



Sunrise Observation Above Arecibo

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Outline

1. Introduction: Scientific Motivations
2. Experiment Design
 1. Pointing Configuration
 2. Pulse Coding
3. Observations
 1. E and Sporadic E Regions
 2. Temperature Evolution
 3. Timescale Considerations
 4. Interesting Feature
4. Conclusion

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Scientific Motivations

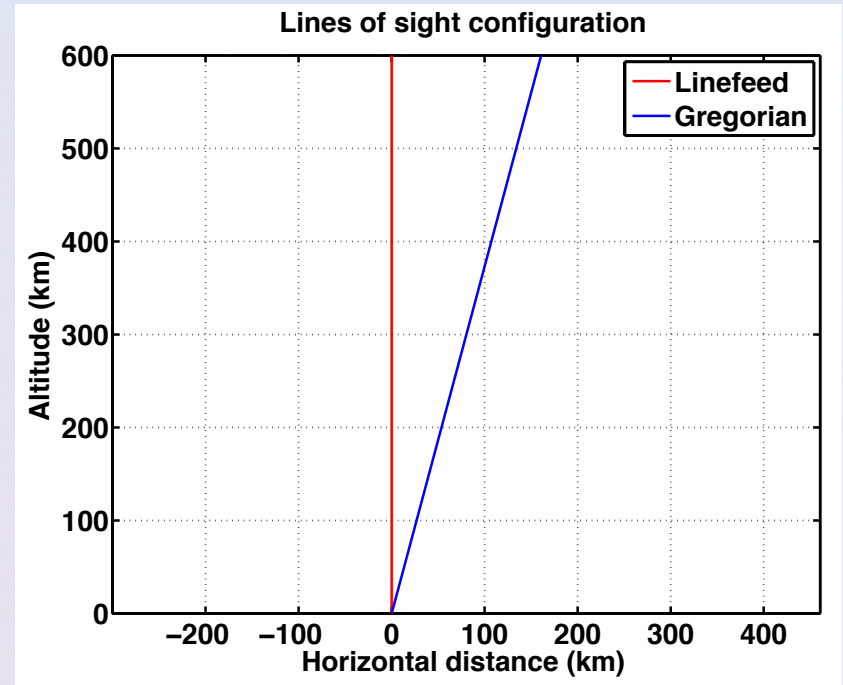
- Nightside ionosphere highly depleted
- Sudden EUV irradiance
 - Photoionisation
 - Altitude effects as Earth's shadow “moves down”
- Timescales of the dawn dynamics?

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Pointing Configuration

- Time: 5:00 to 7:30 (AST)
- Linefeed at zenith
 - Better accuracy
- Gregorian looking east
 - 15° angle with linefeed
 - Expected to “see” sunrise earlier
 - Enables to estimate spatial extension of phenomena
- Experiments: MRACF and Barker Code



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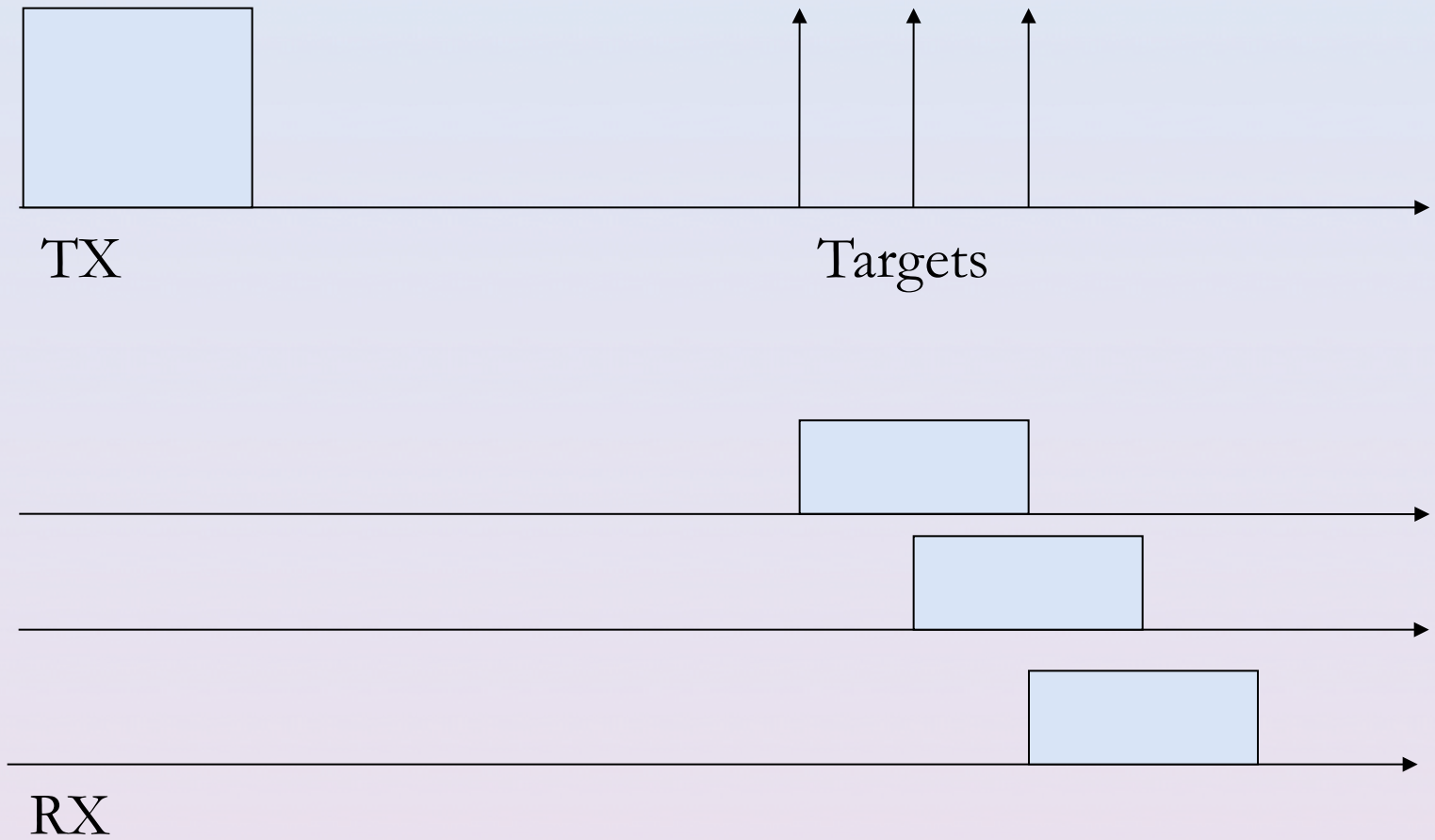
2. Temperature Evolution

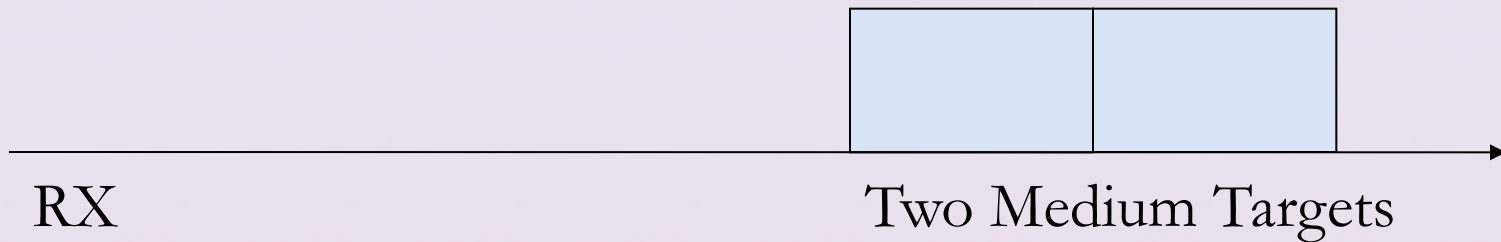
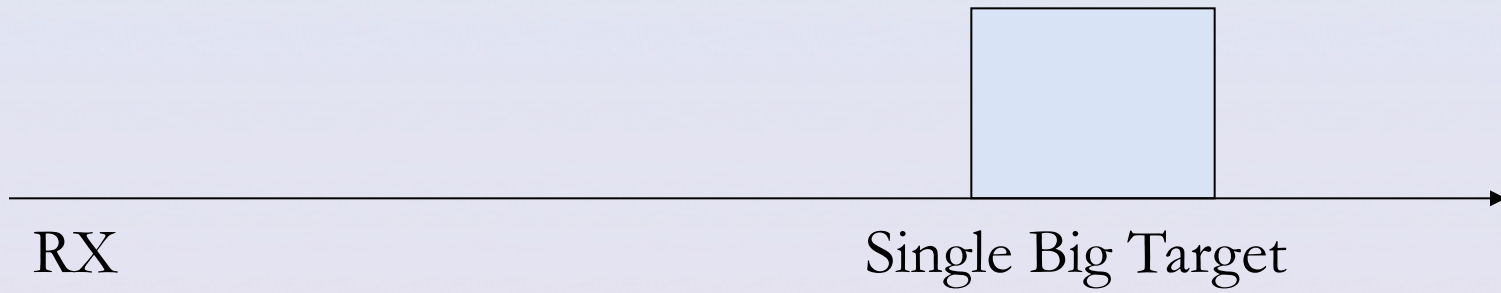
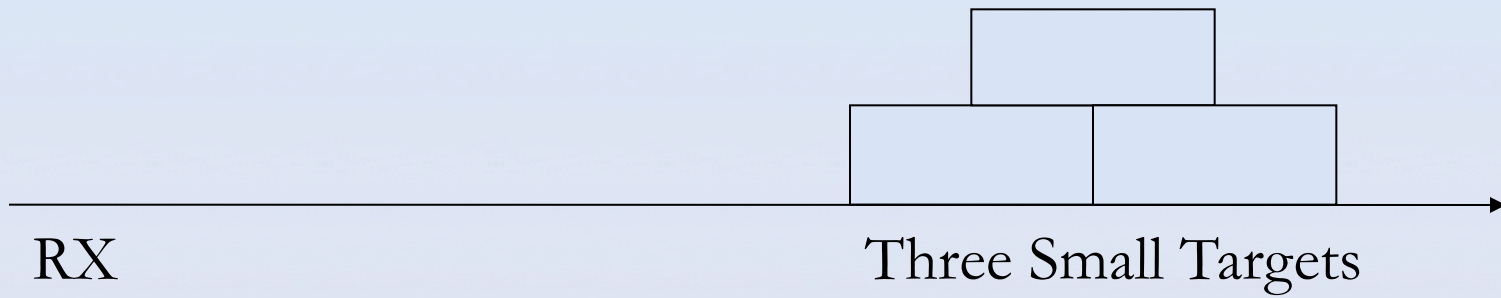
3. Timescale Considerations

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Common Pulse





- Power Limitation For Receiving
- Requirement For Duty Cycle
- Long Pulse
- Bad Resolution

Both Good Resolution & Enough Duty Cycle?

Barker Code

5-digit Barker Code

1 1 1 -1 1

ACF:

1 1 1 -1 1

1 1 1 -1 1:

5

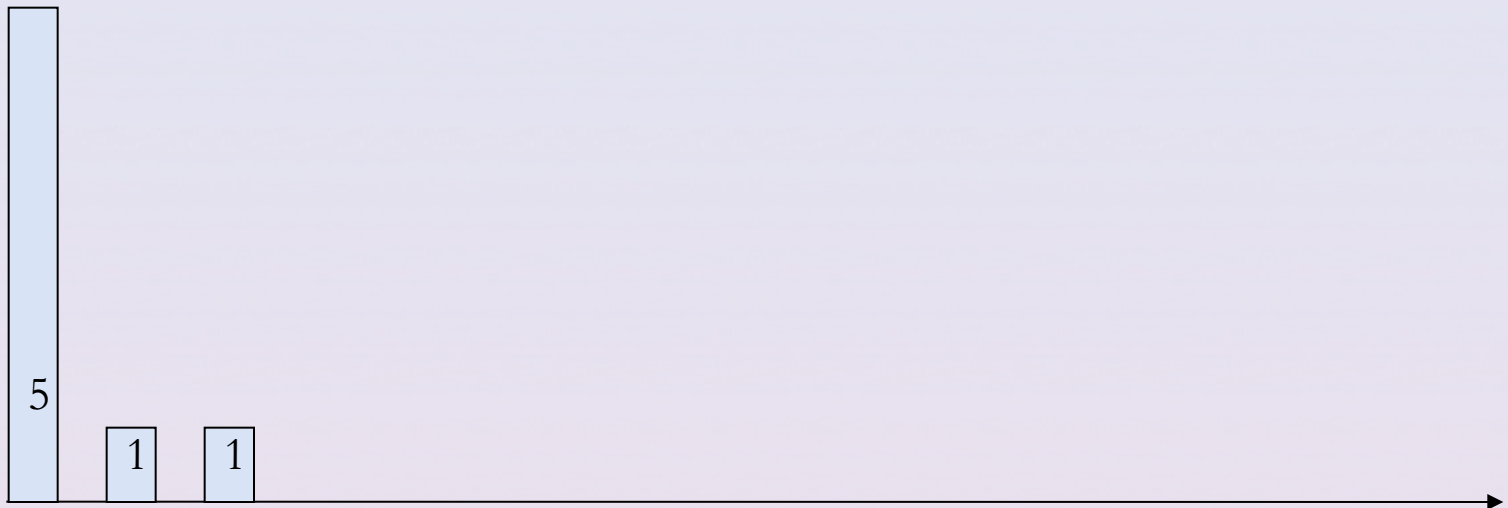
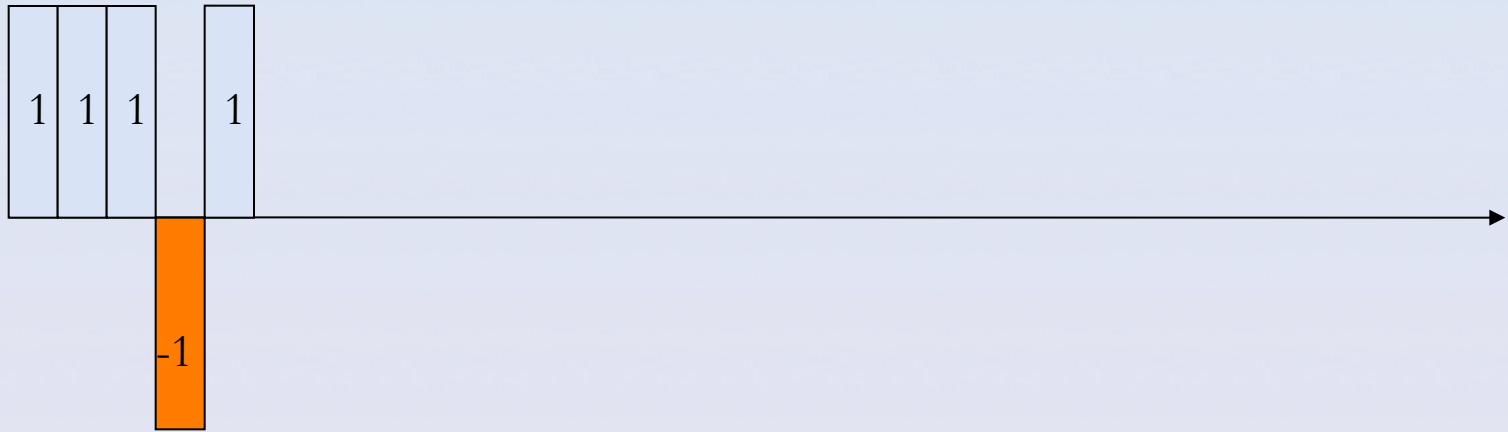
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1

