Ocean Forecast and Analysis Models for Coastal Observatories

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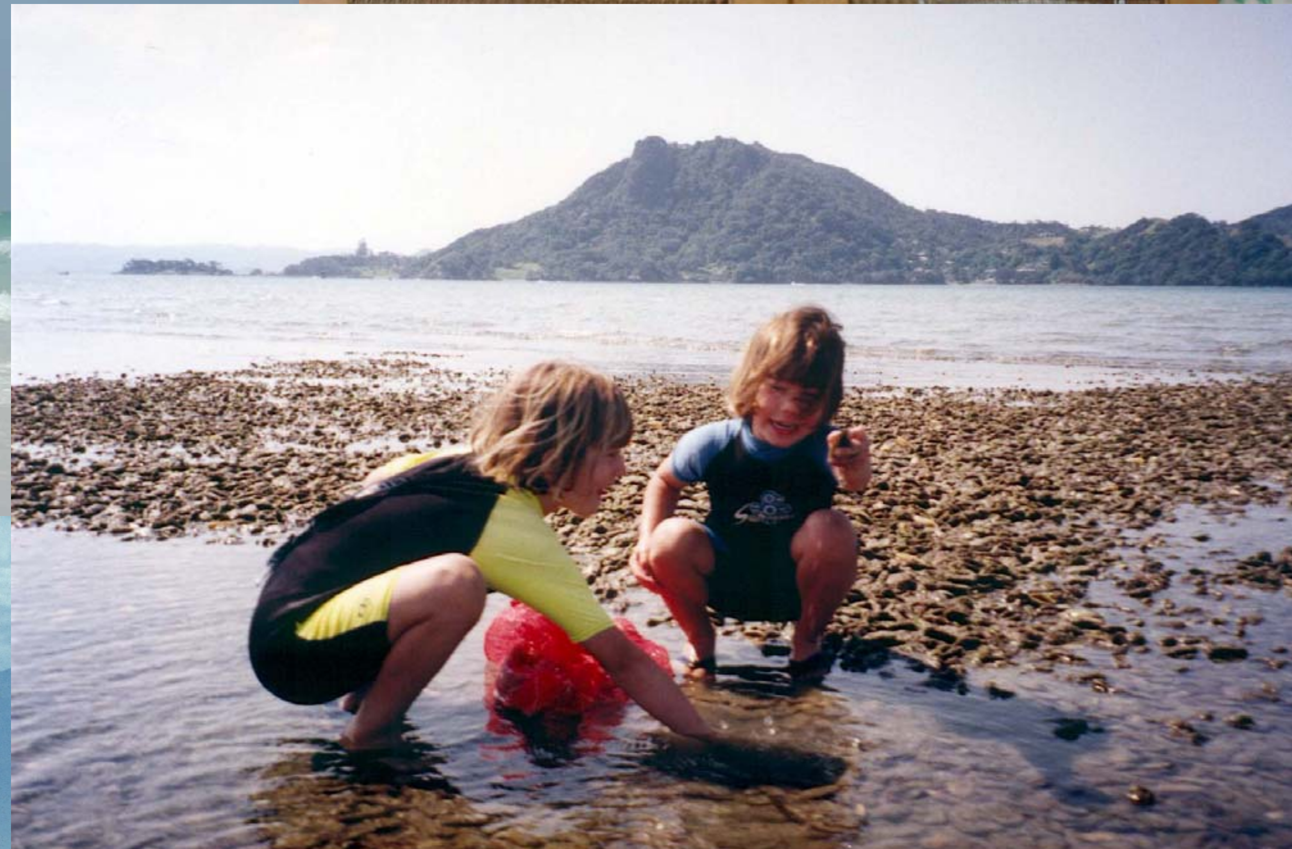
Rutgers, The State University of New Jersey


NZL-82

The Coastal Ocean

- 8% of surface of World Ocean
- 19 to 28% total global ocean primary productivity
- 90% global fish catch

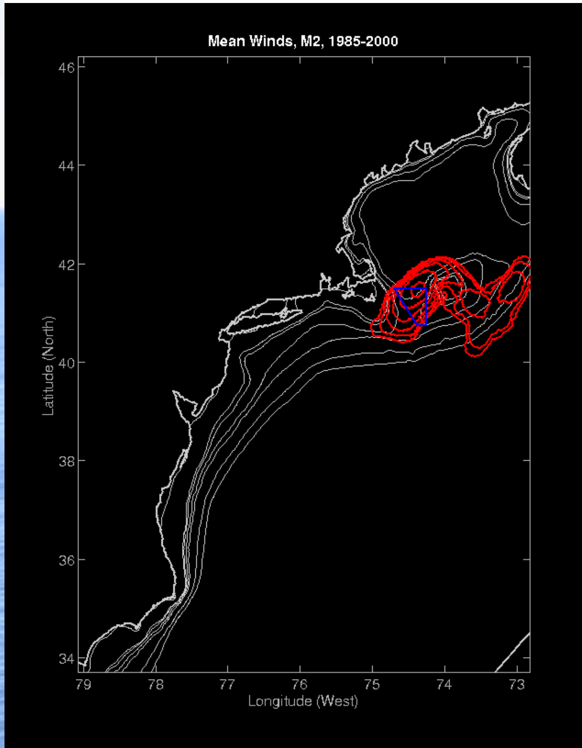
Continental shelf carbon cycle

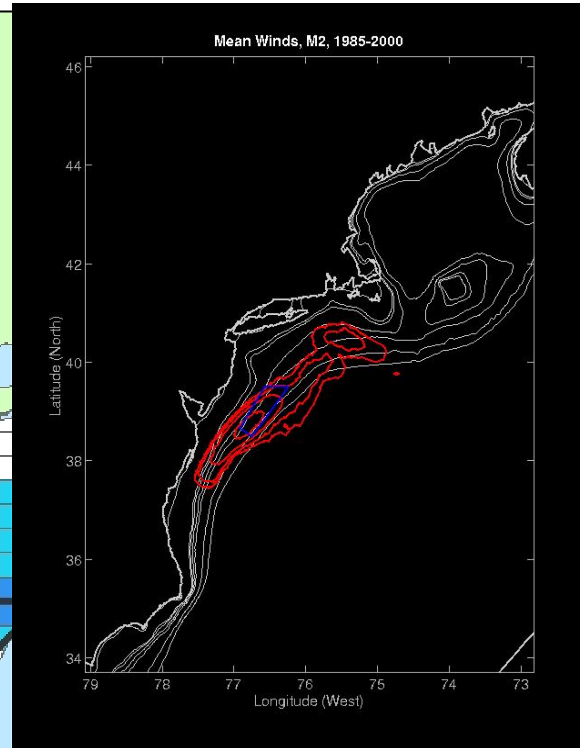
- Globally, river input is ~0.8 PgC yr^{-1}, comparable to the natural flux of CO_2 from the shelf ocean to the atmosphere

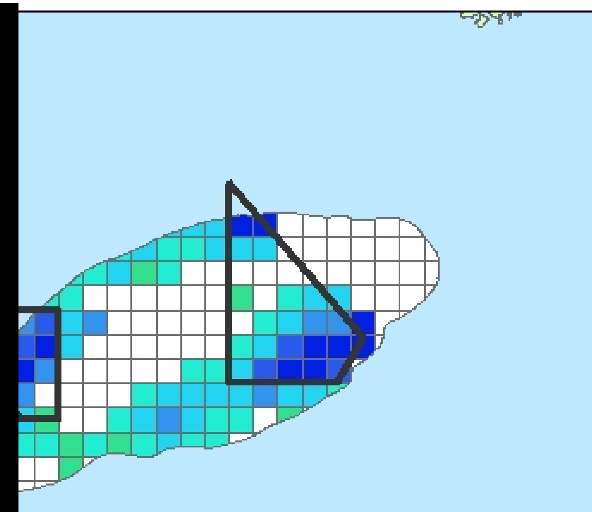
- "Continental Shelf Pump" (atmosphere to shelf bottom waters) could account for 0.6 to 1 PgC yr^{-1} (of ~2 PgC yr^{-1} anthropogenic)

Fisheries:
Help the managers, not just the fishermen

- **Management practices can alter ecosystem**
  - **Georges Bank ground-fish closed areas have aided scallop populations**
  - **Scallop pelagic larval stage lasts 4-8 weeks**
  - **…**

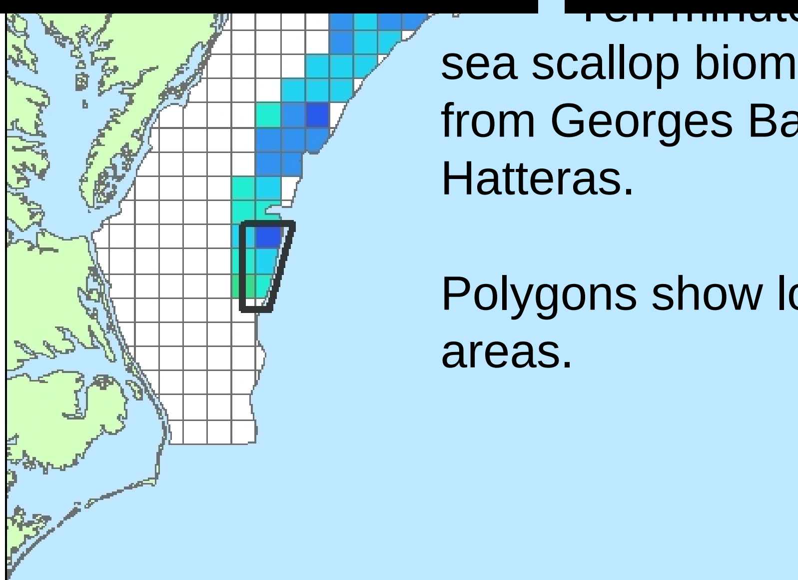






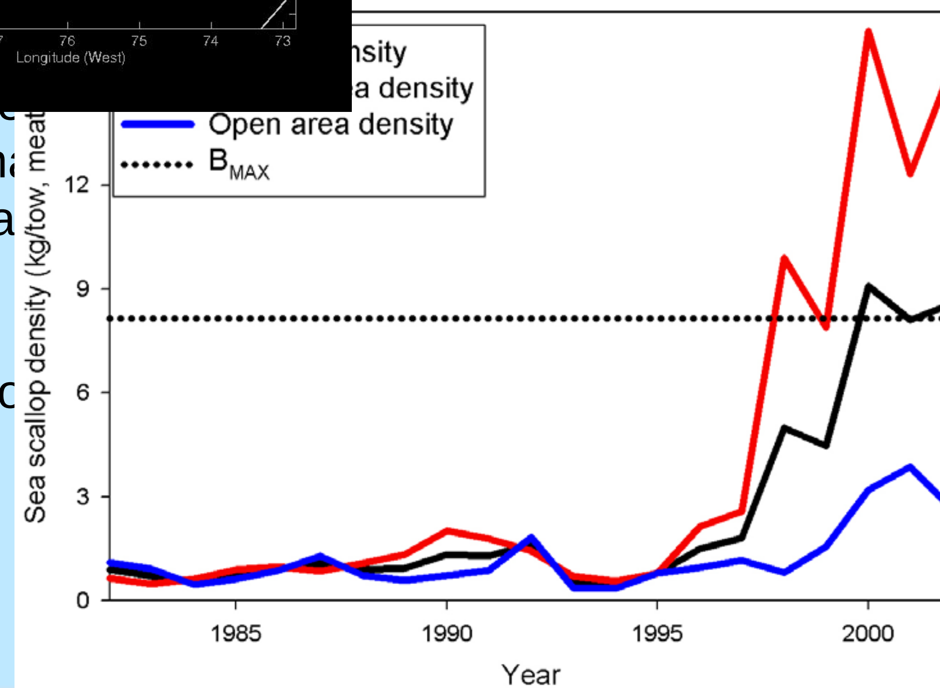
Bank Sea Scallop Density

Annual Sea Scallop Survey



Ten minute
sea scallop bioma
from Georges Ba
Hatteras.

Polygons show lo
areas.



Fisheries:
Help the managers, not just the fishermen

- **Management practices can alter ecosystem**
  - **Georges Bank ground-fish closed areas have aided scallop populations**
  - **Scallop pelagic larval stage lasts 4-8 weeks**
  - **Hypotheses on larval dispersal can be tested using circulation models**
  - **Multi-species management could choose closed areas good for both ground-fish and scallops**

- **Holy Grail of fisheries management is prediction of inter-annual variability that would enable year-by-year adaptive extraction (quotas)**
  - **aside: West Australian Rock lobster**

River runoff and human pollution

- Coastal ocean is a filter for nutrients and sediments from rivers and atmosphere
  - majority are re-mineralized with little export to the deep ocean
- On U.S. East Coast, the discharge of many rivers is modified in estuaries
- Chesapeake Bay: most runoff is assimilated by plankton in the Bay and exported as inorganic nitrogen
- New York: 90% nitrogen is exported unassimilated onto the shelf
  - NY/NJ Harbor sediments are ~4% of MAB load, but 90% of PCBs and 70% of mercury
- Where it goes and how it is transformed depends not just on biogeochemical processes, but also on the physics of coastal ocean

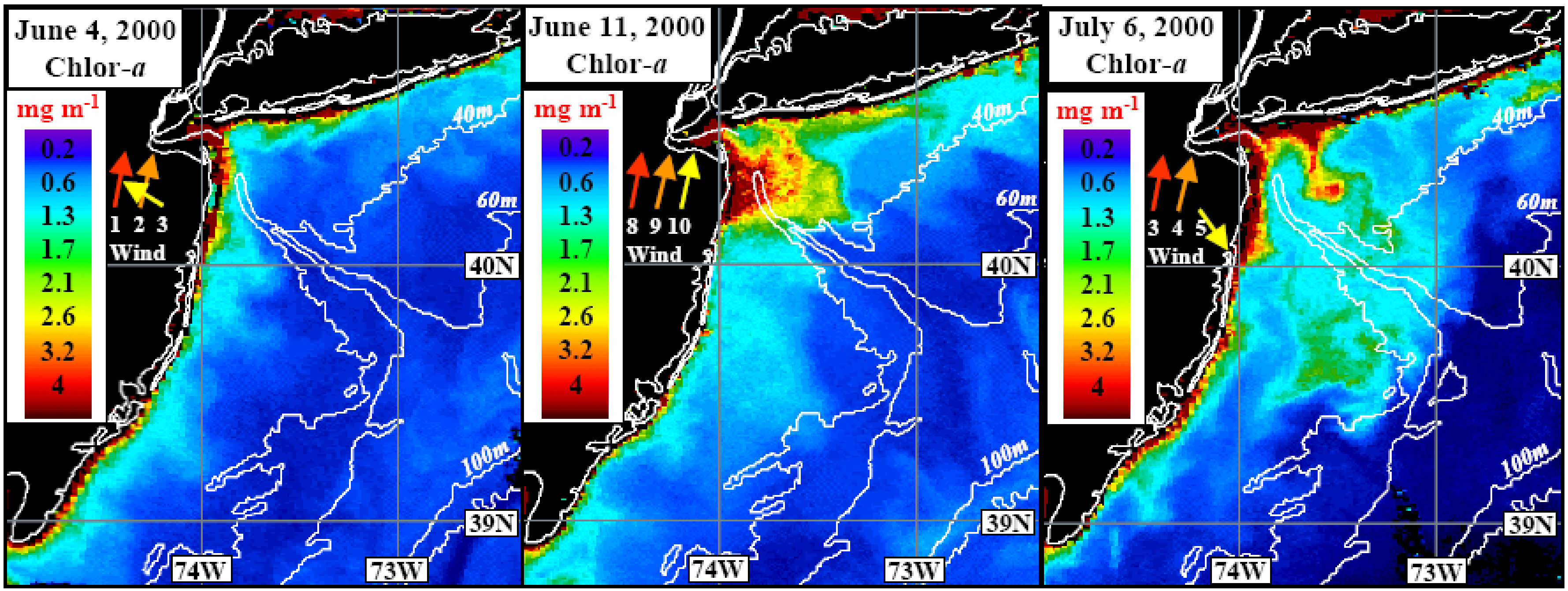
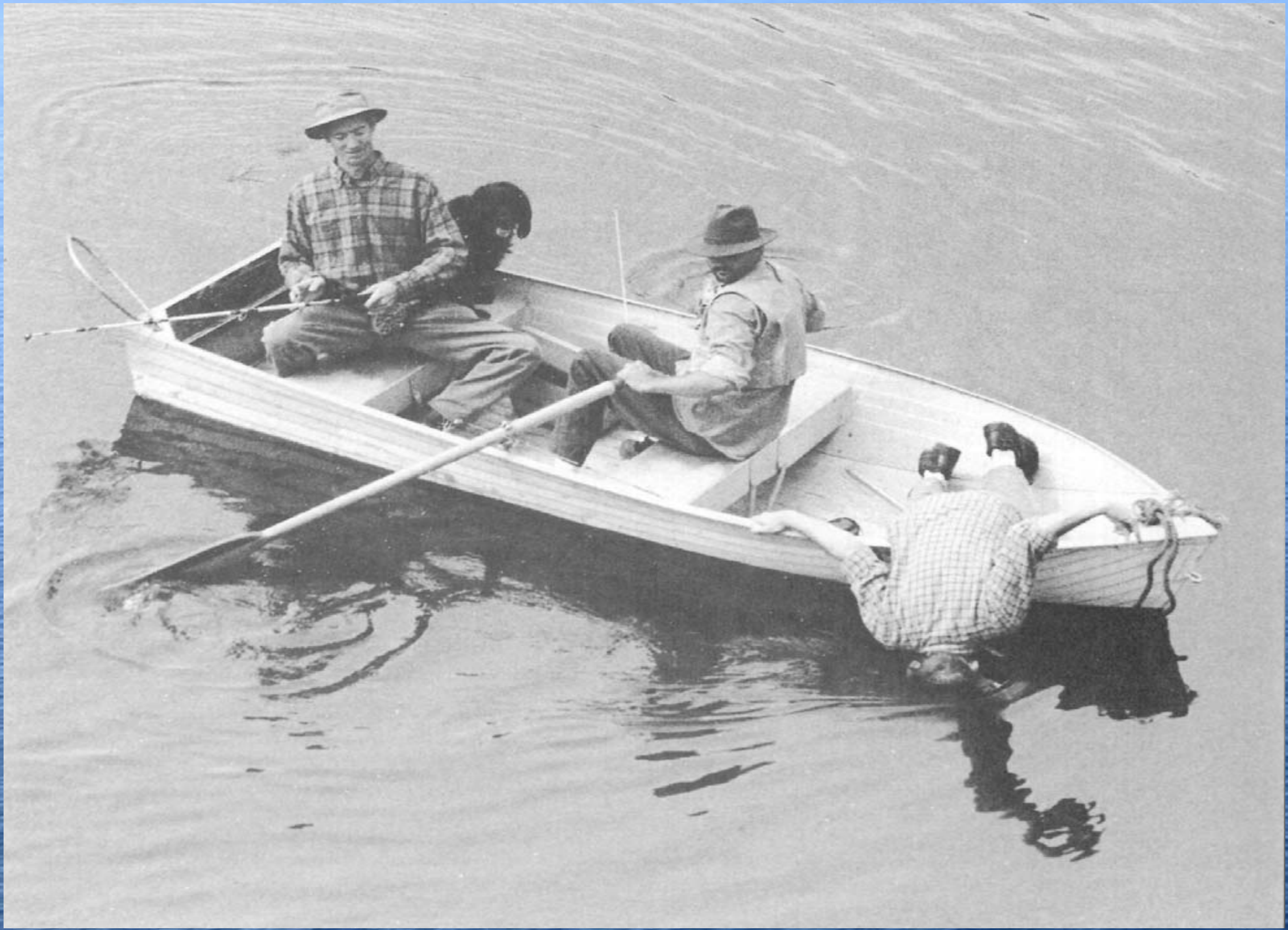


Fig. 2. The evolution of a surface plume from the Hudson River in the summer of 2000 mapped using SeaWiFs.

- Nutrients, carbon, pollutants enter coastal waters and are transported and transformed while resident in shelf waters
- Shelf-sea/deep-ocean exchange affects shelf residence times and supplies nutrients to the shelf ecosystem
- Physical, geochemical and ecosystem processes interact to regulate primary production and bioaccumulation
- Understanding of *processes* is required to assess natural variability and human impacts
- This requires multi-disciplinary observations in coastal regimes characterized by short length scales and rapid variability

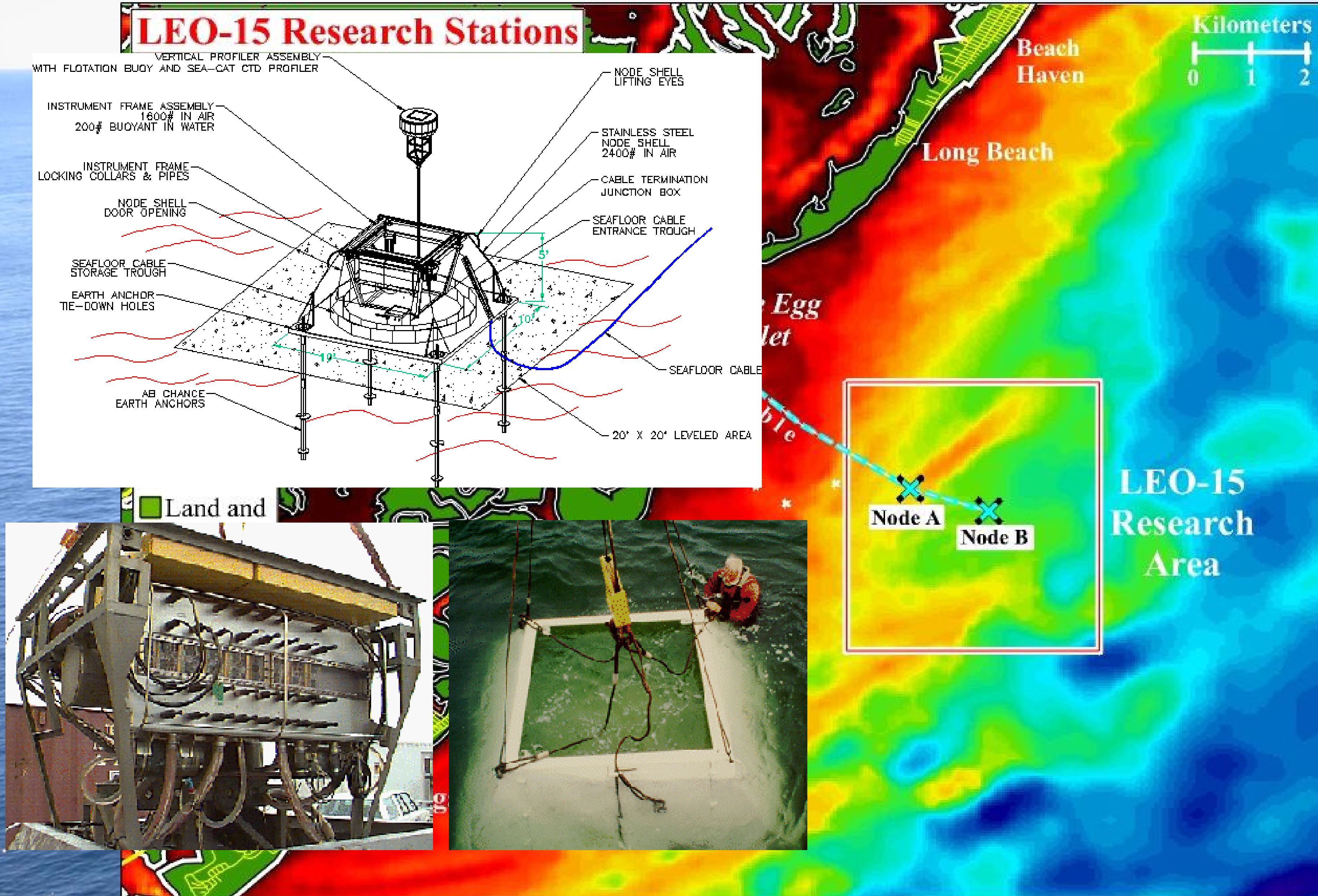
Coastal Observatories



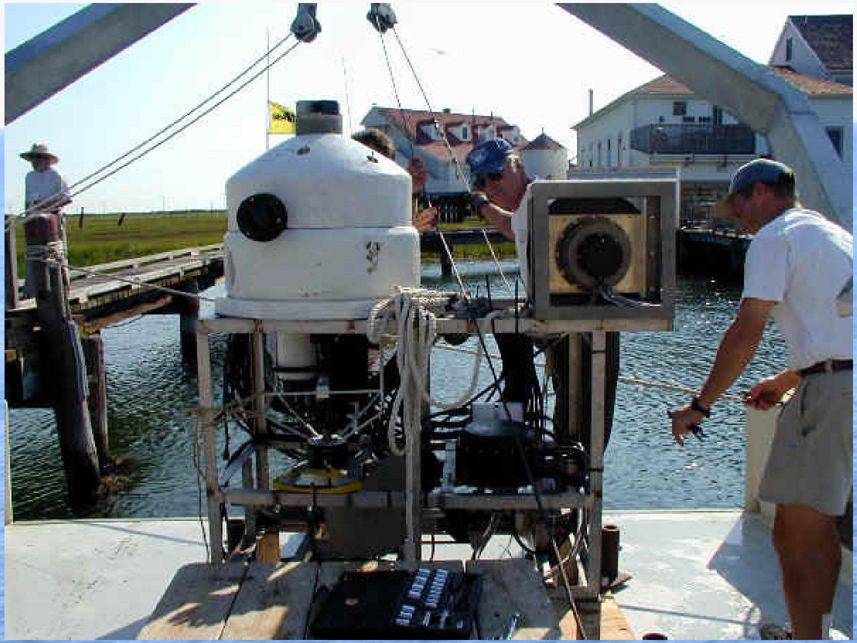
Coastal Observatories

- The "research mode" expeditionary approach encouraged experiments designed to test specific hypotheses
- But how do we capture (unexpected) EVENTS that have major impacts on the system?
- Need a long-term coastal monitoring observatories
- *"Think globally, act locally"*

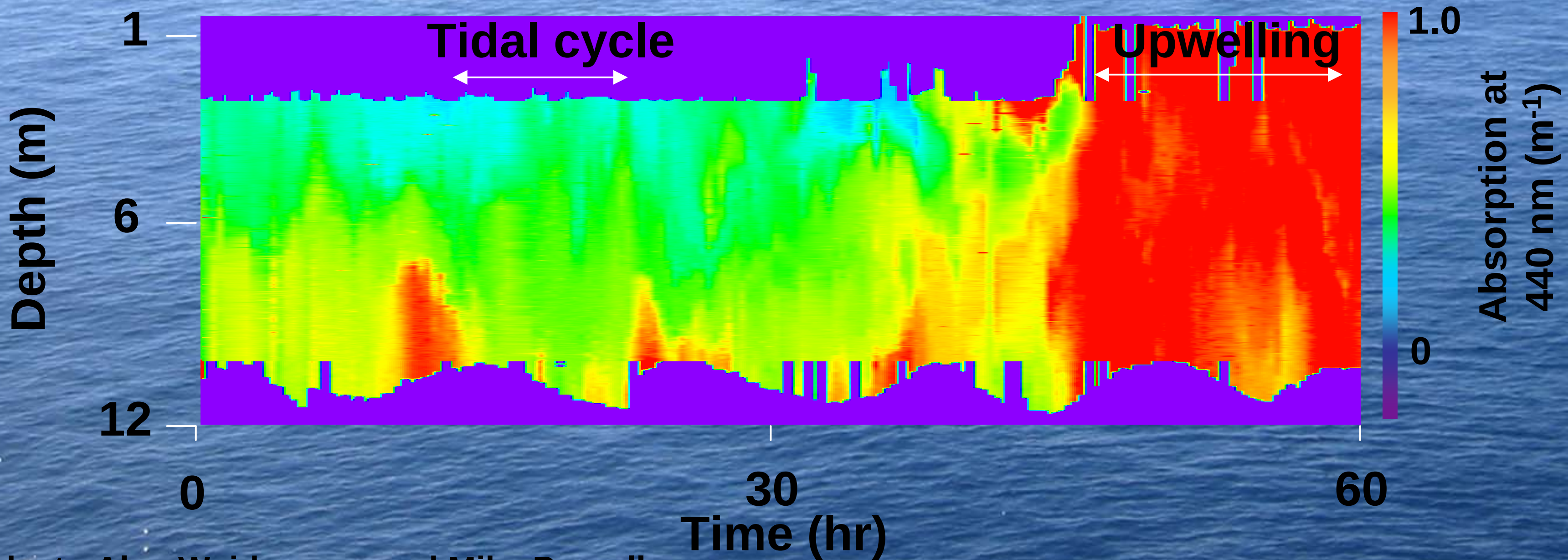
Long-term Ecosystem Observatory (LEO)



Optical profiler deployed on LEO-15 guest port

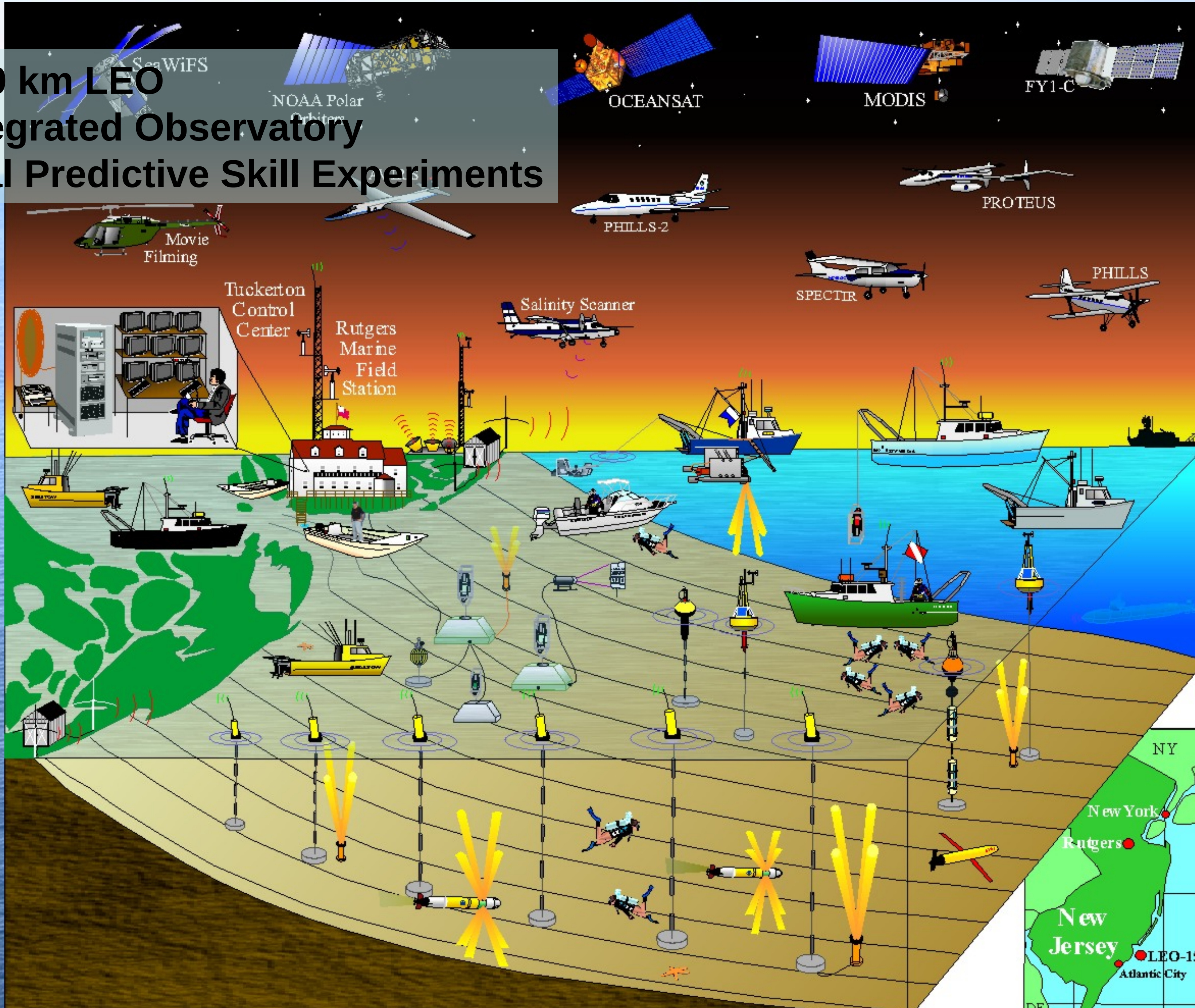


Instrument Package for 2000: ac-9, HiSTAR, FRR, LISST, HS-2, Biolum, VSM

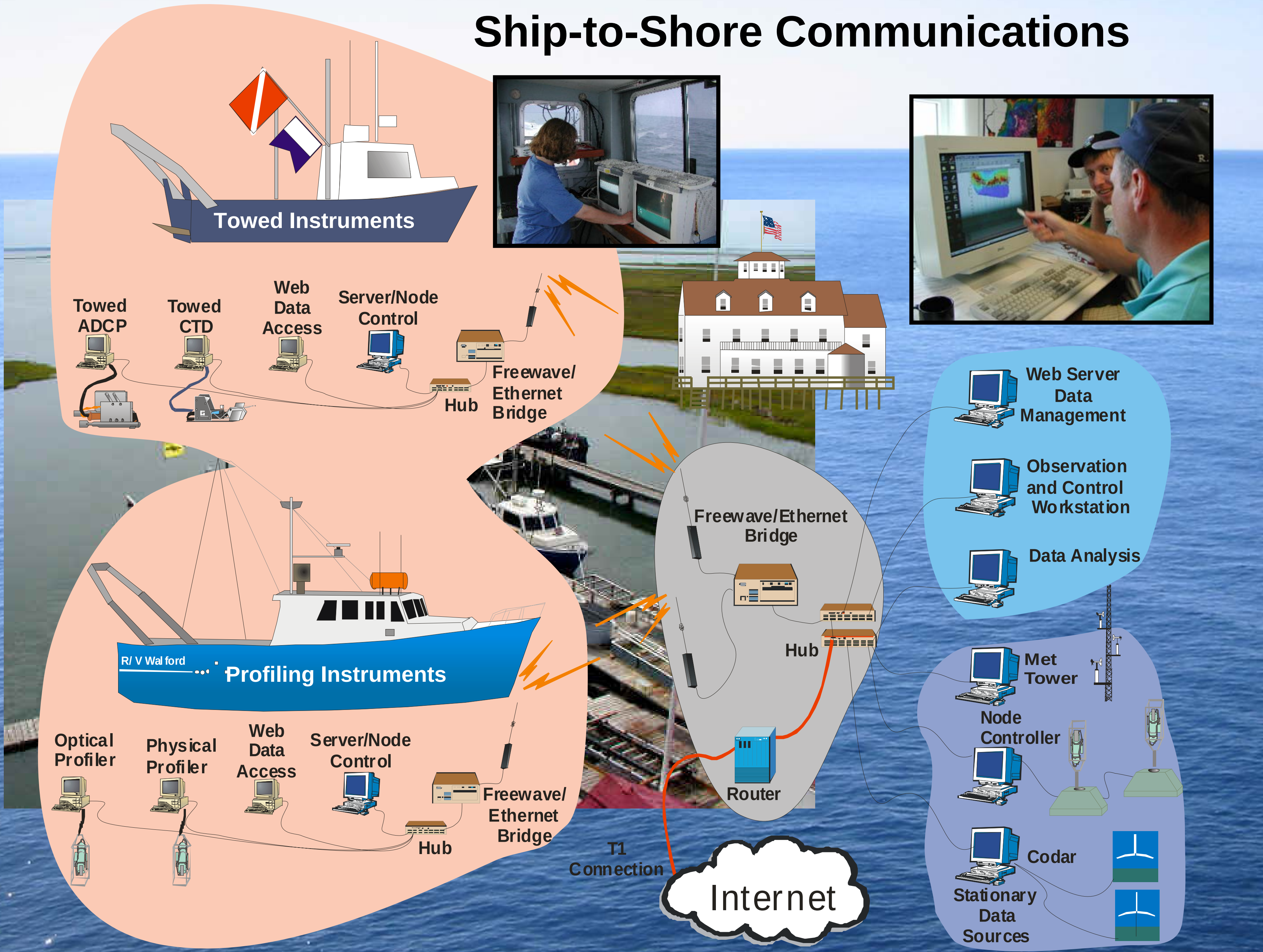


Thanks to Alan Weidemann and Mike Purcell

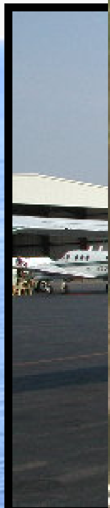
30 X 30 km LEO
An Integrated Observatory
Coastal Predictive Skill Experiments



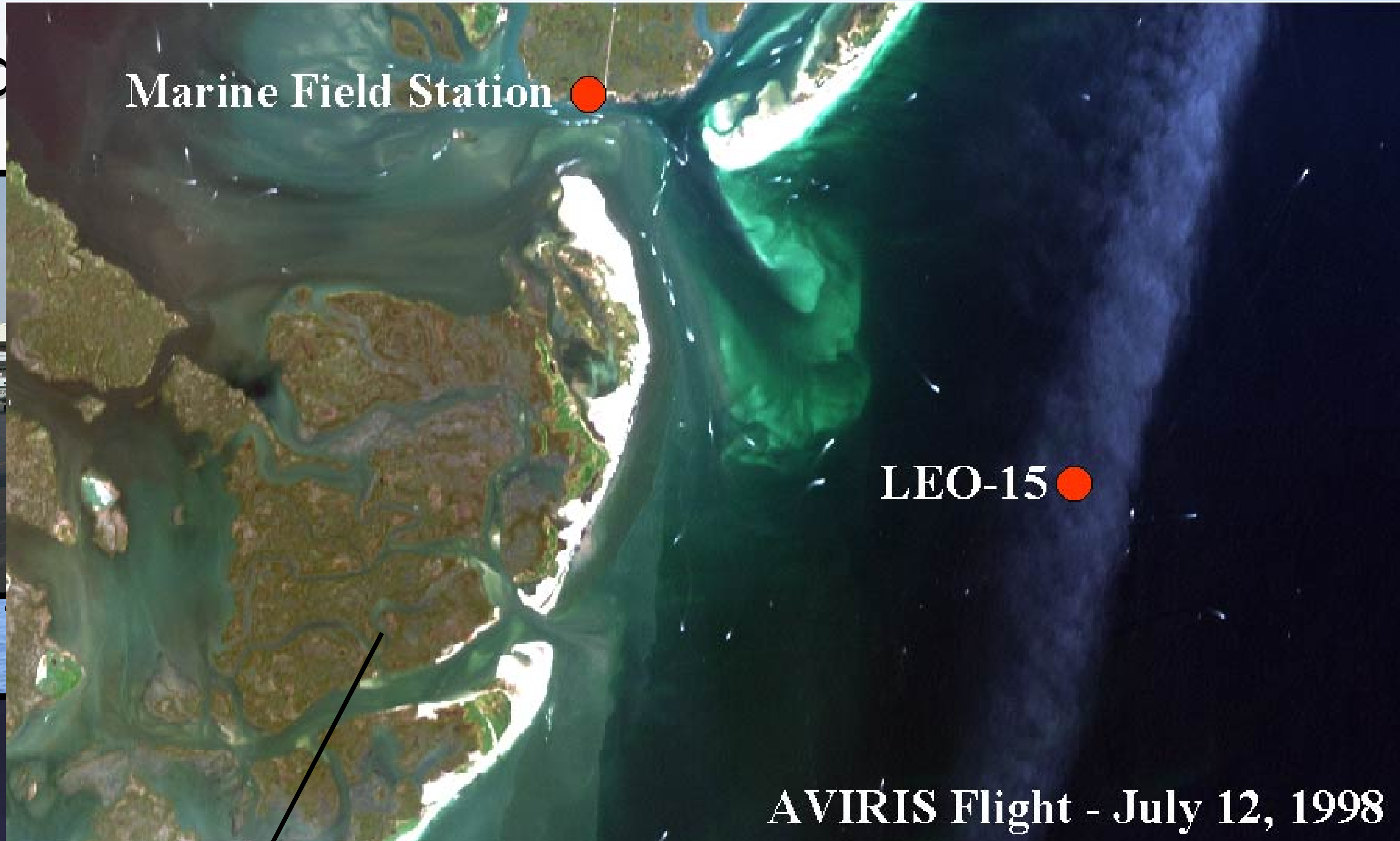
Ship-to-Shore Communications



Ac



Spectral



NASA – AVIRIS

Antanov – NRL PHILLS

LEO Coastal Predictive Skill Experiments

Experimental High-Res RAMS Atmospheric Model

Operational Low-Res COAMPS Atmospheric Model

Experimental 6-km High-Res COAMPS Atmospheric Model

Air-Sea Interaction Model

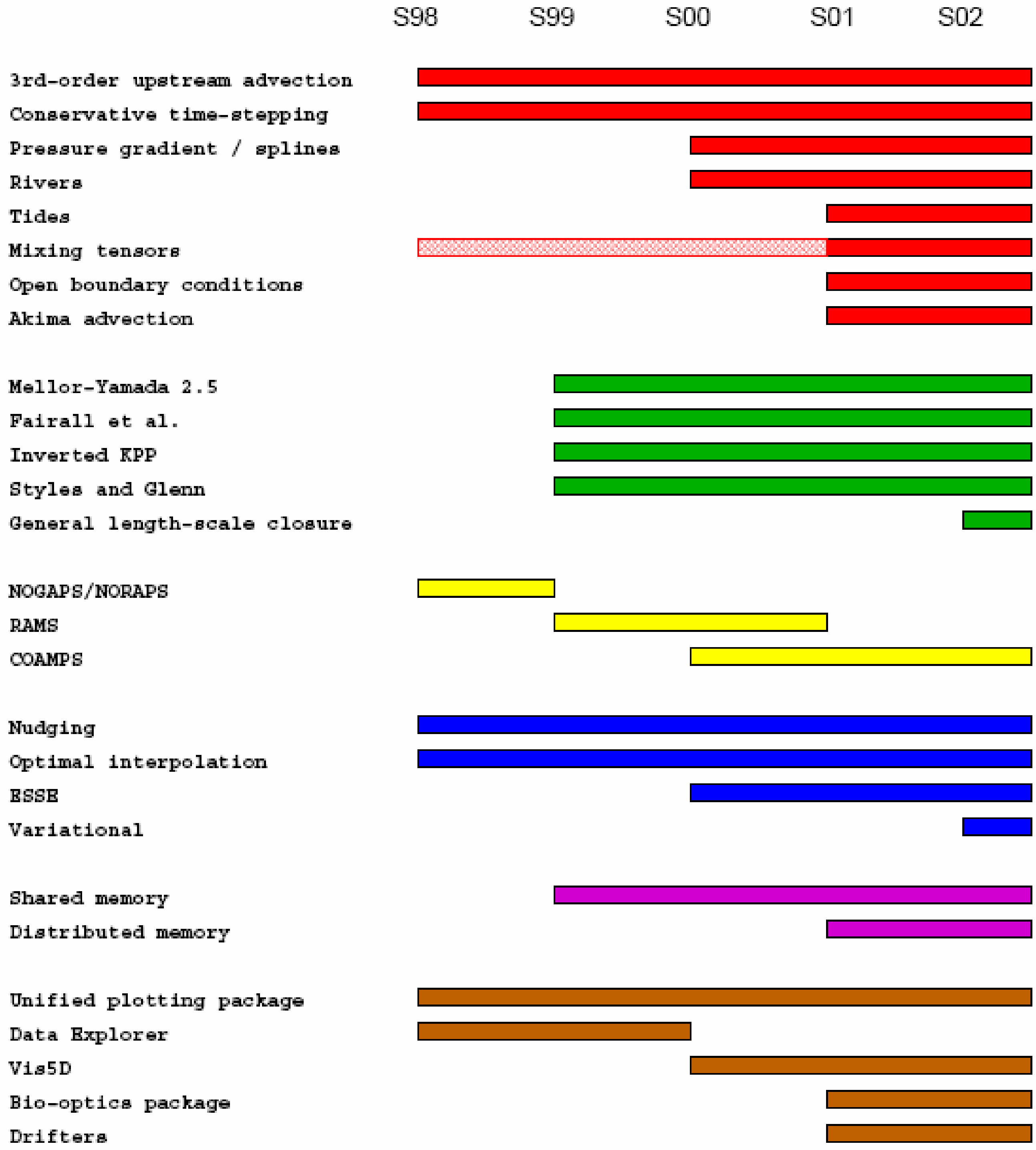
ROMS Assimilation

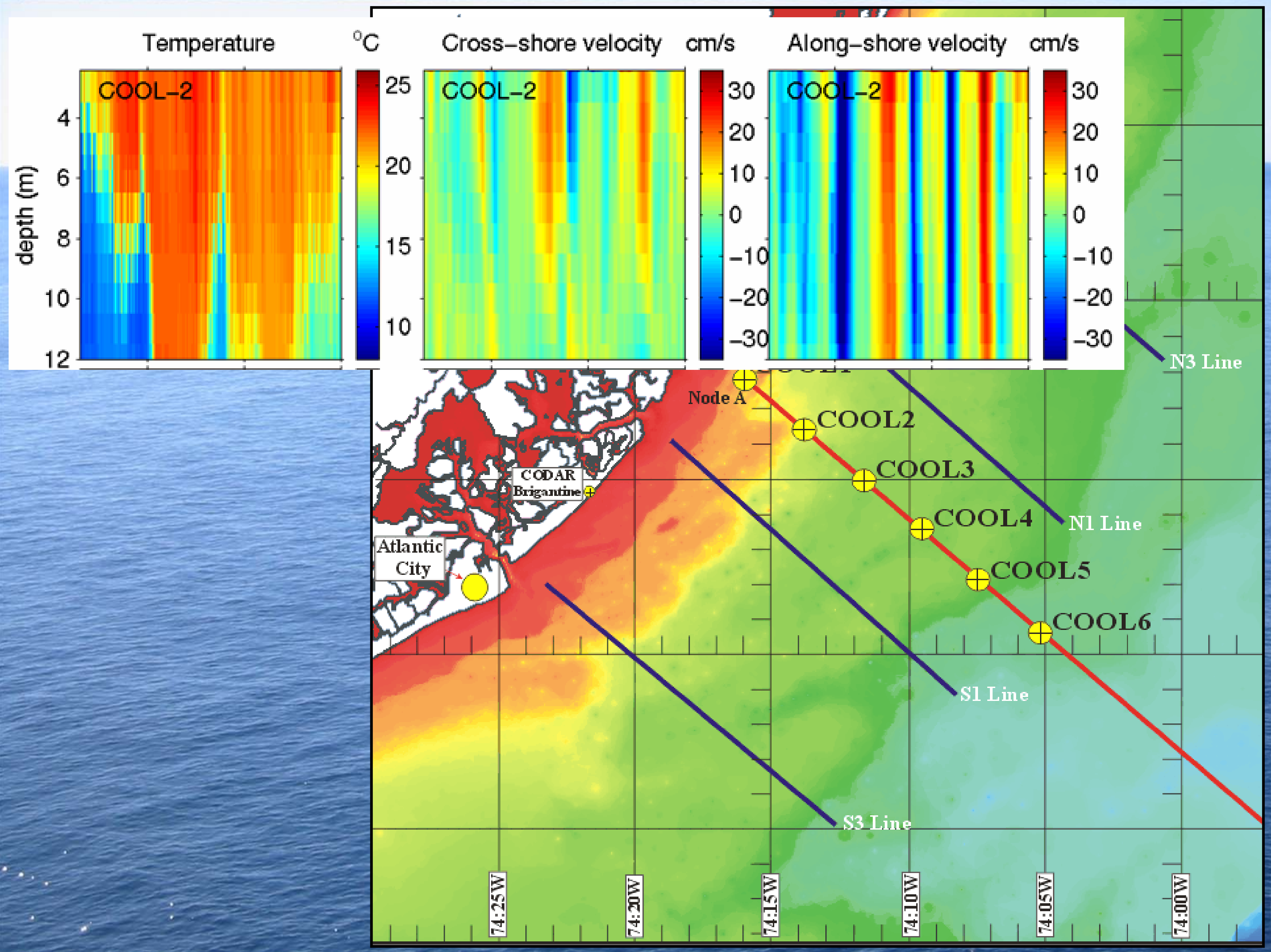
MODAS Assimilation

ROMS Ocean Model (KPP and MY 2.5 Turbulent Closure)

Bottom Boundary Layer Model

3-day ocean forecast briefing for planning ship operations


S98
S99
S00
S01
S02
3rd-order upstream advection
Conservative time-stepping
Pressure gradient / splines
Rivers
Tides
Mixing tensors
Open boundary conditions
Akima advection
Mellor-Yamada 2.5
Fairall et al.
Inverted KPP
Styles and Glenn
General length-scale closure
NOGAPS/NORAPS
RAMS
COAMPS
Nudging
Optimal interpolation
ESSE
Variational
Shared memory
Distributed memory
Unified plotting package
Data Explorer
Vis5D
Bio-optics package
Drifters


Temperature
°C
COOL-2
depth (m)
Cross-shore velocity
cm/s
Along-shore velocity
Node A
COOL2
COOL3
COOL4
COOL5
COOL6
N1 Line
N3 Line
S1 Line
S3 Line
CODAR
Brigantine
Atlantic
City
74:25W
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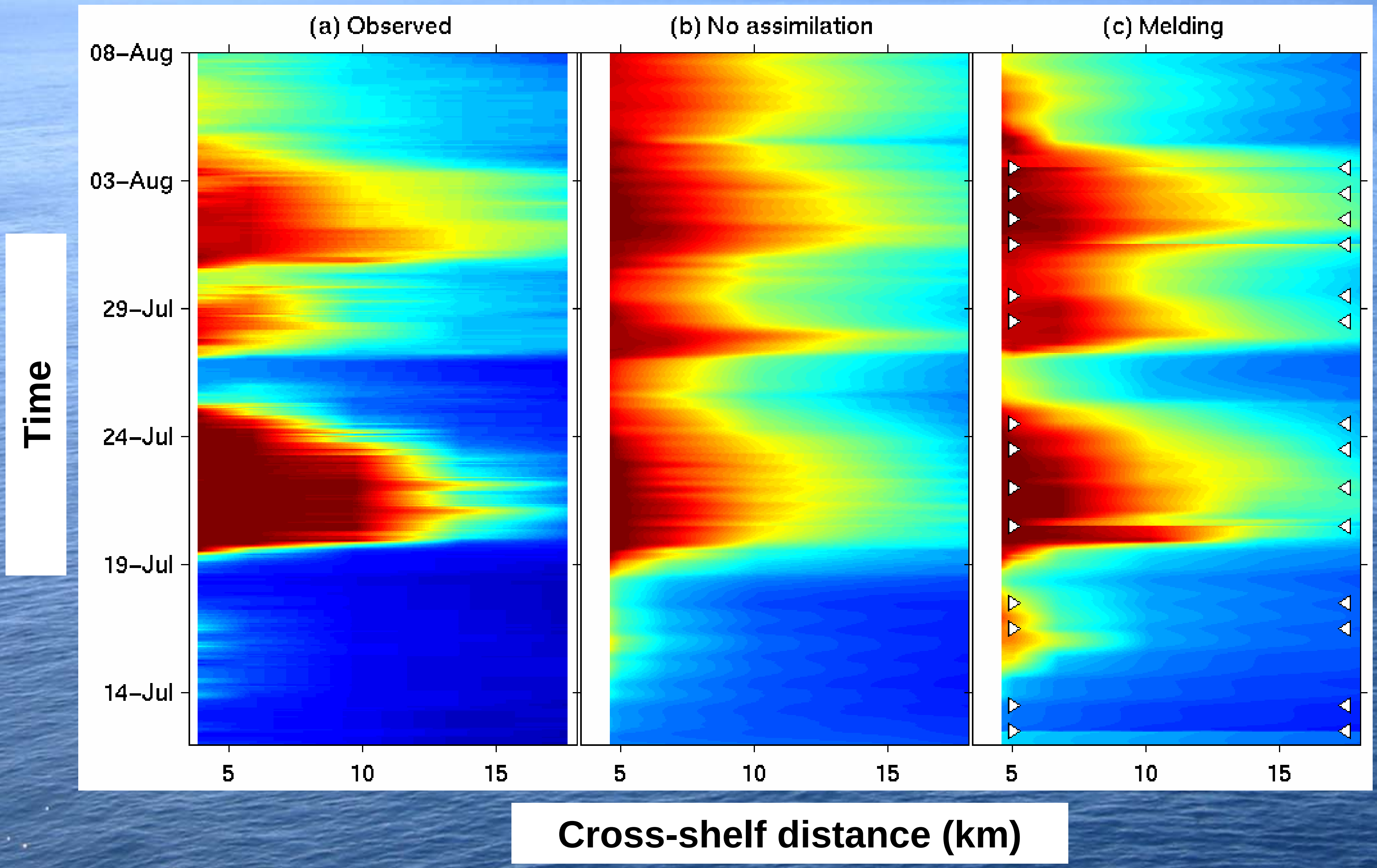
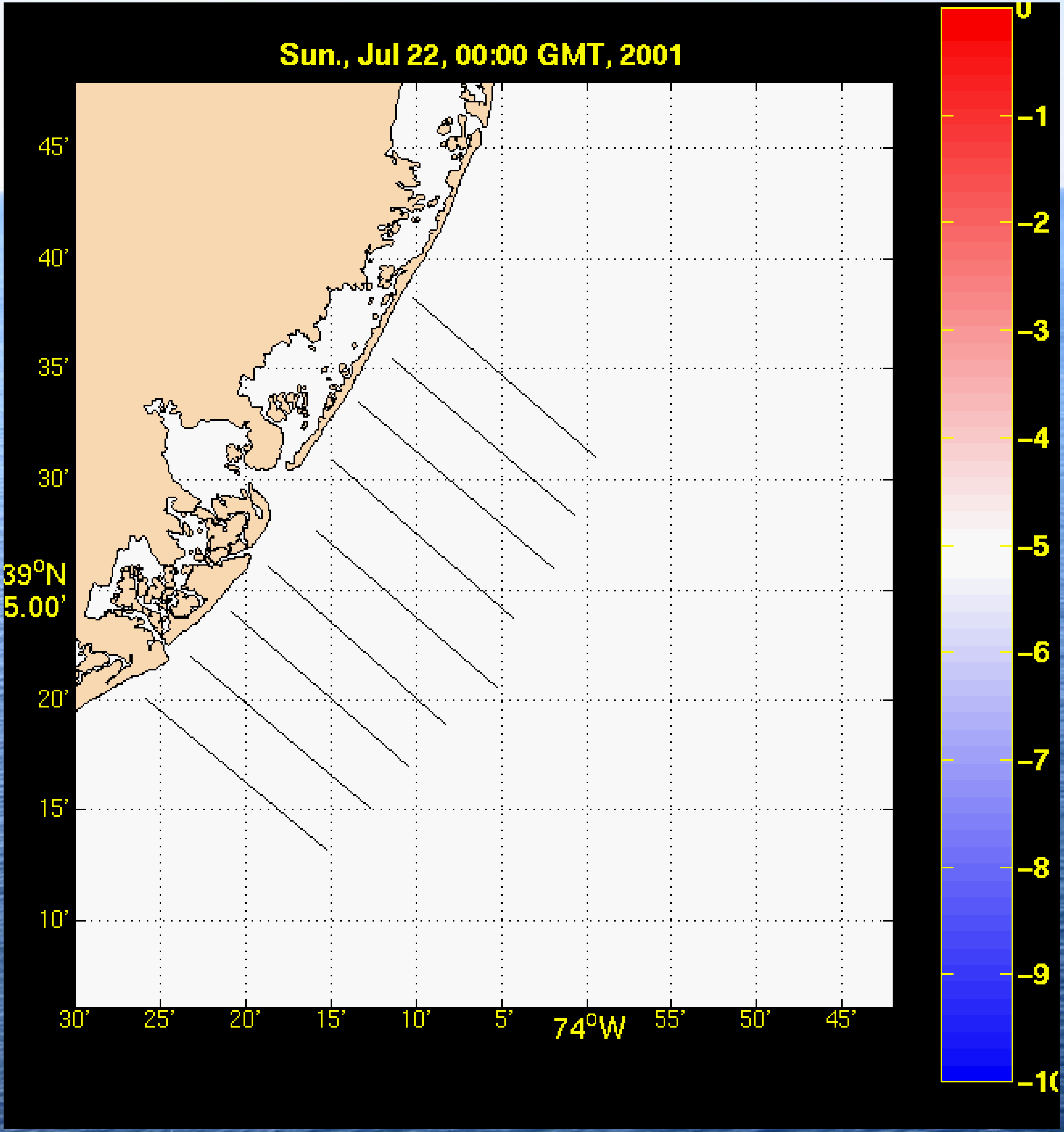
74:10W
74:05W
74:00W

