Radiation Belt Dynamics and the Plasmasphere

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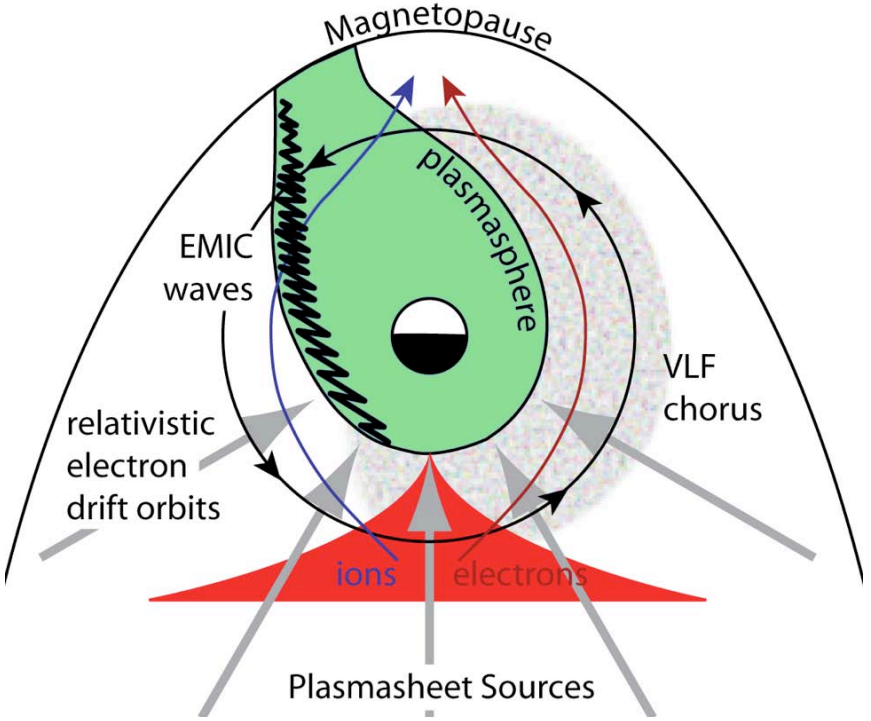
Outline

- Background
  - ionospheric signatures of plasmapause
- Method
  - use of DMSP observations of LIT to identify plasmapause
  - map plasmapause locations to equatorial plane
  - compare with IMAGE plasmasphere observations and SAMPEX energetic particle observations
- Results
  - relativistic electron microbursts

Plasmasphere-radiation belt connection

- Plasmapause (PP) correlates with inner edge of outer radiation belt
- Wave-particle interactions are proposed as the casual link:
  - stormtime EMIC waves inside duskside PP scatter radiation belt particles into loss cone, rapidly depleting outer belt
  - whistler-mode chorus outside PP energizes radiation belt particles over multiple orbits, slowly repopulating belt [Summers et al., 1998, *JGR,* 103:20487]

