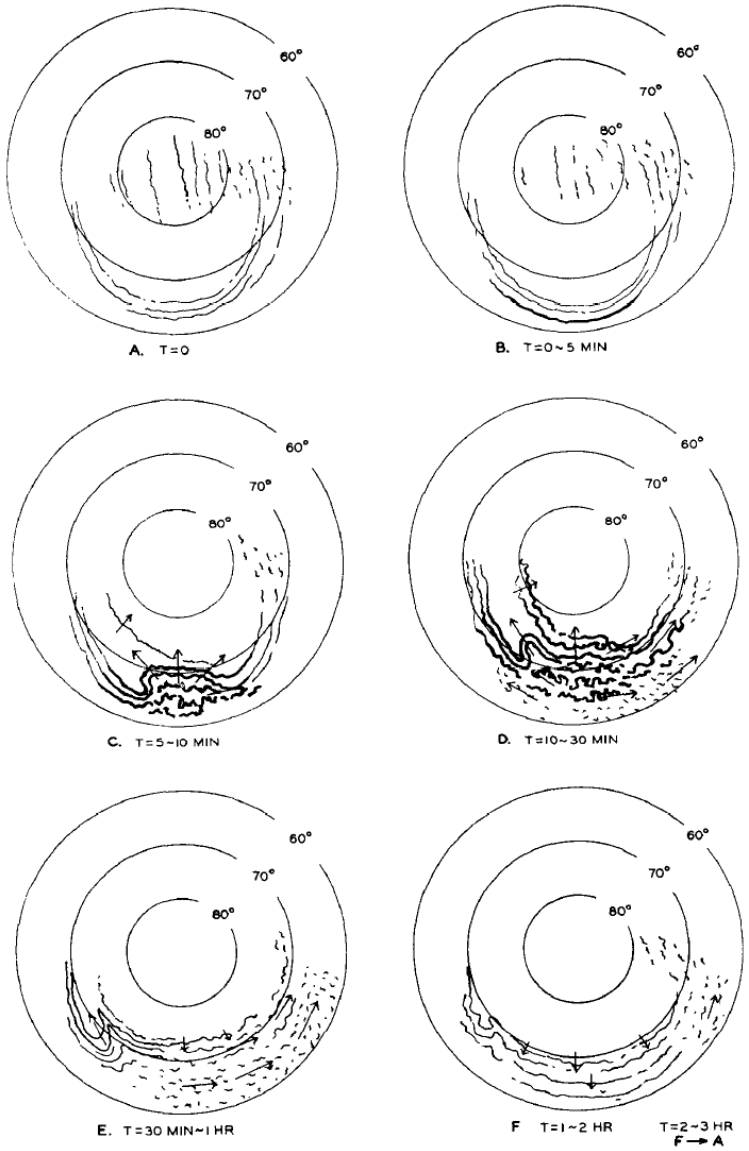
Current system associated with small dipolarization fronts

L. Palin[1], C.Jacquey[2], H. Opgenoorth[1], M.Connors[3], V. Sergeev[4], J.-A. Sauvaud[2], R. Nakamura[5], G.D. Reeves[6], H.J. Singer[7]
, V. Angelopoulos[8], L. Turc[9]

1 Swedish Institute of Space Physics, Uppsala, Sweden.
2 Institut de Recherche en Astrphysique et Plantologie, CNRS/UPS, Toulouse, France.
3 Centre for Science, Athabasca University, Athabasca, Canada.
4 St. Petersburg State University, St Petersbourg, Russia
5 Space Research Institute, Austrian Academy of Sciences, Graz, Austria.
6 Los Alamos National Laboratory, Los Alamos, New Mexico, USA.
7 NOAA Space Weather Prediction Center, Boulder, USA
8 University of California, Los Angeles, USA
9 Scientific Support Office, Directorate of Science and Robotic Exploration, European Space Research and Technology Centre (ESA/ESTEC), Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands

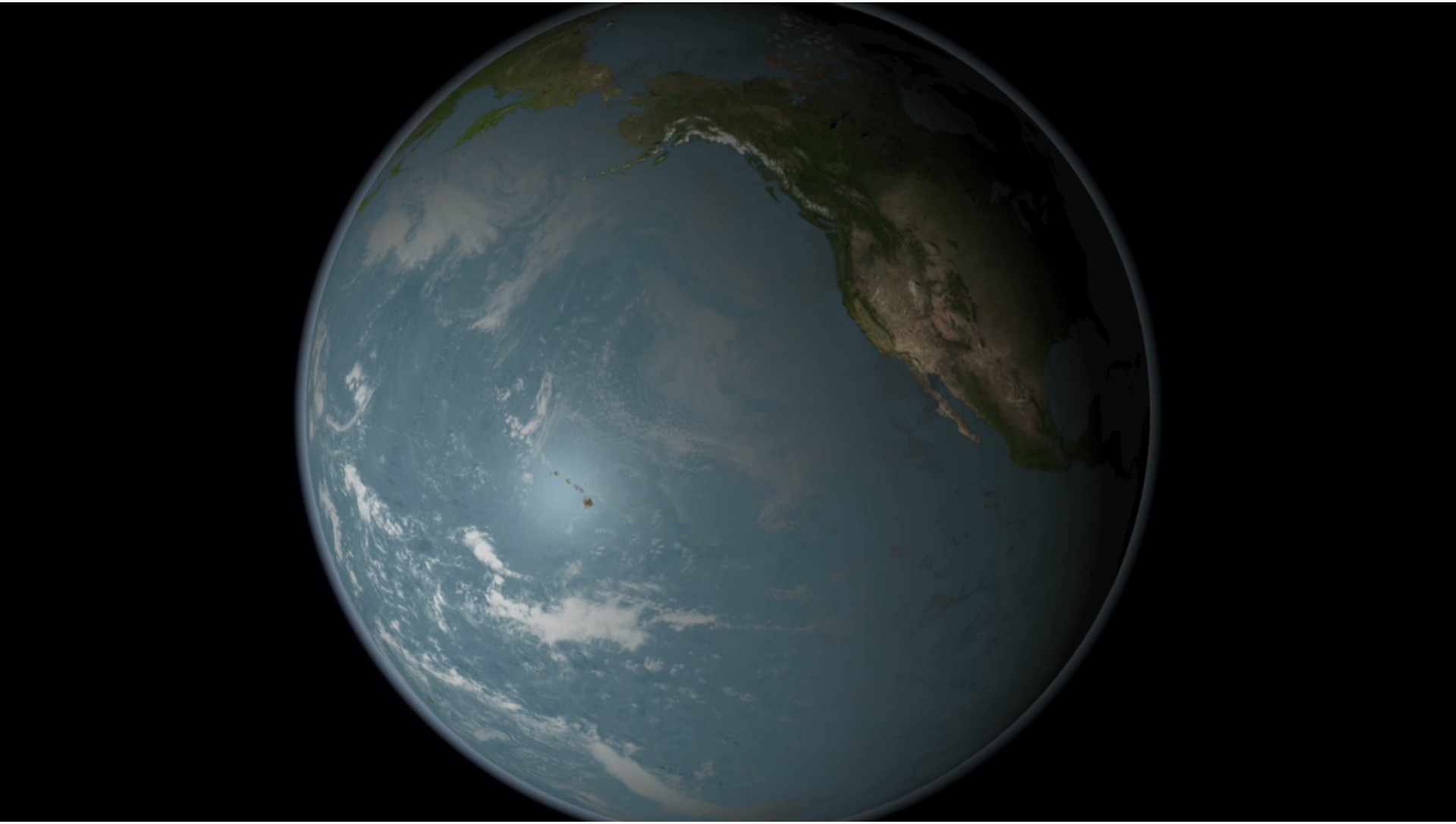
Introduction to substorms

Magnetospheric substorms



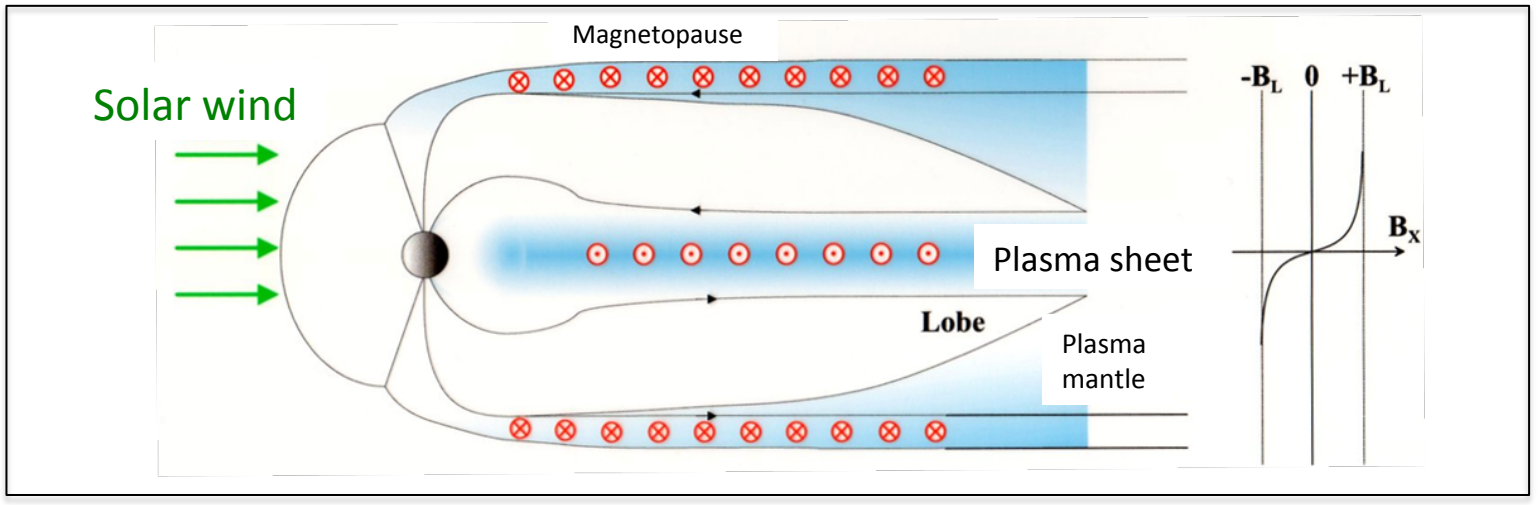
Akasofu, 1964

Magnetospheric substorms



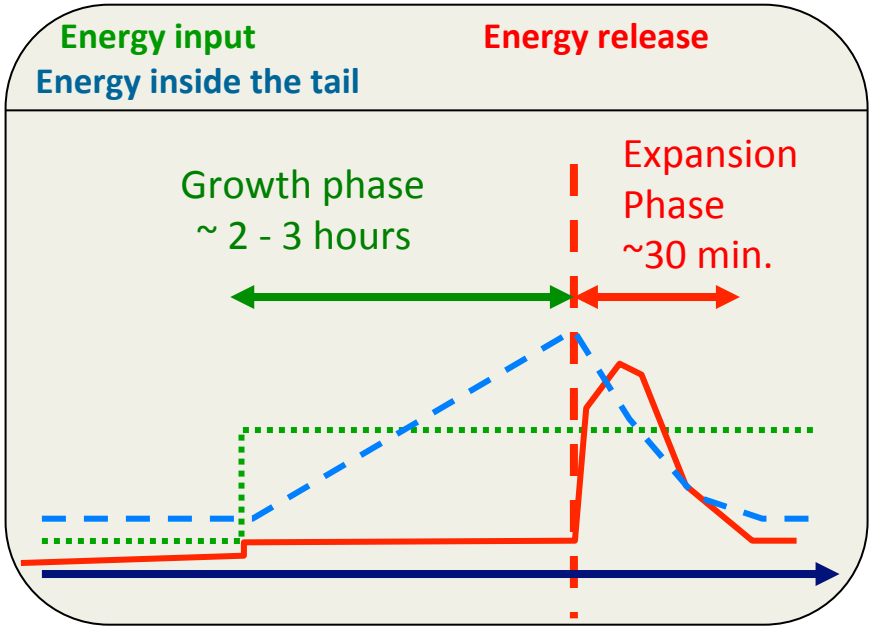
http://cse.ssl.berkeley.edu/artemis/videos/THEMISASI-hires_1280x720.mov

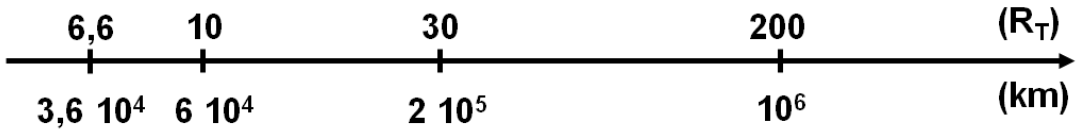
Magnetospheric substorms



<u>Angelopoulos et al, Science, 2008 :</u>

Substorms are global reconfigurations of the magnetosphere involving storage of solar wind energy in Earth's magnetotail and its abrupt conversion to particle heating and kinetic energy.

