F2 peak analysis from PFISR

Group 5
Heba S.Mohamed (SWMC-Helwan Univ)
Mohamed O.Shamat (UMass Lowell)
Komal Kumari (Clemson U.)
Teddy Braden (Canada)
Yu Hong (UTexas Arlington)

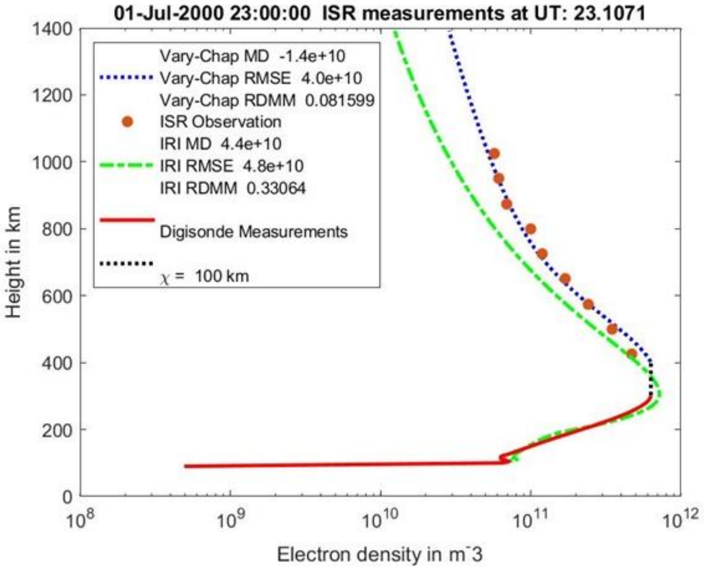
Mohamed

Motivation

- IRI often shows a parabolic electron density profile around the F2 layer peak.
- ISR measurements, on the other hand, often suggest the electron density remains ~constant for few kms at the peak.

What does it mean?- the profile around the F2 layer peak is not parabolic but rather has a flat nose shape.

Let’s investigate!!



(Shamat et al., 2020)

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Experiment Design

What is the appropriate time window for sampling?

Alaska Noon at 22:00 UT and ~14:00 LT- Our time window was between 23:00 UT to 01:00 UT.

We also need good results (high resolution and high sampling rate)

- ❖ High resolution: Long pulse or Alternating pulse- AC (4 beams, 2 frequencies)
- ❖ High sampling rate: How many beams in a minute? -> Vertical beam sampling rate faster. What is the integration time for each record? -> 30 minutes

Any other data sets? (we have Digisonde data in our time window)

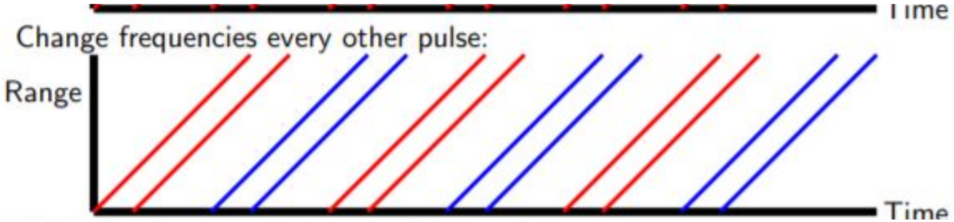
Thanks to David Themens!!

Komal

How many pulses are being integrated in 30 minutes for vertical beam?

Komal

4 beams - 6 beam in a cycle
Beam cycle: Vertical, upB, Vertical, Northwest, Vertical, East
2 Frequencies 449.6 MHz 449.3 MHz 300 KHz apart



(32 codes in the alternating code cycle)
AC - 32 : 32*6*2 = 384 pulses/cycle
Vertical = 384/2 = 192 pulses
Other beams = 64 pulses

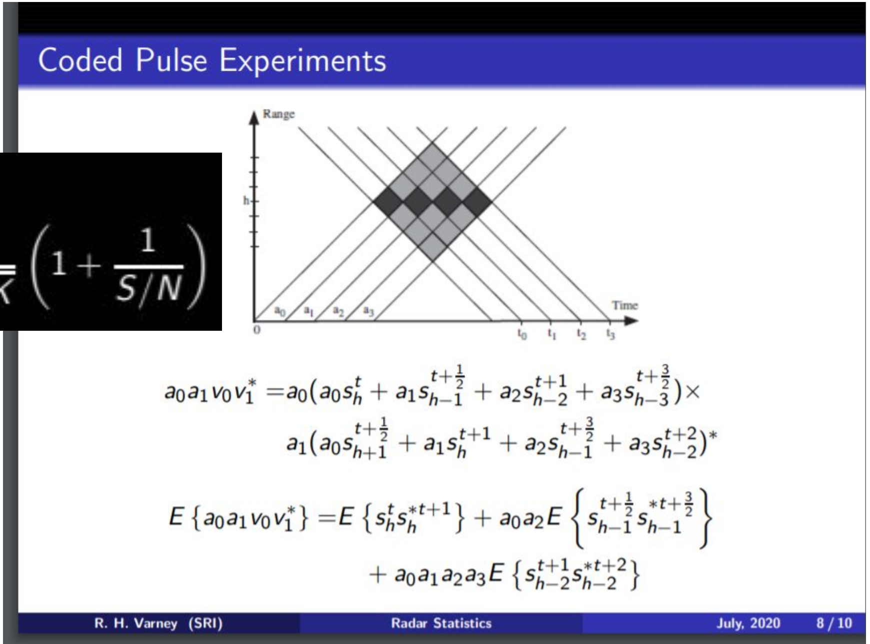
Ipp = 5 ms
384*5ms = 1.92 s
1.92s * 4 = 7.6 ms <u>for each record</u>

$$\frac{\sqrt{Var\left\{\hat{S}\right\}}}{S} = \frac{1}{\sqrt{K}}\left(1+\frac{1}{S/N}\right)$$

