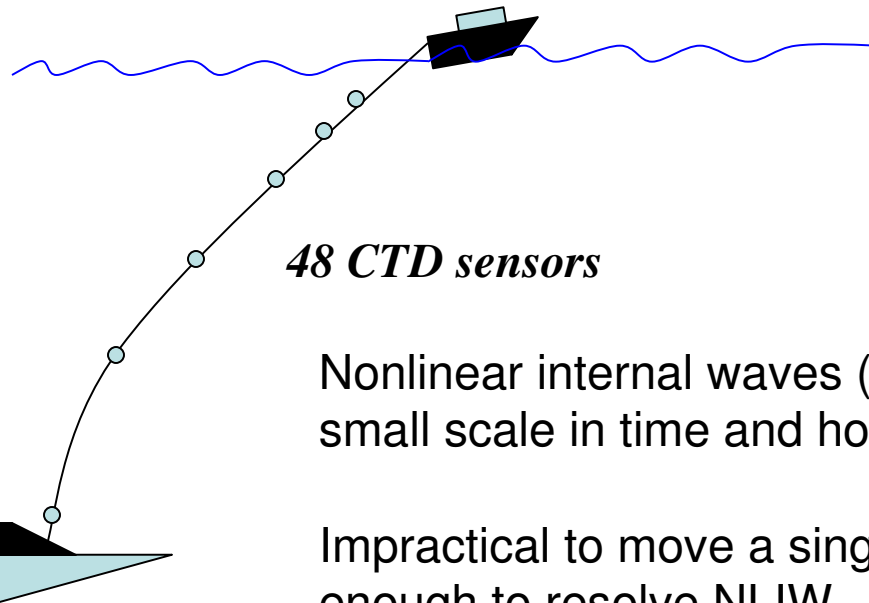# Simultaneous nearby measurements of acoustic propagation and high-resolution sound speed structure containing internal waves

Frank S. Henyey , Kevin L. Williams, Dajun Tang

Applied Physics Laboratory, University of Washington

Towed CTD chain

48 CTD sensors

Depressor

Nonlinear internal waves (NLIW's) have a small scale in time and horizontal extent

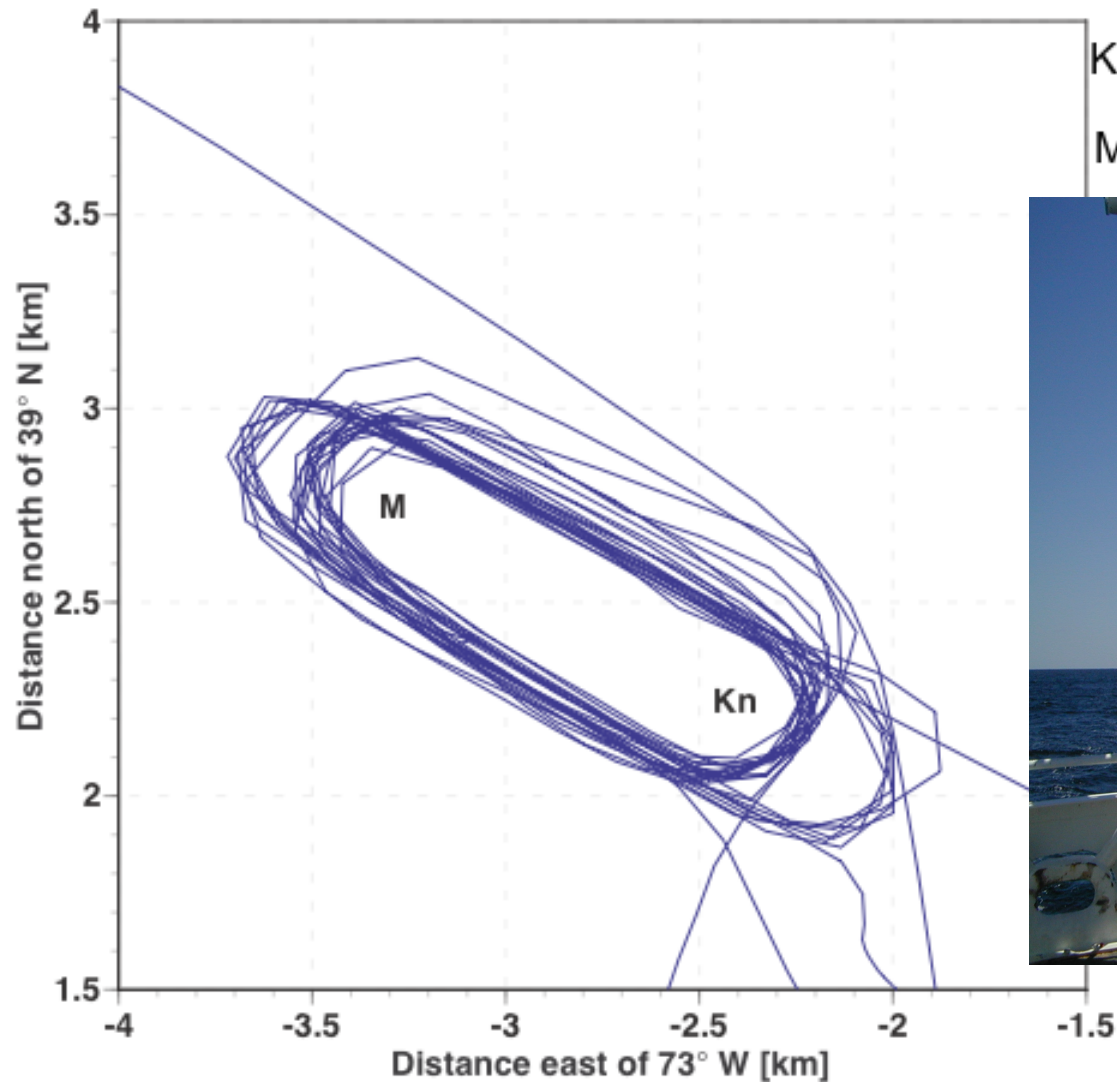Impractical to move a single CTD fast enough to resolve NLIW

The towed chain has the advantage over a mooring that the wave speed and the slow x - v t evolution was measured in SW06 by repeated passes.

