Geoacoustic Inversion in Shallow Water Using Sonobuoys

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IEEE J. Oceanic Engineering (in press)

Modal Mapping Experiment and Geoacoustic Inversion Using Sonobuoys

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***Abstract*—This paper summarizes the results of an experiment whose primary goal was to demonstrate that reliable geoacoustic inversion results can be obtained in shallow water by post-processing acoustic data acquired by GPS-capable sonobuoys. The experiment was conducted aboard the R/V *Sharp* on 5–18 March 2011 off the coast of New Jersey using AN/SSQ-53F sonobuoys with a Global Positioning System (GPS) capability as well as GPS-equipped research buoys originally developed under the Modal Mapping Experiment (MOMAX) project, which provided reliable geoacoustic information to which the sonobuoy results could be compared. It is shown that when low-frequency (<500 Hz) CW signals are acquired on the two types of buoys in a co-located configuration, the geoacoustic models inferred from the sonobuoy data are very similar to those obtained from the MOMAX buoy data. The inversion results also compare favorably with bottom models for the region obtained from other experiments. This work is an important milestone toward achieving the ultimate goal of transitioning a basic research method to an operational scenario in which sonobuoy data are routinely used to infer geoacoustic parameters of the seabed.**

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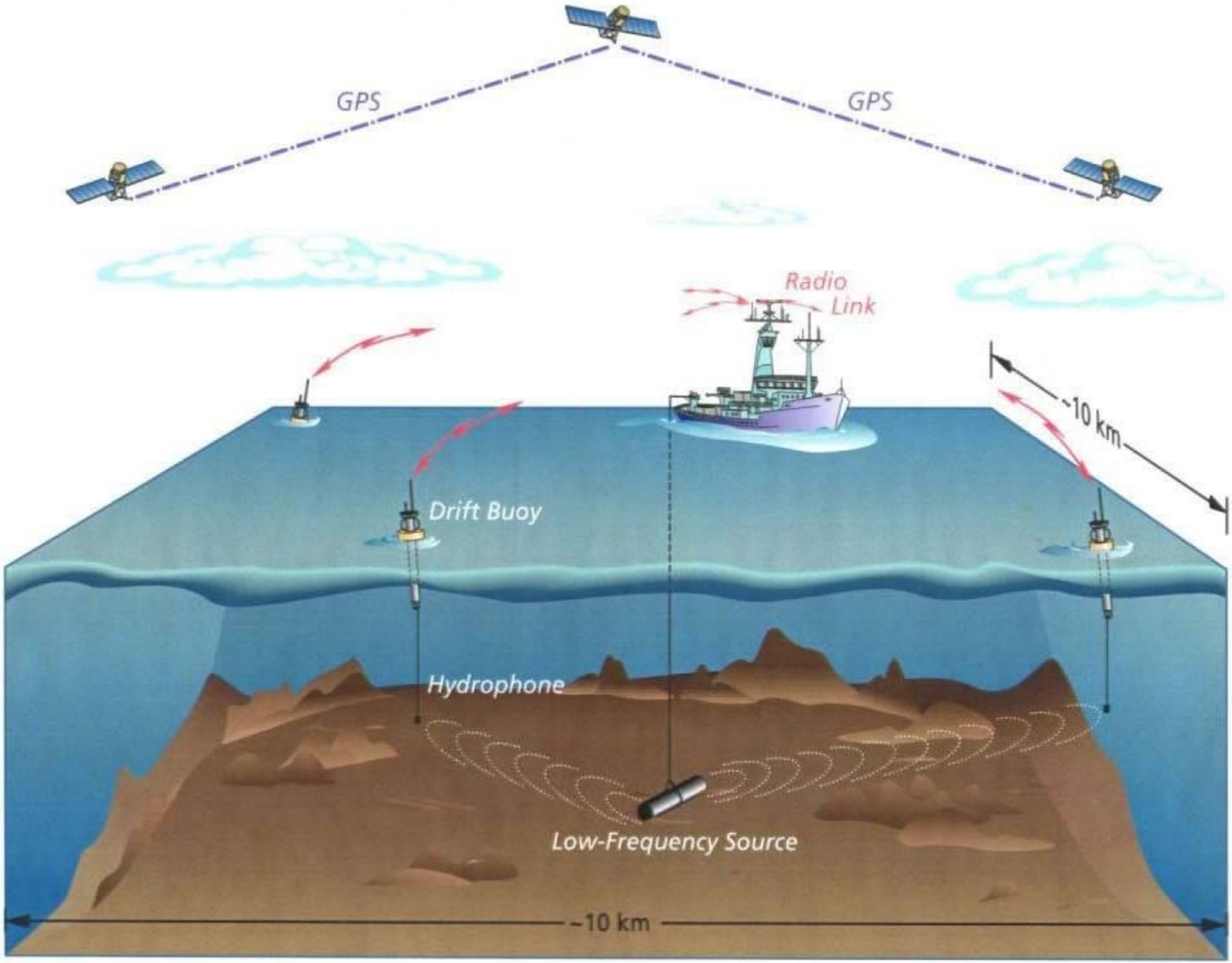
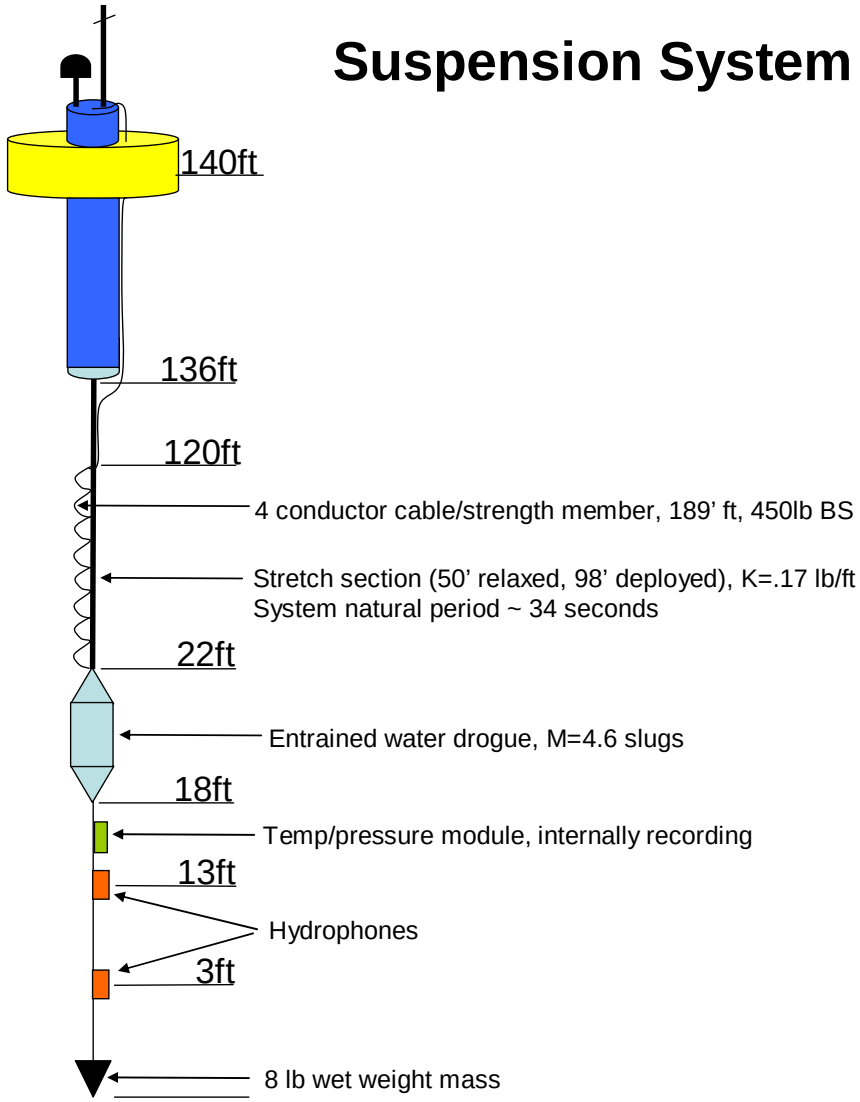

GPS
GPS
Radio
Link
~10 km
Drift Buoy
Hydrophone
Low-Frequency Source
~10 km

MOMAX 4 Drifter Suspension System



vdH, 2006

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MOMAX and AEER Technical Issues

Technical Issues

- *Frequencies and waveforms of interest*
- *Use of GPS and non-GPS capable sonobuoys*
- *Fidelity of sonobuoy signals required for coherent processing*
- *Volume of data required for effective inversions*
- *Spatial scale of geographic areas to be surveyed*

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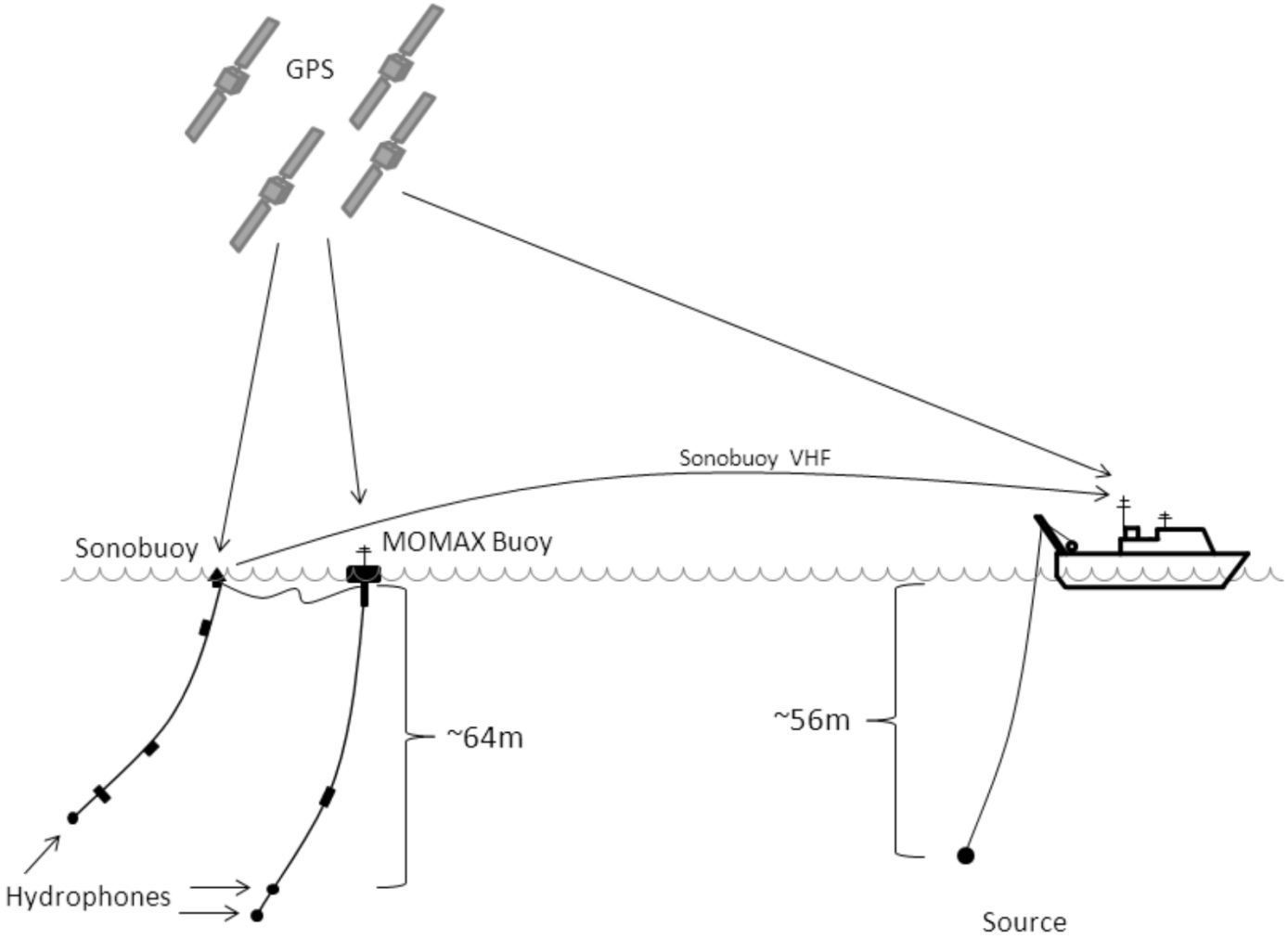
Co-located MOMAX Buoy/Sonobuoy Deployment Schematic



