The MST-ISR-EEJ mode at Jicamarca, fine structure and interferometry with mesospheric echoes

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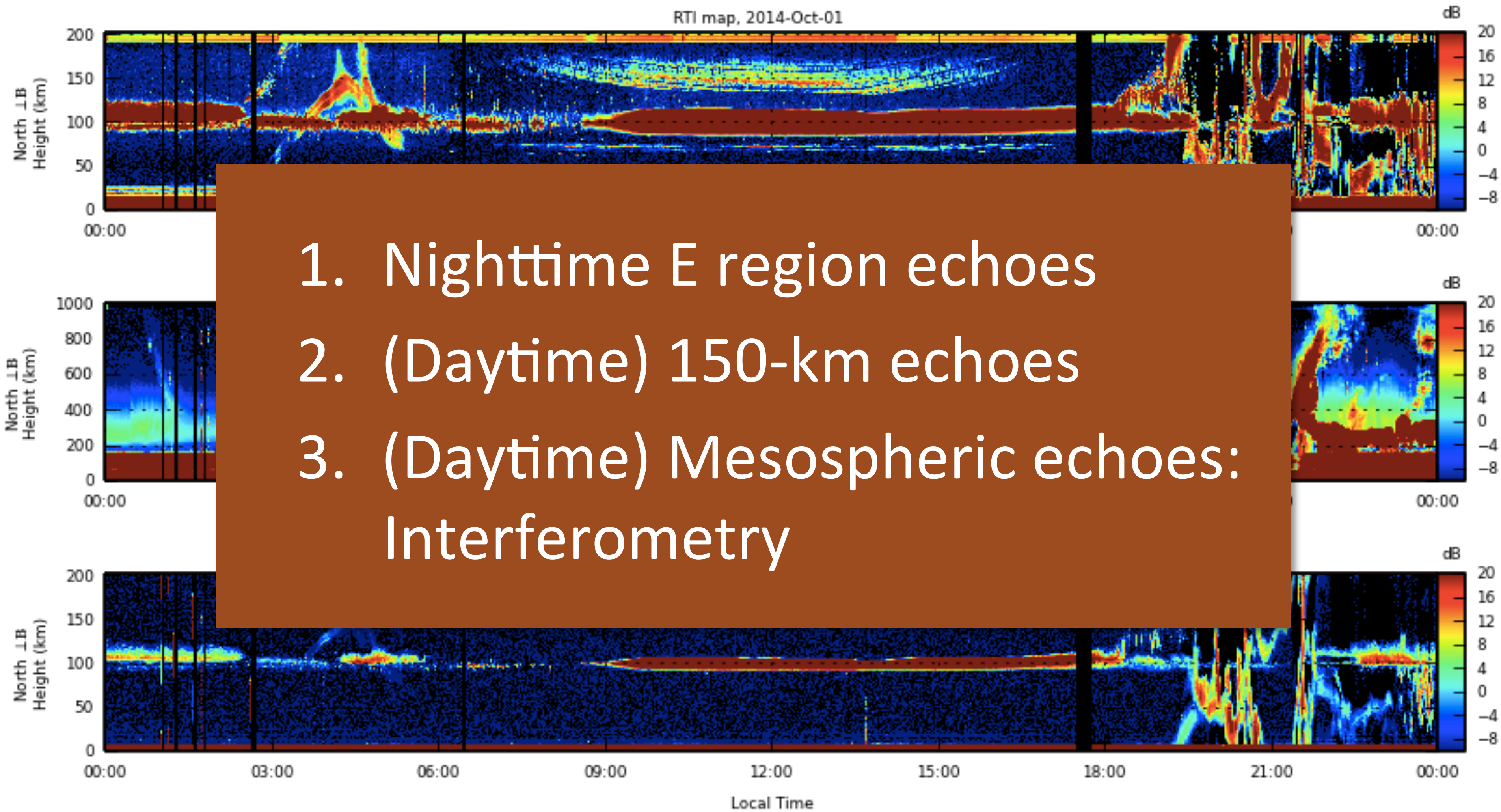
NSF Aeronomy # 1143514
2016 CEDAR Workshop

MST-ISR-EEJ Mode

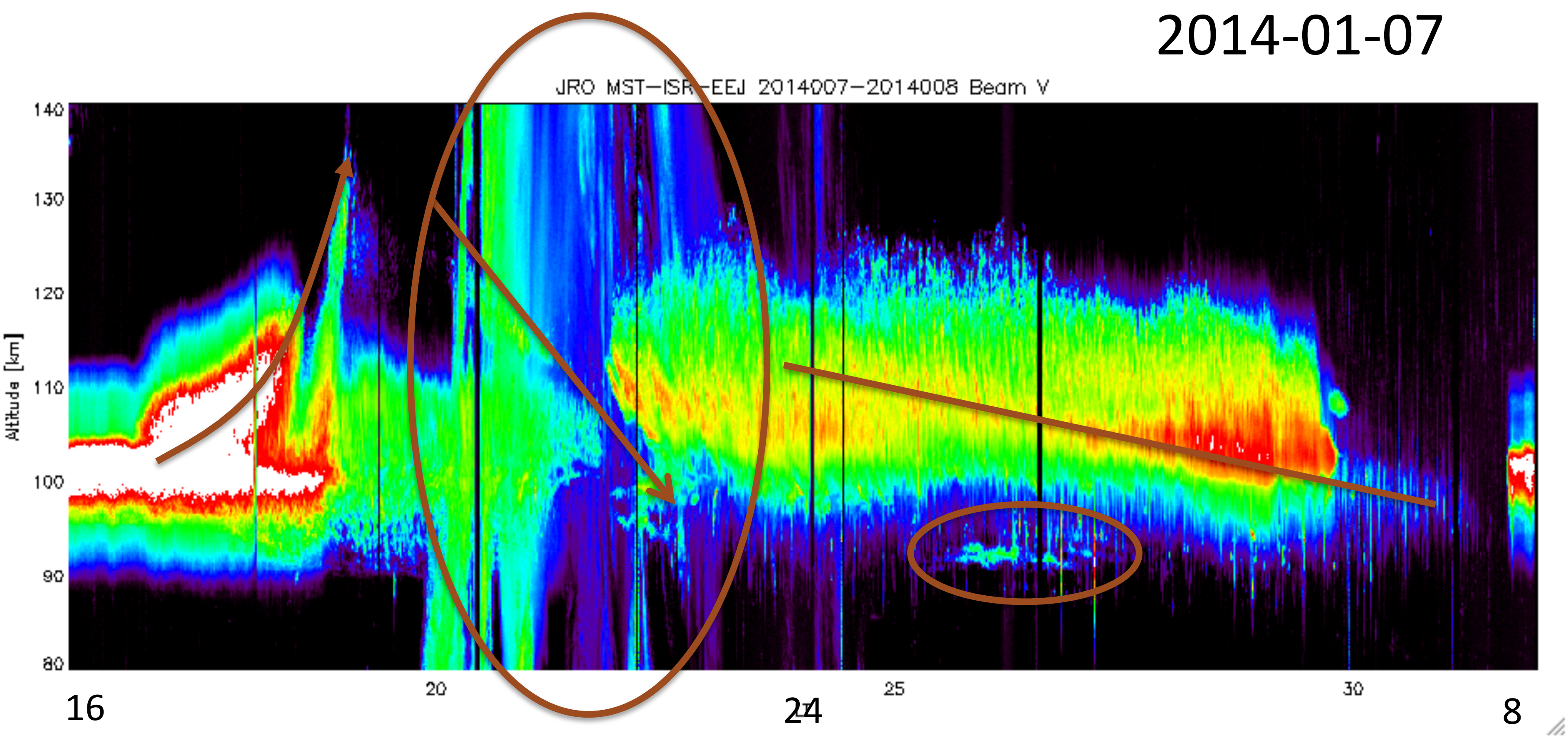
- Objective: Gravity wave processes and coupling in D, E, and F region
- 4 fixed beams, East ⊥B, West ⊥B, South, Vertical
- Big transmitters, ~1.5 MW peak
- MST: 64-baud CC, 150 m, 0-200 km
- ISR: 3-baud Barker, 15 km, 0-1000 km
- EEJ: 1-baud, 150 m, 0-200 km
- 4-day campaigns, day and night, ~2 TB/day
- 8 campaigns between Jan-2014 and Jan-2016
- Data server at U of Illinois (for public access)

Outline

1. Nighttime E region echoes
2. (Daytime) 150-km echoes
3. (Daytime) Mesospheric echoes: Interferometry



Nighttime E region echoes (MST mode)



Pre-Reversal Enhancement

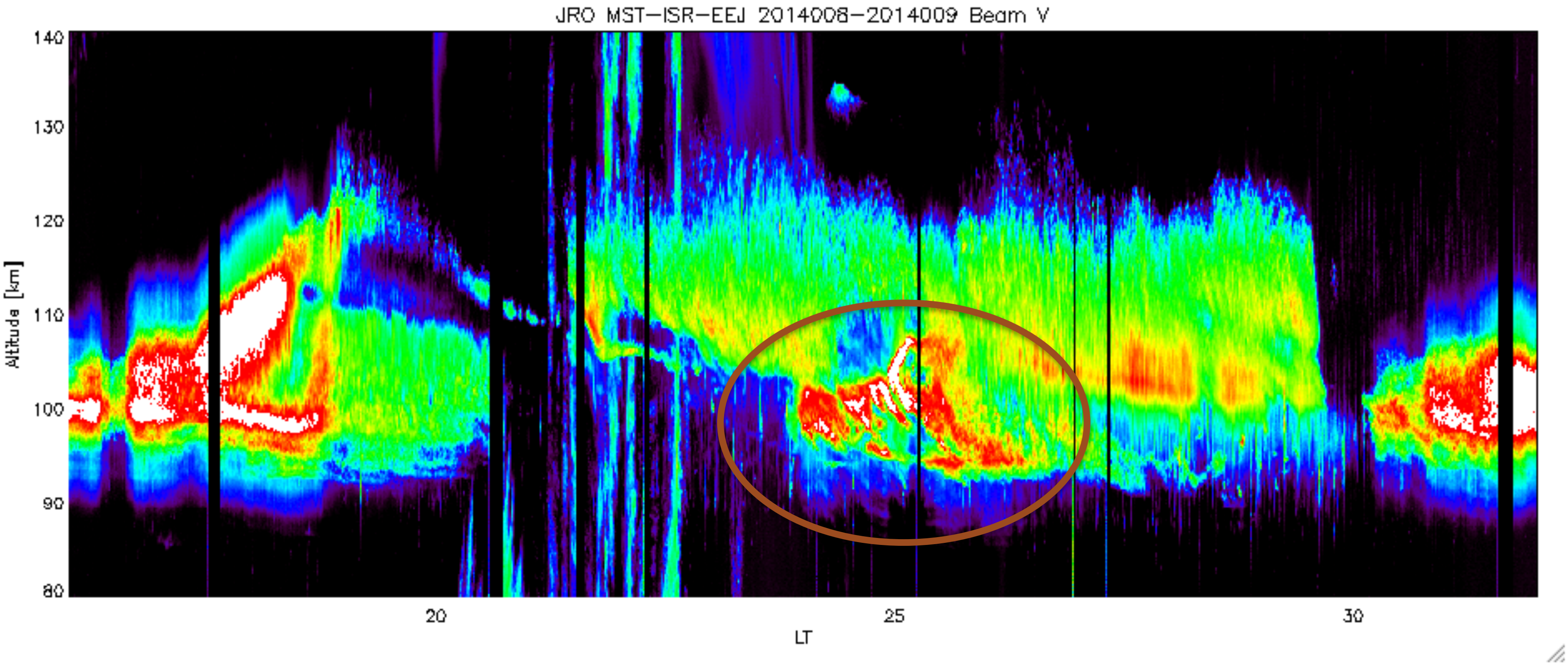
Spread-F (range-aliased)

Ionospheric Descent
(field reversal)

"Sporadic-E"

