Welcome to my lab

Grand Challenges?

-Humans have already altered the Earth system

-Quantitative understanding of the Earth system will require the human processes to be included

-The cost of integrated global system will require ocean observatory networks need to be dual use to allow for sustained support

Our view from the COOL room: Building technology & hopefully knowledge in the coastal ocean

Oscar Schofield, Scott Glenn, Josh Kohut

along w/ collaborators (100s) from Rutgers, WHOI, UNC, U. Maryland, U. Mass., Cal Poly, U Delaware, NRL, Scripps, JPL, MIT, Lamont, U. Florida, USGS, MBARI, Stevens, U Conn

Grad students & Postdocs: Gong, Zhang, Kahl, Gryzmski, Bergmann, Miles, Xu, Durski, Oliver, Sipler, Garzio, Tozzi, Moline, Saba, Montes-Hugo

My nerd family

Faculty


S. Glenn
Physics


O. Schofield
Biology


J. Kohut
Phys/Bio


R. Chant
Physics


R. Dunk
Physics


J. McDonnell
Education


M. Gorbunov
Biology


J. Wilkin
Modeling


U. Kremer
Comp. Sci.


D. Pompili
Engineer


C. Haldeman


T. Haskins

Gliders


D. Aragon


K. Coleman


E. Handel


H. Roarty

CODAR


M. Smith


E. Rivera


L. Ojanen

Satellites


M. Crowley

Software


J. Kerfoot


I. Heifetz


E. Hunter

Coordinator


C. Kohut

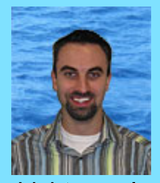
Modeling

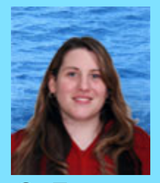

H.Arango


L. Bowers

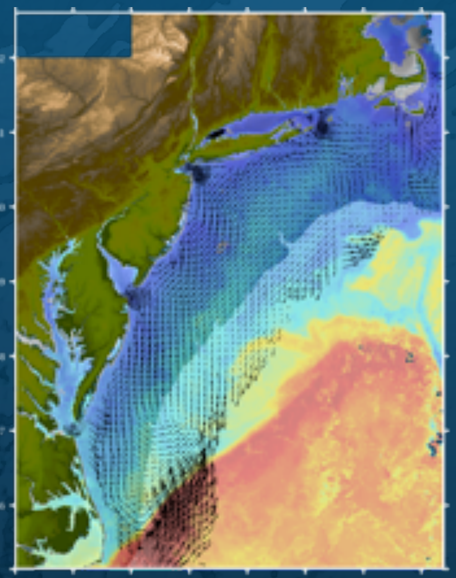

D. Robertson

Education


S. Lichtenwalner


C. Ferraro

Undergrad & Grad Students



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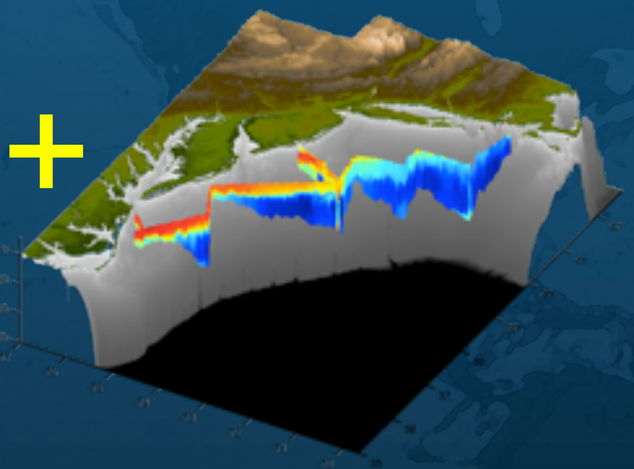

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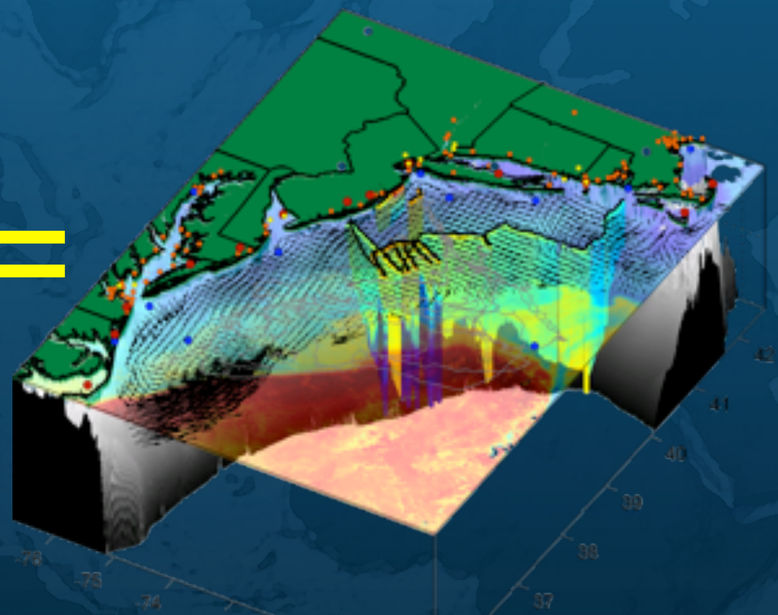
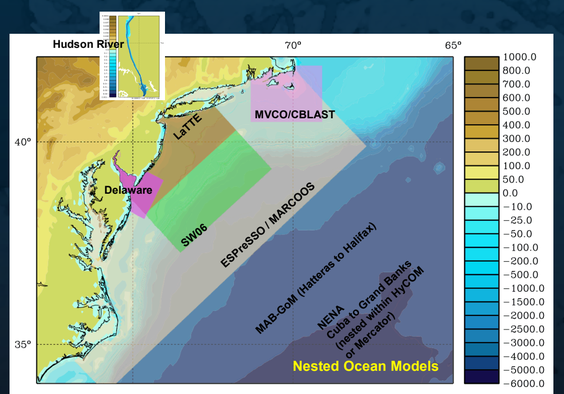


Remote Sensing



Nested Models

Robots

+

S4DVAR procedure

Lagrange function $L = J(\mathbf{x}) + \sum_{i=1}^{N} \tilde{\mathbf{e}}_i^T \left(\frac{d\mathbf{x}_i}{dt} - \mathbf{N}(\mathbf{x}_i) - \mathbf{F}_i \right)$ $\quad \mathbf{F}_i = \mathbf{F}(i\Delta t) \quad \mathbf{x}_i = \mathbf{x}(i\Delta t)$

Lagrange multiplier $\tilde{\mathbf{e}}_i = \tilde{\mathbf{e}}(t_i) = \tilde{\mathbf{e}}(i\Delta t)$

At extrema of L, we require:

$$\begin{cases} \frac{\partial L}{\partial \tilde{\mathbf{e}}_i} = 0 \Rightarrow \frac{d\mathbf{x}_i}{dt} - \mathbf{N}(\mathbf{x}_i) - \mathbf{F}_i = 0 & \text{NLROMS} \\ \frac{\partial L}{\partial \mathbf{x}_i} = 0 \Rightarrow -\frac{d\tilde{\mathbf{e}}_i}{dt} - \left(\frac{\partial \mathbf{N}}{\partial \mathbf{x}} \right)^T \tilde{\mathbf{e}}_i - \delta_{im} \mathbf{H}^T \mathbf{O}^{-1} \left(\mathbf{H}\mathbf{x}_m - \mathbf{y}_m \right) = 0 & \text{ADROMS} \\ \frac{\partial L}{\partial \mathbf{x}(0)} = 0 \Rightarrow \mathbf{B}^{-1} \left(\mathbf{x}(0) - \mathbf{x}_b \right) - \tilde{\mathbf{e}}(0) = 0 & \text{coupling of NL \& ADROMS} \\ \frac{\partial L}{\partial \mathbf{x}(\tau)} = 0 \Rightarrow \tilde{\mathbf{e}}(\tau) = 0 & \text{i.c. of ADROMS} \end{cases}$$

S4DVAR procedure:

(1) Choose an $\mathbf{x}(0) = \mathbf{x}_b$

(2) Integrate NLROMS $t \in [0, \tau]$ and compute J

(3) Integrate ADROMS $t \in [\tau, 0]$ to get $\tilde{\mathbf{e}}(0)$

(4) Compute $\frac{\partial J}{\partial \mathbf{x}(0)} = \mathbf{B}^{-1} \left(\mathbf{x}(0) - \mathbf{x}_b \right) - \tilde{\mathbf{e}}(0)$

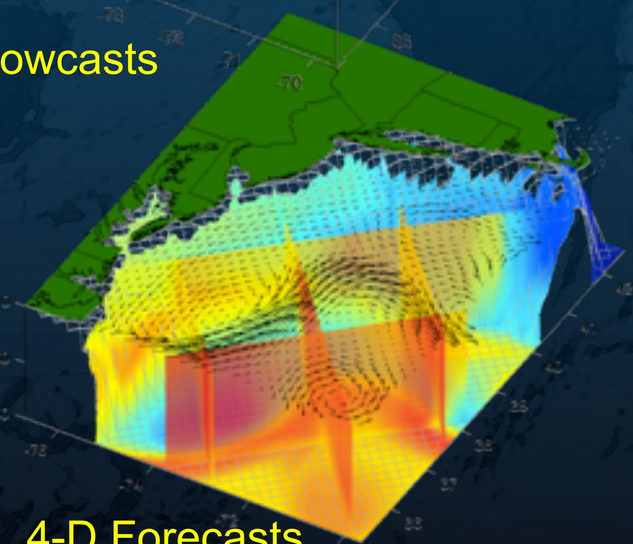
(5) Use a descent algorithm to determine a "down gradient" correction to $\mathbf{x}(0)$ that will yield a smaller value of J

(6) Back to (2) until converged

Data Assimilation

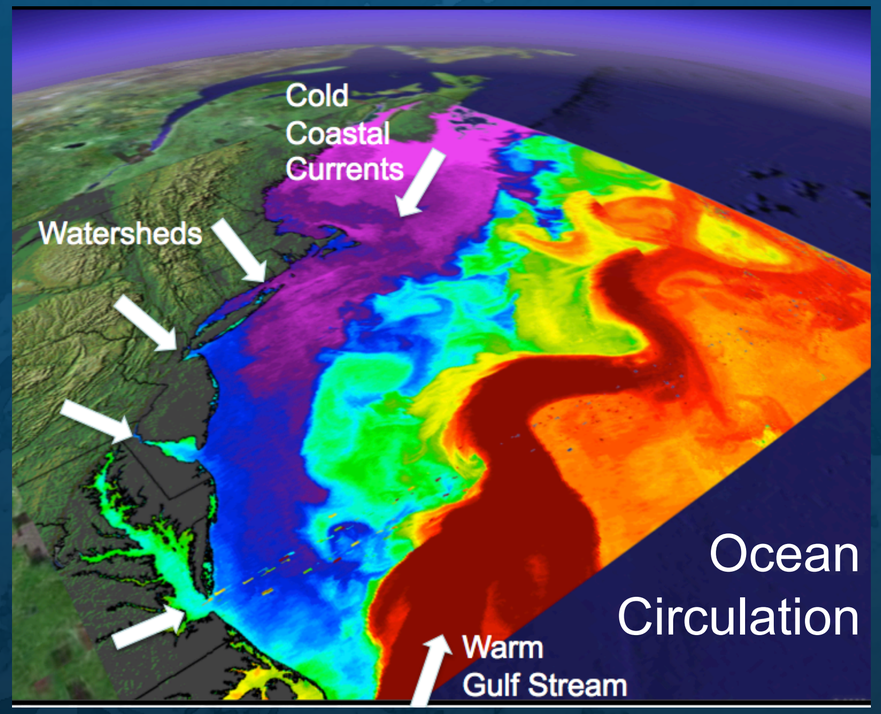
3-D Nowcasts

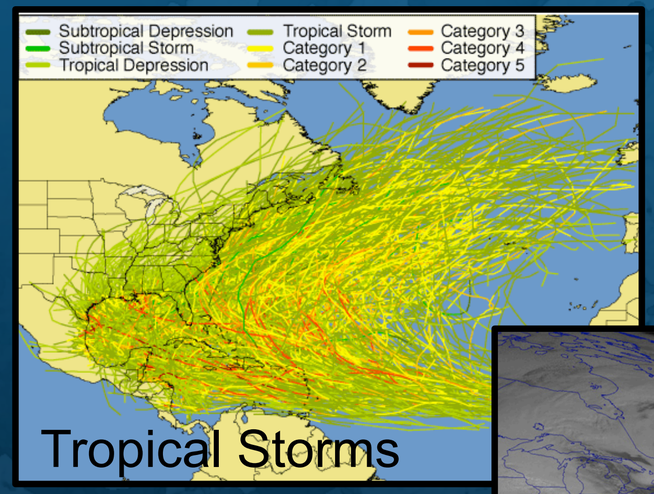
=

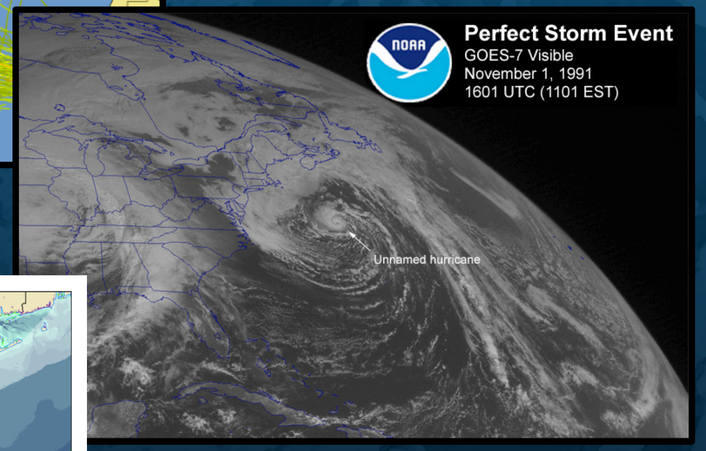


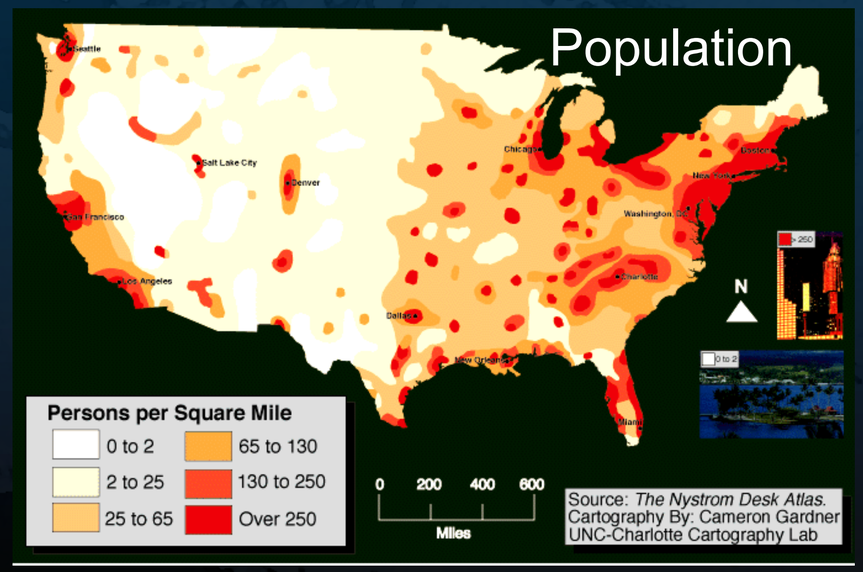
4-D Forecasts

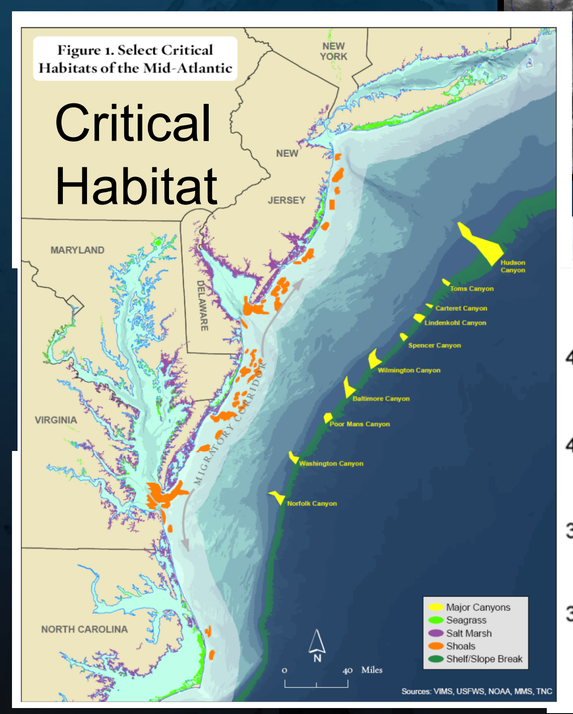
What are the drivers of variability in my laboratory?

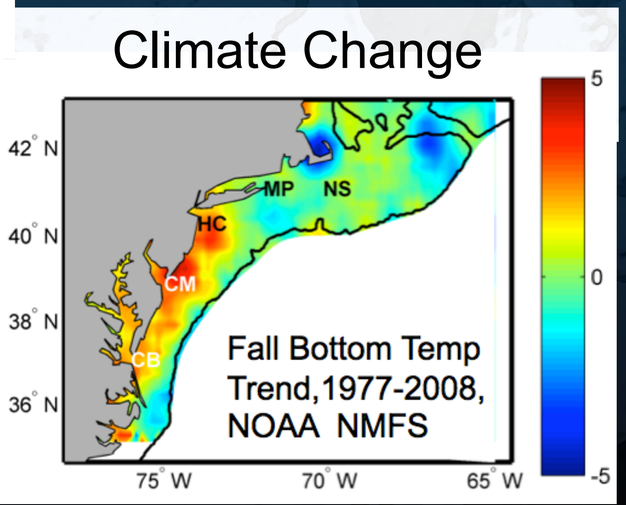








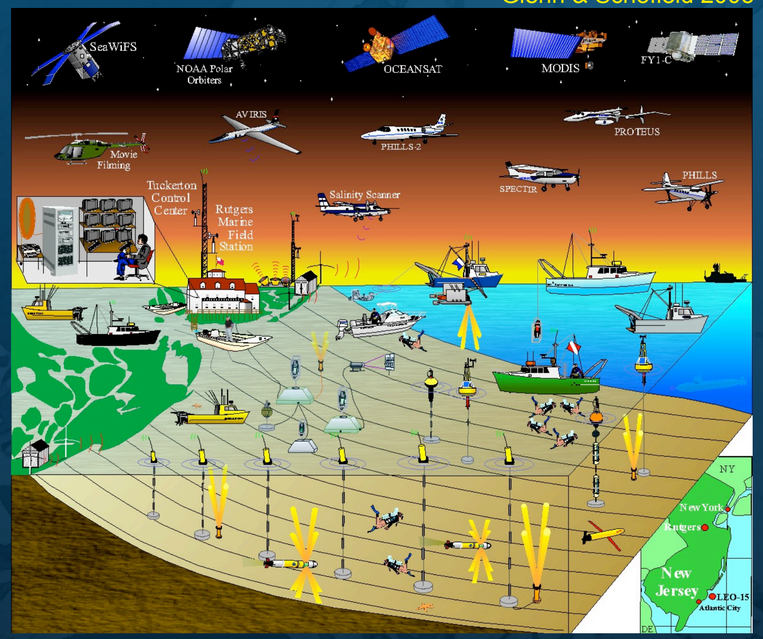




Diverse funding with an evolving suite of questions

Upwelling, hypoxia & coastal predictive skill

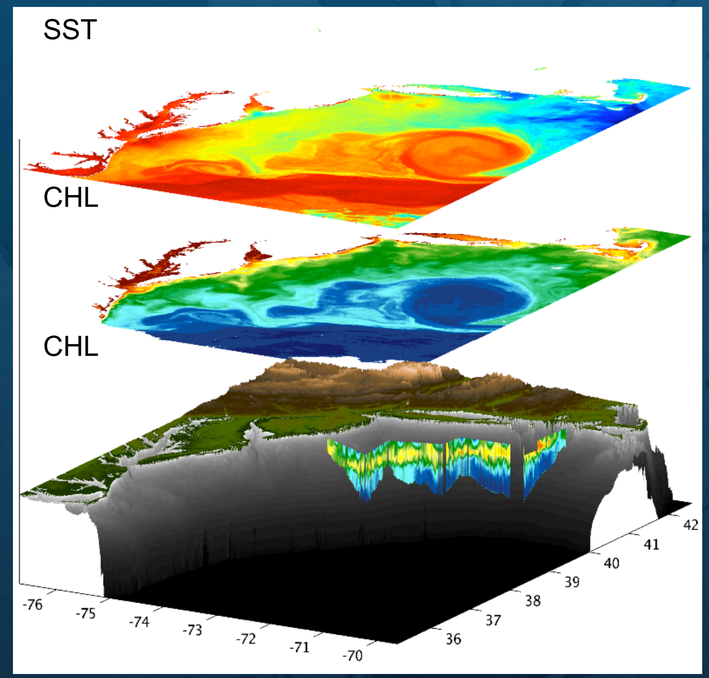
Schofield et al 2002
Glenn & Schofield 2003



1996-2001
Local scale observatories

Shelf transport, land/ocean communication

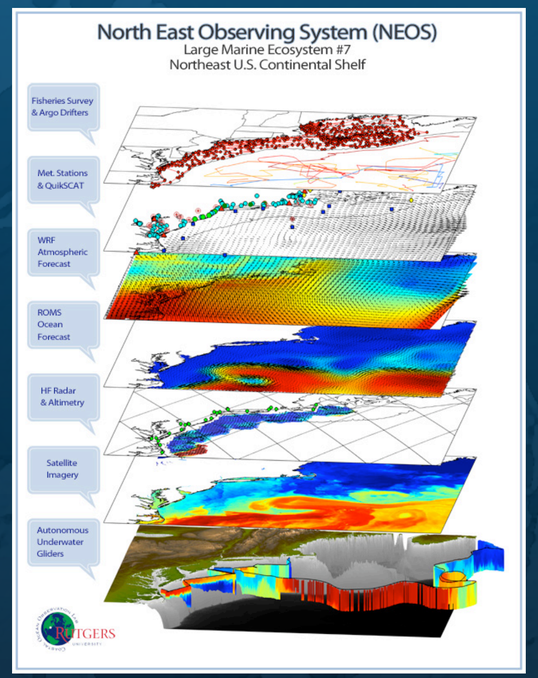
Glenn & Schofield 2009



2001-2006
Regional scale observatories

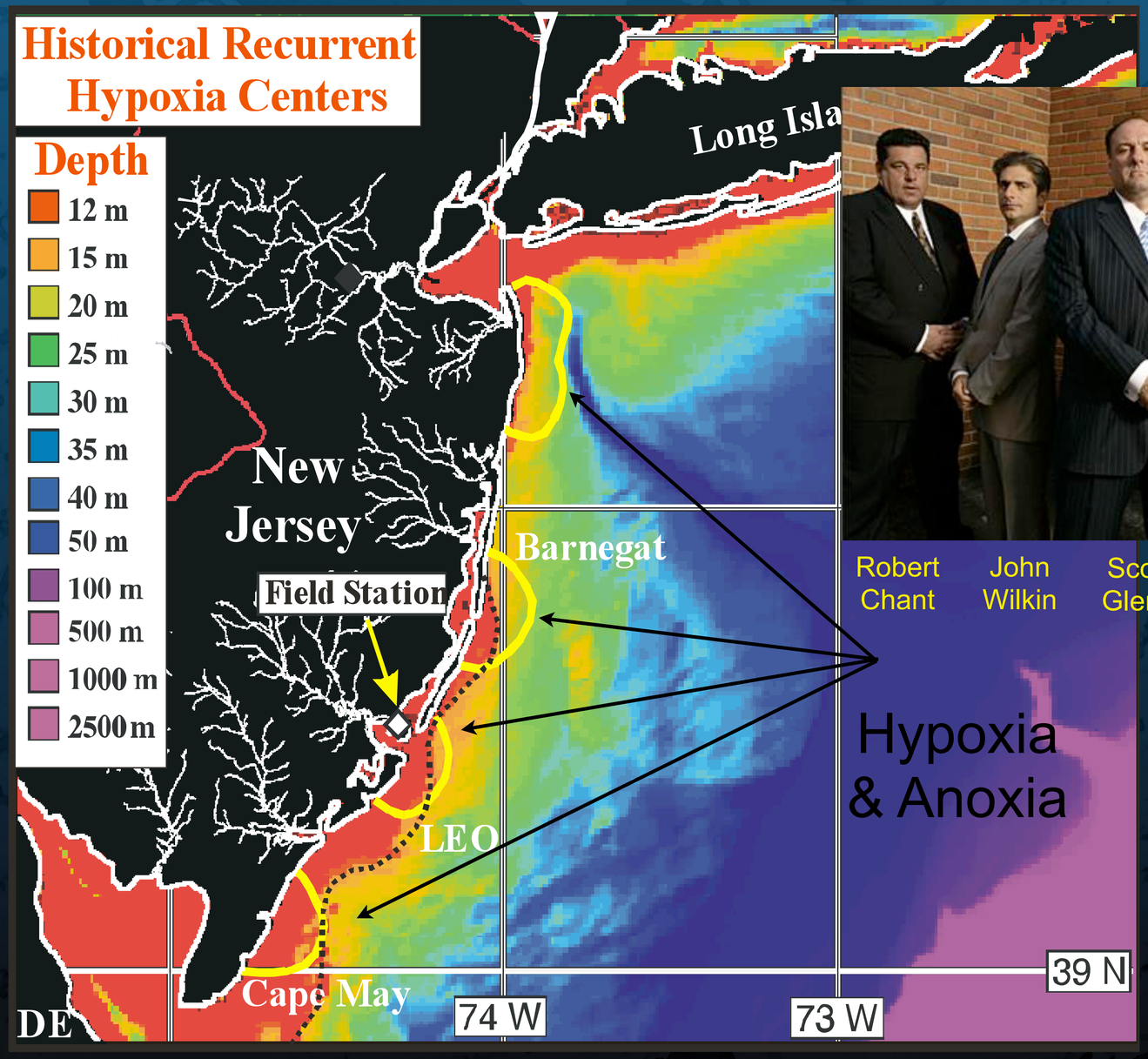
Ecosystem dynamics, climate scale mediated change

Schofield et al. 2011



2006-2011
Large marine ecosystem observatories

Phase development: The nearshore coastal system
Question driving science deployment: Are humans causing coastal hypoxia?



Robert Chant | John Wilkin | Scott Glenn | Josh Kohut | Oscar Schofield

July 6, ’98 - AVHRR

Temperature °C

19 20 21 22 24

40N

Historical Hypoxia/Anoxia Field Station

LEO

39N

75W

74W

July 11, ‘98 - SeaWiFS

Chlor-a (mg/m^3)

.1 .3 .5 1 2 4

40N

Field Station

LEO

39N

75W

74W

D) 8/5/93
CTD Transect

B)

A)

C)

E)

Temp (°C)
10.8
12.2
13.6
15.0
16.4
17.8
19.2
20.6
22.0
23.4
24.8

wind

1 m s^{-1}

F) CODAR & SST – 7/98

Temp.
21
23
25
27

Barnegat delta

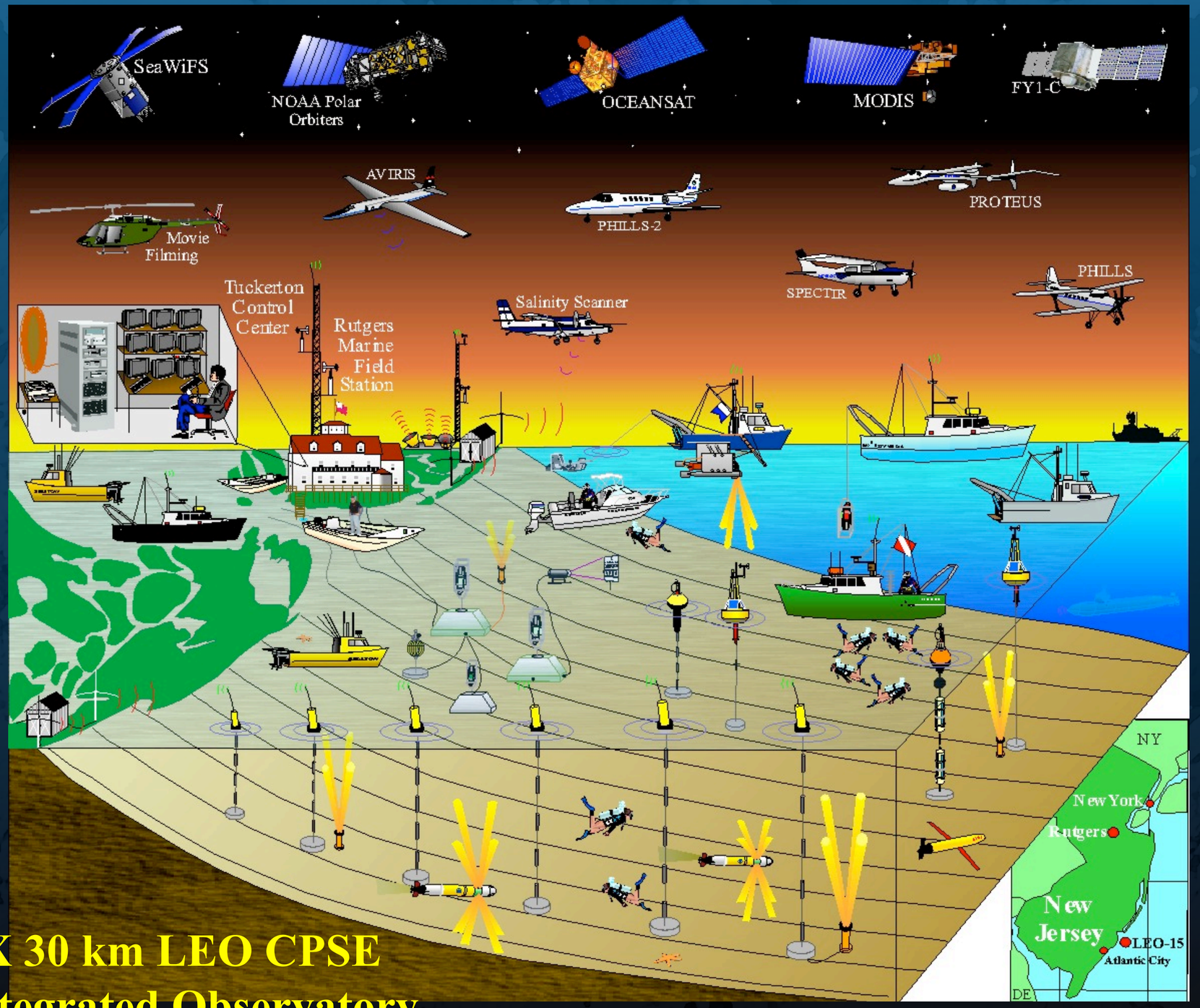
LEO delta

Cape May delta

North

Song et al(JGR) 2002

Figure 6



30 X 30 km LEO CPSE
An Integrated Observatory

Atmosphere/Ocean Physical/Biological Forecast Models

Operational Low-Res COAMPS Atmospheric Model

Experimental High-Res RAMS Atmospheric Model

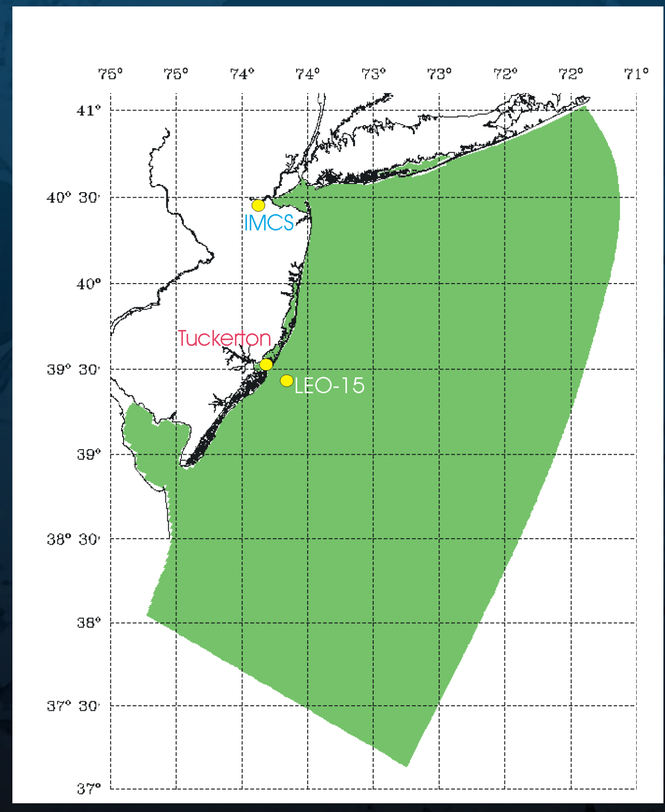
Air-Sea Interaction Model

ROMs Assimilation

MODAS Assimilation

ROMS Ocean Model (KPP and MY 2.5 Turbulent Closure)

