Effect of the internal tide on mid-frequency transmission loss in the Shallow Water 2006 Experiment

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(submitted to IEEE JOE SW06 special collections)

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Goal

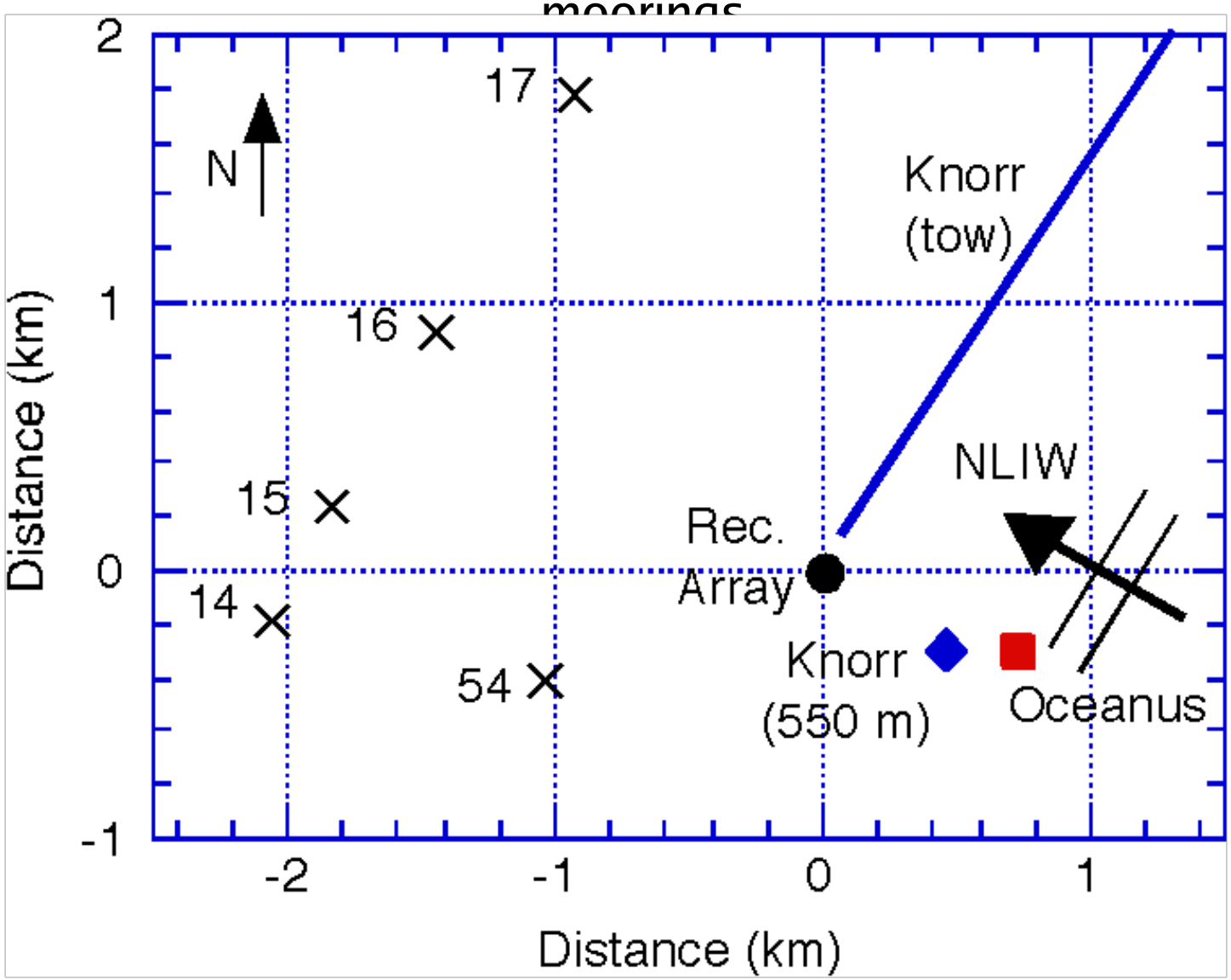
Model mean TL at mid frequencies under slowly time varying conditions due to the internal tide.

Outline

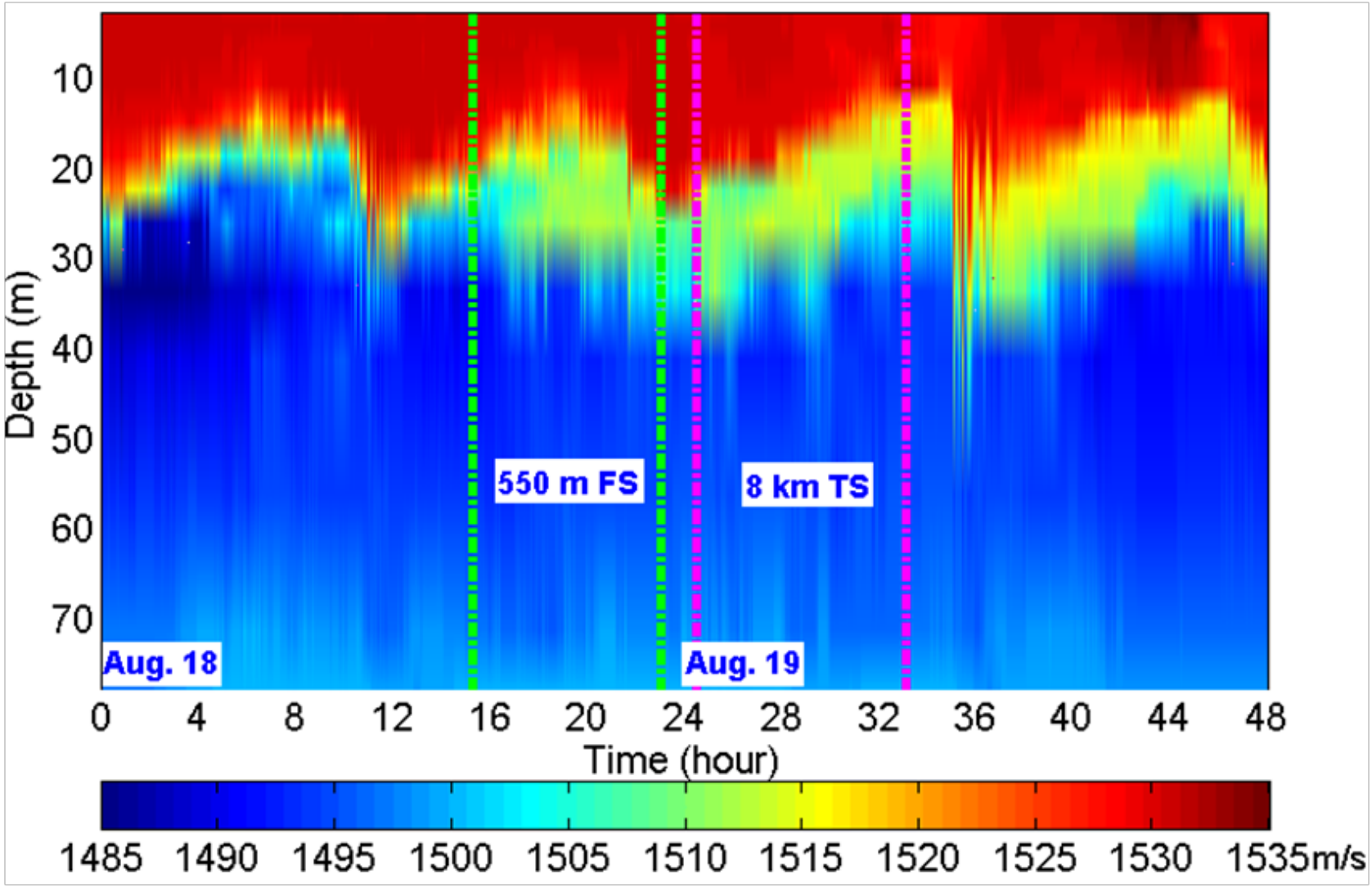
- Ocean data/modeling using multiple mooring data for mid-frequency acoustic modeling.
- Two acoustic data sets and corresponding broadband PE simulation results:

  1. fixed range (550 m) data
  2. towed source data (max 8.1 km)
- Summary and implications.

