SD研究集会
15:10–15:25
March 9, 2023

MI coupling under *low Alfvén Mach number solar wind*: Results of magnetospheric observations and expectation of ionospheric observations

SuperDARN Research Meeting
March 9, 2023, NIPR

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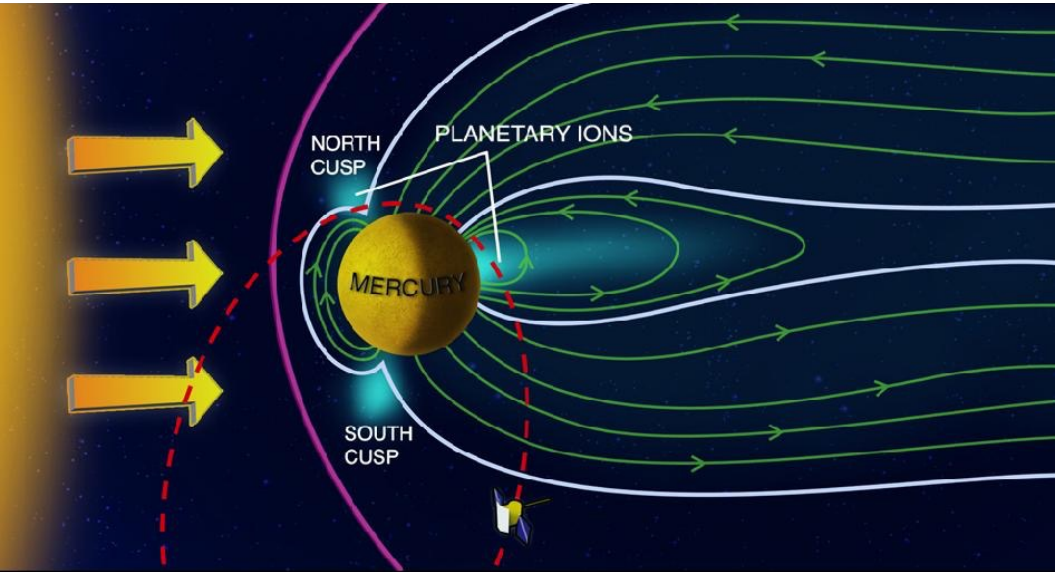
Why Low M_A solar wind?

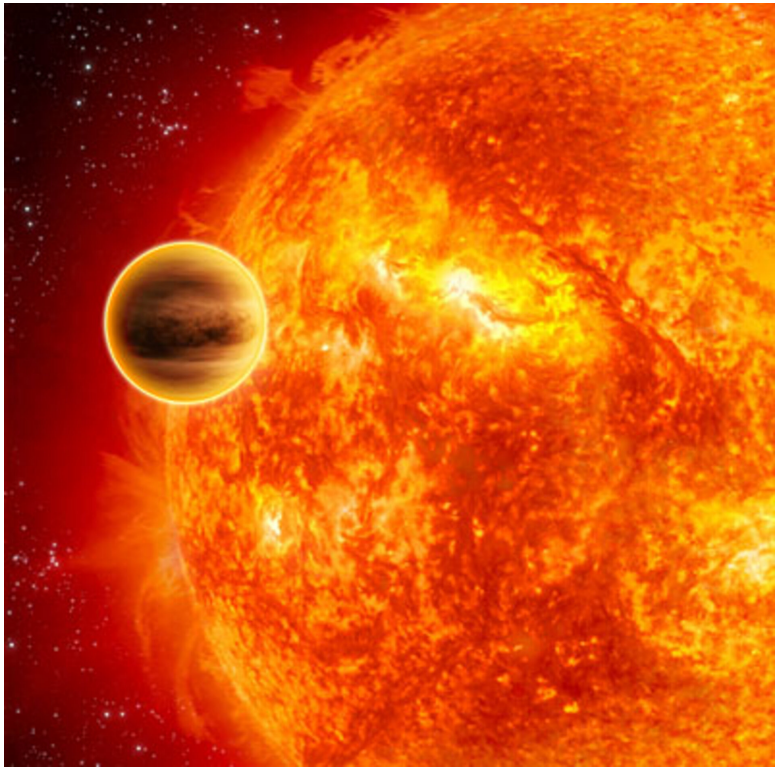
Very rare around Earth, but expected to occur generally in our universe

Lower M_A at inner planetary orbits



NASA

Exoplanets very close to central stars

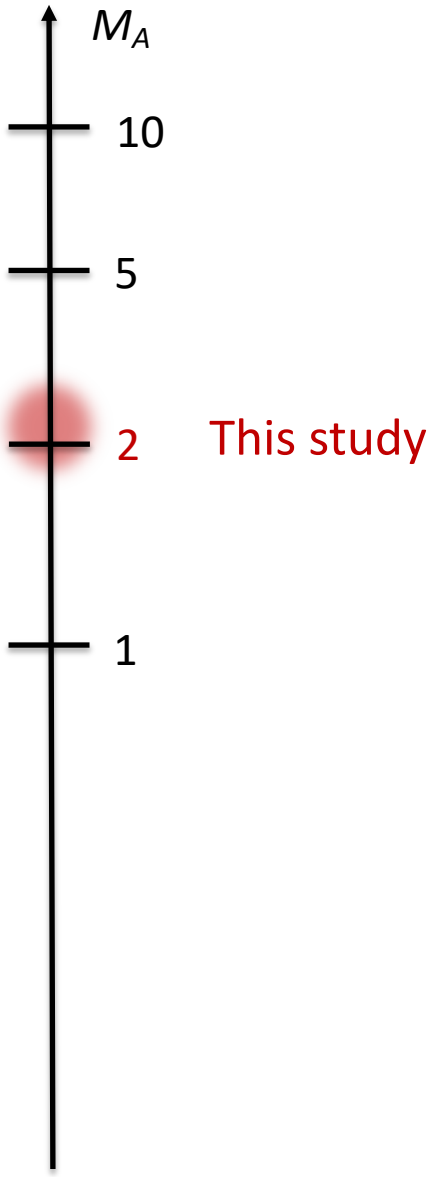


HD 189733b © ESA

$M_A = V_{SW} / V_A$

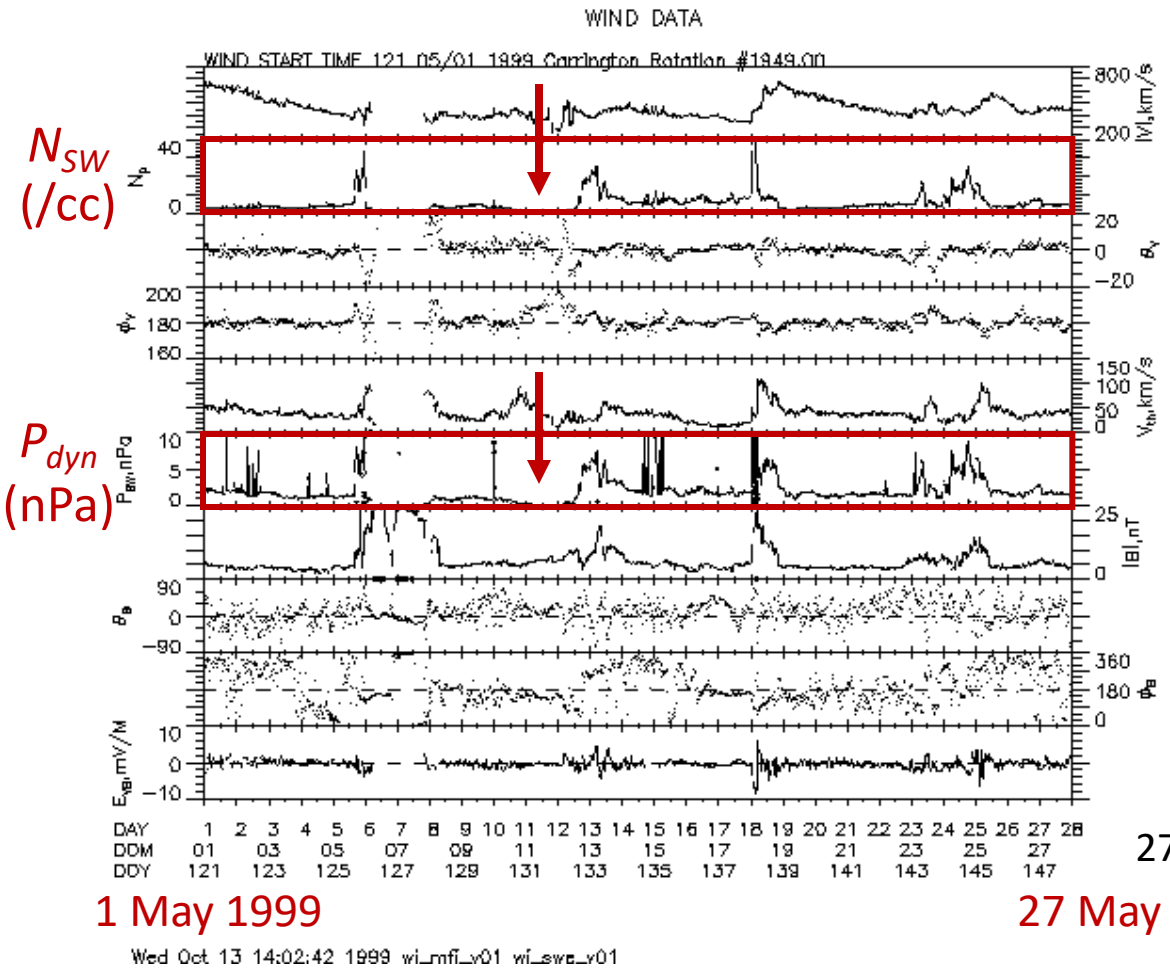
Two different regimes of low M_A solar wind

