The 150-km echo Challenge: Jicamarca Observations

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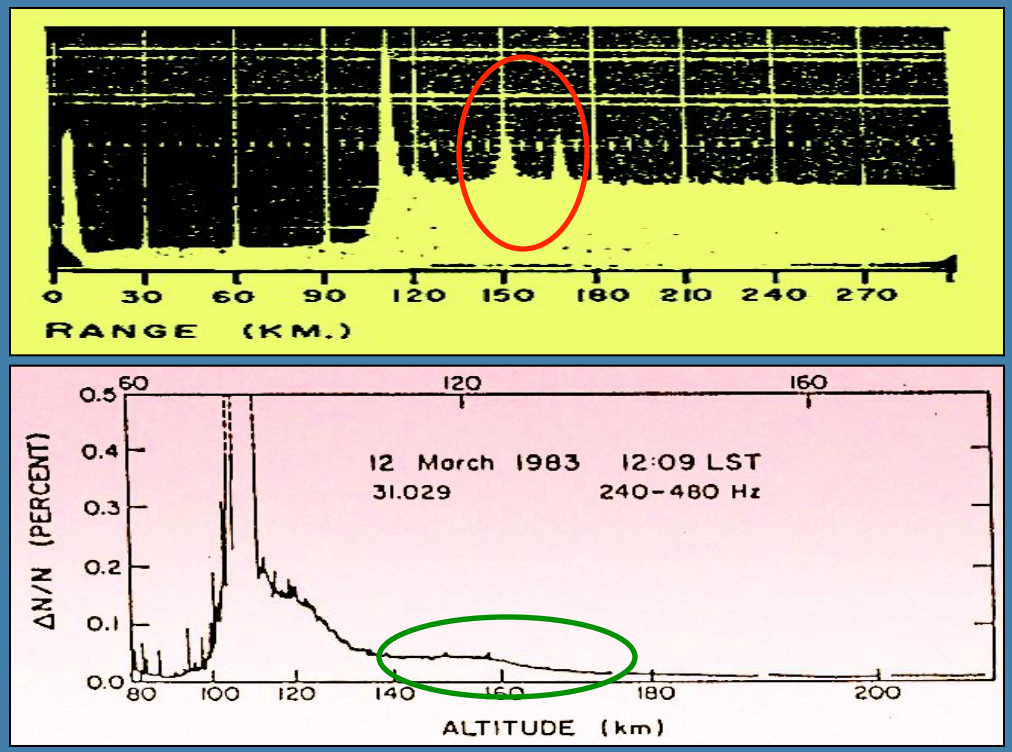
Outline

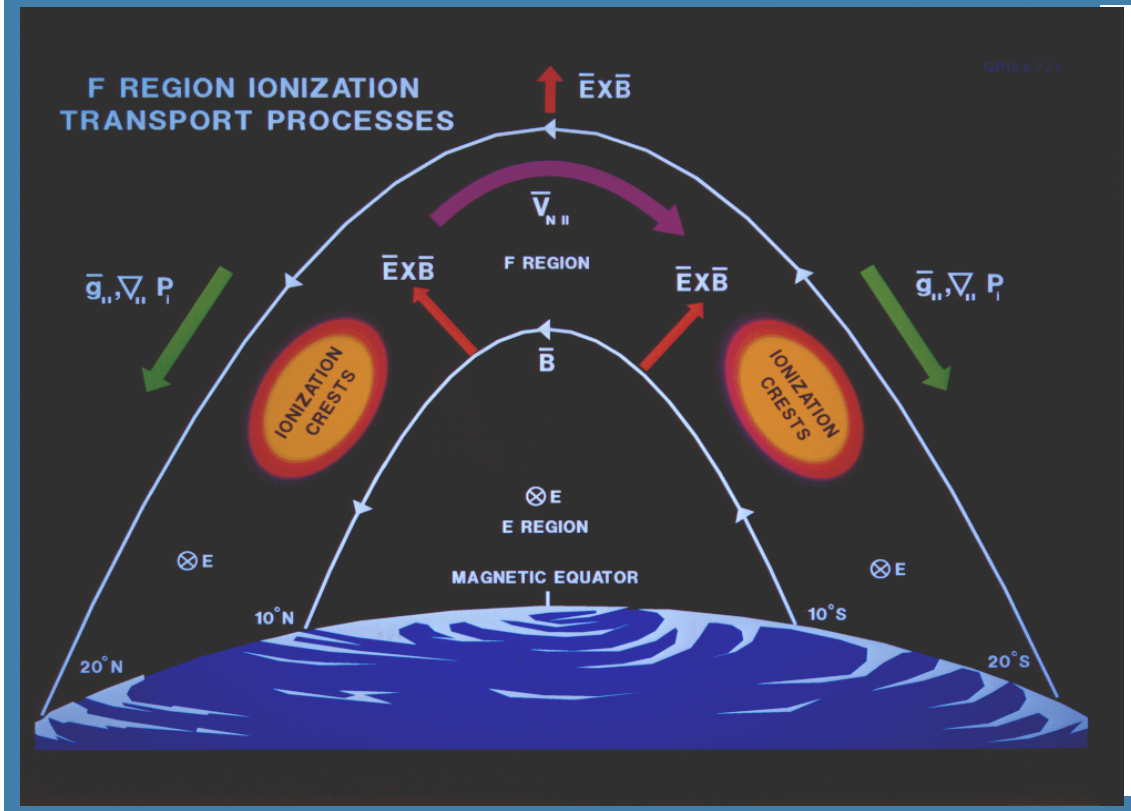
- Introduction: A “radar” puzzle?
- What do we know from previous Jicamarca measurements?
  - Perpendicular observations
  - Off-perpendicular observations
- Unpublished and New observations
  - East-west Structure
  - Ion-line spectra asymmetries
  - Solar Flare dependence
  - Density profiles from Faraday experiments
  - Multi-frequency results

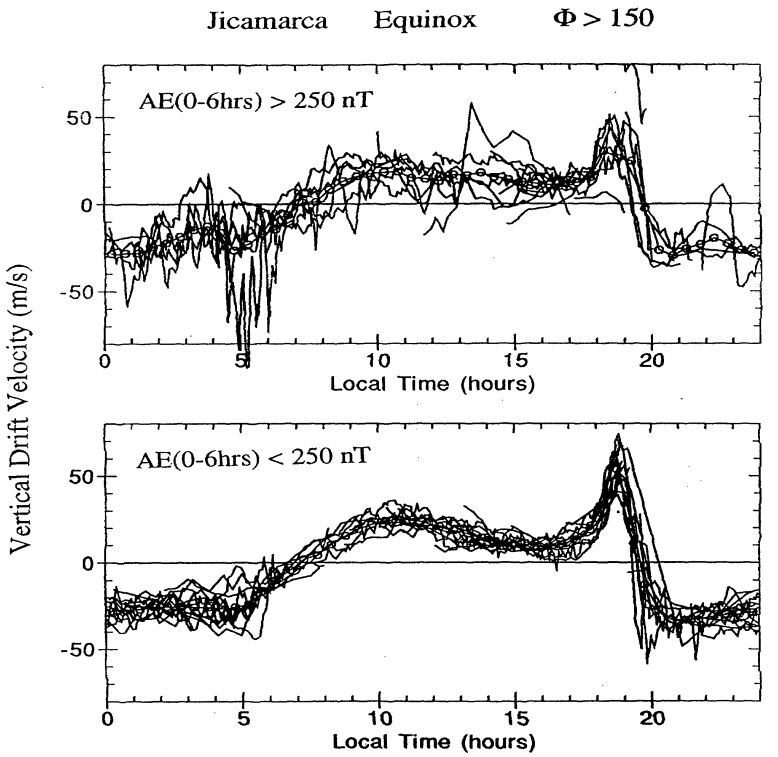
First detection of 150-km echoes

- Jicamarca Observations
  - Balsley [1964]
- Rocket Observations
  - Thumba, India [*Prakash et al.,* 1969]
  - Punta Lobos, Peru [*Smith and Royrvik*, 1985]
- A radar puzzle?



Equatorial Ionosphere

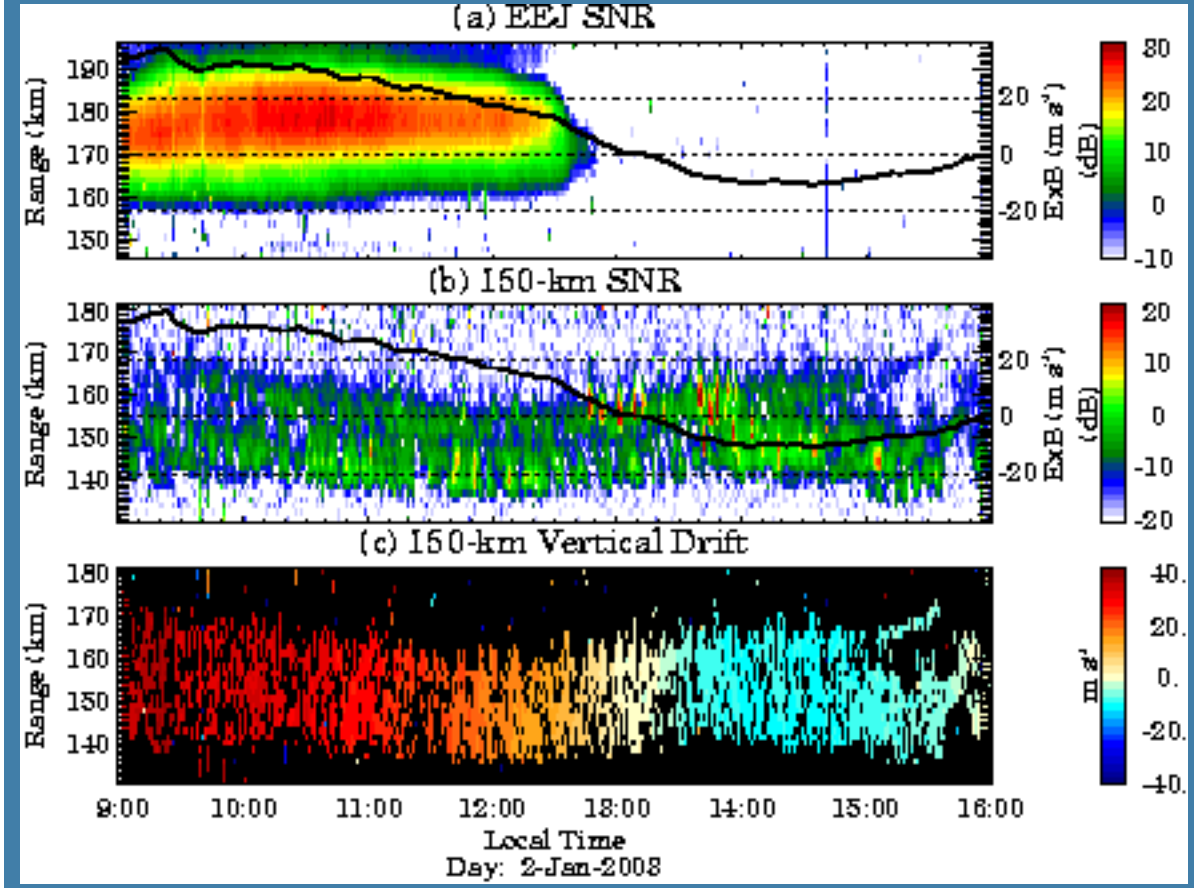




[from *Fejer et al*, 1999]

- **B** field is nearly horizontal
- Daytime:
  - *E*-region E is eastward
  - Off-equatorial E maps to F above mag. Equator -> Upward ExB
  - Formation of Appleton Anomaly
- Around sunset, *F* region dynamo develops and competes with *E*, generates PRE and ExB goes downward (E westward)
- At night upward density gradient is opposite in direction to g, Rayleigh-Taylor unstable, allowing plasma density irregularities to form.

150-km Perpendicular to B main features



Proposed Mechanisms

•Gravity wave wind driven interchange instability [*Kudeki and Fawcett*, 1993

•Low-latitude Es layer instability providing free energy for the growth of interchange instability at equatorial 150-km [*Tsunoda and Ecklund*, 2004]

Main features

•Daytime phenomena

•Occur between 130-180 km

•Necklace shape

•Come from field-aligned irregularities (?)

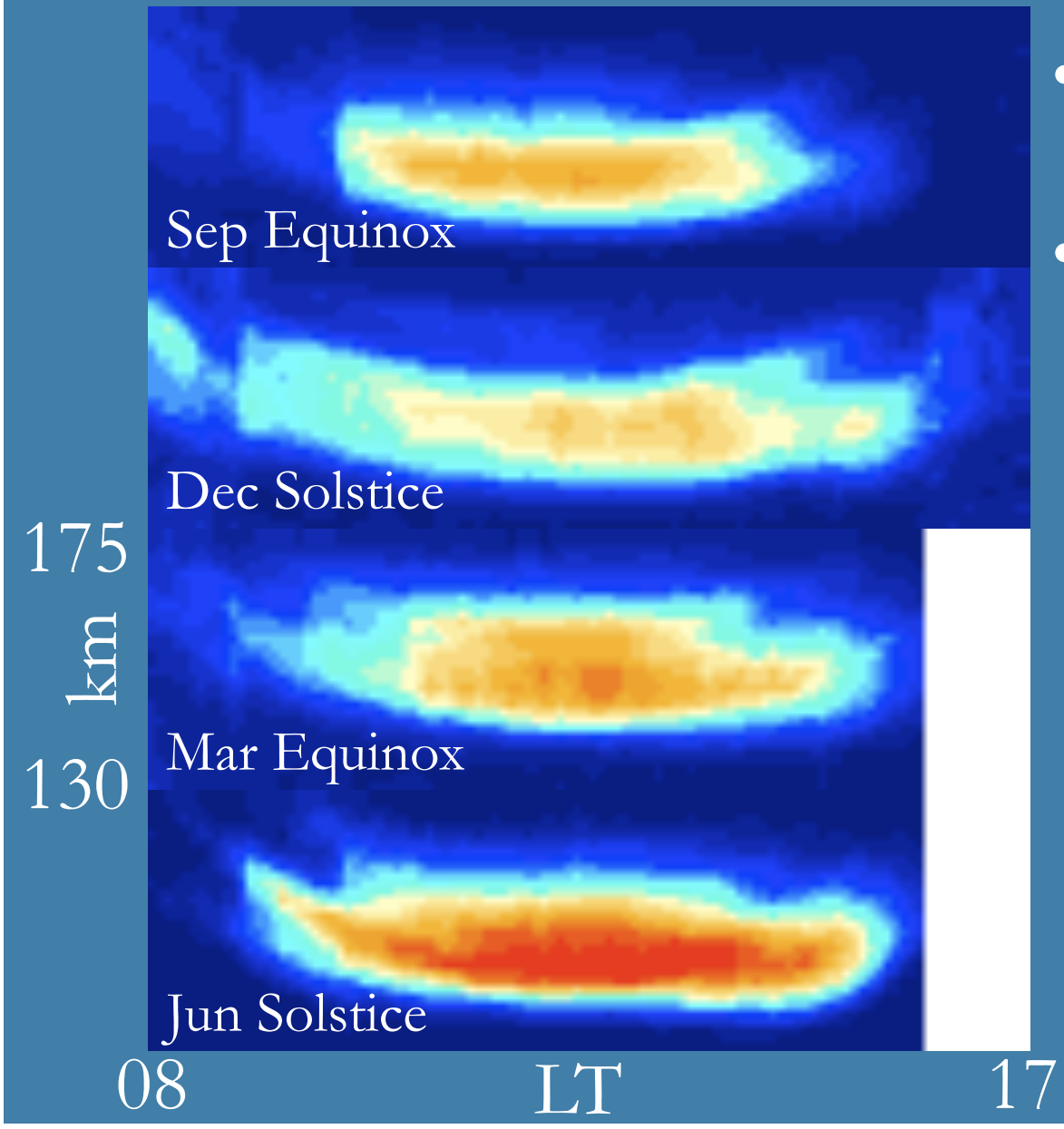
•Observed at different longitudes and within "few" degrees away Mag. Equator

•At Jicamarca they are observed all seasons

•Vz ~ vertical F-region ExB.

