Applying Basin-Scale HyCOM Hindcasts in Providing Open Boundary Conditions for Nested High-Resolution Coastal Circulation Modeling

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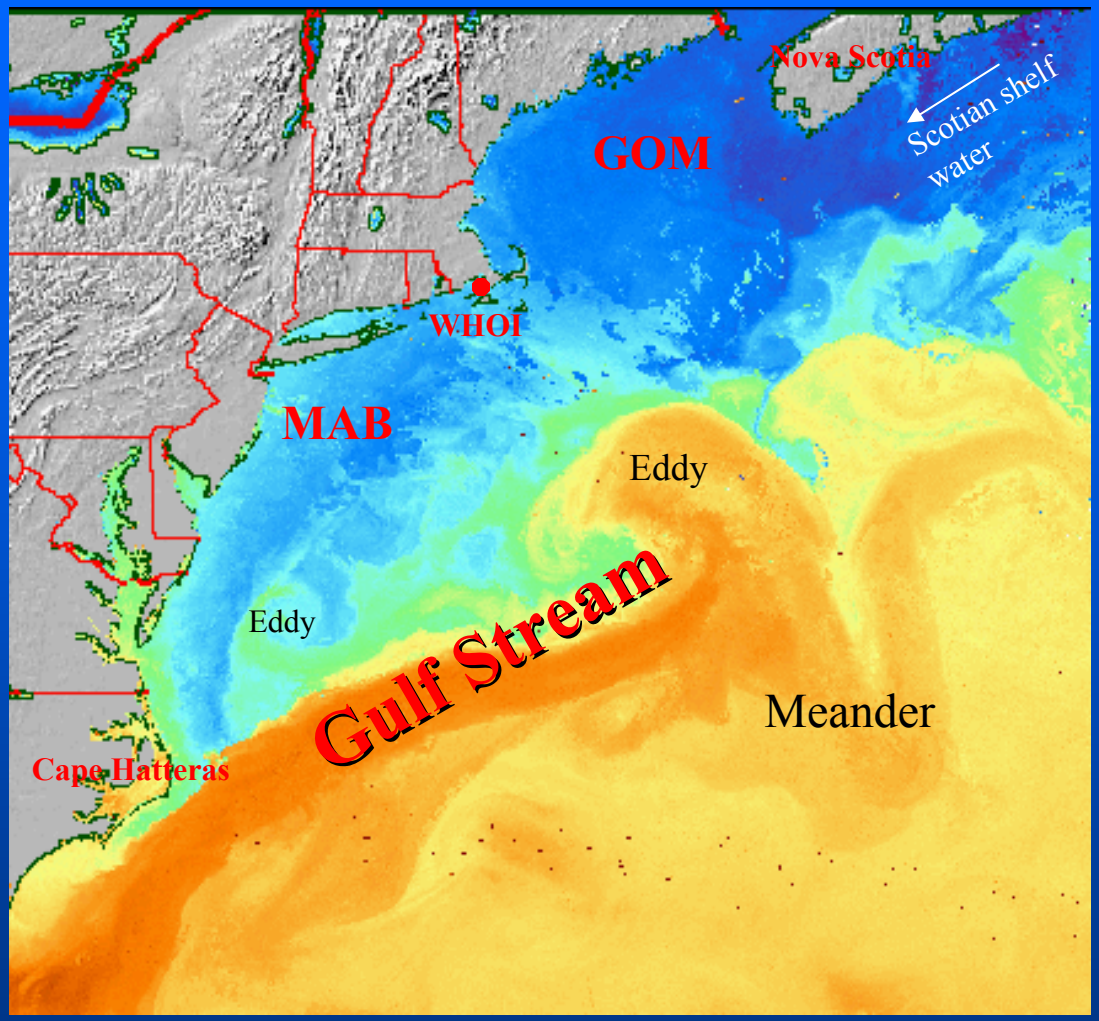
Satellite Sea Surface Temperature



Complex Coastal System

Confluence zone of the subpolar and subtropical western boundary currents

- **Has strong Local Forcing**
  Winds, Heat Flux, River Runoff
- **Has strong Offshore Forcing**
  Gulf Stream Meanders,
  Meso-scale, Sub meso-scale Eddies
- **Has strong Upstream Forcing**
  Cold and fresh Scotian Shelf Water

Understanding the coastal circulation is important to understand many scientifically and societally important coastal ocean problems

Outline

- Modeling Strategy
- Model/Data Comparisons (April –July, 2005)
- Shelf-Scale Mean Circulations (April –July, 2005)
- Shelf-Scale Dynamic Processes (April –July, 2005)
- High-resolution Regional MAB and GOM Circulation
- Summary

Modeling Strategy

- **Basin-scale Hybrid Coordinate Ocean Model (HYCOM)**

  1/12 degree best estimations assimilate satellite observed SSH and SST

- **MAB-GoM Shelf Model (ROMS)**

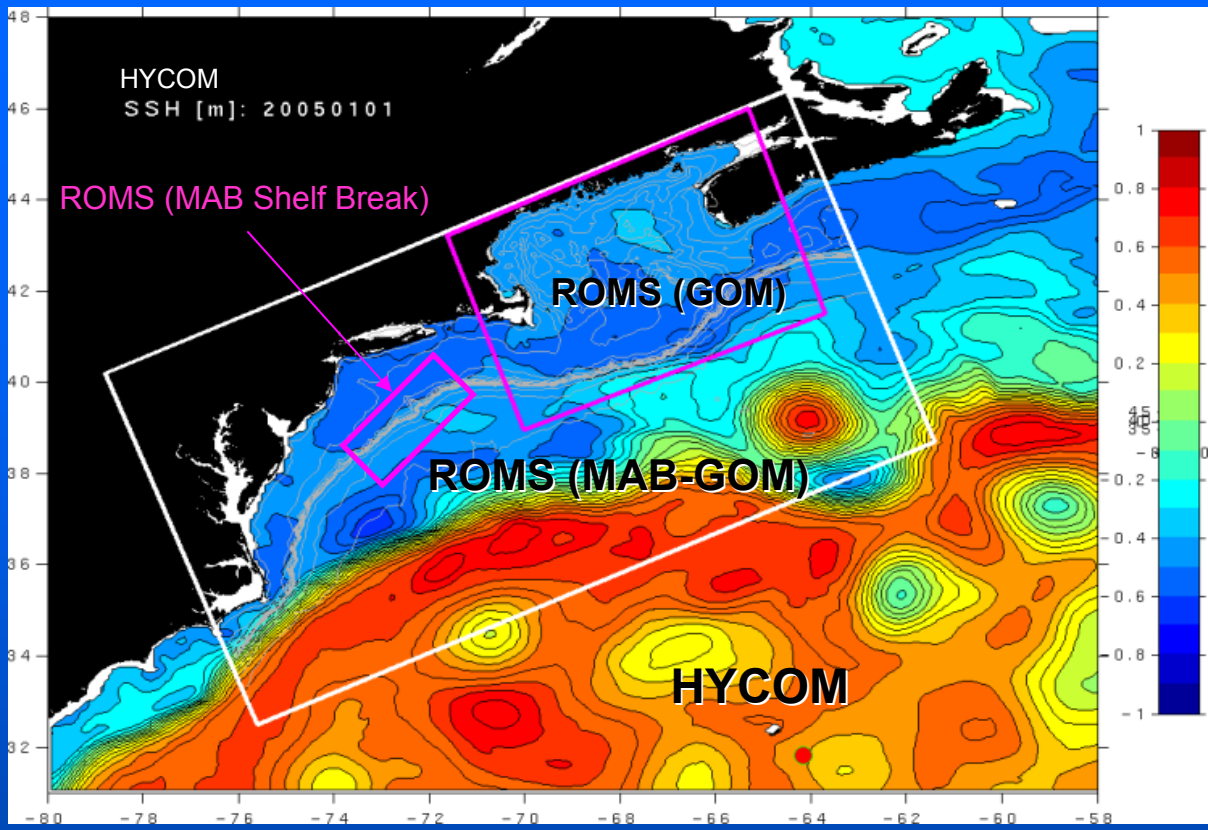
  ~ 3-10 km, 36 layers
  nested inside the HYCOM

