The RENU3 Sounding Rocket and UV Neutral Upwelling Observations

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Abstract

The RENU3 sounding rocket that launched from Andøya Space on November 23rd, 2025, to study neutral upwelling in conjunction with cusp aurora. It launched at 09:52 UT towards Svalbard and reached an apogee of 466 km during an auroral event. The payload hosted a suite of plasma and neutral particle instruments that included the UV-PMT, which measures neutral atomic oxygen emissions of 130.4 nm and 135.6 nm. This brightness is used as a proxy for density. The instrument observed a significant increase in brightness (i.e. neutral atomic oxygen density) as the payload flew over the auroral region, indicating a neutral upwelling event. This work compares the neutral upwelling event with other ground and space measurements to gain a clear understanding of the upwelling process.

UV-PMT

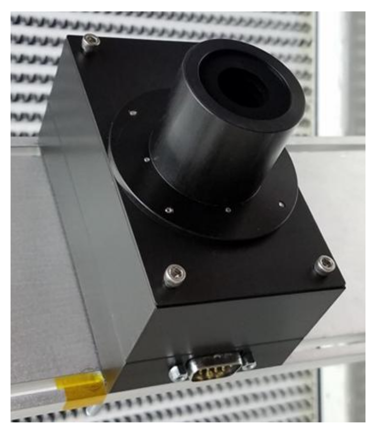

Figure 1. Image of the UV-PMT instrument

- UV-PMT measures brightness of the emission lines 130.4 nm and 135.6 nm
- These are the emission lines of neutral atomic oxygen in the atmosphere
- Measured brightness of emissions relates to the density of neutral atomic oxygen
- During flight, the UV-PMT is pointed along magnetic field lines

RENU3 Sounding Rocket and Auroral Event

- Launched at 09:52 UT on November 23rd, 2025 into and above an auroral event (field line resonance)
- Goal of studying neutral upwelling in relation to auroral events
- Instruments on board include: UV-PMT, Langmuir probe, TIGTOF, ERPA, Fluxgate magnetometer, 8 ion gauges, Winds in track and cross track, thermal winds imager, EPLAS, and IPLAS
- Collaborated with the EISCAT and all sky cameras
- Aurora color indicates that soft electron precipitation

Figure 3. RENU3 launching from Andøya Space

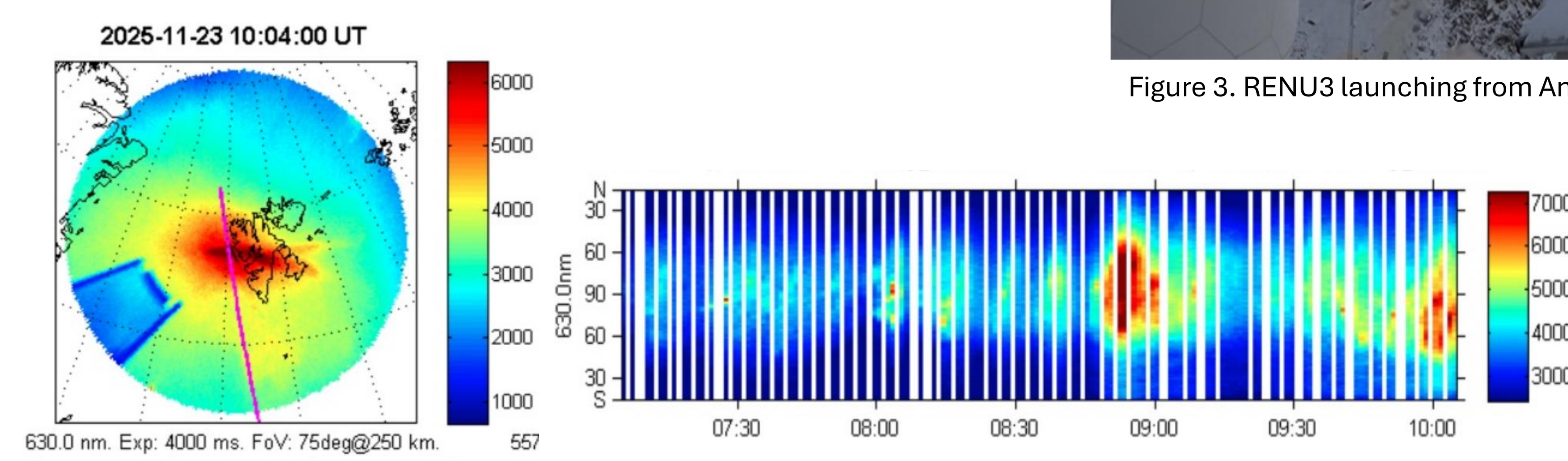

Figure 2. 630.0 nm all sky camera data during launch. Left image includes the rocket trajectory in pink.

