The CARISMA Array of Fluxgate and Induction Coil Magnetometers

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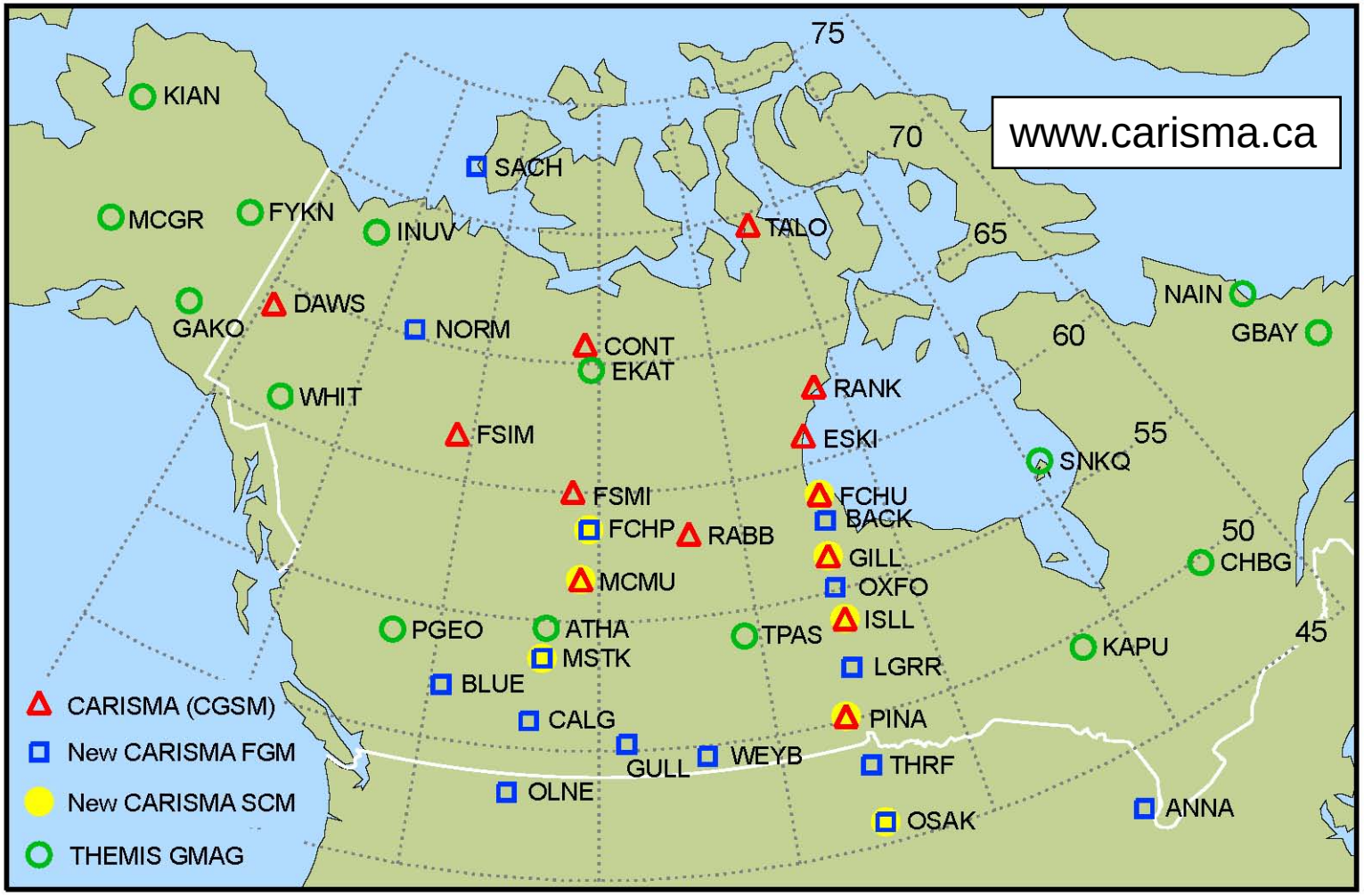
Outline

- The CARISMA magnetometer network: Instrumentation and data products
- CARISMA – RBSP conjunctions
- Ground magnetometer-RBSP conjunctions are a powerful tool for RB science.
  - Meso-scale characterisation of Pc3-5 ULF waves.
  - GB detection of EMIC waves
  - GB determination of plasmapause

