Mid-altitude cusp dynamics and properties during the IMF By dominated intervals

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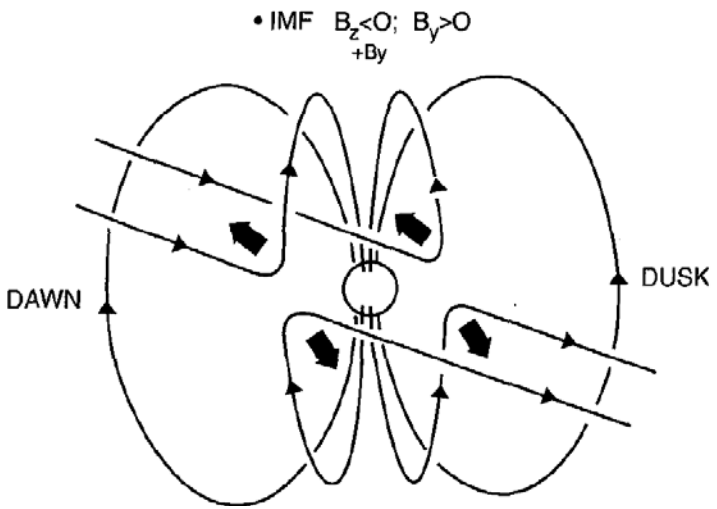
Outline

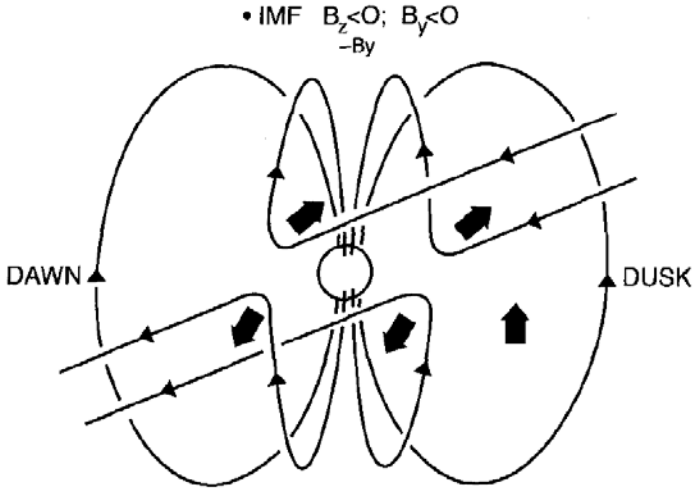
- Motivation
- Overview of cusp longitudinal crossing with dominant IMF By < 0 nT
- Overview of cusp longitudinal crossing with IMF By > 0 nT
- Conclusions

Motivation

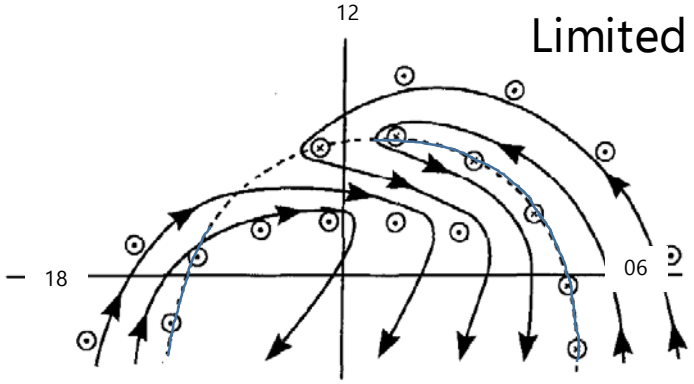
- Cusp is limited in space to 2.5h MLT average and moves in response to IMF By in longitude:
- DMSP observations (*Newell and Meng, 1994)*
- IMAGE observations of auroral proton spot (*Frey et al, 2002, Fuselier et al, 2007)*
- Cluster observations (*Pitout et al, 2006*)
- SuperDARN observations of Pulsed Ionospheric Forms (*Provan et al, 1999*)
- Explained by tilted X–line which maps into ionosphere as 'open magnetopause', forming shifted cusp region with reconnected flux tubes (and hence plasma convection inside the cusp) motion according to the IMF By direction due to tension in magnetic field and solar wind flow (*Gosling et al, 1990; Cowley et al, 1991, Smith and Lockwood, 1996*).

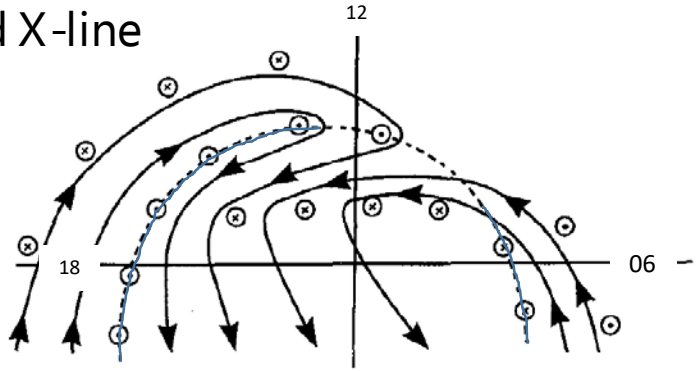
Motivation





Limited in size tilted X-line





IMF By > 0 nT
cusp shifts duskward
plasma convection inside cusp dawnward

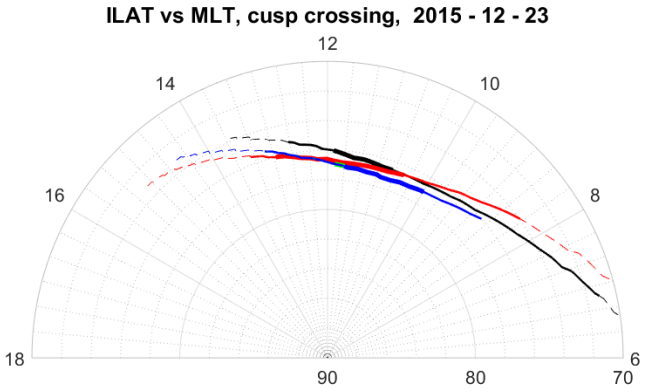
IMF By < 0 nT
cusp shifts dawnward
plasma convection inside cusp duskward

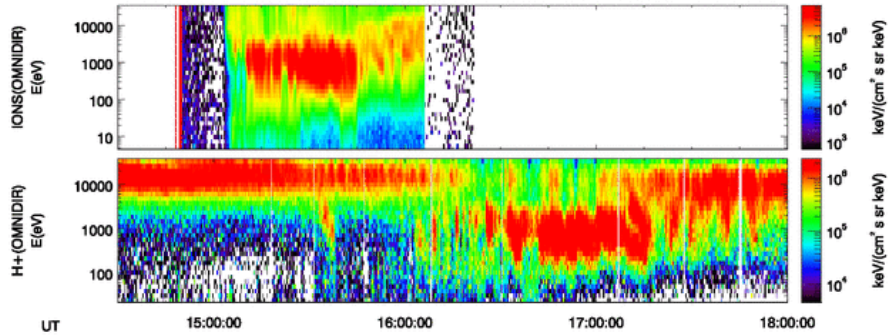
Motivation

- Double cusp structure was observed for dominant IMF By in the DMSP statistical study suggesting that anti-parallel and component reconnection can operate simultaneously (*Wing et al, 2001*). Although as observations were not simultaneous, the question was raised whether this is a spatial structure or temporal structure (*Escoubet at al, 2013*).
- Extended in MLT X-line in MLT, covering both anti-parallel and component reconvention lines (e.g*., Phan et al, 2005, Dunlop et al, 2011*). This suggests that the cusp should be larger than 2.5h MLT and have a complex structure.
- Maximum magnetic shear model – encompassing both tilted X-line and and anti-parallel reconnection sites (e.g., *Trattner et a., 2007, Fuselier et al*, 2007), however for IMF Bz negative it was shown that component reconnection dominates (*Trattner et al, 2007*).
- Limitations of the distant monitoring of the reconnection (e.g., IMAGE only detects the most energetic particles, averaging and fitting data in ground-based measurements, flux of particles from the opposite hemisphere cannot possibly be detected as 'cusp proper' (not energetic enough).
- **Aim:** cusp extension, position, motion, and plasma convection. What we can learn about large-scale reconnection geometry at the magnetopause?

