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Two classes of magnetotail dipolarization fronts observed by Magnetospheric Multiscale Mission: A statistical overview

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We carried out a statistical study of dipolarization fronts (DFs) detected by the Magnetospheric Multiscale mission (MMS) during the full 2017 Earth's magnetotail season. We found that two DF classes can be distinguished: class I (74.4%) corresponds to the standard DF properties and energy dissipation whereas a new class II (25.6%), which includes the six DF discussed in Alqeeq et al. (2022), corresponds to a bump of the magnetic field associated with a minimum of the ion and electron pressures and a reversal of the energy conversion process. The possible origin of this second class is discussed. Both DF classes show that the energy conversion process in the spacecraft frame is driven by the diamagnetic current dominated by the ion pressure gradient. In the fluid frame, it is driven by the electron pressure gradient. In addition, we have shown that the energy conversion processes are not homogeneous at the electron scale mostly due to the variations of the electric fields for both DF classes.

Selection criteria

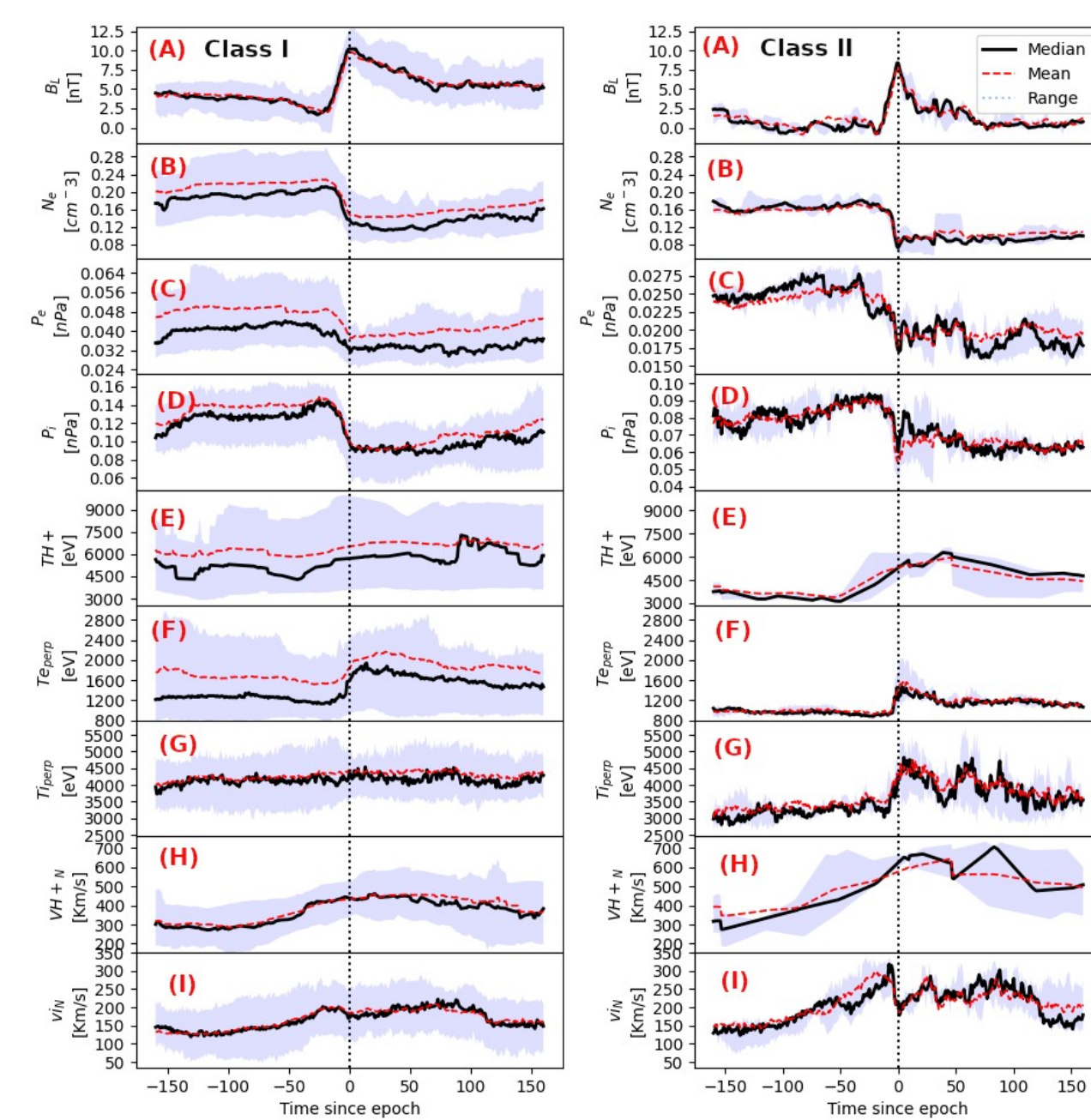
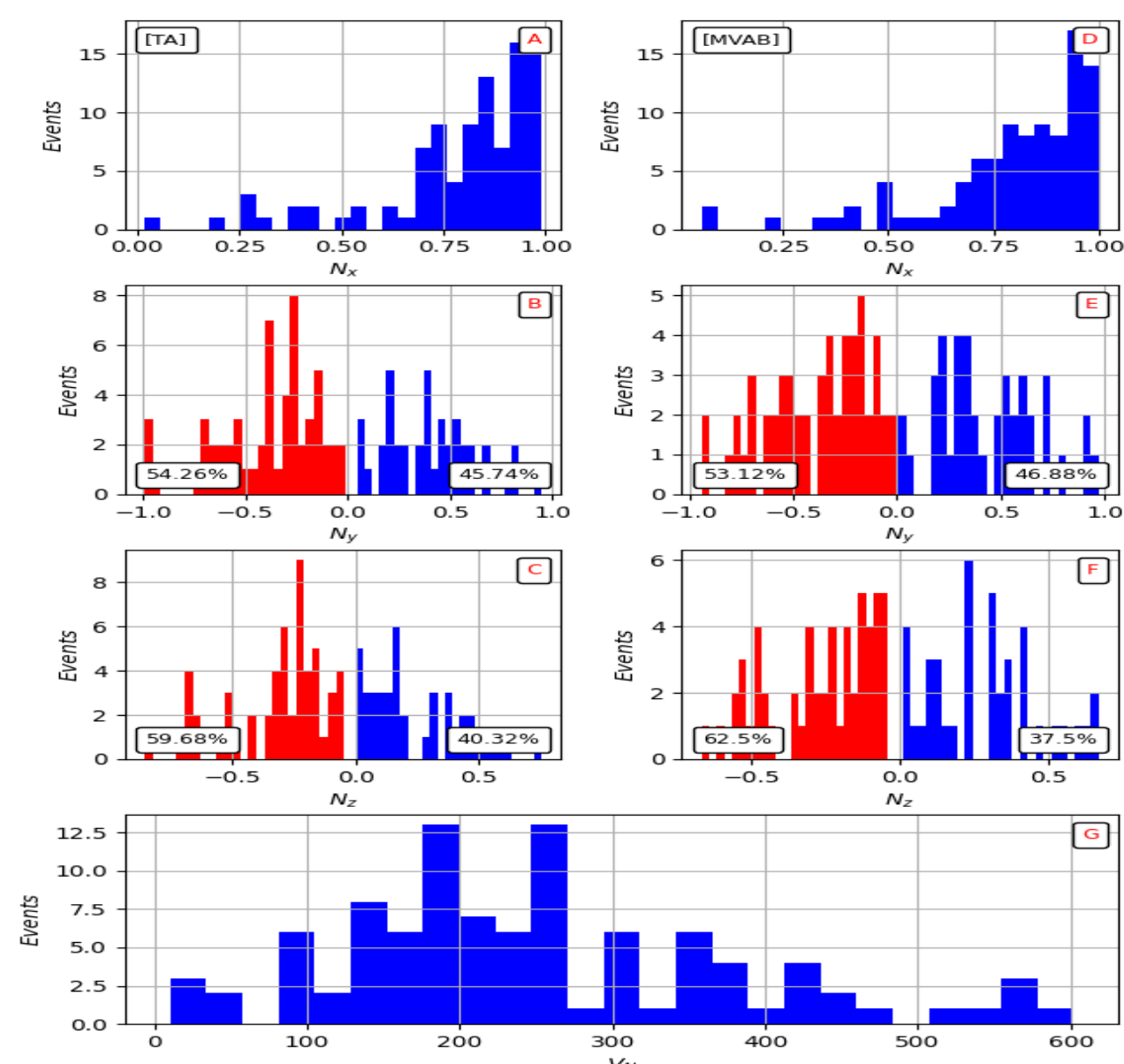
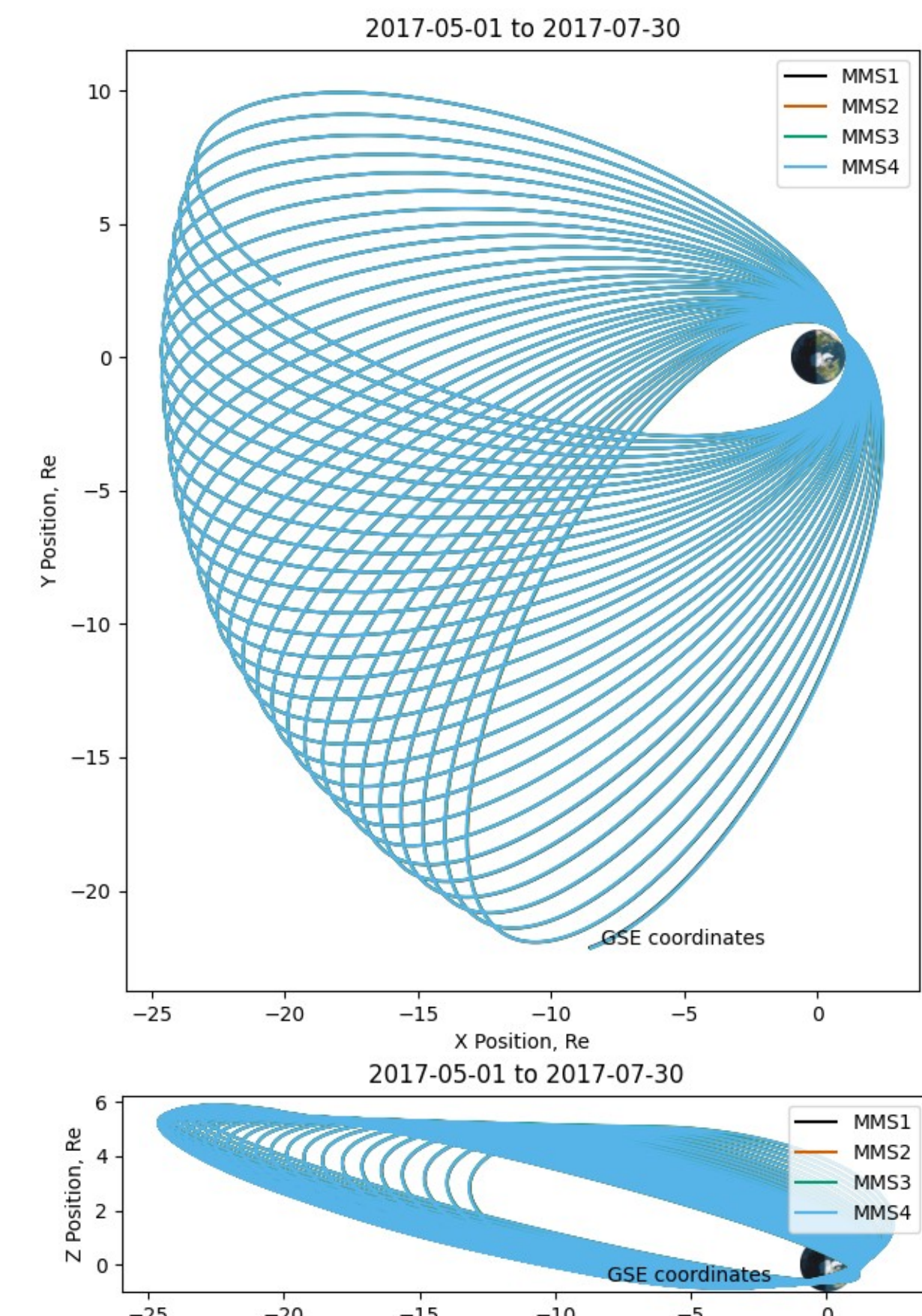
- More than 800 "possible DF" events detected near the Earth's magnetotail equator ($|B_x| < 5nT$), using an AIDapy tool requesting B_z and V_i increases and N_e decrease.
- This first automatic selection is then adjusted manually with the following criteria leading to only 132 DF events:
- Burst mode (partmoms) data are available at least 30s before and after the DF. The head of the DF denotes the time t_0 .
- B_z increase $> 5 nT$
- $V_i > 150 km/s$
- $N_{e,i}$ decrease
- $T_{para,e-i} \sim T_{perp,e-i}$ increases.