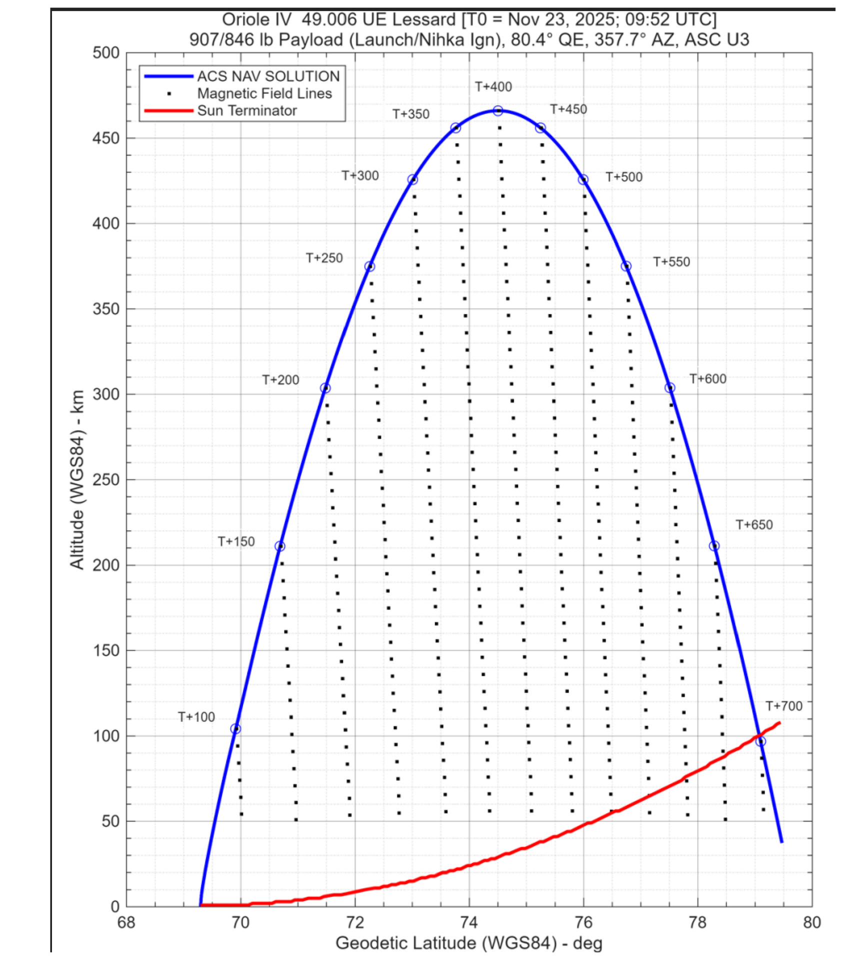

Figure 4. RENU3 trajectory throughout the flight (blue) and the terminator (red). The rocket was largely in daylight.

UV-PMT Observations

- Periodic saturation during flight that indicated sunlight reflected into instrument, filtered out by determining the problem roll angles to produce figure 5
- UV-PMT saw a change of brightness of ~500 Rayleighs while above aurora (~ t+600 s)
- Significant change from the background emissions in the first half of the flight
- First step of the analysis is to calculate the oxygen density for the first half of the flight

- Calculating oxygen density using the GLOW model:
  - Rayleighs measured are paired with the altitude of the rocket at each point
  - Then, calculated change of brightness at each step to convert to volume emission rate (VER) (left figure 8)
  - GLOW model altitude profiles of VER and oxygen density are combined into a relationship of oxygen density and VER (figure 7)
  - VER and density relationship is used with the measured VER to produce an approximate measured oxygen density altitude profile

