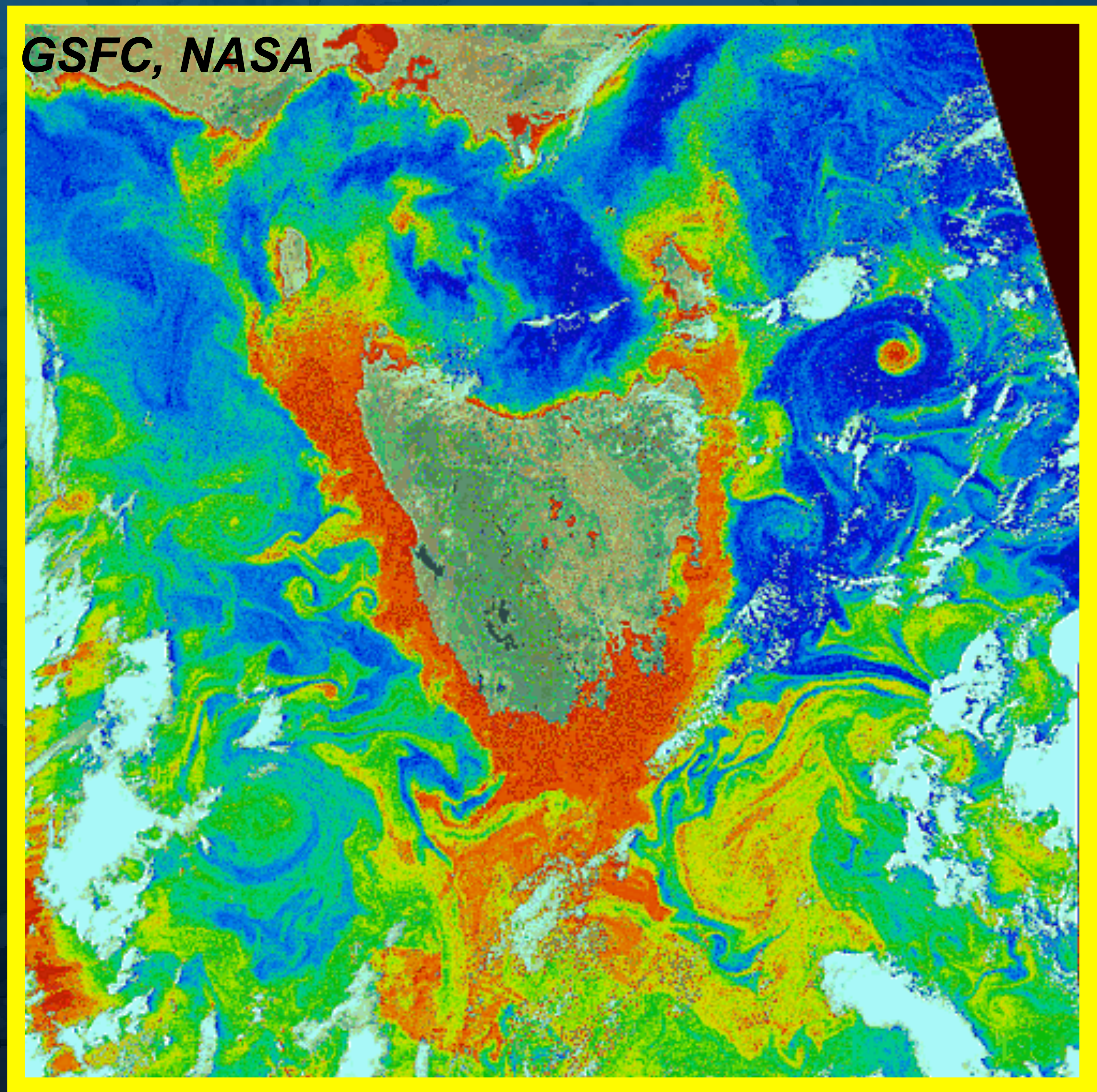