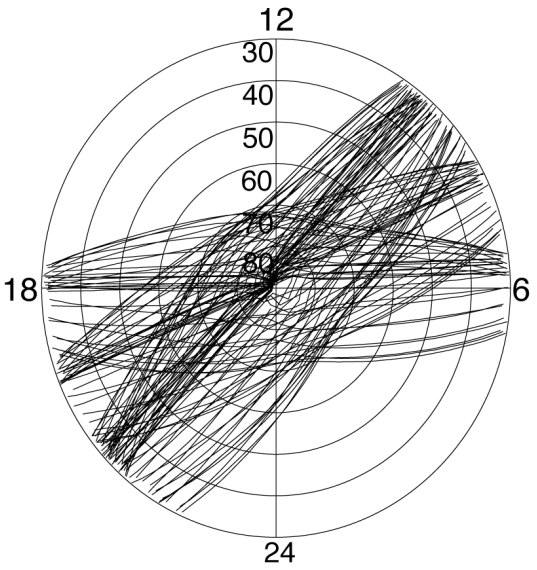


Reeves, after Summers et al., 1998

DMSP

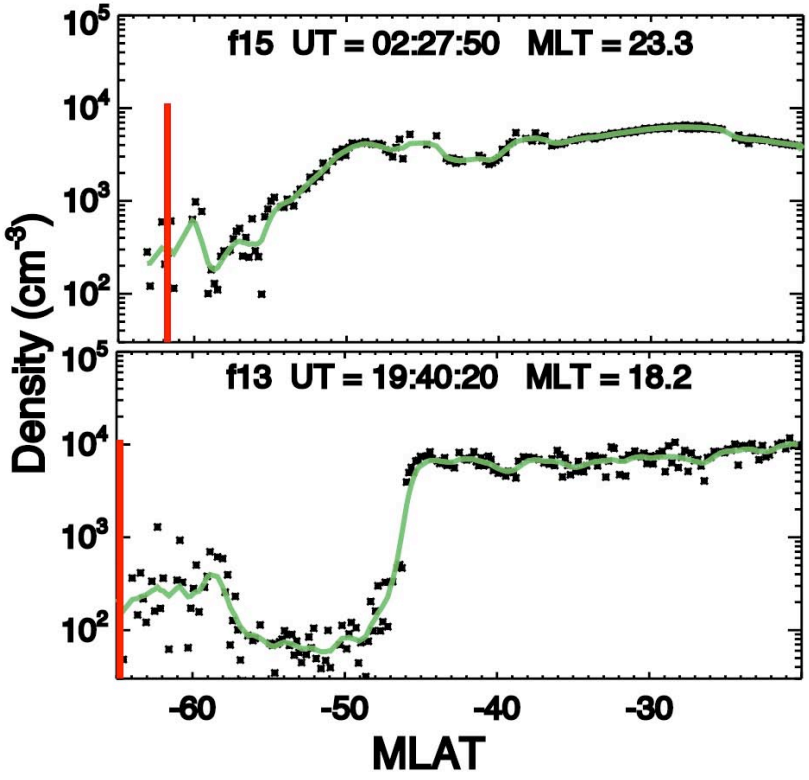
- DMSP satellites: sun-synchronous circular orbits near 840 km alt., 101 min. period, 99° inclination
- 3-4 satellites in operation continuously over 10+ years
- Plot illustrates polar coverage in one day from four DMSP satellites (F11-F14) in MLAT-MLT
  - provides ~50% MLT coverage at 40°, ~75% coverage at 60°
- Instruments include
  - **RPA:** Retarding Potential Analyzer providing ion density, composition, temperature
  - Ion Drift Meter providing cross track ion velocity
  - SSJ/4 or SSJ/5 providing energy spectra/flux of precipitating electrons and ions