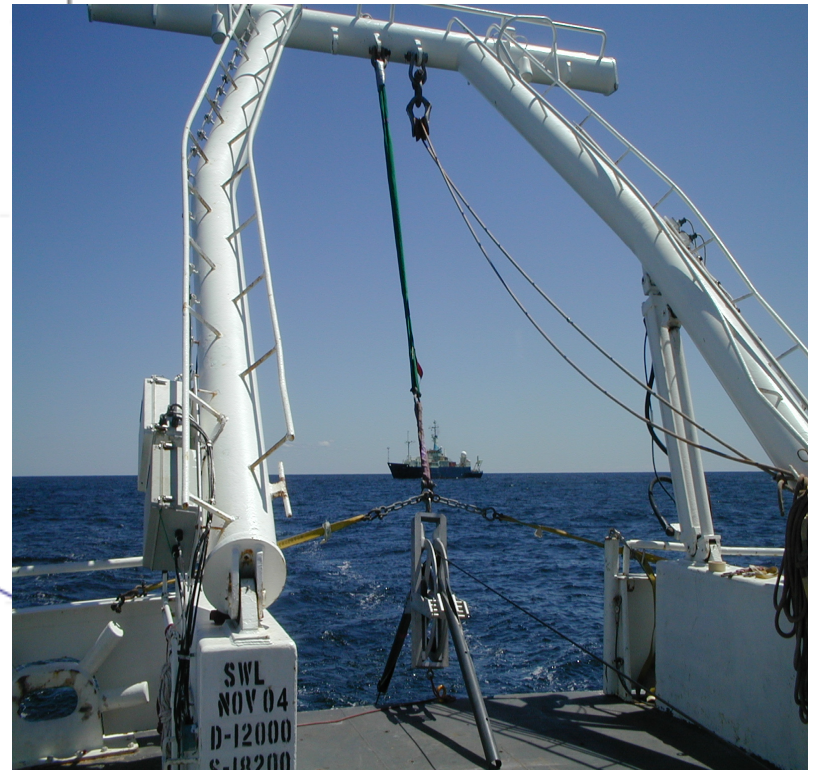Depth, sound speed, and density are extracted from the measurements

GPS Track of the R/V Endeavor with a towed CTD Chain
Aug 11 & 13, 2006

Kn -- Acoustic source on R/V Knorr

M -- Moray receiving mooring

Acoustic measurements

2-10 kHz; various pulse types
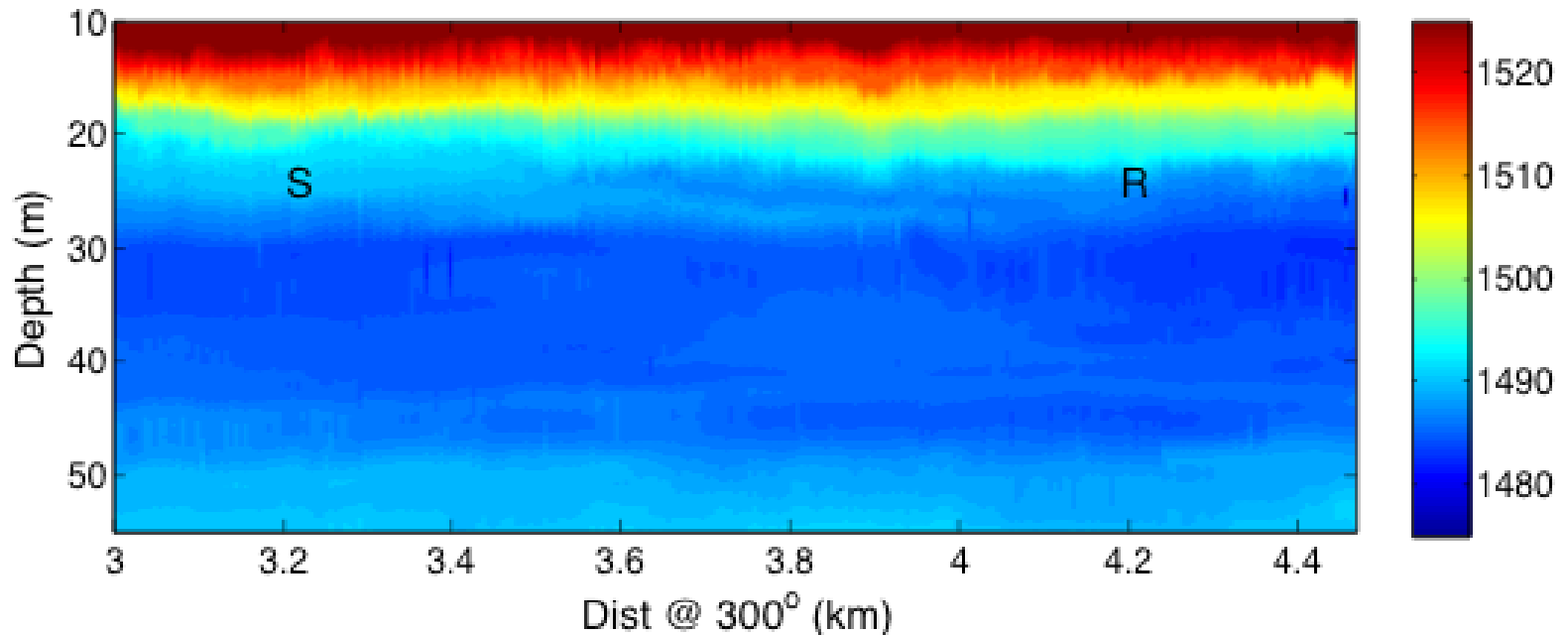
1 km propagation path

Repeated every 20 s

Source at 30 m

Receivers in clusters near 25 m and 50 m

S/N = 45 dB after fm pulse compression

Aug 11

Sound speed extracted from towed CTD data one leg

No large waves

Note the higher sound speed near bottom -- the sound channel shields acoustic energy from the sediments.