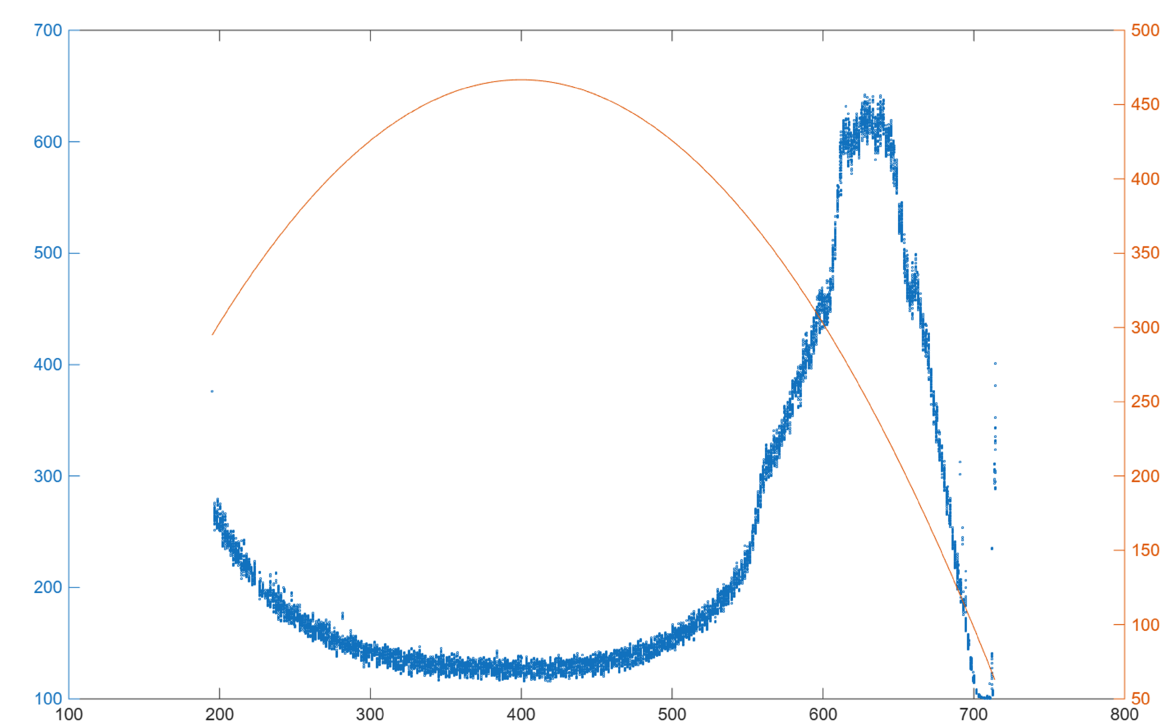

Figure 5. UV-PMT data through the flight duration in Rayleighs (blue) along side the altitude of the rocket at that same time (orange).