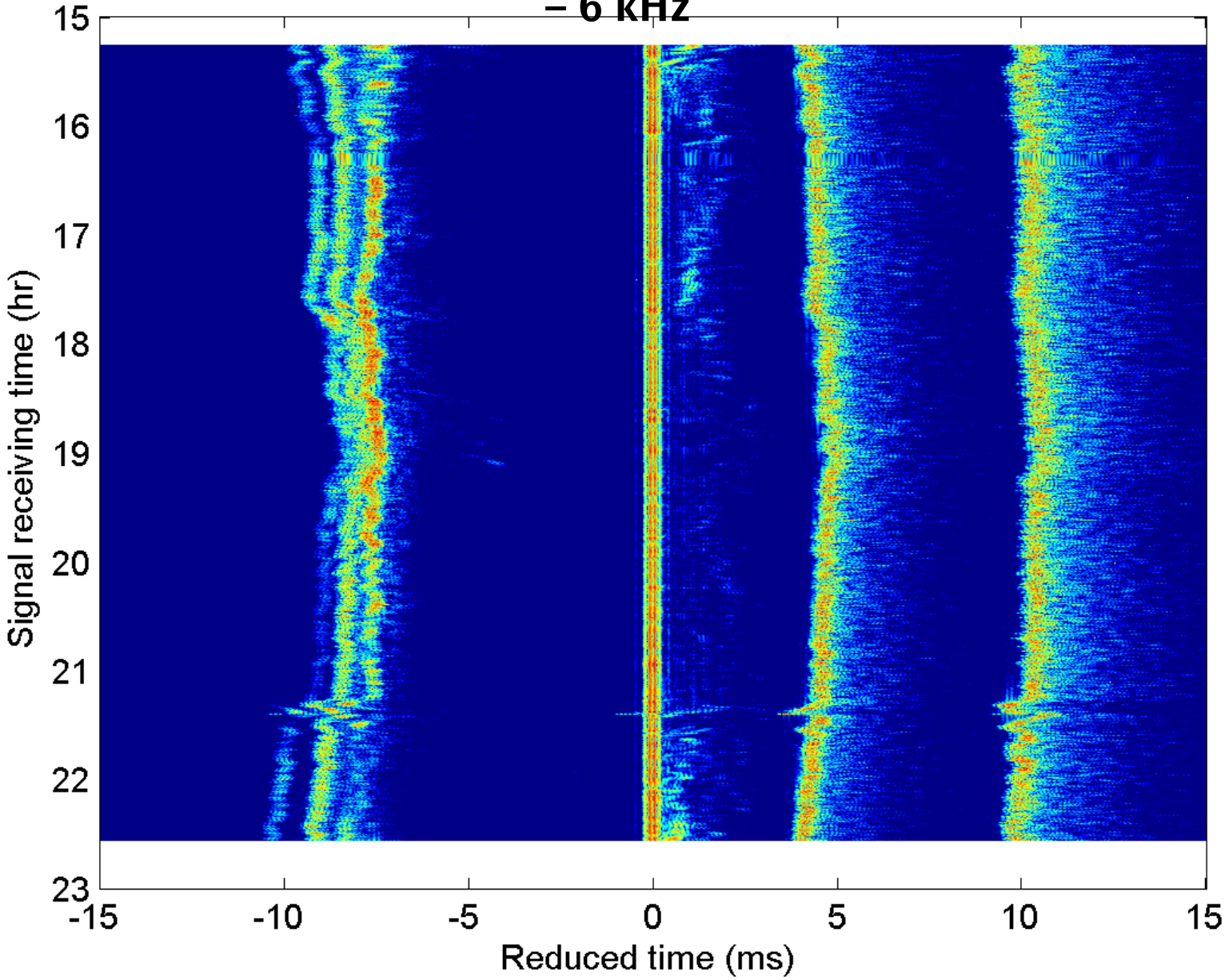
Geometry for acoustic measurements and oceanographic moorings

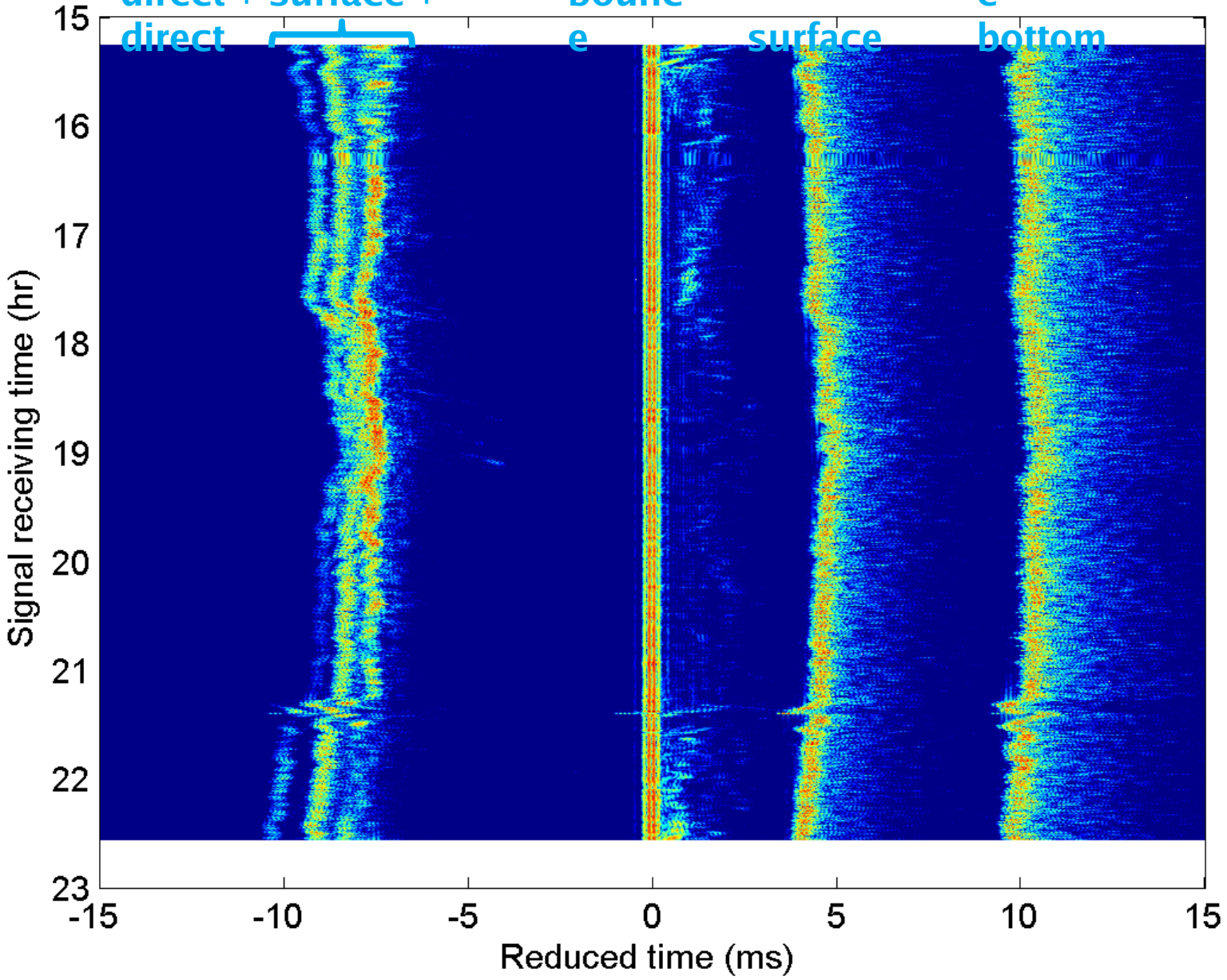


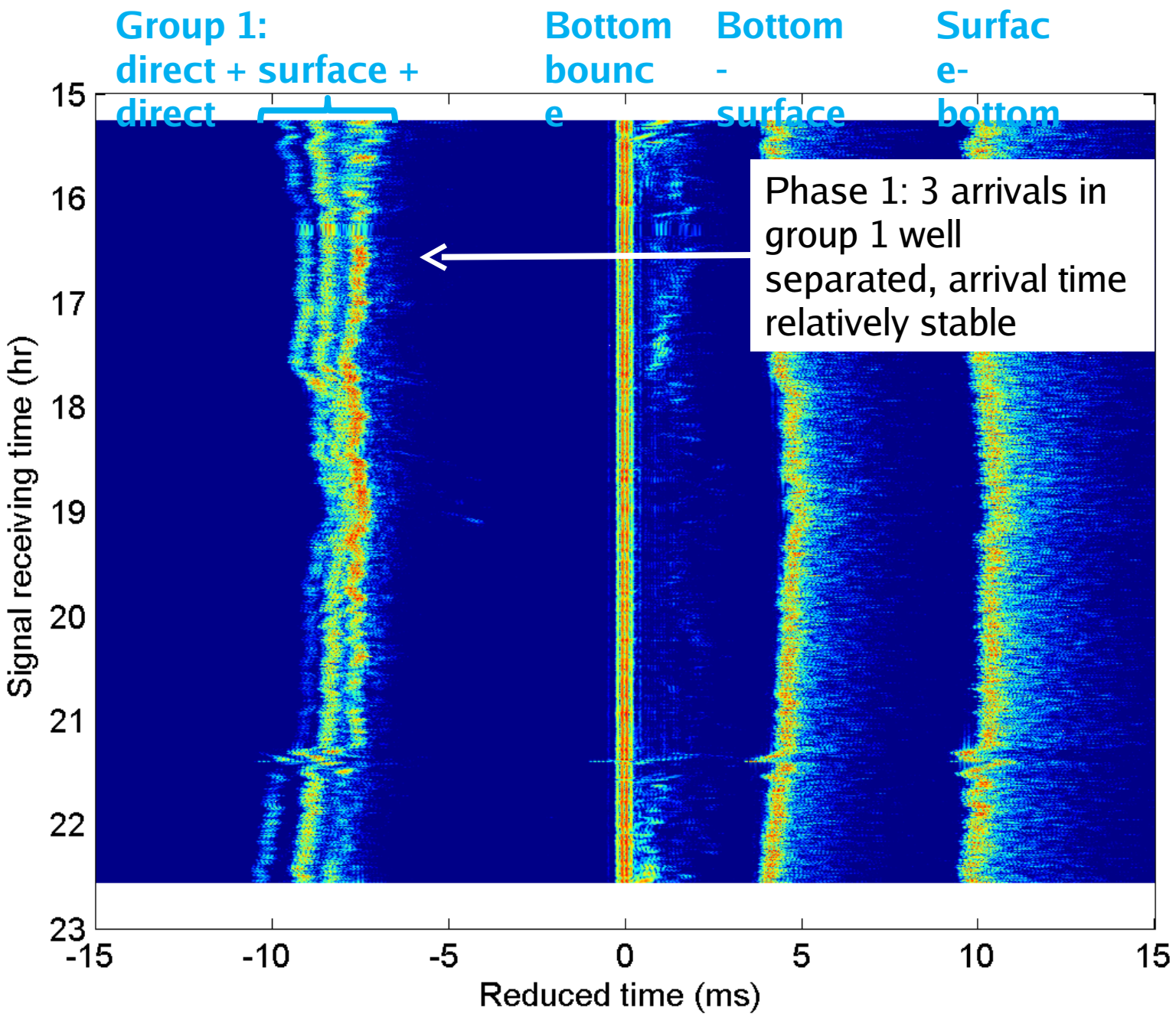
Sound speed recorded from mooring 54 for 18-19 August

