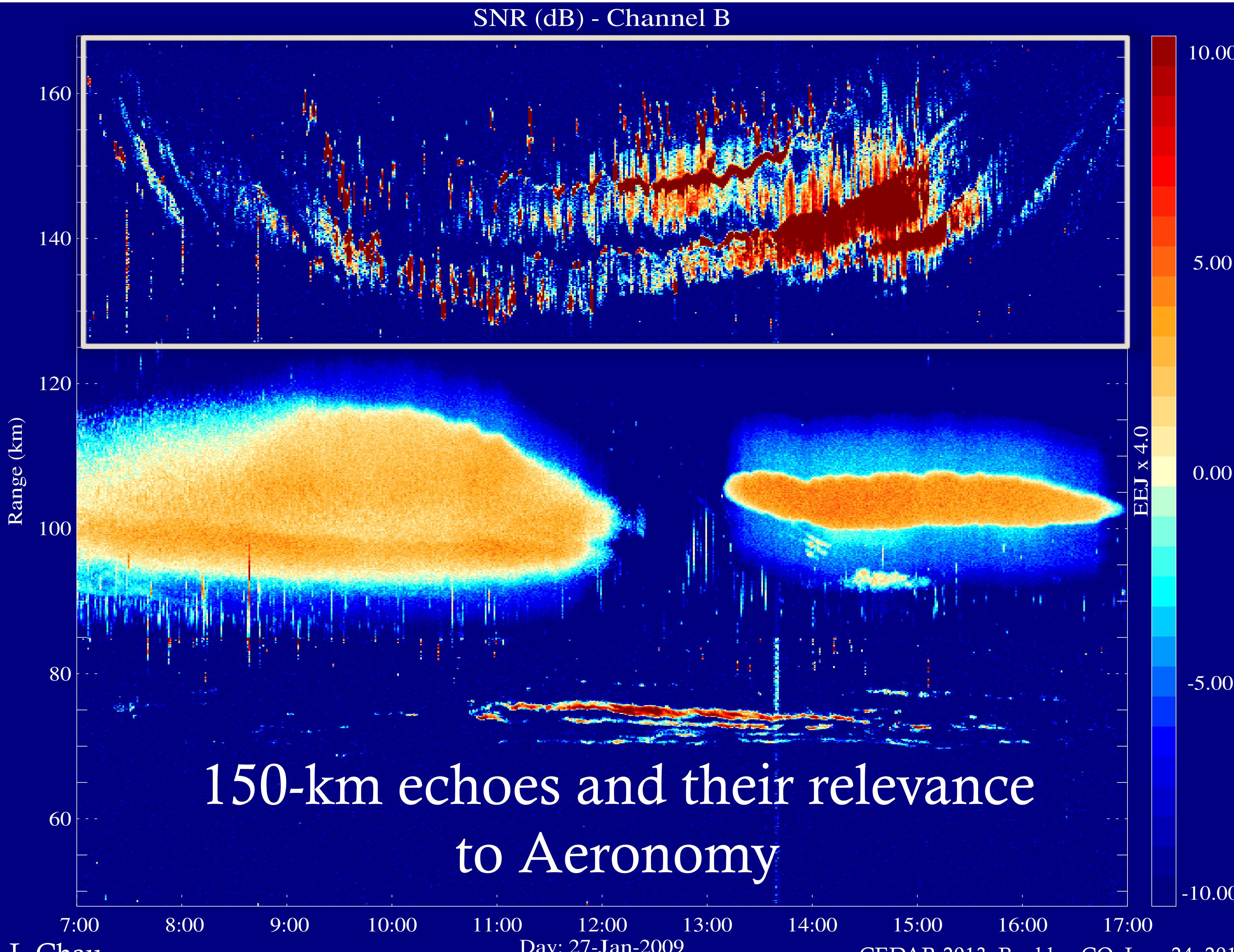

150-km echoes and their relevance to Aeronomy

J. L Chau

CEDAR 2013, Boulder, CO, June 24, 2013

Acknowledgements

E. Kudeki
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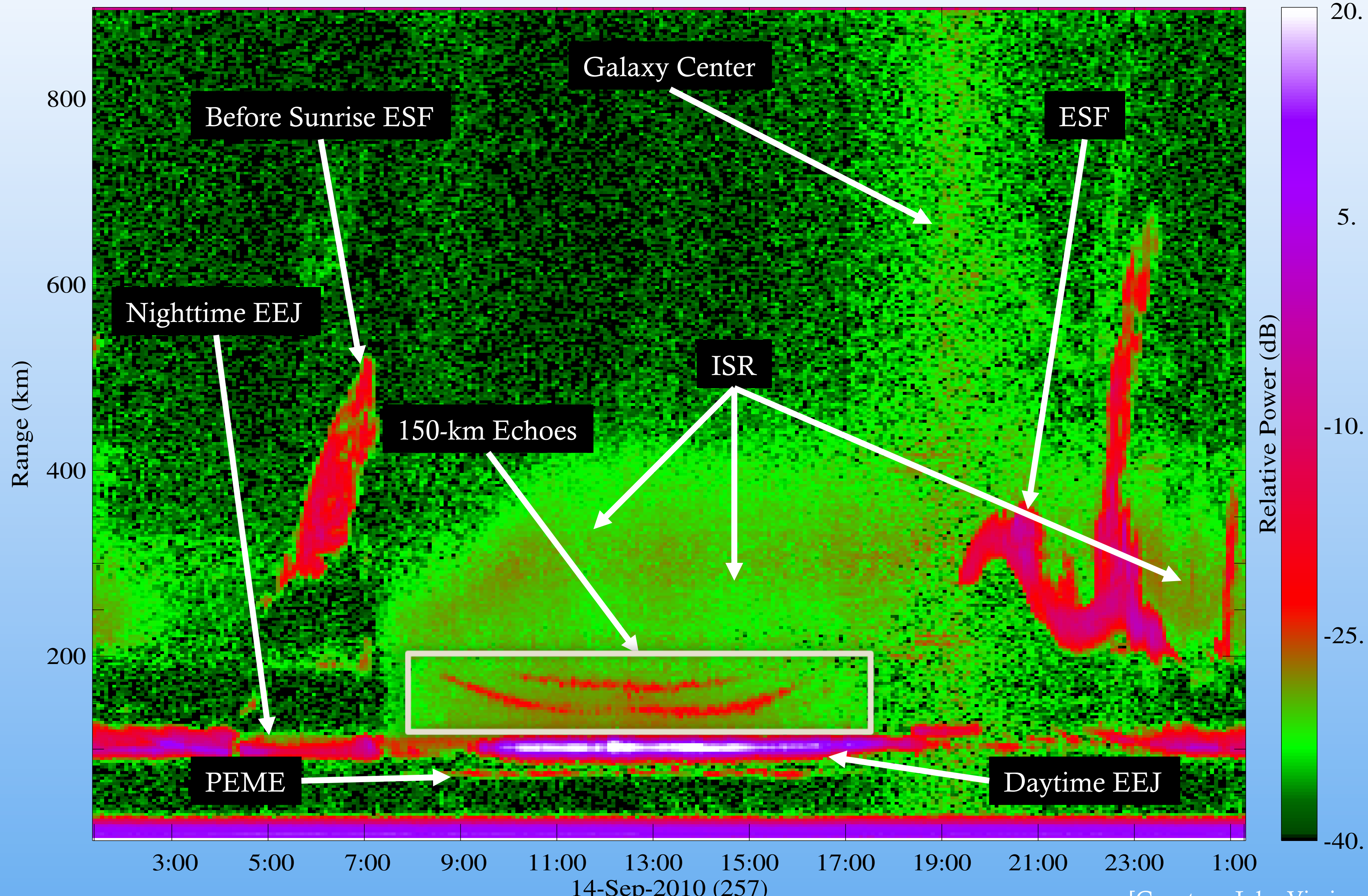
A. Patra
R. Tsunoda
M. Oppenheim
J. Vierinen
J. Garcia

Incoherent and Coherent Echoes over Jicamarca

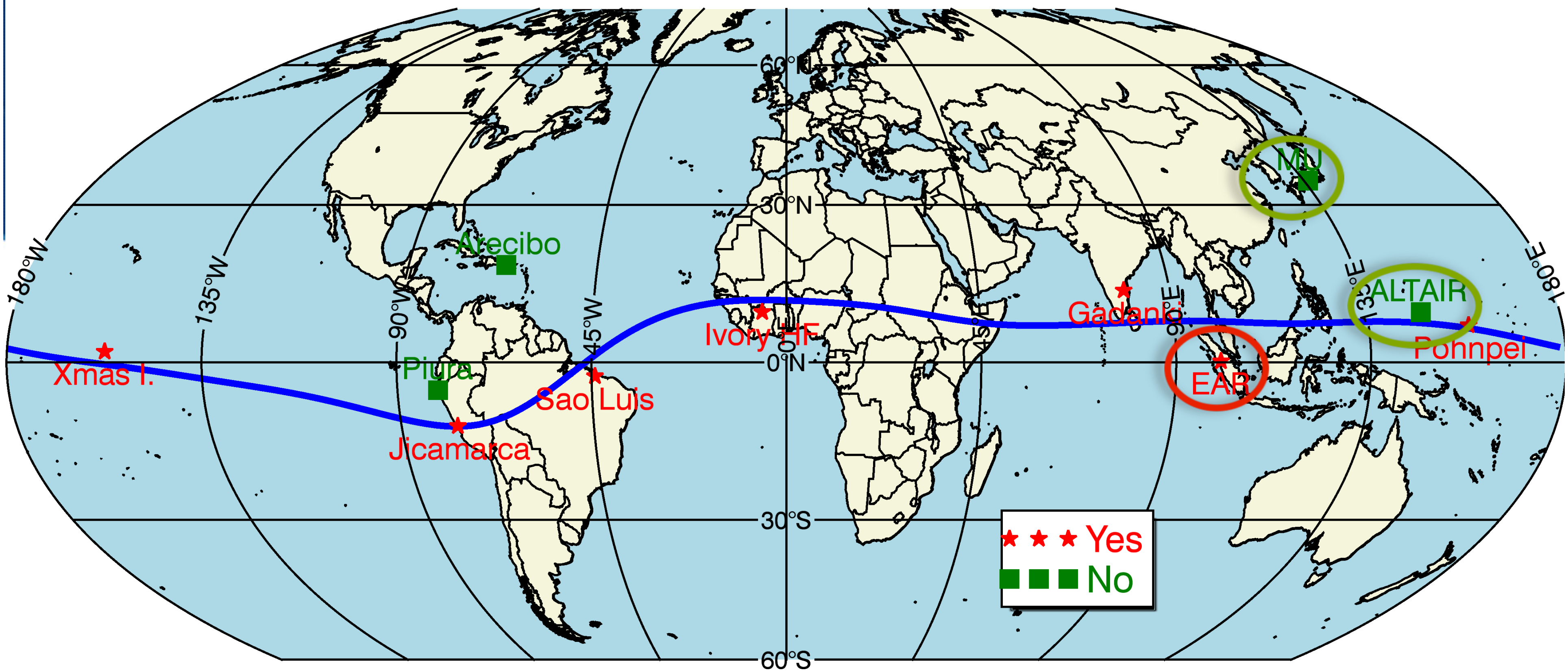


[Courtesy Juha Vierinen]

Names

- The echoes
  - 150-km echoes
  - 150-km junk
  - F_1 echoes
  - Kudechoes
- The topic
  - 150-km riddle
  - 150-km puzzle
  - 150-km challenge
  - Esoteric/private Science

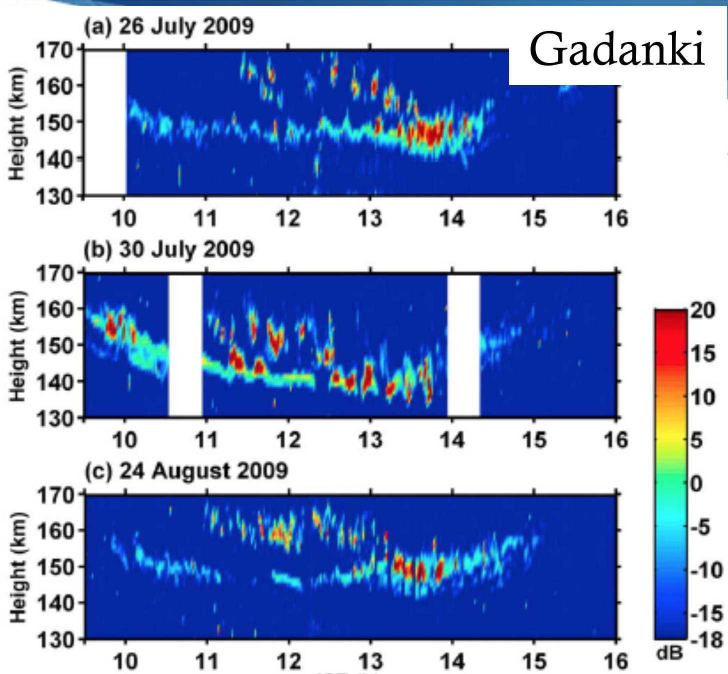
Observations of 150-km echoes

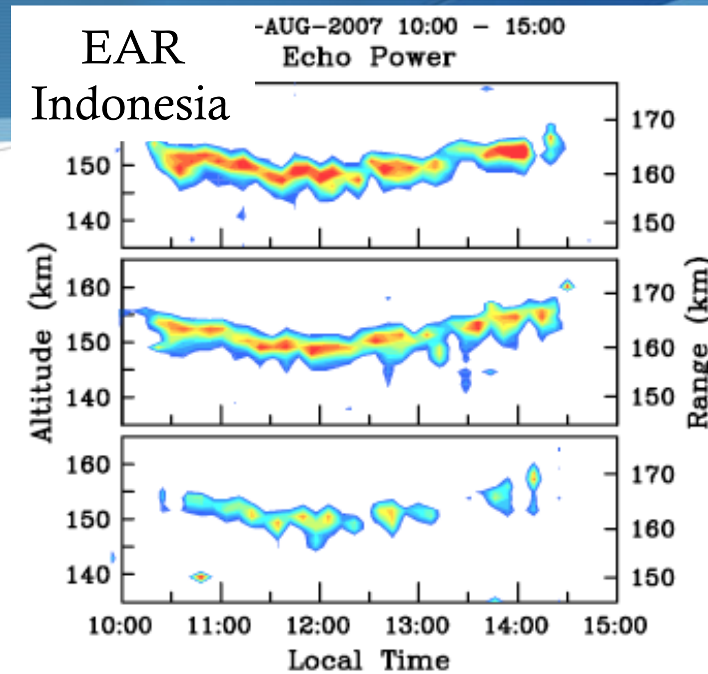


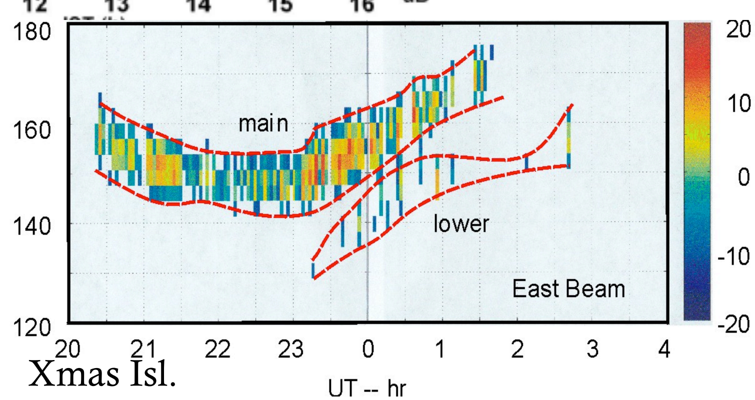
Site	Dip Lat.	Less Sensitivity[1]	Freq.
Jicamarca/JULIA[2]	0.5° S	17 ± 3 dB	50 MHz
Pohnpei	0.3° N	25 ± 3 dB	50 MHz
Sao Luis	2.0° S	~28 ± 3 dB	30 MHz
Gadanki	6.5° N	12 ± 3 dB	53 MHz
EAR	10.0° S	22 ± 3 dB	47 MHz

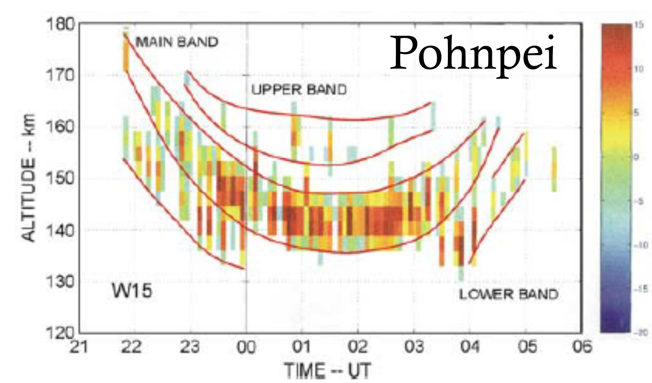
[1]with respect to Jicamarca ISR
[2]only one in the South hemisphere (geographic)

