Aurorally driven nighttime CO_2 NLTE Over Alaska: October, 2021

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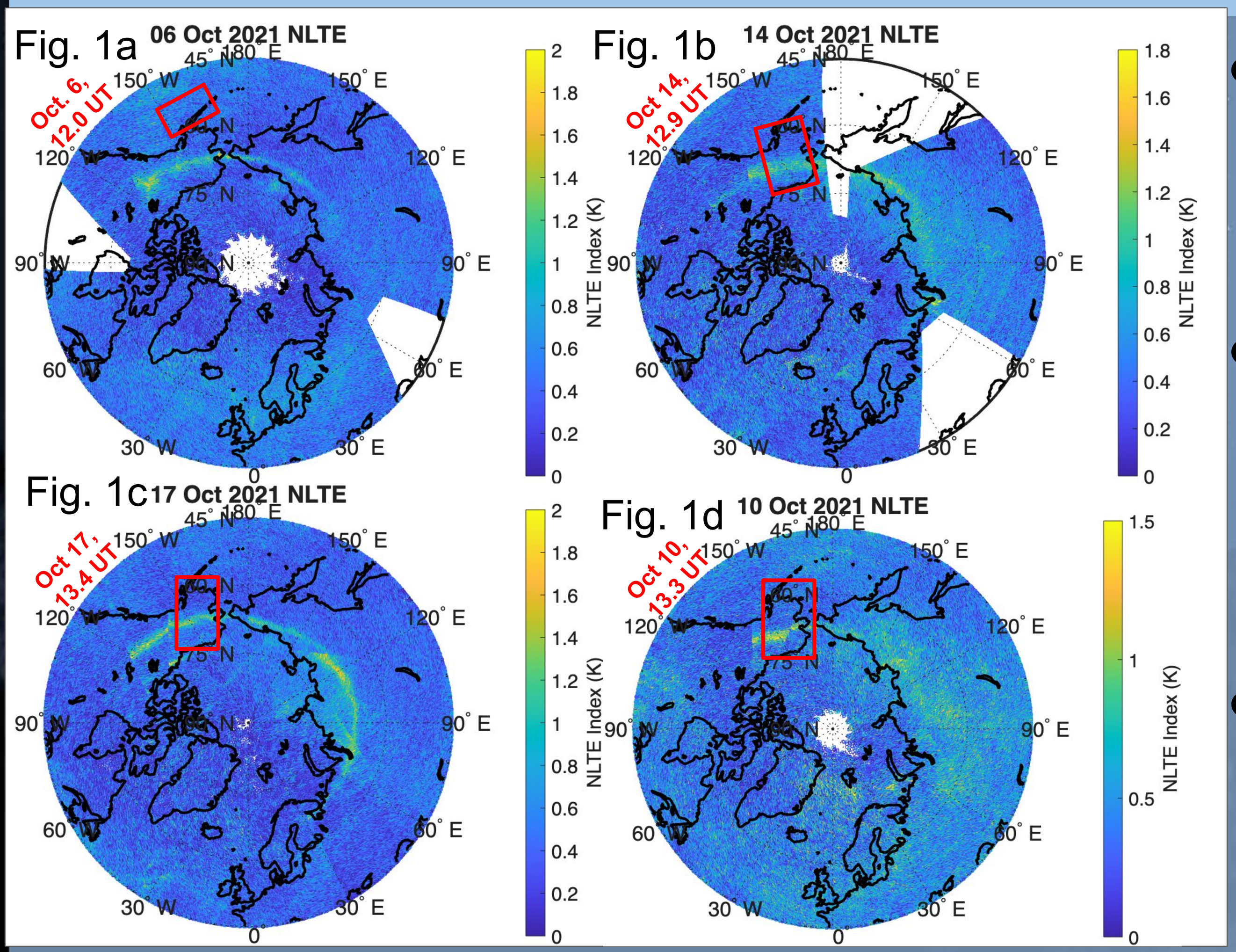
Background

- Local thermodynamic equilibrium (LTE) refers to the atmosphere under normal conditions, while non-local thermodynamic equilibrium (NLTE) occurs during abnormal conditions like geomagnetic storms.
- We hypothesize that aurora is a primary driver of nighttime CO_2 NLTE enhancements.
- The NLTE index addresses a knowledge gap of how excited CO_2 affects nighttime stratospheric and ionospheric chemistry and thermodynamics.
- Connections between nighttime stratospheric CO_2 excitation and ionospheric ionization provides a novel method to track solar-driven energy deposition across various atmospheric layers.
- Better understanding of these enhancements could help predict satellite drag and orbital decay more accurately during times of high solar activity.
- Better understanding of these enhancements may also lead to space weather forecasting improvements.

