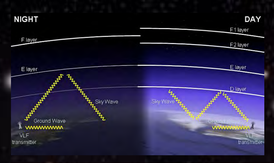

Use of Sudden Ionospheric Disturbance Monitors to Detect Coronal Mass Ejections

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Abstract

The purpose of this research is to study the effect of Earth directed coronal mass ejections (CMEs) on the ionosphere in 2011, and to see if sudden ionospheric disturbance (SID) monitors could be used to predict whether a CME was geoeffective. A CME is a cloud of highly energized particles ejected from the Sun. It is hypothesized that a strong CME will affect the ionosphere, which might be observed in certain data sets. Data was taken from two SID monitors in Vienna receiving transmissions from Norway and France from February through July, 2011. This data was then analyzed relative to the kinetic energy of Earth directed CMEs that occurred during the same time period. The Earth directed CME data was taken from the Large Angle and Spectrometric Coronagraph (LASCO) device on NASA's Solar and Heliospheric Observatory (SOHO). A correlation was found between CME kinetic energy and SID energy, with the maximum correlation at a 6 day lag of the SID data. The 6 day delay accounts for the travel time for the CME to reach Earth. Though the impact of the CME on the ionosphere was observed retrospectively, the research indicates that CMEs may be identified using SID monitors alone.

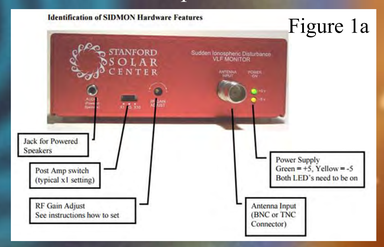
Introduction

A CME is a giant cloud of highly energized solar particles that typically travels at 300 km/s formed by a magnetic field twisting into itself on the Sun's corona. Some CMEs are Earth directed, meaning that there is a chance that the CME will impact the ionosphere. If a high energy CME penetrates the ionosphere, it can cause shifts in electromagnetic signals and disrupt communications. When viewing CME through LASCO, some events appear to emanate from the Sun in all directions. These events are known as halo events. It is believed that halo events are by their nature, Earth directed.

In an effort to better understand space weather in our solar system, SID monitors (Figure 1a) were developed by a team of researchers at Stanford University. SID monitors are used to identify the distortion of the lower ionosphere by radiation emitted from solar flares. However they are being used in this research to identify the impact of CMEs. These monitors are essentially radios that measure the reflection of very low frequency (VLF) radiation off the D region of the ionosphere about 70 – 100 km above the surface of the Earth. The VLF radio waves that are monitored come from several transmitters located around the planet.

The variability of the reflected transmission is dependent upon the charge of the ionosphere. At night, since the Sun is not ionizing particles in the atmosphere, the lower layer of the ionosphere almost disappears. This causes the VLF signals to travel farther into the atmosphere to be reflected back to the surface and this distorts the readings of SID monitors.

Figure 1a

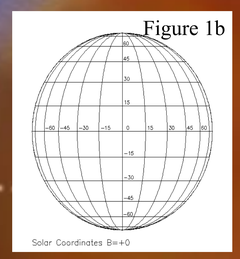


Materials and Methods

CME data was taken from LASCO/SOHO CME Catalog. If a CME was recorded as a halo or partial halo event, it was considered as Earth directed. If the central position angle was +/- 80º (Figure 1b) and the angular width was greater than 50º, the CME was determined to be Earth directed. All other CMEs were disregarded.

Data was taken from two SID monitors: UN-VIENNA016JXN and UN-VIENNA016FTA located at the University of Vienna, Austria. These monitors received low frequency signals from transmitters in Novik, Norway and Sainte-Assise, France, operating at 16.4 kHz and 16.8 kHz respectively. The correlation between CME kinetic energy and SID energy was identified using the CORREL function in Microsoft Excel 2010.