RTP Sea Test - MOMAX V - 5-18 March 2011

R/V Sharp (U. of Delaware) – Woods Hole, MA to Lewes, DE

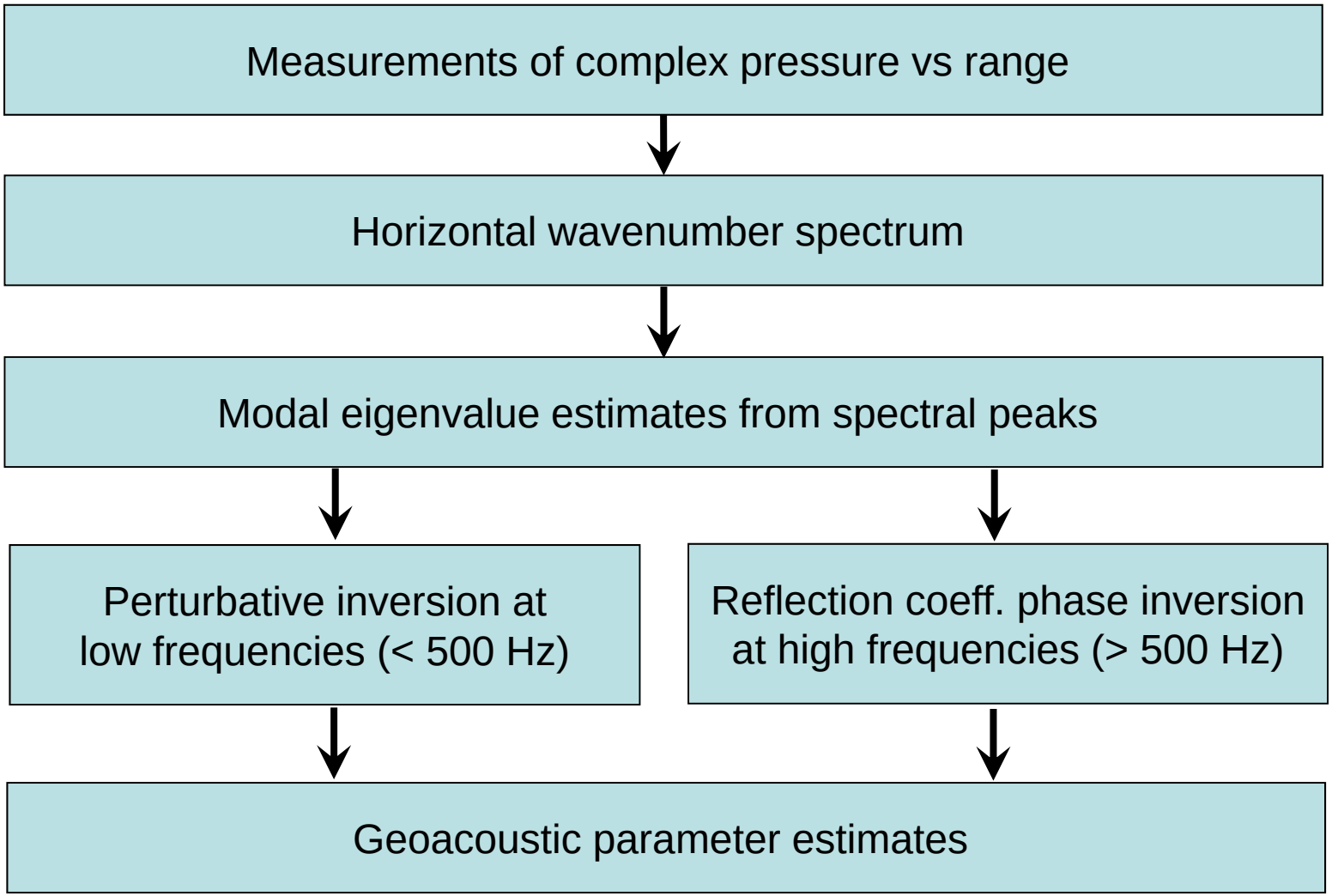
Narrowband and broadband transmissions: 50-1000 Hz

- *Drifting and towed NUWC J15-3 source at 53 m depth*
- *Drifting and towed NUWC G34 source at 8 m depth*
- *Data received on 4 drifting MOMAX buoys, each having hydrophones at 61 m and 64 m depths*
- *Data received on several GPS-capable 53F sonobuoys with hydrophone at 61 m depth, in some cases co-located with MOMAX buoys (~ 5 m lateral separation)*

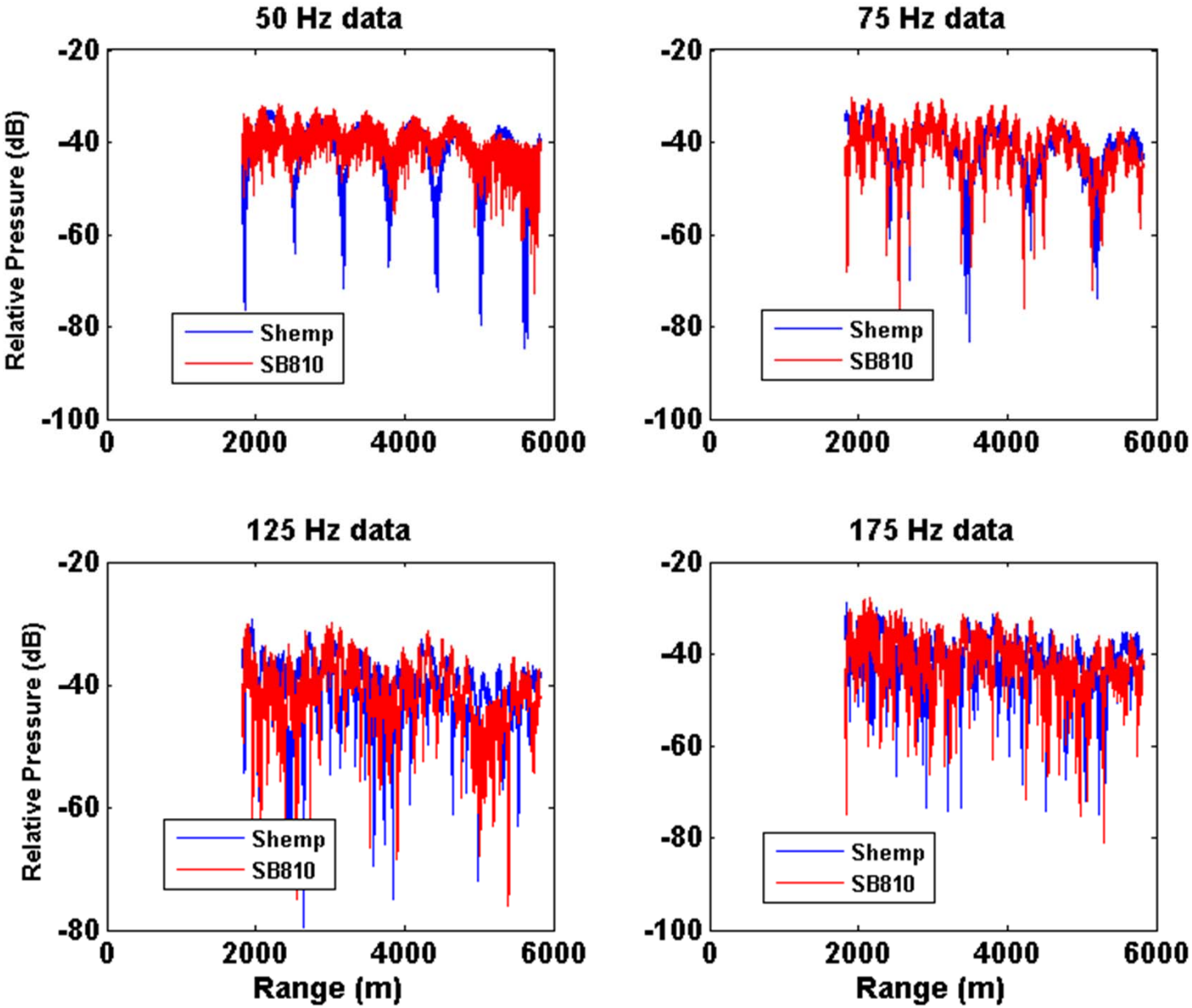
CTD and XBT measurements indicate benign water column in SW06 experimental area

