Lessons learned observing Farley Buneman waves at low, middle, and high latitudes

D. L. Hysell[1], G. Michhue[1], M. F. Larsen[2], R. Pfaff[3], and J. L. Chau[4]

(1) Earth and Atmospheric Science, Cornell University, Ithaca, New York

(2) Physics and Astronomy, Clemson University, Clemson, South Carolina

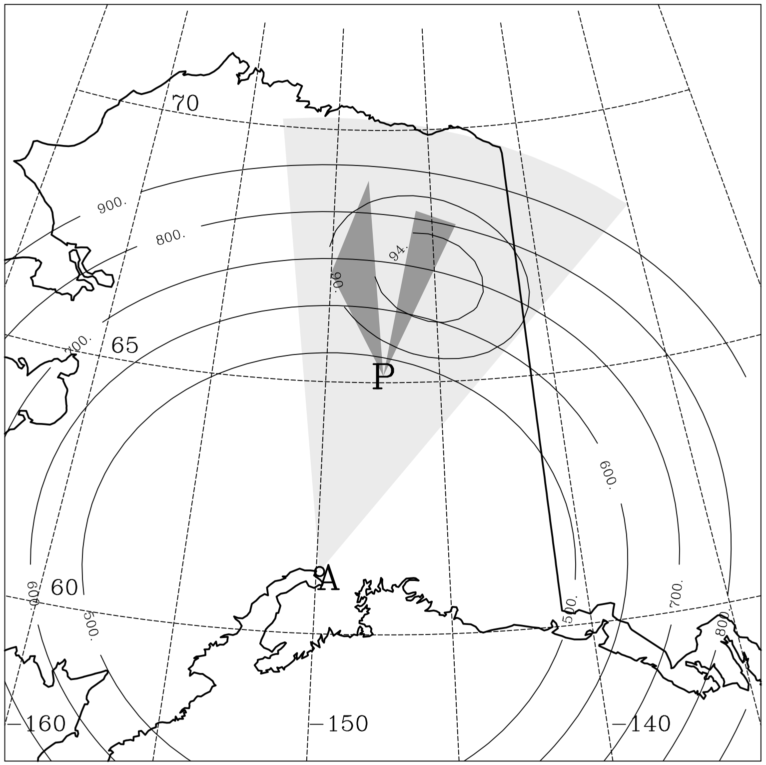
(3) Goddard Space Flight Center, Greenbelt, Maryland

(4) Jicamarca Radio Observatory, Lima, Perú

Farley-Buneman waves

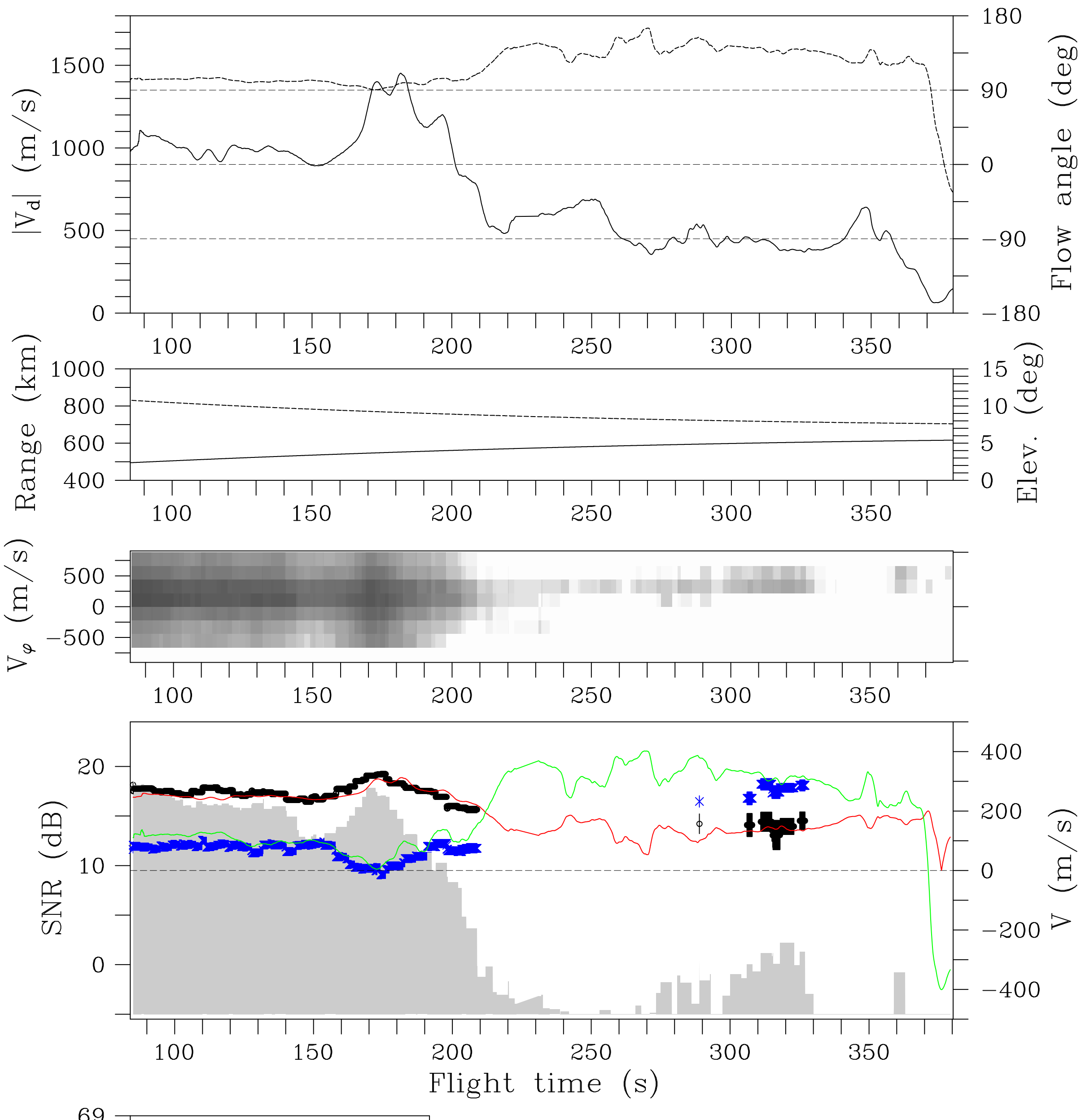
Factors complicating Farley-Buneman wave physics at different latitudes:

- high: strong forcing, wave heating, $k_{||}$ effects
- mid: sporadic *E* layer properties: morphology, composition
- low: large-scale waves



Jan. 17, 2007

JOULE I



|V_d| (m/s)
Flow angle (deg)
1500
1000
500
0
180
90
0
−90
−180
100
150
200
250
300
350
Range (km)
Elev. (deg)
1000
800
600
400
15
10
5
0
V_φ (m/s)
500
0
−500
SNR (dB)
V (m/s)
20
10
0
400
200
0
−200
−400
Flight time (s)

