RENU 2: UV Observations of Atomic Oxygen in the Dayside Cusp

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Abstract

The *Rocket Experiment for Neutral Upwelling 2* (RENU 2) launched into the dayside cusp region on 13 December 2015 out of Andøya Space Center, Norway. The mission included a suite of field and particle instruments designed to examine upwelling of neutral particles in the cusp. One instrument designed and built by the University of New Hampshire was a photomultiplier tube (PMT) to look up the local magnetic field line, filtered specifically for ultraviolet emission lines of atomic oxygen (130.4 nm, 135.6 nm). These emissions provide valuable information about the content of neutral oxygen in the ionosphere above the payload, which plays a critical part in examining neutral upwelling. The SSUSI instrument on the DMSP spacecraft also observes atomic oxygen FUV lines (both 130.4 and 135.6 nm). Three satellites (F16, F17, and F18) passed near the trajectory of the RENU 2 flight within 10 minutes of apogee. This data may provide information about atomic oxygen in the ionosphere/thermosphere including spatial distribution, temporal evolution, and the mechanism of excitation

RENU 2 Background

Mission Objectives

1. To measure neutral gas, ion, and electron temperature enhancements, which will provide an initial assessment of the upwelling process.
2. To measure large- and small-scale Joule heating in the cusp during the RENU 2 overflight. Large-scale data will be acquired by EISCAT; small-scale data (perhaps associated with Alfven waves) will be acquired using onboard electric field measurements
3. To measure the precipitating electron energy input. Theory and observations suggest that various types of electron precipitation contribute to neutral upwelling; knowledge of the precipitating population is critical for understanding this effect.
4. To use measured quantities as inputs to "thermodynamic" and "electrodynamic" models for comparison to the observed upwelling.

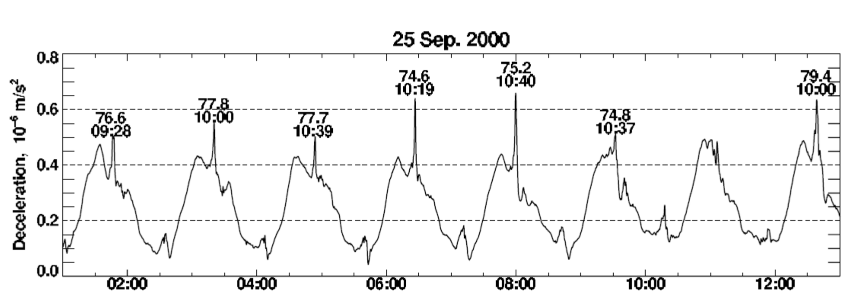
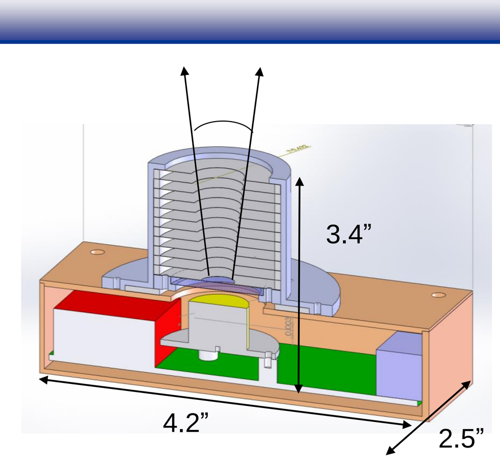


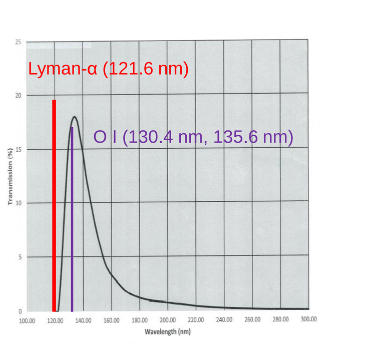
Figure from Luhr et al [2004]. Air drag measured by the accelerometer on board CHAMP. The harmonic variations indicate the range of change over an orbit. Superimposed are small-scale features. The peaks in air drag are labeled by their corrected magnetic latitude and magnetic local time

Lühr, H., M. Rother, W. Köhler, P. Ritter, and L. Grunwaldt (2004), Thermospheric up-welling in the cusp region: Evidence from CHAMP observations, Geophys. Res. Lett., 31, L06805, doi:10.1029/2003GL019314.

