Evaluating the magnetic flux transport in the plasma sheet during geomagnetic storms using MMS + Geotail

Savvas Raptis[1], Slava Merkin[1], Shin Ohtani[1], Matina Gkioulidou[1]

[1] APL/JHU, Laurel, MD, US

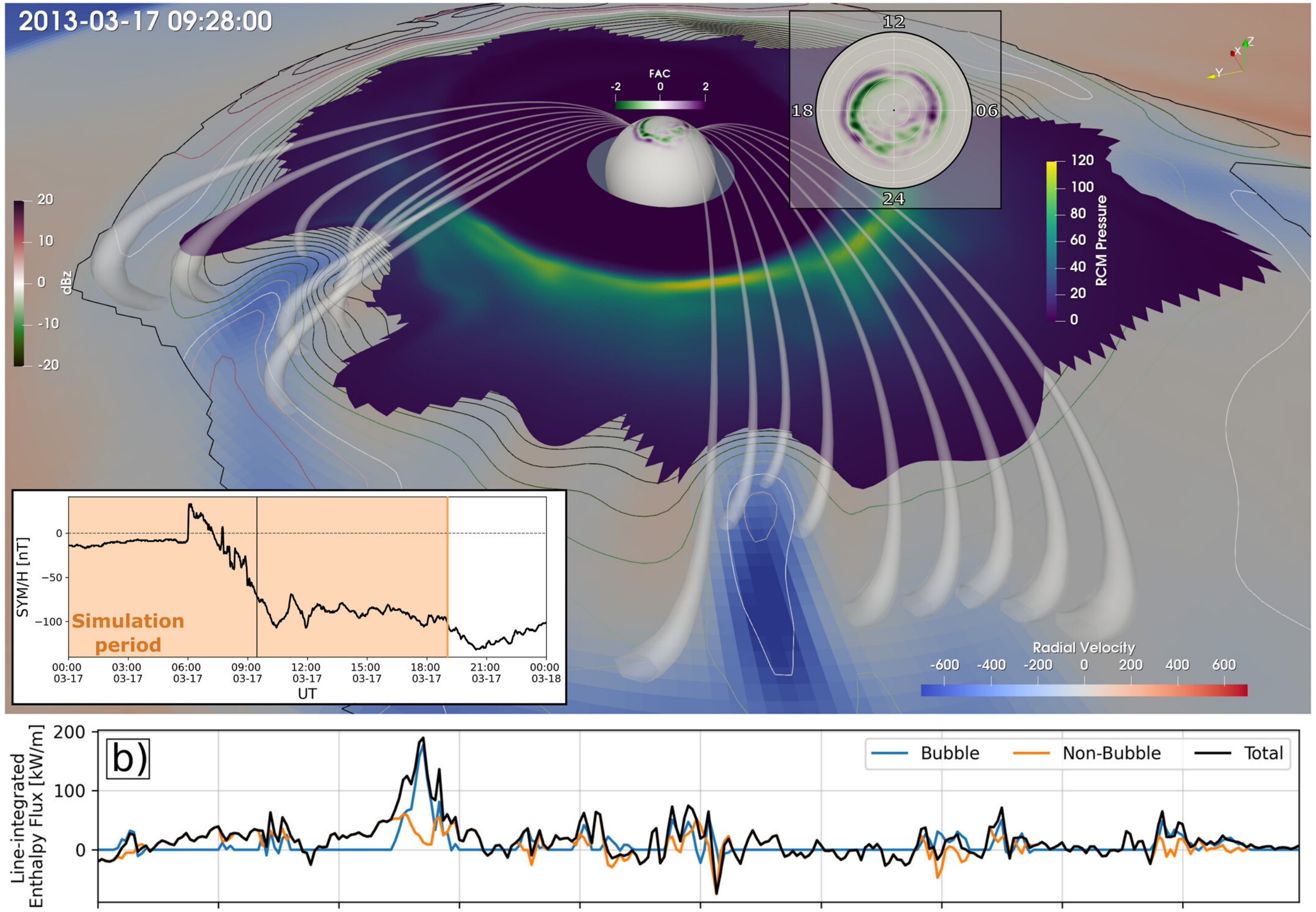
Supported by NASA DRIVE Science Center for Geospace Storms (CGS) - 80NSSC22M0163

savvas.raptis@jhuapl.edu
https://savvasraptis.github.io

CENTER FOR GEOSPACE STORMS

Introduction & Motivation

General Context - Motivation



50% of total energy flux transported into the inner magnetosphere by mesoscale structures

<u>One of CGS objectives:</u>
The role of **mesoscale plasma sheet** transport in the **ring current** build-up

- To tackle this **we need** to establish a **clear understanding** of the overall **plasmasheet transport during quiet and storm times**.

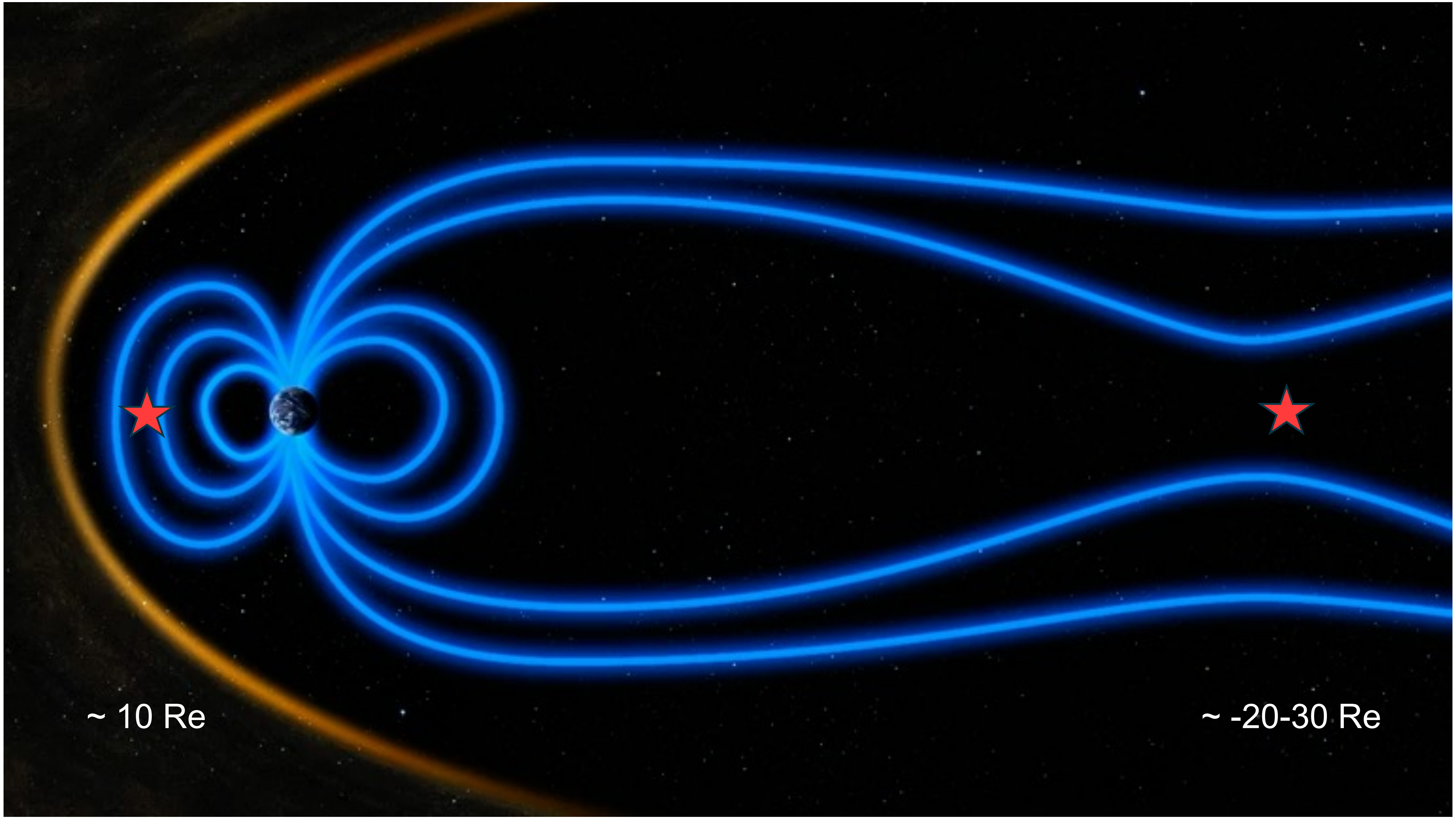
<u>This presentation:</u>

- Focus on **magnetic flux transport** during storms
- Building towards a holistic multi-spacecraft evaluation including mass and energy transport

Sciola+ 2023

https://cgs.jhuapl.edu

Powering the magnetotail



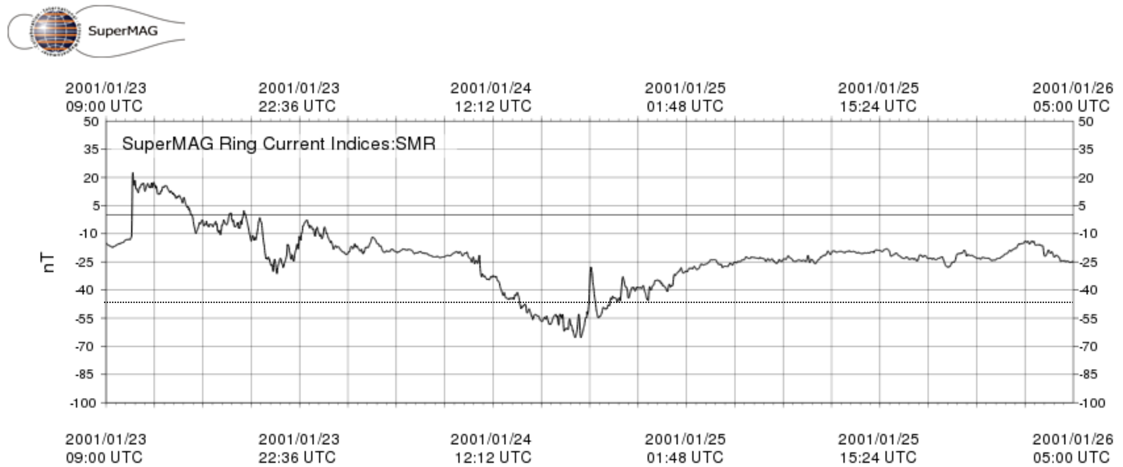
Credits: ESA/ATG medialab

Data used

Ground

SMR: Ring current index based on all ground magnetometers at geomagnetic latitudes (mlat) between -50 and +50 degrees;