[from *Kudeki and Fawcett.*, 1993 and *Fawcett*, 1999]

150-km Perp: Statistical Occurrence 2001-2005



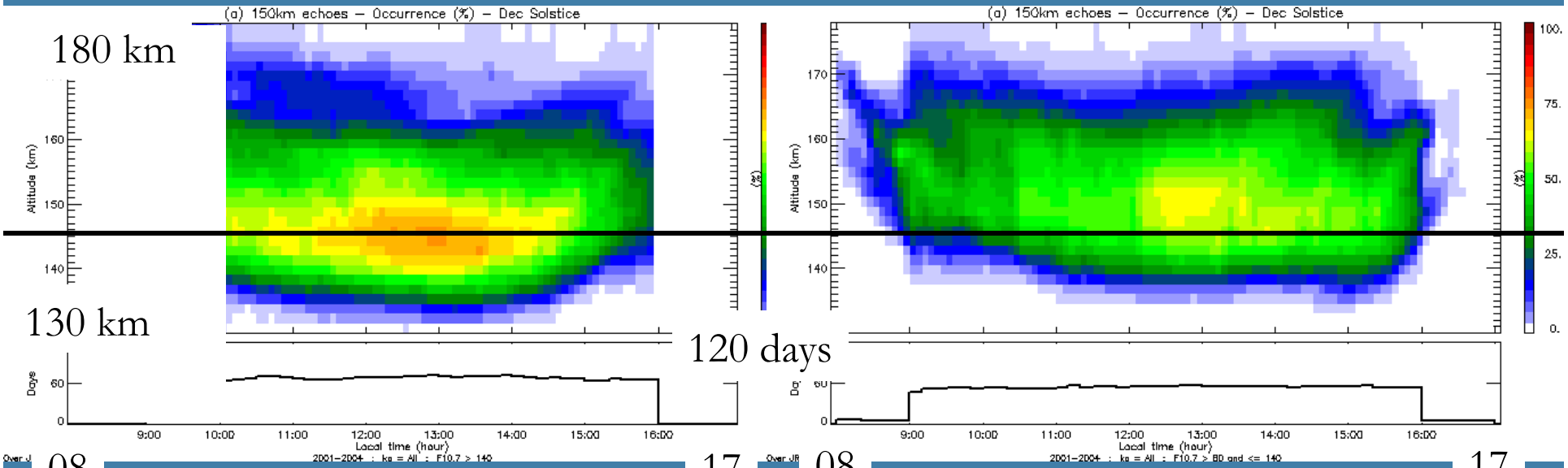
- Echoes are observed during all seasons.
- Seasonal differences on:
  - Layering
  - Altitude of occurrence
  - Intensity of the echoes

[from *Chau and Kudeki*, 2006]

150-km echoes - Statistics: 2001-2004 December Solstice

F10.7 > 140

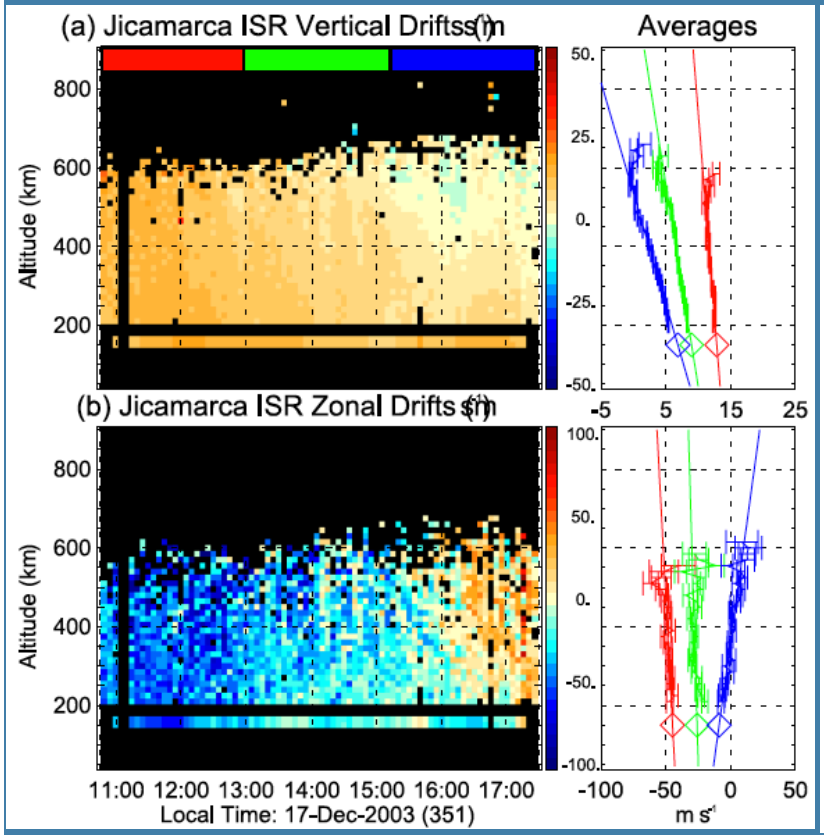
80 < F10.7 <= 140

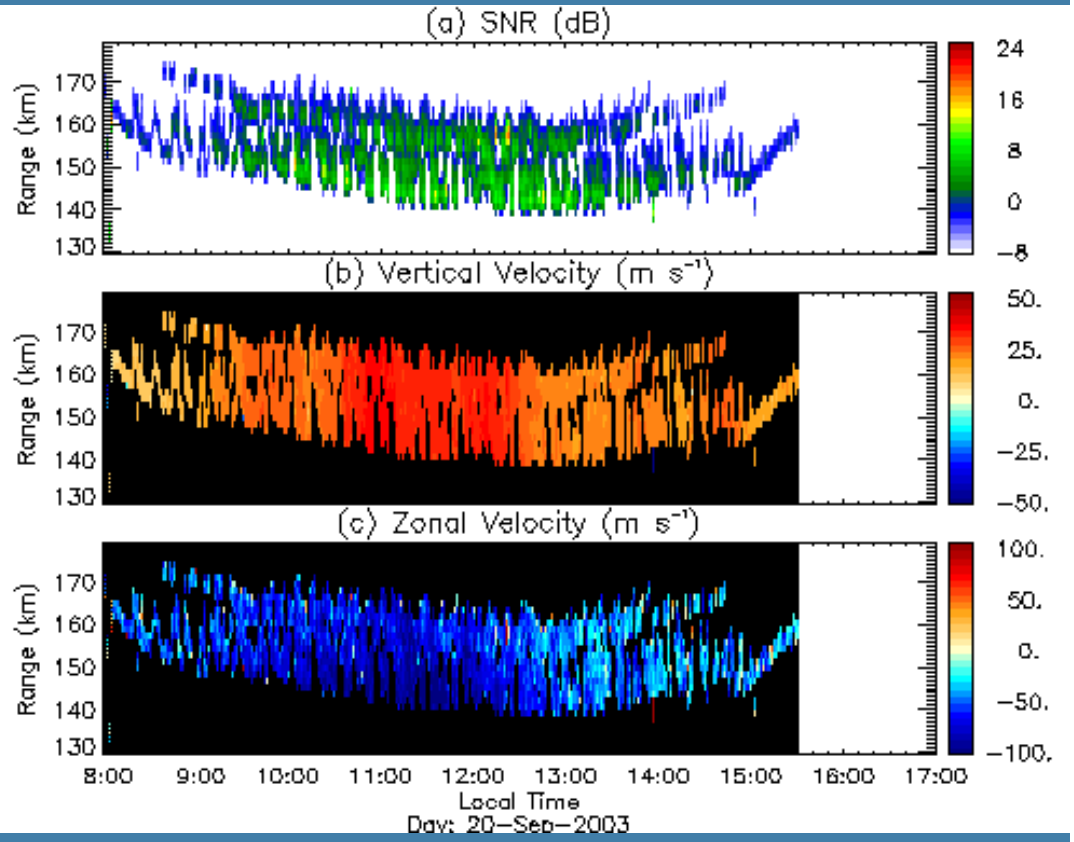


High solar conditions
- Lower altitudes
- More frequent
- Less layering

[from *Chau and Kudeki*, 2006]

ISR Drifts vs 150-km drifts

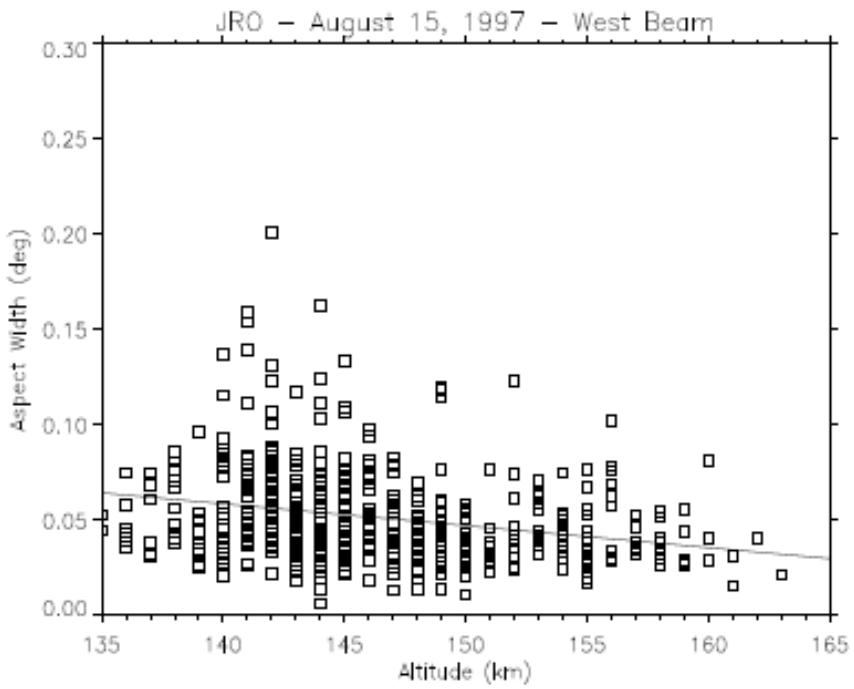


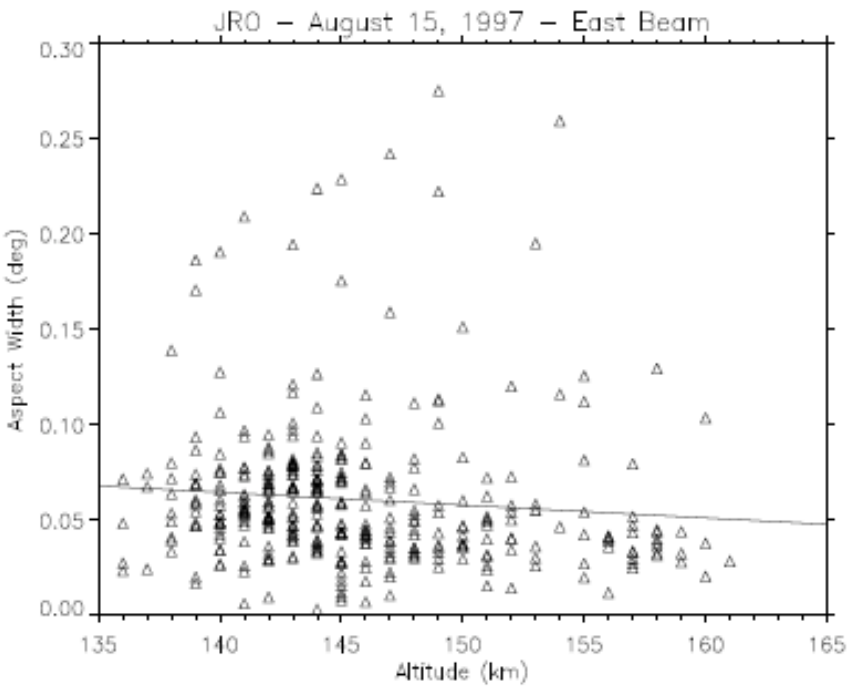


$$V_x \approx -(\Sigma_H/\Sigma_P)V_z + \int (\sigma_P * U_n ds)/\Sigma_P$$

[from *Chau and Woodman*, 2004]

150-km Aspect Sensitivity



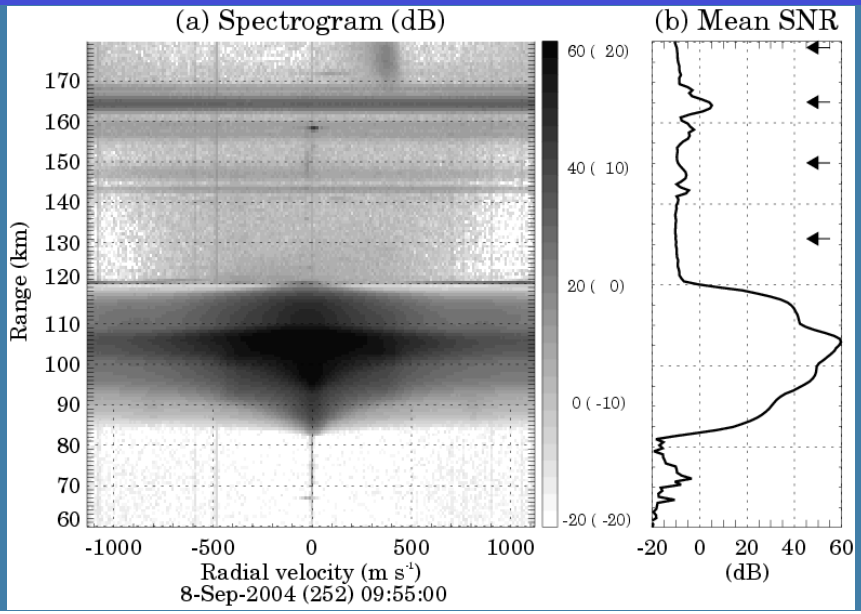


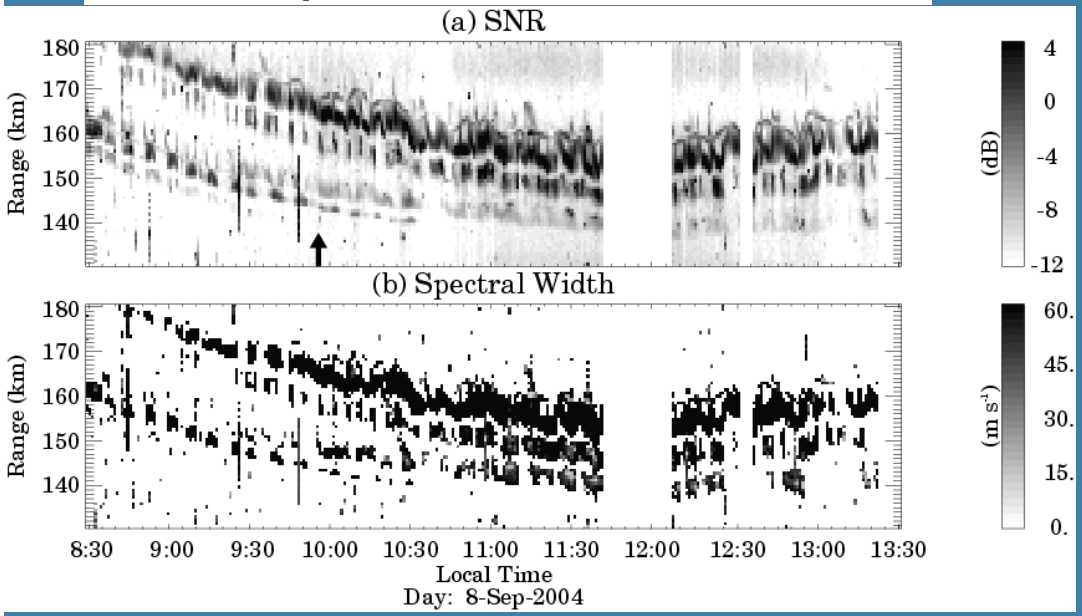
"We conclude that aspect widths of the 150-km echoes are smaller than those of the electrojet and that the central tendency of 0.05° presented above can be considered an upper bound of the aspect width of the 150-km echoes."

[from *Fawcett*, 1999, Ph.D. Thesis]

Off-Perpendicular 150-km Echoes

Off-perpendicular to B 150-km echoes

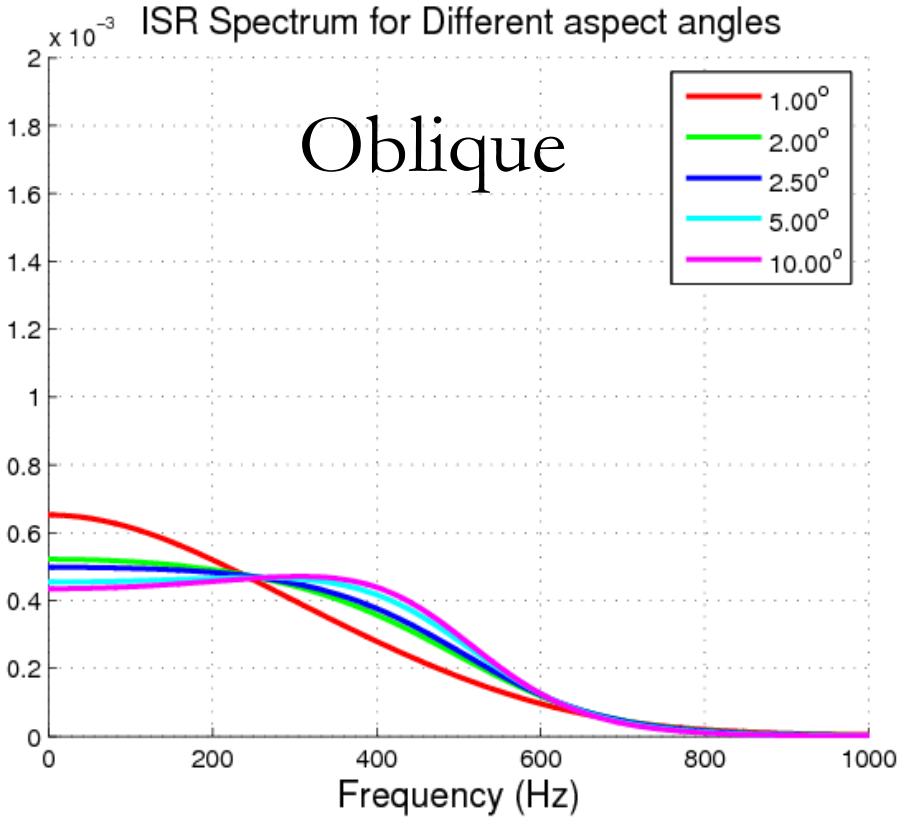


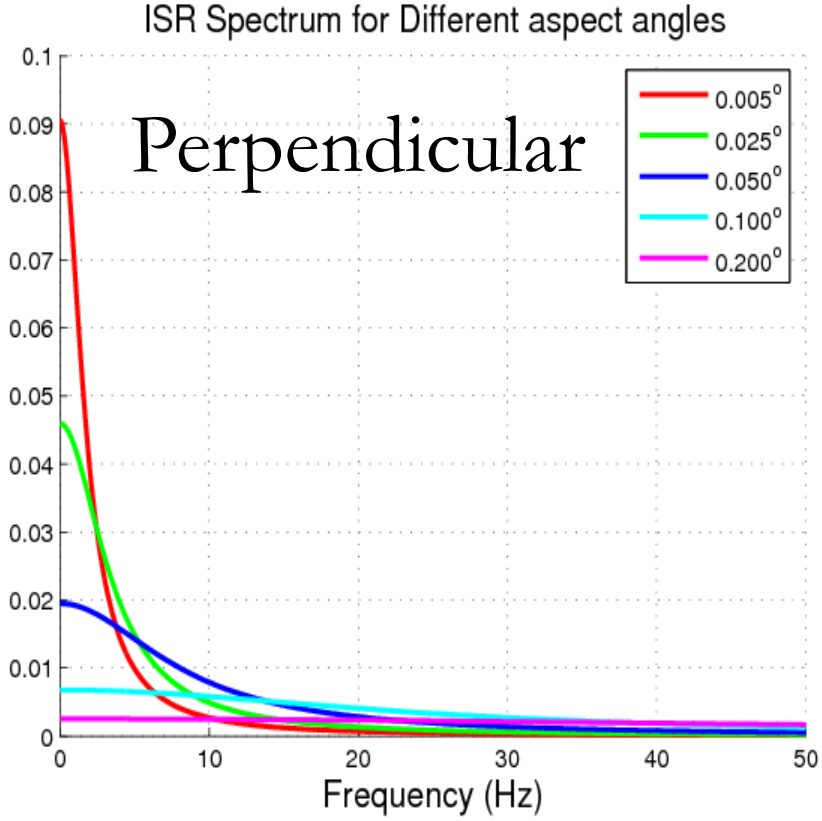


- Surprisingly, 150-km echoes are also observed at few degrees away from perpendicular to B (~1.8°) ("Oblique").
- Oblique echoes present similar altitude-time dependence to Perpendicular observations.
- Oblique 150-km echoes present unexpected wide spectra (spectra widths > 1000 m/s).
- Questions:
  - What is the actual spectrum shape?
  - What is the angular brightness of these irregularities?
  - Are these echoes due to density enhancements?

