UNH Modeling for RENU2

RENU 2 Science Team Meeting I

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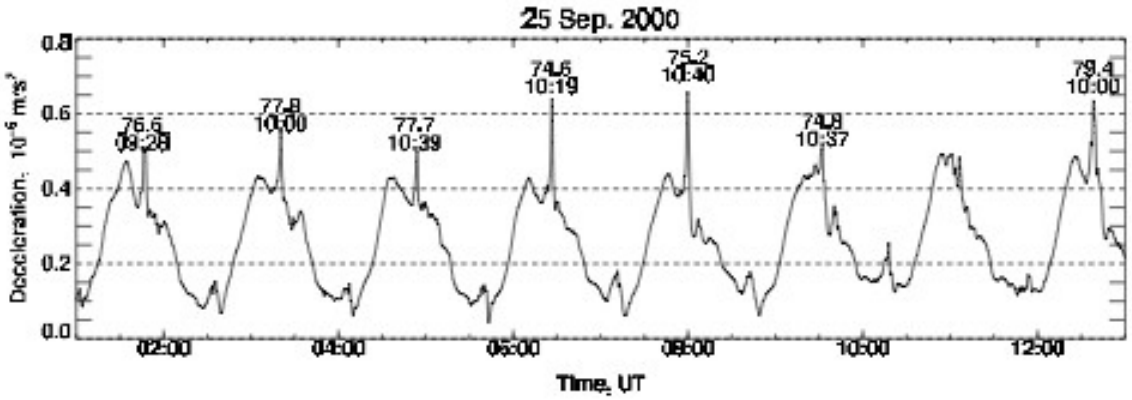
(Model: Antonius Otto, UAF)

CHAMP satellite

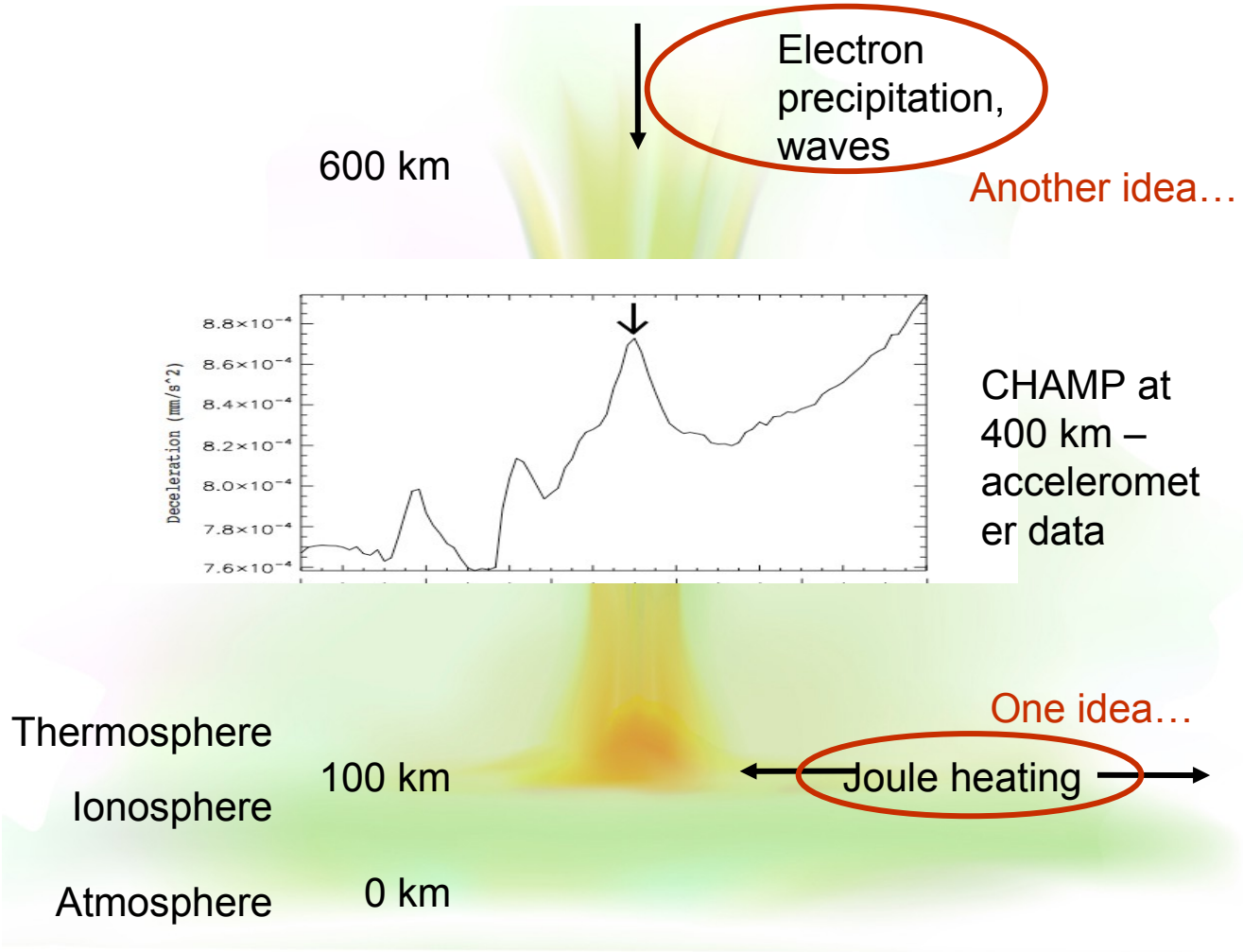


Plot showing 8 orbits of the CHAMP satellite, at 400 km altitude, nearly polar inclination. Vertical axis shows accelerometer data, with narrow spikes ("bumps") in the vicinity of the cusp region.