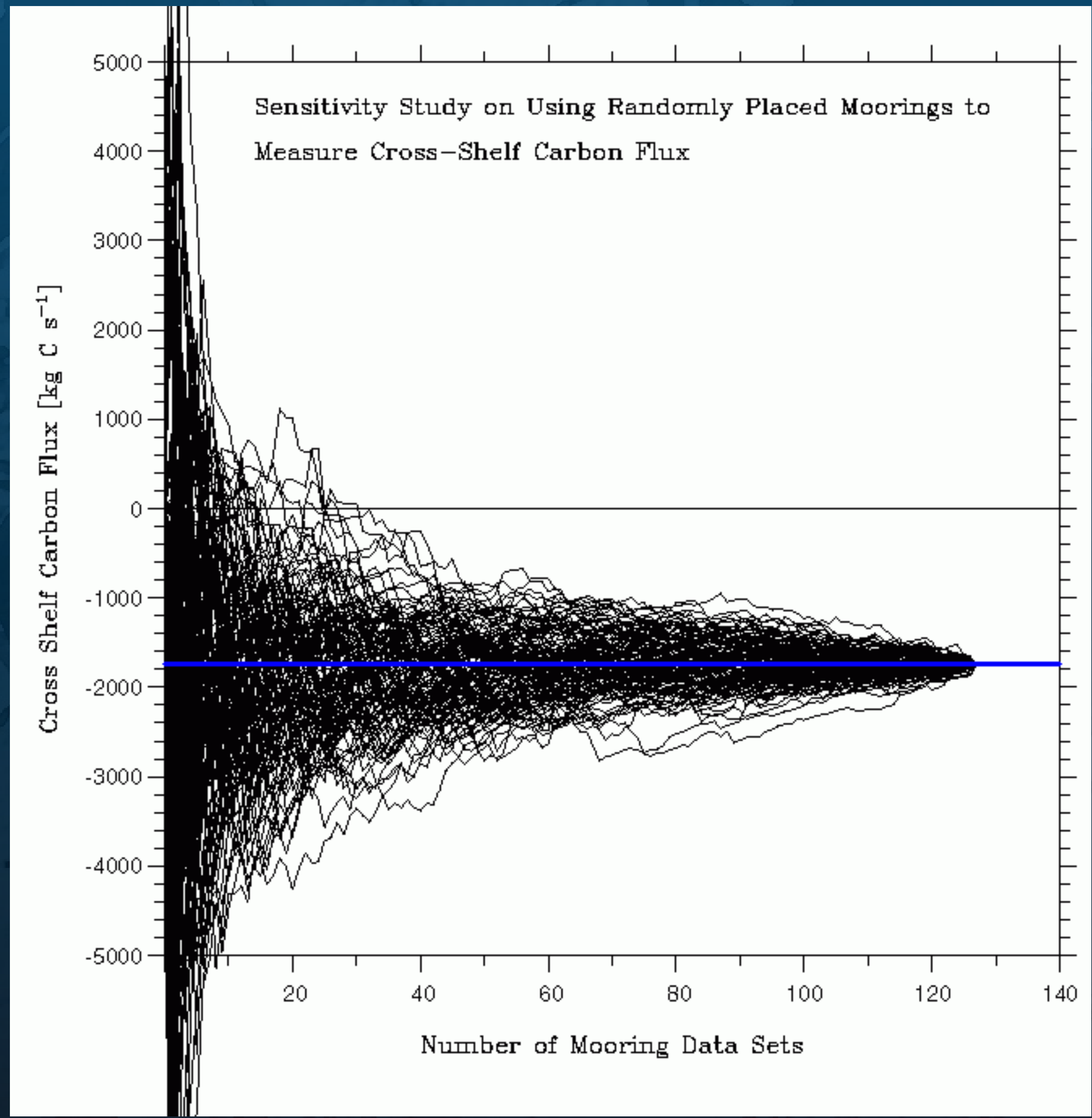
Rise of the Machines

