University of New Hampshire

Magnetosphere Ionosphere Research Lab

Results from Rocket Experiment for Neutral Upwelling (RENU 2)

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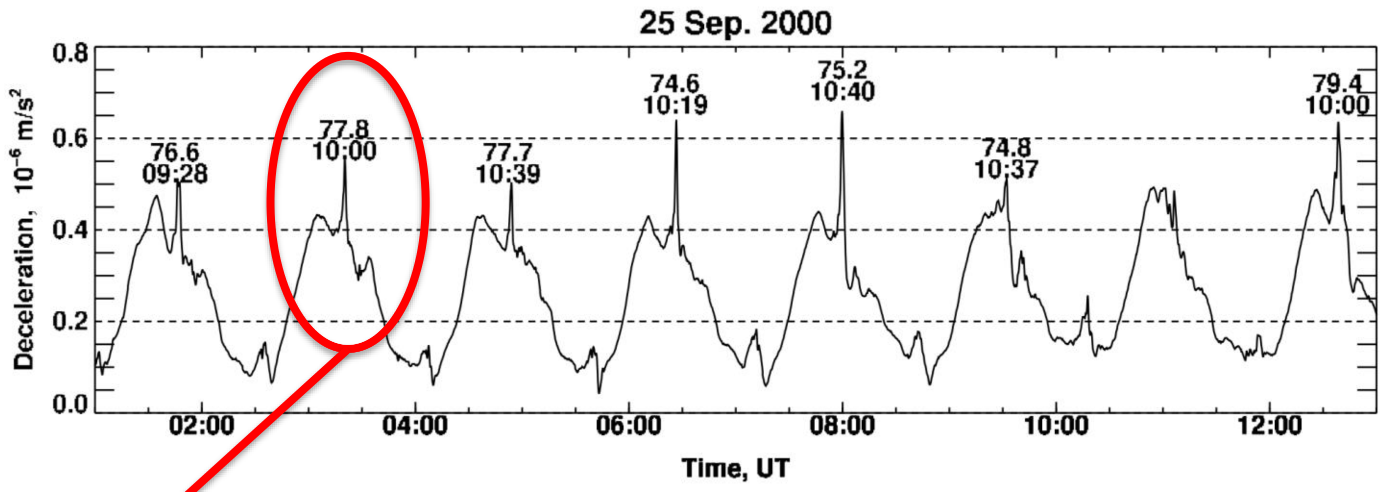
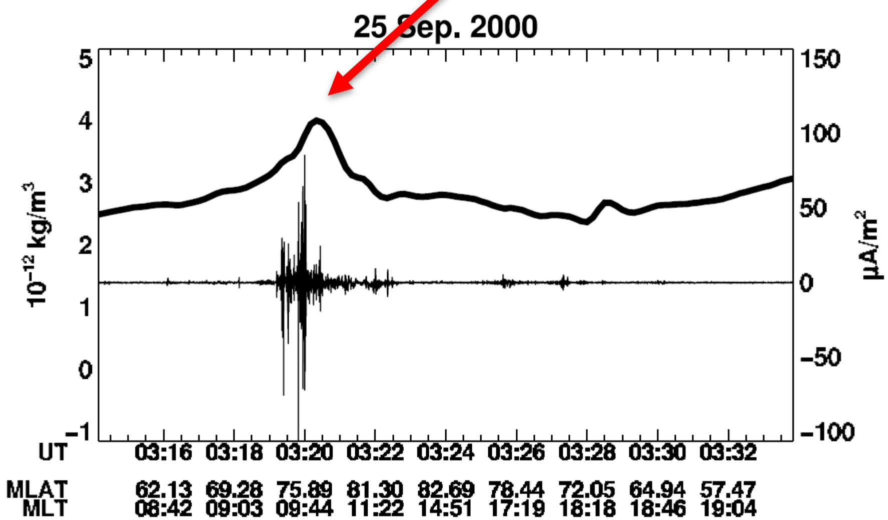
Grad students: *Bruce Fritz* and David Kenward (UNH), Meghan Harrington and Spencer Hatch (Dartmouth)

Outline

- Science introduction
- Mission overview
- Quick look at data
  - Electron measurements (M. Lessard, UNH)
  - Visible PMTs (J. Hecht, Aerospace)
  - Magnetic fields (K. Lynch, Dartmouth)
  - Ion measurements (K. Lynch, Dartmouth)
  - Ion gauge neutrals (J. Clemmons, Aerospace)
  - UV PMT (M. Lessard, UNH)

Introduction - CHAMP Results





TOP: 8 orbits of CHAMP accelerometer data at 400 km altitude, nearly polar inclination. Narrow spikes observed near the cusp region.

BOTTOM: Spikes often are *observed in conjunction with small-scale currents* (by the magnetometer) – i.e. electron precipitation and, presumably, aurora.

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

Introduction - Drivers for small-scale neutral upwelling

1. Fundamentally driven by Joule heating

Crowley, G., D. J. Knipp, K. A. Drake, J. Lei, E. Sutton, and H. Luhr (2010), Thermospheric density enhancements in the dayside cusp region during strong BY conditions, Geophys. Res. Lett., 37, L07110, doi:10.1029/ 2009GL042143.

2. Soft precipitation (part of the "Type 2" ion outflow process)

Sadler, F. B., M. Lessard, E. Lund, A. Otto and H. Luhr (2012), Auroral precipitation/ion upwelling as a driver of neutral density enhancement in the cusp, Journal of Atmospheric and Solar-Terrestrial Physics 87–88.