Seafloor temperature at cross-shelf line through the center of LEO





Sun., Jul 22, 00:00 GMT, 2001
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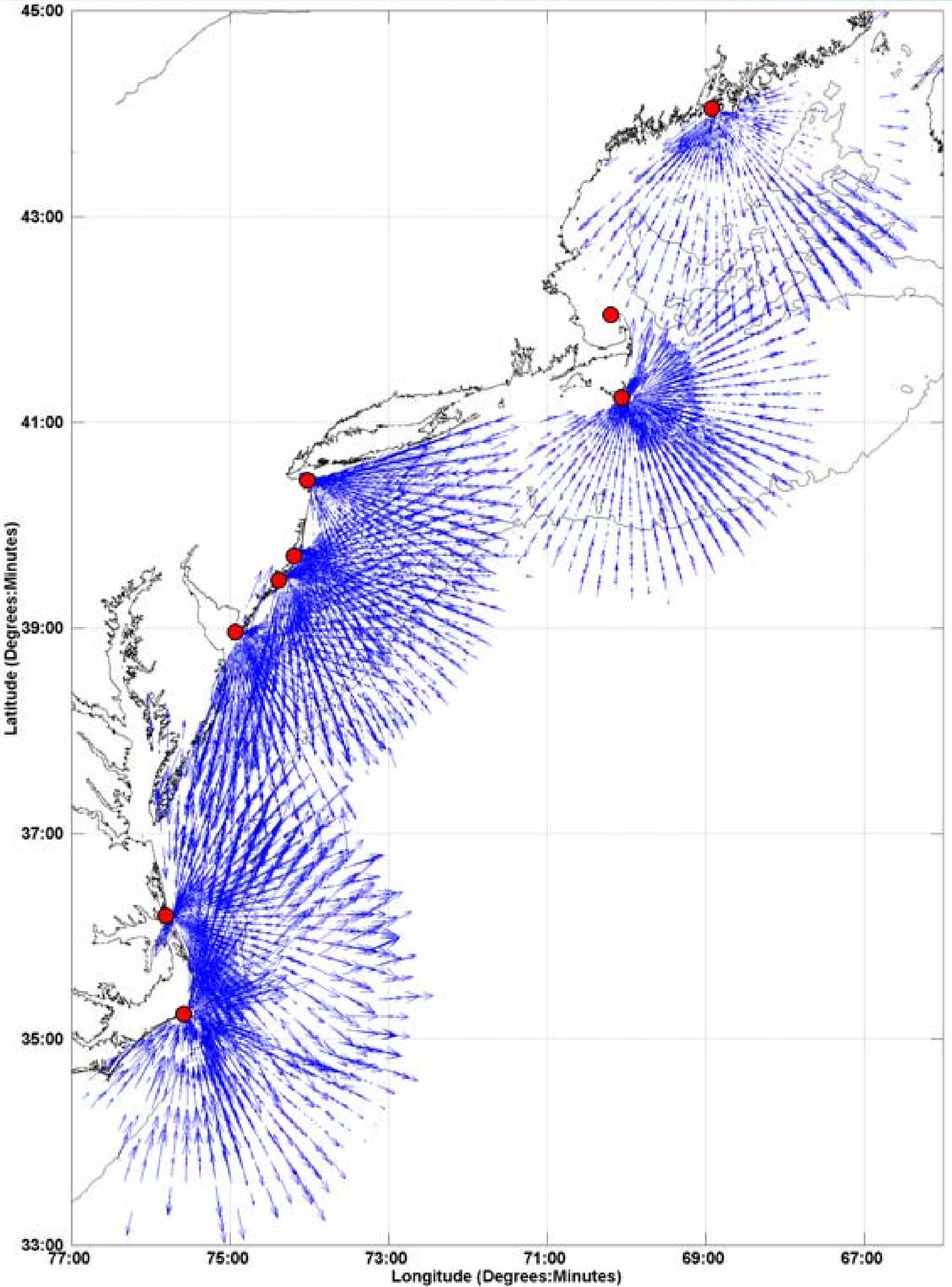
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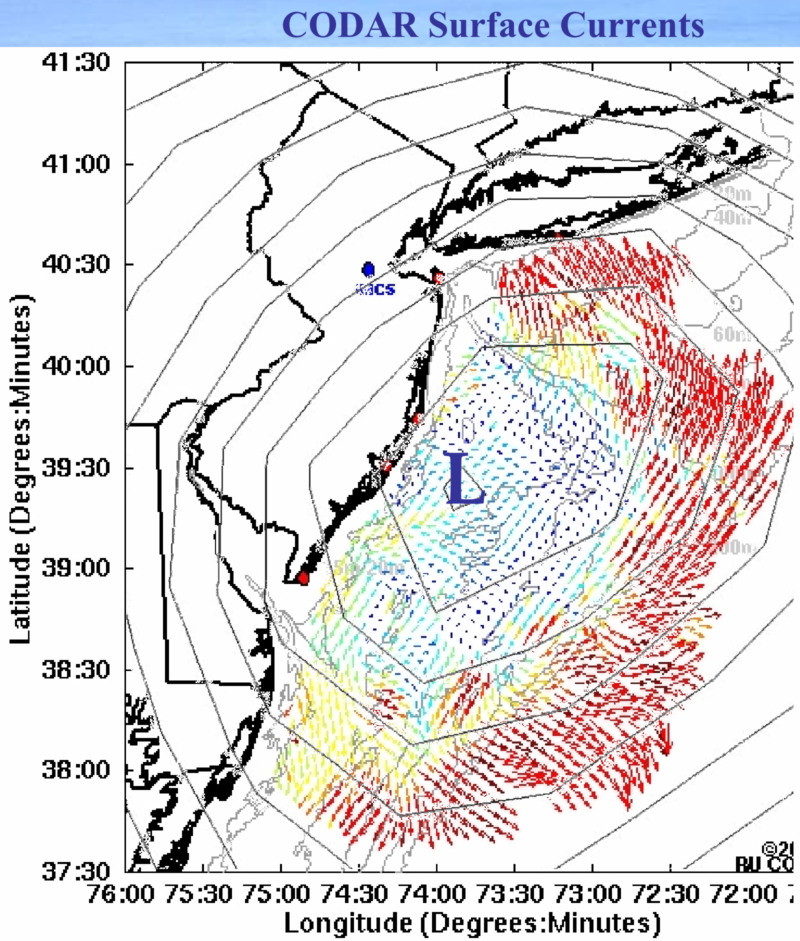
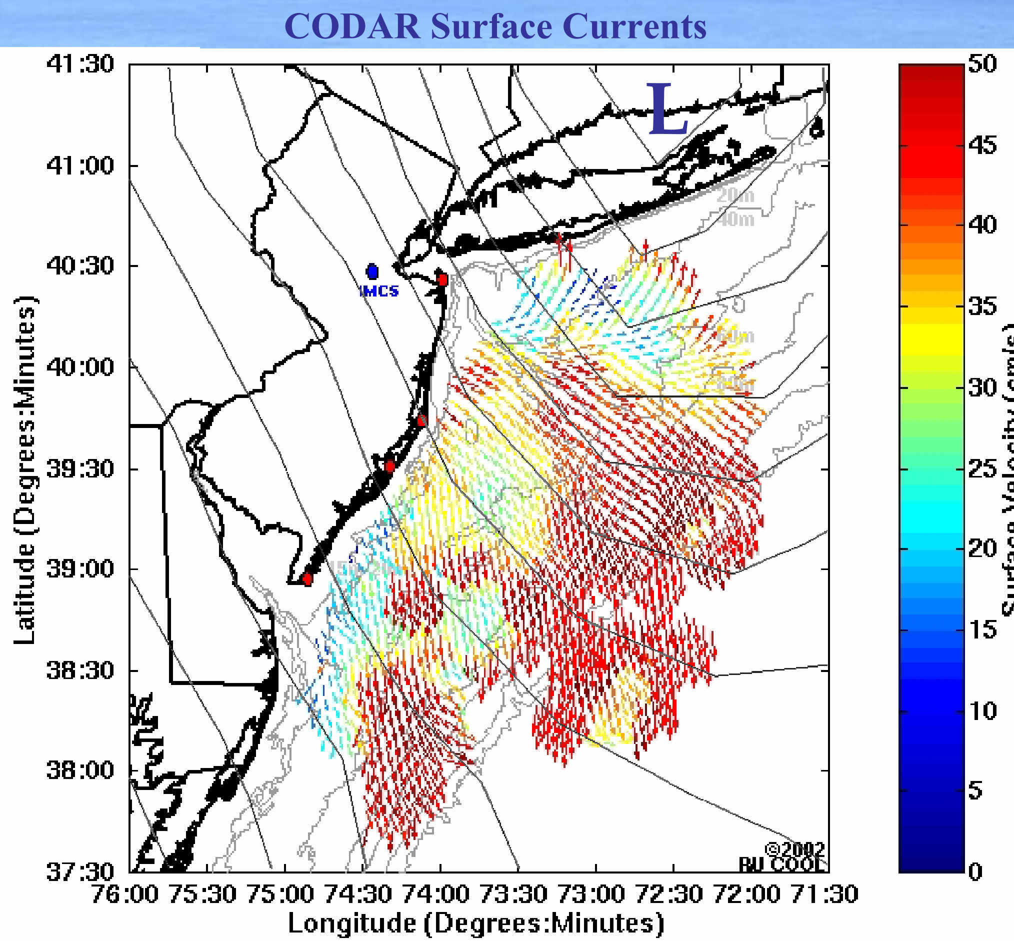
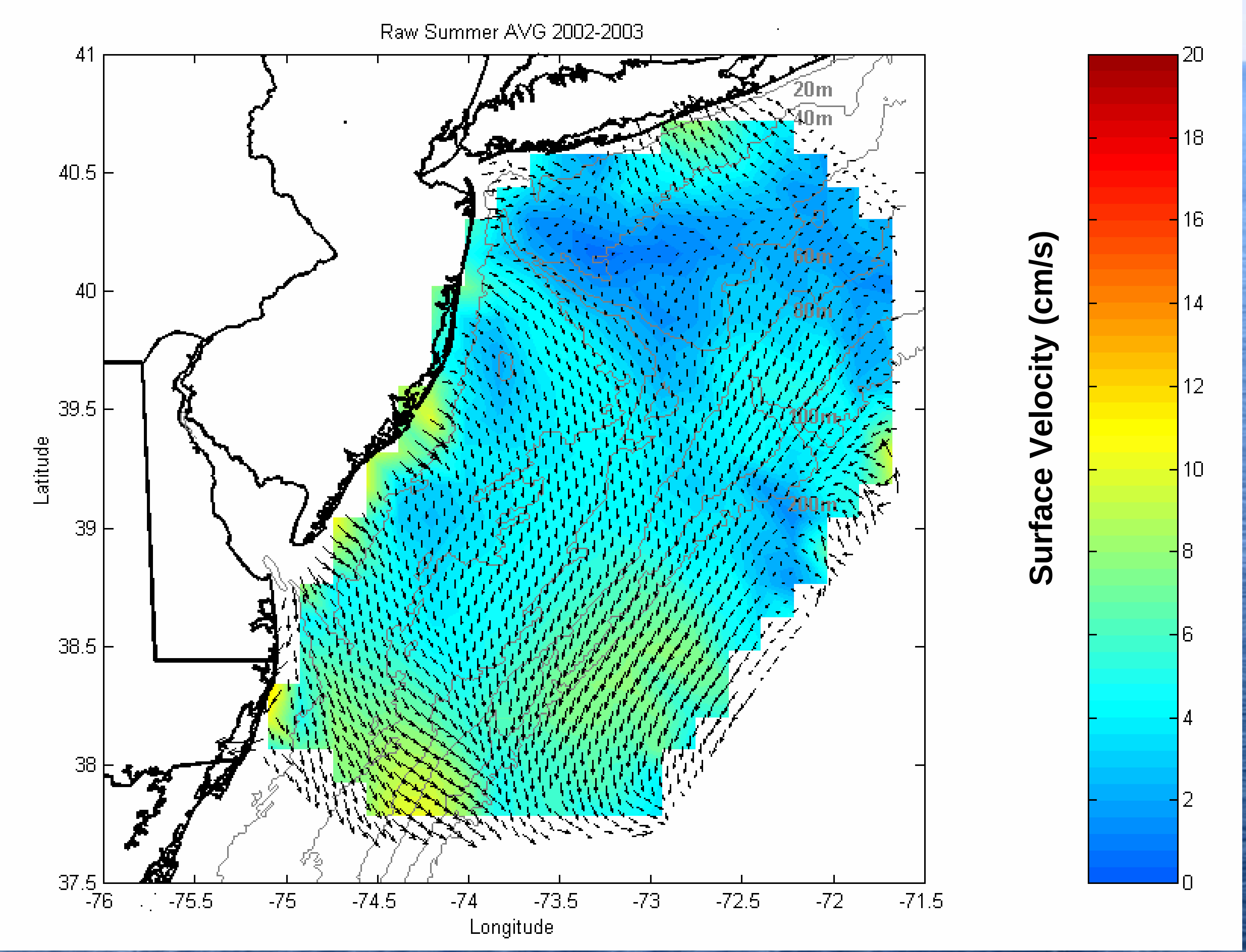
16 Oct 2002: 1800 GMT

17 Oct 2002: 1800

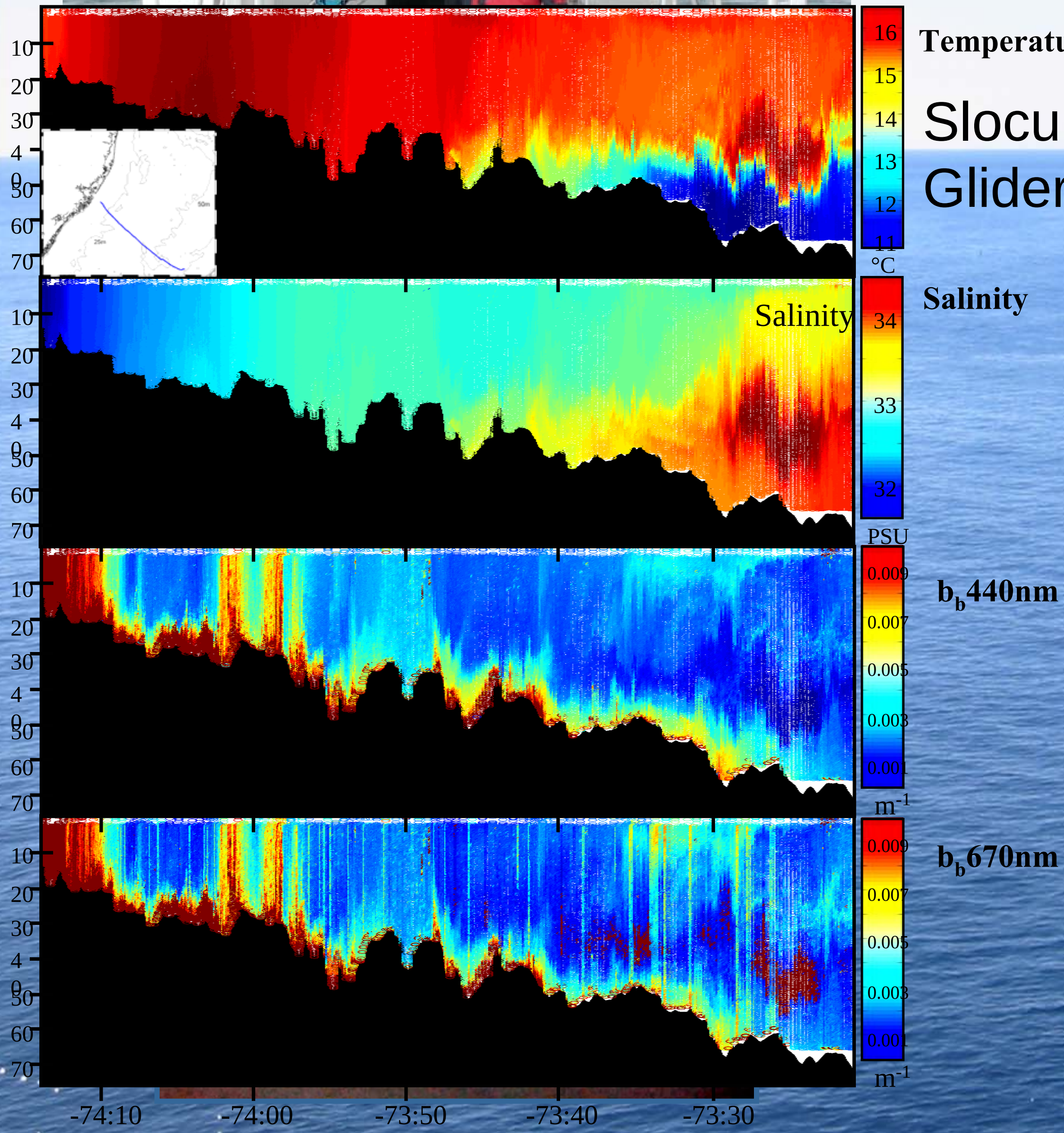


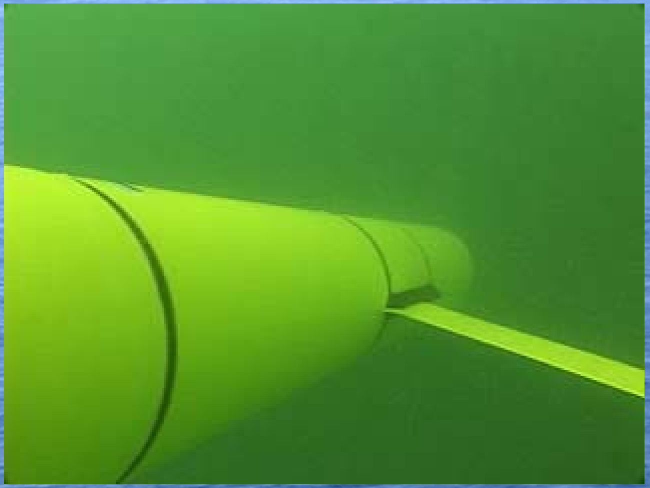


Average Surface Currents (2002-2003)



Slocum Autonomous Glider – Webb Research





Josh Kohut

Scott Glenn

Hernan Arango

Dale Haidvogel

Bob Chant

John Wilkin

Hugh Roarty

John Kerfoot

Liz Creed

Katja Fennel

Eli Hunter

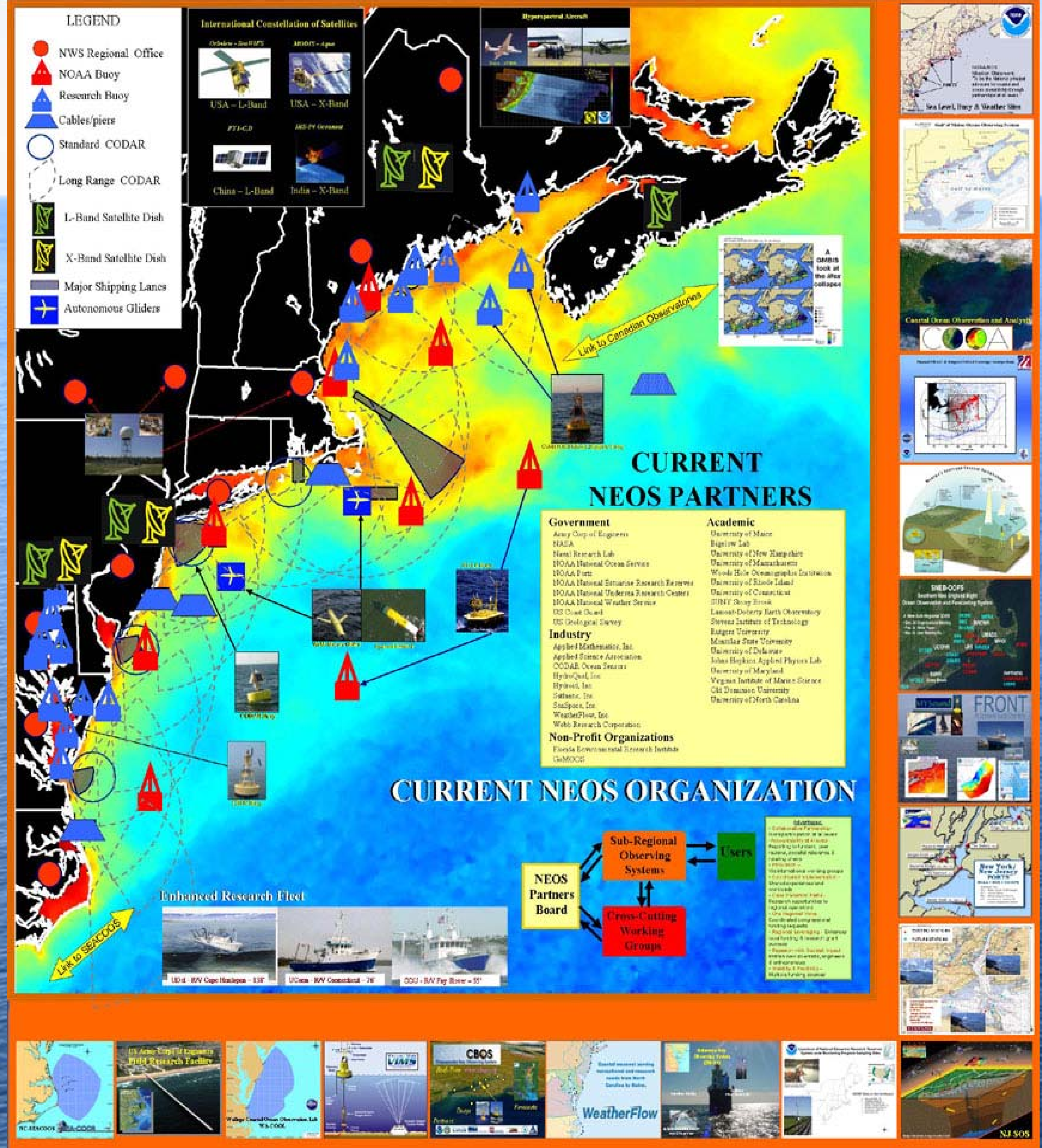
New Jersey Shelf Observing System

Regional Scale Observatories

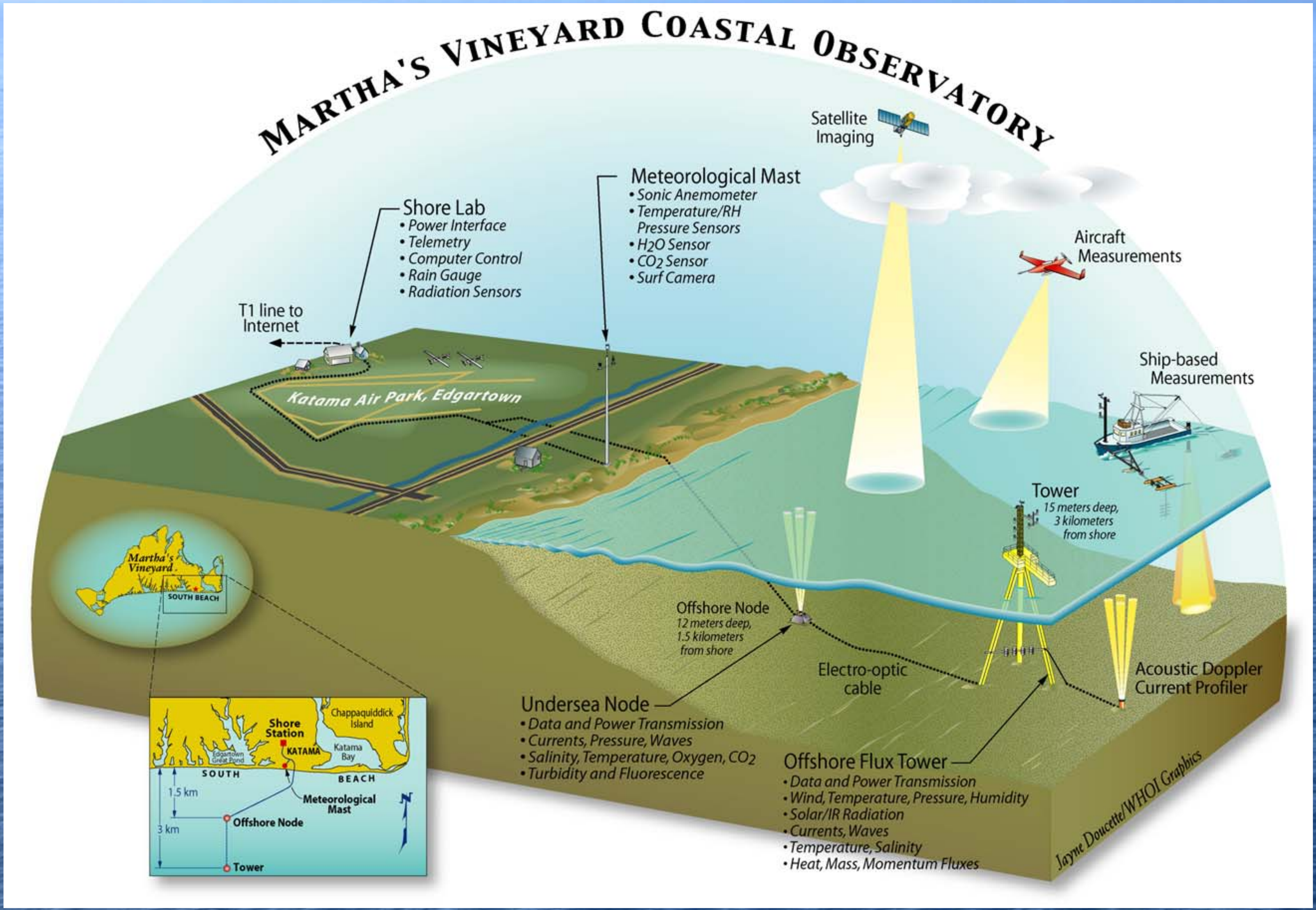
NEOS, a science consortium established in 2000 provides a regional footprint.

Sub-regional observatories and technology/science working groups.

Current groups include: DODS data management, satellite remote sensing, CODAR, AUVs, bio-optics standards, buoys, waves, shelf carbon biogeochemistry, extreme weather, economic products



MVCO: Martha's Vineyard Coastal Observatory and CBLAST



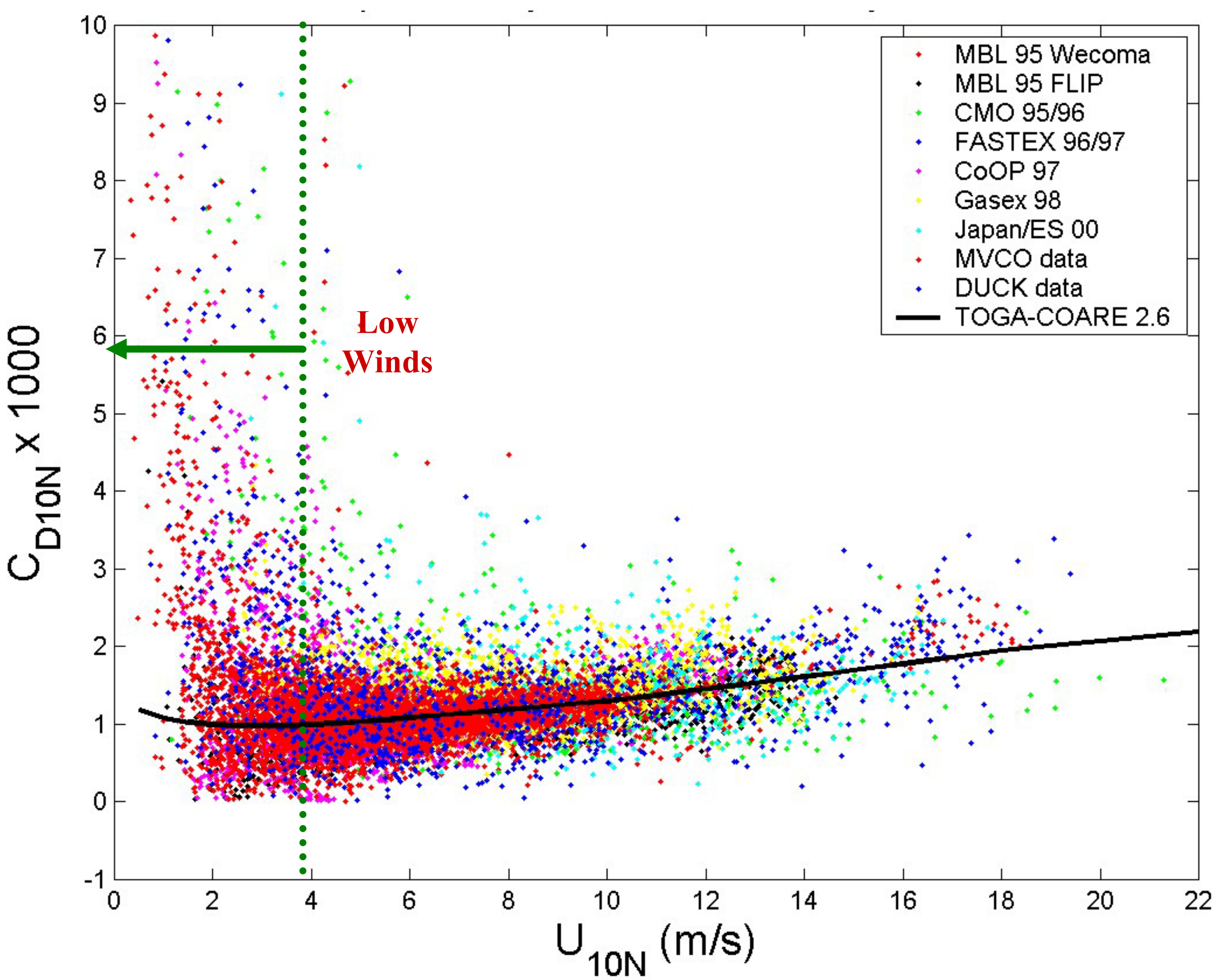
CBLAST:
Coupled Boundary Layers and Air-Sea Transfer

The ONR CBLAST-Low program focuses on air-sea interaction and coupled atmosphere/ocean boundary layer dynamics at low wind speeds where processes are strongly modulated by thermal forcing.

- Precise observations of air-sea fluxes and turbulent mixing from CBLAST are ideal for evaluating the vertical turbulence closure schemes employed in ocean models.
- This comparison will be possible provided the model captures the essential features of the ocean heat budget on diurnal to several day time-scales, and spatial scales of order 1 km.
- Modeling complements the interpretation of the field observations by quantifying unobserved lateral transport and mixing of heat.

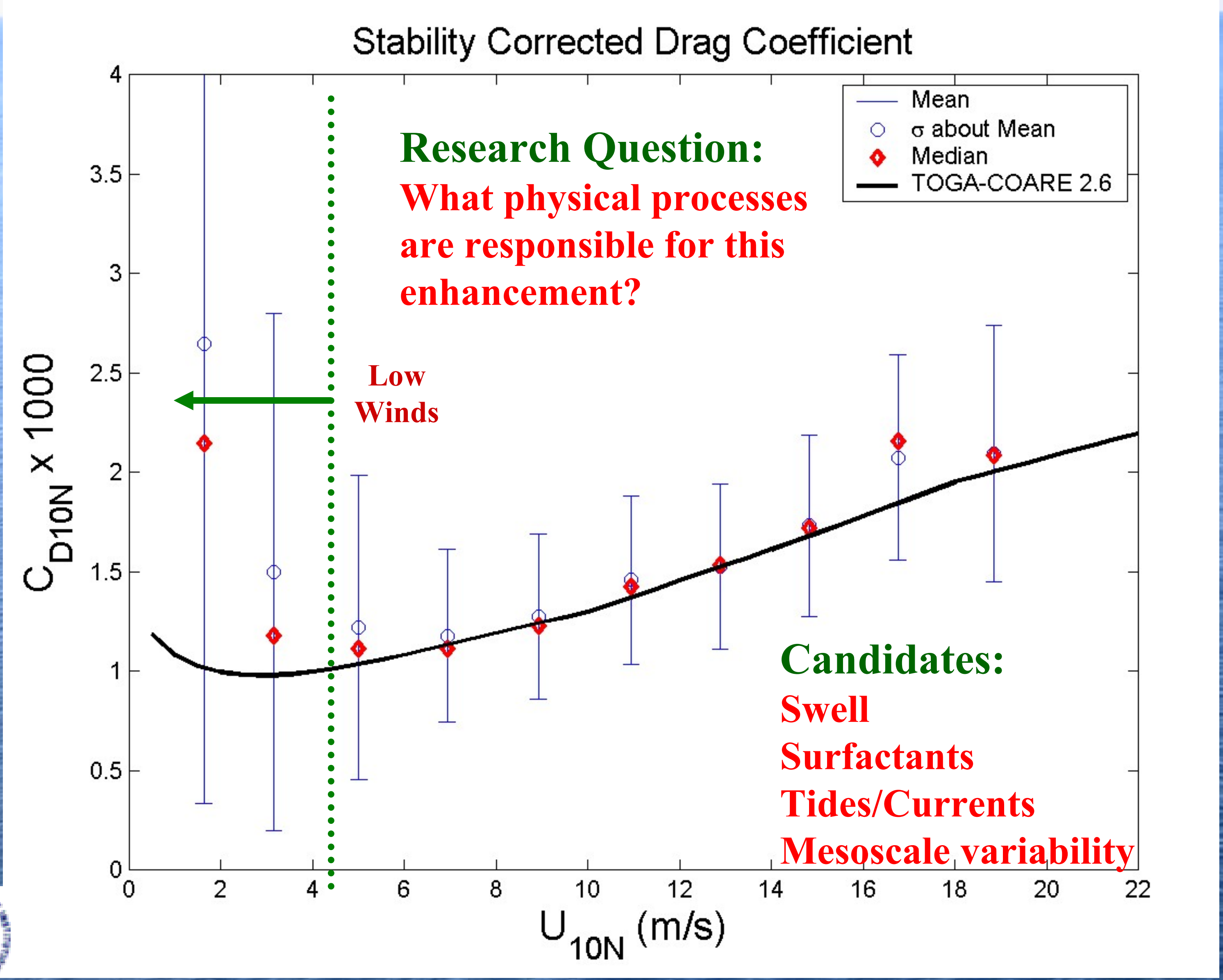
Improve Flux Parameterizations

$$\tau = \rho C_D \Delta U^2$$



Improve Flux Parameterizations

$$\tau = \rho \, C_D \, \Delta U^2$$

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b
c
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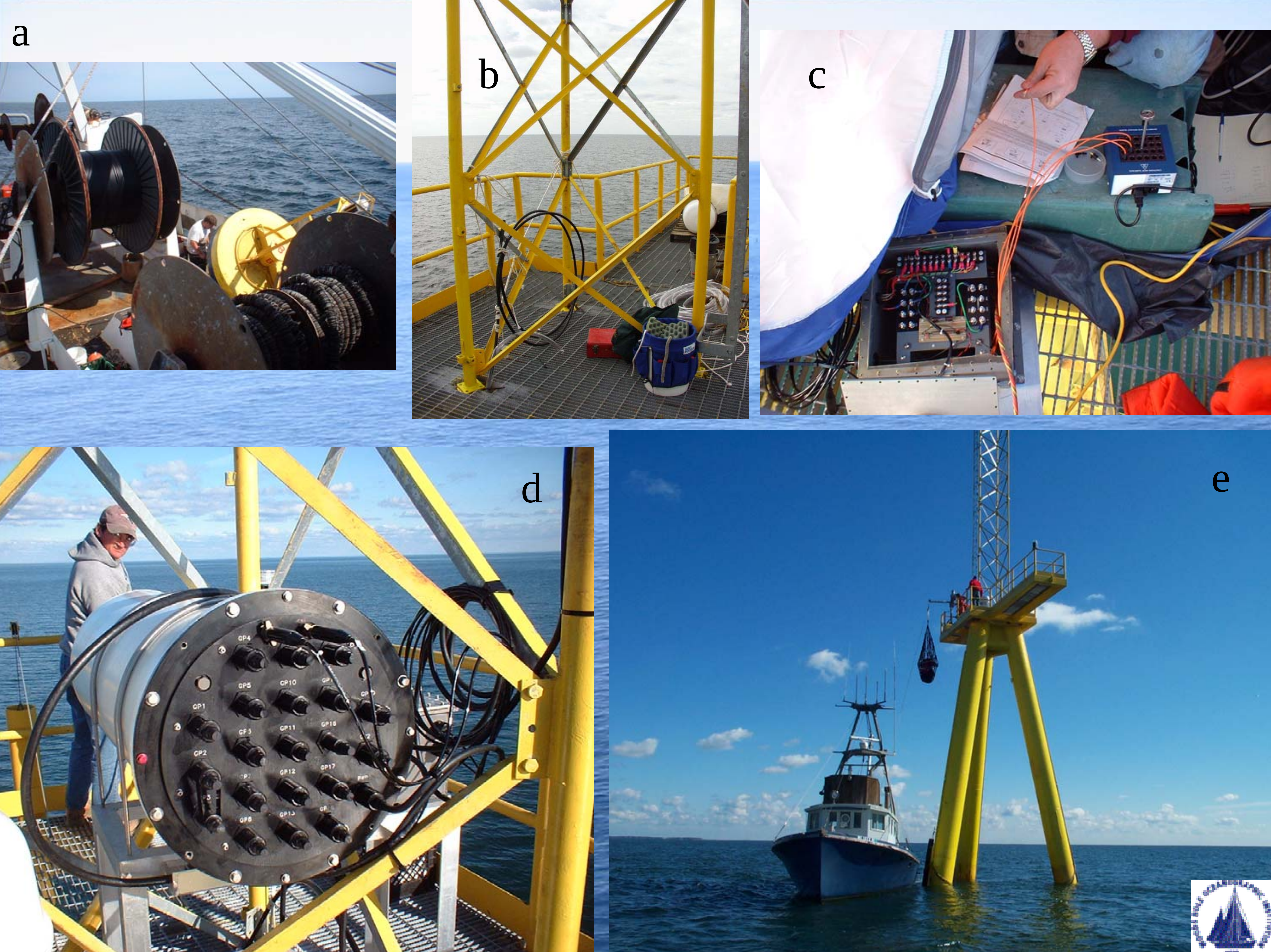
a
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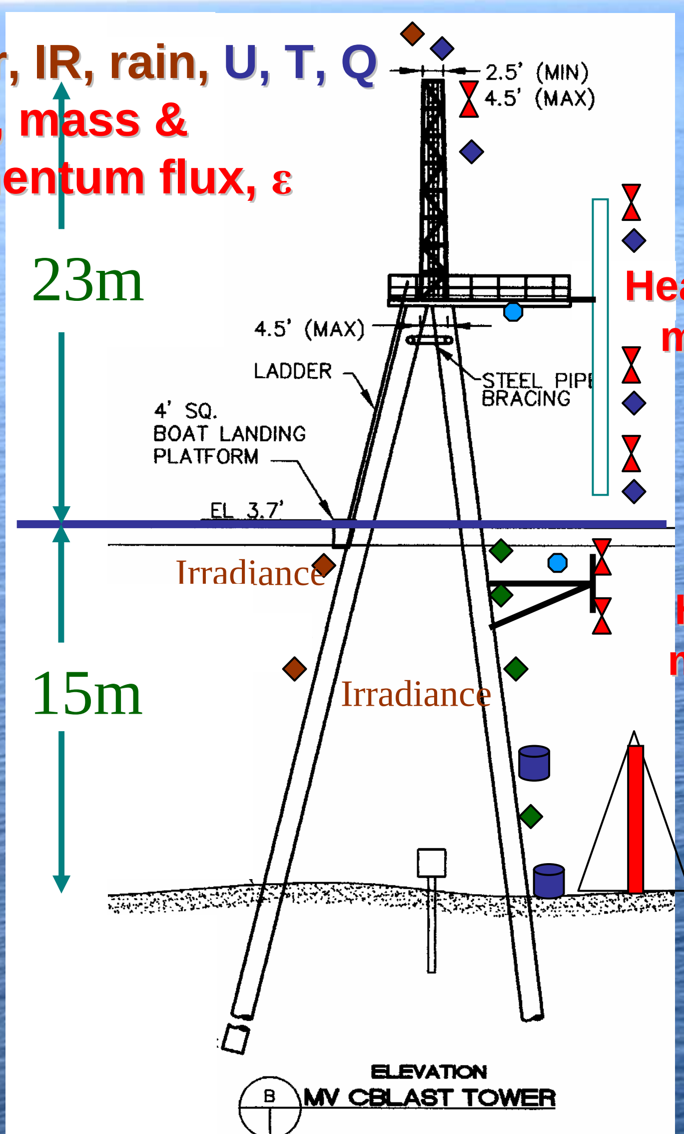
CBLAST Air-Sea Interaction Tower

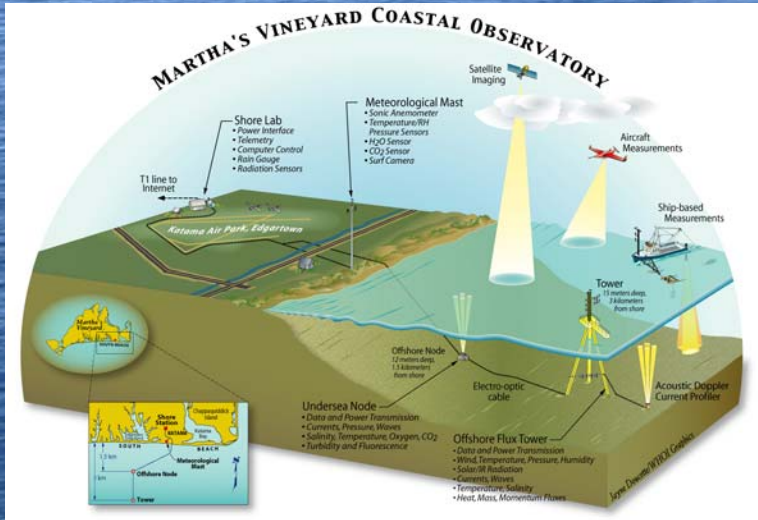
Solar, IR, rain, U, T, Q
Heat, mass & momentum flux, ε



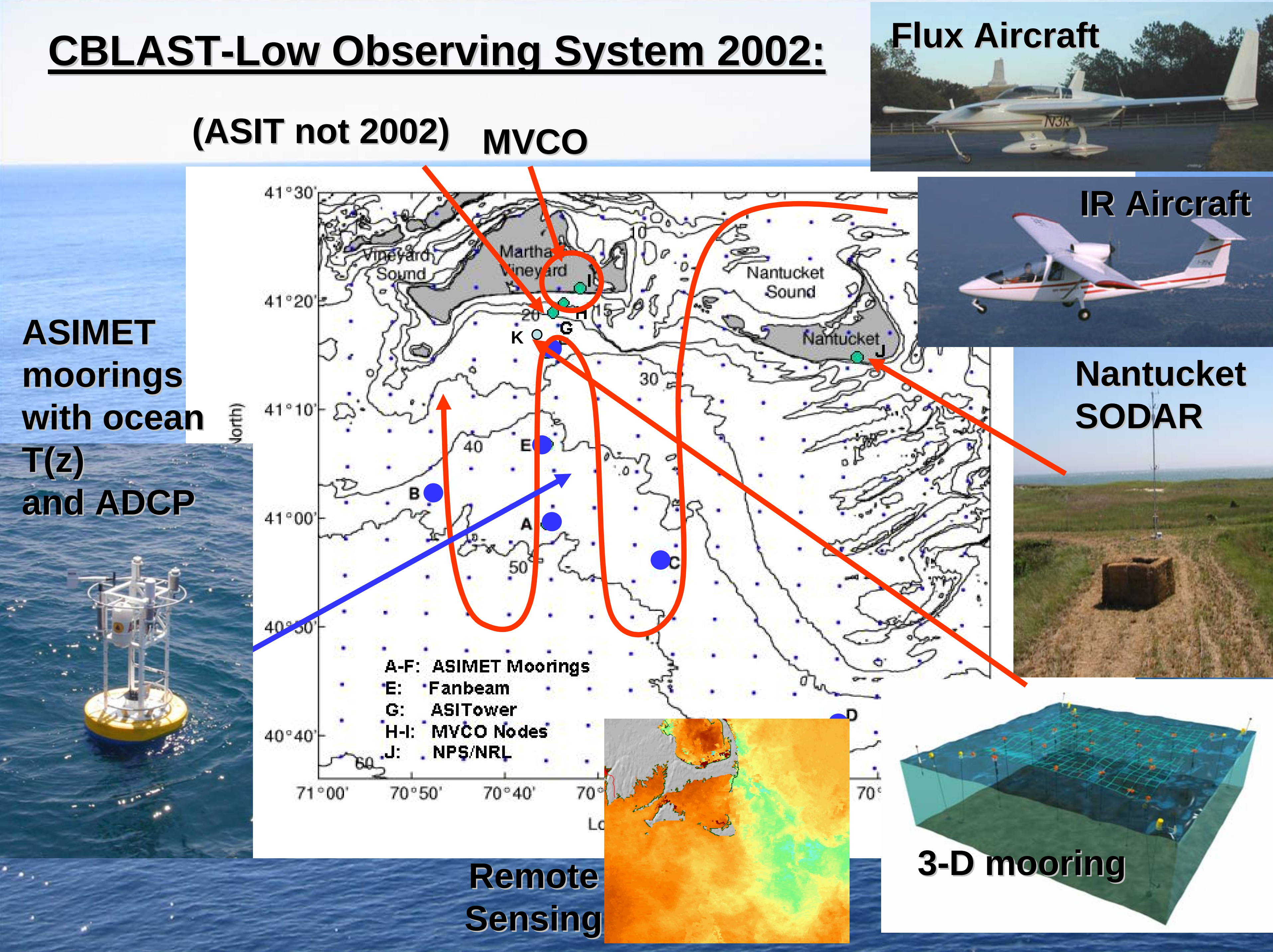
U, T, Q
Heat, mass & mom. flux, ε
Waves

Waves
T, S
Heat, mass mom. flux, ε

Moving profiler w/ fixed flux packages

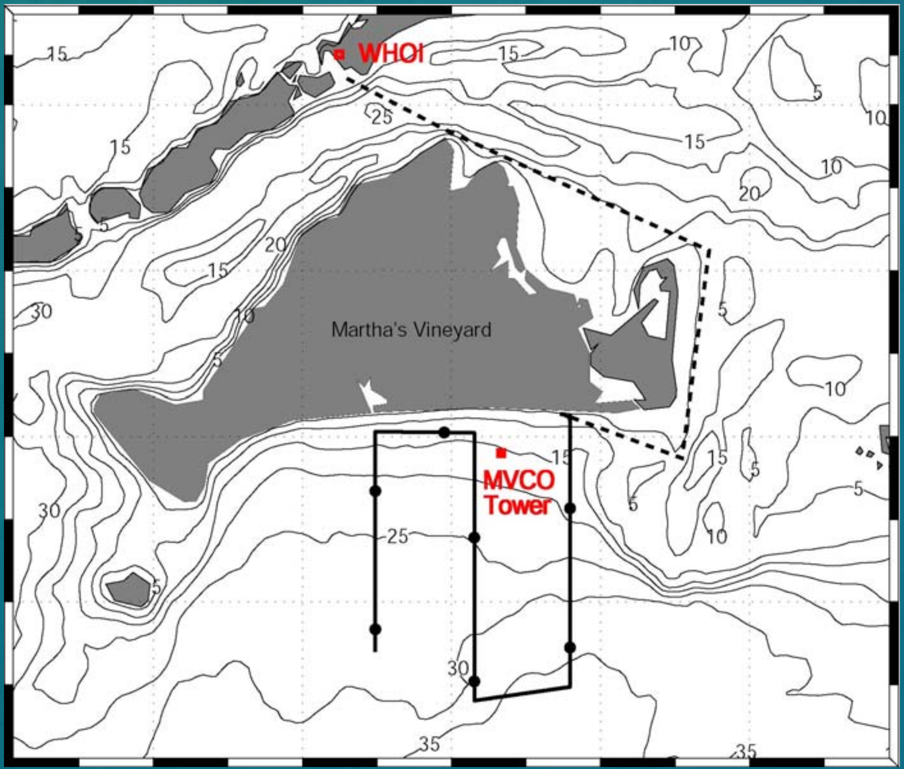


CBLAST-Low Observing System 2002:



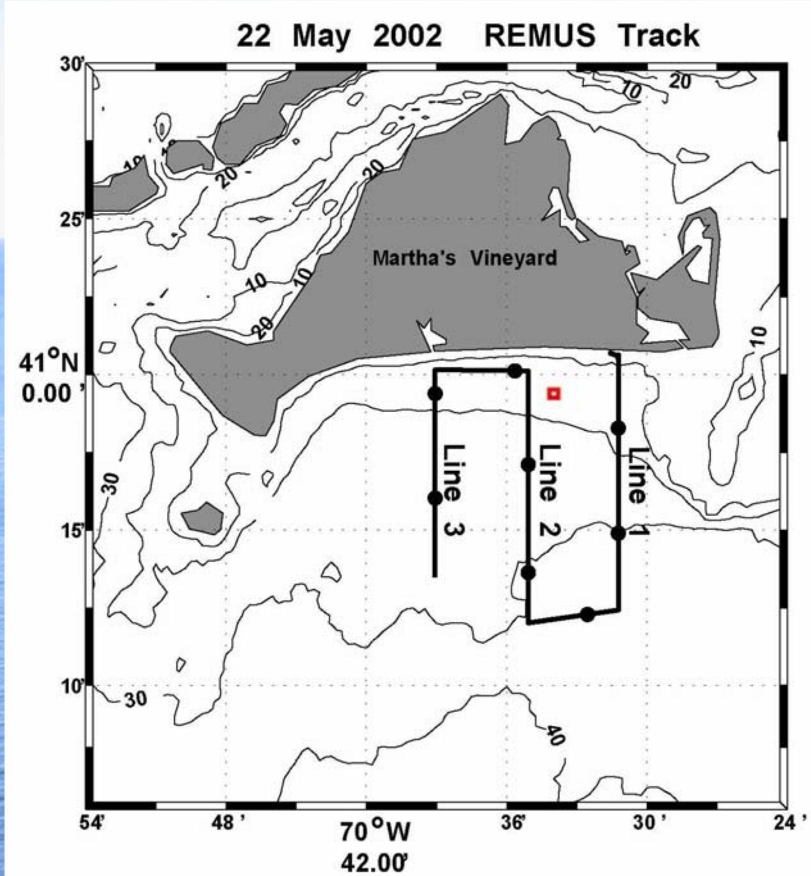
Autonomous Measurements of Temperature, Salinity and Currents over the Inner-Shelf at the Martha's Vineyard Coastal Observatory

Courtesy of Kipp Shearman, WHOI

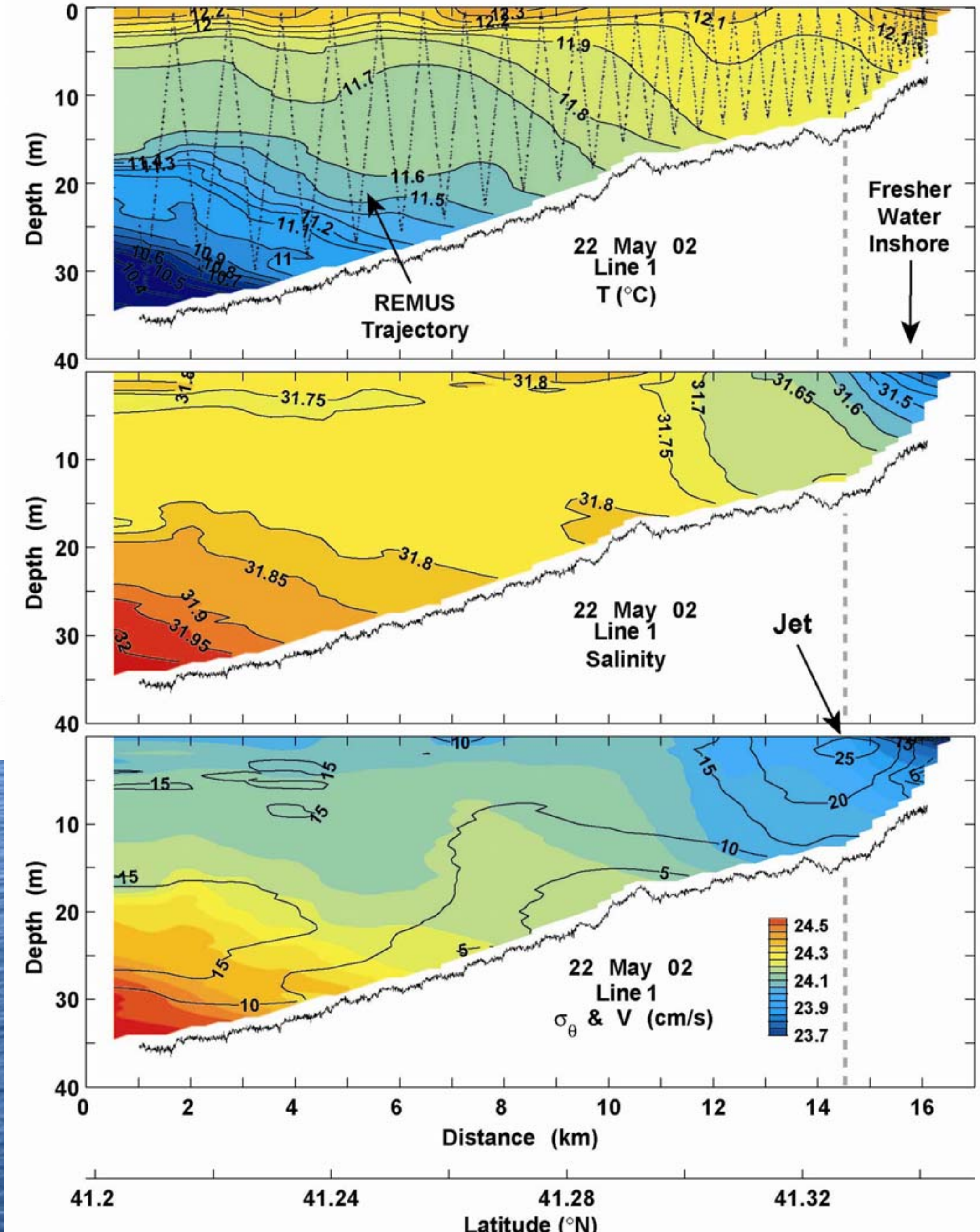


Goals:

- Demonstrate utility of AUVs in observatory science
- Understand inner-shelf stratification variability



Line 1

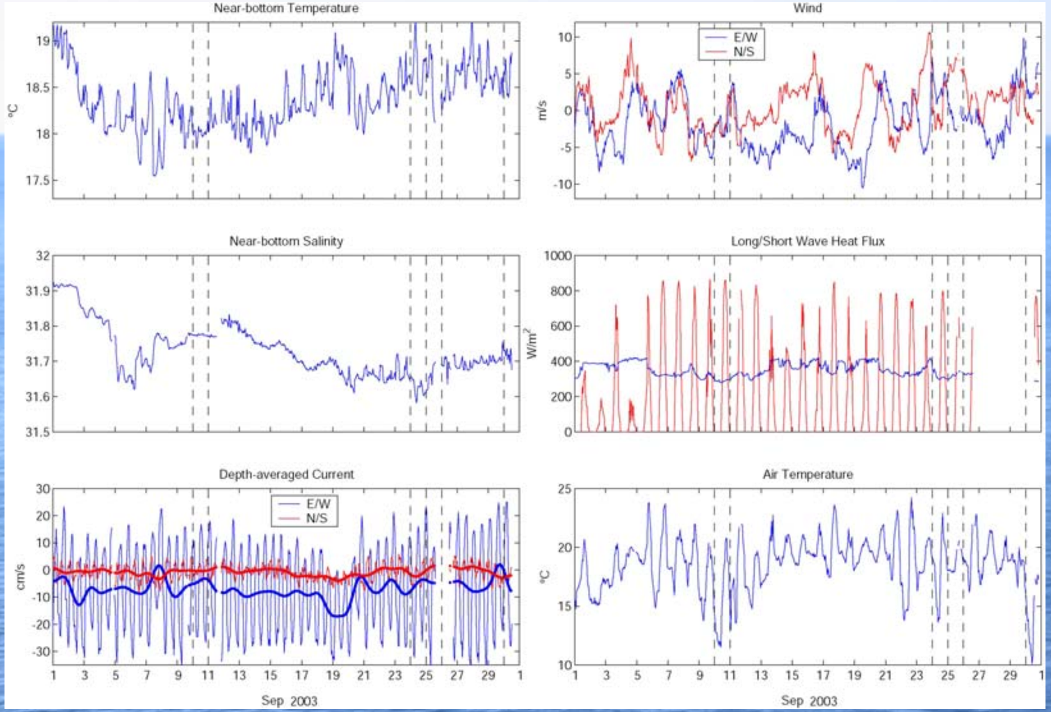


May 2002 Observations:

Fresh water plume inshore

~4 km wide

Strong (25 cm/s) along-shelf flow



Sep 2003 Observations:

Variable winds, zero mean

Weak subtidal current variability, but mean westward along-shelf flow

Semidiurnal buoyant plume now warm not fresh

The Regional Ocean Modeling System (ROMS) has been configured for a region of the southeastern New England shelf encompassing the CBLAST observation area

Purpose:

Obtain model hind-cast of summertime ocean conditions that captures the essential features of the ocean heat budget on diurnal to several day time-scales, and spatial scales of order 1 km

The Regional Ocean Modeling System (ROMS) has been configured for a region of the southeastern New England shelf encompassing the CBLAST observation area

Motivation (1)

Model evaluation:

Compare model heat budget to observations:

- Evaluate heat budget sensitivity to vertical turbulent closures in ROMS
- Evaluate heat budget sensitivity to air-sea flux bulk formulae
- Evaluate contribution to hind-cast skill of meteorological model (COAMPS) compared to using observed marine boundary layer conditions

Motivation (2)

Observational data analysis:

Horizontal mixing and advection are largely unobserved by the CBLAST field instrumentation.

