Study of High-Latitude Ionospheric Behavior During Post Sunset Time

Group-2

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ISR Summer School-2020
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Physical Research Laboratory (PRL)

ILLINOIS INSTITUTE OF TECHNOLOGY

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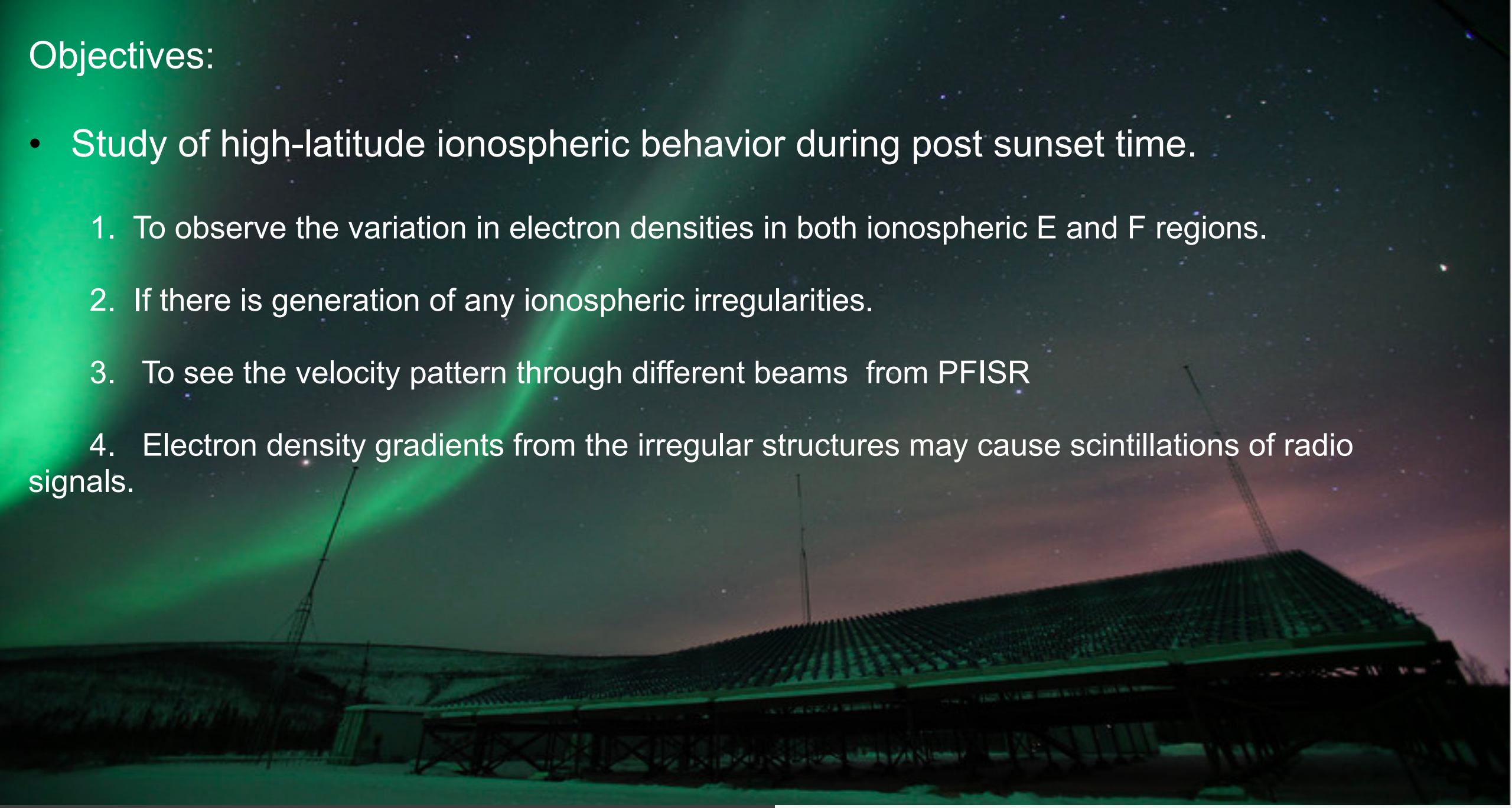
Outline

- Background
- Experimental data
- Observations: E and F region
  - ISR
  - GPS
- Summary



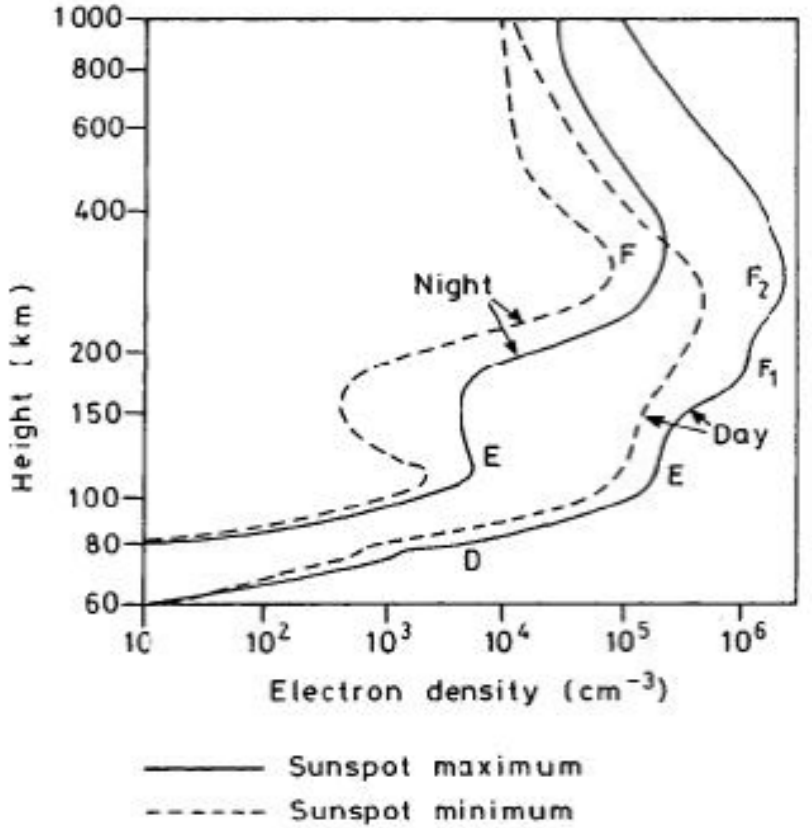
Objectives:

- Study of high-latitude ionospheric behavior during post sunset time.

1. To observe the variation in electron densities in both ionospheric E and F regions.
2. If there is generation of any ionospheric irregularities.
3. To see the velocity pattern through different beams from PFISR
4. Electron density gradients from the irregular structures may cause scintillations of radio signals.

Background

- In the daytime, sun is the source of ionization
- After the sunset, production stops, charge recombination starts
- Upward flayer movement
- Geomagnetic condition like, interplanetary magnetic field, solar wind plays important role in the high latitude ionospheric dynamics



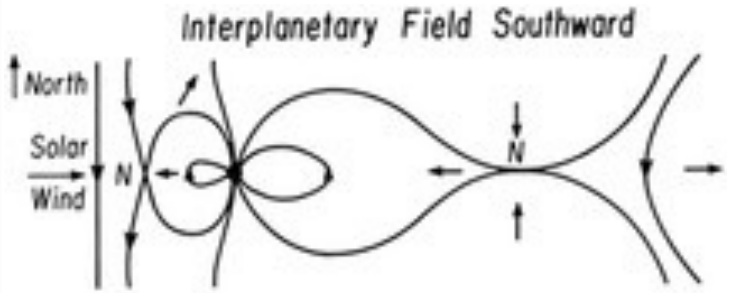
After W. Swider, Wallchart Aerospace Environment, US Airforce Geophysical Laboratory

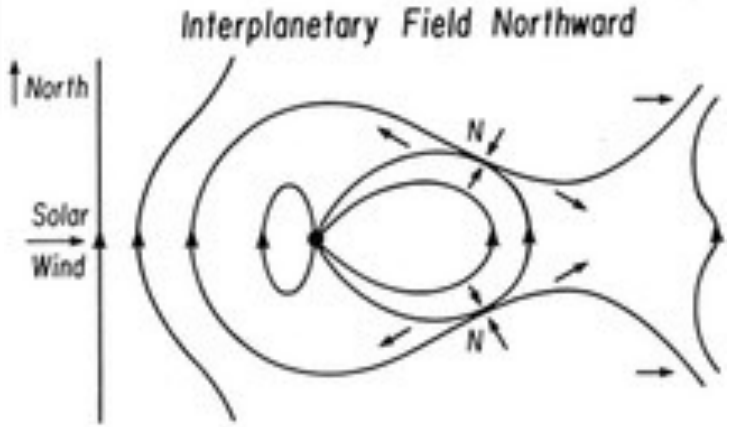
Background

- Electric field generated due to solar wind and space weather effect:

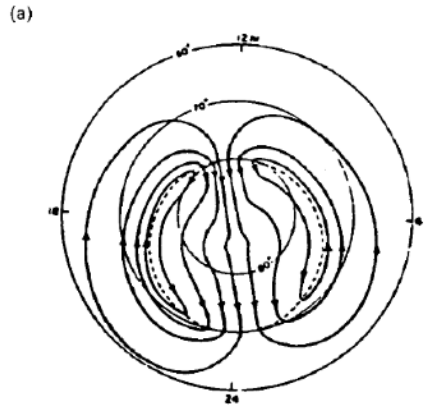
  $E_{sw} = - V_{sw} \times B_{IMF}$

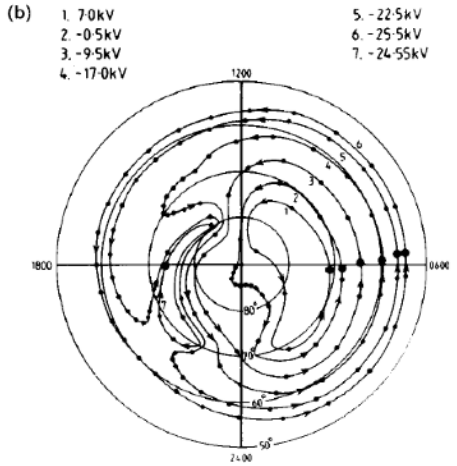
- Auroral convection
- Irregularities and scintillation





Northward
IMF
[Dungey, 1964]





(a) R. W. Spiro et al., 1978
(b) S. Quegan et al., 1982

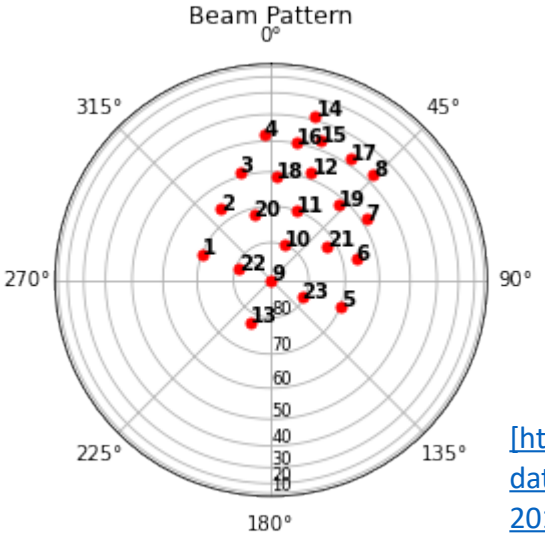
Experimental data

Poker Flat Incoherent Scatter Radar (PFISR):
Location:
Latitude: 65^0 N
Longitude: 147^0 W

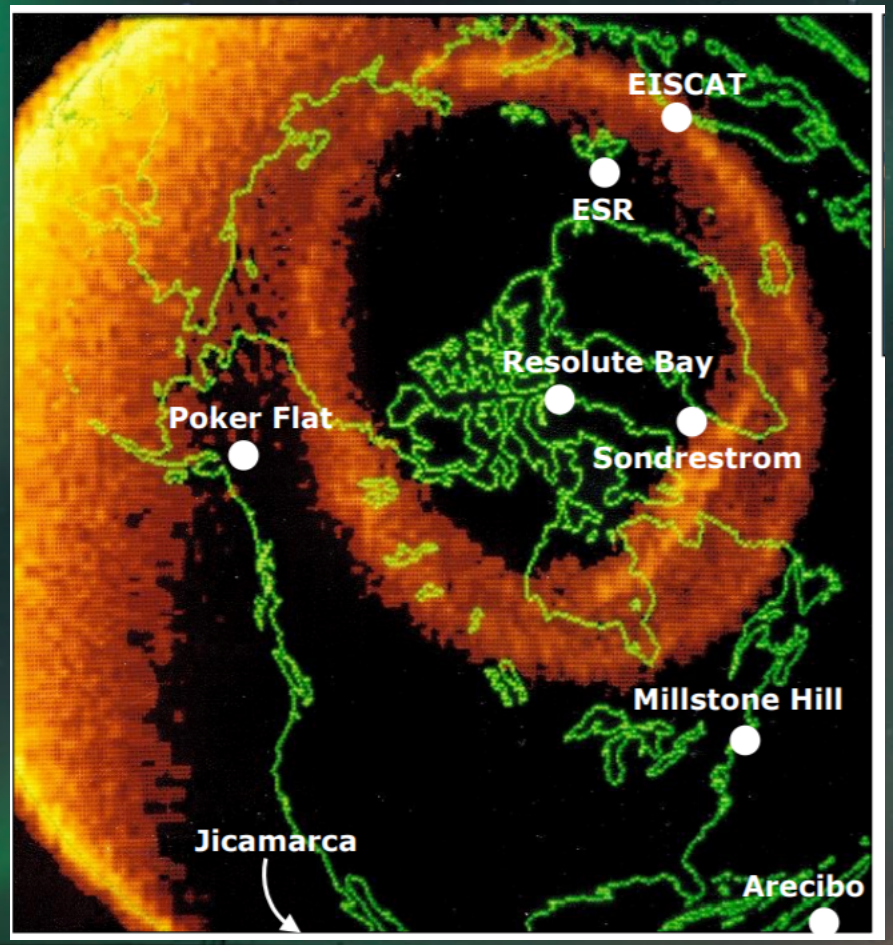
Date and Time of Observation:
29 Jul 2020
07:00 UT- 09:00 UT