Other Observations at ~50 MHz

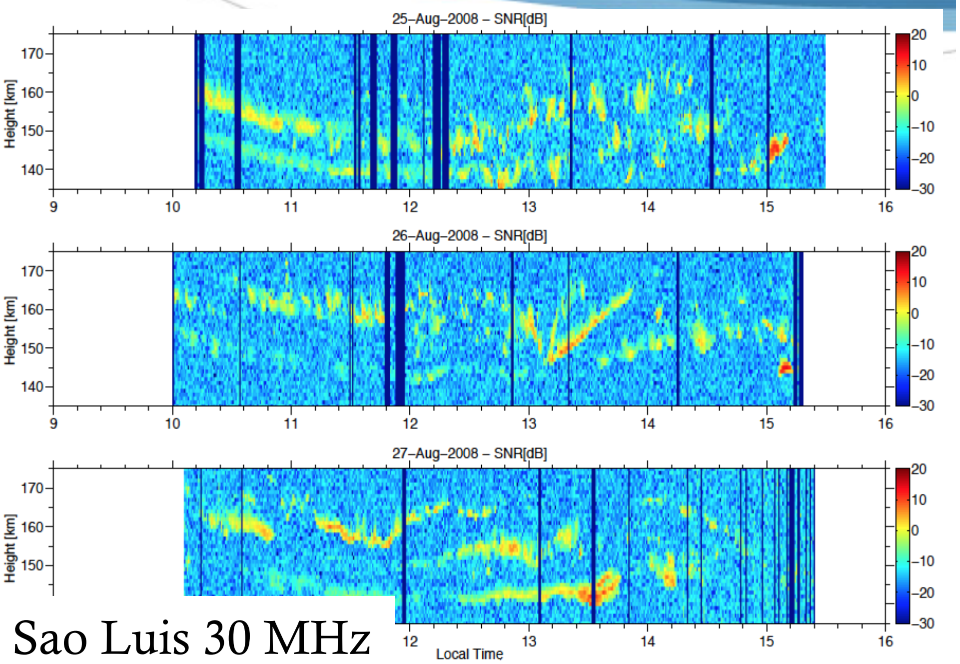


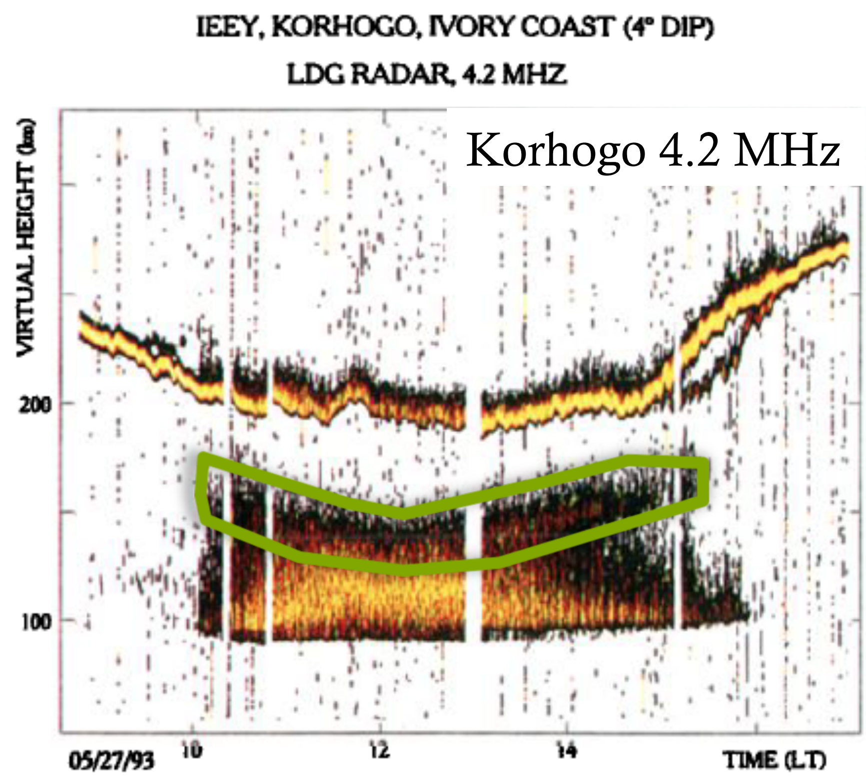






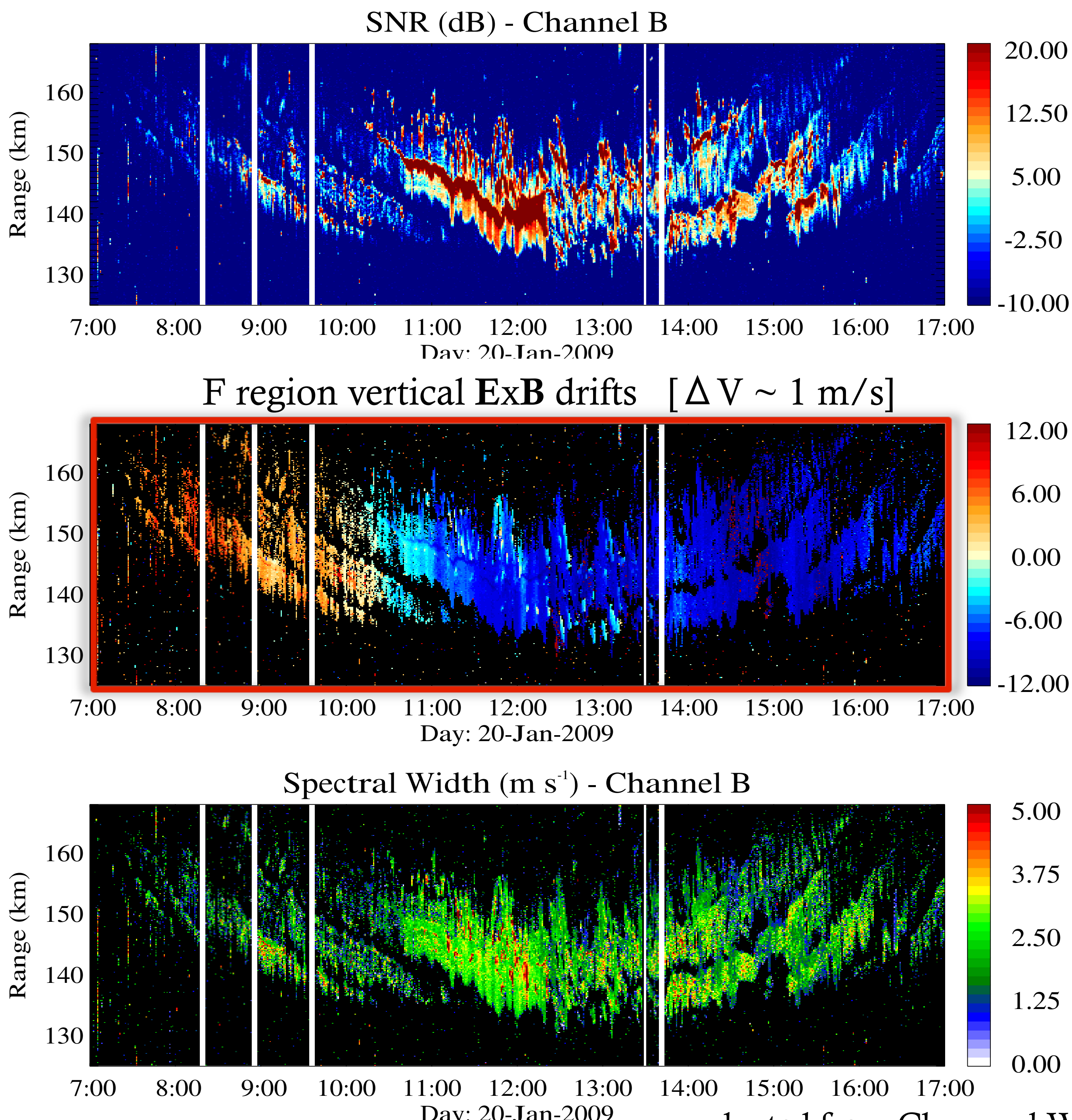
Observations at other frequencies





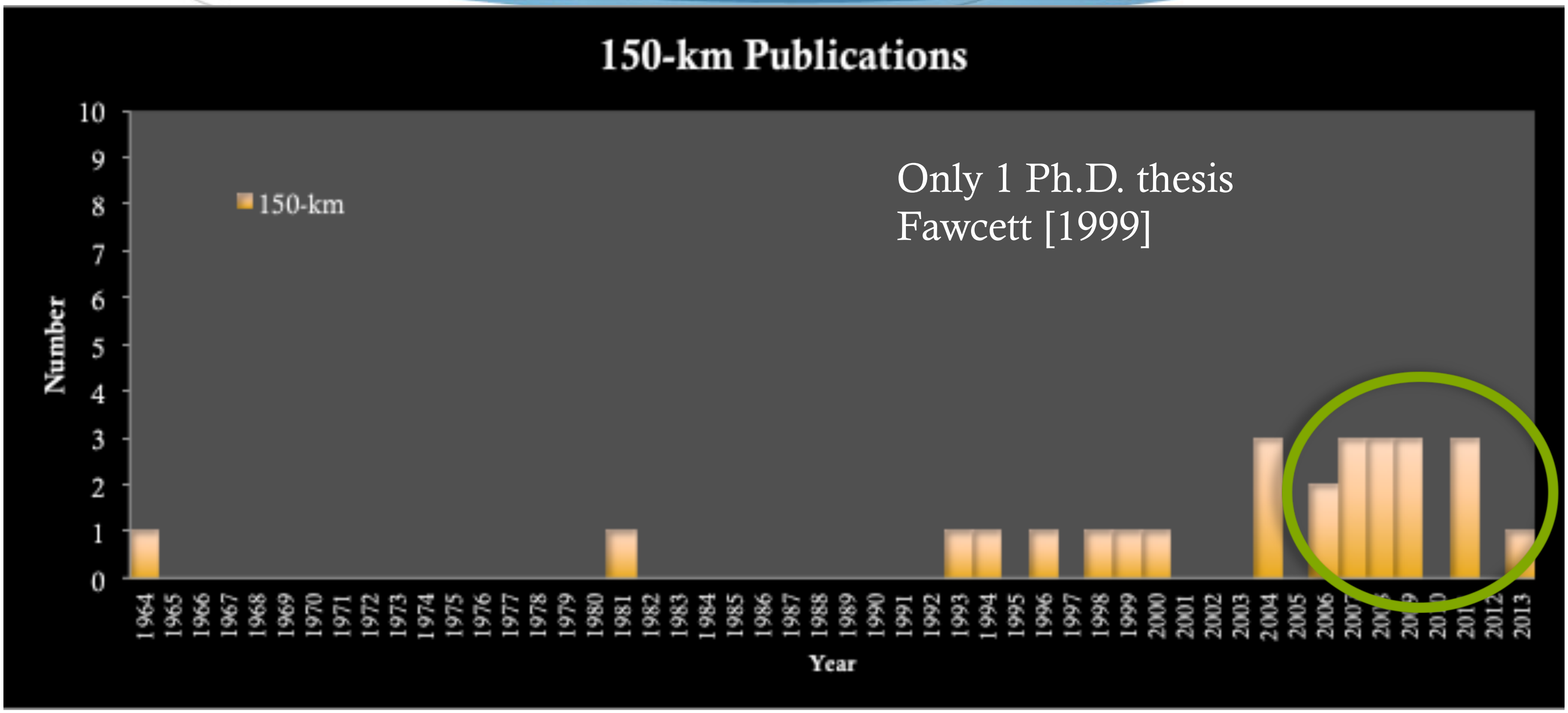
Main Features

- Daytime phenomena
- Occur between 130-180 km
- Necklace shape (1-5 layers)
- Observed with beams perpendicular to **B**
- Seasonal occurrence
  - All seasons (Peru, Brazil, India)
  - Summer (Pohnpei).
- Low-latitude observations (as far as 10^{o}S dip lat.)
- Proposed mechanisms: Interchange instability
  - GWs wind-driven
  - Zonal neutral winds and/or vertical E acting on horizontal Ne gradients
- Vz ~ vertical F-region ExB.
  - ~150 days/year at Jicamarca

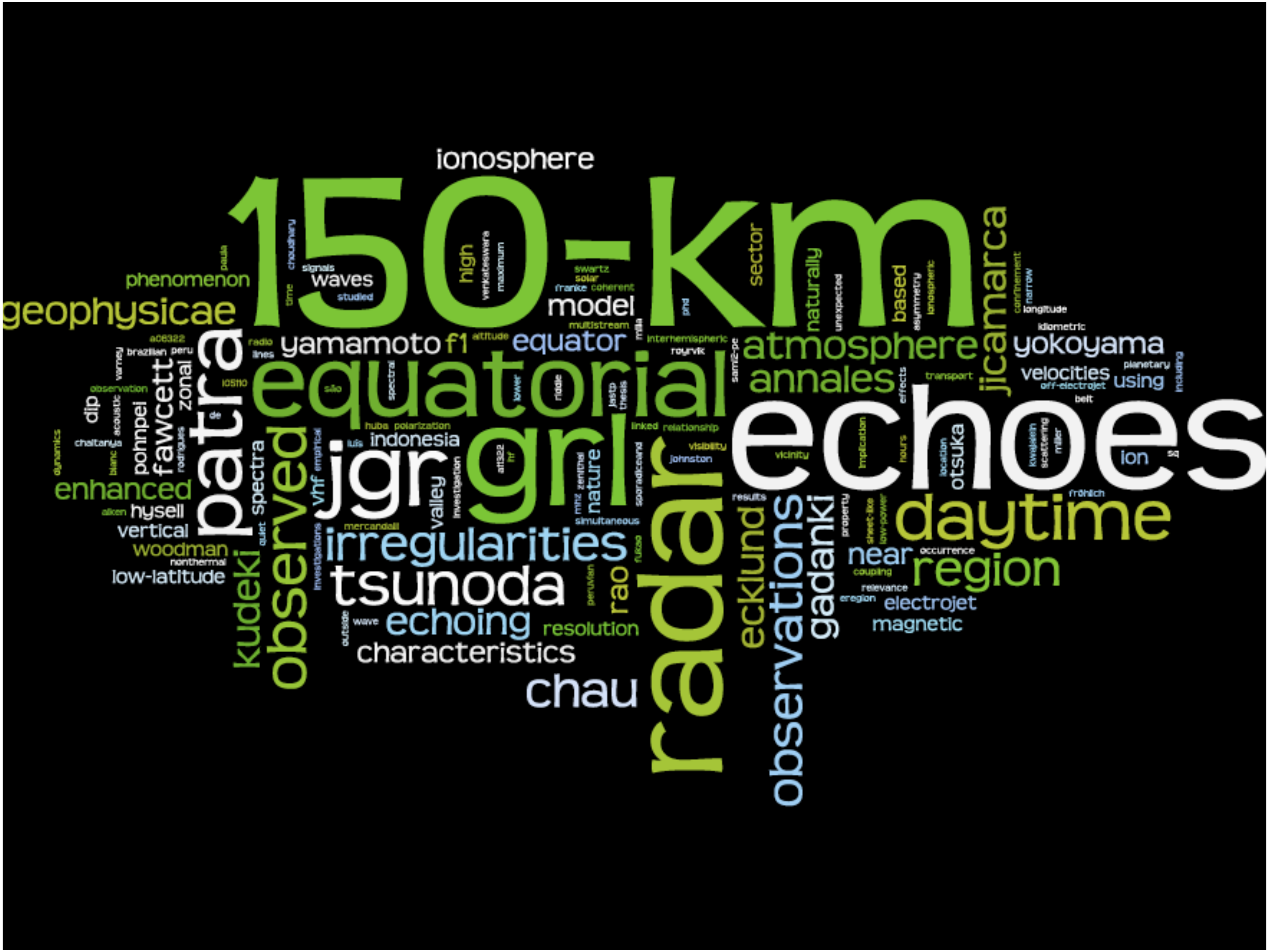


adapted from Chau and Woodman [2004]

