Simultaneous nearby measurements of acoustic propagation and high-resolution sound speed structure containing internal waves

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Experiment

Part of Shallow Water 2006 (SW06)

Measure environment and acoustic propagation together (2 ships + mooring)

Effect of Nonlinear internal waves (NLIW's)

Quantitative, deterministic computation of acoustic effects from NLIW's

Mid-frequency broadband acoustics: 1.5 to 10 kHz [0.13 ms resolution]


SWL
NOV 04
D-12000
S-18200

Data Collected

Aug. 13, 2006

Environmental measurements:

Towed CTD chain ~ 50 CTD units, ~1 m vertical spacing

7 loops around acoustic path (1.5 loops with NLIW's)

2 s sampling @ 6 kts

ship's GPS for positioning (R/V Endeavor)

Ship's CTD profile ~ 1 hr before the NLIW's arrived (R/V Knorr)

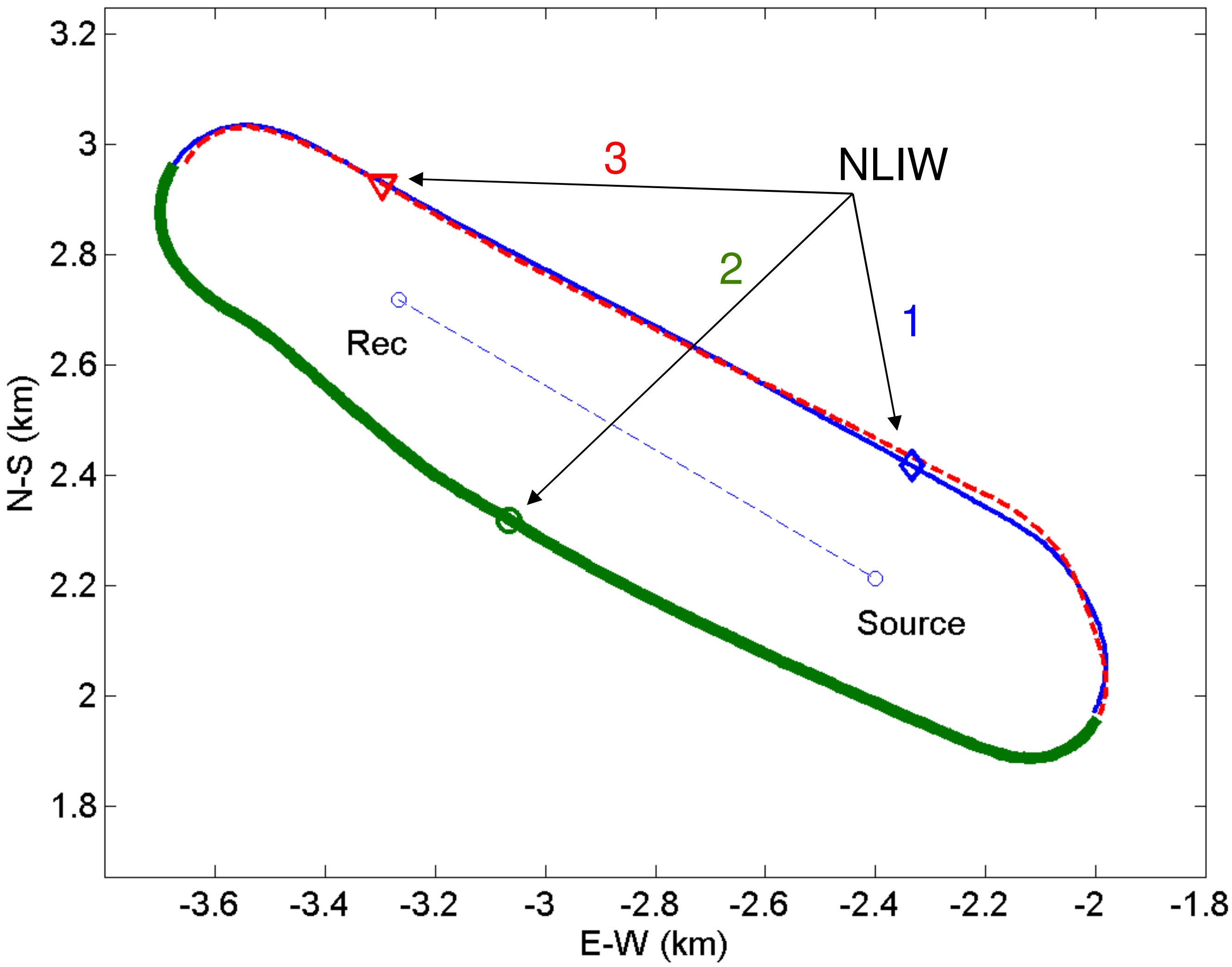
Acoustic measurements:

Broadband pulse every 13 s from R/V Knorr to MORAY receiver mooring

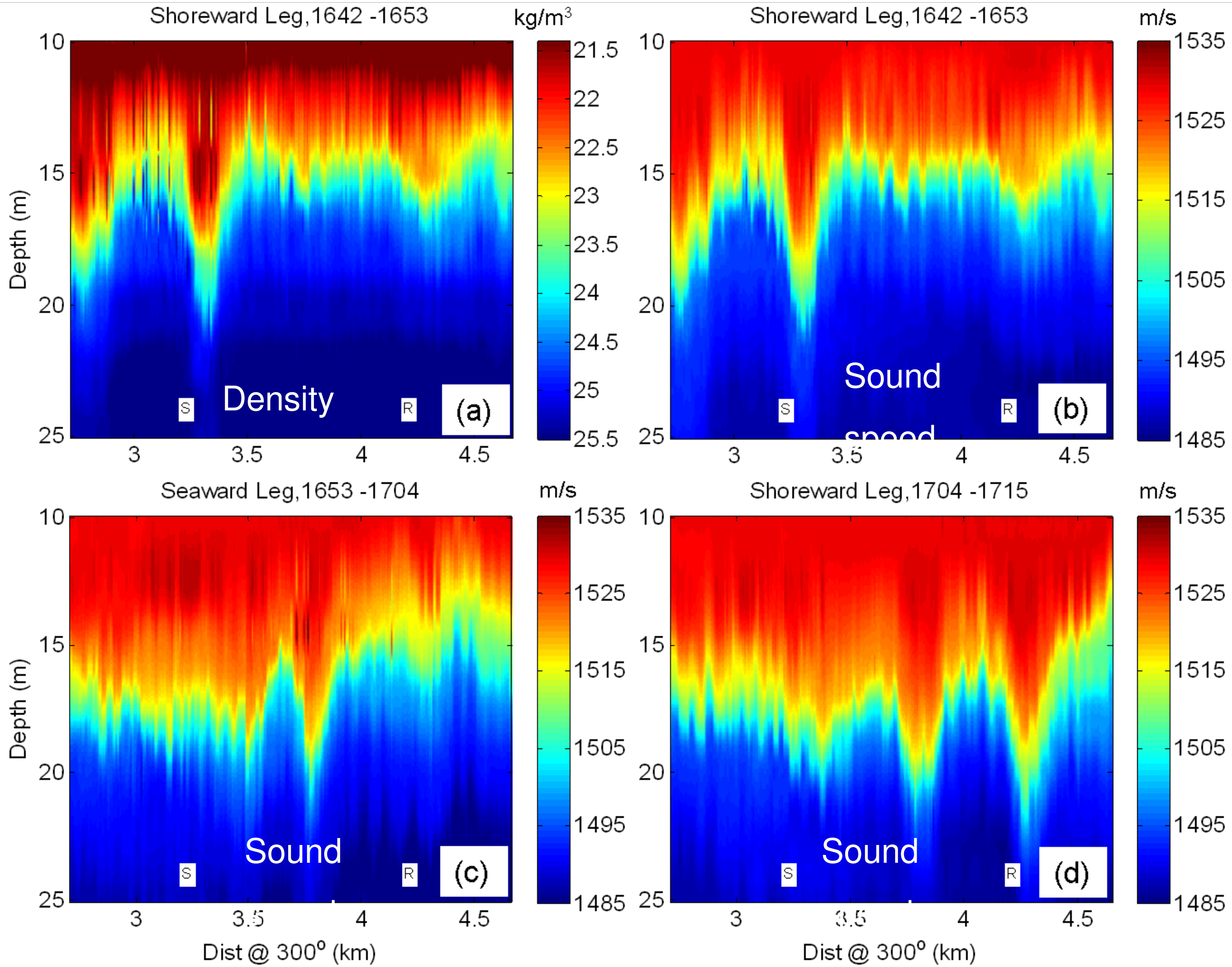
1 km acoustic path at 300° compass heading