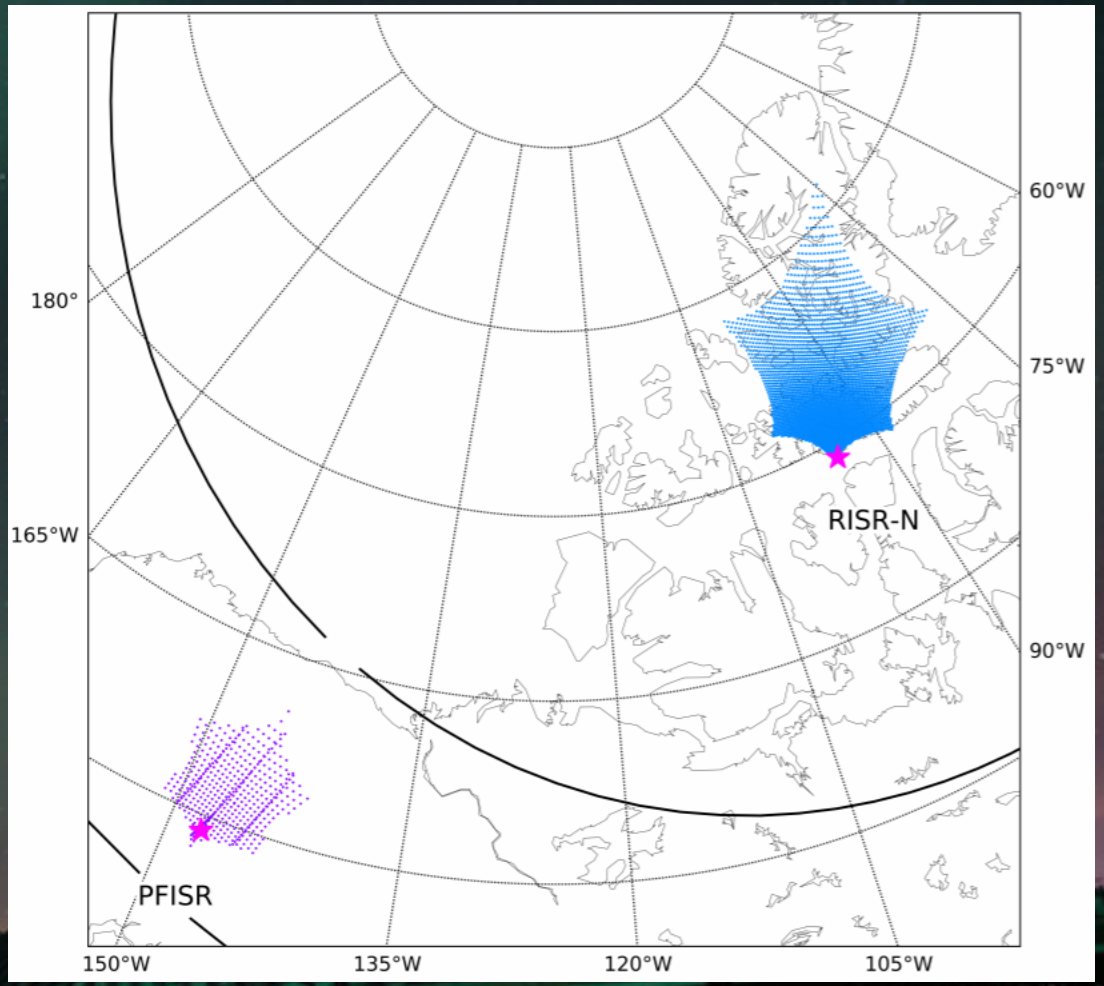
Beam used: Themis36
No. of beams: 23

Data Taking Computer (DTC) used in PFISR
DTC0-Alternating code
DTC1, DTC2- Long Pulse
DTC3- Single pulse 330 sec long pulse

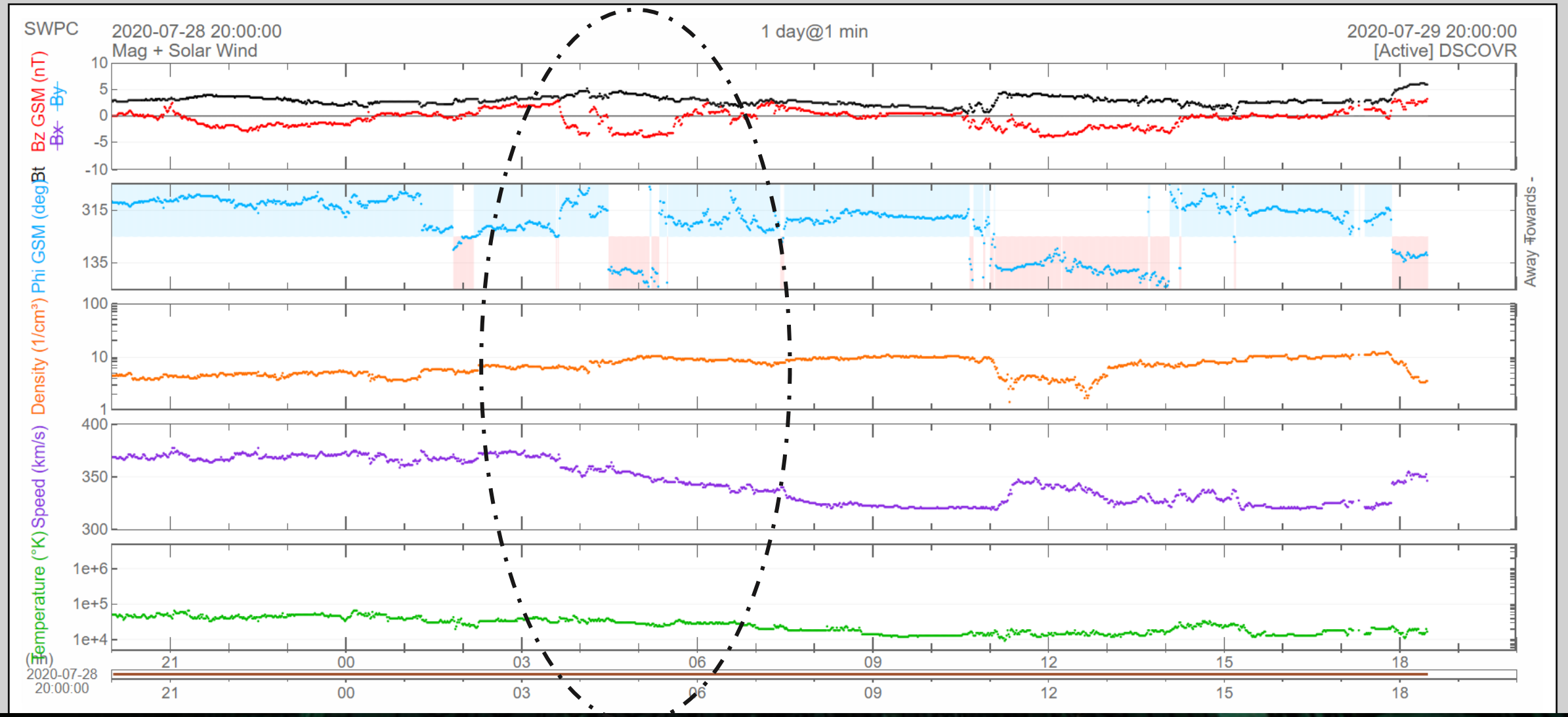


[https://data.amisr.com/database/61/experiment/20180310.001/3/1]


EISCAT
ESR
Resolute Bay
Poker Flat
Sondrestrom
Millstone Hill
Jicamarca
Arecibo


180°
165°W
150°W
135°W
120°W
105°W
60°W
75°W
90°W
RISR-N
PFISR

Space weather condition:



https://www.swpc.noaa.gov/products/ace-real-time-solar-wind

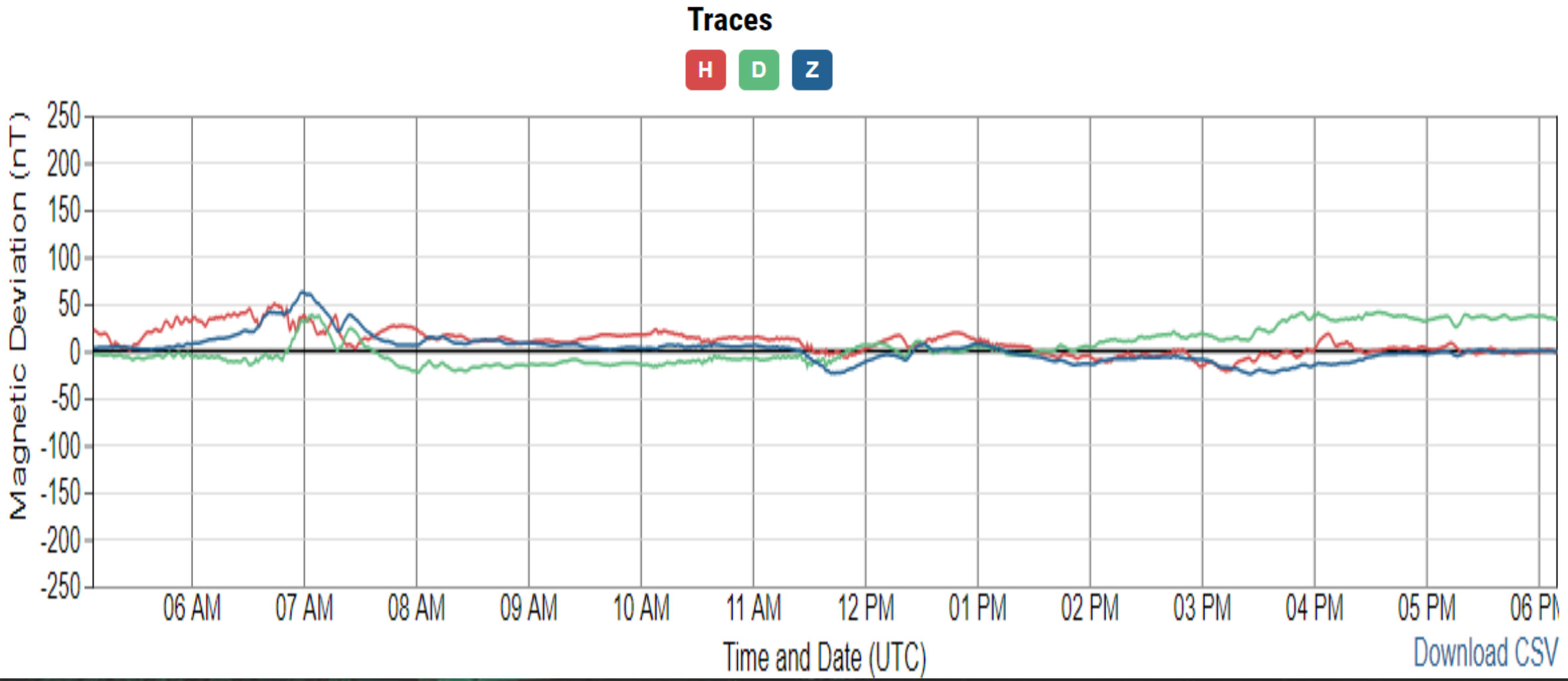
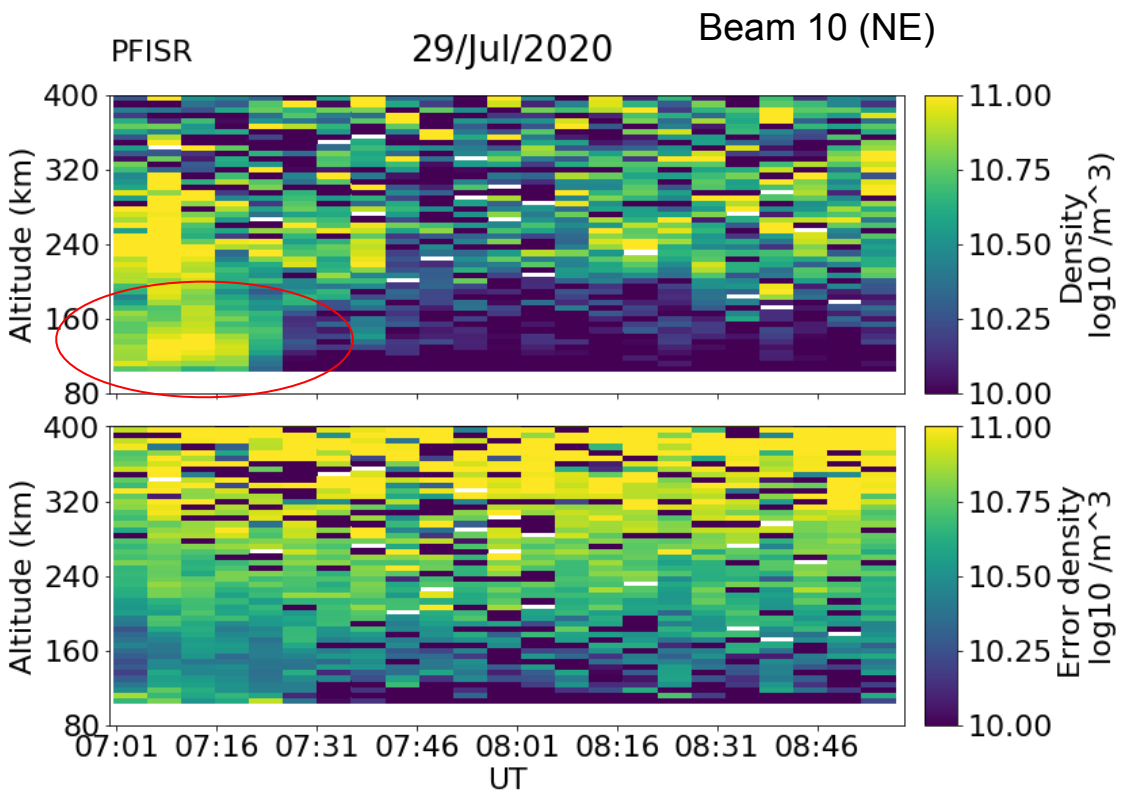
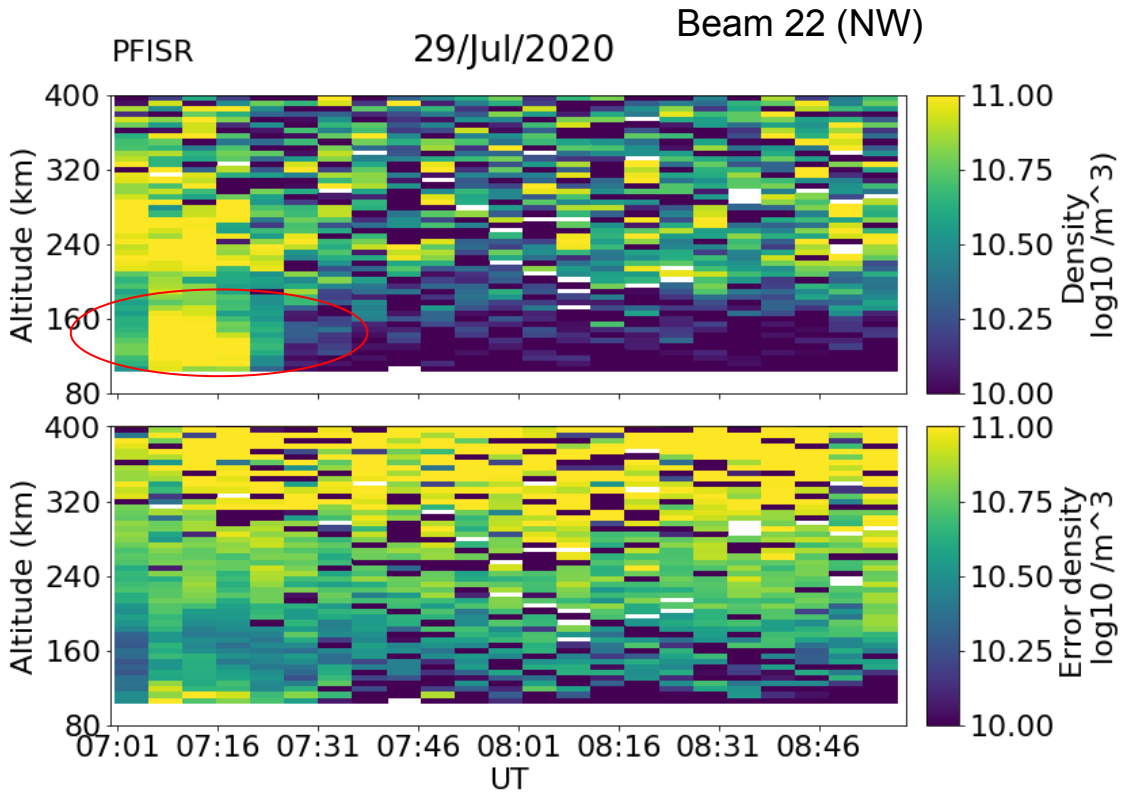