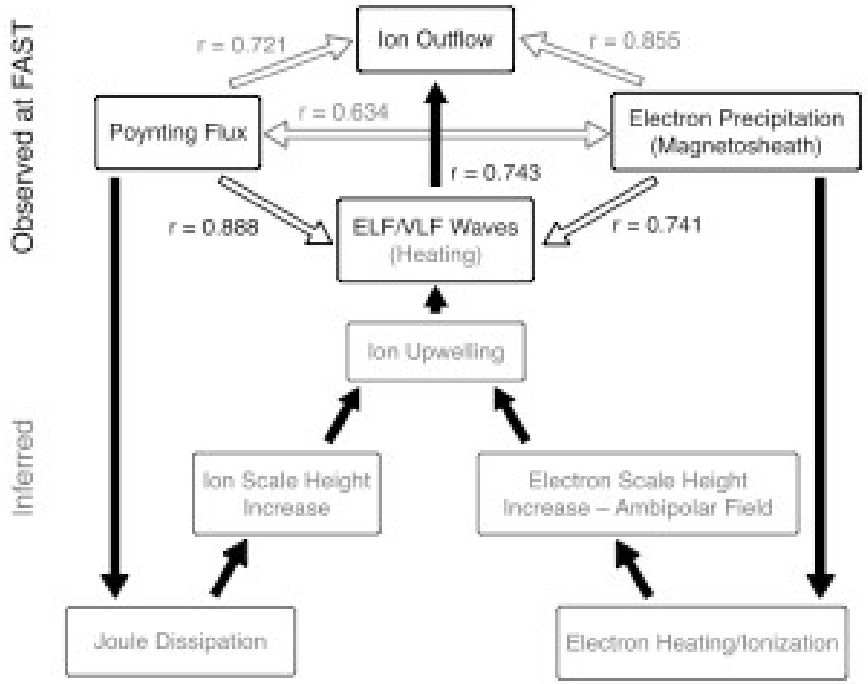
Spikes are observed in conjunction with small-scale currents (observed by the magnetometer), e.g., electron precipitation and, presumably, aurora.

Lühr et al., Thermospheric up-welling in the cusp region: Evidence from CHAMP observations, Geophys. Res. Lett., 31, 6805, 2004.

Is upwelling driven by Joule heating or by soft electron precipitation (and/or strong FAC)?



Ion outflow sources



Altitudes:

800-1000+ km

500-600 km

200+ km

Two primary sources of ion outflow:

- Ion heating through dissipation of downward Poynting flux.
- Electron heating through soft electron precipitation.

Sketch from R. Strangeway, et. al., 2005

Auroral Precipitation Model

- Auroral precipitation is one driver of cusp density enhancement
- Soft electrons heat ambient electrons
- Electrons expand upwards, establishing ambipolar electric field
- Ions are pulled upwards by electric field
- Momentum from ions drag neutrals upwards
- Requires "cooking time" of 10 - 30 (?) minutes

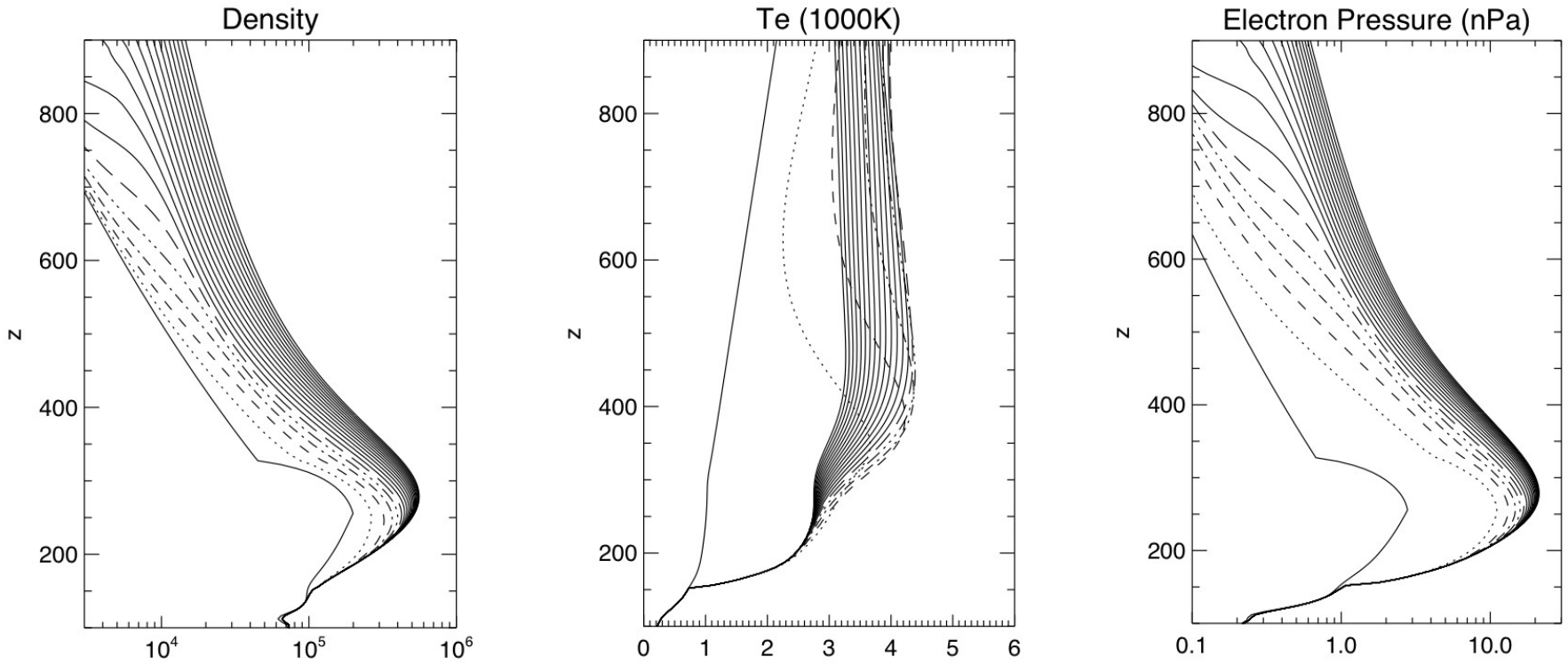
Numerical Model (Otto)

