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An investigation of the relationship between the CME and the Geomagnetic Storm

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ABSTRACT

The primary objective of this work is to look for any conceivable link between the geomagnetic storm and coronal mass ejection (CME) events. The relevant data for both CME and geomagnetic storm occurrences have been obtained from the Solar and Heliospheric Observatory mission's LASCO and the NOAA Space Weather Prediction Center, respectively, for the same time span (February 1999 to December 2007). We performed Multivariate Singular Spectral Analysis (MSSA), Semblance Analysis, and Multifractal cross-correlation detrended fluctuation (MFXDFA) analysis to achieve our target. We also applied MSSA to investigate the causal link between the two data sets mentioned above. The analysis identifies the supportiveness factor between the data series and the possibility of a one-way statistical relationship between the data series is also verified. Then, Semblance and MFXDFA were used to detect the presence of any conceivable local phase relationship (time and frequency-dependent) and cross-correlation in the data sets. To make our analysis more persuasive, we must use all three methods. The Semblance analysis reveals positive and negative phase correlation between the signals under investigation at different time sub-intervals, whilst the MFXDFA validates the long-term power-law cross-correlations.

1. Introduction

The Earth's magnetic field can be considered our home planet's only defence against high-energy particles and harmful radiation emitted by the Sun. The scientific community is aware that significant disturbances in the geomagnetic field caused by various solar activities may jeopardise the functioning of critical infrastructures reliant on space-based assets and have terrestrial consequences. However, the underlying mechanisms are still poorly understood. This work has attempted to investigate the statistical association and nature of dependency between the Coronal mass ejection (CME) and the geomagnetic storm occurrence by analysing CME linear speed and Planetary K-index data.

Coronal mass ejection (CME) is a type of extreme solar event that happens when a giant cloud of magnetically charged plasma is ejected from the Sun's corona and travels at extremely high speeds (thousands of kilometres per second) into interplanetary space. When a CME collides with our planet's atmosphere, it injects large amounts of energy into the Earth's magnetosphere, which causes a massive disturbance in the geomagnetic field and triggers a geomagnetic storm. An intense geomagnetic storm poses a severe threat to our civilised society, as it can disturb almost every aspect of modern technology, like power grids, global communication navigation systems and complicate modern civilisation's operations (Hapgood, 2012; Kappenman, 1996, 2012; Thomson et al., 2010) The magnitude of the geomagnetic storms can be characterised and quantified by the value of the Planetary K-index (Kp-index) which is based on a global average of abnormal geomagnetic field variations (Menvielle and Berthelier, 1991). The Kp-index ranges from 0 to 9, with an intense geomagnetic storm defined as one with a value greater than or equal to 5. NOAA Space Weather Prediction Center (SWPC) derives the estimated 3-hour Planetary K-index using the data from ground-based magnetometers located in different countries.

The CME linear speed data were collected from February 1999 to December 2007 as obtained from the Solar and Heliospheric Observatory (SOHO) mission's Large Angle and Spectrometric Coronagraph (LASCO) as compiled in the CME catalogue[1] (Gopalswamy et al., 2009). Gopalswamy, et al. identified four primary attributes of a CME as 'linear speed', 'width', 'CPA', and 'acceleration' in their research work, whereas the 'linear speed' attribute has been taken here as the most appropriate parameter compared

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[1] http://cdaw.gsfc.nasa.gov/CME_list/index.html.

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