Methods

- MVAB and TA methods are applied on magnetic field data. They give similar front normal.
- MVAB was set to be:
- L: always oriented northward
- M: directed downward
- N: earthward
- Almost no preferential directions of propagation along y and z.
- N_y : $\sim (+) 54\%$, $\sim (-) 46\%$
- N_z : $\sim (+) 60\%$, $\sim (-) 40\%$
- VN : $\sim 200 km/s$

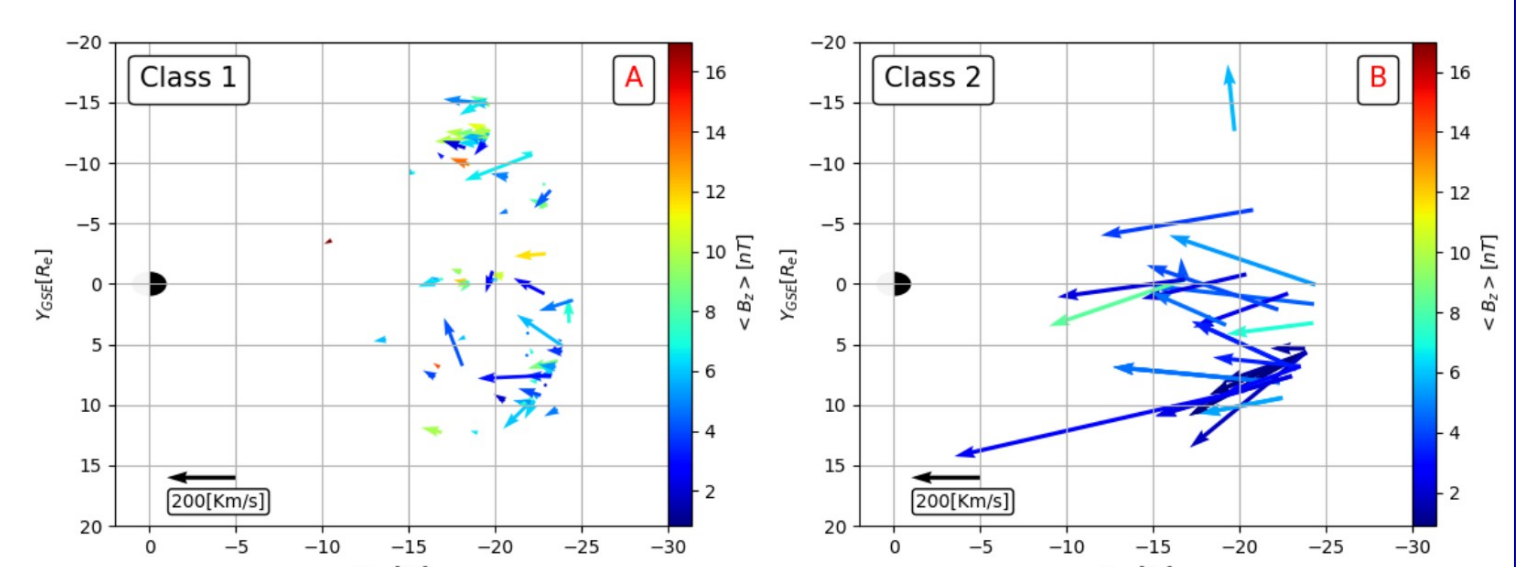
Two classes of magnetotail DFs

- Class I "classic type"** (74.4%) corresponds to a slow decrease of the magnetic field after the DF and is associated with smaller ion velocity and hotter plasma [e.g., Schmid et al., 2015; Huang et al., 2015; Yao et al., 2015; Zhong et al., 2019].
- Class II "new type"** (25.6%) has the same time scale for the rising and the falling of the magnetic field (a bump) associated with a minimum of ion and electron pressures and faster velocity.