Treated equivalently as DST and SYM-H indices traditionally used for geomagnetic storms (Note: differences exist)



Gjerloev (2011, 2012), Newell and Gjerloev (2012)

In-situ

- Plasma moments from spectrometers
- Magnetic field from fluxgate magnetometer

MMS* (2015 - now)
Geotail** (1992 – 2022)
THEMIS (2007 – Now) - TBD

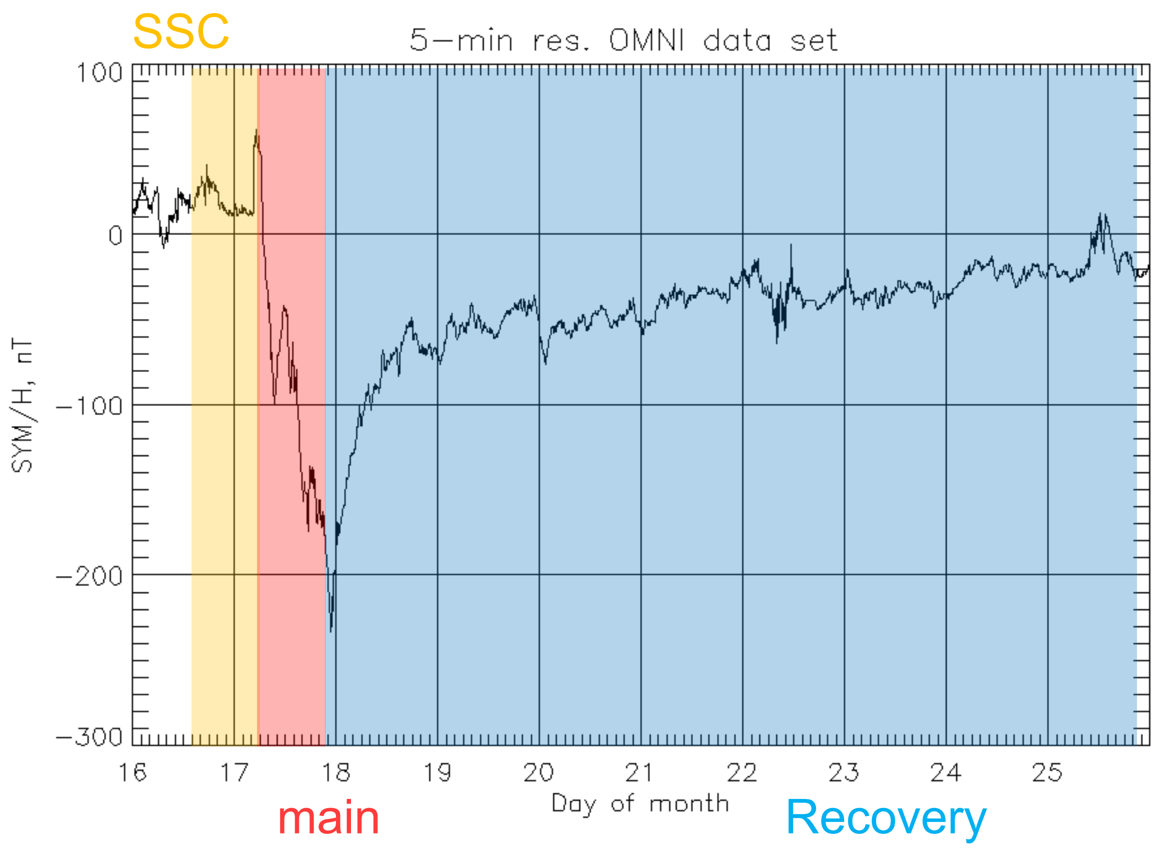
*Currently showing HPCA (~10s) results not FPI (4.5s) (i.e., H+ not ions)
**Currently showing results of 12s resolution up to 2014

Methods & Results

Gather storms & define their phases → Classify plasmasheet observations → Analyze their properties

Definitions & Criteria used

Geomagnetic storms

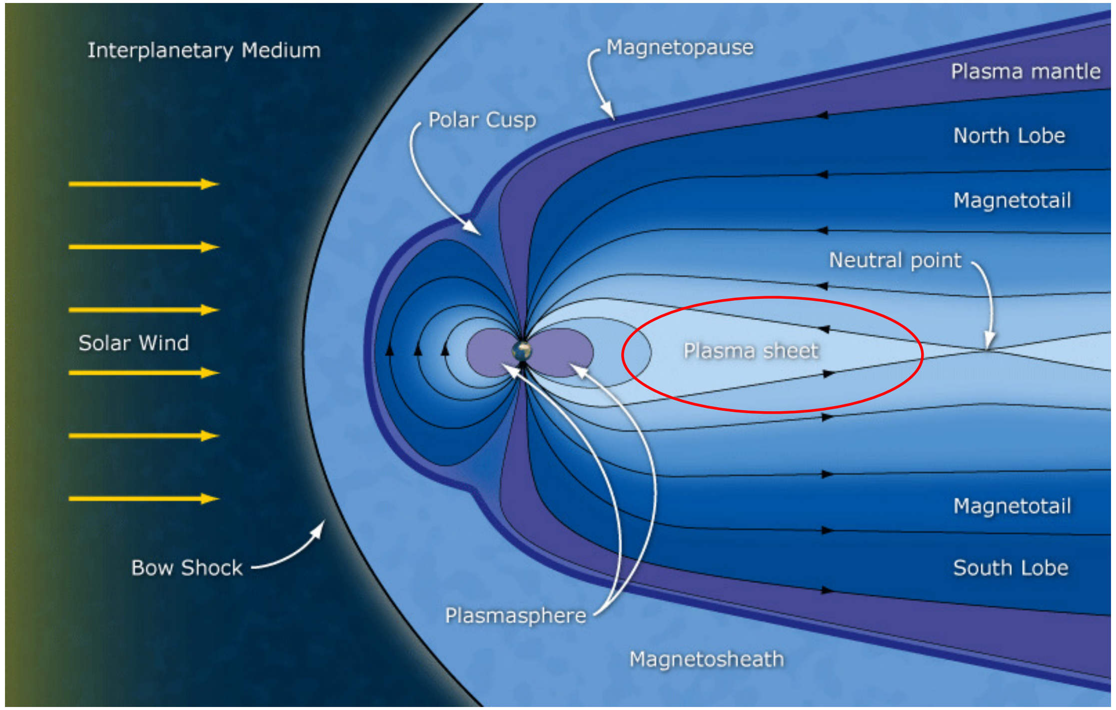


SMR < -50 nT

Plasmasheet

Example Criteria to find CSP

1. $|Y_{GSM,4°}| < 10$
2. $-5 < X_{GSM,4°} < -30$
3. $\beta = \frac{P_{the}}{P_{mag}} > 1$
4. $|Bz| > \sqrt{Bx^2 + By^2}$