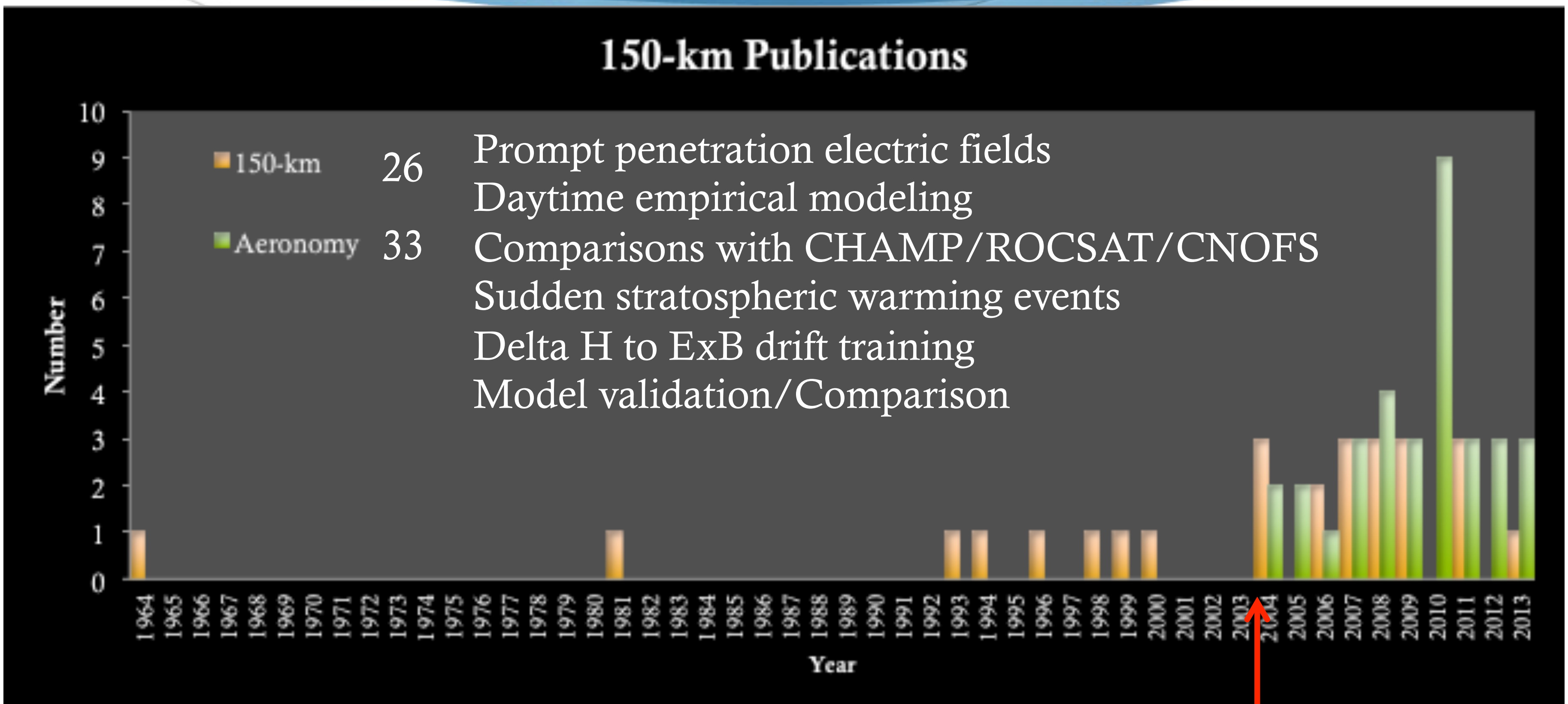
150-km Publications



Consulting with the experts


150-km
echoes
radar
equatorial
grl
jgr
patra
observed
observations
irregularities
tsunoda
daytime
region
atmosphere
annales
jicamarca
yokoyama
geophysicae
ionosphere
model
yamamoto
equator
chau
echoing
characteristics
kudeki
ecklund
gadanki
enhanced
fawcett
phenomenon
waves
indonesia
near
electrojet
magnetic
resolution
velocities
using
ion
otsuka
hysell
vertical
woodman
low-latitude
spectra
pohnpei
zonal
dip
f1
high
sector
naturally
based
rao
nature
valley
vhf

Relevance to Aeronomy: Publications



Chau and Woodman [2004]

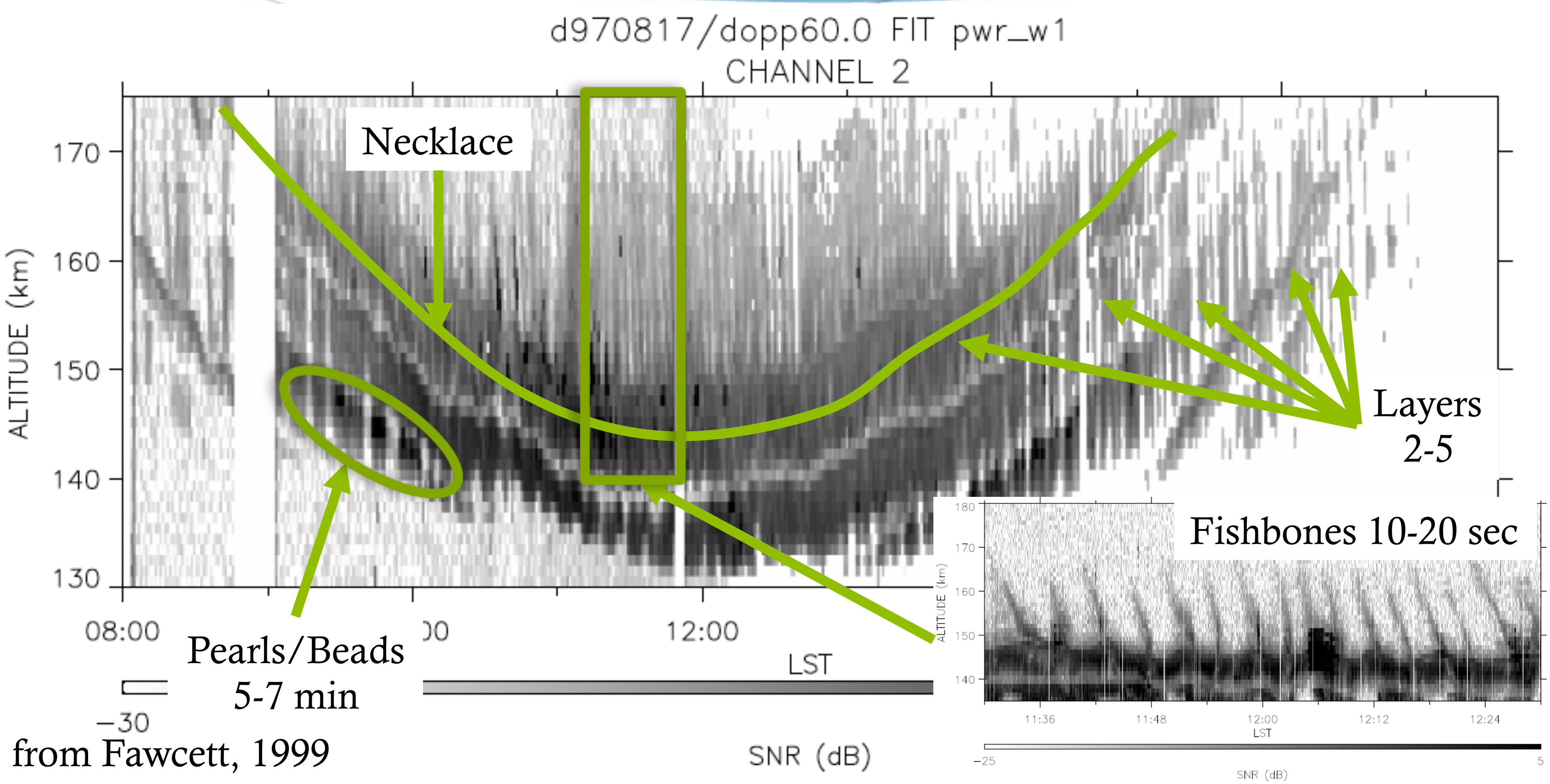
the remaining 30 minutes

- Background
- Main features (published and unpublished)
  - Perpendicular to B observations
  - Observations at HF
  - Naturally Enhanced Ion Acoustic Lines (NEILs)
  - NEILs vs. FAIs.
- Relevance to Aeronomy
- Summary

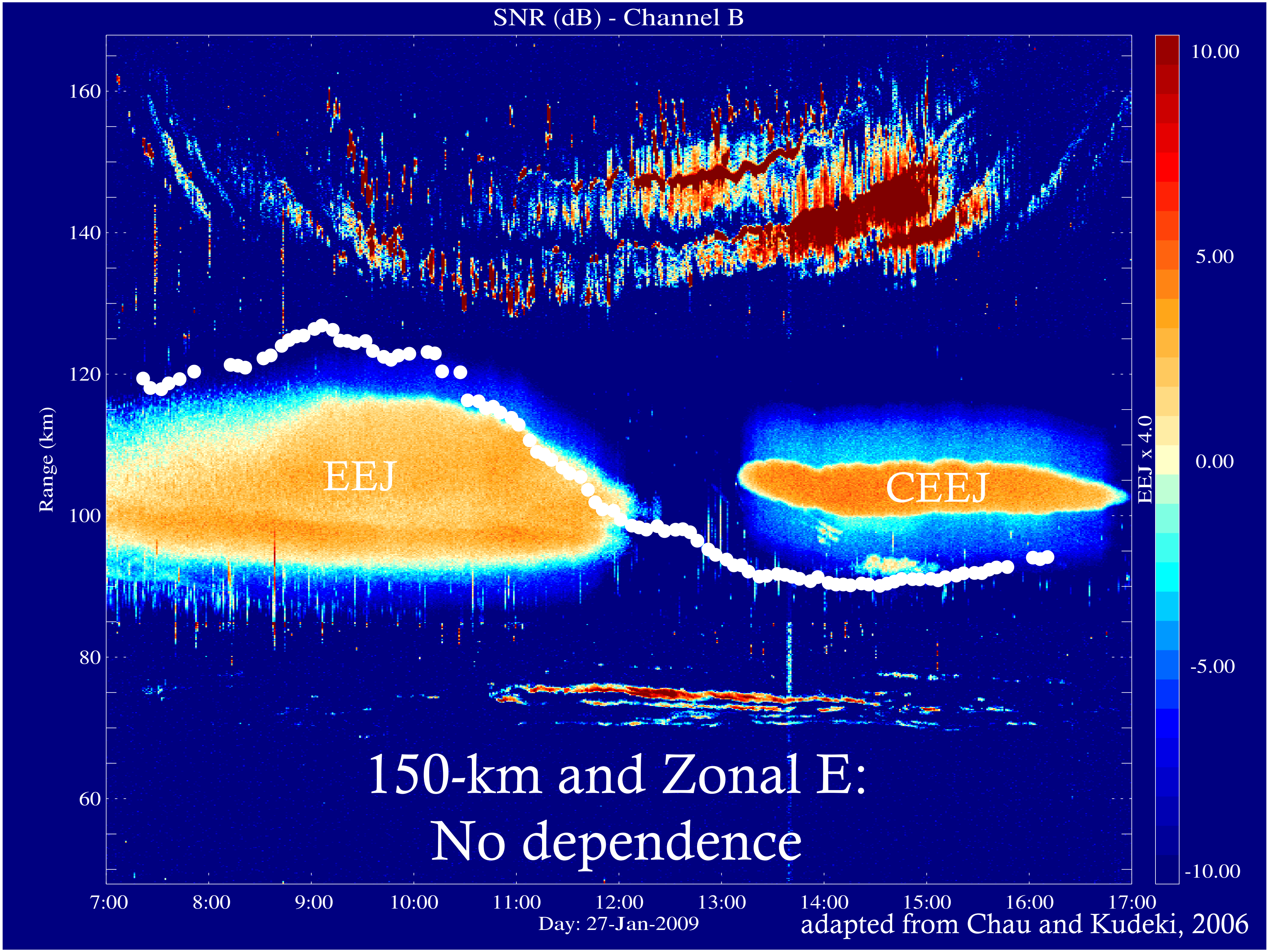
Equatorial Daytime Valley Region

- Transition region: Upper E molecular ions and lower F atomic oxygen ion.
- Collisions with neutrals start to be less important as the altitude increases.
- E region coupling: magnetic field lines around 140–170 km are mapped to both the north and south E regions that are located just outside the EEJ belt.
- Intermediate layers (metallic ions?) are known to occur at these altitudes but so far they have not been observed at equatorial regions during the day.
- Te/Ti: Large ratios are expected and observed during the day.
- Critical layers. Lower atmospheric waves are suppressed ..
- Maximum photoelectron production rate.

Types of 150-km echoes



from Fawcett, 1999



SNR (dB) - Channel B
Range (km)
160
140
120
100
80
60
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
Day: 27-Jan-2009
EEJ
CEEJ
EEJ x 4.0
10.00
5.00
0.00
-5.00
-10.00
150-km and Zonal E:
No dependence
adapted from Chau and Kudeki, 2006

Day-to-day and Seasonal Variability

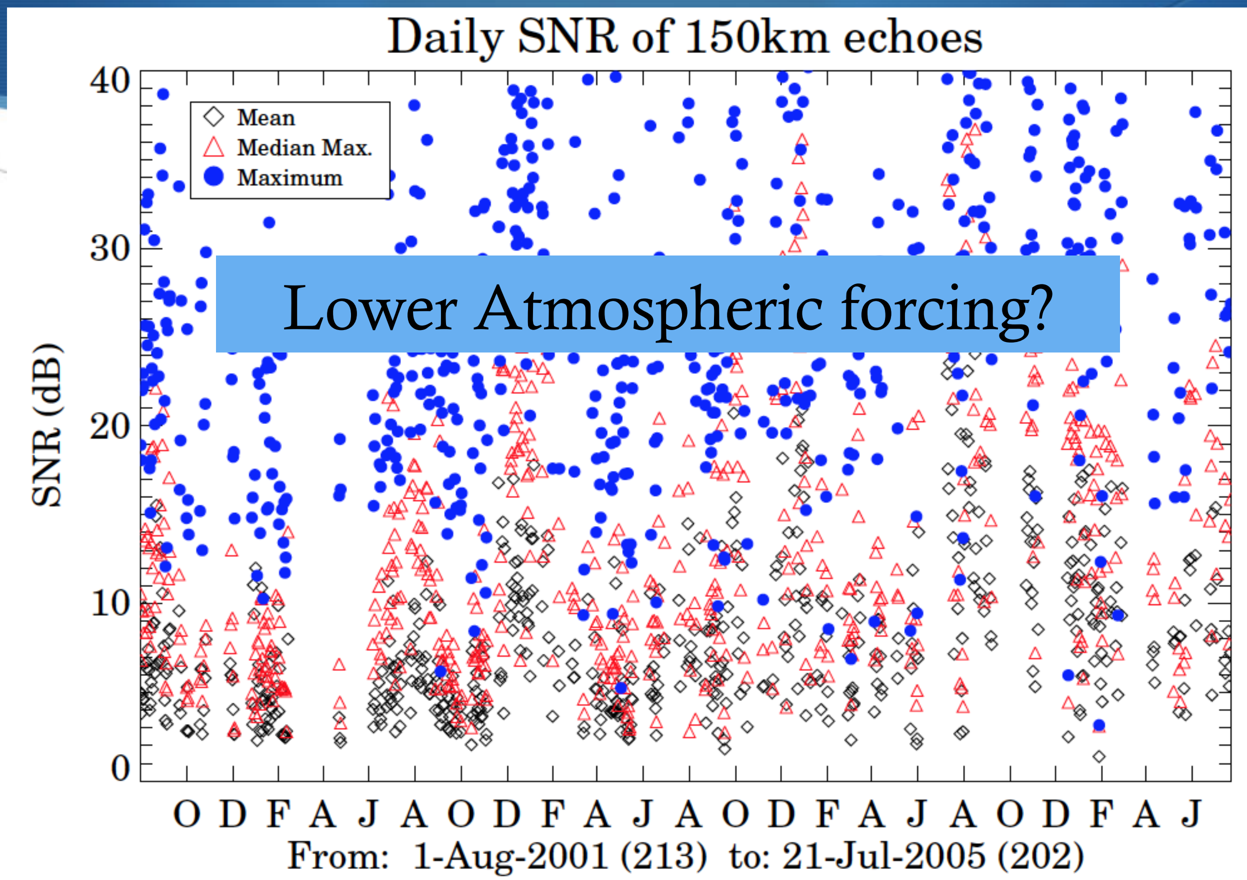
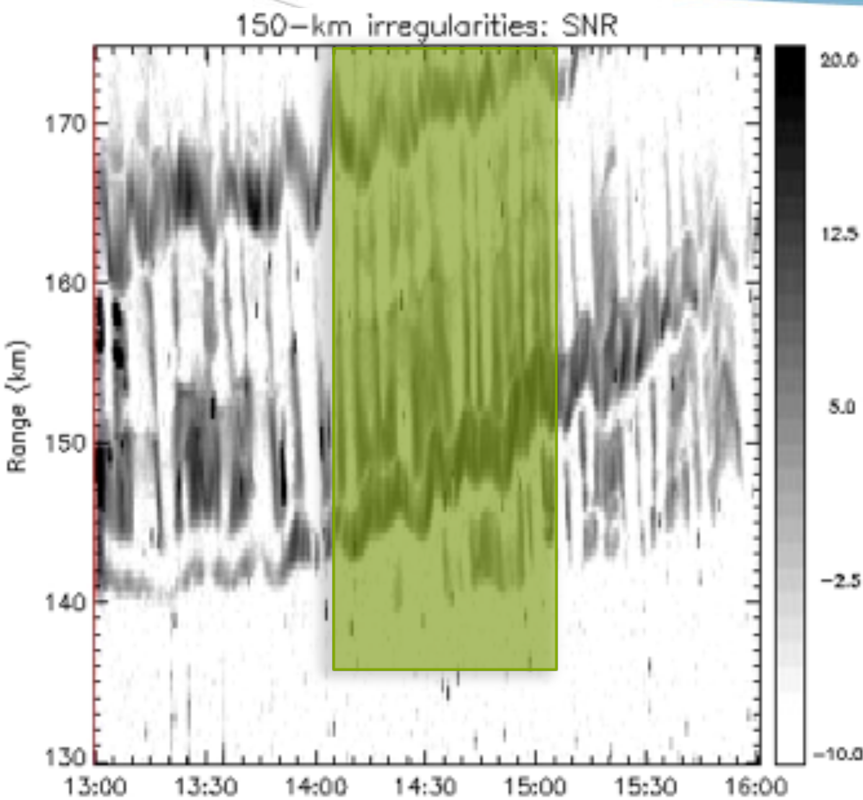
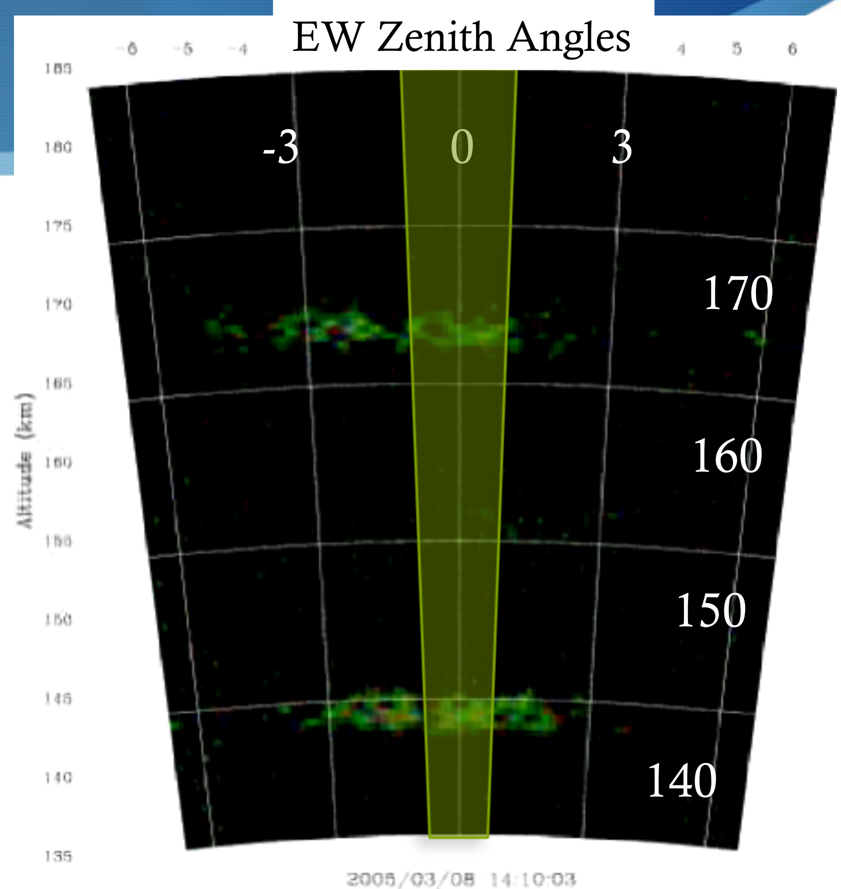


