Sei whale localization and vocalization frequency sweep rate estimation during the New Jersey Shallow Water 2006 (SW06) experiment

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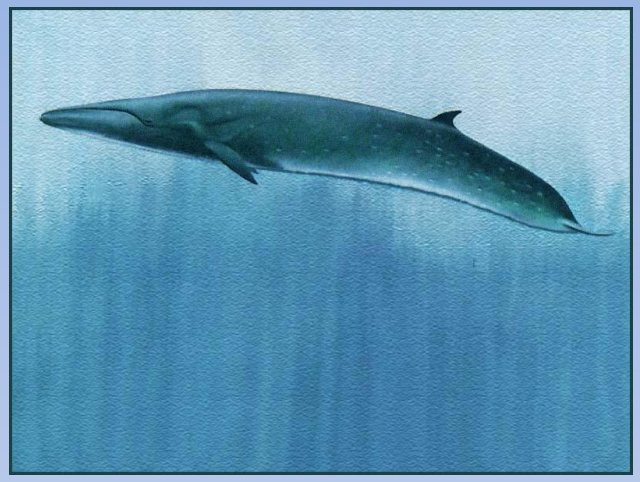
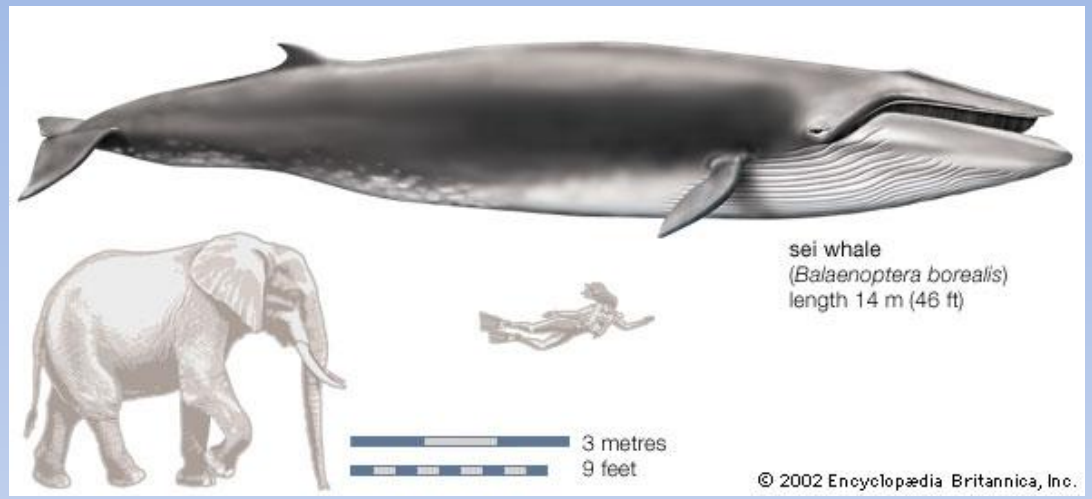
Outline



Sei Whale

Sei whales and the SW06 experiment
Sei whale vocalizations
Our approach and results
Conclusions

Sei Whales



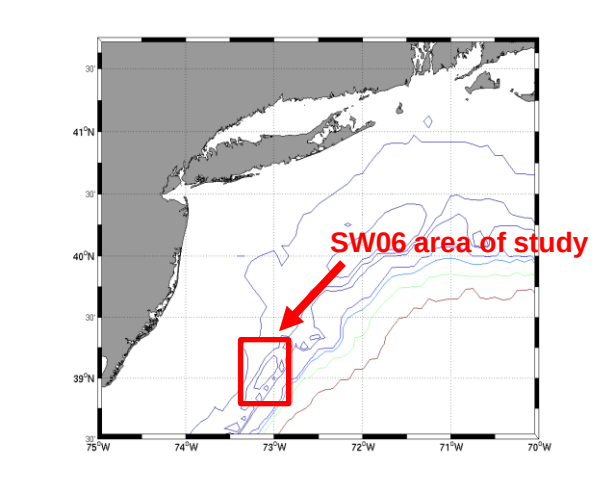
Relatively little is known about their vocalizations

