Ionospheric Plasma in the Magnetotail

W.K. Peterson

LASP

University of Colorado, Boulder

Acknowledgements: T. Moore, A. Korth, J. Scudder, C. Russell V. Angelopoulos, H. Collin, O.W. Lennartsson, D. Baker, X. Li, and A. Yau

Outline

What have we leaned from previous investigations of ionospheric plasma in the magnetotail?

Sources | Losses | Structure | Dynamics

Why haven't we been able to answer "important" questions?

Where and how do substorms start?

Is there an undetected cold plasma component in the plasma sheet?

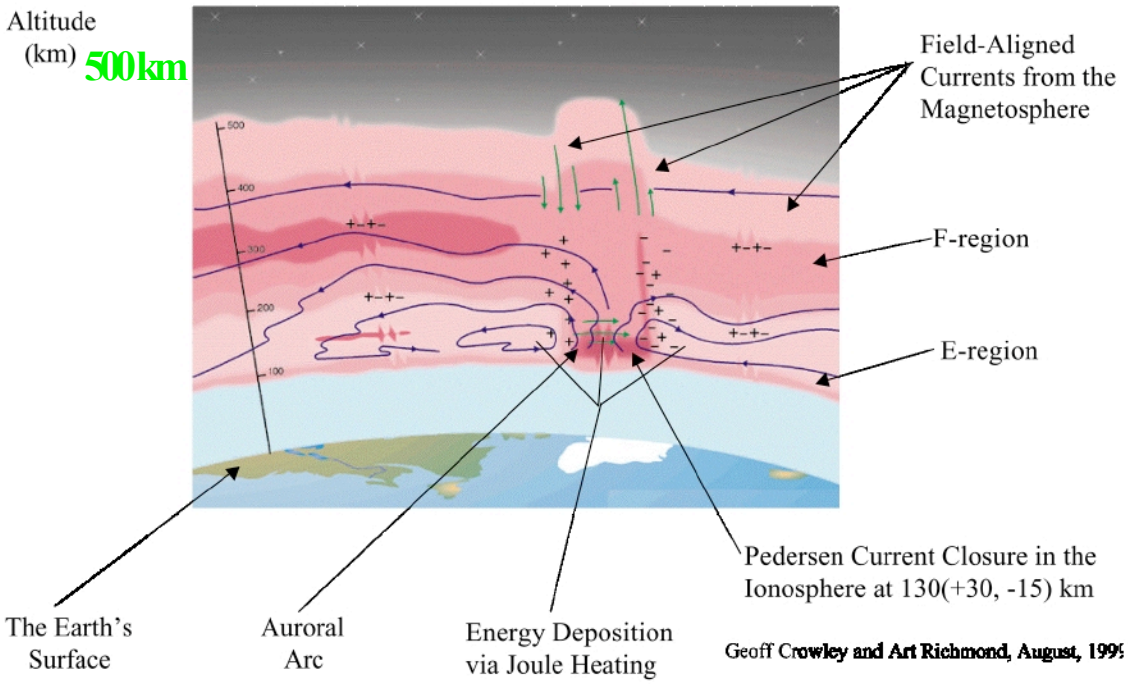
What kinds of questions should we be asking of the the Cluster, Image, and Polar data sets?