- M_A >1 Fast mode bow shock
  - Usually, M_A is 5 – 10 at Earth orbit
  - Rarely, M_A becomes as low as ~2
- M_A<1 No bow shock
  - Alfvén wings?
  - Slow mode shocks?



low M_A solar wind

- low-density solar wind
- low dynamic pressure
- low M_A (Alfvén Mach number)



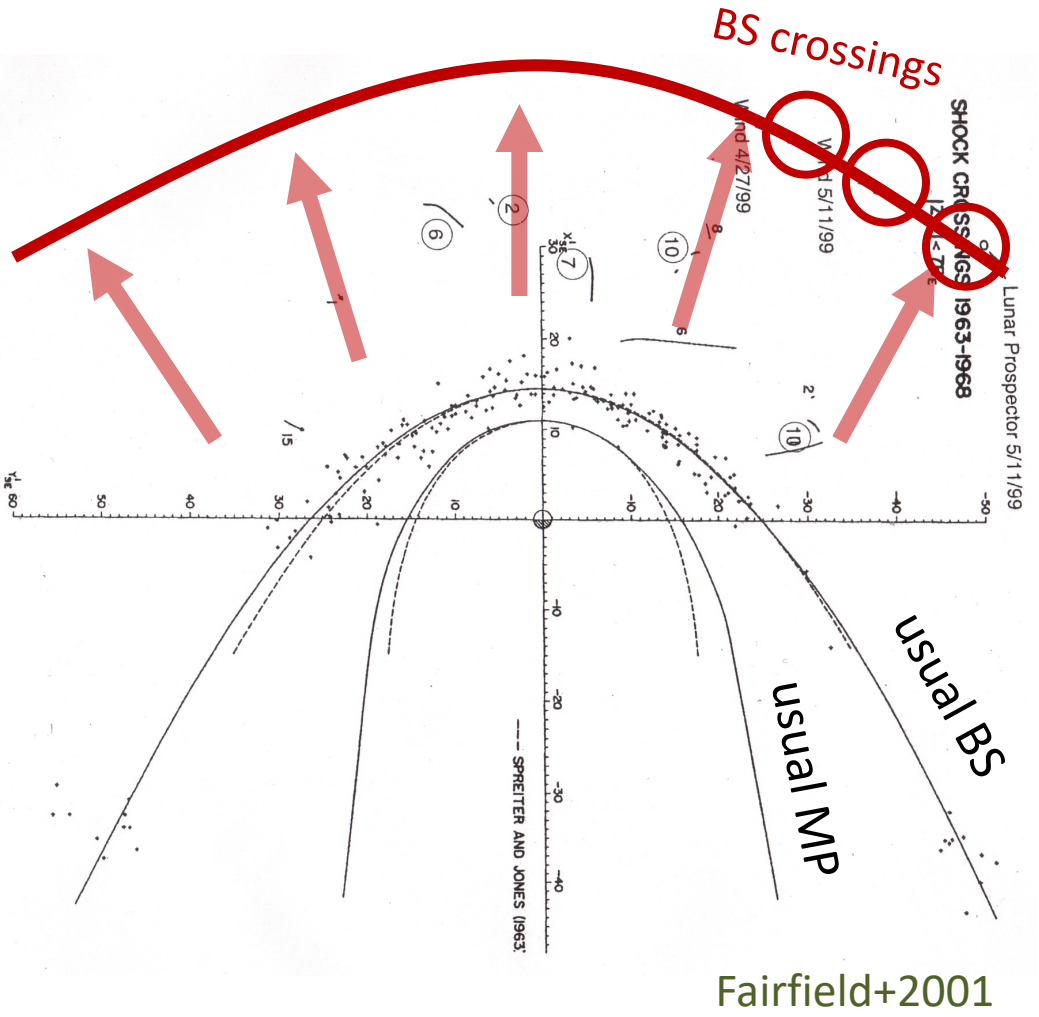
Low density event in May 1999

27-day data

Unusual BS location

Sunward expansion of the BS

- Wind and LP observations
- far upstream of the usual location
  - X~40 R_E (April and May 1999)
- thickening of the M'sheath
  - specific heat
  - M_A



Fairfield+2001

How are the magnetosphere and the ionosphere under low M_A solar wind?

North-South asymmetry (Nishitani+2003)

- Low-density solar wind on May 11, 1999
- IMF: BX<0, BY>0 (Outward Parker spiral)
- Data: Syowa HF radar & DMSP ion driftmeter
- North-South asymmetry of the Ionosphere
  - Very fast westward flows in the Southern (dark) Hemisphere
  - the presence (absence) of solar illumination for the absence (presence) of the strong and localised ionospheric flows

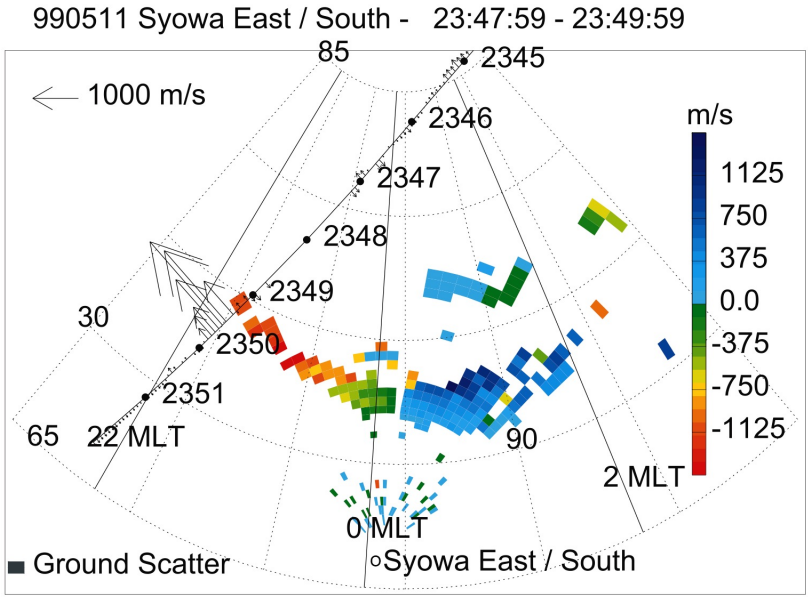


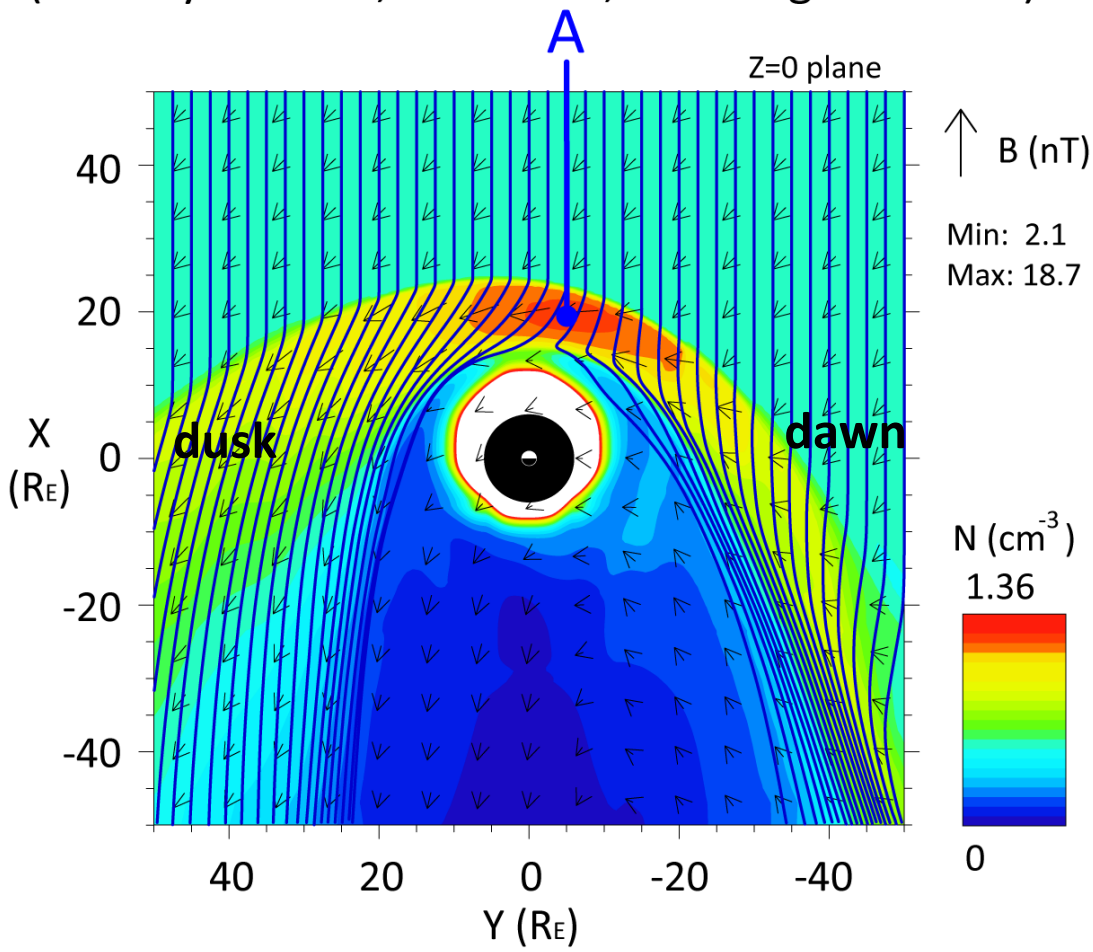
Figure 5. Two-dimensional distribution of the line-of-sight velocities obtained by the Syowa East and Syowa South SuperDARN radars from 2348 to 2350 UT. The plasma drift speed distribution measured by the ion driftmeter on board the DMSP-F12 satellite is overlaid onto the figure.

