Statistical Properties of Dipolarization Fronts Observed by MMS

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Introduction

Dipolarization fronts in the geomagnetic tail are transient structures characterized by a sharp positive increase in the northward component of the geomagnetic field, B_z. These transient structures play an important role in transporting energy and magnetic flux to the inner magnetosphere.

Detection of dipolarization fronts and events is performed via two separate algorithms: one for the near-magnetotail (defined here as $X_{GSM} < -9\ R_E$) and another for the inner magnetosphere ($X_{SM} > -9\ R_E$). In these algorithms, we use modified identification criteria from Schmid et al. (2019) and Ohtani et al. (2018). As dipolarization fronts move Earthward, their speed decreases - making it necessary to increase the search-window size from 30 seconds to 2 minutes. Detection of inner magnetosphere events also often coincides with regions of dipolarization, shown in the right panel of Figure 1.

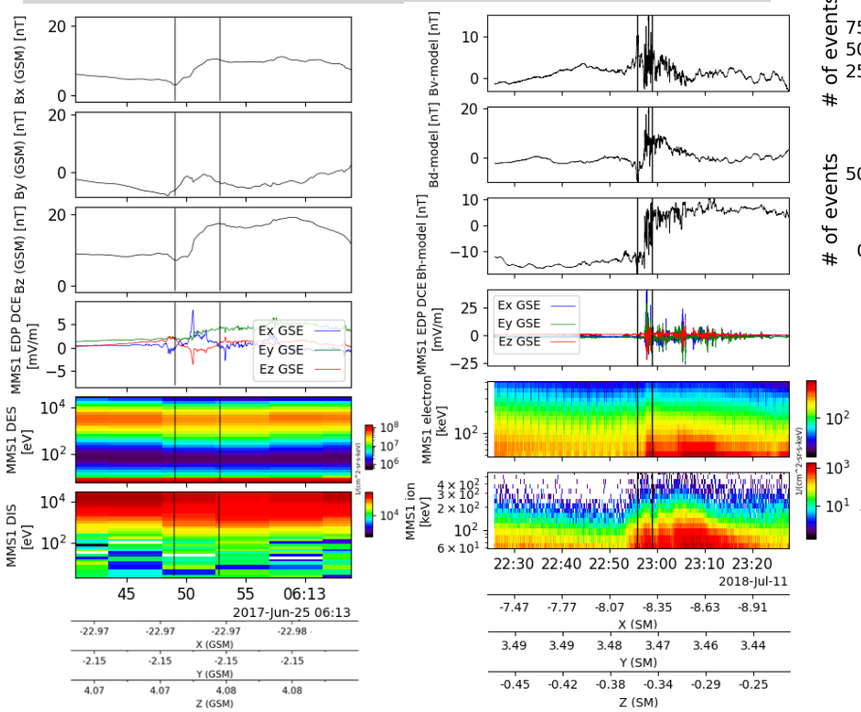


Figure 1: Magnetotail dipolarization front (left) and inner magnetosphere dipolarization event (right). Magnetotail spectrograms are obtained from FPI while inner magnetosphere spectrograms are from FEEPS.

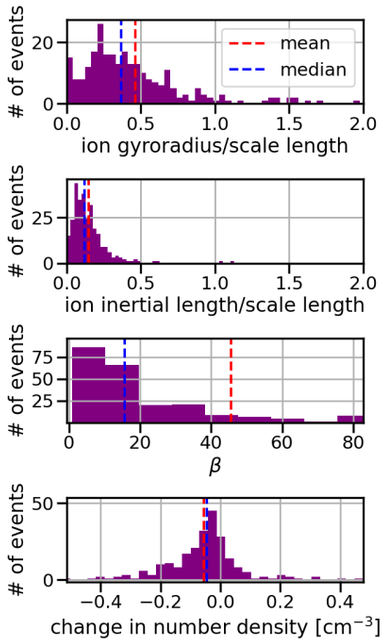
Interplanetary and Geomagnetic Conditions

Using the SML and SMR indices from SuperMAG along with interplanetary B_z and flow speed from OMNI, we can relate the occurrence of dipolarization fronts and events with these geomagnetic conditions. Shown on the right are the SML and SMR indices, indicating substorm and storm activity (respectively). As indicated by the red bars in between the plots, dipolarization fronts and events often occur in association with disturbed conditions.

During the 2018 tail season, we see a variety of activity in the form of:

- Substorms and storms
- Corotating interaction regions (CIR) and high-speed streams
- An interplanetary coronal mass ejection (ICME)
- Alfvénic fluctuations

Statistical Plasma Properties



From our list of 351 magnetotail DFs and 29 inner magnetosphere events, we've compiled some statistics of plasma-related quantities.

Here, we define "scale length" as the distance between min(Bz) to max(Bz), obtained from the timing normal velocity. Quantities for magnetotail events are calculated using FPI and for the inner magnetosphere, HPCA is used.

Some typical properties of the plasma include:

- Mean & median ion gyroradius/ scale length: 0.46 & 0.37
- Mean & median ion inertial length/scale length: 0.15 & 0.12
- Mean & median β: 45.5 & 15.6
- Mean & median change in density: -0.053 & -0.042 [cm^{-3}]
- Majority of events include decrease in number density

Figure 2: Ion gyroradius, ion inertial length, and β are obtained with FPI (magnetotail) and HPCA (inner magnetosphere).