Vertical 192*4 = 768 pulses / 7.6 s
Other beams 64*4 = 256 pulses / 7.6 s

30 minutes*(60 second/minute)/7.6s = total records

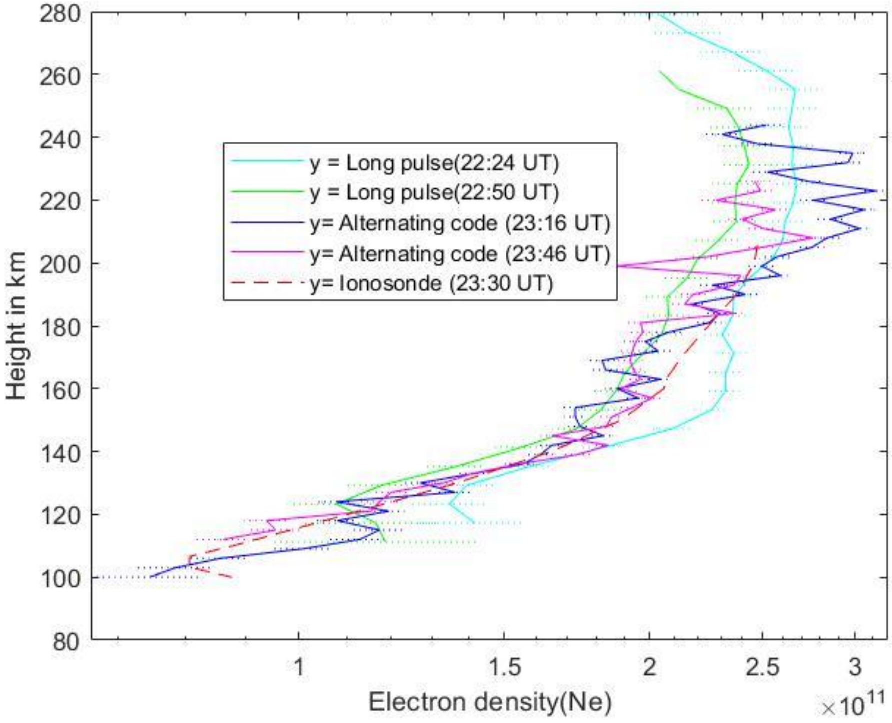
Total Vertical beam = 236 * 768 = 181 248 pulses
Other beams = 236 * 256 = 60 416 pulses
(Those are the number of cycles “K” that we use for the ISR probability or “error statistics” equation)



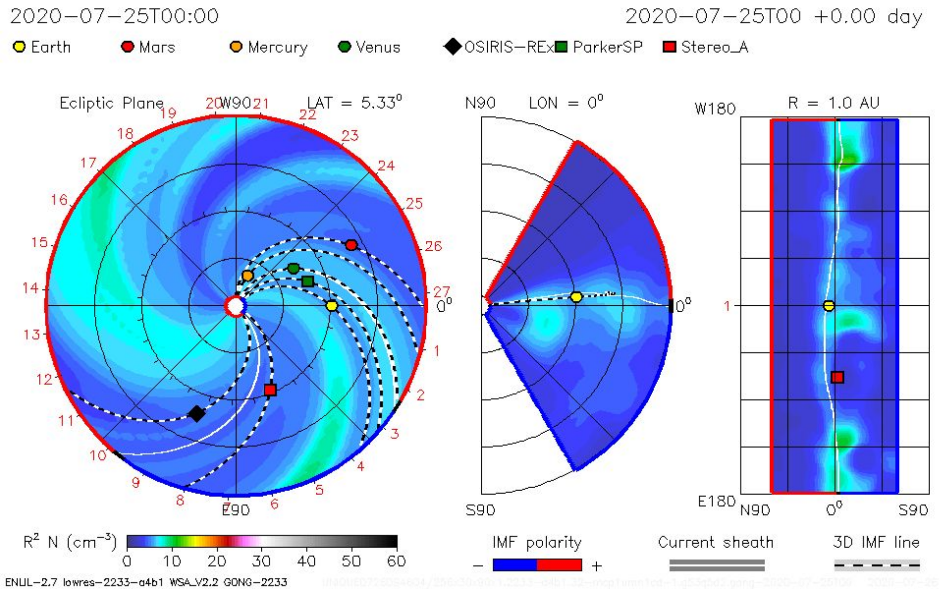
Long pulse vs Alternating code pulse (vertical beam)

The high altitude region with high errors are not plotted here.

Fitted data with large fitting errors may result from a variety of reasons.

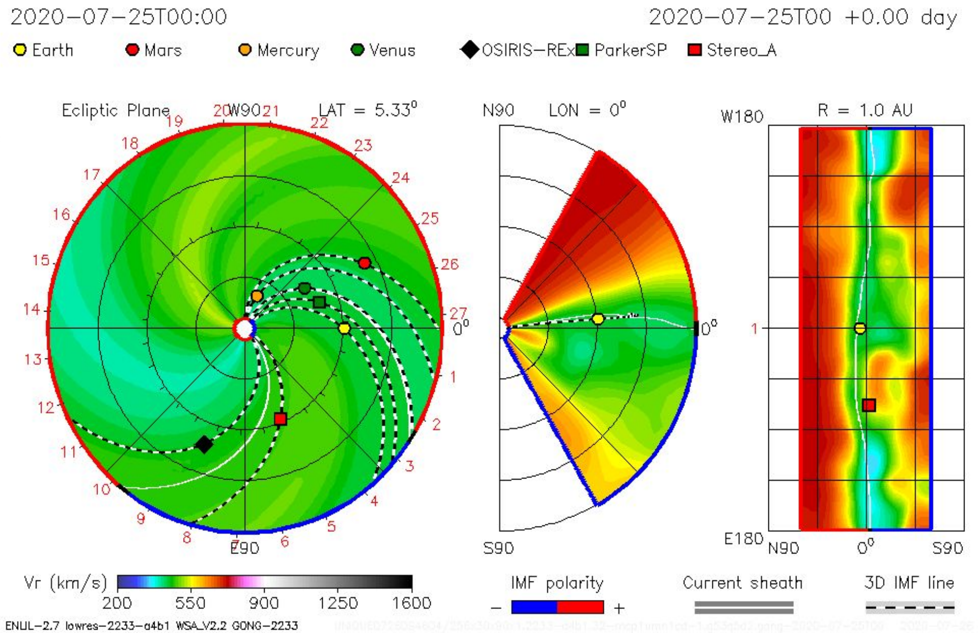


Solar activity and IMF directions



IMF polarity is negative

Solar wind ~500km/s



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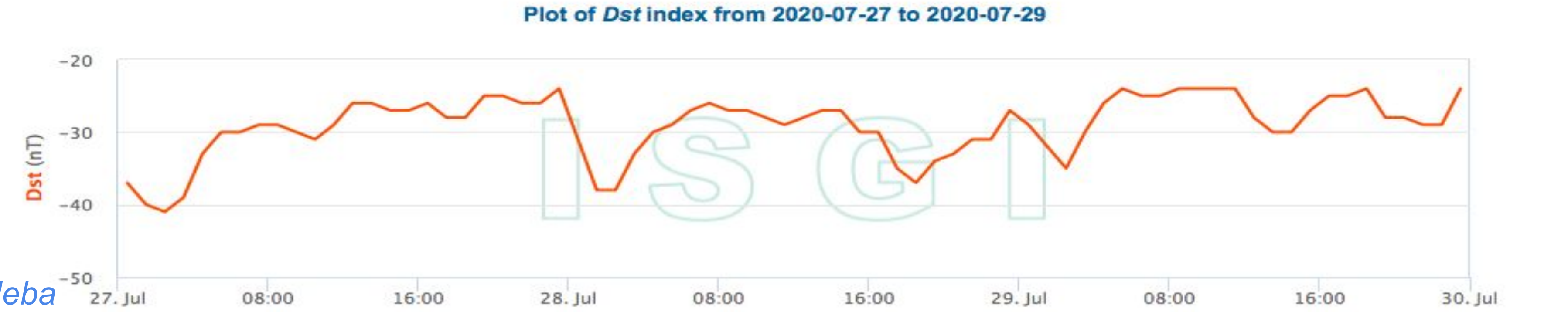
What is the IMF and Bz condition in our time window?

