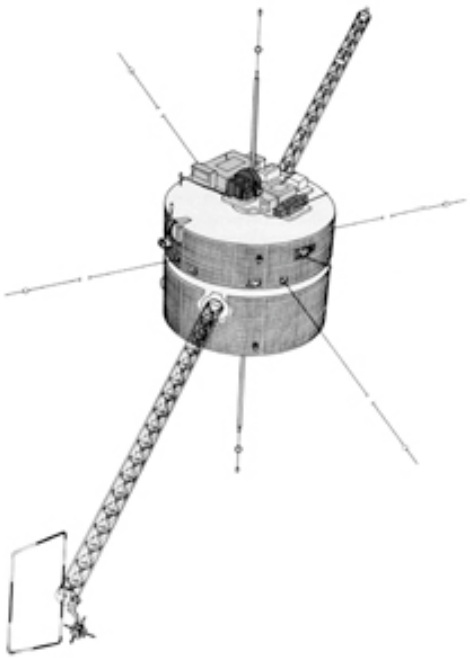
The Ionospheric Source of O^+ Ring Current Plasma



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1 LASP

2 LOCKHEED MARTIN
We never forget who we're working for®

3 THE UNIVERSITY OF IOWA

Why?

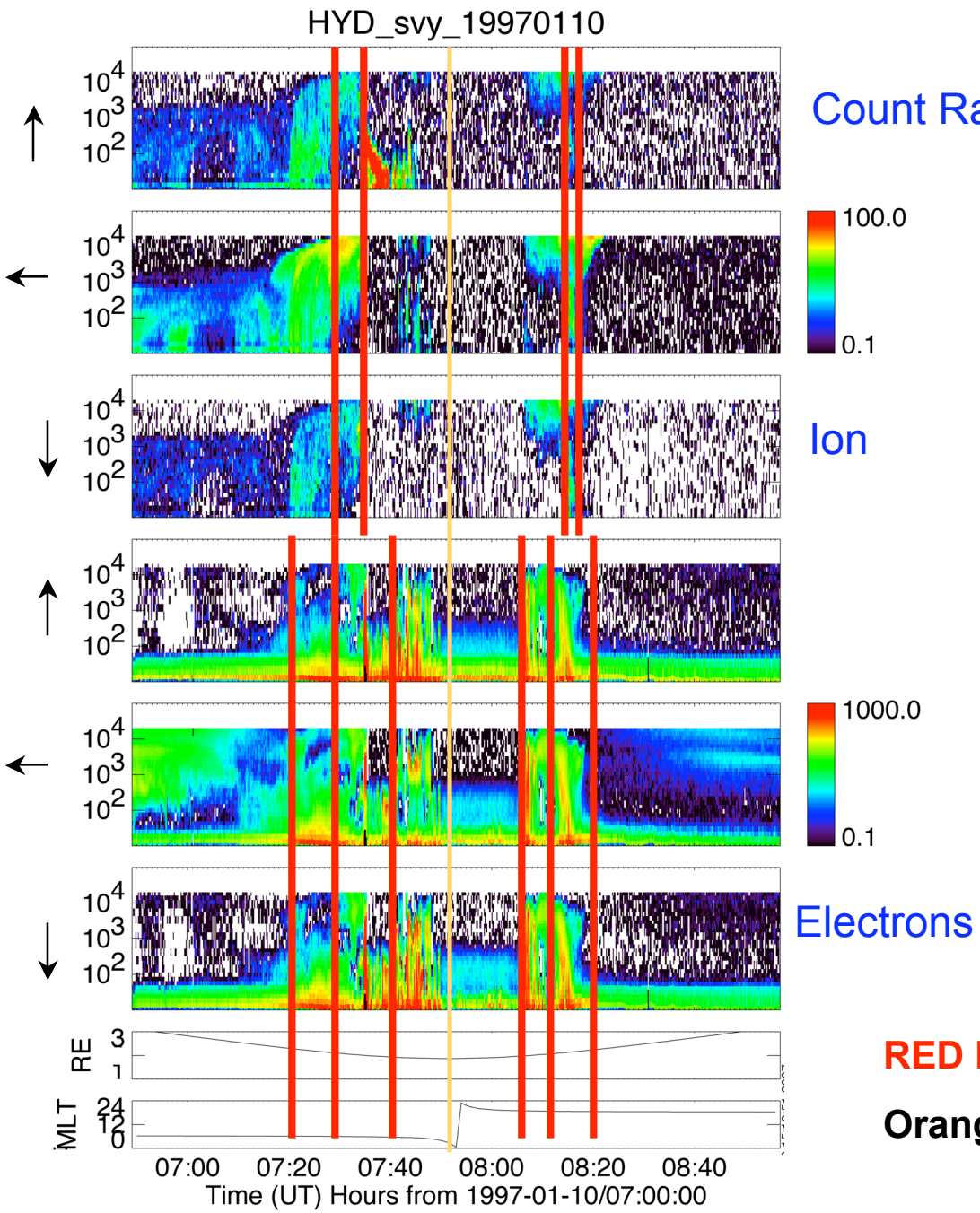
- Almost all of the ring current plasma comes from the **plasma sheet**, which is in turn supplied by the ionosphere and solar wind.
- We know that O^+ ions from the ionosphere are present in all regions of the magnetosphere at low levels even during geomagnetically quiet intervals.
- **We also know heavy ionospheric ions such as O^+ play a role in the evolution of geomagnetic storms,**
  - **but we are not sure exactly what that role is.**
- Large-scale modeling efforts constrained by observations provide the fastest path forward to increasing our understanding.
- **One of the obstacles to effectively using the extensive information about ion outflow to constrain large-scale magnetospheric models has been the lack of information about the distribution of the ion outflow in relation to large-scale magnetospheric features such as the auroral oval.**

What?