- *Water depth ~ 70 – 80 m*

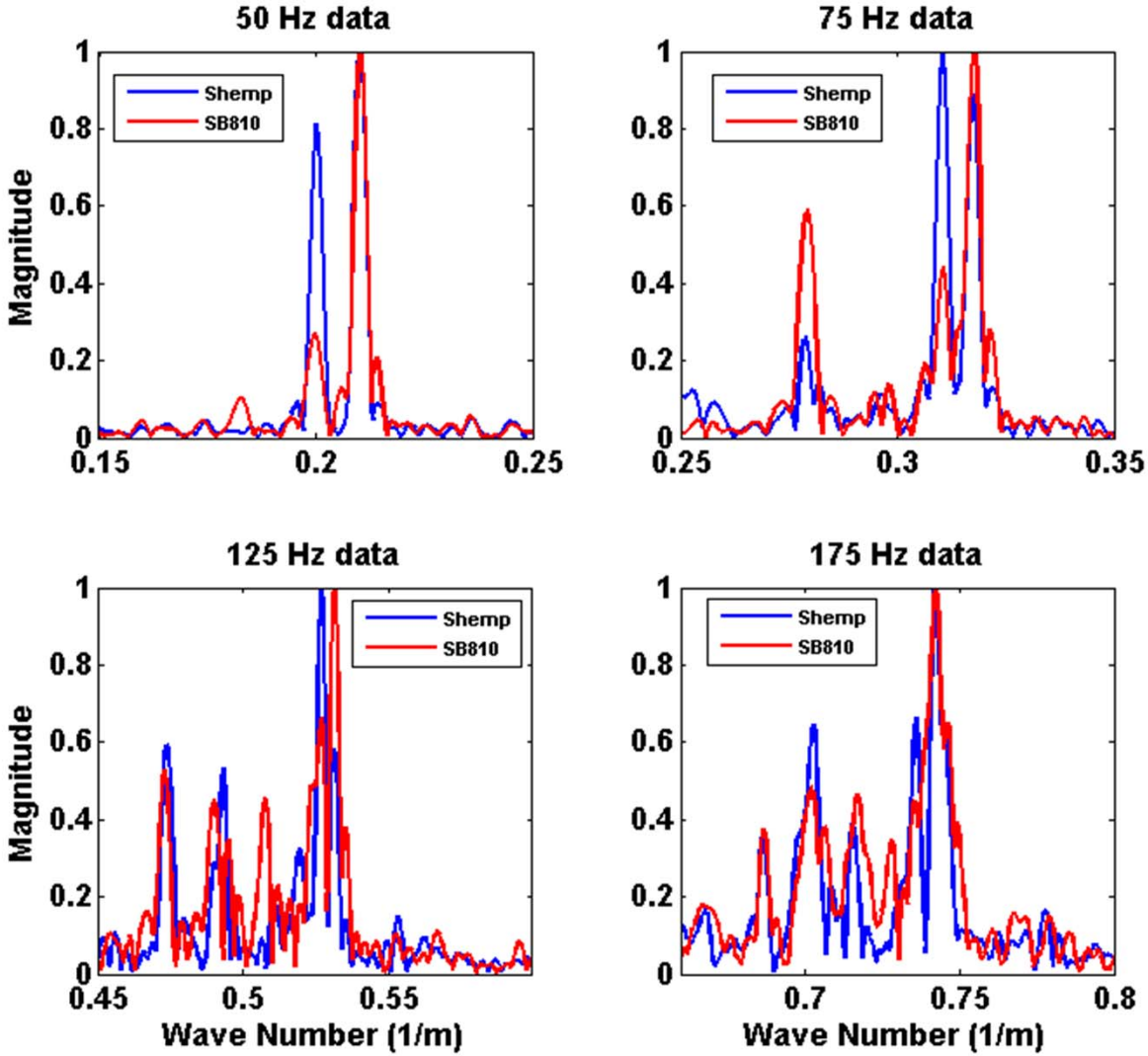
Inversion flow chart



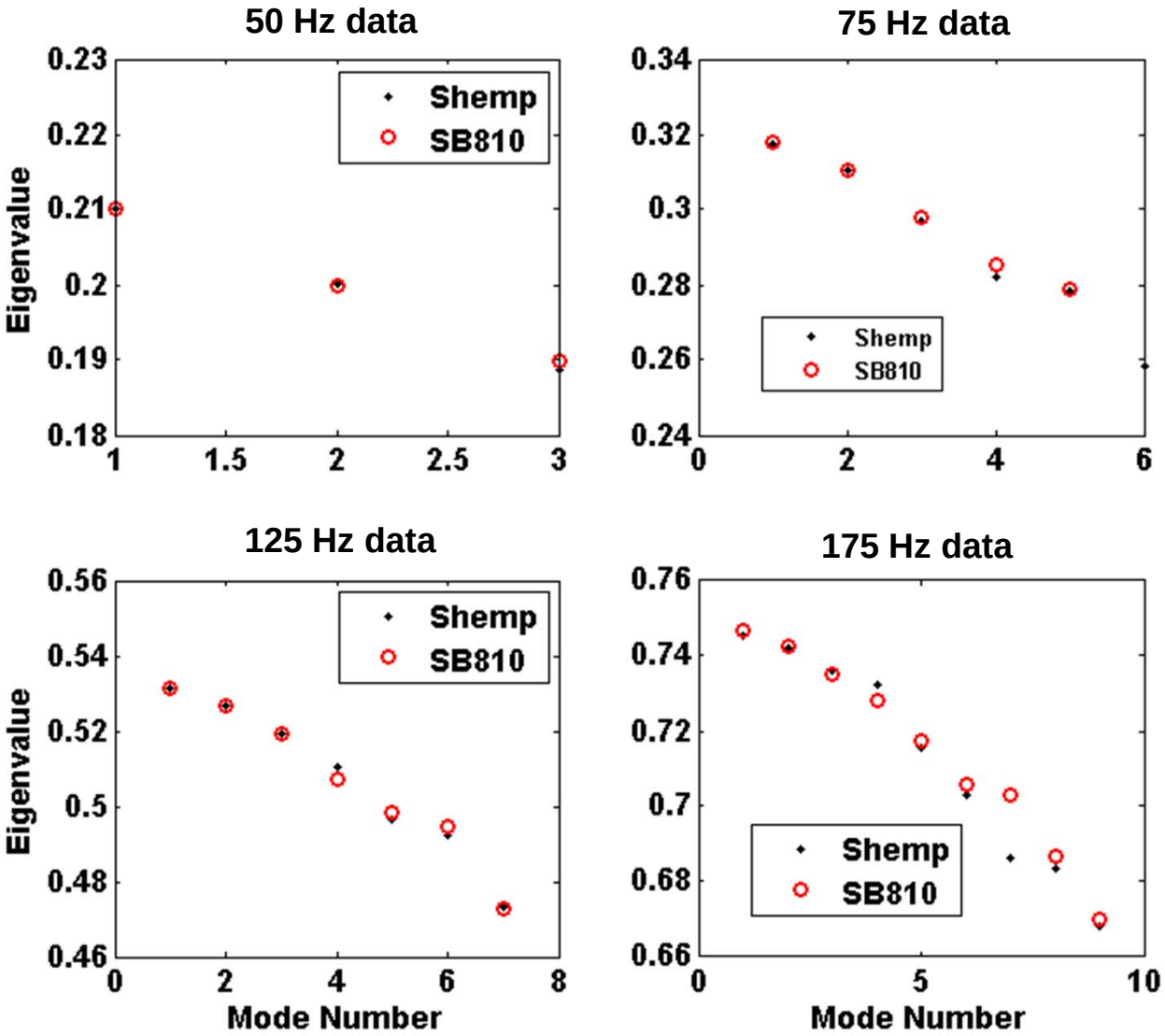
Pressure field: Shemp and SB810



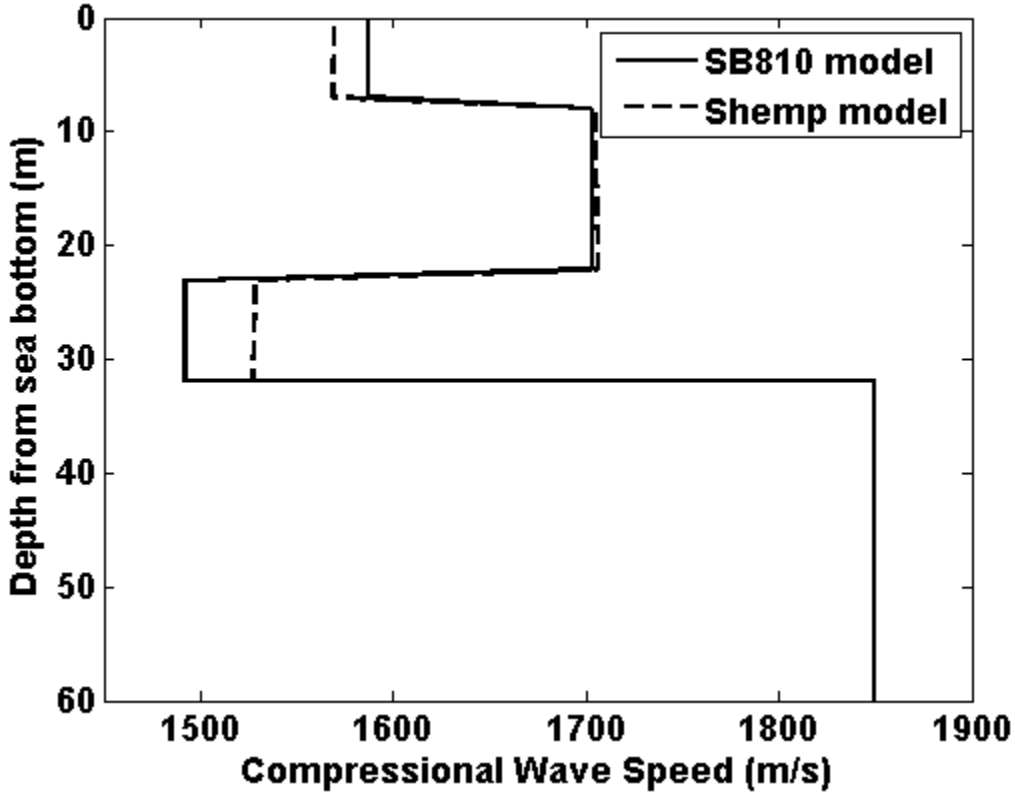
Green's function: Shemp and SB810



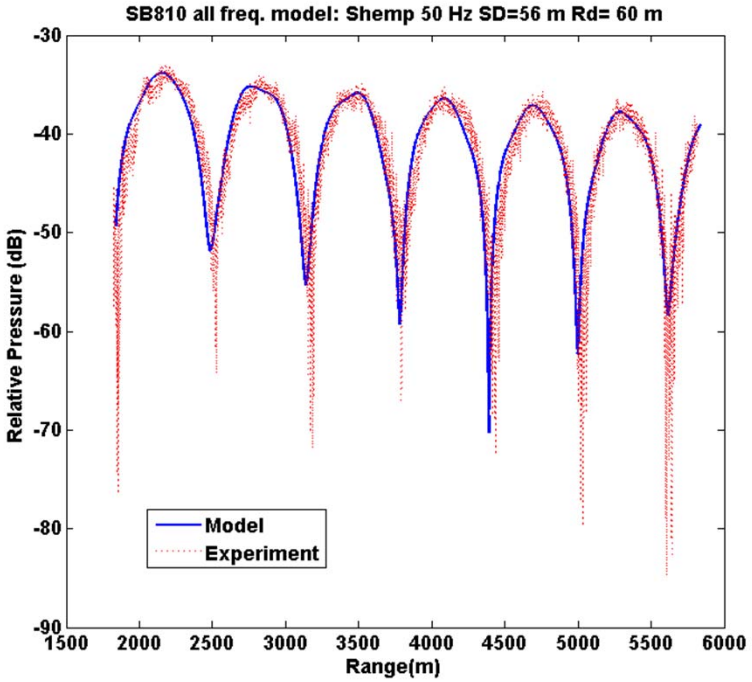
Eigenvalues: Shemp and SB810

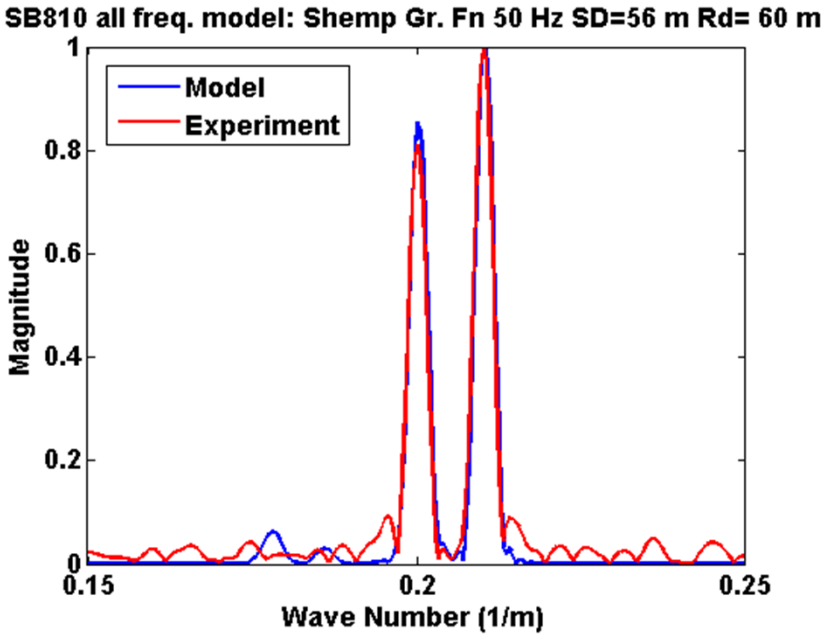


Bottom Models Shemp and SB810



SB810 Model: Shemp 50 Hz





MOMAX V Lessons Learned & Recommendations

Perform experiment in late winter/early spring to ensure a homogeneous water column