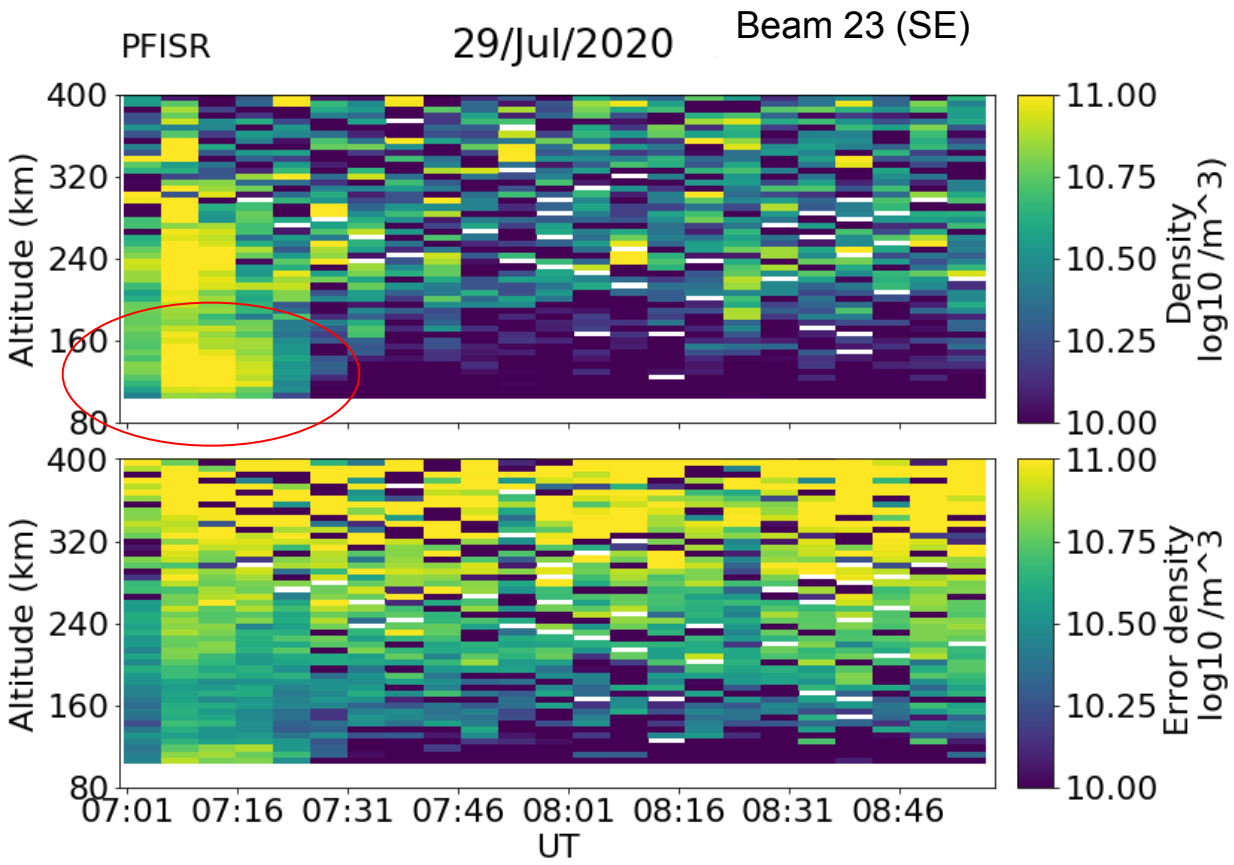
Figure: Variation in Magnetic Deviations during our experiment measured by Poker Flat magnetometers.

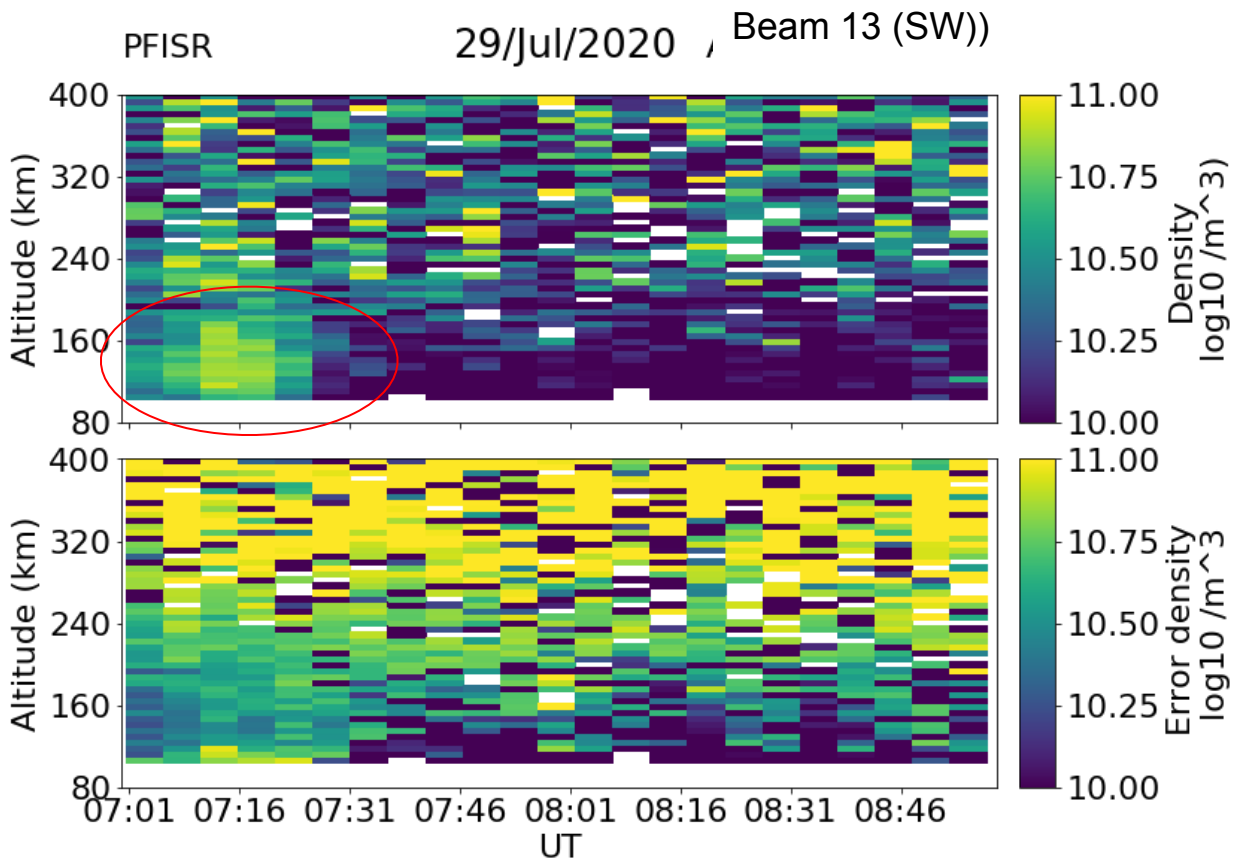
Observations: ISR

Long pulse 5min uncorrected electron density






PFISR
29/Jul/2020
Beam 23 (SE)
Altitude (km)
400
320
240
160
80
11.00
10.75
10.50
10.25
10.00
Density
log10 /m^3)
Error density
log10 /m^3
07:01 07:16 07:31 07:46 08:01 08:16 08:31 08:46
UT


PFISR
29/Jul/2020
Beam 13 (SW))
Altitude (km)
400
320
240
160
80
11.00
10.75
10.50
10.25
10.00
Density
log10 /m^3)
Error density
log10 /m^3
07:01 07:16 07:31 07:46 08:01 08:16 08:31 08:46
UT

E region 7:00-7:20UT

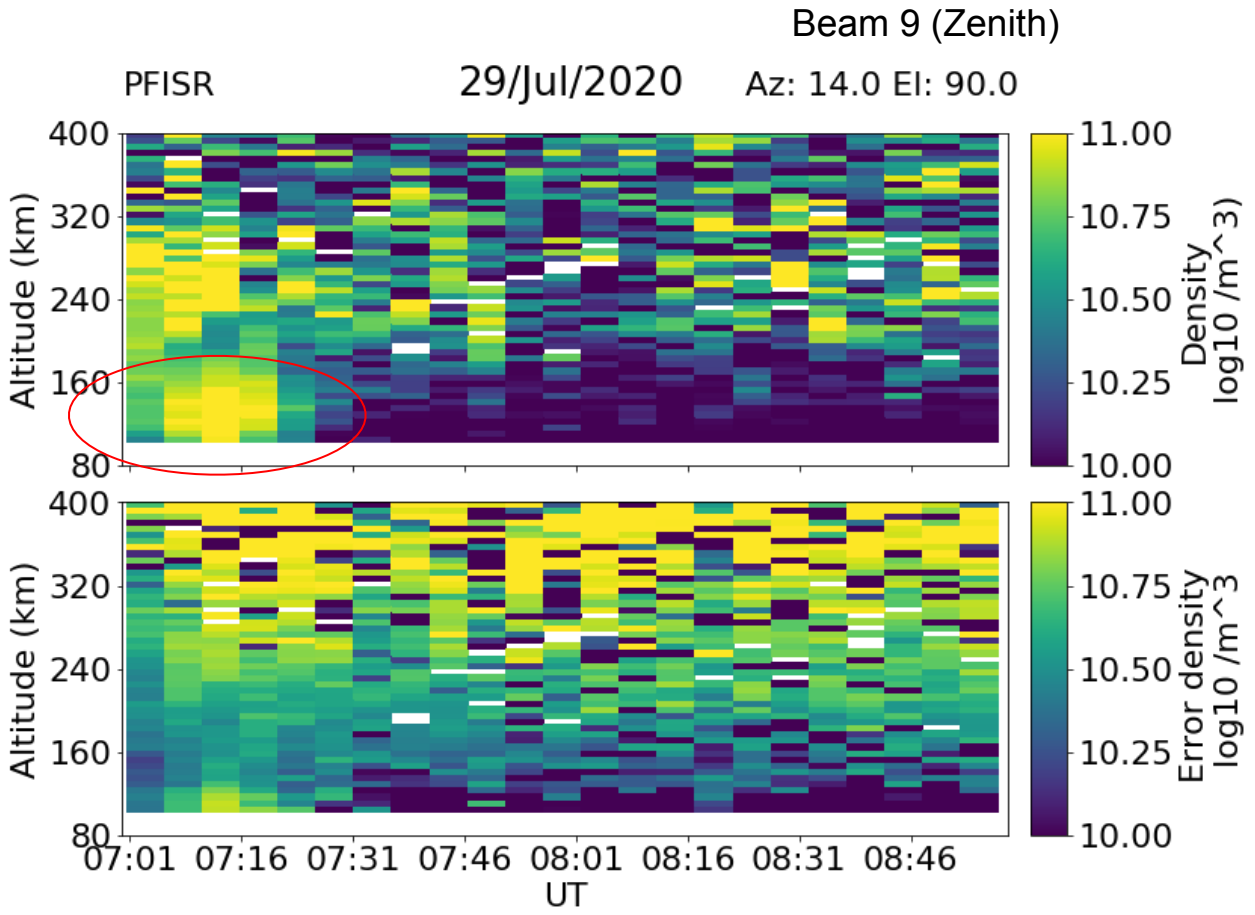
- Enhancement of Ne
- Aurora precipitation around 110km

No F region detected

- Altitude precipitation depends on the electron energy [Fang et al.]

High density error specially in F region

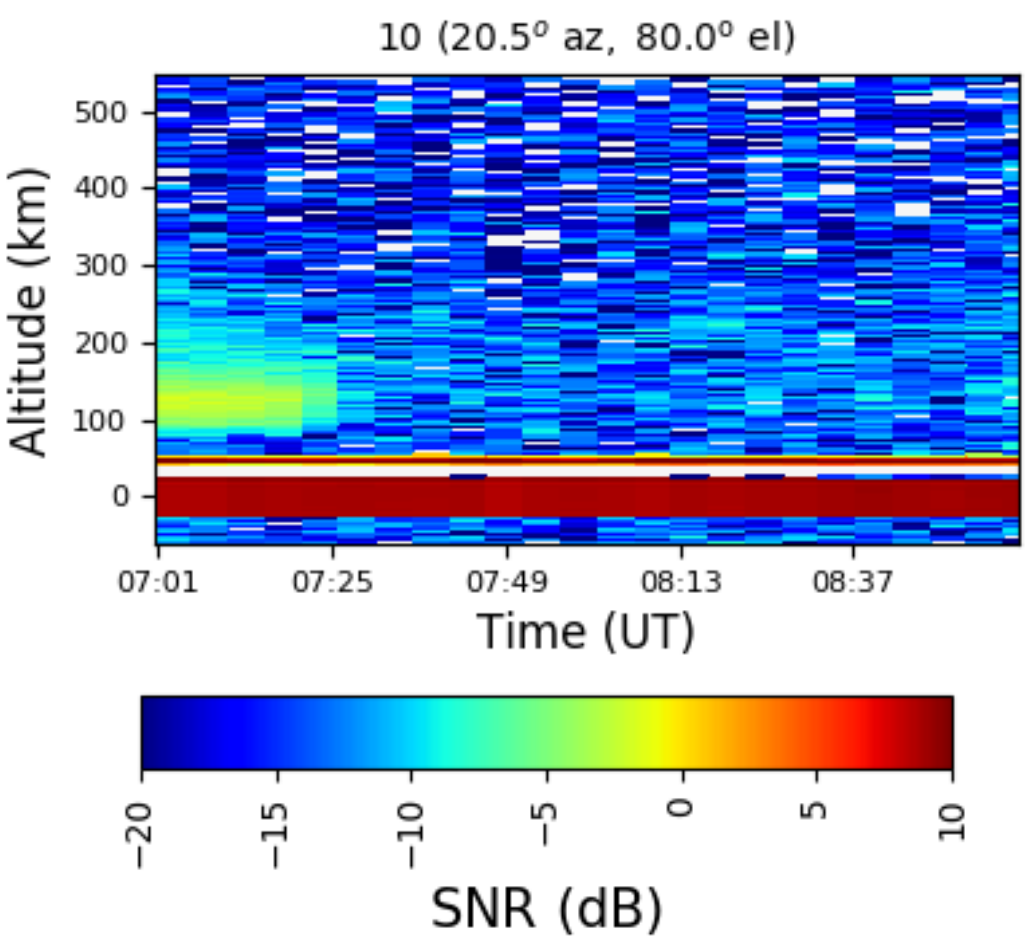
- Not enough electron density to scatter the signal

