Impact of shelfbreak fronts on long-range underwater sound propagation in the continental shelf area

Ying-Tsong Lin[1], Alexey Shmelev[1], James F. Lynch[1], Arthur E. Newhall[1], Pierre F. J. Lermusiaux[2] and Glen Gawarkiewicz[1]

1 Woods Hole Oceanographic Institution, Woods Hole, MA

2 Massachusetts Institute of Technology, Cambridge, MA

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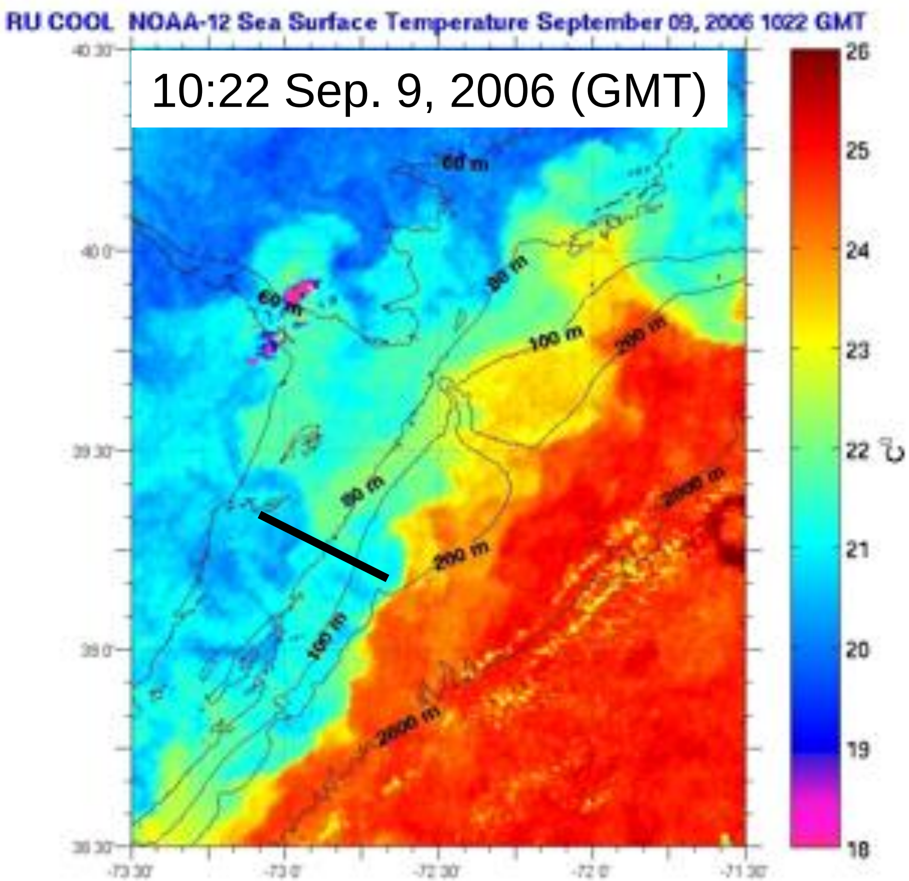
3-D feature of the Shelfbreak front off New Jersey

Field observations during the SW06 experiment

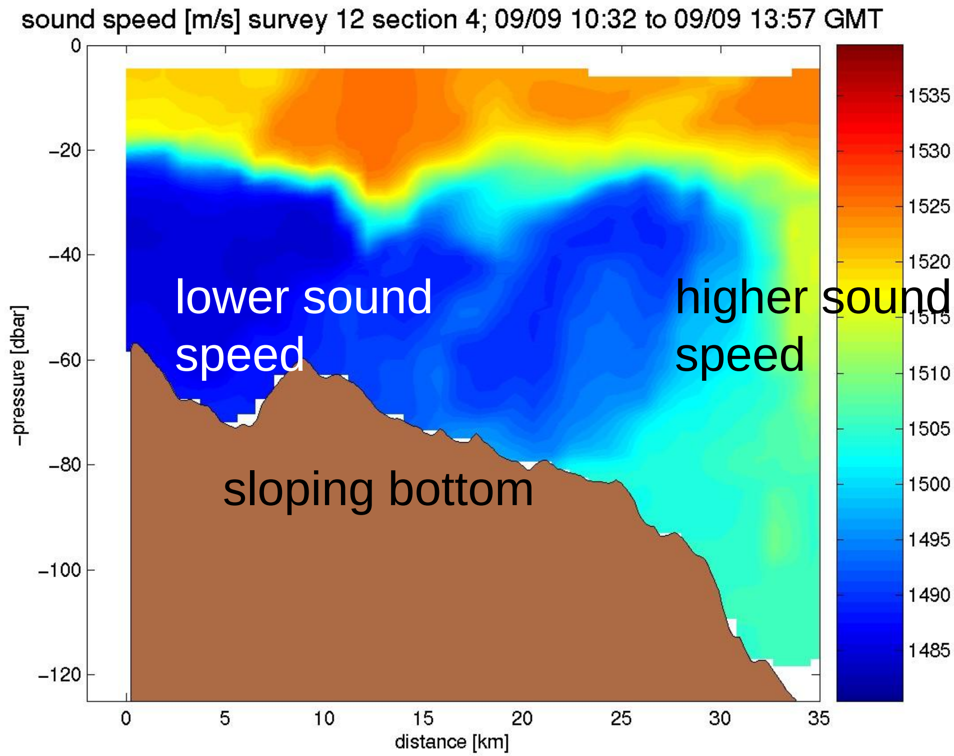


Sea Surface Temperature Satellite Image

2°×2° block centered at Hudson Canyon

The Coastal Ocean Observation Lab (COOL) at Rutgers University, NJ

10:32 to 13:57, Sep. 9, 2006 (GMT)



Vertical Structure

Scanfish sound speed data

Glen Gawarkiewicz, WHOI

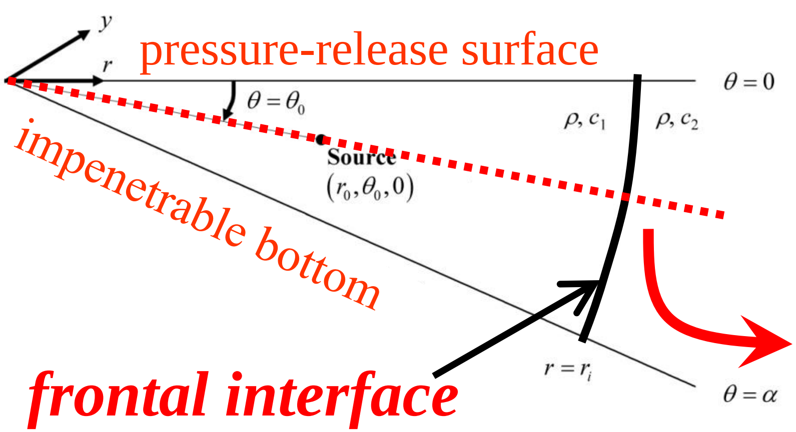
3-D acoustic effects from shelfbreak fronts