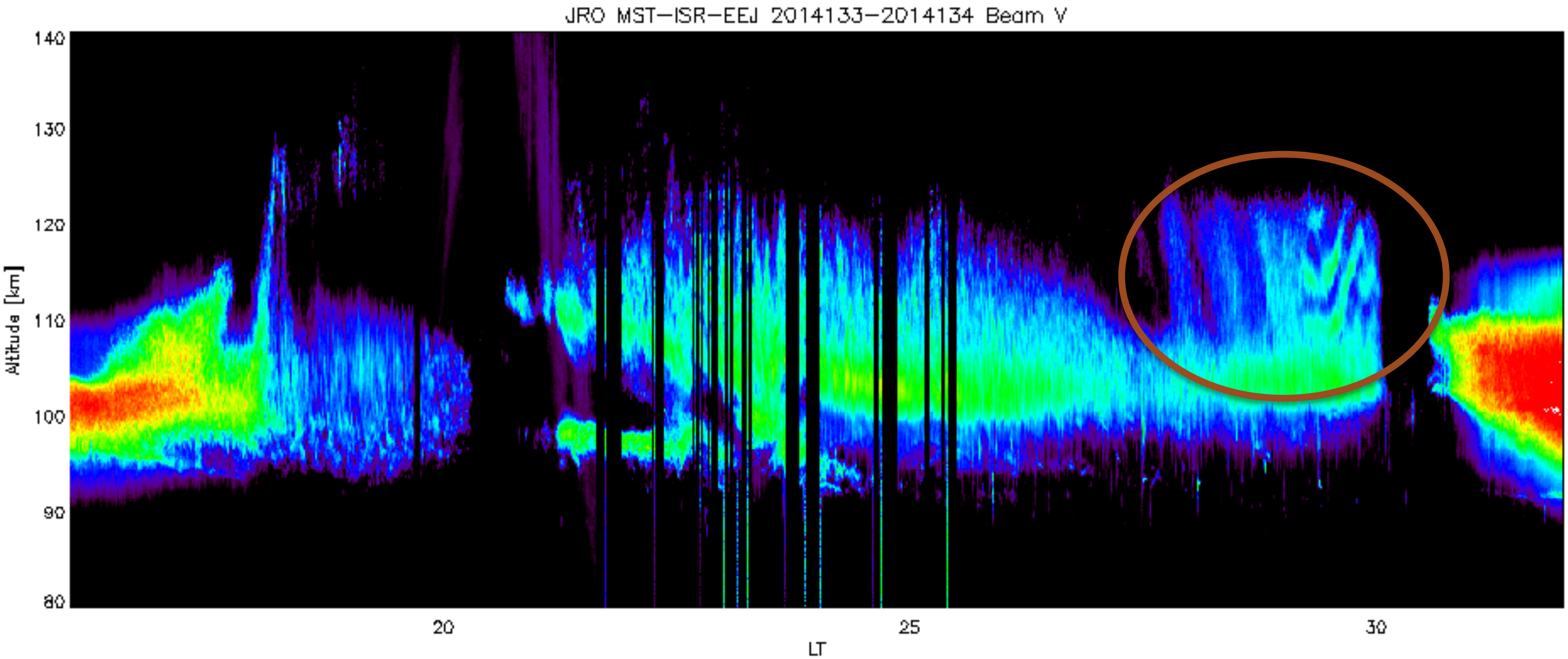
Tidal phase

2014-01-08



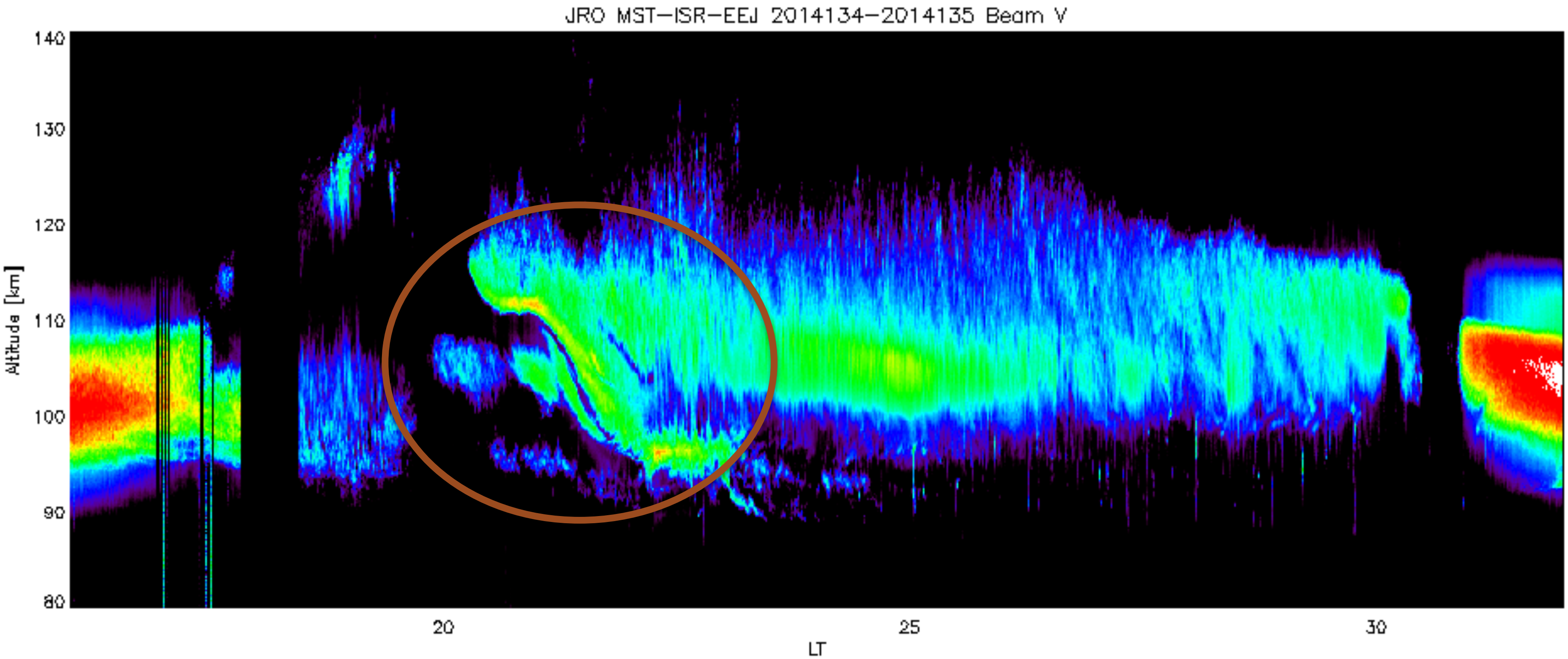
E field anomaly?