Dawn-dusk asymmetry

- SW conditions
  - **Parker spiral** B=(-5,5,0) nT
  - Vsw=(-432,0,0) km/s
  - N=0.5 /cc, T=10 eV
  - ***M_A*=2.0**
- Results
  - **Dawn-dusk asymmetry of BS and magnetotail**
  - flow deflection
  - dense magnetosheath around 10-12 LT

Magnetic effects at the BS !
But, no observation in the tail.

Flows around the magnetosphere under M_A=2.0
(Density contour, flow lines, and magnetic field)



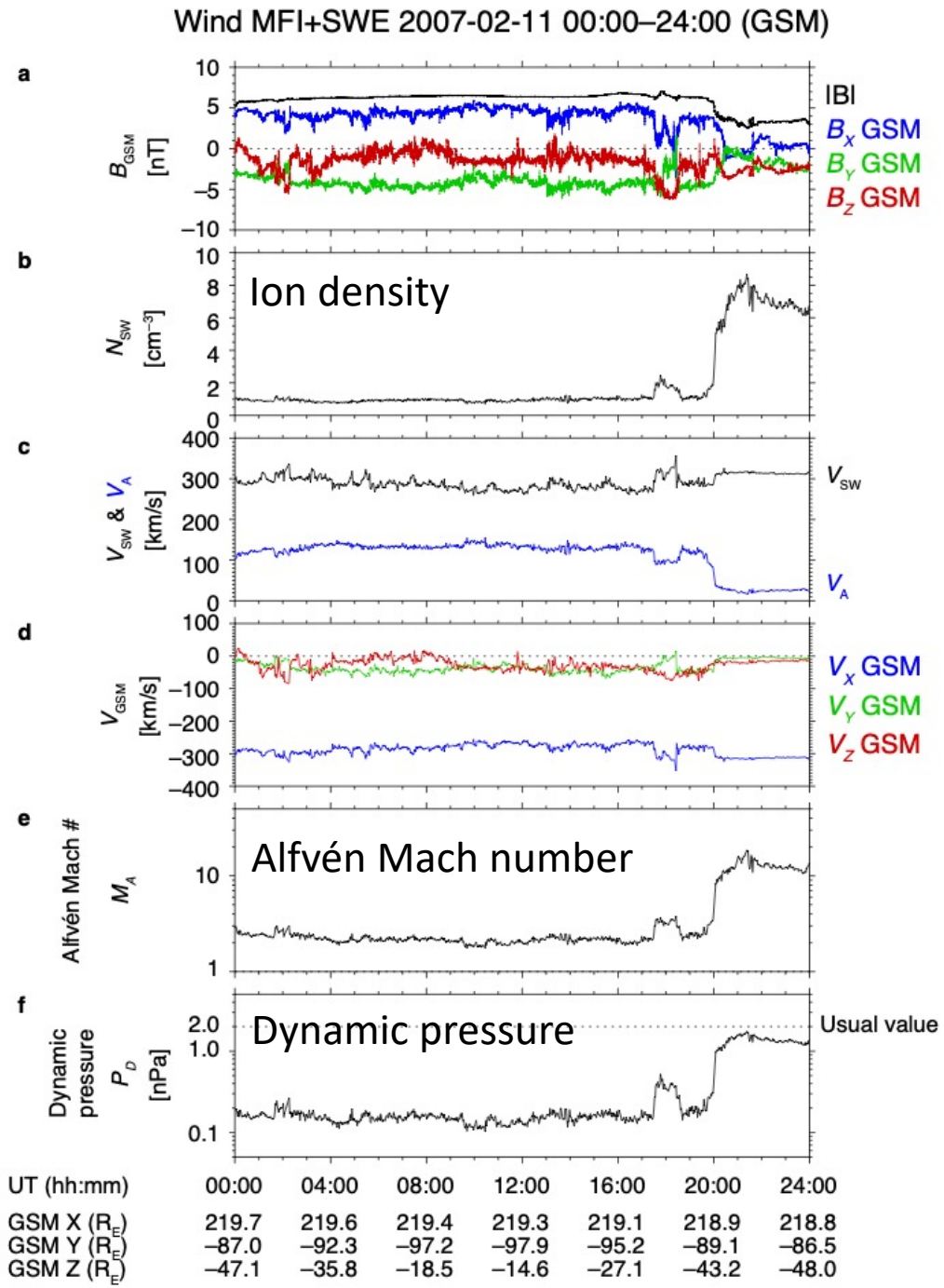
At point A:
N=1.2/cc, Vx=(-120 **60** -8) km/s

Nishino+2008 Phys. Rev. Lett.

Motivation & Objectives

- How are the bow shock, the magnetopause, the magnetosphere and the ionosphere under low M_A and Parker-spiral solar wind?

  - ✓ How is the shape of the magnetosphere?
  - ✓ Enhanced magnetic reconnection at magnetopause?



Solar wind

Parker spiral IMF (sunward Bx)

$Bz < 0$

Wind location (GSE)
(219, –99, 0.7) Re

N_{SW} ~ 1 /cc

Very slow solar wind (~280 km/s)

High Alfvén speed (~140 km/s)

Large V_Y <0

Cf. Janardhan+2005

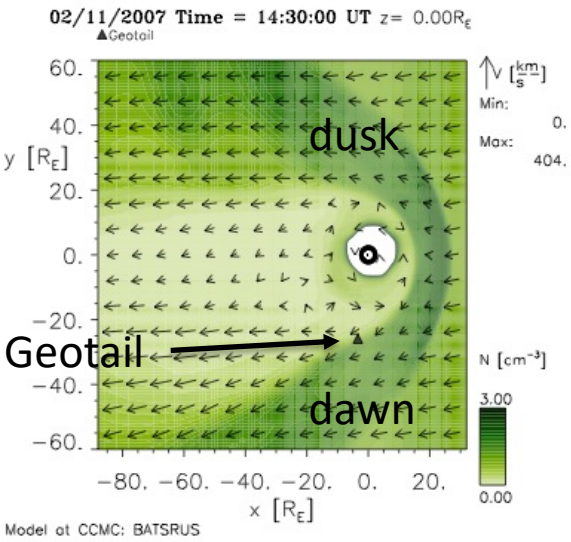
M_A~2

P_{dyn}~0.14 nPa

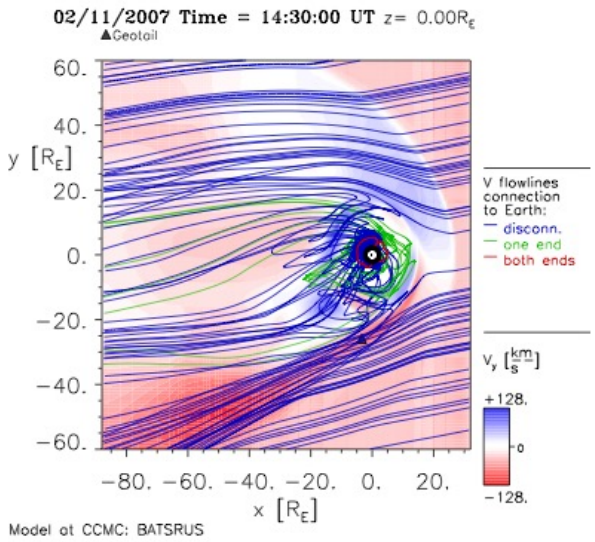
Nishino et al. 2022c EPS

Global MHD simulation (BATS-R-US)

a N contour & V



b V_Y contour & Flowlines

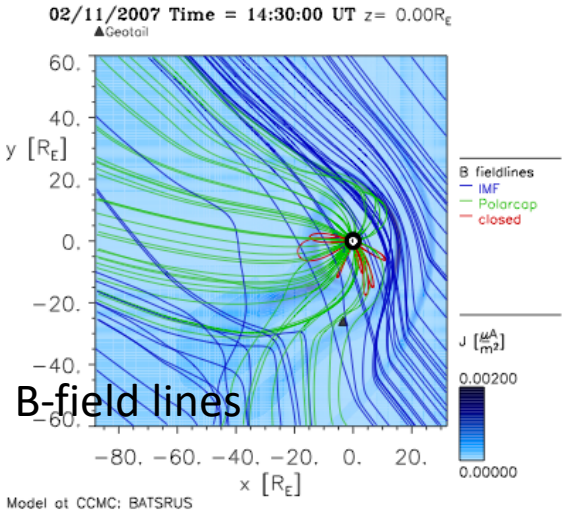


Deformation of magnetosphere

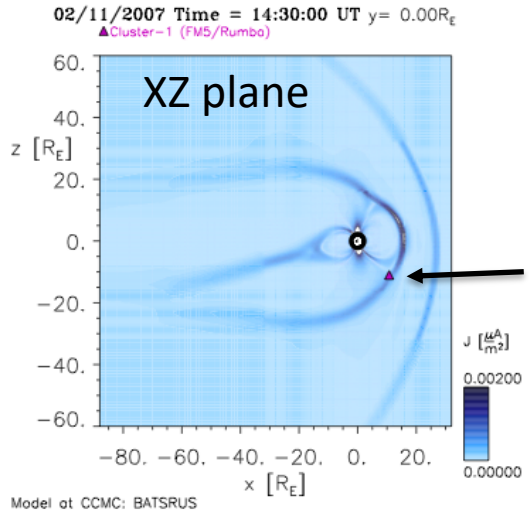
Dawn-dusk asymmetry

Dawnward shift of magnetotail
1. By non-negligible VY in the SW
2. Additional dawnward expansion

