In situ Observations of Energy Inputs During a Cusp Neutral Density Enhancement

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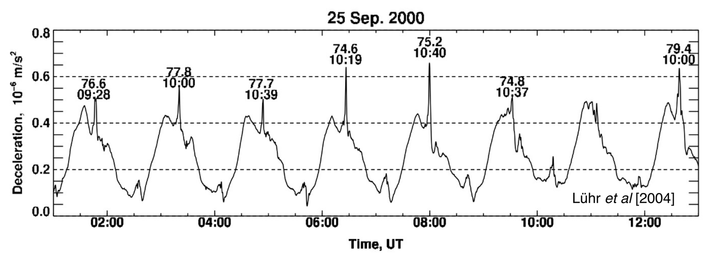
Abstract

The Rocket Experiment for Neutral Upwelling (RENU2) sounding rocket launched from Andoya, Norway on December 13, 2015 at UT 7:34. The rocket was equipped with a full suite of particle and field instruments in order to observe and characterize upwelling and the driving processes within the cusp region. Ground support for the mission included EISCAT and SuperDARN radars, a ULF magnetometer, as well as all-sky imagers and meridian scanning photometers. A serendipitous conjunction with GRACE and two DMSP satellites provide multipoint measurements of the same event which not only show a neutral density enhancement within the cusp region but also create what might be the most detailed observations of an upwelling event to date. Data are presented which show observations of density enhancement above the payload, as well the "energy budget" of the event as measured by the particle and field instruments of RENU2.

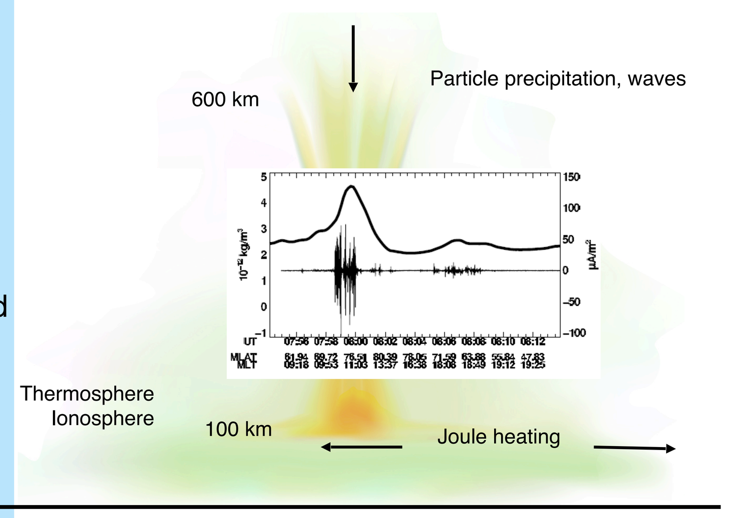
Introduction and Background

Luhr , *et al.* [2004] reported CHAMP satellite observations showing large deceleration spikes while traversing the cusp region due to enhanced neutral density an increased scale heights. RENU2 sought to characterize the driving mechanisms for neutral density enhancements in the cusp region.