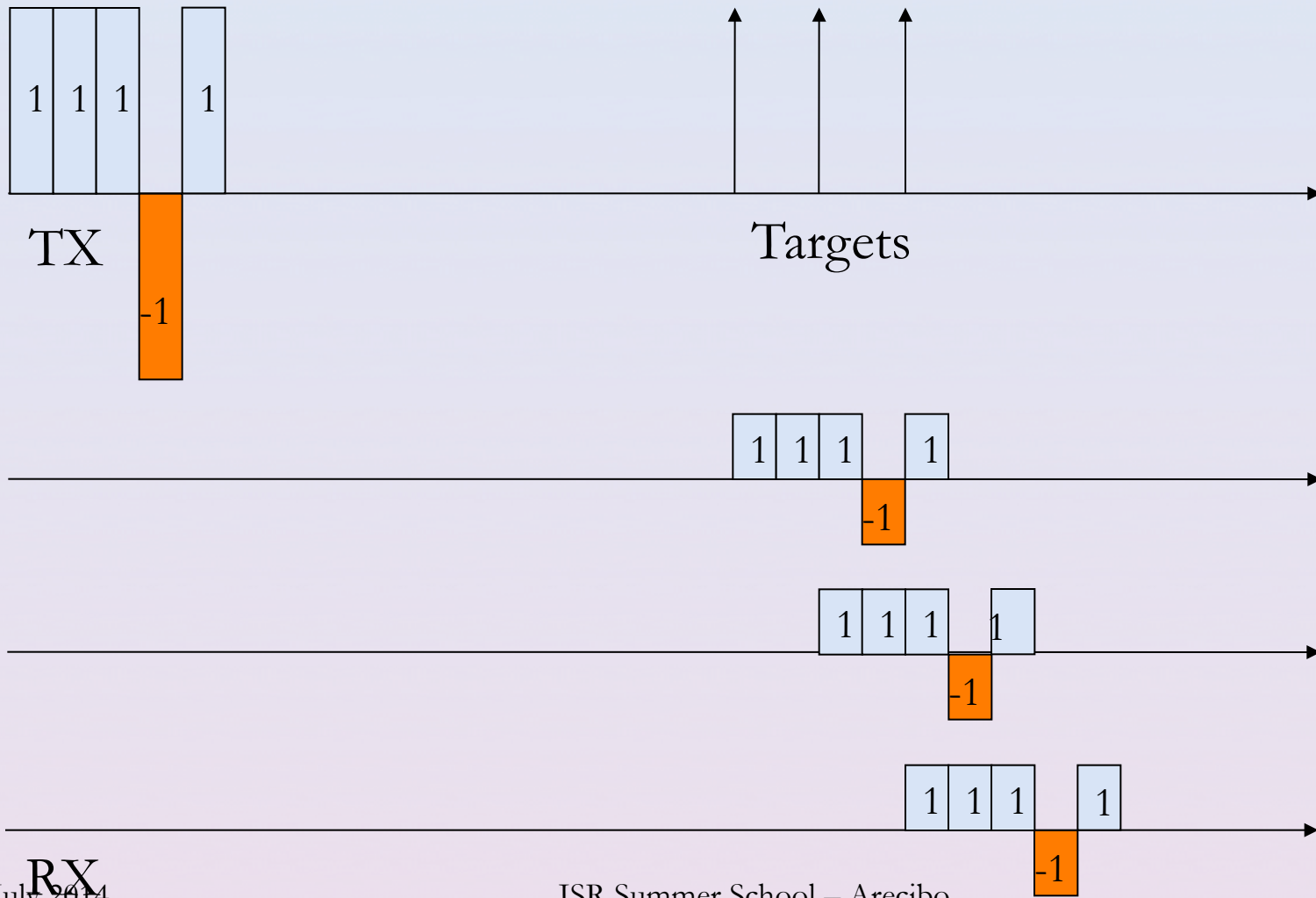
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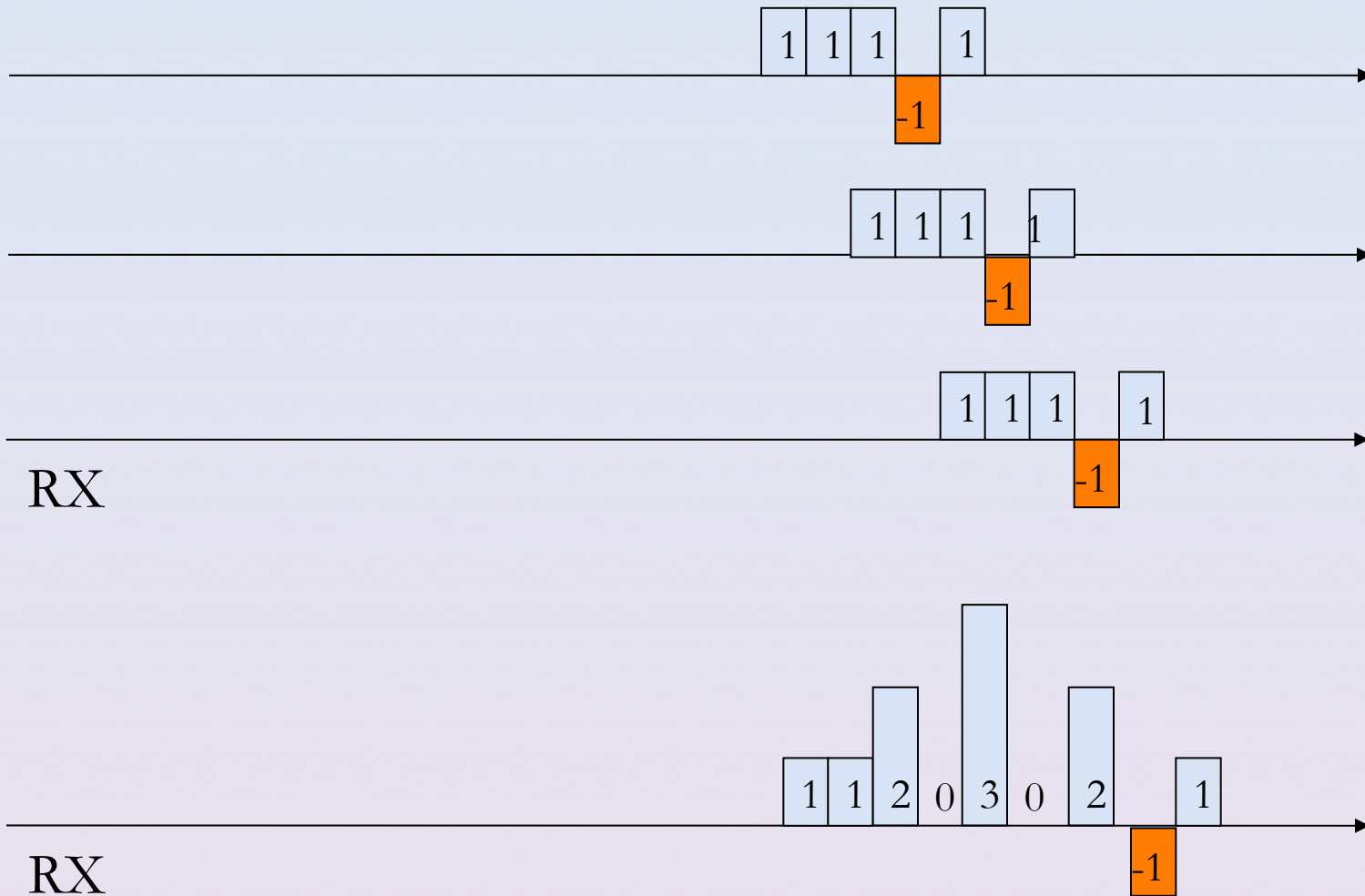
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5 0 1 0 1

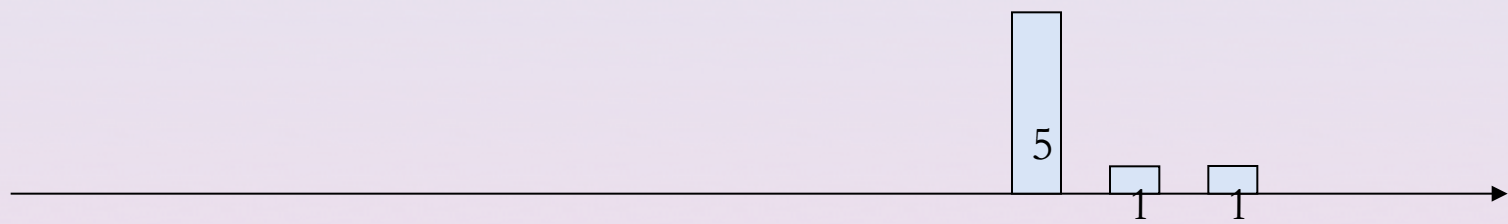
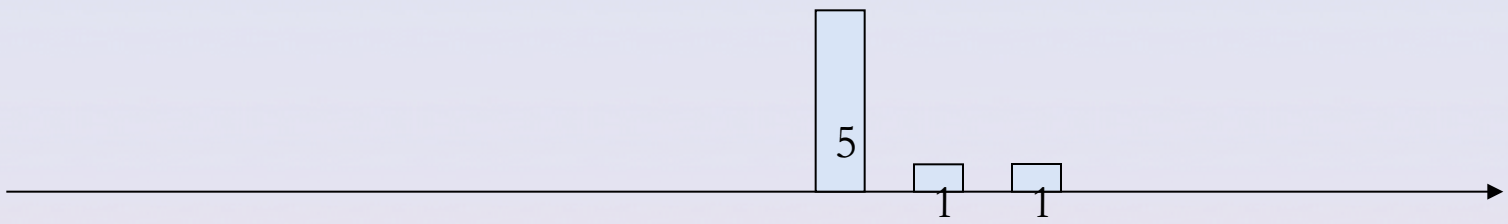
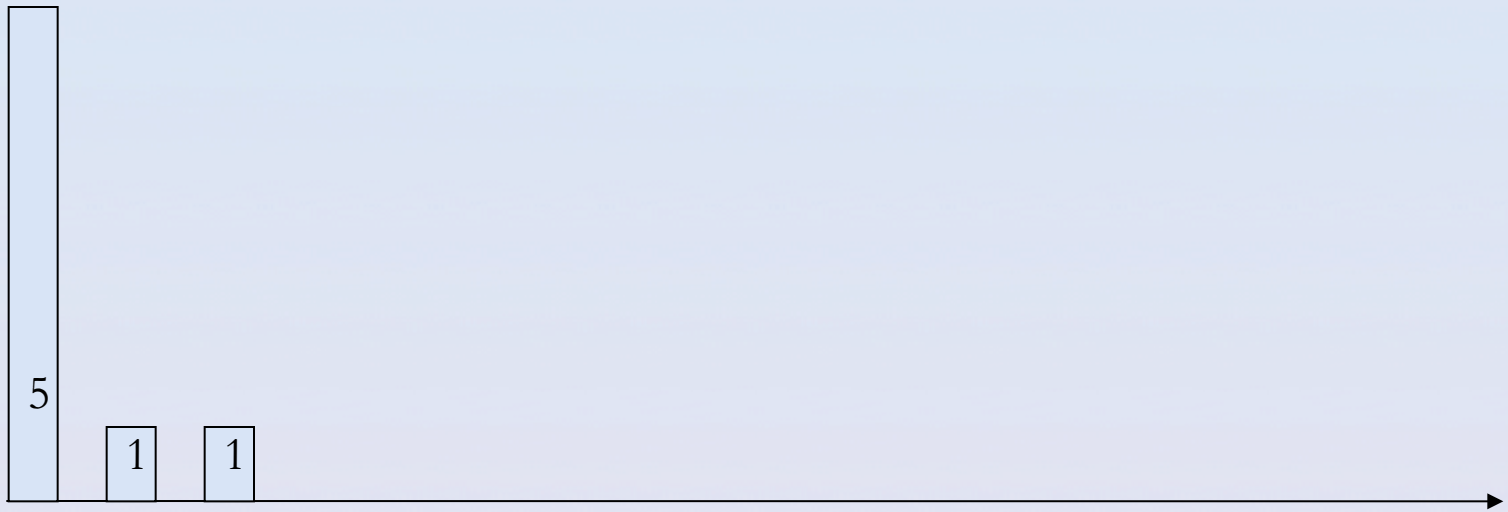