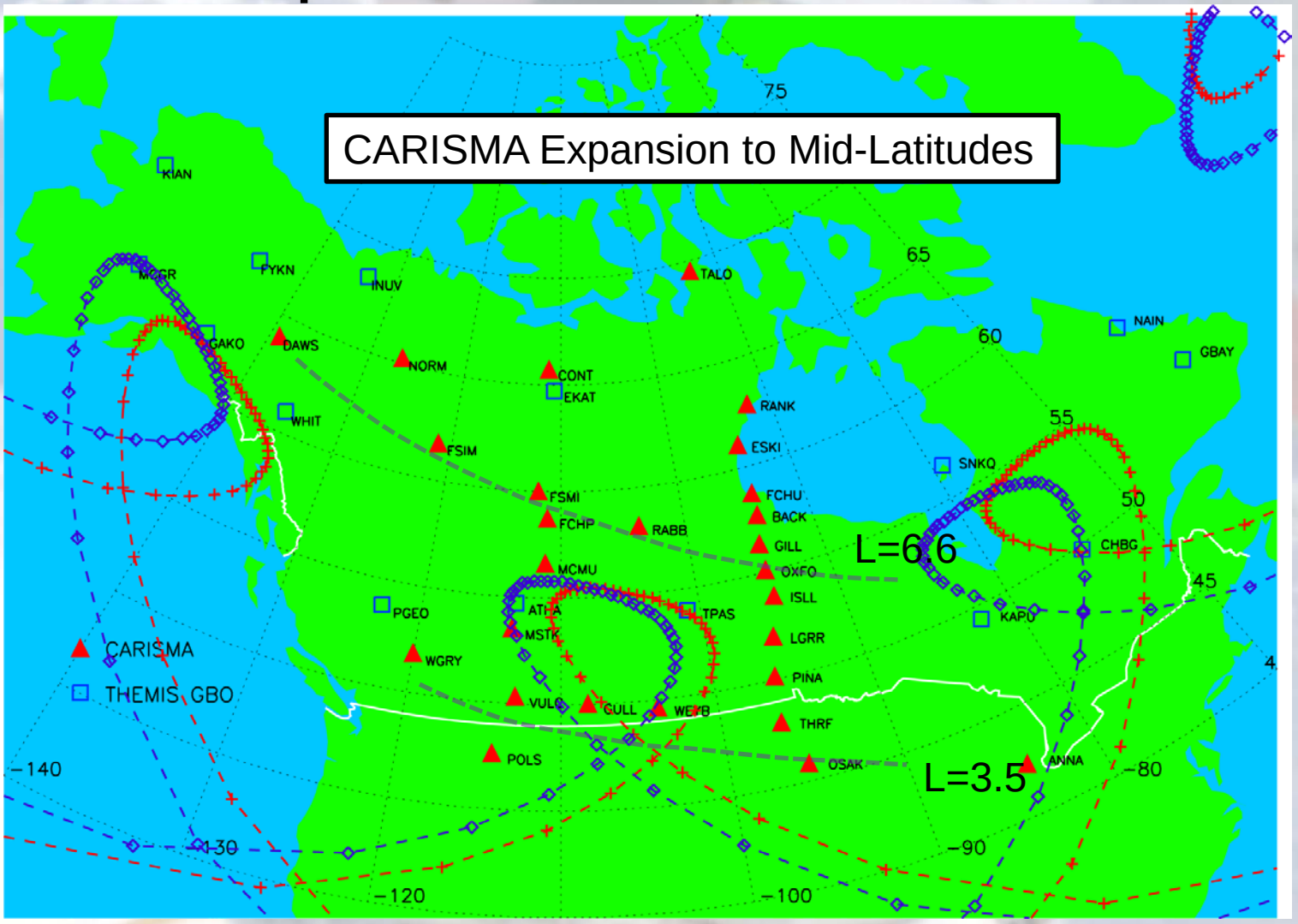
Expanded CARISMA Magnetometer Array



Data Products

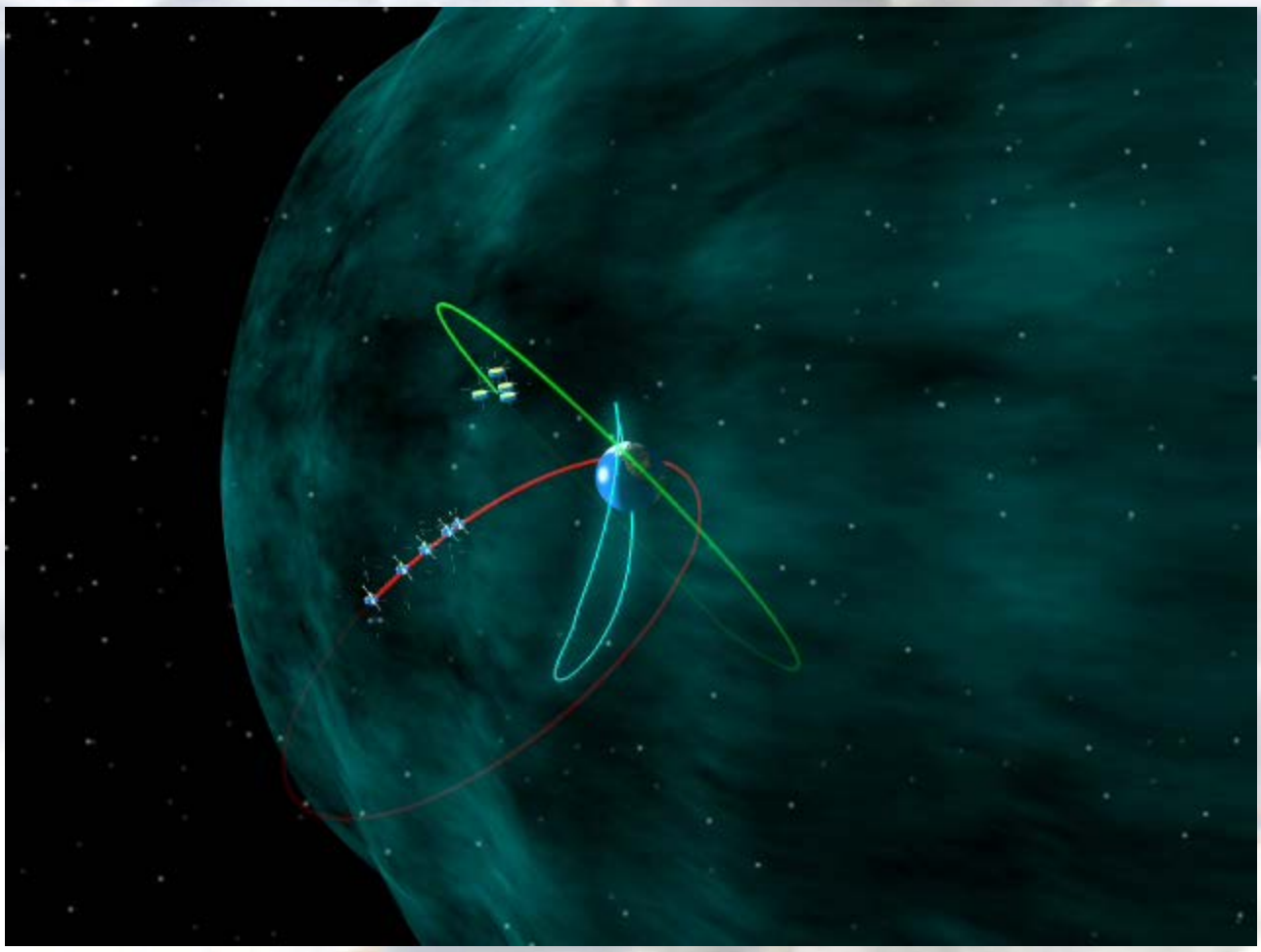
- Fluxgate Magnetometers
  - 28 sites, XYZ (24 currently operational)
  - 8 samples/second (available on request)
  - 1 sample/second standard data product
  - 2 samples/second CDF rotated into HDZ for THEMIS
- Induction Coil Magnetometers
  - 8 pairs, HD
  - 100 samples/second raw data (available on request)
  - 20 samples/second standard data product
- Data Access
  - Open data policy
  - Online access coming very soon at www.carisma.ca
  - On request to PI, Project Manager or info@carisma.ca

Example RBSP GB B-field Trace



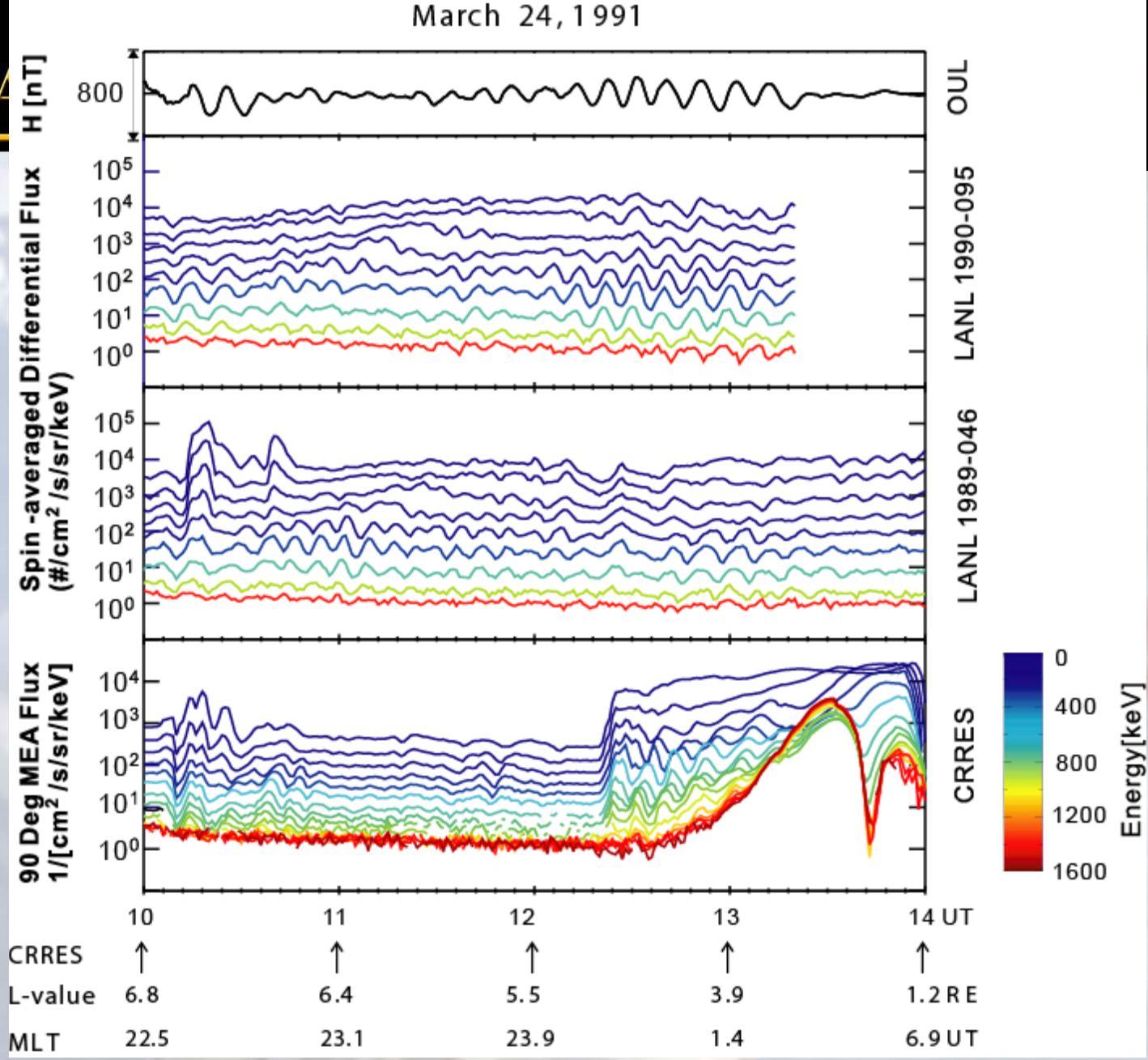
Meso-Scale Pc3-5 Wave Characterisation

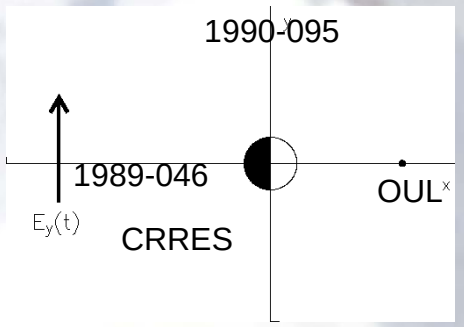
Phase Propagation of ULF Waves



- Phase propagation of ULF waves is critical for resonance with MeV electrons.
- Difficult or impossible to measure with RBSP depending on geometric probe separation.