Bottom Boundary Layer Model

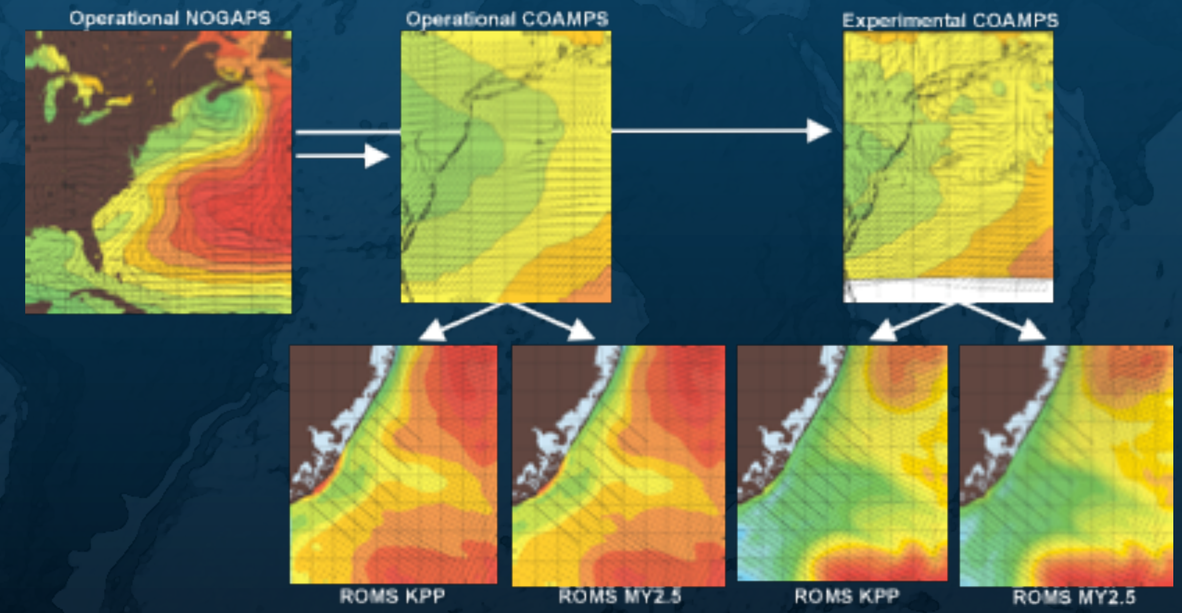


Month Long Experimental Effort

HyCODE 2001 Modeling Forecast Cycles

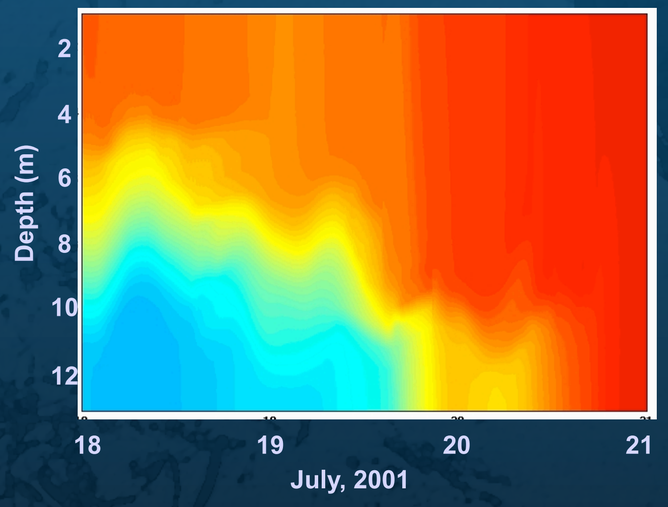
Sun	Mon	Tues	Wed	Thurs	Fri	Sat
July 8	9	10	11	12	13	14
			Forecast Cycle 1			
			Briefing			
15	16	17	18	19	20	21
Forecast Cycle 2			Forecast Cycle 3			
Briefing			Briefing		Black Moon	
22	23	24	25	26	27	28
Forecast Cycle 4			Forecast Cycle 5			
Endeavor Arrives						
Briefing			Briefing			
29	30	31	Aug 1	2	3	4
Forecast Cycle 6			Forecast Cycle 7			
Briefing			Briefing			
5	6	7	8	9	10	11
Forecast Cycle 8			Endeavor Departs			
Briefing						

2001 Real-time Ensemble Forecasts

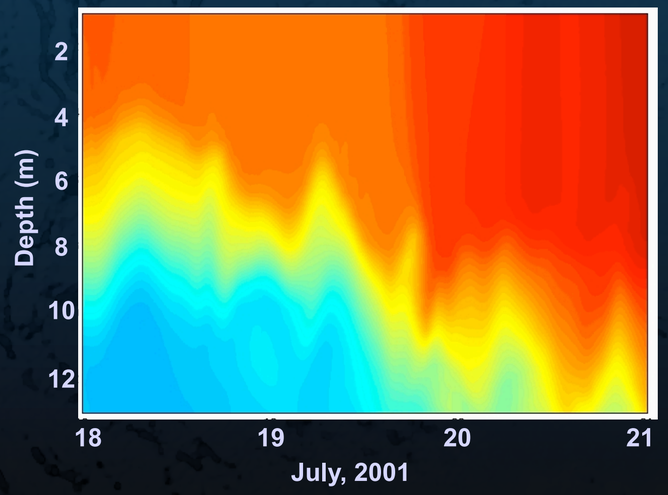


Real-time validation of the ensemble forecasts

HR COAMPS / ROMS

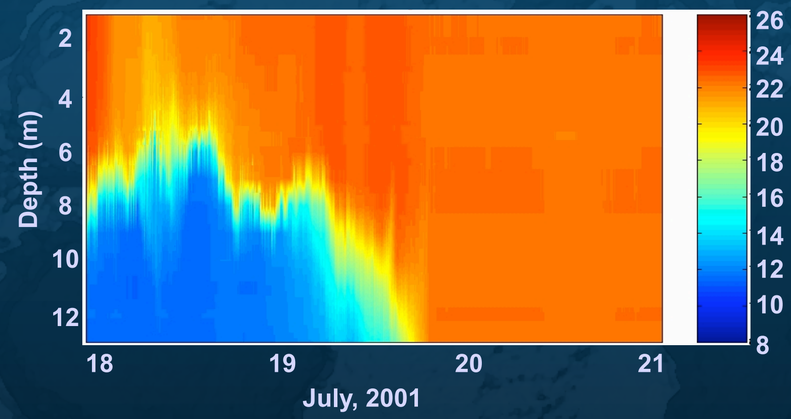


KPP

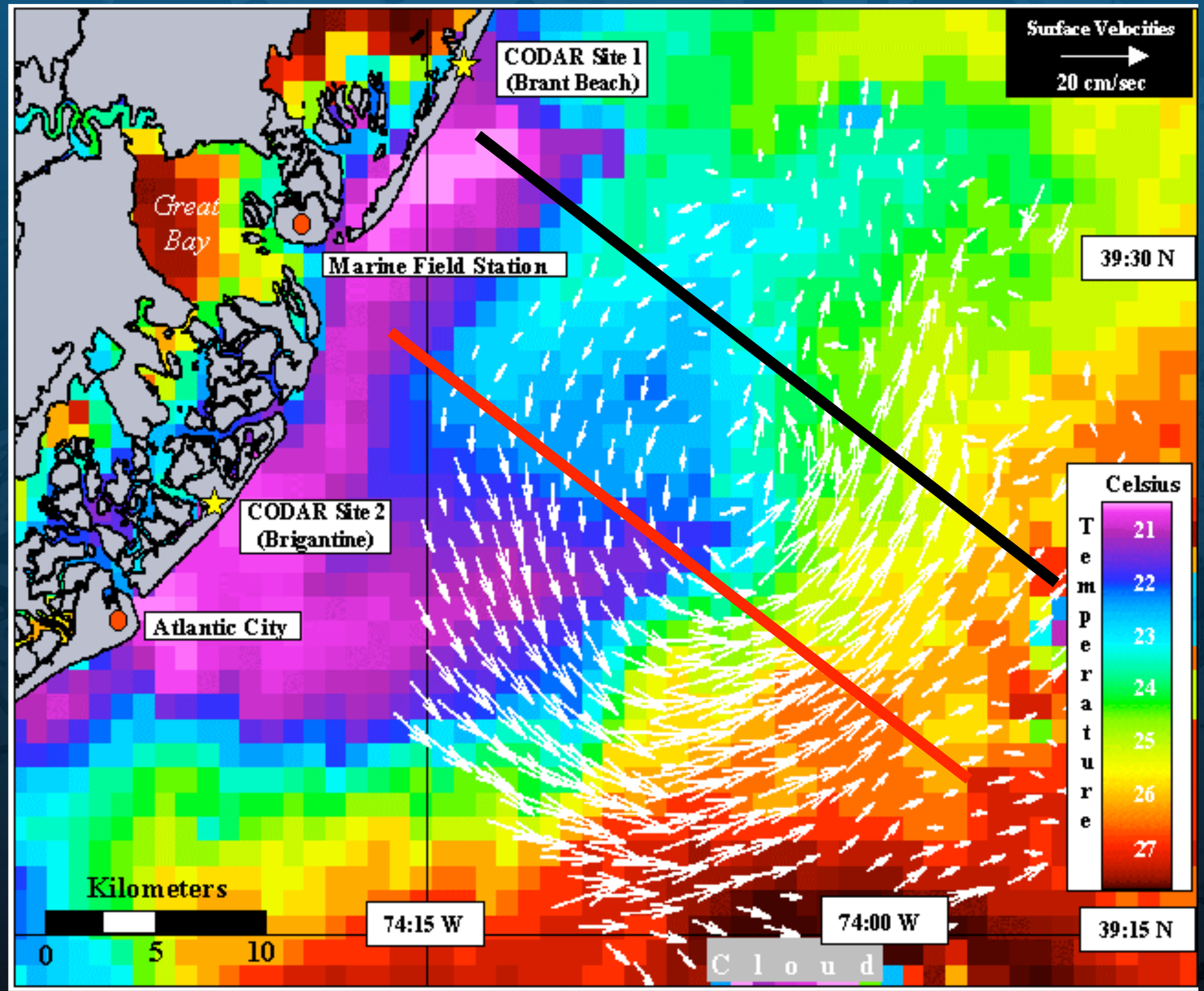


MY2.5

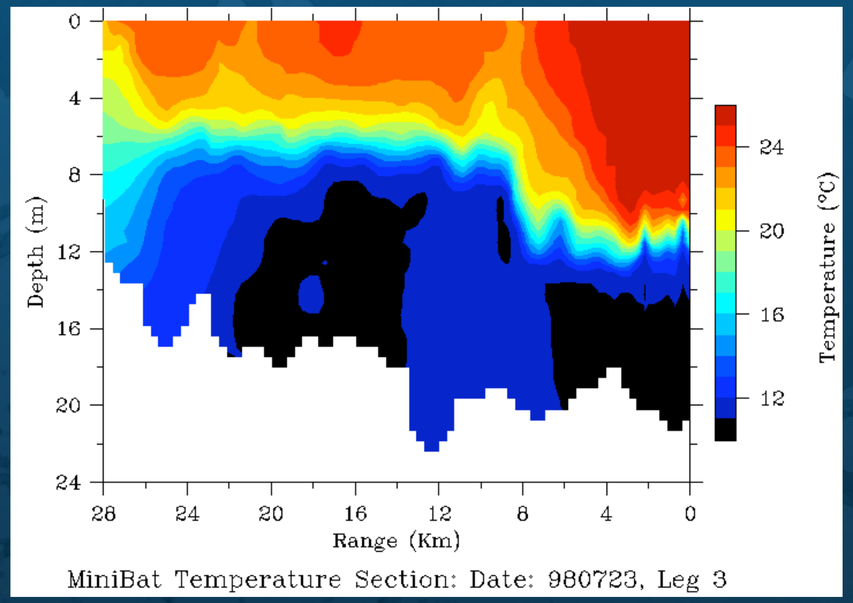
Thermistor

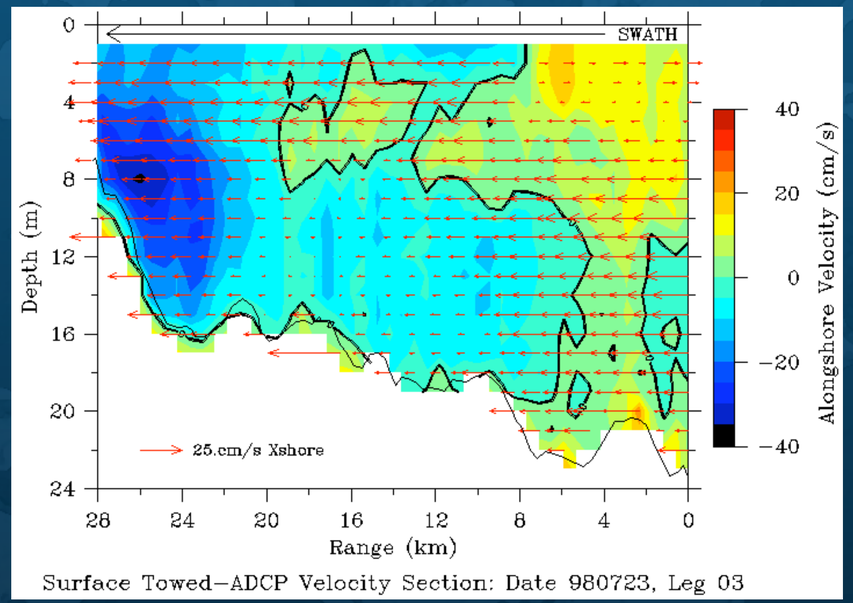


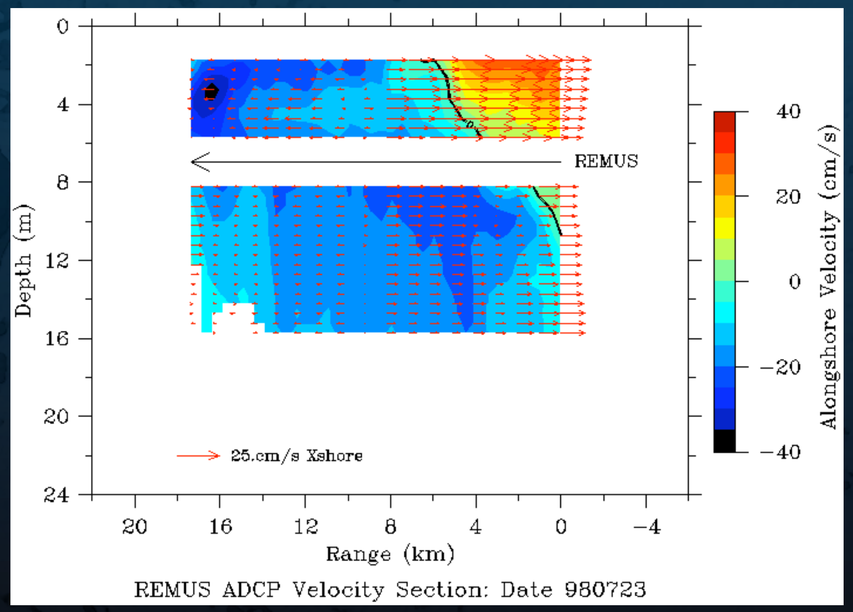
-In an observationally rich environment, ensemble forecasts can be compared to real-time data to assess which model is closer to reality and try to understand why.

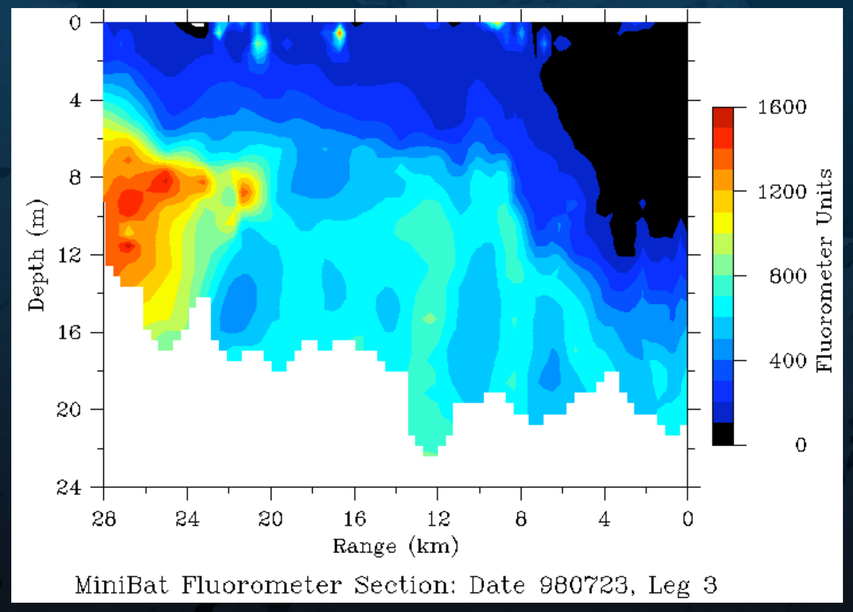

Surface Velocities
20 cm/sec
CODAR Site 1
(Brant Beach)
Great
Bay
Marine Field Station
39:30 N
CODAR Site 2
(Brigantine)
Atlantic City
Celsius
Temperature
21
22
23
24
25
26
27
Kilometers
0
5
10
74:15 W
74:00 W
39:15 N
Cloud

Shipboard surveys

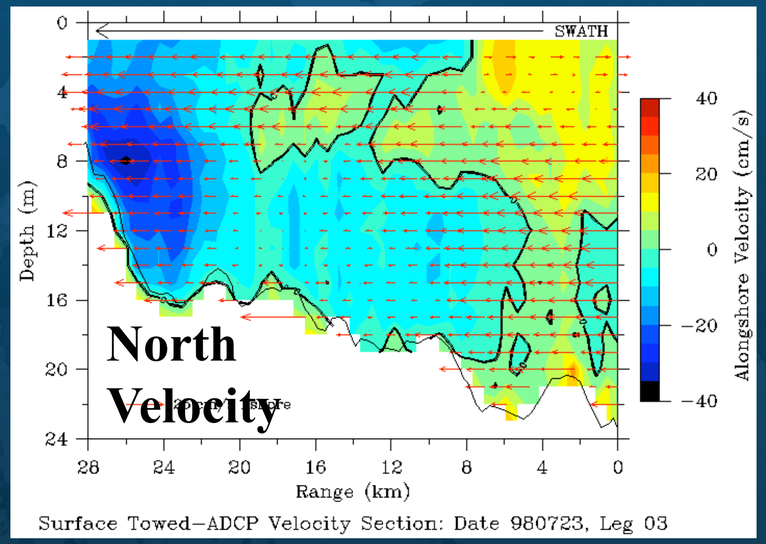


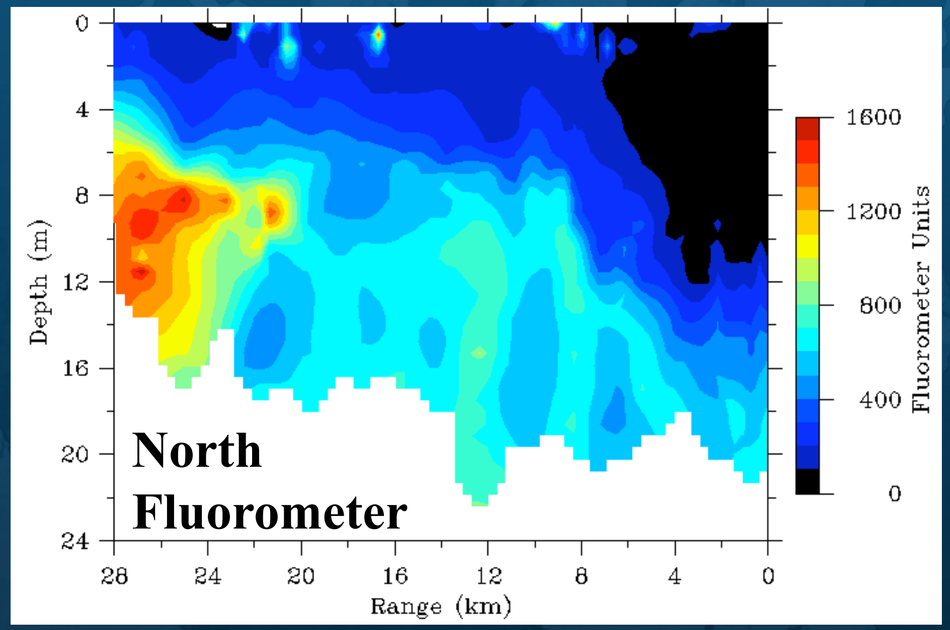


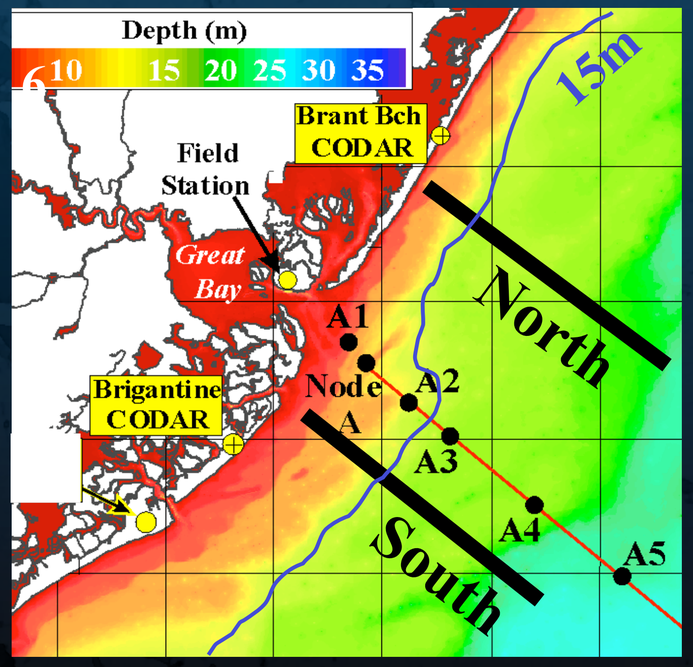


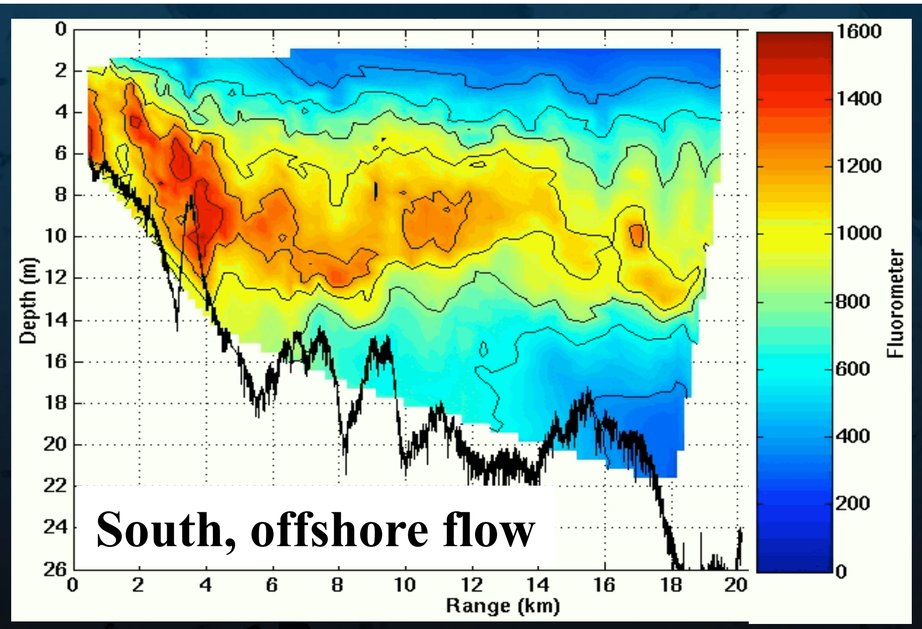


Adaptive Sampling of Resolved Scales- Shipboard & AUV surveys

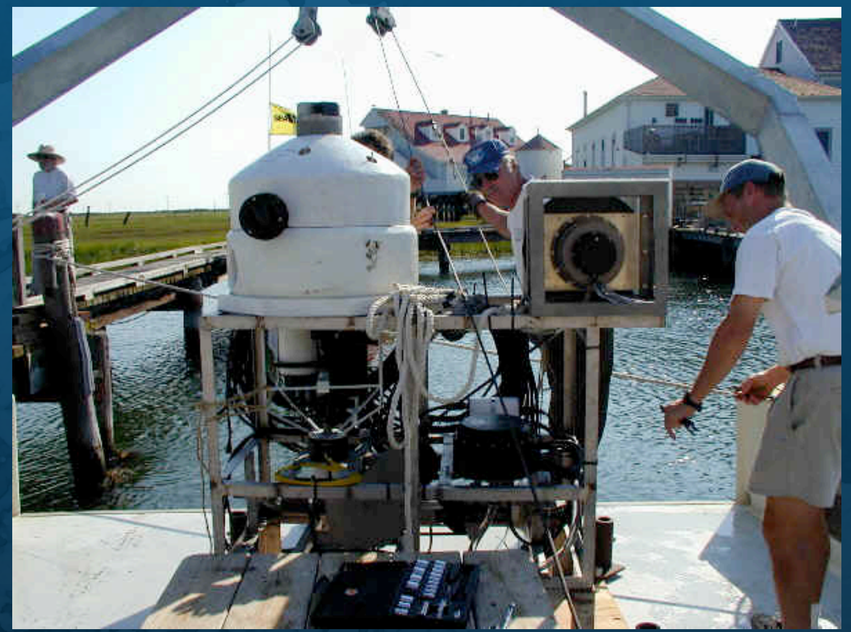




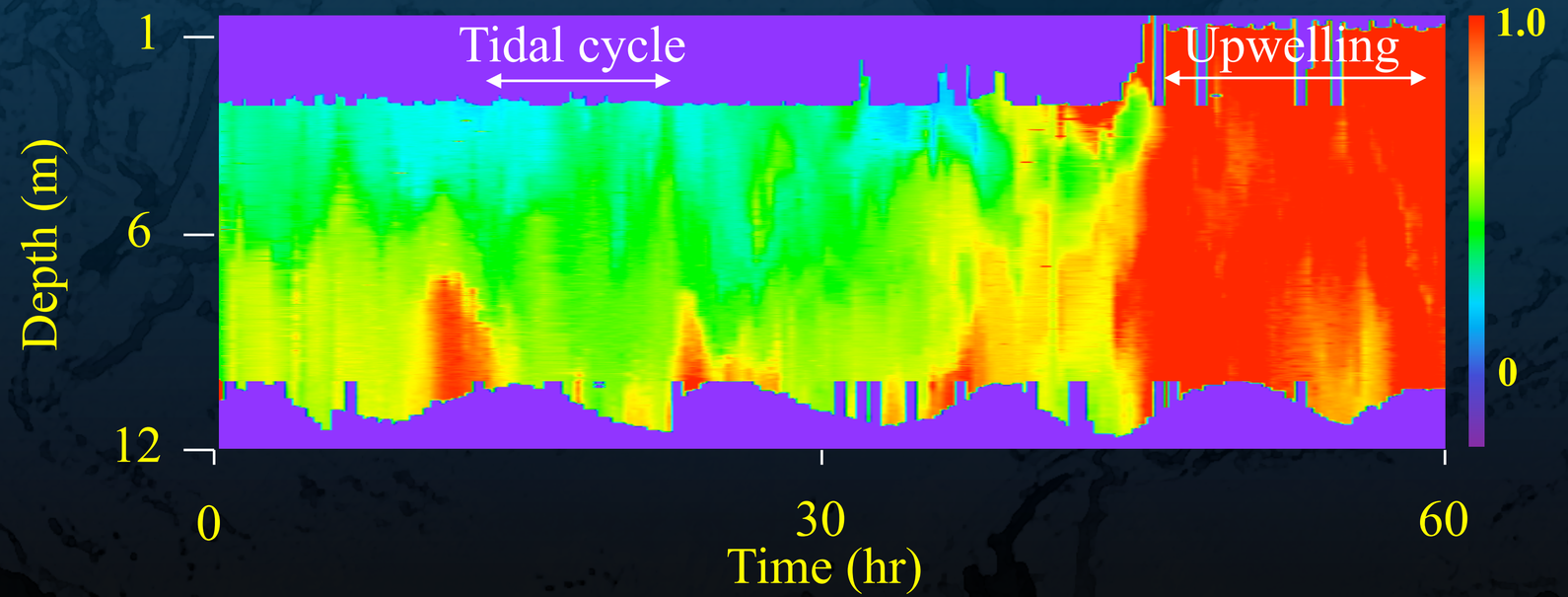




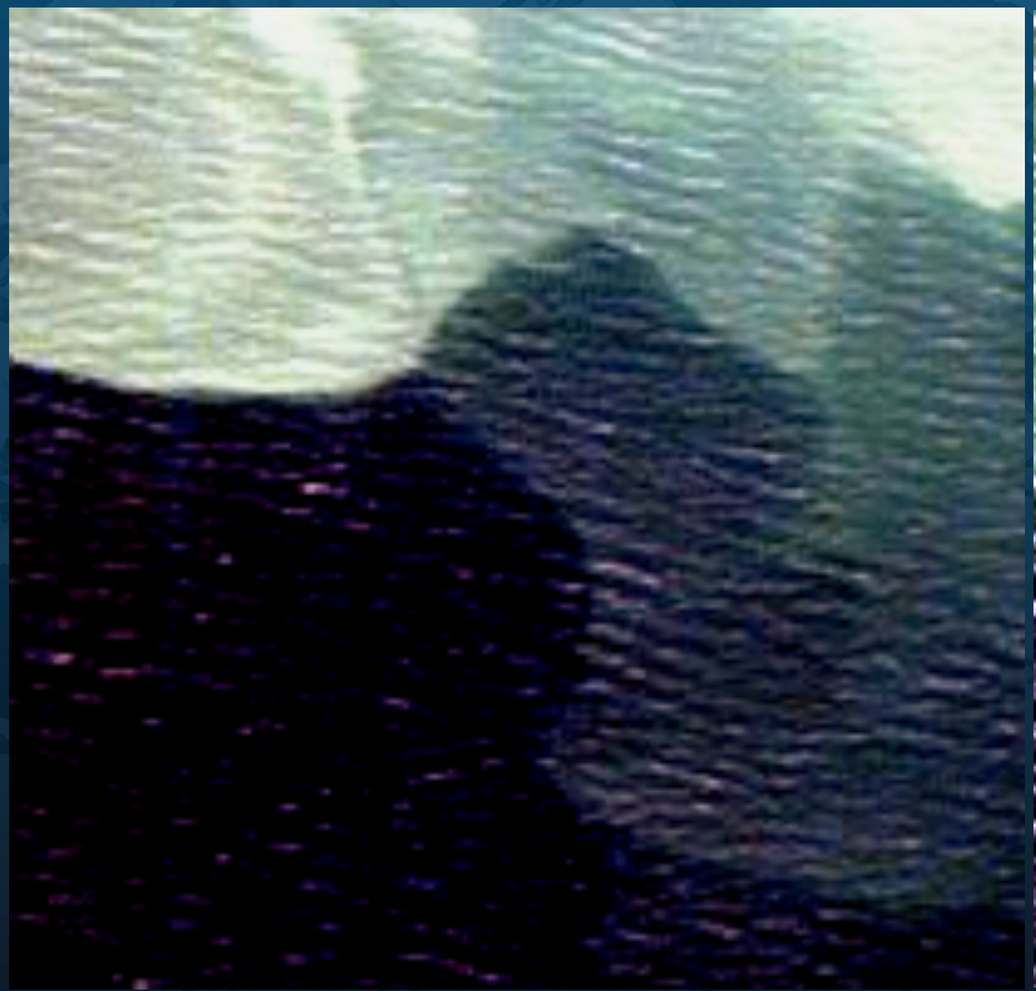
Optical profiler deployed on LEO-15 guest port

