University of New Hampshire

Rocket Experiment for Neutral Upwelling

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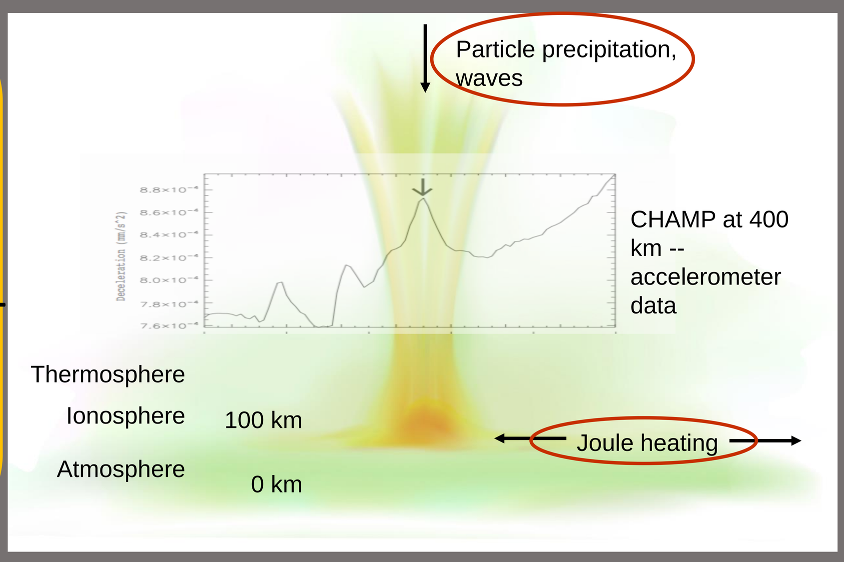
ABSTRACT: Observations from the CHAMP satellite from 2004 show relatively small scale heating in the thermosphere. Several different mechanisms have been proposed to explain this phenomenon. The RENU 2 rocket mission includes a suite of 14 instruments which will acquire data to help understand processes involved in neutral upwelling in the cusp. Neutral, ion, and electron measurements will be made to provide an assessment of the upwelling process. SUPERDarn measurements of large- scale Joule heating in the cusp during overflight will also be acquired. Small-scale data which could possibly be associated with Alfvén waves, will be acquired using onboard electric field measurements. *In-situ* measurement of precipitating electrons and all other measurements will be used in thermodynamic and electrodynamic models for comparison to the observed upwelling. Preliminary data are reported here.

Science Goals and Motivation

Motivation: Neutral upwelling in the cusp region has a measureable effect on the decay of satellite orbits. Results from CHAMP satellite reported indicate significant deceleration at cusp region, where strong FAC were also measured[1]. Several proposed theories will use the *in-situ* measurements from RENU2 as inputs and output comparisons to what was seen.

Relevant Processes:

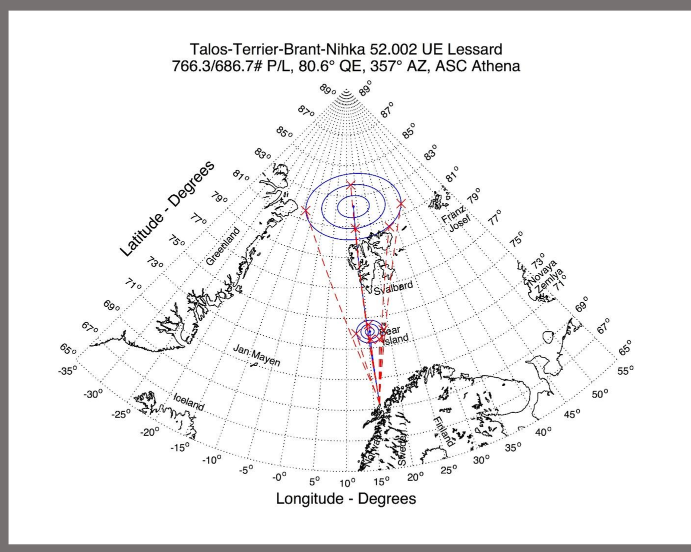
1. Joule heating of thermosphere and ionosphere causes neutral upwelling – Type 1
2. Soft electron (~100eV) precipitation heats ambient electron population, causes ambipolar field, lifts ions – Type 2
3. BBELF waves at higher altititudes (400 – 600 km) energize upwelled ions which then outflow

