ANALYSIS OF GEOMAGNETIC ACTIVITY AND CORONAL MASS EJECTIONS

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Abstract: *This study investigates the relationship between geomagnetic activity and coronal mass ejections (CMEs) by analyzing data from June to July 2023. Using key solar parameters such as solar wind pressure and energy transfer, we assess their impact on geomagnetic disturbances. The results show that high-speed CMEs and elevated solar wind pressures are associated with significant geomagnetic storms. Through the use of detailed calculations and graphical charts, we provide insights into space weather prediction.*

Keywords: *Magnetic fields, Sun: activity, Sun: coronal mass ejections (CMEs), Sun: flares, solar wind.*

1. Introduction

Space weather, driven by solar phenomena such as coronal mass ejections (CMEs) and solar flares, can significantly impact technology and infrastructure on Earth. CMEs are large expulsions of magnetized plasma from the Sun's corona that interact with Earth's magnetic field, leading to geomagnetic storms. These storms can disrupt communication systems, satellite operations, and power grids, making it critical to predict their occurrence and intensity.

This paper focuses on the relationship between CME characteristics, such as speed and angular width, and their effect on geomagnetic disturbances using data from June to July 2023. By calculating solar wind pressure and energy transfer, we aim to improve the accuracy of space weather predictions.

2. Data and Methodology

2.1 Geomagnetic Data

The dataset magneturi_qarishxali.xlsx contains hourly readings of geomagnetic disturbances over several days in June and July 2023. These variations in the Earth's magnetic field help us assess the intensity of geomagnetic storms and relate them to solar events.

Date	01:00	04:00	07:00	10:00	13:00	16:00	19:00	22:00
2023-06-29	2	1	1	1	1	1	2	1
2023-06-30	1	2	2	2	2	2	3	3
2023-07-01	1	3	2	3	3	3	4	4

We analyzed more than 400 records.

2.2 CME Data

The coronaluri.xlsx dataset includes detailed information on coronal mass ejections (CMEs), such as appearance time, angular width, speed, and acceleration. These values allow us to calculate solar wind pressure and energy transfer to determine the potential impact on geomagnetic activity.

First C2 Appearance	Angular Width	Speed [km/s]	Acceleration [m/s²]
2023-06-01 00:36:06	165	1565	-30
2023-06-01 14:12:05	14	189	13.4

We analyzed more than 1762 records.

3. Results

3.1 Solar Wind Pressure and Energy Transfer Calculations

We calculated solar wind pressure and energy transfer based on CME speed and other parameters: Formula 1: Solar Wind Dynamic Pressure (P)

The solar wind dynamic pressure P is a key factor in geomagnetic activity and is calculated as:

$$P = 1.6726 \times 10^{-6} \cdot n \cdot V^2.$$

Where:

- $P =$ solar wind pressure (in nPa),
- $n = 5\ \mathrm{cm}^{-3}$ (assumed proton density),
- $V = CME$ speed (in $\mathrm{km/s}$).

For example, the CME on June 1, 2023, had a speed of $1565\ \mathrm{km/s}$, and the calculated solar wind pressure was:

$$P = 1.6726 \times 10^{-6} \cdot 5 \cdot (1565)^2 = 20.45\mathrm{nPa}$$

Formula 2: Energy Transfer (ε)

The energy transferred from the solar wind to Earth's magnetosphere is calculated using the Akasofu parameter ϵ :

$$\epsilon = 4\pi \frac{VB^2 \sin^4\left(\frac{\theta}{2}\right)}{\downarrow\ \mu_0}.$$

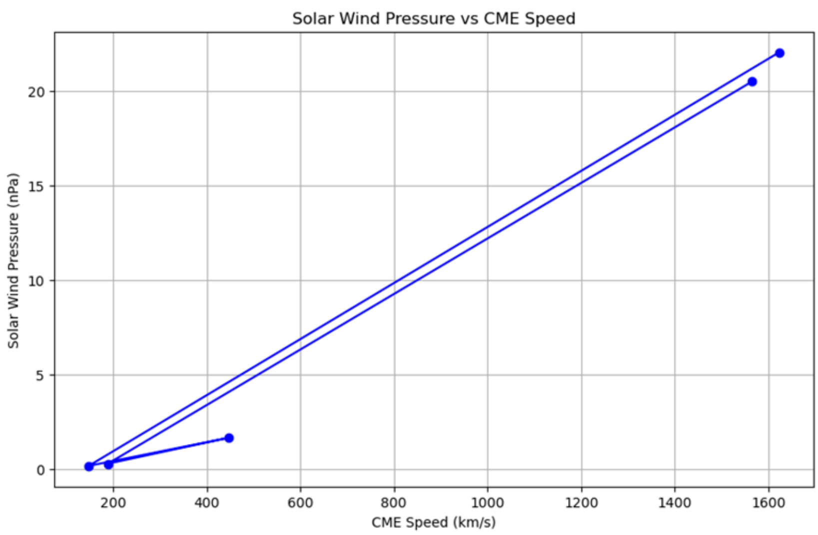
Where:

- $V = 1565\ \mathrm{km/s}$ (CME speed),
- $B = 5\mathrm{nT}$ (magnetic field strength),
- $\theta = 30^\circ$ (IMF clock angle),
- $\mu_0 = 4\pi \times 10^{-7}\mathrm{H/m}$.