This affects closure of the observed heat budget, especially:

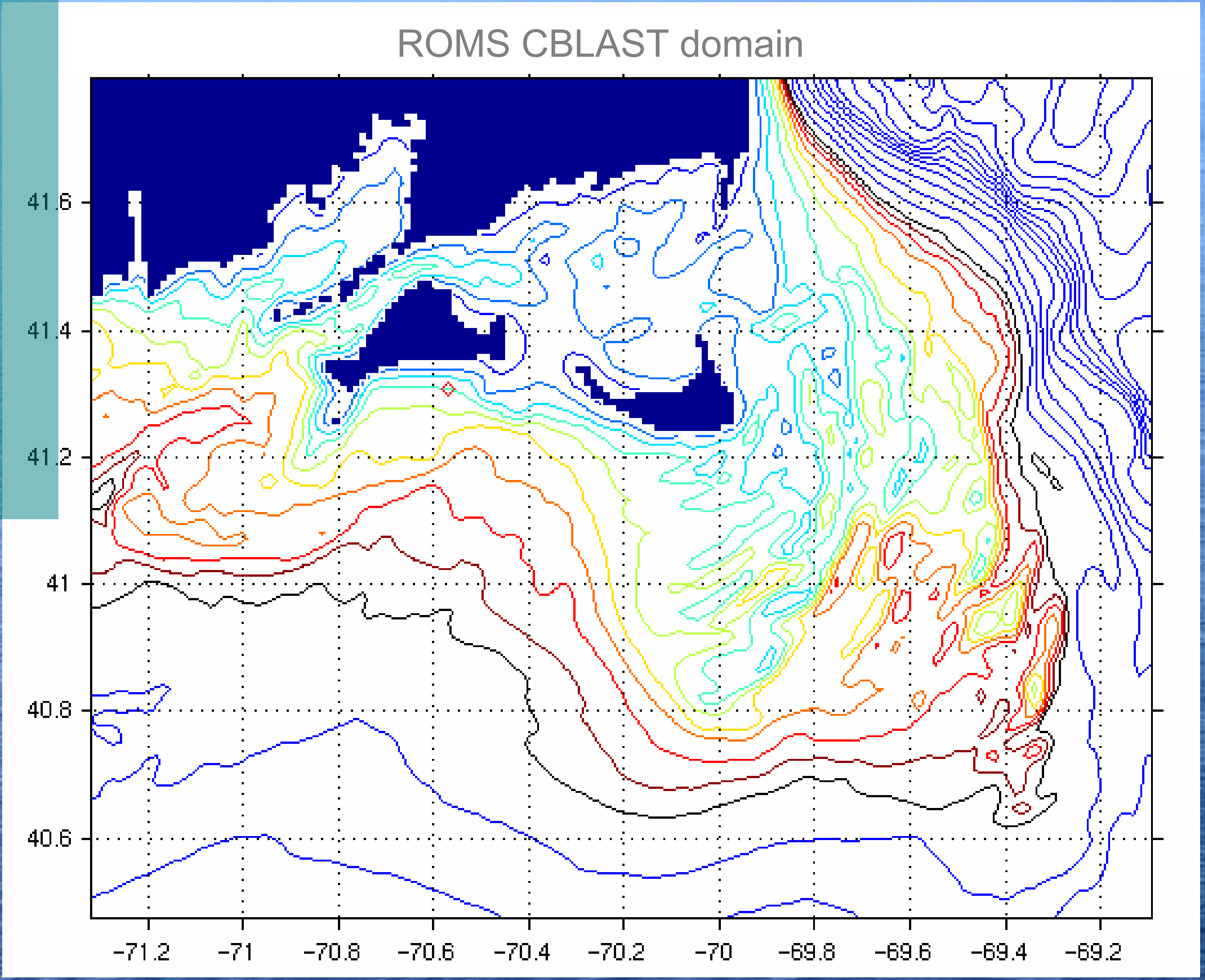
- Advection of vertically mixed waters originating on the Nantucket Shoals
- Advection past MVCO of tidally generated eddies transporting Vineyard Sound water through Muskeget channel

1 km grid resolution

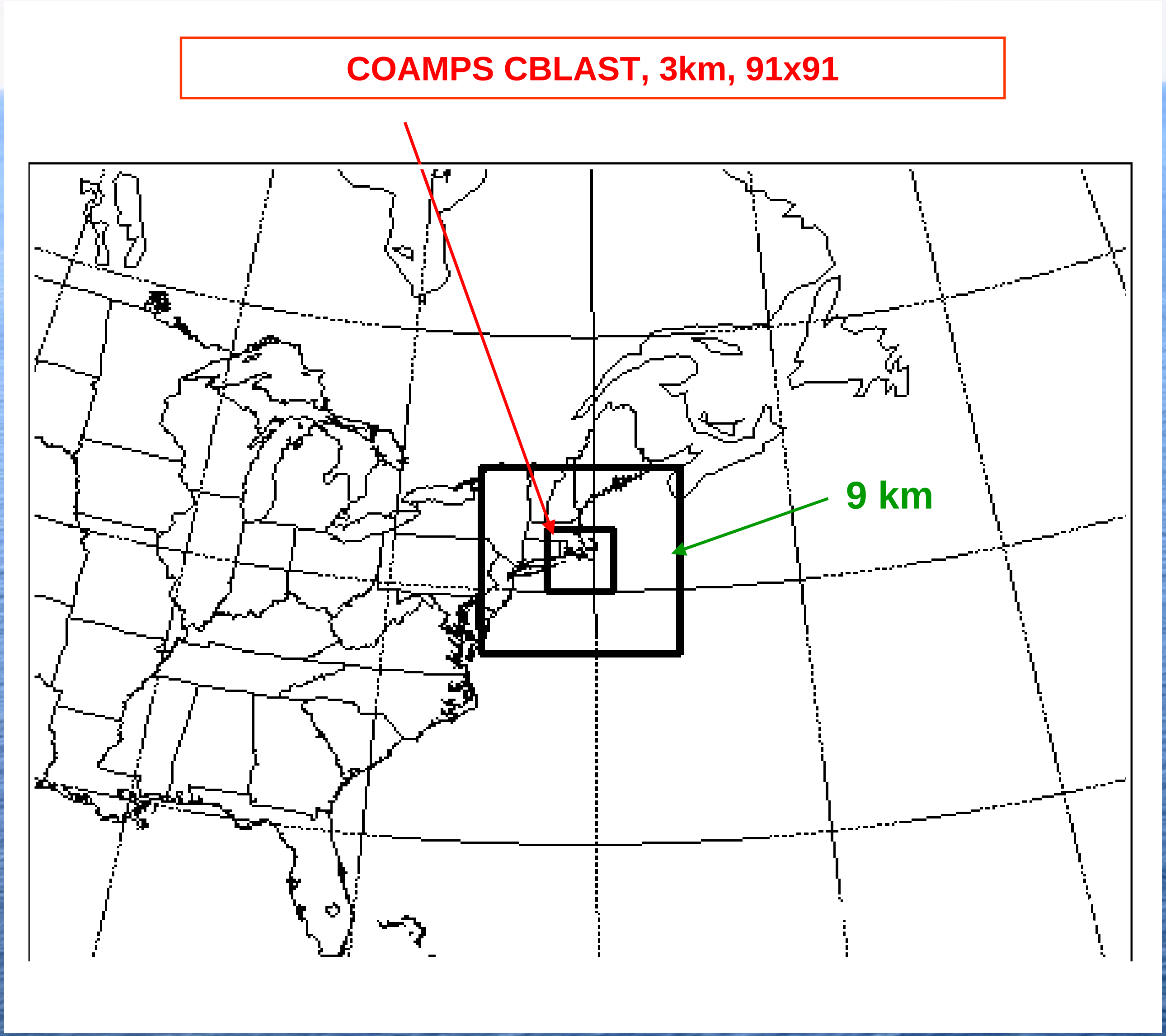
20 vertical levels (stretched s-coordinate)

Initial and inflow/outflow boundary conditions from bi-monthly climatology (Naimie et al. 1994)

Tides



Surface forcing:

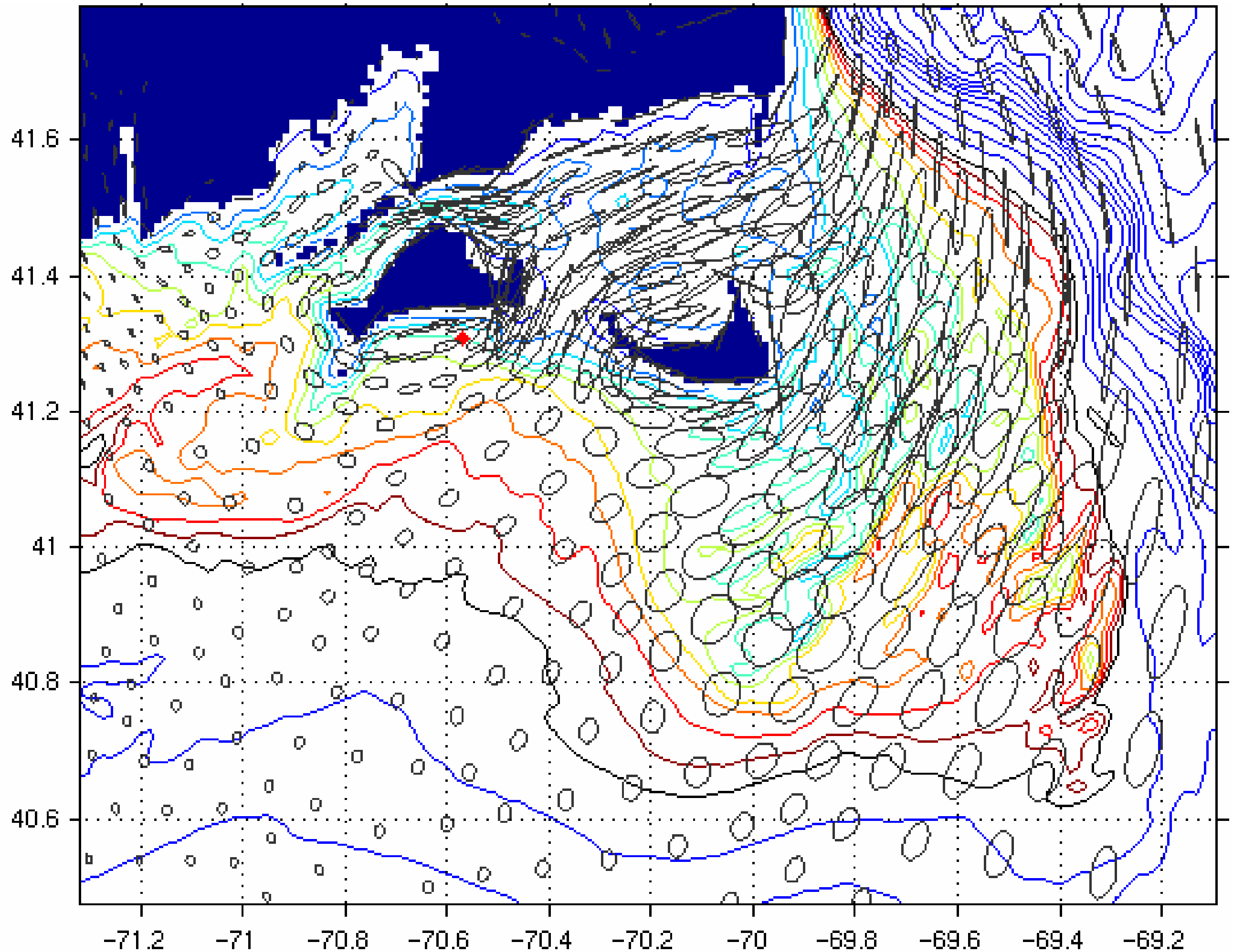


Heat and momentum fluxes from bulk formulae

- model SST
- T_{air}, p_{air}, q_{air}, u_{10}, v_{10} from 3-km resolution nested COAMPS 6-72 hr forecast
- observed downward shortwave and long-wave at MVCO

Courtesy S. Wang and Q. Wang, NRL

Tidal elevation and depth-average velocity are imposed at the ROMS domain open boundary



M_2 tide displacement ellipses from ADCIRC

ROMS model attributes

- Split-explicit, free-surface, hydrostatic, primitive equation model
- Generalized, terrain-following vertical coordinates and orthogonal curvilinear, horizontal coordinates, Arakawa C-grid
- 3rd-order upstream-biased advection
- 3rd-order predictor/corrector time-stepping; weighted temporal averaging; reduced pressure gradient and mode-splitting error
- Split-explicit time-stepping of barotropic/baroclinic modes constrained for conservation of volume and tracer constancy in time-evolving coordinate system (due to free-surface)
- Continuous, monotonic reconstruction of vertical gradients to maintain high-order accuracy
- Parallel distributed- and shared-memory portable F90/F95 code
- Dynamic allocation of memory via de-referenced pointer structures (for multiple levels of nesting).

Split-explicit, free-surface, hydrostatic, primitive equation model

Generalized, terrain-following vertical coordinates and orthogonal curvilinear, horizontal coordinates, Arakawa C-grid

3rd-order upstream-biased advection

3rd-order predictor/corrector time-stepping; weighted temporal averaging; reduced pressure gradient and mode-splitting error

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Parallel distributed- and shared-memory portable F90/F95 code

Dynamic allocation of memory via de-referenced pointer structures (multiple levels of nesting).

PO > roms > RomsFAQ - Mozilla Firefox

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http://marine.rutgers.edu/po/index.php?model=roms&page=RomsFAQ

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Regional Ocean Modeling System

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59909 Visits

Frequently Asked Questions About ROMS

This document contains answers to some of the most frequently asked questions on the **ROMS** mailing list sent to roms@imcs.rutgers.edu.

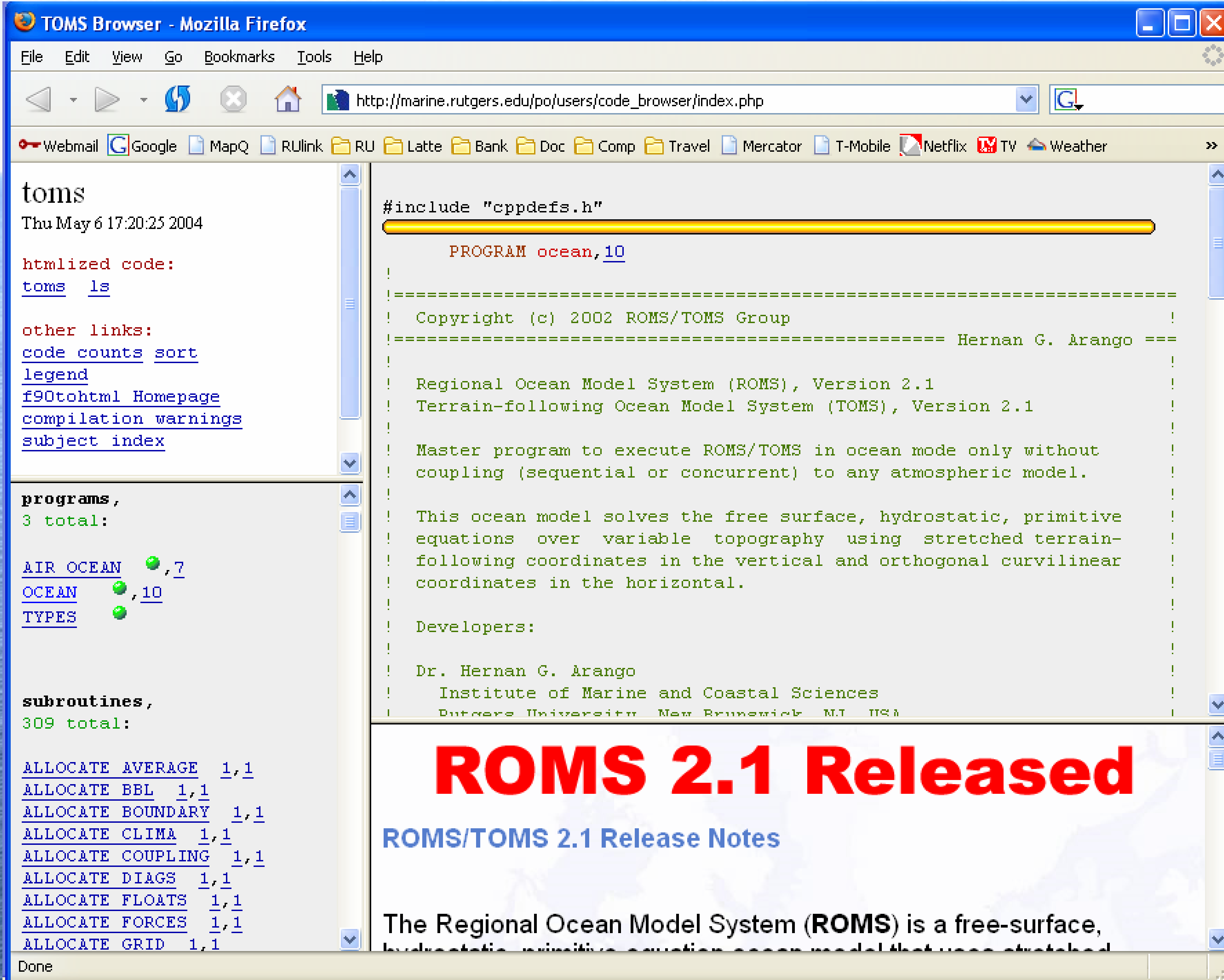
General

- What Is ROMS?
- Who developed ROMS?
- How do I get the ROMS code and its associated software?
- What is new in the ROMS 1.0 beta releases?
- Is there a mailing list for ROMS discussions and questions?
- Who else uses ROMS?
- What are some references for ROMS?
- Is there a manual describing how to use ROMS and its associated software?

Platforms and Portability

- What does ROMS run on?
- How to run ROMS in serial mode?
- How to run ROMS in parallel shared-memory computers?
- Is there an MPI version of ROMS?
- Why does ROMS requires a special CPP?

Done


TOMS Browser - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
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Webmail Google MapQ RUlink RU Latte Bank Doc Comp Travel Mercator T-Mobile Netflix TV Weather
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subject index
programs,
3 total:
AIR_OCEAN ,7
OCEAN ,10
TYPES
subroutines,
309 total:
ALLOCATE_AVERAGE 1,1
ALLOCATE_BBL 1,1
ALLOCATE_BOUNDARY 1,1
ALLOCATE_CLIMA 1,1
ALLOCATE_COUPLING 1,1
ALLOCATE_DIAGS 1,1
ALLOCATE_FLOATS 1,1
ALLOCATE_FORCES 1,1
ALLOCATE_GRID 1,1
#include "cppdefs.h"
PROGRAM ocean,10
!
!==
! Copyright (c) 2002 ROMS/TOMS Group !
!== Hernan G. Arango ===
! !
! Regional Ocean Model System (ROMS), Version 2.1 !
! Terrain-following Ocean Model System (TOMS), Version 2.1 !
! !
! Master program to execute ROMS/TOMS in ocean mode only without !
! coupling (sequential or concurrent) to any atmospheric model. !
! !
! This ocean model solves the free surface, hydrostatic, primitive !
! equations over variable topography using stretched terrain- !
! following coordinates in the vertical and orthogonal curvilinear !
! coordinates in the horizontal. !
! !
! Developers: !
! !
! Dr. Hernan G. Arango !
! Institute of Marine and Coastal Sciences !
ROMS 2.1 Released
ROMS/TOMS 2.1 Release Notes
The Regional Ocean Model System (ROMS) is a free-surface,
Done

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ROMS Documentation Discussions, suggestions and corrections to ROMS/TOMS documentation currently under developement. Moderators robertson, arango	6	8	13 Sep 2004 16:00 tim_cera
ROMS FAQ Frequently Asked Questions about ROMS usage Moderators robertson, arango	25	45	16 Sep 2004 07:40 jivica

Done

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Introduction

There are at present within the field of ocean general circulation modeling four classes of numerical models which have achieved a significant level of community management and involvement, including shared community development, regular user interaction, and ready availability of software and documentation via the World Wide Web. These four classes are loosely characterized by their respective approaches to spatial discretization (finite difference, finite element, finite volume) and vertical coordinate treatment (geopotential, isopycnic, sigma, hybrid).

The earliest class of ocean models, and still the most widely applied, was pioneered by Kirk Bryan and his colleagues at GFDL utilizing low-order finite difference techniques applied to the oceanic primitive equations written in geopotential (z-based) coordinates. At present, variations on this first OGCM are in place at Harvard (Harvard Ocean Prediction System, HOPS), GFDL (Modular Ocean Model, MOM (MOM), the Los Alamos National Lab (Parallel Ocean Program, POP), the National Center for Atmospheric Research (NCAR Community Ocean Model, NCOM), and other institutions. A set of geopotential models based upon a structured, finite volume disctretization has also been developed at MIT (MITgcm).

During the 1970's, two competing approaches to vertical discretization and coordinate treatment made their way into ocean modeling. These alternatives were based respectively on vertical discretization in immiscible layers ("layered" models) and on terrain-following vertical coordinates ("sigma" coordinate models). In keeping with 1970's-style thinking on algorithms, both these model classes used (and, by and large, continue to use) low-order finite difference schemes similar to those employed in the geopotential coordinate models.

Done

Subgridscale parameterizations

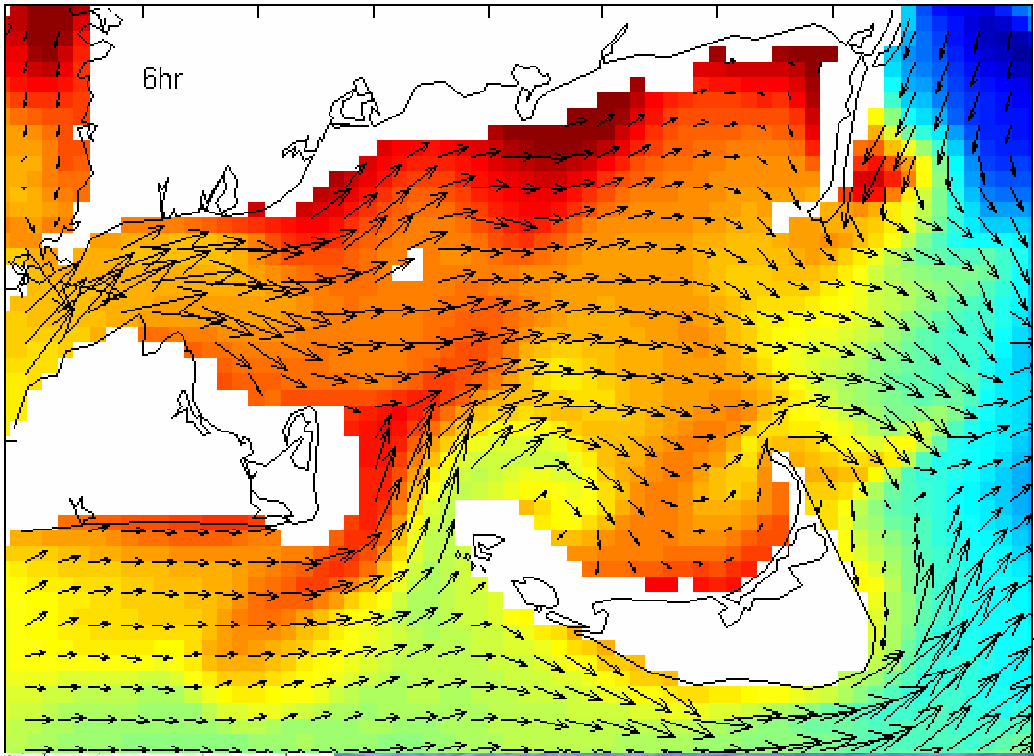
- Horizontal mixing of tracers along level, geopotential, isopycnic surfaces
- Transverse, isotropic stress tensor for momentum

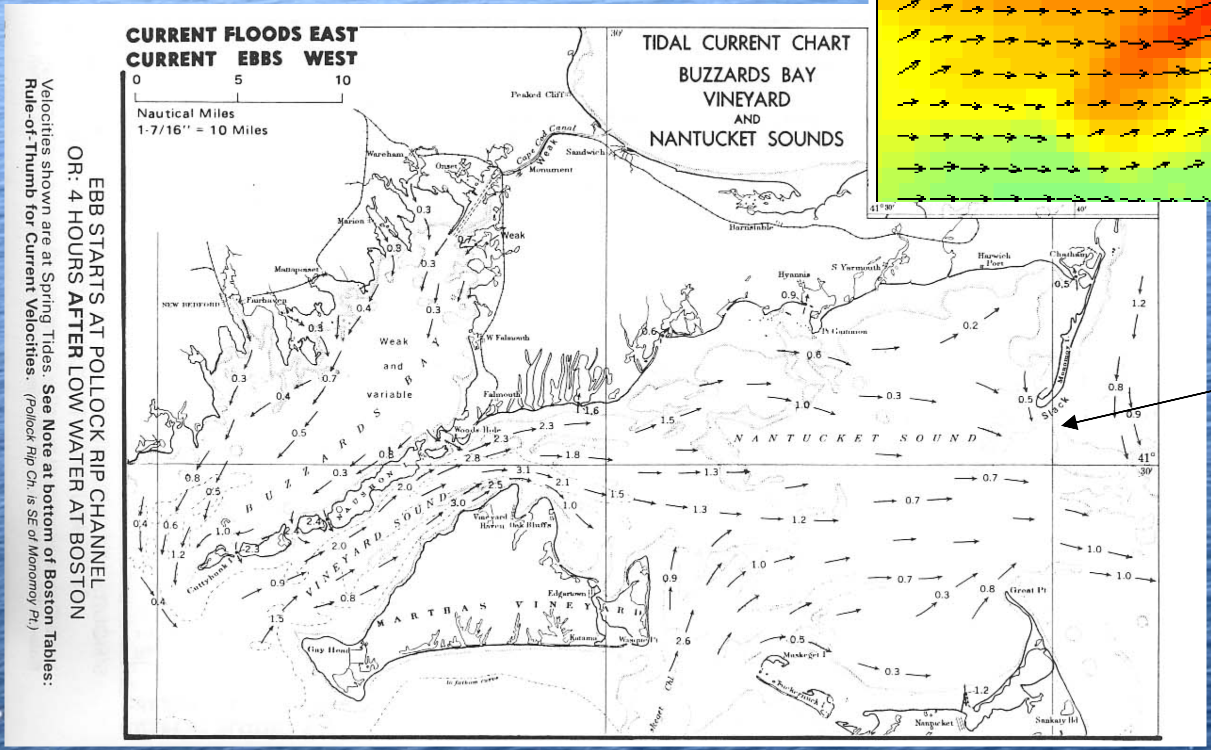
Vertical turbulence closure options

- Mellor-Yamada level 2.5
- k-profile parameterization (KPP) surface and bottom closure scheme (Large et al., 1994, Durski et al., 2001)
- Generalized Ocean Turbulence Model*
    - 2 (dynamic) equations for turbulent kinetic energy and a generic macro length scale
    - Eddy viscosity and diffusivity product TKE, length scale and a non-dimensional stability function
    - The stability functions are the result of various second-moment closures
    - Encompasses k-ε, k-ω, k-kl (Mellor-Yamada) and others

From “Eldridge’s Tide Tables”

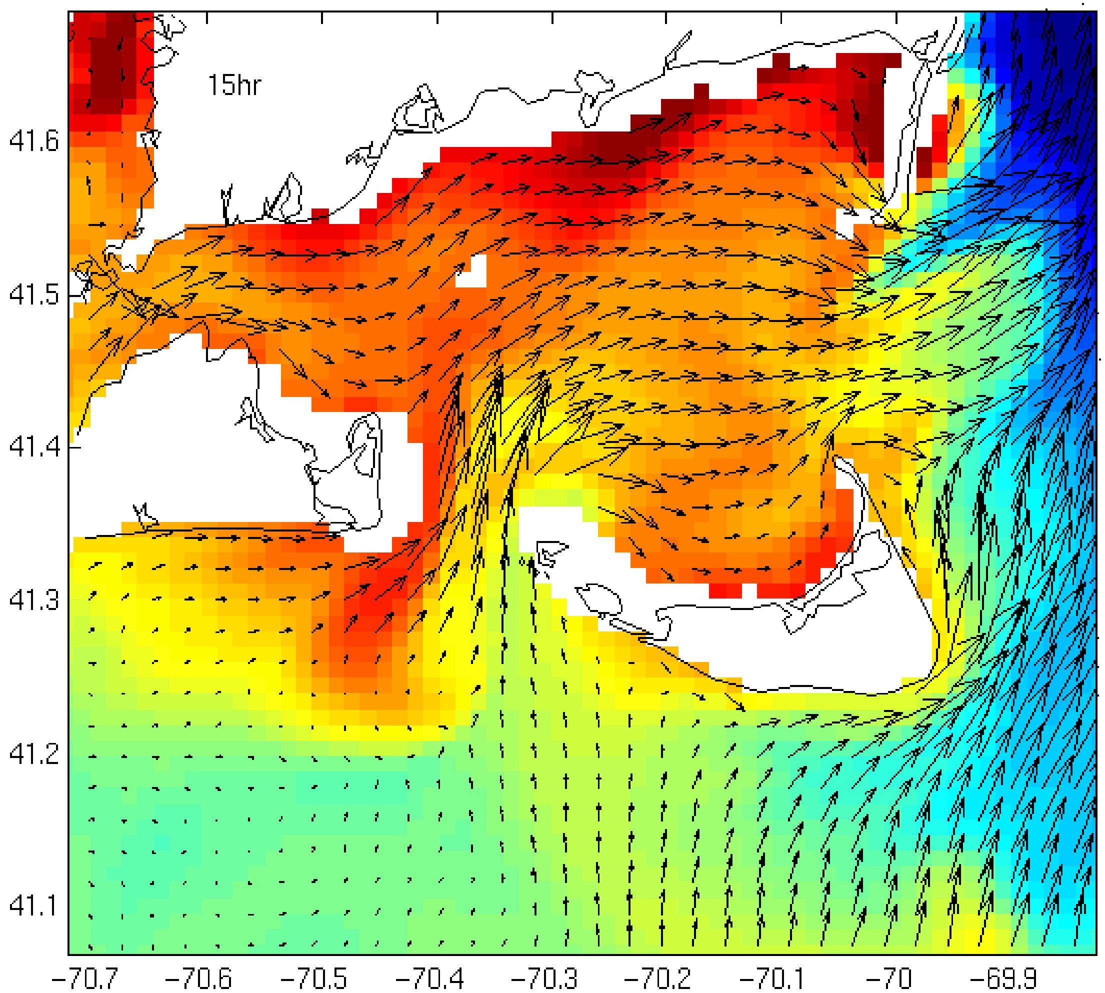
Ebb starts at Pollock Rip Channel OR: 4 hours AFTER low water at Boston





Pollock Rip Channel

(slack water at beginning of ebb)



15hr
41.6
41.5
41.4
41.3
41.2
41.1
−70.7
−70.6
−70.5
−70.4
−70.3
−70.2
−70.1
−70
−69.9

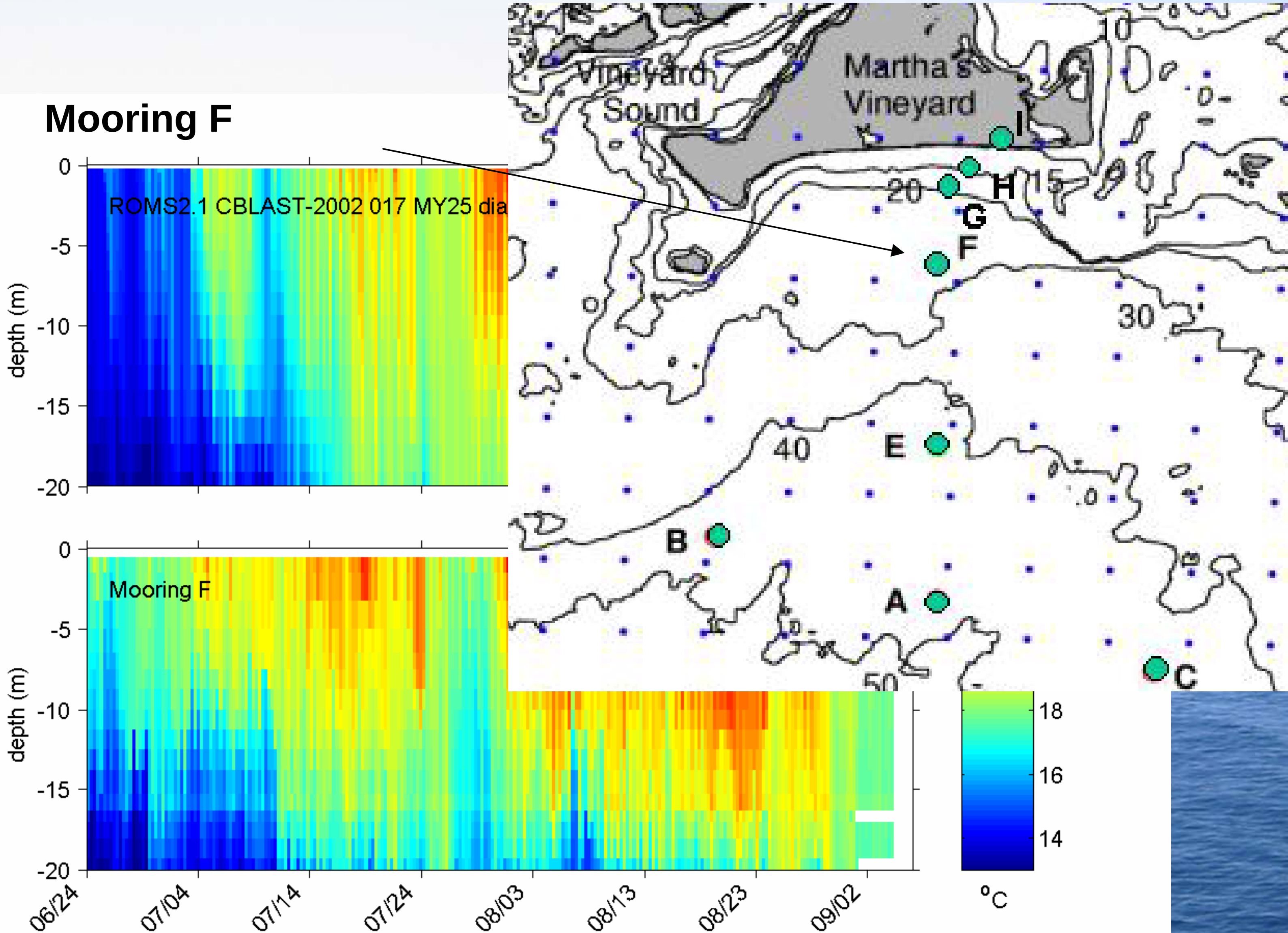
Validation

- Example: Compare model to mooring temperature time series

Sensitivity

- Example: Vertical turbulence closure parameterization

Mooring F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Mooring F
depth (m)
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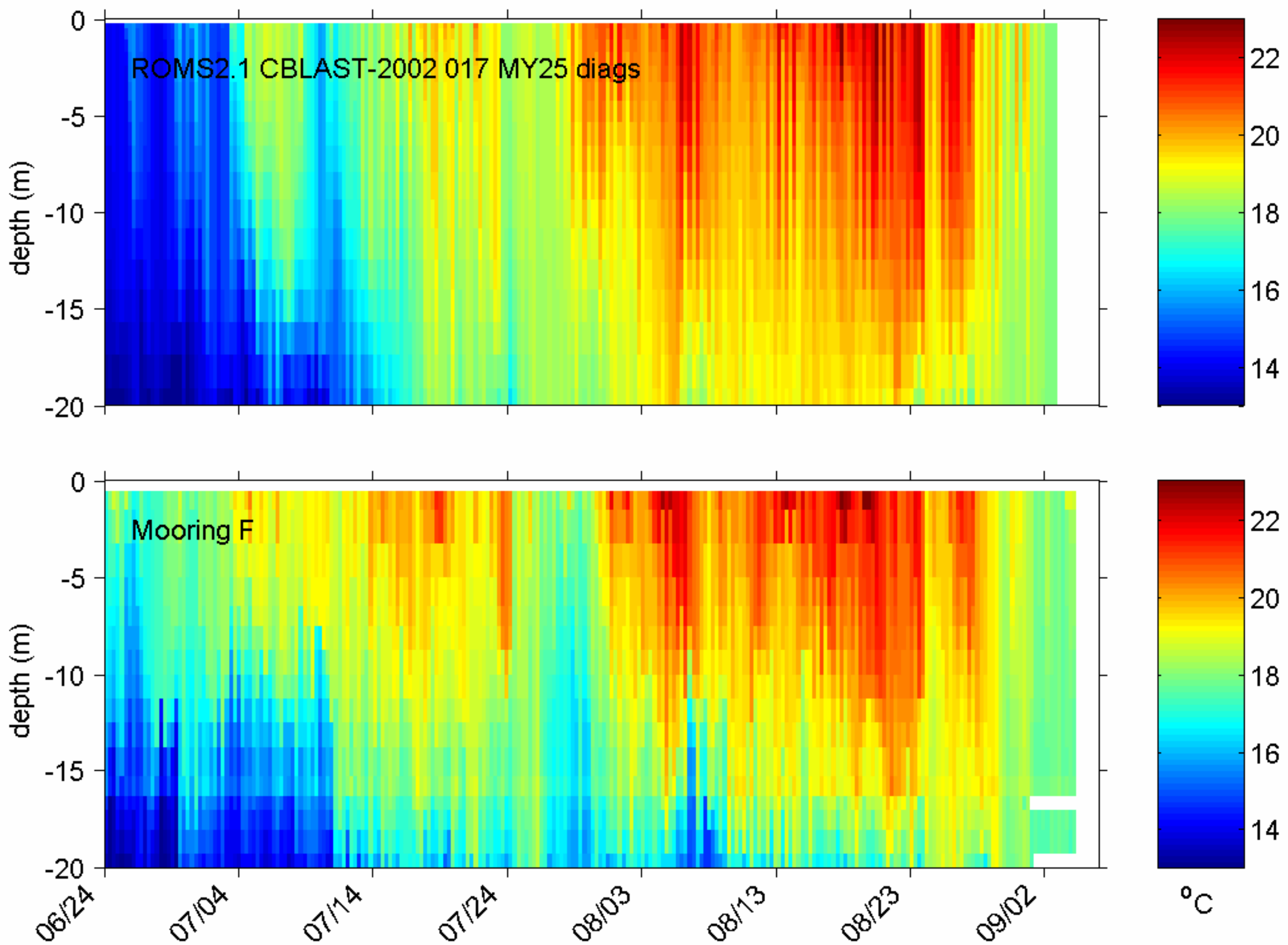
-5
-10
-15
-20
06/24
07/04
07/14
07/24
08/03
08/13
08/23
09/02
18
16
14
°C
Vineyard Sound
Martha's Vineyard
I
H
G
F
E
B
A
C
10
15
20
30
40
50


ROMS2.1 CBLAST-2002 017 MY25 diags
Mooring F
depth (m)
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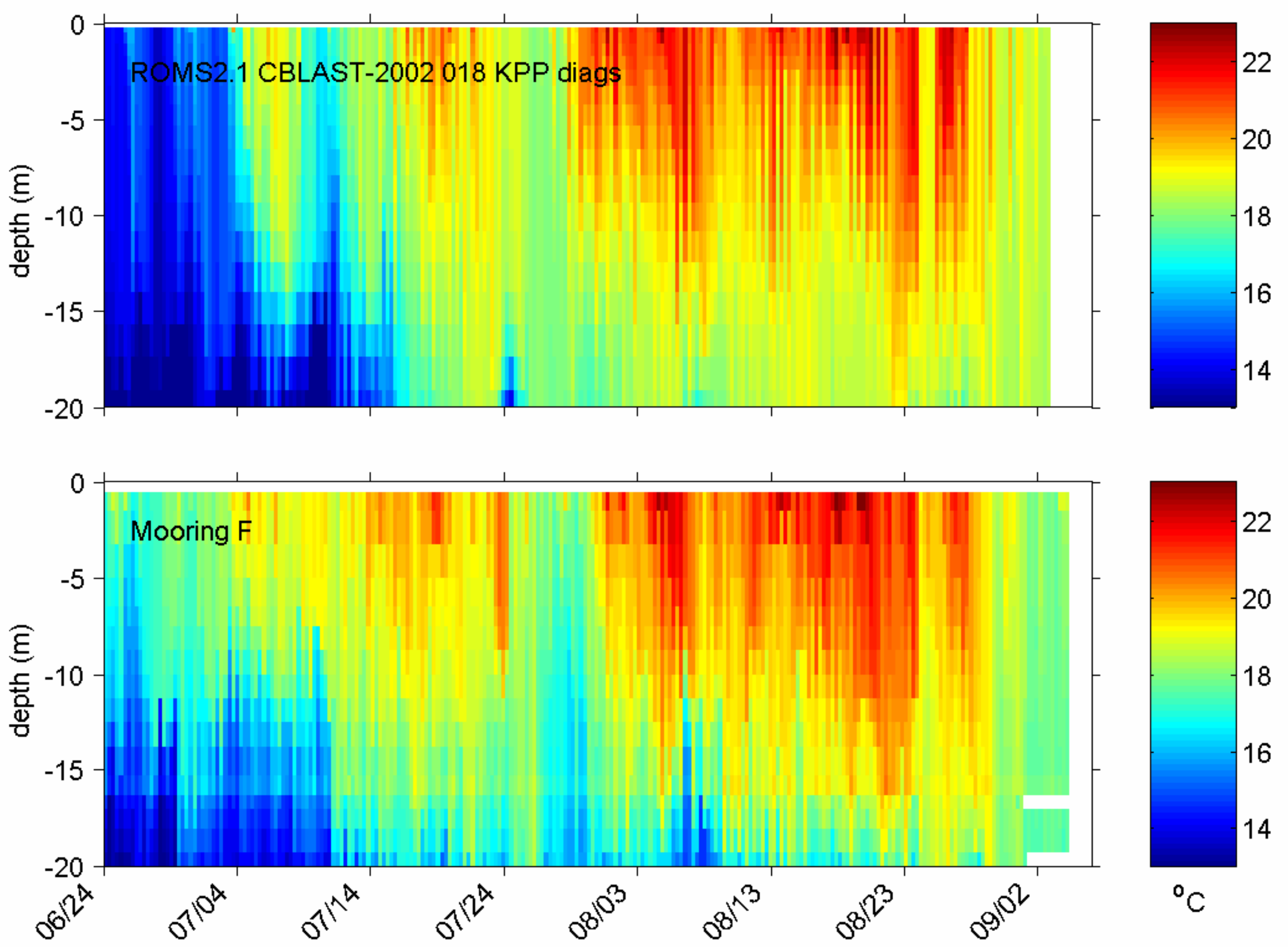
-5
-10
-15
-20
06/24
07/04
07/14
07/24
08/03
08/13
08/23
09/02
22
20
18
16
14
°C



ROMS2.1 CBLAST-2002 018 KPP diags
Mooring F
depth (m)
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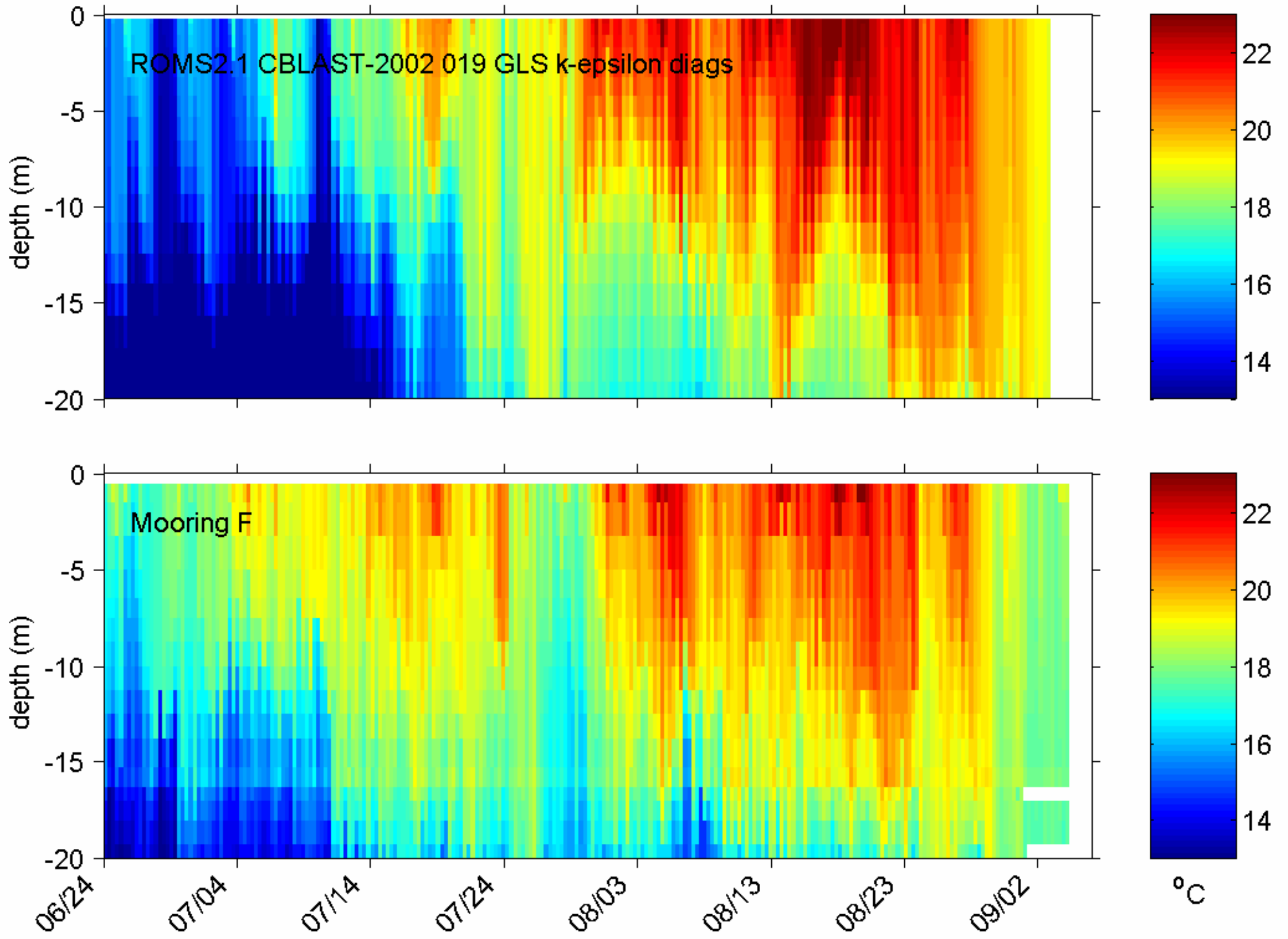
-5
-10
-15
-20
06/24
07/04
07/14
07/24
08/03
08/13
08/23
09/02
22
20
18
16
14
°C


ROMS2.1 CBLAST-2002 019 GLS k-epsilon diags
Mooring F
depth (m)
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-10
-15
-20
06/24
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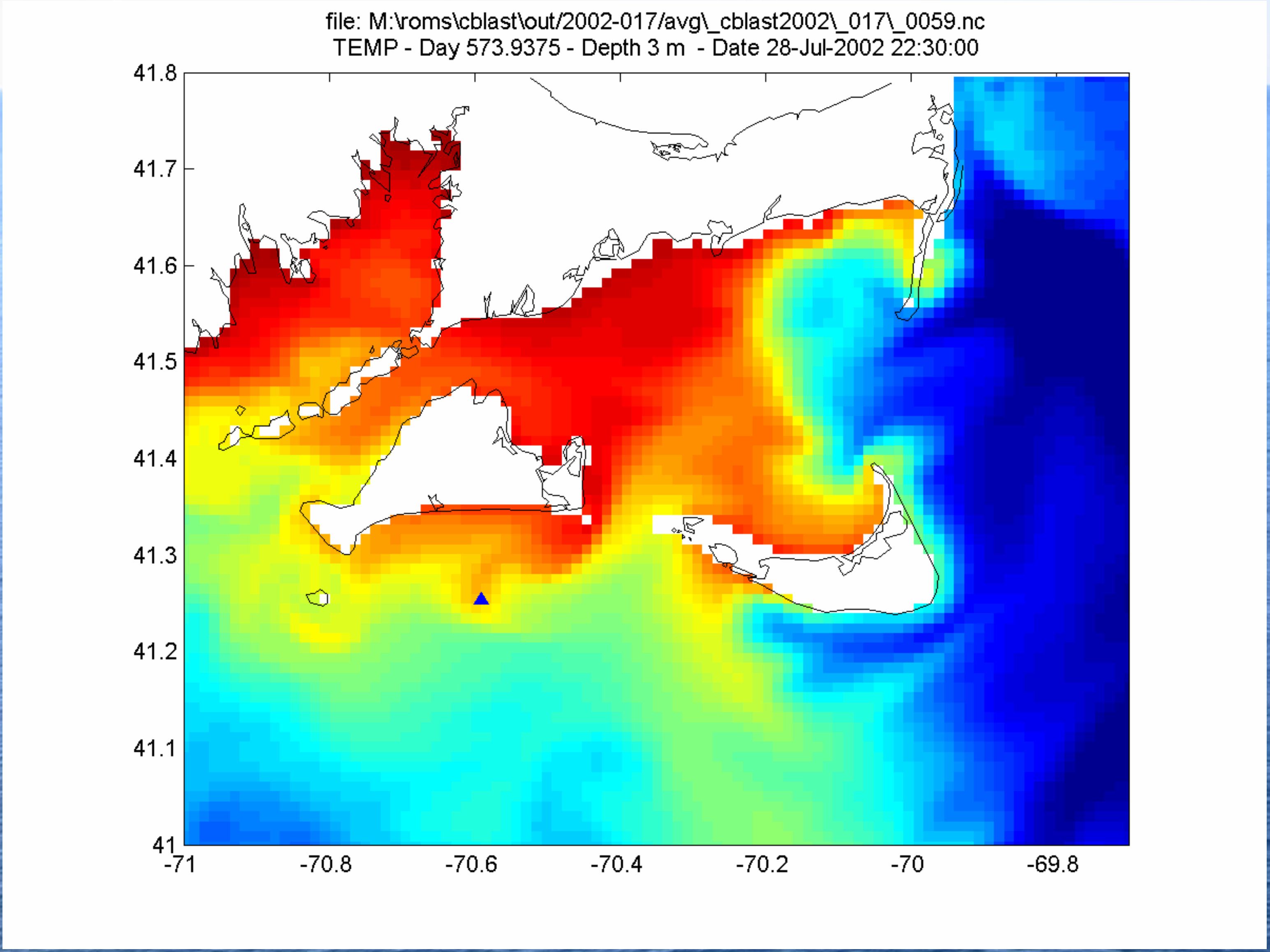
08/03
08/13
08/23
09/02
22
20
18
16
14
°C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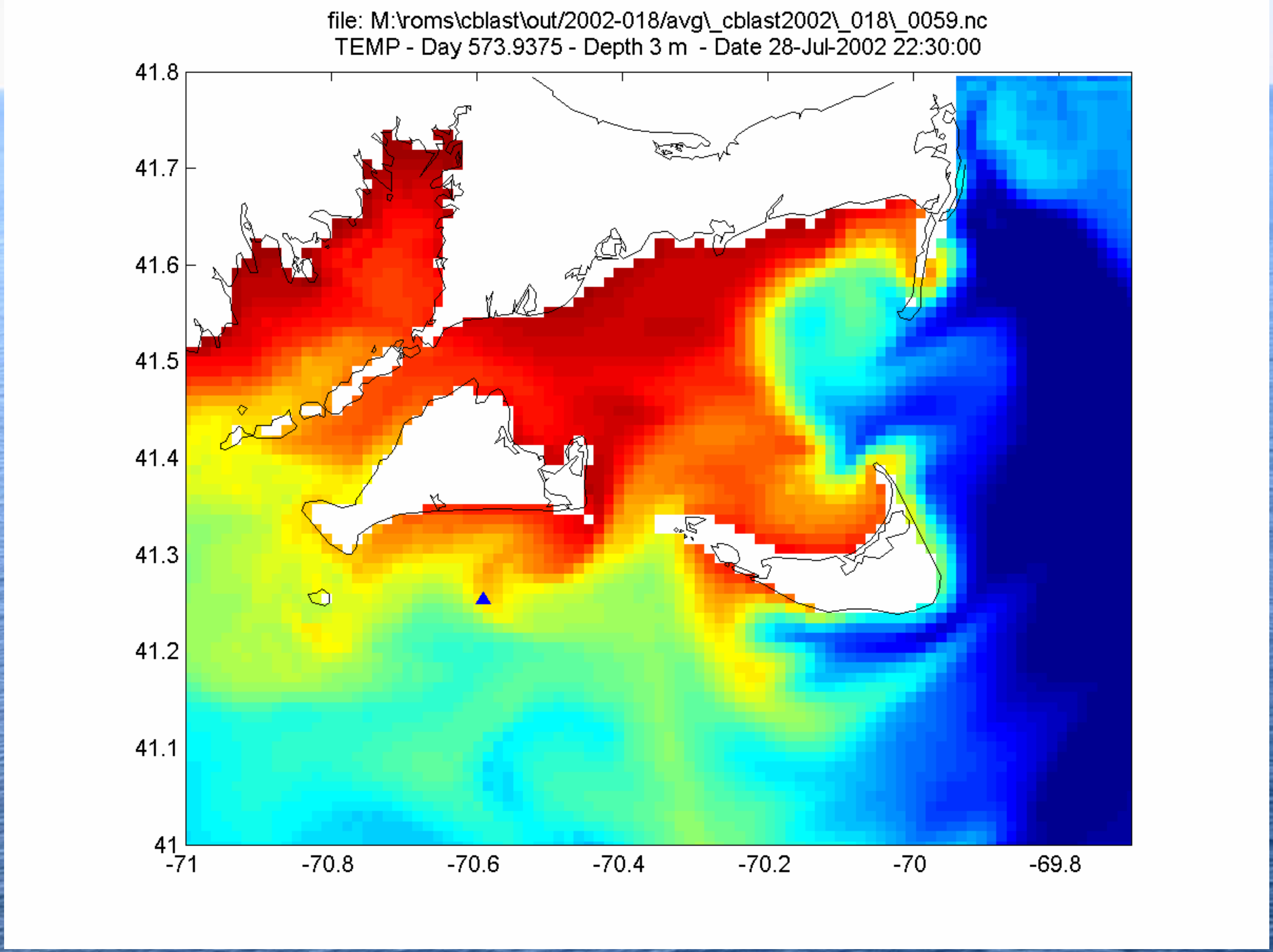
TEMP - Day 573.9375 - Depth 3 m - Date 28-Jul-2002 22:30:00
41.8
41.7
41.6
41.5
41.4
41.3
41.2
41.1
41
-71
-70.8
-70.6
-70.4
-70.2
-70
-69.8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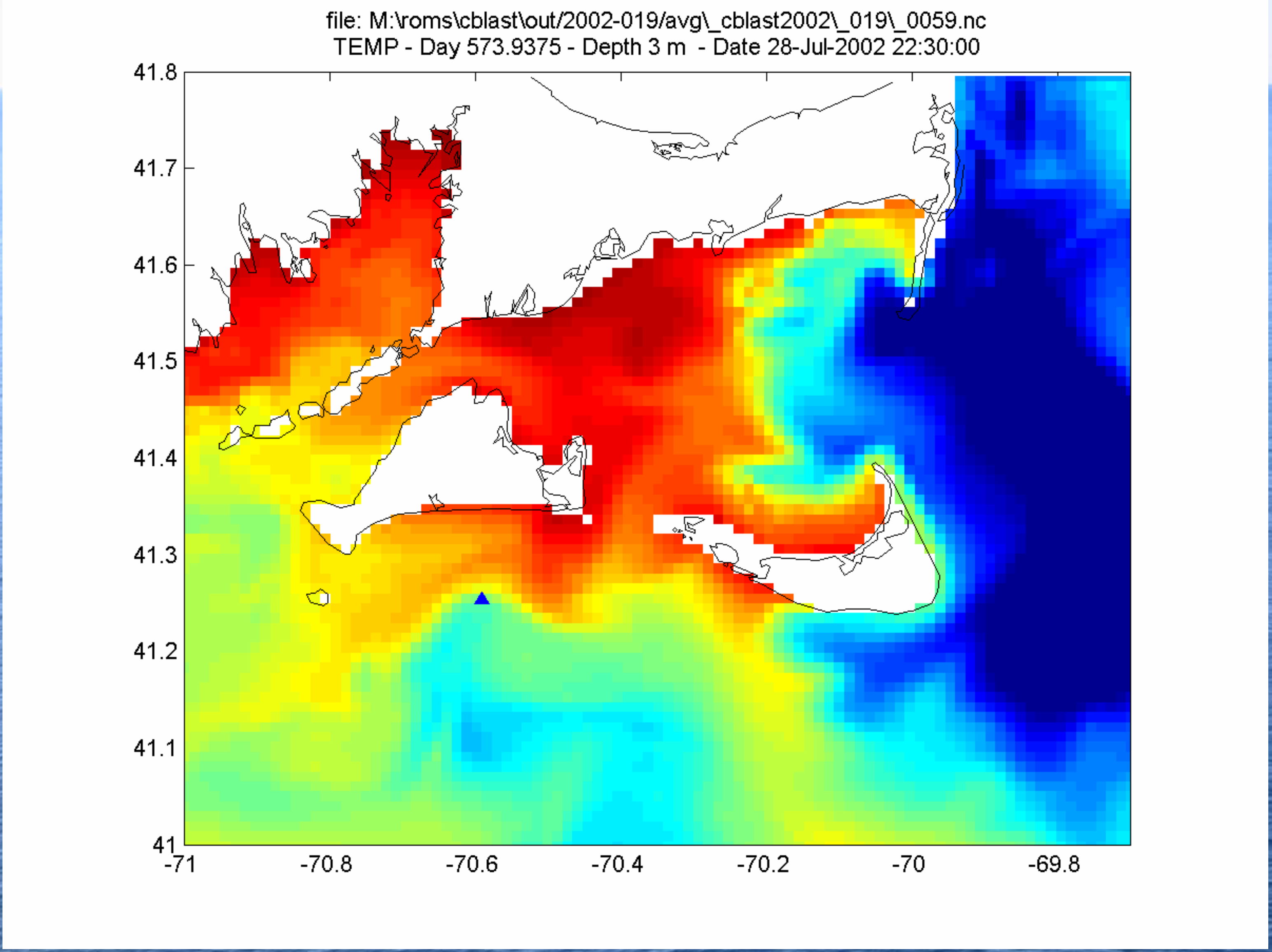
-70
-69.8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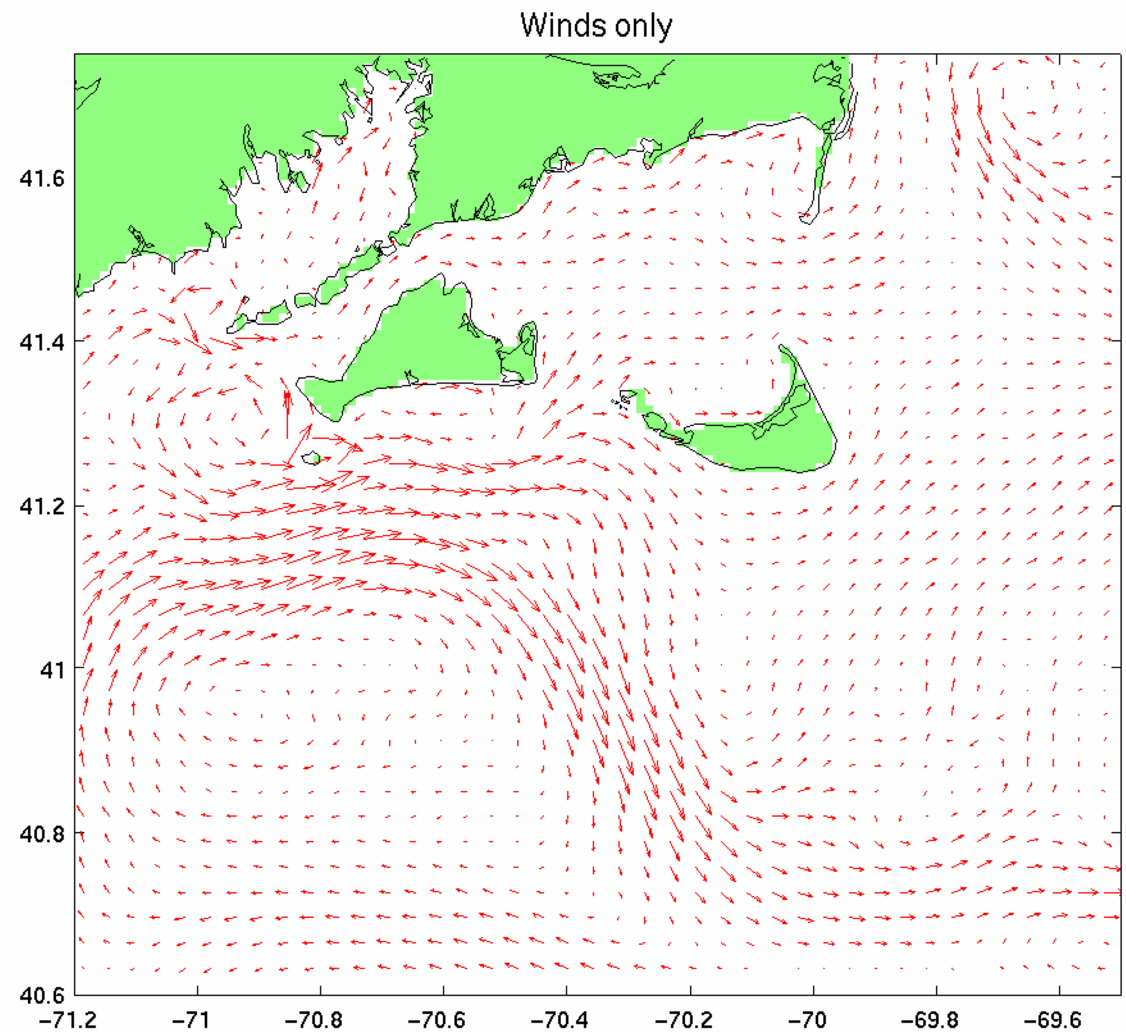
41.7
41.6
41.5
41.4
41.3
41.2
41.1
41
-71
-70.8
-70.6
-70.4
-70.2
-70
-69.8

Using models for understanding regional ocean processes, or …

Never mind the forecast …
let's learn something about the ocean

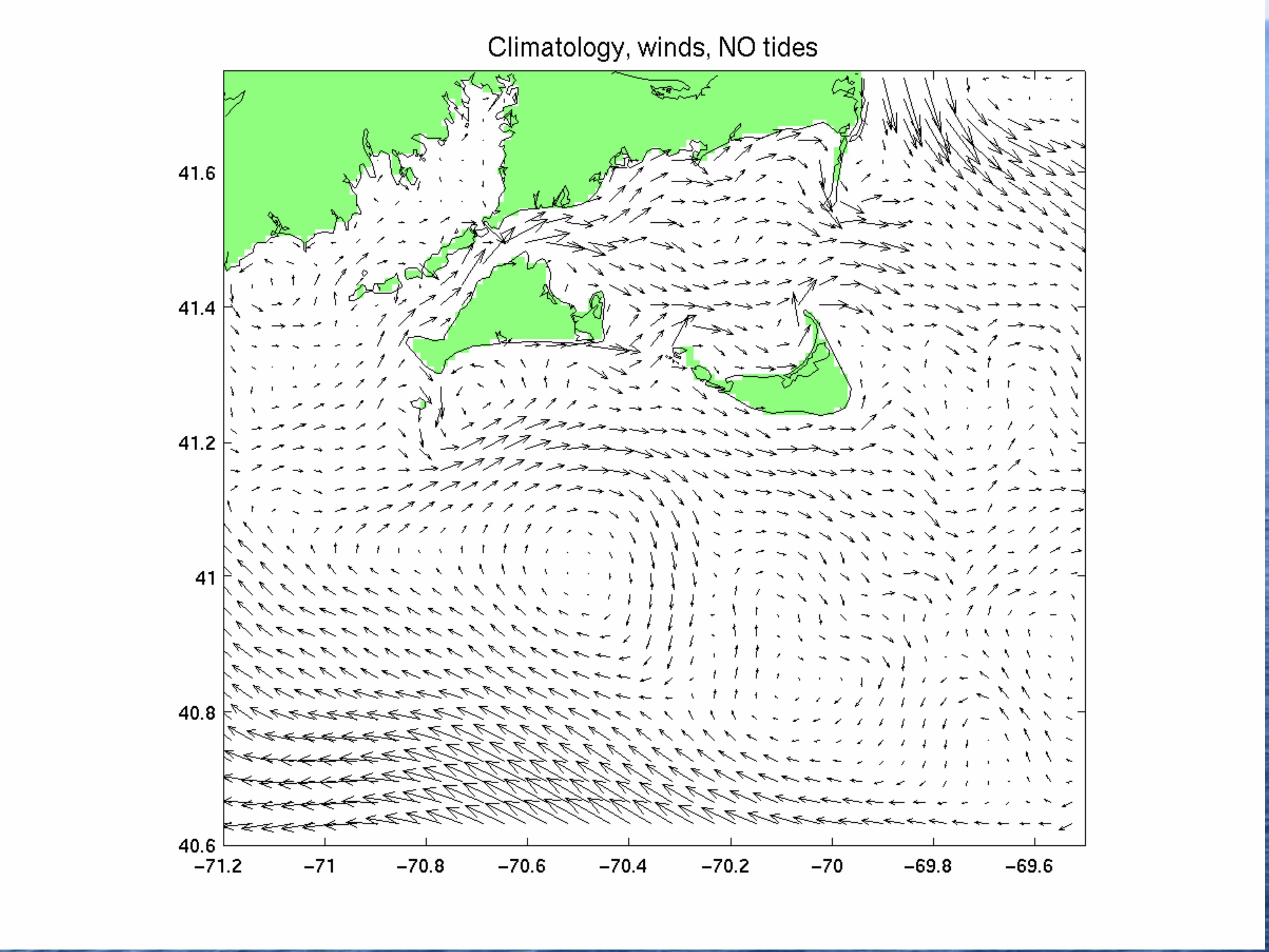
Southwest of Martha’s Vineyard, and within Vineyard Sound, winds drive eastward depth averaged flow.