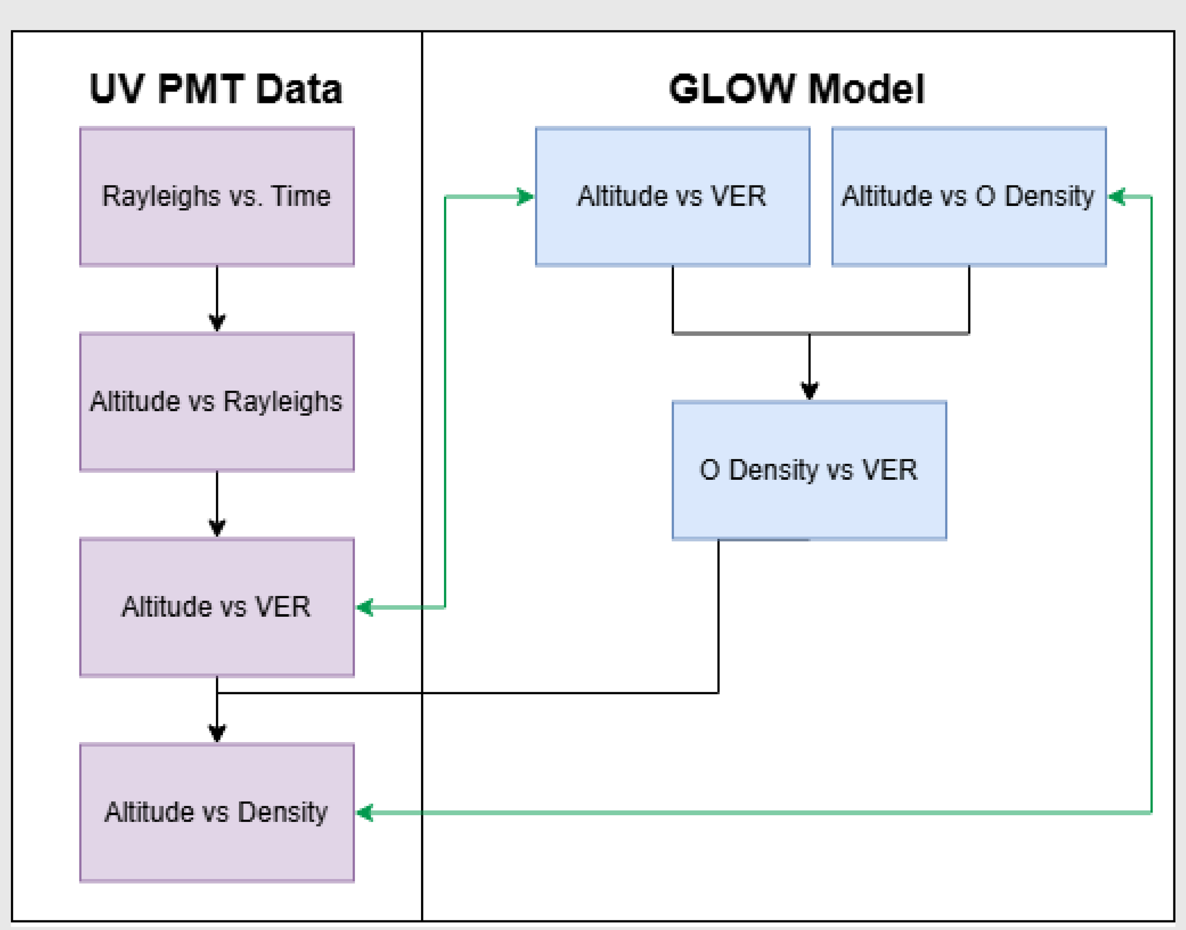

Figure 6. Flow chart of the analysis of the UV-PMT data for the first half of the flight. Uses the GLOW model to approximate neutral atomic oxygen density. Green lines indicate points of comparison

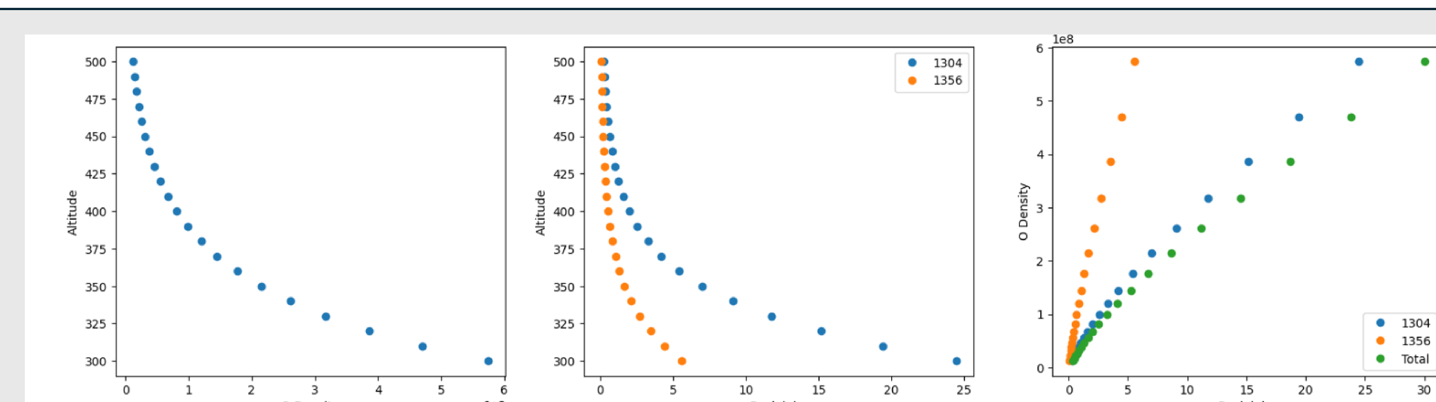

Figure 7. GLOW model outputs of altitude vs. neutral atomic oxygen density (left), altitude vs. volume emission rate (middle), and combining volume emission rate and oxygen density (right) . The middle and right plots show emissions of 130.4 nm, 135.6 nm, and the total is the combined two emissions.