- **High-Res Regional GoM Model (ROMS)**

  ~ 1- km, 36 layers
  nested inside the MAB-GOM ROMS

- **High-Res MAB Regional Shelf Break Model (ROMS)**

  ~ 1- km, 36 layers
  nested inside the MAB-GOM ROMS

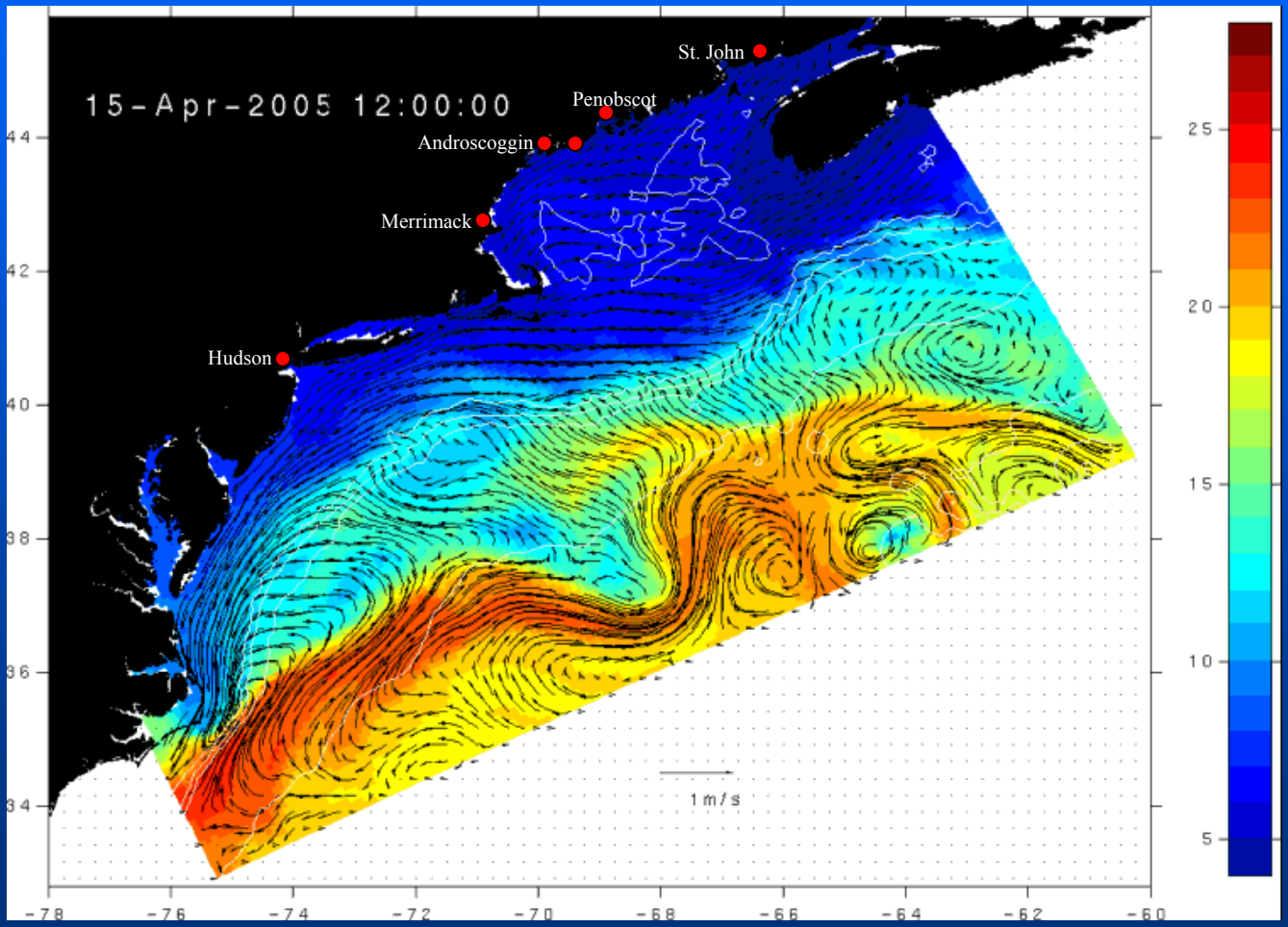


HYCOM T/S fields are used as the coastal models' initial conditions

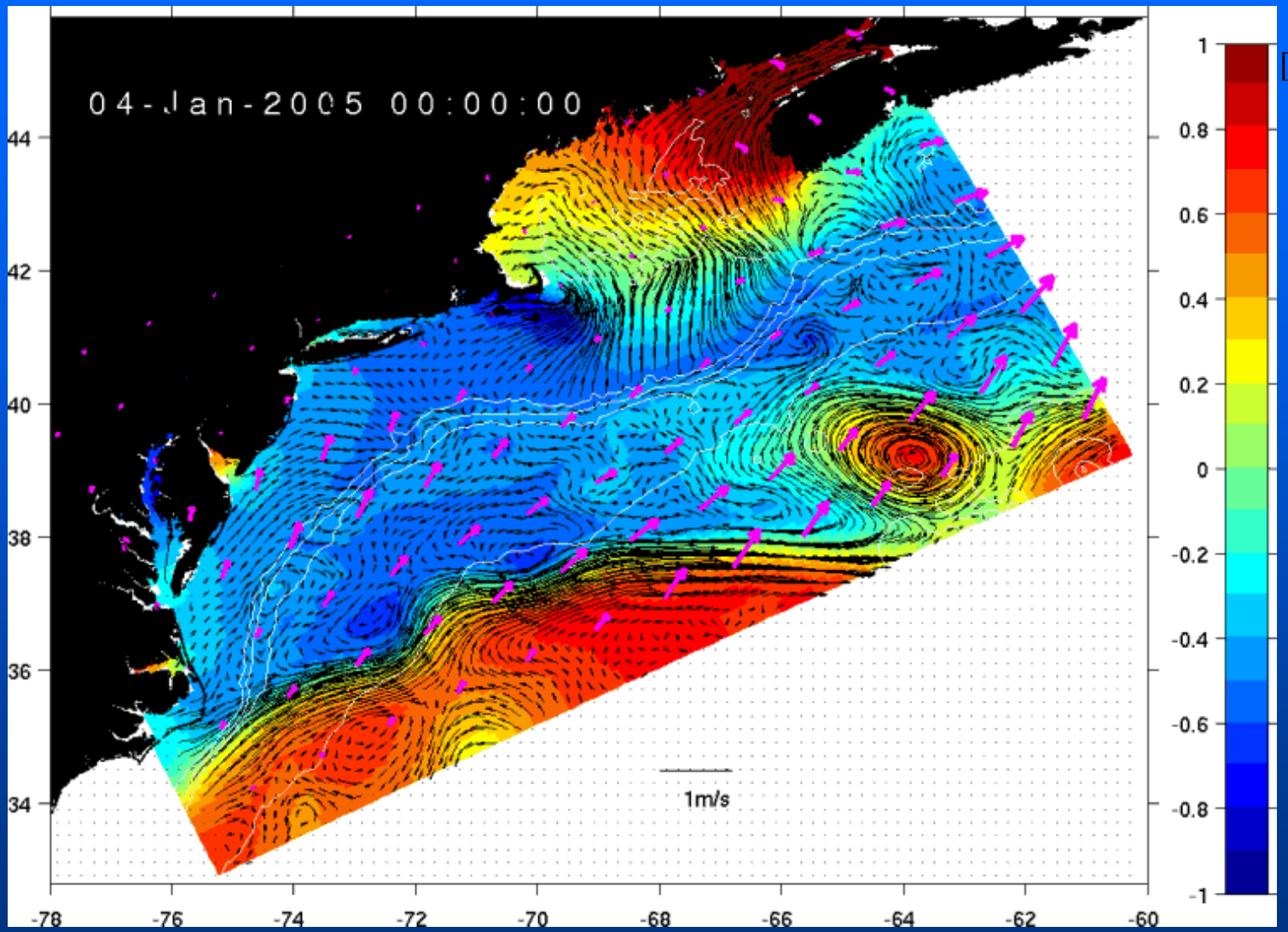
1-way nesting technique is applied to bring in deep ocean momentum and buoyancy fields (zeta, ubar, vbar, u, v, temp, salt) to the nested coastal Models

The objective of multiple-nesting is to bring deep-ocean influence to the coastal region in a dynamically consistent, and quantitatively accurate manner, thereby facilitating the realism of high-resolution coastal circulation modeling

Nested ROMS Modeled Daily-averaged SST and Surface Currents (April 15-July 31, 2005)



Modeled Sea Surface Height, Surface Current, along with Surface Wind fields. inclusive of tidal forcing (K_1, O_1, Q_1, M_2, S_2, N_2, K_2)



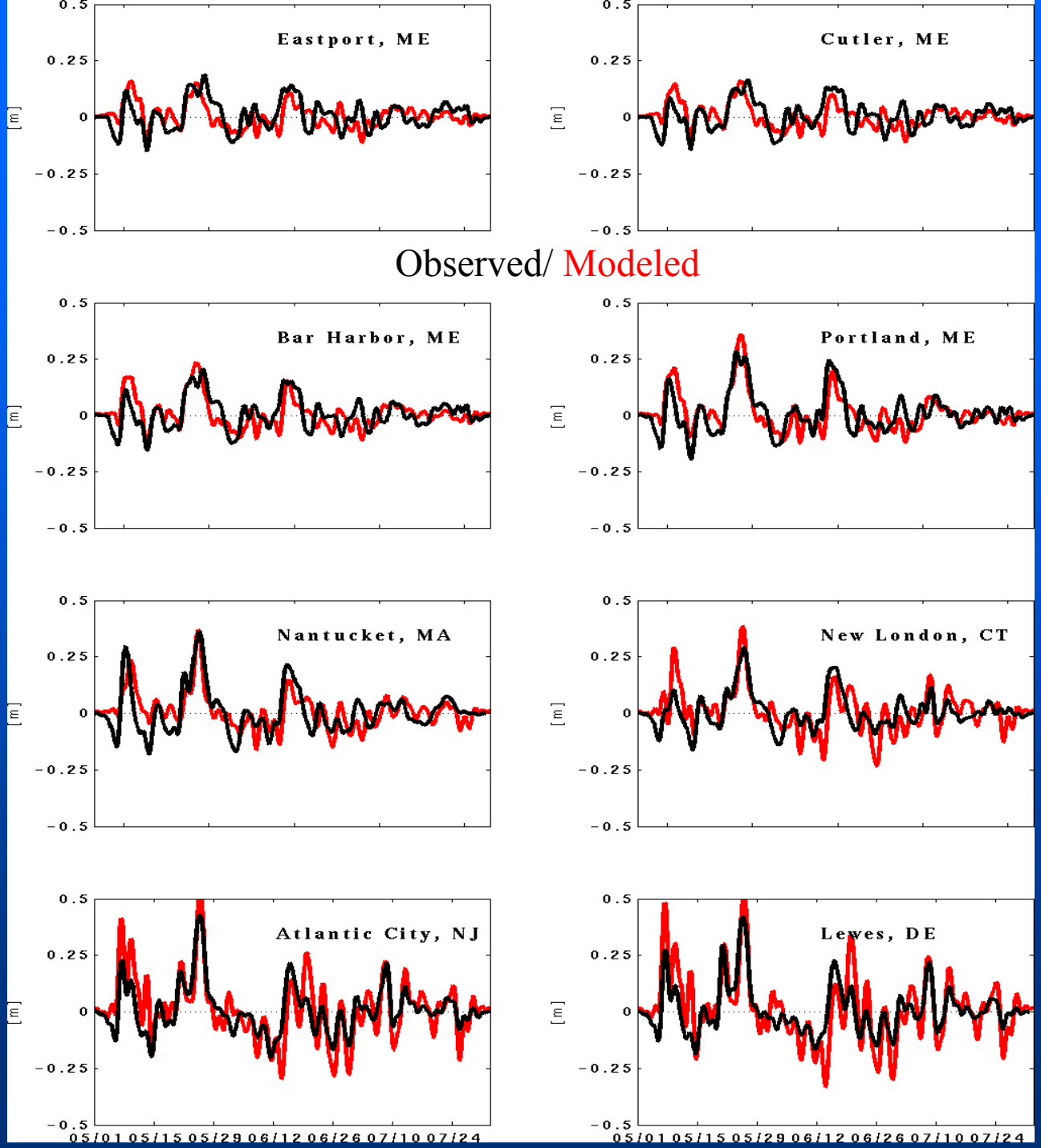
$$u = (u_{subtidal} + u_{tidal}) + \sqrt{g/h}(\varsigma - \varsigma_{subtidal} - \varsigma_{tidal})$$, Flather (1976)

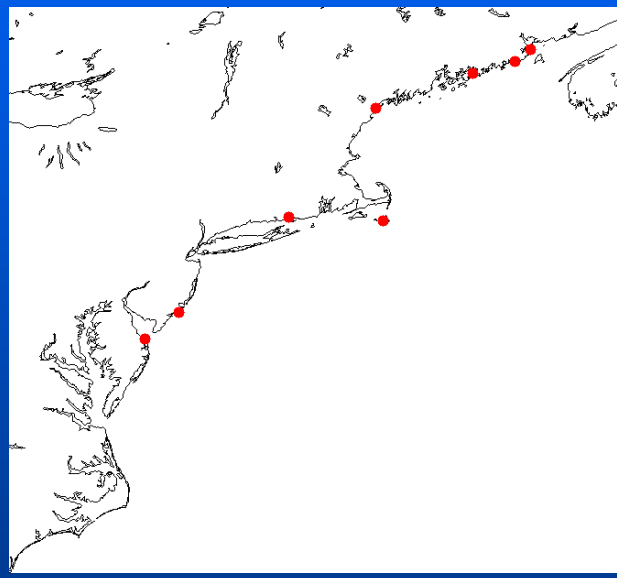
Subtidal Coastal Sea Level Comparisons

(May 1 – July 31, 2005)