a Current density at Z=0

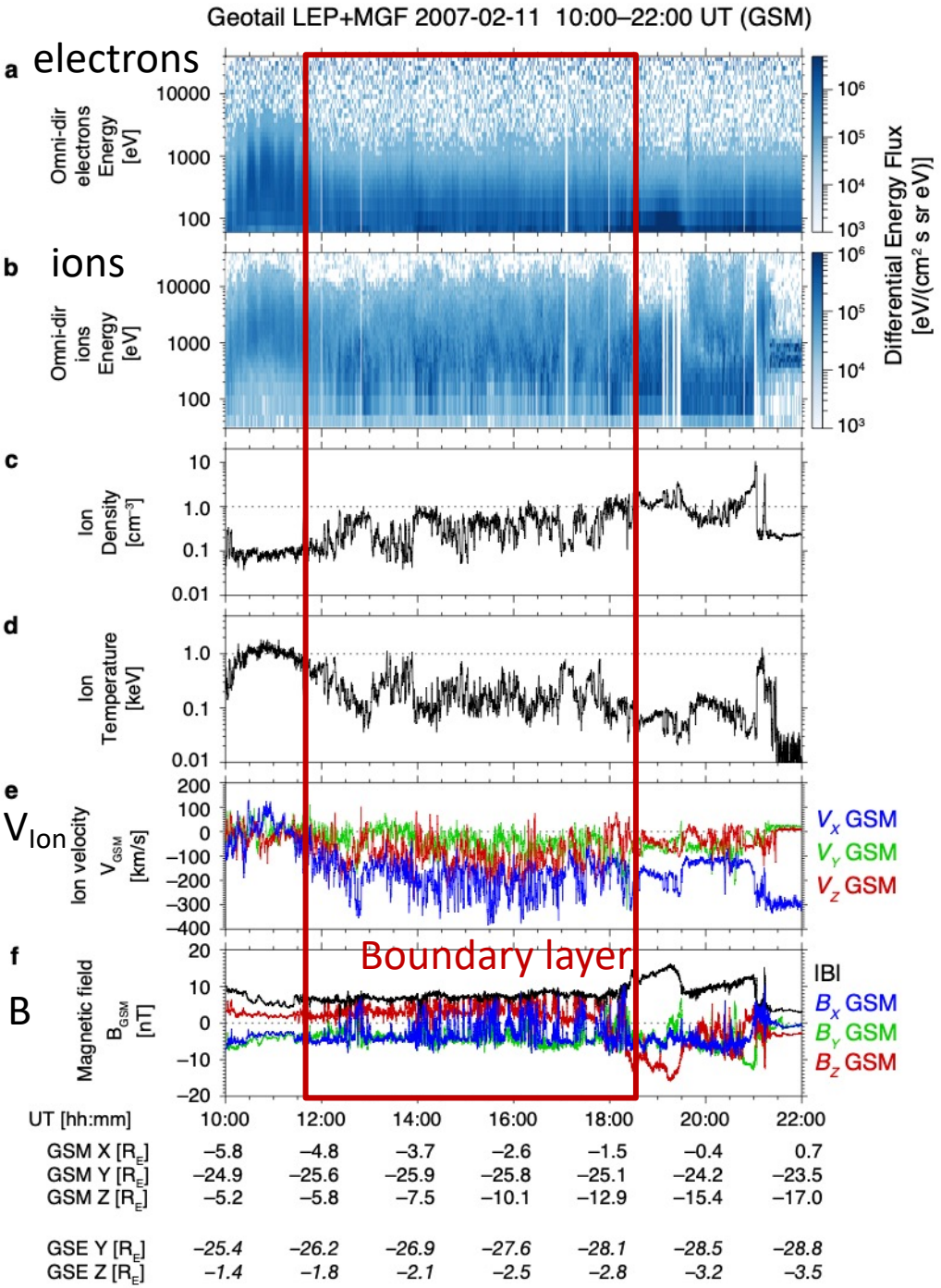


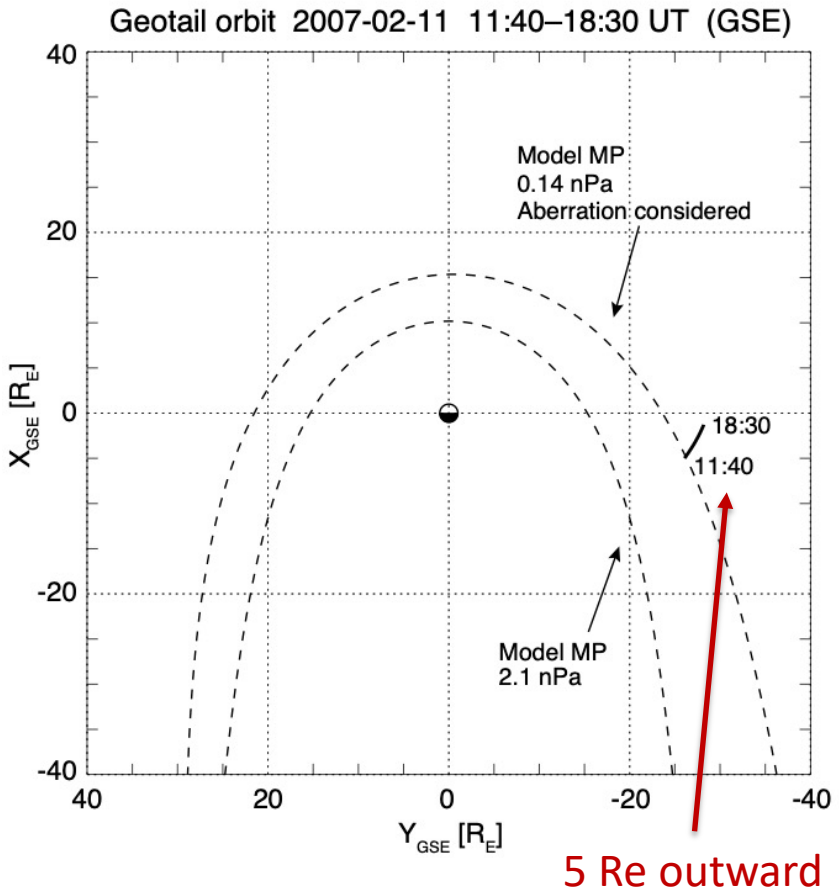
b Current density at Y=0



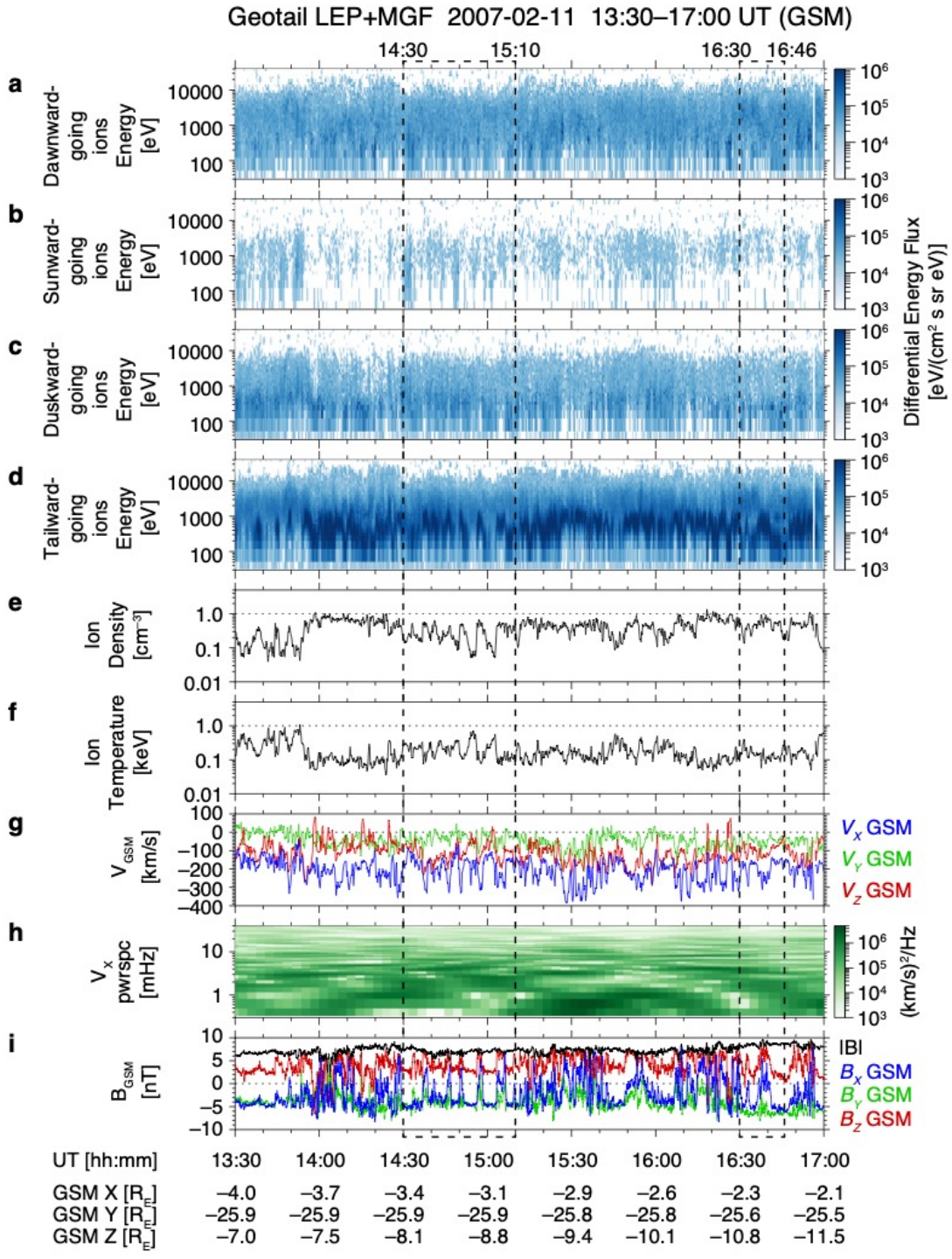
Nishino et al. 2022c EPS

Geotail (dawnside)