3. Increased Joule heating at F-region altitudes due to enhanced conductivity (due to soft precipitation)

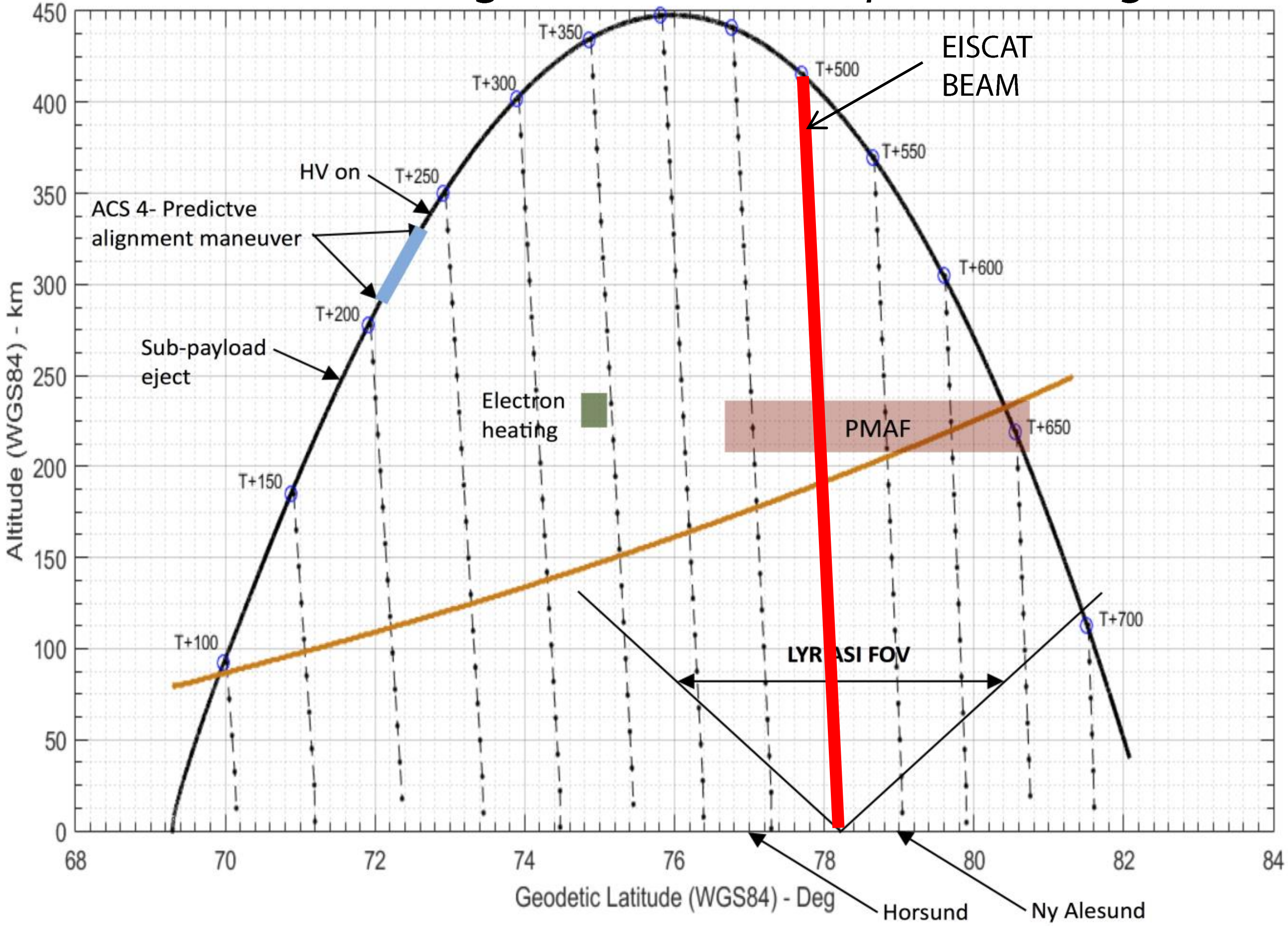
Zhang, B., W. Lotko, O. Brambles, M. Wiltberger, W. Wang, P. Schmitt, and J. Lyon (2012), Enhancement of thermospheric mass density by soft electron precipitation, Geophys. Res. Lett., 39, L20102, doi:10.1029/2012GL053519.

4. Direct particle heating, higher altitude Joule heating

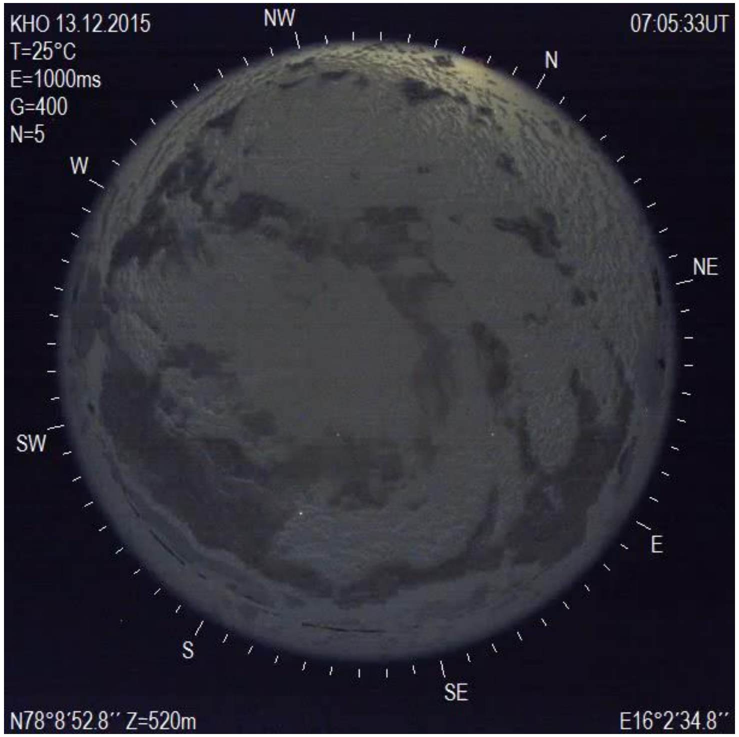
Brinkman, D. G., R. L. Walterscheid, J. H. Clemmons and J. H. Hecht (2016), High-resolution modeling of the cusp density anomaly: Response to particle and Joule heating under typical conditions, J. Geophys. Res. Space Physics, 121, 2645-2661, doi:10.1002/2015JA021658.