36-hr low-pass filtered

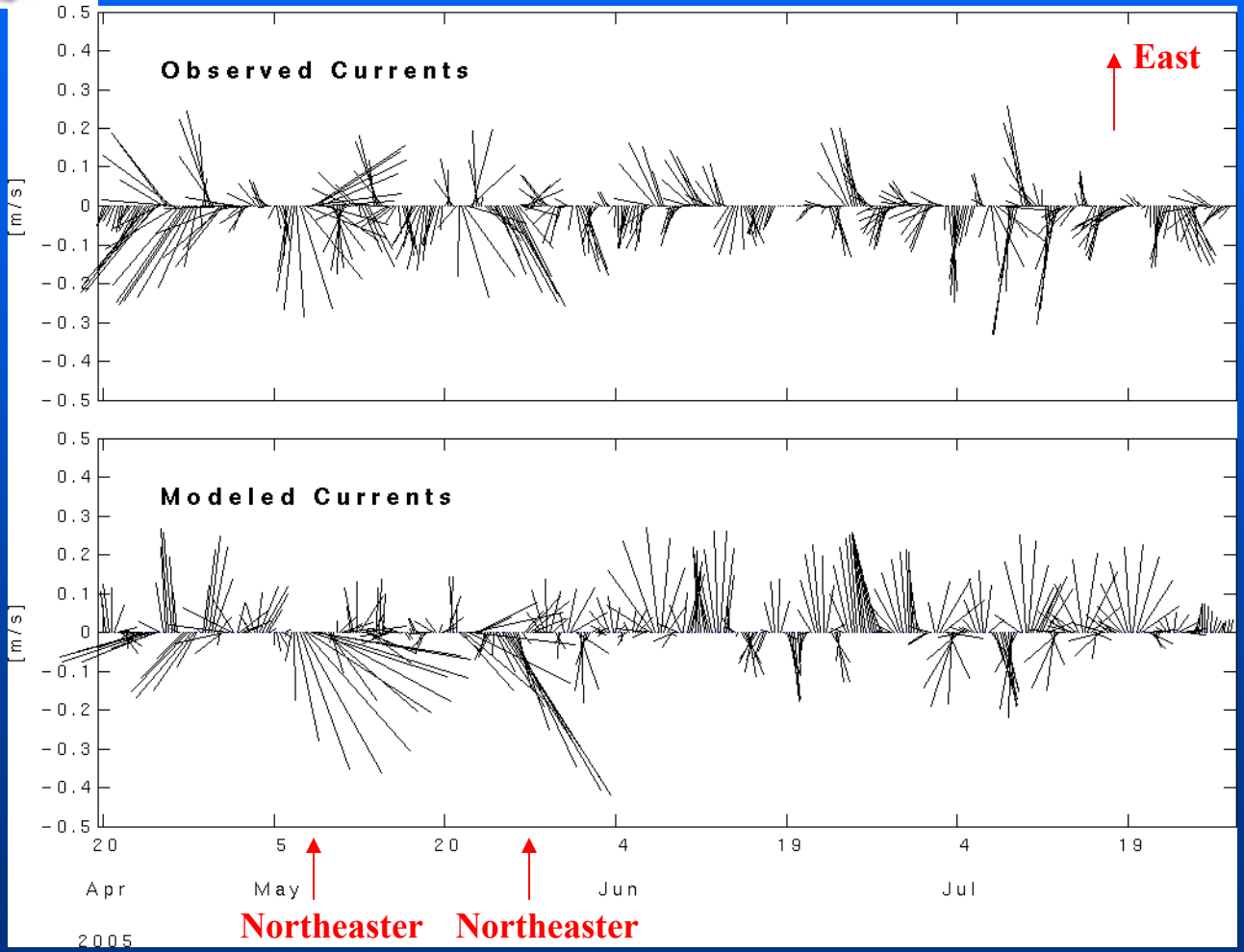
Observed/ Modeled





ADCP Current Comparisons

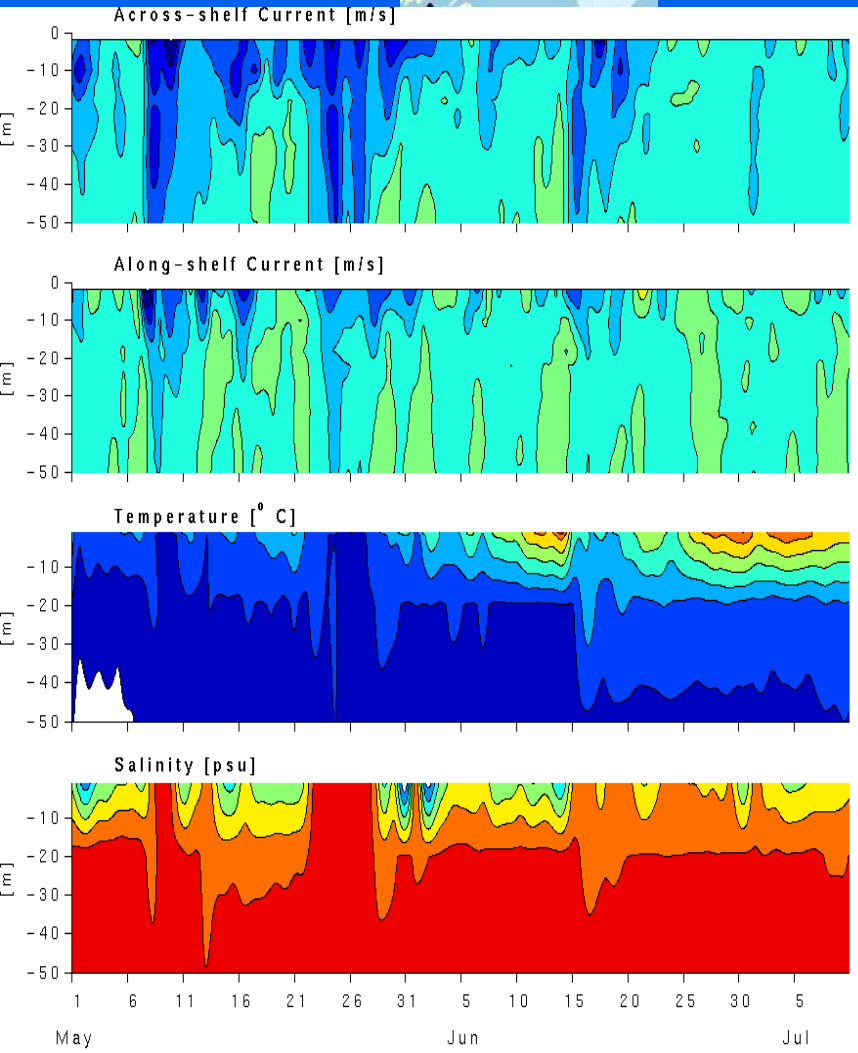
(at 15 m isobath in Martha's Vineyard Coastal Observatory [MVCO])



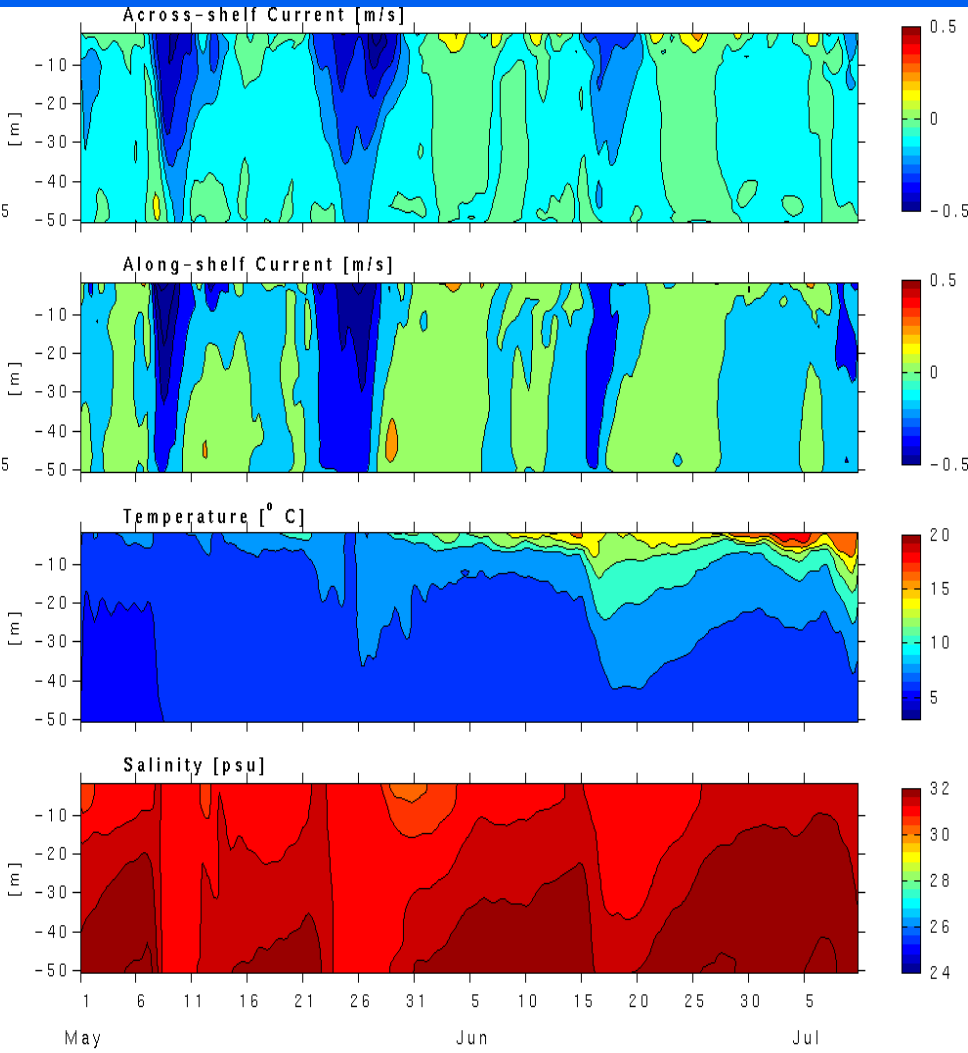
GoMOOS Mooring B (50 m isobath)

Problem of initial conditions!