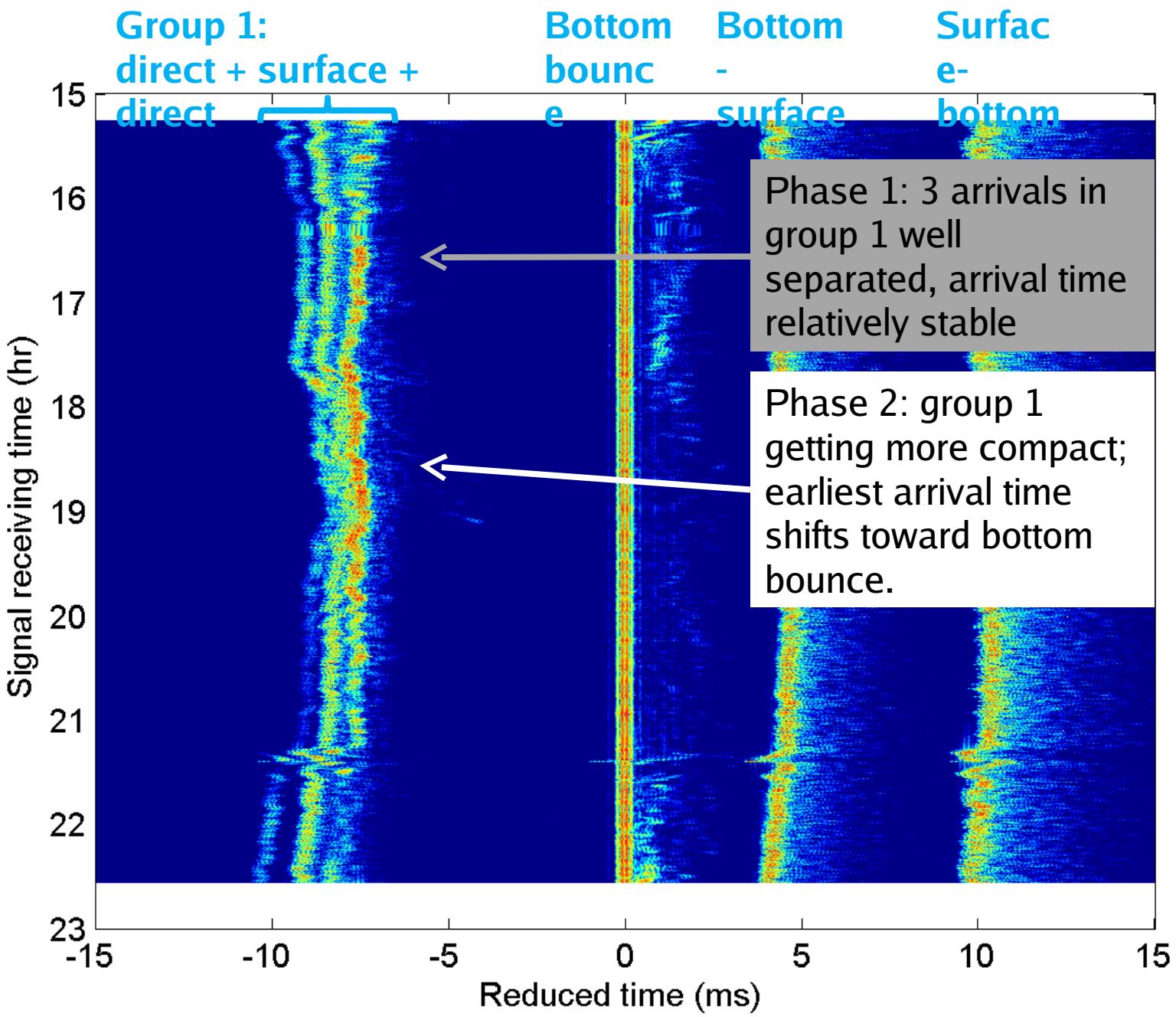


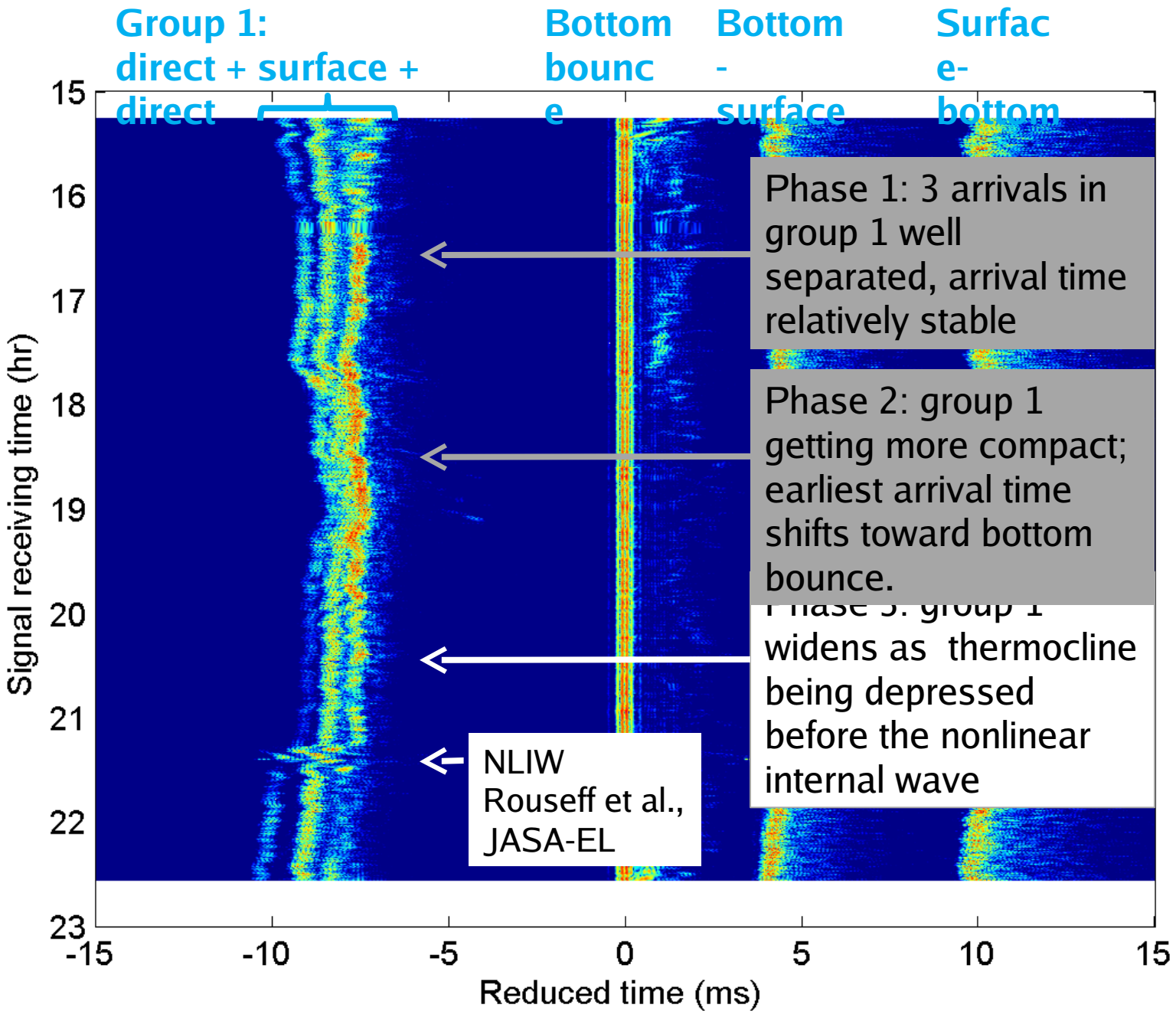
Acoustic data I: 550 m fixed range intensity, receiver depth 25 m, 1.5 – 6 kHz




Group 1:
direct + surface +
direct
Bottom
bounc
e
Bottom
-
surface
Surfac
e-
bottom
Signal receiving time (hr)
15
16
17
18
19
20
21
22
23
-15
-10
-5
0
5
10
15
Reduced time (ms)


Group 1:
direct + surface +
direct
Bottom
bounc
e
Bottom
-
surface
Surfac
e-
bottom
Phase 1: 3 arrivals in group 1 well separated, arrival time relatively stable
Signal receiving time (hr)
15
16
17
18
19
20
21
22
23
-15
-10
-5
0
5
10
15
Reduced time (ms)


Group 1: direct + surface + direct
Bottom bounce
Bottom - surface
Surface- bottom
Phase 1: 3 arrivals in group 1 well separated, arrival time relatively stable
Phase 2: group 1 getting more compact; earliest arrival time shifts toward bottom bounce.
Signal receiving time (hr)
15
16
17
18
19
20
21
22
23
-15
-10
-5
0
5
10
15
Reduced time (ms)