Themes
-Some of the new technologies your generation will have
-There are MANY UNKNOWN UNKNOWNS
-Automation is coming

Natural Variability: Where do you put a mooring? Where do you drive the ship? When should you be out there?



Color variability at multiple scales around Tasmania from CZCS (winds? currents? bottom topography?)



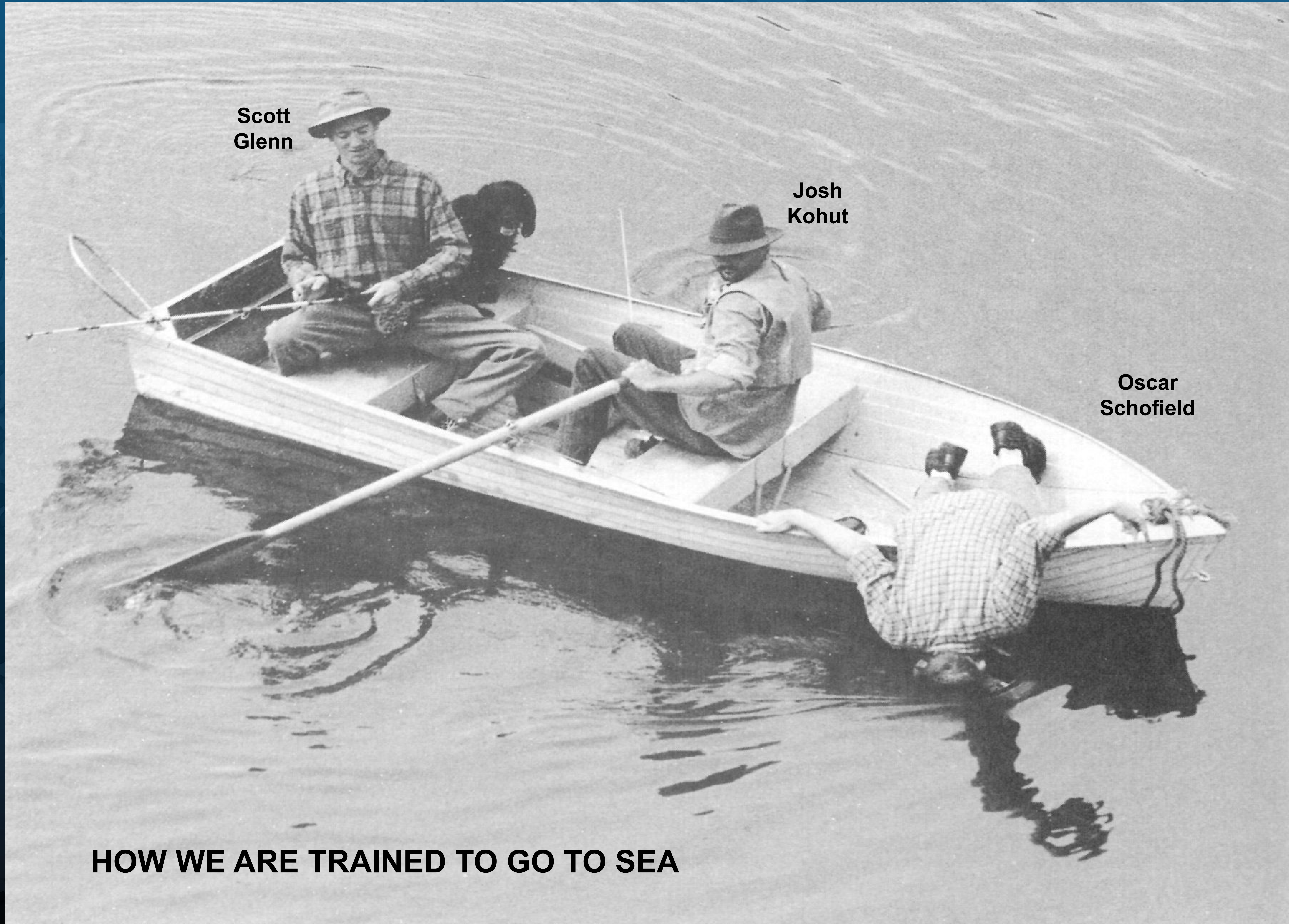
Simulations of required number of moorings to predict THE SIGN of cross shelf carbon transport

