Neutral Thermospheric Density Retrievals with ICON EUV Spectrometer

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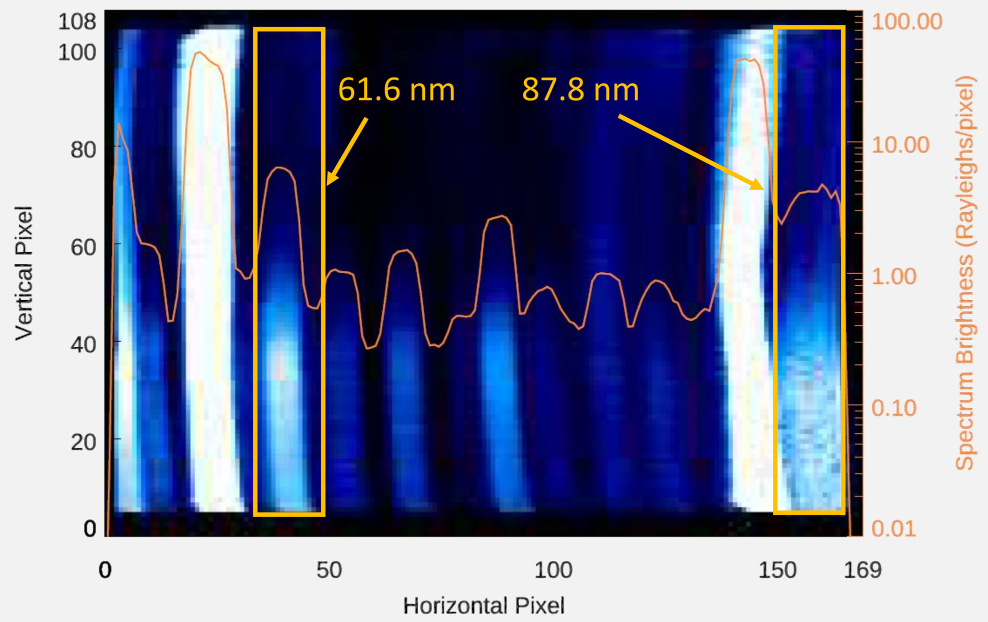
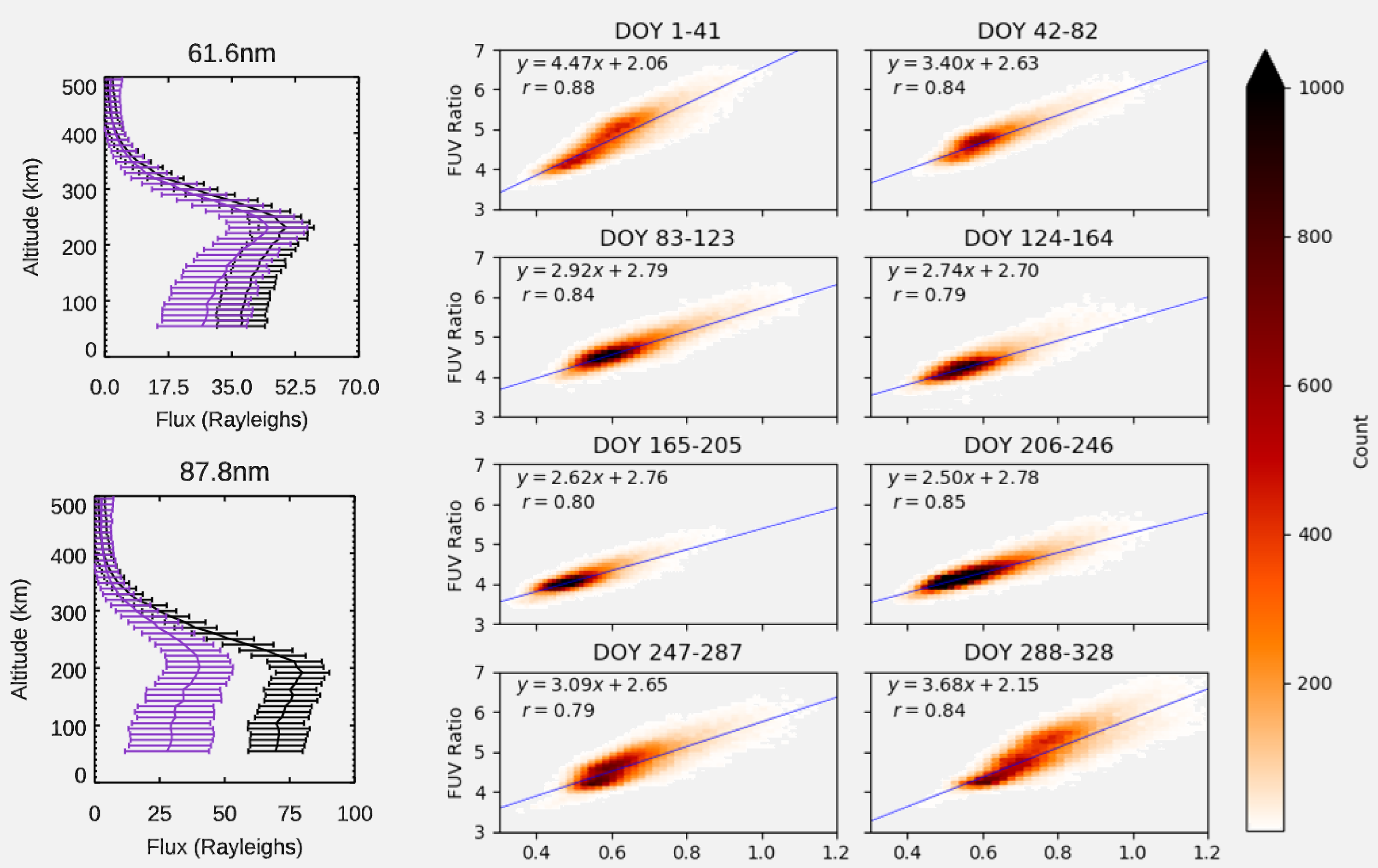
Introduction