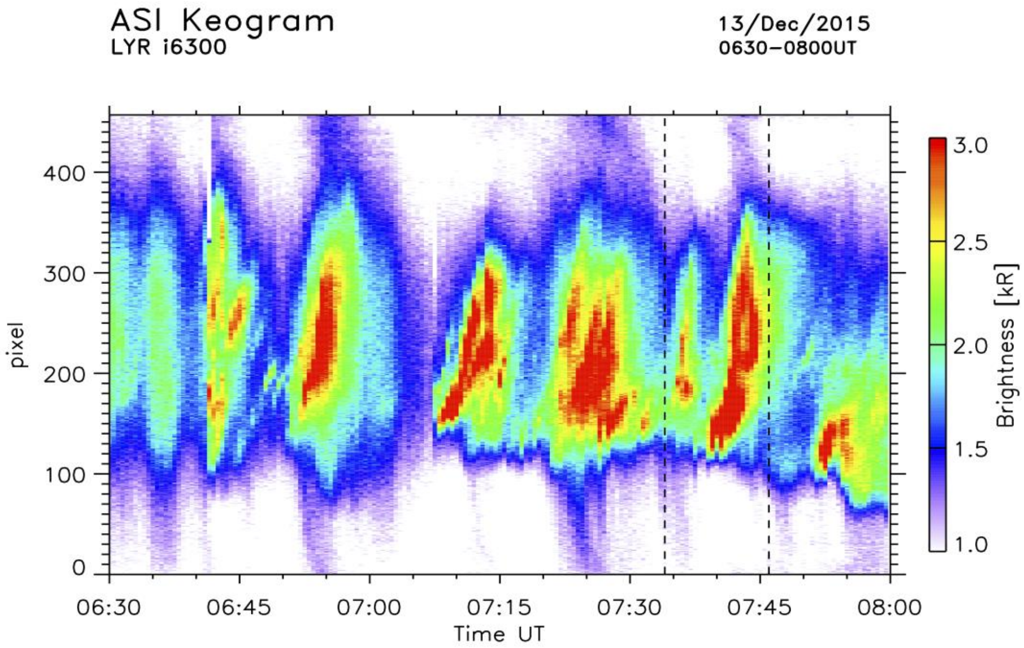
Mission description

Objective: launch an appropriately instrumented sounding rocket through the cusp region (e.g., over Svalbard) during an event with soft electron precipitation and Joule heating. *Ensure that adequate heating has occurred.*



Launch event



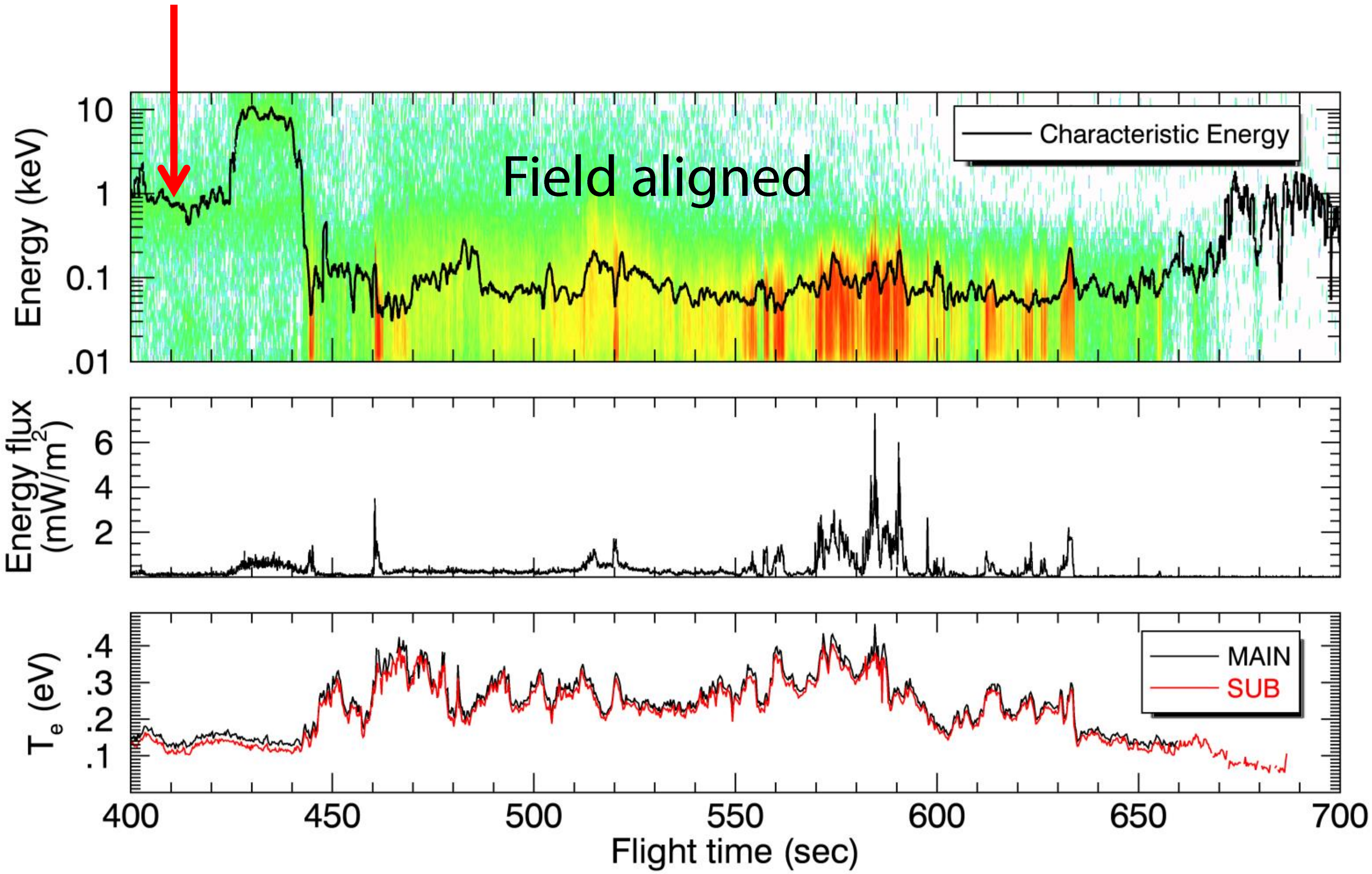


Dayside reconnection drives PMAFs and stepped ions

-- Field aligned precipitation
-- Electron energies of ~100 eV
-- Poleward propagation ~ 1 km/s

Results - Electrons (M. Lessard, David Kenward, UNH)

Apogee of 447 km at T+409 (still in plasma sheet)



