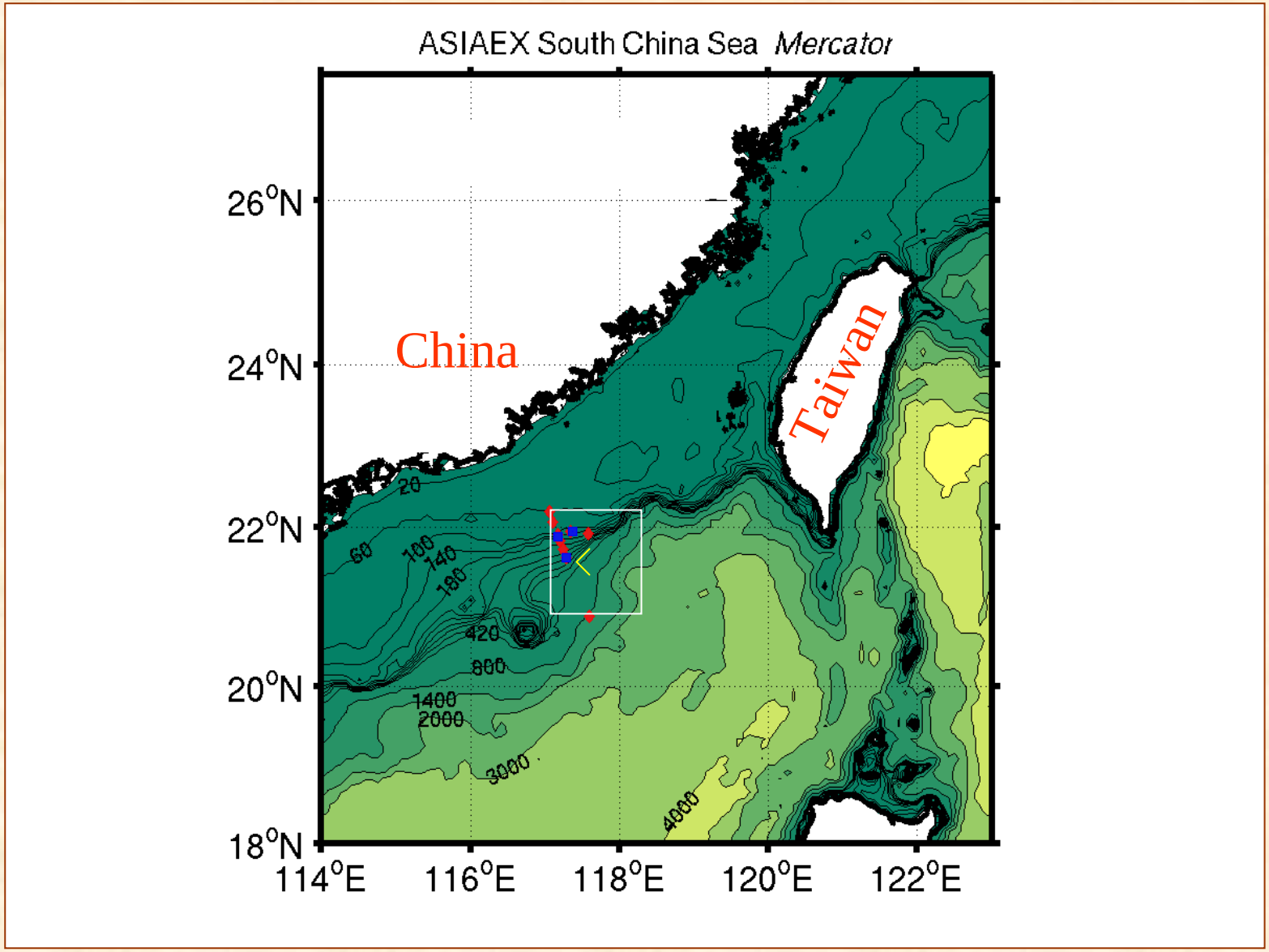
Fluctuating pulse statistics in a South China Sea Shelfbreak area*, and issues regarding data, theory and simulation comparisons

Timothy Duda

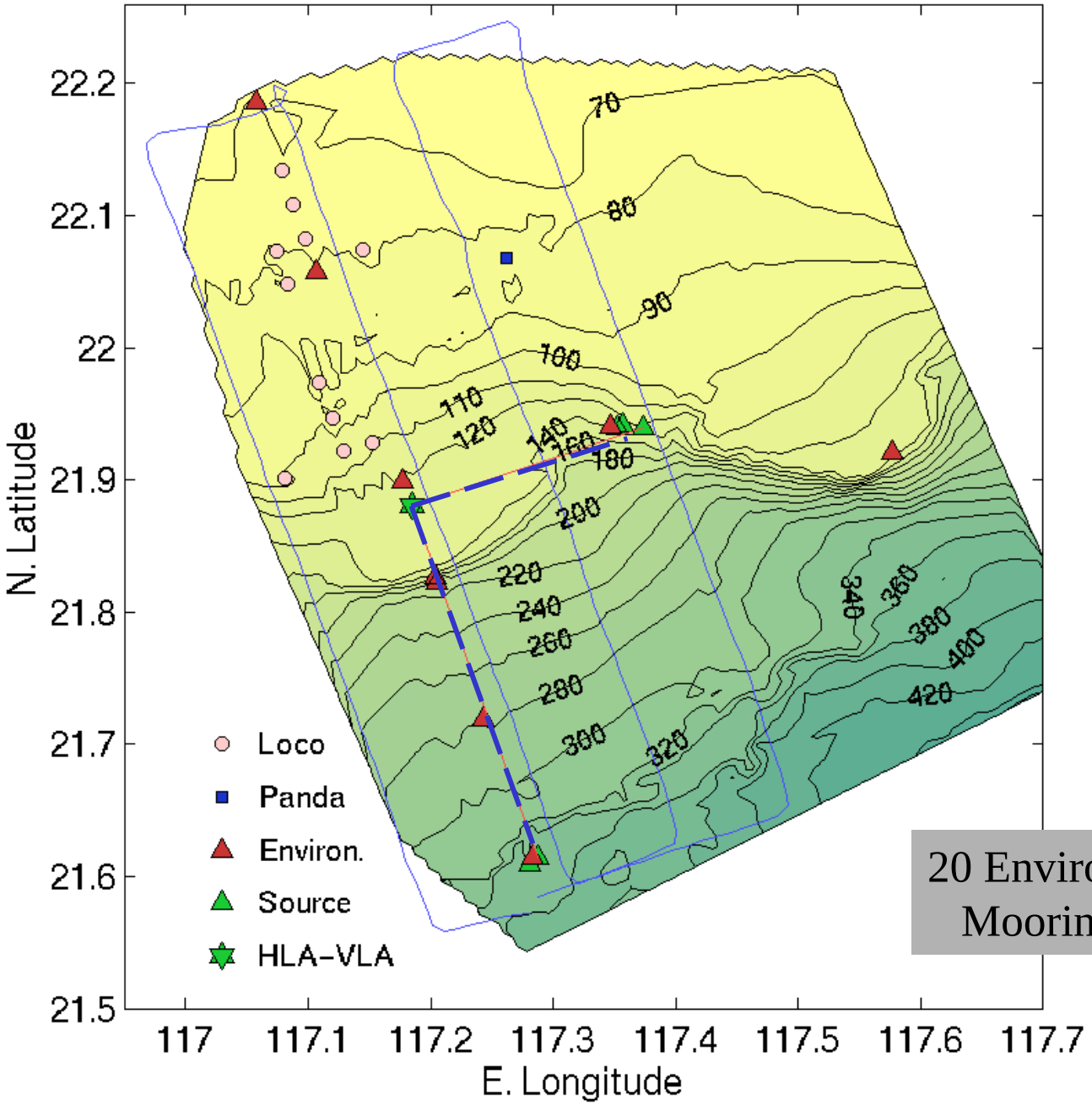
Woods Hole Oceanographic Institution, Woods Hole MA USA

* ASIAEX international study

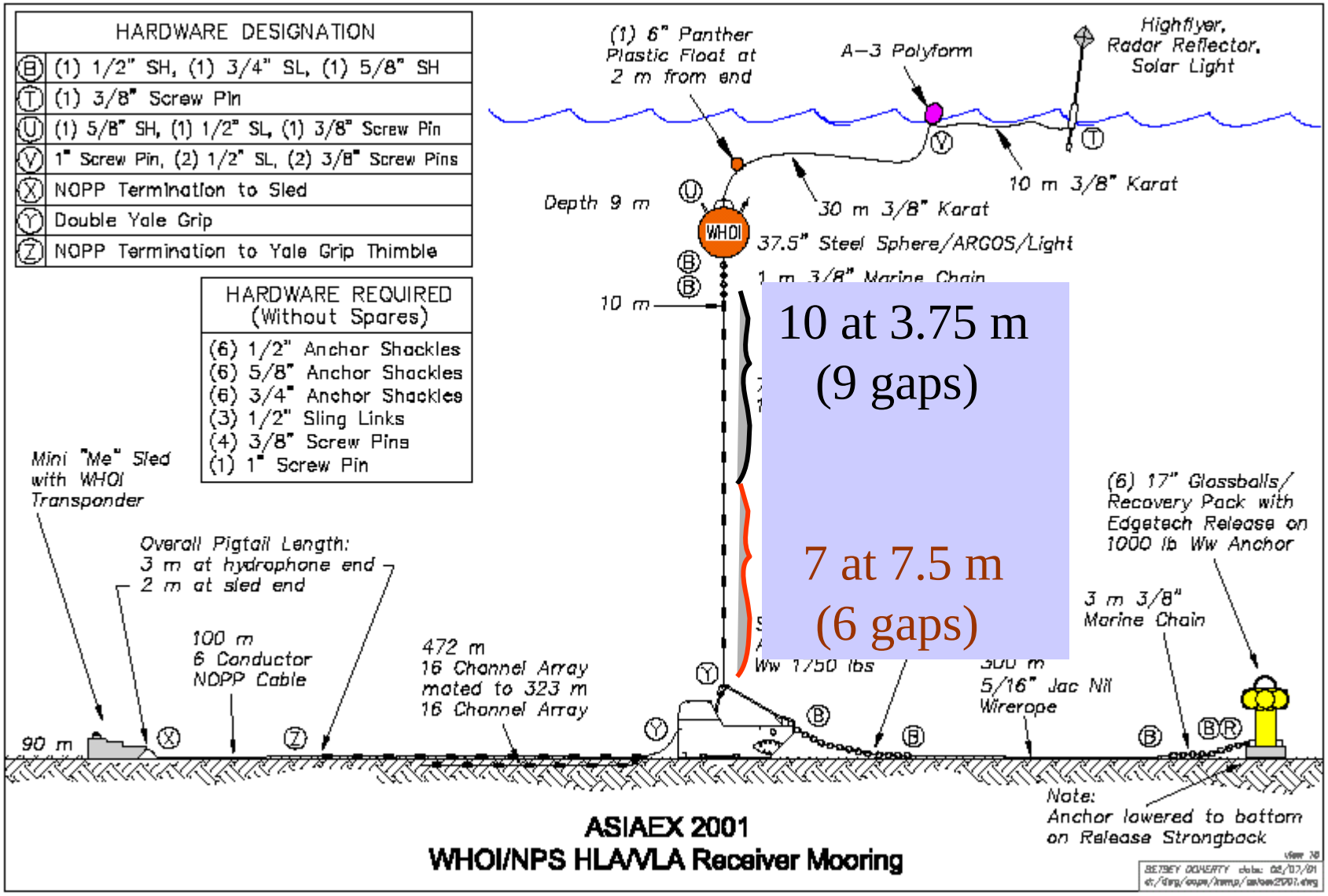
Capturing Uncertainty DRI: Final Review
15-17 June 2004



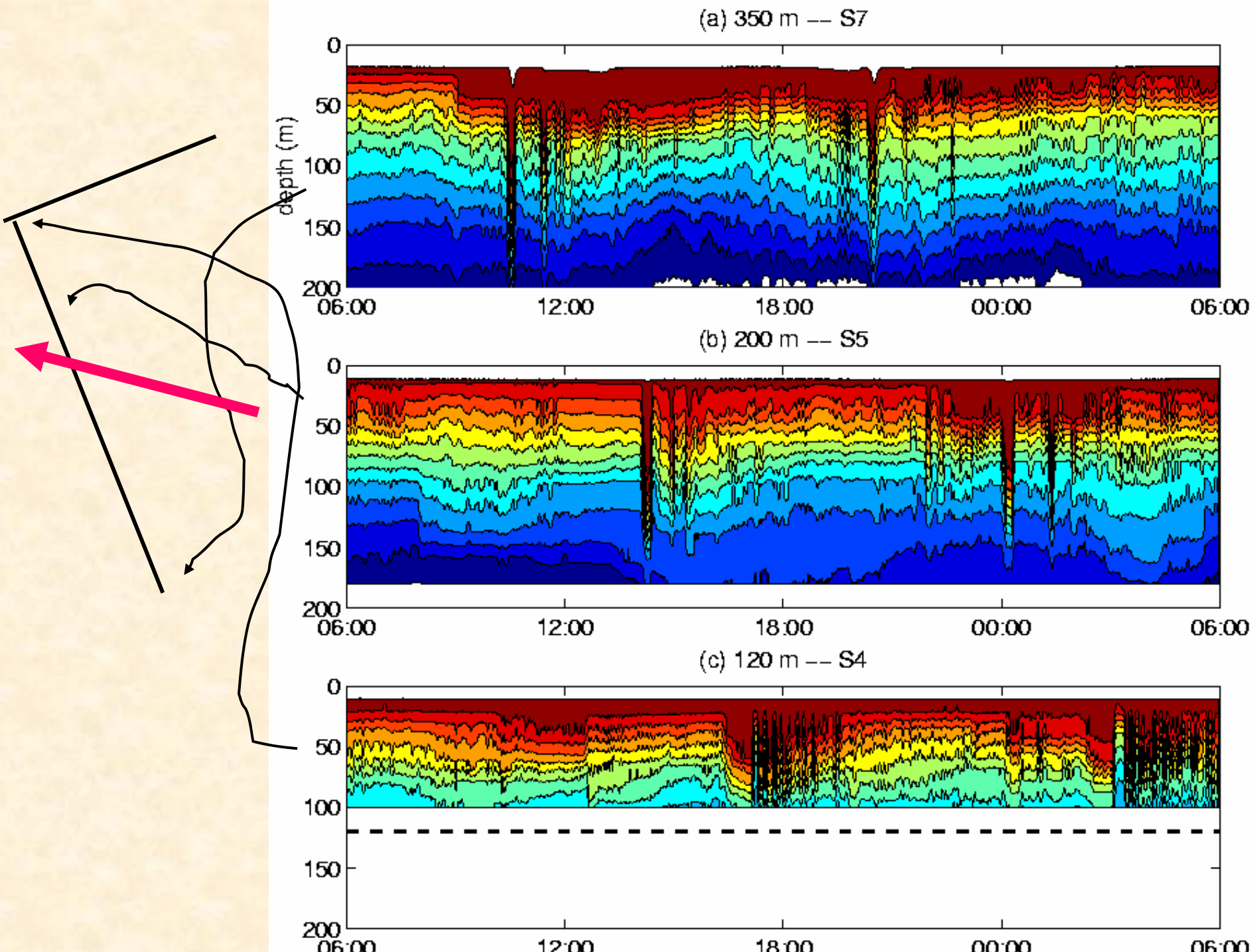
Asian Seas International Acoustics Expt, South China Sea component. US portion sponsored by ONR.



