
Nightflare
Group 4
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Candace Gray, Ben Marcotte, Viplaw Bhandari

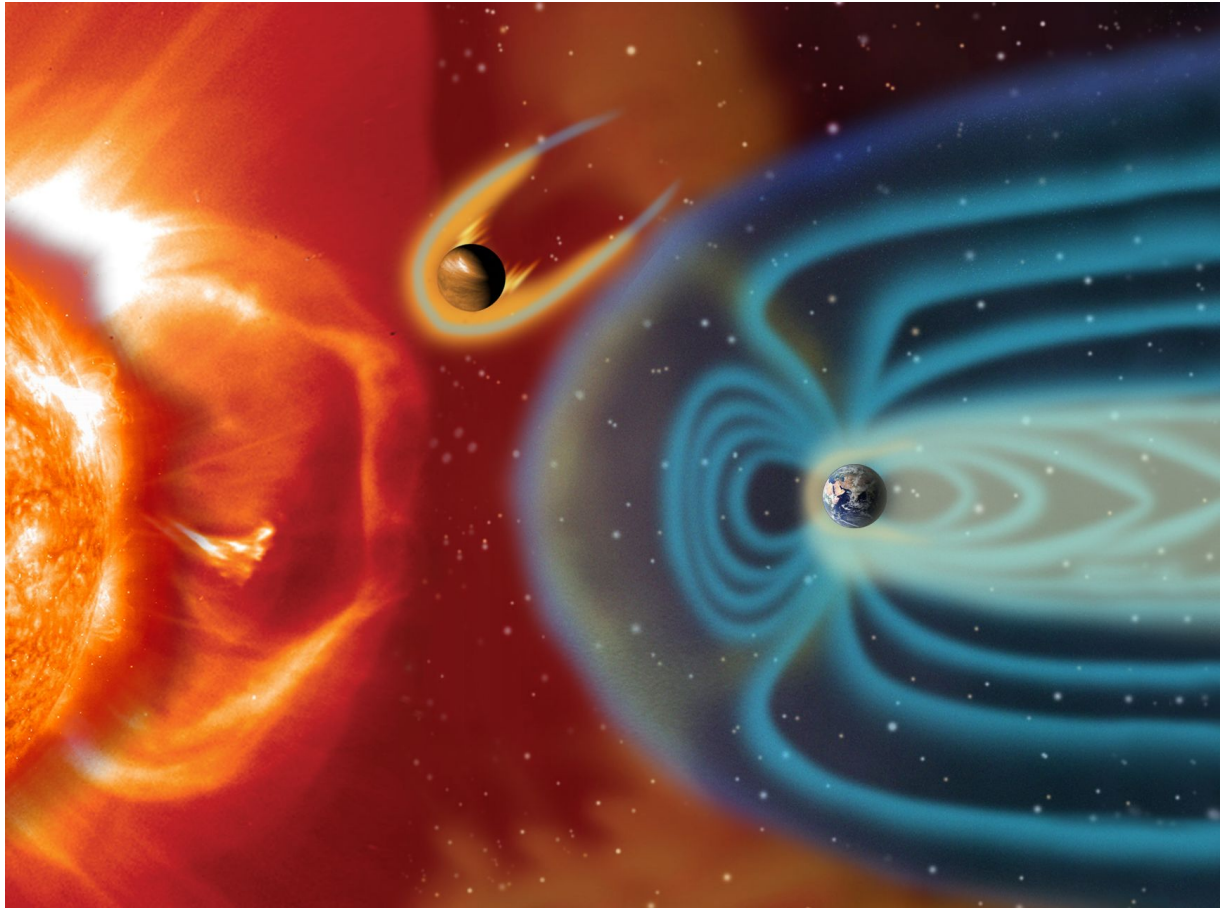

How do daytime solar flares affect the nighttime terrestrial ionosphere?

Outline

- Motivation (Name)
  - Solar flare erupted before observations
- Background (Name)
  - Sun
  - Impact on ionosphere
- Observations (Name)
- Results
  - PMSR (Team effort)
  - Sporadic E region (Tedi)
  - Auroral precipitation (name)
- Discussion
  - Connection between auroral precip and presence of PMSR and sporadic E?
  - Connection between solar storms? (Candace)
  - Connection between meteor showers? (Candace)
  - Look during northern summer, solar max, meteor storms (Candace)

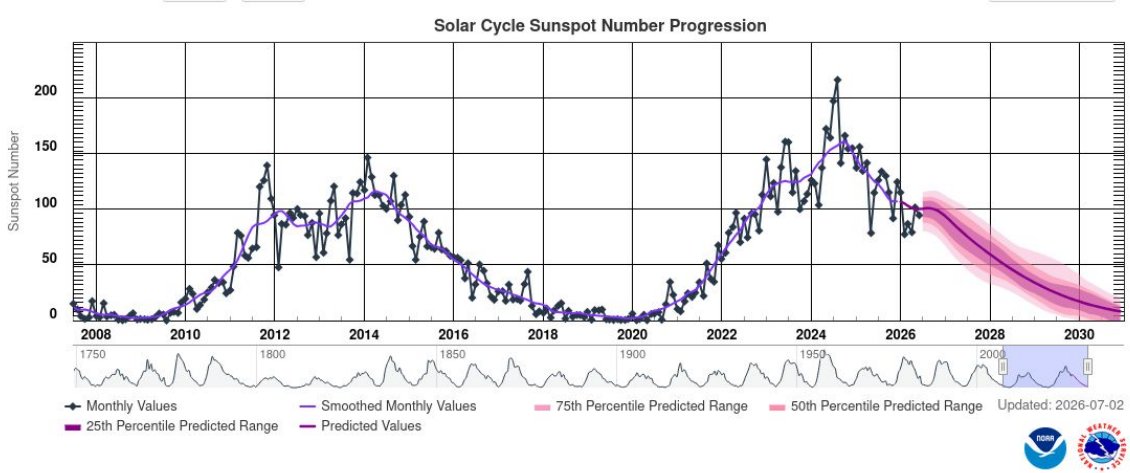
Background

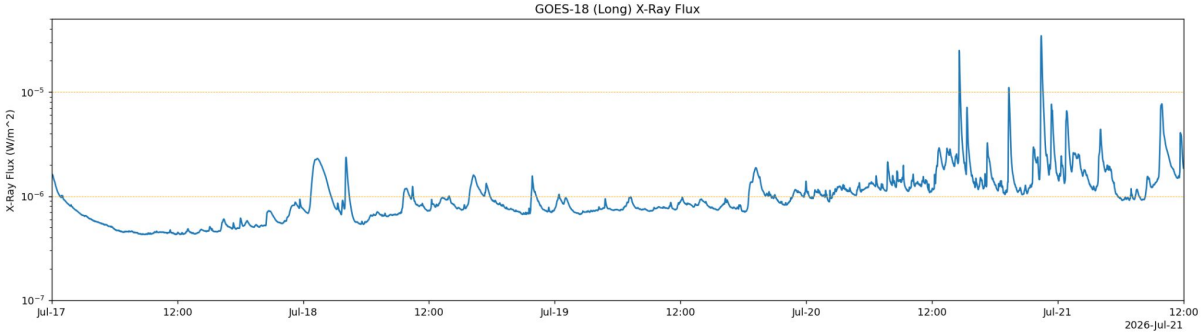
The Sun affects all aspects of the Earth’s atmosphere. Changes in solar activity will produce changes in our atmosphere to varying degrees. By studying both the Sun and Earth’s atmosphere, we can better understand stellar - planetary connections.



Background

- The Sun varies in an 11 year solar cycle.
- We are currently in the declining phase of Solar Cycle 26, with solar max peaking in 2024.
- The Sun was fairly quiet the week up to our July 21, 2026 observations.
- Several M flares erupted hours before our observation of the Earth's ionosphere.



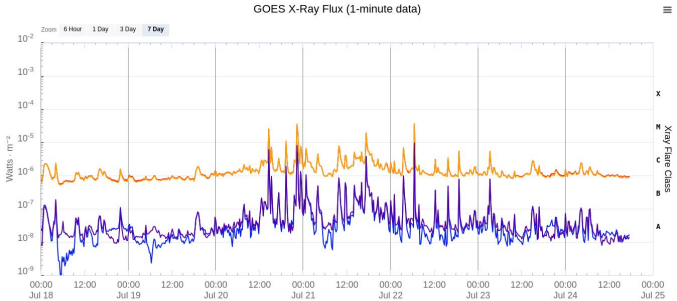


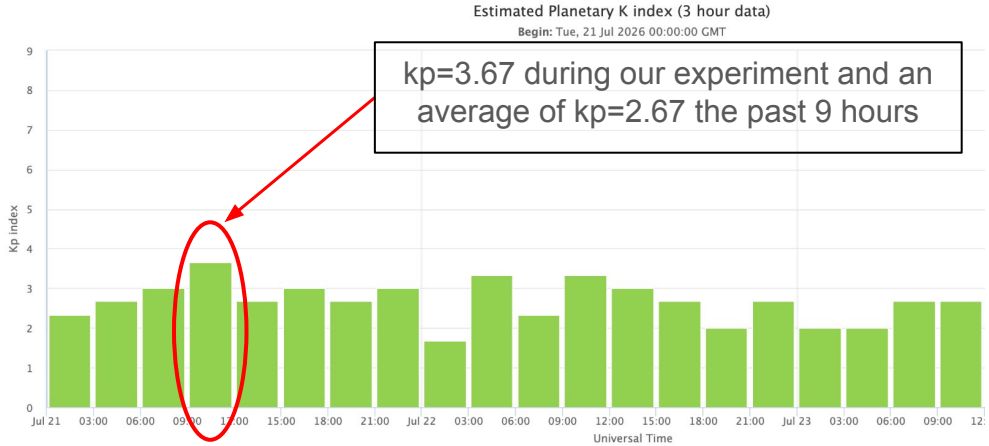
Rafael

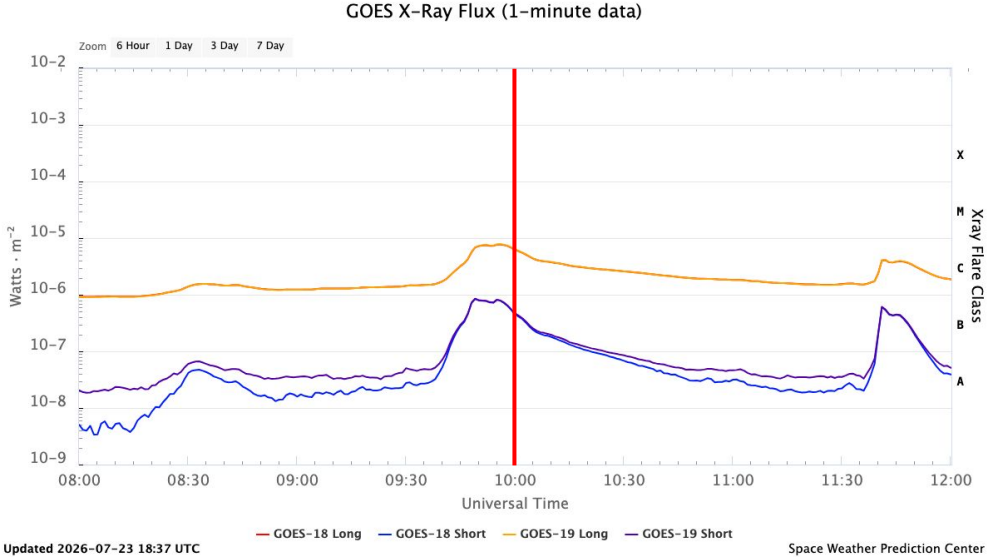
Background

Using Poker Flat Incoherent Scatter Radar (PFISR) located in Alaska, we were able to find evidence of Sporadic E layers, PMSE, and auroral precipitation. Our experiment includes the long pulse, alternating code, and barker code modes of the ISR.

July 20th, we had found a M class solar flare which prompted our investigation on its effects on night time auroral

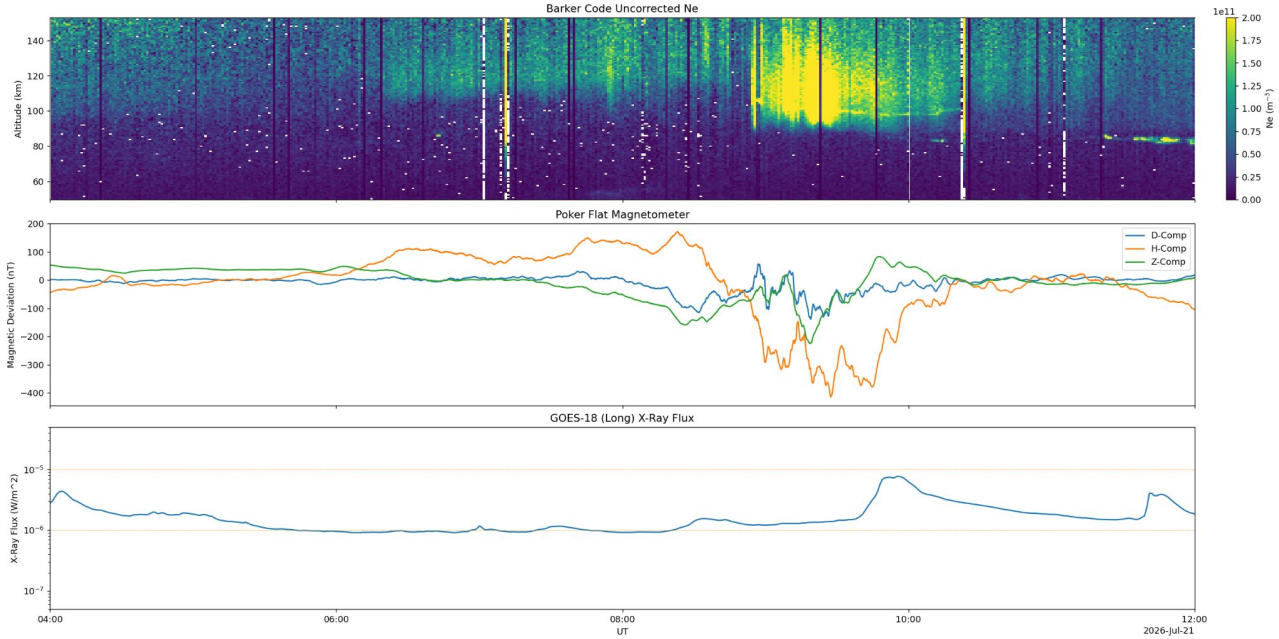




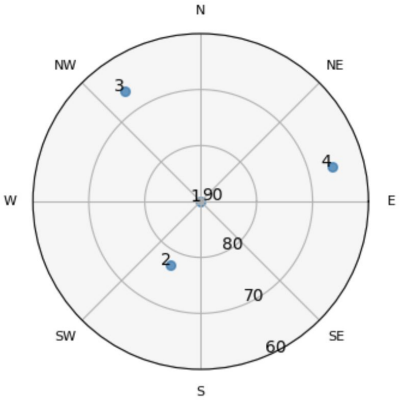


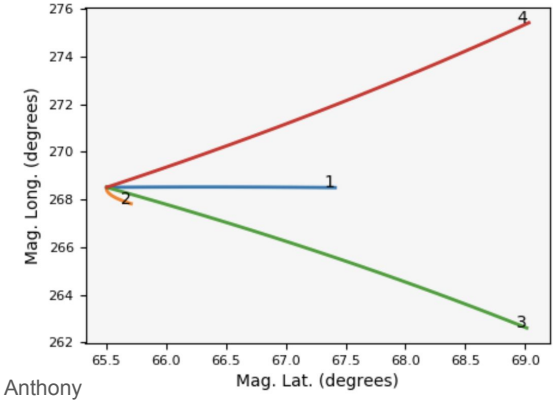
Motivation

The science goal of this experiment is to analyze the impact of daytime solar flares on ionospheric conditions at night.