- Three fluid model (electron, ion, neutral)
- Two dimensional (x and z)
- Includes ionization, recombination, electron heating
- Interial terms allow for two-fluid wave propagation
- Lummmerzheim (1992) for ionospheric transport
- Allows study of various general processes: heating, ion outflow, auroral lumosity, etc
- Details in Zhu et al, 2001

Numeric modelling of ionospheric and thermospheric evolution (sample results)

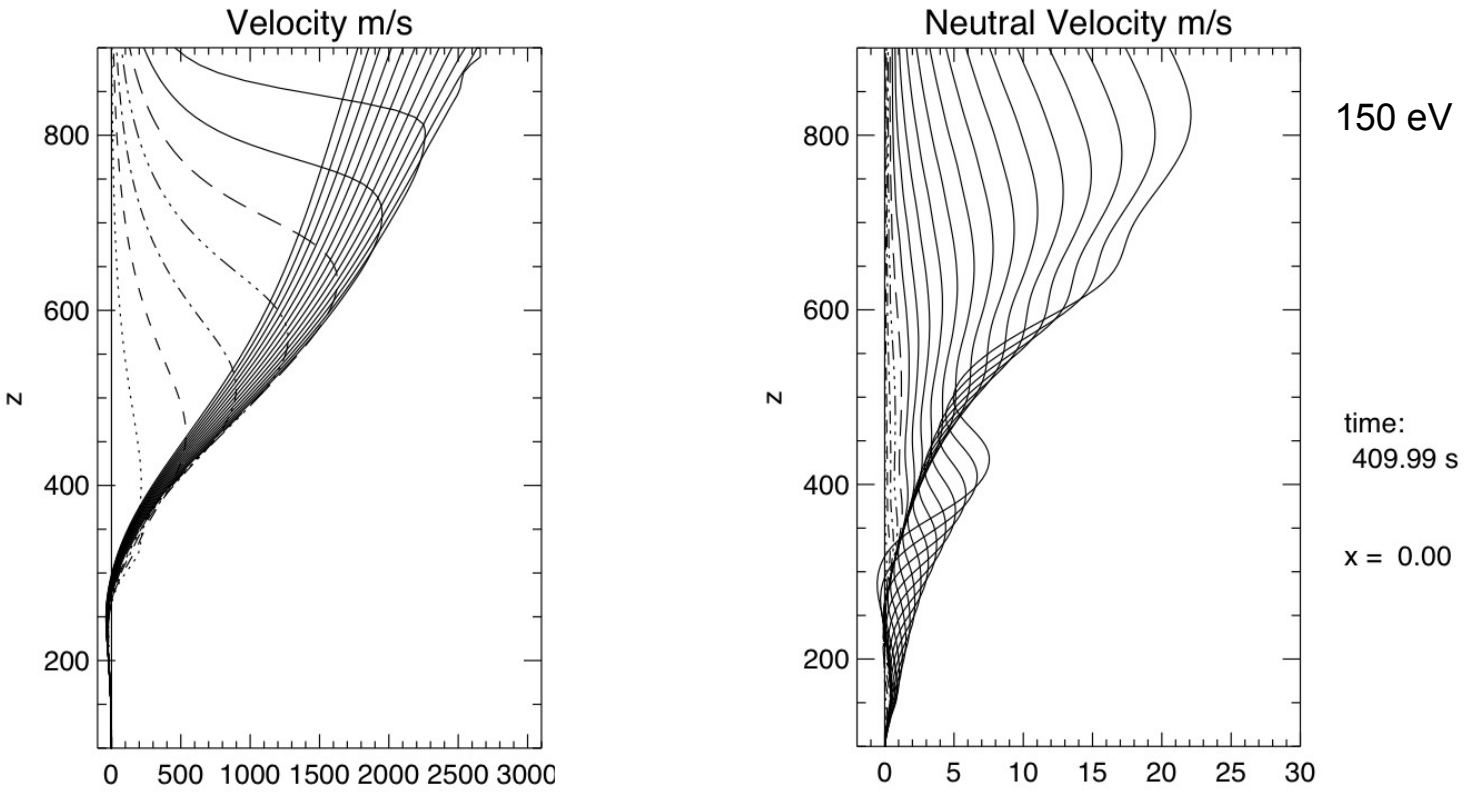
- Model plots give typical evolution of plasma and neutral changes
- 4 mWm^2 precipitation (data) with characteristic energies of 150 eV (data) and 300 eV (for comparison)
- Plots give one-dimensional profiles of the thermospheric structure
- Illustrate the evolution over 7 minutes
- Snapshots every 20.5 seconds.

