Where's the Cusp?

Thirty Years of Real and Imaginary Aeronomical Signatures of the Magnetospheric Cusp

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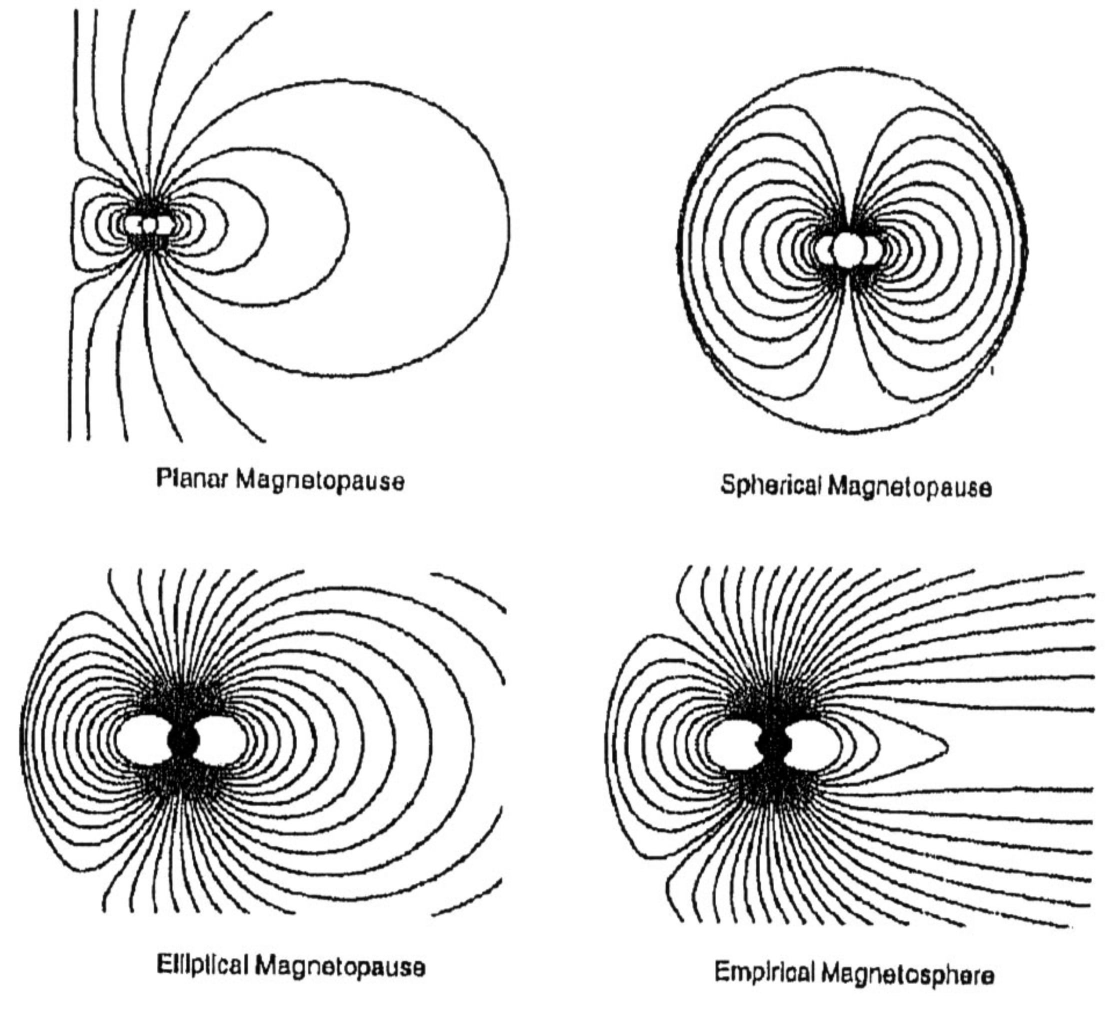
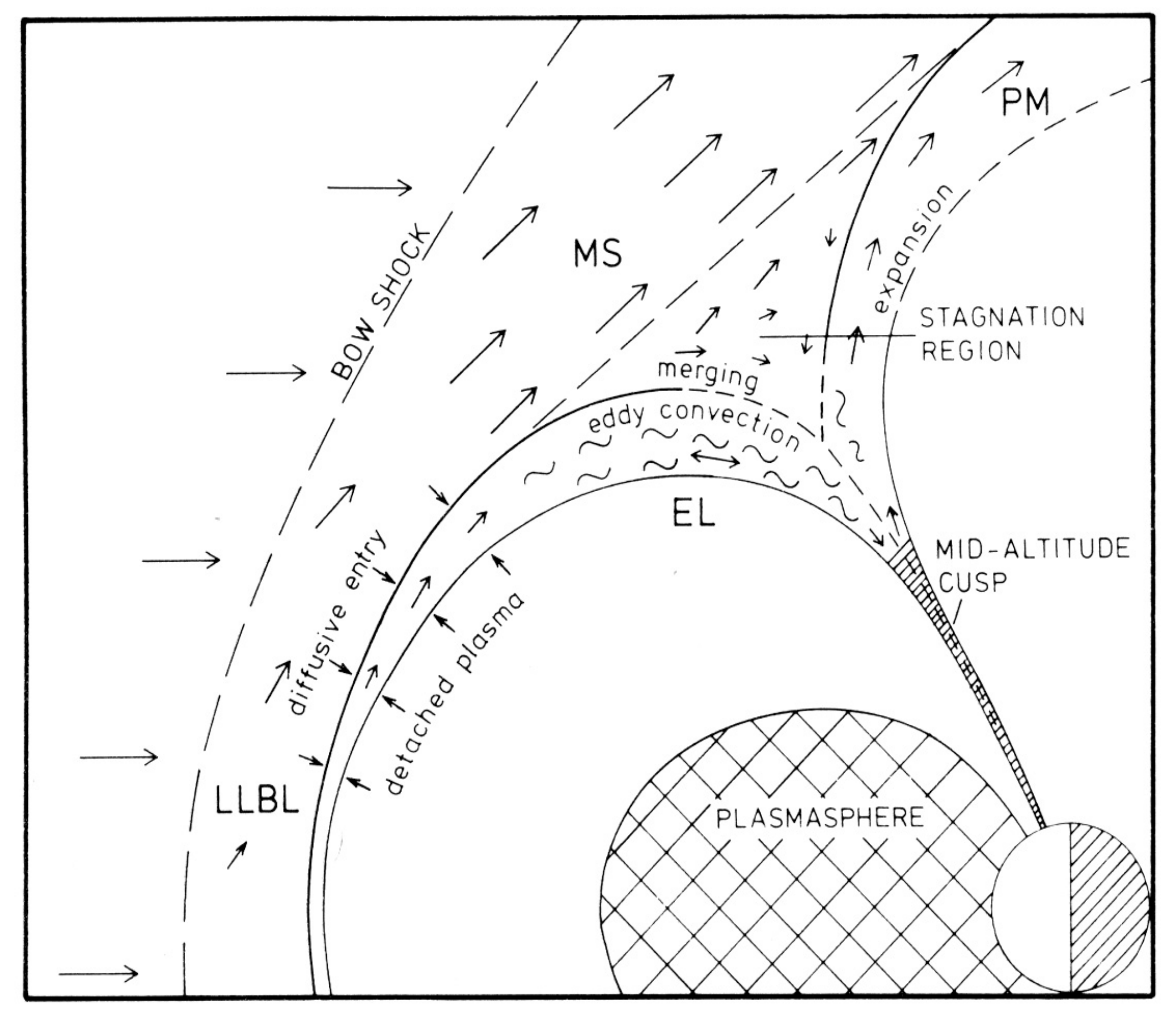
Magnetospheric Cusps

- Cusps were expected from Chapman and Ferraro image dipole model (1931).



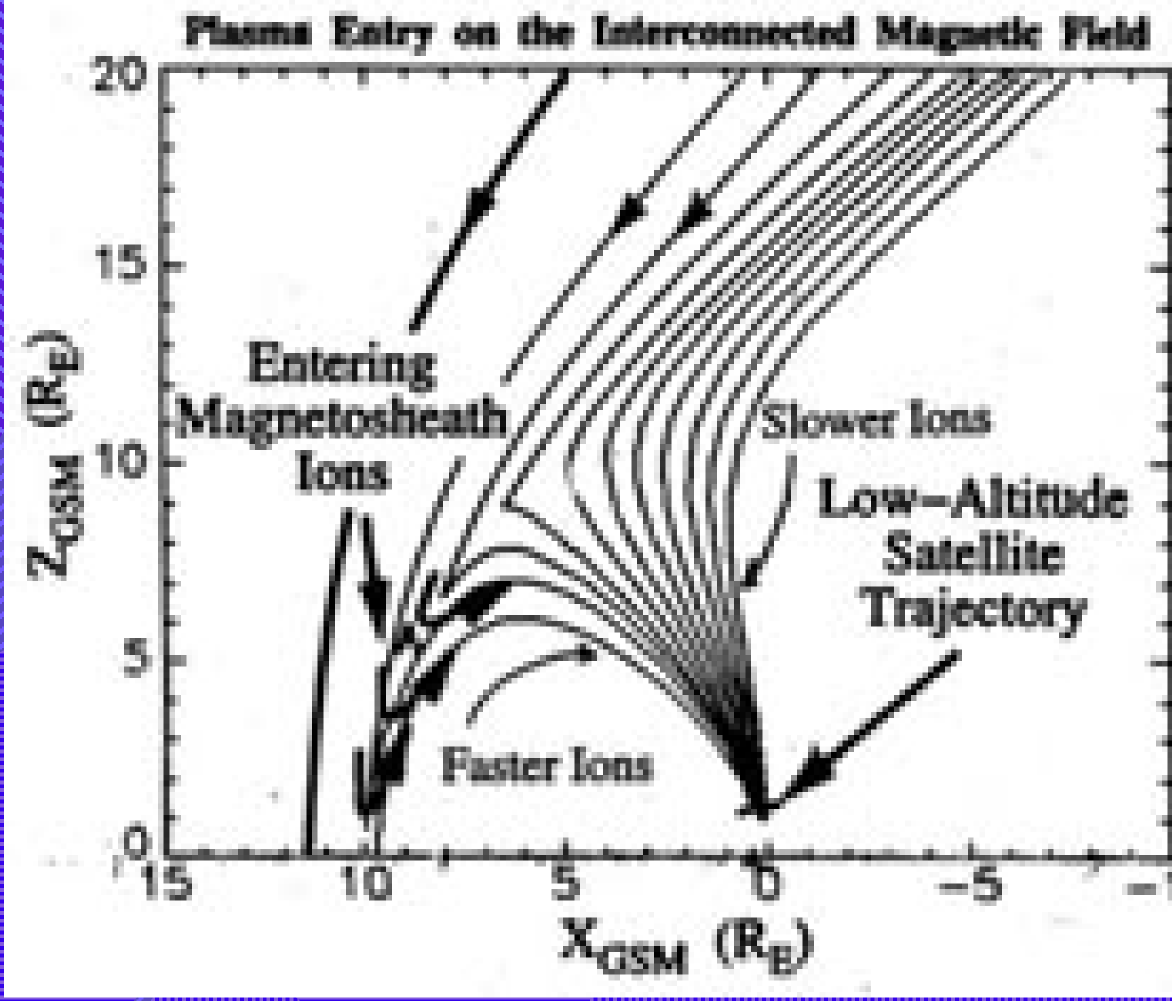
Magnetospheric Cusps

- Thought of as a chimney to the solar wind with direct access of particles to the ionosphere.
- Strictly speaking, then, there is no ionospheric signature of this cusp.