# Acoustics on Aug 11

Large fluctuations in intensity

The mean field is fit by spreading loss + seawater absorption
with random phase modes. The mode cutoff is assumed
to be at the bottom critical angle.

There is no large random attenuation to explain the fluctuations
Not fish.
Not Creamer mechanism -- most likely suppressed by
the high-c layer near the bottom.
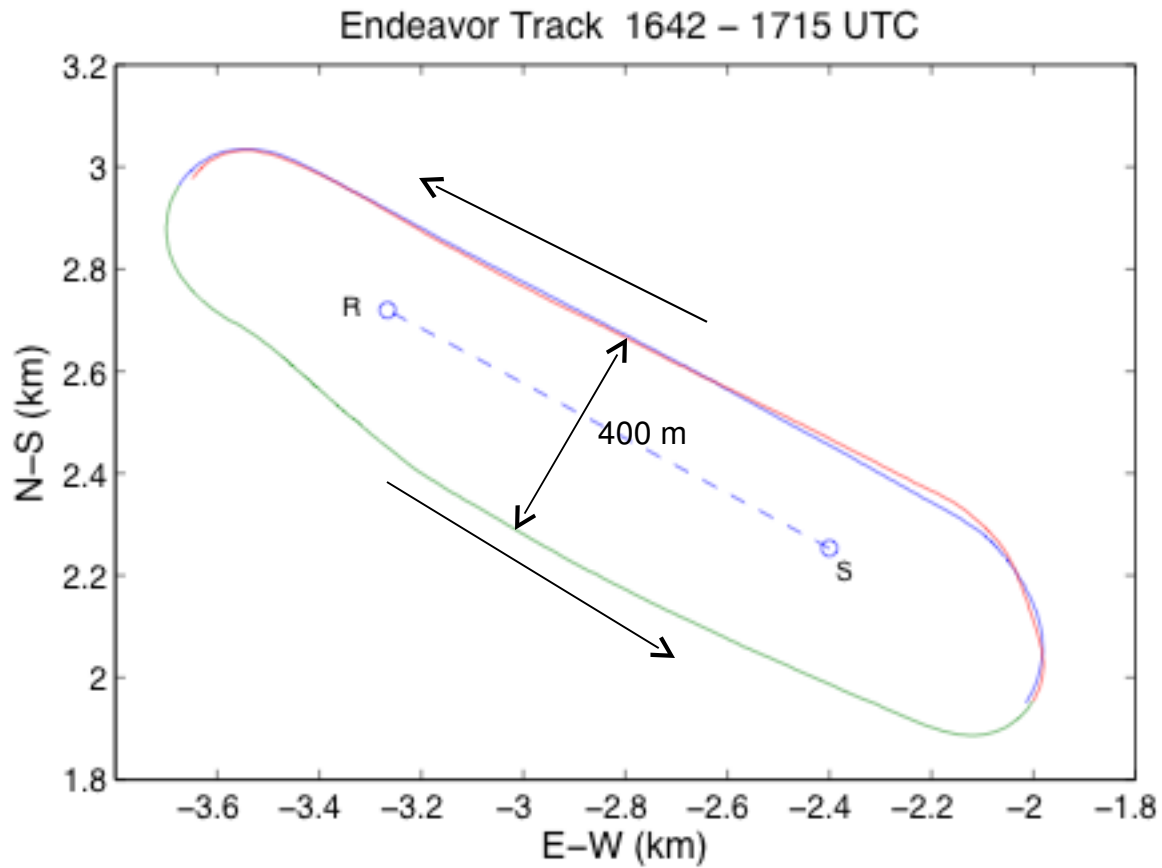
Intensity distribution