- We have used data from the Polar satellite to determine the average number and energy fluxes of escaping energetic (15 eV < E/q < 33 keV) H^+ and O^+ ions in **boundary related coordinates** during geomagnetically quiet times (Dst < -50).
- The **characteristic energy of escaping ions** is determined from the ratio of energy and number fluxes.
- During quiet times, we found that the characteristic energies in the dayside and nightside auroral regions were moderately uniform.
- **Characteristic O^+ energies in the dayside and night side auroral zones are 120 and 700 eV respectively.**
- **For H^+ the energies are 280 eV and 1.2 keV respectively**.
  - These energies are upper limits because the thermal component below 15 eV has not been included.

Result

- Our analysis suggests that that the paths for transport of O^+ into the plasma sheet and ring current are significantly different druing quiet and activie times.

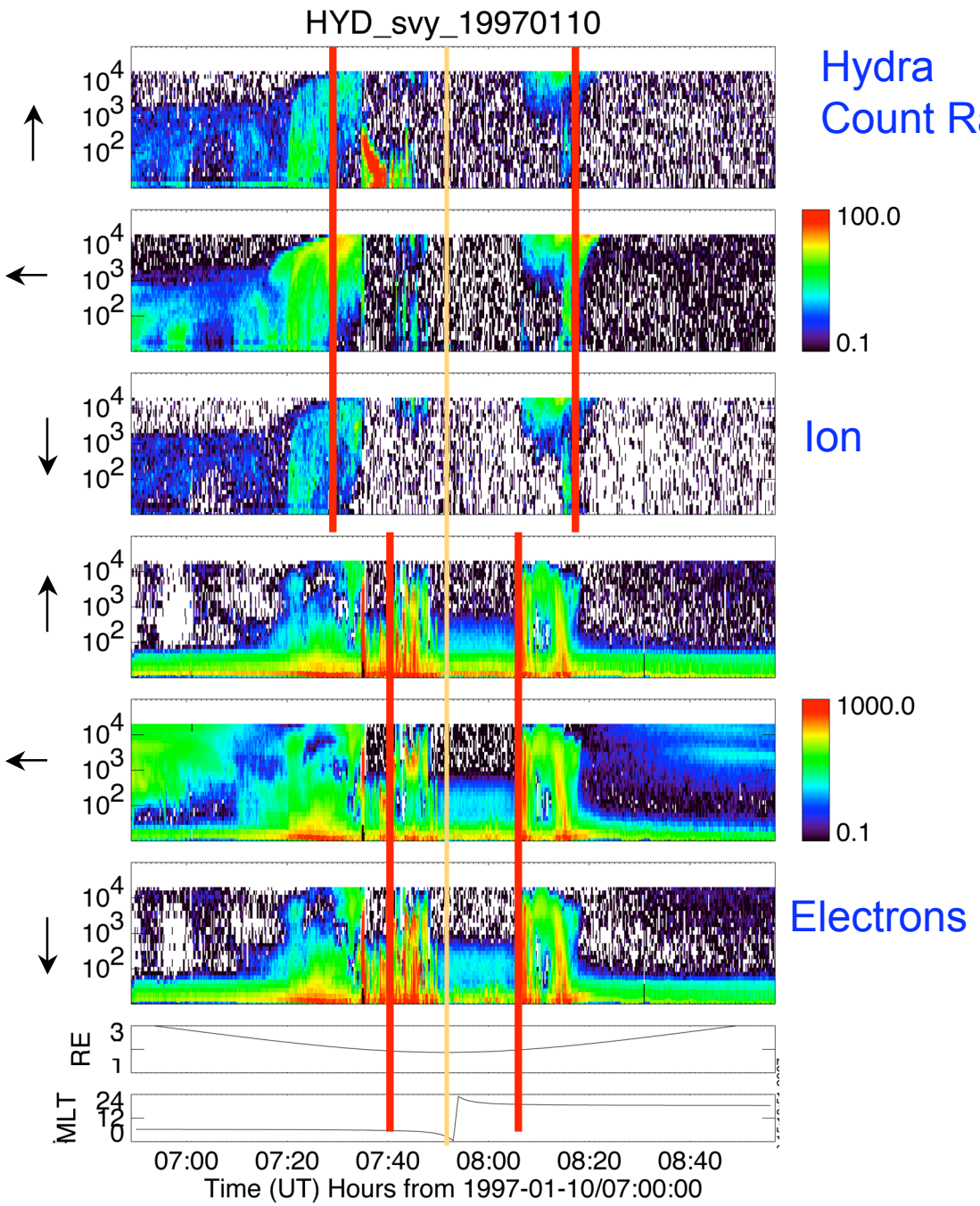


Boundaries?

