Effects of the Terminator on E and F-region Ionospheric Dynamics

ISR Summer School 2025

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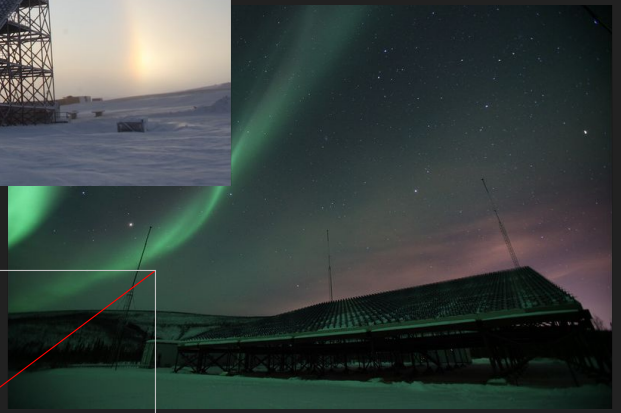
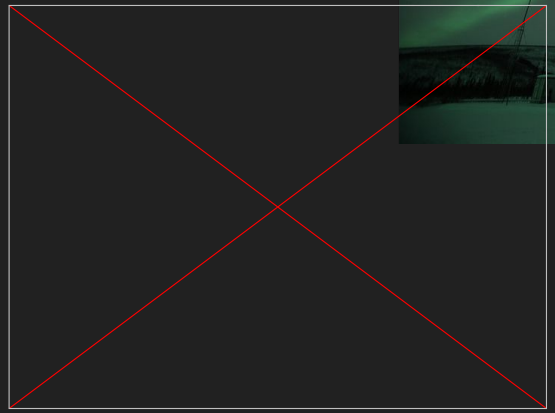




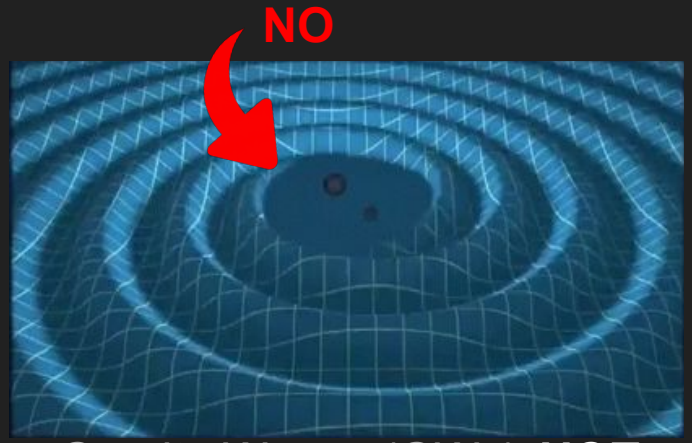
Experiment Design - Idea

Traveling Ionospheric Disturbances (TID) affect communication on Earth (e.g. HF radio, GNSS/GPS) due to the anomalies in the ionosphere. These disturbances affect the propagation of waves due to anomalies in plasma density. Additionally, these effects can cause geomagnetic induced currents which harm electrical infrastructure (i.e. power grids).

Region of Interest: E and F region

- Thinning/broadening of E, F-region allows visibility of perturbations.
- TIDs are often associated with GWs in the neutral atmosphere that propagate across regions.

★ Primary Goal: Try to observe a terminator-driven TID.
★ Secondary Goal: Analyze the background state during the transitionary period into nighttime before, during, and after sunset.



Gravity Waves (GWs) ***NOT*** Gravitational Waves

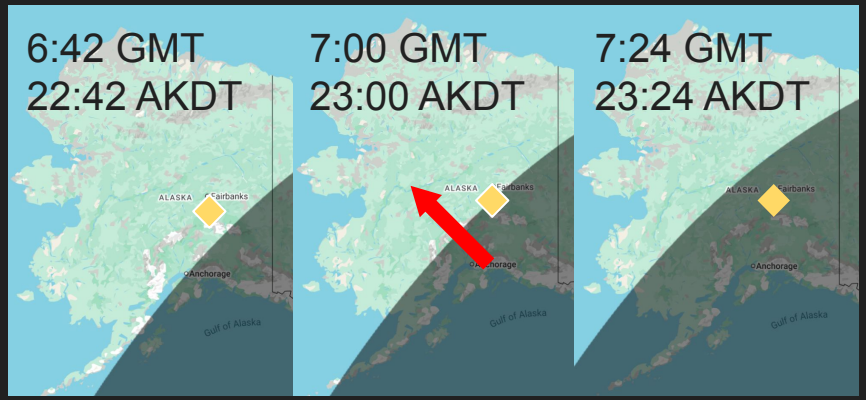
Experiment Design - Logistics

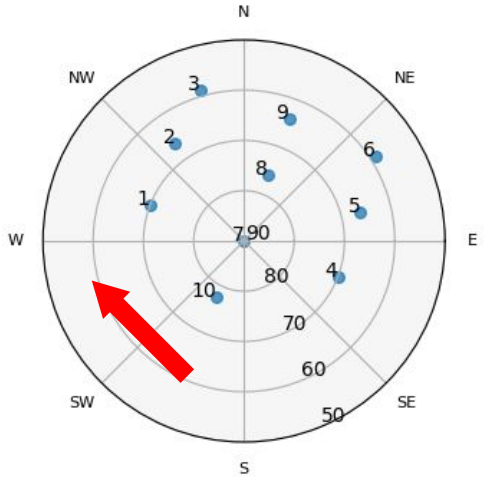
Mode: PFISR2 Long Pulse + AC (E+F region)

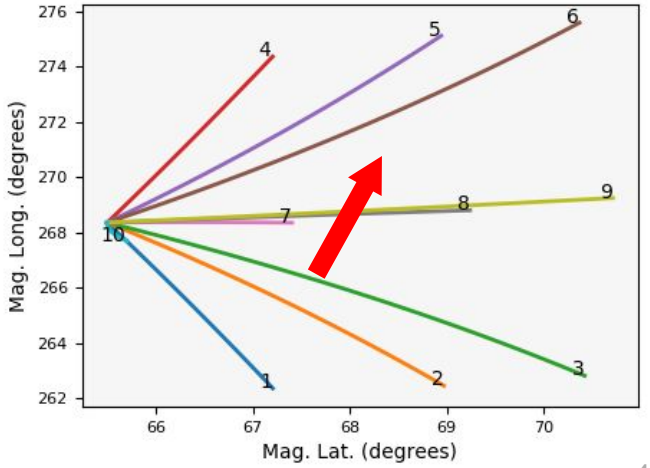
Beams: Positioned to ideally catch terminator row-by-row as it passes SE to NW.

Time: 22:00 - 00:00 AKDT, 06:00 - 08:00 UTC/GMT

*Approximate direction of terminator







Challenges

Asti: “It is highly unlikely that you will see TIDs.”

Asti, the next day: “You should look at dNe/Ne. There might be something.”

- ➔ The biggest challenge is resolving the perturbation such that we can see density anomalies.
- ➔ Secondary challenge: Expect less extreme changes due to long, high-latitude daylight throughout all 24 hours.

Relevant Papers

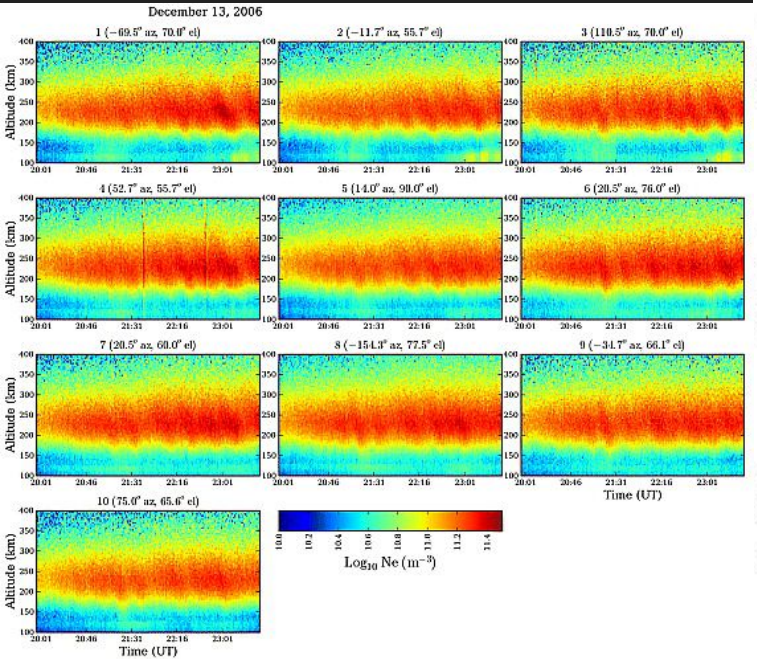
Space Sciences | Free Access

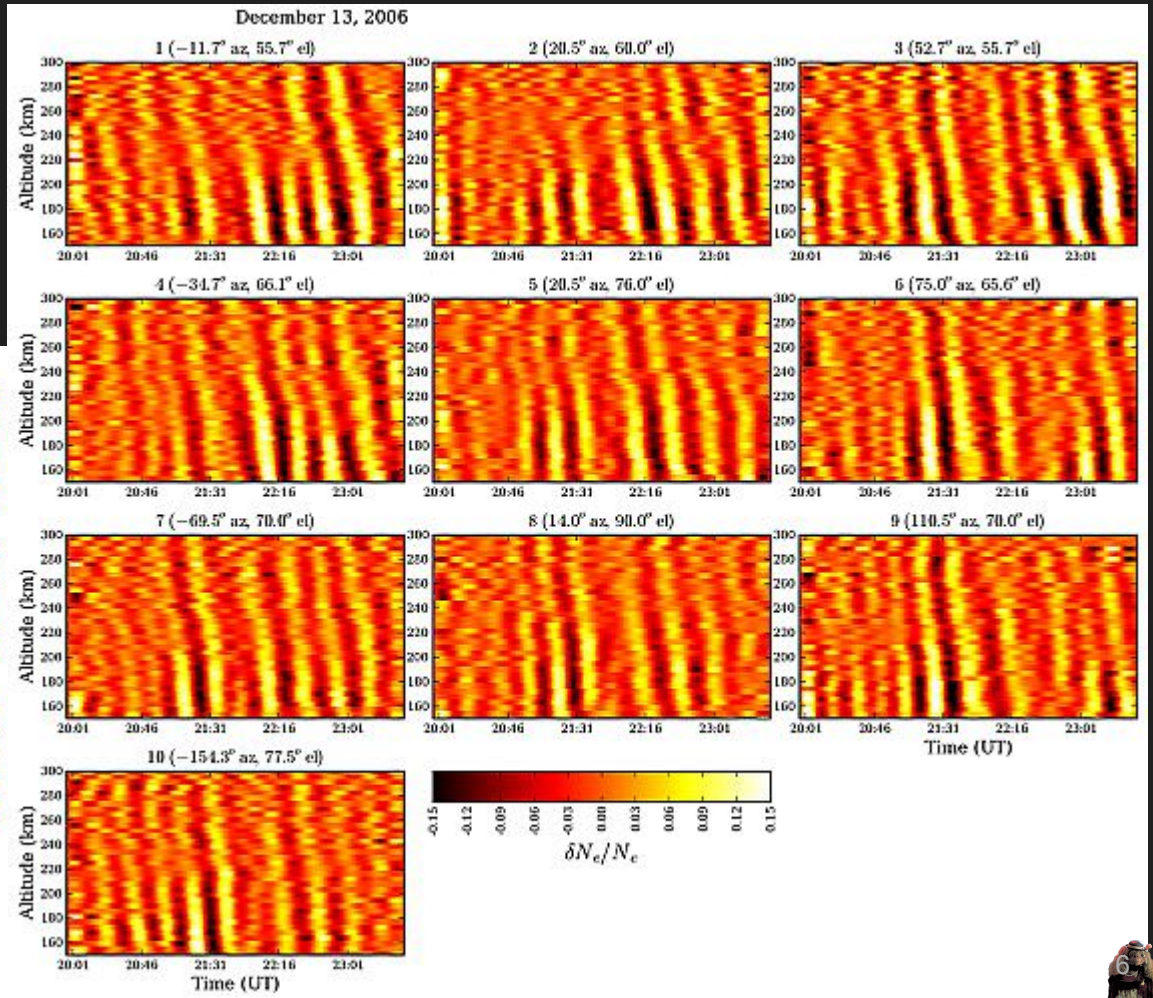
Three-dimensional measurements of traveling ionospheric disturbances with the Poker Flat Incoherent Scatter Radar

Michael J. Nicolls, Craig J. Heinselman

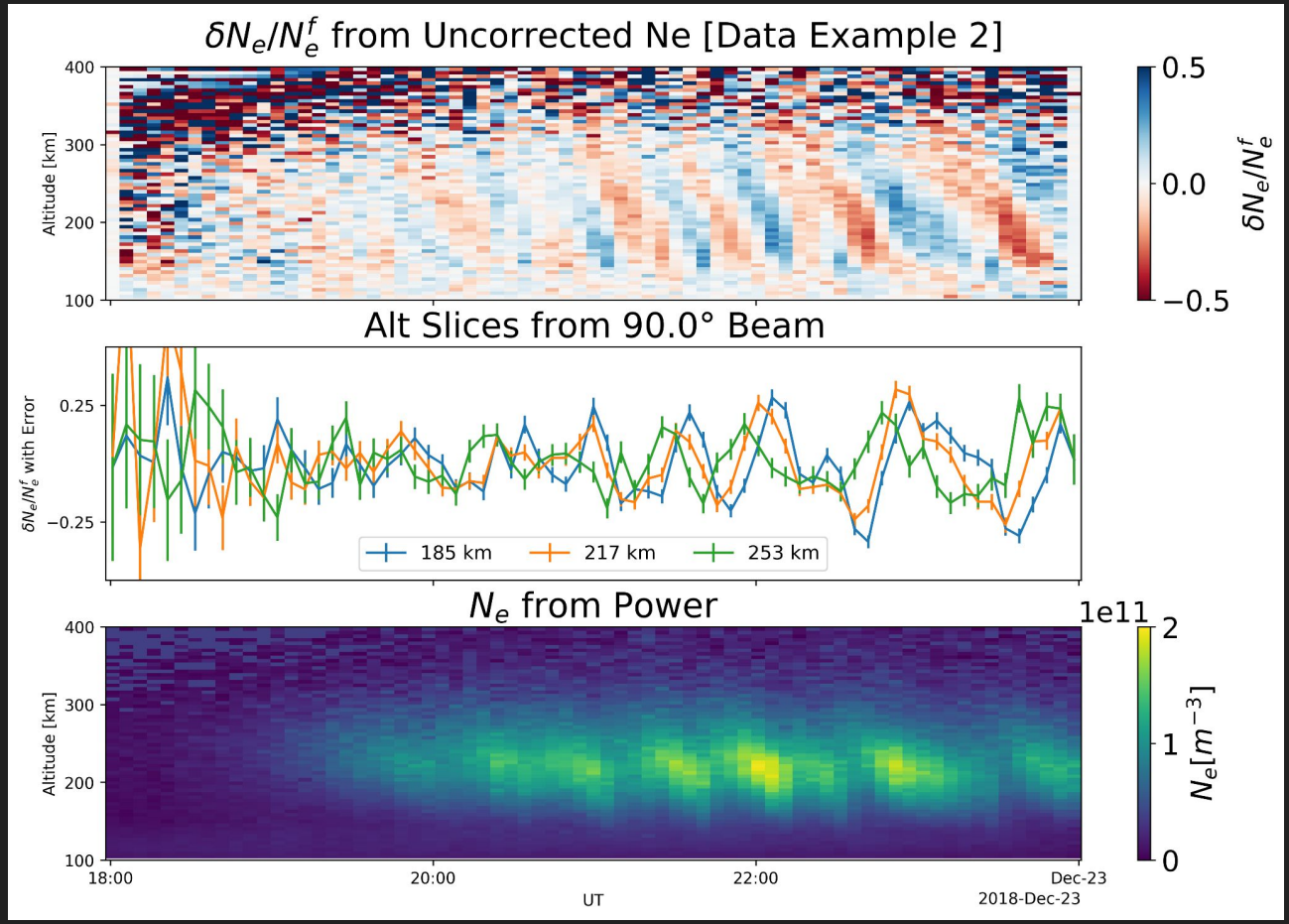
First published: 13 November 2007 | https://doi.org/10.1029/2007GL031506 | Citations: 80