80 m depth

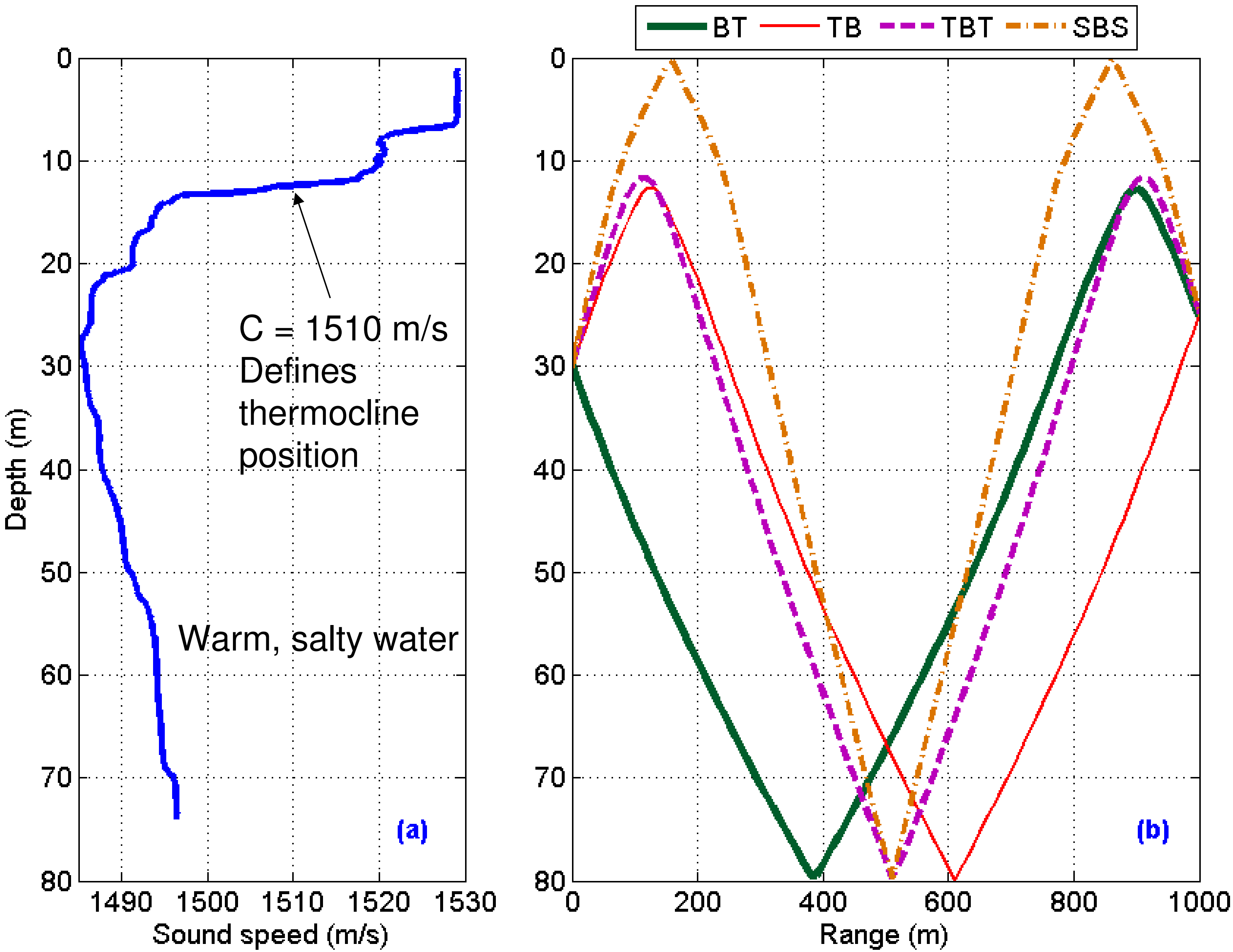
Endeavor track & acoustic path



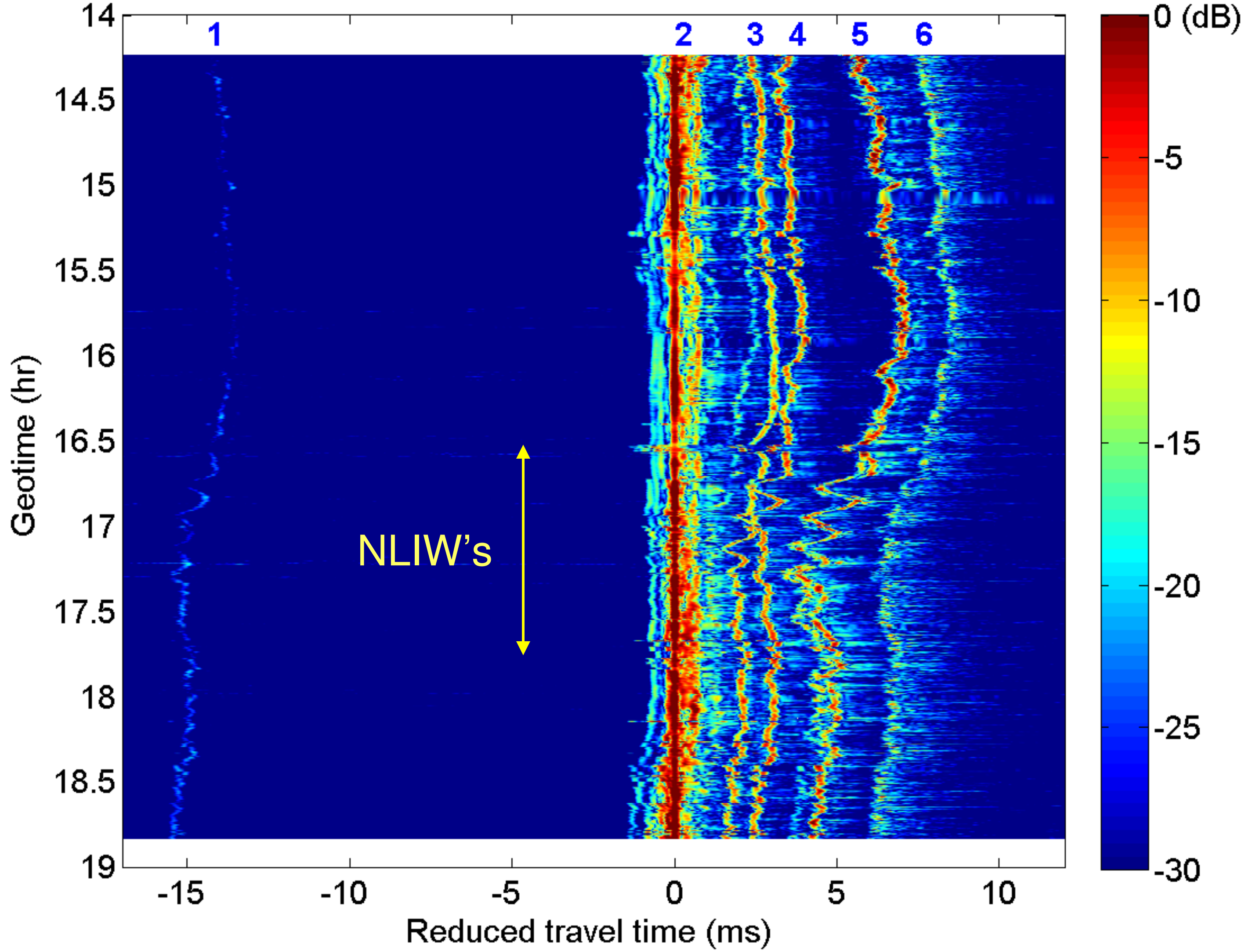
Distances from 73° W, 39° N


Shoreward Leg,1642 -1653
kg/m3
Depth (m)
Density
S
R
(a)
Shoreward Leg,1642 -1653
m/s
Sound
speed
(b)
Seaward Leg,1653 -1704
m/s
Sound
(c)
Shoreward Leg,1704 -1715
m/s
Sound
(d)
Dist @ 300° (km)
Dist @ 300° (km)

