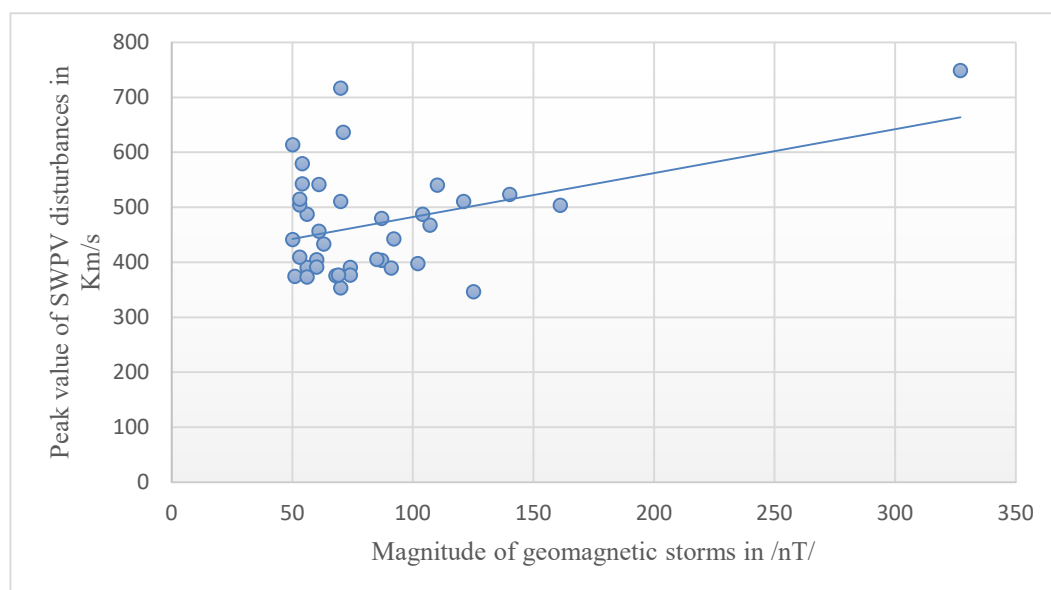


Fig.5 Shows scatter plot between magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind plasma velocity during the period of ascending phase of solar cycle 25.

3.6 Correlation Between Magnitude of P-CMEs Related Geomagnetic Storms and Peak Value of Disturbances in Solar Wind Plasma Temperature During Ascending Phase of Solar Cycle 25

In this correlative study to see that how the magnitudes of P-CMEs related geomagnetic storms are correlated with peak value of disturbances in solar wind temperature events. We have plotted a scatter diagram between the magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind plasma temperature events in fig.6. It is clear from the figure that most of the P-CMEs related geomagnetic storms which have large magnitude are associated with such disturbances in solar wind temperature events which have large peak values, but the magnitude of these two events do not have any fixed proportion, we have found some P-CMEs related geomagnetic storms which have large magnitude but they are associated with such disturbances in solar wind temperature events which have small magnitude and some P-CMEs related geomagnetic storms which have small magnitude but they are associated with such solar wind temperature events having large peak values. These results indicates that although these events do not have any quantitative relation but the P-CMEs related geomagnetic storms of higher magnitude are generally associated with such disturbances in solar wind temperature events which have relatively higher peak values. Positive correlations with correlation coefficient 0.50 have been found between magnitude of P-CMEs related geomagnetic storms and peak values of solar wind temperature disturbances during ascending phase of solar cycle 25.

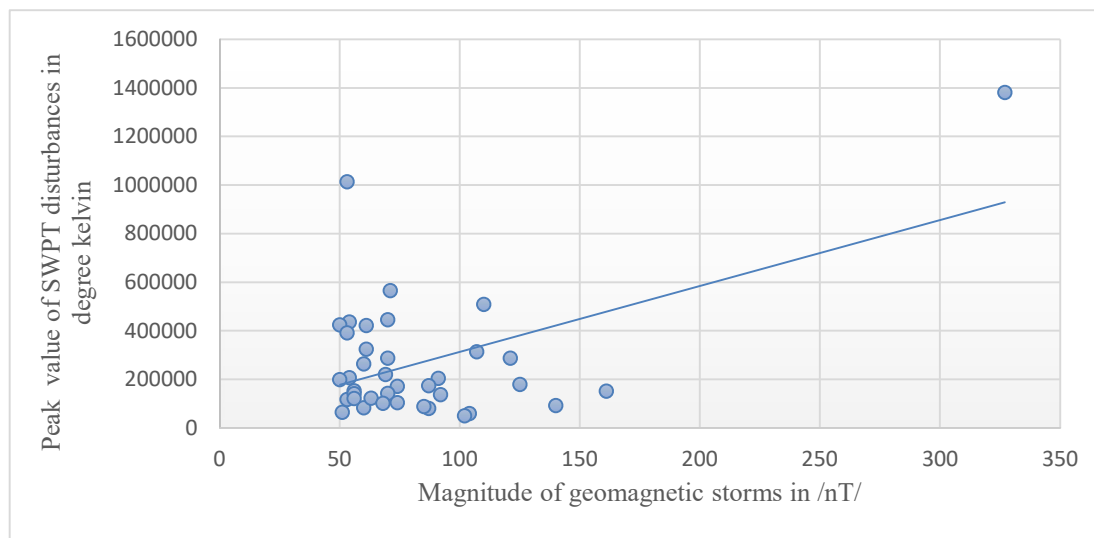


Fig.6 Shows scatter plot between magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind plasma temperature during the period of ascending phase of solar cycle 25