[from *Chau*, 2004]

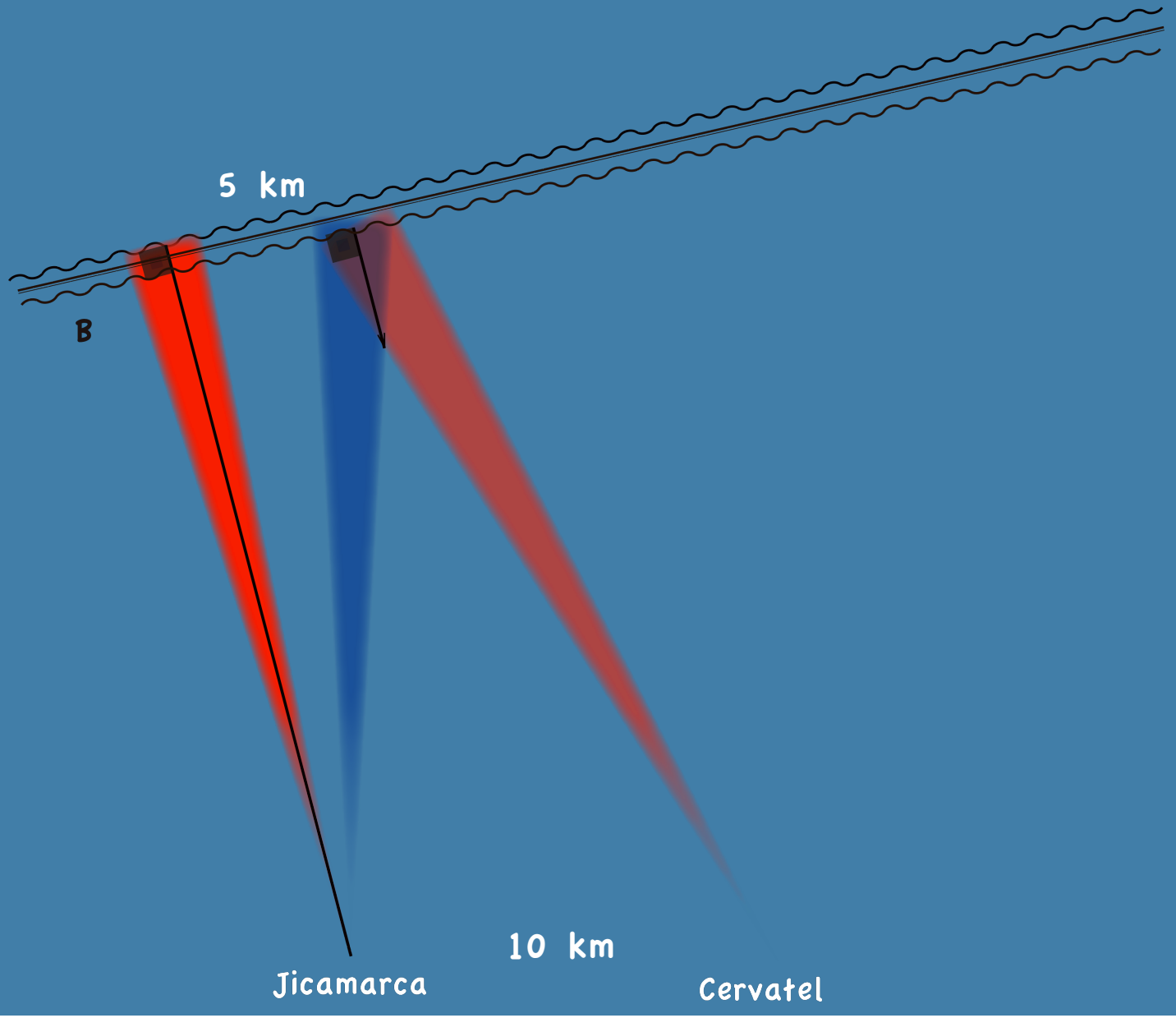
Incoherent Scatter Spectra



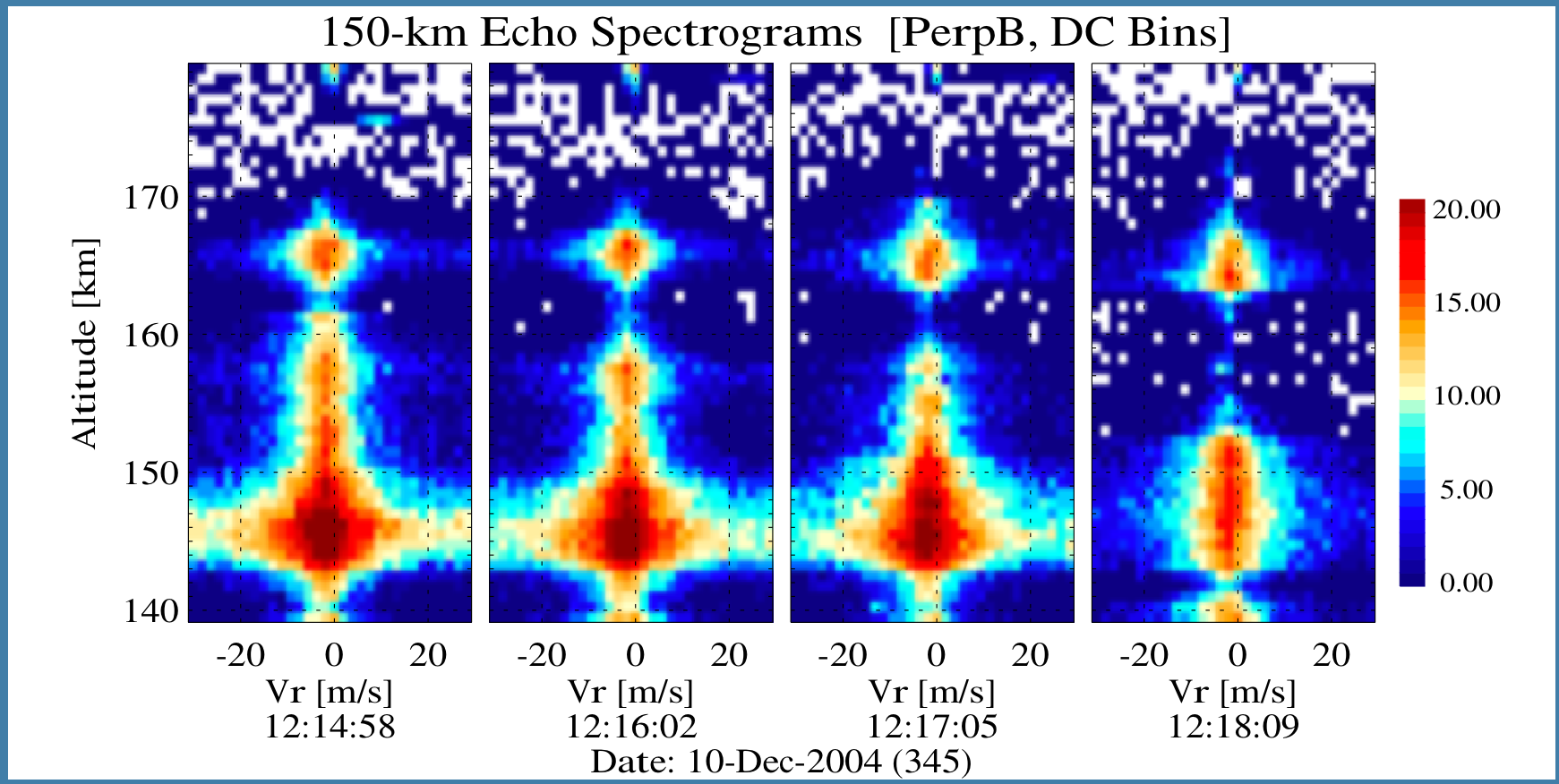


- Spectra are wide (>1000 m/s or 300 Hz at 50 MHz) and independent of α within typical antenna beam widths.
- Spectra get narrower (less than 150 m/s) for smaller α and change very quickly.
- Measured spectra results from a convolution of spectra with different widths due to finite antenna beam width.

150-km Experiments: Oblique vs. Perpendicular

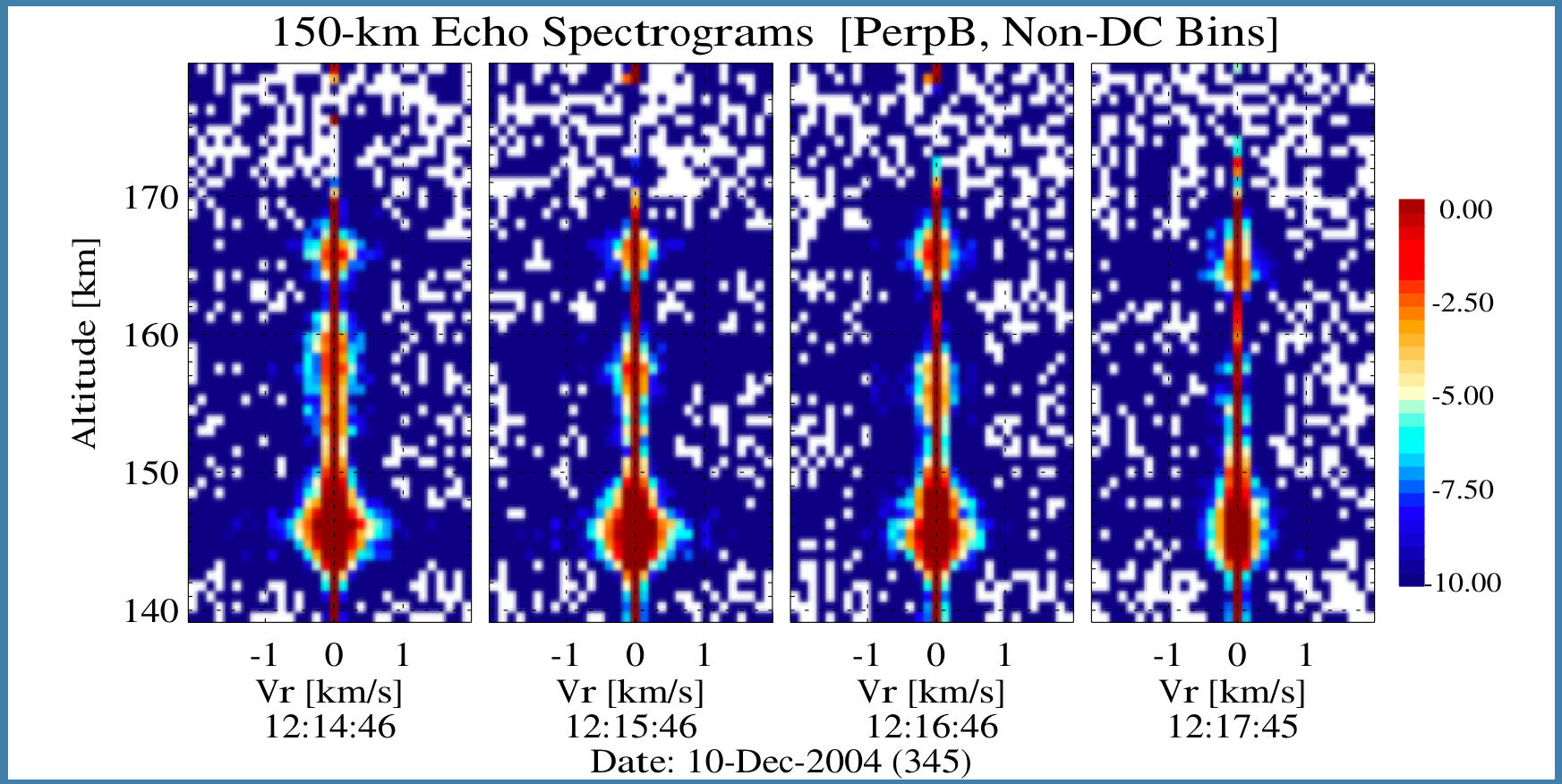


Perpendicular Spectrograms after coherent integrations



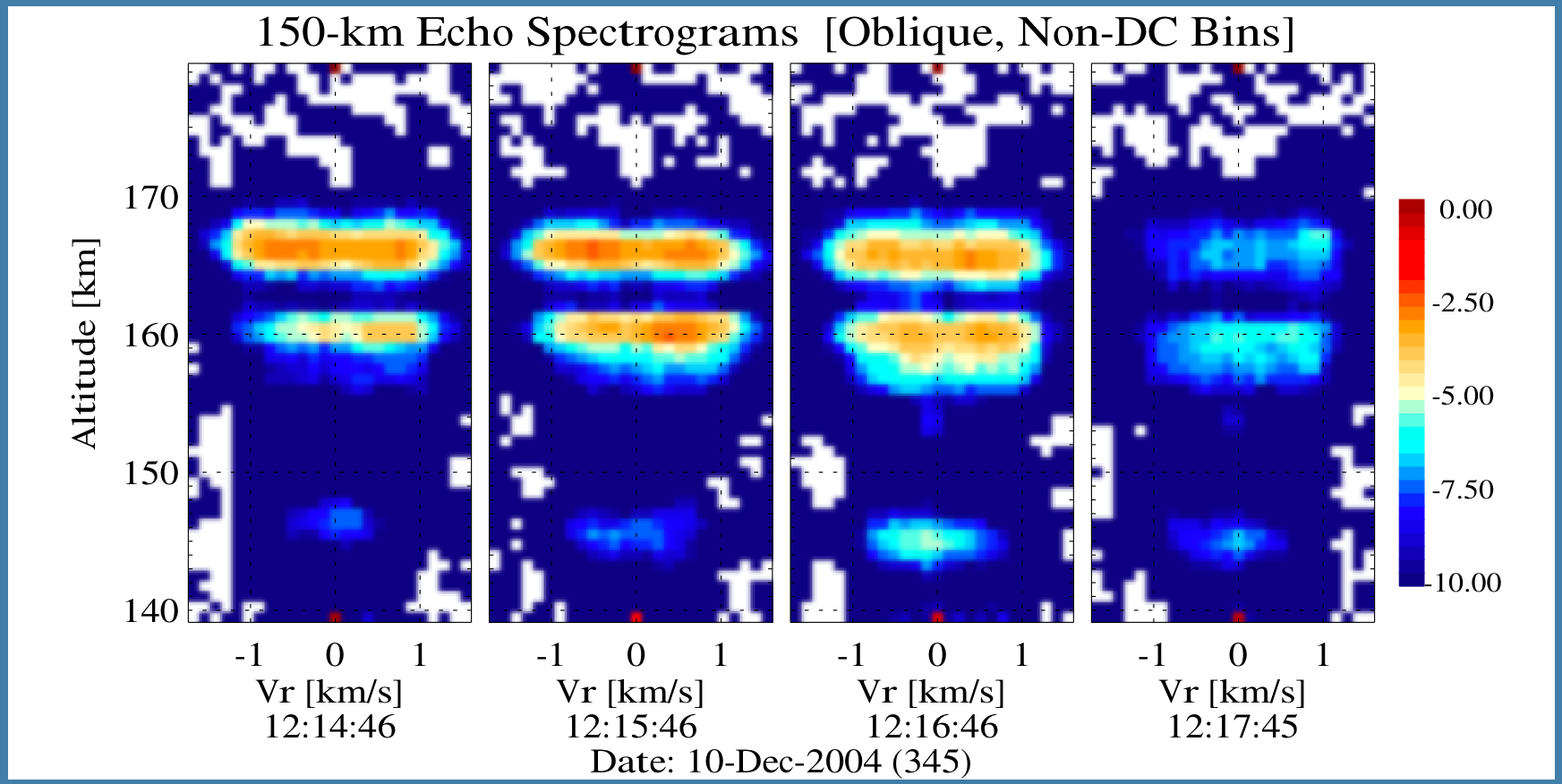
[from *Chau et al.*, 2009]