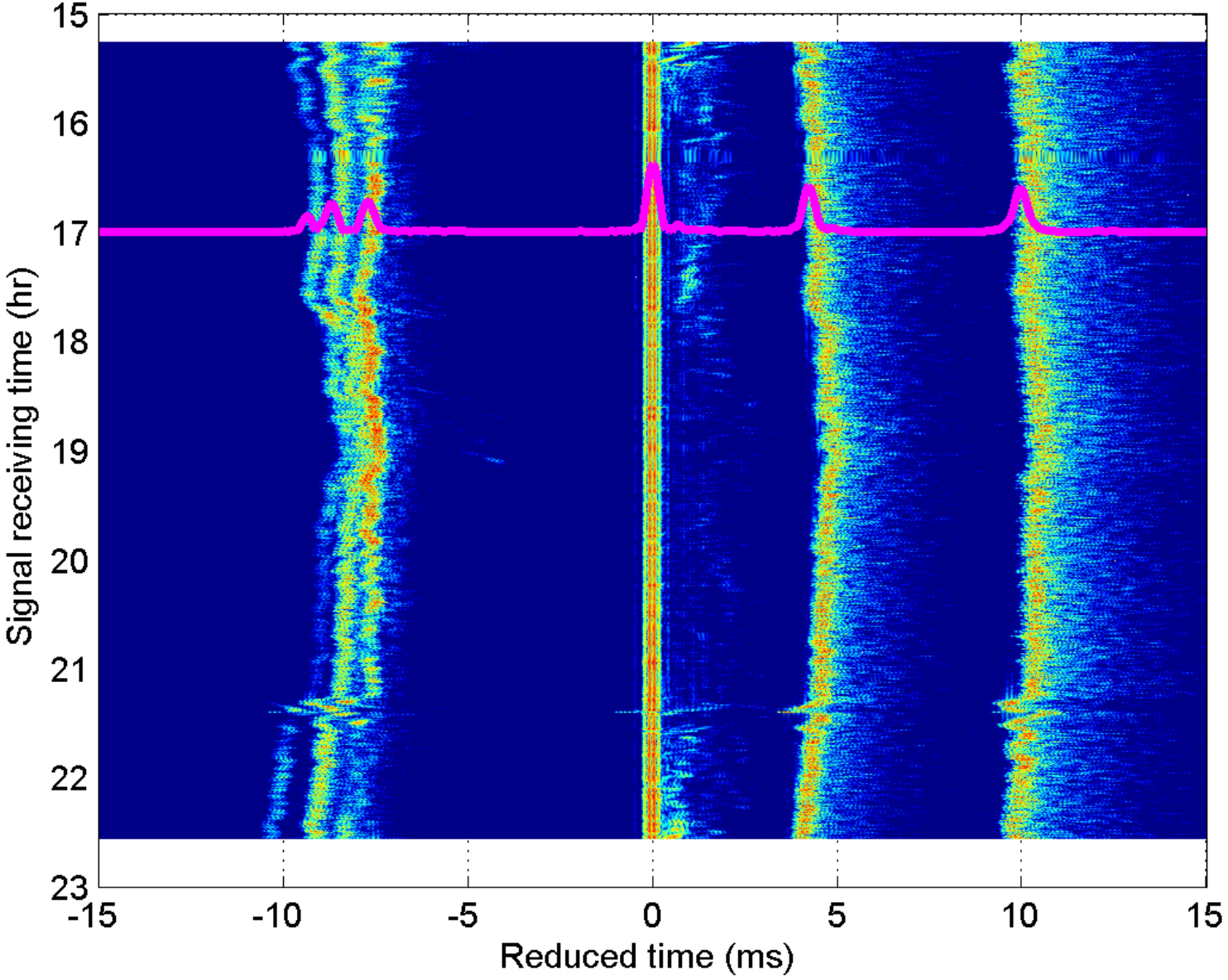

Group 1: direct + surface + direct
Bottom bounce
Bottom - surface
Surface- bottom
Phase 1: 3 arrivals in group 1 well separated, arrival time relatively stable
Phase 2: group 1 getting more compact; earliest arrival time shifts toward bottom bounce.
widens as thermocline being depressed before the nonlinear internal wave
NLIW
Rouseff et al., JASA-EL
Signal receiving time (hr)
15
16
17
18
19
20
21
22
23
-15
-10
-5
0
5
10
15
Reduced time (ms)

Simulation strategy

- Goal: develop a range-independent acoustic model to simulate observed arrival structure.
- Approach: broadband Parabolic Equation simulation.
- Example: Fourier synthesis of PE runs in 1.5 - 6 kHz with pulse length 400 ms using a CTD profile from the KNORR.

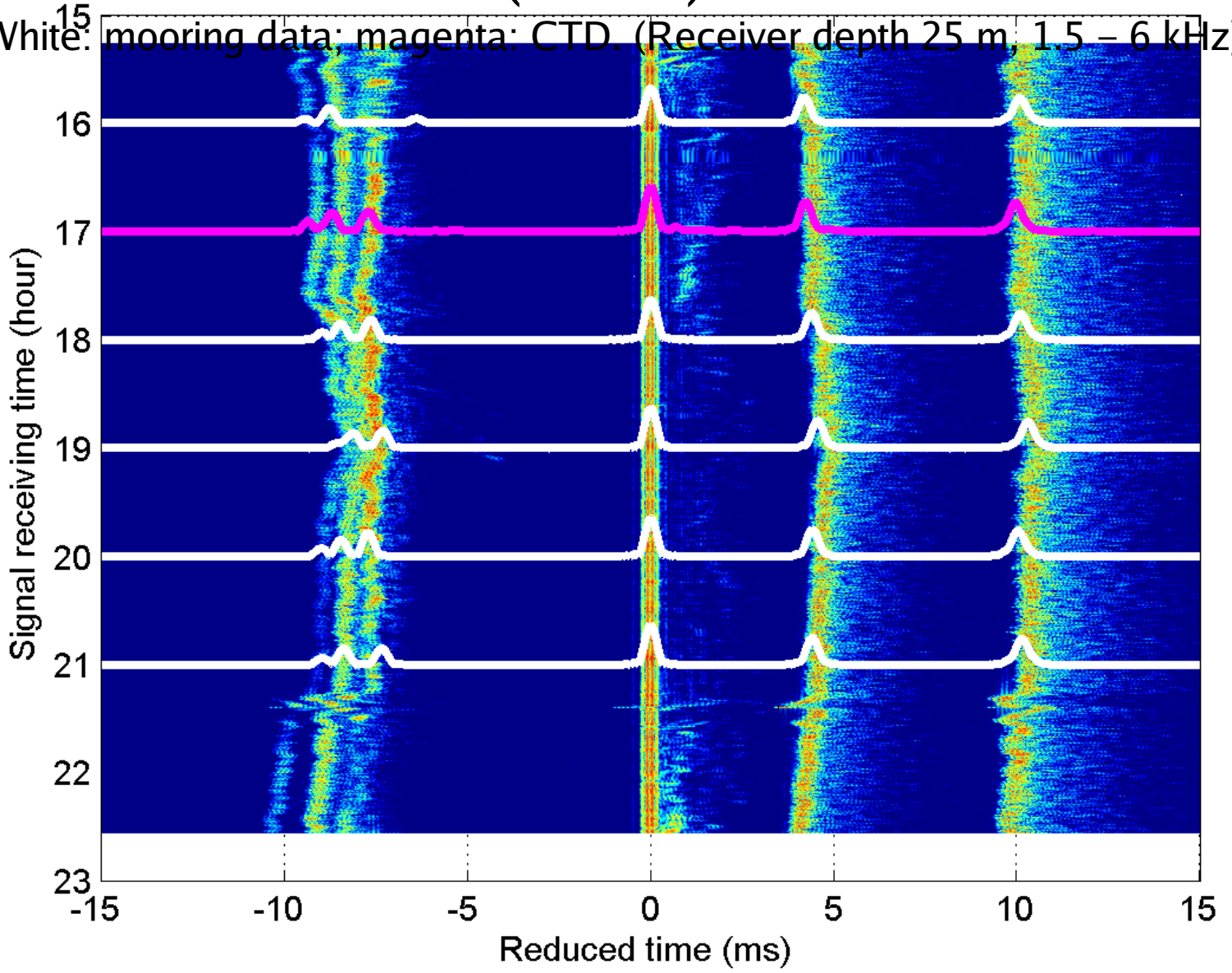
Acoustic data versus broadband PE simulation

(CTD input, receiver depth 25 m, 1.5 – 6 kHz)