- Identify auroral boundaries dynamically from Polar/Hydra electron and ion 15-s resolution scans
  - **For all perigee passes from March 1996 to December 1998**

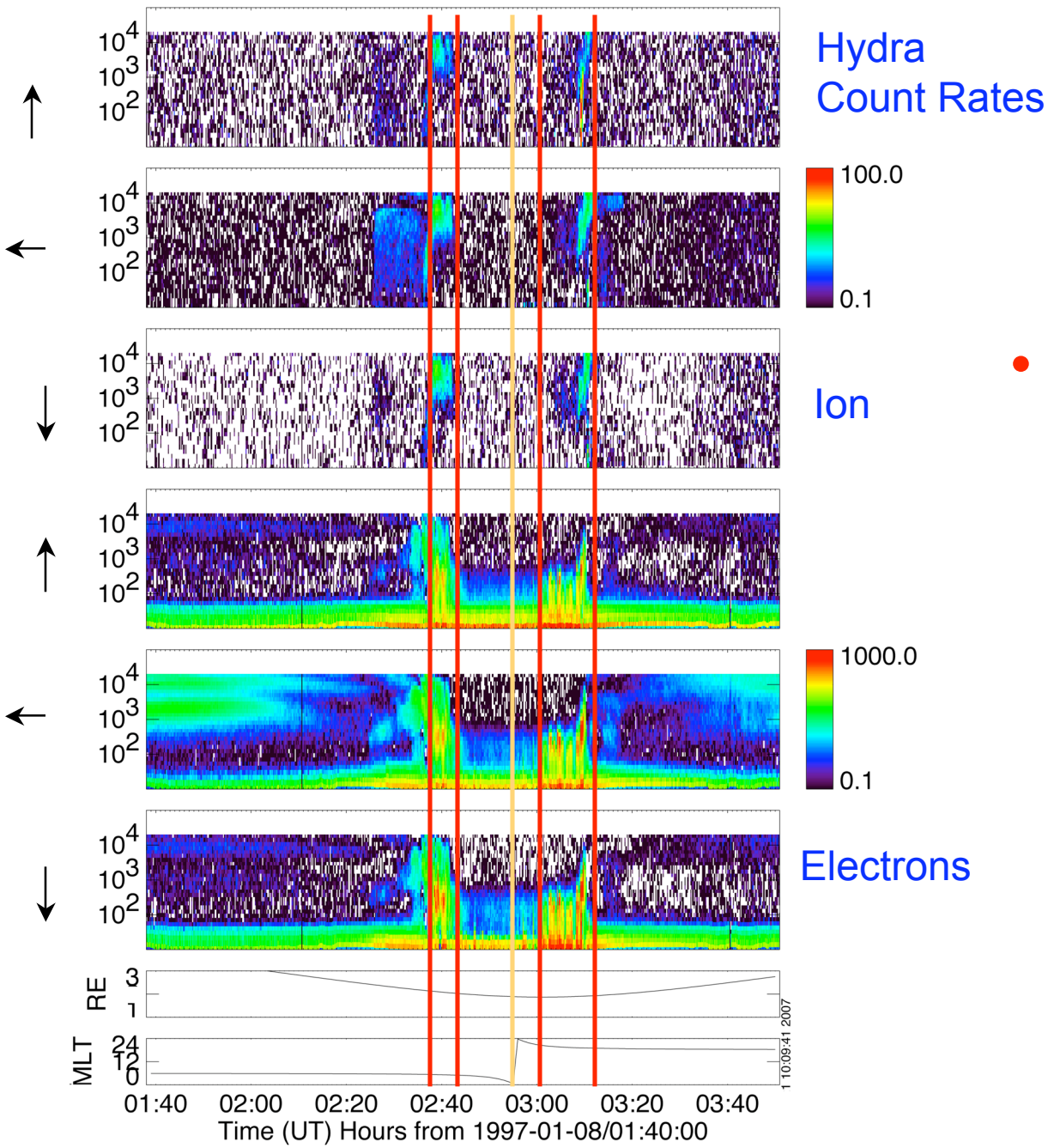
RED lines are boundaries

Orange lines is highest latitude reached



How?

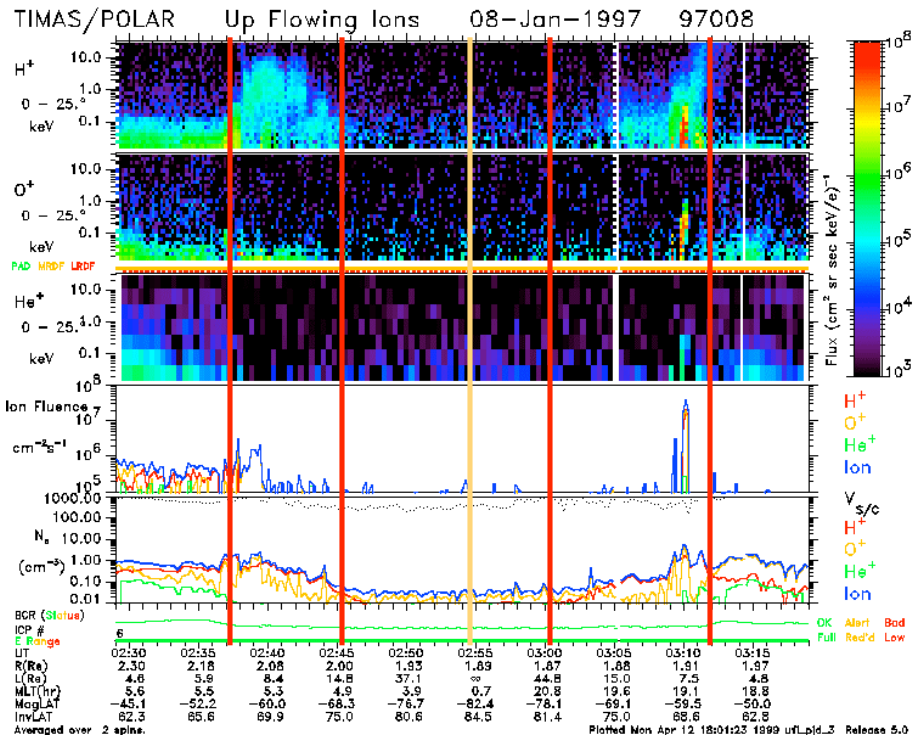
- Use the highest latitude electron and lowest latitude ion boundaries identified and the highest latitude reached