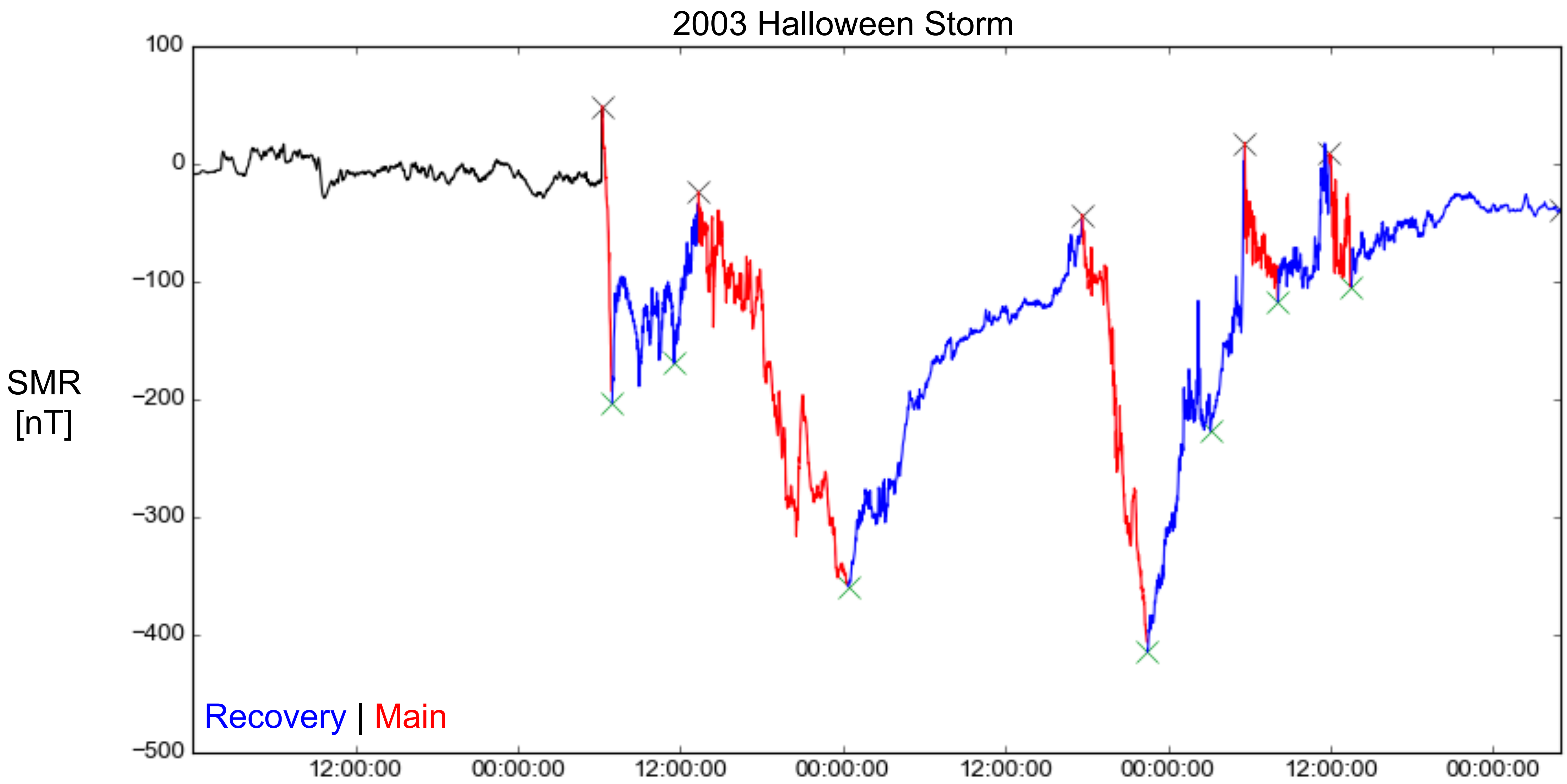


See e.g., Ohtani 2021

Disclaimer: absolute numbers can be sensitive to criteria

See e.g., Ohtani+ 2008, Guild+ 2008, Roziers+ 2009, Vo+ 2023

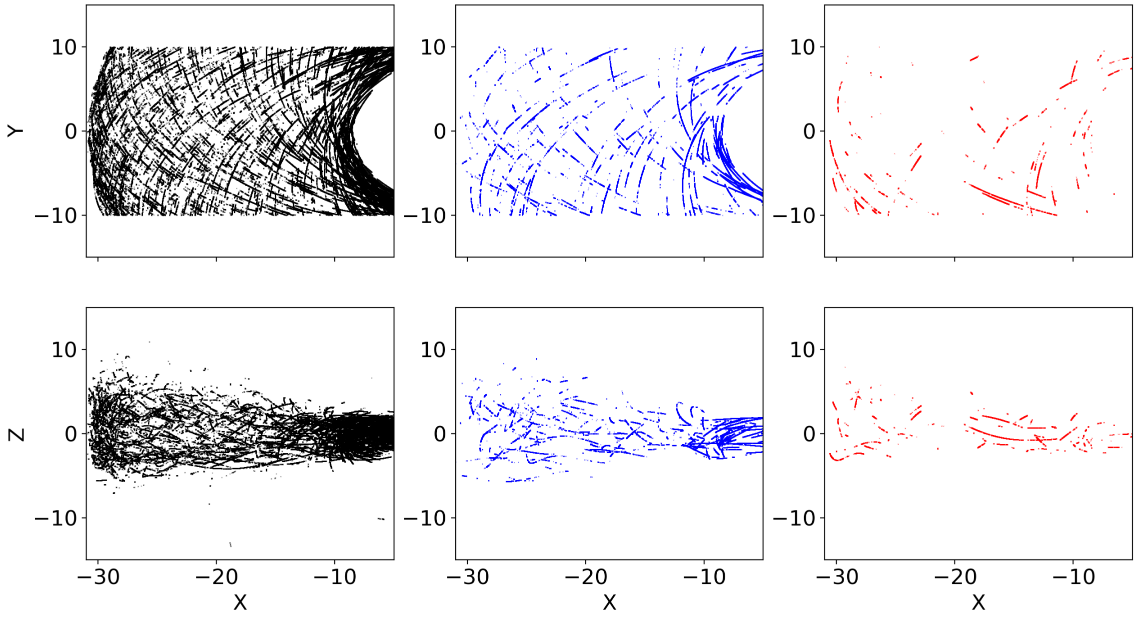
Storm phases automatic classification



Verified with methodology of Ohtani 2021

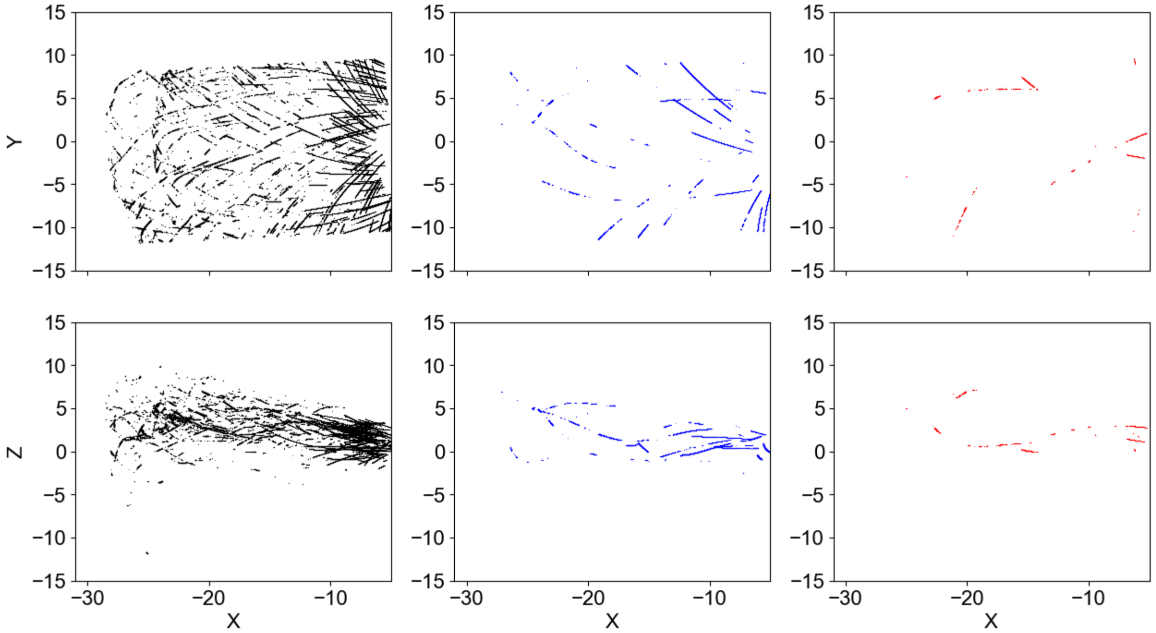
Plasmasheet Coverage per mission – Strict Criteria

Geotail (1994 – 2014)



Quiet : 393,379 (85%)
Reco : 56,061 (12%)
Main : 11,546 (3%)

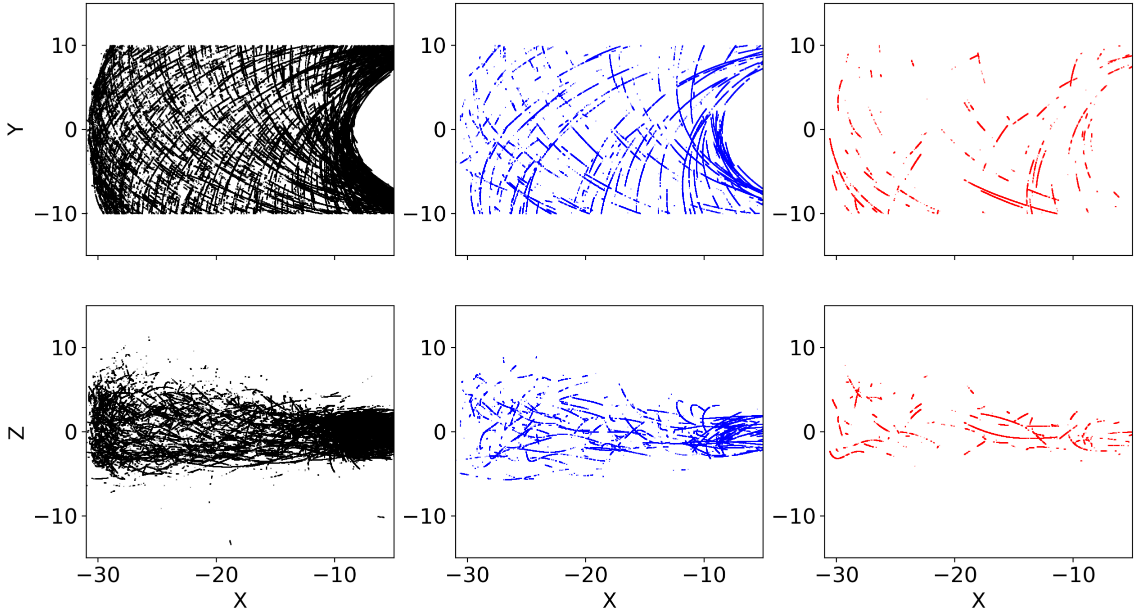
MMS (2016 – 2024)



Quiet : 112,099 (88%)
Reco : 13,336 (10%)
Main : 2,205 (2%)

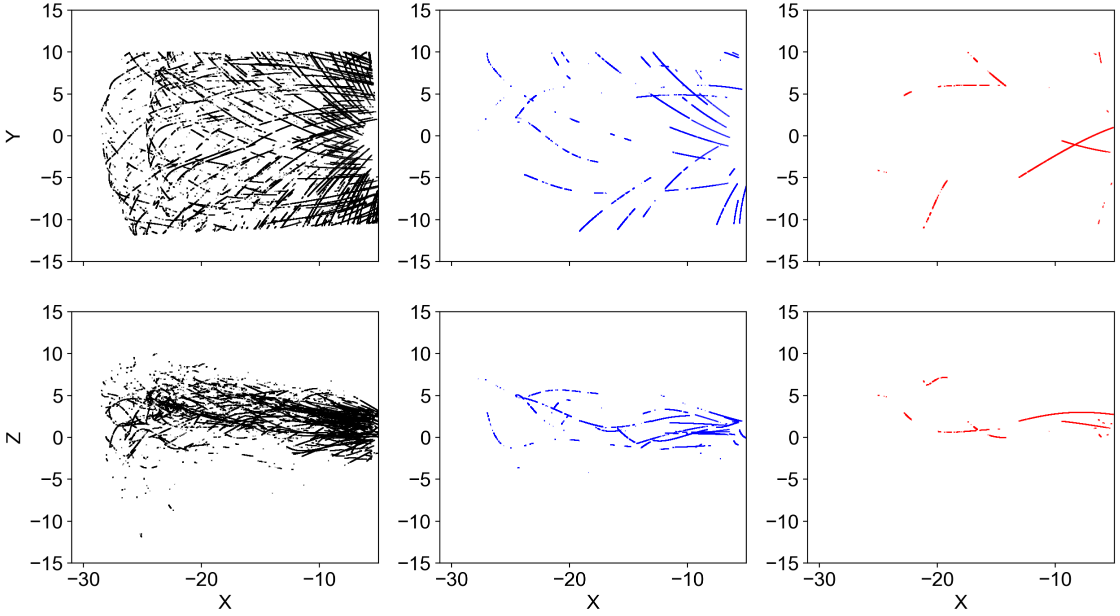
Plasmasheet Coverage per mission – Flexible* Criteria

Geotail (1994 – 2014)



Quiet : 779,557 (+98%)
Reco : 10,6258 (+90)
Main : 22,797 (+99%)

MMS (2016 – 2024)

