Seismic Oceanography and the *R/V Langseth*

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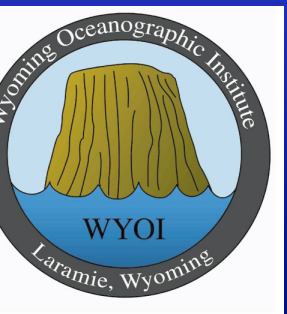
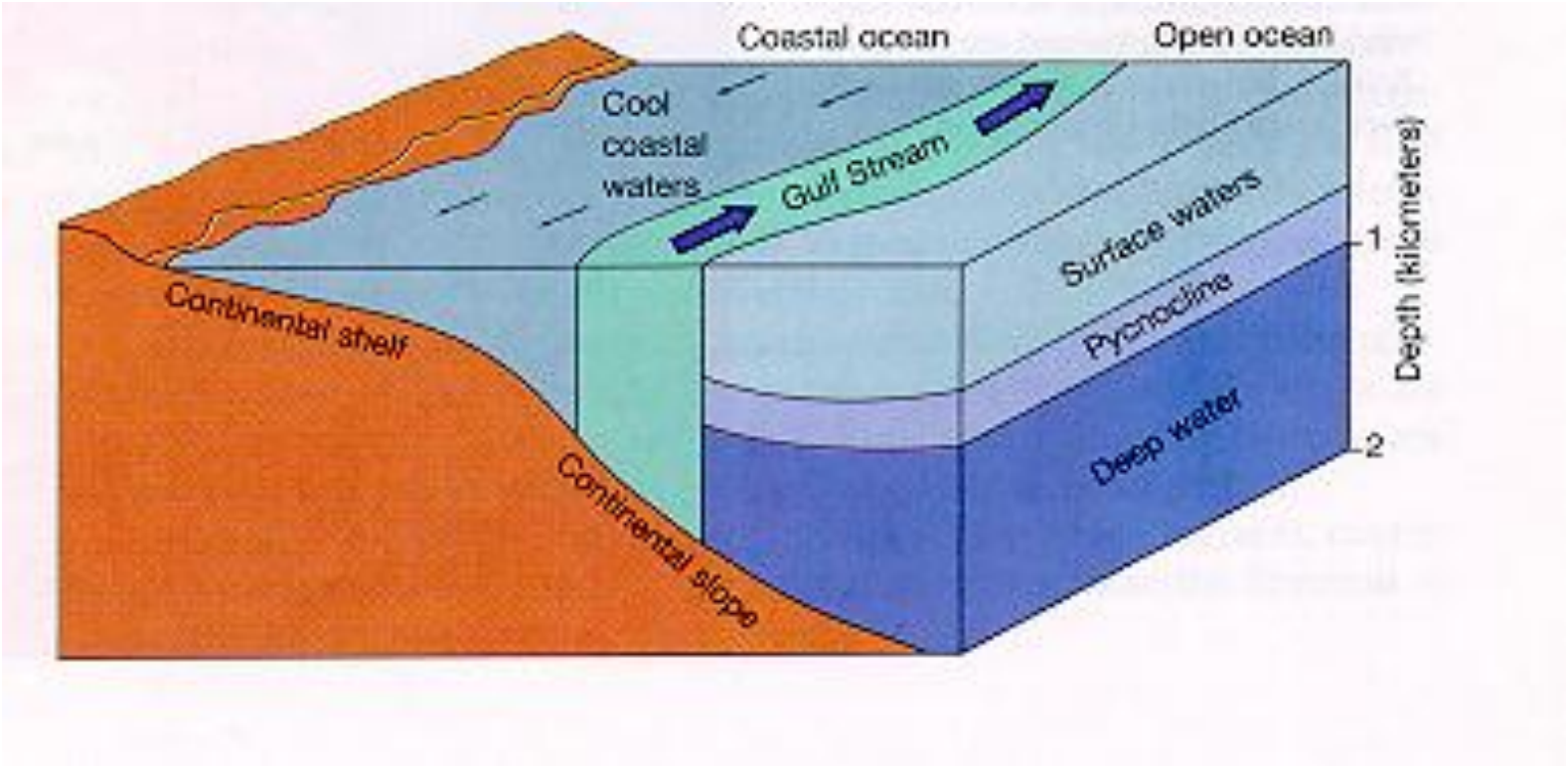
Acknowledgments:

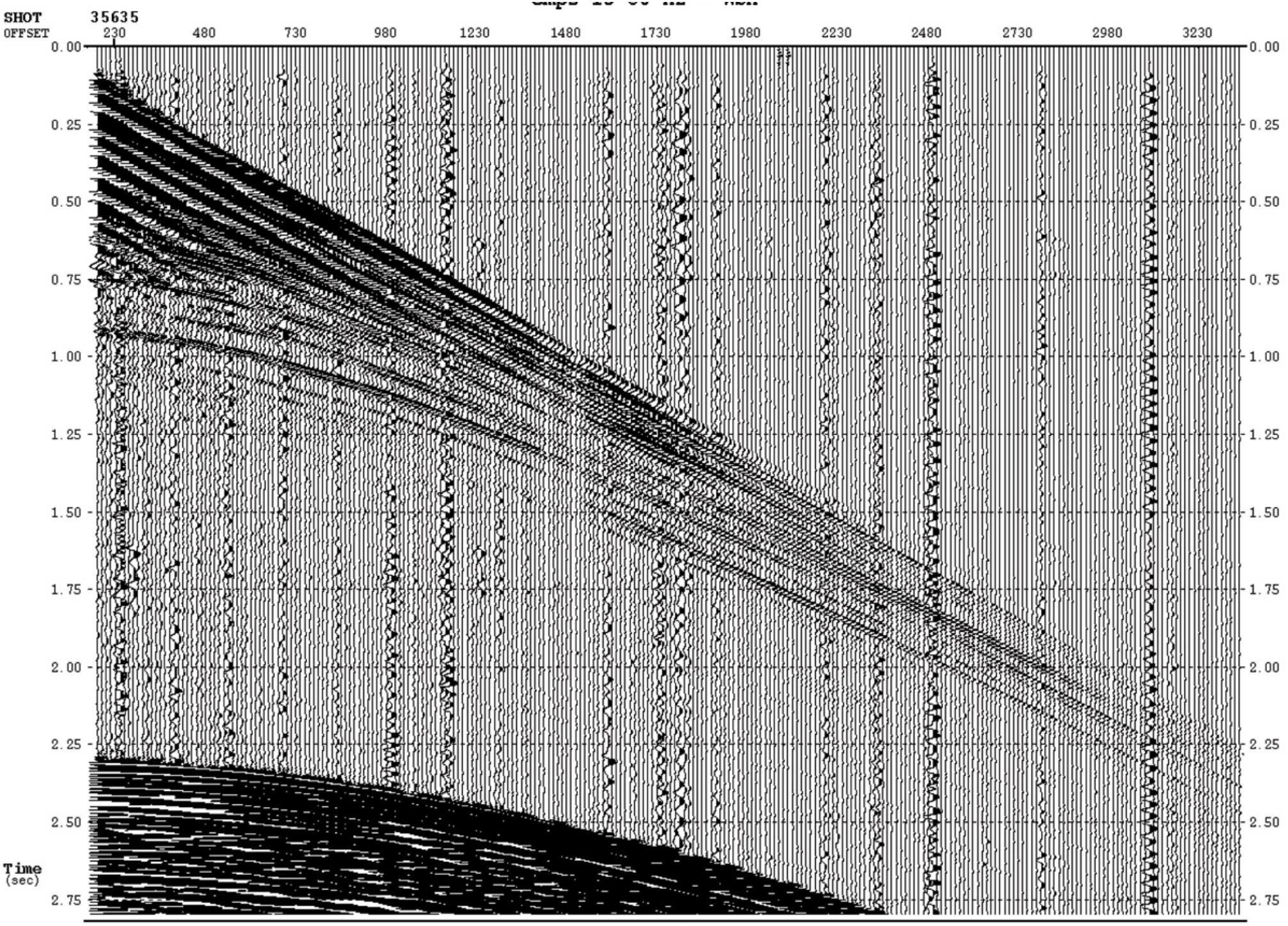
- Ray Schmitt, WHOI
- Ilker Fer, Bjerknes Center, Bergen
- Pedro Páramo
- Papia Nandi
- Joel Seymour
- Andrew Bullock
- Scott Pearse



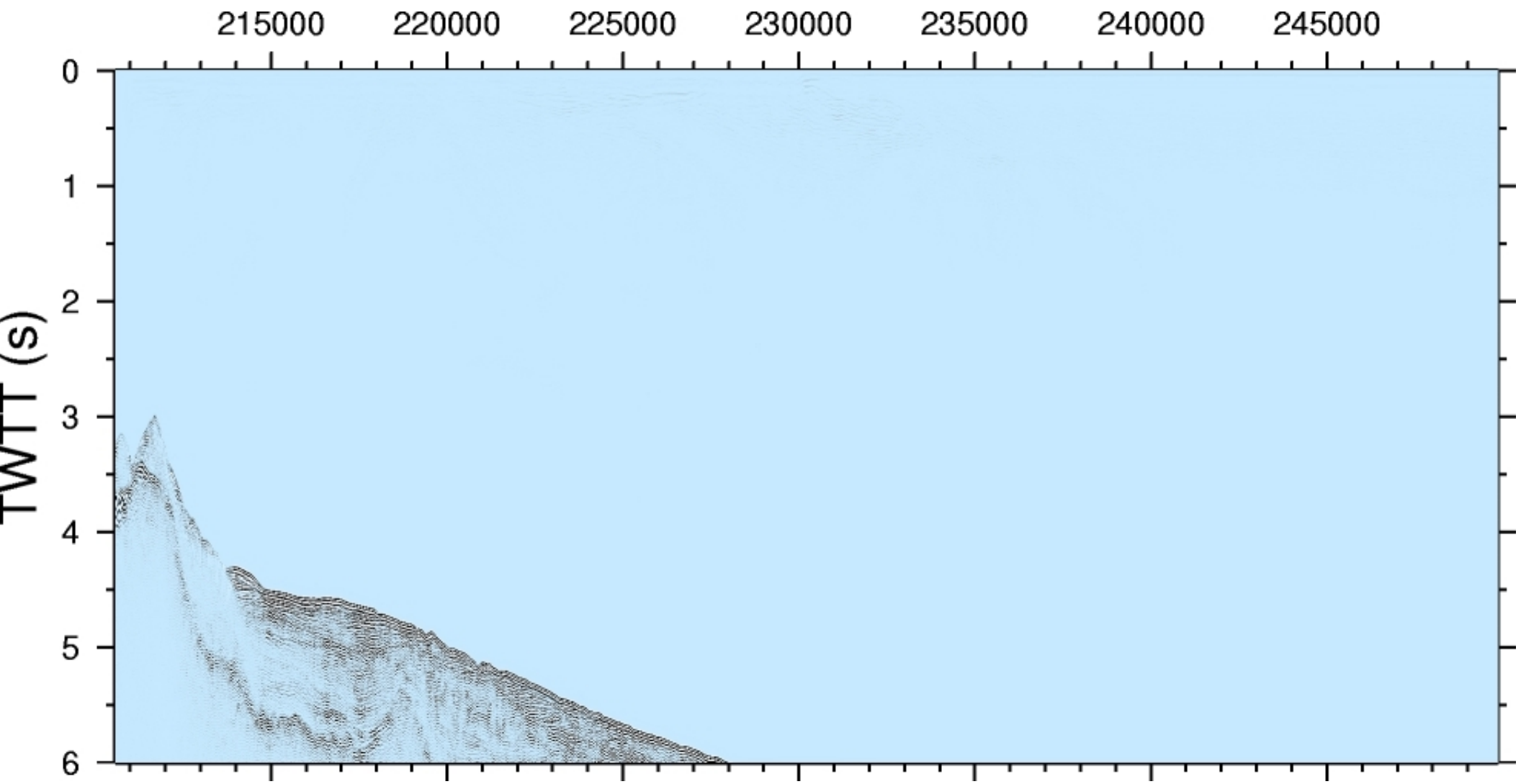
Outline

- What is Seismic Oceanography (and who cares)?
- A Quick Tour of Results
- The Future: S.O. on the *Langseth*


Coastal ocean
Open ocean
Cool coastal waters
Gulf Stream
Surface waters
Pycnocline
Deep water
Continental shelf
Continental slope
Depth (kilometers)
1
2


SHOT 35635
OFFSET
230
480
730
980
1230
1480
1730
1980
2230
2480
2730
2980
3230
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
Time
(sec)

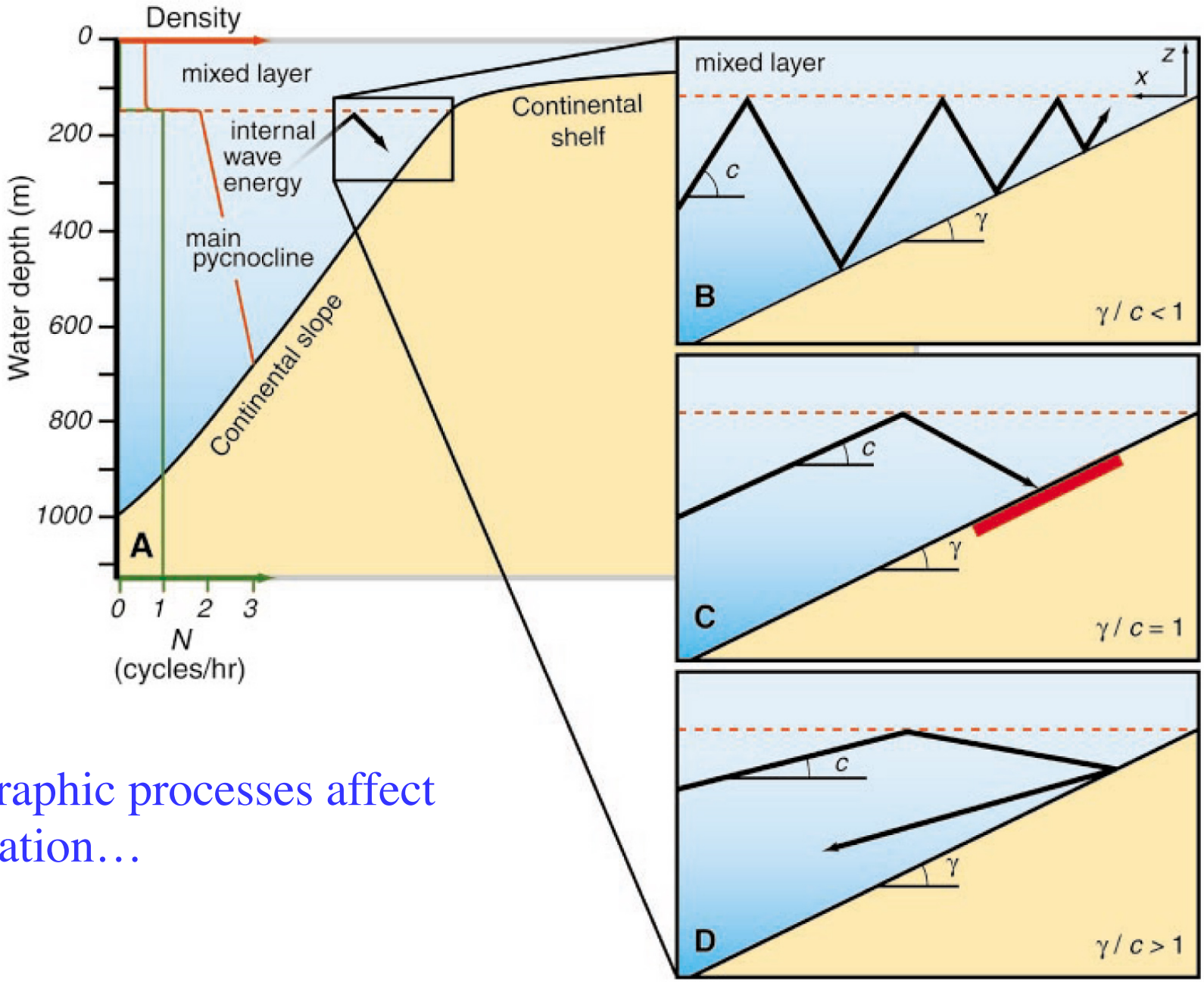
Seismic Oceanography = Imaging oceanic fine-structure with seismic reflection data



Why Care?