DMSP Coverage October 19, 1998



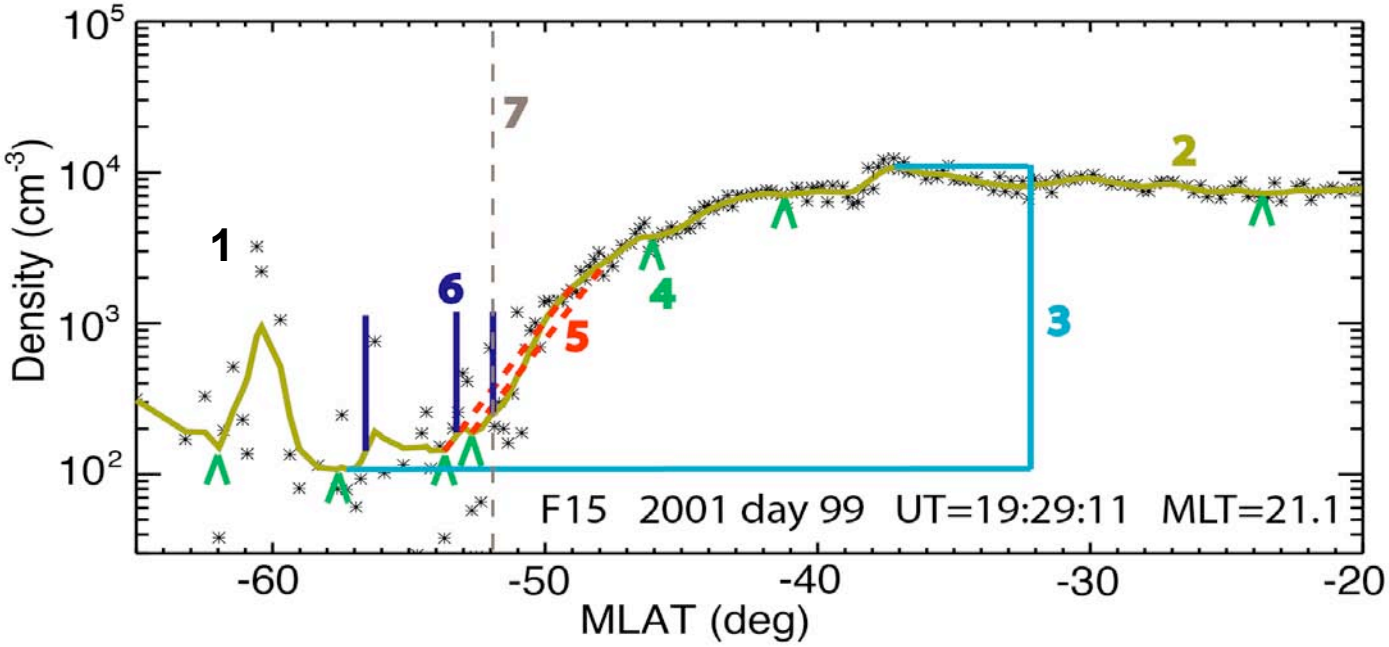
LIT as ionospheric signature of plasmapause

- Light ion trough (LIT)--steep latitudinal gradient in ionospheric H^+/He^+ density near equatorial edge of auroral zone
- Light ion trough (LIT) is proposed as one of the more consistent signatures [Taylor and Walsh, 1972, *JGR, 77*:6716; Horwitz *et al.*, 1990, *JGR, 95*(A6):7949]
- Some have found the LIT tends to be equatorward of other plasmapause identifications [Foster *et al.*, 1978, *JGR, 83*:1175; Grebowsky *et al.*, 1978, *PSS, 24*:1177]