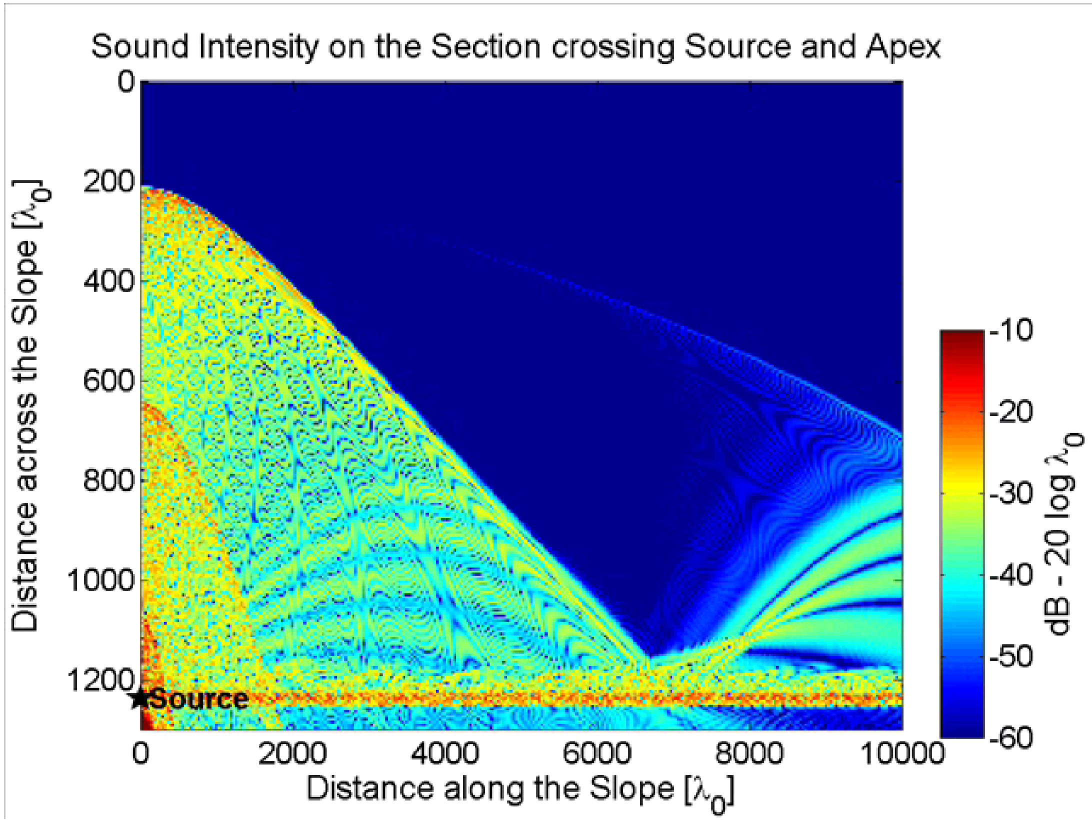
Idealized model study:

3-D Rigid-Bottom Wedge with a Frontal Interface

- **Continuous wave signal propagation**

  Source moves from the front to the wedge apex on the same θ angle, following the red line shown below.





Slope angle 1/10º (~1.75/1000 slope)

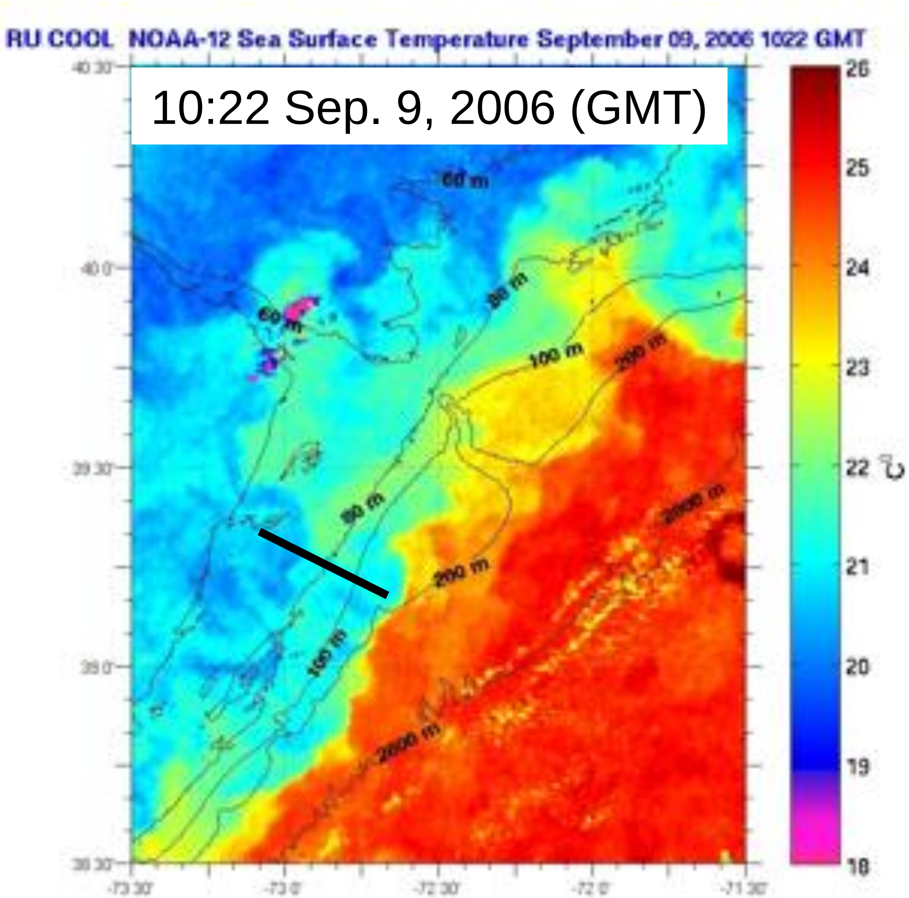
Water sound speed

inside 1,500m/s, outside 1,530m/s

Normalized Frequency 1,500/λ_0

3-D feature of the Shelfbreak front off New Jersey

Field observations during the SW06 experiment



Sea Surface Temperature Satellite Image

2º×2º block centered at Hudson Canyon

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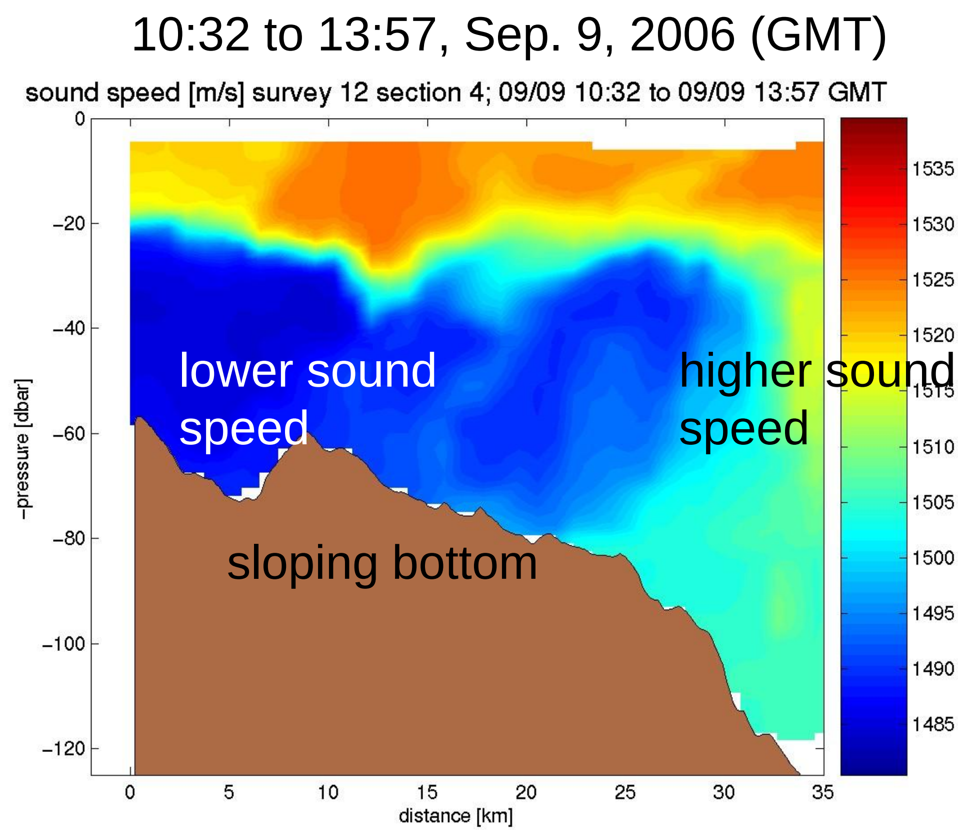