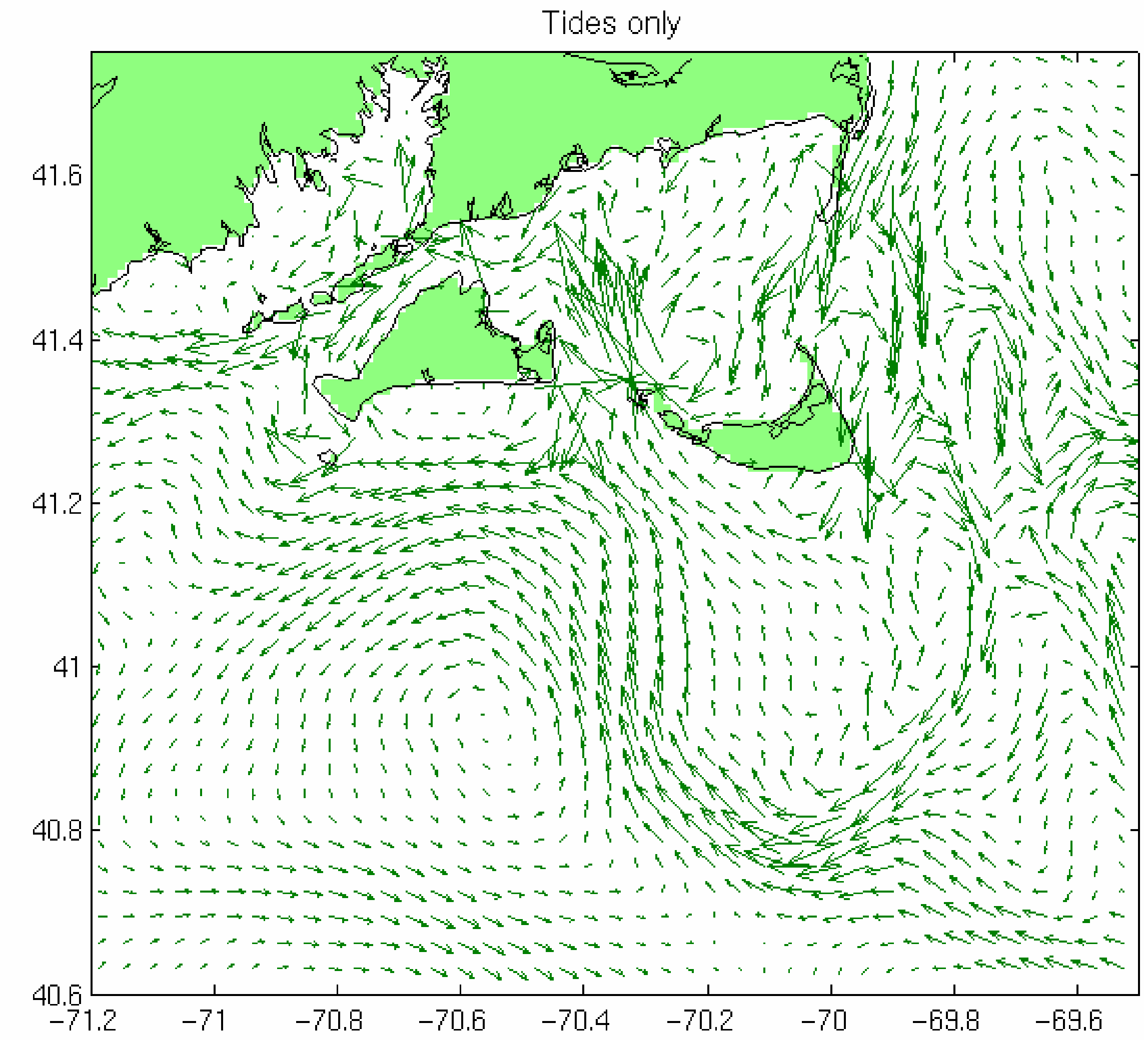
The field experiment you can’t do:

Turn physics off and on.

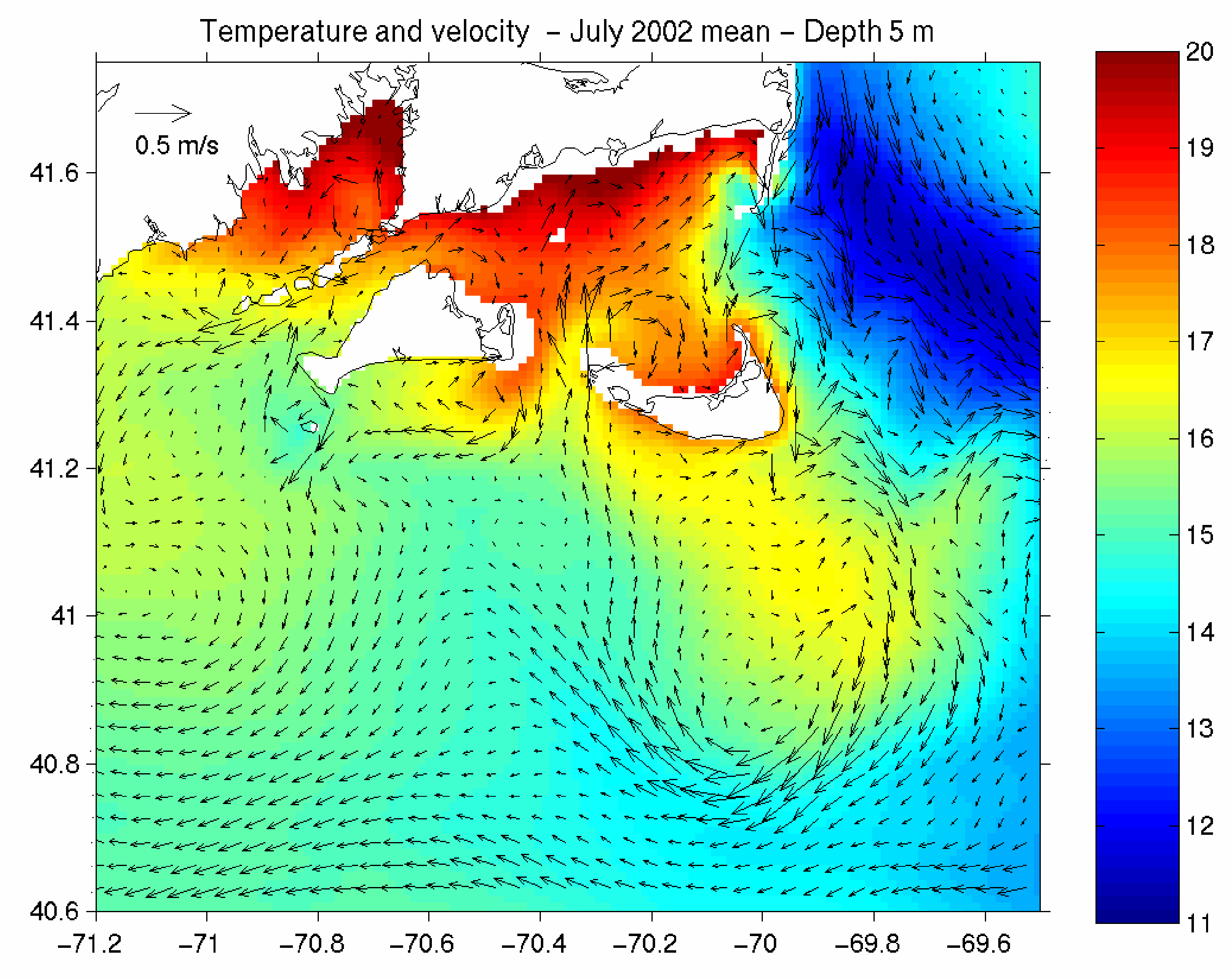
The open boundary climatology imposes a south and westward flow from the Gulf of Maine, through Great South Channel and around Nantucket Shoals.

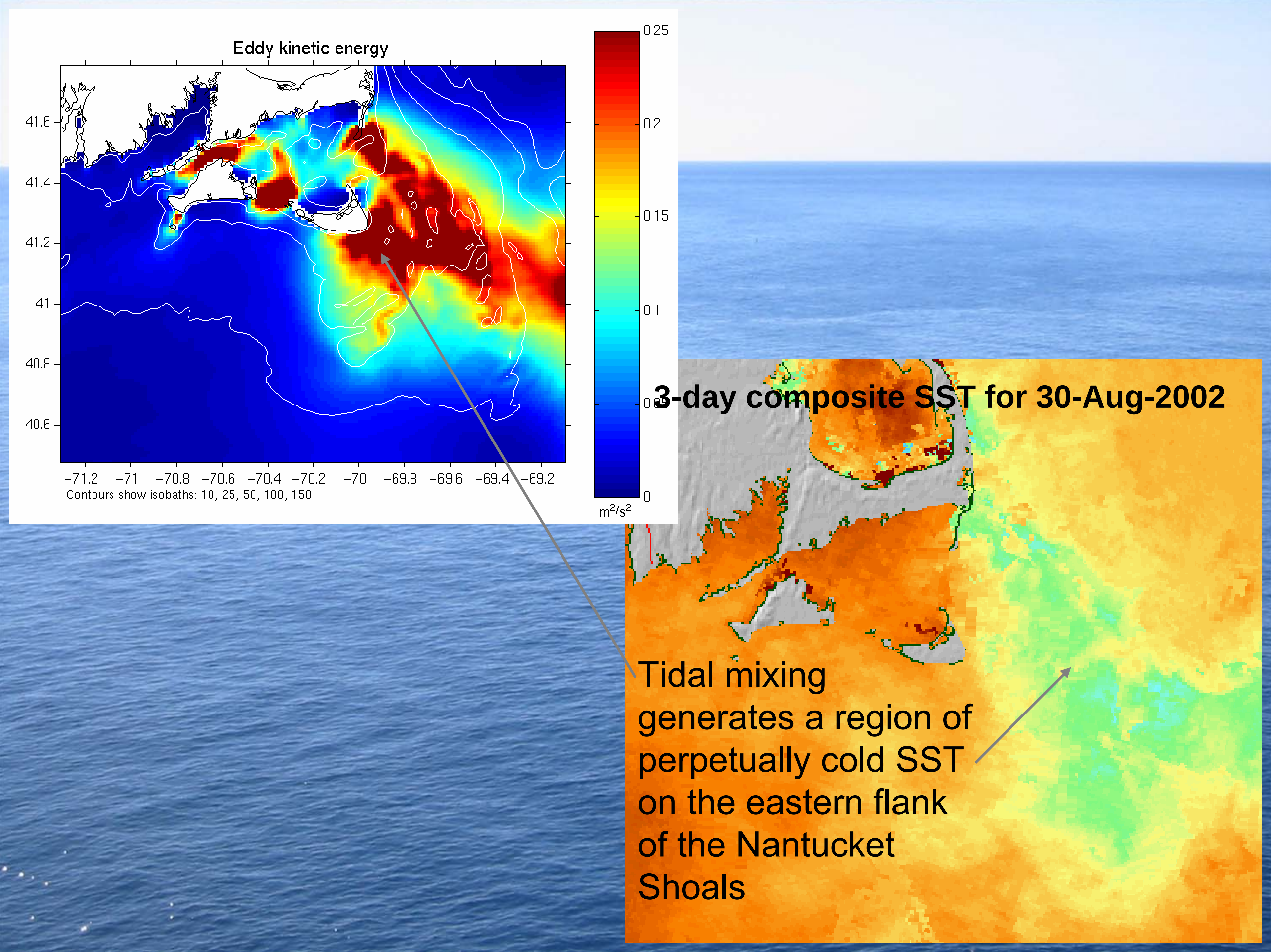


Circulation around Nantucket Shoals is augmented by tidal rectified anti-cyclonic flow that carries water into Vineyard Sound through Muskeget Channel



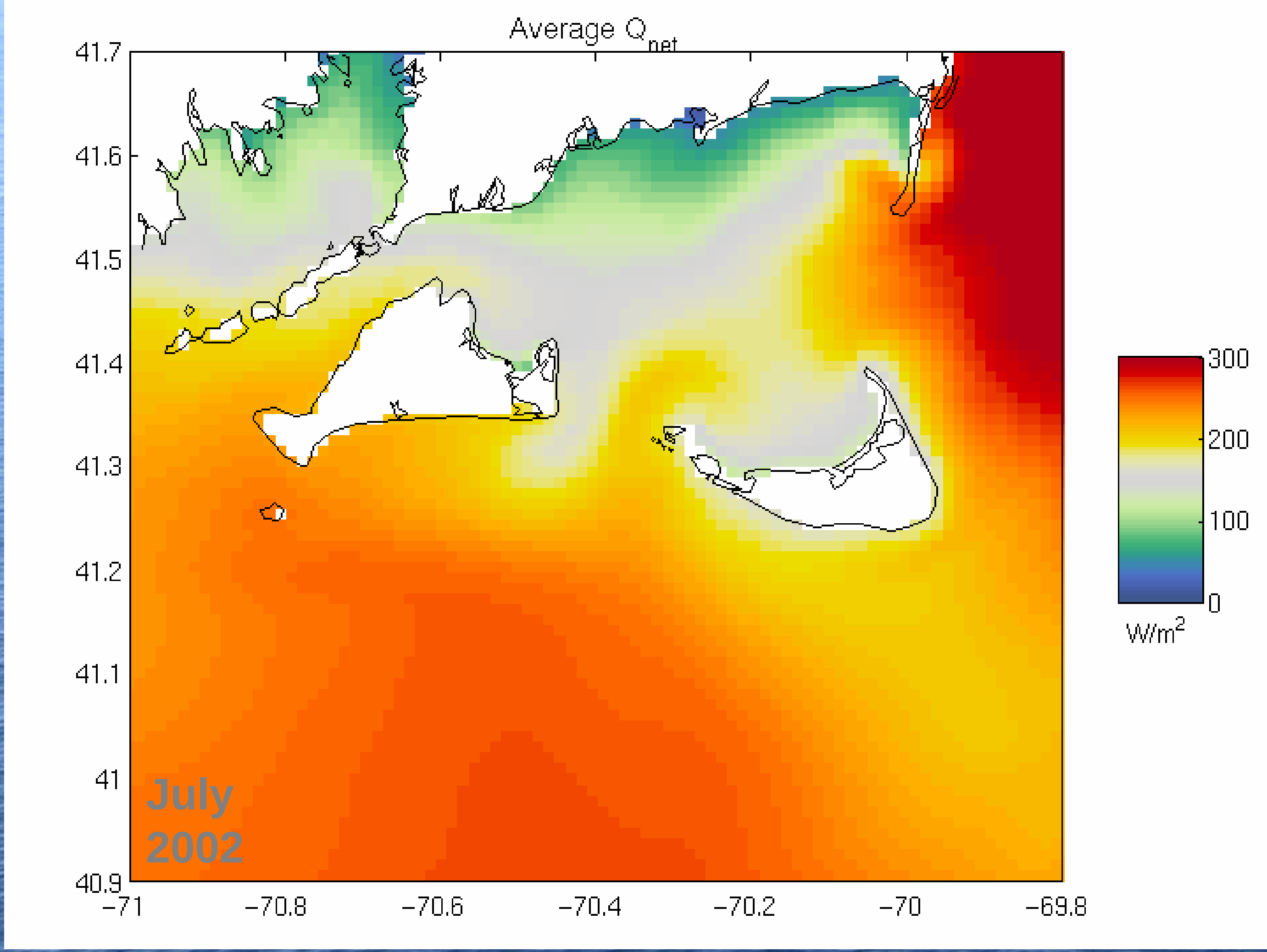
Put it all together and you get:




Eddy kinetic energy
41.6
41.4
41.2
41
40.8
40.6
−71.2 −71 −70.8 −70.6 −70.4 −70.2 −70 −69.8 −69.6 −69.4 −69.2
Contours show isobaths: 10, 25, 50, 100, 150
0.25
0.2
0.15
0.1
0
m2/s2
3-day composite SST for 30-Aug-2002
Tidal mixing generates a region of perpetually cold SST on the eastern flank of the Nantucket Shoals

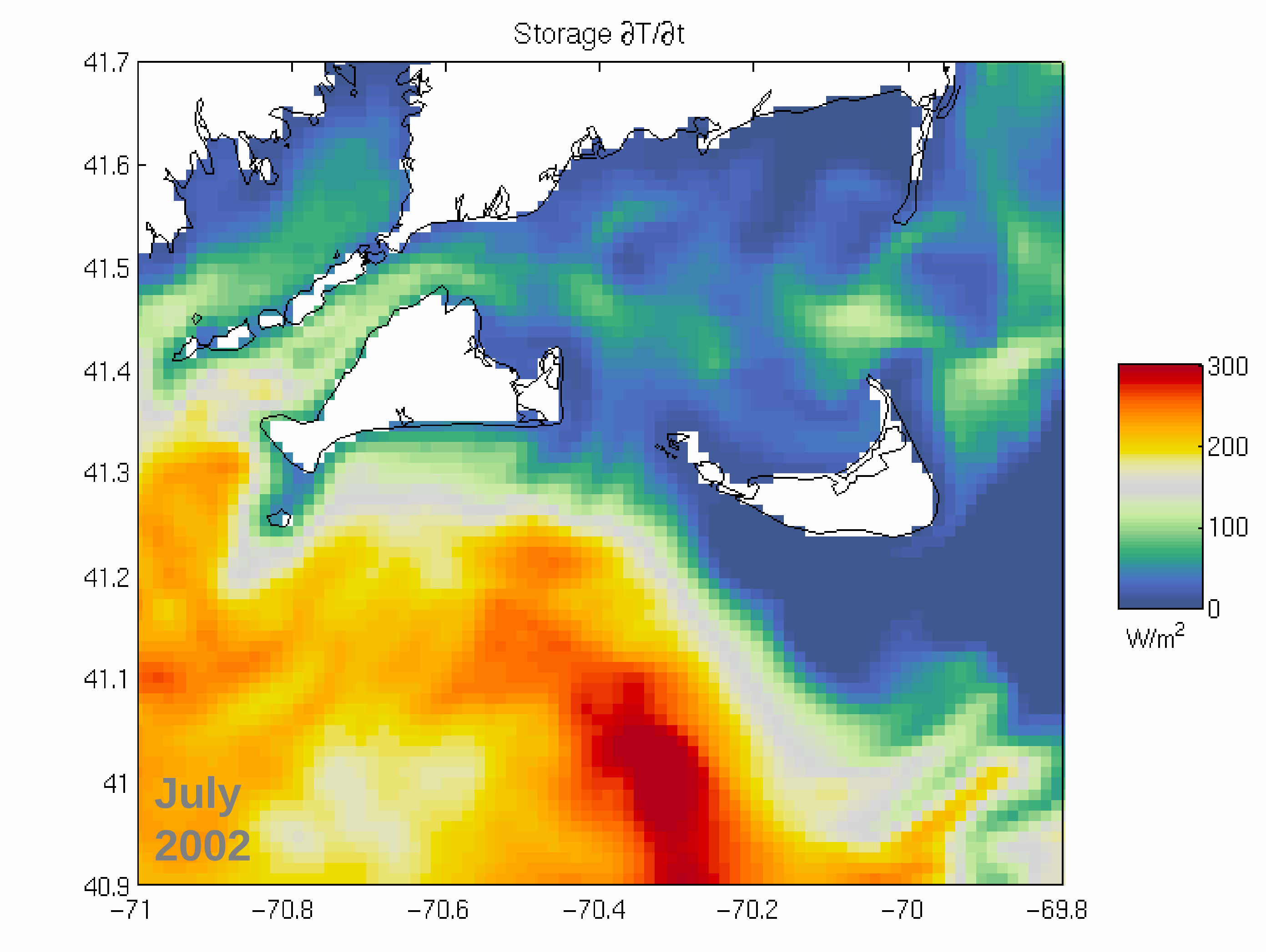
Air-sea flux (Q_{net}) is greatest east of Vineyard Sound where SST is cold, but is largely balanced by divergence due to tidal mixing.

Positive warms the ocean



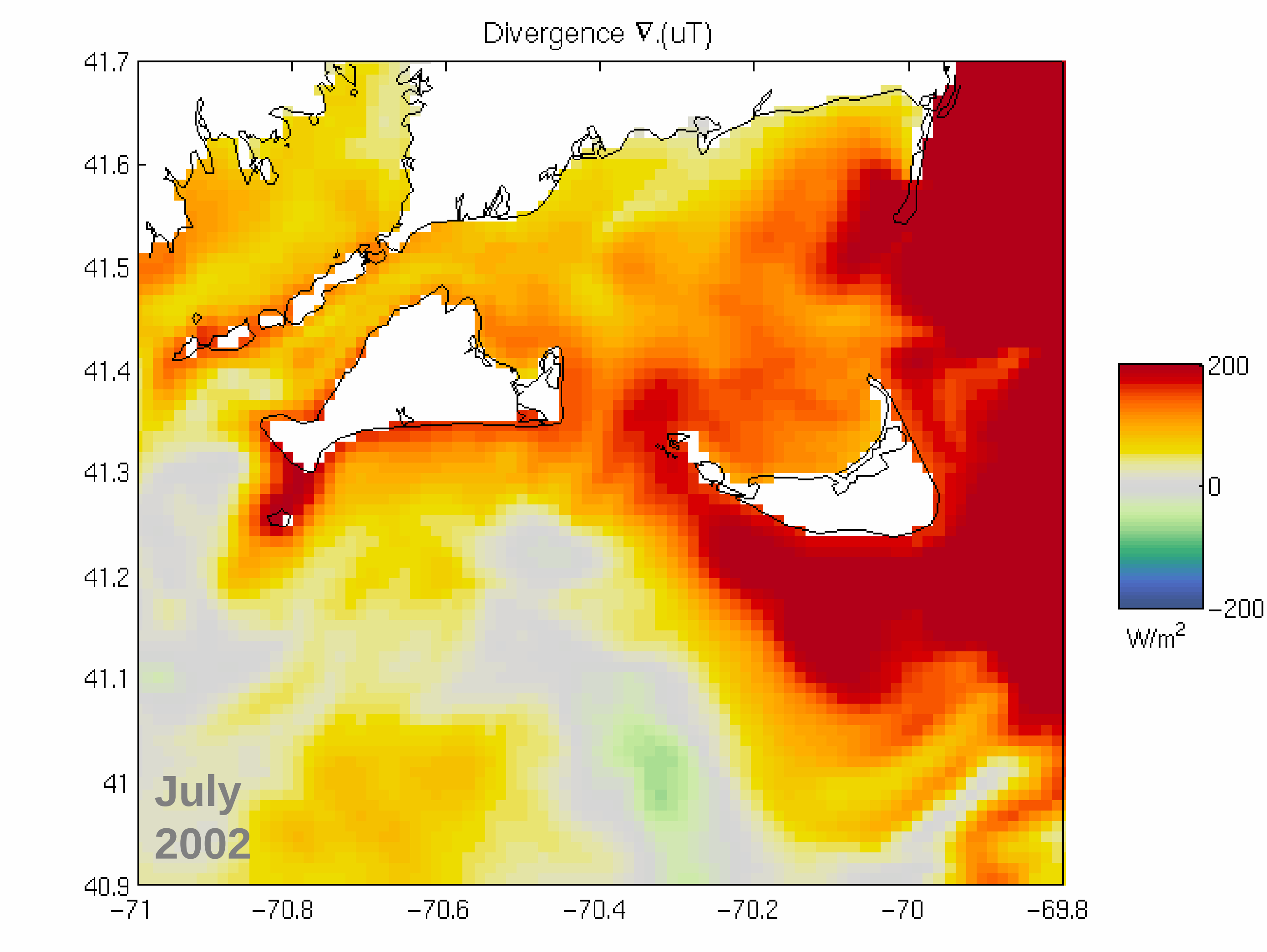
Ocean temperature increase (storage) is largest south of The Islands, primarily due to surface heating.

Positive, the ocean is getting warmer

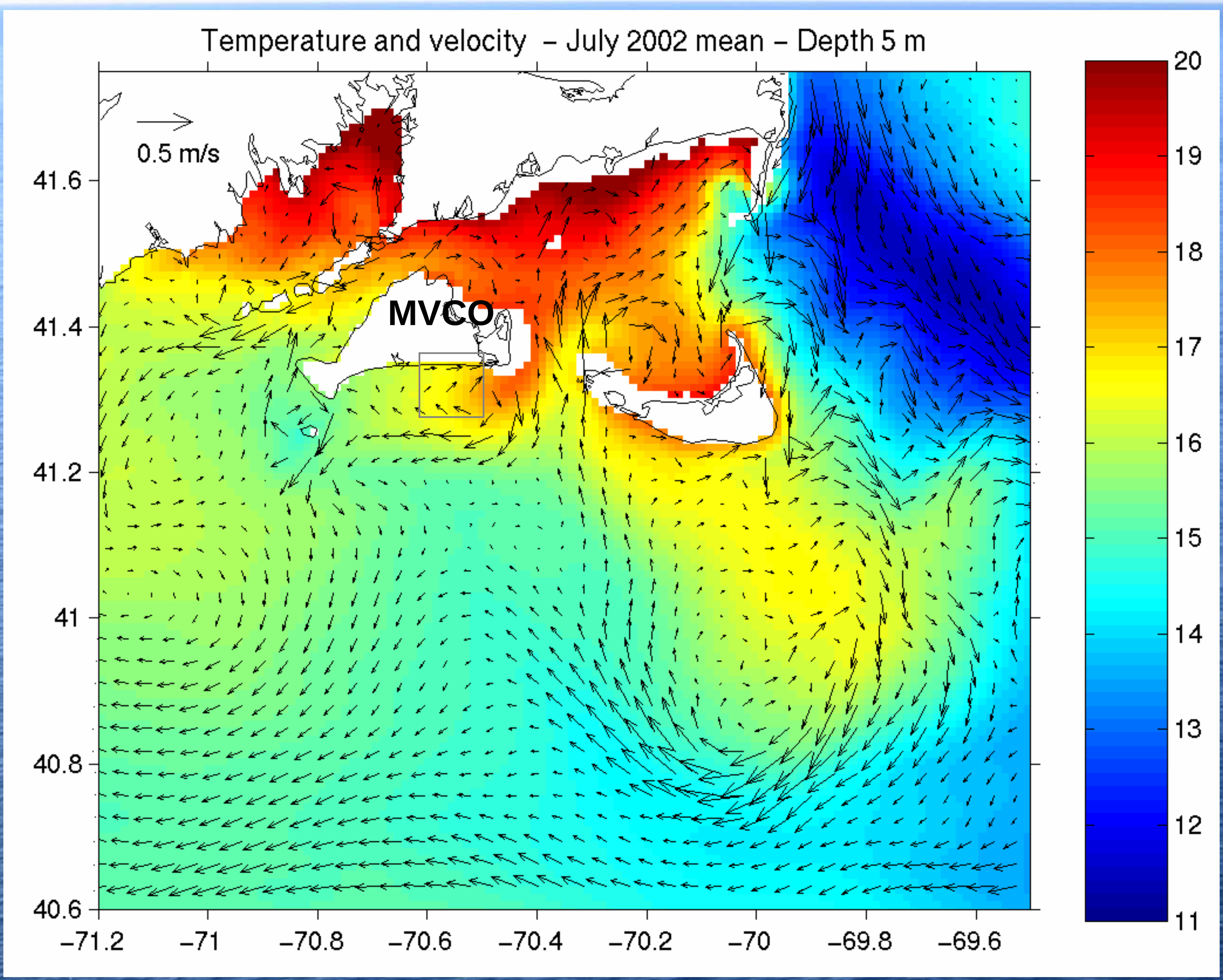


Horizontal divergence is small in the region of the *B-C* ASIMET moorings - indicating a region of approximate 1-D vertical heat balance suited to evaluating ROMS vertical turbulence closures.

Positive cools the ocean



Time mean advection cools the box at, on average, 200 W/m^2. The net "eddy" divergence <$u'T'$> warms the MVCO region at about 50 W/m^2.



Time series of the heat budget in a box near MVCO shows half the air-sea flux goes to warming the water column, and half is removed by lateral divergence.

Episodic positive divergence (cooling) events arrest the warming trend.

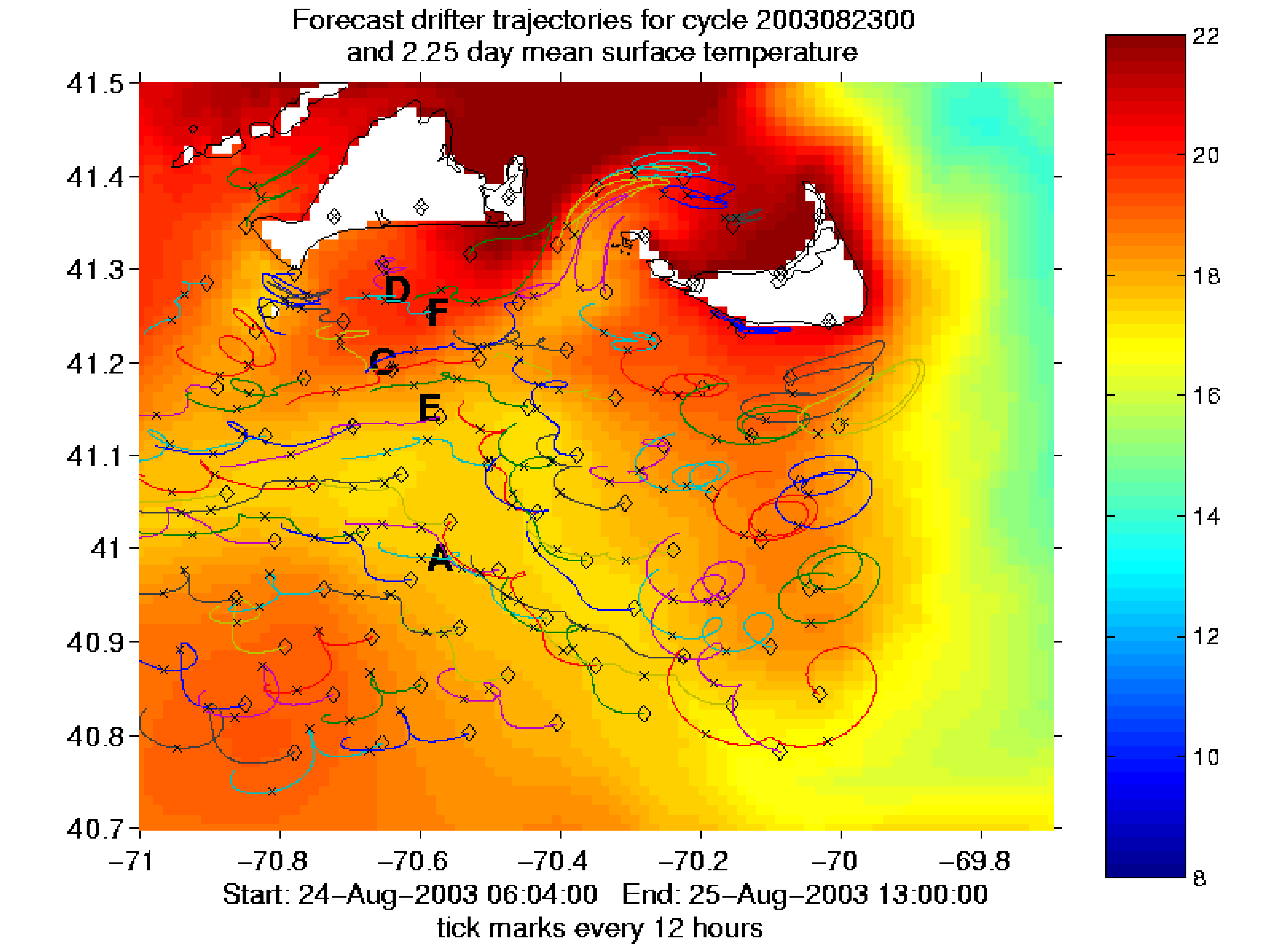
OK, OK, if you insist I will make a forecast …

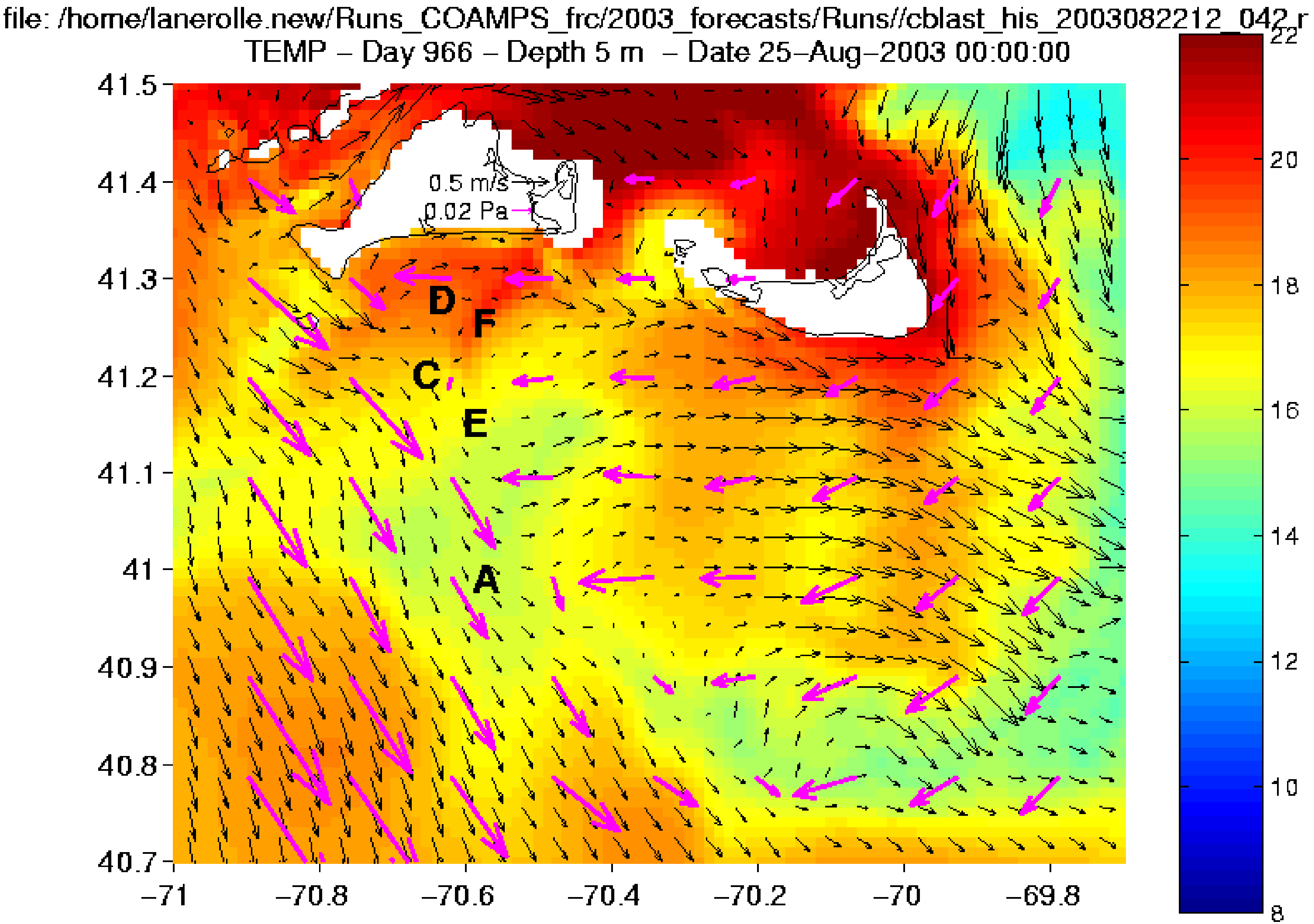
But, if I don’t know whether it has any skill, is it worth doing?

Yes, because it focuses the mind.

If nobody ever looks at it, can it be wrong?

Constraints on operating coastal vessels and deploying instruments made it difficult to use forecasts


Forecast drifter trajectories for cycle 2003082300
and 2.25 day mean surface temperature
41.5
41.4
41.3
41.2
41.1
41
40.9
40.8
40.7
−71
−70.8
−70.6
−70.4
−70.2
−70
−69.8
D
F
C
E
A
22
20
18
16
14
12
10
8
Start: 24−Aug−2003 06:04:00 End: 25−Aug−2003 13:00:00
tick marks every 12 hours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TEMP – Day 966 – Depth 5 m – Date 25–Aug–2003 00:00:00
0.5 m/s
0.02 Pa
D
F
C
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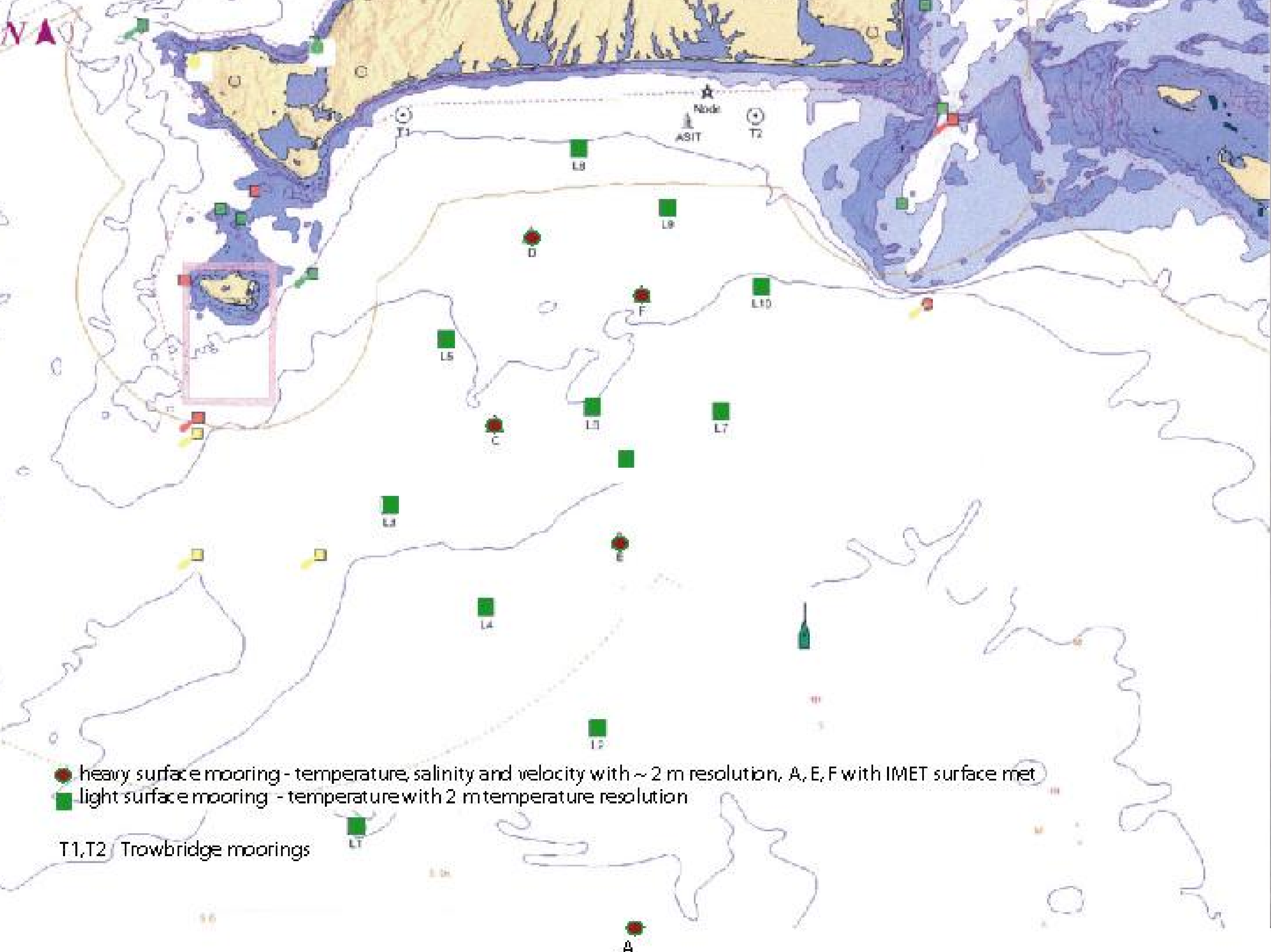
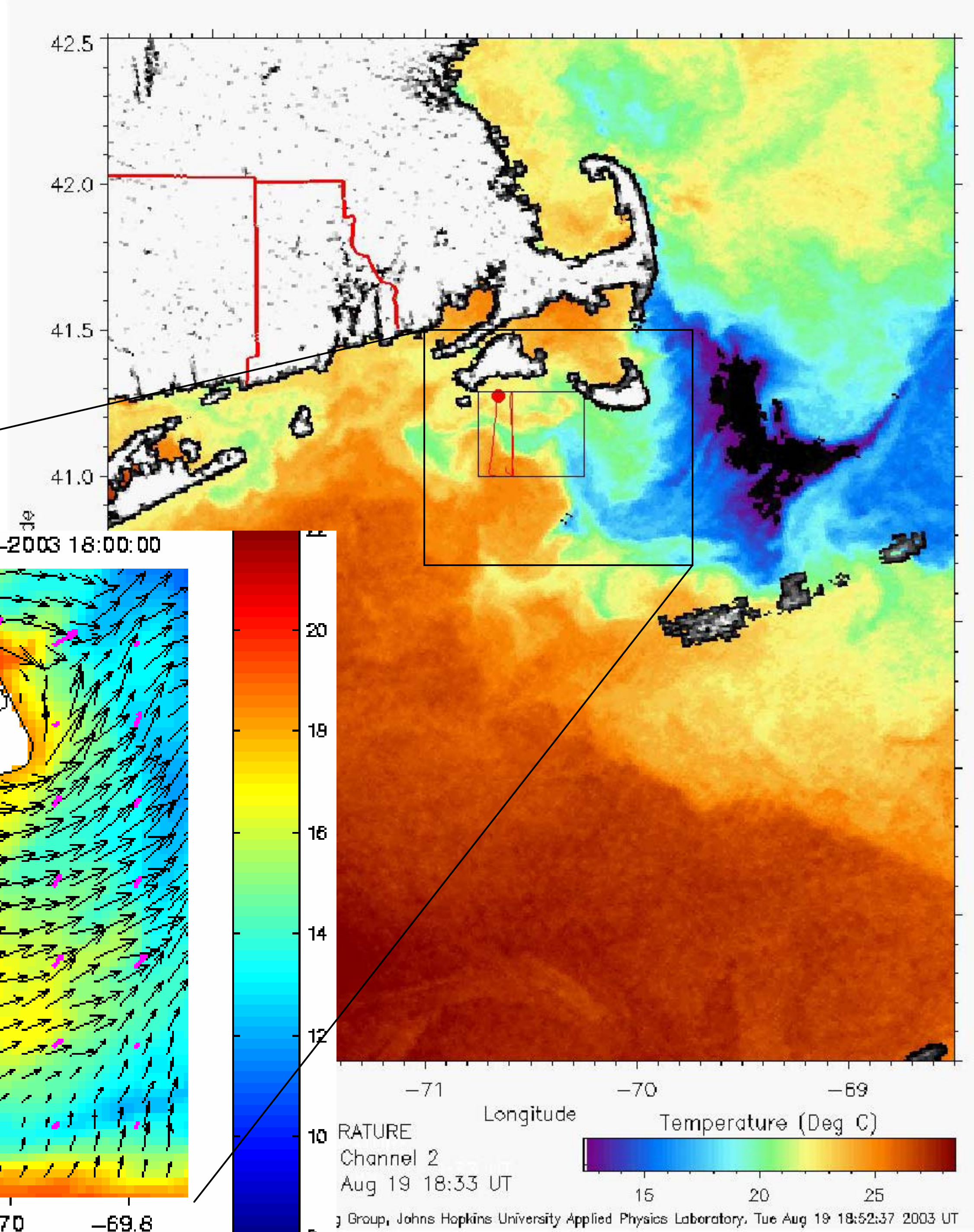
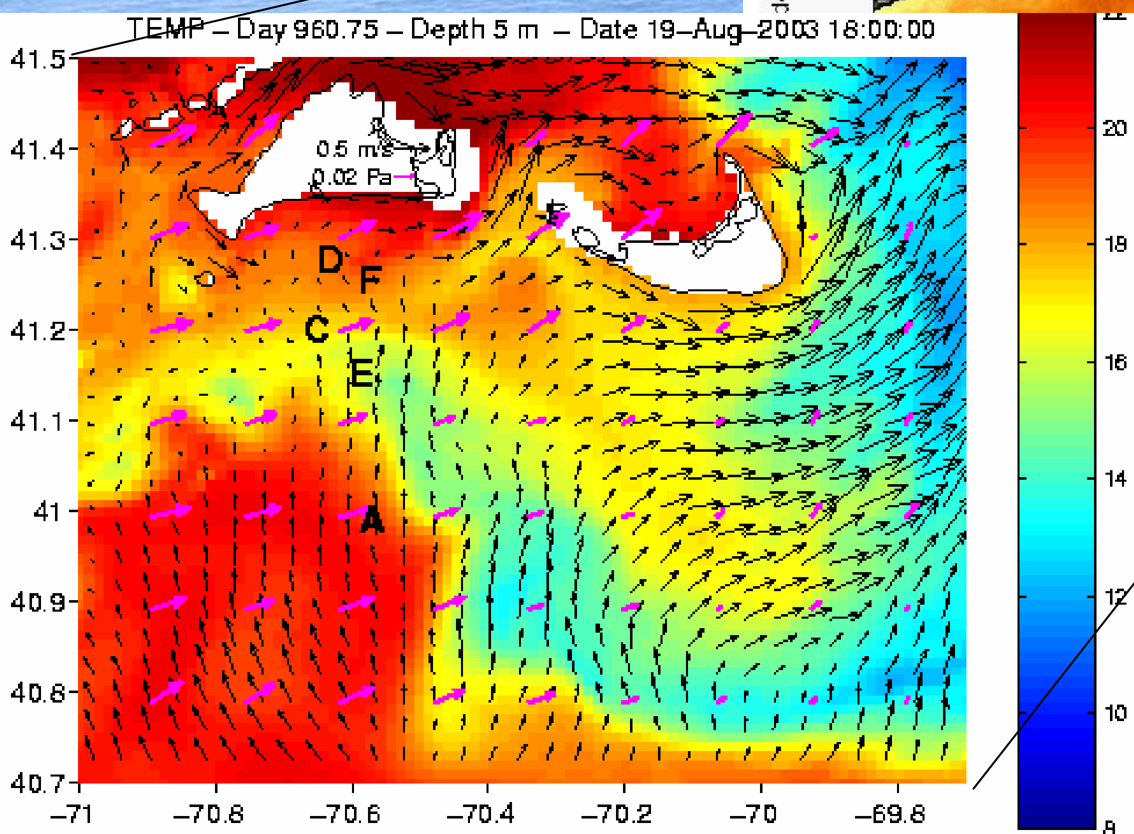
41.5
41.4
41.3
41.2
41.1
41
40.9
40.8
40.7
−71
−70.8
−70.6
−70.4
−70.2
−70
−69.8
22
20
18
16
14
12
10
8


N
T1
Node
ASIT
T2
L8
L9
D
F
L10
L5
L3
L7
C
E
L4
A
heavy surface mooring - temperature, salinity and velocity with ~ 2 m resolution, A, E, F with IMET surface met
light surface mooring - temperature with 2 m temperature resolution
T1,T2 Trowbridge moorings

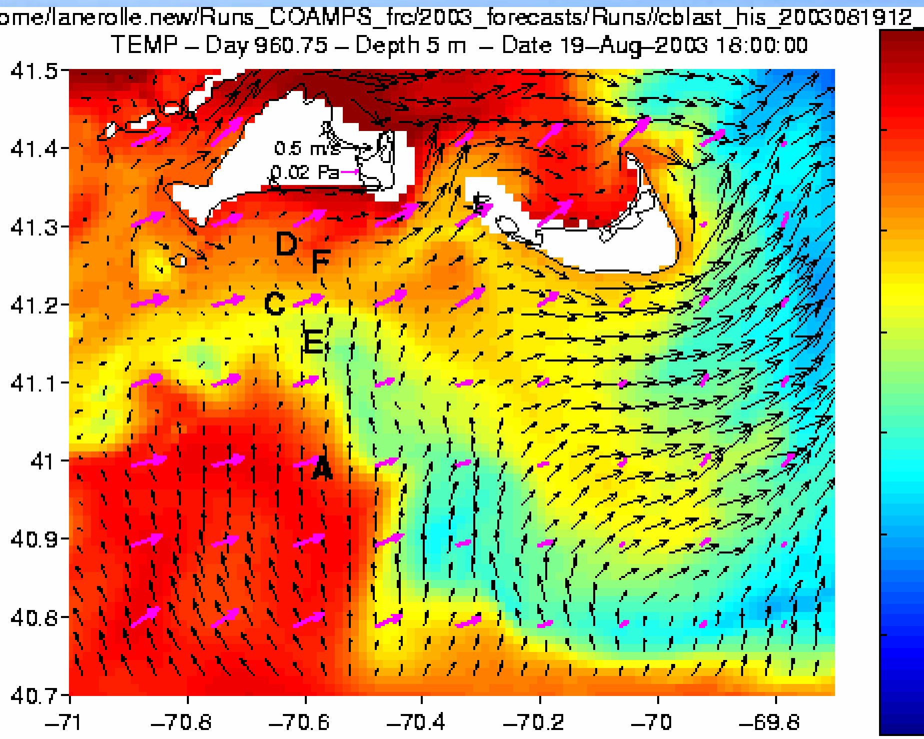
Satellite SST and ship track from August 19, 2003