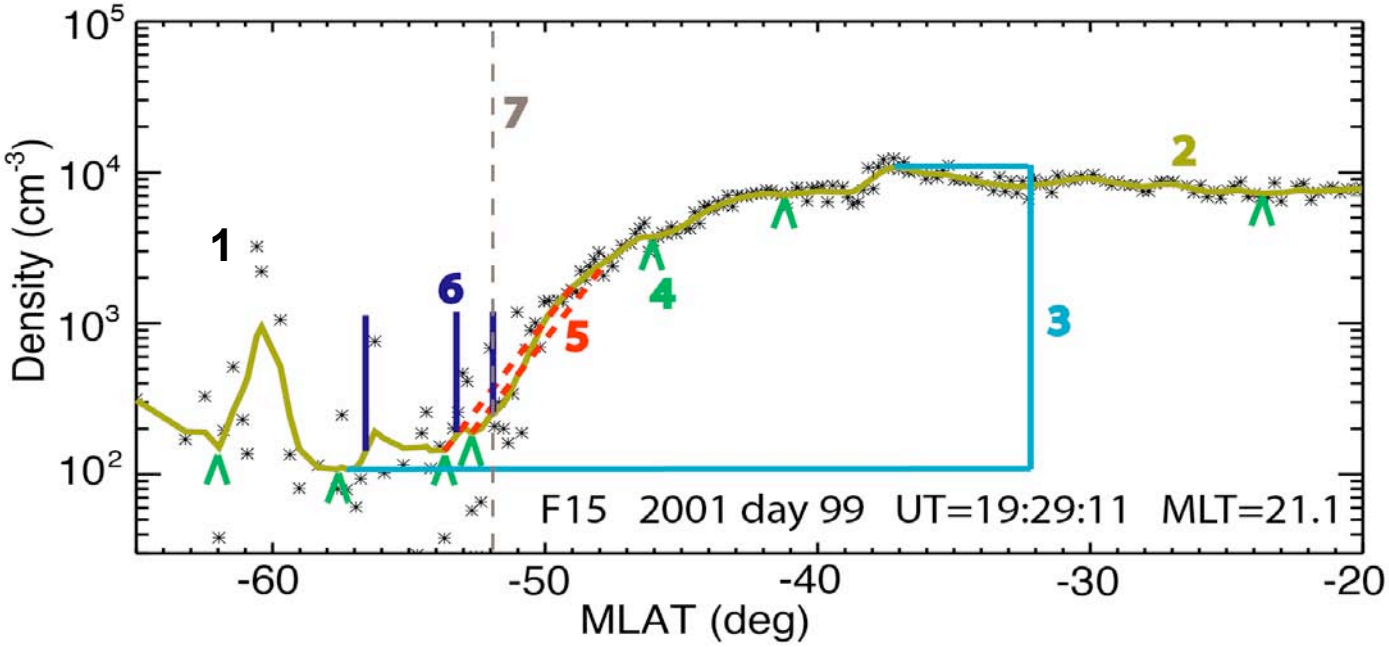
Method: algorithm for LIT ID

- [1] use DMSP [H^+] data from 20-65° MLAT N/S
- [2] smooth data with Hanning window with fixed MLAT width
- [3] if maximum dynamic range is less than a factor of 10, ignore pass
- some passes rejected manually (too noisy, no LIT, etc.)
  - typically LIT not observable for SZA < 95°