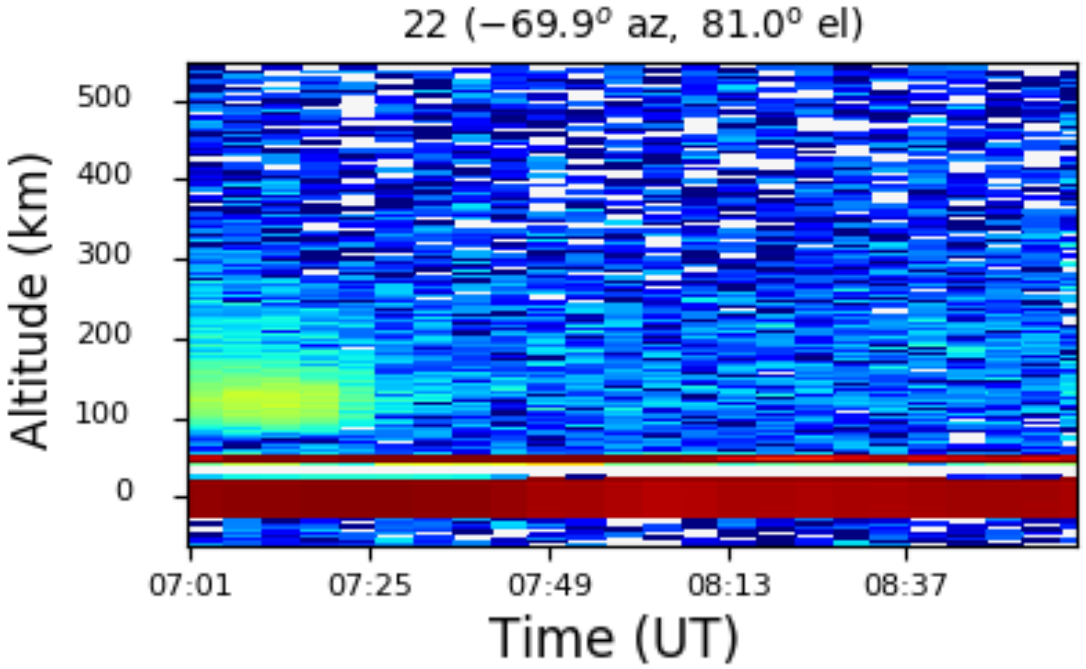


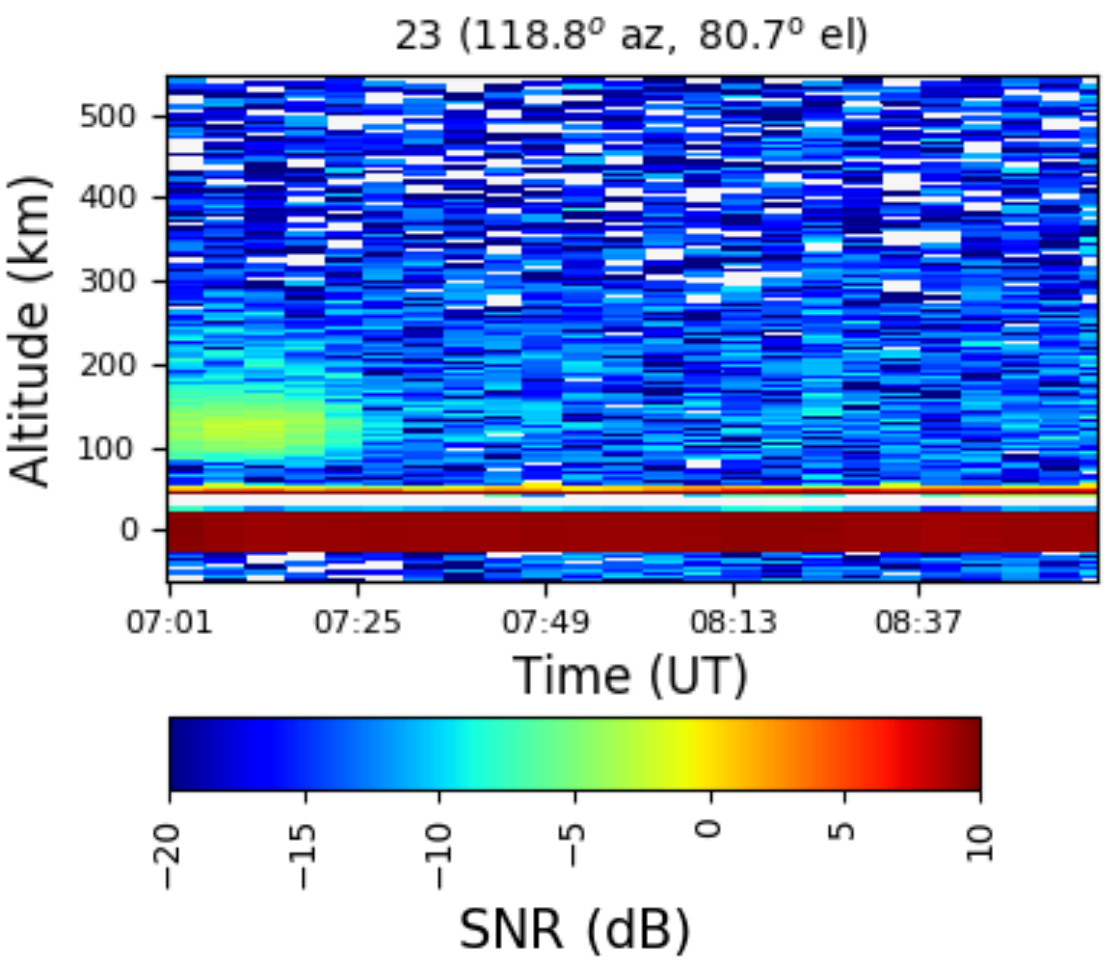
Fang, Xiaohua, et al. “Electron Impact Ionization: A New Parameterization for 100 EV to 1 MeV Electrons.” *Journal of Geophysical Research: Space Physics*, vol. 113, no. A9, 2008, doi:10.1029/2008ja013384.

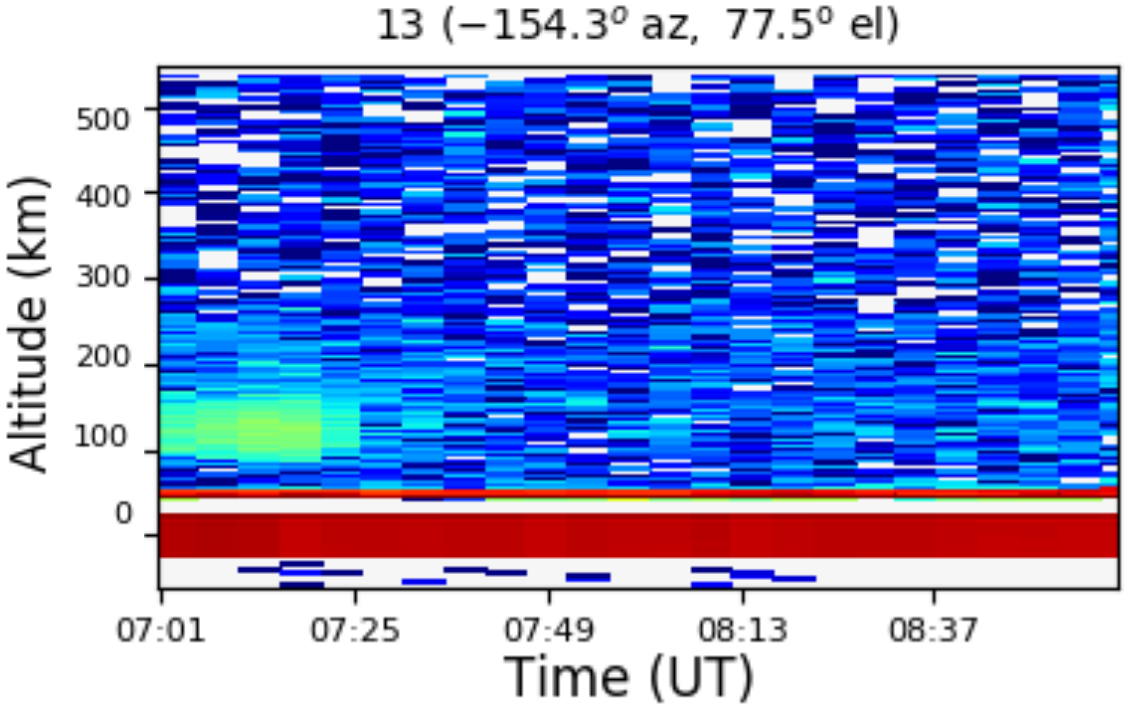
Observations: ISR

Long pulse 5min uncorrected SNR





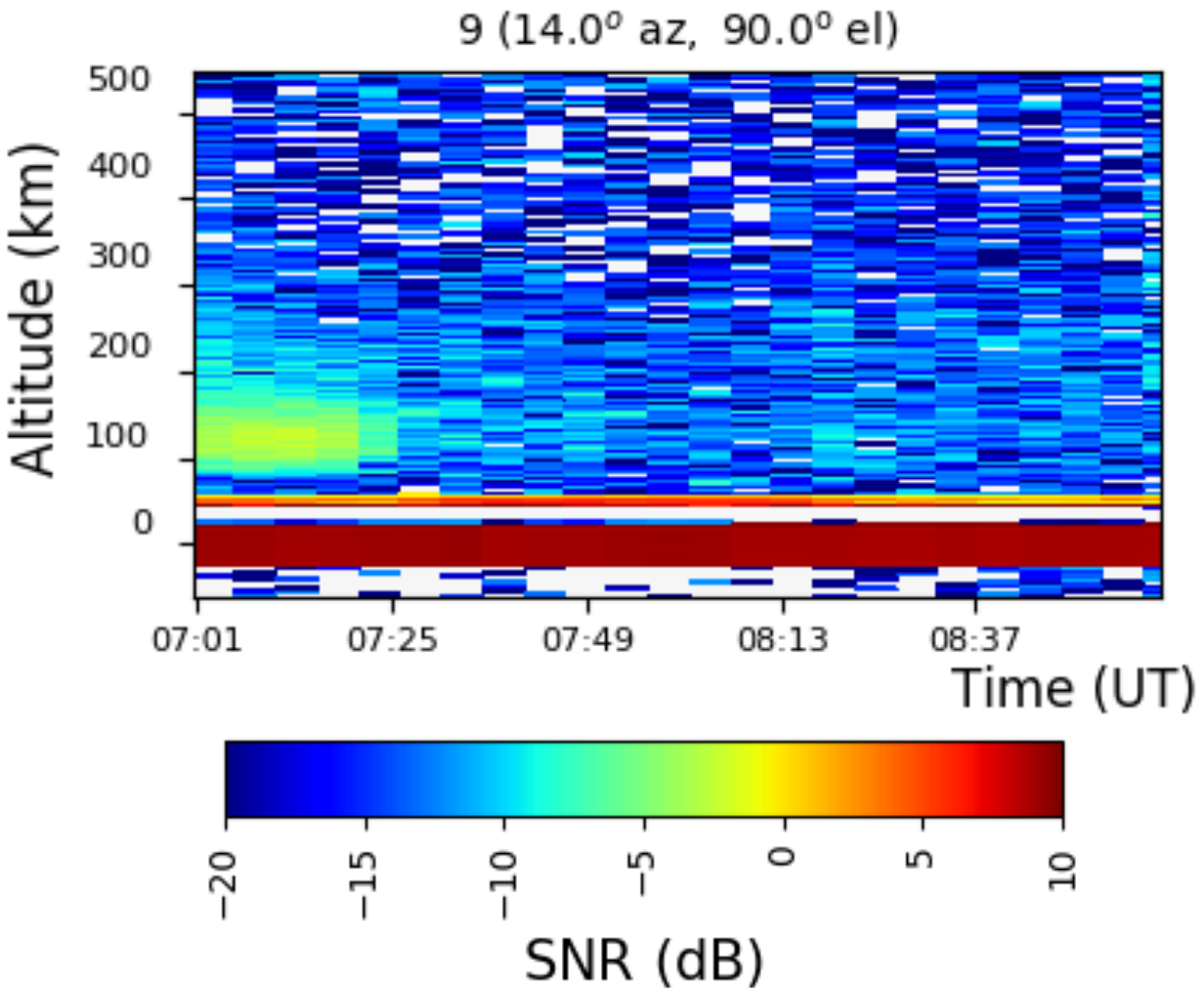

23 (118.8^o az, 80.7^o el)
Altitude (km)
500
400
300
200
100
0
07:01
07:25
07:49
08:13
08:37
Time (UT)
−20
−15
−10
−5
0
5
10
SNR (dB)


13 (−154.3^o az, 77.5^o el)
Altitude (km)
500
400
300
200
100
0
07:01
07:25
07:49
08:13
08:37
Time (UT)

Increase of SNR between 7:00UT-7:20UT

Around 115 km SNR ~-1dB

Relative error?



Observations: ISR

Derivation of relative error of Ne during aurora precipitation in E region (7:00-7:20UT at ~115km)

K number of samples:

Long pulse: ~64 pulses per ~14.6 seconds per beam.

Integration time 5 min=300 seconds

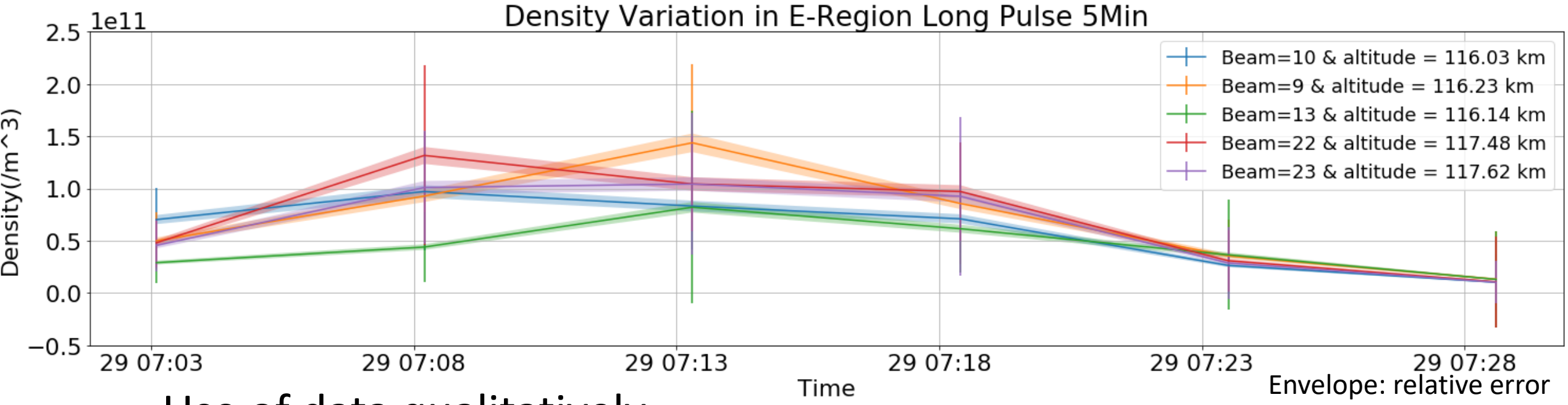
K~1344

SNR - 1dB=0.794

Relative error =

$= 1/\sqrt{K}\,(1+1/SNR) \sim$

~6.2%



Use of data qualitatively

Envelope: relative error

Error bar: error from PFISR data

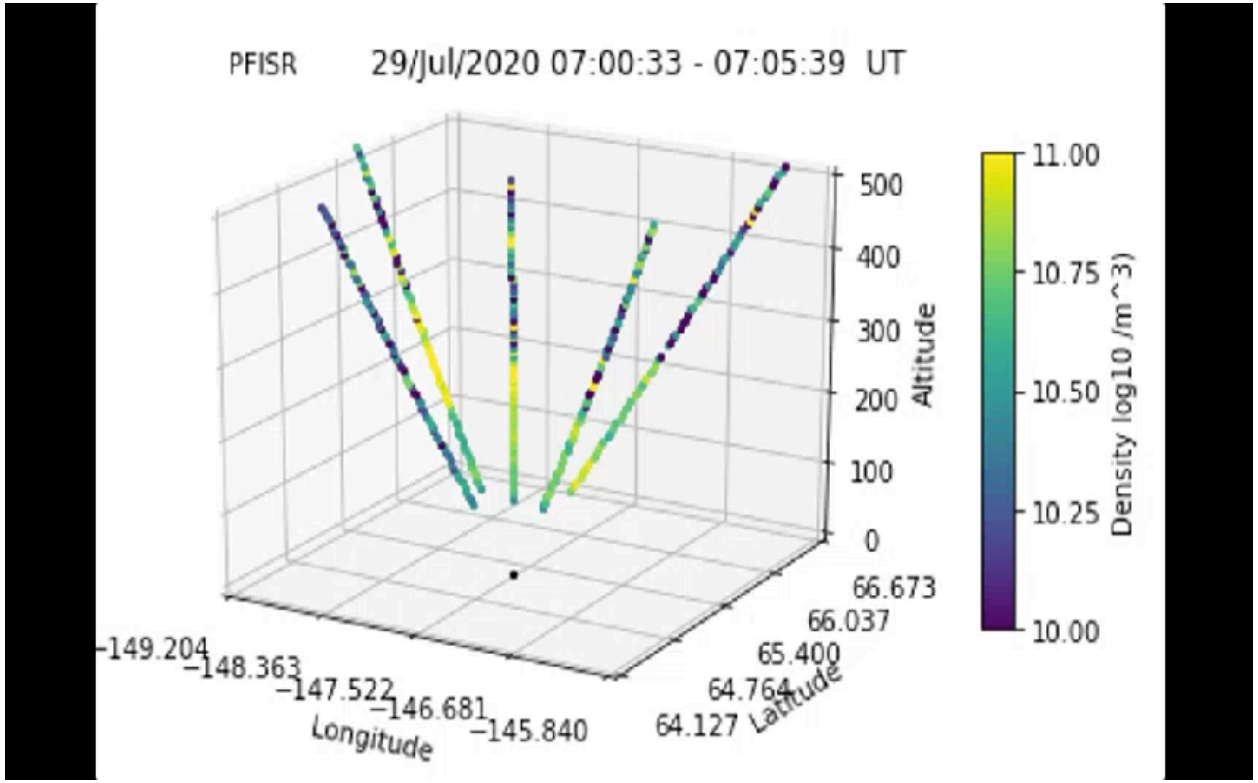
Observations: ISR

Long pulse 5 min Electron Density along beams in 3D

Electron density enhancement in all directions during 7:00UT-7:20UT

1 or 2 Kev electrons, Auroral precipitation

Behavior in each direction?

