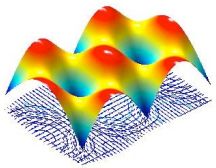

SWAP Project Overview and NEAR Lab Involvement

Richard Campbell

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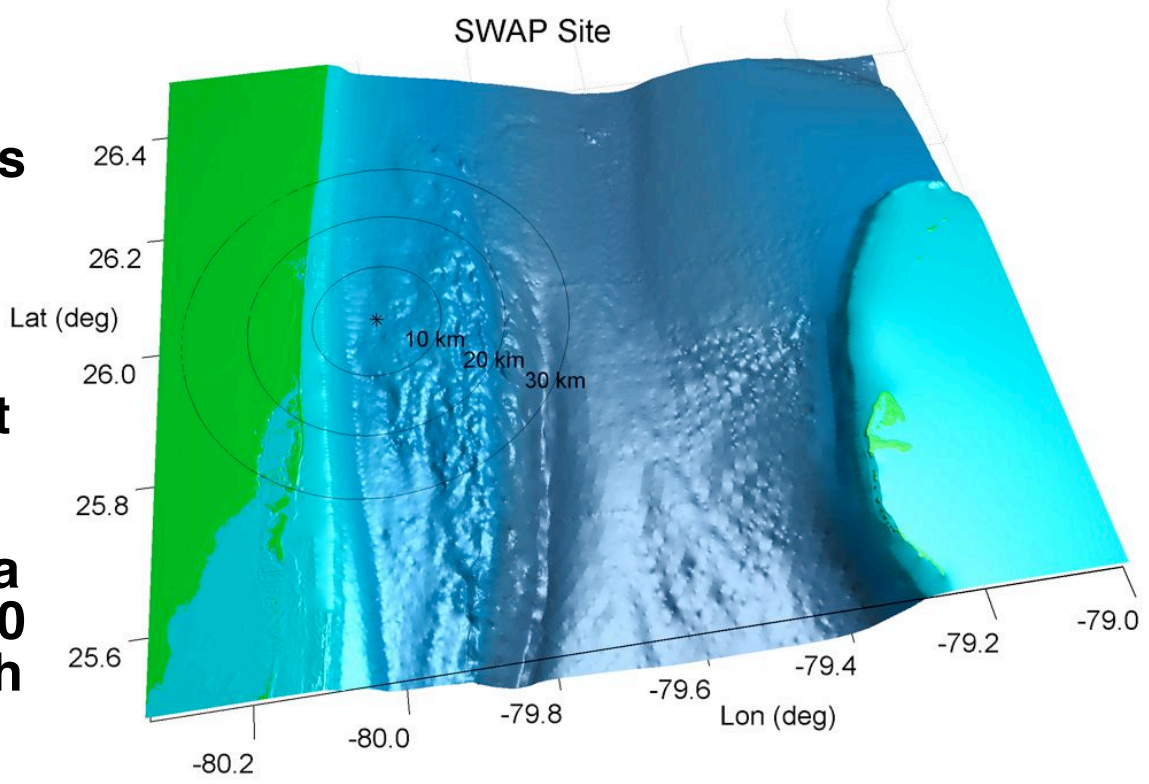
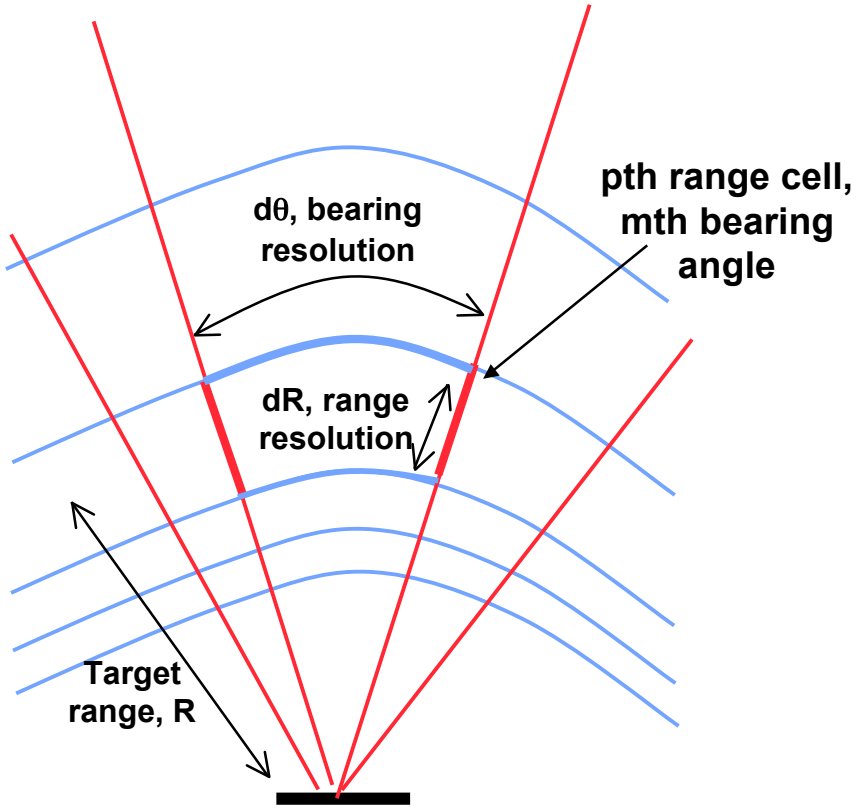
SWAP Overview