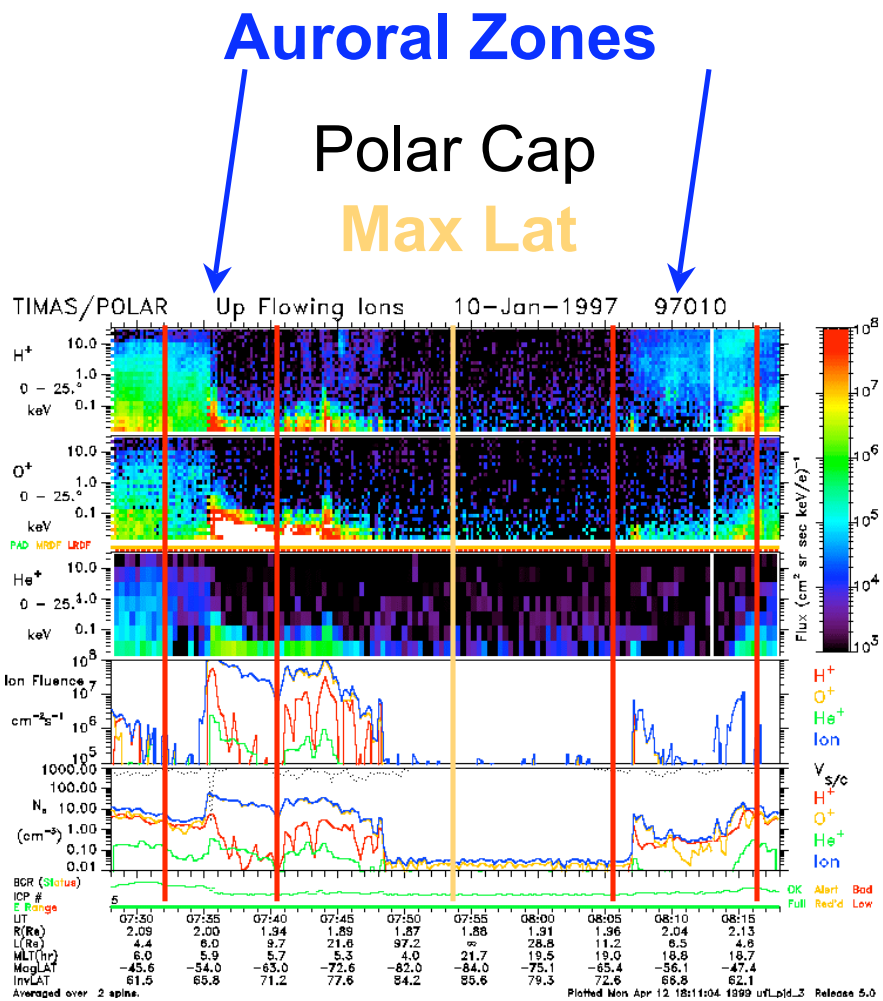
Another Example

- Boundary ID technique
  - Developed for DMSP by Newell et al.
  - Adapted to FAST by Andersson et al.
  - **Adapted to Polar here**