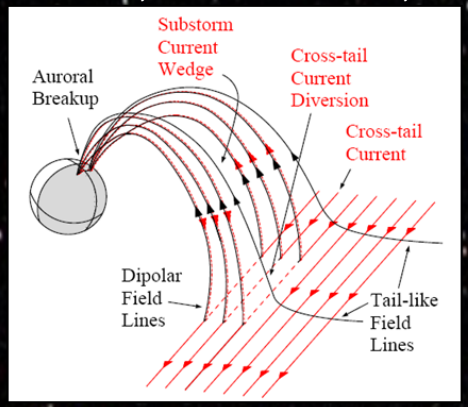




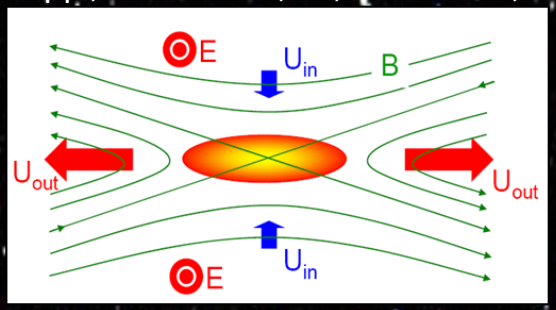
Some substorm signatures :

- Aurora
- Electrojets
- Field alined currents
- Substorm current wedge
- Current reduction
- Dipolarization
- Particle injection
- Magnetic reconnection
- Plasmoïds

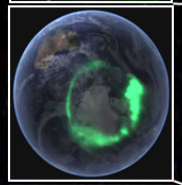
Akasofu, 72 - McPherron, 73

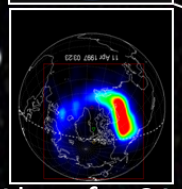


Coppi, 66 - Hones, 73, 80 – Baker, 96

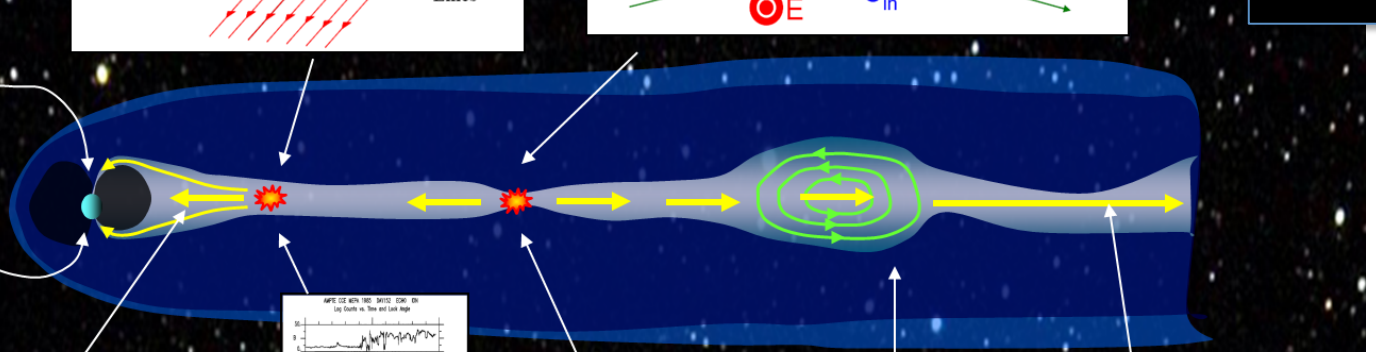


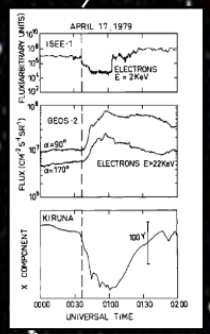
VIS, UV, X



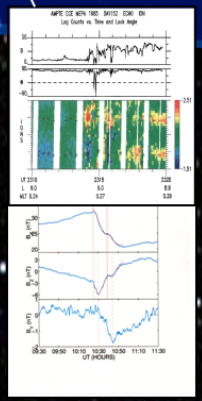


Akasofu, 64

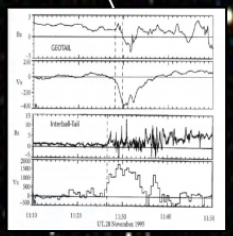


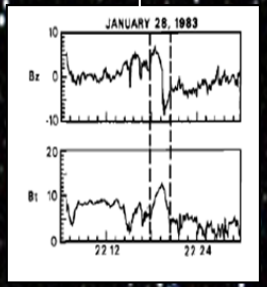


McPherron, 70

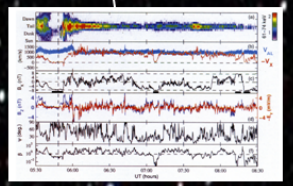


Sauvaud and Winckler, 80





Hones, 77

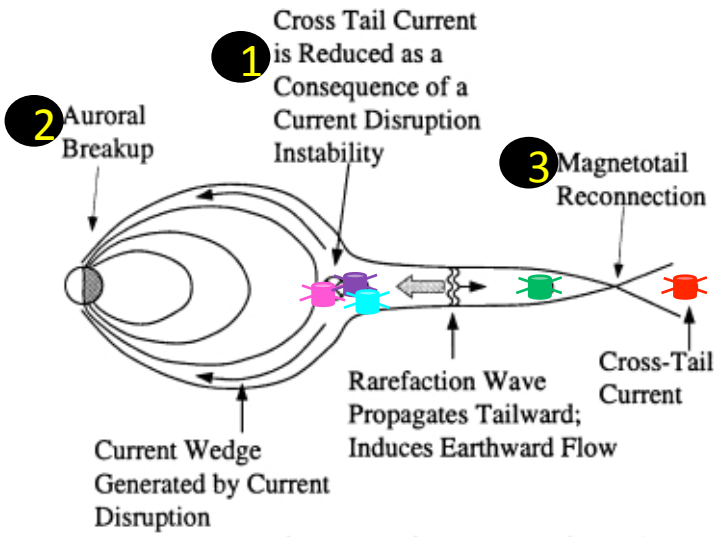


Jacquey, 94
Rouquette 2000

Substorms models

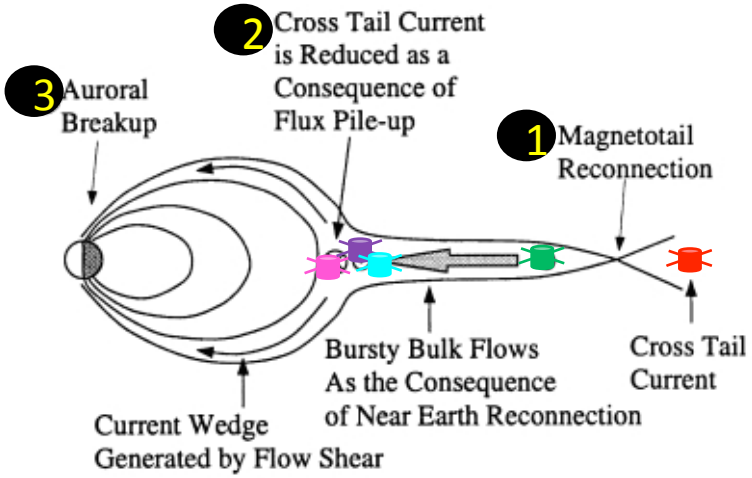
Lui, 1996

Current Disruption (CD)

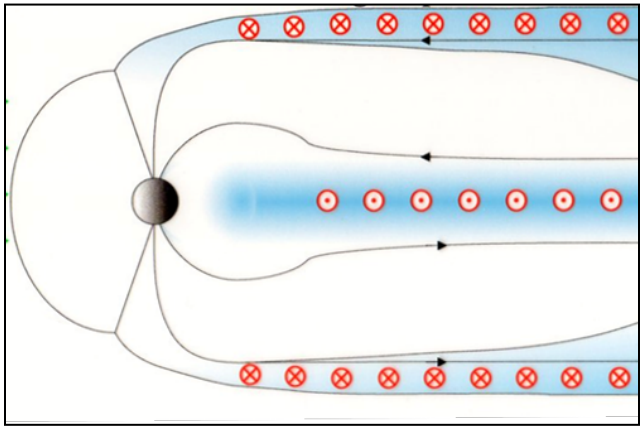


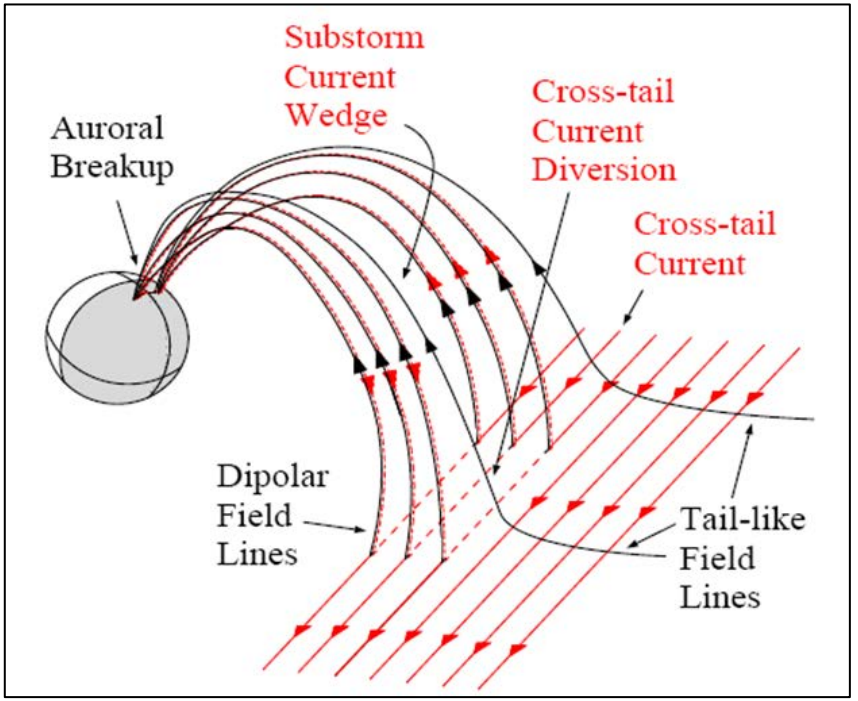
Baker et al, 1996

Near Earth Neutral Line (NENL)



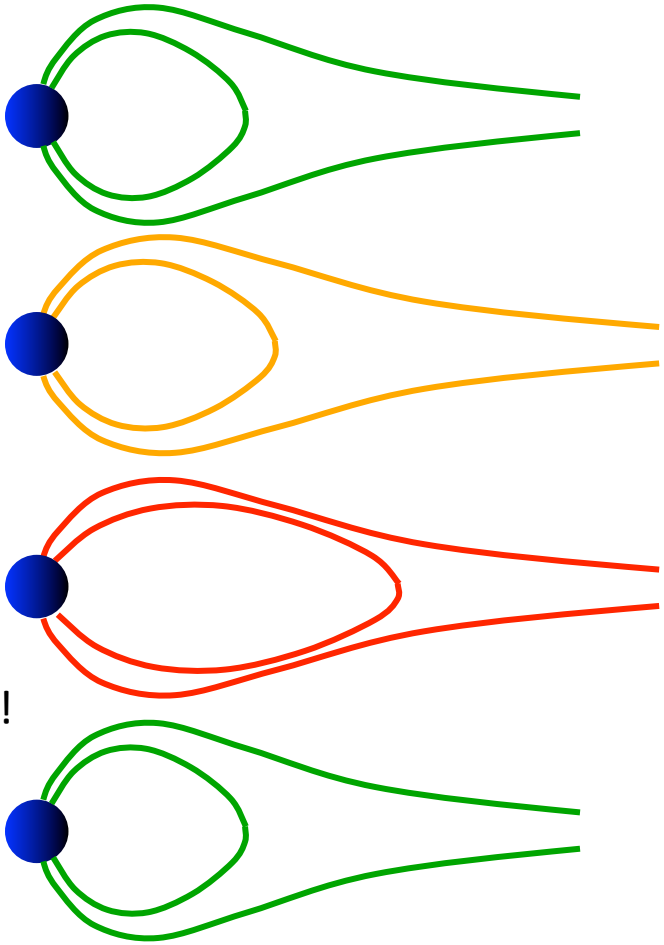
Key signature in substorms : **Substorm Current Wedge**





Magnetosphere-Ionosphere coupling

Key signature in substorms : **dipolarization**



Bz increases !