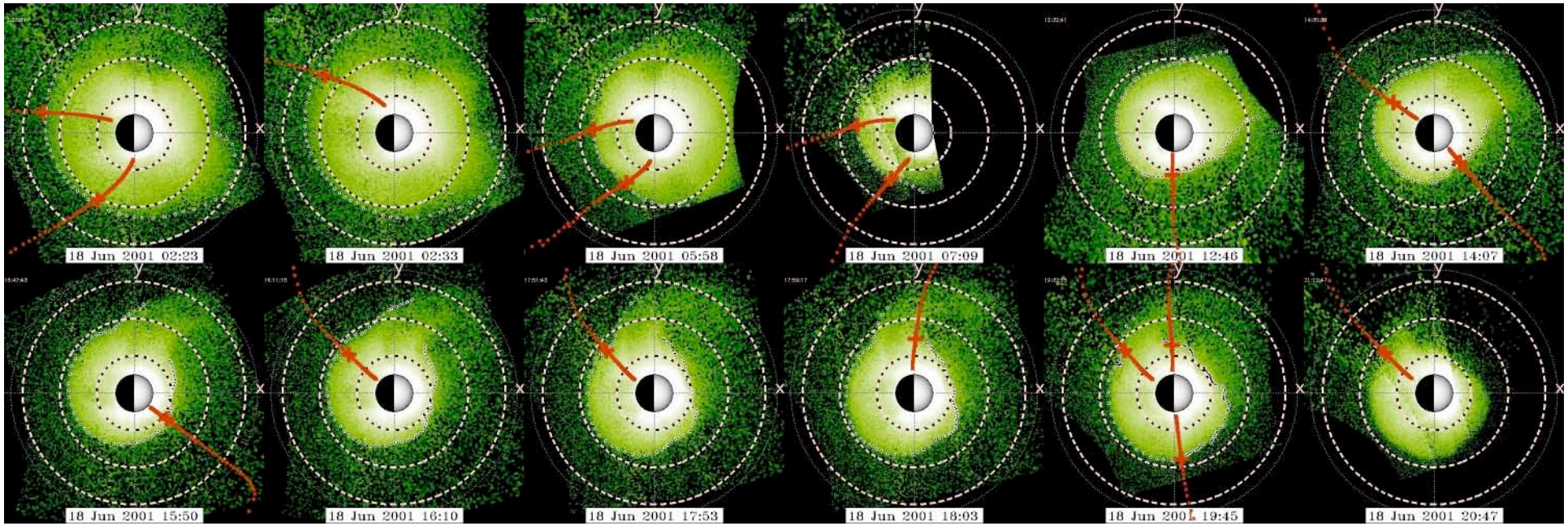
Method: algorithm for LIT ID

- [4] identify all local minima in smoothed density
- [5] identify subset of minima with steep equatorward rise in density
- [6] move equatorward to location where density is 30% greater than at minimum
  - value chosen to avoid bias from broad minima (mean ΔMLT ~ 1°)
- [7] manually identify one such location as PP



Initial results: mapped IDs from 1-day study

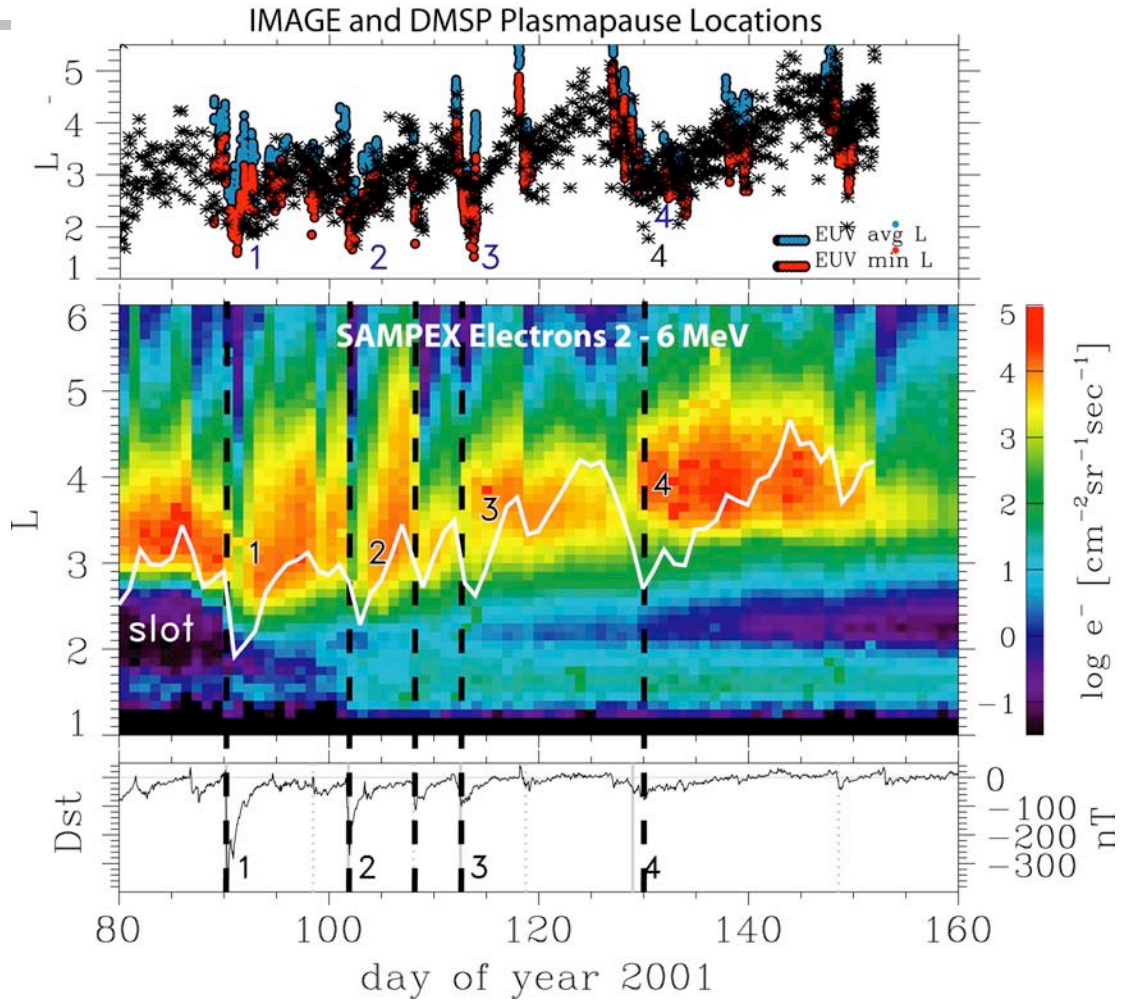
- For 18 June 2001, plots show IMAGE EUV images of plasmasphere projected to SM X-Y plane, Sun at right
- Red lines show mappings of DMSP orbit track to SM X-Y plane, red cross shows identified plasmapause



