Tomographic Reconstruction of the Cusp Using RENU 2 and DMSP Measurements

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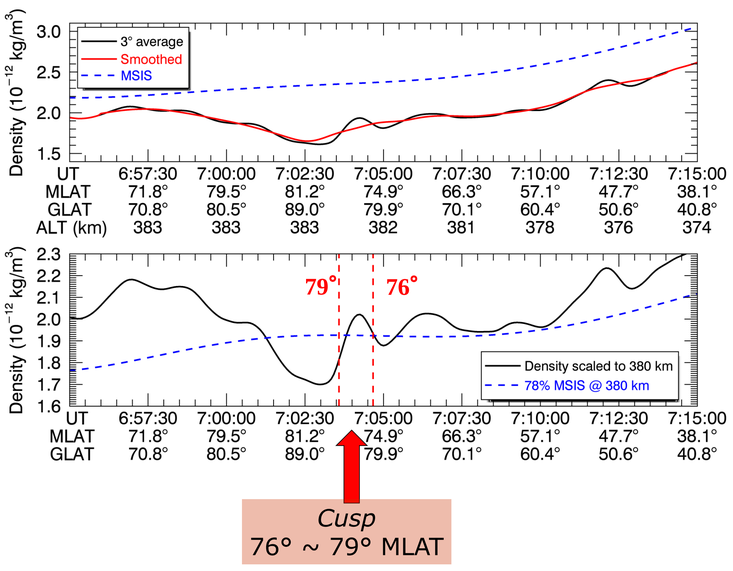
Abstract

The ***Rocket Experiment for Neutral Upwelling (RENU) 2*** sounding rocket mission launched from the Andøya Space Center on 13 December 2015 into the dayside cusp region. An Ultraviolet Photometer Tube (UV PMT) measured signatures of atomic oxygen above the payload in a region of soft electron precipitation. The instrument detected a clear enhancement in signal as the payload descended through the cusp, a potential indicator of an enhanced neutral population. Tomographic reconstruction of data from the Special Sensor Ultraviolet Limb Imager (SSULI) on DMSP F19 has provided two-dimensional structure of thermospheric O I 135.6 nm emissions in the region of the RENU 2 trajectory. SSULI data were inverted using Volume Emission Rate Tomography (VERT), a technique based on image space reconstruction algorithms. The SSULI inversions provide context for the RENU 2 measurements of the cusp, and will ultimately be used to calculate neutral density.

1. Neutral Upwelling

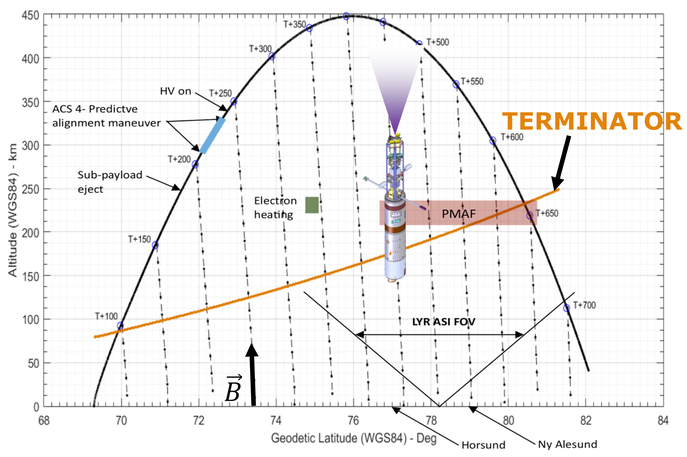
Atmospheric density measured by GRACE on 13 Dec 2015



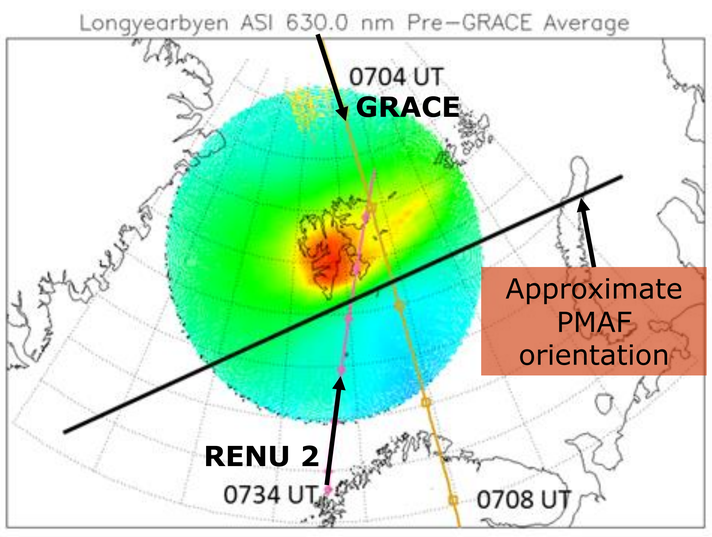
GRACE measured a ~10% density increase at cusp latitudes, half the 20% threshold used in statistical studies (e.g. Huang et al. [2017]).