6 hour forecast

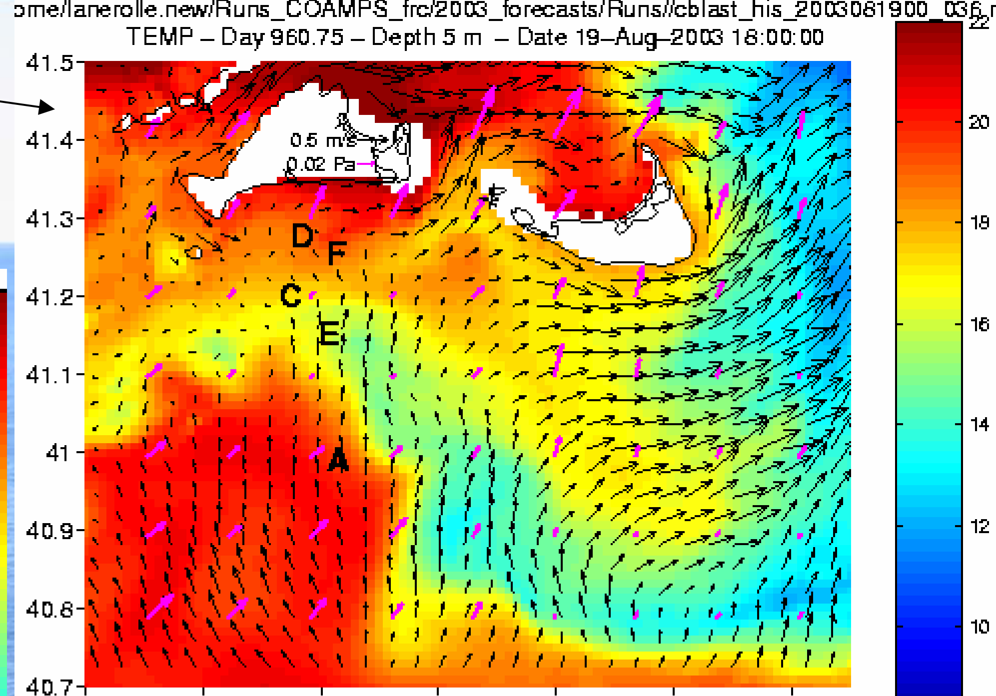




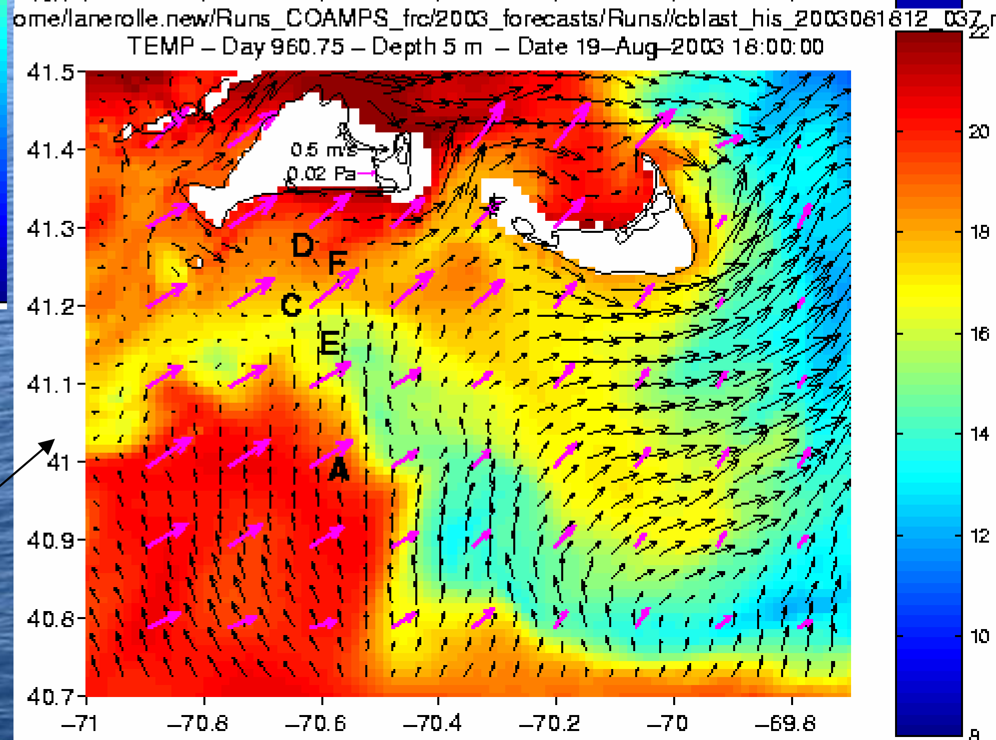
6 hour forecast



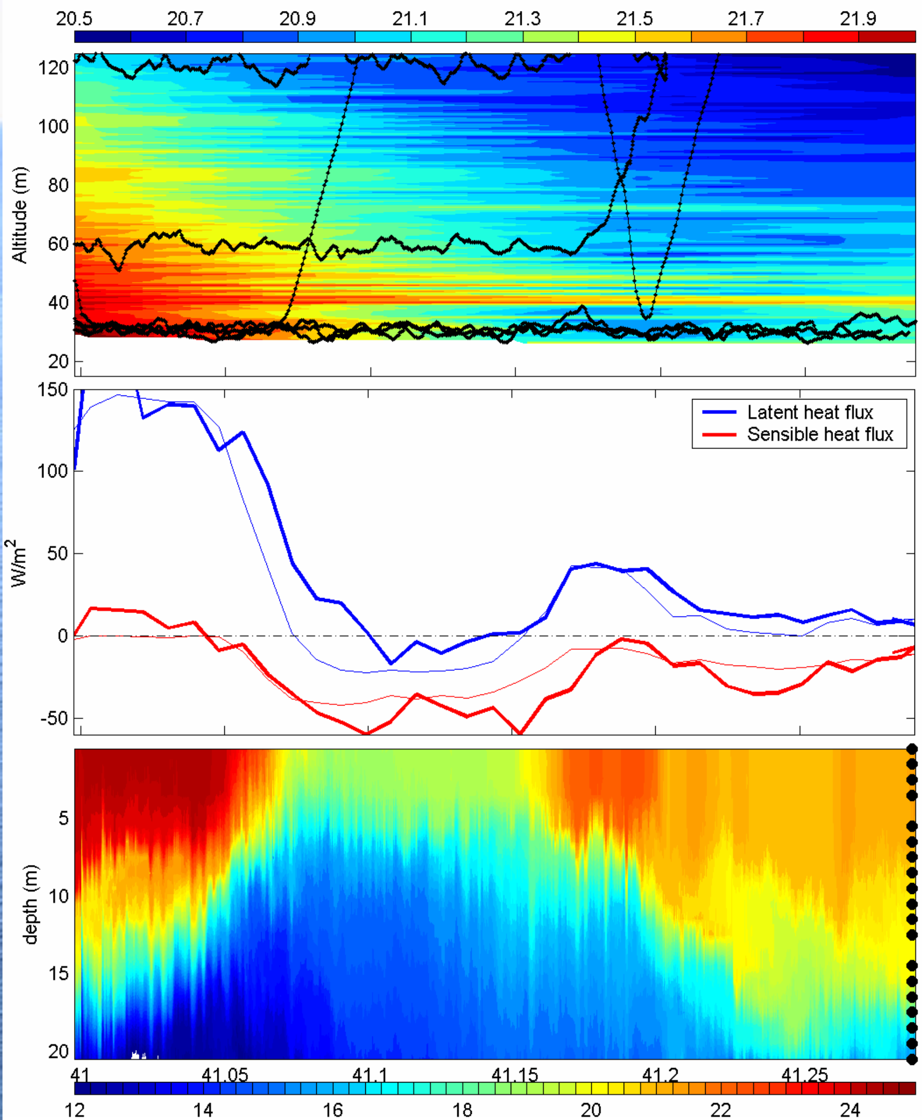
18 hour forecast



30 hour forecast

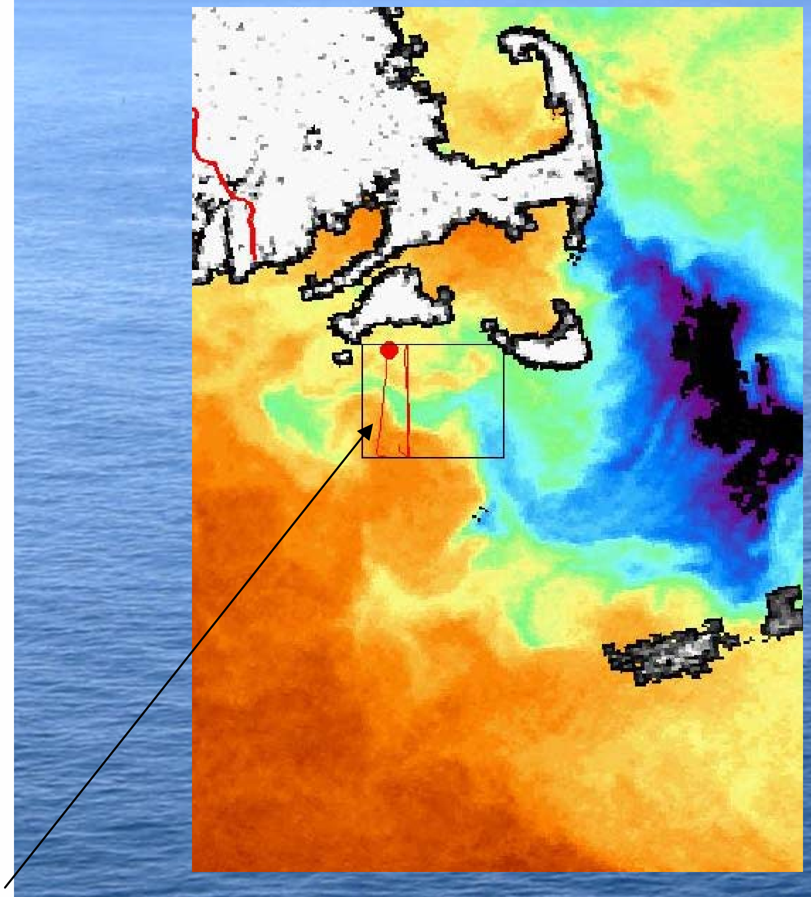


Pelican air temperature (°C)

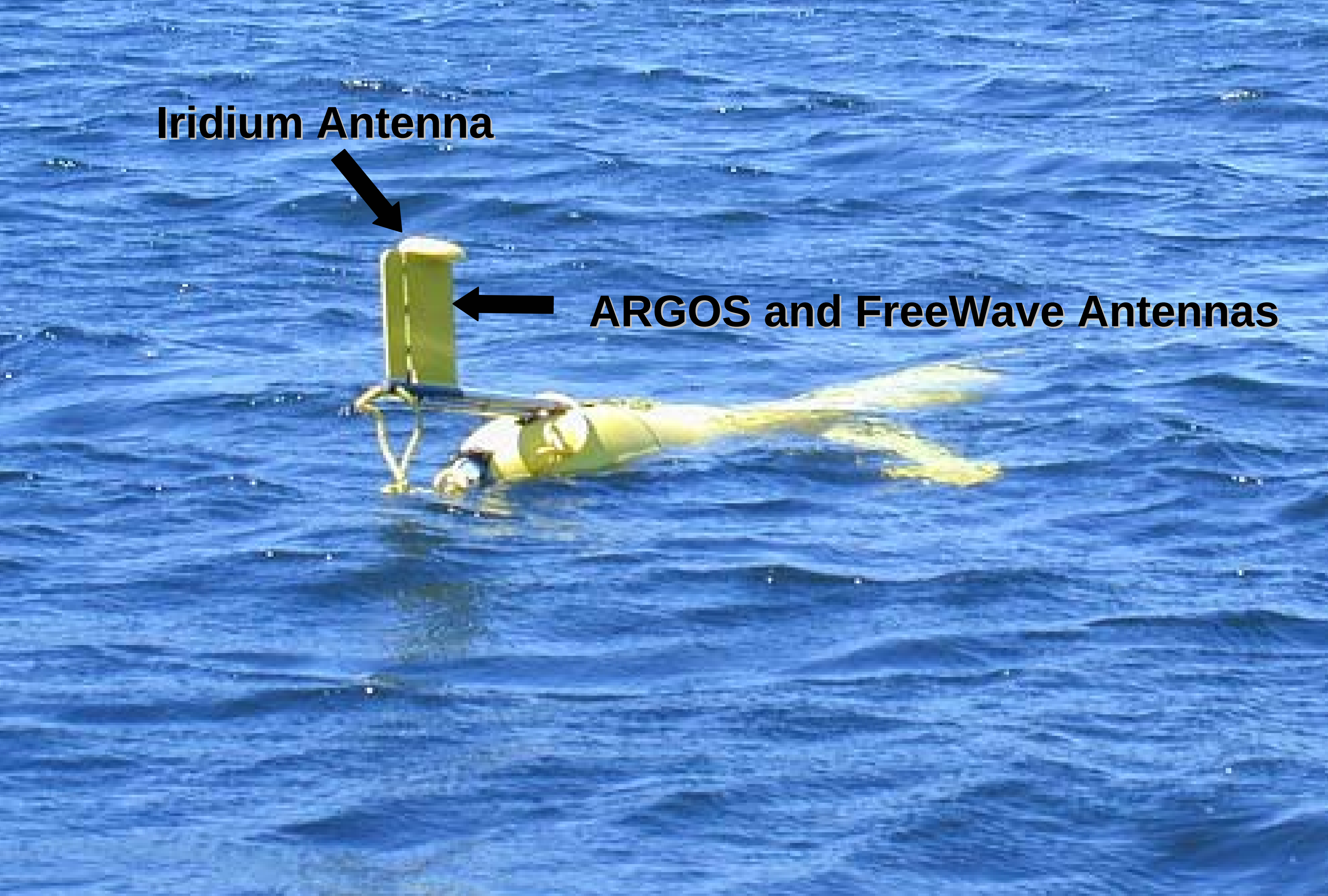


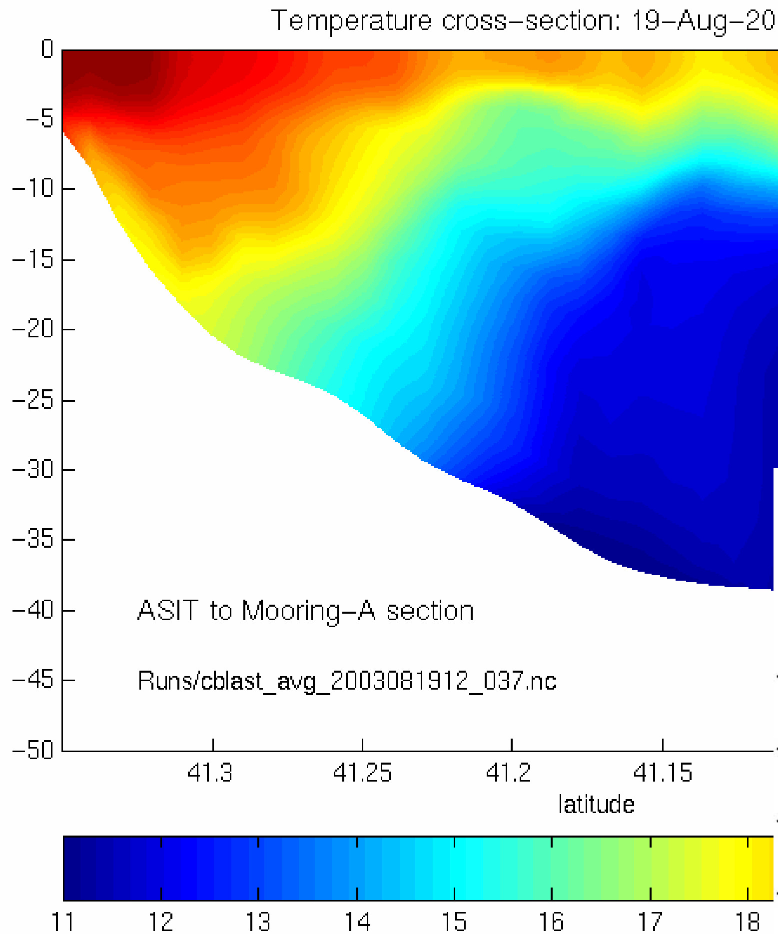
Subsurface temperature (°C)

SST and ship track

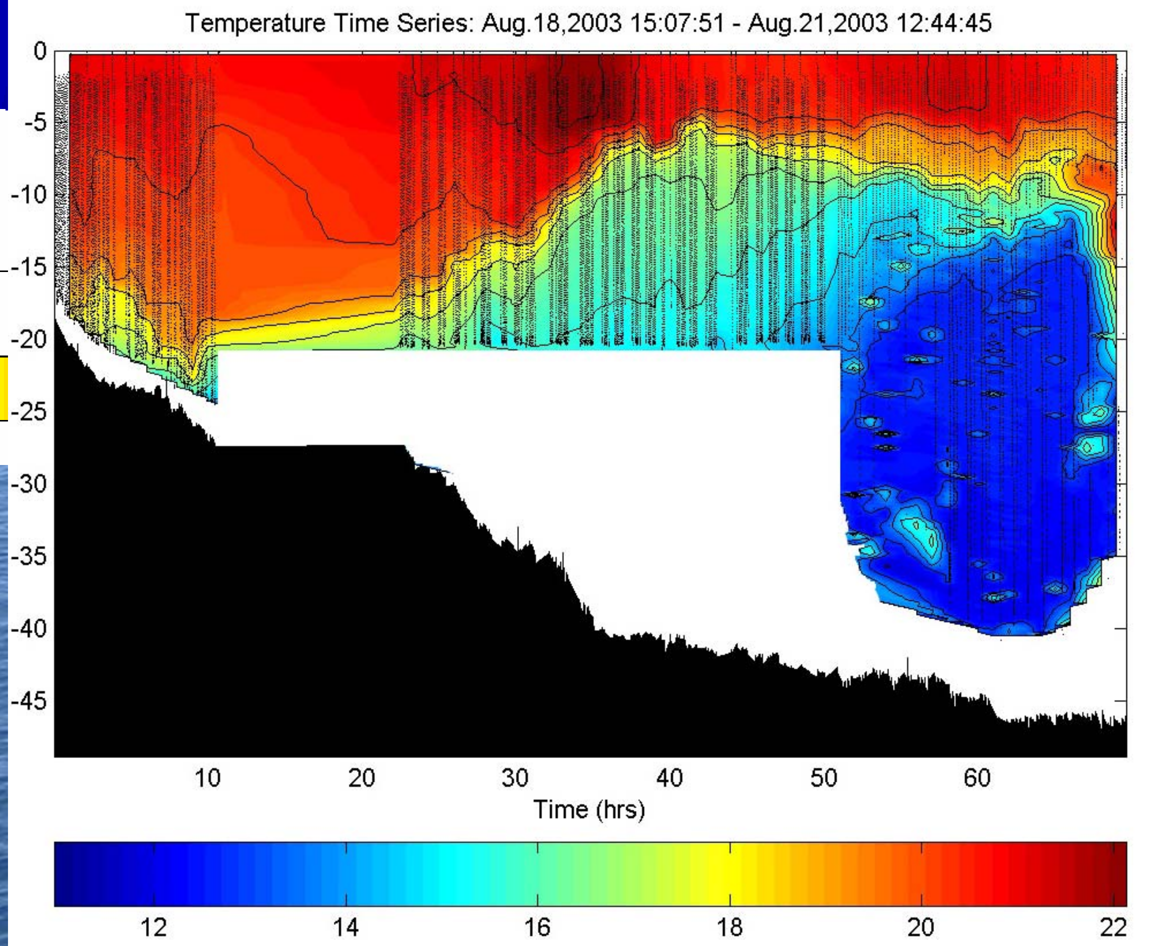


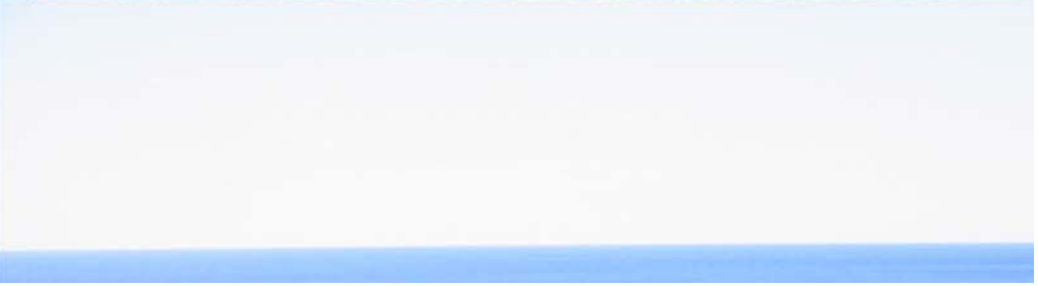
Slocum Electric Glider Communication

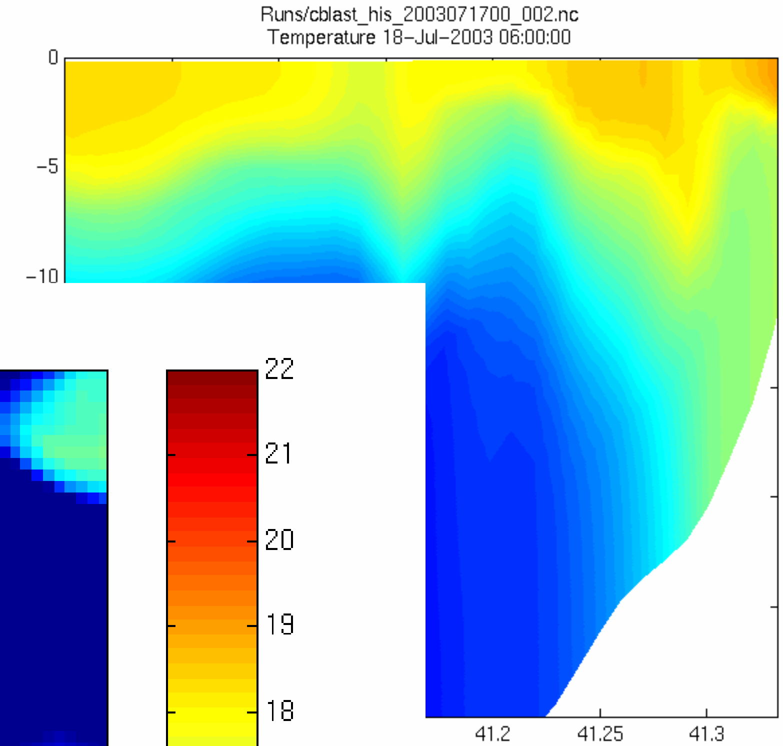


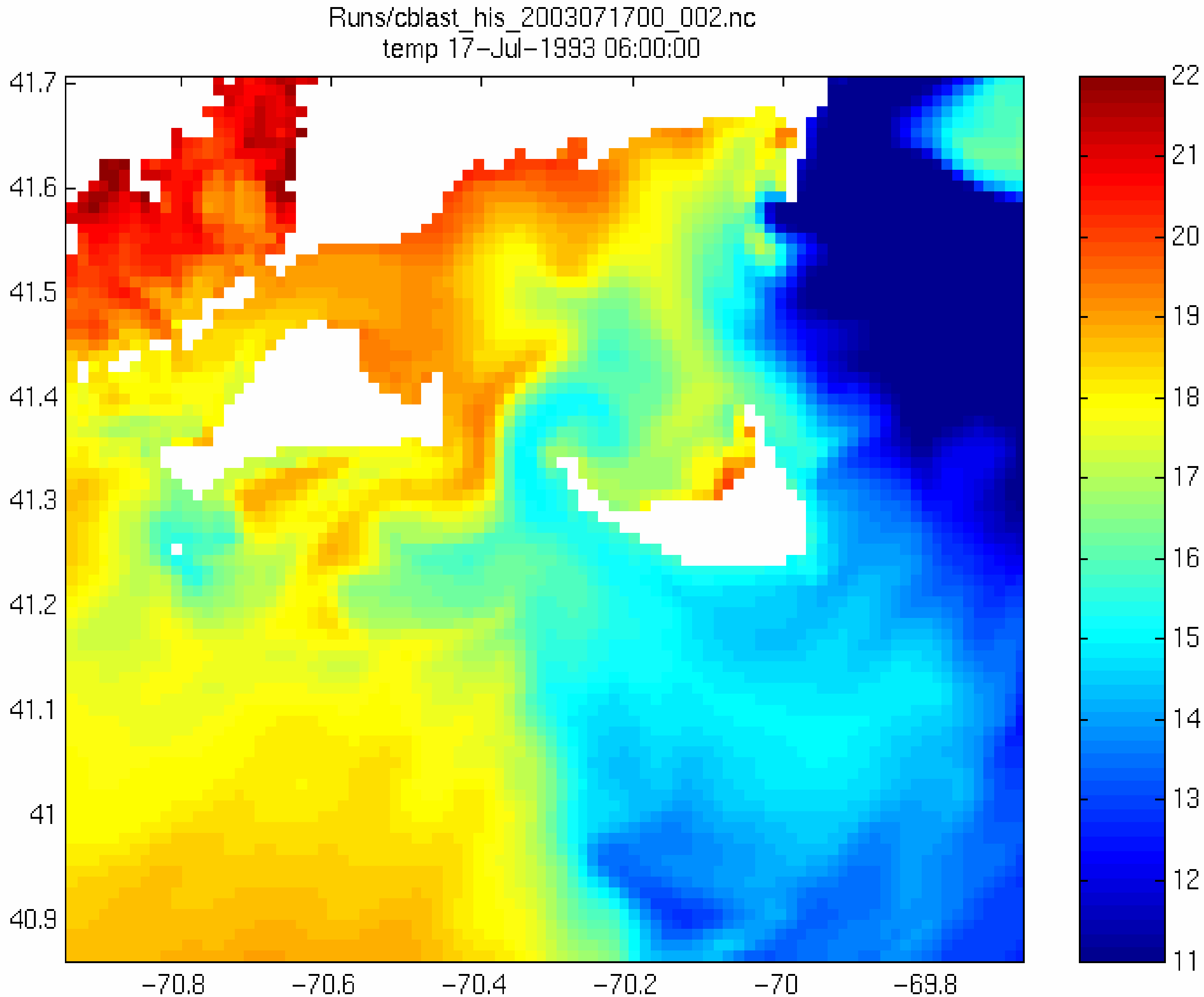


Raw CTD data acquired via Iridium from a Slocum Glider transiting between ASIT and mooring-*A.*






Runs/cblast_his_2003071700_002.nc
Temperature 18-Jul-2003 06:00:00
0
-5
-10
41.2
41.25
41.3


Runs/cblast_his_2003071700_002.nc
temp 17-Jul-1993 06:00:00
41.7
41.6
41.5
41.4
41.3
41.2
41.1
41
40.9
-70.8
-70.6
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-69.8
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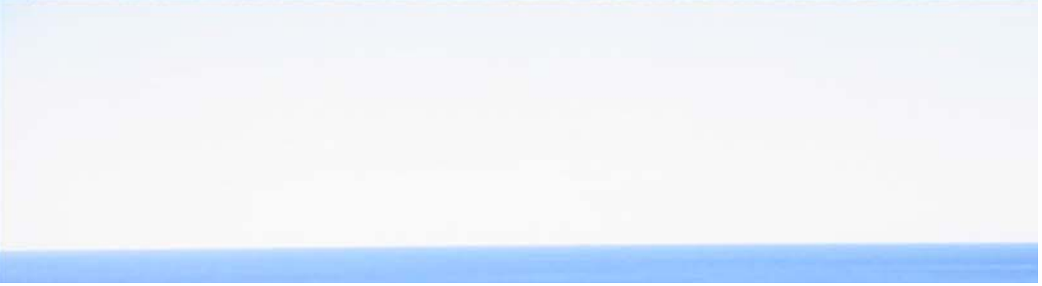
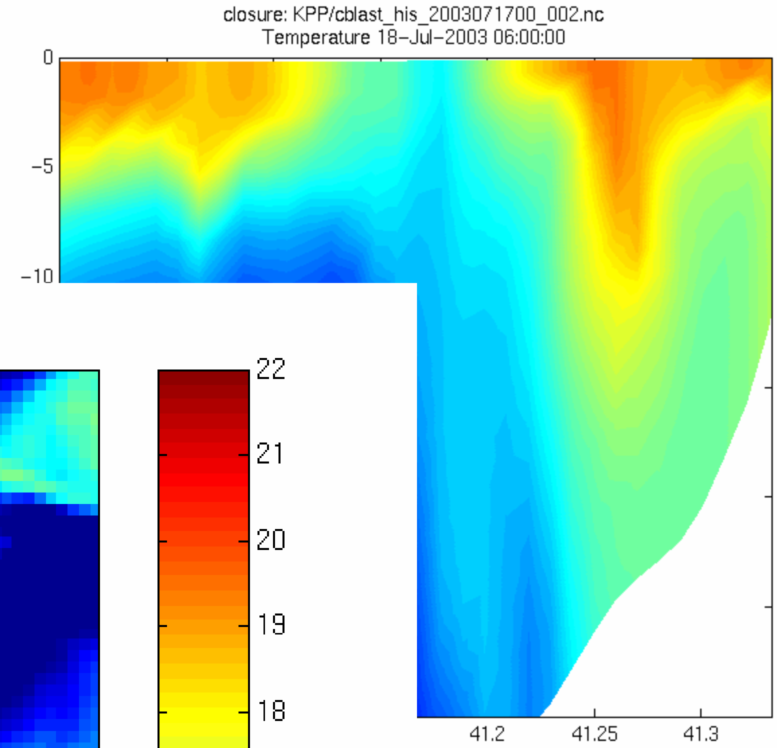
11

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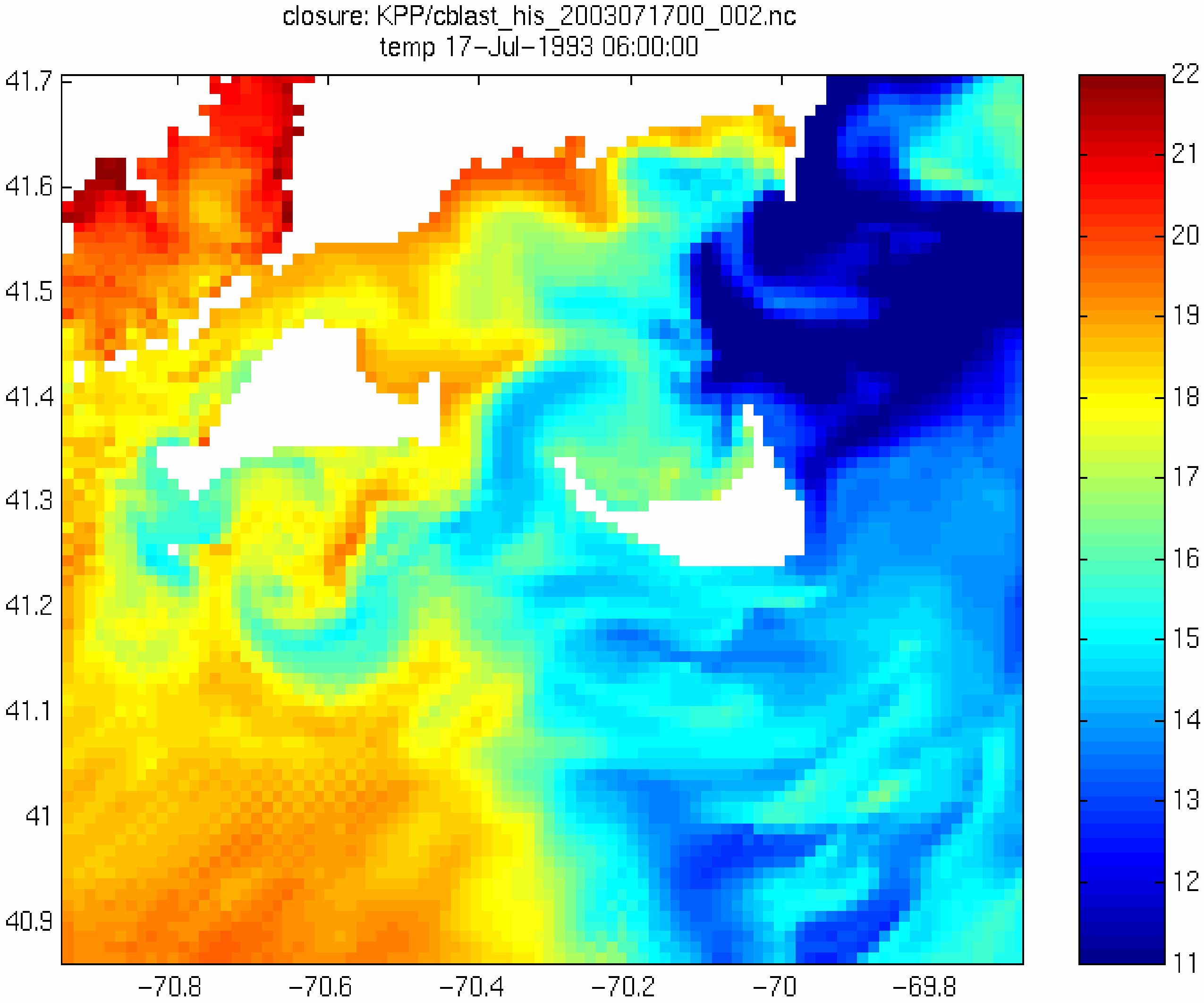
41.25
41.3


closure: KPP/cblast_his_2003071700_002.nc
temp 17−Jul−1993 06:00:00
41.7
41.6
41.5
41.4
41.3
41.2
41.1
41
40.9
−70.8
−70.6
−70.4
−70.2
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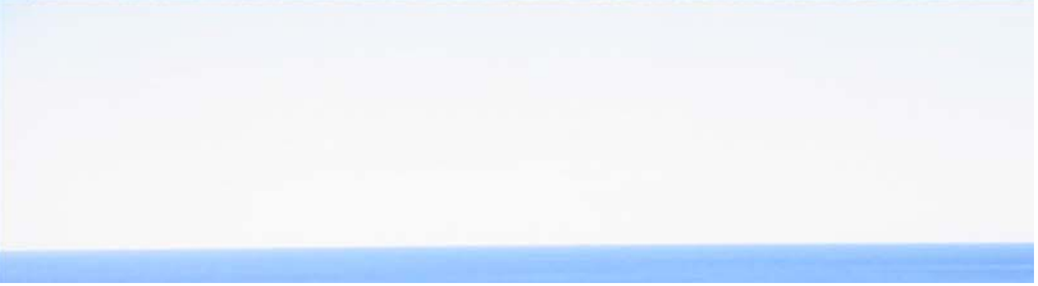
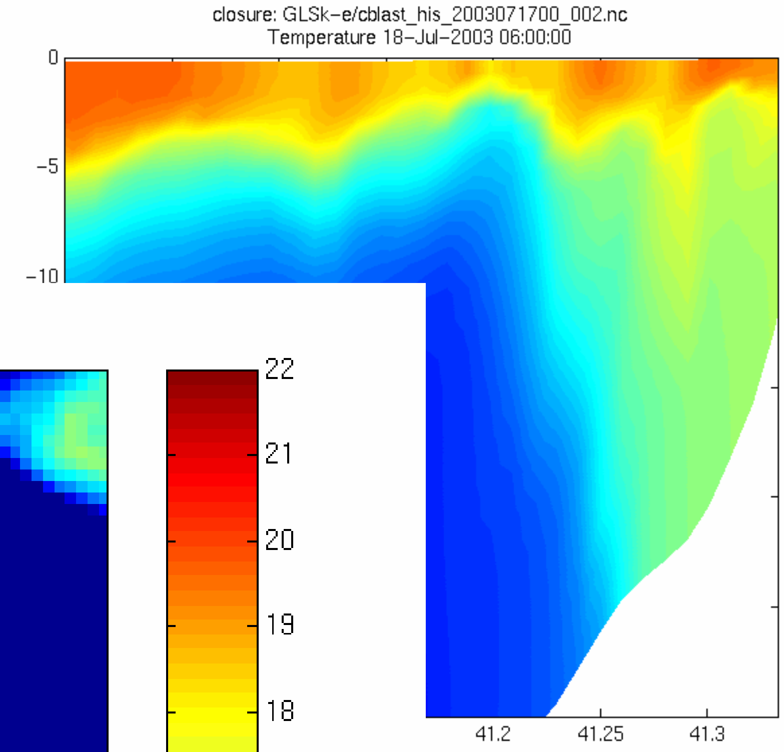
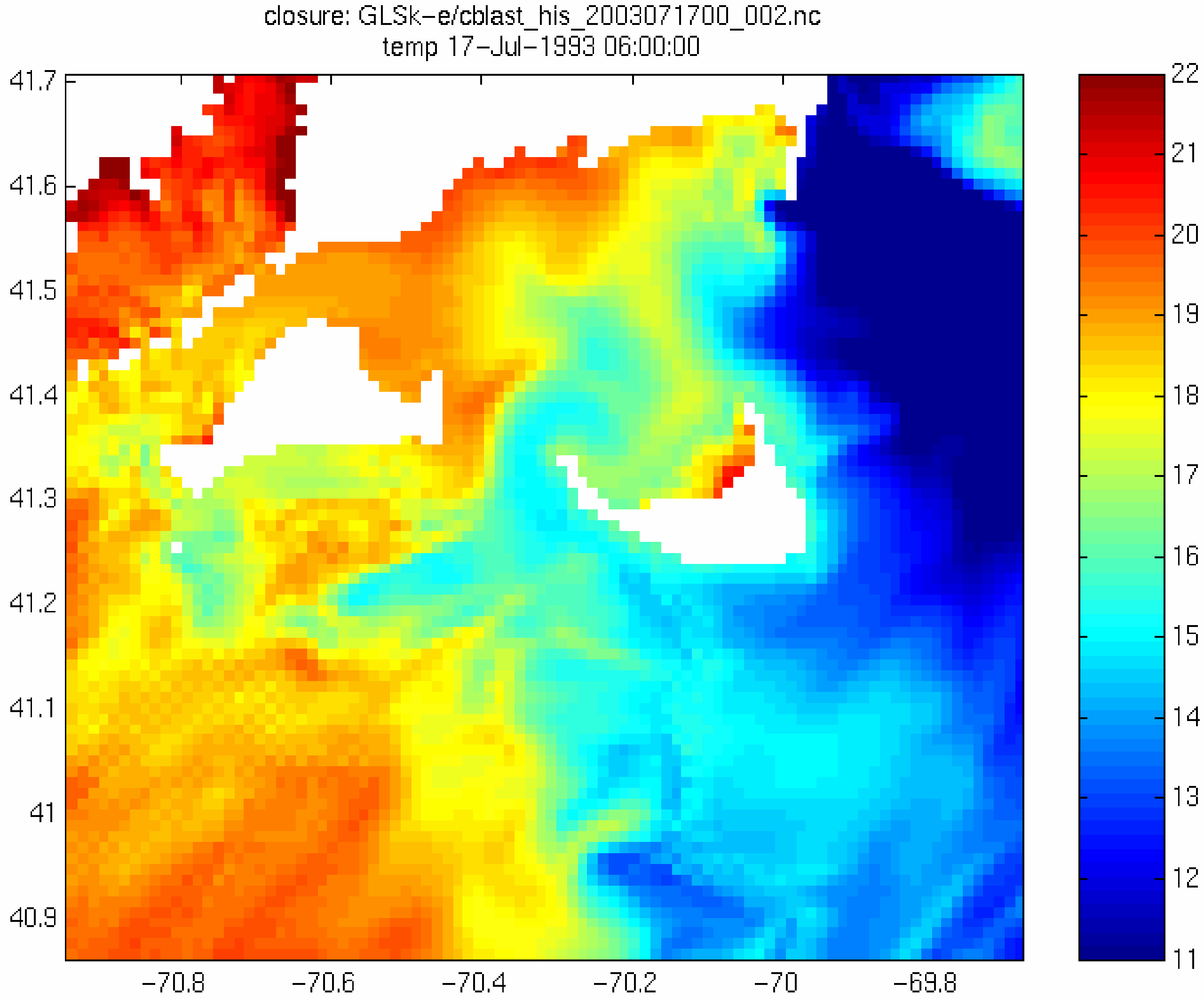
11




closure: GLSk-e/cblast_his_2003071700_002.nc
Temperature 18-Jul-2003 06:00:00
0
-5
-10
41.2
41.25
41.3


closure: GLSk-e/cblast_his_2003071700_002.nc
temp 17-Jul-1993 06:00:00
41.7
41.6
41.5
41.4
41.3
41.2
41.1
41
40.9
-70.8
-70.6
-70.4
-70.2
-70
-69.8
22
21
20
19
18
17
16
15
14
13
12
11

CBLAST:

Ocean modeling lessons:

- A high-resolution coastal model, carefully constructed, has intrinsic forecast skill without assimilation
- Differing vertical turbulence parameterizations lead to different 3-dimensional coastal mesoscale flows
- CBLAST data suited to turbulence closure evaluation:
  - Combination of direct air-sea flux and in situ oceanic conditions for validation
  - Eventually we will compare to vertical turbulence observations
- Spatially variable atmospheric forcing (COAMPS) is important
- Heat budget requires further analysis of horizontal/vertical circulations: overturning/upwelling vs. depth-average flow contributions, especially at moorings and ASIT

CBLAST:

Oceanography lessons:

- **Tides affect the circulation and heat budget through residual mean currents and vertical mixing**
- **Wind-driven upwelling circulation contributes to the heat budget southwest of Martha's Vineyard**
- **Lateral heat transport is large in much of the region, including near MVCO, and will need to be considered in the analysis of CBLAST heat budgets**
- **Vineyard Sound, Nantucket Shoals, MVCO, shows differing heat balances in July mean**
- **Modeling shows a 1-D heat balance occurs near the B-A-C MET mooring sites, which suggests vertical turbulence closures might be evaluated locally there**

The capability to simulate regional dynamics at high resolution has generated new applications for the model (= funding!)

Processes controlling seasonal variability of phytoplankton over the inner shelf:

Bio-optical instrumentation at MVCO gives information on

- **phytoplankton abundance**
- **community structure**
- **growth rate**

We know that primary production is very patchy …

Is the variability local, or advected from somewhere else?

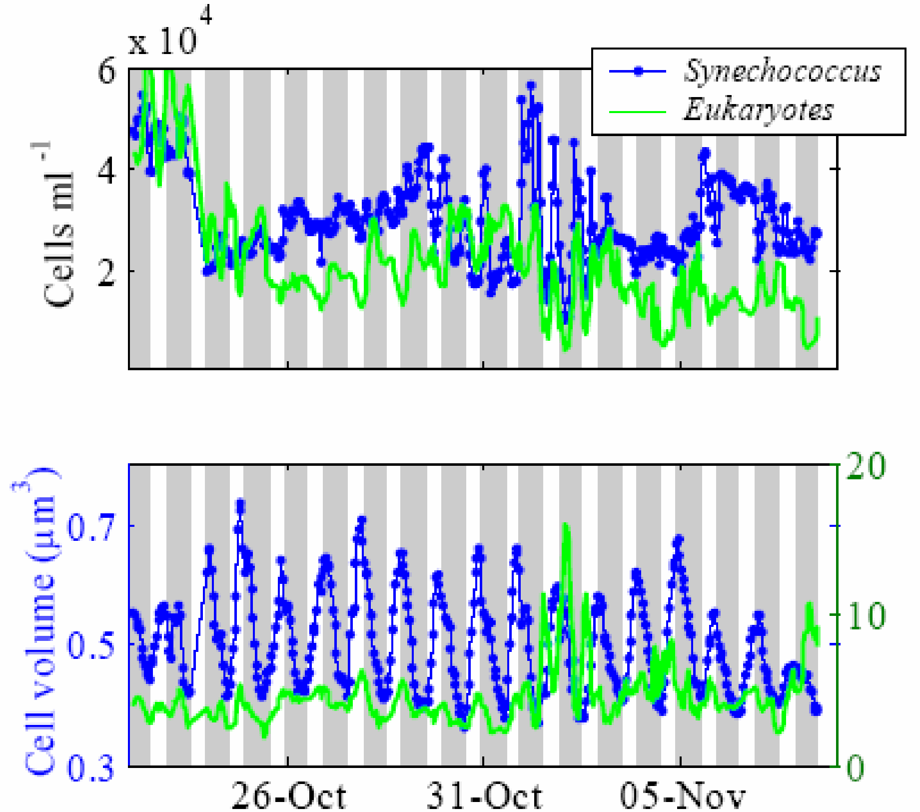


Figure 7. Example of phytoplankton time series observations from a test deployment of FlowCytobot at MVCO in 2002. Abundance and average cell volume for the cyanobacteria genus *Synechococcus* and a group of mixed taxonomy eukaryotic pico- and nano-phytoplankton were separately quantified with hourly resolution. Diel variations in cell size, which we have used to quantify cell growth rates (Sosik et al. 2003), are prominent for Synechococcus and large changes in average cell size for eukaryotes (likely indicative of species changes) occurred around 1 and 7 November in conjunction with storm events.

The capability to simulate regional dynamics at high resolution has generated new applications (=funding!)

Processes controlling seasonal variability of phytoplankton over the inner shelf:

Bio-optical instrumentation at MVCO gives information on

- phytoplankton abundance
- community structure
- growth rate

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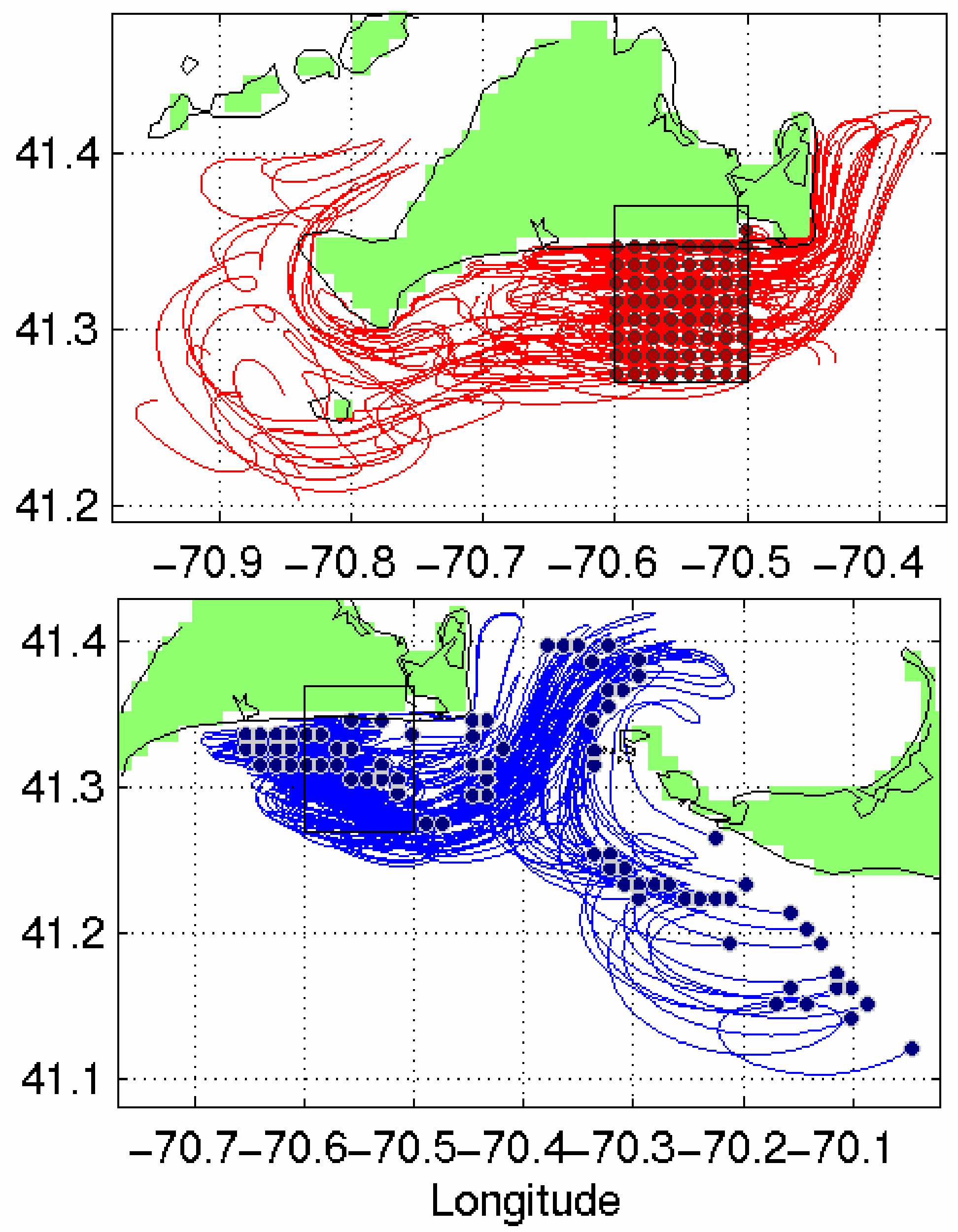


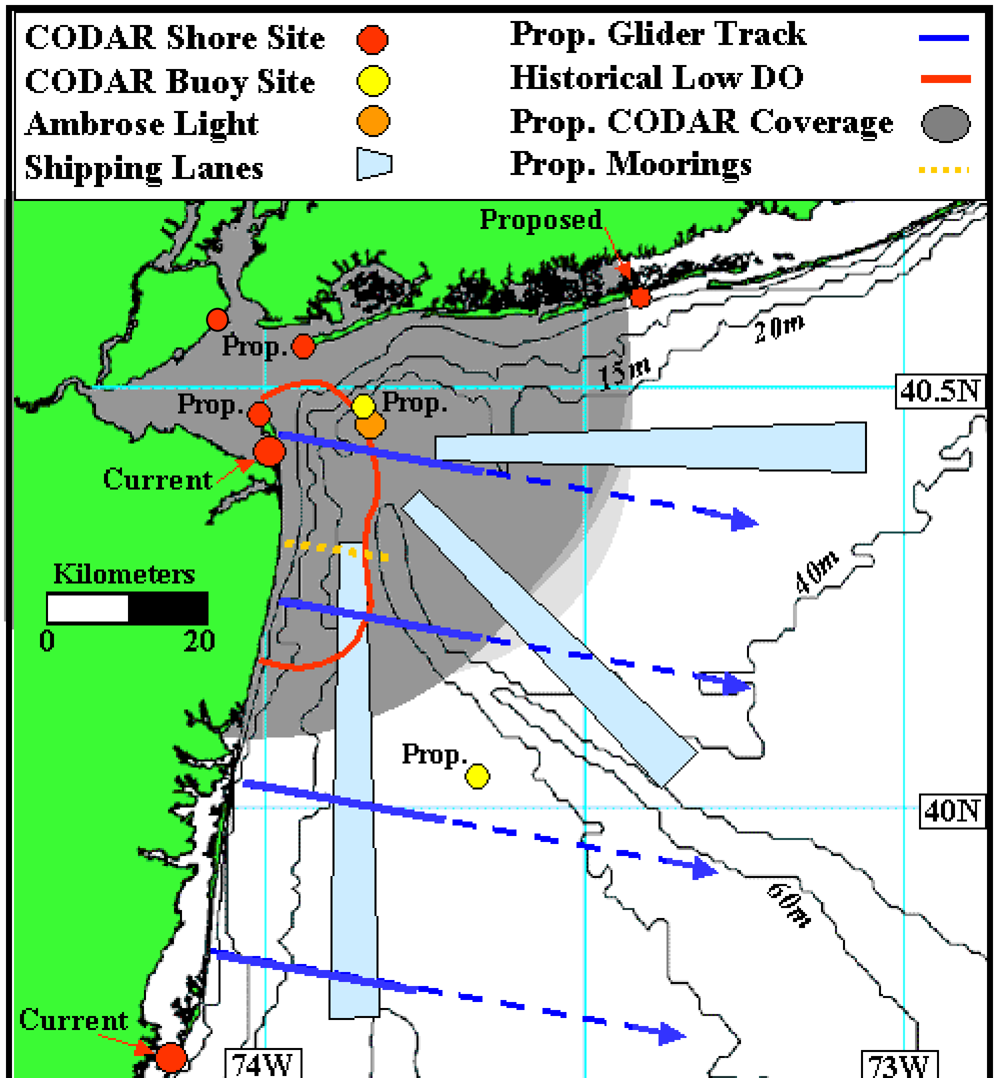
LATTE

- Using NJSOS to study the transport and transformation of the Hudson River plume

- NY/NJ Harbor discharges 4% sediment load in Mid-Atlantic Bight, but 96% of PCBs and 69% of mercury

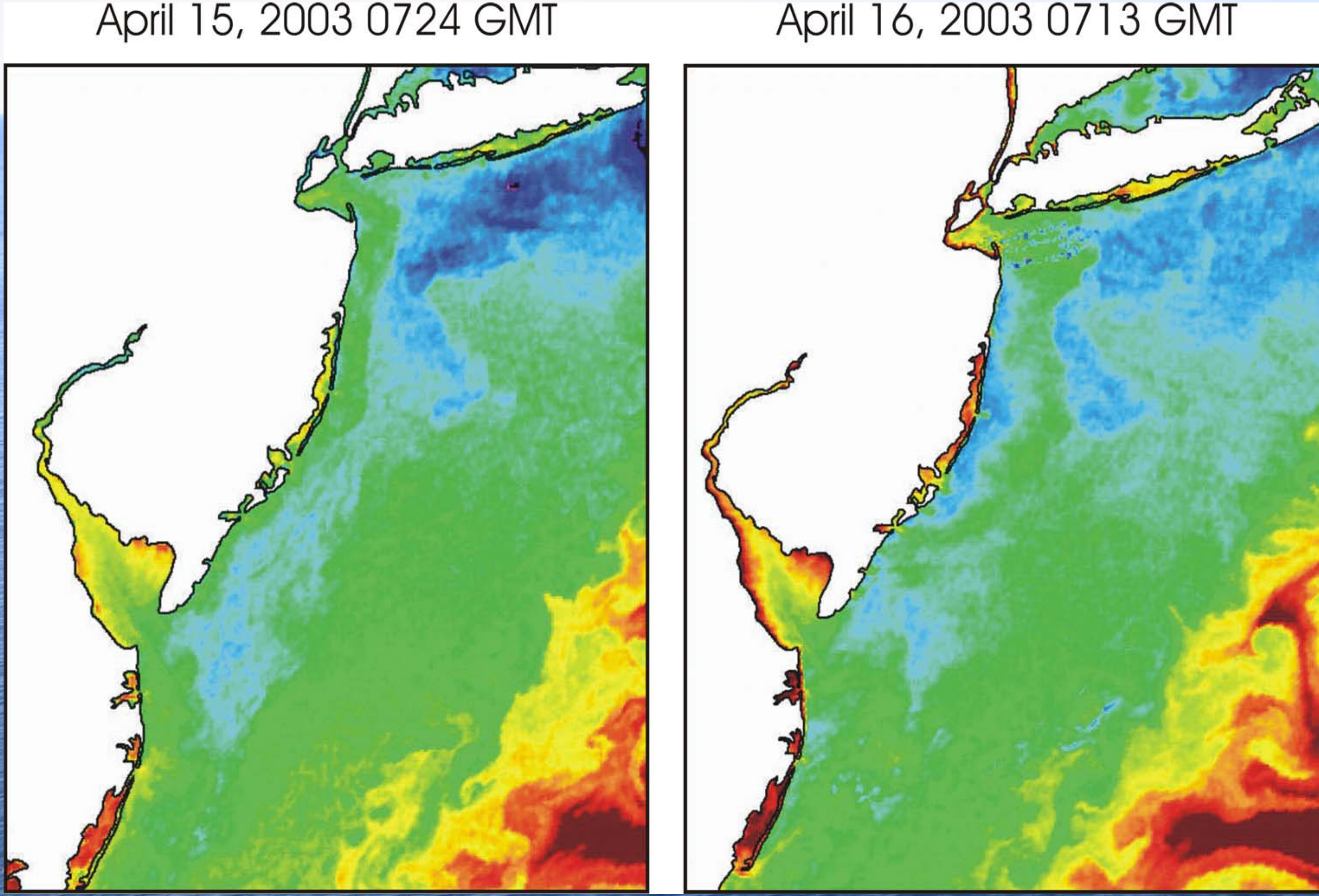
- Each spring, we inject dye in the plume and track it, monitoring:
  - physics
  - chemistry (nutrients, metals, caffeine …)
  - optics
  - ecology (PP, zooplankton, bioaccumulation …)

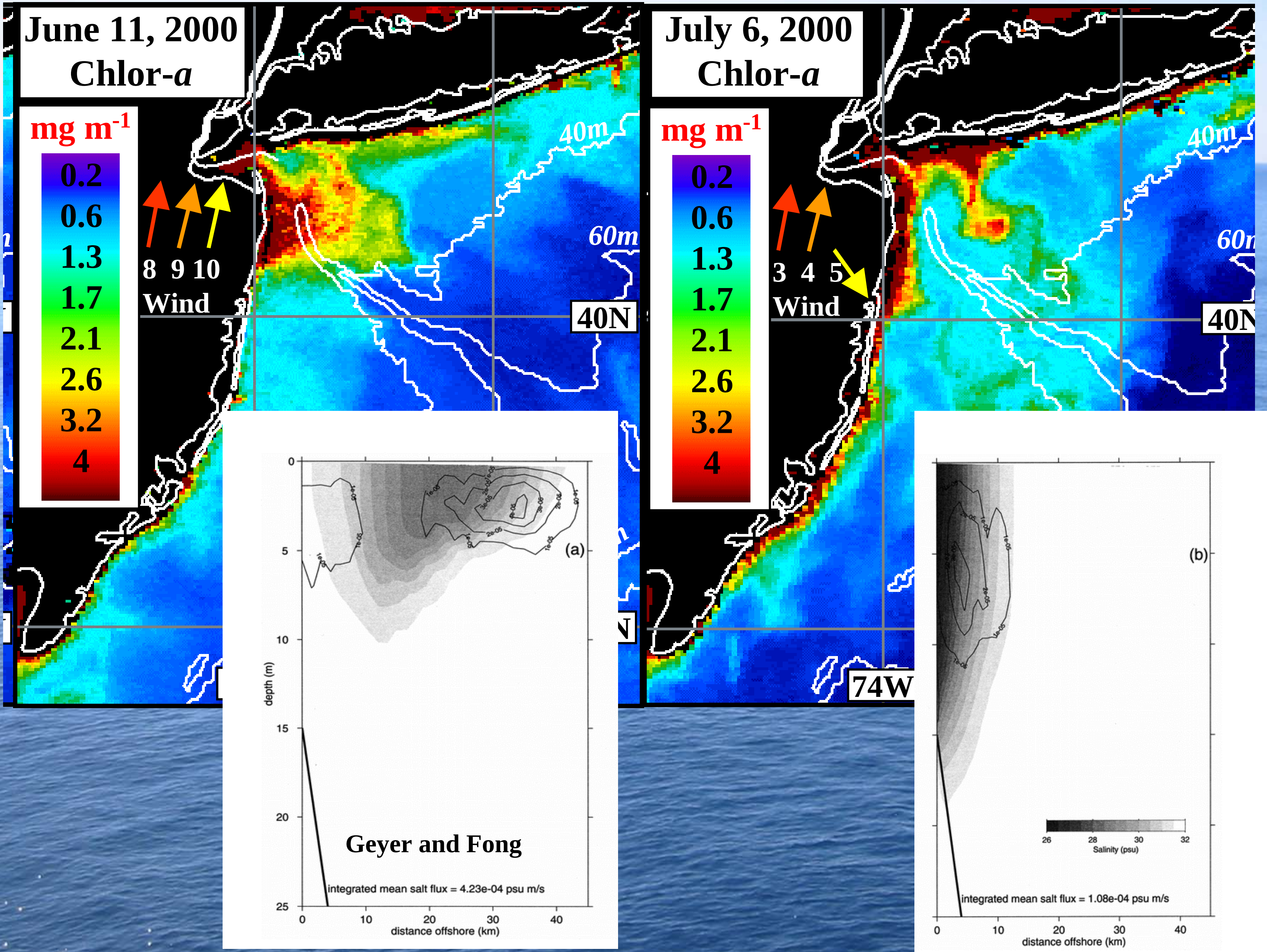
Lagrangian studies of the transport, transformation and biological impact of nutrients and contaminant metals in a buoyant plume: A process study in an operational ocean observatory.



LaTTE

[1]Rutgers, [2]Lamont-Doherty, [3]U. Mass Boston, [4]FERI, [5]Calpoly, [6]U. Fla.


