Harvard Projects

1. **Dynamics of Oceanic Motions (ARR)**

2. **Physical and Interdisciplinary Regional Ocean Dynamics and Modeling Systems (PFJL)**

3. **MURI-ASAP (Adaptive Sampling And Predictions)**

4. **PLUSNET: Persistent Littoral Undersea Surveillance Network**

5. **AWACS: Autonomous Wide Aperture Cluster for Surveillance**

6. **Pending:**

   - **Interdisciplinary Modeling and Dynamics of Archipelago Straits**

Undersea Surveillance Seascape

Tom Curtin et al, ONR

Sensors
Energy
Comms
Navigation
Control
Modeling

ONR 31/32/33/35/NRL Team Efforts

6.1 Adaptive Mobile Networks

Targeted observations
Cooperative behavior

Adaptive gain Clutter/Noise suppression

Four dimensional target discrimination
Mobile sensor environmental adaptation

Target interdiction with mobile sensors

Fixed surface nodes

Component technologies

Fixed bottom nodes

Adaptive path planning

Prototype system integration and testing

6.2 Adaptive Mobile nodes

6.3 Trip wires, track and trail

Adaptive Sampling and Prediction Using Mobile Sensing Networks (ASAP)

Autonomous Wide Aperture Cluster for Surveillance (AWACS)

Undersea Persistent Surveillance (UPS-PLUSNet)

Undersea Persistent Glider Patrol / Intervention (Sea Sentry)

Undersea Bottom-stationed Network Interdiction (CAATS)

Persistent Ocean Surveillance (POS)

Congressional Plus-ups

ONR/DARPA/NAVSEA SBIR efforts

Littoral Anti-Submarine Warfare (FNC)

Autonomous Operations (FNC)

Persistent Littoral Undersea Surveillance (PLUS) (INP)

PMS-403
PEO-LMW
Submarine T&T

Task Force ASW
PEO-IWS Theater ASW BAA

ONR Team-Efforts

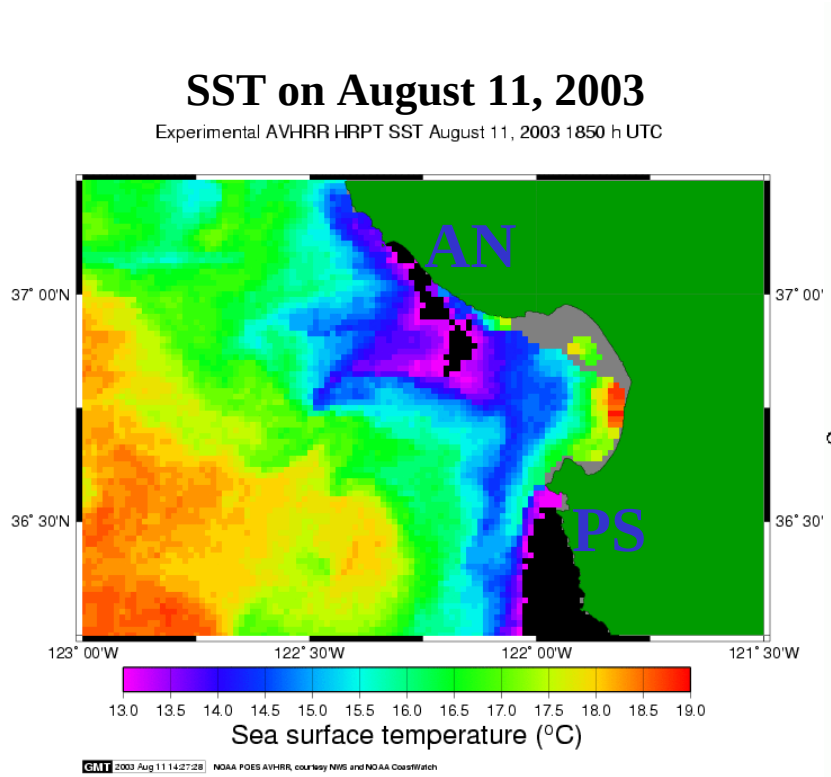
(with Harvard as co-PI)