Find it @ University of Alaska Fairbanks

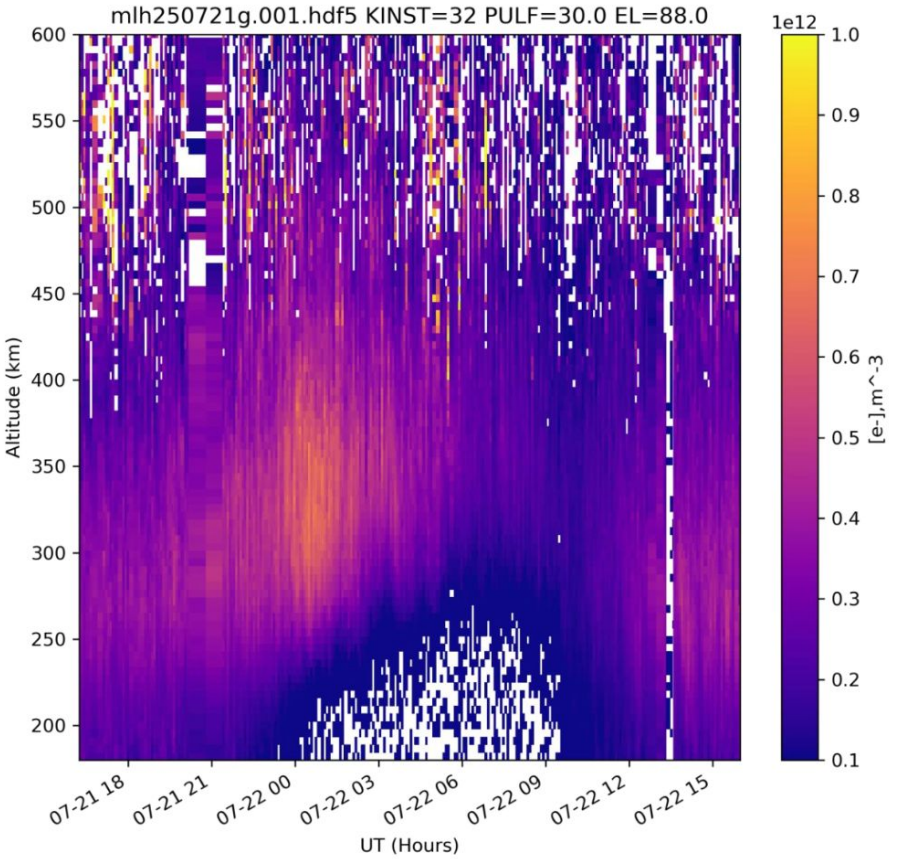


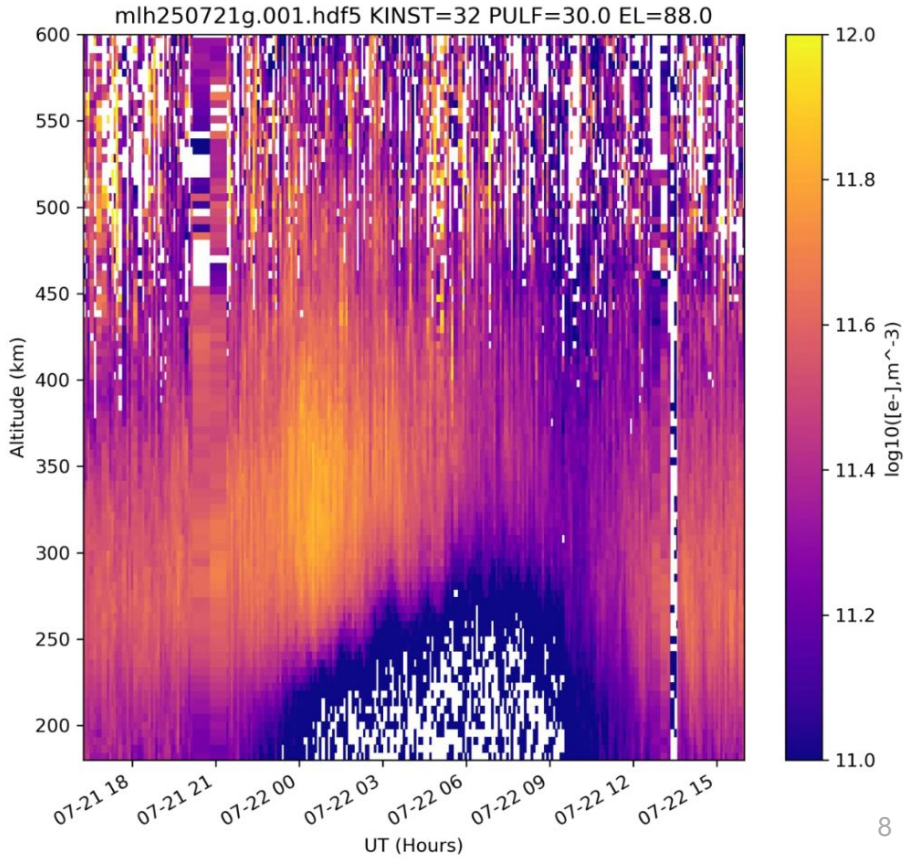


Example of TID Detection with $\delta N_e / N_e^f$

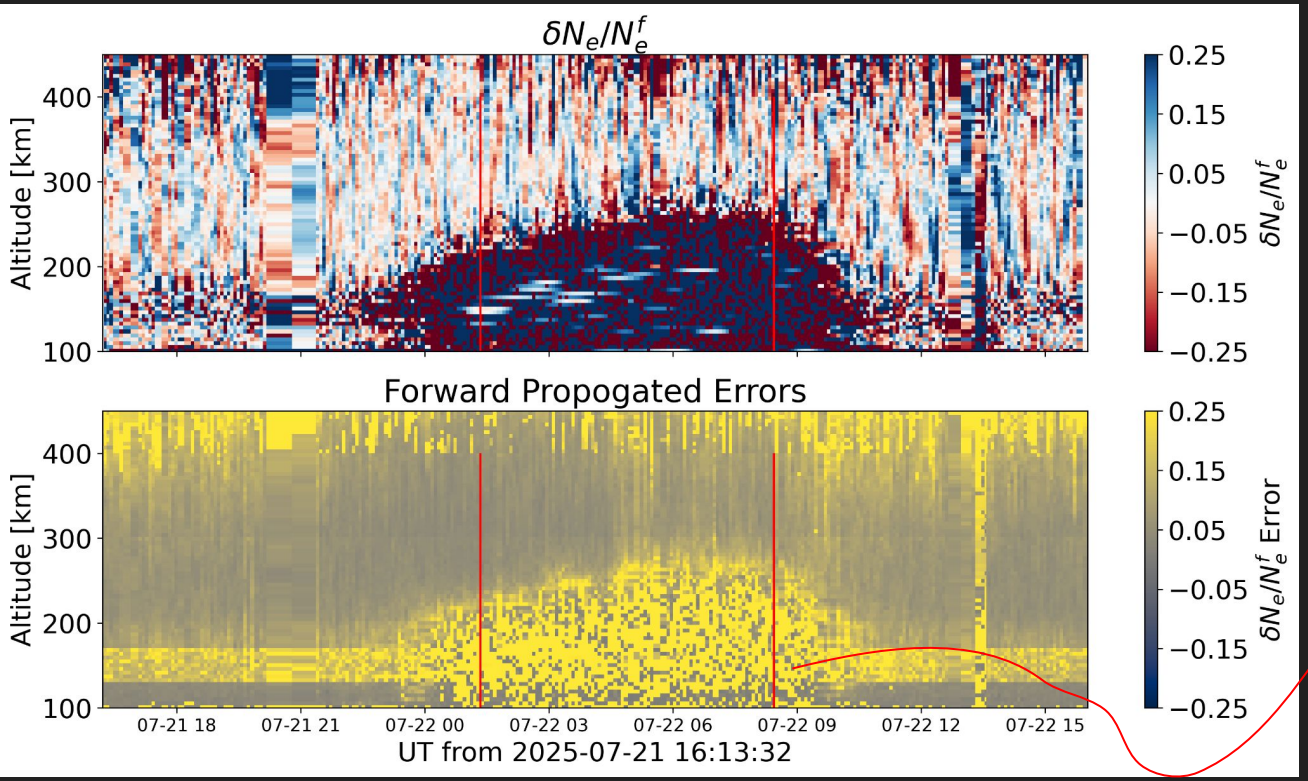


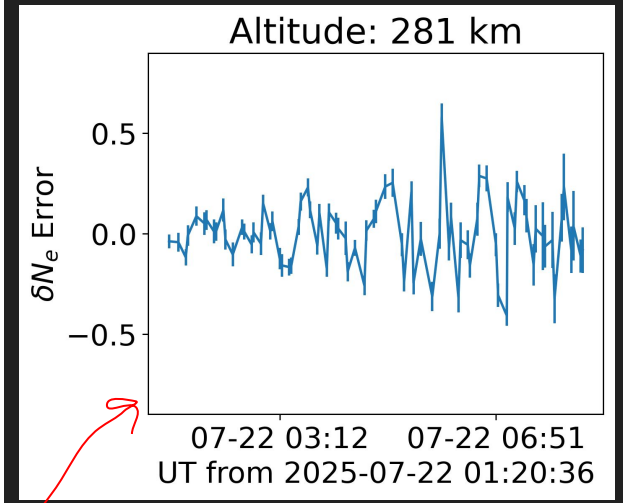
Millstone Hill Electron Density Observations