Numerical Model Results



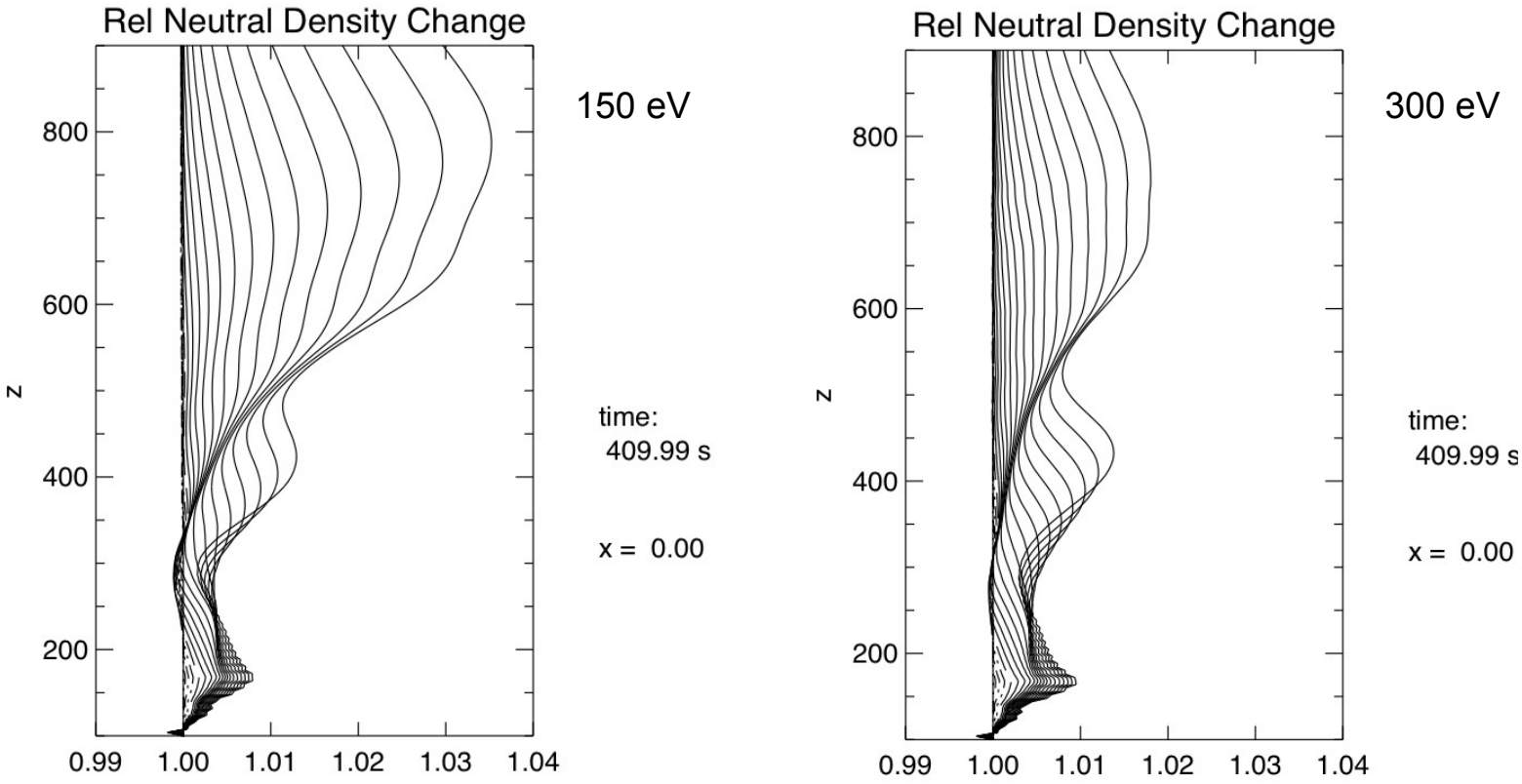
Electron density, temperature, and pressure (150 eV)

Numerical Model Results



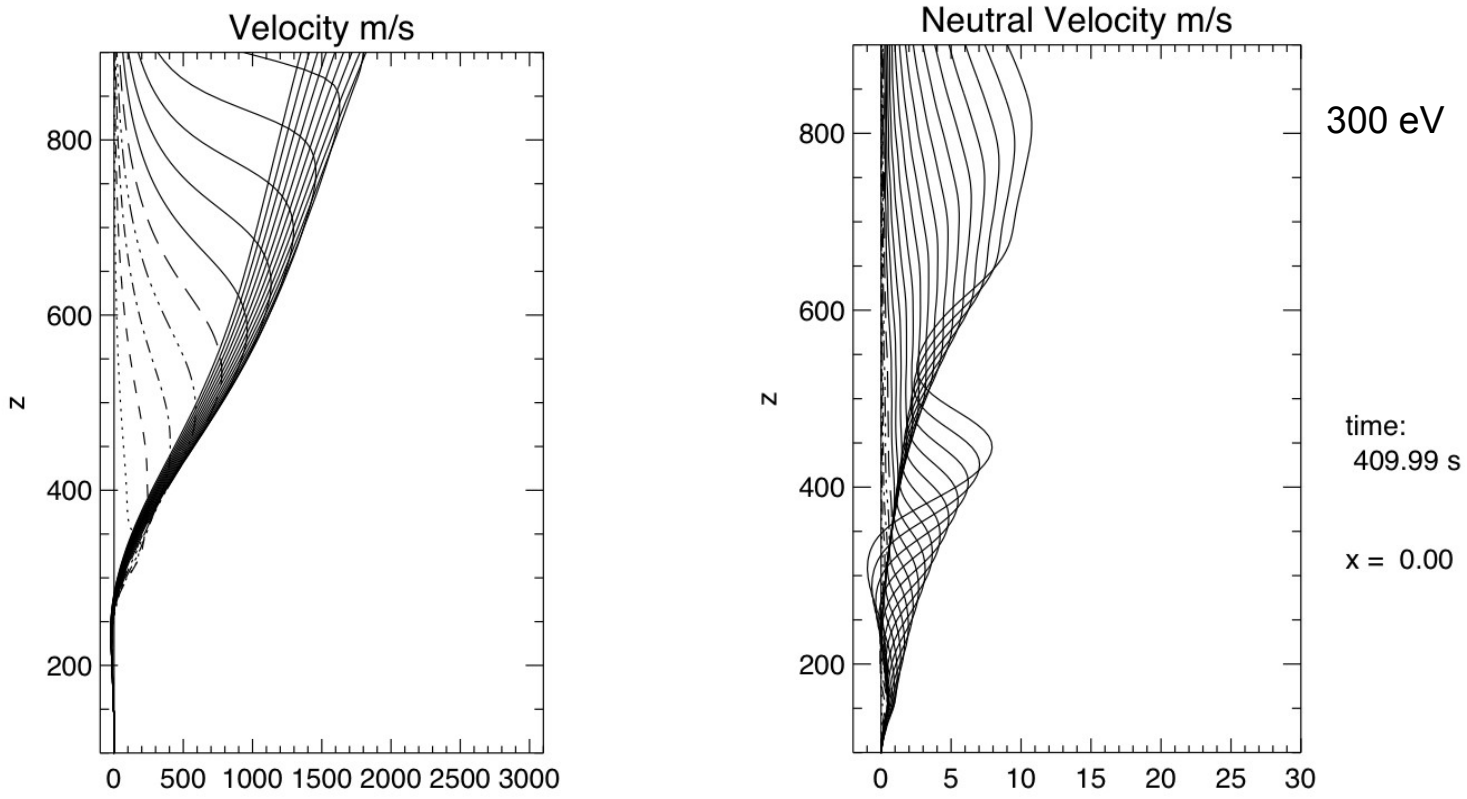
Ion and Neutral vertical velocity (150 eV)

