Cluster survey of the mid-altitude cusp

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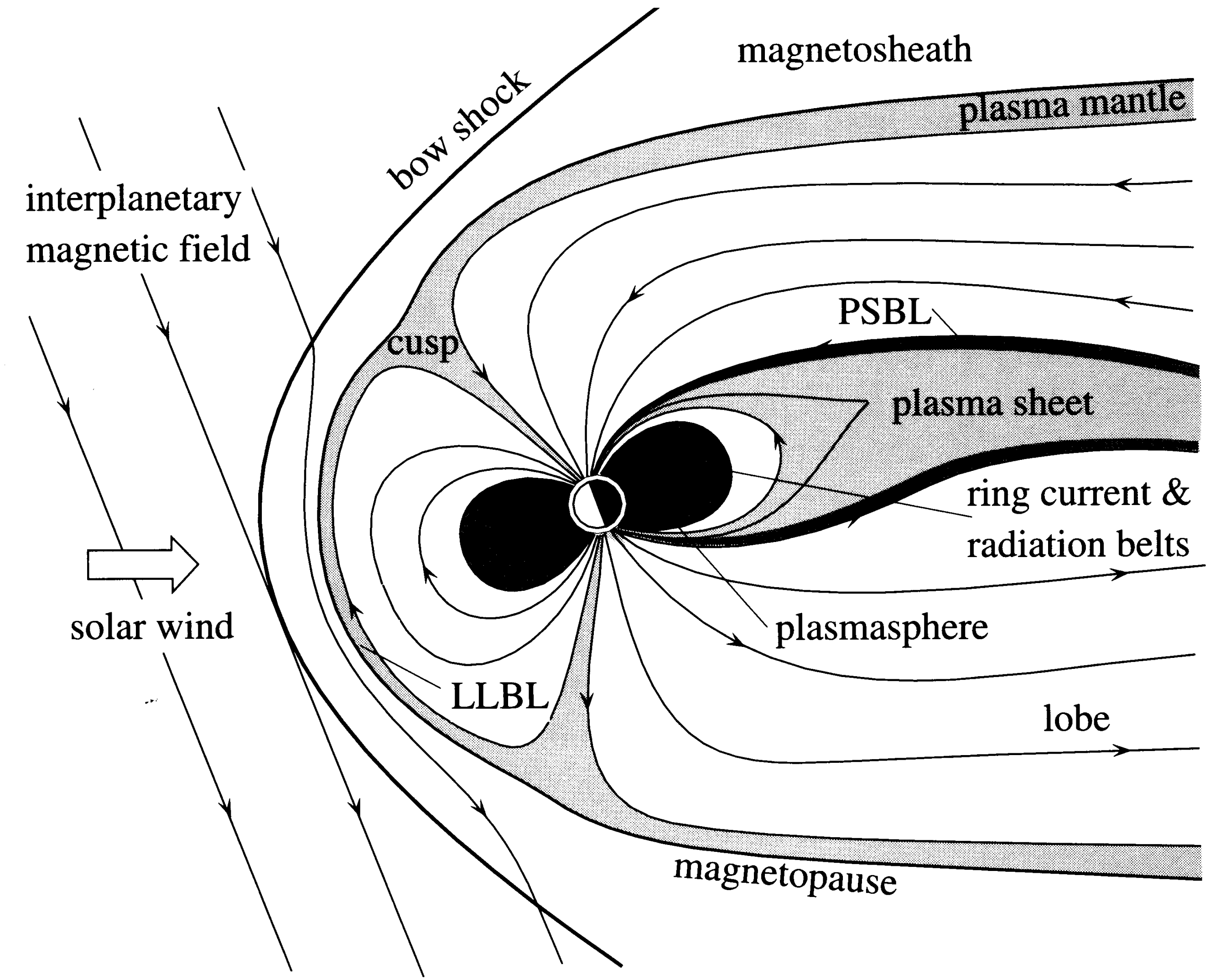
The polar cusp



Selection criteria for identifying mid-altitude cusps

- 08<MLT<16 → early July – late October
- Density: $d_{cusp} \geq d_{SW}$
- Precipitating ions: pitch-angle < 30°
- Mean ion energy $<E_i>$ ~ 2-3 keV/e
- Ion energy flux: $F_i > 10^7$ ev/cm^2 s sr ev

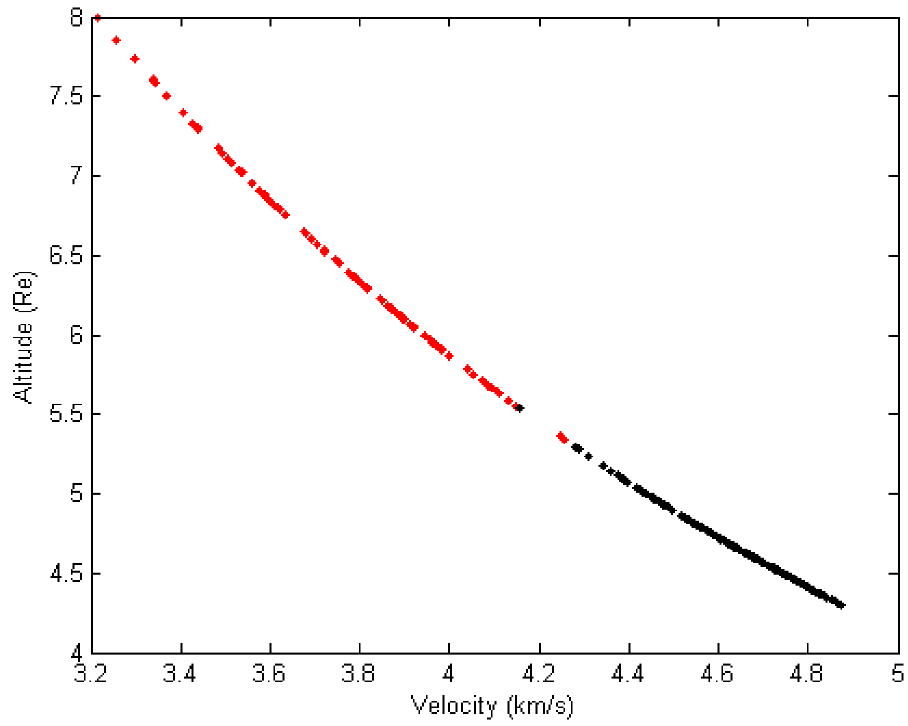
- Study performed on years 2001-2004

Number of cusp crossings

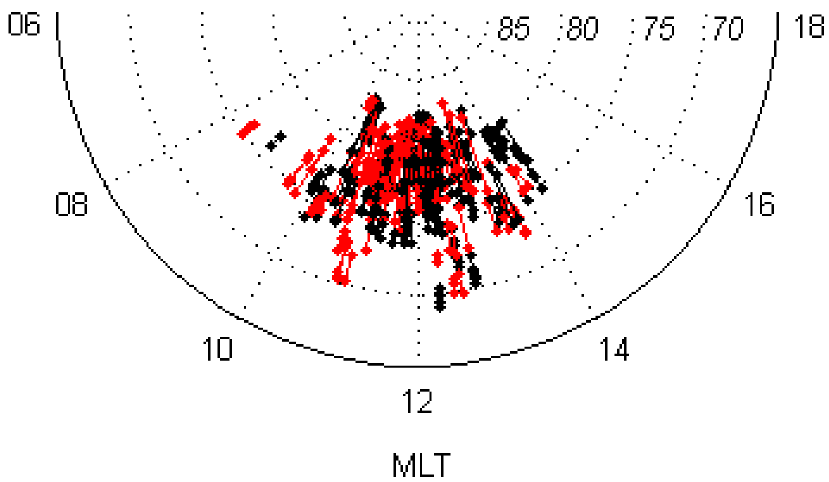
- Only 262 out of 960 passes in the mid-altitude dayside magnetosphere were identified as cusp crossings (~27% of the passes).
- Explanations:
  - data gaps (CIS instrument off, problem with the instrument, maneuvers)
  - wide MLT range chosen (from 8 to 16 MLT) → cusp can be missed
  - an unfavorable IMF-By may move the cusp towards the opposite MLT sector. This illustrates the relative longitudinal narrowness of the cusp at those altitudes.