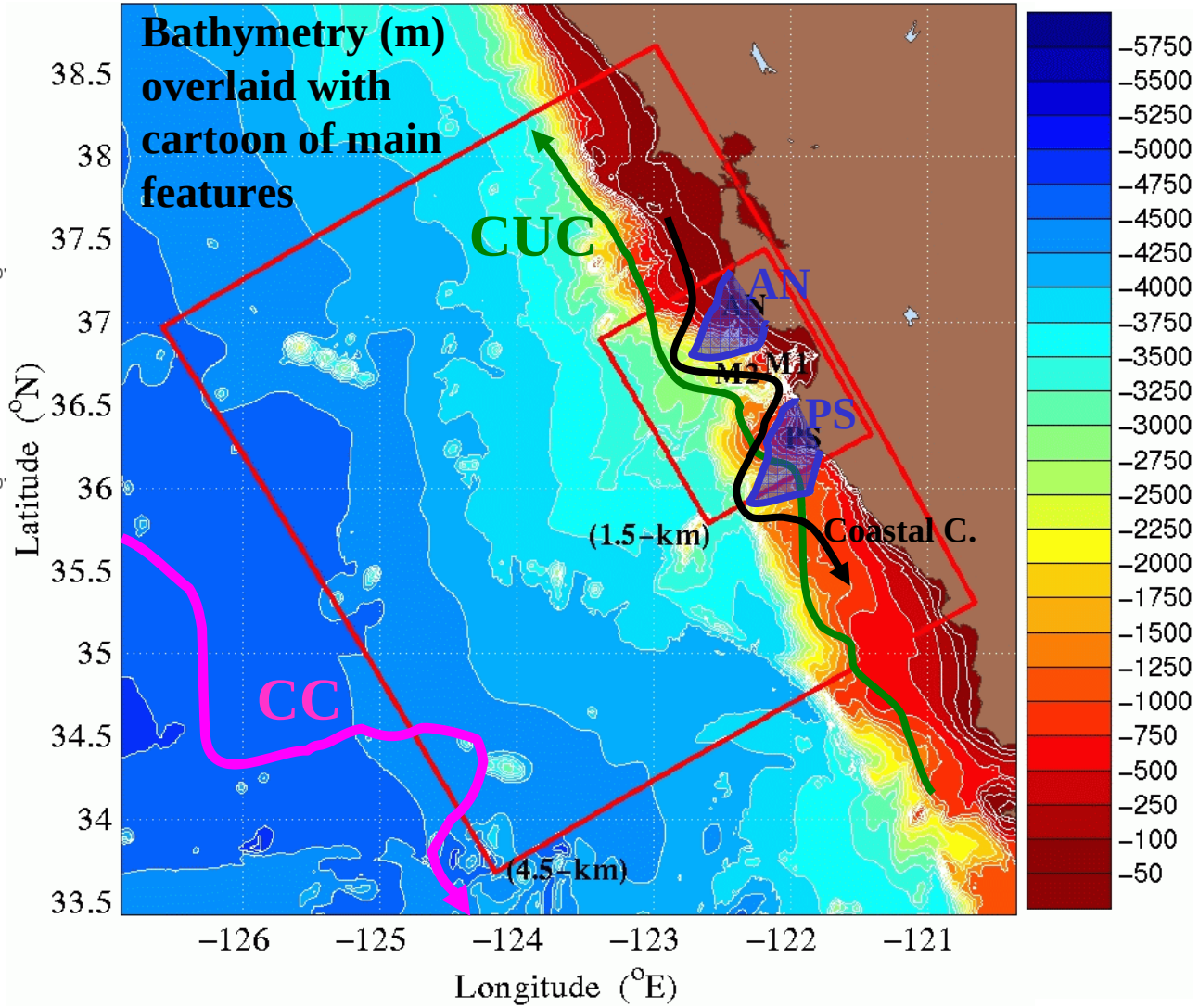
ONR
DARPA
NAVSEA

Italics: potential new program

MURI-ASAP: Adaptive Sampling And Predictions

REGIONAL FEATURES of Monterey Bay and California Current System





REGIONAL FEATURES

- **Upwelling centers at Pt AN/ Pt Sur:**……Upwelled water advected equatorward and seaward
- **Coastal current, eddies, squirts, filam., etc:**….Upwelling-induced jets and high (sub)-mesoscale var. in CTZ
- **California Undercurrent (CUC):**……..Poleward flow/jet, 10-100km offshore, 50-300m depth
- **California Current (CC):**……Broad southward flow, 100-1350km offshore, 0-500m depth