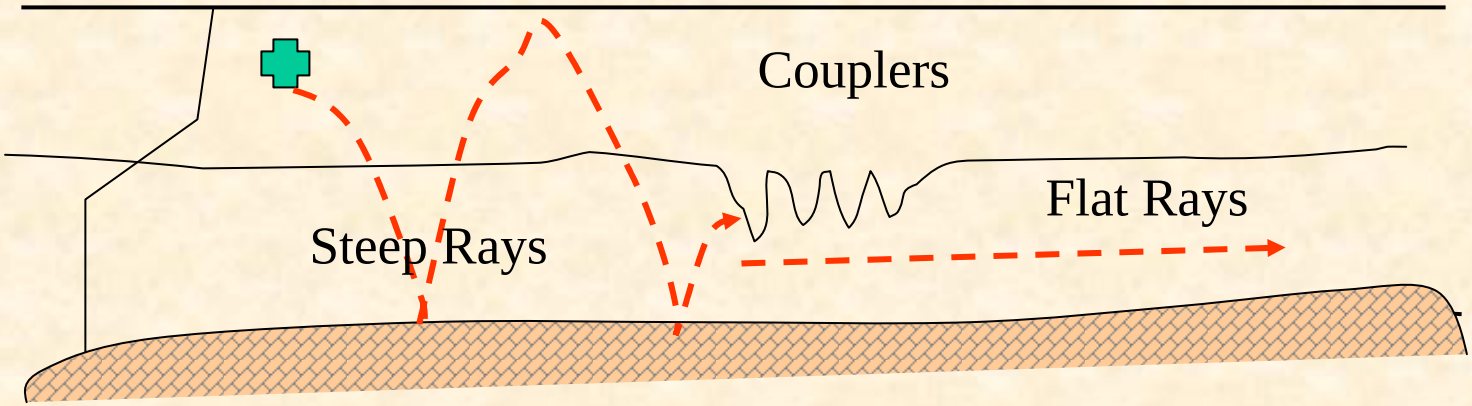
20 Environmental Mooring Sites



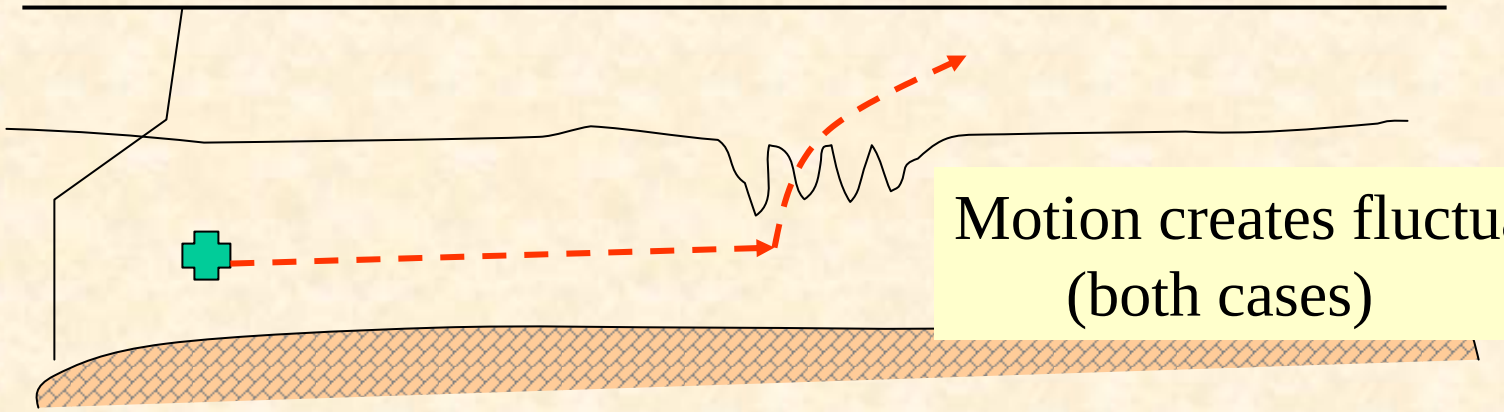
124 m depth ; 16-channel VLA ; 37-118m


(a) 350 m -- S7
(b) 200 m -- S5
(c) 120 m -- S4
depth (m)
0
50
100
150
200
06:00
12:00
18:00
00:00
06:00

Two Cases

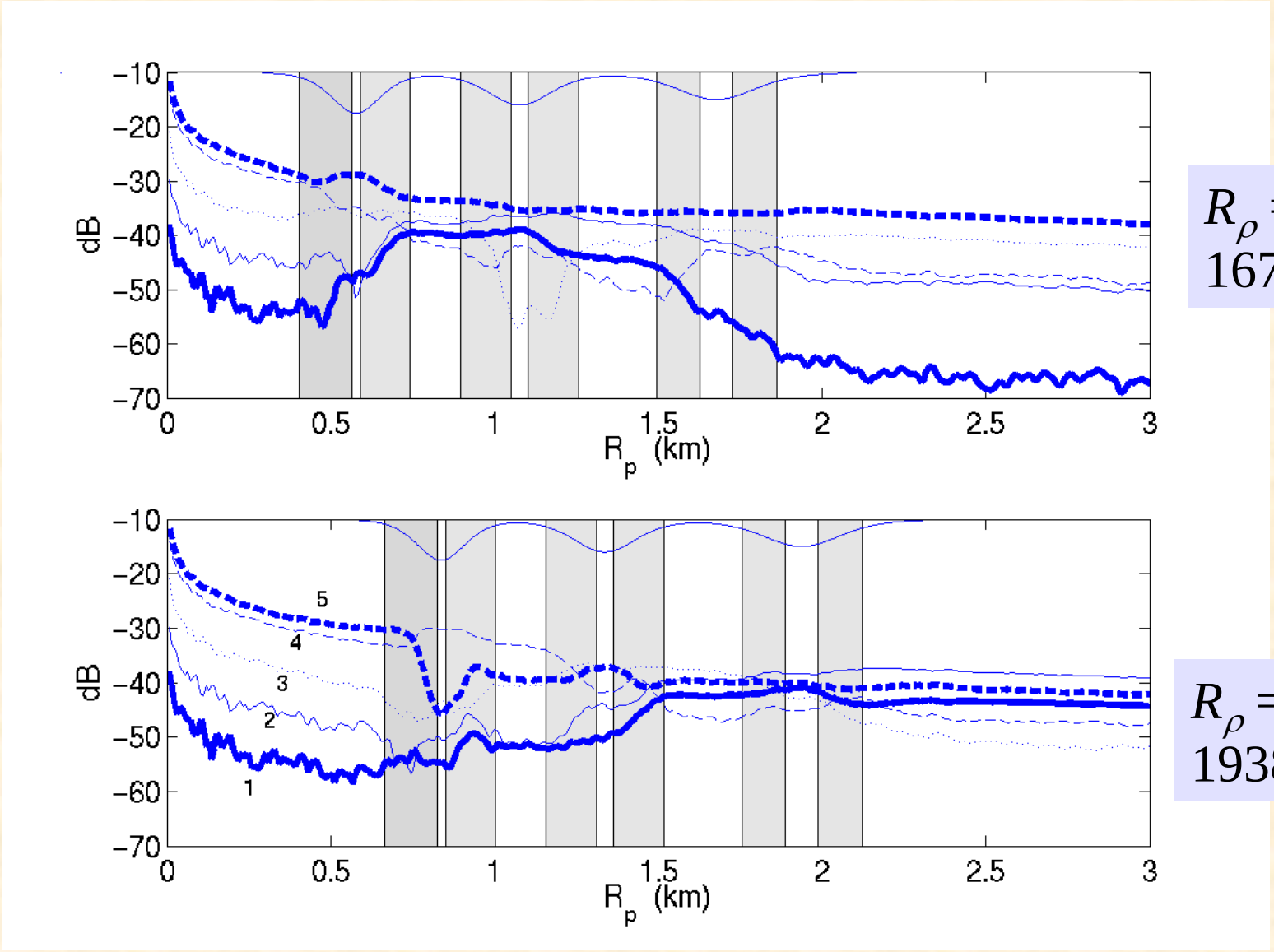


Distant gain for discrete source, filled noise notch



Motion creates fluctuations (both cases)

Loss Case (i.e. Yellow Sea style)

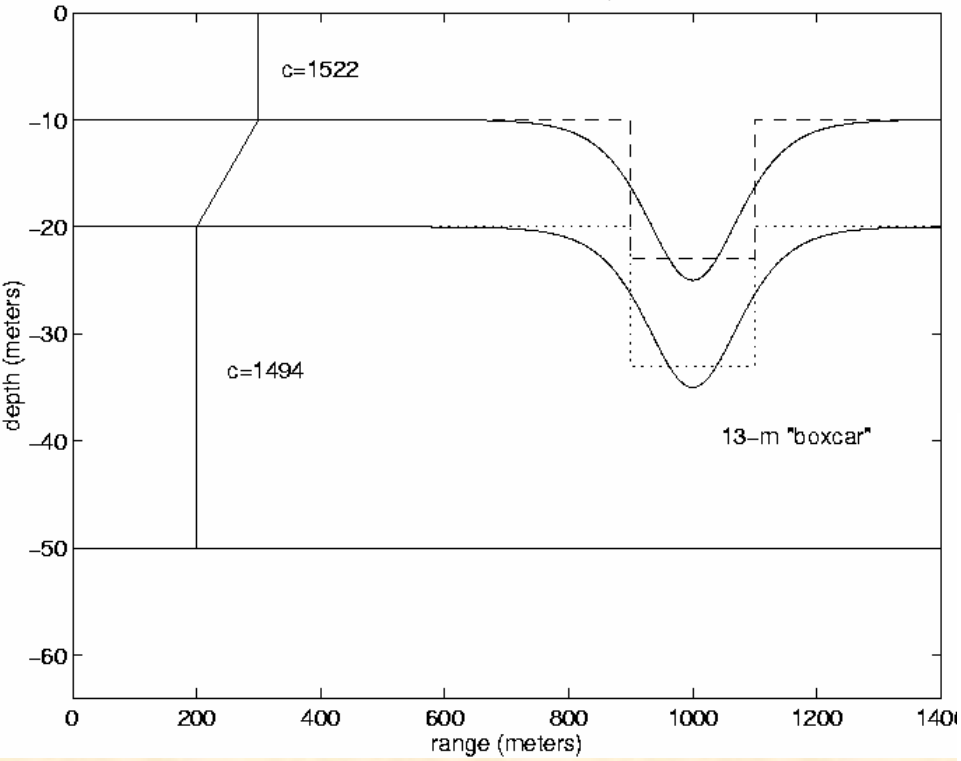


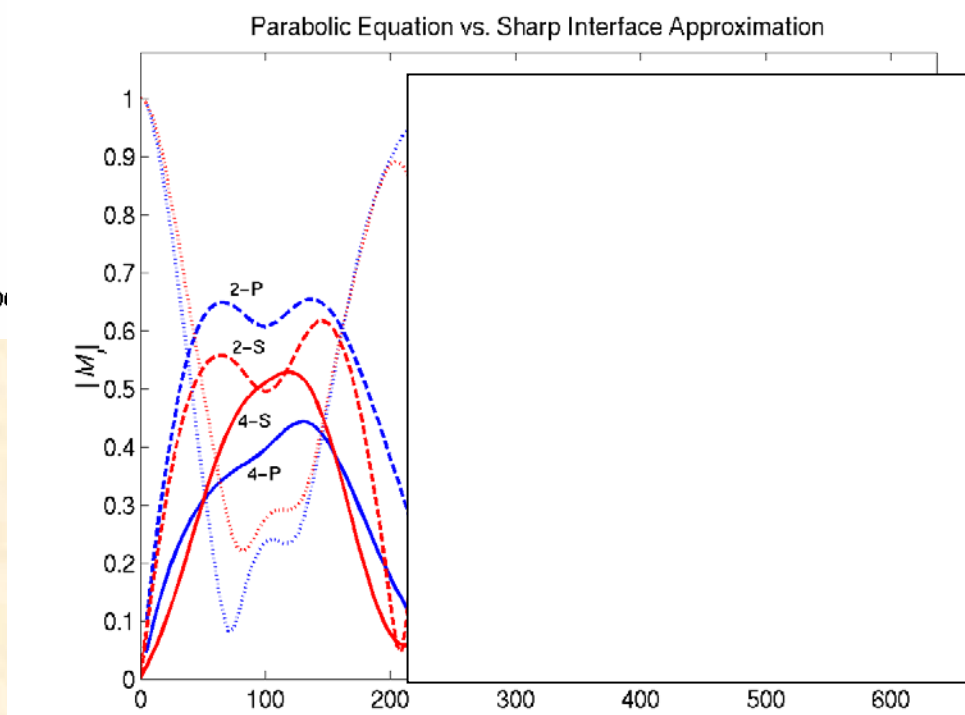
R_ρ = 1678 m

R_ρ = 1938 m

Six discrete mode coupling events, no $k_{wave}/\Delta k_{ij}$ resonance required.

