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Response of the Earth's thermosphere to interplanetary coronal mass ejections

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Abstract

In this contribution we address the Earth's thermospheric response to interplanetary coronal mass ejections. We investigate several ICME events by means of neutral density measurements from the low-Earth orbiting satellites GRACE. Furthermore we correlate these observations with data from the ACE satellite located at L1 upstream of the Earth. By analyzing the data, high correlations between the neutral density and various combinations of ICME parameters can be found.

1. Motivation

Part of the solar wind energy supplied to the Earth's magnetosphere is deposited into the thermosphere via particle precipitation and Joule heating. During periods of high coronal mass ejection (CME) activity, short timescale (1-2 days) variations in the thermosphere are driven by magnetospheric energy input rather than by variations in the solar EUV flux (e.g., [2], [5]). We perform a statistical study based on GRACE satellite drag measurements during 2003-2010 to quantify the large-scale response of the thermospheric neutral density to the energy input by interplanetary CMEs (ICMEs).

2. Data and Methods

We studied the relationship between geomagnetic disturbances and thermospheric density by using accelerometer measurements by GRACE. After calibrating the raw observations, atmospheric neutral densities were deduced considering the effect of solar radiation pressure, horizontal winds and gas surface interactions [4]. During periods of geomagnetic disturbances the maximum of the signal is found at high latitudes (Fig.1). In the period July 23, 2003 - August 3, 2010 a total of 106 ICMEs measured in-situ at L1 upstream of Earth are listed in R&C [7]. In this presentation we focus on 20 events in which we can also detect distinctive peaks in the neutral density of the Earth's upper atmosphere.

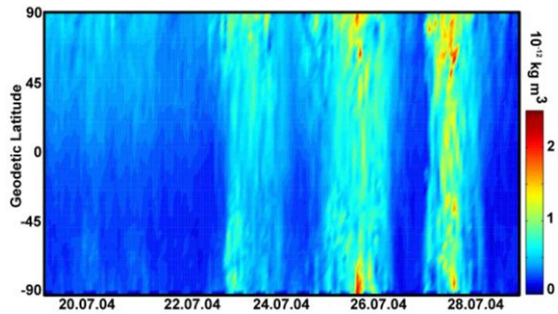

Figure 1: Neutral densities observed by GRACE during July 2004 – clearly visible the impact of 3 ICME's on the Earth's thermosphere.

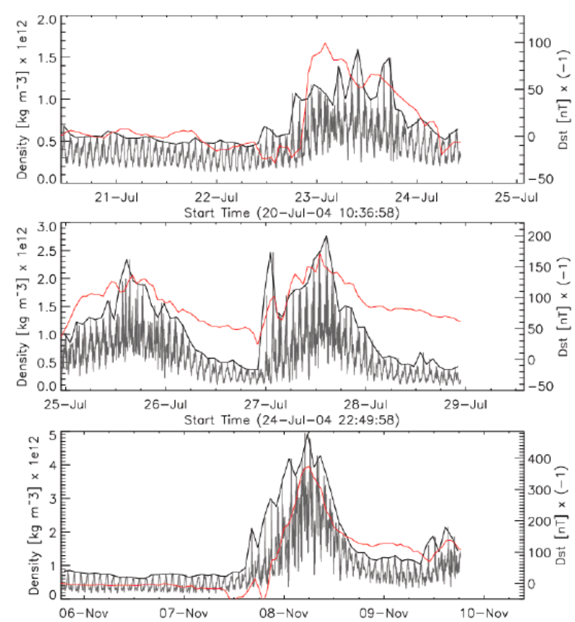

Figure 2: Evolution of the Dst index [nT] (multiplied by -1; red line and GRACE density measurements [kg m^{-3} x10^{-12}] black line.

3. Results and Conclusions

Figure 1 shows for a sub-sample of three events the temporal evolution of the Dst index and the associated density increase in the thermosphere. The profiles of Dst index and thermospheric density are very closely related. In order to compare different ICMEs characteristic with the neutral density we apply an envelope function to the GRACE signal to derive the maximum intensity per satellite revolution (black line in Fig.2). Subsequently, the highest correlation with the density is found for v_max*Bz (with Bz the magnetic field in z-direction using GSE coordinates). Figure 3 shows a scatter plot of these two quantities, revealing a correlation of cc=0.76, which can be approximated by a linear relation.

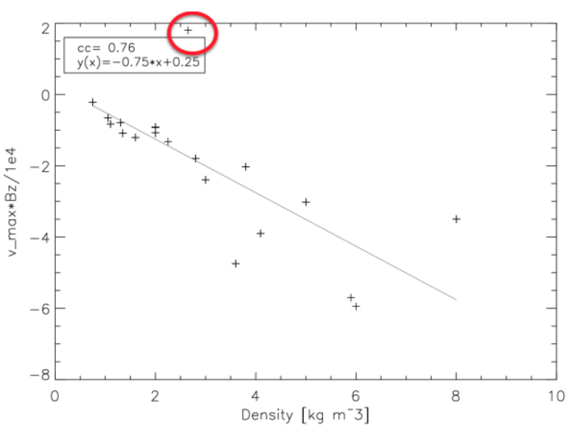

Figure 3: Maximum thermospheric density against v_max*Bz.

About 20% of ICMEs arriving at the ACE satellite cause an increase of the neutral density in the Earth thermosphere. For these events, we obtain a high correlation between thermospheric density and geomagnetic activity index Dst (see e.g., case study by [1]). 17 out of the 20 analyzed ICME events show typical characteristics of magnetic clouds (MCs; [3]), including a smooth rotation of the magnetic field vector. With one exception (Oct. 24, 2003), all ICMEs causing a thermospheric density enhancement have a strong negative Bz component [6]. It turned out that the combined parameter v_max*Bz has a higher correlation with the thermospheric density than the individual v_max and Bz parameters.

Acknowledgements

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