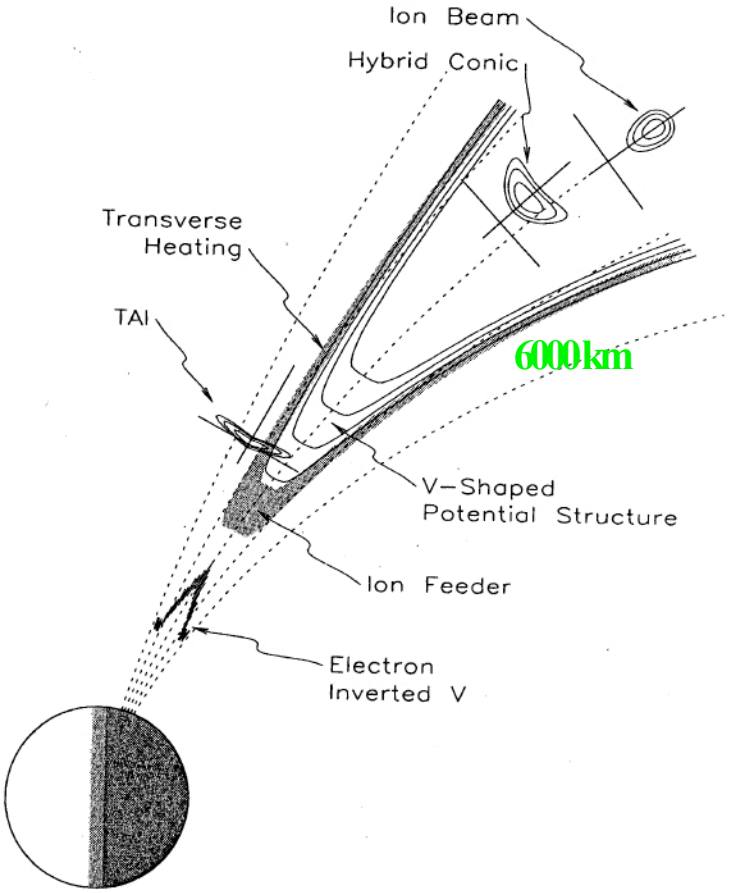
Sources of plasma

- **Solar wind - the HELIOGENIC component**
  - **H^+ He^{++} O^{6+} O^{5+}**
  - Dominant during geomagnetically quiet intervals
  - Entry by **injection, diffusion, and convection**.
    - Only episodic investigations, no clear observational basis to support the dominance of any one picture of solar wind entry or their relative importance.
- **Ionosphere - the GEOGENIC component**
  - **H^+ He^+ O^+ N^+ O^{++} O_{2+} NO^+ N_{2+}**
  - Dominant during geomagnetically *very active* intervals
  - **Many processes are involved** in the energization and transport of geogenic ions from the ionosphere to the magnetotail
    - There are good, long term, calibrated data bases of ion outflow and plasma sheet composition available from ISEE/ICS, DE/EICS, Akebono/SMS, and Polar/TIMAS

Geogenic Source Processes

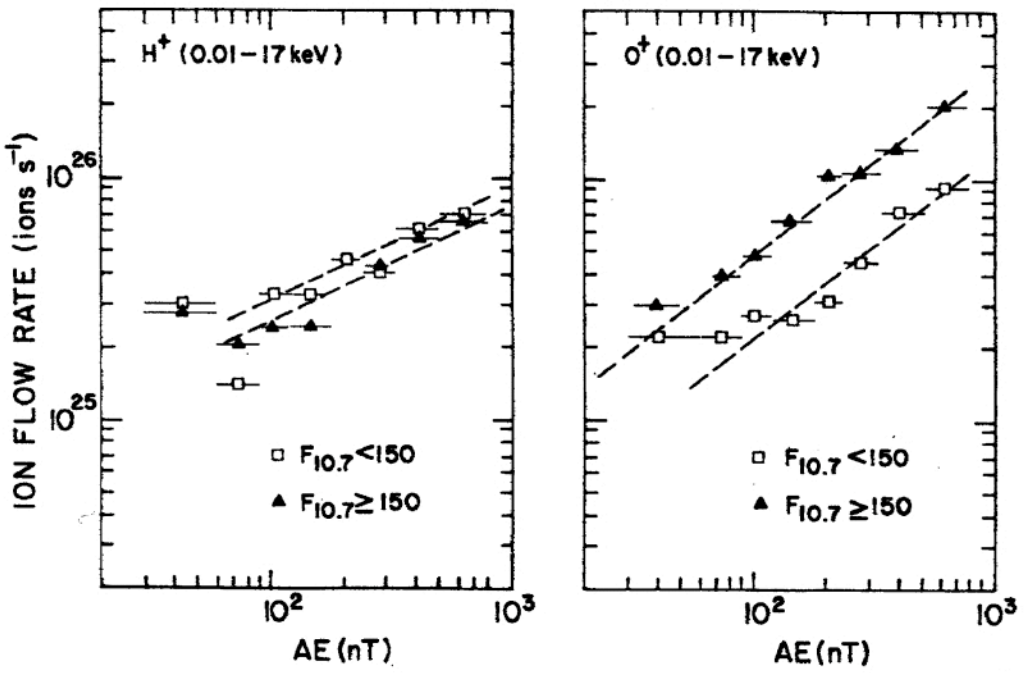
The ionosphere is not a thin conductor!



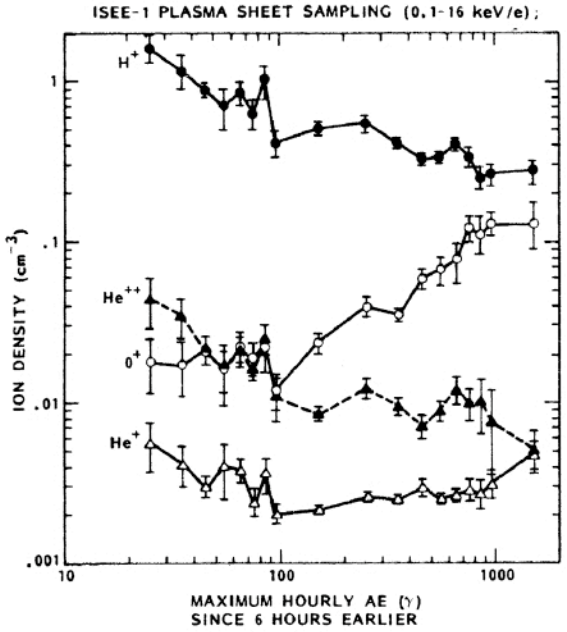


Relative flux and energy of H^+ He^+ O^+ N^+ O^{++} O_{2+} NO^+ and N_{2+} are strong functions of position, as well as geomagnetic and solar activity.