Fig. 6. Time series of 150-km SNR values: mean (◇), median of higher values (△), and maximum values (•). Measurements were conducted between August 2001 and July 2005.

from Chau and Kudeki. [2006]

EW Structure

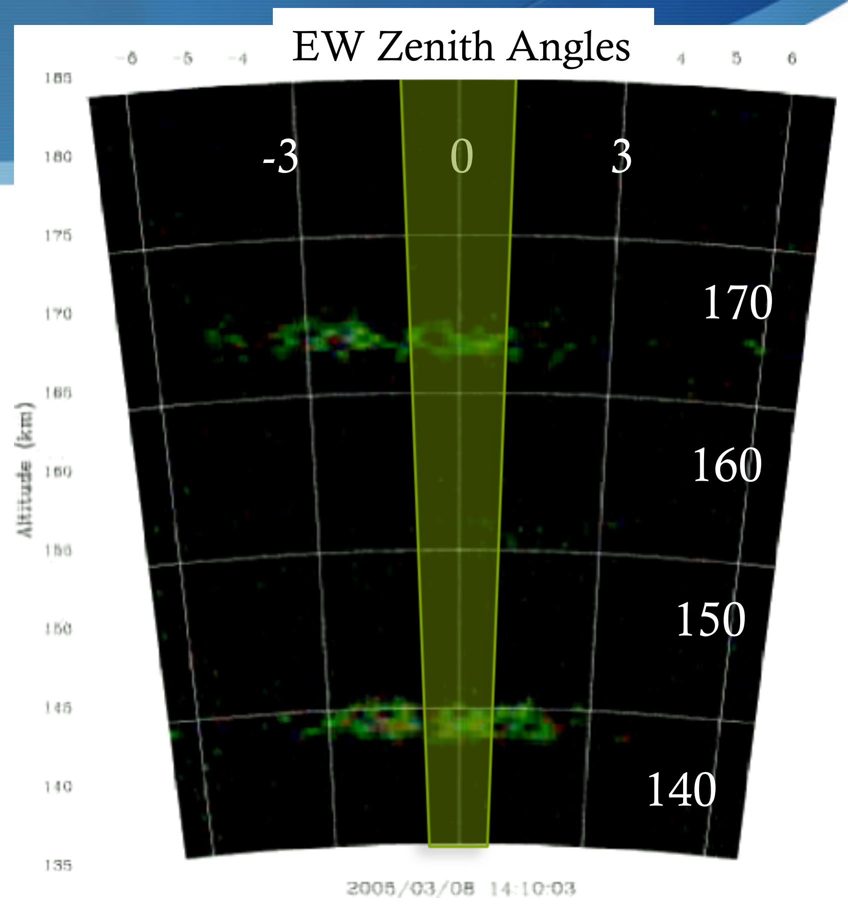




Courtesy D. Hysell

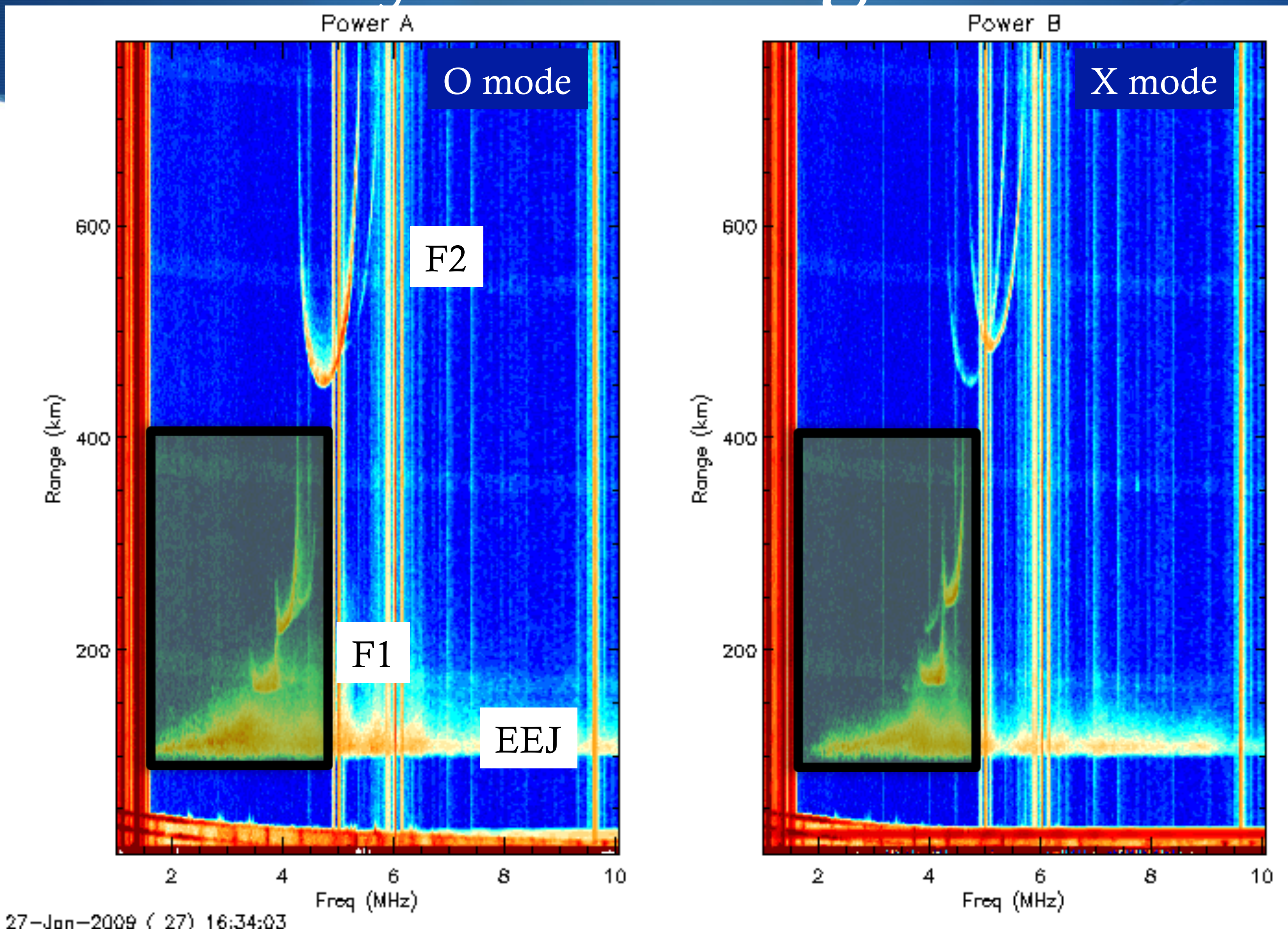
EW Structure

- 150-km EW structures are wider than typical Jicamarca beams, supporting the early Fawcett, 1999 results, but contrary to the strong zonal asymmetry observed over EAR/Pohpei/Xmas Islands.
- "Blob" motion doesn't represent proper motion.
- EW observed "motion" are a combination of electron density time/zonal/meridional modulation (neutral winds, GWs, …)

