Behaviour of Geomagnetic storm, horizontal geomagnetic field and solar wind parameters during solar flare and CMEs event.

S N A Syed Zafar¹, S N Hazmin², M H Jusoh³, A N Dagang⁴, M A M Adzni⁴, R Umar¹∗

¹ East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia.
² School of Fundamental Science, Universiti Malaysia Terengganu, 21300 Kuala Terengganu, Malaysia.
³ Faculty of Electrical Engineering, Universiti Teknologi Mara, Shah Alam, Selangor, Malaysia
⁴ Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

Abstract. Space weather is driven by solar activities by pulling out the variety of phenomenon such as solar flare and coronal mass ejection (CMEs). It been discovered the CMEs and solar flares have causes disturbance at near-Earth space. This paper is to examined the behaviour of geomagnetic storm, horizontal geomagnetic field and several solar wind parameters during solar flare and CMEs event at minimum of solar cycle of 24. Observational result found that association of strongest solar flare and CMEs have declined the geomagnetic storm until -150nt at 8th September 2017. Following to this, the H component reading also slightly decreased at three magnetometer location respectively. Solar flare and CMEs released the energetic particles that could disturbed the radio communications at the Earth and electronic equipment. Therefore, it was required to study and understanding the solar flare and CMEs event.

1. Introduction

Solar activity has significant effect to the climate and mankind. The sun is magnetic variable star that fluctuates on times scales ranging from a fraction of a second to billions of years [1][2]. These magnetic activities of sun have affected the disturbance through the interplanetary space which is powerful than normal solar wind. The increasing of solar activity causes the large of fluxes of energetic proton thus form the super geomagnetic storm [3]. Solar flares, coronal mass ejections (CMEs), coronal hole, high solar wind speed and solar energetic particles are all forms of solar activity. Meanwhile, the Dst index, SYM/H, Kp value and Ultra Low Frequency (ULF) was described as behaviour of geomagnetic field [4]. Solar wind parameter such as solar wind speed (Vsw), Interplanetary Magnetic field (IMF), proton density (Np) and dynamic pressure solar wind speed (Pdyn) was narrated the stronger of solar activity. According to Singh et al. (2014), the CMEs and solar flare contributed the great effect solar wind parameter and geomagnetic storm [5]. They described that there was high correlation of CMEs and horizontal geomagnetic storm. A large of CMEs are containing 10¹⁶ grams of matter that can accelerated to few million miles per hour of spectacular explosion. When CMEs hit the earth, it can excite the geomagnetic storms [6]. Solar flare has given strong impact to the magnetic storm and solar wind speed (Vsw) refer to Singh and Mishra (2015) [7]. Solar flares are sudden explosive that releasing energy (~10¹⁹ - 10²⁵) originated from active region of sun to the space, thus effect the ionosphere. Not all solar flares accompanied by CMEs. Figure 1 is illustrated of solar flare event. There was also high variation of horizontal geomagnetic field, H component reading caused by the great geomagnetic storm and solar wind speed according to Anuar et al. 2018 [8]. The main objective
of this paper to observe the behaviour of geomagnetic storm, horizontal geomagnetic component and several solar wind parameters during solar flare and CMEs event. Then we have discussed the characteristic of CME and solar flare with solar wind parameters and geomagnetic storm. Lastly, the conclusion has been done.

![Figure 1. Illustration of Solar flare event (https://www.solarham.net/)](https://www.solarham.net/)

2. Methodology

2.1 Solar Event and Geomagnetic storm

In this paper, two of solar event has been selected which is solar flare and Coronal Mass Ejections (CMEs) during of solar cycle of 24. This study was done in minimum phase of solar cycle 24. This solar event was analysed with solar wind parameter, geomagnetic storm and geomagnetic field for three days of observation from 6th September 2017 to 8th September 2017. For this paper, geomagnetic storm is measured the disturbance storm by observed the change of SYM/H values. It estimates the globally variation of earth magnetic field of horizontal component magnetic equator based on the measurement of magnetometer location station. The geomagnetic storm also has their class which is weak stage (-30<\text{Dst}<-50nt), moderate (-50<\text{Dst}<-100nt), intense (-200<\text{Dst}<-100nt) and super storm (\text{Dst}<-200) [9]. The Dst index and SYM/H is similar parameter, the comparison of Disturbance storm time index (Dst Index) and SYM/H was only time interval where is Dst index in every 3 hour and SYM/H is per minute data. The solar event were taken from SolarHam website (https://www.solarham.net/regions.htm) and space weather live (https://www.spaceweatherlive.com/). Meanwhile, the SYM/H of data were collected from OMNI website (https://omniweb.gsfc.nasa.gov/form/omni_min.html). The data used was high resolution which in one-minute interval.