Duda and Preisig, 1999, IEEE JOE





Wave scale length L (m)

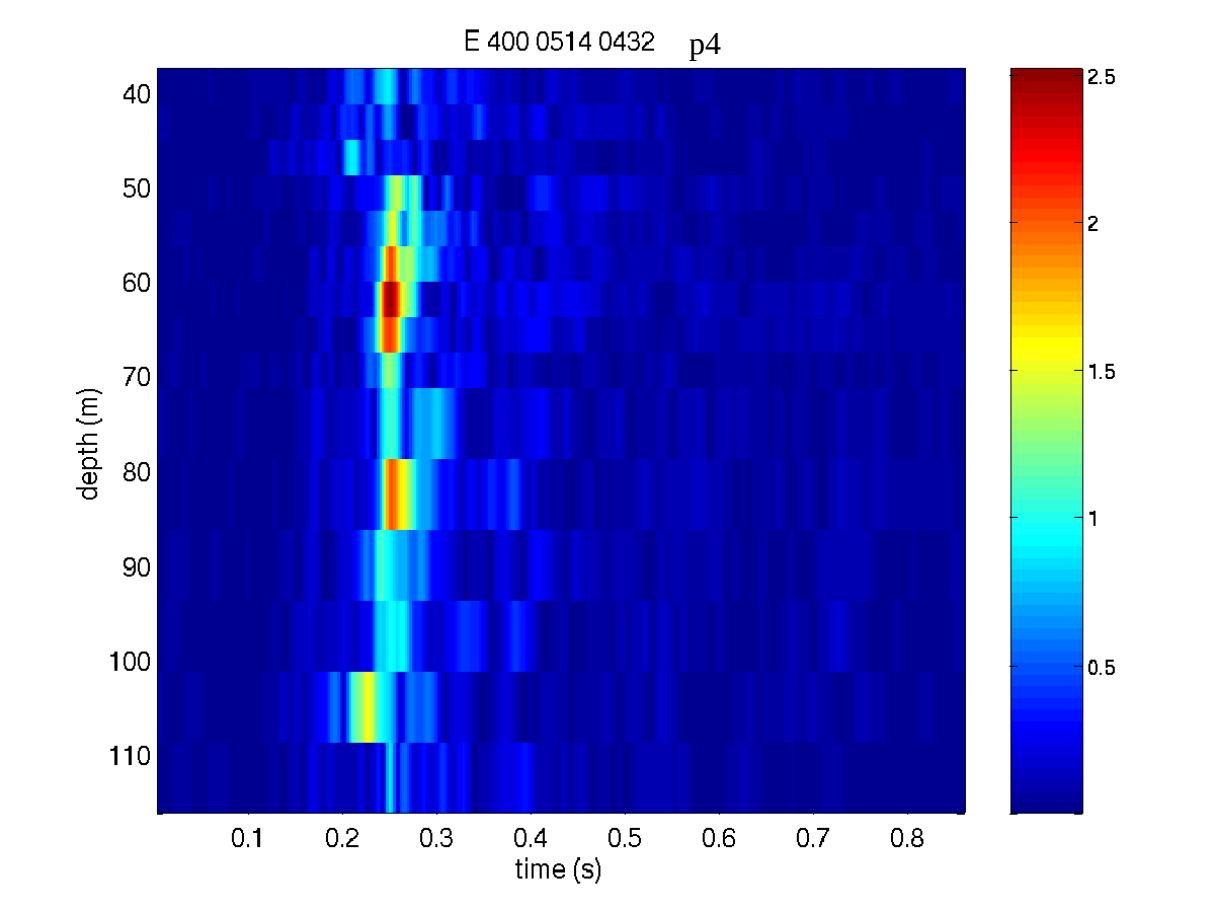
Preisig and Duda, 1997, IEEE JOE

Comments on comparing theoretical, simulated, and field-observed fluctuations

- **Identical quantities are not available for comparison:**
  - Theory: monochromatic, normal statistics (or similar), stationarity, simple seafloor, a few scattering objects.
  - Simulation: Monochromatic, or pulse analysis with limited ensemble averaging. More complex seafloor properties than theory allows, probably not fully realistic. More scatterers.
  - Our observations: 100-Hz pulse bandwidth, seafloor and water column not fully known, incomplete sampling of the acoustic field (SNR, limited # phones).
- **Other mismatches of computed and utilized features:**
  - Real systems may utilize processed output: peak levels, beam power, VLA field vector, or more sophisticated derived quantities. Some theories can provide fluctuations of these.
  - Simulations can do better.

Individual 400-Hz matched-filter pulse, 100-Hz bw, observed with VLA

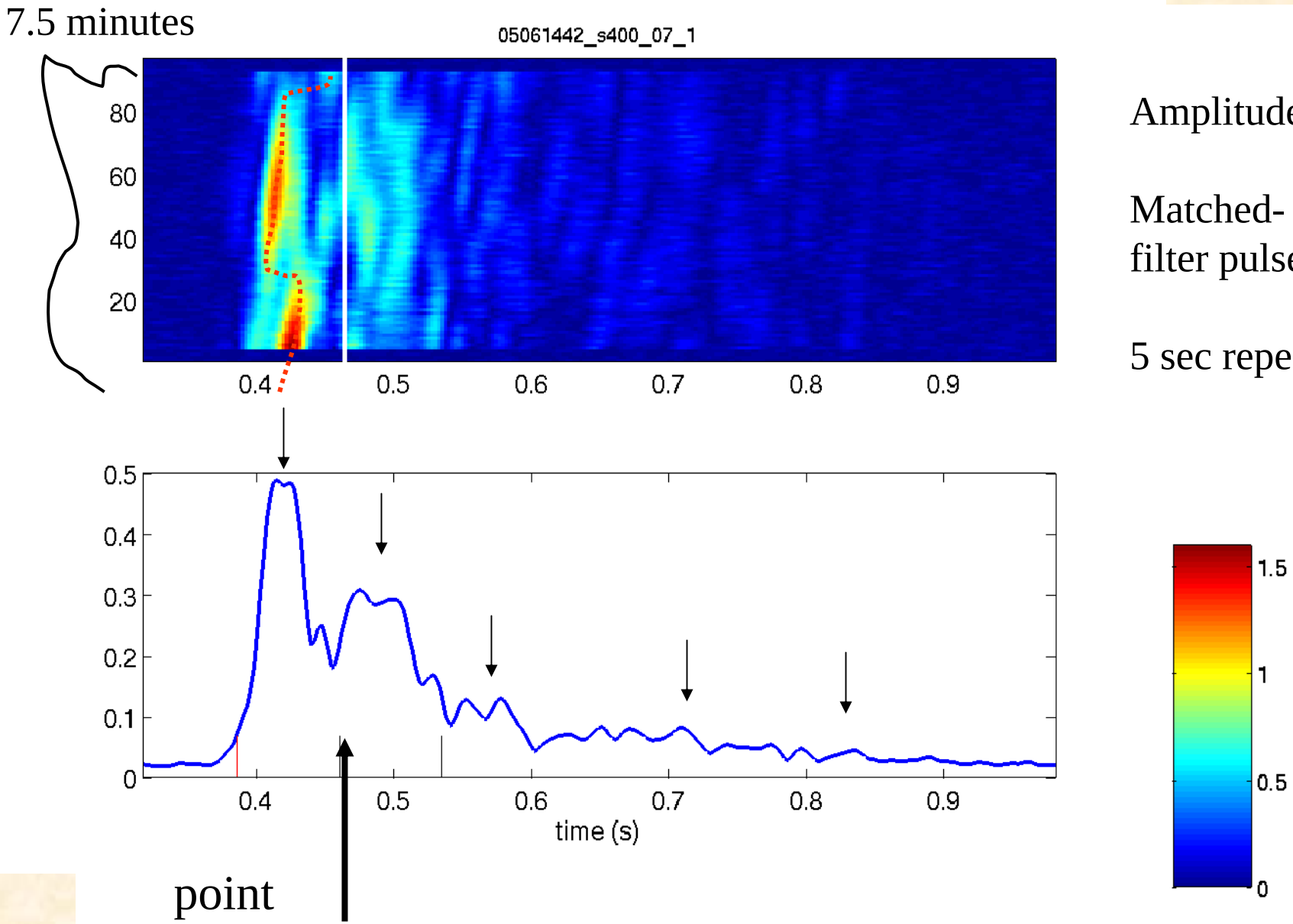
Amplitude(t,z) shown in color with arbitrary linear scale



Looking at 3 quantities today: Depth and pulsetime inten. sum (incoh.)