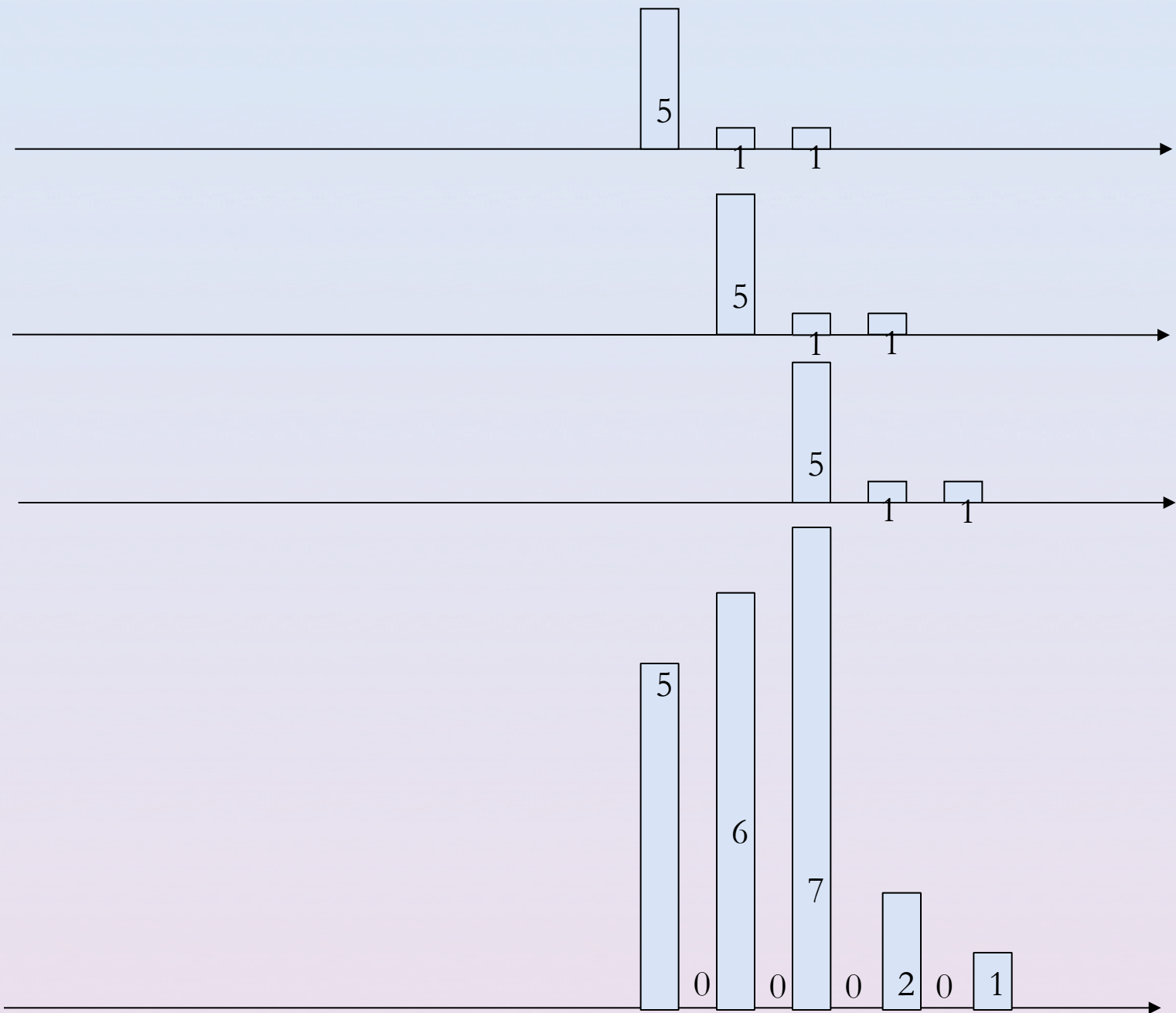
5-digit Barker Code

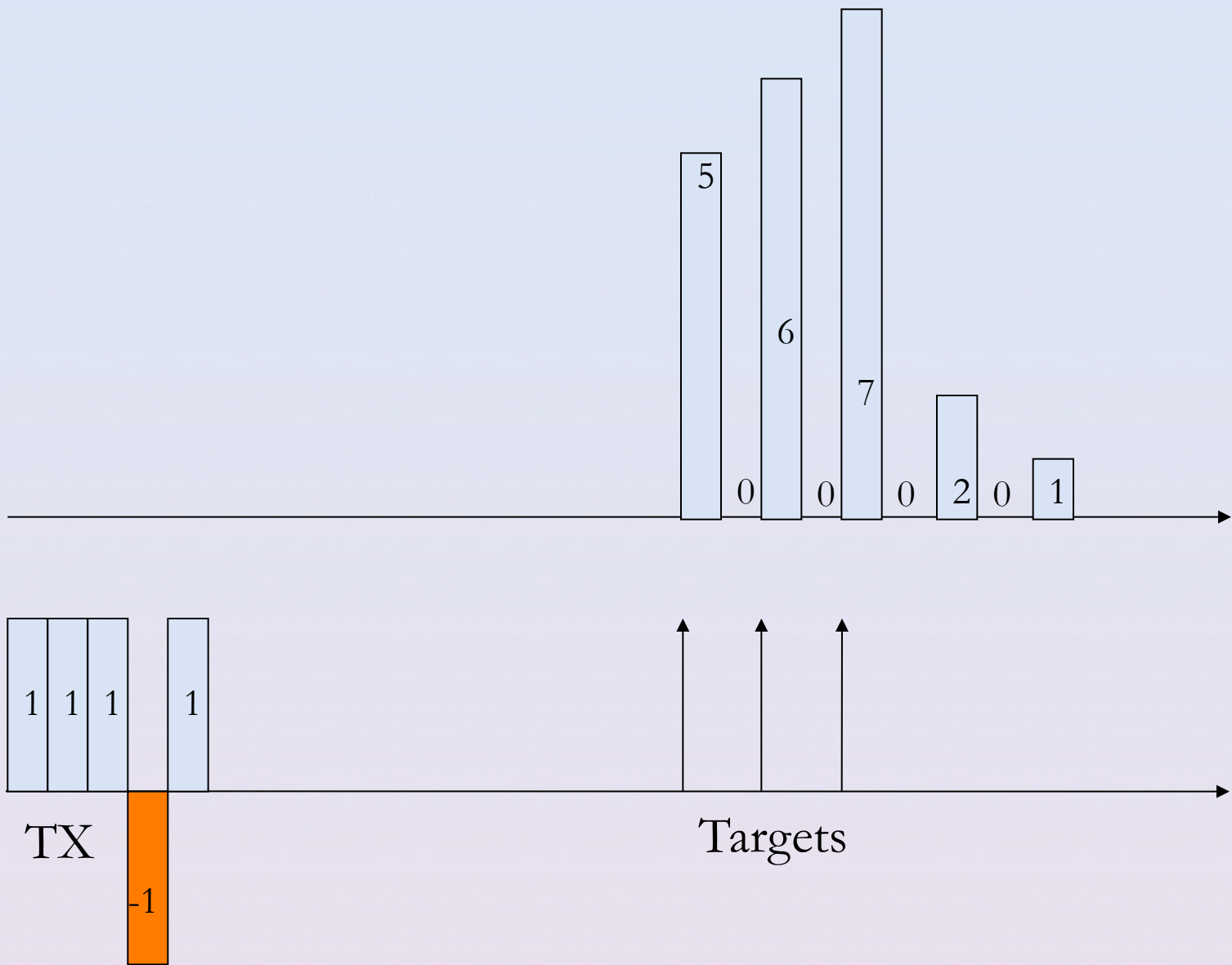




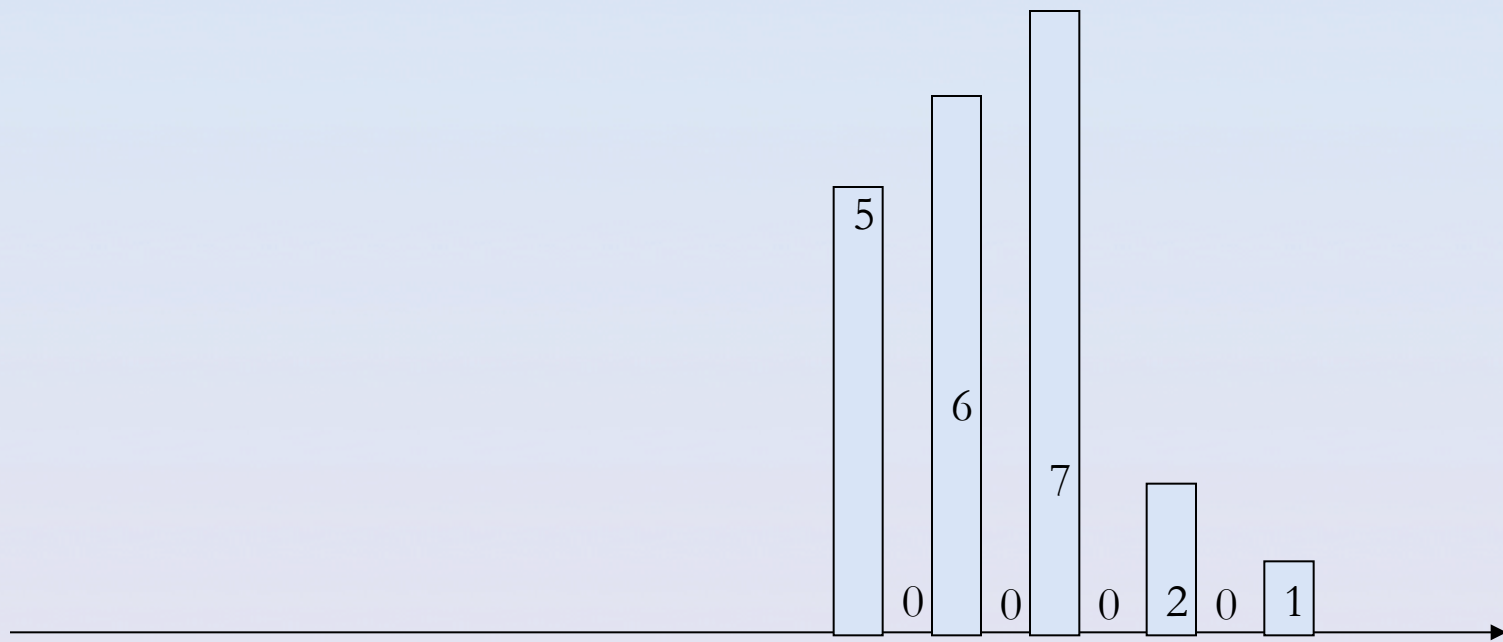
Total Receiving







Targets are Clearly Recognizable!



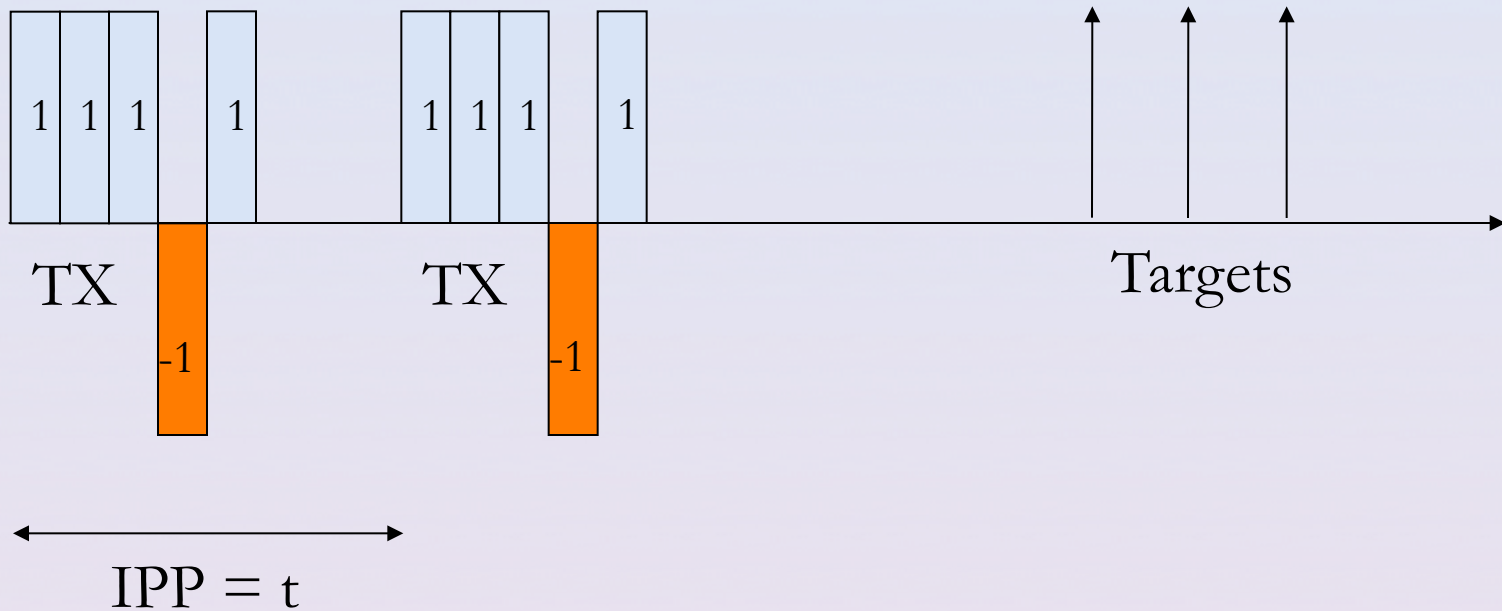
Shortage:

No frequency information! Neither Spectrum

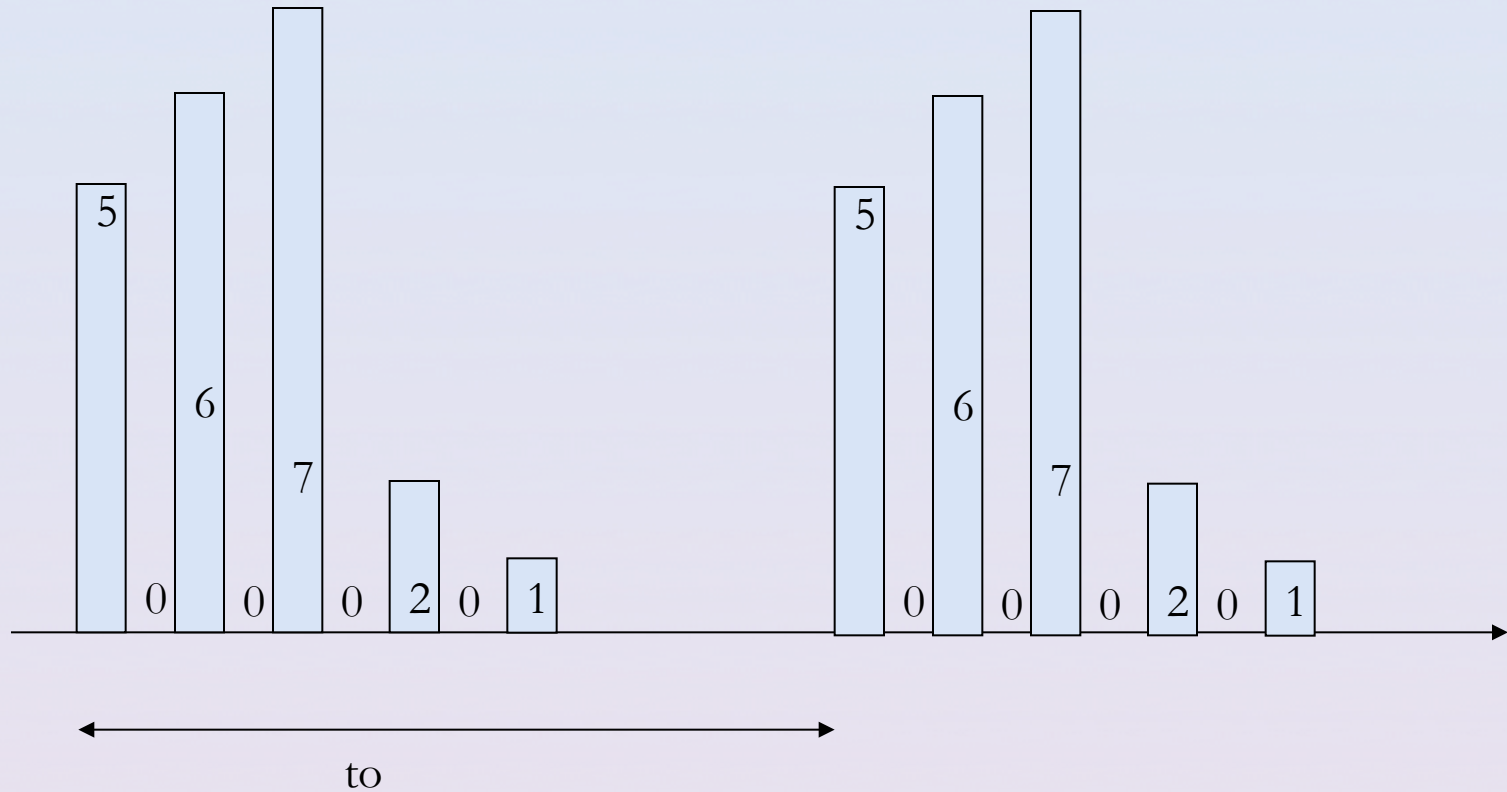
Only provides limited parameters.

One way to improve:

Multi-Pulse



Total Receiving After ACF

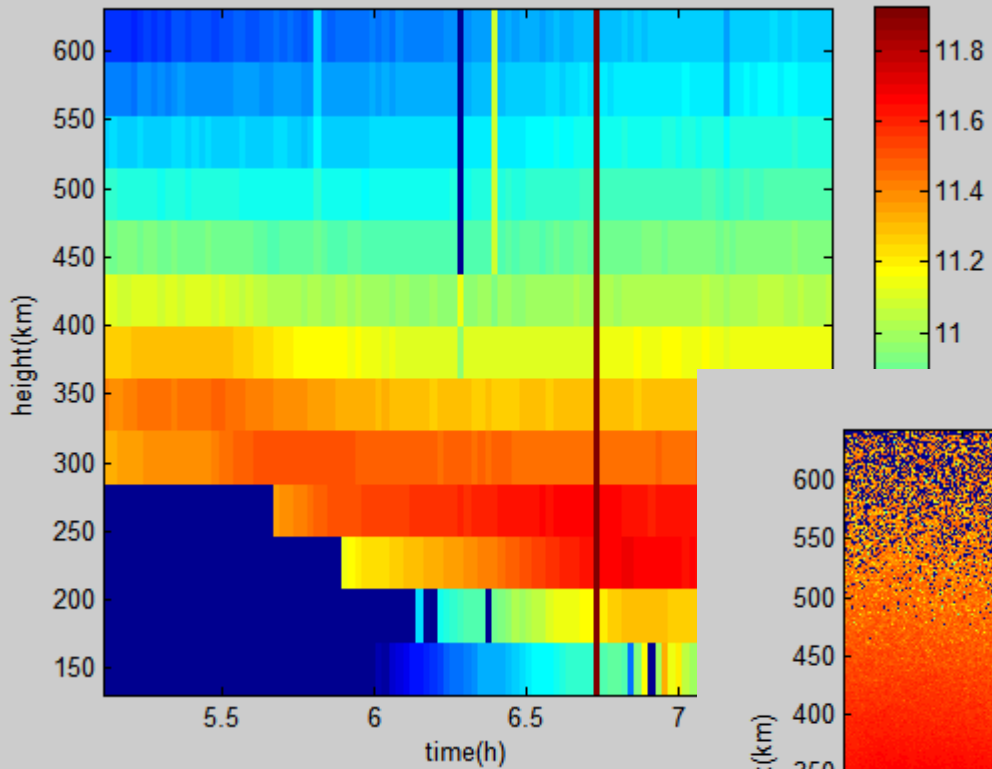


Provides frequency information

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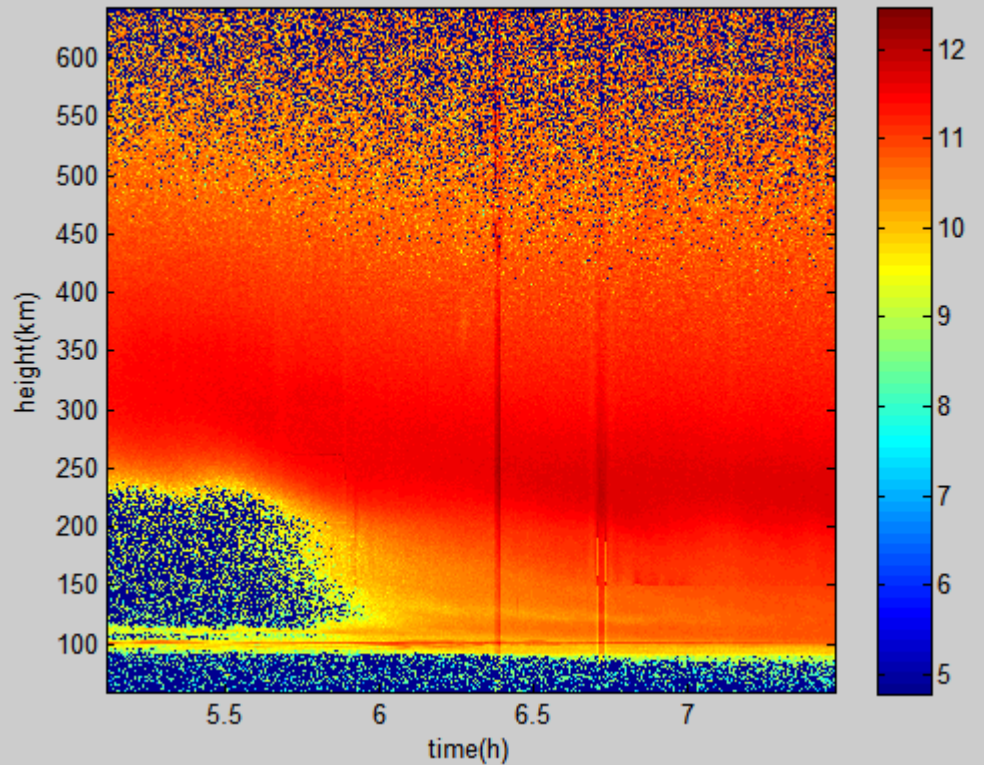
mracf;inefeed mracf Electron Density