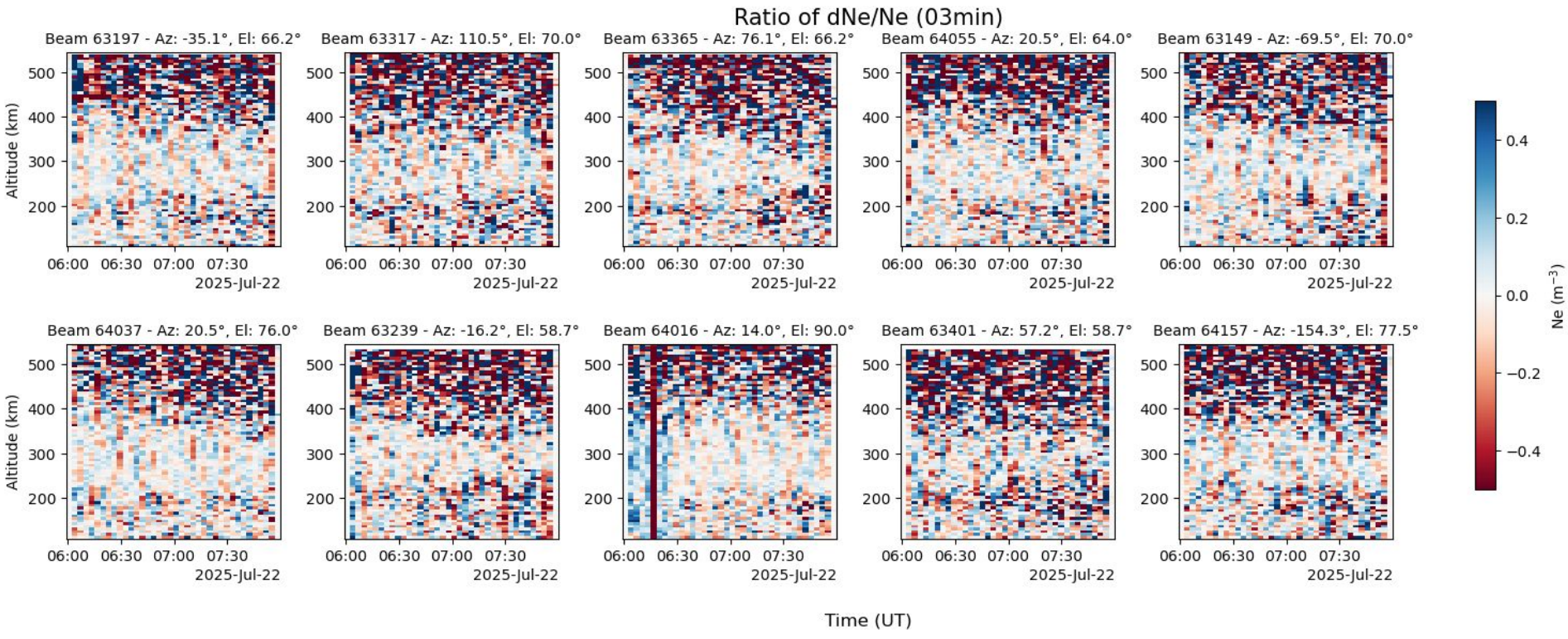


Midlatitude Terminator Driven TIDs at Millstone Hill



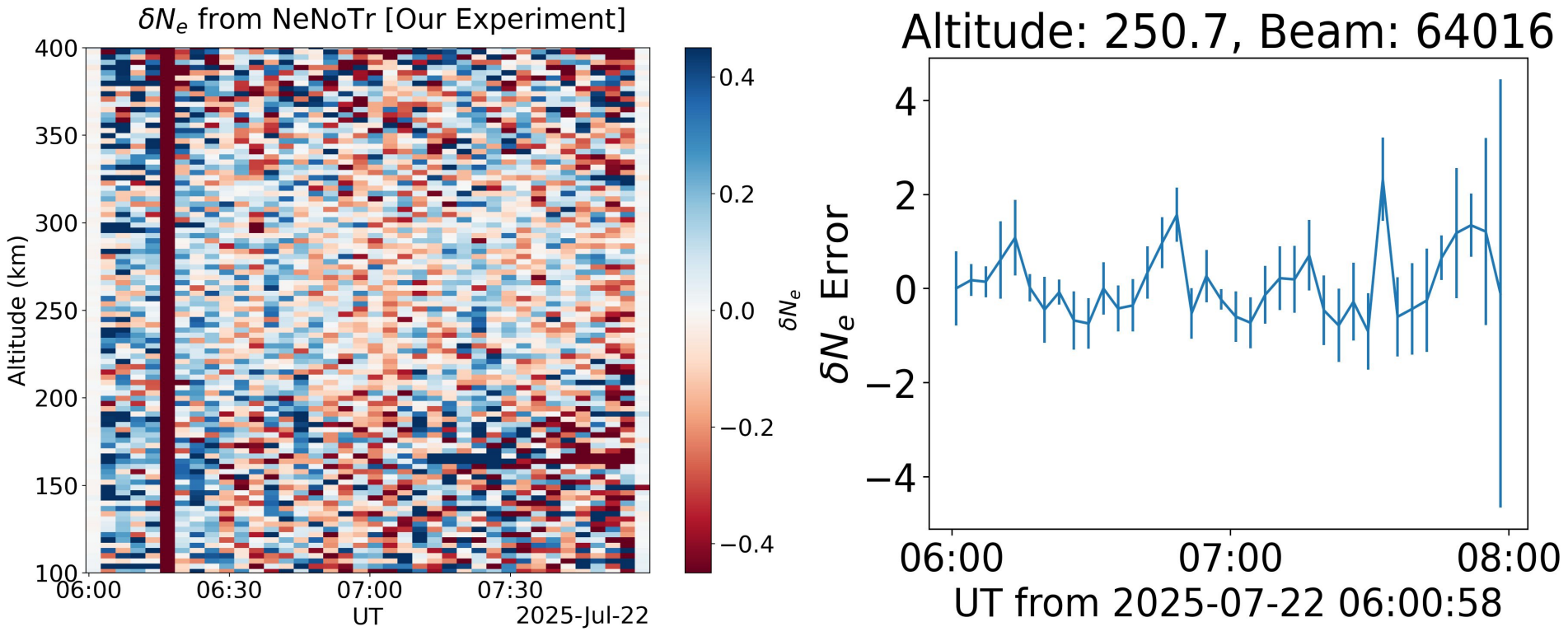


Results - TID Hunting



Possible TID signatures, but oscillations are more significant and higher frequency than Heinselman/Negale signatures→ Requires more analysis.

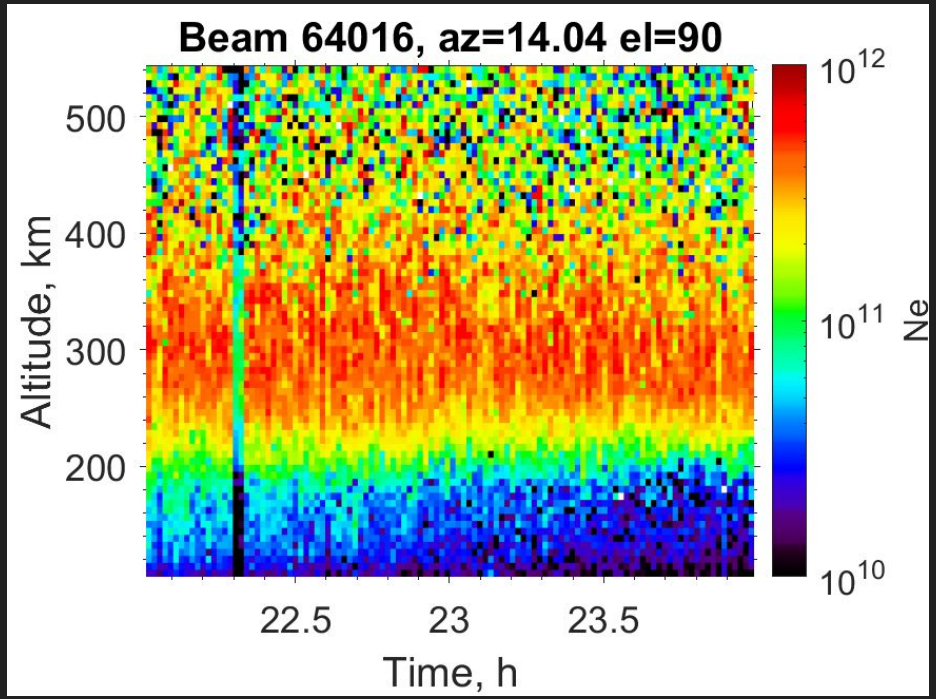
Looking at Ne from Power



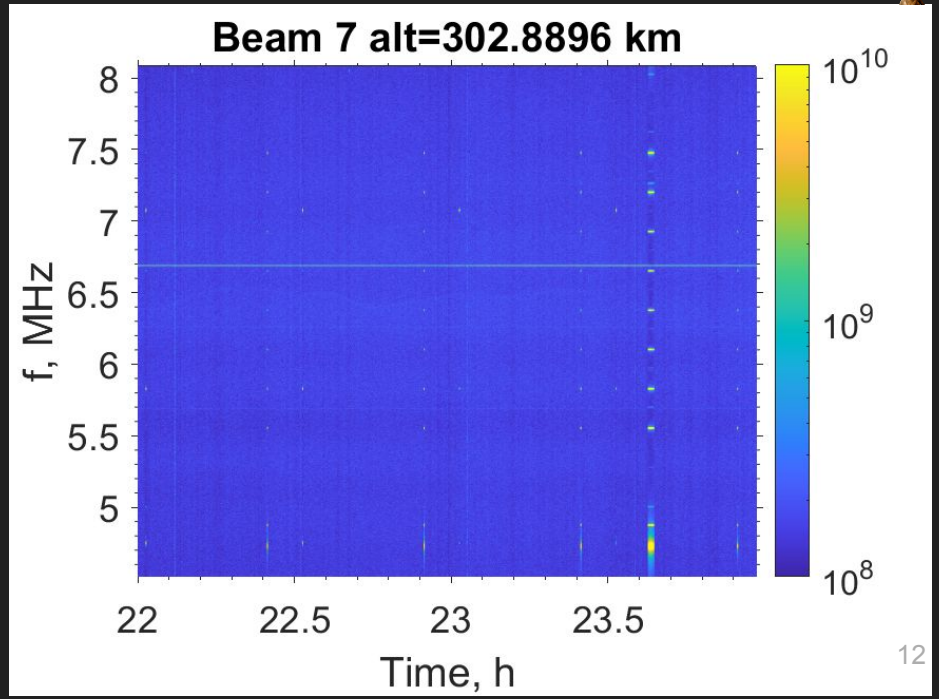
Take note of the peaks from the altitude slice!