Anderson et al., 2008, *GRL*, doi:10.1029/2008GL033978

Initial results: comparison to SAMPEX

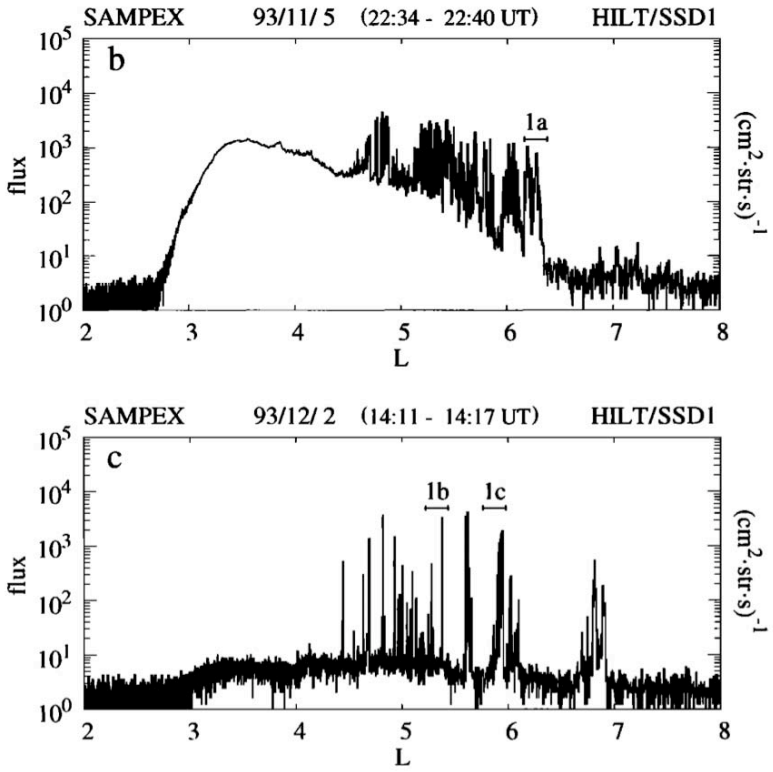
- Using 1790 plasmapause IDs from 72-day study
- top: PP IDs from DMSP (black) compared to IMAGE
- middle: daily average of our PP IDs (white) compared to SAMPEX electron flux
- Correlation in PP movement and Dst, movement of inner edge of outer radiation belt



base image from Goldstein et al., 2005

Microbursts

- Microbursts: short duration (<1 sec) bursts of relativistic electrons observed in LEO
  - First reported by Brown and Stone [1972, *JGR*, 77:3384]
  - Associated with dawnside and post-storm RB recovery [Nakamura et al., 2000, *JGR*, 111:A11S02]
  - Innermost occurrences associated with modeled PP location [Lorentzen et al., 2001, *GRL*, 28:2573]