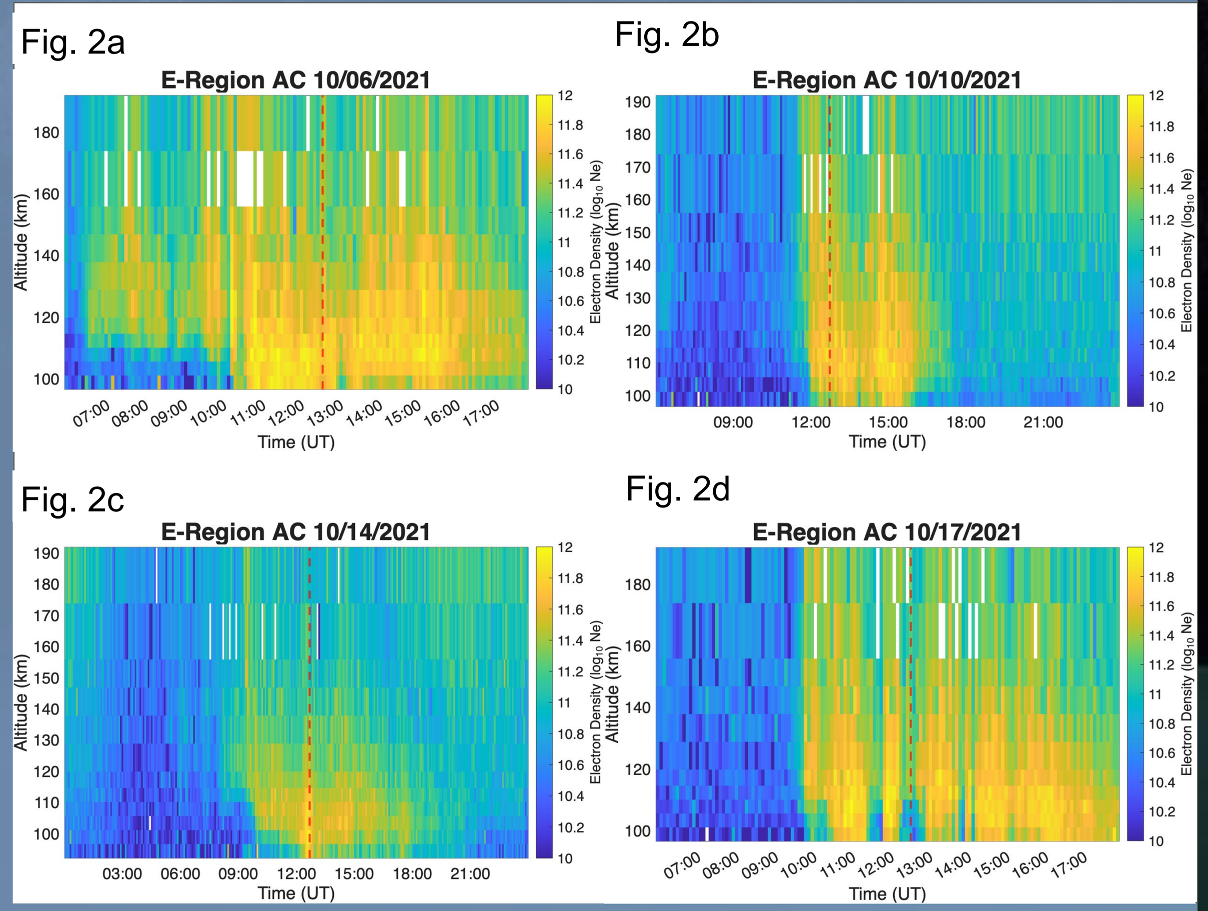
Instruments

- Atmospheric infrared sounder (AIRS) onboard NASA's Aqua Satellite provides global measurements of CO_2 infrared emissions in the stratosphere (~35 km) from above with a spatial resolution of ~13.5 km.
- Poker Flat Incoherent Scatter Radar (PFISR) measures ionospheric parameters, including electron density, from ~60 to ~500 km. This study focuses on the E-Region (90-200 km).