Experiment Design & Beam Geometry





Time: July 21st, 10:01 - 12:01 UT

Location:
65.12992° N, 147.47104° W, 213 m
Poker Flat Research Range, Fairbanks, Alaska.

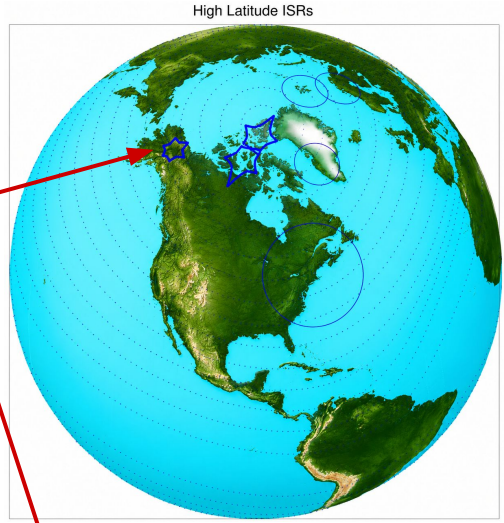
Modes: Long Pulse, Alternating Code, and Barker Code

Transmitting Frequency Band: 449 - 450 MHz

Beamcode: Azimuth, Elevation:

1. 64016: 14.04, 90.00 (vertical)
2. 64157: -154.30, 77.50 (upB)
3. 64964: -34.69, 66.09
4. 65066: 75.03, 65.56

PFISR



Anthony

Noctilucent Clouds and Polar Mesospheric Summer Echoes

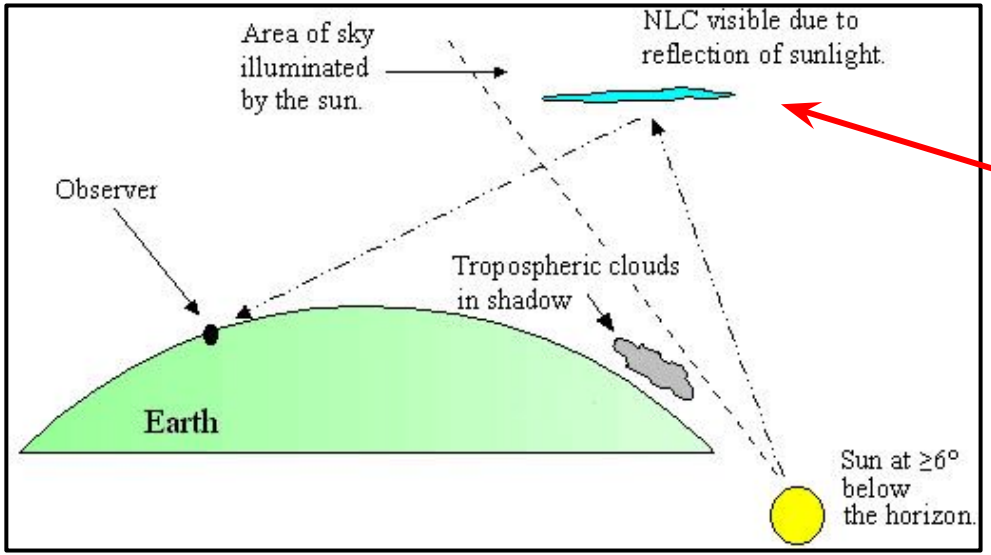


Figure from http://www.nightskyhunter.com

Figure from https://cloudappreciationsociety.org/

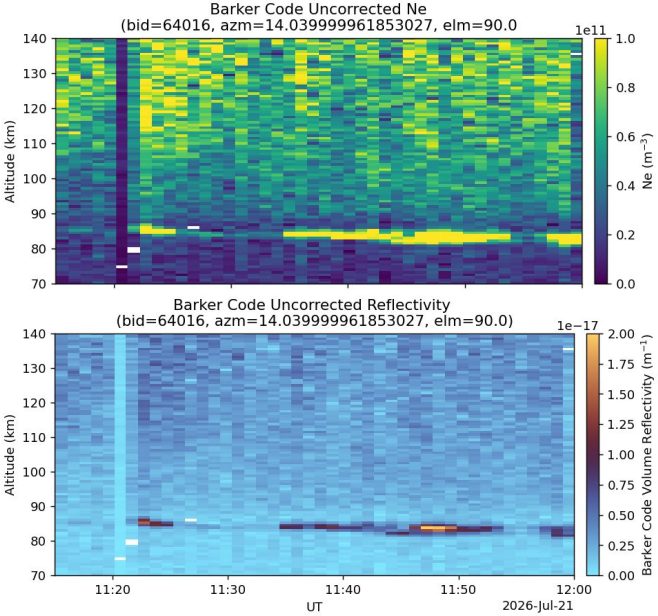
Polar Mesospheric Summer Echoes (PMSE)

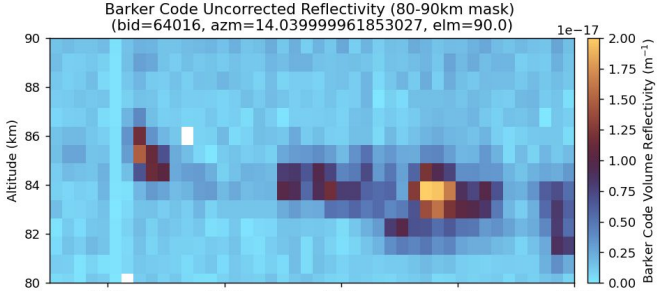
PMSE were observed during our experiment from 11:00 UT to 12:00 UT but should be represented as volume reflectivity by multiplying by the effective cross scattering of each electron. We apply this calculation to the first plot. We detected PMSE in all four beams but we choose the vertical beam to investigate.

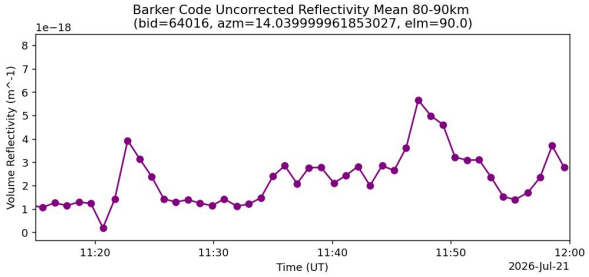
$$\eta = (4.99 \times 10^{-29} m^2)\, n_e$$

Where η = reflectivity in m^-1

and n_e = electron density in m^-3.



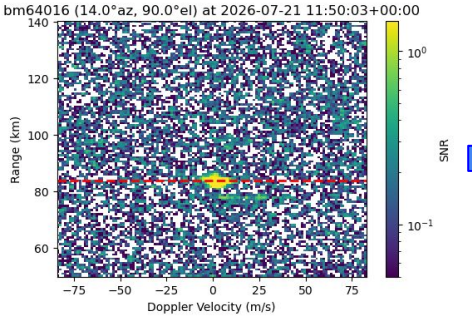


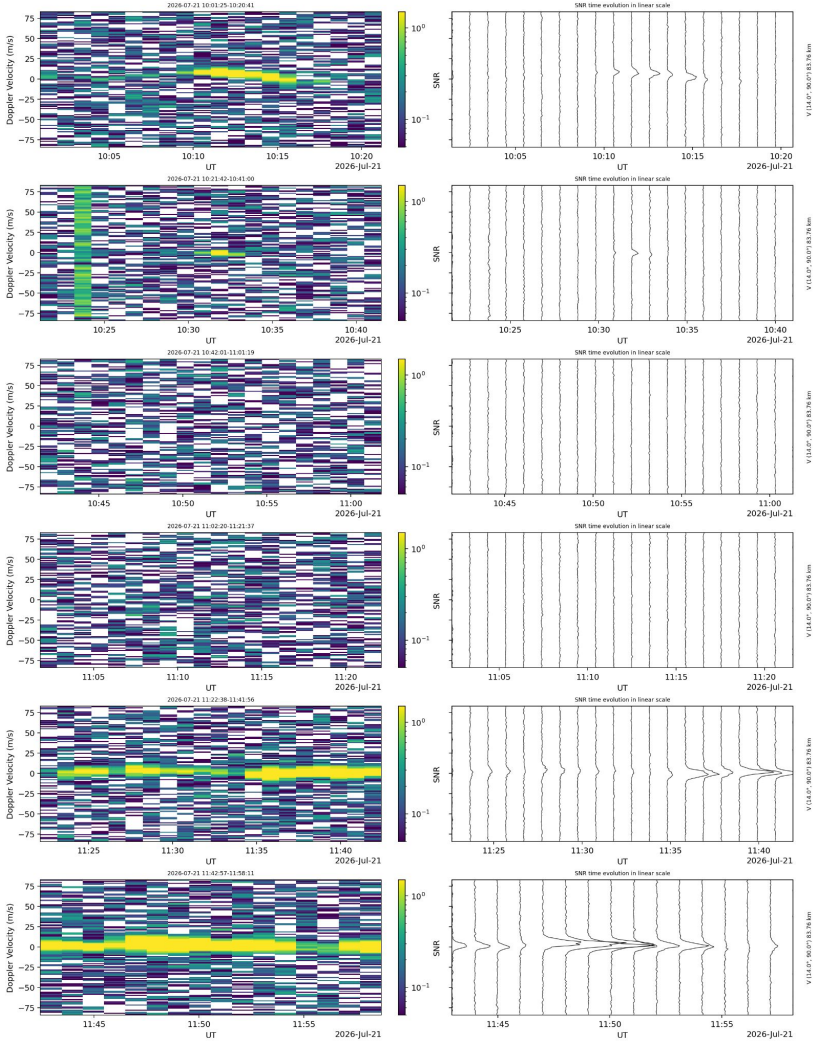


Anthony

PMSE Cont.

We also obtained a level 1 spectra analysis of the PMSE using a methodology found in a previous paper which reported on multi-beam spectral observations of PMSE on PFISR data *(Nicolls. et al, 2018)*.



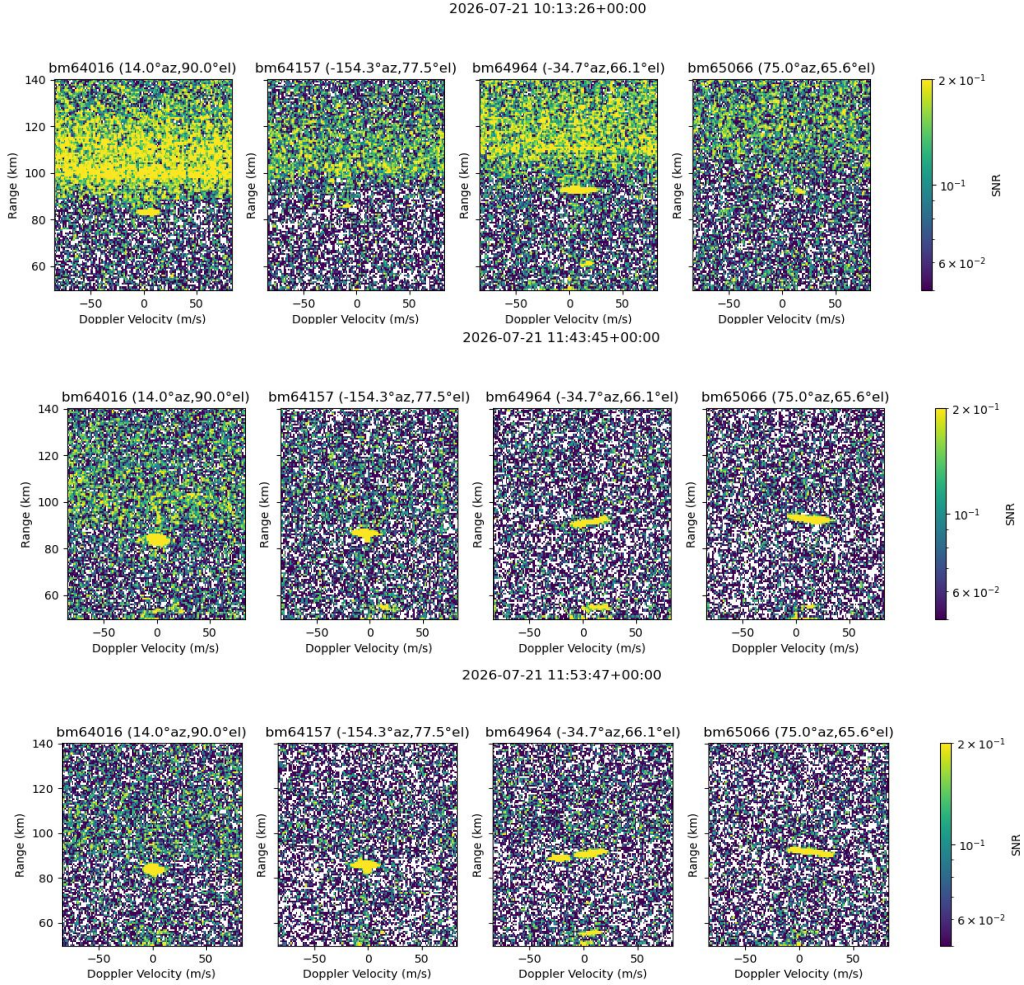


Implementation:

a) Take an 83km altitude slice while preserving the full Doppler velocity for 20 minutes of spectra. Then plot each slice as a vertical column and vary them in time.

b) Take each vertical column (1 min resolution) of plot a. and plot them as individual lines with a scaling factor applied.