Numerical Model Results



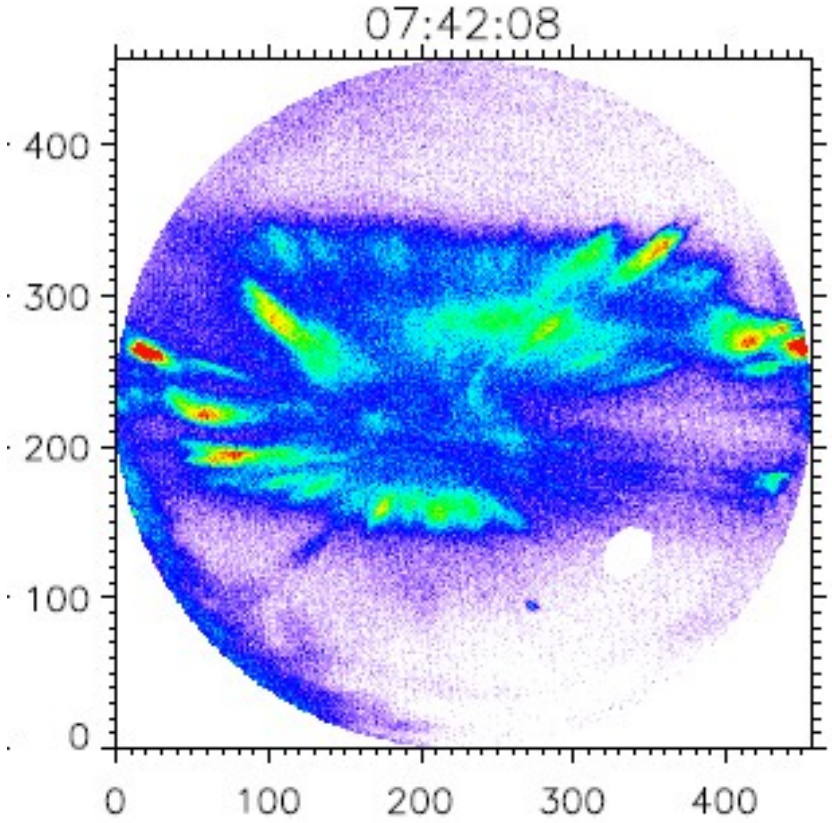
Relative neutral density increase: 150 eV vs. 300 eV

Numerical Model Results

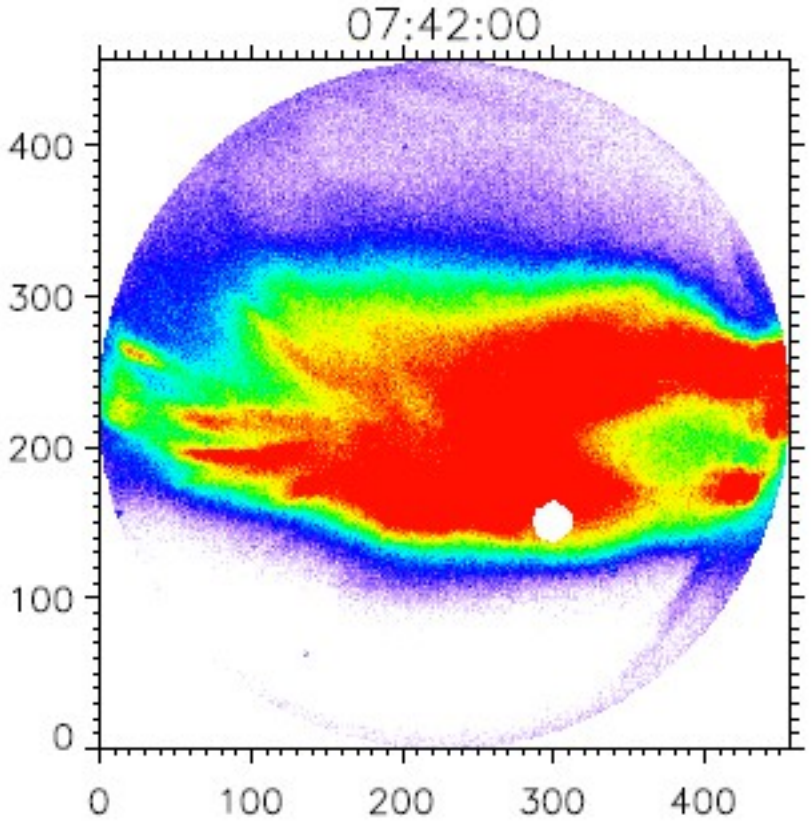


Ion and Neutral vertical velocity (300 eV)