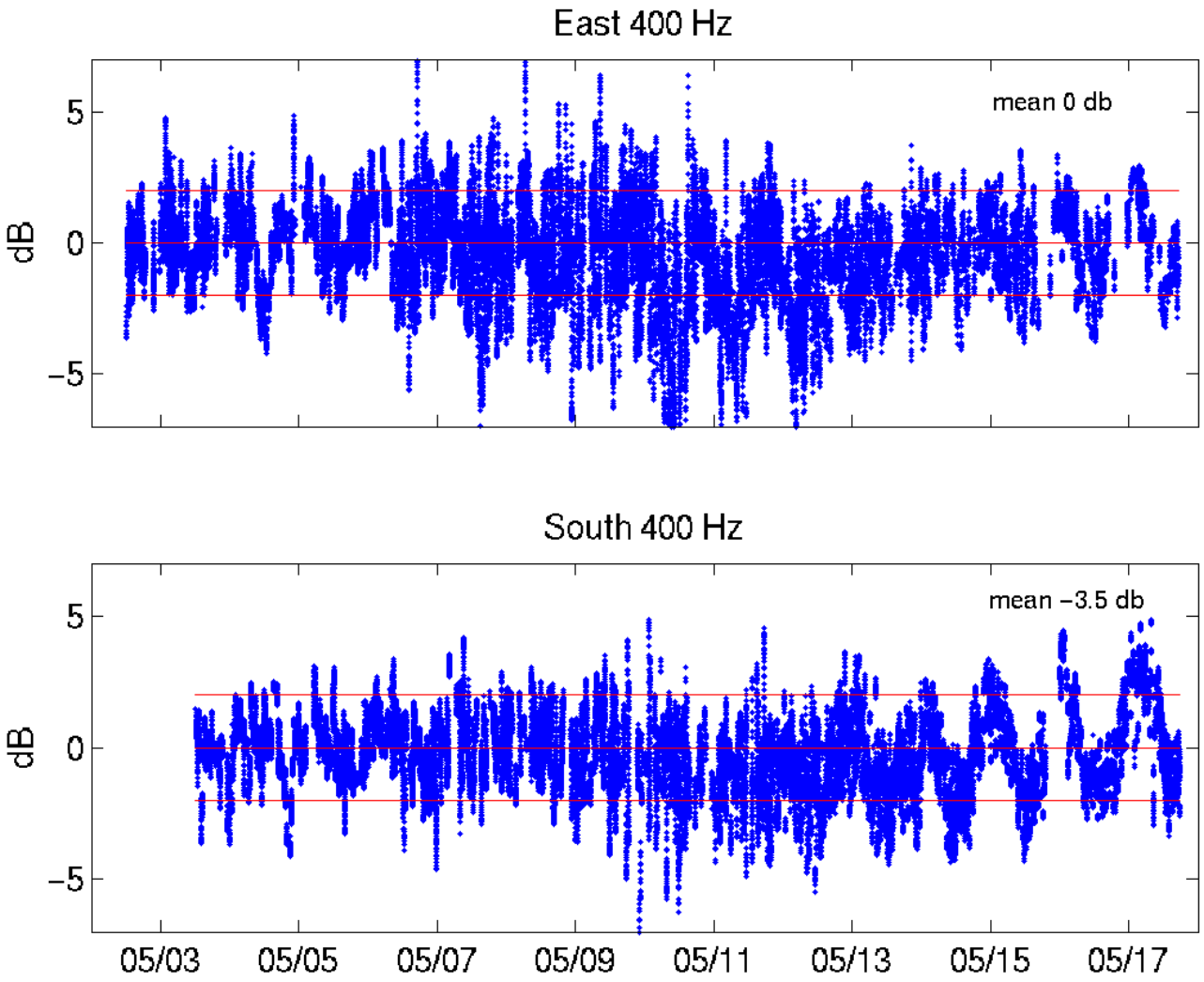
At single depths: “point’’ intensity

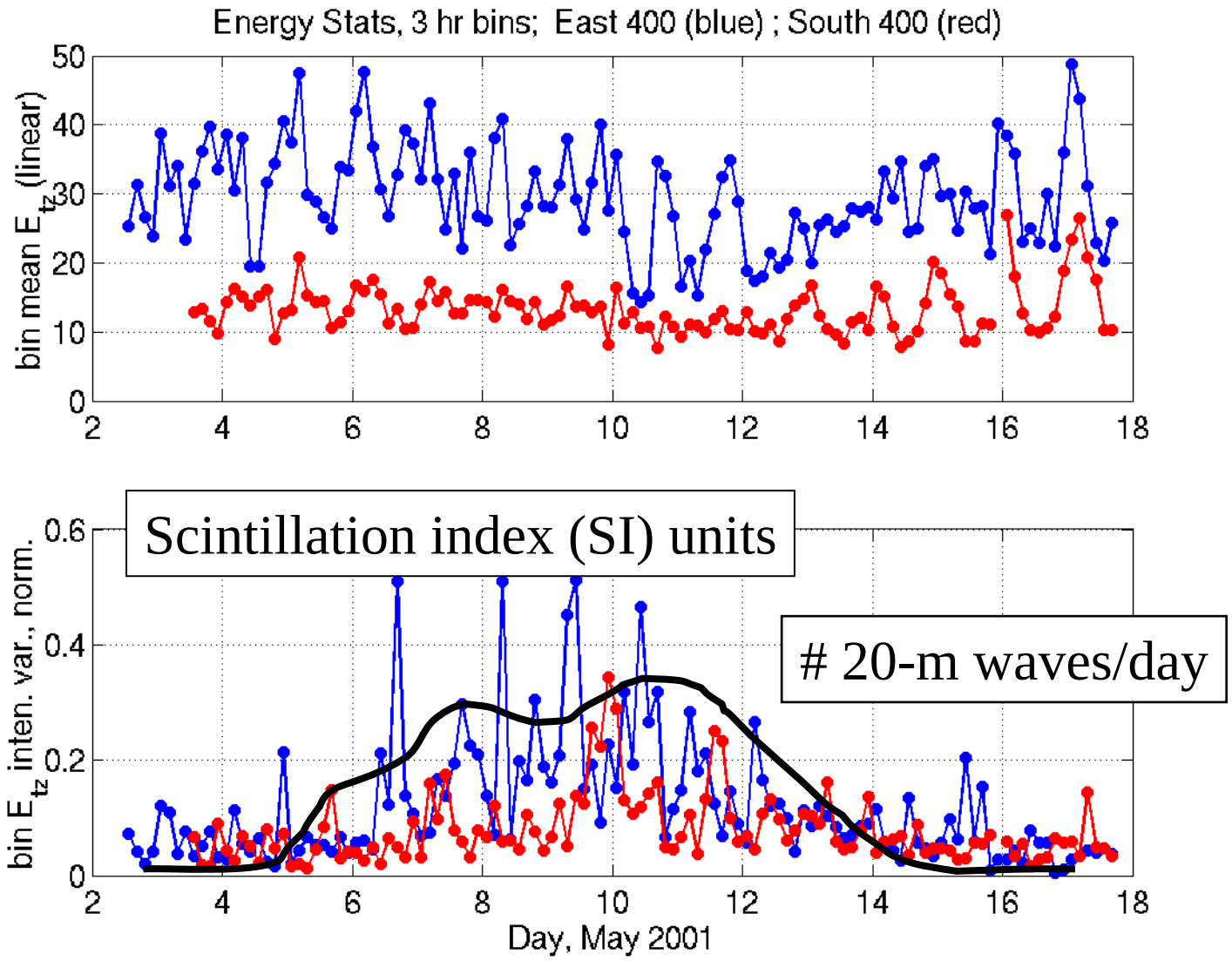
At single depths: peak intensity



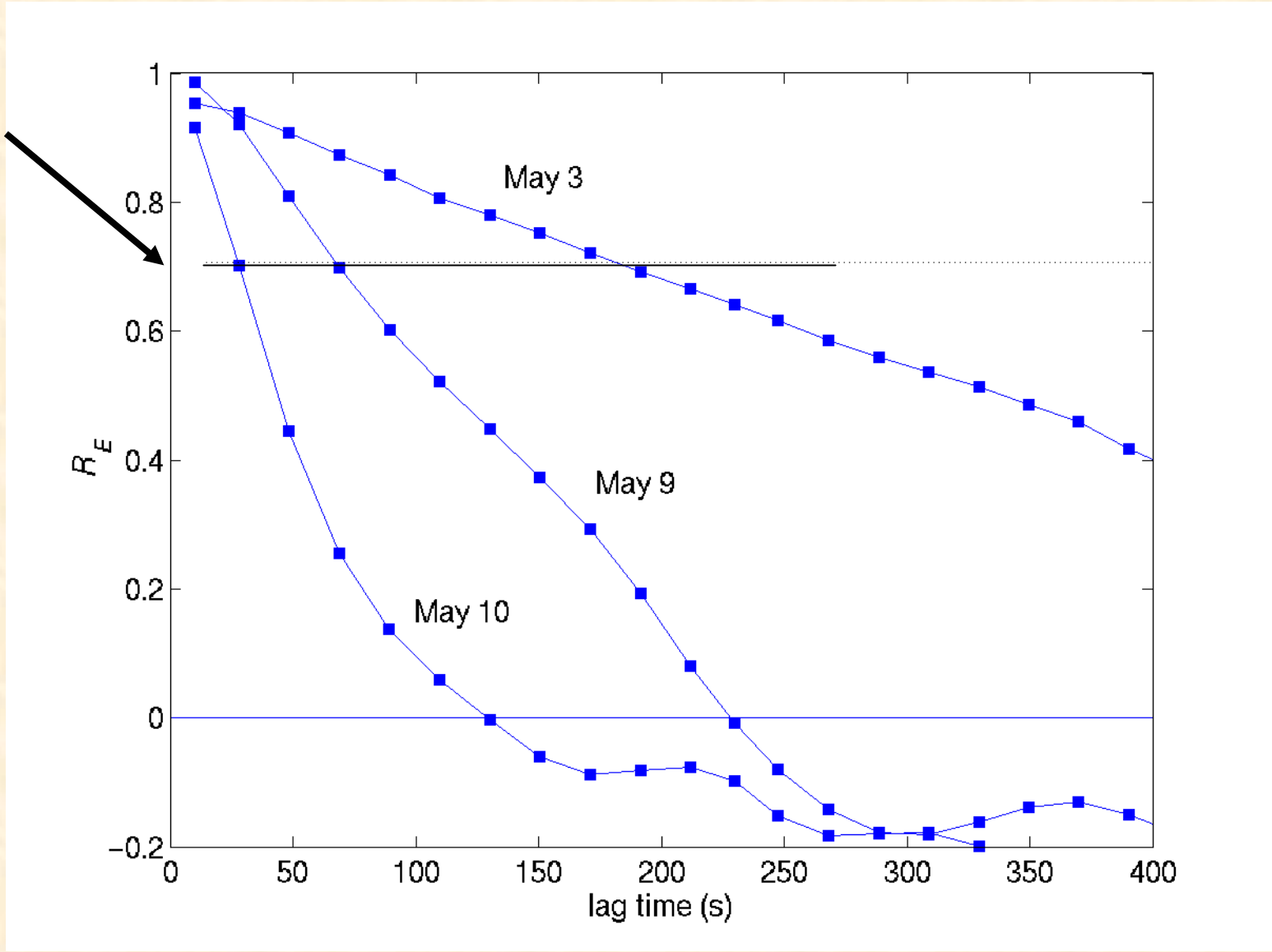
Channel 7 , ~ 65 m depth

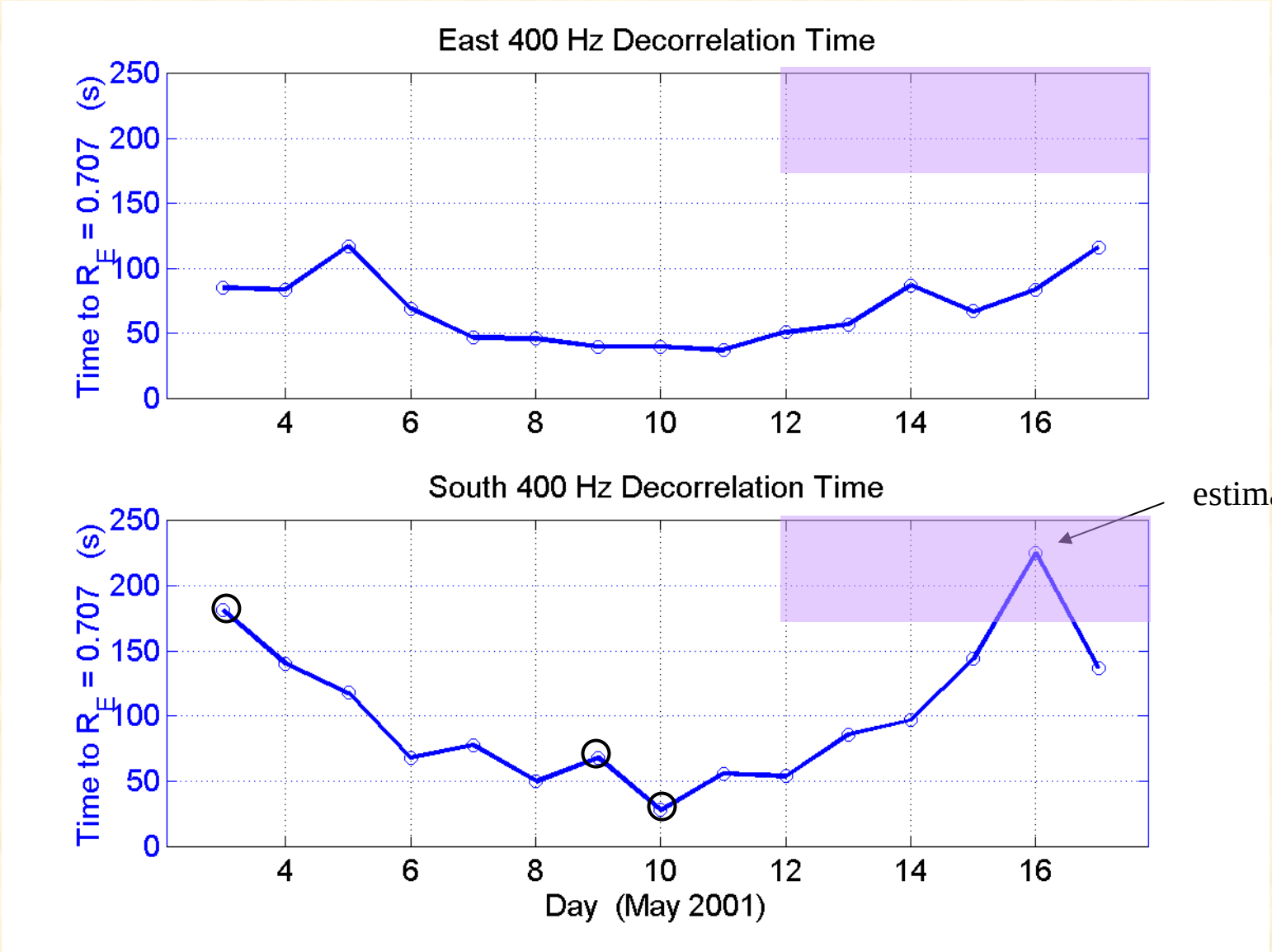
Depth/pulsetime integrated intensity; E_{tz} *(broadband)*
Fluctuations of this mimic simulated results for the case of moving wave packets




Energy Stats, 3 hr bins; East 400 (blue) ; South 400 (red)
bin mean E_{tz} (linear)
Scintillation index (SI) units
20-m waves/day
bin E_{tz} inten. var., norm.
Day, May 2001

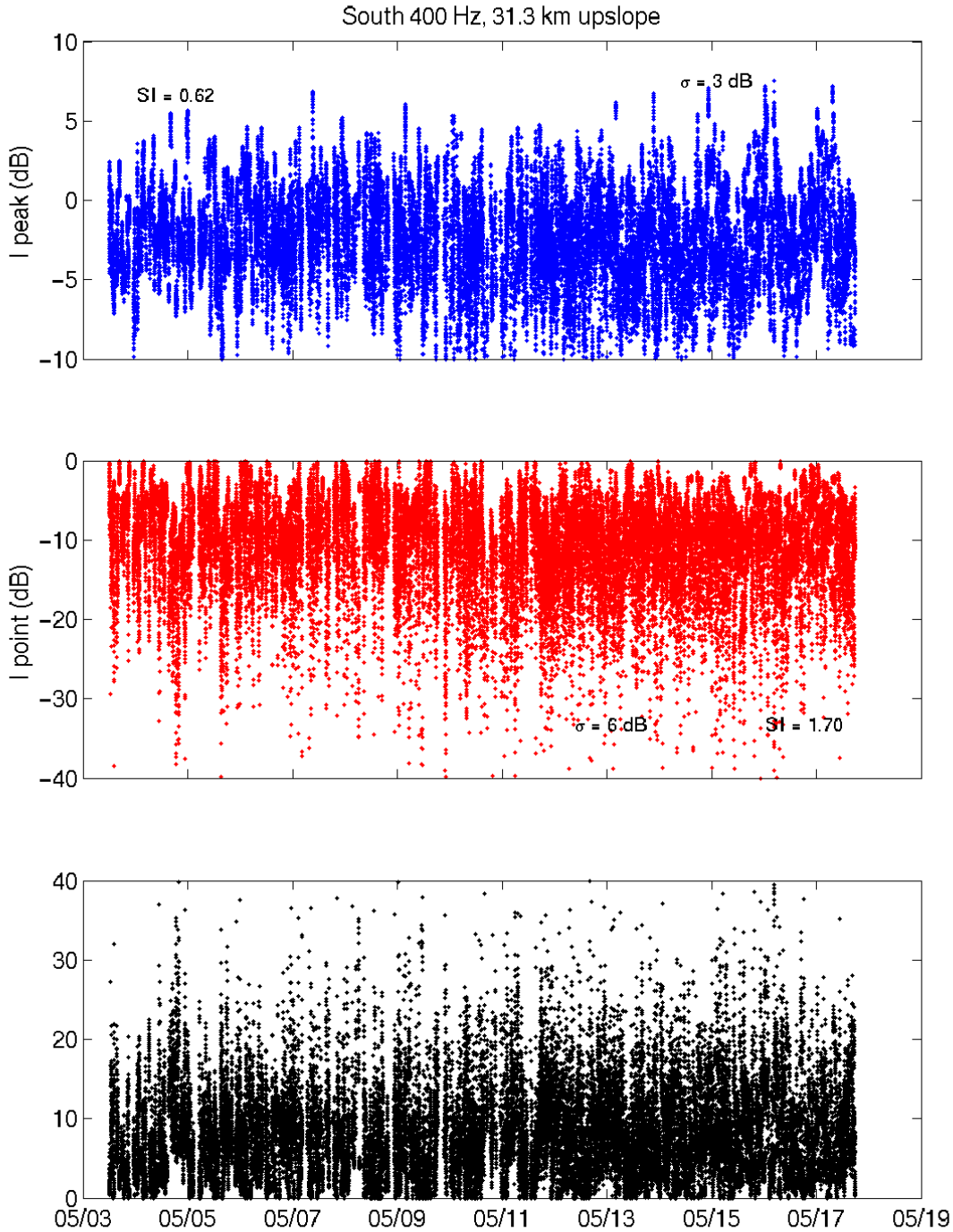
South 400 Hz : 3 daily autocorrelation functions of E_{tz}




East 400 Hz Decorrelation Time
Time to R_E = 0.707 (s)
250
200
150
100
50
0
4
6
8
10
12
14
16
South 400 Hz Decorrelation Time
estimate
Time to R_E = 0.707 (s)
250
200
150
100
50
0
4
6
8
10
12
14
16
Day (May 2001)