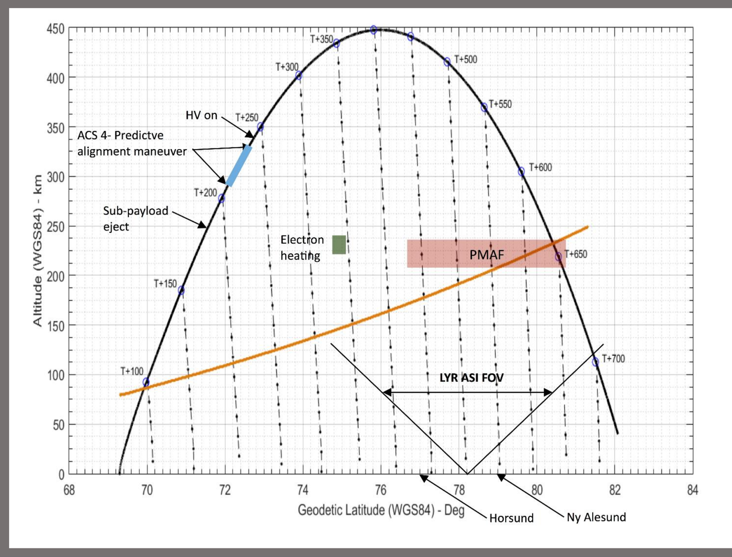


Proposed theories for small-scale neutral upwelling – primary driving mechanisms

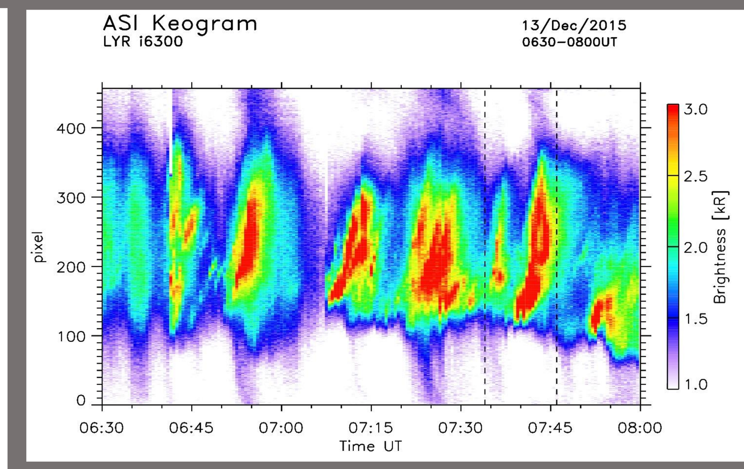
1. Upwelling fundamentally driven by Joule heating[2]
2. Type 2 ion outflow[3]
3. Soft electron precipitation, enhancing conductivities in F-region, enables increased Joule heating[4]
4. Direct particle heating with higher altitude Joule heating[5]

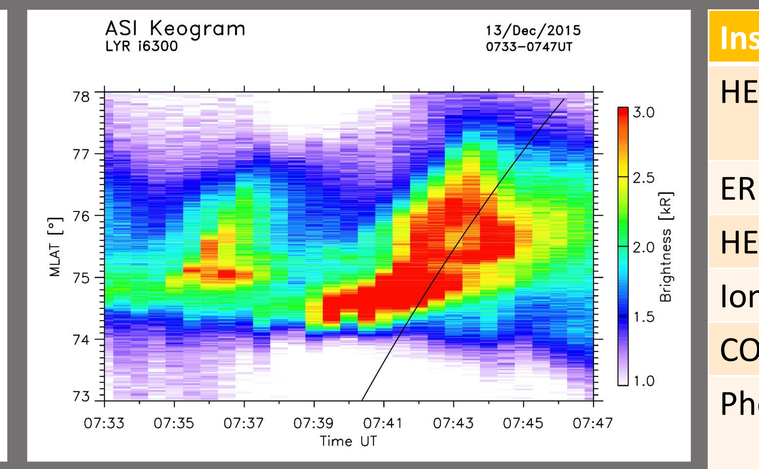
Launch Conditions





Above: Planned and actual trajectory for RENU2 flight (left). Flight timeline and context for ground support aspects of mission.