- **The Shallow Water Array Performance (SWAP) project, funded by the Office of Naval Research, is designed to explore the limits of large-aperture passive sonar array processing capability in a shallow-water environment with moving surface ship interference. The array, off the eastern coast of Florida near Ft Lauderdale, has 500 elements with a total length of approximately 900 meters.**



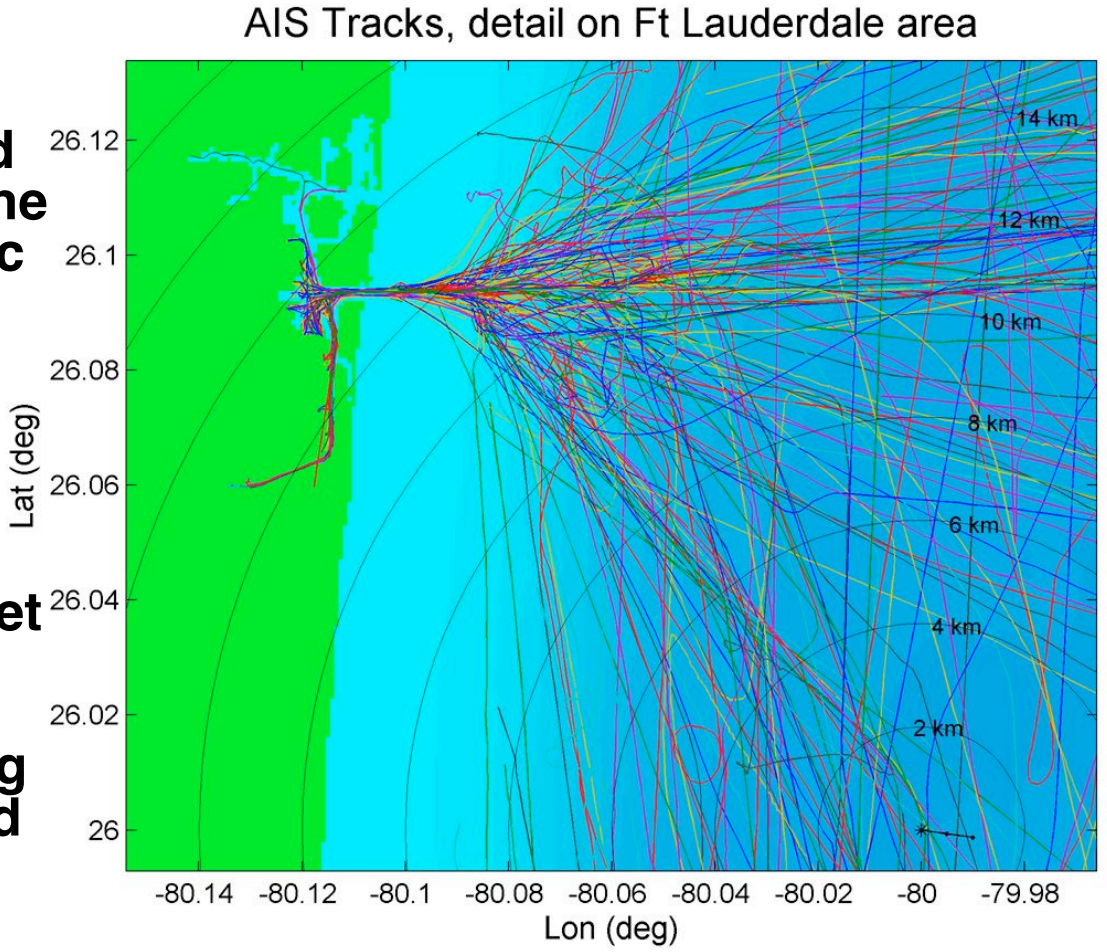
SWAP Overview

- The NEAR Lab at Portland State is tasked with determining the physical limits of array signal gain in this environment. One challenge for the processing is the length of observation time needed by traditional adaptive beamforming formulations - with an array of this size and element quantity, the resolution of range and bearing cells is such that a ship may move across many cells during the snapshot time, spreading the resulting eigenvector structure and decreasing effective signal gain. A central question is the trade-off between array gain and this eigenvector spreading loss.



SWAP Overview