The NASA ICON extreme- UV (EUV) instrument is a 1D imaging spectrometer (one spatial, one spectral dimension) which measures limb airglow in the 54-88 nm range.



The instrument measures the F-region ionosphere using O⁺ airglow at 83.4 nm and 61.6 nm. Both are produced by solar photoionization of O, but the former scatters off O⁺ while the latter is optically thin. In addition to these two features, the EUV instrument measures airglow profiles at 10 other wavelengths, including a band near 87.8 nm. (Sirk et al. 2017).

ICON also carries a far-UV (FUV) instrument, which measures column O/N_2 on the disk via the brightness ratio of O 135.6 nm and N_2 LBH band dayglow. (Stephan et al. 2017). By comparing the FUV 135.6/LBH ratio to the EUV sub-limb brightness ratio of 61.6/87.8, my previous work showed that the 87.8 nm feature has a N_2 parent and that the EUV measurements contain information about the neutral thermosphere. (Tuminello et al. *under review*)



Motivation and Research Question

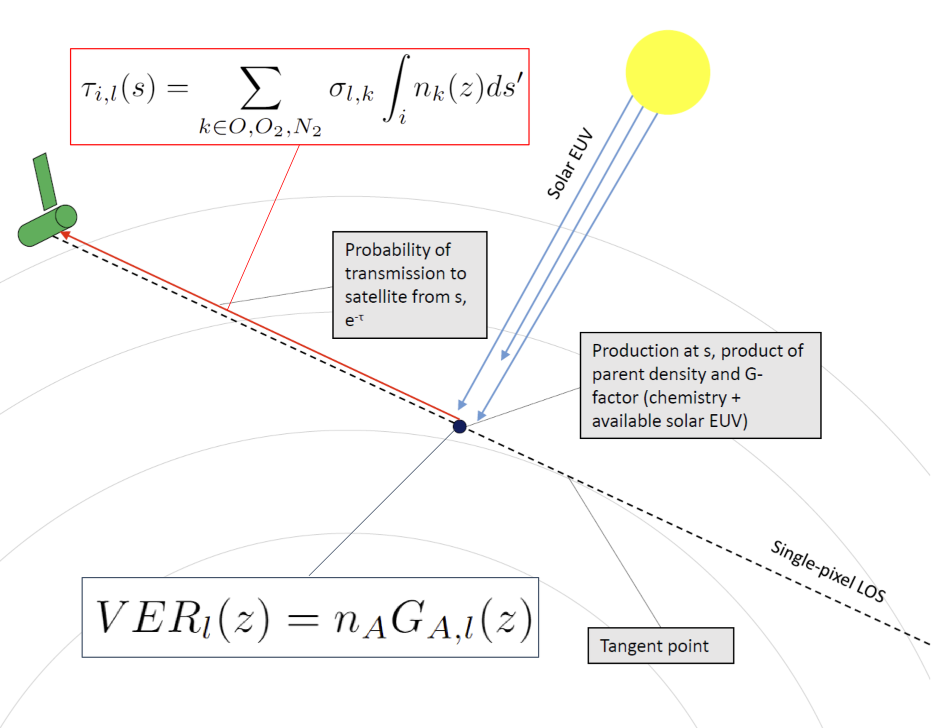
- FUV measurements typically used for thermosphere retrievals have some disadvantages: conjugate photoelectrons, auroral electrons, and ionospheric contamination.
- Can ICON EUV airglow profiles be inverted into thermospheric density profiles?