Cusp GI 2015 campaign, large IMF By

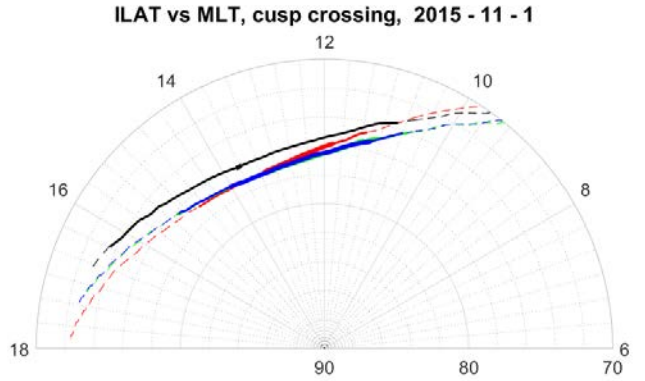
IMF By < 0 nT dominant

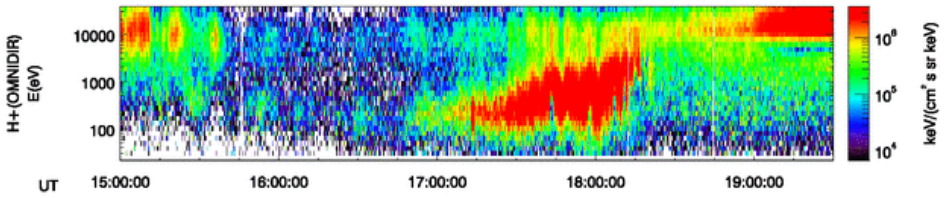




Cluster moved from dayside/post-noon OCB to the pre-noon OCB, both times crossing from/to the plasma sheet.