Top Three Tasks to Carry Out/Problems to Address

1. **Determine details of three metrics for adaptive sampling (coverage, dynamics, uncertainties) and develop schemes and exercise software for their integrated use**

2. **Carry out cooperative real-time data-driven predictions with adaptive sampling**

3. **Advance scientific understanding of 3D upwelling/relaxation dynamics and carry out budget analyses as possible**

Persistent Littoral Undersea Surveillance Network (PLUSNet)

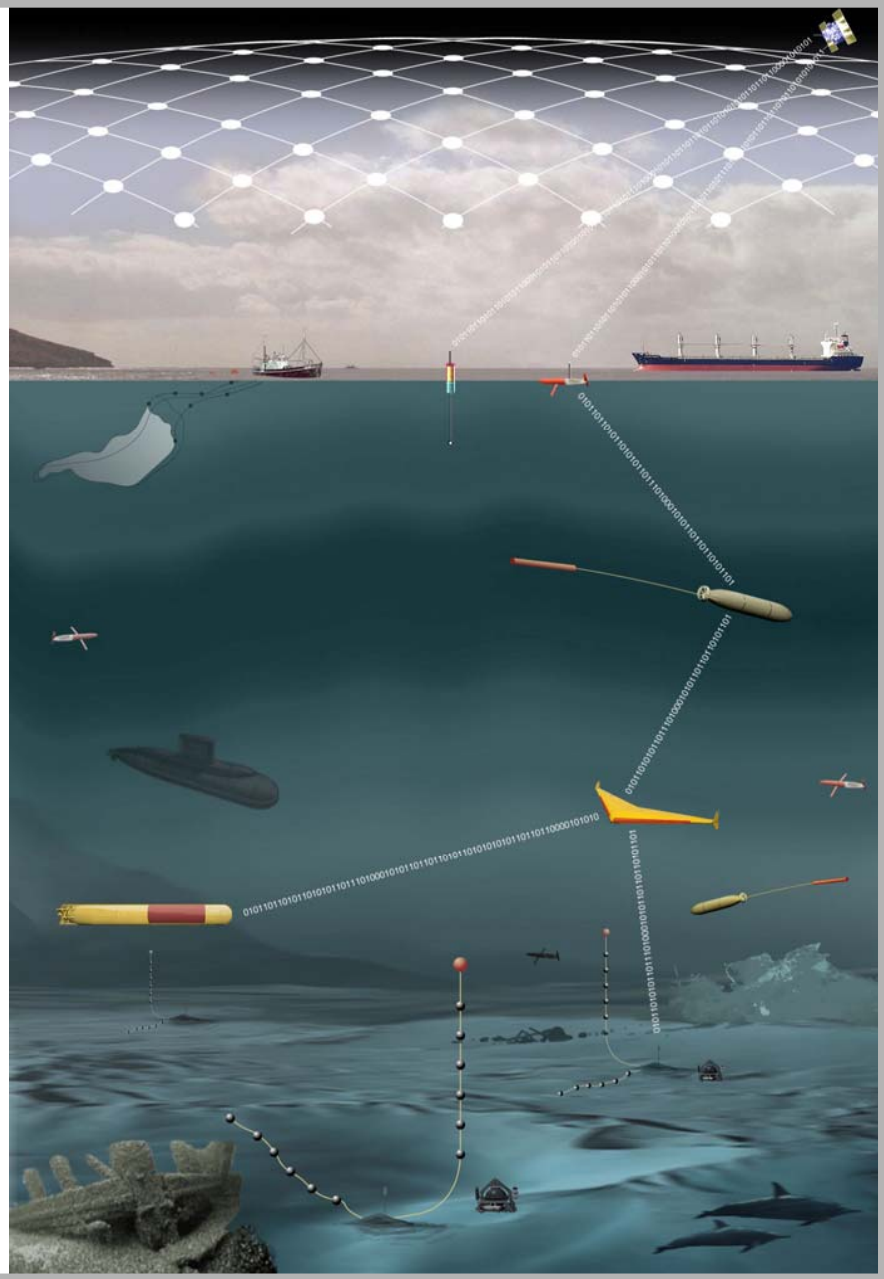
Lead: Kuperman, Schmidt et al.