heuristic model

$$\hat{C}_s(V_d) = 400 + 1.1 \times 10^{-4} V_d^2$$

$$\overline{\omega}/k = \hat{C}_s(V_d)\cos\theta + v$$

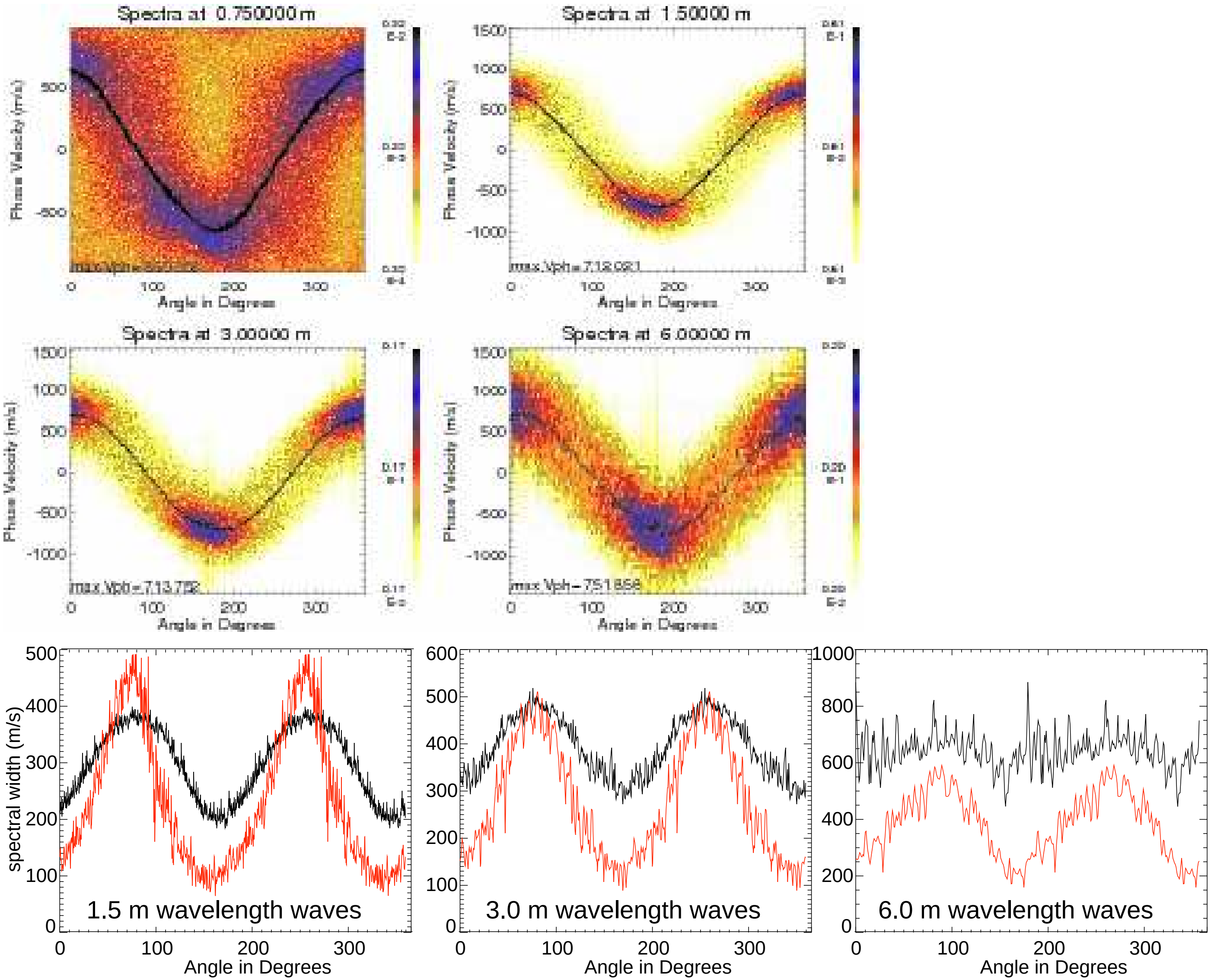
$$\delta\omega_{\mathrm{rms}}/k = \alpha \hat{C}_s(V_d)|\sin\theta| \quad \alpha \sim 1/2$$

$$v_\phi = v_g \cos\theta$$

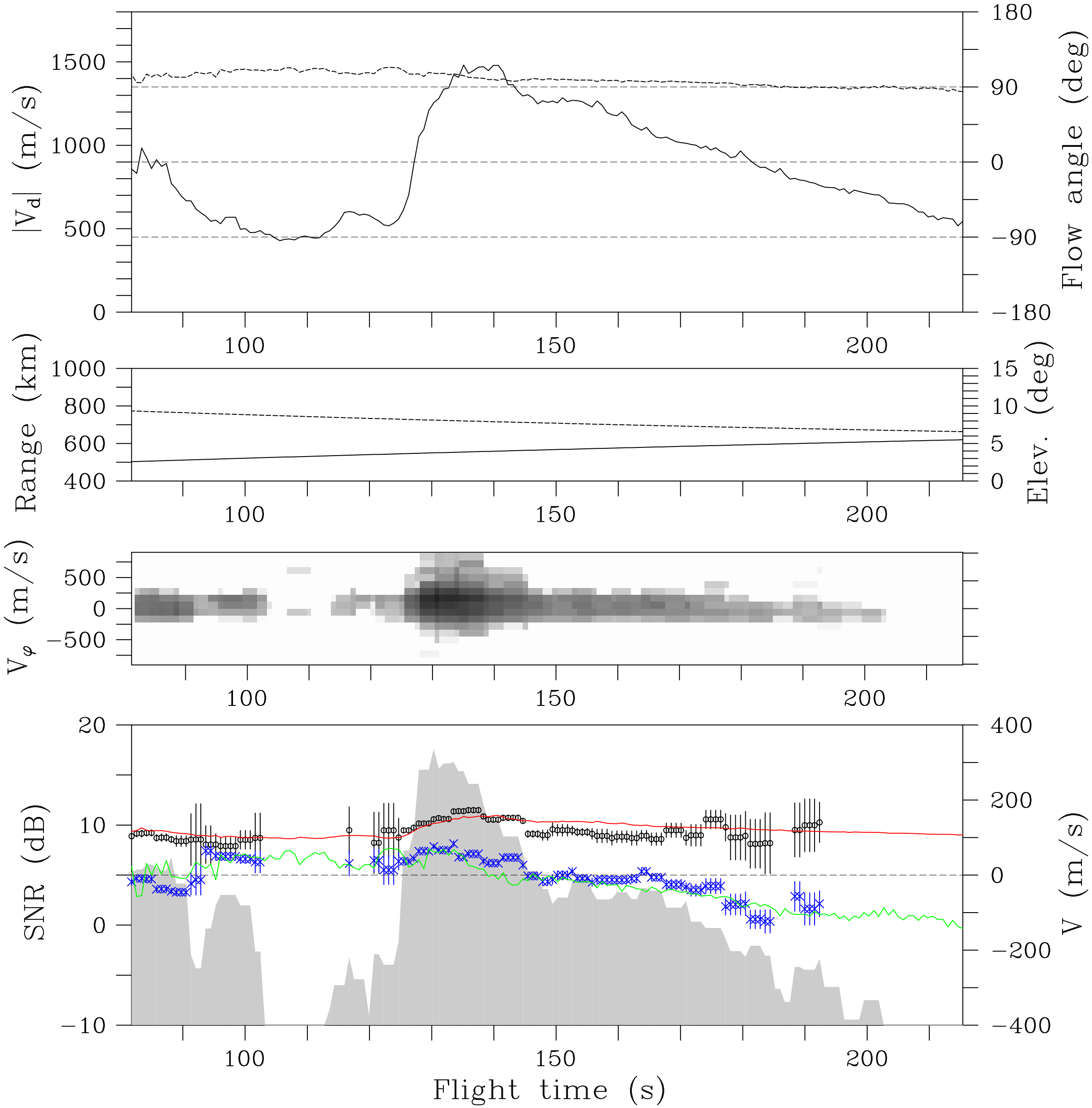
$$\delta\omega_{rms} = |\sin\theta| \left(\sqrt{k^2 C_s^2 + \Gamma^2} - \Gamma \right)$$