Rumsfeld "Unknown unknowns"

Prior to Deployment

After to Deployment

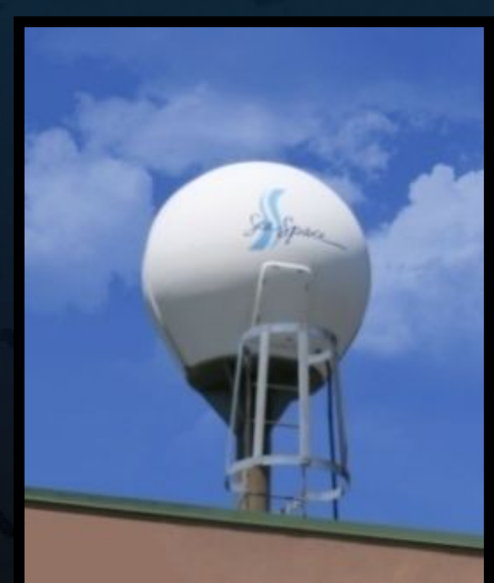

Rumsfeld “Unknown unknowns”

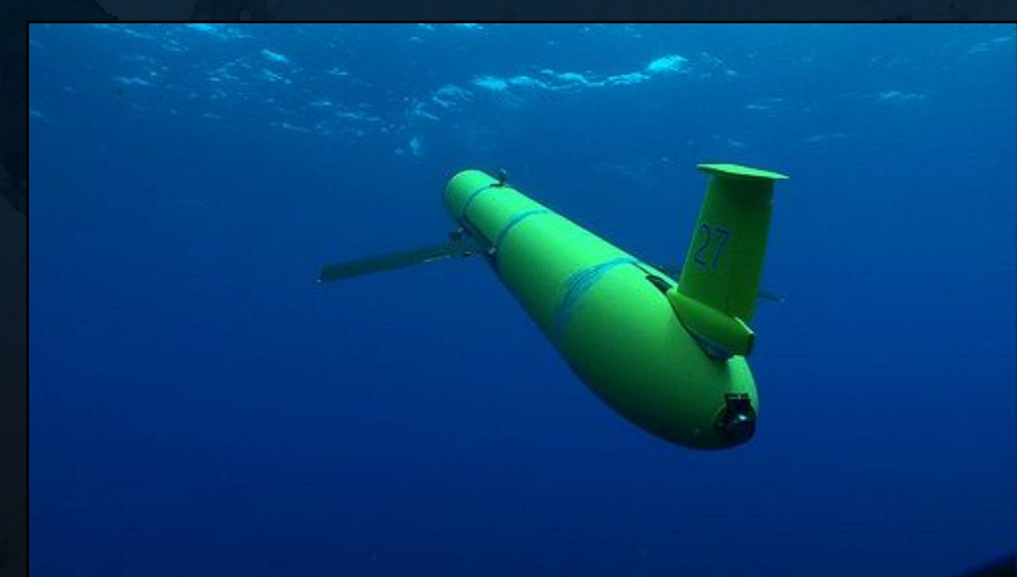

Scott
Glenn