Results - Plasma Line

Vertical Beam

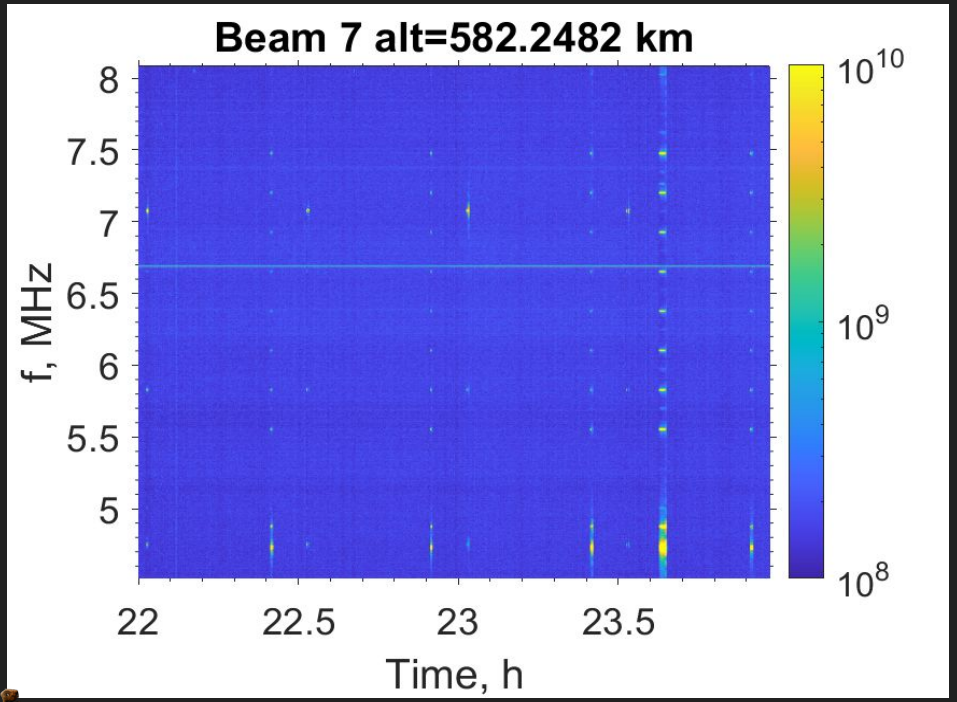


Plasma line spectrum: original

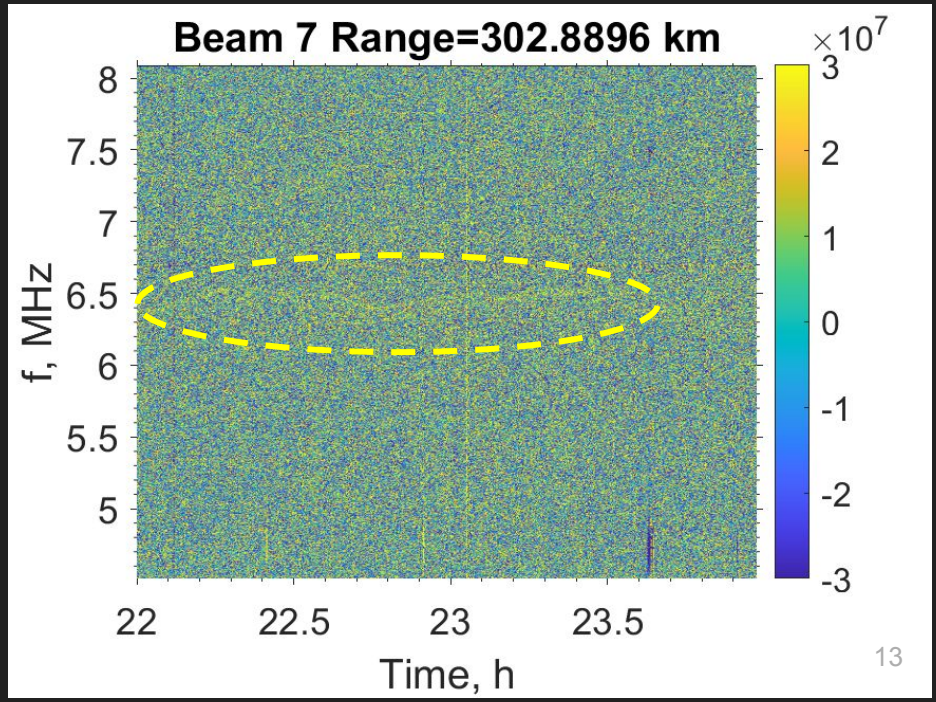


Results - Plasma Line

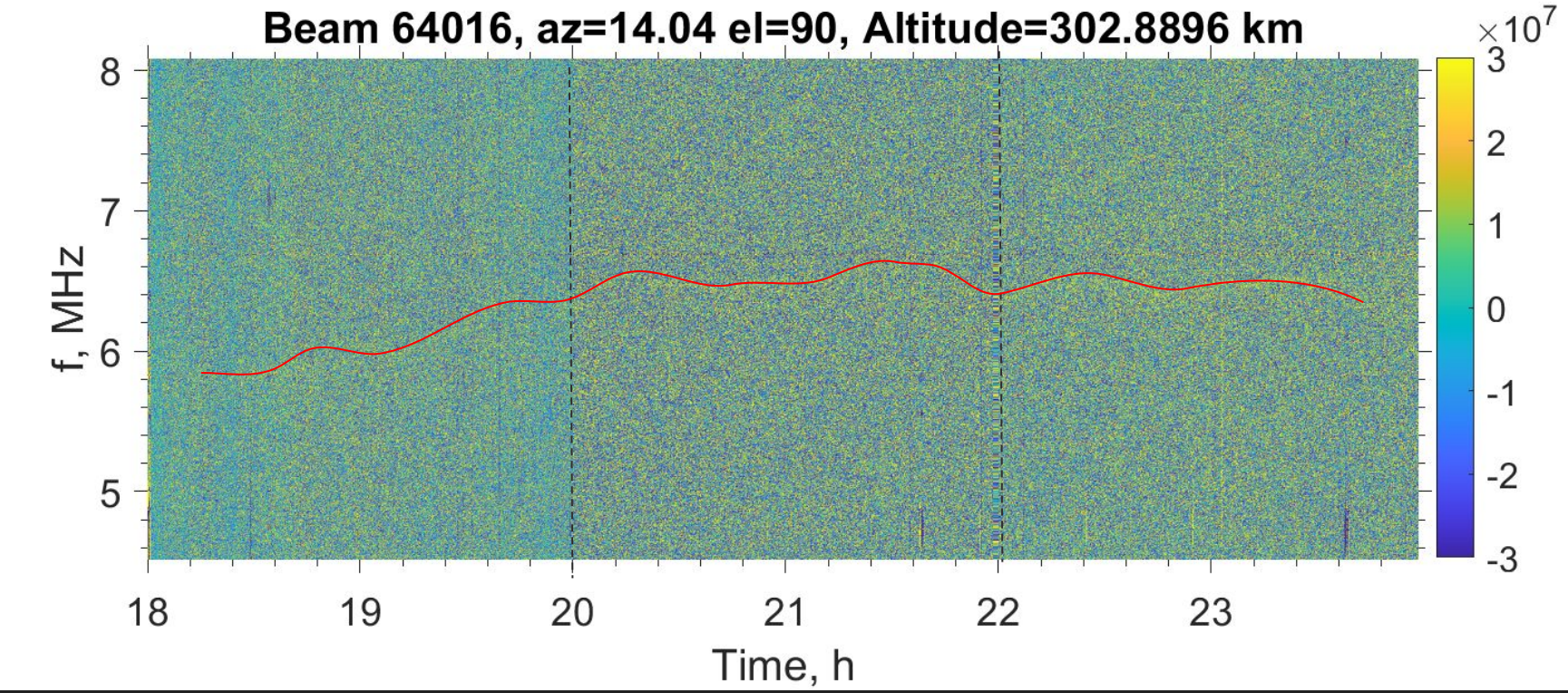
Plasma line spectrum: original



Plasma line spectrum: relative value

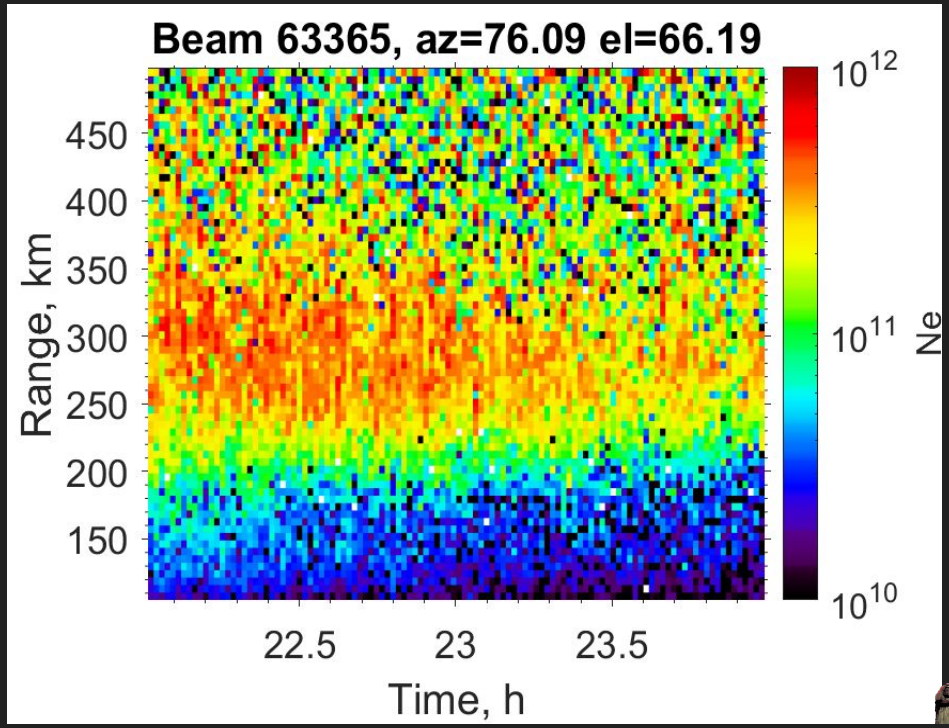


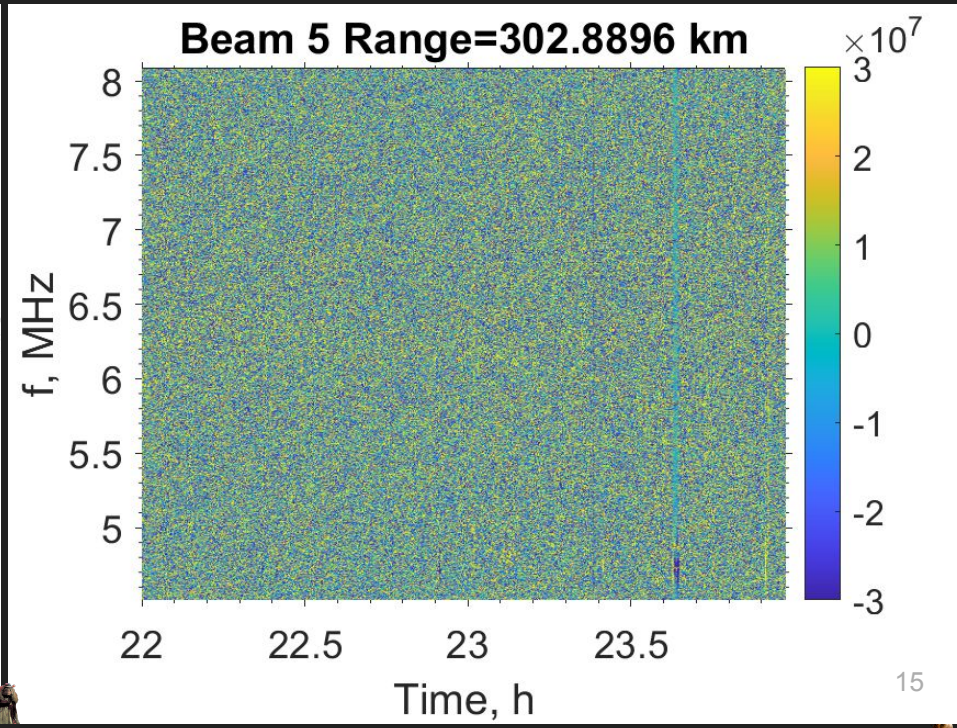
Results - Plasma Line Spectrum, 6 hour



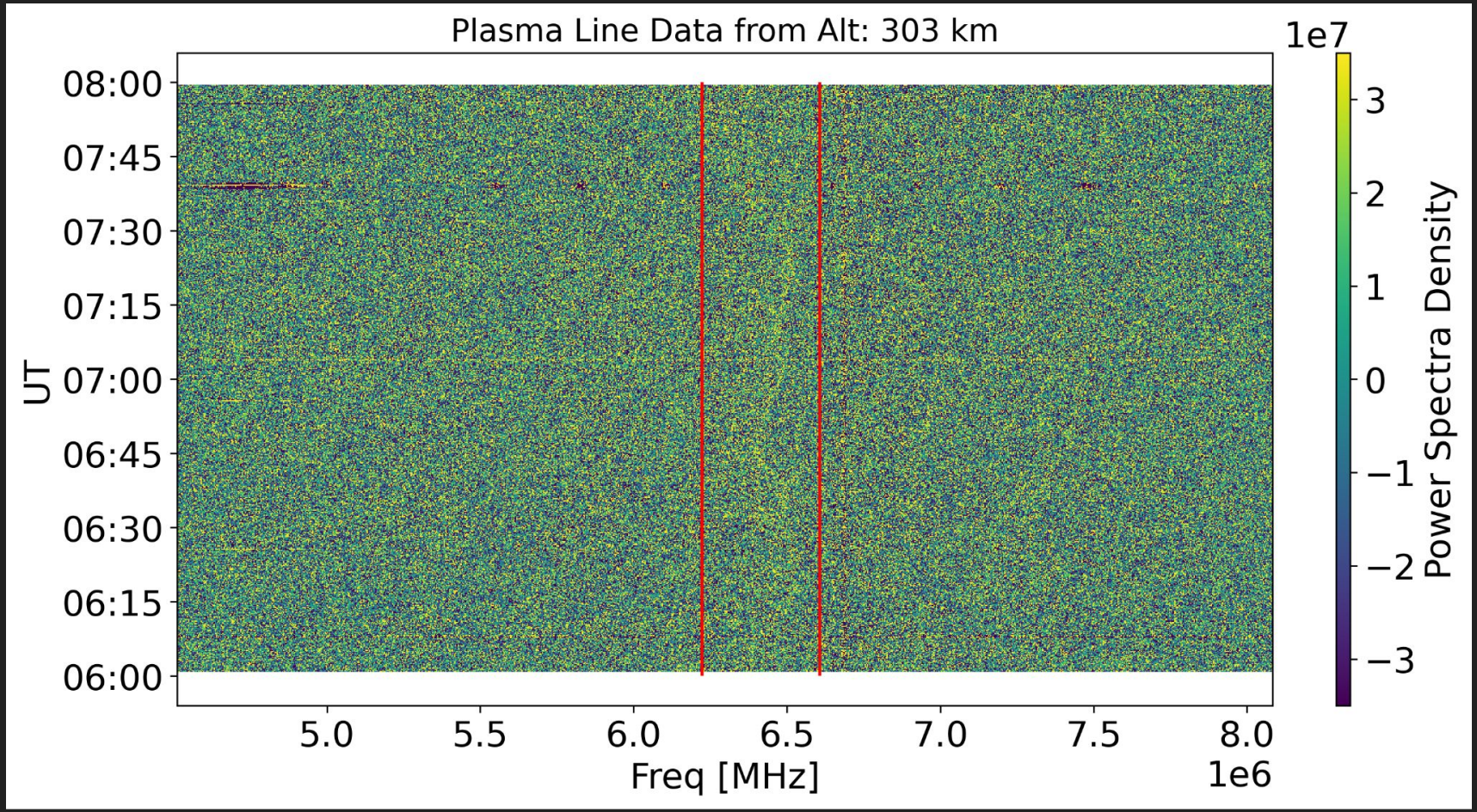
Results - Plasma Line

Terminator & plasma line spectrum

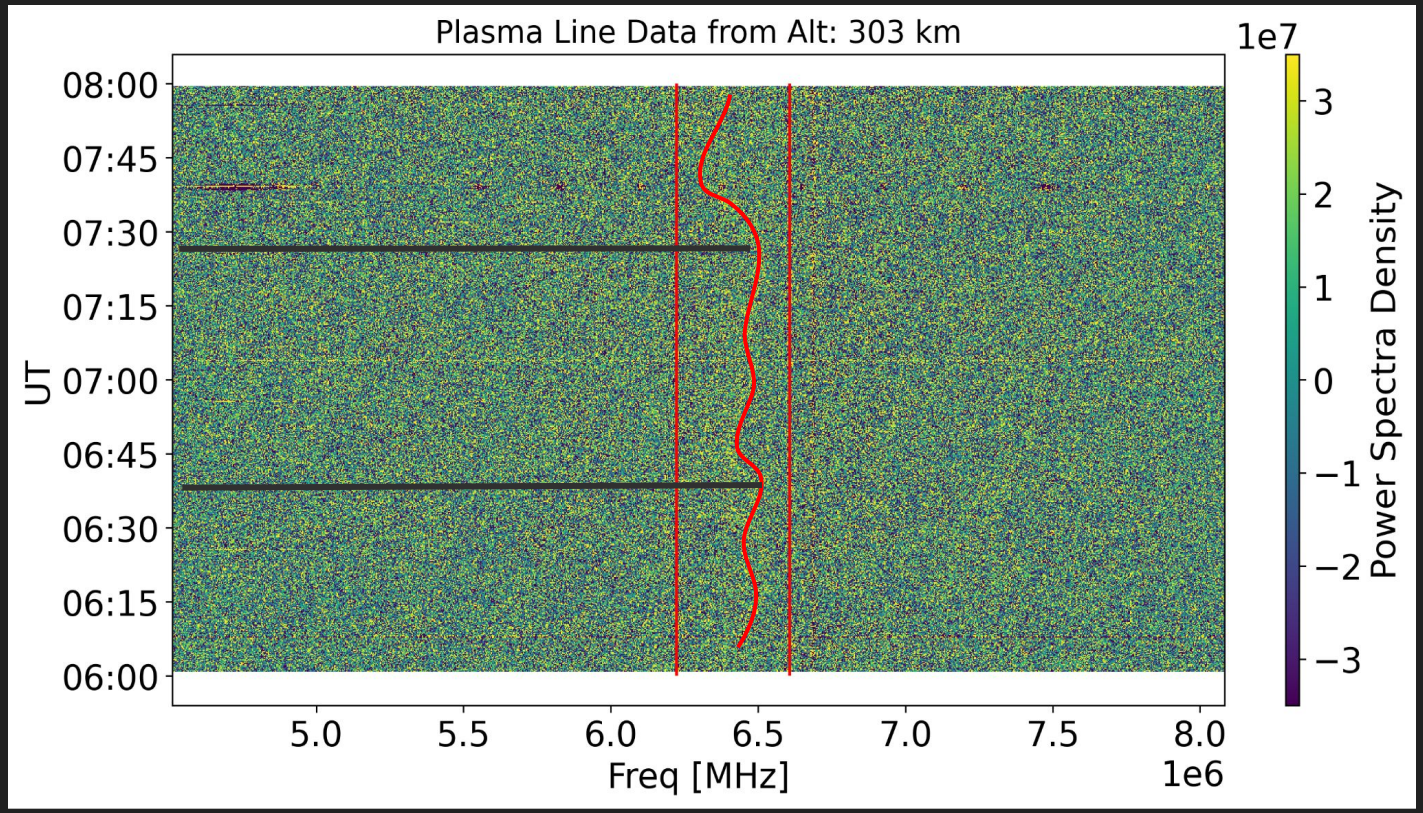




Plasma Line Enhancement for Our Experiment



Plasma Line Location



First, Trace the plasma line.

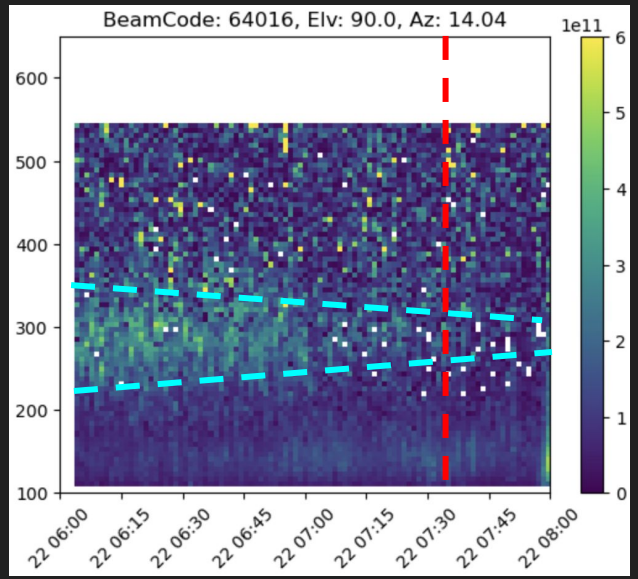
We see a frequency fluctuation with a period of ~1 hour.