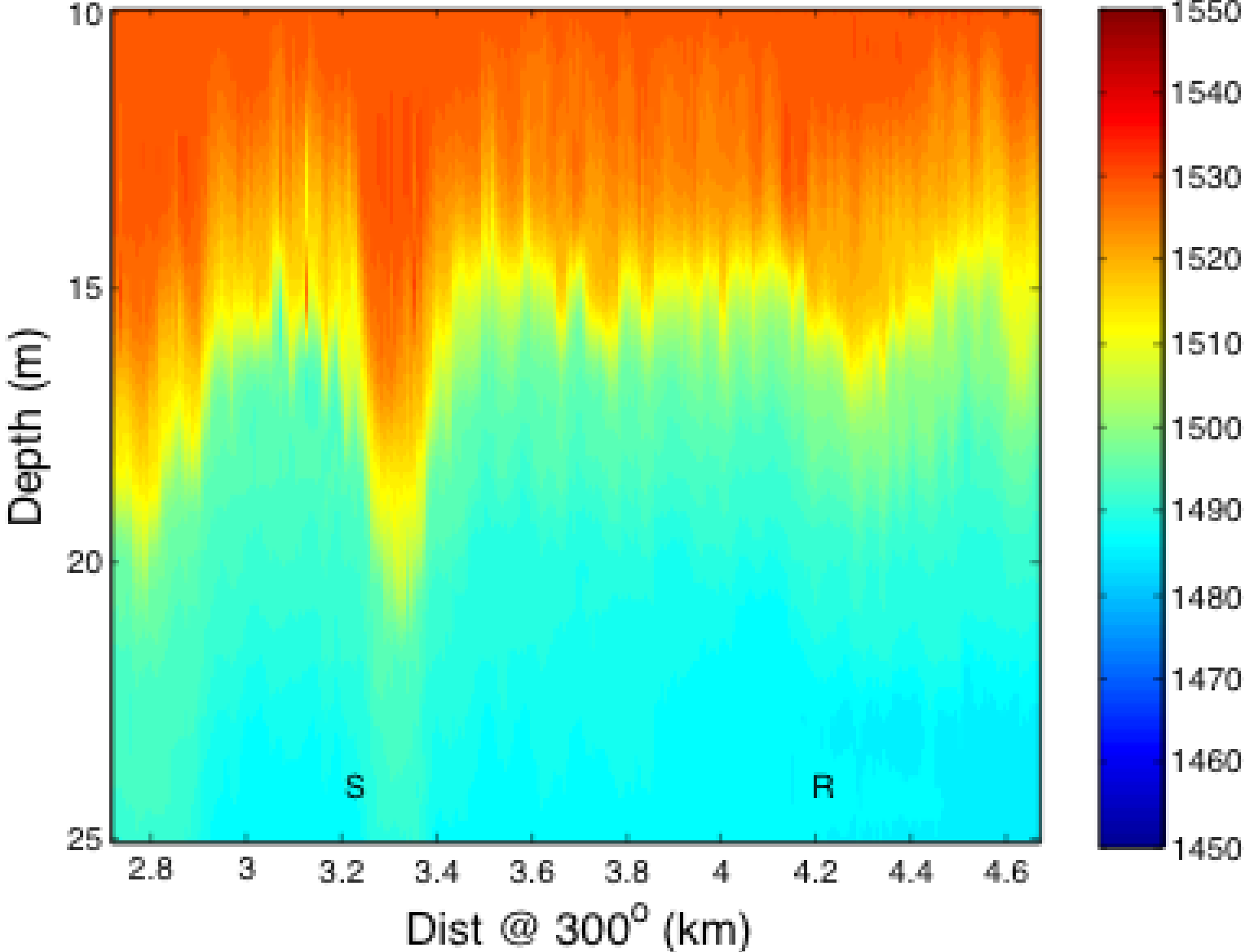High-tail cumulative distribution function