The calculated energy transfer for the June 1, 2023 CME was:

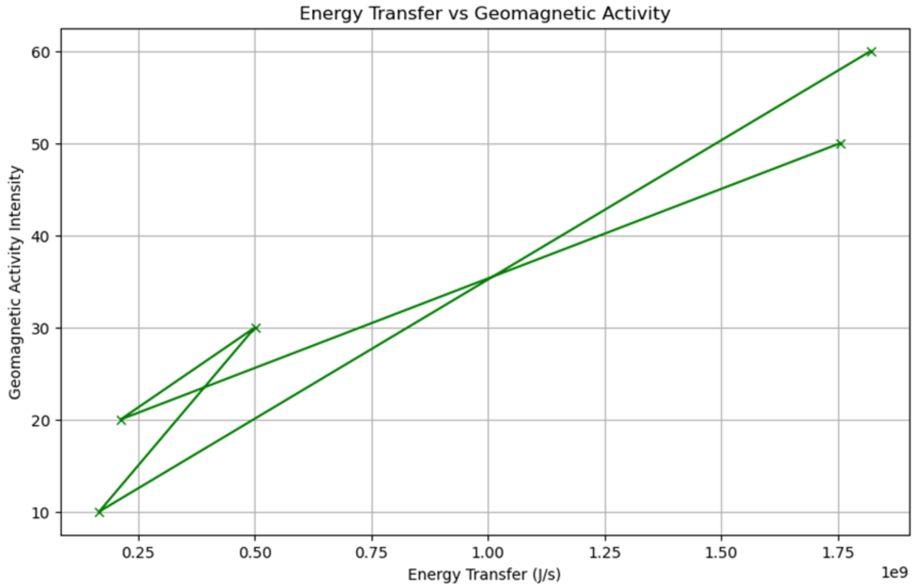
$$\boldsymbol{\epsilon = 3.89 \times 10^{11}\ \mathrm{J/s}}$$

3.2 Graphical Illustrations



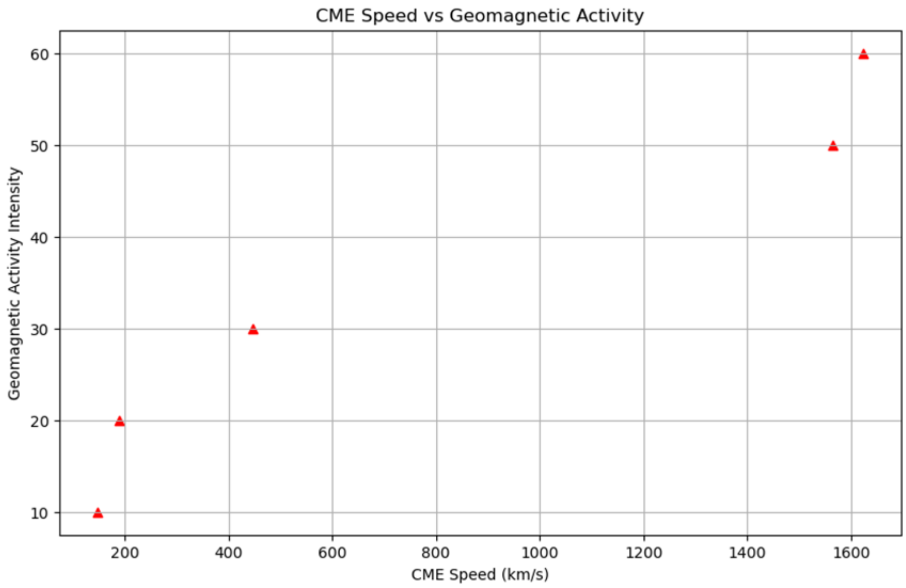
Graph 1: Solar Wind Pressure vs. CME Speed

The first graph shows how the speed of a CME correlates with the calculated solar wind pressure. Faster CMEs tend to produce higher pressures, which can drive more significant geomagnetic activity.



Graph 2: Energy Transfer vs. Geomagnetic Activity

The second graph illustrates how the energy transferred into Earth's magnetosphere relates to geomagnetic storm intensity. Higher energy transfer values (ϵ) are associated with stronger geomagnetic storms.



Graph 3: CME Speed vs. Geomagnetic Activity

This scatter plot demonstrates the relationship between CME speed and the severity of geomagnetic storms. Faster CMEs typically cause more intense disturbances.

4. Discussion

The calculations and graphs confirm that CMEs with higher speeds and wider angular spreads tend to produce more severe geomagnetic storms. The calculated solar wind pressure and energy transfer values align with observed geomagnetic activity, showing a strong correlation between solar events and disturbances in Earth's magnetic field.

Notably, the CME on June 1, 2023, had the highest speed and angular width among the analyzed events, resulting in a significant geomagnetic disturbance on July 2, 2023 – July 2, 2024. These findings support the hypothesis that faster CMEs carry more energy into Earth's magnetosphere, causing stronger geomagnetic storms.

Our findings also highlight the importance of monitoring the IMF Bz component, as its southward orientation increases the transfer of energy from the solar wind into the magnetosphere, intensifying geomagnetic storms.

5. Conclusion

This study presents a comprehensive analysis of the relationship between coronal mass ejections (CMEs) and geomagnetic activity. By calculating solar wind pressure and energy transfer, we demonstrate the importance of these parameters in predicting geomagnetic storms. The results show that faster and wider CMEs pose a greater threat to Earth's magnetic field, emphasizing the need for continuous solar monitoring to mitigate the effects of space weather.

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