Long term average source flux and plasma sheet density



Yau et al. from DE -1



Lennartsson from ISEE -1

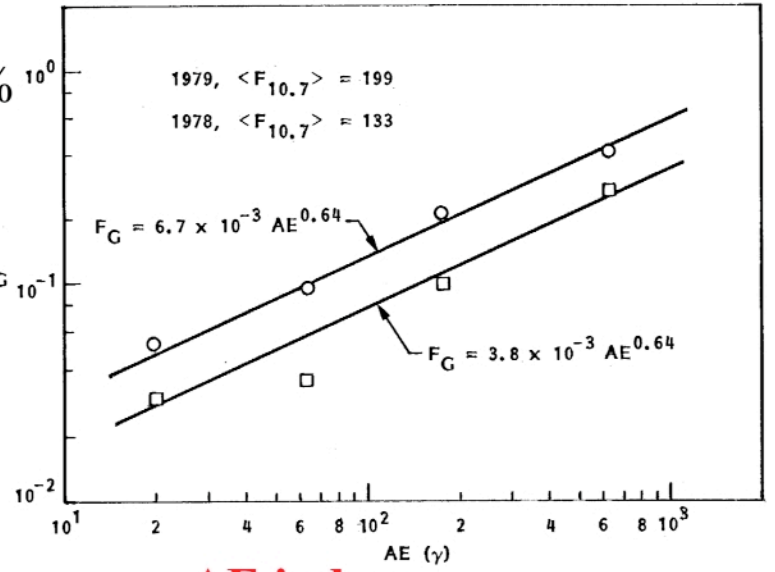
Shelley [COSPAR, and AGU, 1986] combined these statistical studies and a simple, static, model of the plasma sheet volume to provide a first order estimate of the variation of the plasma sheet composition as a function of **magnetic** and **solar** activity

Estimated fraction of the Plasma sheet of **Geogenic** origin

100%

10%

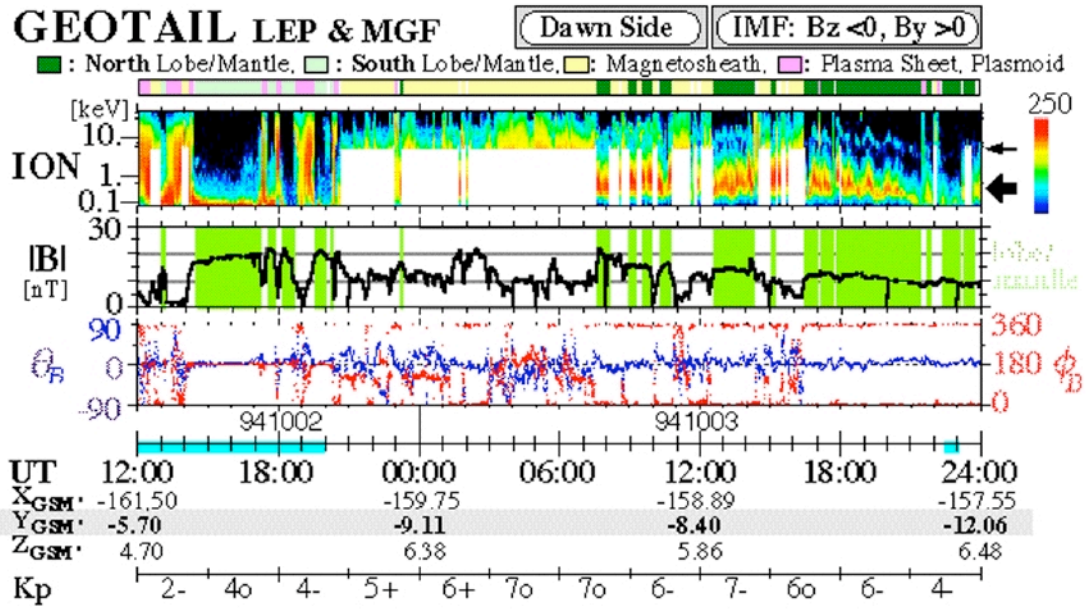
Two levels of solar activity



AE index

Chappell used basically the same DE outflow data and argued that the ionosphere was more than adequate to populate the plasma sheet at all times.

How much O^+ escapes down tail?



from [*Seki et al., JGR*, 1998a]

Seki et al. used Geotail data to estimate the flux of oxygen escaping down tail and found only about 10% of the flux expected from the DE -1 data.

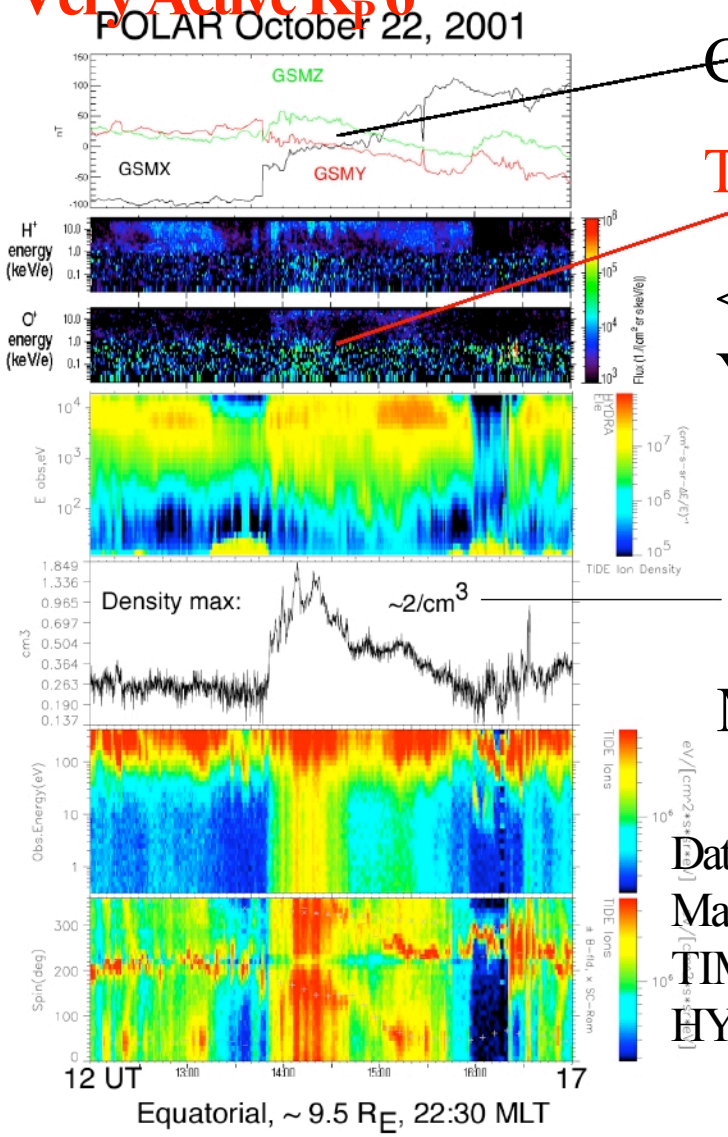
Where is the missing oxygen? Did Geotail/LEP miss it or did it not escape?