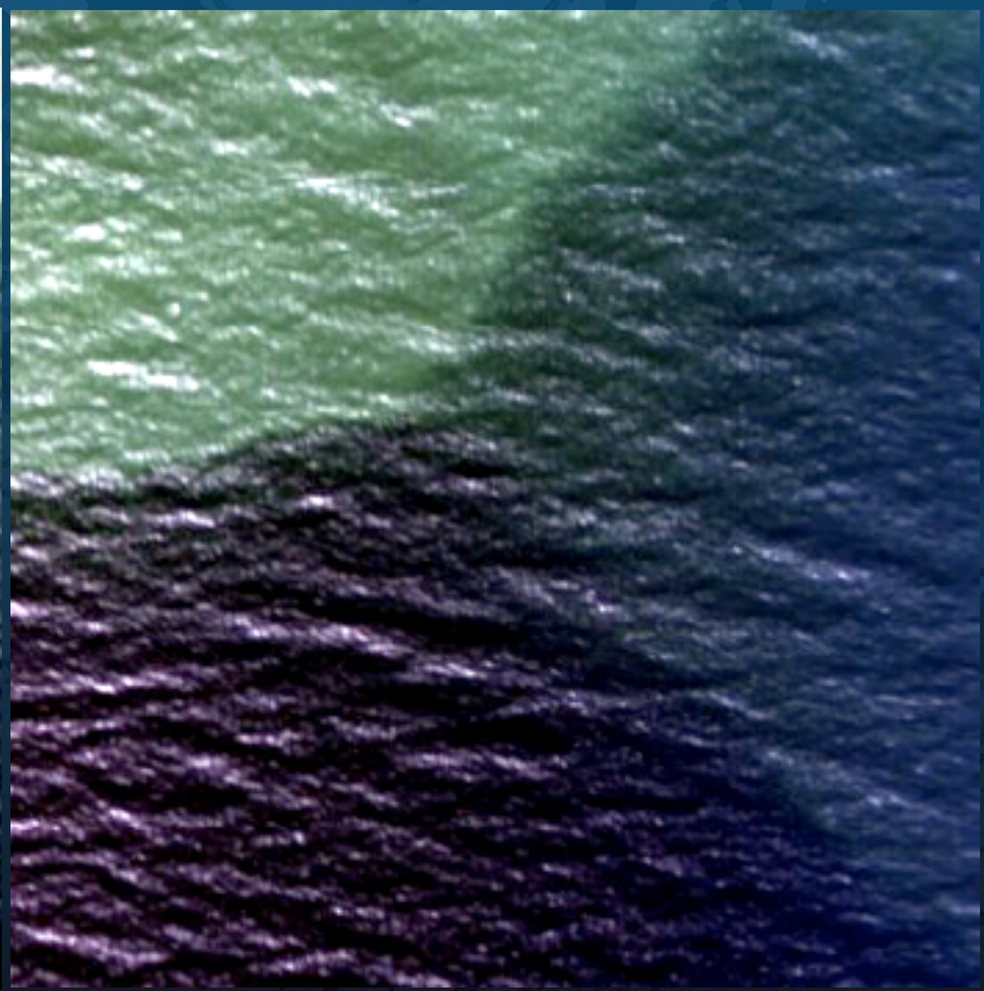


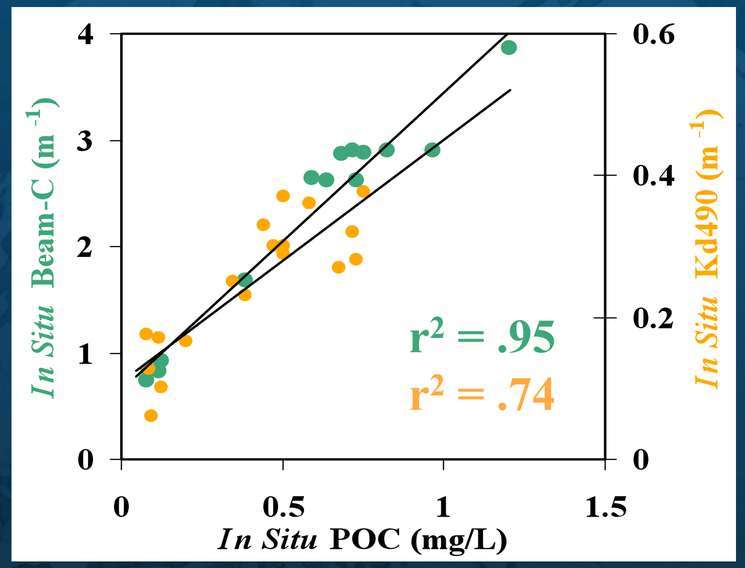
Nerd summer camp



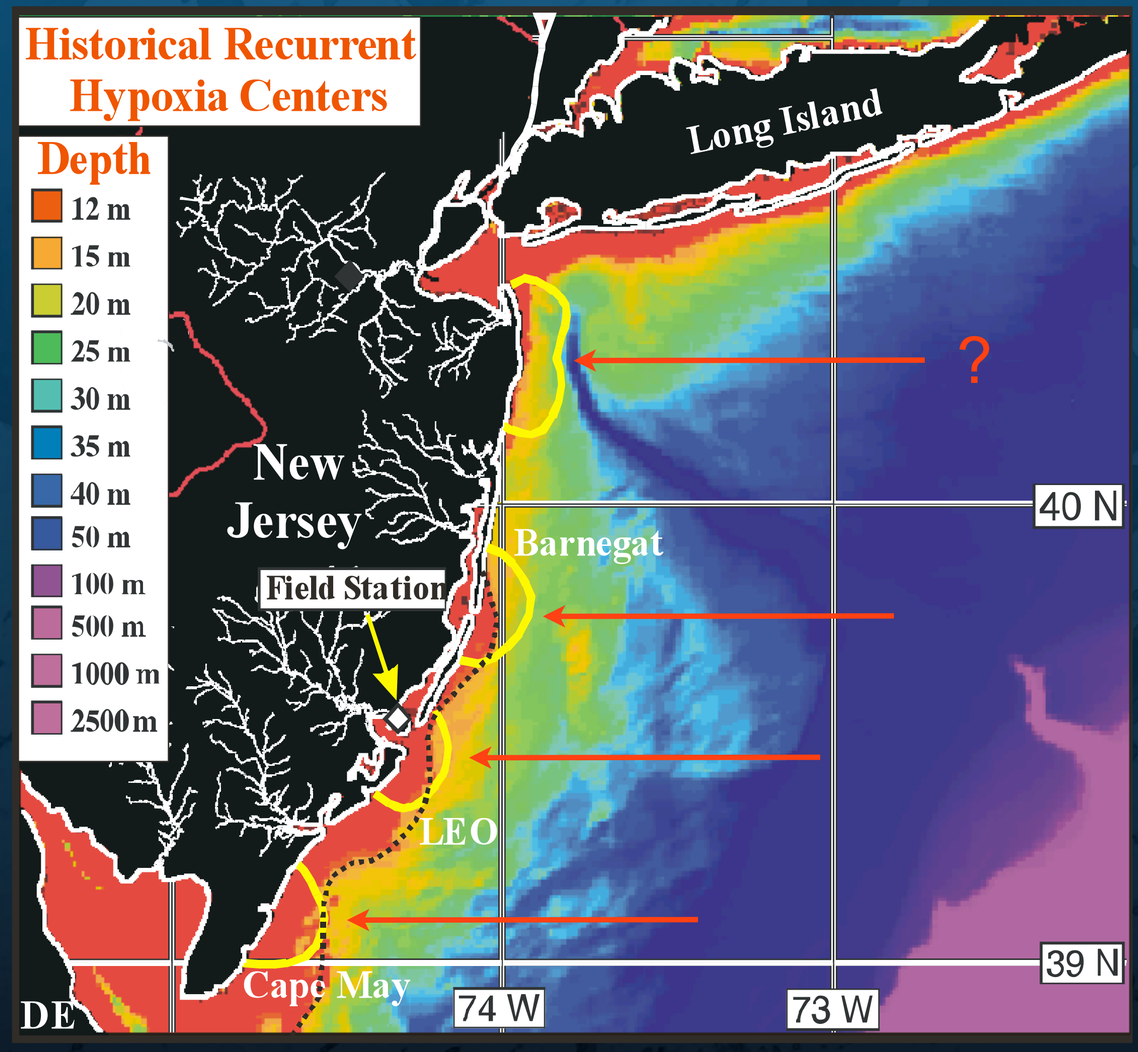
That Pristine Blue NJ Water







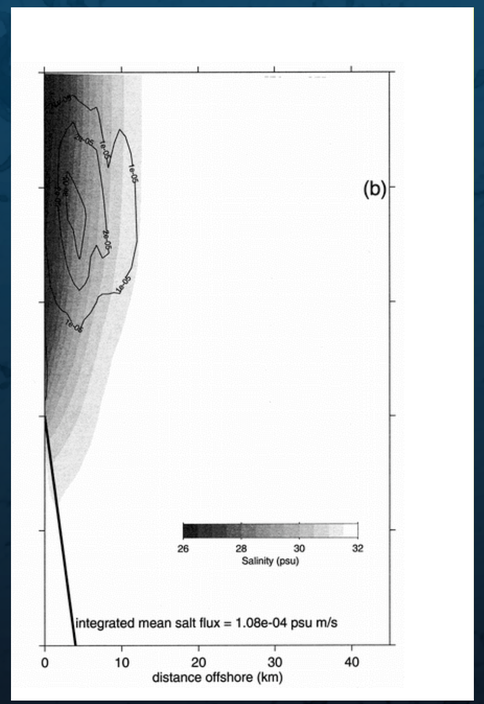
POC represents potentially
182 µmol oxygen/kg
Upwelling can account
For spatially distribution
of recurrent upwelling eddies



What is happening in the northern zone?

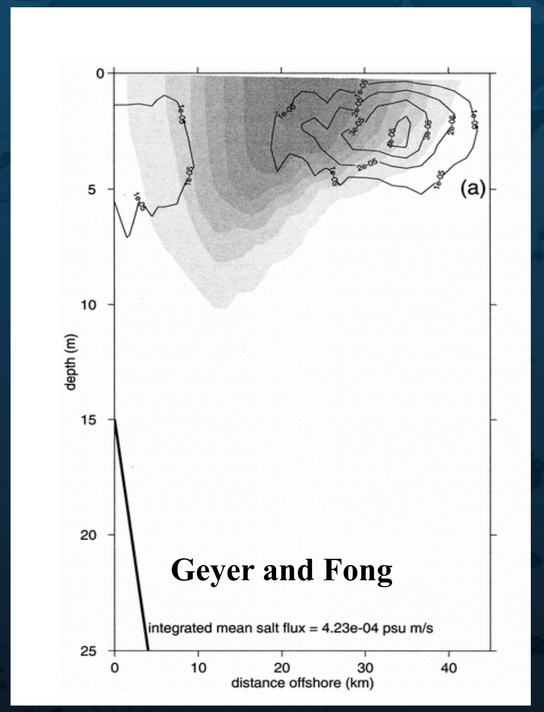
Science focus Land-Ocean: How does the dynamics in the physical oceanography influence the transport and transformation of the particulate and dissolved matter in coastal buoyant plumes?

Downwelling



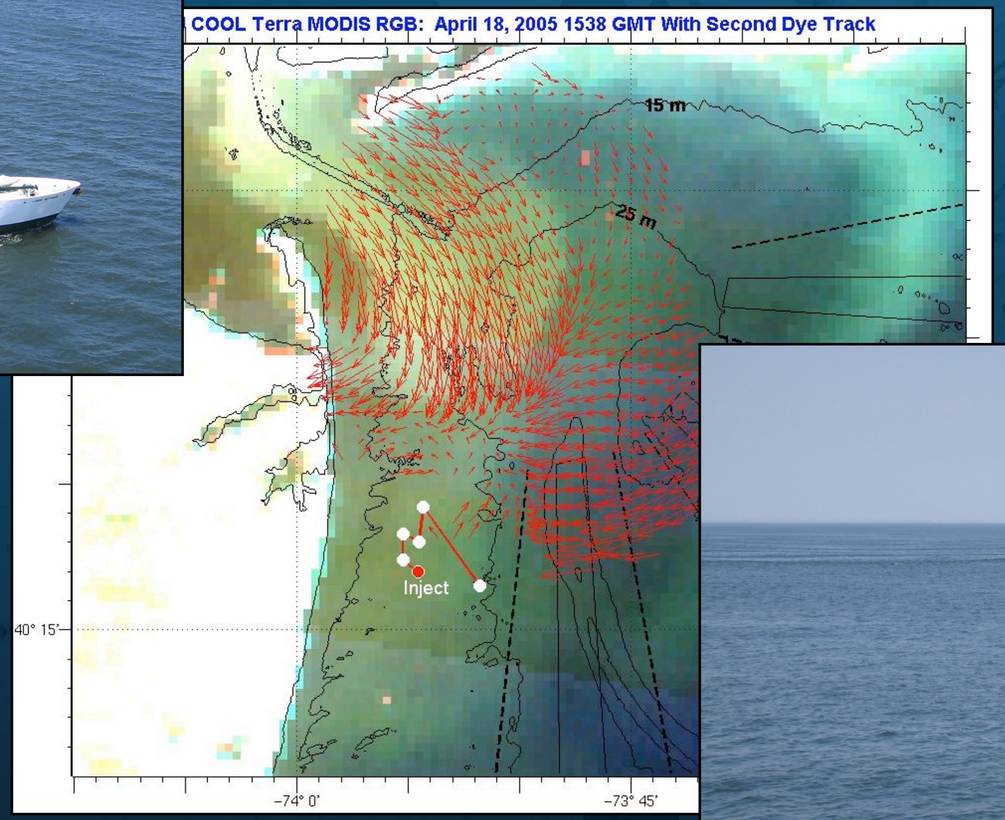
Southern flowing turbid plume

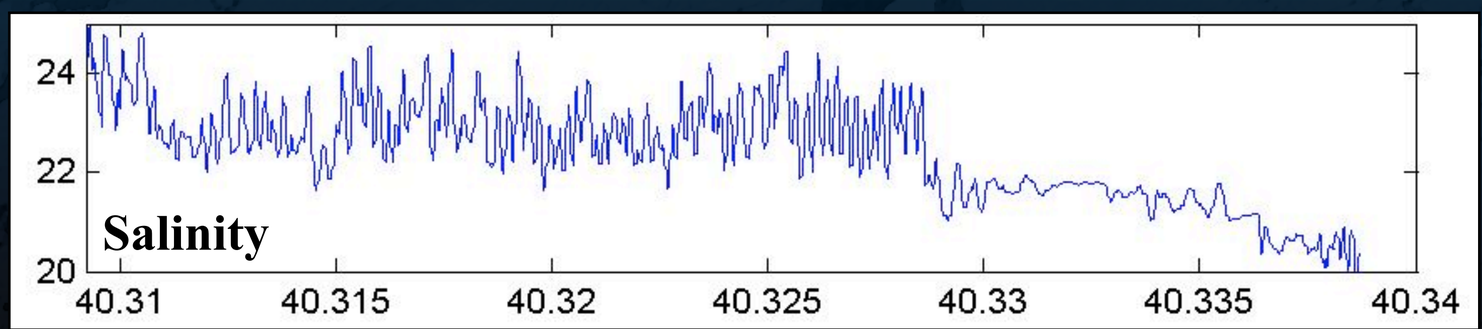
Upwelling



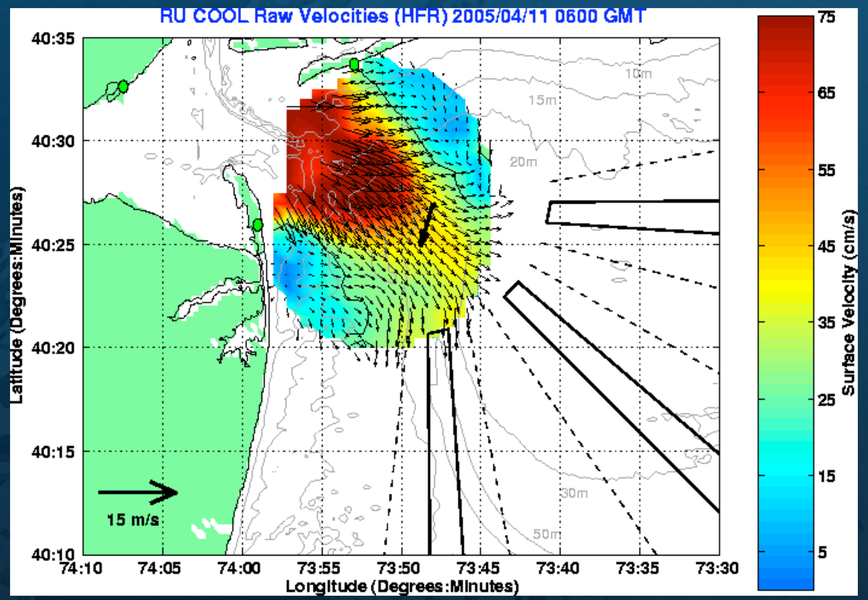
Eastern offshore flowing shallow turbid plume

Input of organic matter is pulsed to coastal system as floods and punctuated tidal squirts. Example, a tidal bore as it flows past the R/V Cape Hatteras



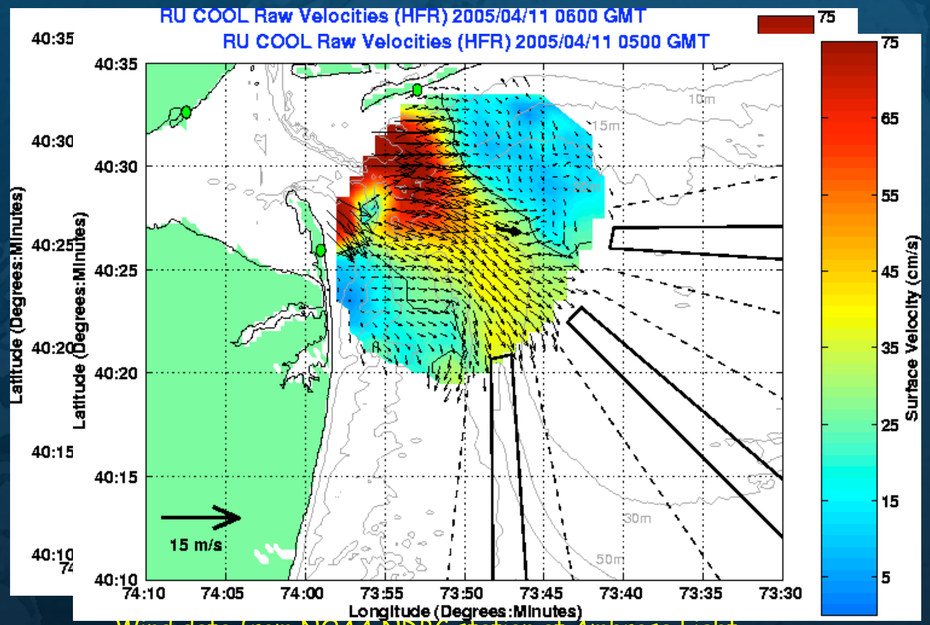


HF RADAR tracking and dye labeling of plume



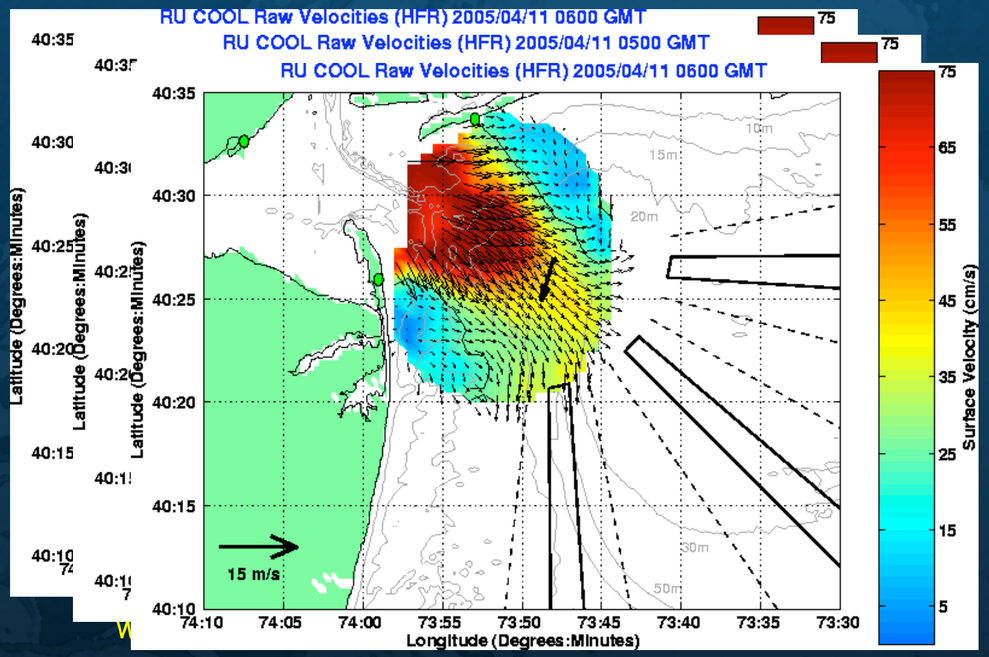
Wind data from NOAA NDBC station at Ambrose Light

HF RADAR tracking and dye labeling of plume

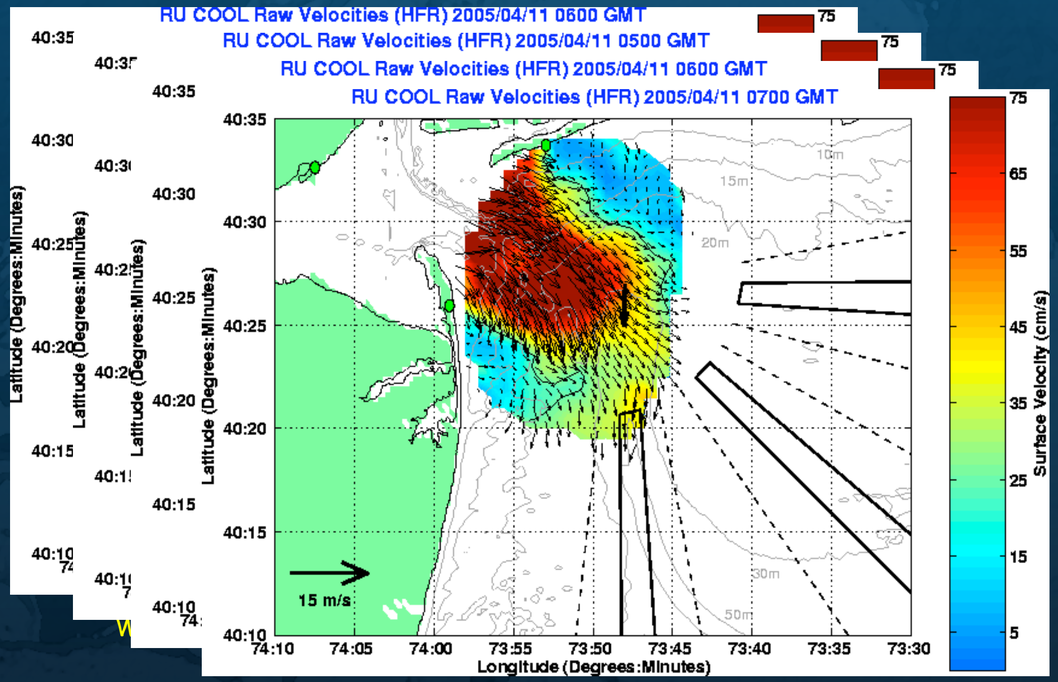


Wind data from NOAA NDBC station at Ambrose Light

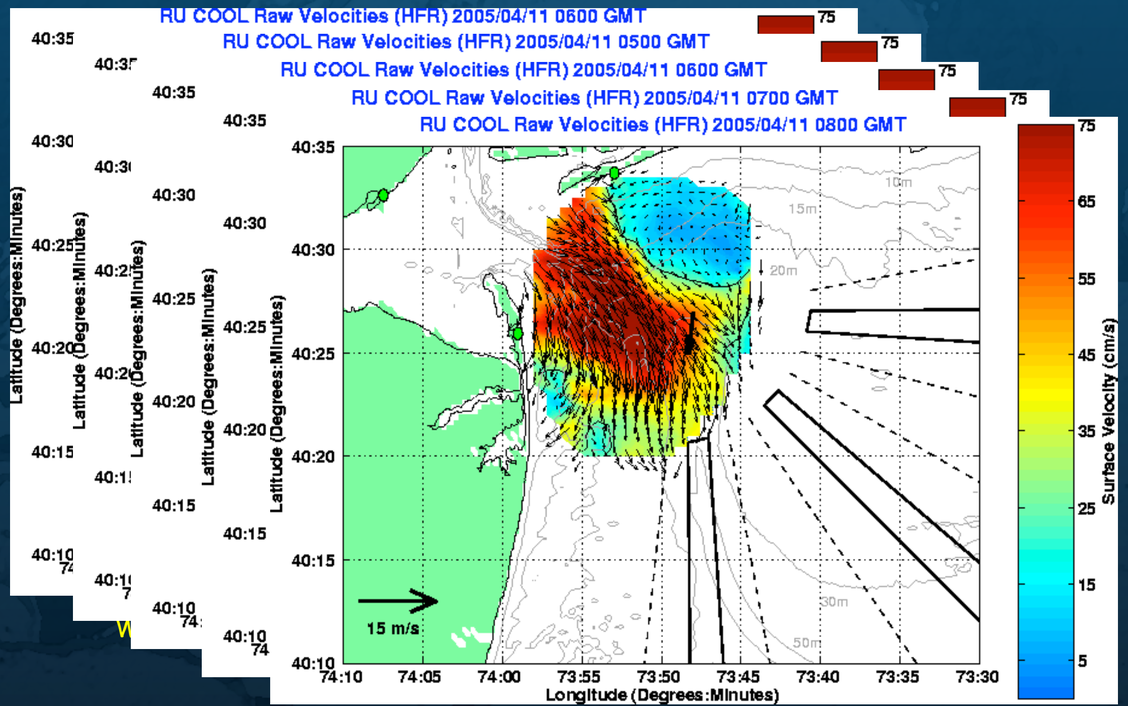
HF RADAR tracking and dye labeling of plume



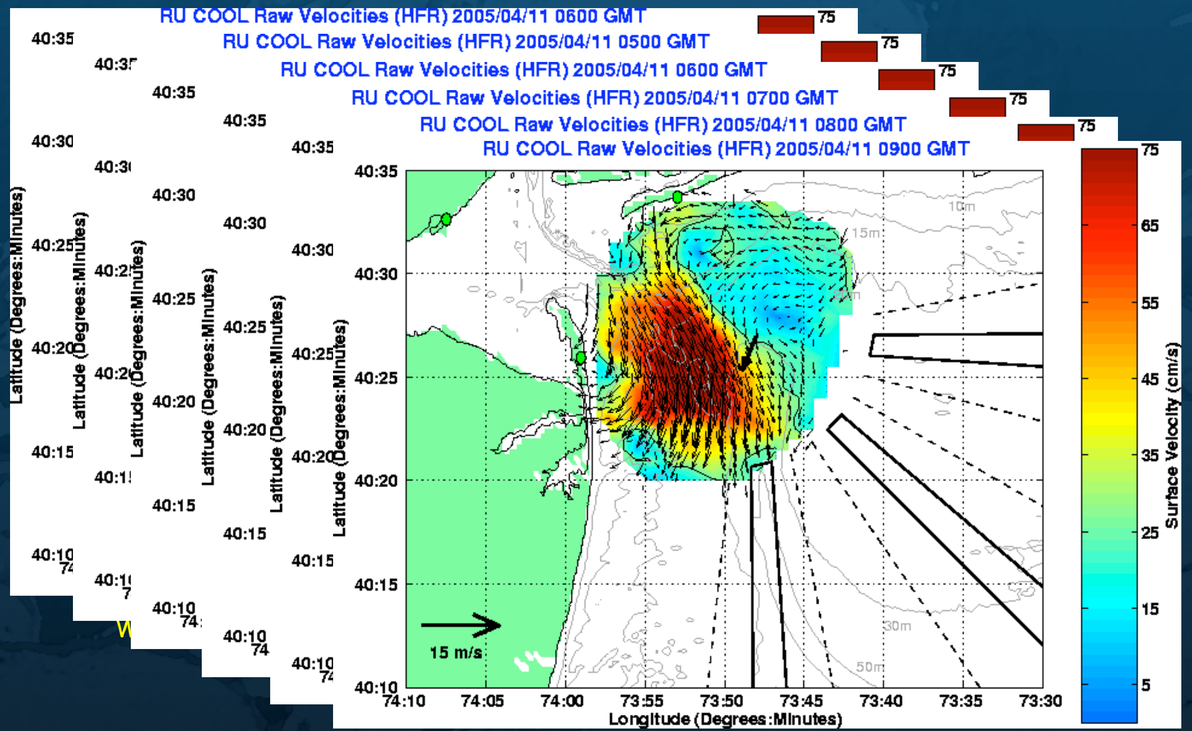
HF RADAR tracking and dye labeling of plume



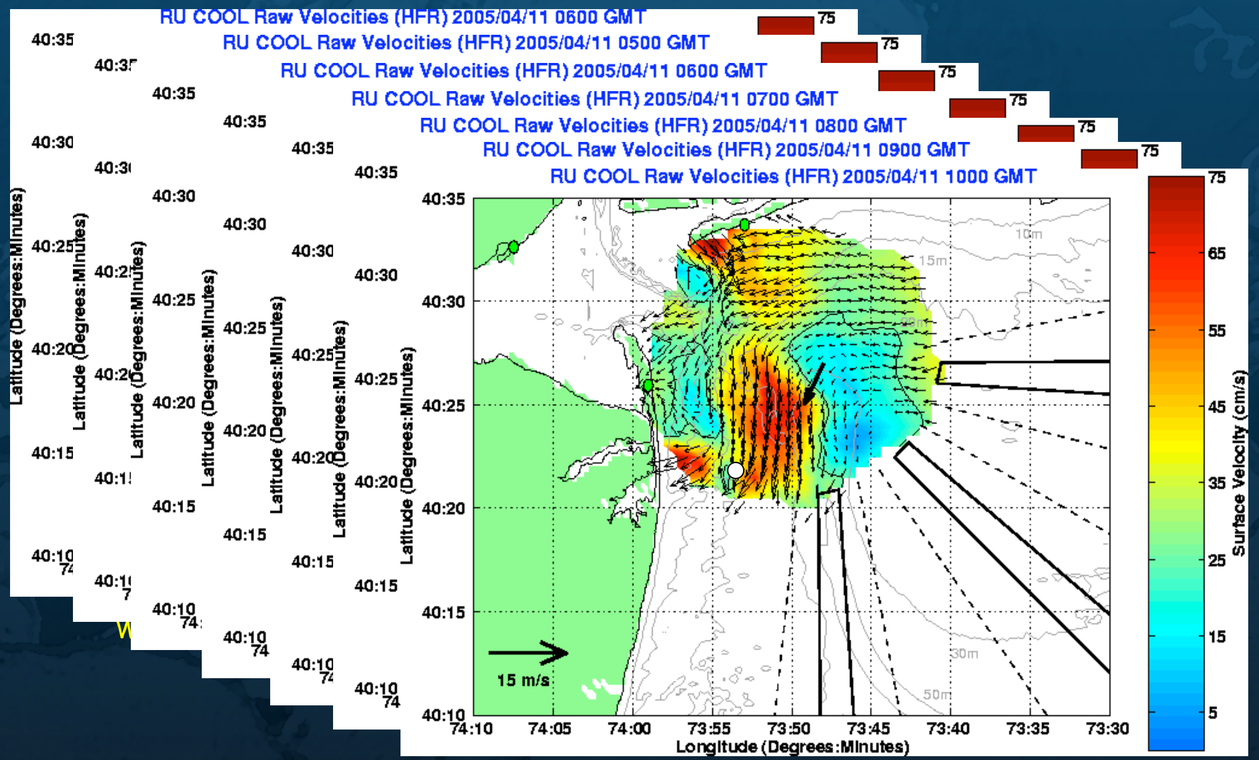
HF RADAR tracking and dye labeling of plume



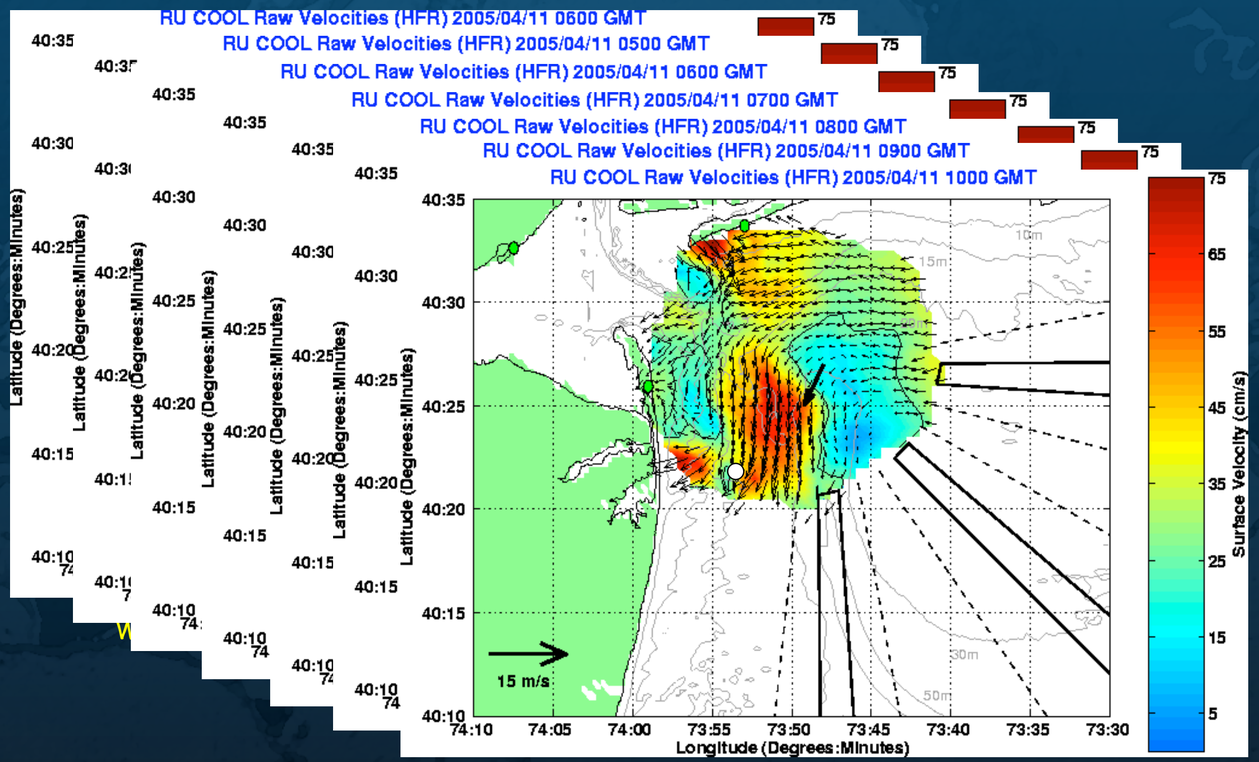
HF RADAR tracking and dye labeling of plume