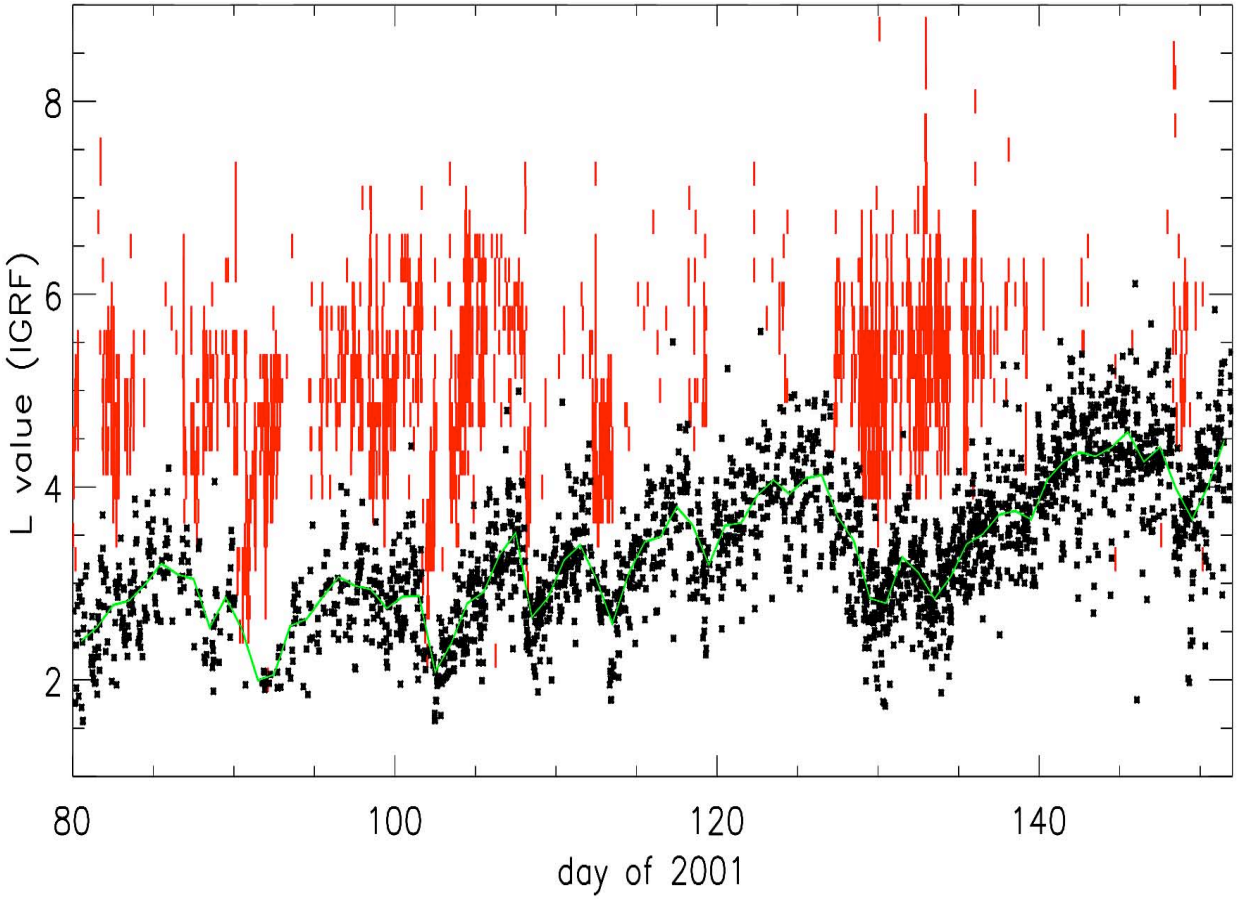


Nakamura et al., 2000

- They are believed to represent wave-particle scattering of RB particles into the loss cone
  - Side effect of energization by whistler chorus outside PP
  - Linked to VLF chorus [Lorentzen et al., 2001, *JGR*, 106:6017]
  - Linked to ULF activity at low L shells [O'Brien et al., 2003, *JGR*, 108:1329]