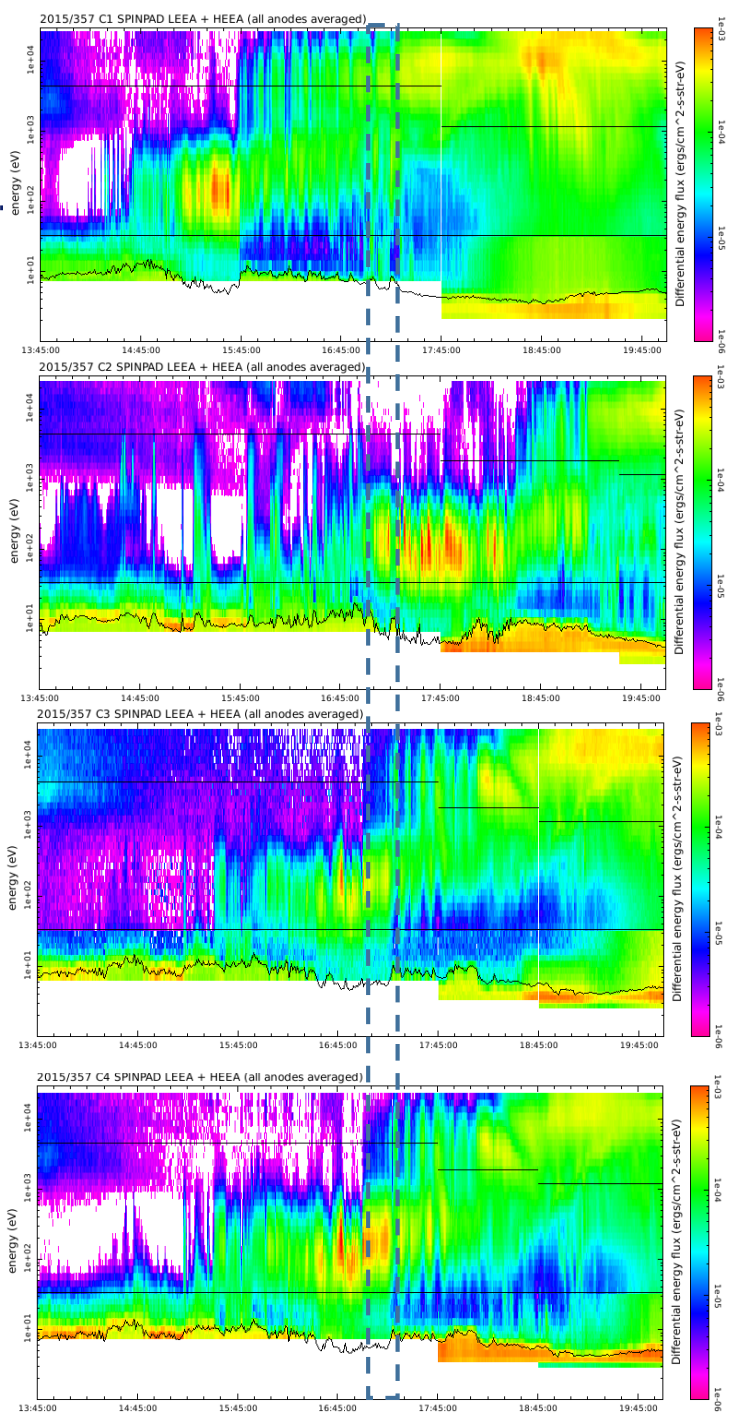
IMF By > 0 nT, By ~Bz

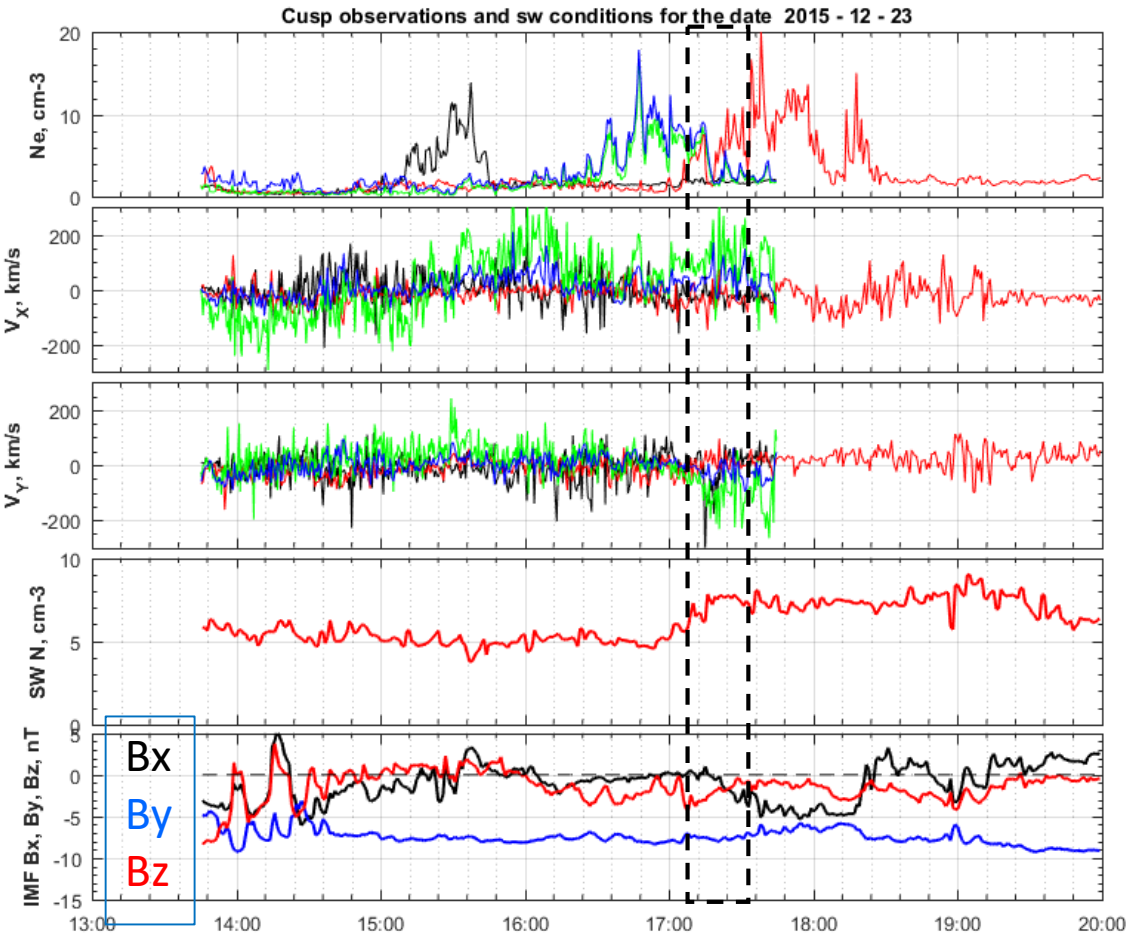




Cluster moves from the polar cap, mantle, cusp, OCB – strong latitudinal component - exits through the equatorward OCB.

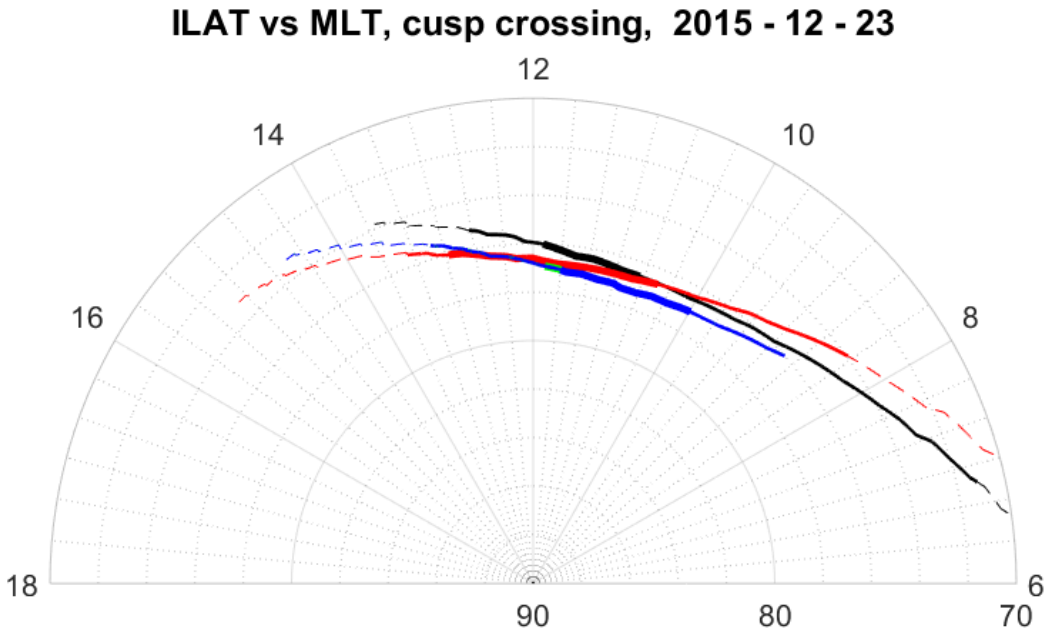
23/12/2015 , IMF By < 0 nT

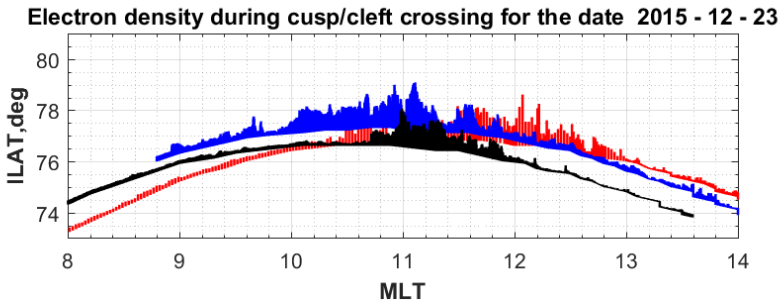




- Dominant IMF By < 0 nT
- Simultaneous cusp: 17:05-17:16 UT

23/12/2015, IMF By < 0 nT



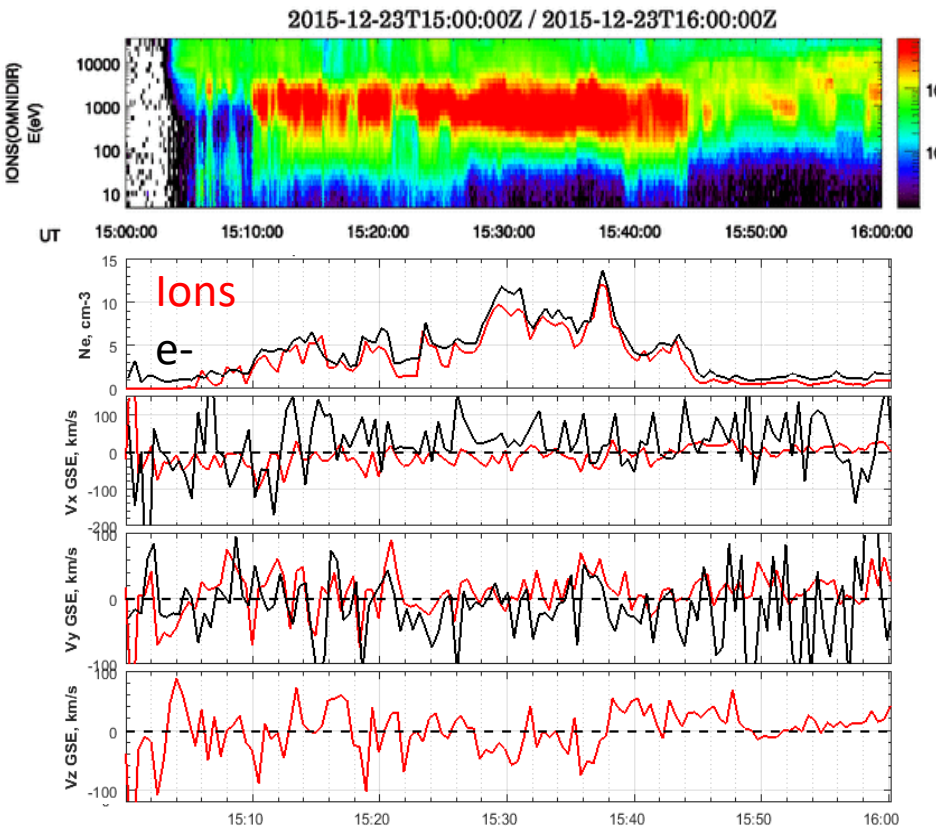


- Cusp shifted towards dawn on SC1 and SC3/4, broader cusp on SC2.
- No consistent motion of cusp boundaries.
- Effects of orbit bias and cusp motion in latitude.