Kp reaches +2 on 28 July at 01 am in the morning
And ap shows 9 ، while Dst is -38 nT on 02:30



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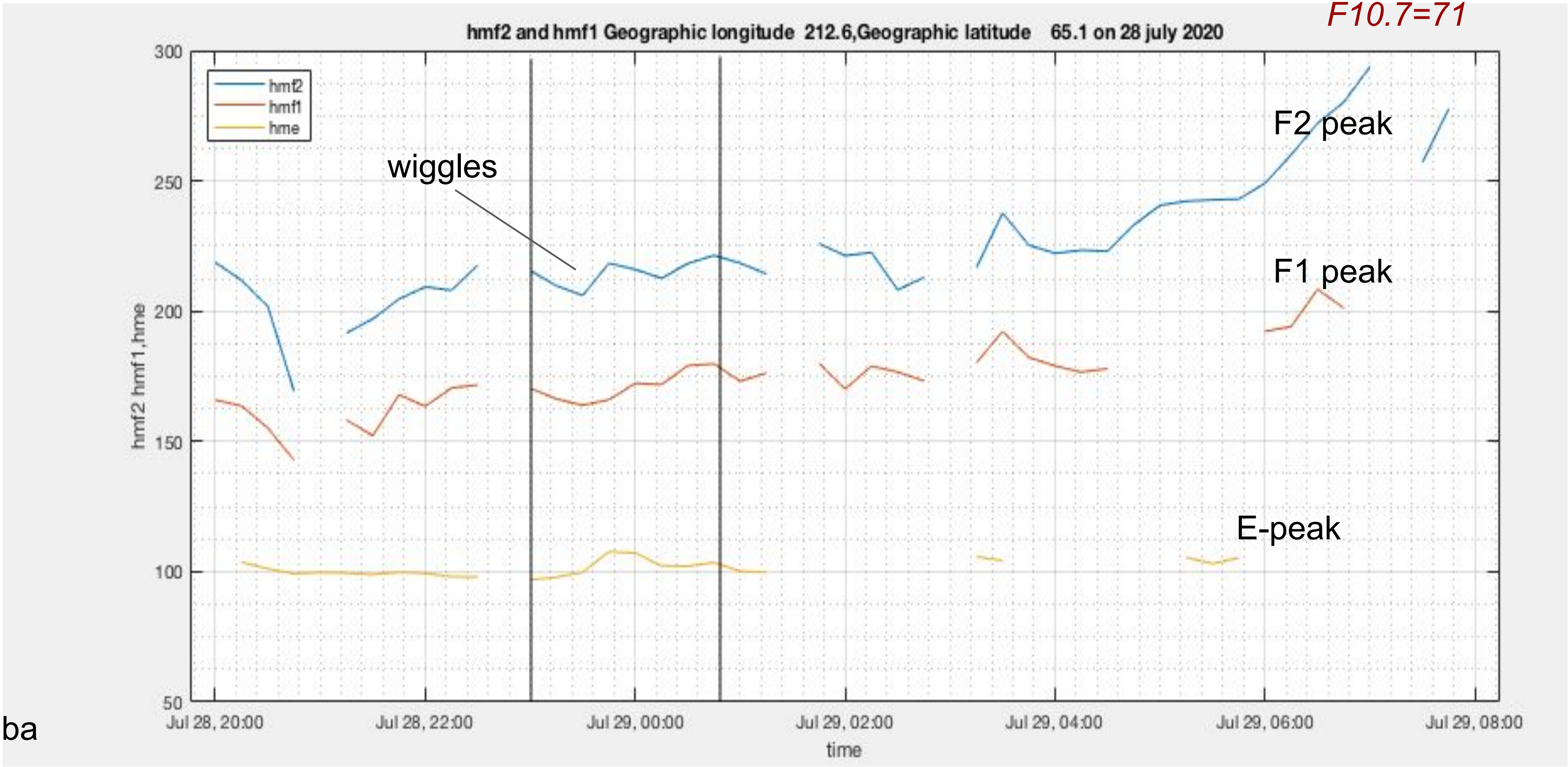
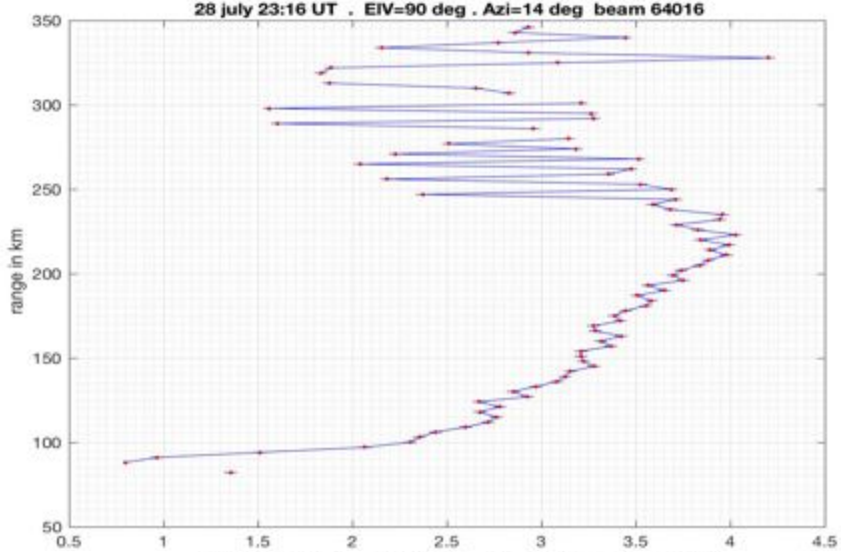
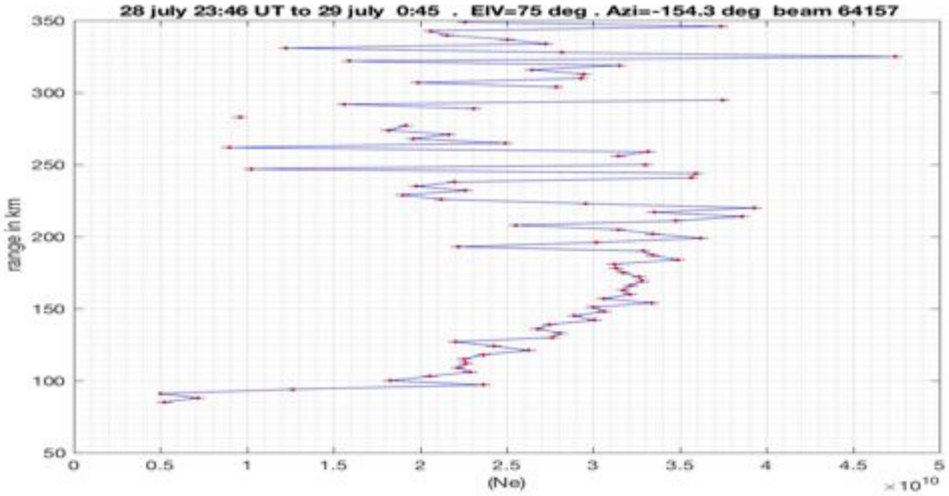
HmF2 peak from Digisonde in the time window