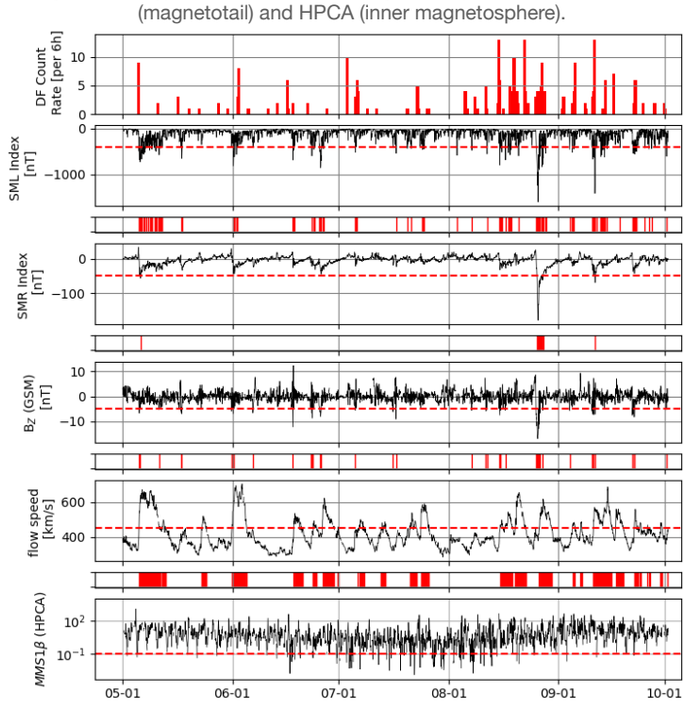


Figure 3: Geomagnetic and interplanetary conditions during the 2018 tail season. Red bars under quantities indicate "active conditions" while the red dashed lines indicate the corresponding threshold. Red dashed line on β plot indicates the threshold between the central plasma sheet and plasma-sheet boundary layer.

Statistics of Normal Vectors

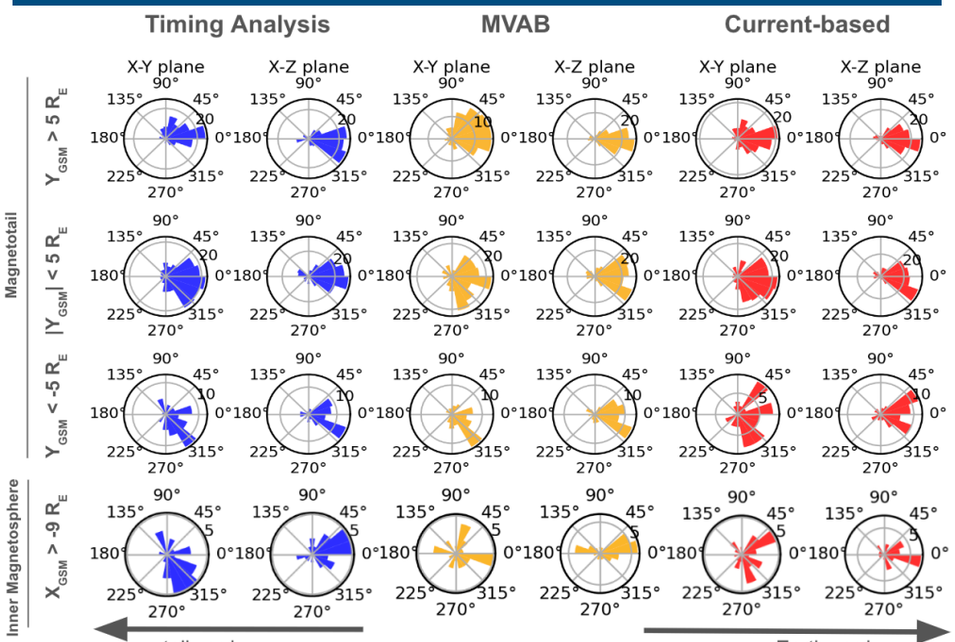


Figure 4: Polar histograms of normal vectors, separated by position in magnetosphere.

Normal vectors to the front/regions are determined using three methods: minimum variance analysis (MVA), timing analysis, and a current-based method. The current-based method is performed by taking the normalized cross product of the current with the L (northward) component with MVA.

For events detected in the magnetotail, agreement (<25° difference) between methods is quite good:

- Timing analysis/MVA: 68.4%
- Current-based/MVA: 60.5%
- Current-based/timing analysis: 59.1%

We can also see that magnetotail events that are detected in the duskward/dawnward region seem to point duskward/dawnward as well. This may be related to intrinsic dawn-dusk asymmetries or the shape of the DF.

For inner magnetosphere events however, this agreement is not nearly as good. Only ~14% of events are in agreement between all three methods. For MVAB in the inner magnetosphere, the lack of a more "front-like" B_z profile (in comparison to the magnetotail) makes determining a normal direction much less reliable. The current-based method may also not be valid, as other currents present may distort the result. Of the three methods, we believe timing analysis to be the most reliable for this region.

References & Acknowledgments

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