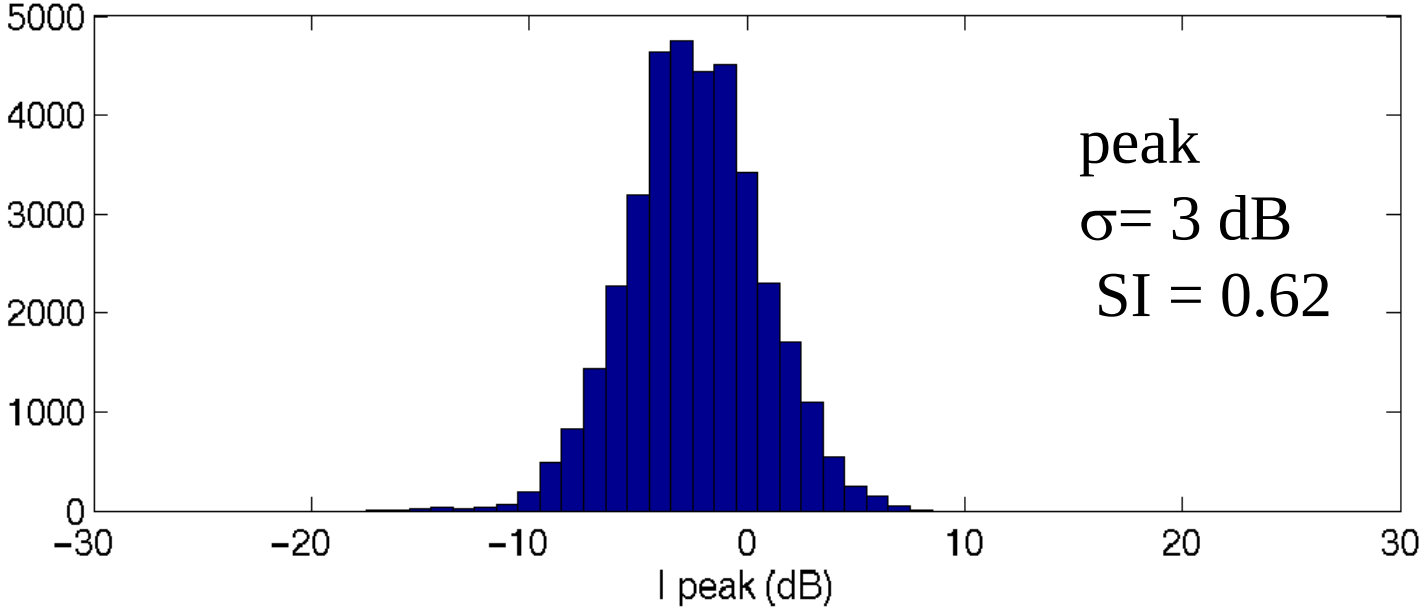
Channel 7

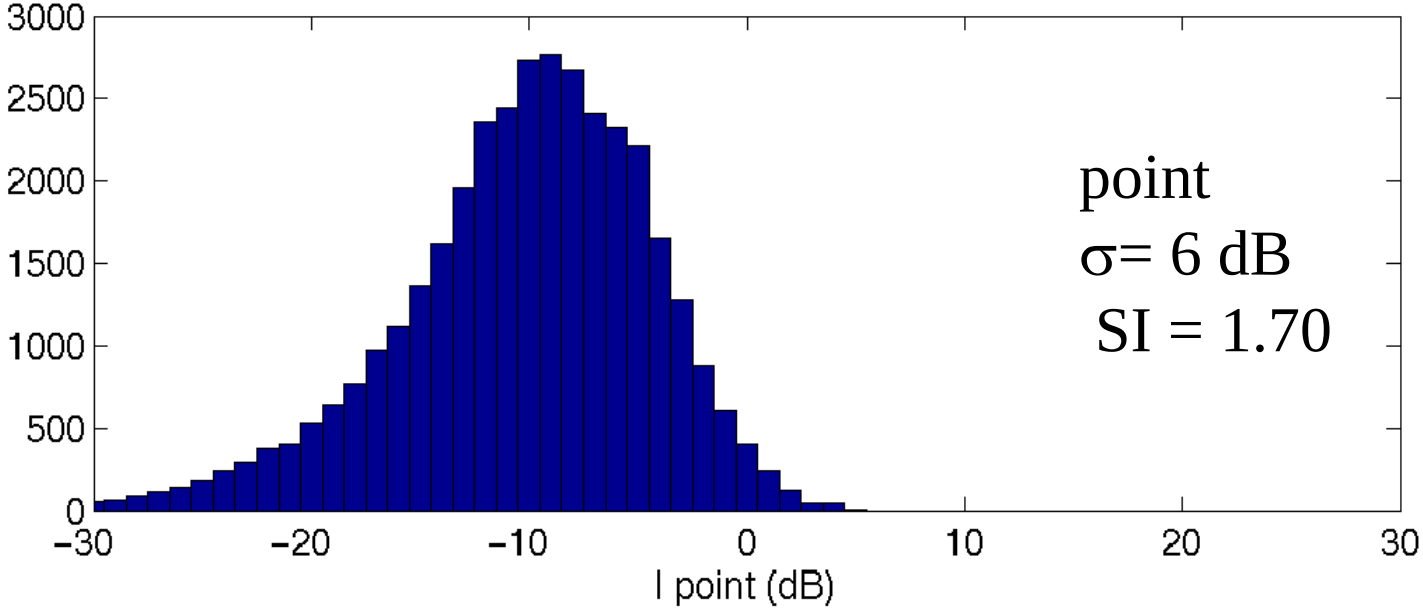
An attention getting quantity: Peak intensity, i.e. from an unidentified source.



peak
σ= 3 dB
SI = 0.62

point
σ= 6 dB
SI = 1.70

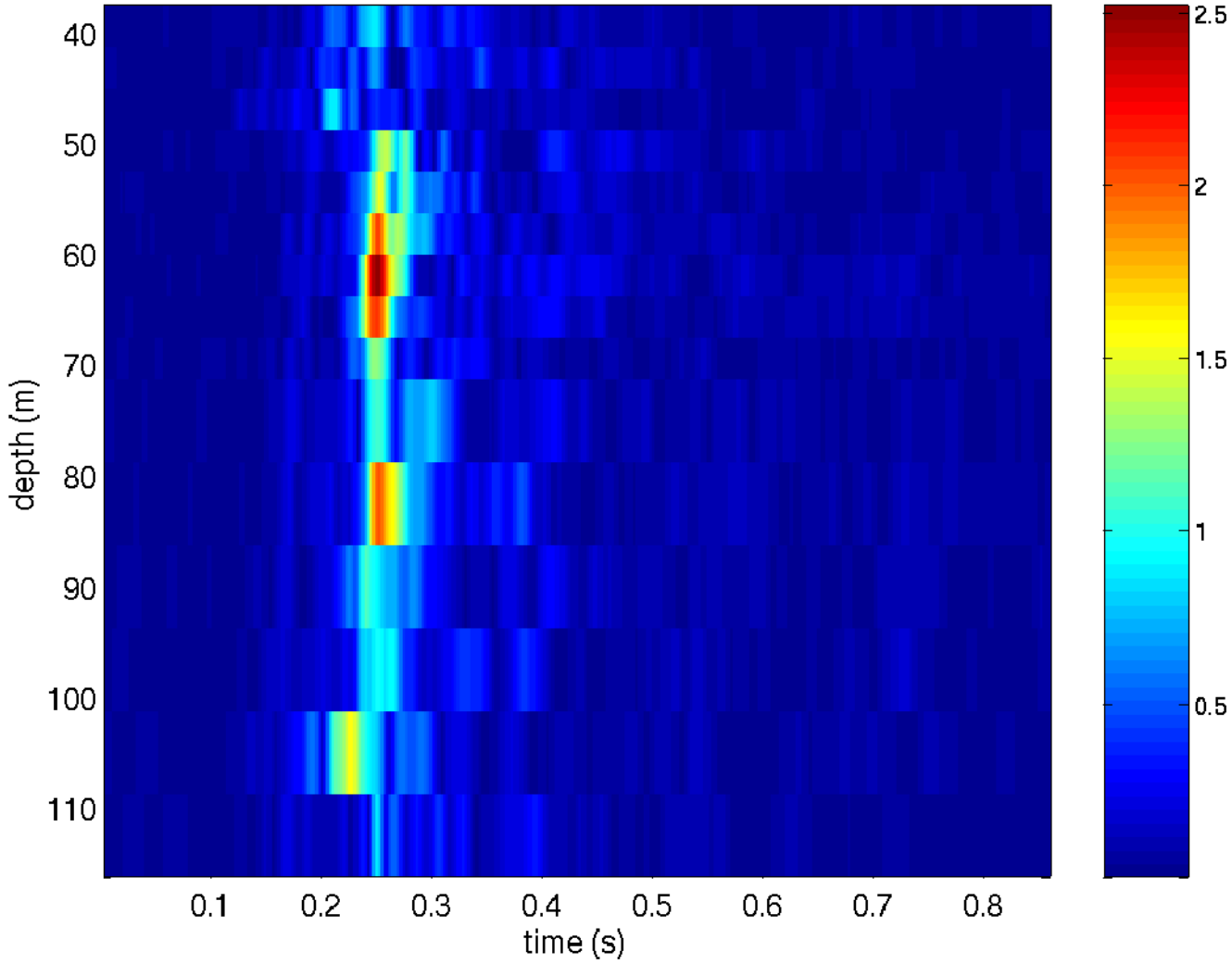

5000
4000
3000
2000
1000
0
−30
−20
−10
0
10
20
30
I peak (dB)
peak
σ= 3 dB
SI = 0.62


3000
2500
2000
1500
1000
500
0
−30
−20
−10
0
10
20
30
I point (dB)
point
σ= 6 dB
SI = 1.70

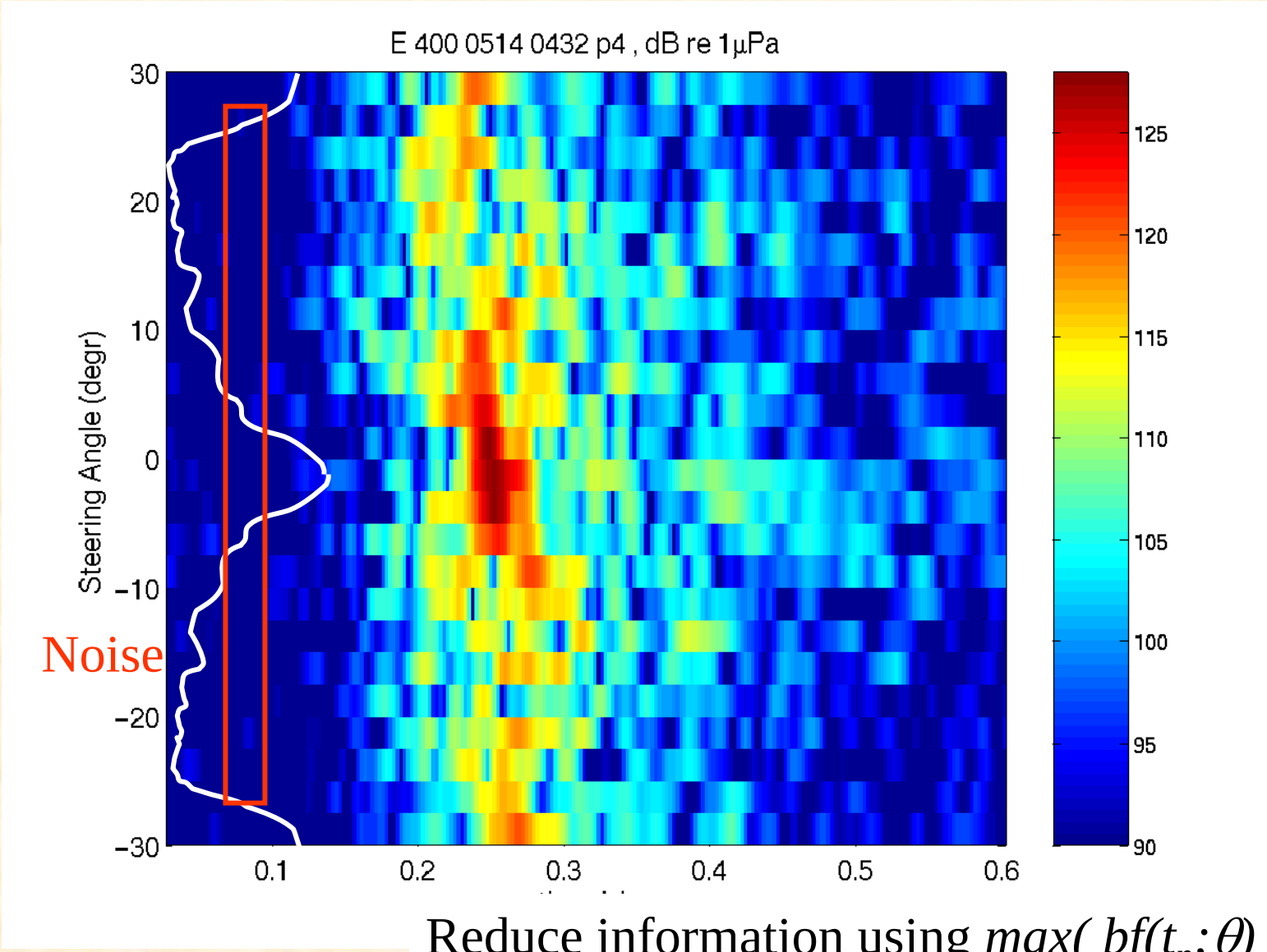
Individual 400-Hz matched-filter pulse, 100-Hz BW, observed with VLA

Amplitude(t,z) shown in color with arbitrary linear scale

Beamformed output… Pulse shown again …



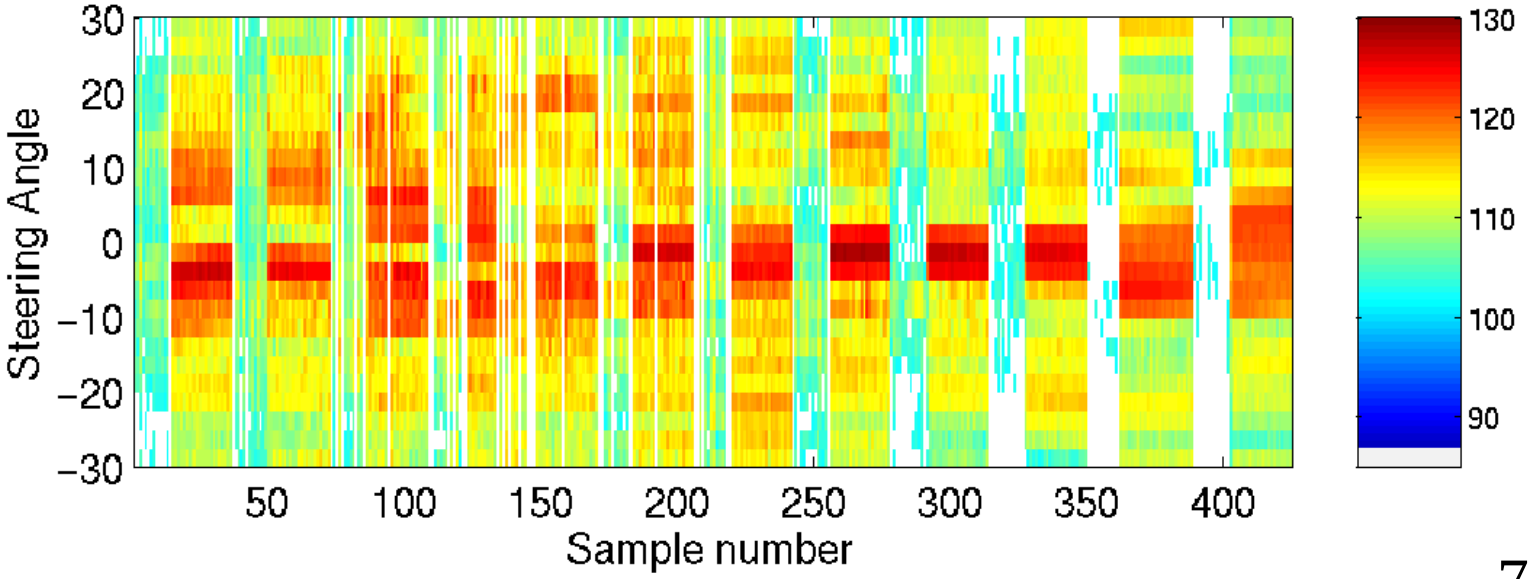
Same pulse beamformed. Unequal spacing, no taper, for now assume plane waves for PRIMER analysis compatibility *Logarithmic*