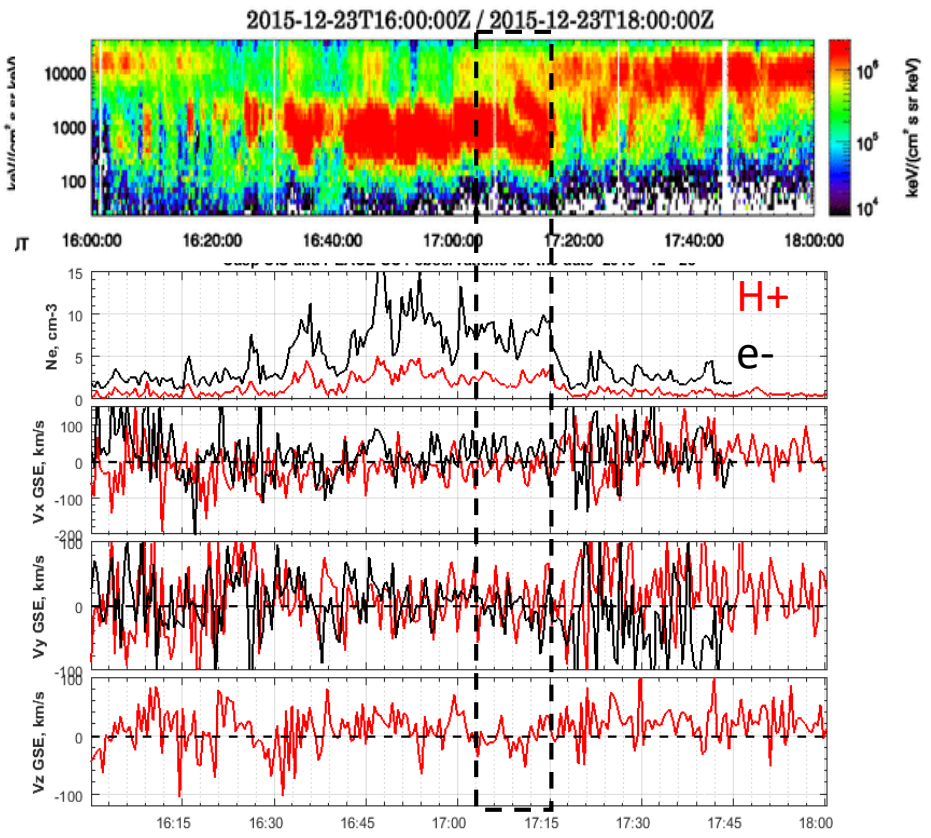
	LLBL in/out		Cusp in/out		Cusp size	Boundaries motion	
	MLT, h	ILAT, deg	MLT, h	ILAT, deg	MLT, h	entry	exit
SC1	12.7 – 6.9	75.2 – 71.2	11.9 – 10.7	76.6 – 76.0	1.2		
SC3/4	13.1 – 8.8	75.4 – 76.0	11.7 – 9.9	77.0 – 77.1	1.8	dawnw.	dawnw.
SC2	13.5 – 8.4	75.3 – 74.0	13.0 – 10.5	76.6 – 76.0	2.5	duskw.	duskw.

23/12/2015, IMF By < 0 nT

SC1 convection

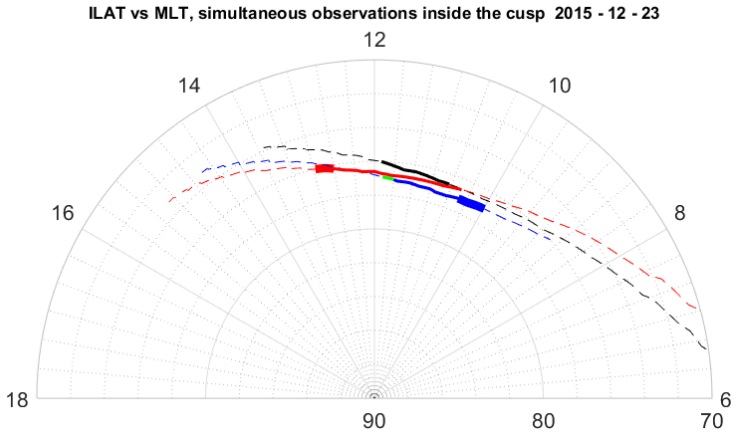


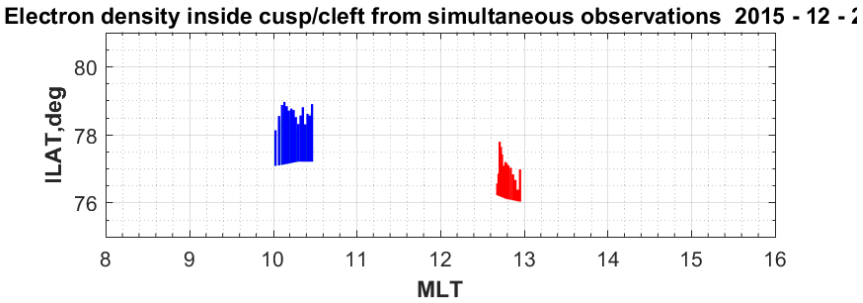
SC4 convection

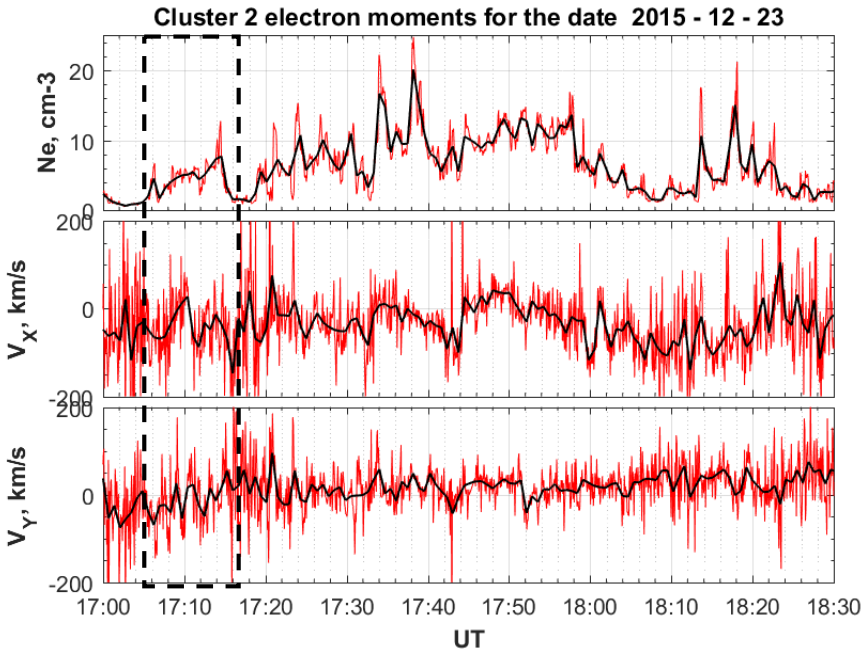


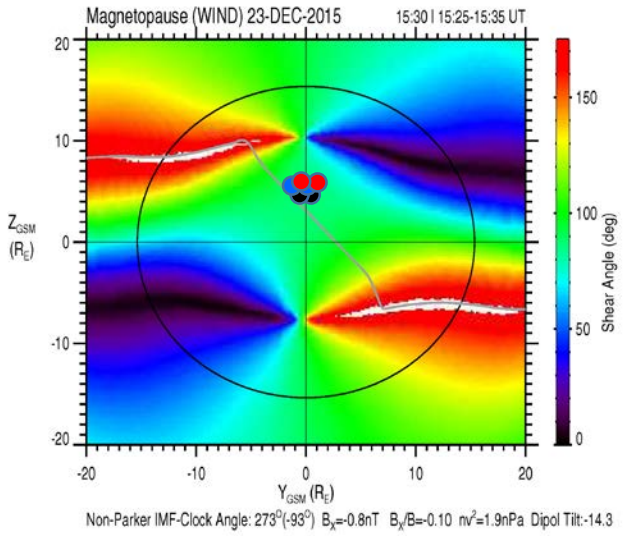
- Not the best agreement between velocities calculated based on ion and electron measurements. Many short-time variations in Vx and Vy.
- SC1: duskward and antisunward convection during injections.
- SC4 (and SC3) – duskward and mainly anti-sunward convection.
- During simultaneous cusp observations between SC2 and SC3&4: duskward and sunward