Upward H^+ O^+ and He^+ from TIMAS

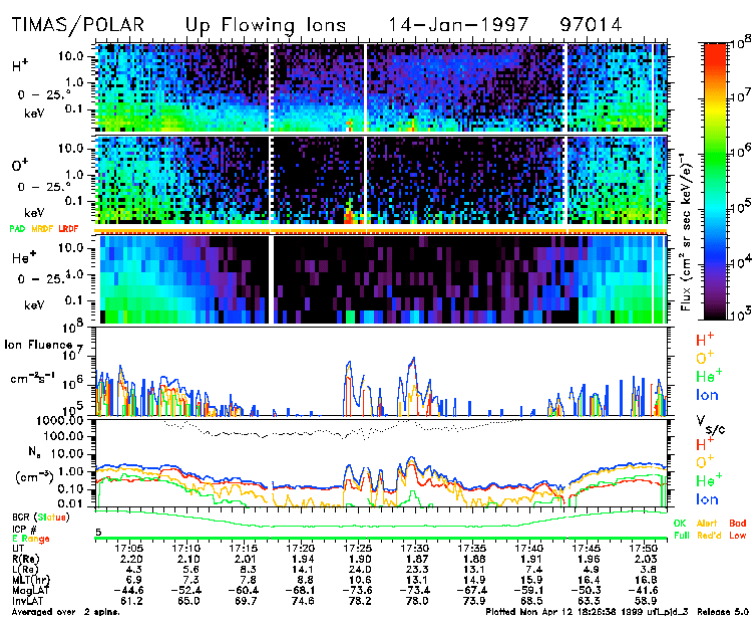


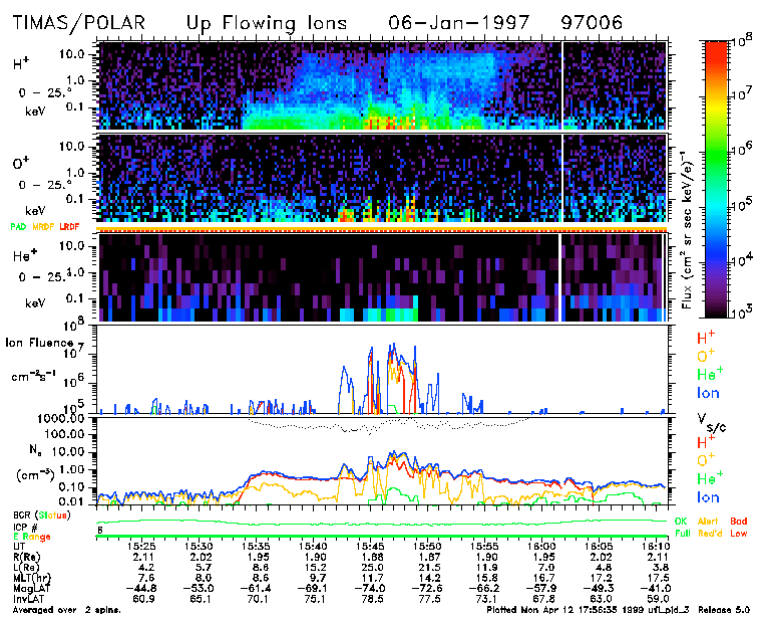
Times of the dynamic auroral boundaries determined from Hydra are used to organize mass-resolved TIMAS data.



Ambiguities in boundary identification

- From 1-14 Jan 1997
  - 19 orbits and 38 possible auroral zones
  - 26 Auroral zones were identified
  - **12 auroral zones were not resolved because of ambiguous or non existent boundaries**





O^+ INVL vs. Boundary Coordinates

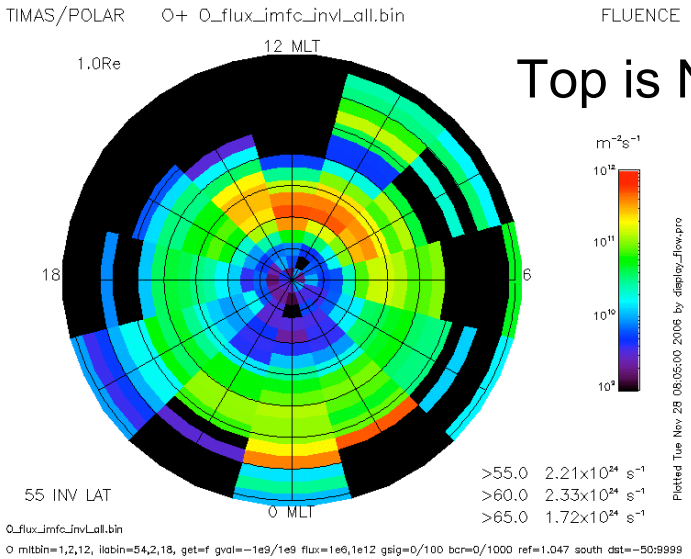
15 eV < E/q < 33 keV

D_{ST} > -50

March 1996 - December 1998

Polar Perigee (< 3 R_E) Data

Net Upflowing Flux in units of m^2/s with "loss cone" correction



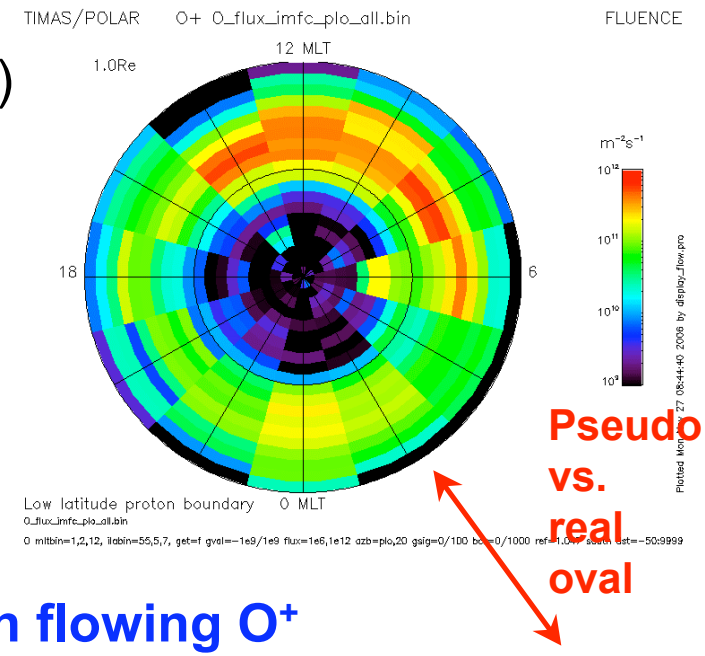
Top is NOON (12 MLT)

$\langle K_P \rangle = 2^-$

$\langle D_{ST} \rangle = -11$

$\langle A_E \rangle = 207$

$\langle F_{10.7} \rangle = 89$



Pseudo vs. real oval

Black areas are regions of net down flowing O^+

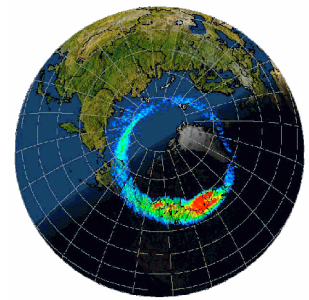
MLT vs. INVL

54° < INVL < 90°

MLT Vs Pseudo Latitude:

10 Auroral Zone Bins

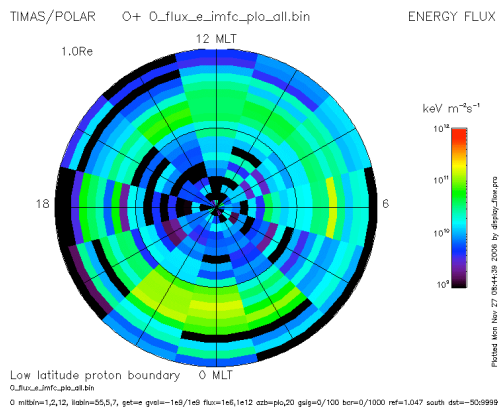
10 Polar Cap Bins



~3% of the O^+ outflow occurs in the Polar Cap

O^+ Characteristic Energy

O^+ Energy Flux



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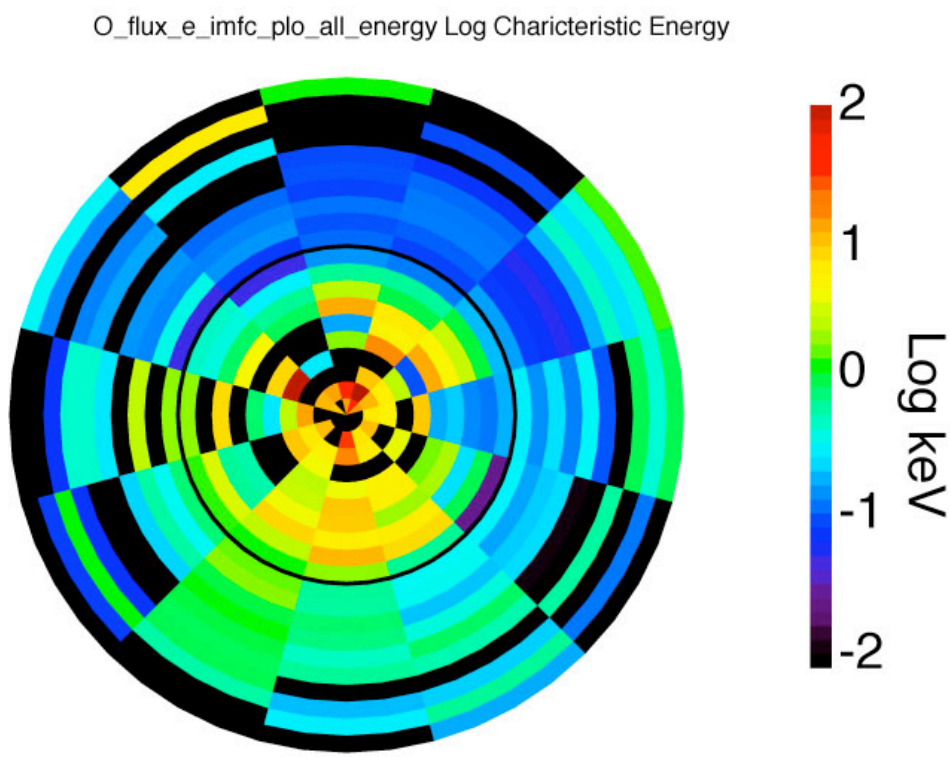
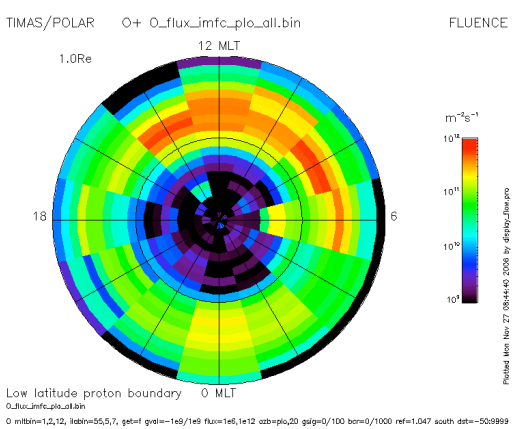
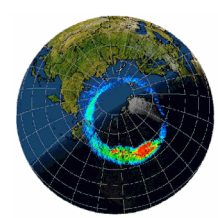


Divided by O^+ Number Flux



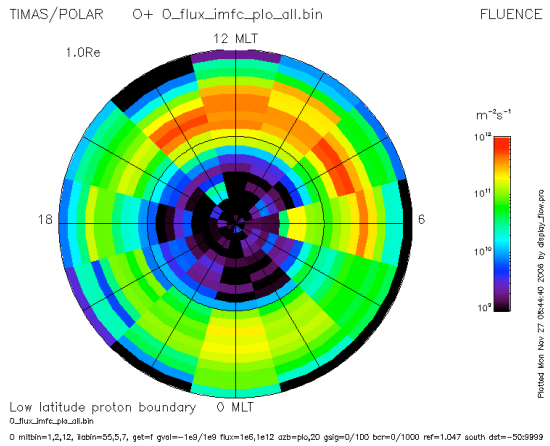
In the polar cap low upward fluxes are intermittently highly energized resulting in high and variable characteristic energies