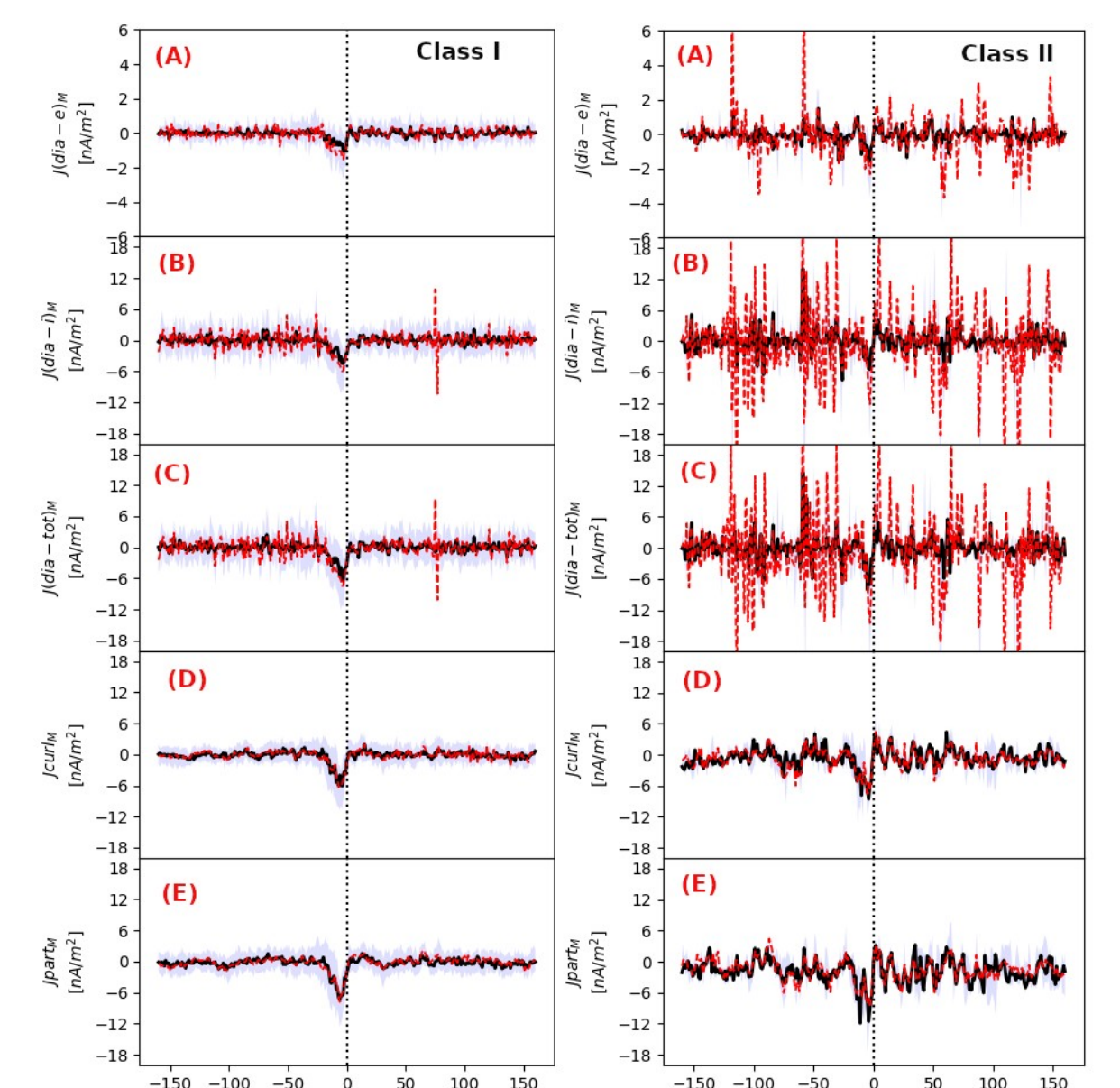
Equatorial XY GSE Plane

- Class I** DF locations and propagations are relatively **random**
- Class II** DF have preferentially **duskward locations** and propagations with **larger velocities**.



Current density comparison

- For both classes:
- Small values but good agreement within $< 10 nA/m^2$
- Ion diamagnetic current is dominant ($\sim 72\%$)
- In Class II the reversal in $J_{part,M}$ (E) & $J_{curl,M}$ (D) is due to the reversal of the diamagnetic current (C), dominated by ions (B)