April 15, 2003 0724 GMT
April 16, 2003 0713 GMT

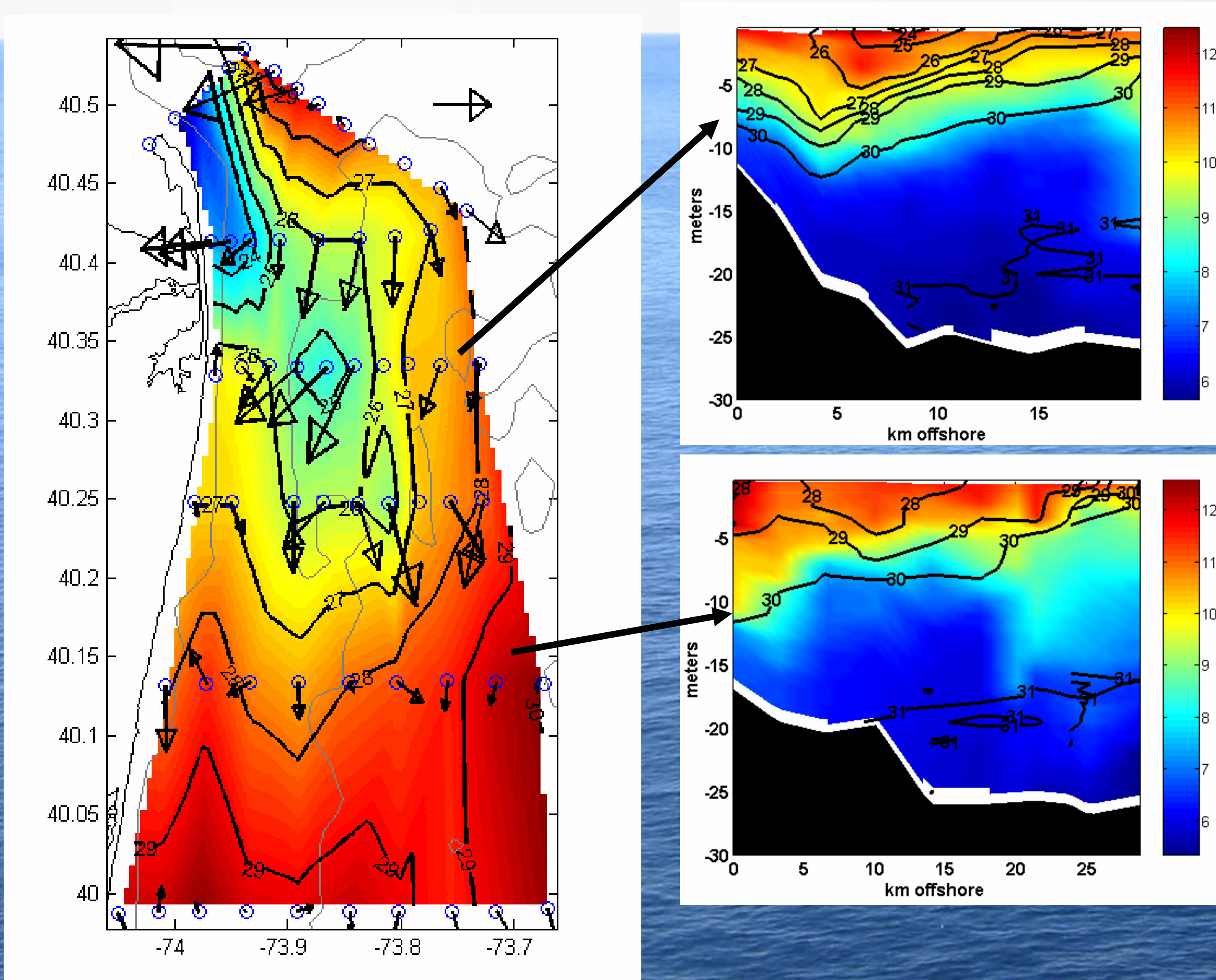


June 11, 2000
Chlor-a
mg m-1
0.2
0.6
1.3
1.7
2.1
2.6
3.2
4
8 9 10
Wind
40m
60m
40N
July 6, 2000
Chlor-a
mg m-1
0.2
0.6
1.3
1.7
2.1
2.6
3.2
4
3 4 5
Wind
40m
60m
40N
74W
(a)
depth (m)
integrated mean salt flux = 4.23e-04 psu m/s
distance offshore (km)
Geyer and Fong
(b)
Salinity (psu)
integrated mean salt flux = 1.08e-04 psu m/s
distance offshore (km)

Top view (salinity)

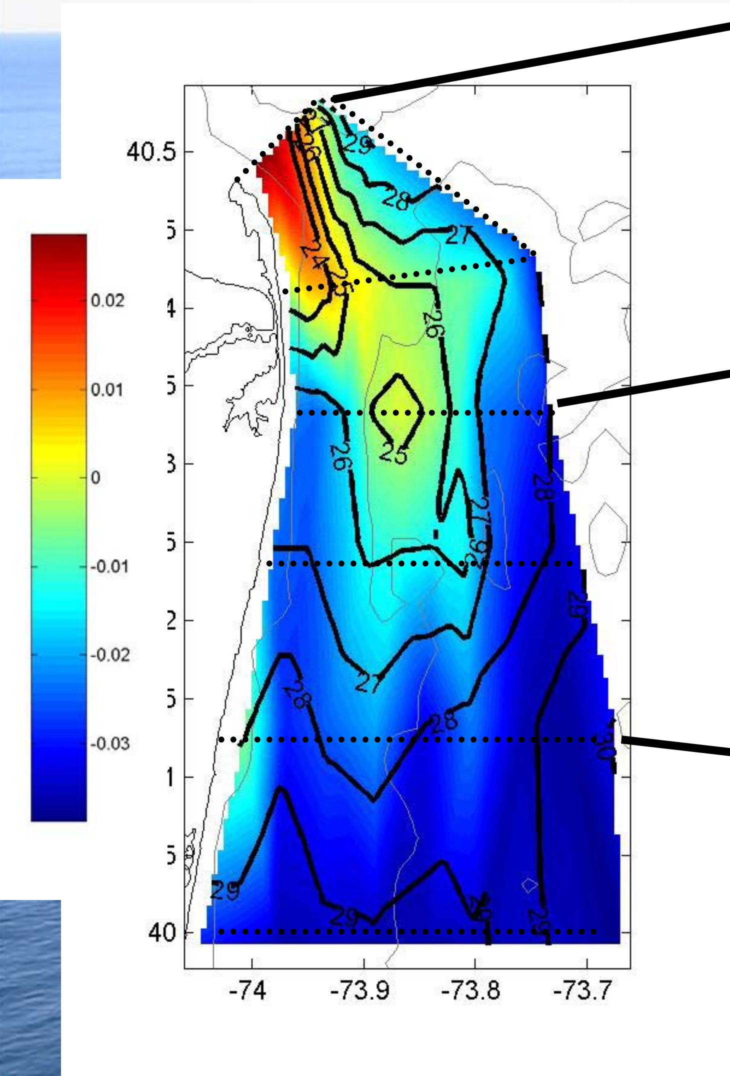
Cross-shore sections

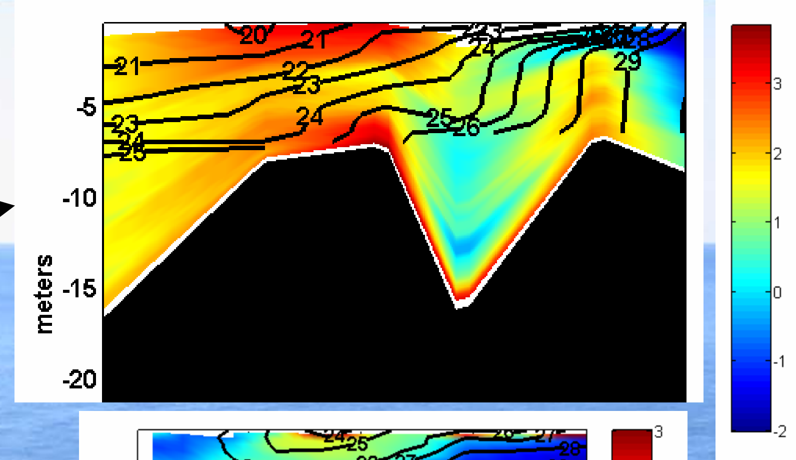
(contours show salinity, Colors show temperature)

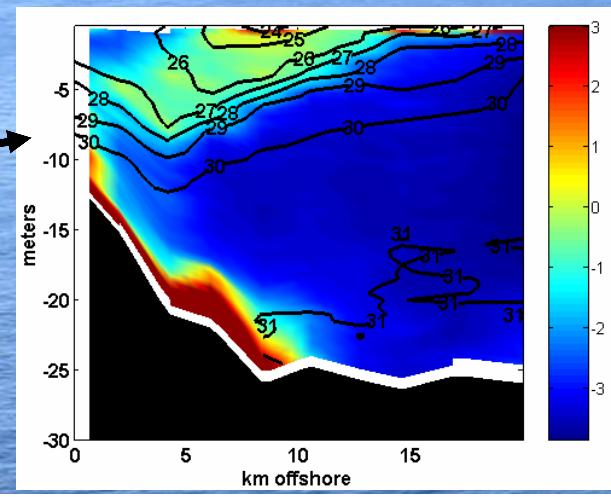


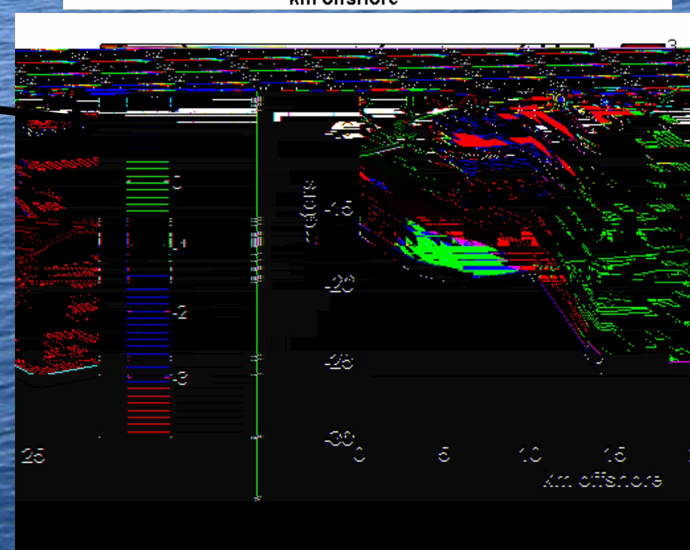
OBS (volts)

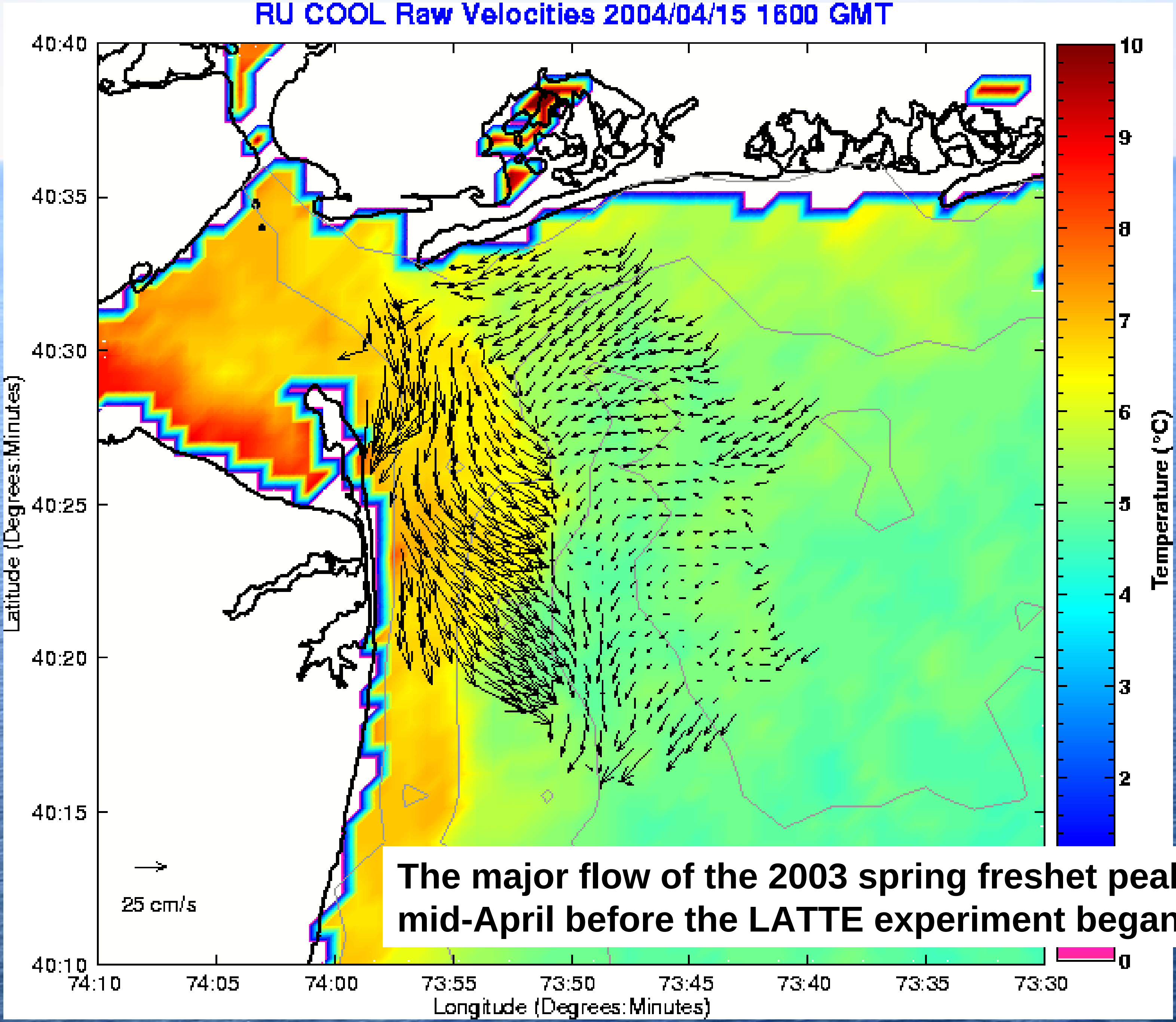
Contours show salinity











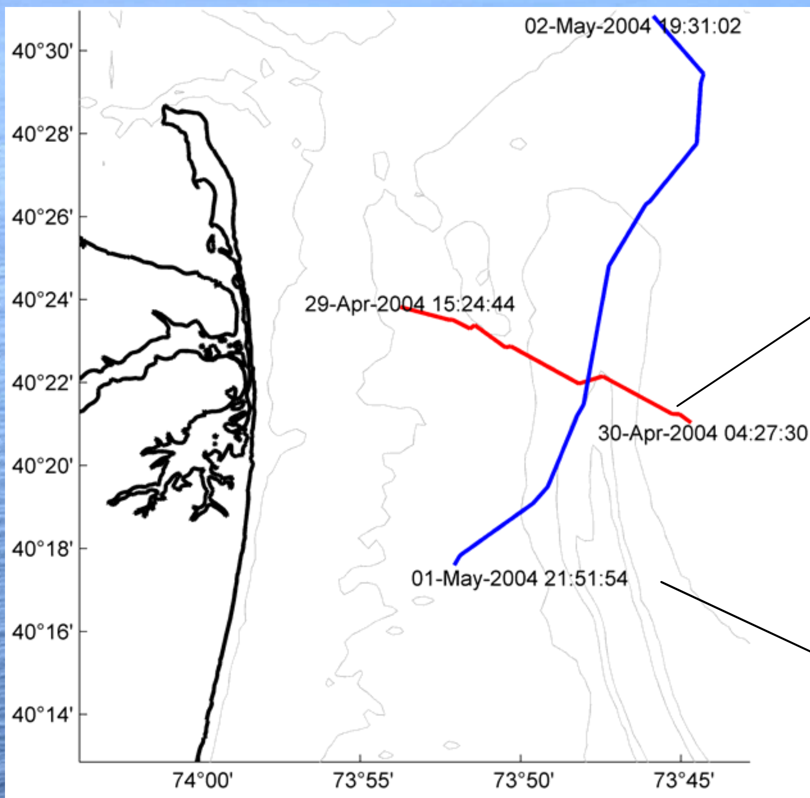
The major flow of the 2003 spring freshet peaked in mid-April before the LATTE experiment began.


R/V Cape Hatteras
NJN

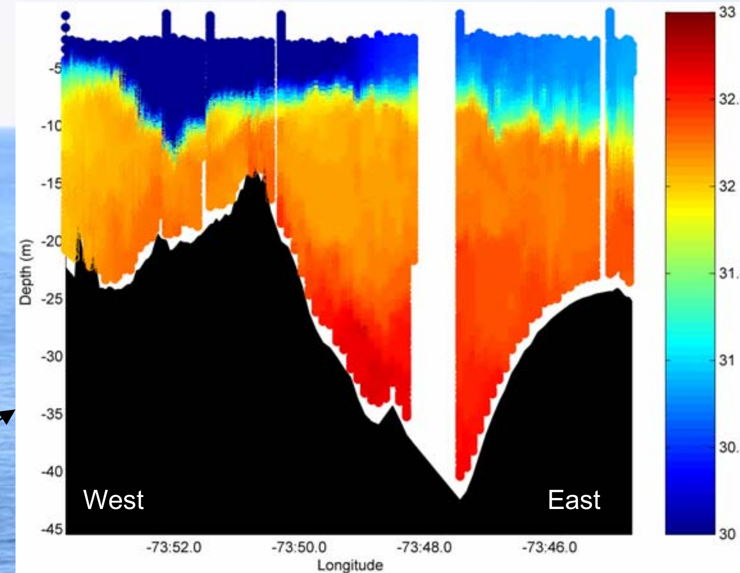

R/V Connecticut
NJN


Bob Chant
NJN
RUTGERS UNIVERSITY PHYSICAL OCEANOGRAPHER NEWS

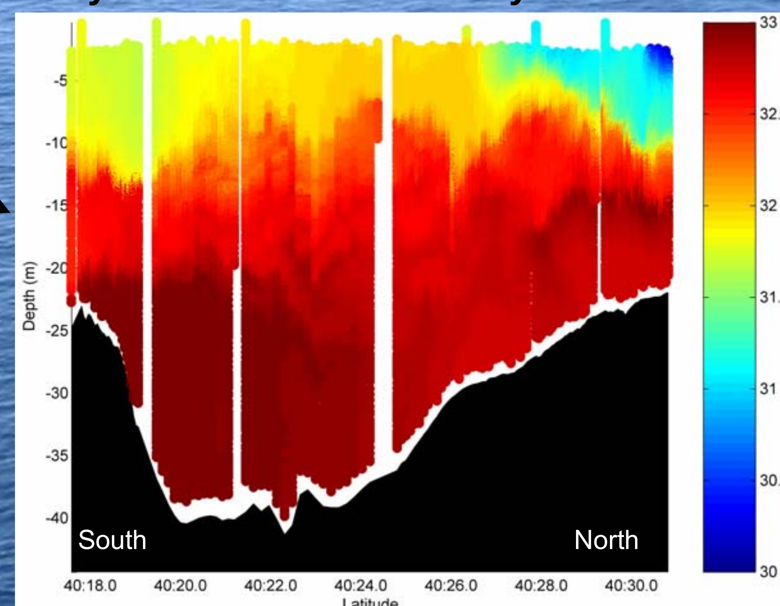
RU02 – Hudson River Plume

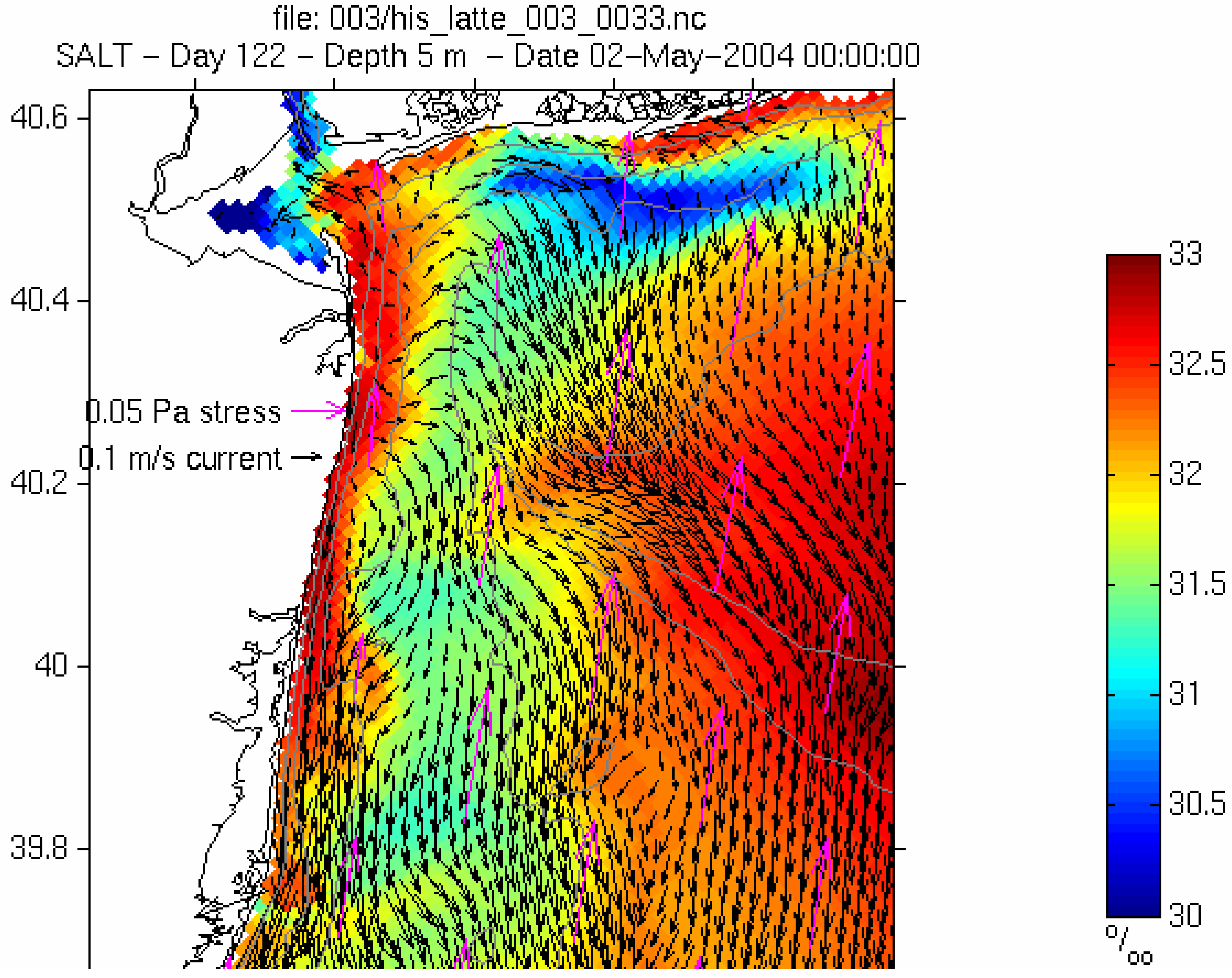


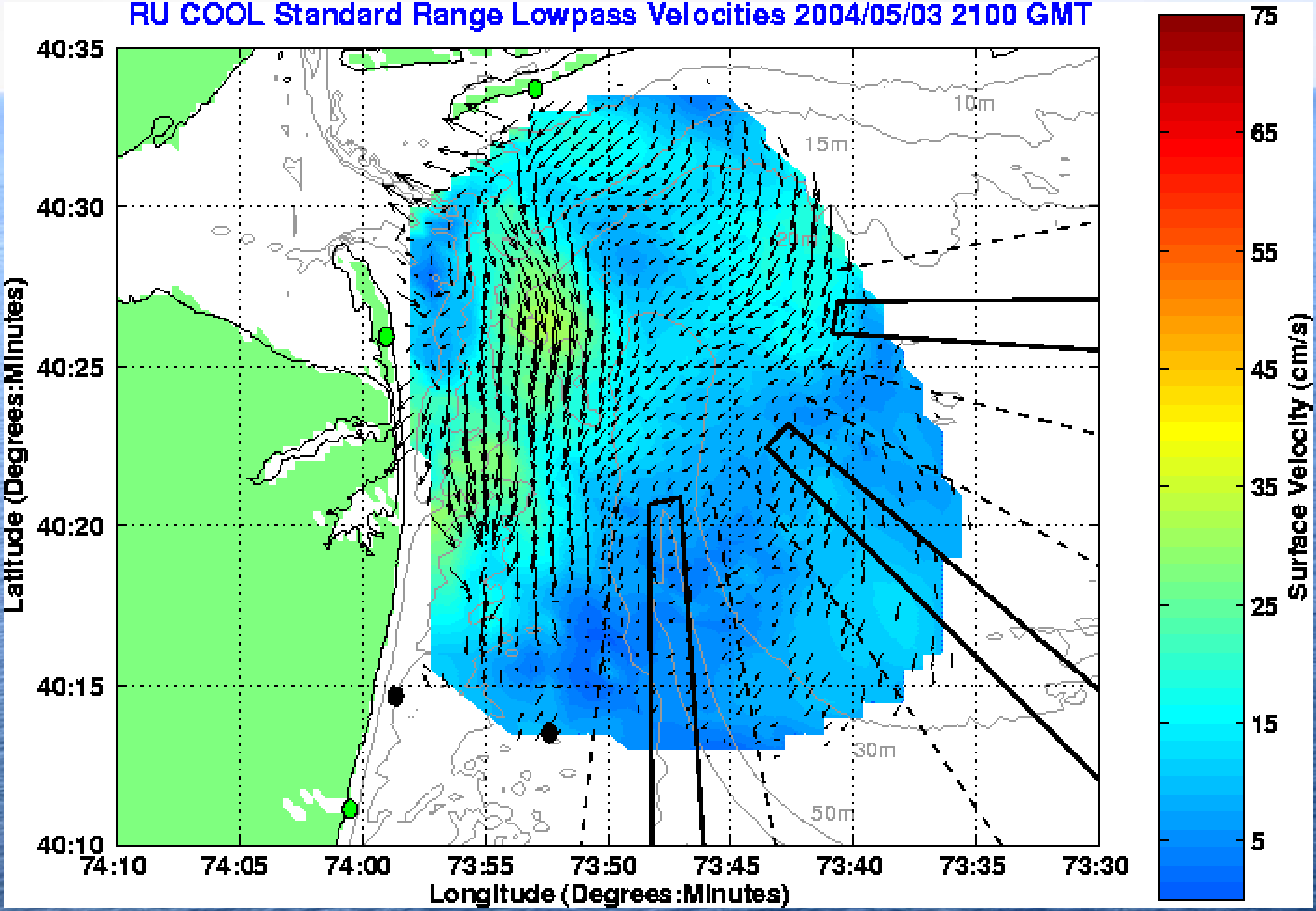
29-Apr-2004 15:24:44 – 30-Apr-2004 04:27:30



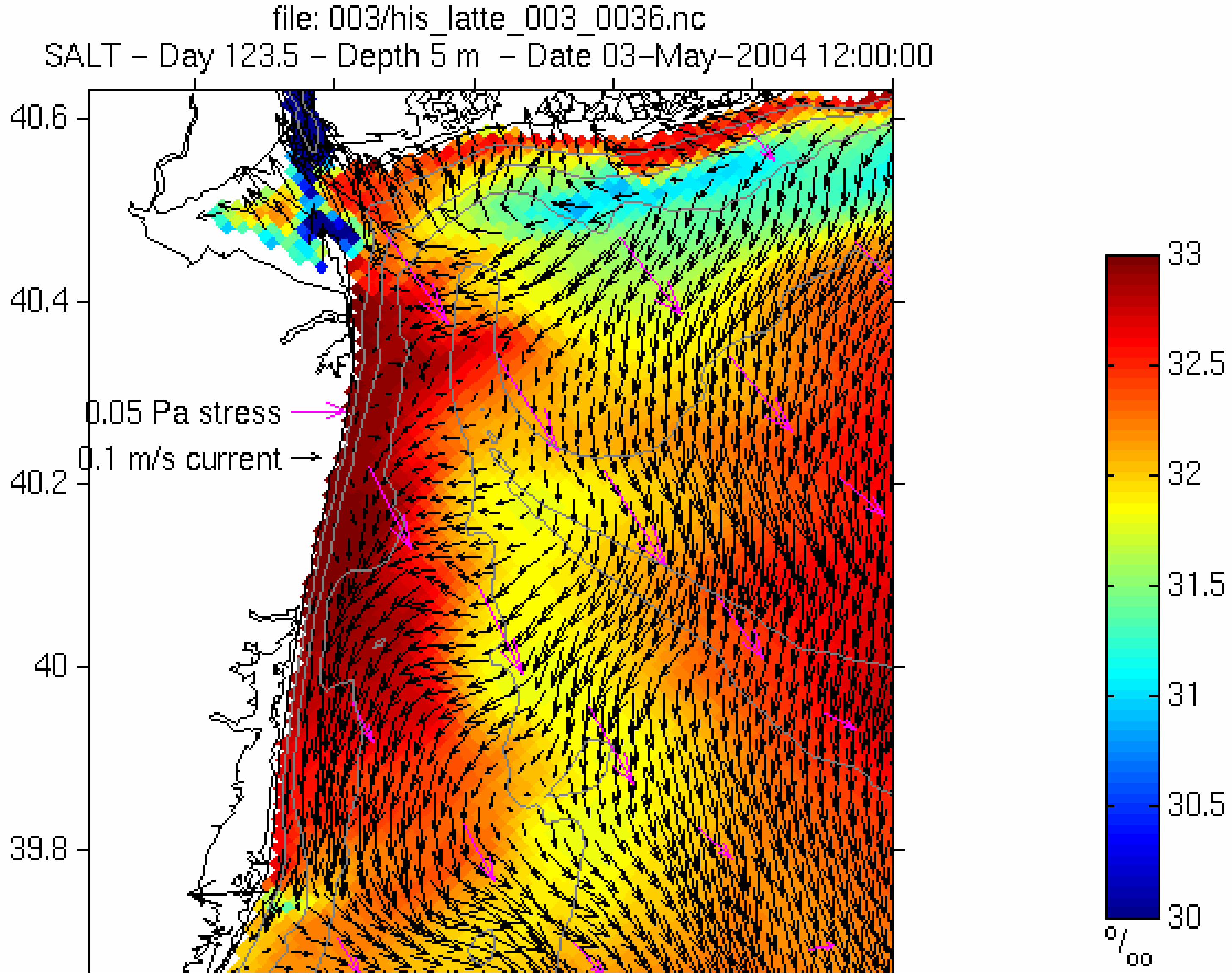
01-May-2004 21:51:54 – 02-May-2004 19:31:02

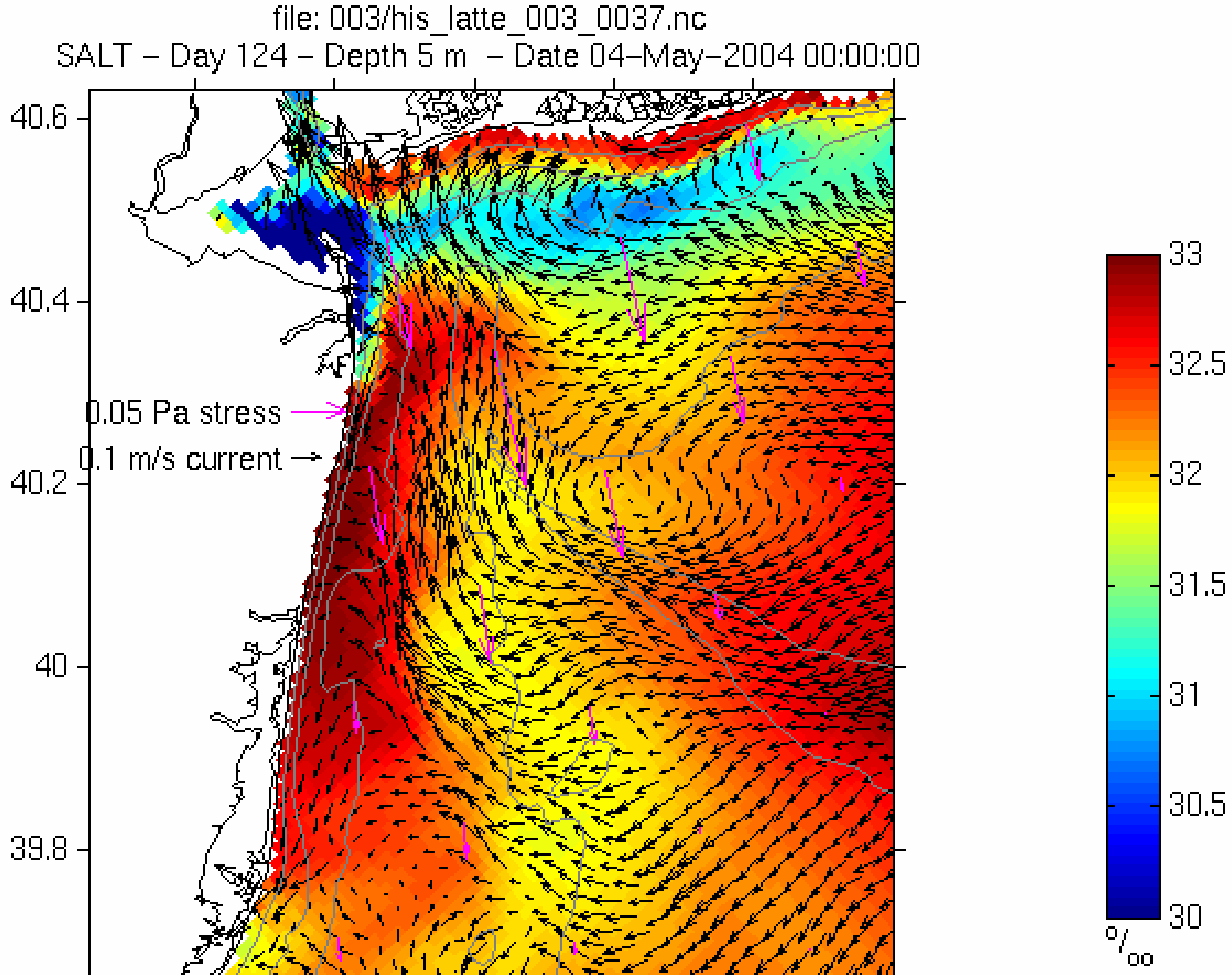



file: 003/his_latte_003_0033.nc
SALT – Day 122 – Depth 5 m – Date 02–May–2004 00:00:00
40.6
40.4
40.2
40
39.8
0.05 Pa stress
0.1 m/s current
33
32.5
32
31.5
31
30.5
30
o/oo

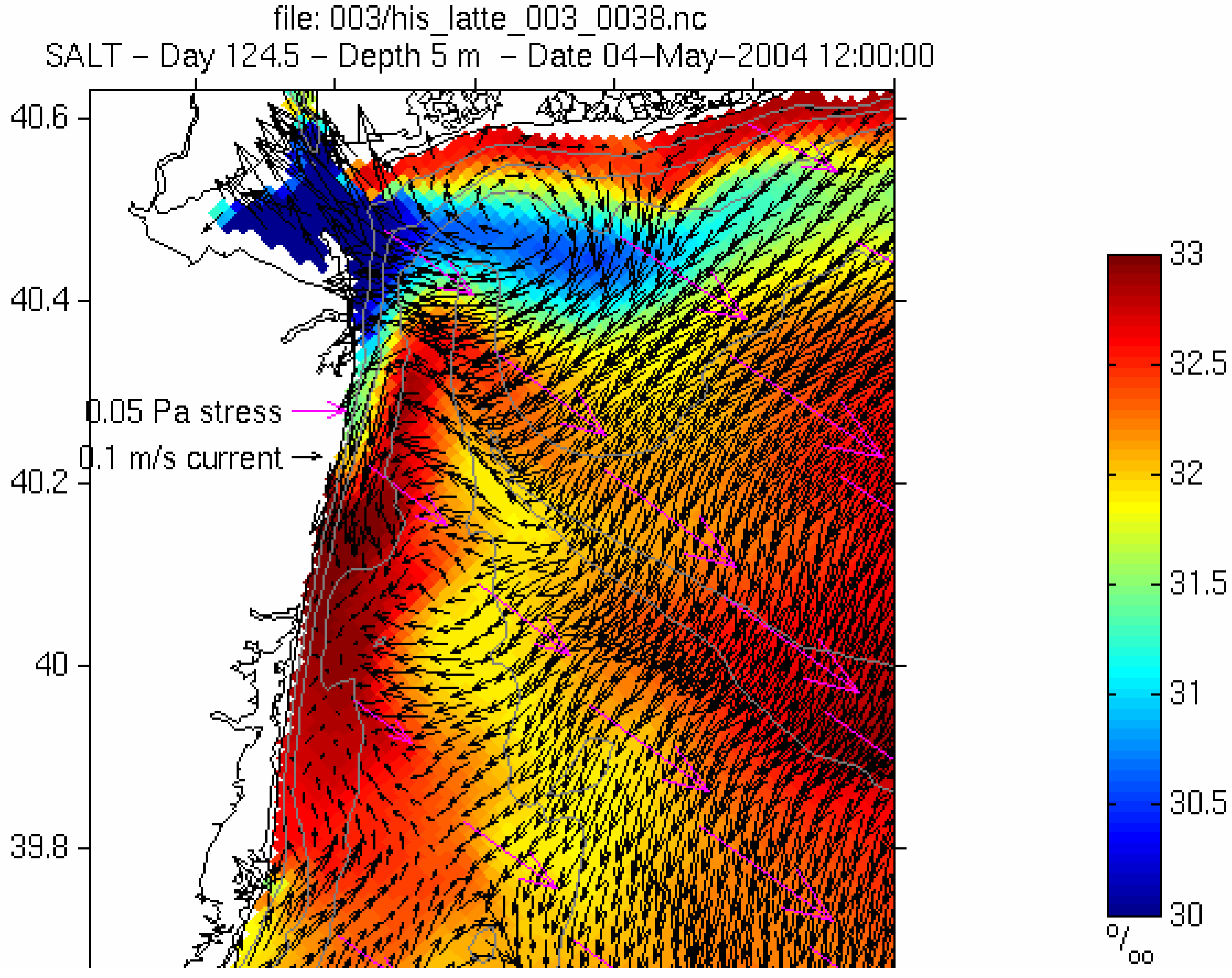


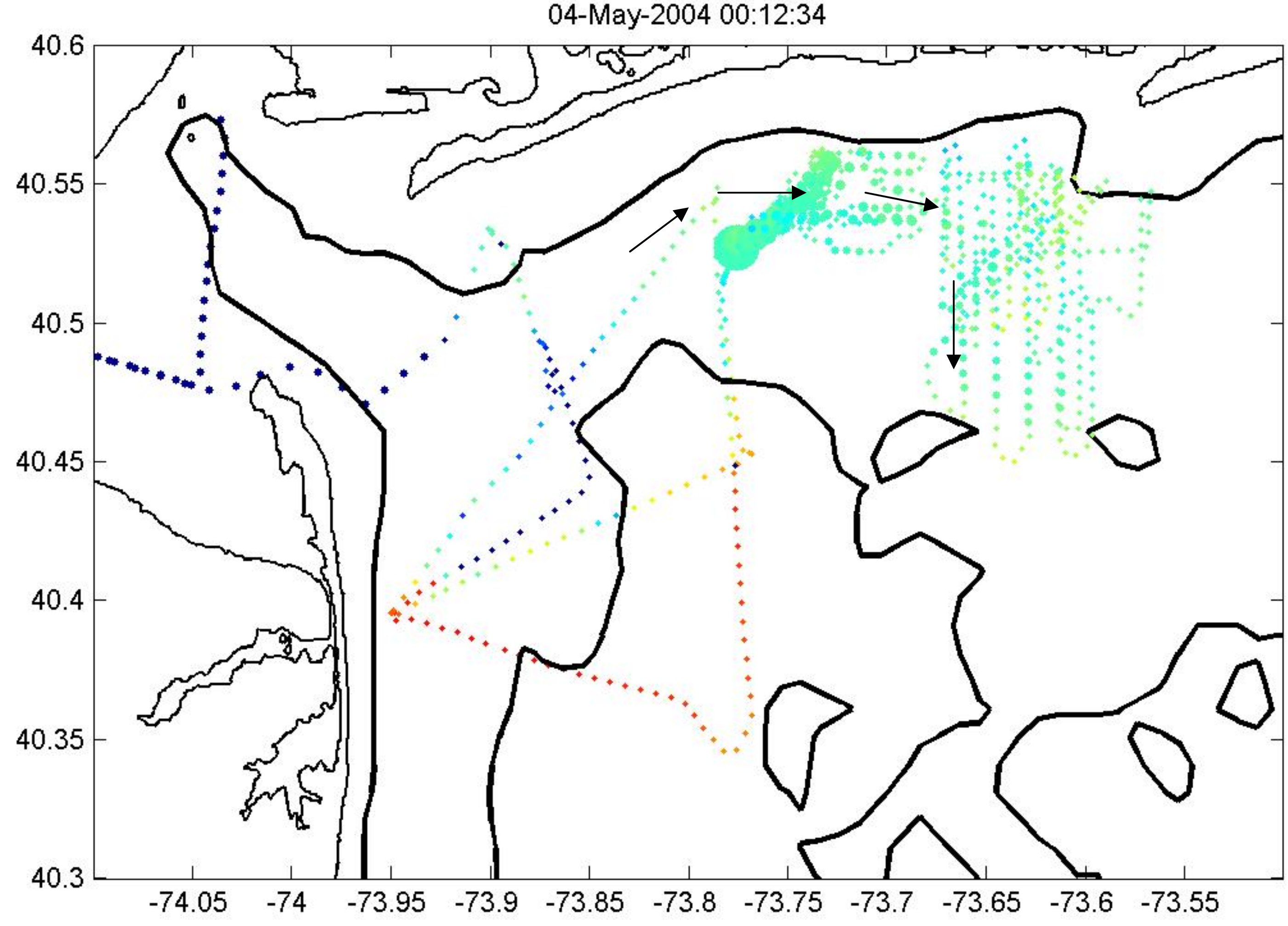
RU COOL Standard Range Lowpass Velocities 2004/05/03 2100 GMT
40:35
40:30
40:25
40:20
40:15
40:10
74:10
74:05
74:00
73:55
73:50
73:45
73:40
73:35
73:30
Latitude (Degrees:Minutes)
Longitude (Degrees:Minutes)
10m
15m
30m
50m
75
65
55
45
35
25
15
5
Surface Velocity (cm/s)

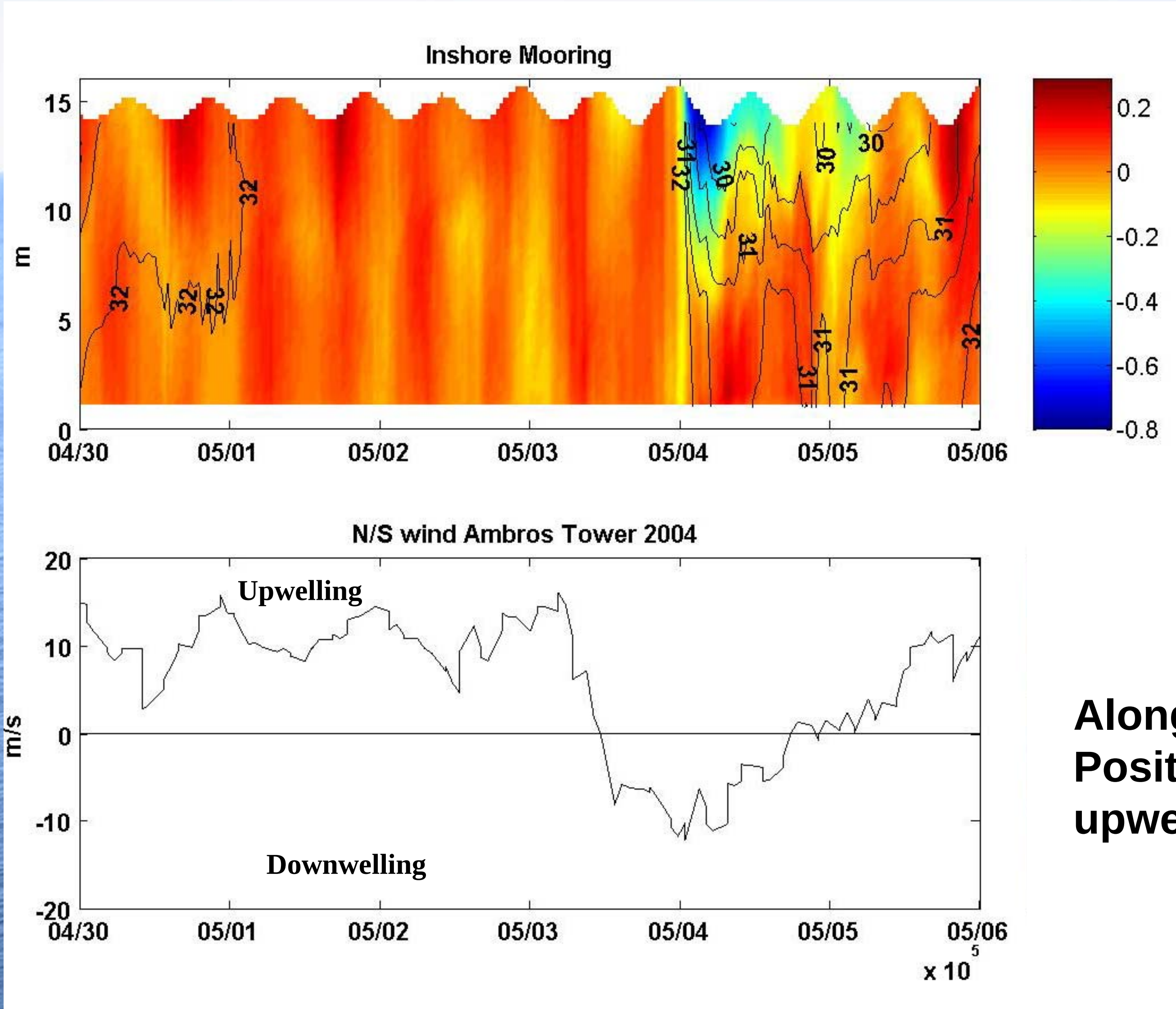

file: 003/his_latte_003_0036.nc
SALT – Day 123.5 – Depth 5 m – Date 03–May–2004 12:00:00
40.6
40.4
40.2
40
39.8
0.05 Pa stress
0.1 m/s current
33
32.5
32
31.5
31
30.5
30
o/oo



file: 003/his_latte_003_0037.nc
SALT – Day 124 – Depth 5 m – Date 04–May–2004 00:00:00
0.05 Pa stress
0.1 m/s current
40.6
40.4
40.2
40
39.8
33
32.5
32
31.5
31
30.5
30
o/oo

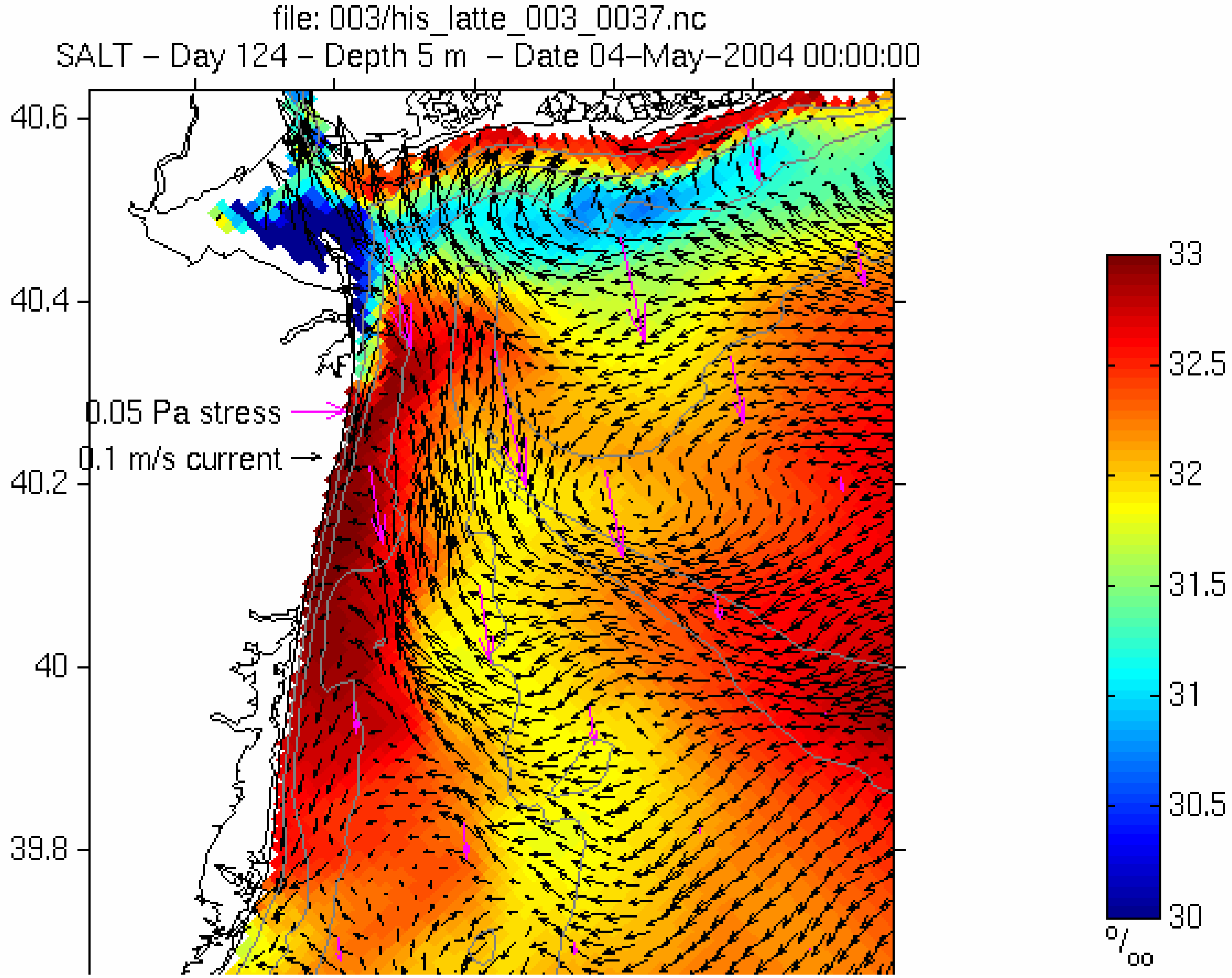

file: 003/his_latte_003_0038.nc
SALT – Day 124.5 – Depth 5 m – Date 04–May–2004 12:00:00
40.6
40.4
40.2
40
39.8
0.05 Pa stress
0.1 m/s current
33
32.5
32
31.5
31
30.5
30
°/oo


04-May-2004 00:12:34
40.6
40.55
40.5
40.45
40.4
40.35
40.3
-74.05
-74
-73.95
-73.9
-73.85
-73.8
-73.75
-73.7
-73.65
-73.6
-73.55

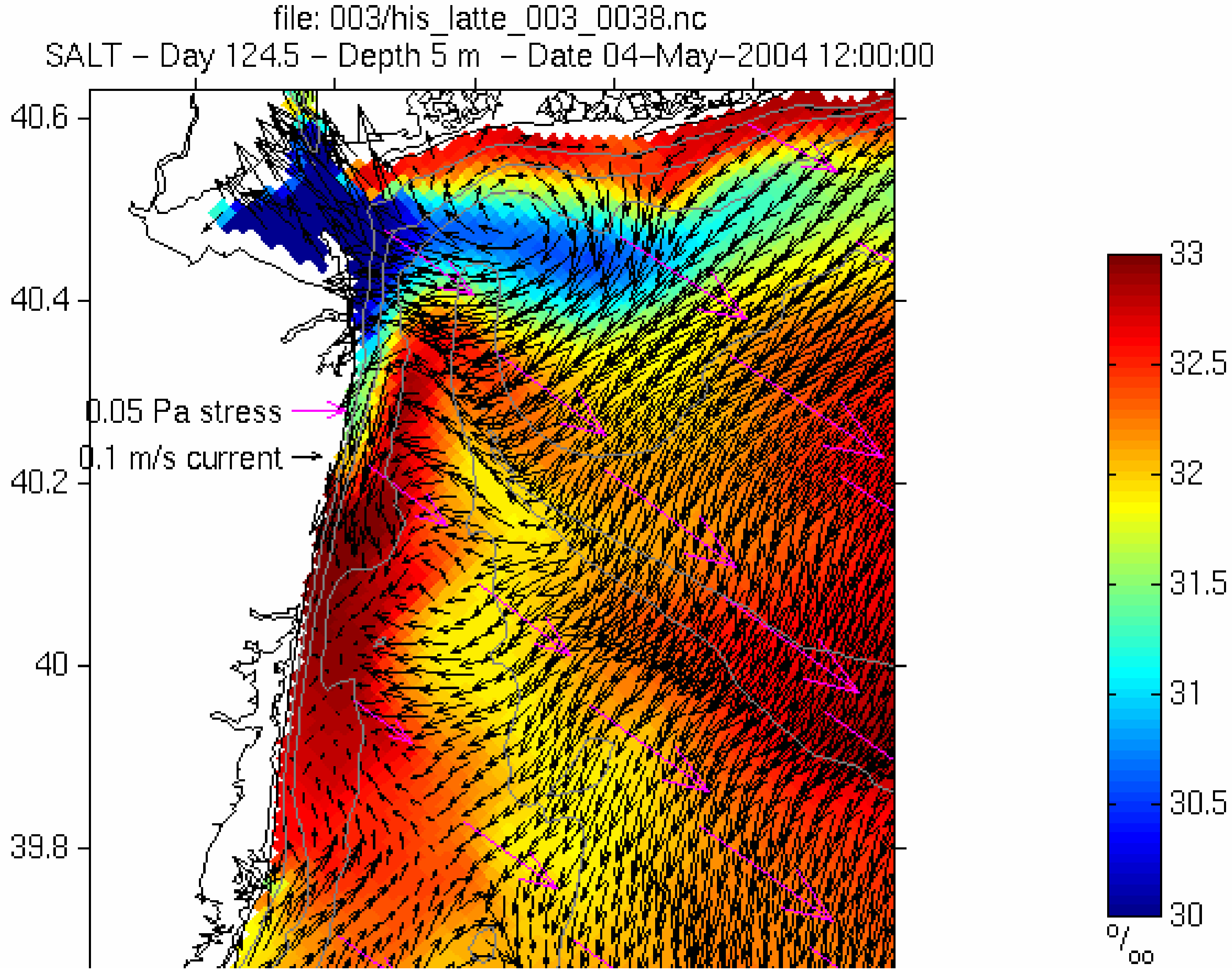


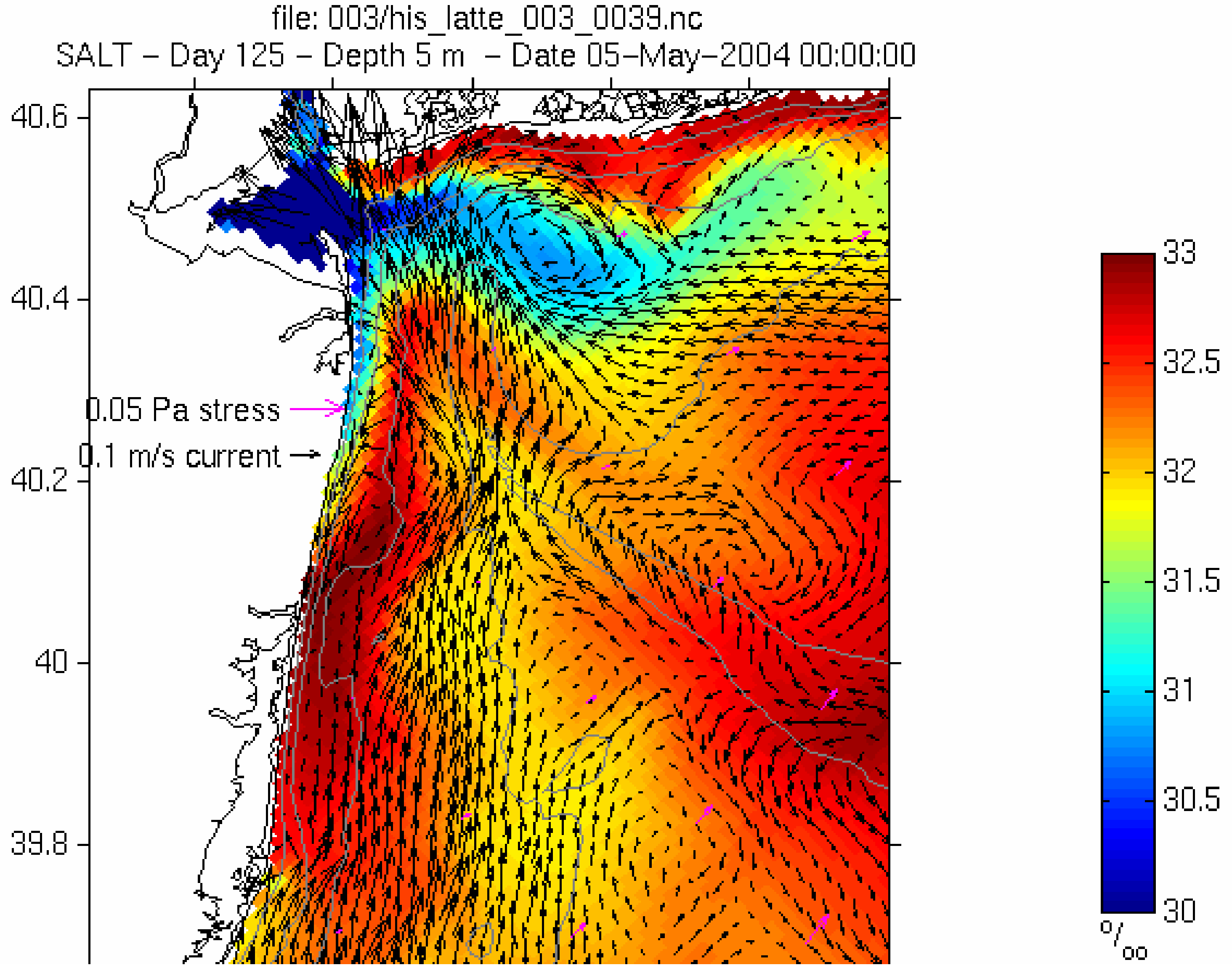
Along shore velocity (color) and salinity (contours) from inshore moorings in 15 m water. Positive currents are to the north.