- S.O. is an entirely new way of looking at the ocean
- Images offer new insight into many processes, with implications for ocean mixing, climate, etc.
- Opportunity to use *Langseth* on new class of problems
- Application to 4D earth imaging

Seismology has much to offer to the PO community.



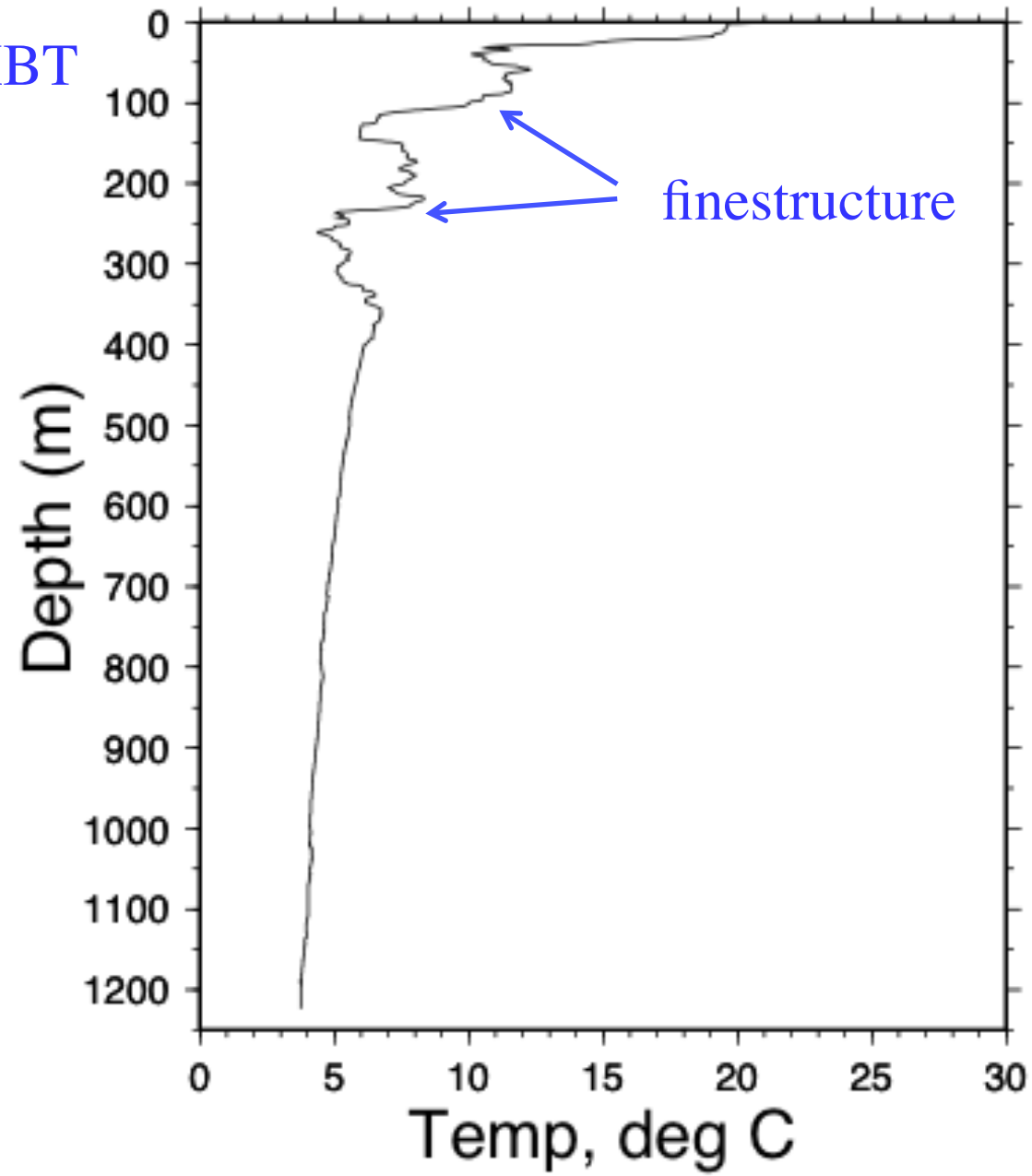
Oceanographic processes affect sedimentation…

Cacchione et al., 2002, *Science*

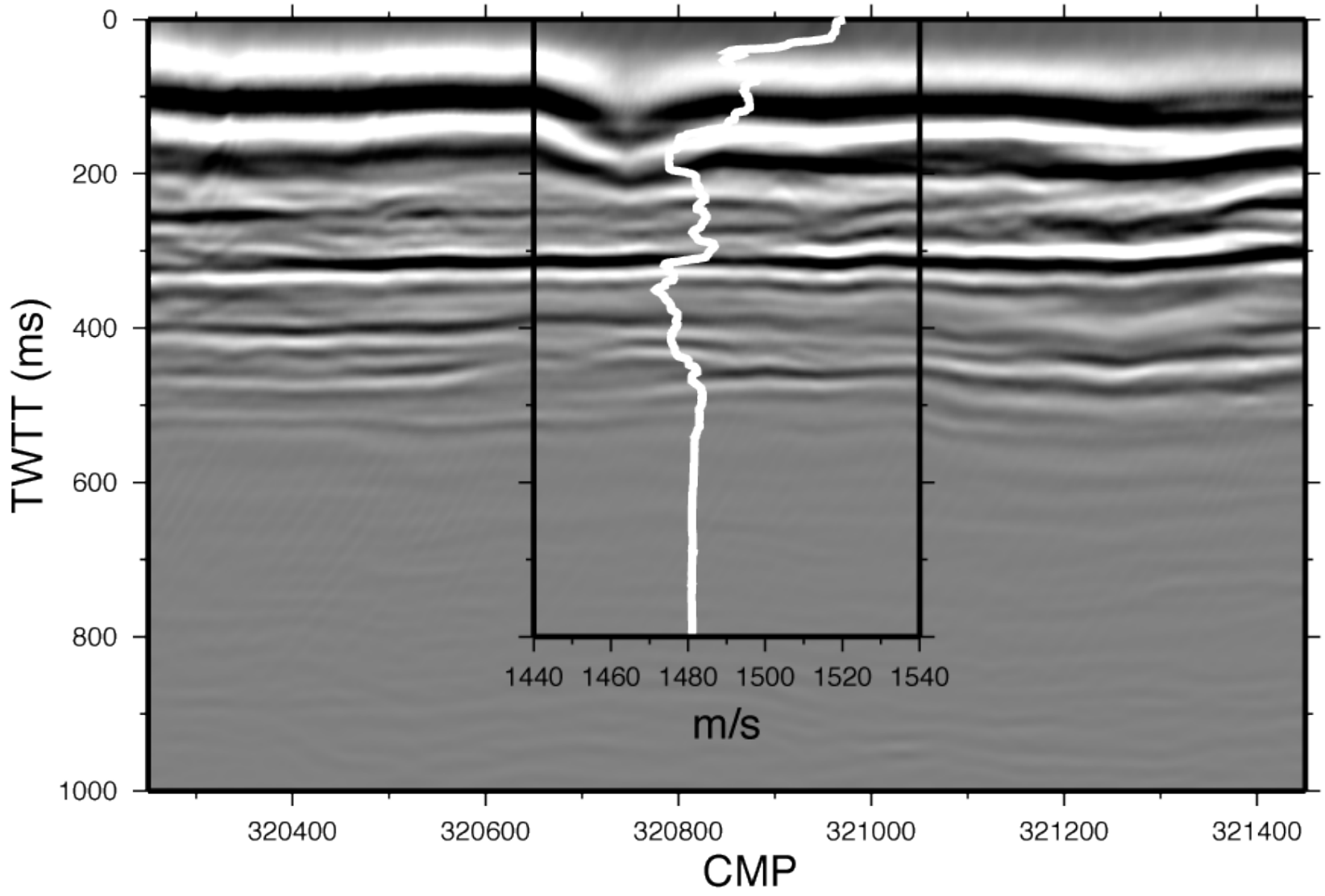
What Causes the Reflections?

- Abrupt vertical changes in physical properties (density and/or sound speed) of the water column
- These changes are caused by changes in either:
  - Temperature (dominant factor)
  - Salinity
- For typical seismic frequencies, sensitive to layers on the scale of 5-30 m; i.e. **finestructure**

Example:
Newfoundland Basin XBT



Reflection Seismology Images Finestructure



Holbrook et al., 2003, *Science*

What Causes the Finestructure?

(1) Internal waves

(2) Intrusions (double-diffusive phenomena)

(± Isopycnal stirring)

-> (1) and (2) have distinct signatures in reflection images

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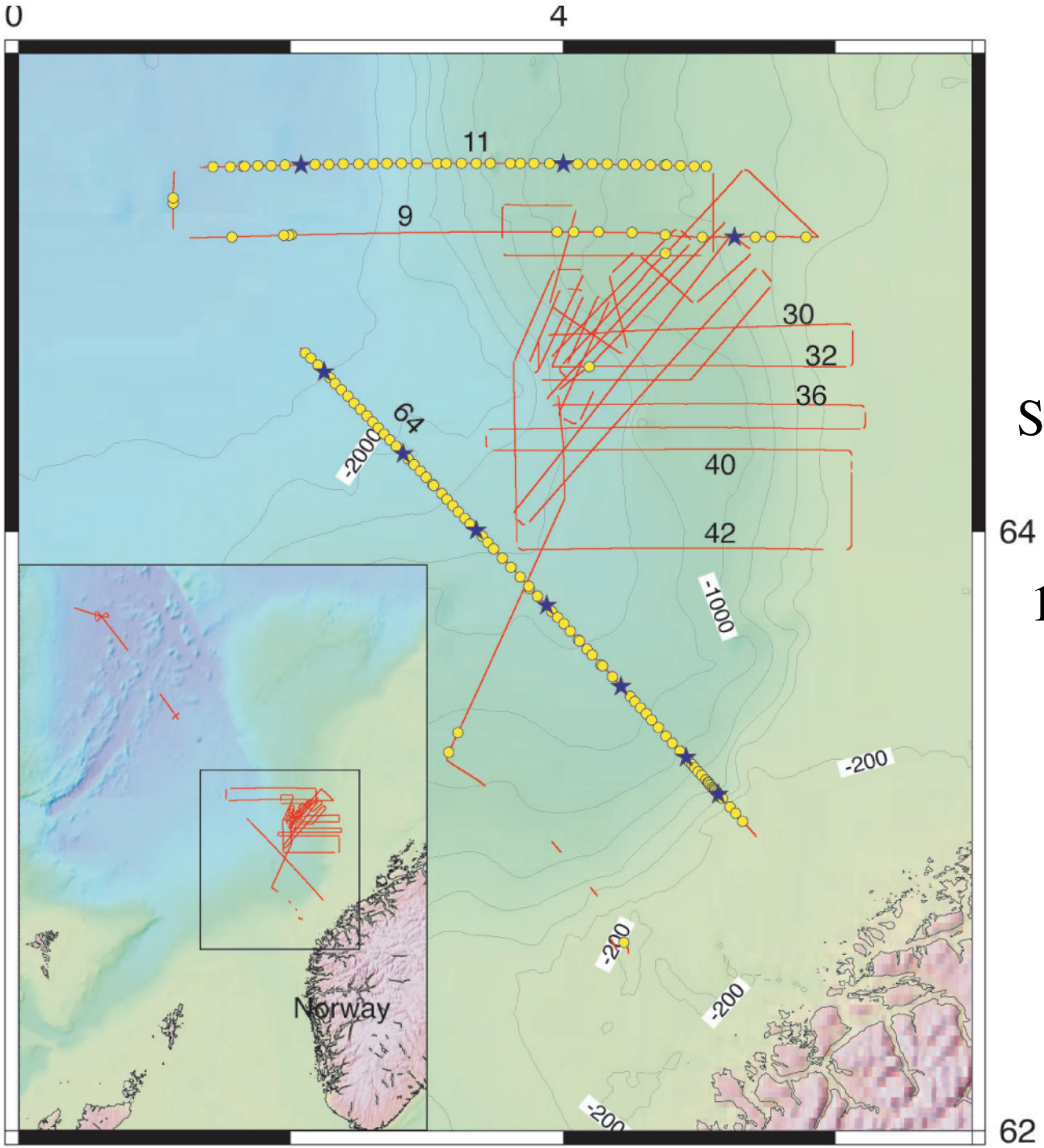
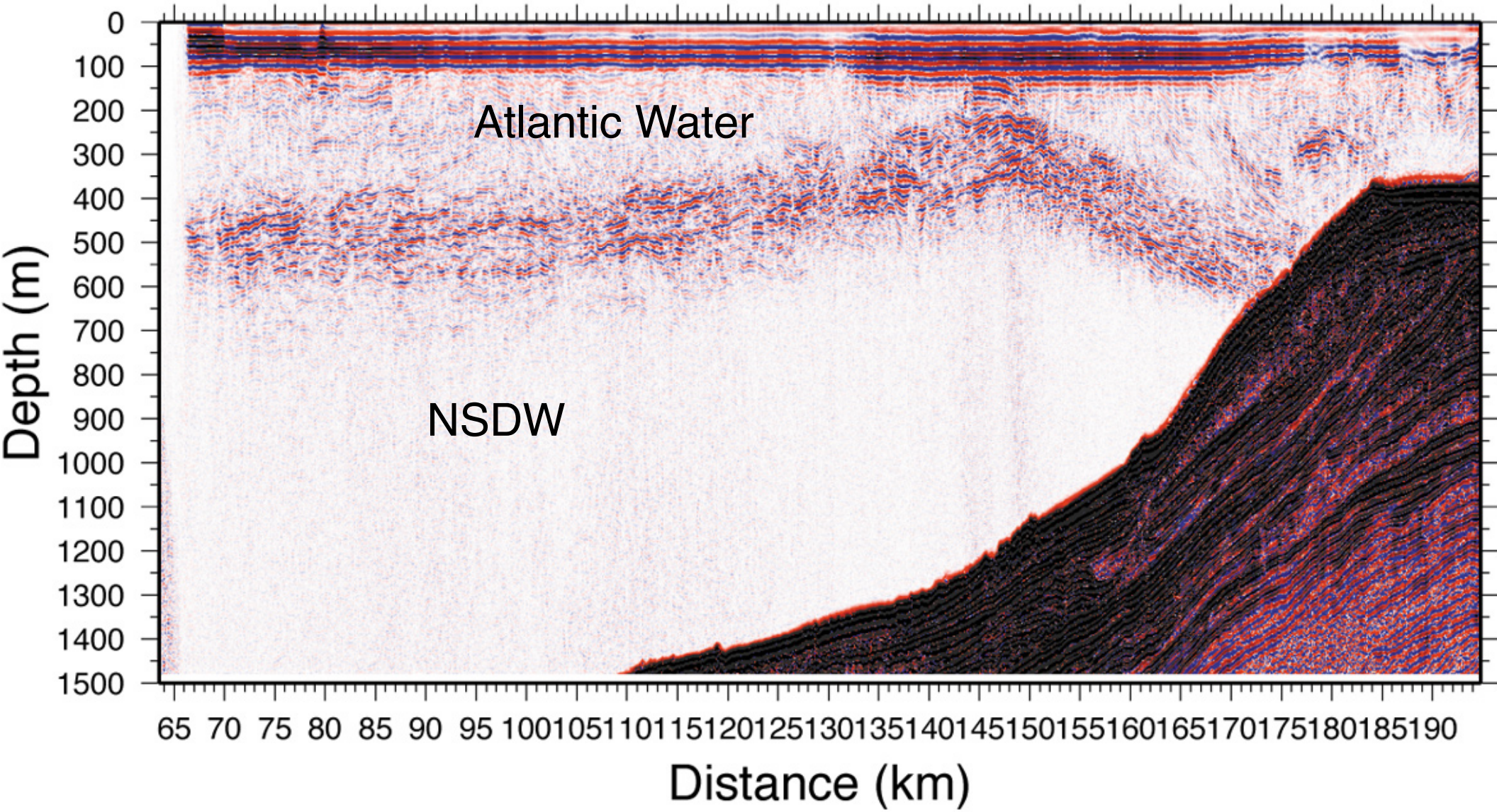