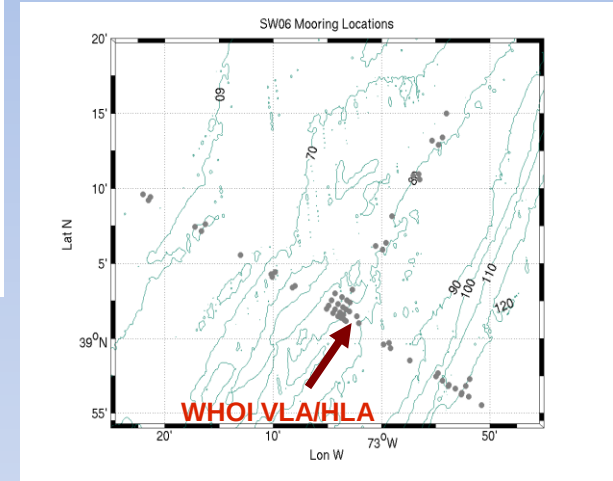
- Loud, long, low-frequency sounds
- Frequency modulates from ~120 to ~40Hz in our receptions
- Vocalizations often seen in pairs, sometimes triplets
- 150+ recorded vocalizations in our data during 2 days (Sep 12,13)
  Most activity seen during early evening

We will study these vocalizations more in depth

- track, locate (range and depth)
- recreate source signature (unknown)
- identify individuals

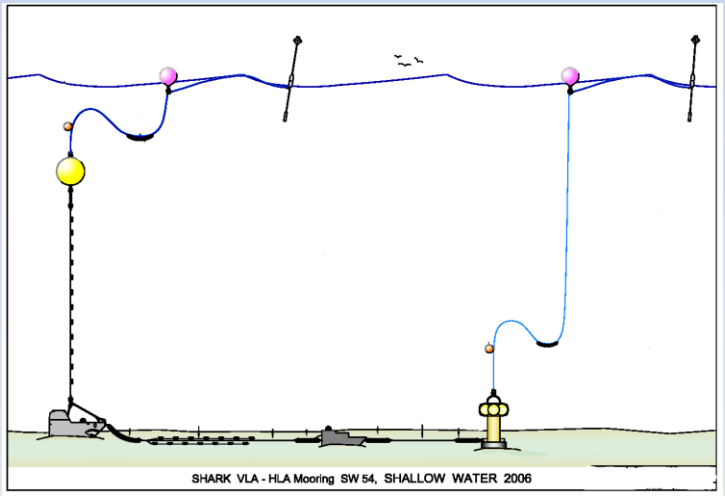
Shallow Water 2006 (SW06) Experiment



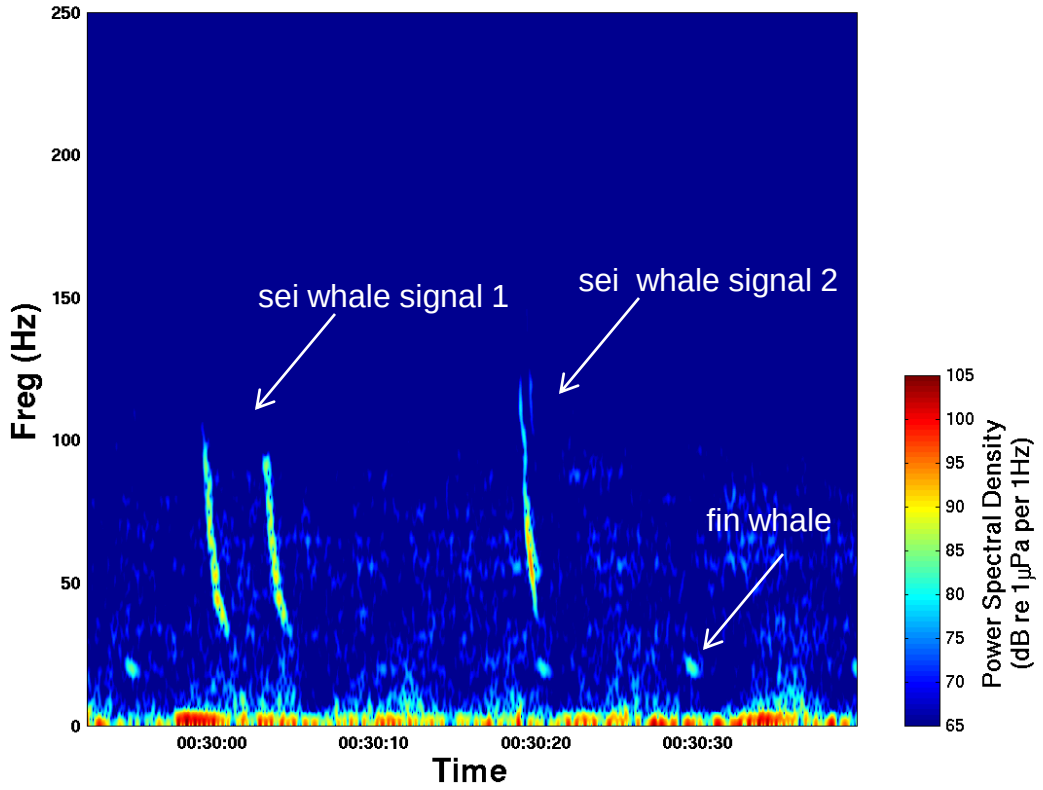


Mode propagation approach
- low frequency
- broadband
- shallow water
- Vertical hydrophone line array
- Horizontal line array