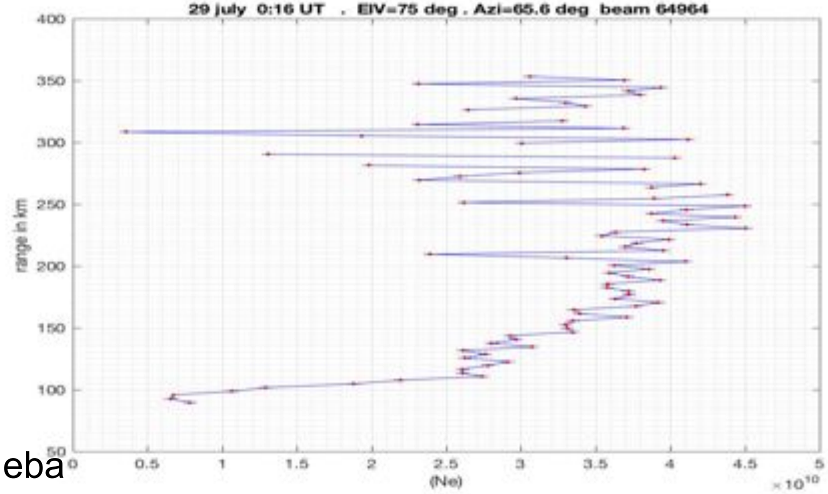
Notice the wiggles (possibly TIDs but we need error bar)

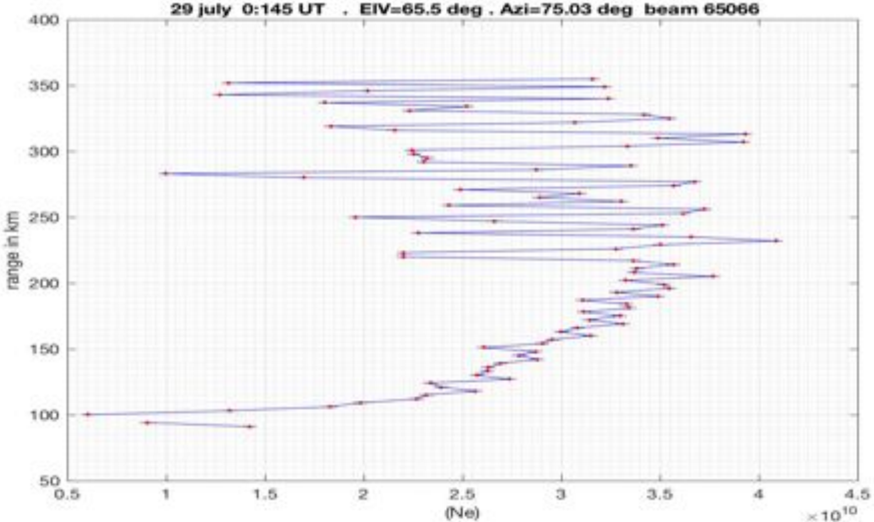


Heba


28 july 23:16 UT . ElV=90 deg . Azi=14 deg beam 64016
range in km


28 july 23:46 UT to 29 july 0:45 . ElV=75 deg . Azi=-154.3 deg beam 64157
range in km
(Ne)
×10^10


29 july 0:16 UT . ElV=75 deg . Azi=65.6 deg beam 64964
range in km
(Ne)
×10^10

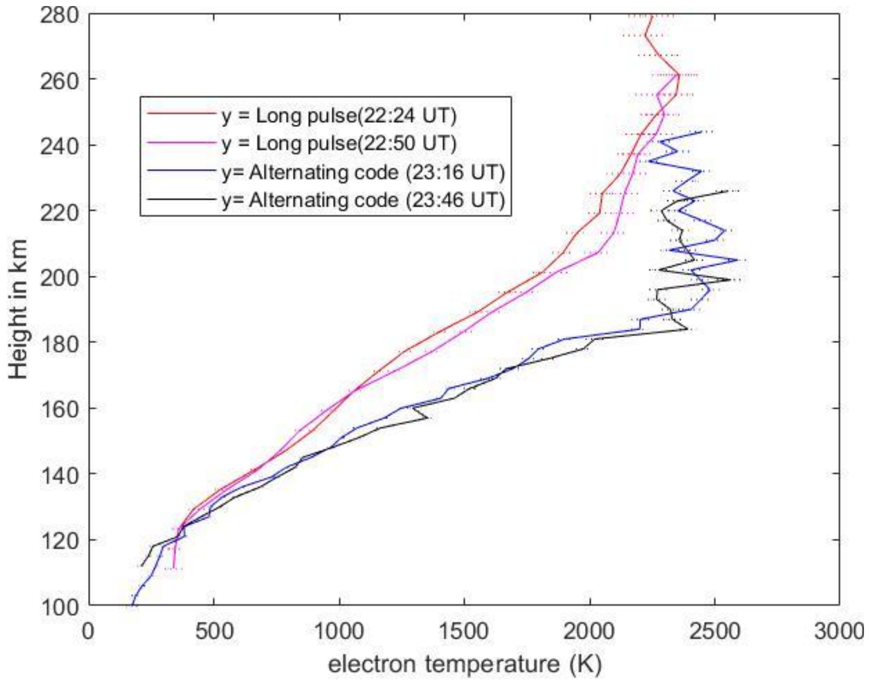

29 july 0:145 UT . ElV=65.5 deg . Azi=75.03 deg beam 65066
range in km
(Ne)
×10^10