– *This strategy avoids the negative effects of water column variability on the solution of the geoacoustic inverse problem*

Conduct experiment in a well-studied area that facilitates comparisons with previous measurements

– *The New Jersey Shelf remains an attractive area, but there may be other areas with a greater variety of sediment type (e.g., both hard and soft) that should be considered*

Incorporate the use of COTS sensors used by the operational Navy (e.g., sonobuoys)

– *This approach offers the opportunity for the development of geoacoustic survey methods that can be applied to large geographical areas in an operational Navy context*

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Future Work:

Conduct MOMAX experiment with large number of sonobuoys (e.g., 15-20)

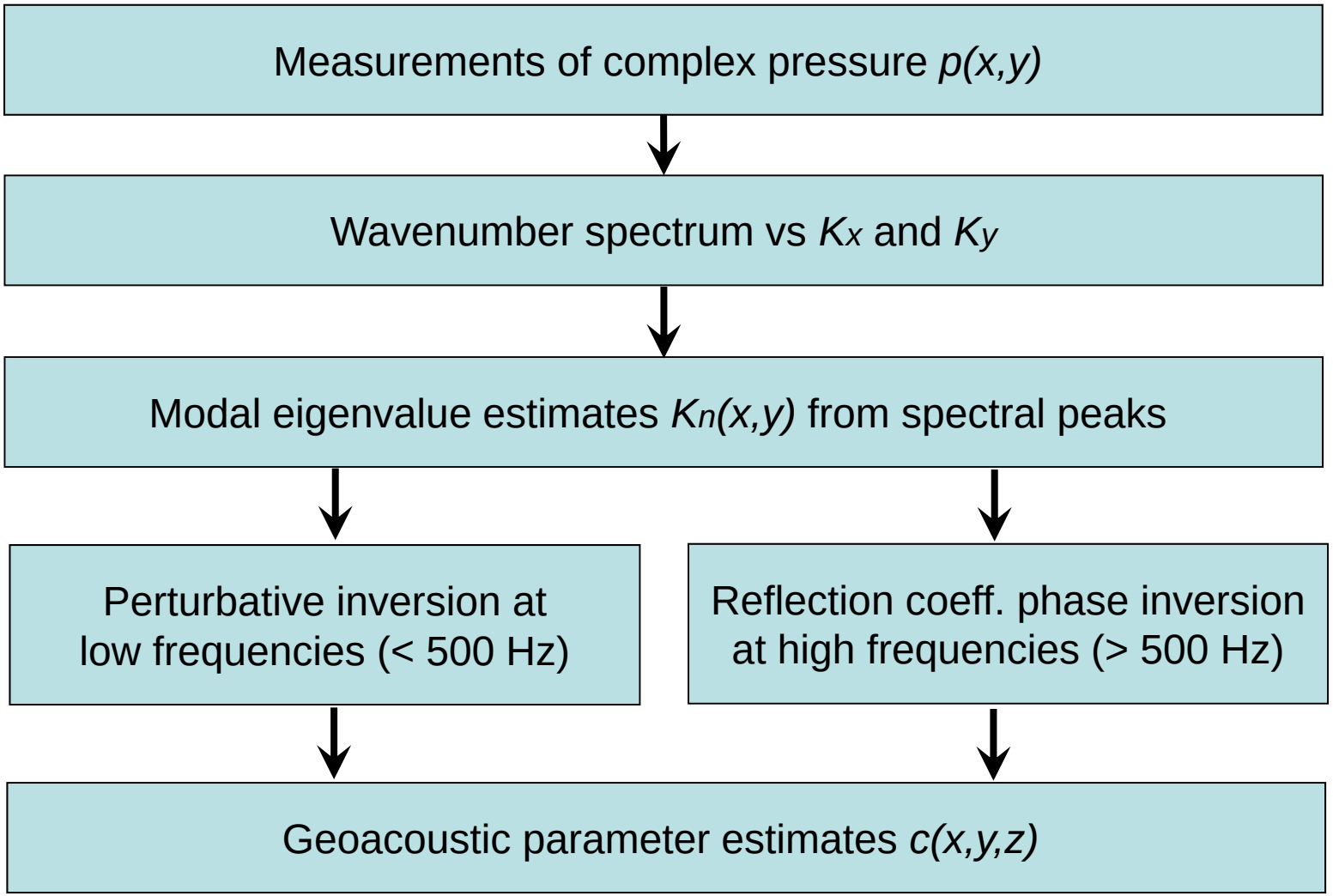
– *This approach will provide a 3D characterization of the normal mode field as well as an opportunity to invert for the 3D geoacoustic parameters*

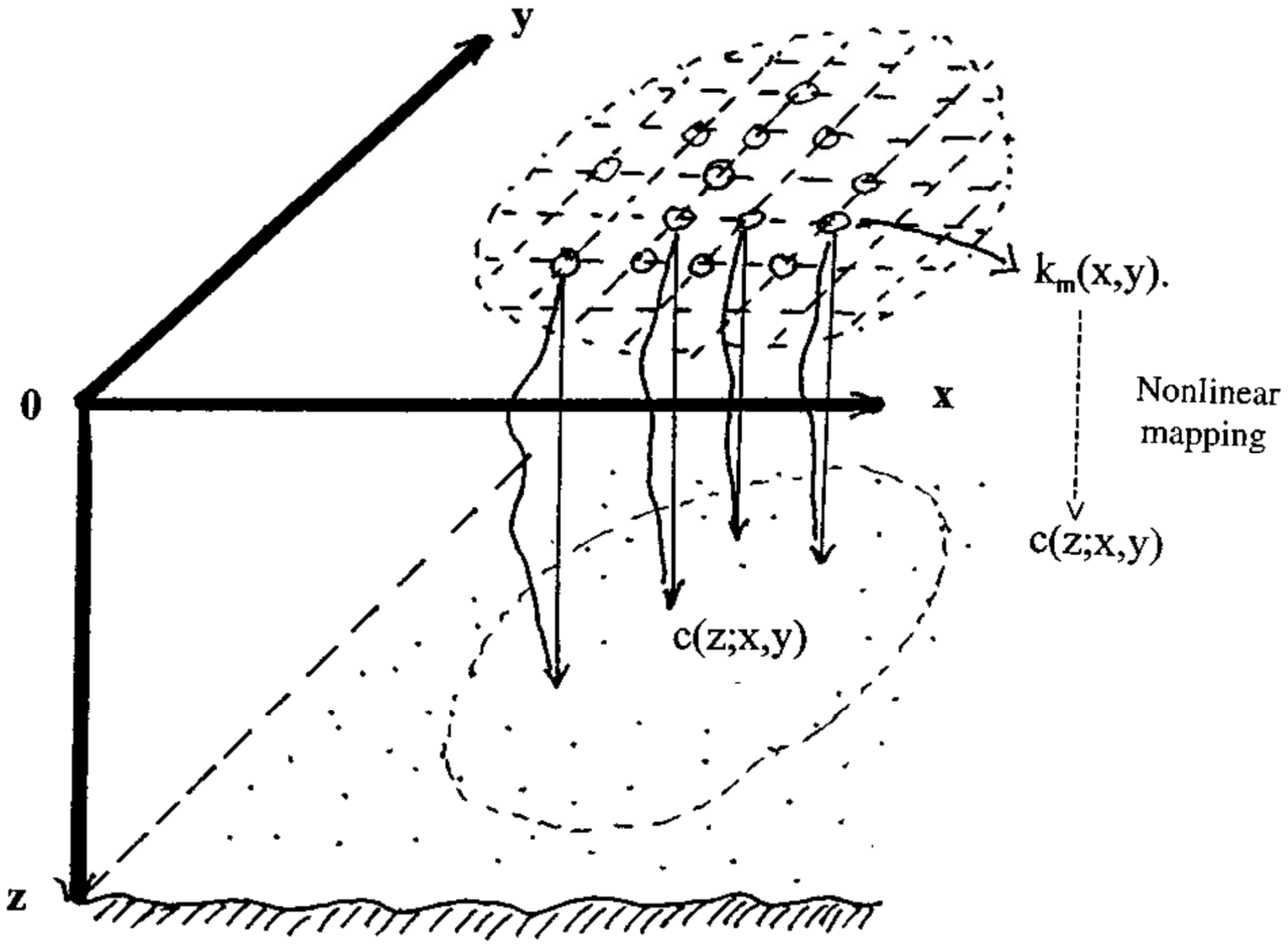
Conduct joint sea test with NAVAIR

Acknowledgments:

– *Subramaniam D. Rajan, Scientific Solutions, Inc.*

Inversion flow chart





E.C. Shang, Y.Y. Wang, and A.G. Voronovich, J. Acoust. Soc. Am. **102**, 3425-3432 (1997)