- Global reconfiguration of the magnetic field in the tail
- also observable at geosynchronous orbit

Dipolarization VS Dipolarization fronts

(Lui et al, 2013)

	Dipolarization	Dipolarization Fronts
Bz increase ?	Rapid and large (many minutes)	Transient (1-2min)
Magnetic fluctations ?	Large	-
Propagation ?	Tailward	Earthward
What are they ?	Temporal manifestations of local dynamic process (global reconfiguration of the magnetosphere)	Plasma discontinuities (ahead of plasma flow)
Origin ?	Current disruption	Magnetic reconnection
When ?	Just prior to substorm onset	After substorm onset (always)

Dipolarization fronts & plasma flow

In the central plasma sheet

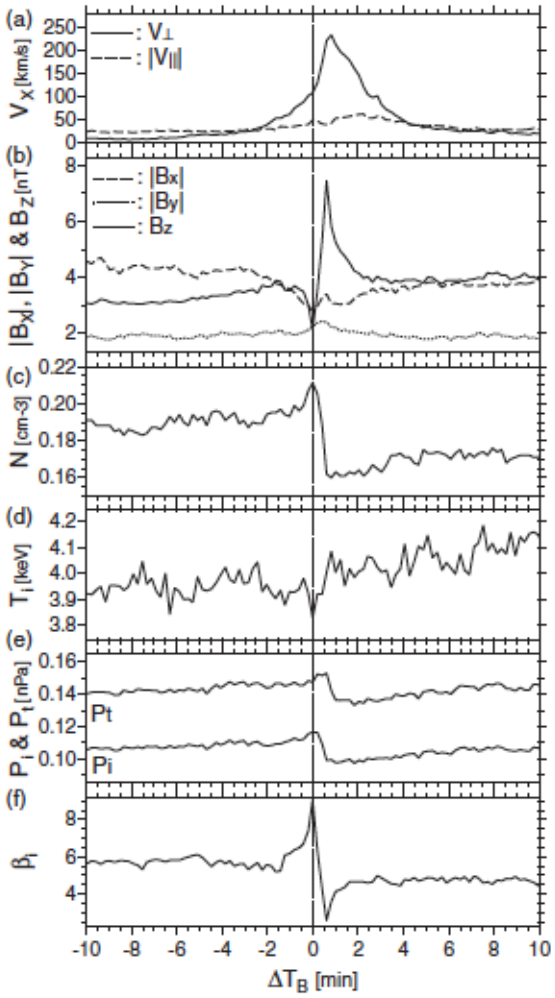


Fig. 2. The magnetic field and ion plasma parameters superposed for 818 fast Earthward flow events observed in the CPS by Geotail spacecraft with the start of a B_z increase used as the zero time (from Ohtani et al., 2004).

(Ohtani et al, 2004)

Bursty Bulk Flows

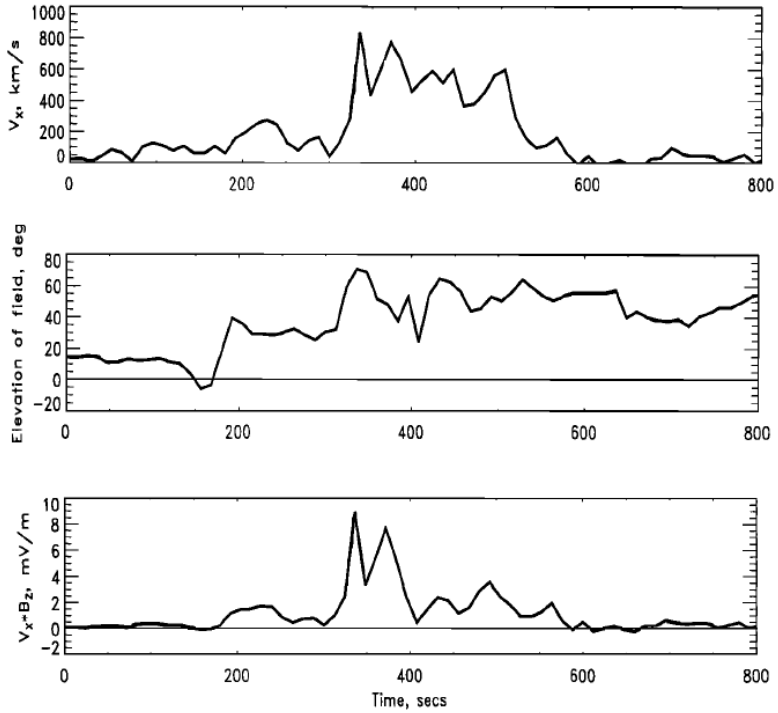


Figure 3. A typical BBF observed by Geotail near X_{AGSM} = -25 R_E. The BBF started at 02:55:03 UT on October 31, 1994 (at 300 s on the time axis in the plot). Displayed are the X-component of the ion bulk velocity V_X, the elevation of the magnetic field, and the dominant component of the electric field, $V_X B_Z$. The dipolarization of the plasma sheet that accompanies the BBF can clearly be seen in the plot of the elevation. The time resolution is 12 seconds.

Schödel et al, 2001

BBF are strong, transient and localized increases of plasma transport observed in the plasma sheet.

Two criteria to identify them :

- Bulk flow
  Vx > 400km/s
  (Angelopoulos et al, 1992)
- Flux transport along the tail
  ~VxBz > 2mV/m
  (Schödel et al, 2001)

BBF bounce

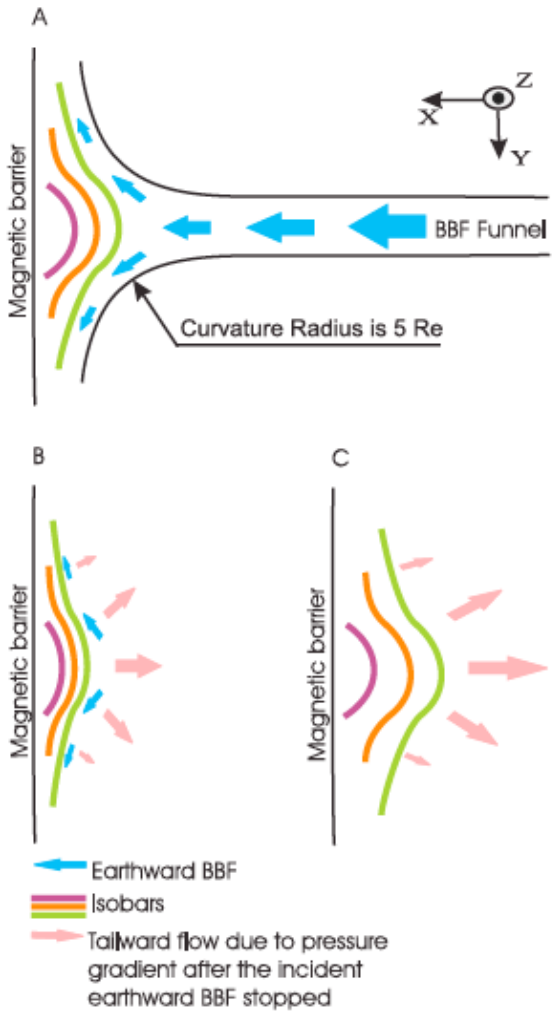


Figure 9. A sketch illustrating in (X, Y) GSM plane (a) the interaction of the earthward-moving BBF with a magnetospheric barrier, (b) consequent stopping of the earthward BBF and starting of tailward flows due to radial pressure gradients, and (c) smoothing of the pressure gradients over larger scales tailward.

(Panov et al, 2010)

- Average bulk velocity not independant of radial distance in the CPS
- Whereas, the average transport rate of magnetic flux is nearly constant
- In the near Earth, cross-tail flows have to be taken into account :

$\Rightarrow E_H = [\ (V_X B_Z)^2 + (V_Y B_Z)^2\ ]^{1/2}$

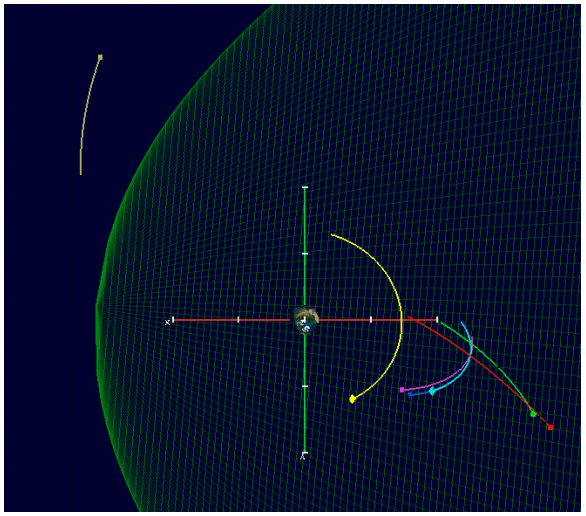
$\Rightarrow E_H > 2\text{mV/m}$

$\Rightarrow$ Rapid Flux Transport event (RFT)

Themis observations in the near tail (~10-15Re)

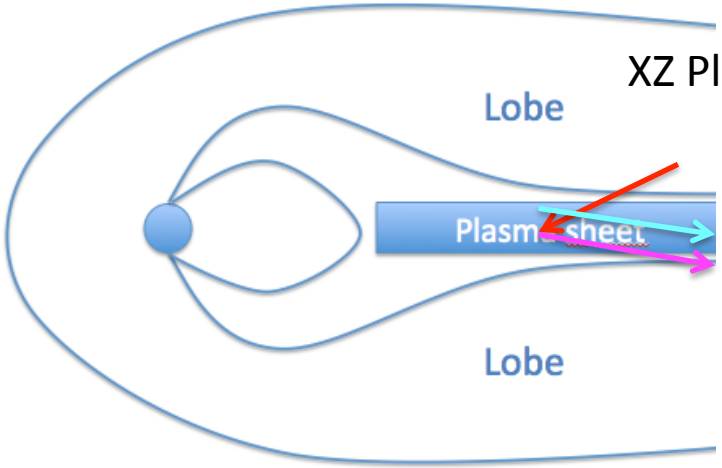
Several successive plasma sheet activations composed of DF and BBF