MRACF

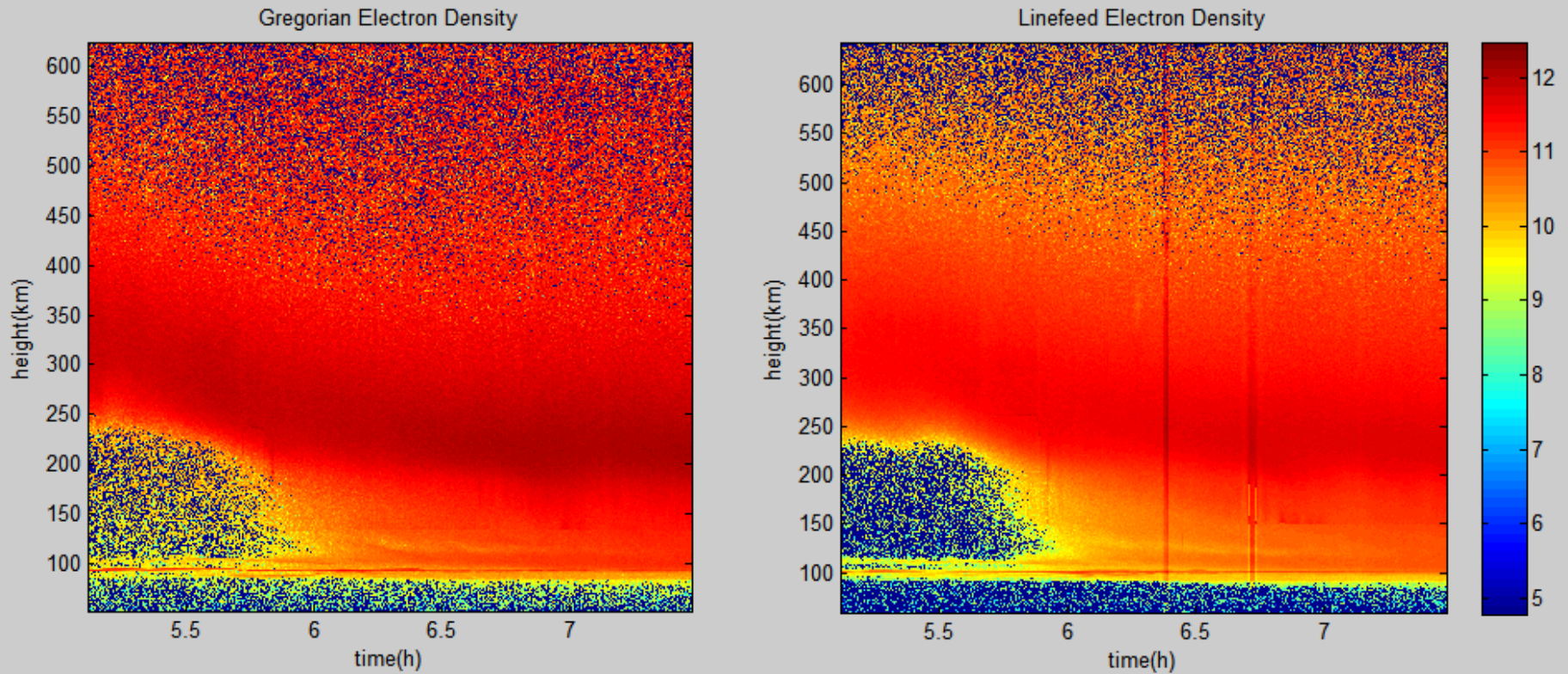
So so...

Linefeed Electron Density

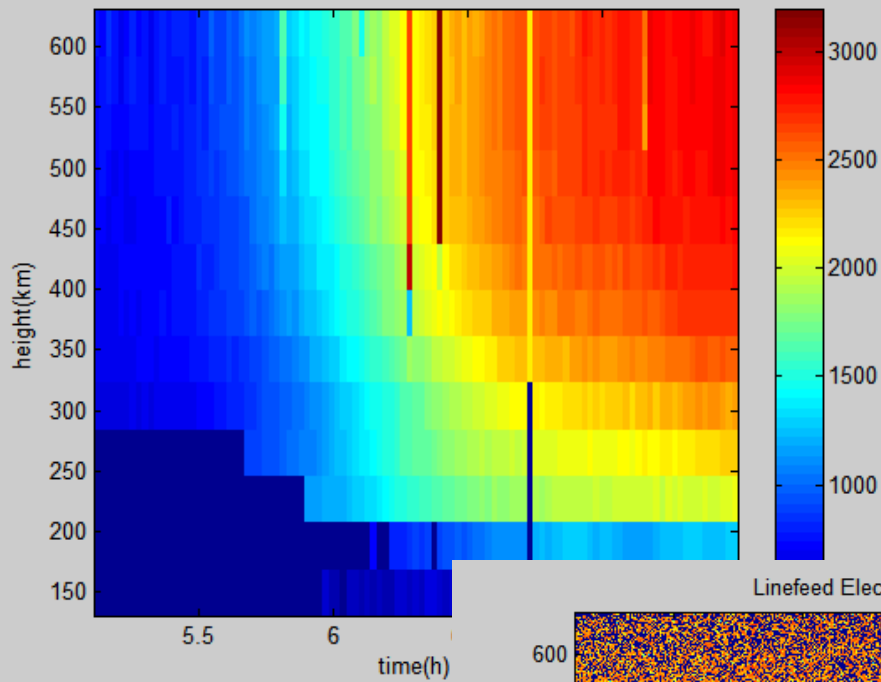


- Barker code
- Nice!

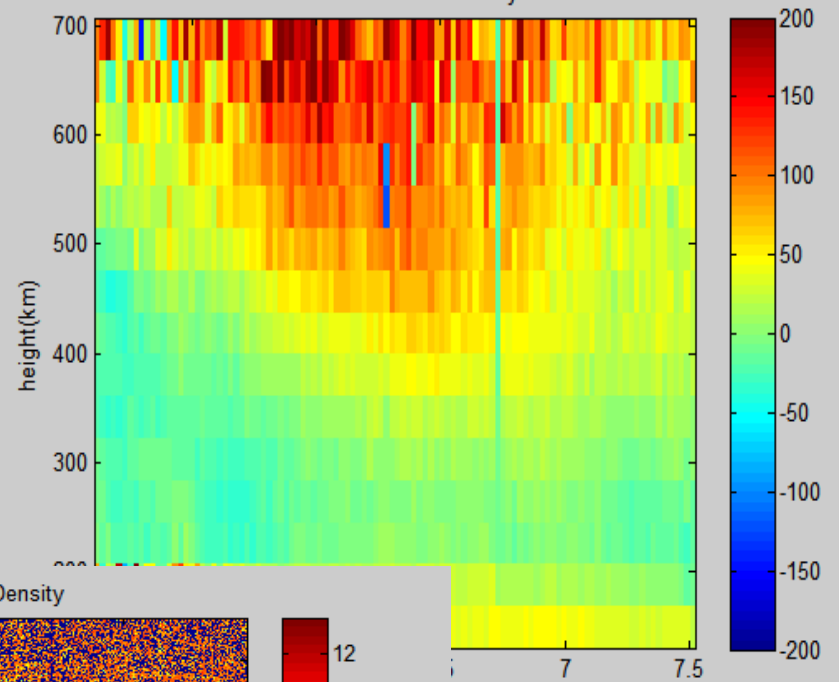
Gregorian vs Linefeed



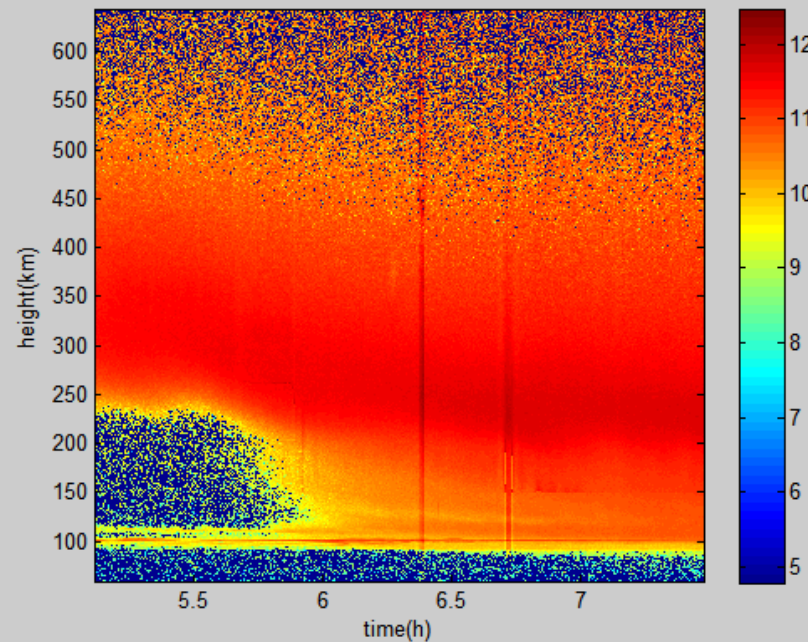
mracf_{inefeed} mracf Electron Temperature(T_e)



feedline mracf Ion Velocity

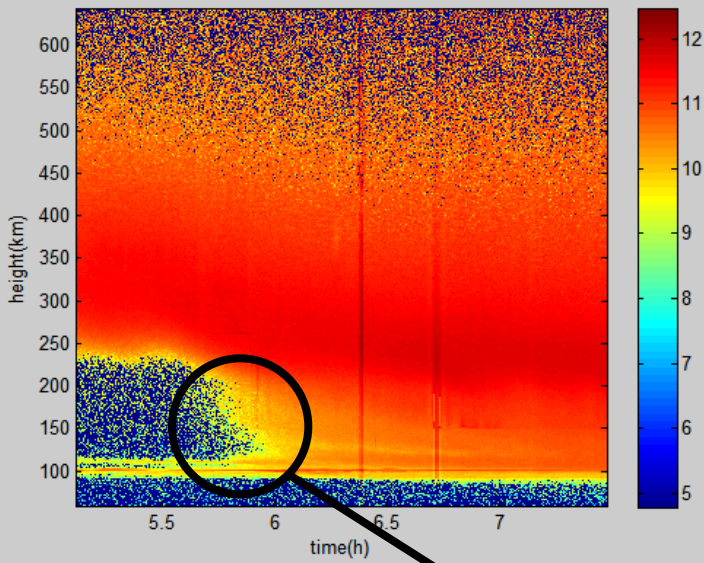


Linefeed Electron Density

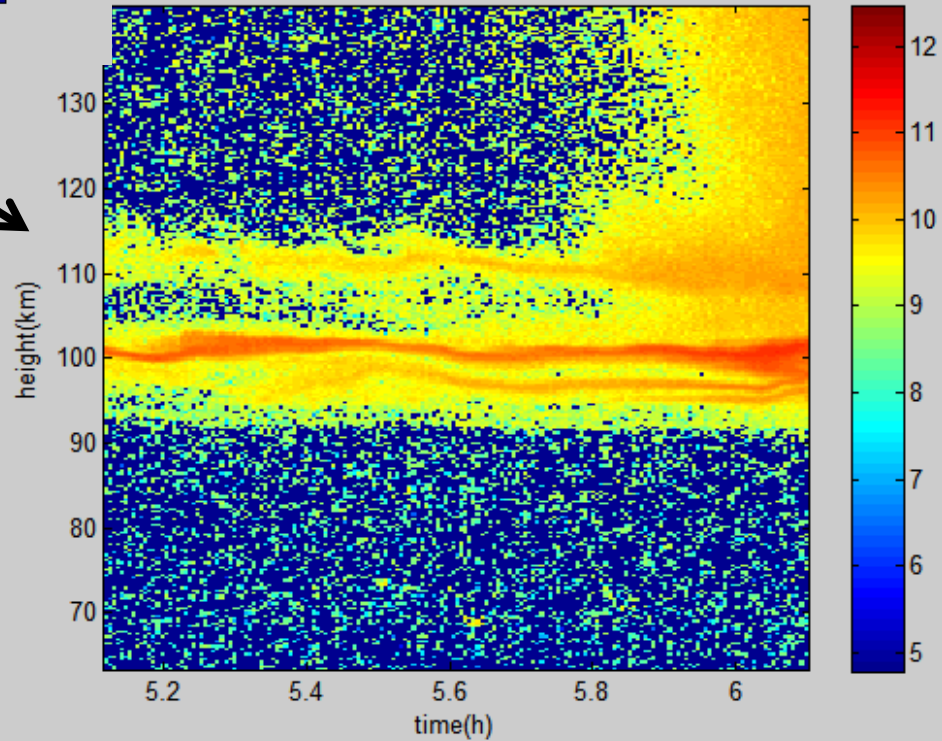


Sunrise!