- **To explore this question, tracks from actual ships in the vicinity of the array site, combined with sound speed and bathymetry data from the site, are used in an adiabatic normal mode simulation to predict the acoustic response across the array. The resulting simulated snapshots are used in adaptive and non-adaptive formulations to predict target detection performance as a function of the interference environment and processing parameters, for both full and sub-aperture processing schemes.**



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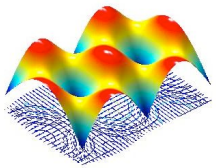


AIS Track Analysis

- Motivation: Develop a high-level model of the signal environment
  - Determine typical behavior and distribution of large ships
  - AIS (Automatic Identification System) provides this data
  - Large ships are a typical loud noise source

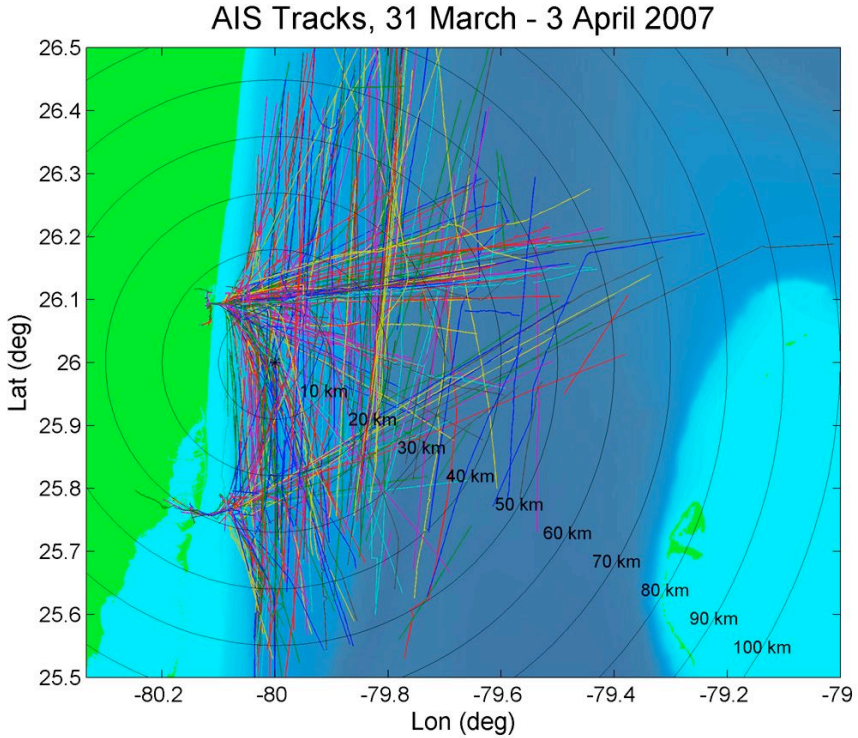
- We are interested in:
  - How many ships appear within a certain range of the array, as a function of time
  - Whether this is correlated with the tide and other factors
  - Whether there are high-traffic channels within range of the array, and how well they represent the distribution of ships
  - Typical time for a ship to transit the audible range