Spacecraft velocity vs. altitude

- For each cusp crossings, the velocity and the altitude of the spacecraft have been plotted in this figure.
- One can see that cusp encouters in the southern hemisphere (in red) occur at higher altitude and slower than in the northern hemisphere (in black).



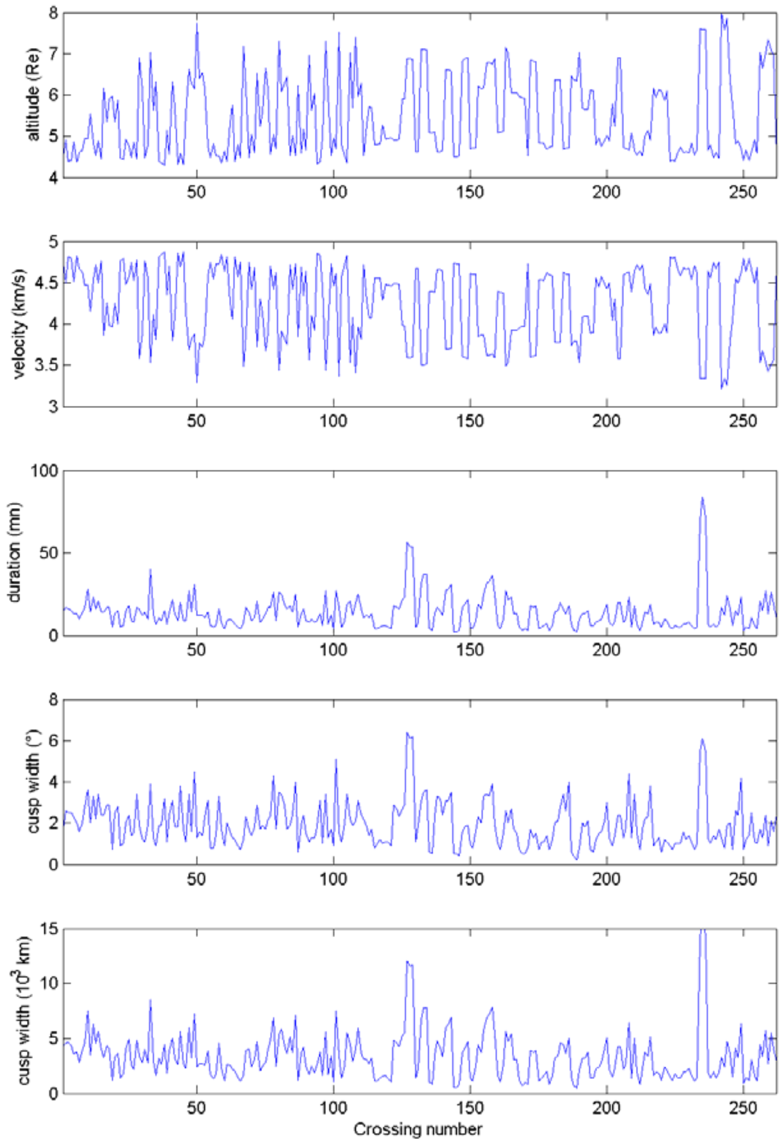
MLT-ILAT distribution



Black/red: northern/southern hemisphere.

All cusp crossings are located near magnetic noon and between ~70° and ~80° ILAT

Latitudinal width of the mid-altitude cusp



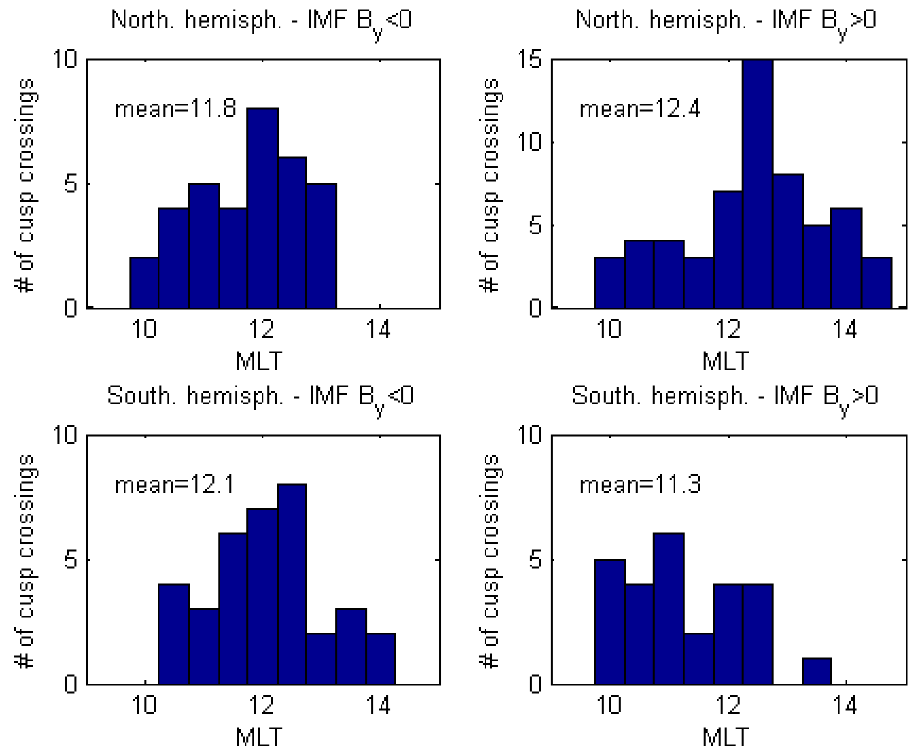
•Mean crossing duration: 14 min

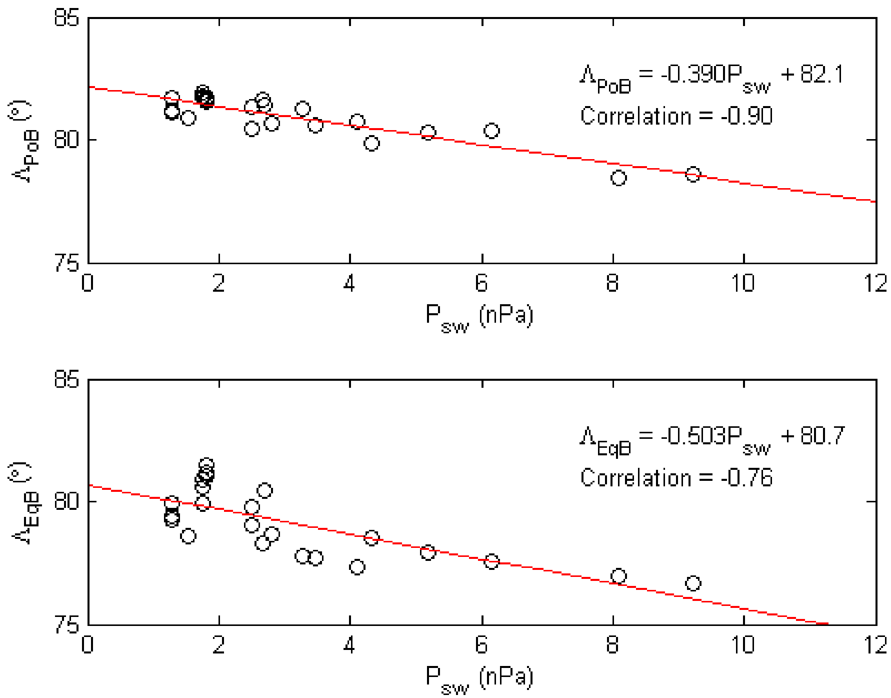
•Mean latitudinal width:

- 3400 km
- 2°

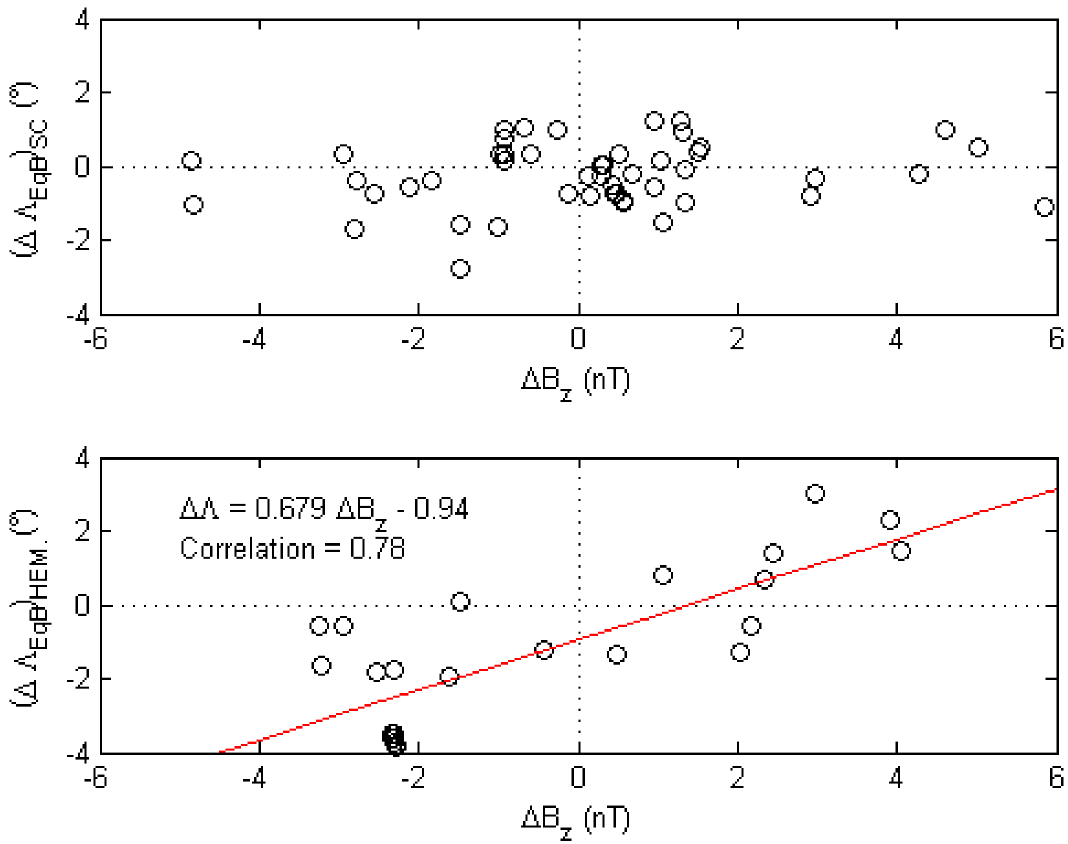
Cusp location vs. IMF

- Longitudinal dynamics governed by IMF-B_y
- Latitudinal dynamics governed by IMF-B_z (magnetic erosion under southward IMF)
- Latitudinal dynamics under Northward IMF mainly governed by solar wind dynamic pressure.