23/12/2015, IMF By < 0 nT



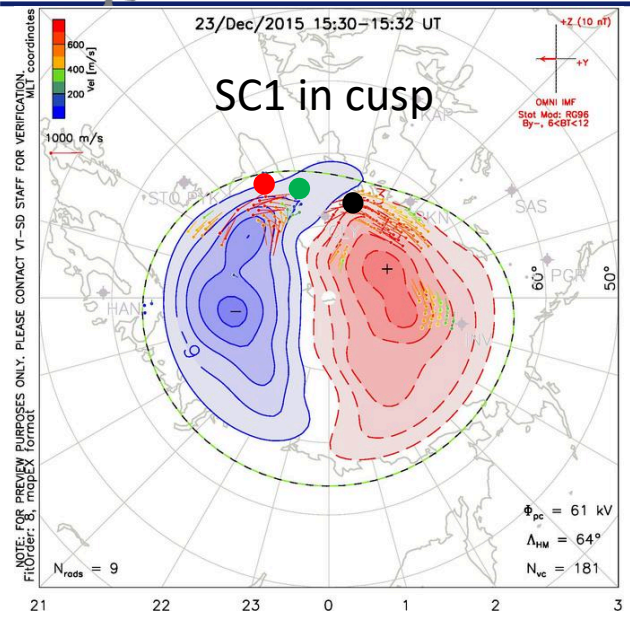


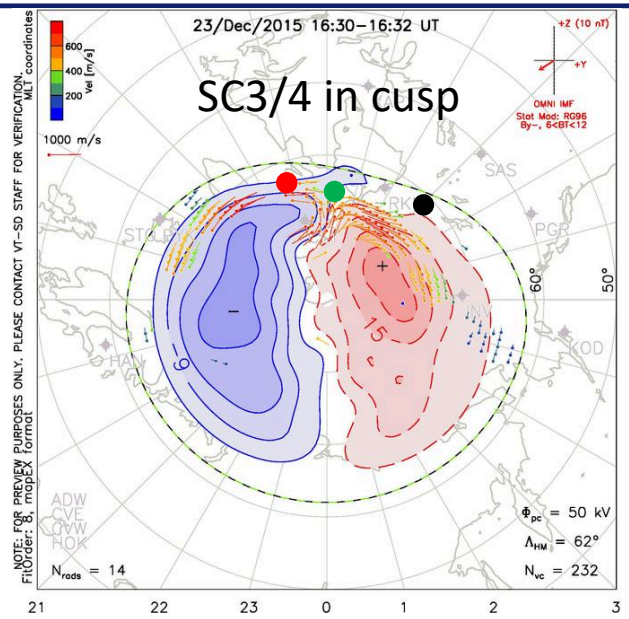


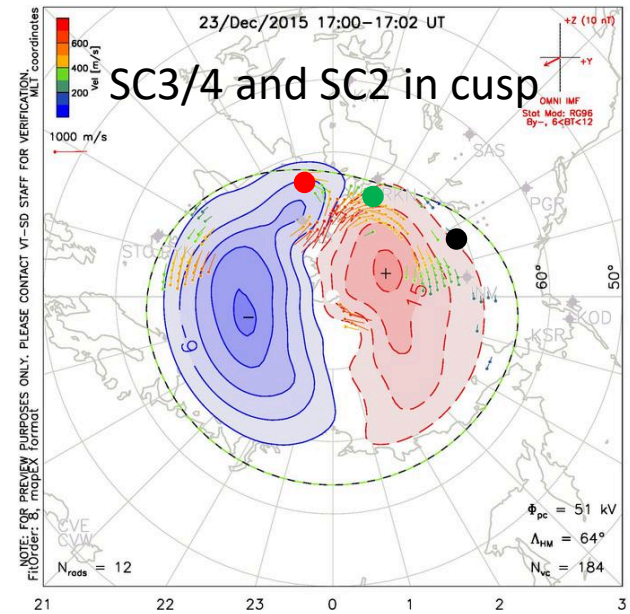


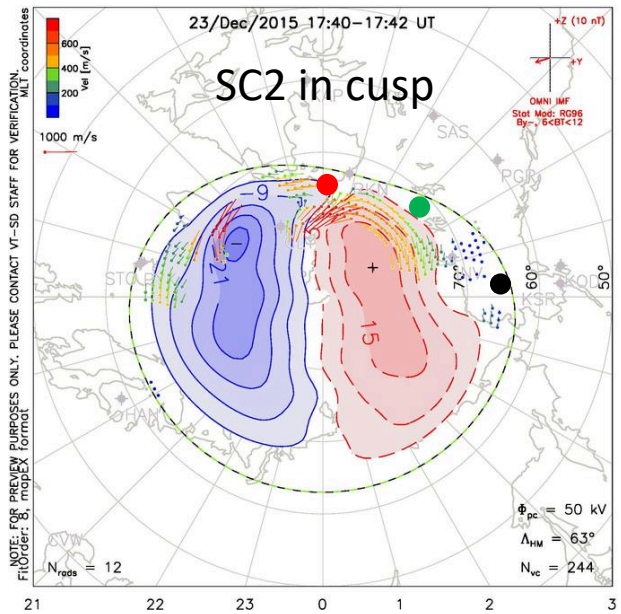
- SC4 exits cusp at 10h MLT, at higher latitude. Vx slightly sunward, Vy positive: from anti-parallel reconnection
- SC2 entering cusp at lower latitude, at ~13h MLT Vx antisunward, Vy dawnward
- Suggestive of double cusp (spatial) structure, simultaneously observed by 3 Cluster SC.
- SC2 Vy dawnward does not agree with expectations