2014-05-14



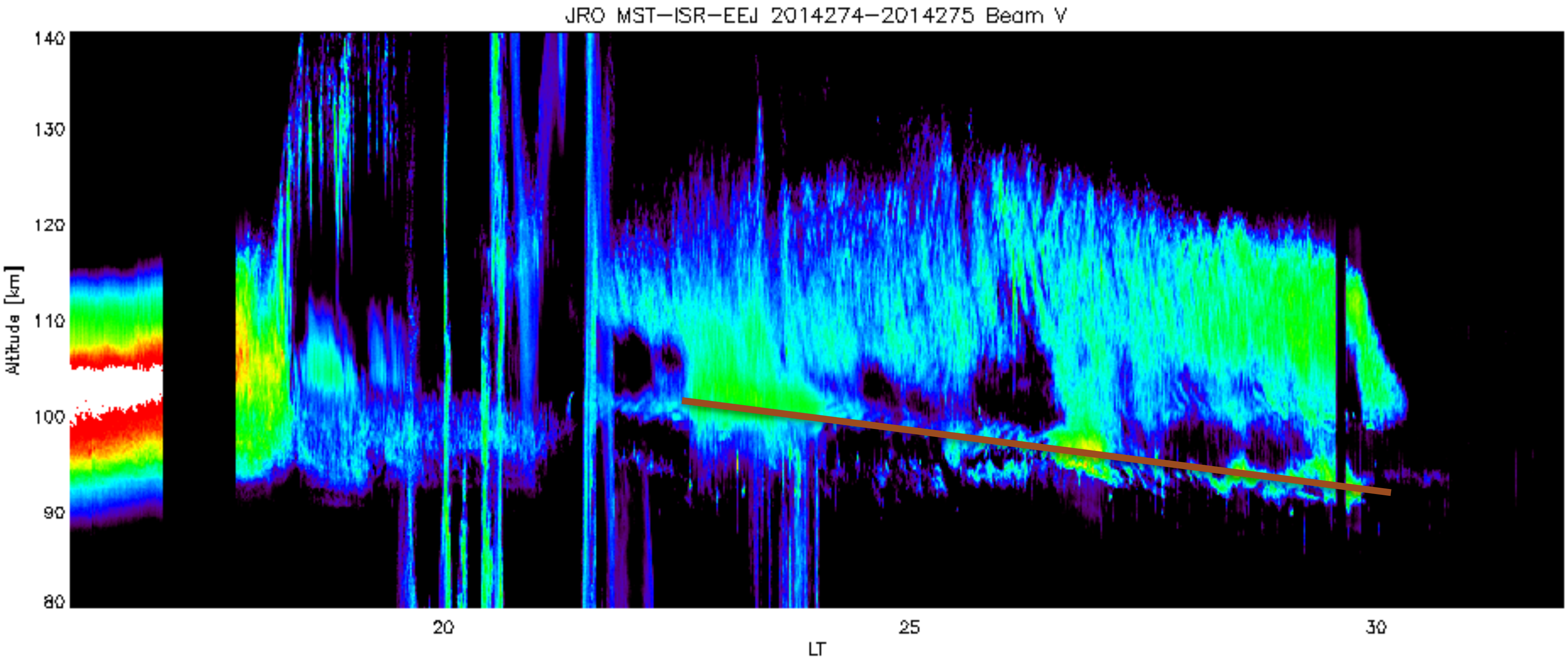
morning ascent

2014-01-15



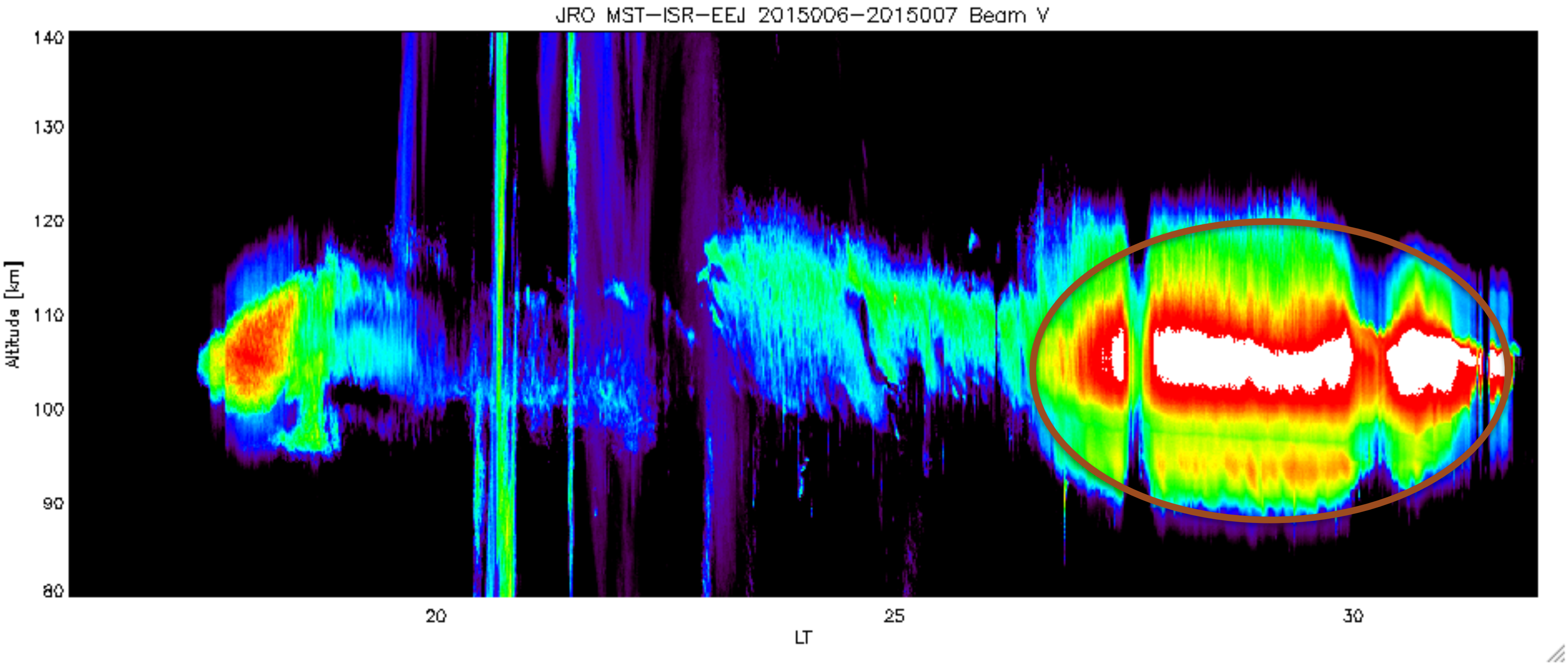
“elegant” descent

2014-10-01



lower “tidal” layer

2015-01-06

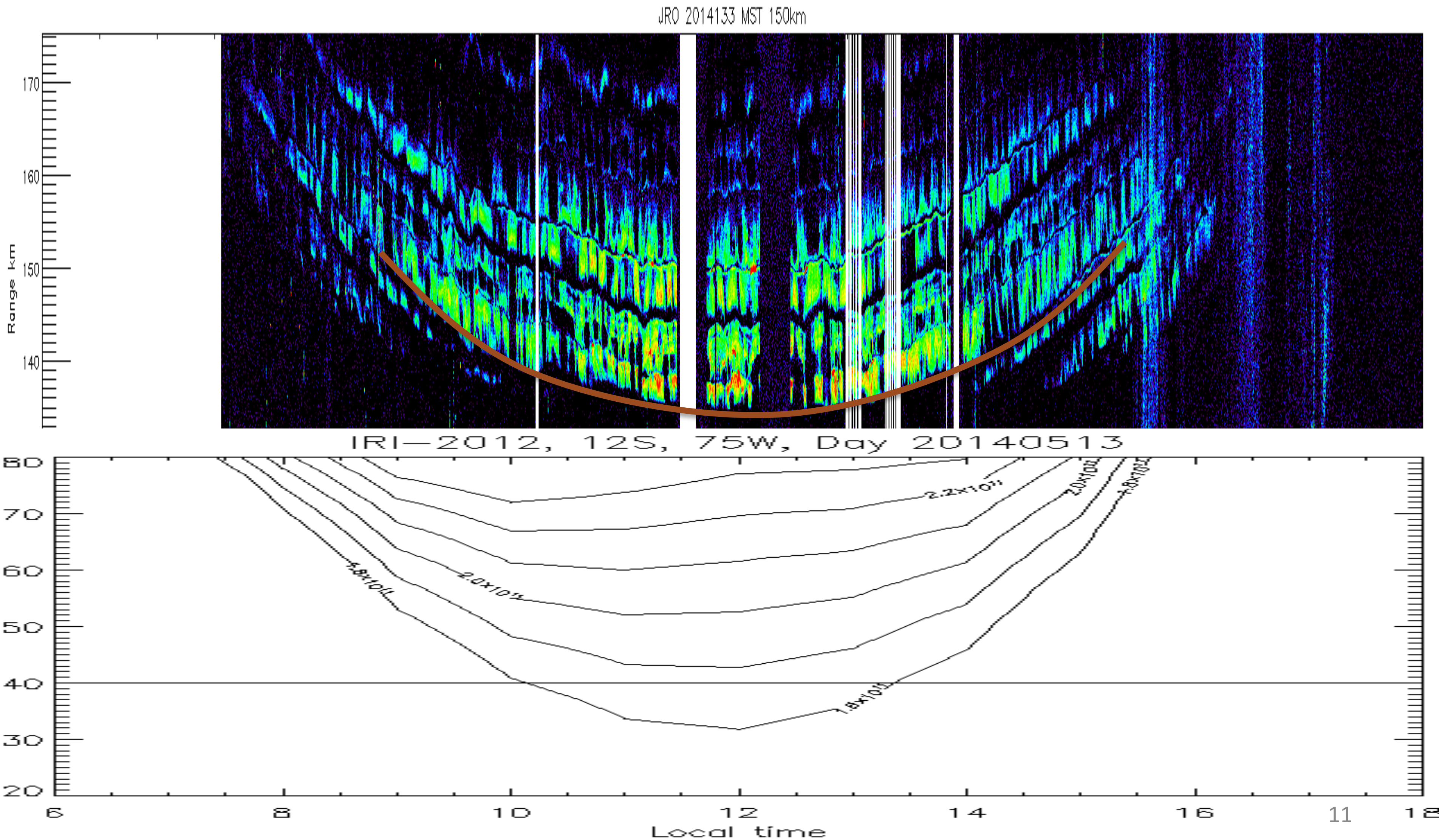


meteor shower
Quadrantids

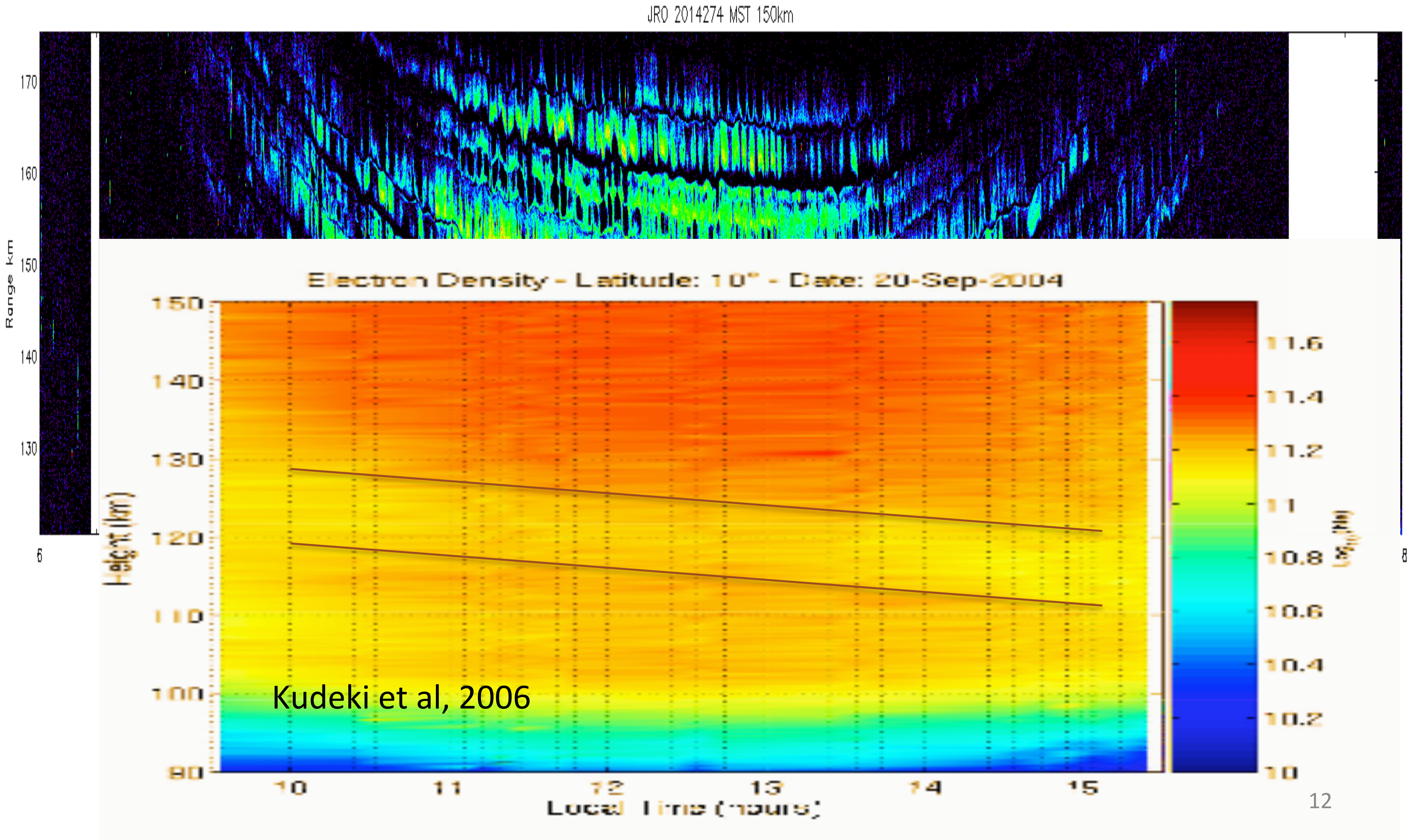
Nighttime E region echoes - Summary

- Fundamental studies on nighttime electrojet, plasma waves and instabilities
- Day-to-day variability, especially during pre-reversal enhancement and spread-F development is less understood
- Lack of complementary measurements of
  - neutral metals and metal ions;
  - including sporadic and tidal metal layers
  - plasma gradient
  - neutral winds and temperatures (some by meteors)
  - electric fields