From DE -1 data Yau estimated that the net outflow of Oxygen was 5 x 10^7 Kg/yr and concluded that the net escape was balanced by oxygen created by photodissociation of water in the atmosphere. Seki

et al. used the same data and estimated that the equivalent of 18% of the current atmospheric oxygen has escaped.

Structure of the plasma sheet

Very Active K_P 6



Current Sheet

Thick Thin

< 100 eV O^+

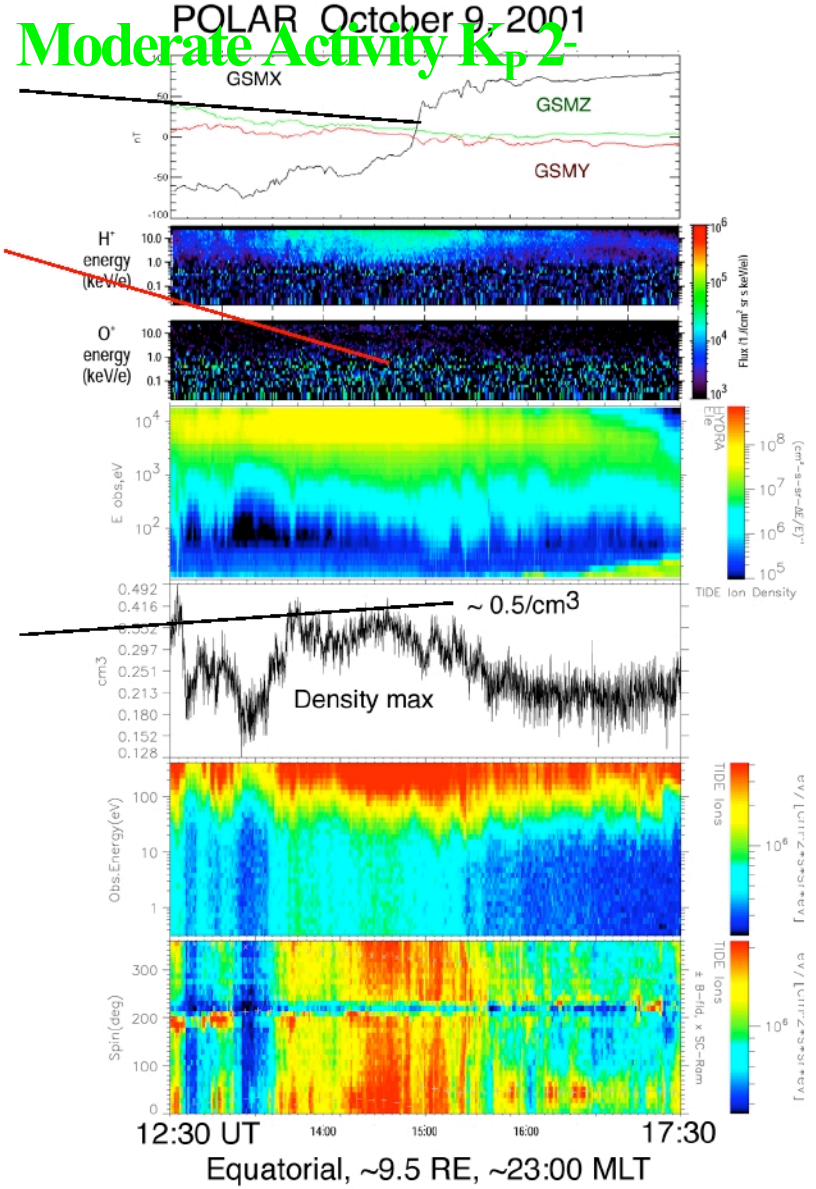
Yes No

Electrons

Max Density

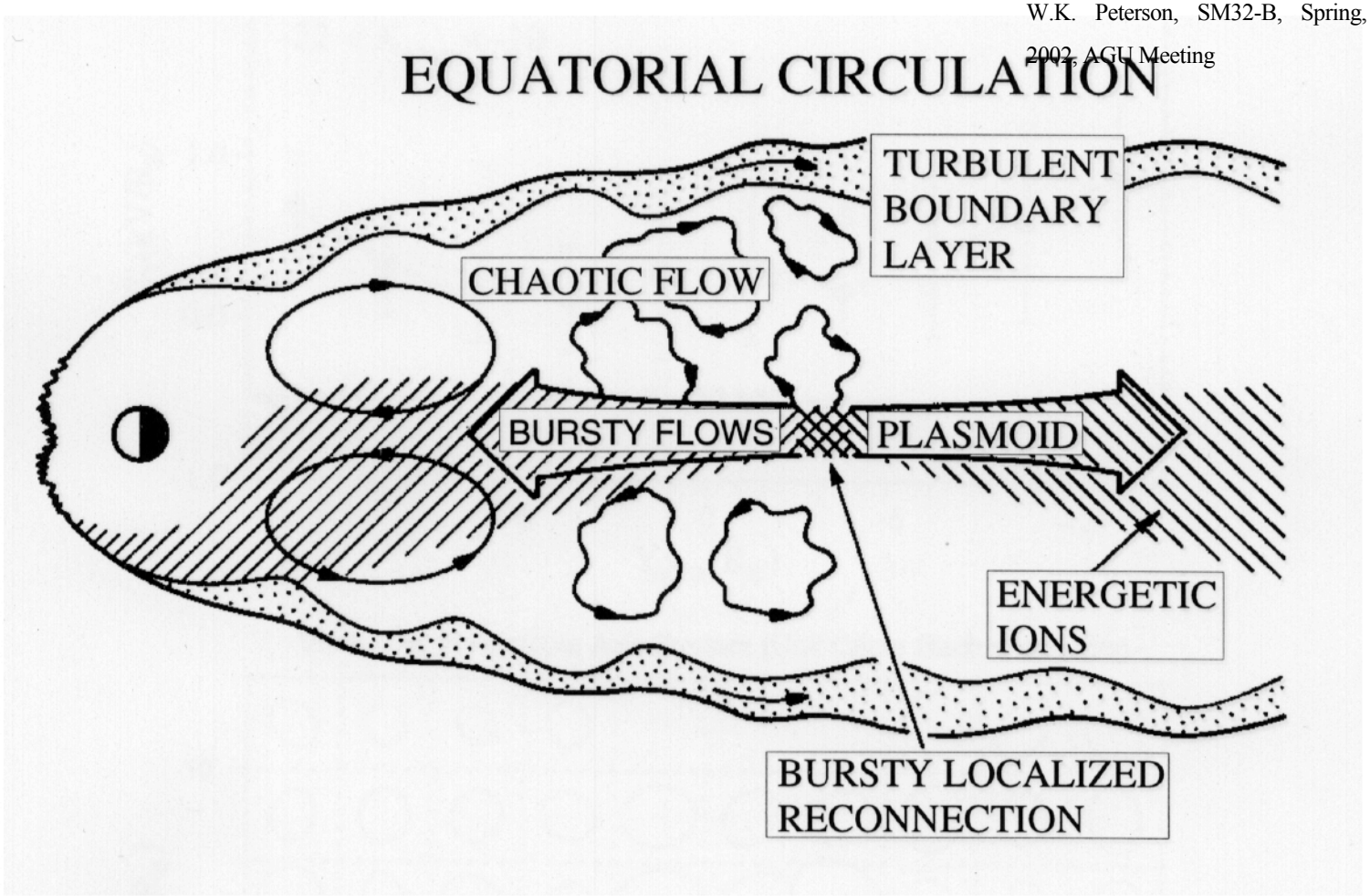
Data from:
Magnetometer (top)
TIMAS (next 2)
HYDRA (panel #4)

Moderate Activity K_P 2-



TIDE (bottom 3)