$$\Gamma \equiv \frac{\nu_i \Omega_e}{2\nu_e} \frac{\mathcal{C}}{k L_{rms}}$$

PIC simulations

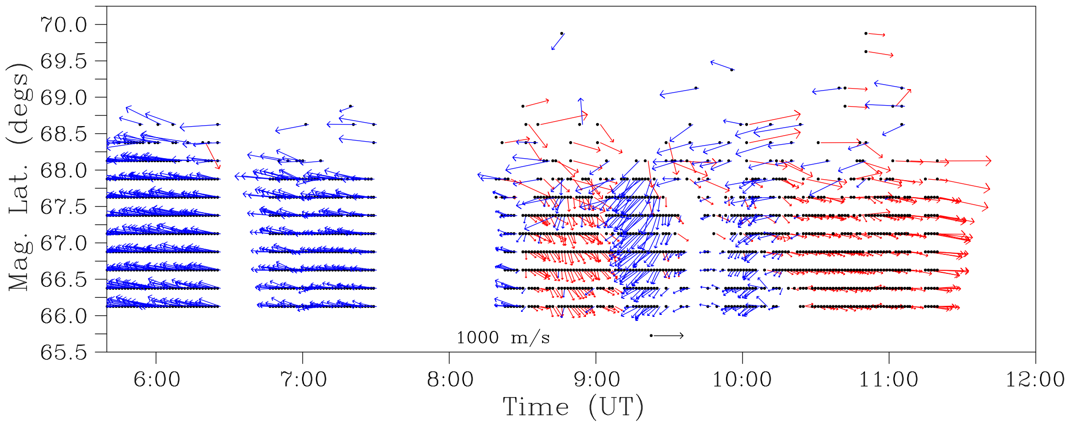


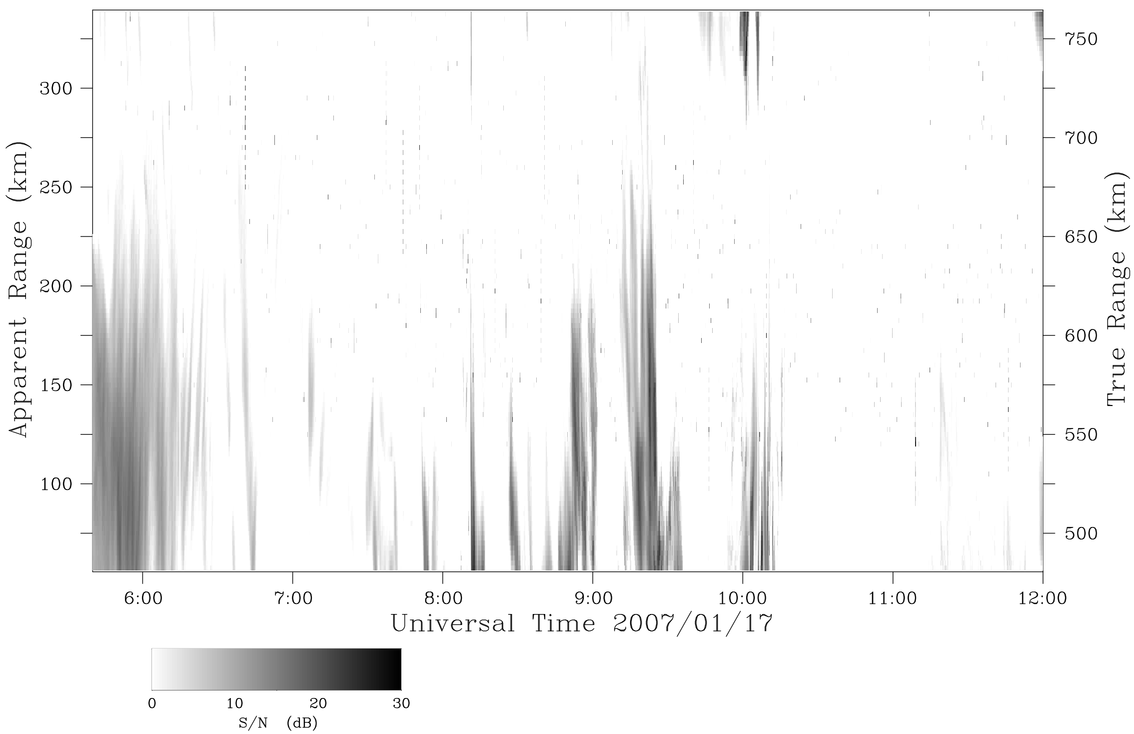
JOULE II



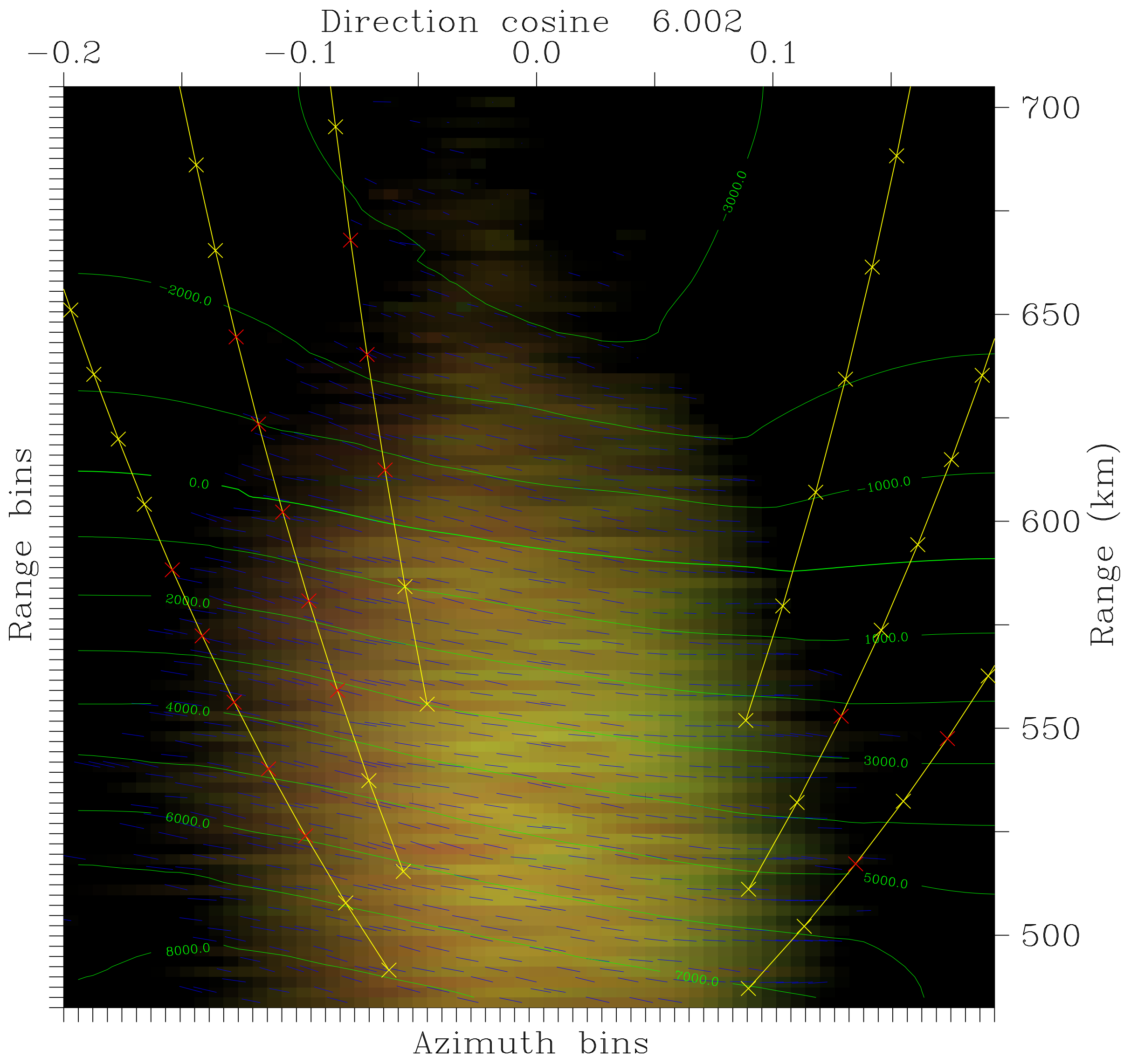
|V_d| (m/s)
Flow angle (deg)
1500
1000
500
0
180
90
0
−90
−180
100
150
200
Range (km)
Elev. (deg)
1000
800
600
400
15
10
5
0
V_φ (m/s)
500
0
−500
SNR (dB)
20
10
0
−10
V (m/s)
400
200
−200
−400
Flight time (s)