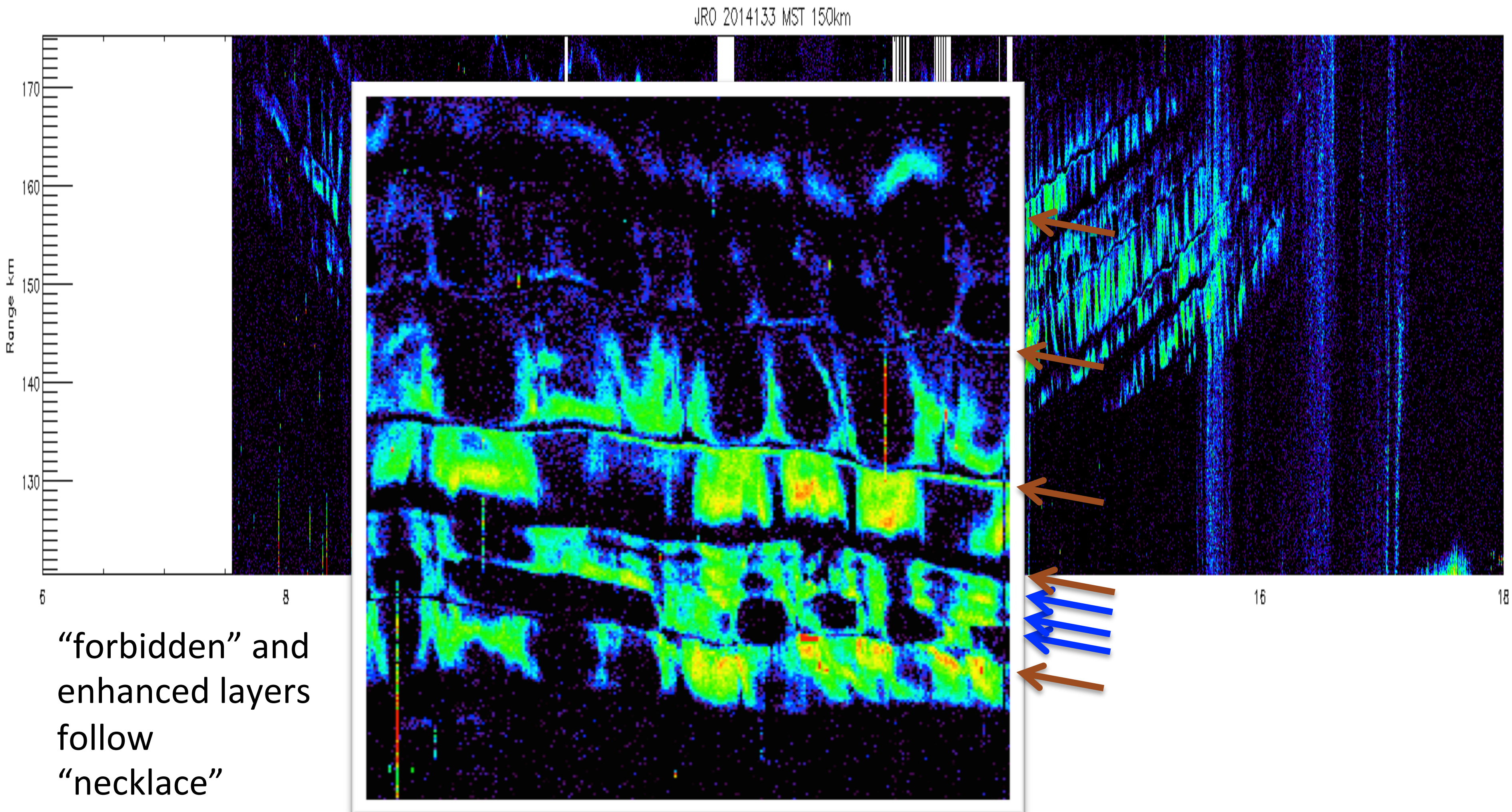
150-km echoes – bottom line



150-km echoes – bottom line

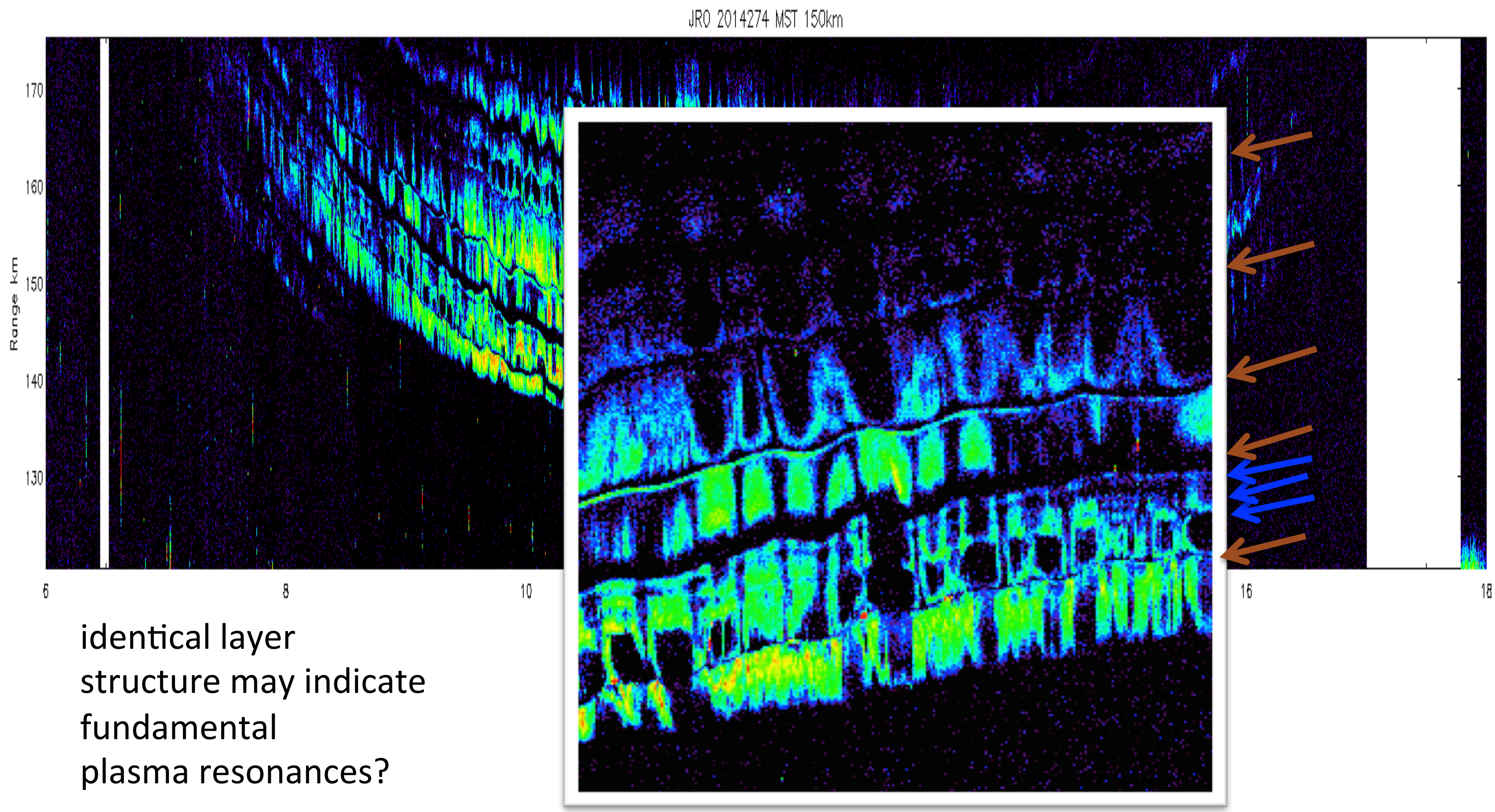


150-km echoes – layer fine structure



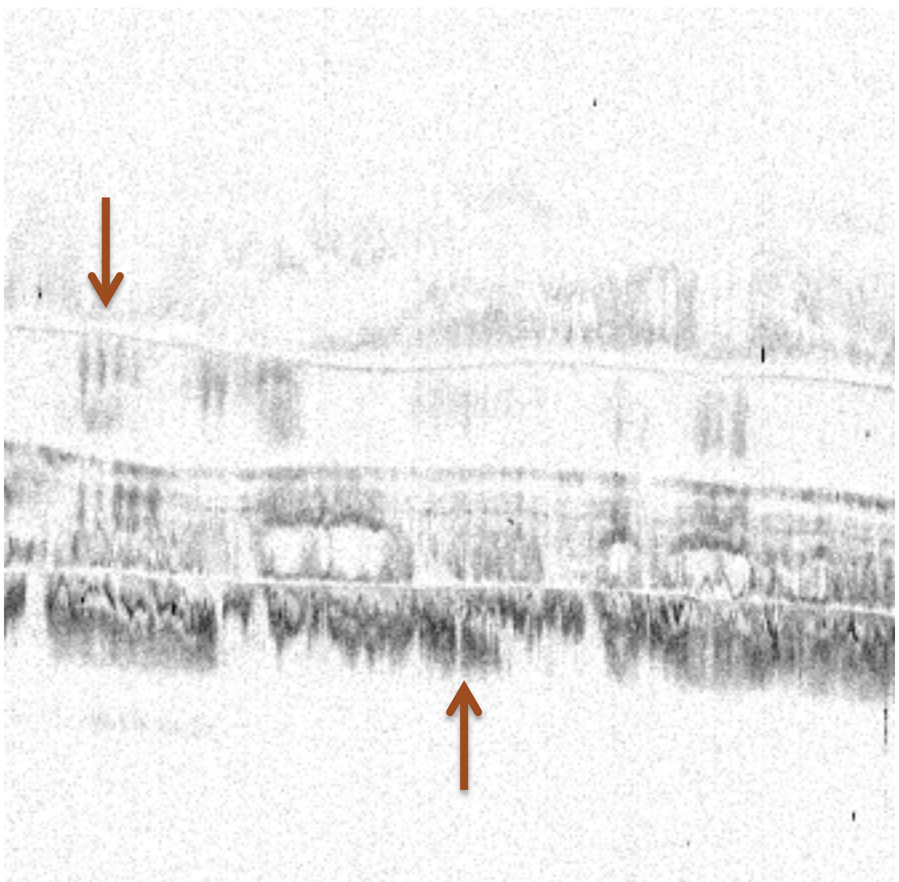
"forbidden" and enhanced layers follow "necklace" throughout day

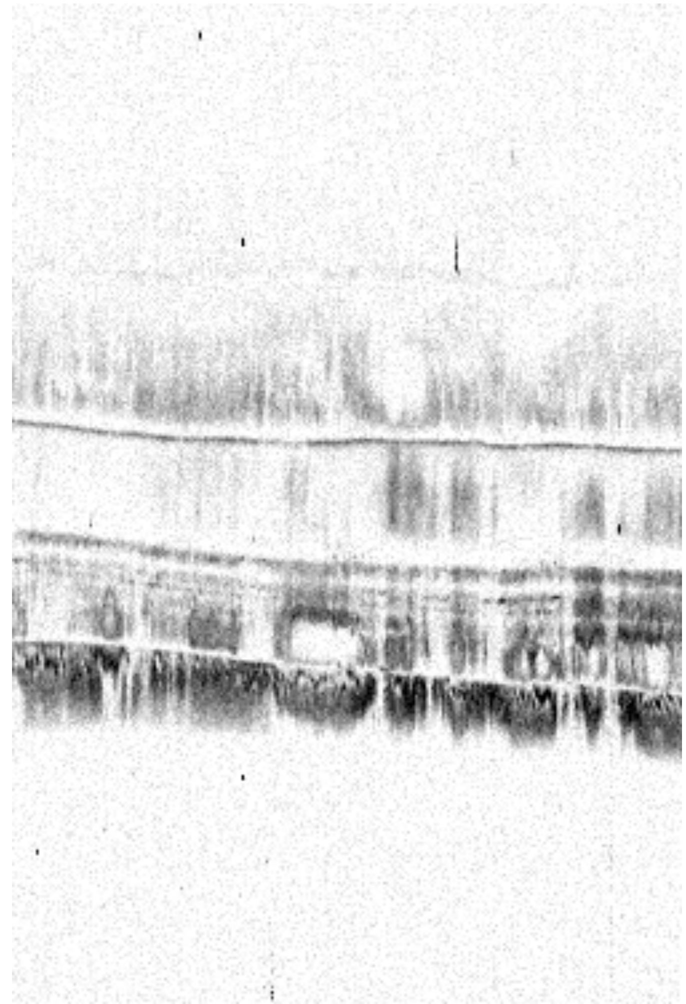
150-km echoes – layer fine structure



identical layer
structure may indicate
fundamental
plasma resonances?

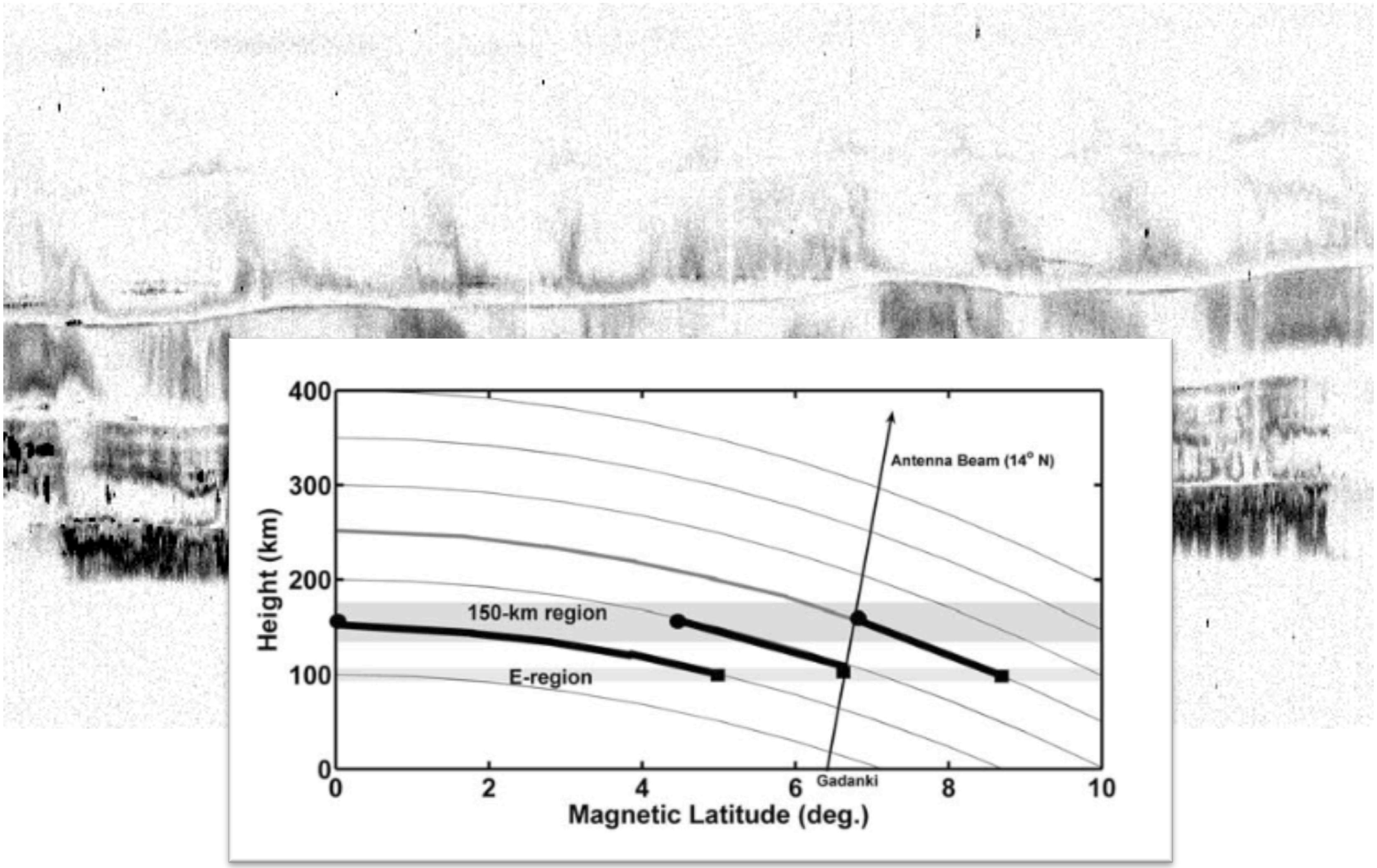
150-km echoes – fast pulsations





10-15 minutes of data with 4 second integrations
high-resolution RTI reveal power modulations with periods of 20-30 seconds

150-km echoes – fast pulsations



Alfvén wave propagation along magnetic fieldlines?