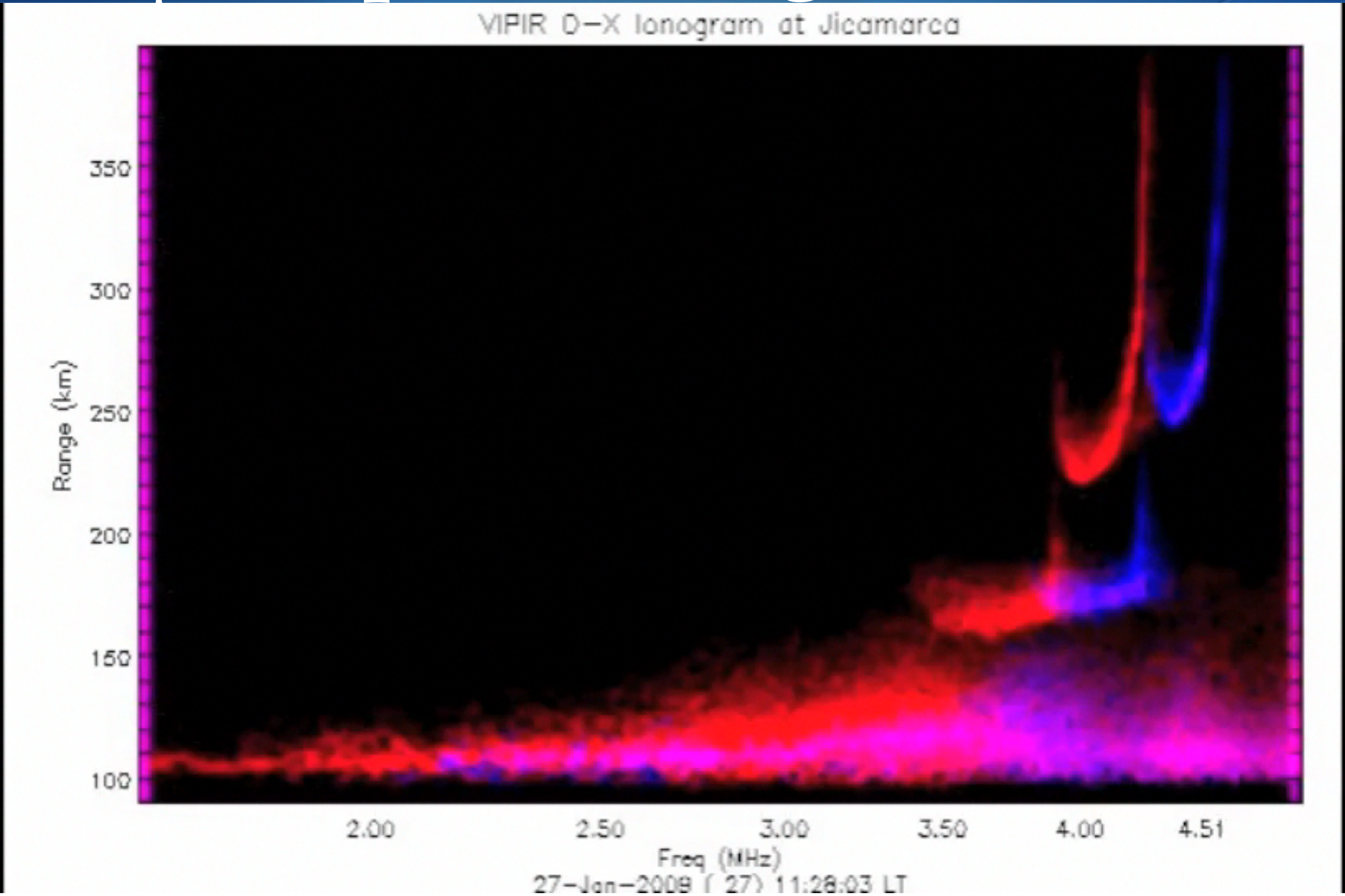


Courtesy D. Hysell

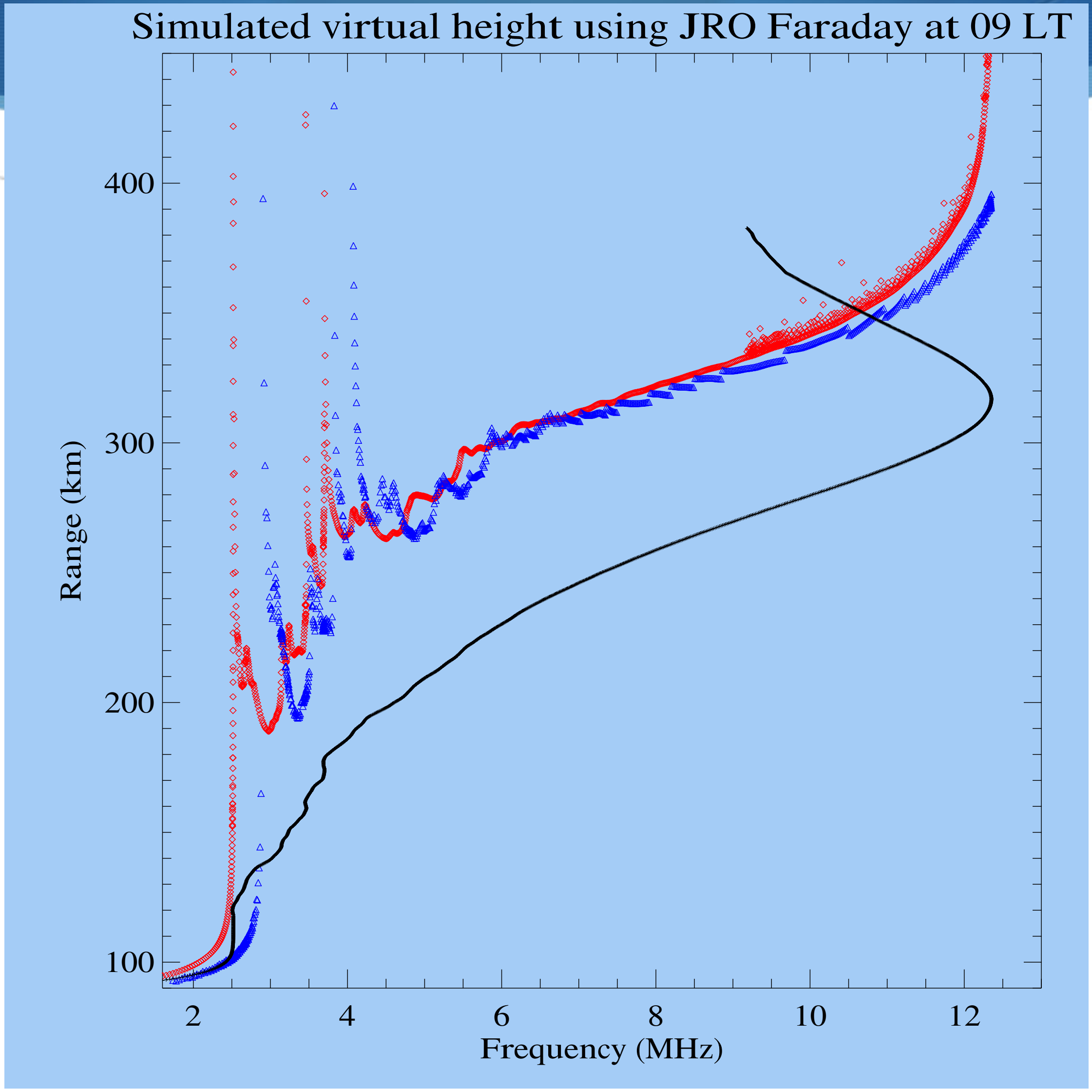
Daytime Ionogram



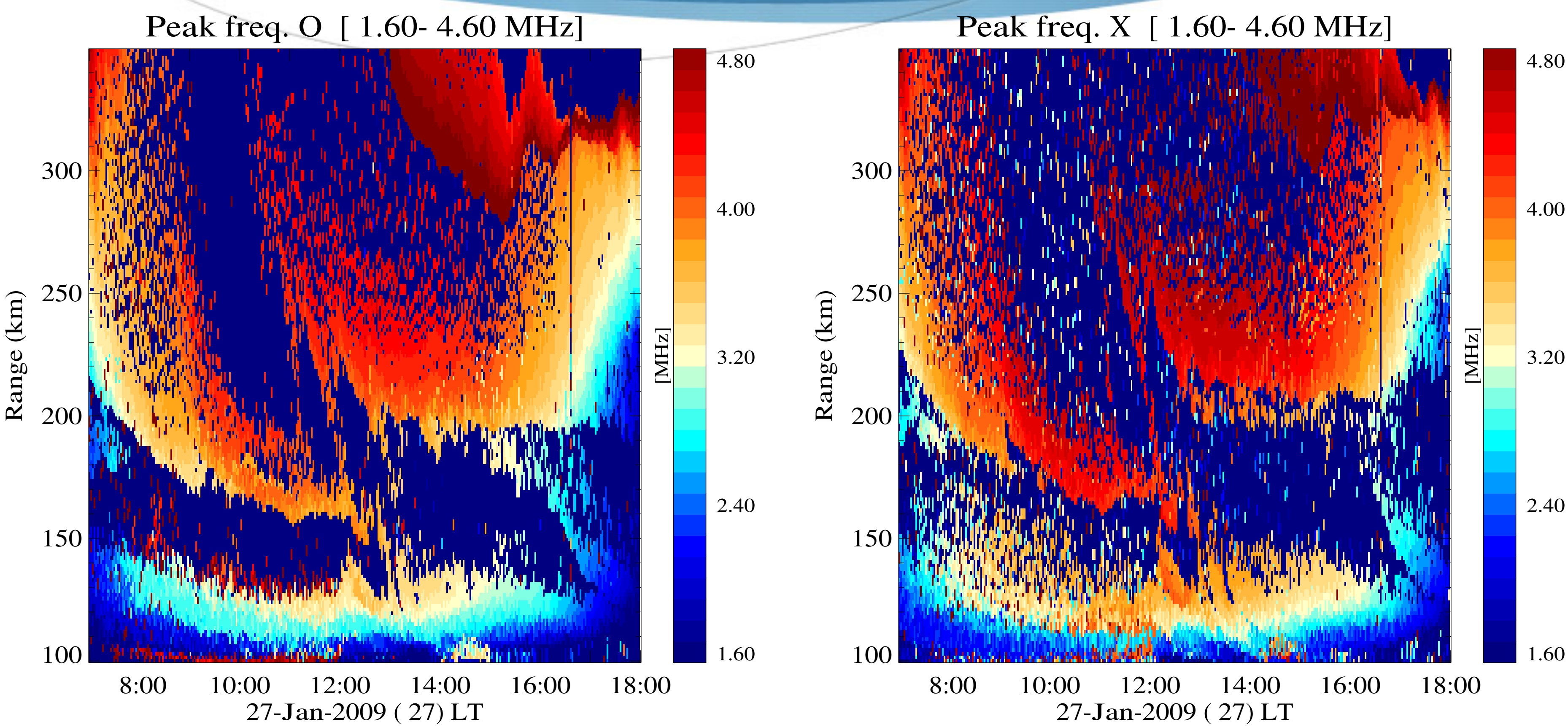
F_1 temporal/range behavior



Valley Ne and Virtual Height

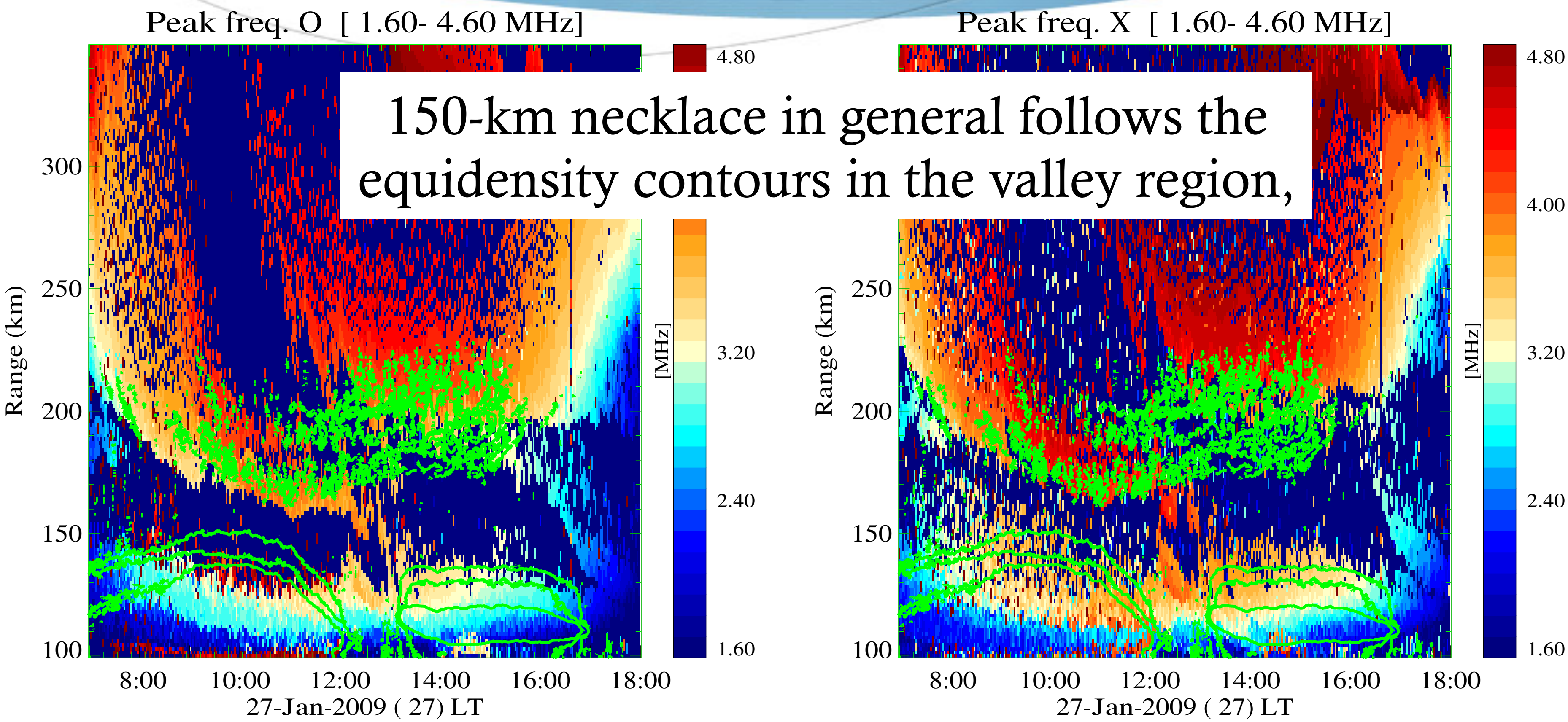


Daytime Valley Region: HF signatures



from Chau et al., 2010

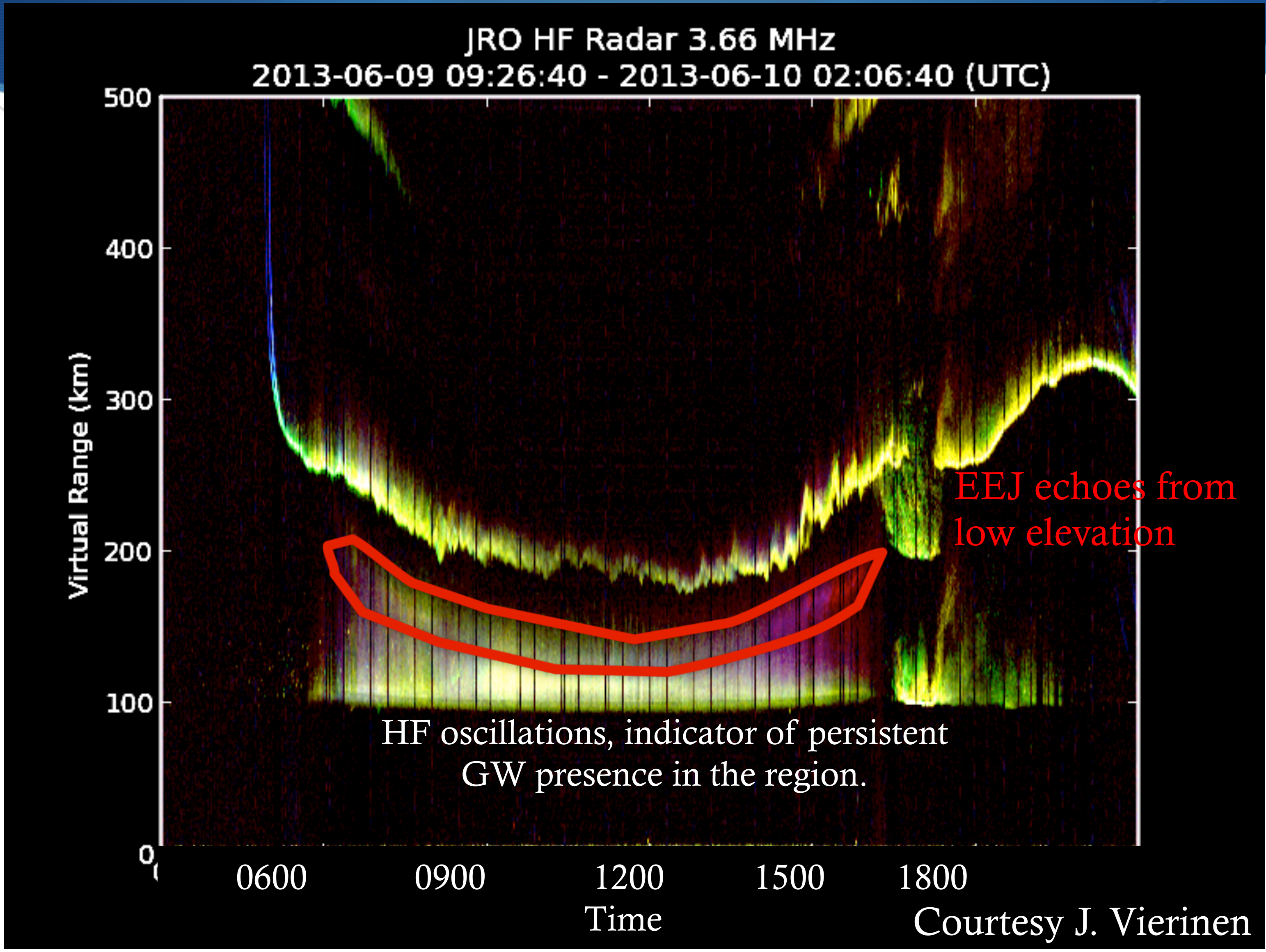
Daytime Valley Region: HF signatures



150-km necklace in general follows the equidensity contours in the valley region,