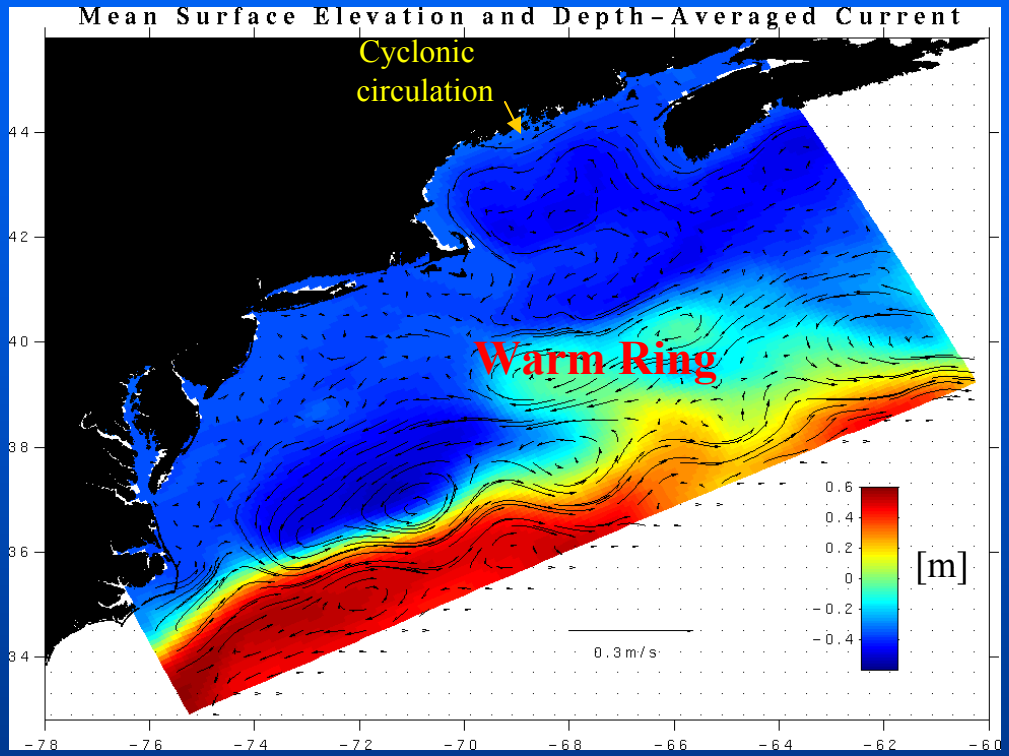
Observation

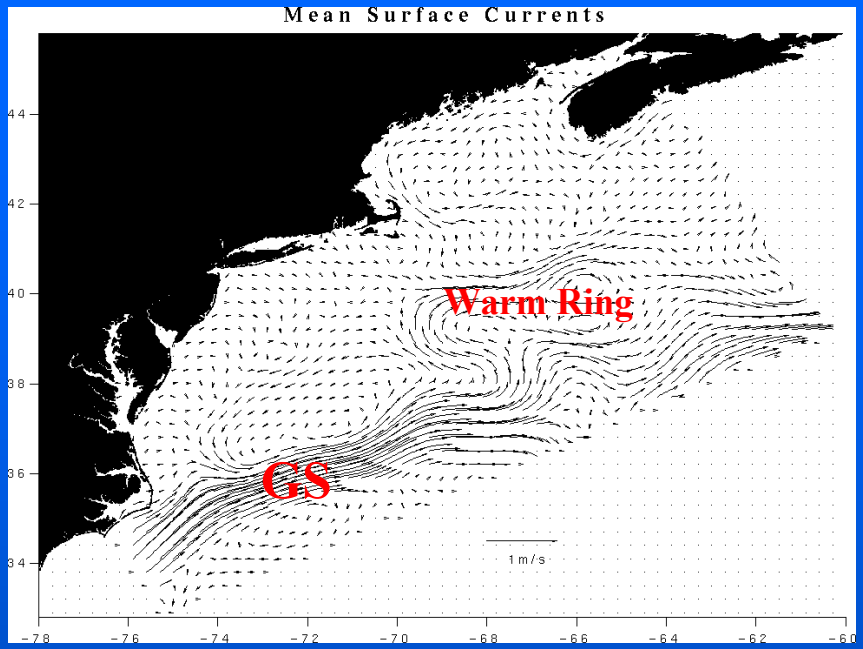


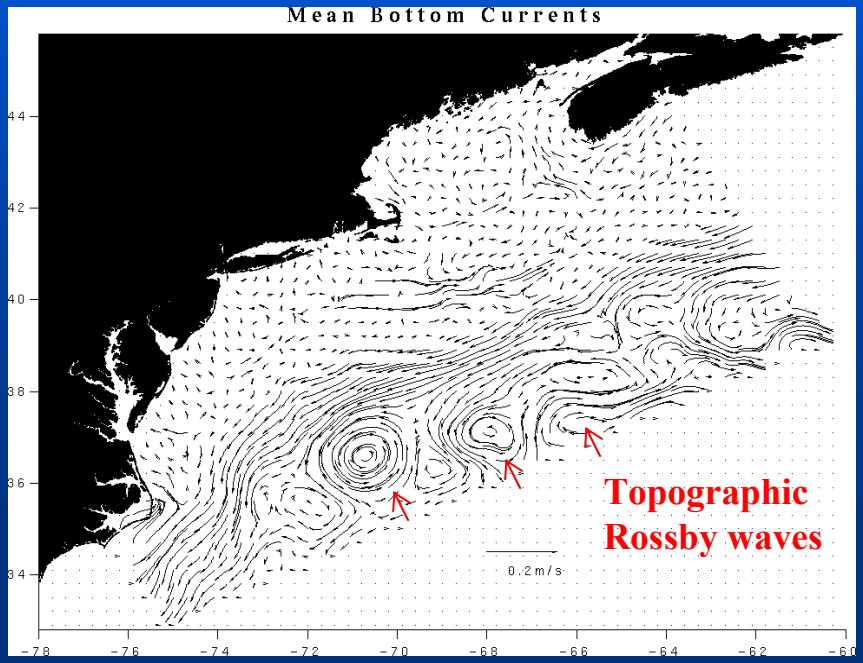
Model

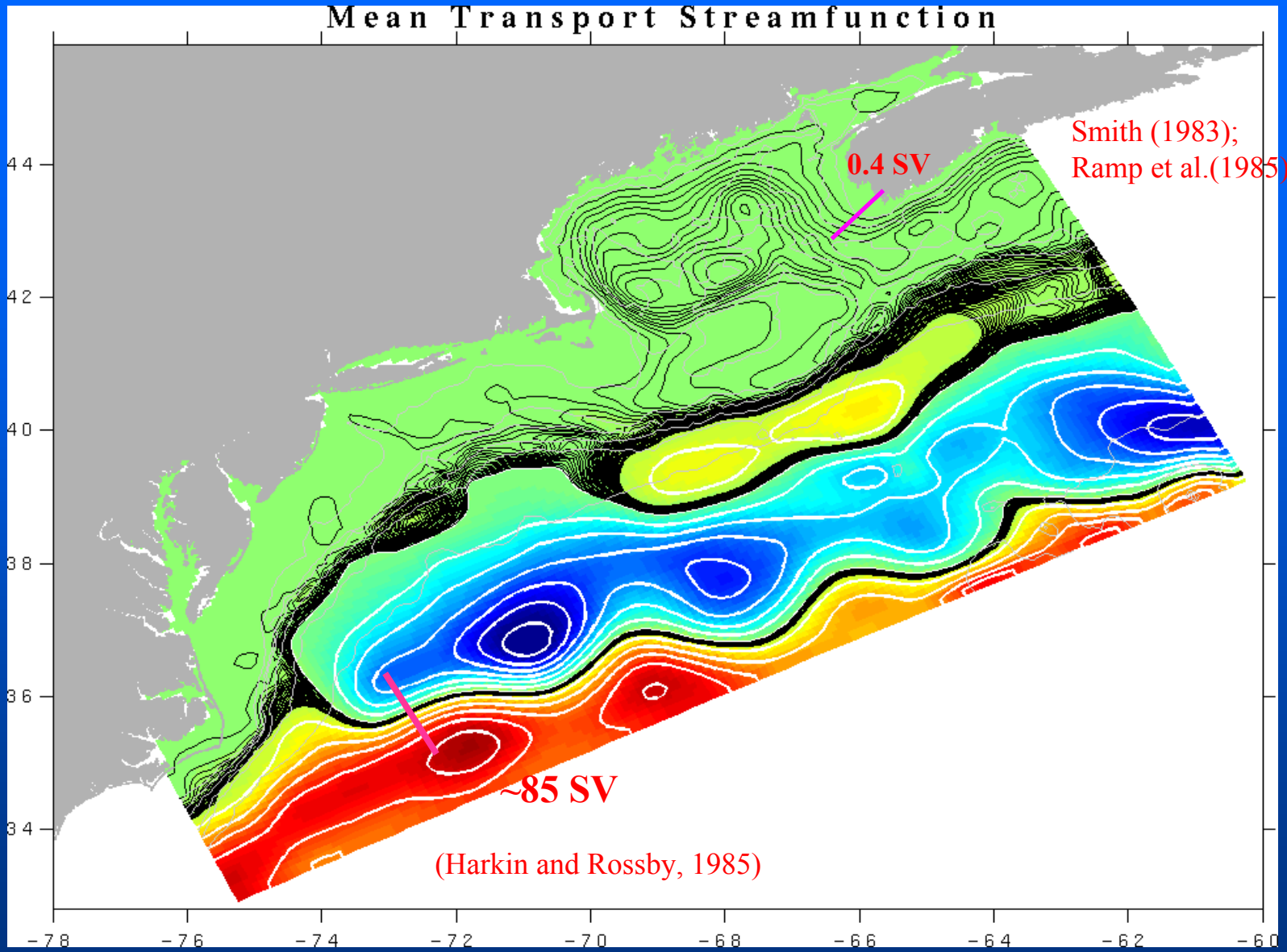


Shelf-Scale Mean Circulation (May –July , 2005)

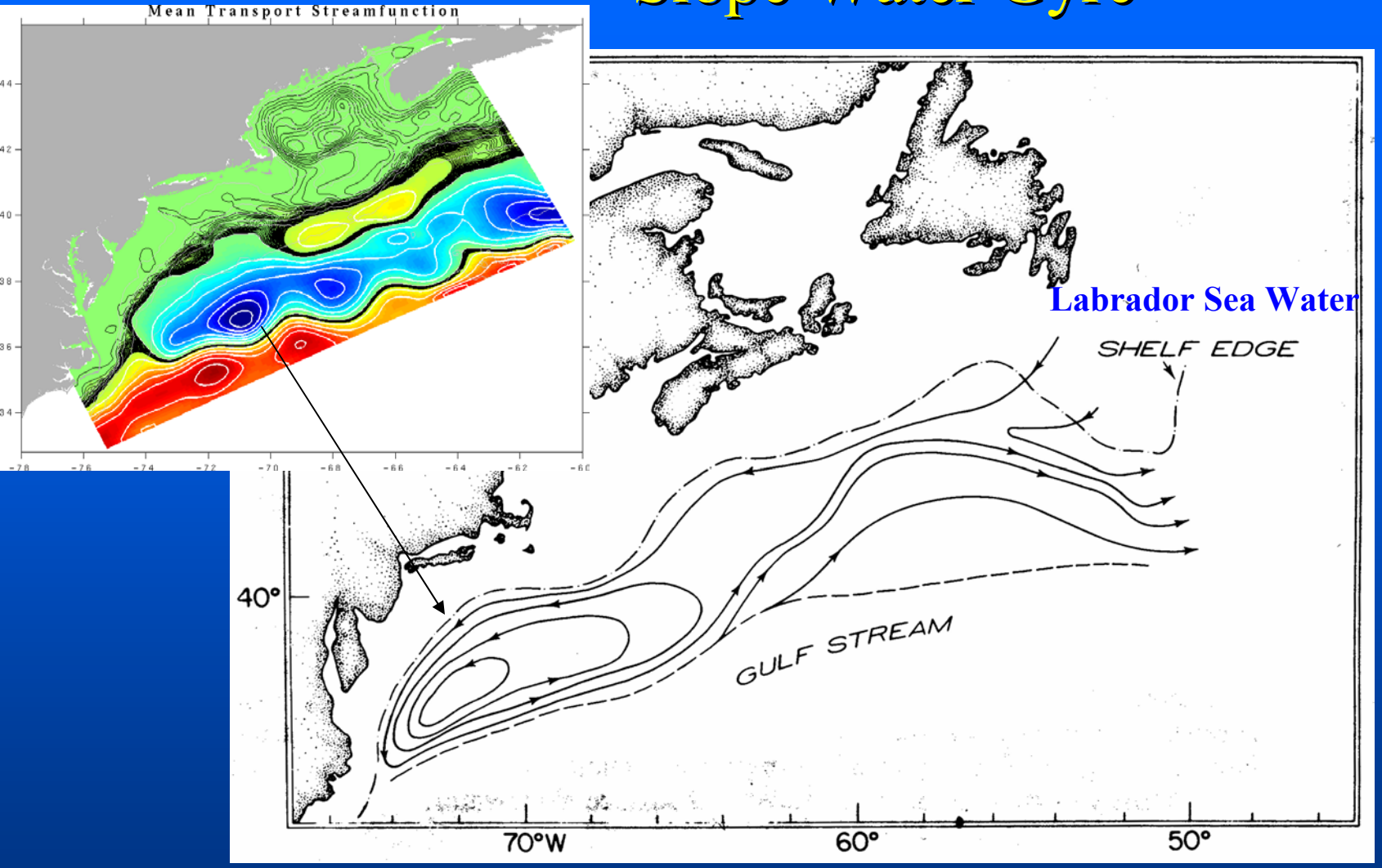






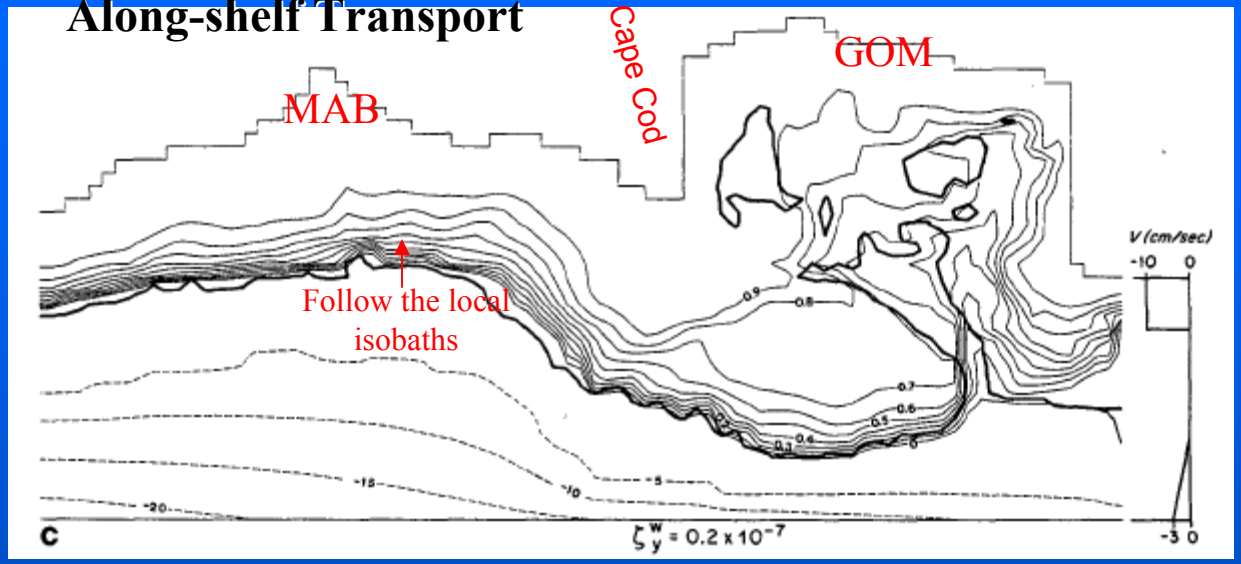

Mean Transport Streamfunction
44
42
40
38
36
34
-78
-76
-74
-72
-70
-68
-66
-64
-62
-60
0.4 SV
Smith (1983);
Ramp et al.(1985)
~85 SV
(Harkin and Rossby, 1985)

Slope Water Gyre



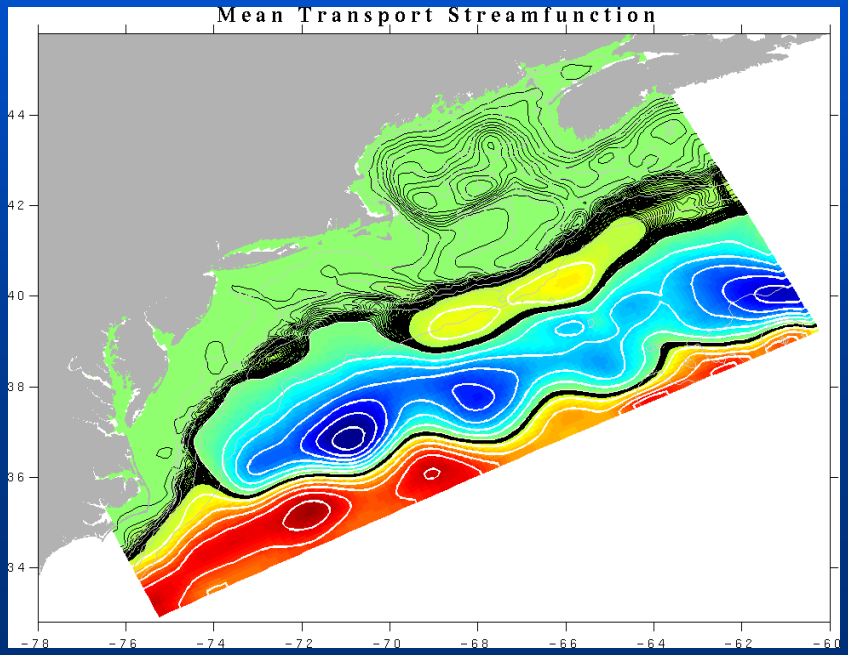
Csanady and Hamilton (1988), Circulation of slope water, *Cont. Shelf Res.*, 8, 565-624.