2. RENU 2 Mission Details

The payload descended into the cusp through a poleward moving auroral form (PMAF), and spent ~200 s in the precipitation region

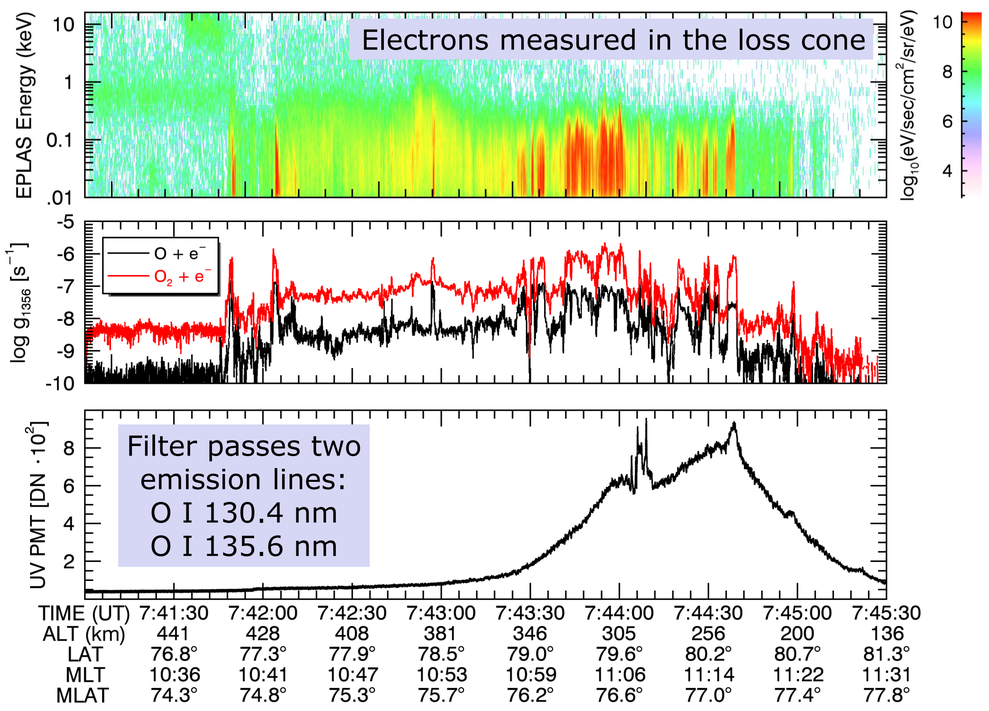


Images from UiO ASI system are acquired every 30 sec and averaged to show typical PMAF location



GRACE missed the peak of the precipitation (heating). Neutral winds may also reduce the cusp enhancement.

3. RENU 2 Results



Electron collisions are the main source of O I (λ = 135.6 nm) production. The RENU 2 EPLAS instrument measured electron flux, $\varphi(E)$. Excited state oxygen atoms, O^*, emit photons from several reactions, including:

$$O + e^- \rightarrow O^*(^5S) \rightarrow O(^3P) + h\nu$$
$$O_2 + e^- \rightarrow O + O^*(^5S) \rightarrow O(^3P) + h\nu$$

An excitation rate called the g-factor, g_O, is calculated using collision cross-sections, $\sigma_O(E)$:

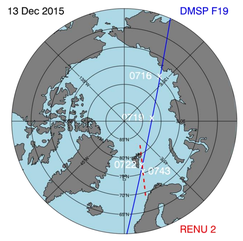
$$g_O(z,\theta) = \int_0^\infty \sigma_O(E)\,\varphi(E,z,\theta)\,dE$$

Photons emitted at the excitation rate are detected by the UV PMT

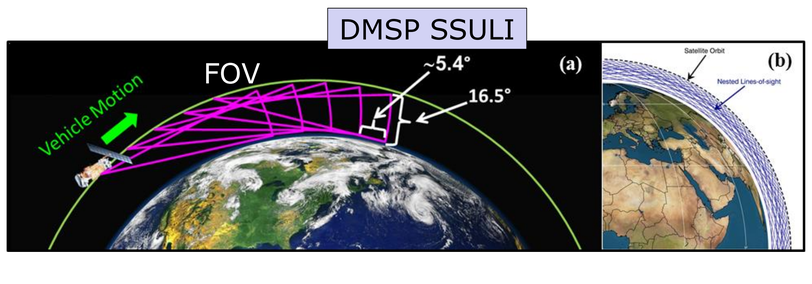
Key RENU 2 Observations

- ✓ Soft precipitation extends across ~3° in magnetic latitude
- ✓ UV PMT begins to measure signal below 350 km altitude
  - ➢ Broad structure likely due to 130.4 nm
  - ➢ Peaked structure likely due to 135.6 nm
  - ➢ Sharp drop-off implies structure in latitude
- ✓ Magnetic latitude of PMT signal lines up with GRACE measurement