Linefeed Electron Density

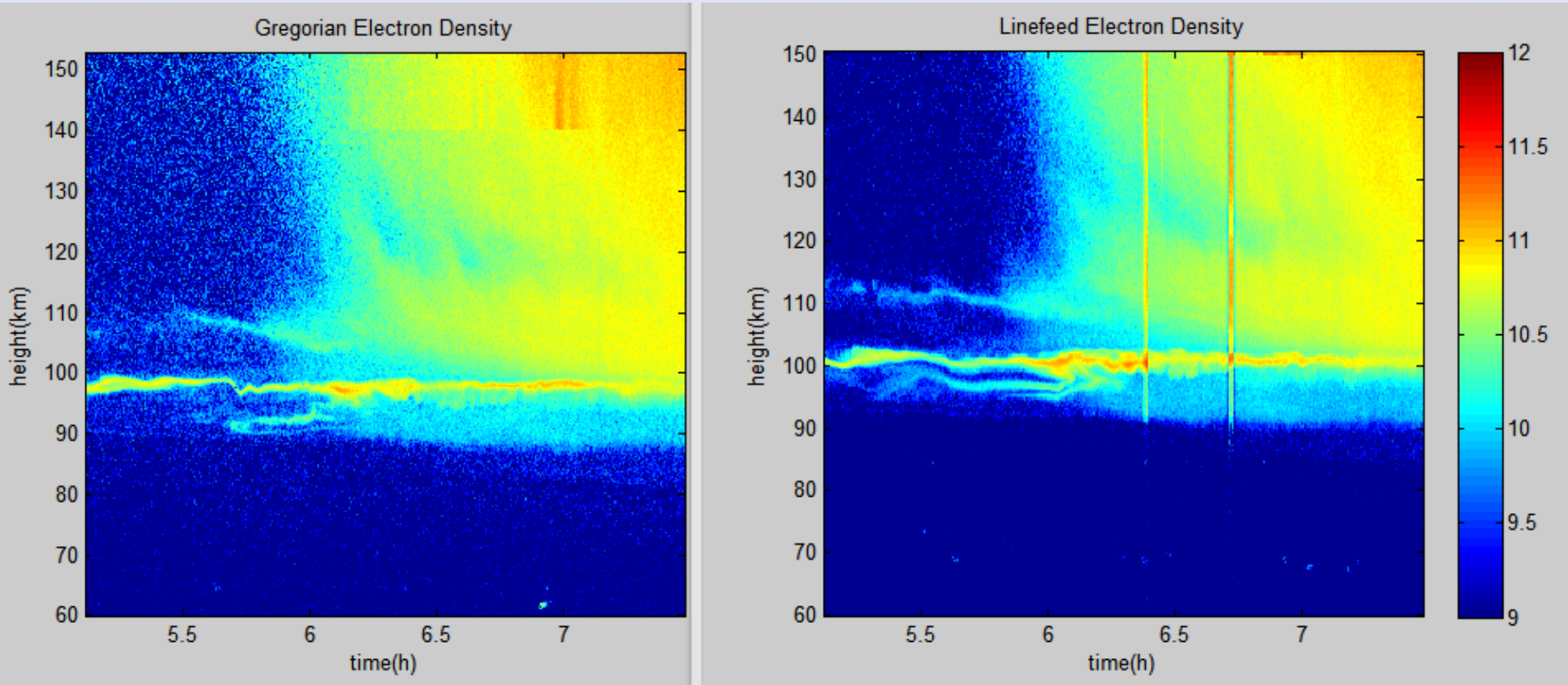


Linefeed Electron Density

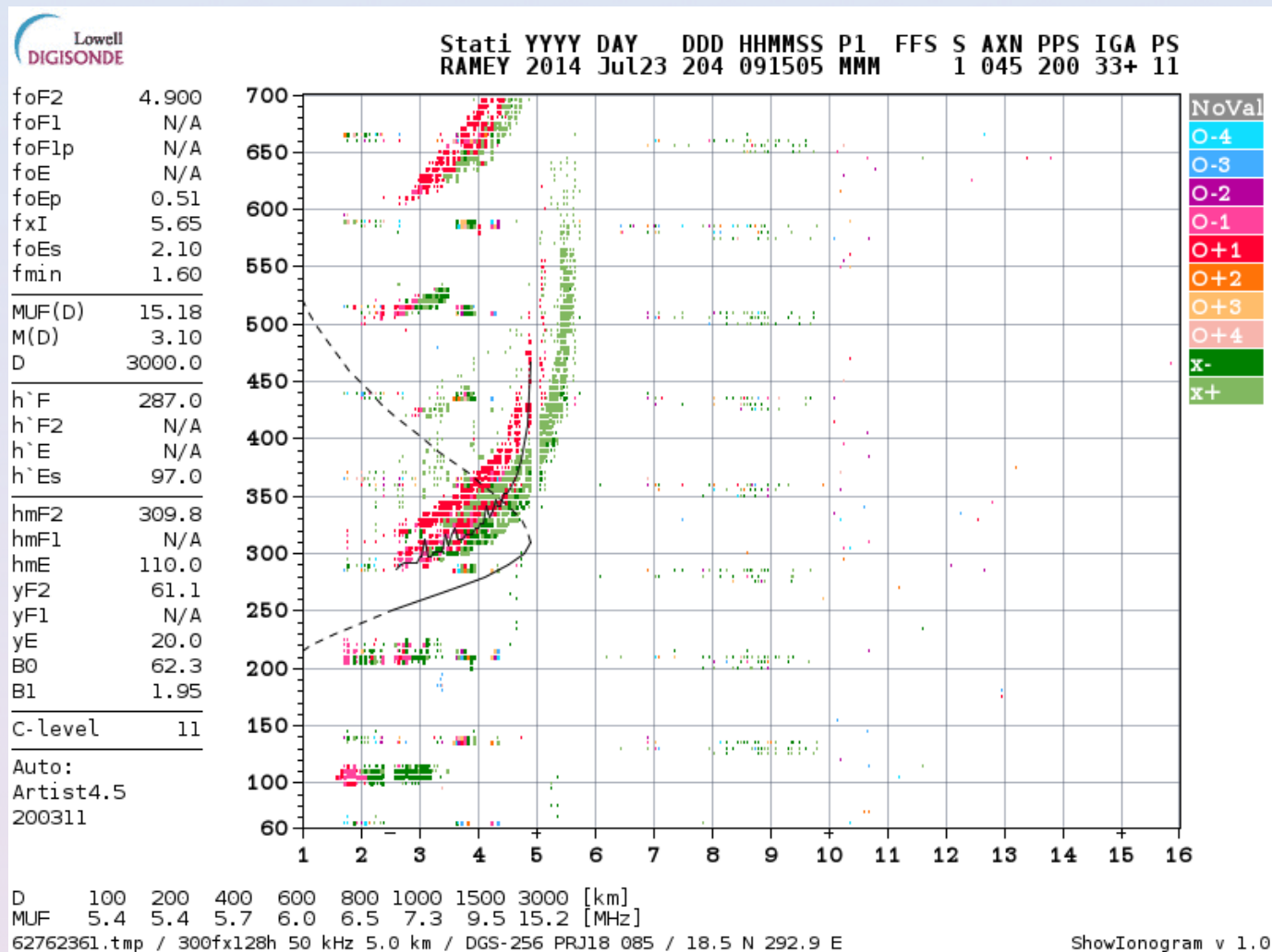


Layers!

Gregorian vs Linefeed



Ionogram confirms it is a sporadic E layer



Stati YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS
 RAMEY 2014 Jul23 204 113005 MMM 1 045 200 32+ 11

foF2 6.525
 foF1 3.87
 foF1p N/A
 foE 2.46
 foEp 2.43
 fxI 7.10
 foEs 2.45
 fmin 1.70

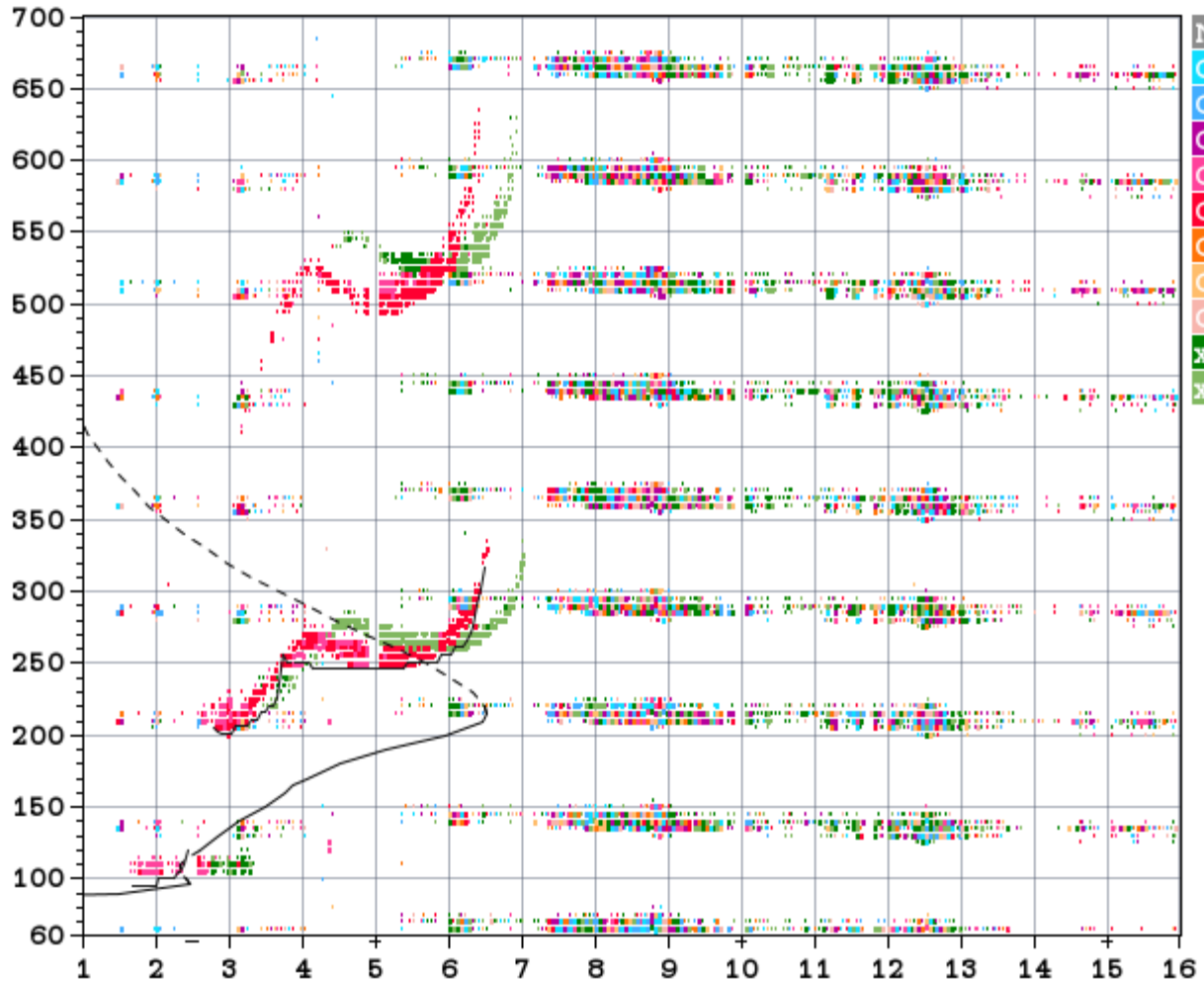
MUF(D) 24.52
 M(D) 3.77
 D 3000.0

h`F 201.0
 h`F2 246.0
 h`E 95.0
 h`Es 95.0

hmF2 214.3
 hmF1 165.0
 hmE 96.8
 yF2 36.5
 yF1 36.9
 yE 8.5
 B0 59.0
 B1 1.16

C-level 11

Auto:
 Artist4.5
 200311



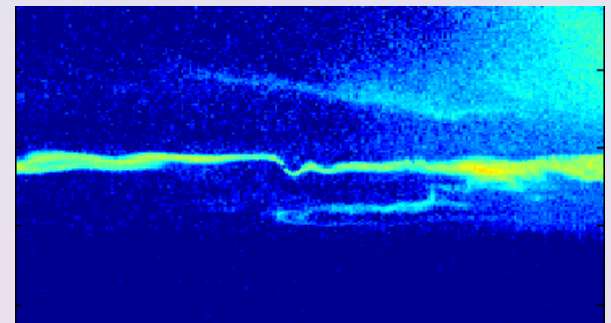
D 100 200 400 600 800 1000 1500 3000 [km]
 MUF 7.0 7.1 7.5 8.2 9.1 10.4 14.3 24.5 [MHz]

17880748.tmp / 300fx128h 50 kHz 5.0 km / DGS-256 PRJ18 085 / 18.5 N 292.9 E

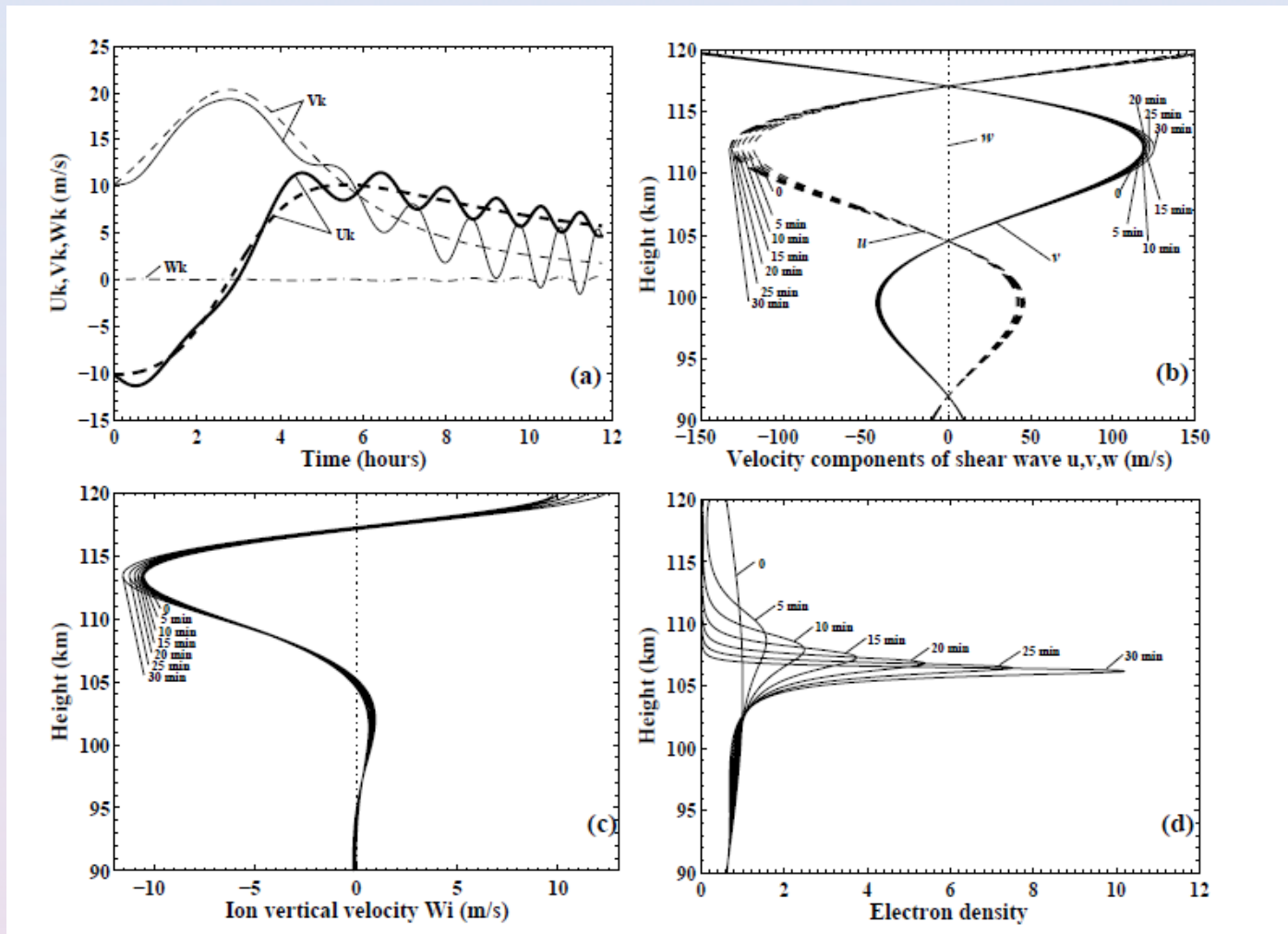
ShowIonogram v 1.0

Sporadic E

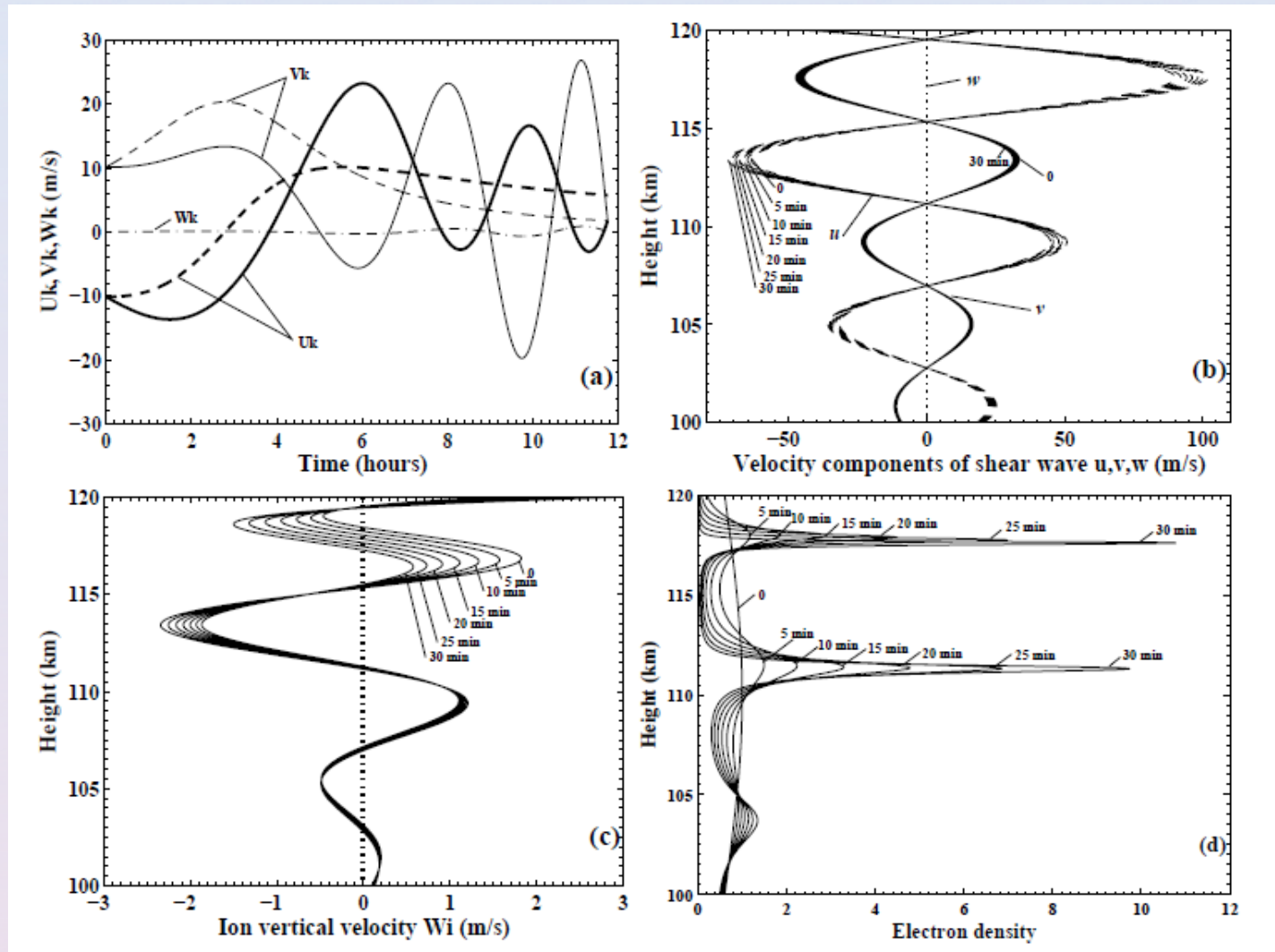
- Smaller “clouds” of unusually ionised atmospheric gas in the lower E region (located at altitudes of approx. 90 to 160 km)
- Sporadic E activity peaks in the summer time in both hemispheres (@ right time, right place!)
- Neutral winds provide an essential source of free energy that both sets up the layers and drives them unstable (wind shear theory)