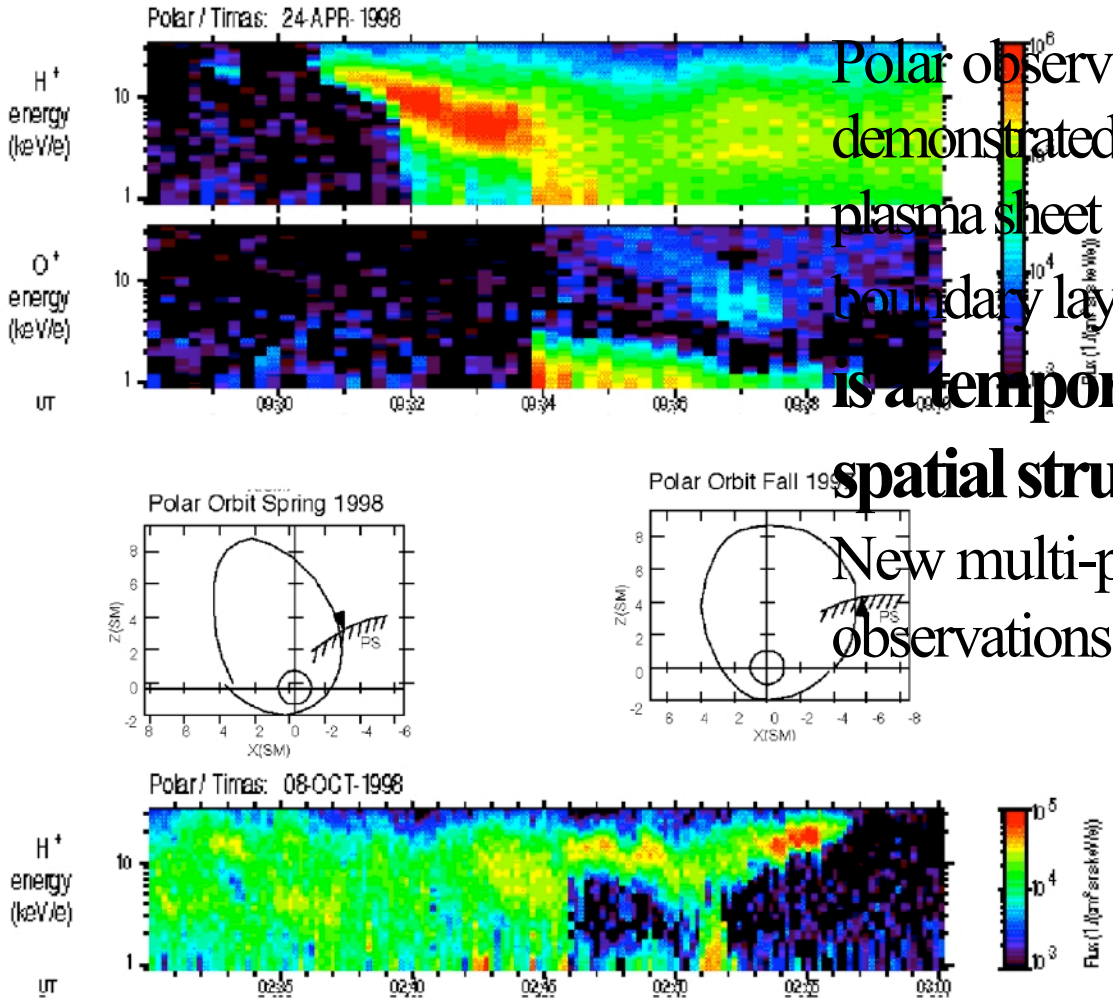
Dynamics of the magnetotail plasma



From Angelopoulos, GEM, 1999

Geotail observations that
validated this interpretation
were summarized by
Terasawa this morning

Temporal vs Spatial Structures or Dynamics



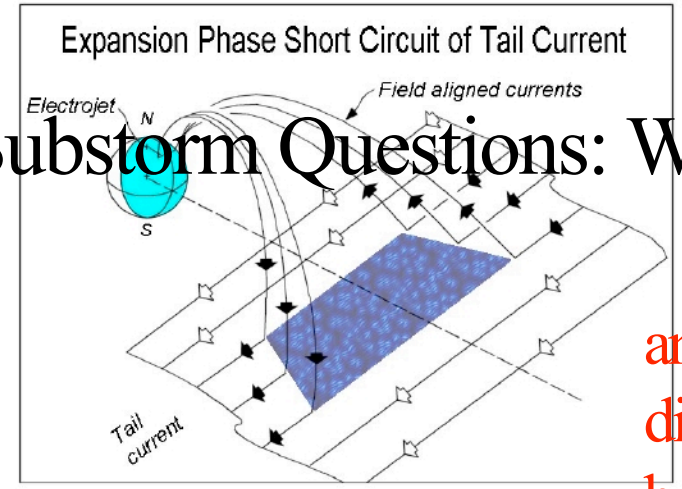
Polar observations demonstrated that the plasma sheet boundary layer **(PSBL) is a temporal, not spatial structure.**

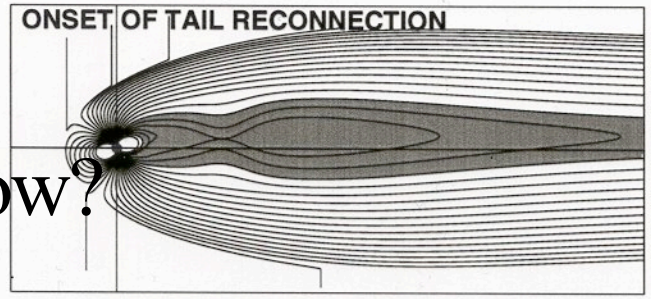
New multi-point observations from

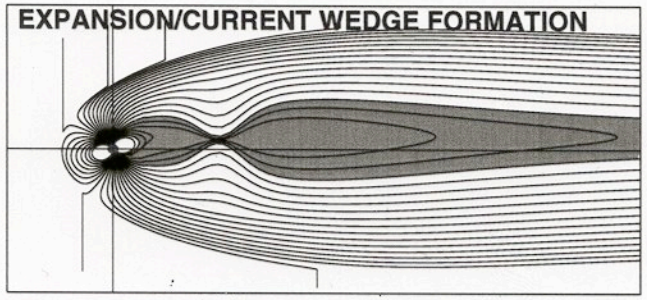
Cluster confirm this.