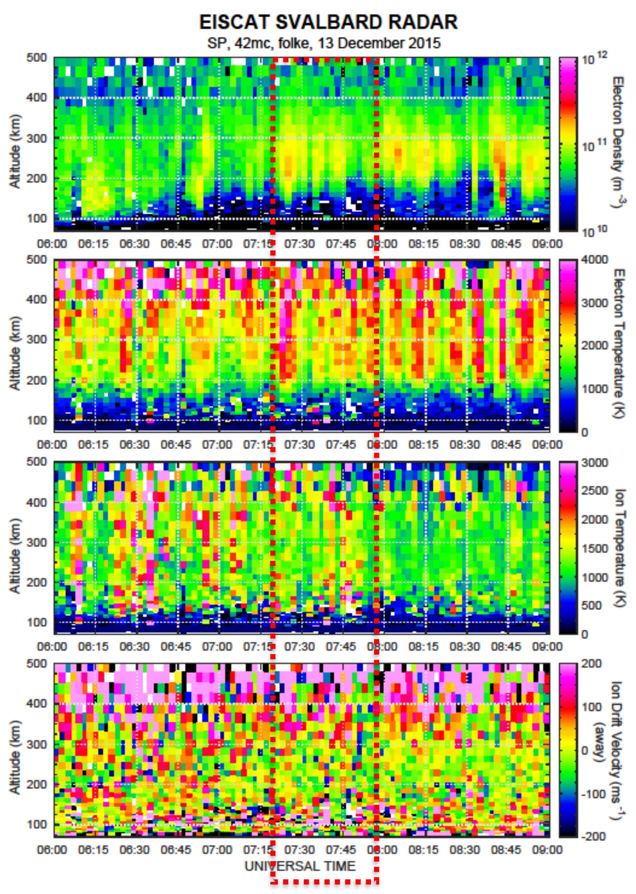
CHAMP deceleration spikes reported by Luhr, *et al.* [2004] in the cusp region alongside small-scale field aligned currents. Decelerations are most notable in northern hemisphere, exact time and latitude listed in figure at the spike.

Three mechanisms are thought to contribute. 1: Joule heating of the ionosphere/thermosphere 2: Soft electron precipitation heating the ambient ionosphere, causing ambipolar field 3: Wave-Particle interactions which may include BBELF waves interacting with ions at higher altitudes and Alfven waves interacting with electrons

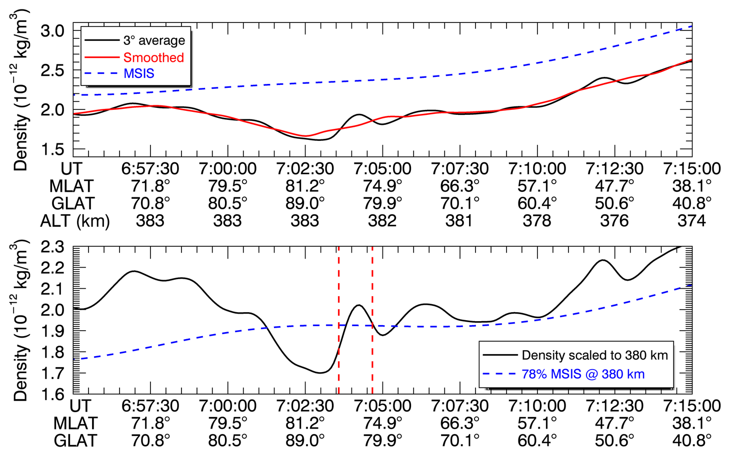


Competing theories as to how these mechanisms lead to neutral density enhancements. 1: Fundamentally through large scale joule heating 2: Soft electron precipitation enhancing F-region conductivity and enabling, enhanced joule heating 3: direct heating through electron precipitation 4: Type II ion outflow + momentum transfer to neutrals