- Fast anti-sunward (tailward) flow
- Vx : –100 to –400 km/s
- (No flow reversal)



Semi-periodical flows

Magnetopause encounters
- Higher density
- Lower temperature
- Faster anti-sunward flow

Anti-sunward ion flows
- V_X ~ –300 km/s

Vx fluctuations of several mHz
- (Surface waves?)

B variation in direction
No change of intensity

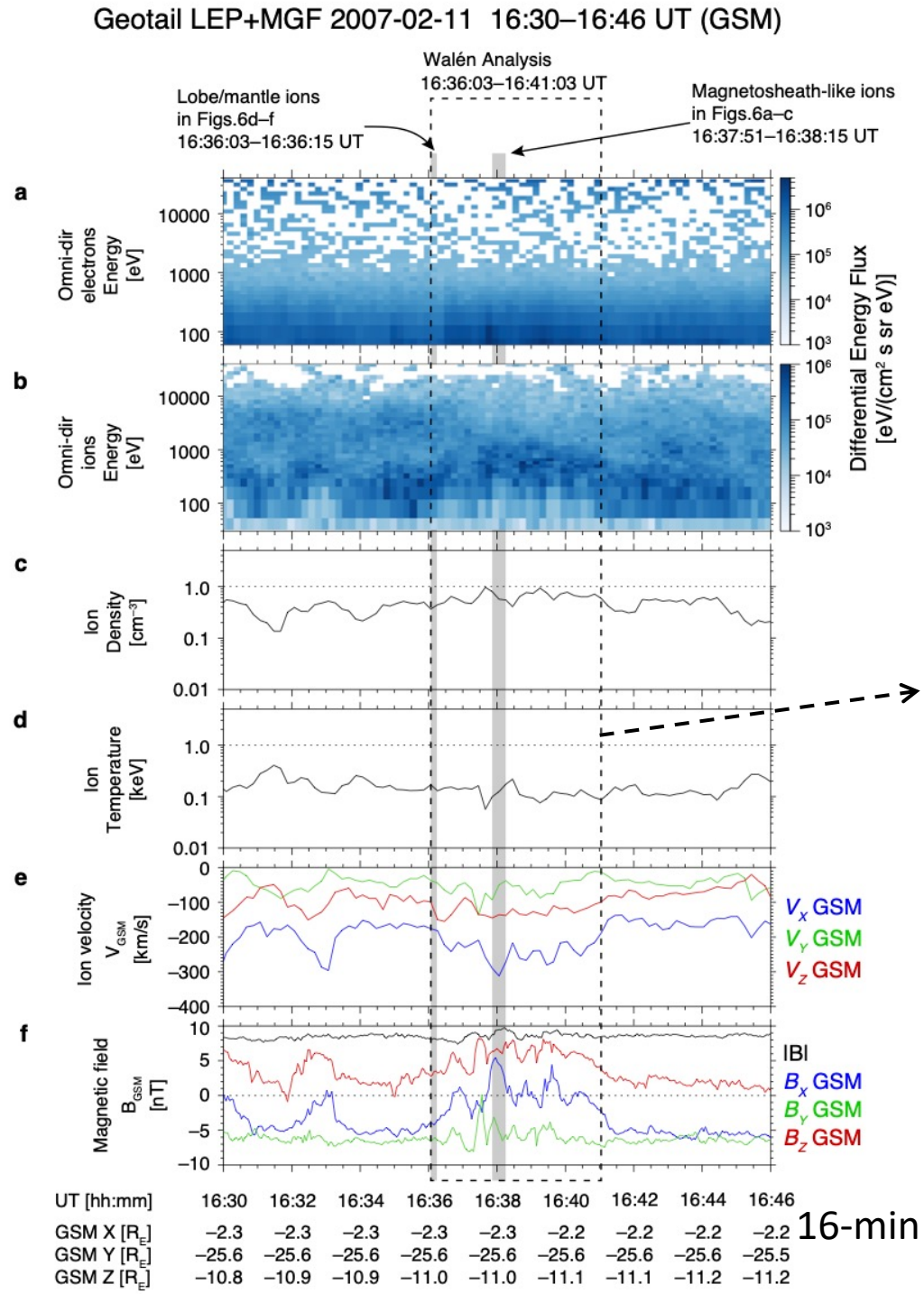
3D ion data after 16:28 UT

Walén analysis

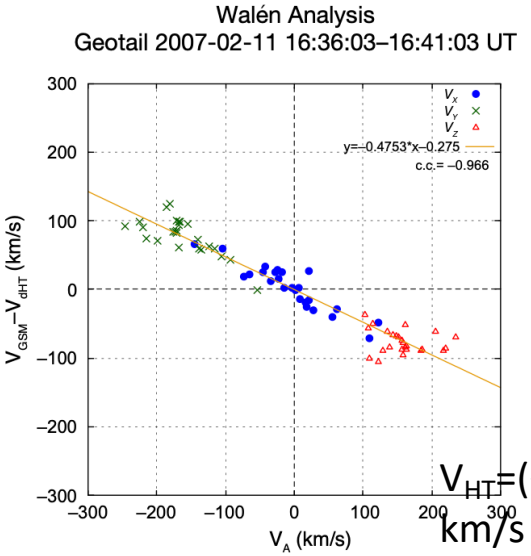
Alfvénic disturbances

→ Rotational discontinuity

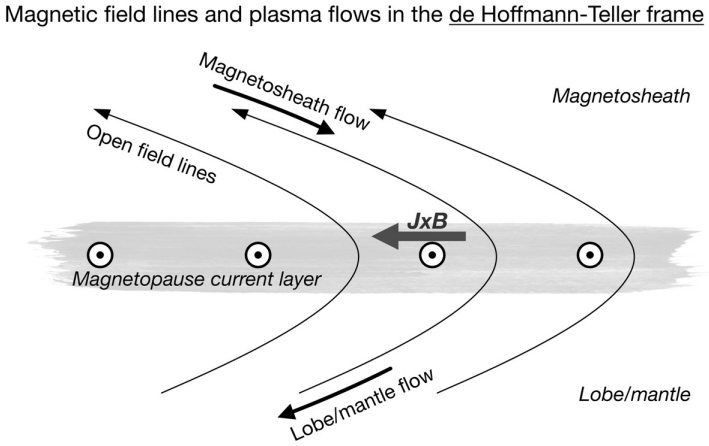
→ **Open field line by dayside reconnection**