Sept. 2003 - Norwegian Sea

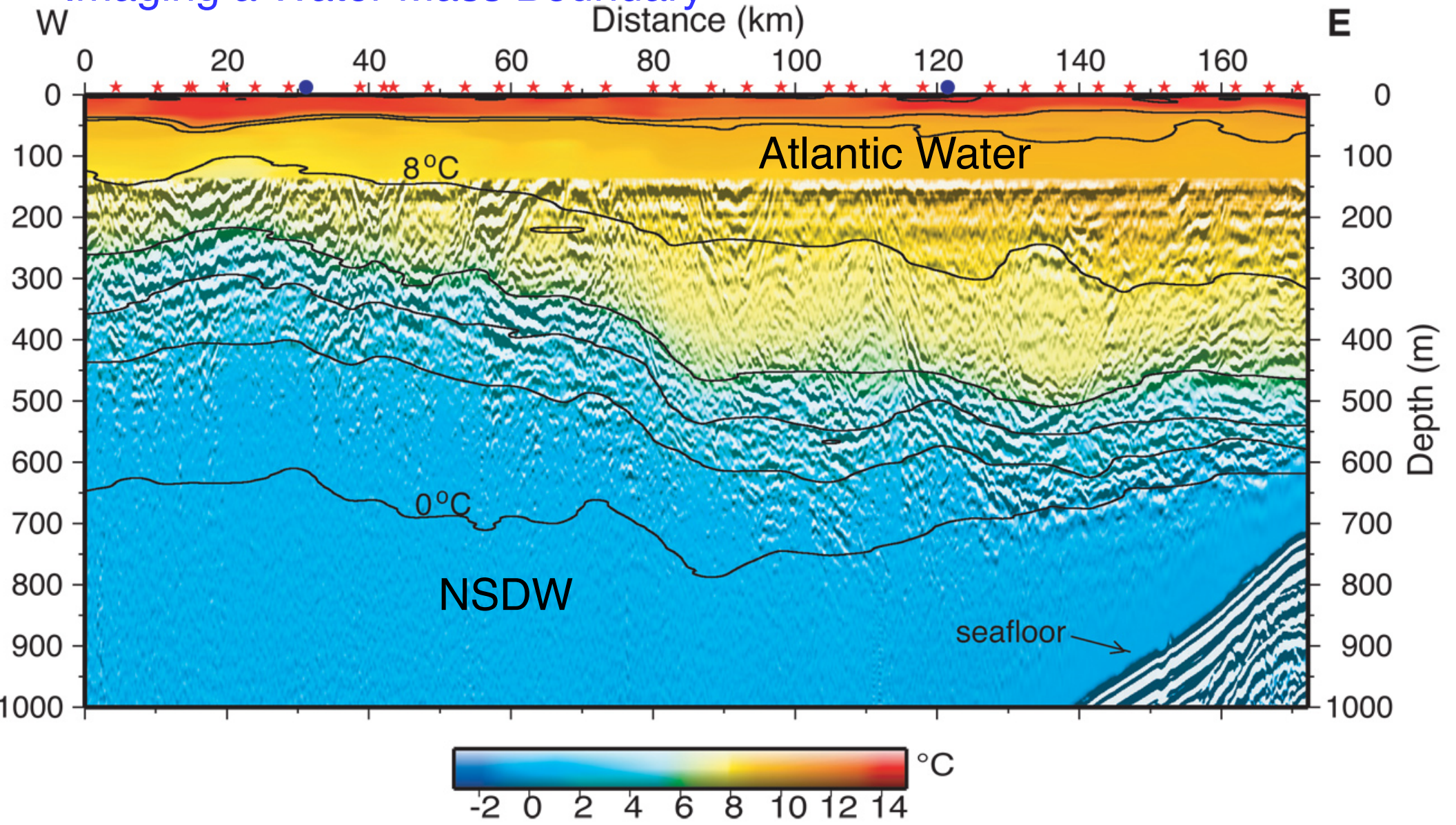
R/V Ewing

Seismic acquisition: NSF-ODP

112 XBT + 12 XCTD funded by NSF-PO

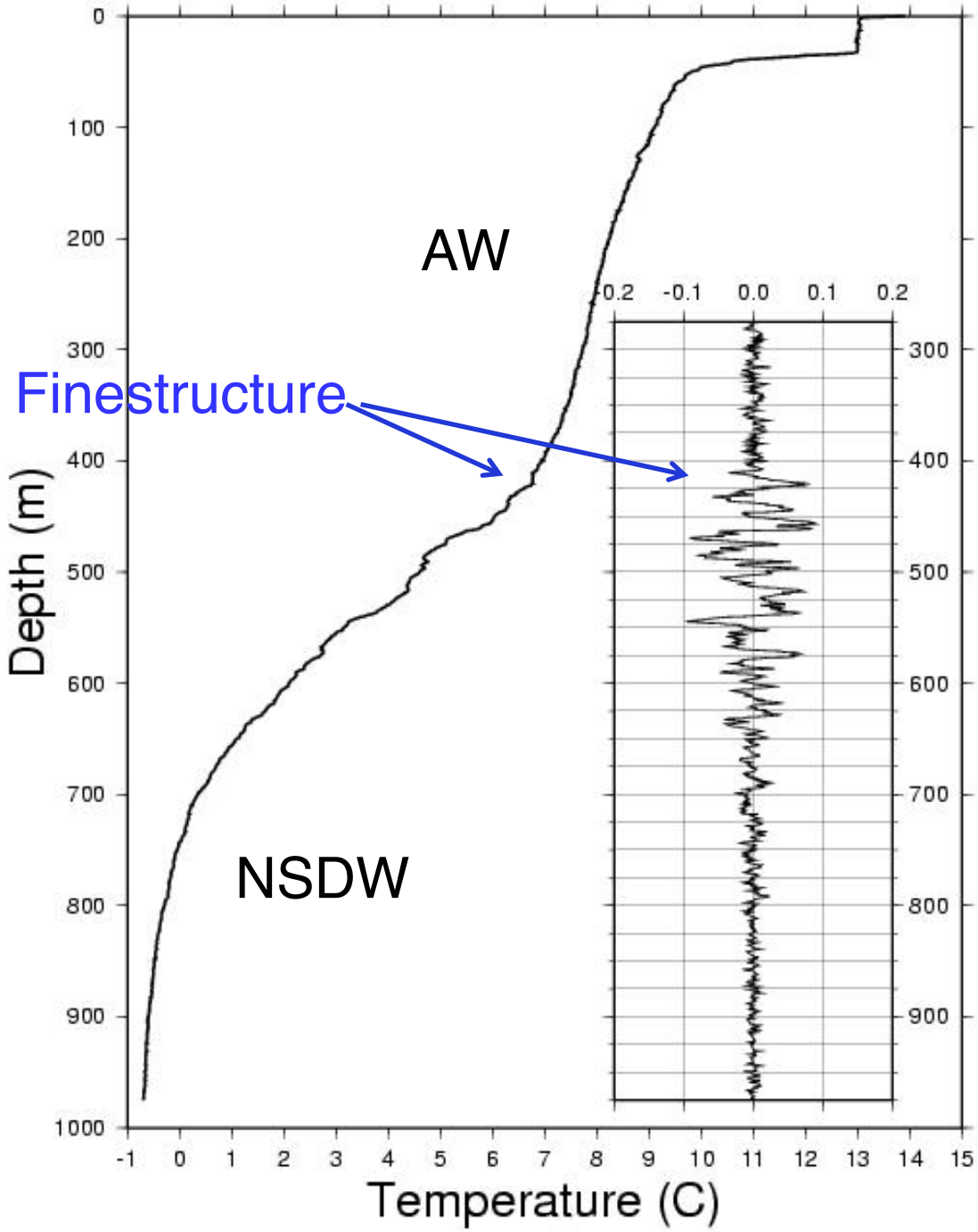

Atlantic Water
NSDW
Depth (m)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190
Distance (km)

Imaging a Water Mass Boundary



Nandi et al., 2004, *GRL*

Sensitivity of Method



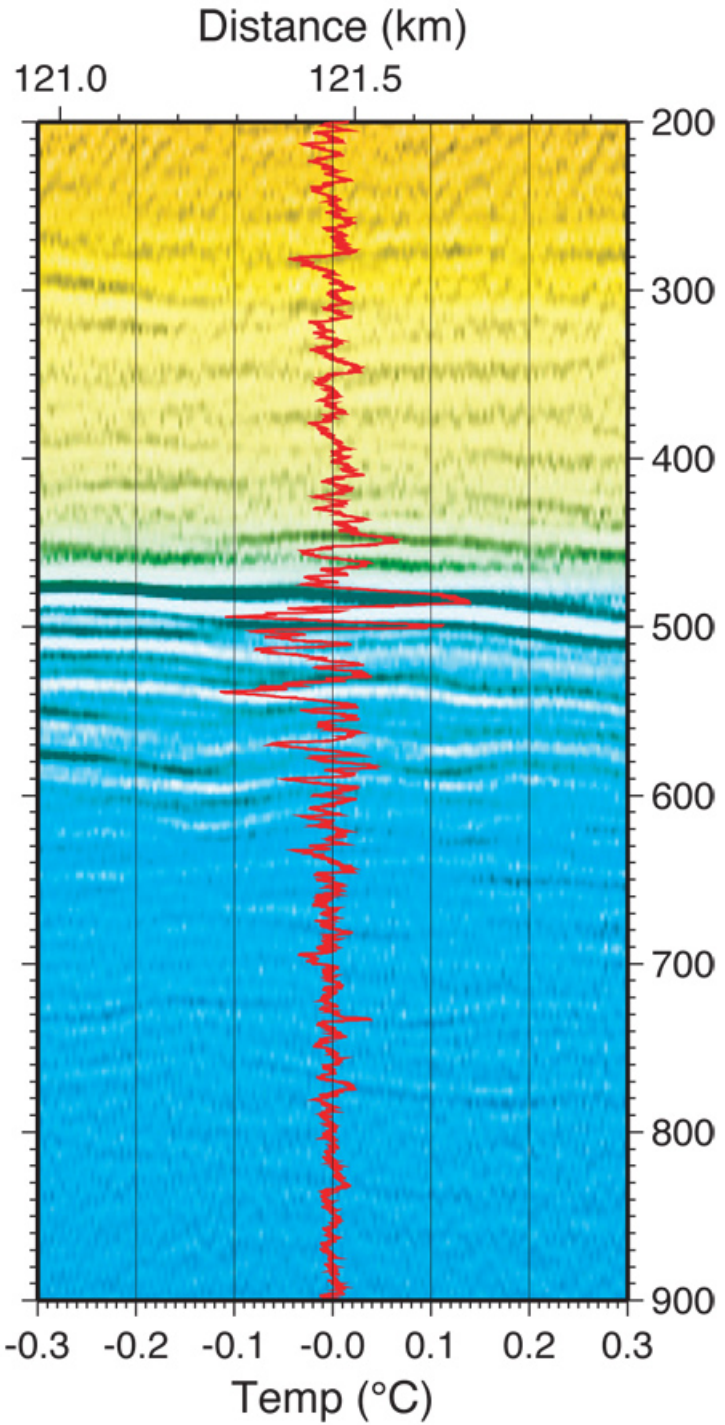
Nandi et al., 2004, *GRL*

Sensitivity of Method

Comparison of XBT & seismic data shows that reflections can be detected from interfaces across which temperature changes by ~0.04°C.