UV PMT

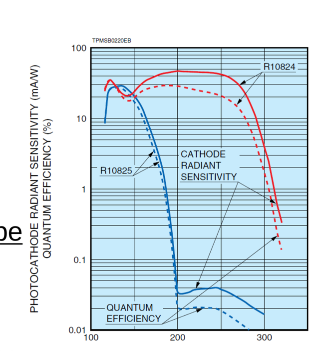


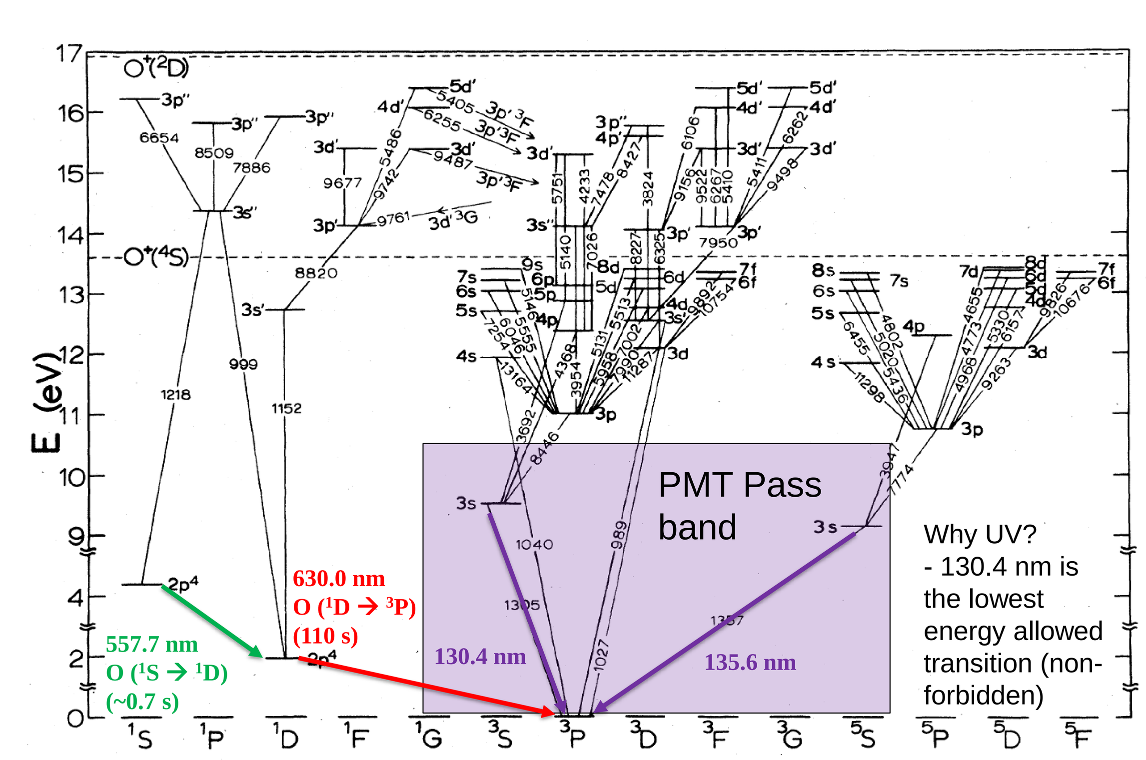
- Detects atomic oxygen (O I) emissions at 130.4 nm and 135.6 nm
  - Excludes Lyman-alpha (121.6 nm)
- FOV = 12.5°
- 10 Hz sample rate
- Uncooled
- Custom mech. and elec. designs