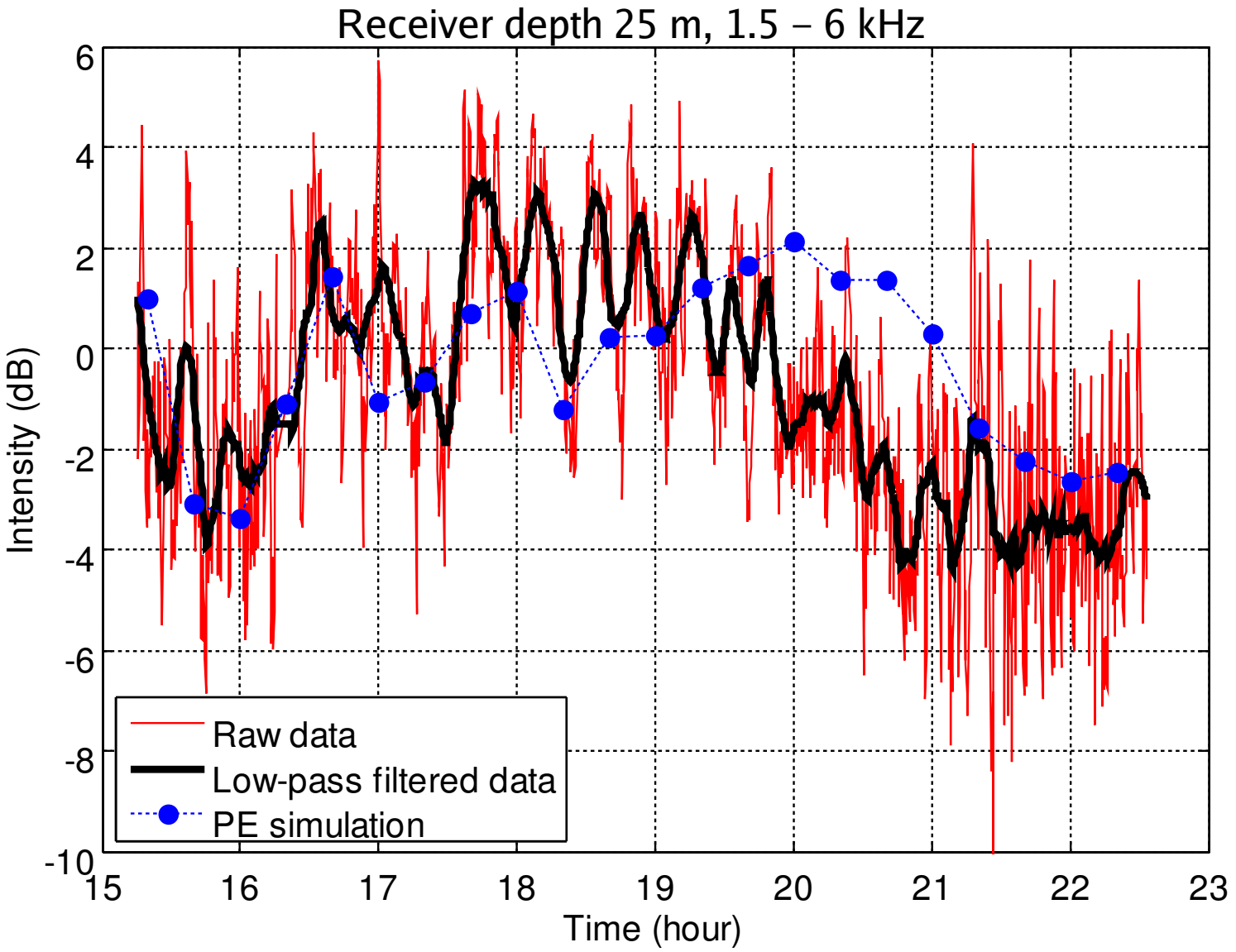


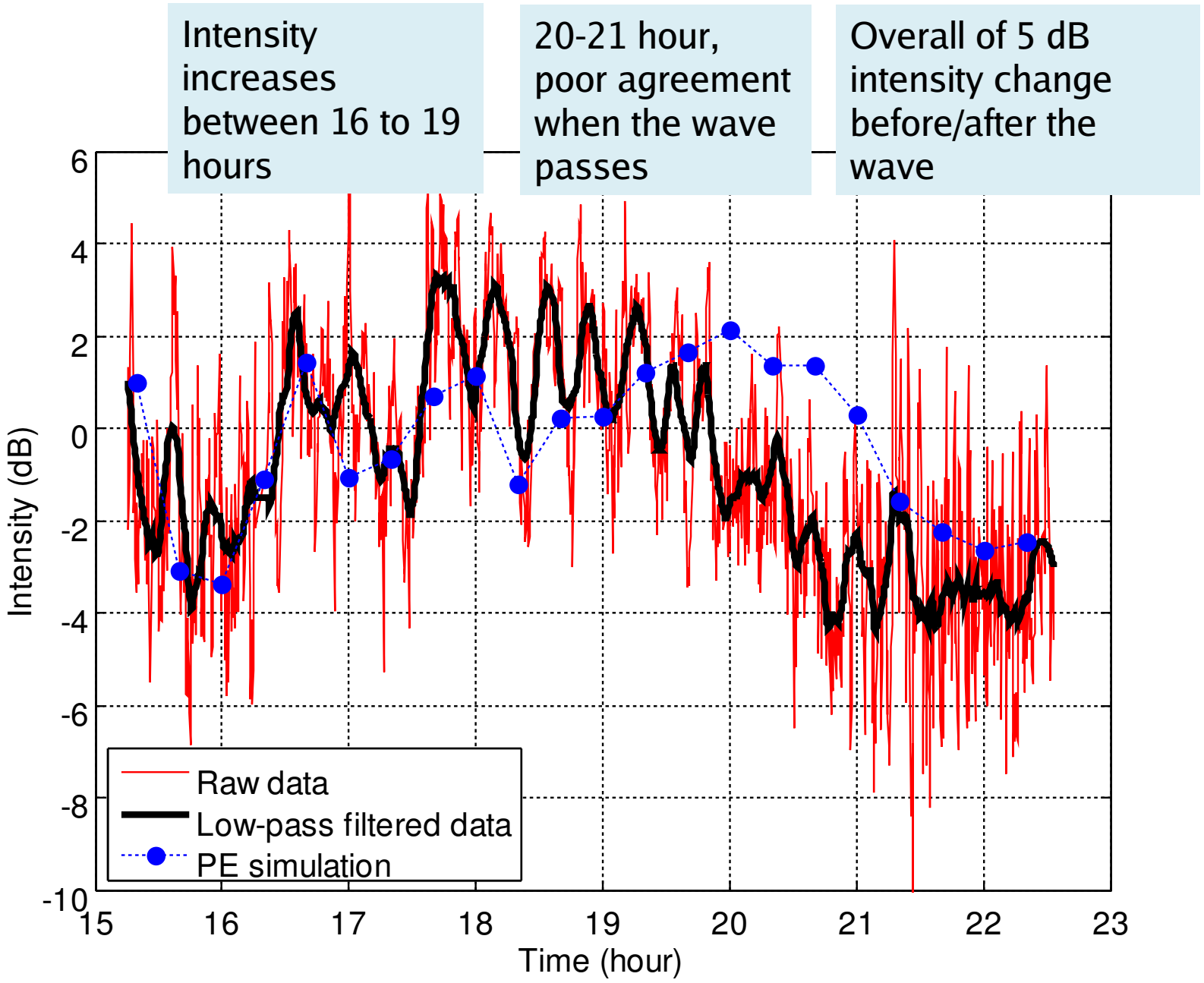
Acoustic data versus broadband PE simulations (cont'd)

White: mooring data; magenta: CTD. (Receiver depth 25 m, 1.5 – 6 kHz)

