Large Geomagnetic Storms Drives by Solar Wind in Solar Cycle 24

Doha Al-Feadh¹, Wathiq Al-Ramdhan²

¹ Basra University /College of Science /Physics Department/ Iraq
² Environmental Pollution Research Unit/ South Technical University/Iraq
E-mail: doha.mansoor@uobasrah.edu.iq

Abstract. Various solar phenomena cause anomalous circumstances in the interplanetary magnetic field (IMF) and solar wind plasma emissions. These will produce geomagnetic field disturbances for near earth space at 1AU known as geomagnetic storm.

A selection of solar magnetic storm for the period (2010-2017) have been analyzed, associated with disturbance geomagnetic storm intensity (Dst) less than (-50 nT). Through the study epoch, we found 50 great solar magnetic storms, 32 were moderate, 16 were strong, and two were severe. The major severe storm occurred on 17th of March in 2015 with (Dst ~ -223 nT). The most of Coronal Mass Ejection (CME) that initiated the geomagnetic storms have visual width of 360 degree, and with sky plane speed around (350-2500) Km s⁻¹. There is a better correlation for sunspot number than (CME sky plane speed with Dst index. In this investigation, we notice that the strength of geomagnetic storms has a behavior that is in harmony with solar activity extent.

The reciprocal relation between geomagnetic activity and solar activity infers that space systems and many communications could be harmfully precious for numerous years after an exciting solar maximum.

Keywords. Solar cycle, Coronal Mass Ejection, Magnetic Storm.

1. Introduction

The reputation of studying geomagnetic storms is beneficial to discover adverse effects in space and many communication systems. The interaction between Earth's magnetosphere and interplanetary magnetic field causes magnetic storm with long period and concentrated stream, which allows energy transport to the magnetosphere of the Earth by solar wind (e.g. [1, 2, and 3]).
Geomagnetic storms caused by a strong geomagnetic disorder is associated with Coronal Mass Ejection (CME) and Co-rotating Interaction Region (CIR). (CIR) originates from coronal holes in the polar and high altitude regions of the sun. The varying phases of sunspot cycle are leading to the geomagnetic storms. High speed solar wind is related with the minimum phase of solar cycle, which is the dominant part of solar activity [4,5]. While in the maximum phase of solar activity, the fast interplanetary (CME) caused the geomagnetic storms[6,7].

Disturbance geomagnetic storm intensity (Dst) describes a measure of a rim of westward current around earth leading to magnetic disturbances on the ground [8,9,10]. The geomagnetic storms classified as moderate storms were Dst less than -50nT, intense storms with Dst ≤ -100nT, super storms with Dst less than -200nT, and severe storms were Dst less than -300nT[11].

In this paper the numerical study has been performed to study geomagnetic storms with various (Dst- index). The relationship between solar wind parameters, CME’s behaviour and Dst-index has been discussed.

2. Data analysis

The purpose of this study is to find the effect of solar wind parameters on the Dst-index. The records are composed from the available sources supplied by the multi satellites which were well connected to the field-lines near earth. The wind plasma and magnetic field data which included 1-hour averages attained from the WIND SME and MFI groups for the events after 1995 up to date can be downloaded from OMNI Web home pages (http://omniweb.gsfc.nasa.gov/form/dx1. html.). Our data of available Dst index through daily-hourly of Dst≤−50nT is composed automatically from Dst index provided by the World Data Center for Geomagnetism, Kyoto, Japan. Selection of storms is running through daily-hourly Dst data of Dst≤−50nT. We employed LASCO catalog (https://cdaw.gsfc.nasa.gov/CME_list/) to estimate the heliocentric location and linear speed of the CMEs.

3. Results and Discussion

A selection of solar magnetic storm for the period (2010-2017) have been analyzed, associated with (Dst) less than (-50 nT), using Dst records that tabulates the amount and vigor of geomagnetic storms for the period of a solar cycle (24). Through this period 50 large geomagnetic storms have remained observed to mollify range conditions: 32 were moderate, and 16 were strong, and there are two super geomagnetic storms that occurred at 17th of March 2015 and 23rd of June 2015 sorted as per occurrence with years in Figure (1).
From Figure (1) it is apparent that during 2010 (Solar lowest year) only three moderate storms have happened and 10 geomagnetic (5 moderate and 5 intense) storms in 2012. It was so found that supreme numbers of geomagnetic storm occurred in year 2015, while year 2012 and 2014 were the maxima of the solar cycle-24, the year 2017 signifies minimum sunspot activity through the downward part of solar cycle-24, the large numbers of geomagnetic storm appended in the year 2012 and 2015. We notice that the strength of geomagnetic storms has a behavior that is in harmony with solar activity extent.

Figure 2. Sunspot number and Dst (nT) related with the time of geomagnetic storms activity.
Figure (2) presents the sunspot number and the maximums of Dst for the geomagnetic storms per year to the 50 geomagnetic storms that occurred during the period 2010-2017. This figure gives the evidence of the correlation between the maximum and minimum phases of sunspot number and yearly occurrence of geomagnetic storm. In figure (3), a linear correlation between Dst and sunspot number was found. The correlation coefficient (mathematical determination can be studied in [12]) is (-.028) between the Dst index and the sunspot number.

![Figure 3. Relation between Sunspot number and the maximum negative Dst.](image)

Figure (4) presents maximum values reached by the CME sky plane speed with the Dst (max.). A wide range of velocities varying between 350 and 2500 kms-1. The correlation coefficient between the CME sky plane speed and peak Dst has been found to be -0.244.