Josh
Kohut
Oscar
Schofield
HOW WE ARE TRAINED TO GO TO SEA

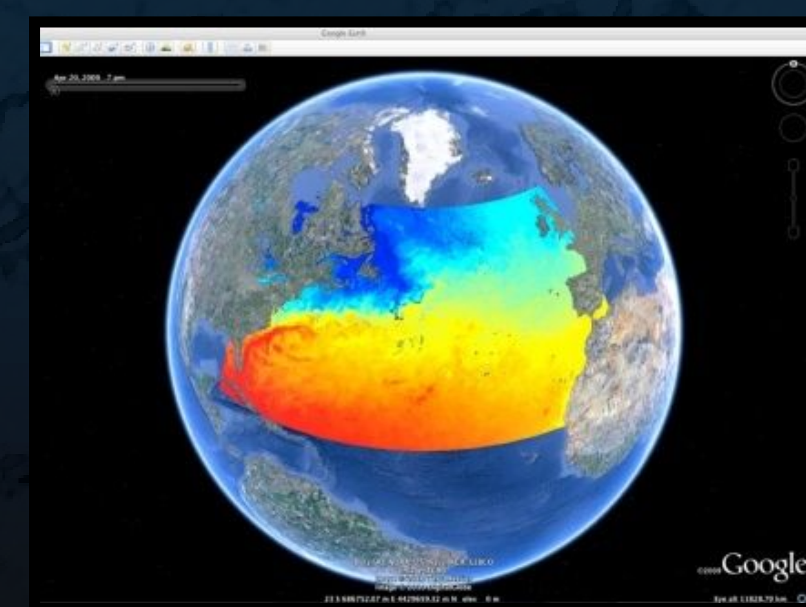
Ocean is hard to sample

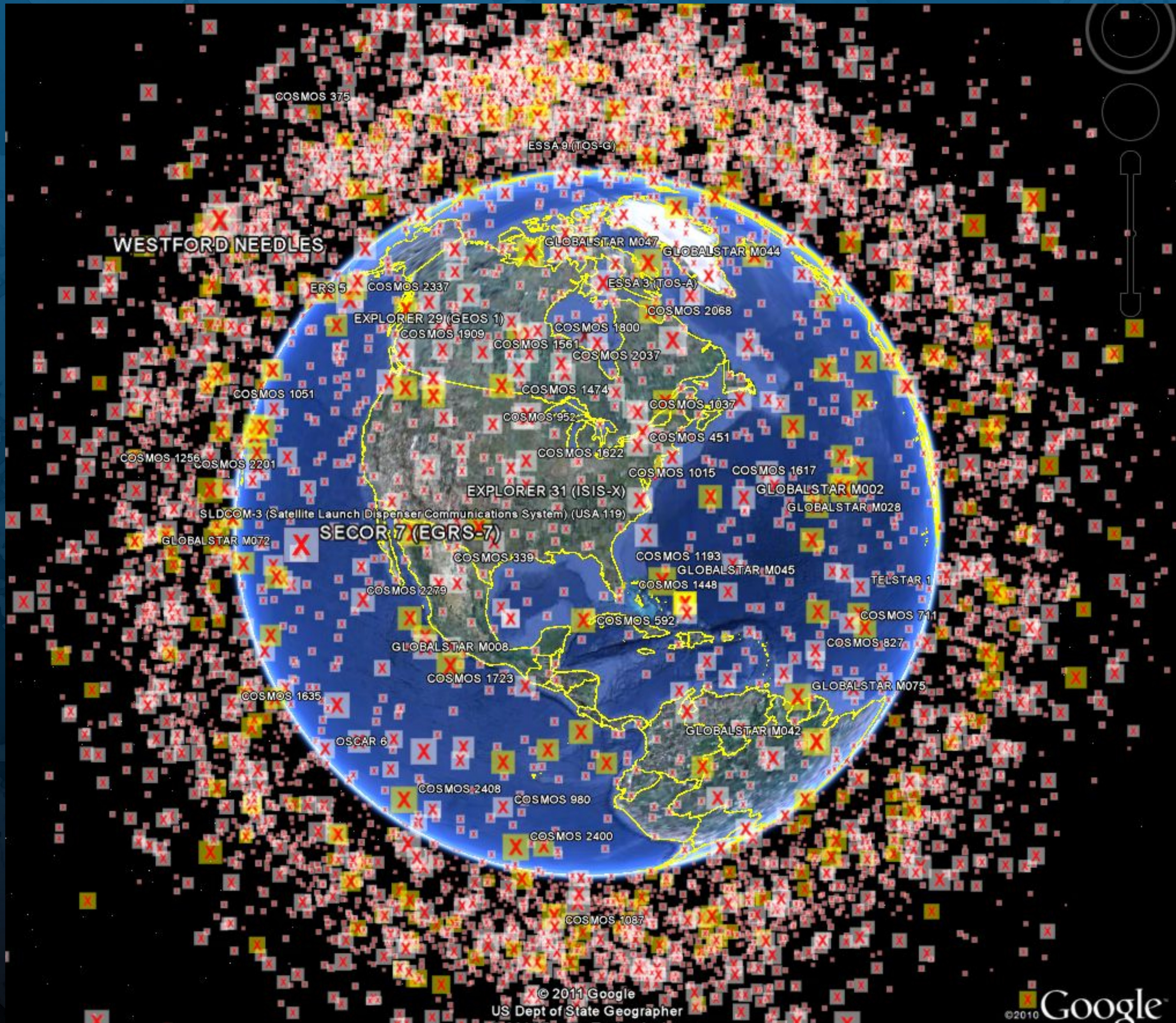
Technology will rescue us!!!!