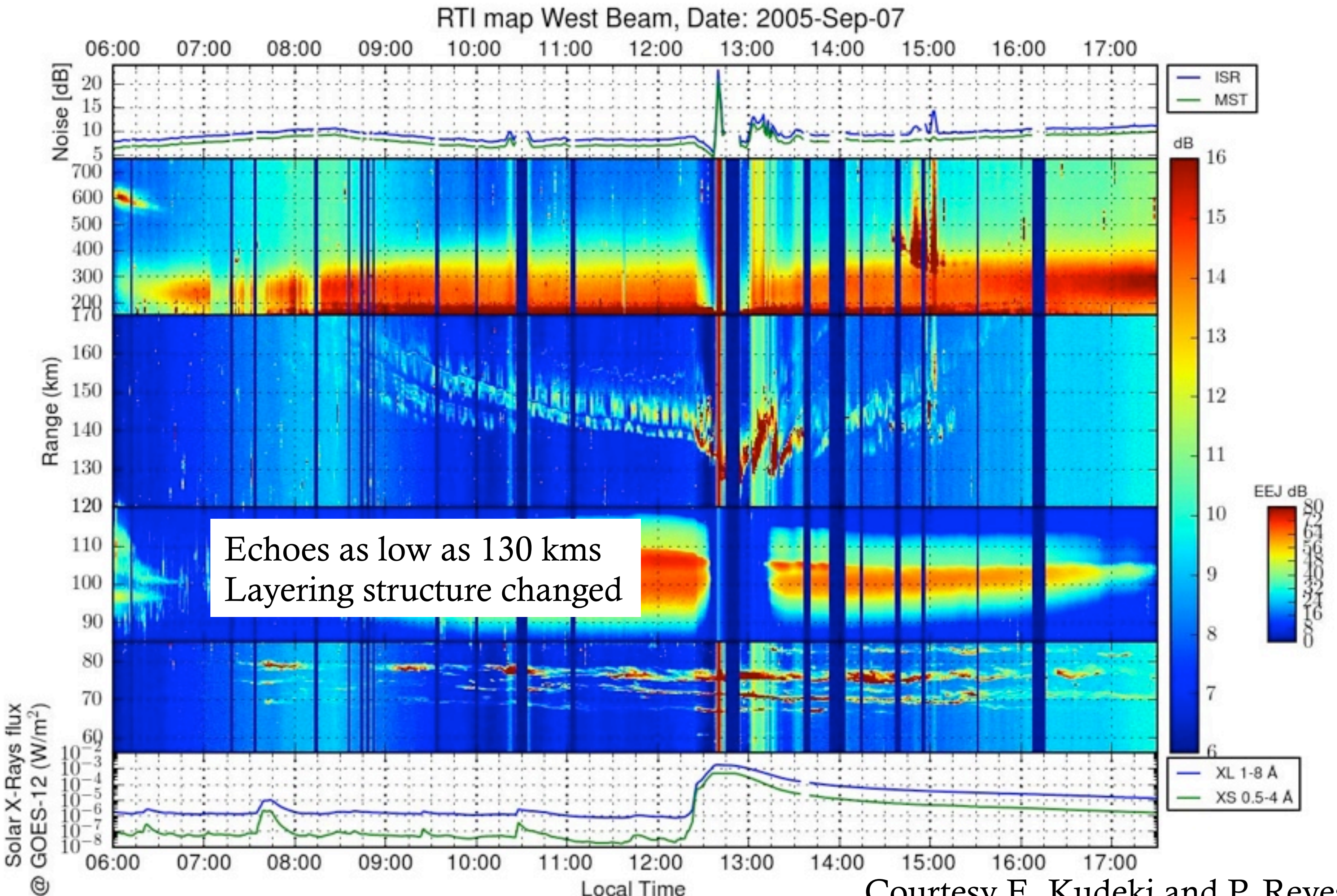
from Chau et al., 2010

3.66 MHz signatures



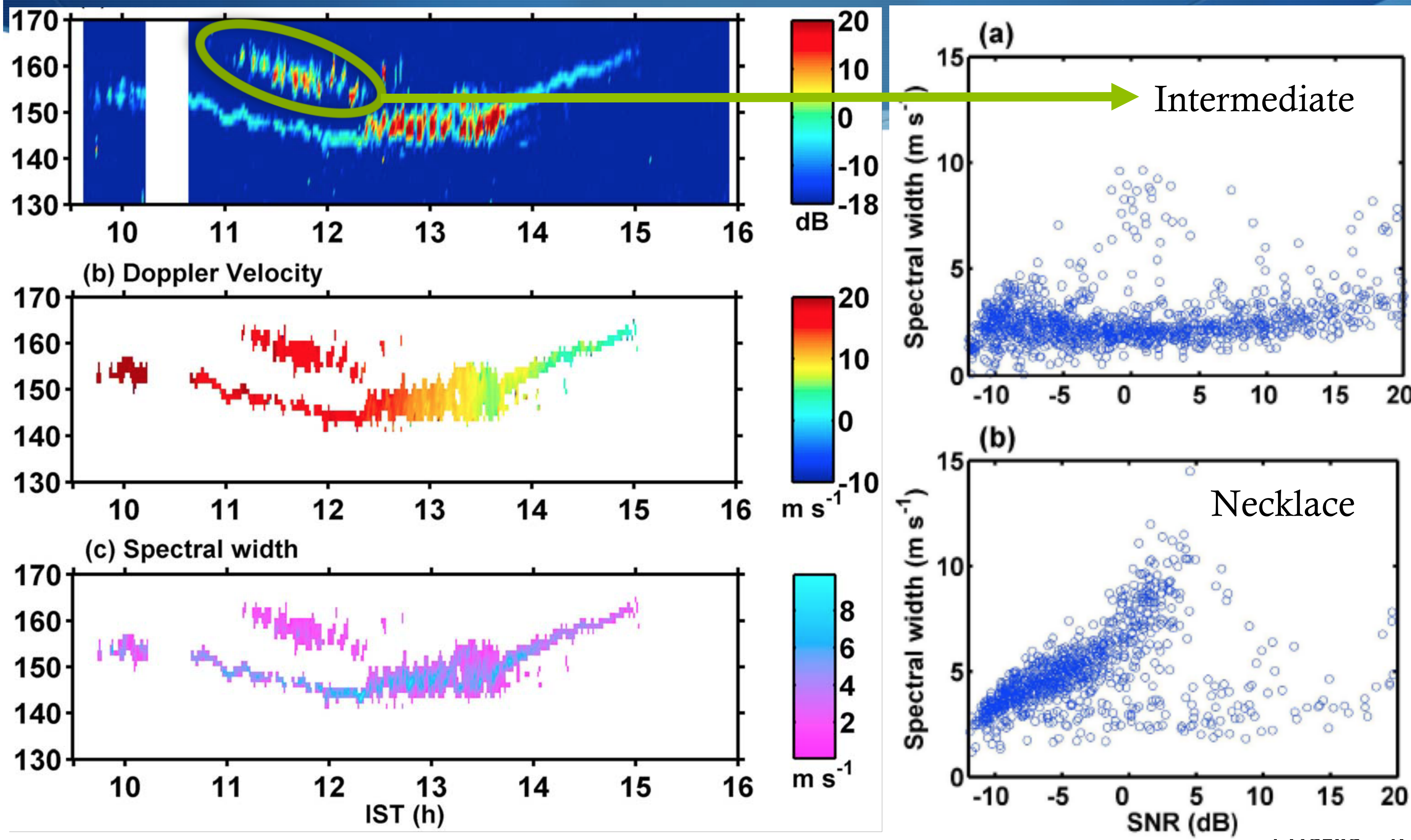
Courtesy J. Vierinen

150-km Echoes and Solar Flares



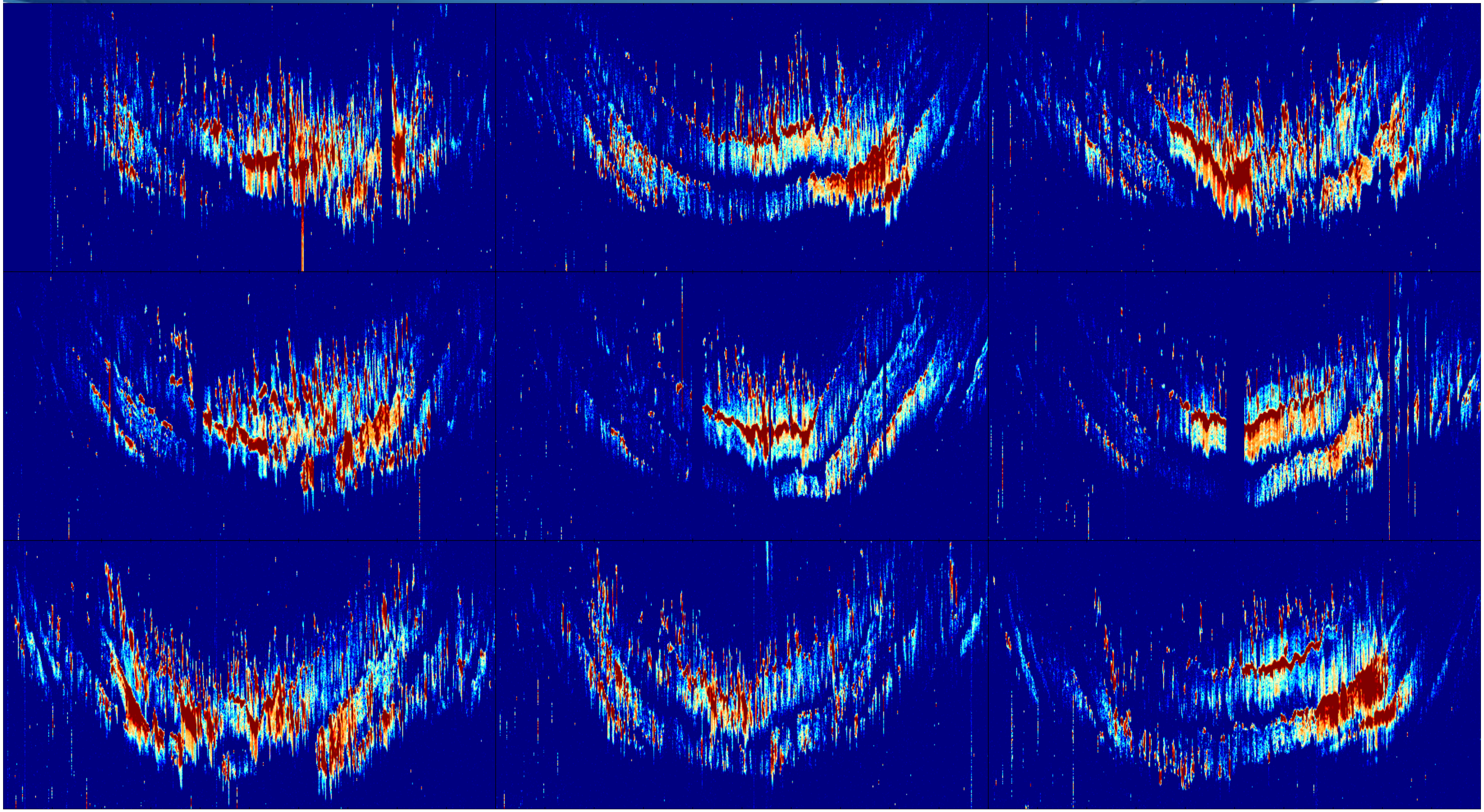
Courtesy E. Kudeki and P. Reyes

Gadanki Echoes: Necklace vs Intermediate layers

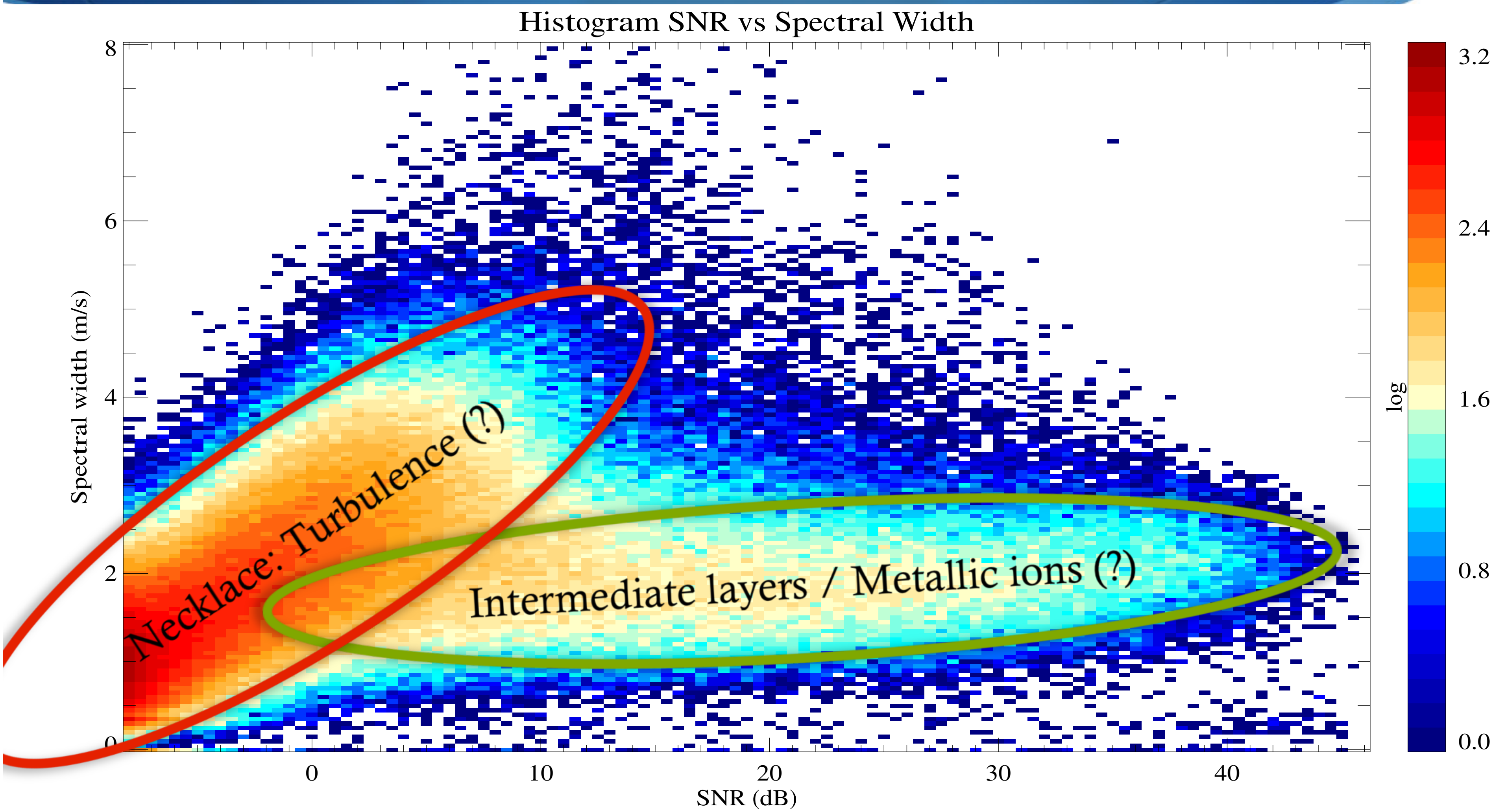


[*Patra*, 2011]

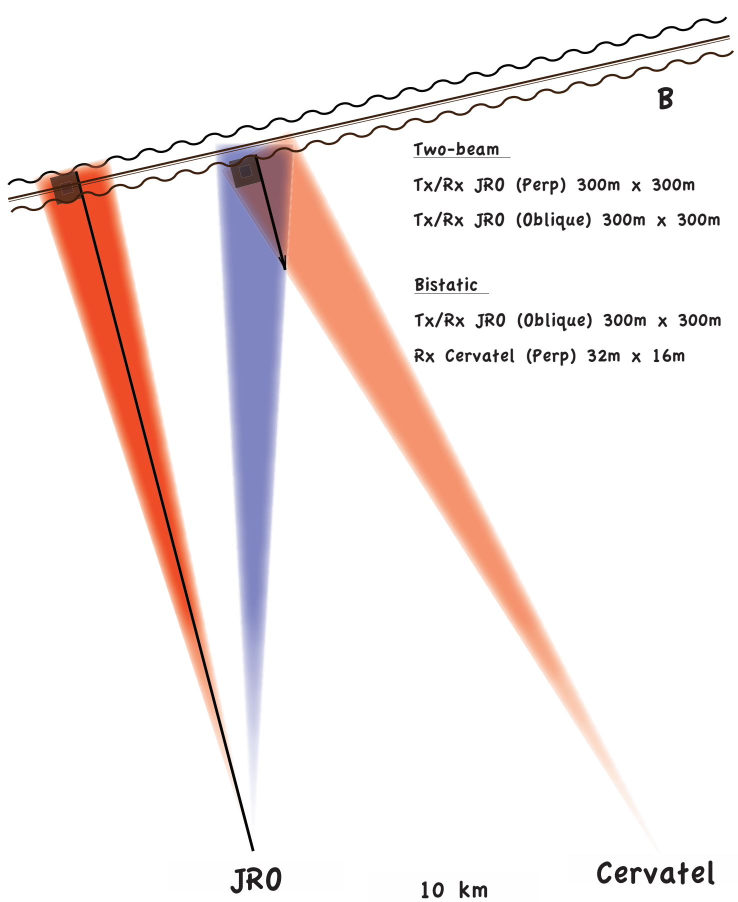
Jicamarca Observations: SNR January 2009