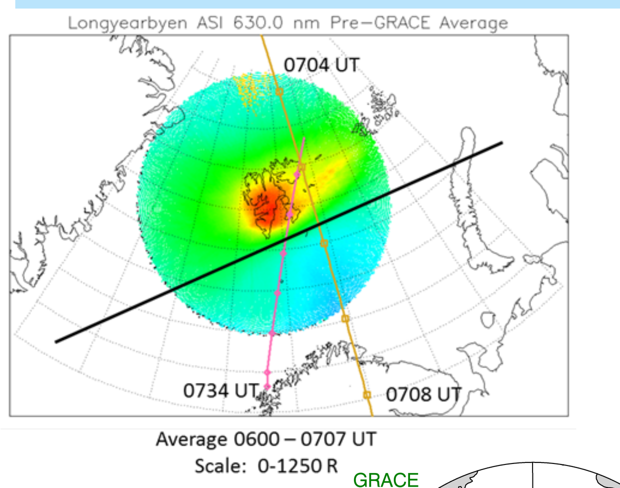
Flight Conditions

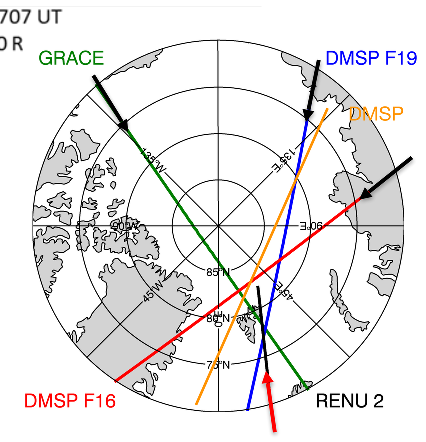


Prior to launch, several poleward moving auroral forms (PMAFs) were observed to pass overhead (visible in the ASI frames shown elsewhere on the poster)t. This ensured that adequate heating of the ionosphere-thermosphere had occurred. The effects of the PMAFs are visible in EISCAT data (**Above**). The first two plots show electron density and temperature enhancements associated with the PMAFs. The red box indicates from about 15 minutes pre-launch waiting for the appropriate conditions and then the flight time for RENU2. Ion upwelling signature is visible in at the top of plot 4 in the middle of the red box as a grouping of red pixels indicating enhanced ion velocity.