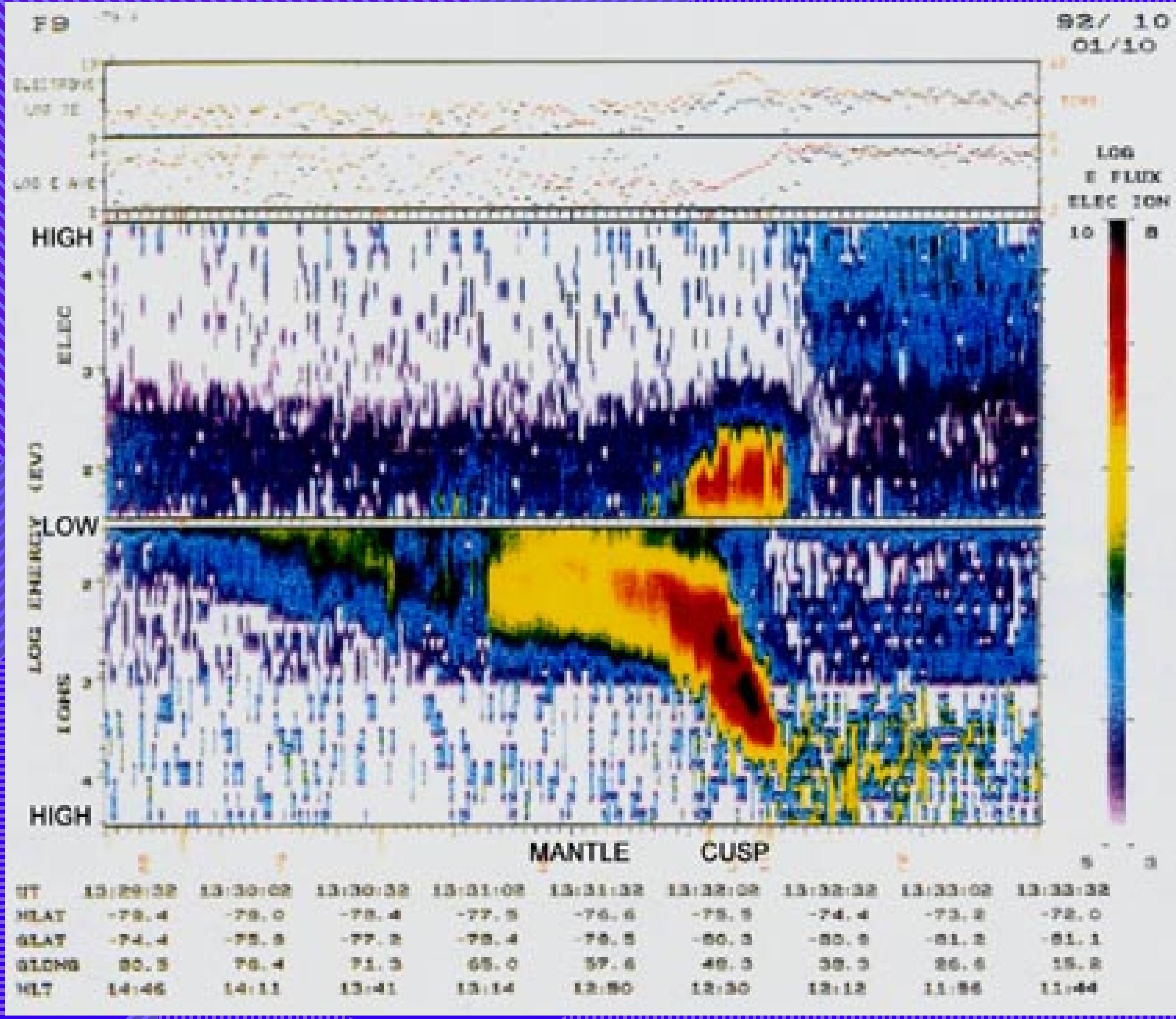
High Altitude Satellite Cusp

- Paschmann, et al. and Russell, et al. observed dispersion of low energy ions associated with the high altitude cusp and mantle.



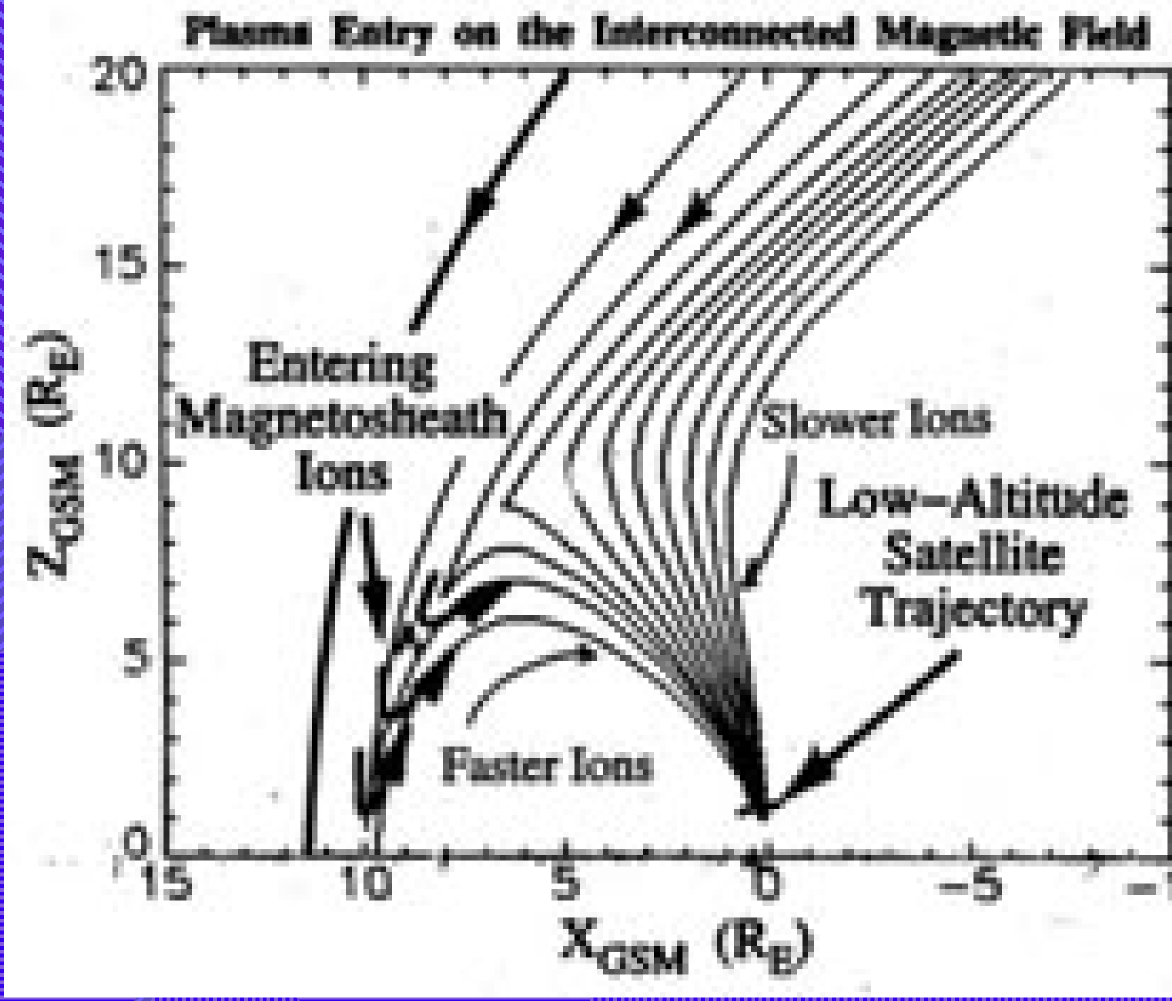
Low Altitude Satellite Cusp

- The DMSP satellite (835km altitude observed ion energy dispersion in the cusp and in the mantle.
- Discrete electron arcs are also observed in the cusp and mantle

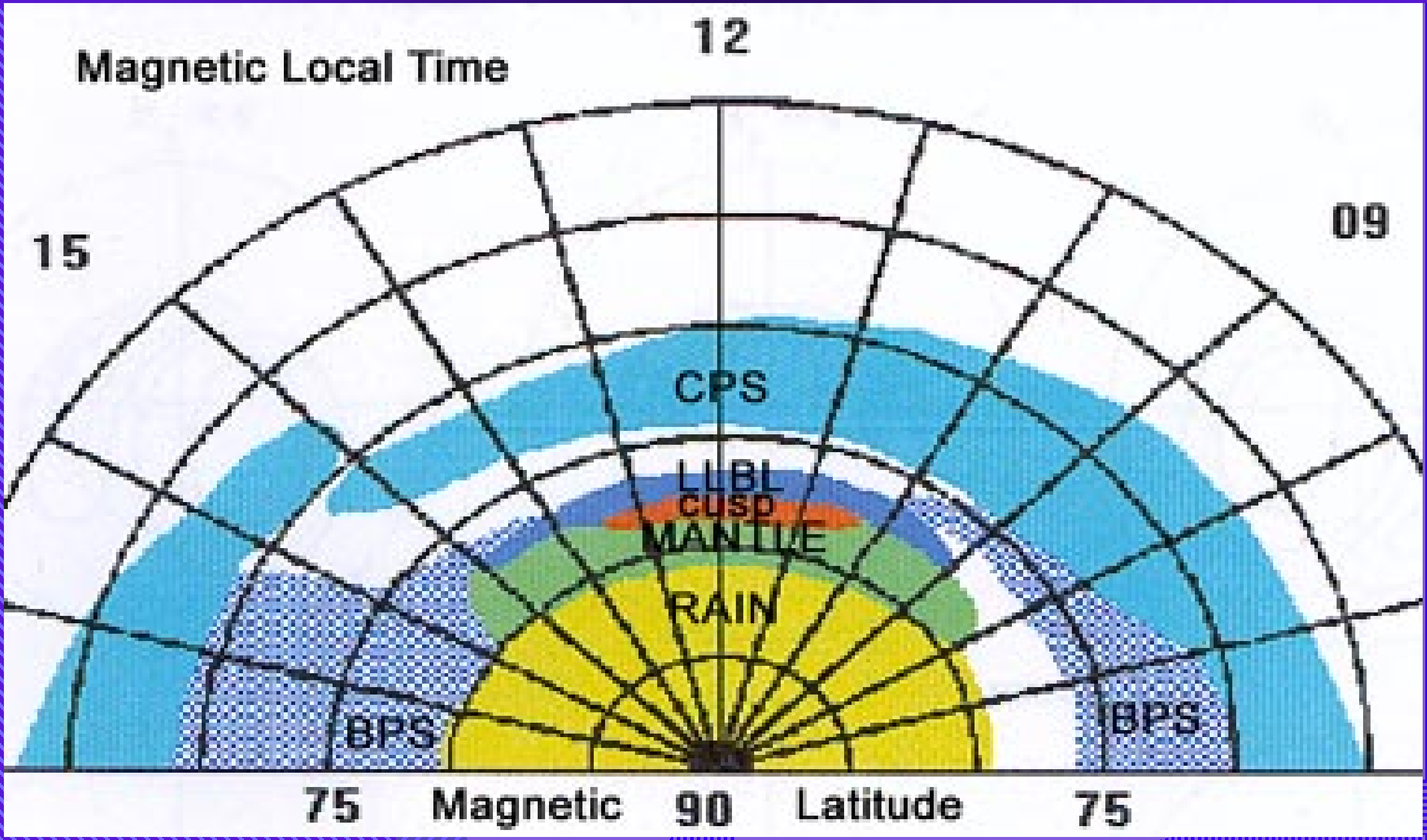


Low Altitude Satellite Cusp

- The merging process results in magnetosheath ions accelerated in the cusp.
- Ions leak out in mantle.
- Ion energy is inversely proportional to latitude.
- Electrons precipitate in the same two regions, but they are too fast for dispersion, and are accelerated by another process, dependent on the conductivity of the ionosphere.



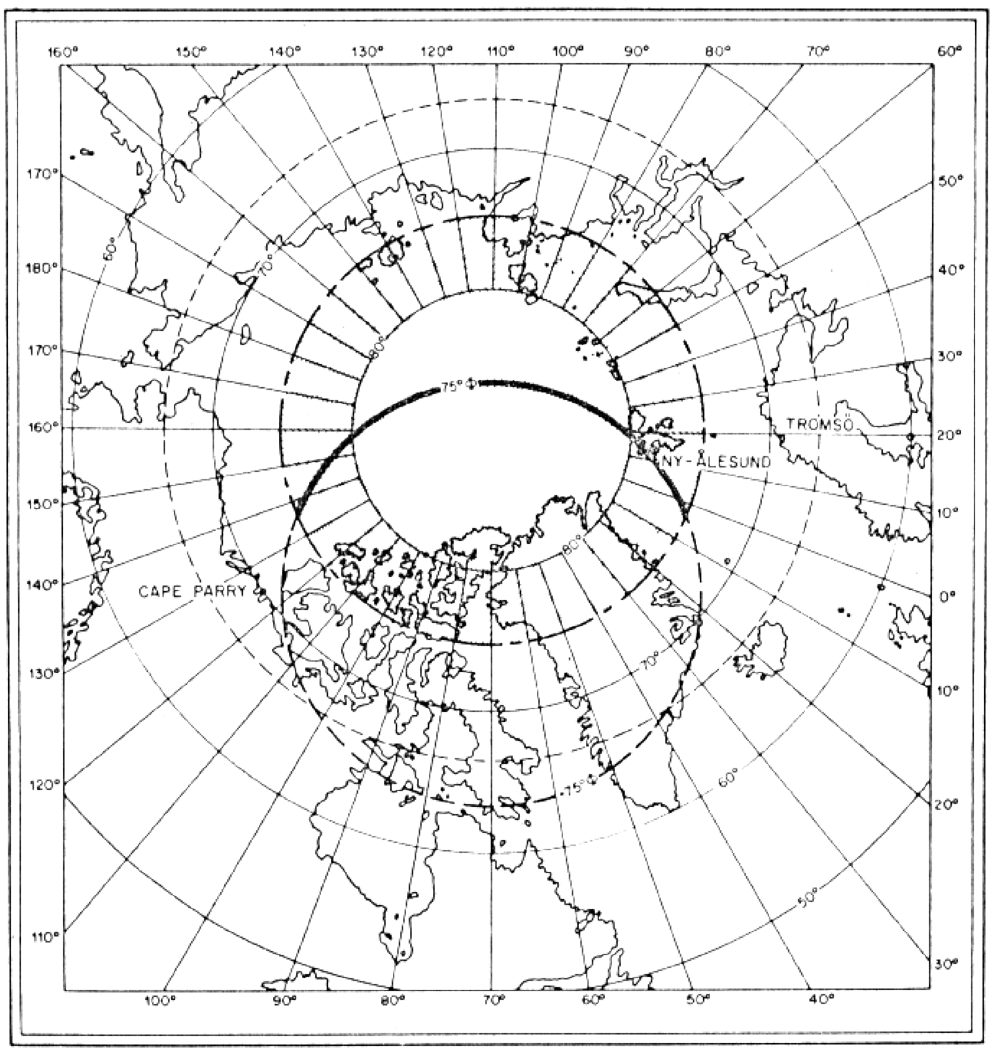
Low Altitude Satellite Cusp



- Approximately three hours wide.