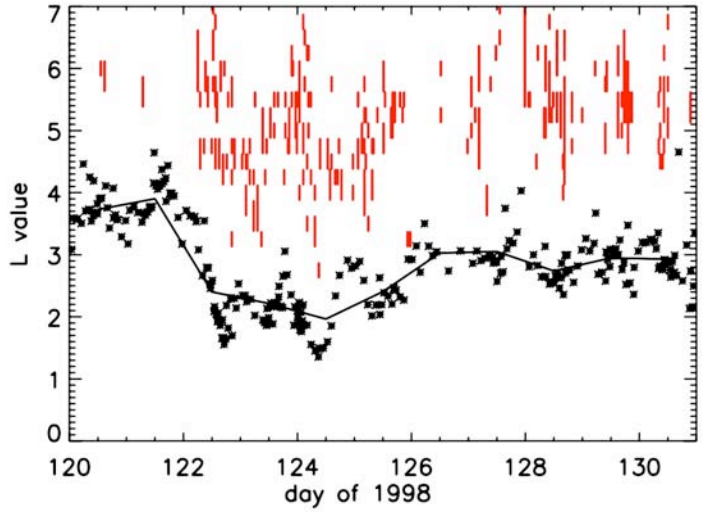
Initial results: microbursts

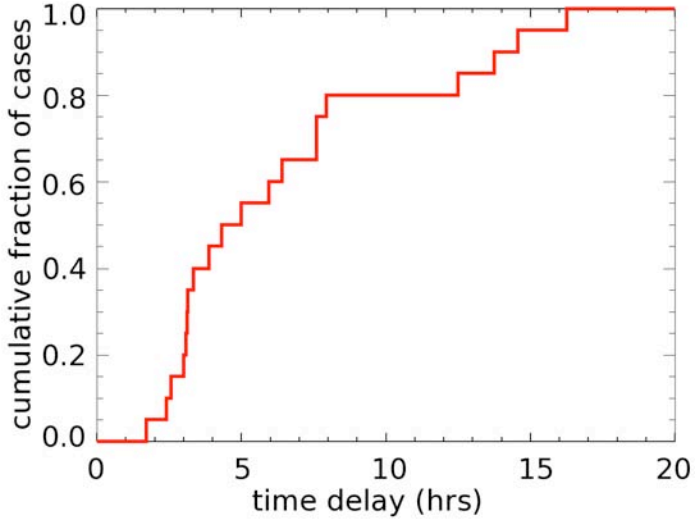
- red: SAMPEX-identified microbursts
- black: all DMSP-based plasmapause IDs
- shows strong correlation in radial dynamics
  - During erosion, inward movement of microbursts follows inward PP movement within hours



Initial results: microbursts

- Top: plasmapause IDs (black) and microburst locations for days 30 April-10 May 1998, dawn side (MLT 0200-1100)
  - Microbursts consistently outside PP locations
- Bottom: for fixed L value bins, cumulative fraction of cases with maximum time delay between last PP ID and first microburst (for four 2001 storms)
  - Microbursts follow erosion by as little as a few hours
  - Significant increase begins after delay of ~3 hours (this represents an upper limit given sampling issues)





Conclusions

- We have obtained initial results from a method of identifying the plasmapause using DMSP observations of the LIT.
- Comparisons show good correlation with IMAGE plasmapause IDs and SAMPEX radiation belt flux observations.
- Initial results from comparisons to SAMPEX microburst observations show microbursts follow plasmapause erosion on timescales of a few hours
- This approach will be applied to full DMSP database: ~15 years of observations--covering full lifetime of SAMPEX.
- Database will be used for event studies and to statistically analyze correlation of plasmapause-radiation belt dynamics.