- Adaptive Environmental Assessment and Predictions with distributed network of fixed and mobile sensors

- Coordination via network control architecture and covert communications

- Real time sensing of the tactical and oceanographic environments allows reconfiguring the distributed network of sensors for improved DCL

- Existing and emerging technologies available within the PLUSNet Team enables a system level concept demonstration in three years



PLUSNet: Harvard Research Thrusts

1. Multi-Scale and Non-Hydrostatic Nested Ocean Modeling

- Research and develop relocatable sub-mesoscale nested modeling capability:
  - Higher-resolution hydrostatic model (Mini-HOPS)
  - HOPS coupled with non-hydrostatic models (2D to 3D, e.g. Lamb, Smolarkiewicz or MIT-GCM)
- Compare parameterizations of sub-mesoscales and boundary layers, and evaluate with HOPS and ROMS (run at HU, collaborate with Scripps)
- Couple mini-HOPS/ESSE with selected sonar performance prediction (End-2-End System)

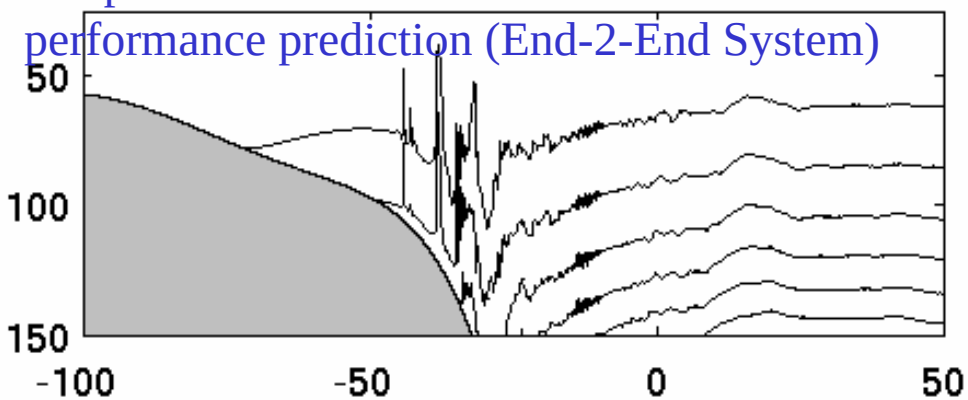


Fig 1. Density cross-section with internal waves and solitons using 2.5D non-hydrostatic Lamb model (HU collaborating with A. Warn-Varnas)

2. Coupled Physical-Acoustical Data Assimilation in real-time

- Integrate and optimize physical-acoustical DA software with Mini-HOPS and AREA
- Initiate coupled physical-acoustical-seabed estimation and DA