PFISR convection

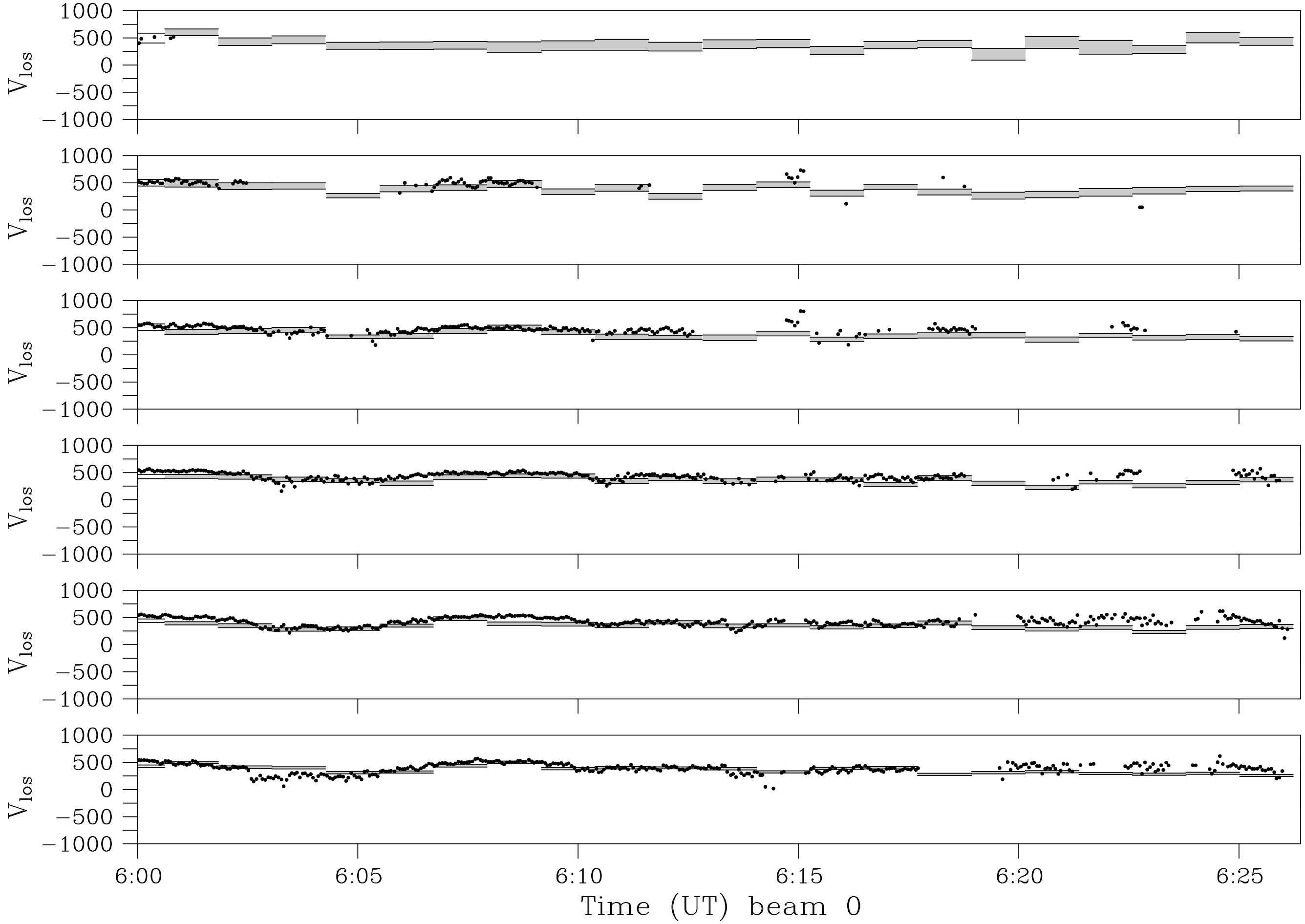




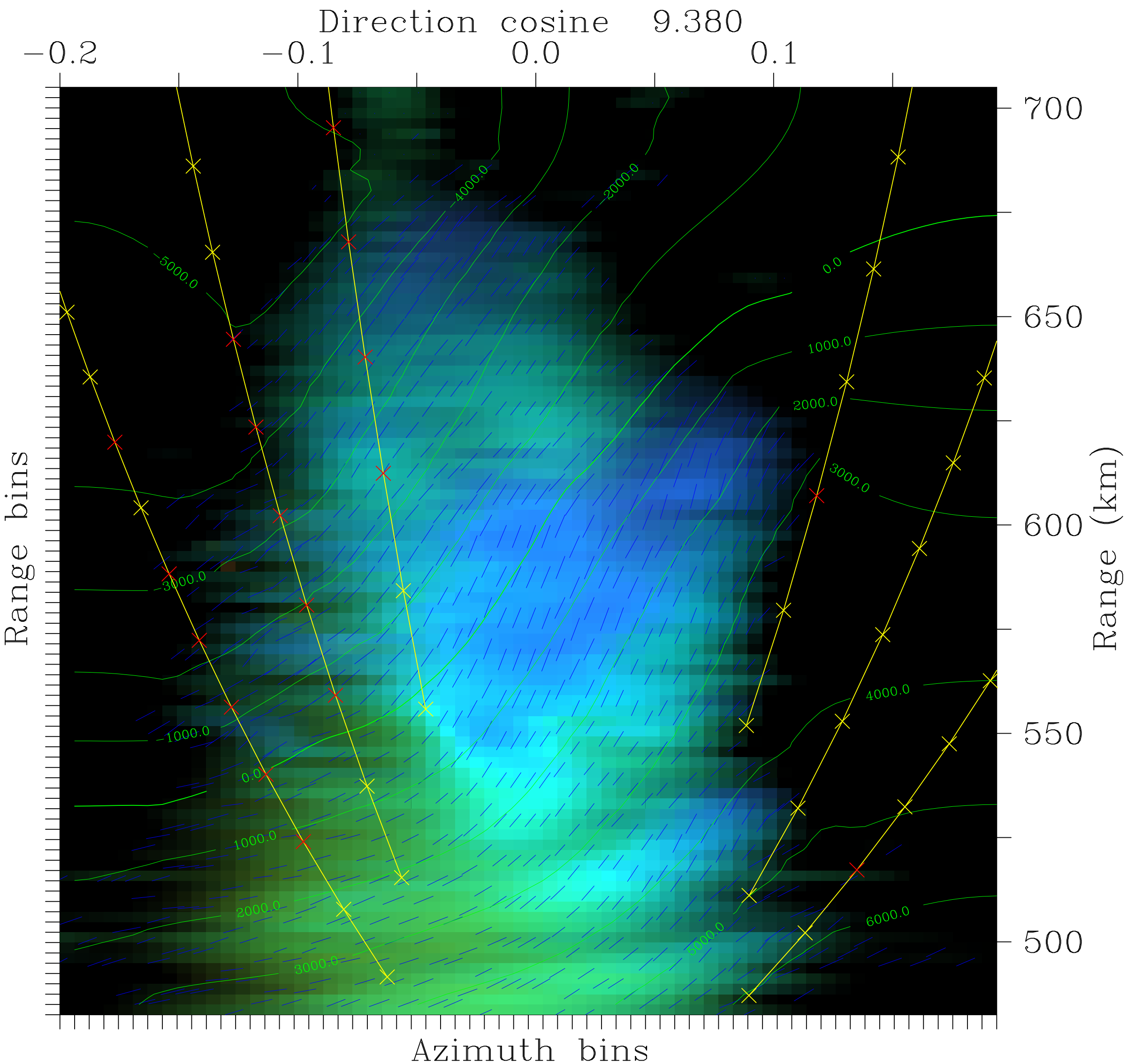
0600 UT


Direction cosine 6.002
−0.2
−0.1
0.0
0.1
700
650
600
550
500
Range (km)
Range bins
Azimuth bins
−3000.0
−2000.0
−1000.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
8000.0