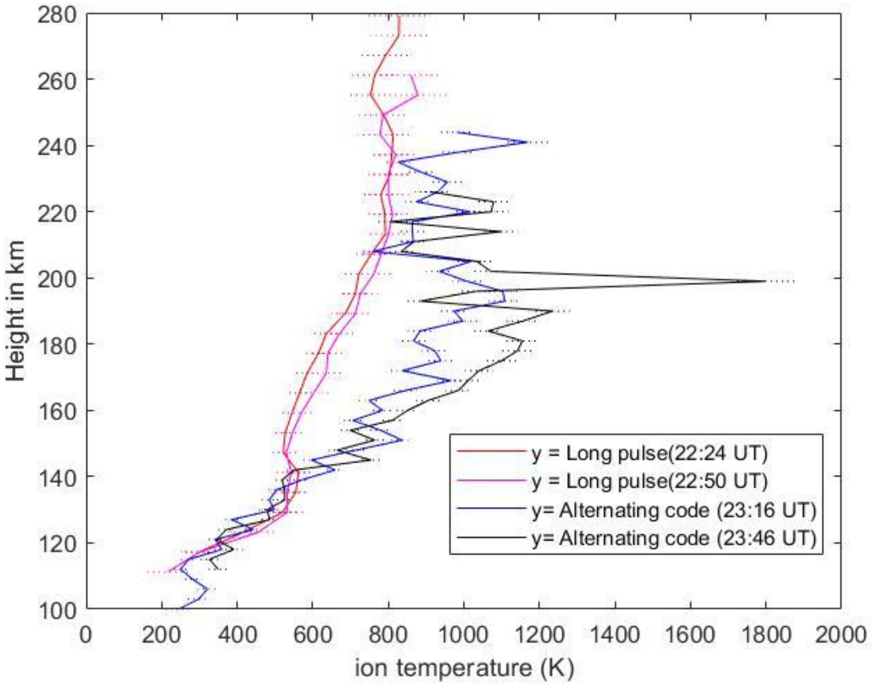
Heba

Why the wiggles in AC code results?

$$\frac{\omega}{k} = \sqrt{\frac{k_B T_e + \gamma_i k_B T_i}{m_i}} = V_s$$

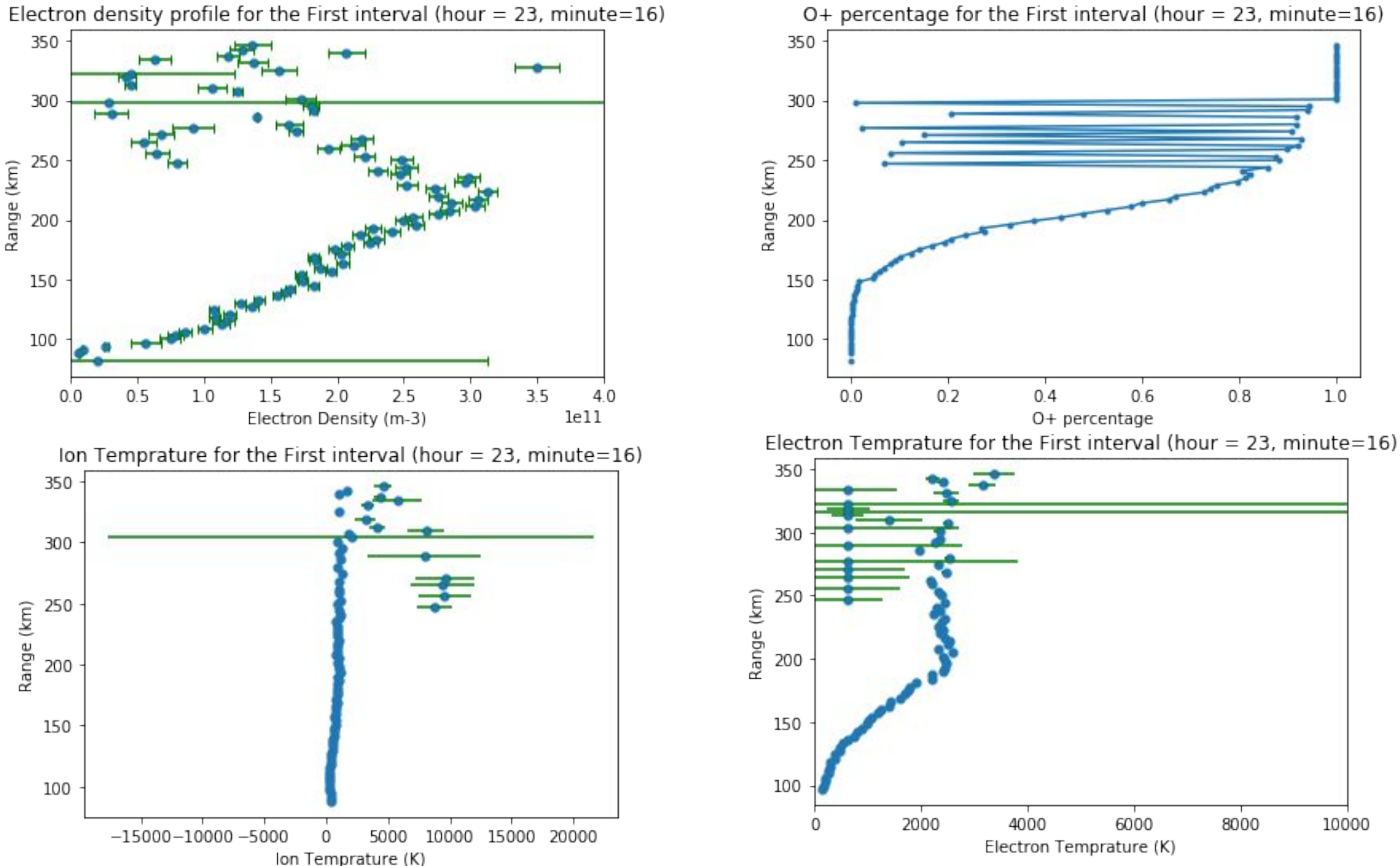
Fitted data with large fitting errors may result from a variety of reasons , for example, the inapplicability of the theoretical model to the actual scatter physics, inappropriately determined or specified ion compositions, or low signal-to-noise ratios.





