Investigating Large-Scale Gravity Waves in ICON Far Ultraviolet Data

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Introduction

- NASA's Ionospheric Connection Explorer (ICON) Explorer has collected thermosphere data in the 90–300 km altitude range.
- Using data from the Far Ultraviolet Imaging Spectrograph (FUV) onboard, it has been observed that there are large-scale structures within the data (smaller than the long-term tidal variations, but too large to be attributed to noise).
- Previously, large-scale variations have been observed using thermospheric wind data from the Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI) instrument, and were proposed to be inertia gravity waves.
- While observations of gravity waves are relatively common in the MLT (mesosphere/lower thermosphere), observations in the middle thermosphere are lacking. FUV observations, with the exception of Bossert et al [2022] and rare campaigns by GOLD [England et al., 2020], are an understudied method for characterizing gravity waves in this region.

Data and Methods

- The FUV instrument measures the altitude profile of OI and N2 in the upper atmosphere (one emission line from O at 135.6 nm, the shortwave profile, and one emission band from N2 at around 157 nm- which is the longwave profile)
- The instrument also simultaneously measures 6 profiles (6 "stripes") of FUV emission, separated by 3 degrees horizontally at a 12 s cadence. (Figure 1)

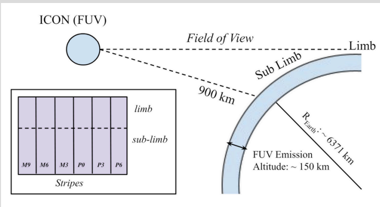

Fig 1: Showcases the observing geometry of ICON's FUV instrument, as well as the 'stripes' for each observation.

- The data was processed by splitting it into individual orbits, and then taking a rolling mean of 17 samples, which is ~3.5 minute (~1500 km) window.

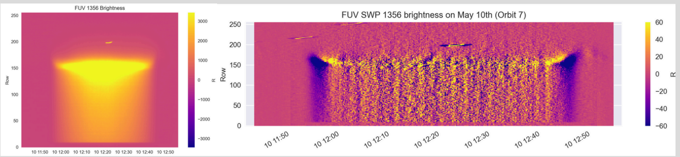

Fig 2 : The plot on the left is the raw data for the selected orbit of FUV data, and the right is after subtracting the rolling mean. This illustrates periodic vertical banding structures in the sub-limb (the lower disk operations).

- There are clear periodic structures seen in the sub-limb data, but it is unclear whether these are gravity wave signatures or artifacts from data processing (Figure 2)
- If these are real physical structures, as the instrument measures emission from the different stripes, the structure should appear in consecutive stripes with a time delay.
- In order to determine whether this is the case, a lagged cross-correlation is run between the different stripes of data for each orbit.
  - Interpolation is used in order to upsample the original data.
  - This analysis is run for every single combination of stripes (15 combinations), and the determined offsets are plotted against the angle difference.

Lagged Cross Correlation

- Only the data below Row 125 was selected to get the sub-limb behavior. (Figure 3)

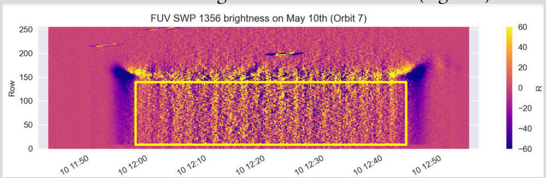

Fig 3: This illustrates the region of focus for the FUV emission of Stripe P0. The rows below 125 are selected for all subsequent analysis to ensure that only the sub-limb behavior is being studied, and other features such as stars and the start and ends of the orbit are cut out.

- All of the rows were averaged to get the signals for each of the stripes (Figure 4)
- Upon correlating, observed an asymmetry with a time offset from 0 between the two stripes. (Figure 5)

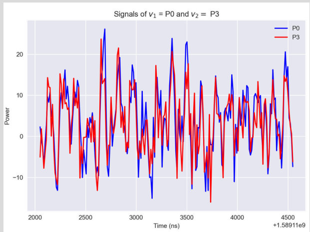

Fig 4: This showcases the row-averaged signals of Stripe P0 and Stripe P3 (+3 degree offset). The cross correlation is run on this data.