Along shore wind speed. Positive winds are upwelling favorable

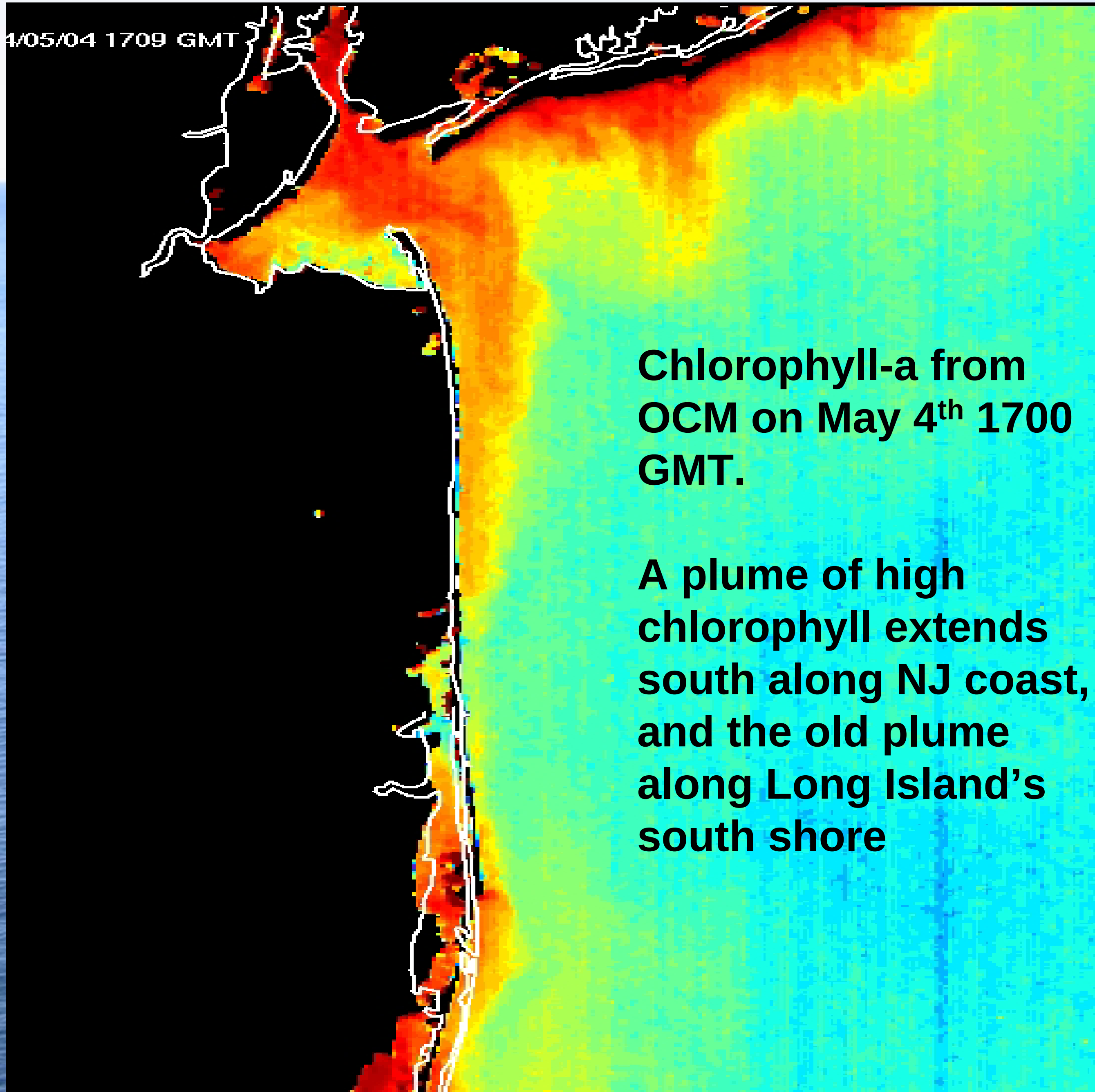


file: 003/his_latte_003_0037.nc
SALT – Day 124 – Depth 5 m – Date 04–May–2004 00:00:00
0.05 Pa stress
0.1 m/s current
40.6
40.4
40.2
40
39.8
33
32.5
32
31.5
31
30.5
30
°/oo


file: 003/his_latte_003_0038.nc
SALT – Day 124.5 – Depth 5 m – Date 04–May–2004 12:00:00
40.6
40.4
40.2
40
39.8
0.05 Pa stress
0.1 m/s current
33
32.5
32
31.5
31
30.5
30
°/oo

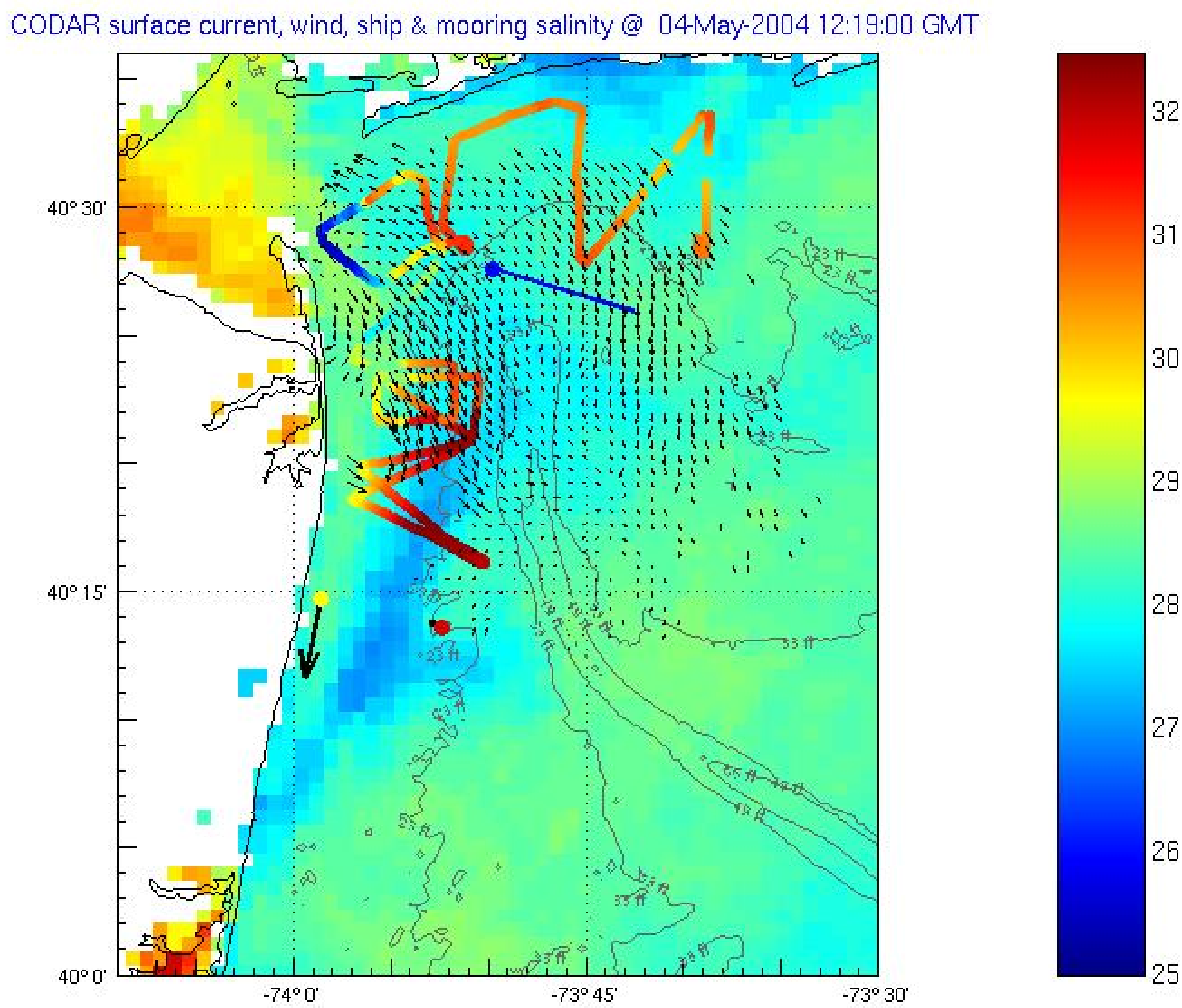


file: 003/his_latte_003_0039.nc
SALT - Day 125 - Depth 5 m - Date 05-May-2004 00:00:00
40.6
40.4
40.2
40
39.8
0.05 Pa stress
0.1 m/s current
33
32.5
32
31.5
31
30.5
30
°/oo

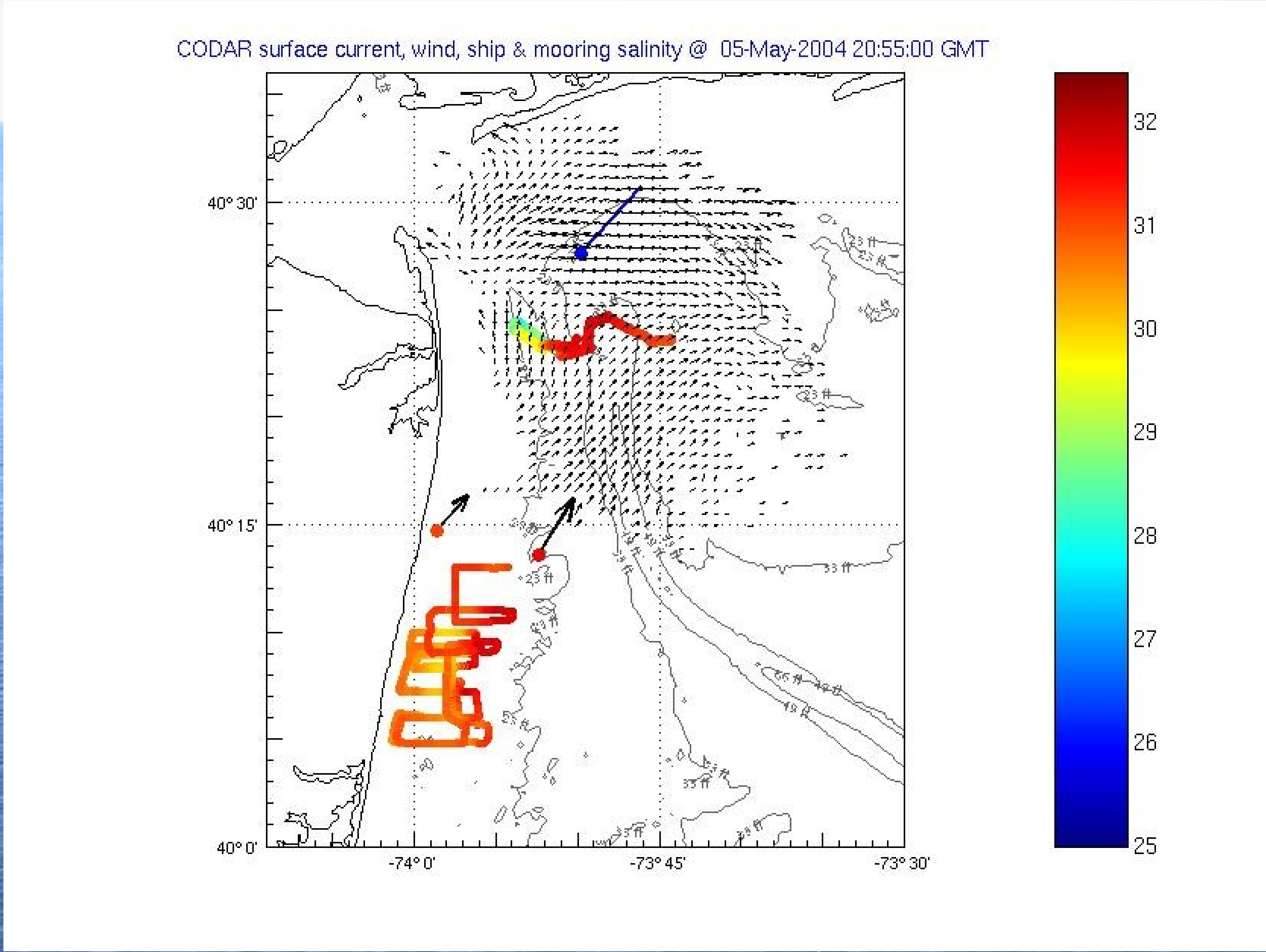


Chlorophyll-a from OCM on May 4th 1700 GMT.

A plume of high chlorophyll extends south along NJ coast, and the old plume along Long Island’s south shore



CODAR surface current, wind, ship & mooring salinity @ 04-May-2004 12:19:00 GMT
40° 30'
40° 15'
40° 0'
-74° 0'
-73° 45'
-73° 30'
32
31
30
29
28
27
26
25

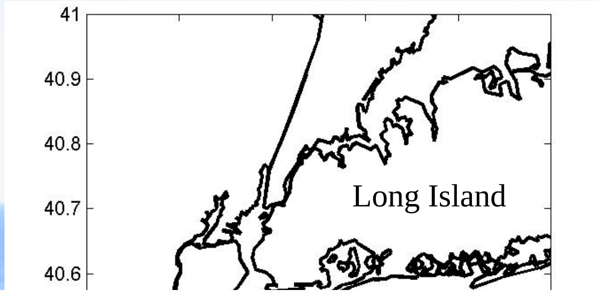


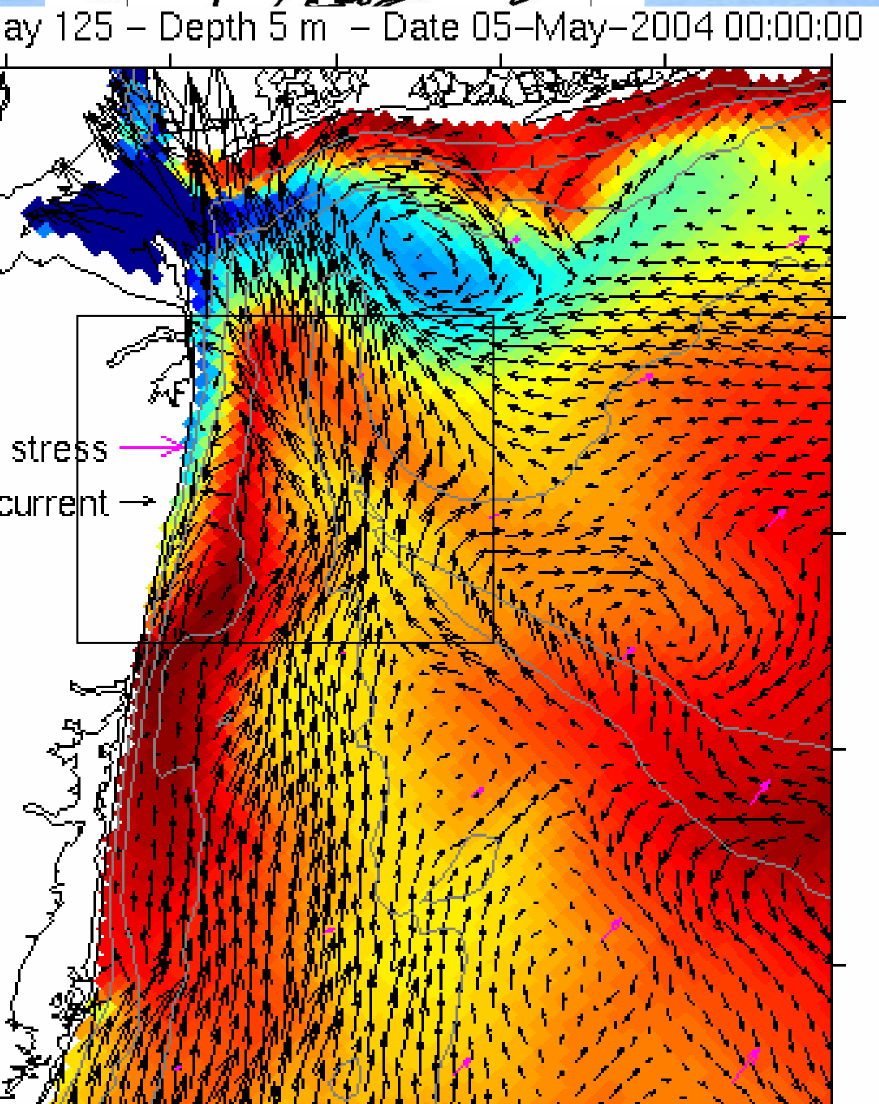
CODAR surface current, wind, ship & mooring salinity @ 05-May-2004 20:55:00 GMT
40° 30'
40° 15'
40° 0'
-74° 0'
-73° 45'
-73° 30'
32
31
30
29
28
27
26
25

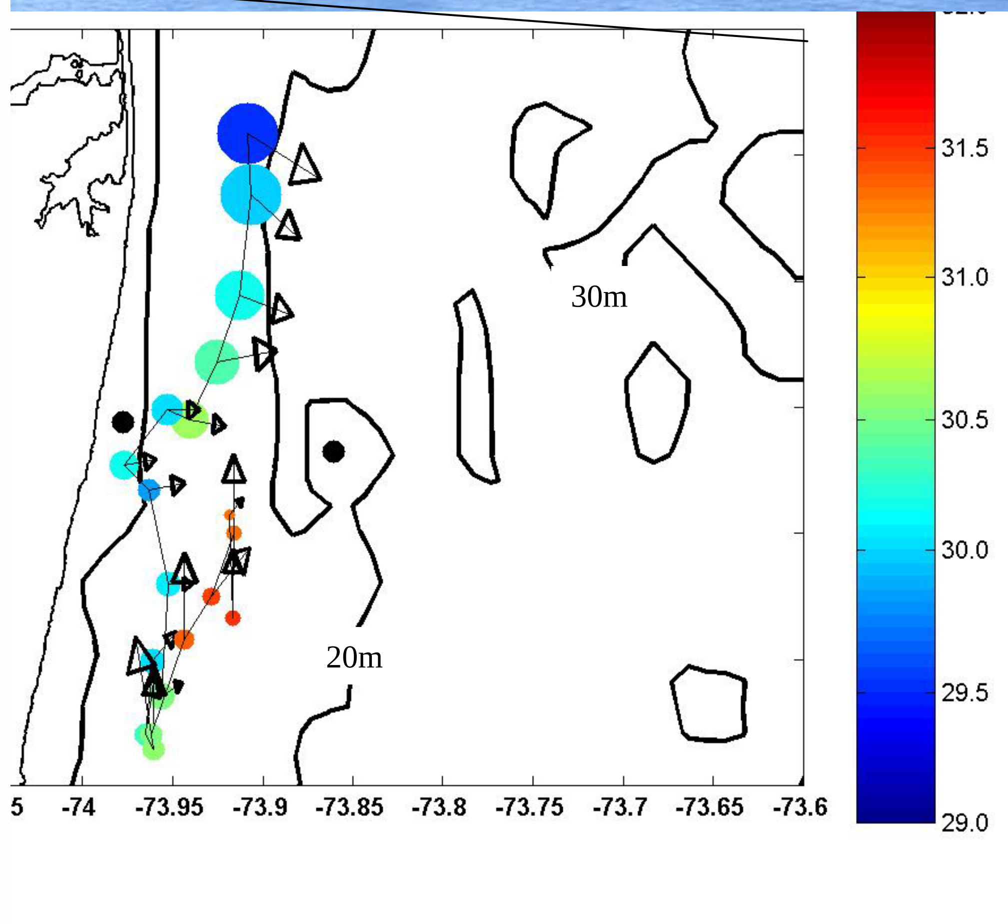
Dots show location of the maximum dye concentration every 2 hours.

The size of the dot is scaled by dye concentration and its salinity is depicted by color.

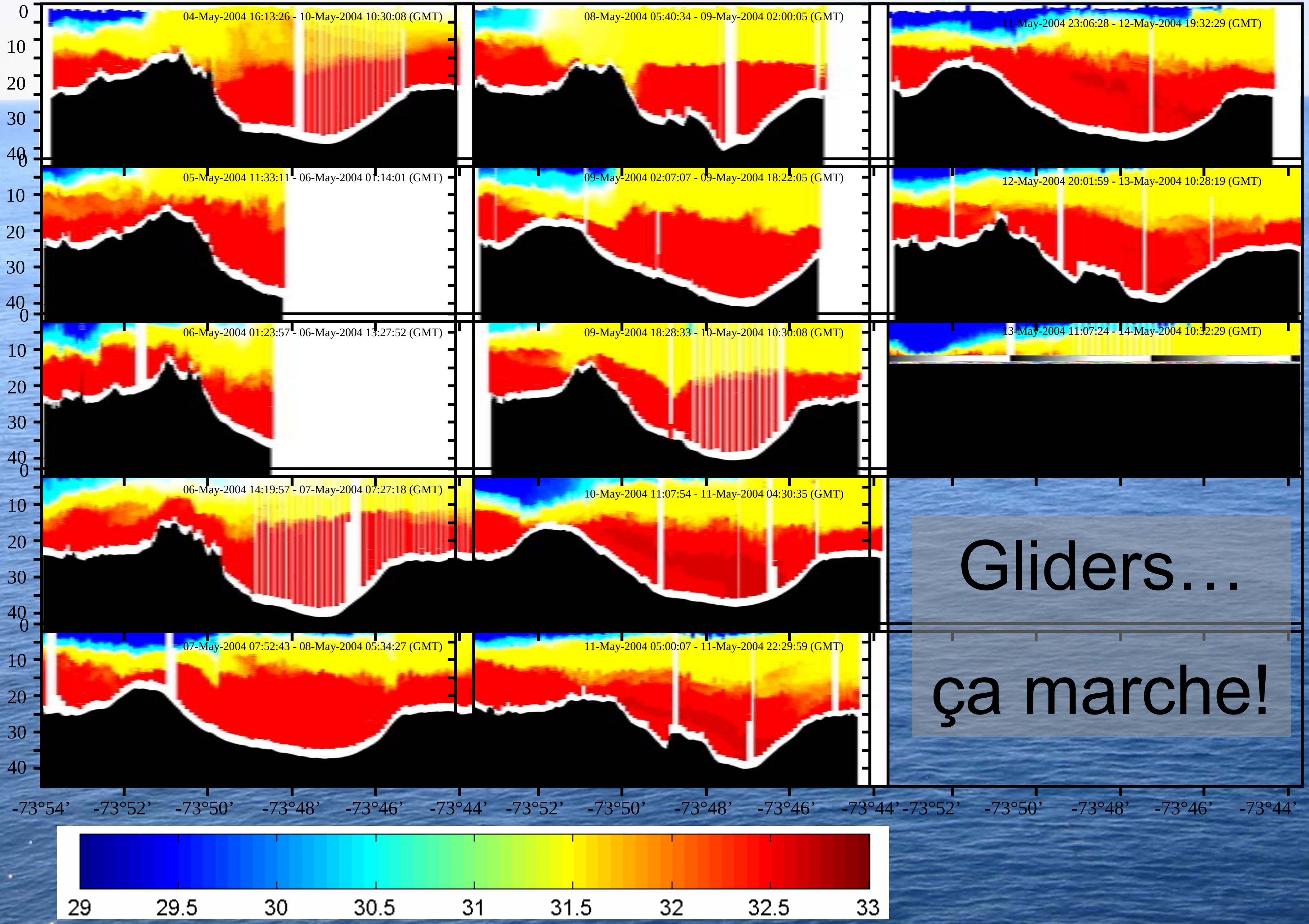
s depict winds: Northerly to southerly
e after dye passed 40.2ºN.







LATTE 2004 Salinity Cross-Sections: Hudson River Plume



Gliders…

ça marche!

Summary

- New technologies are expanding our ability to study coastal <u>processes</u> by simultaneously observing physics, geochemistry and ecology at resolutions suited to quantitative interdisciplinary analysis

- Long-term point time series and repeat observations

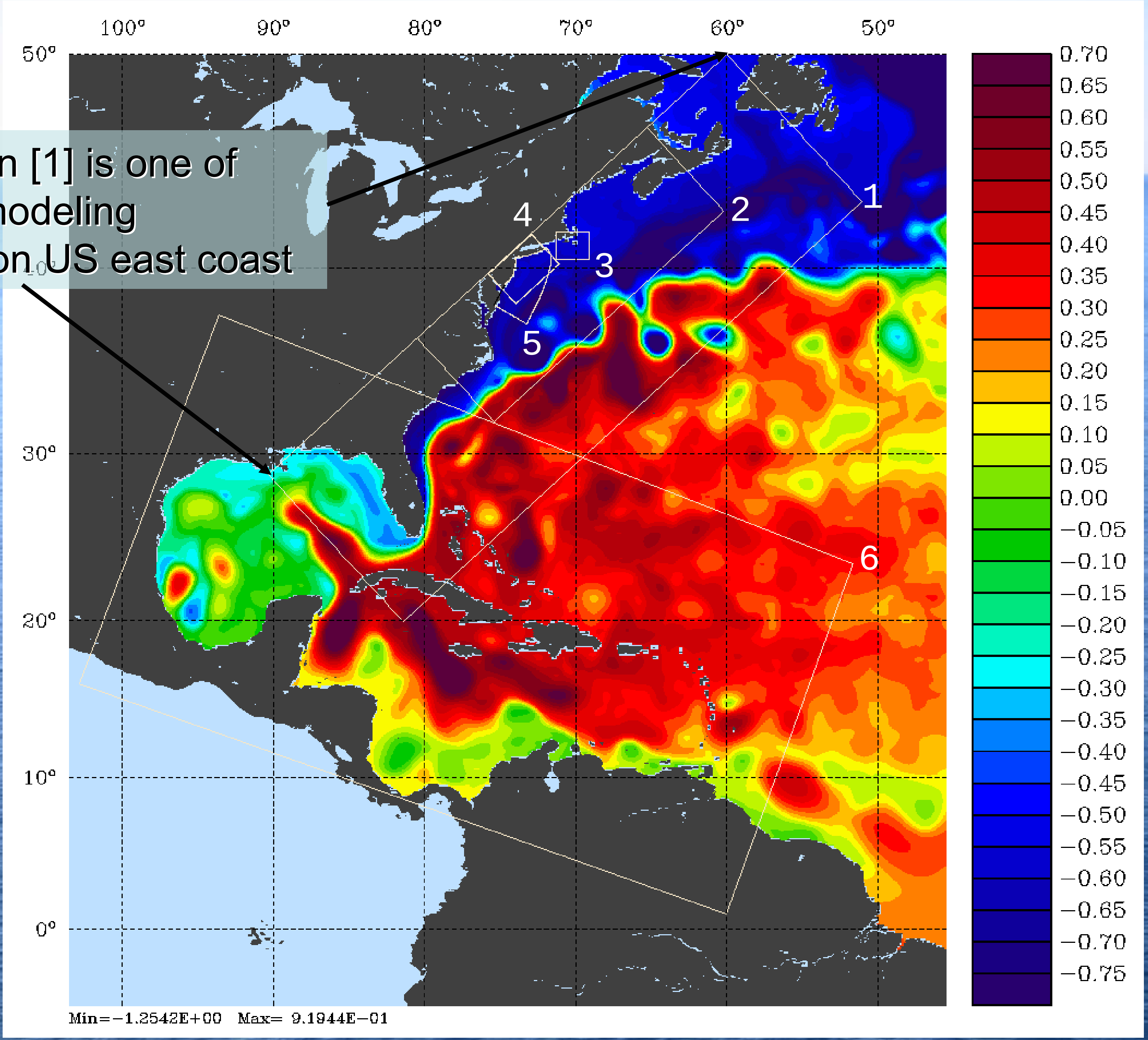
- Observing system developments are matched by advances in ocean modeling:
  - high resolution; accurate forcing; adequate CPU
  - more accurate numerical algorithms
  - realistic parameterizations of subgridscale physics

- Coastal ocean forecasts complement the operation of coastal observatories:
  - Explore conceptual ideas and test hypotheses
    - Process-oriented dynamic studies (e.g. idealized physics)
    - Lagrangian pathways (Where did the water come from?)
  - Synthesis tool with coupled geochemical-ecosystem-optics models
  - Adaptive sampling design (real-time)
  - Observing system design
- Models have the skill to become short-term ocean prediction systems for coastal waters

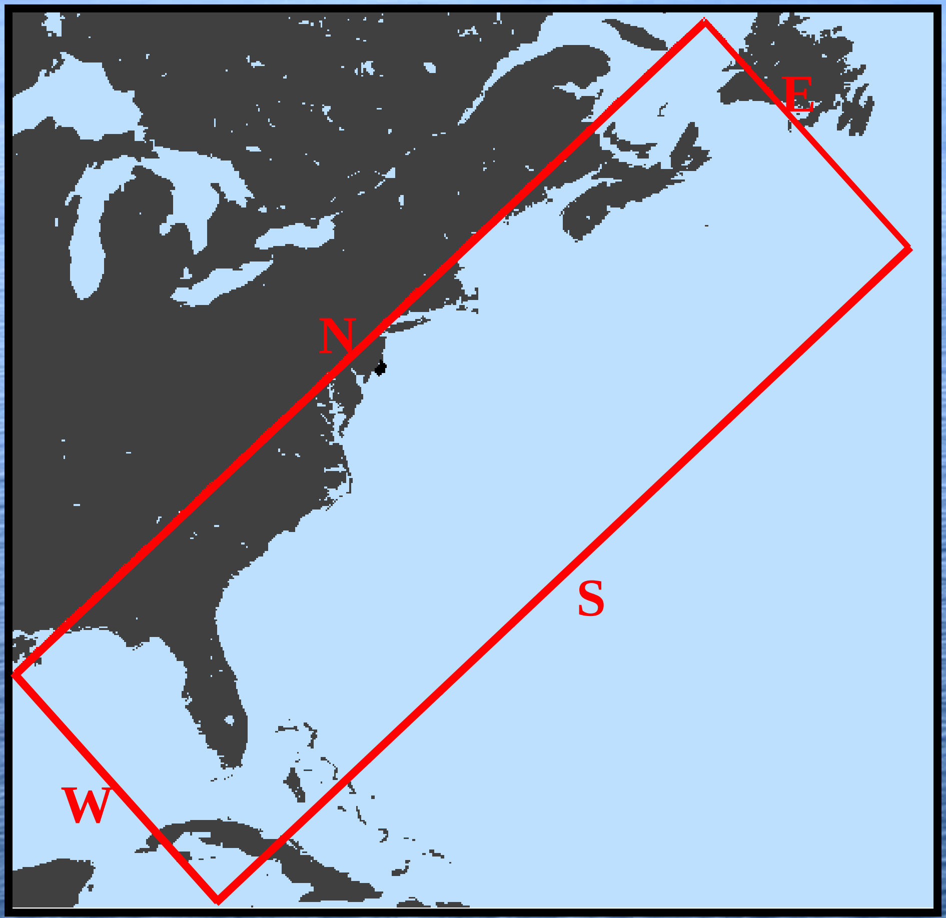
NENA

- Northeast North America shelf model
- Continental shelf nutrient and carbon budget
- Simple nesting within basin scale models

NENA domain [1] is one of several RU modeling applications on US east coast



1-way nested grid open boundary conditions



- **Tracers and 3D momentum: Clamped to interpolated values from larger grid time snapshots**

- **2D normal momentum: Flather boundary conditions**

$$\overline{U}^{n+1} = \overline{U}_b + (g/h)^{1/2}(\zeta^n - \zeta_b)$$

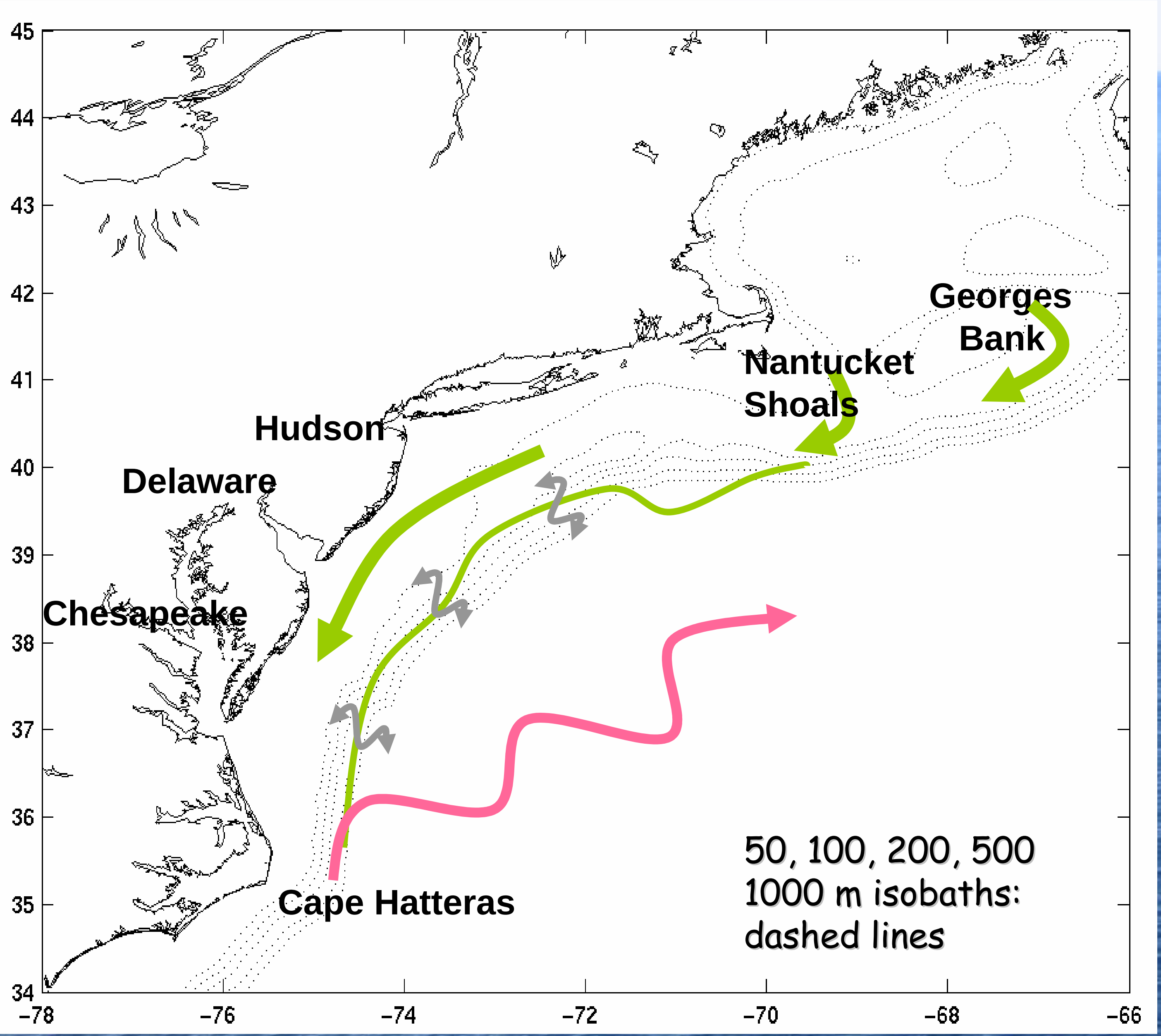
- **2D tangential momentum: Chapman boundary conditions**

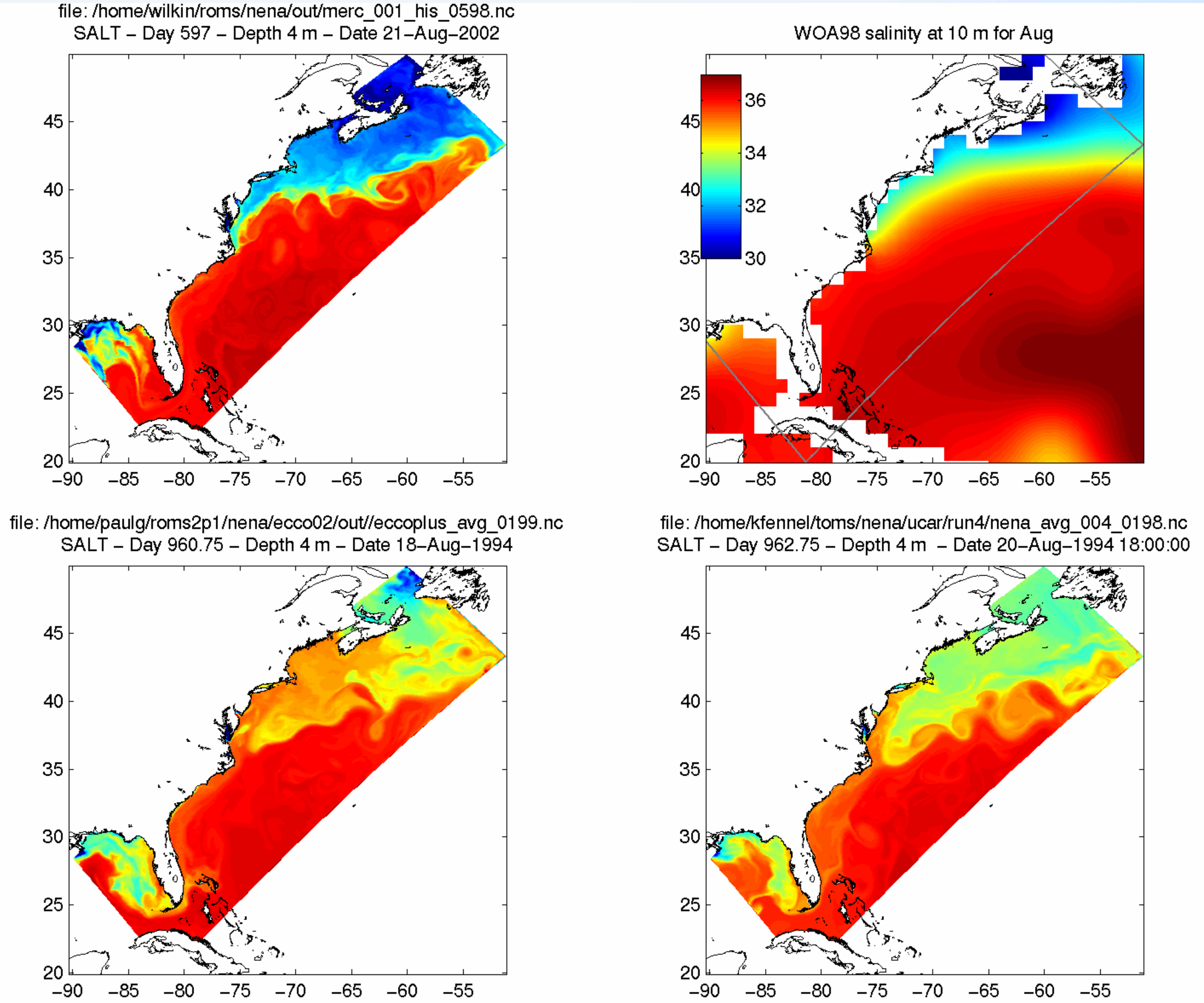
$$\overline{V}^{n+1} = (\overline{V}^n + c\overline{V}^{n+1})/(1-c), \qquad c = \frac{\Delta t}{\Delta x}(gh)^{1/2}$$

- **Free-surface: Chapman boundary conditions**

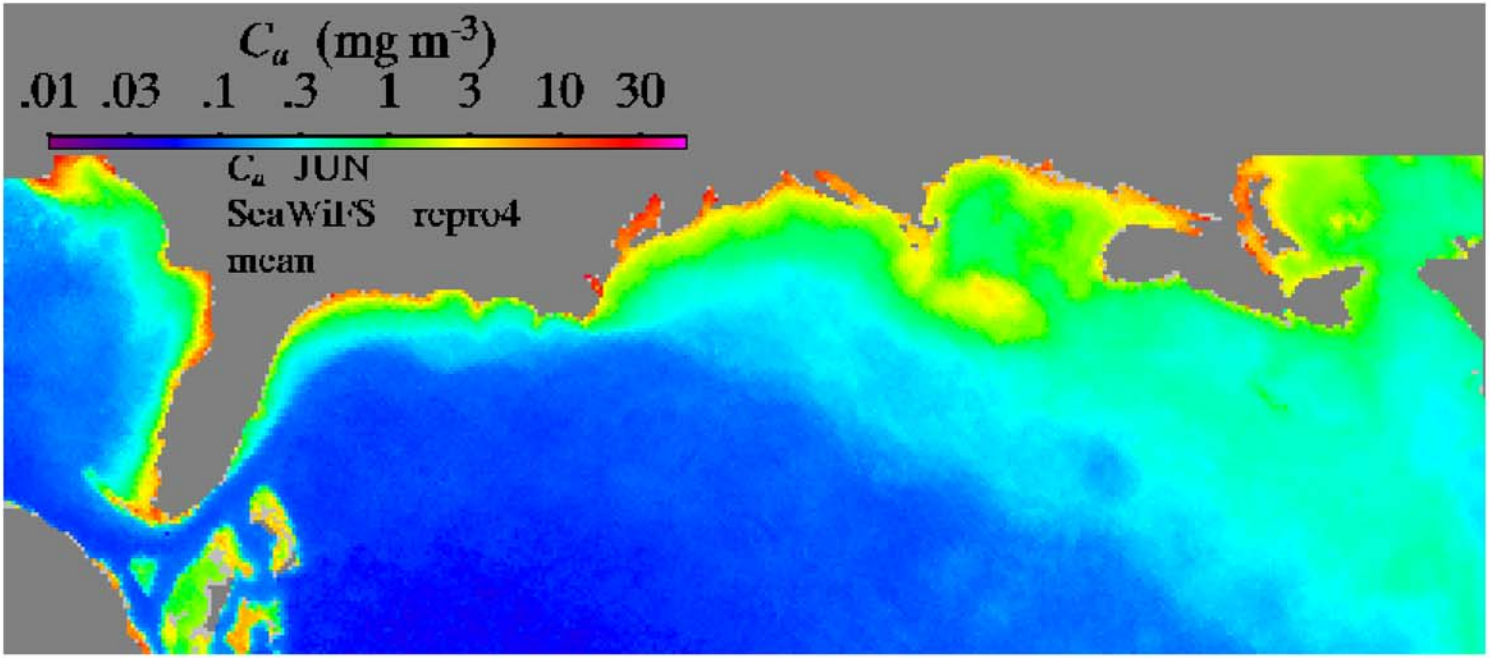
$$\zeta^{n+1} = (\zeta^n + c\zeta^{n+1})/(1-c), \qquad c = \frac{\Delta t}{\Delta x}(gh)^{1/2}$$

Mid Atlantic Bight (MAB)

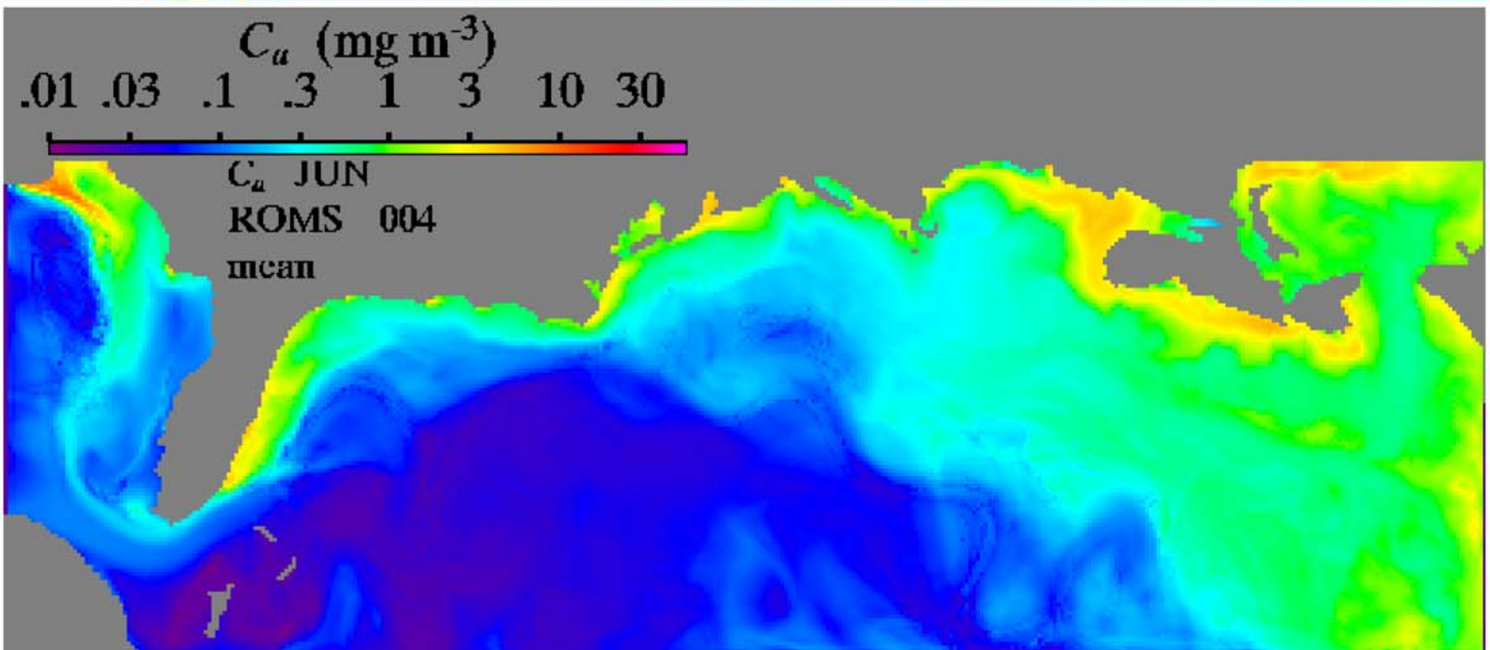



file: /home/wilkin/roms/nena/out/merc_001_his_0598.nc
SALT – Day 597 – Depth 4 m – Date 21–Aug–2002
WOA98 salinity at 10 m for Aug
36
34
32
30
file: /home/paulg/roms2p1/nena/ecco02/out//eccoplus_avg_0199.nc
SALT – Day 960.75 – Depth 4 m – Date 18–Aug–1994
file: /home/kfennel/toms/nena/ucar/run4/nena_avg_004_0198.nc
SALT – Day 962.75 – Depth 4 m – Date 20–Aug–1994 18:00:00
45
40
35
30
25
20
−90
−85
−80
−75
−70
−65
−60
−55

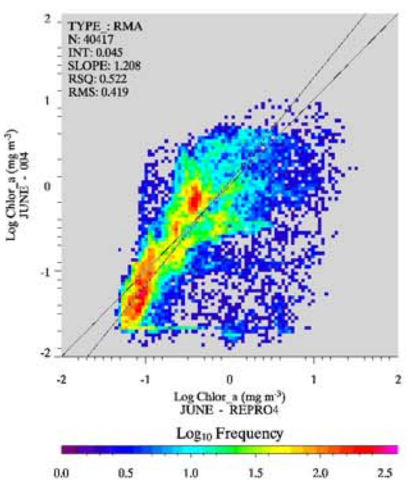
CHLOR_A
June



C_a (mg m^{-3})
.01 .03 .1 .3 1 3 10 30
C_a JUN
SeaWiFS repro4
mean

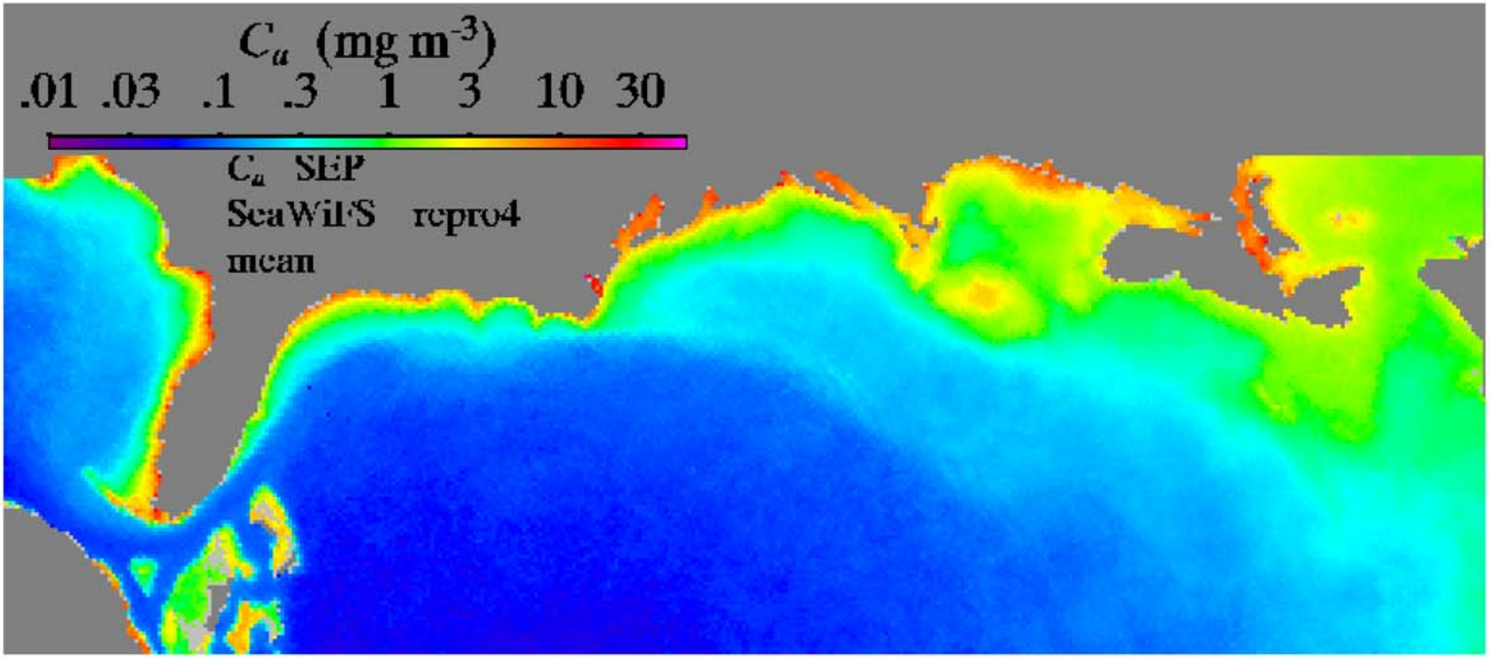


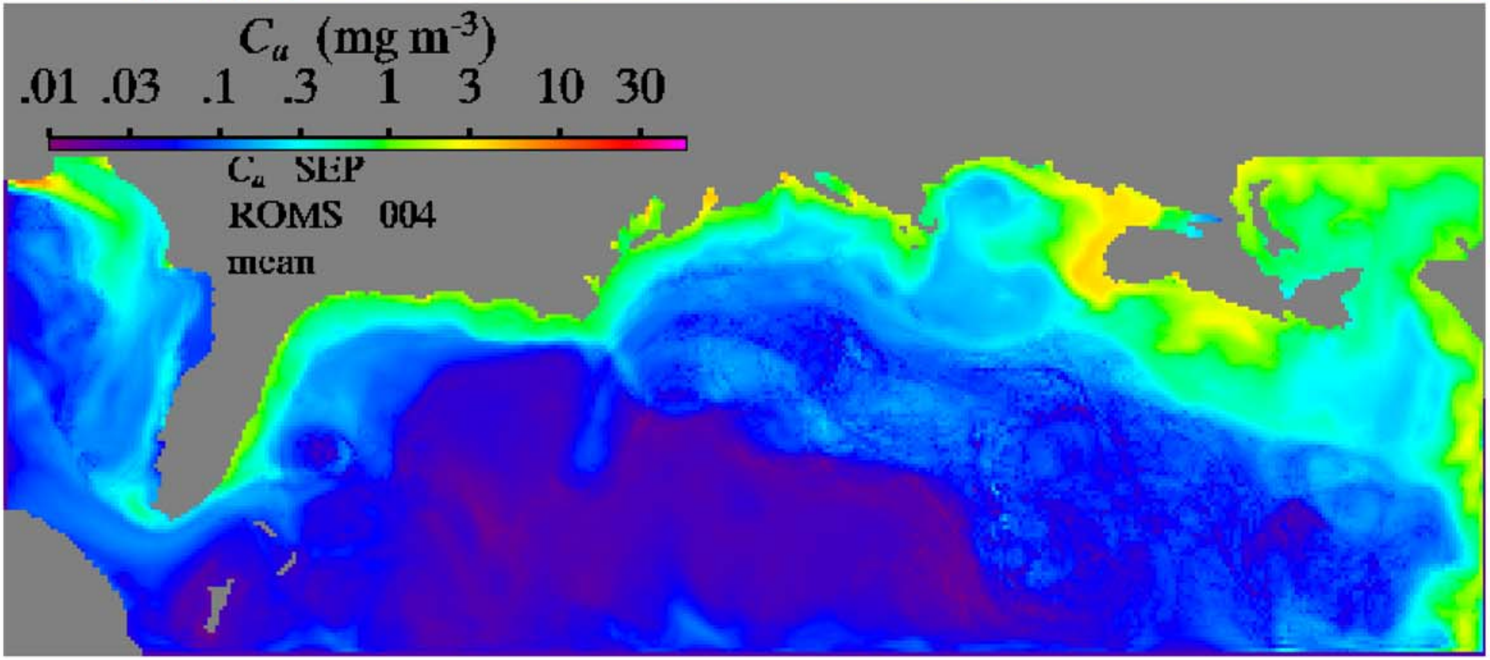
C_a (mg m^{-3})
.01 .03 .1 .3 1 3 10 30
C_a JUN
ROMS 004
mean

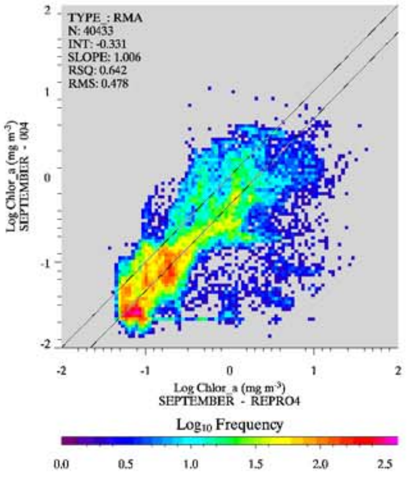


TYPE_: RMA
N: 40417
INT: 0.045
SLOPE: 1.208
RSQ: 0.522
RMS: 0.419
Log Chlor_a (mg m^{-3})
JUNE - 004
Log Chlor_a (mg m^{-3})
JUNE - REPRO4
Log_{10} Frequency
0.0 0.5 1.0 1.5 2.0 2.5

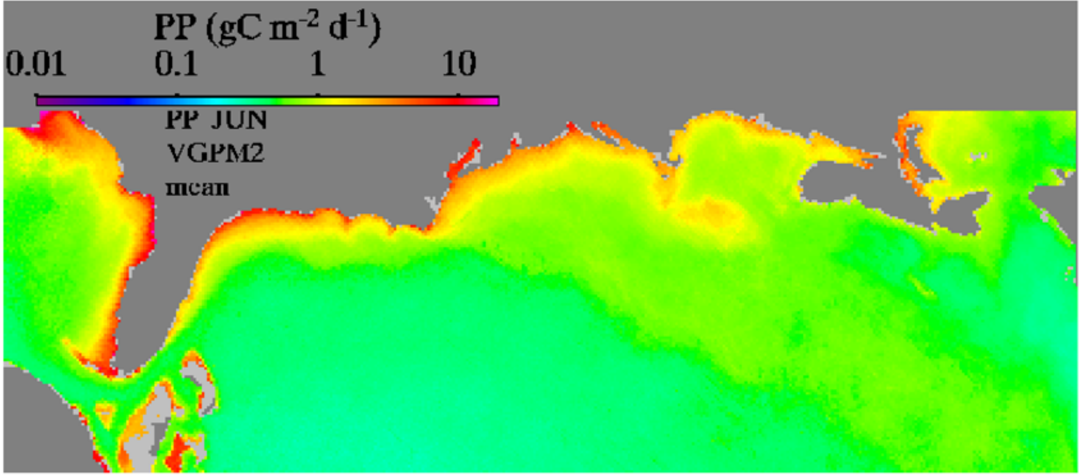
CHLOR_A September



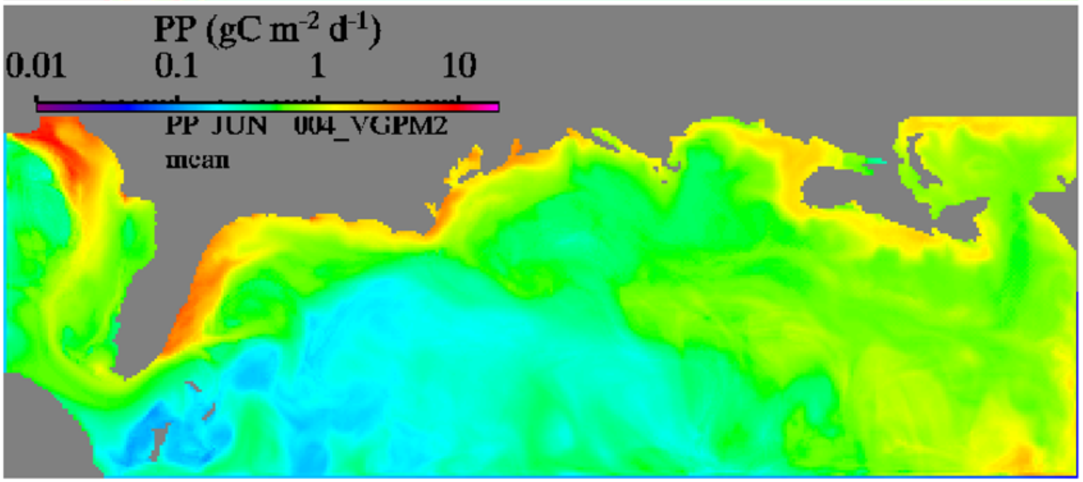




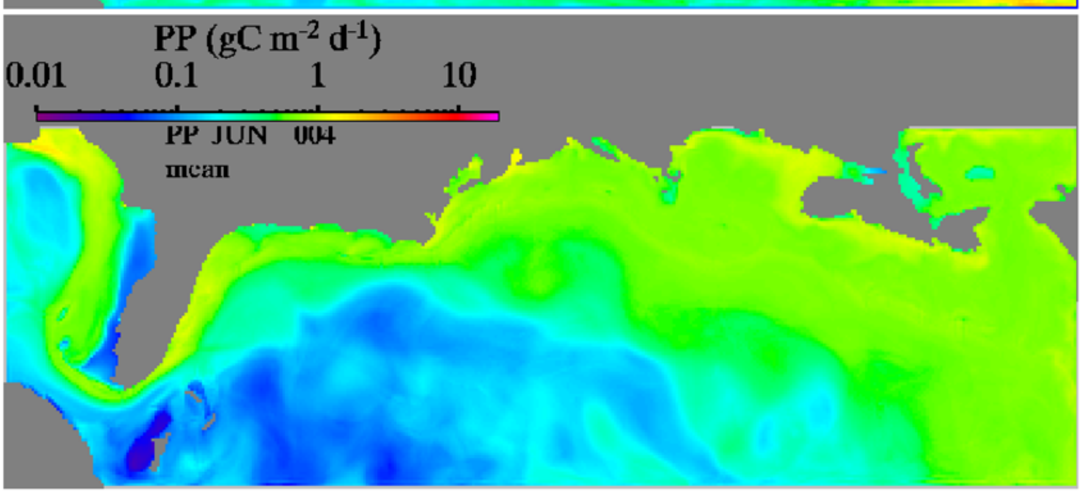
PPD
June



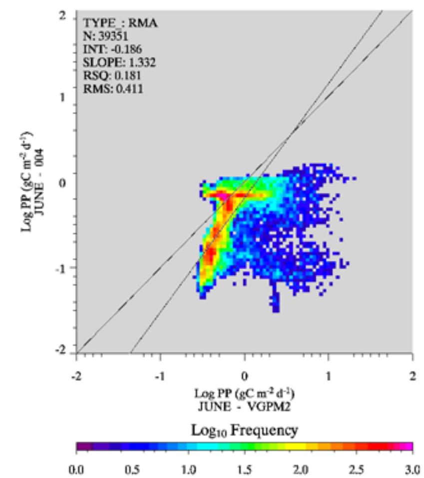
PP (gC m-2 d-1)
0.01 0.1 1 10
PP JUN
VGPM2
mean