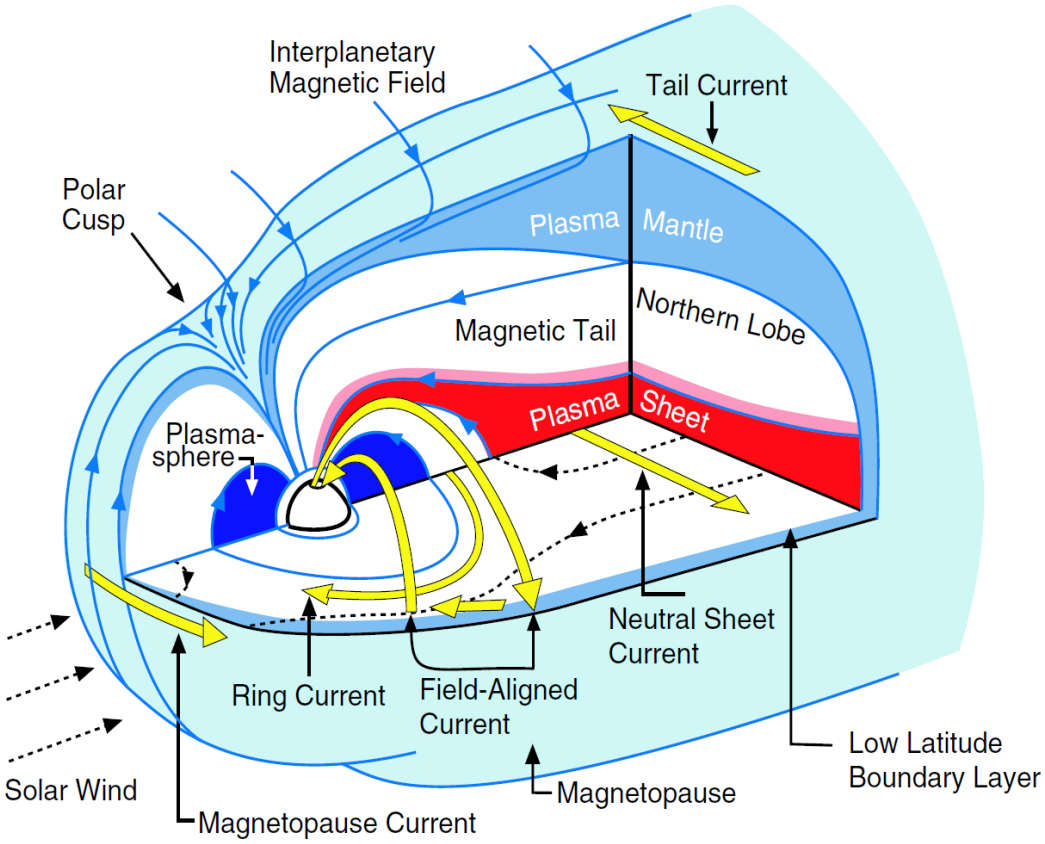
16-min data



V_{HT}=(−242, −136, −49) km/s in GSM

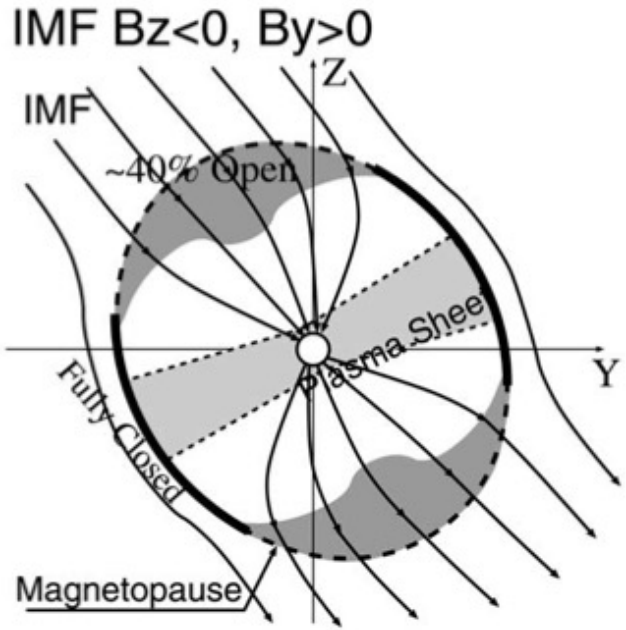


Lobe/mantle



De Keyser et al. 2005

Location of open magnetopause
(view from the Sun)

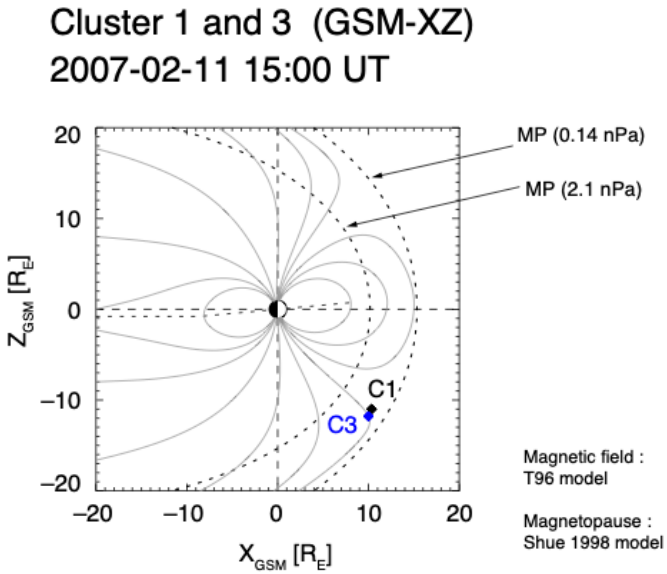


Hasegawa et al. 2002a

Cluster at southern cusp

C1 on magnetosphere side
C3 on magnetosheath side

- Ion jets in boundary layer (14:17-) , 430 km/s
- **Flow reversal → X-line nearby**



Magnetosheath flow at C3 (~160 km/s)
Slower than ion jet at C1

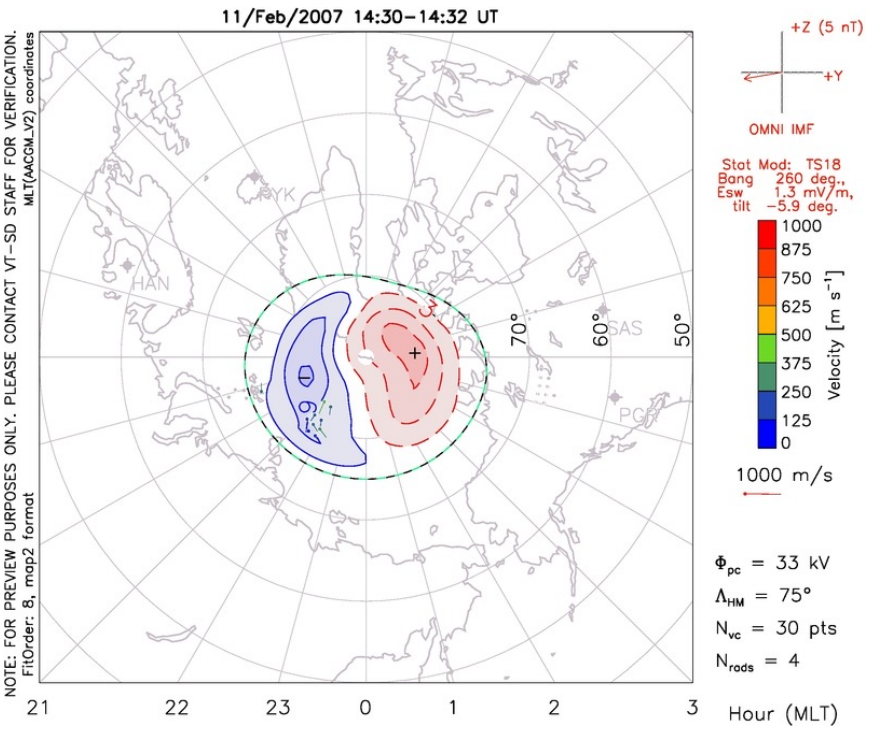
Summary & Discussion

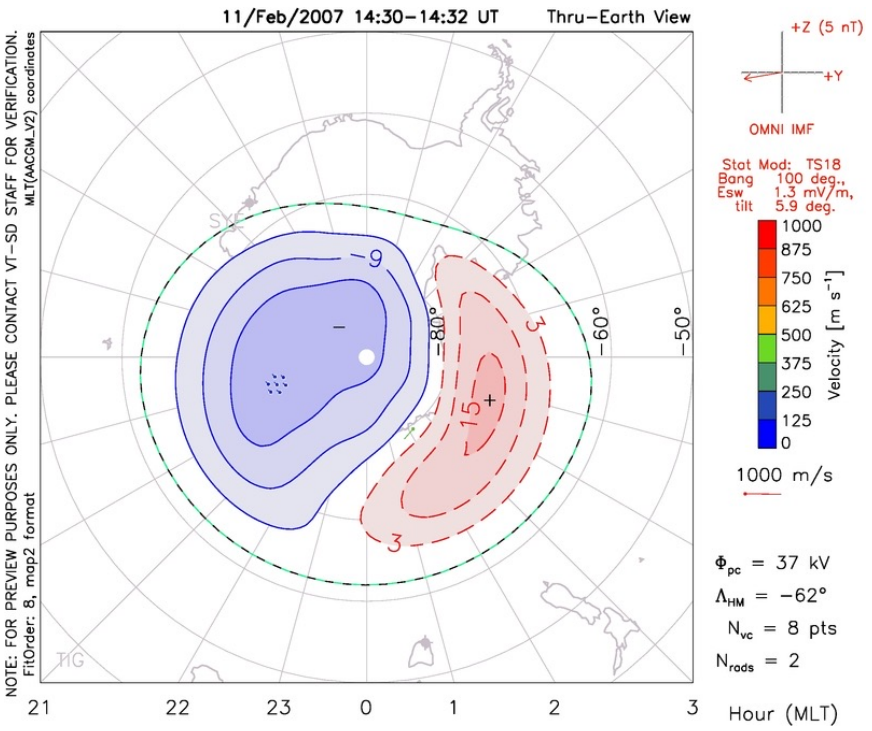
- Asymmetric deformation of the magnetosphere
  - First observational evidence
- Low M_A (~2) & Oblique IMF
- Enhanced magnetic reconnection at dayside MP
- Anti-sunward ion flows at dawn MP
  - Plasma inflow into lobe/mantle through open field lines
  - Semi-periodic encounter (Surface wave?)