W.K. Peterson, SM32-B, Spring, 2002, AGU Meeting

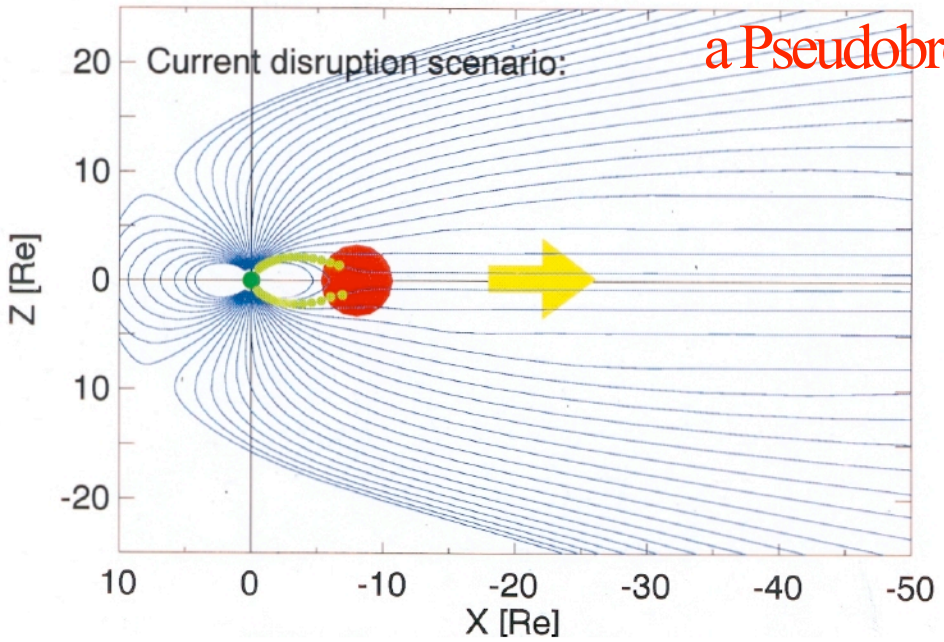
Substorm Questions: Where, When, How?

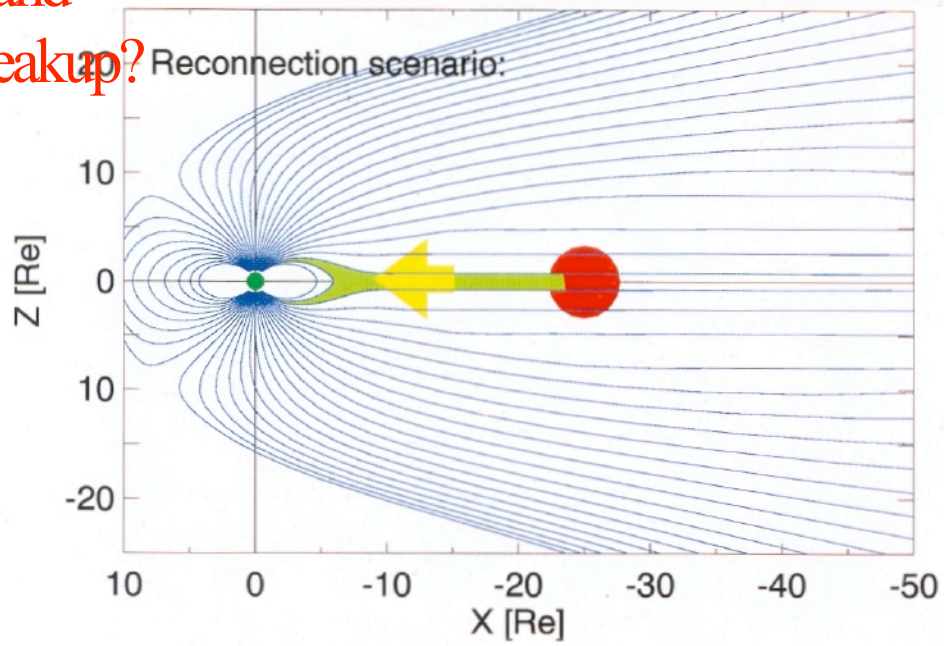




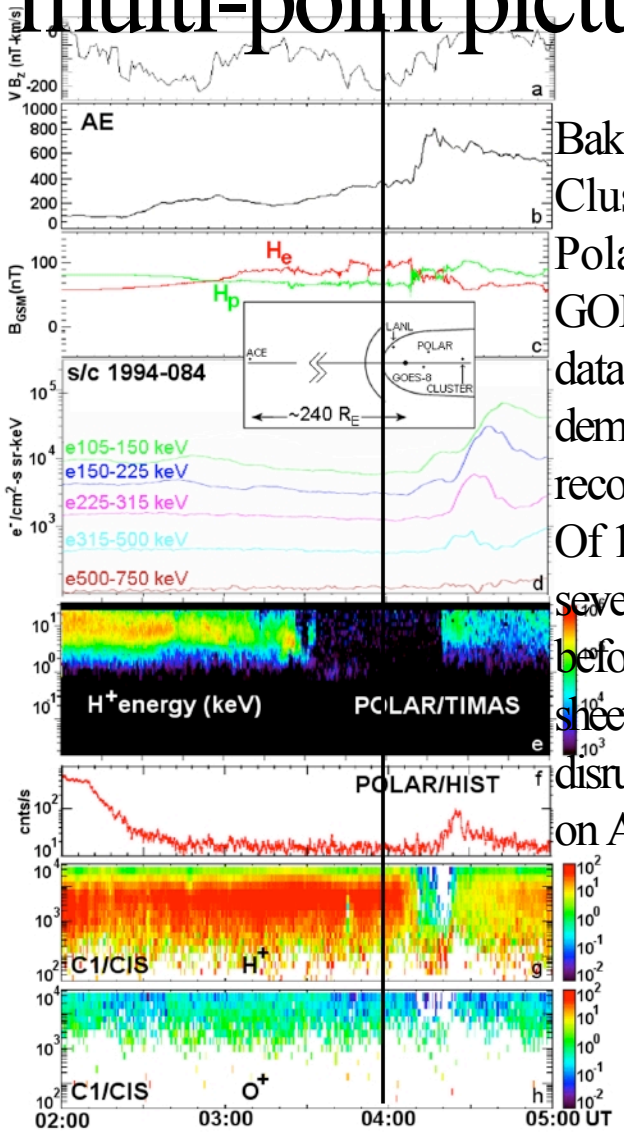


and What is the difference between a substorm and a Pseudobreakup?