GEOTAIL and ACE : solar wind
THEMIS and GOES : tail

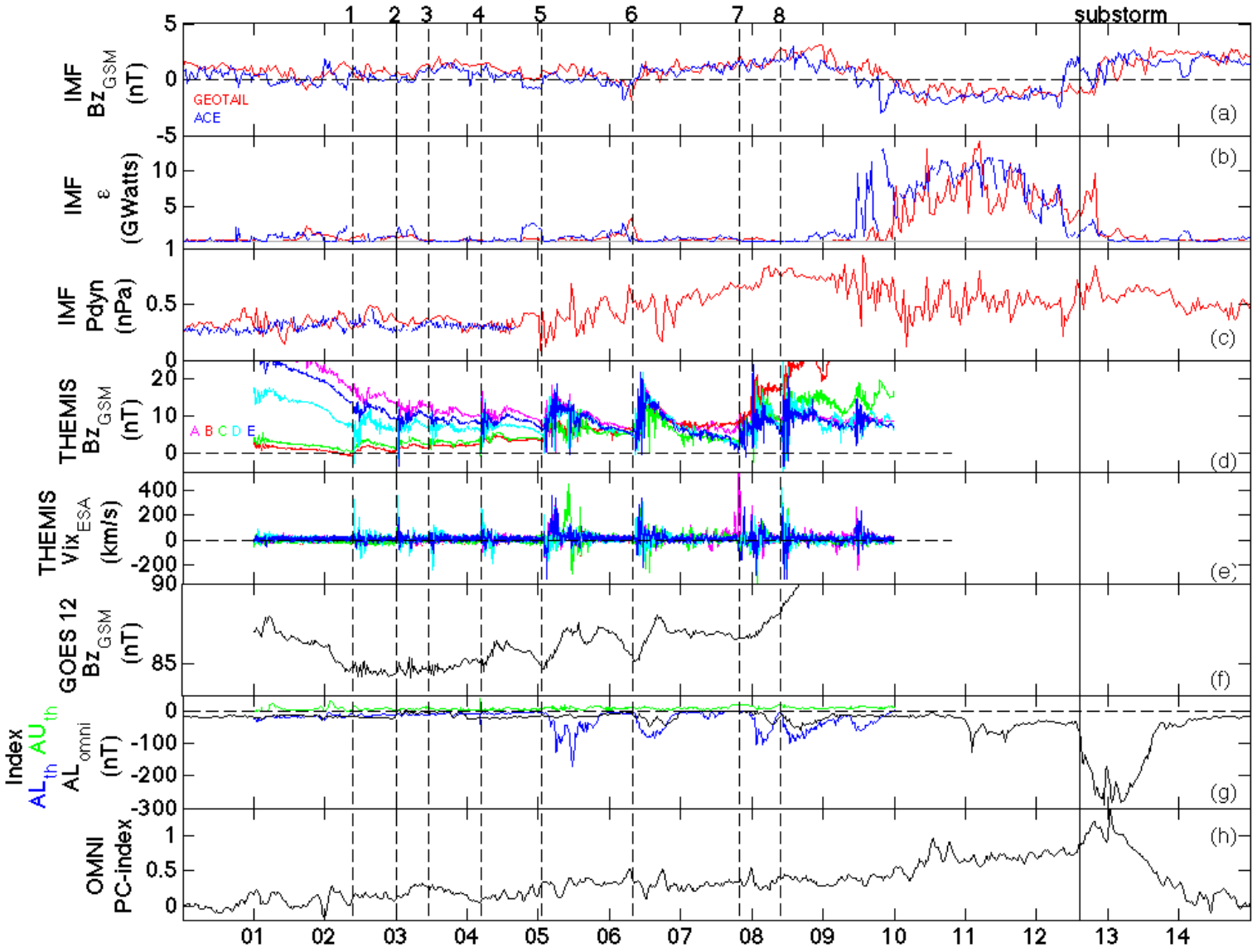


Position of probes in the XY plane

Good coverage for 8 hours



Overview


1
2
3
4
5
6
7
8
substorm
IMF Bz GSM (nT)
GEOTAIL
ACE
(a)
IMF ε (GWatts)
(b)
IMF Pdyn (nPa)
(c)
THEMIS Bz GSM (nT)
A B C D E
(d)
THEMIS Vix ESA (km/s)
(e)
GOES 12 Bz GSM (nT)
(f)
Index AU th ALth AL omni (nT)
(g)
OMNI PC-index
(h)
01
02
03
04
05
06
07
08
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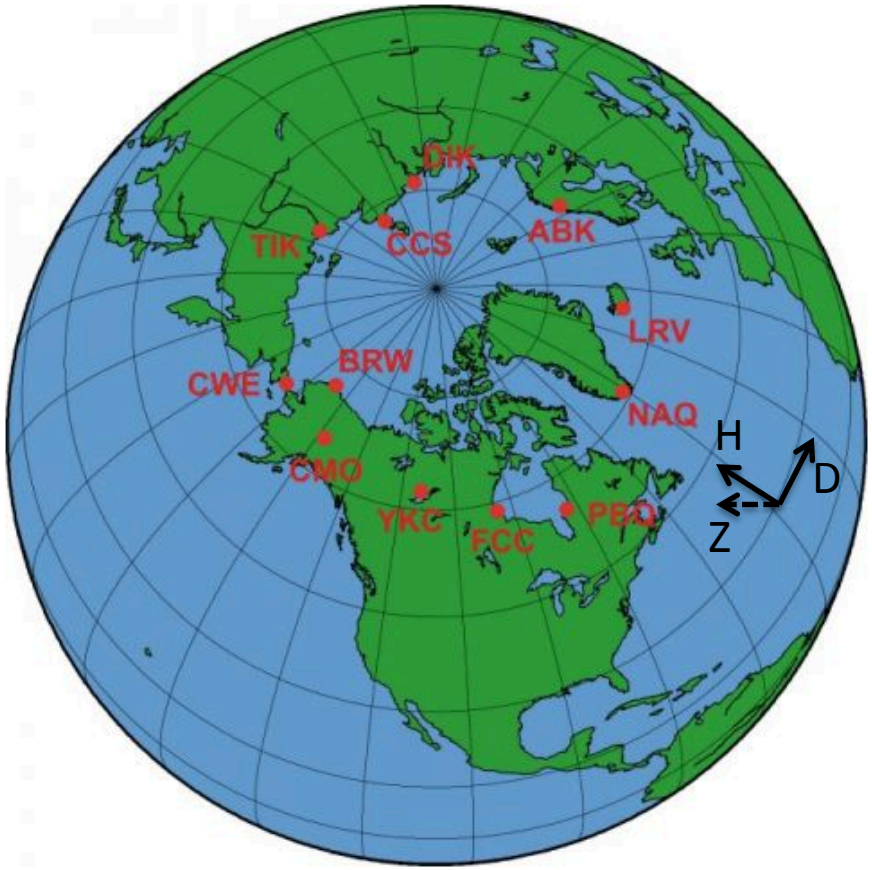
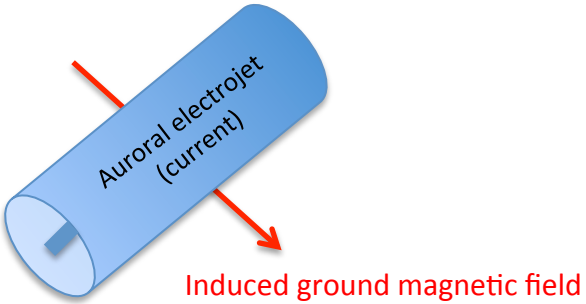
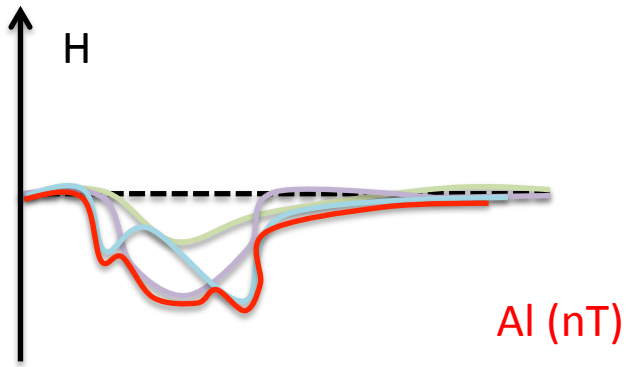
11
12
13
14

Auroral Electrojet Index
Al



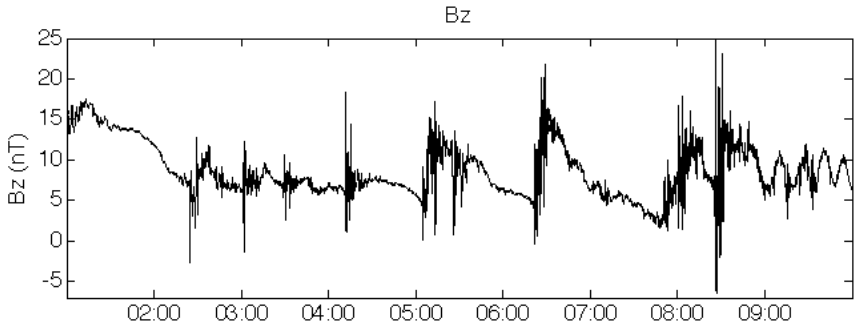




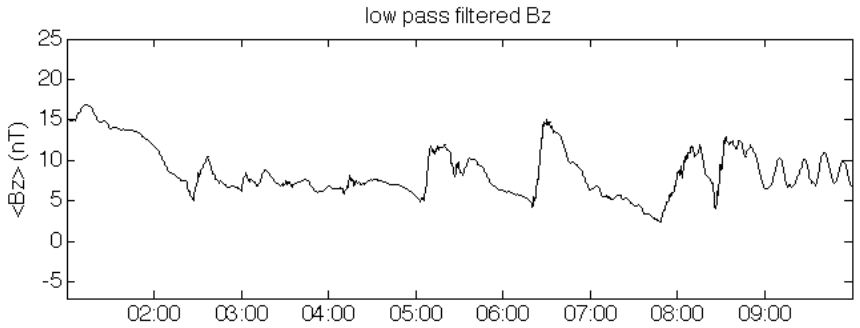
- H toward magnetic north pole
- Z vertical on site
- D to complete the system

Timing : THEMIS D

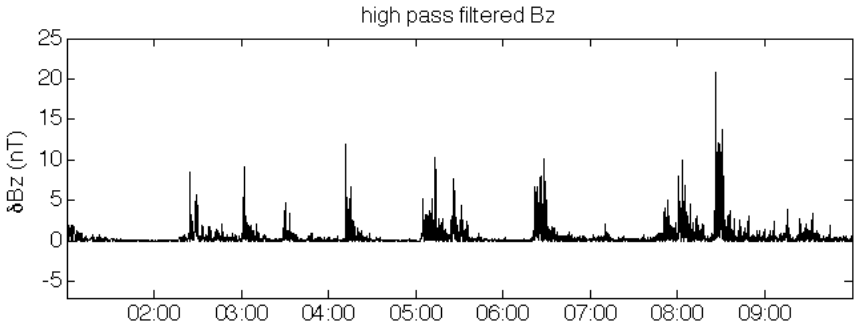
Bz



<Bz>
Centered moving average
on 100sec of Bz

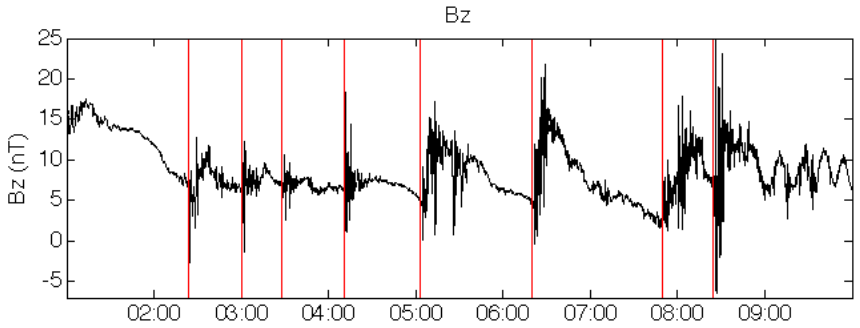


δBz = Bz - <Bz>



Timing : THEMIS D

Bz



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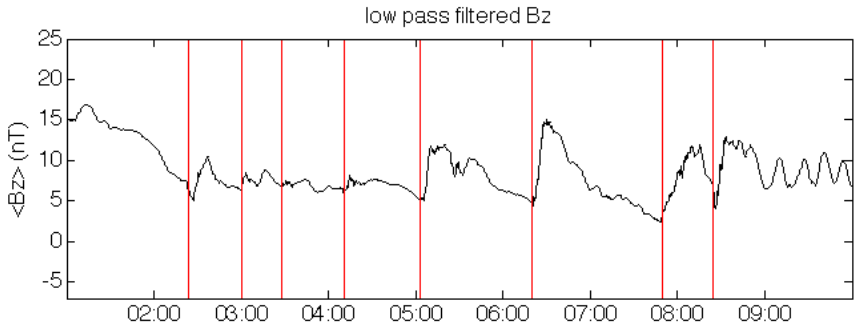
Centered moving average
on 100sec of Bz