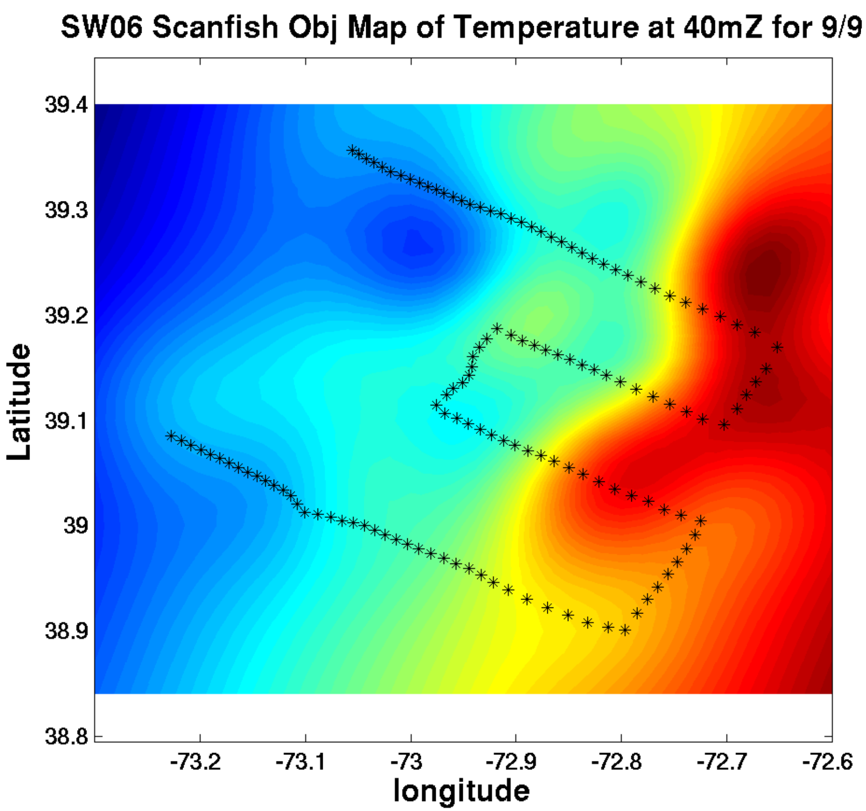
Vertical Structure

Scanfish sound speed data

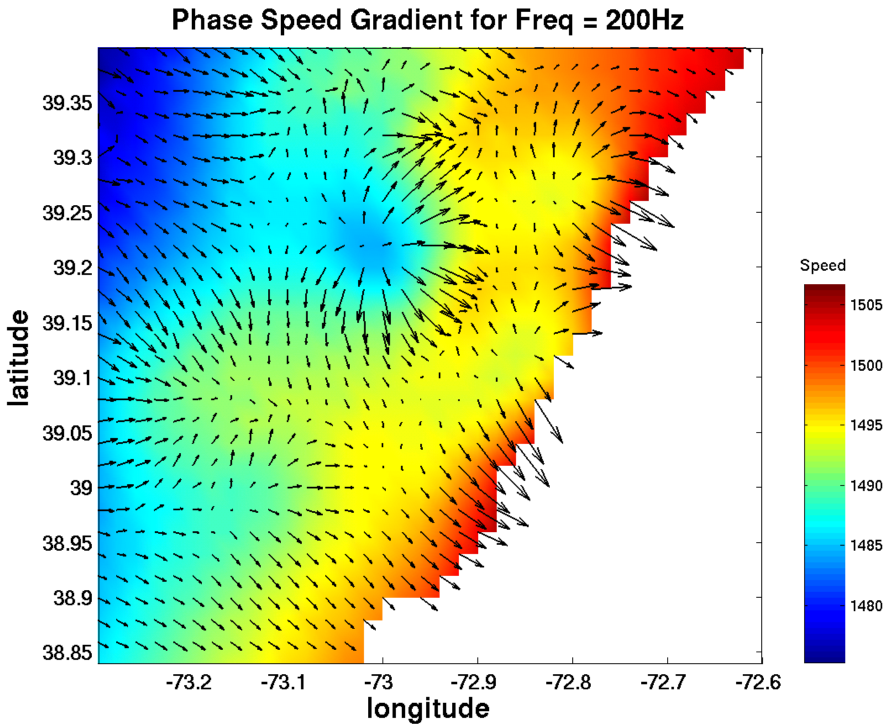
Glen Gawarkiewicz, WHOI

Objective map of the Scanfish data in the SW06 experiment

Water temperature at 40 m depth



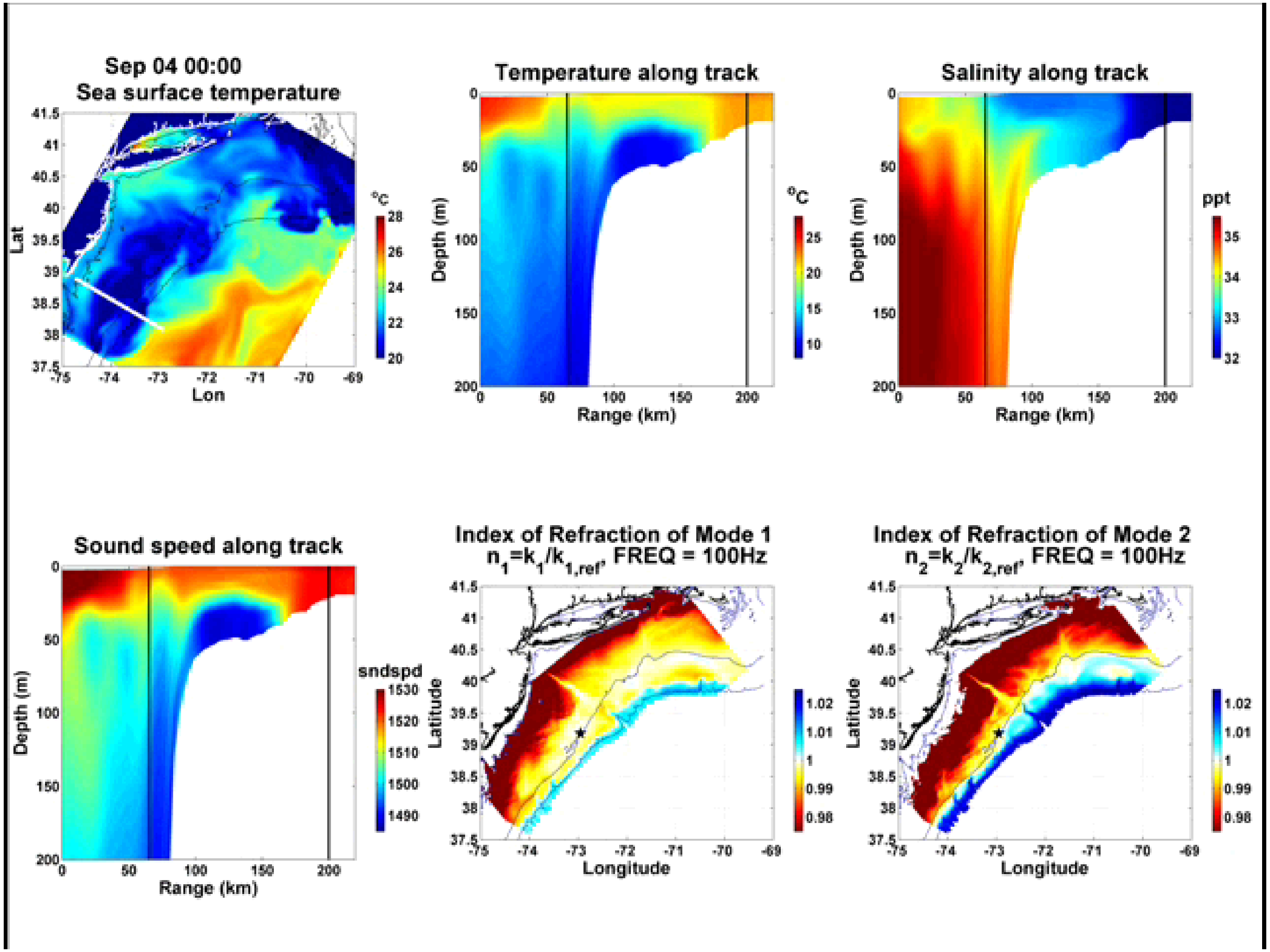
Phase speed of acoustic Mode 1 at 200 Hz



Realistic model study: *4-D Ocean Acoustic Field Prediction*

- **4-D ocean fields from a data assimilation model (MIT - MSEAS) by P. F. J. Lermusiaux are employed.**

Sep 4
to Sep 7



- **Acoustic normal mode wavenumbes are calculated, and the indices of modal refraction are presented in the lower-right two panels. The modal phase speeds in red areas are faster, which cause acoustic modes to refract away and propagate toward lower phase speed areas (blue and white areas).**