References

Sirk et al. 2017: doi:10.1007/s11214-017-0384-2
Stephan et al. 2017: doi: 10.1007/s11214-018-0477-6
Tuminello et al. (*under review*): doi: 10.1002/essoar.10511230.2
Meier 2021: doi: 10.1029/2020JA029059

Methodology

The EUV Forward Model



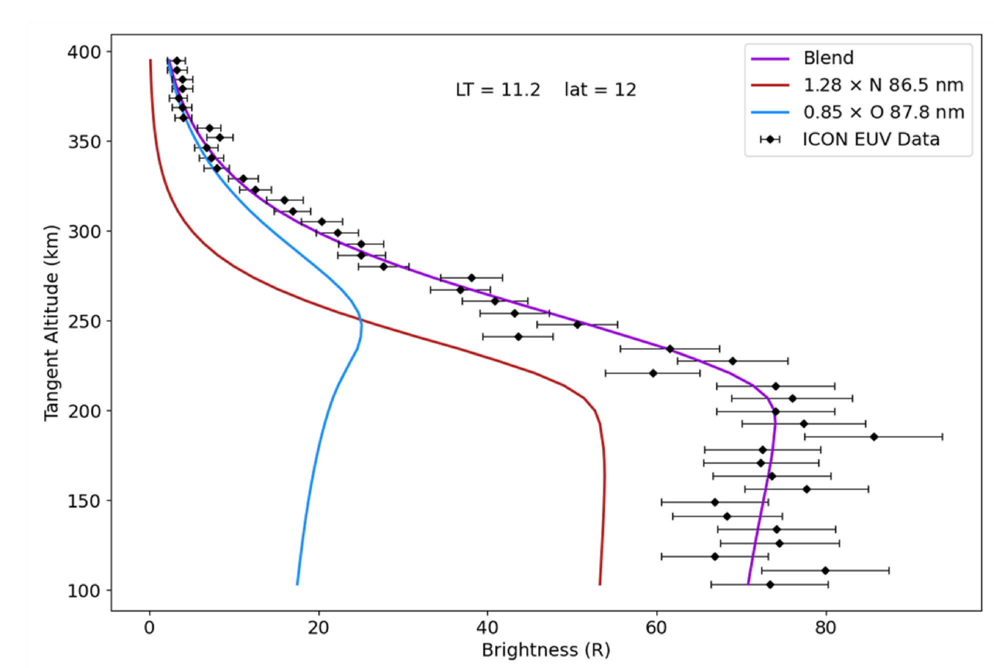
We model the EUV emissions under production by solar and photoelectron excitation and transport with pure absorption by neutral O, O_2, and N_2. We scale condition-dependent G-factors for 83.4 nm and 108.5 nm to model production. We use cross-sections from Conway (NRL) to calculate absorption.

Integration along the line of sight yields the brightness of a single pixel.