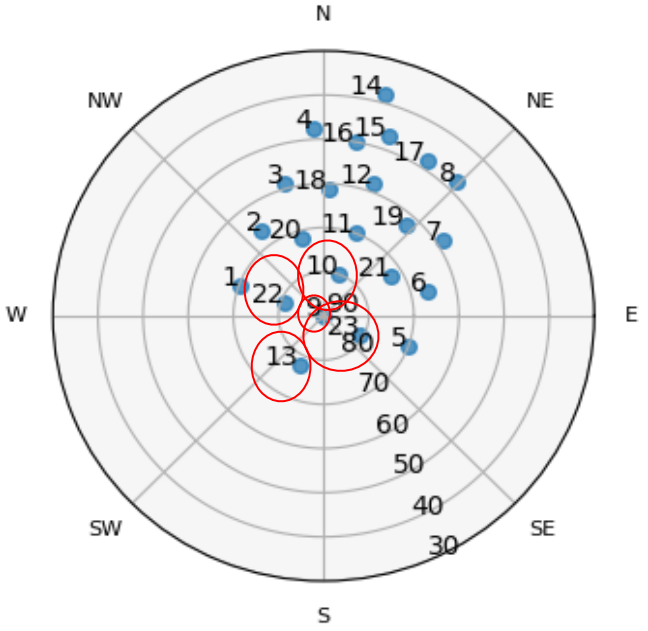


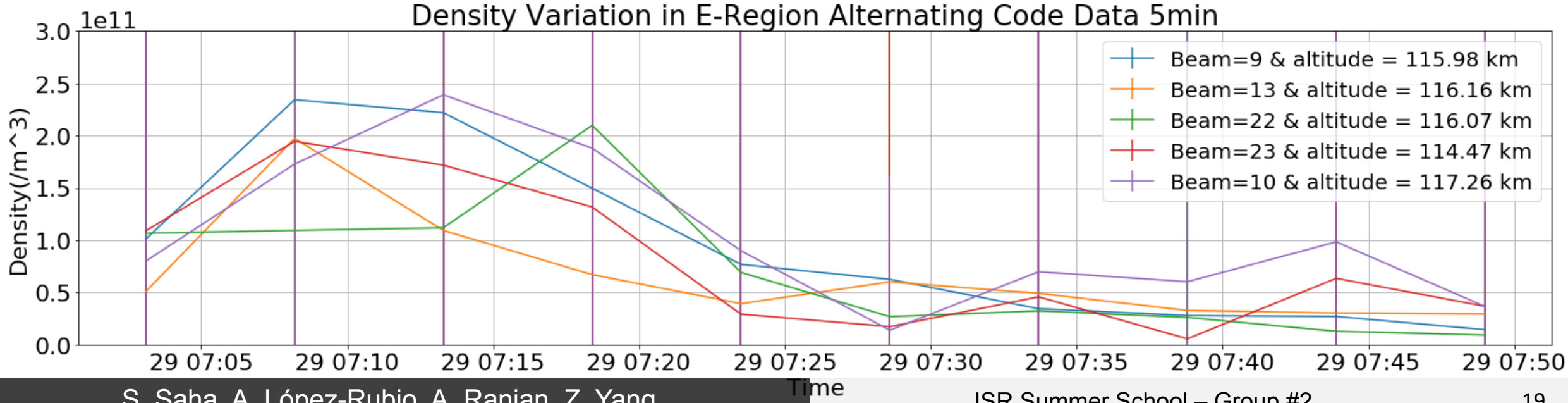
Observations: ISR

Alternating code Electron Density at 115km

Ne enhancement: 9,13,23 (south west) +10 (north)+22(east)