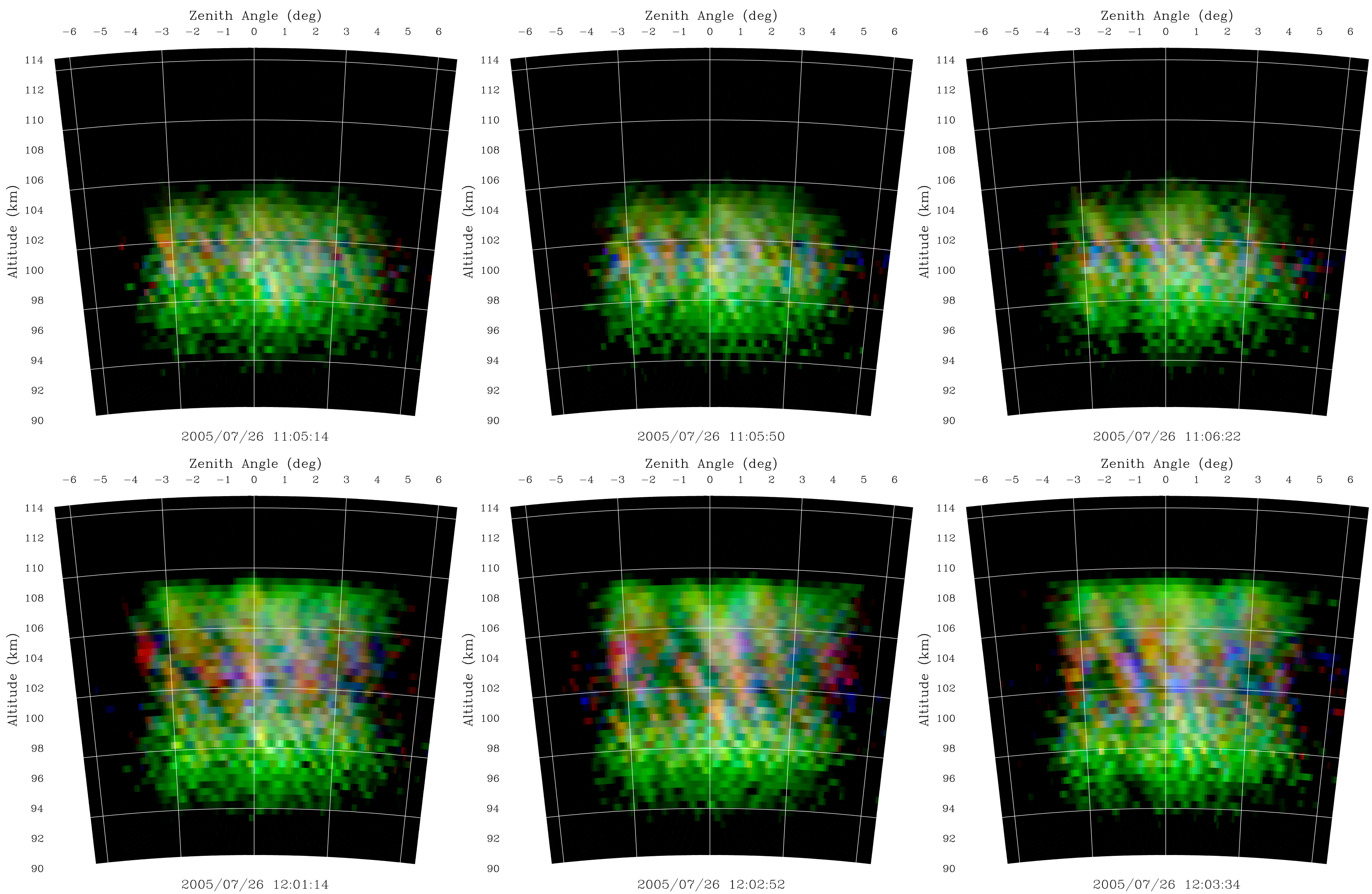
PFISR los



0925 UT

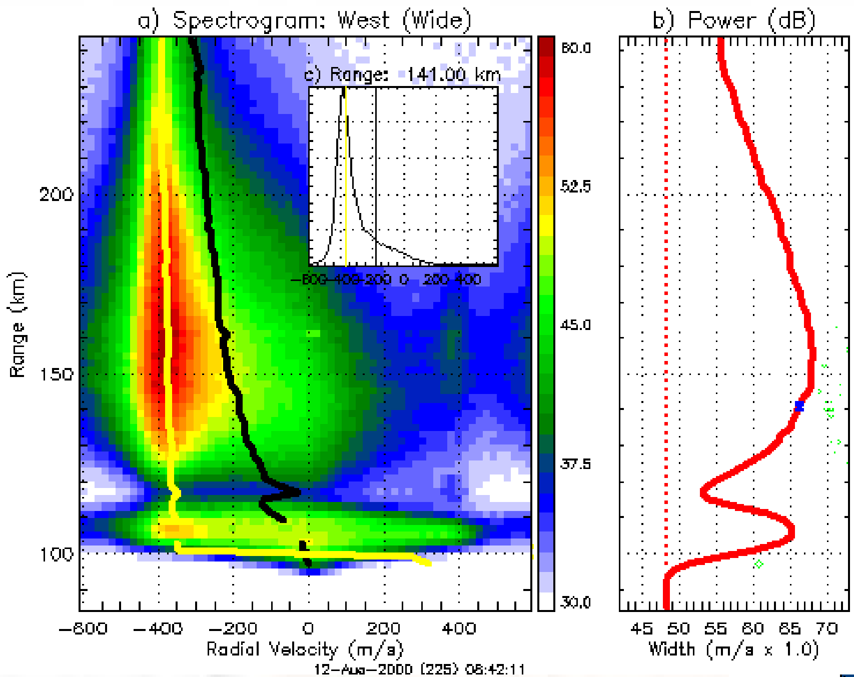

Direction cosine 9.380
−0.2
−0.1
0.0
0.1
700
650
600
550
500
Range bins
Range (km)
Azimuth bins

large-scale waves



Normal vs. Counter EEJ Spectra

(*Woodman and Chau* [2002])