Pseudo vs. real oval

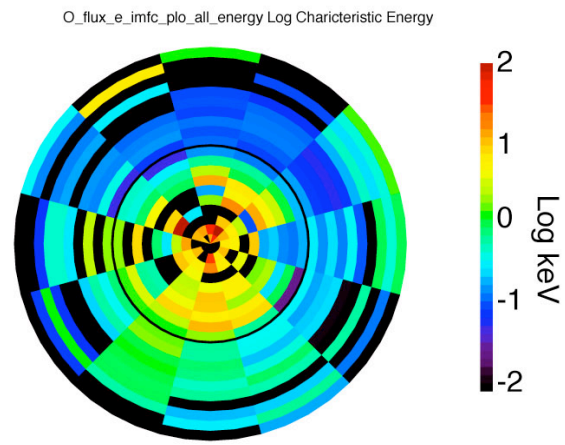


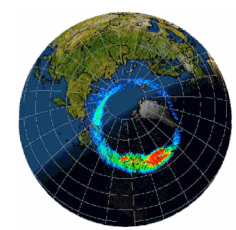
Where Do O^+ Ions Go During Geomagnetically Quiet Intervals?

Source Flux



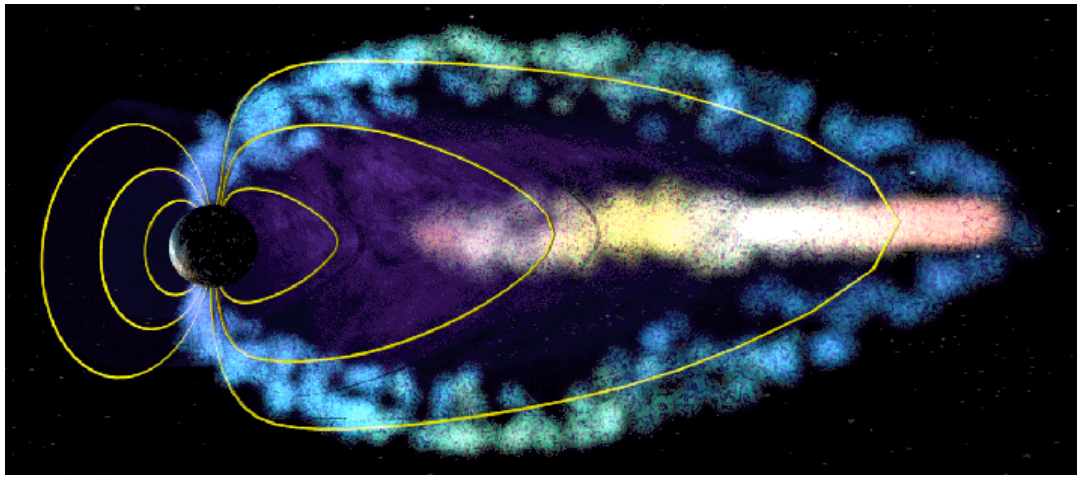
Source Energy



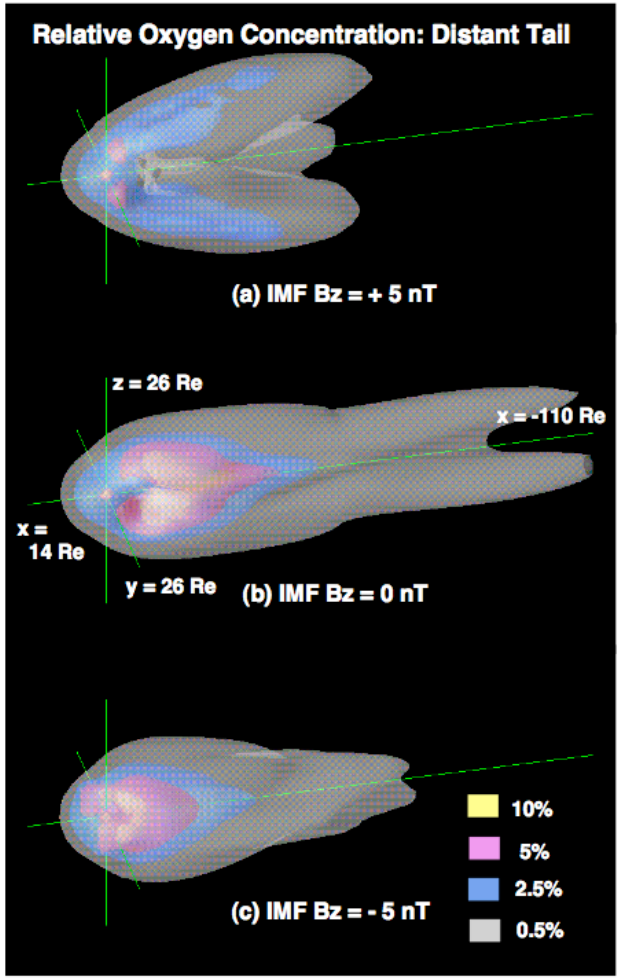


Pseudo vs. real oval

The O^+ source population is not consistent with this cartoon!!!