Same time of peaks in the NeNoTr Data

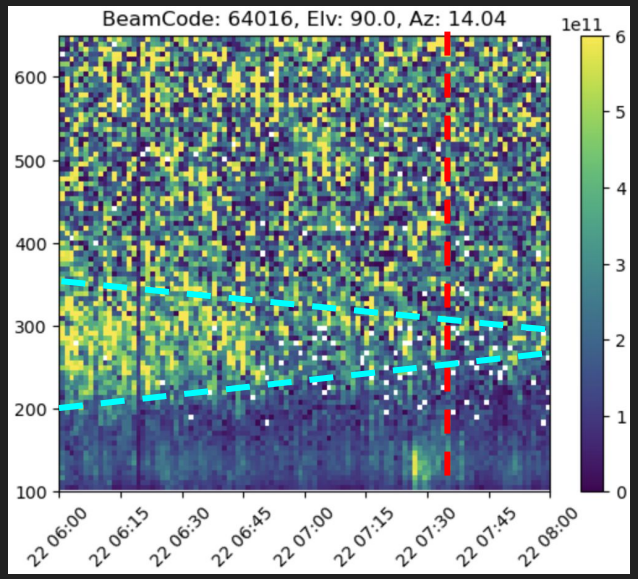
Minor TID Signature

Results - This Night Through History

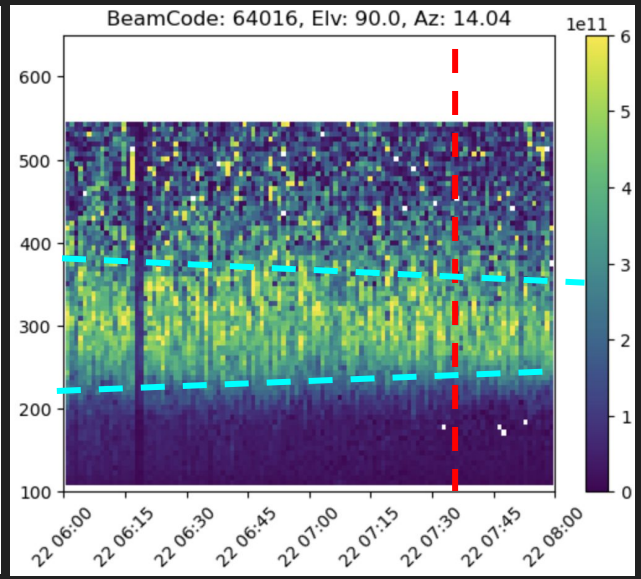
→ 1-min fitted integrated long pulse (Ne)



Themis36 - Auroral and convection measurements
2022-07-22



Long duration measurements in support of the IPY
2024-07-22



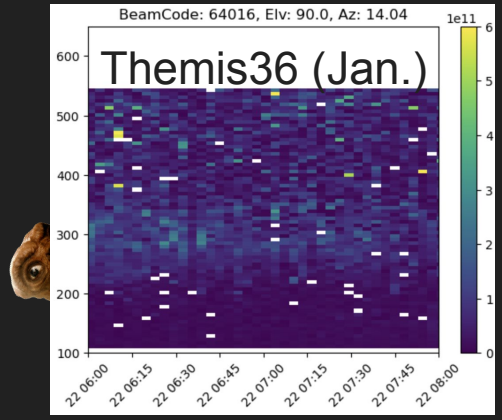
Effects of the Terminator on E and F-region Ionospheric Dynamics
2025-07-22

Densities taper off as twilight and sunset approaches. *Sunset time in Fairbanks, AK: 7:33 GMT

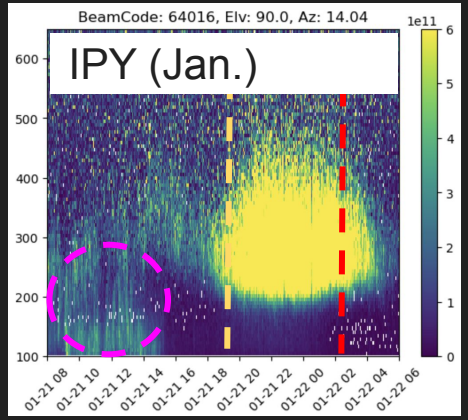
Results - Seasonality

→ 3-min fitted integrated long pulse (Ne)

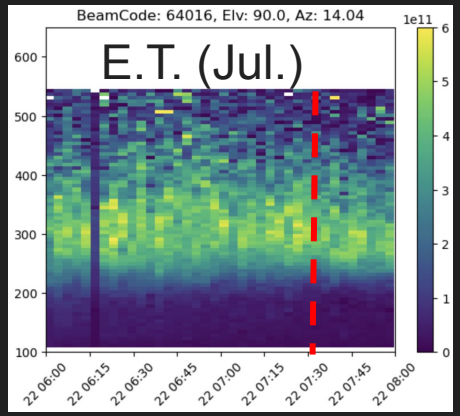
2022



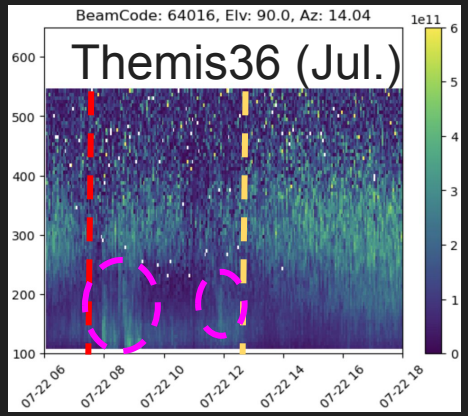
2024



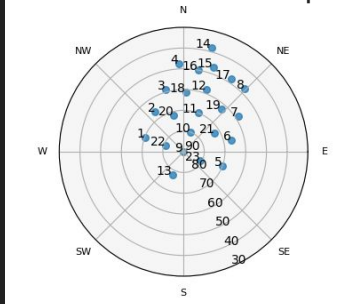
2025



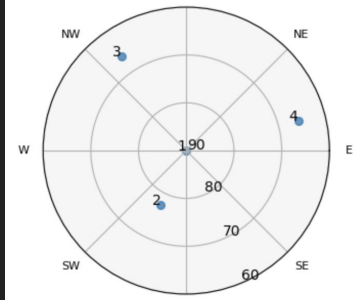
2022



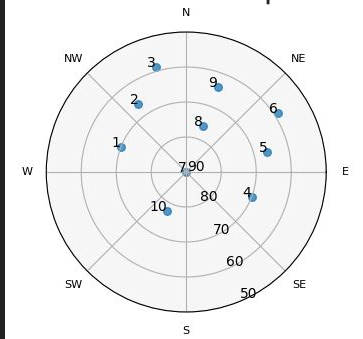
Themis36 Beam Map



IPY Beam Map

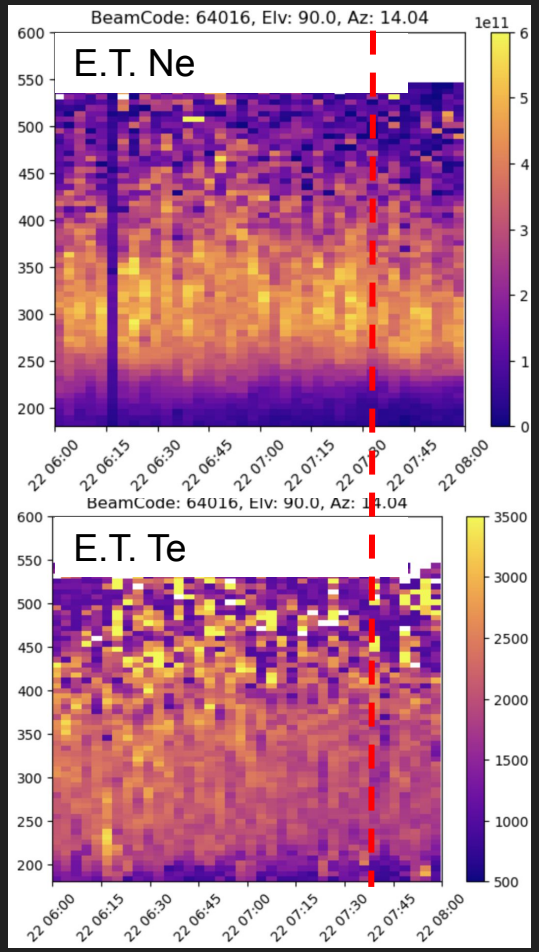


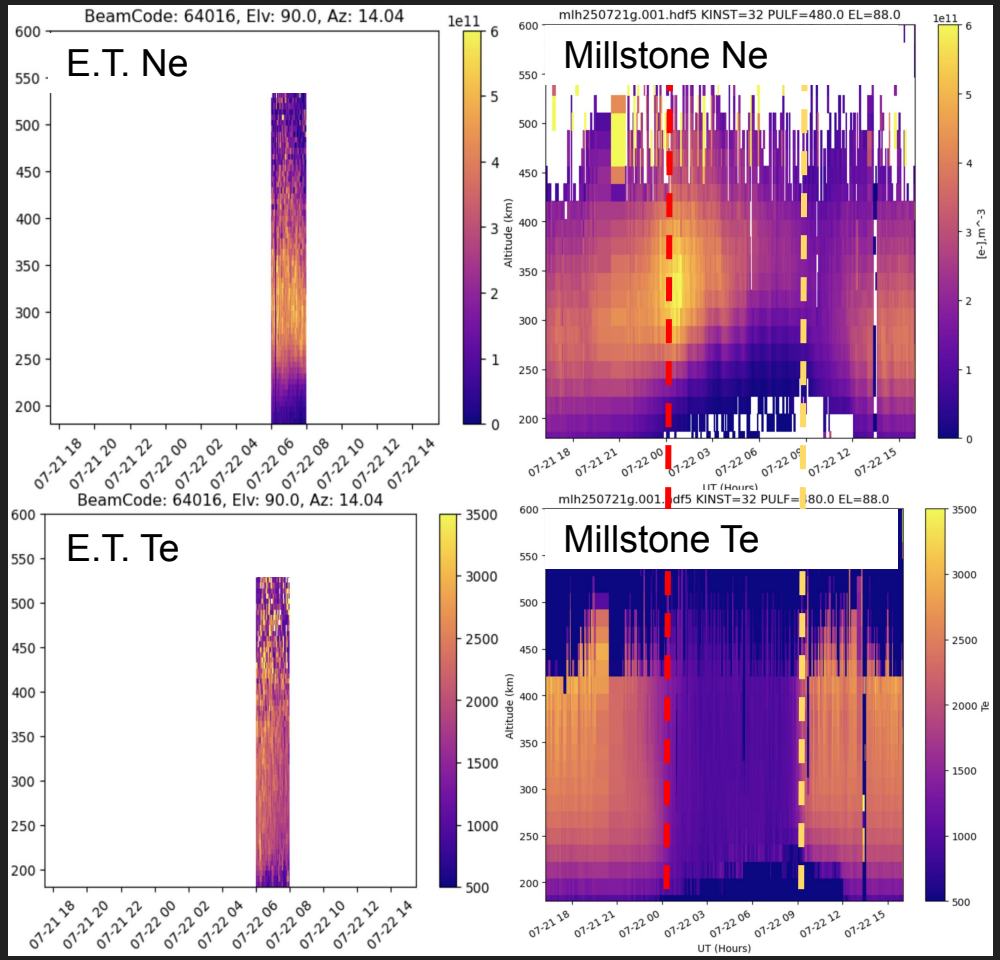
E.T. Beam Map



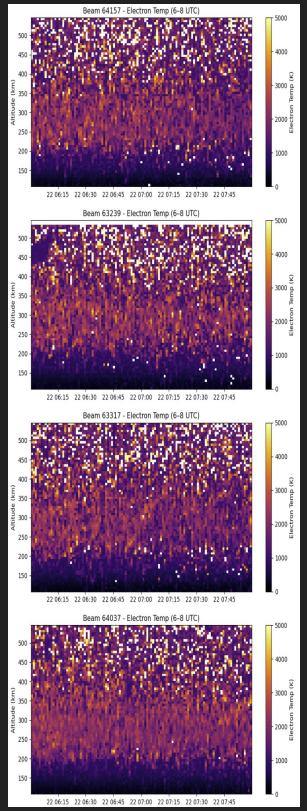
*Sunset/sunrise time in Fairbanks, AK: 7:33 GMT, Aurora