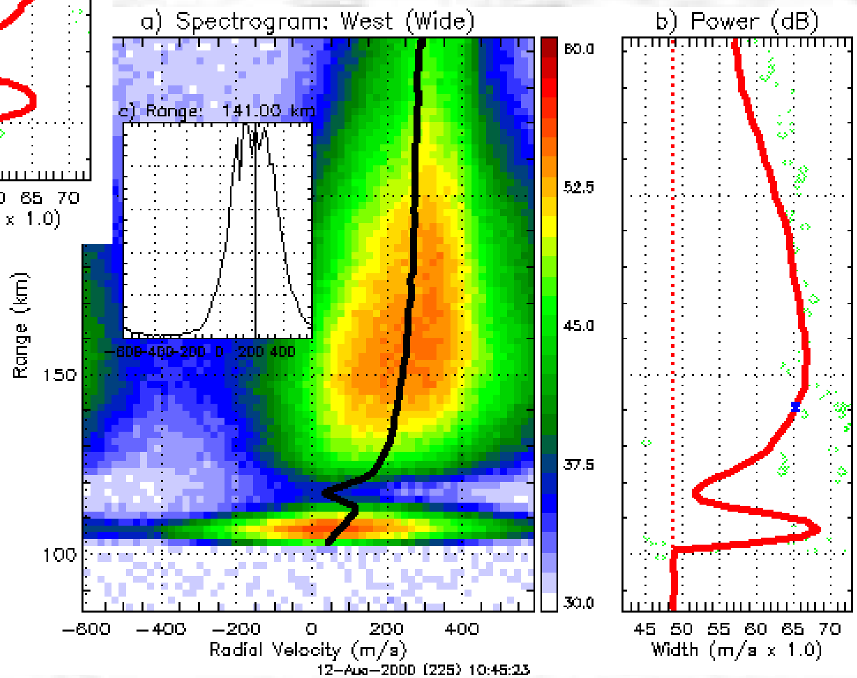


Normal

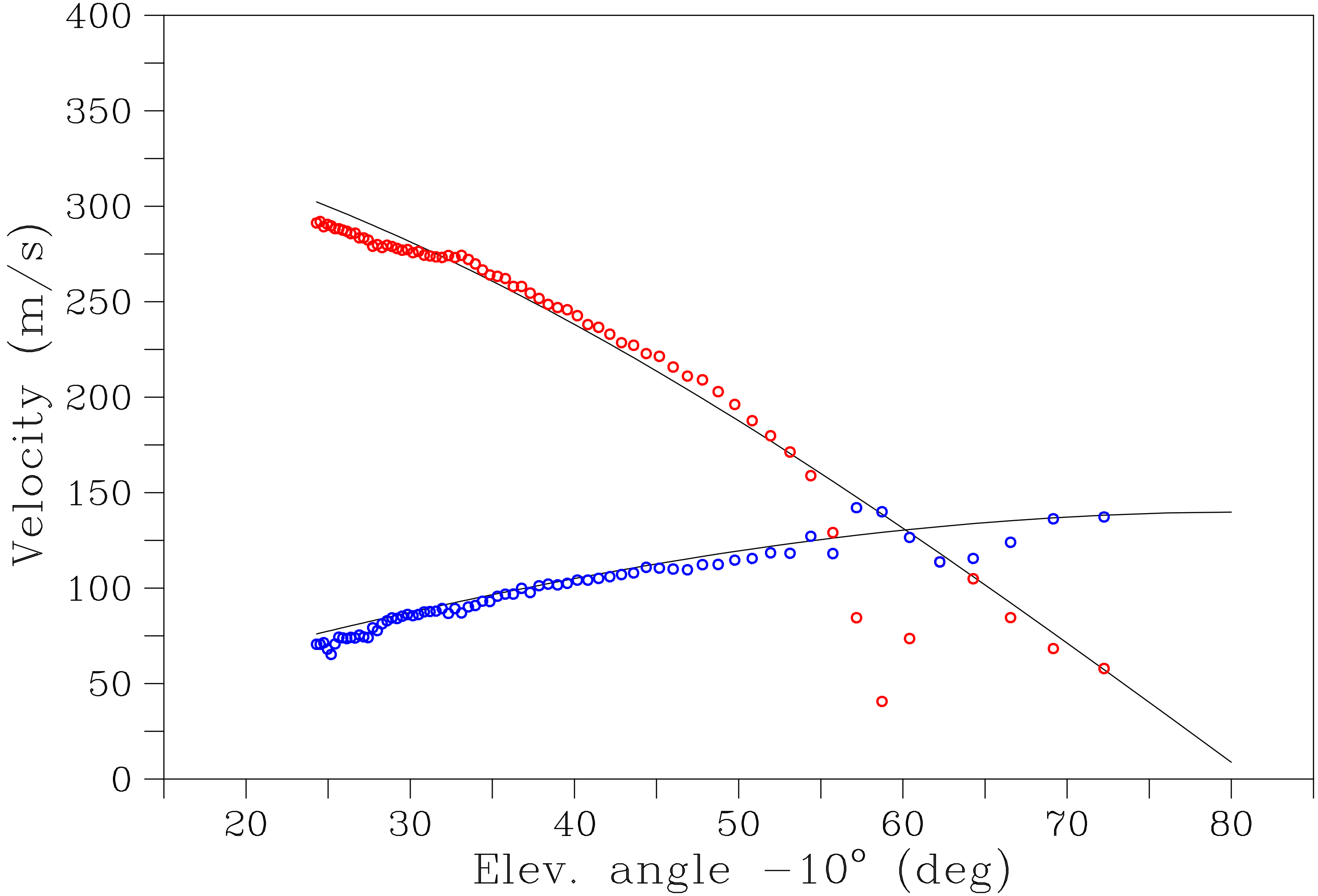
- Type I (yellow) and type II (black) echoes.

CEEJ

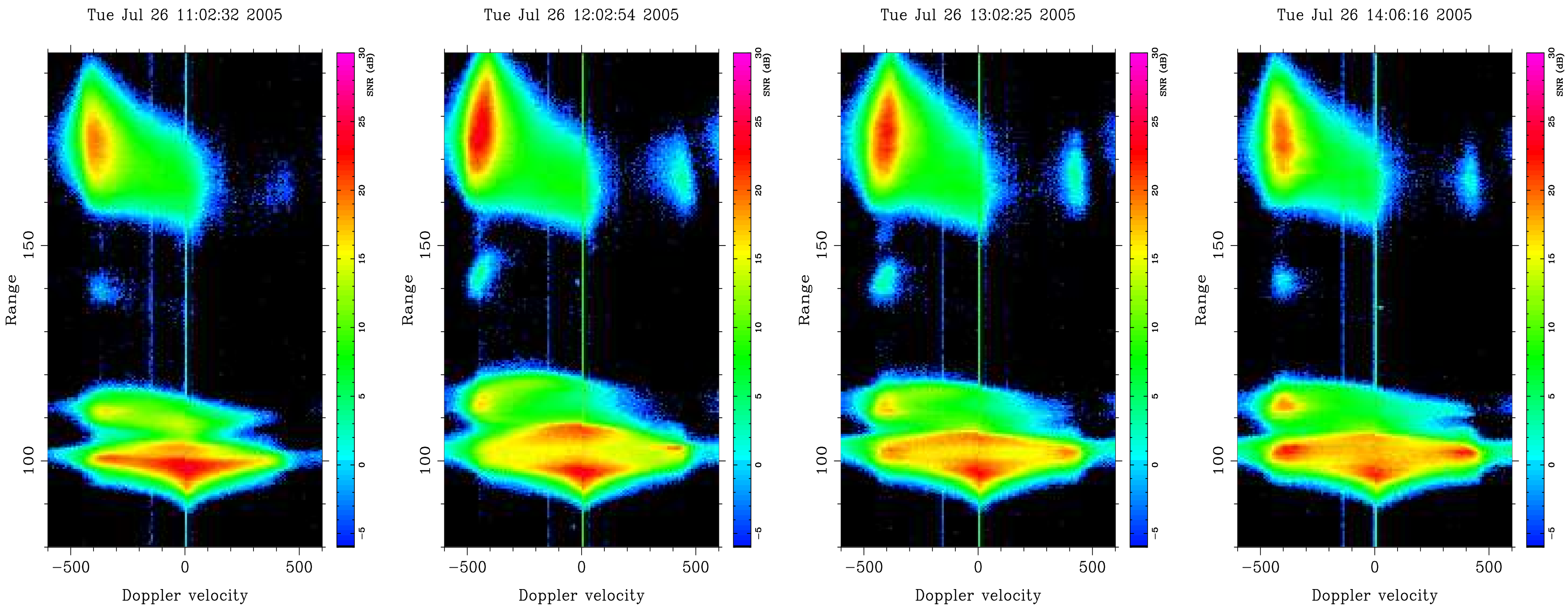
- Pure type I echoes, Doppler shows cosine dependence!