3-D Adiabatic mode solution

$$\rho(\vec{r})\nabla\cdot\left(\frac{1}{\rho(\vec{r})}\nabla P(\vec{r})\right)+k^2(\vec{r})P(\vec{r})=-4\pi\delta(\vec{r}-\vec{r}_s)$$ 3-D wave equation

$$P(x,y,z)=\sum_m \Gamma_m(x,y)\Psi_m(x,y,z)$$ vertical mode decomposition

vertical modes satisfy the next normal mode equation

$$\rho(z)\frac{d}{dz}\left(\frac{1}{\rho(z)}\frac{d}{dz}\Psi_m(x,y,z)\right)+\left(\frac{\omega^2}{c^2(x,y,z)}-\xi_m^2(x,y)\right)\Psi_m(x,y,z)=0$$

2-D wave equation for the modal amplitude

$$\left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}\right)\Gamma_m+\xi_m^2(x,y)\Gamma_m=-4\pi\frac{\Psi_m(x_s,y_s,z_s)}{\rho(z_s)}\delta(x-x_s)\delta(y-y_s)$$

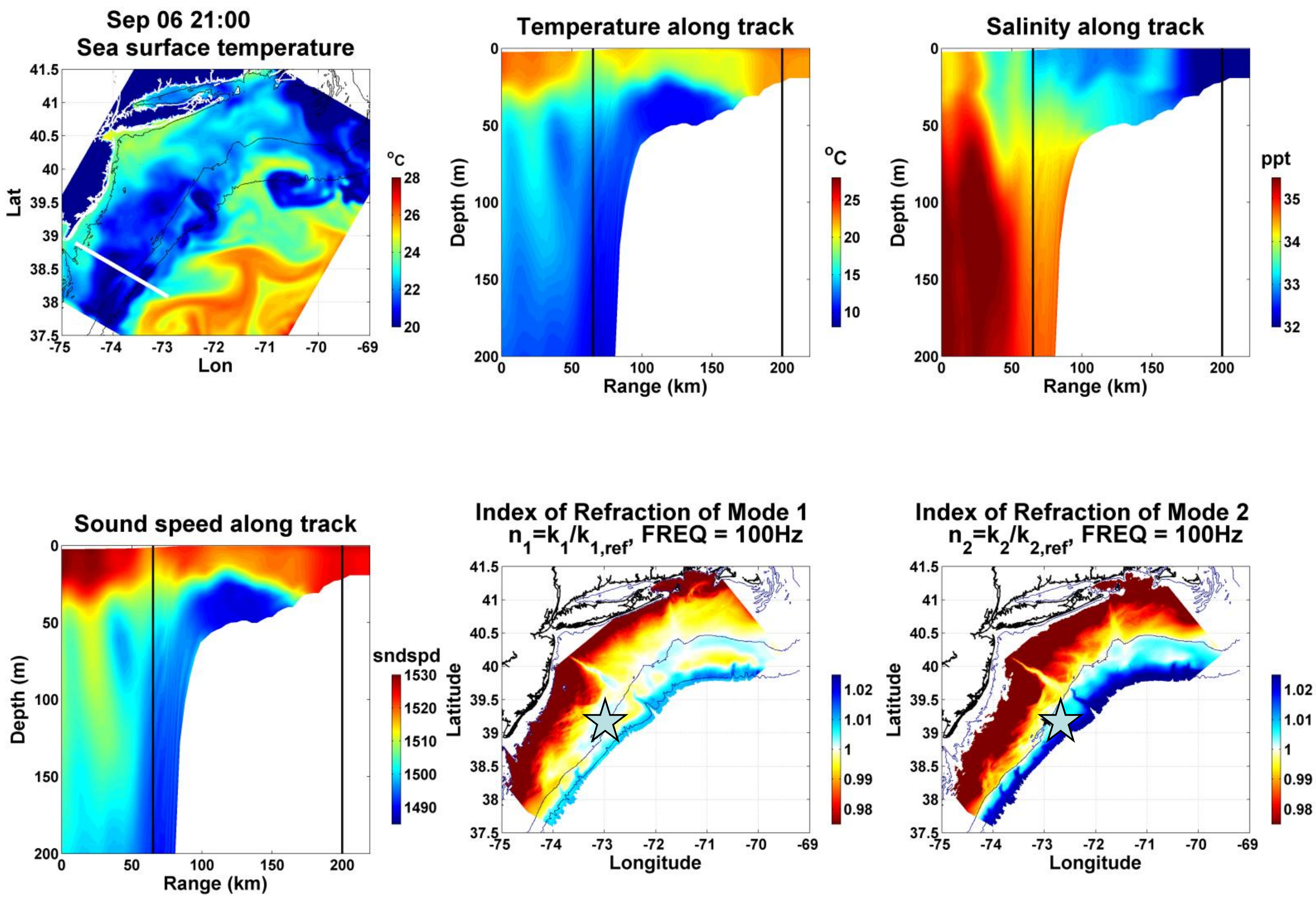
- Utilize 2-D PE to solve modal amplitude equation to include horizontal refraction