Patra and Rao, 2007

150-km echoes - Summary

- Day-to-day and seasonal variability of "necklace"
  - relation to local electron density profile
- Fine structure in layers is very similar each day
  - "forbidden" and enhanced layers
  - point to fundamental plasma resonances
- Very short period pulsations
  - possibly due to waves along the magnetic field lines
- Gravity wave modulation due to vertically propagating waves
  - similar to VIPER dynasonde results (P. Reyes; Negrea et al./Wallops Island)

Mesospheric echoes

2011130 - 10 May 2011 - RTI

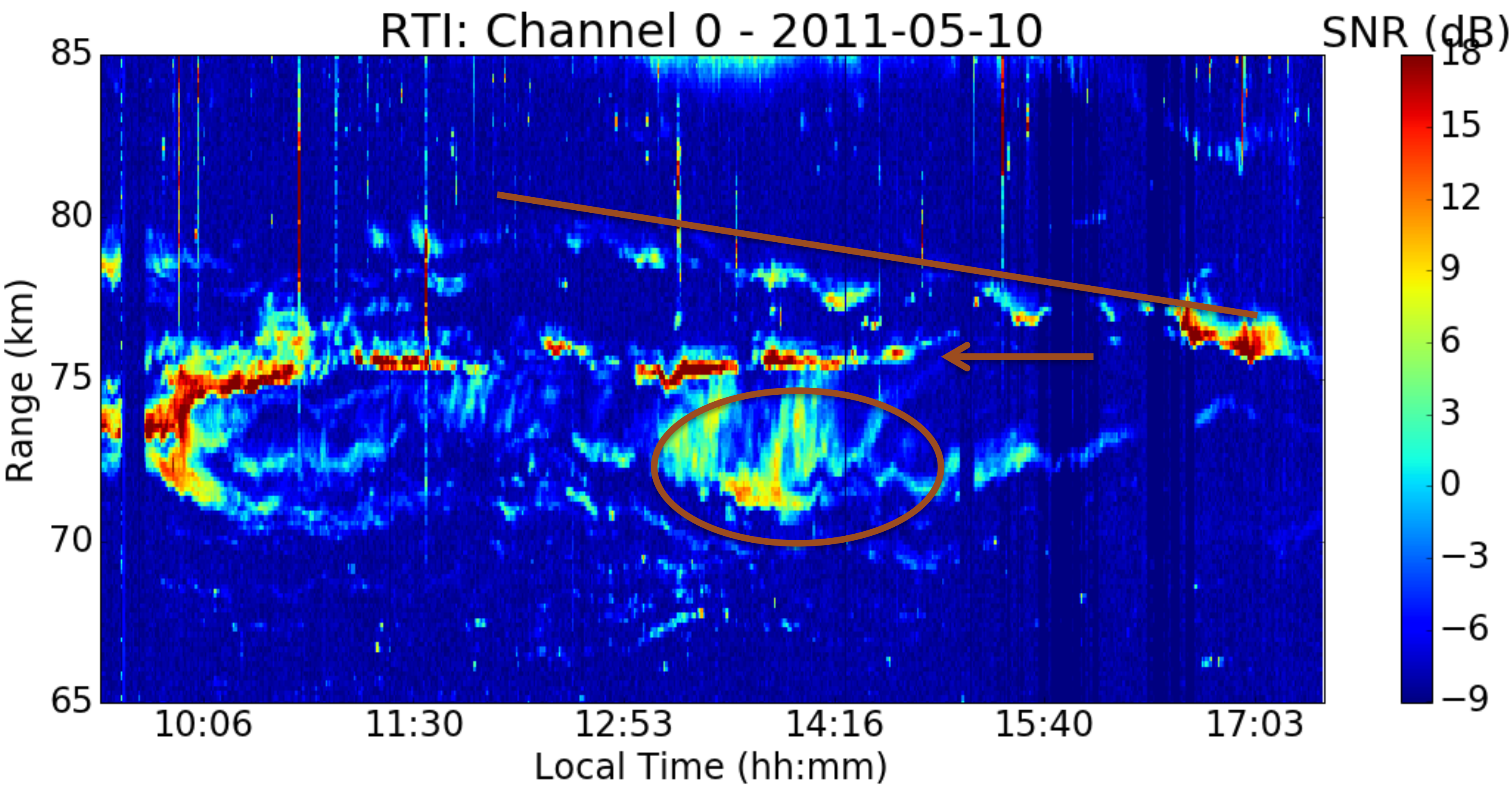
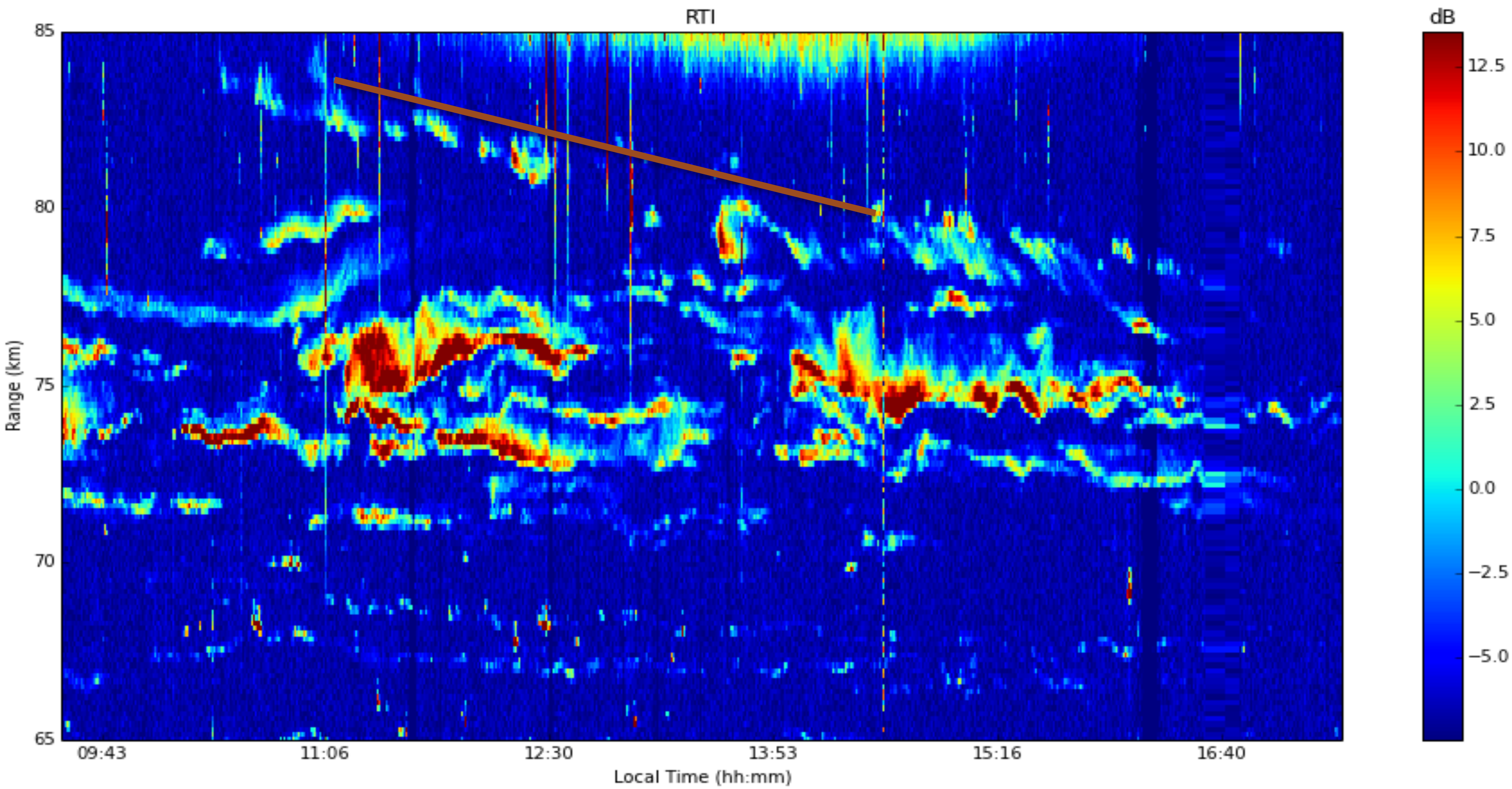