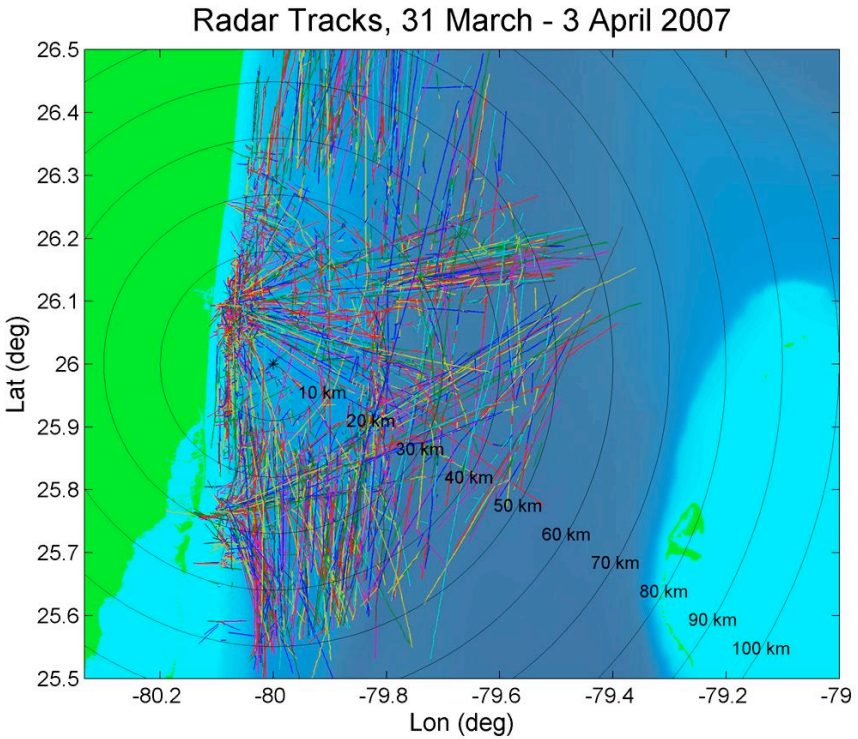
AIS and Bathymetry Data

- Radar and AIS Data from SFTF
  - 94 continuous hours, beginning midnight 31 March 2007 EST
  - AIS required for vessels over 300 tons
  - 275 MB of NMEA 0183 string data, reduced to 9 MB
    - Time converted to integer minutes, unused NMEA fields removed
    - MATLAB still takes a while to parse and manipulate this data
  - Supplied by Will Venezia, South Florida Test Facility

- Bathymetry data from NOAA
  - Currently used as geographic reference
  - Will be used for range-dependent acoustic propagation model
  - 3 arcsecond resolution (85 m x 92 m at SFTF latitude), finer than 1 m depth resolution
  - Distance and bearing calculations done in geographic coordinates to avoid spherical surface errors. Direct paths are great circles, etc.