$\Delta\Lambda_{EqB}$ vs. ΔB_z

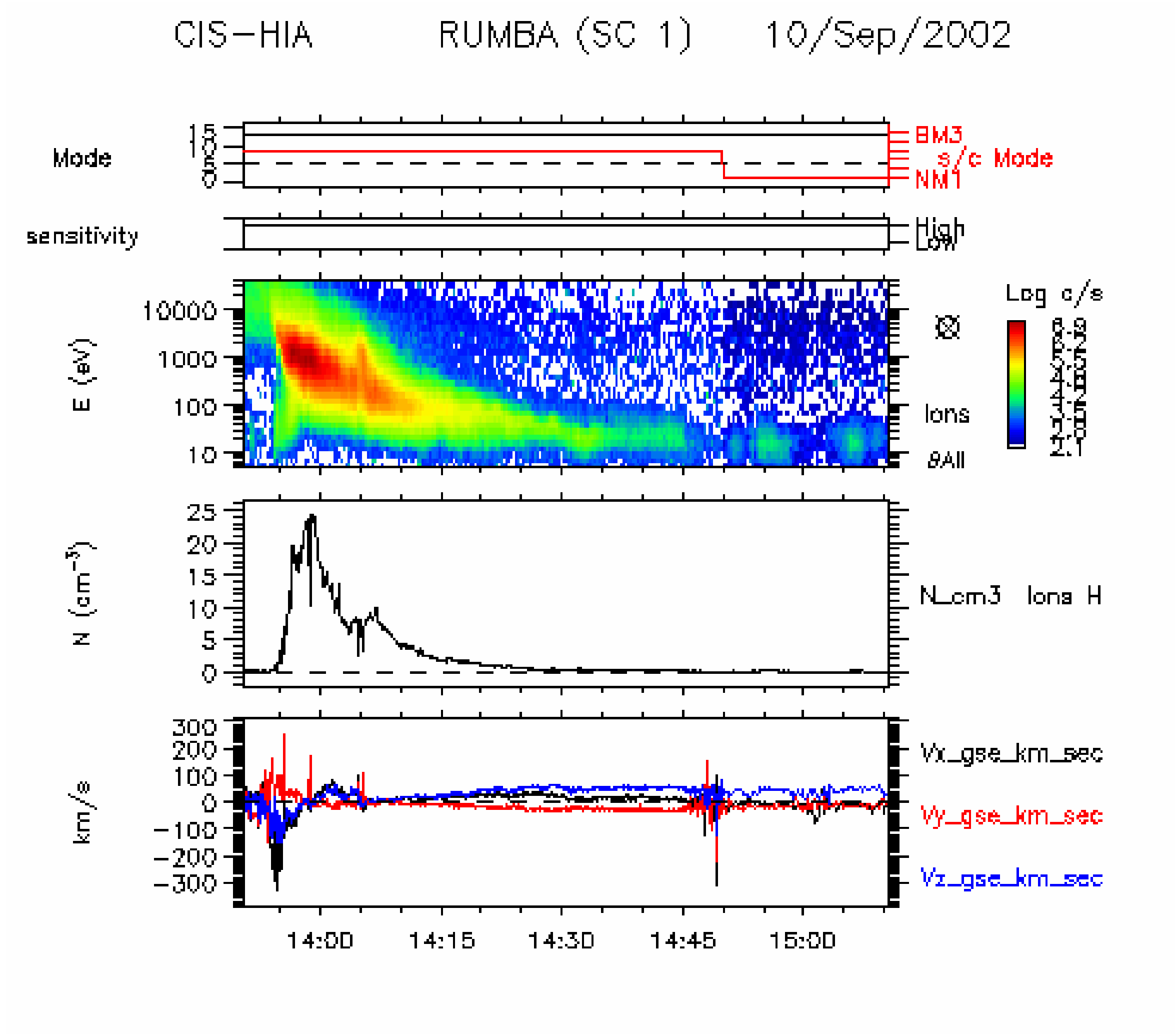


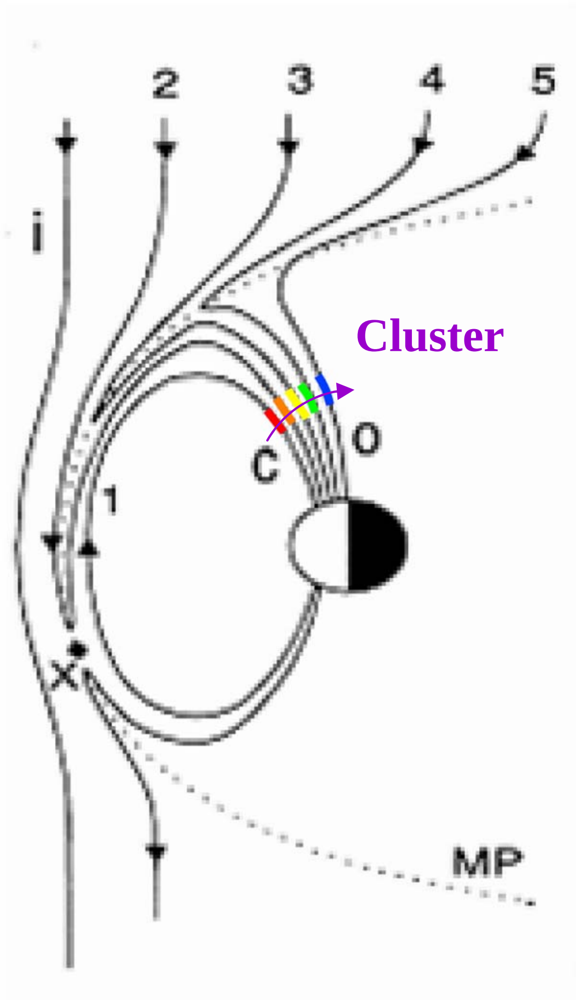
Explanation: erosion process very fast → cusp velocity must increase for high ΔBz

Cusp dynamics and altitude

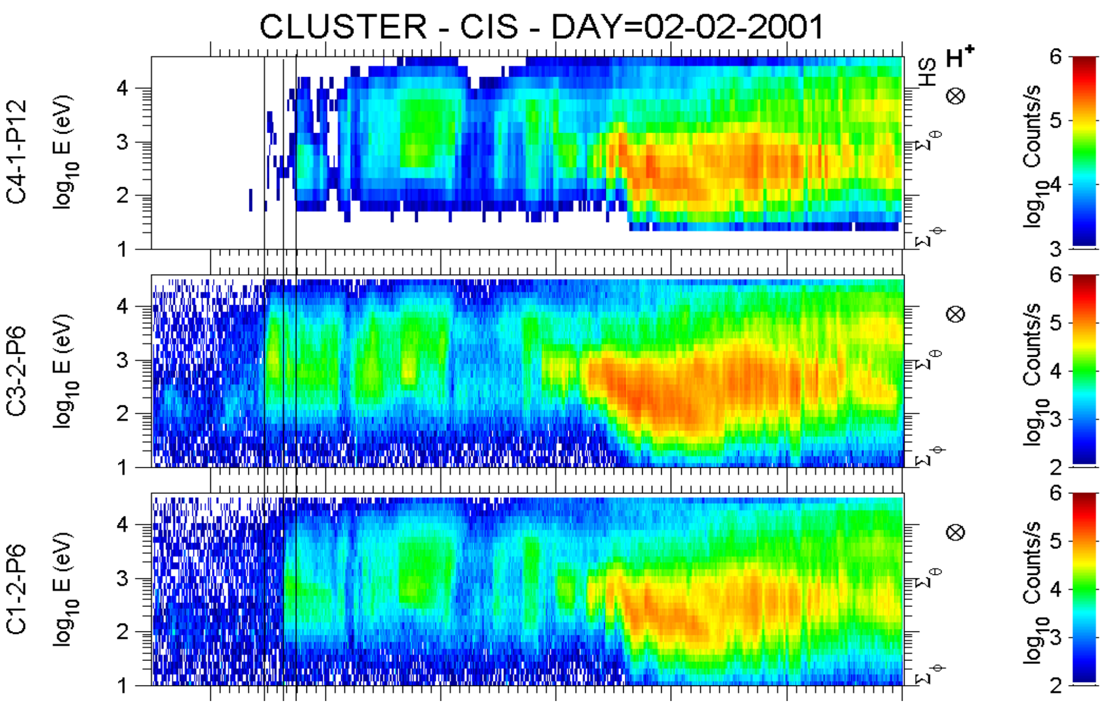
- Correlation between the IMF-By and the MLT sector is higher in the southern hemisphere (-0.61) than in the northern hemisphere (0.50). Likewise, correlation between the IMF-Bz and the latitude of the cusp equatorward boundary is greater in the southern hemisphere (0.68 and 0.65) than in the northern hemisphere (0.55 and 0.48).
- Cusp more mobile at $8R_E$ than at $5R_E$ higher altitudes (less constrained by geomagnetic field?), not only in latitudes (*Newell, Palmroth*), but also in longitudes.

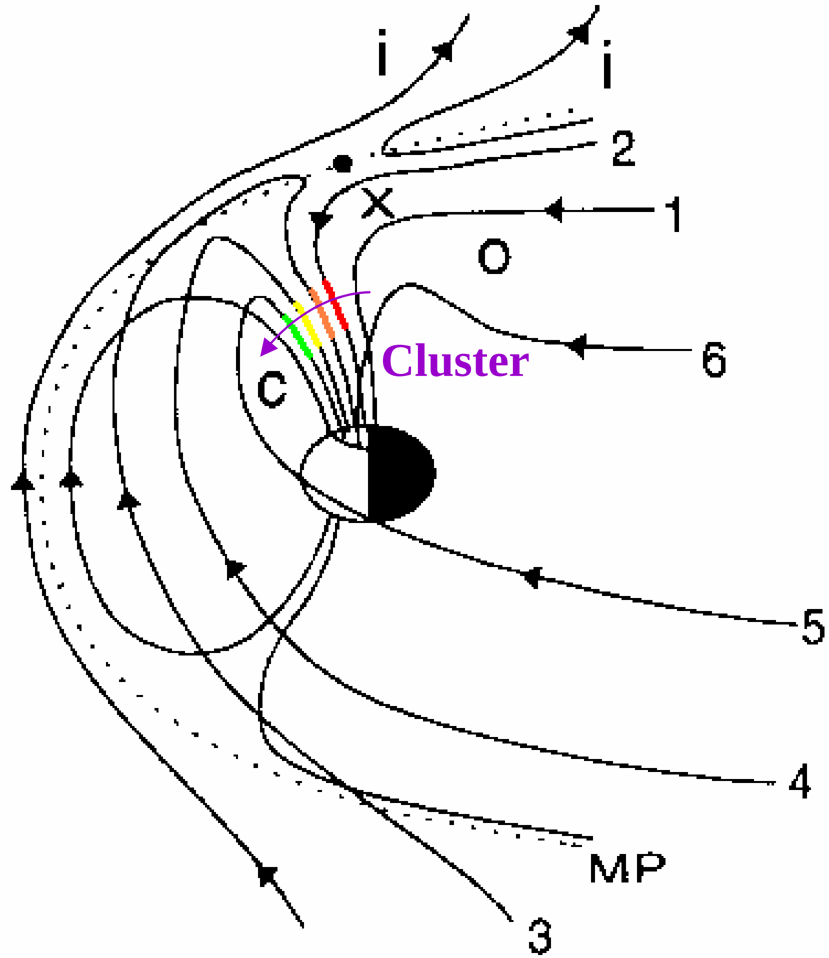
Ion dispersion in the cusp – Southward IMF





Ion dispersion in the cusp – Northward IMF





Morphological classification

We have identified four great classes of cusp crossings. These classes are defined on morphological and large-scale criteria.