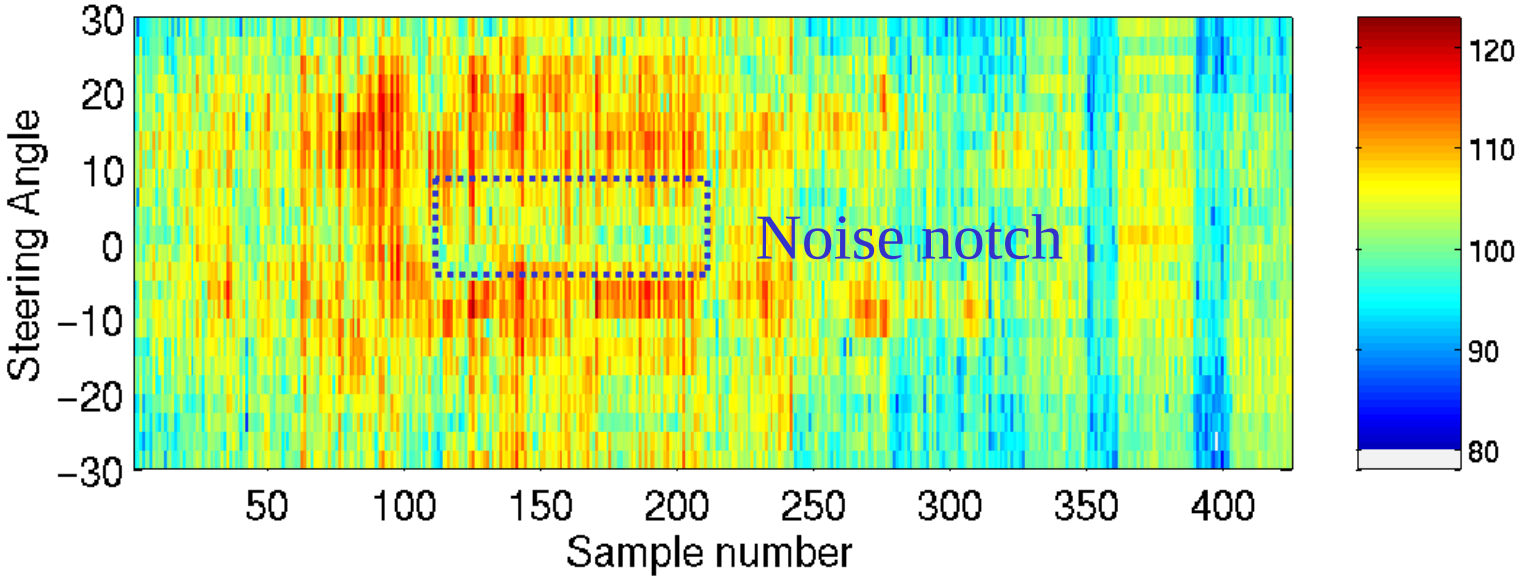
Reduce information using *max(bf(t_p;θ))*