RENU2 footprint, T+600



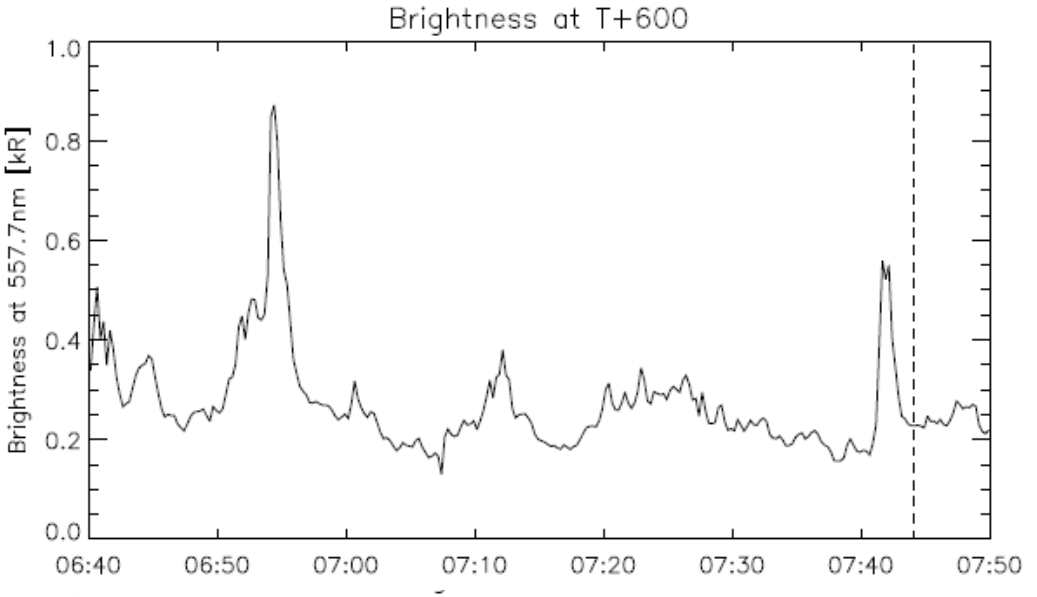
557.7 nm



630.0 nm

[Lasse Clausen, Oslo]

Brightness History
At footprint
Previous Hour



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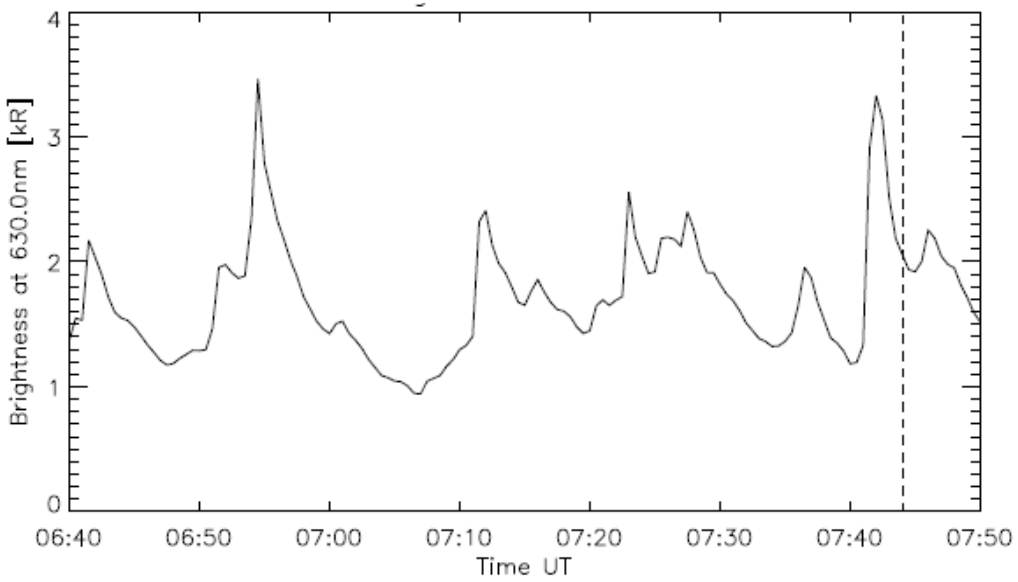
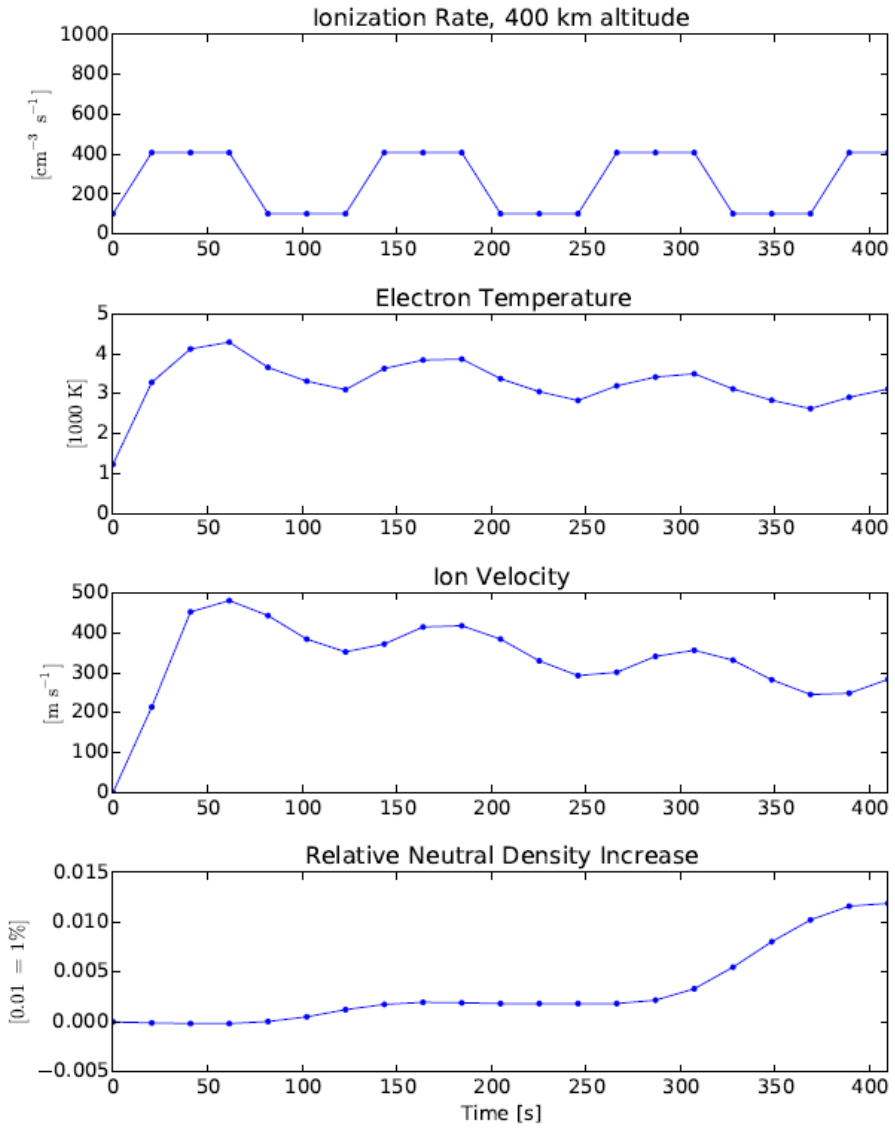


630.0 nm



Model Results:

- Aurora pulsed on/of
- 150 eV electron energy
- 1 mW/m^2 background
- 4 mW/m^2 Aurora “on”

- 400s simulation
- On/off pulses at 66s

- Upward ion velocity remains high
- Neutral density increase w/ Aurora “off”


Questions?