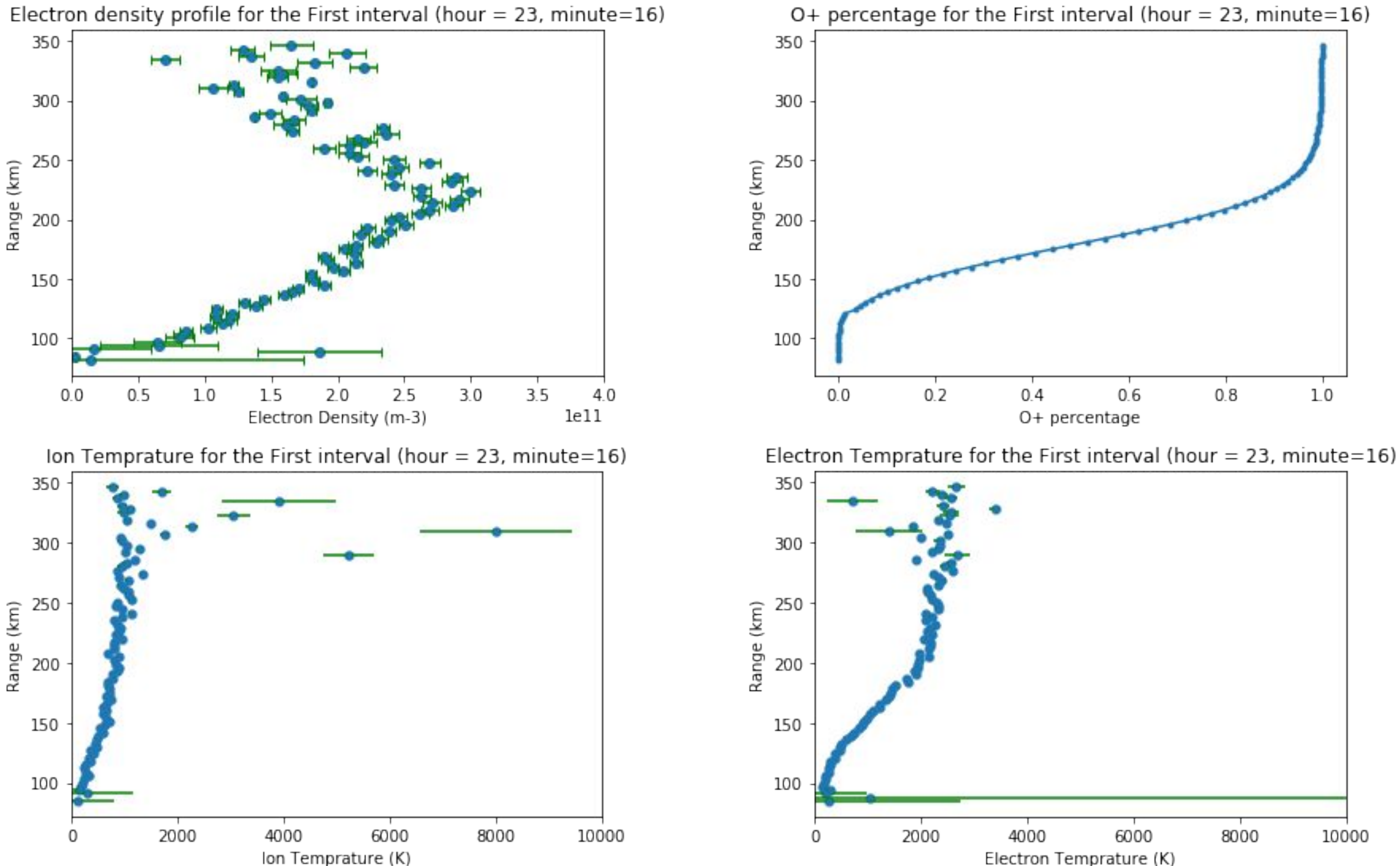
Teddy

Ion Composition: For Alternating code, Vertical Beam



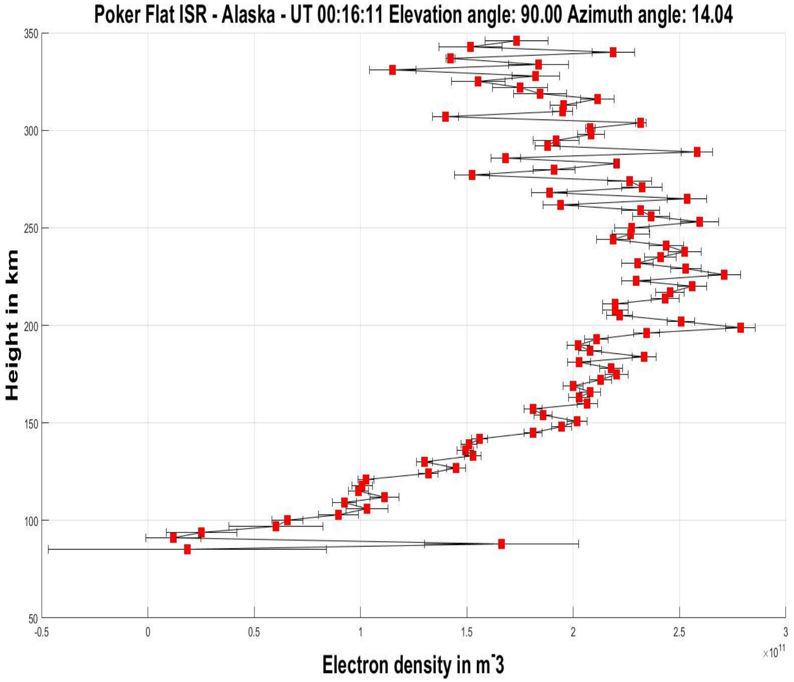
Teddy

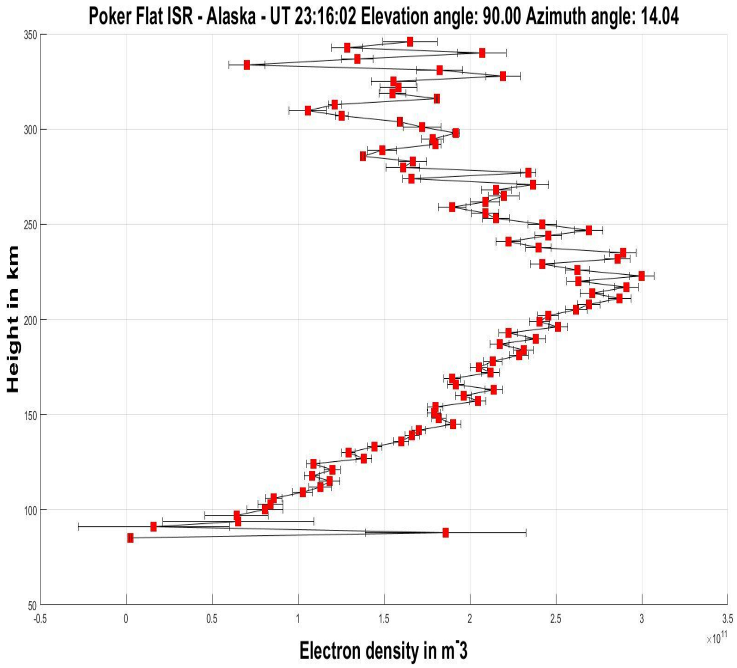
Ion Composition Model Fixed



Teddy

Time evolution of NeF2 (Vertical beam)