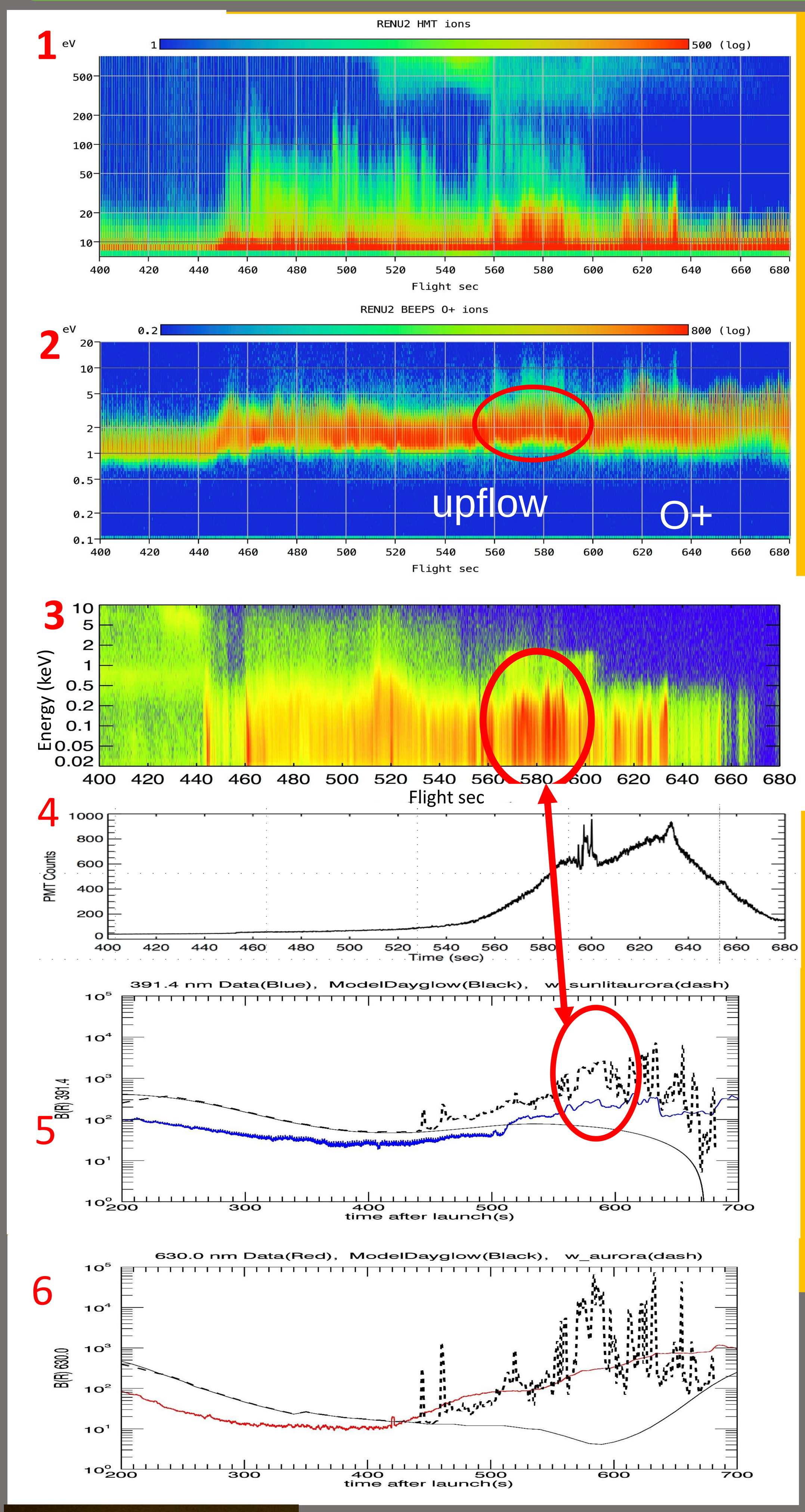




Above: Keograms show auroral conditions during launch. Waited for several PMAFs to move through before launch to ensure adequate heating. Black line indicates RENU2 trajectory. **Right:** Instrumentation aboard RENU2