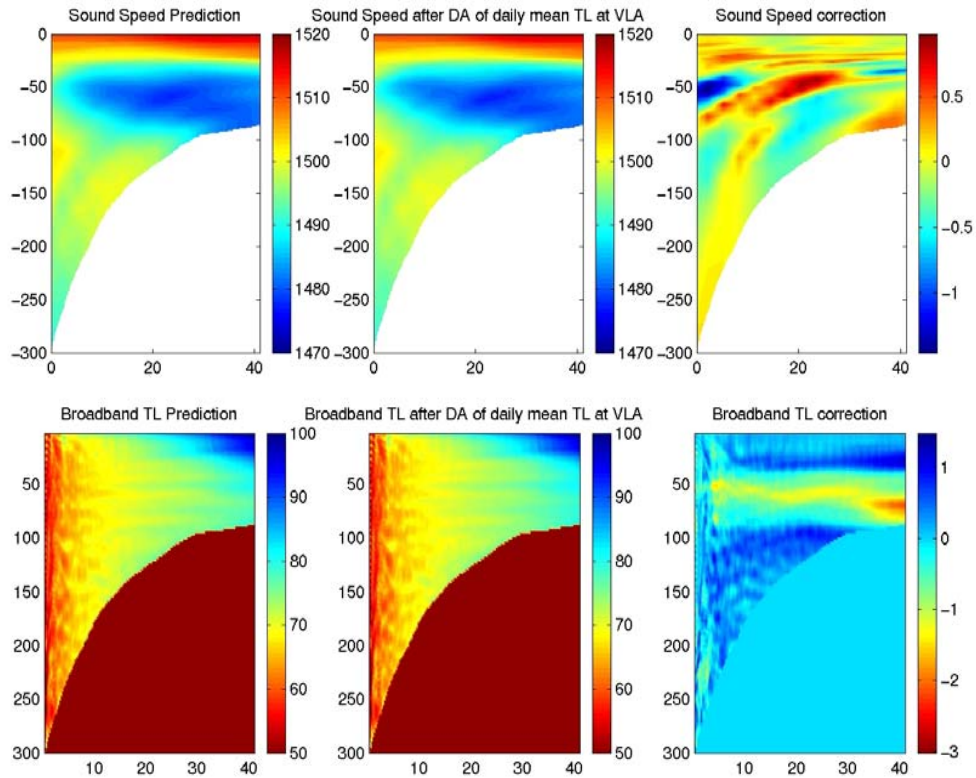


Fig 2. C and TL, before and after coupled DA of real data

3. Acoustical-Physical Nonlinear Adaptive Sampling with ESSE and AREA

- Implement and progressively demonstrate in FY05-06-07 experiments an automated adaptive environmental sampling, integrating mini-HOPS and ESSE with AREA

Example: Which of the 4 sampling tracks for tomorrow (see Fig. 3a below) will optimally reduce uncertainties the day after tomorrow?

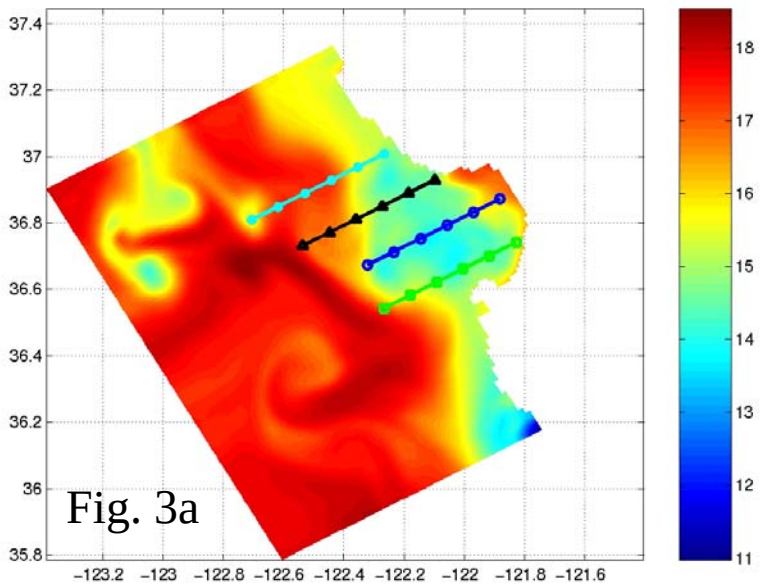
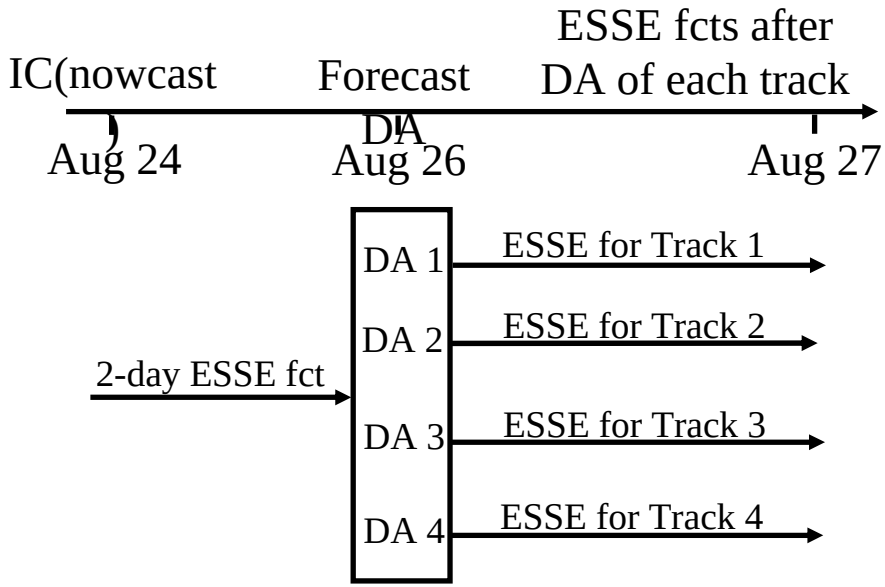