March 24 1991 Storm





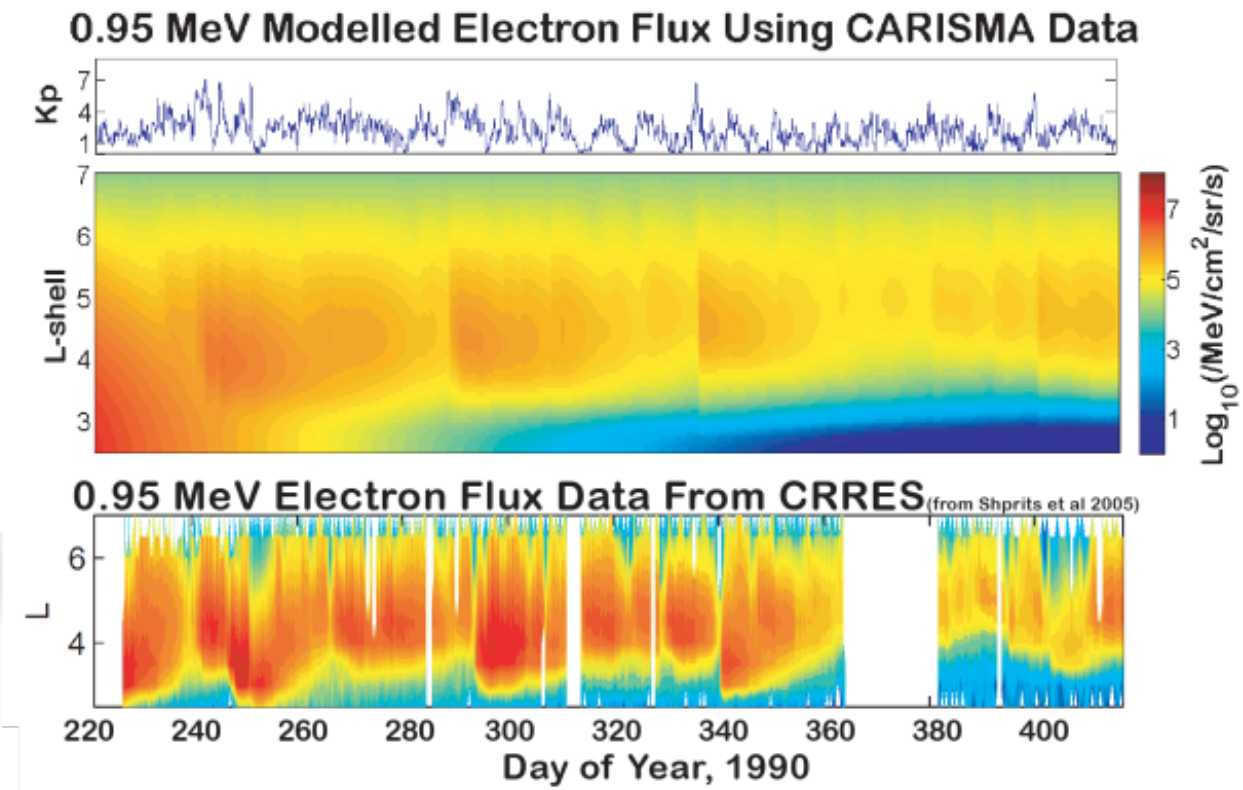
Thanks to LANL and CDAWeb for LANL and CRRES Data.

ULF Wave Radial Diffusion

- New set of ULF wave-derived electric and magnetic radial diffusion coefficients (Ozeke et al., JGR, 2012). Statistics based on 20 years of CARISMA data.

- Ozeke et al. D-LL characterised by Vsw and Kp – can be applied to RBSP events and compared to observations. Test of diffusion theory.

Test D-LL Radial Diffusion Simulation



- Ozeke et al. (2012) Kp dependent D-LL.
- Flux at fixed E constructed with multiple PSD simulations.
- Fixed outer BC.
- Simple fixed loss timescale 10 days.

Ozeke (UofA Lead): Future implement PADIE loss (with Horne) and variable outer BC.

Ground-Satellite Conjunction Studies and Diagnosis of EMIC Waves

EMIC waves: Relation to Plumes?

- Role of EMIC waves in MeV electron dynamics at edge of plasmasphere and plumes?