- WKB solution of neglecting horizontal refraction

$$P(r)\approx\sqrt{\frac{2\pi}{k_n(r)\,r}}\cdot\frac{\Psi_m(x_s,y_s,z_s)}{\rho(z_s)}\cdot e^{i\frac{\pi}{4}+i\int k_n(r)dr}$$

Modal TL Calculations

Case 1: SW06 Acoustic Site

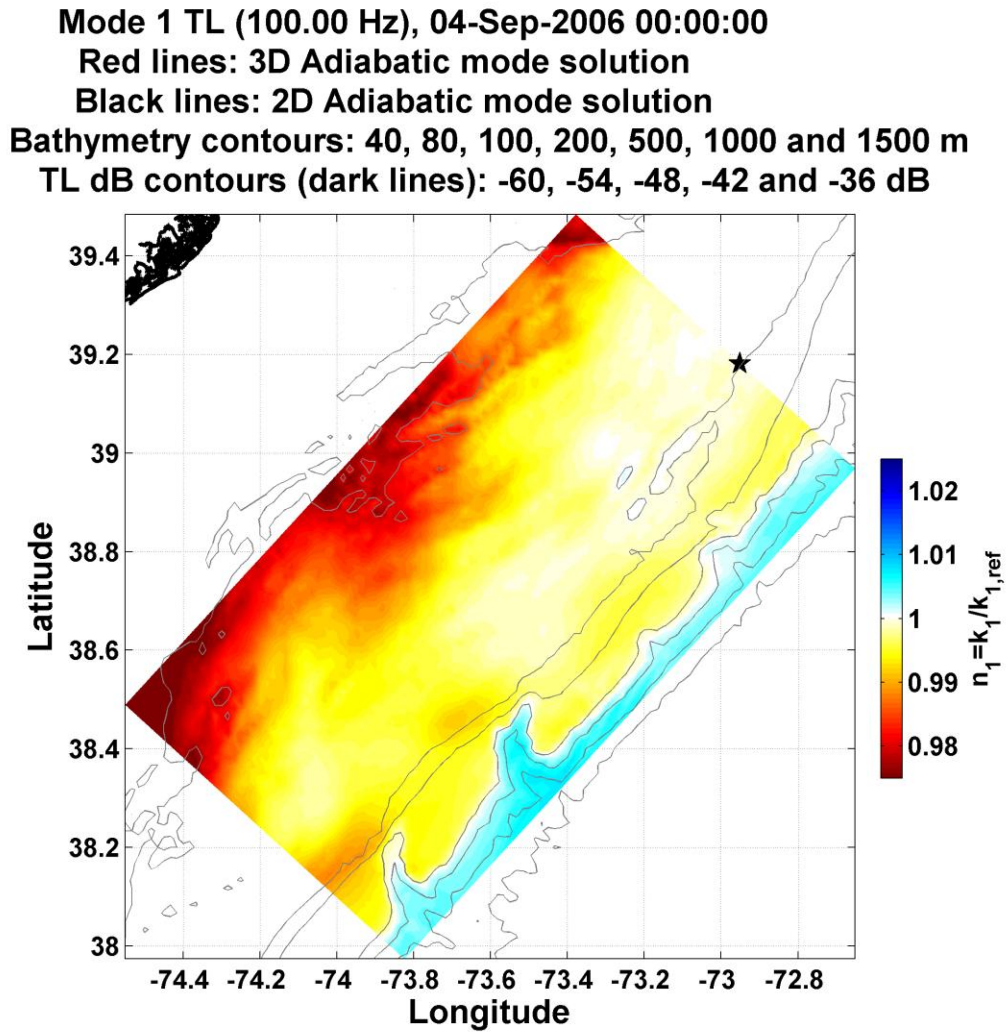


Realistic model study: *4-D Ocean Acoustic Field Prediction*

- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 1: SW06 Acoustic Site (Source Frequency 100 Hz)

Mode 1 intensities (contours), plotted along with modal refractive index



on shore

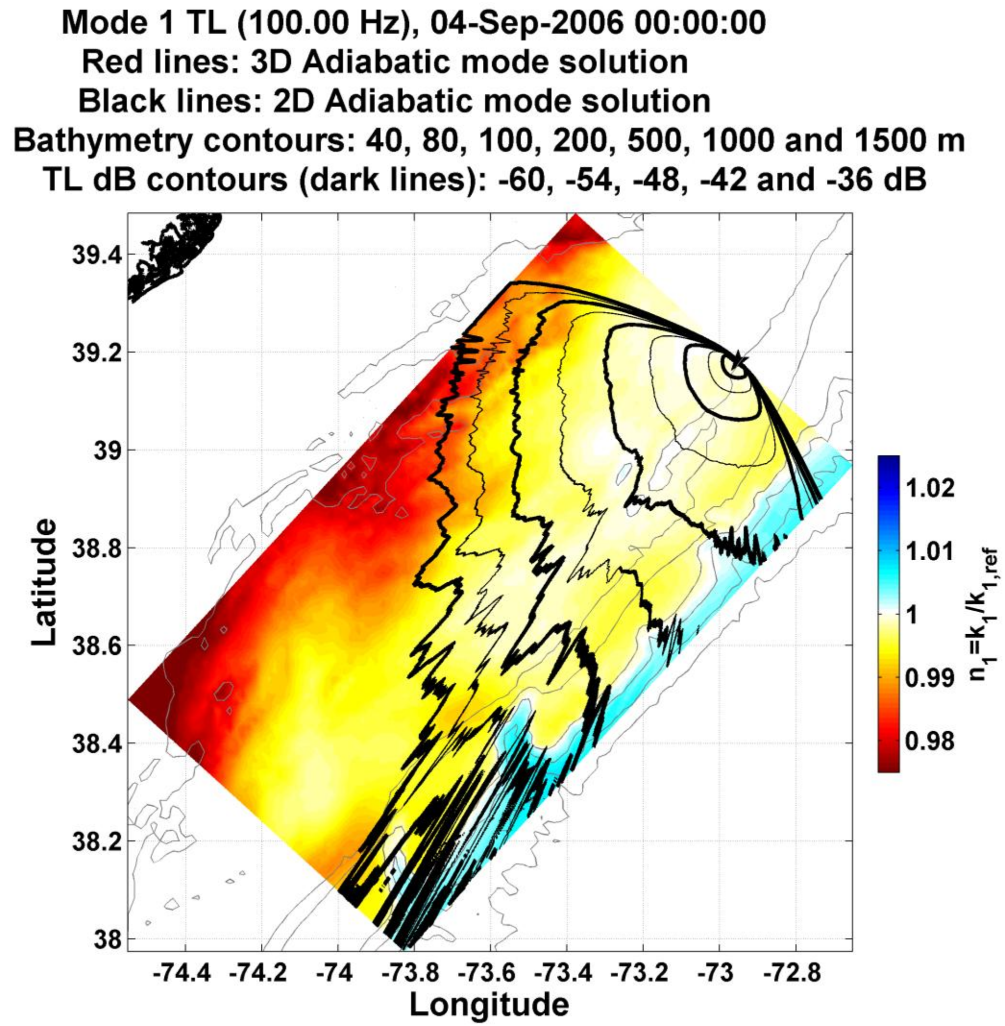
150 km x 80 km

Realistic model study: *4-D Ocean Acoustic Field Prediction*

- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 1: SW06 Acoustic Site (Source Frequency 100 Hz)