![Figure 4. Relation between CME sky plane speed and Dst.](image)
Figure (5) indicates the disturbance in all solar plasma/magnetic data relative to the sunspot number with the study storms' time. This disturbance occurred and was observed by satellite at the geostationary orbit in the near Earth space whereas the magnetic field variation and ring current depressions are recorded by a network of observatories well located all over the world. There are frequent storms that appear in 2012 (the extreme stage of solar cycle), and in 2015 (the descending phase of it).

Figure 5. (a) variation of plasma temperature for the geomagnetic storms, (b) is the plasma density, (c) is the plasma speed, (d) is the south magnetic field's component, and the (e) is sunspot number for the study storms' time.

Figure 6. The plasma/field and Dst data for the super storm 17of March 2015 for the period 14-19 March 2015 to present the effect of the MC on the plasma/field parameters with time,(a) is Dst index(nT), (b) sunspot number for the study storms' time, (c) variation of plasma temperature for the geomagnetic storms, (d) the plasma speed, (e) the plasma density, (f) the south magnetic field's component for the study storms' time.
Magnetic cloud (MC) arrived at 17 of March 2015 produced by CME directed to the Earth which erupted on 15 of March 2015 with sky plane speed (1120Km/sec). The direction of CME's source region is very important in the acceleration of solar energetic particles [13]. Figure (6) shows for this event the change in the solar wind parameter according to the disturbance in the plasma speed, rising in the plasma temperature and beta (definite by the proportion of the gas pressure to the magnetic pressure). Largely descending in the interplanetary magnetic field in the south zone (s) component (IMF Bs) directed to the correlation between Earth’s magnetic field and the IMF lines according to the presence of this MC. The reciprocal relation between geomagnetic activity and solar activity infers that space systems and many communications could be harmfully precious for numerous years after an exciting solar maximum.

4. Conclusions

The relationship between solar wind parameters and geomagnetic storm intensity (Dst) has been discussed and analyzed. We noticed that there are two maximums in the solar cycle 24, the first occurred in 2012 while the second in 2014. From this study we can conclude that:

1. There are 50 large solar magnetic storms in the period 2010-2017, 32 were moderate, 16 were strong, and two were super, related with the corotating interaction region.
2. There are 18 events from the 50 magnetic storms having Dst less than (-100 nT), which has a good relationship with sunspot number detected around maximum solar cycle 24.
3. The greatest intense storm with Dst equal to (-223 nT) occurred on 17 of March 2015 in the solar cycle-24 generated by MC with high speed CME.
4. The most of Coronal Mass Ejections (CMEs) that caused the geomagnetic storms have visual width of 360 degree, and velocities (350-2500) Km per second.
5. There is a better correlation between sunspot number than CME sky plane speed with Dst index.

Acknowledgement

We do appreciate the SPDF OMNI Web database as the source of data at NASA GSFC as the provenance of data used in issuance and the Dst index from the World Data Center in Kyoto, Japan. These include 1-hour averages of near-Earth solar wind parameters obtained from the OMNI1 (formally OMNI) database (http://omniweb.gsfc.nasa.gov/). CME catalog is generated and maintained at the CDAW Center by NASA and The Catholic University of America in cooperation with the Naval Research Laboratory. SOHO is a project of international cooperation between ESA and NASA.
References

[1] Tsurutani, B. T., W. D. Gonzalez, A. L. C. Gonzalez, F. Tang, J. K. Arabello and M. Okada, 1995, *J. Geophys. Res.*, **100**, 21717–21733.

[2] Gonzalez, W. D., Joselyn, J. A., Kamide, Y., Kroehl, H. W., Rostoker, G., Tsurutani, B. T., and Vasyliunas, V. M, 1994, *J. Geophys. Res.*, **99**, 5771–5792.

[3] Wu, R. P. Lepping3, 2006, *Ann. Geophys.*, **24**, 3383–3389.

[4] Tsurutani, B.T., E. Echer, F.G. Guarnieri, and W.D. Gonzalez, 2011a, *J.Atmos.Sol.Terr.Phys.*, **73**, 164.

[5] Prestes, A., Klausner, V., Ojeda-González, A., and Serra, S. L, 2017, *Adv. Space Res.*, **60**, 1850–1865.

[6] Ojeda-González, A., Mendes, O., Calzadilla, A., Domingues, M. O., Prestes, A., and Klausner, V., 2017b, *Astrophys. J.*, **837**, 156.

[7] Danilov, A. D., 2013, *Adv. Space Res.*, **52**, 343–366.

[8] Wilson, R. M., 1990, *Solar Phys.*, **125**, 143±158.

[9] Loewe, C. A. and Prölss, G. W., 1997, *J. Geophys. Res.*, **102**, 14209–14214.

[10] Deminov, M. G., Deminova, G. F., Zherebtsov, G. A., and Polekh, N. M., 2013, *Adv. Space Res.*, **51**, 702–711.

[11] Sham Singh, A. C. Panday, Kalpana Singh & A. P. Mishra, 2017, *International Journal of Pure and Applied Physics*. ISSN 0973-1776, **13**, Number 1, pp. 35-43.

[12] Goshtasby, A. S, Gage, S.H., Bartholic, J. F. , 1984, *IEEE Trans. Pattern Analysis and Machine Intelligence*, **6** (**3**), 374-378.

[13] Doha Al-Feadh, Ali AL-Bekheet and Wathiq Al-Ramdhan, 2018, *J. Phys.: Conf. Ser.* **1032**, 012035.