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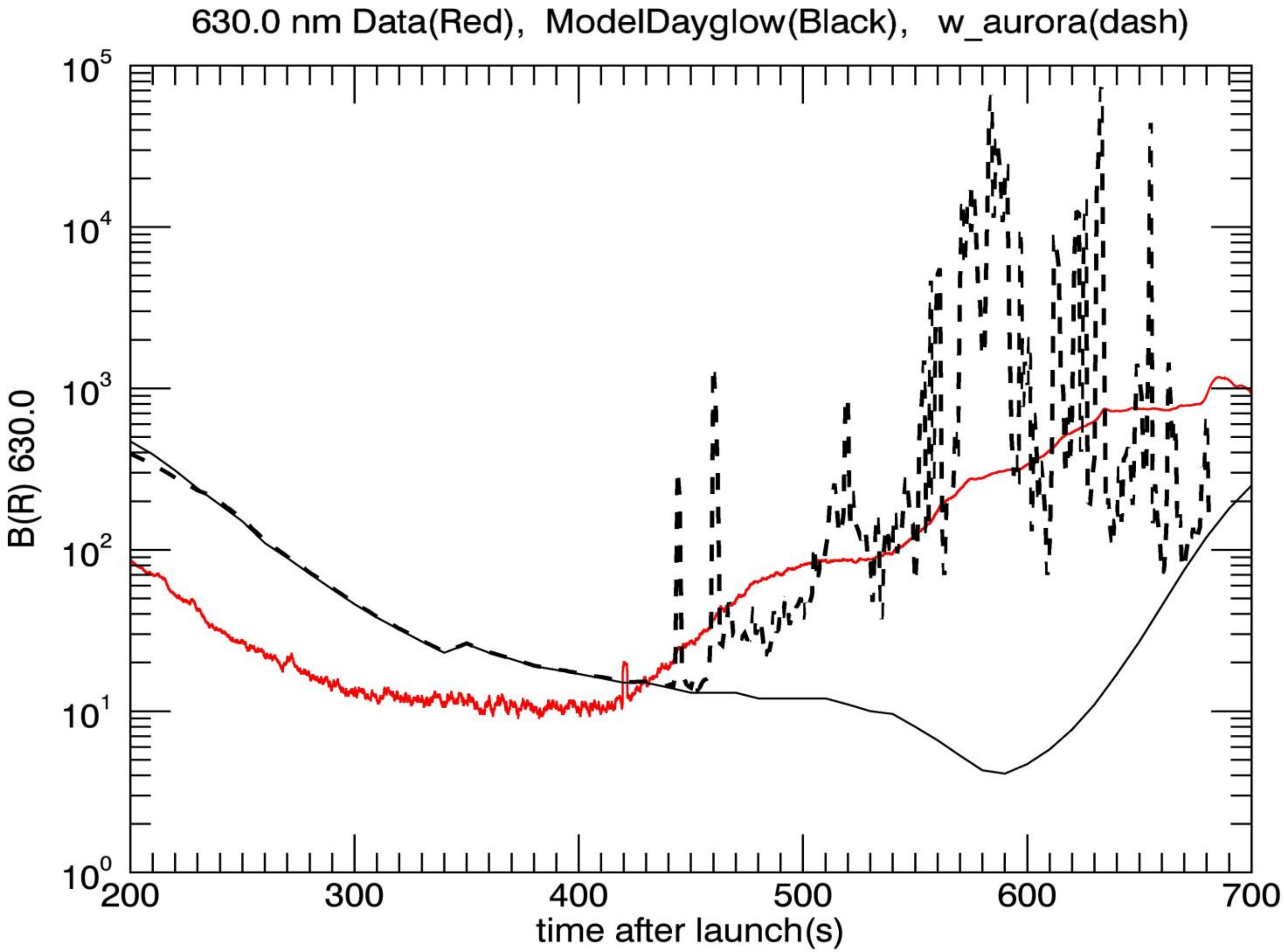
Results - Visible photometer data (J. Hecht, Aerospace)