WHOI VLA/HLA was our primary receiver.
Deployed at 80 m water depth.
Sampled at ~10 kHz
Frequency band 10 Hz to 5000 Hz.
Directly N-S orientation



Sei whale vocalizations and fin whale vocalizations



125 recorded vocalizations during Sep 12 -> 13

Identified sei whale signals
50 Hz bandwidth
Harmonics evident in many signals
Same whale or 2 (or 3) individuals?

Original sound bandpass filtered

x2 and bandpass filtered

Normal mode back propagation approach

Beamform using horizontal line hydrophone array to find bearing

Mode filter the received signal

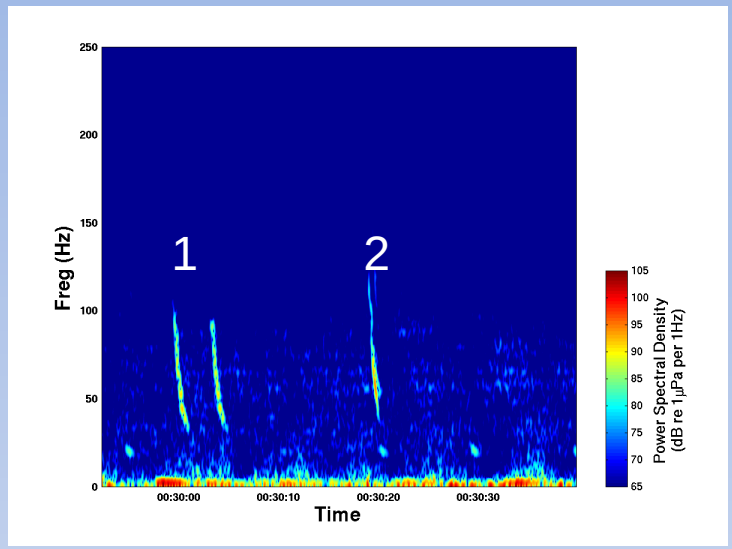
Back propagate to calculate range to source

Reconstruct original source signal at range and find depth of source

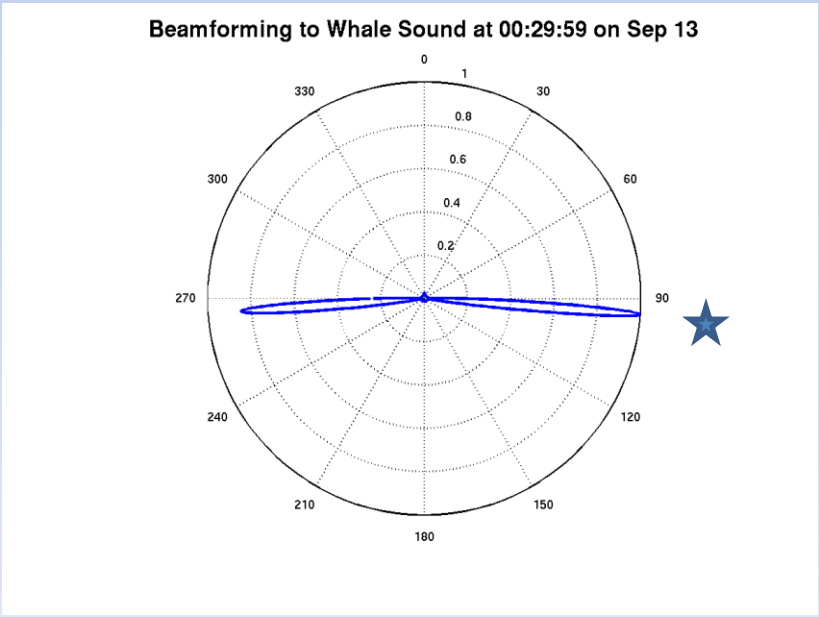
Calculating bearing using horizontal line array data

Beamformed on three sei whale signals
- Two are distinct individual whales
- The paired signal is from the same individual
- The later single signal is from another