Perpendicular Spectrograms without coherent integrations



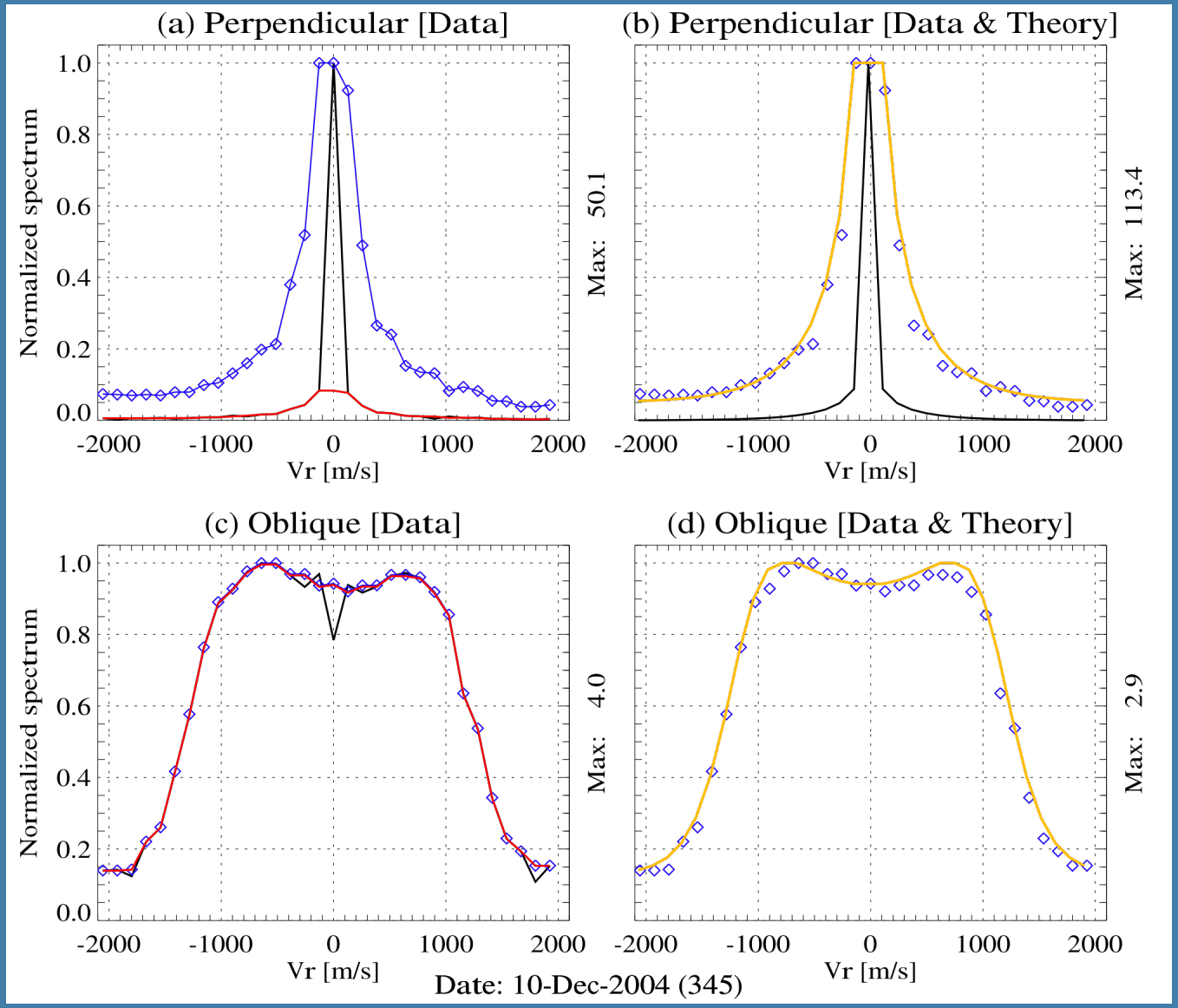
[from *Chau et al.*, 2009]

Oblique spectrogram



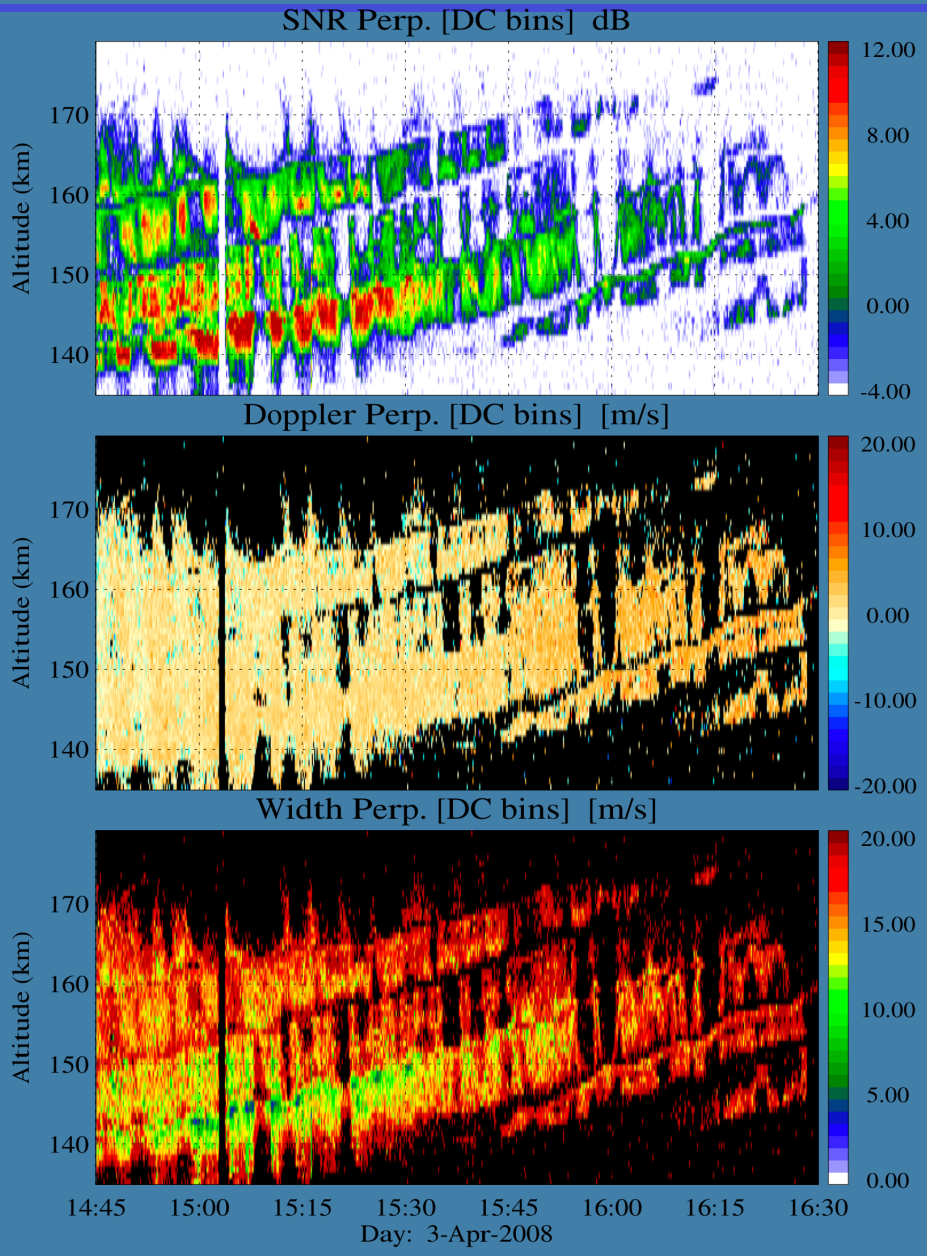
[from *Chau et al.*, 2009]

150-km Spectra: Oblique vs. Perpendicular



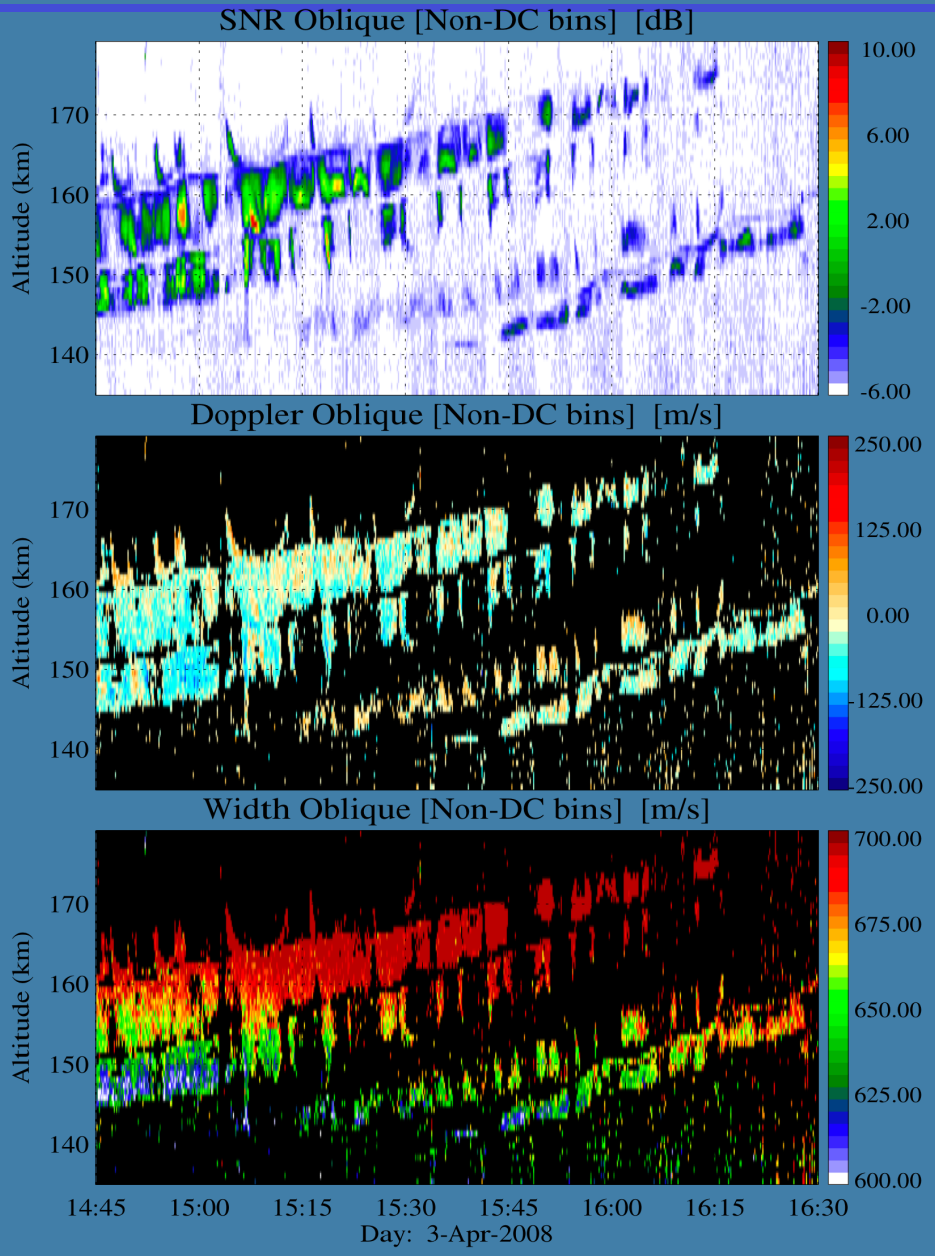
[from *Chau et al.*, 2009]

150-km Perpendicular Parameters



[from *Chau et al.*, 2009]

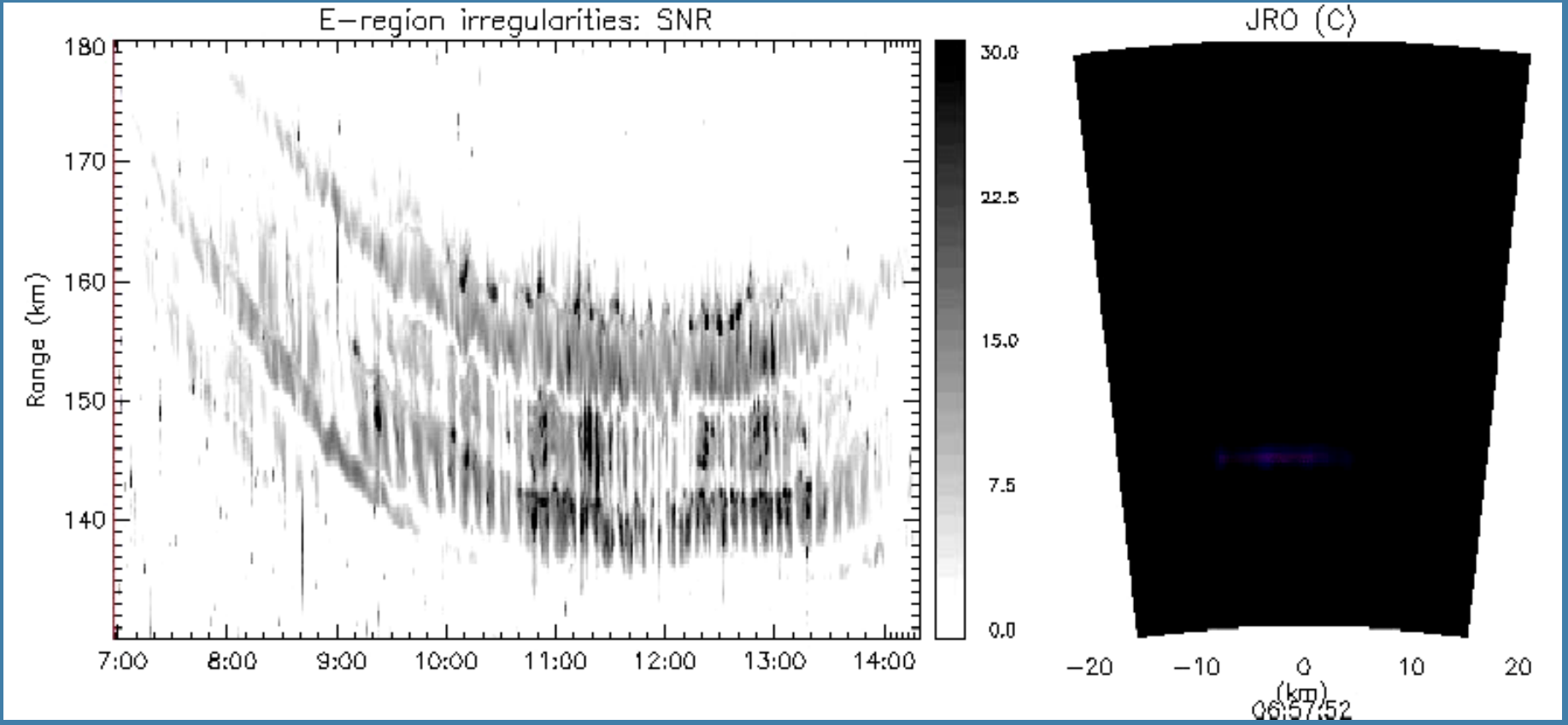
150-km Oblique Parameters



[from *Chau et al.*, 2009]

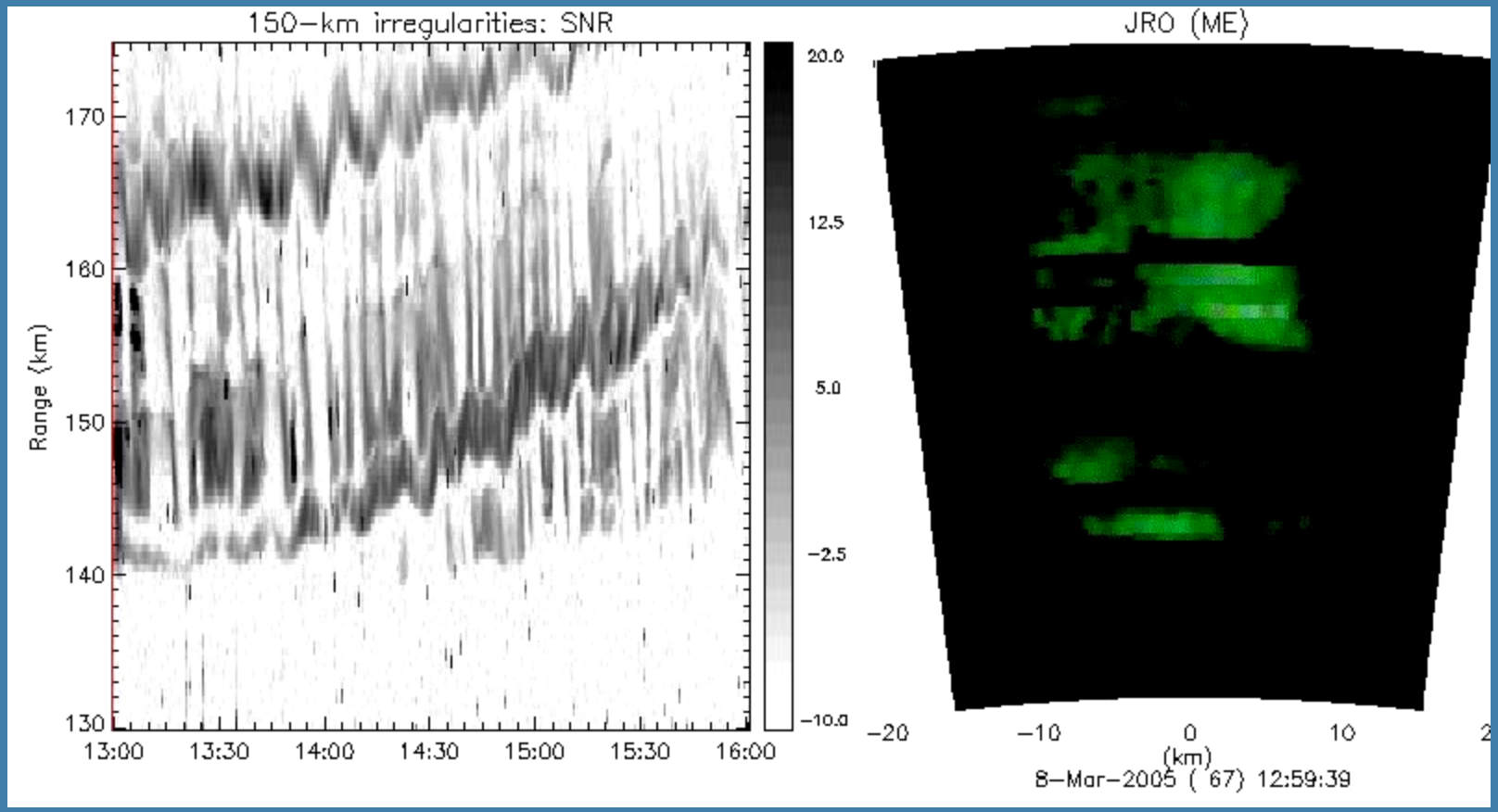
Unpublished and New Observations

150-km echoes – EW Structure (1): NS Modulation?