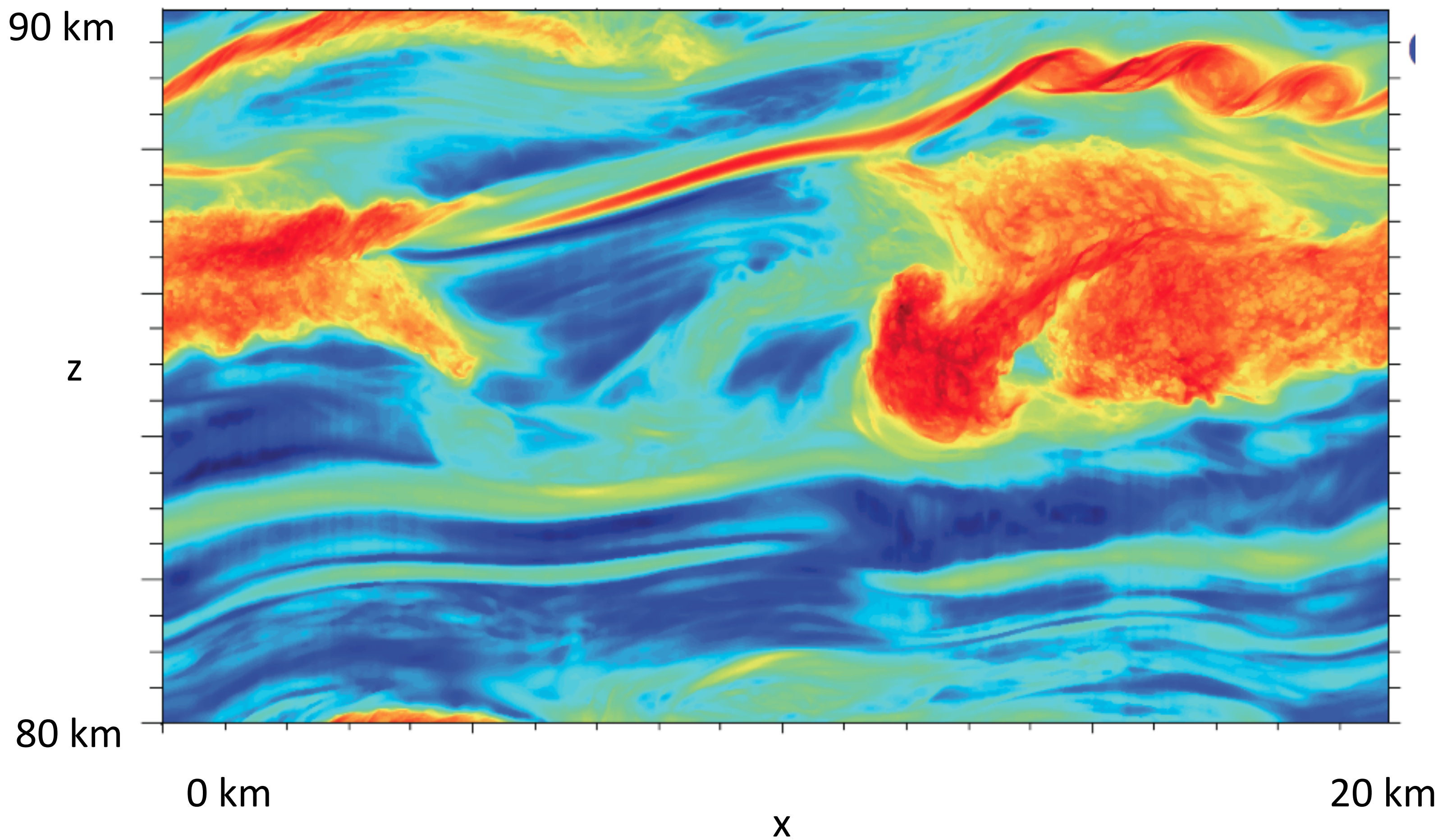
Figure: Evan Figg

Mesospheric echoes
2011131 - 11 May 2011 - RTI

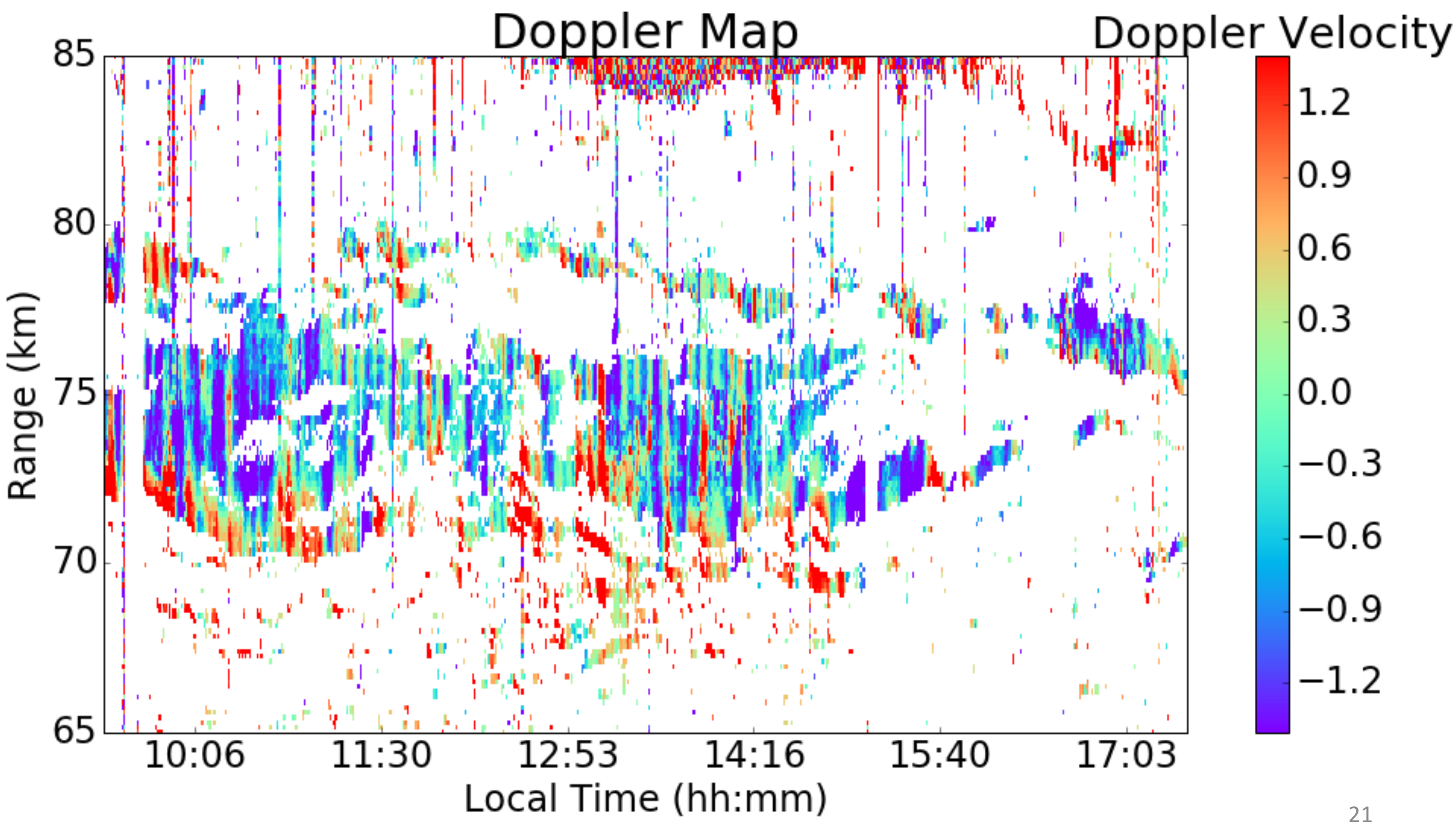


Gravity wave – fine structure interactions

Direct Numerical Simulation (DNS), Fritts et al., CEDAR, 2012

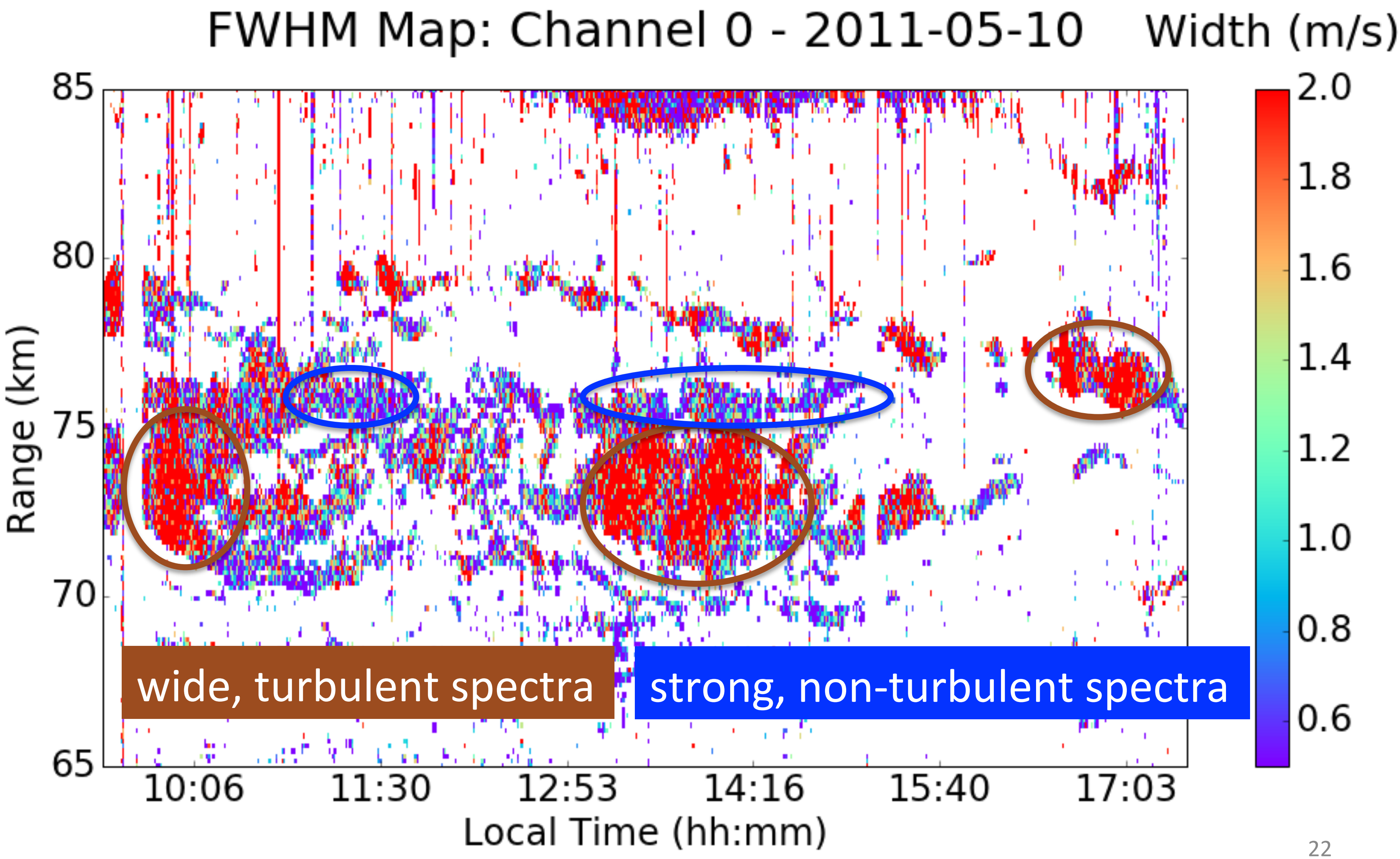


Mesospheric echoes – Vertical velocity



Mesospheric echoes – Spectral width

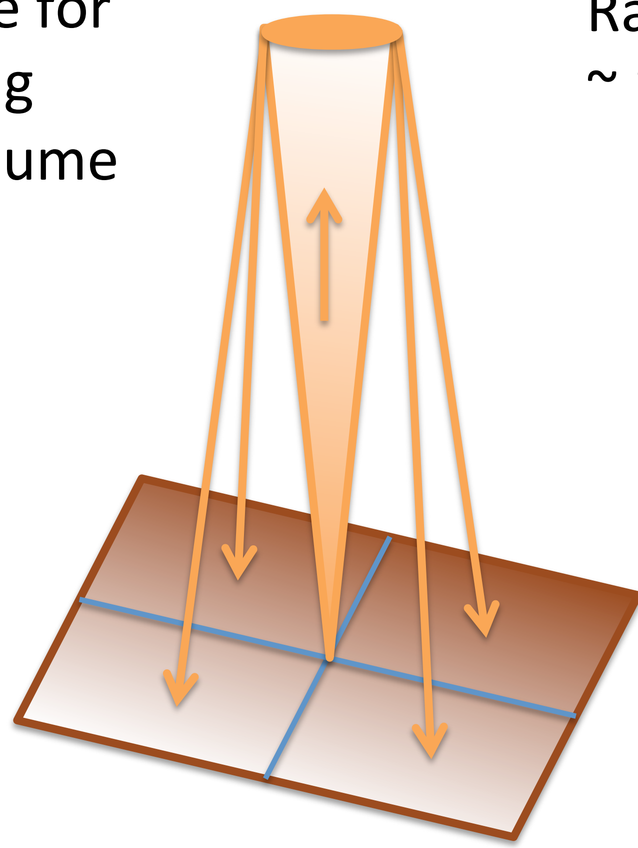
(from generalized Gaussian fit)



Mesospheric echoes – interferometry

Goal: Find evidence for individual scattering targets in radar volume (vs. volume filling)