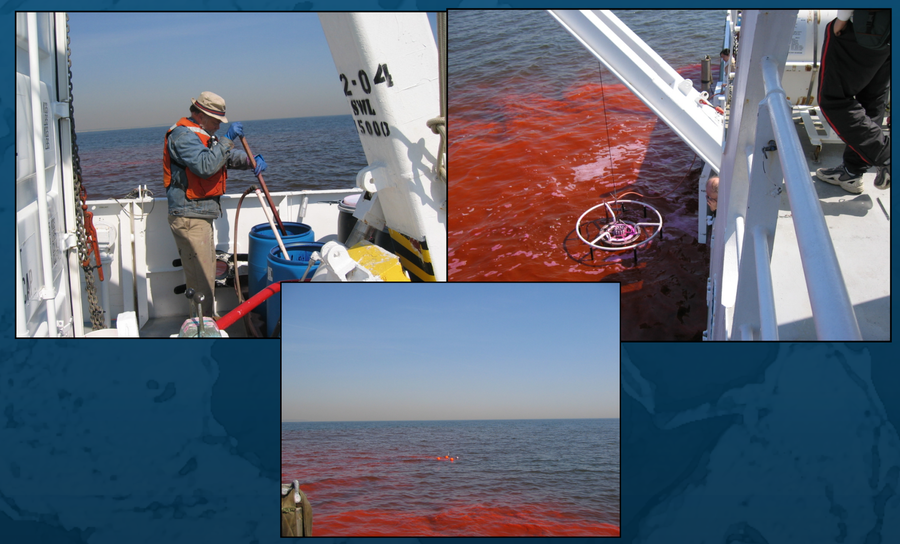


HF RADAR tracking and dye labeling of plume

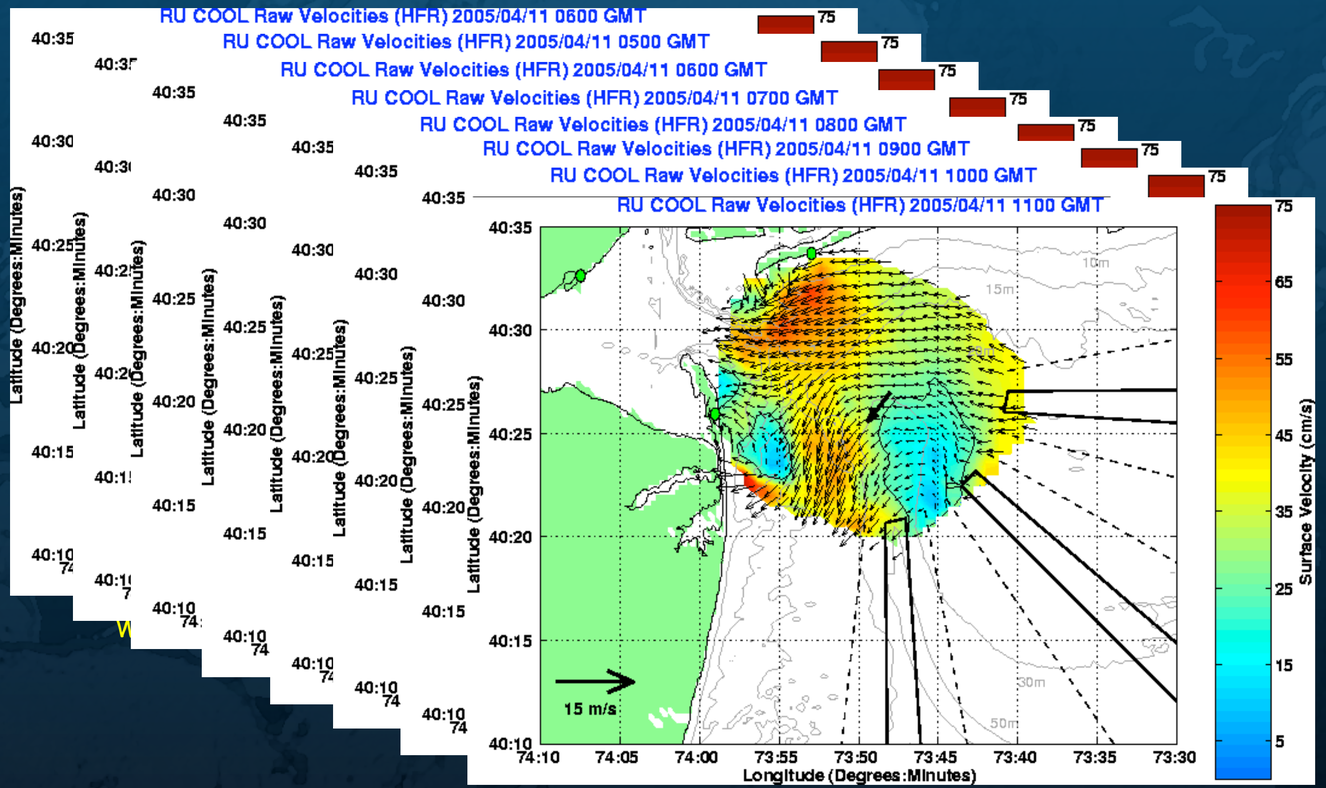


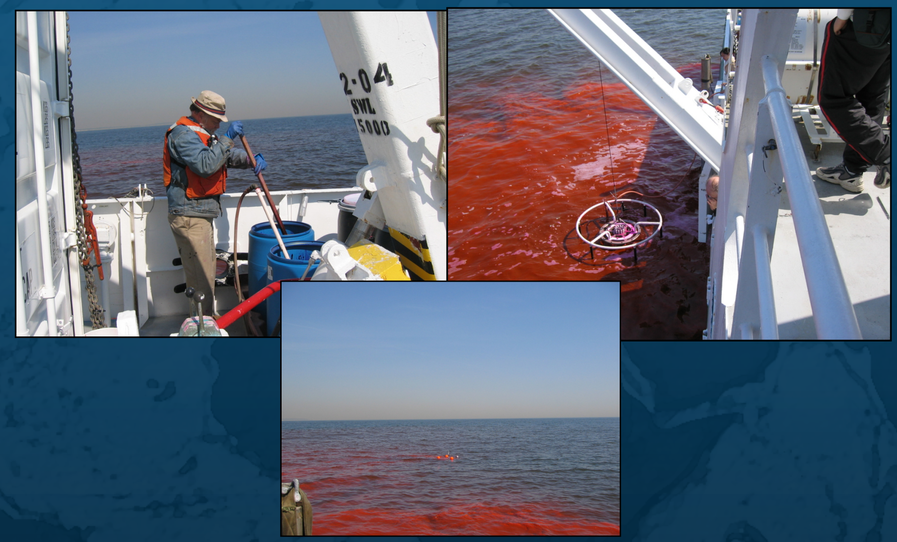
HF RADAR tracking and dye labeling of plume





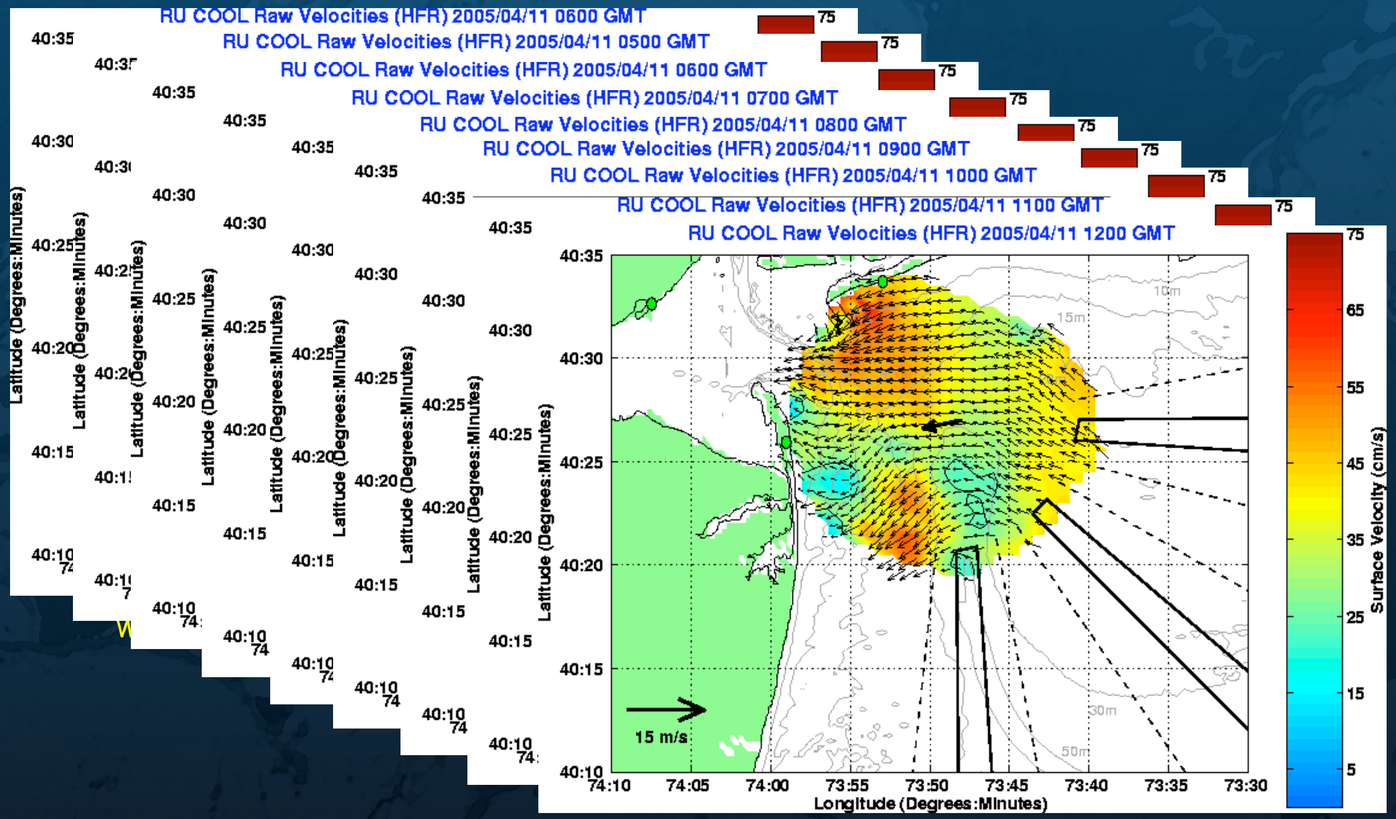
HF RADAR tracking and dye labeling of plume



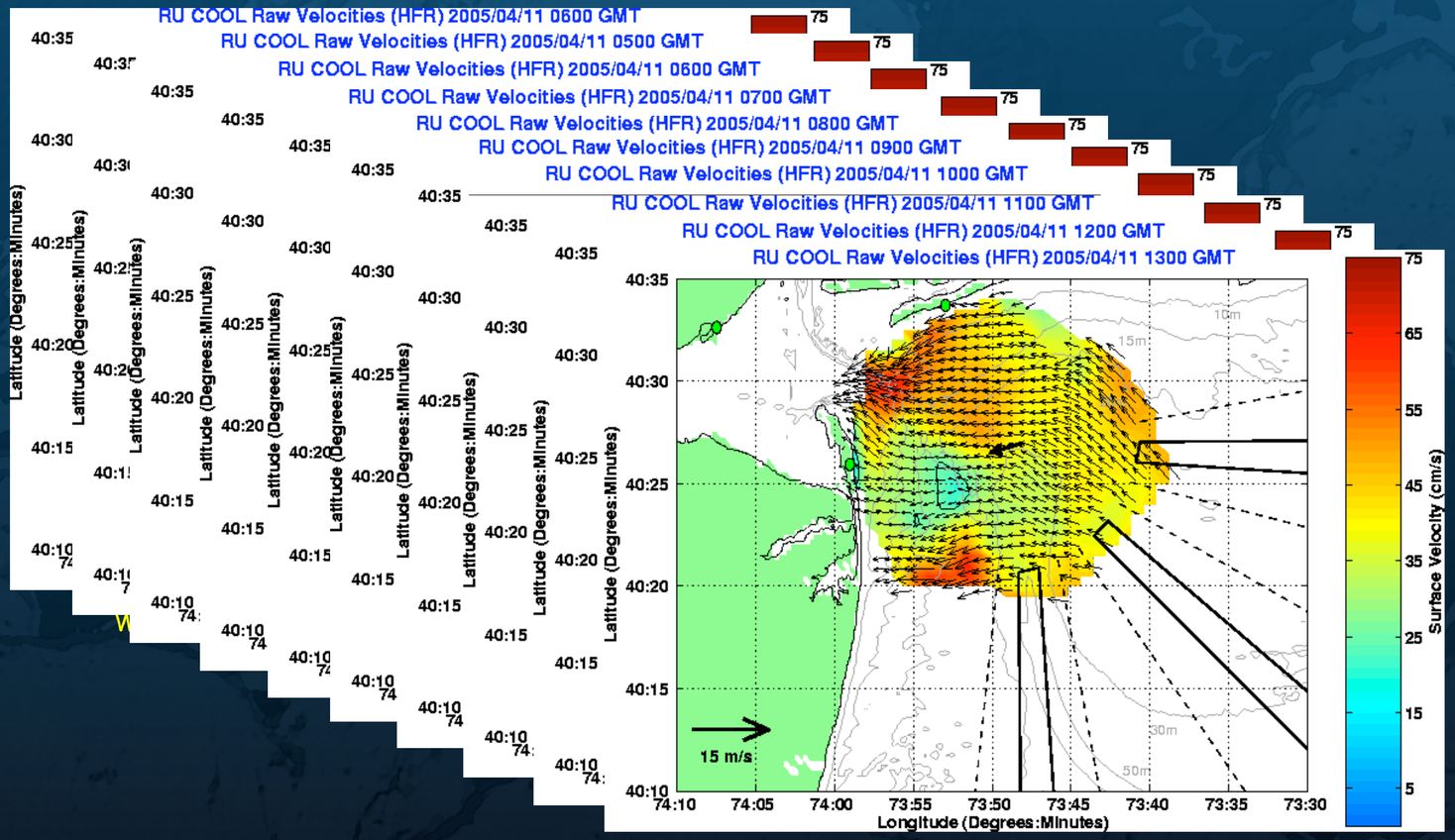


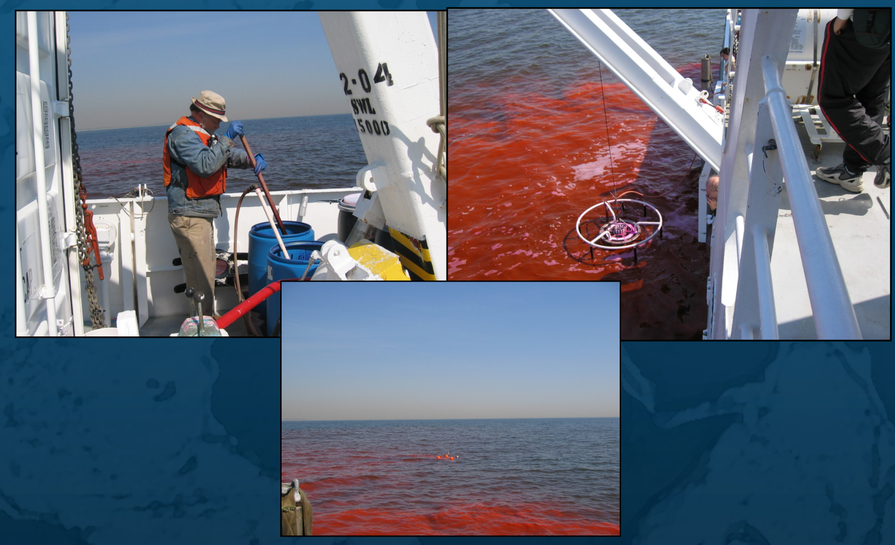
Friday, July 1, 2011

HF RADAR tracking and dye labeling of plume

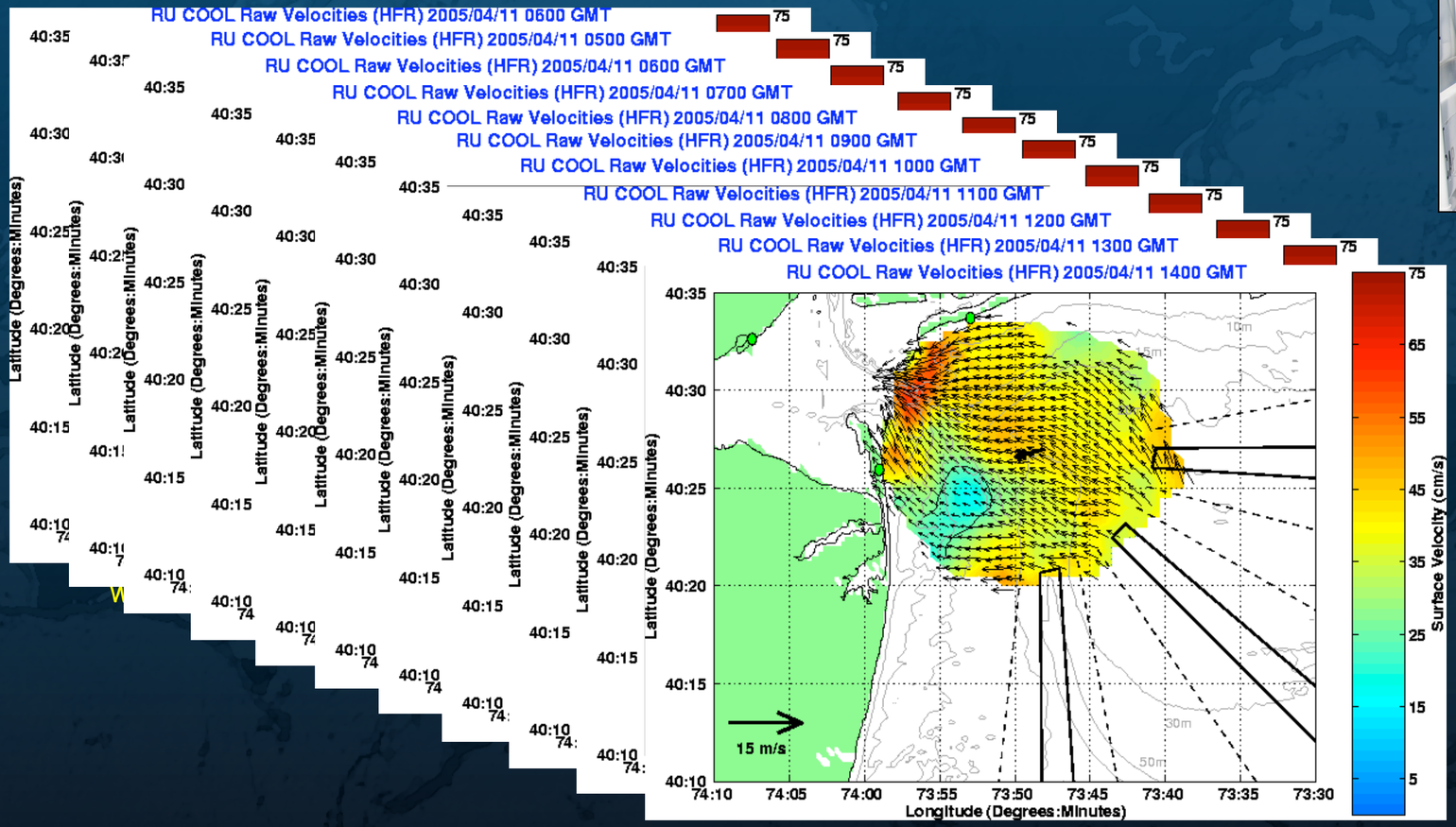


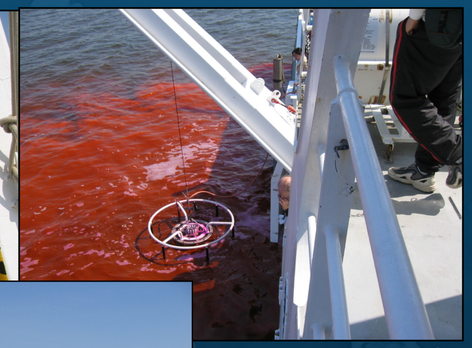
HF RADAR tracking and dye labeling of plume



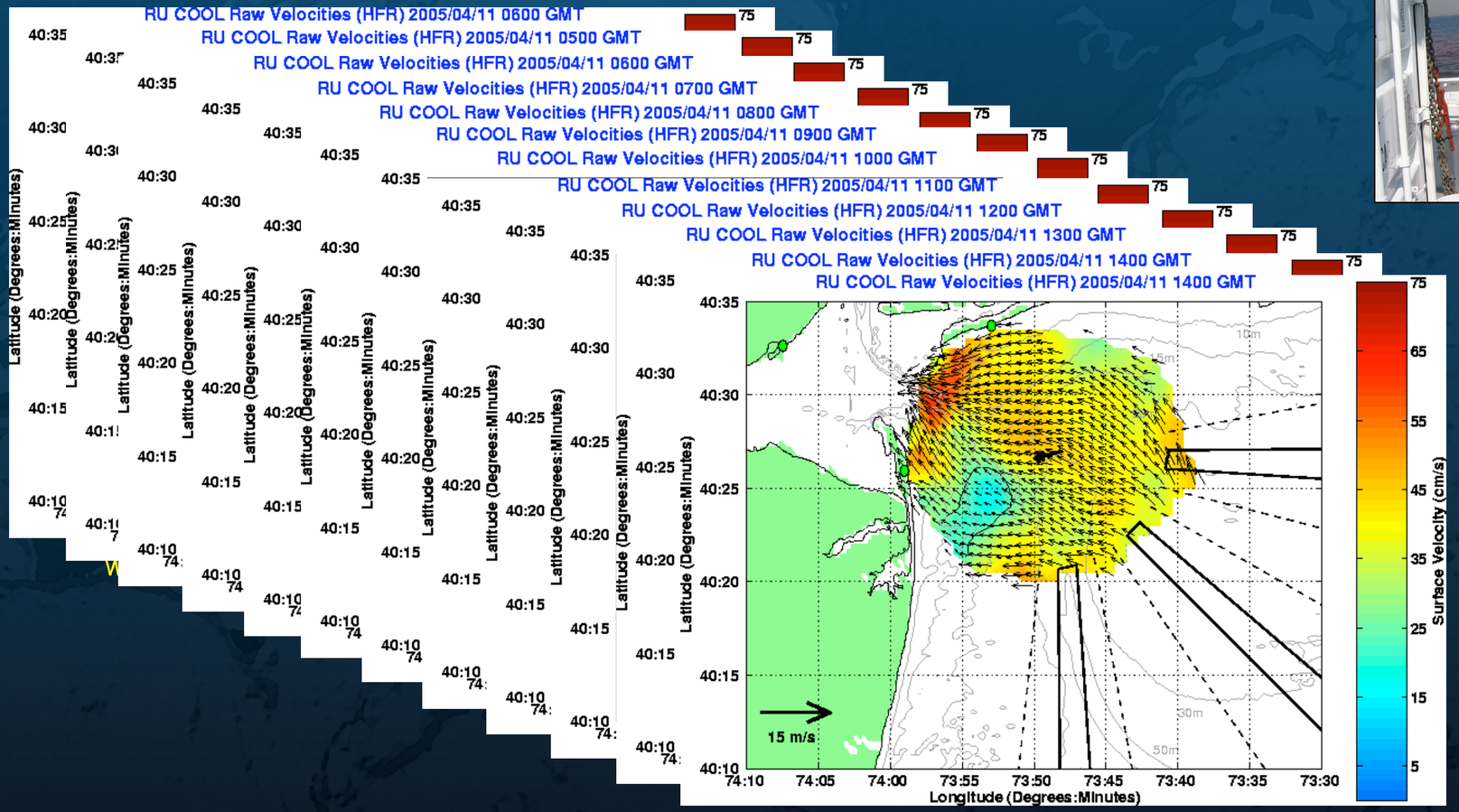


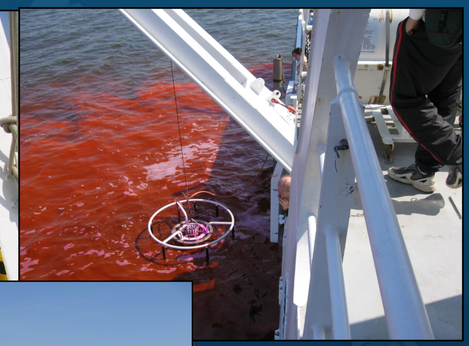
HF RADAR tracking and dye labeling of plume



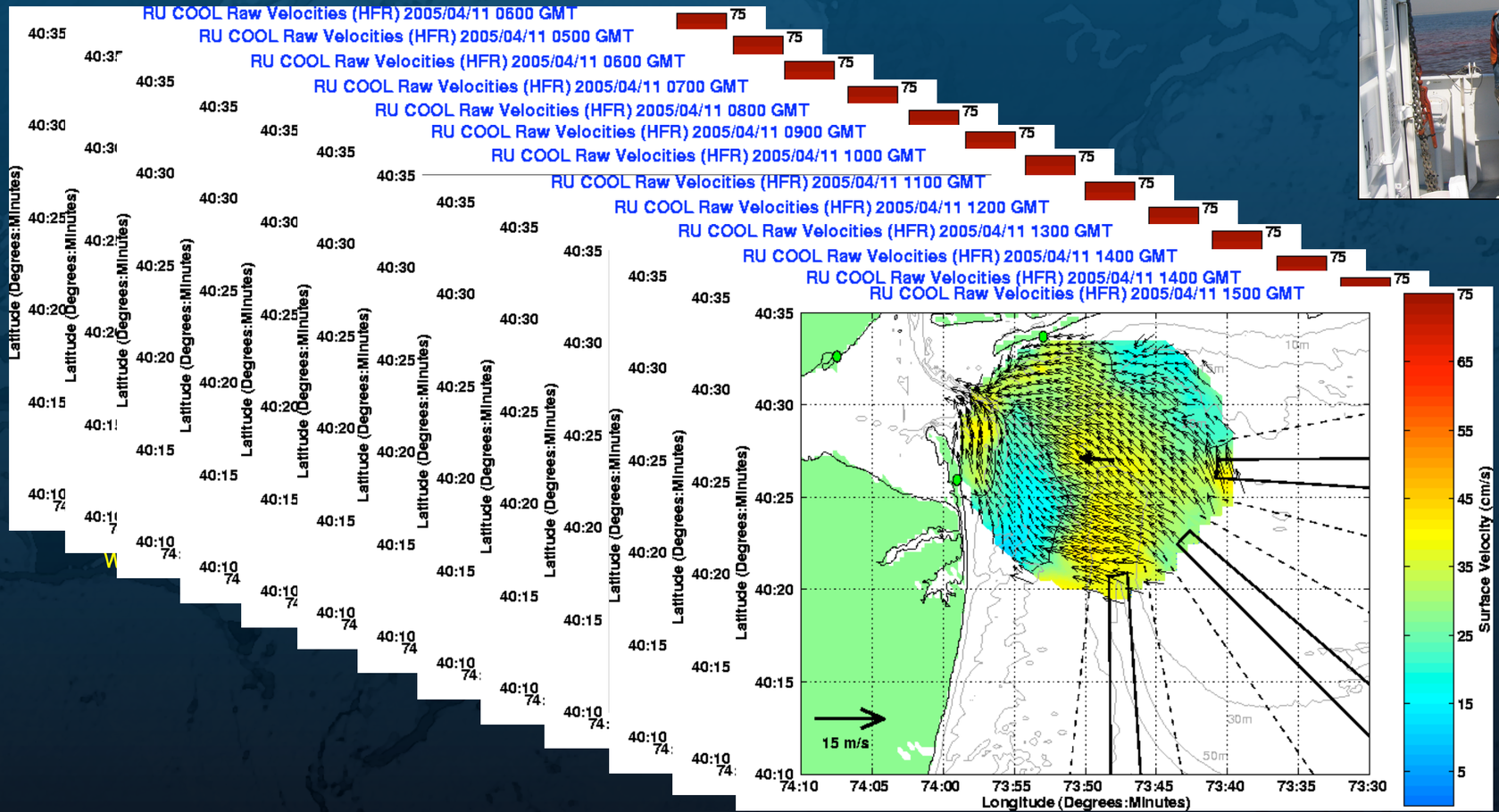


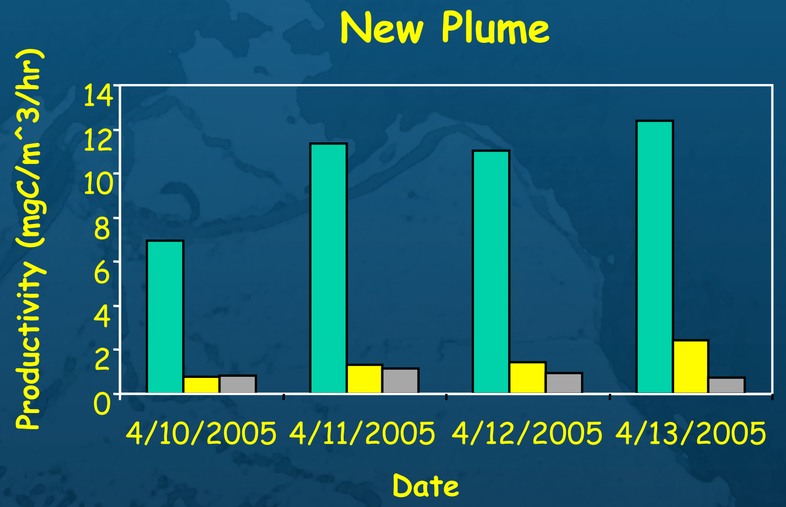
HF RADAR tracking and dye labeling of plume

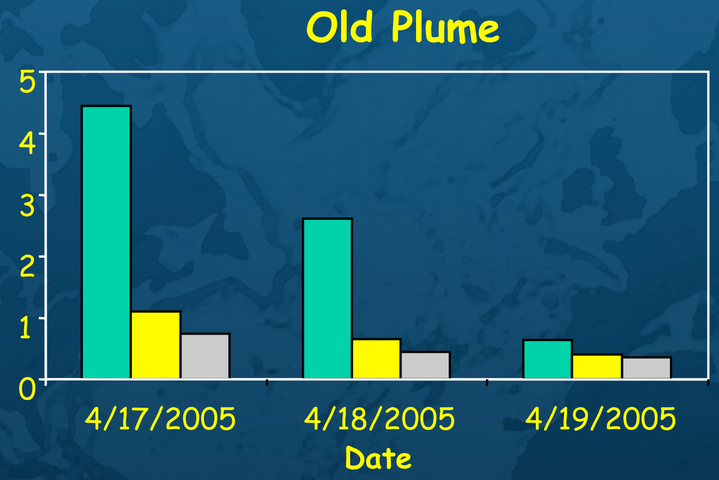


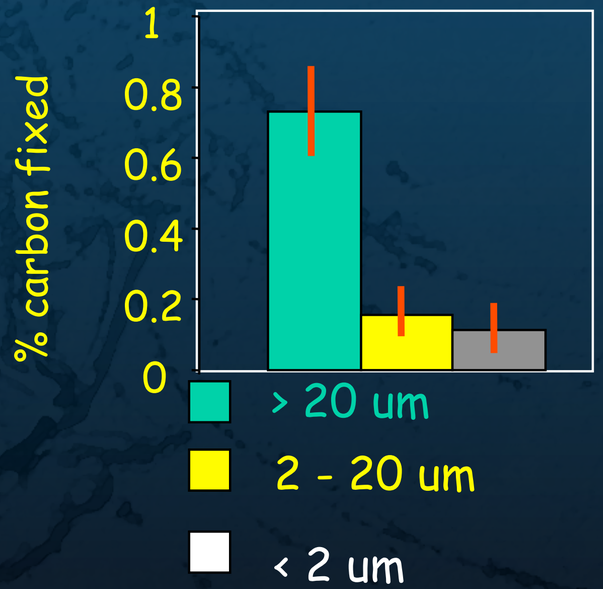


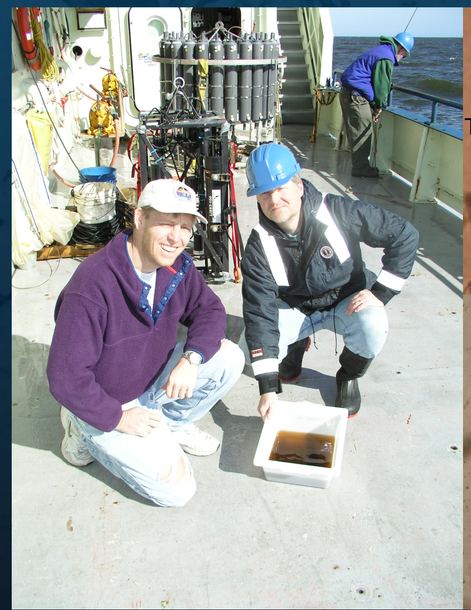
HF RADAR tracking and dye labeling of plume



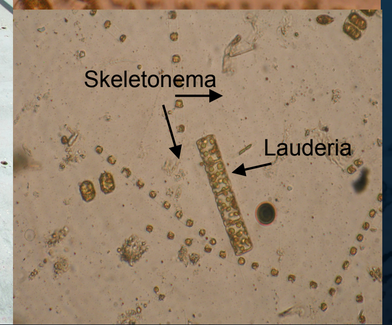

New Plume
Productivity (mgC/m^3/hr)
14
12
10
8
6
4
2
0
4/10/2005
4/11/2005
4/12/2005
4/13/2005
Date

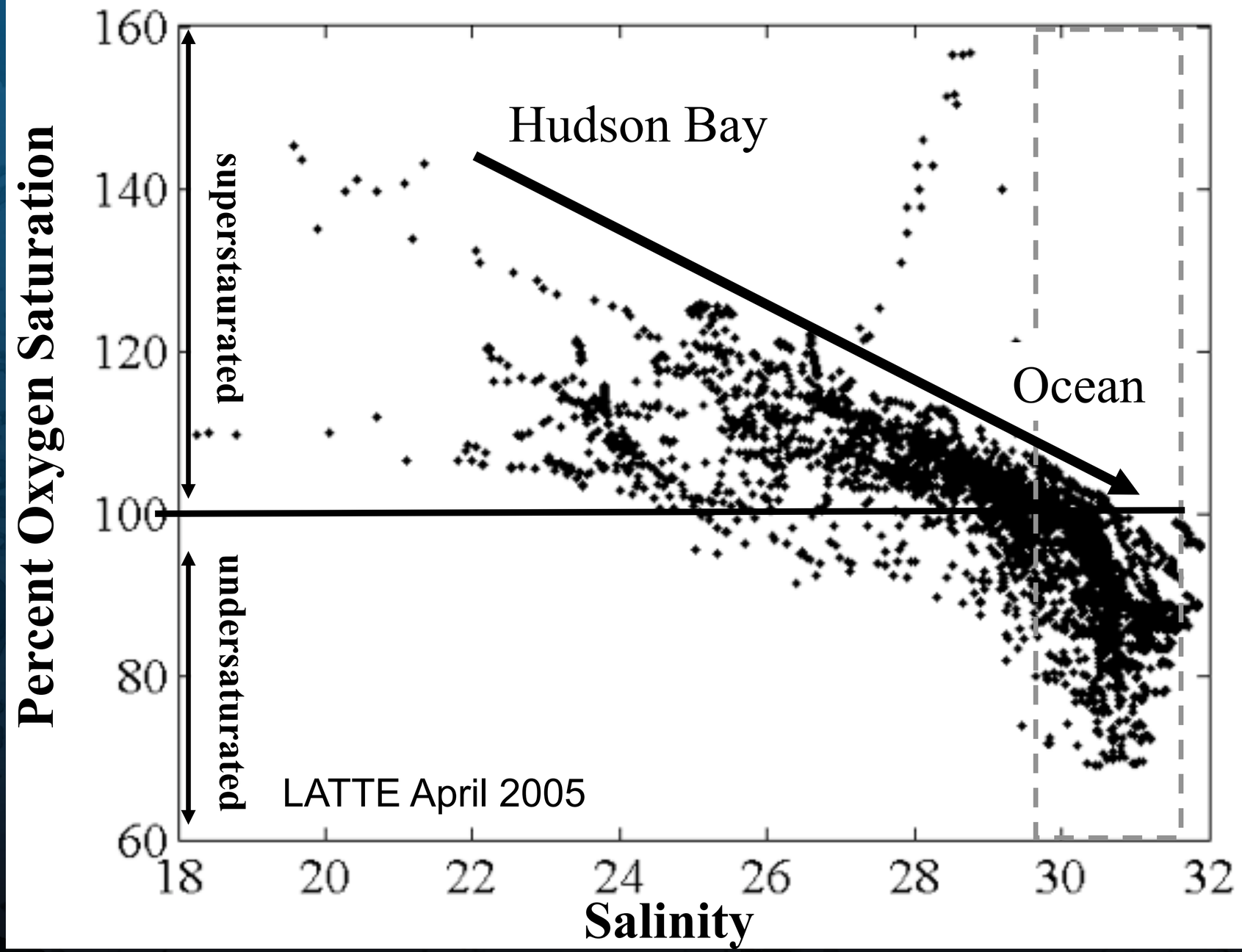

Old Plume
5
4
3
2
1
0
4/17/2005
4/18/2005
4/19/2005
Date


% carbon fixed
1
0.8
0.6
0.4
0.2
0
> 20 um
2 - 20 um
< 2 um



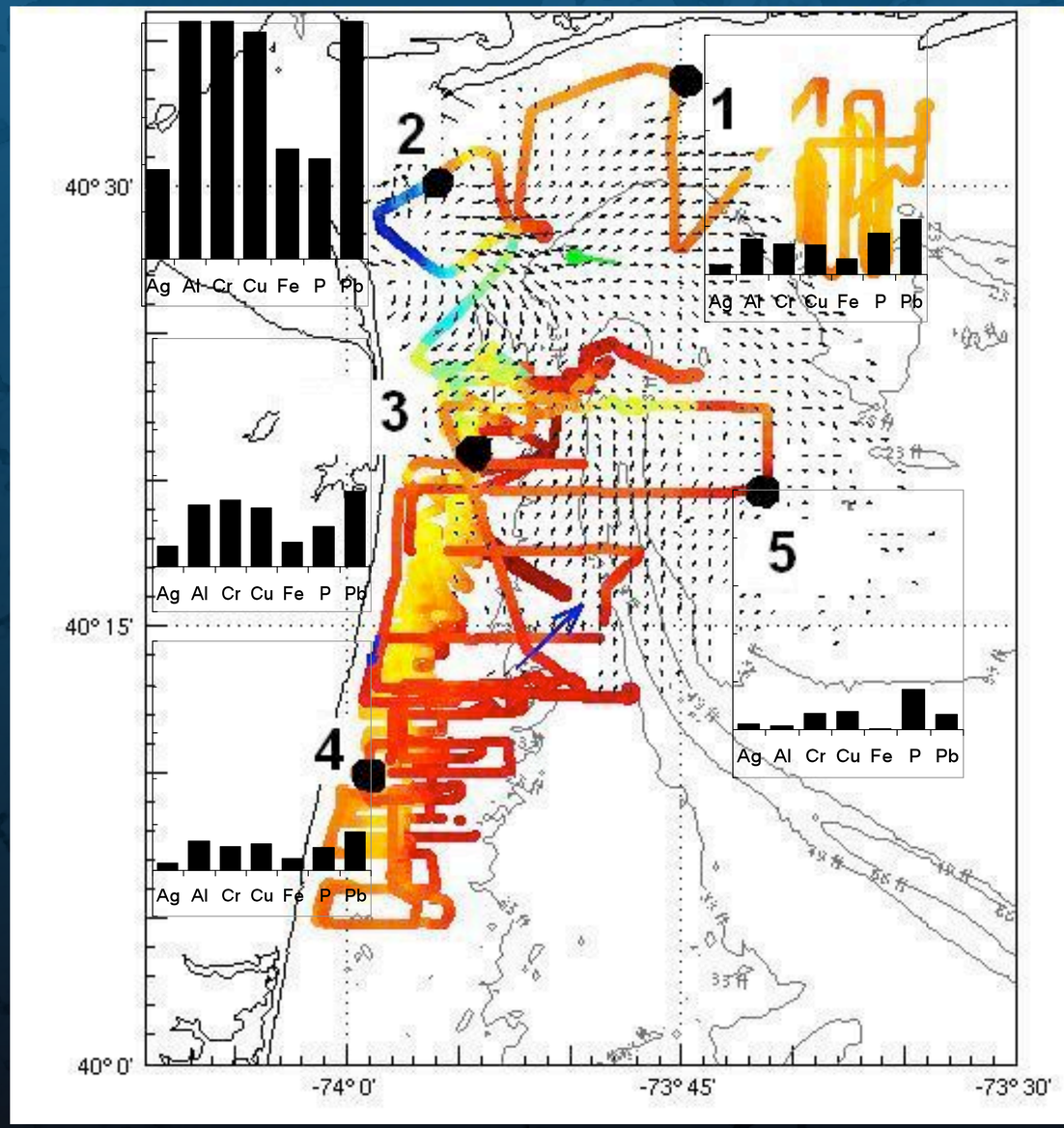

Thalassiosira
Stephanopyxis sp.