- Significant temporal as well as vertical structure is observed. However, very little EW structure is observed using 20s integrations.
- Echoes disappear or appear in the EW, suggesting a modulation in the NS direction in agreement with dual beam observations reported by *Fawcett* [1999].

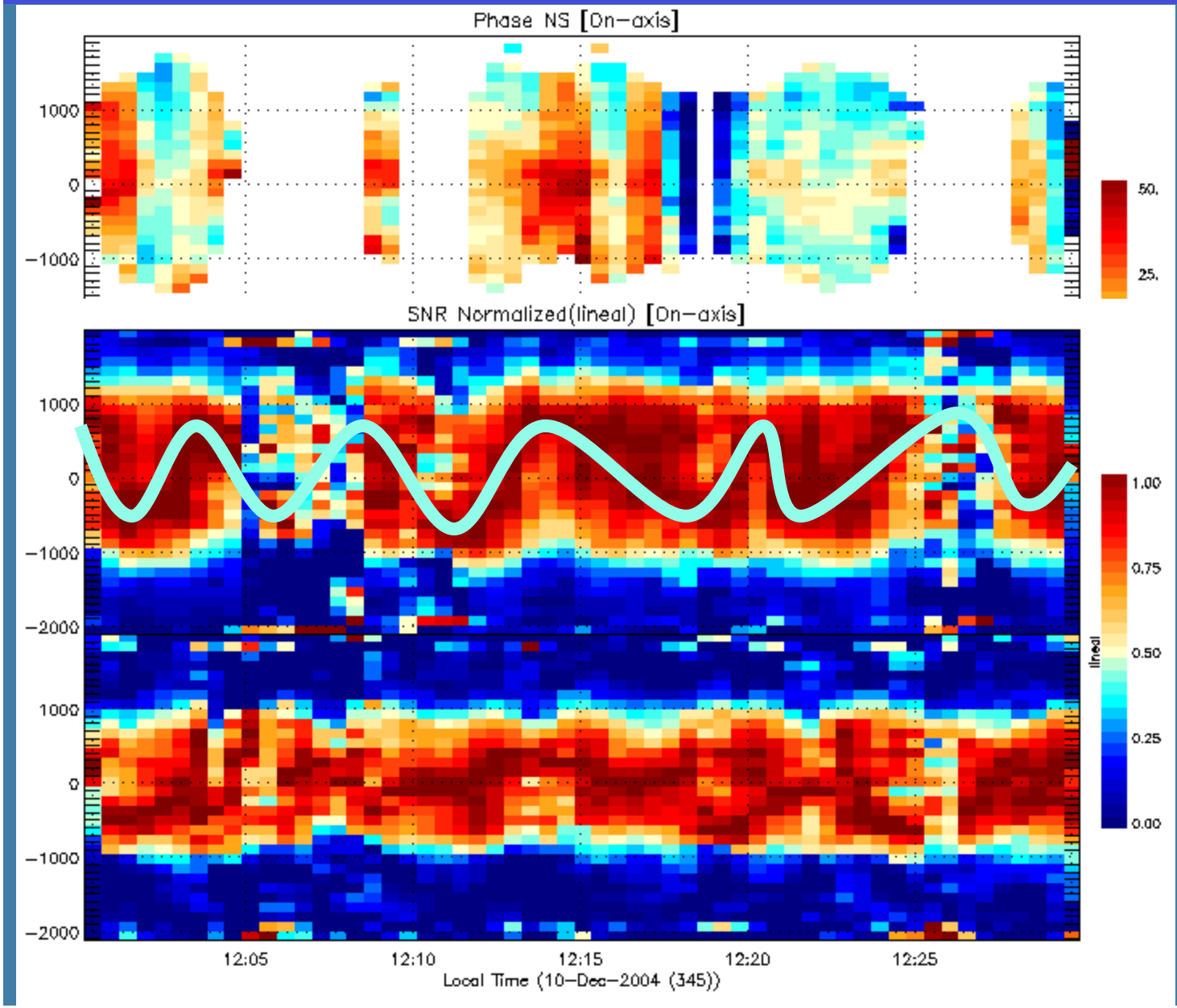
150-km echoes - Imaging: EW Structure on top NS Modulation



- On some occasions, clear EW structure is observed using imaging, again being modulated by larger scale NS structure (pearls in the necklace).
- e.g., note shears and drift reversals around 1440

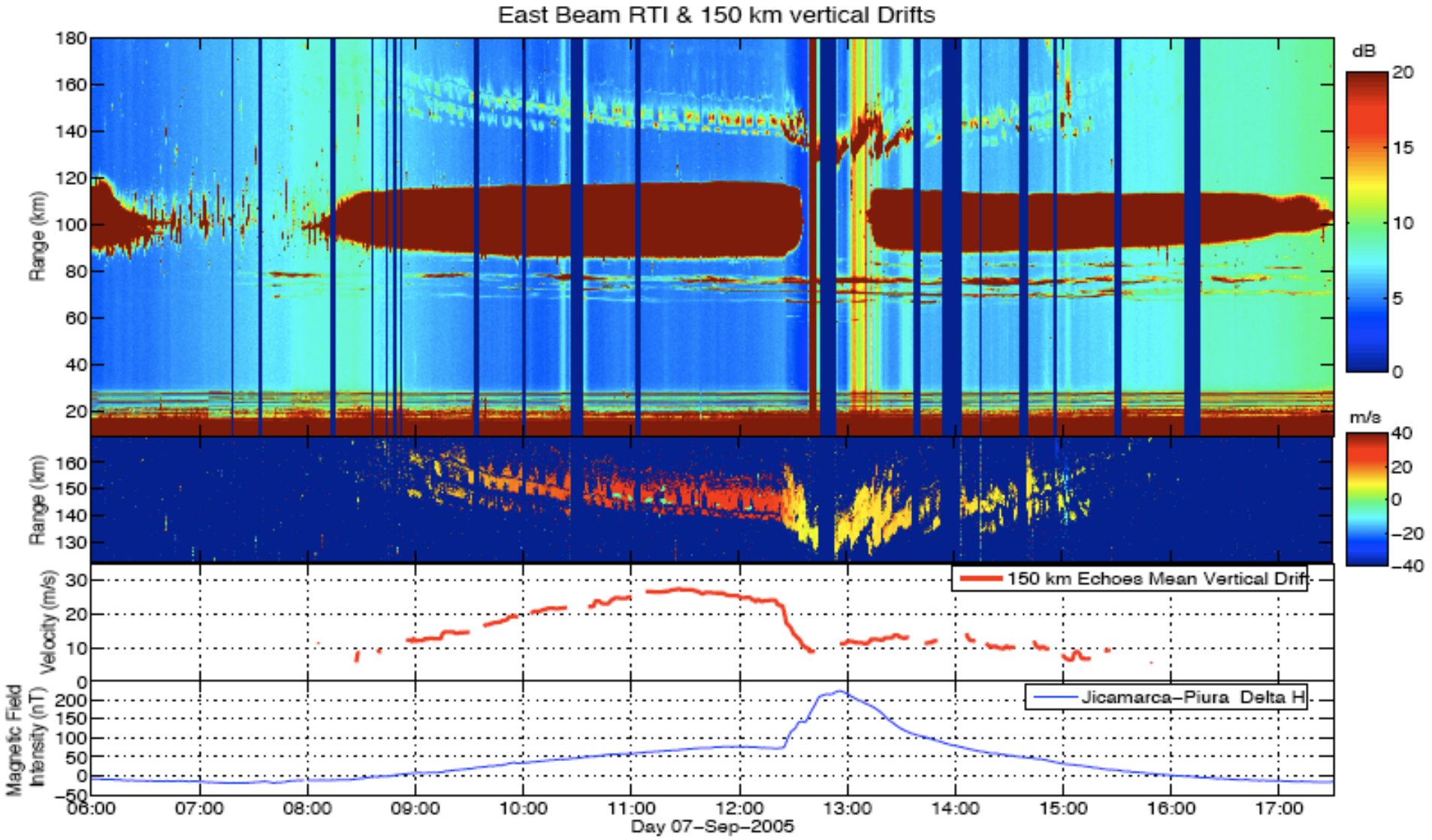
Higher Resolution

Ion-line Spectrum and NS Structure



- Above 150 km: Spectra is wider and with an oscillating peak with a period ~5-10 min.
- Below 150 km: Spectra is narrower, peak is not well defined.
- Spectra structure appear to be associated to changes in location of the scattering center.

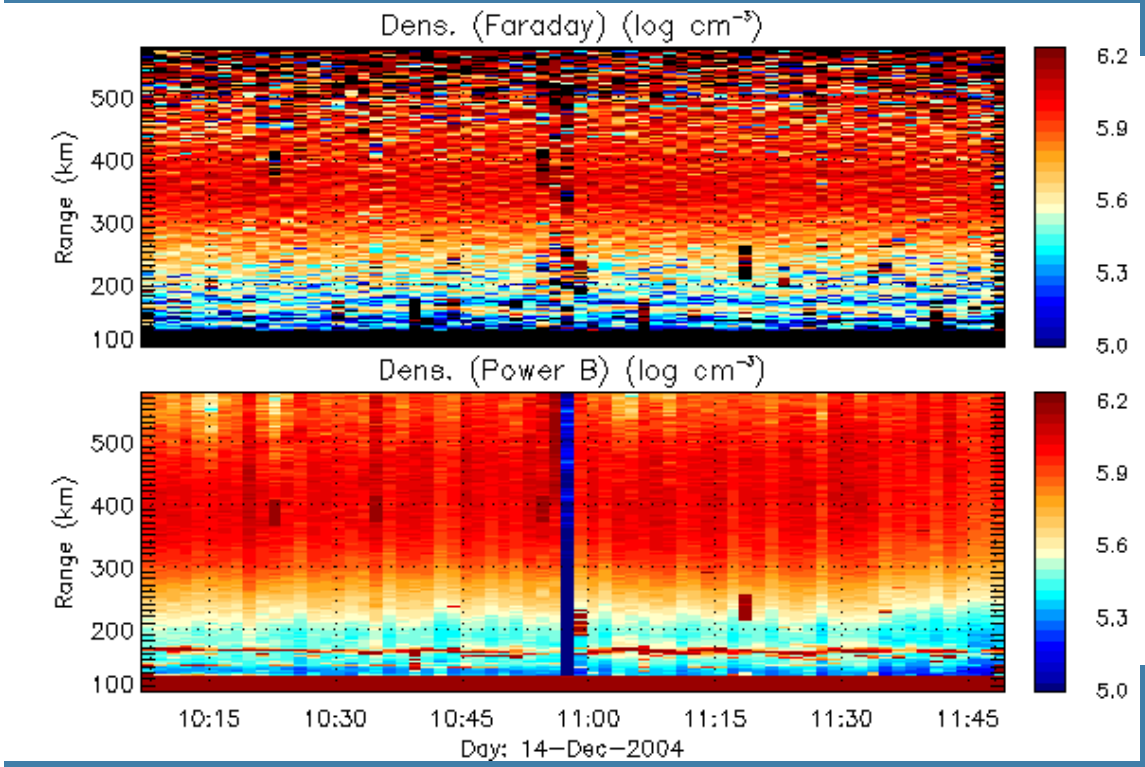
Solar Flare dependence

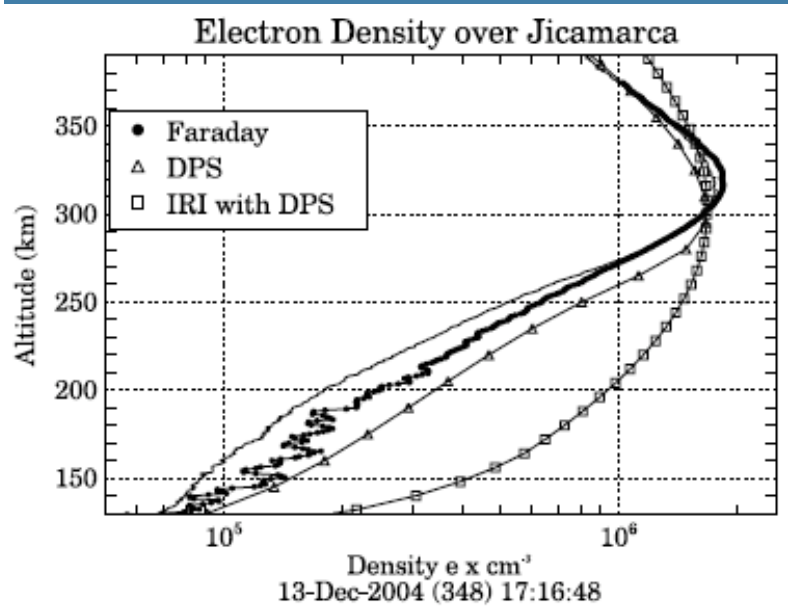


Solar flare 07-Sep-2005

[Courtesy of P. Reyes]

Faraday Density Experiments (1)

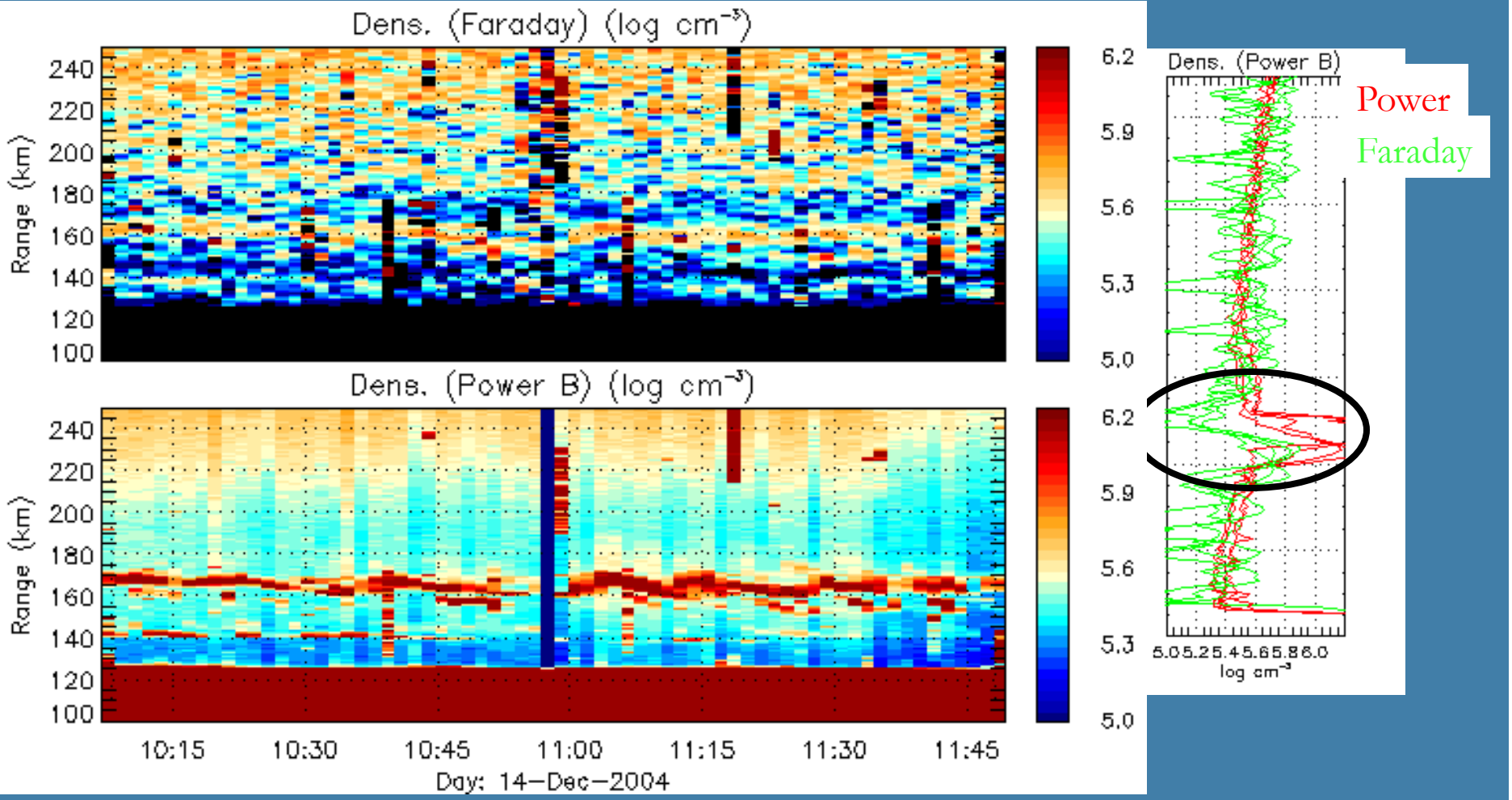




[from *Chau and Woodman.*, 2005]