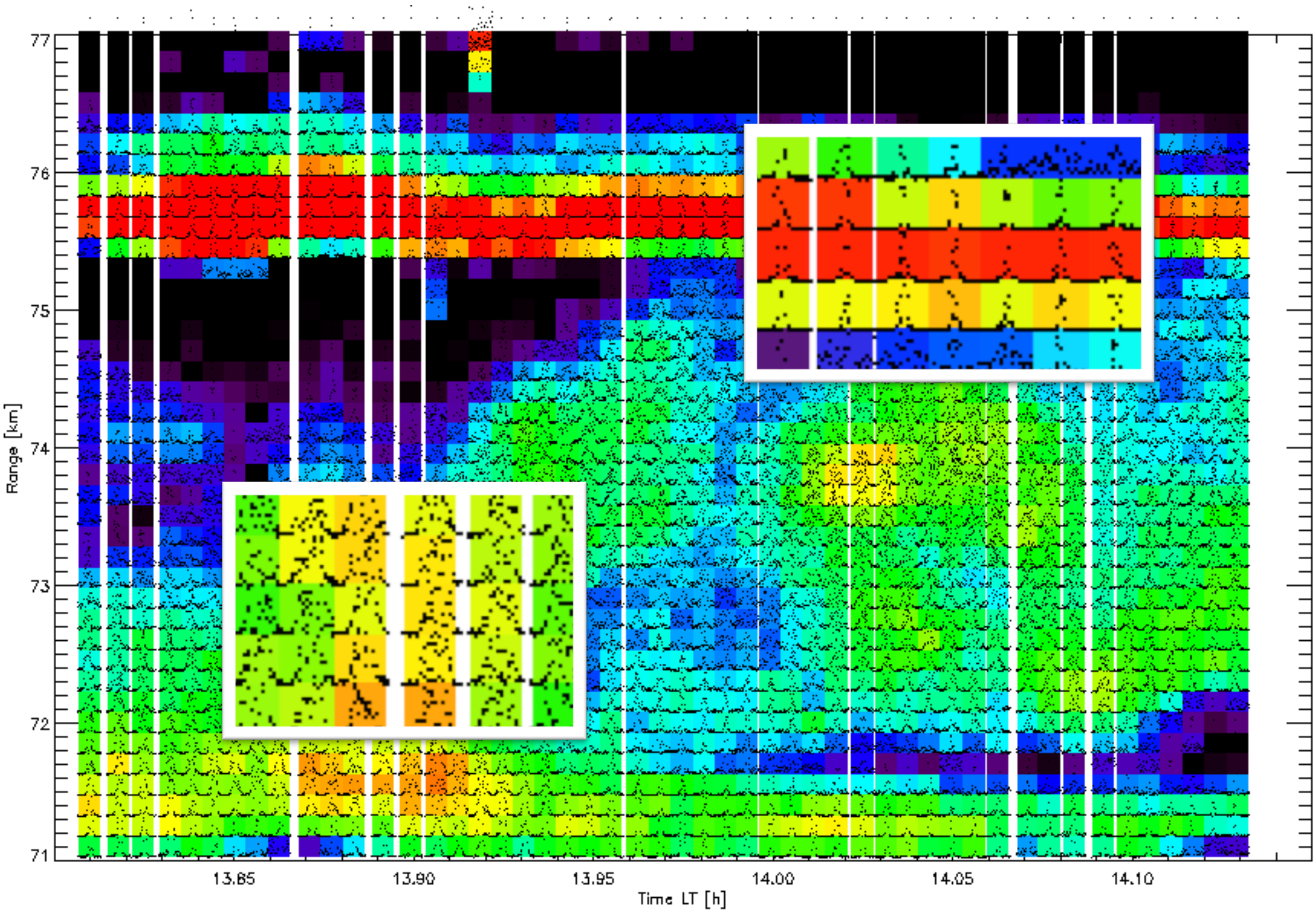
Radar volume @ 75 km
~ 1500 m Ø x 150 m



Similar experiment as Kudeki, 1988; but with 10 times smaller radar volume

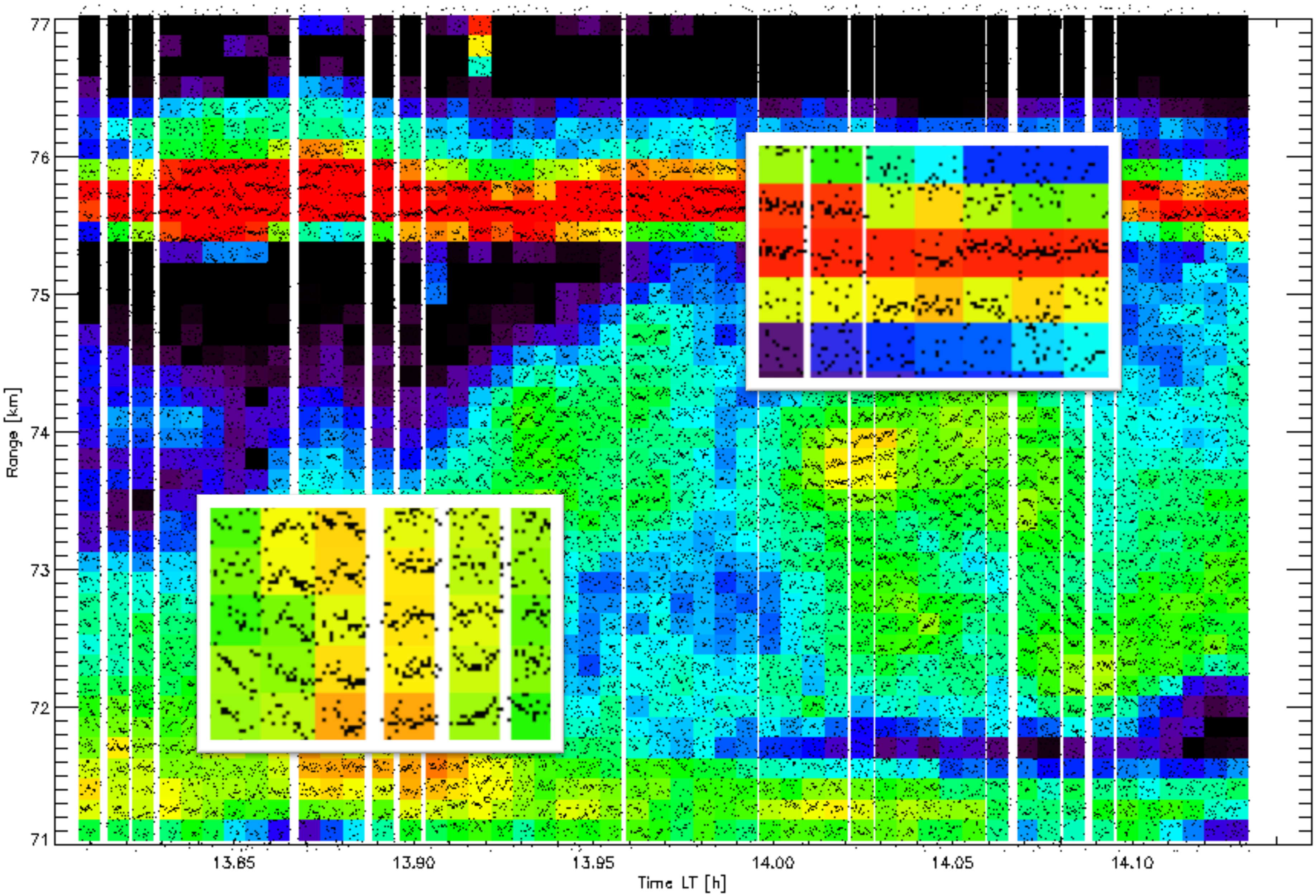
Interferometry/ Imaging on much (10,000 x) stronger PMSE echoes; e.g. Yu, Palmer, Chilson, ESRAD, 2001; Fernandez et al, EISCAT, 2005, …

Self-spectra, 16 coherent and 4 incoherent integrations, 256-point FFT, ~22 sec spectra



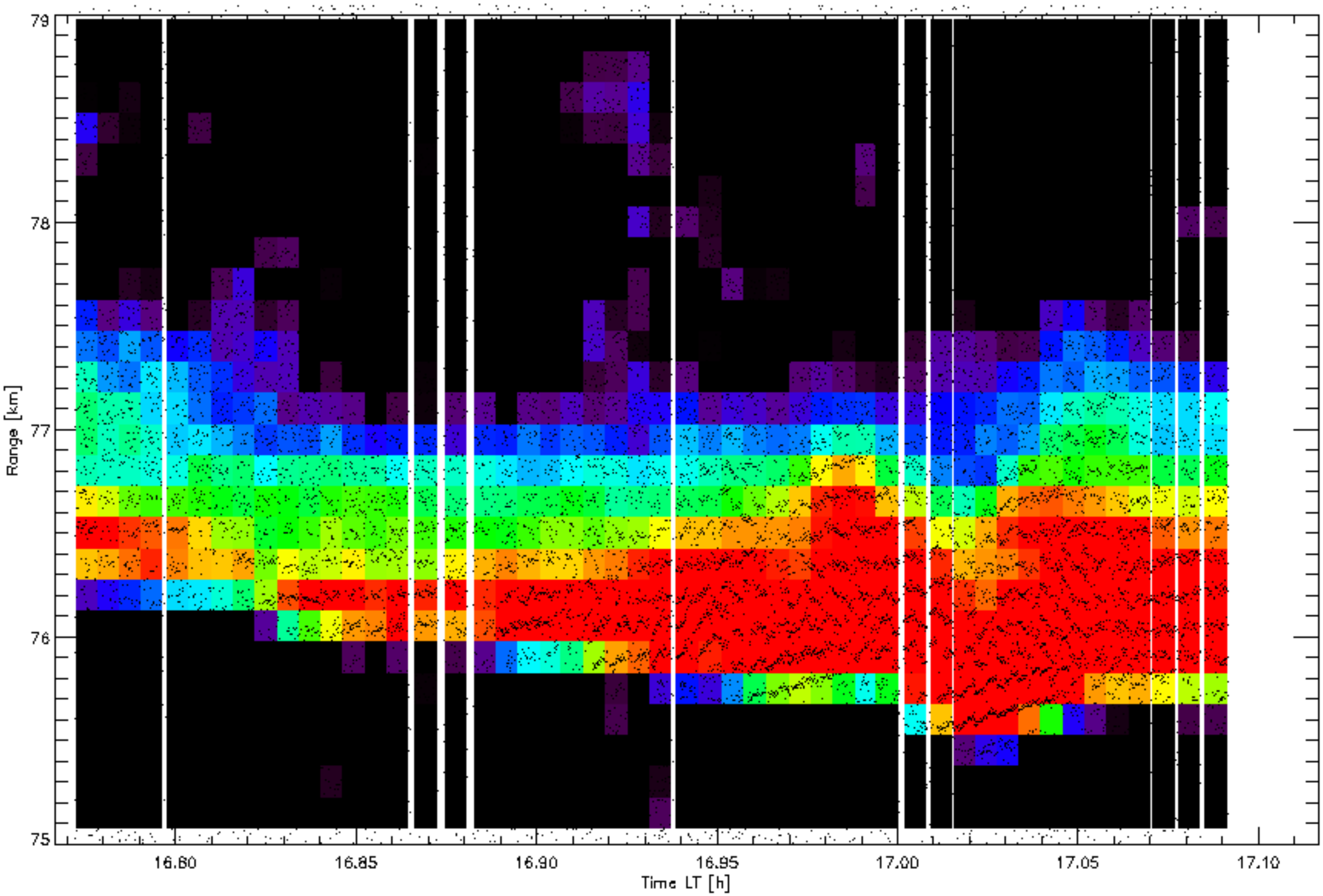
normalized **self-spectra**, -10 … 10 m/s, Channel 0, SNR as color scale -10 ... 20 dB

Cross-spectra, phase of normalized cross-spectra for coherence > 0.6



same as previous, but phase –π … +π for normalized **cross-spectra**, Channels 0-1

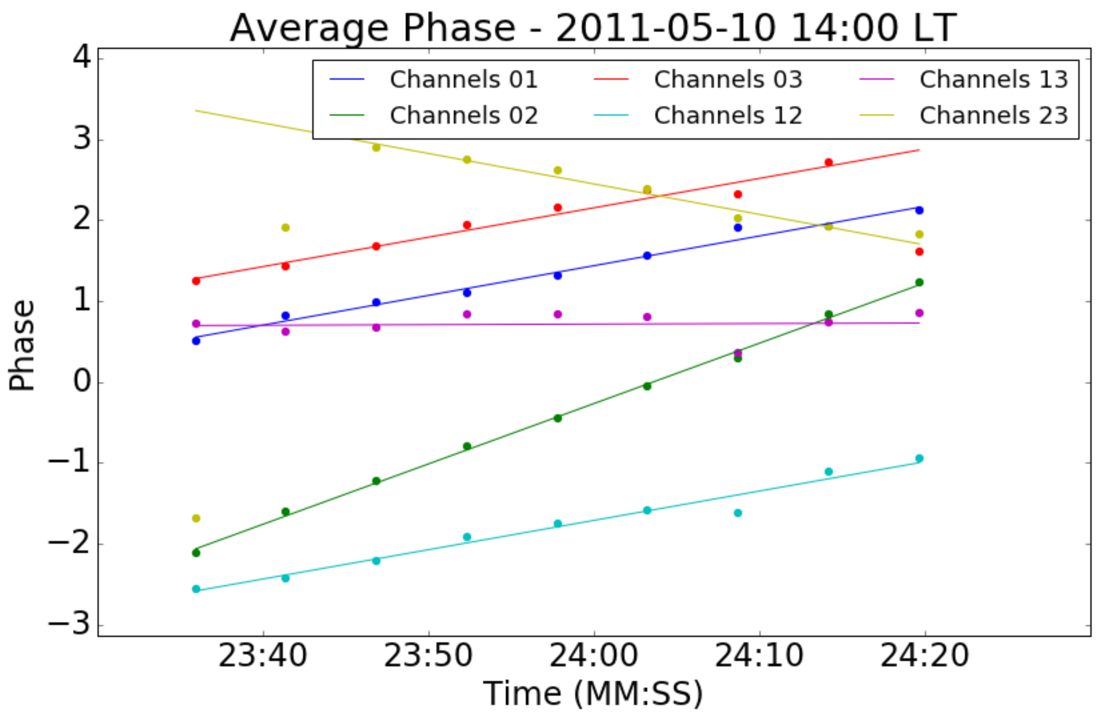
Cross-spectra; example for phase spectra in turbulent layer



complex variation of phase spectra, consistent horizontal bulk motion

Mesospheric echoes - interferometry

- Basic interferometry suggests evidence for individual, (partially) reflecting patches ("glints") in the radar volume
- Phase progression yields consistent horizontal trace velocity for all interferometric baselines