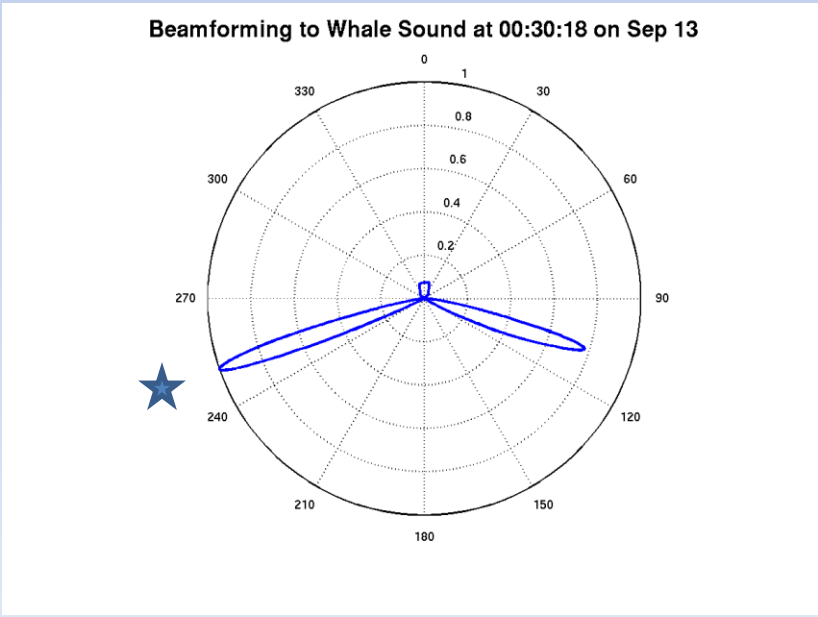
Since array was slightly curved, we also beamformed in sections to verify L/R ambiguity.



Sei whale signal 1



Sei whale signal 2



Normal mode back propagation approach

Beamform using horizontal line hydrophone array to find bearing

Mode filter the received signal

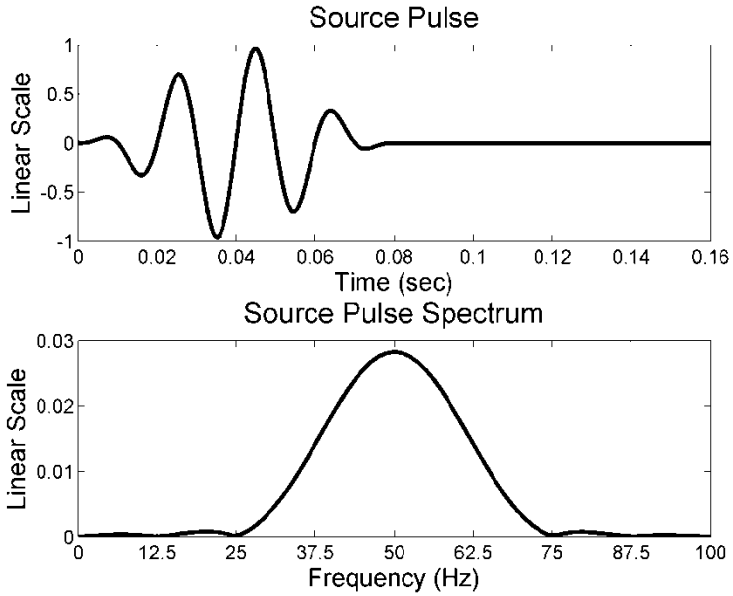
Back propagation to calculate range of source