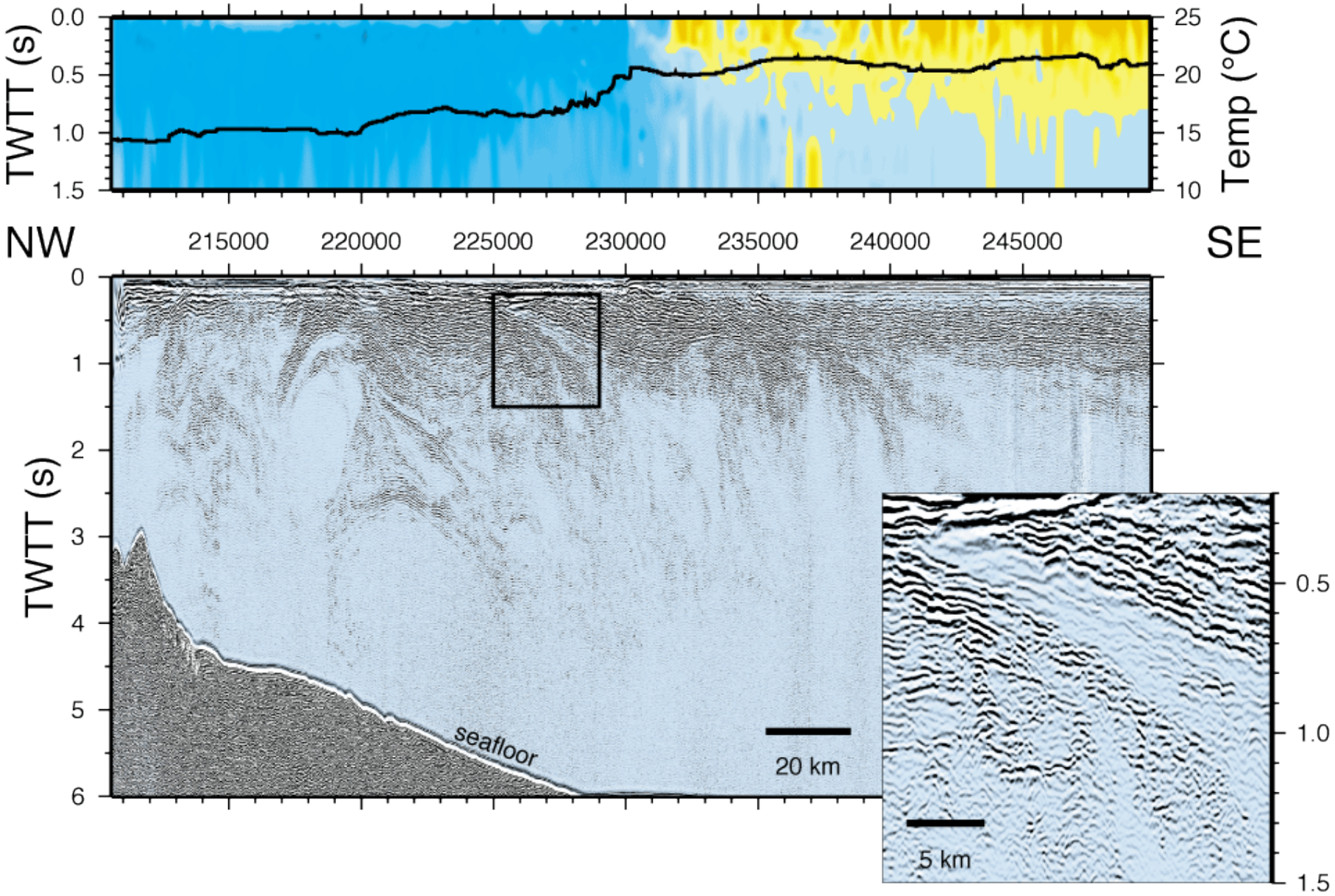
MCS imaging picks up essentially ALL finestructure at a detection limit comparable to a Sippican XBT.