Fig. 3a

Use HOPS/ESSE and compute average error reduction over domain of interest. For full domain, best error reduction here (see Fig 3b on the right) is with Track 1



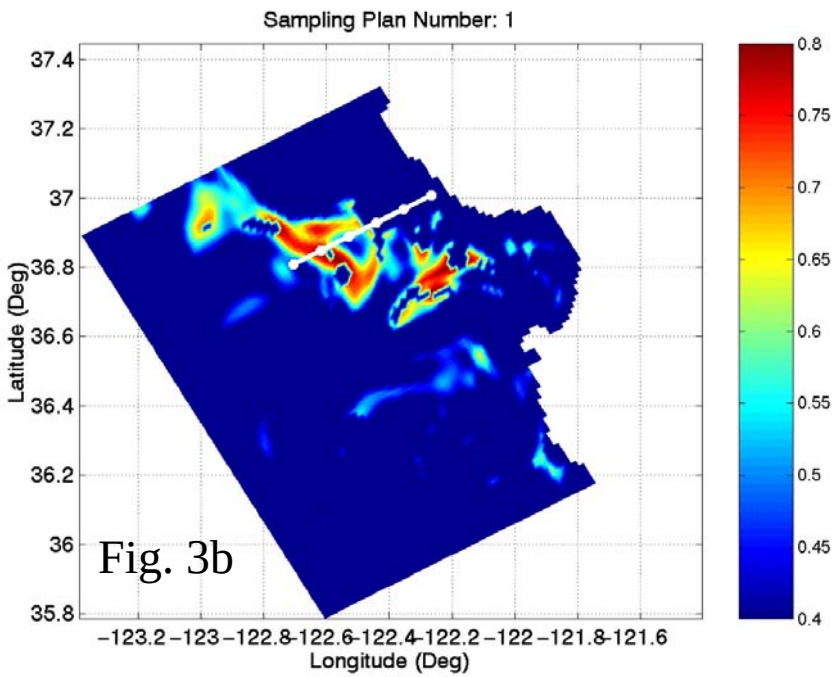


Fig. 3b

AWACS:
Modeling Set-Up for Ocean Dynamics
(Middle Atlantic Bight Shelfbreak Front – Hudson Canyon):

Pierre Lermusiaux, Pat Haley, Oleg Logoutov

Division of Engineering and Applied Sciences, Harvard University

Present Collaborators:
Glen Gawarkiewicz
Phil Abbot
Kevin Heaney
C-S Chiu

http://www.deas.harvard.edu/~pierrel

---

1. **HU Research Goals and Objectives**
2. **Modeling Domains and Bathymetry**
3. **Tidal Forcing for 2-Way nested simulation with new free-surface HOPS**
4. **Report of ASAP – AWACS Meeting (Princeton, June 24, 2005)**

AWACS Team Meeting January 11-12, 2006

Harvard AWACS Research Goal and Objectives

Goal: Improve modeling of ocean dynamics, and develop and evaluate new adaptive sampling and search methodologies, for the environments in which the main AWACS-06, -07 and -09 experiments will occur, using the re-configurable REMUS cluster and coupled data assimilation

Specific objectives are to:

i. Evaluate current methods and develop new algorithms for adaptive environmental-acoustic sampling, search and coupled DA techniques (Stage 1), based on a re-configurable REMUS cluster and on idealized and realistic simulations (with NPS/OASIS/Duke)

ii. Research optimal REMUS configurations for the sampling of interactions of the oceanic mesoscale with inertial oscillations, internal tides and boundary layers (with WHOI/NPS/OASIS)