$$I_{i,l} = \int_i VER(z)\, e^{-\tau(s)} ds$$

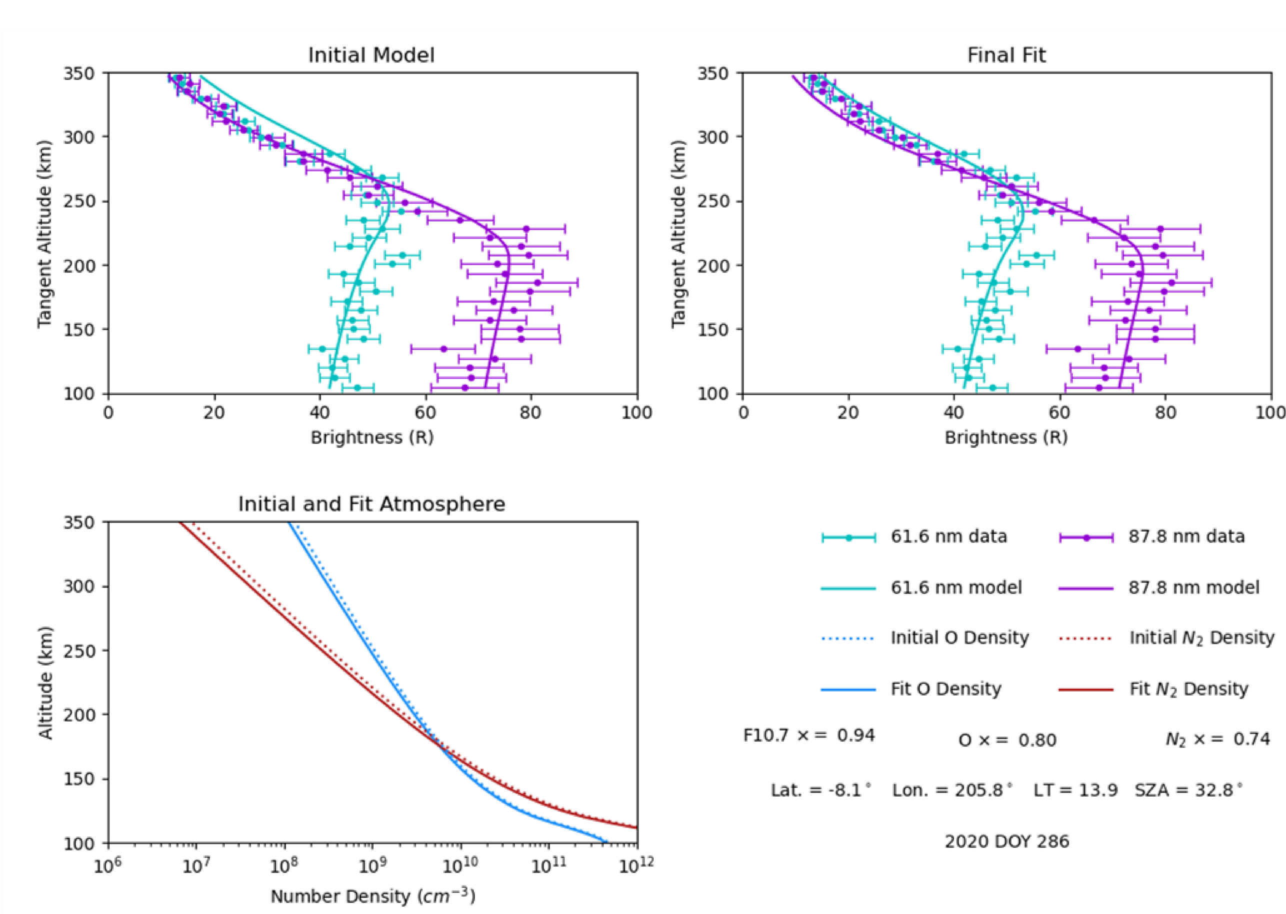
The Identity of the 87.8 nm Feature

The 87.8 nm emission is best modeled as a blend of O and N features. We determine the scaling of the respective G-factors by fitting forward model to the EUV data using a constantly scaled MSIS00 atmosphere. We find that the fits vary with local time, so we incorporate this as a lookup table.