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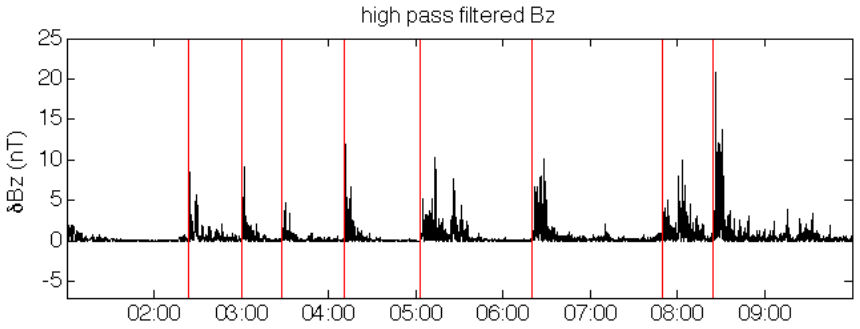
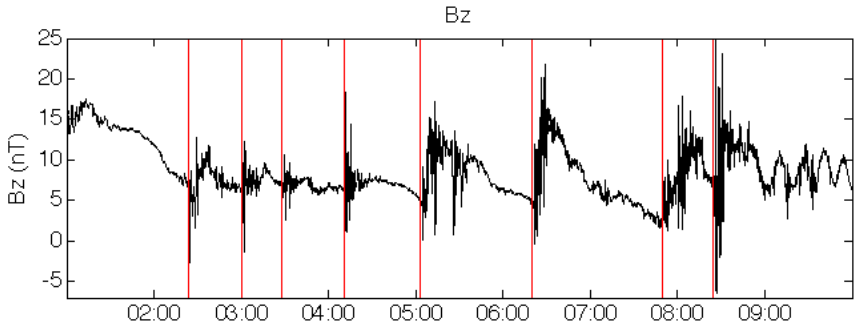
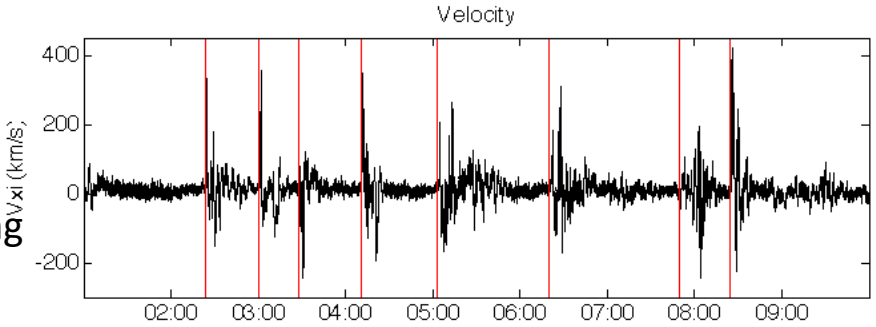


Plasma flows in the tail

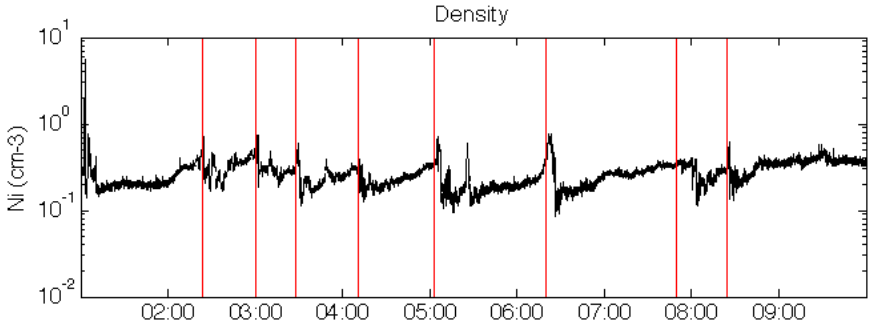
Bz



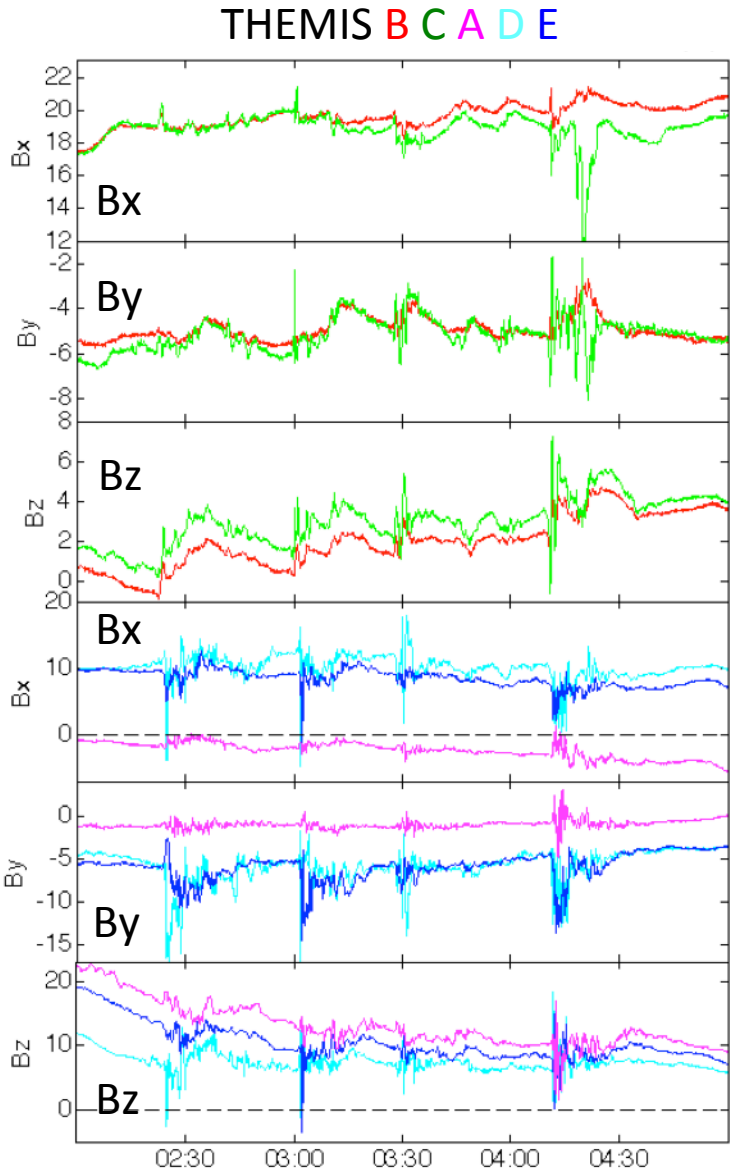
Vx
Oscillations
Consistent with flow braking



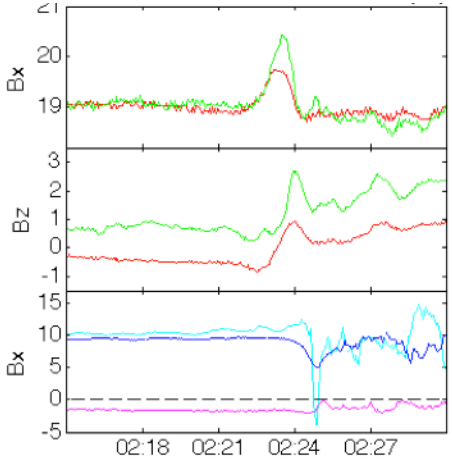
Density
Drop after onset

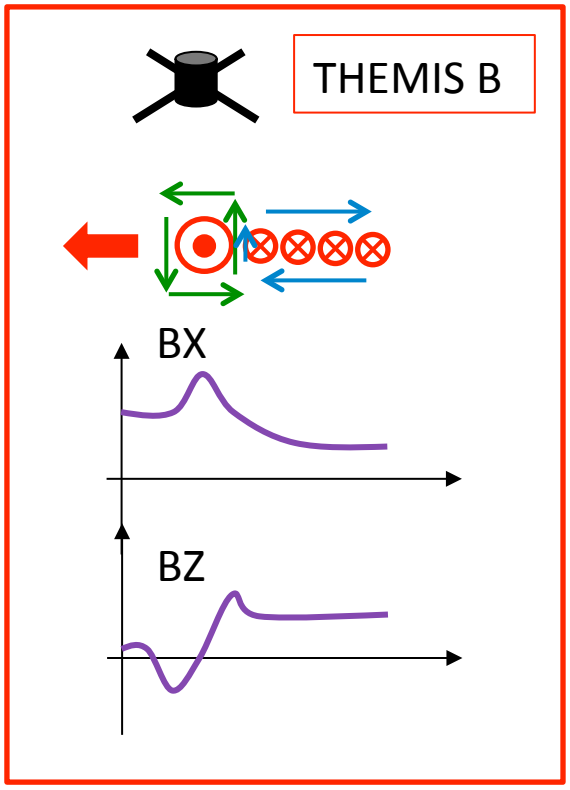


Events 1 & 4



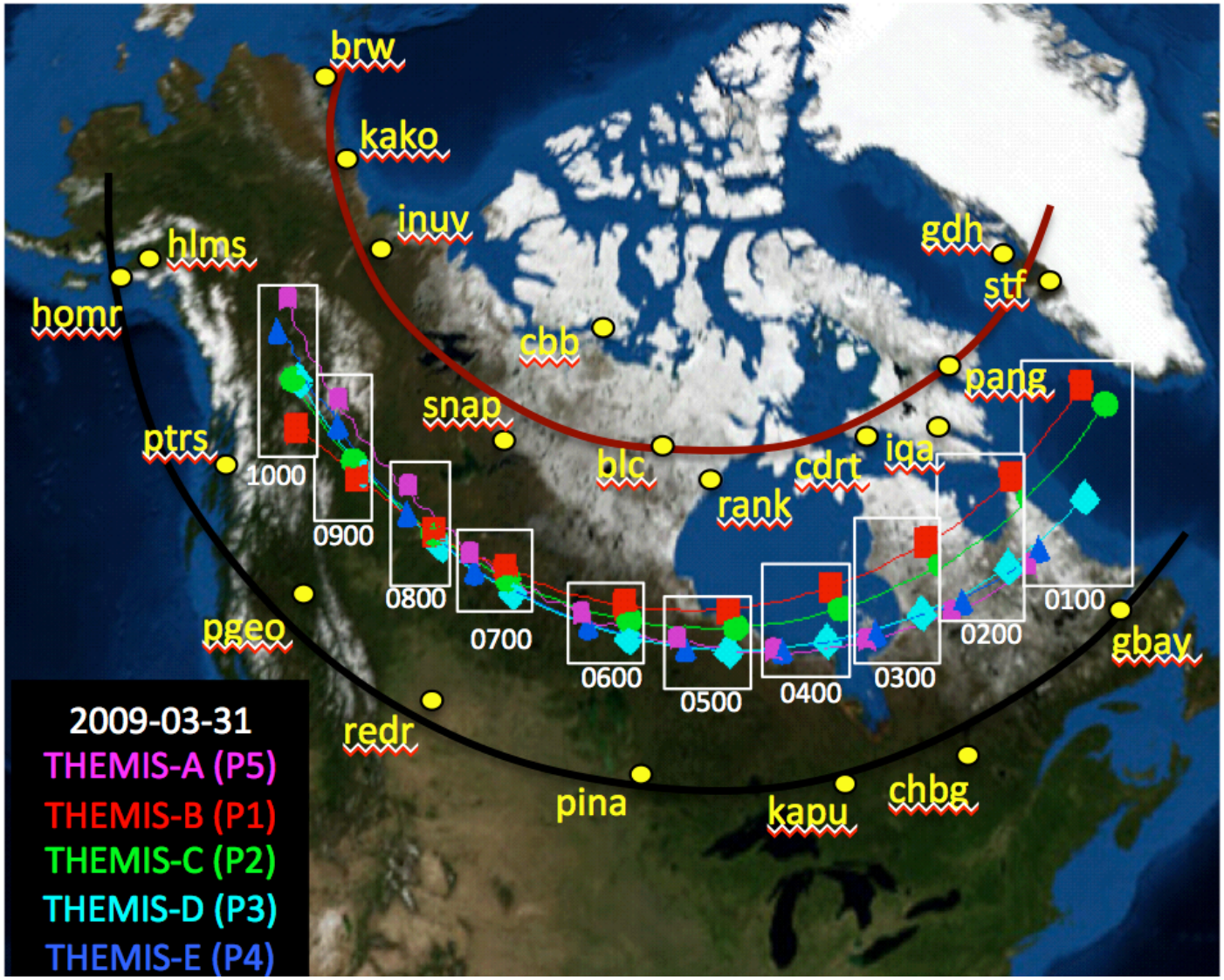
Event 1





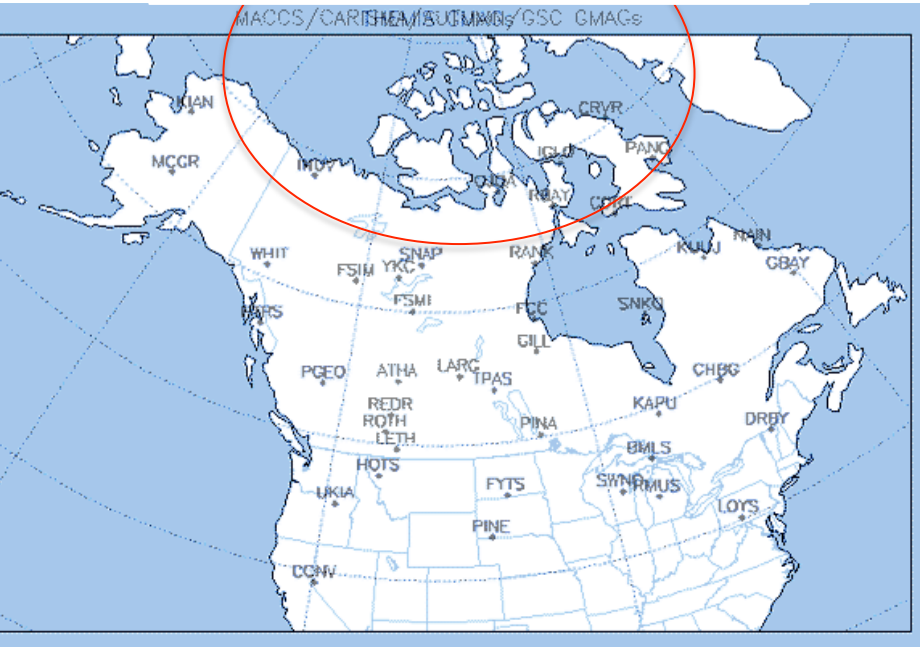
Lobe magnetic field variations are similar to NFTEs (Nightside Flux Transfer Events)