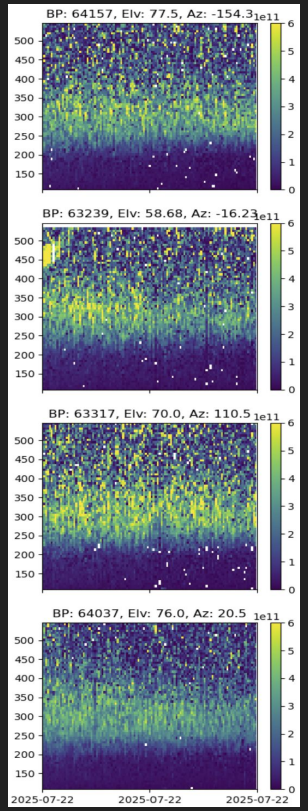
Results - Latitude Dependencies

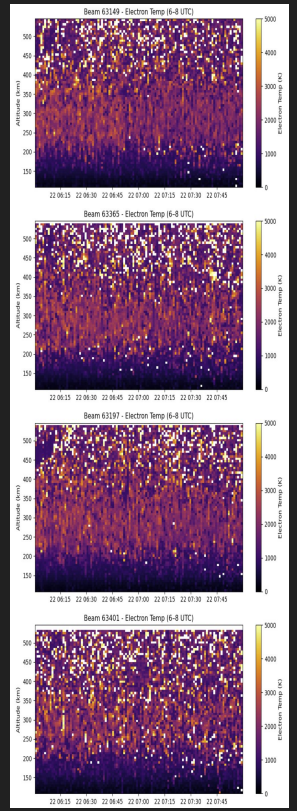


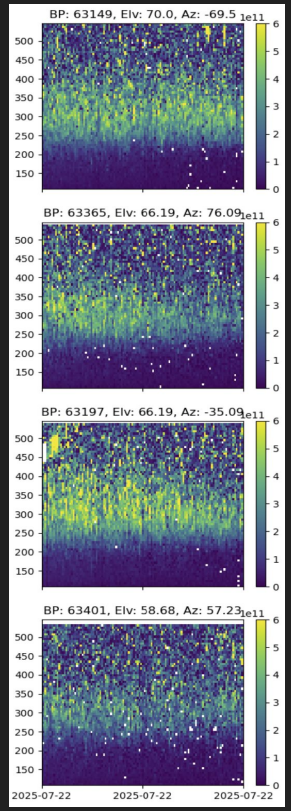


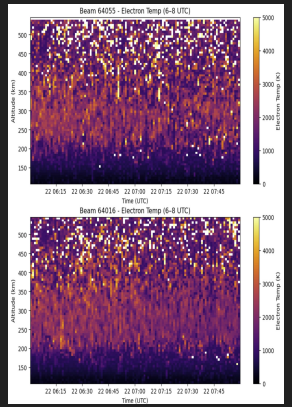
Results - Electron Temperatures

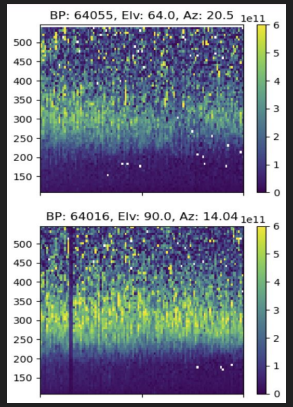






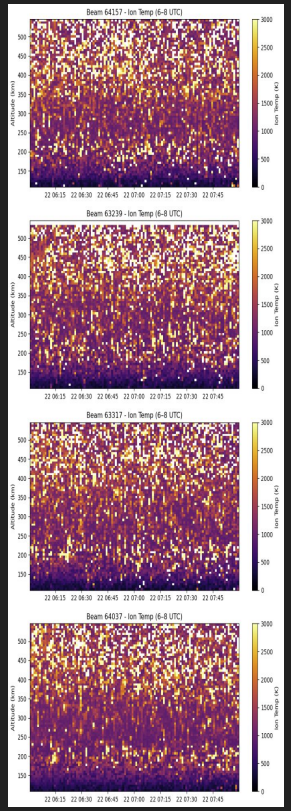


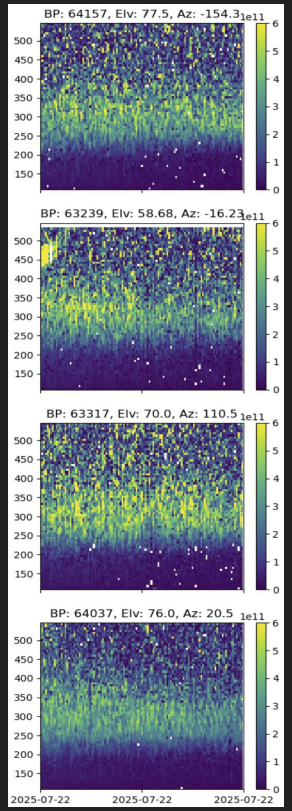


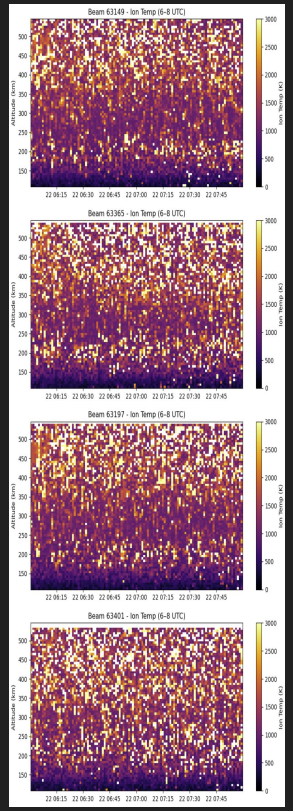


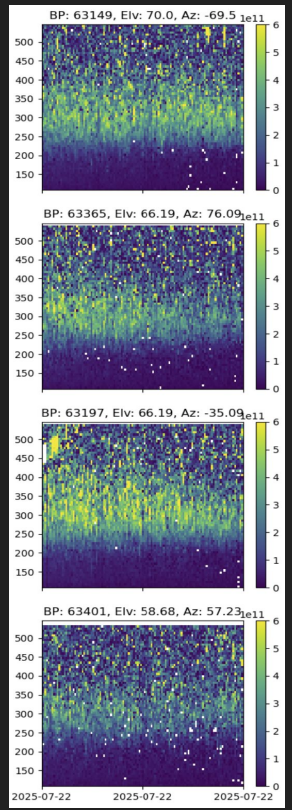
→ 1-min fitted integrated long pulse (Te)

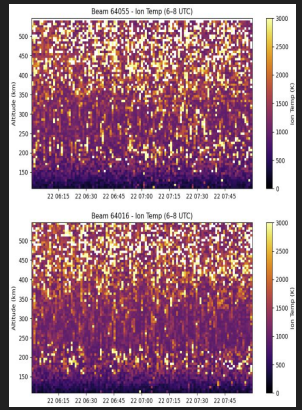
Results - Ion Temperatures

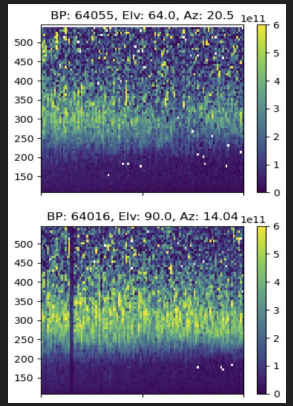






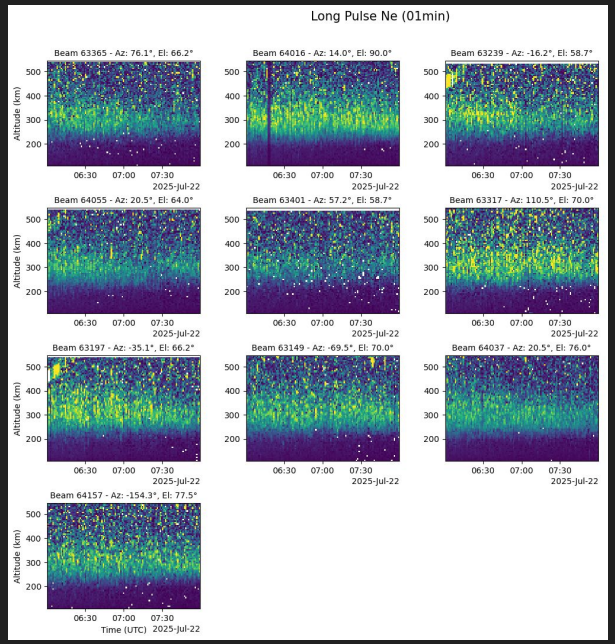


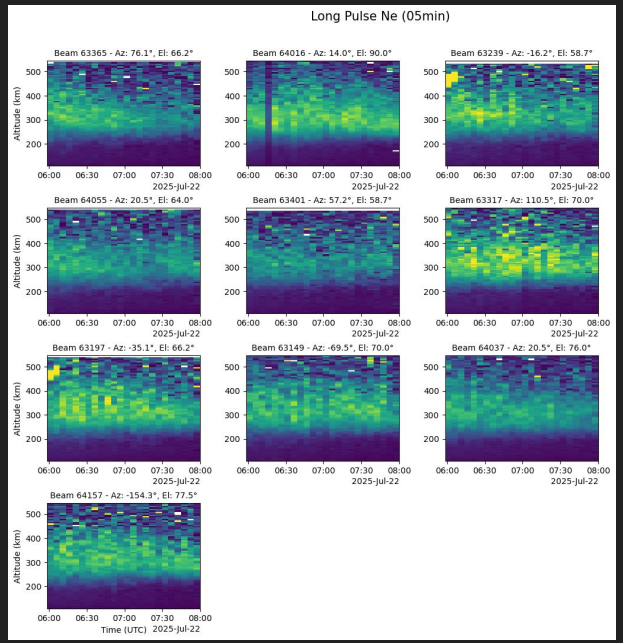




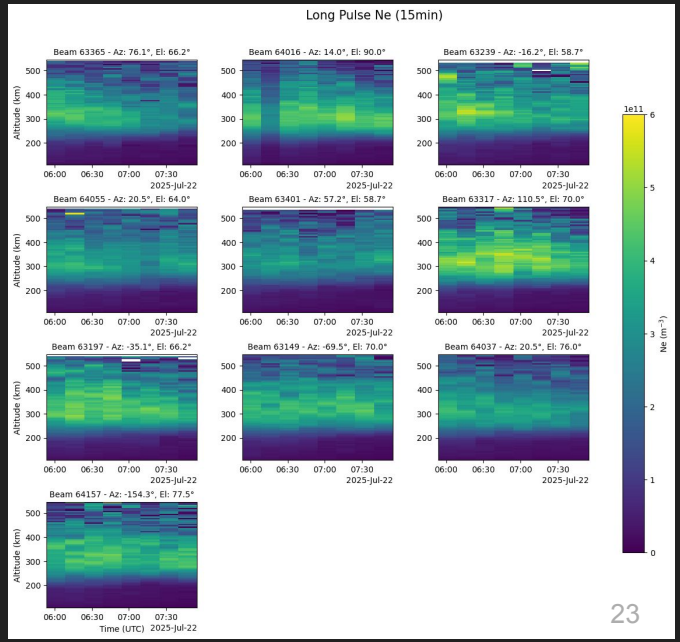
→ 1-min fitted integrated long pulse (Ti)

Results - Integration Times (Ne)

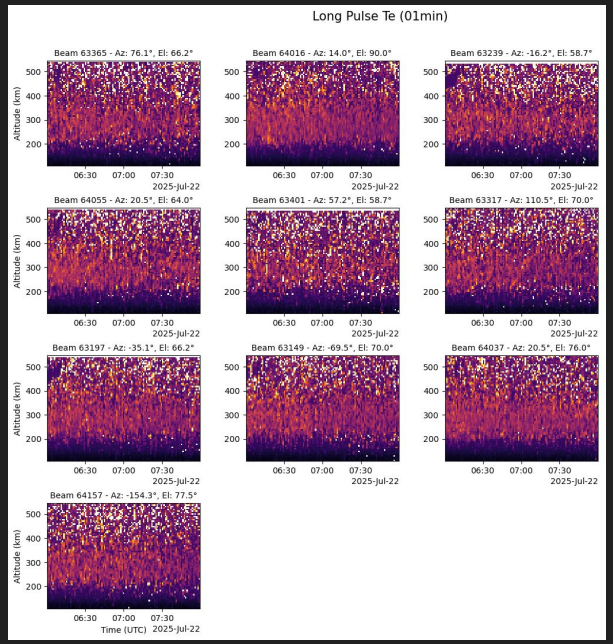


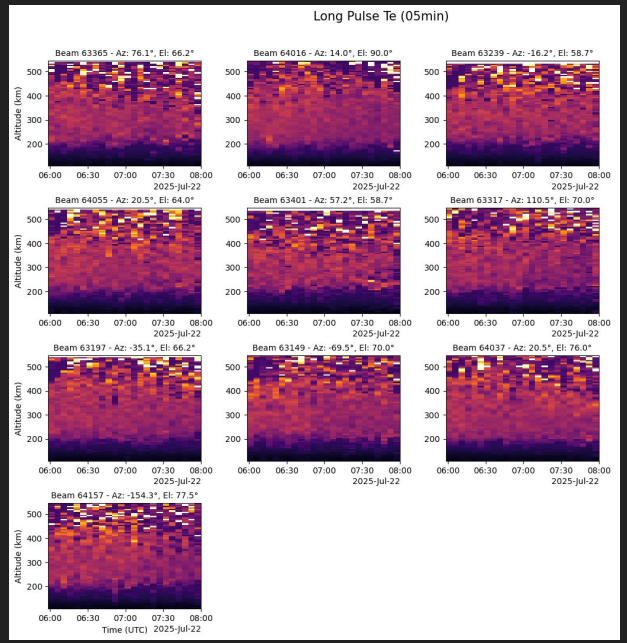


★ Integration times introduce varied results, so we should take this into account during data analysis.



Results - Integration Times (Te)





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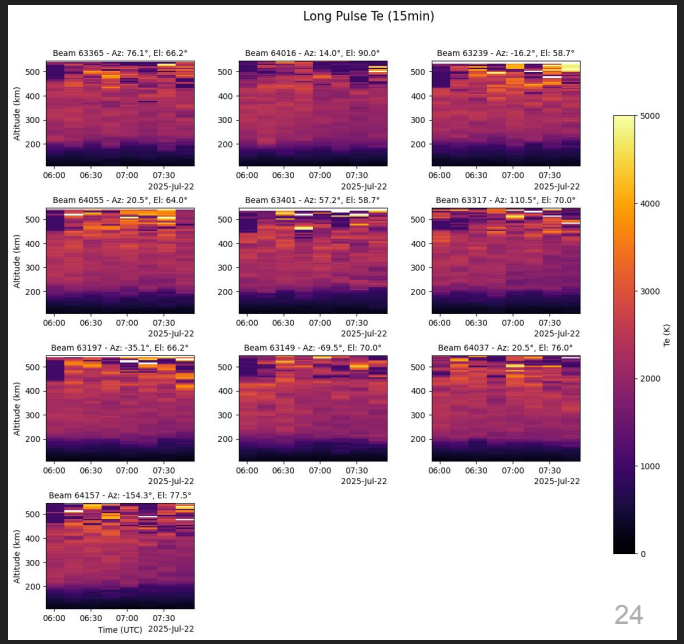
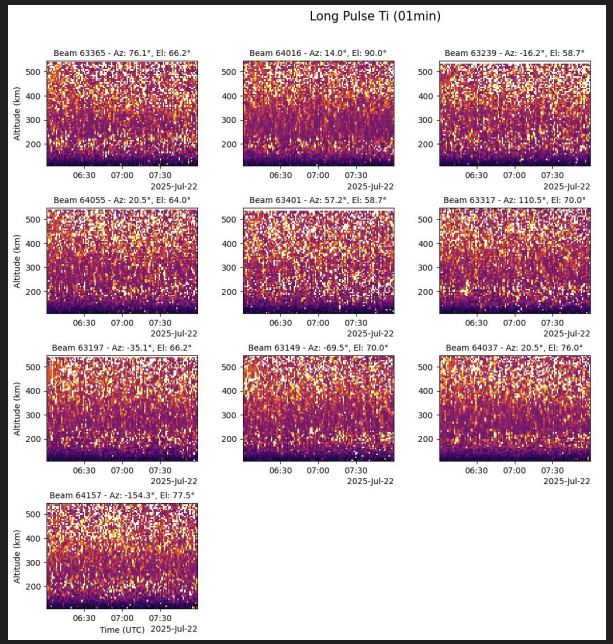
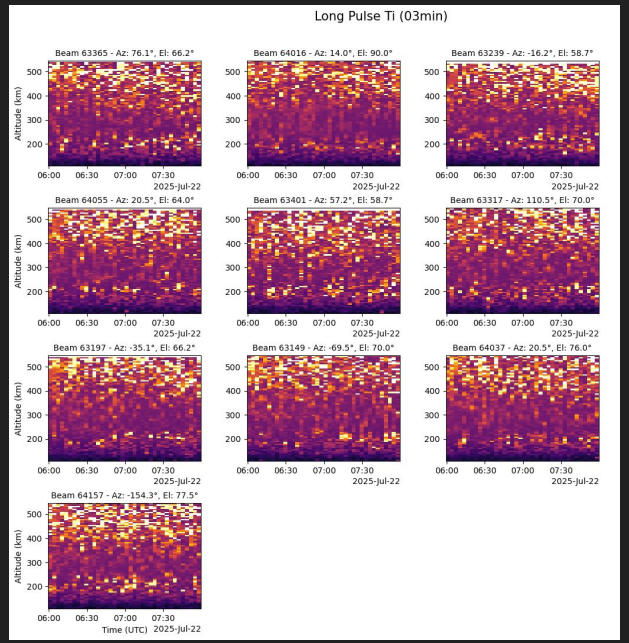
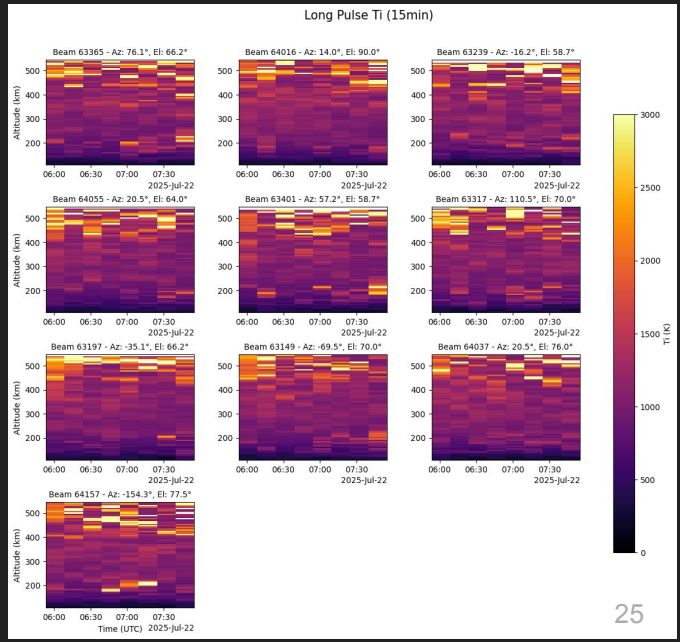