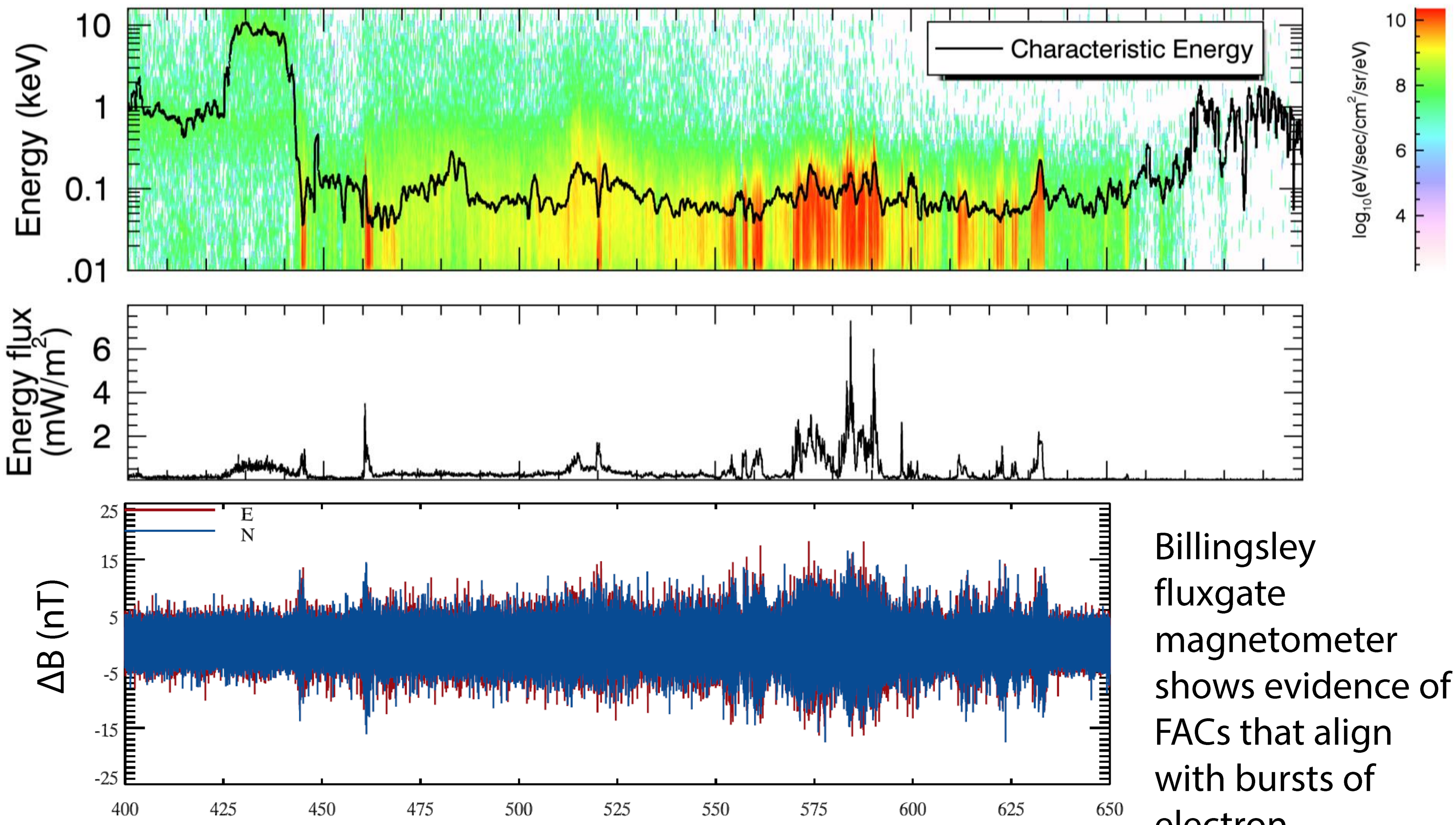
AURIC- calculates dayglow emissions

B3C electron transport model - calculates auroral emissions

Not shown: 557.7 nm & 391. 4 nm

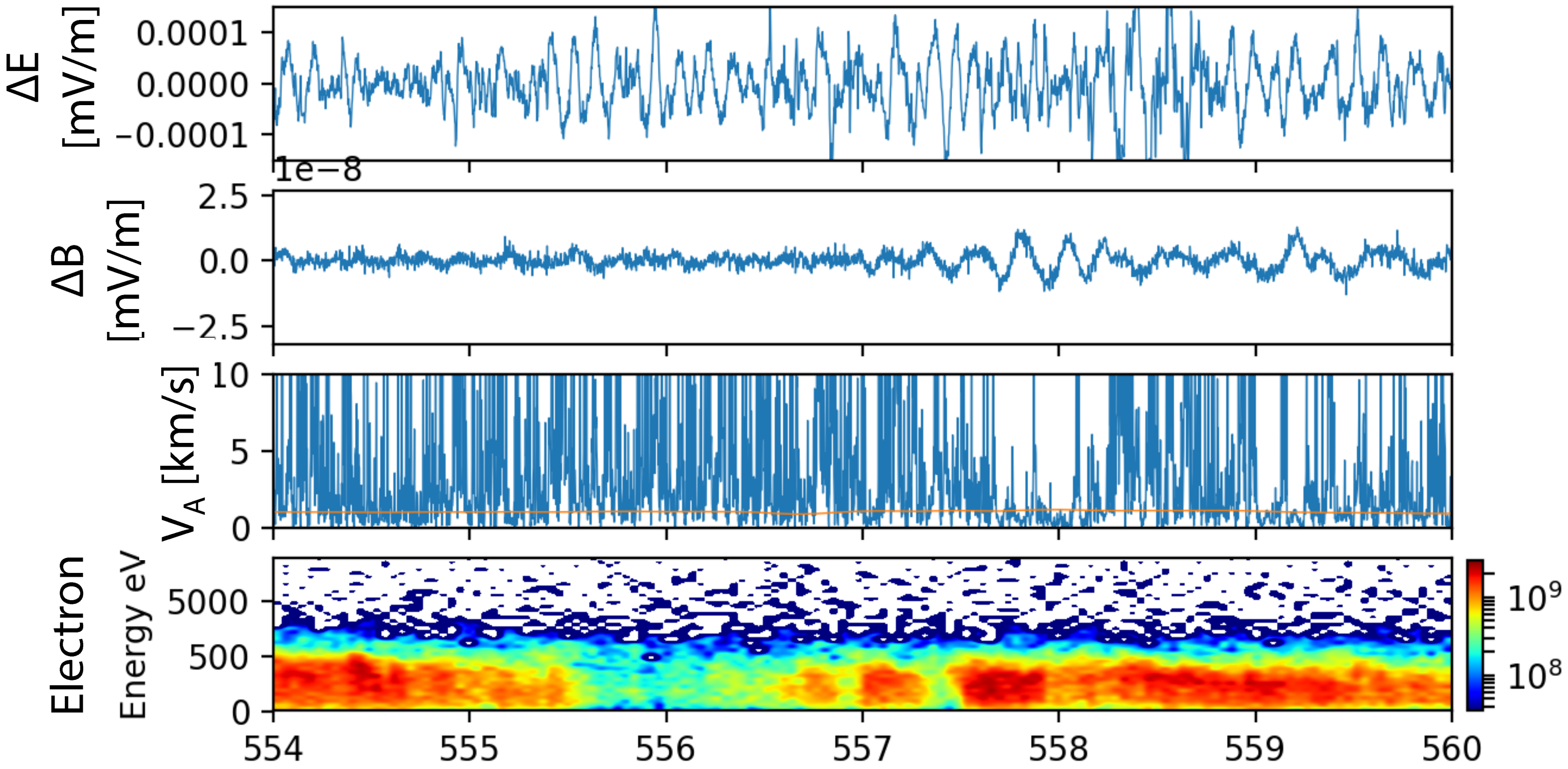


Results - B Fields, FACs (K. Lynch, M. Roberts, Dartmouth)



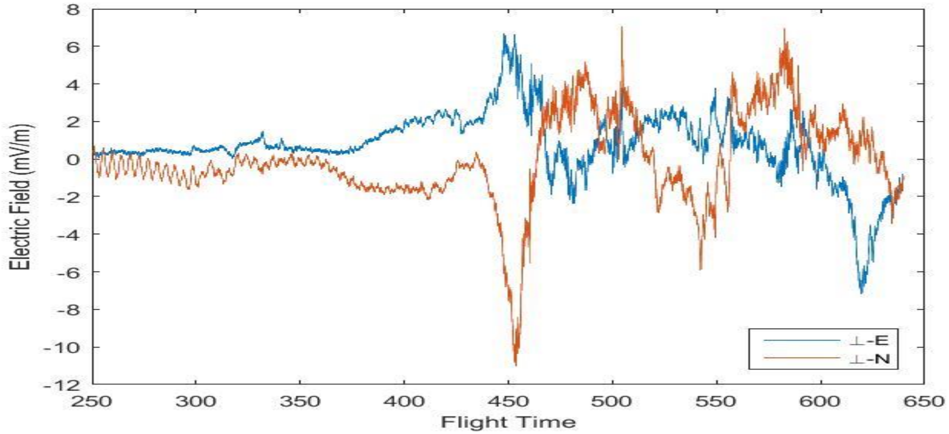
Billingsley fluxgate magnetometer shows evidence of FACs that align with bursts of electron precipitation