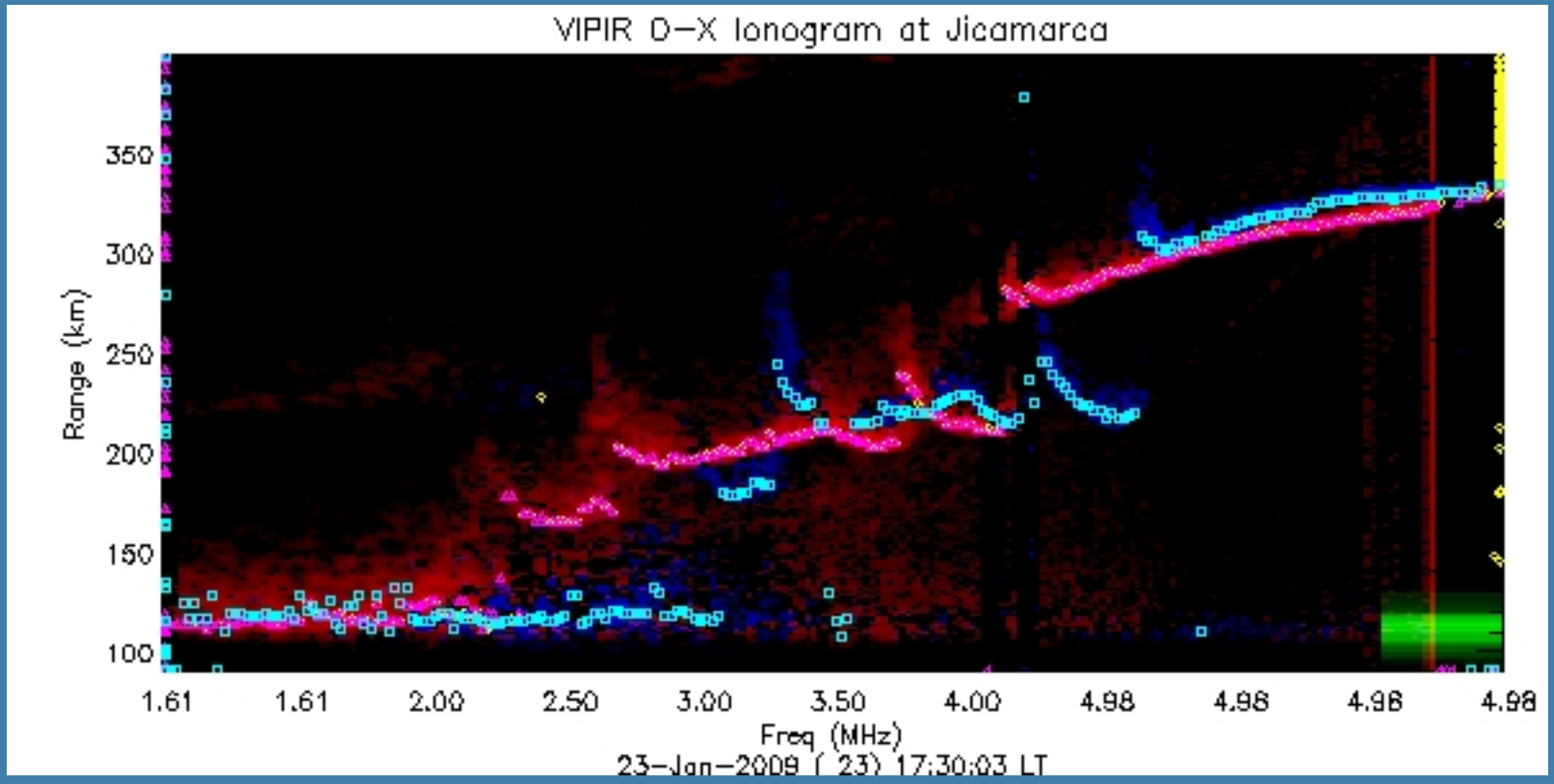
For Incoherent scatter, Power is proportional to N

Faraday density experiments (2)

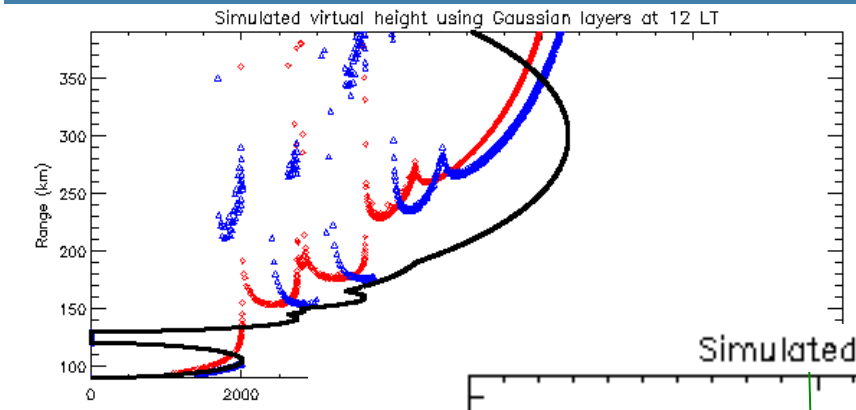


150-km echoes appear to correlate with density depletions/enhancements below or above.

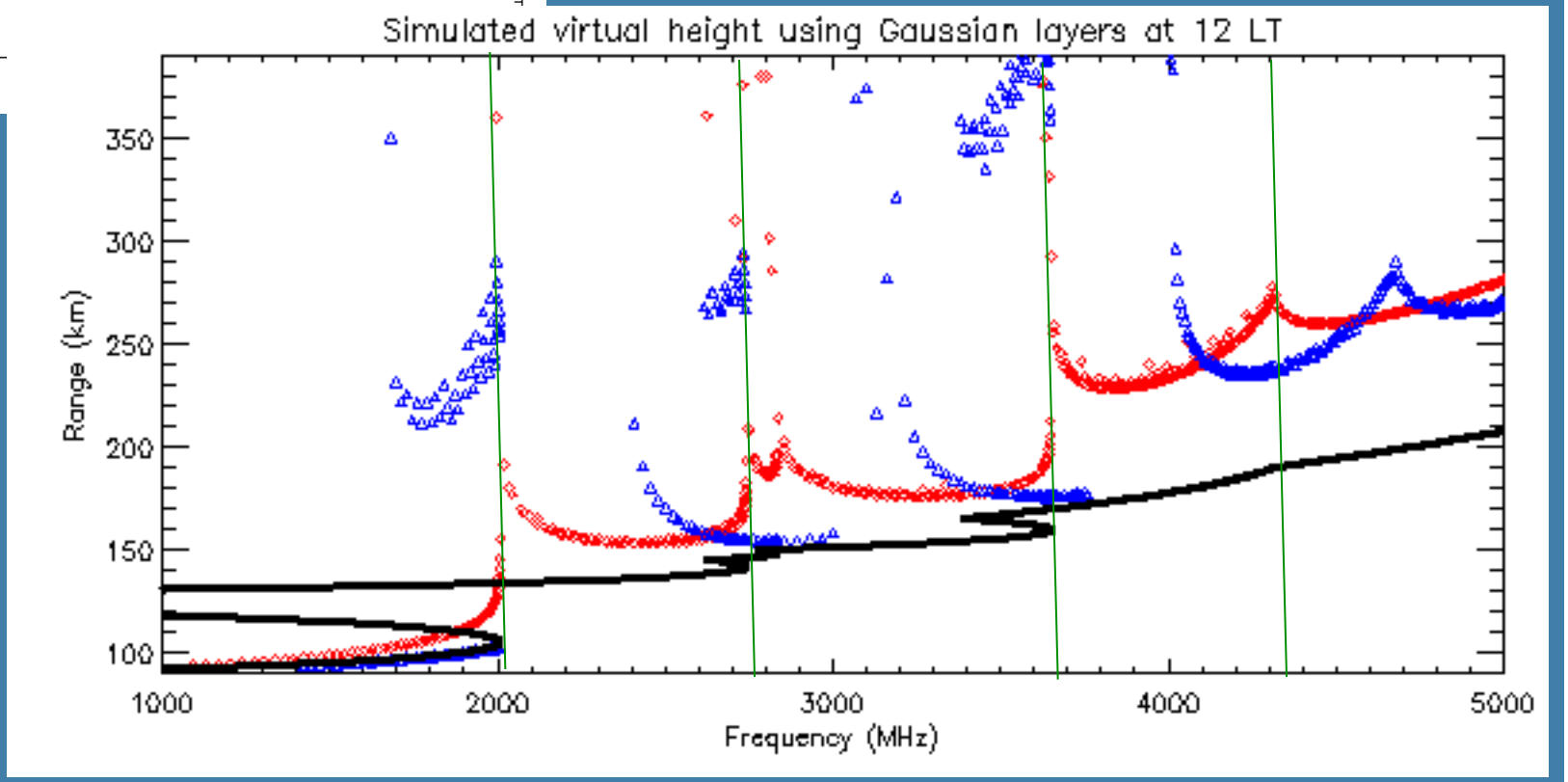
Digital Ionograms (VIPIR)