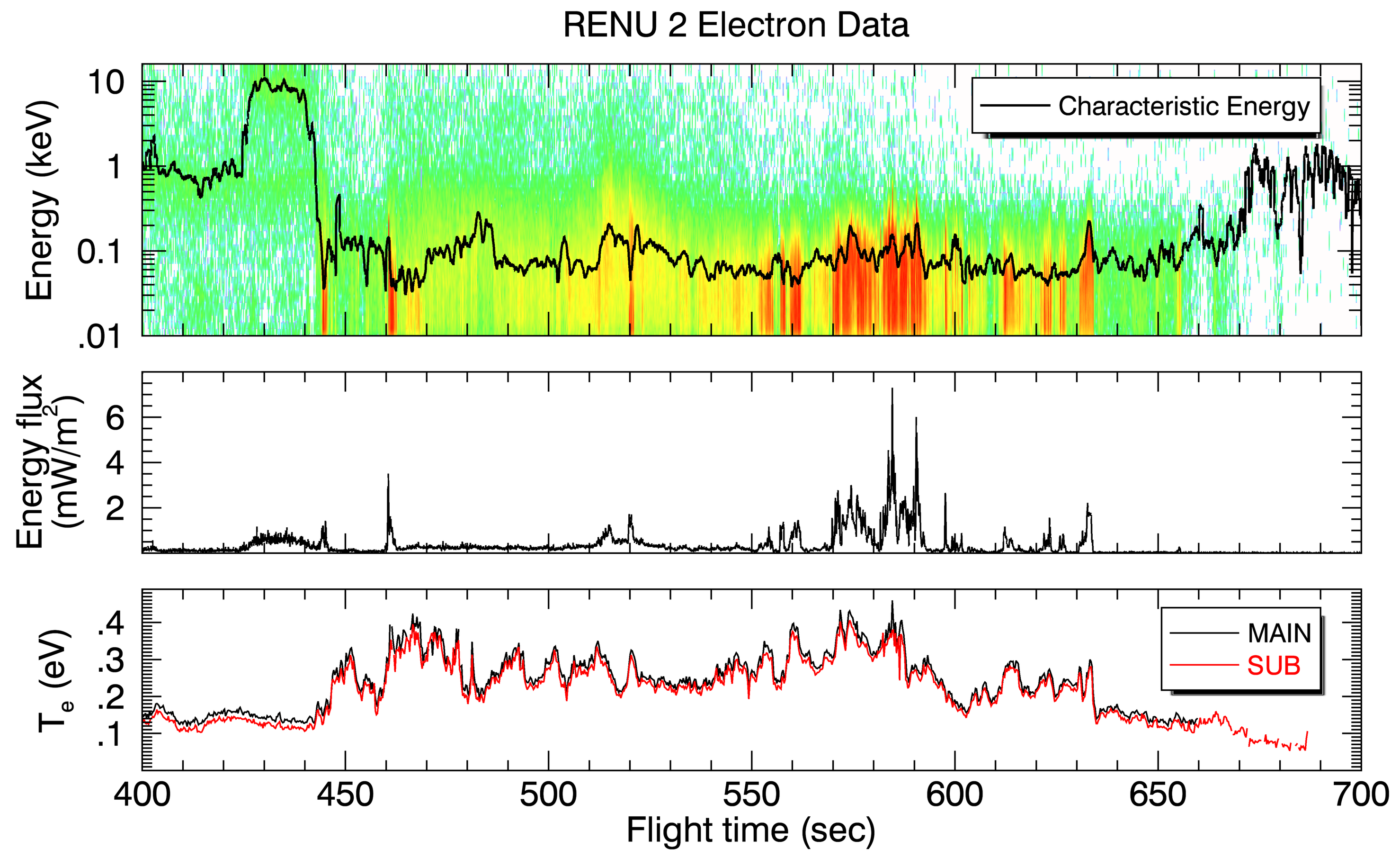


Top: GRACE and MSIS showing density in the cusp region 30 minutes pre-launch, second panel shows GRACE data scaled to 380 km along with scaled MSIS model. Red dashed lines indicate latitudes for RENU2. **Below:** Summed ASI data shows where the location of most intense PMAFs were, bottom plot depicts trajectories of respective satellites and RENU2