Doppler Velocity vs Range at different time- PMSE seems (at different beam condition)



- Echoes appear in multiple beams with narrow Doppler widths.
- PMSE intensity and structures are shown at ~ 10:13UT, ~ 11:42 UT & 11:54UT

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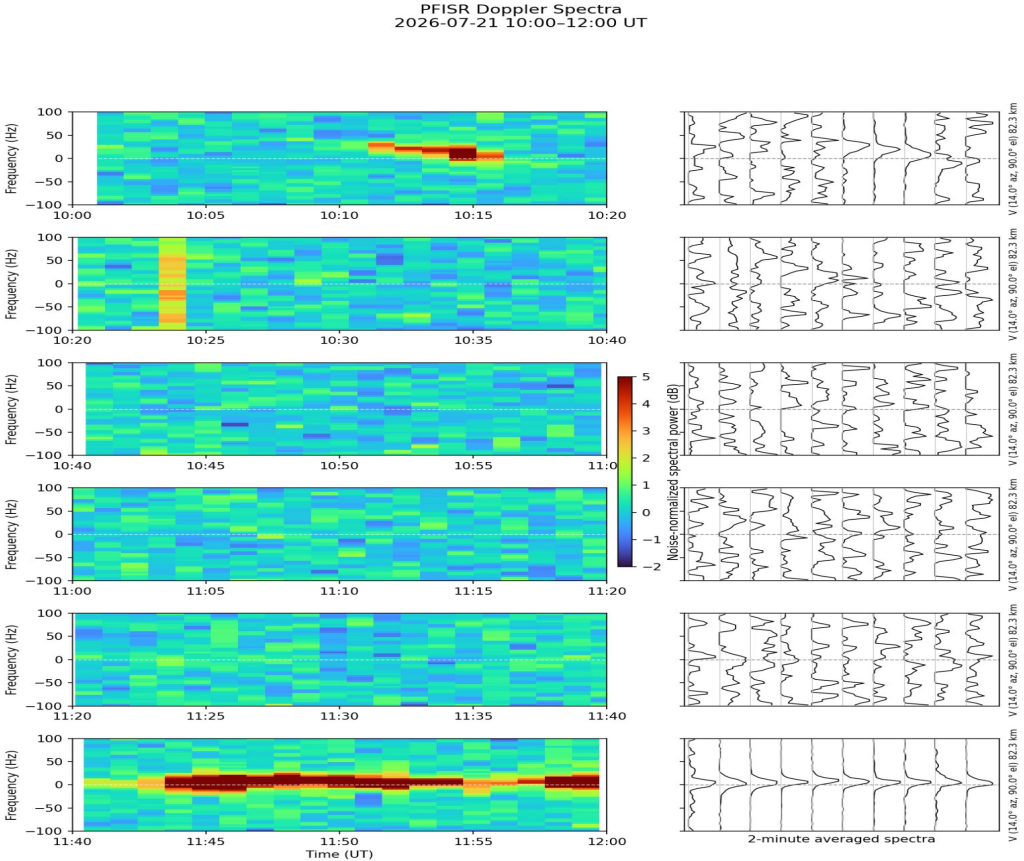
PMSE Doppler Spectral Characteristics at 82.26 km



- range-gate spacing is approximately **0.7495 km**,nearest-gate interval of approximately **82.26 ± 0.375 km**

- Narrow spectral width indicates a small Doppler-velocity spread and weak velocity fluctuations in the PMSE region near 82.3 km.

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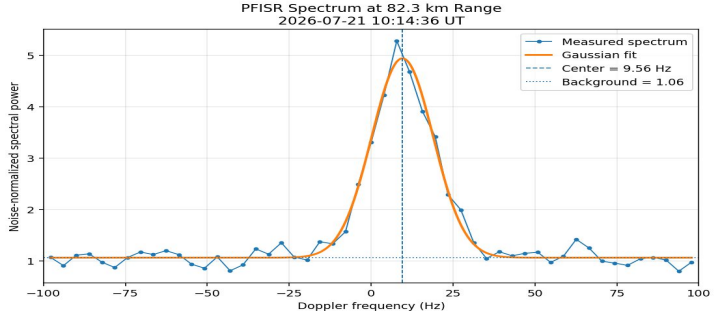
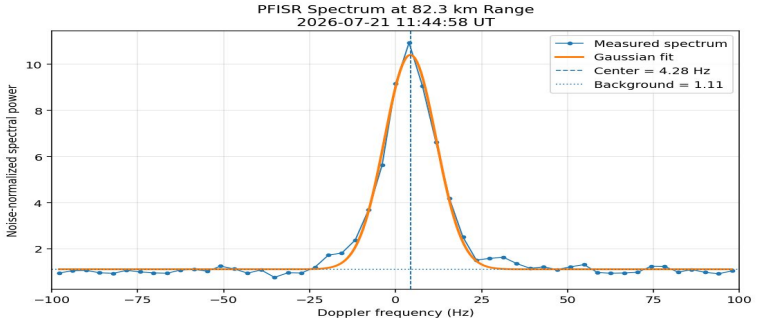
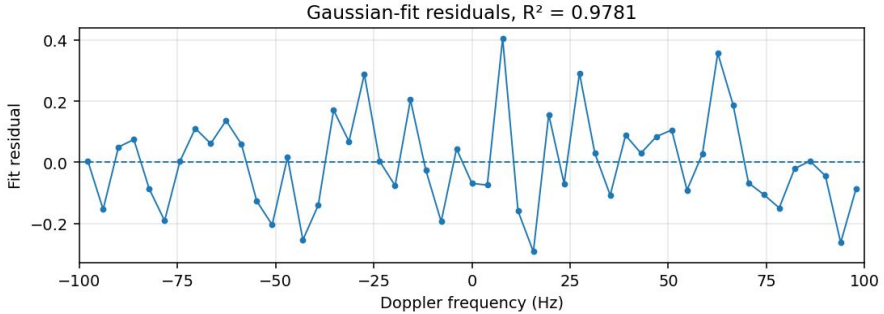
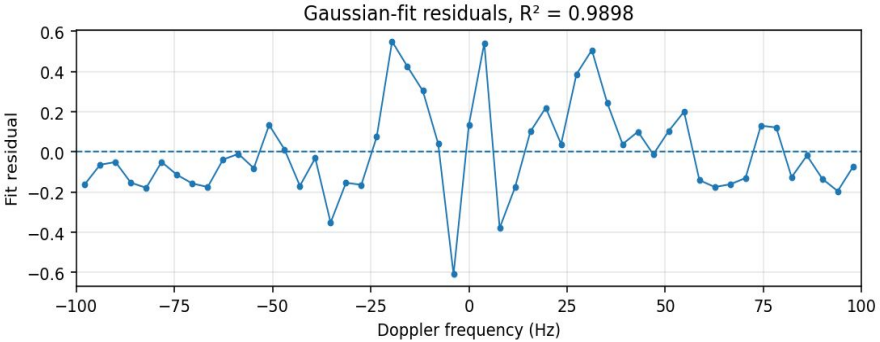
PMSE Doppler Spectral Characteristics at 82.26 km, and Gaussian-fit check









The observed PMSE spectral width is **22.11 ± 0.66 Hz FWHM**, corresponding to a velocity width of **7.37 ± 0.22 m/s**

PMSE spectral width is 17.71 ± 0.36 Hz FWHM, corresponding to a velocity width of **5.90 ± 0.12 m/s**.

The decrease in spectral-center frequency from 9.56 to 4.28 Hz indicates a reduction in the line-of-sight velocity of the PMSE scattering layer, potentially associated with
- changing mesospheric winds or -gravity-wave modulation.

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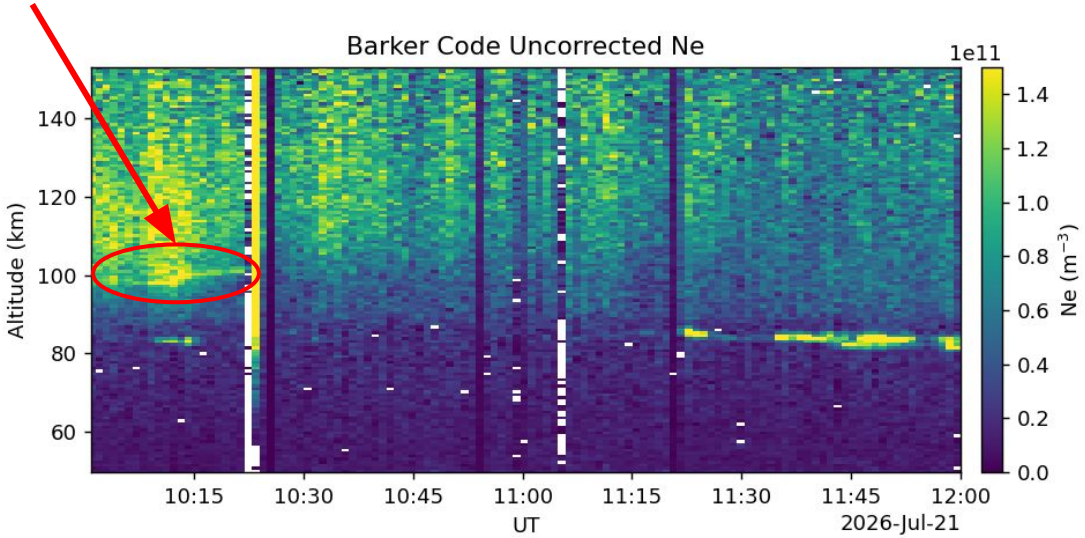
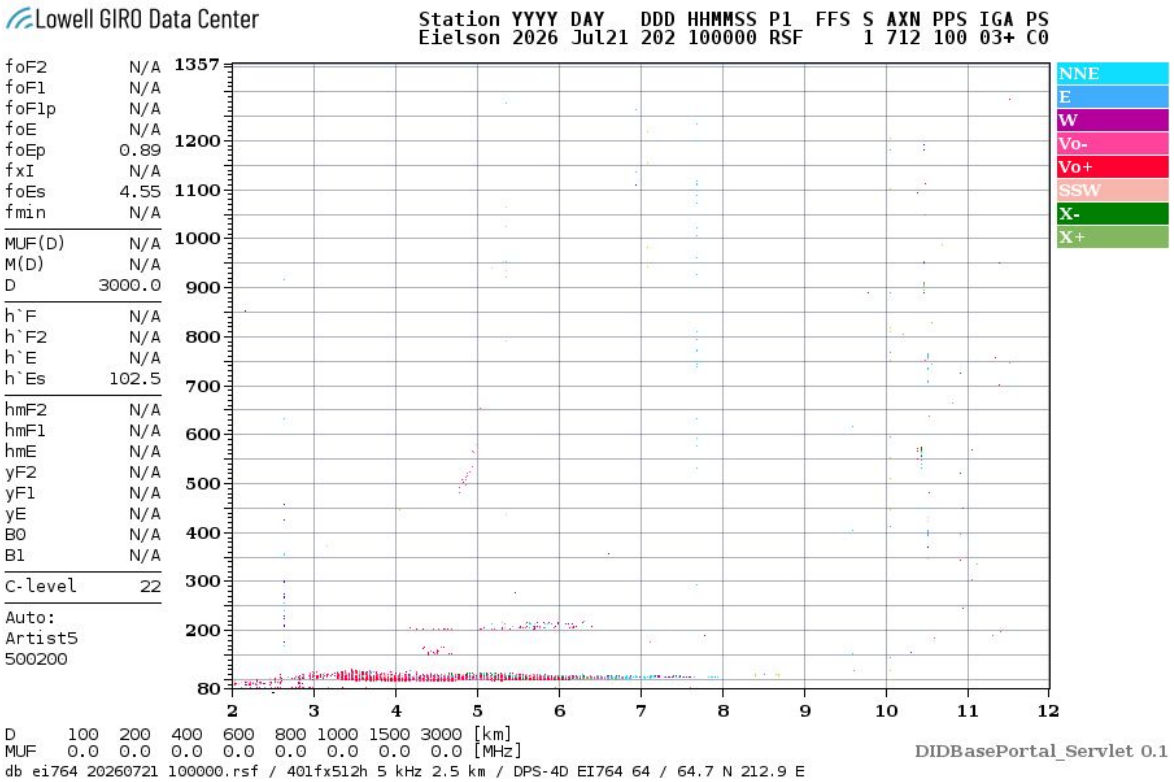
Sporadic E

- We also noticed the possibility of a Sporadic E at the 100km layer.
- Sporadic E layers are the result of wind shearing with metallic ions in the E-region.
- They result in radio waves being unable to propagate above 15 MHz.
- We tried to cross correlate with different ionograms to confirm its existence.