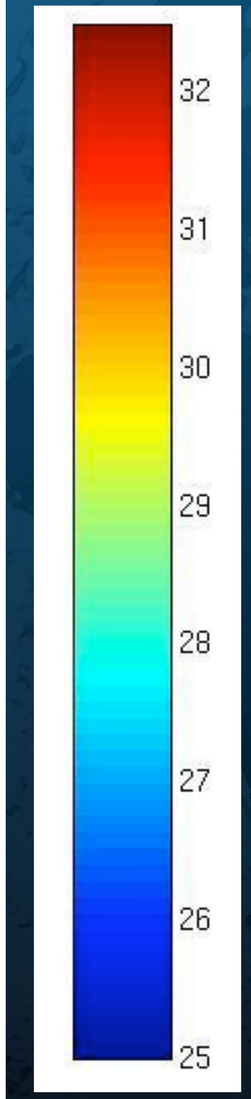

Skeletonema
Lauderia


Hudson Bay
Ocean
supersaturated
undersaturated
LATTE April 2005
Percent Oxygen Saturation
Salinity
160
140
120
100
80
60
18
20
22
24
26
28
30
32

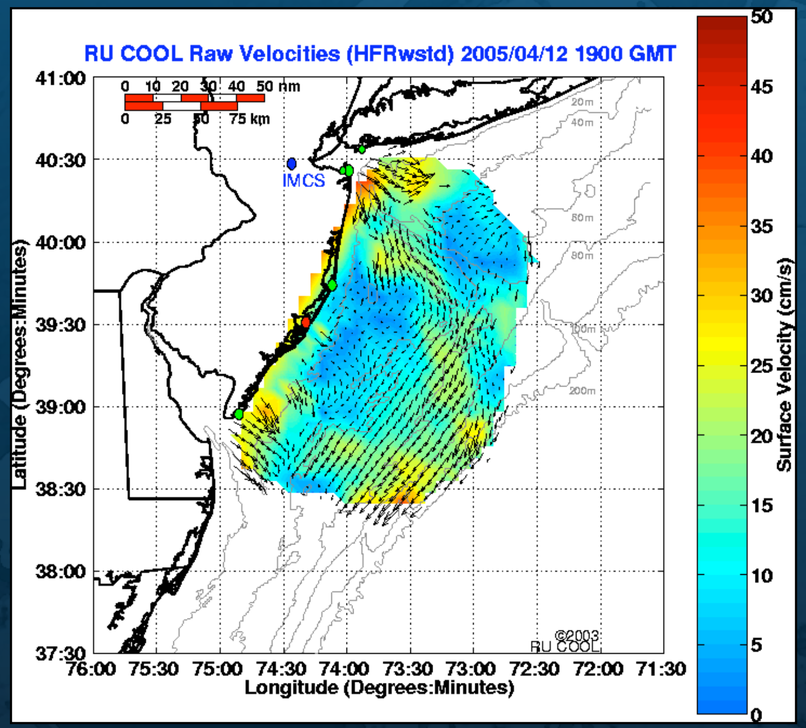
>20 μm particulate trace metals and phosphorus - Ag, Al, Cr, Cu, Fe, P, Pb

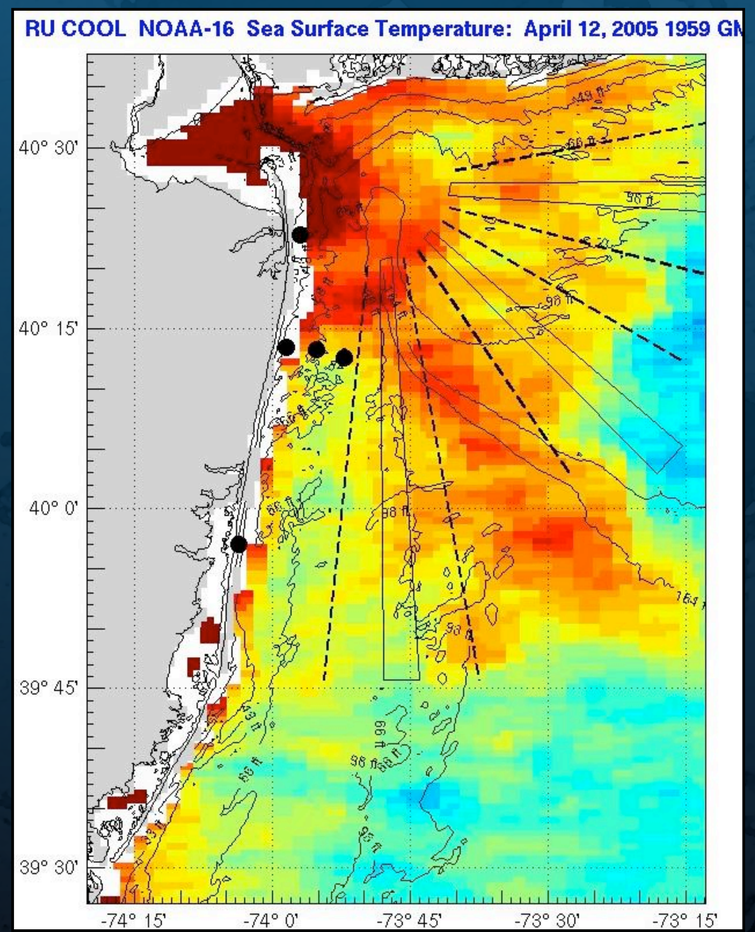
50 ng L^{-1}
(Al, Fe, P μg L^{-1};
Ag x 10, Al x 5, P x 10)

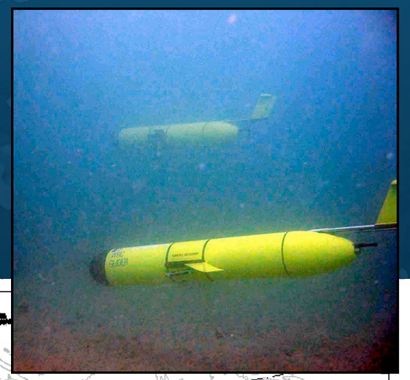


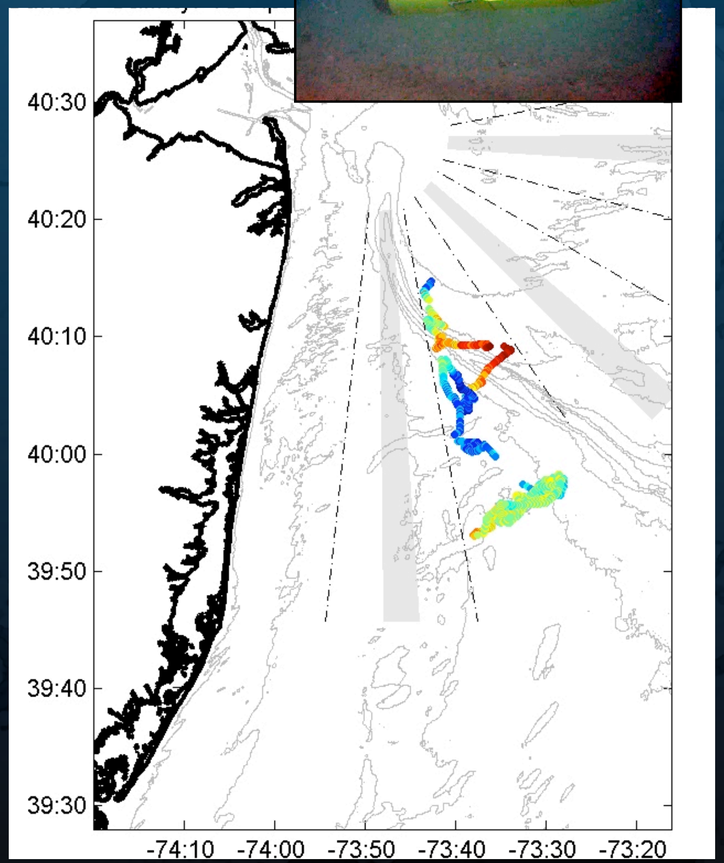


Freshwater Plume Moves Out Across the Shelf: Hudson Shelf Valley







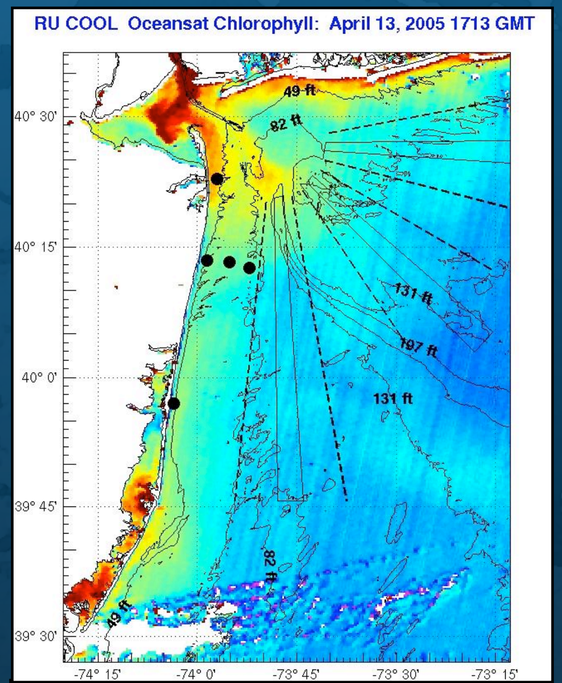


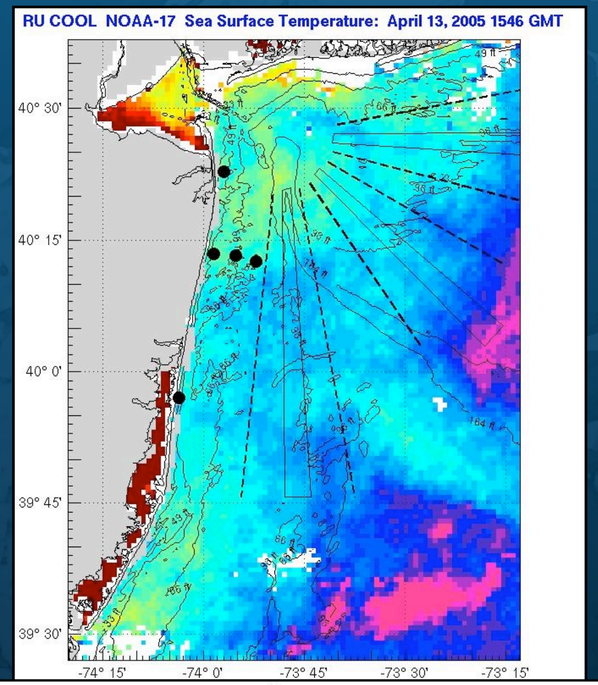
LaTTE 2005 --Post Injection 2 – Final shipboard survey After luring the Cape Hatteras offshore.

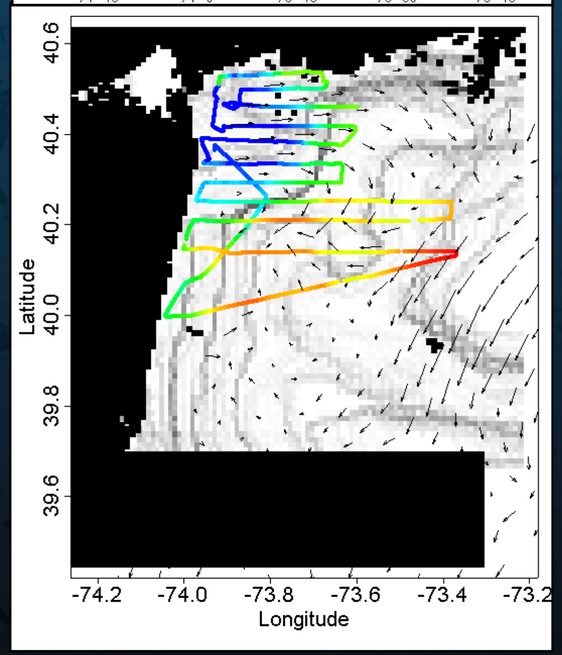
"The survey began on the 'Highway'. We were near the glider when it surfaced. We saw currents ripping southward in a 10 m thick layer of freshwater along the highway -- perhaps the most significant freshwater transport we saw all week."

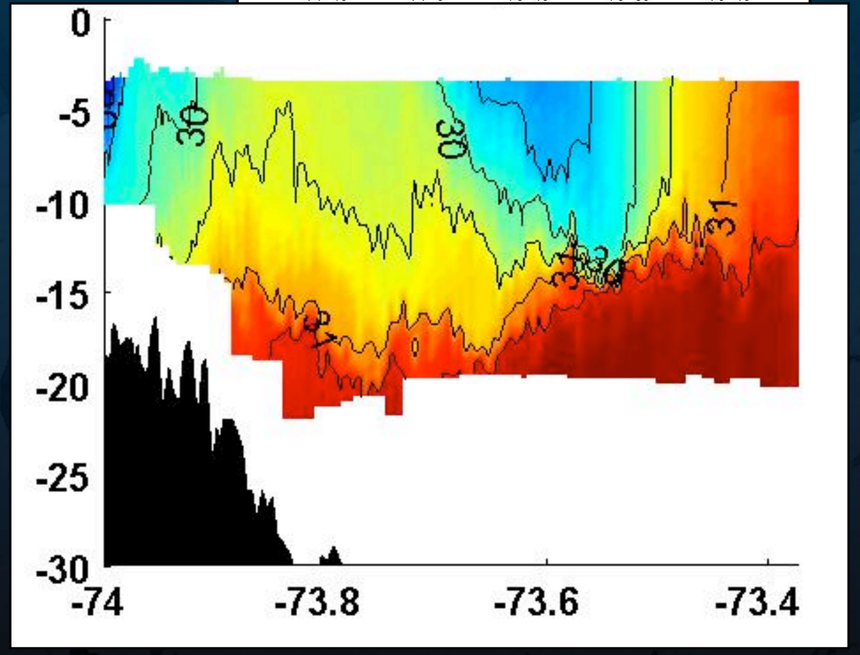
"Perhaps the most perplexing to me is 'the Highway' and why there has been a lack of a strong coastally trapped flow this week."

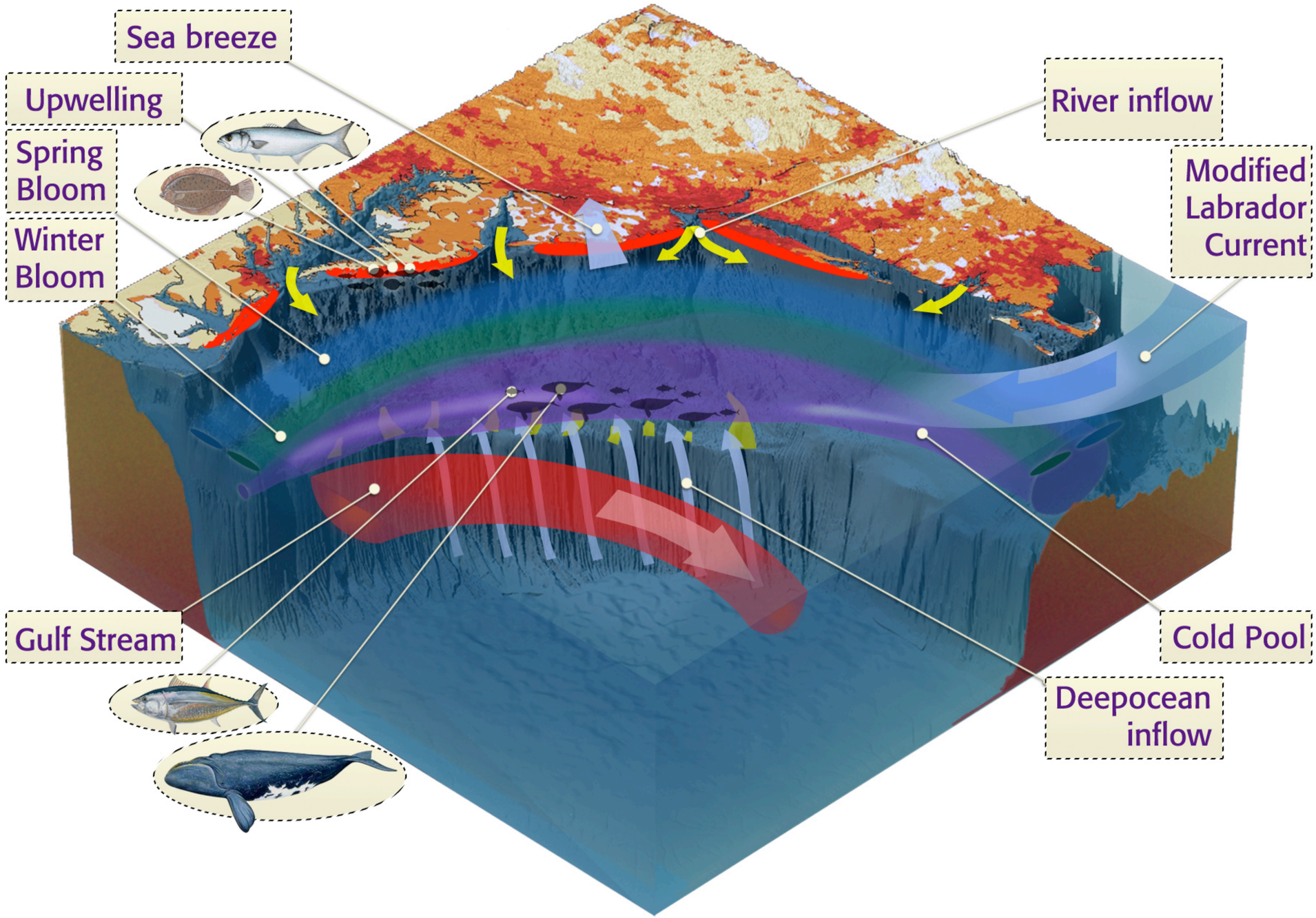
--- Bob Chant aboard the Cape Hatteras, April 21, 2005

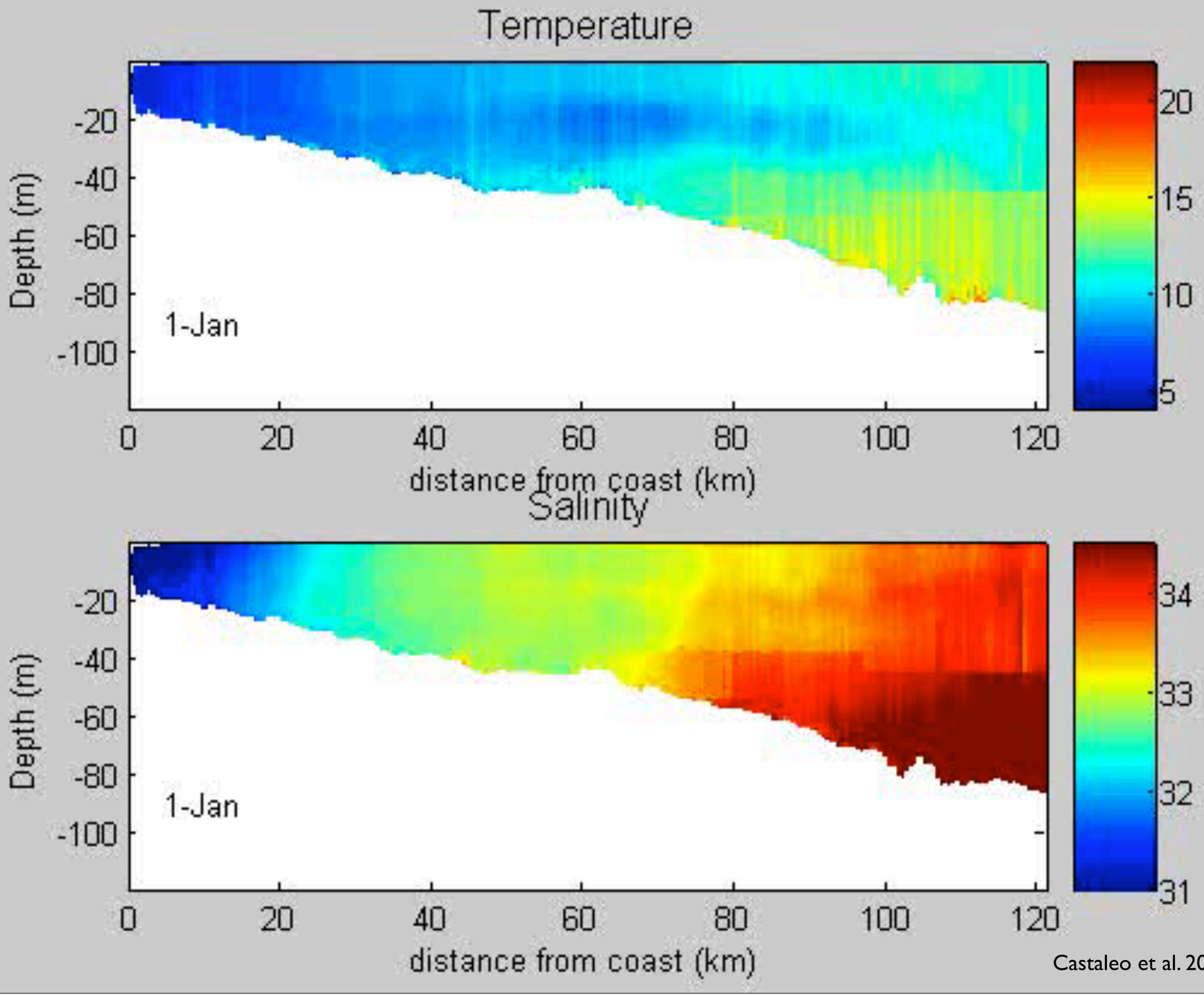

RU COOL Oceansat Chlorophyll: April 13, 2005 1713 GMT
40° 30'
40° 15'
40° 0'
39° 45'
39° 30'
-74° 15'
-74° 0'
-73° 45'
-73° 30'
-73° 15'
49 ft
82 ft
131 ft
197 ft
131 ft
82 ft
49 ft

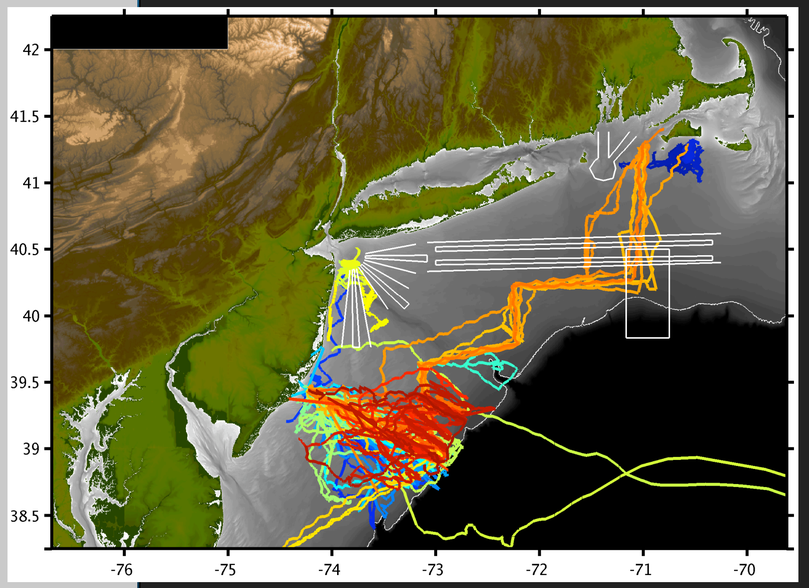

RU COOL NOAA-17 Sea Surface Temperature: April 13, 2005 1546 GMT
40° 30'
40° 15'
40° 0'
39° 45'
39° 30'
-74° 15'
-74° 0'
-73° 45'
-73° 30'
-73° 15'


Latitude
40.6
40.4
40.2
40.0
39.8
39.6
-74.2
-74.0
-73.8
-73.6
-73.4
-73.2
Longitude


0
-5
-10
-15
-20
-25
-30
-74
-73.8
-73.6
-73.4
30
30
31


Sea breeze
Upwelling
Spring Bloom
Winter Bloom
River inflow
Modified Labrador Current
Gulf Stream
Cold Pool
Deepocean inflow





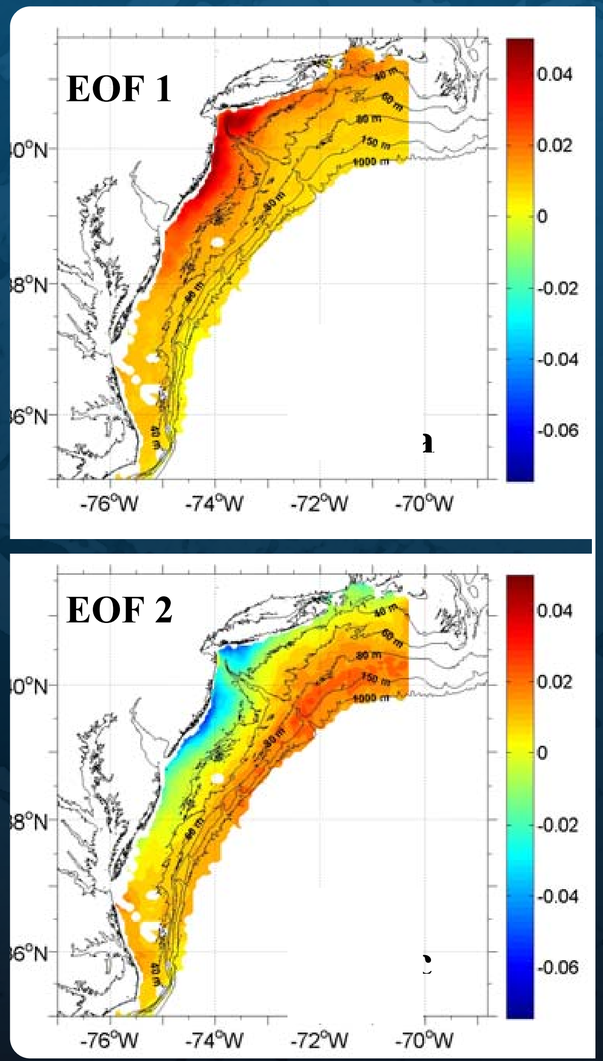
MAB stratification dominates the hydrography of the shelf.