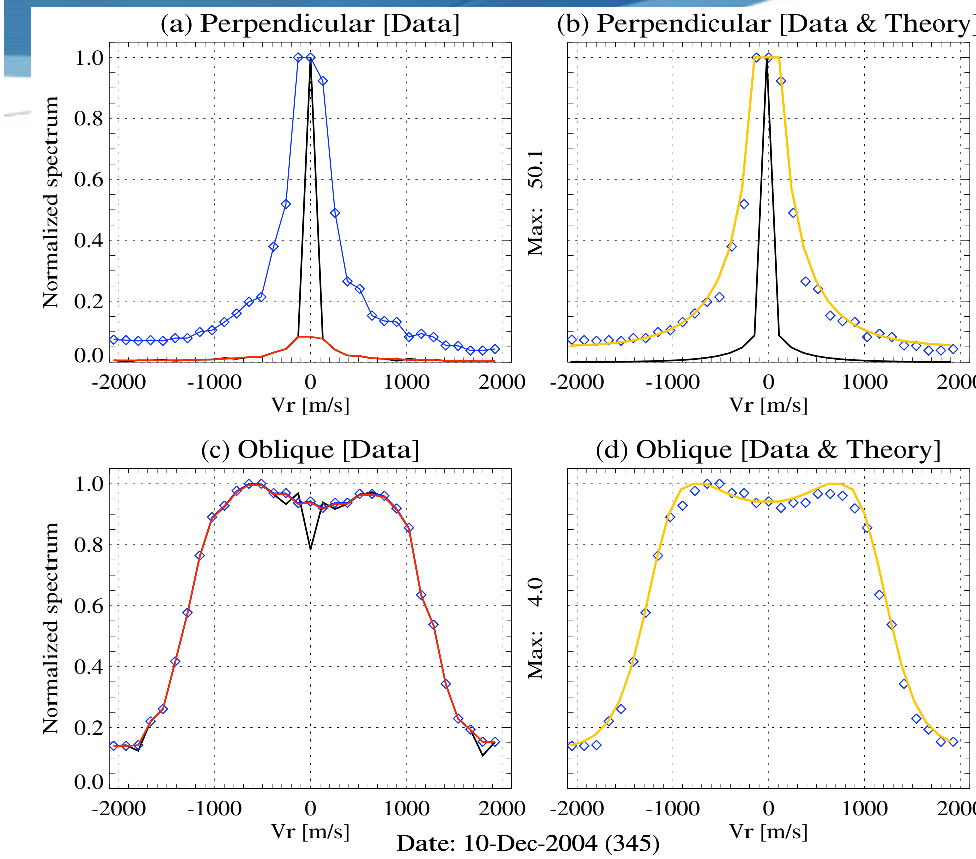


Histogram SNR vs Spectral: January 2009

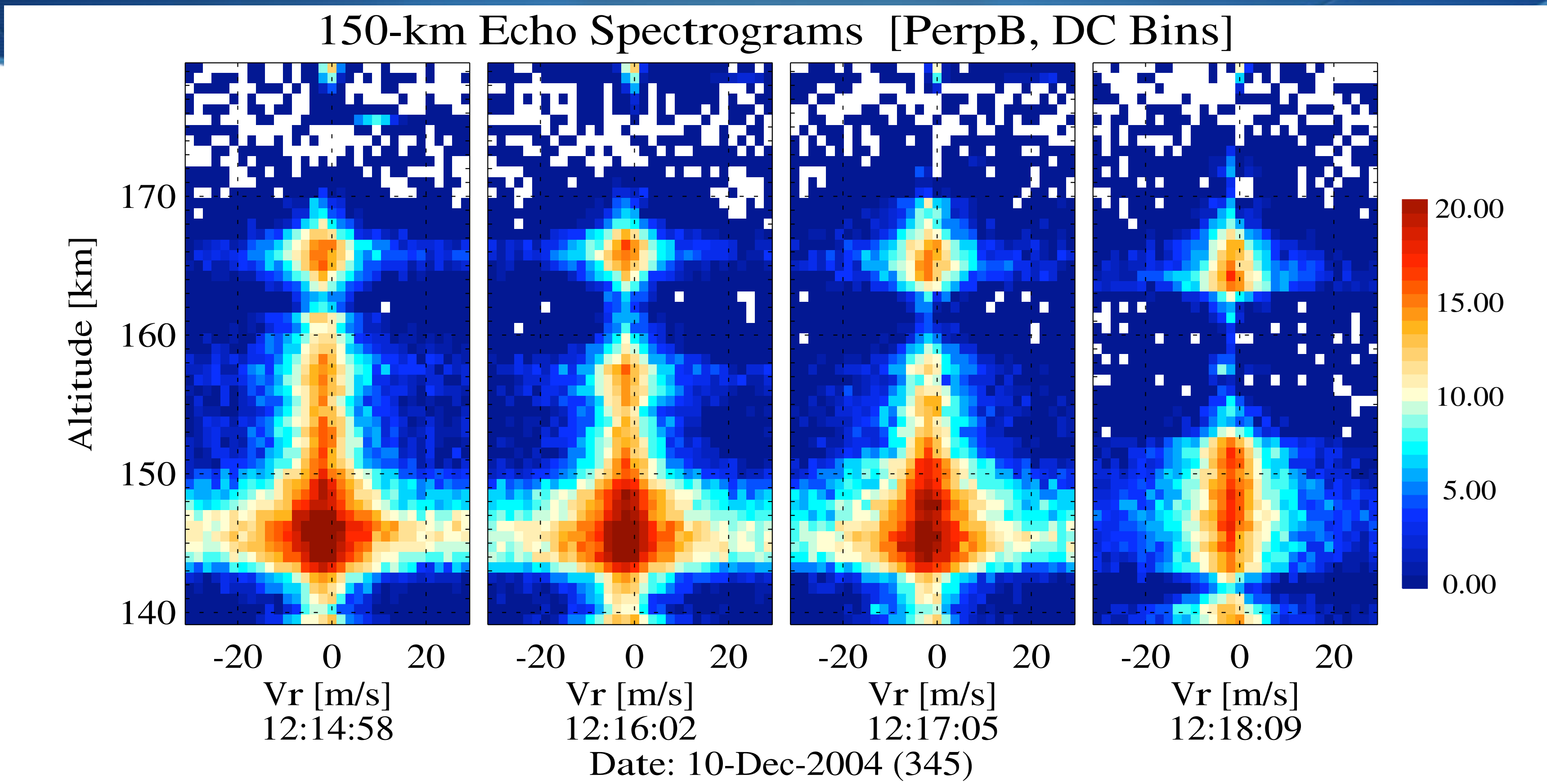


Naturally Enhanced Ion-acoustic Lines (NEILs) Oblique vs. Perpendicular Observations