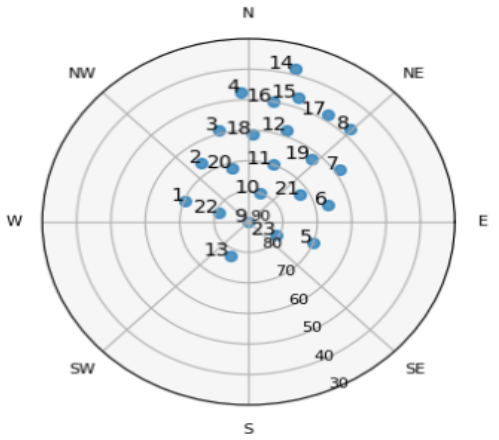
Auroral arc moving northwest ward

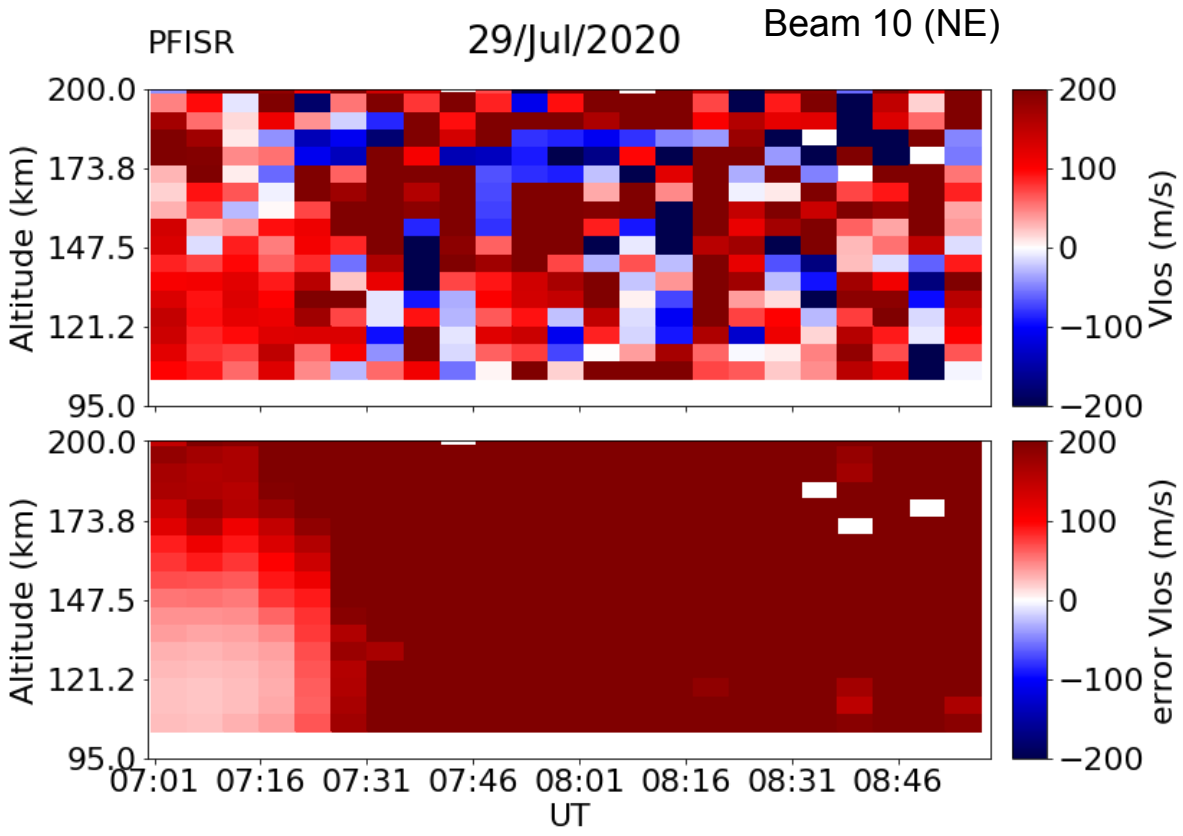


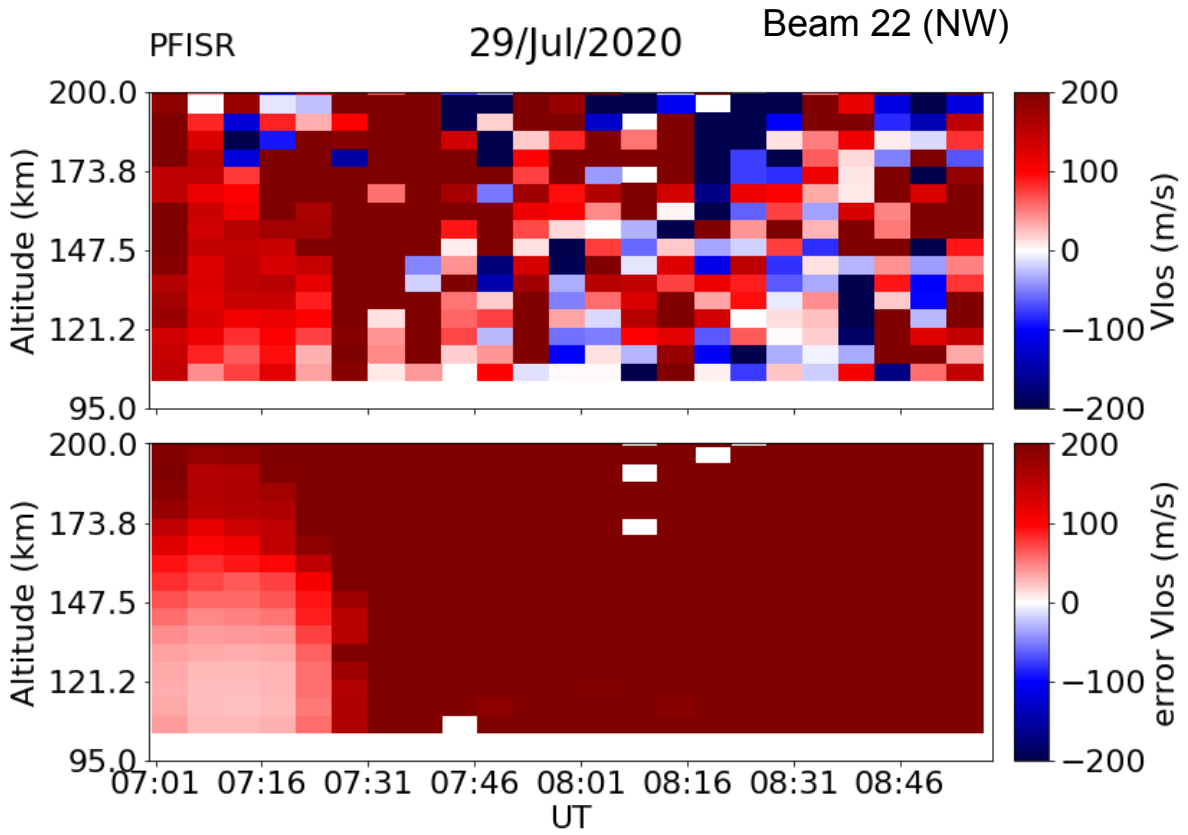


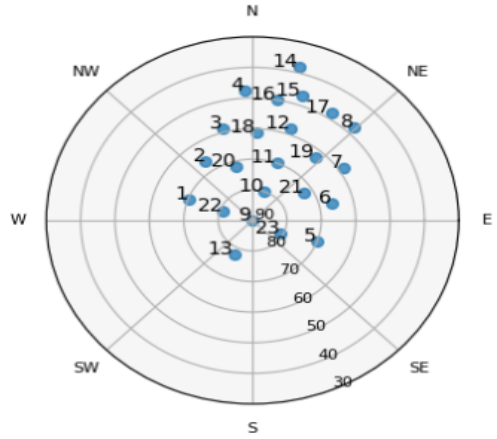
Observations: ISR

Long pulse 5 min velocity LOS per beams

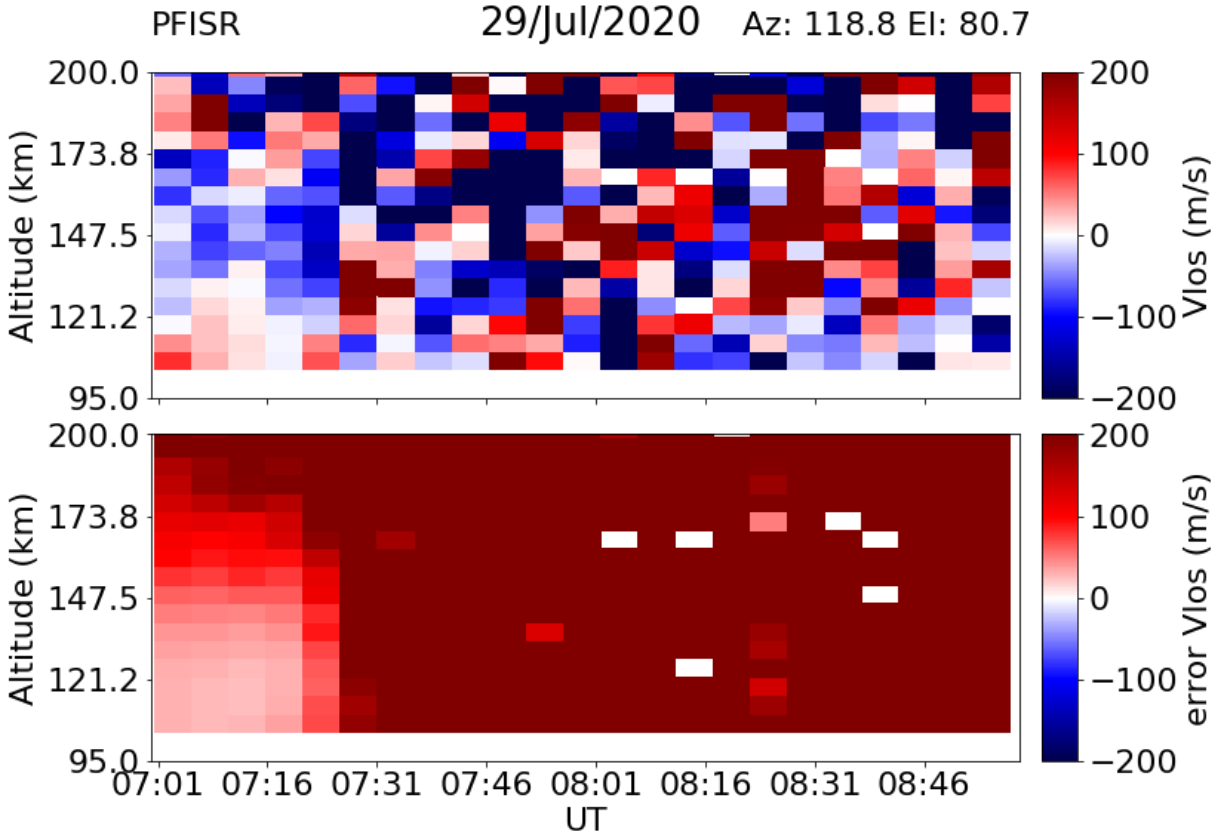




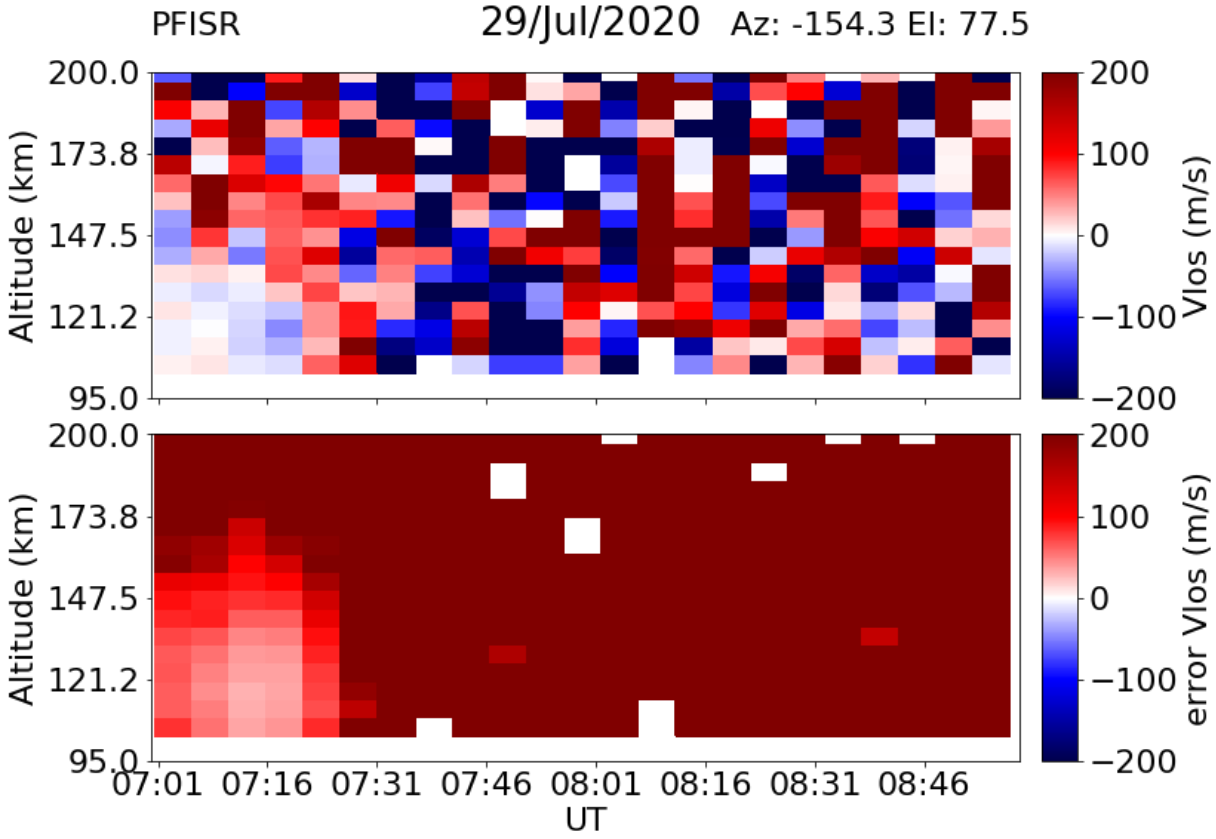




Beam 23 (SE)

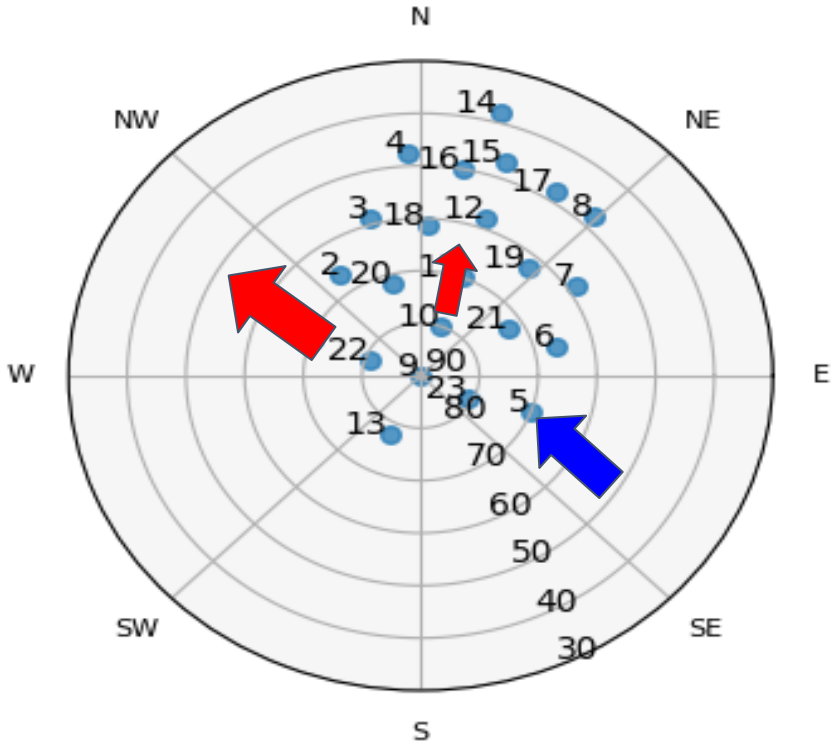


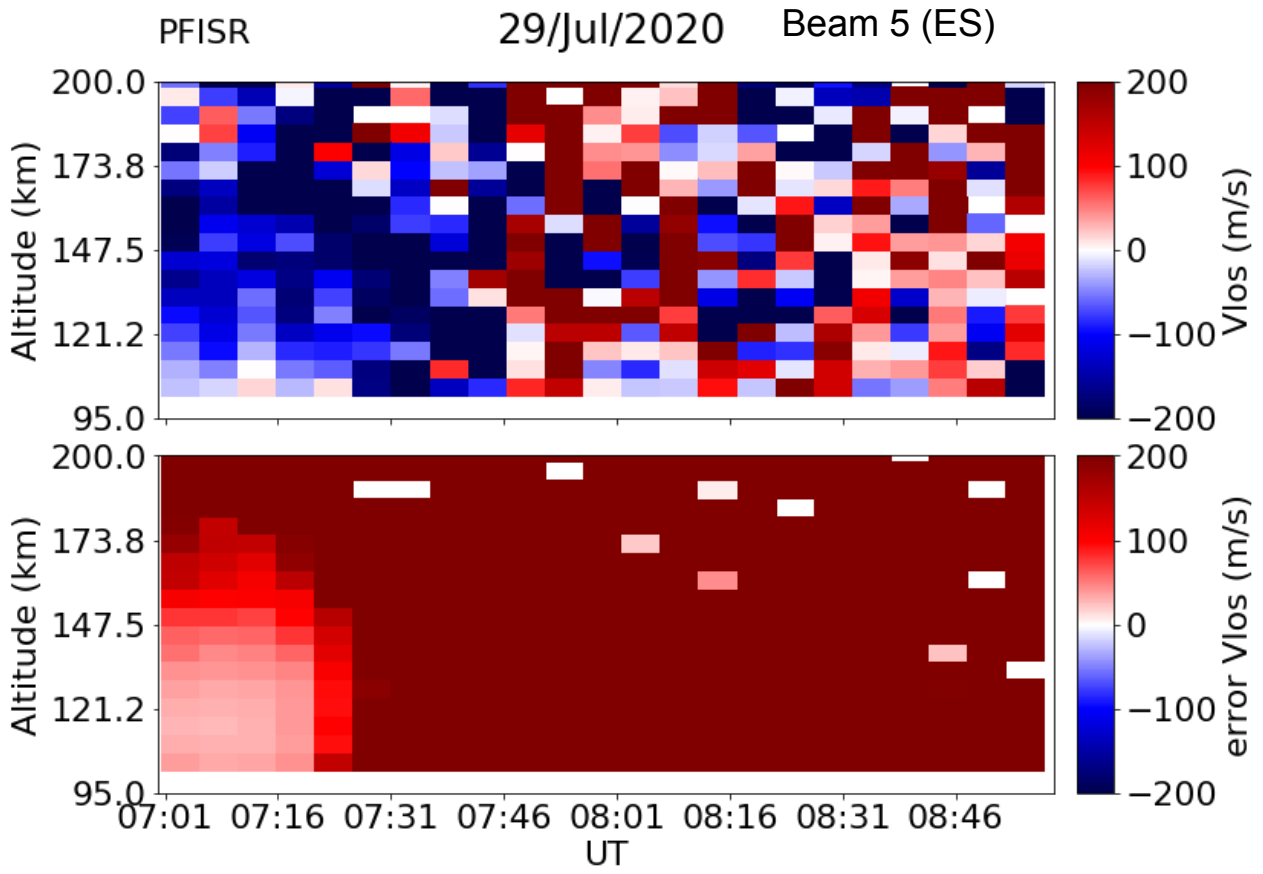
Beam 13 (SW))



Velocity drift during auroral precipitation:

North westward drift



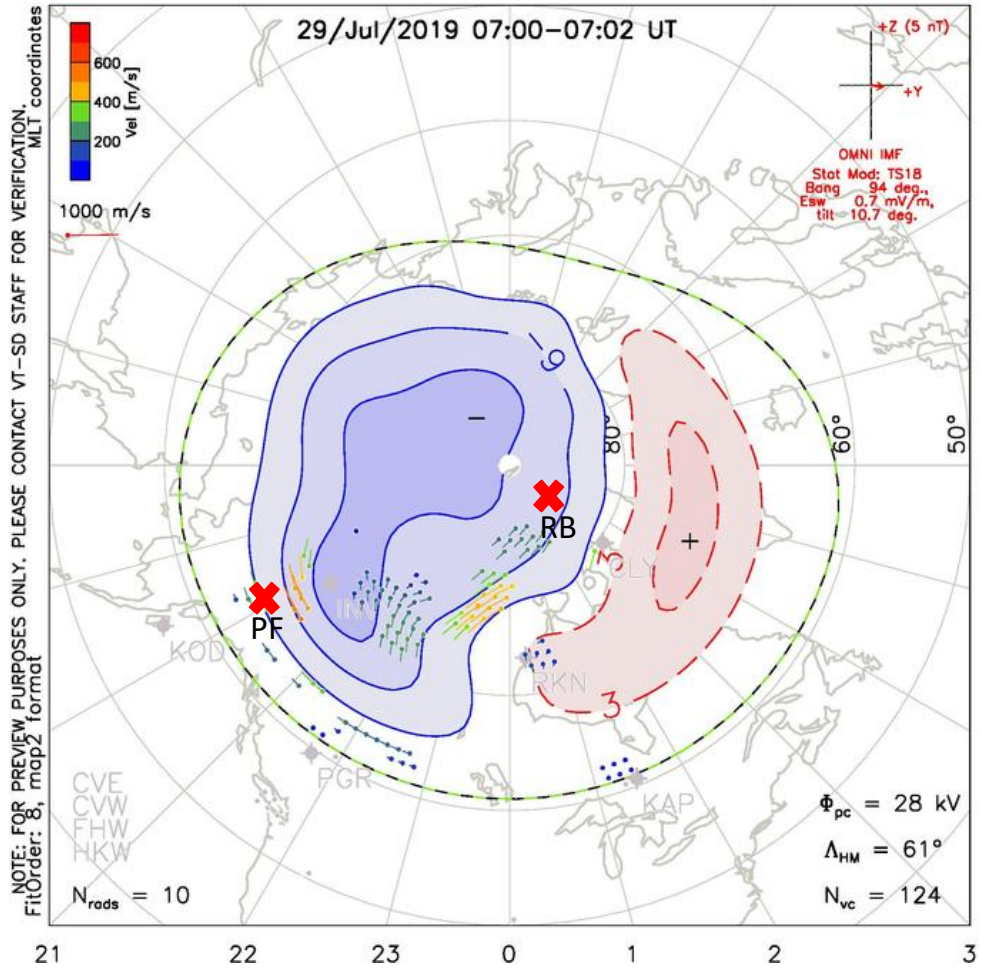


Comparison to SuperDARN data

Data from last year (similar conditions)

Conductivity indicates northwest drifts

PFISR data agrees with what was expected



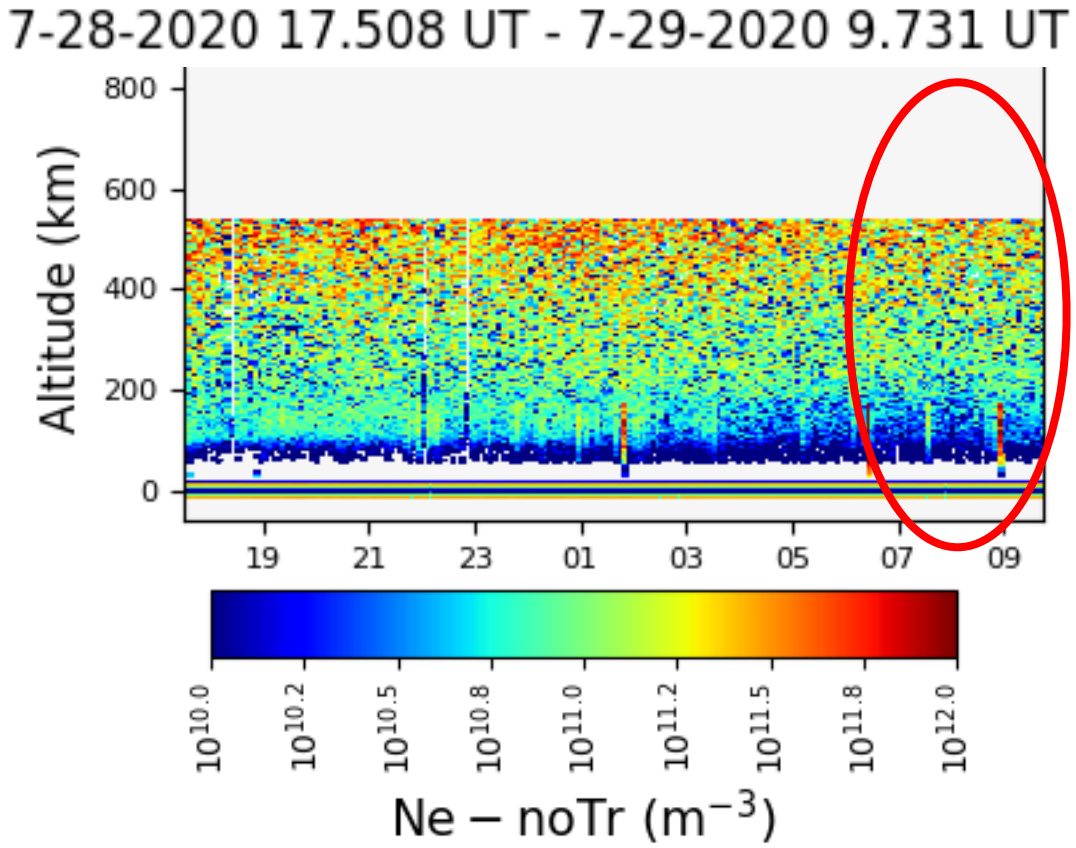
http://vt.superdarn.org/tiki-index.php?page=Conv+map+overview