Temperature stratification extreme, 25 to 8 degrees in a only three meters

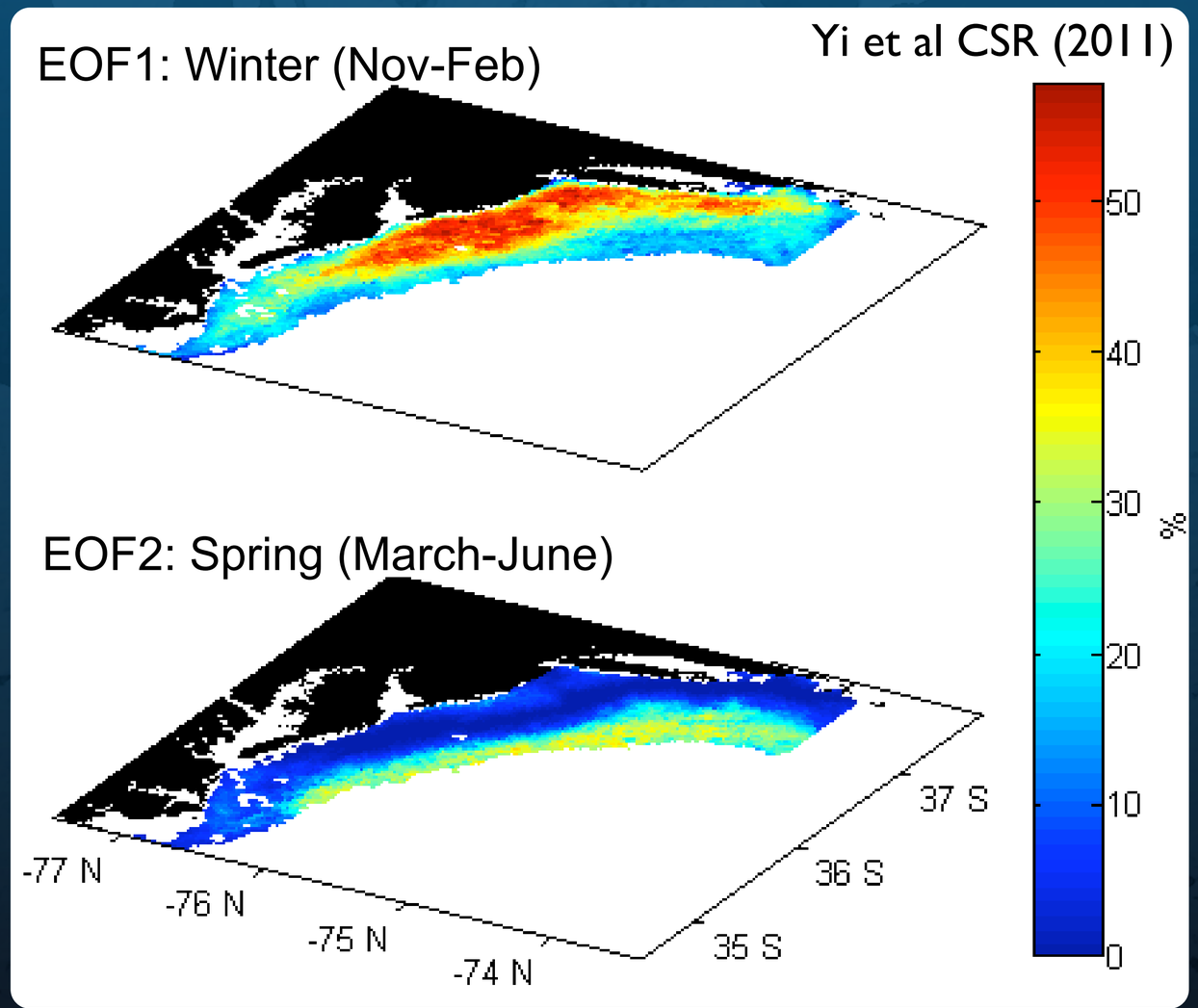
Salinity gradients show inshore and offshore gradients

Castaleo et al. 2008, 2010

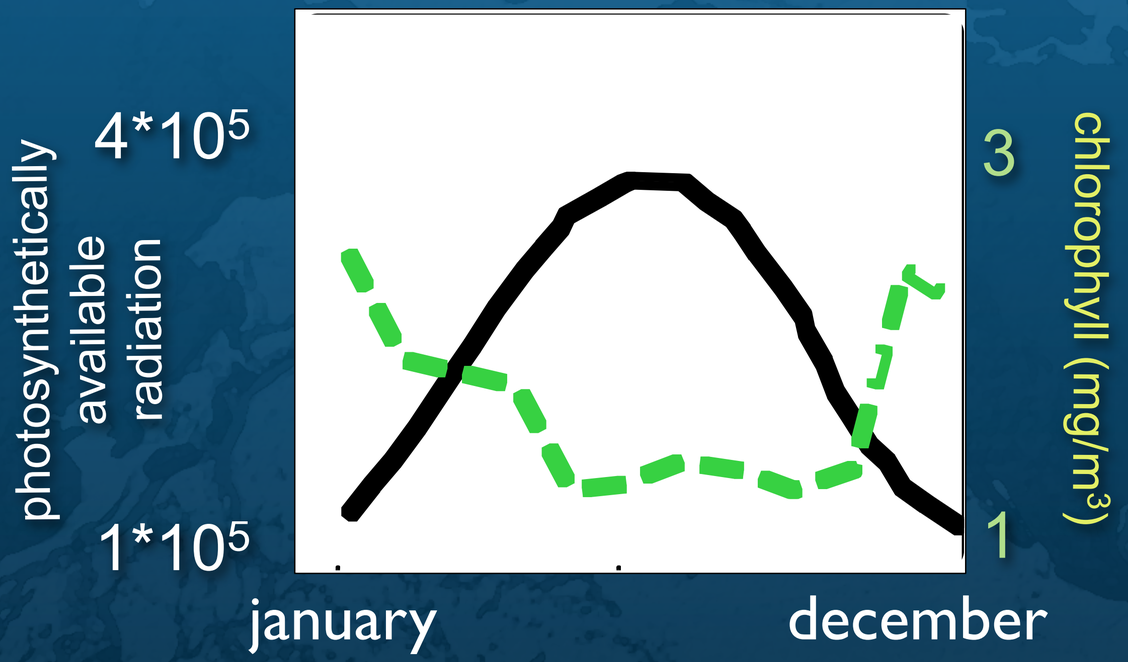
Dynamics in phytoplankton variance is described by 2 modes. Mode 1 occurs in the winter on the inner shelf. Mode 2 occurs in spring on the outer shelf. Summer phytoplankton explain little of the shelf-wide variance however is extremely important to the nearshore coastal ecosystems



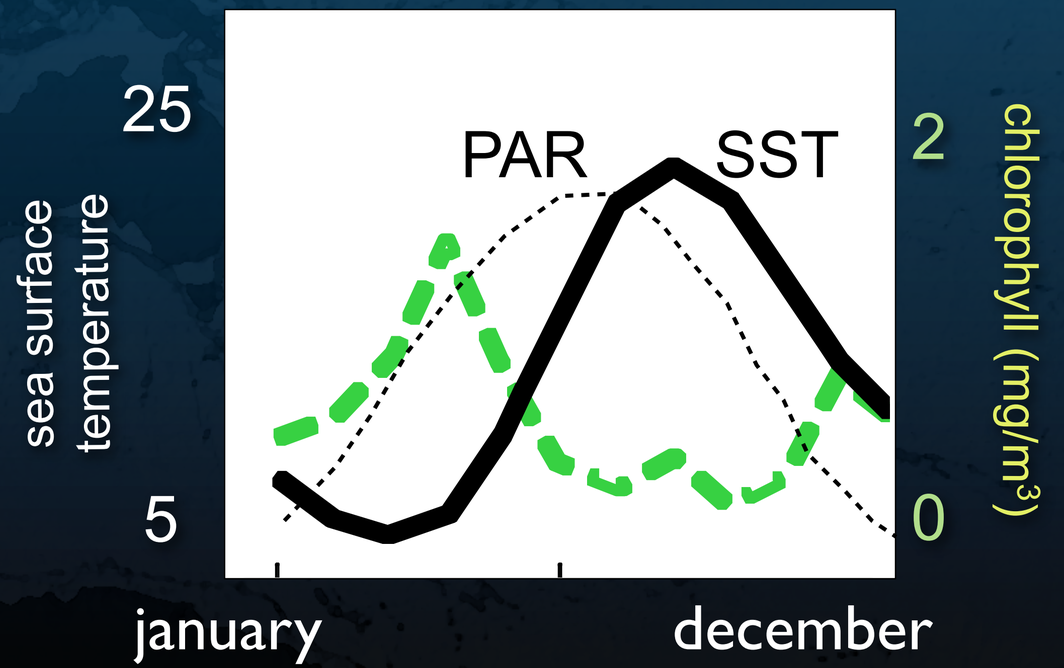
Two major EOF modes



% of Variance explained by the two major EOF modes as a function of space

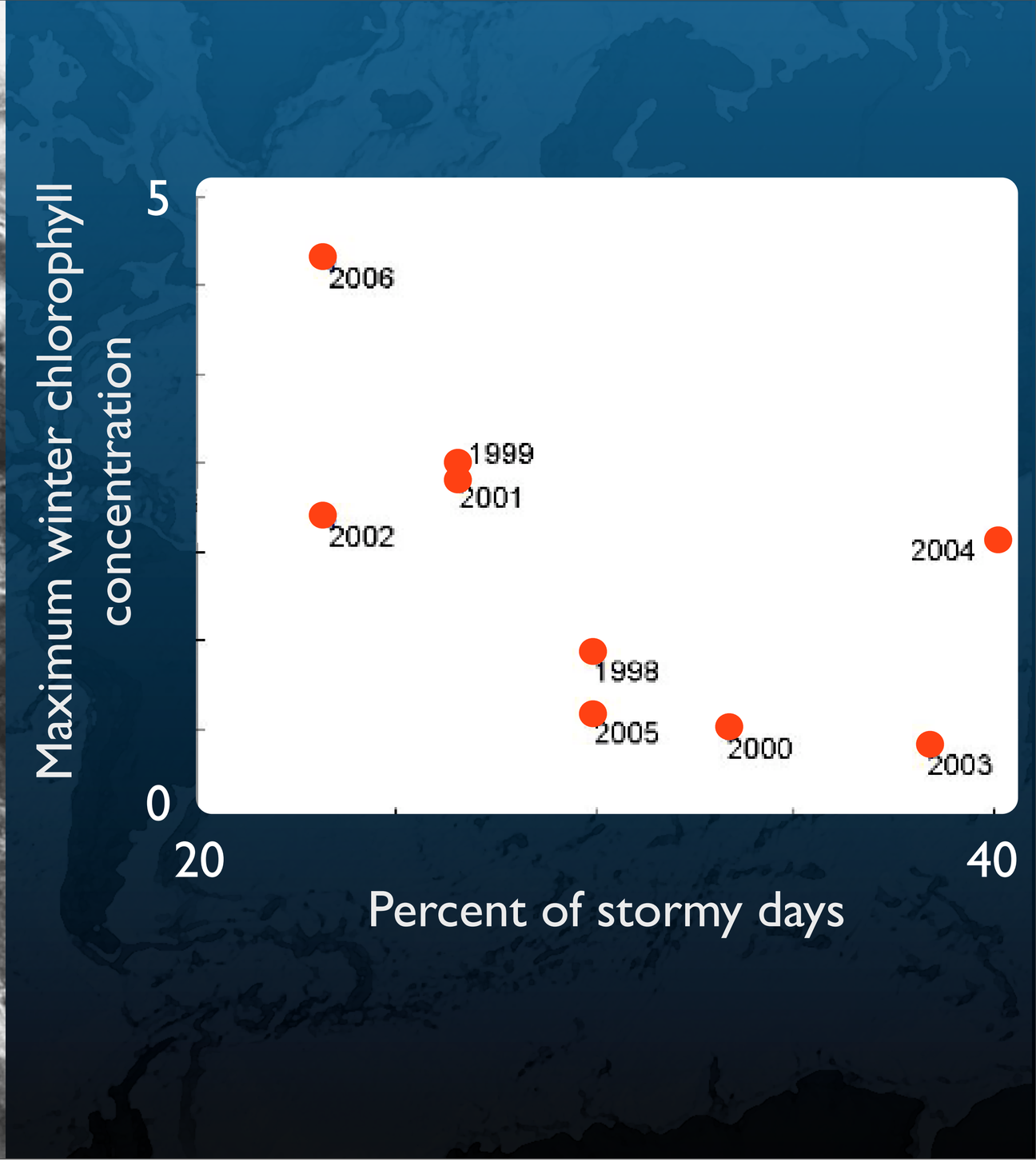


Mode 1: Largest and most recurrent bloom. Occurs during the dimmest months of the year which is interesting.

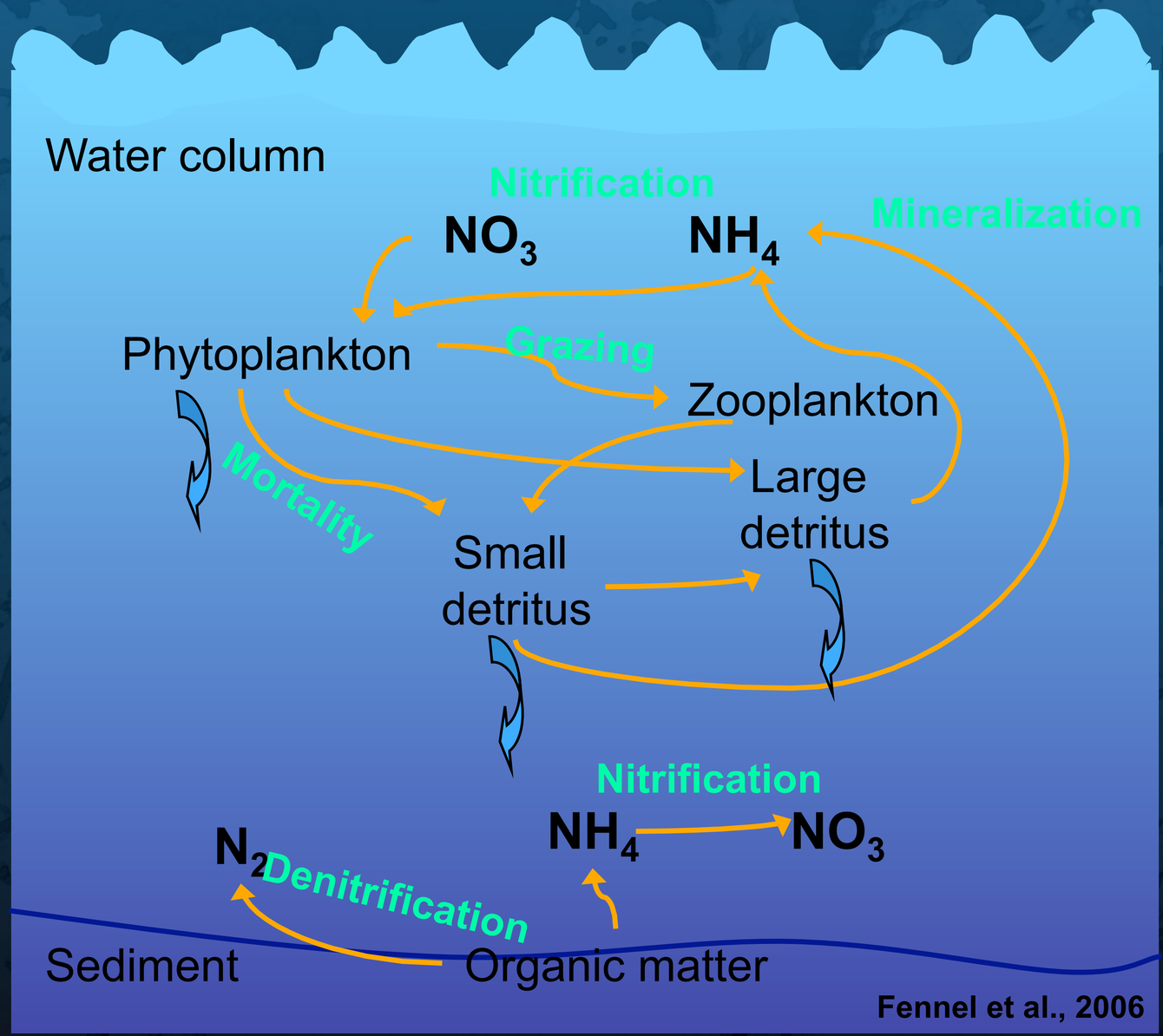


Mode 2: The canonical spring bloom which occurs prior to strong shelf stratification.

Schofield et al. 2008

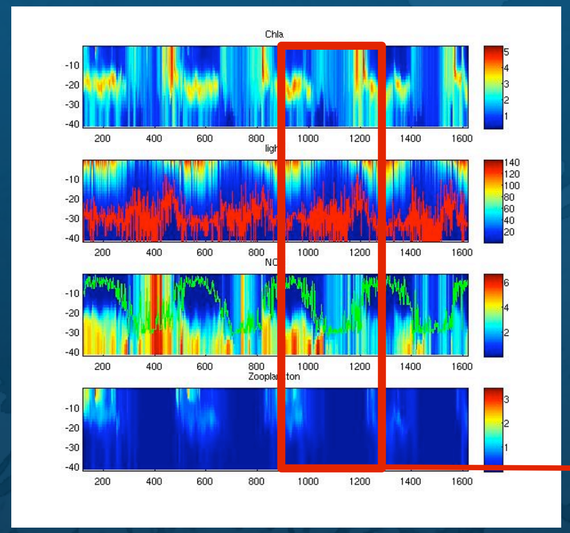

Maximum winter chlorophyll concentration
5
0
20
40
Percent of stormy days
2006
1999
2001
2002
2004
1998
2005
2000
2003

Biological Modeling System



Model assumes N is the main limiting

Xu et al. submitted



Light limitation

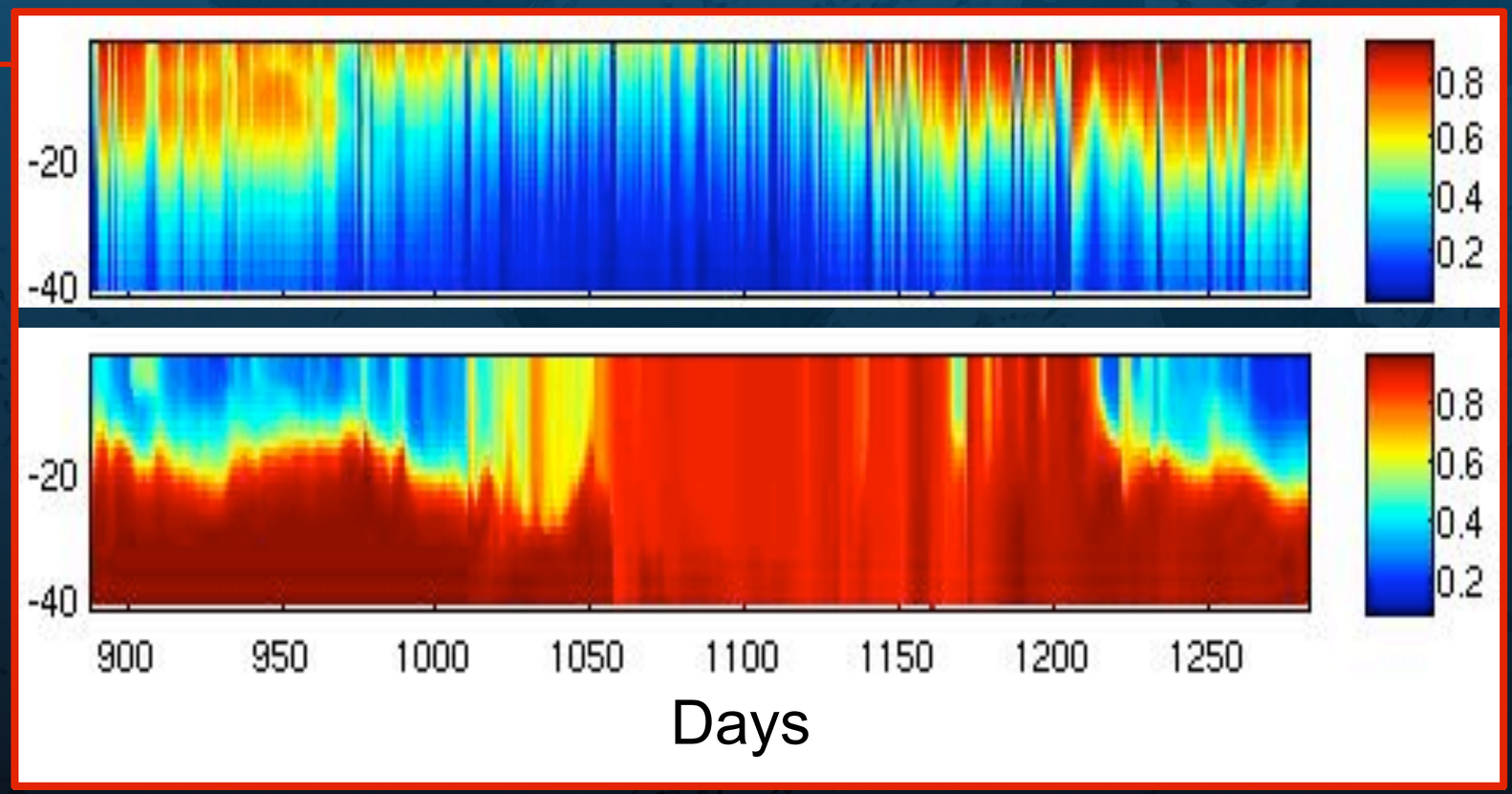
$$f(I) = \frac{\alpha I}{\sqrt{\left(\mu_{\max}^2 + \alpha^2 I^2\right)}}$$

Nutrient limitation

$$NO3 = \frac{NO3}{K_{NO3} + NO3} + \frac{1}{\left(1 + NH4 / K_{NH4}\right)}$$

$$L_{NH4} = \frac{NH4}{K_{NH4} + NH4}$$

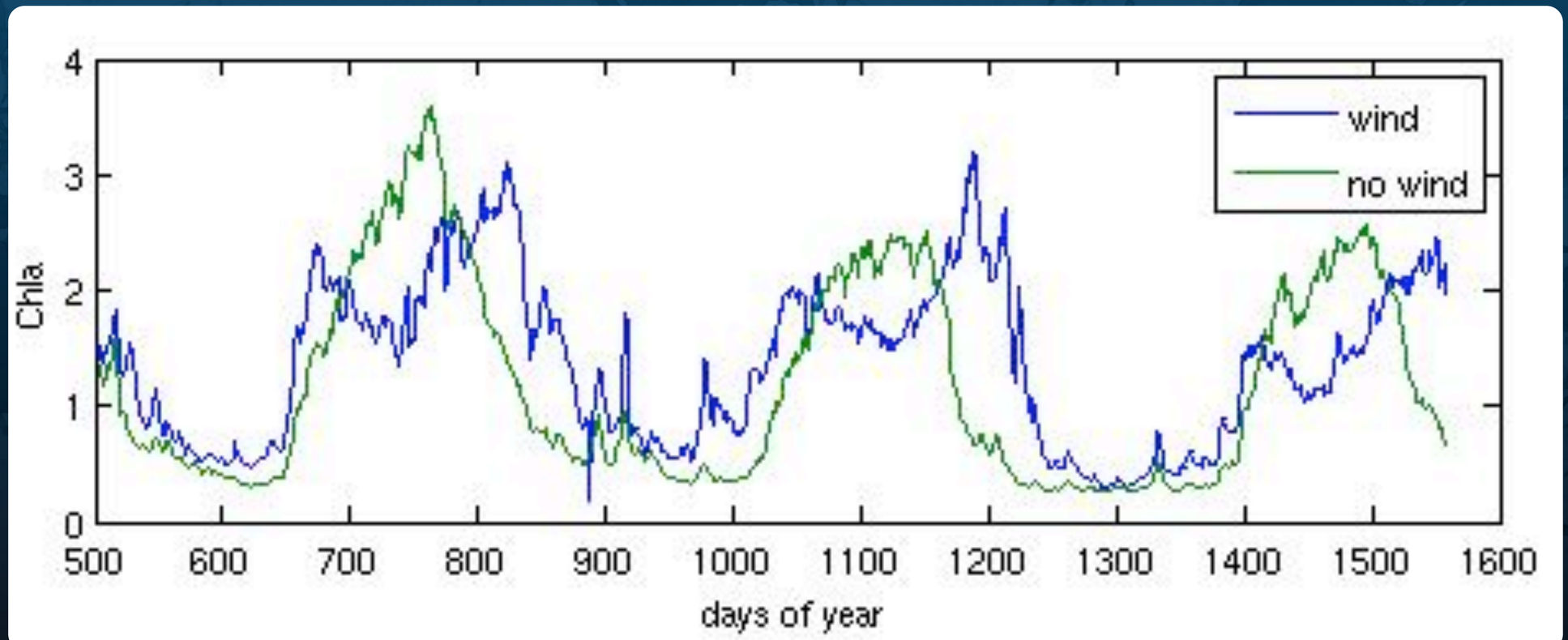
$$\mu = \mu_{\max} \bullet f(I) \bullet (L_{NO3} + L_{NH4})$$



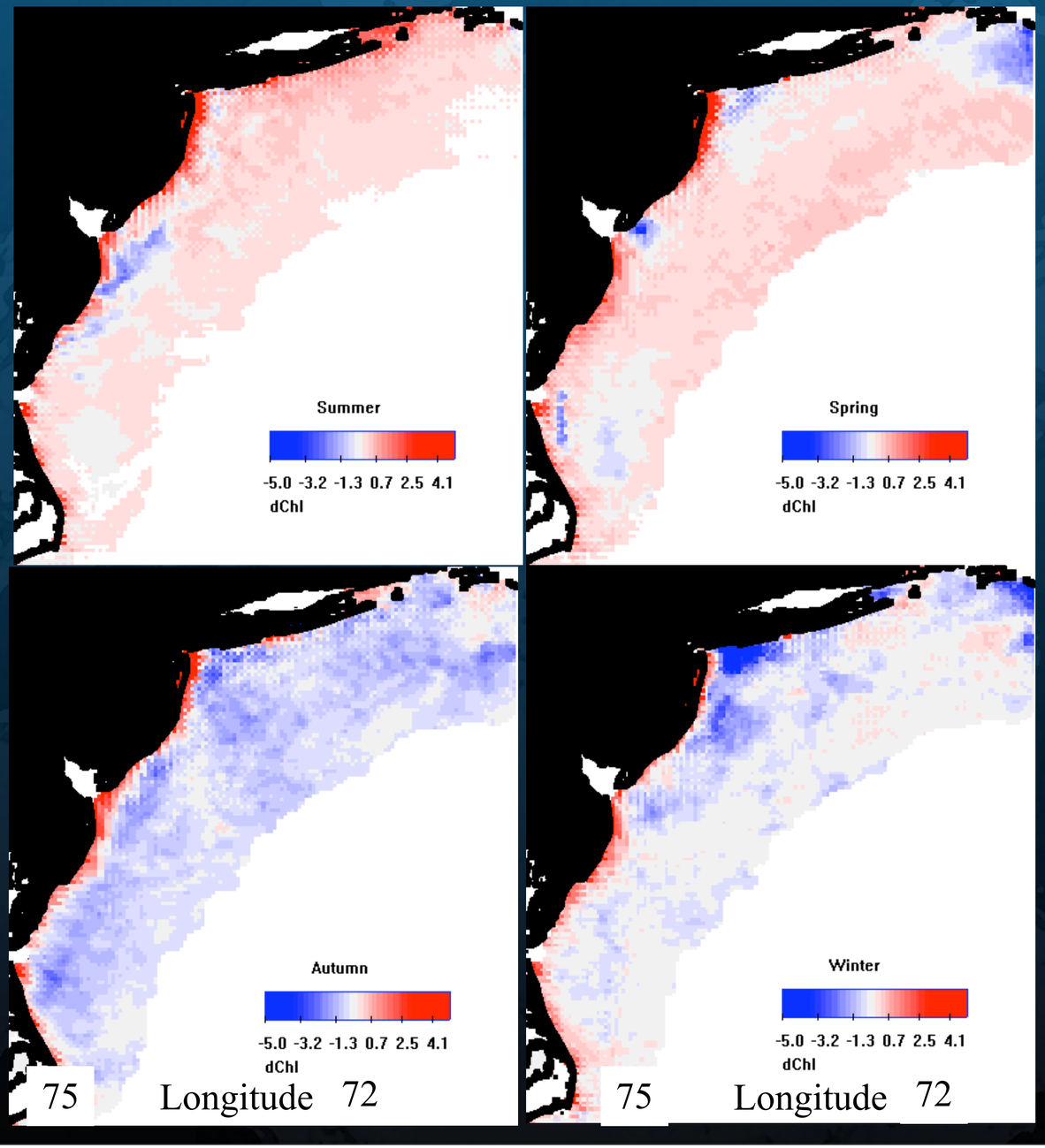
Numerical experiment: Measured wind and no wind in Zone 1

No wind condition, later bloom, larger bloom during darkest winter months, but integrated productivity over the winter is smaller by ~20%

Yi et al submitted

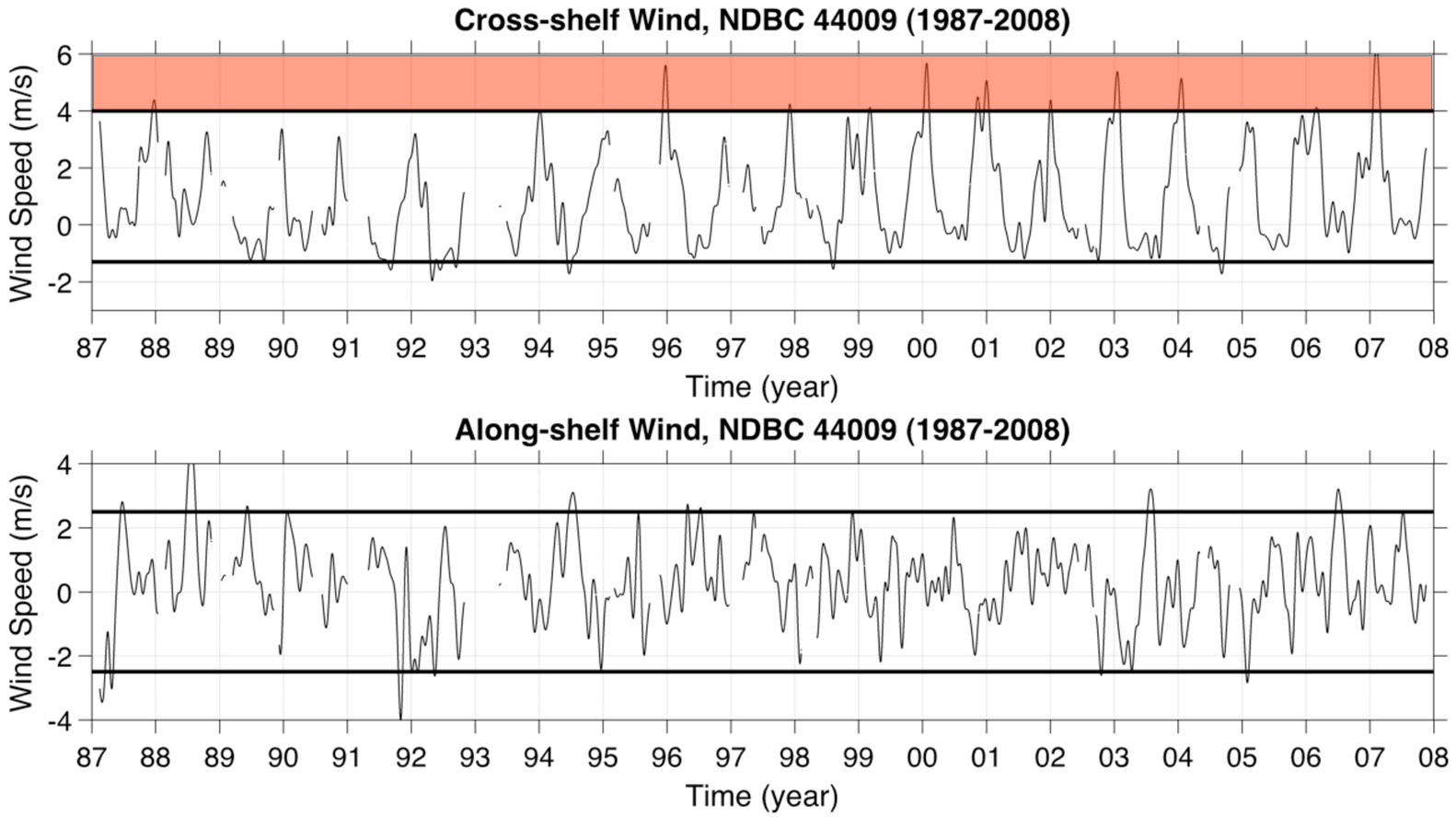


CZCS (1978-1986) and SeaWiFs (1998-2007)

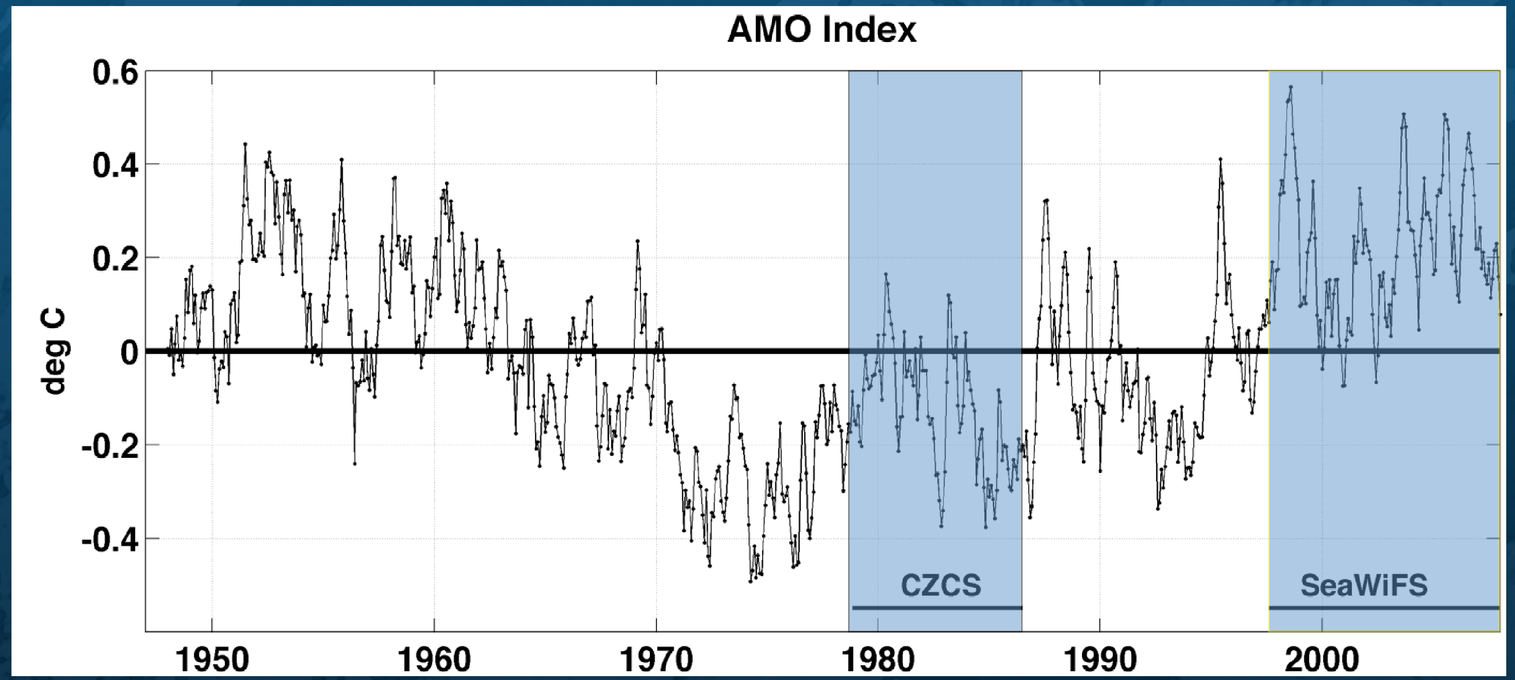


Season	1978–1986	1998–2006	Difference	% Change
Spring	2.52	2.74	0.21	8
Summer	1.73	2.02	0.29	14
Fall	3.89	2.73	-1.16	-43
Winter	3.61	2.80	-0.81	-29
Total	**13.00**	**11.35**	**-1.66**	**-14**

Declines in the Winter Bloom?



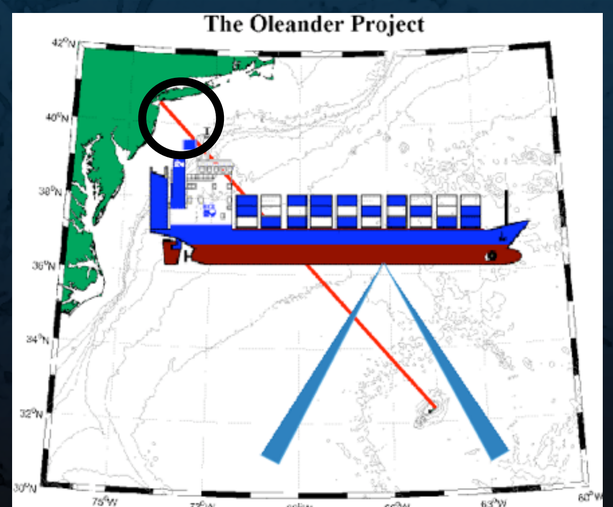
Declines in the Winter Bloom?



winter winds

duration of shelf stratification

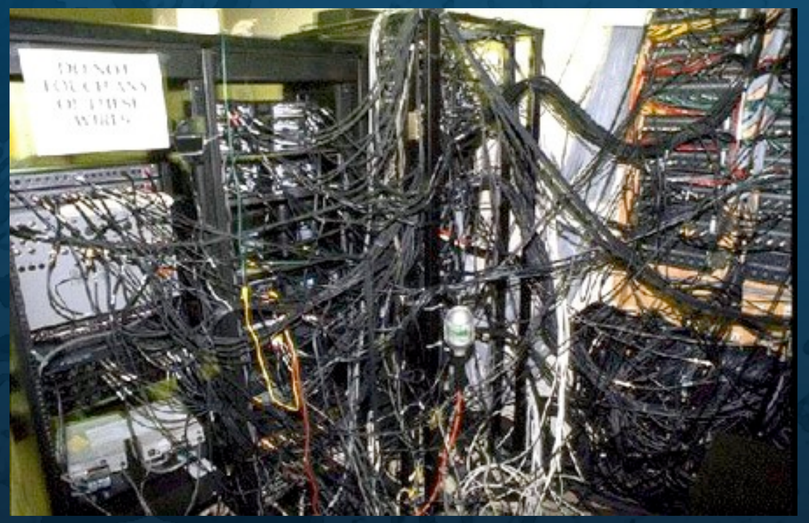
annual phytoplankton biomass



WHERE DO WE GO FROM HERE?