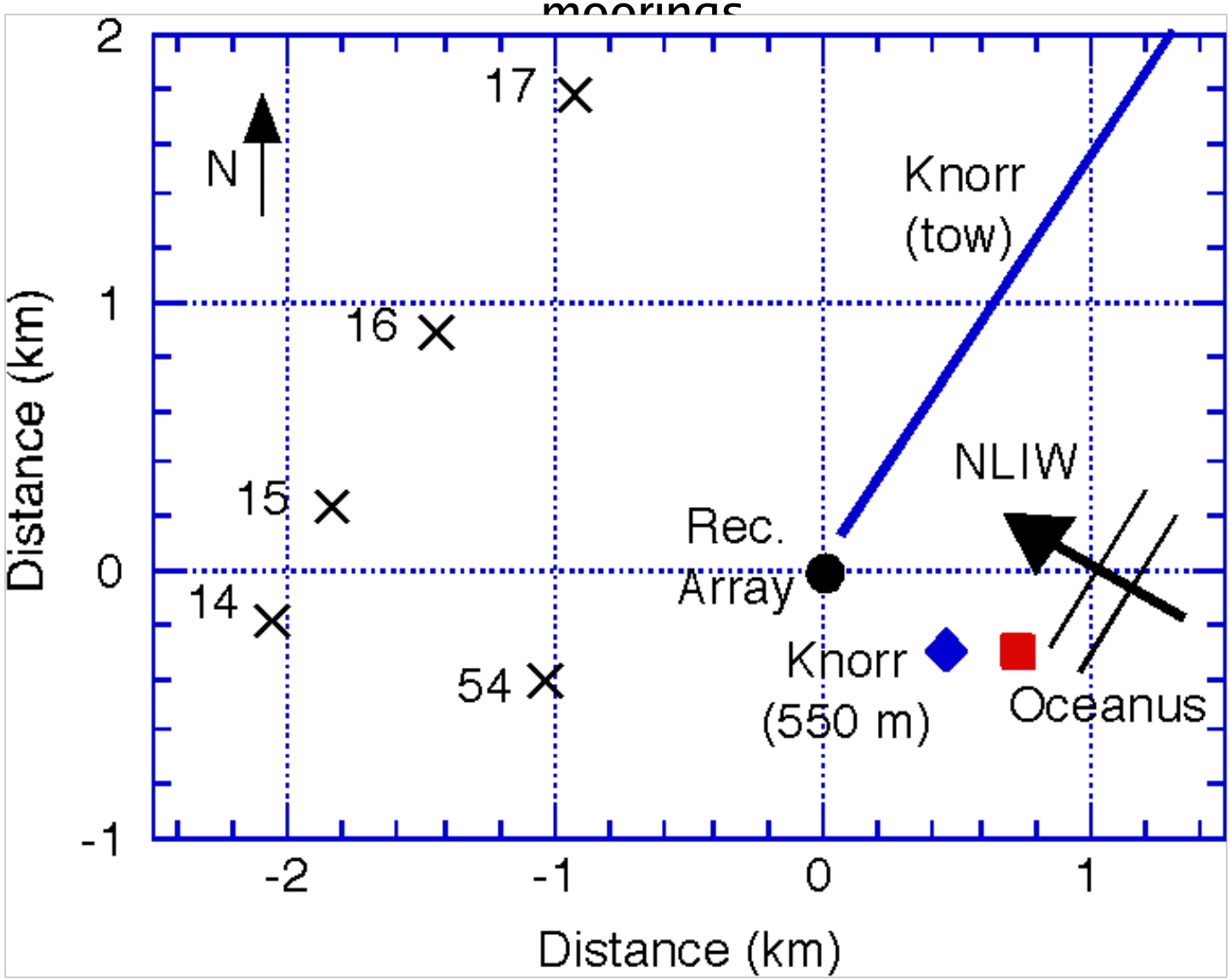


Data/model comparison of acoustic intensity of the first arrival group

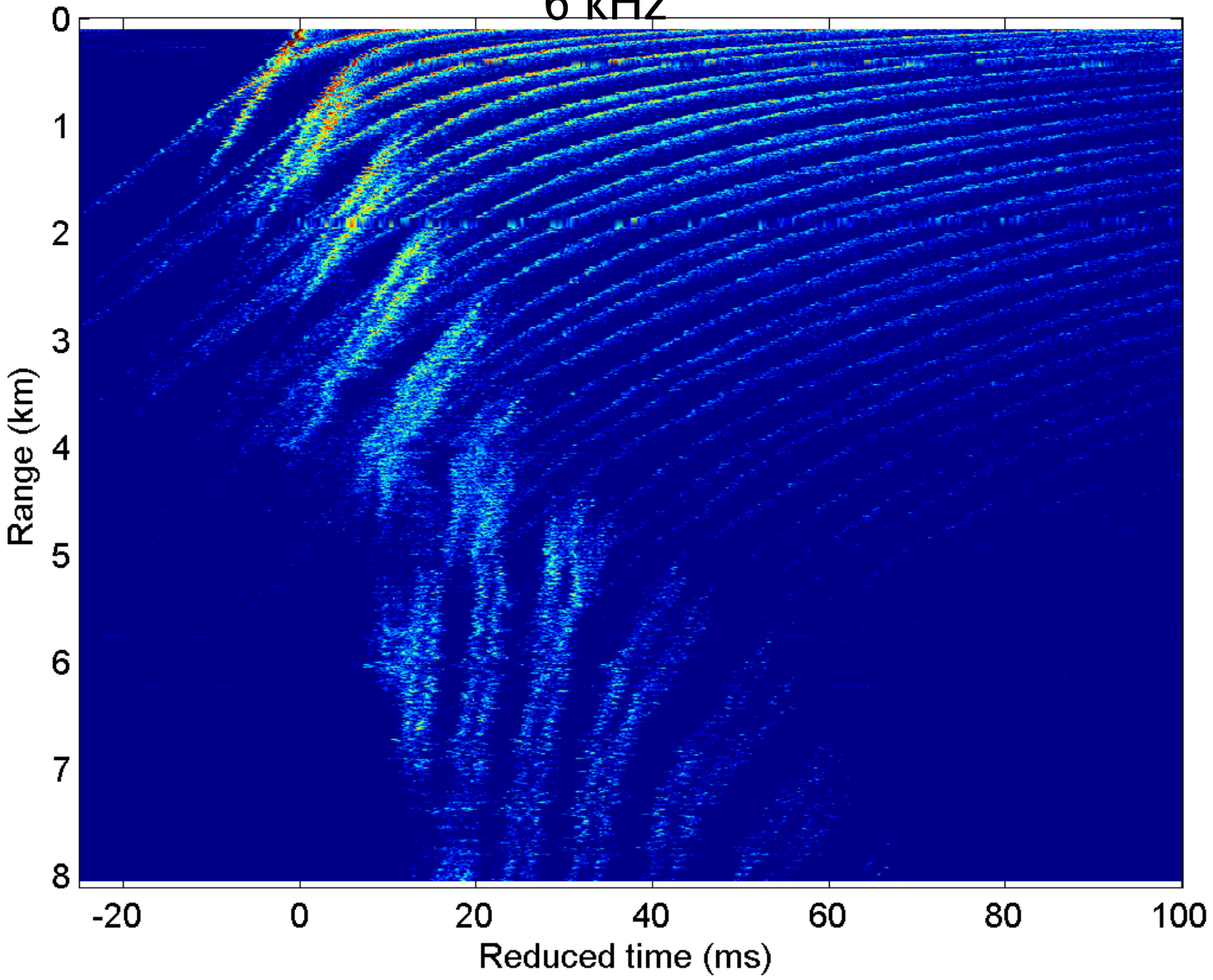


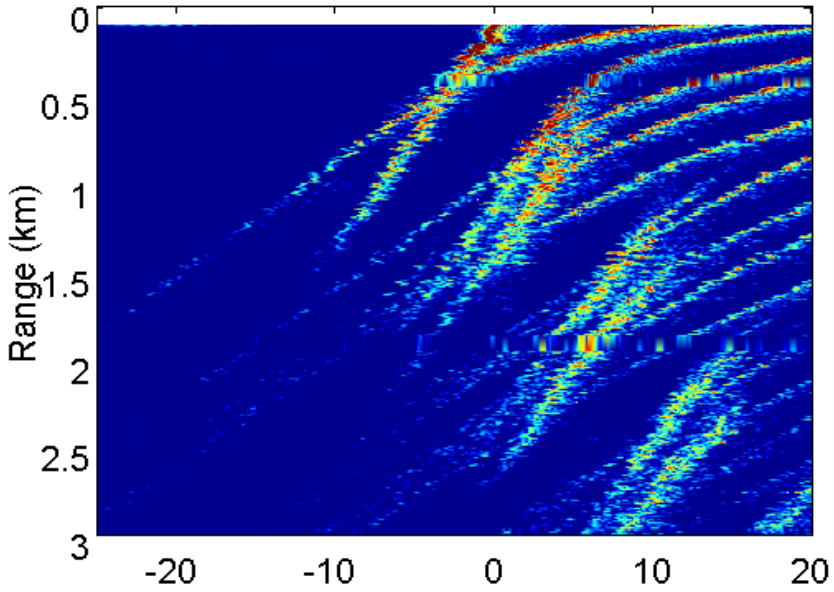

Intensity increases between 16 to 19 hours
20-21 hour, poor agreement when the wave passes
Overall of 5 dB intensity change before/after the wave
Intensity (dB)
Time (hour)
Raw data
Low-pass filtered data
PE simulation
6
4
2
0
-2
-4
-6
-8
-10
15
16
17
18
19
20
21
22
23

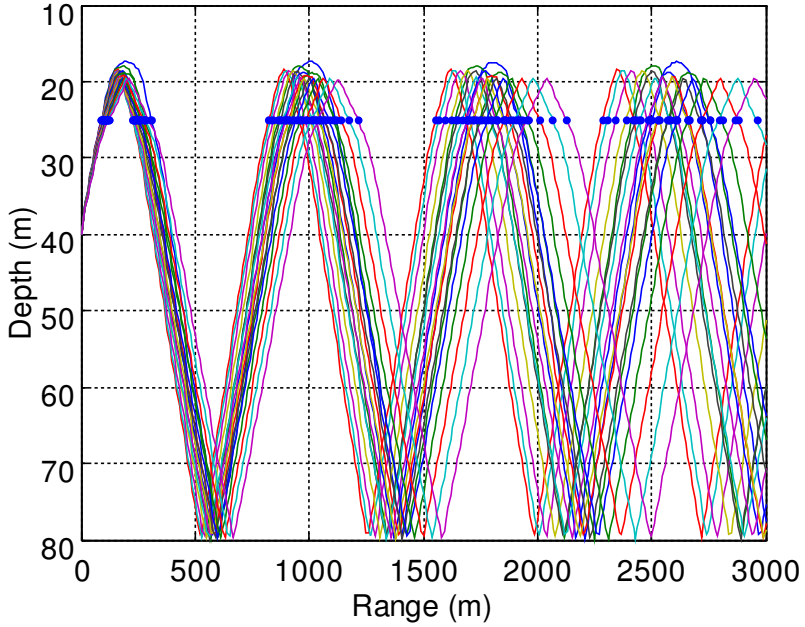
Geometry for acoustic measurements and oceanographic moorings

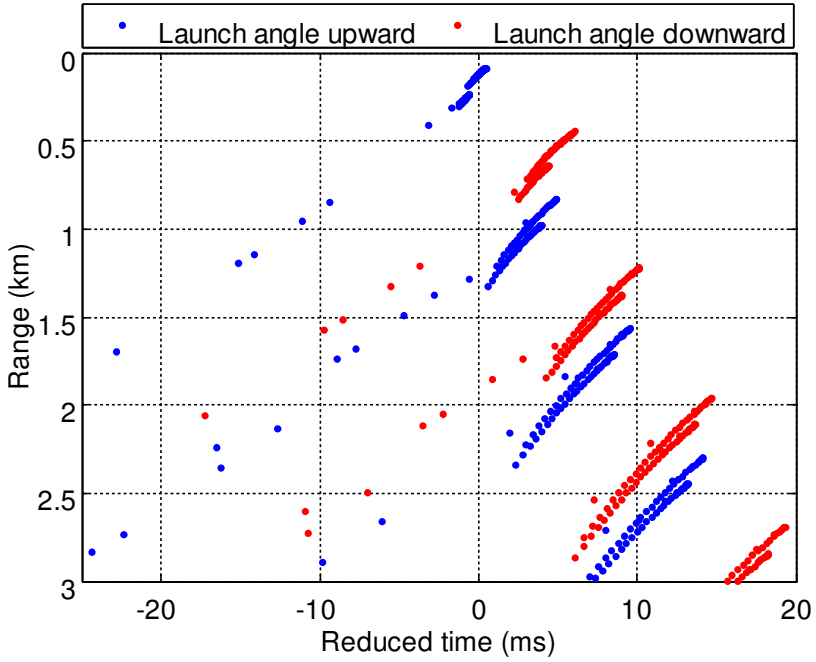


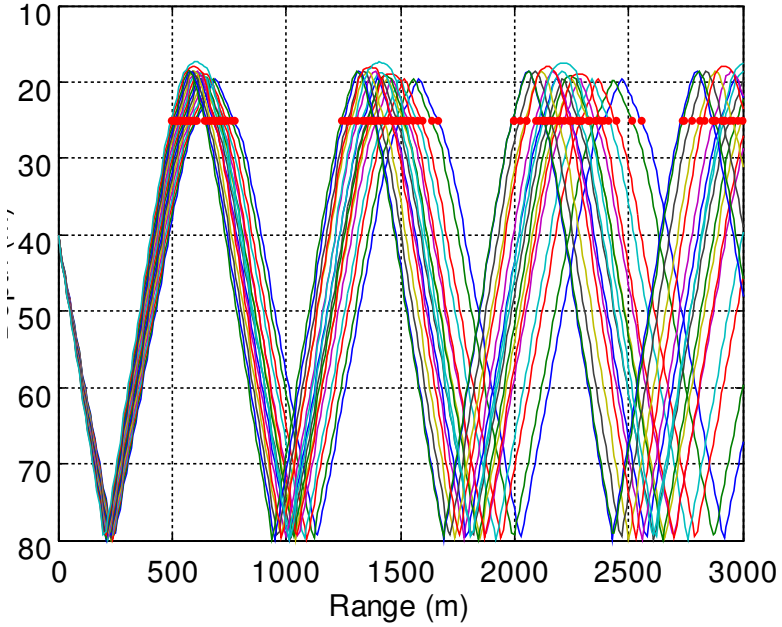
Acoustic data II: towed source data at receiver depth 25 m, 1.5 – 6 kHz