6.2/6.4 Rapid Transition Project Reviews
07 August 2012

Geoacoustic Inversion in Shallow Water Using Through-the-Sensor AEER* Signals

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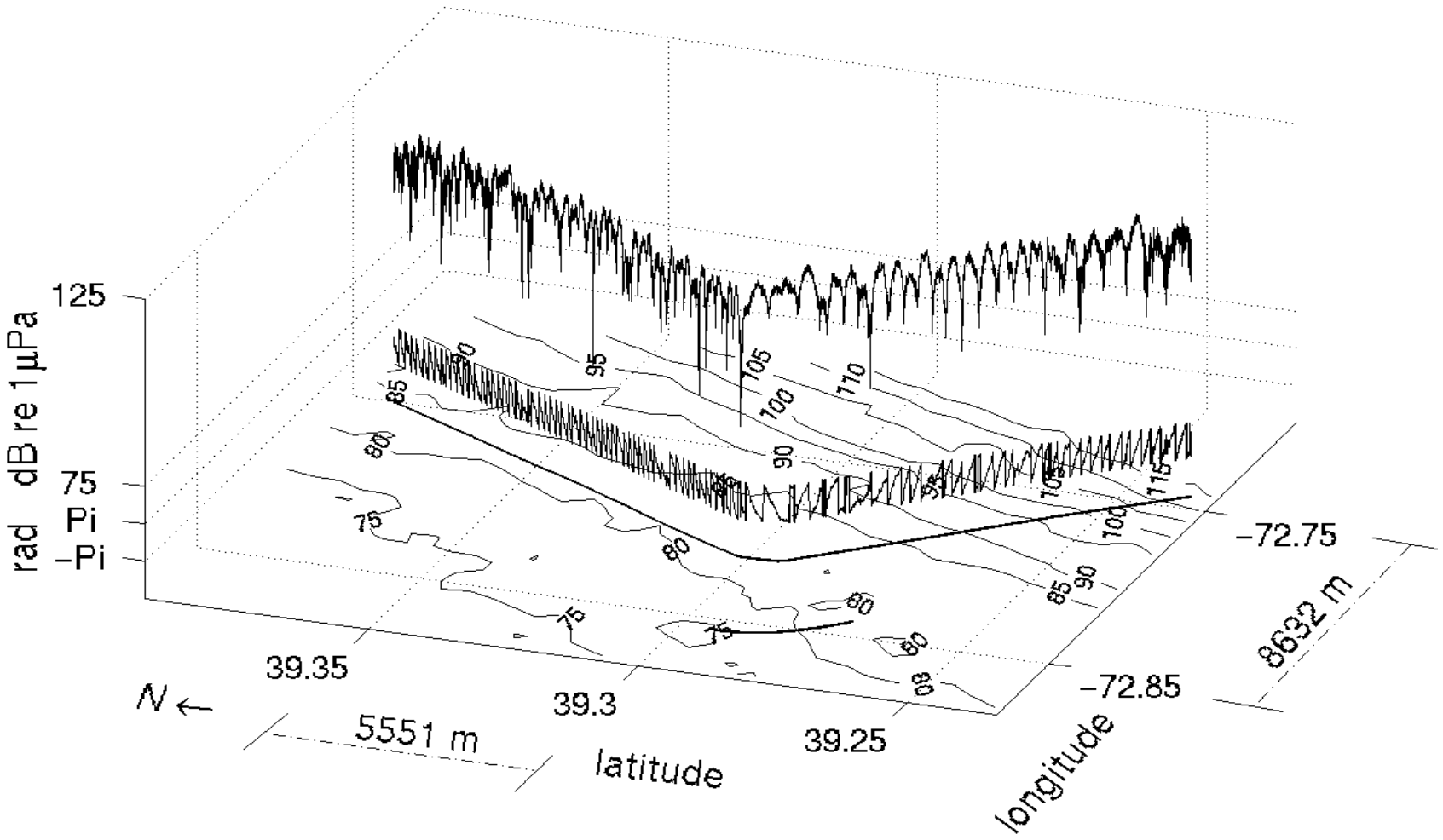
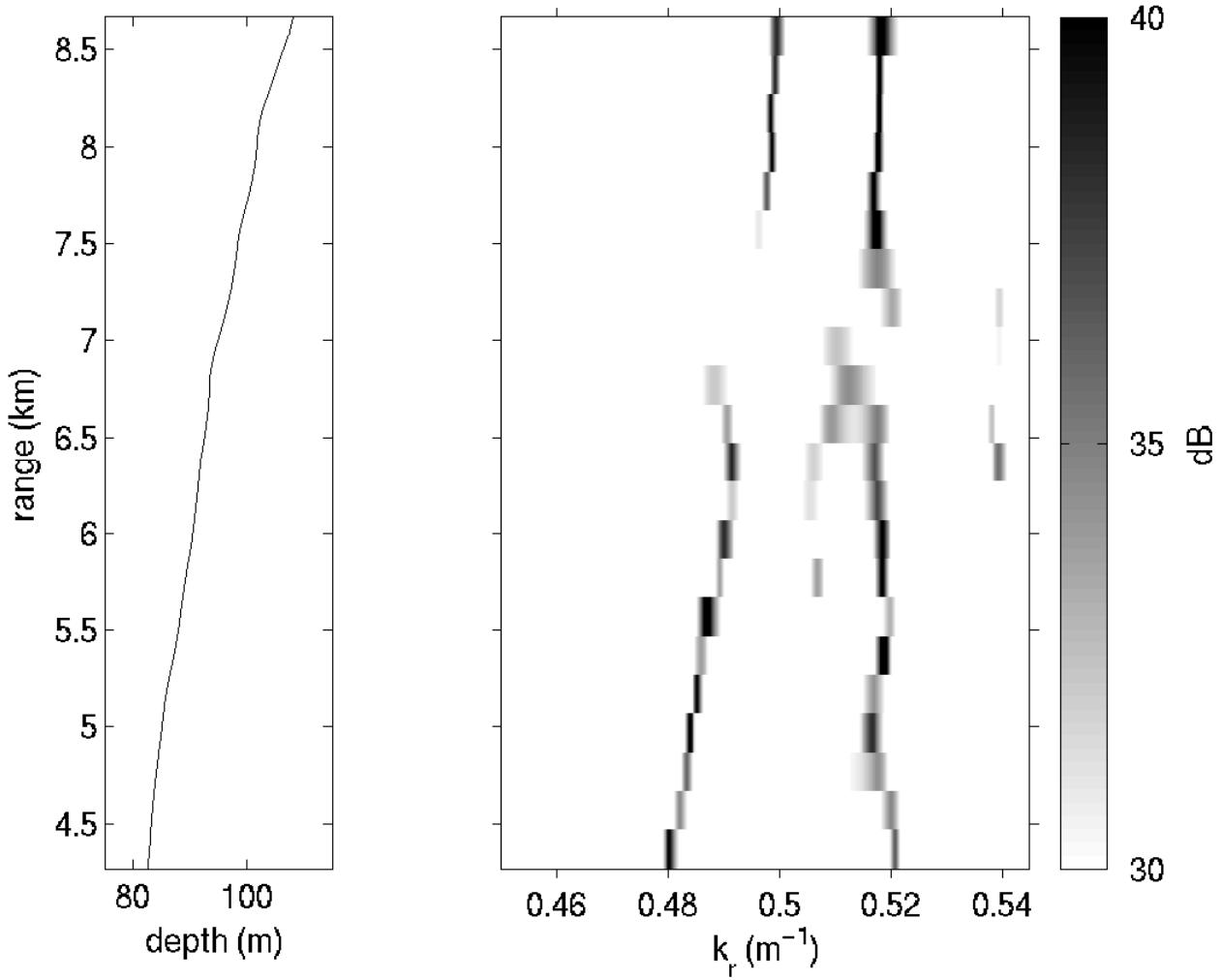
Cynthia J. Sellers & Keith von der Heydt (WHOI)