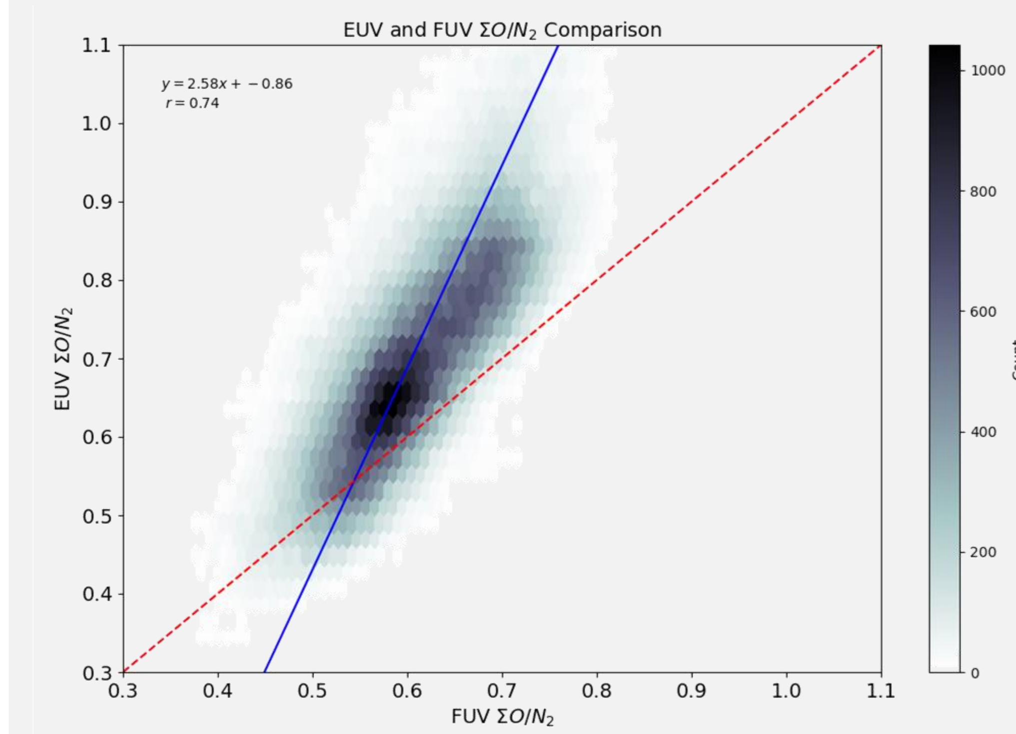


The Retrieval Algorithm

To retrieve atmospheric densities, we start with a scaled MSIS00 atmosphere and use the Discrete Inverse Theory algorithm to iteratively adjust the MSIS F10.7 input and O and N_2 scalars to produce a realistic atmosphere where the forward model best fits the data.