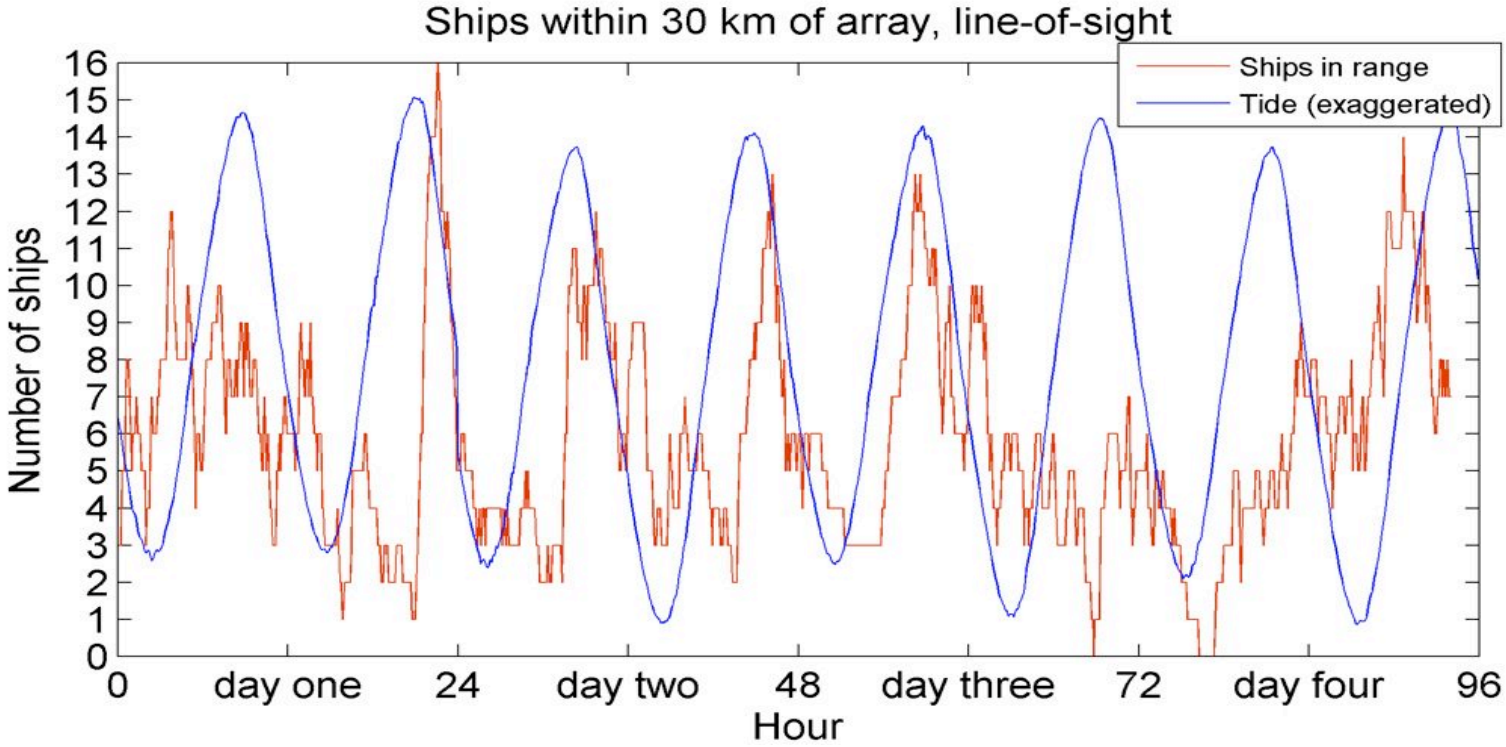
Radar and AIS Data from SFTF



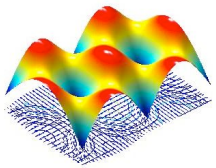


- **Ship tracks from radar and Automatic Identification System (AIS)**
  - **Radar looks east with horizon at ~50 km**
  - **Radar data has intermittent tracks, blind spots, AIS is more stable**