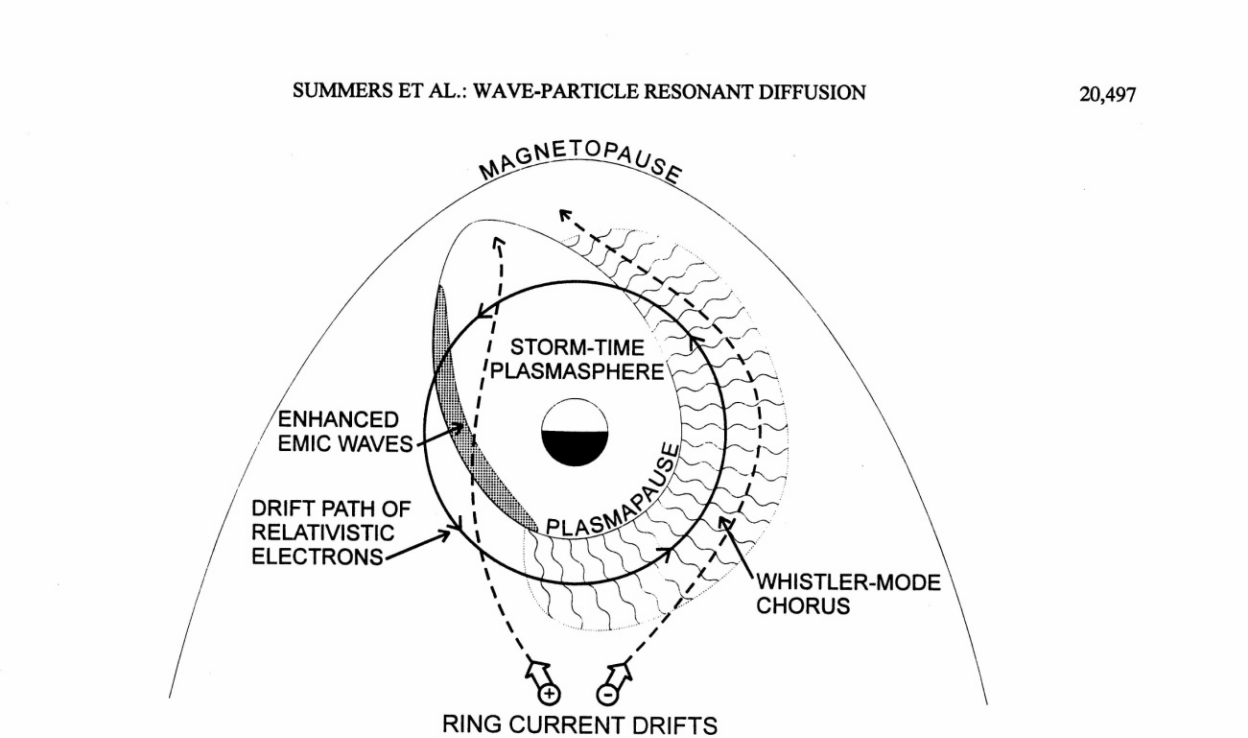
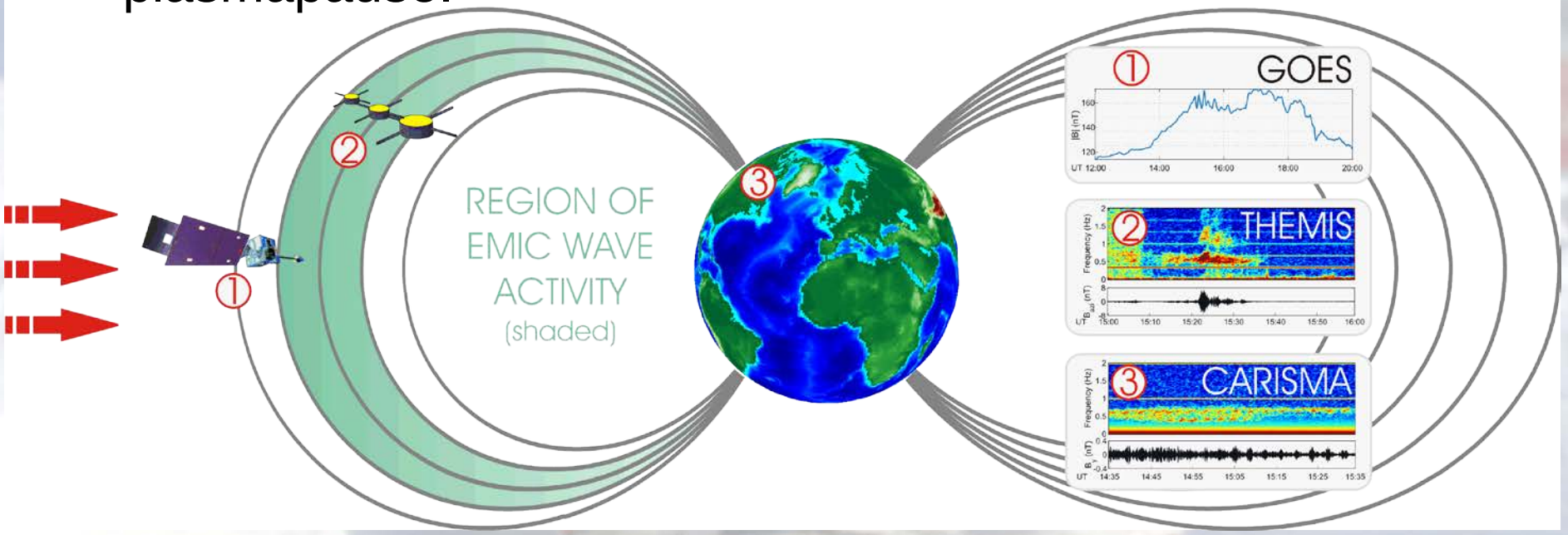


Figure 7. Schematic diagram showing spatial distribution of whistler mode chorus and EMIC waves during magnetic storms in relation to the position of the plasmapause and the drift paths of ring current (10–100 keV) electrons and ions and relativistic ($\gtrsim$ 1 MeV) electrons.

Localised EMIC Waves at the Plasmapause

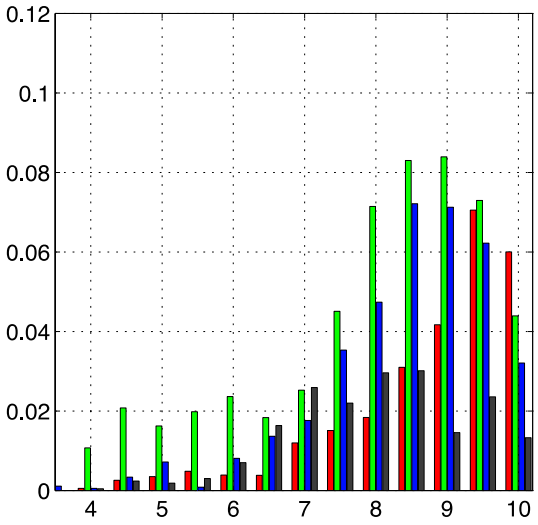
- Narrow region (< 1 Re) of EMIC waves inside the plasmapause.



Usanova et al., GRL, 2008.

THEMIS FGM EMIC Element Statistics

1 < Pdyn < 2 nPa

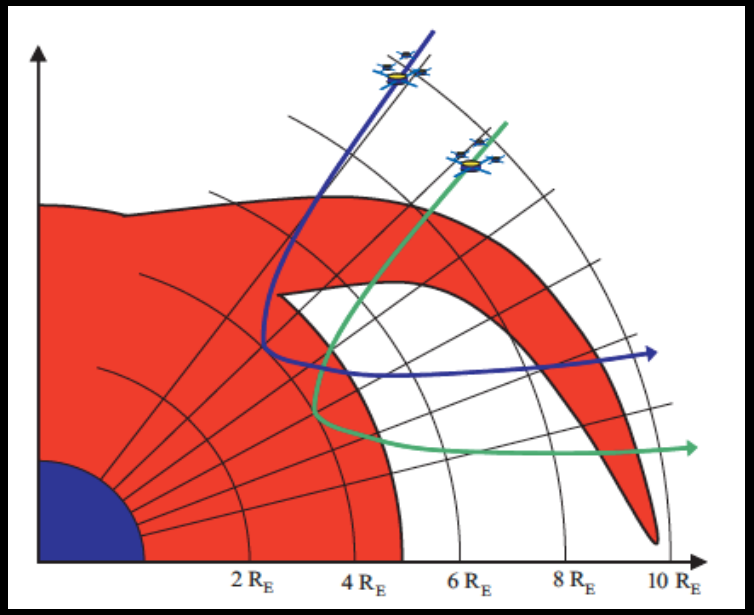


- 4 s/c THEMIS data 2007-2011.
- Binned by Pdyn and LT sector
- Rises with Pdyn; peaks noon and afternoon.
- Occurrence rate of EMIC very low but higher in the outer magnetosphere than the inner.

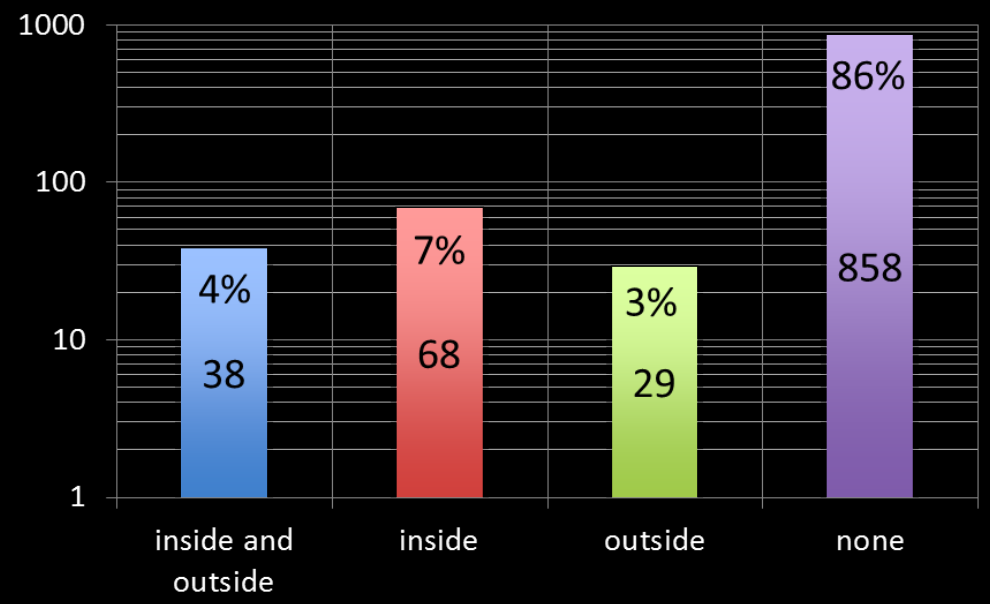
Usanova et al., JGR, Submitted 2012

Cluster Plume Crossings 2001-2006

Schematic showing the plume



Event Statistics



- Darrouzet et al., Ann Geophys. (2008) routinely identified plume crossing by Cluster.
- They used Cluster WHISPER instrument that measures high-frequency electric fields

and derived electron plasma density from electron plasma frequency.