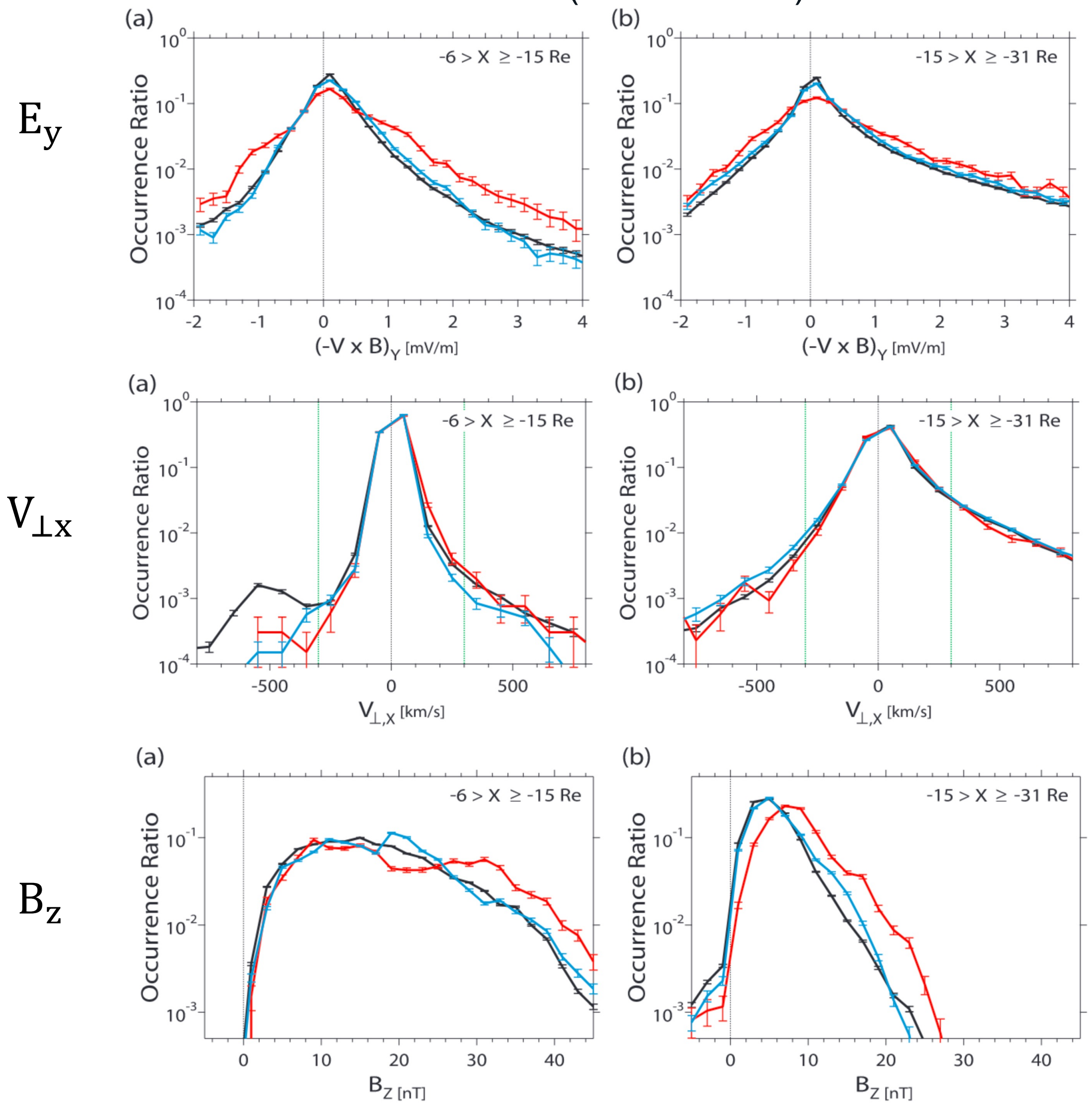


Quiet : 250,749 (+124%)
Reco : 25,466 (+90%)
Main : 6,097 (+175%)

*Combine Ohtani 2008, Guild 2008, Roziers 2009, limit Y to 10 Re – changes in statistical properties: ~0 - 20%

Confirmation of previous results

Geotail (1994 – 2006)



Ohtani & Mukai 2008

Findings:

1. Ey increase during storm times
2. Increase realized through Bz enhancement rather than V⊥x

✓ Reproduced with MMS (2015 – 2024)
✓ Reproduced with Geotail (1994 – 2014)

❖ Expand to distribution along X [GSM], and R
❖ Investigate potential Dawn/Dusk asymmetries

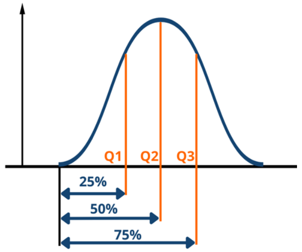
Take a step Further

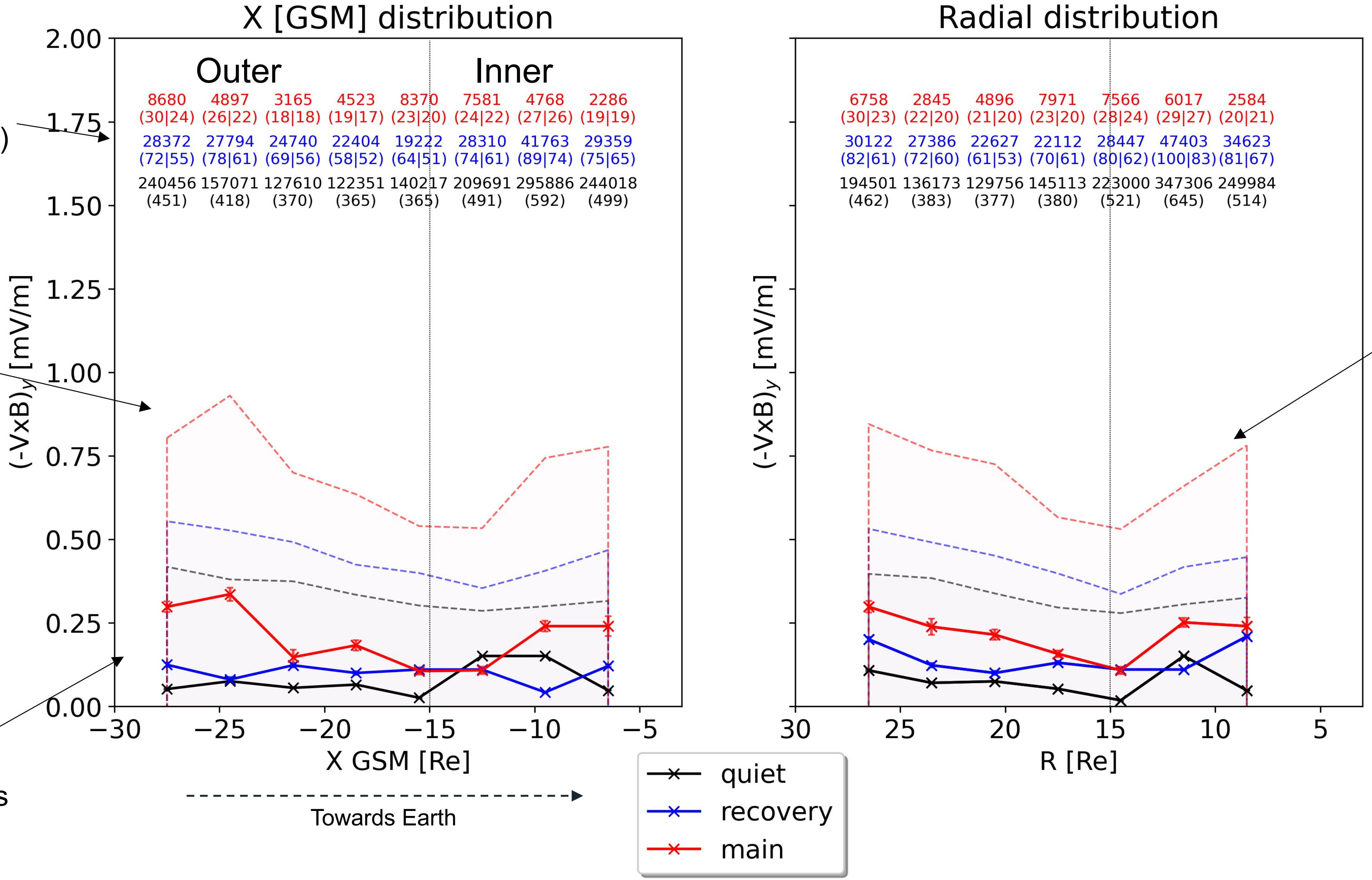
1) Evaluate the distribution in X and radial distance

(-VxB)y– spatial distribution - Geotail

points
(days|storms)