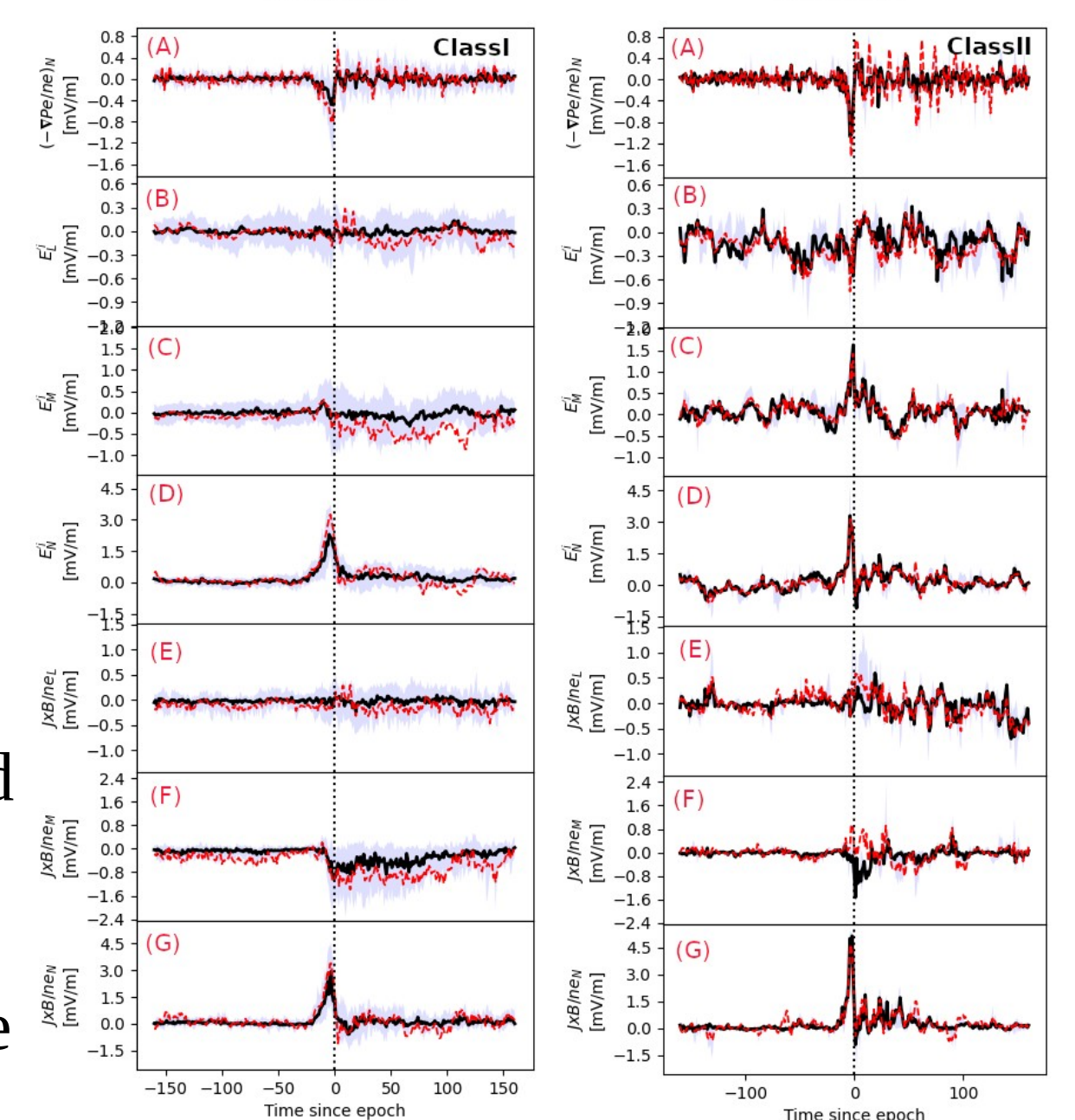


Ion Ohm's Law

$$\mathbf{E} + \mathbf{v}_i \times \mathbf{B} = \frac{\mathbf{J} \times \mathbf{B}}{en} + \frac{1}{en} \nabla \cdot \mathbf{P}_e - \frac{m_e}{e} \frac{d\mathbf{v}_e}{dt}$$