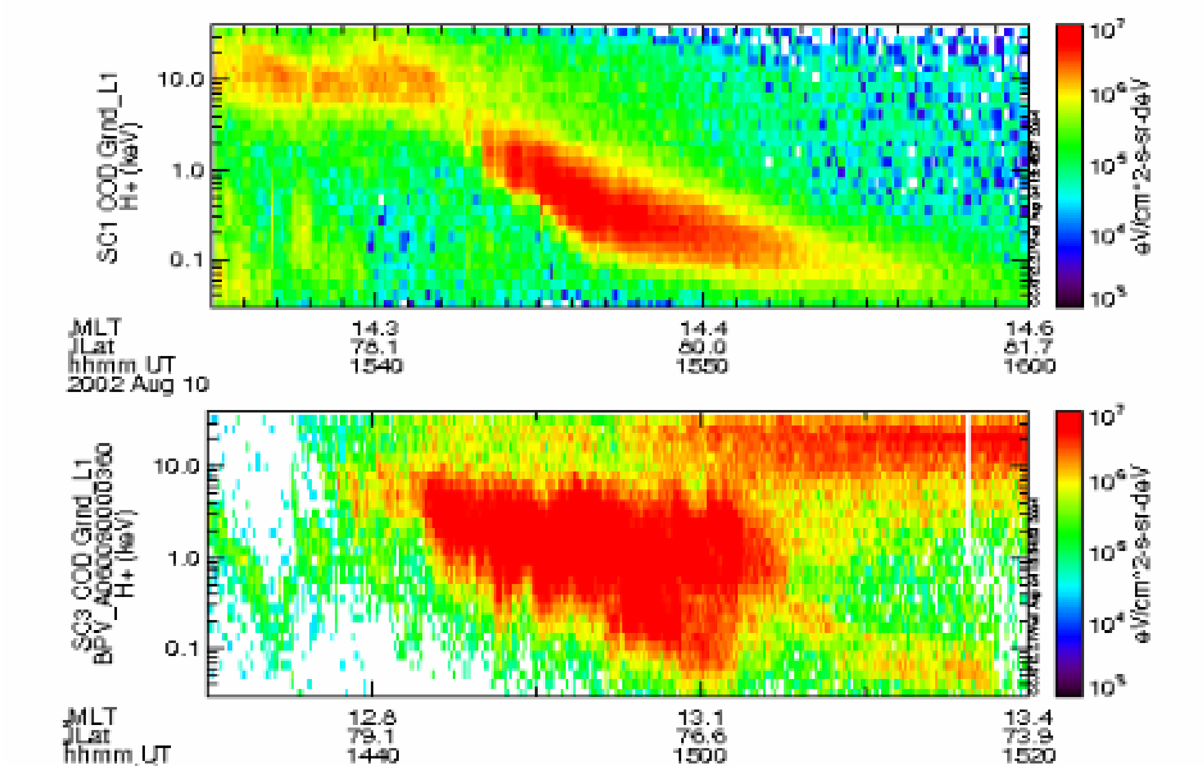
a) Dispersed cusps. Those cusps exhibit the textbook velocity filter effect with high-energies at low latitudes and lower energies at high latitudes. Those cusps are expected to occur under southward IMF.

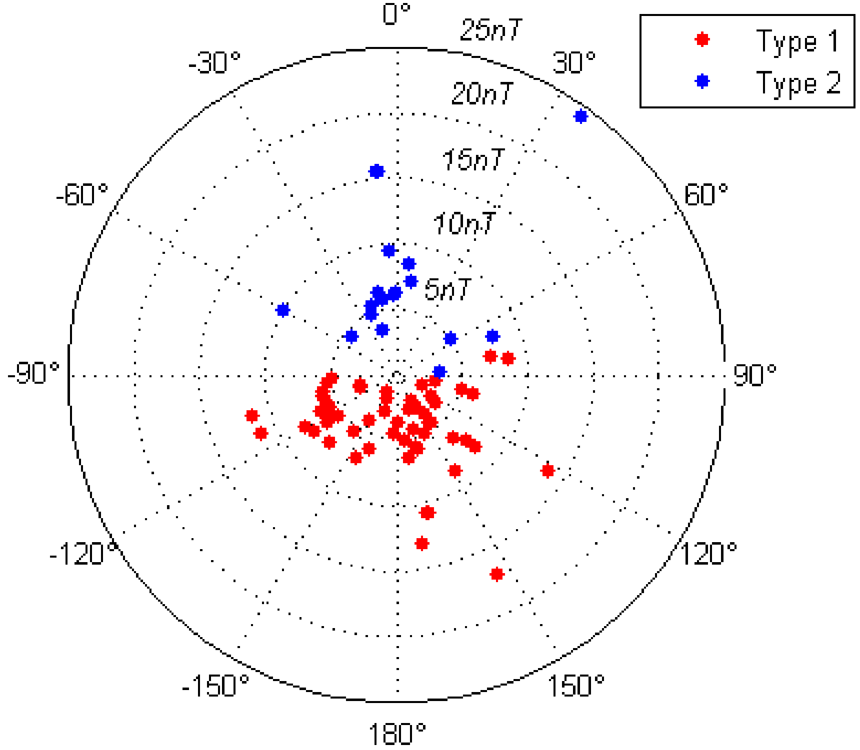
b) Reverse dispersed cusps. Those cusps show dispersions with high-energy ions at high latitudes and lower-energy ions at lower latitude. They are typically expected for northward IMF (lobe reconnection).

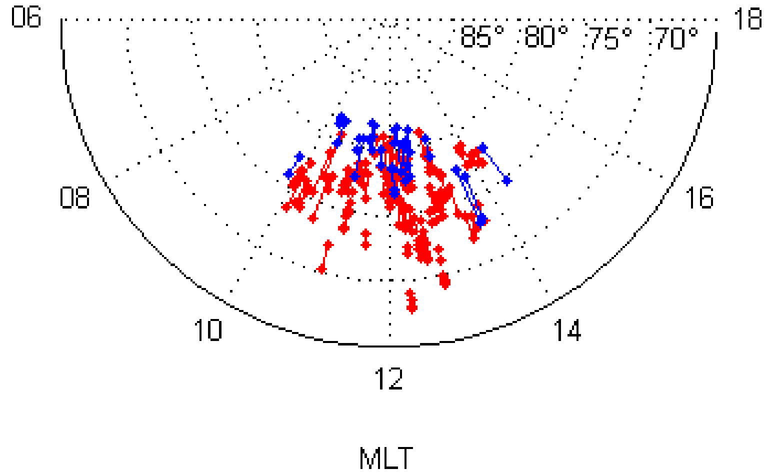
c) Discontinuous cusps. This category will particularly draw our attention, as it is there that we expect cases of double cusps. We define discontinuous cusps as having at least two components in the ion spectrogram, among which at least one clear large-scale dispersion.

d) Irregular cusps. We will consider a cusp crossing as irregular basically when it won't fit in any other categories. A priori, those cusps will be highly variable and structured. We can foresee that they will occur under highly variable IMF.