CTD profile @ 15:30



Acoustic Data



t(arrival 2) = 0

NLIW model

3. Find thermocline depth (c = 1510 m/s) for towed CTD every 2 s; low pass

5. Find front of both waves, back of first wave (2 m above deepest part)

7. Linearly interpolate in space & time from all 3 legs

9. Fill in linearly interpolated amplitude, back of wave 2 & bore (15 meters $\rightarrow$ 17 m)

11. Connect with a smooth curve

13. Fill in the other sound speeds using 15:30 SSP
Vertically Lagrangian mode 1

Measured internal wave parameters

	Front of first wave	Back of first wave	Front of second wave
Speed	0.587 m/s	0.606 m/s	0.564 m/s
Bearing	324.3¡	316.8¡	331.4¡
Time at 73W, 39N	15:14:26	15:19:57	15:23:01
Speed along acoustic path	0.643 m/s	0.632 m/s	0.658 m/s
Average		0.644 m/s	

NLIW model

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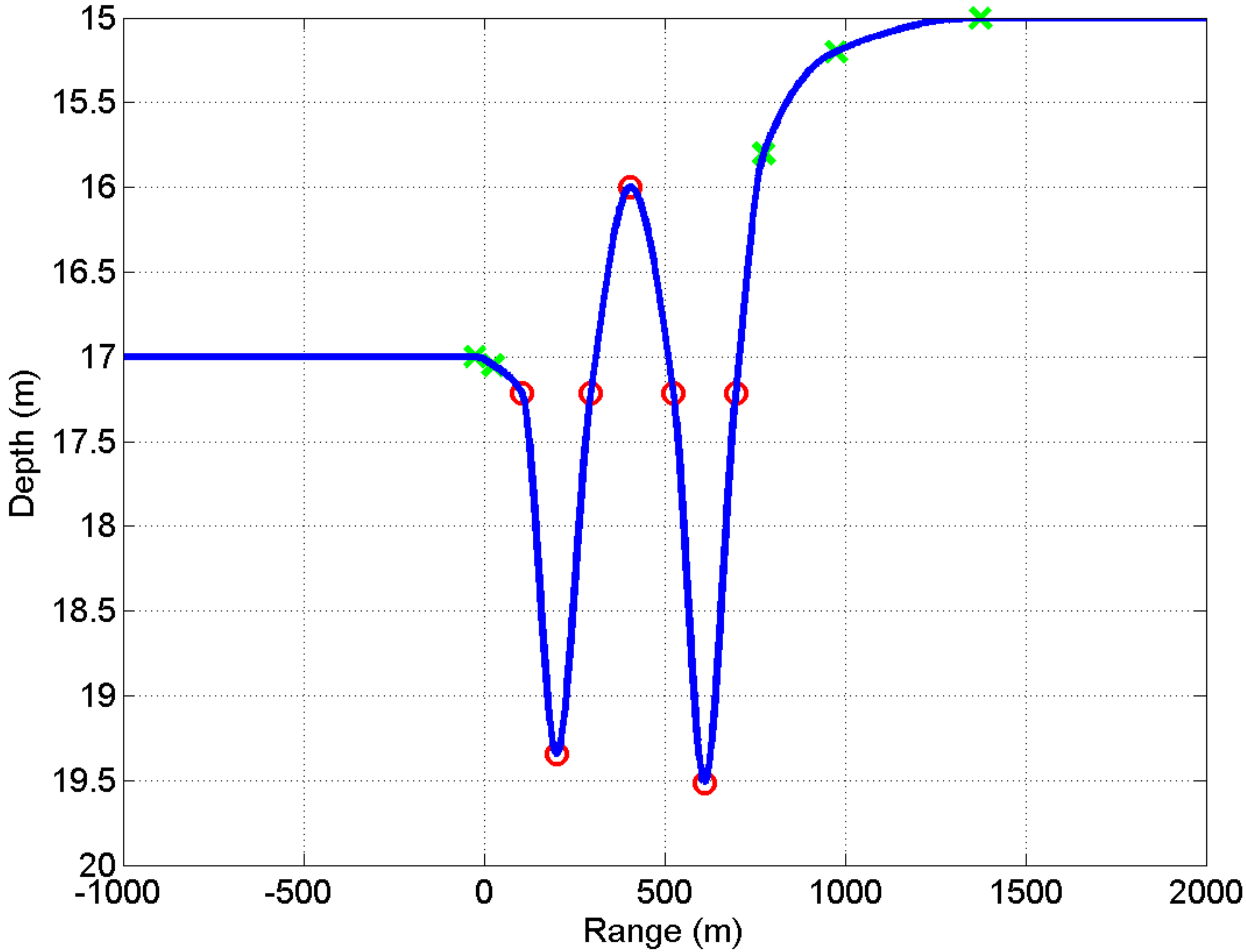
    Vertically Lagrangian mode 1


15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
Depth (m)
-1000
-500
0
500
1000
1500
2000
Range (m)