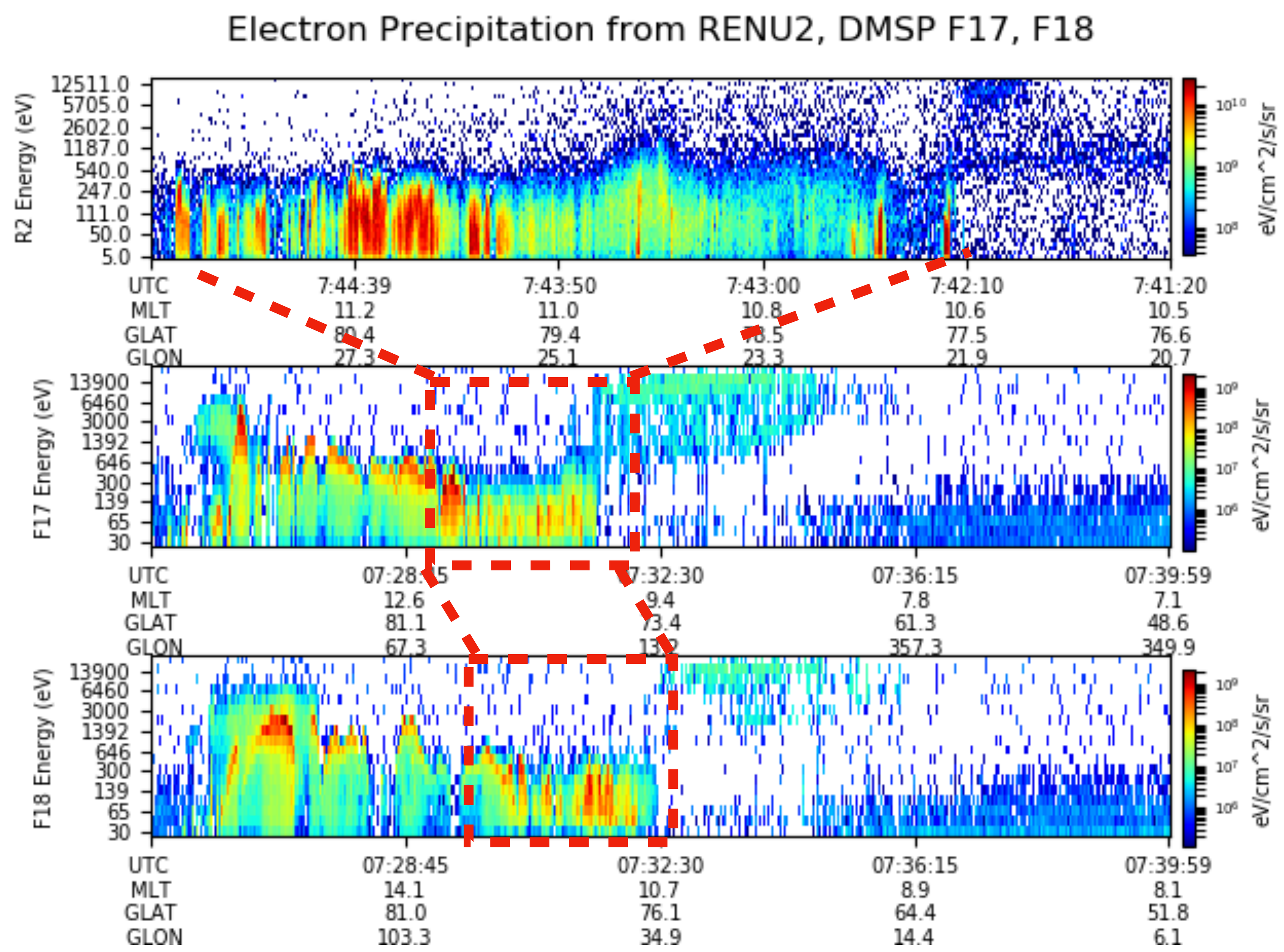




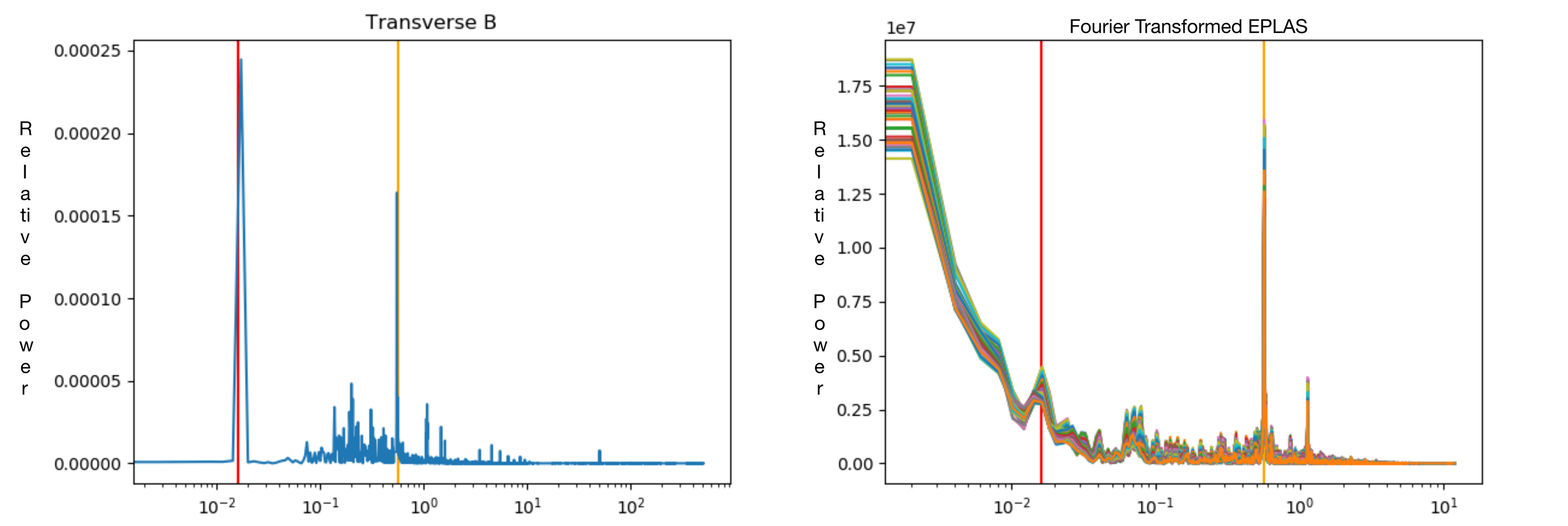
Observations - In Situ



Above: Electron spectra are shown from before entering the PMAF until exit taken by the Electron Plasma (EPLAS) instrument. EPLAS has a 360 degree view with 10 deg resolution. It collects data in 42 energy steps from 5 - 14700 eV, one energy step ever 1 ms. One full spectrum is collected every 42 ms. Middle plot depicts the integrated energy flux collected of just the precipitating electrons (pitch angles from +/-20 degrees) and the bottom plot shows the ionospheric response — the electron temperature recorded by the Electron Retarding Potential Analyzer (ERPA) instrument. Of note is the fine scale structuring within the PMAF, with some of the enhancements in precipitation on the order of 10s - 100s of meters.