Extra Slides

- (Extra slides follow this one)

Possible Enhancement Drivers

- Large-scale Joule heating (canonical).
- Soft electron precipitation, via direct heating of neutrals by collision, or (more likely) via ambipolar electric fields, ion up/outflow and the collisional drag associated with this (including charge exchange).
- Alfven waves (i.e., Alfvenic aurora) may provide small-scale Joule heating (in addition to soft electrons).
- Small-scale, field-aligned currents may support upwelling via ohmic heating (due to resistance - Coulomb collisions- between electrons and ions).

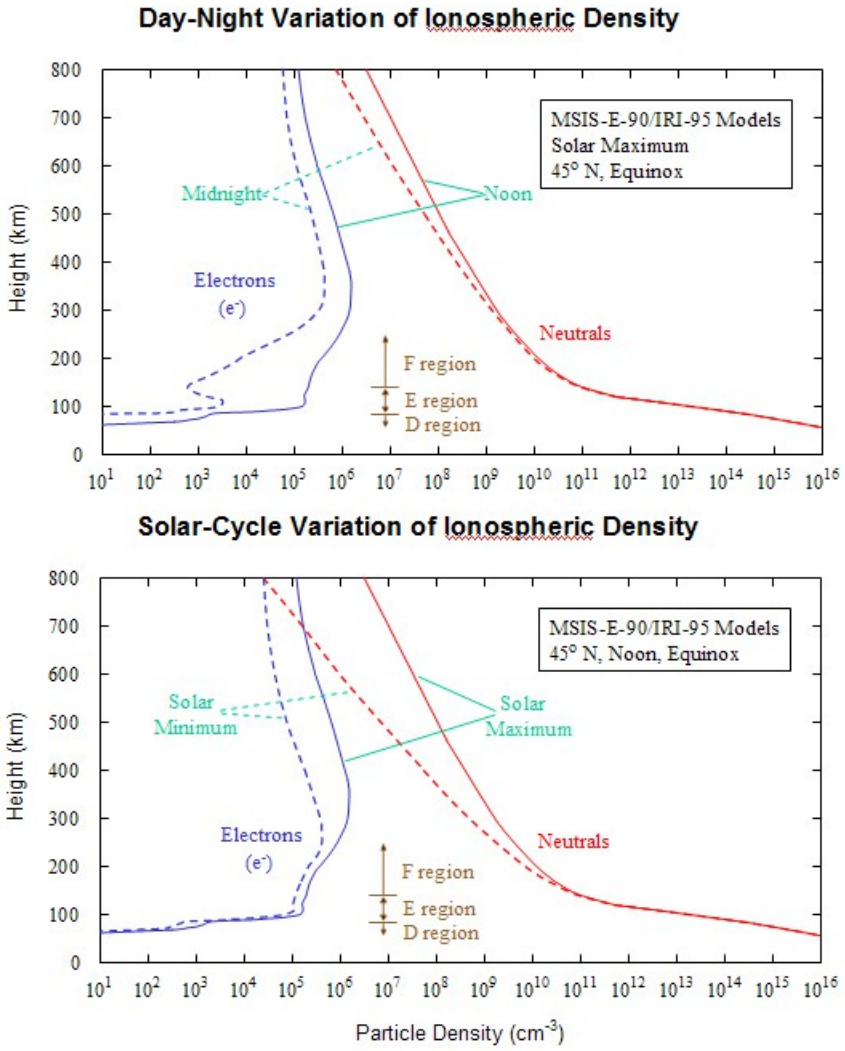
Auroral Precipitation Driven Density Enhancement in the Cusp

Outline:

- Background on neutral upwelling in the cusp and possible explanations
- Auroral Precipitation Model overview (theoretical / physical model)
- Feb 5, 2003 event (CHAMP & FAST data)
- Numerical simulation results (computational model)

(See http://mirl.sr.unh.edu/ for published paper on this topic.)
(Collaborators: M. Lessard, E. Lund, A. Otto, H. Lühr)
(Sadler, et. al., JASTP 2012)