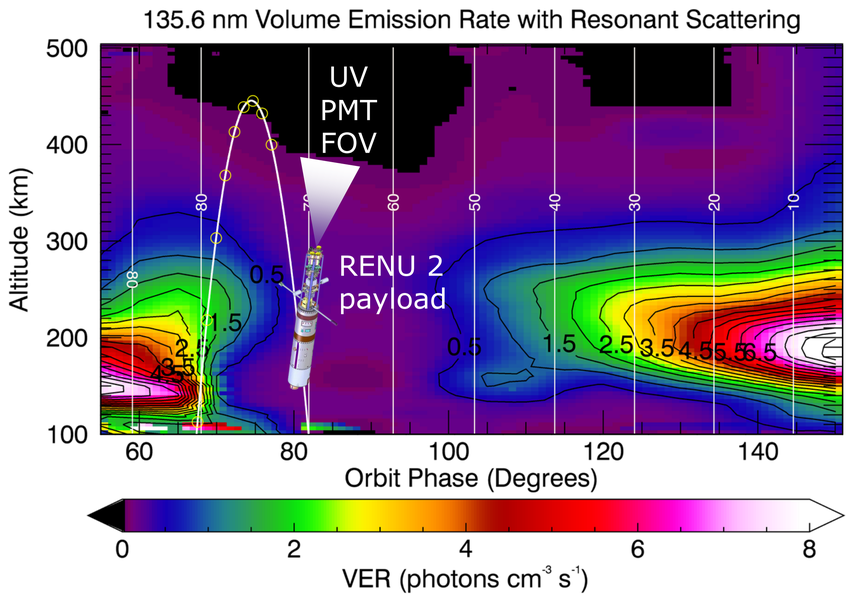
Further context for the RENU 2 UV PMT measurement comes from the DMSP F19 spacecraft



4. DMSP Tomographic Reconstruction



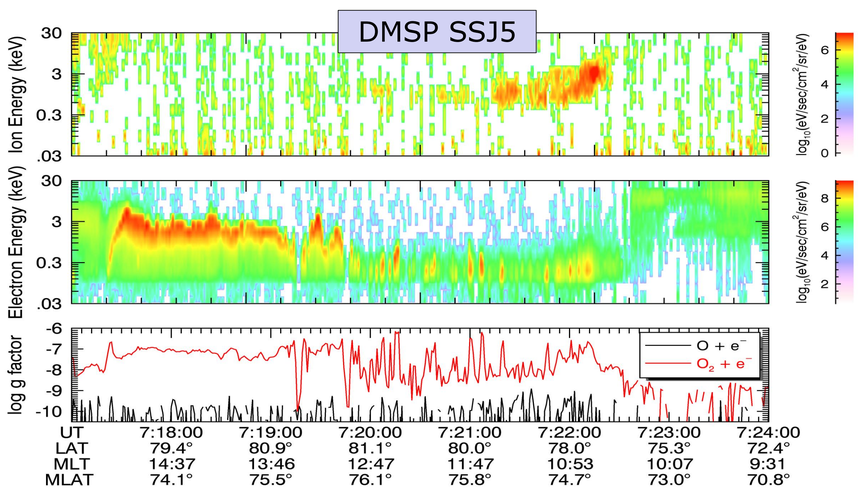
SSULI is a UV spectrograph on DMSP, oriented to view the limb along the orbital track every 92 sec
- 80 - 170 nm spectral range
- 100 - 750 km altitude
- 10 - 15 km vertical resolution



SSULI intensity measurements (I_{1356}) are used to reconstruct volume emission rates (ε_0) through an inversion process.

$$I_{1356} = \frac{10^{-6}}{4\pi}\int_0^\infty \varepsilon(z,\theta)\,ds(z,\theta)$$

The VERT technique is a fast, non-negative iteration based on Least-Squares Positive Definite (LSPD) algorithm [Dymond, 2017].



DMSP SSJ5 ion measurements of stepped precipitation provide confidence that F19 passed through the cusp.

Soft electron precipitation is low relative to RENU 2 measurements due to transit between PMAFs

Number density, n_O, will be calculated based on ε_0 and g_O

$$\varepsilon_0(z,\theta) = g_O(z,\theta)\,n_O(z,\theta)$$

5. Conclusions

- ✓ RENU 2 successfully launched into cusp aurora on 13 December, 2015
- ✓ UV PMT observed O I emissions in a region of soft precipitation
- ✓ Ambiguity due to RENU 2 changes in altitude/latitude partially resolved via DMSP F19
- ✓ SSULI tomography provides first two-dimensional view of cusp emission structure

In progress

- ❑ Electron transport (e.g. GLOW) to propagate SSJ5 precipitation data
- ❑ Radiation transport to account for multiple scattering of photons
- ❑ Inclusion of I_{1304} to replicate UV PMT signal

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