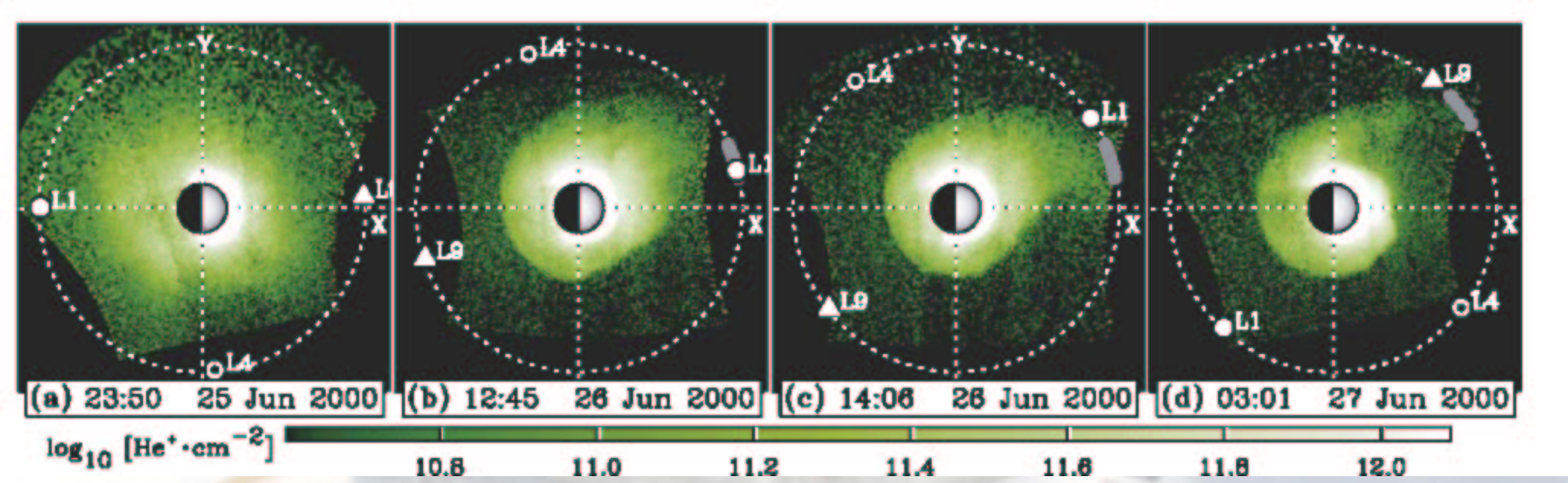
- Their statistics includes 993 plume crossings between 2001-2006.

EMIC waves were observed during 106 (11%) out of 993 plume crossings:
4% inside and outside; 7% inside.

Usanova, Darrouzet, Mann and Bortnik, 2012

GB Magnetometer Sensing of Plasmapause and Plumes

IMAGE Satellite EUV images from Goldstein et al, 2004.



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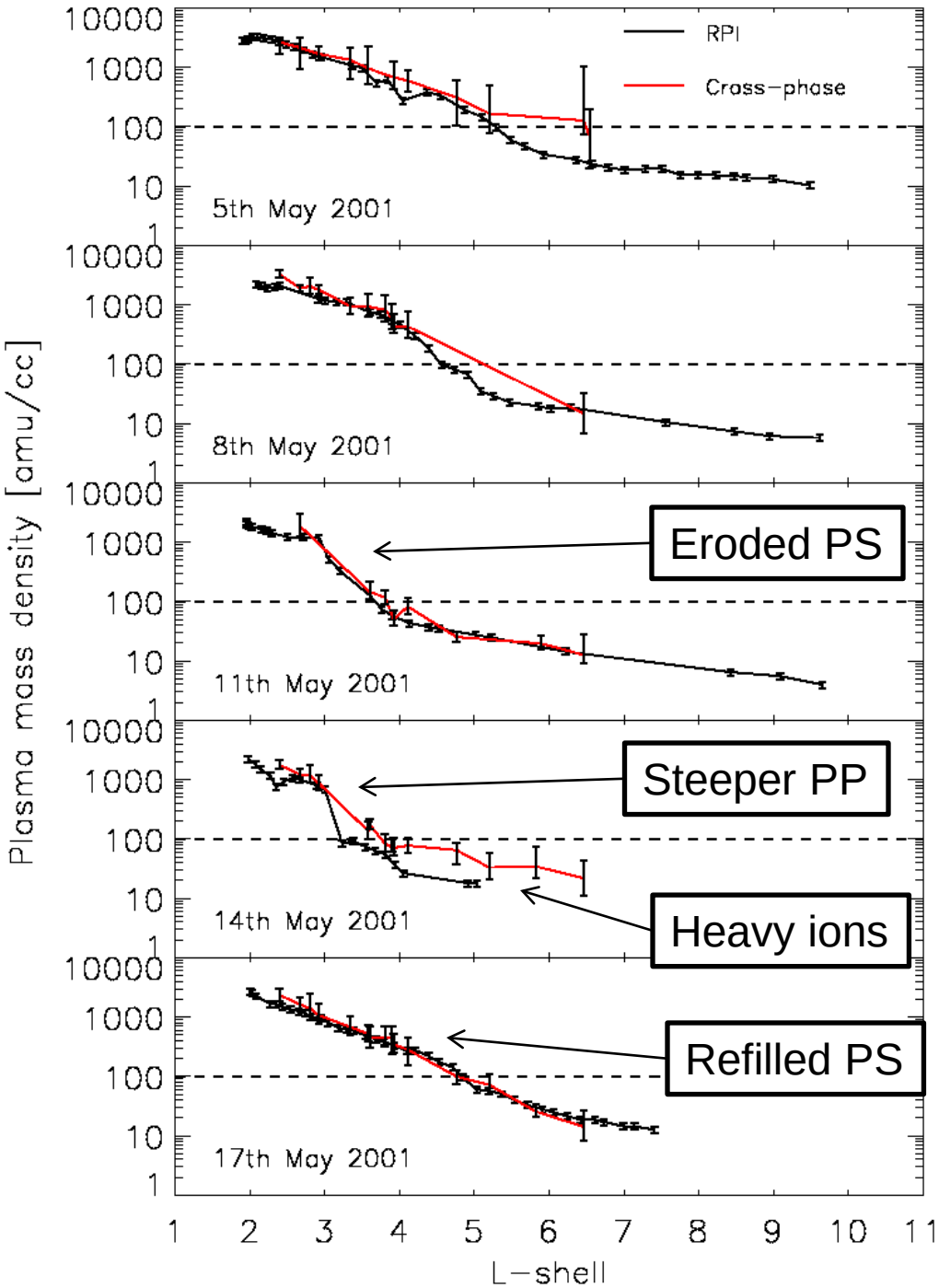
Cross-phase and IMAGE RPI plasma mass density profiles.

- Equatorial plane cross-phase densities have been calculated assuming a dipolar field geometry and a r^{-3} radial density distribution.
- In-situ RPI electron number densities are shown.
- The heavy ion population may be inferred from the difference between the two profiles.

Dent et al., JGR, 2006.