Pelham Research Optical VUV Filter
- Peak Wavelength – 134.0 nm
- Peak Transmission – 18.0%
- FWHM – 19.5 nm
- Material – CaF_2

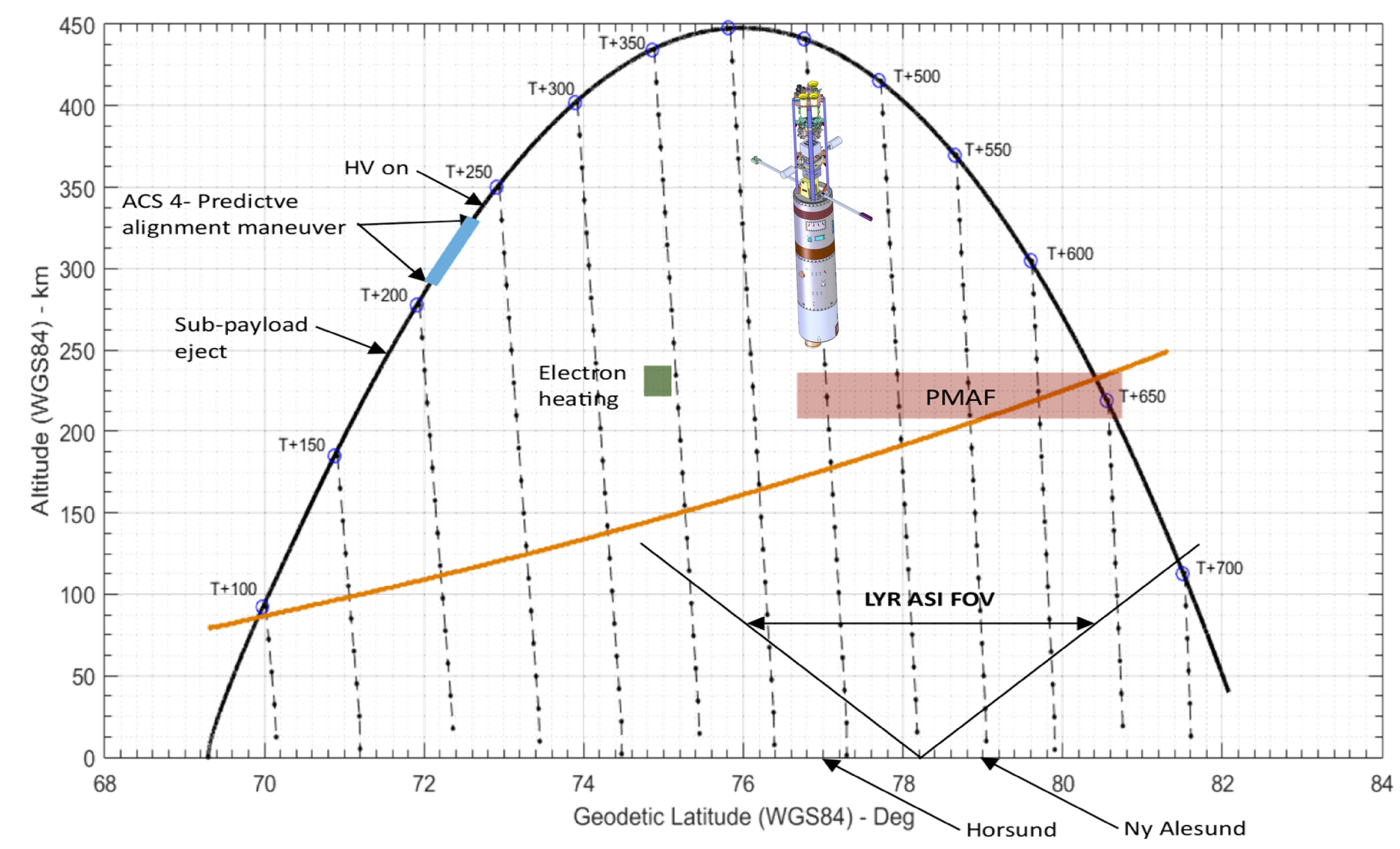
Hamamatsu R10825 Photomultiplier Tube
- Spectral response – 115 to 195 nm
- Maximum response – 130 nm
- Photocathode material Cs-I
- Maximum quantum efficiency ~26.0 %