2.2 Solar wind parameter

The CME and Solar flare were perceived with solar wind parameter. The solar wind parameter data were obtained from OMNI website (https://omniweb.gsfc.nasa.gov/form/omni_min.html) which provided by the Space Physics Data Facility (SPDF) based at NASA’s Goddard Space Flight Center in Greenbelt, MD U.S.A. The SPDF were erected to detect the electromagnetic and plasma environment in the geo-space in real time. The data were supplied from few satellites, for instance Interplanetary Monitoring Platform-8 (IMP 8), Interplanetary Physics Laboratory (Wind) and Advanced Composition Explorer (ACE). In this paper, we have included several of solar...
wind parameter which is (1) solar wind speed \(V_{sw}\), (2) horizontal magnetic field component \(B_z\), (3) solar wind dynamic pressure \(P_{dyn}\), (4) Input energy solar wind \(IE\). To determine the input energy, the formula below was used. This all data was in one-minute interval.

Solar input energy = \(V_{sw}B_z^2F(\theta)I_o^2\) Watt or ergs \([10][11]\)

where, \(V_{sw}\) = solar wind speed \((\text{km/s})\), \(B_z\) =magnitude of IMF \((\text{nt})\), \(I_o\) = Earth’s radius \([\text{km}]\), \(F(\theta)\) = function of the angle, \(\theta\) \((\text{By/Bz})\).

2.3 Geomagnetic field, \(H\) component

The analysis of horizontal geomagnetic field \((H\) component) were done by using of \(N\) component and \(E\) component at three location of magnetometer which is ABG, HER and DAW. The data were collected from SuperMAG website \((\text{http://supermag.jhuapl.edu/)\}}\). SuperMAG is worldwide collaboration of organization and national agencies that currently provides of 300 ground magnetometers. The stations in SuperMAG providing absolute measurements \((\text{e.g. Intermagnet Observatories})\) as well as stations providing relative measurements are included. The data provided is one-minute interval. The details of selected ULF magnetometer location were performed in Table 1 below.

| Magnetometer location | Abbreviation | Geographic | Geomagnetic |
|----------------------|--------------|------------|-------------|
|                      |              | Latitude \((^\circ)\) | Longitude \((^\circ)\) | Latitude \((^\circ)\) | Longitude \((^\circ)\) | Region          |
| Alibag               | ABG          | 18.62      | 72.87       | 12.08          | 145.25           | INDIA           |
| Hermanus             | HER          | -34.43     | -42.07      | -42.07         | 82.55            | South Africa    |
| Dawson city          | DAW          | 64.05      | 220.89      | 66.14          | -87.68           | Canada          |
3. Result

In this study, the selected solar event which is solar flare and CMEs were observed with solar wind parameters and geomagnetic storm. The observation of earth geomagnetic field with solar wind parameter and geomagnetic storm also been conducted at three magnetometer locations which ABG, HER and DAW. This selected magnetometer location was located near the Earth equator region. For the present case, we have considered the solar flare and CMEs in 2017 during the minimum phase of the solar cycle of 24. The details of selected solar activity were listed as Table 2 below:

| Date            | Solar activity | Time (UT) |
|-----------------|----------------|-----------|
|                 | Solar flare    | CME       |
| 6th September 2017 | Class X 9.3 | YES | 12:02 |
|                 | Class M 2.5 | No | 15:56 |
|                 | Class M 1.4 | No | 19:30 |
| 7th September 2017 | Class X 1.3 | YES | 14:26 |
|                 | Class M 3.9 | No | 23:59 |
| 8th September 2017 | Class M 8.1 | No | 07:49 |
|                 | Class M 2.9 | No | 15:47 |
|                 | Class M 2.1 | No | 23:45 |

Table 2. List of solar flare and CMEs at 6th until 8th September 2017
We have analyzed analysis from 6th September 2017 until 8th September to observe the variation of a geomagnetic storm, solar wind parameter and horizontal geomagnetic field with solar flare and CME. Based on the analysis, there was observed that there is no enhancement of solar wind speed (Vsw) on 6th September 2017, the Vsw increased rapidly from 400km/s to 650km/s and continued until the end of 7th September 2017. The Vsw has increased again from 500km/s to 880km/s and decreased gradually at the end of 8th September 2017. Meanwhile, dynamic solar wind pressure (Pdyn) also increased with the Vsw from 0 until 14 nPa and declined until the end of 7th September 2017. At the edge of 7th September 2017, the Pdyn rose from 2 until 10 nPa and keep uniform until the end of 8th September 2017. Based on Figure 3 above, IMF Bz is showed the decreasing plot which indicating negative value at the end of 7th September 2017 from 8nt to -30nt and continued pointed southward until early 8th September 2017. This indicates that were reconnection of magnetic due to northward to the southward of solar wind. It means that there is a penetration of the magnetic field into the ground [12].