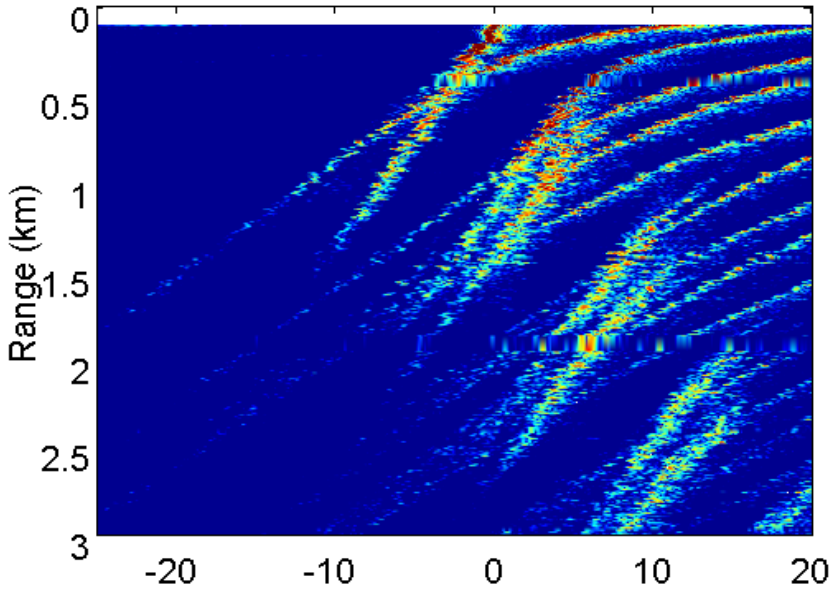


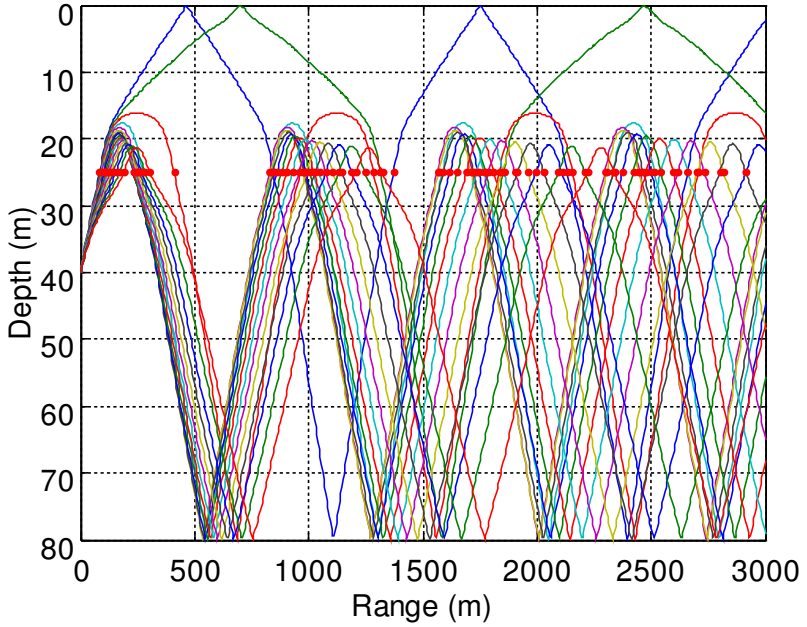

Range (km)
0
0.5
1
1.5
2
2.5
3
-20
-10
0
10
20

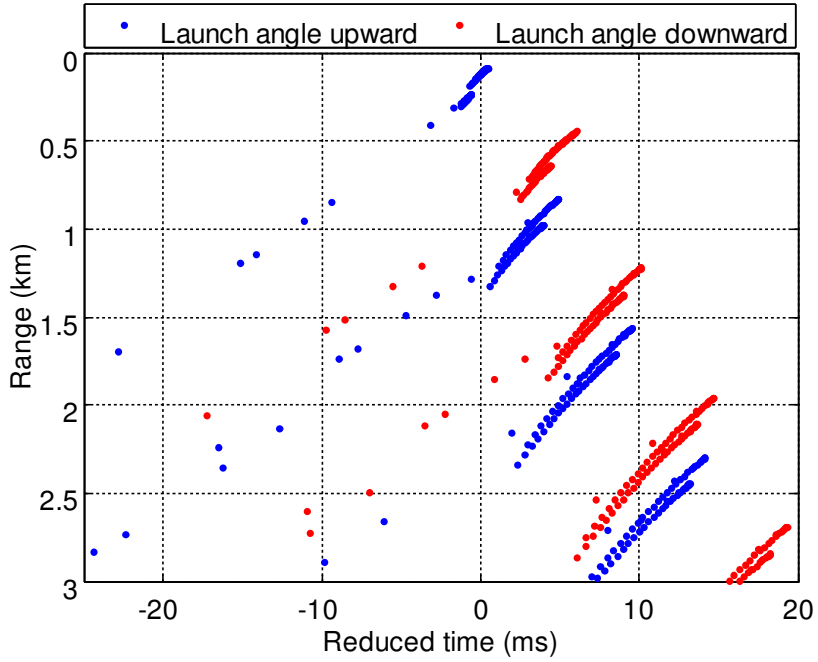

Depth (m)
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
Range (m)

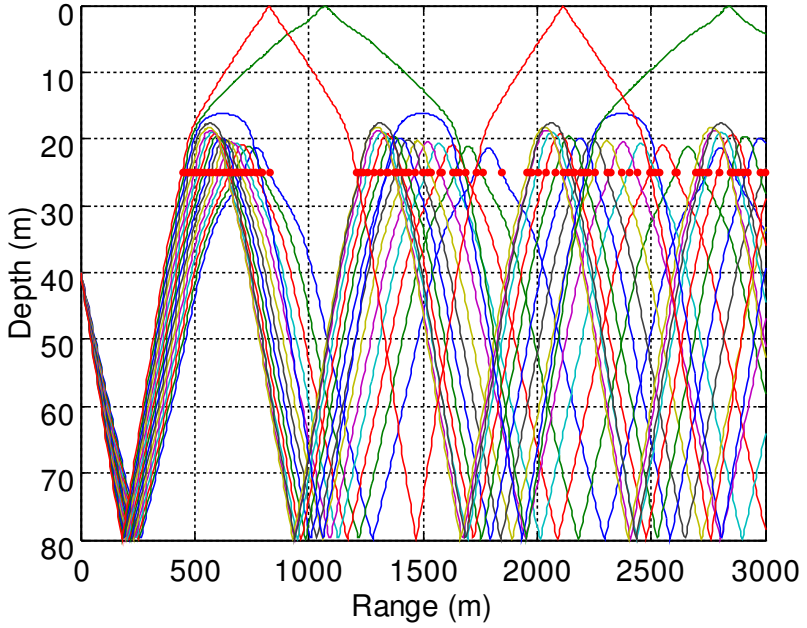

Launch angle upward
Launch angle downward
Range (km)
0
0.5
1
1.5
2
2.5
3
-20
-10
0
10
20
Reduced time (ms)


10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
Range (m)

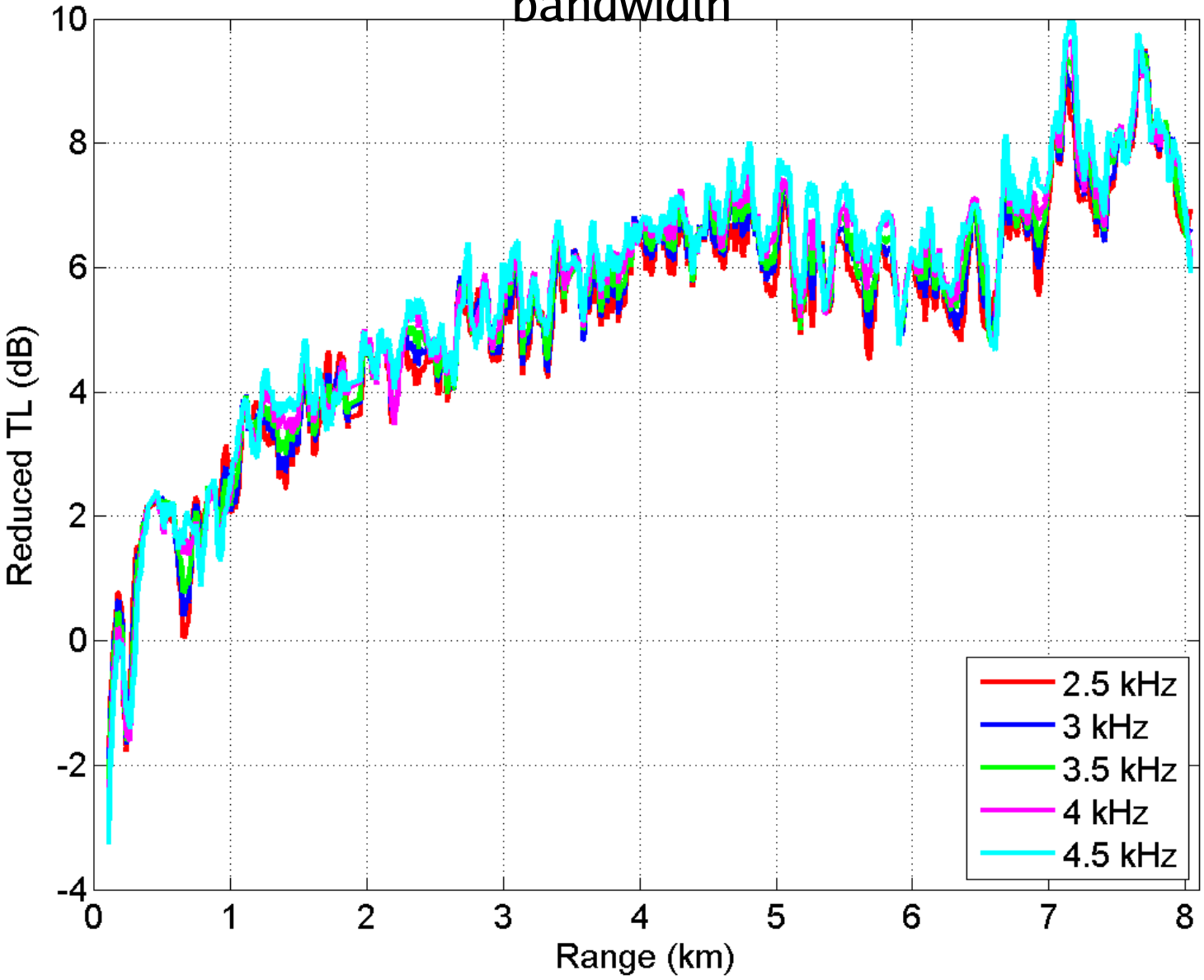

Range (km)
0
0.5
1
1.5
2
2.5
3
-20
-10
0
10
20


Depth (m)
0
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
Range (m)