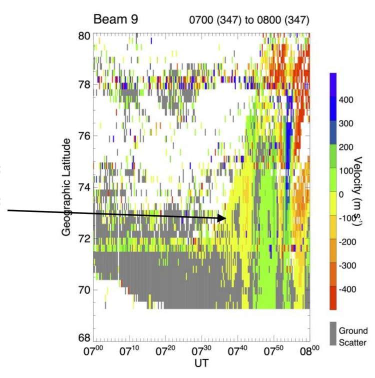
Schulman, M. B., F. A. Sharpton, S. Chung, C. C. Lin, and L. W. Anderson (1985), Emission from oxygen-atoms produced by electron-impact dissociative excitation of oxygen molecules, Phys. Rev. A, 32(4), 2100–2116, doi:10.1103/PhysRevA.32.2100.

Launch

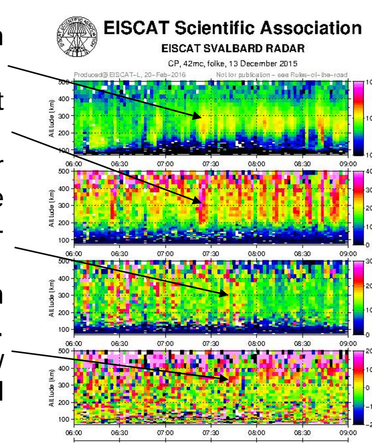


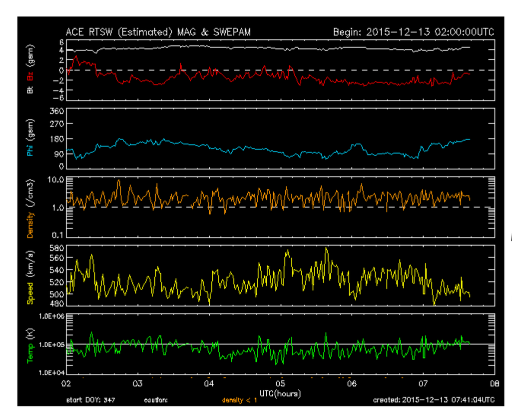
Launched into cusp
How did we know?

- Evidence from Finland SuperDARN of rotation into the cusp – the onset of poleward ionospheric flows. Launch was at 07:34 UT.



- Several transient enhancements in F-region ρ_e (consistent with the cusp)
- Several transients in T_e (consistent with PMAFs)
- Joule heating mostly seen in the hour prior to launch, but maybe some weak Joule heating around 07:38 - 07:48 UT
- Weak ion upflow in topside region (above 400 km altitude) throughout. Around 07:34 - 07:48 UT, ion upflow appears to have been extending all the way down to 300 km altitude