Ground based coverage

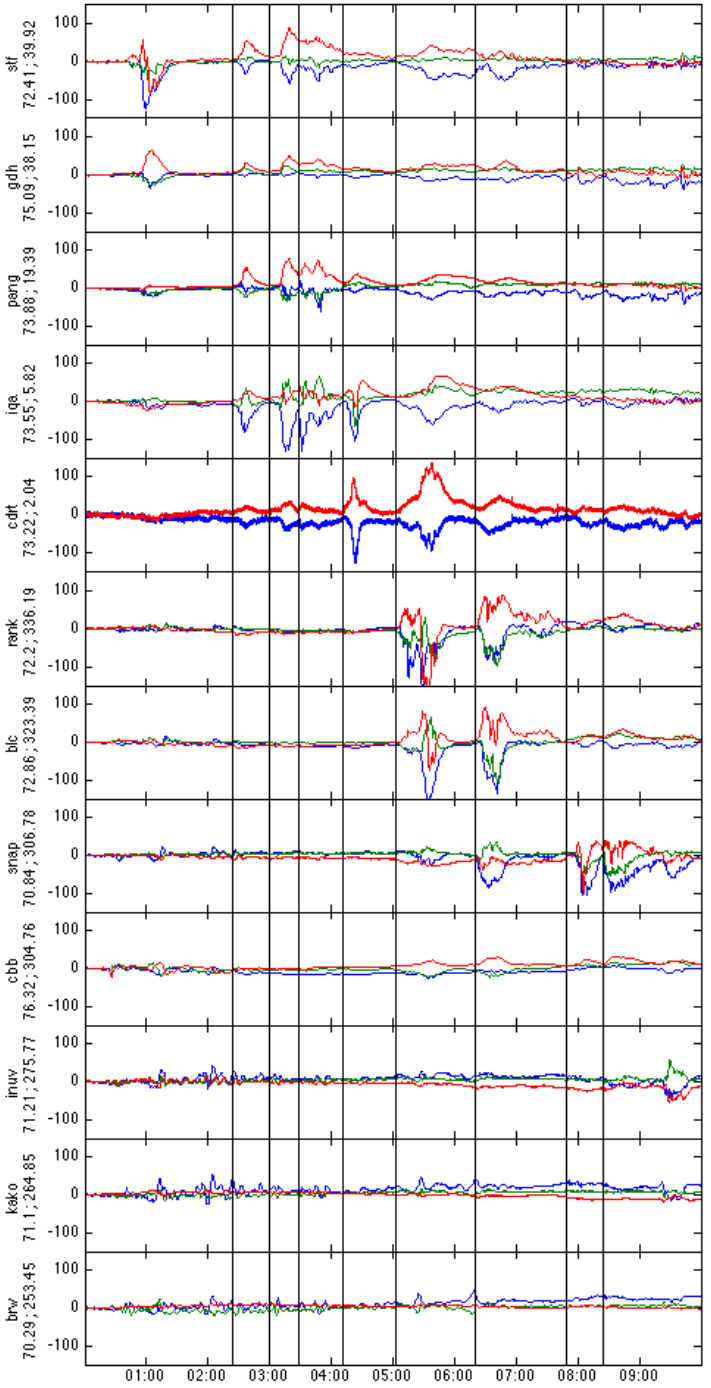


High latitude data

H D Z



Magnetogram scale -150 to 150 nT



39,92

38,15

19,39

5,82

2,04

336,19

323,39

306,78

304,76

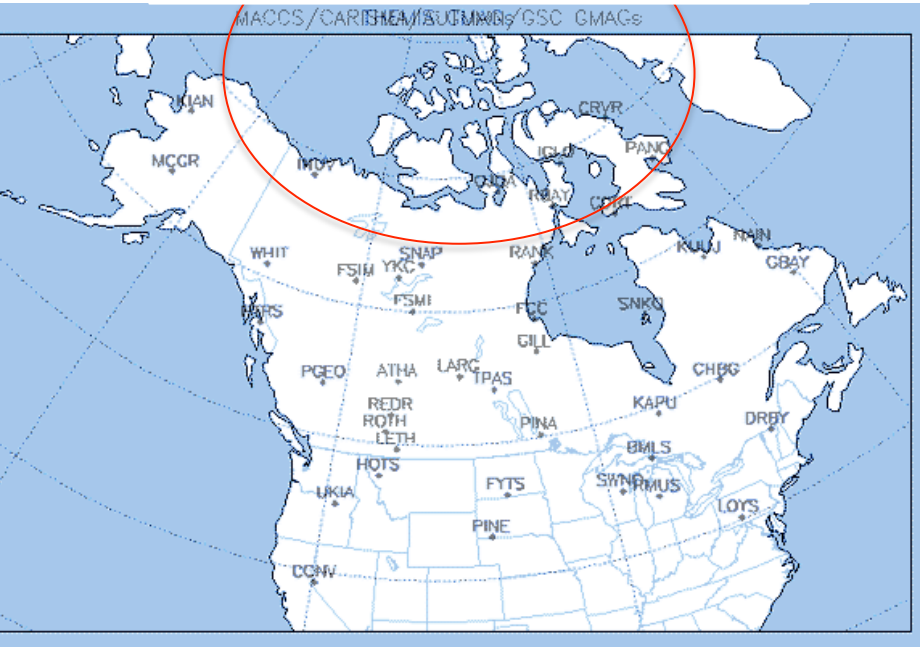
275,77

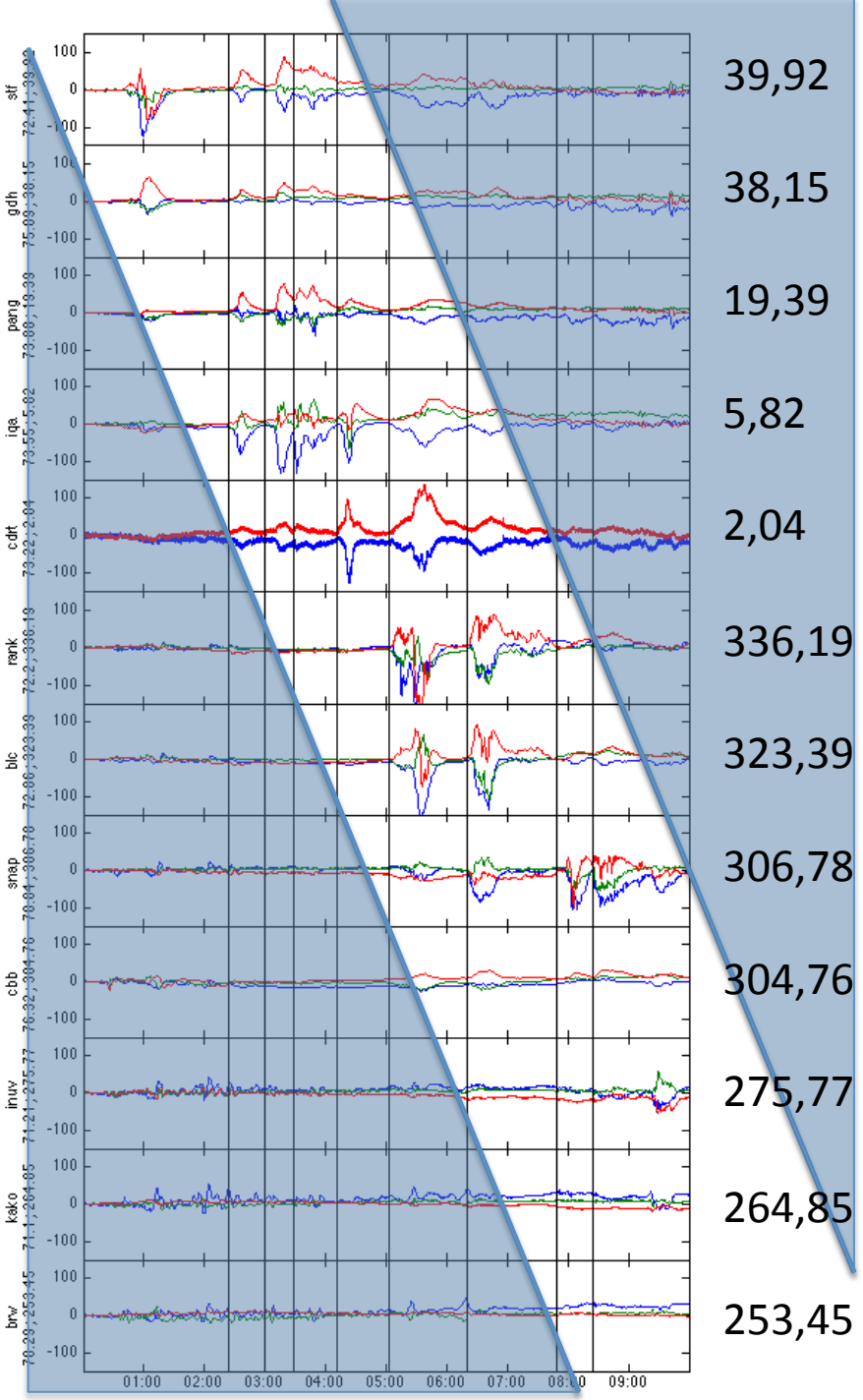
264,85

253,45

High latitude data

H D Z





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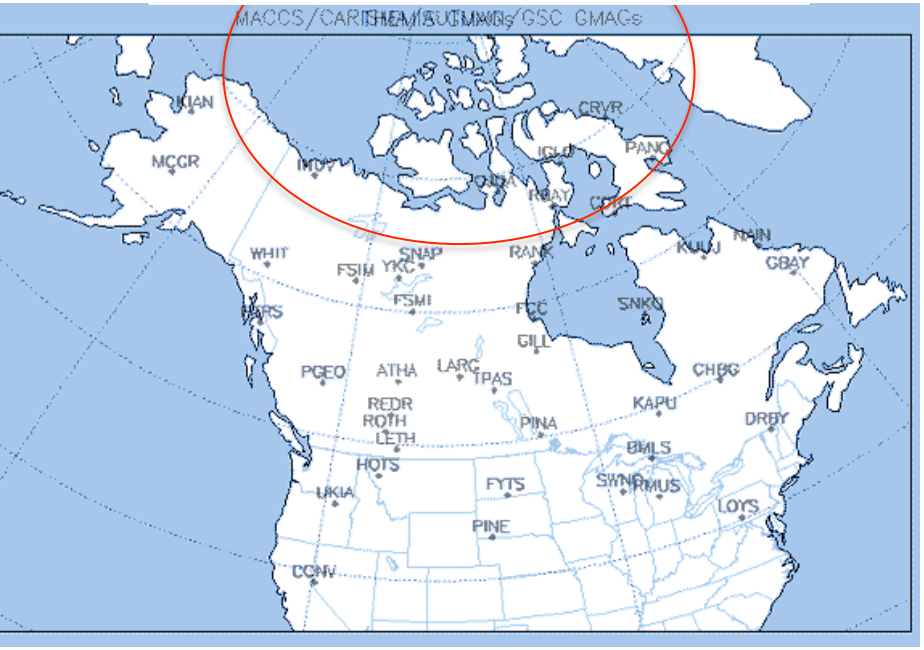