Thermospheric variability



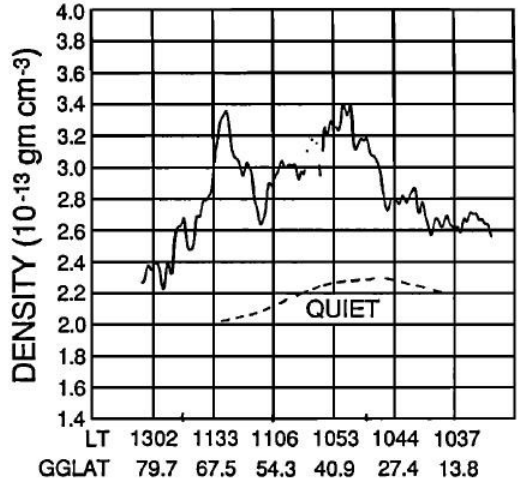
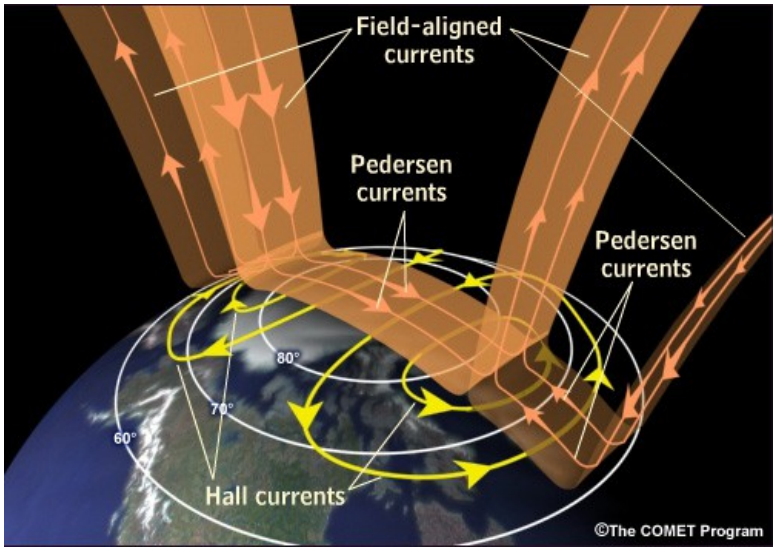
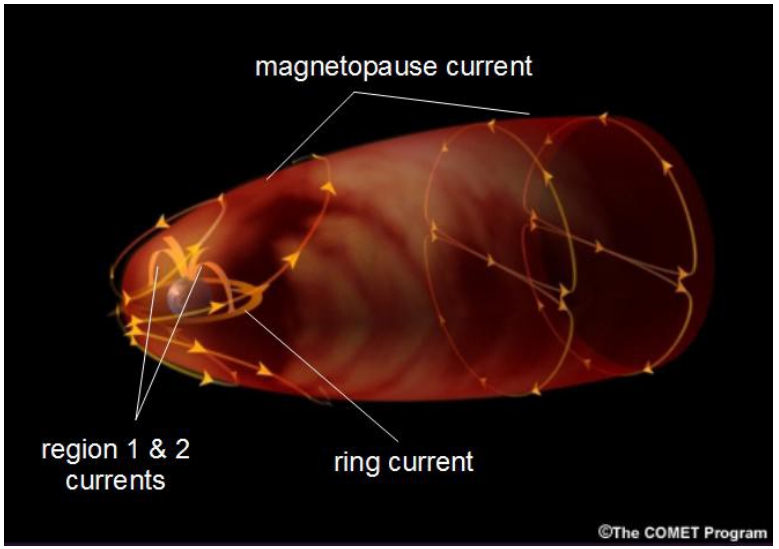
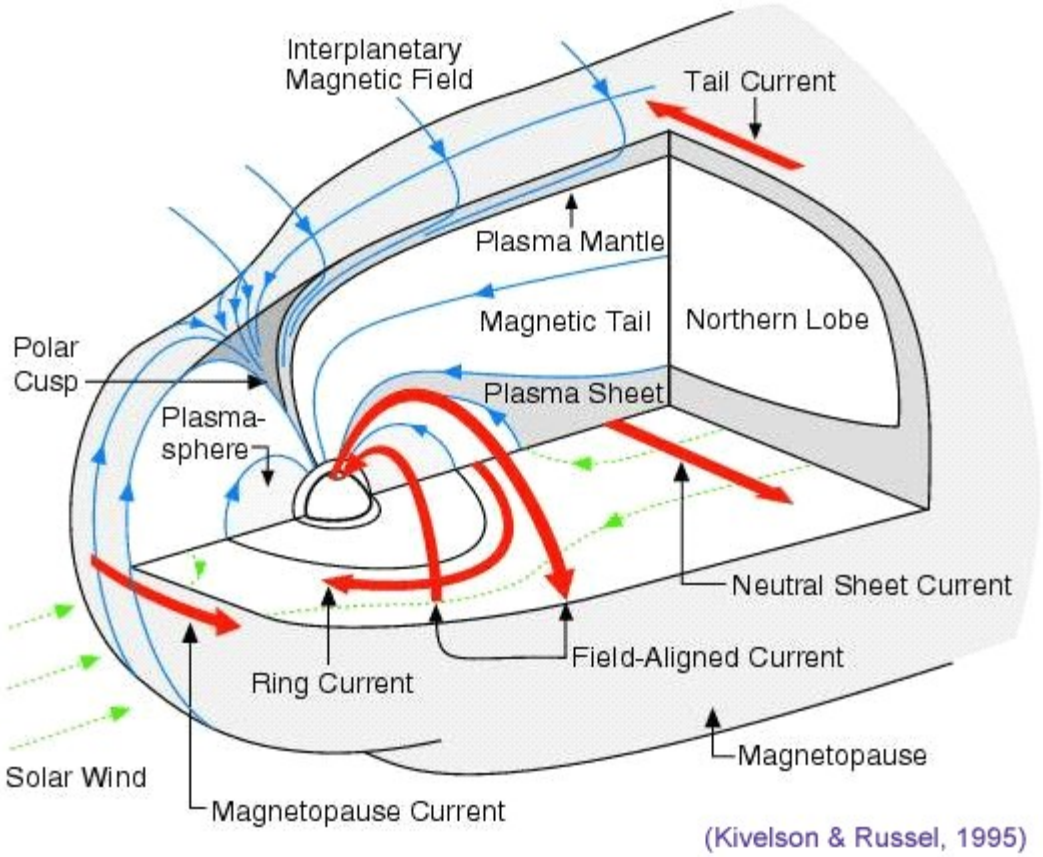


Figure 1. Comparison of measured density variations for active (solid curve) and quiet (dashed curve) conditions at 200 km as a function of geographic latitude for a polar orbiting satellite in the 1040-2240 LT plane.

Magnetospheric Currents and Joule Heating






Interplanetary
Magnetic Field
Tail Current
Plasma Mantle
Magnetic Tail
Northern Lobe
Polar
Cusp
Plasma-
sphere
Plasma Sheet
Neutral Sheet Current
Field-Aligned Current
Ring Current
Magnetopause
Solar Wind
Magnetopause Current
(Kivelson & Russel, 1995)

Future Work (e-POP)

- Enhanced Polar Outflow Probe (e-POP) - scientific payload for CASSIOPE satellite
- Launched 16:00 UTC Sep 29 2013 (finally!) via SpaceX Falcon 9
- Elliptical polar orbit: 325 to 1500 km
- 8 instruments: ion, neutral, electron, imager
- UNH / Dartmouth collaboration studying e-POP cusp data & model comparison