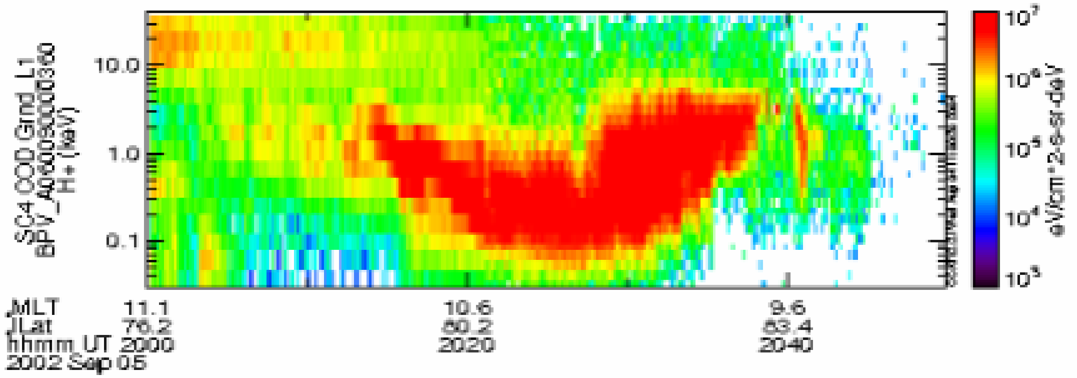
Morphologies (1)

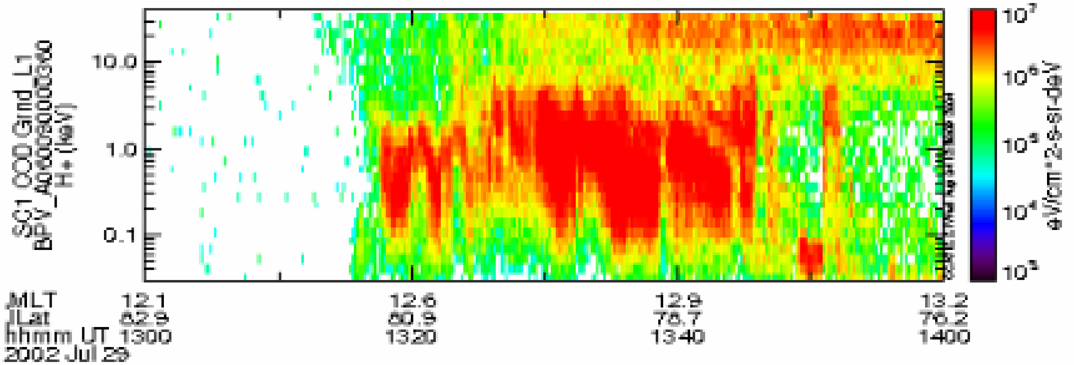




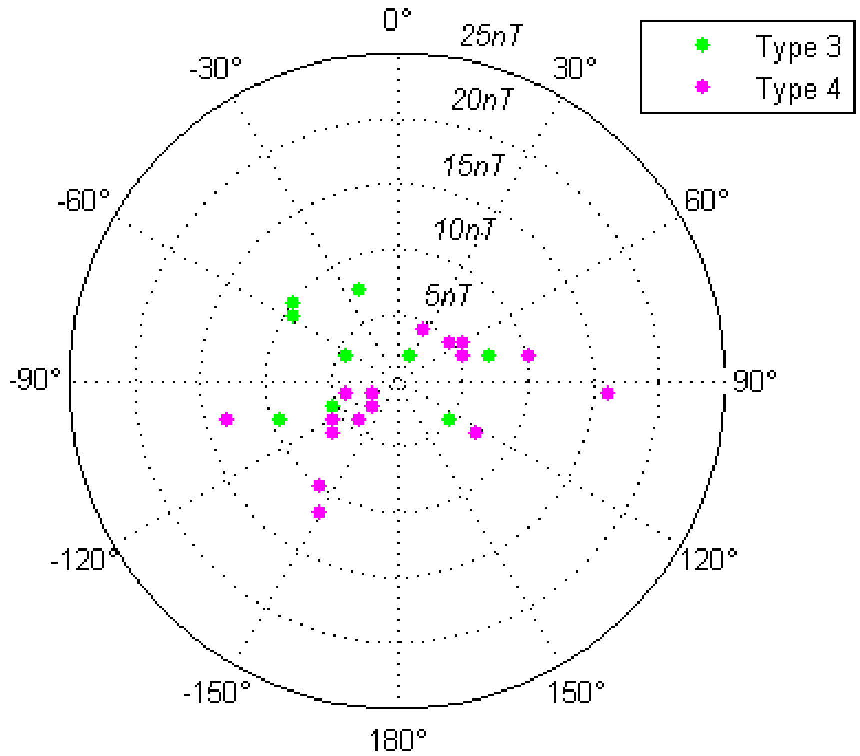


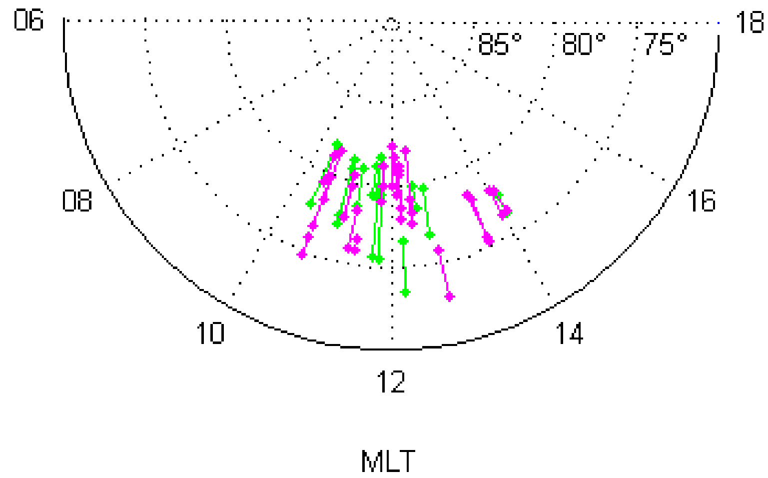
Morphologies (2)



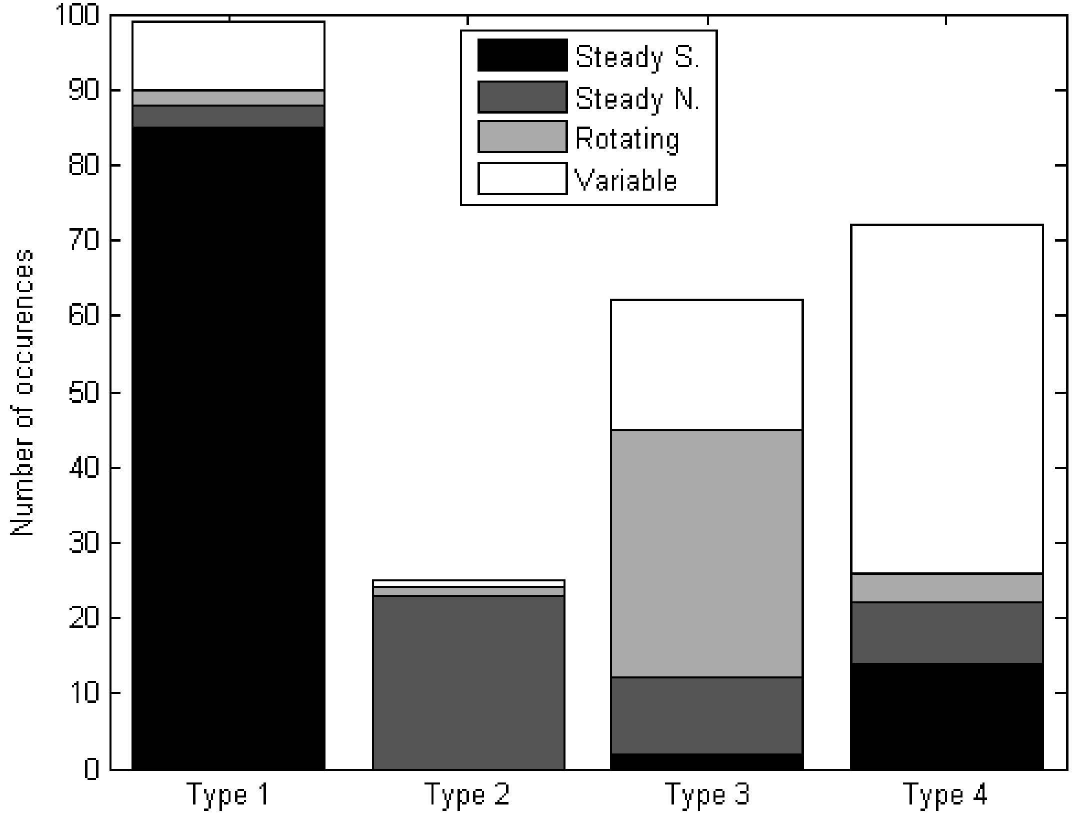


Component reconnexion?