Future studies

- Ionospheric response
  - Enhanced Dungey-cycle flows in the ionosphere ?
  - Upward FAC from ionosphere to magnetosheath ? (Lopez+2010)
  - SuperDARN [Other events], SuperMAG, DMSP

SuperDARN



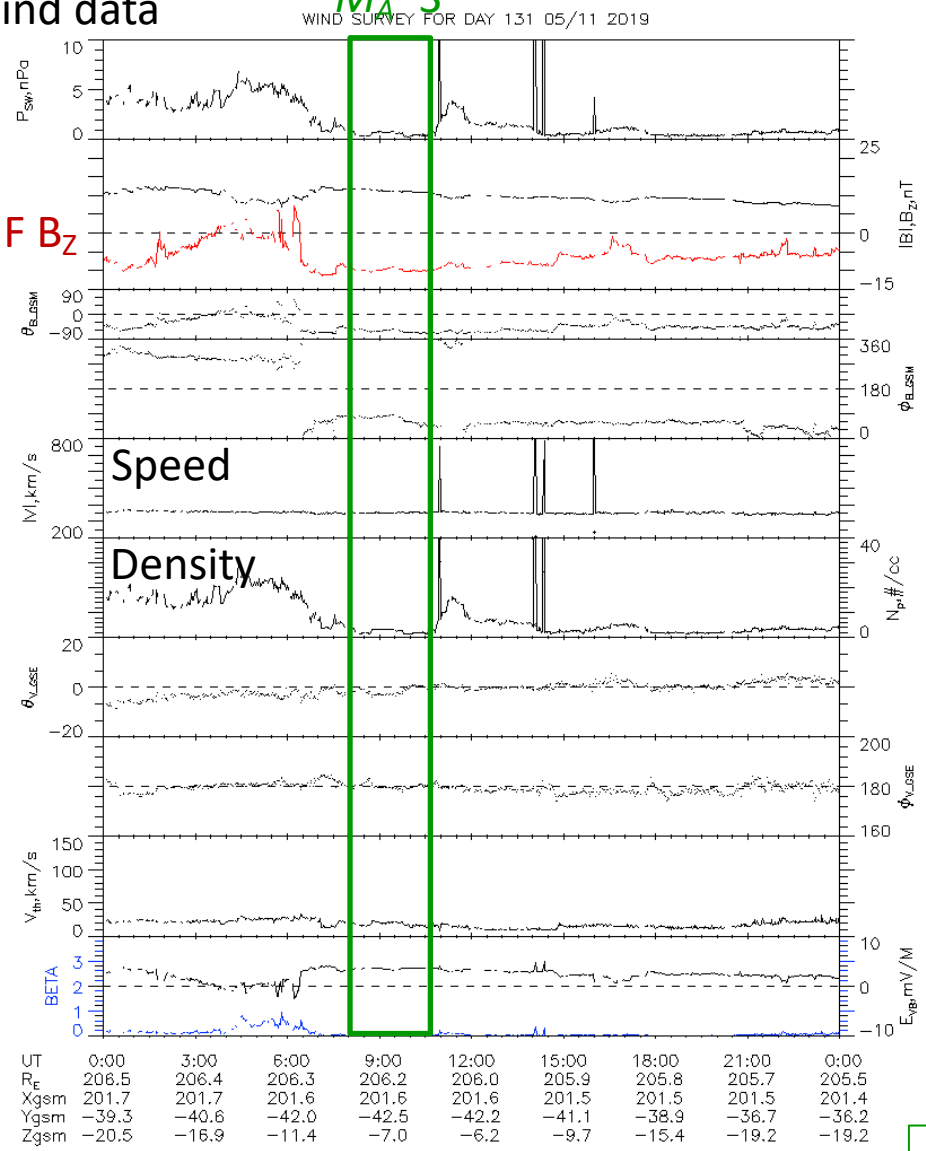


Few data points on Feb. 11, 2007

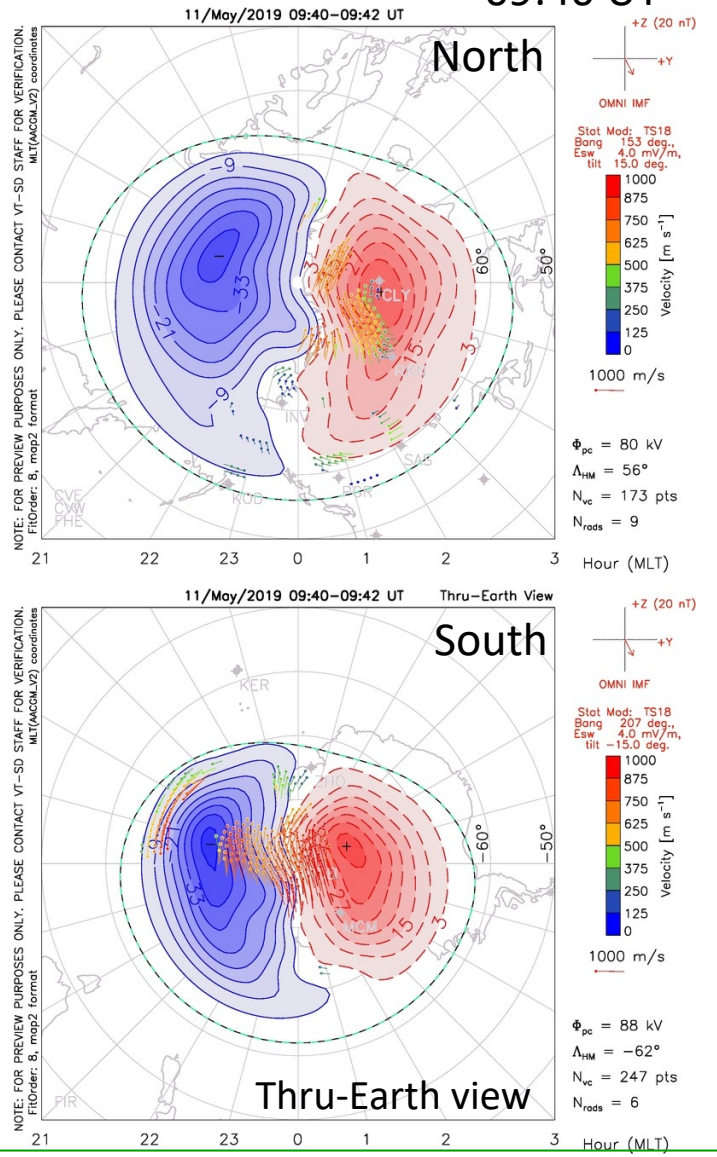
2019/05/11 event

Wind data

M_A~3



09:40 UT



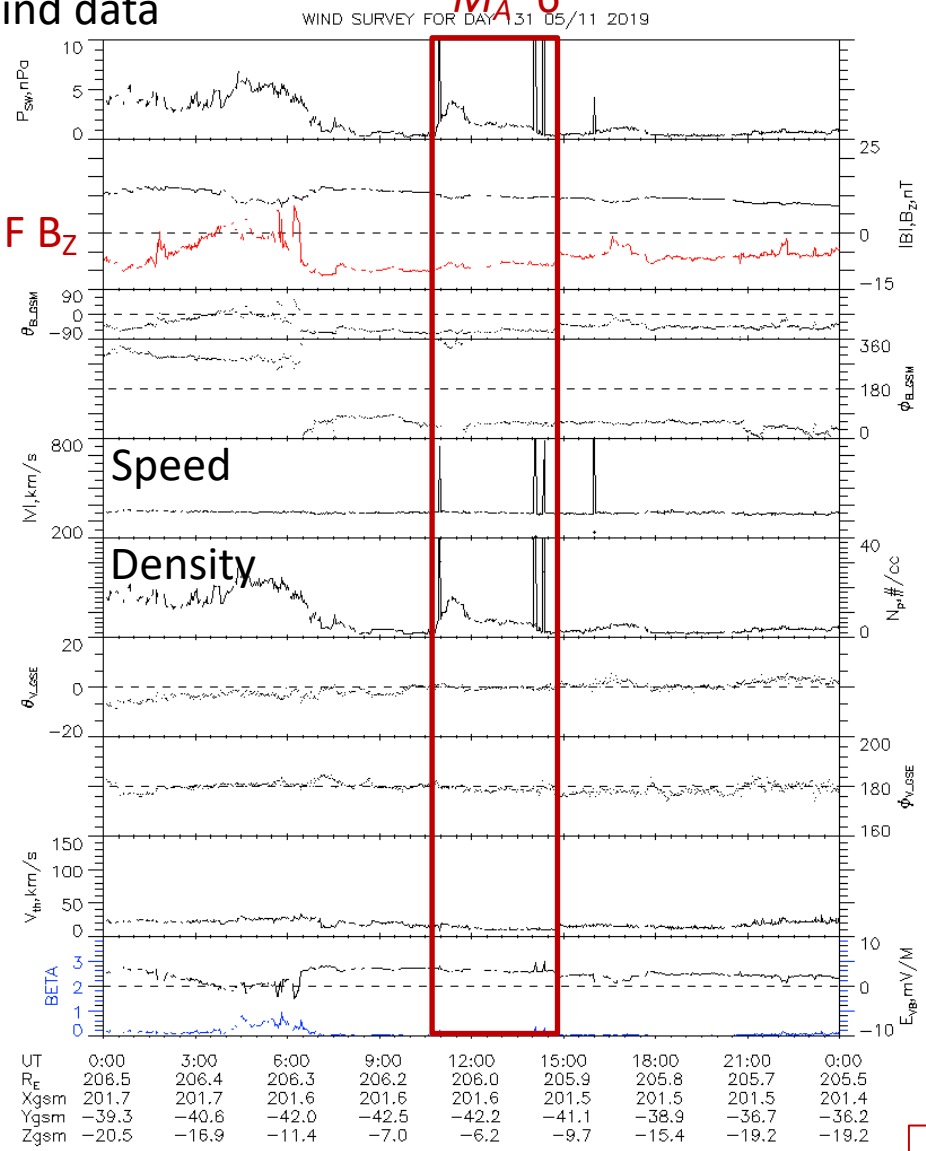
Higher convection speed during low M_A ?