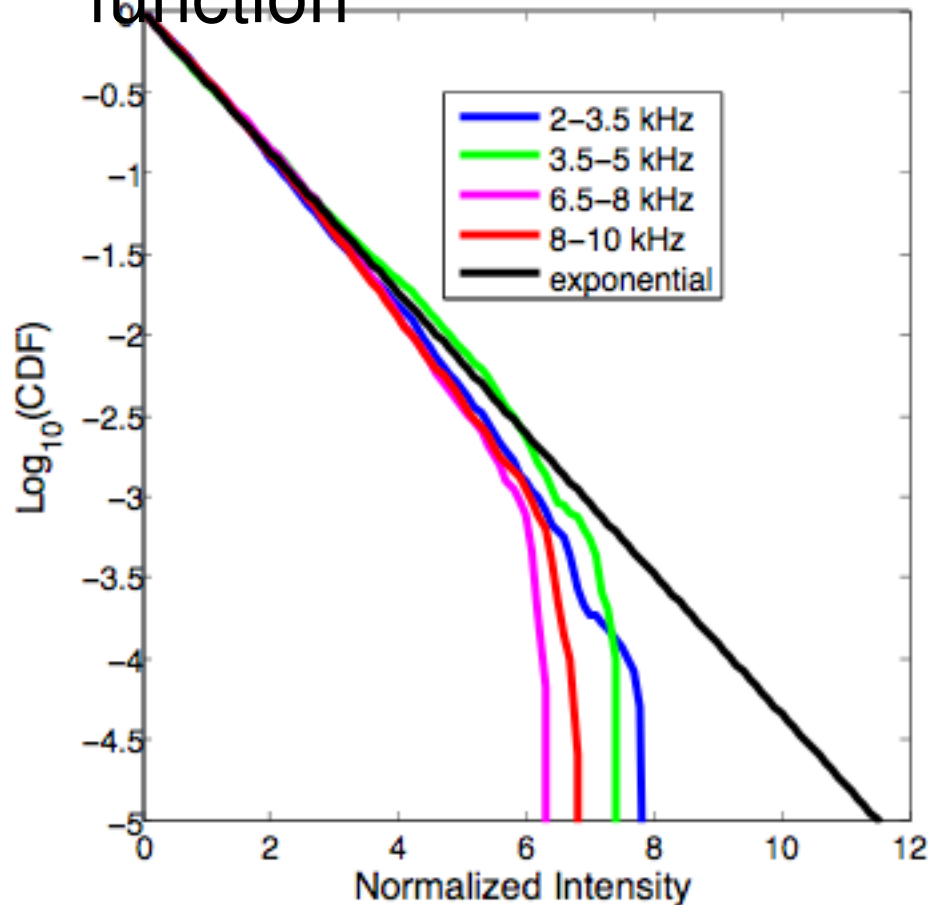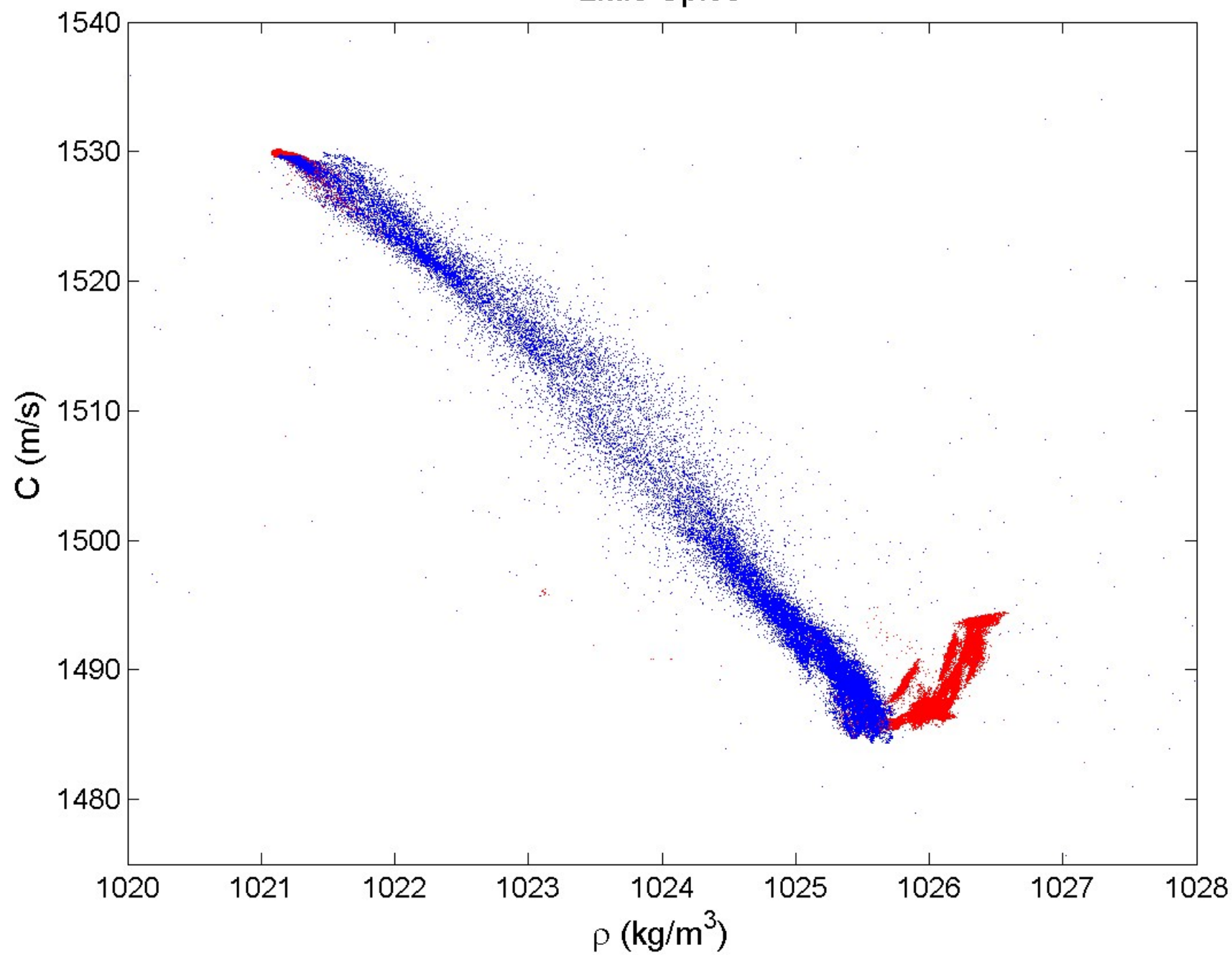