Summary and Conclusions

- CARISMA is well located for RBSP conjunctions
- Ground magnetometer-RBSP conjunctions are powerful tool for RB science.
  - Meso-scale characterisation of Pc3-5 waves.
  - GB detection of EMIC waves
  - GB determination of plasmapause
  - Potential detection of heavy ions (eg with spacecraft potential from EFW)
  - Others... (including ionospheric Alfven resonator)
- Welcome collaborative studies with RBSP (and other platforms)
- Data freely available from www.carisma.ca or on request


Image U.S. Geological Survey
©2009 Google

Statistical Analysis of EMIC Waves in Plasmaspheric Plumes from Cluster Observations

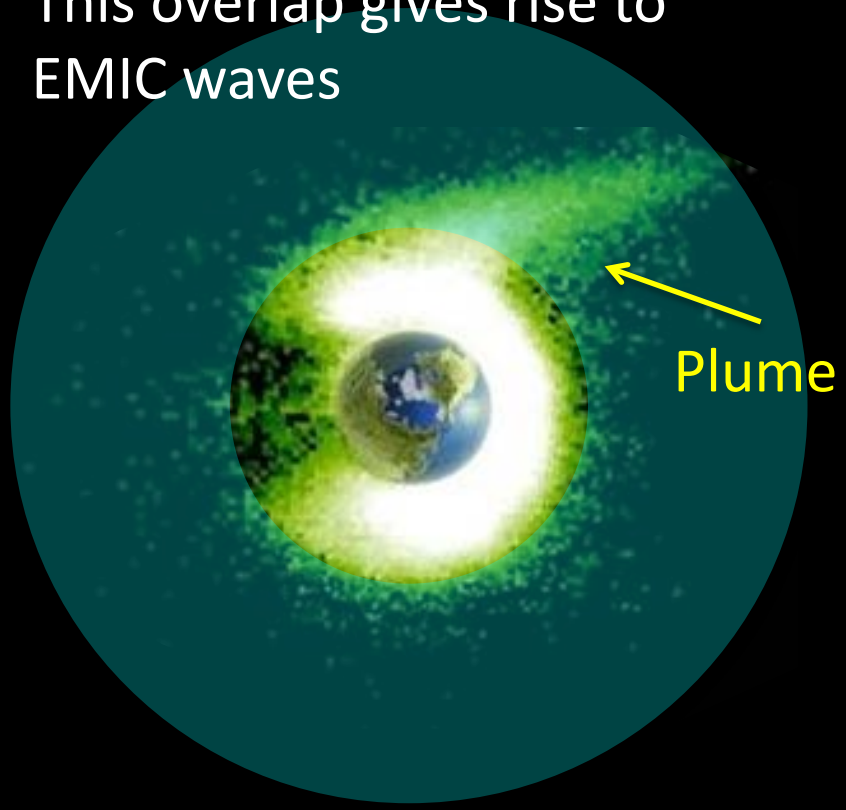
M. E. Usanova[1], F. Darrouzet[2], I. R. Mann[1], J. Bortnik[3]

[1]University of Alberta, Canada
[2]Belgian Institute for Space Aeronomy, Belgium
[3]UCLA, USA

To be submitted to JGR 2012

EMIC Waves in Plasmaspheric Plumes

This overlap gives rise to EMIC waves



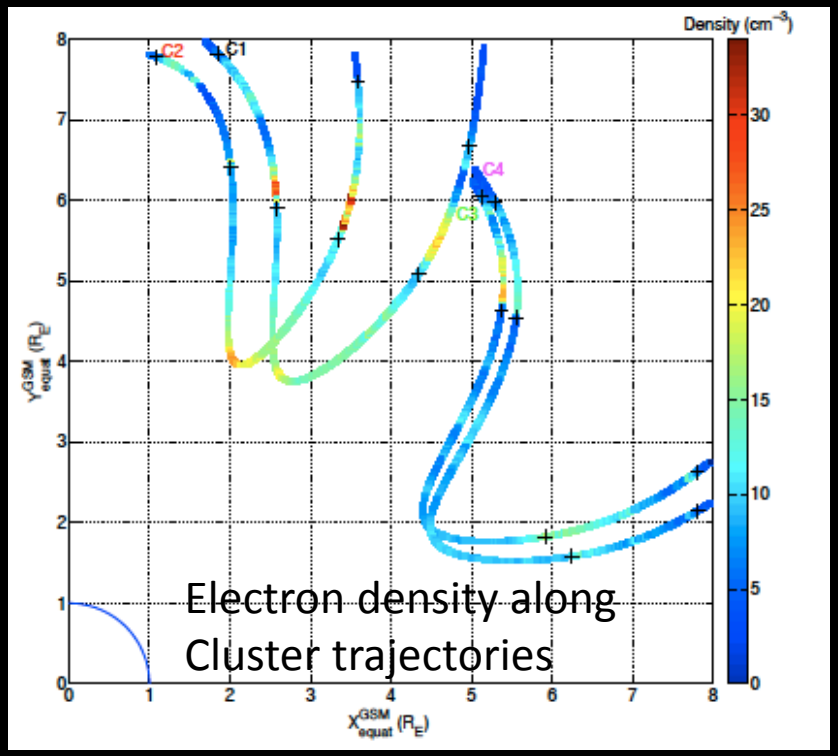
Courtesy: Jerry Goldstein

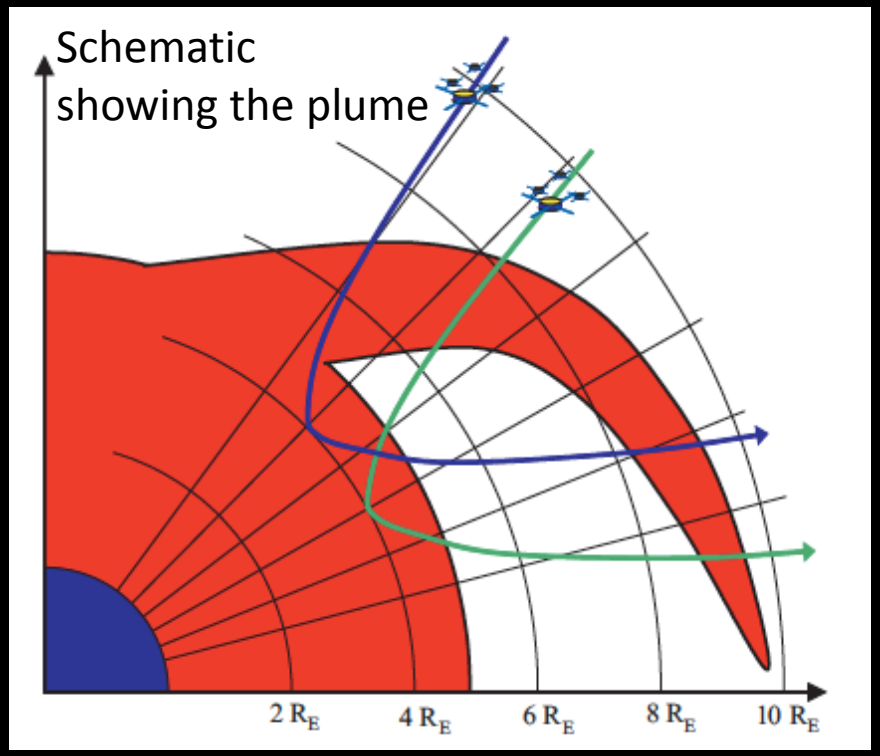
Plasmaspheric plume is a portion of the outer plasmasphere on the dayside are transported sunward, during disturbed geomagnetic conditions.

The presence of cold dense ions lowers the ion cyclotron instability threshold (Gary et al., 1994). Energetic protons drifting westward from dusk may become unstable when they encounter the enhanced cold plasma densities within the plasmaspheric plume.

Case studies: Spasojevic et al., GRL 2004; Fuselier et al., JGR 2004; Morley et al., JGR 2009.