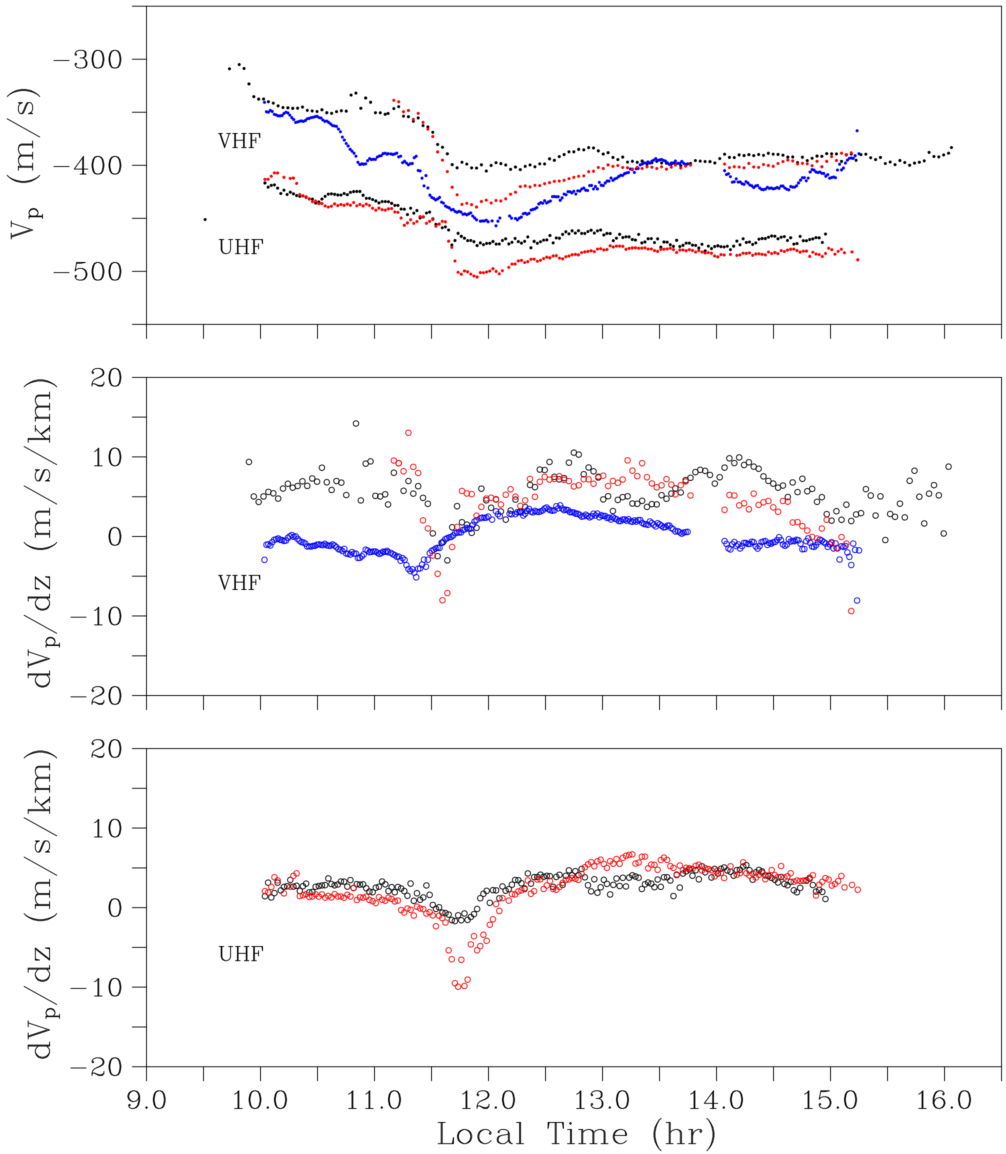
counter electrojet



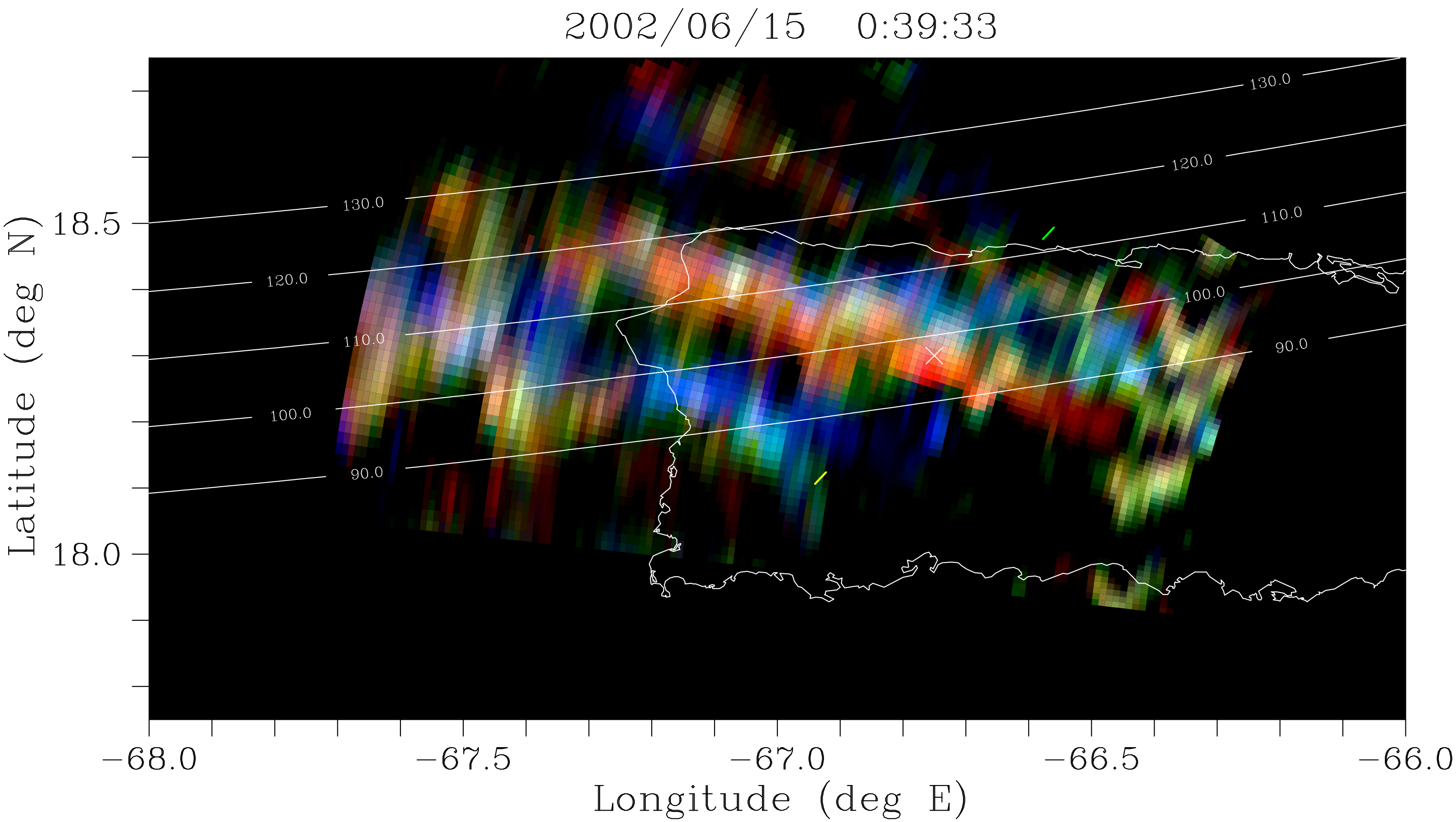
oblique echoes



line-of-sight Doppler 102 km



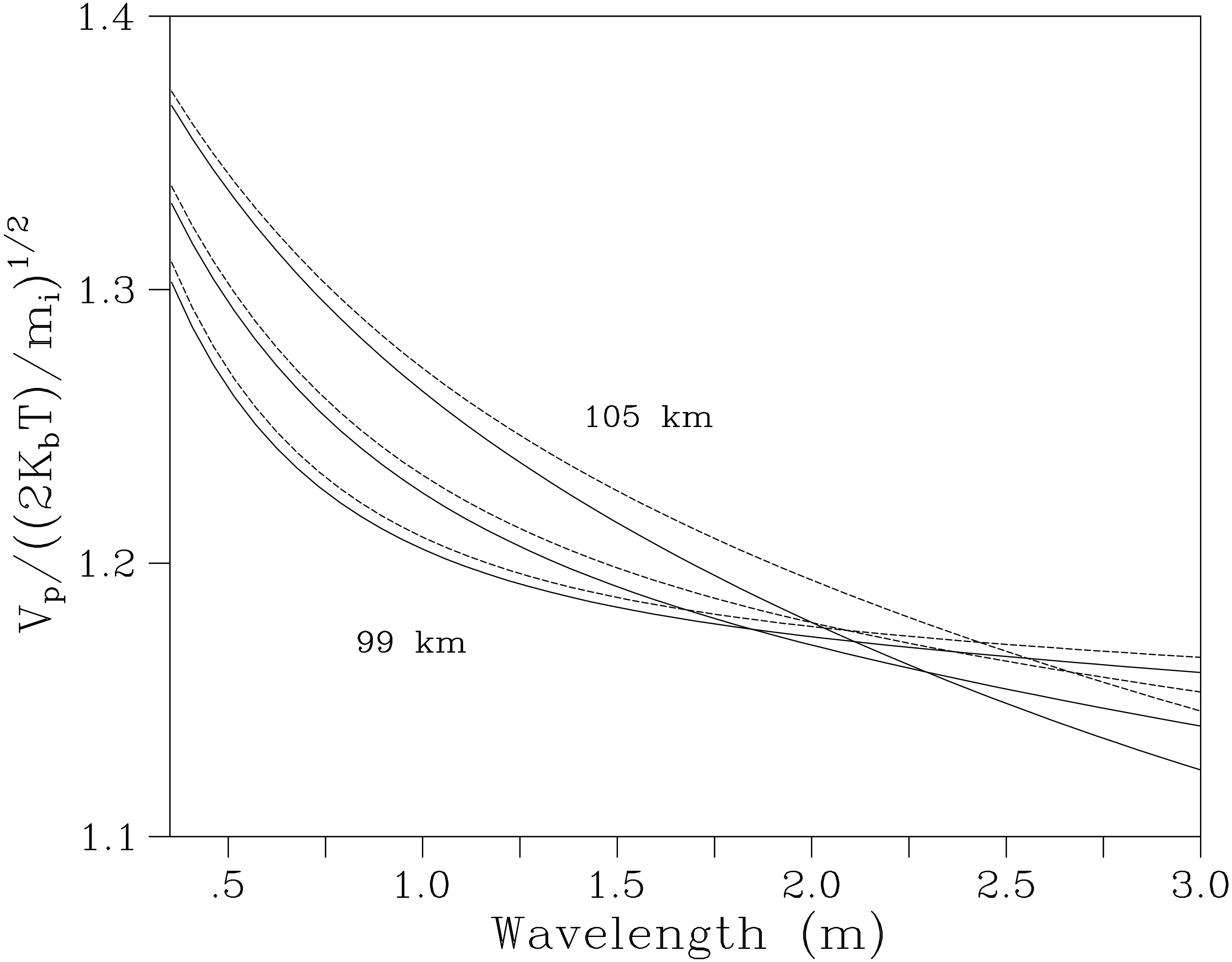
midlatitude implications?