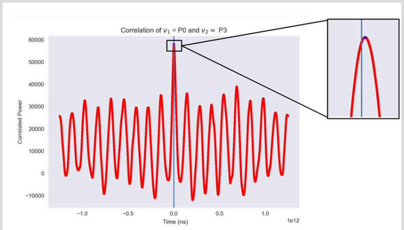

Fig 5: Results of the crosscorrelation between Stripes P0 and P3 for the selected orbit- there is asymmetry, and upon zooming in, a small offset from zero in the peak.

- By calculating the actual distance to FUV emission to be 900 km-2200 km using the ancillary file, if the structure is physical, it should take 7s - 16s for this structure to appear between consecutive stripes.
  - The slope of a line of best fit through the scatterplot is not 0 though, so the occurrence is happening almost (though not exactly) simultaneously in all of the stripes. (Figure 7)
  - The reason for this behavior is still being investigated.

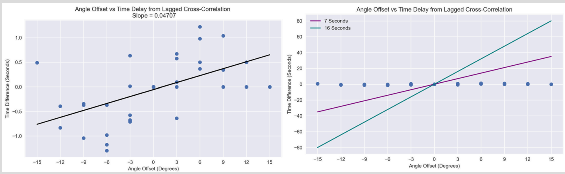

Fig 7: The plot on the left of this figure showcases the relationships between the angle offsets and the determined time difference from the lagged cross correlation. It is clear that the slope is not 0, but as depicted on the rightwards plot, it is not within the range of 7s-16s either.

Statistical Analysis

- The slope of the lines for the angle offsets does not seem to be exactly zero in many cases, but in order to understand the ongoings, it is essential to see whether these slopes are consistent and significant.
- A preliminary analysis was conducted where this process was repeated on ~35 days of data (15 orbits each) (Figure 8).

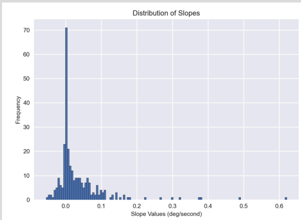

Fig 8: Histogram showcasing the distribution of slopes from the angle offset vs time delay plots (arbitrary days selected from Jan 1st to Jun 1st, 2020). We see that a large portion of the slopes are nonzero.

Comparative Study: Long Wave Profiles

- As aforementioned, the FUV instrument also measures a Long Wave profile at the N2 emission line.
- As observed in prior studies Greer et al. [2018] & Bossert et al [2022], if a gravity wave is present, the OI and N2 emissions should be anticorrelated.
- With some additional rolling mean smoothing applied to both the SWP and LWP data, we can see that there still seems to be a periodic structure present (Figure 9)

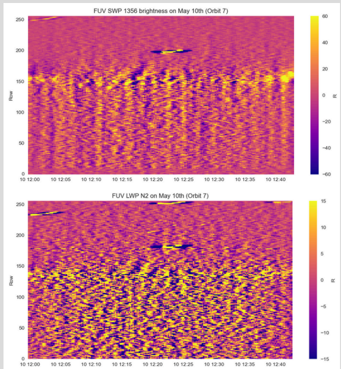

Fig 9: Plots showcasing both the OI and N2 emissions for the same orbit. Though fainter and noisier, there seems to still be an underlying structure in the LWP data.

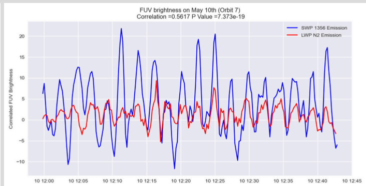

Fig 10: Finding the correlation between the LWP and SWP for the selected orbit results in a positive, significant correlation.

- Selecting the sub-limb region and running a correlation analysis between the LWP and SWP in this case shows a positive, significant correlation.
  - This finding implies that the structures observed are likely not gravity waves.

Conclusions

- Upon processing both the longwave and the shortwave profile data, we see vertical structures that were hypothesized to be signatures of gravity waves in the sub-limb of the FUV data.
  - By looking at the cross correlation between subsequent stripes, this observed structure appears almost simultaneously in all of the stripes.
  - Running a correlation on the LWP and SWP data yields an anticorrelated relationship, though this analysis must be repeated to ensure these results are consistent throughout various daytime orbits in the year.
- Based upon this work so far, it does not seem like these signatures are gravity wave signatures in the sub-limb, and alternative ideas are being explored.

References

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