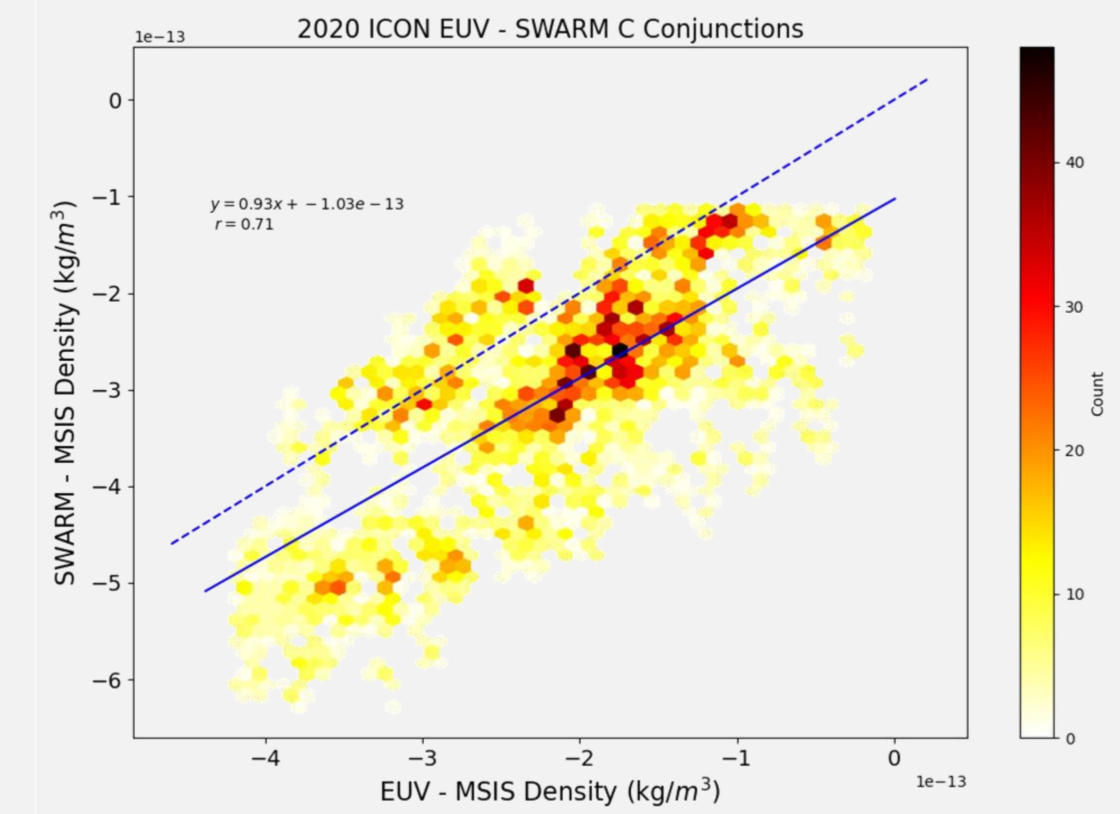


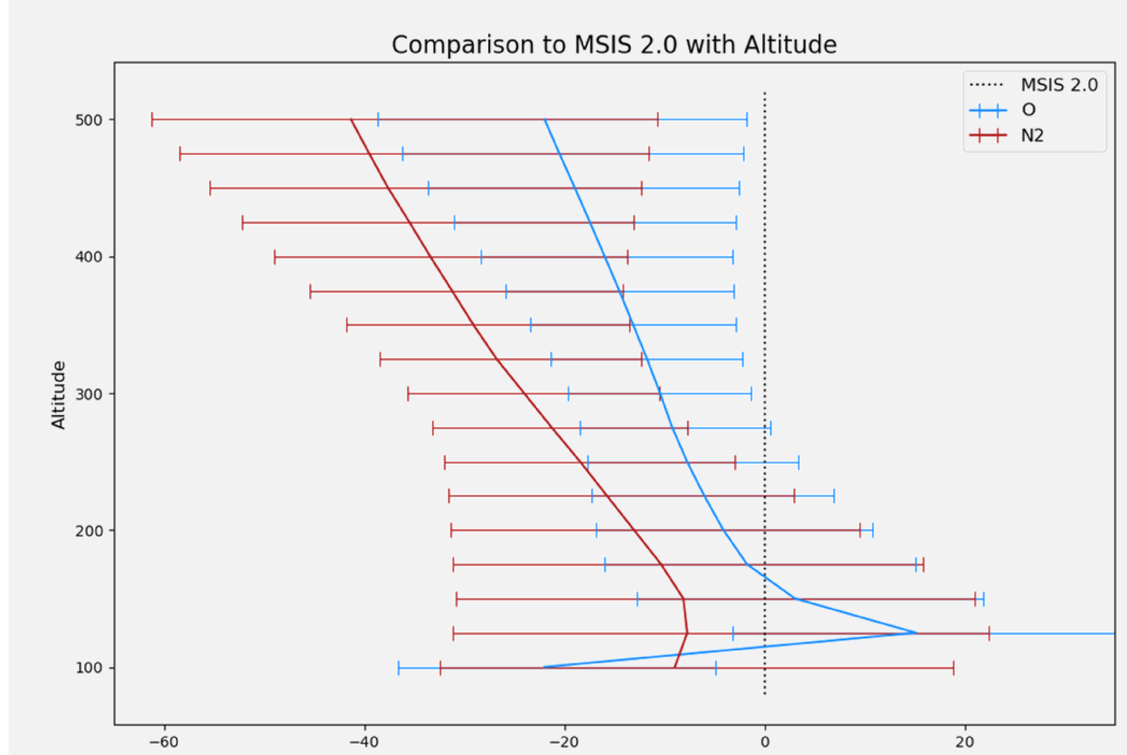
Results and Validation



By integrating the density profiles downward until the N_2 column density reaches 10^{17} cm^{-2}, we obtain the column O/N_2 ratio (Meier 2021), which is measured by the ICON FUV instrument. This figure shows the correlation between FUV disk O/N_2 and the retrieved EUV O/N_2. The EUV instrument tends to retrieve higher values of O/N_2. We have improved this by making an adjustment to the 61.6 nm profiles. (Not shown, ask me about it!)

ESA's SWARM-C satellite measures mass density at around 450 km altitude. This figure shows the correlation between the SWARM and EUV residuals from scaled MSIS00. The dashed line indicates unity, while the solid line is a linear fit. The correlation indicates that the EUV retrieval is successful in measuring variation from MSIS.





Early comparisons to MSIS 2.0 suggest that retrieved O and N_2 densities are systematically low (this is consistent with high O/N_2). The increased discrepancy with altitude indicates that we have a smaller retrieved scale height.

Conclusion

- Can we measure density profiles with the EUV? **Yes, but** many systematic sources of uncertainty stand in the way of a reliable retrieval.
- The results show that the retrieval is seeing variations which are measured by other instruments, but the EUV measurement shows a bias against both the SWARM and FUV measurements.
- Sources of systematic uncertainty include absorption cross-sections, G-factor scaling, and that the low spectral resolution prevents us from identifying the exact N line that we're seeing. The combination of higher resolution cross-section measurements and limb spectra would help to address this.

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