Cusp from the Ground

- Aircraft measurements of dayside aurora in late 1960s observed low energy electrons (high 6300 A/ 5577 A emission ratio.
- Ground-based measurements of the ionospheric signatures of the cusp in the 1970s (ionosondes Cape Perry, optical Svalbard).



Nightside/Dayside Aurora

- Equatorward boundary of dayside aurora inversely proportional to AE.
- Dayside Lat. Controlled by Nightside current system?

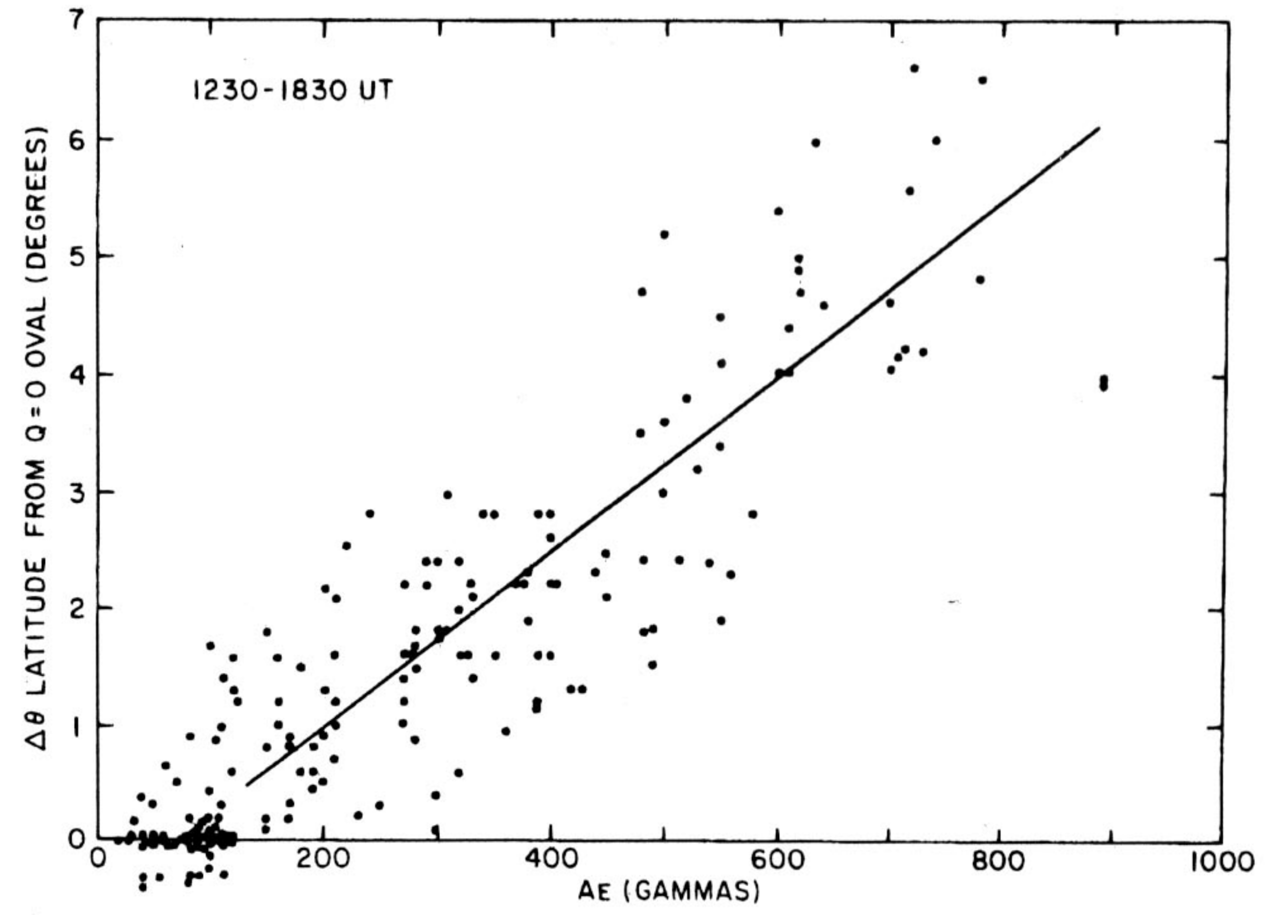
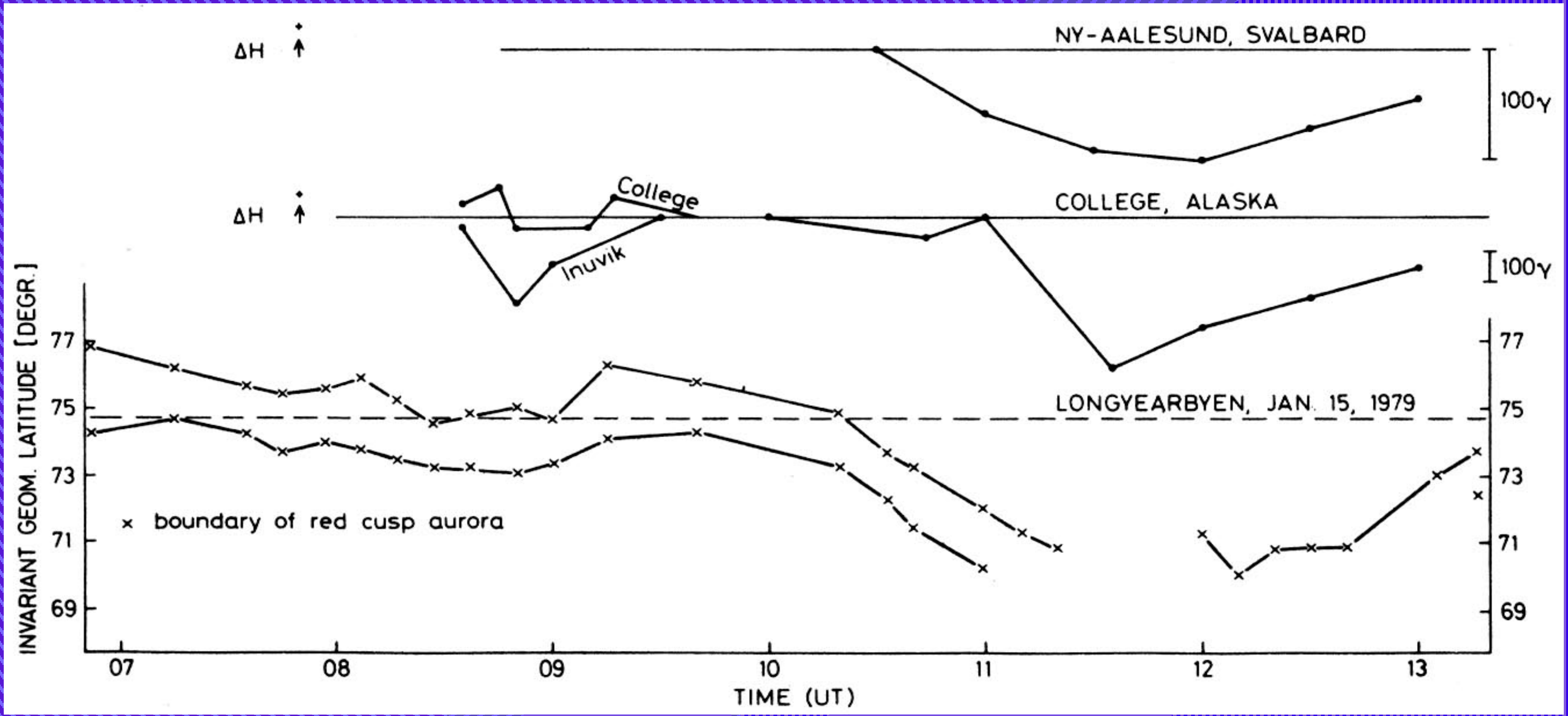


Fig. 1. Position of the equatorward boundary of dayside aurora versus *AE* (±3 hours from local noon).

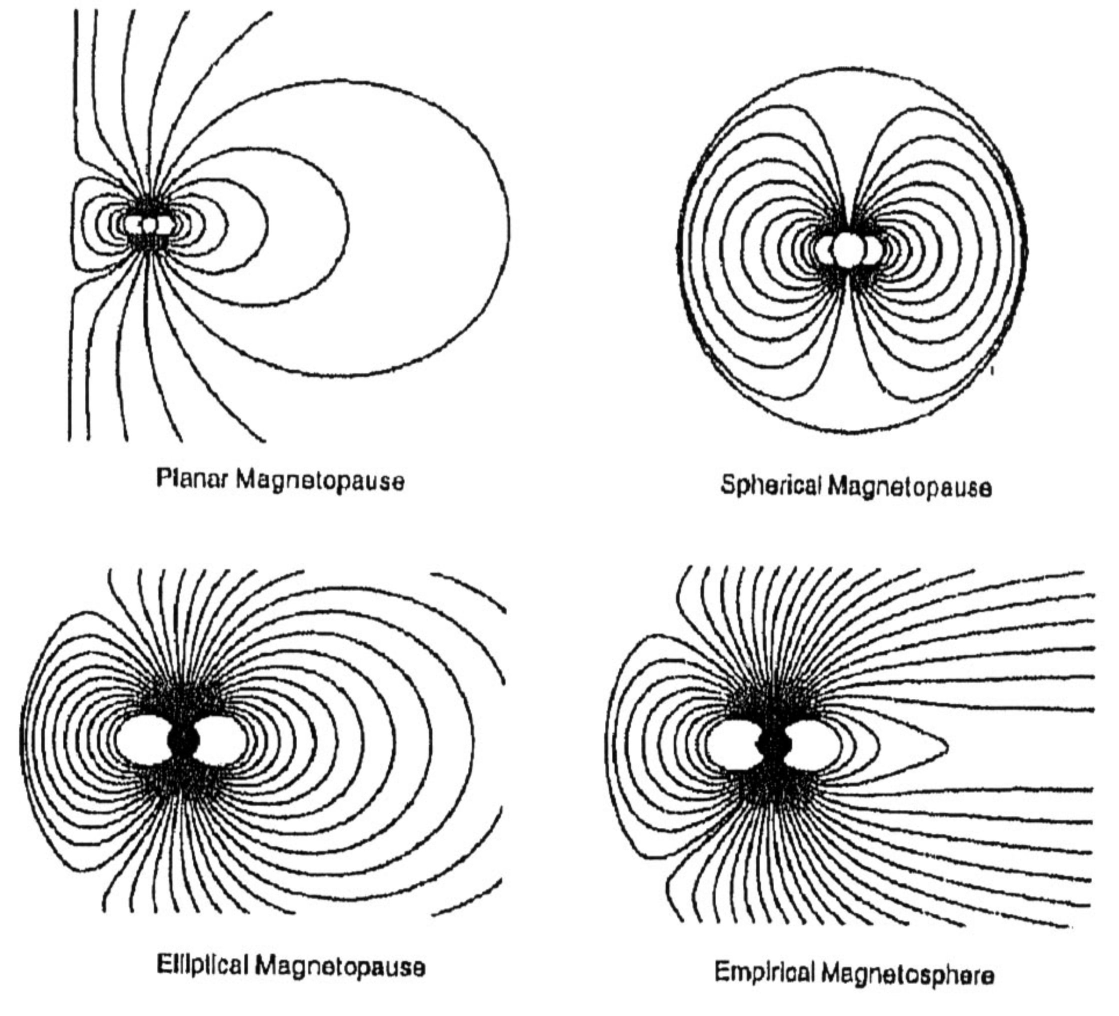
Nightside/Dayside Relationship



- The dayside latitude did follow the nightside current system development, but the dayside had its own current system. Weaker, but separate.
- The dayside latitude of the aurora turned out to be controlled by IMF Bz.

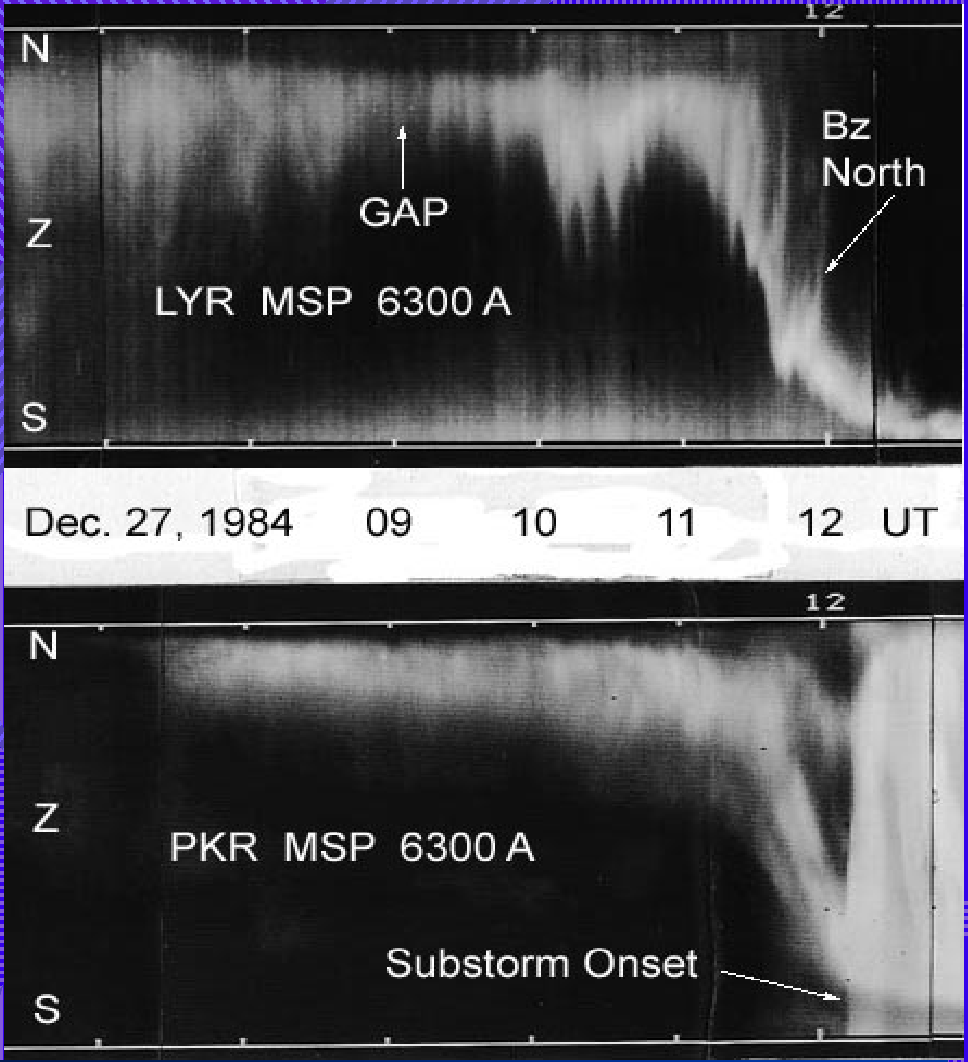
Nightside/Dayside Relationship

- Position of the cusps depends on the shape of the magnetopause.
- We should not have been surprised, then, that the latitude of the dayside aurora is controlled by IMF, not AE.