NLIW model

3. Find thermocline depth (c = 1510 m/s) for towed CTD every 2 s; low pass

5. Find front of both waves, back of first wave (2 m above deepest part)

7. Linearly interpolate in space & time from all 3 legs

9. Fill in linearly interpolated amplitude, back of wave 2 & bore (15 meters $\rightarrow$ 17 m)

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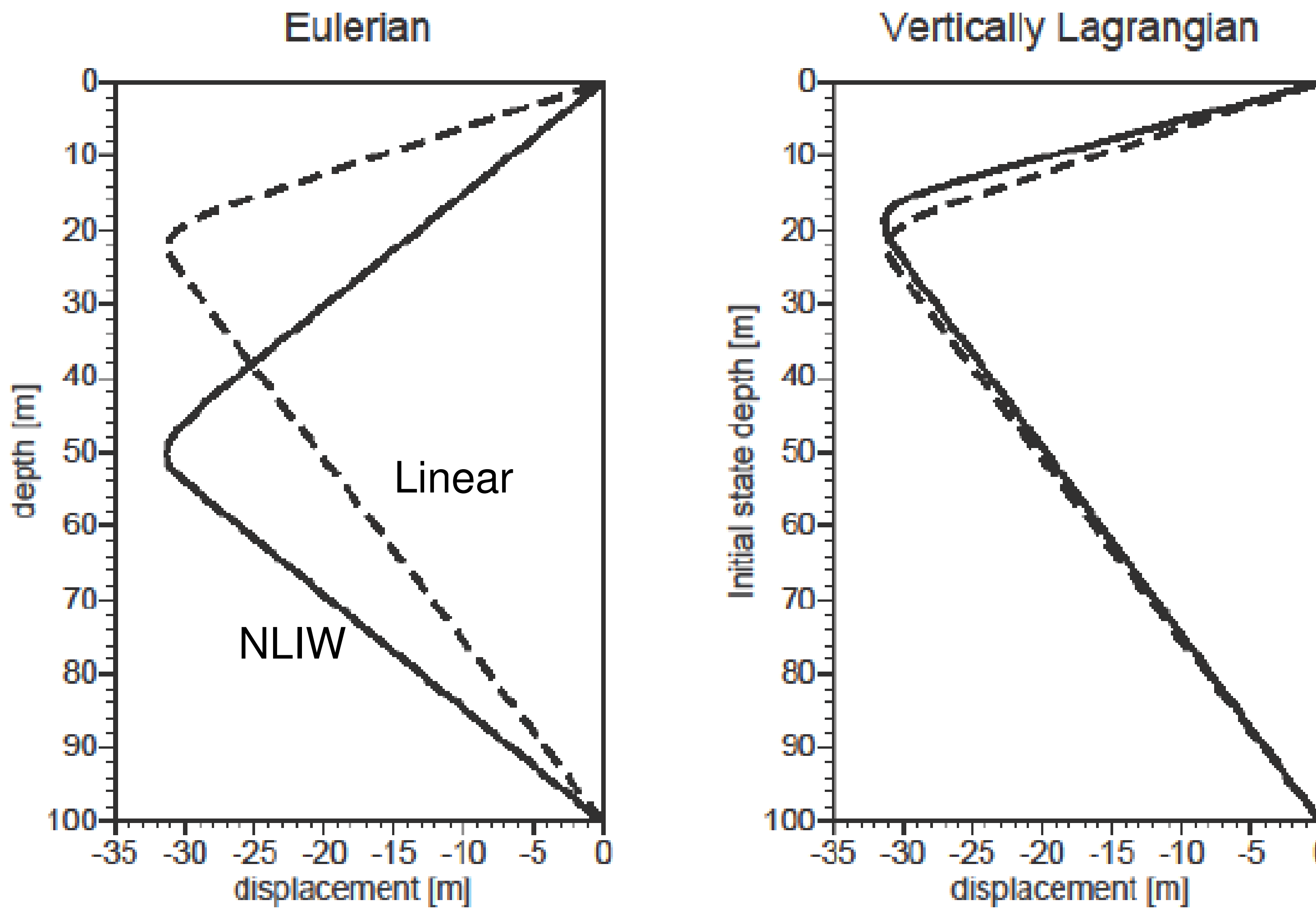
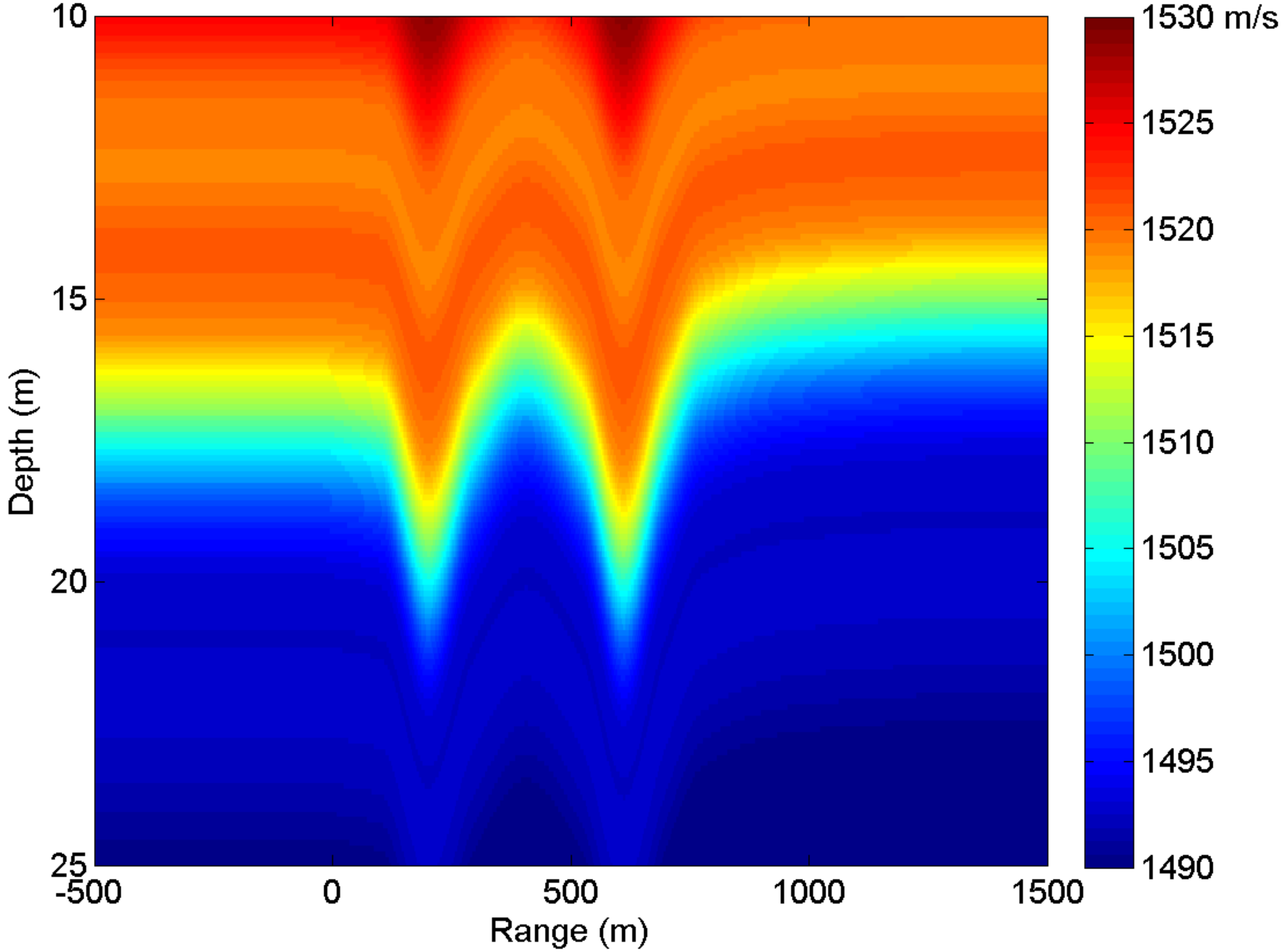
Vertically Lagrangian mode 1