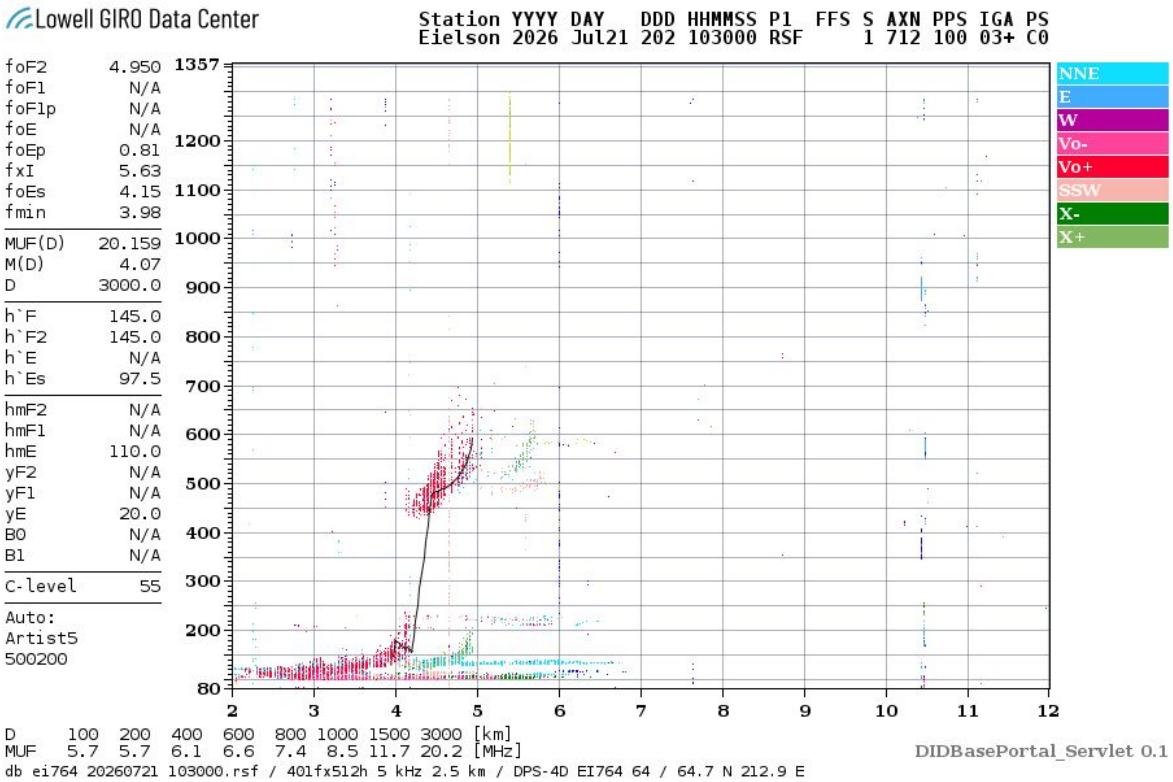


Ionosonde: 10 UT



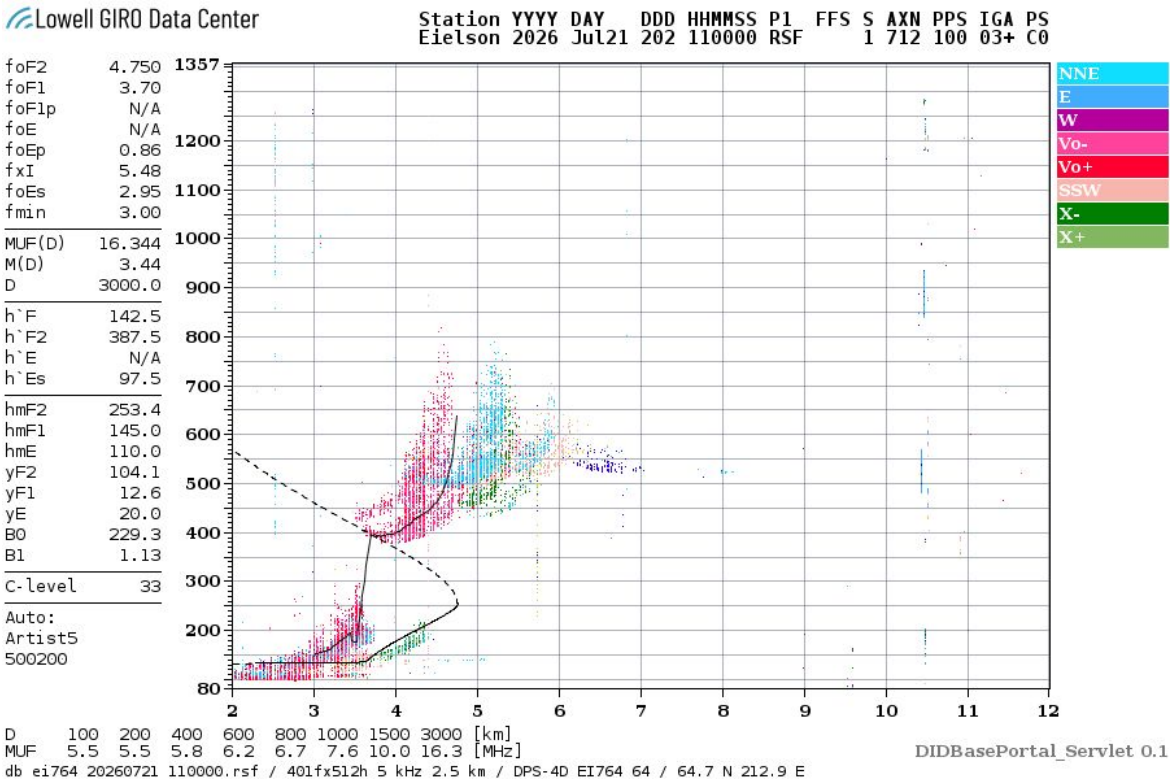
From: https://giro.uml.edu/ionoweb/#

Ionosonde: 10:30 UT



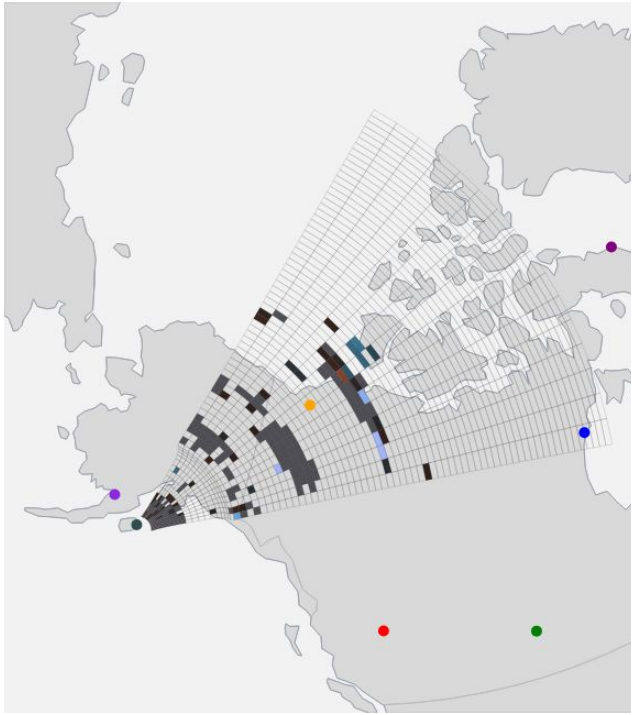
From: https://giro.uml.edu/ionoweb/#

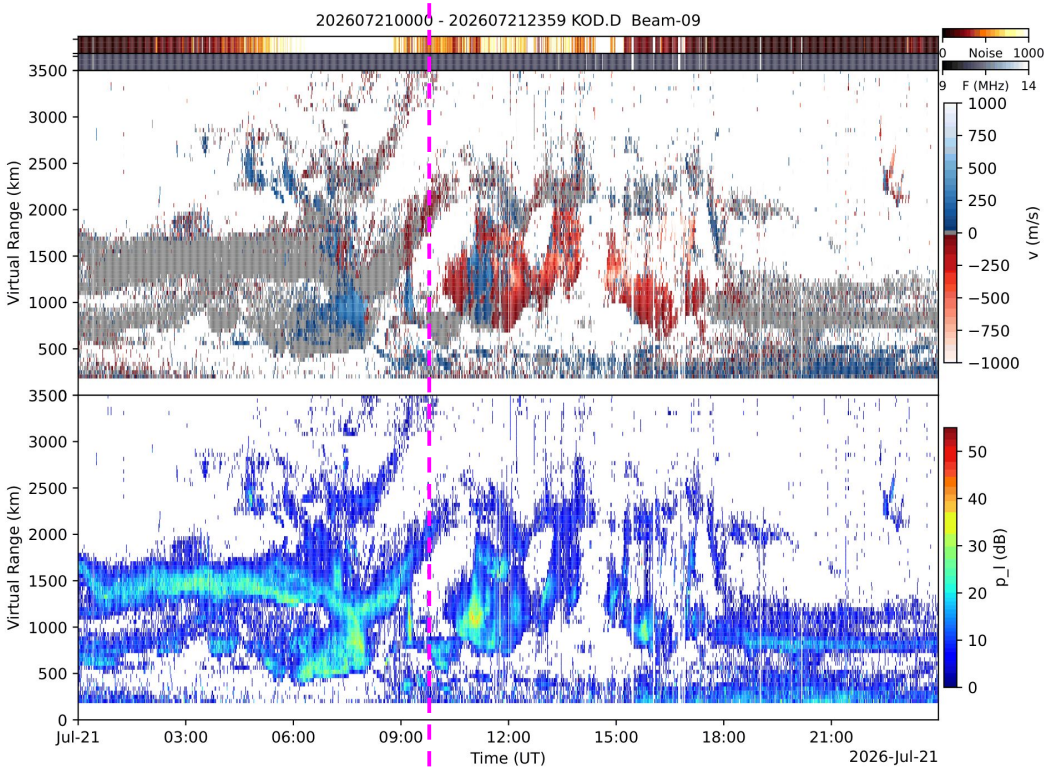
Ionosonde: 11 UT



From: https://giro.uml.edu/ionoweb/#

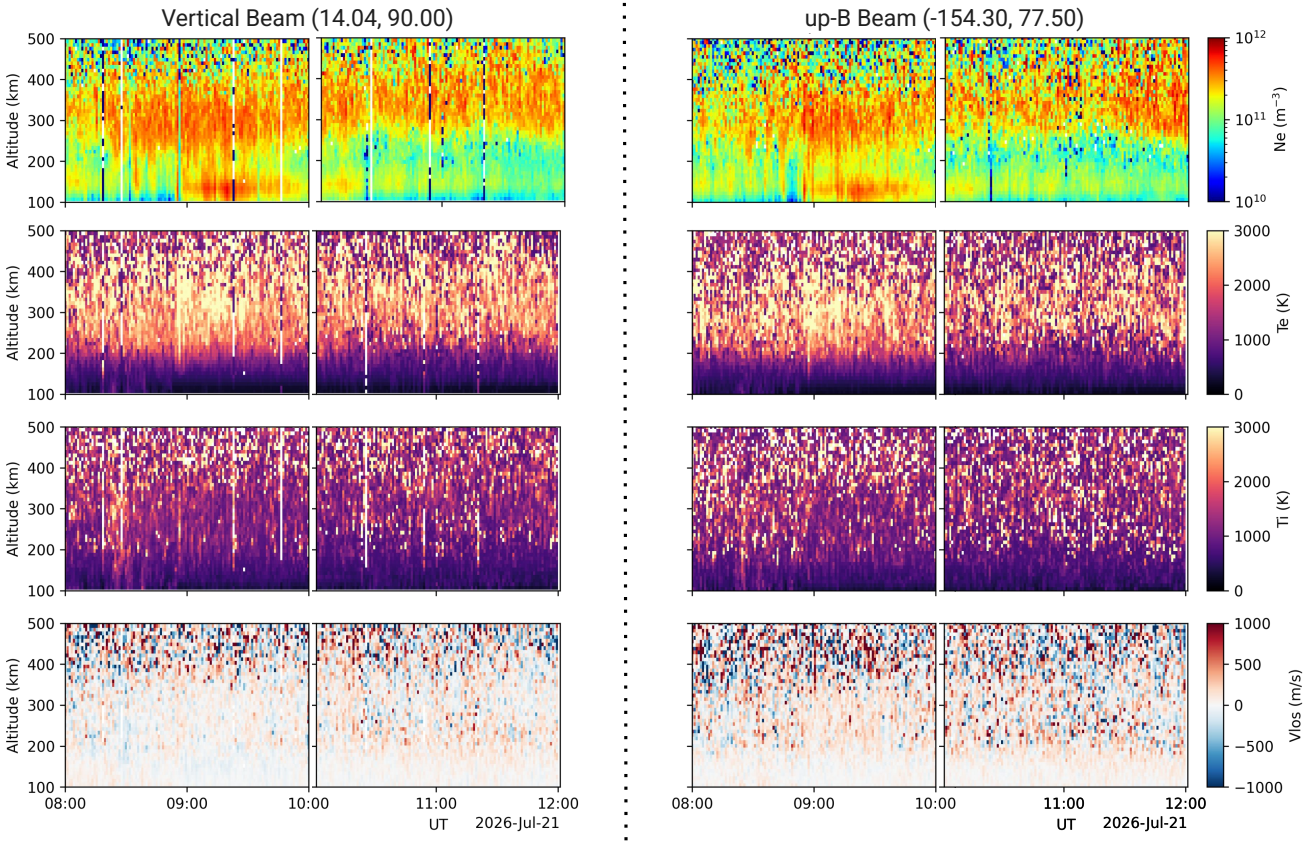
SuperDARN: Kodiak



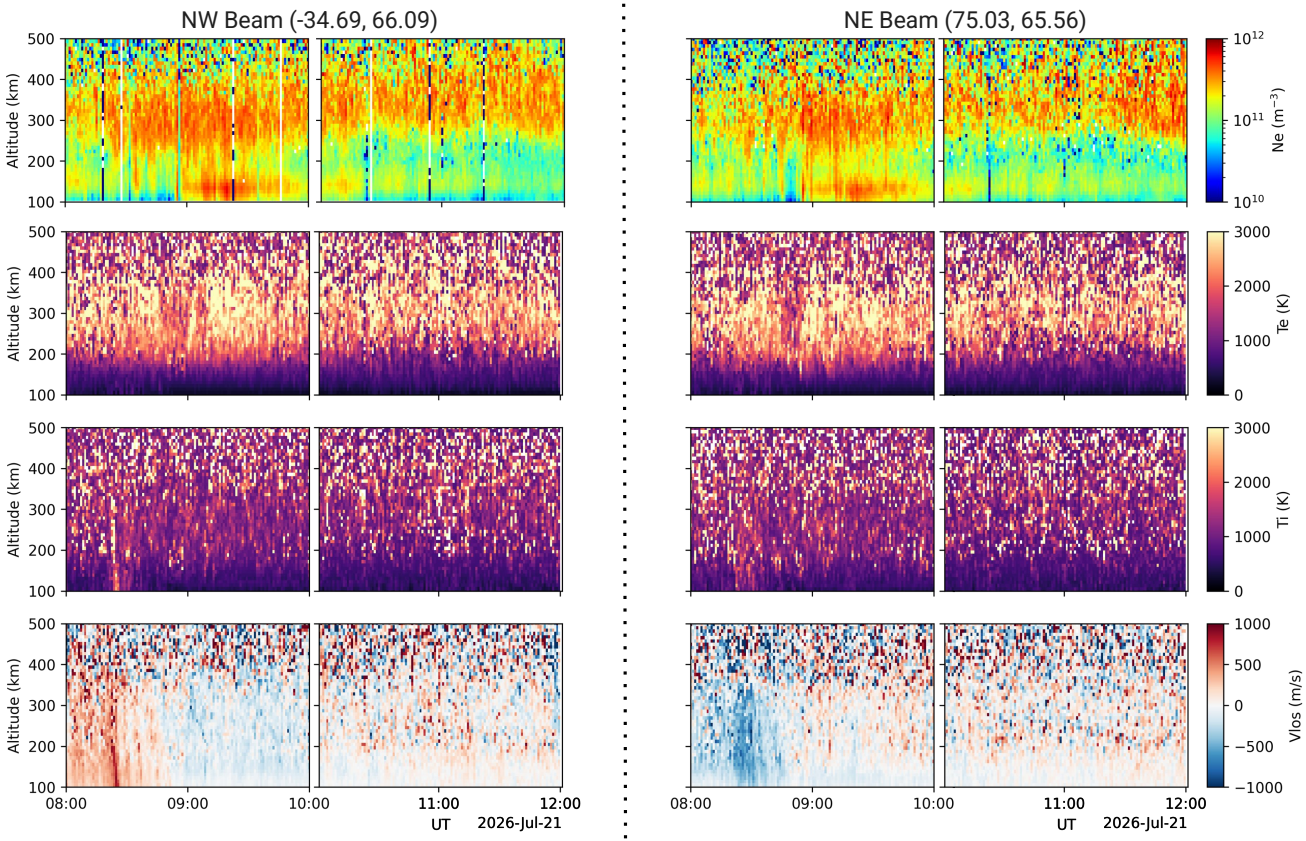


From: https://superdarn.met.psu.edu/summary-plots

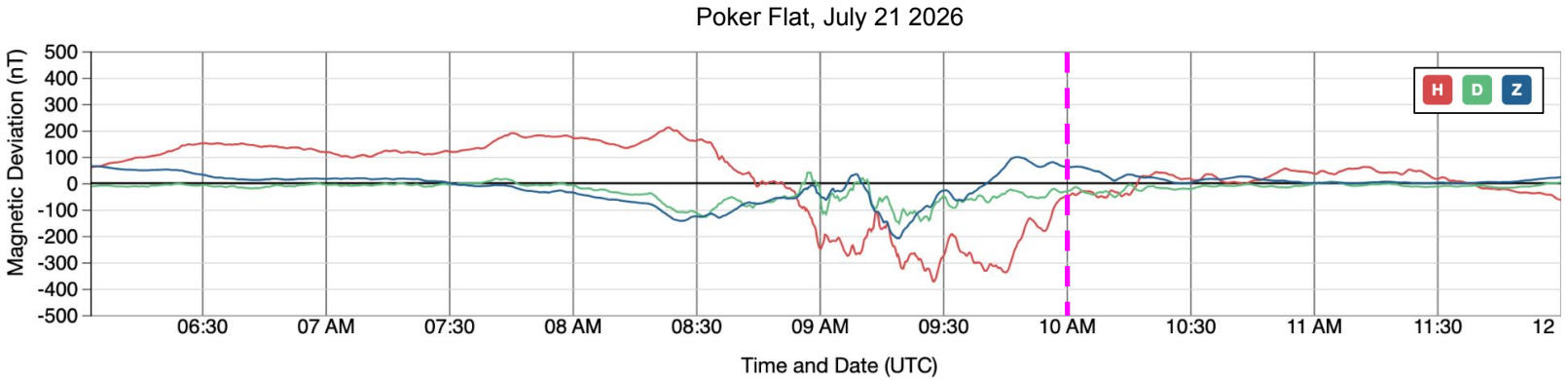
Long Pulse


Vertical Beam (14.04, 90.00)
up-B Beam (-154.30, 77.50)
Altitude (km)
Ne (m^{-3})
Te (K)
Ti (K)
Vlos (m/s)
08:00