Nandi et al., 2004, *GRL*



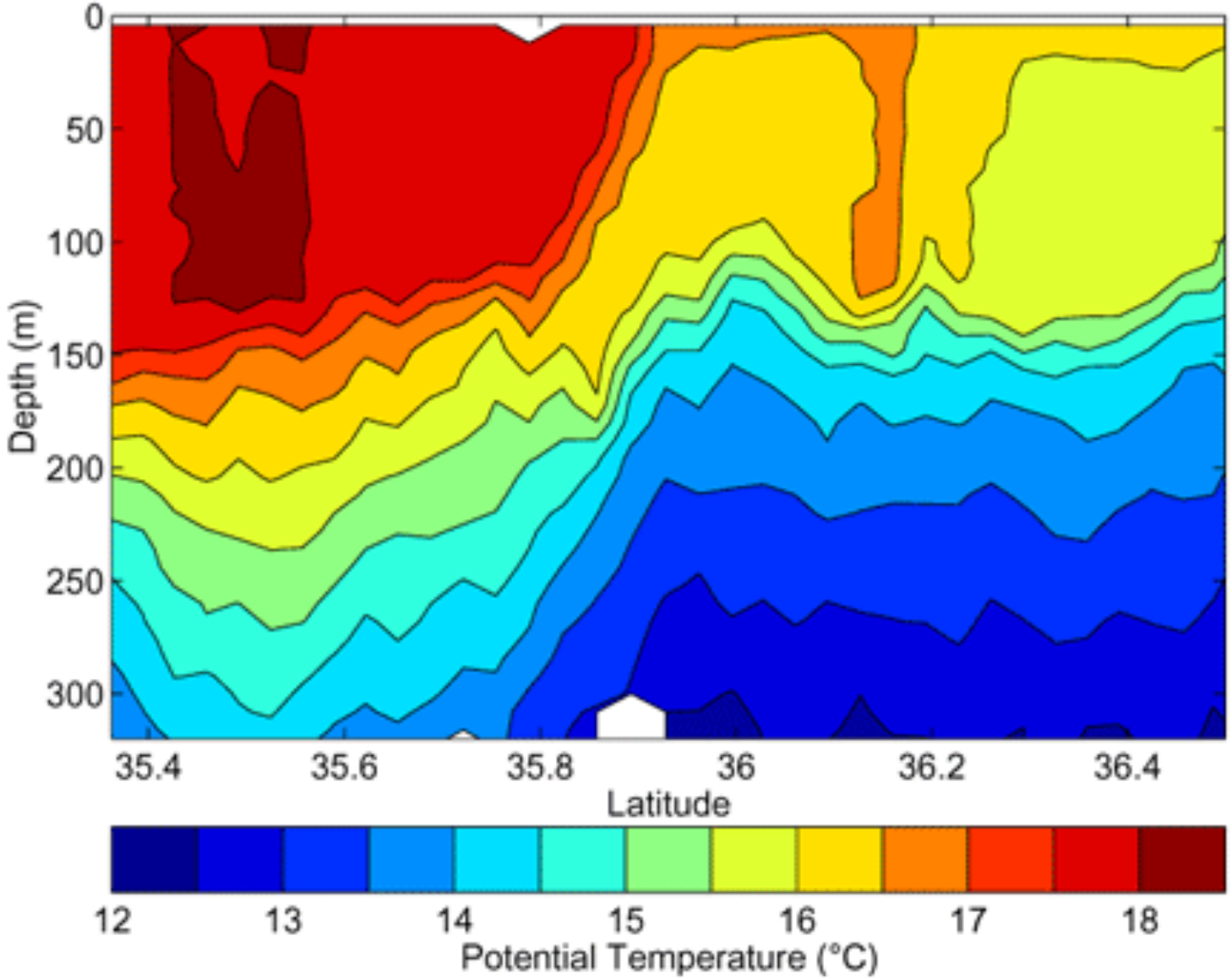
Newfoundland
Basin

Fronts

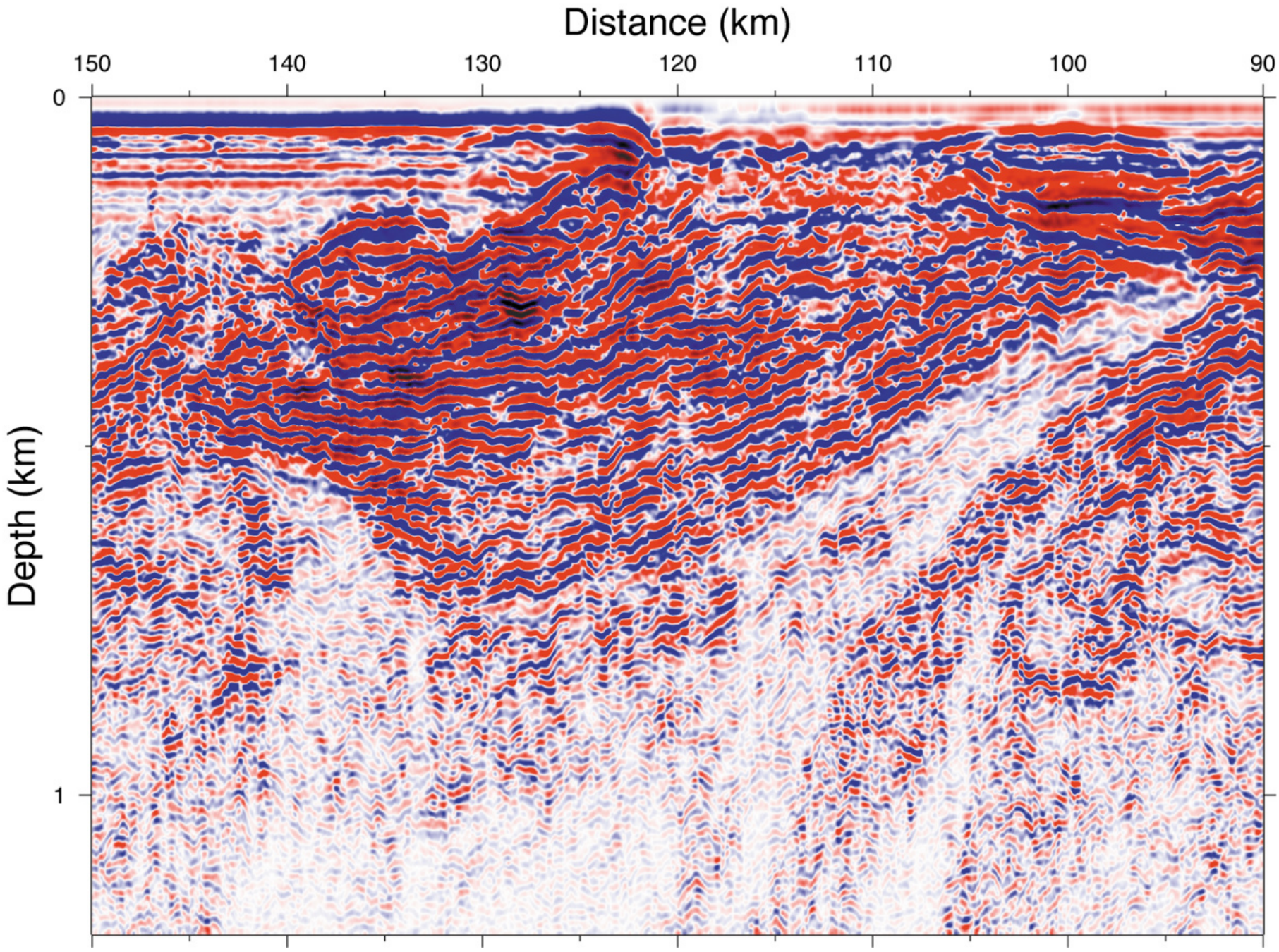


Holbrook et al., 2003, *Science*

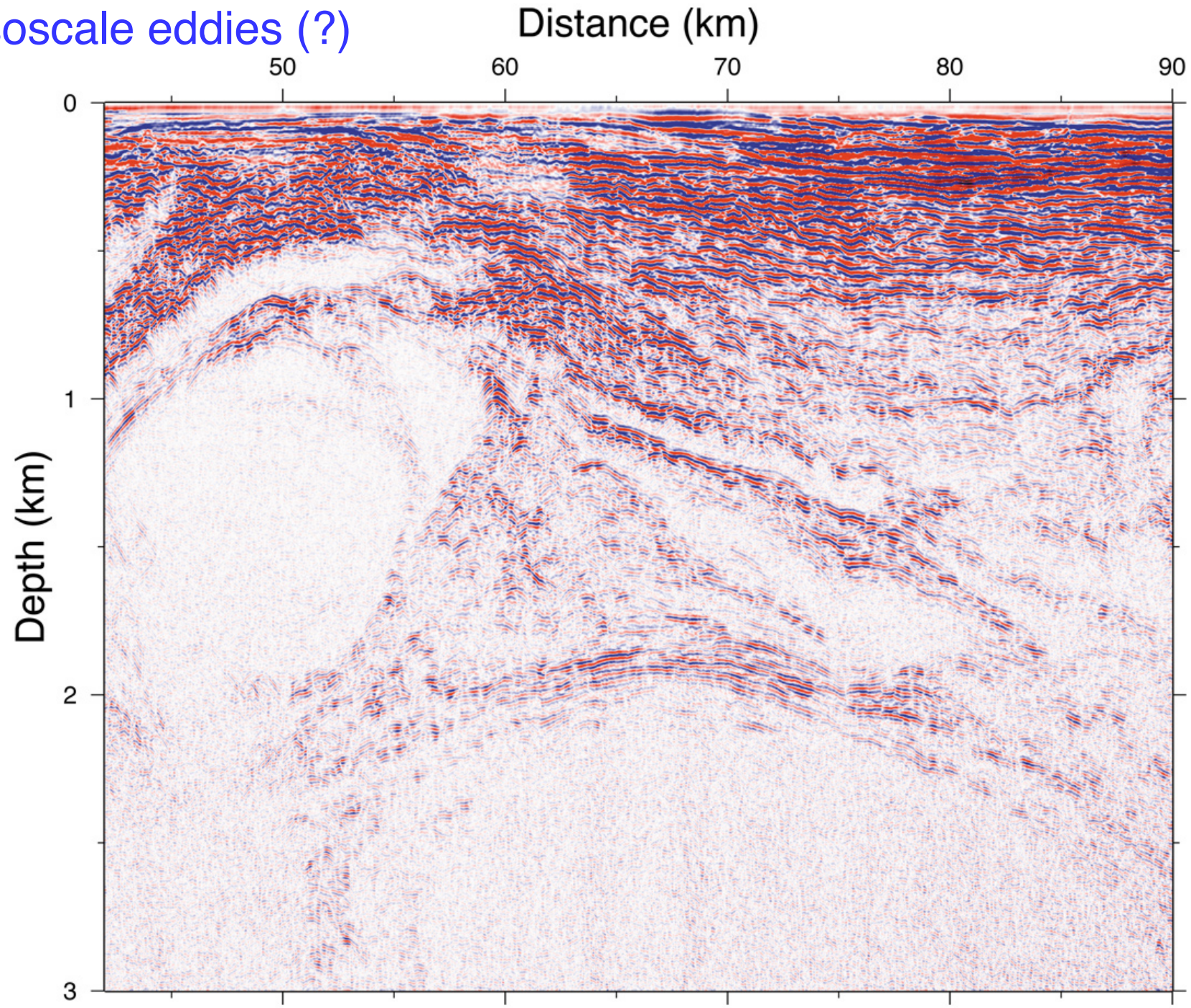
Fronts



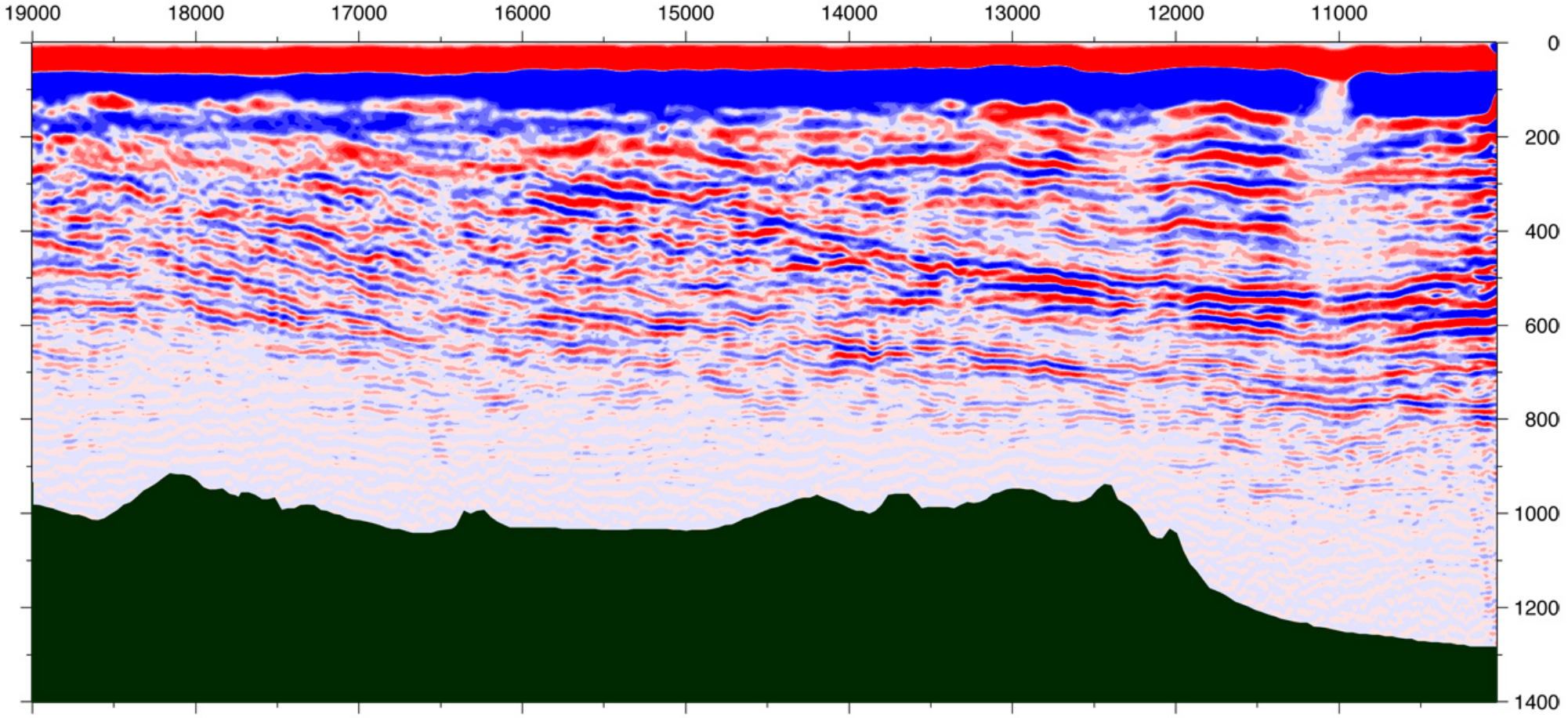
Dan Rudnick, SIO


Distance (km)
150
140
130
120
110
100
90
0
1
Depth (km)

Mesoscale eddies (?)



Warm-core rings

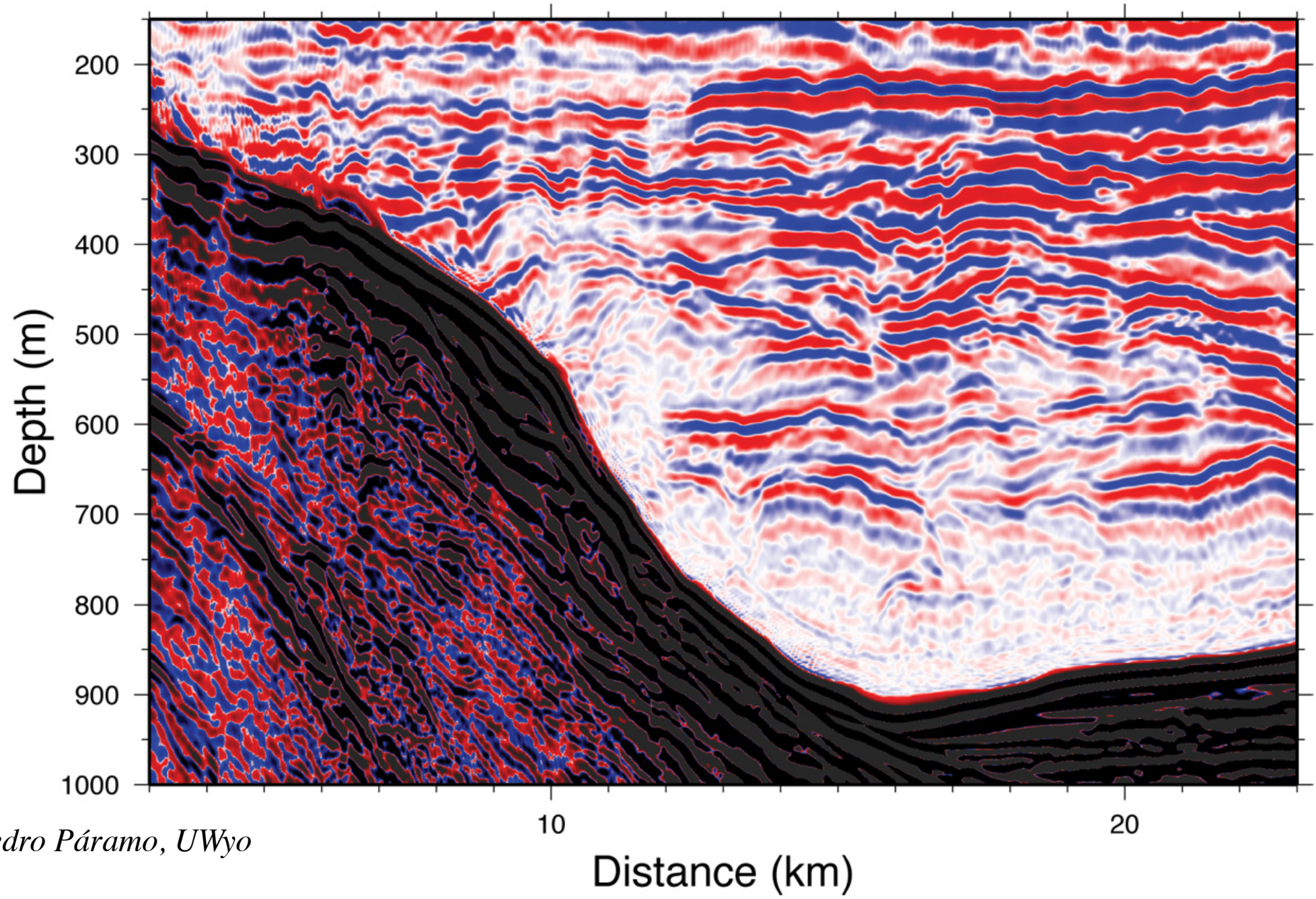


Data acquired by M/V Western Legend!