224-Hz source, 31.3 km upslope

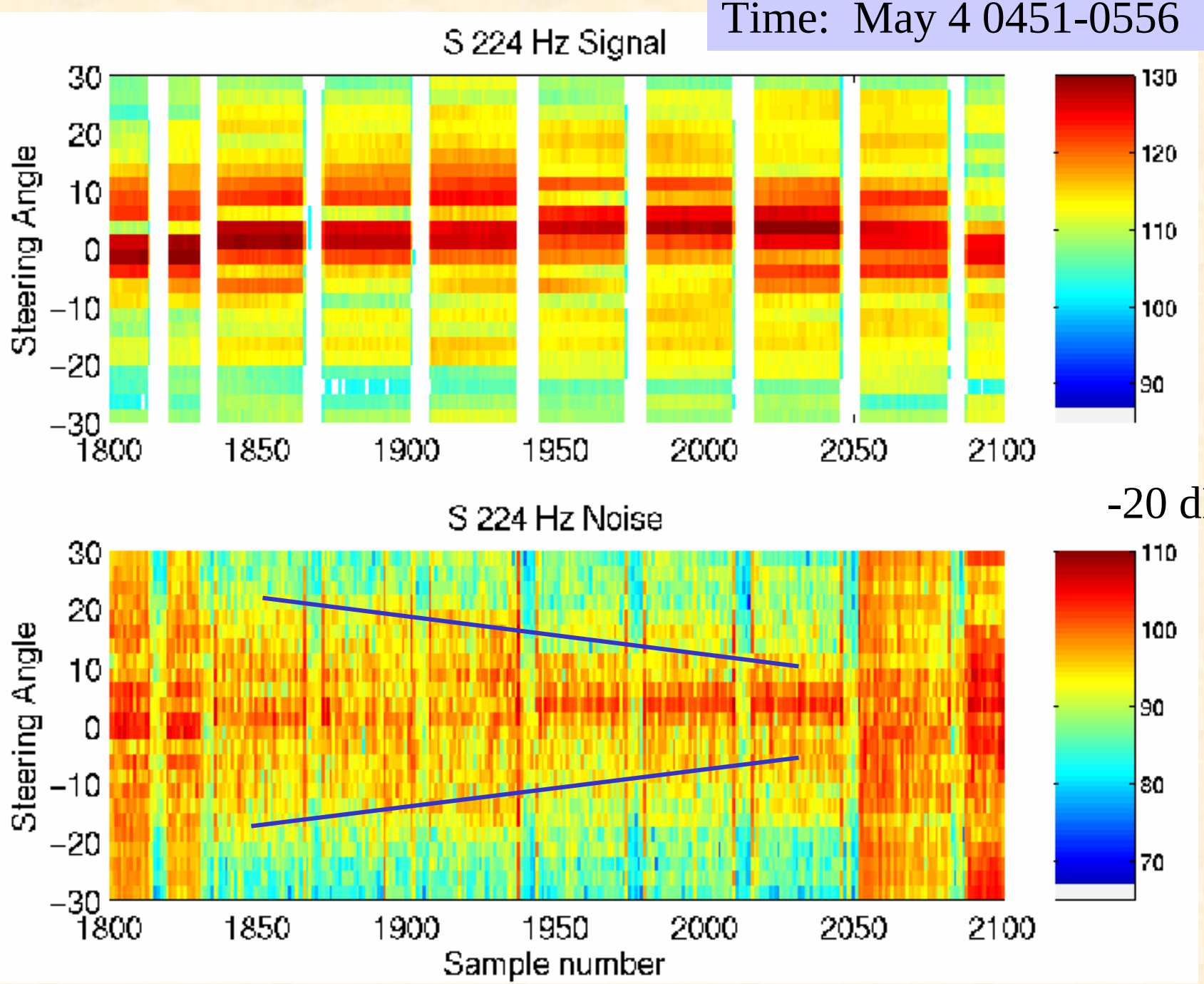
Time: May 4 0000-0100



-7 dB



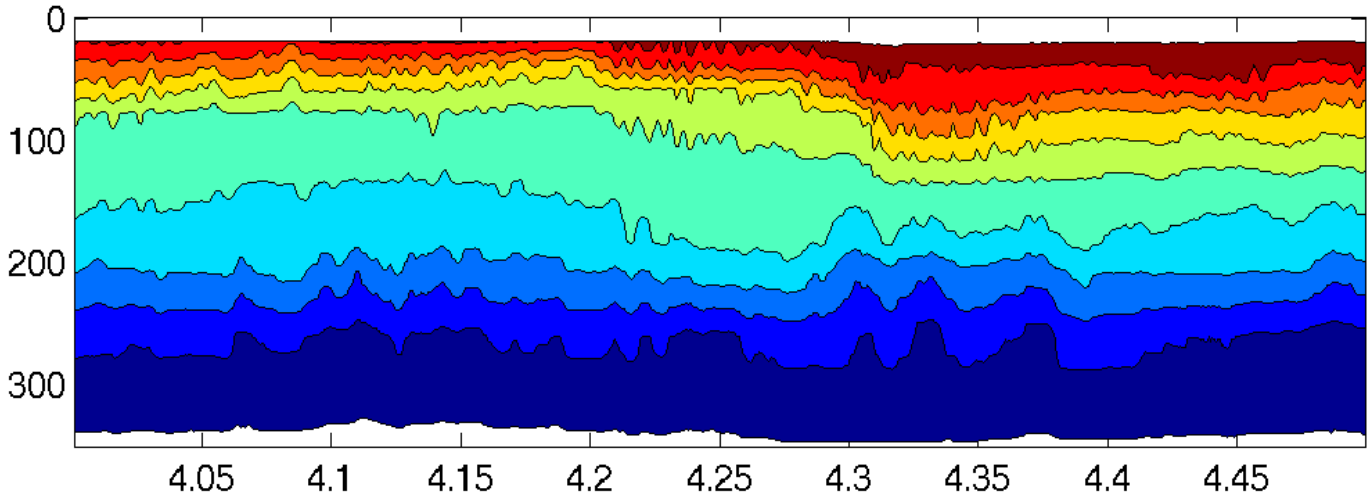
Time: May 4 0451-0556



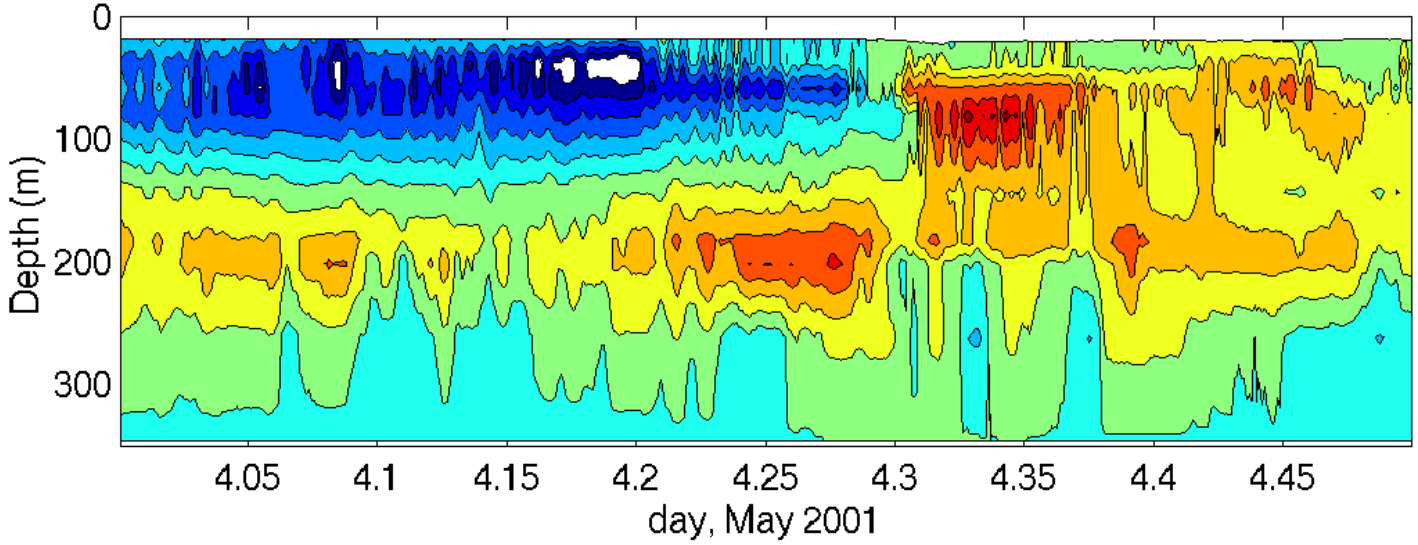
-20 dB

Source site conditions

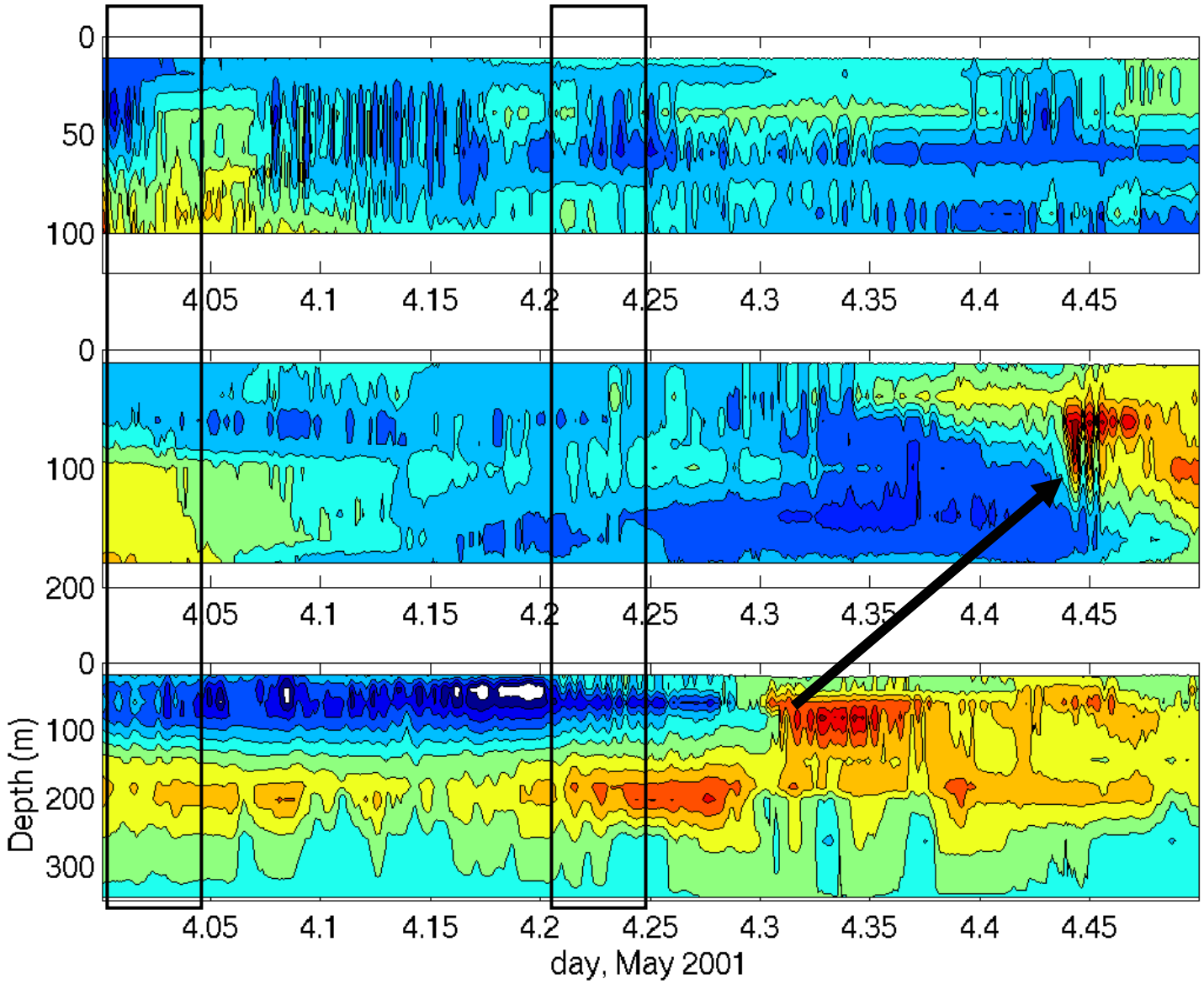
Sound speed 1500-1540 m/s by 4



ss perturb. -8 to 8 by 1.5



Sound speed perturbations

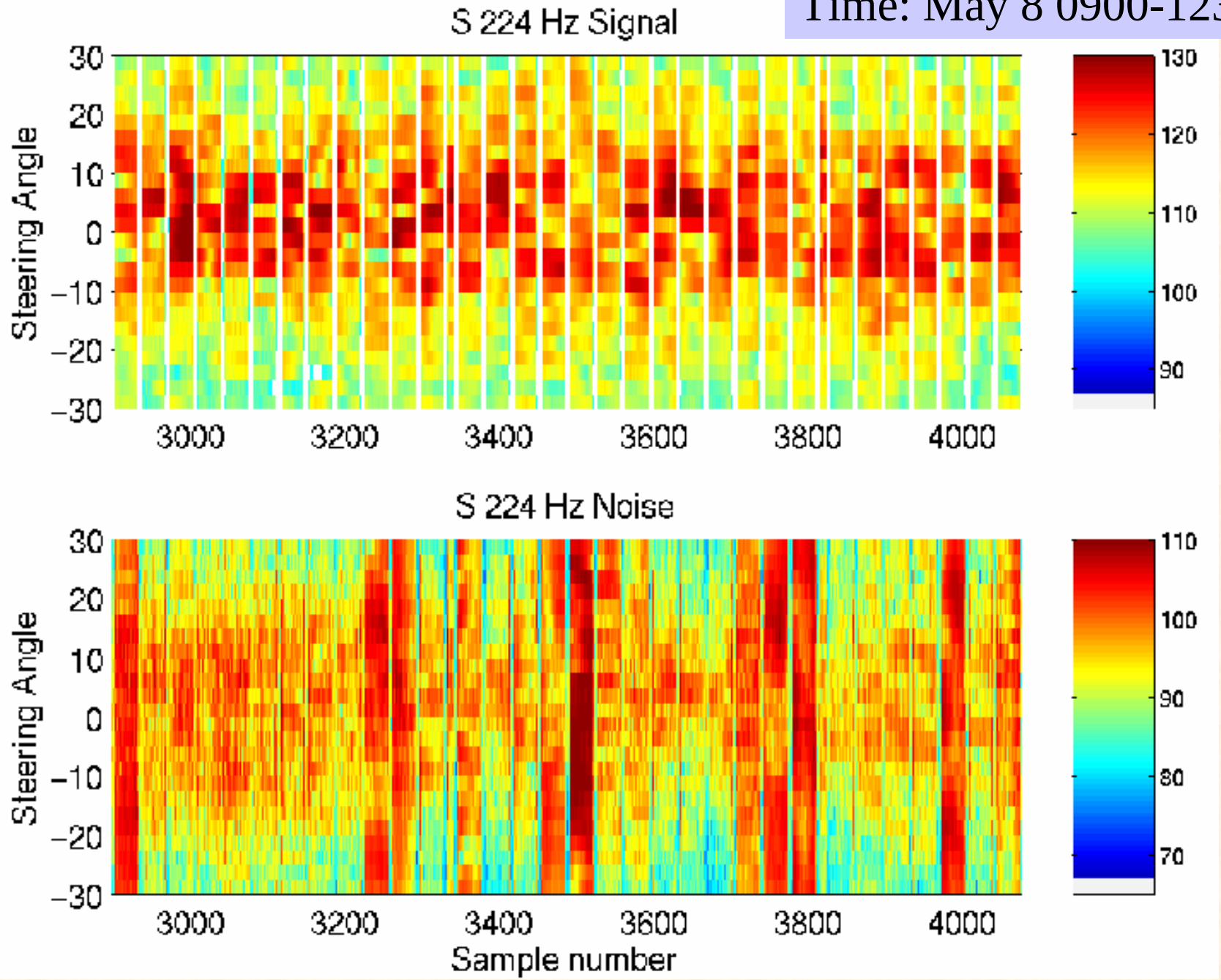


VLA (steady activity)