SI = 1.0

Nearly saturated

Aug 13
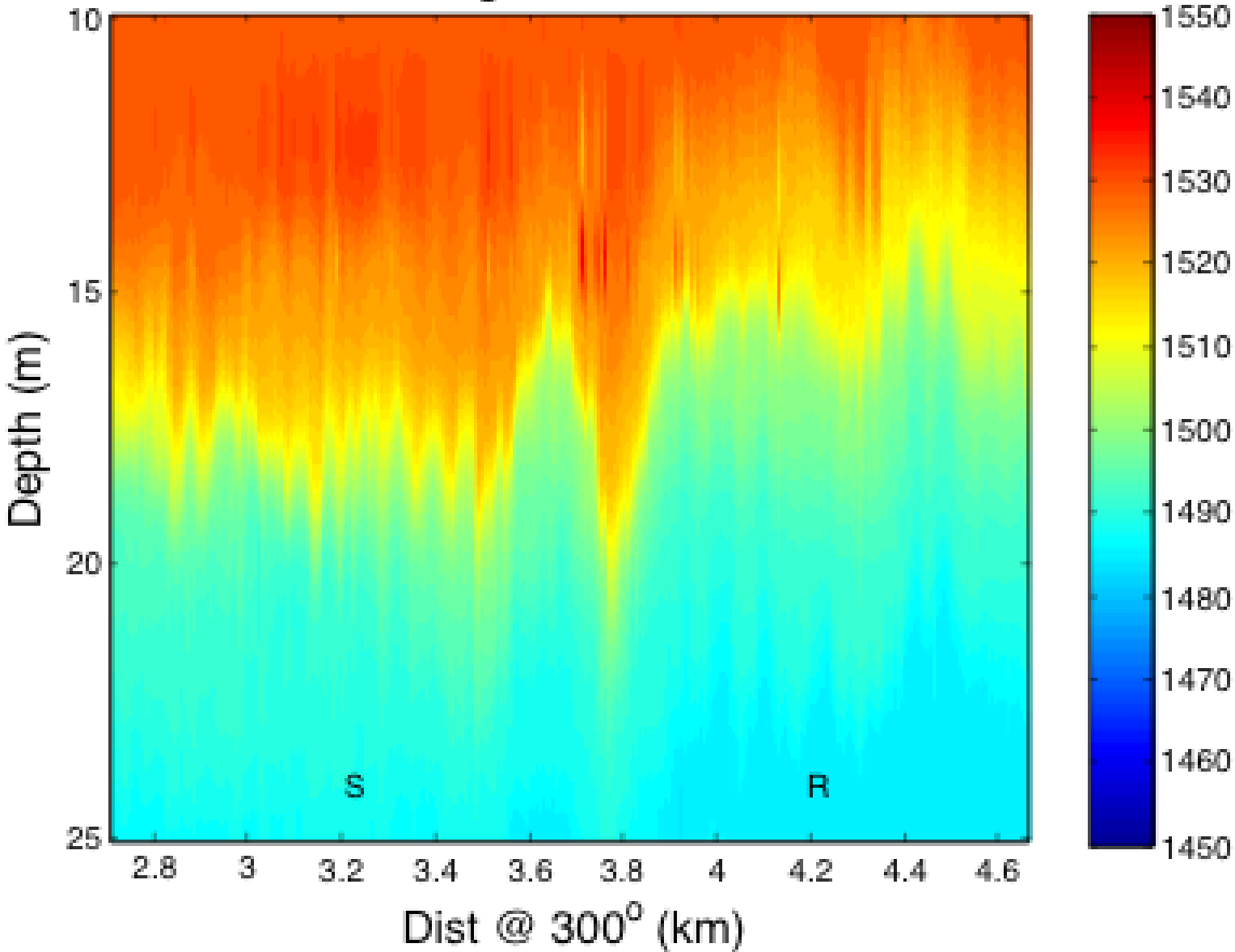

Endeavor Track 1642 – 1715 UTC
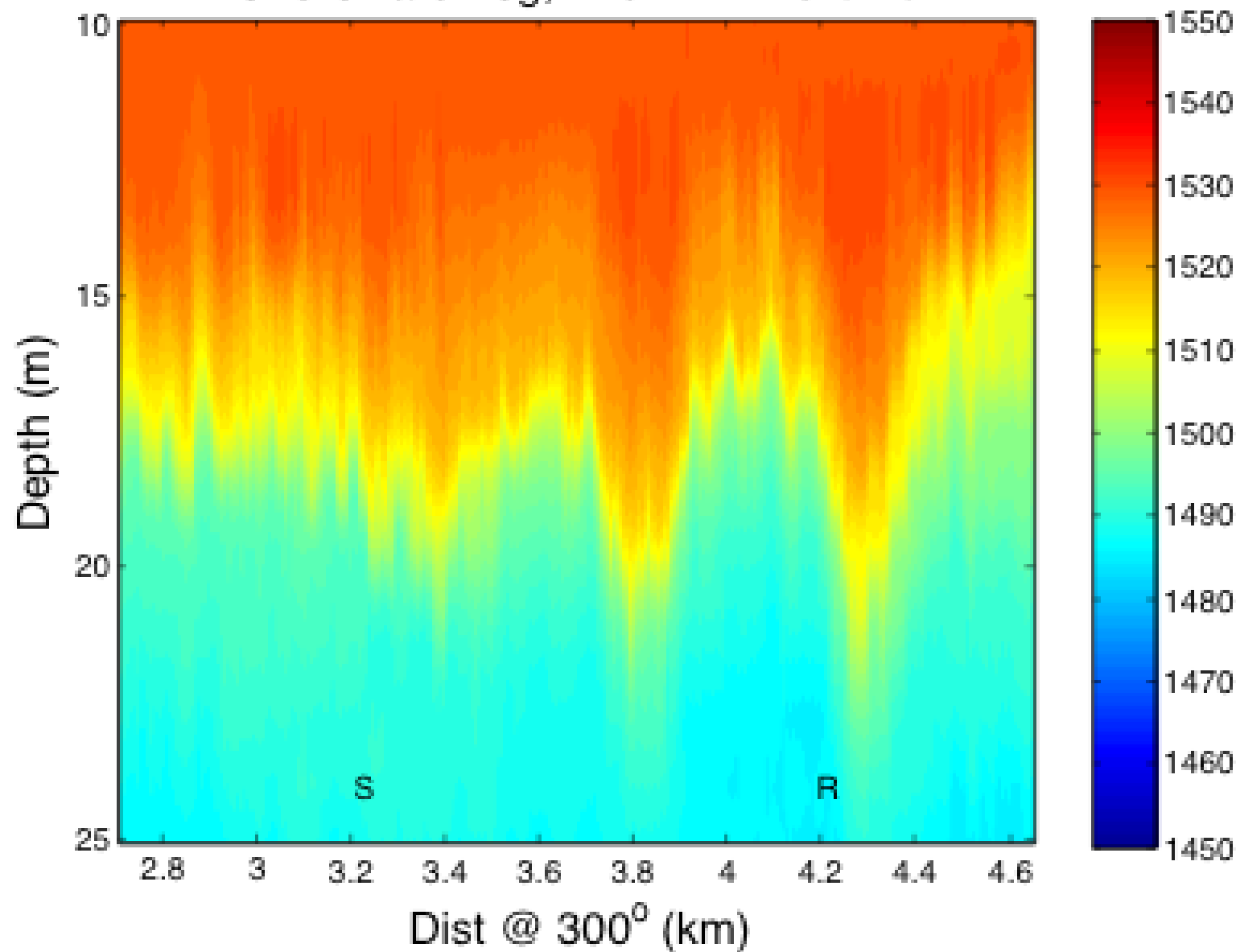
(Distances from 73°W, 39°N)