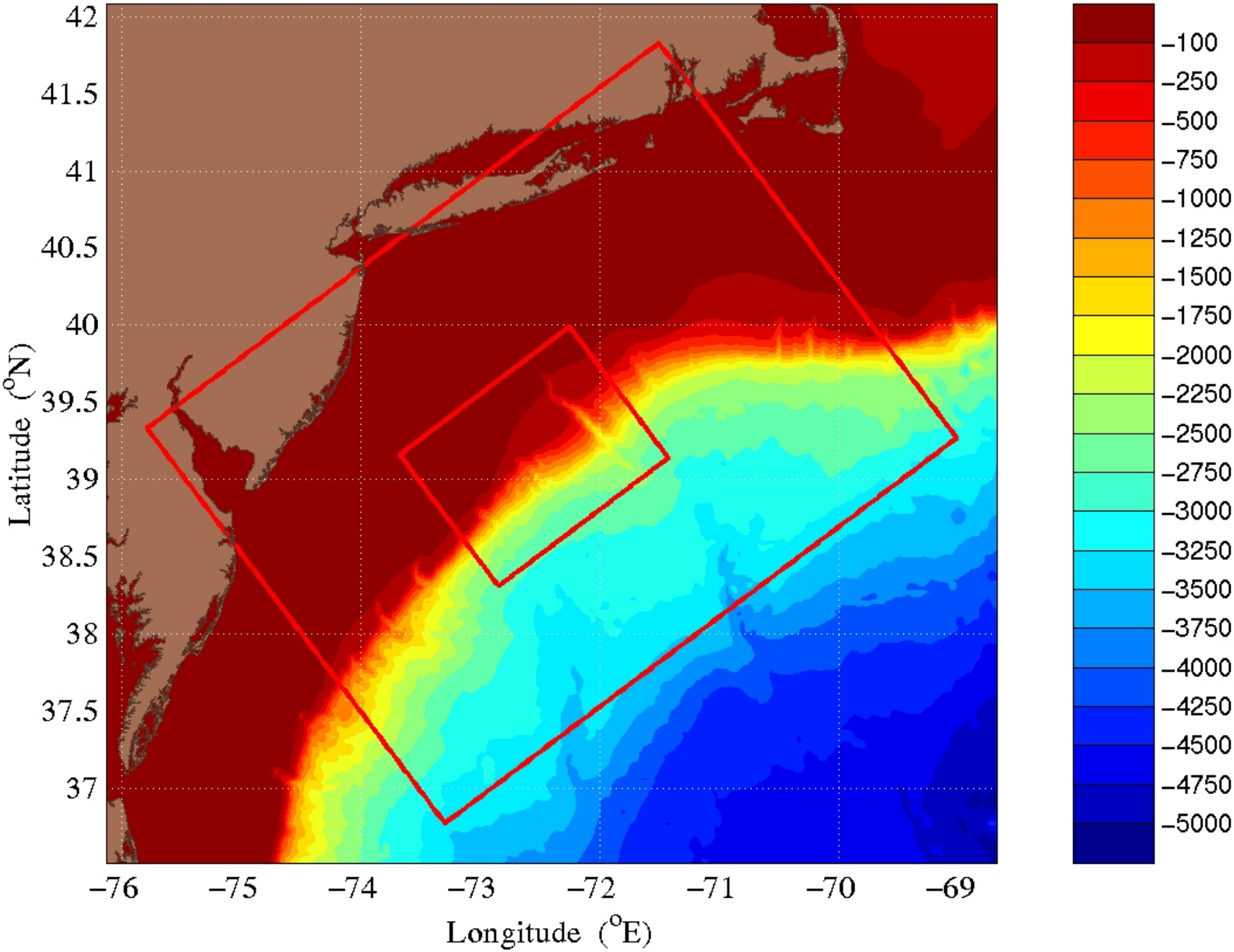
iii. Develop new adaptive ocean model parameterizations for specific AWACS-06, -07 and -09 processes, and compare these regional dynamics (with WHOI)

iv. Provide near real-time fields and uncertainties in AWACS-06, -07 and -09 experiments and, in the final 2 years, develop algorithms for fully-coupled physical-acoustical DA among relocatable nested 3D physical and 2D acoustical domains (with NPS)

v. Provide adaptive sampling guidance for array performance and surveillance (Stage 2), and link HU research with vehicle models and command and control