QL plots generated at VT website

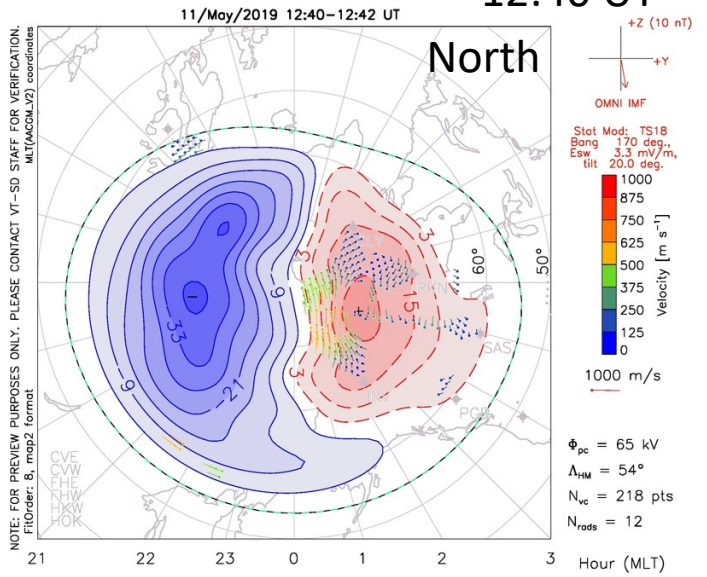
2019/05/11 event

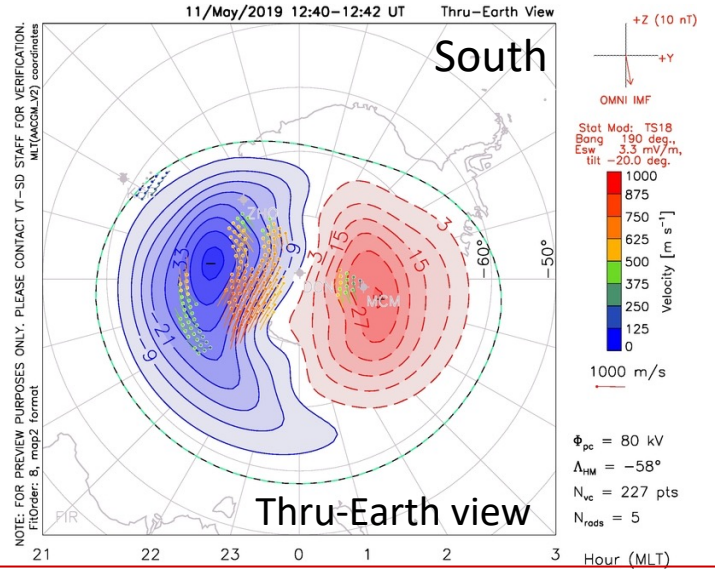
Wind data

M_A~6



12:40 UT



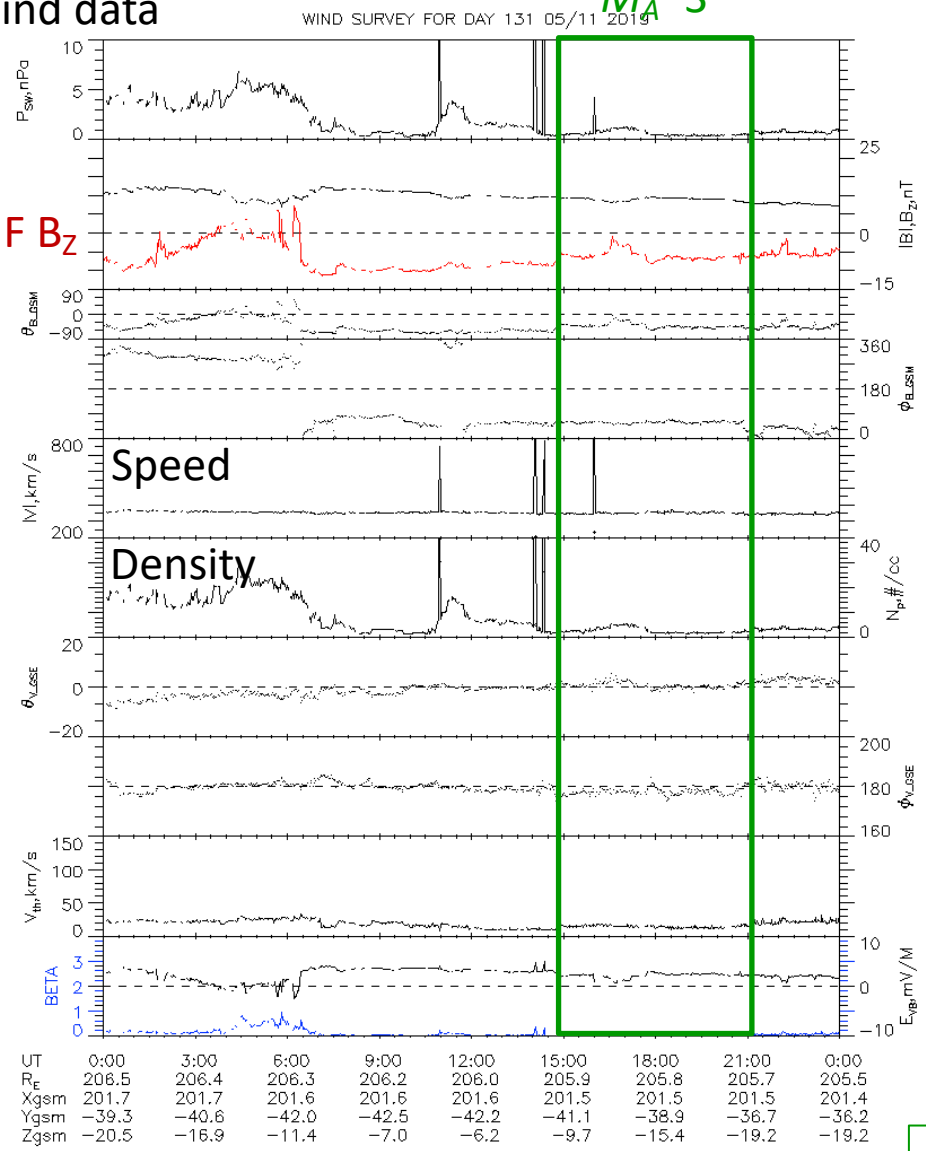


Smaller convection speed during higher M_A ?

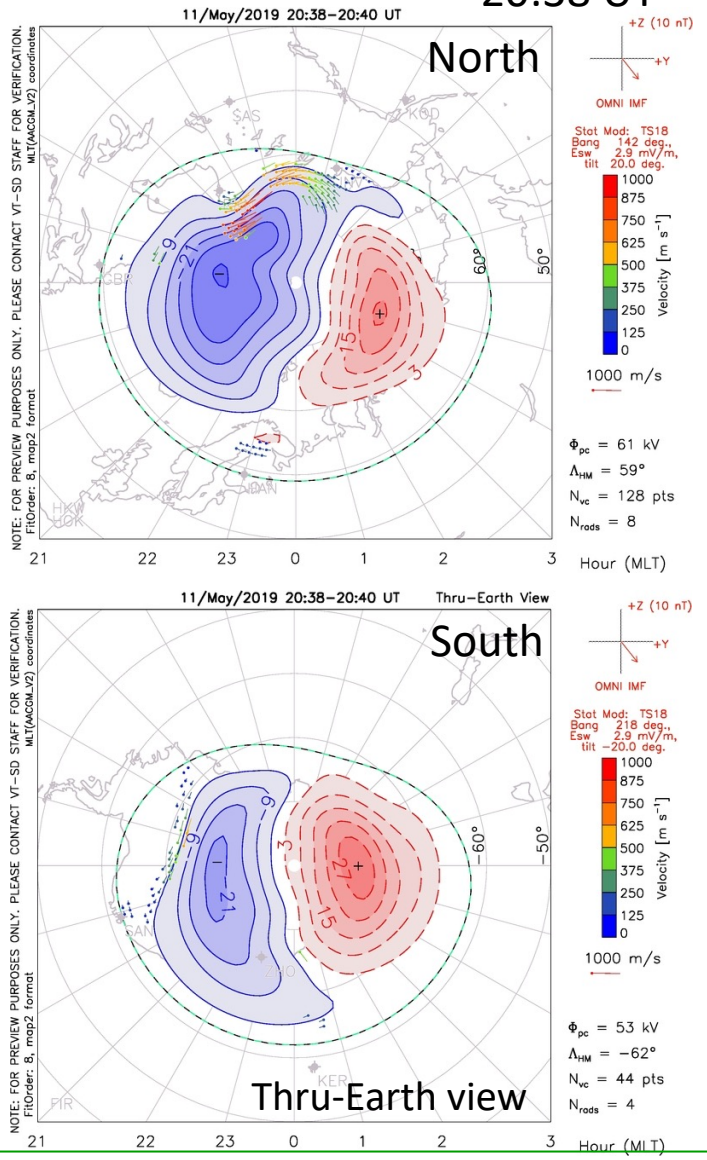
2019/05/11 event

Wind data

M_A~3



20:38 UT



Higher convection speed during low M_A ???

Next step: under low M_A solar wind

- Magnetotail plasma transport
  - Statistical study with Geotail, THEMIS-ARTEMIS, Cluster, MMS
- Inner magnetosphere
  - Development of the ring current?
  - Arase (ERG) data & CIMI model
- Polar regions
  - Weaker magnetic field
  - Enhanced ionospheric convection? --> SuperDARN data