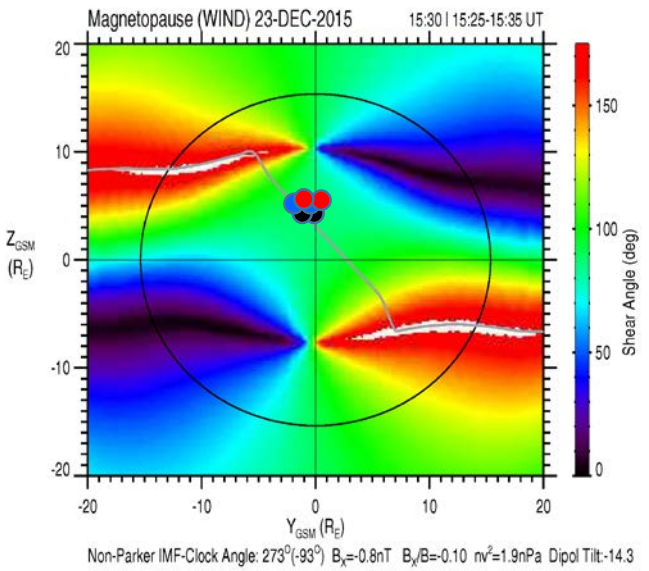
23/12/2015 event, IMF By < 0 nT





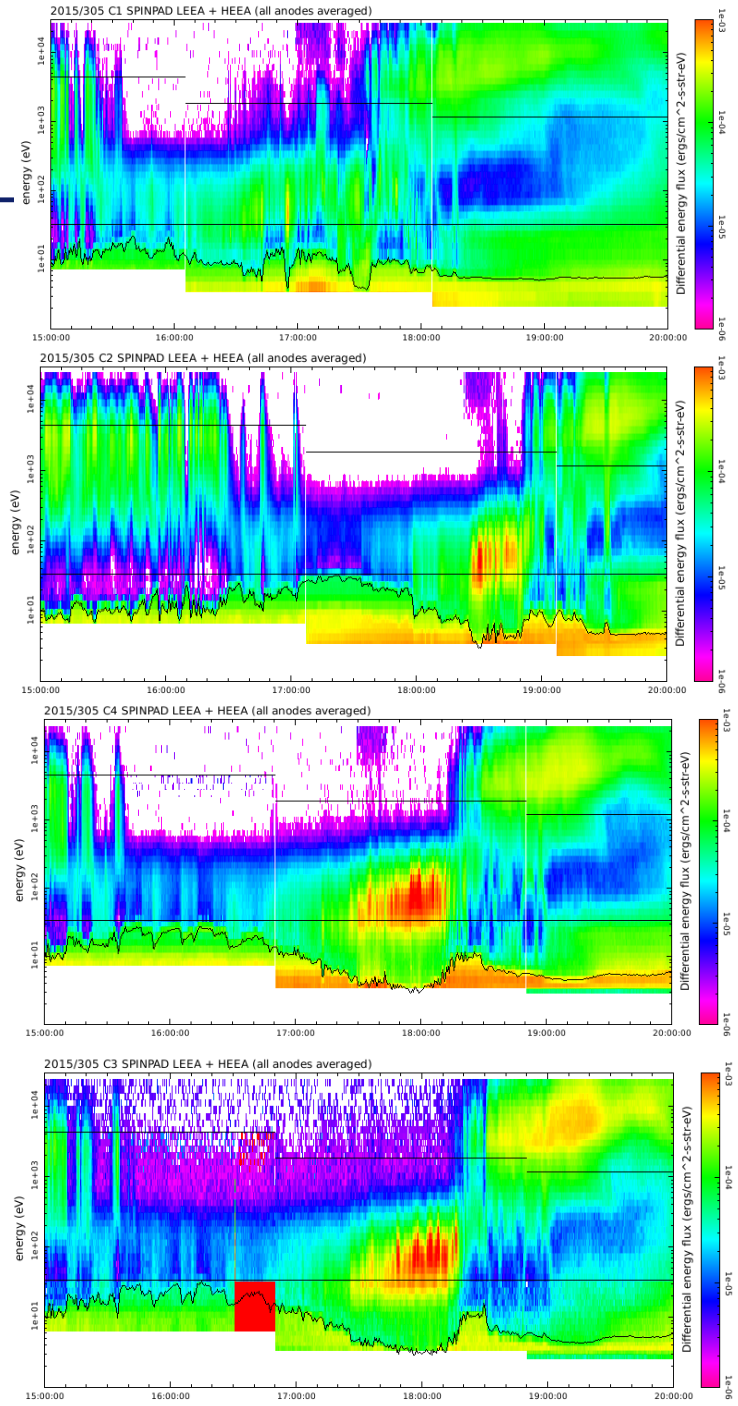


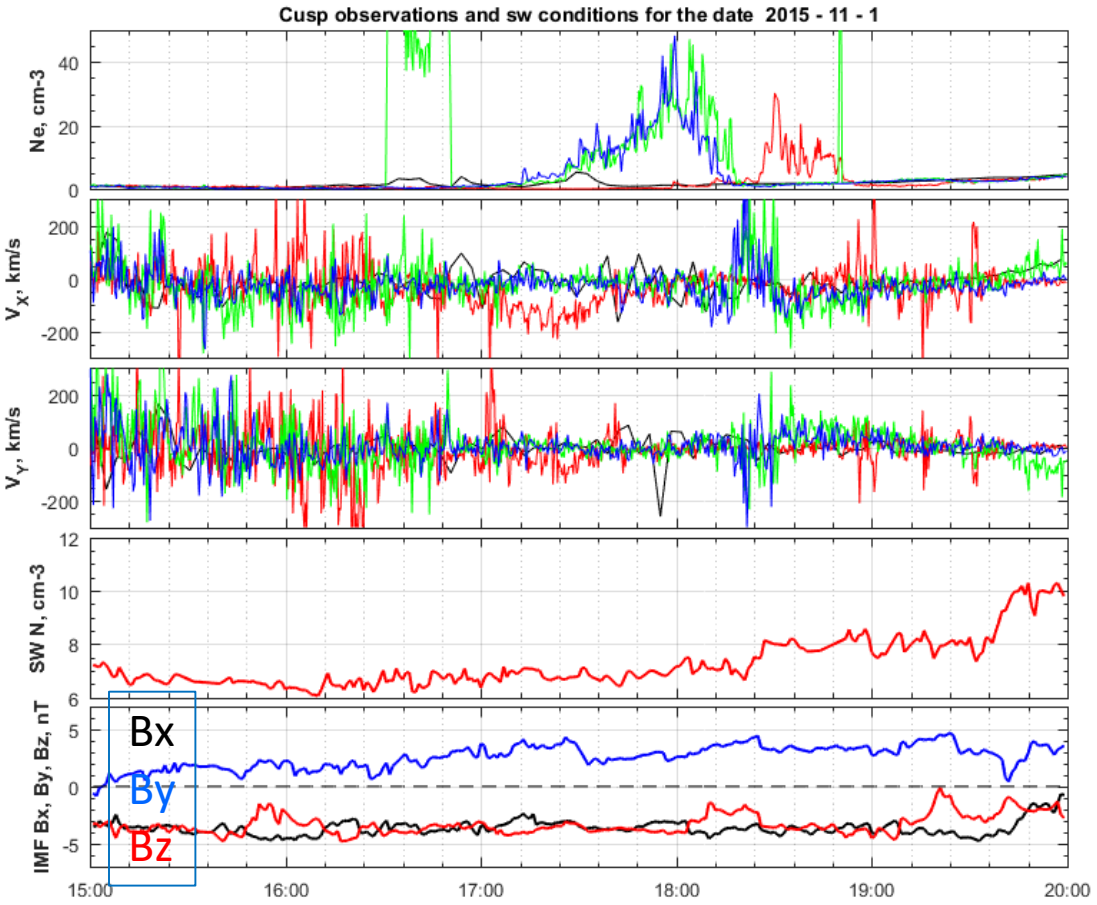




- SC2 enters the cusp at ~13h MLT Vx antisunward, Vy dawnward
- SC2 is close to 'turn-over' point of the dusk convection cell