Mode 1 intensities (contours), plotted along with modal refractive index



on shore

Realistic model study: *4-D Ocean Acoustic Field Prediction*

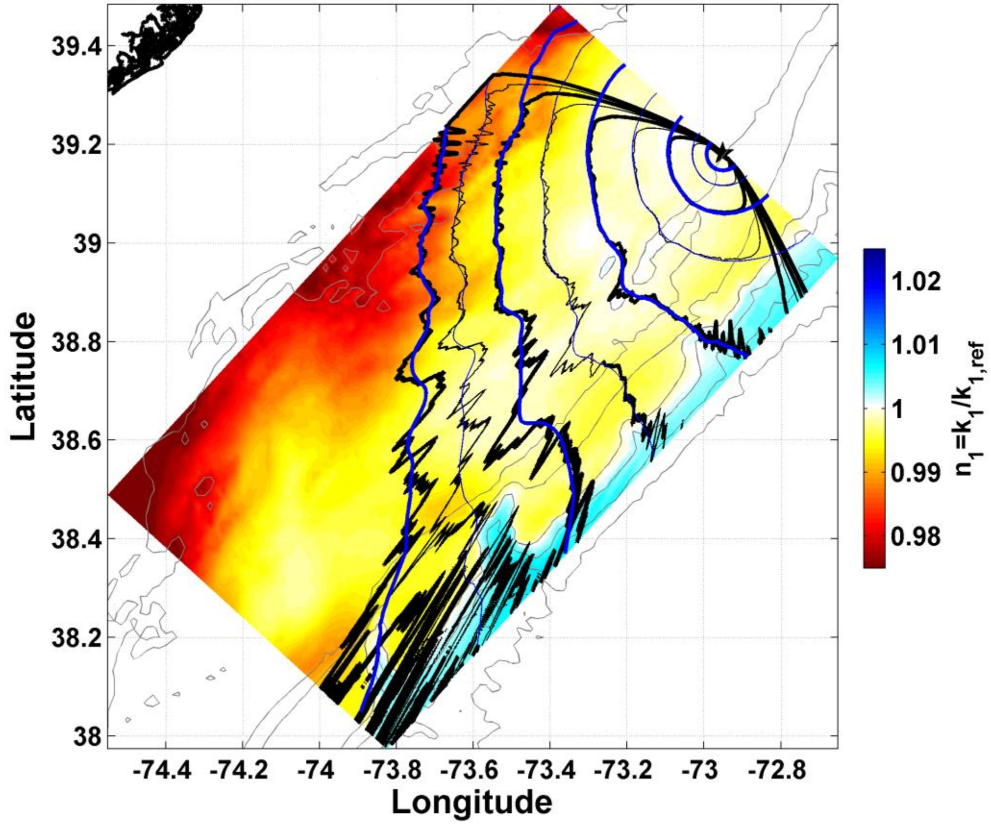
- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 1: SW06 Acoustic Site (Source Frequency 100 Hz)

Mode 1 intensities (contours), plotted along with modal refractive index

on shore

Mode 1 TL (100.00 Hz), 04-Sep-2006 00:00:00
Red lines: 3D Adiabatic mode solution
Black lines: 2D Adiabatic mode solution
Bathymetry contours: 40, 80, 100, 200, 500, 1000 and 1500 m
TL dB contours (dark lines): -60, -54, -48, -42 and -36 dB



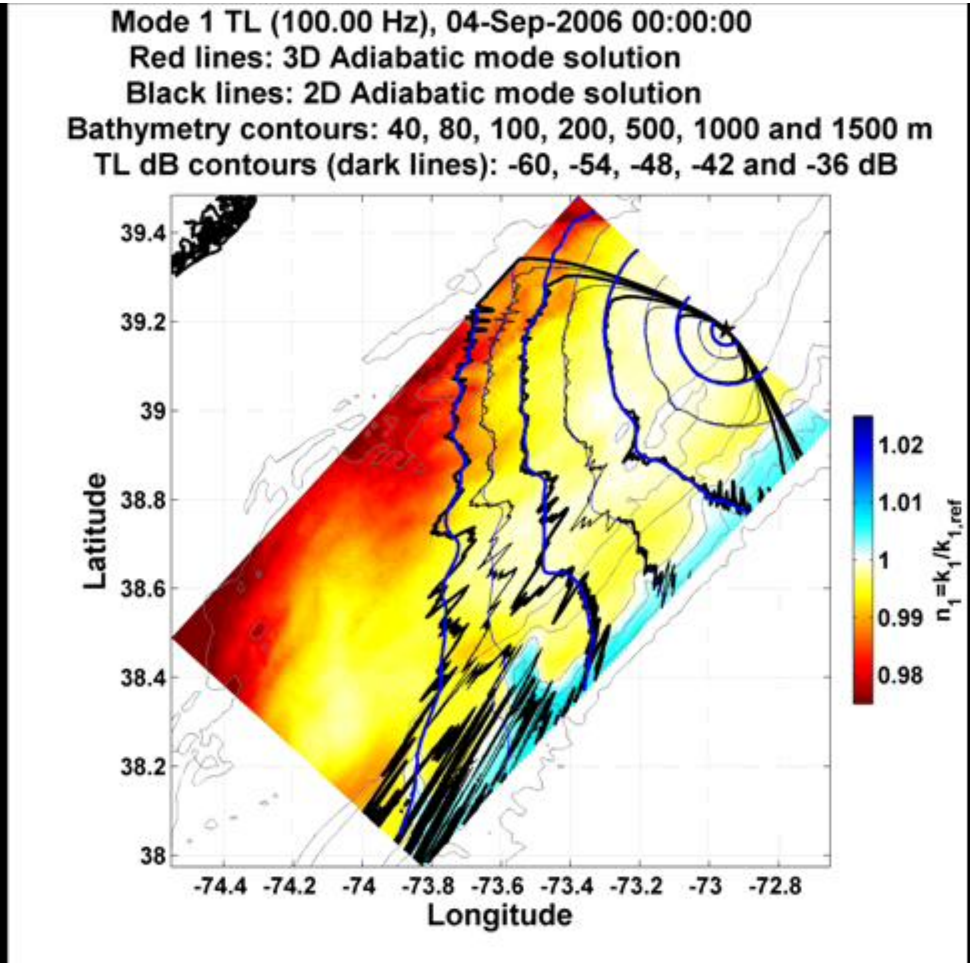
Realistic model study: *4-D Ocean Acoustic Field Prediction*

- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 1: SW06 Acoustic Site (Source Frequency 100 Hz)

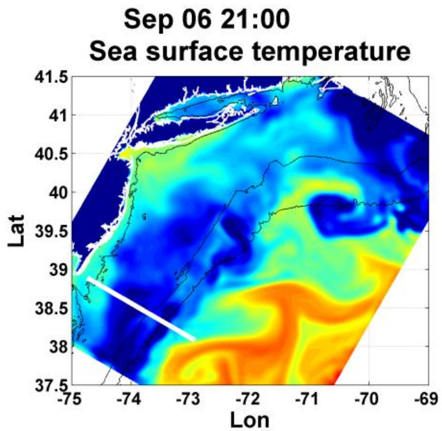
Mode 1 intensities (contours), plotted along with modal refractive index