Launch angle upward
Launch angle downward
Range (km)
0
0.5
1
1.5
2
2.5
3
-20
-10
0
10
20
Reduced time (ms)


Depth (m)
0
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
Range (m)

Reduced transmission loss at receiver depth 25 m with 1 kHz bandwidth



Modeling strategy

roadband PE simulations

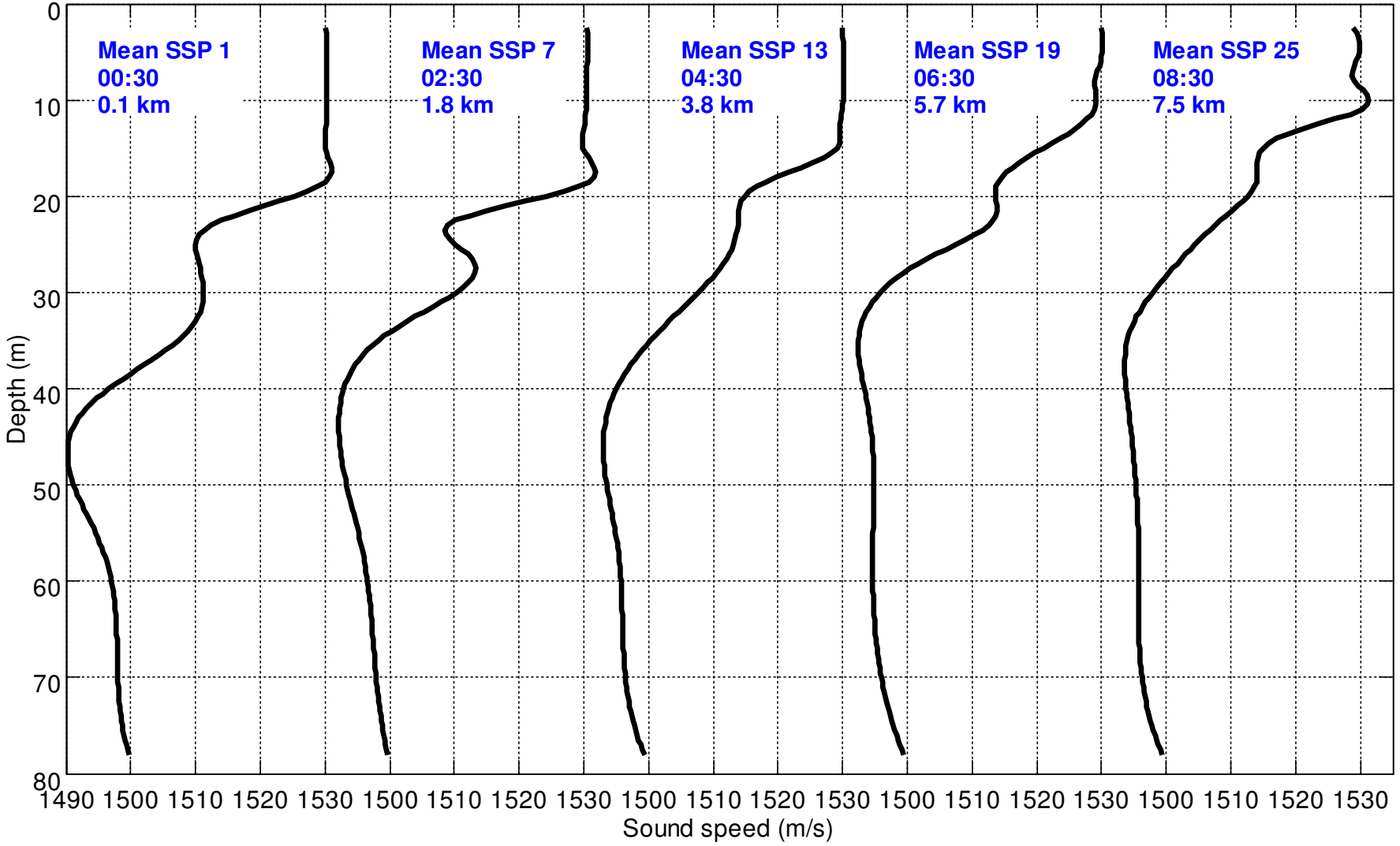
se Mooring 54 for SSPs.

reak 8.5 h data into 27 20-min windows.

verage SSP over the window.

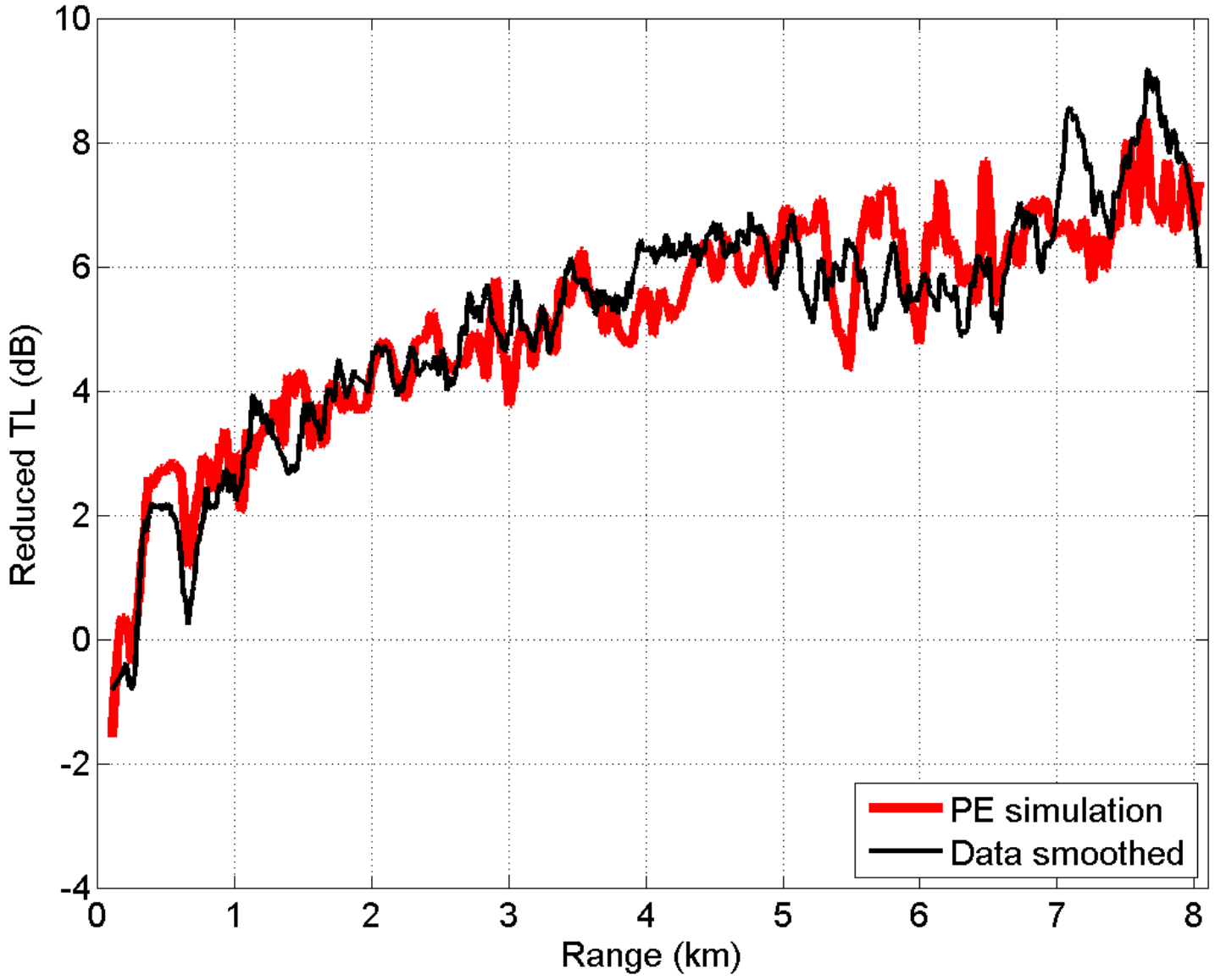
esult: range-independent, slowly varying

Progress of sound speed profiles using Mooring 54 over 8 h period



Data/model comparison of reduced transmission loss

receiver depth 25 m, 2.5 kHz ± 1 kHz bandwidth



Summary Acoustic Data and Modeling

Acoustical effects of the rising thermocline:

1. 550 m data: changing arrival pattern and 5 dB change in acoustic intensity.
2. Towed source data: 2 dB change in acoustic intensity.

Broadband PE together with range-independent / slow time-varying ocean model captures gross characteristics of TL.

1. At 550 m, good model/data agreement for both intensity and arrival pattern.
2. For towed source, overall good agreement.

Implications

- Acoustical effects of the rising thermocline are significant, observable, and predictable.
- Nearby mooring data improve acoustic modeling.
- The observed acoustic variations due to the internal tide impacts geoacoustic inversion.