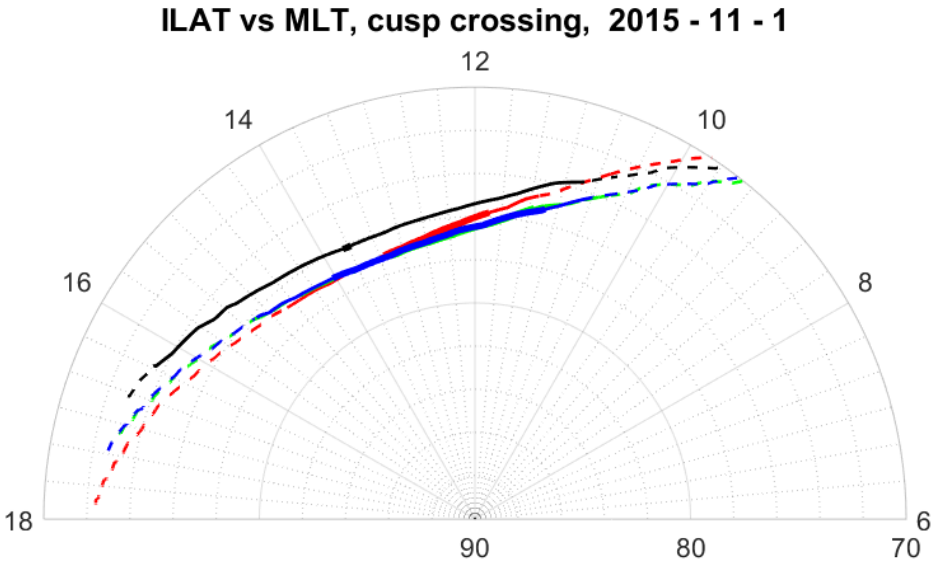
01/11/2015, IMF By > 0 nT

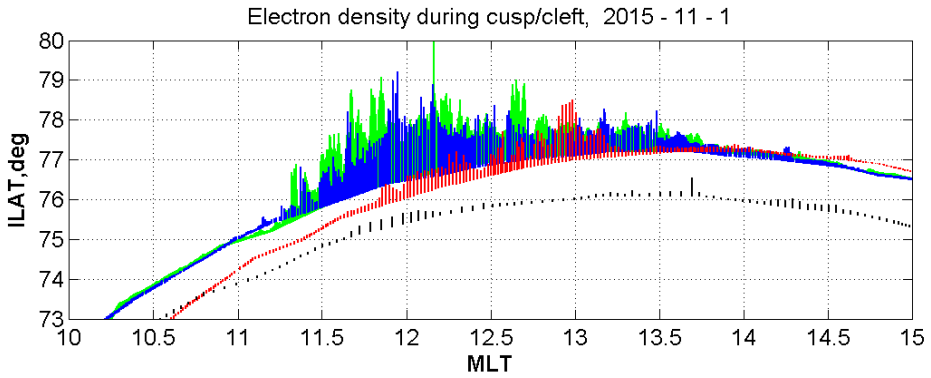




- Stable IMF By ~ Bz, By > 0 nT

01/11/2015 event, IMF By > 0 nT

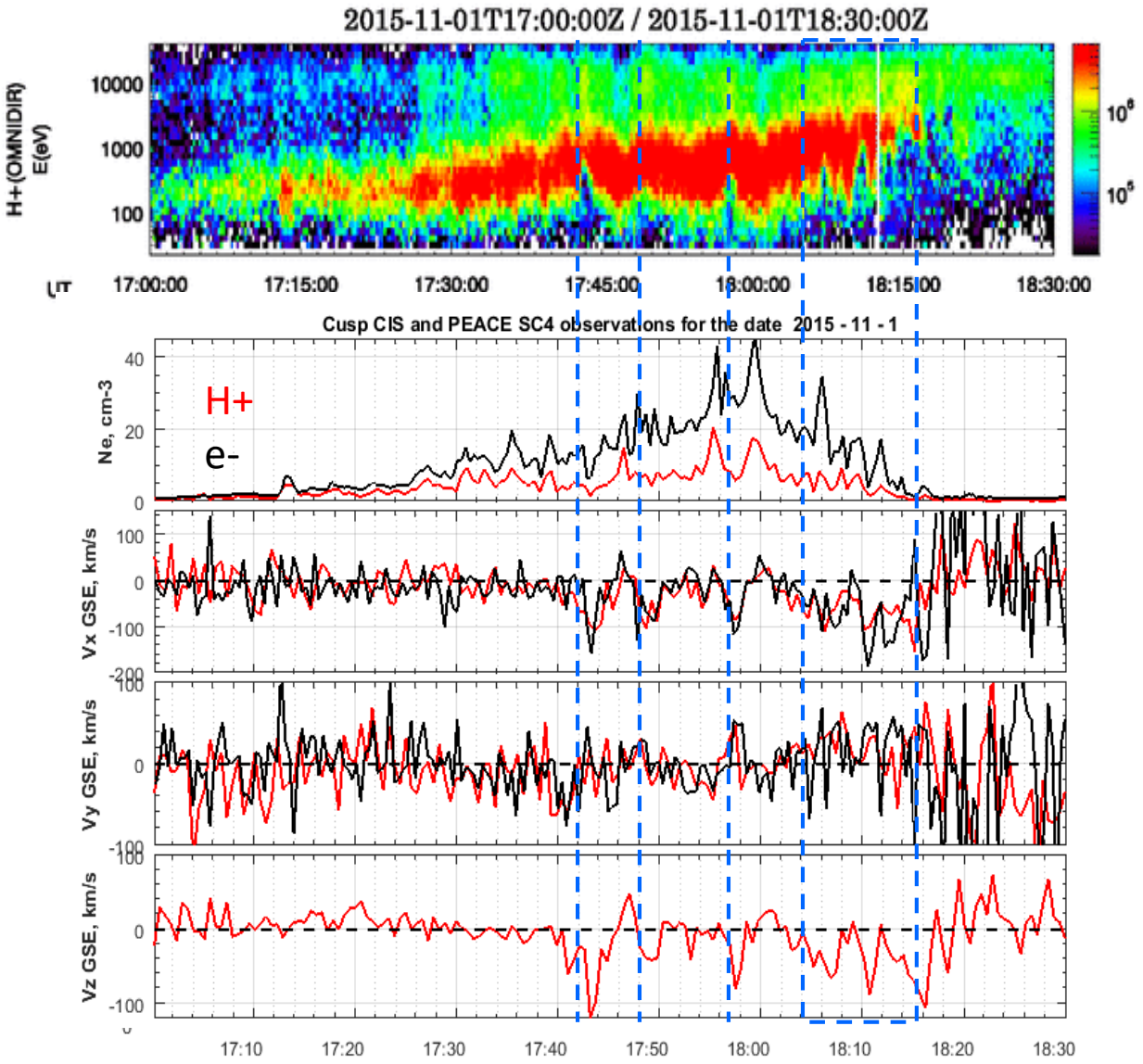




- Cusp is observed shifted duskward
- No consistent motion of the cusp boundaries

	LLBL in/out		Cusp in/out		Cusp size	Boundaries motion	
	MLT, h	ILAT, deg	MLT, h	ILAT, deg	MLT, h		
SC3/SC4	15.2 – 10.6	76.2 – 74.1	13.8 – 11.2	77.2 – 75.3	2.6		
SC2	14.8 – 11.3	76.9 – 74.8	13.2 – 11.8	77.1 – 75.8	1.4	dawnw.	duskw.