Solid: 50%
Dotted: 75%



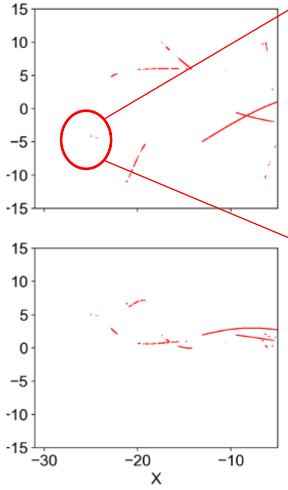


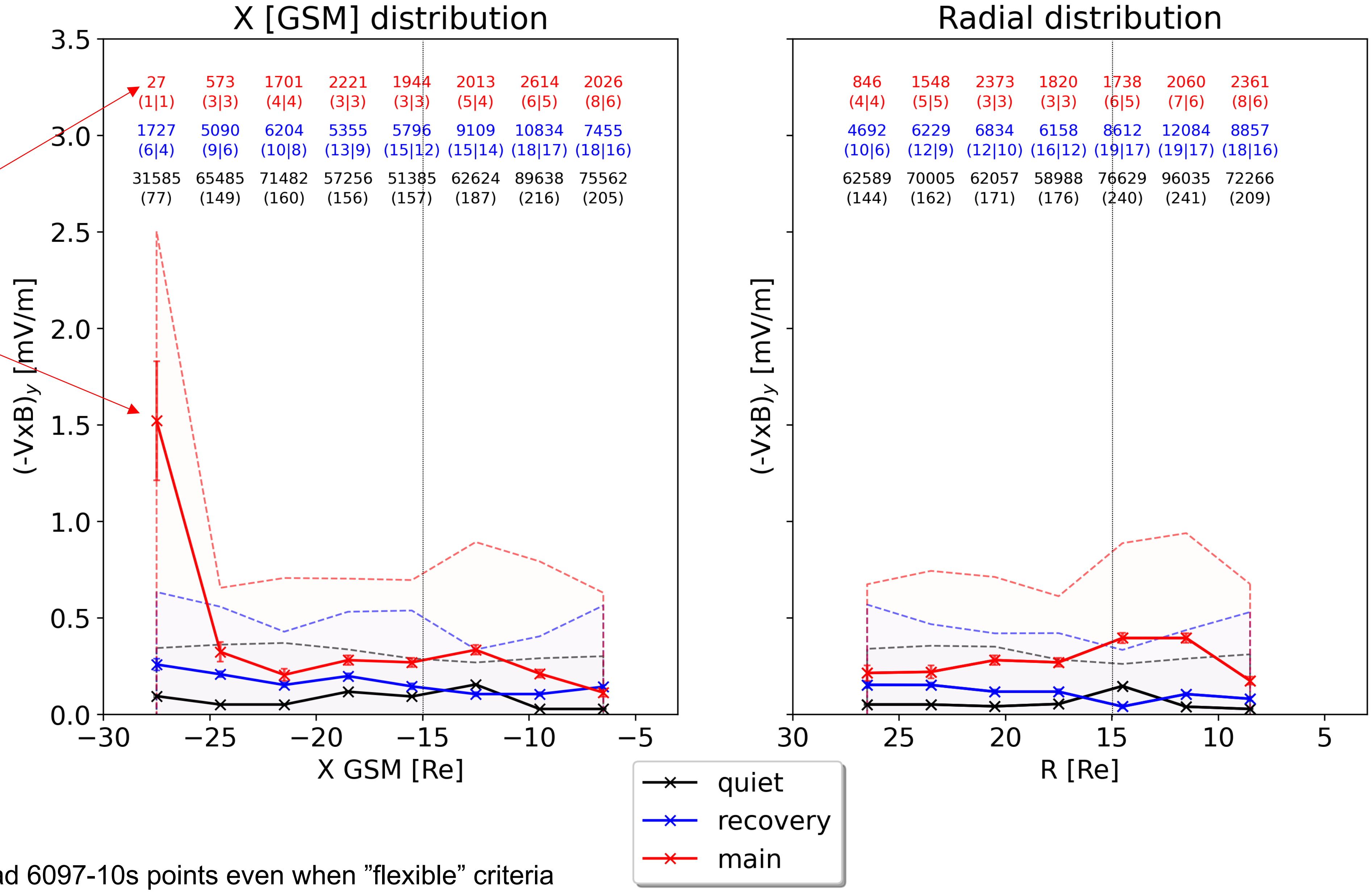
Storm Ey ↑

Overlapping bins
width = 8 Re
step = 3 Re

(-VxB)y – spatial distribution - MMS

XY plane
Storm times



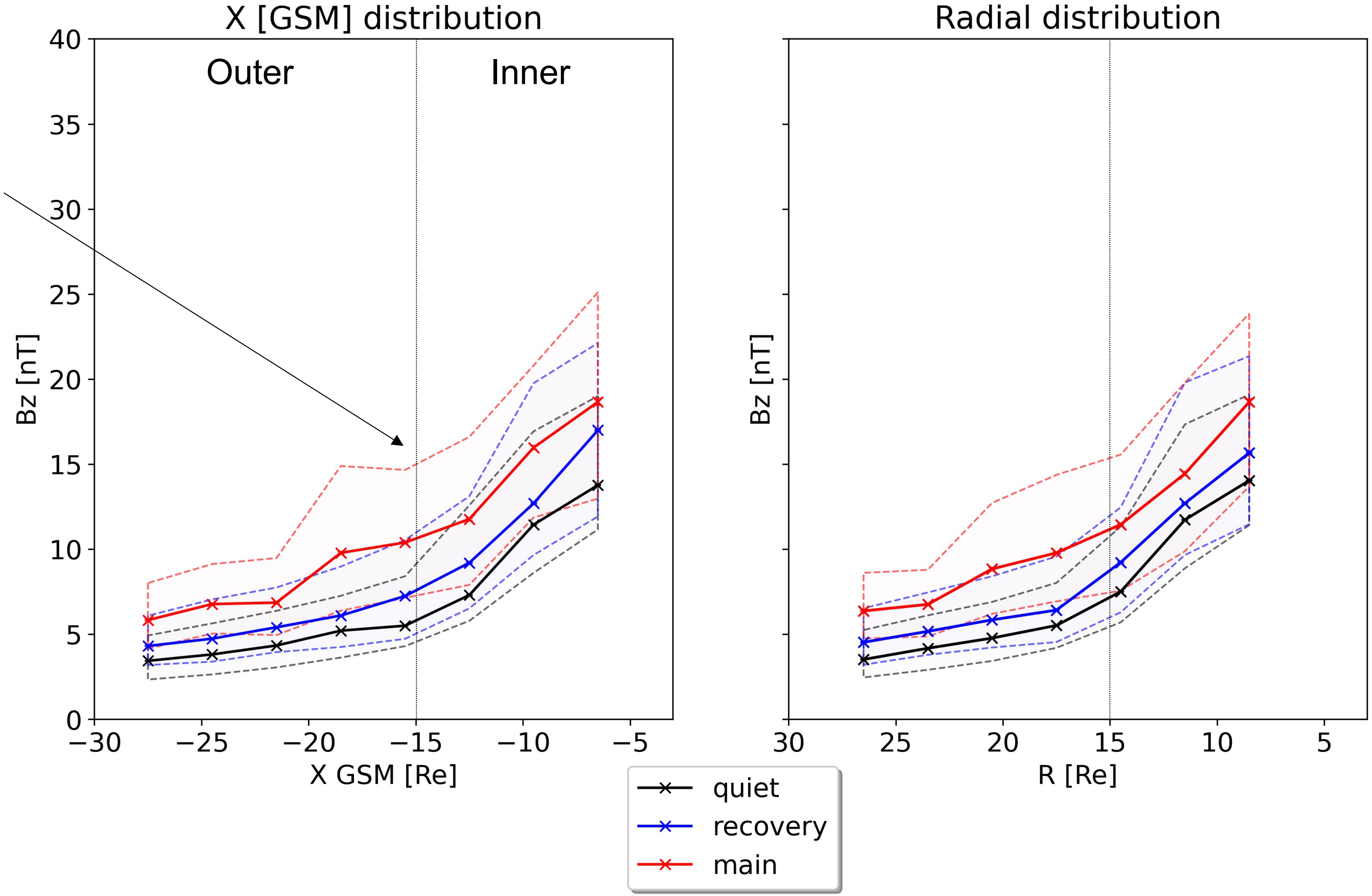


<u>MMS</u>
Similar results
Less statistics

Reminder: main had 6097-10s points even when "flexible" criteria

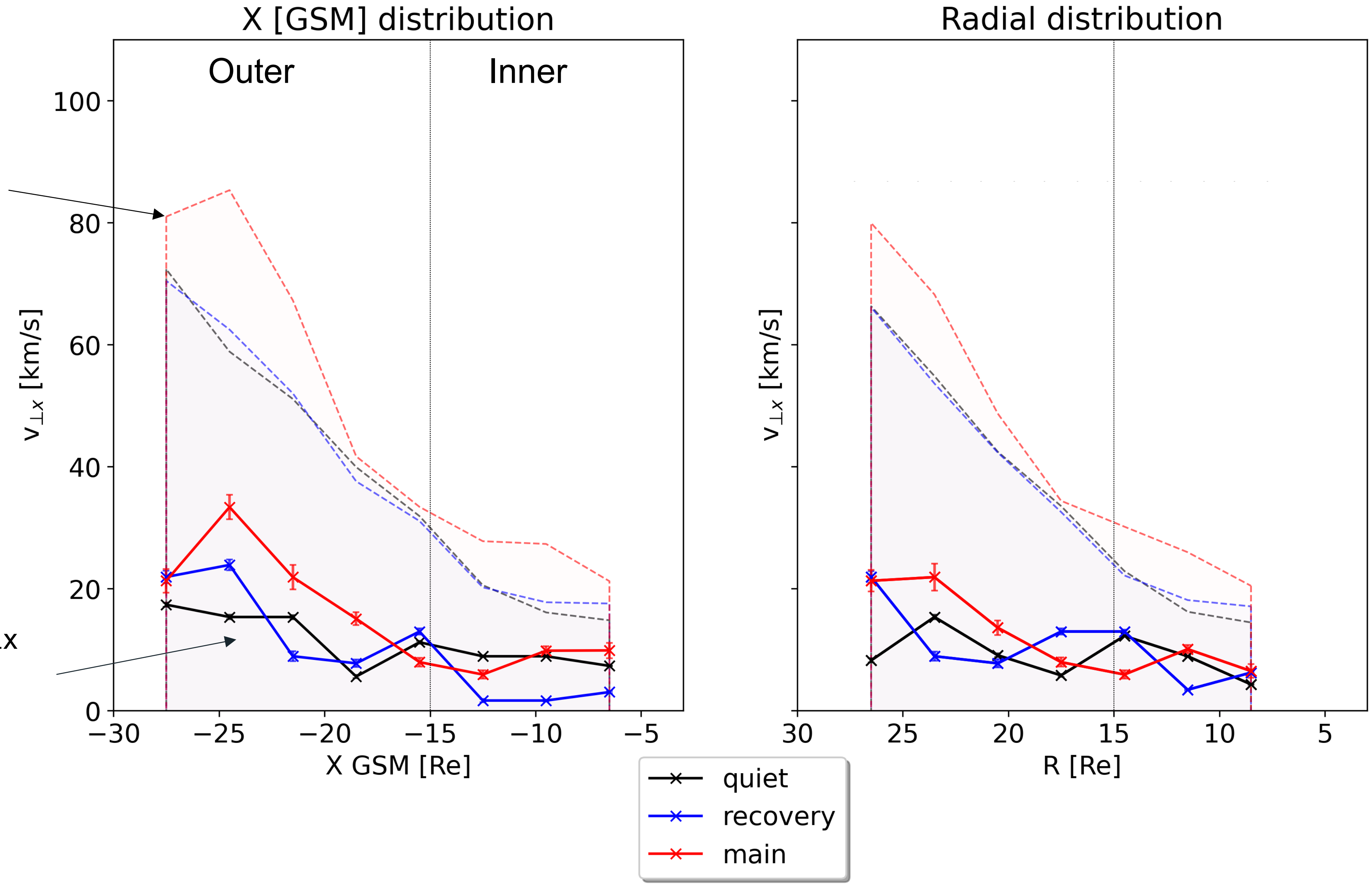
Bz – spatial distribution - Geotail

- Storm Bz elevated throughout the tail



V⊥x – spatial distribution - Geotail

- 75%V⊥x slightly enhanced
- Median V⊥x relatively constant



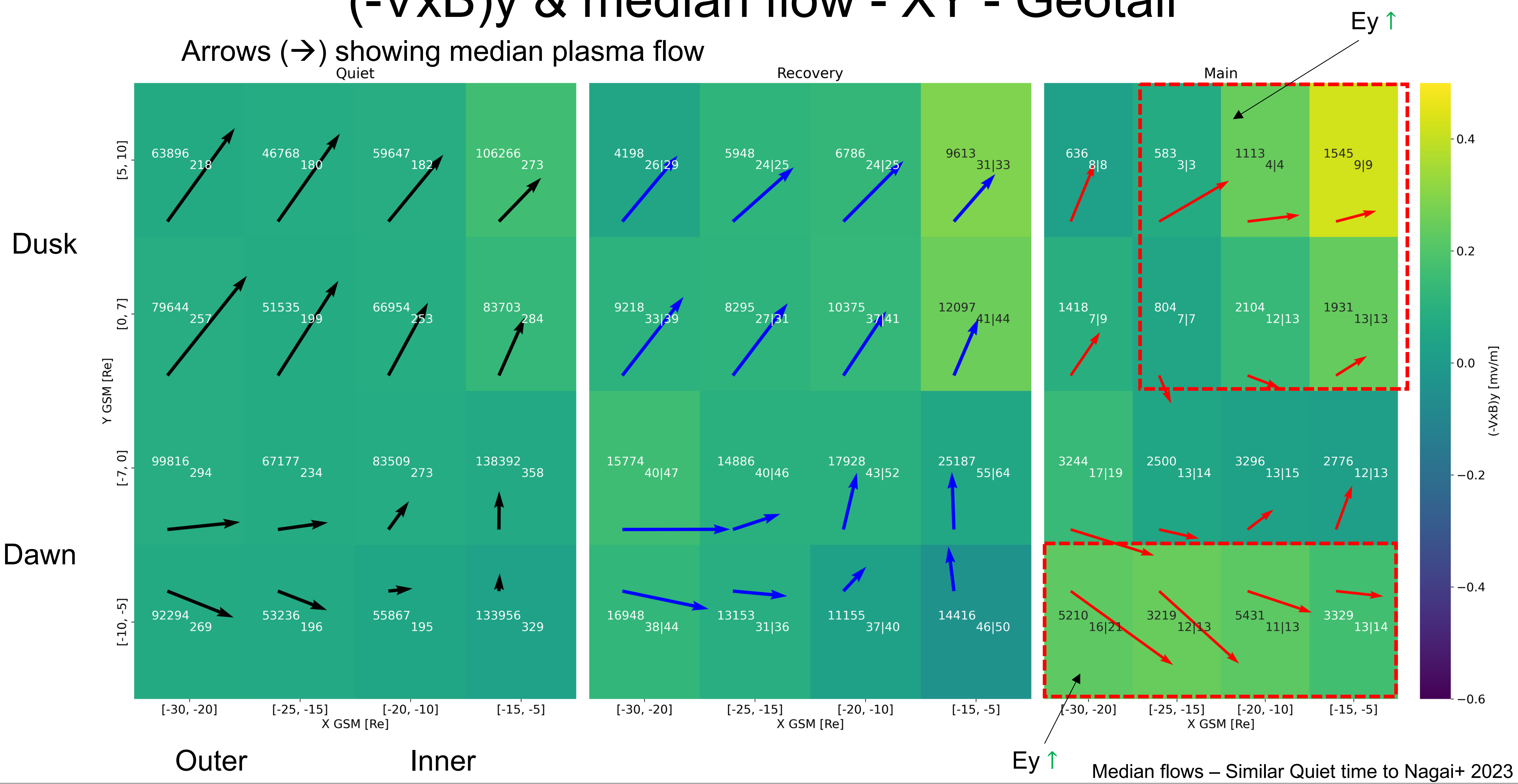
Take a step Further