Shoreward Leg, 1642 – 1653 UTC

Little Spice

Seaward Leg, 1653 – 1704 UTC

Shoreward Leg, 1704 – 1715 UTC

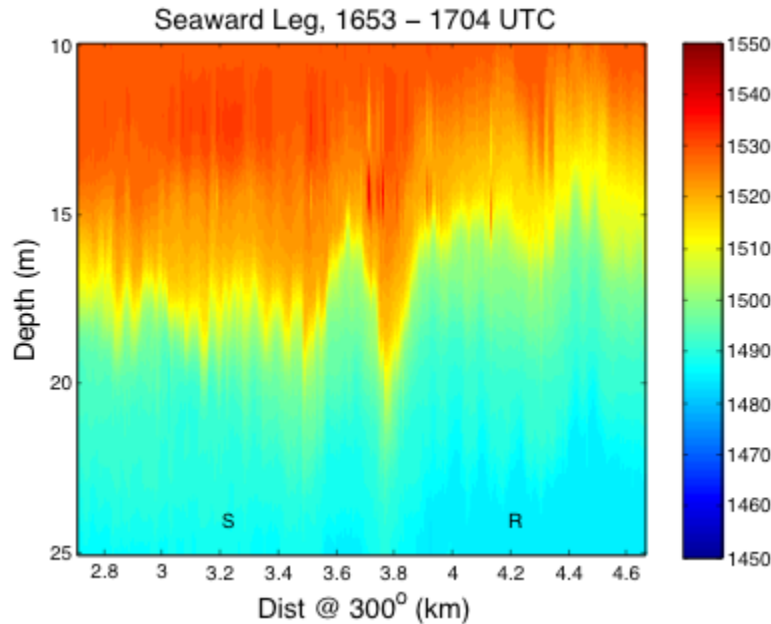# Simple example of interpolation

Corrections not needed

Seaward Leg, 1653 – 1704 UTC

Shoreward Leg, 1704 – 1715 UTC

$$\frac{v}{\cos q} = 0.6 \, m/s$$

Shoreward Leg, 1642 – 1653 UTC
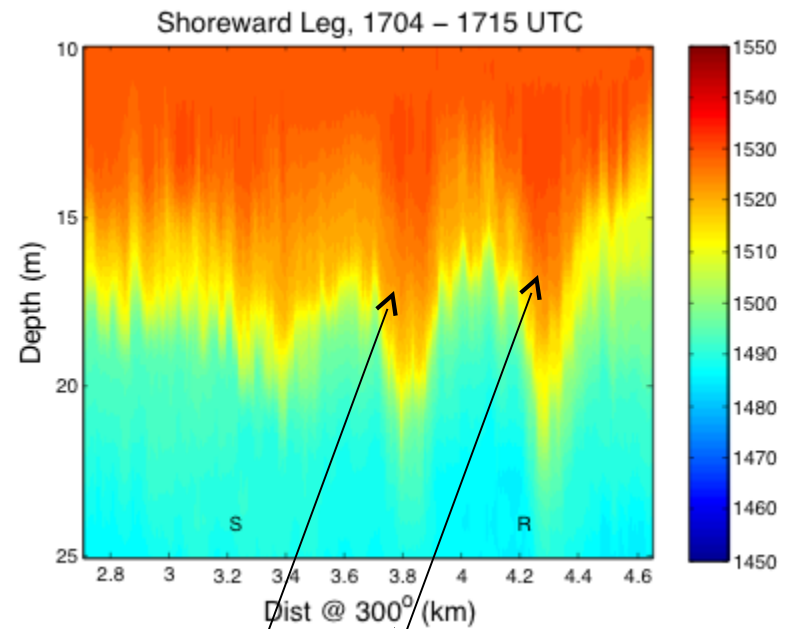
Ship speed = 3.5 m/s
Spacing on shoreward legs = 500 m – 86 m = 414 m
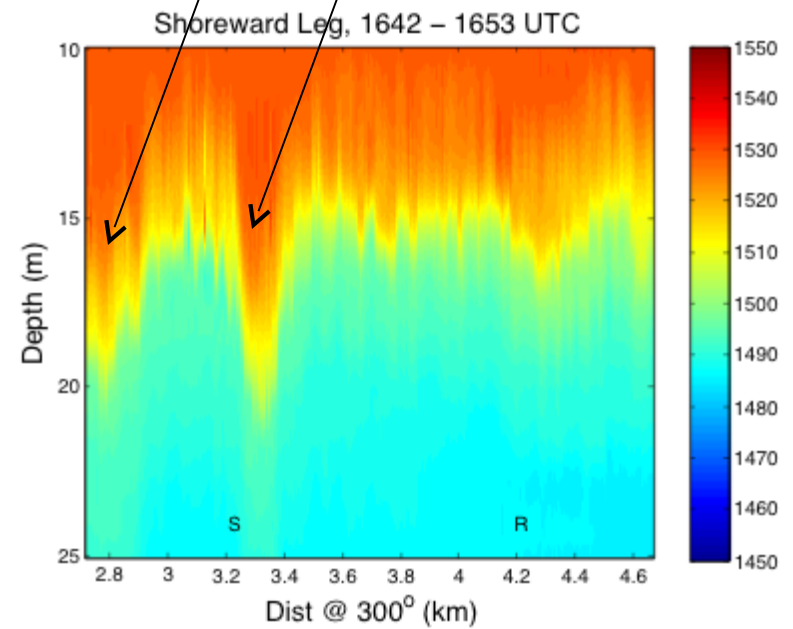Spacing on seaward leg   = 300 m + 52 m = 352 m