Cluster Plume Crossings from Whisper





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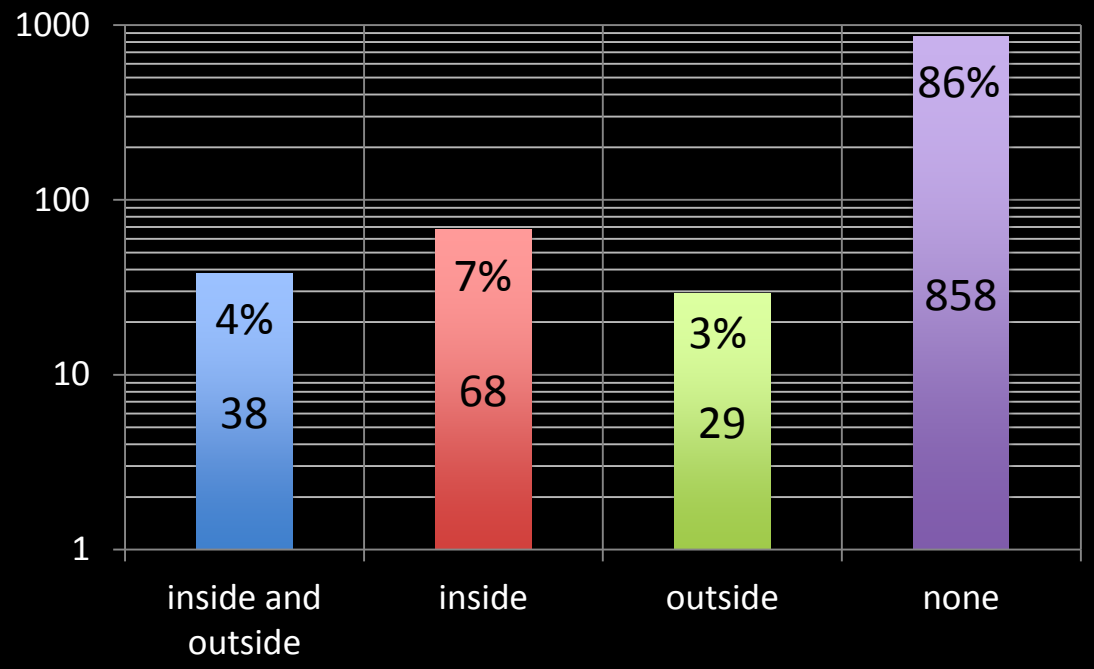
Event Statistics



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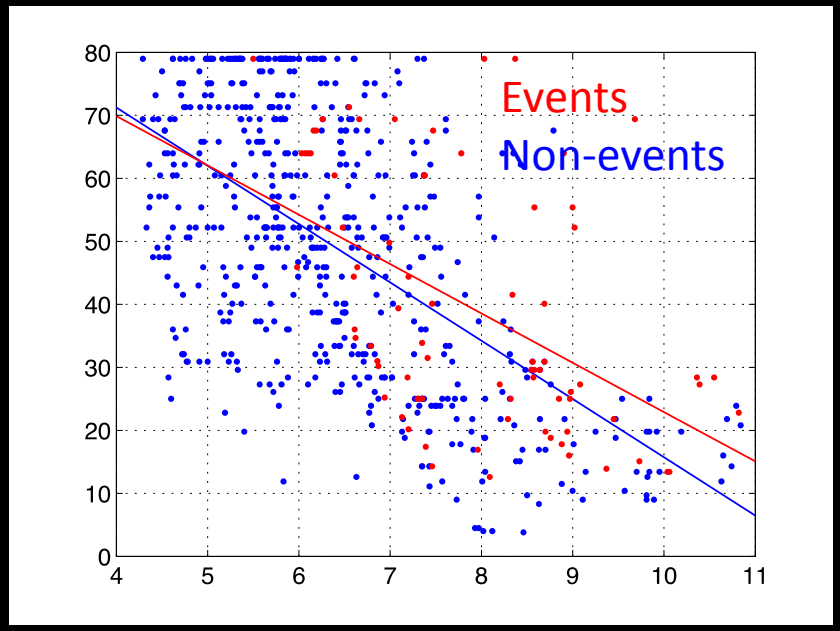
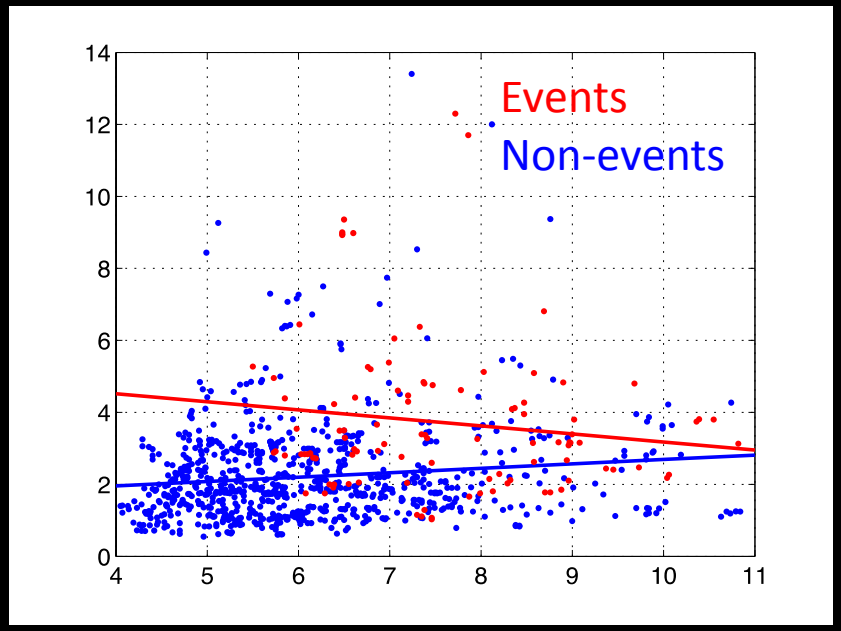
Event Statistics: Density and P_{dyn} vs. L





- The density difference between the events and non-events is insignificant (left panel).
- EMIC events occurred during higher solar wind dynamic pressure than non-events (right panel).