Figure 1b



Results

Figure 2a

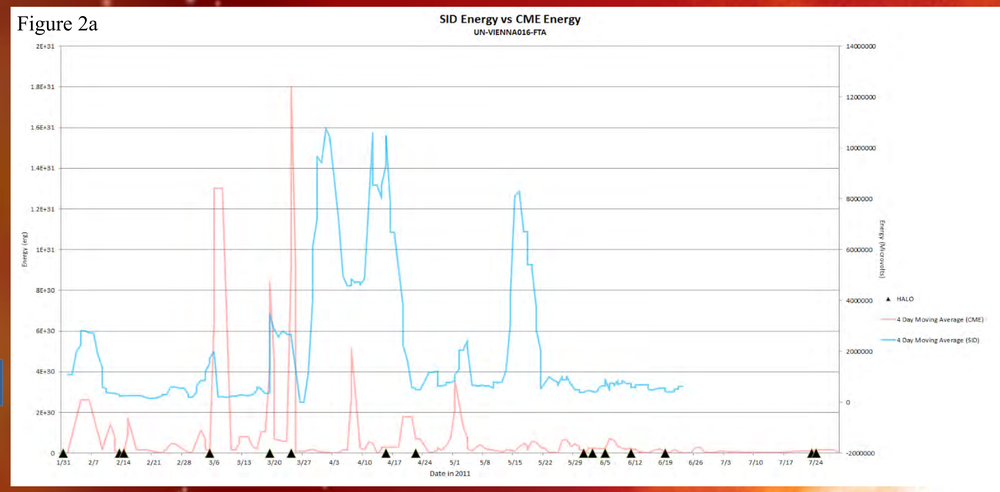


Figure 2b

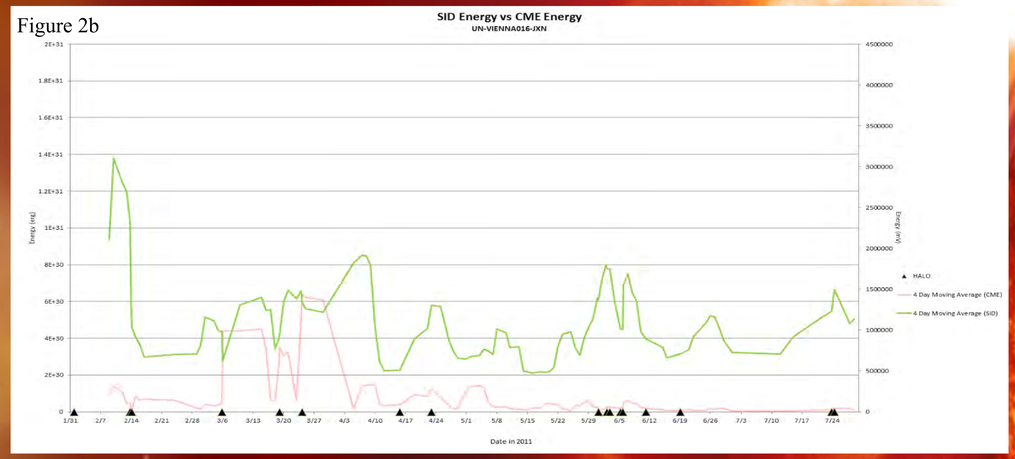
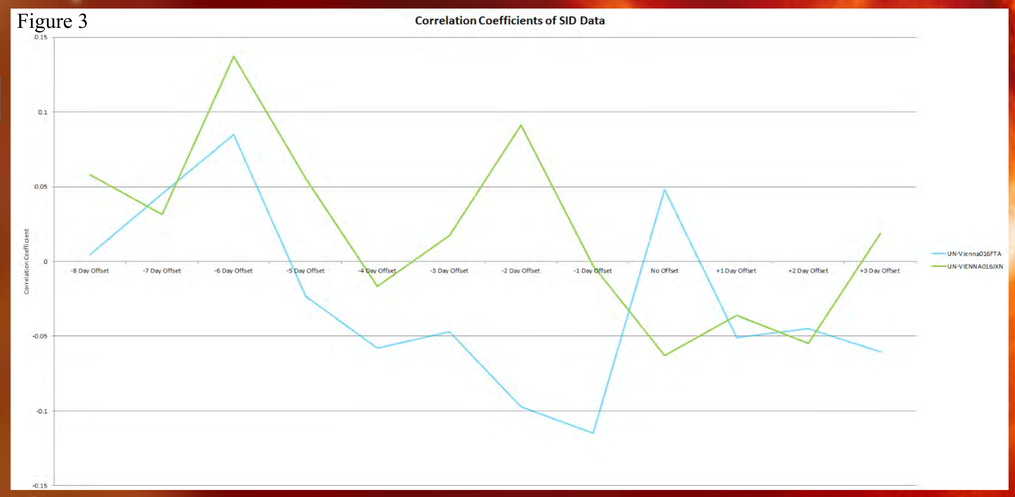