VIPIR Simulated profiles

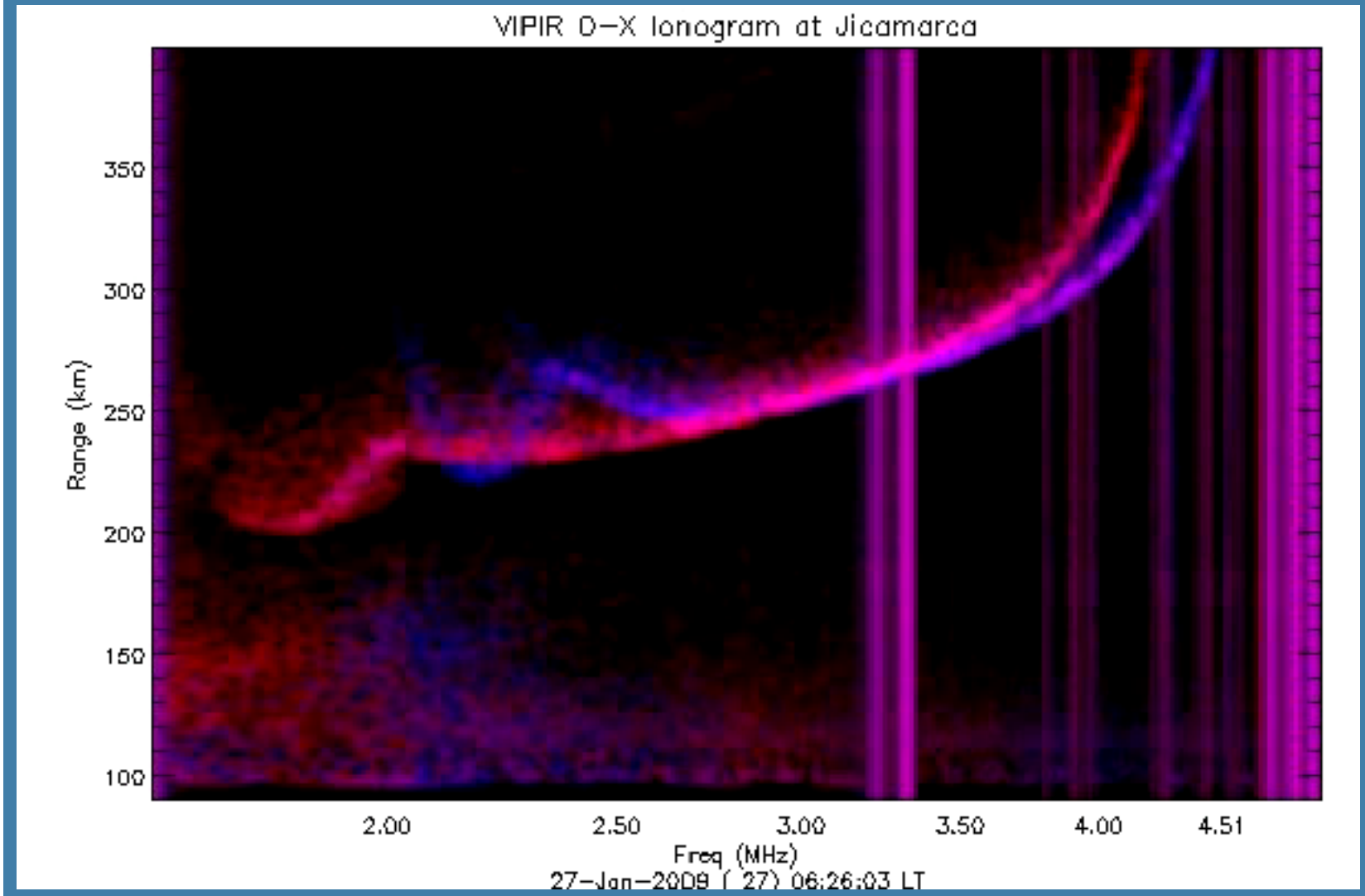


$$f \propto \sqrt{N}$$



140-170 km => virtual heights of 160-210 km

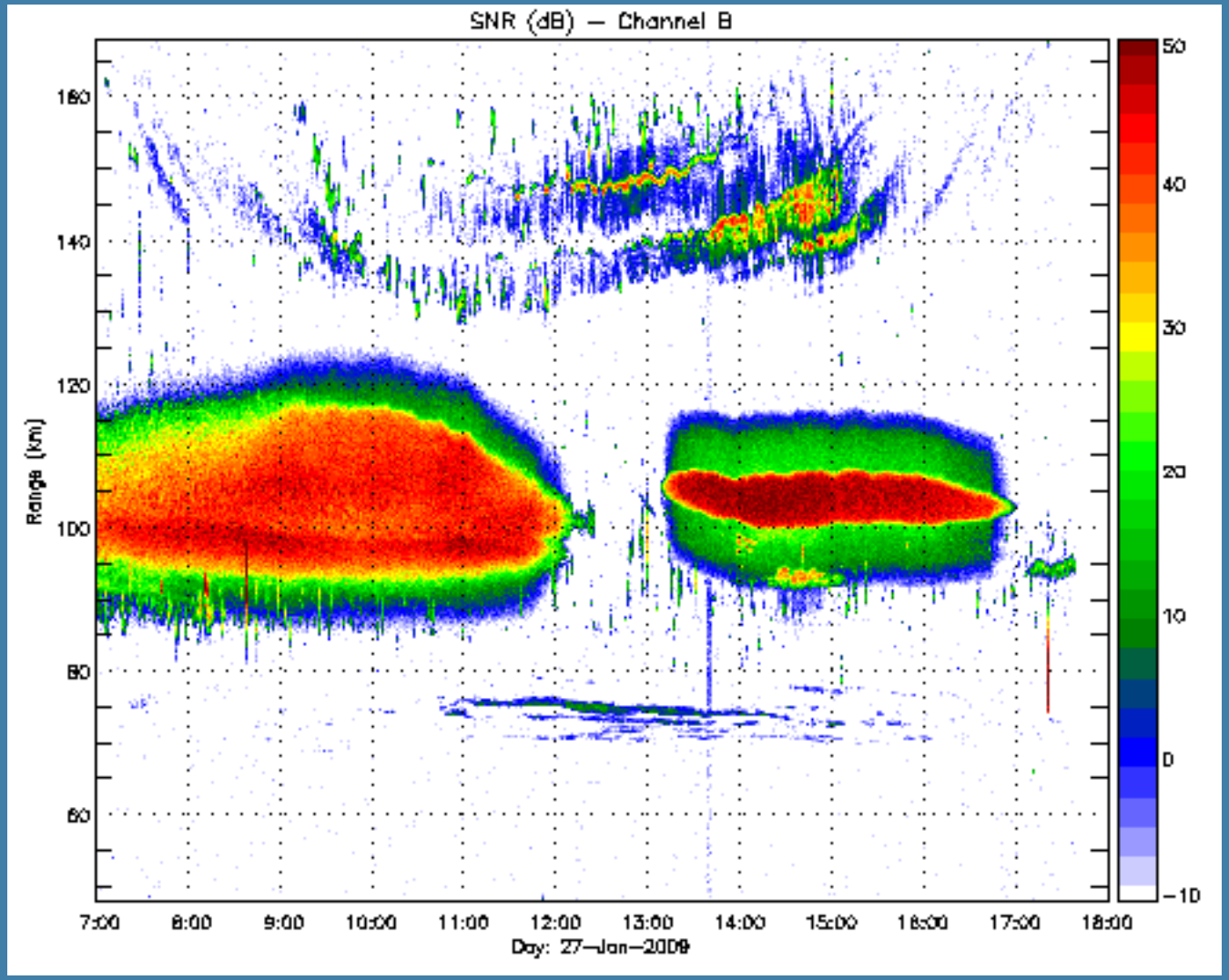
VIPIR Ionograms: Every 2 minutes



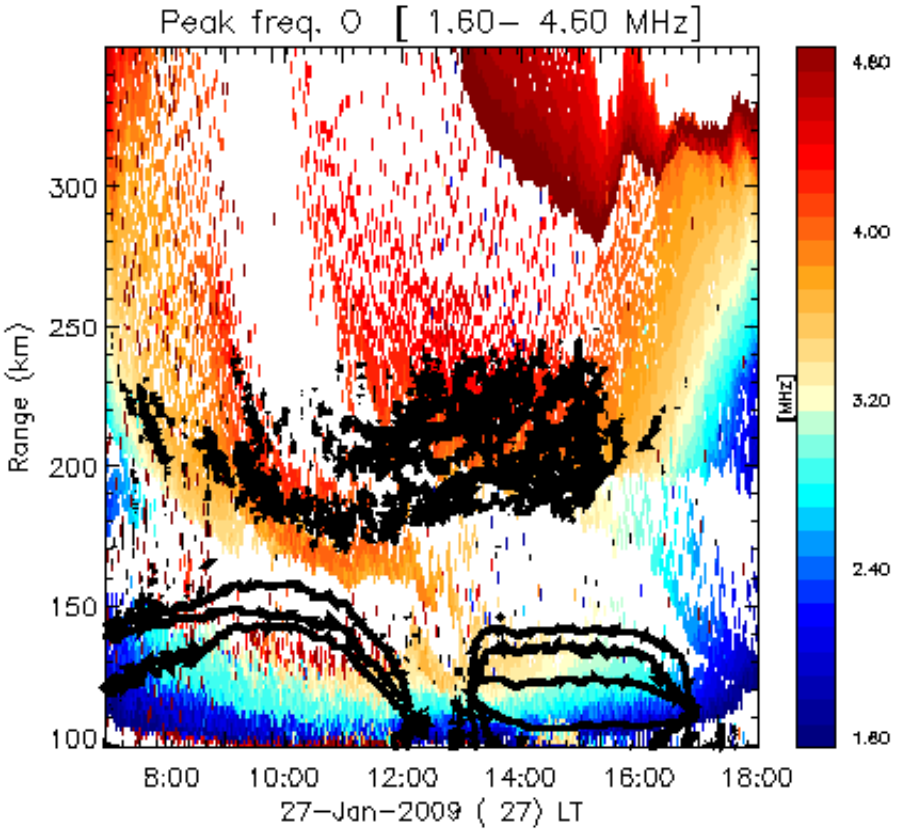
170 km

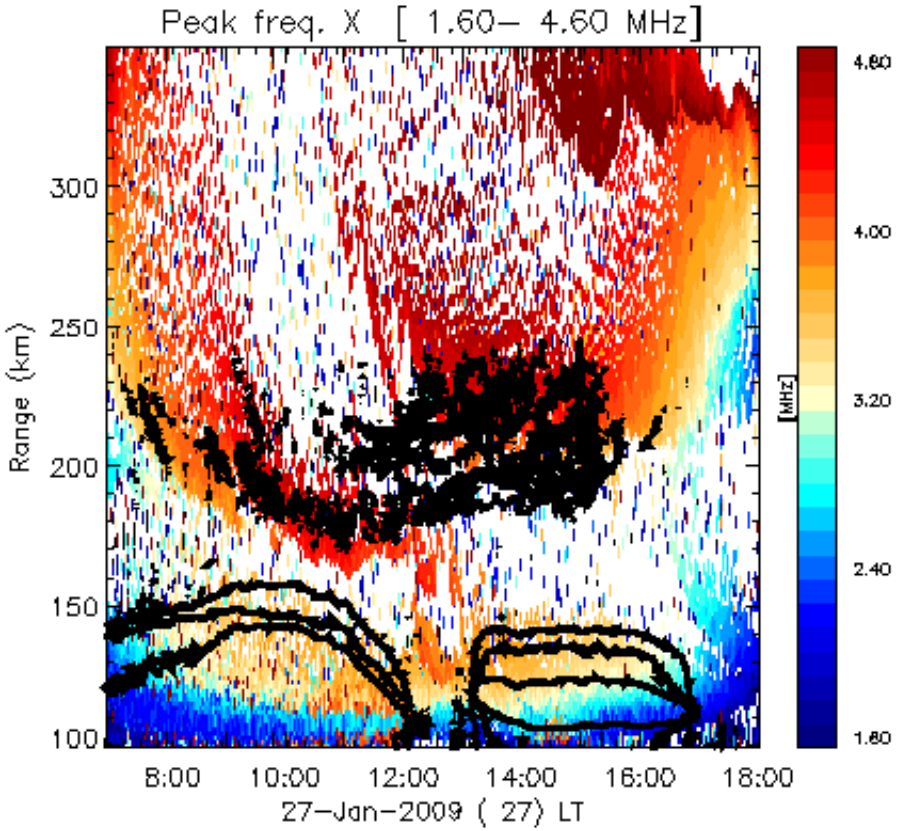
140 km

150-km observations at 50 MHz



Plasma Frequency vs. 150-km irregularities





Equatorial Daytime Valley Region

- In this region occurs the transition between the dominant molecular ions of lower altitudes and F-region dominant atomic oxygen ion.
- Collisions with neutrals start to be less important as the altitude increases.
- Magnetic field lines around 140–170 km are mapped to both the north and south E regions that are located outside the EEJ belt.
- Intermediate layers are known to occur at these altitudes but so far they have not been observed at equatorial regions during the day.
- Large electron to temperature ratios are expected and observed during the day.
- Maximum photoelectron production rate occurs around 150 km.
- Highly-structured electron density profiles (altitude, time, and horizontal?)

Is this a challenge?

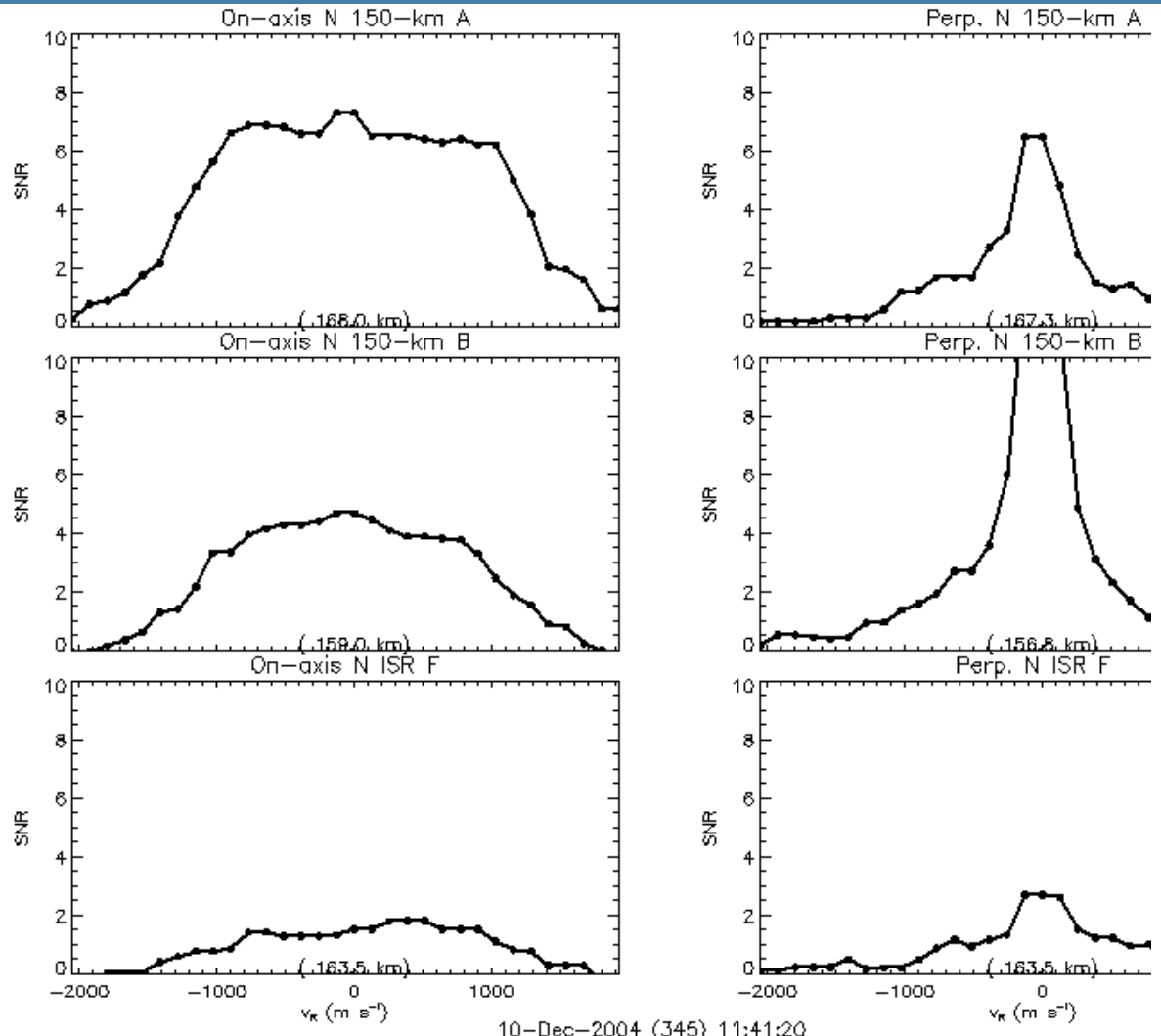
Recent 150-km findings (2)

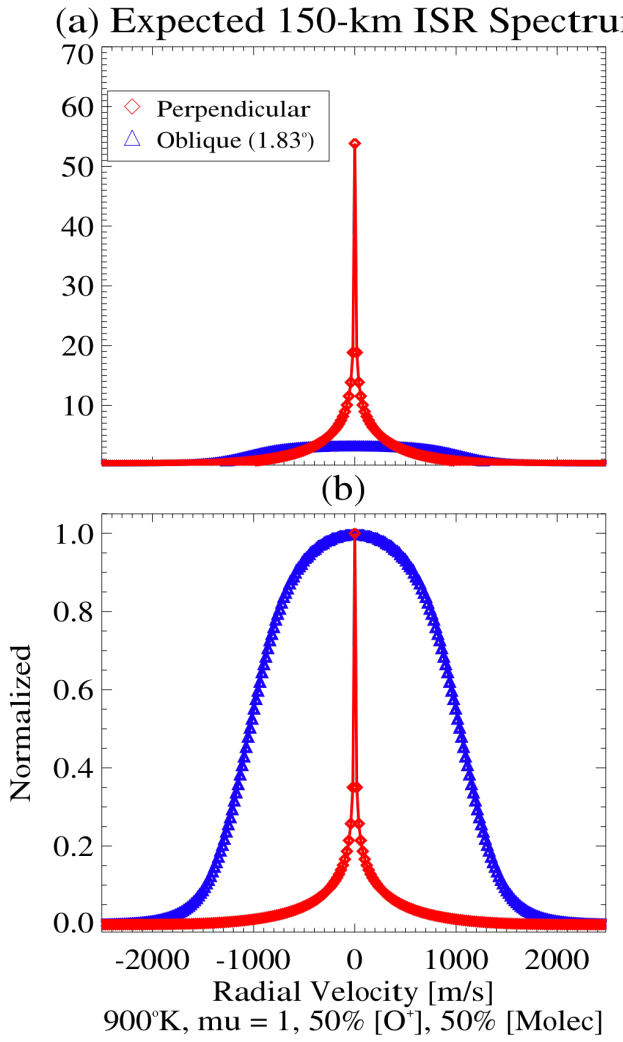
- Density from Faraday measurements
  - Errors are high, but one see deterministic patterns as function of time and altitude that are correlated with the 150-km echoes.
  - 150-km enhanced echoes, although present wide spectra, do not occur on regions of high densities.
  - Enhanced echoes appear to occur on regions of +ve and -ve density gradients (see depleted regions above and below enhanced echoes).

Recent 150-km findings (3)

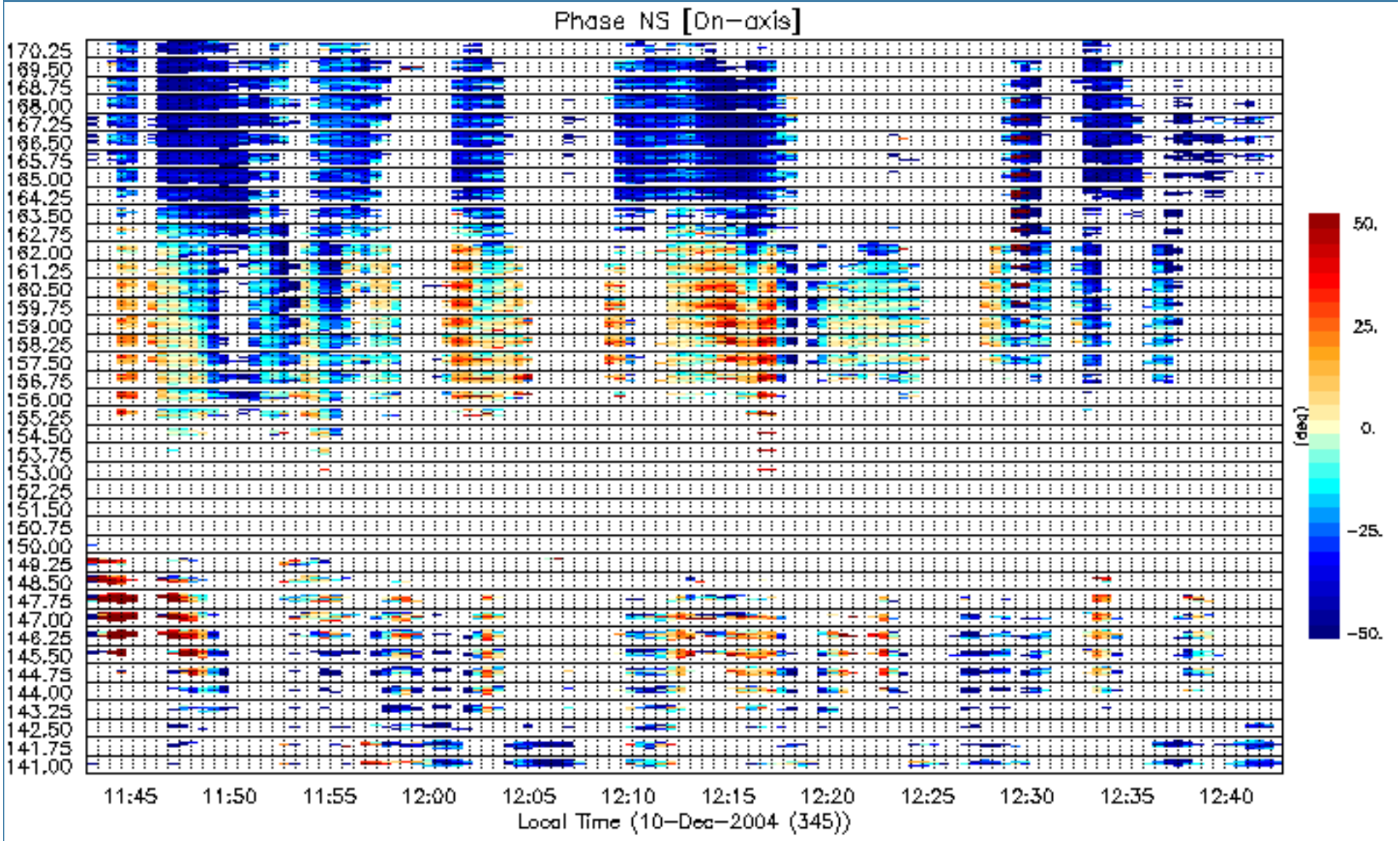
- Interferometry results
  - Scattering centers of "oblique" echoes oscillate both in time (5-10 min) and altitude (5-8 km)
  - Scattering centers from angles "close to perp. to B" echoes also oscillate, but apparently not in phase with the oblique centers, suggesting a meridional modulation.
  - Scattering centers of FAI also oscillates but with smaller amplitudes, they do not coincide with off-perp. echoes.