![Figure 3](image3.png)

**Figure 3.** Variation of solar wind parameter and horizontal geomagnetic storm, a) Interplanetary magnetic field, IMF Bz, b) solar wind (Vsw), c) dynamic pressure solar wind and d) SYM/H during 6th September until 8th September 2017

![Figure 4](image4.png)

**Figure 4.** Solar input energy, IE during 6th September until 8th September 2017
Following this, the input energy solar wind, IE also presented the small enhancement on 7th September 2017. The IE increased rapidly on 8th September 2017 from $1 \times 10^{19}$ ergs to $15 \times 10^{19}$ ergs and started to lessen until the end of the day. This is presented there were high solar wind input energy penetrated the Earth. Figure 4 is exhibited the variation of solar wind input energy. SYM/H is similar to Dst Index which measures the geomagnetic storm at the horizontal Earth magnetic field. The comparison of the Dst Index and SYM/H is time resolution. Dst index was in every 3-hour data, while SYM/H was per minute data. From the graph of Figure 3 above, it was shown that the SYM/H plot was static on 6th September 2017. There was a decline of SYM/H at the end of 7th September 2017 which at -50nt indicated of the weak storm. After that, the SYM/H plot continued to drop to -150nt until early 8th September 2017 which designated as the moderate storm. Subsequently, it is remained to vary from -50nt until -110nt specified in the recovery phase of the storm.

Based on the graph of the H component at three magnetometer locations in Figure 5, there was a decrement of the value of H component at ABG, HER and DAW respectively. The ABG is varied from $3.820 \times 10^4$ nt to $3.804 \times 10^4$ nt, at the end of 7th September 2017, $3.815 \times 10^4$ to $3.795 \times 10^4$ at early of 8th September 2017 and increased again until the end of 8th September 2017. The variation at HER with geomagnetic value declined from $1.064 \times 10^4$ to $1.055 \times 10^4$ nt at the end of 7th September 2017 and the value has fallen again from $1.060 \times 10^4$ to $1.000 \times 10^4$ nt at early of 8th September 2017. The H component at DAW was dropped from $1.180 \times 10^4$ nt to $0.920 \times 10^4$ nt from the end of 7th September 2017 until early of 8th September 2017. At the end of 8th September 2017, the H component showed the dropped again and continued the uniform pattern.

From the analysis that has been done, we have concluded that strongest solar flare (X 9.3) class and m class with CMEs event during 6th September 2017 has led to the occurrence of weak (SYM/H=-50nt) at end of 7th September 2017 and moderate geomagnetic storm (SYM/H=-150nt) at early of 8th September 2017. Meantime, it was reported the solar wind was high within two days of the event which in range (400-650km/s) at the end of 7th September.
2017 and (500-880km/s) at early 8th September 2017. This shows that solar wind and dynamic pressure increased with the geomagnetic storm. As a result of higher solar wind speed and dynamic pressure during the main phase of the geomagnetic storm which at early 8th September 2017. A solar flare is a reconnection of magnetic that driven a huge explosion of the sun which impacts the space weather thus disturbed the Earth’s geomagnetic field [13][14]. The CMEs have their magnetic field which can bang into the Earth’s magnetic field resulting occurrence of the geomagnetic storm [15]. Besides, the geomagnetic storm with Bz has strong colerration [16]. From the result, it was shown when SYM/H dropped to -50nt, the Bz plot is slightly decreased. The southward Bz component indicating the occurrence of the geomagnetic storm. Following this, solar wind input energy, IE was rapidly high from the end of 7th September 2017 until early 8th September 2017. This occurrence of the moderate storm may due to the CME drives solar wind shock waves to interact with the Earth’s magnetic field. The CME may trigger the strongest solar flare on 6th September, thus spreads and reached Earth magnetosphere on the morning of 8th September which indicates the main phase of a geomagnetic storm. As well as the reading horizontal geomagnetic field, H component at ABG, HER and DAW also presented the changes which are decreasing of values end of 7th and early 8th September 2017 during the existence of geomagnetic storm. In this study, the high changes of H component are observed at these three geomagnetic locations at the end of 8th September 2017 as well as the recovery phase. We have observed high lessen of H component at DAW station compared to the ABG and HER due to the CME with the solar wind and dynamic pressure brought high momentum of input energy penetrated the Earth from the northward to southward at DAW station [8]. Moreover, the location of DAW magnetometer was at high latitude as there were a direct of geophysical effect from the space [8].

4. Conclusion

From the result that we have obtained, we have inferred that the strongest solar flare class (X 9.3) and CMEs event on 6th September 2017 has led to the moderate geomagnetic storm event at early 8th September 2017. In time, the Bz component rapidly decreased indicating there was a penetration of the magnetic field into the ground. Subsequently, the maximum solar wind speed with 880km/s and high dynamic pressure was acquired at early 8th September 2017 and it may cause by the occurrence of the strongest solar flare event on 6th September 2017. The association of the strongest solar flare and CMEs event also has affected the decrement of H component value during a moderate geomagnetic storm at three selected magnetometers especially at DAW station.

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