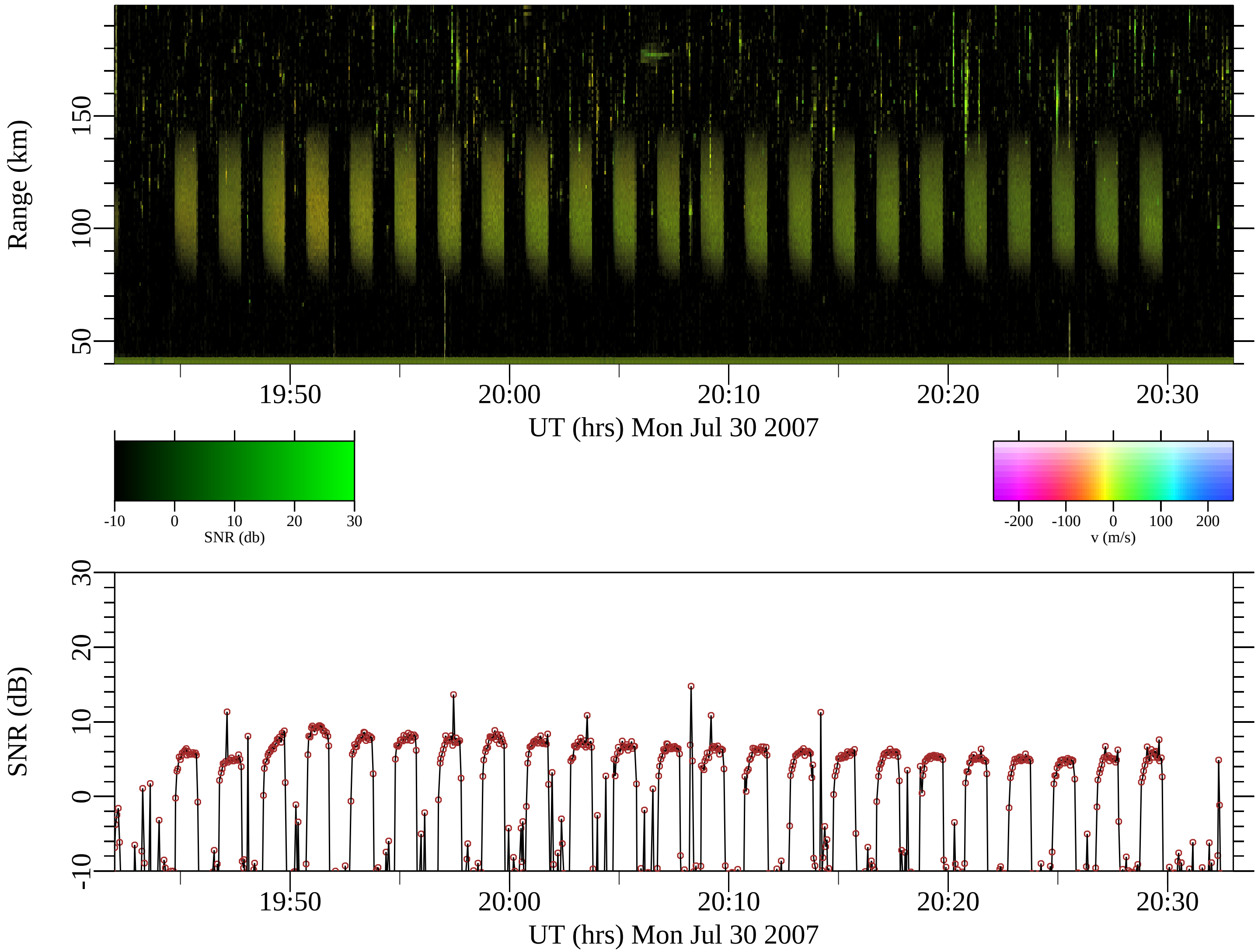
summary

- Spectral moments of coherent echoes from Farley Buneman waves in auroral electrojet are predictable, invertible functions of the vector electric field.
- Absent radar imaging, radar spectra are apt to represent a spatial superposition. Note that small flow angle echoes will tend to dominate the composite spectra when they are present.
- Large-scale waves permit all (or almost all) flow angles to be present within the scattering volume in the equatorial electrojet.
- Sine/cosine spectral moments again evident in equatorial counter electrojet, where flow angle can be readily identified.
- Similar ideas probably hold at midlatitudes (beware).

electron thermal effects

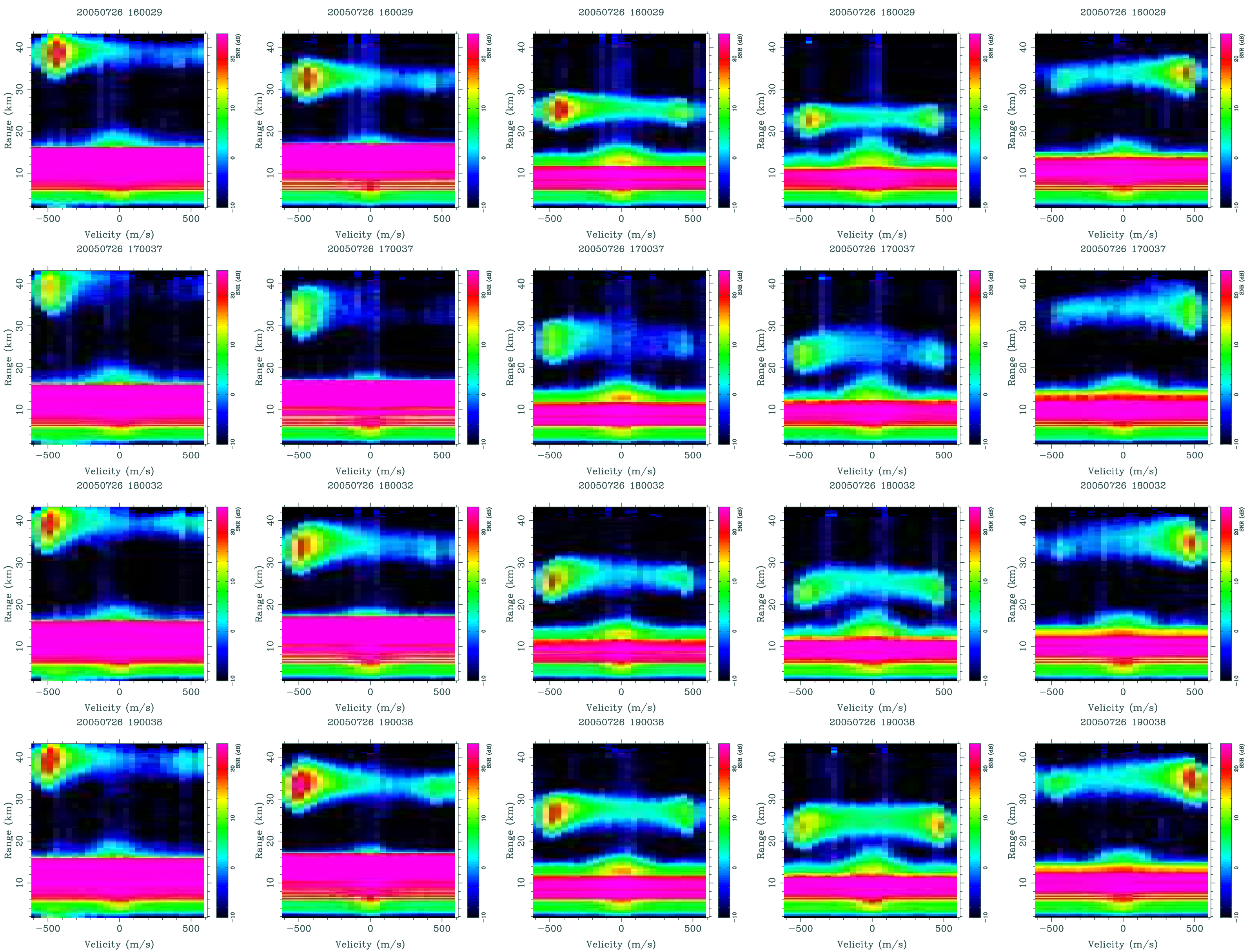


ionospheric modifications



July 30, 2007

UHF results


20050726 160029
20050726 170037
20050726 180032
20050726 190038
Range (km)
Velicity (m/s)
SNR (dB)