Results - Alfvénic aurora (PRELIMINARY!! D. Kenward, UNH)

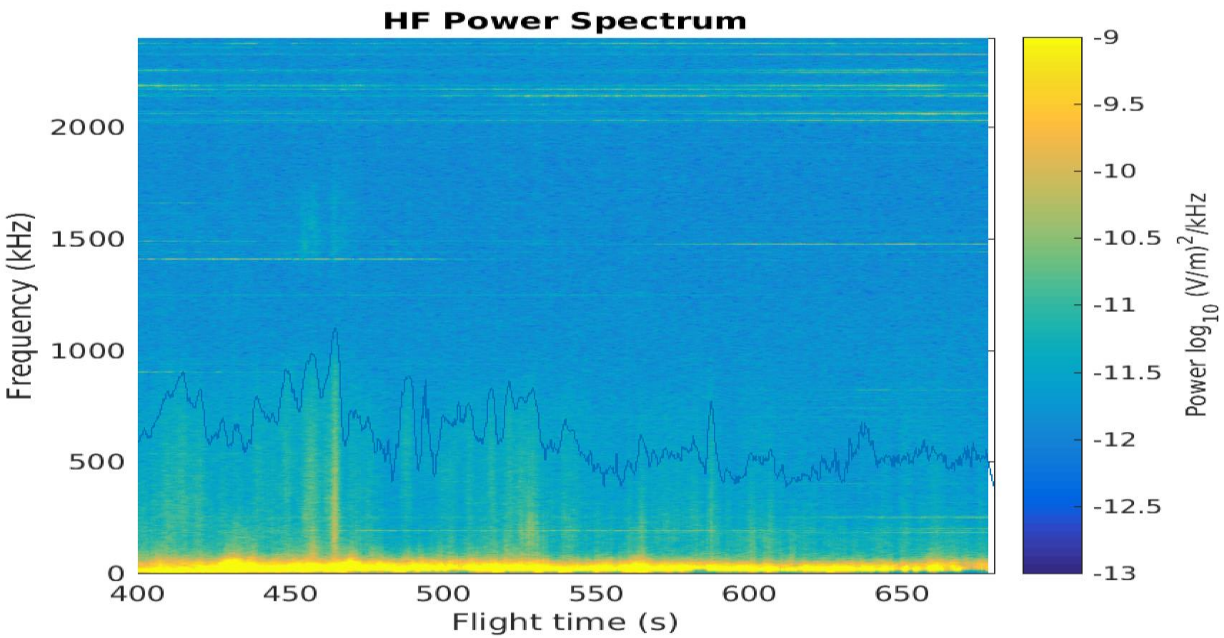


Results - E Fields (D. Hysell, Cornell; M. Harrington, S. Hatch, Dartmouth)

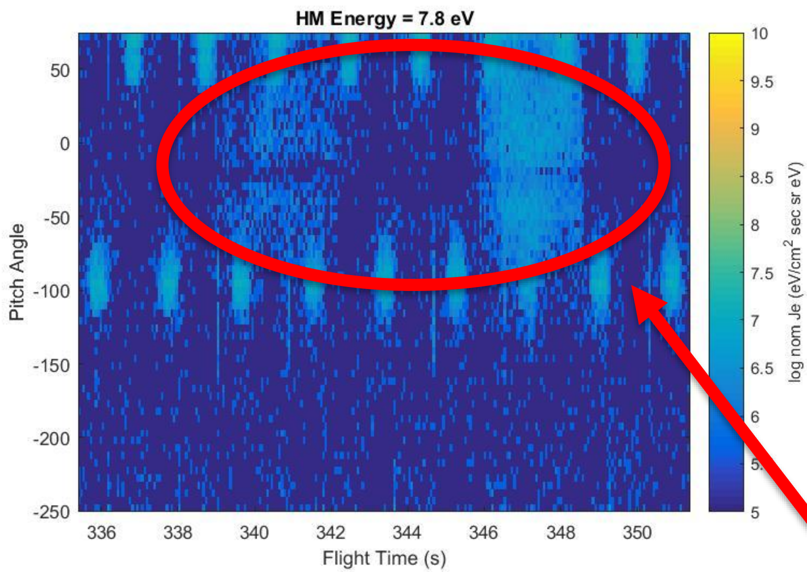
DC fields used with commercial fluxgate magnetometer data to calculate flow velocities
- Plot from M. Harrington thesis defense