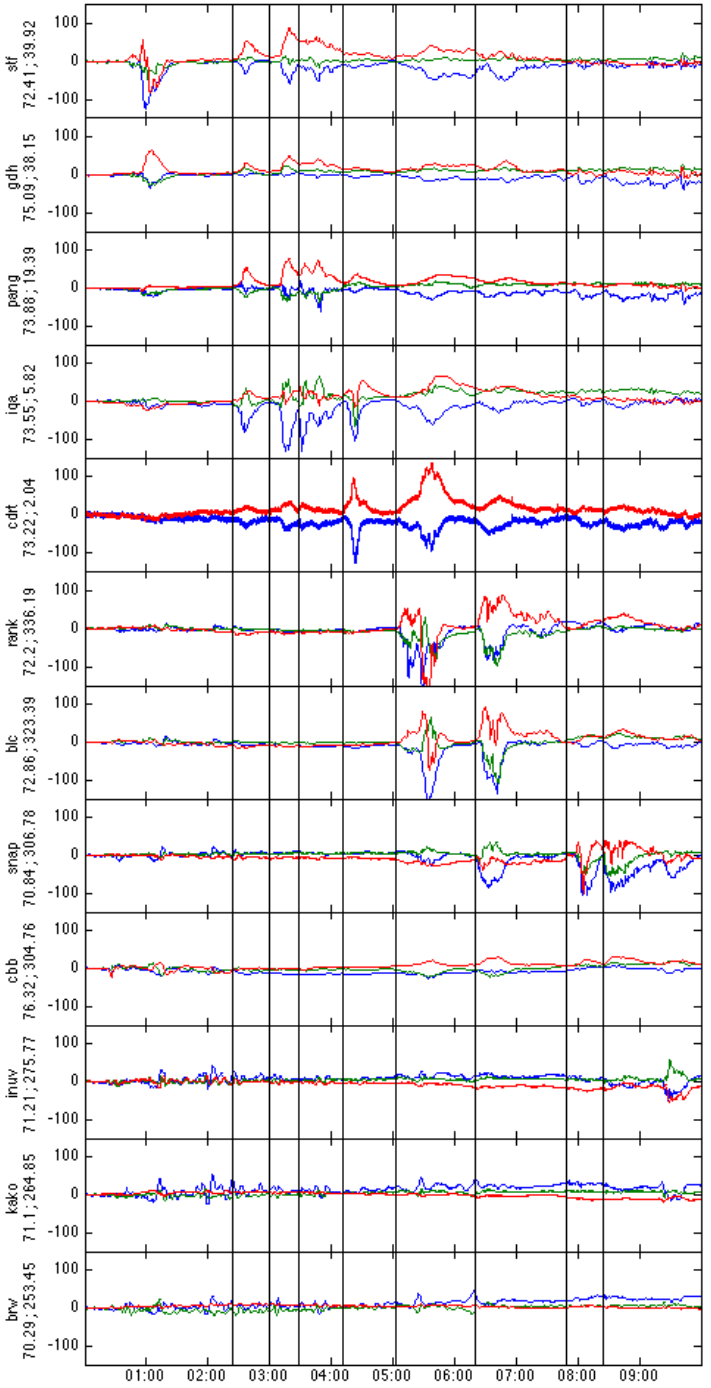

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2,04

336,19

323,39

306,78

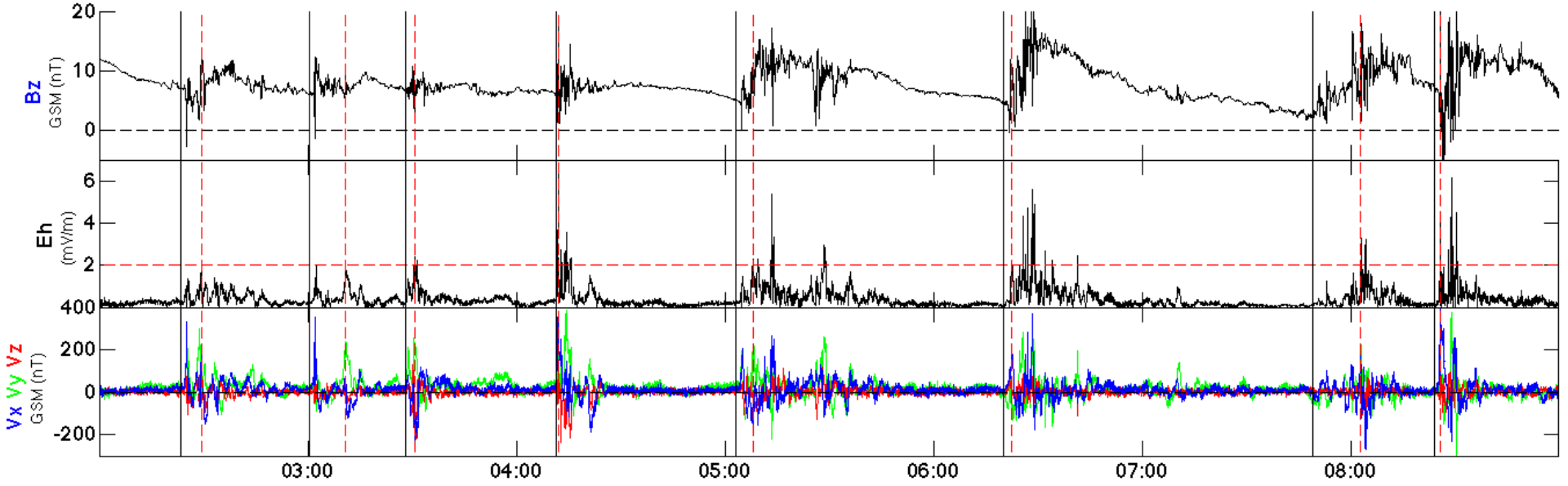
304,76

275,77

264,85

253,45

BBF-RFT number

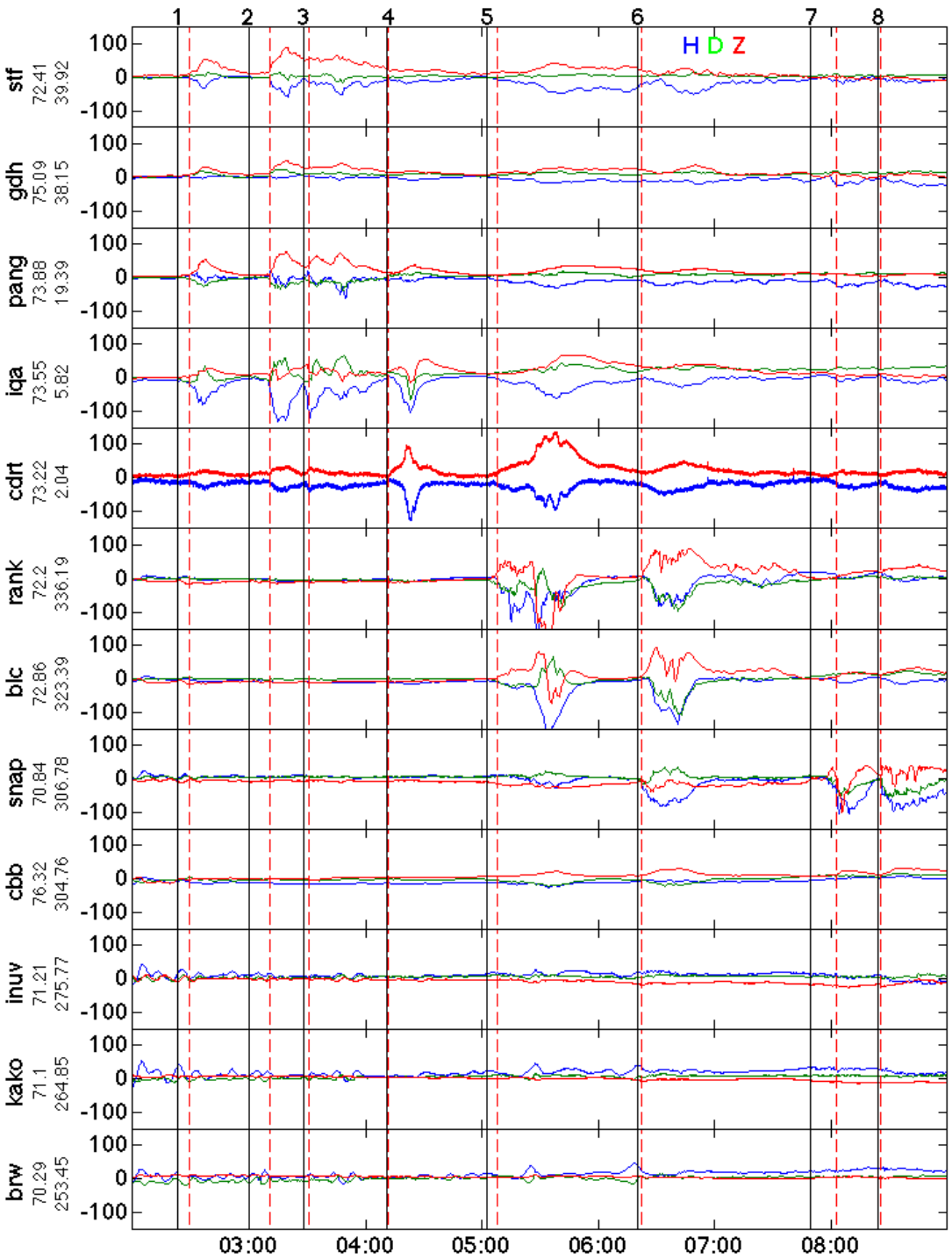


$\Rightarrow E_H = [\ (V_X B_Z)^2 + (V_Y B_Z)^2\ ]^{1/2}$

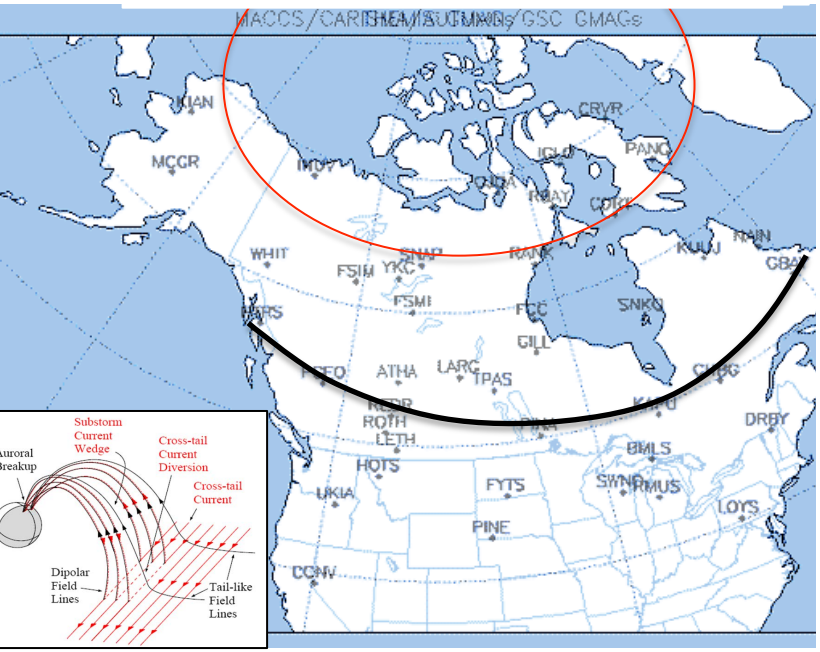
$\Rightarrow E_H > 2\text{mV/m}$

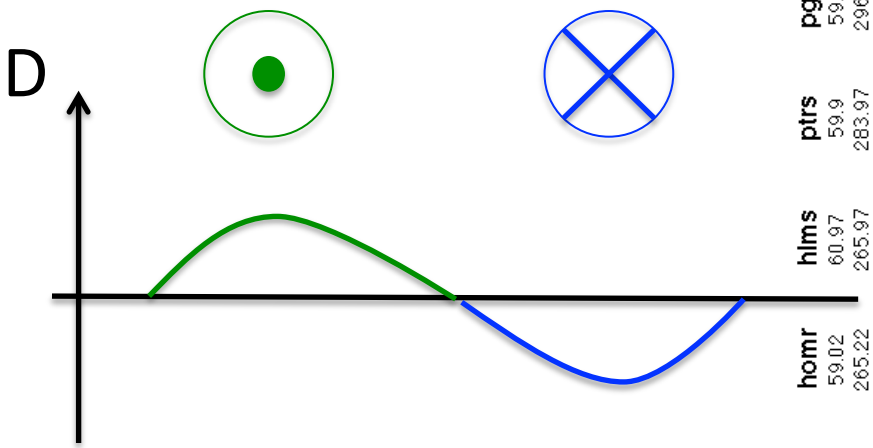
$\Rightarrow$ Rapid Flux Transport event (RFT)