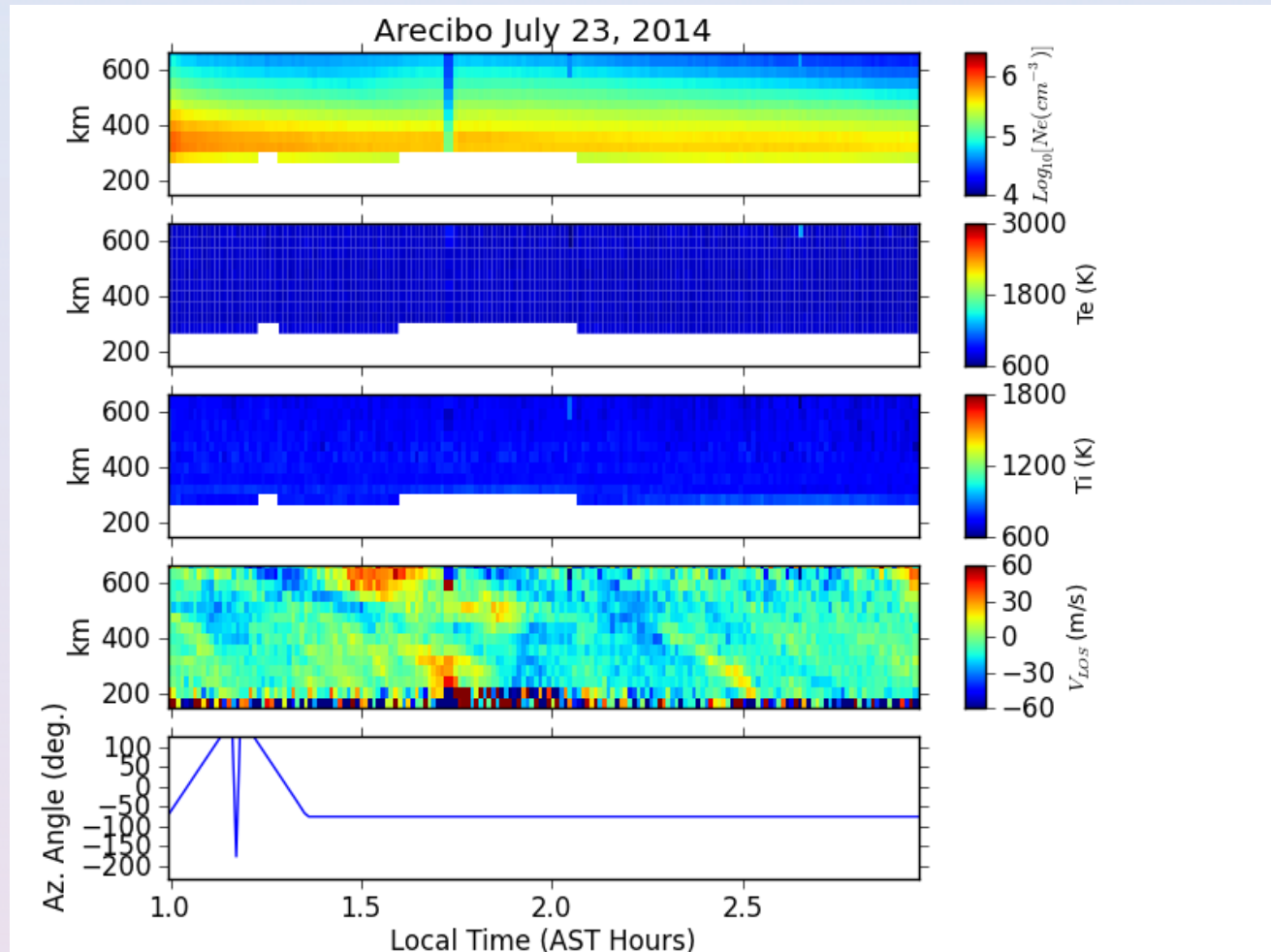
Sporadic E formation by vertical perturbations in a horizontal wind shear flow



Sporadic E multilayer formation (cont.)



Vortical uplift shown in ISR velocity measurement (Courtesy from Group 5)



Where do sporadic E layer ions come from?



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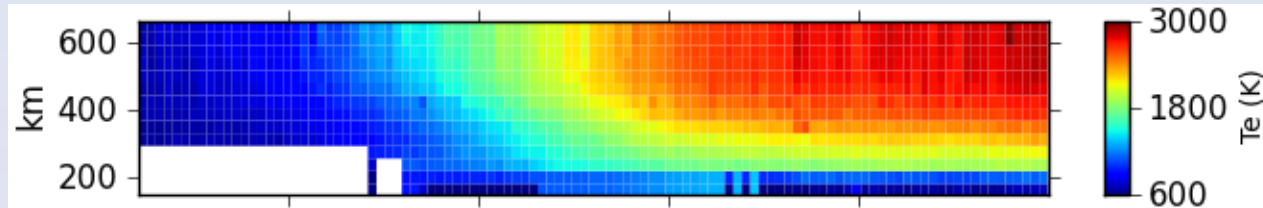
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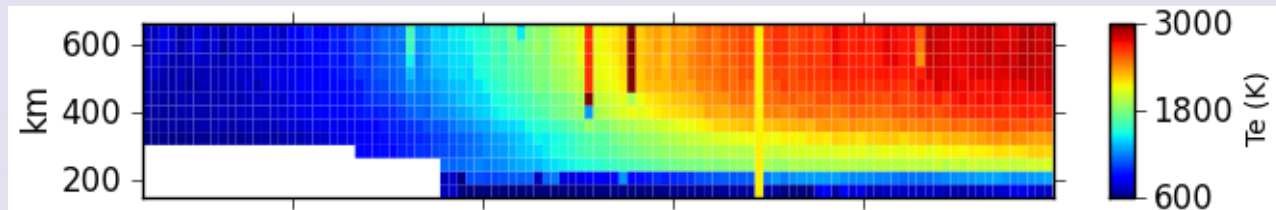
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Electron Temperature (T_e)

Gregorian



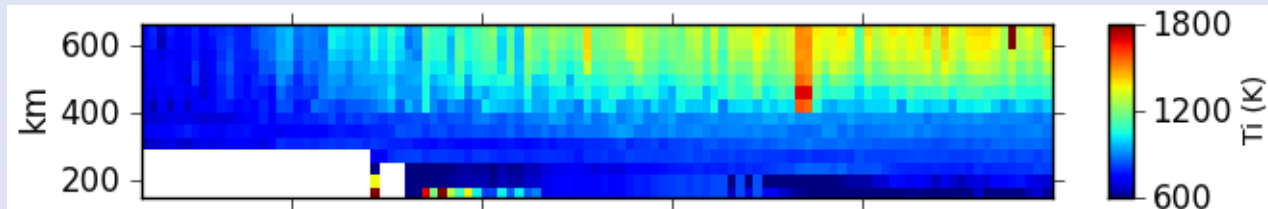
Linefeed



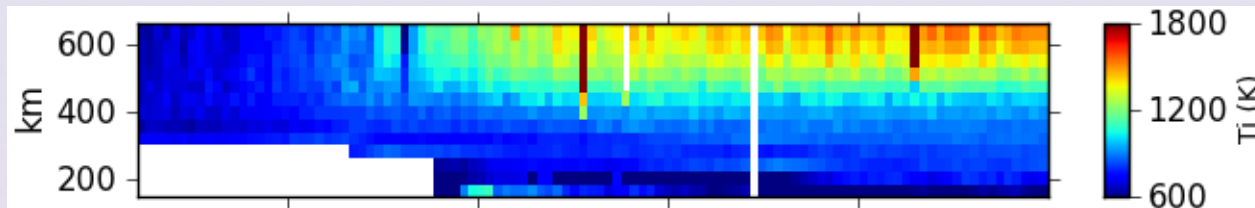
- The increase in the electron temperature is related to magnetic aspects, which is why this increases with the arrival of sunset
- Delay between the start of temperature increase due to the orientation of the antennas

Ion Temperature (T_i)

Gregorian



Linefeed

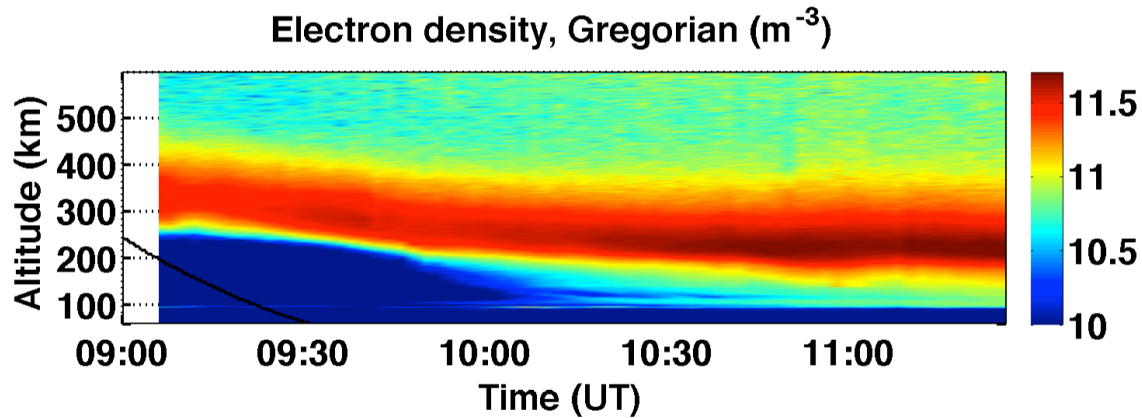
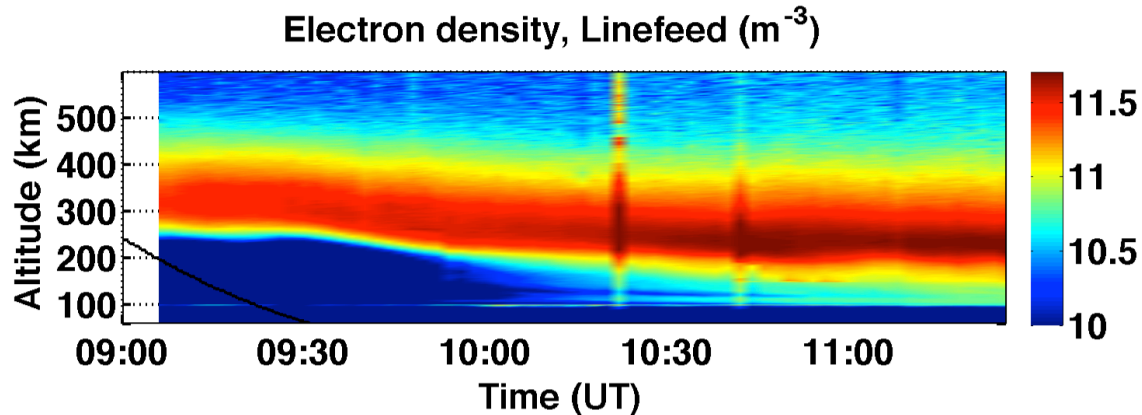


- The increase in the ion temperature is due to collisions with neutral particles which have a different distribution for different altitudes of the atmosphere for this reason it is different from the electrons

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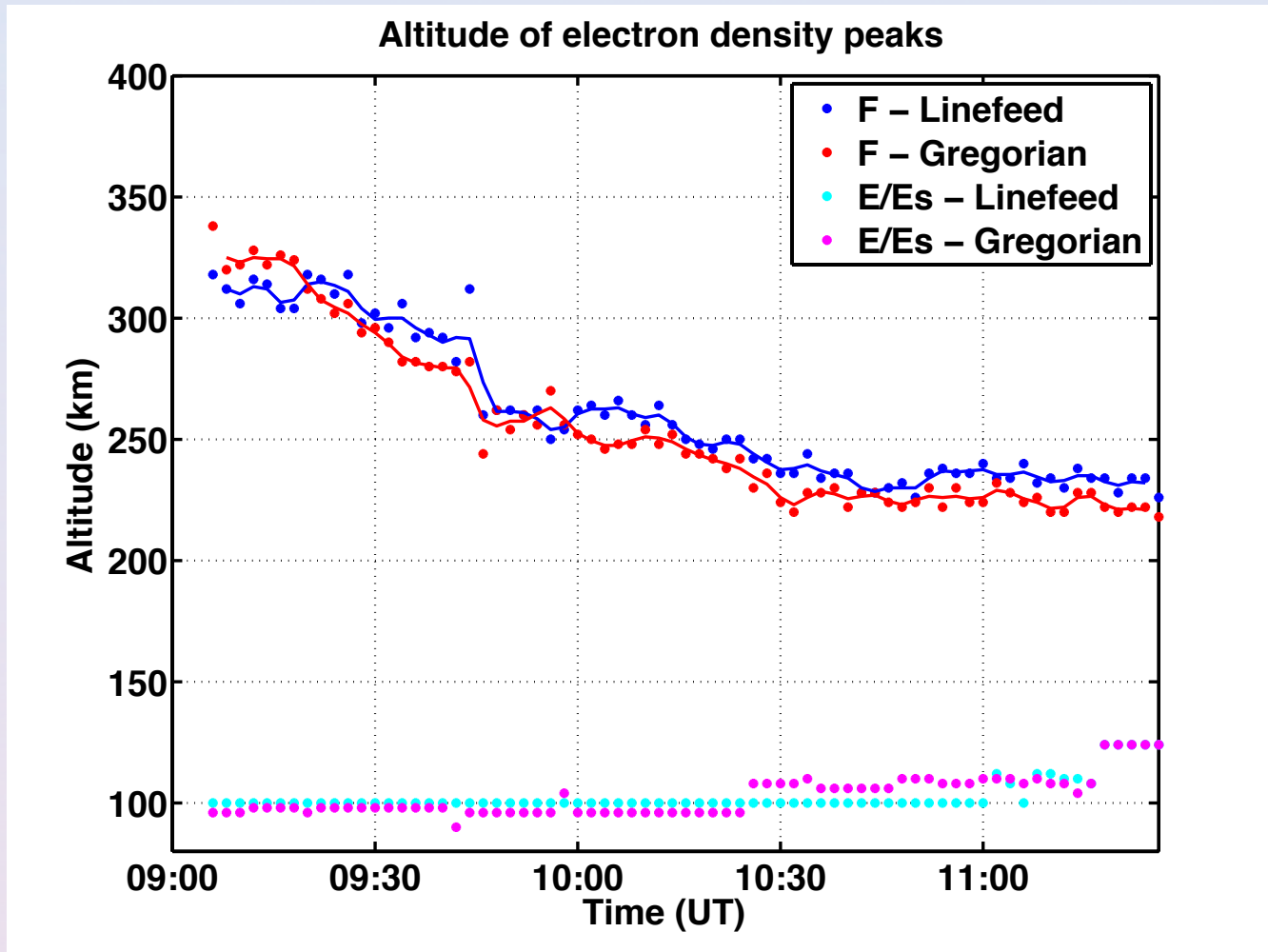
Barker-Code Electron Density Data



Resolution:

- Time: 2 min
- Altitude: 2 km

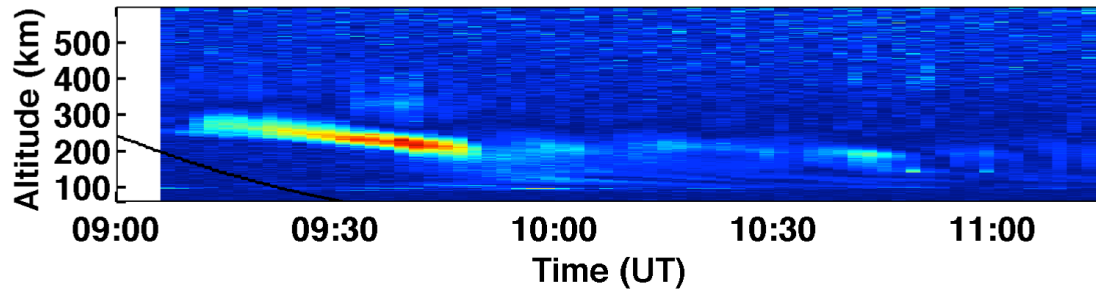
Peak Altitudes Evolution



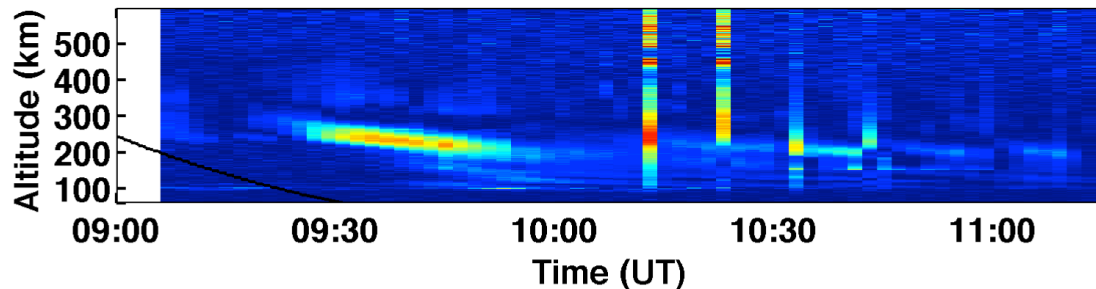
Detection of Photoionisation

- Estimation of $\frac{\partial n_e}{\partial t}(z, t) \simeq \frac{n_e(z, t + \delta t) - n_e(z, t)}{\delta t}$

Electron density gradient, Gregorian

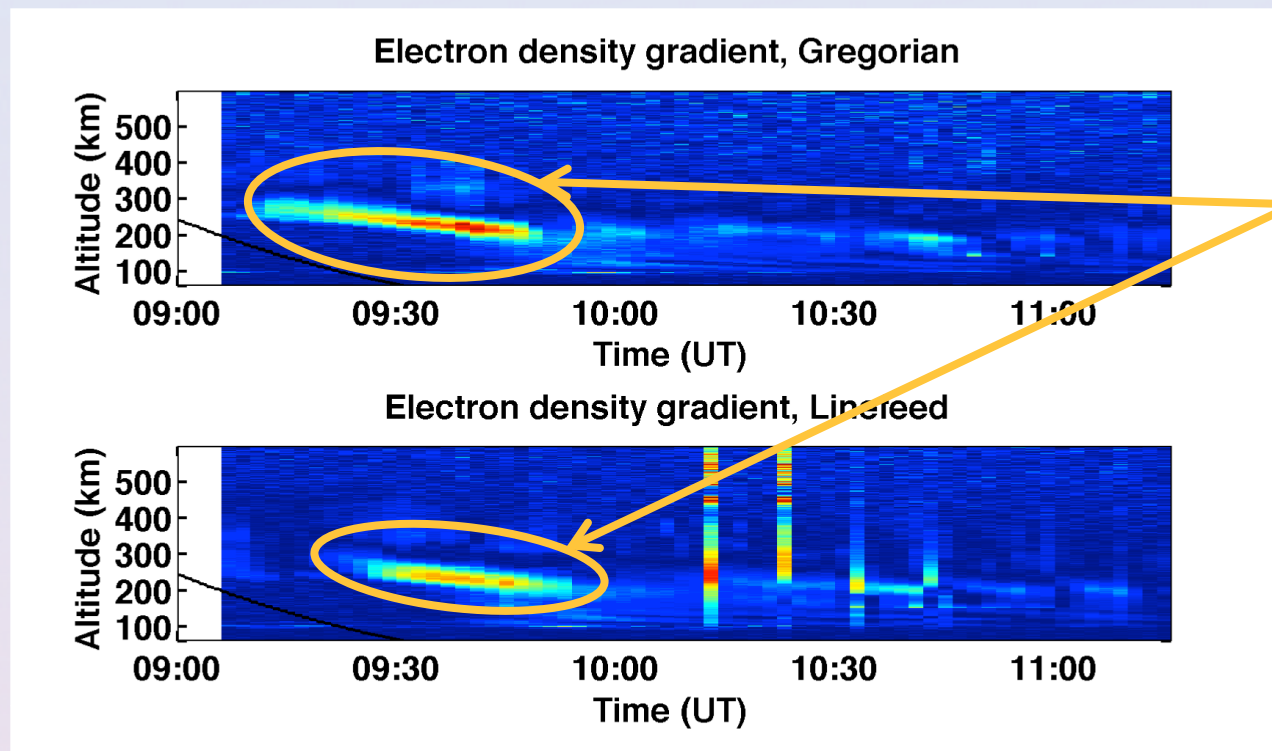


Electron density gradient, Linefeed

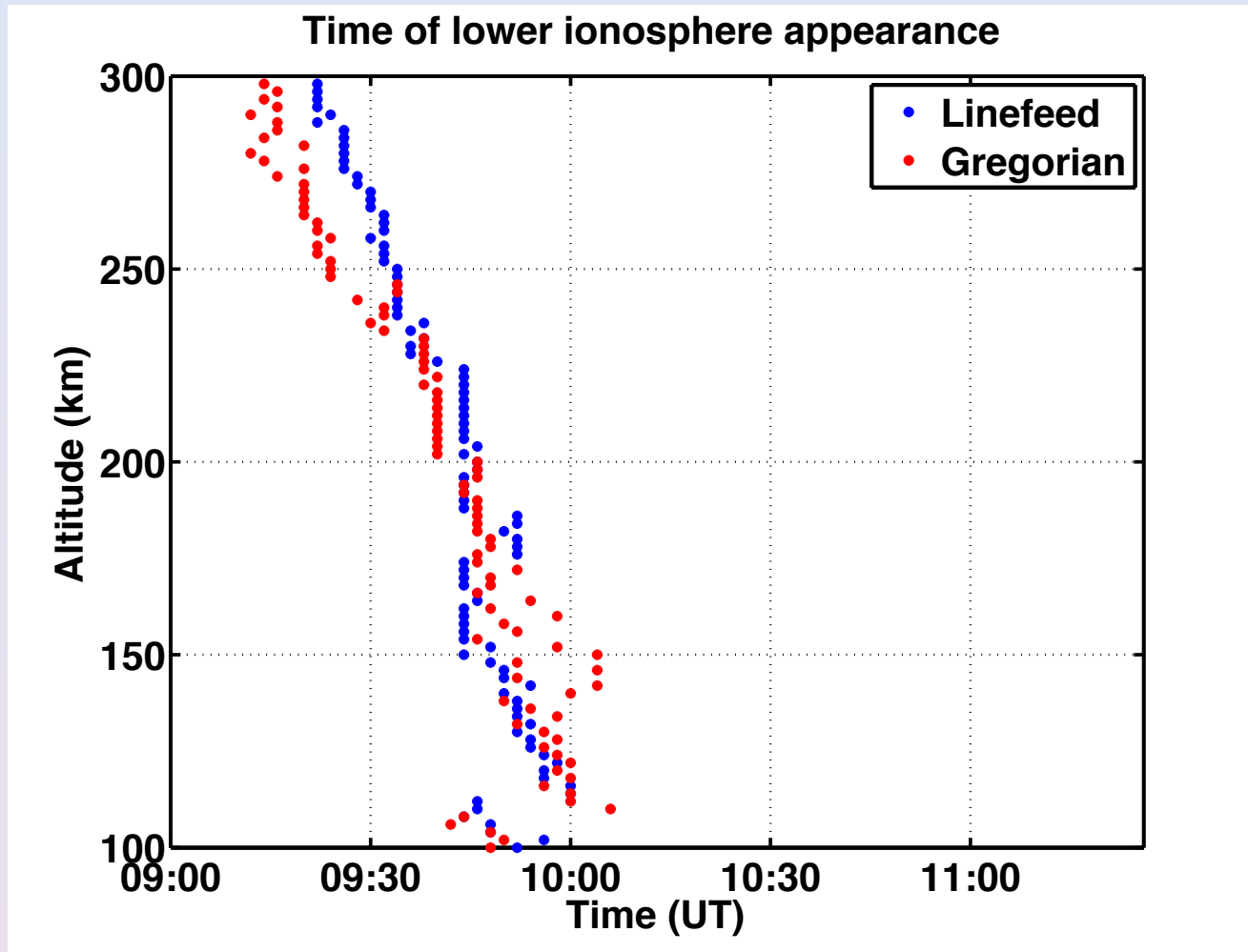


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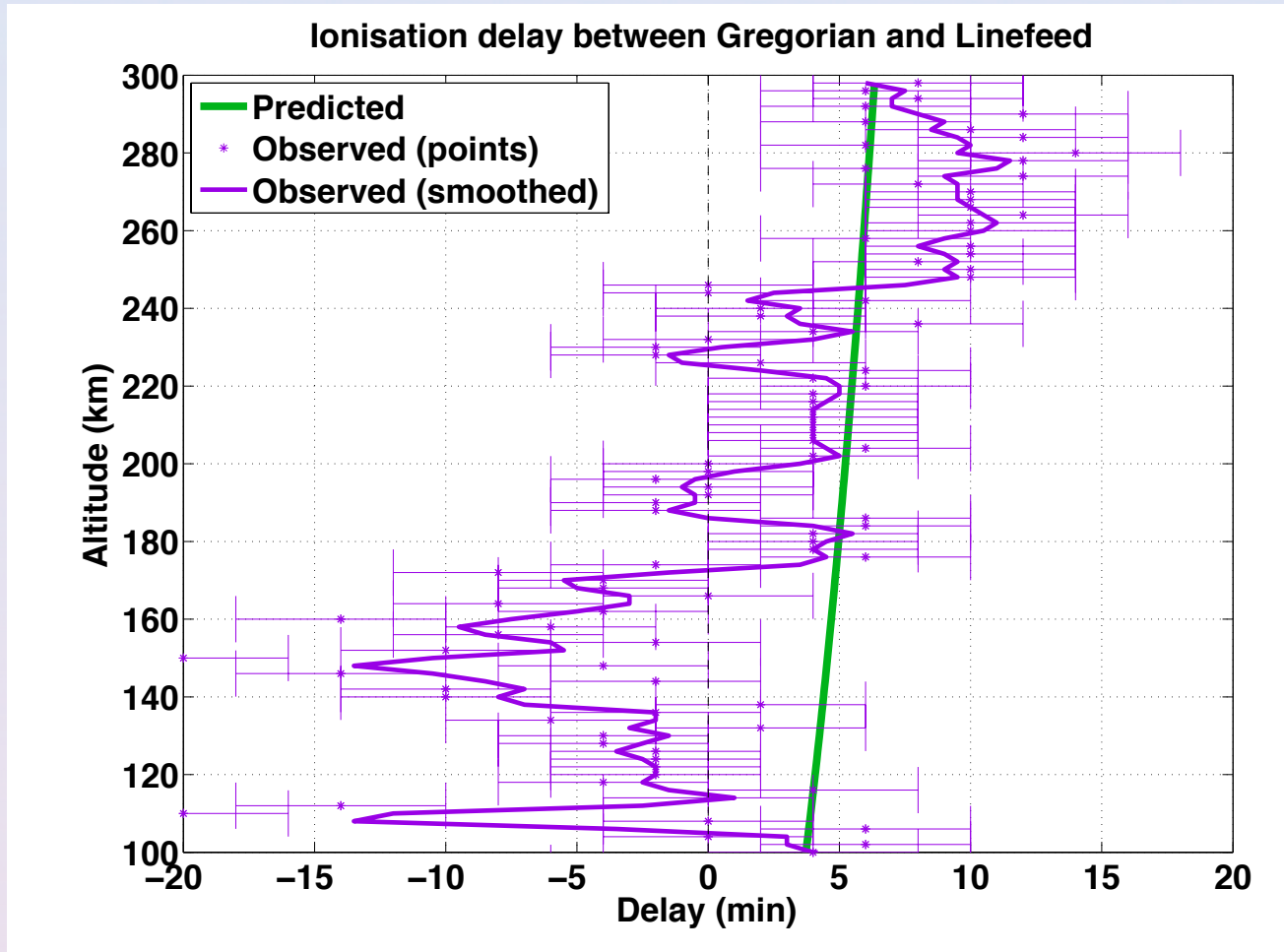
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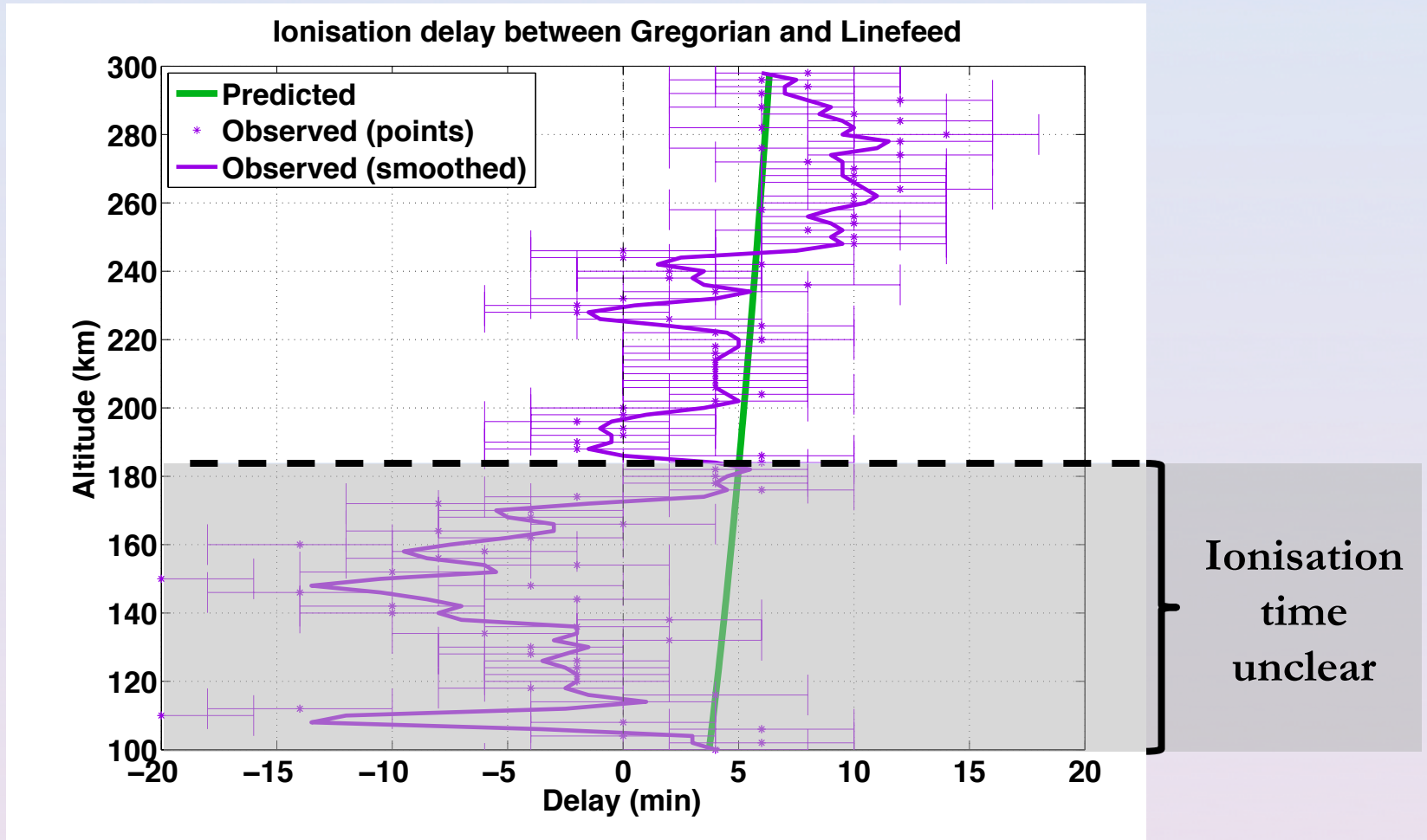
Lower Ionosphere Appearance