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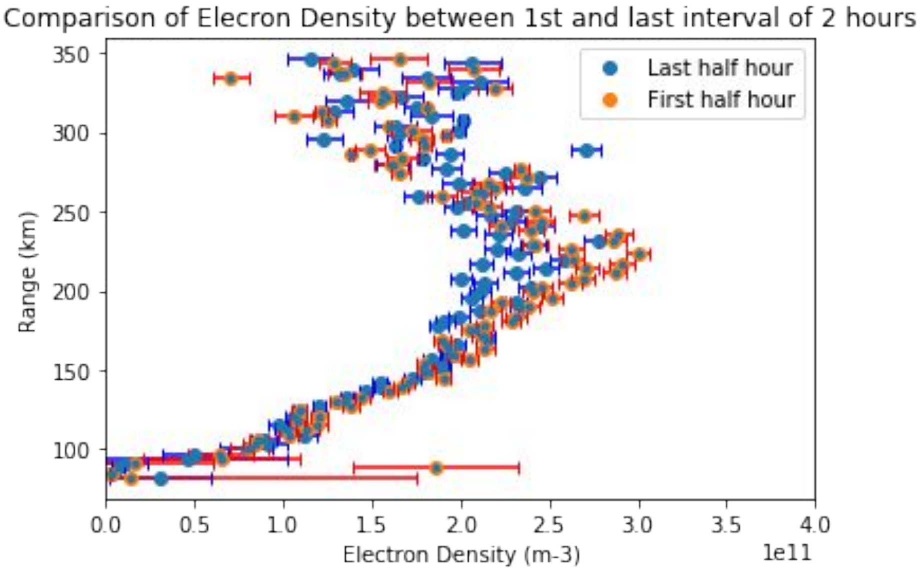
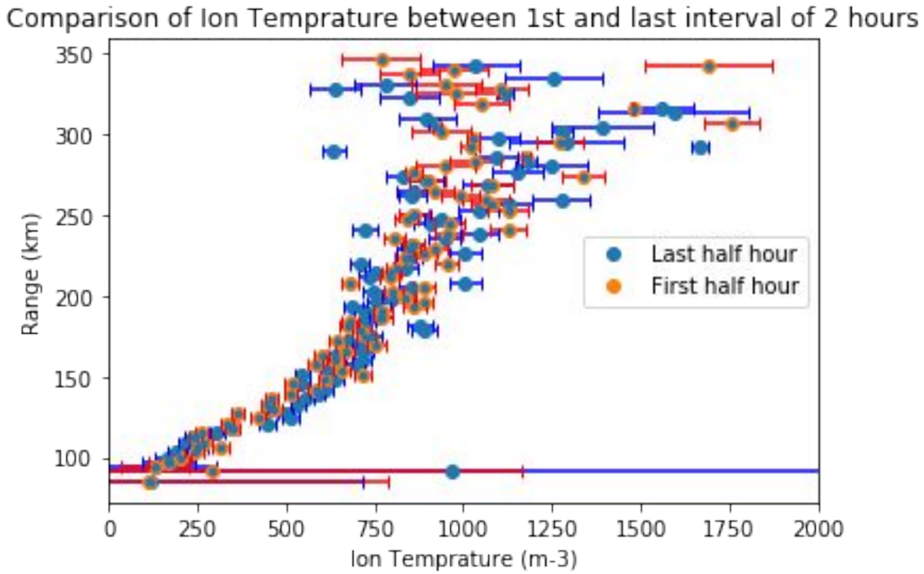
Changes over the two hours
Notice the shape of NeF2-peak!!





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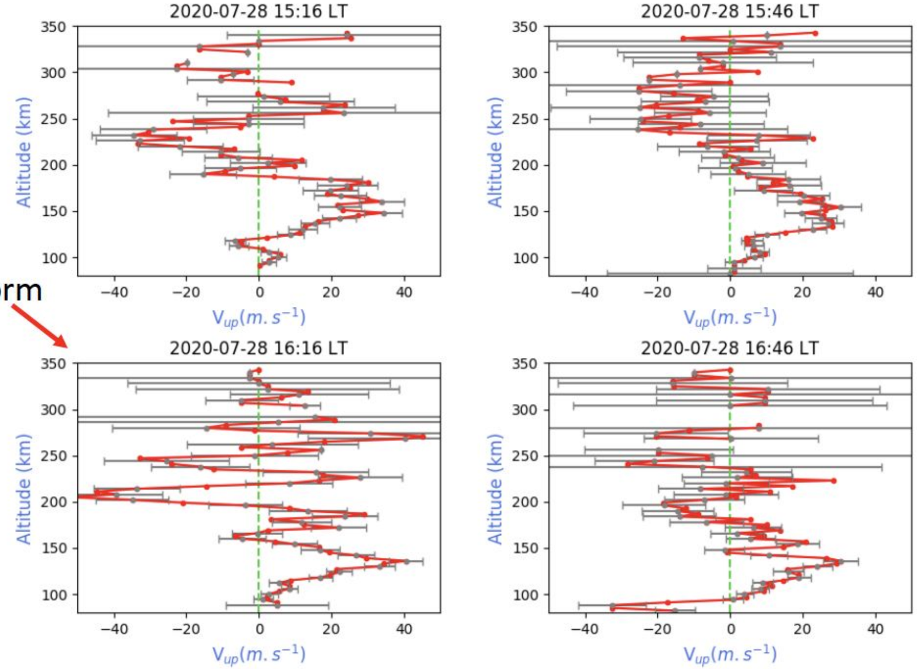
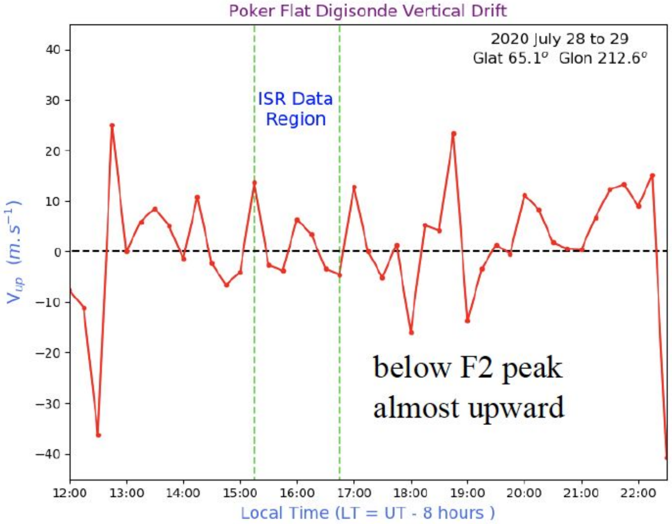
Vertical Velocity

```
#%% convert ion v_los into the 3-D velocities
v_up = vel * np.sin(d2r*elm)
v_e = (vel * np.cos(d2r*elm))*np.sin(d2r*azm)
v_n = (vel*np.cos(d2r*elm))*np.cos(d2r*azm)
alt  = rag * np.sin(d2r*elm)
```