09:00
10:00
11:00
12:00
UT
2026-Jul-21

Long Pulse


NW Beam (-34.69, 66.09)
NE Beam (75.03, 65.56)
Altitude (km)
Ne (m^{-3})
Te (K)
Ti (K)
Vlos (m/s)
08:00
09:00
10:00
11:00
12:00
UT
2026-Jul-21

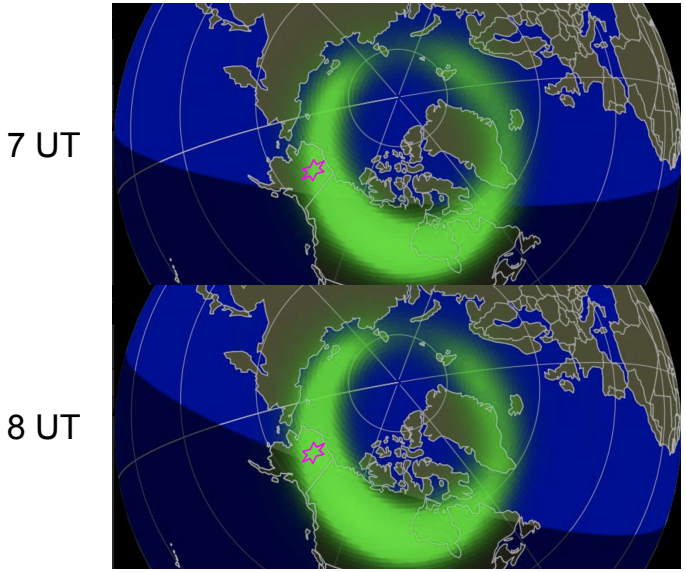
Magnetometer

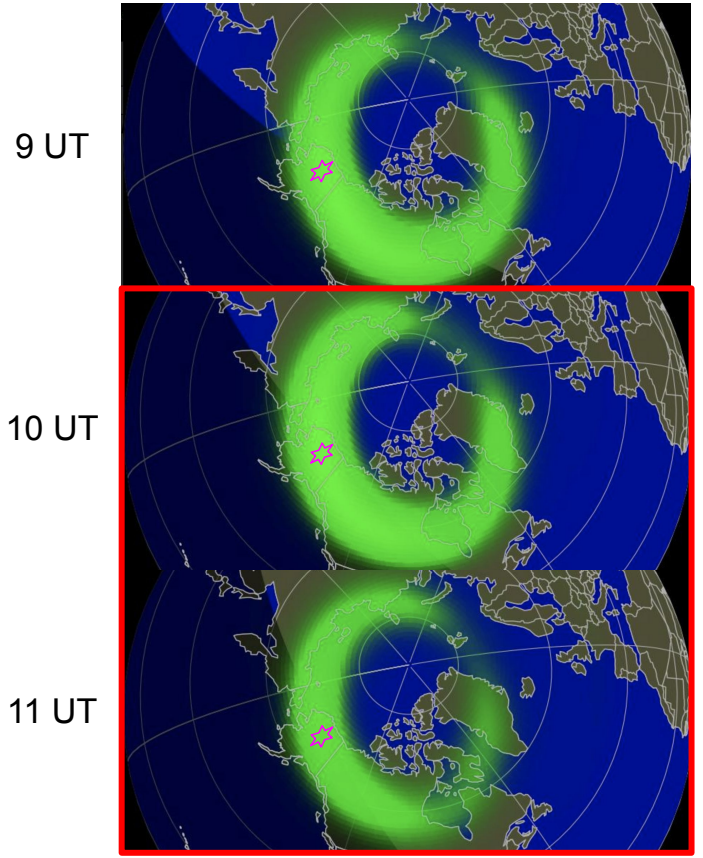


\+ Eastward electrojet
\- Westward electrojet

From: https://www.gi.alaska.edu/monitors/magnetometer/archive

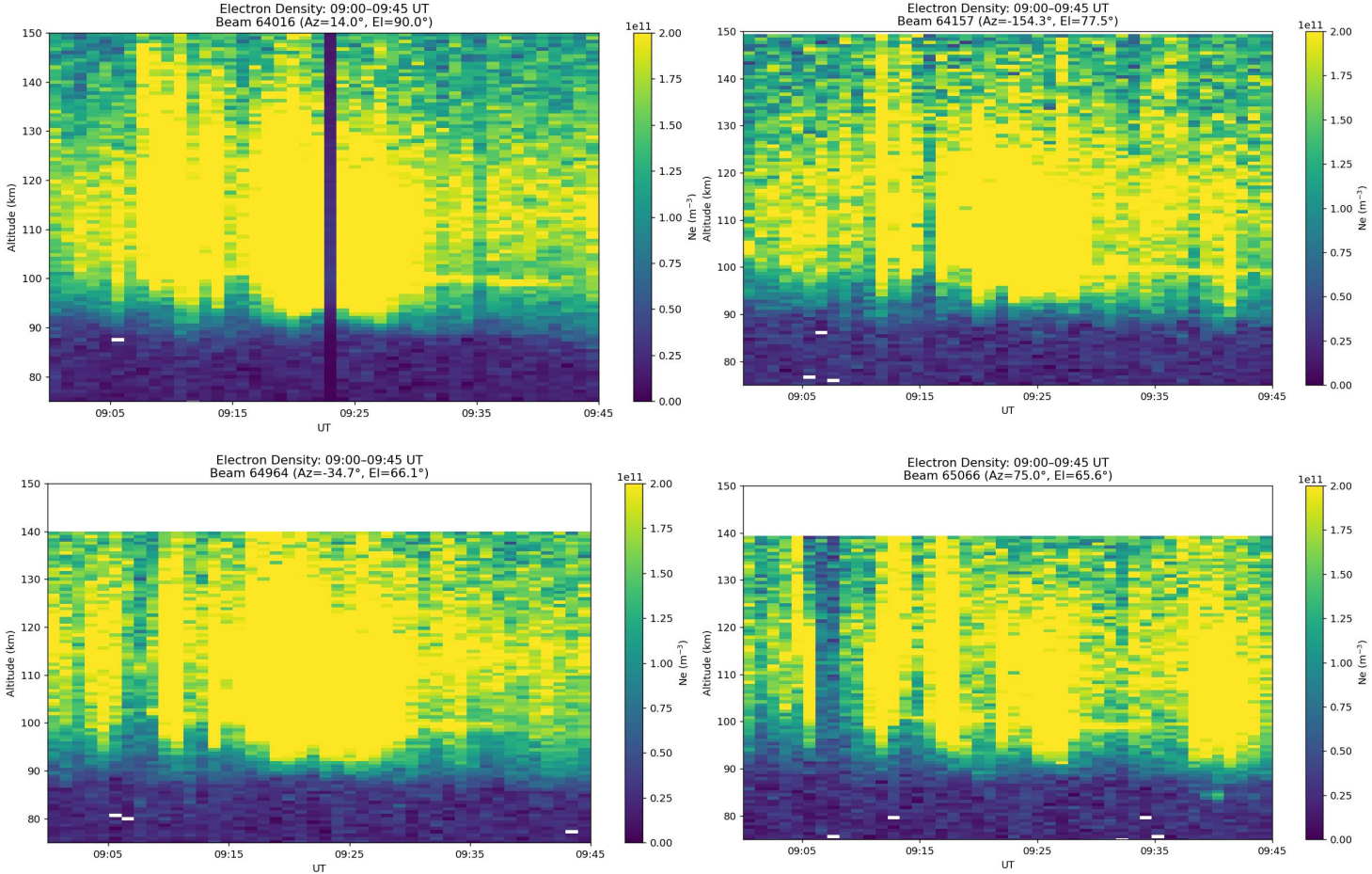
Auroral Oval





From: https://www.spaceweather.gov/

Auroral E-Region Electron Density Across different AMISR Radar Beams



-Beam-to-beam differences show **spatial structure and movement of the auroral precipitation**.