Transport Stream Functions

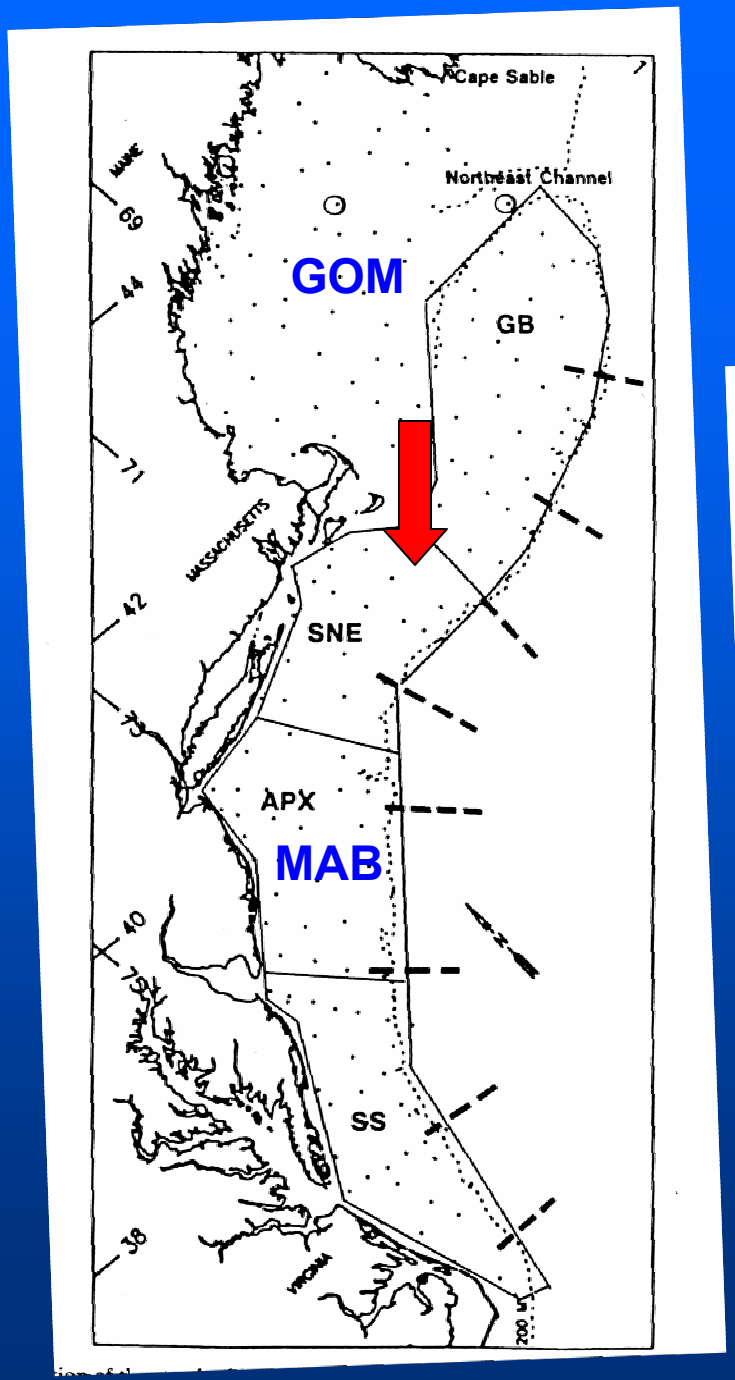


Chapman et al.(1986). *"On the continuity of mean flow between the Scotian shelf and the Middle Atlantic Bight"*. JPO

Idealized, barotropic solution



Both ***stratification*** and the presence of offshore ***Warm core ring*** reduce the along-shelf transport



10-yr hydrographic data by the Marine Resource Monitoring, Assessment and Prediction Program (MARMAP)

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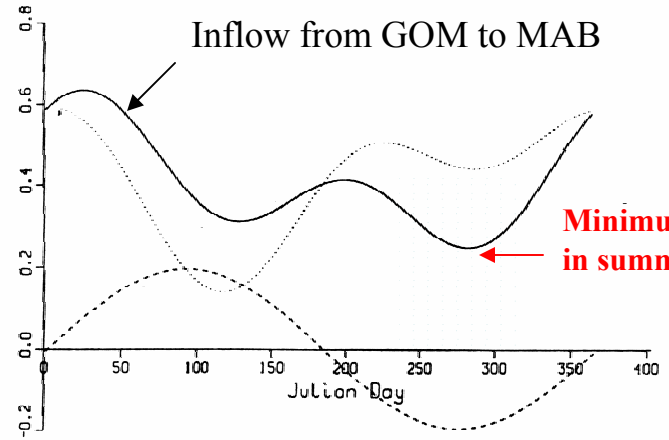
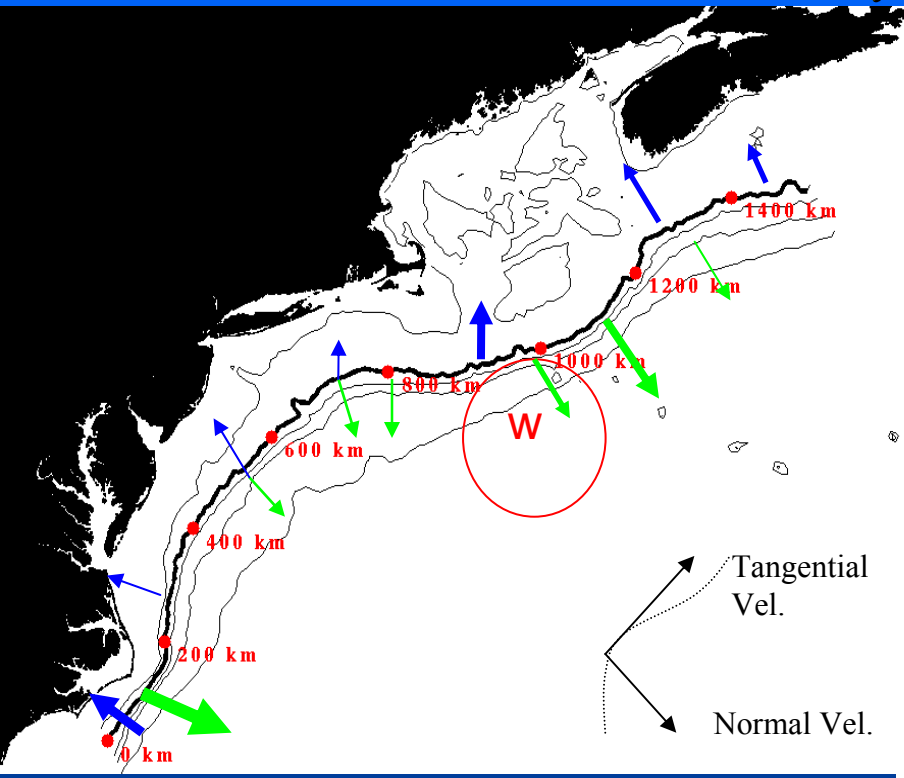


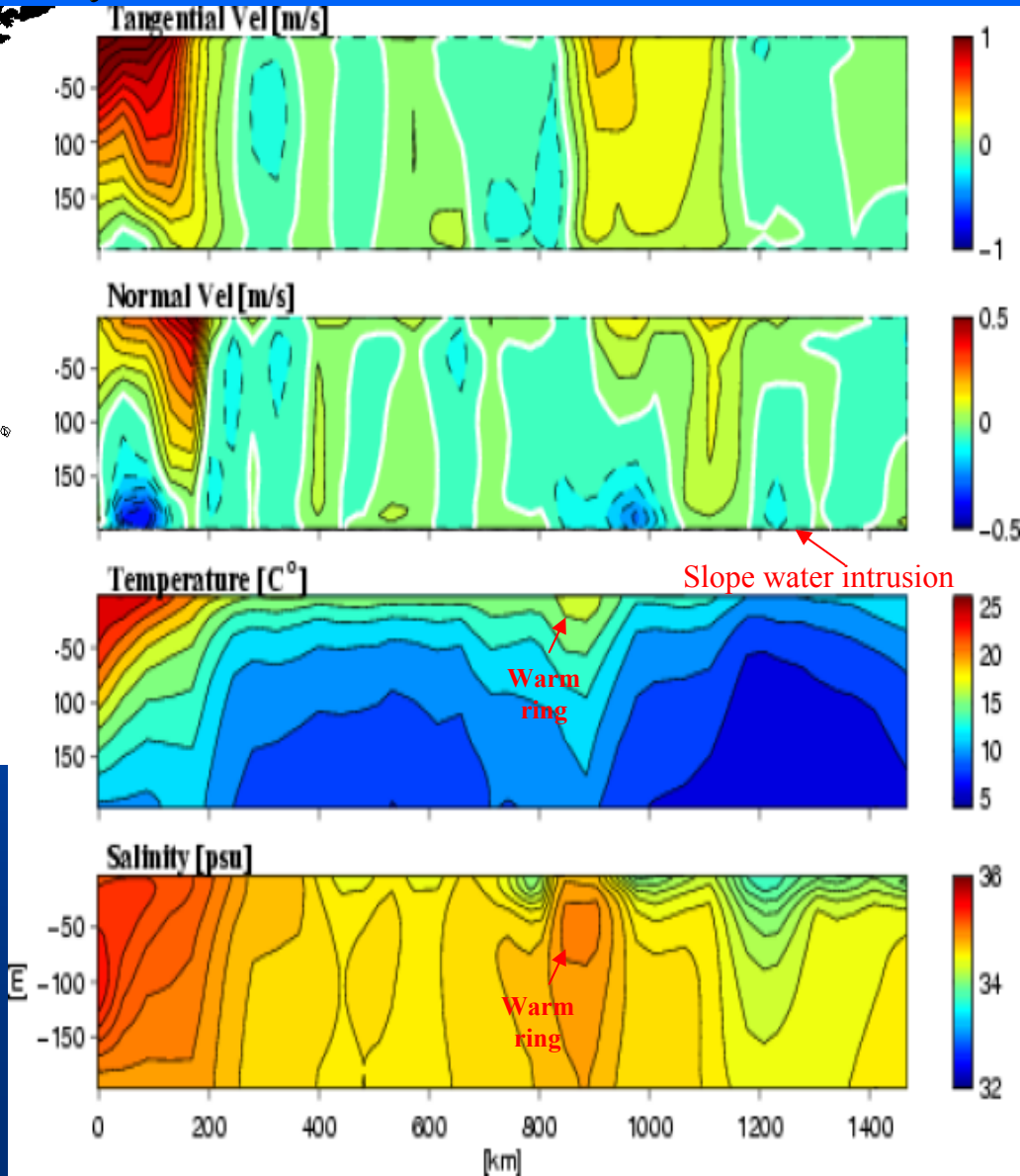
Fig. 6. The annual cycle of the three terms in the shelf water budget (equation 1) for the Middle Atlantic Bight: inflow, T_i (——); volume rate of change, $\dot{V}$ (– – –); and outflow, T_o (····). The units are 10^6 m^3 s^{-1}.

Mountain(1991): *The volume of shelf water In the Middle Atlantic Bight: seasonal and interannual variability, 1977-1987.* CSR

Mean Current and water properties at the shelf break (along 200-m isobath)