storm



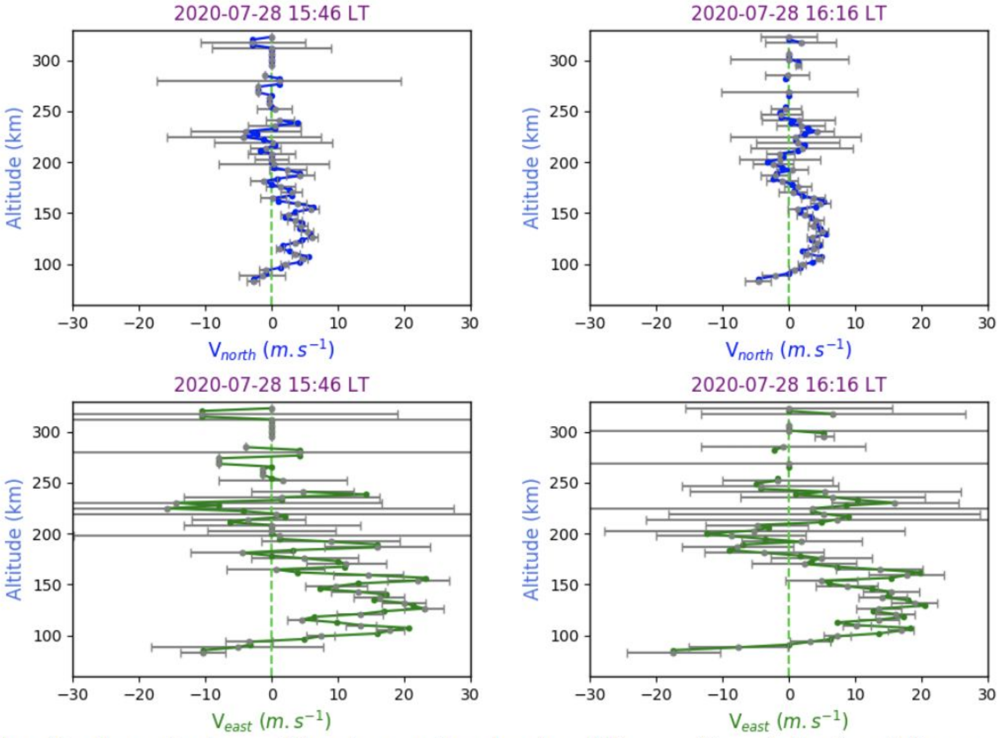
Altitudinal variation of vertical velocity (V_{up}) derived from ISR in four different LT (LT=UT-8, vertical beam elm=90°)



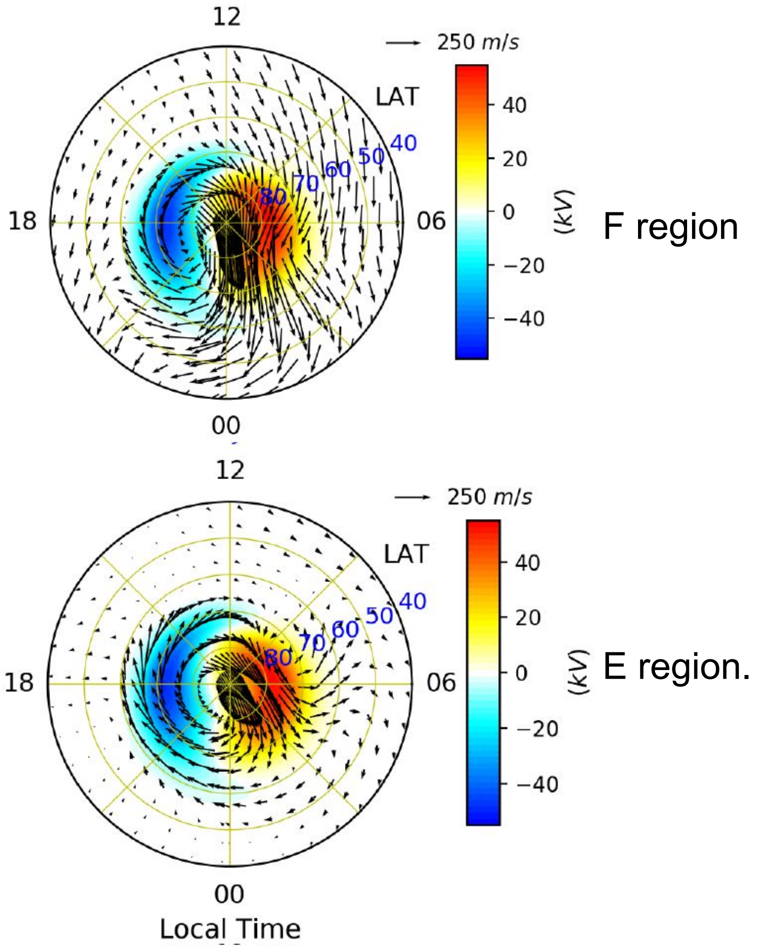
Temporal variation of vertical derived from Ionosonde (**d(hmF2)/dt**) with the ISR data region window

- First two intervals: downward (above) & upward (below) → increase the peak (parabolic)
- Last two intervals: disturbing and different gradient → constant variation along altitude

Horizontal Velocity



Altitudinal variation of horizontal velocity (V_{east} & V_{north}) derived from ISR in four different LT (LT=UT-8, 4th beam elm=65°)



High-latitude electric electric potential (convection) and horizontal speed (sqrt (V_{east}^2+V_{north}^2)) GITM simulation

Summary

- We see a variability in the shape of the F2 peak. We first see a parabolic shape but over the span of two hours, the peak recedes to a flat (constant) shape.

- The electron density from alternating code experiment is consistent with the results derived from Ionosonde below F2 peak.

- Due to the ambiguity between the Te/Ti and mi, the ion composition must be modelled. When our models misbehave, the errors associated can propagate through to other parameters such as electron density.

- The vertical velocity below and above F2 peak height has significant impact on the electron density (gradient) at F2 peak, which has been confirmed by ISR and Ionosonde.

- In order to clarify the dynamics process of electron density at F2 peak, more investigation (eg., gravity waves and TIDs) are needed.

Acknowledgement

- We thank all the instructors especially Dr. Ashton Reimer and Dr. Roger Varney from the ISR Summer School for their kind help both on lectures and research work

- We acknowledge Dr. David Themens from the University of New Brunswick for providing the Digisonde Data from Poker Flat station.

Thanks! Questions?