The Magnetosphere is Three Dimensional



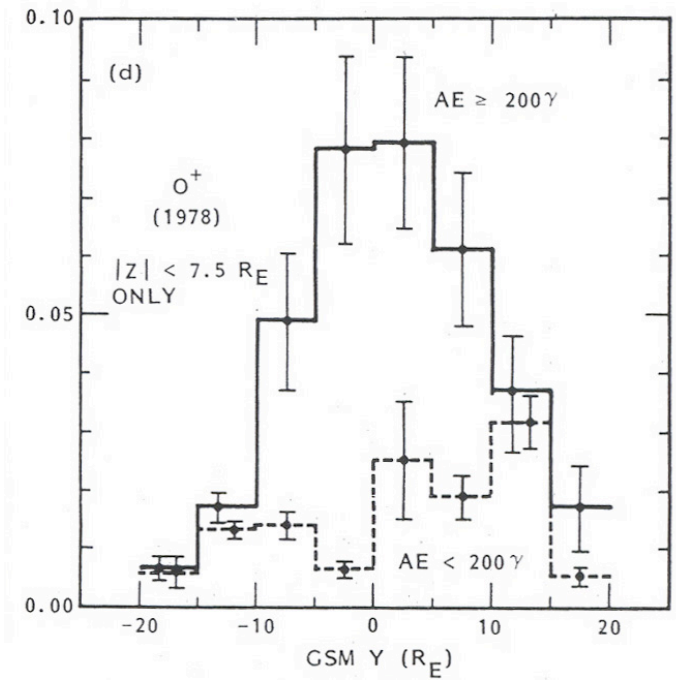
Winglee's simulation

The main source of O^+ plasma at quiet times is NOT from the polar cap.

- **O^+ Plasma convects primarily around the dawn and dusk sides during geomagnetically quiet times**

O^+ Density

--- AE < 200
__AE > 200



Lennartsson and Shelley '86

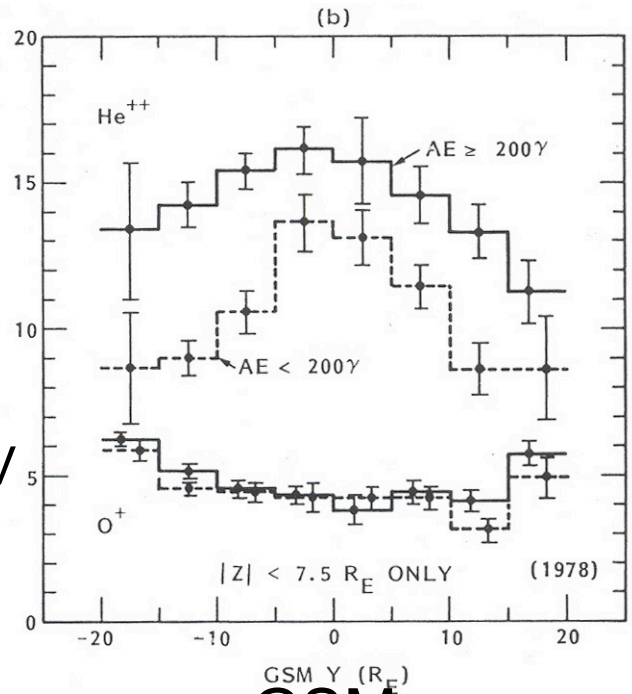
More ISEE-1 results from the near tail

Lennarsson and Shelley JGR 1986

O^+ and He^{++} Energy (keV)

20 keV

5 keV

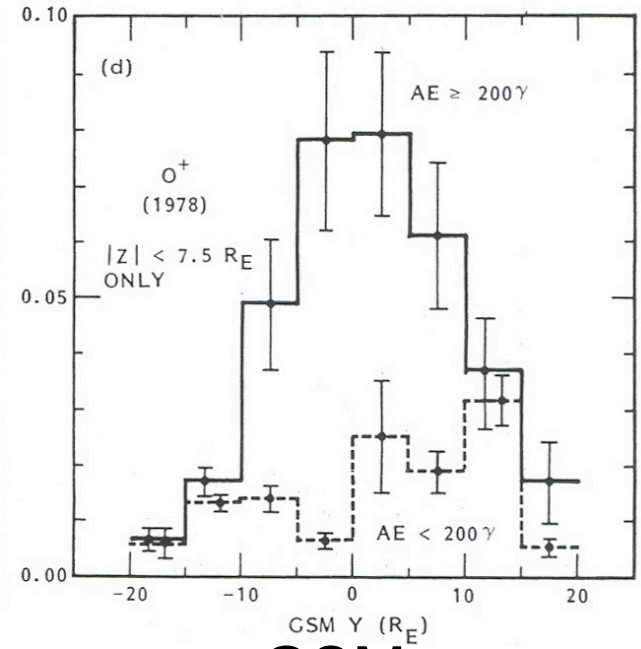


GSM_Y

--- AE < 200

__AE > 200

O^+ Density



GSM_Y

Suggests that at active times energization of thermal O^+ from the polar wind and transport over the polar cap becomes signficant

Result

- Our analysis suggests that that the paths for transport of O^+ into the plasma sheet and ring current are significantly different duing quiet and activie times.

We we are not exactly sure what role heavy ionospheric ions such as O^+ play in the evolution of geomagnetic storms.

- **O^+ is continuously transported to the plasma sheet**
- **O^+ has different transport paths under quiet and active geomagnetic conditions.**
- **Characteristic O^+ velocities and therefore transit times are long compared to magnetospheric reconfiguration times.**
  - **100 eV O+ has a velocity of ~ 20 R_E/hr**
- Large-scale modeling efforts constrained by observations provide the fastest path forward to increasing our understanding.
- **Past particle pushing exercises have not fully taken into account the activity sensitive transport paths.**

Future Work

- We need to push the observed O^+ source population in boundary coordinates in dynamic models of magnetospheric fields to see under what circustances they can build up to create sufficent pressures to modify the magnetospheric configuration