150-km Spectra: Oblique vs. Perpendicular

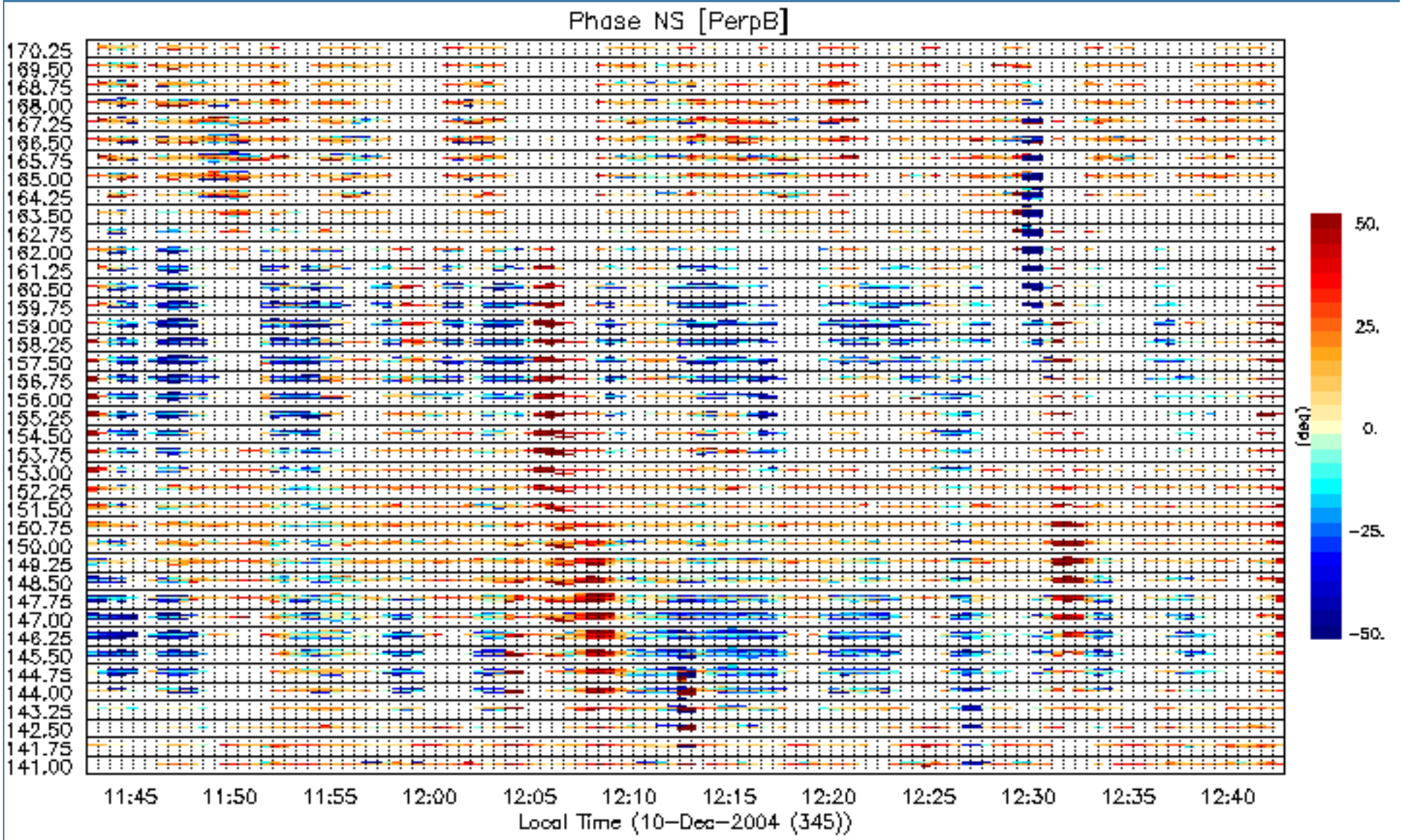




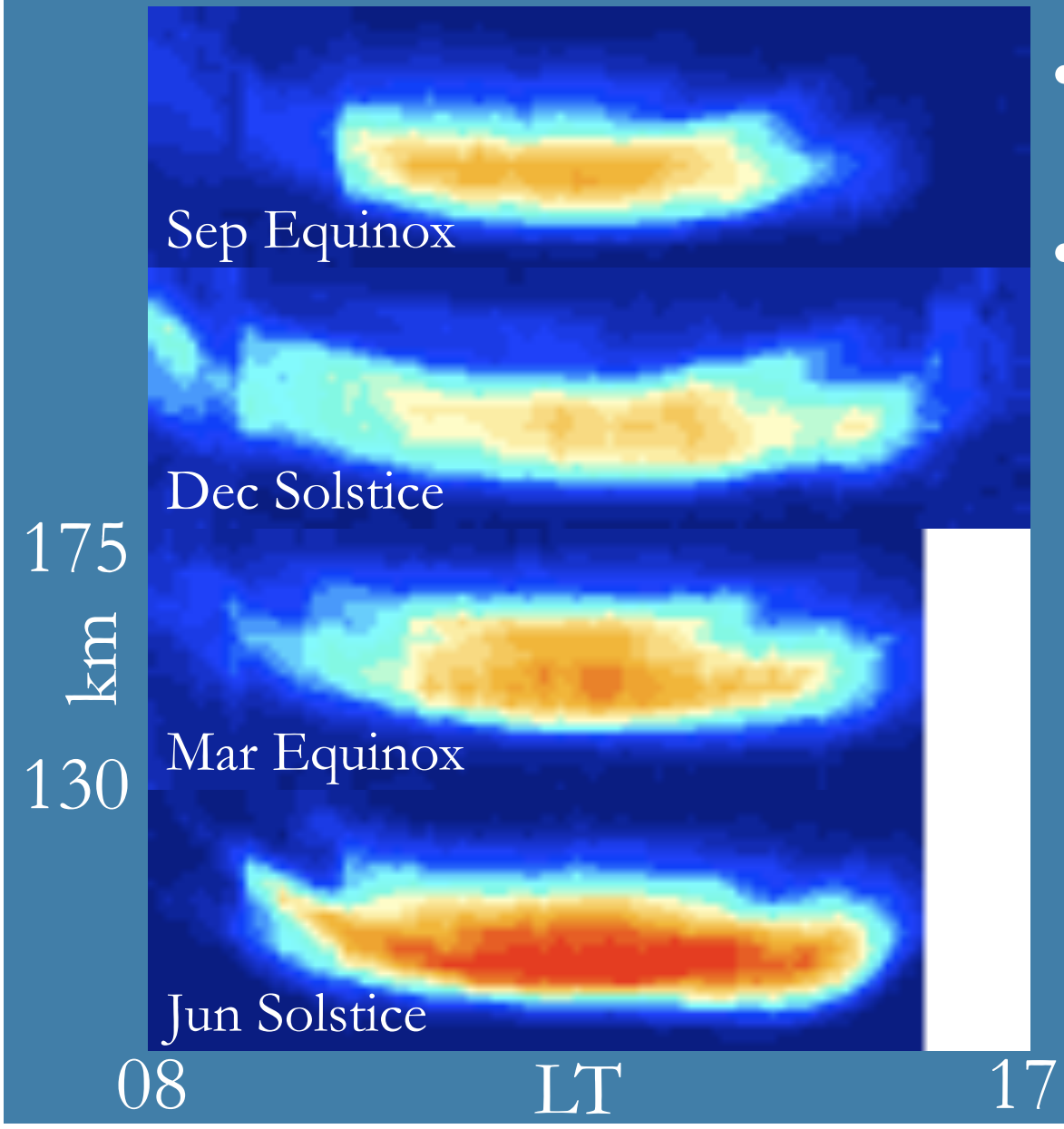
NS Structure: On-axis



NS Structure: Around Perp to B.



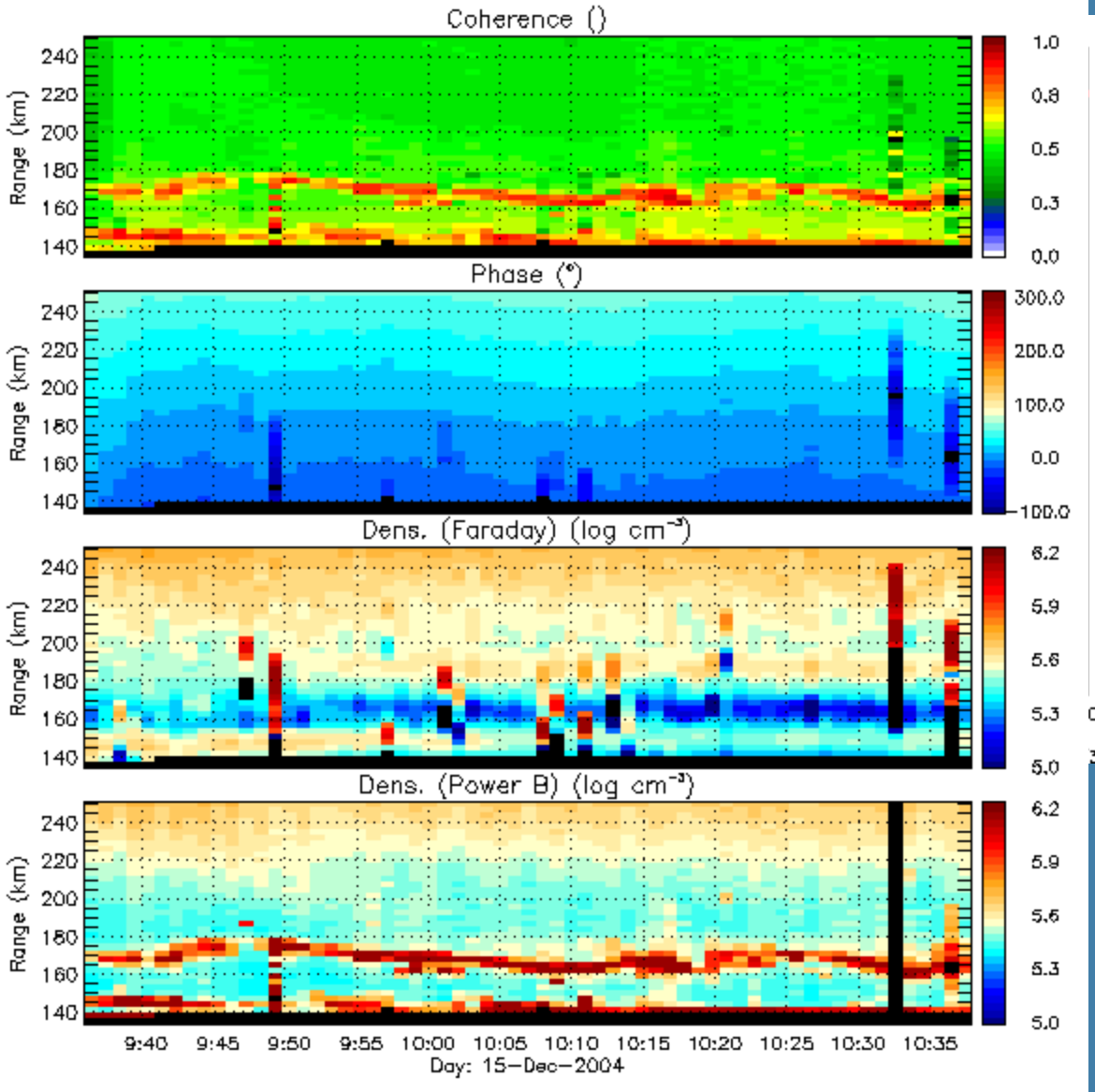
150-km Perp: Statistical Occurrence 2001-2005

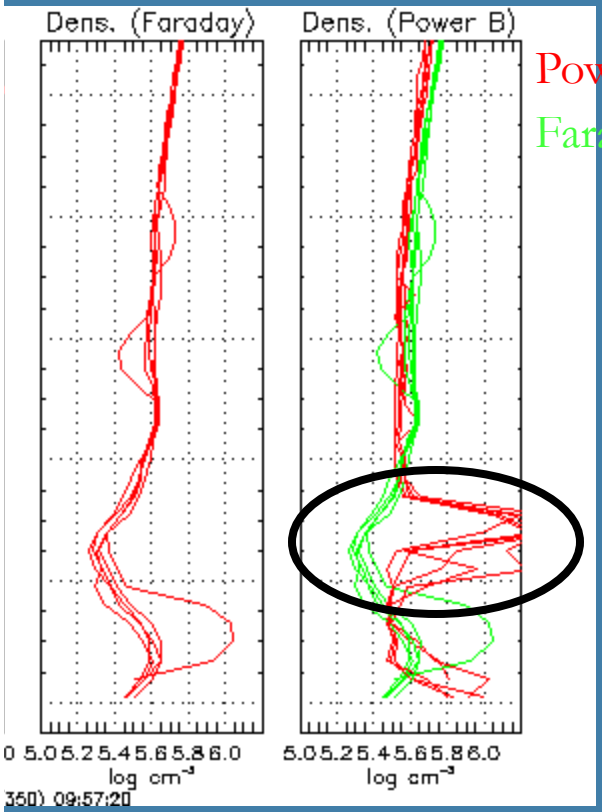


- Echoes are observed during all seasons.
- Seasonal differences on:
  - Layering
  - Altitude of occurrence
  - Intensity of the echoes

[from *Chau and Kudeki*, 2006]

Faraday density experiments (2)

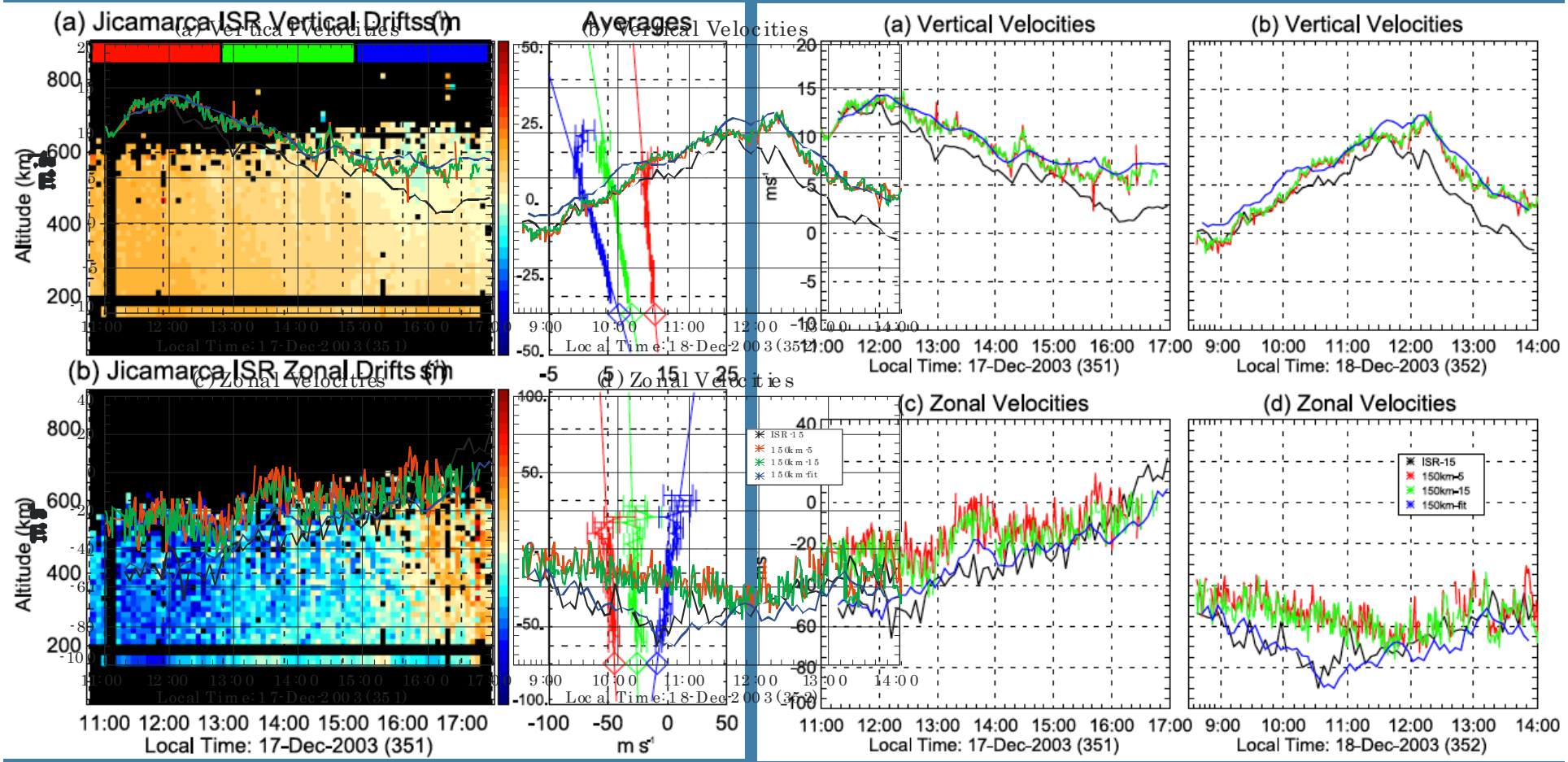




Coherent Radars: 150-km Echoes

Radar Frequency	Configurations/ Techniques	Coherent Targets	Main Derived Parameters
MF	Monostatic/Multi-Static	PEME/PMSE	Irregularity Power, Drifts, and spectra shape
HF	Multi-beam	Specular Meteors	Neutral winds
VHF	CW/Pulsed	Other meteors	Electric fields
UHF	Multi-station	E region	Electron Density
	Interferometry	150-km/Valley	Neutral Temperatures
	Imaging	F region	GWs/Tides/PWs
	Multi Frequency		
	Passive		

ISR Drifts vs 150-km drifts



$$V_x \approx -(\Sigma_H/\Sigma_P)V_z + \int (\sigma_P * U_n ds)/\Sigma_P$$

[from *Chau and Woodman.*, 2004]

VIPIR "Range-time" parameters