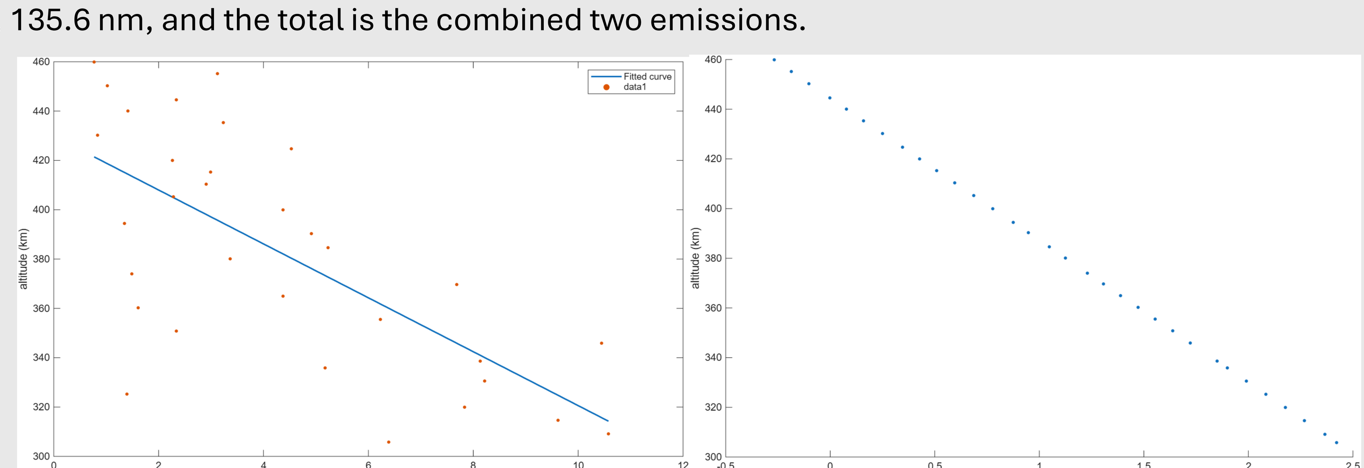

Figure 8. Comparing the measured volume emission rate during flight (left), and the resulting altitude vs. neutral atomic oxygen density (right) that results from combining the GLOW fit from figure 7 with the measured volume emission rate.

Optical Density

- Calculated optical density using GLOW output of oxygen density
- Used cross-section values of $9.331 * 10^{-14}$ cm^2 and $2.499 * 10^{-18}$ cm^2 for 130.4 nm and 135.6 nm respectively (Meier 1991)
- 135.6 nm is optically thin
- 130.4 nm is optically thick at lower altitudes but significantly drops off at 300 km +

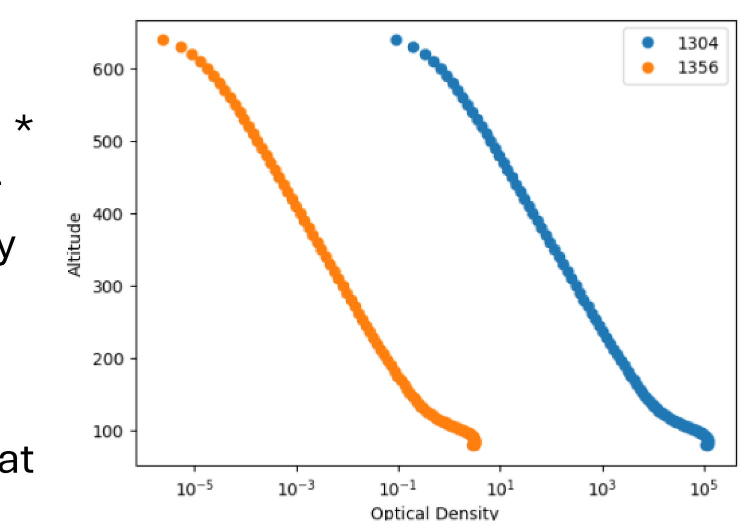

Figure 9. Optical density for 130.4 nm and 135.6 nm calculated at multiple altitudes calculated using the GLOW output of oxygen density

Conclusions

1. RENU3 observed a significant neutral upwelling event
2. Change of brightness of ~500 Rayleighs while above aurora
3. Approximated background neutral oxygen density using the GLOW model

Future Analysis
- Use optical density calculations from GLOW to better approximate measured brightness during flight
- Inversion to extract density from the event side of data
- Compare the impacts of Joule heating and soft electron precipitation as methods of upwelling (thermal or electromagnetic)

Acknowledgements

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Citations

K. F. Dymond, S. E. Thonnard, R. P. McCoy and R. J. Thomas, "An optical remote sensing technique for determining nighttime F region electron density," in *Radio Science*, vol. 32, no. 5, pp. 1985-1996, Sept.-Oct. 1997, doi: 10.1029/97RS01887.

R. R. Meier. Ultraviolet spectroscopy and remote sensing of the upper atmosphere. Space Science Reviews, 58(1):1–185, 1991. ISSN 1572-9672. doi: 10.1007/BF01206000.

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