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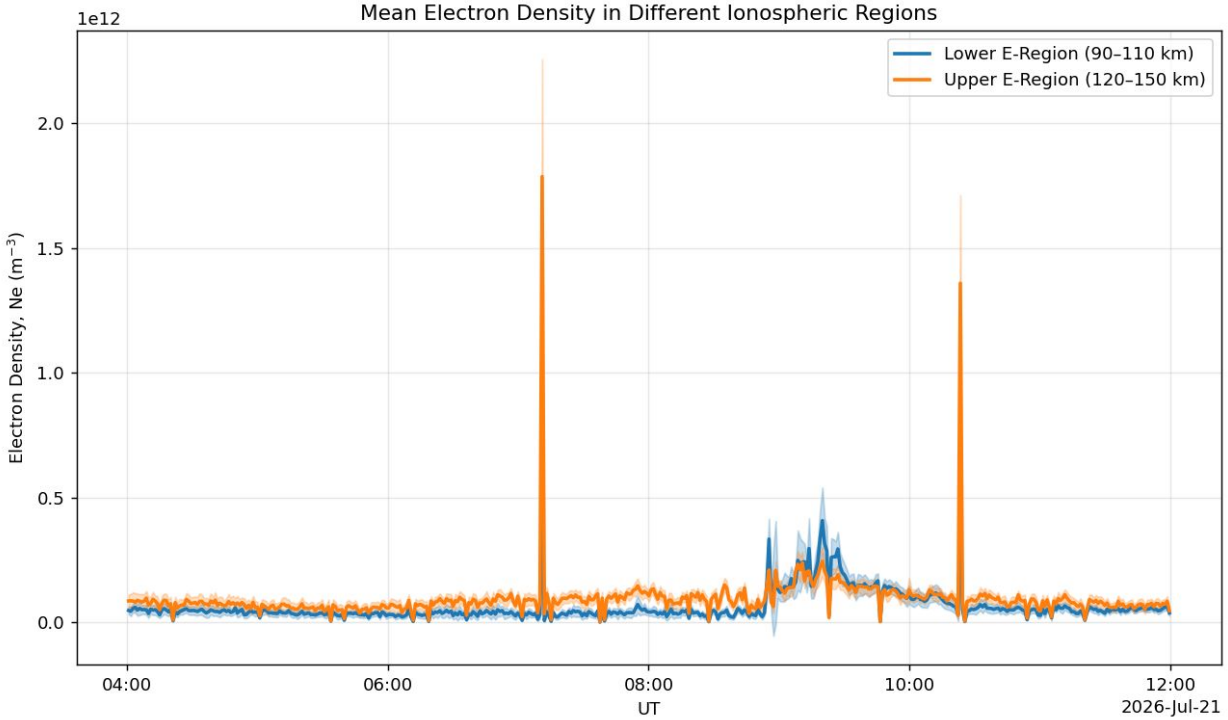
Average Electron density in E- Region



Used - (beamcode: azimuth, elevation):
(64016: 14.04, 90.00),

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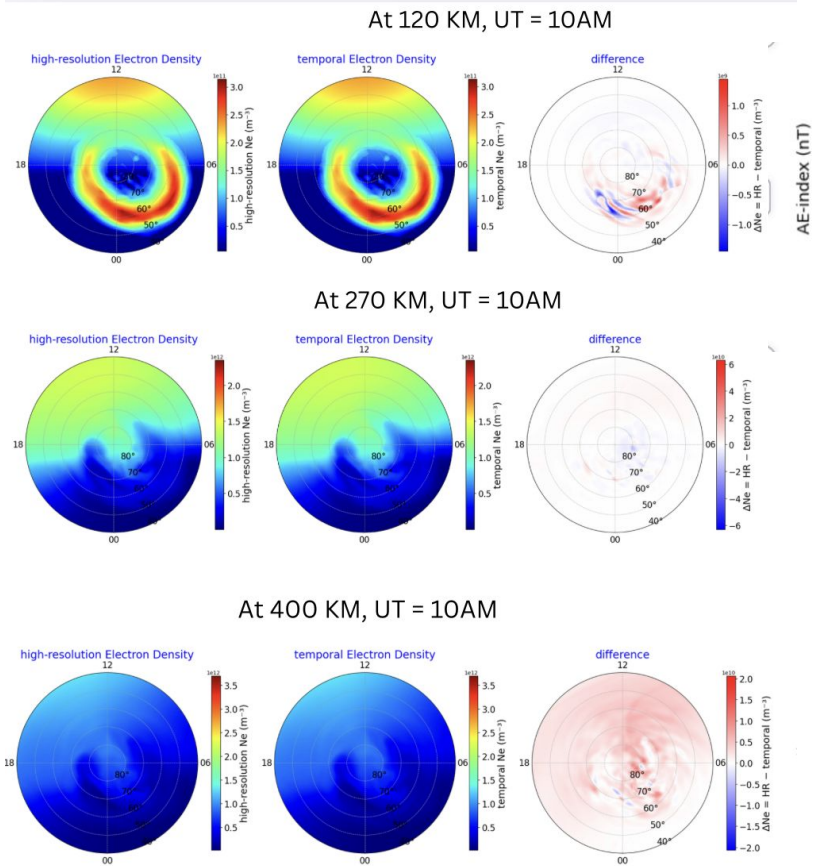
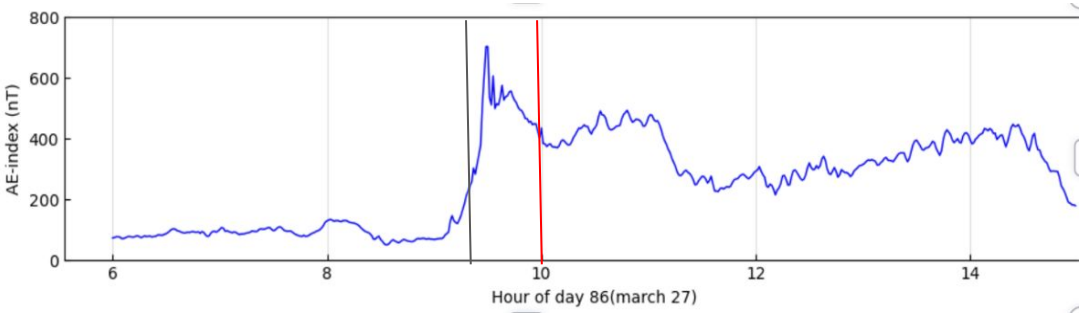
Altitude-Dependent Auroral Electron Density During the 27 March 2014 Substorm- GITM Model, using SuperDARN data

a



b



- The difference between the high-resolution and temporally smoothed electron density reveals mesoscale temporal variations with removing very rapid variations.
- to look transient feature,
  Work is extended from 10 min to 1 hours.

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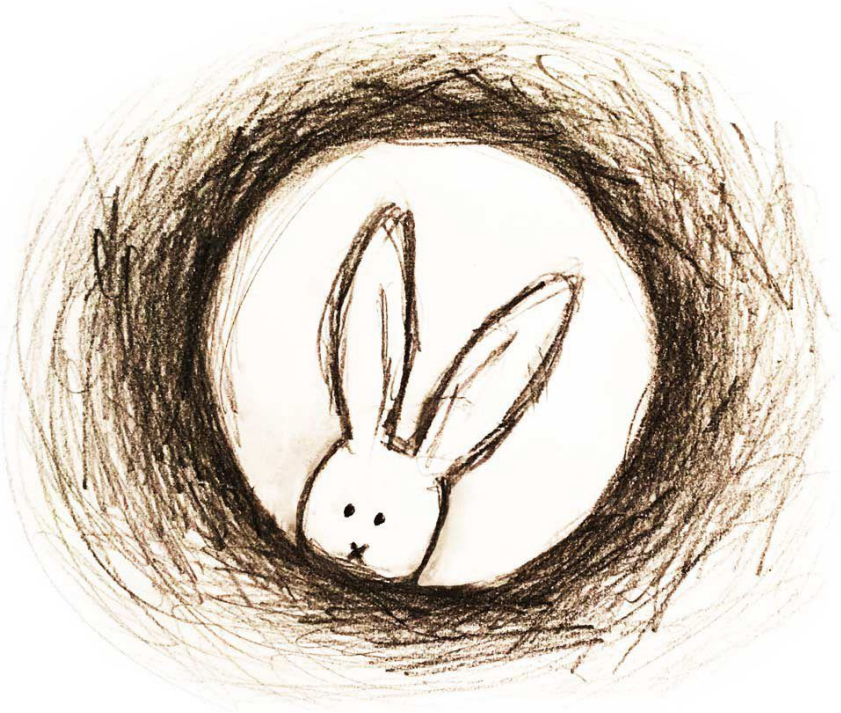
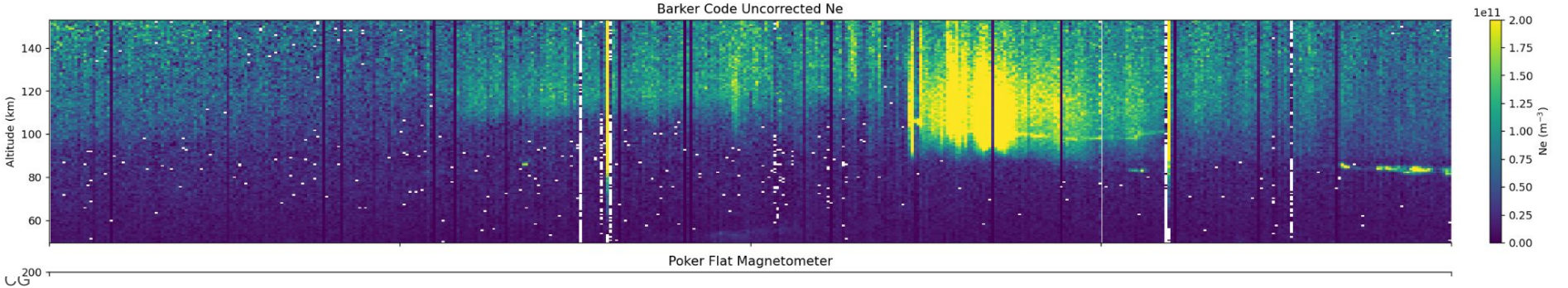
Discussions

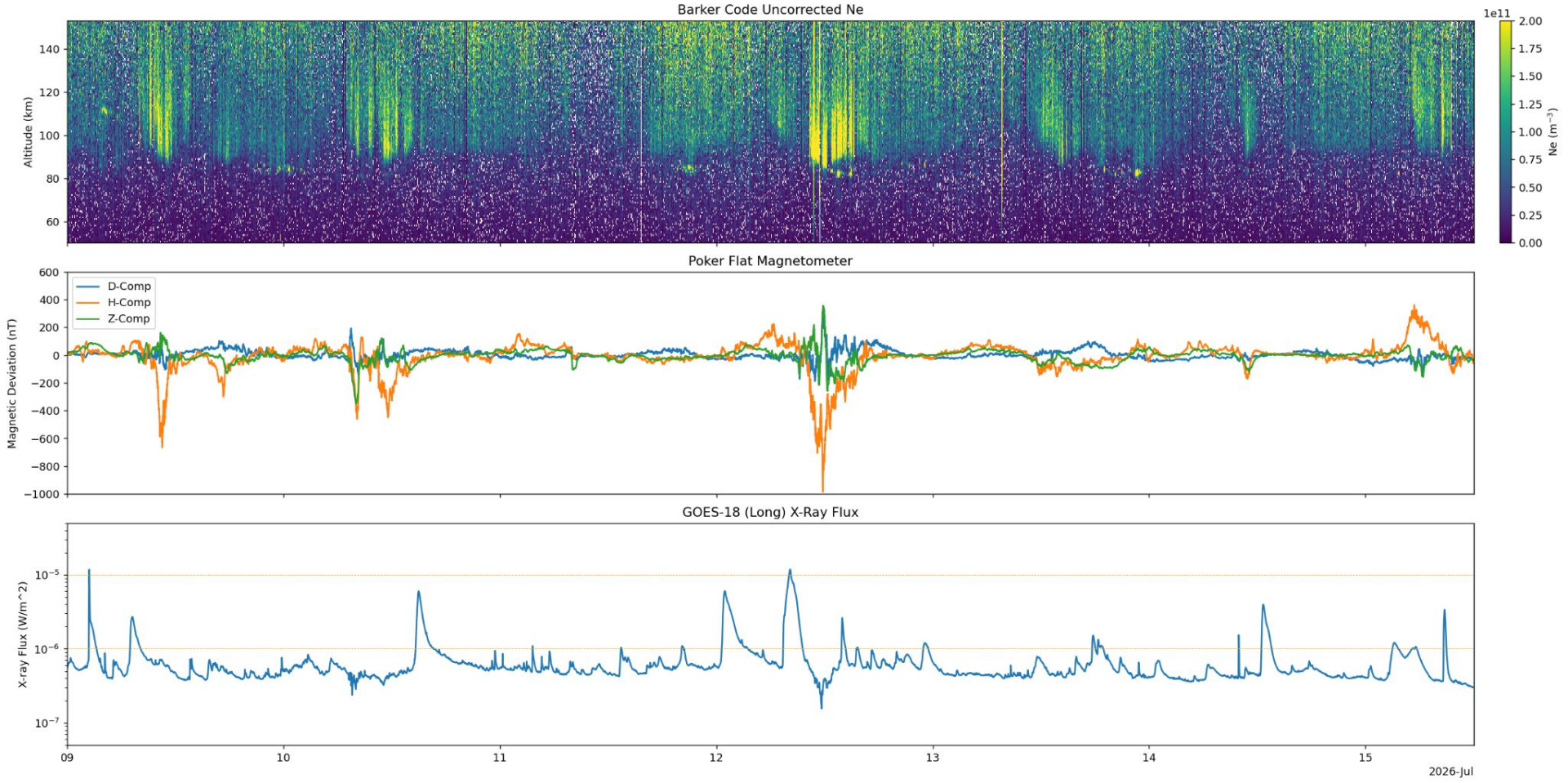
- PMSE, sporadic E region, and auroral precipitation *appear* to be interconnected!
- Do previous observations support this hypothesis?
- Are there potential trends between the intensity of sporadic E, PMSE, and solar activity?