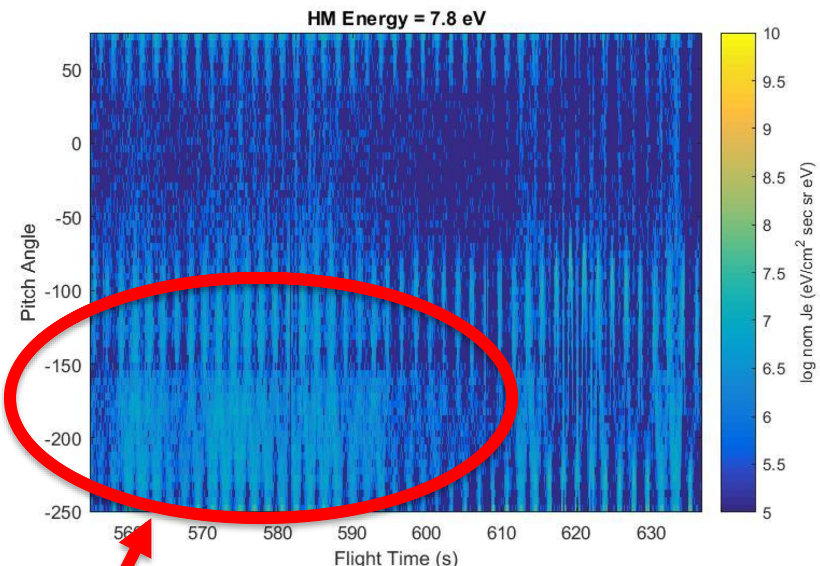


HF wave power spectrum analysis
- Work begun by S. Hatch, needs further analysis



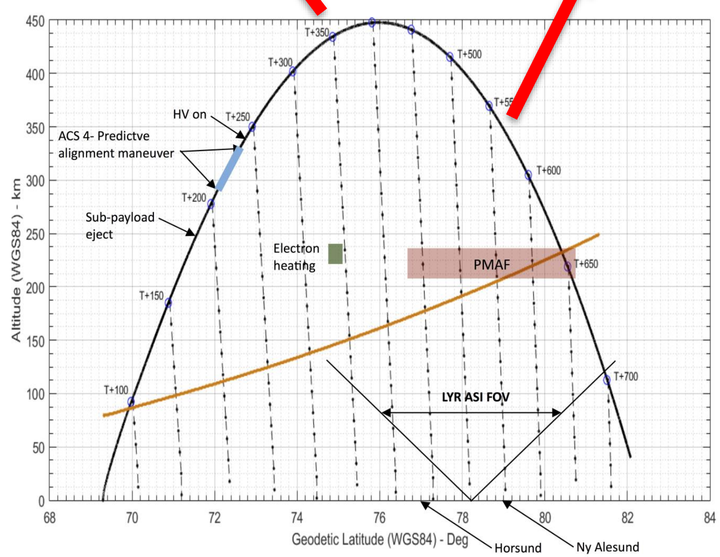
Results - Ions, selected results (K. Lynch, M. Harrington, Dartmouth)





<u>Downflow</u>

- ~ t+346 s
- Periodic signature due to RAM population
- Prior to PMAF
- v = 1.3 km/s



<u>Upflow</u>

- t+ 575 s
- One of several examples
- v = 2 km/s

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Results - IG (J. Clemmons, Aerospace)

Forward sensor used for upleg, aft sensor for downleg
- Overlap near apogee (408 s)

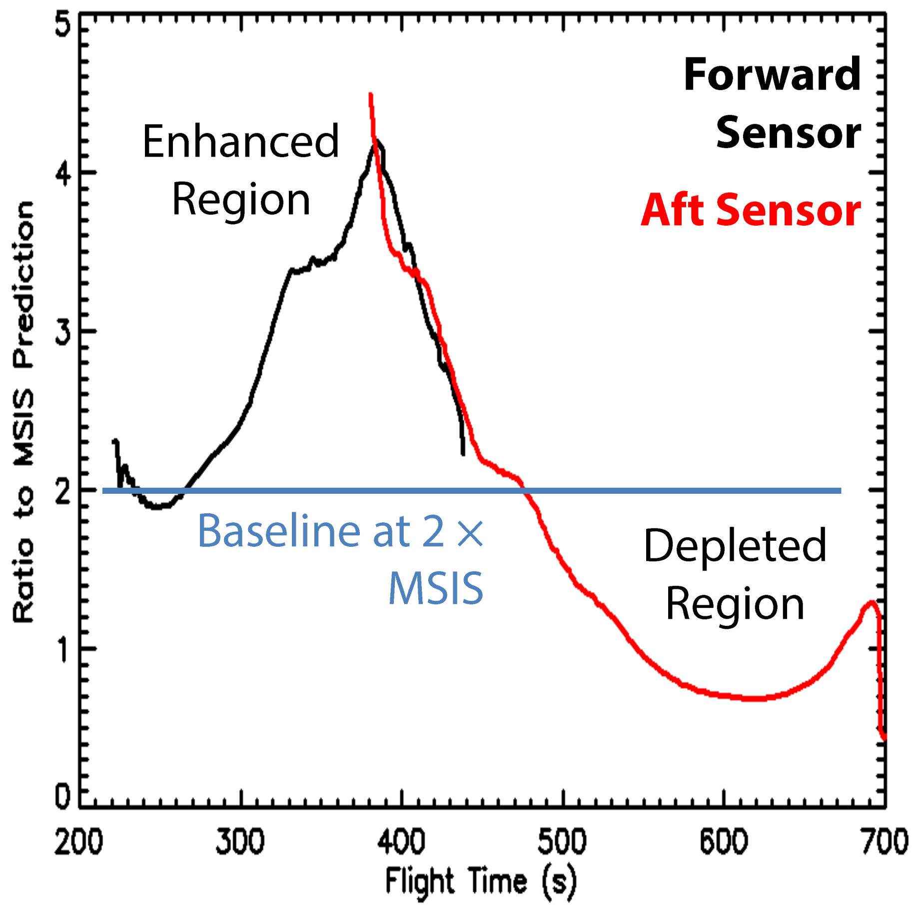
Baseline atmospheric level seems to be at about 2 x MSIS prediction

Enhanced density relative to baseline (~ 300 s to 450 s)
- Equatorward of main cusp precipitation

Depleted density (relative to baseline) seen after about 480 s
- Within main cusp precipitation

Can this be explained by temporal effects?

IG density / MSIS prediction



Why a depletion???