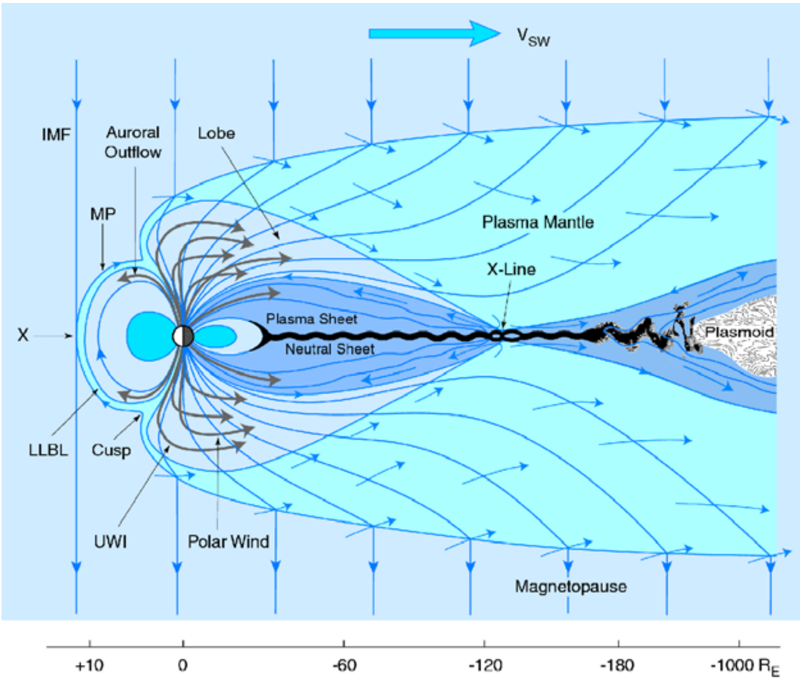


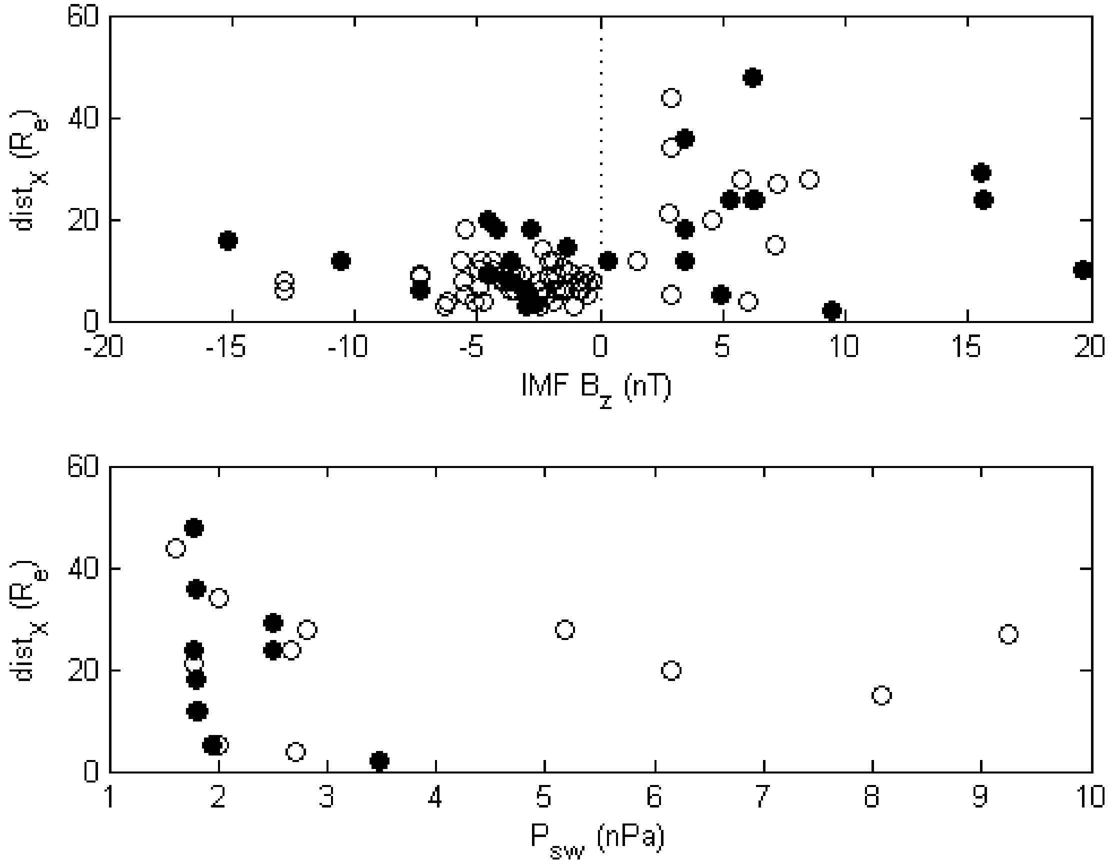


Occurrence of cusp categories and IMF

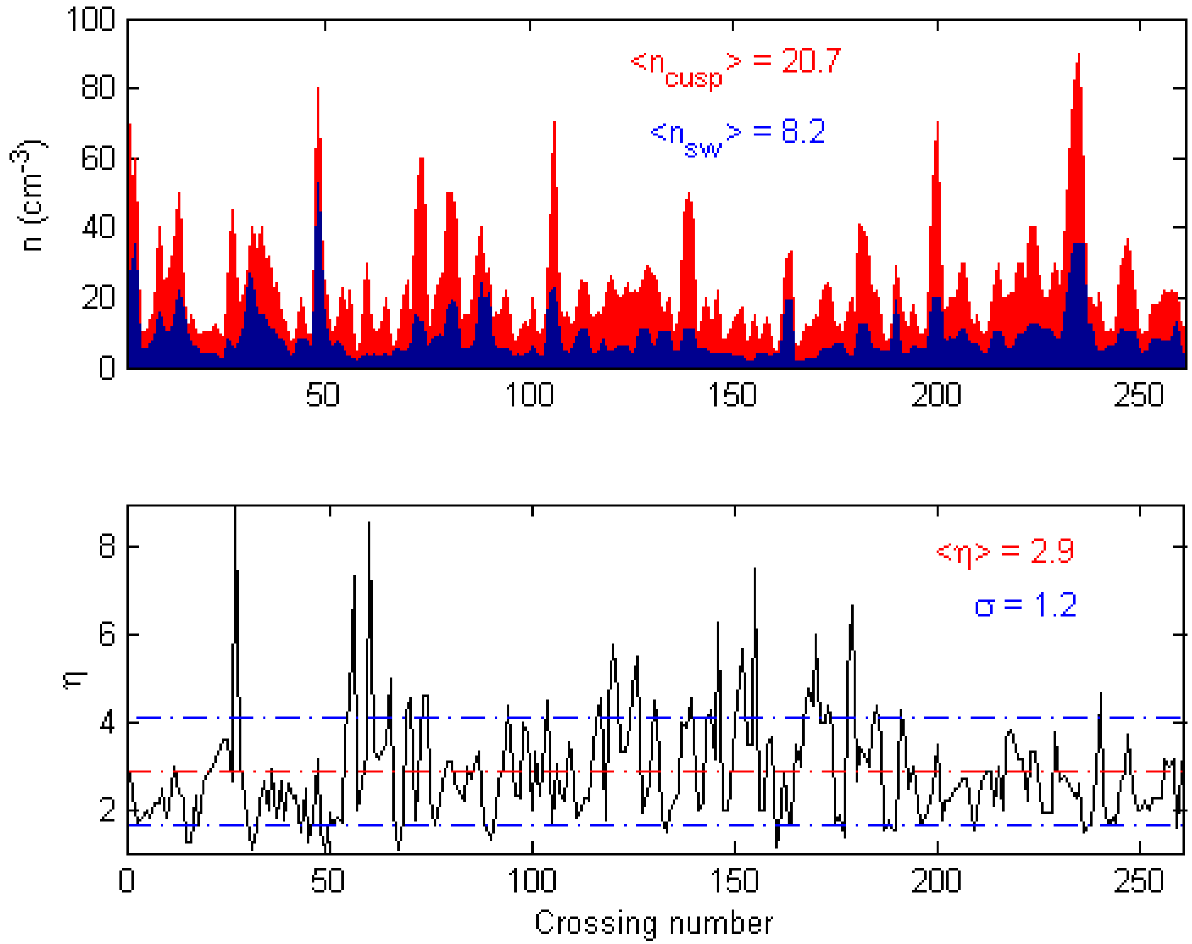


Distance satellite - site de reconnexion





Density in the mid-altitude cusp



Cusp density - IMF effect

- We have also calculated the same average ratio $<\eta> = <d_{cusp}/d_{sw}>$ for northward and southward IMF separately.
- This confirms the common concept that the magnetosphere is more open under negative IMF Bz.

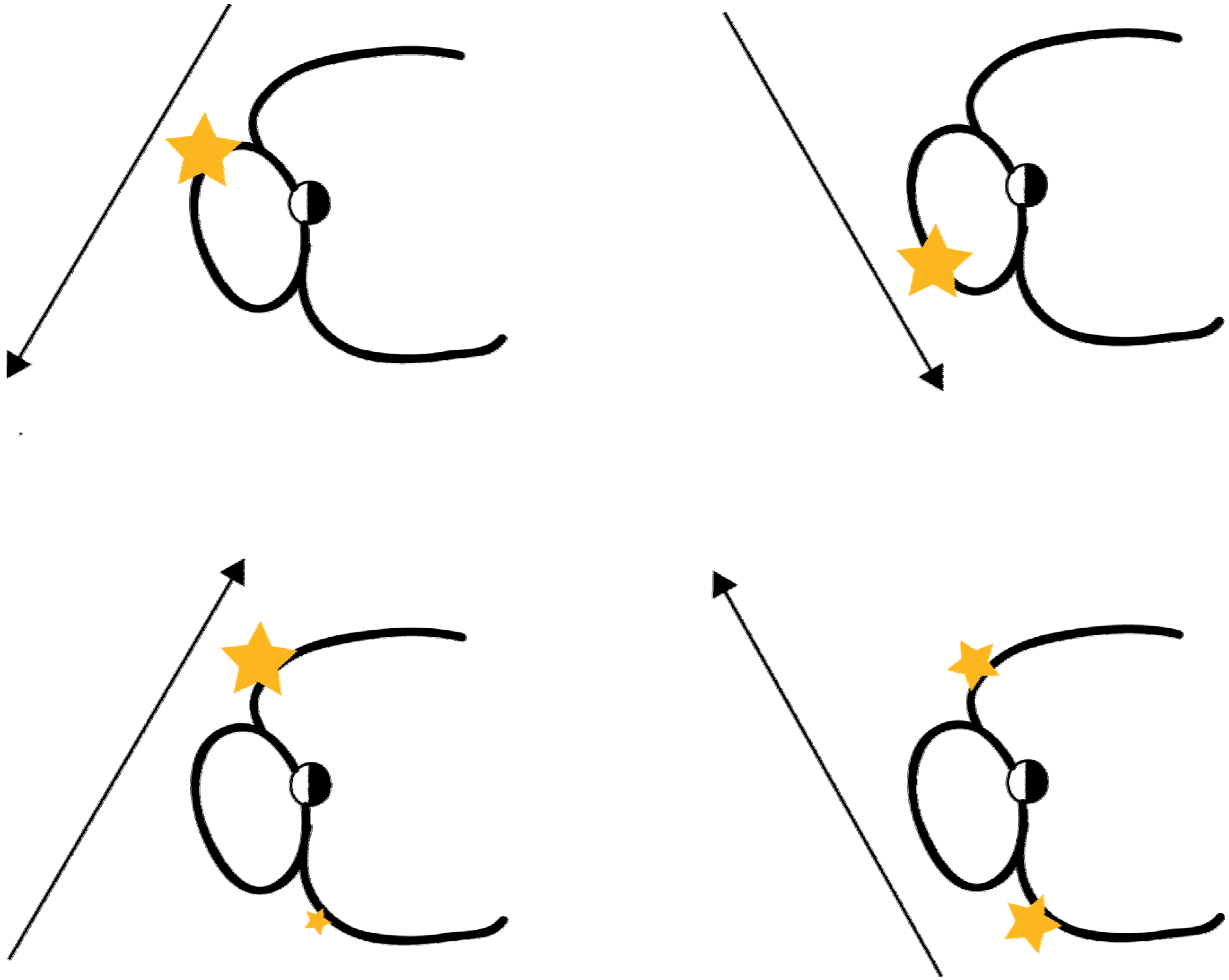
	All IMF	North. IMF	South. IMF
$<d_{cusp}>$	20.7	21.9	19.9
$<\eta>$	2.9	2.5	3.0

Cusp density – hemispheric effect

As predicted by Xue et al. (1997), the summer hemisphere cusp is denser than the winter hemisphere cusp.

	Pre-equinox	Post-equinox
Northern hemisphere	21.8	16.5
Southern hemisphere	20.7	21.2

Density distribution in the two polar cusps - 1



Density distribution in the two polar cusps - 2

	Pre-equinox			Post-equinox		
	$<\eta_{north}>$	$<\eta_{south}>$	α	$<\eta_{north}>$	$<\eta_{south}>$	α
All IMF	3.1 (113)	2.7 (80)	1.16	2.6 (33)	2.9 (35)	0.92
Case 1: $B_z<0$; $B_x>0$	3.6 (24)	3.2 (22)	1.13	2.3 (9)	2.1 (4)	1.11
Case 2: $B_z<0$; $B_x<0$	3.3 (44)	2.3 (10)	1.44	2.3 (7)	2.4 (1)	0.96
Case 3: $B_z>0$; $B_x<0$	2.6 (20)	1,9 (5)	1.37	1.7 (1)	2.9 (7)	0.59
Case 4: $B_z>0$; $B_x>0$	2.4 (5)	2.4 (13)	1.01	2 (1)	2.1 (6)	0.95

Conclusions

- We have performed a statistical study of 4 years (4 times 4 months in fact) of Cluster data in the dayside mid-altitude cusp. We have gathered a weath of informations on the location, the prevailing solar wind conditions and the plasma parameters of the cusp and we have presented a few samples, a few examples of what can be done with the data we have collected.
- We have documented the observations of the mid-altitude cusp as seen by the Cluster fleet (width, duration, altitude, occurence).
- We have studied the cusp morpholgies and found that nicely dispersed cusps are far from being the majority. We took the opportunity to search for double cusps and found possible candidates.
- More importantly maybe, we have been able to draw conclusions on the reconnection process itself by looking at the dynamics of the cusp and its morphologies. Indeed, some features can be explained only by component reconnection.
- A close look at the density distribution in the two hemispheres allowed us to qualitatively conclude on the favored reconnection sites at the magnetopause.