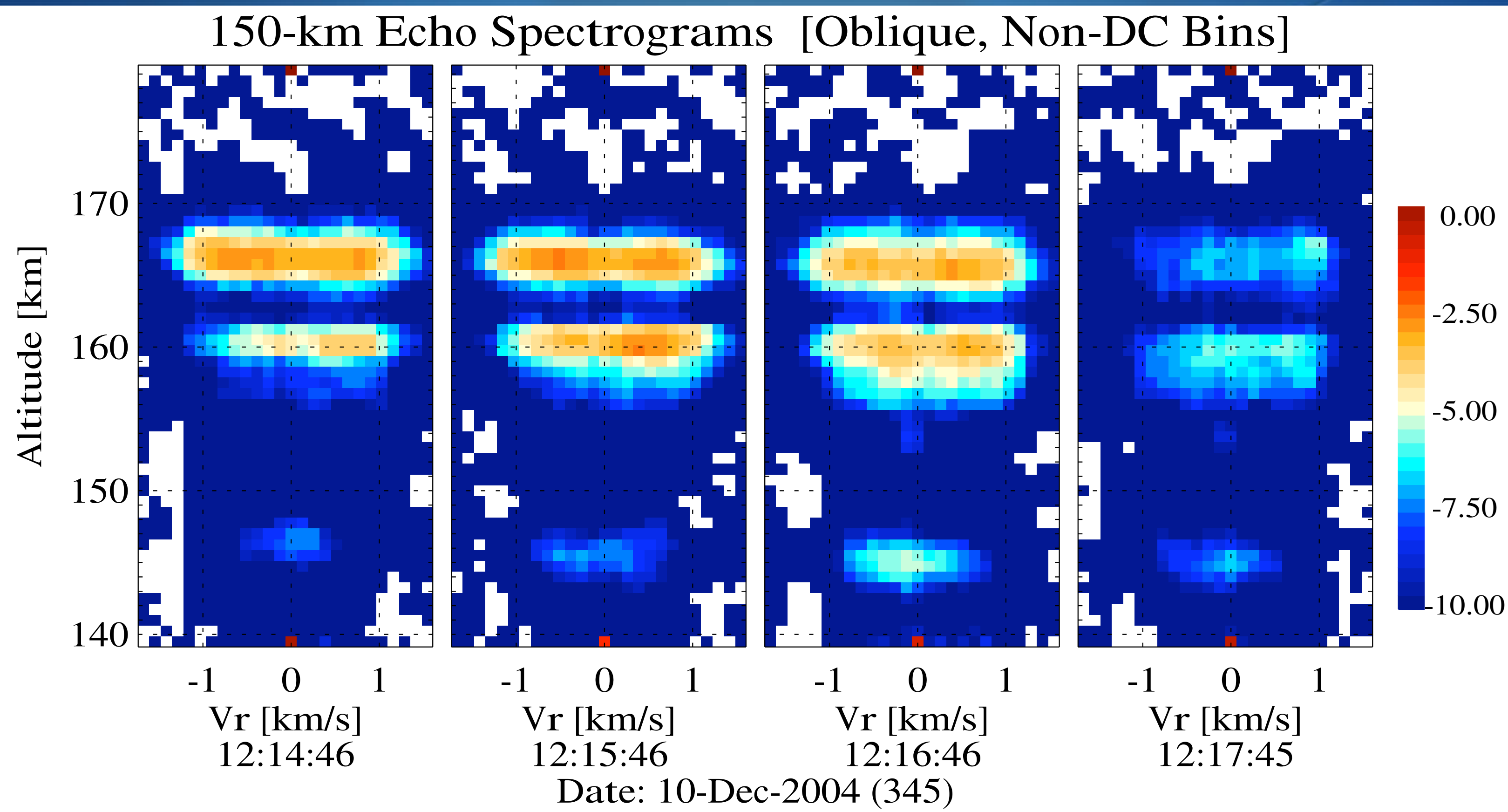




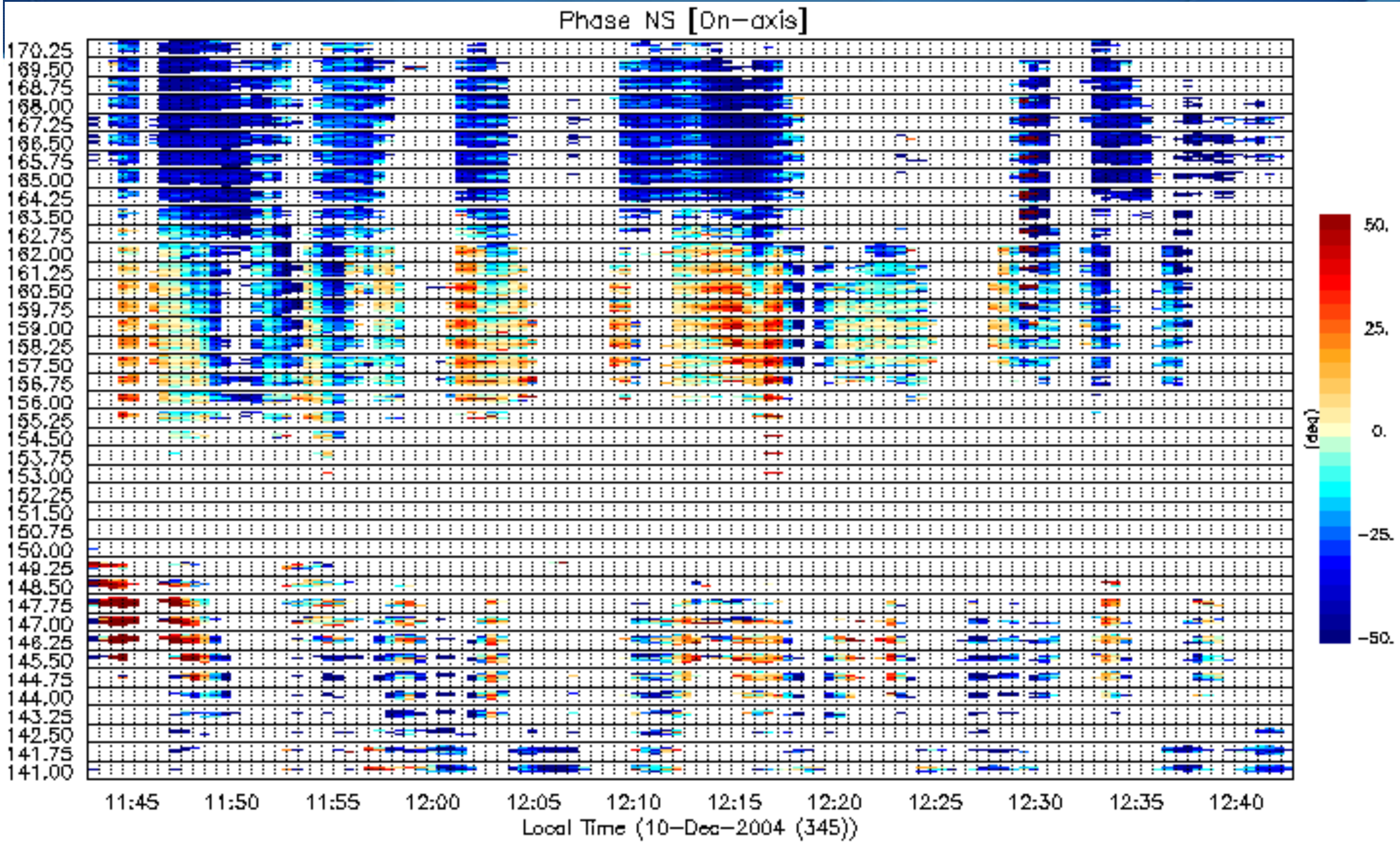
Perp. to B Spectrograms



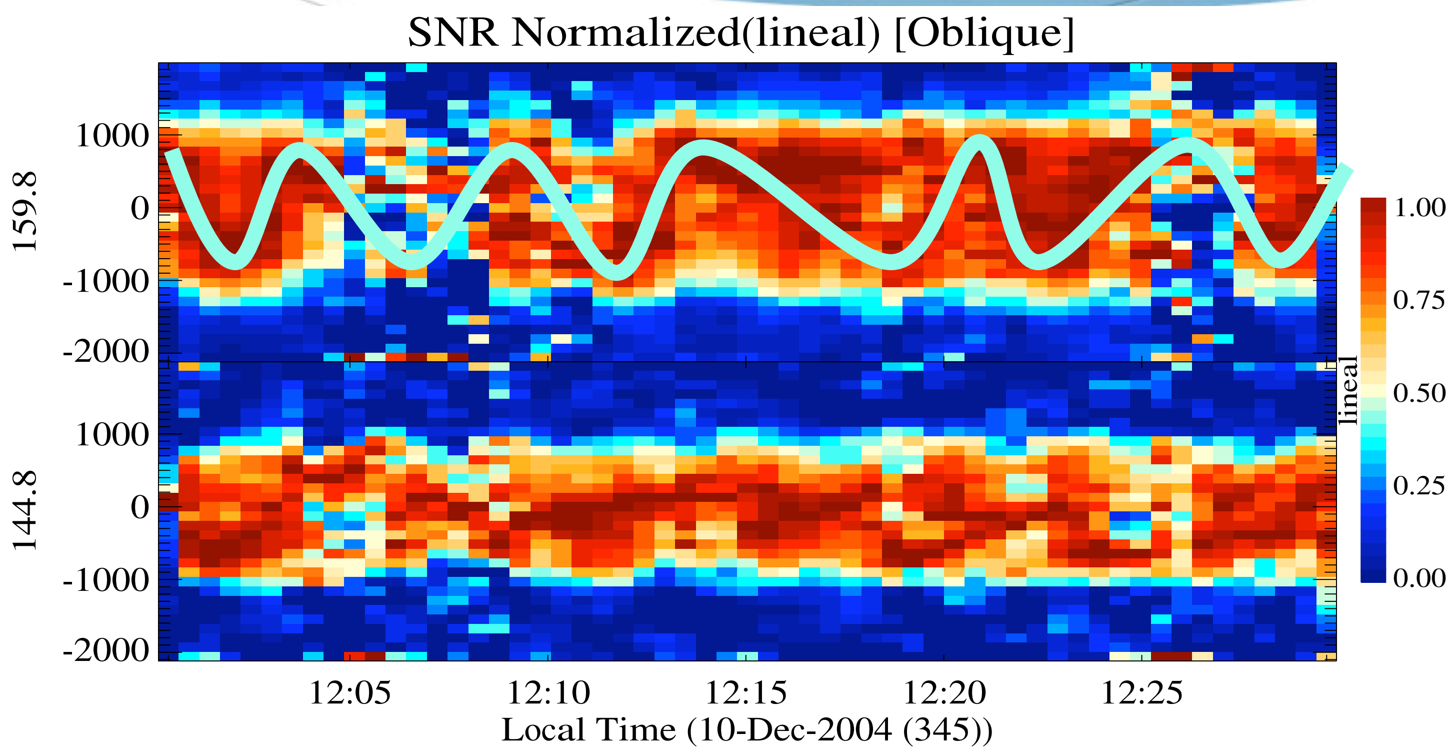
Oblique spectrogram



NEILs: NS Structure



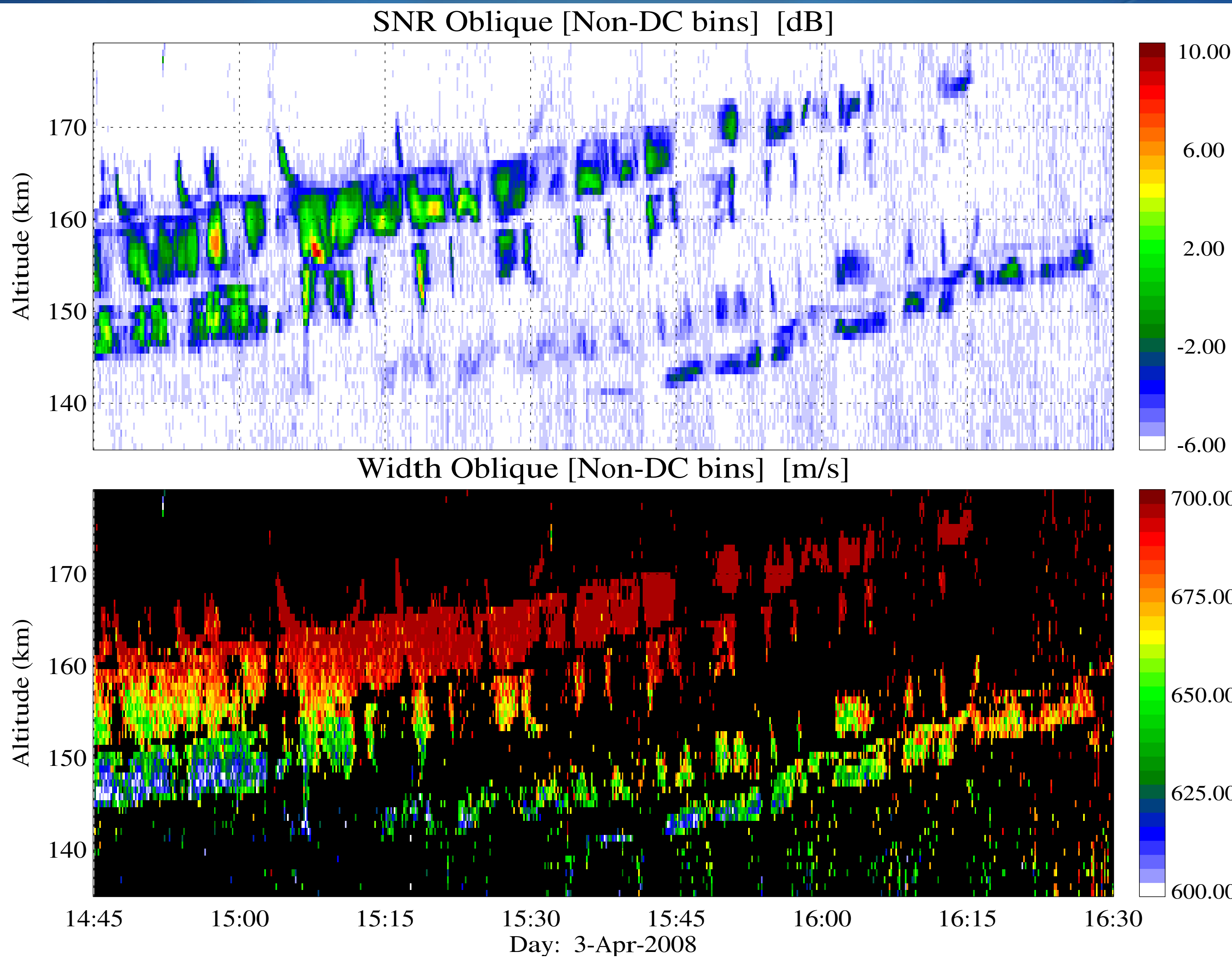
NEILs: spectrum asymmetry



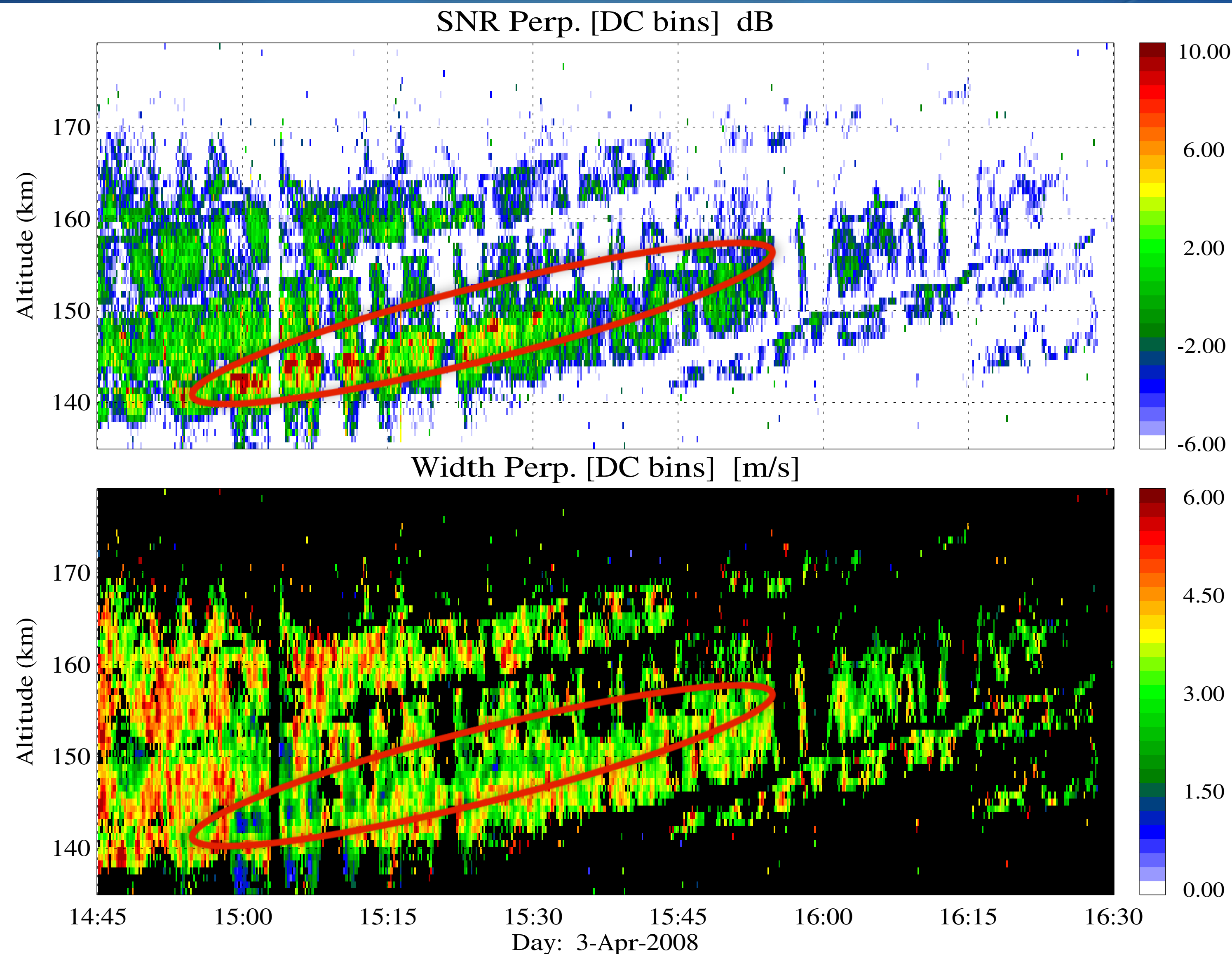
- Above 150 km: Spectra is wider and with an oscillating peak with a period ~5-10 min.
- Below 150 km: Spectra is narrower, peak is not well defined.

What causes the asymmetry?
Parallel currents?

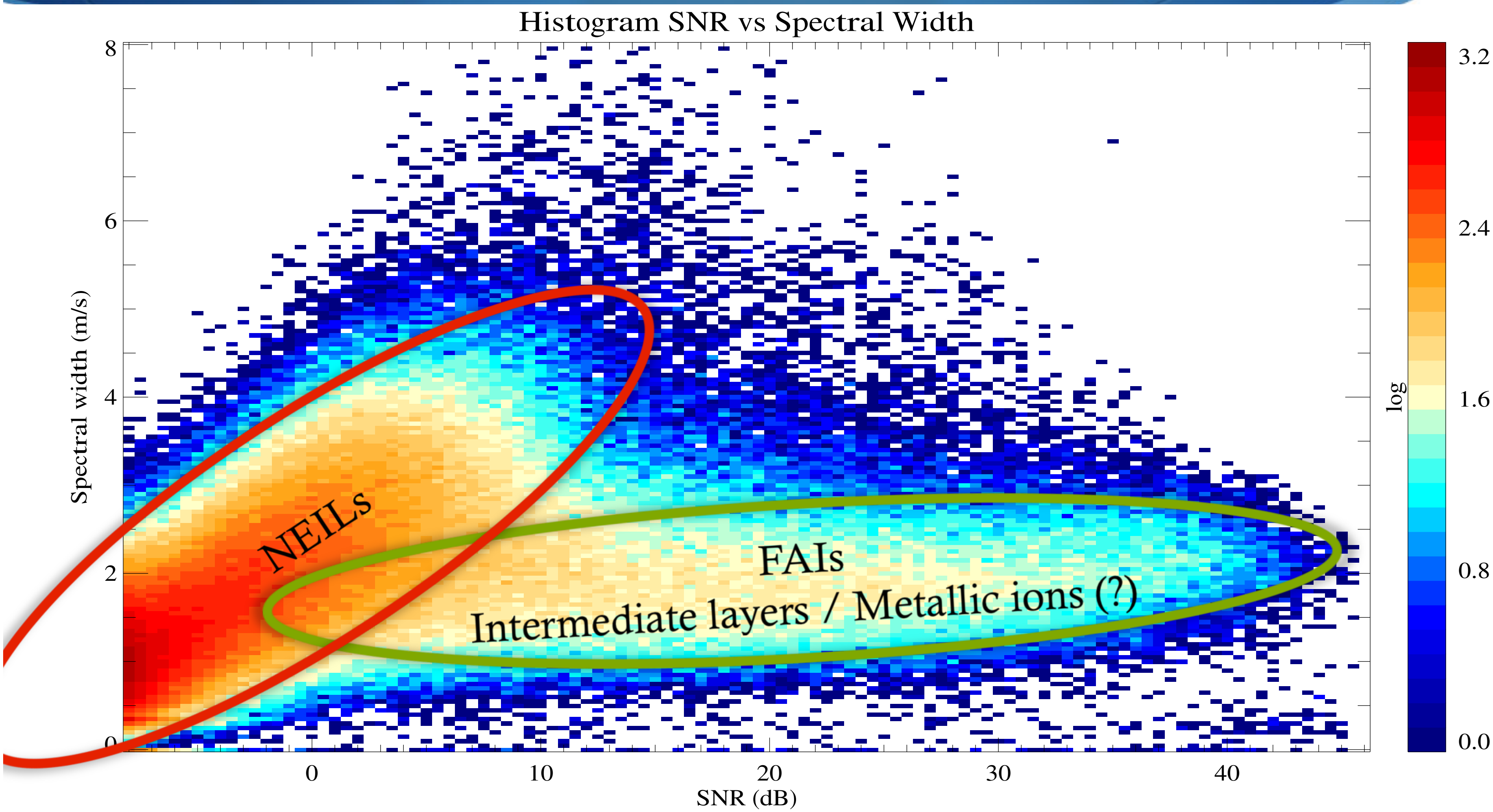
150-km Oblique Parameters



150-km Perpendicular Parameters



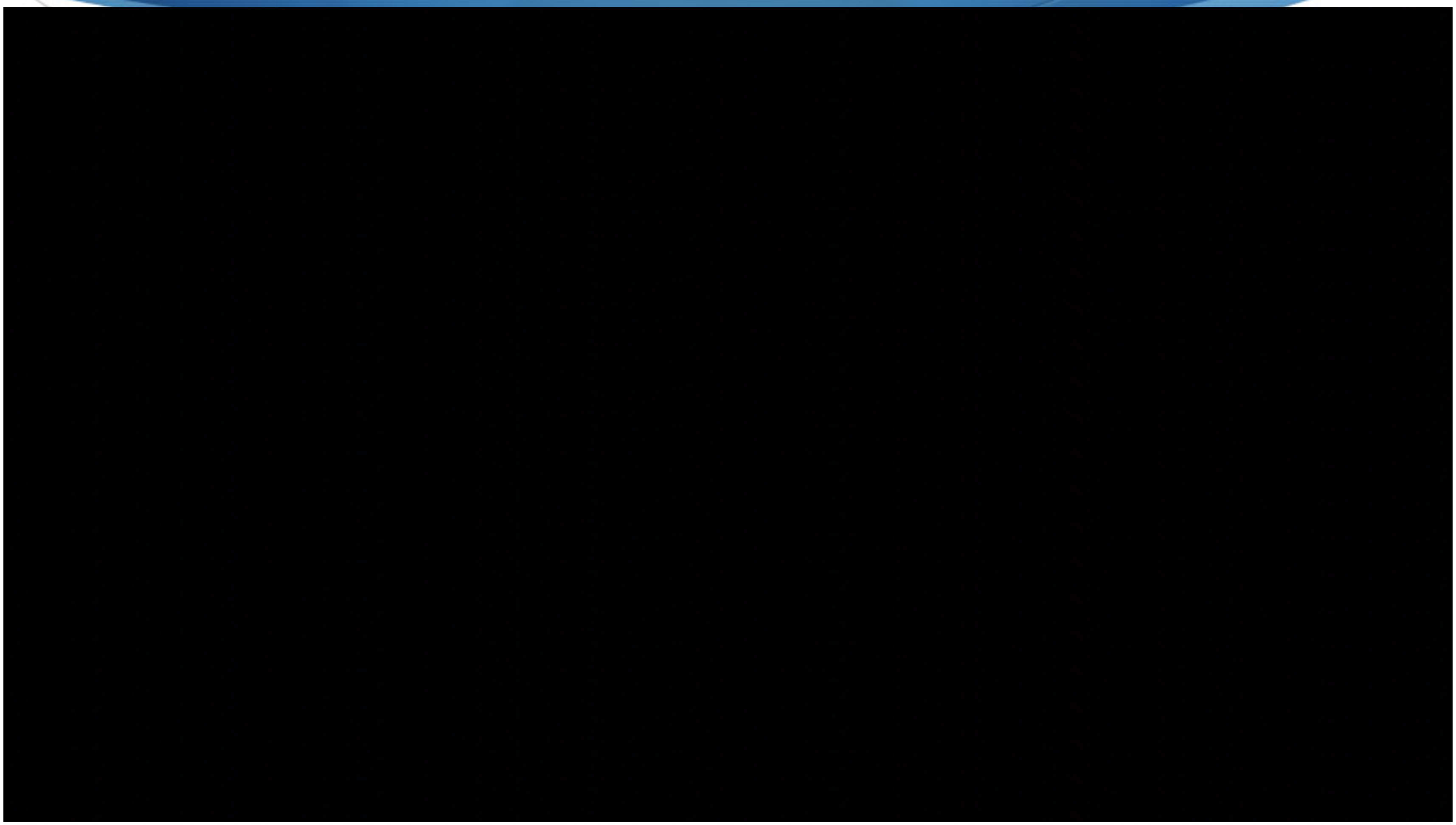
NEILs vs FAIs



Relevance to Aeronomy Important components

Variable	Evidence
Bottom F1 density gradient	Necklace, Eclipse echoes
Photoelectrons	Solar dependence, Necklace, Solar Flare, NEILs?
Gravity waves	“Pearls”, "Beads”, HF signatures
Metallic ions	Spectral width “independent” of SNR
Turbulence	Spectral width ∝ SNR
Meridional winds	NEILs NS angles, Intermediate layers
Tides	Intermediate layers
E region coupling	Pohnpei summer occurrence
Parallel currents	NEILs asymmetry
Alfven waves / EM effects	“Fishbone” echoes

The Six blind Men and 150-km echoes



adapated from http://www.youtube.com/watch?v=iBqgr5xZLz0

Relevance to Aeronomy

Radio Science Plasma Physics	Facility/Instrument Product	Aeronomy

Investigation

- Interferometry
- Bistatic Faraday Rotation
- Meteor-trails
- **150-km echoes**
- Small aspect angle IS effects
- Mesospheric echoes
- EEJ, ESF, irreg, μ physics
- Inverse methods

Capability

- Radar imaging
- E region densities, winds
- MLT winds
- **Comprehensive E-fields**
- Coulomb collision model
- Perp. IS modes
- Low-power modes
- Full-profile mode

Contribution

- C/NOFS Science
- ITM Coupling
- SSW
- Storms and PPE
- Photoelectrons
- Enhanced IS
- Therm. grav. Wave
- Topside
- E/F coupling

Relevance to Aeronomy: Understanding the echoes

will require

- Improvement of radar techniques and instruments
- Additional instruments/ measurements
- Finding and testing the plasma/ instabilities and plasma/neutral coupling at work.

e.g., pulsing schemes, inverse theory, higher dynamic range rxs, ..

e.g., AMISR, Heater, in-situ probes (rockets, sub orbital vehicles), …

e.g., learning from the heating community, PIC simulators, …

Relevance to Aeronomy: Understanding the echoes

will require

- Improvement of radar techniques and instruments
- Additional instruments/ measurements
- Finding and testing the plasma/ instabilities and plasma/neutral coupling at work

would allow

- Understanding of fundamental physics.
- Better definition of the daytime Ne at the low latitude valley region
- Measurements of Vx, Te, Ti, and composition of the valley region, with less sensitive radars.
- The understanding of the role of neutral dynamics, including lower atmospheric forcing, not only in the echoes but also in the region.

Where do we stand? (1)

- There are mainly two types of echoes:
  - From Field-Aligned Irregularities (FAIs) (the minority at Jicamarca and majority at other less sensitive sites)
  - From Naturally Enhanced Ion-Acoustic Lines (NEILs) (majority of echoes at Jicamarca)

- Possible sources of energy
  - Density gradients for FAI + metallic ions
  - Small density gradients + Photoelectrons for NEILs: a kind of kinetic instability process whereby photoelectron energy is channeled to enhance the ion/electron lines off-perp/perp B at meter scales.

Perhaps, in both cases meridional GW action has a way of modulating the enhancement process, e.g., via parallel currents driven in the region.

Variable
Bottom F1 density gradient
Photoelectrons
Gravity waves
Metallic ions
Turbulence
Meridional winds
Tides
E-region coupling
Parallel currents
Alfven waves / EM effects

Where do we stand? (2)

- Understanding the enhancement process
  - This might be the last frontier for ISR theory, perhaps understand the role of production on ISR:
    - A sort of "production noise" peculiar to the equatorial ionosphere owing to its "distance" (field aligned) from the underlying E-region terminators.
      - Recall that 7-10 min pulsations ("pearls") have an underlying ~10-30 s pulsations (Alfven waves?)
- … why only at low latitudes and meter scale frequencies?

Variable
Bottom F1 density gradient
Photoelectrons
Gravity waves
Metallic ions
Turbulence
Meridional winds
Tides
E-region coupling
Parallel currents
Alfven waves / EM effects