Comparison of two reference frames

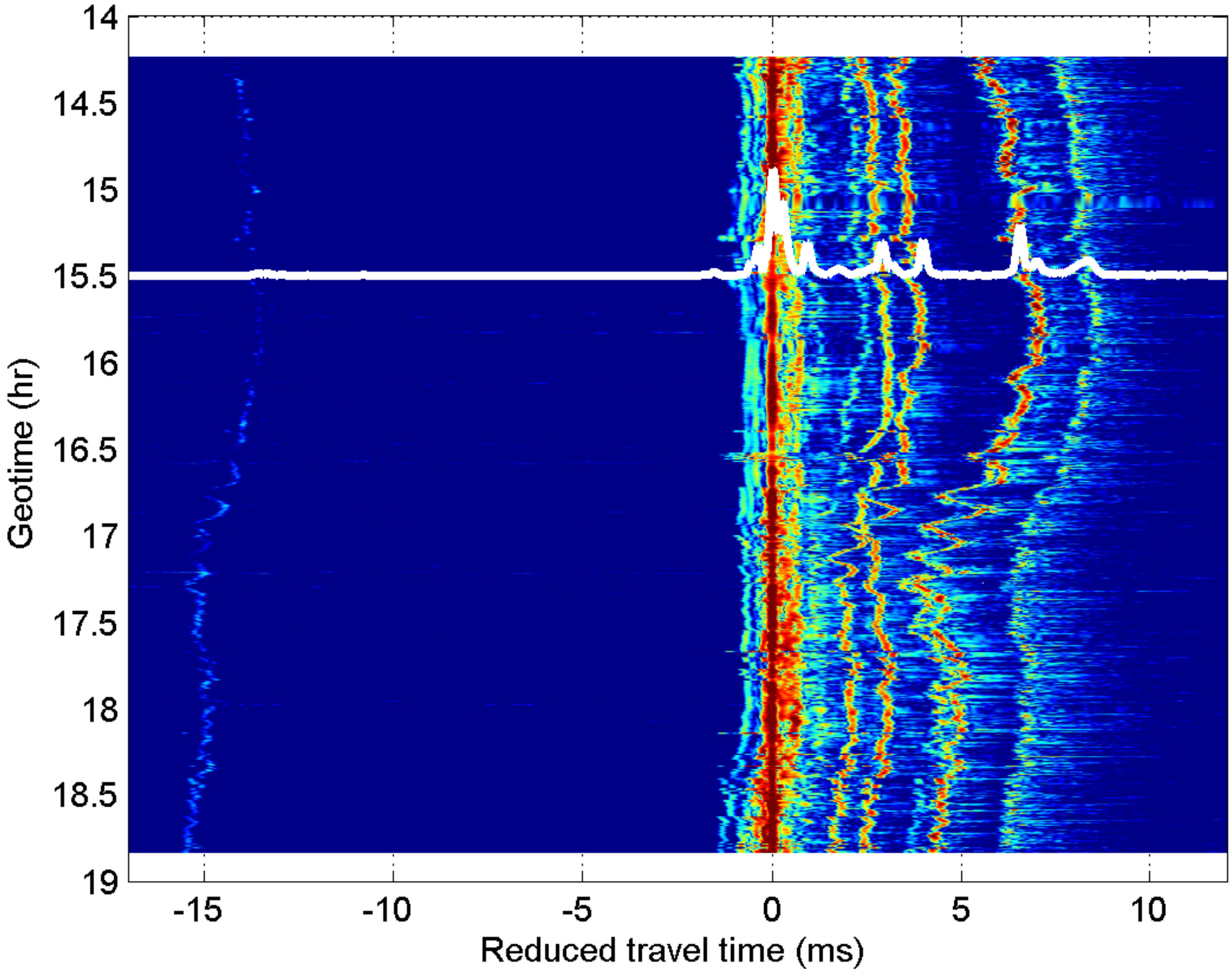


Following K. Lamb

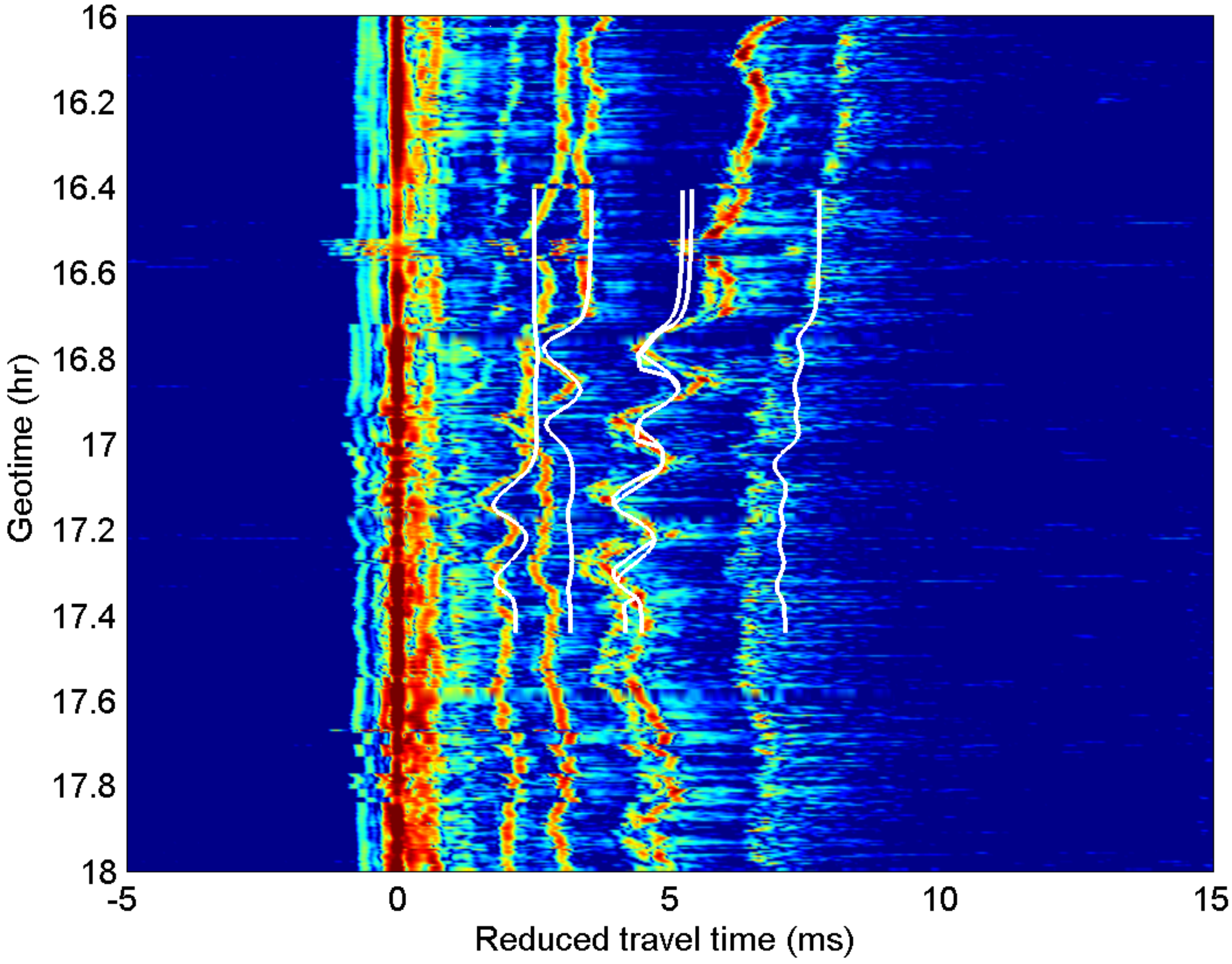


1530 m/s
1525
1520
1515
1510
1505
1500
1495
1490
10
15
20
25
Depth (m)
-500
0
500
1000
1500
Range (m)

Range-independent PE calculation (15:30)