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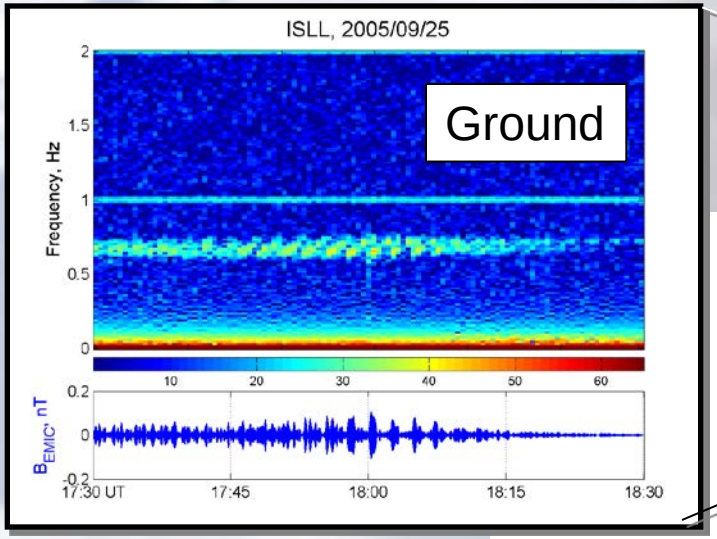
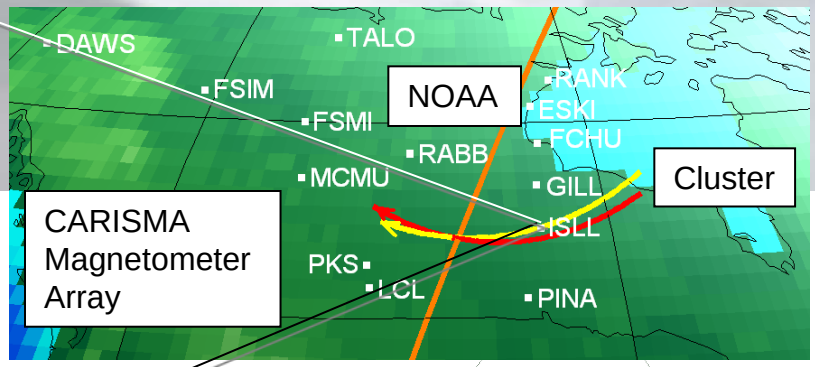
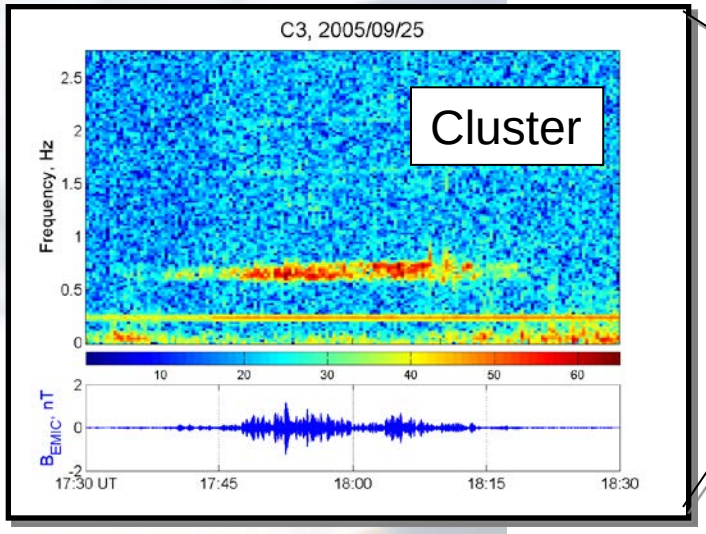
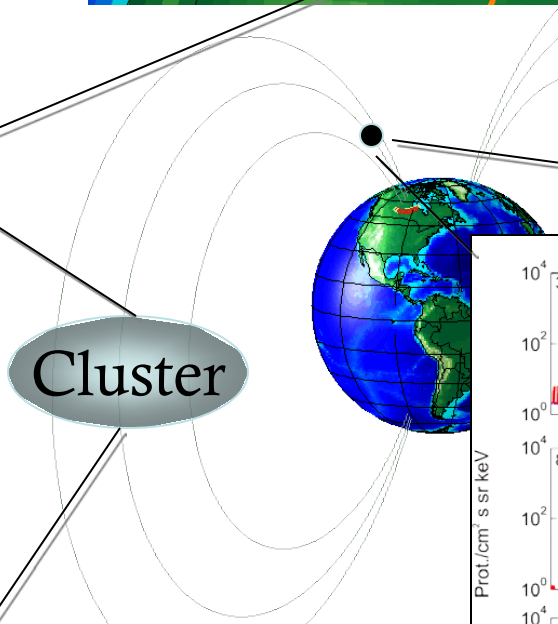
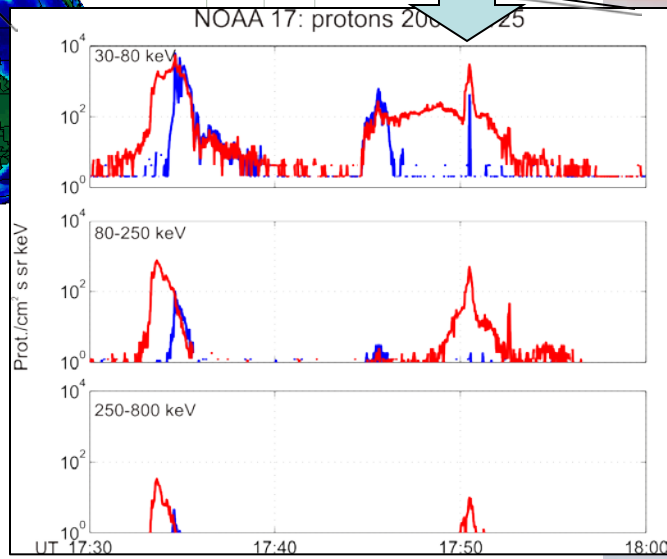








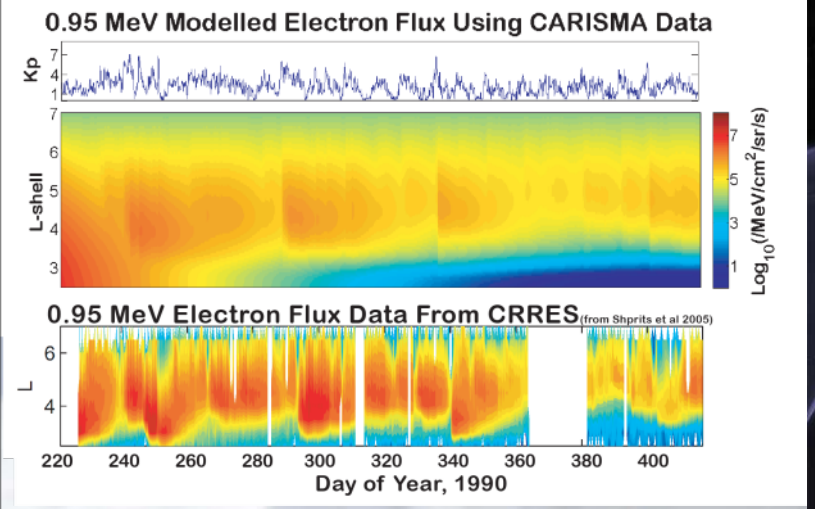
30-80 keV Proton Precipitation

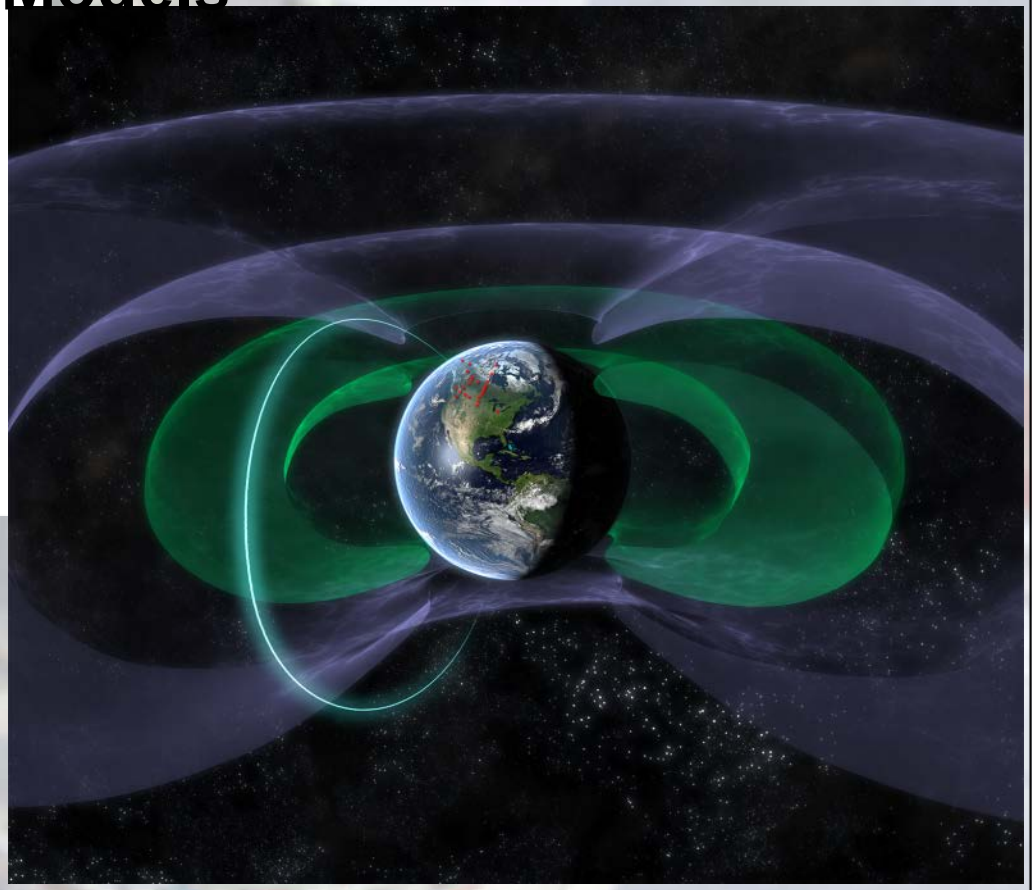


NOAA data courtesy of Finn Soraas.

Usanova et al., JGR, 2010

Space Weather Now- and Fore-casting with ULF Wave Models





Diffusion coefficients derived from CARISMA ULF data mapped along the field lines into the equatorial plane of the outer radiation belt.