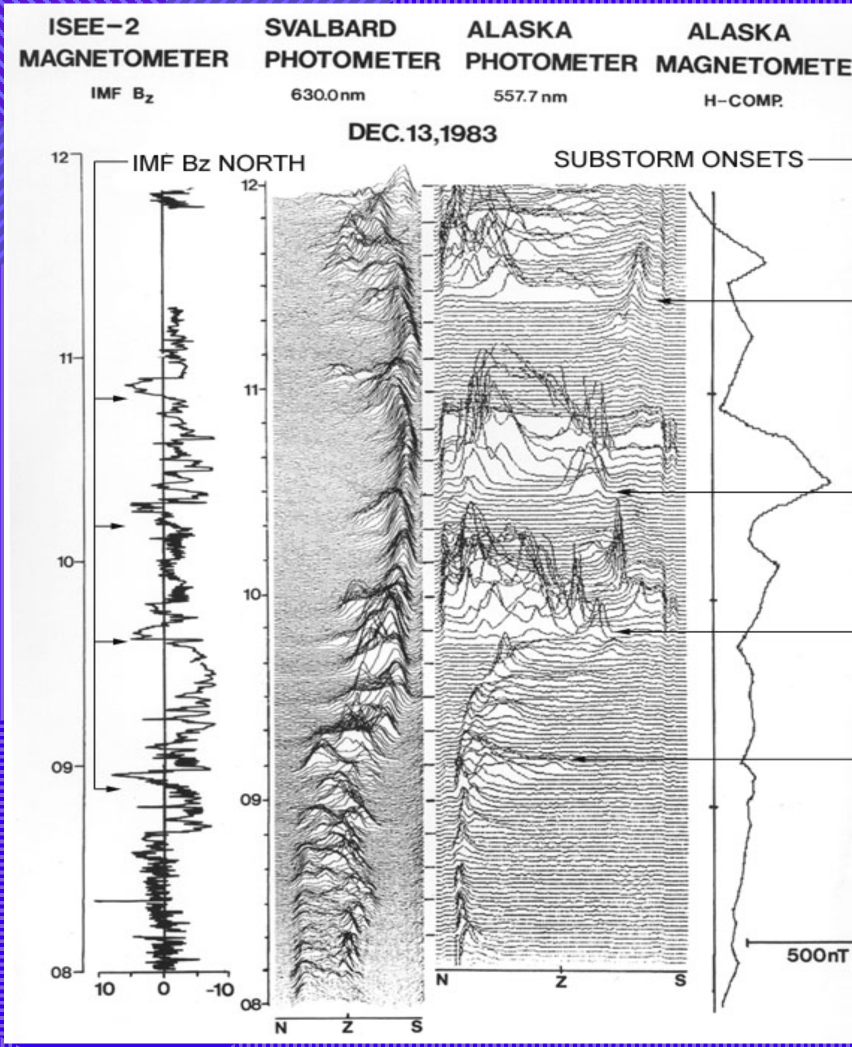
Nightside/Dayside Relationship

- Observations from Svalbard and Alaska showed IMF Bz southward turning begins equatorward movement simultaneously on day and night side.
- No evidence of substorm on dayside although IMF Bz turns N just before onset.



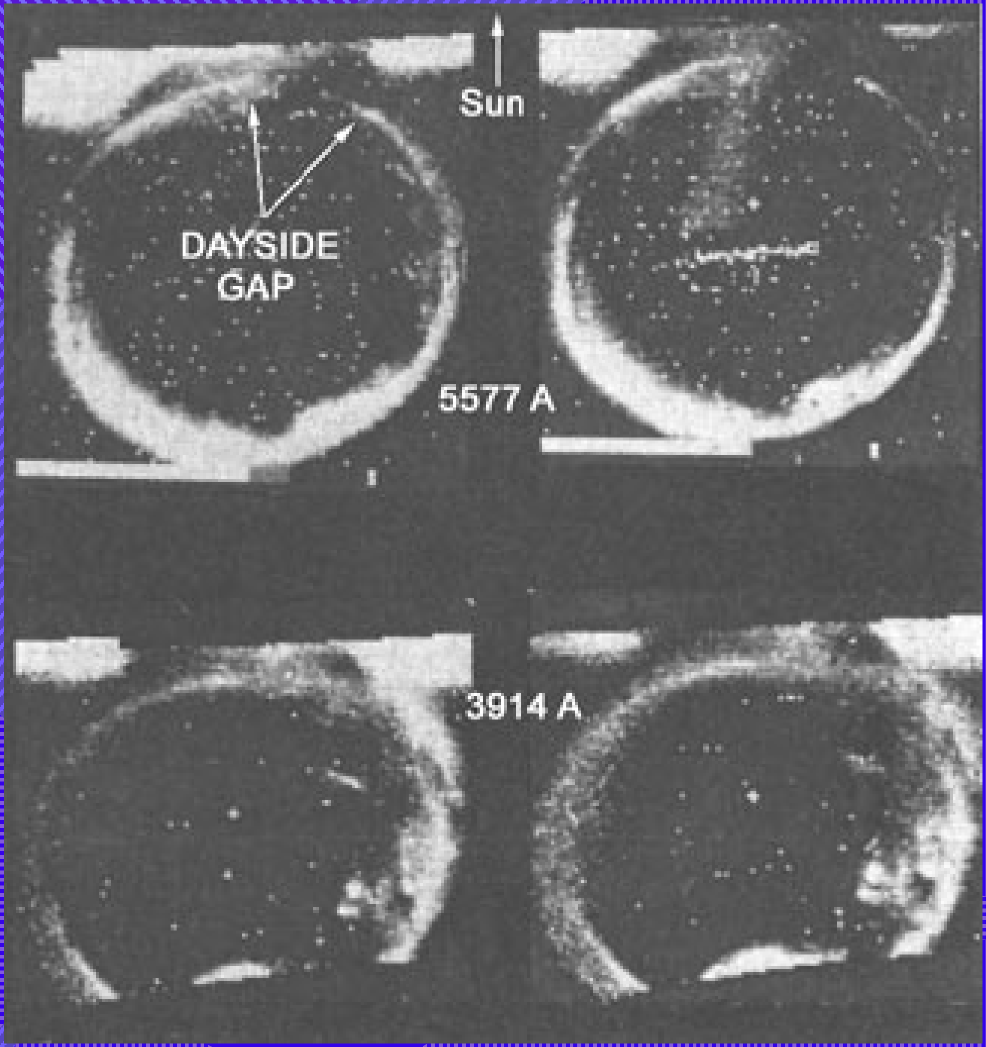
Nightside/Dayside Relationship

- Auroral substorm onset has been associated with convection halt.
- Convection stops when IMF Bz turns N.
- Dayside aurora moves N when IMF Bz turns N.
- Dayside signature of auroral substorm onset is impulsive N movement of auroral zone some minutes before onset. This indicates halt of convection.



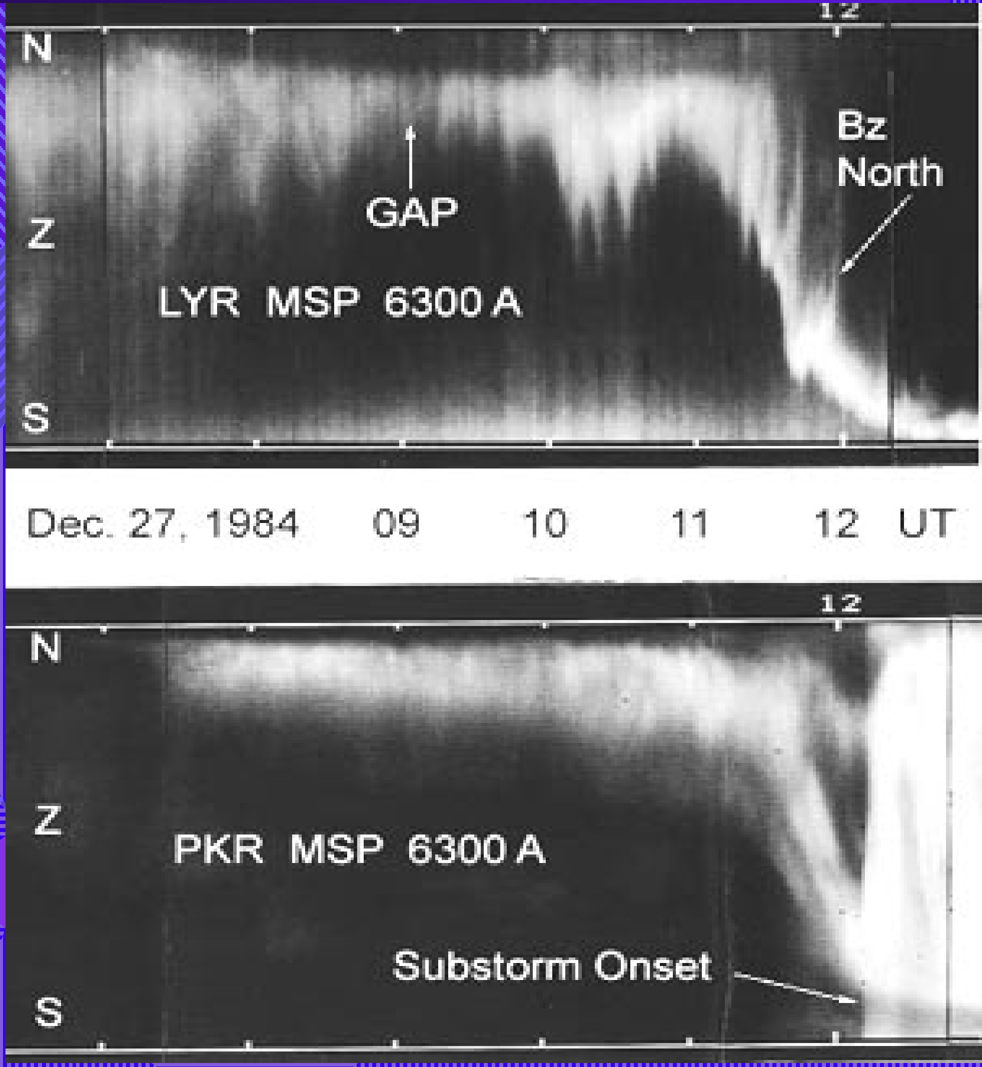
Optical Cusp Signatures

- Cogger and Shepherd's first satellite observations from ISIS.
- Dayside gap in 5577 Å.
- No gap in 3914 Å because resonant in sunlight
- 6300 Å dominates dayside aurora.