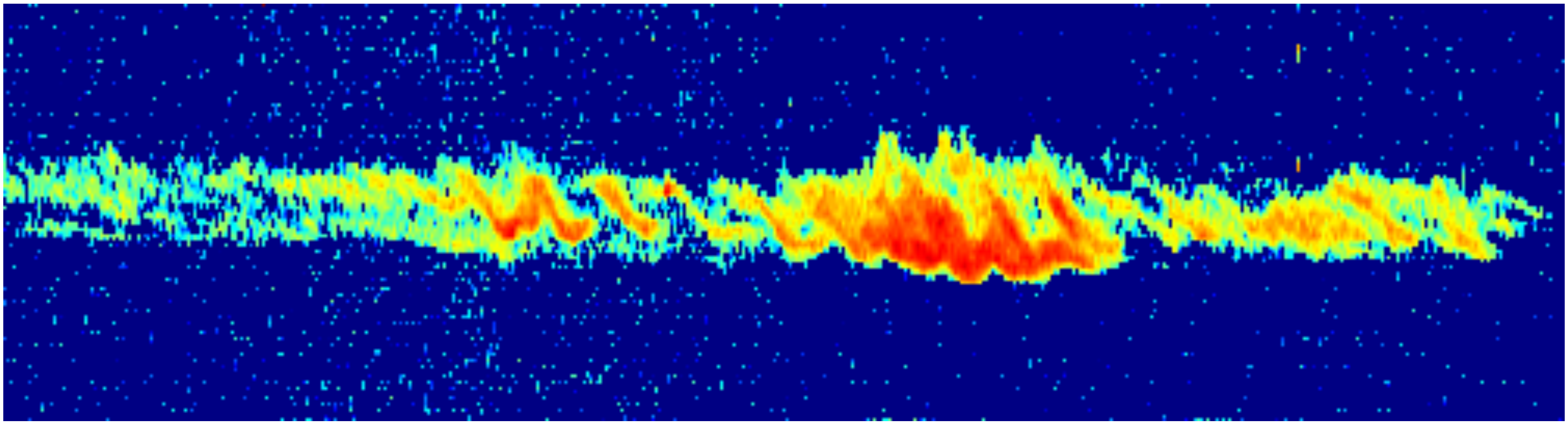


E. Figg

Mesospheric echoes - Summary

- First observations of <u>localized scatterers</u> in Jicamarca mesospheric echoes
- Example suggests a deep, convective and turbulent layer capped by a stable, non-turbulent layer
- Physical mechanism or plasma processes that cause glints is still unclear (similar to PMSE?)
- Interferometry and basic imaging may help understand details of gravity wave breaking and instabilities in the equatorial mesosphere

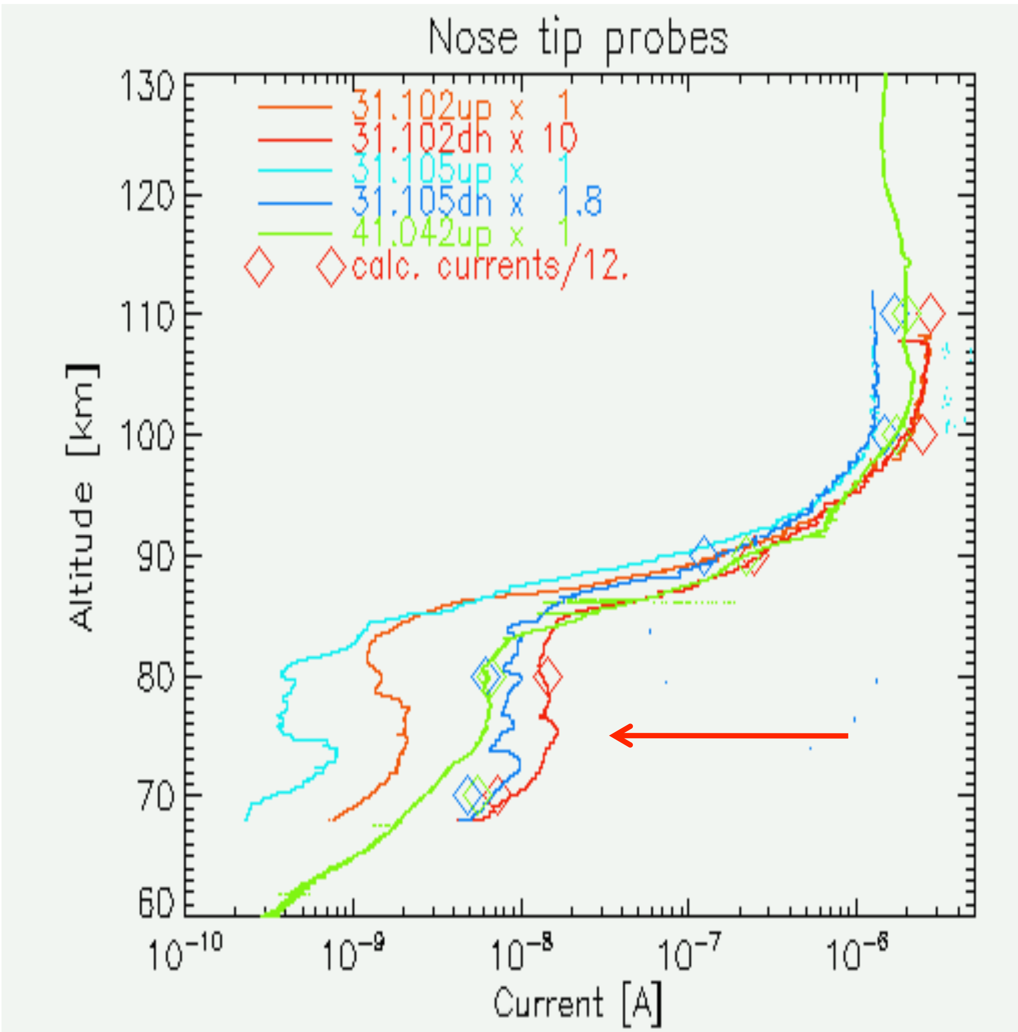
Thank you!



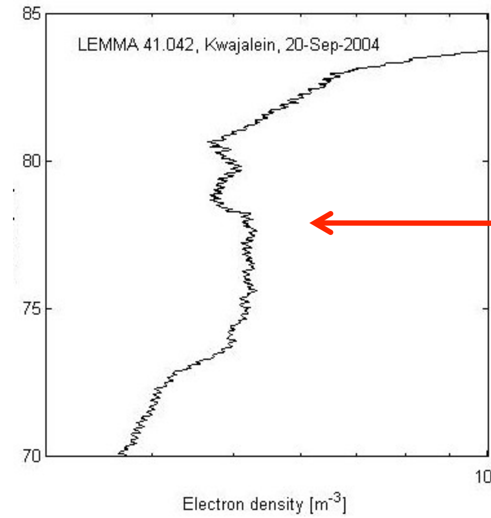
Example of KHI train on 1/8/2014
~1 hour, ~77 km

Equatorial electron density profiles, 70 - 80 km

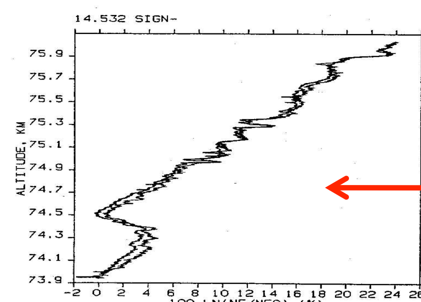
3-meter fine structure remains elusive



1976, 1994, 2004

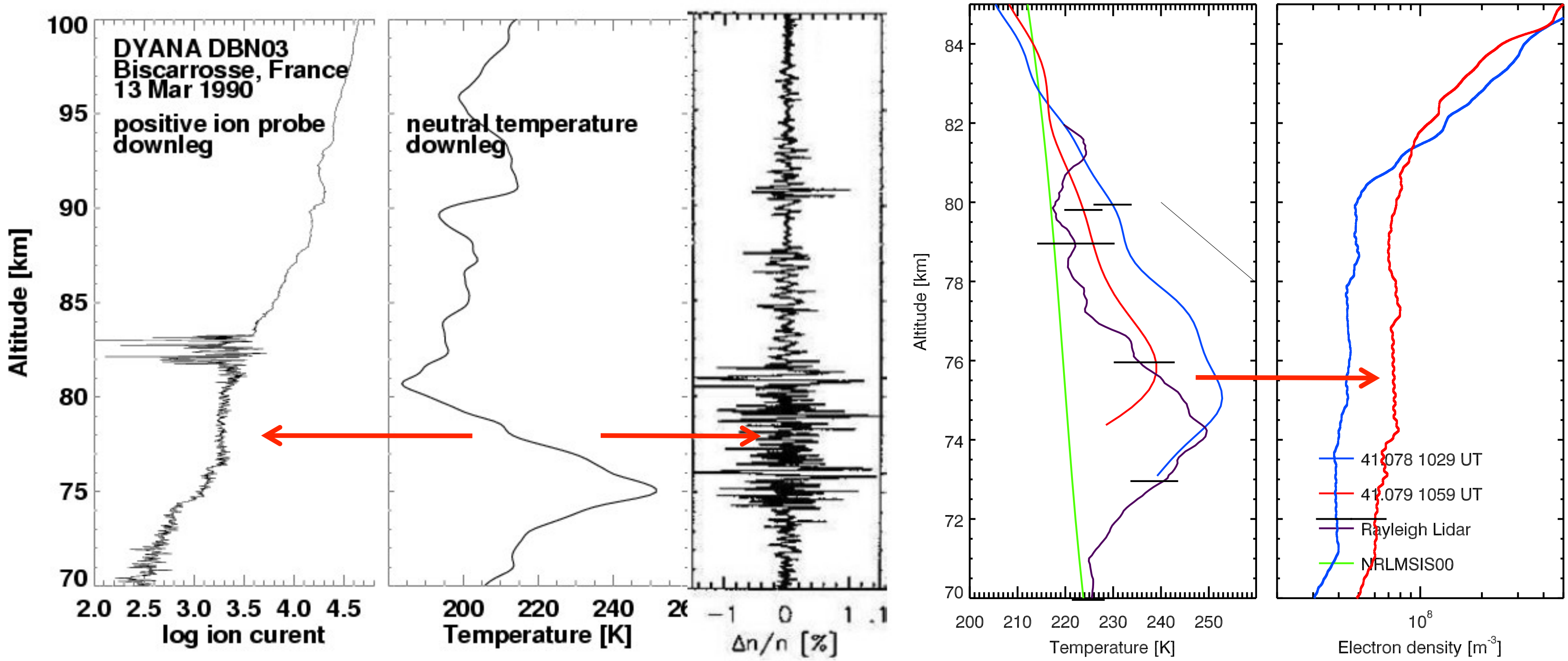


How are these steps related to VHF echo structure?



Goldberg et al., 1997; Lehmacher et al., 2006; Smith and Klaus, 1976; Das et al., 2009

Mesospheric instability layers
(mid and high latitude)



Lehmacher and Lübken, 1995; Lehmacher et al., 2011; Collins et al., 2011