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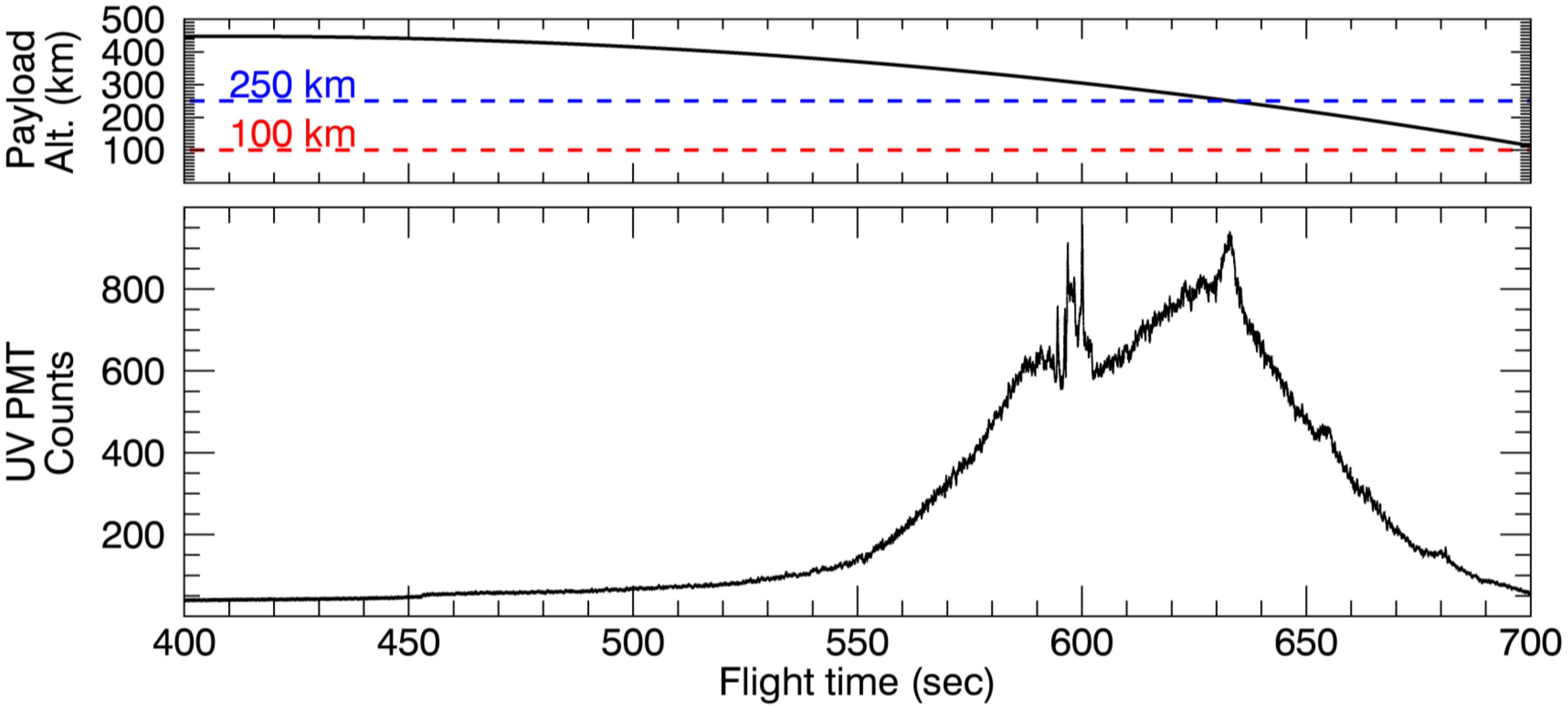
Results - UV PMT (M. Lessard, UNH)

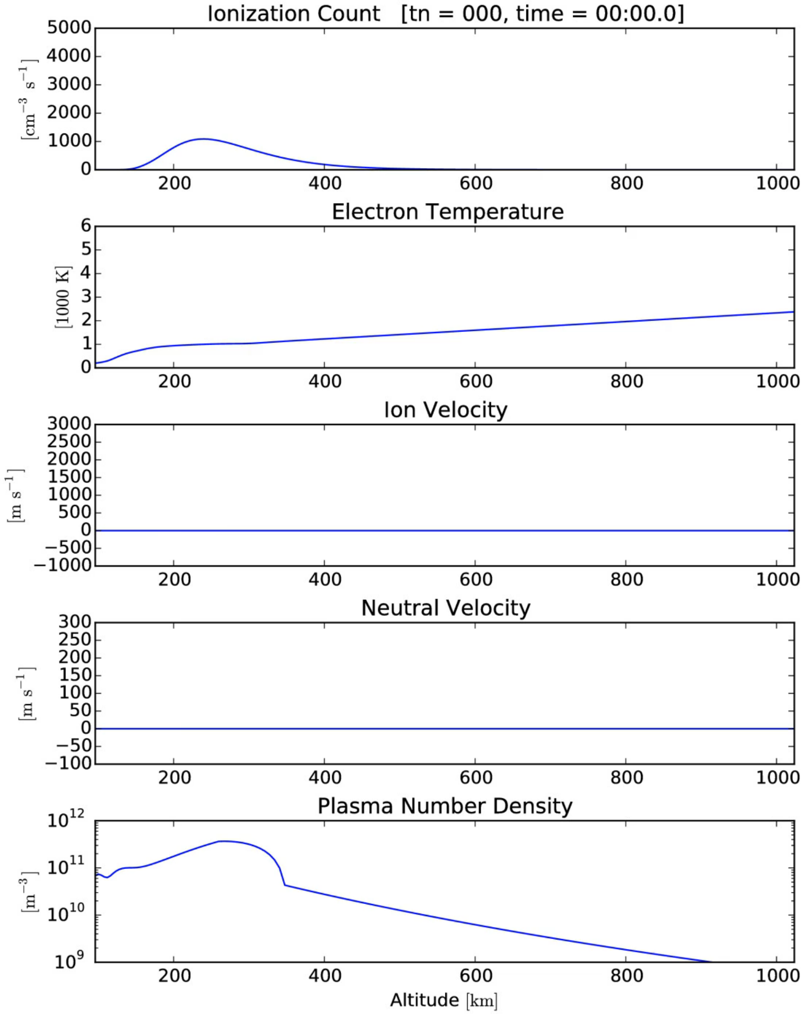


Passband looks at O I emissions (130.4 nm + 135.6 nm)

- Enhancement concurrent w/ peak energy flux of precipitating electrons
- Optical depth of 130.4 nm makes analysis complicated
- Peaked structure possibly due to 135.6 nm excitation due to precipitation

Otto-Sadler Model

- 3-fluid model* includes:
  - Inertial ion, electron and neutral terms
  - Detailed chemistry
  - Magnetic field.
- Outputs include density, velocity, temperature of all species
- Small-scale behavior
  - e.g. 1 km; <1 s
- 24 minute simulation of IT dynamics
  - Precipitation cycles on/off ~ 6 min intervals
  - Emulates passage of PMAFs



*Sadler et al. [2012]

Conclusions

1. PMAFs play a critical role in neutral upwelling in the cusp
   - Consist of clusters of small-scale, intense auroral arcs that drift poleward
   - Highly correlated with negative Bz
2. RENU 2 results suggest that N2+ “upflow” needs to be addressed in models
3. The Otto/Sadler model predicts that the effect is an integral part of ion outflow.
   1. Also predicts the development of depletion regions.
4. The work by B. Zhang shows the importance of including ion outflow for predicting neutral upwelling with global-scale models.

Future work

1. Investigate vertical density profiles of neutrals (i.e., depleted regions)
2. Investigate the role of N2+ in ion outflow and neutral upwelling (observationally & numerically)
3. Integrate the Otto/Sadler model and Zhang model

We welcome interested collaborators!!! Please come talk to me here / via email (bruce.fritz@unh.edu) or email Marc Lessard directly (marc.lessard@unh.edu)

Questions?

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