Instrument	Institution	Sensitivity
HEEPS Electrons	UNH/Dartmouth	6 eV – 18 keV
ERPA	UNH	.06 eV – 3 eV
HEEPS Ions (3)	Dartmouth	.1 eV – 1keV
Ion Gauge	Aerospace	>10^{-10} T
COWBOY (E-field)	Cornell	0-20 kHz
Photometers	Aerospace	391, 630, 844.6 (nm) @ 30cts/s/R
UV PMT	UNH	130.4 and 135.6 nm (atomic Oxygen)
Fluxgate Magnetometer	Cornell	+/- 60,000 nT
Racetrack Magnetometer	UNH/SWRI	2.9 pT/√Hz @1Hz

Observations



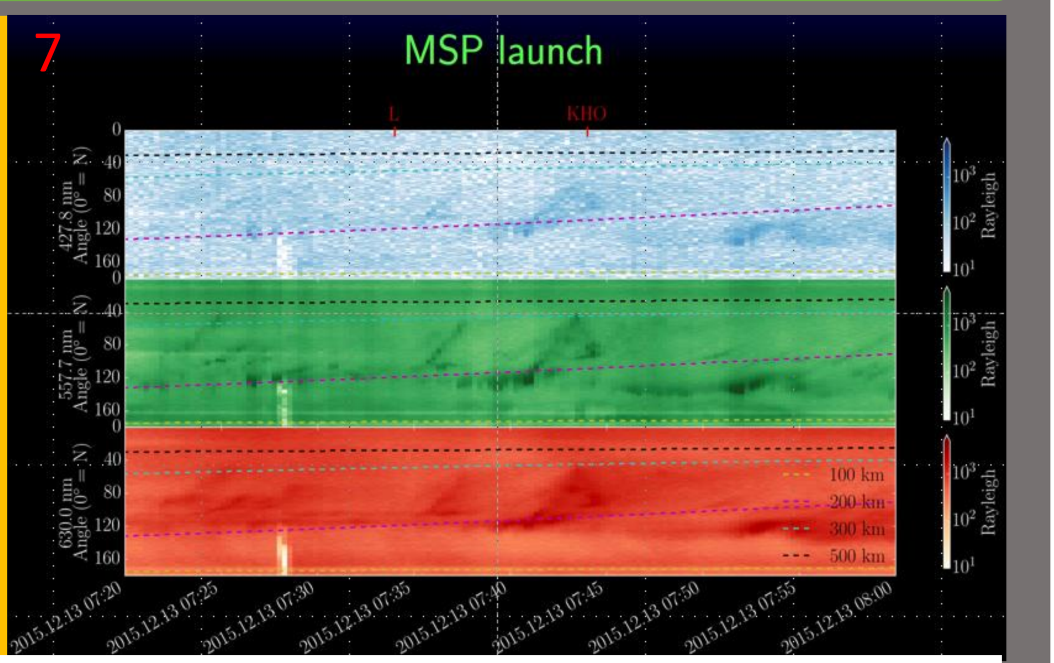
1&2, Ions (Dartmouth): Selected ion data in **(1)** shows possible (bottom of) stepped ion precipitation which has been associated with reconnection . **(2)** displays upflow signatures in the BEEPS O+ ion instrument.