3.7 Correlation Between Magnitude of P-CMEs Related Geomagnetic Storms and Peak Value of Disturbances in Solar Wind Plasma Pressure During Ascending Phase of Solar Cycle 25

In this correlative study to see that how the magnitudes of P-CMEs related geomagnetic storms are correlated with peak value of disturbances in solar wind pressure events. We have plotted a scatter diagram between the magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind plasma pressure events in fig.7. It is clear from the figure that most of the P-CMEs related geomagnetic storms which have large magnitude are associated with such disturbances in solar wind pressure events which have large peak values, but the magnitude of these two events do not have any fixed proportion, we have found some P-CMEs related geomagnetic storms which have large magnitude but they are associated with such disturbances in solar wind pressure events which have small magnitude and some P-CMEs related geomagnetic storms which have small magnitude but they are associated with such solar wind pressure events having large peak values. These results indicates that although these events do not have any quantitative relation but the P-CMEs related geomagnetic storms of higher magnitude are generally associated with such disturbances in solar wind pressure events which have relatively higher peak values. Positive correlations with correlation coefficient 0.76 have been found between magnitude of P-CMEs related geomagnetic storms and peak values of solar wind pressure disturbances during ascending phase of solar cycle 25.

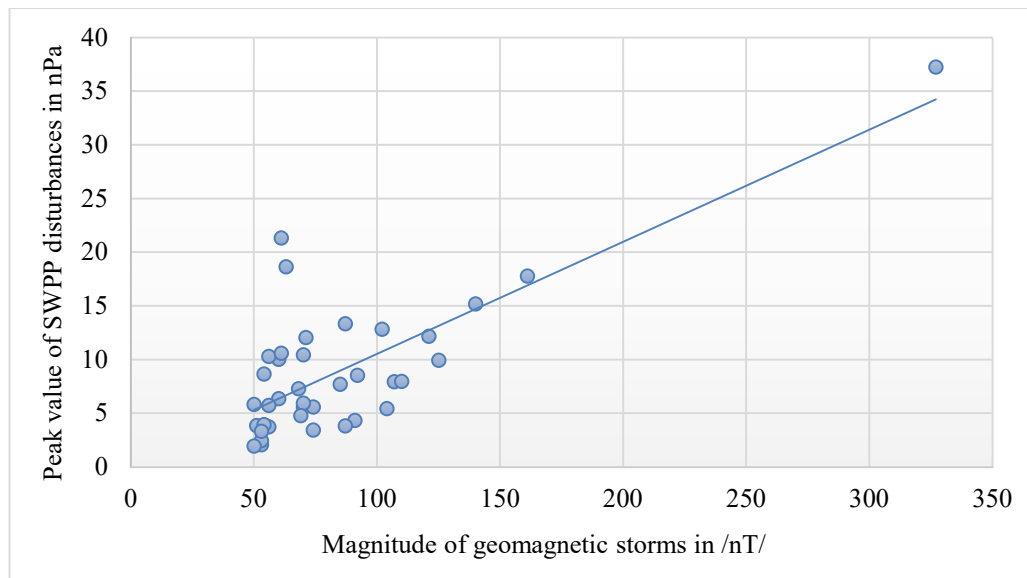


Fig.7 Shows scatter plot between magnitude of P-CMEs related geomagnetic storms and peak value of disturbances in solar wind plasma pressure during the period of ascending phase of solar cycle 25.

4. Main Results

1-We have observed that all the partial halo coronal mass ejection related geomagnetic storms (GMs) are associated with X-ray solar flares (SFs) of different categories.

2-Positive correlation with correlation coefficient 0.27 has been found between magnitude of P-CMEs related geomagnetic storms and speed of associated P-CMEs.

3-Large positive correlation with correlation coefficient 0.73 has been found between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of associated disturbances in IMFB,

4-Large positive correlation with correlation coefficient 0.85 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of associated disturbances in IMFBz.

5-Positive correlation with correlation coefficient 0.40 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of disturbances in SWPV.

6-Positive correlation with correlation coefficient 0.50 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of disturbances in SWPT.

7-Positive correlation with correlation coefficient 0.76 between magnitude of P-CMEs related geomagnetic storms (GMs) and peak value of disturbances in SWPP.

5. Conclusion

In this investigation partial halo coronal mass ejection related geomagnetic storms observed during the ascending phase of solar cycle 25 are analysed with solar flares, disturbances in solar wind plasma parameters solar wind plasma velocity, solar wind plasma temperature, solar wind plasma pressure, interplanetary magnetic fields, and southward component of interplanetary magnetic fields. We have concluded that partial halo coronal mass ejections (CMEs) associated with hard X-ray solar flares and disturbances in interplanetary magnetic fields, southward component of interplanetary magnetic fields, solar wind plasma velocity, solar wind plasma temperature and solar wind plasma pressure responsible to generate geomagnetic storms (GMs).

Conflict of Interest

We have no conflicts of interest to disclose.

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