1) Evaluate the distribution in X and radial distance

2) Investigate the 2D variability in XY GSM plane

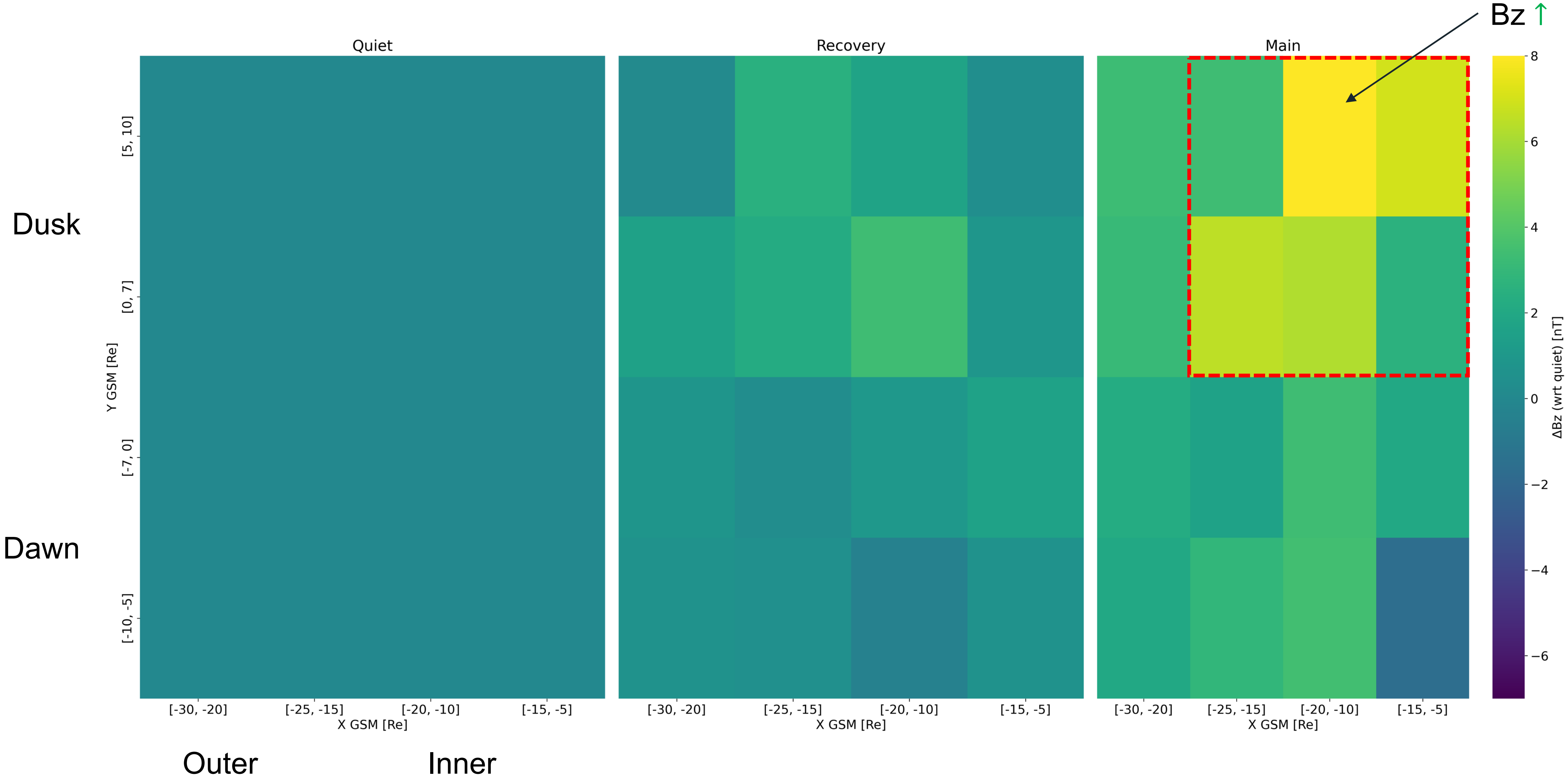
(-VxB)y & median flow - XY - Geotail

Arrows (→) showing median plasma flow

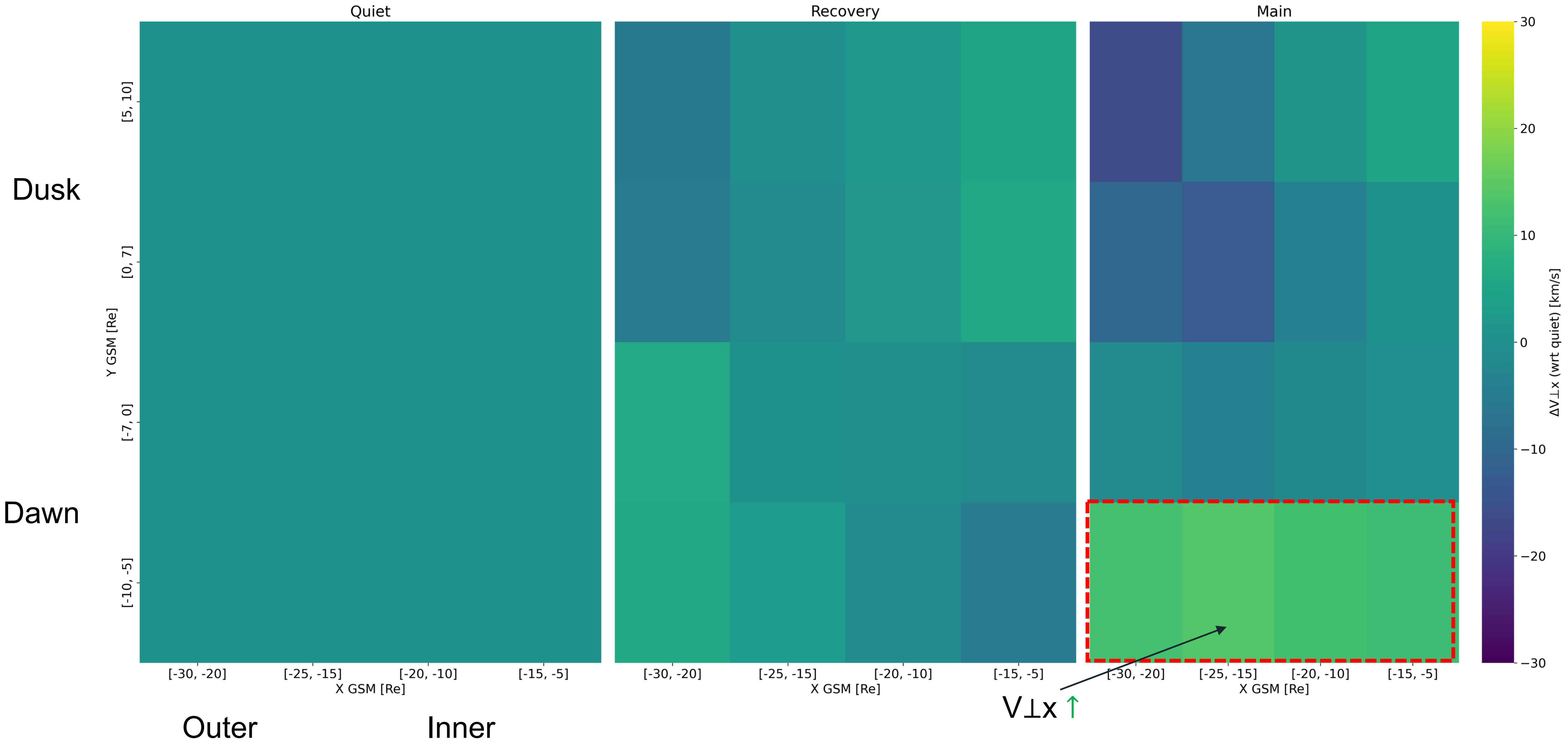


Median flows – Similar Quiet time to Nagai+ 2023

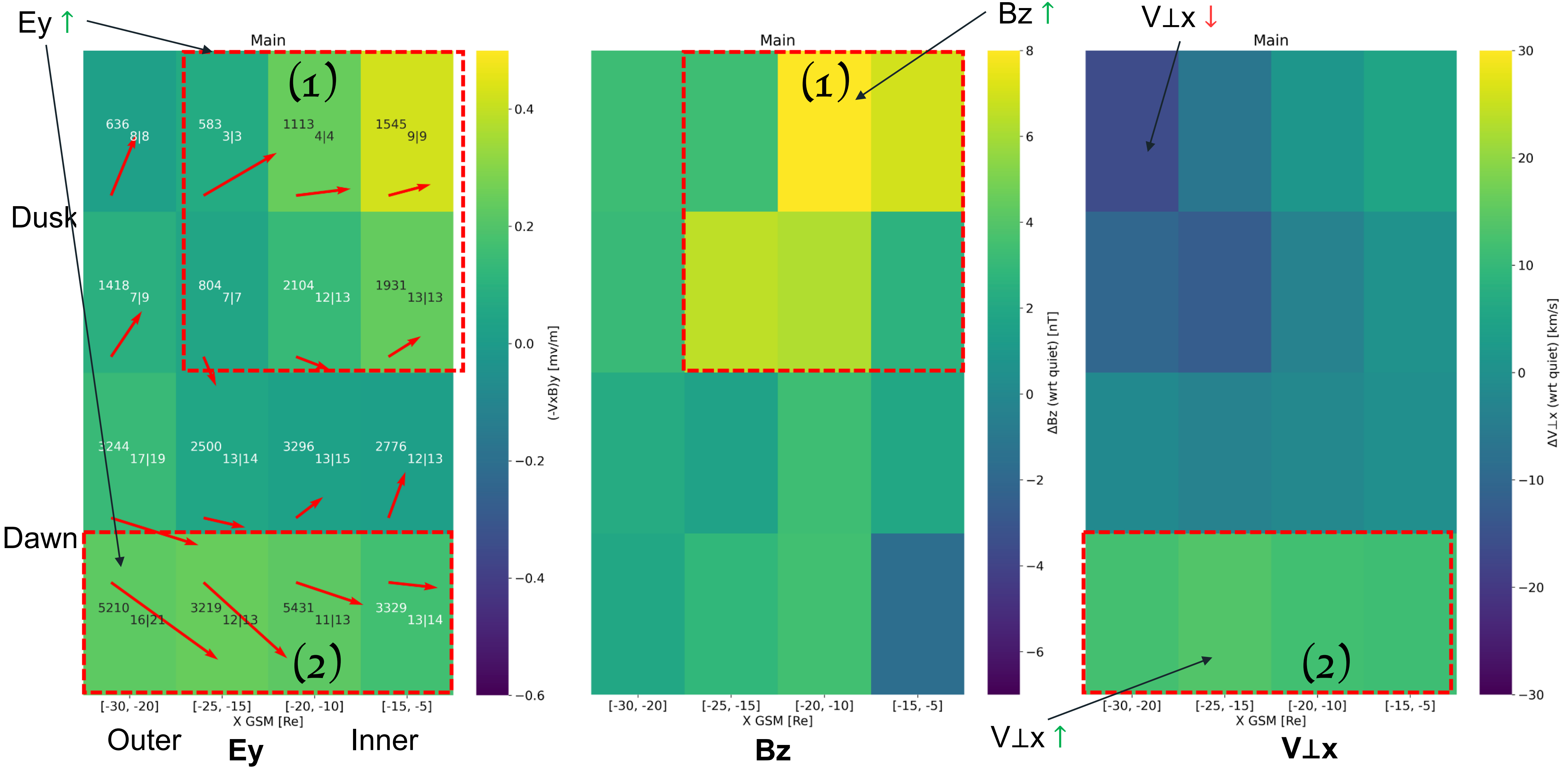
ΔBz (wrt quiet phase) - XY - Geotail



ΔV⊥x (wrt quiet phase) - XY - Geotail



Storm - Main Phase Behavior



Discussion & Conclusion

Summary

<u>During storm times:</u>

1. **Plasmasheet during storm times has eevated Ey** associated with **increased Bz**, and **limited enhancement of** V⊥x throughout the whole magnetotail.

2. **During Storm times:**