Delays Between Lines of Sight



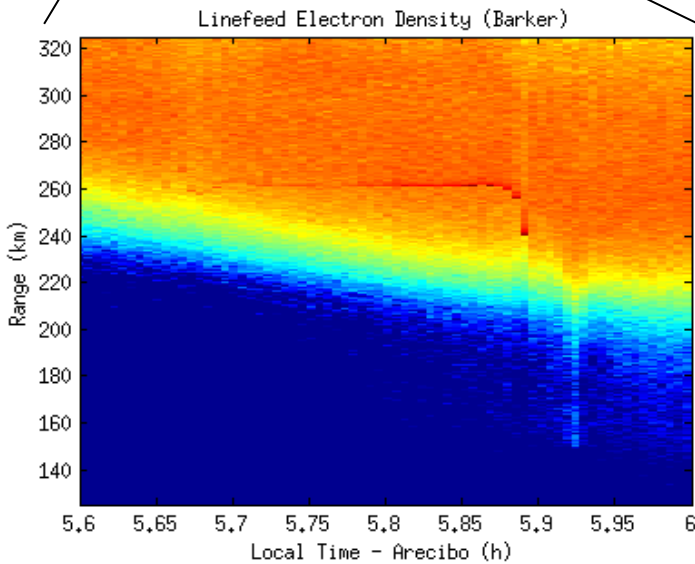
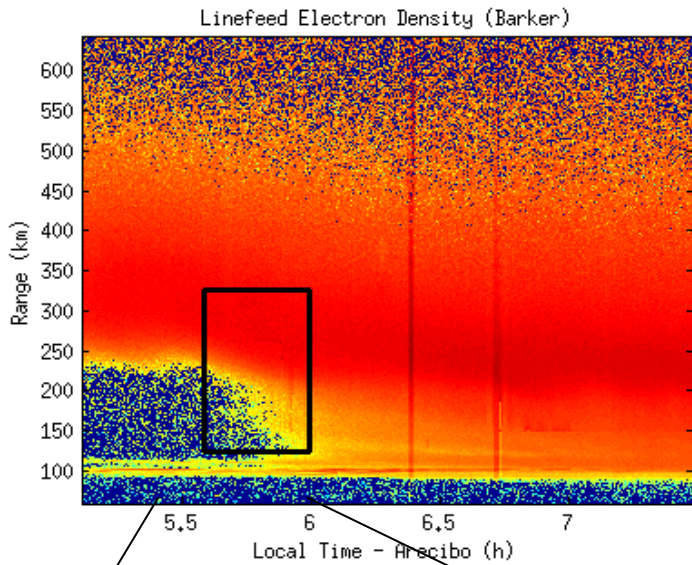
Delays Between Lines of Sight



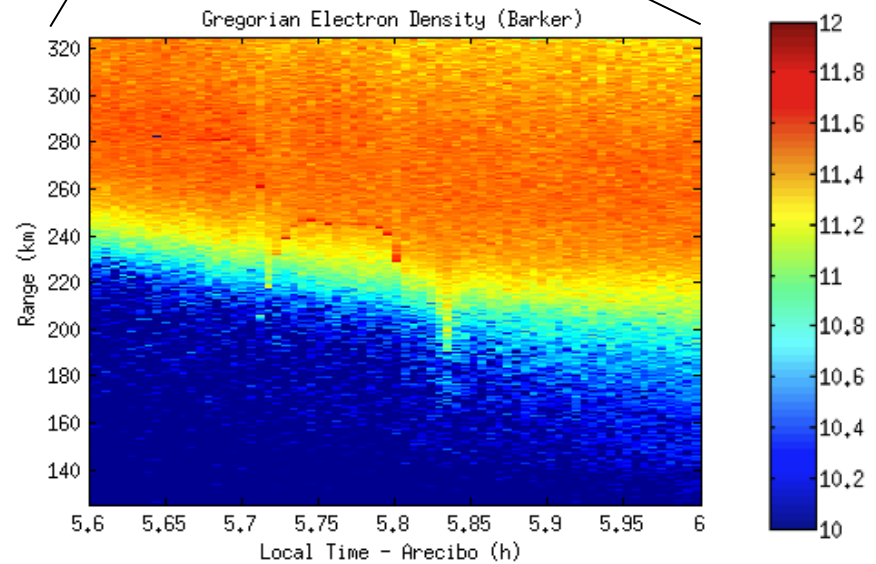
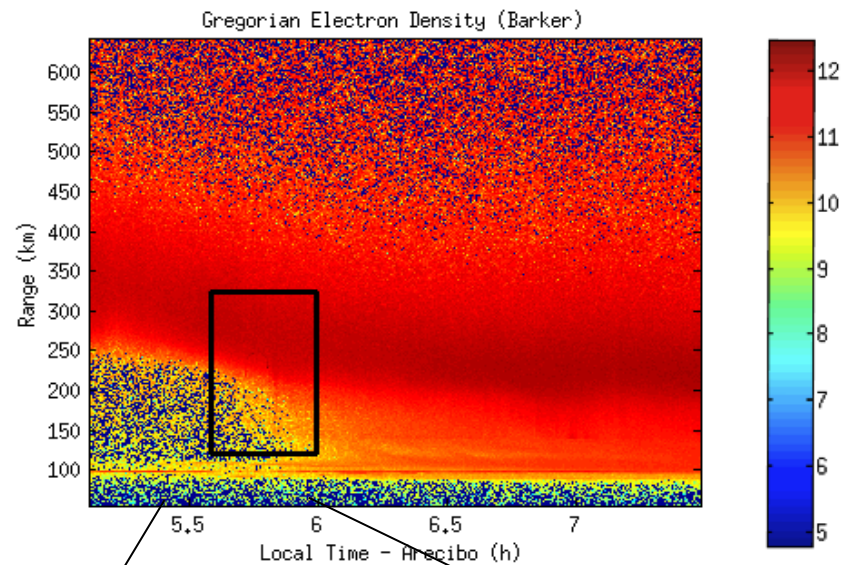
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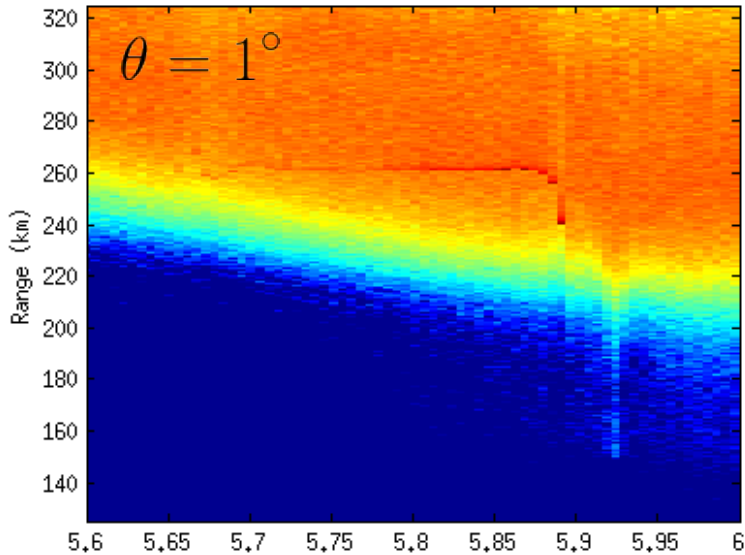
$\theta = 1^\circ$



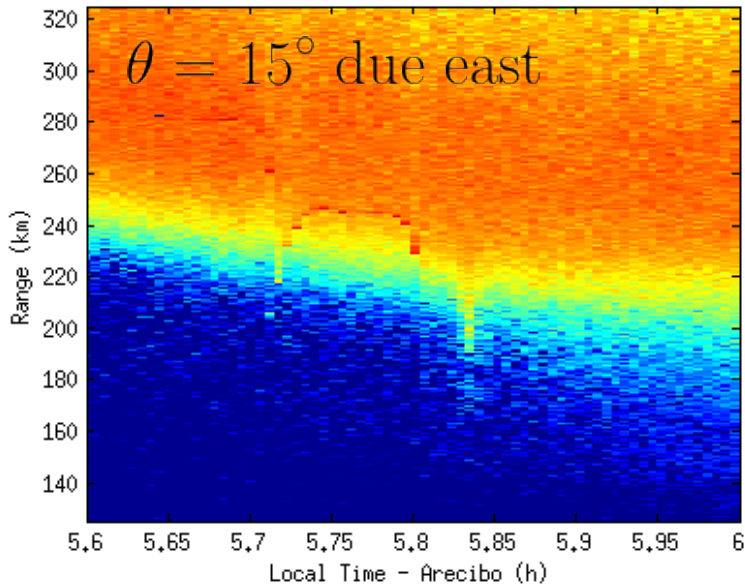
$\theta = 15^\circ$ due east



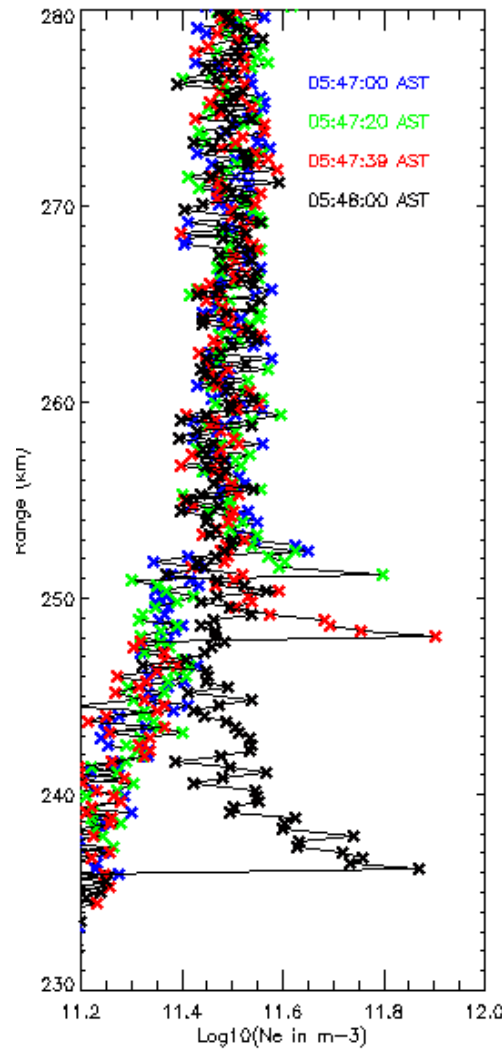
Linefeed Electron Density (Barker)



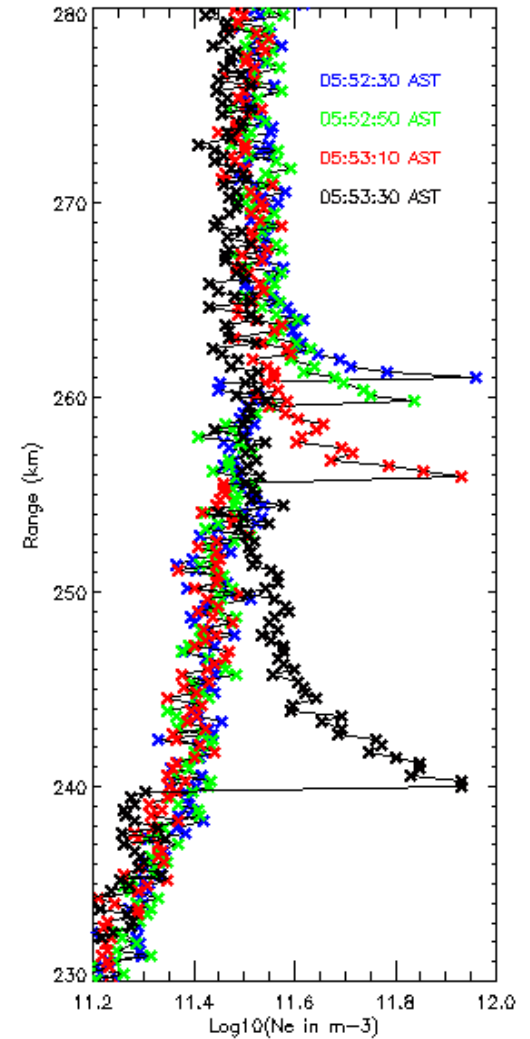
Gregorian Electron Density (Barker)



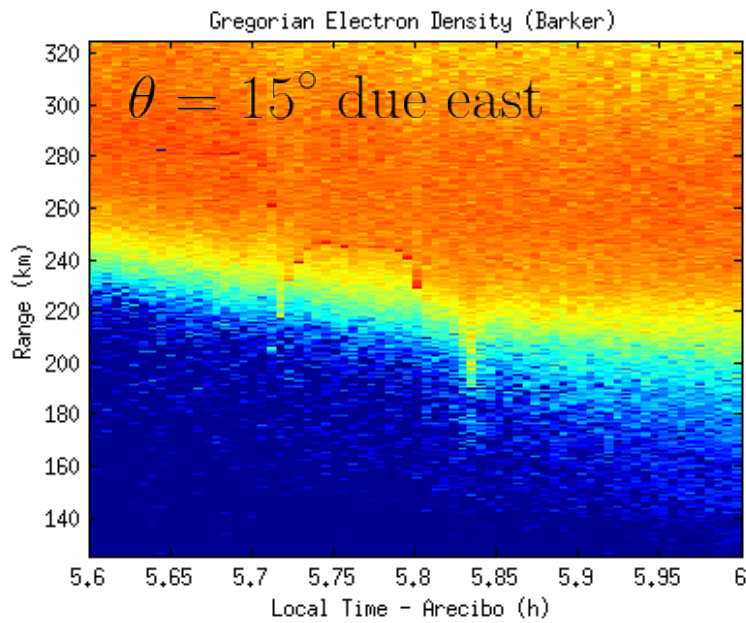
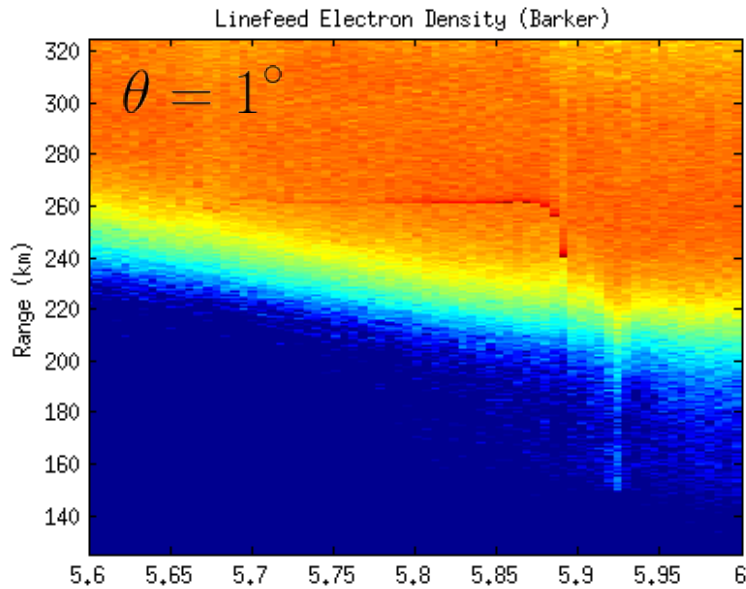
$\theta = 15^\circ$ due east



$\theta = 1^\circ$



$\Delta T \approx 5\text{min } 30\text{sec}$
Seperation $\approx 70\text{km}$



How?

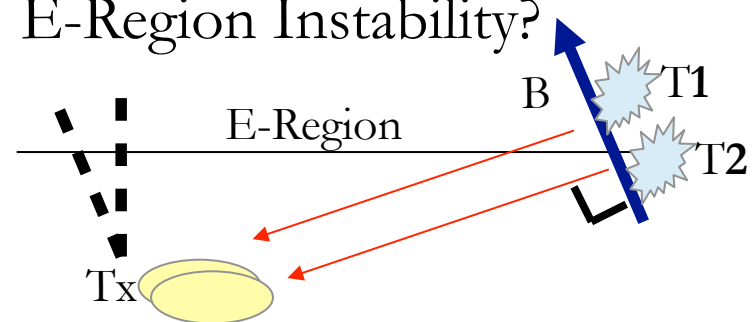
- Range Aliasing?
- Scatter from Sidelobes?
 - One Sidelobe?
 - Two Sidelobes?

What?

- Satellite?

$$h_{\text{sat}} \approx c \times T_{\text{IPP}}/2 + h_{\text{signal}} \approx 1000\text{km}$$

- Meteor?
- Ocean Scatter (boat)?
- Airplane?
- E-Region Instability?



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Summary and Perspectives

- Sunrise observation along two lines of sight
 - Ionisation due to EUV irradiance observed
 - Delays quite consistent with predictions
- Presence of a stable sporadic E layer
 - Formation? Study of the neutral winds
- Interesting feature around 5:35 AST
 - Some ideas for interpretation
 - Consider where **B** perp. to side lobe @ E region



Thank you for your attention!

Questions?