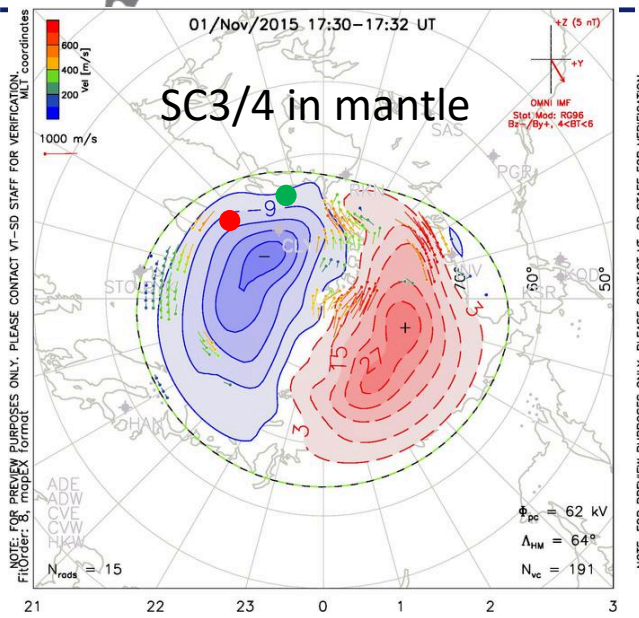
01/11/2015, IMF By > 0 nT

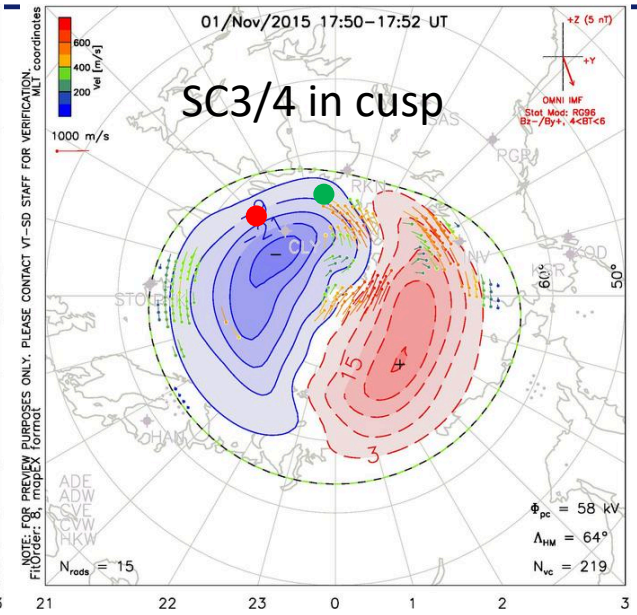


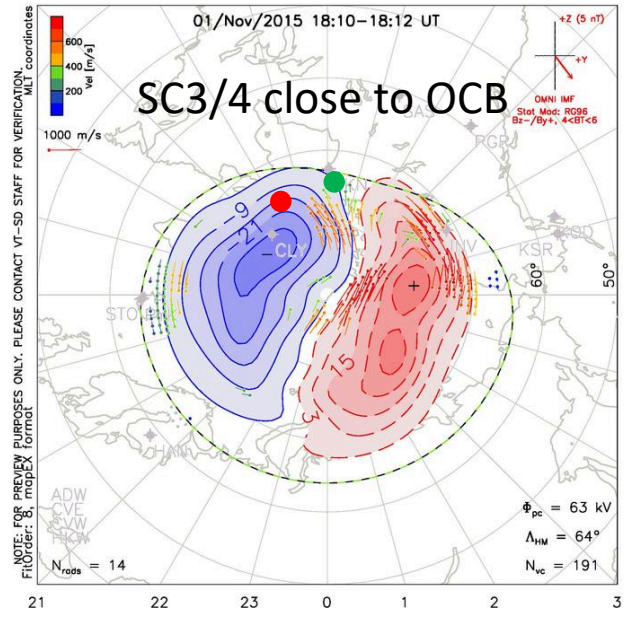
SC4 (SC3):

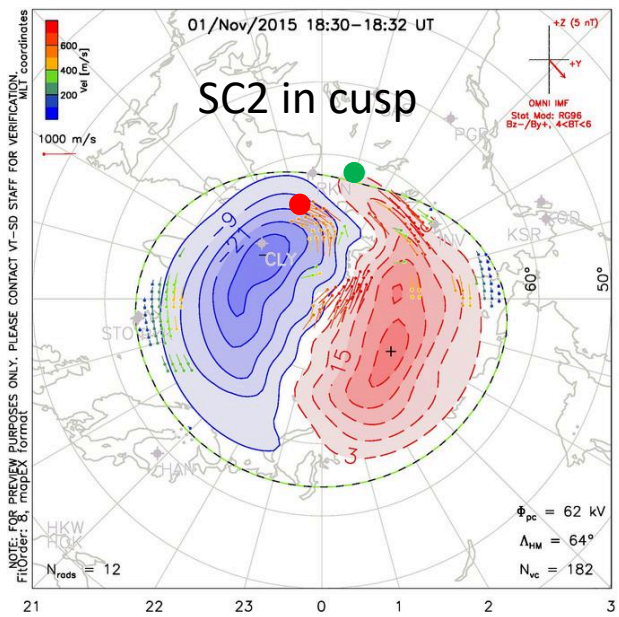
- In the main cusp separate flux tubes: anti-sunward and duskward convection at the start, relaxing into very low convection slightly dawnward convection with time.
- Closer to the OCB: antisunward and duskward convection.
- Bursts of duskward convection do not agree with the model expectations.

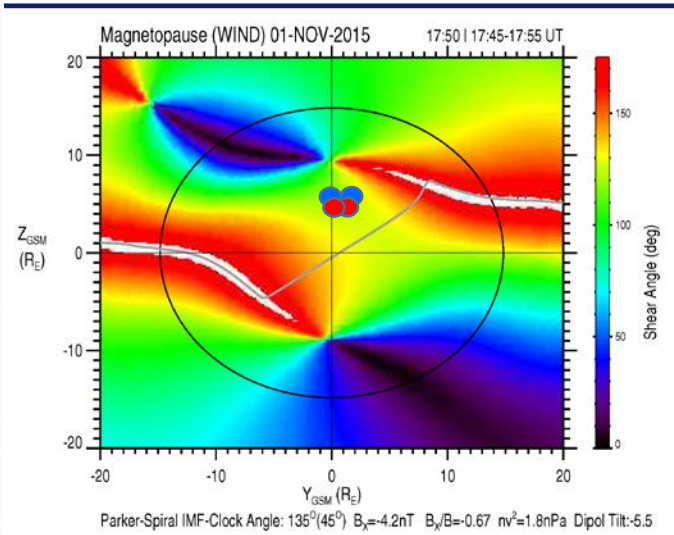
01/11/2015, IMF By > 0 nT











- SC3/4: crossing through separate flux tubes, anti-sunward and duskward convection at the start, relaxing into very low convection slightly dawnward .
- No agreement with SuperDARN (although not much data at the Cluster footprints)
- Close to the turn –over point of dusk convection cell.

Conclusions

- Cusp was limited in size and was shifted around the noon according to the IMF By in agreement with previous studies. In this study: possible effect of the orbit, and possibly only partial cusp was observed.
- No clear motion of the duskward and dawnward boundaries in agreement with the expected IMF By.
- For the case with strong IMF By Cluster observations were suggestive of double cusp spatial structure, with one cusp region locating at higher latitude and another cusp at lower latitude, formed by different reconnection processes simultaneously.
- Plasma convection inside the cusp did not always agree with the expected convection governed by IMF By:
  - For the case with strong IMF By negative, opposite to expected convection was observed at the turn-over point of dusk convection cell.
  - For the case with IMF By/Bz comparable and By positive, a complex convection was observed inside the cusp, flux tubes moved antisunward and duskward at the start and then downward with time.
- These observations are suggestive of complex reconnection geometry at the dayside magnetopause or/and oscillating magnetosphere/OCB due to ULF wave activity.