WHERE DO WE GO FROM HERE?

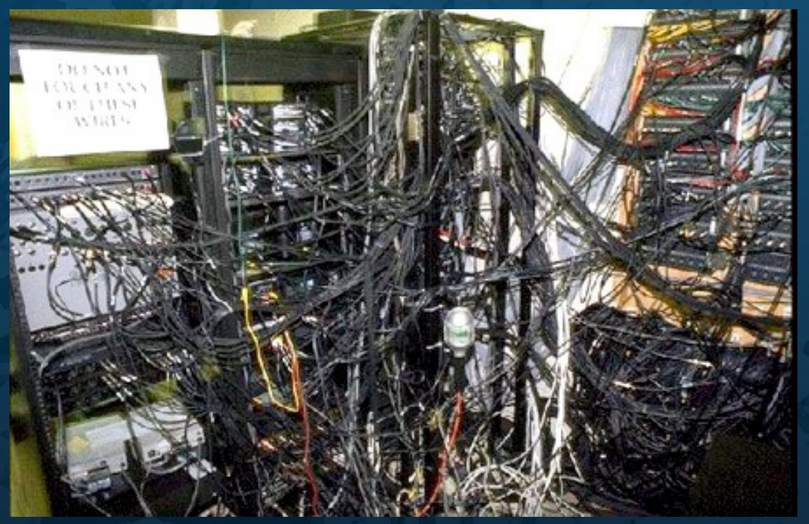
Machines have improved



A technicians solution
in integrating the observatory components

WHERE DO WE GO FROM HERE?

Machines have improved



A technicians solution
in integrating the observatory components

People need to sleep and are fragile

Humans become the bottle neck for collecting data bytes

WHERE DO WE GO FROM HERE?

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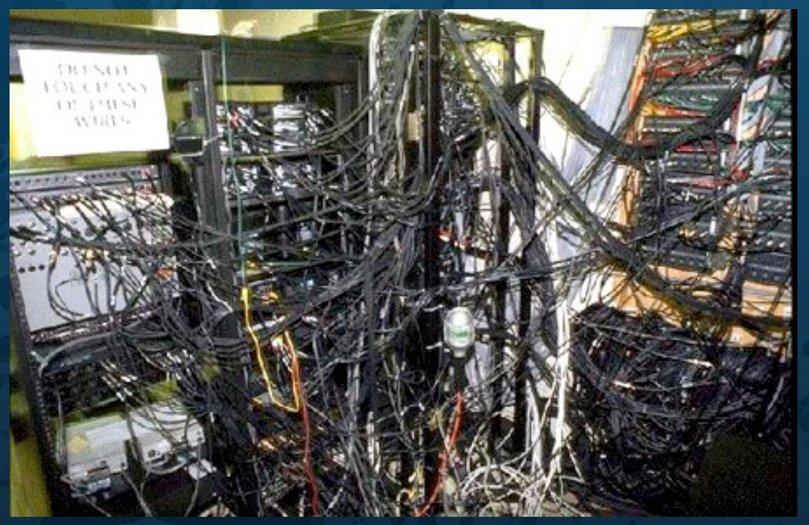


A technicians solution
in integrating the observatory components

People need to sleep and are fragile

Humans become the bottle neck for collecting data bytes

Scientists need time to think

Oscar tries to reintegrate into society after the LATTE experiments

The OOI Observing System Experiment (OSE)

Nov 2 to Nov 13 2009

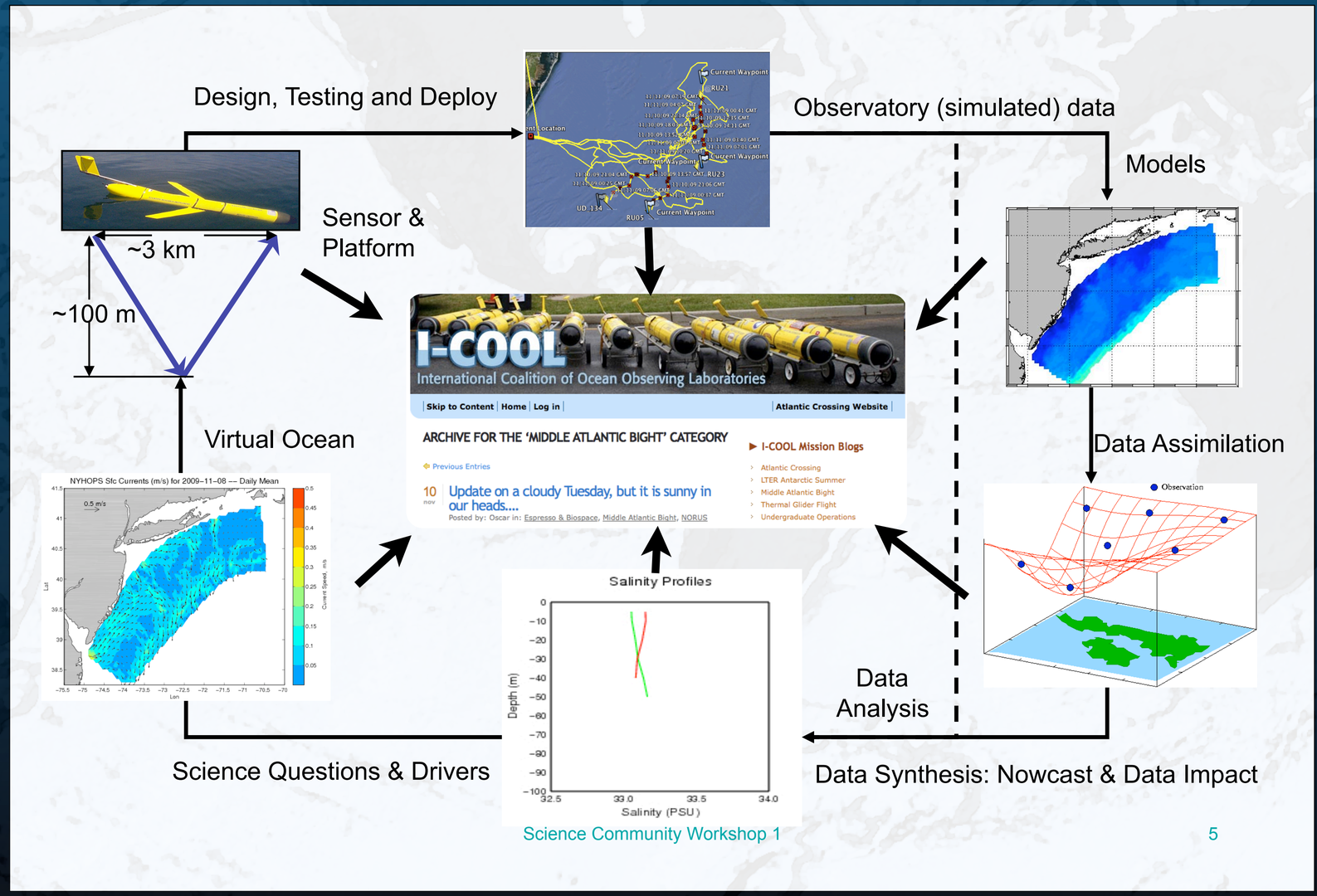
Idea of Test (May 2009)

↓

Virtual Test (Sep 2009)

↓

Wet Test (Nov 2009)

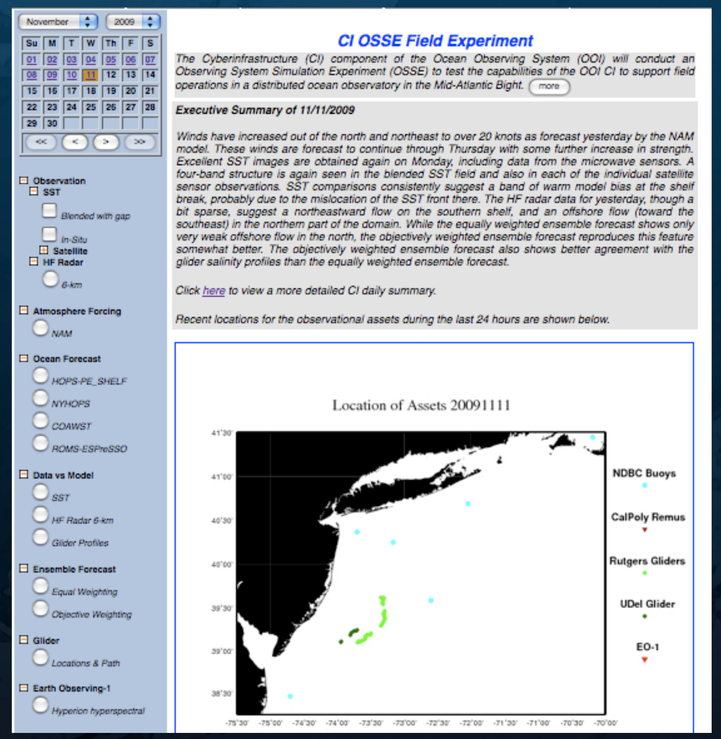


The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Scientists were distributed throughout the country & interacted in real-time

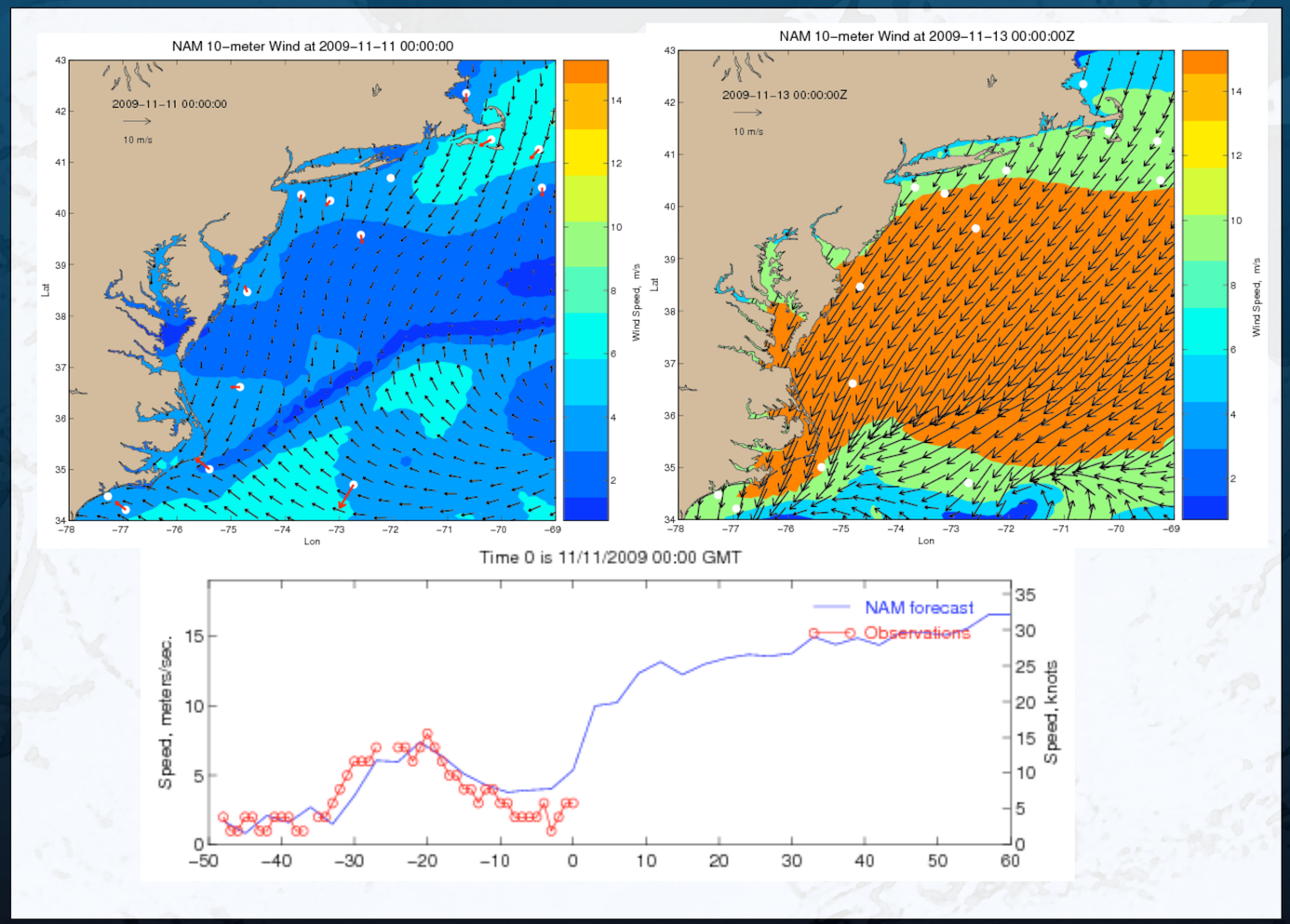
Community Blog

Data Portal



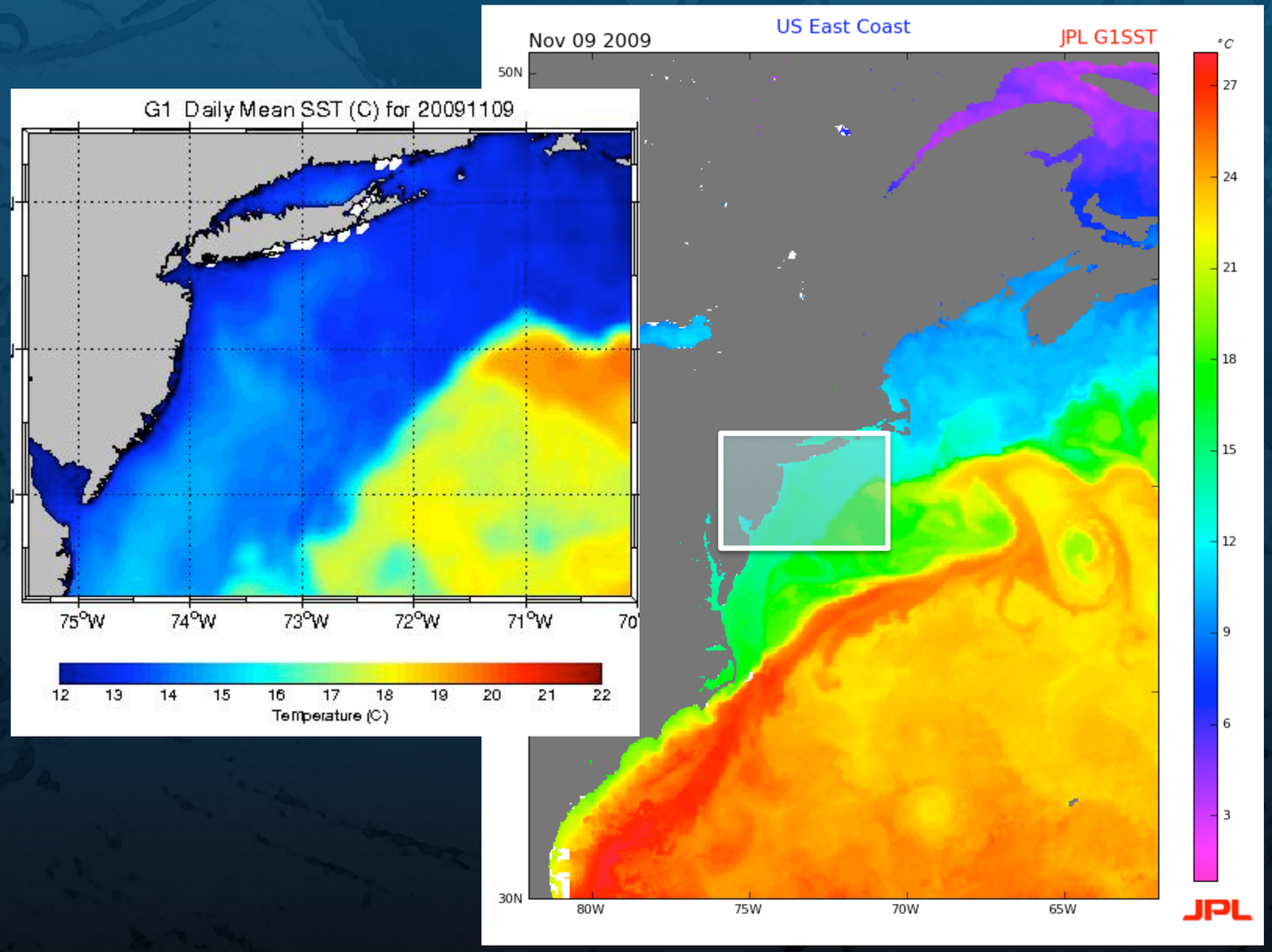
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Weather Forecasts



The OOI Observing System Experiment (OSE)

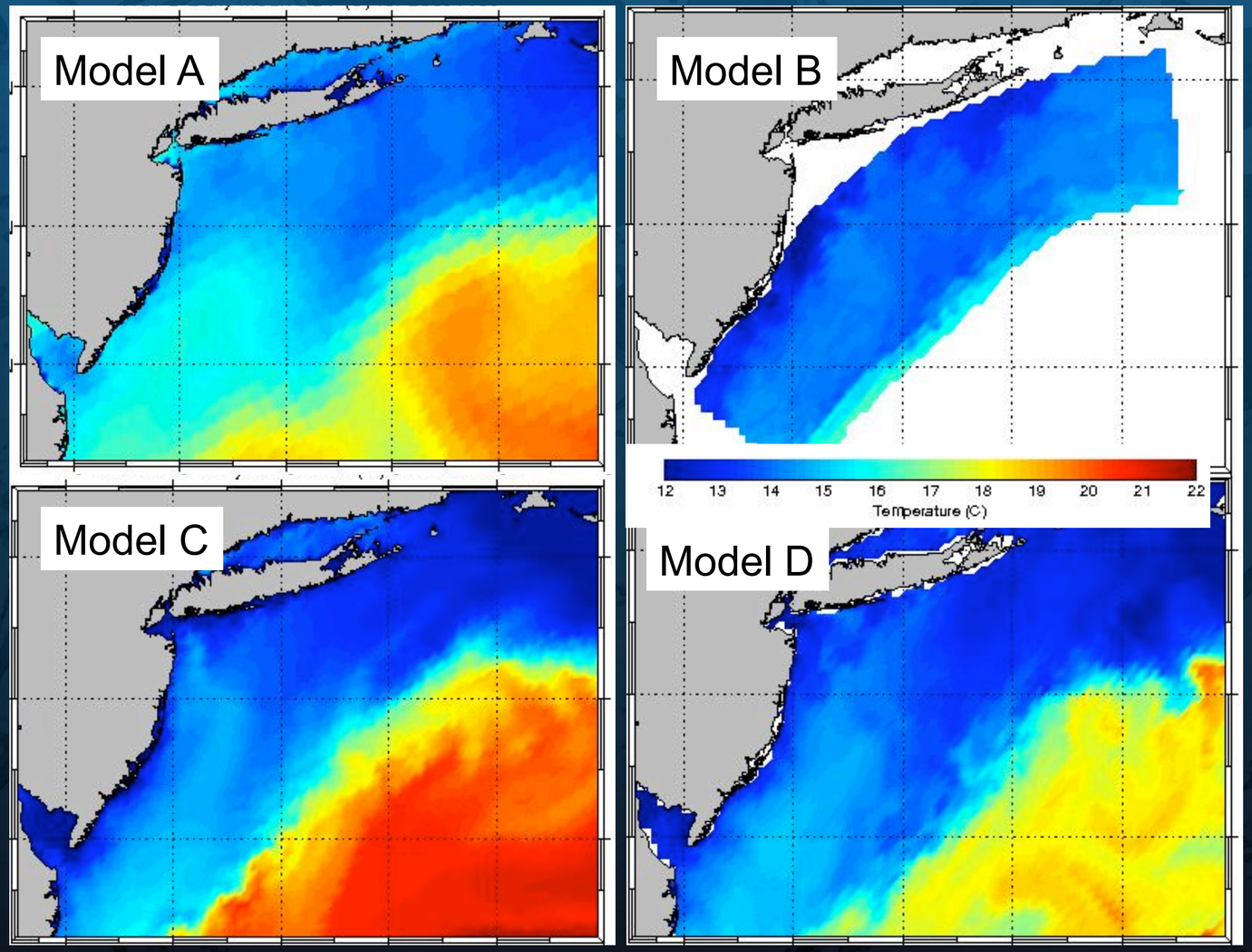
5 different satellite sensors



The OOI Observing System Experiment (OSE)

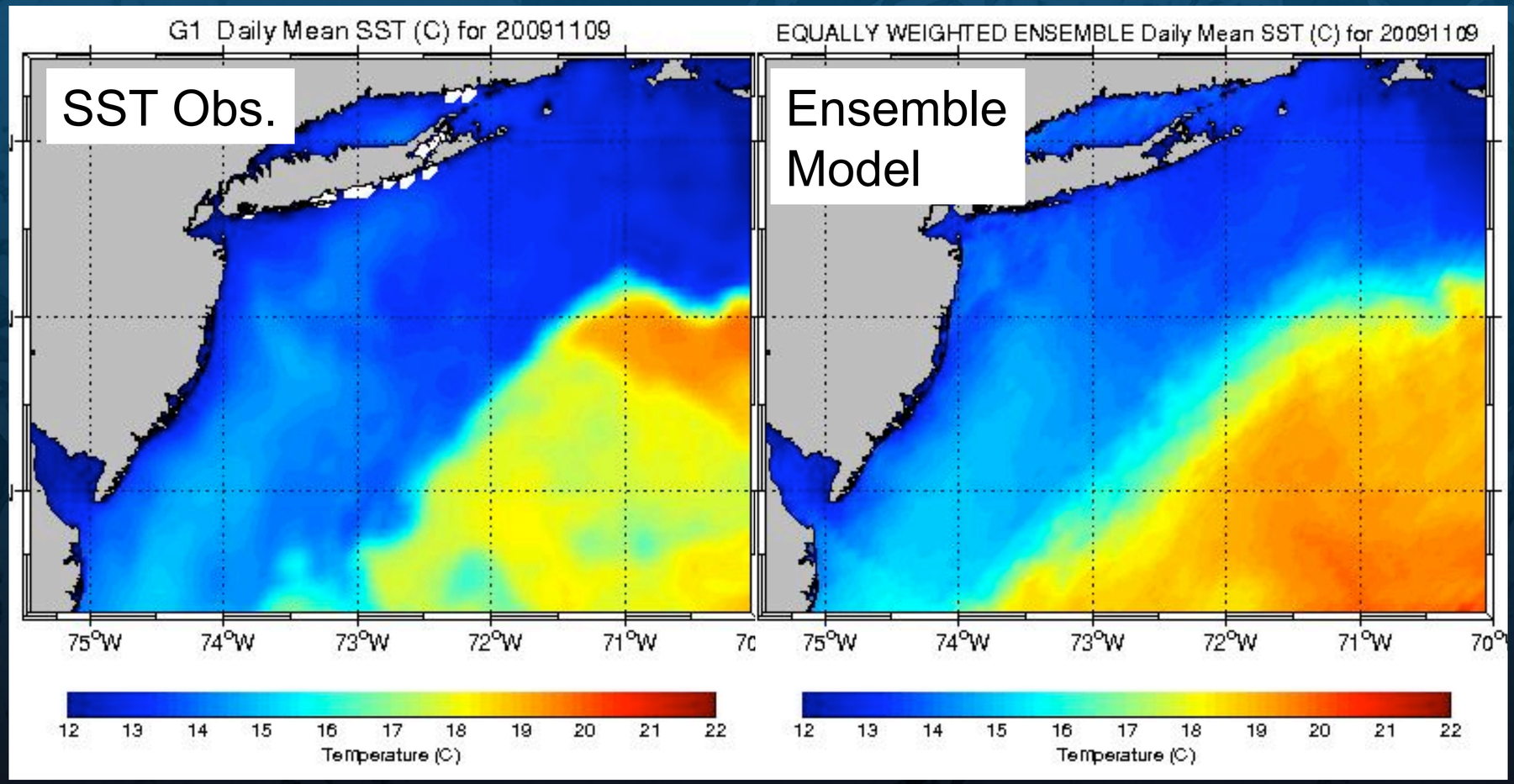
5 ocean numerical models run in forecast mode:

2 versions of ROMS
2 versions of HOPs
1 version of POM



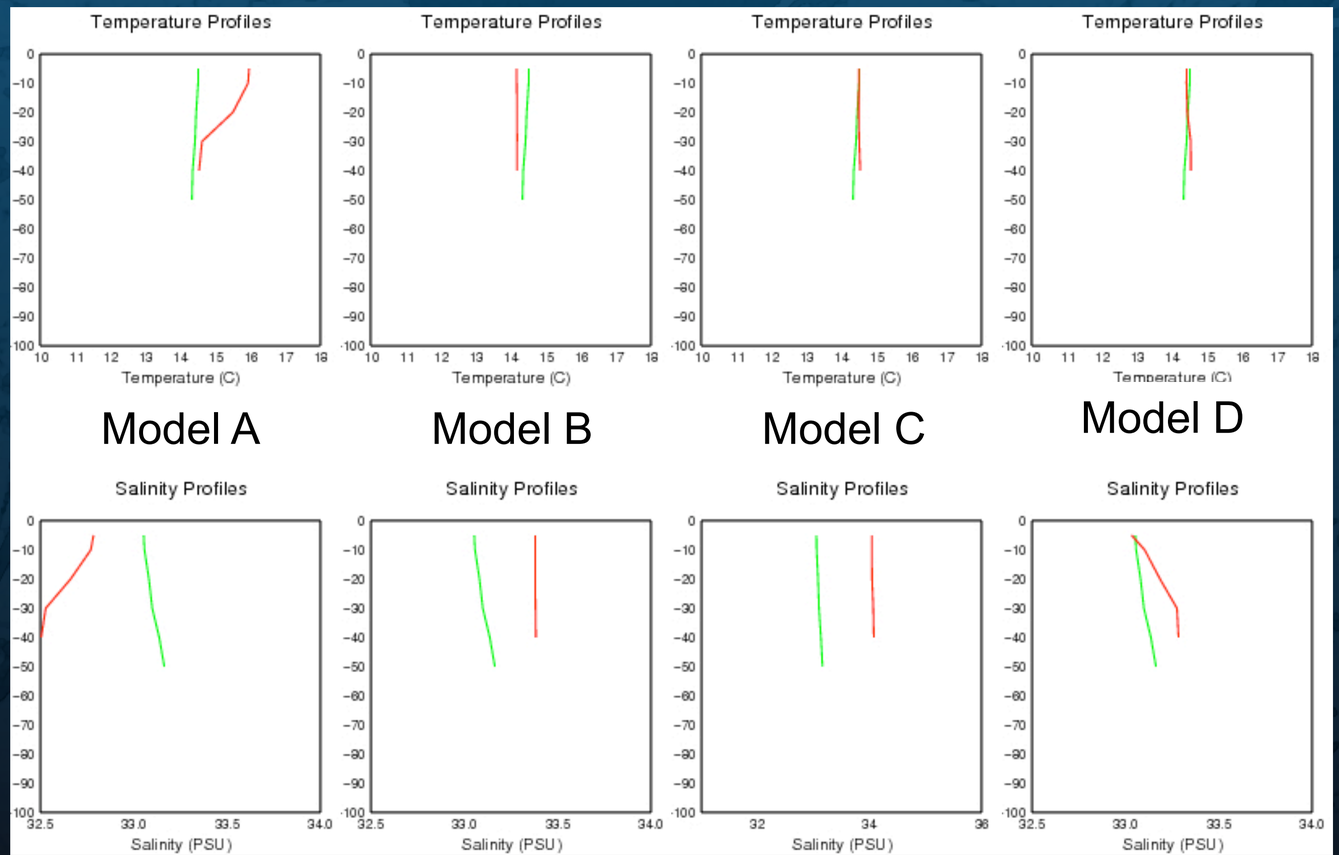
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Scientists could compare observations (single platform or means) with models (individual or means)



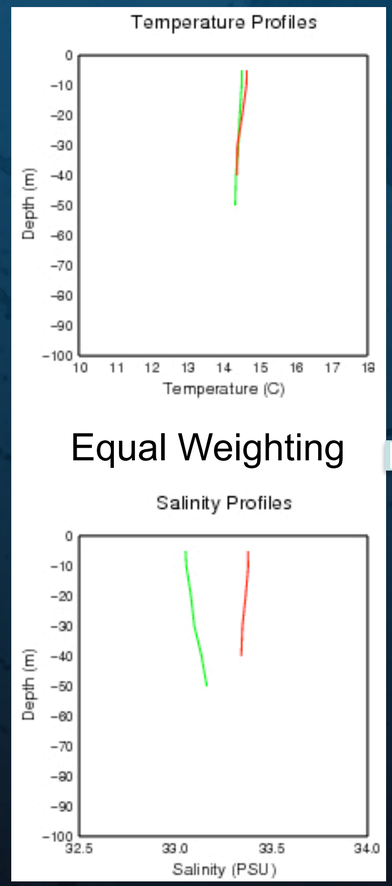
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

The same for *in situ* measurements

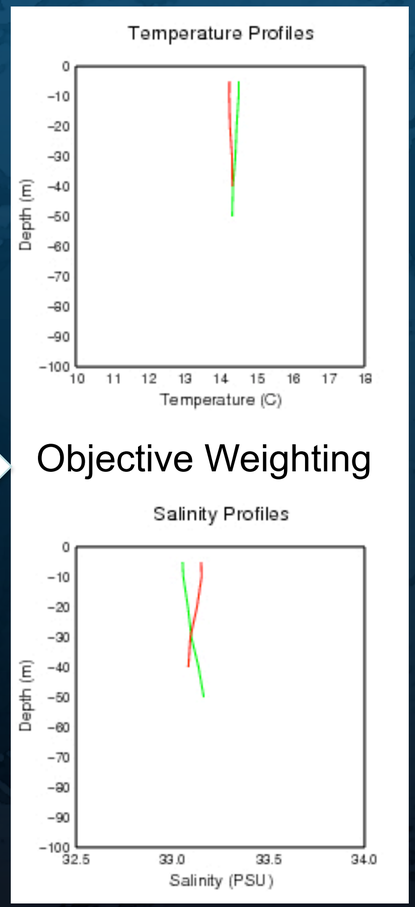


The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Discussion during experiment develops new tools during the experiment



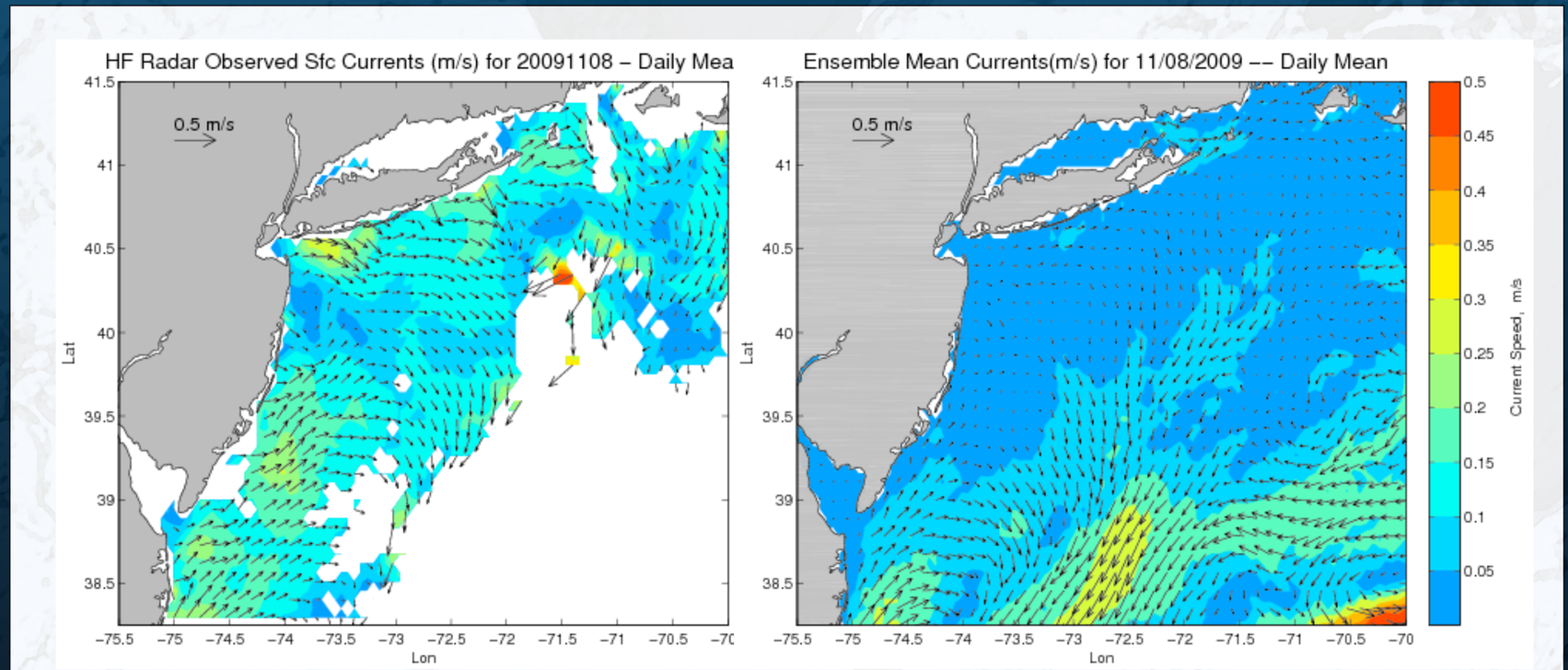
Equal Weighting



Objective Weighting

The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Observation model comparisons spurred discussion on tools for synthesis