Joel Seymour, UWyo

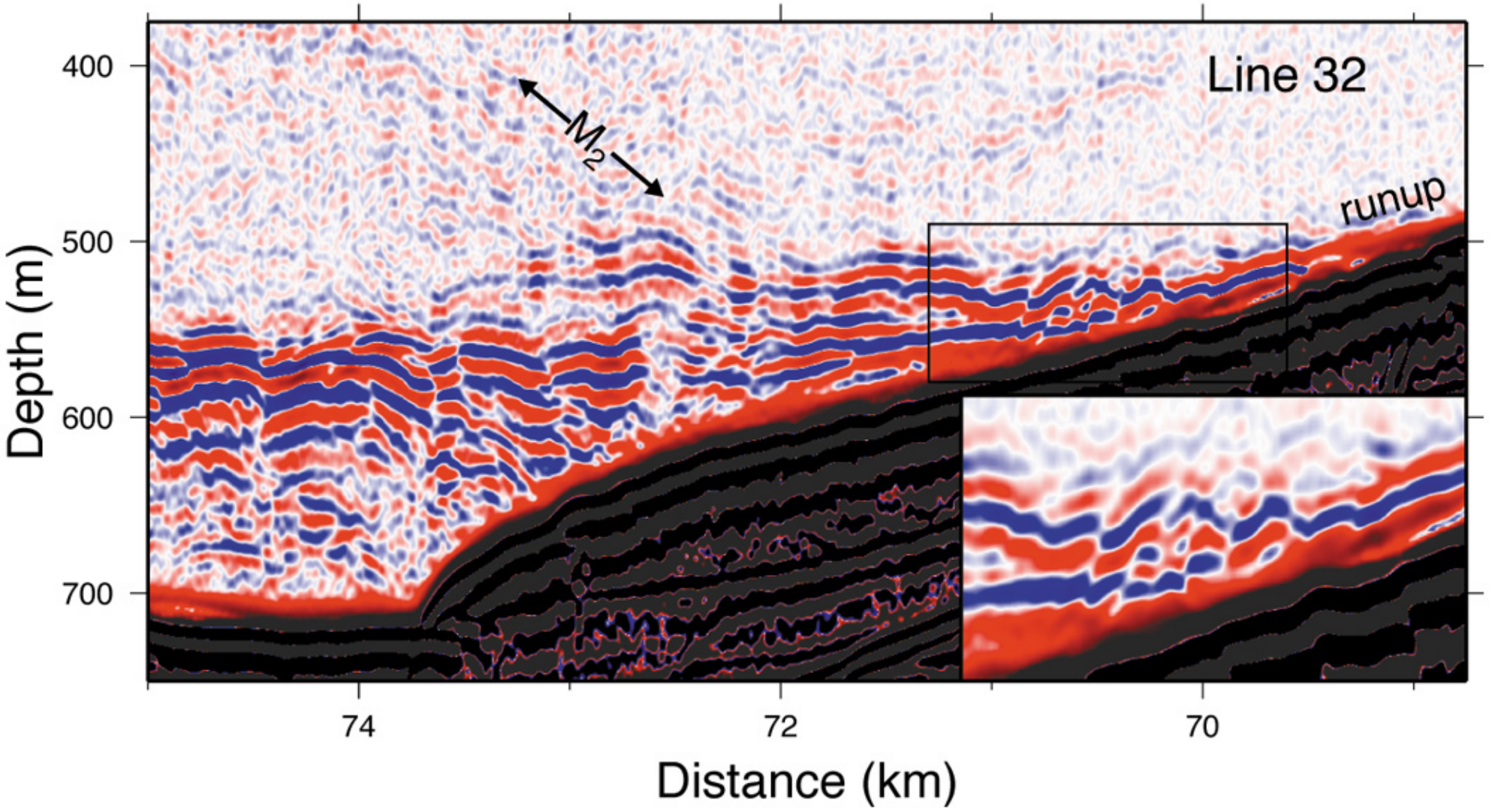
Data courtesy of: Schlumberger

Turbulent Boundary Layers

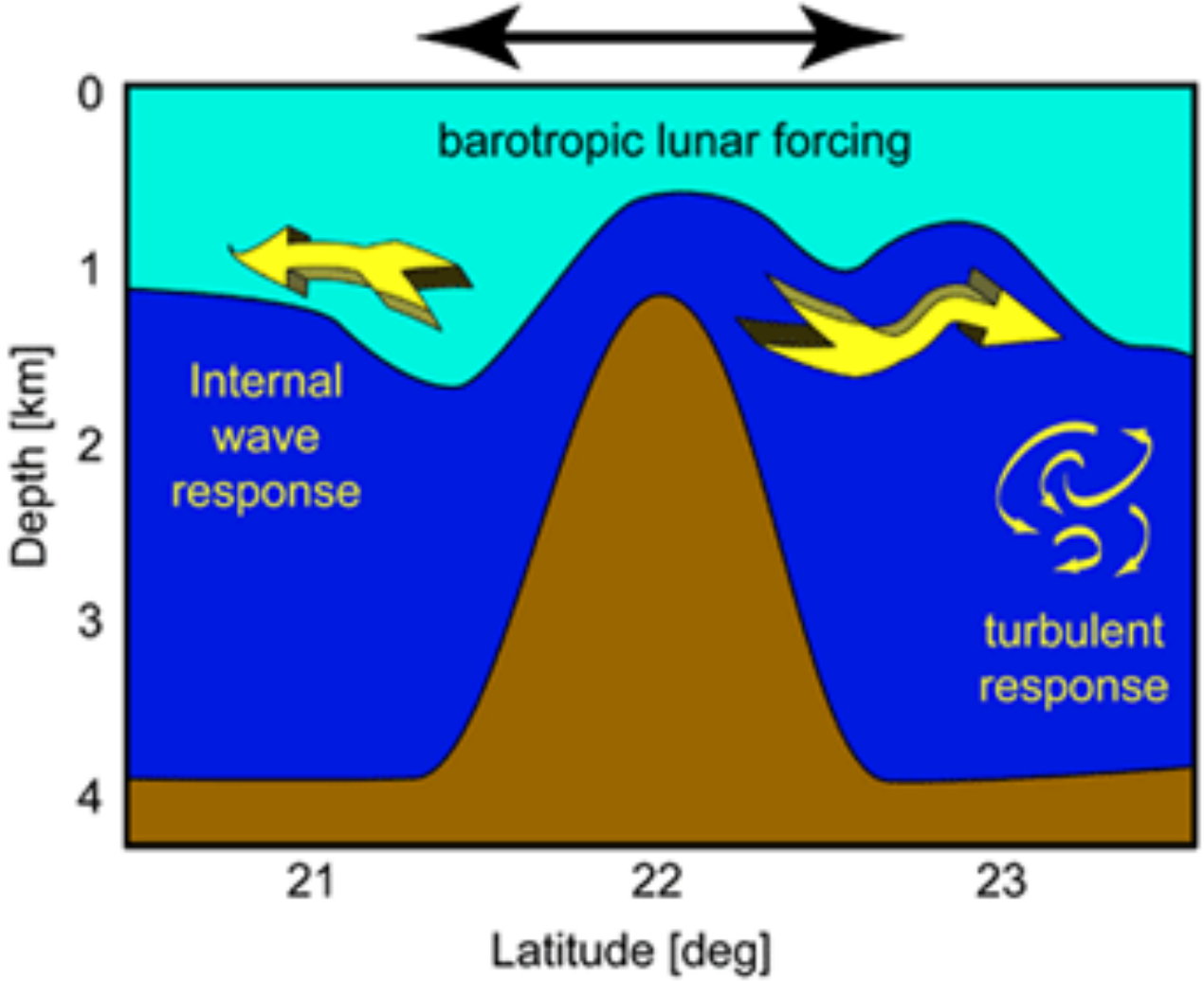


Pedro Páramo, UWyo

Breaking Internal Waves?

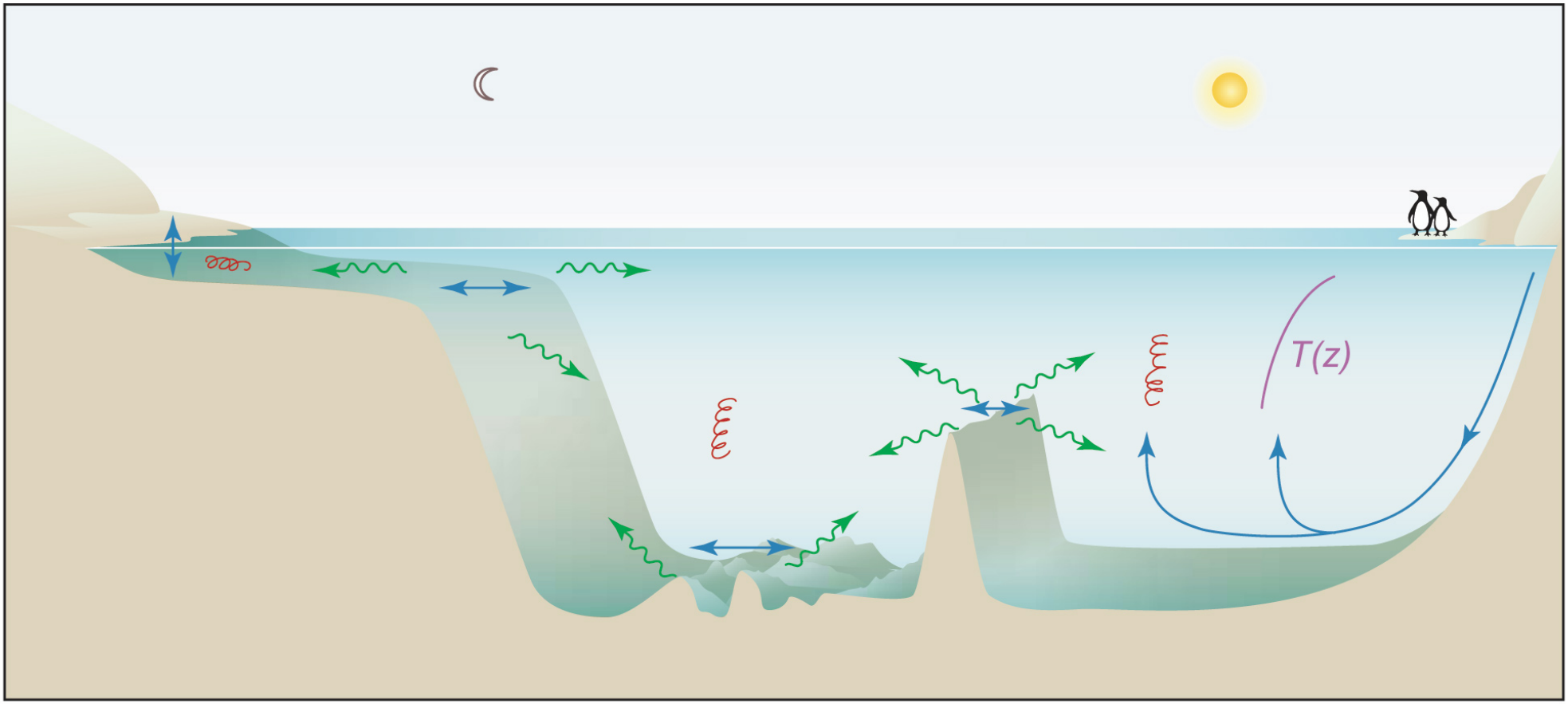


Internal Tides (M_2)



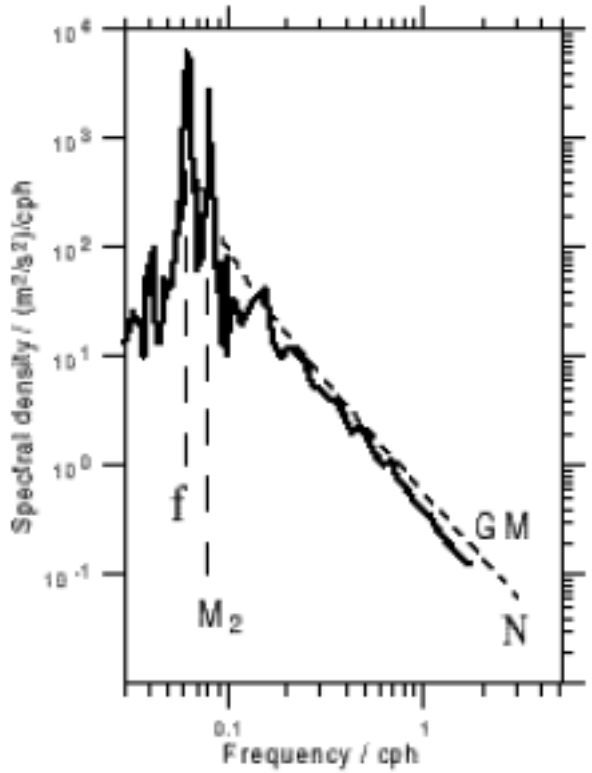
Jonathan Nash, OSU

Internal waves drive mixing in the ocean



Garrett, 2003, *Science*

Internal waves have a consistent spectral content, described by the Garrett-Munk spectrum (GM)

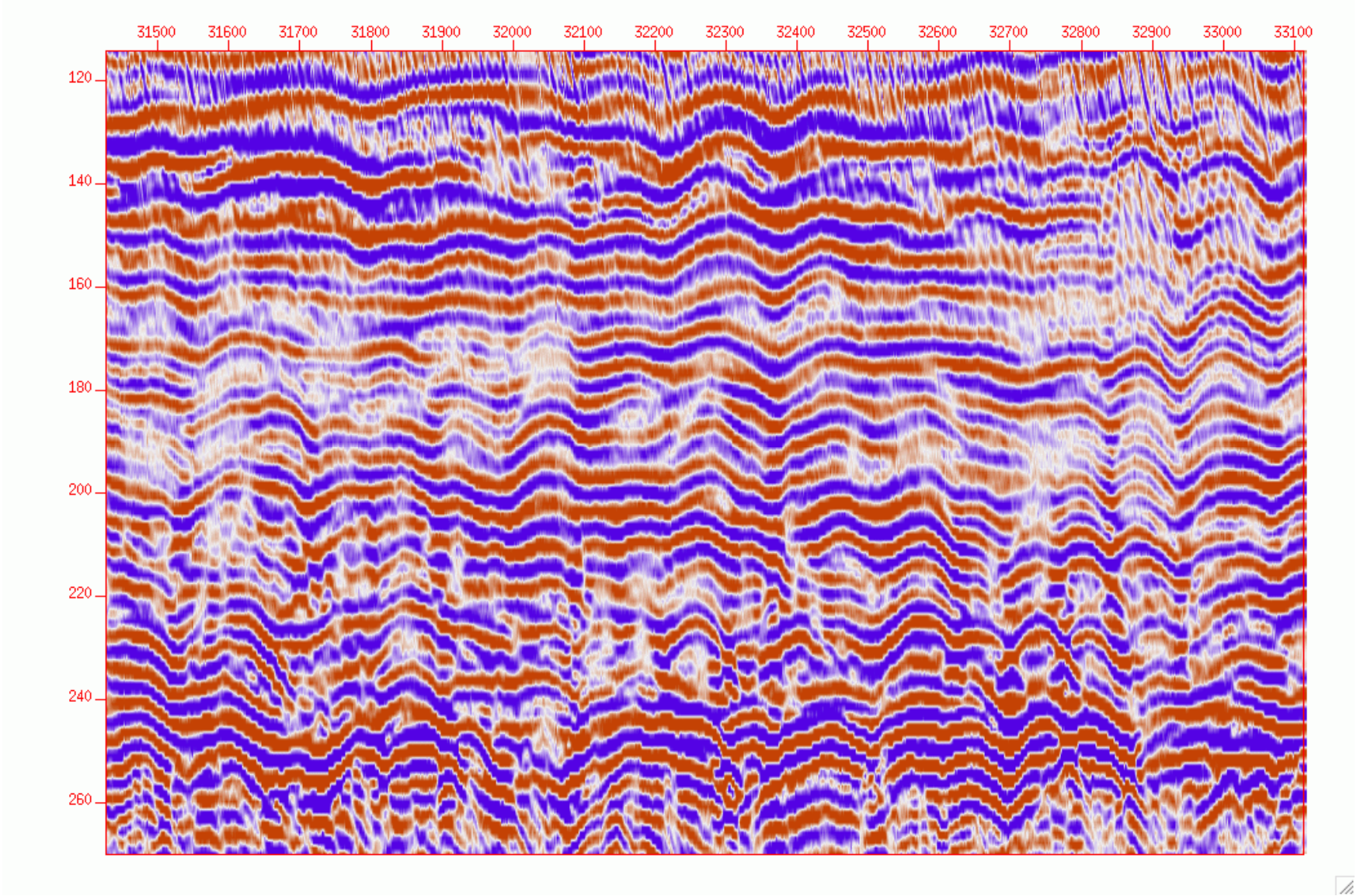


Mueller and Briscoe

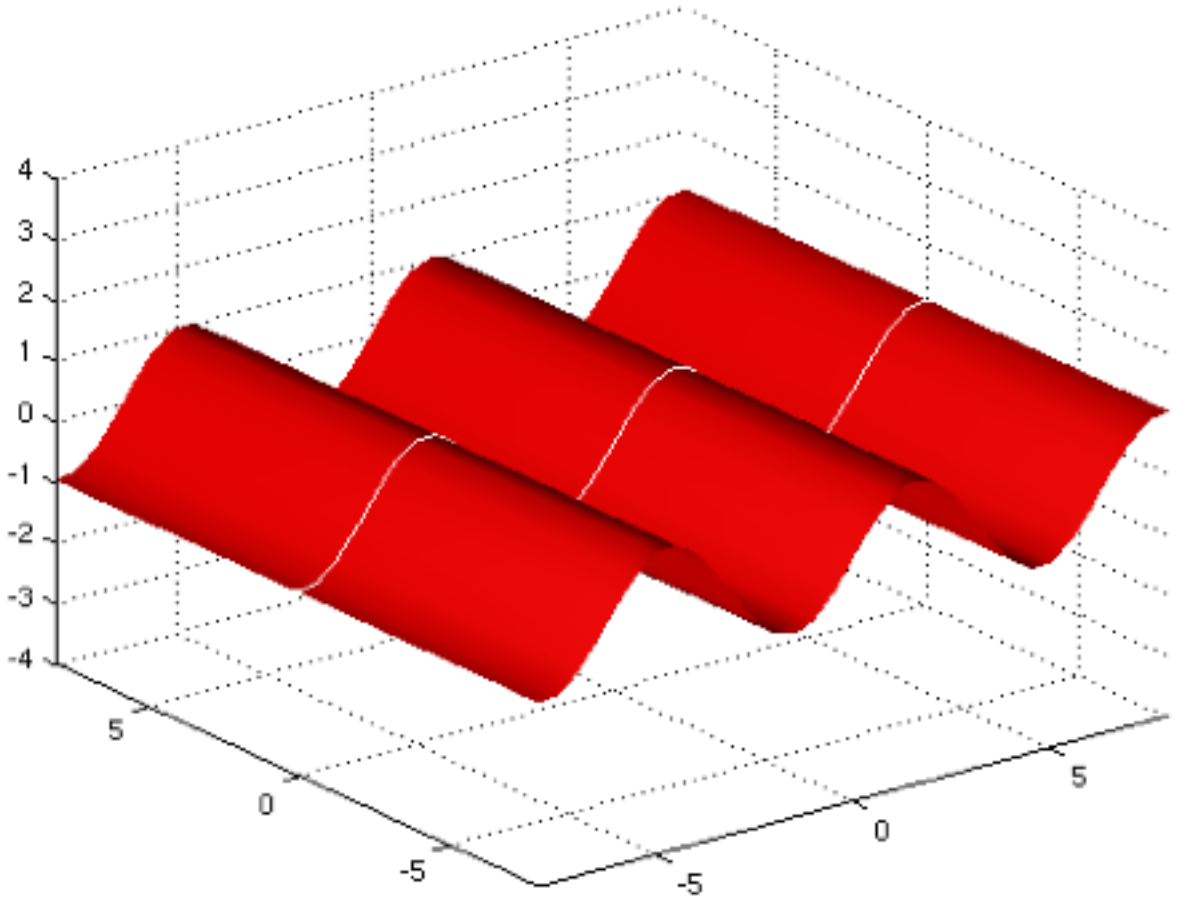
Internal Waves: Two Manifestations in Seismic Images