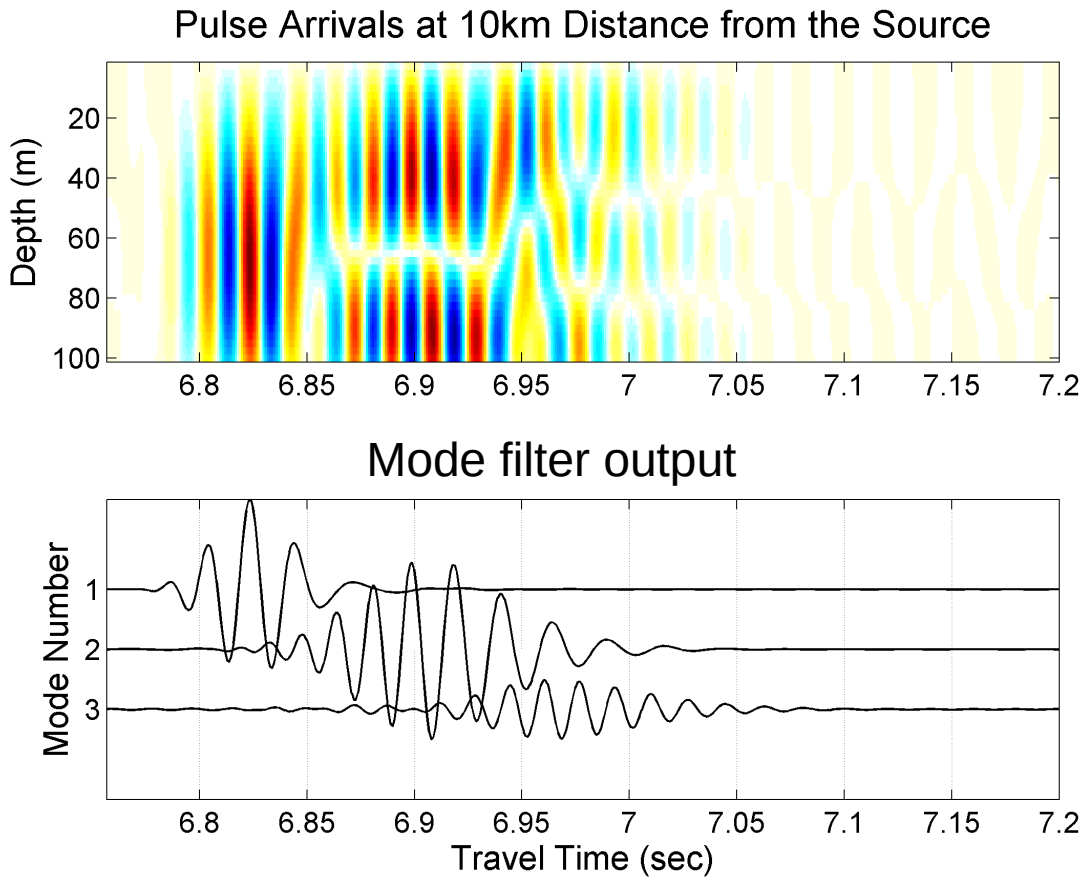
Reconstruct original source signal at range and find depth

Acoustic normal mode filtering

Mode filtering is performed using the vertical line array to resolve individual modal arrivals

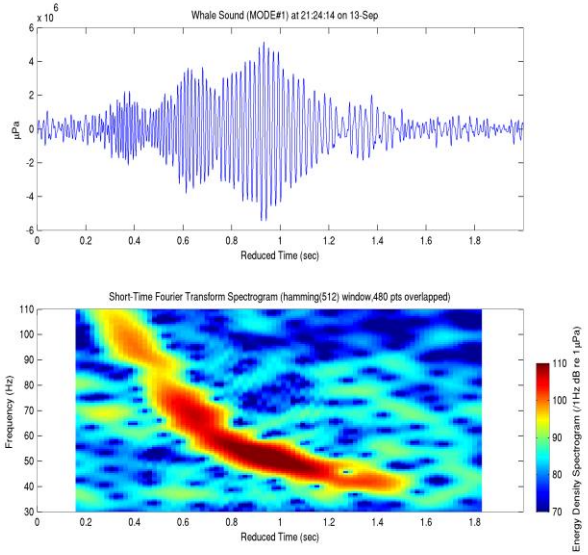
Simulation example of a sound pulse propagation in the mixed-layer waveguide model. (Source at 25m depth, fc = 50Hz, BW = 50Hz)