Difference   62 m
Distance between legs
            400 m

Angle between waves   9°
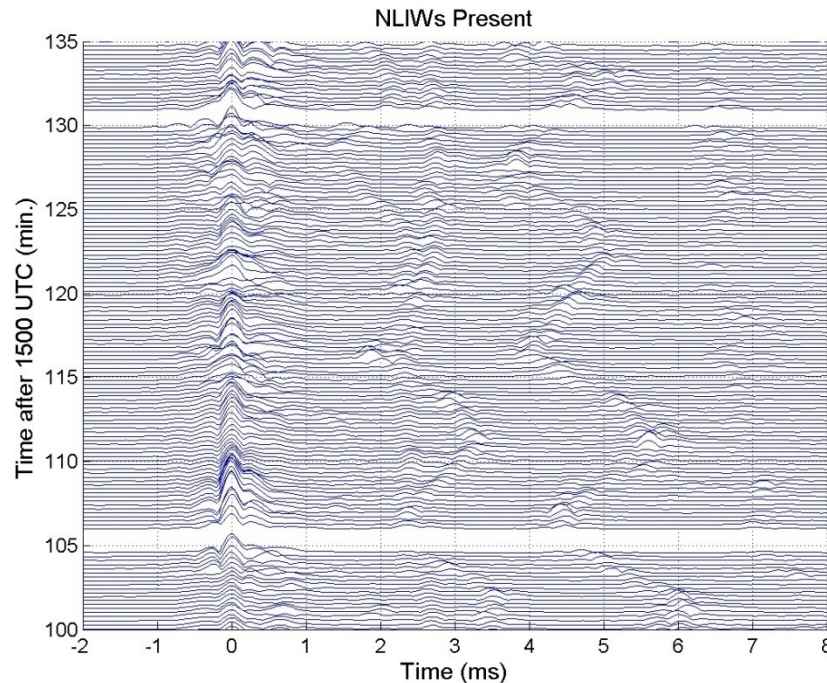
Estimate from radar image on Knorr   10°

By such interpolation, the waves on the acoustic path can be reconstructed.
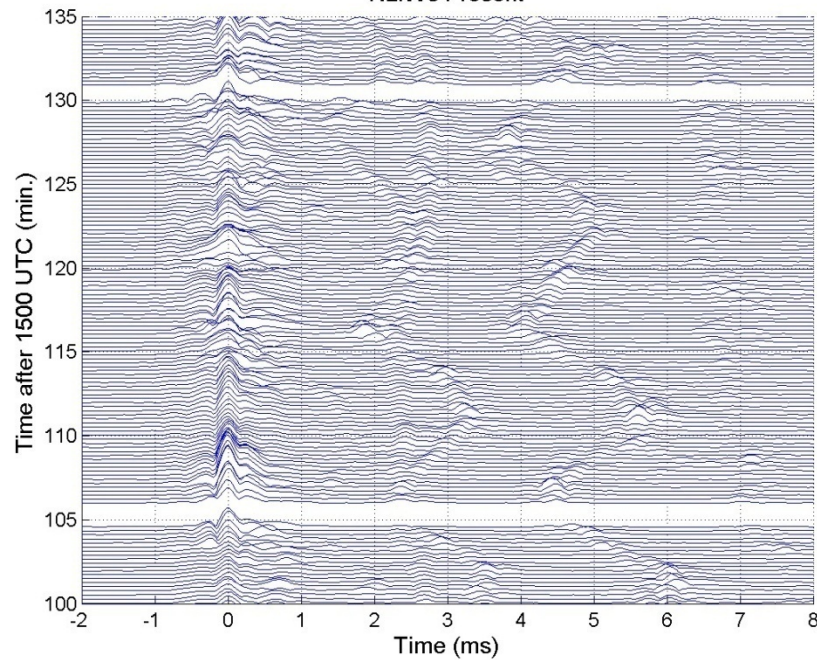
The resulting sound speed field can be used in an acoustic propagation code.

The predicted acoustics can be compared to the measured acoustics

Time relative to first arrival (source position uncertain & changing)
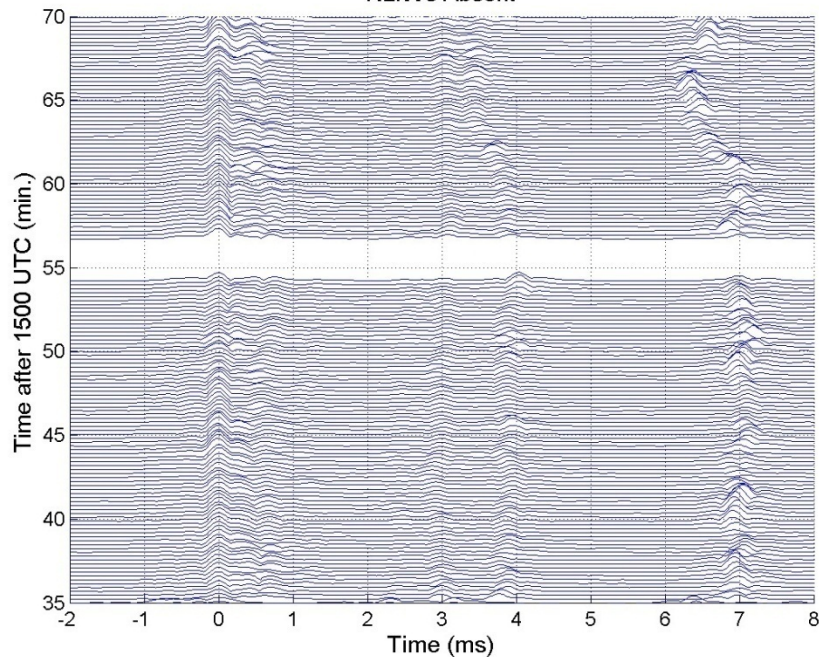
With NLIW's present:

Relative times change

between no-wave & wave

within wave event

First arrival scintillates much more

Relative intensity changes

Arrival time is very sensitive to SSP

Acoustic field with internal solitary wave

2 kHz, absorbing layer at 60 m, source at 30 m

QuickTimeª and a
decompressor
are needed to see this picture.

Summary

- Acoustics (at 1 km) depends strongly on water column properties

- Scattering by small internal waves studied stochastically

- When NLIW's are in the acoustics path, received signals are dramatically different from those when no NLIW is present

- Scattering of sound by NLIWs will be studied deterministically.