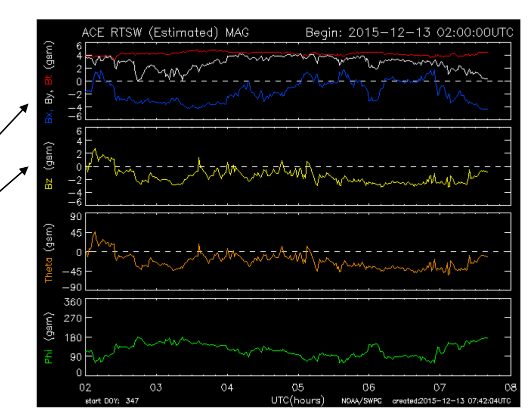




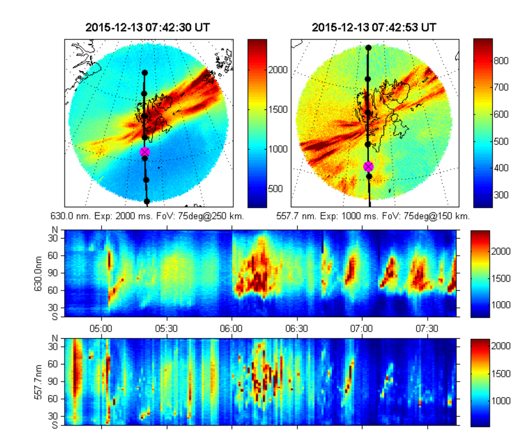
ACE Data

Estimated propagation time of approximately 50 minutes.

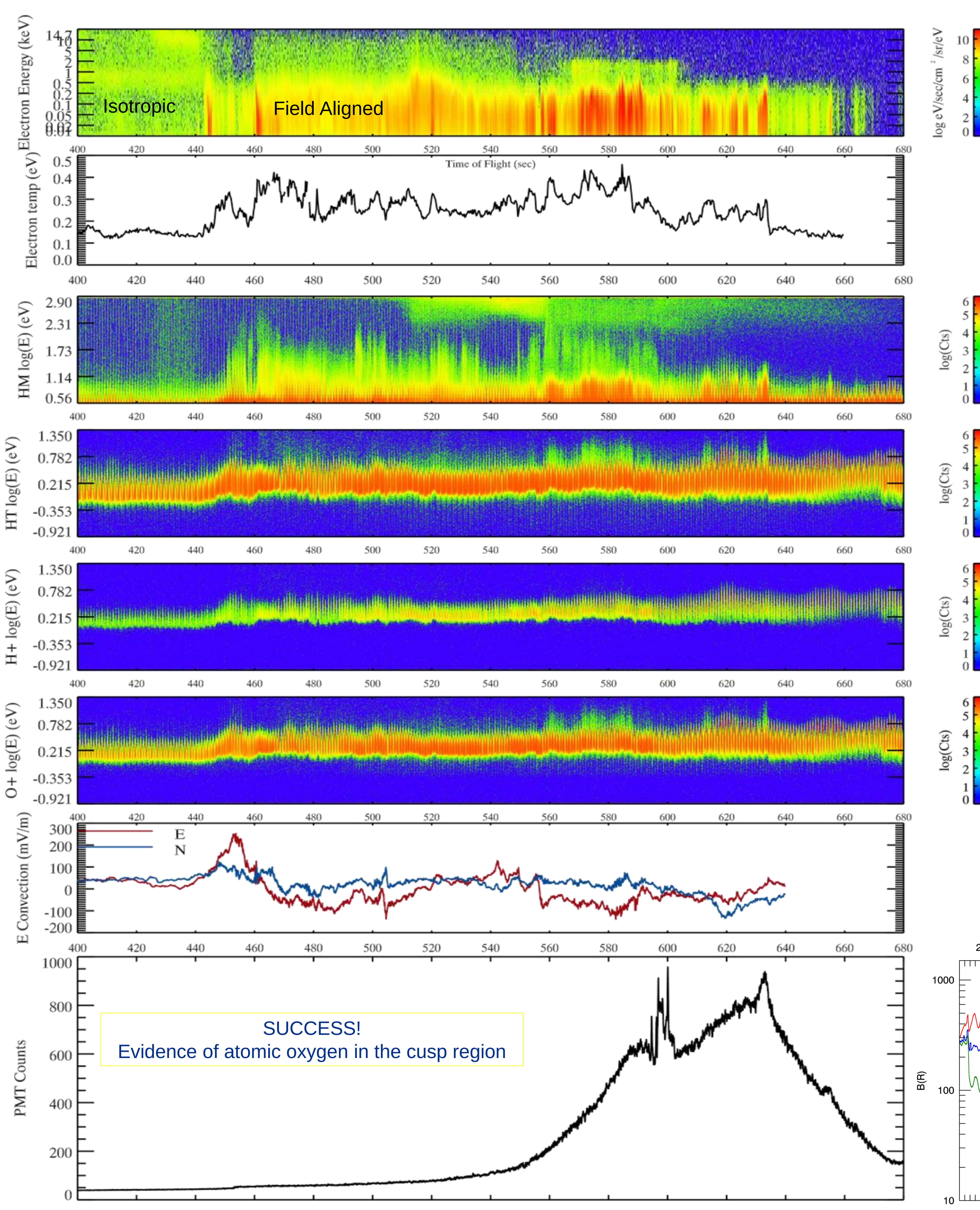
- Positive B_y
- Negative B_z
- Typical density
- Solar wind slightly elevated