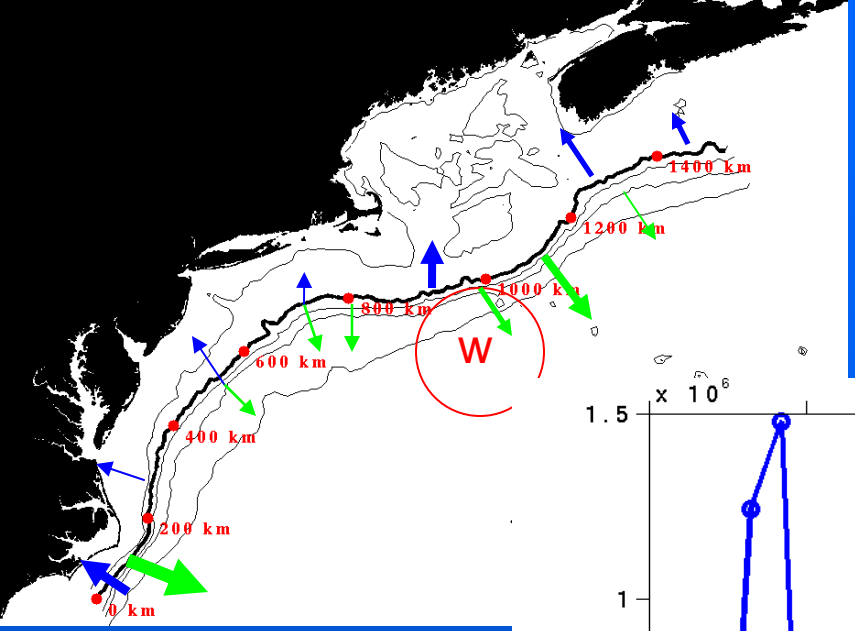
May-July, 2005

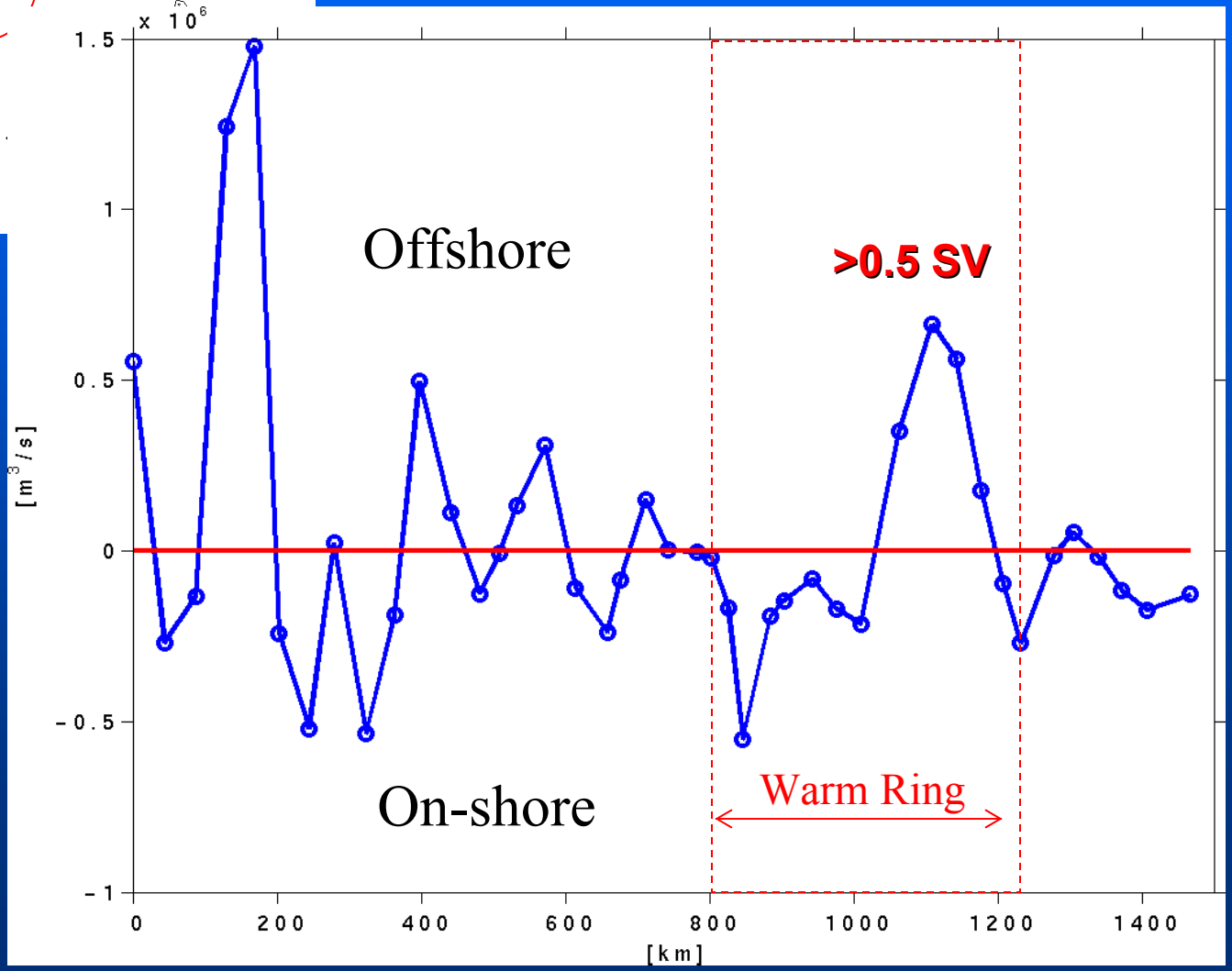




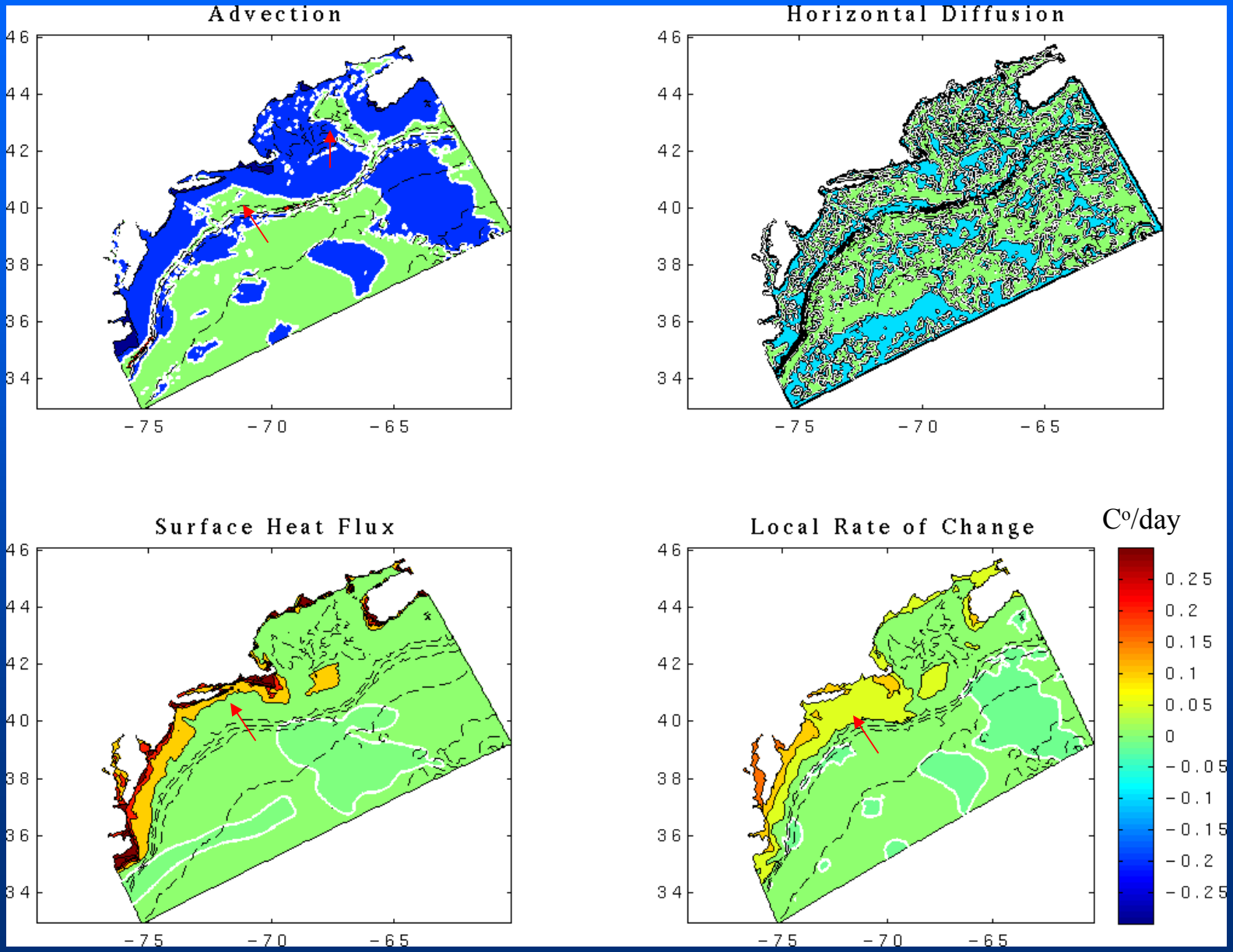
Mean Across-shelf Transport:

$$q = \iint u_N \, dz ds$$

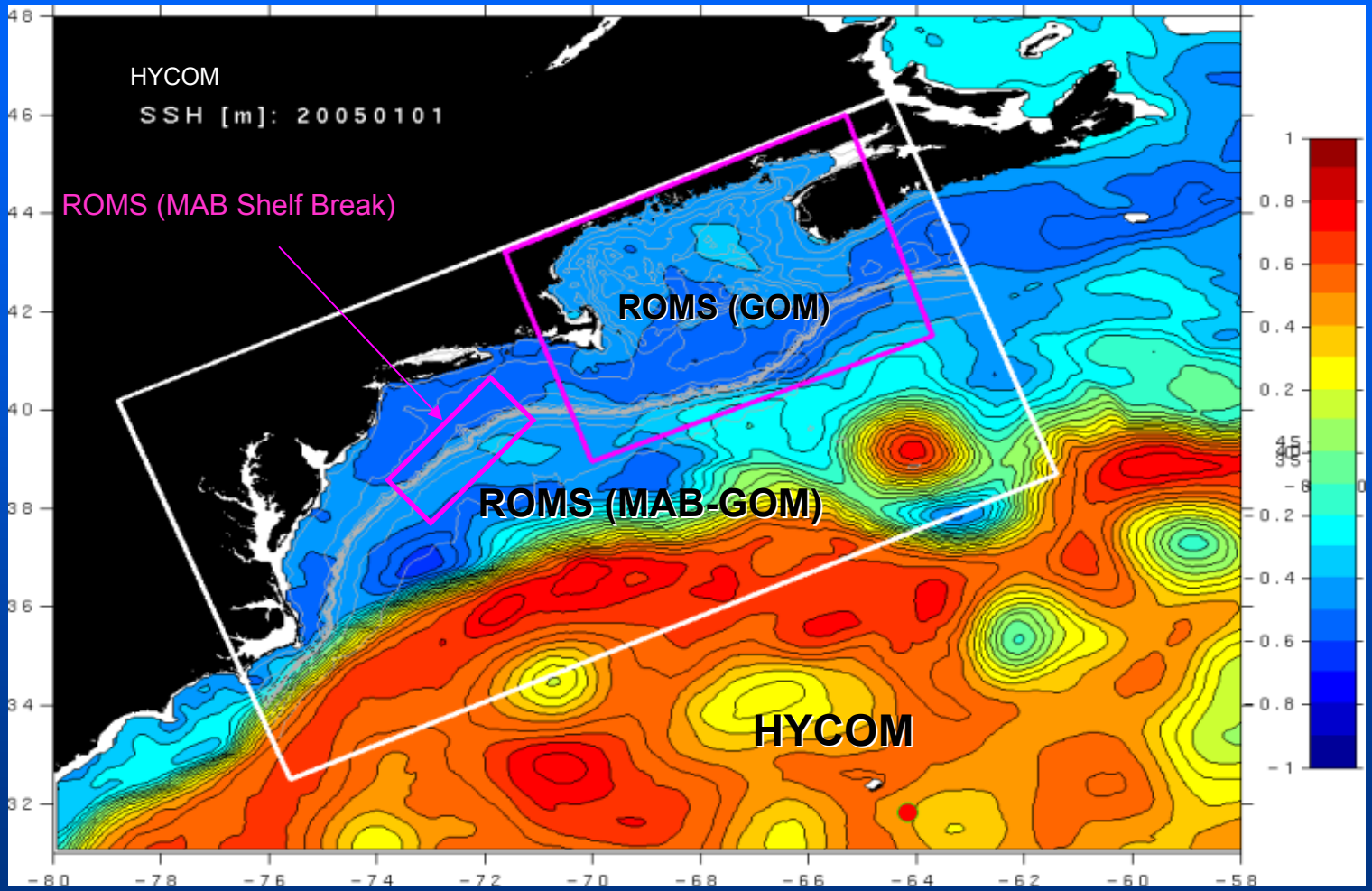




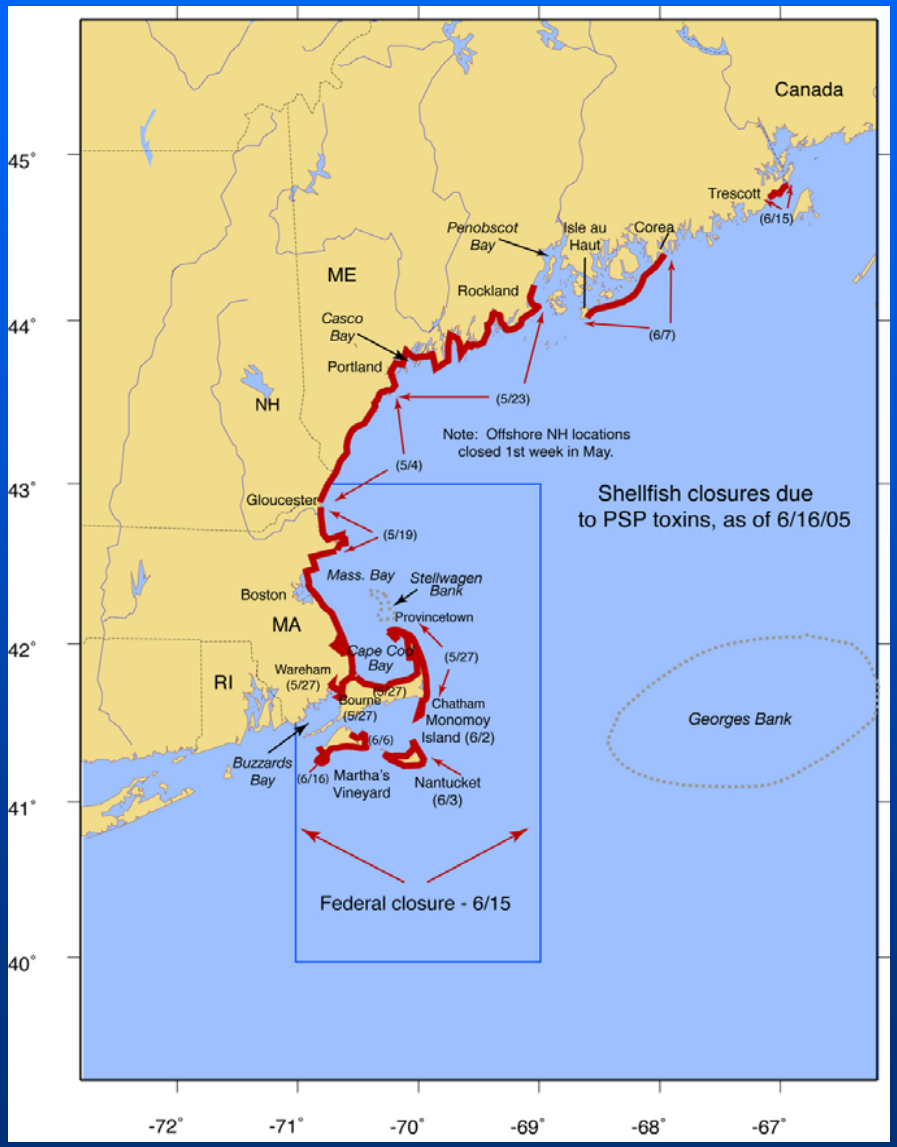
Mean Depth-integrated Temperature Balance (May-July 2005)