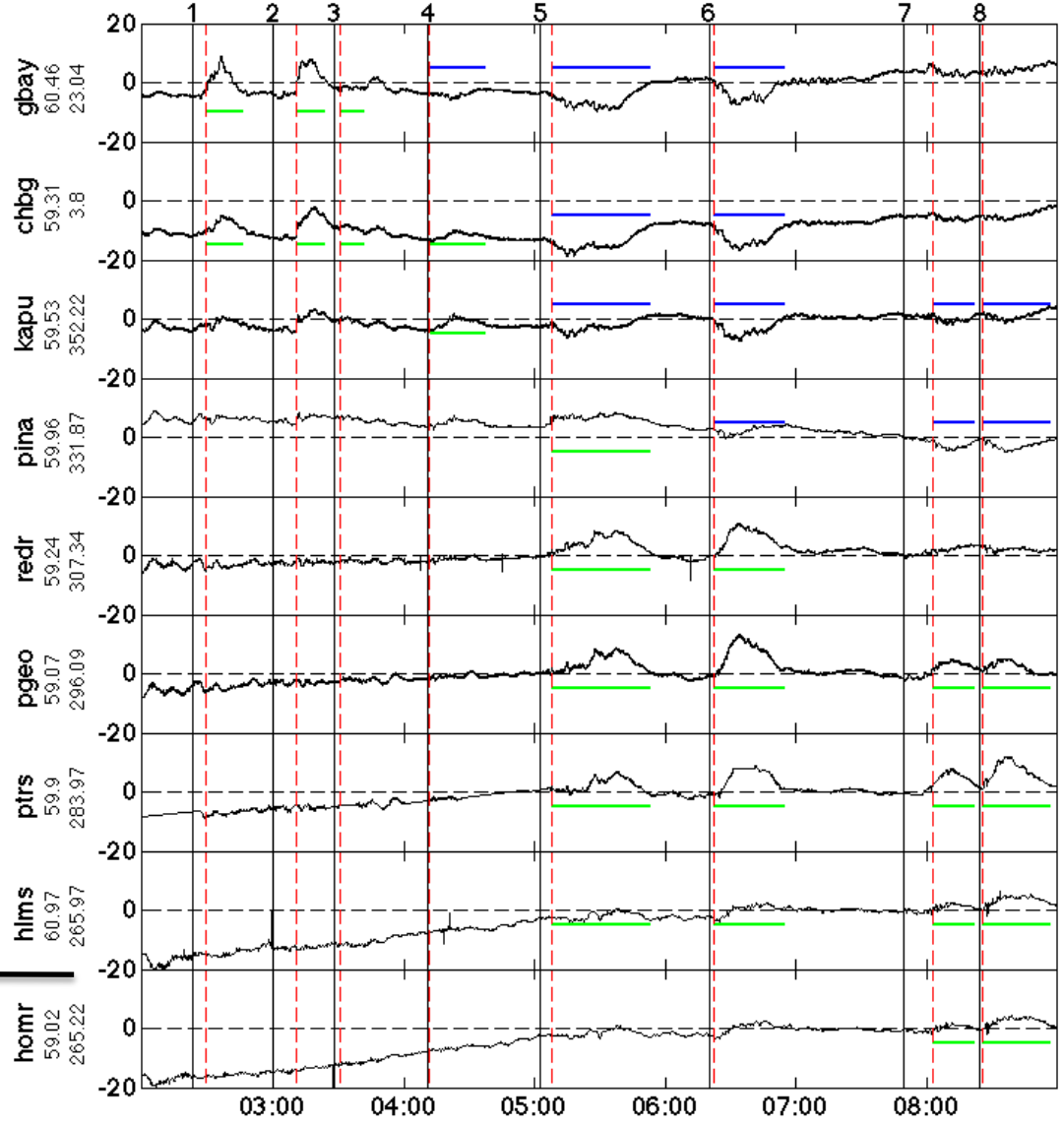
High latitude data



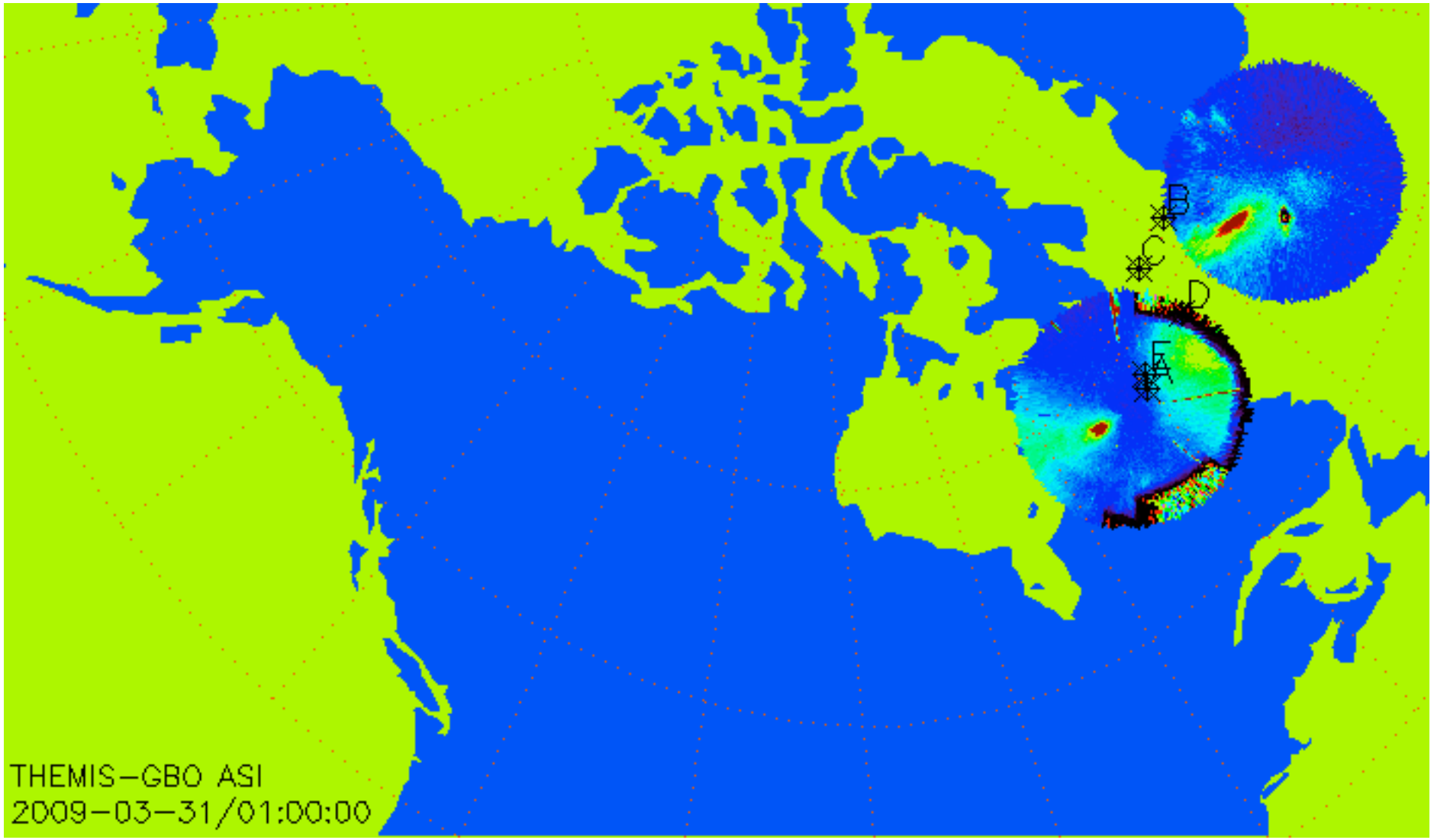
Wedgelet observed at midlatitude







0100-0900 UT

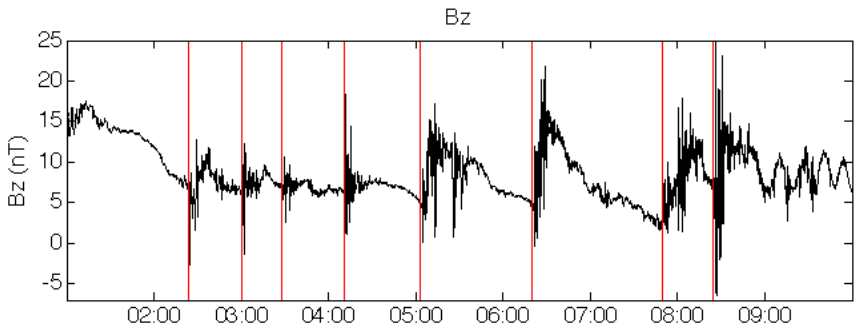


New parameter introduced by V. Sergeev

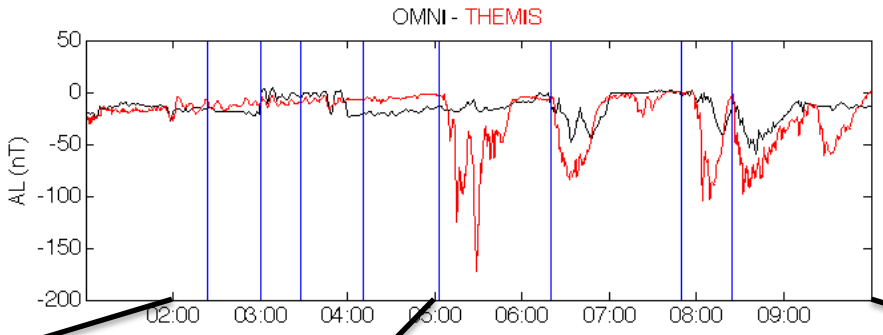
eTN

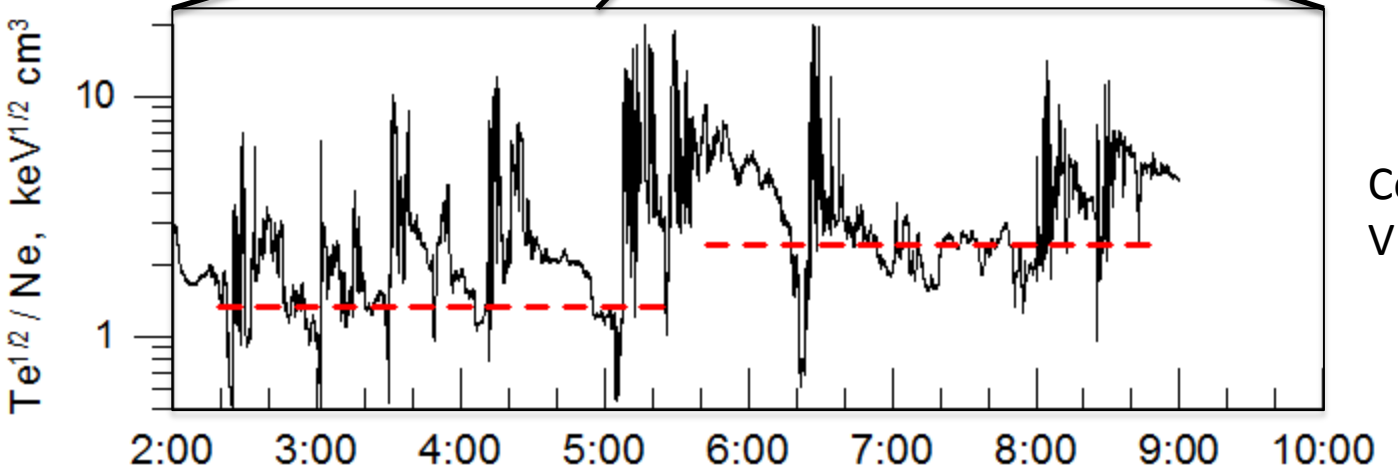
ICS-14

Bz



AL index





Courtesy of V. Sergeev

Role of small DF

- Very small events like 1-3, are unlikely to be detected by automated routines based on threshold variation

- Nevertheless, they show the same ground based signatures as substorms.

- They seem to differ only by the number of involved RFT.

Summary and conclusions

- 8 succesive PS activations with good spacecraft and ground based coverage.
- At least one RTF by PS activation which seem to be responsible for wedgelets creation.
- Small DF, also associated with wedgelets.
- There seem to be no threshold and no physical difference other than magnitude, so we may have observed the smallest form of substorm.

What is next ?

- This events observed from the lobes are called NFTE.
- In the present study, we observed NFTE in quiet time.
  - They create small SCW
- We found NFTE happening after a real substorm onset.
  - They modulate the SCW

Cluster study : no data in plasma sheet but same lobes signatures.