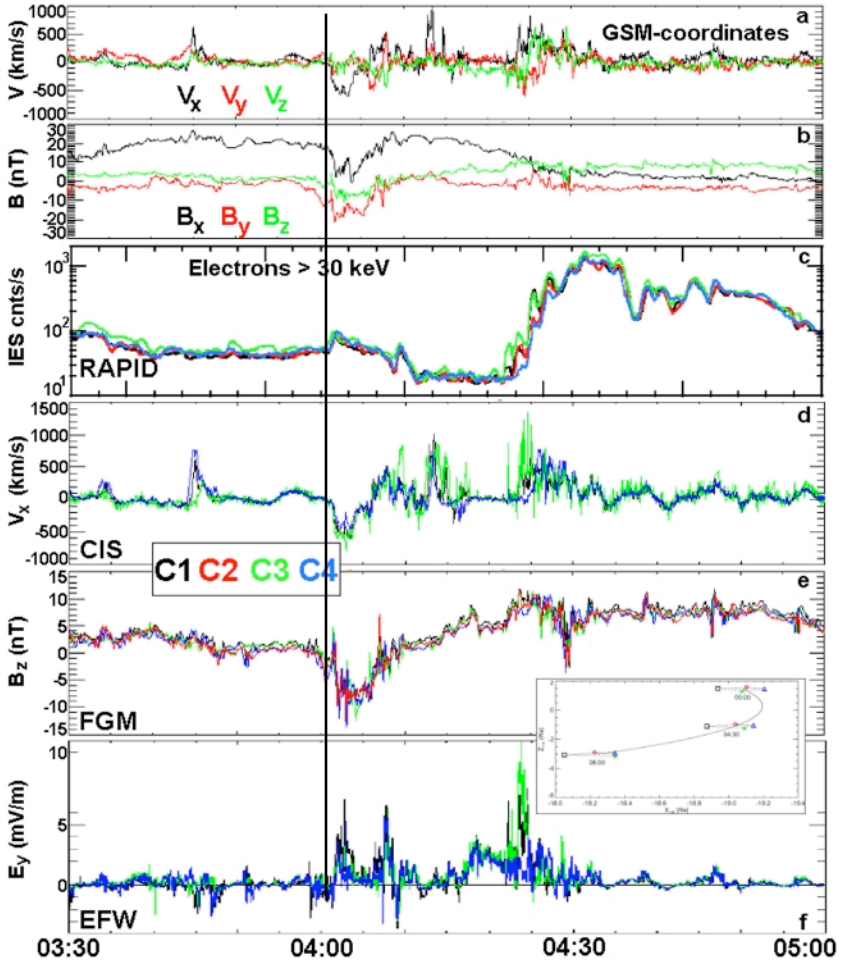




Cluster/Polar/Image are now providing a multi-point picture of the plasma sheet.



Baker et al., showed Cluster, IMAGE, Polar, LANL, GOES and ground data this AM that demonstrate that reconnection inside Of 19 RE occurred several minutes before the current sheet was disrupted at ~04:08 on August 27, 2001.



Assume Cluster/Polar/Image spacecraft and ground based observations can answer the substorm Where? and When? questions.

We are left with the How? Question

What basic plasma physics processes or mechanism(s) are responsible for initiation of reconnection and current disruption?

Or does it make more sense to investigate the "How?" question in the framework of Self Organized Criticality

How important is O^+ initiation of the tearing mode plasma instability?

- Baker et al. [1982] noted that a "blob" of O^+ in the plasma sheet would make it more unstable to the tearing mode described by Schindler.
- Cladis and Francis [1992] suggested that the the pressure associated with O^+ "blobs" in the plasma sheet modifies the magnetic field and drive

instabilities that lead to substorms

The observational evidence for O^+ tearing mode association with substorm onset is not convincing

- Daglis and his colleagues in a series of papers have reported observations "suggesting" or "consistent with" but not "proof of" the O^+ tearing mode occurring at or near substorm onset time (not position!)
- Lennartsson, on the basis of statistical evidence from ISEE-1 and AMPTE asserts that O^+ blobs are not generally assoicated with substorm onset.

What kind of Evidence do we need?

- Schindler's analysis was 2-D
- Electrons stabilize the plasma against the tearing mode

- We need updated estimates of the ranges of parameters over which O^+ "blobs" in the plasma sheet are unstable to the tearing mode?
  - Density Temperature Physical Size

Evidence?

The Daglis/Lennartsson disagreement comes down to:

Have the relevant observations been made at the right place at the right time?

The answer is no!

Best Candidates:

InterBall Tail beyond 15 R_E

Cluster

Questions we should address using Cluster/Polar/Image data sets

- What are the relative importance of the various solar wind entry mechanisms (injection/diffusion/convection)
- Structure and dynamics of the thin current sheet
- Substorm initiation
  - Current wedge and reconnection relative timing
- Evidence for O^+ "blobs" in association with substorm onset.

Conclusions

- We still don't understand plasma sheet dynamics well at all!
- We know enough now to ask some more focused questions of the data.
- We have spectacular, new, data coming in from Cluster, Image, and Polar now that Polar apogee is near the equator.