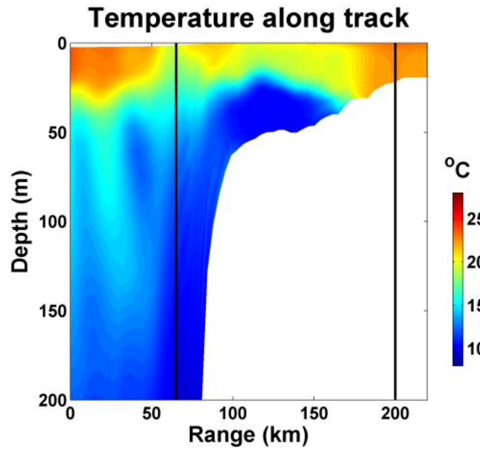
on shore

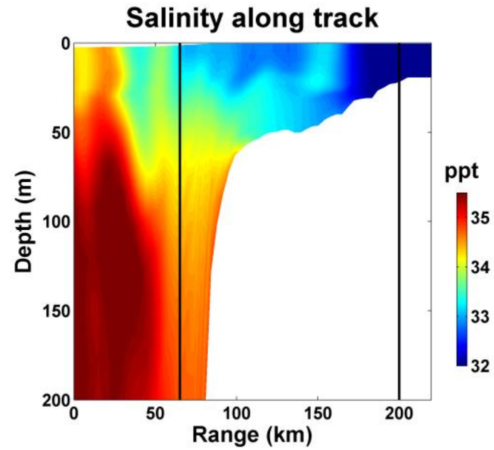


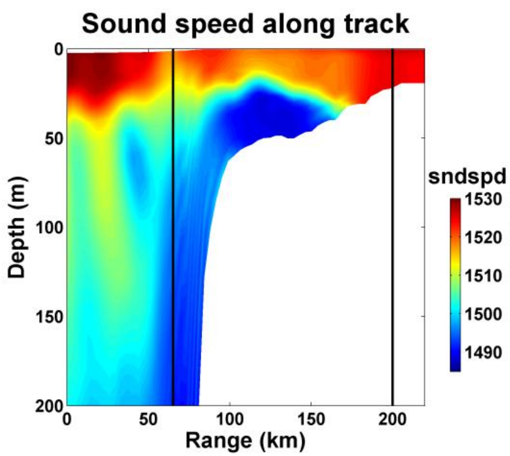
Modal TL Calculations

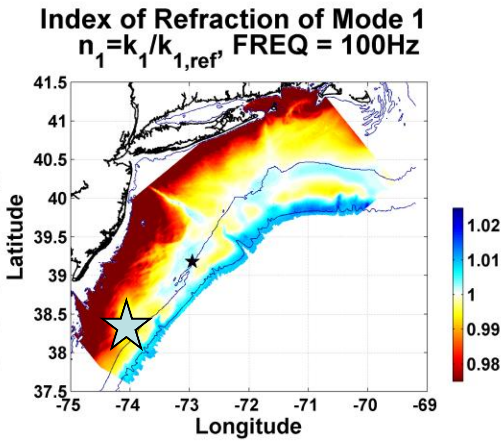
Case 2: Cold Pool

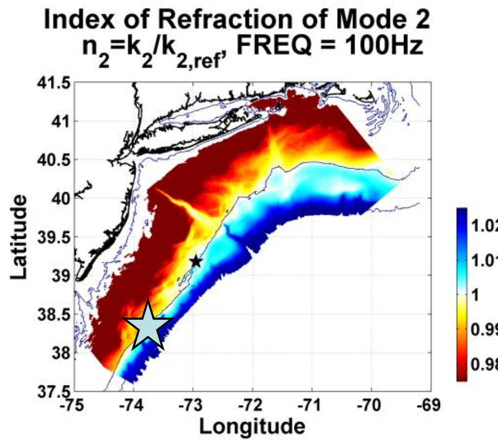












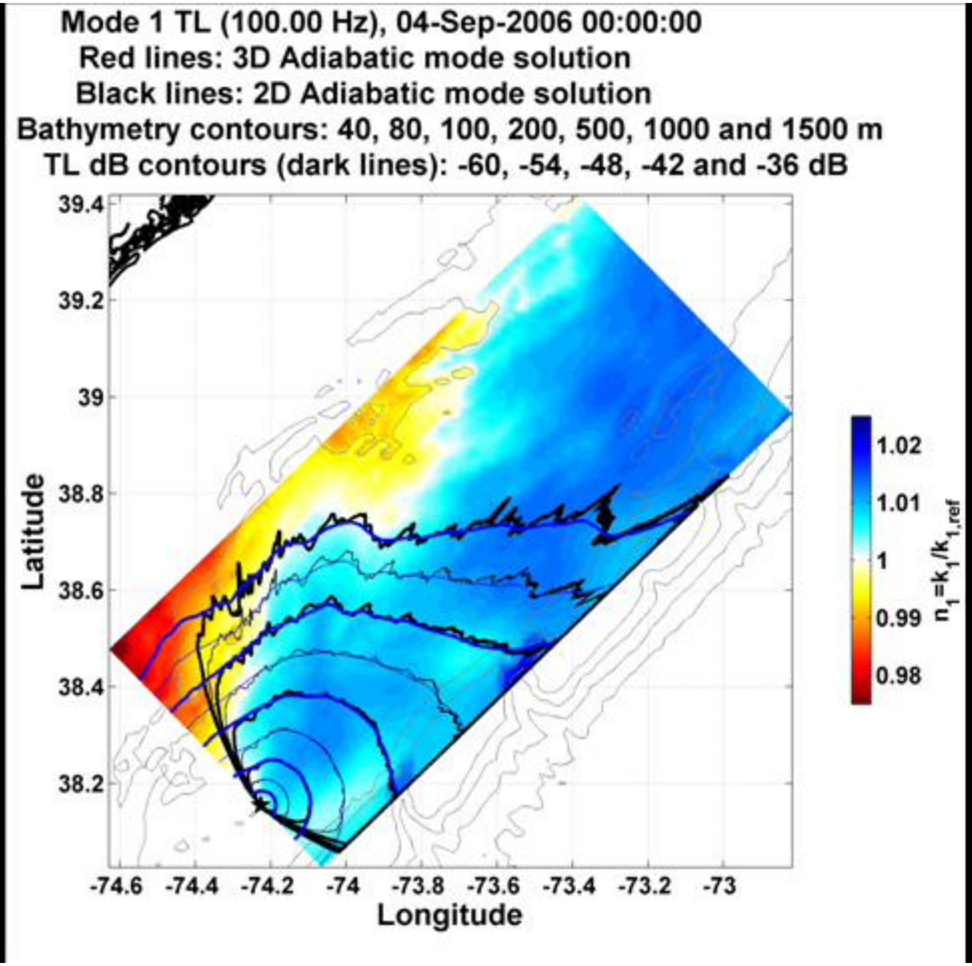
Realistic model study: *4-D Ocean Acoustic Field Prediction*

- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 2: Mesoscale Eddy (Source Frequency 100 Hz)