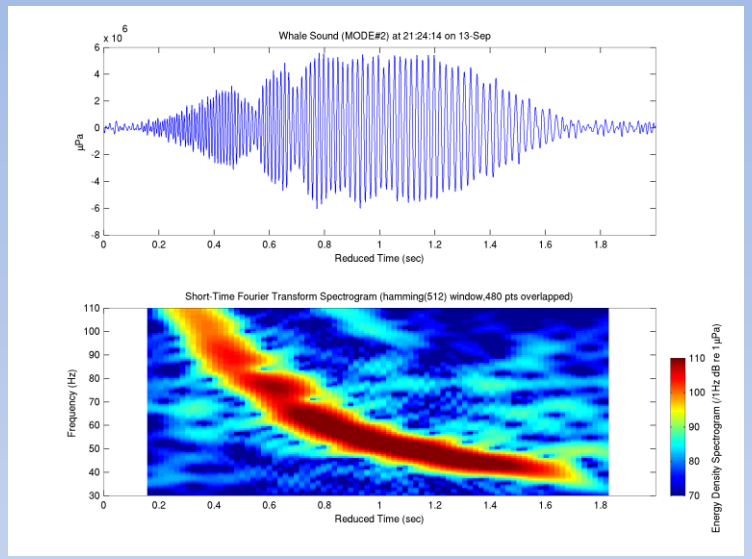


Mode filtering using vertical line array data

Mode 1

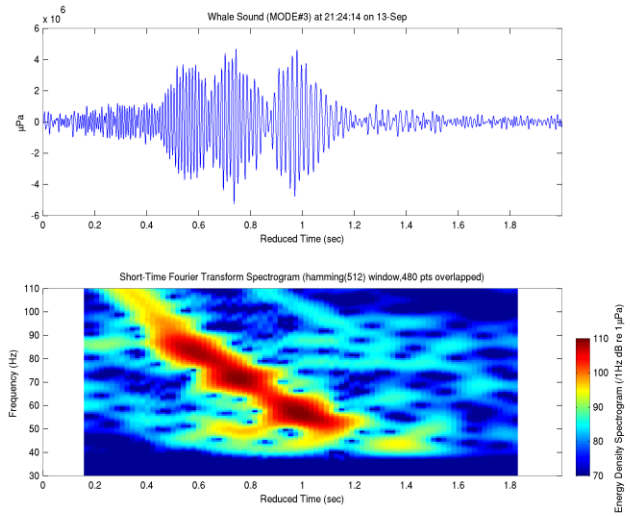


Mode 2

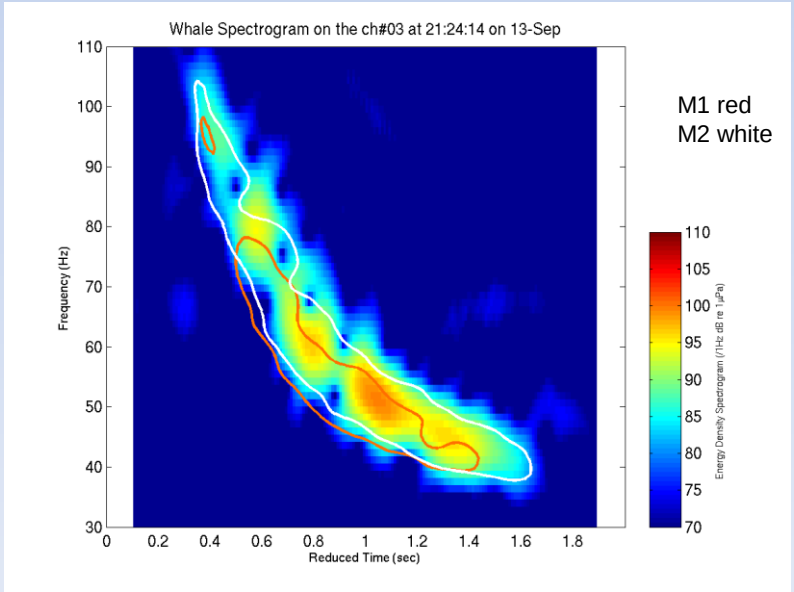


Sei whale signal with mode 1 and mode 2 overlayed on signal from **Channel 3** on Sept 13

Mode 3



Mode 3 is not seen on hydrophone #3 but appears on others. This is due to mode 3 having a null at this depth.



M1 red
M2 white

Normal mode back propagation approach

Beamform using horizontal line hydrophone array to find bearing

Mode filter the received signal

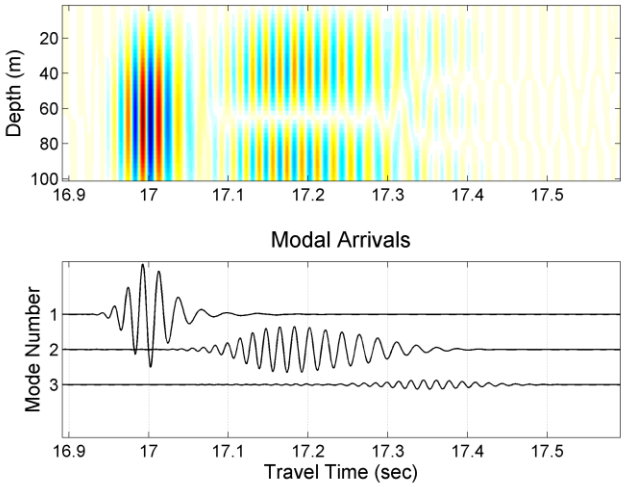
Back propagation to calculate range of source

Reconstruct original source signal at range and find depth

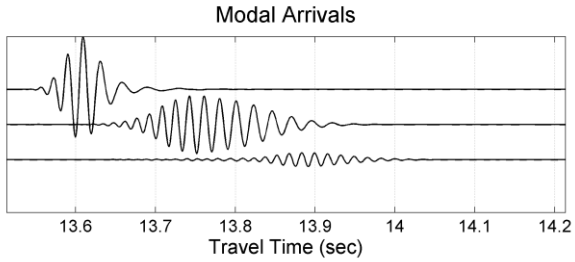
Low-frequency broadband source localization by back-propagating acoustic normal modes

- We use modal dispersion to localize a sound source.
- The first step is to implement a ***mode filter*** to obtain individual modal arrivals. Then, back propagate the modal arrivals with their own group speeds, which are derived from the ***waveguide parameters***. The ***source range estimate*** is where the back-propagated modes line up with each other.