Figure 3



For figures 2a & 2b, SID data is delayed by 6 days to account for CME travel time. All data is represented by a 4-day moving average.

Figure 2a: Vienna SID Monitor receiving signals from the FTA transmitter in France. An increase in SID energy seems to correlate with Earth directed CMEs.

Figure 2b: Vienna SID Monitor receiving signals from the JXN transmitter in Norway. The increase in SID energy seems to correlate with Earth directed CMEs.

Figure 3: The correlation coefficient for the JXN and FTA frequencies at different offsets. Notice that with a 6 day delay in SID data, the correlation coefficient is highest for both frequencies.

Sponsors:
National Aeronautics and Space Administration (NASA)
Goddard Space Flight Center Office of Education (GSFC)
Goddard Institute for Space Studies (GISS)
New York City Research Initiative (NYCRI)
CUNY Queensborough Community College

Acknowledgements:
Dr. Paul Marchese
Dr. Marie C. Damas
NSF award AGS-1359293 REU Site: CUNY/GISS Center for Global Climate Research

References

Gardner, F., & Pawsey, J. (1953). Study of the ionospheric D-region using partial reflections. Journal of Atmospheric and Terrestrial Physics, 321-344.

Kim, R., Cho, K., Kim, K., Park, Y., Moon, Y., Yi, Y., Dryer, M. (2008). CME Earthward Direction as an Important Geoeffectiveness Indicator. ApJ The Astrophysical Journal, 1378-1384.

Mishra, W., Srivastava, N., & Davies, J. (2014). A Comparison Of Reconstruction Methods For The Estimation Of Coronal Mass Ejections Kinematics Based On Secchi/hi Observations. ApJ The Astrophysical Journal, 135-13

R. Schwenn, A. Dal Lago, E. Huttunen, W. D. Gonzalez. The association of coronal mass ejections with their effects near the Earth. Annales Geophysicae, European Geosciences Union (EGU), 2005, 23 (3), pp.1033-1059

Tsurutani, B., Verkhoglyadova, O., Mannucci, A., Lakhina, G., Li, G., & Zank, G. (2009). A brief review of "solar flare effects" on the ionosphere. Radio Sci. Radio Science.

Zhang, J., Richardson, I. G., Webb, D. F., et al. 2007, JGRA, 112, 10102

Zhou, G., Wang, J., & Cao, Z. (2014). Correlation between halo coronal mass ejections and solar surface activity. Astronomy and Astrophysics A&A, 1057-1067

http://cdaw.gsfc.nasa.gov/CME_list/

http://sid.stanford.edu/database-browser

Conclusion and Future Work

Based on this research, it can be concluded that CMEs have an effect on the Earth's ionosphere measurable by SID monitors. A stronger correlation was observed with the JXN transmitter broadcasting from Norway, possibly due to its proximity to the Magnetic North Pole.

The LASCO instrument aboard SOHO appears to have difficulty measuring the kinetic energy of halo type CMEs. This impacts the correlation analysis because halo type CMEs are high energy events that aren't fully accounted for in this research. However, when halo events are marked with the other CME data a visual correlation can be made. The variability of CME travel times also affects the correlation analysis. With accurate travel time data, a stronger correlation is predicted.

Suggestions to further this research include: discovering methods for estimating missing kinetic energy data and travel times for CME, expanding the data beyond 6 months and use of SID monitors closer to the magnetic poles.