   1. **Inner-Dusk observations showing more dipolar magnetic fields**
   2. **Outer-Dawn** are associated to **relatively faster flows**

Future Work

- Validate results using FPI instrument (MMS)
- Evaluate mass and energy flux transport
- Validate findings with THEMIS mission & expand Geotail dataset to 2022
- Quantify contribution of mesoscale transient phenomena across different missions

Please contact me with thoughts, feedback, and comments: savvas.raptis@jhuapledu

Supported by NASA DRIVE Science Center for Geospace Storms (CGS) - 80NSSC22M0163

Extras

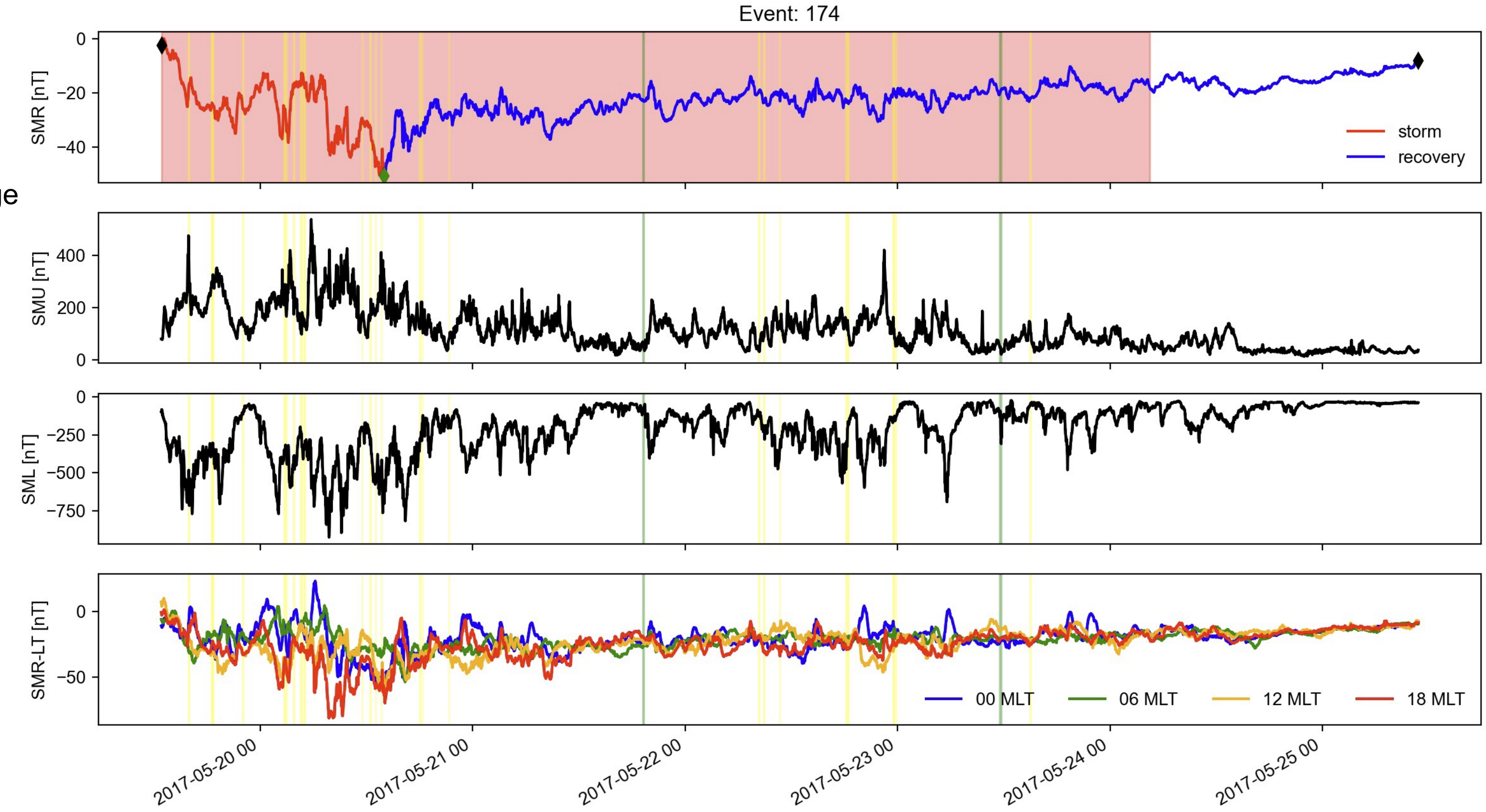
Future work:
Connecting storms to SC coverage & to transients