Observations: ISR

Resolute Bay North ISR Longe pulse 5 min

No significant change in Ne during 7:00-7:20UT (just showing one of the beams)

RB-N inside polar cap

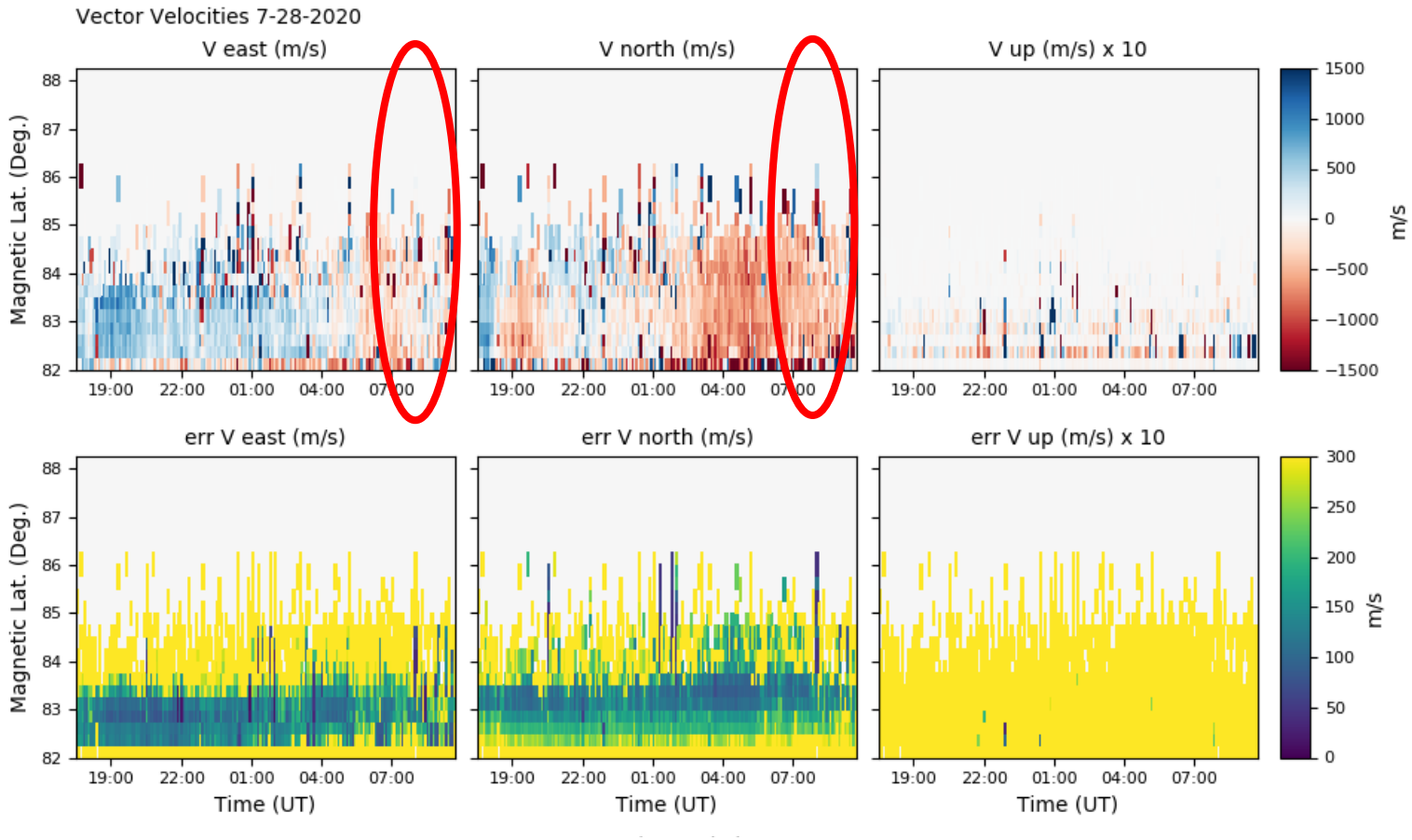


Observations: ISR

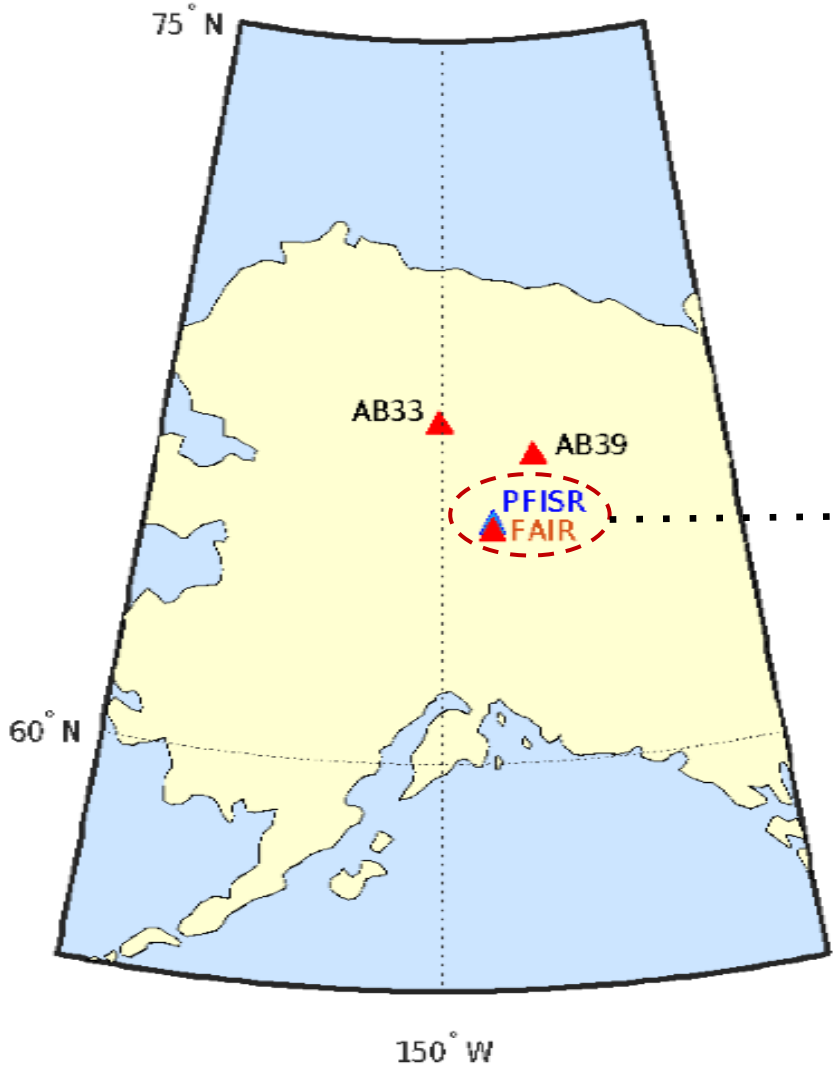
Resolute Bay North ISR

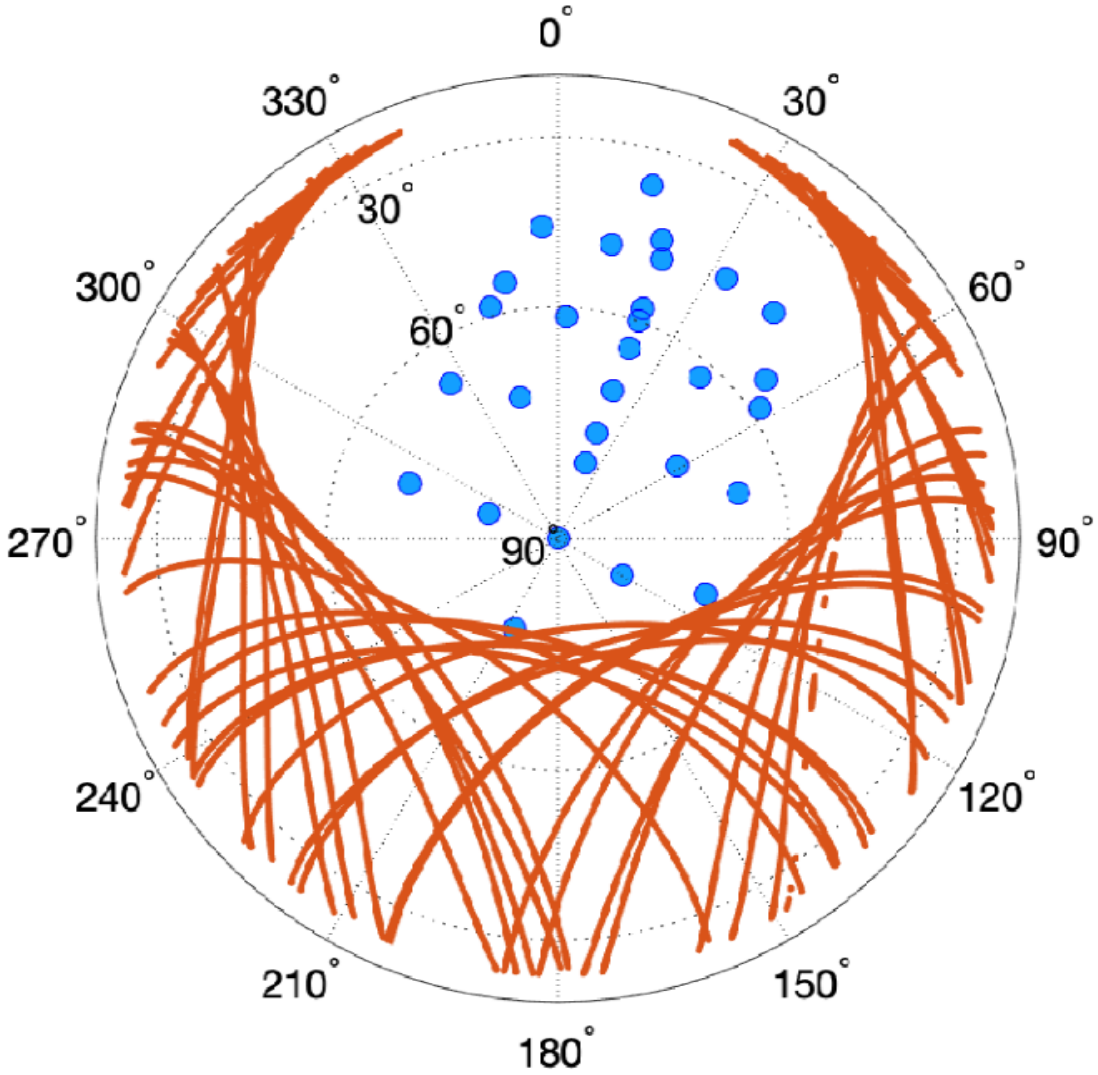
Velocity southwards

Agrees with SuperDARN data

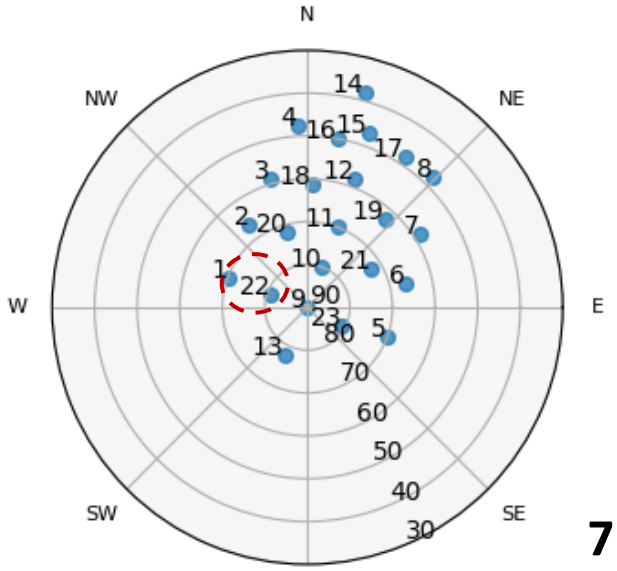


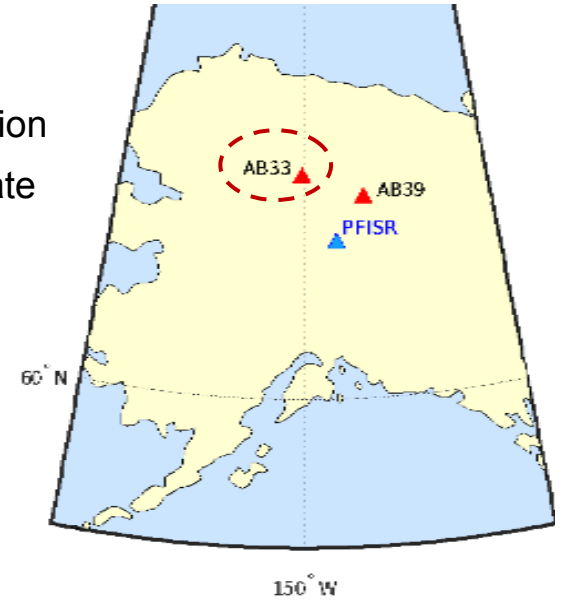
Observations: GPS





Case 1: Postsunset Irregularities



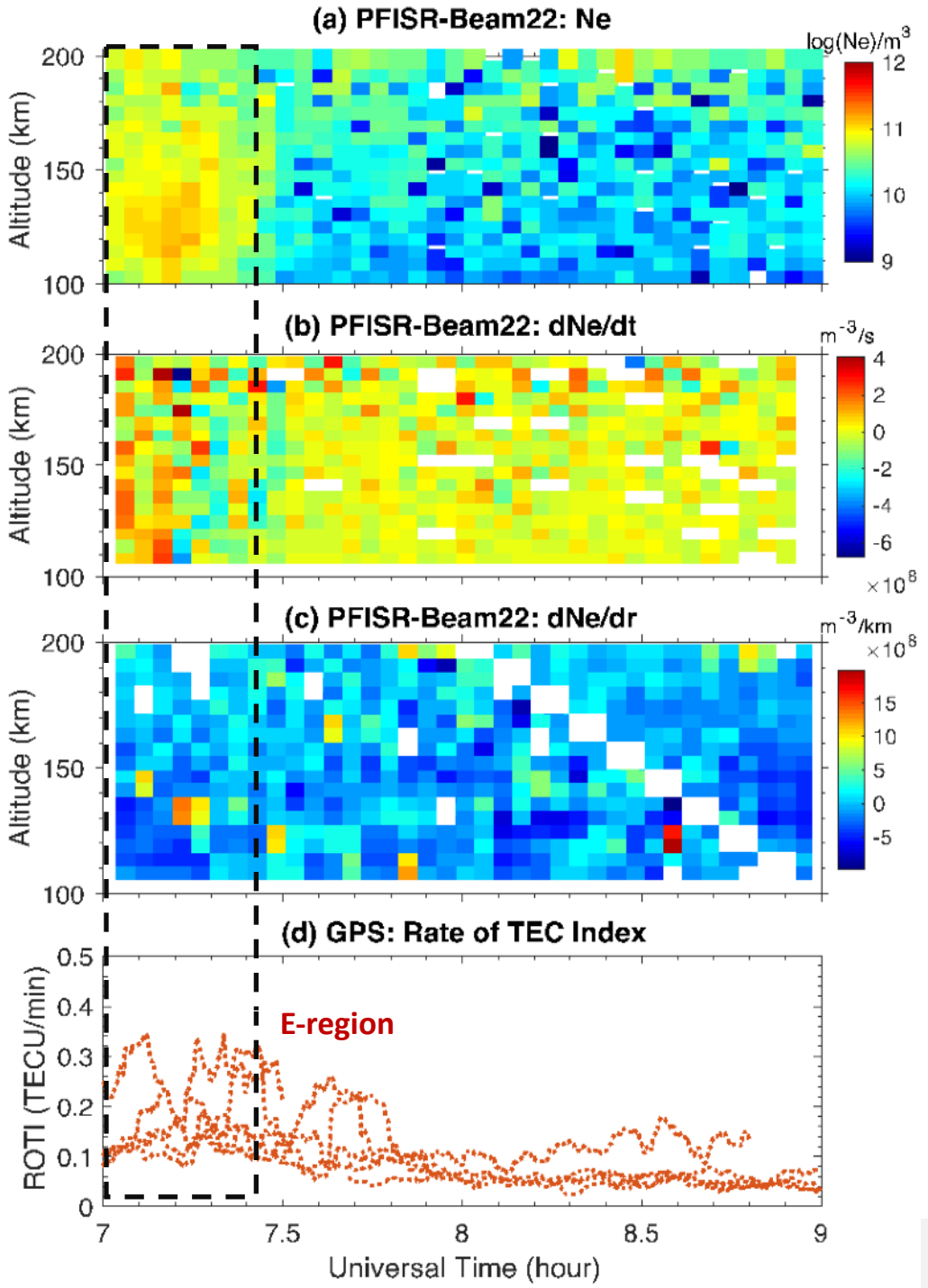


CORS GPS station

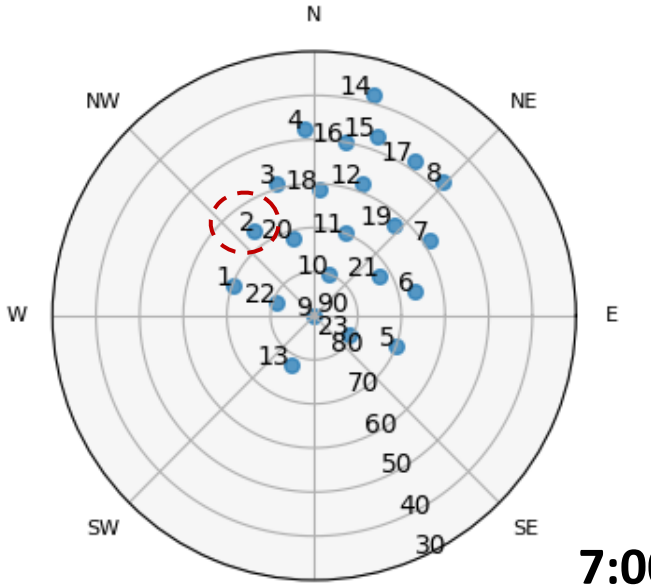
15s sampling rate

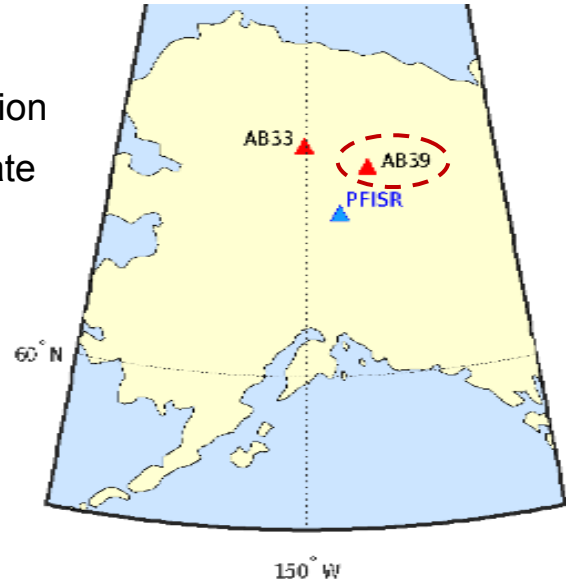
7:00UT-7:20UT

07/29/2020



Case 2: Postsunset Irregularities



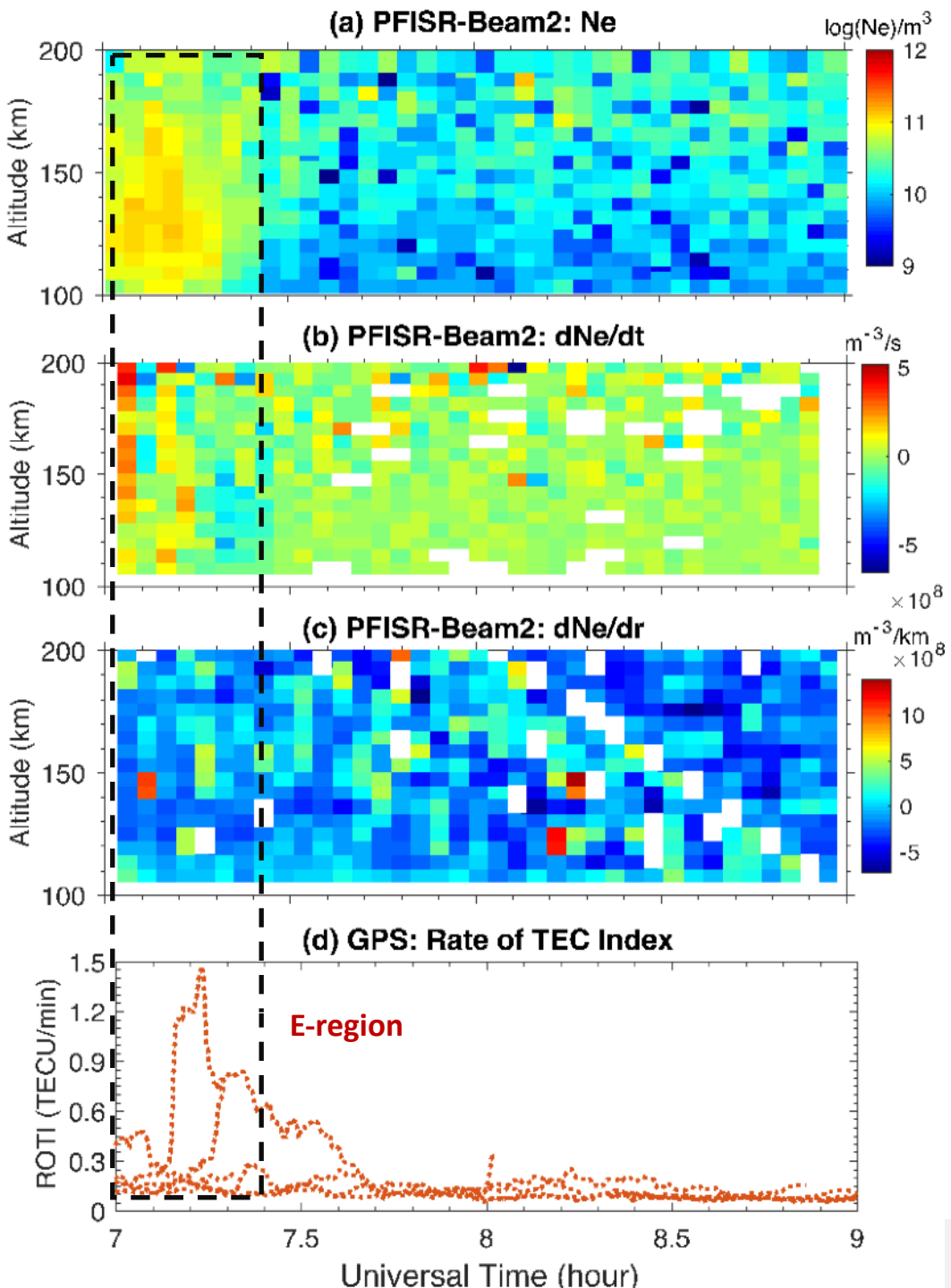


CORS GPS station

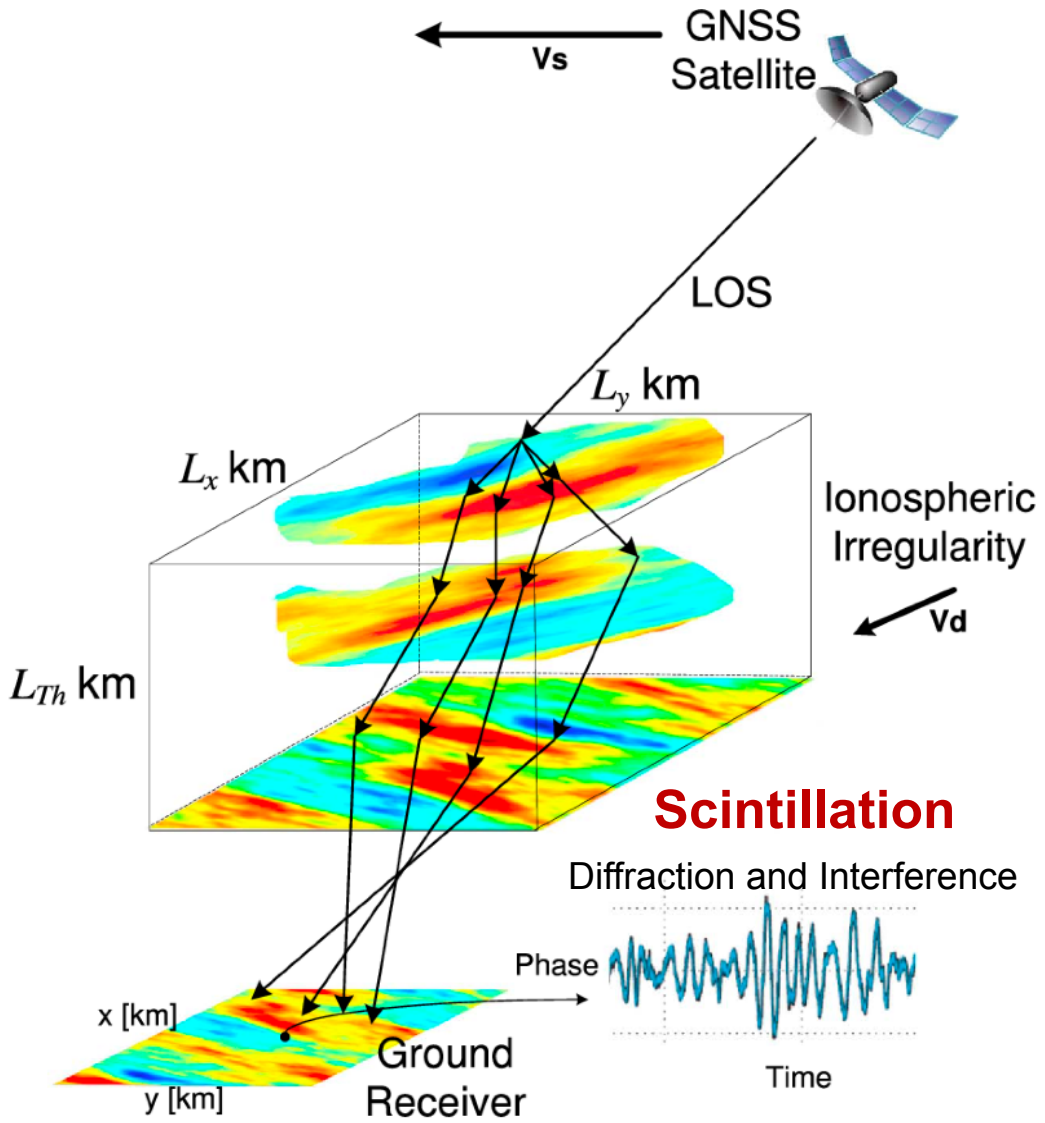
15s sampling rate

7:00UT-7:20UT

07/29/2020

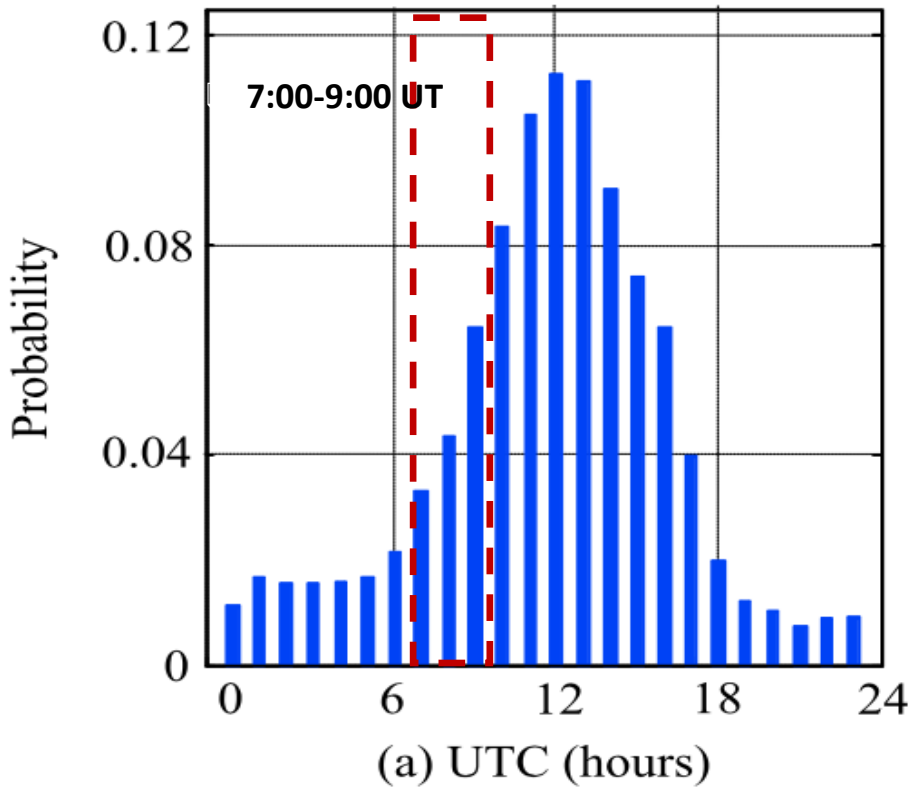


Impacts of E-region ionospheric behavior: Scintillation



Deshpande, K.B., et al., JGR, 2014

Gakona, Alaska (62.39°N, 145.15°W)



Jiao, Yu, et al. "Characterization of high-latitude ionospheric scintillation of GPS signals." *Radio Science* 48.6 (2013): 698-708.

Summary

- Solar activity detected around 4:30 UT
- Observation of PFISR data
  - Auroral precipitation enhancement of electron density in E region in all directions from 7:00 UT to 7:20 UT
  - No significant change in electron density in F region
- Observation of GPS
  - Irregularities in total electron density observed at 7-8UT
  - Related to the auroral precipitation effects in E region
  - Scintillations may occur with large density gradient

Acknowledgements

ISR Summer School 2020 has been very informative for us, thanks for organizing it online in this pandemic situation.

Thanks to all the speakers.

Thank you!

Questions and Suggestions