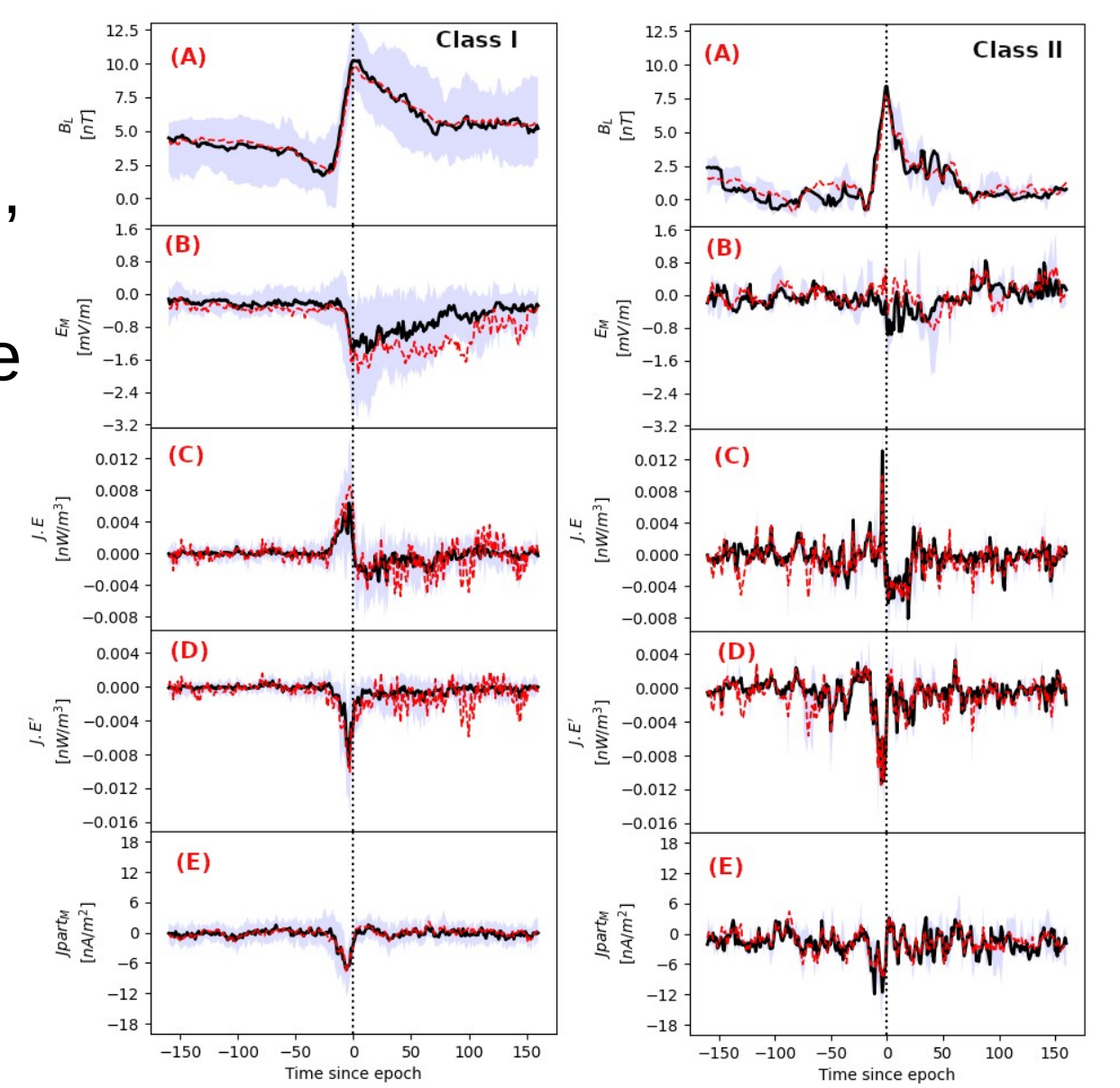
Ideal ion frozen-in Hall electric field Electron pressure gradient Initial term

- For both classes in the N direction, ions are decoupled (D) mostly by the Hall electric field (G) but electron pressure gradient also contributes (A).
- For class II in the M direction, ions are decoupled (C), but the Hall field (median $\sim -1.6 mV/m$, mean $+0.8 mV/m$) suggests that the contribution from the electron pressure gradient could be quite large too ($\sim +3.4 mV/m$, $+1 mV/m$, respectively).



Energy conversion

- For both classes ahead of DF, in the s/c frame, $J_{part,E} > 0$ Dissipation (C) (energy is dissipated from the electromagnetic field to the particles).
- For class II behind DF, in the s/c frame, $J_{part,E} < 0$ Dynamo (C) (the energy is transferred from the particles to the electromagnetic field).
- For both classes ahead of DF, in the ion & electron frames, $J_{part,E} < 0$ Dynamo (D) (energy goes from particles to field).



Conclusion/ For the full magnetotail season of 2017:

- Class I "classic type" (74.4%) corresponds to a slow decrease of B after the DF and is associated with smaller ion velocity and hotter plasma.
- Class II "new type" (25.6%) has a bump B profile associated with a minimum of ion and electron pressures and faster velocity as shown in Alqeeq et al. 2022, and it is found mostly on the duskside.
- For both categories we found a good agreement between current densities calculated from particles, Curl B and J_{diaM} (single S/C method).
- For both categories we found that ions are mostly decoupled from the magnetic field by the Hall fields.
- The electron pressure gradient term is also contributing to the ion decoupling and likely responsible for an electron decoupling at DF.