*Advanced Extended Echo Ranging
**currently at ONR

125 Hz Pressure Magnitude and Phase



Horizontal Wavenumber Spectrogram: Cross-Shelf Track



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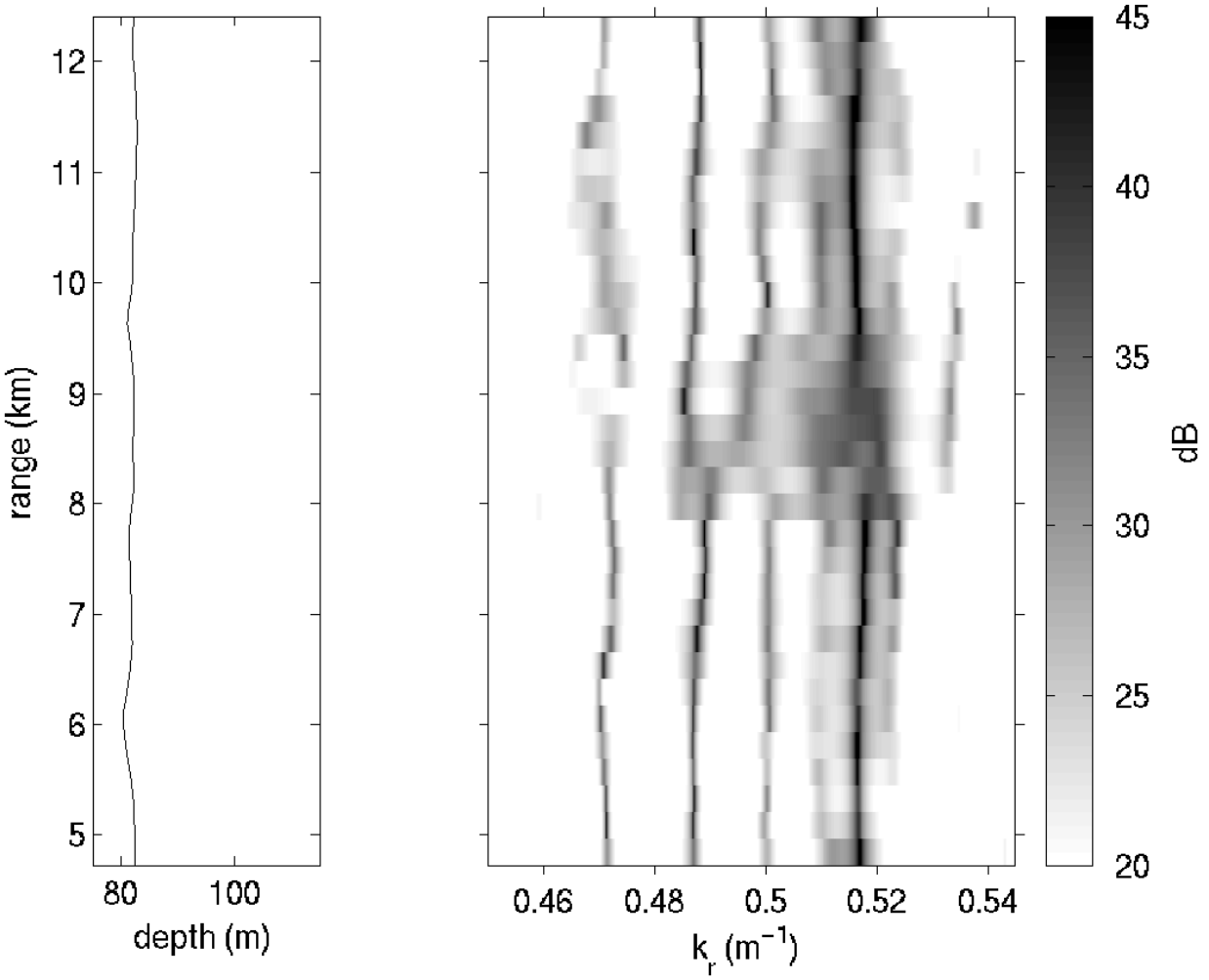
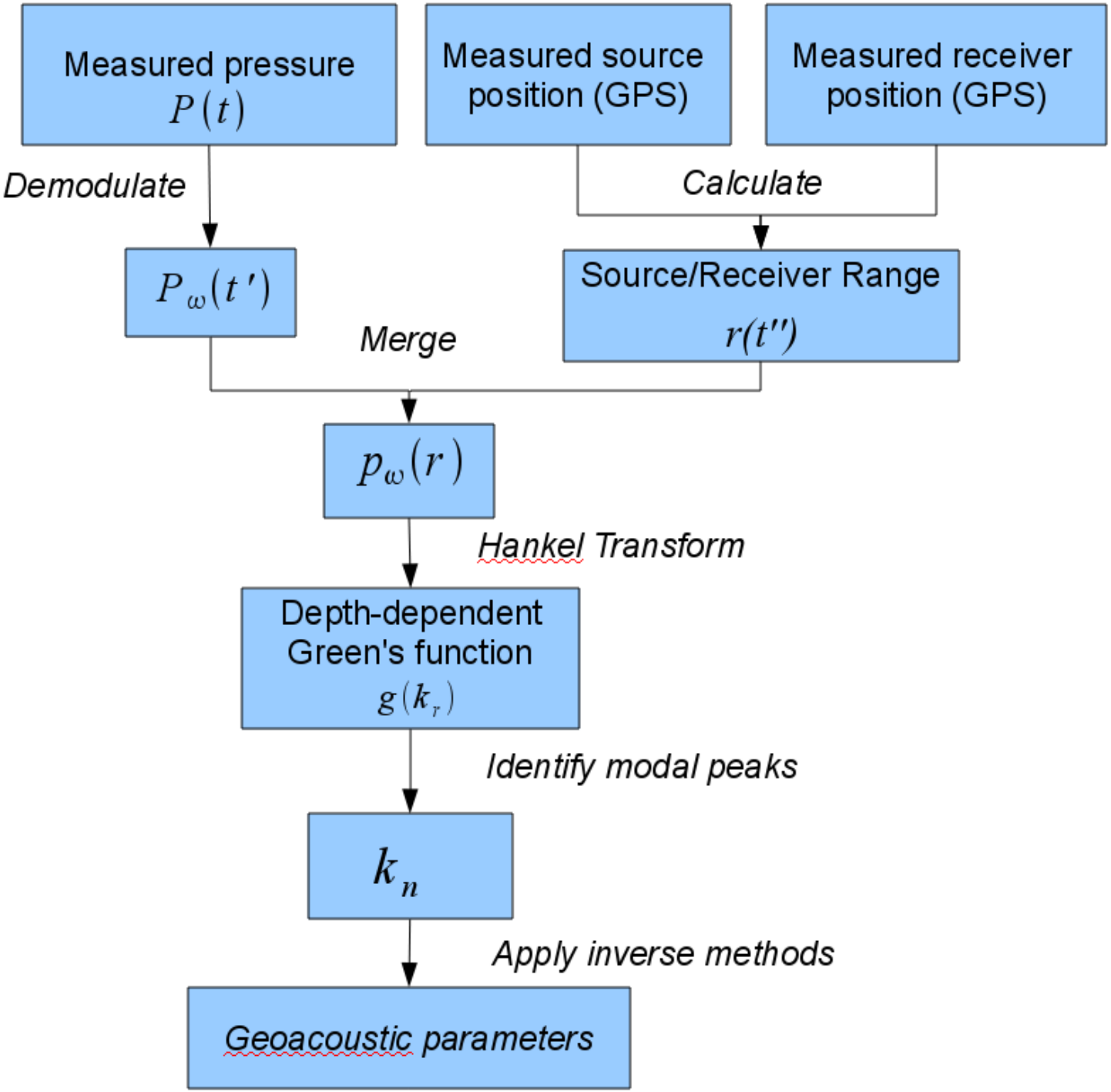
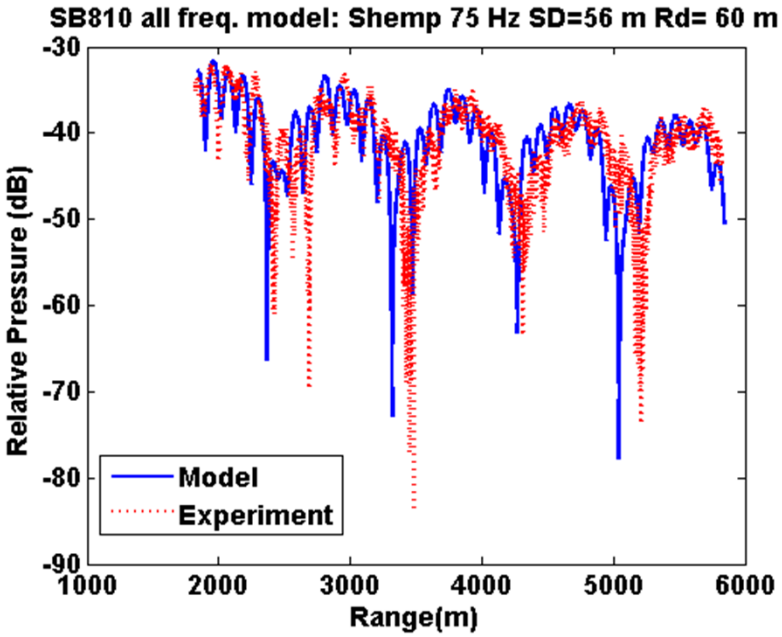
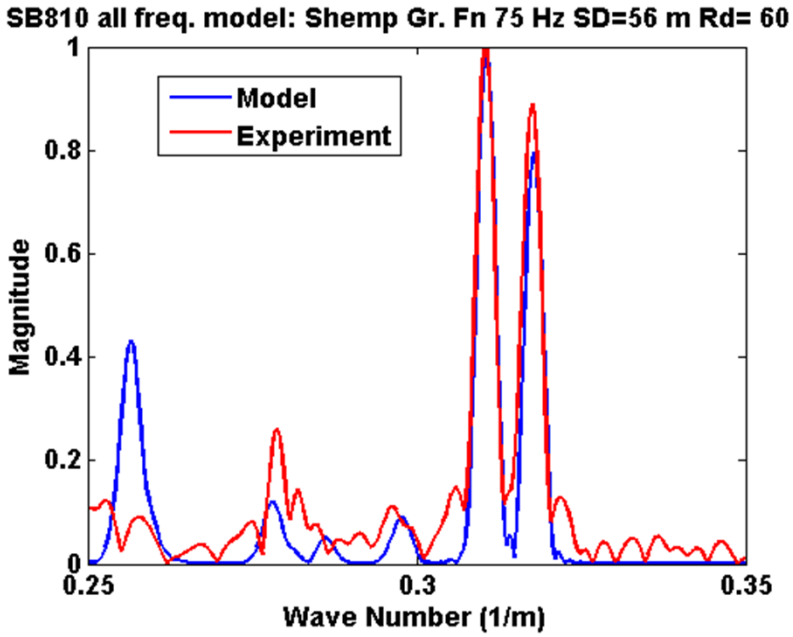
Horizontal Wavenumber Spectrogram: Along-Shelf Track



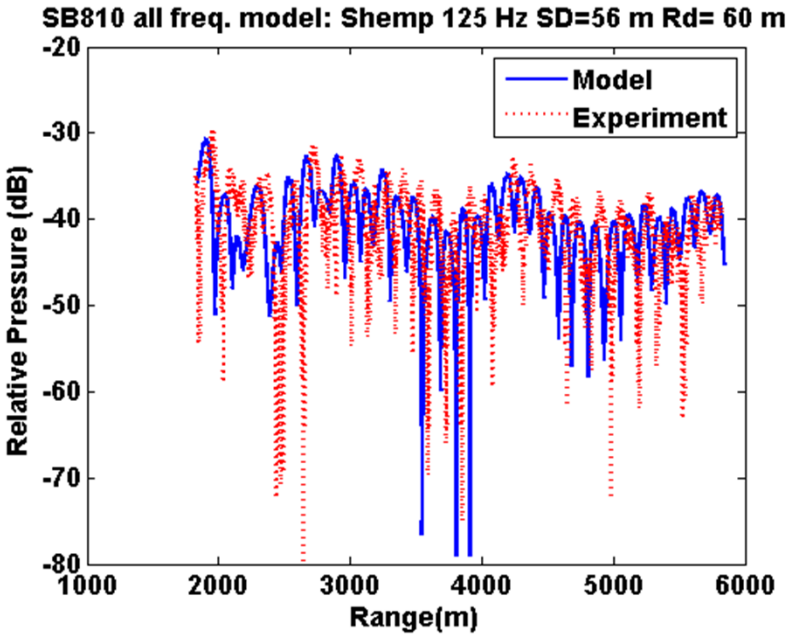

Measured pressure
$P(t)$
Measured source position (GPS)
Measured receiver position (GPS)
Demodulate
Calculate
$P_\omega(t')$
Source/Receiver Range
$r(t'')$
Merge
$p_\omega(r)$
Hankel Transform
Depth-dependent Green's function
$g(k_r)$
Identify modal peaks
k_n
Apply inverse methods
Geoacoustic parameters