Results - Integration Times (Ti)

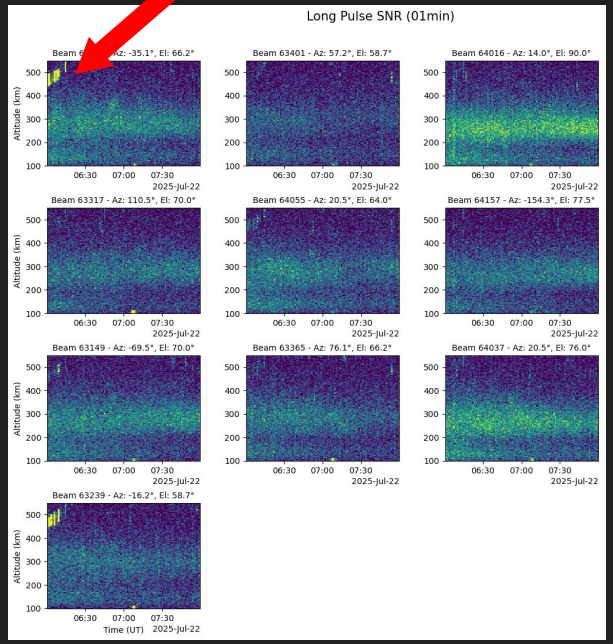


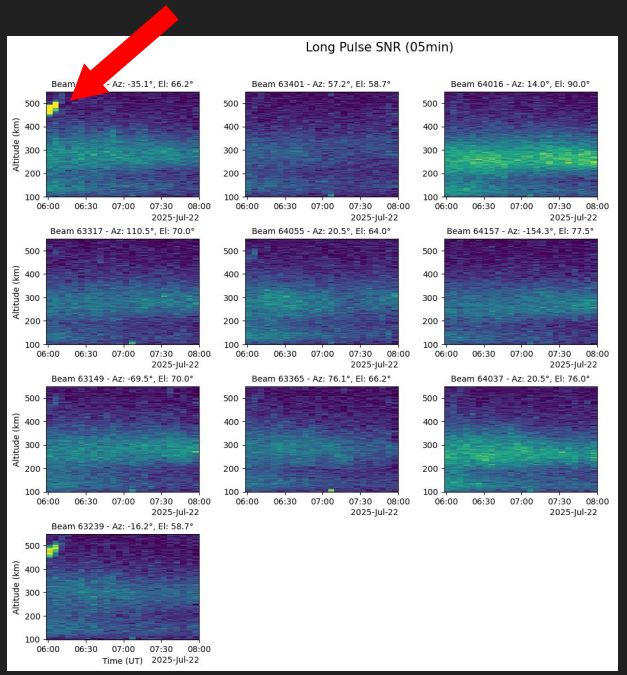


★ Integration times introduce varied results, so we should take this into account during data analysis.

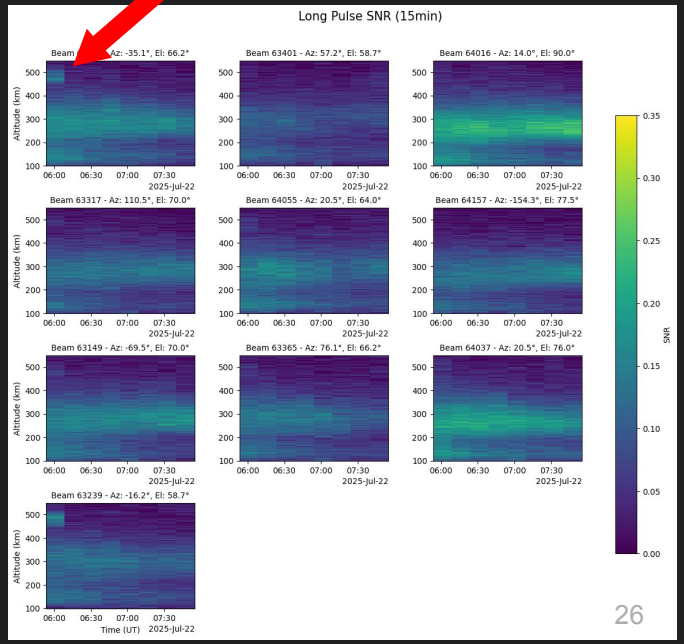


Results - Integration Times (SNR = dNe/Ne)



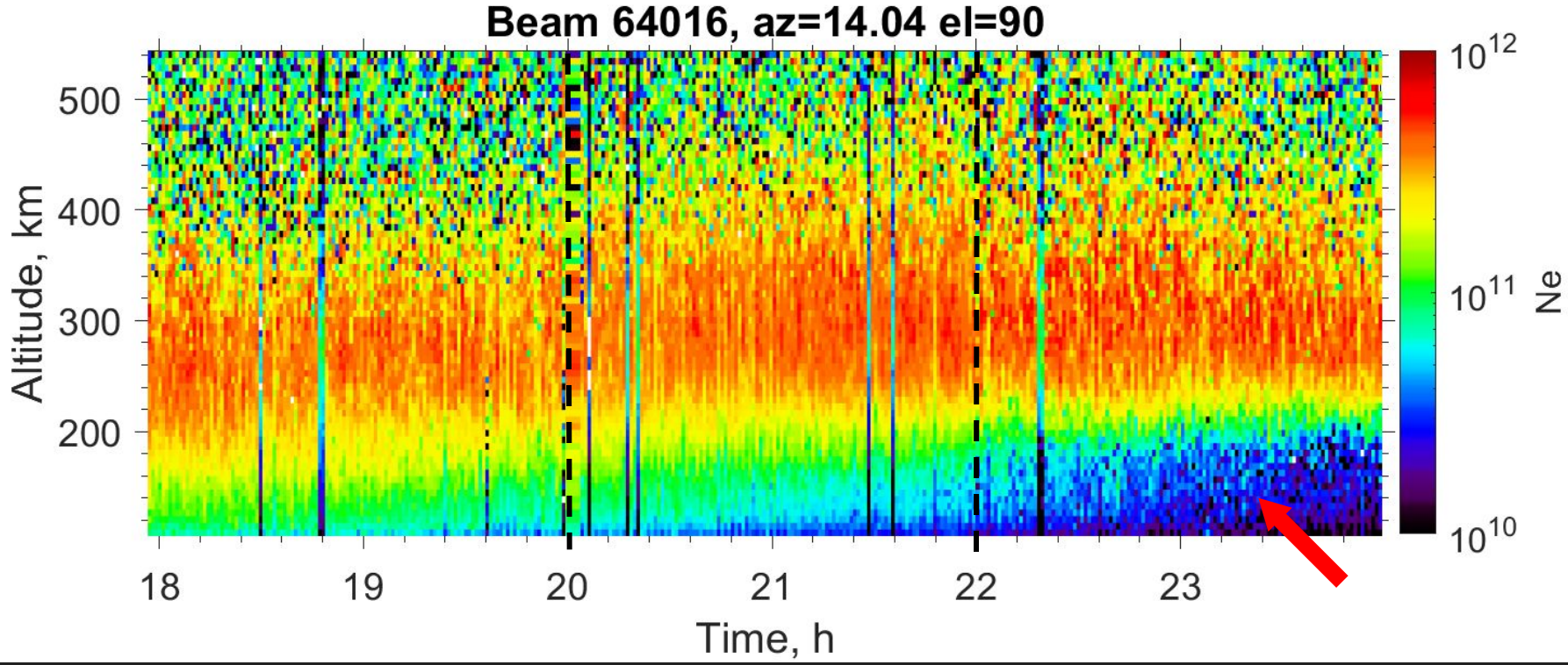


Notice satellite interference might get confused with something else at higher integration times!!