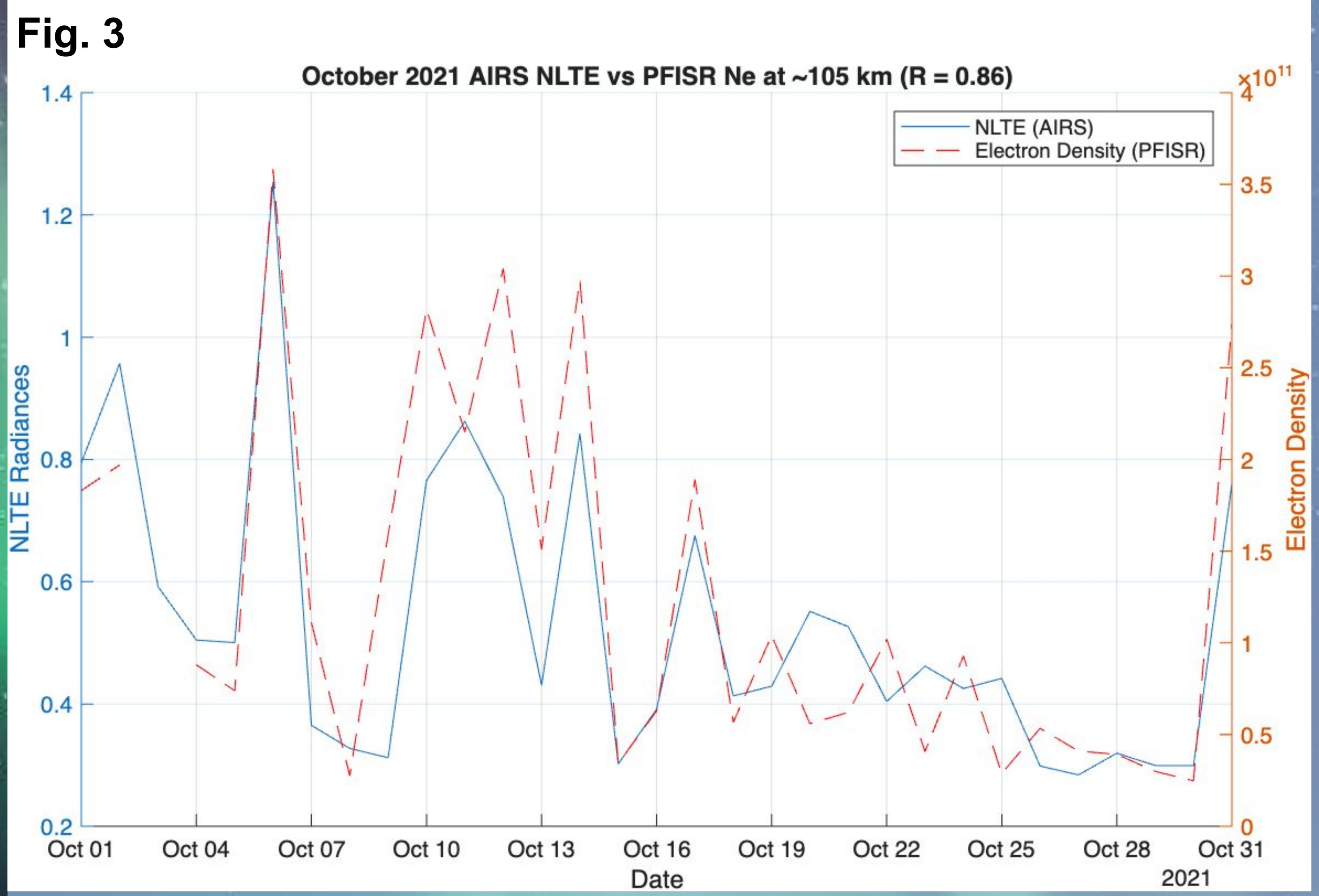
Data and Methods



- Figures 1a-1d: 4.26 µm and 15 µm radiances from AIRS to derive the NLTE index based on methodology established by Bossert et al., (2023).
- Examined nighttime conditions (Solar Zenith Angle >100◦) over the Poker Flat Research Range (64◦–66◦N, 146◦–148◦W) to calculate average NLTE radiances within the constrained area.
- Red boxes represent individual AIRS granules at the noted time & date over the constrained area.
- Figures 2a-2d: E-region electron densities ($\log_{10}$ Ne) from ~90-200 km obtained from PFISR (alternating code, 5 min fitted, zenith beam).
- Altitudes were constrained to between 90 and 200 km, and non-physical negative density values were removed.
- Targeted 105 km to calculate average electron density aligned with an average of the AIRS transit time, plus 5 min before and 5 min after.
- Dashed red lines highlight the time in which AIRS took measurements, allowing comparison.



Results



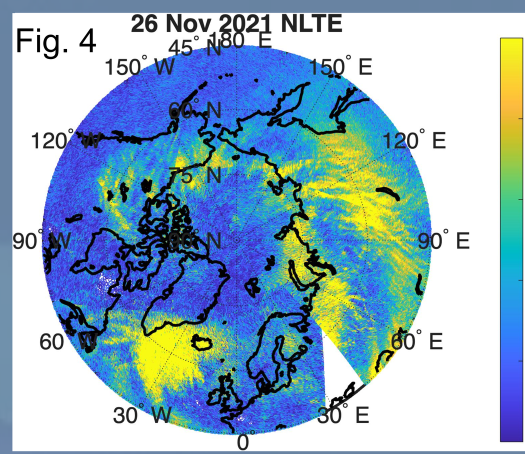
- Figure 3: Average NLTE enhancements (blue) over Poker Flat Research Range were compared to average electron densities at ~105 km (orange, dashed) during AIRS transit times.
- October 3rd was removed from the calculation due to a gap in data.
- The Pearson correlation coefficient and P-value were calculated to determine statistical significance between NLTE enhancements and electron densities at ~105 km.

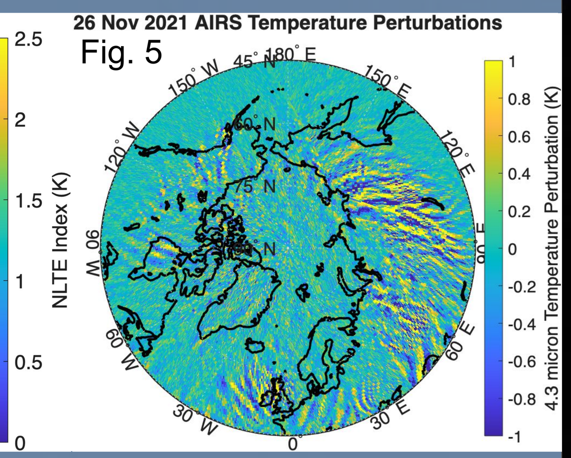