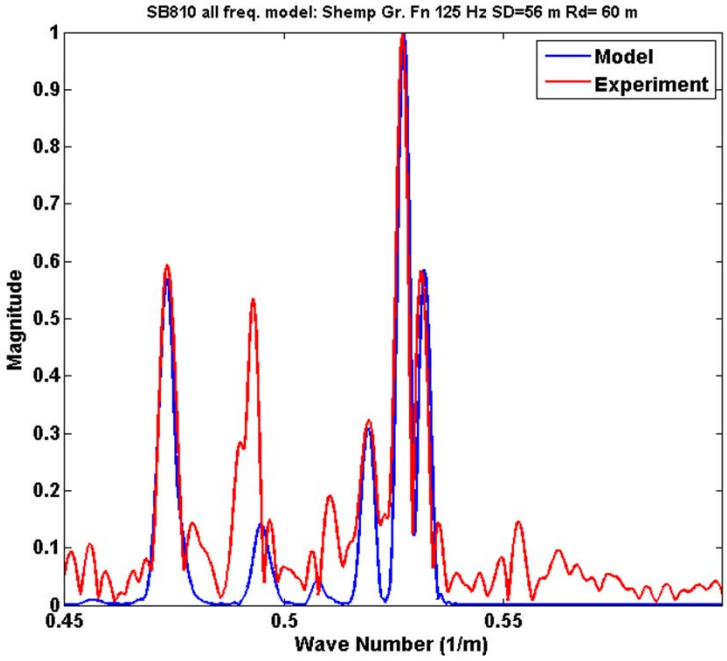
SB810 Model: Shemp 75 Hz



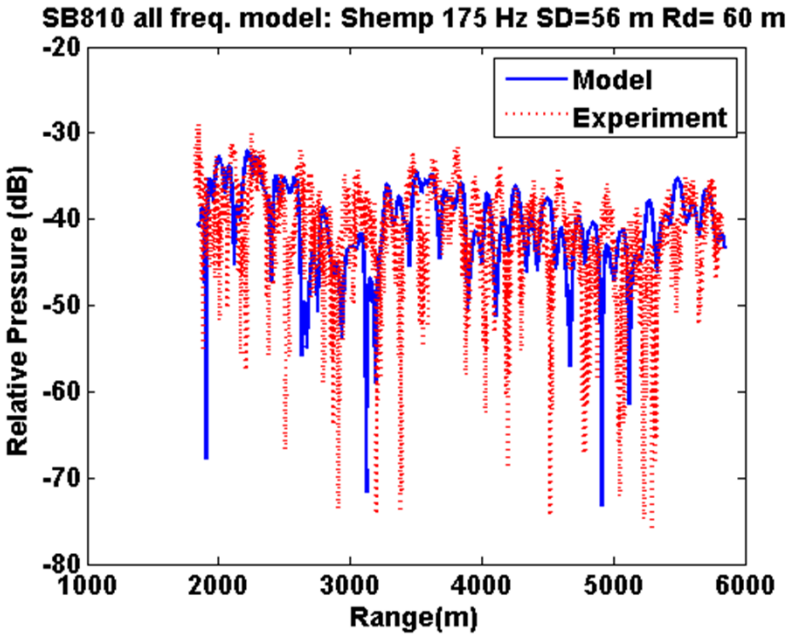


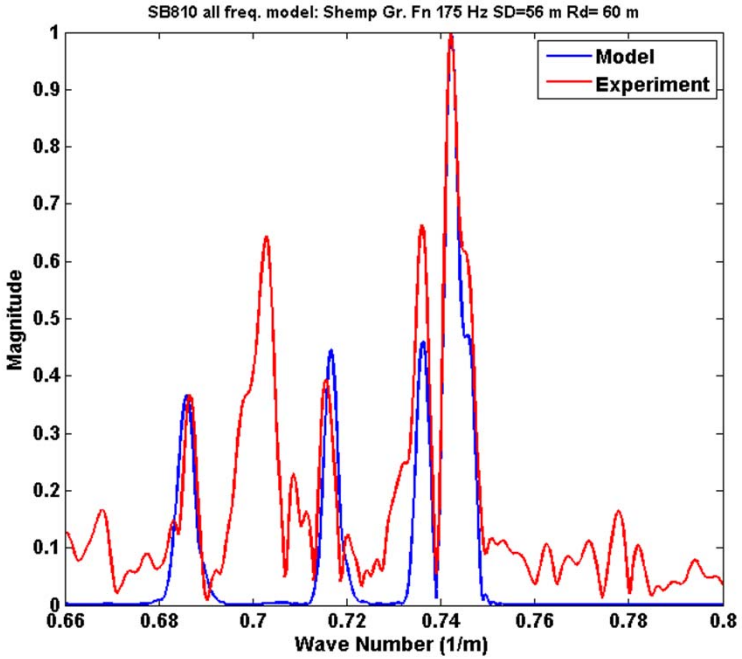
SB810 Model: Shemp 125 Hz

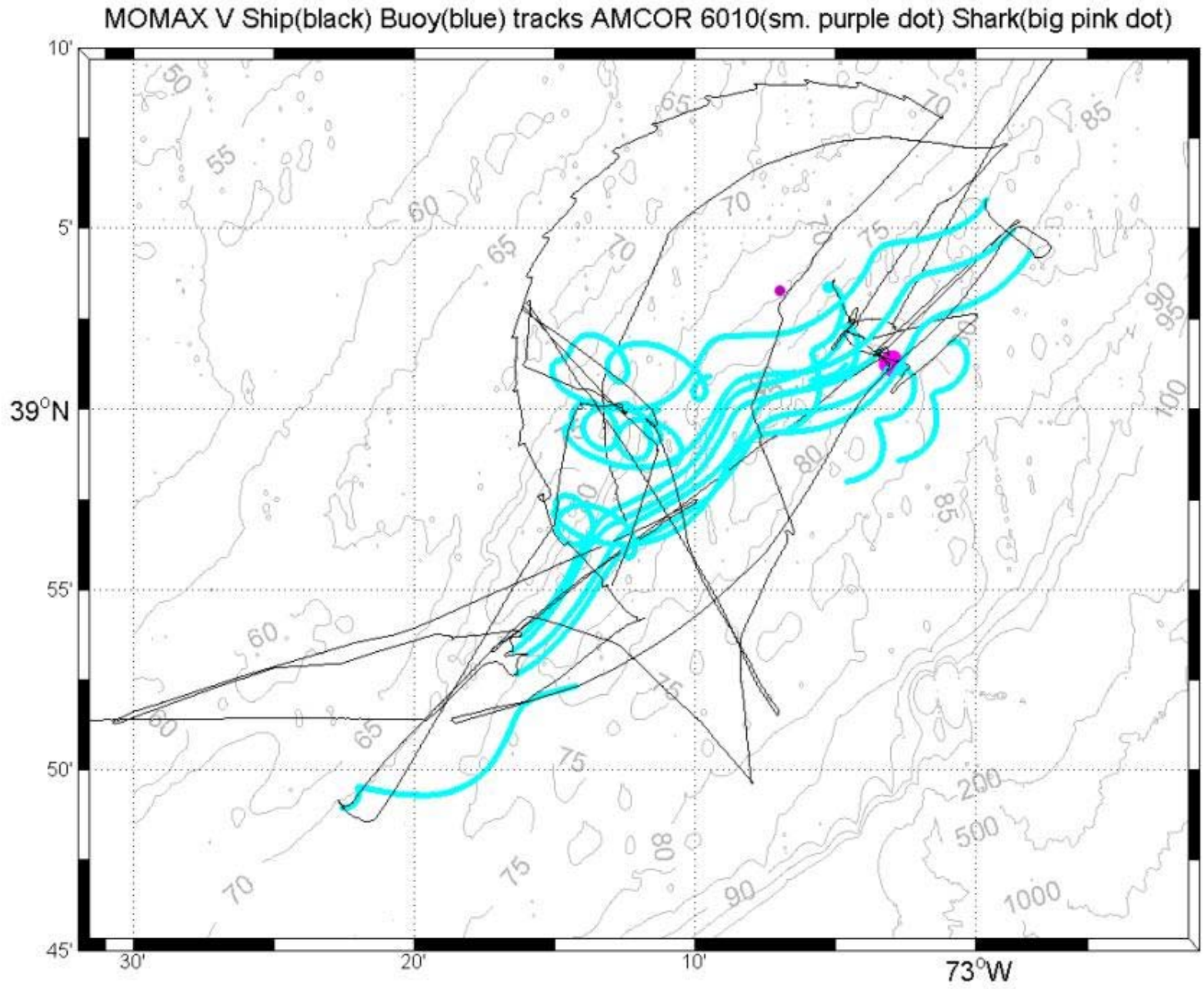




SB810 Model: Shemp 175 Hz






MOMAX V Ship(black) Buoy(blue) tracks AMCOR 6010(sm. purple dot) Shark(big pink dot)
10'
5'
39°N
55'
50'
45'
30'
20'
10'
73°W
50
55
60
65
70
75
80
85
90
95
100
200
500
1000

Prediction of field measured by Shemp using bottom model from SB810 data

- Receiver depth: 60 m
- Source depth: 56 m
- Pressure field computed using adiabatic mode theory and Kraken propagation code
- Attenuation: 0.05 dB/kHz/m in sediment layers and half space