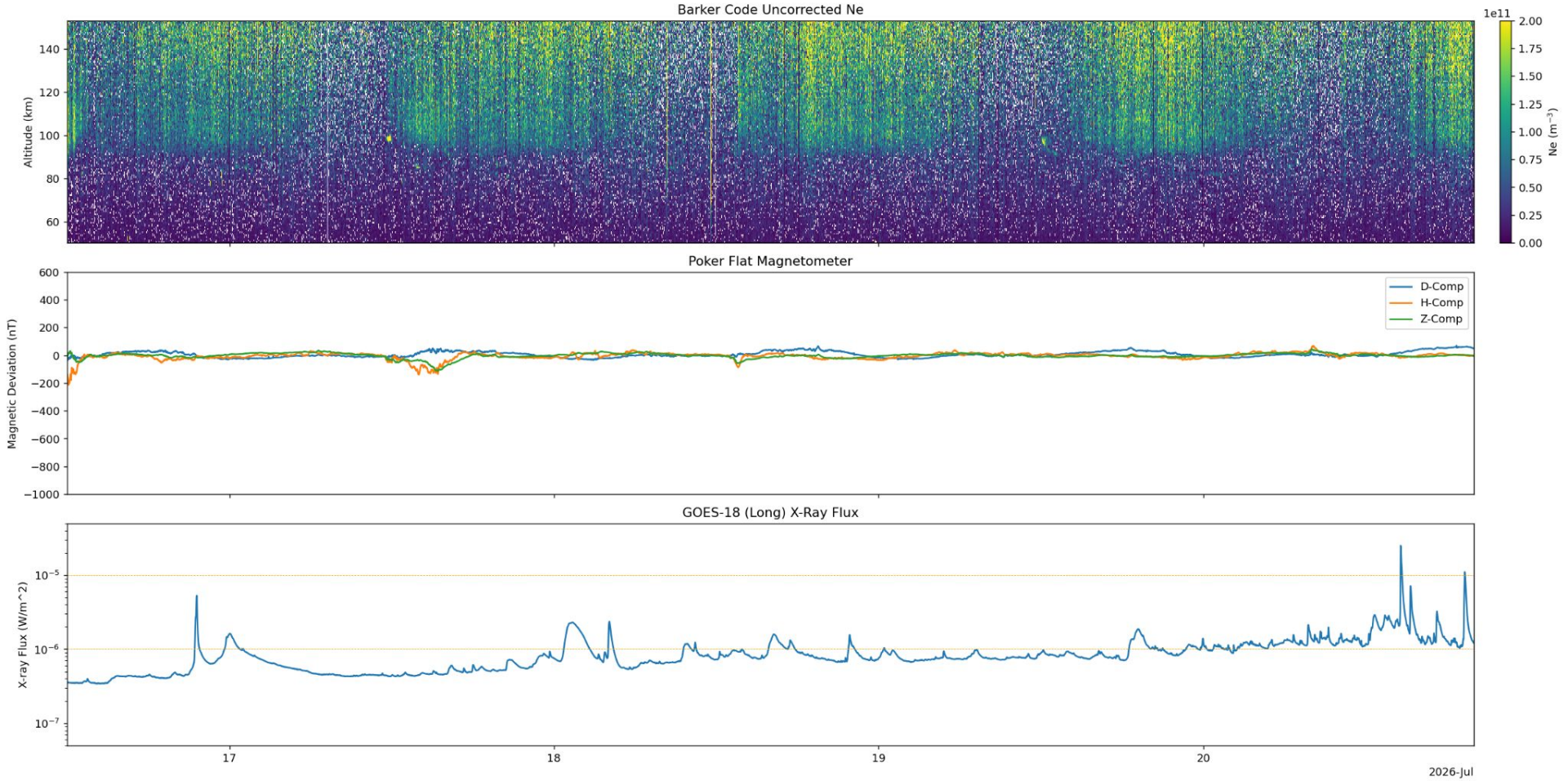
High Geomagnetic Activity, High Solar Activity

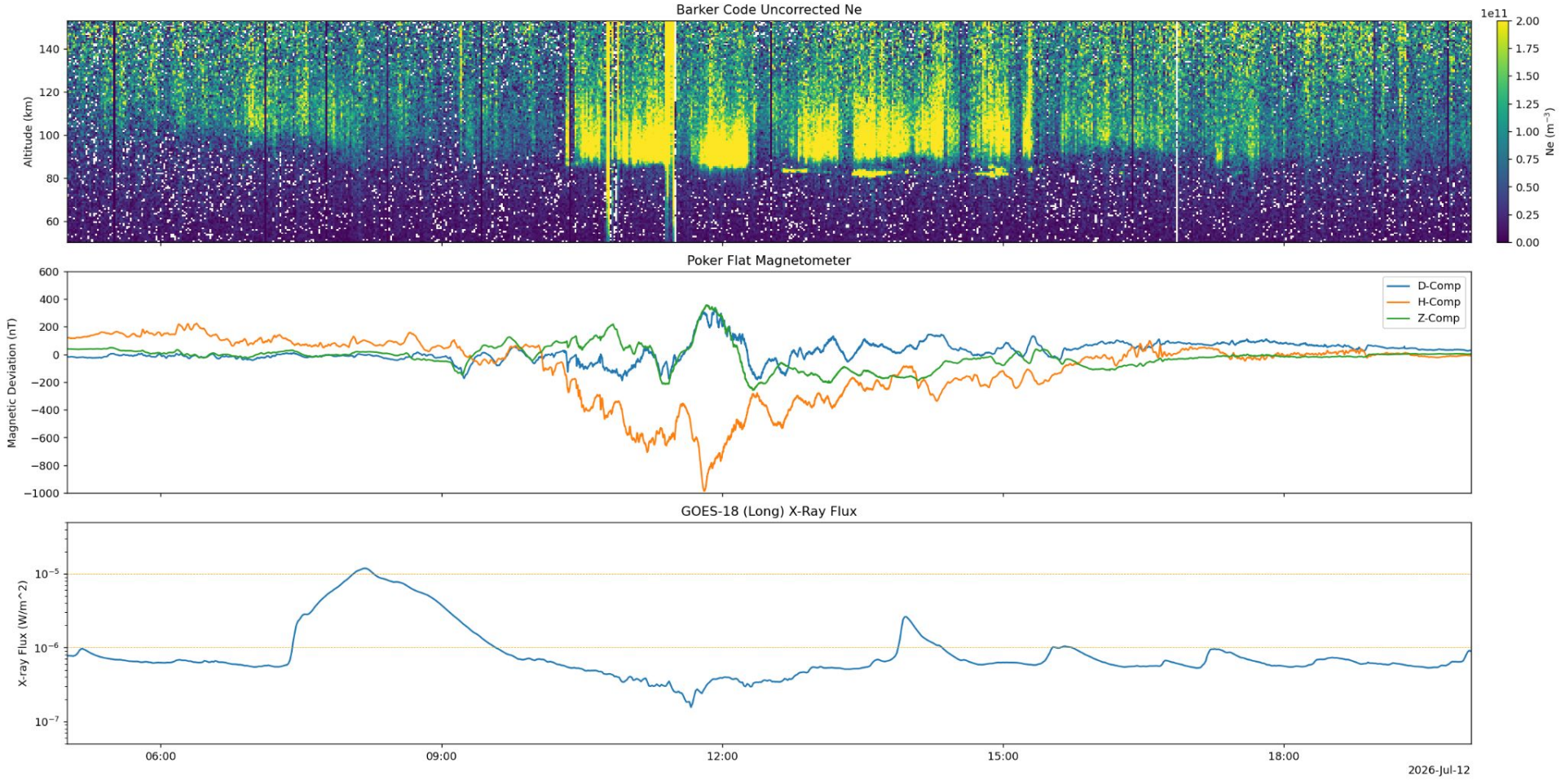
Start: 07-09-2026, 00:00
End: 07-15-2026, 12:00



Low Geomagnetic Activity, Low Solar Activity

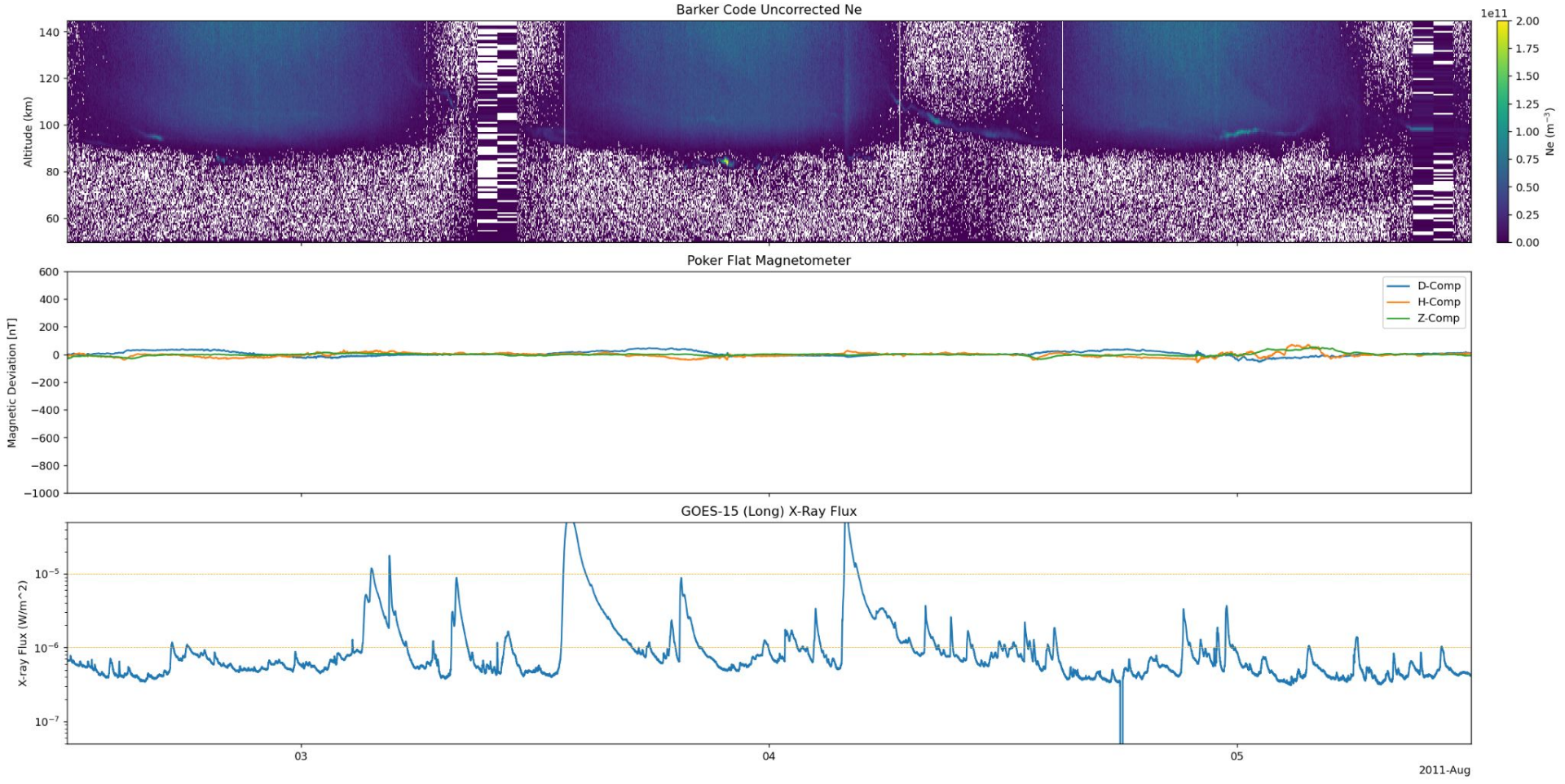
Start: 07-16-2026, 00:00
End: 07-20-2026, 20:00




Barker Code Uncorrected Ne
Altitude (km)
1e11
Ne (m^{-3})
Poker Flat Magnetometer
Magnetic Deviation (nT)
D-Comp
H-Comp
Z-Comp
GOES-18 (Long) X-Ray Flux
X-ray Flux (W/m^2)
06:00
09:00
12:00
15:00
18:00
2026-Jul-12

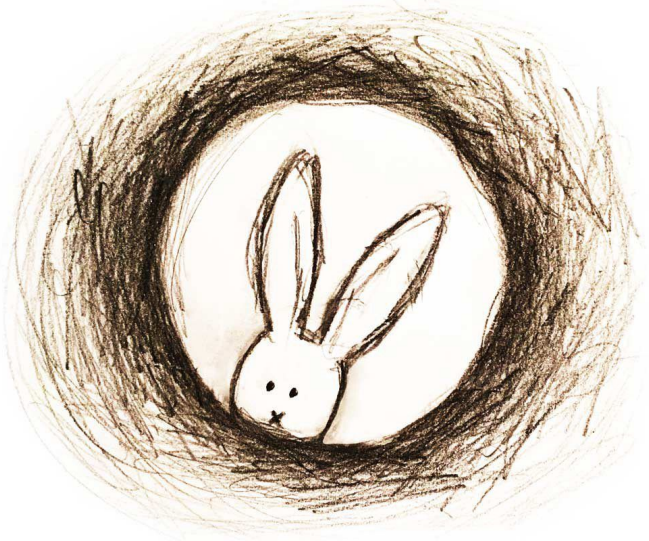
Low Geomagnetic Activity, High Solar Activity

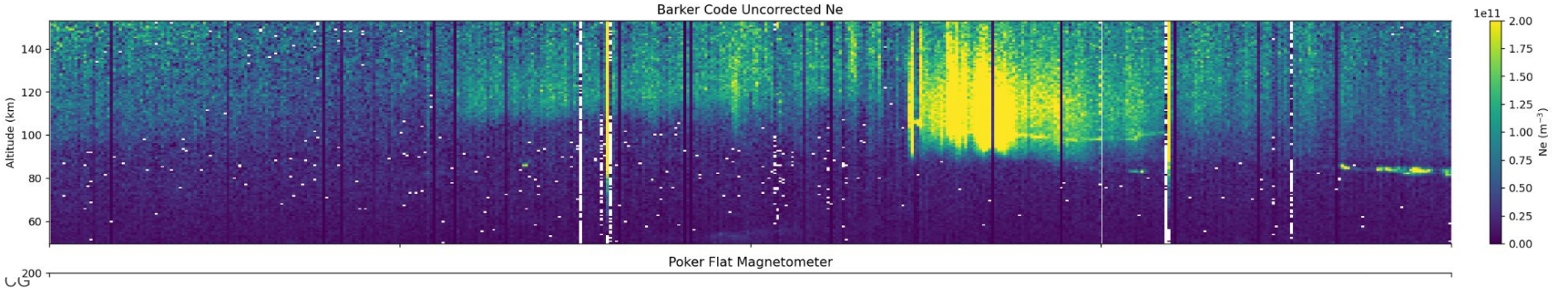
Start: 08-02-2011, 12:00
End: 08-05-2011, 12:00



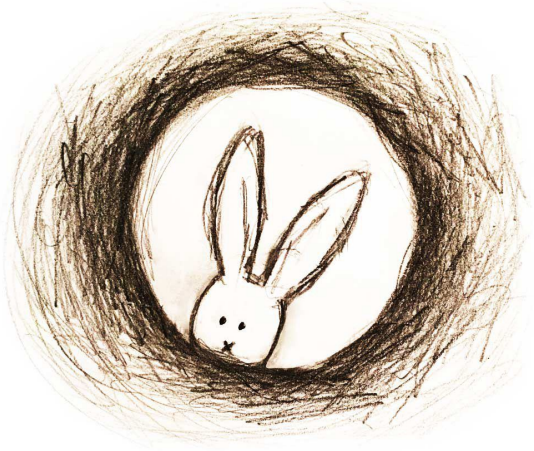
Discussions

- Sporadic E is metal heavy.
- Does intensity or occurrence of sporadic E increase in the presence of bolides?