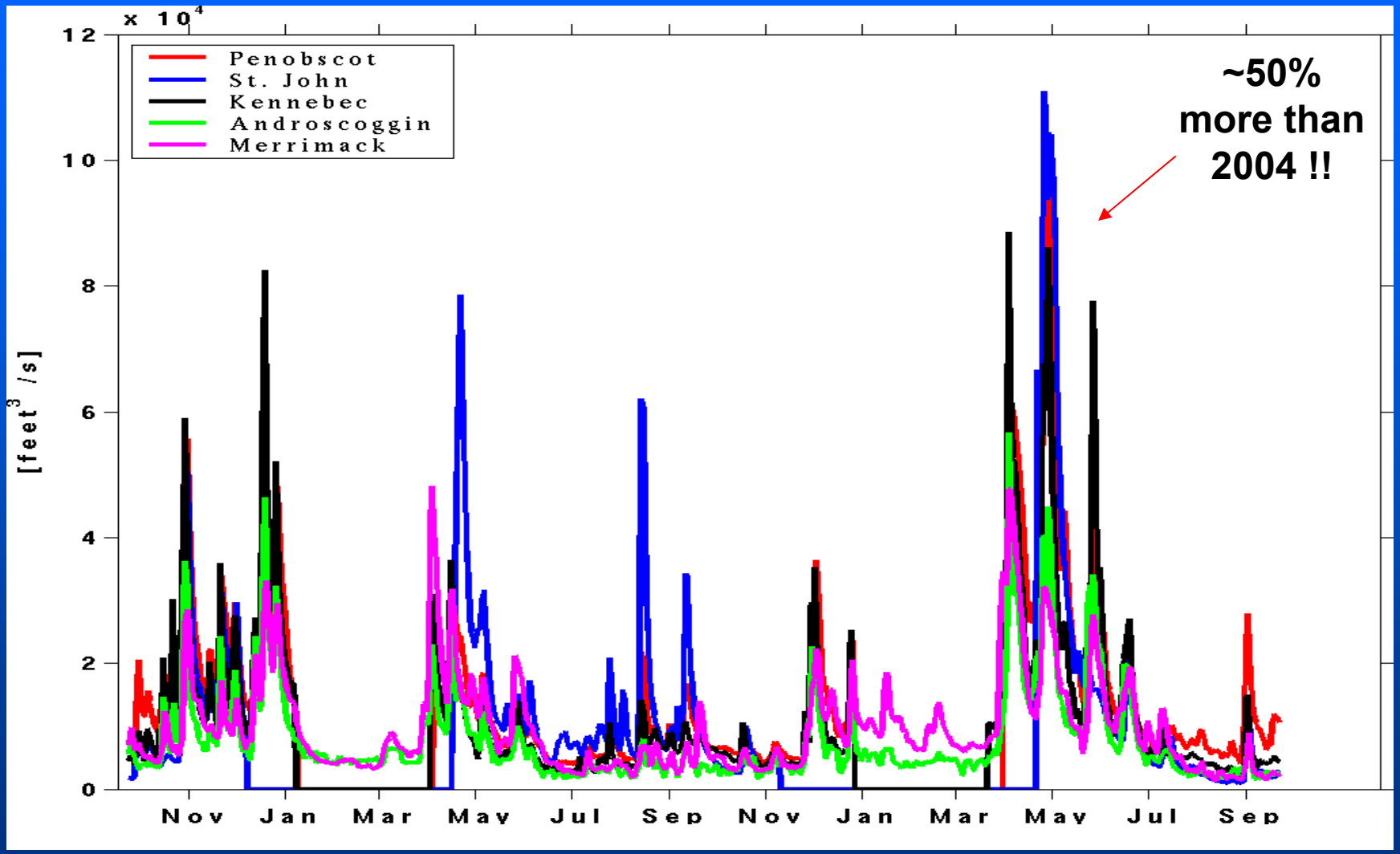
High-resolution Regional GOM and MAB Model Solutions



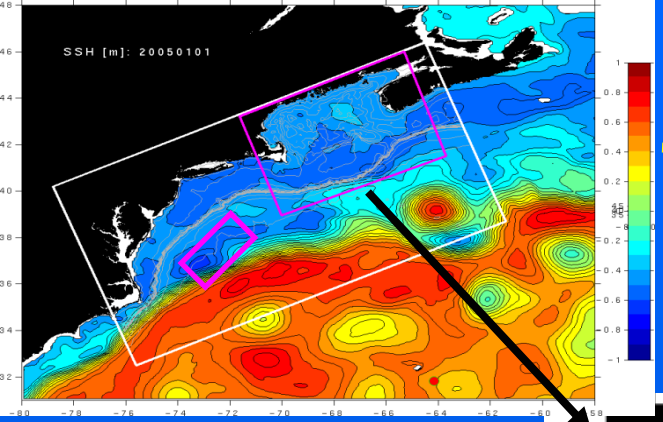
Red Tides in summer 2005, the largest outbreak in the past 30 yrs



Coastal River Runoffs Measured by USGS Gauges

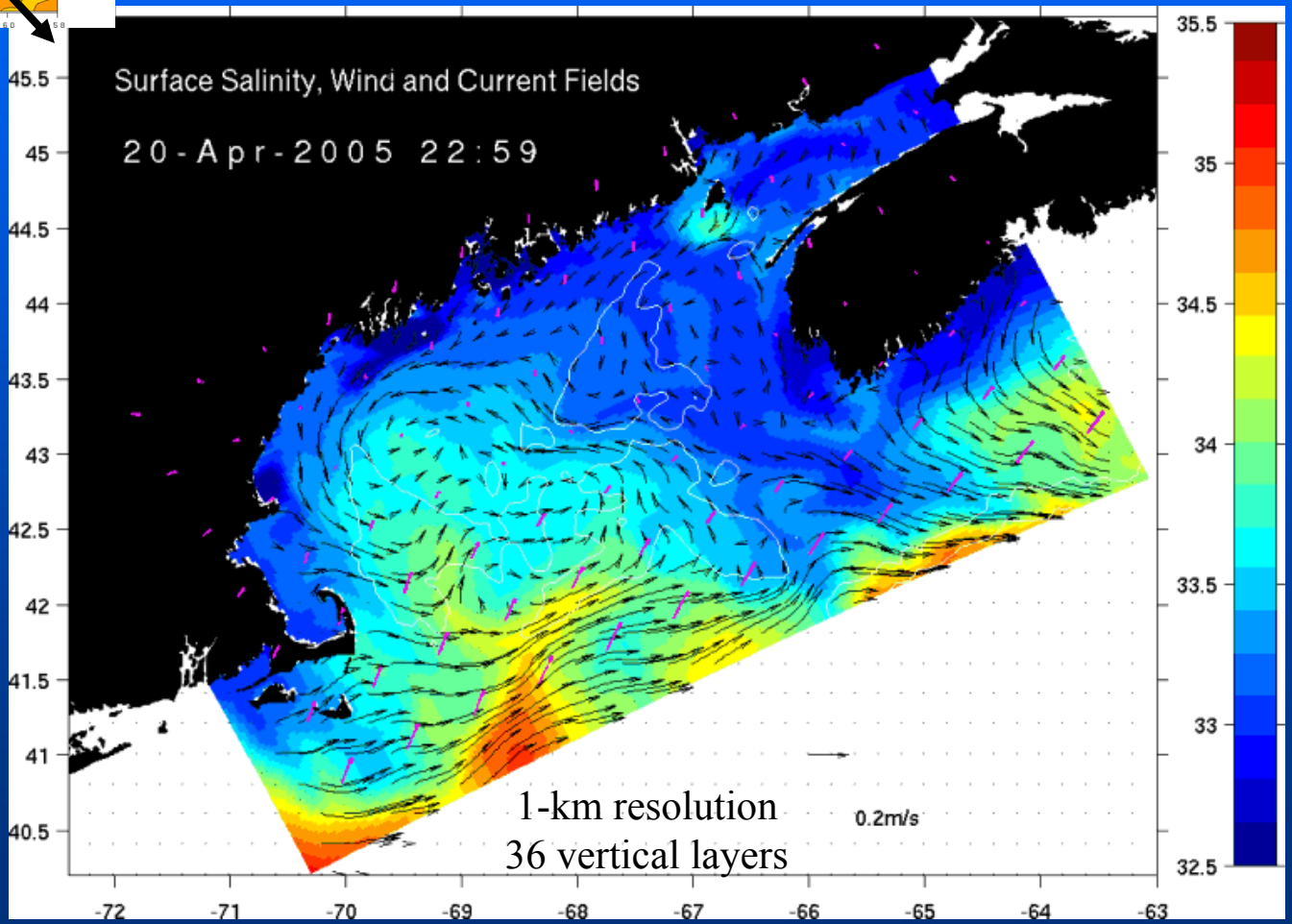


Tidally-averaged High-Res GOM Nested Model Surface Salinity and Surface Currents

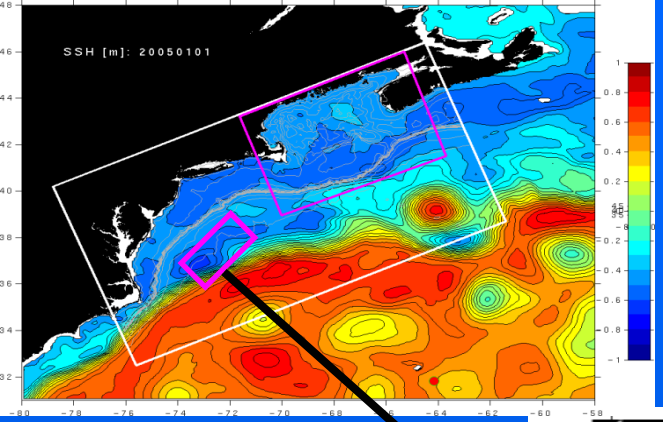


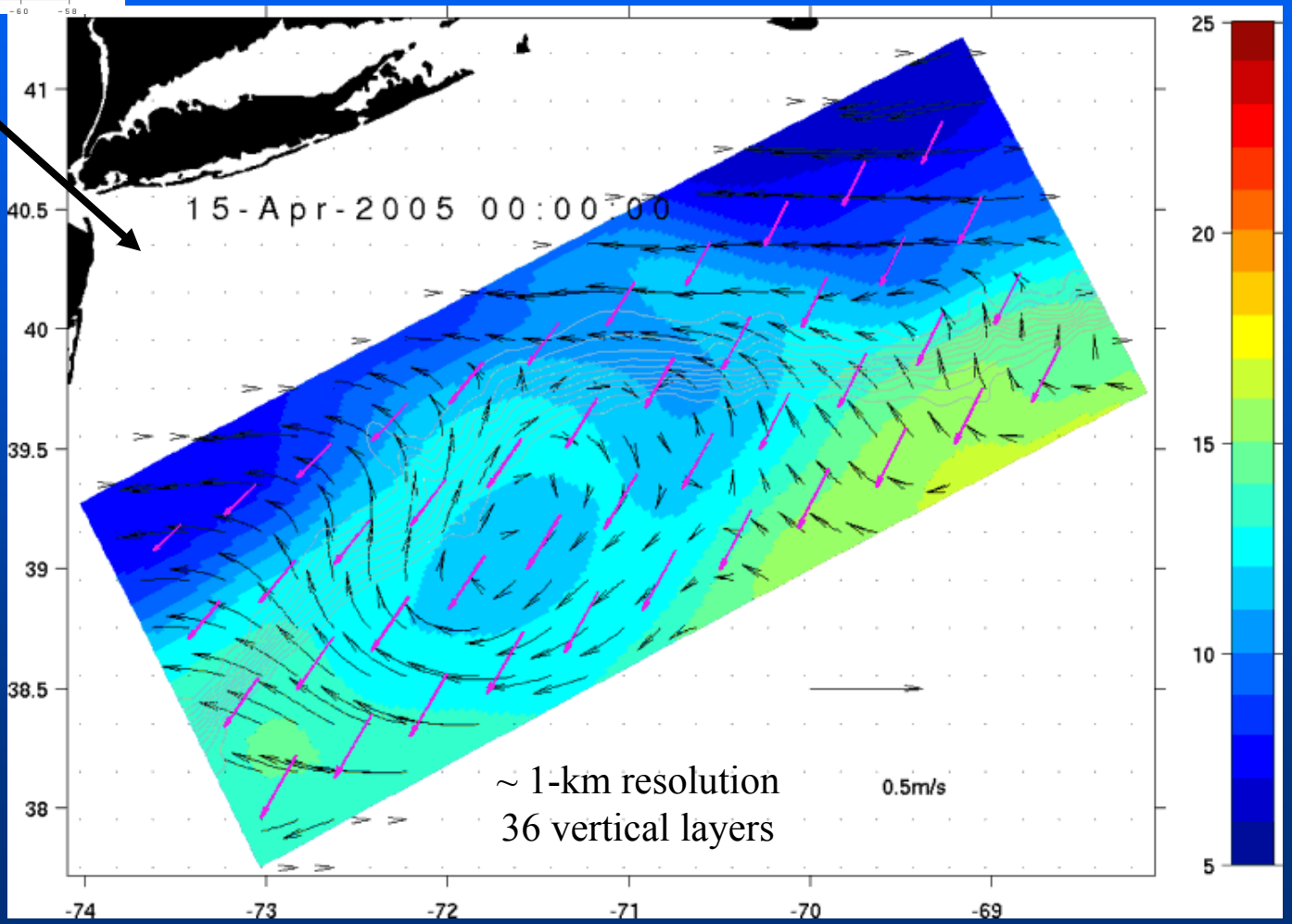
Ongoing work:

Couple ROMS Circulation with the Red-tide Population Dynamic model (*Stock et al.*, 2005)

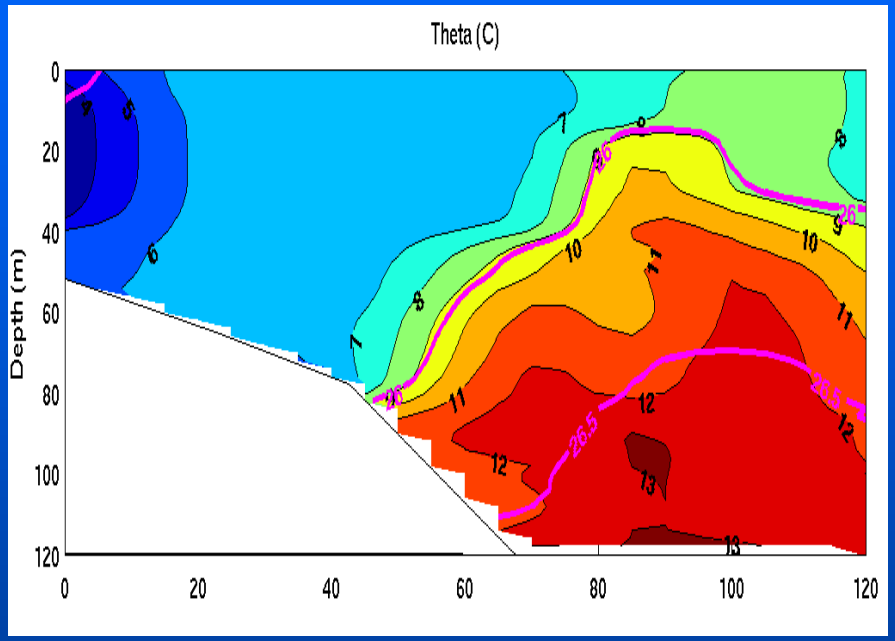


Nested High-Res MAB Shelf Break SST and Surface Currents



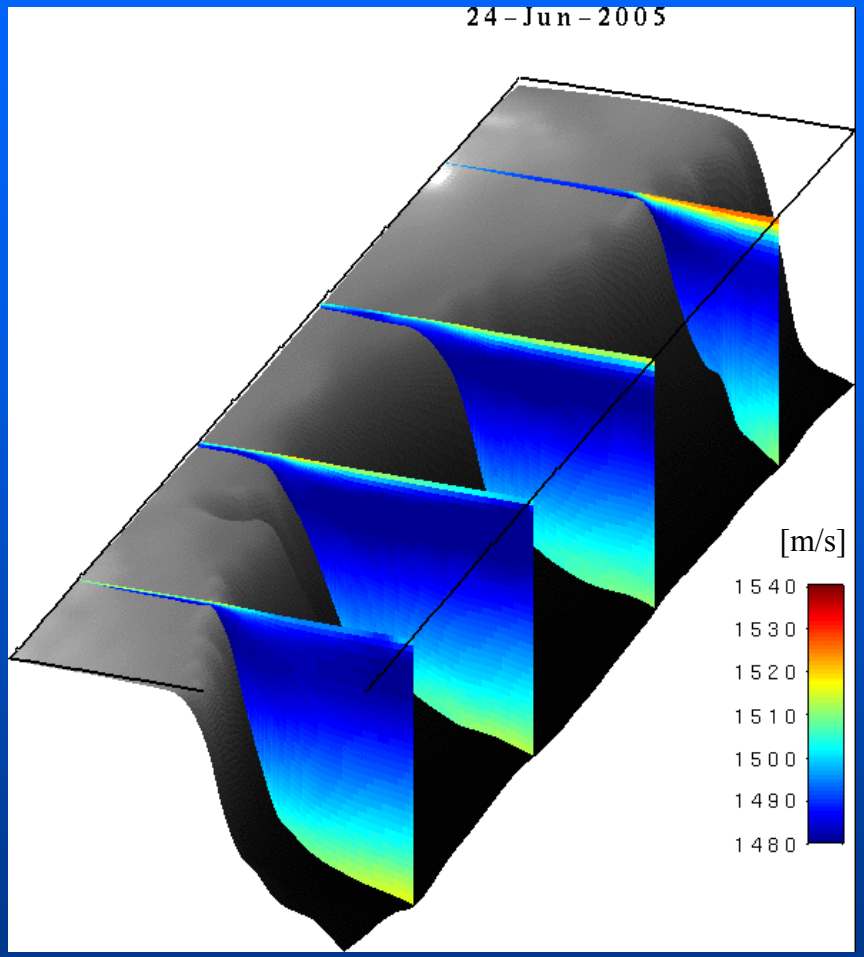


Shelf Break Secondary Circulation
Ekman Layer convergence and Boundary Layer detachment



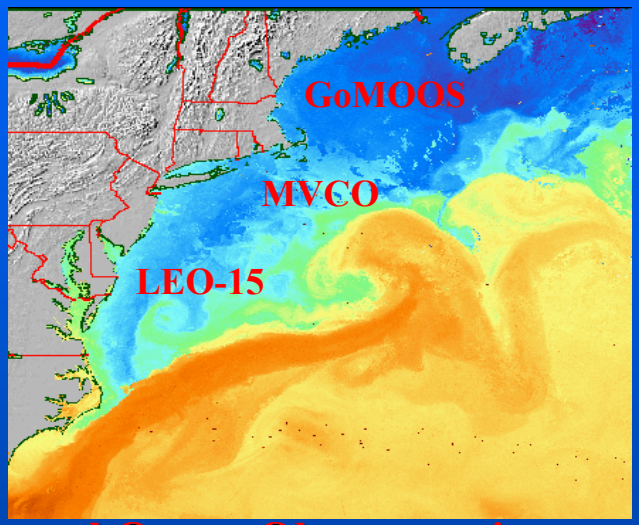
Barth et al. (1998). GRL
Pickart (2000), JPO
Linder et al. (2004), JGR

Sound Speeds



Adjoint sensitivity analysis and variational data assimilation using the tangent linear model (TLM) and adjoint model (ADM) for ROMS

Moore et al. (2005)

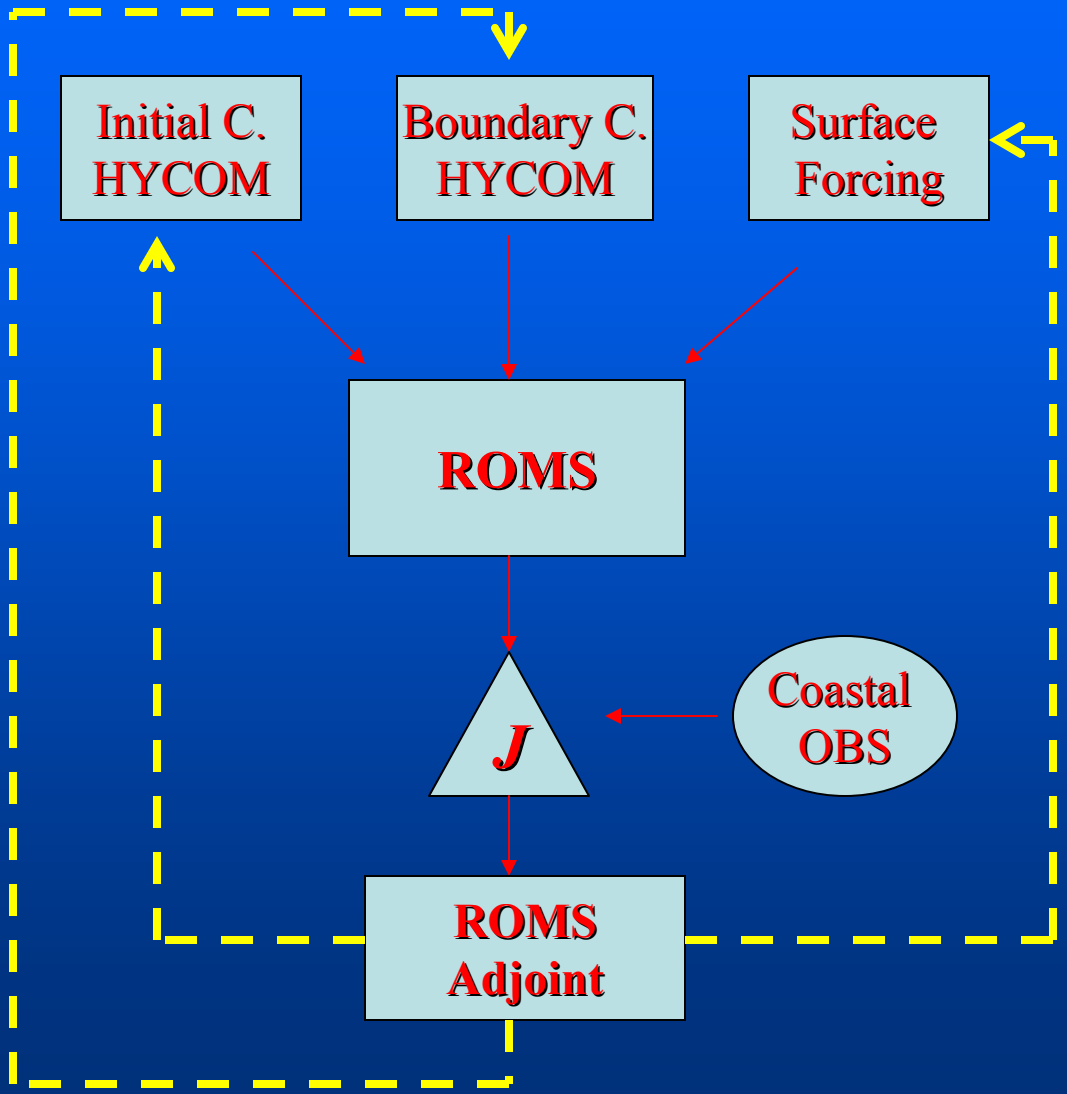


Coastal Ocean Observatories

Coastal sea levels
Moored/shipboard ADCP currents
CODAR currents
Moored/ship measured hydrography
Glider/Remus measured hydrography

Satellite observations

SST, SSH, ocean colors



More results to come…

Summary

- A regional modeling system is constructed in a multi-nested configuration to provide circulation hindcast and model synthesis for the GOM and the MAB. The model takes both the local forcing and the deep ocean forcing provided by HyCOM best estimations, facilitating more realistic model realization of coastal circulation.

- Model/data comparisons show reasonable skills of the nested coastal ocean model. Challenges in getting correct coastal stratification remain. The bias in the HYCOM T/S fields need to be resolved.

- Along-shelf transport in the GOM and the MAB is modulated by the shelf stratification and offshore warm core rings. So does the shelf-wide temperature balance. Shelf waters tend to move offshore in the summer time, therefore the direct flux from the GOM to MAB is reduced.

- Nested high-resolution GOM and MAB shelf break models are being used to study the biophysical process in the GOM, and the shelf break circulation and exchange processes in the MAB.

- Recent advancements of ROMS TLM and ADM are promising and can provide useful info/evaluation for HYCOM solutions. More results to come …