MMS: 8284 | BBFs: 1414 points

Red = MMS coverage

Green = IP shocks

Yellow = BBFs

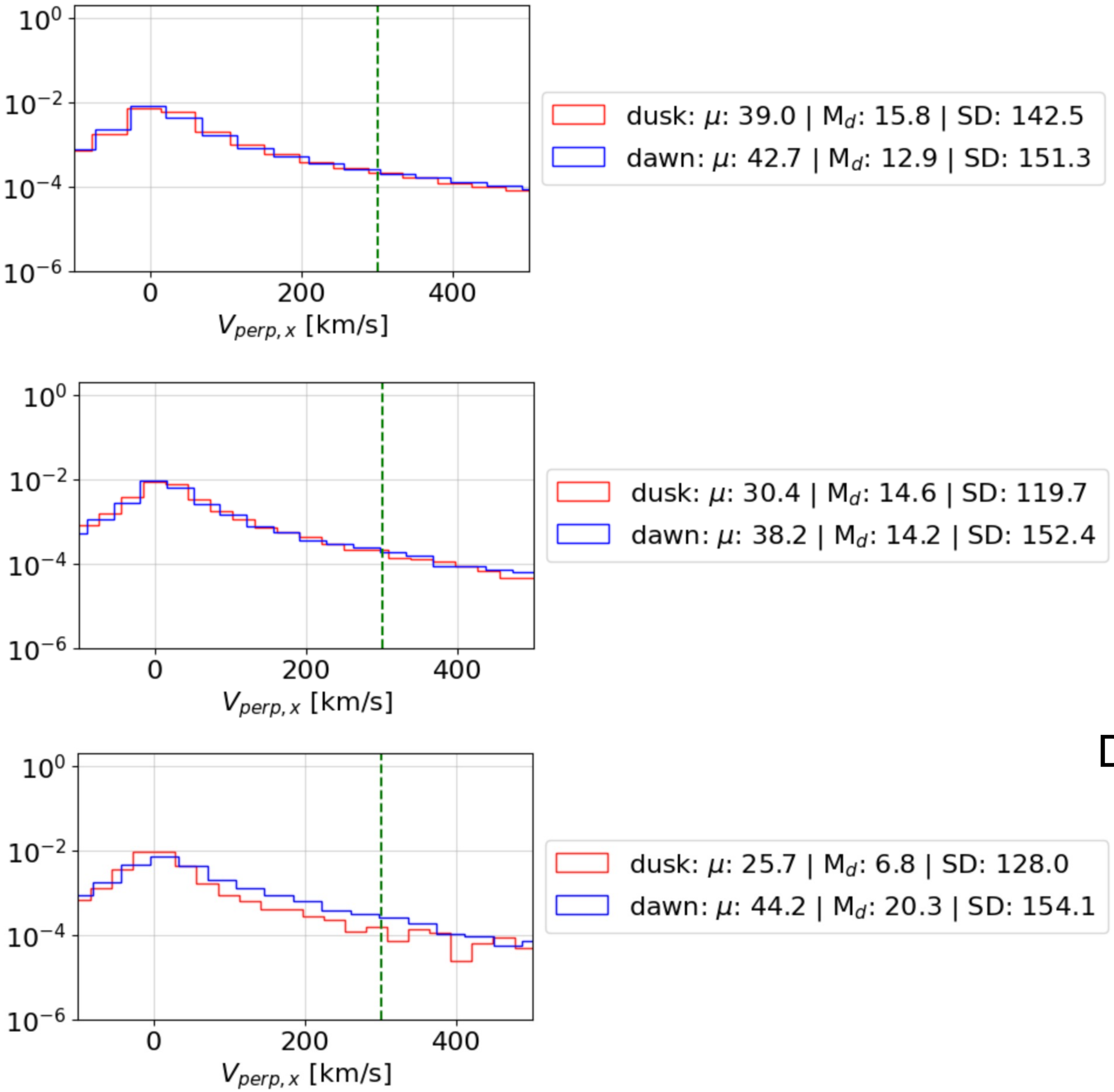


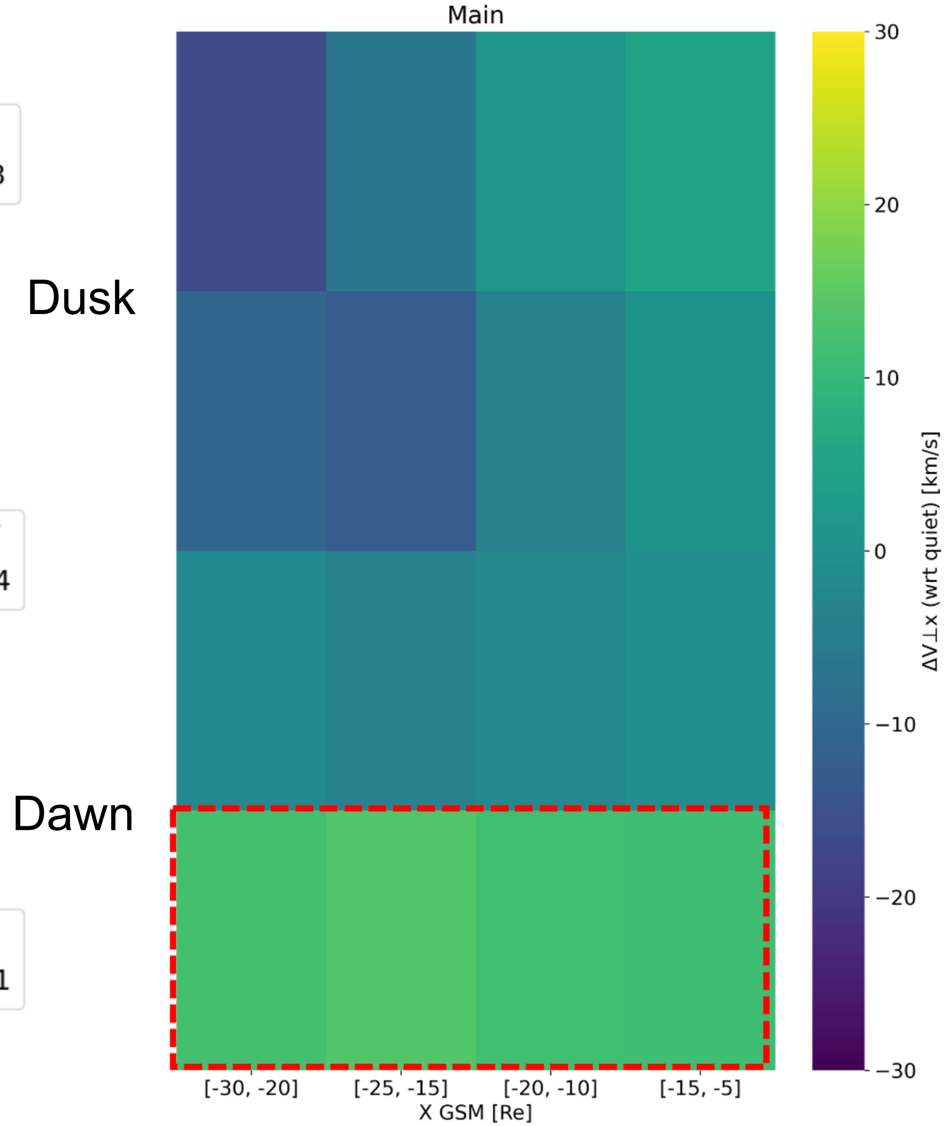
Dusk – Dawn Asymmetry Velocity

Quiet

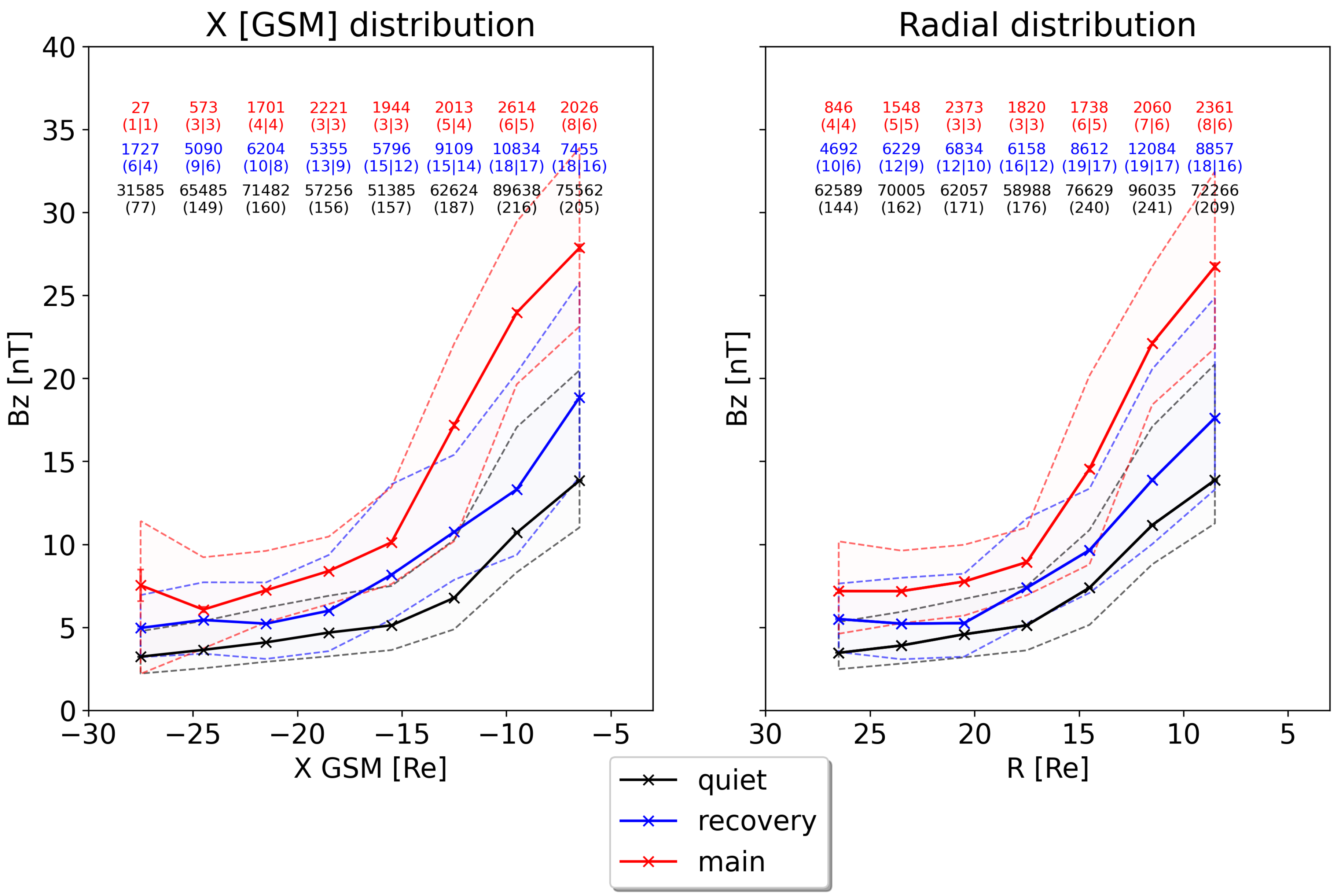
Recovery

Main





Bz – spatial distribution - MMS



V⊥x – spatial distribution - MMS