Ray Trace with NLIW's
TB, BT, TBT,SBS arrivals



Modeling results

The ray trace captures the main features in the arrival time

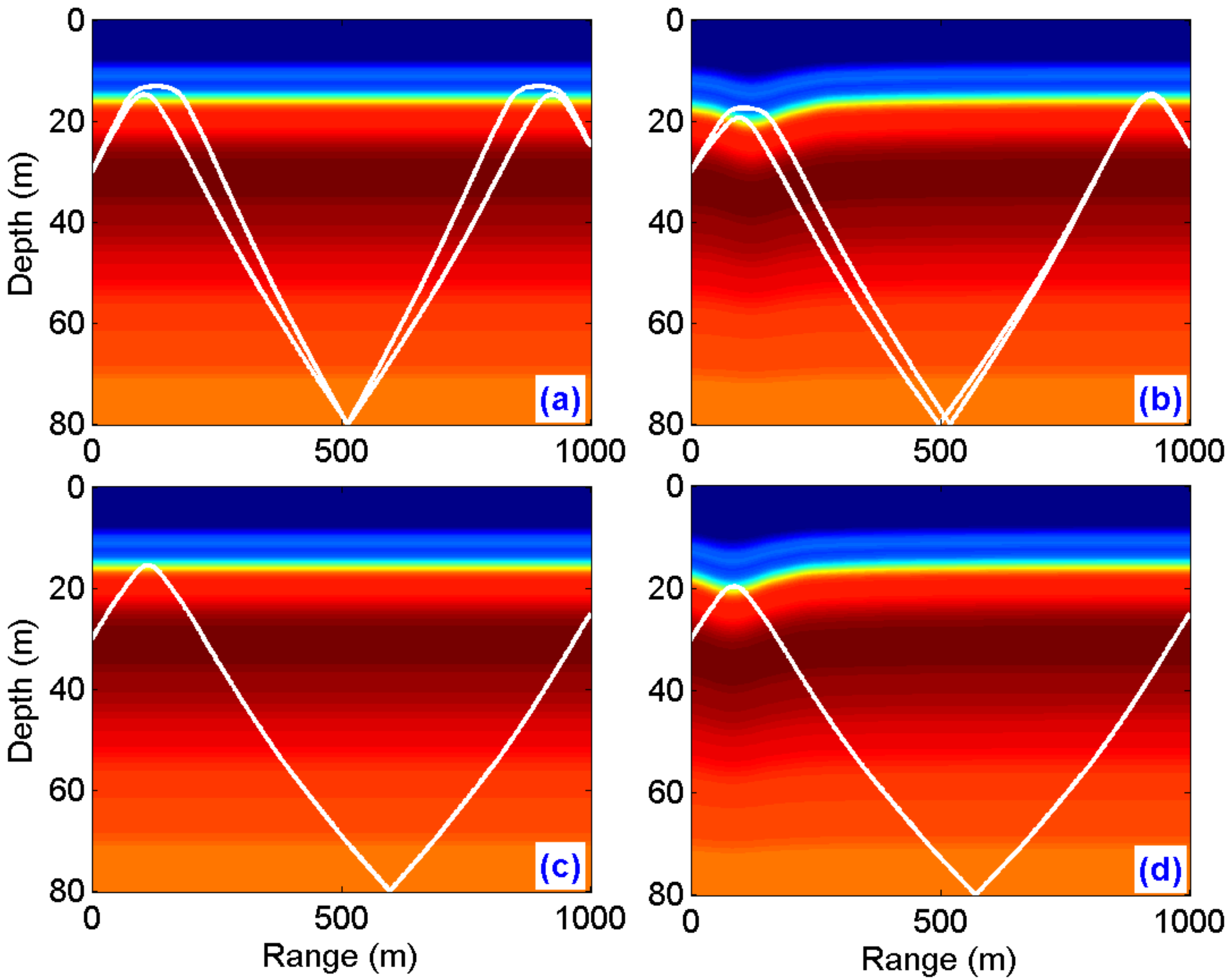
~ 1 ms shortening of travel time when the ray turns in the thermocline and a wave coincides with that turning point

Passing through the thermocline has much less effect

Can we understand the systematic 1 ms shortening?

1. *Ray path different (2nd order perturbation)*
2. *Faster sound speed (1st order)*

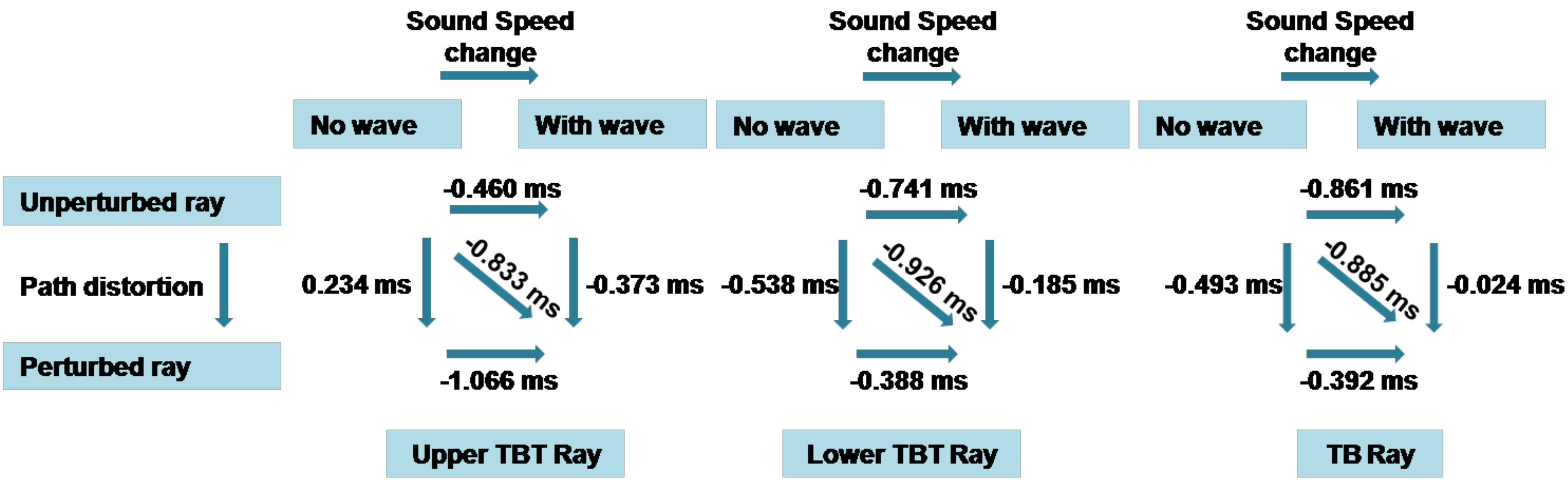
Selected rays



TBT rays

TB ray

Interpretation ?



SBS ray: ~ 0 from path distortion, ~0.3 ms from ss change, events overlap

Conclusions

Towed chain measurements can be interpolated onto the acoustic path, but some assumptions are needed.

Acoustic modeling (PE & ray trace) obtains correct travel time.

Rays turning in the thermocline with a wave present are 1 ms faster

Attempted interpretation is partially successful