- Scanning MSP at KHO (Longyearbyen, Svalbard) tracked PMAFs moving overhead throughout the morning (see bottom left)
- All-Sky Cameras at both Longyearbyen and Ny-Alesund provided visible context during the launch window



RENU 2 Measurements



EPLAS electron detector
- 360 pitch angle resolution
- Electrostatic top hat analyzer
- Isotropic plasma sheet electrons prior to ~440 s
- Field aligned population after 440 s

ERPA electron detector
- Thermal electron population
- Electrostatic analyzer

HEEPS-M
- Super Thermal Ions
- 3 – 790 eV
- Signatures of upflowing ions between 560-580 s
- Potential Stepped ion population?

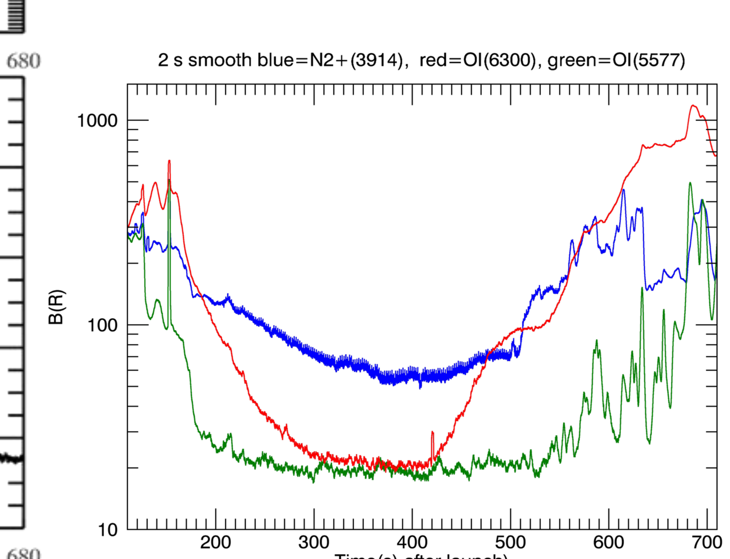
HEEPS-T
- Thermal Ions
- 0.1 – 22 eV

BEEPS
- 6 – 800 eV
- H+ and heavier ions (O+)

COWBOY
- 0-20 kHz, 0-1 kHz VLF
- Convection DC E-field

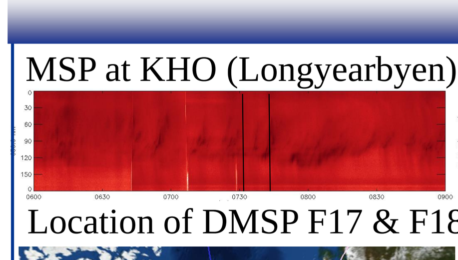
UV PMT
- Pointed above payload
- Uncalibrated

Aerospace PMTs
- Pointed above payload
- O, N_2^+ (sunlit aurora)