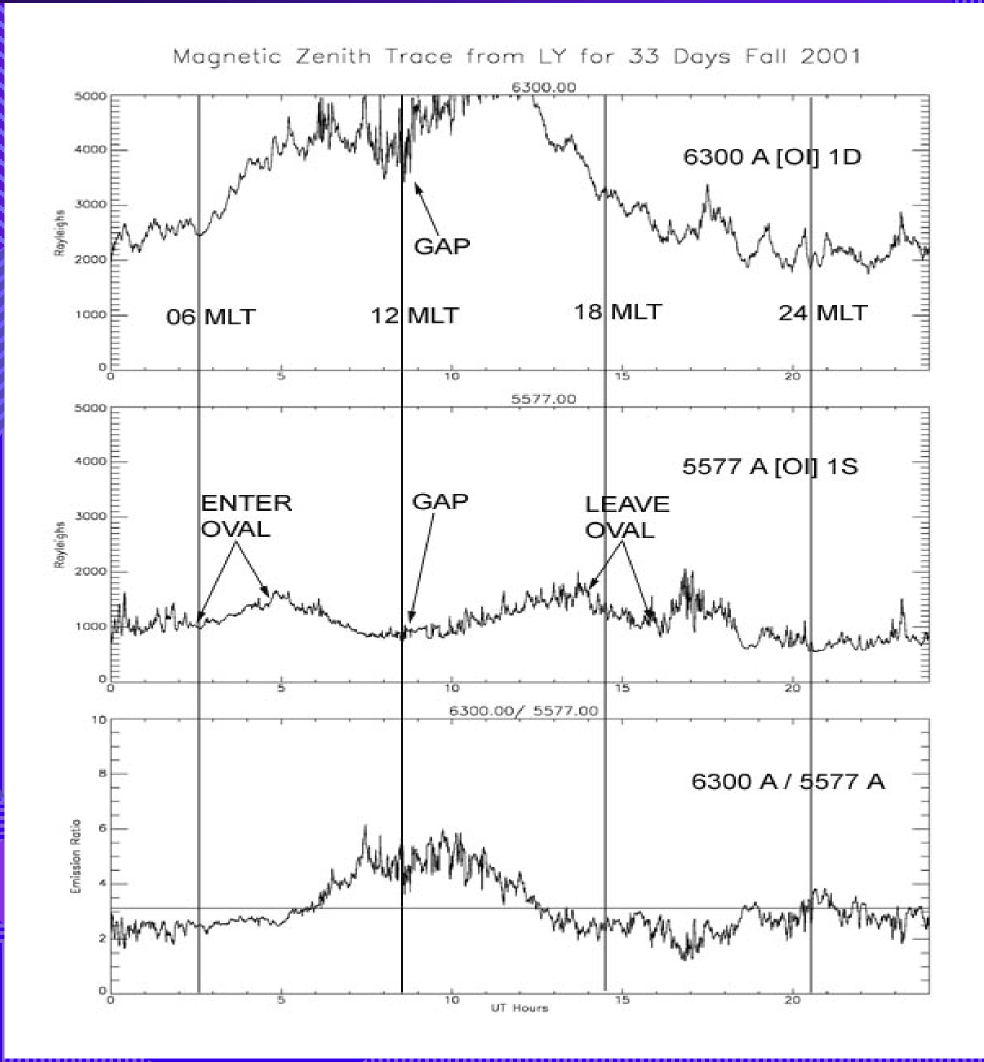
Optical Cusp Signatures

- We observed approximately one hour around magnetic noon of aurora with 6300 Å [OI] predominant (5577 Å gap).
- Essentially a great red aurora every day in the gap.



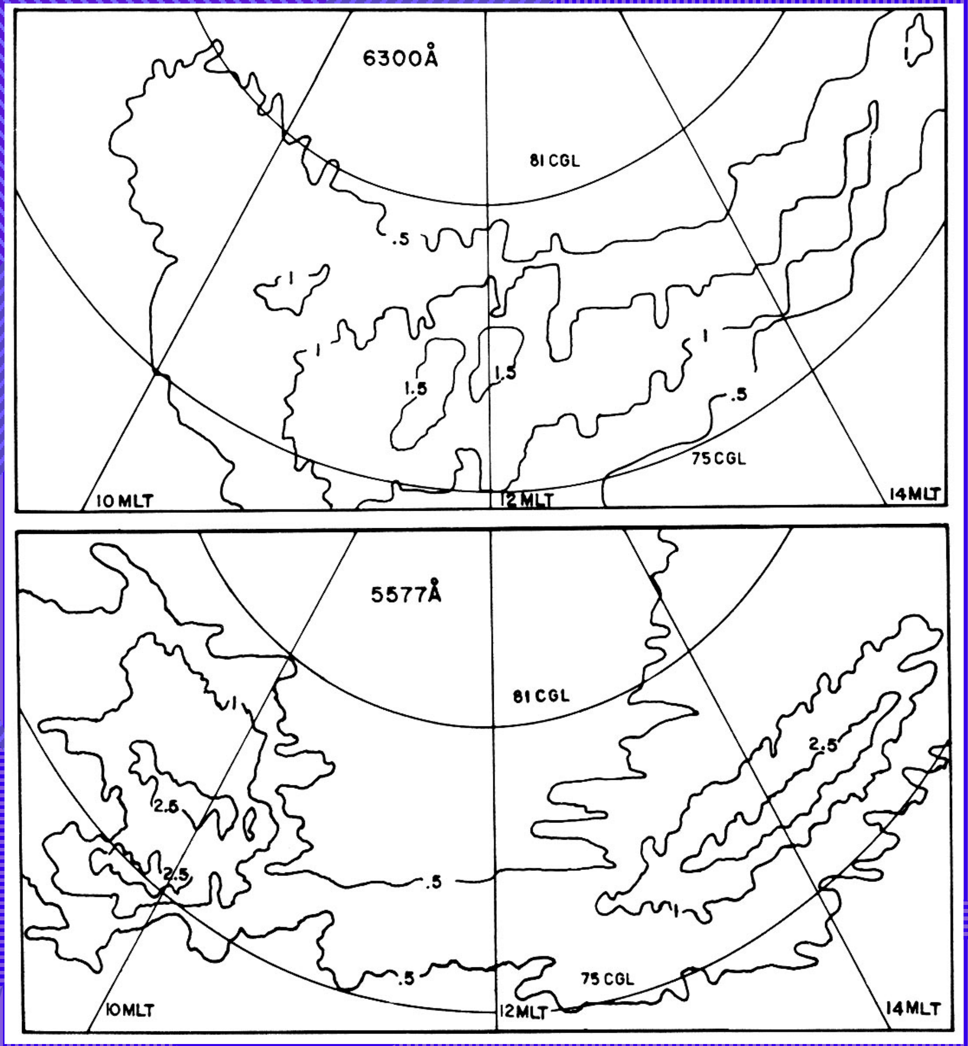
Optical Cusp Signatures

- 33 day average of green line and red lines magnetic zenith in LYR.
- 5577 Å gap is really a minimum about magnetic noon.
- 6300 Å shows two peaks on either side of mag noon.
- Optical "Cusp" is 5 to 8 hours wide.



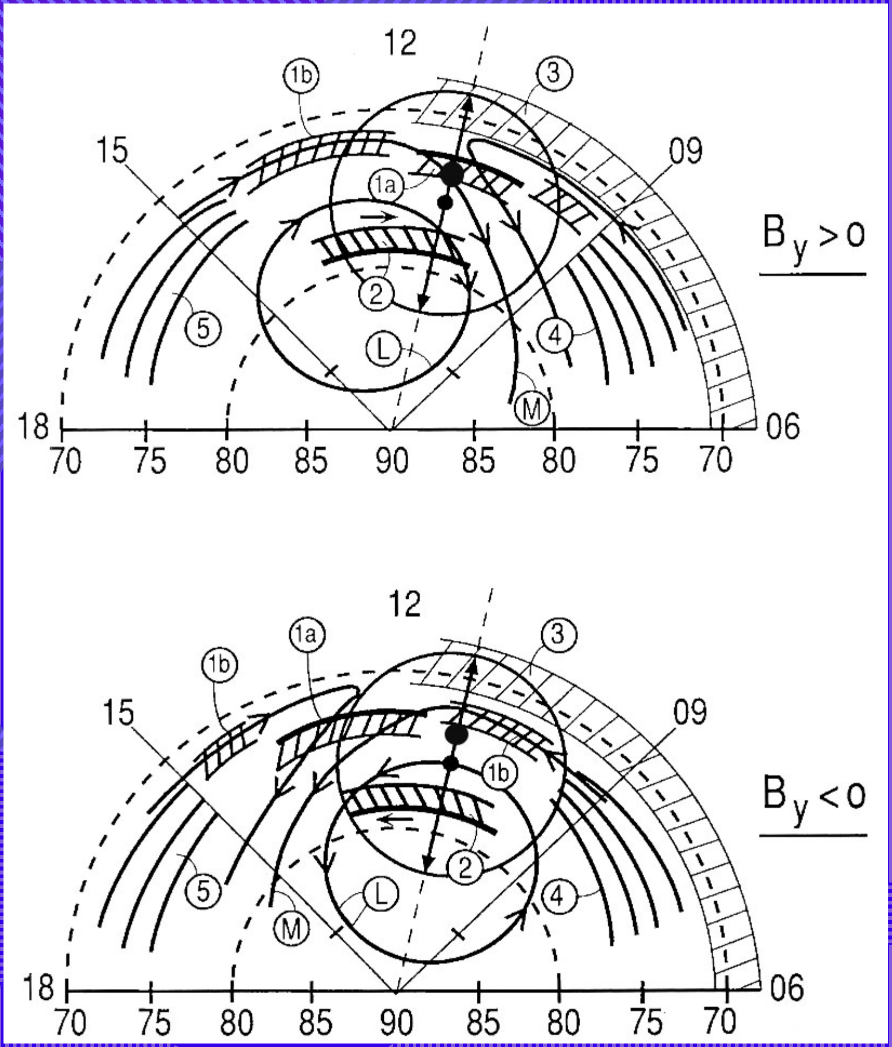
Optical Cusp Signatures

- Cogger's first satellite observations from ISIS are similar to averages in previous slide.
- Day side 5577 Å gap.
- Dual 6300 Å peaks in dayside gap.
- 5 to 8 hours wide.



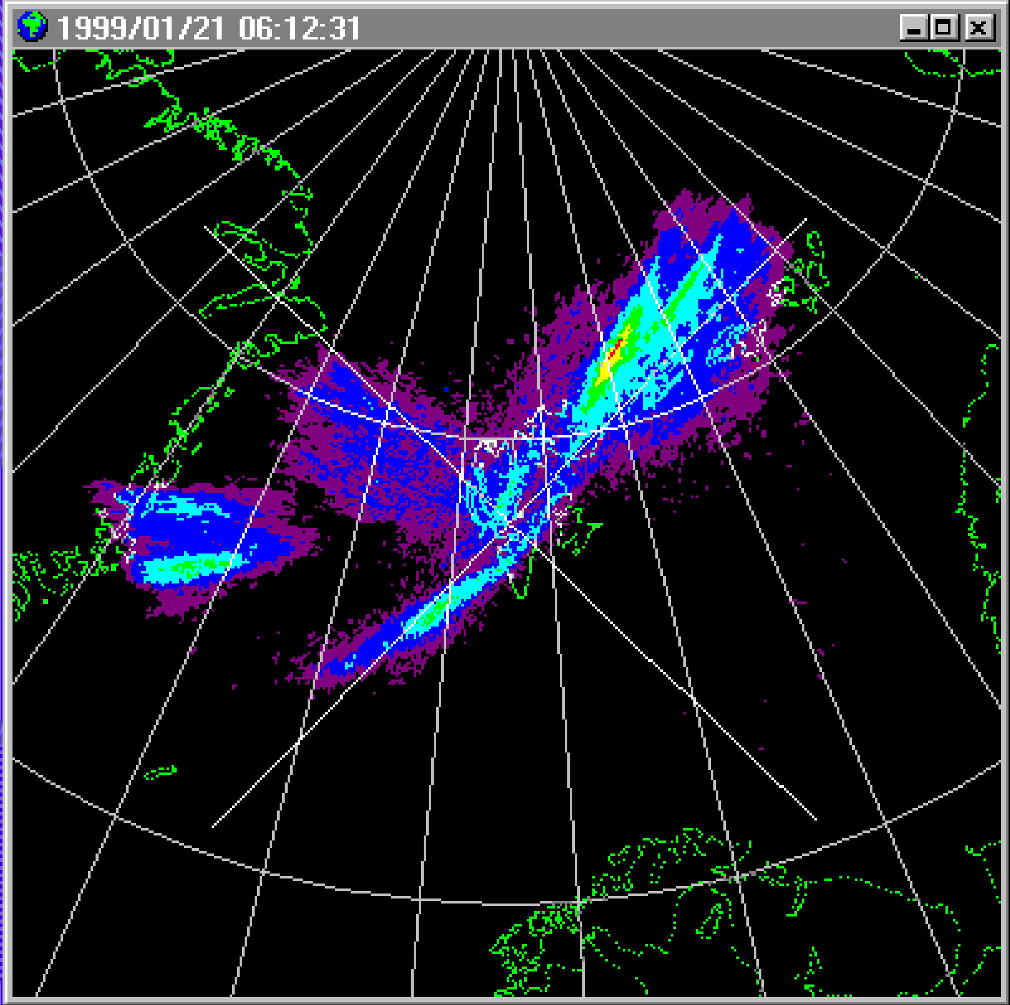
Optical Cusp Signatures

- Sandholt, et al. Auroral Types
- Type 1a and 1b– Merging line and throat PMAFs, respectively. Occur on open or closed field lines for IMF Bz S or N, respectively.
- Type 2 – Discrete arcs on open field lines convecting poleward.
- Type 3 – Pulsating aurora inside trapping boundary.
- Type 4&5