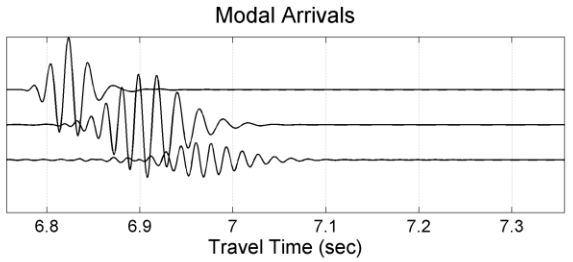
received signal
(simulation)



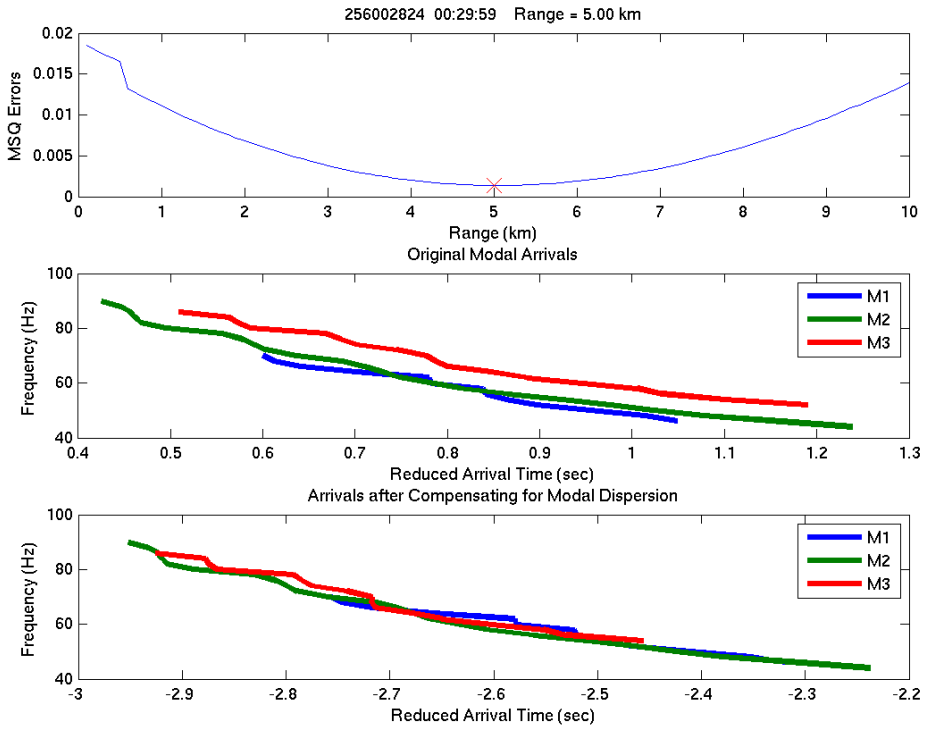
back propagate modes for 5 km



back propagate modes for 15 km



Range estimation for sei whale signal 1



Least square fit estimation

Frequency tracking of original modal arrivals

Frequency tracking of back propagated modes at estimated source localization.