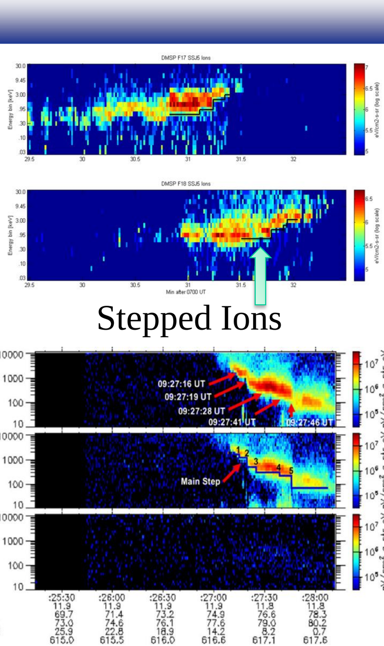


DMSP

MSP at KHO (Longyearbyen)



Location of DMSP F17 & F18



RENU 2 apogee occurs near 0741 UT

SSUSI: UV Measurement →
Special Sensor Ultraviolet Spectrographic Imager
- 130.4 nm
- 135.6 nm

← SSJ5 Ion precipitation
Stepped Ion Precipitation is indicative of dayside reconnection

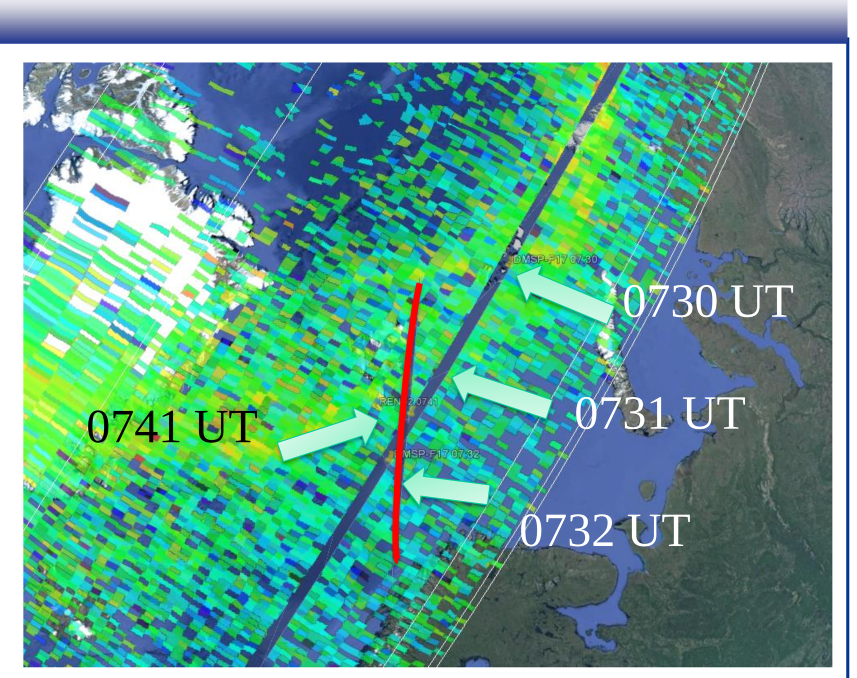


Figure to right: Lunde, J., Buchert, S. C., Ogawa, Y., Hirahara, M., Seki, K., Ebihara, Y., Sakanoi, T., Asamura, K., Okada, M., Raita, T., and Häggström, I.: Ion-dispersion and rapid electron fluctuations in the cusp: a case study, Ann. Geophys., 26, 2485-2502, doi:10.5194/angeo-26-2485-2008, 2008.

Conclusion

- ✓ RENU 2 successfully launched into cusp aurora on 13 December, 2015
  Several observations help verify the presence and location of the cusp
- ✓ The UV PMT worked well enough to see a measurable signal of atomic oxygen in the cusp region
  - Instrumental limitations will make interpreting the data difficult: filter band pass will make separation of UV excitation from particle precipitation difficult
  - Optical depth of ionosphere complicates interpretation of 130.4 nm emission line
- ✓ DMSP provides measurements that will help with interpretation of RENU 2 data
  - SSJ5 particle precipitation helps to verify cusp ion precipitation
  - SSUSI SIS measurements helps to determine relative abundance of 130.4 nm and 135.6 nm signals
- ✓ Calibration of the PMT will provide additional information about the measurement

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