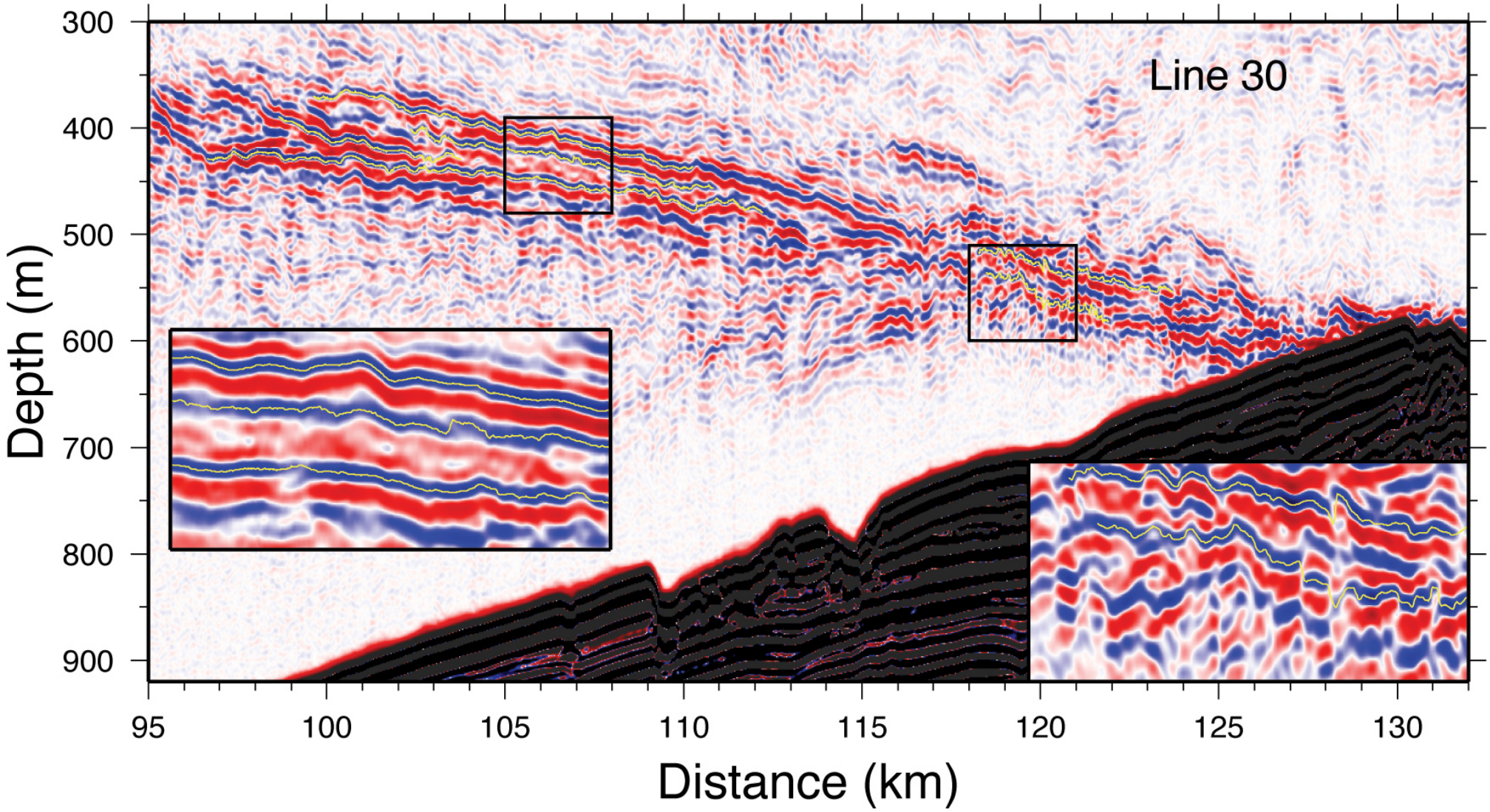
(1) Creation of (reversible) finestructure

(2) Deformation of existing finestructure

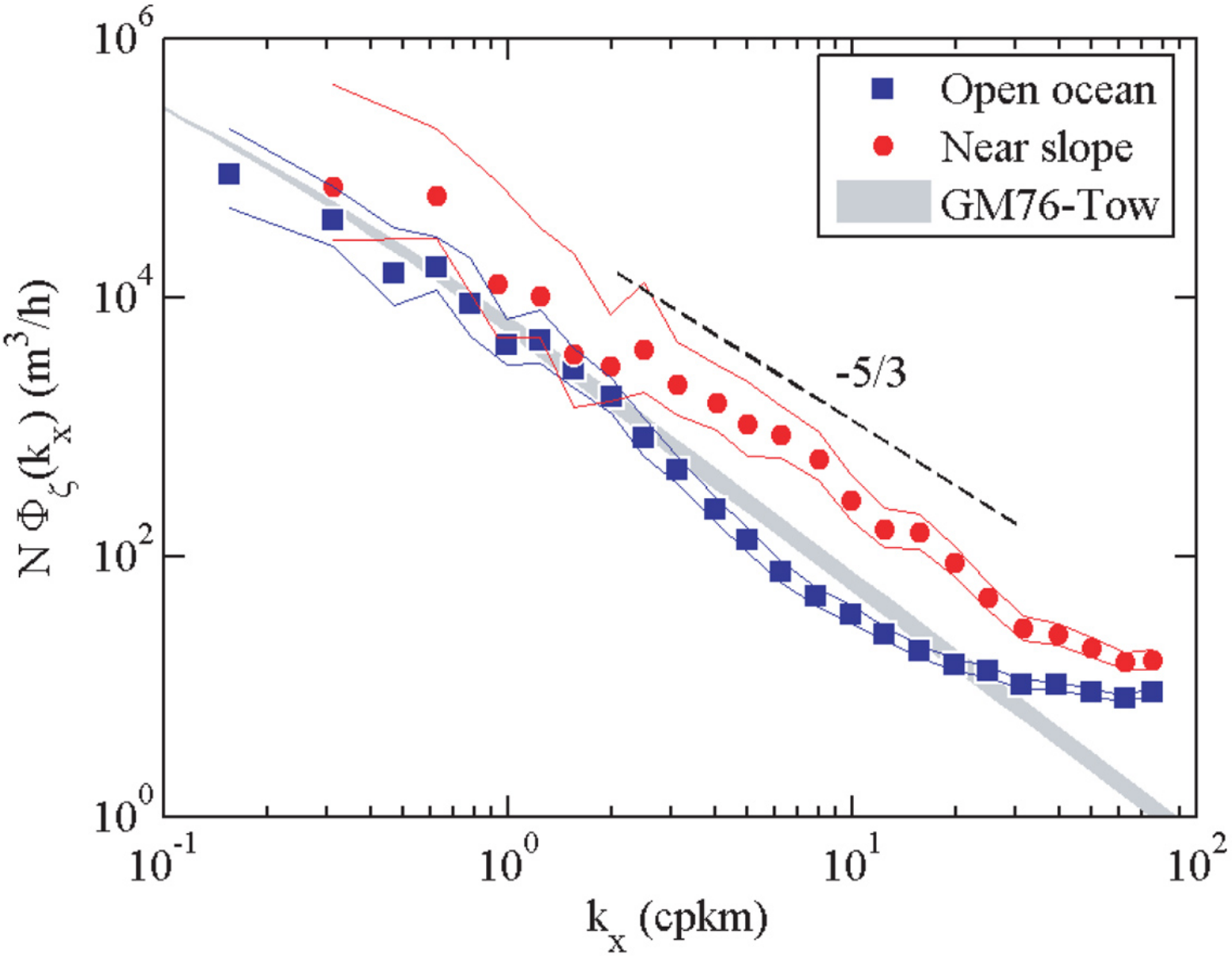


Internal wave deformation of finestructure (image: 11 km x 500 m)


4
3
2
1
0
-1
-2
-3
-4
5
0
-5
-5
0
5



Holbrook and Fer, 2005, *GRL*



Holbrook and Fer, 2005, *GRL*

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2D Seismic Oceanography

- Continuing analysis of archived data
- Joint seismic/PO field programs
  - *Langseth* + expendables (XBT, XCTD, XCP)
  - 2-ship (MCS + PO)
- LOTS more XBT's on all seismic cruises
  - (also helpful for MMM - sound propagation in H_2O)

3D seismic oceanography

Expect new insights into many processes:

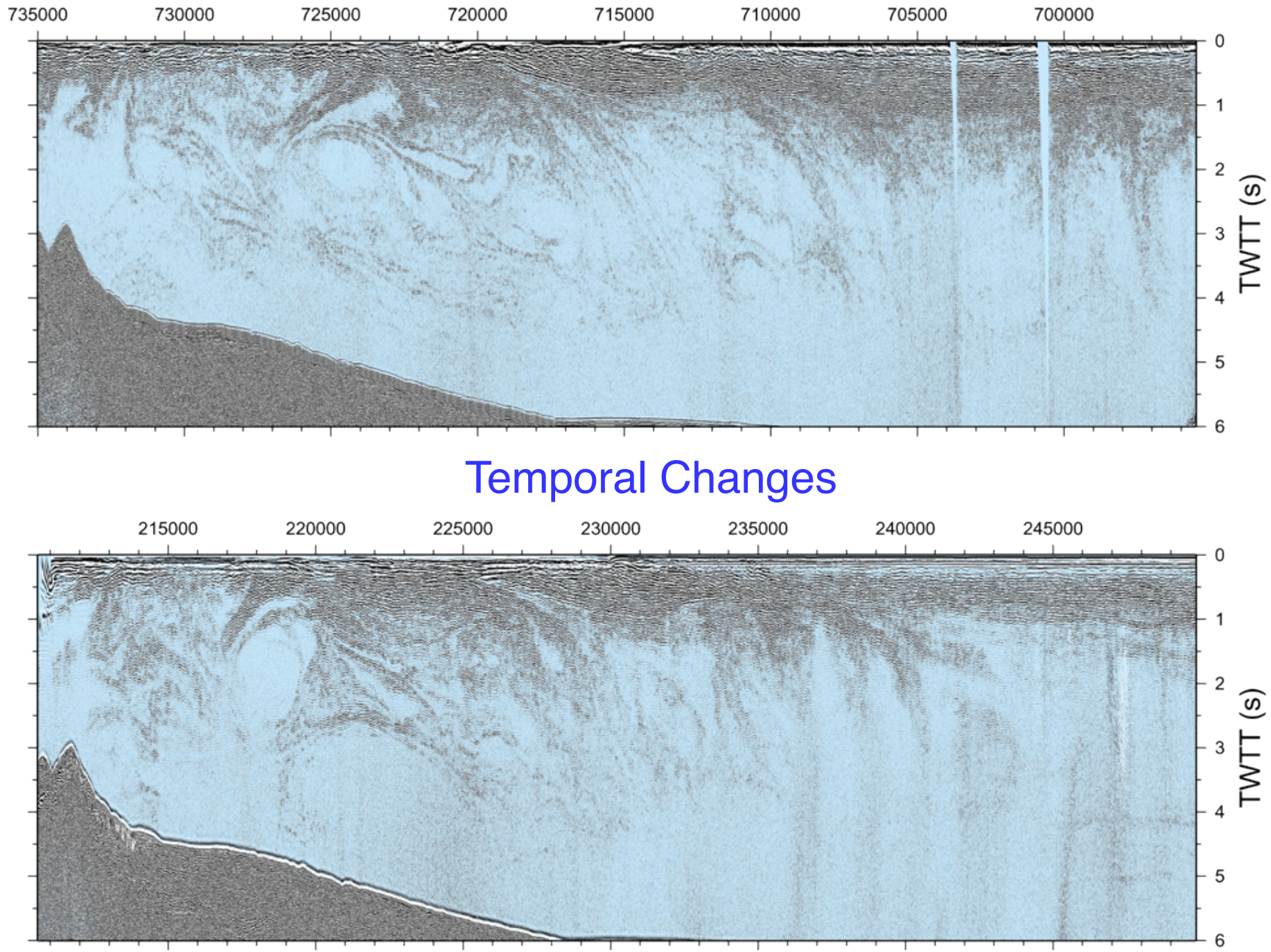
- Internal waves
- Intrusions
- Thermohaline staircases
- Fronts and cross-frontal exchange

=> Vertically “stacked” objectives (Earth + ocean)