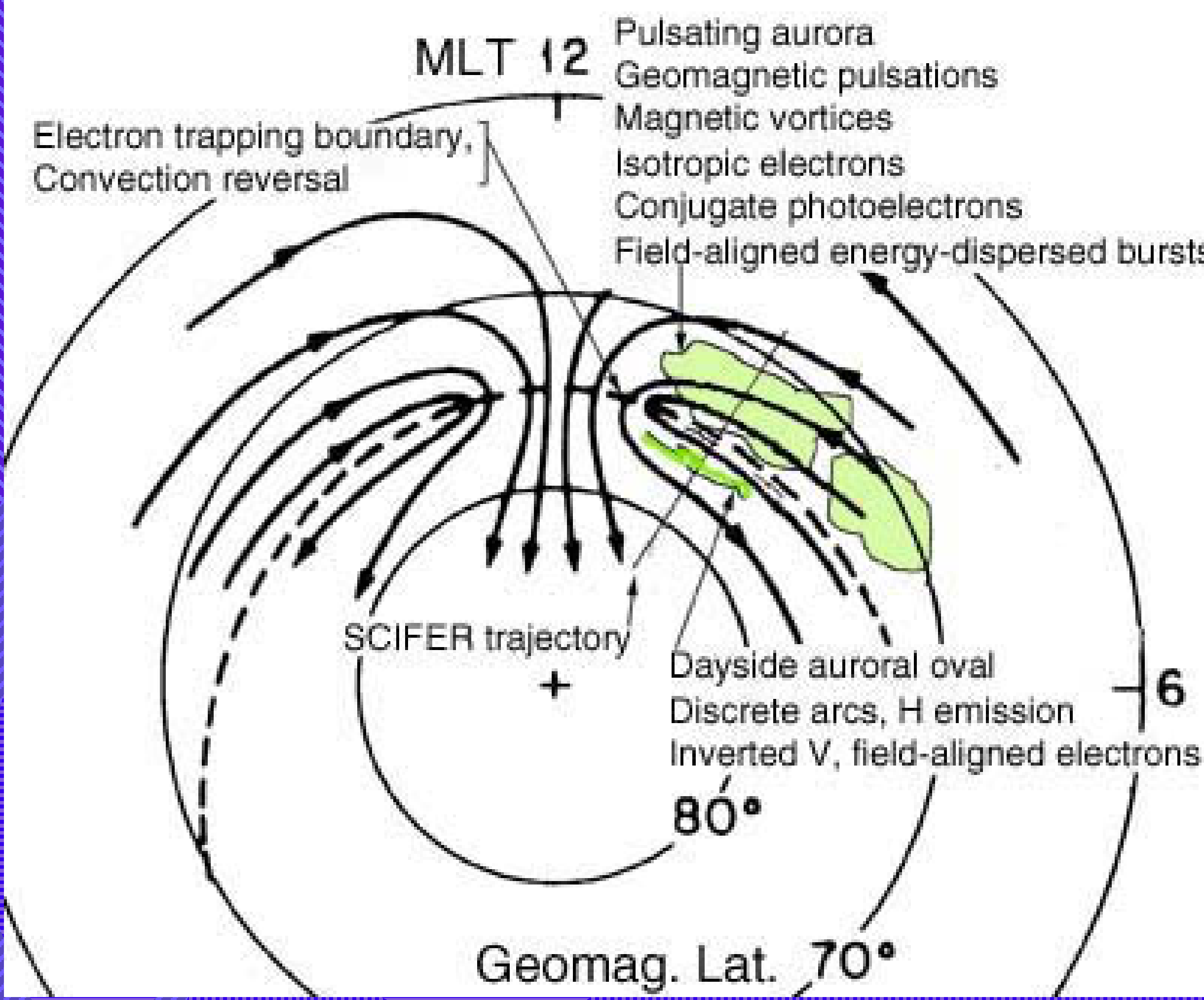
Optical Cusp Signatures

- Optical Convection Signature
- Types 4 and 5 may be the convecting arcs at the end of a convection cell.



Optical Cusp Signatures

- PMAFs 6 hours wide.
- Optical signature of soft precipitation is 6 hours wide.
- No evidence of continuous merging



Magnetic Cusp Signatures

- Pc5 associated with the LLBL.
- Symmetric about noon.
- Associated with Travelling Magnetic Vortices.
- Not necessarily travelling.
- Not associated with cusp or discrete aurora in cusp.
- Predominantly morning side.

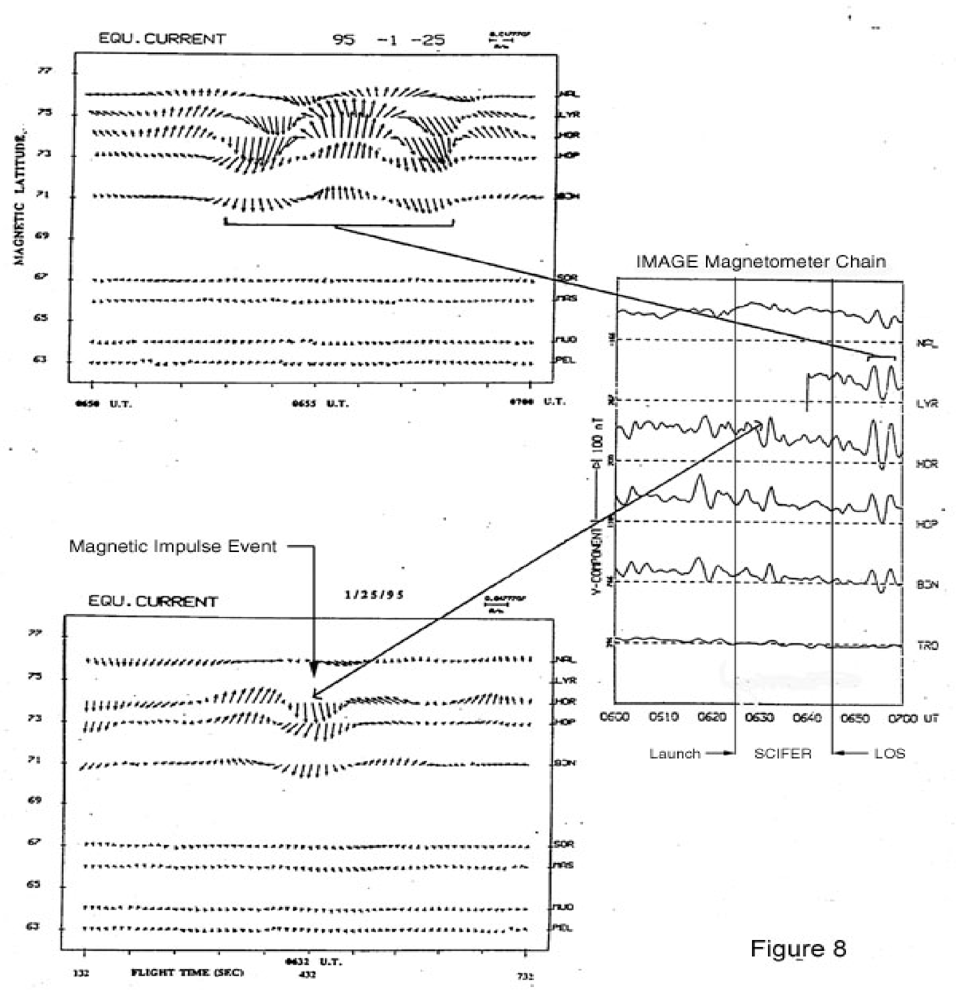
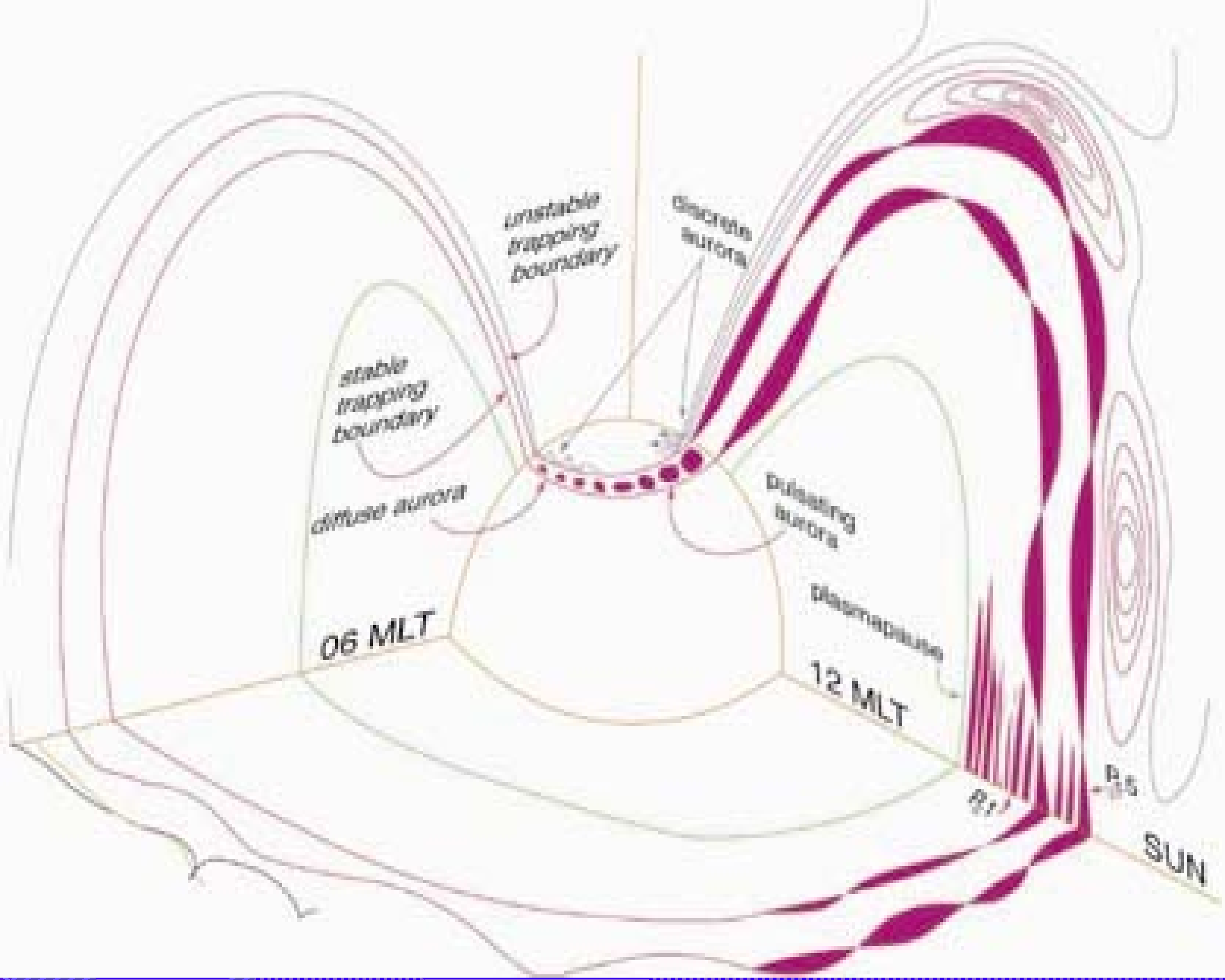


Figure 8

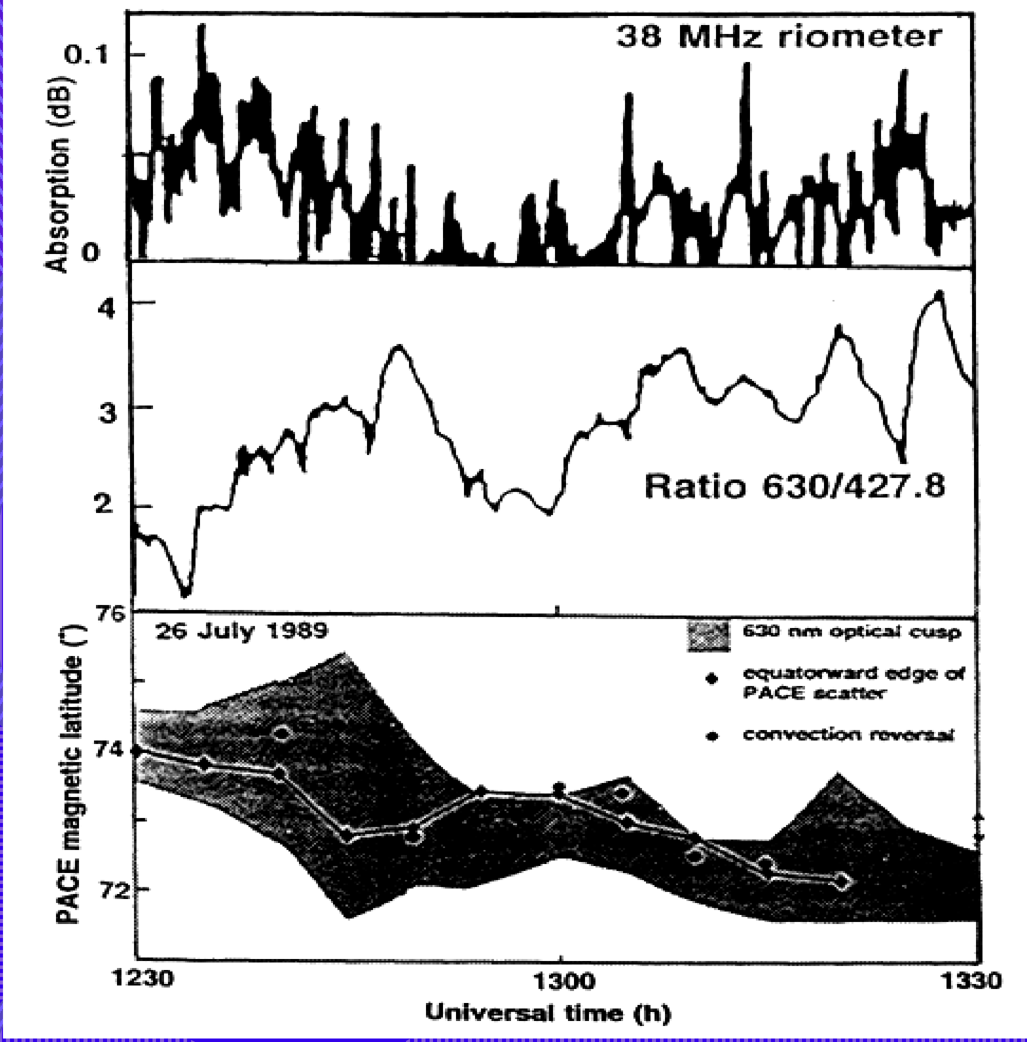
Magnetic Cusp Signatures

- Magnetic signatures mainly resonance effects on closed field lines.
- Produced by merging, pressure and penetration? Equatorward of cusp.