Results - Ne Decay

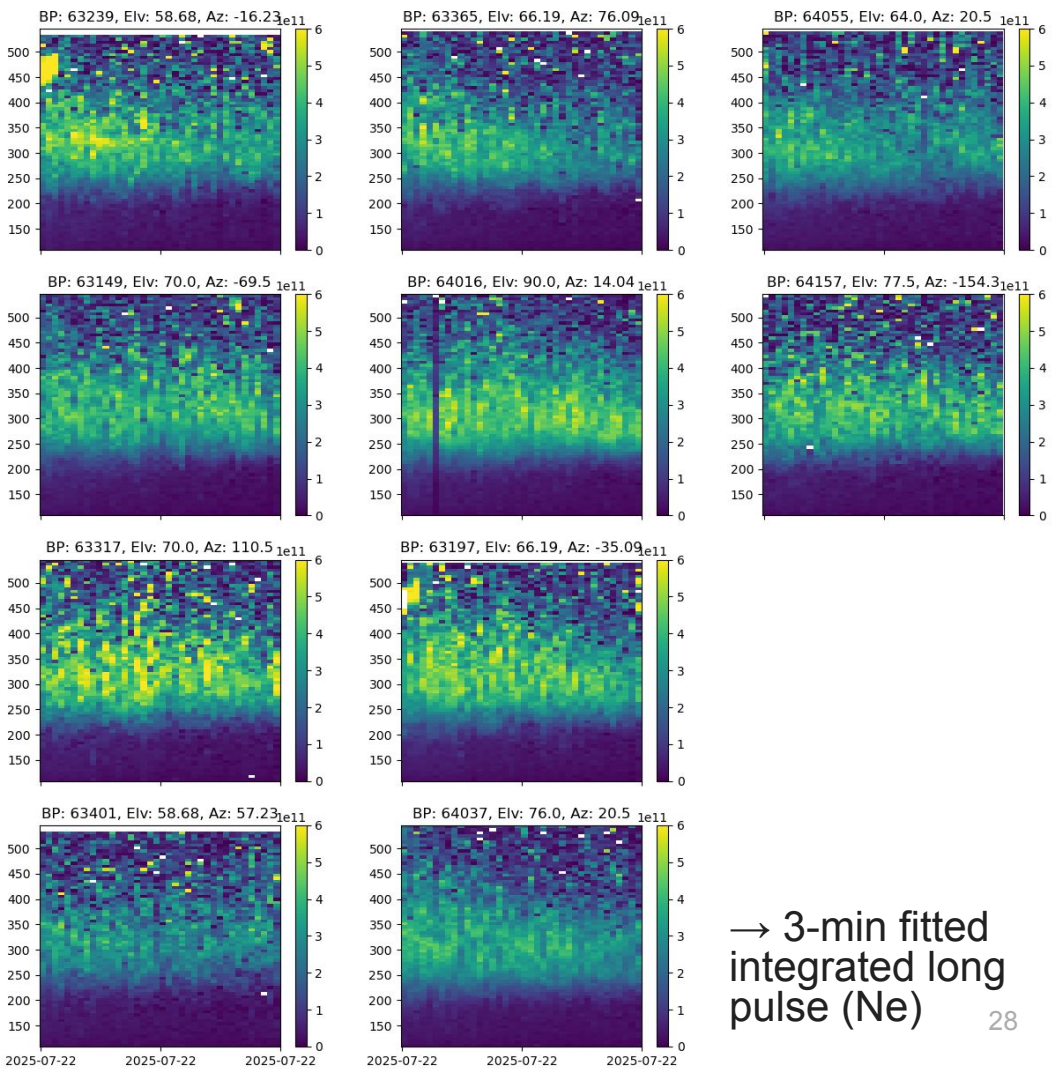
→ 1-min fitted long pulse



Group 1 Group 5 Group 2

Results - F-Region Decay @300km

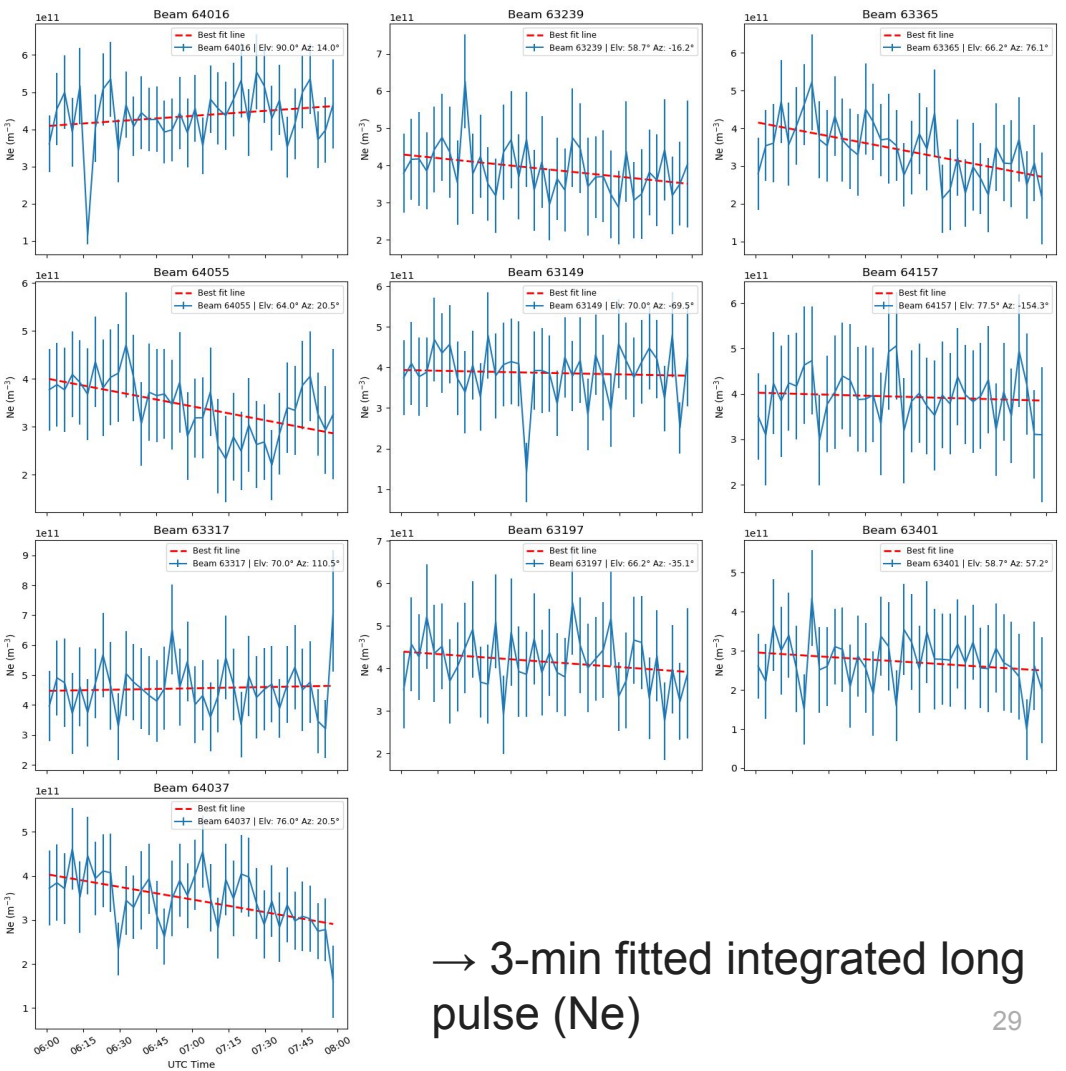
Beam ID	% Decrease in Ne
64016	13.30
63239	-18.62
63365	-35.38
64055	-29.00
63149	-3.62
64157	-4.37
63317	3.81
63197	-11.09
63401	-15.80
64037	-28.42



→ 3-min fitted integrated long pulse (Ne)

Results - F-Region Decay @300km

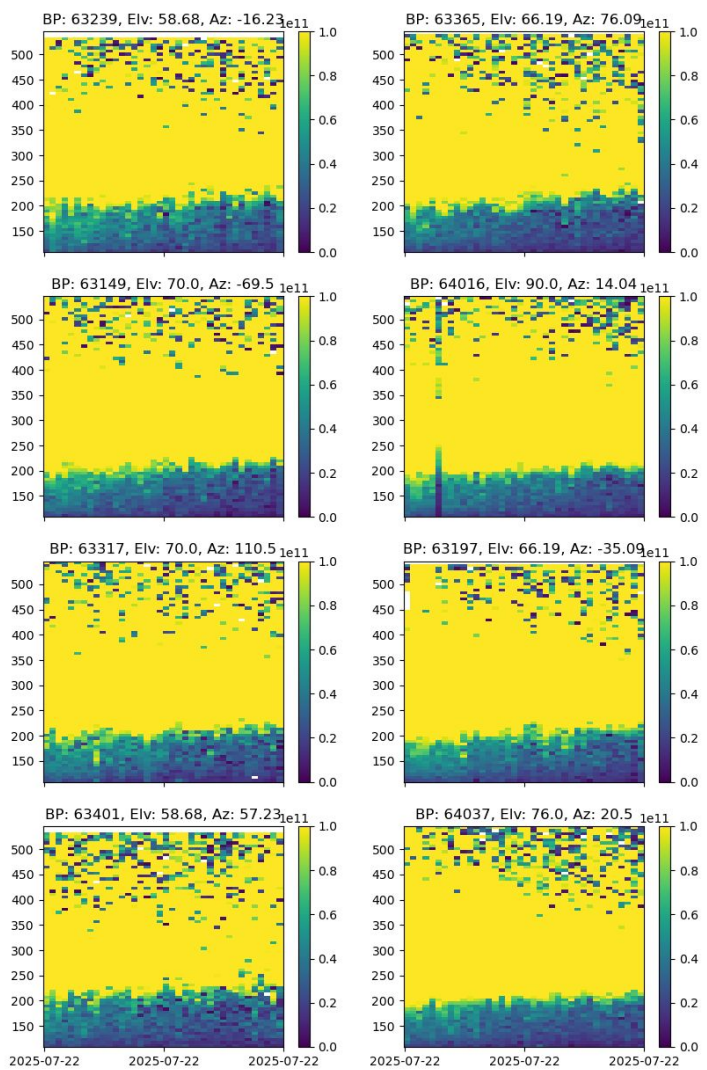
Beam ID	% Decrease in Ne
64016	13.30
63239	-18.62
63365	-35.38
64055	-29.00
63149	-3.62
64157	-4.37
63317	3.81
63197	-11.09
63401	-15.80
64037	-28.42



→ 3-min fitted integrated long pulse (Ne)

Results - E-Region Decay @150km

Beam ID	% Decrease in Ne
64016	-57.62
63239	-54.94
63365	-49.77
64055	-41.78
63149	-58.09
64157	-67.39
63317	-60.77
63197	-54.05
63401	-30.90
64037	-50.29

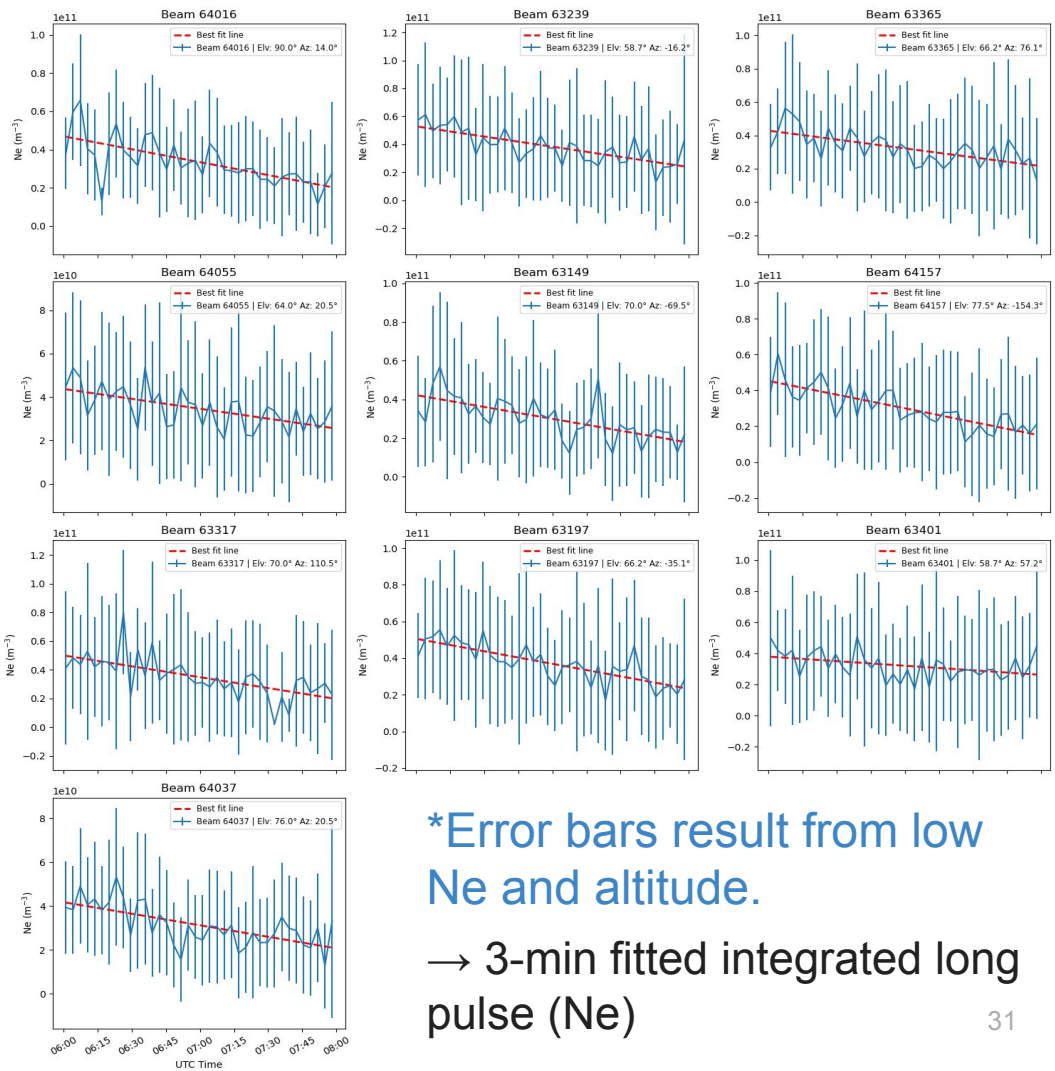


*F-Region oversaturated to emphasize E-region gradient.

→ 3-min fitted integrated long pulse (Ne)

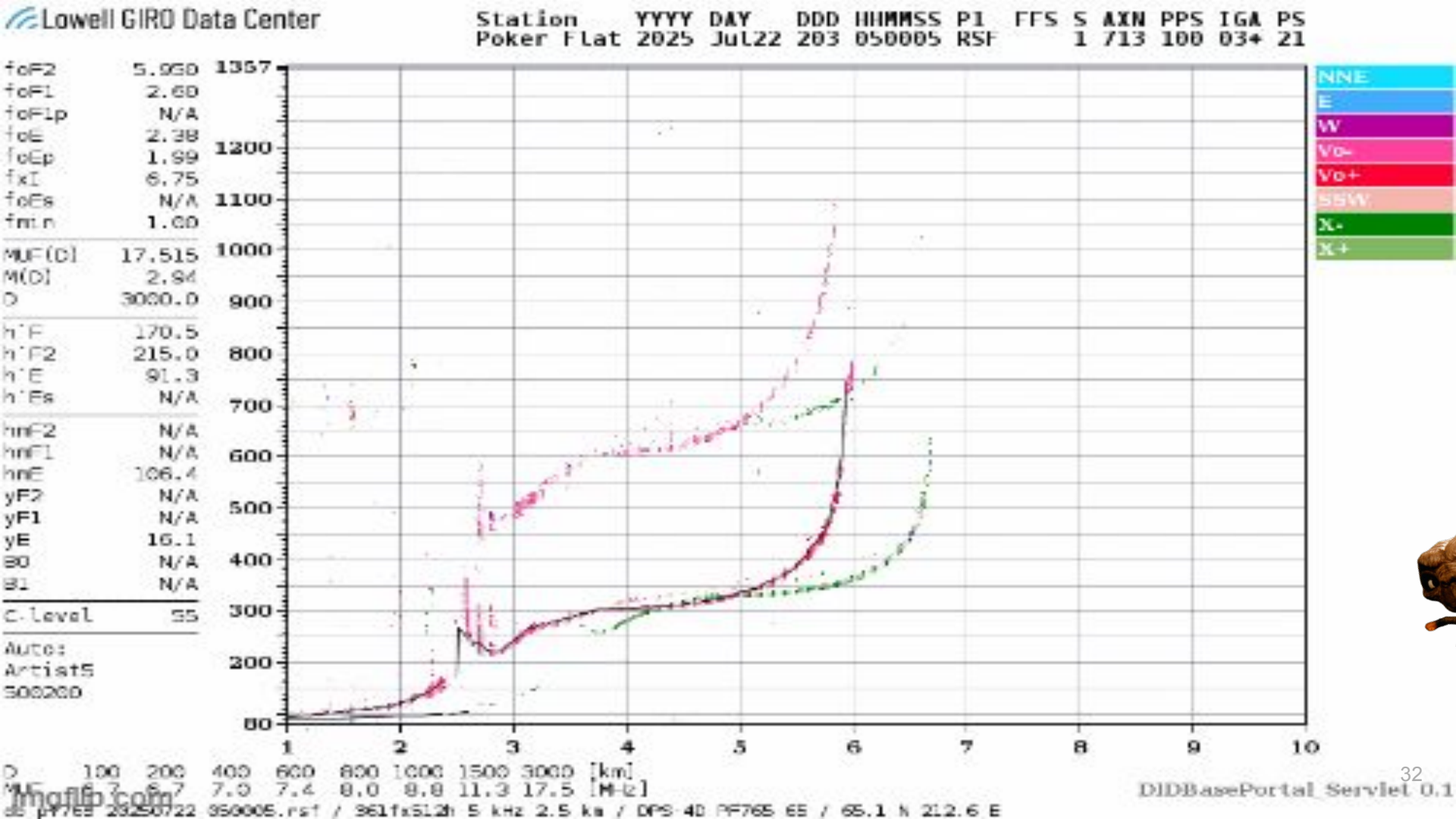
Results - E-Region Decay @150km

Beam ID	% Decrease in Ne
64016	-57.62
63239	-54.94
63365	-49.77
64055	-41.78
63149	-58.09
64157	-67.39
63317	-60.77
63197	-54.05
63401	-30.90
64037	-50.29



*Error bars result from low Ne and altitude.

→ 3-min fitted integrated long pulse (Ne)


Lowell GIRO Data Center
Station YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS
Poker Flat 2025 Jul22 203 050005 RSF 1 713 100 034 21
foF2 5.950
foF1 2.60
foF1p N/A
foE 2.38
foEp 1.99
fxI 6.75
foEs N/A
fmin 1.00
MUF(D) 17.515
M(D) 2.94
D 3000.0
h'F 170.5
h'F2 215.0
h'E 91.3
h'Es N/A
hmF2 N/A
hmF1 N/A
hmE 106.4
yF2 N/A
yF1 N/A
yE 16.1
B0 N/A
B1 N/A
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Auto:
Artist5
500200
NNE
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Vo-
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SSW
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1 2 3 4 5 6 7 8 9 10
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Closing Thoughts

1) We found a density perturbation in our experiment in the fitted data, uncorrected data, and plasma line data. These are signatures of a minor TID.

2) Wintertime measurements are much more dependant on the Sun's position (faster sunsets/sunrises contribute to stronger gradients).

3) E-region decay occurs much quicker than F-region decay, driven by higher recombination rates and lack of photoionization at lower altitudes.

THANK YOU!

Questions?