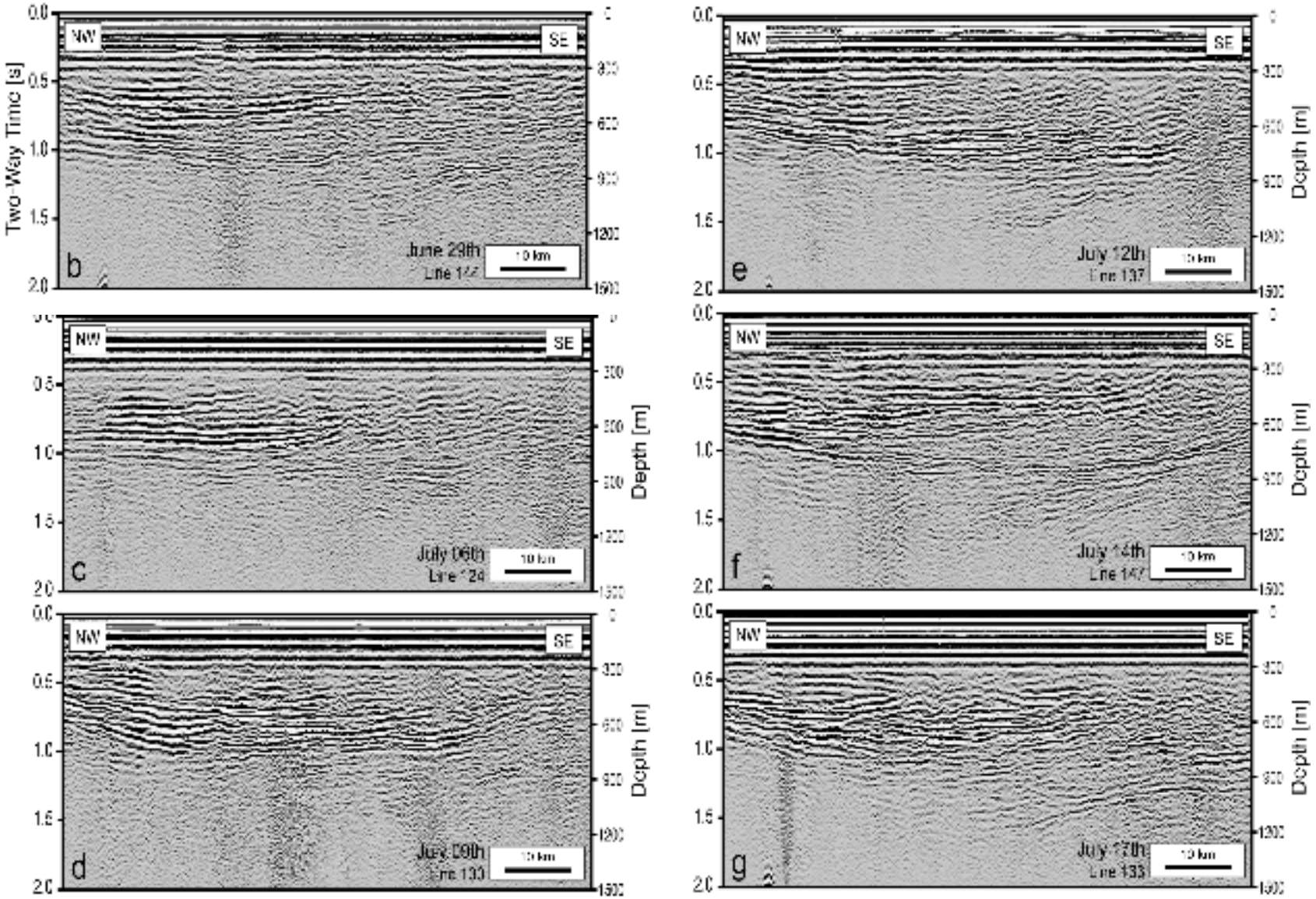
But…the water column poses special challenges to 3D imaging

=> It is dynamic on timescales of hours to days.

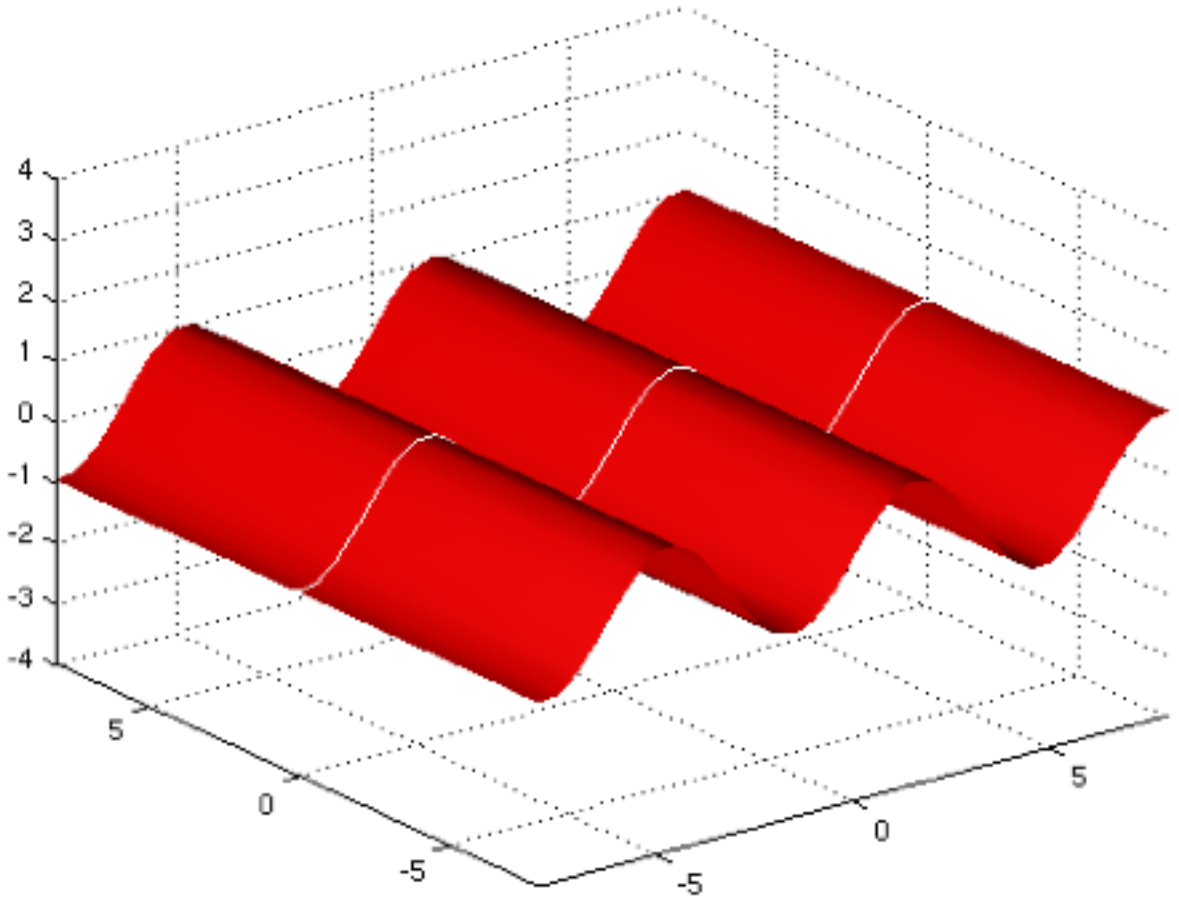
- Standard 3D images will only be piecewise continuous
- Swath-by-swath imaging is feasible


735000
730000
725000
720000
715000
710000
705000
700000
0
1
2
3
4
5
6
TWTT (s)
Temporal Changes
215000
220000
225000
230000
235000
240000
245000
0
1
2
3
4
5
6
TWTT (s)

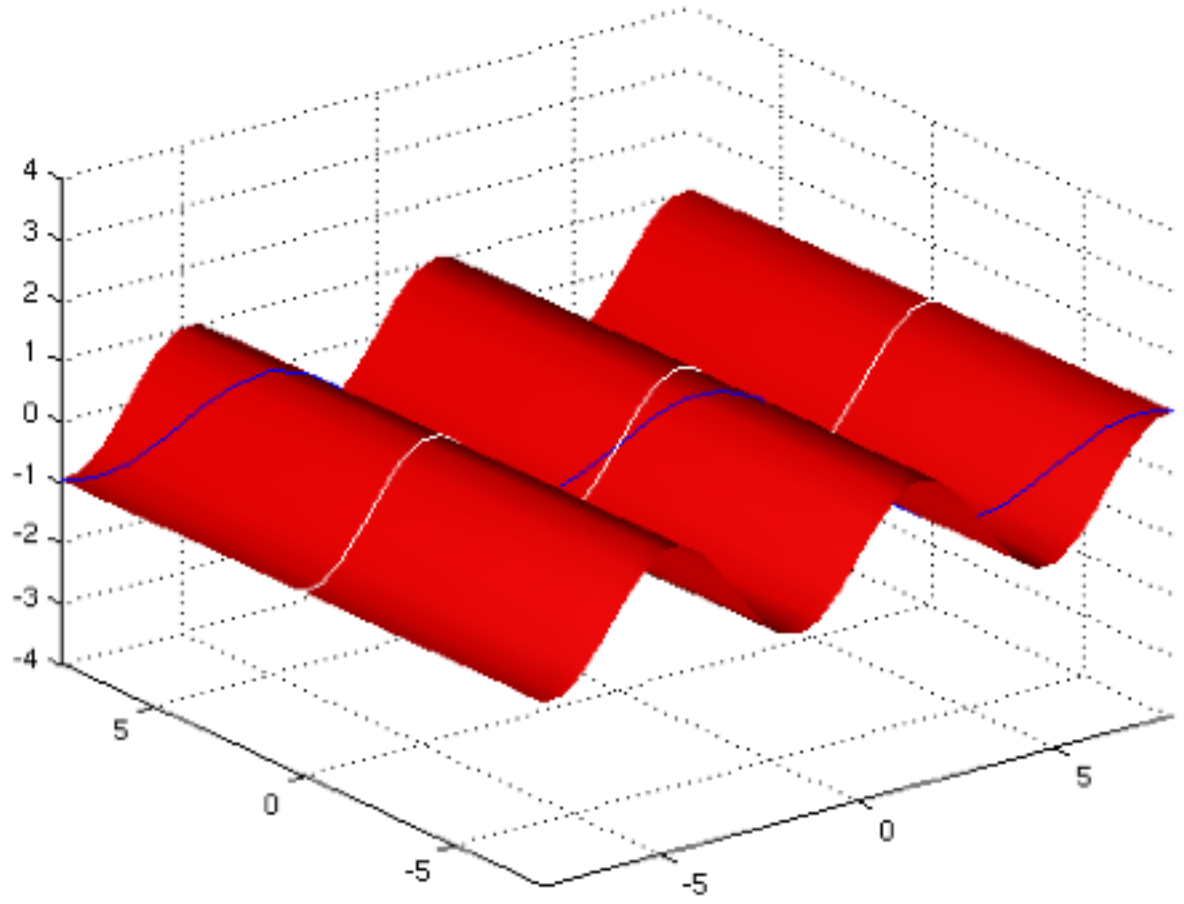
Temporal Changes: main features may remain stable



Tsuji et al., 2005, *GRL*

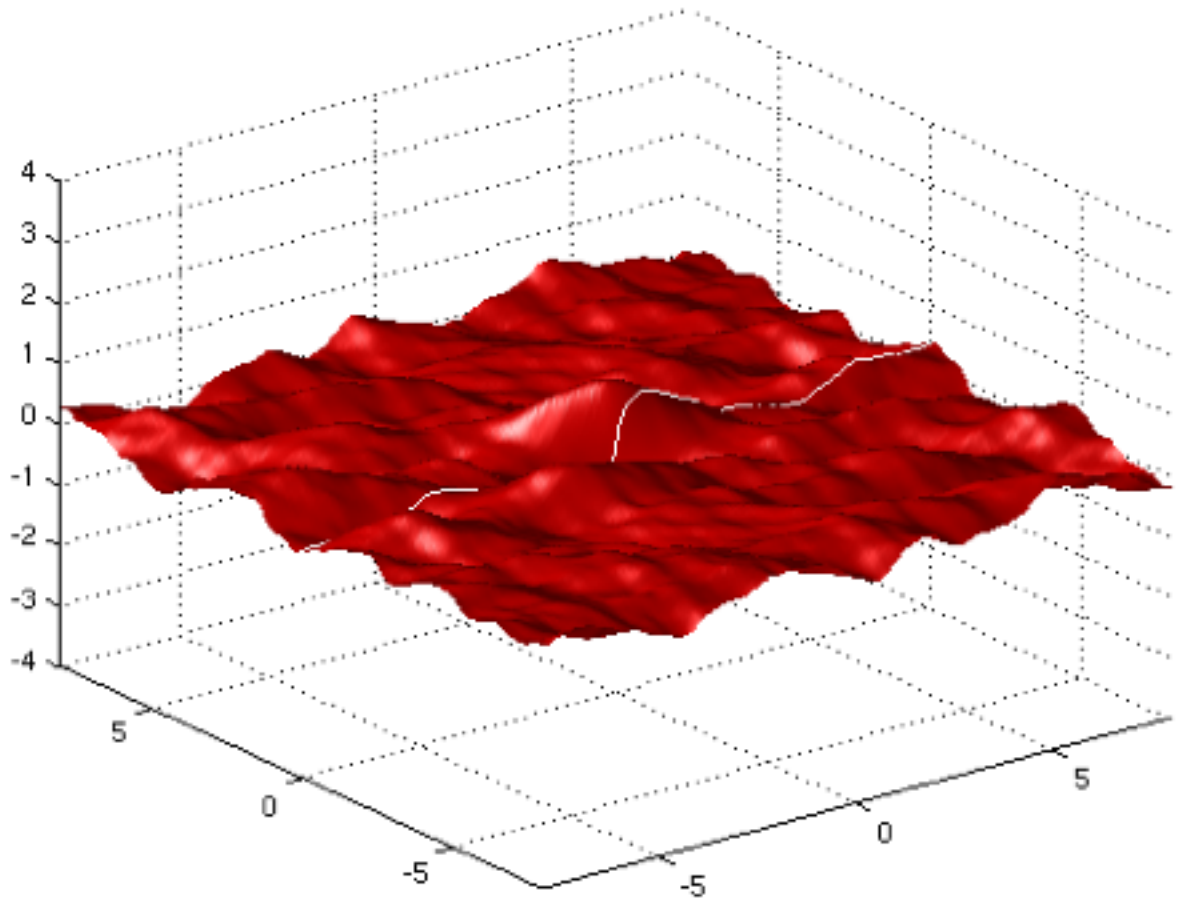

4
3
2
1
0
-1
-2
-3
-4
5
0
-5
-5
0
5

Possible “Red Shift” in inferred Kx spectra: 3D data needed



Expected interface shape for a Garrett-Munk IW field

=> Is the IW field isotropic?



Conclusions

- Marine reflection seismology is well "tuned" to detect thermohaline finestructure.
- Features such as thermohaline intrusions, internal waves, mesoscale eddies, and boundaries between water masses can be imaged, over full ocean depth, at high lateral sampling [O(5 m)].
- The seismic reflection method can provide quantitative information on the internal wave field.
- Seismic reflection data constitutes a large, untapped resource for imaging ocean structure and dynamics.
- The MCS community has an opportunity to make a significant contribution to physical oceanography.