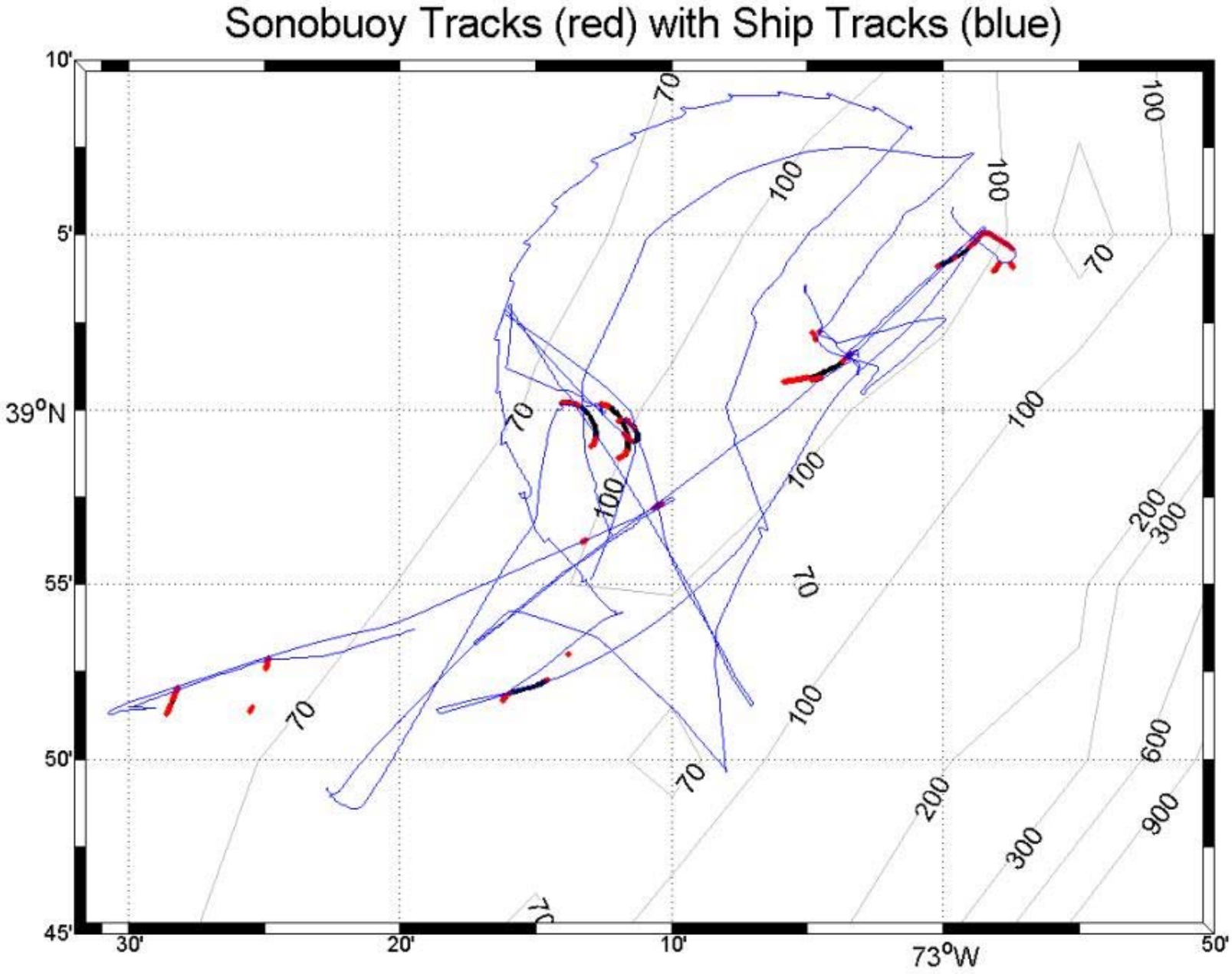
Typical MOMAX Data

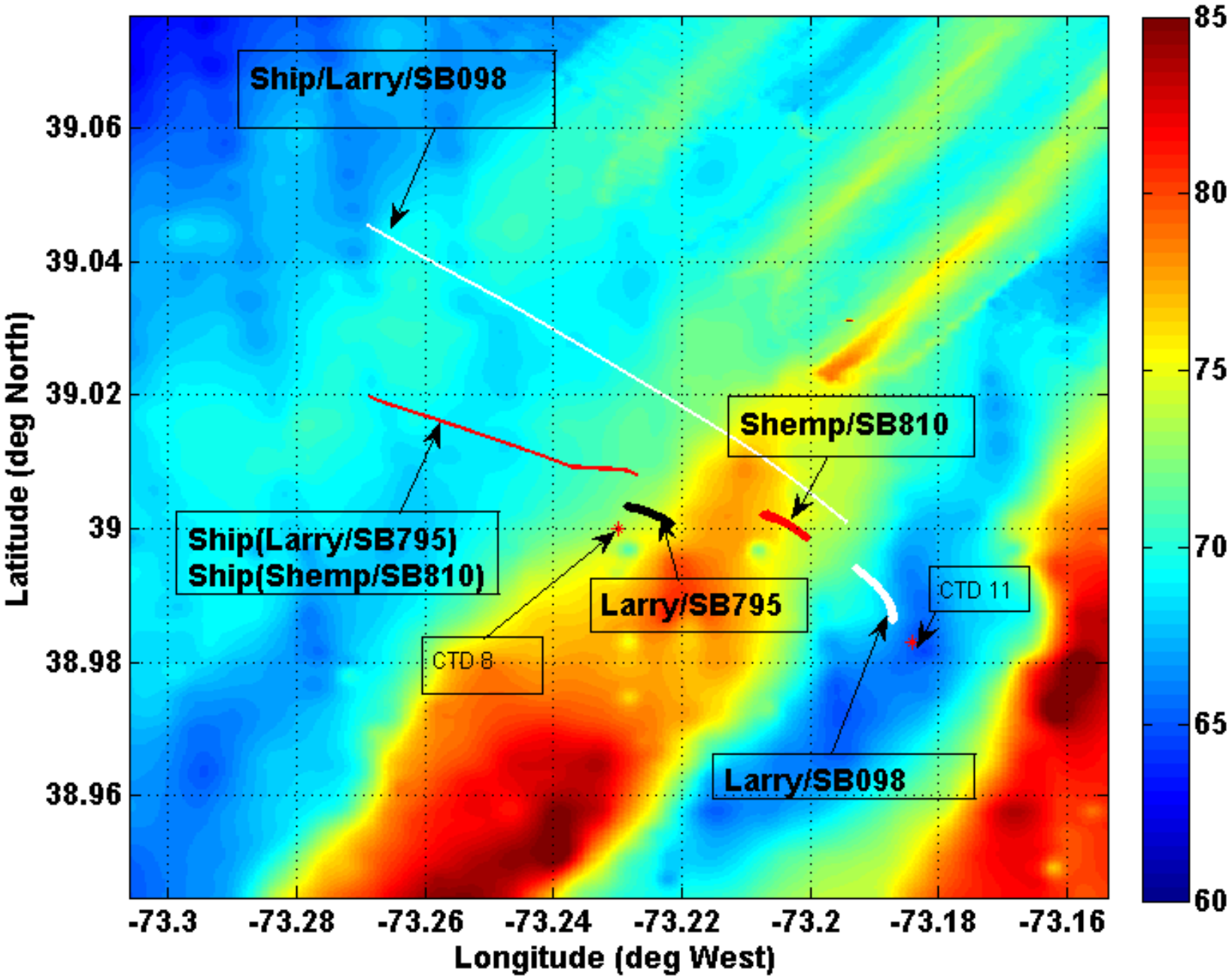
CW transmissions at 20, 50, 75, 125, and 175 Hz

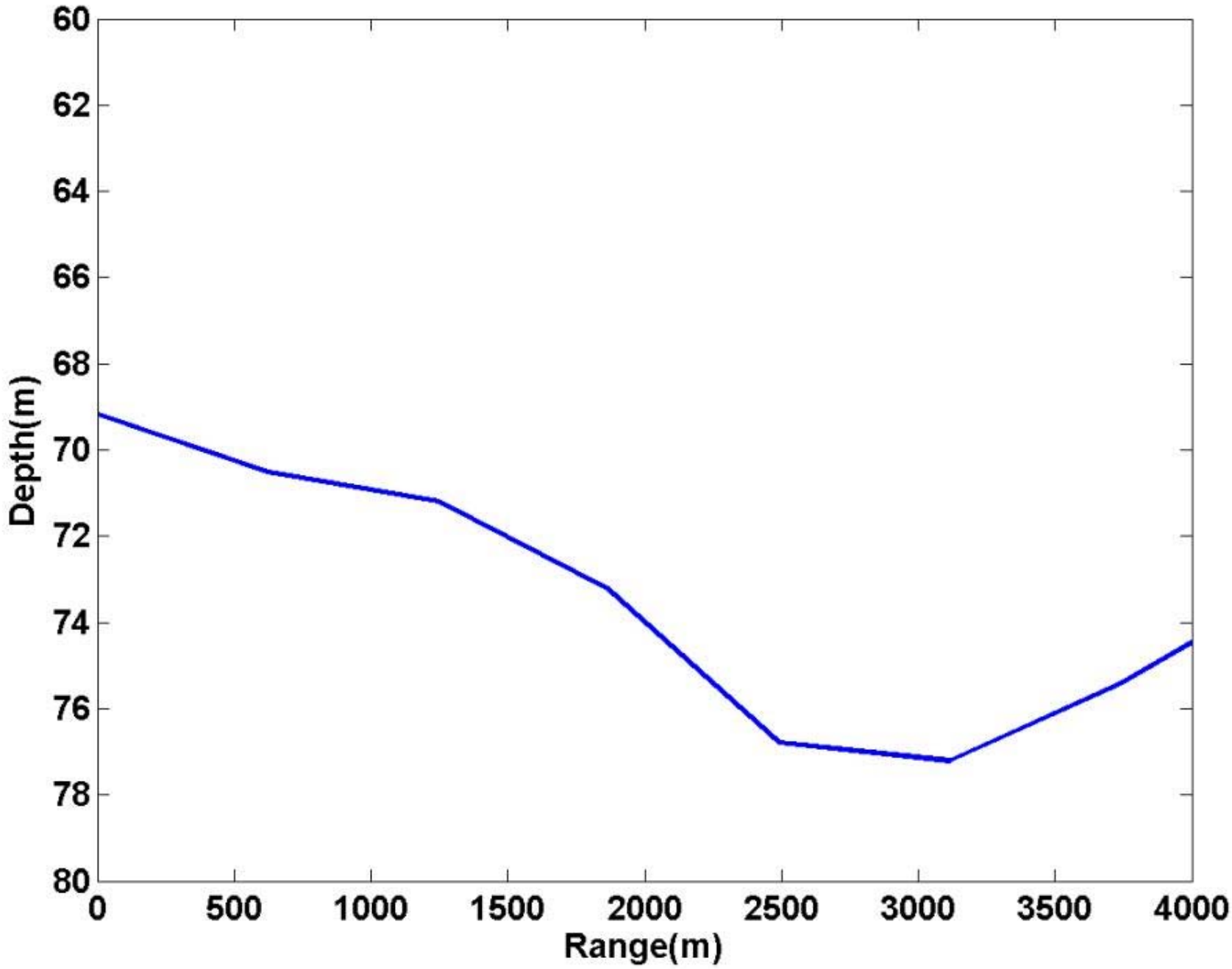
- *Drifting, underway, moored, or anchored source at 40 m or 60 m depth*
- *Source-receiver ranges up to 20 km*
- *Data received on 4 drifting MOMAX buoys, each having hydrophones at 40 m and 43 m depths*
- *Precision GPS navigation for source and receivers*

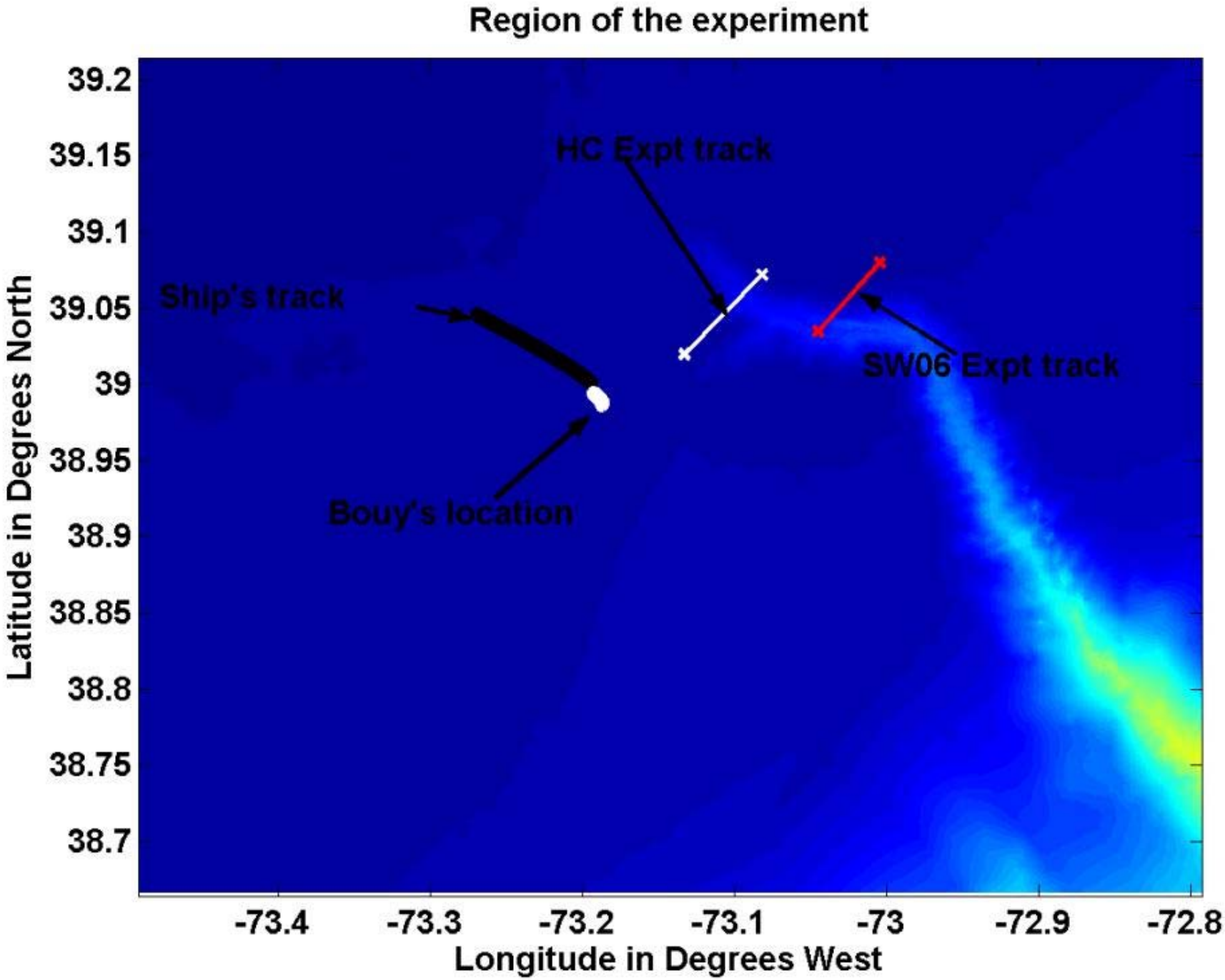
Temperature measurements obtained on

- *Source string*
- *4 drifting MOMAX buoys*


Sonobuoy Tracks (red) with Ship Tracks (blue)
10'
5'
39°N
55'
50'
45'
30'
20'
10'
73°W
50'
70
100
200
300
600
900


Ship/Larry/SB098
Shemp/SB810
Ship(Larry/SB795)
Ship(Shemp/SB810)
Larry/SB795
CTD 8
CTD 11
Larry/SB098
39.06
39.04
39.02
39
38.98
38.96
Latitude (deg North)
-73.3
-73.28
-73.26
-73.24
-73.22
-73.2
-73.18
-73.16
Longitude (deg West)
85
80
75
70
65
60


60
62
64
66
68
70
72
74
76
78
80
Depth(m)
0
500
1000
1500
2000
2500
3000
3500
4000
Range(m)


Region of the experiment
HC Expt track
Ship's track
SW06 Expt track
Bouy's location
Latitude in Degrees North
39.2
39.15
39.1
39.05
39
38.95
38.9
38.85
38.8
38.75
38.7
-73.4
-73.3
-73.2
-73.1
-73
-72.9
-72.8
Longitude in Degrees West