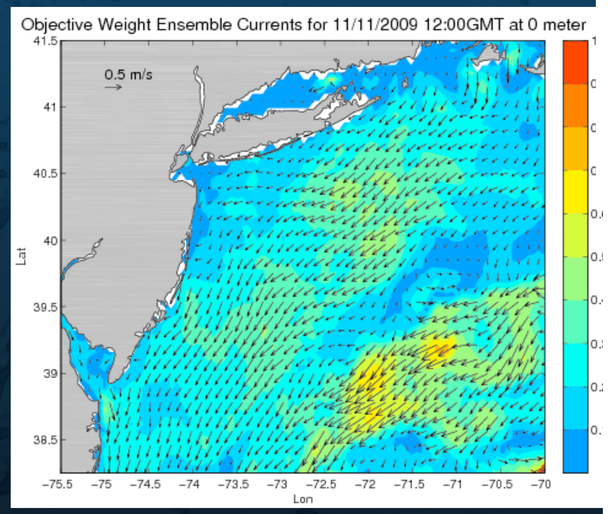


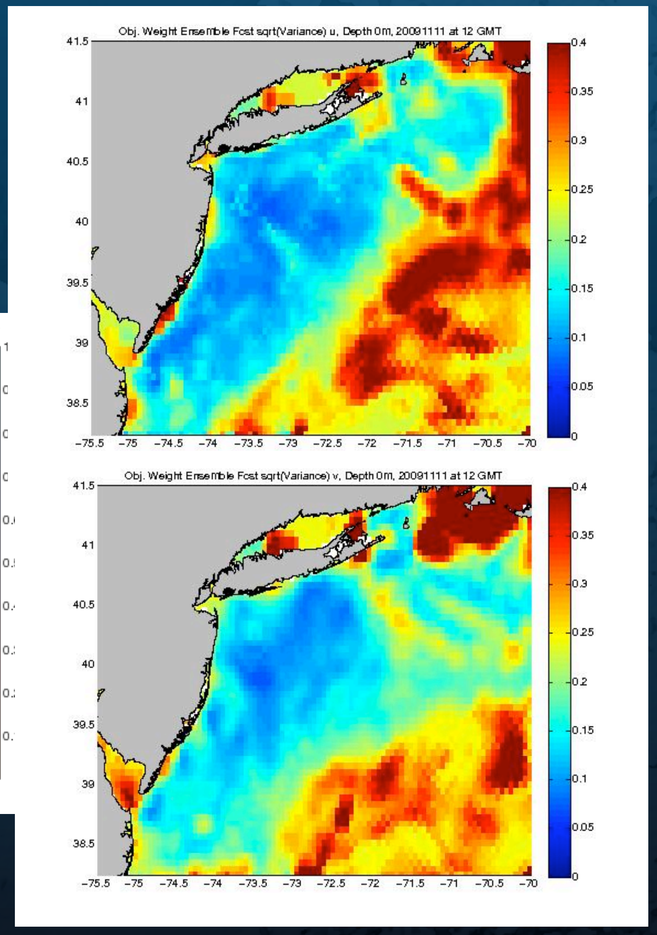
HF Radar Obs

Ensemble Model

The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Ensemble mean model

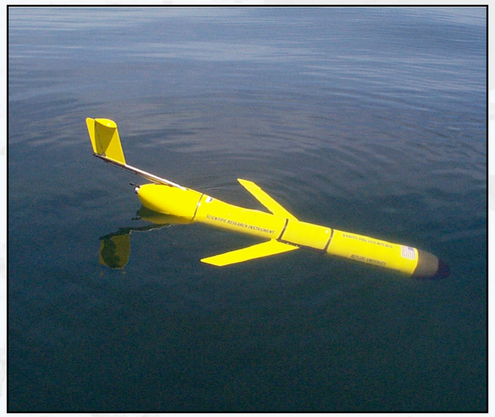




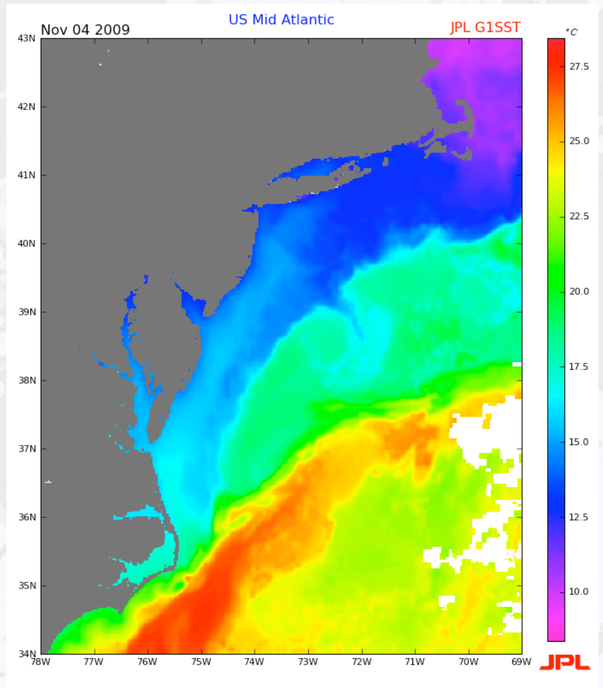
Variance in *u* velocity component

Variance in *v* velocity component

The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009



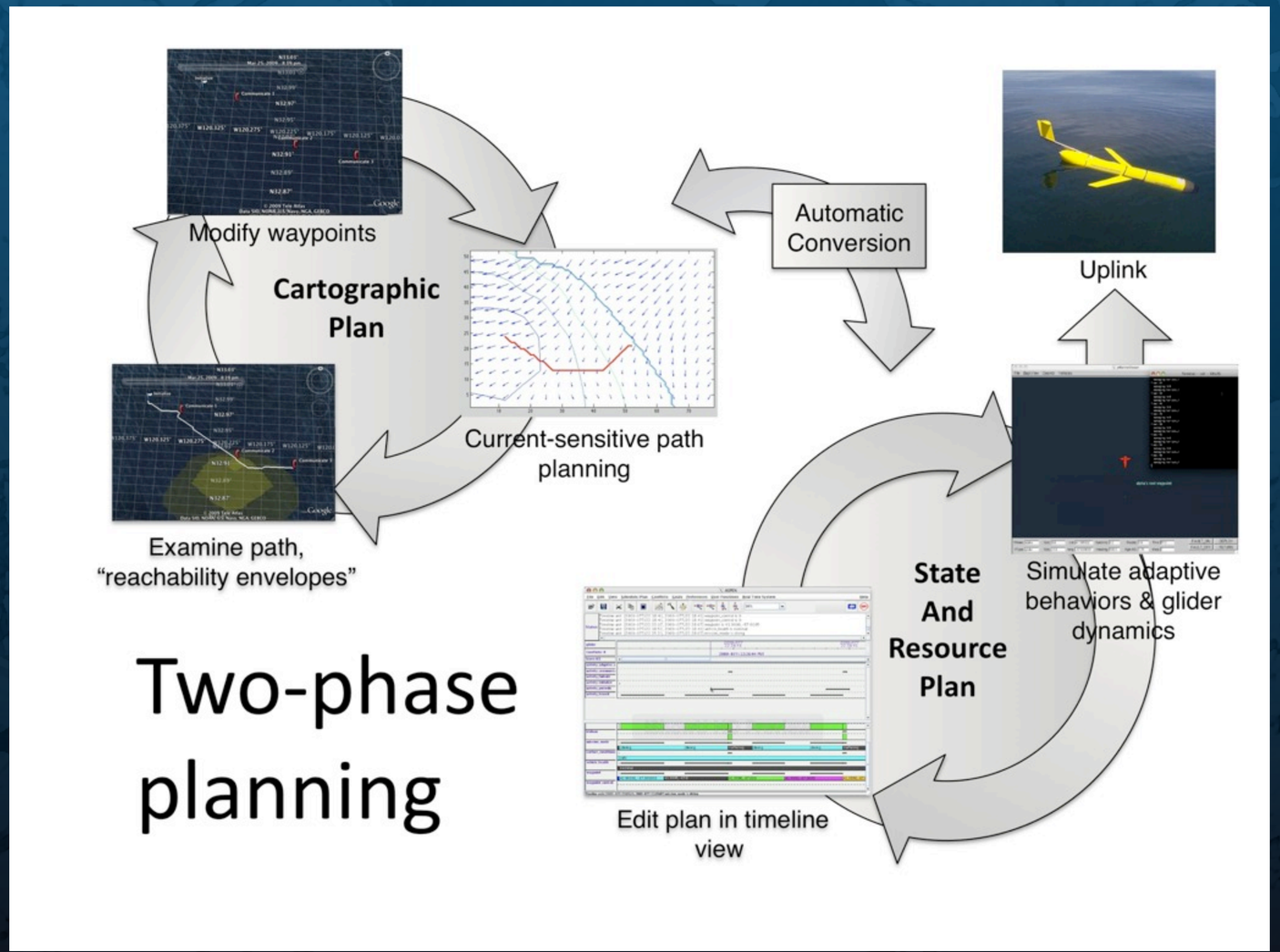
- Known constraints (slow 0.5 knot, Battery, shipping lanes)
- Uncertain constraints (time-varying 3D currents)
- Operate autonomously & re-plan daily



- From A to B in the shortest time
- Follow a time-varying feature (shelf-slope salinity intrusion)

The OOI Observing System Experiment (OSE)

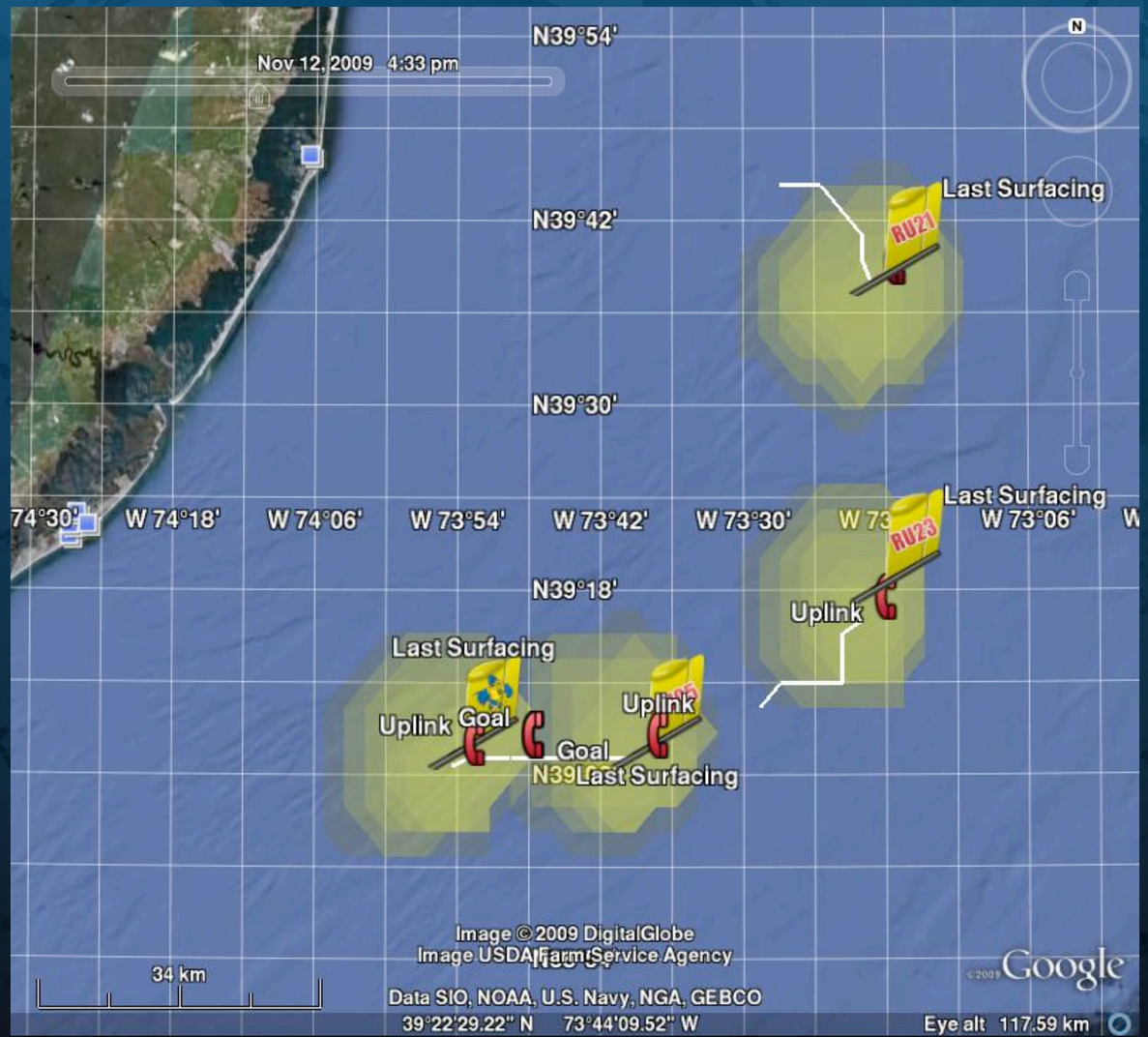
Scientific community



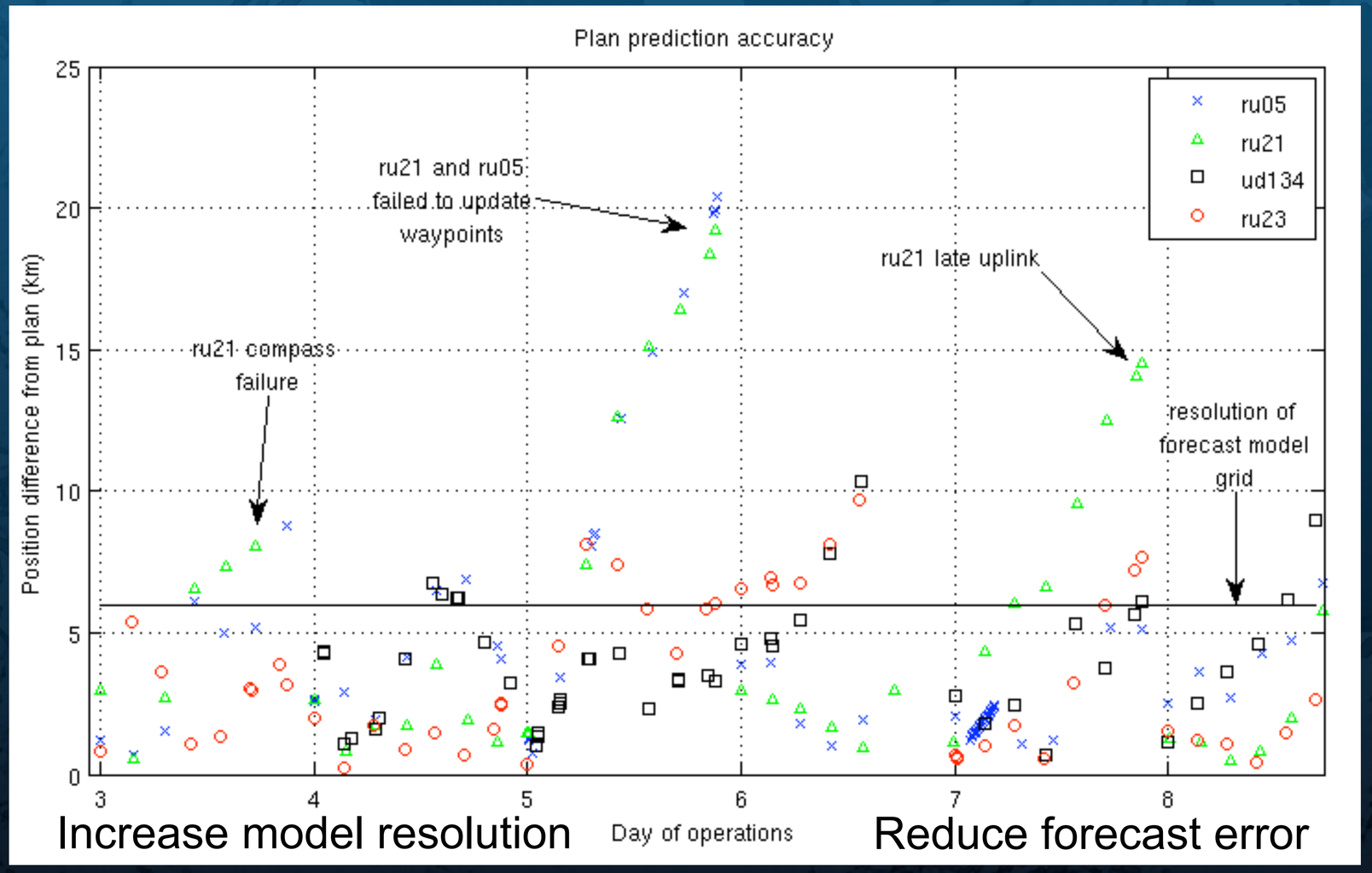
Marine operators

The OOI Observing System Experiment (OSE)

Distributed decision making using live web service tools



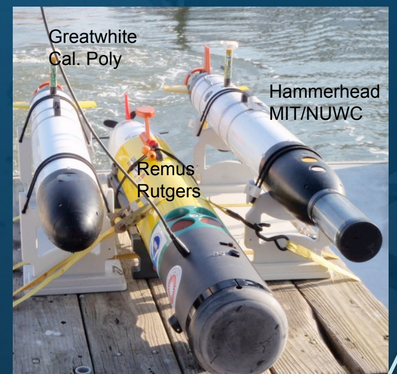
The OOI Observing System Experiment (OSE)

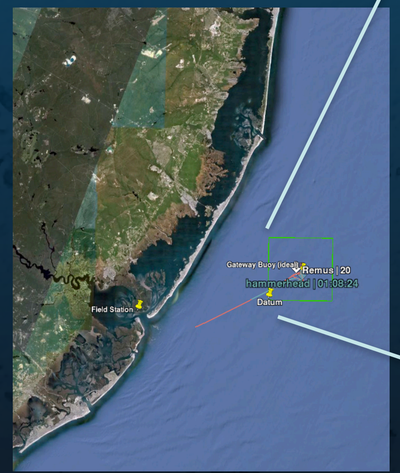


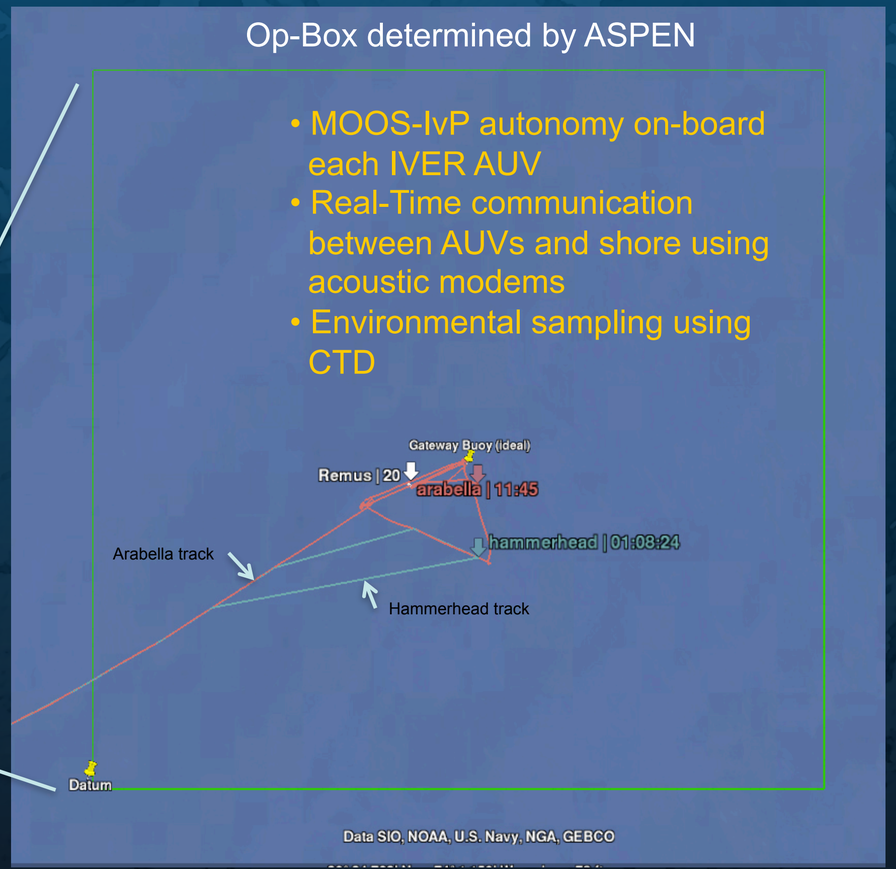
How well did we do?

The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

- High resolution underwater planning
- Smart robots
- Distributed control







The OOI Observing System Experiment (OSE)

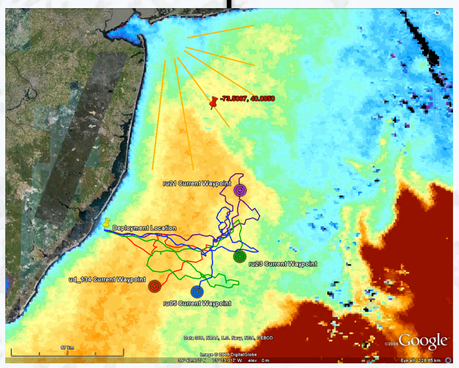
Science Alerts

Scientists

Science Campaigns

Science Agents

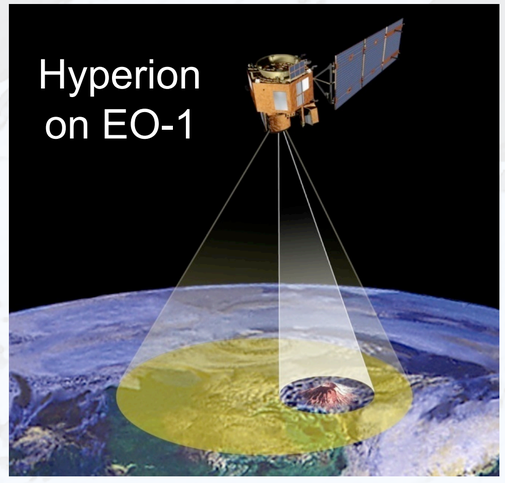
Science Event Manager
Processes alerts and
Prioritizes response observations



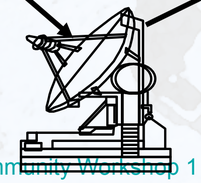
Observation Requests

EO-1 Flight Dynamics
Tracks, orbit, overflights,
momentum management

ASPEN
Schedules observations on EO-1

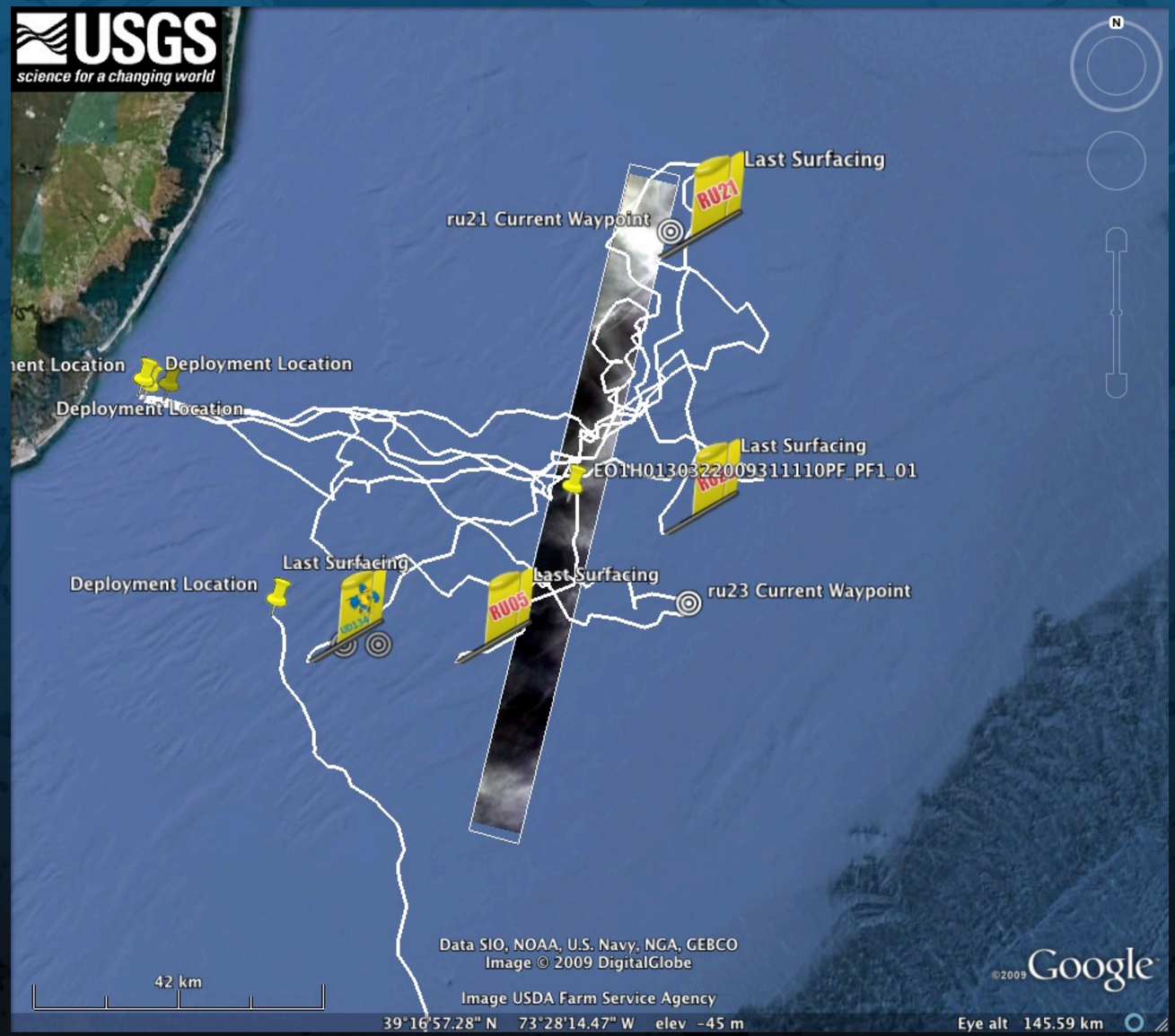


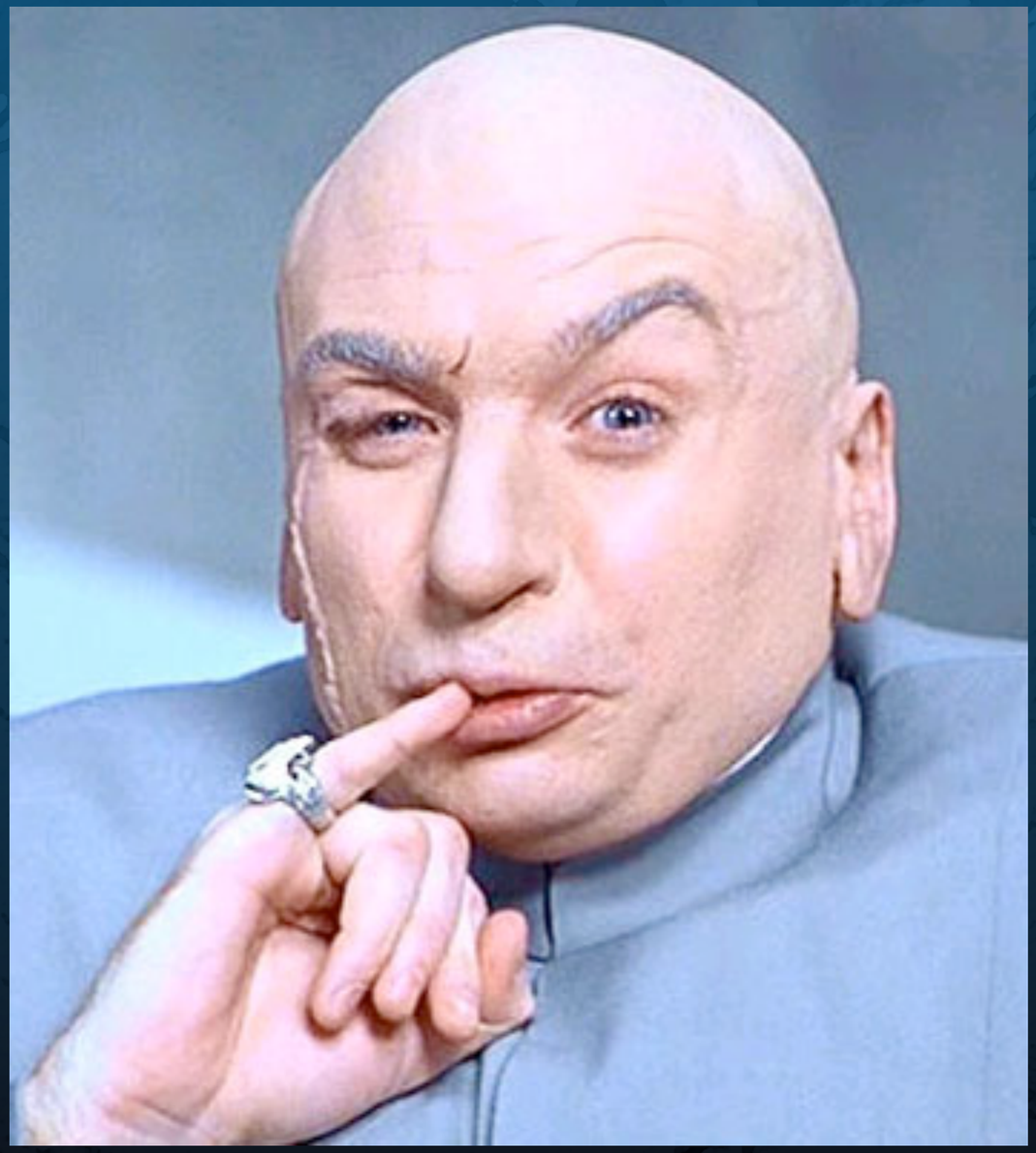
Updates to onboard plan



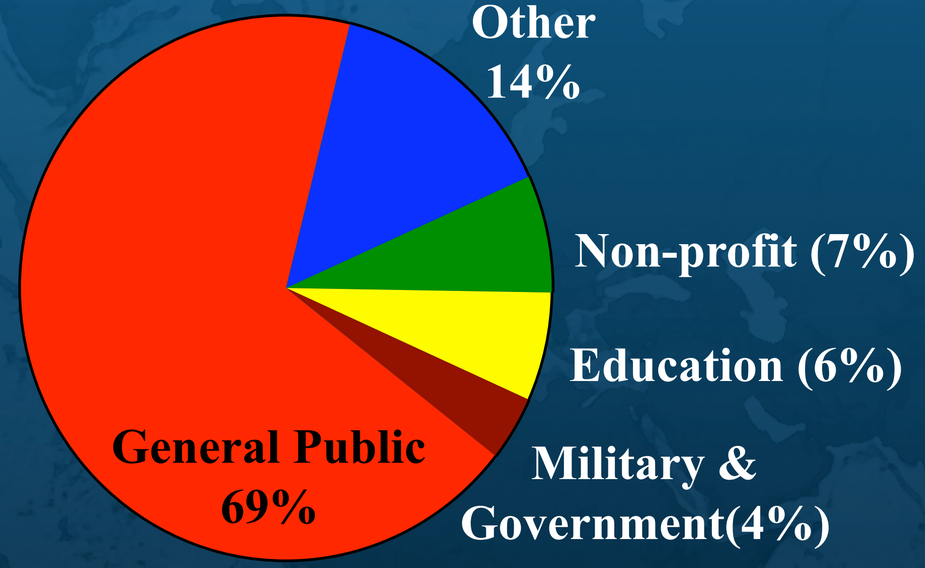
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

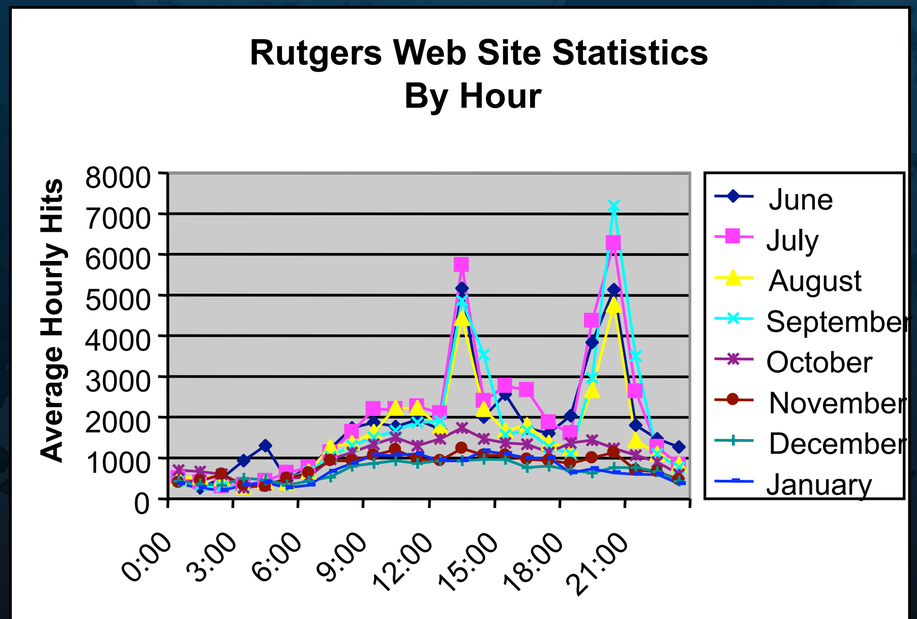
Hyperion on EO-1
7.5 km by 100 km
(30 m resolution)





Rutgers Web Site Statistics





~250,000 web hits a day