Mode 1 intensities (contours), plotted along with modal refractive index

on shore



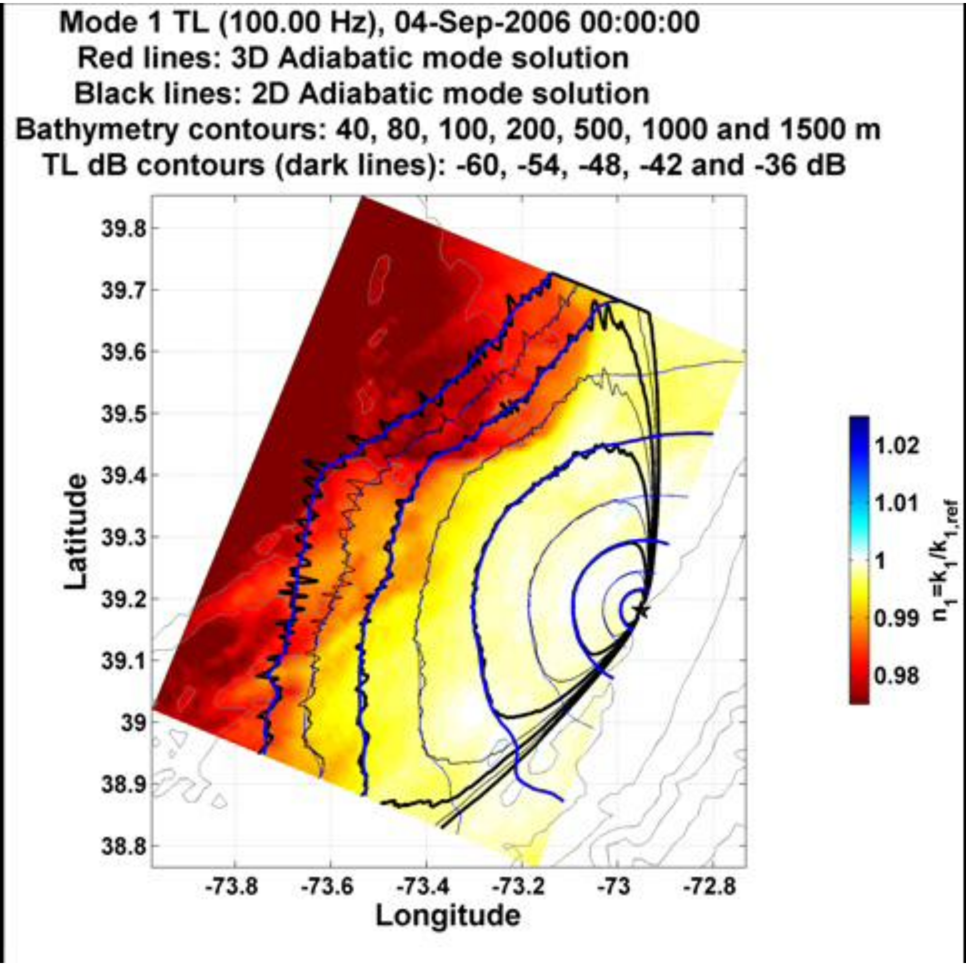
150 km x 70 km

Realistic model study: *4-D Ocean Acoustic Field Prediction*

- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 3: Bottom (Source Frequency 100 Hz)

Mode 1 intensities (contours), plotted along with modal refractive index



on shore

70 km x 100 km

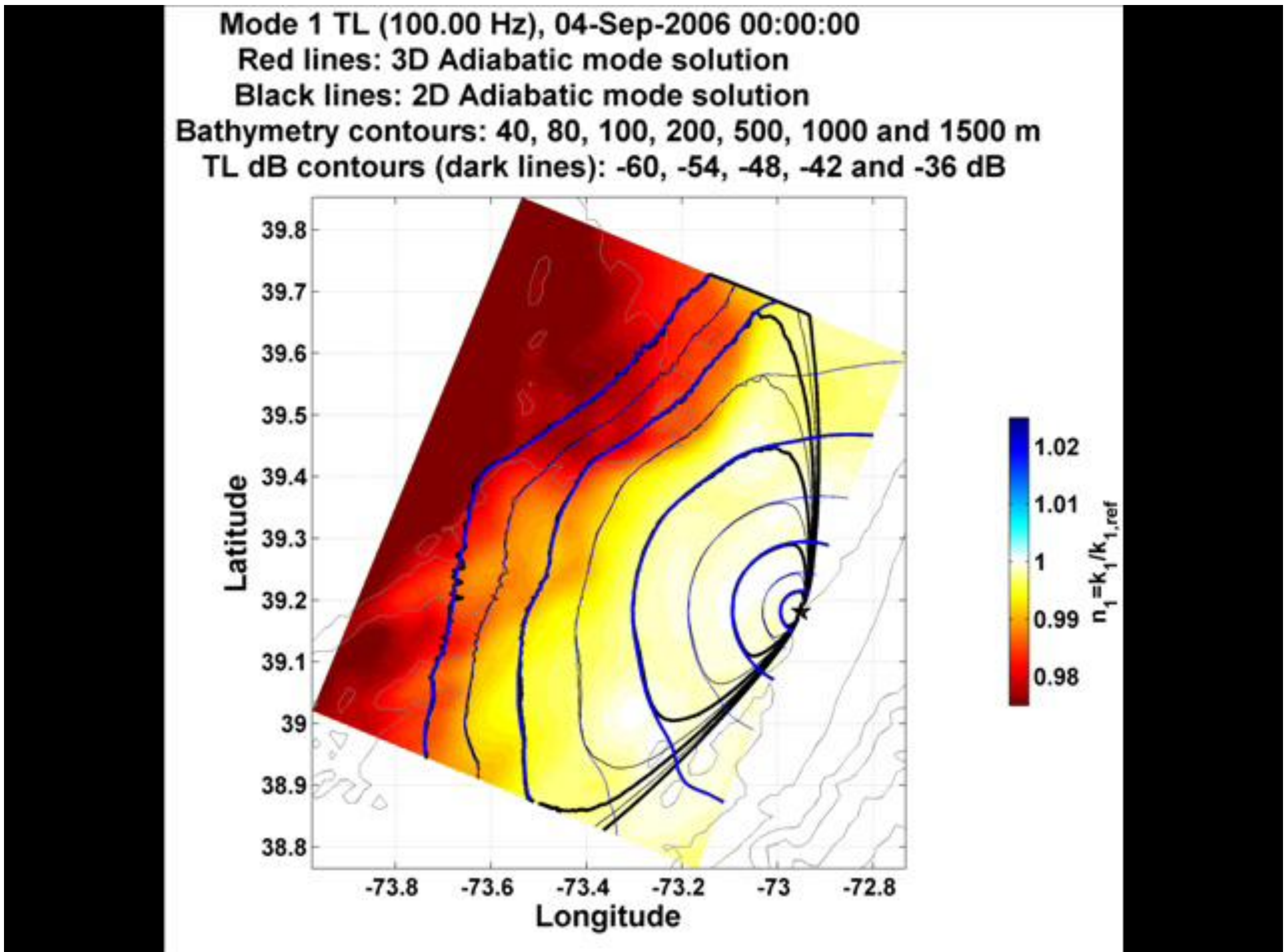
Realistic model study: *4-D Ocean Acoustic Field Prediction*

- Modal intensities predicted by the vertical modes and horizontal PE approach

CASE 3: Bottom (Source Frequency 100 Hz)

Mode 1 intensities (contours), plotted along with modal refractive index

on shore



Summary

- Joint 3-D acoustic effects from shelfbreak fronts and bathymetry/slope
- Realistic ocean model from the MIT-MSEAS has been employed, and an approach of vertical modes and horizontal PE enables us to investigate 3-D normal mode propagation on the continental shelf area.

Future work

- We need higher ocean model resolution.
- Full 3-D calculation to capture the 3-D mode coupling