Mid

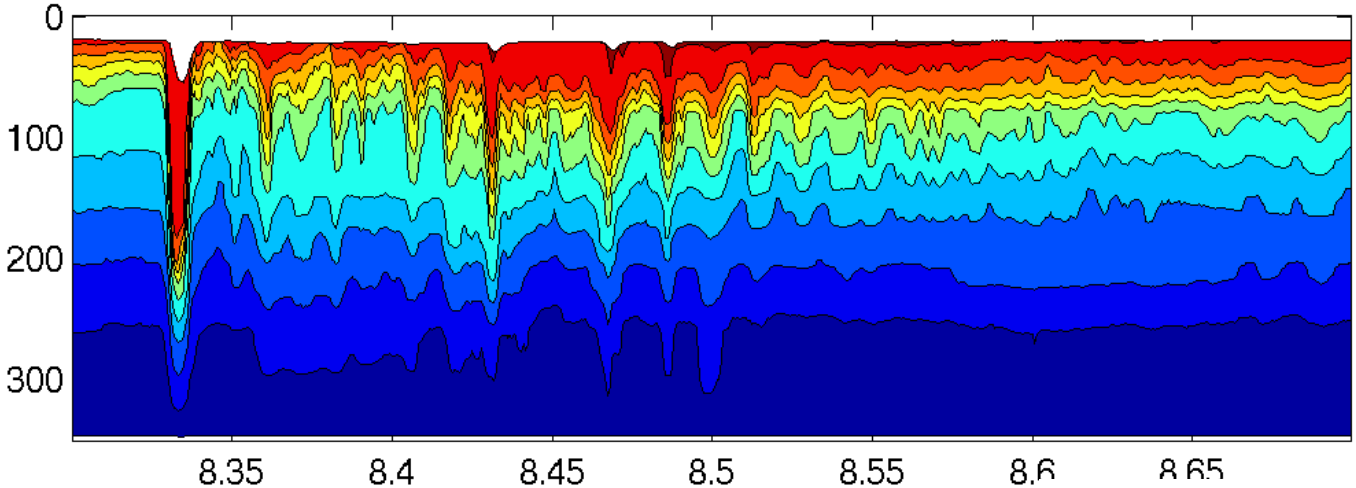
Source

Time: May 8 0900-1230

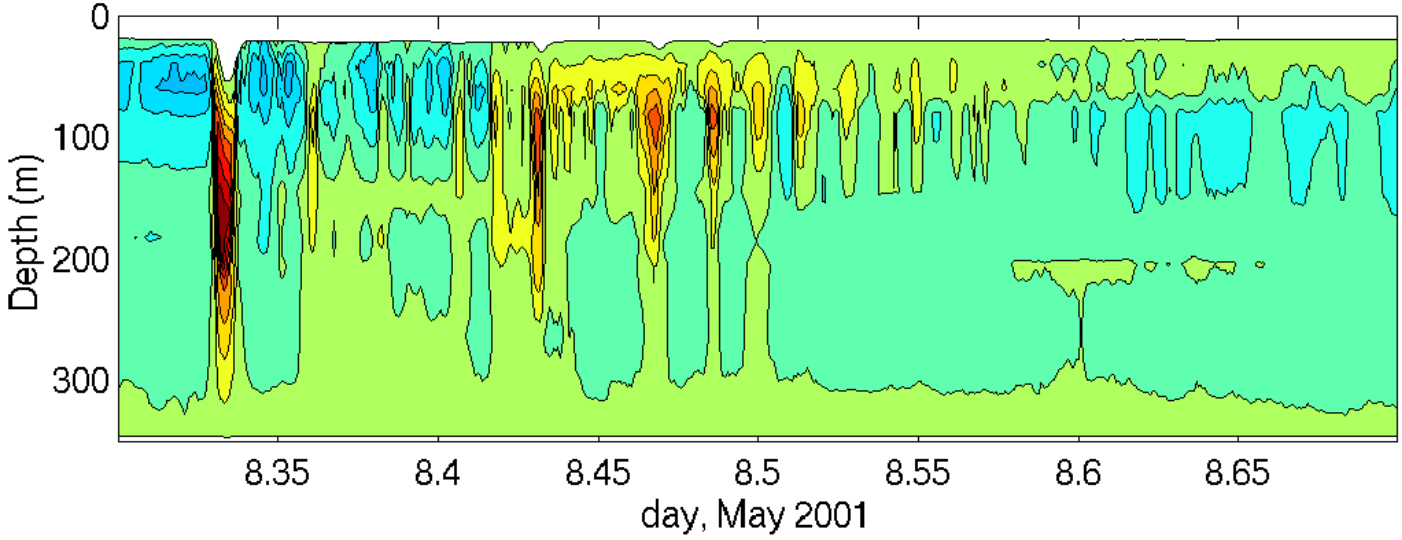


Source site conditions

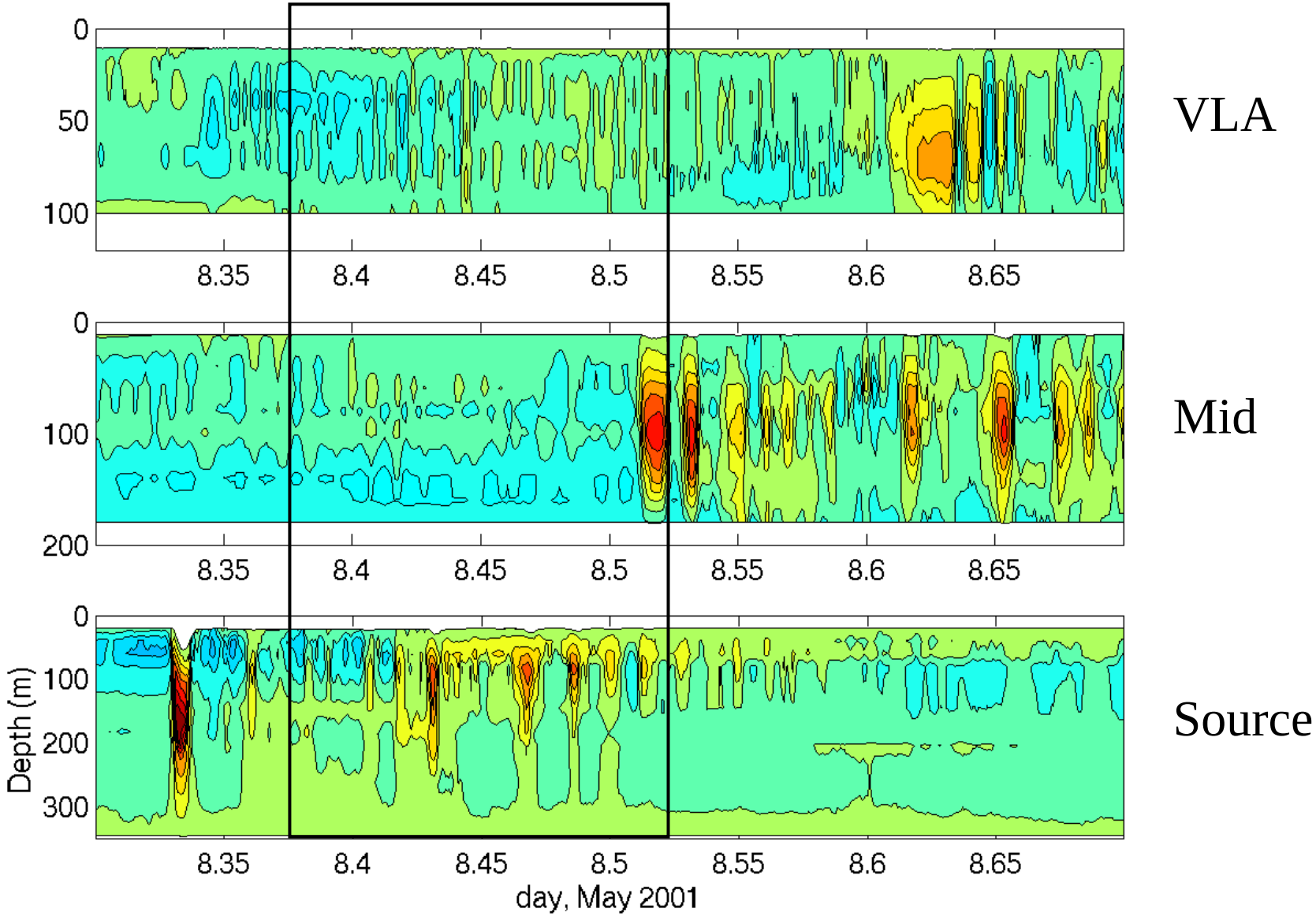
Sound speed 1500-1540 m/s by 4



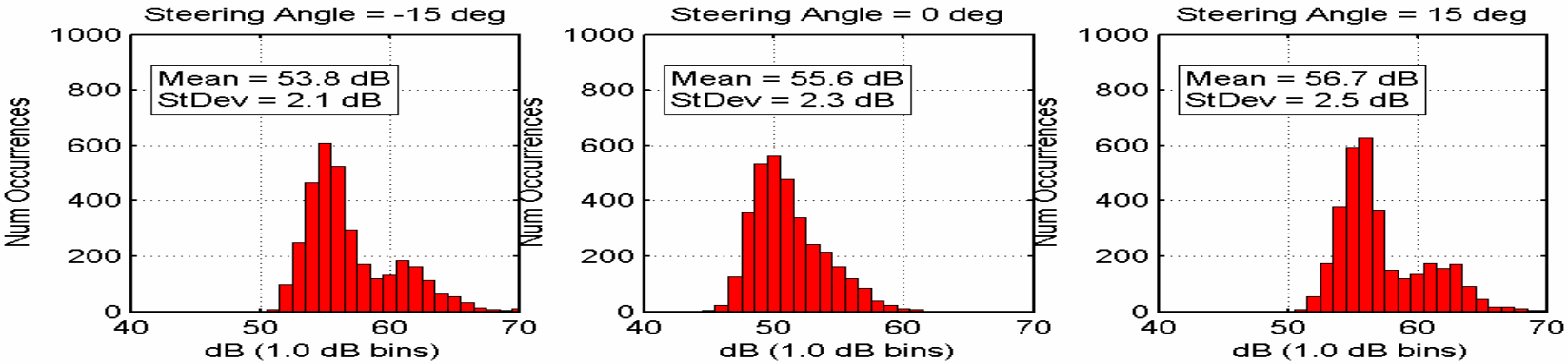
ss pert. -24 to 24 by 3

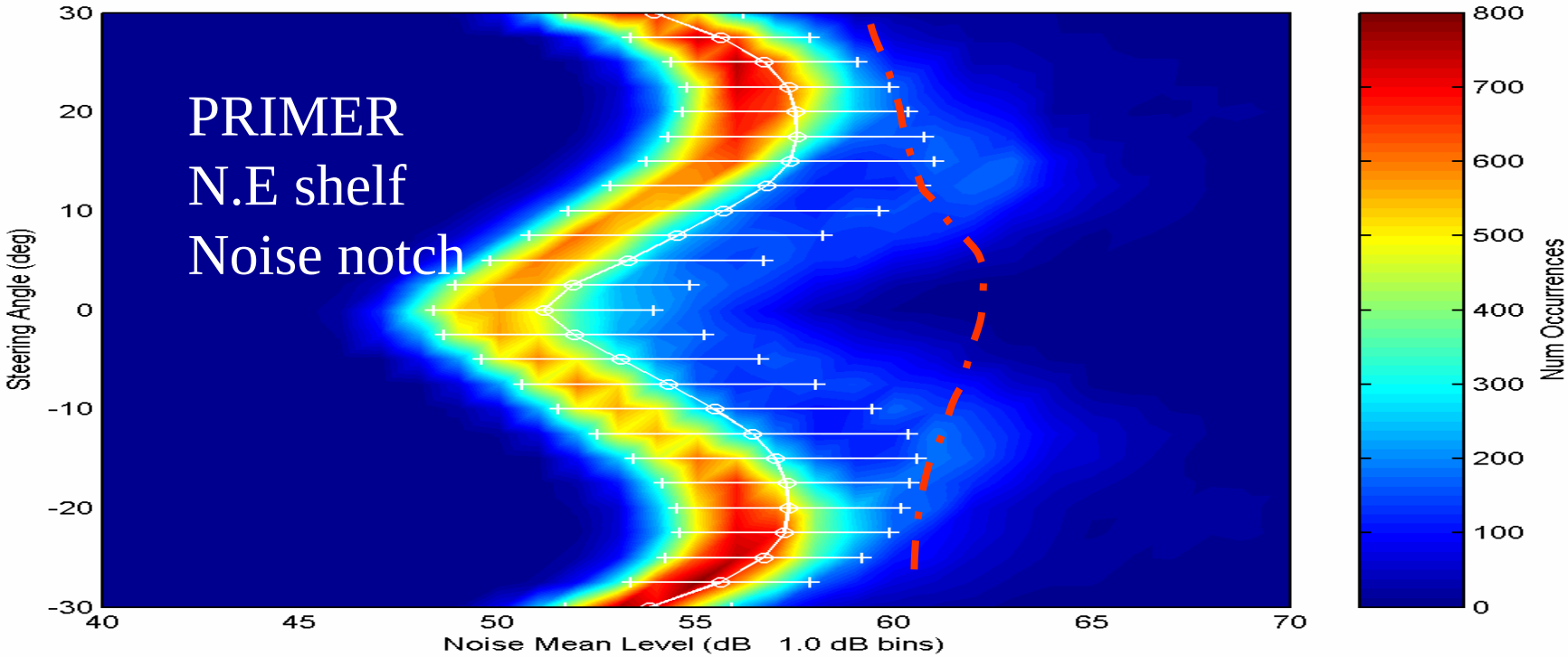


Sound speed perturbations



Beamformed Mean Noise Histogram. Source = 224 Hz, 8/1/96
Inactive Oceanogr, 10 hr period, DISK09A, 119 Trans Cycles, 3332 Pings, 10 Hr period





Summary

- Theories unlikely to be comprehensive enough to describe field data. Simulations can do better but are still incomplete.
- ASIAEX signal energy variations **support temporally-varying mode coupling** as a source of fluctuation.
- **Selected peak levels** are less variable that point statistics, which are what basic theories can predict. They also appear log-normal.
- Signal beam patterns change from high-angle to low angle with 20-30 minute time scale when only small ss perturbations are present, vary more rapidly and have broader beams when large ss pertubations (large nonlinear internal waves) are present. **Directional changes are consistent with temporally variable mode coupling.**
- Noise directionality shows similar variations as signal.
- Low-angle "Noise Notch" of the PRIMER Expt. is rarely seen. Hourly or daily computation of directionality show no notch, unlike PRIMER.
- PRIMER and ASIAEX sites have different fluctuation character.

Analysis of VLA Pulse Receptions: Thus far, studies of these quantities, with only basic comparison to theory

- Pulse time- and depth-integrated intensity, for comparison with simulations ***(incoherent)*** *Duda, Lynch, et al. article*

- Autocorrelation of VLA signal vector R(z), to test stability of matched-field processing ***(vector)*** *Mignerey and Orr article*

- Pulse-evolution behavior ***(mixed methods)*** *Chiu et al. article*

- Statistics of peak levels, energies as function of depth ***(individual phones)*** *Duda, Lynch, et al. article (above)*

- Vertically-steered beamforming output levels ***(phase coherent)*** *This talk*

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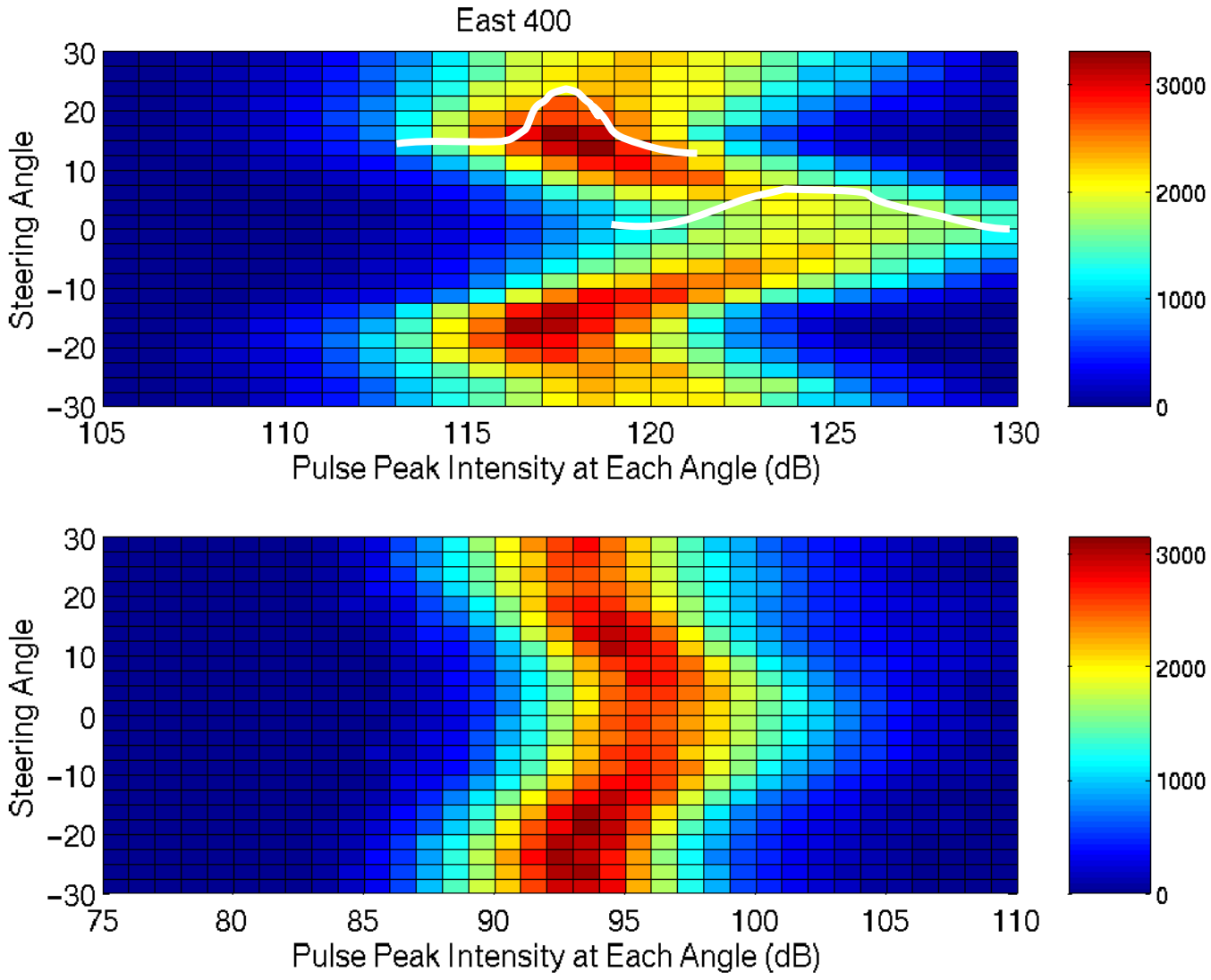
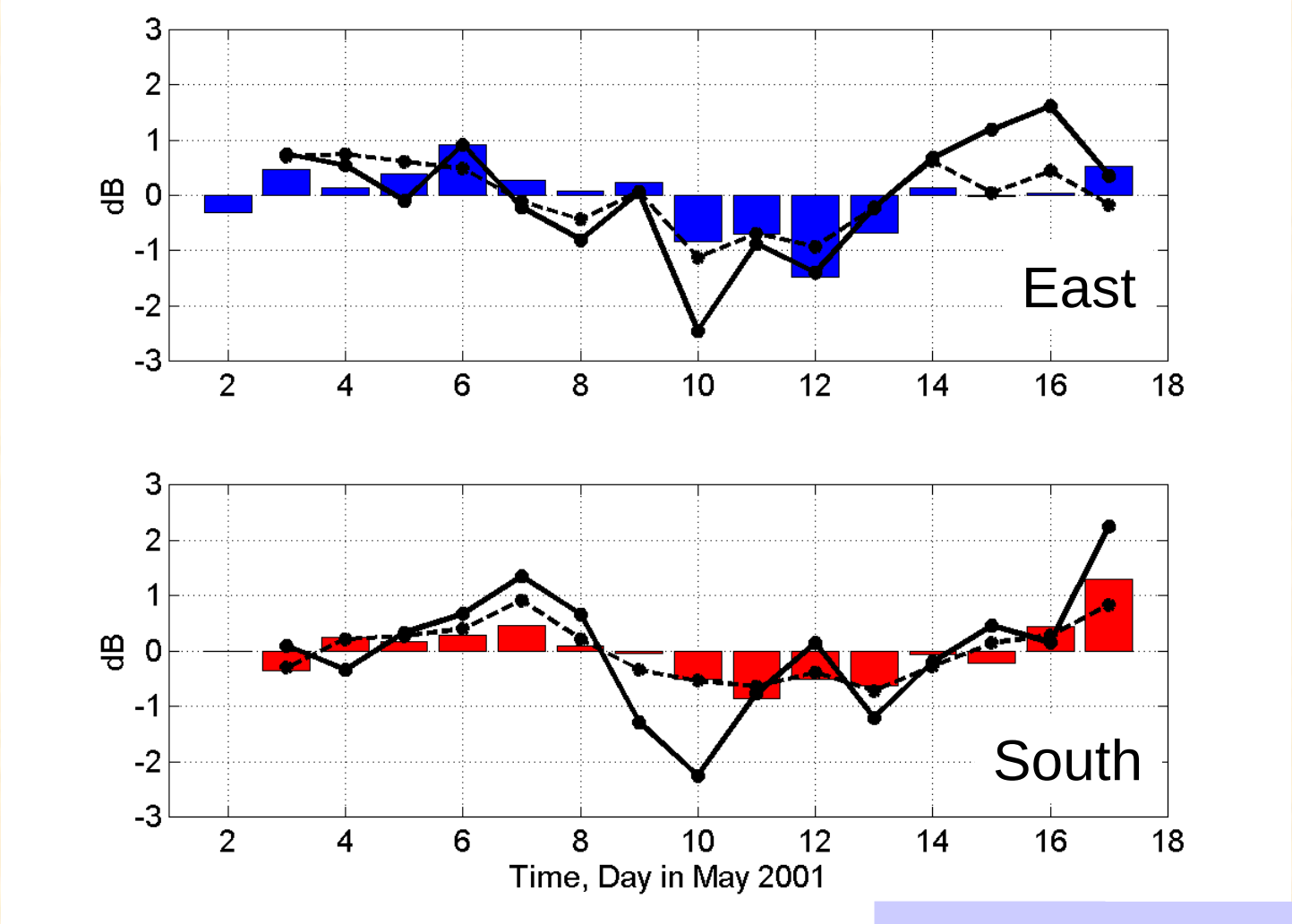
Signal Prob. Density Functions

Noise Prob. Density Functions



Note : 400 Hz along slope

Fluctuations of mean levels, computed daily, 400 Hz (zero-mean)



bars.. Incoherent E_{tz}

Beamform, sum θ

Beamform, θ = 0°

Summary

- Beamformed 400-Hz signals and noise both show complex variability with a breadth of time scales.
- Signal and SNR are both greater at near-horizontal angles than at higher angles. Low angles have greater signal variance.
- Daily averaged coherently processed signal level varies, and behaves like the incoherently computed “energy”, but these do not correspond perfectly with the internal wave activity pattern.
- Low-angle “Noise Notch” of the Primer Expt. is not seen here, nor (of course) is filling-in of the notch at active times. Continuous coupling ??
- Variability of incoherent SI corresponds well with the internal wave activity pattern, suggesting variable signal mode coupling; variable low-angle beamformed output, also suggestive of variable coupling-corresponds less well with internal wave activity pattern.
- Thus far, only tentative signal-noise correlations seen (not shown), possibly caused by array deformation.
- Need to improve beamforming (use $c(z,t)$), add mode filtering analysis.