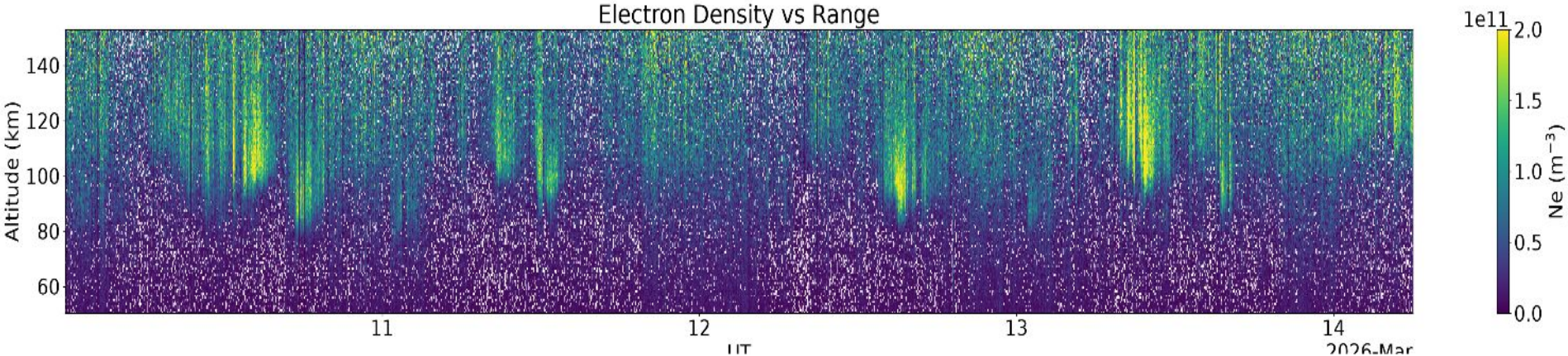


- Bolides over Alaska
  - March 10, 2026
  - April 24, 2025
  - Sept 30, 2021
  - Oct 15, 2020



CG

- Bolides over Alaska
  - March 10, 2026 - nothing
  - April 24, 2025 - no data
  - Sept 30, 2021 - nothing
  - Oct 15, 2020 - no data



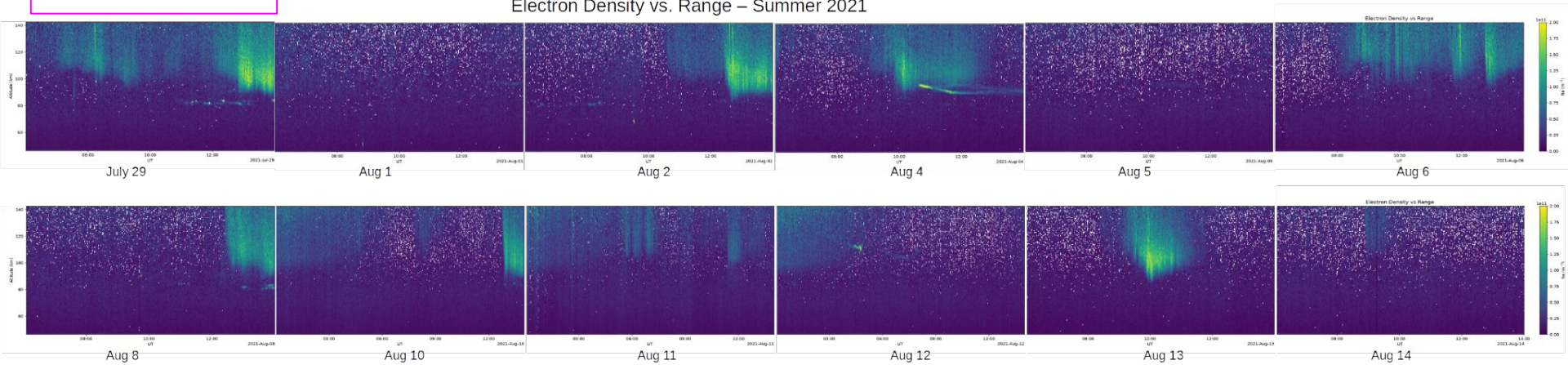
CG

- Perseid meteor shower correlation?
  - Peak in late July - early August
  - Observations from July 29 - Aug 14, 2021 with a strong peak on Aug 13, 2021

CG

CME

Electron Density vs. Range – Summer 2021

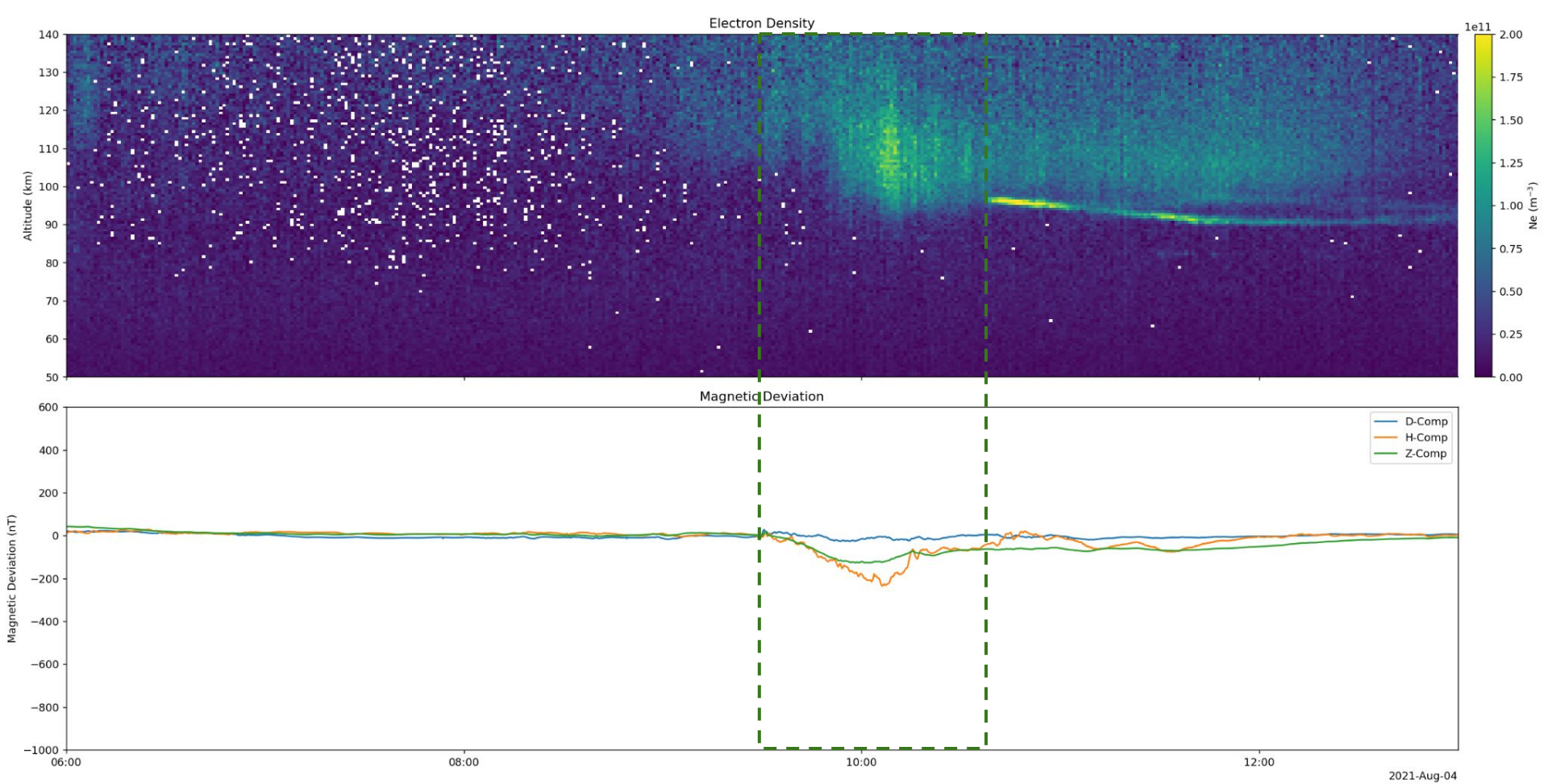


CME

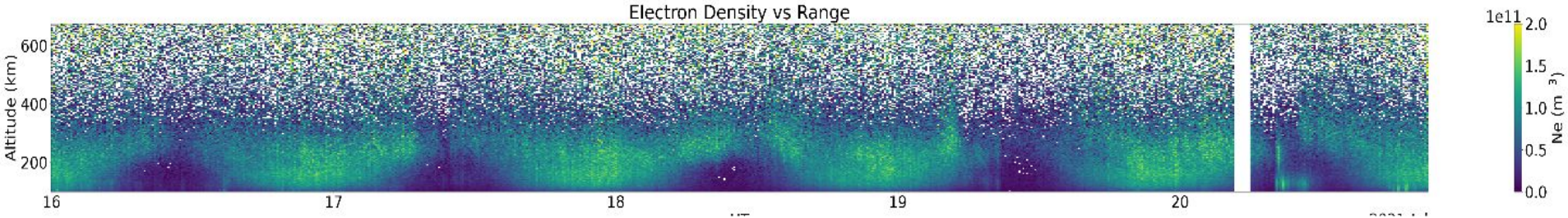
Perseid Meteor Shower Peak

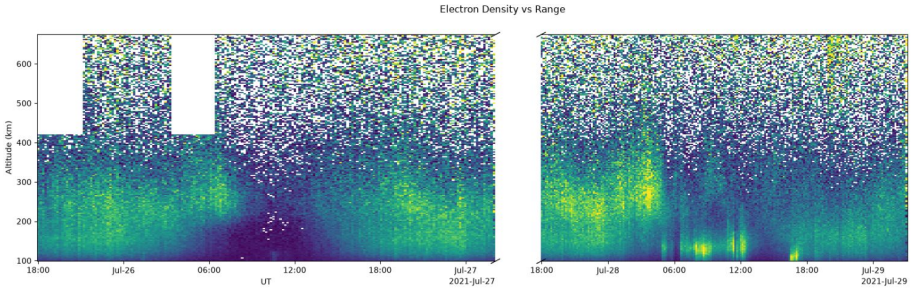
July 29 - Aug 14, 2021

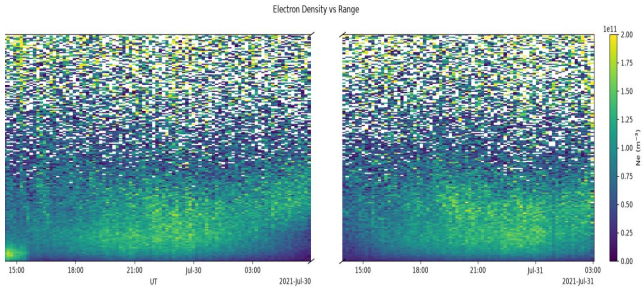
CG


Electron Density
Altitude (km)
1e11
Ne (m^{-3})
Magnetic Deviation
Magnetic Deviation (nT)
D-Comp
H-Comp
Z-Comp
06:00
08:00
10:00
12:00
2021-Aug-04

Earthquakes in Alaska - 8.2 Mag, July 29, 6:15 UT





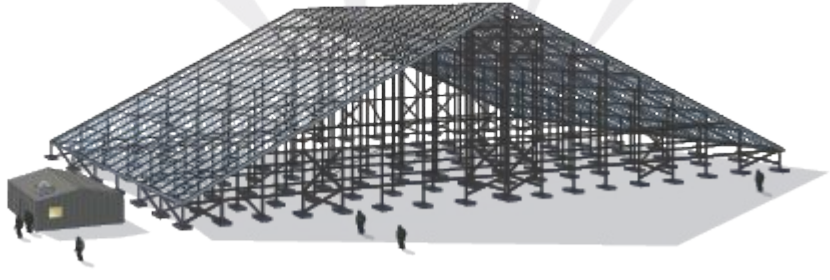


CG

Potential Future Studies

- Are there correlations between sporadic E and:
  - solar max vs solar min
  - Meteor storms
  - Bolides
  - Earthquakes
  - Volcanoes
- Can Sporadic E be observed on other planets?

AMISR Advanced Modular Incoherent Scatter Radar



Incoherent Scatter Radar Summer School

CG

For fun!

https://www.youtube.com/watch?v=hbW0gv0UbSk