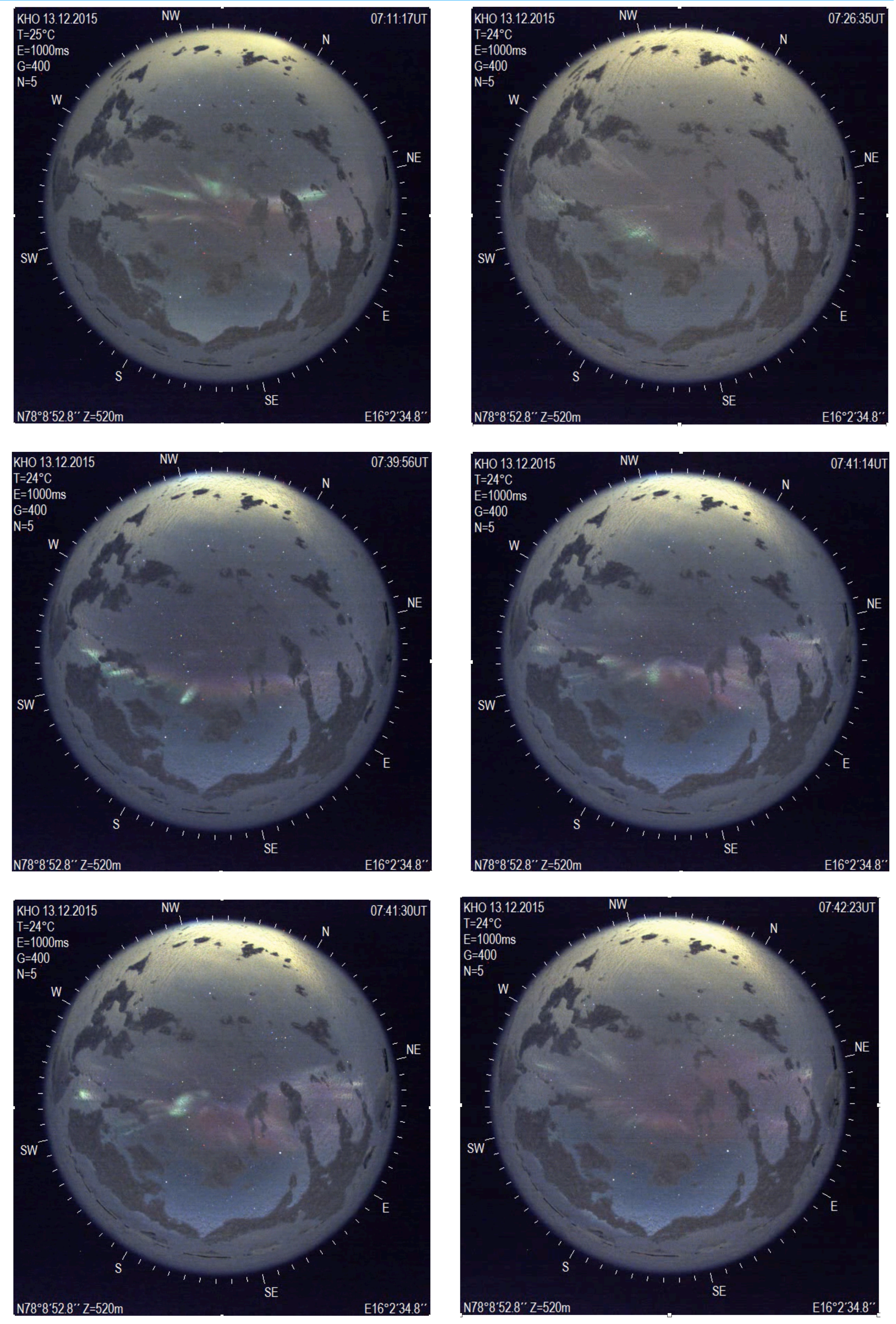


Above: Electron precipitation data from RENU2 (top) and two DMSP satellites (as labeled) are shown for comparison. F17 and F18 passed through the region ~10 minutes prior to RENU2. Due to it's lower speed, RENU2 is able to collect much finer detail (for note: spectra for RENU2 is reversed for better latitudinal comparison). Of interest, RENU2 sees particle fluxes roughly an order of magnitude greater. Solar wind conditions remained steady during the ten minutes between flights, and ASI data helps enable comparisons between the measurements.



Above: A Fourier transform of each energy channel from EPLAS shows electrons arriving preferentially at a rate of .016hz. The transverse in situ B component is likewise transformed and shows a large peak in wavepower at .016hz, suggesting the possibility of wave-particle interactions. More work needs to be done, including looking for the same B component on ground based flux gate magnetometers across Svalbard. Note: Red vert line denotes .016hz, orange vert line is payload spin.

Observations - Ground



Above: Six selected ASI frames show typical structures within a PMAF, with the last 4 showing the evolution of one PMAF. Previously, these enhancements were called 'bursty' suggesting a time-like variance [Pfaff, *et al* 1998]. Though a 1-to-1 comparison with structures observed by EPLAS is difficult, comparison of the two demonstrates the fine spatial structure within the PMAF, with temporal variations on longer scales.

Conclusions

Three Main Takeaways from this work:

1. Poleward Moving Auroral Forms exhibit fine scale spatial structuring, however, their appearance in data of having a 'bursty' behaviour is an effect of measurements being made as the spacecraft travels through an event.
2. PMAFs are an excellent example of cross-scale coupling. A single PMAF may traverse several hundred kilometers with fine scale structure within the PMAF depositing energy on the order of several mW/m^2 over only 10s - 100s of meters in local extent.
3. The suggestion of wave - particle interactions within a PMAF, and the variance of electron flux within PMAFs during reasonably steady conditions leads one to infer that incident Poynting Flux on the ionosphere could play a stronger role than previously considered in the cusp. Work needs to be done to investigate Poynting flux at different heights in the ionosphere (400km difference between RENU2 and DMSP satellites in the area)

References

1. **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.**
2. **R. Pfaff, J. Clemmons, C. Carlson, R. Ergun, J. McFadden, F. Mozer, M. Temerin, D. Klumpar, W. Peterson, E. Shelley, E. Moebius, L. Kistler, R. Strangeway, R. Elphic, C. Cattell (1998), Initial FAST observations of acceleration processes in the cusp, *Geophys. Res. Lett.*, 25, doi: 10.1029/98GL00936**