Coherent Radar Cusp Signatures

- Triangles show pole ward edge of narrow spectral width in radar return.
- Shaded is 6300 Å cusp aurora.
- 8 hours wide, same as optical.
- Spectral width associated with PMAFs

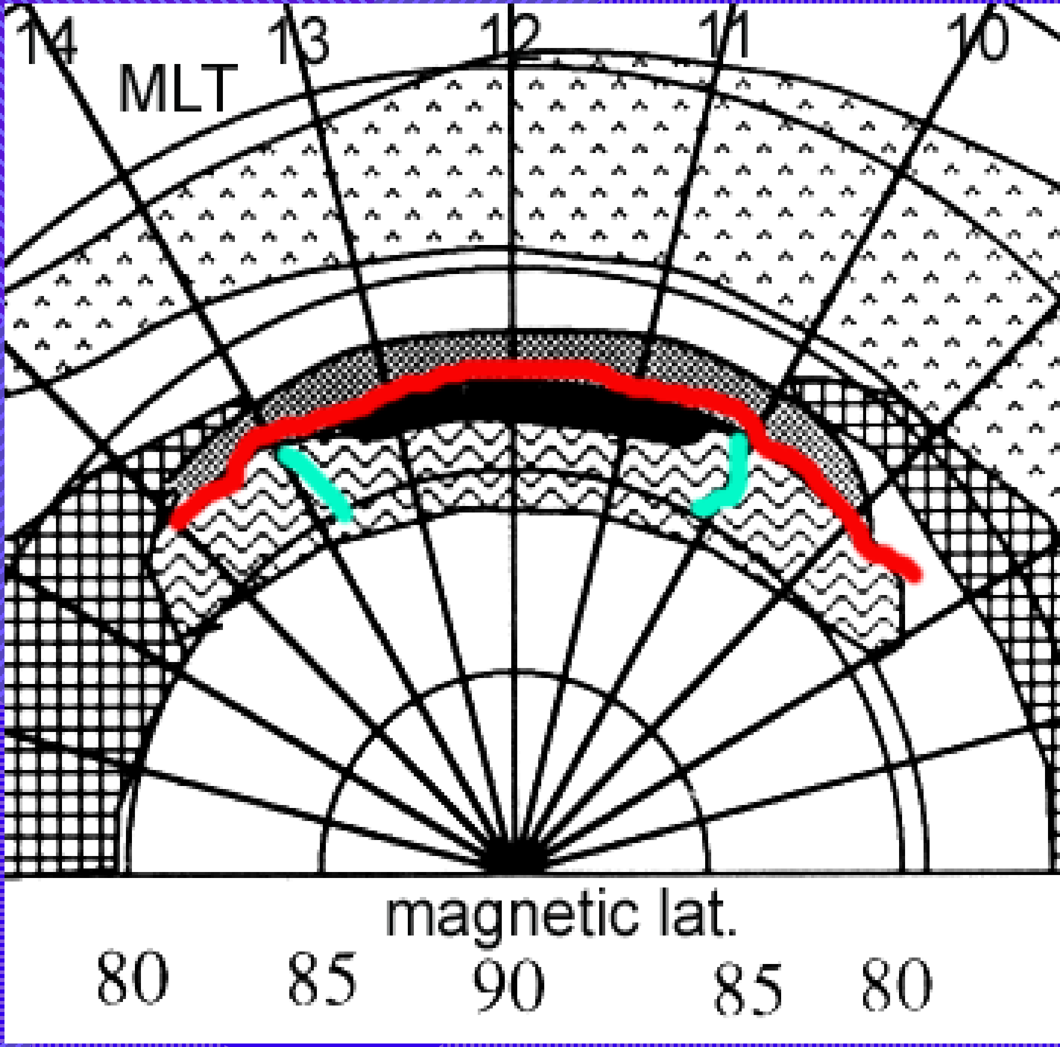


Incoherent Radar Cusp Signatures

- Incoherent scatter radar shows poleward moving forms.
- These forms have the same location and time history of PMAFs.
- Radar forms occur two hours on either side of noon.
- PMAFs (optical cusp) are wider.

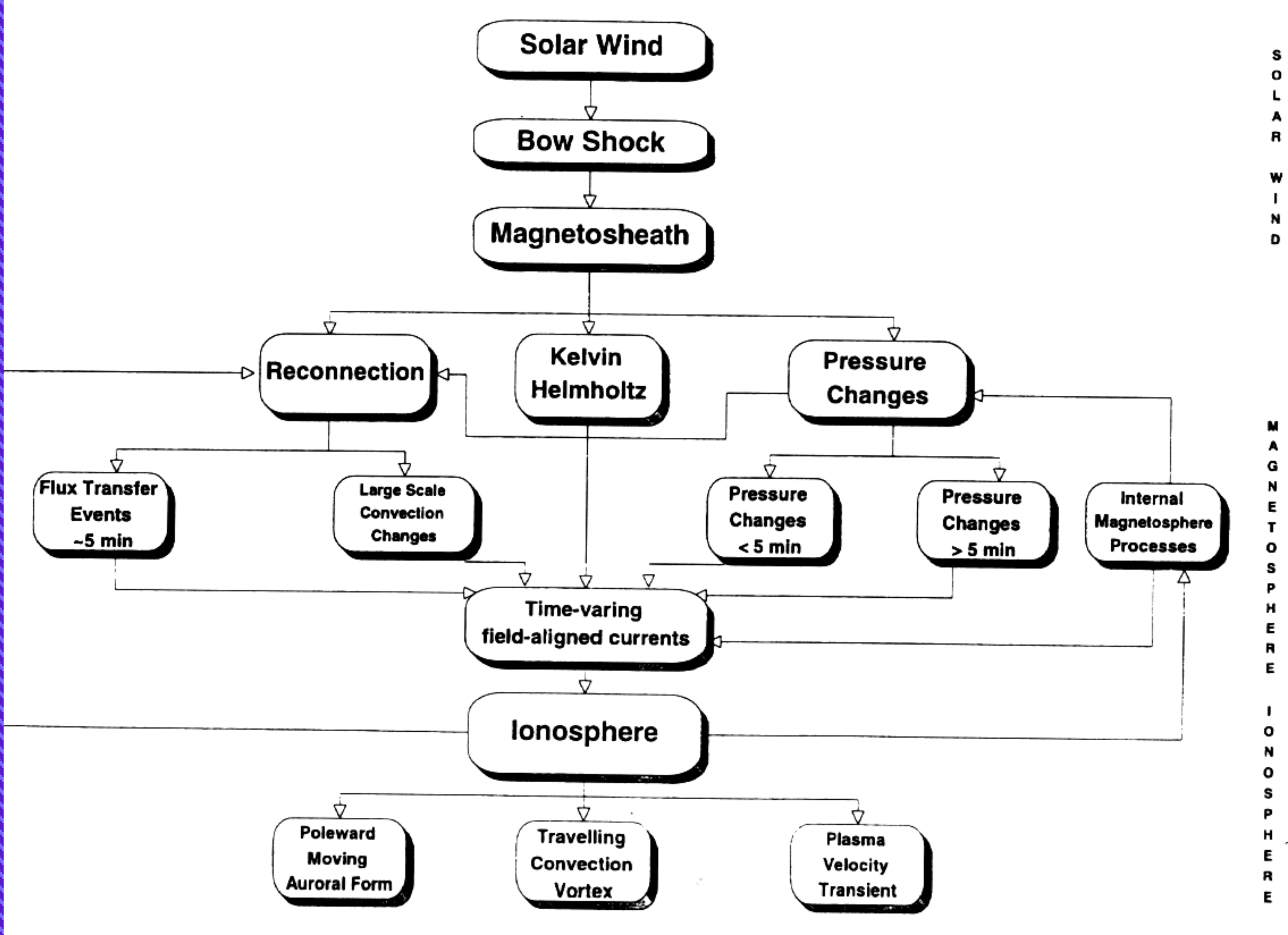
Summary Cusp Signatures

- Cusp precipitation is 6 to 8 hours wide.
- Convection reversal separates LLBL from cusp (red).
- Pulsations equatorward, discrete arcs poleward.
- Diaroic cusp is 4 hours wide (blue).
- Cusp is 100 to 200 km deep, but continuous with mantle and polar rain to nightside.



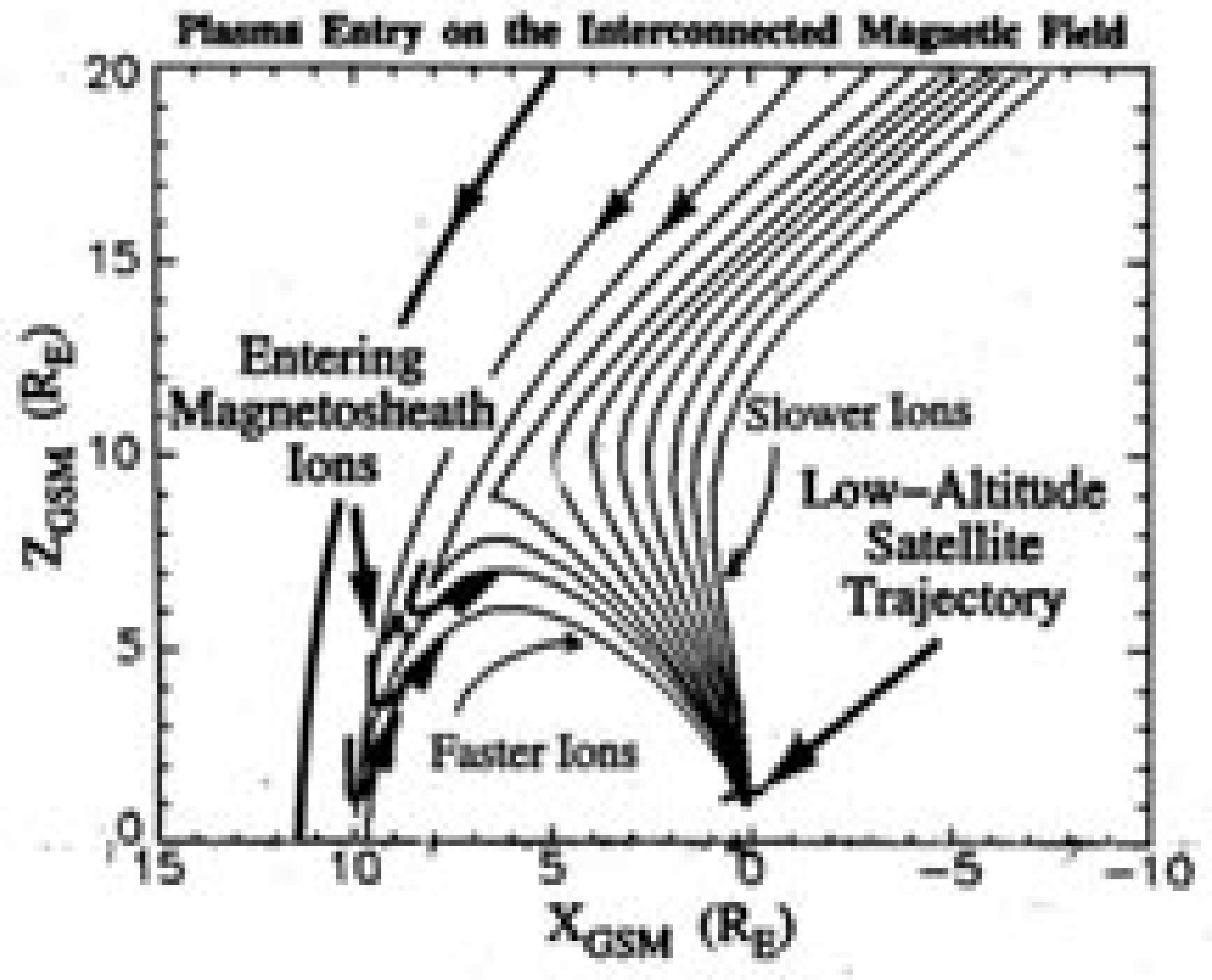
Plasma Transfer Events

- Plasma transfer (night and day) is the challenge to relate solar wind to aurora.
  - Magnetic Merging
  - Viscous Interaction
  - Solar Wind Pressure
  - Impulsive Penetration?

