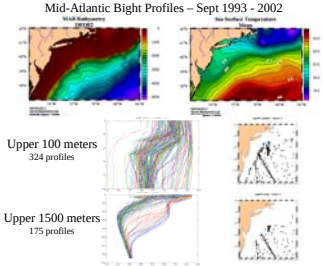
Cluster-Based Characterization of Ocean Variability

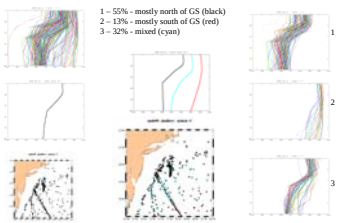
D. N. Fox[1], P. Gallacher[1], A. Warn-Varnas[1] and R. Broome[2]
[1]Naval Research Laboratory, Stennis Space Center, MS, 39529-5004
[2]Planning Systems Inc. Slidell, LA

Acoustic propagation can be highly sensitive to specific features in the sound speed structure of the ocean. Short of in situ measurements, it can be useful to characterize an area based on historical and modeled profiles to determine if there are a few dominant modes that occur and how often those modes occur. In many areas, in situ measured profiles are sparse or unavailable. Using measured profiles and certain derived parameters of acoustic relevance, we examine the resulting clusters and compare them with those derived from numerical ocean models.

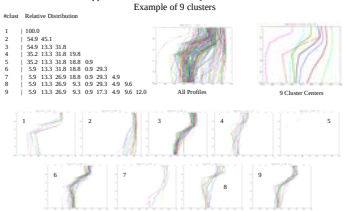
Mid-Atlantic Bight Profiles – Sept 1993 - 2002



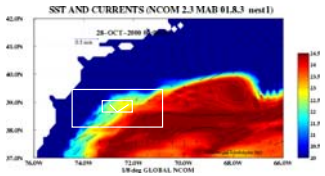
Mid-Atlantic Bight Profiles – Sept 1993 – 2002
Upper 100 meters: Case of 3 presumed clusters



Mid-Atlantic Bight Profiles – Sept 1993 – 2002
Upper 100 meters: How many clusters to use?
Example of 9 clusters



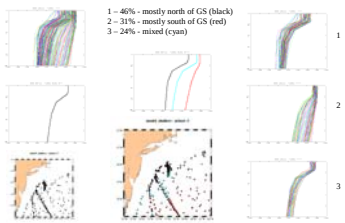
MAB Nests



Navy Coastal Ocean Model (NCOM) MidAtlantic Bight Version

- Horizontal
  - C grid, dx = dy = 1/8°, 12km
  - First nest, dx =dy = 1/24°, 4km
  - Second nest, dx =dy = 1/72°, 1.33km
- Vertical
  - 41 levels, 21 sigma, 20 z, dz varies between approx. 1m and 100m
- Bathymetry
  - DBDB5 enhanced with DBDB2 and Sandwell and CIA coastline (Ko and McKinney)
- Temporal
  - Leapfrog, dt = 360 sec, dt = 120 sec, dt = 40 sec
- Forcing and Initial Conditions
  - COAMPS West Atlantic Domain Wind Stresses
  - NCOM Global 1/8° Model
    - Currents (U, V), Sea surface elevation, Temperature, Salinity
  - ADCIRC
    - 8 Tidal components

Mid-Atlantic Bight NCOM Model – Sept 2000
Upper 100 meters: Case of 3 presumed clusters



Cluster analysis uses similarity measures to group observations together. Three choices must be made:

1. Selecting the parameters for the analysis. We want the clusters to define profiles which are acoustically similar, so the we chose sound speed, mixed layer depth, and near-surface vertical sound speed gradient.

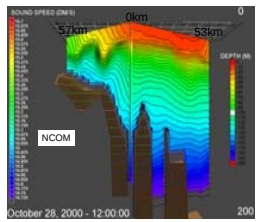
2. The measure of similarity, also called the resemblance coefficient. Three resemblance coefficients (Euclidian distance, cosine coefficient, and coefficient of shape difference) were tried.

3. The clustering method, which defines how observations are grouped together based on their resemblance coefficients. Two algorithms, Ward's minimum variance and the Un-weighted Pair-Group Method using Arithmetic Averages were examined.

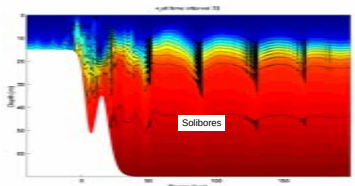
The best results were obtained using the Euclidian distance and applying Ward's minimum variance algorithm.

Navy Coastal Ocean Model (NCOM)

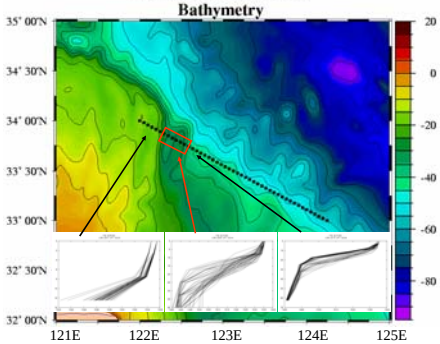
Dynamic Ocean Model



Lamb (1994) model



Soliton Model Locations Bathymetry



Most of the profiles extracted from the model showed no acoustically significant variability except near the shelf break, where strong soliton formation occurred.

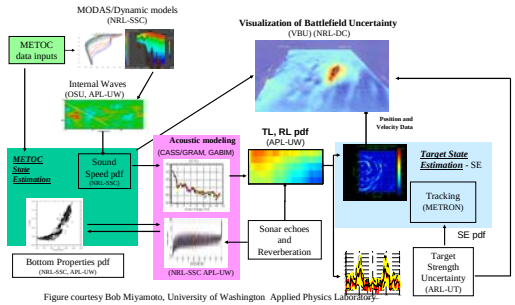
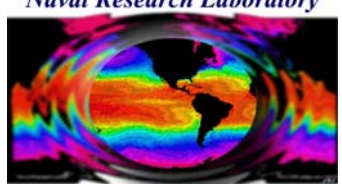


Figure courtesy Bob Miyamoto, University of Washington Applied Physics Laboratory

The ultimate objective is to use existing science to characterize and represent the uncertainty in the tactical and environmental picture due to uncertainty about environmental features that affect active acoustic detection of submarines.

The mean and variability within each cluster are used by other applications to examine the impact on acoustic propagation (such as tranmission loss) to provide a more realistic measure of the probability of detecting undersea targets and it's uncertainty.