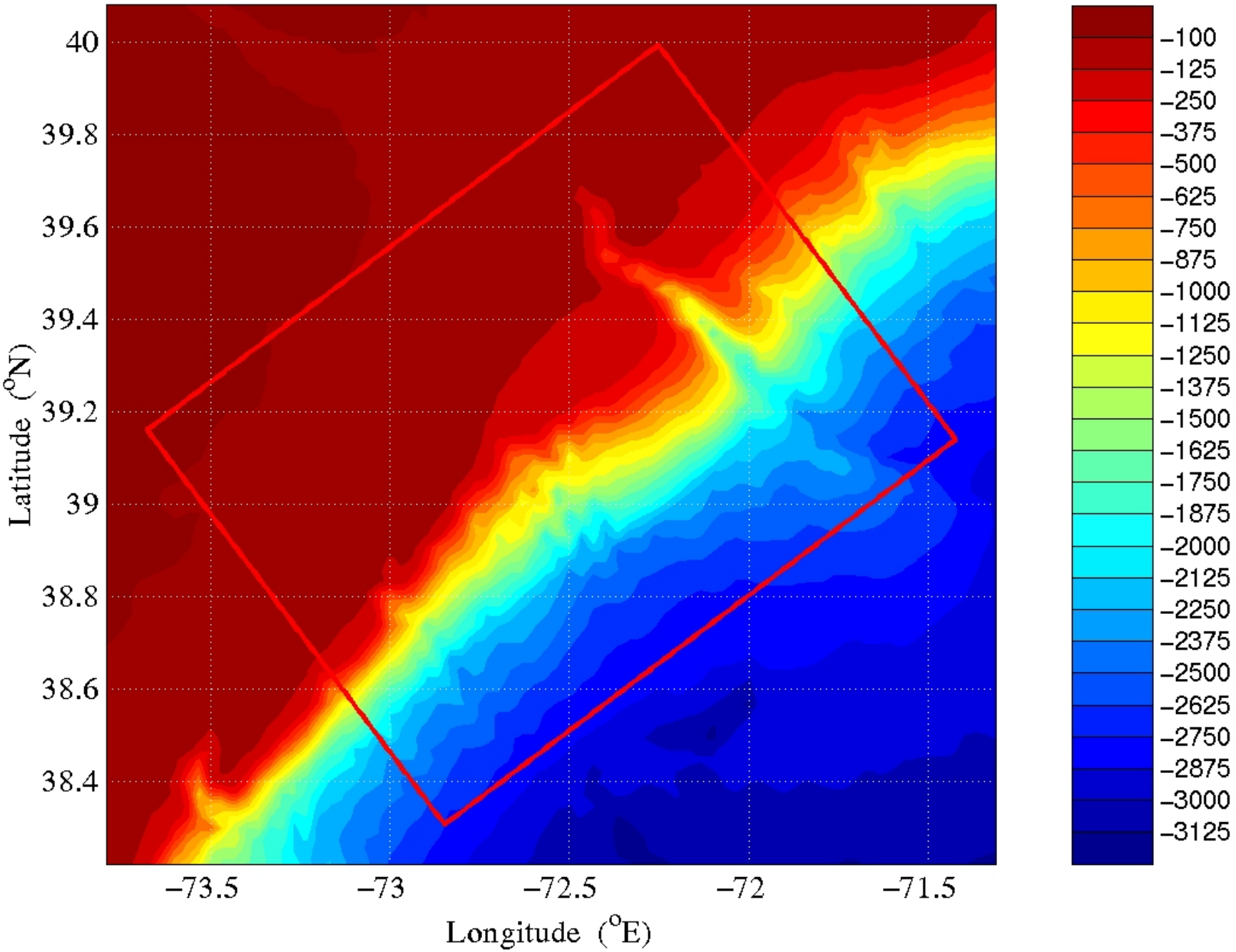
Model Domains overlaid on Bathymetry

(NOAA soundings combined with Smith and Sandwell)



SW06-Hudson Canyon Domain overlaid on Bathymetry

(NOAA soundings combined with Smith and Sandwell)



Preliminary Ocean Sampling Plans for AWACS/SW06

Glider, Scanfish Track and HU High-Res Model