Sei whale signal 2 range estimation was at 800 m

Normal mode back propagation approach

Beamform using horizontal line hydrophone array to find bearing

Mode filter the received signal

Back propagation to calculate range of source

Reconstruct original source signal at range and find depth

Depth estimation and reconstruction of source signal

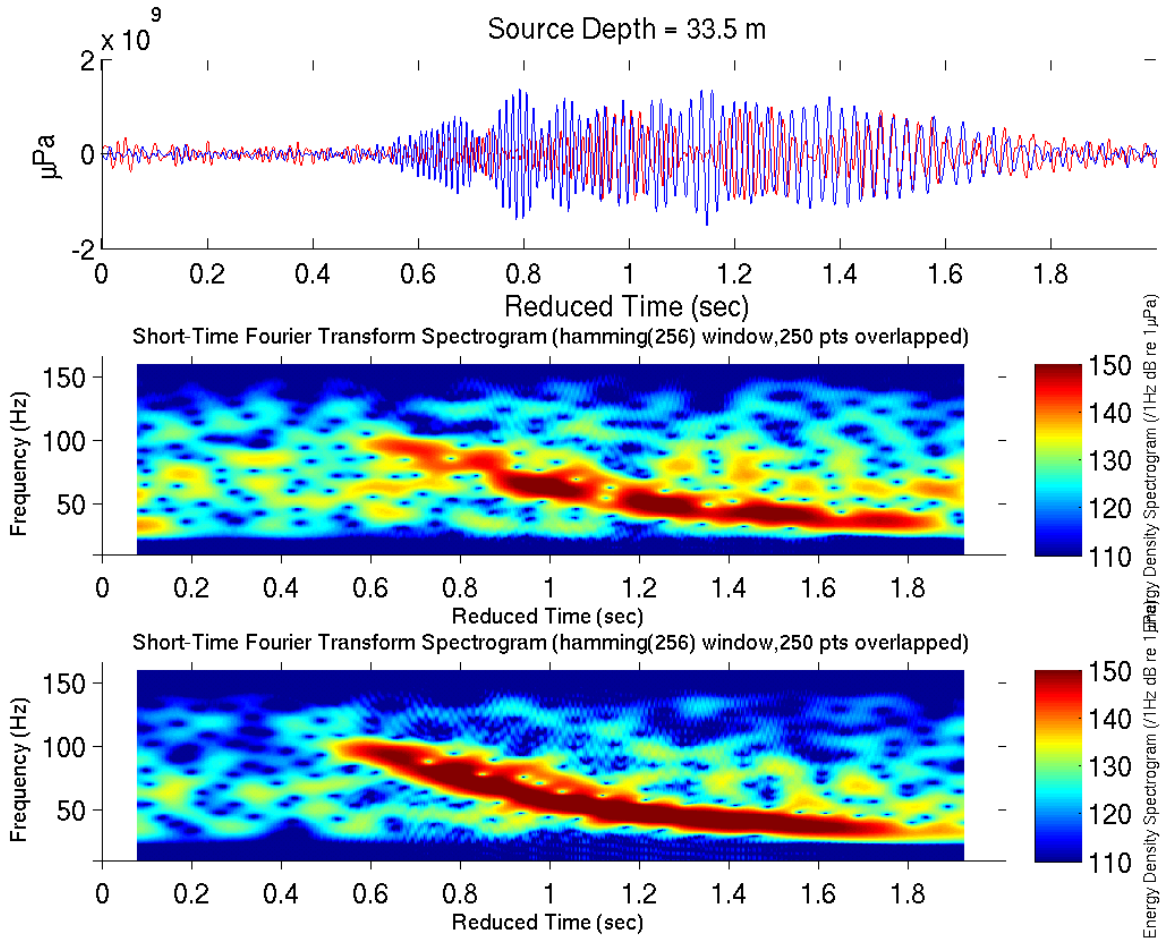
We know direction and range

Now reconstruct source signal of each mode for all possible depths.

Depth estimate is chosen by finding the best (least squares) fit between the reconstructed modal source signals.

Signal peaks and nulls are lined up.

Final reconstruction of the source signal at range and depth for signal 1



mode 1 red
mode 2 blue

mode 1 reconstruction

mode 2 reconstruction

Summary of study

	Sei whale signal 1 (pair)	Sei whale signal 2
Bearing	93° East	109° West
Range	5000 m	800 m
Depth	33.5 m or 73 m*	34 m or 66.5 m *
Frequency range of signal	100-30 Hz	120-35 Hz
Original sweep rate from 100-40 Hz	1.7 sec	1.07 sec
Reconstructed sweep rate from 100-40 Hz	1.35 sec	.87 sec

* Note: 2 possible depths here since they both are close to our depth-selection criteria.

Conclusions from this study

Seiwhale vocalization reconstruction performed

* Source signal rate
  Sweep rate is non-linear
  ~1 second, singles and pairs
  The 2 whales had different freq ranges

  Signal duration shortened from received signal
  due to acoustic normal mode dispersion

* Good estimation of directionality

* Range and depth estimates might have some uncertainty
  Need better environment (water column and bottom) information

* Depth of all vocalizations are subsurface (below thermocline)

* Using localization and frequency content, we can identify if signals are from same individual.

* More to be done!
  We hope to be able to identify each individual in our data from its source signature.
  Count individuals, count numbers in groups, migratory speeds and direction…,
  We want to compare our results with other sei whale studies (ie pacific)
  .