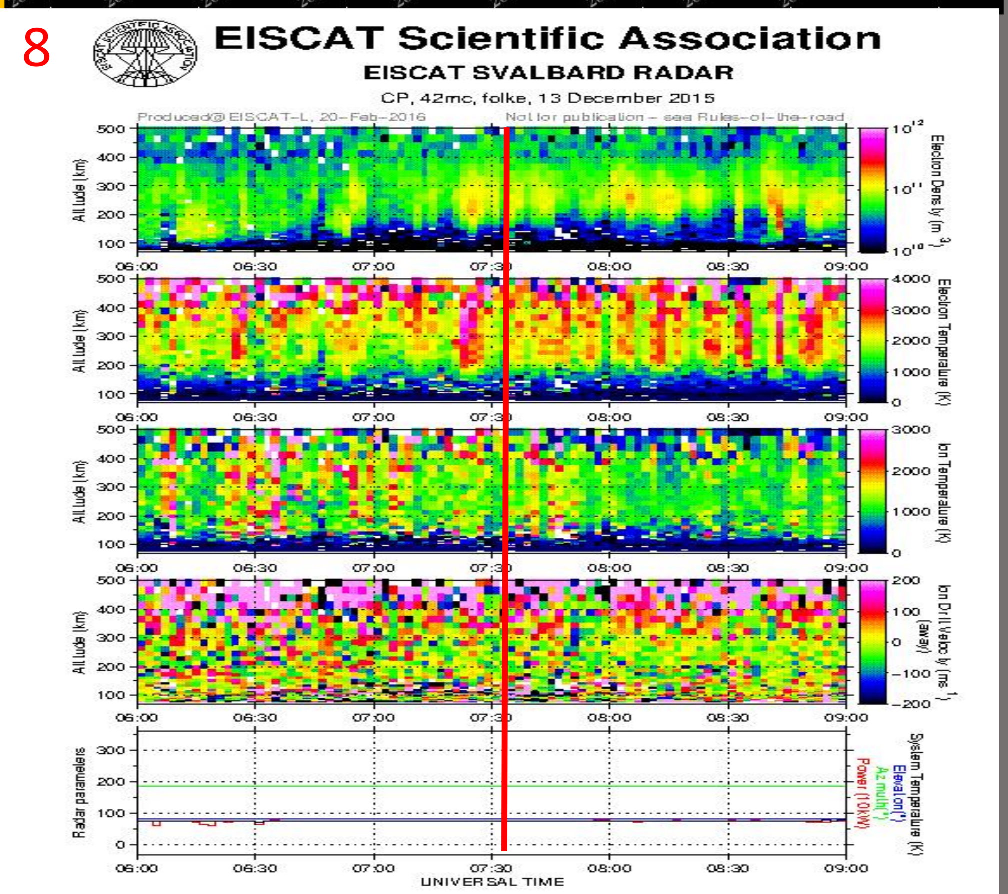
3, Electrons (UNH): EPLAS instrument provides important context for other instruments. Energy flux (not pictured) from this instrument is a key input in many modelling efforts.

4, UVPMT (UNH): 130.4nm emission driven by e- precipitation or solar UV. Broad 'bump' appear to be due to UV photoemission. 135.6nm driven by precipitation, perhaps the narrow structure seen.

5,6 Photometers (Aerospace): Observations show N2+ ion and oxygen signatures that have upwelled.

7, KHO MSP (UNIS): Keogram shows different color channels during launch. Dashed lines represent intersection of terminator at given altitude. This provides evidence for photometer signatures which are associated with sunlit aurora. **8, EISCAT:** Several transient electron enhancements in density and temperature within F-region, which is consistent with the cusp. These signatures would be consistent with Poleward Moving Auroral Forms (PMAFs) Joule heating mostly in hour prior to launch, with some possible around 7:38 – 7:48 UT. Weak ion upflow above 400km throughout. Vertical red line through plots indicate launch time.





Conclusions

The flight trajectory of RENU2 took it directly over a PMAF. Excellent ground based observations enabled the timing of the launch to ensure that significant heating events had occurred such that neutral upwelling would be present. Preliminary results show that upwelling was indeed present during the flight. Payload was completely successful, and all data necessary to feed into relevant models should be available. Early results highlight several topics of interest. Photometer data brings N2+ ions into the ion outflow conversation as part of sunlit aurora and demonstrates upwelling of neutral oxygen. Electron and stepped ion precipitation signatures along with fields data (Alfven waves) fuel investigation into reconnection.

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Citations: 1. Luhr et al., Thermospheric up-welling in the cusp region: Evidence from CHAMP observations, Geophys. Res. Lett., 31, 6805, 2004. **2.** Crowley, G., D. J. Knipp, K. A. Drake, J. Lei, E. Sutton, and H. Lühr (2010), Thermospheric density enhancements in the dayside cusp region during strong BY conditions, Geophys. Res. Lett., 37, L07110, doi:10.1029/2009GL042143. **3.** Sadler, F. B., M. Lessard, E. Lund, A. Otto and H. Lühr (2012), Auroral precipitation/ion upwelling as a driver of neutral density enhancement in the cusp, Journal of Atmospheric and Solar-Terrestrial Physics 87–88. **4.** 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. **5.** 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 condi- tions, J. Geophys. Res. Space Physics, 121, 2645-2661, doi:10.1002/2015JA021658.