Results: Ships within audible range



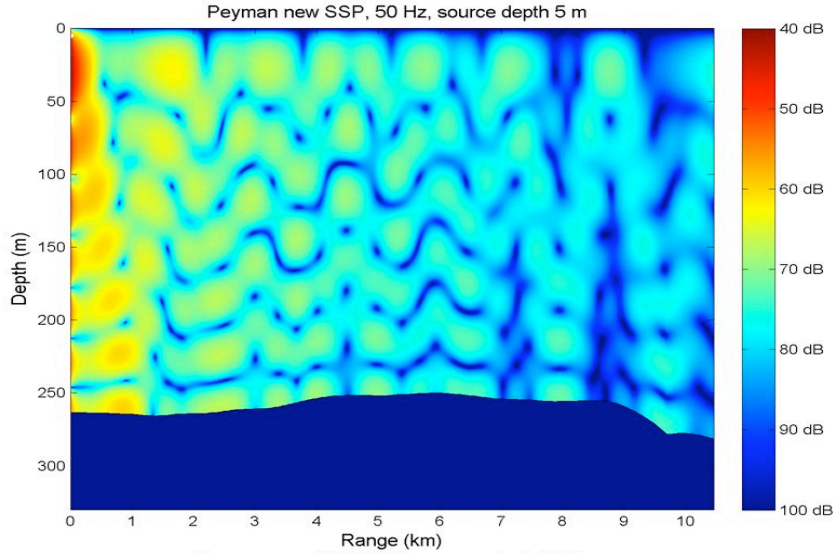
- No more than sixteen AIS tracks within audible range, usually less
- Consecutive spikes strongly correlated with slack tide
- Tide data is from a NOAA sensor site at Virginia Key near Miami
- Audible range is taken to be 30 km omnidirectional
- Line of sight is defined as a great circle path through water > 3m deep, this filters out ships docked inside Ft Lauderdale