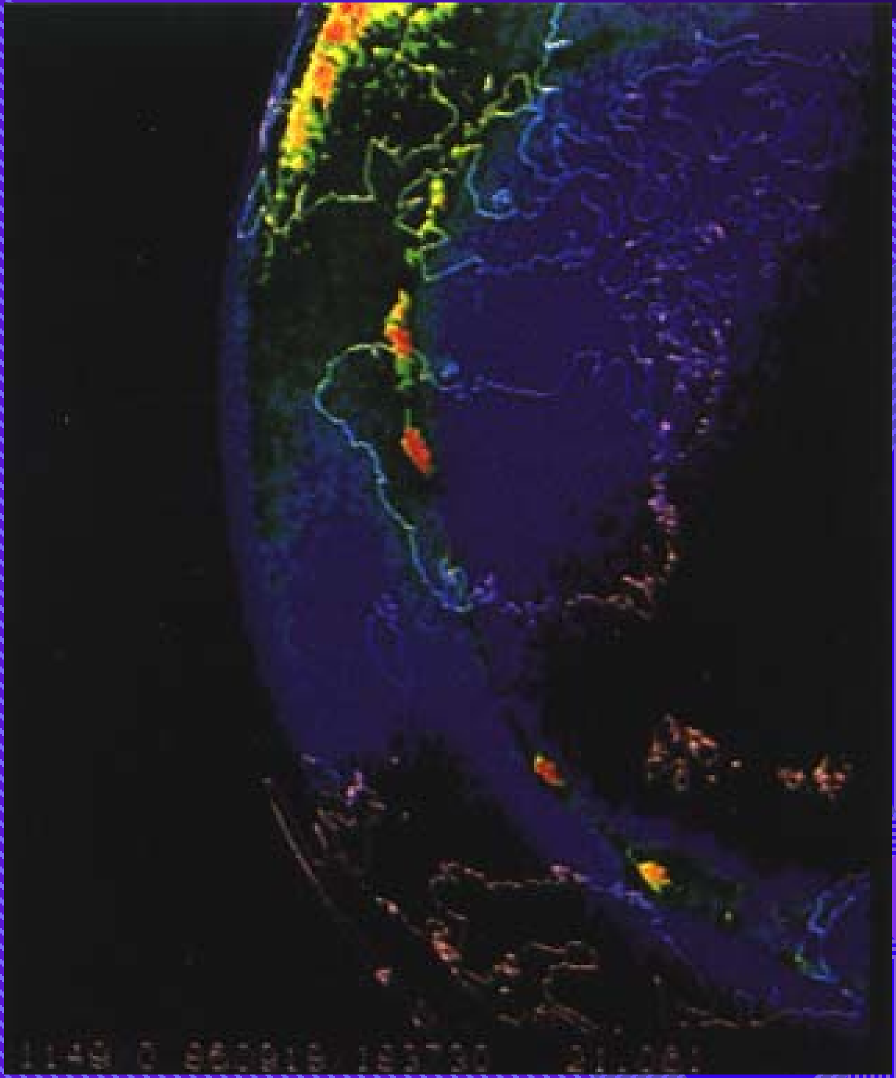


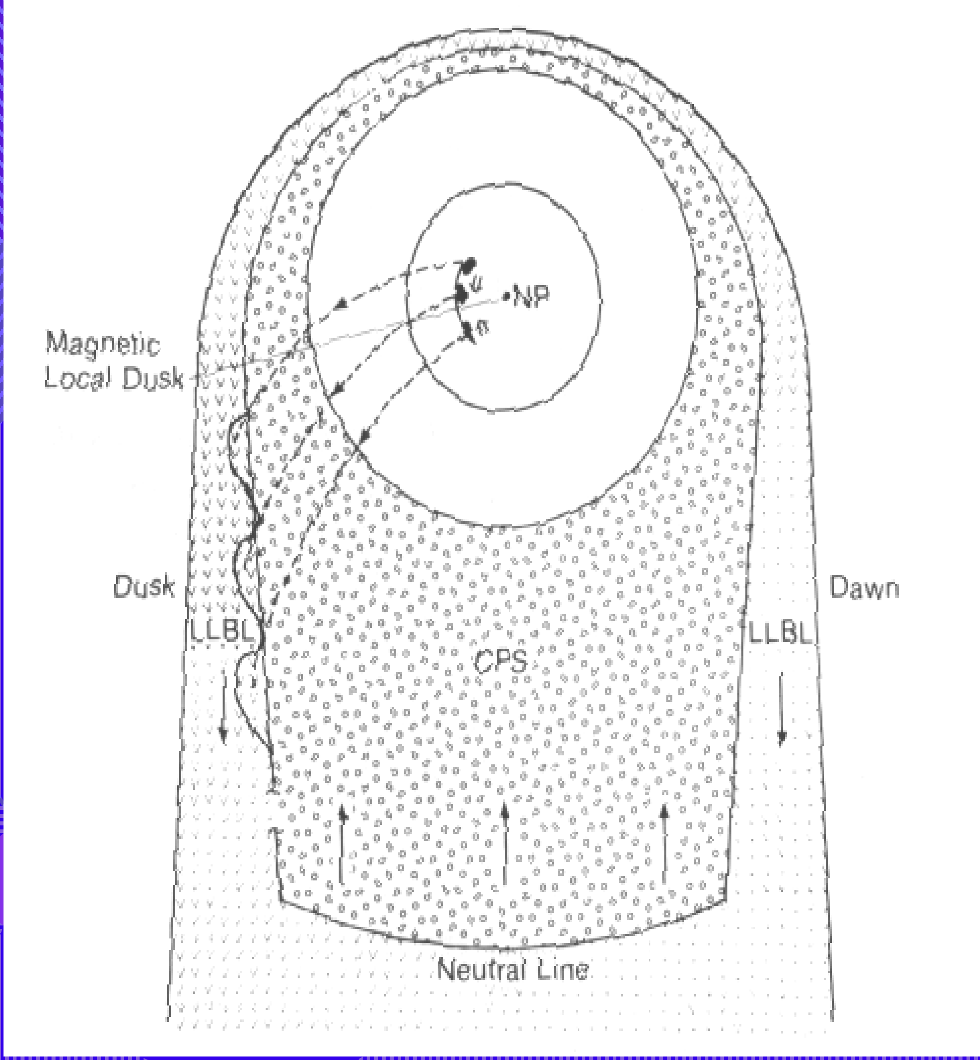
Magnetic Merging

- Locus of anti-parallel fields at magnetopause leads to ionospheric signatures consistent with sporadic electron and proton transfer.



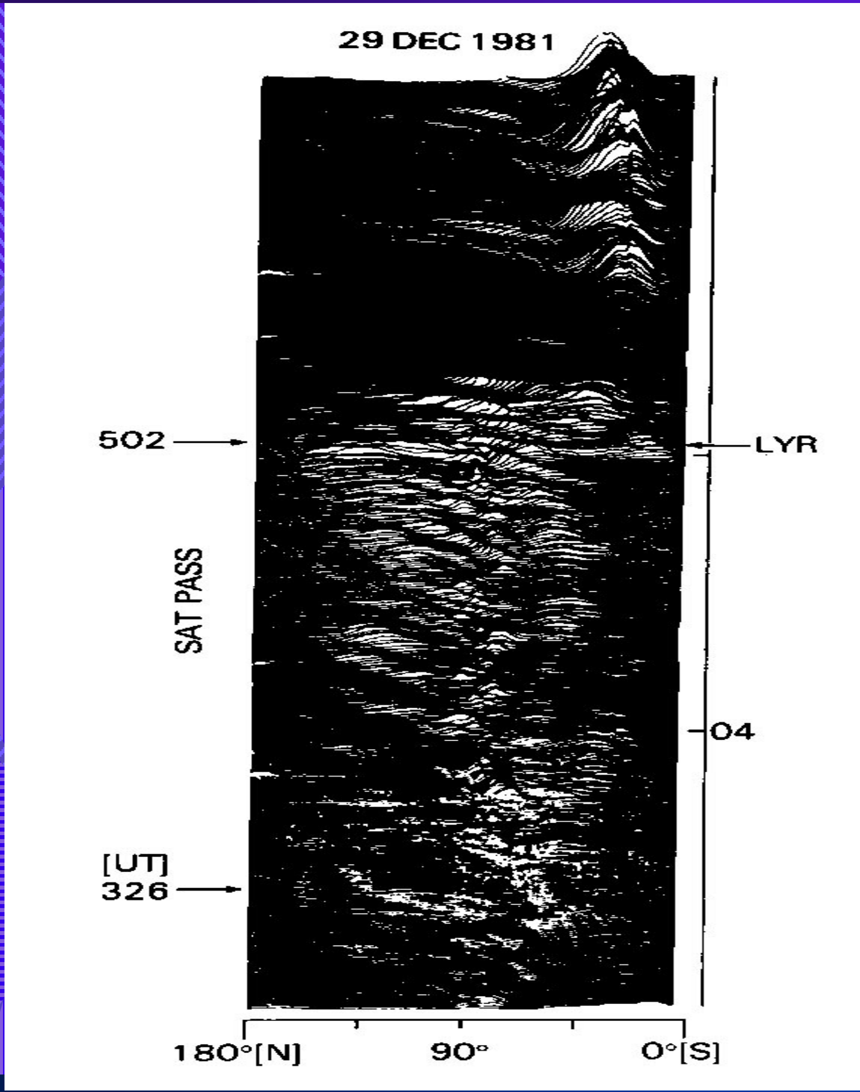
Viscous Interaction



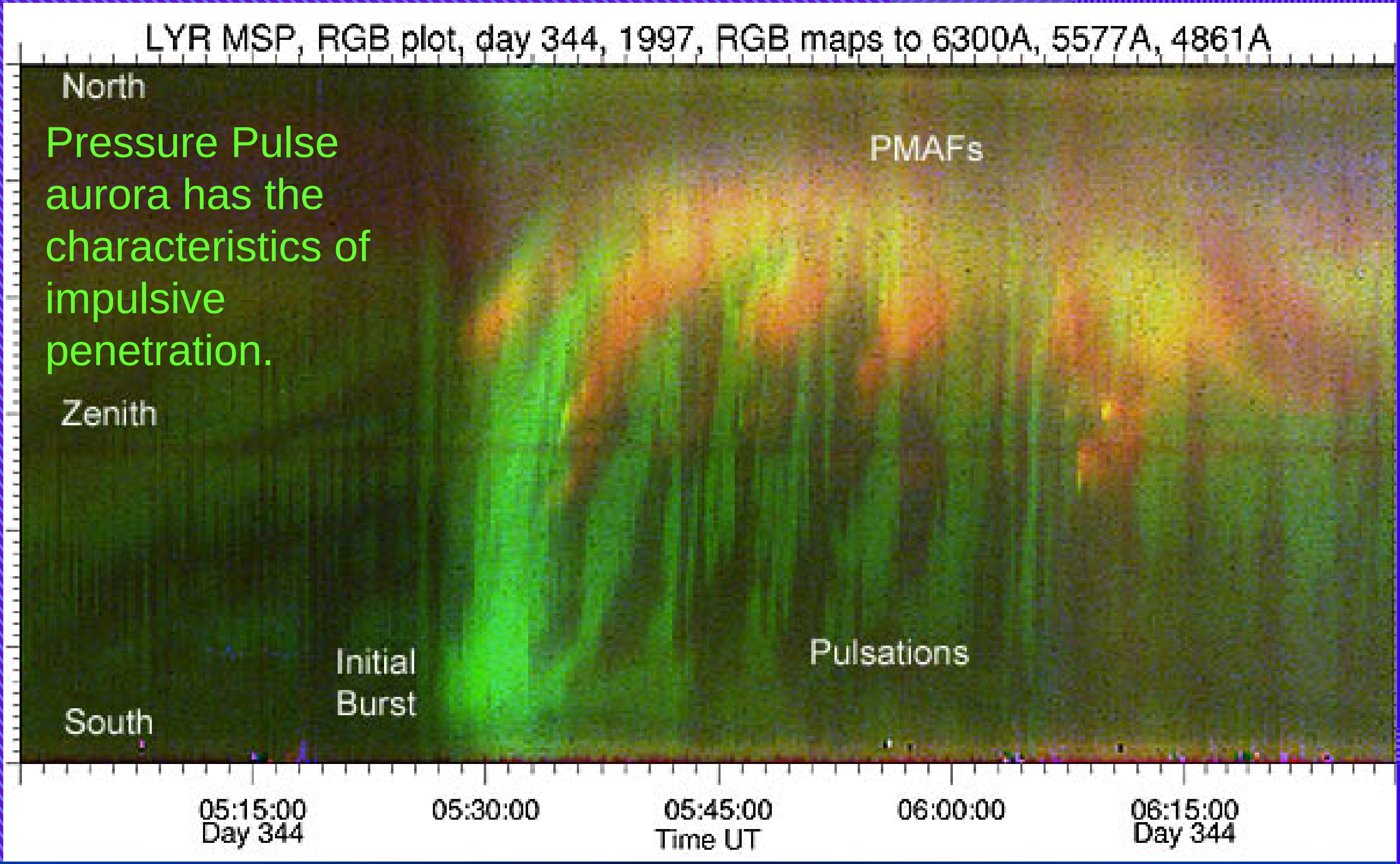


Solar Wind Pressure

- Solar wind shock front causes world wide SSC.
- Energetic ions & electrons precipitated from inside closed field lines.
- As pressure wave engulfs magnetosphere, aurora moves around oval to nightside @15 km/s.



Solar Wind Pressure



Pressure Pulse aurora has the characteristics of impulsive penetration.

Cusp Summary

- The ionospheric signatures of the cusp are all in agreement that it is about 6 to 8 hours wide in MLT, centered on magnetic noon.
- The diaroic region of the cusp is 2 to 4 hours wide, centered on noon.
- The dayside aurora, like the nightside aurora, is loosely separated by the trapping boundary into diffuse and discrete aurora. Both types, however, are controlled mainly by IMF processes at the magnetopause.
- The dayside diffuse aurora is on closed field lines (LLBL) with hard precipitation, and field line resonance effects.
- The dayside discrete aurora is on either newly opened or newly closed field lines, softer precipitation, and associated with the cusp.