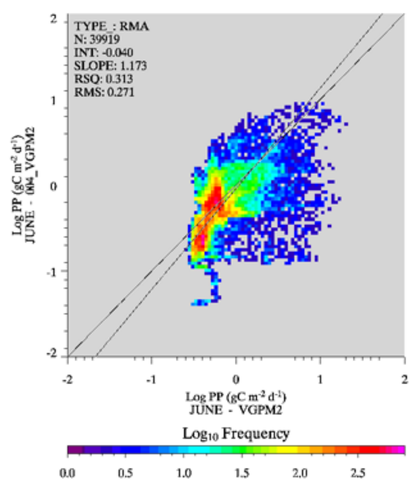
PP (gC m-2 d-1)
0.01 0.1 1 10
PP JUN 004_VGPM2
mean



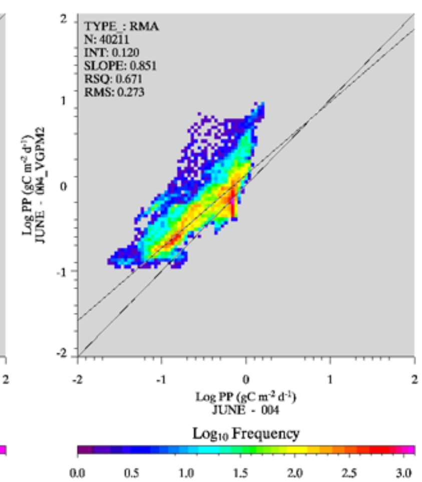
PP (gC m-2 d-1)
0.01 0.1 1 10
PP JUN 004
mean



TYPE_: RMA
N: 39351
INT: -0.186
SLOPE: 1.332
RSQ: 0.181
RMS: 0.411
Log PP (gC m-2 d-1)
JUNE - 004
Log PP (gC m-2 d-1)
JUNE - VGPM2
Log10 Frequency
0.0 0.5 1.0 1.5 2.0 2.5 3.0

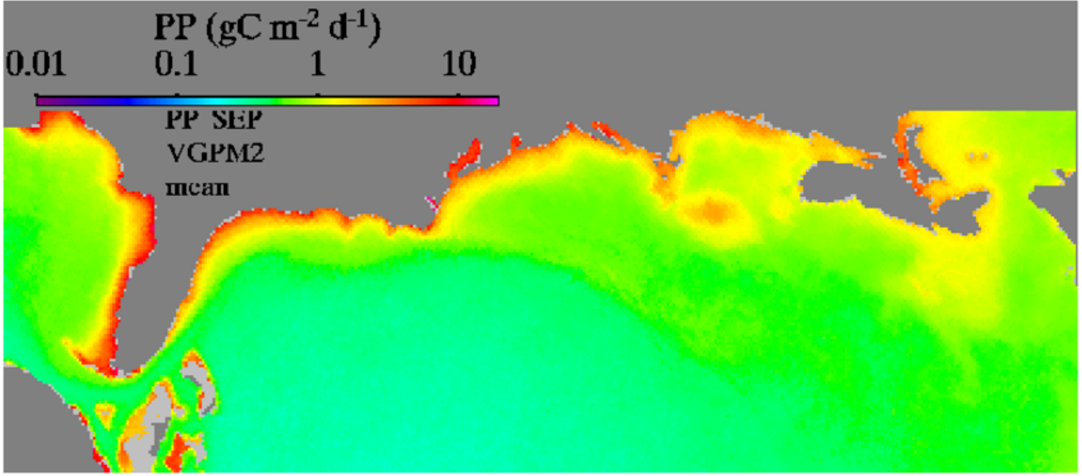


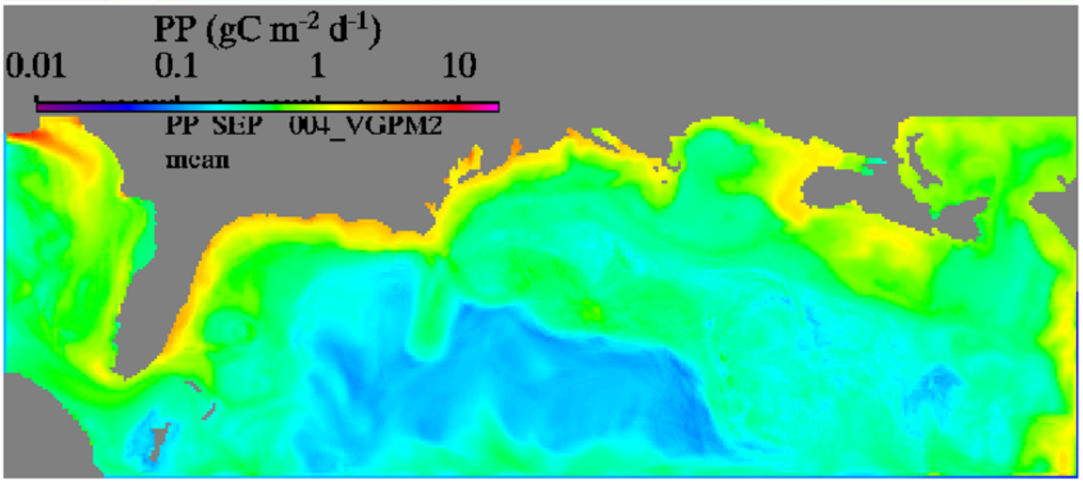
TYPE_: RMA
N: 39919
INT: -0.040
SLOPE: 1.173
RSQ: 0.313
RMS: 0.271
Log PP (gC m-2 d-1)
JUNE - 004_VGPM2
Log PP (gC m-2 d-1)
JUNE - VGPM2
Log10 Frequency
0.0 0.5 1.0 1.5 2.0 2.5

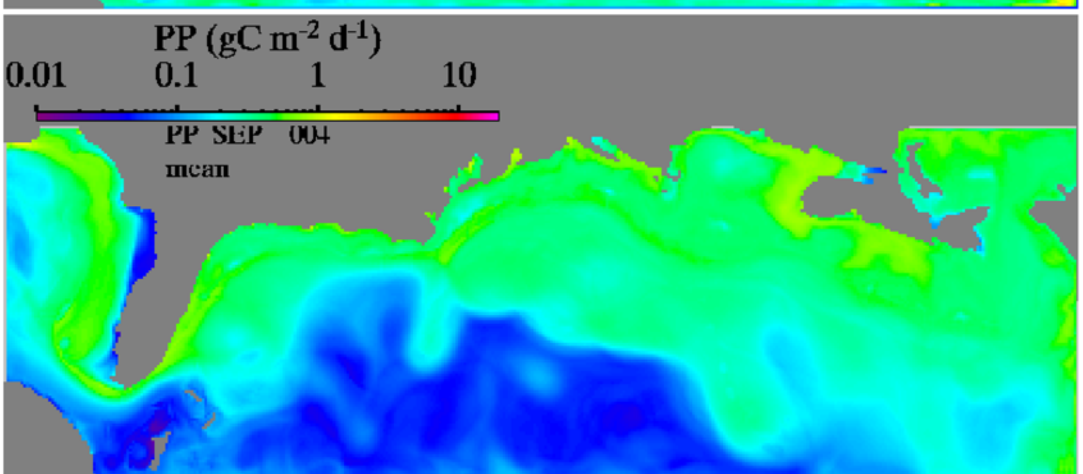


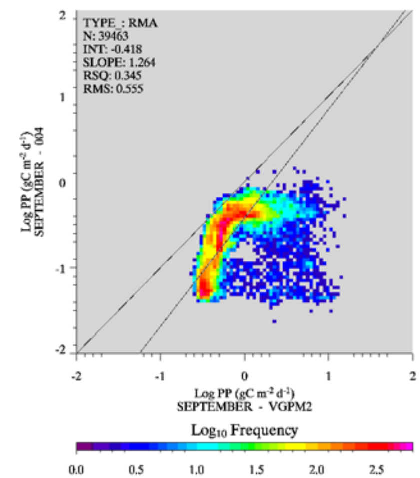
TYPE_: RMA
N: 40211
INT: 0.120
SLOPE: 0.851
RSQ: 0.671
RMS: 0.273
Log PP (gC m-2 d-1)
JUNE - 004_VGPM2
Log PP (gC m-2 d-1)
JUNE - 004
Log10 Frequency
0.0 0.5 1.0 1.5 2.0 2.5 3.0

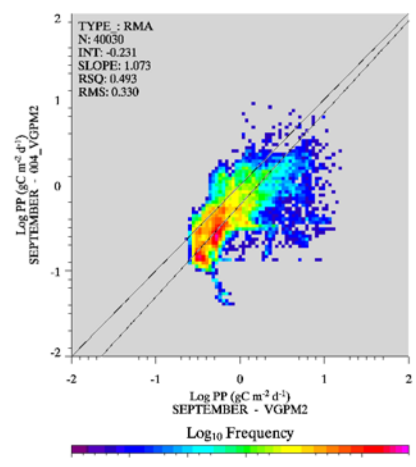
PPD
September

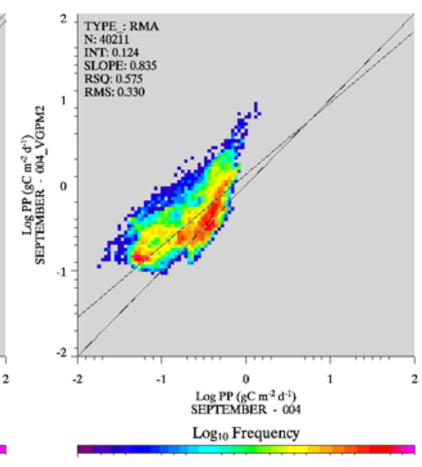




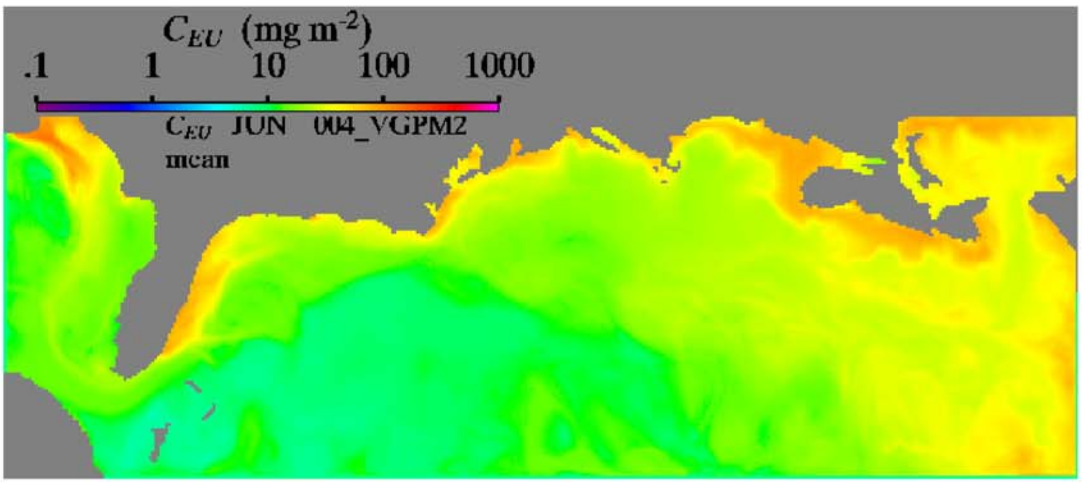


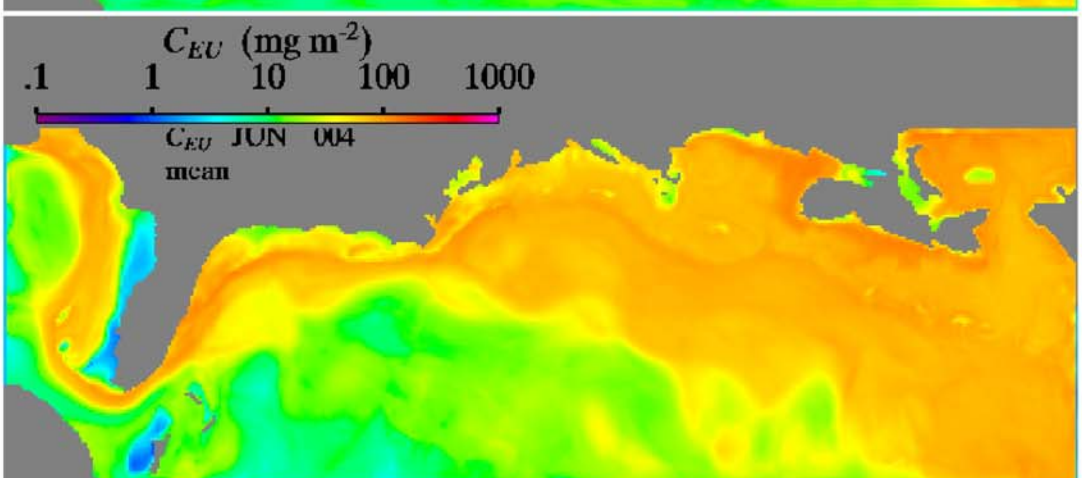


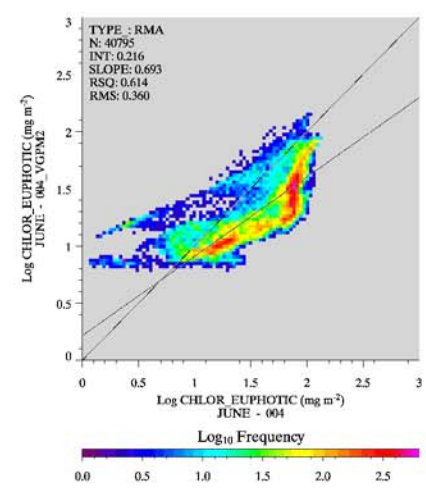




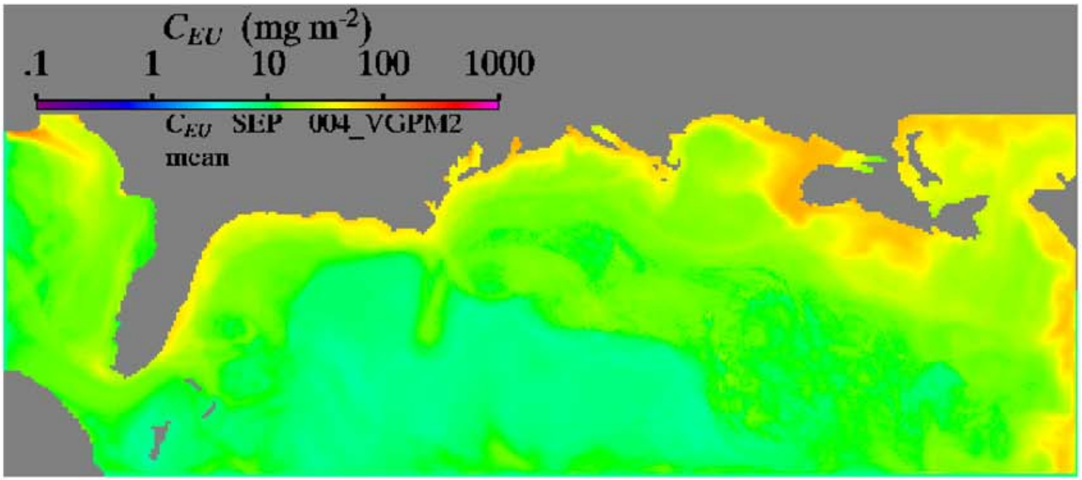
CHLOR_EUPHOTIC
June

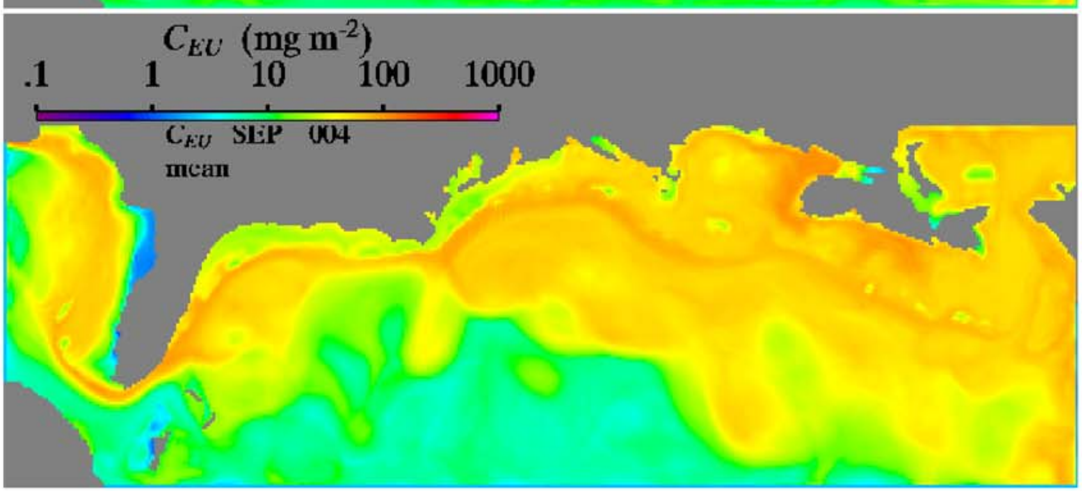


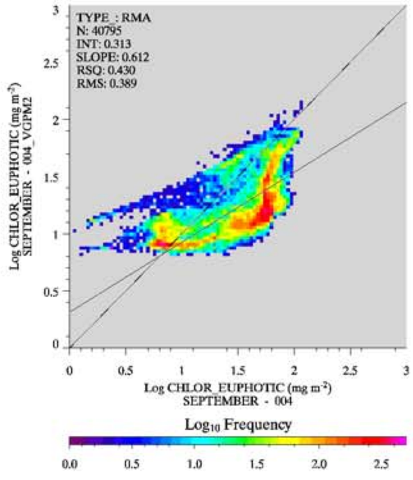




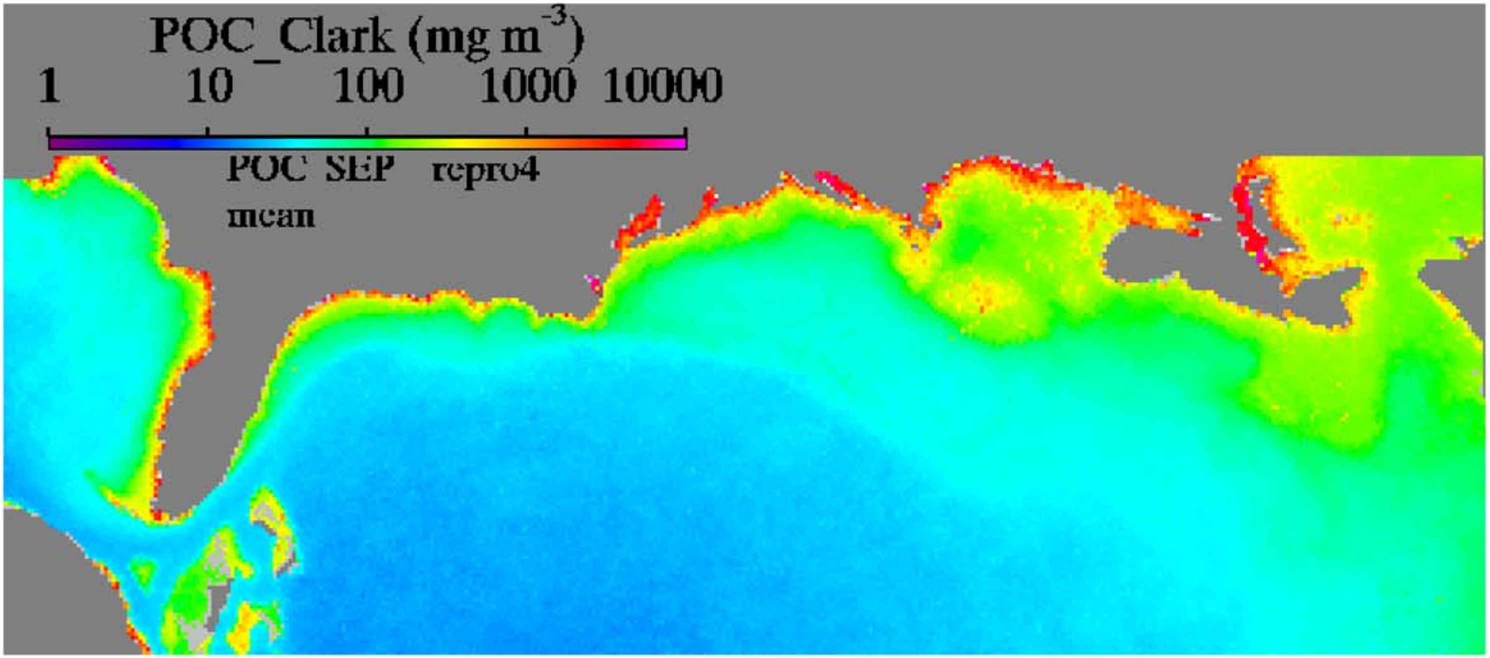
CHLOR_EUPHOTIC
September

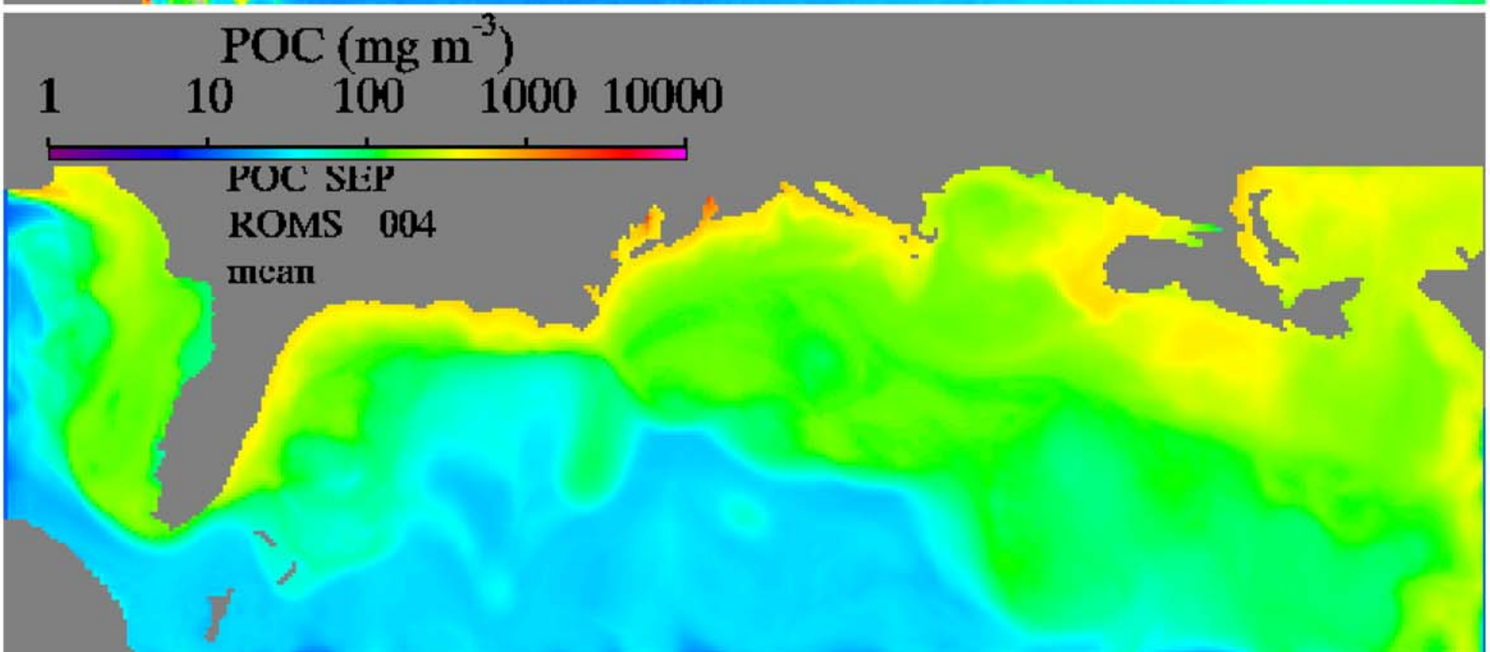


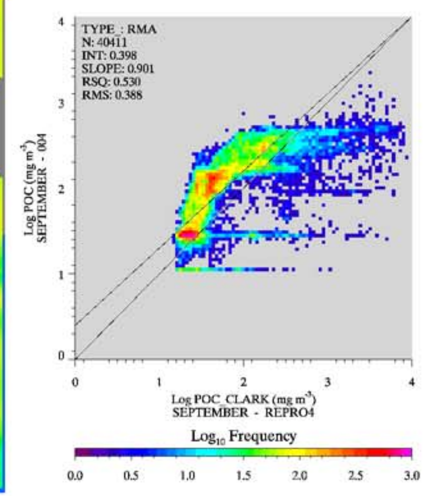


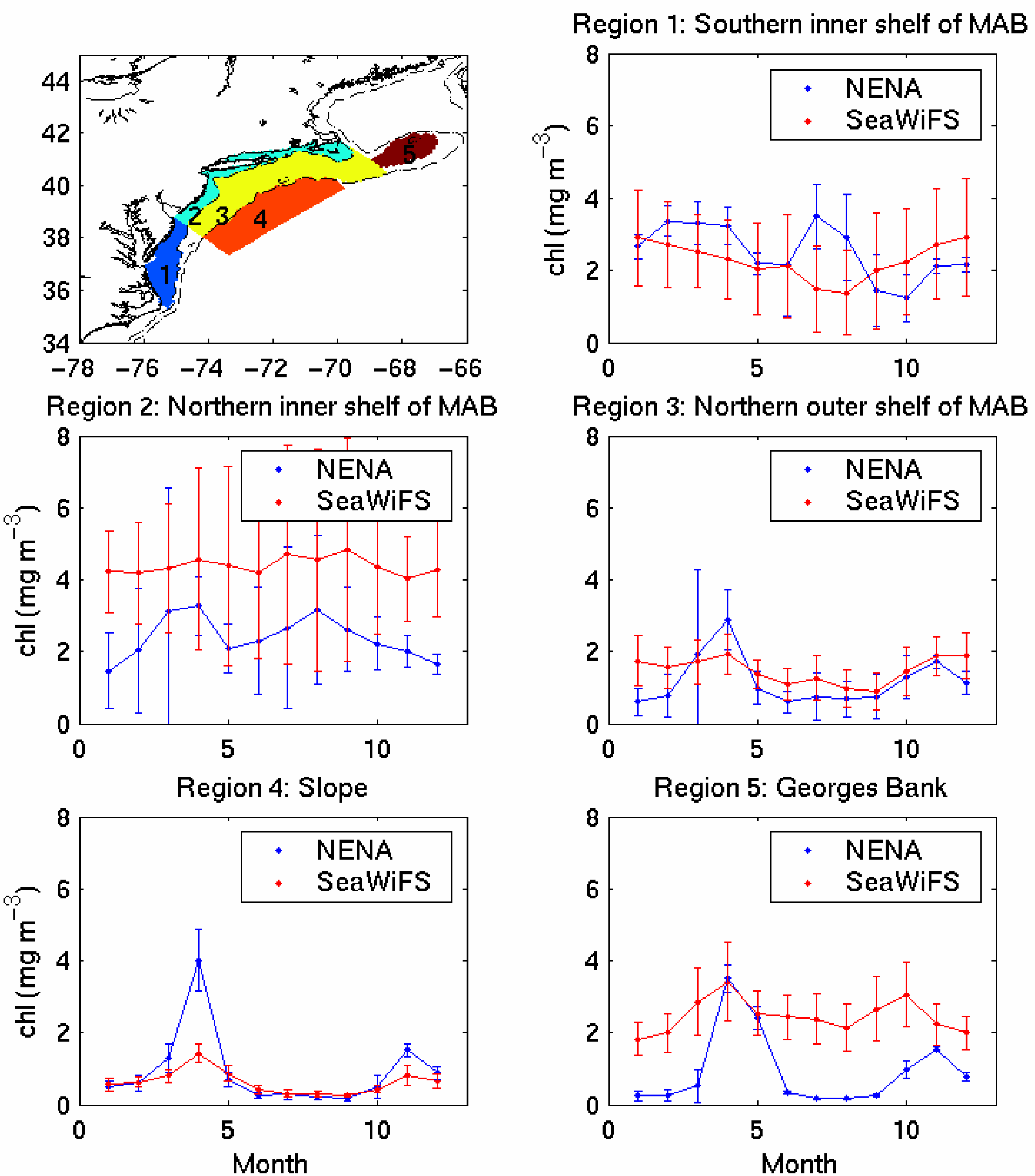


POC September

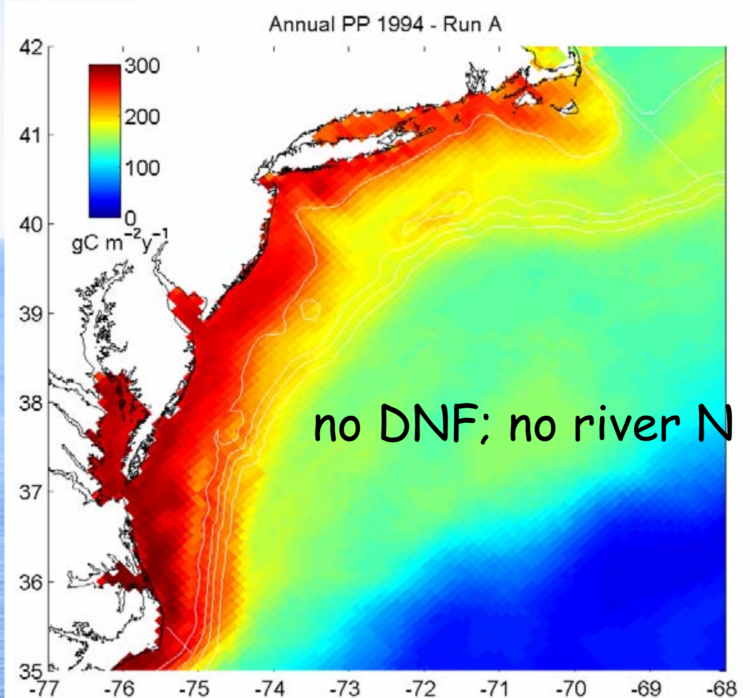




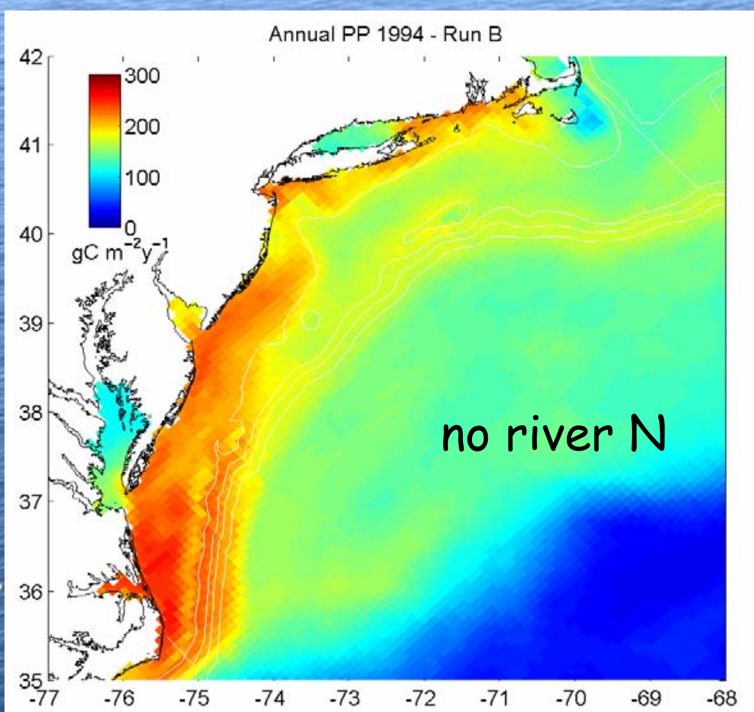


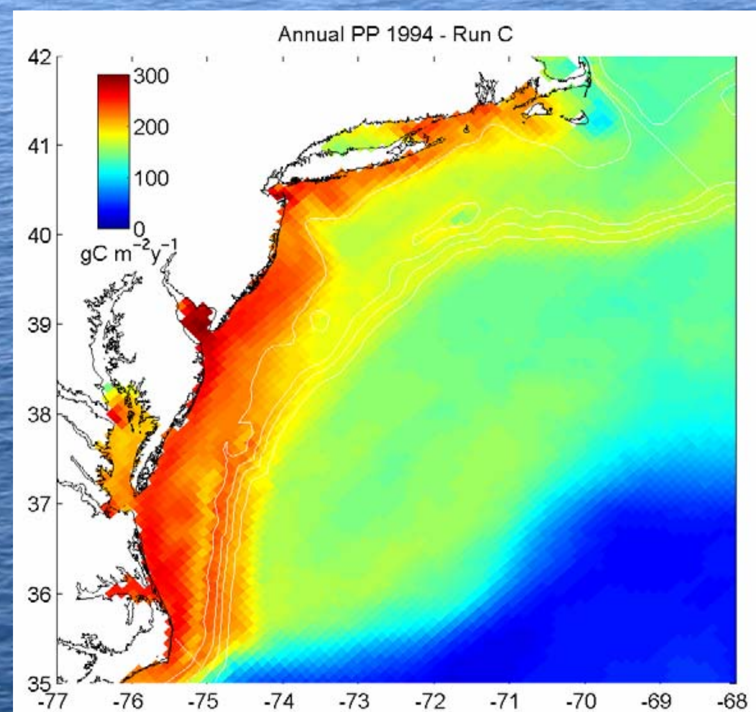


Region 1: Southern inner shelf of MAB
Region 2: Northern inner shelf of MAB
Region 3: Northern outer shelf of MAB
Region 4: Slope
Region 5: Georges Bank
NENA
SeaWiFS
chl (mg m^{-3})
Month

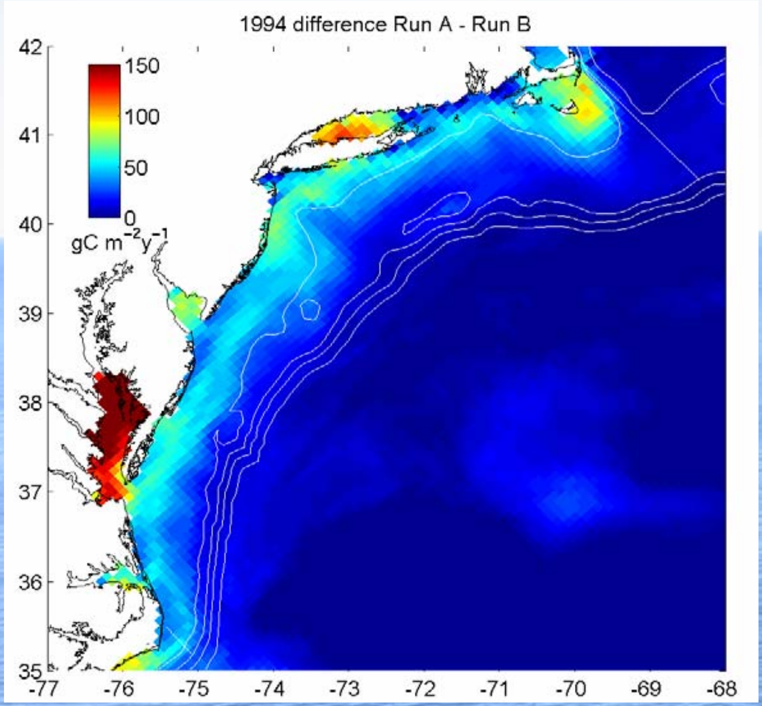


A	**227 gC /m2 /y**	
B	**184 gC /m2 /y**	**20% reduction from A**
C	**200 gC /m2 /y**	**10% increase from B**

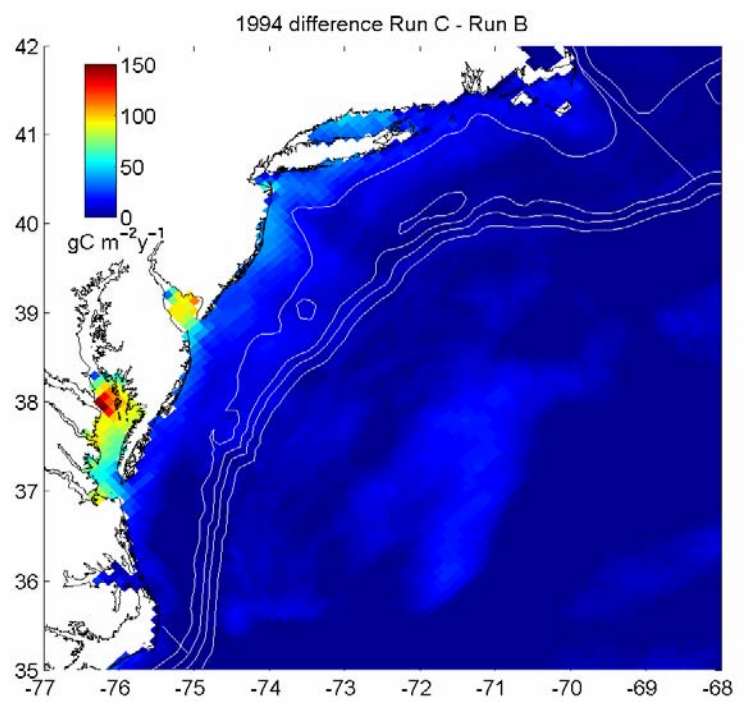




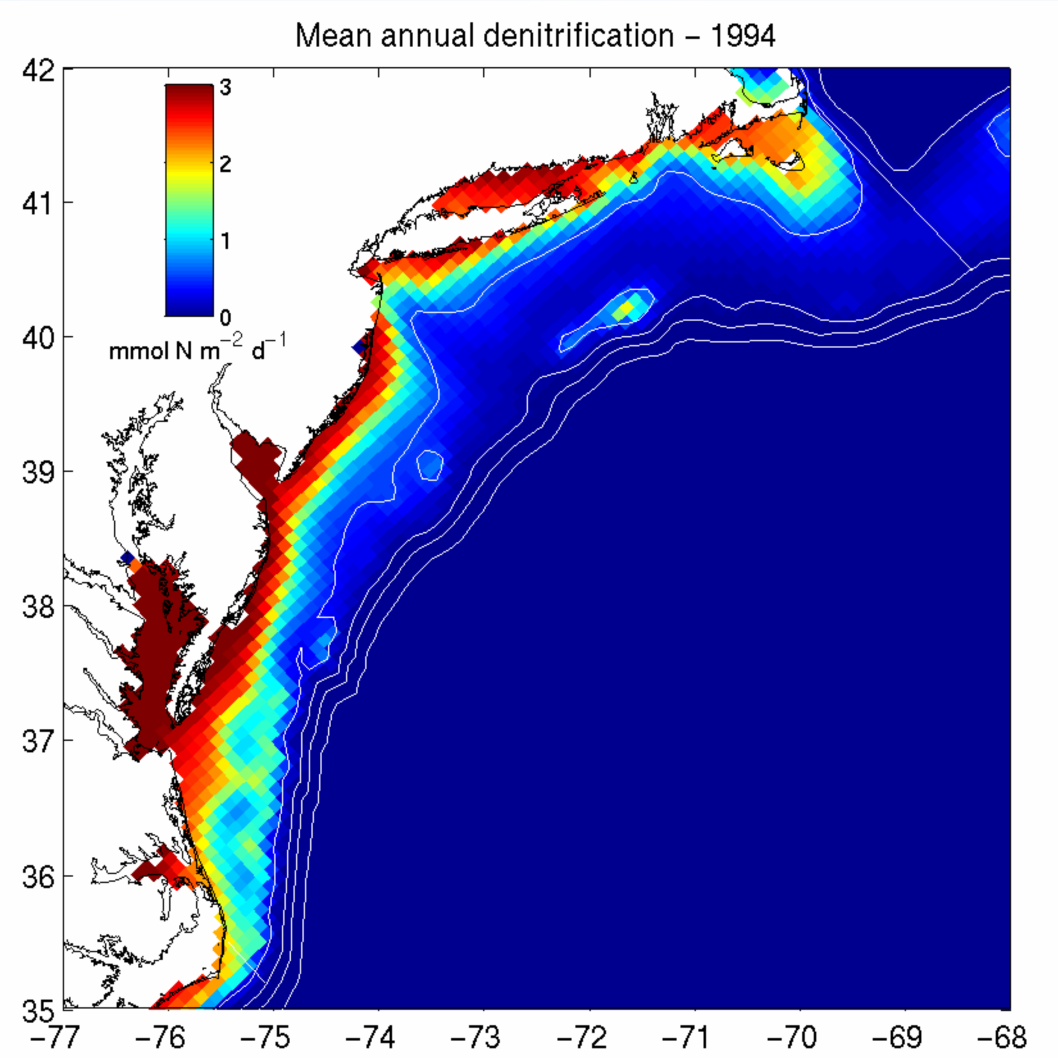
Primary productivity differences



reduction due to denitrification



Increase due to riverine inputs



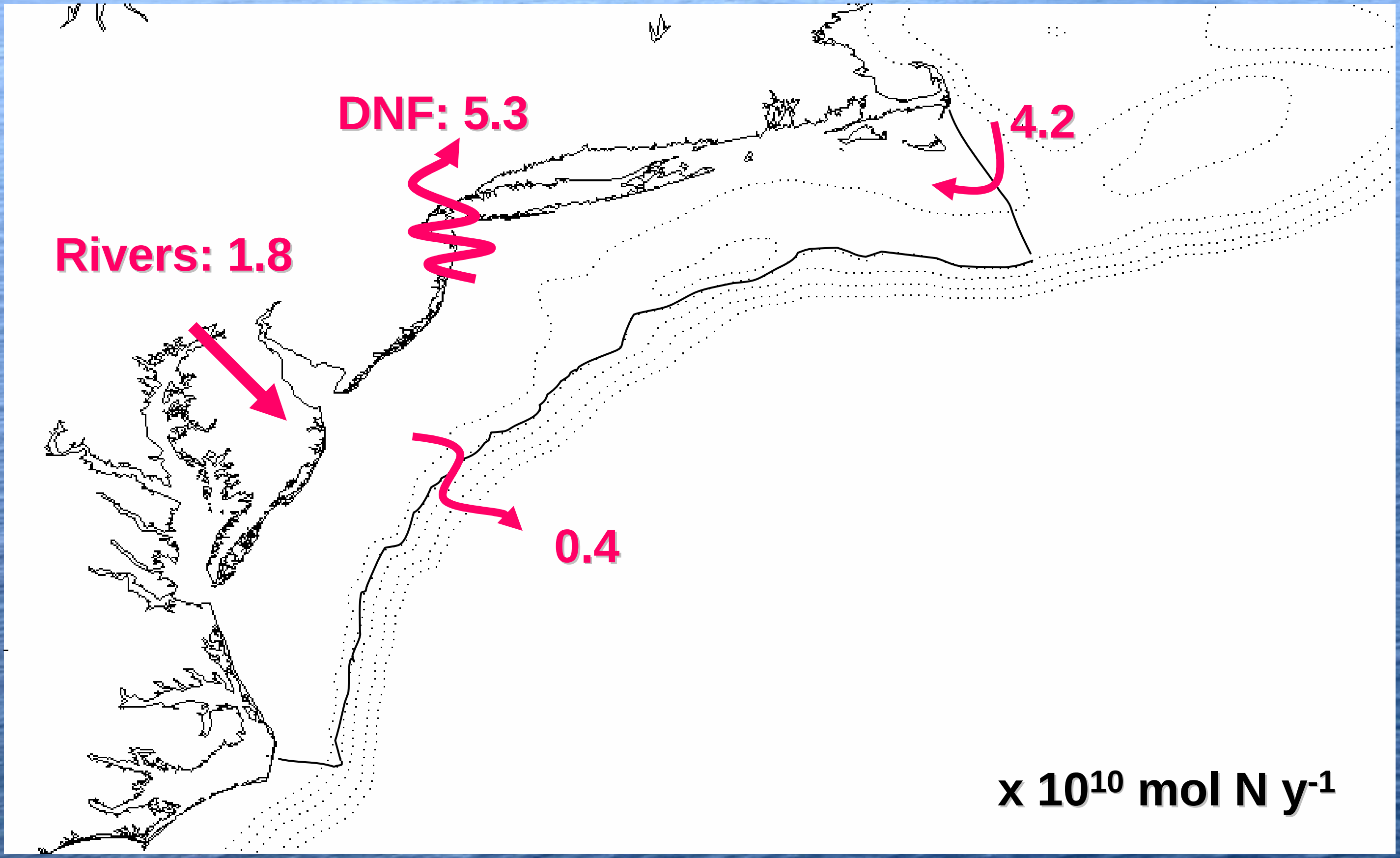
Mean annual denitrification flux in MAB:
1.1 mmol N /m2 /y

Observational estimates for North Atlantic Shelves:
0.7 mmol N /m2 /y

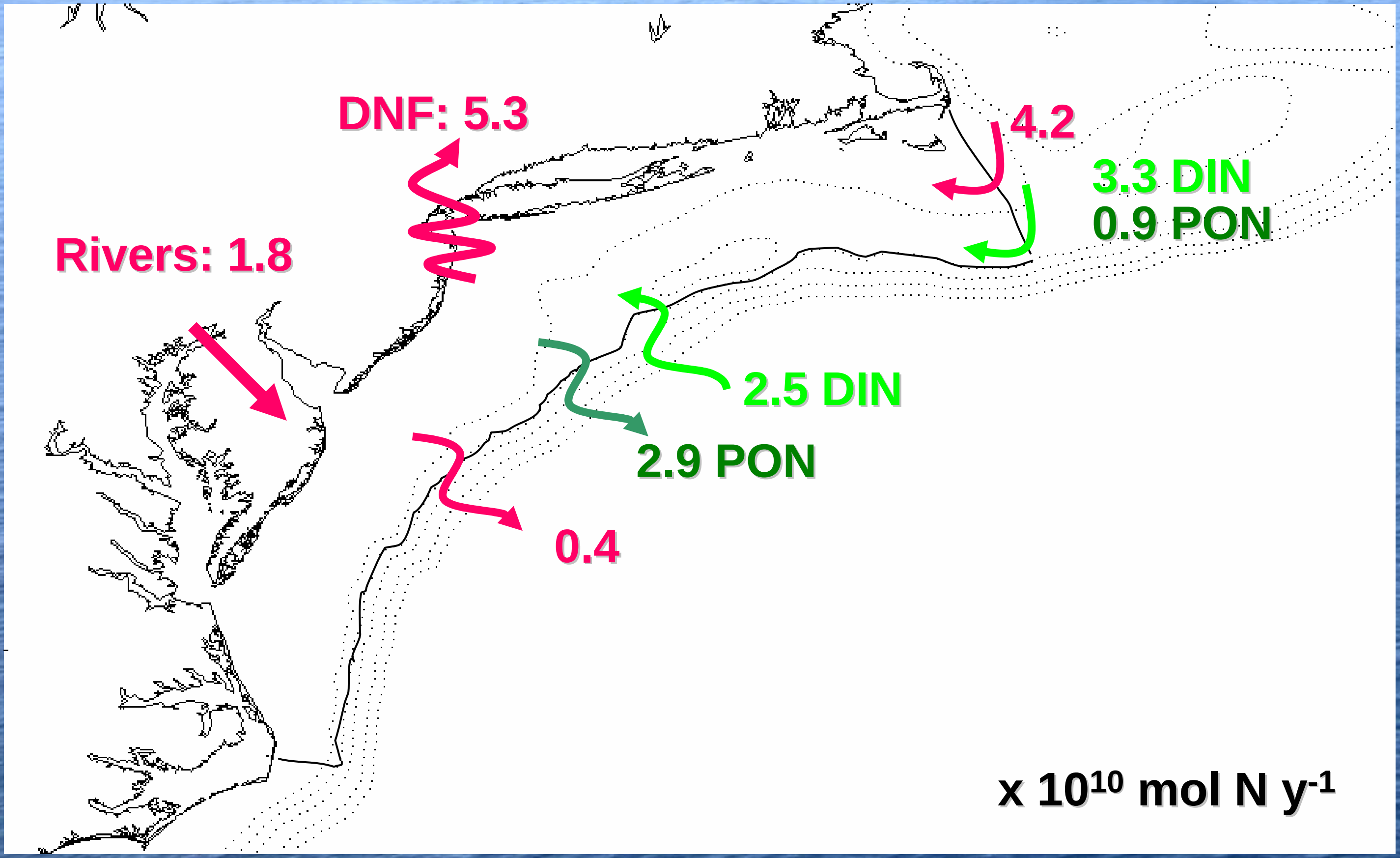
Nova Scotia to Cape Hatteras:
1.4 mmol N /m2 /y

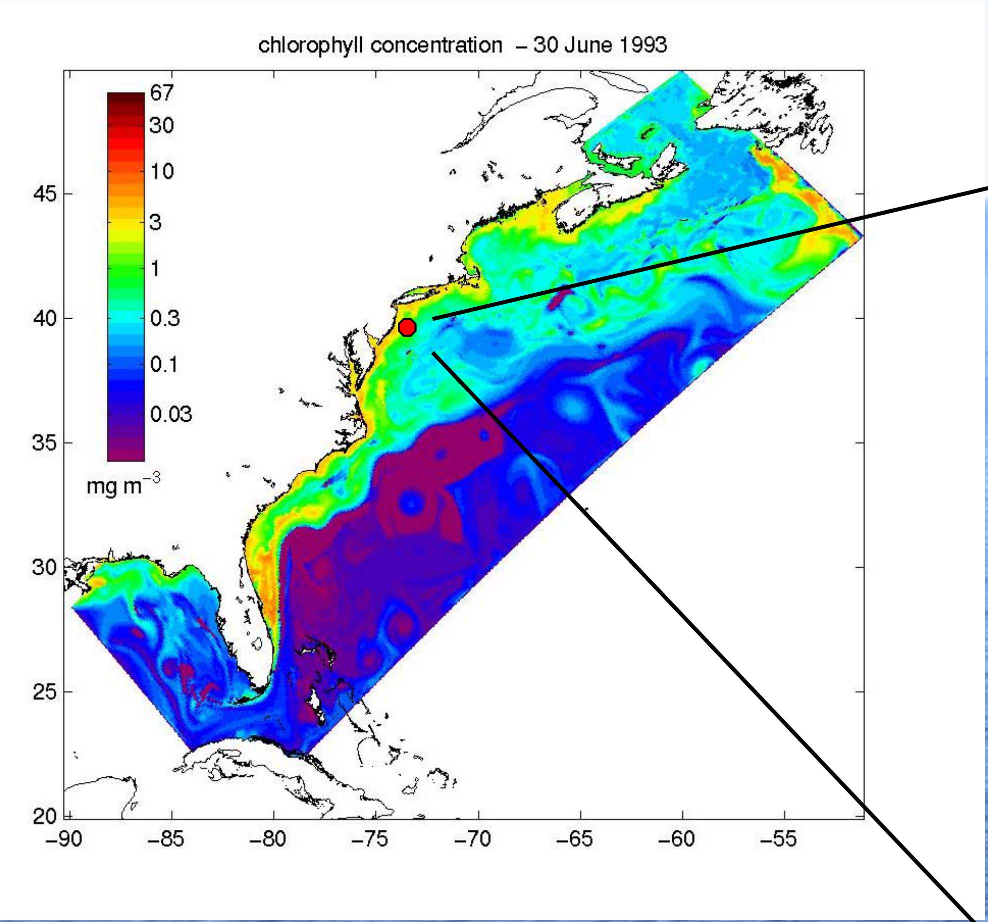
(Seitzinger and Giblin 1996)

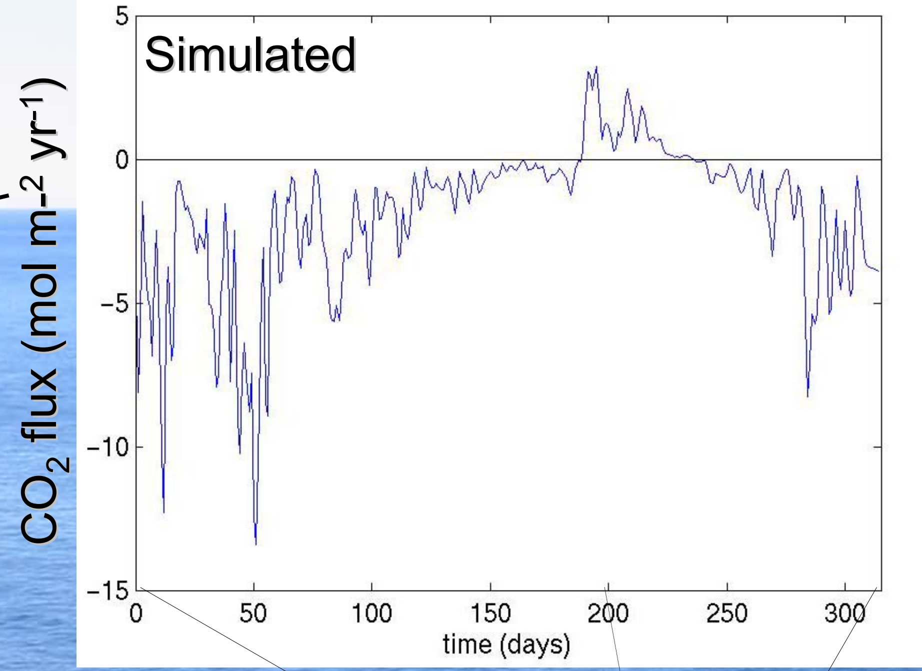
- denitrification removes 60% of all N entering MAB

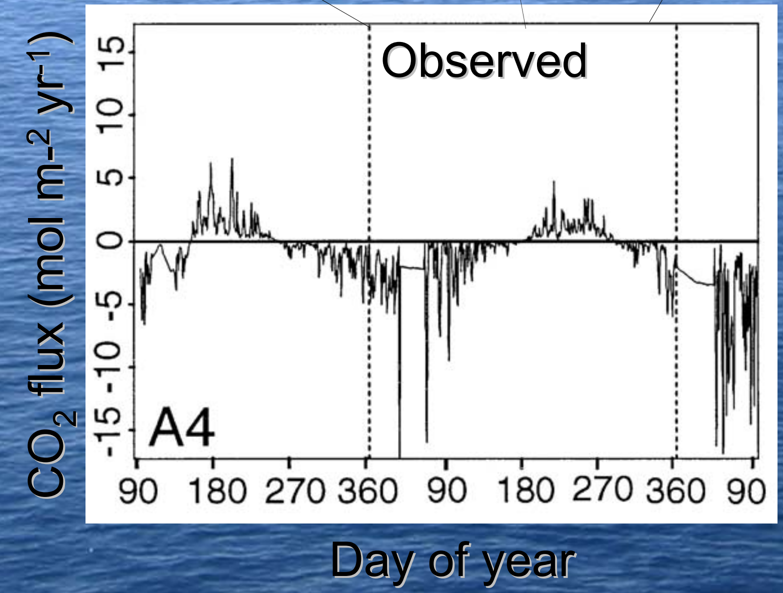


- denitrification removes 60% of all N entering MAB
- remainder exported as PON
- inflow from north is mostly in form of DIN
- cross-isobath export of PON
- cross-isobath import of DIN









<u>Air-sea CO2-flux:</u>

- simulated (above and top right)

- observed (bottom right)
Boehme et al., Mar. Chem. 1998

Implications for C-cycle

Assume:

N supply to MAB is matched by C supply in Redfield ratio;

N loss due to denitrification is matched by outgassing of CO_2

5.3 x10^{10} mol N y^{-1} ~= 4.2 x10^{12} gC y^{-1}

Extrapolated to North Atlantic shelf area:

0.18 PgC y^{-1}

30% of the North Atlantic C uptake

-0.6 PgC y^{-1} (Takahashi et al. 2002)

Summary

- Nested bio-physical model within large scale circulation model (boundary artifacts?)
- Spatial variability in simulated surface chlorophyll agrees well with SeaWiFS, although some features are missing (e.g. Georges Bank)
- Tool for quantitative understanding of shelf processes and their role in biogeochemical cycling
- Denitrification removes more than half the nitrogen entering the MAB (much more than river inputs)
- Extrapolation to the NA basin suggests this sink off-sets 30-60% of N_2-fixation
- Implications for carbon cycling