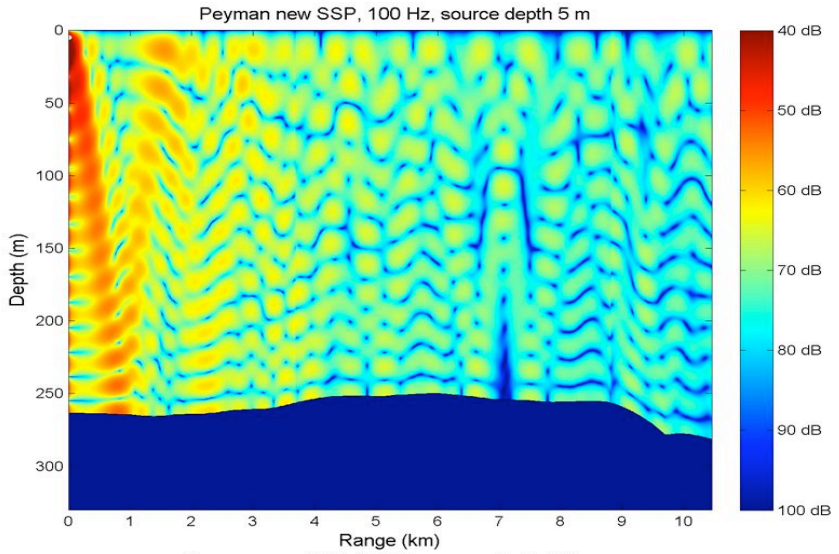


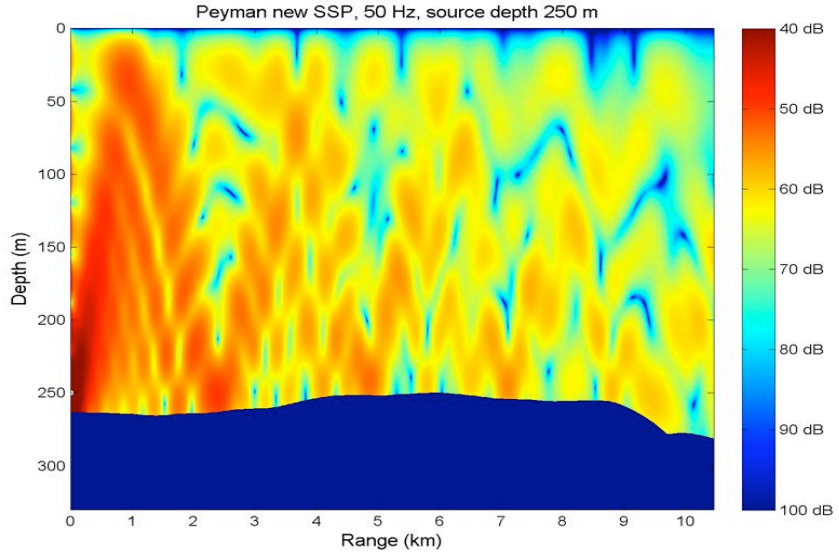
Adiabatic Transmission Loss Model

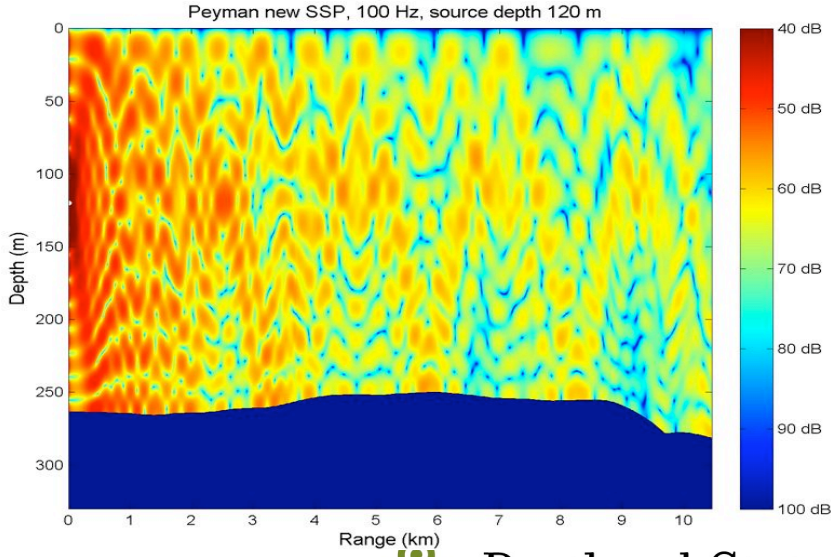
- KRAKEN is used to compute all modes at a range of water column depths for a given environment
- Matlab routines assemble modes in an adiabatic approximation for the given bathymetry cross-section
- Pressure field is accurate for weakly varying bathymetry
- TL at various distances agrees with established theory for normal mode propagation

Adiabatic Transmission Loss Model









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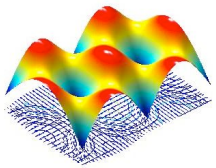
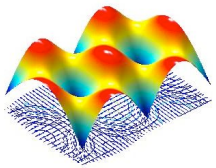


Summary and Ongoing Work

- AIS data from SFTF provides sample ship tracks
- Bathymetry and sound speed profile data from the site are fed to KRAKEN in an adiabatic approximation model for each receiver element due to each point along the track
- This can be done with one or many targets and interference sources by summing the pressure vectors due to each source, and noise can be added
- The resulting pressure vector can be used to evaluate conventional and adaptive beamforming techniques



Publications

- Characterization and migitation of noise for Shallow Water Array Performance (SWAP). Lisa M. Zurk and Richard Campbell, submitted to Pacific Rim Underwater Acoustics Conference 2007
- Effect on Surface Ship Interference on Adaptive Beamforming for the Shallow Water Array Performance (SWAP) Project. Richard Campbell & Lisa M. Zurk, submitted to Acoustical Society of America 2007