Conclusions

- We found a Pearson correlation coefficient of $R = 0.86$ at ~ 105 km for the averaged NLTE temperature enhancements and PFISR electron densities.
- We found a P-value of $1.56 * 10^{-9}$ ($P < 0.05$), which shows a link between NLTE enhancements and electron densities at ~105 km.
- These findings suggest a strong and statistically significant connection between ionospheric ionization and nighttime stratospheric CO_2 excitation.
- These findings support our hypothesis that upper atmospheric energetic particle precipitation drives lower atmospheric CO_2 excitation during the polar night.

Future Work

- Preliminary research shows a potential connection between nighttime CO_2 NLTE enhancements (Fig. 4) and polar-vortex-enhanced gravity waves (Fig. 5).
- We plan to investigate electron densities at different altitudes to compare differing energy levels of particle precipitation and their effect on NLTE.





Acknowledgements

Supported in part through the Arizona NASA Space Grant Consortium, Cooperative Agreement 80NSSC20M0041 or 80NSSC25M7084. 80NSSC20M0041 is for funding between FY20-25. 80NSSC25M7084 is for funding between FY25-29.
Additional support for this work was provided by NSF AGS 1936373.

References

1. Bossert, K., Hoffmann, L., Mlynczak, M., & Hunt, L. (2023). Observations of 4.26 µm CO2 Auroral Emissions From AIRS Nadir Sounder Measurements. *Geophysical Research Letters,* 50(11). https://doi.org/10.1029/2023gl103856