My Lab (Coastal Ocean Observation Lab: COOL)









Satellites
-Thousands of satellites

-After the ships one of the great technical revolutions for oceanography


3518 Floats
30-Jun-2012
Argo
60°E
120°E
180°
120°W
60°W
0°

AUVs: They can be big

Autosub
Southampton Oceanography Center UK

Hugin
Kongsberg Simrad, Norway

Martin-600
Maridan, Denmark

Explorer family,
ISE research, Canada

Odyssey,
Bluefin Robotics, USA

Thanks to Gwynn Griffiths

AUVs: They can be small

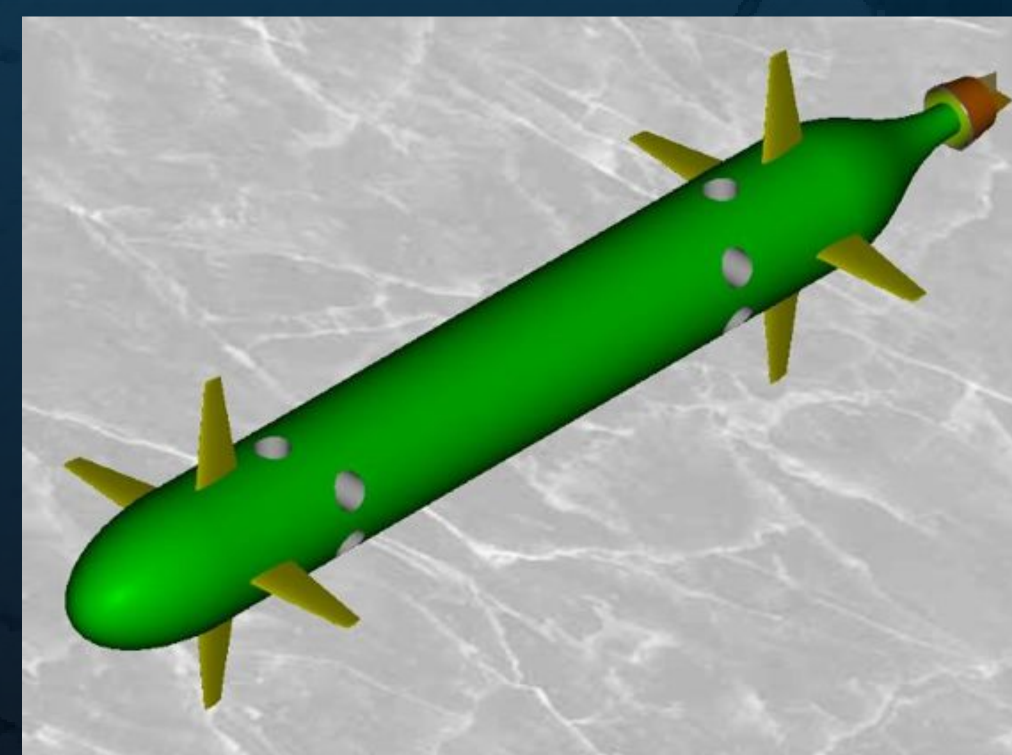
Slocum gliders

Mauve

REMUS

Seaglider

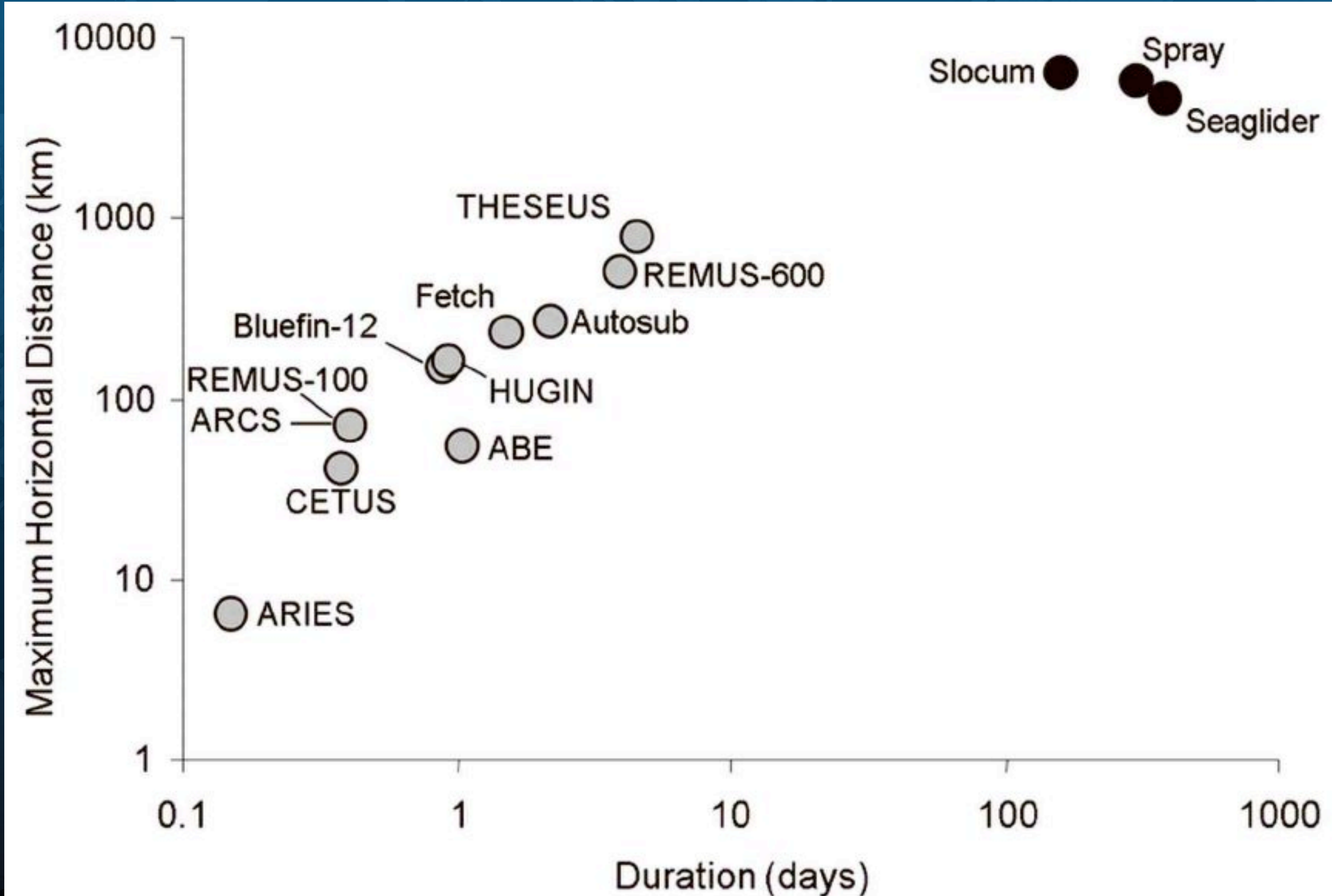
Spray

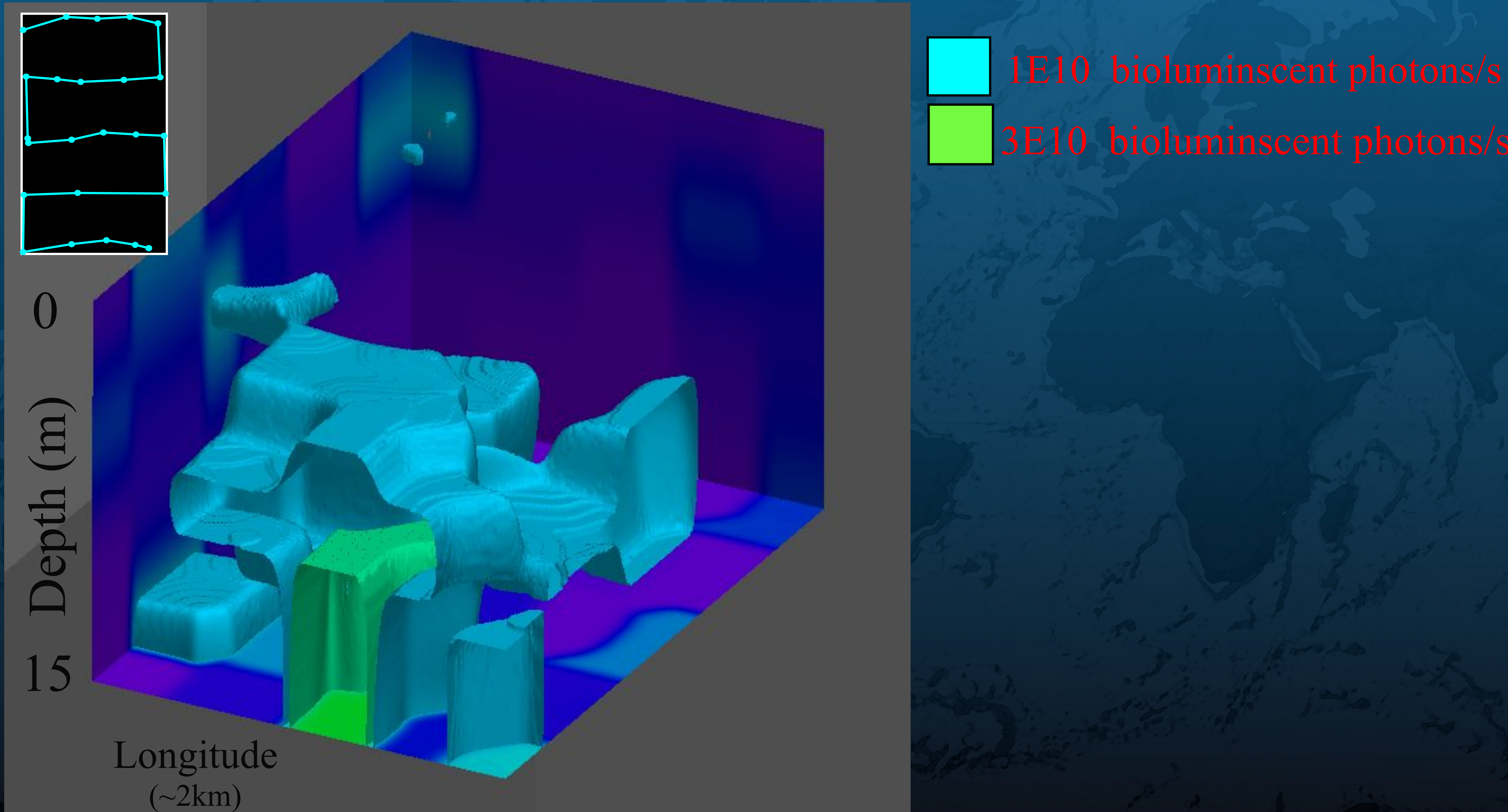


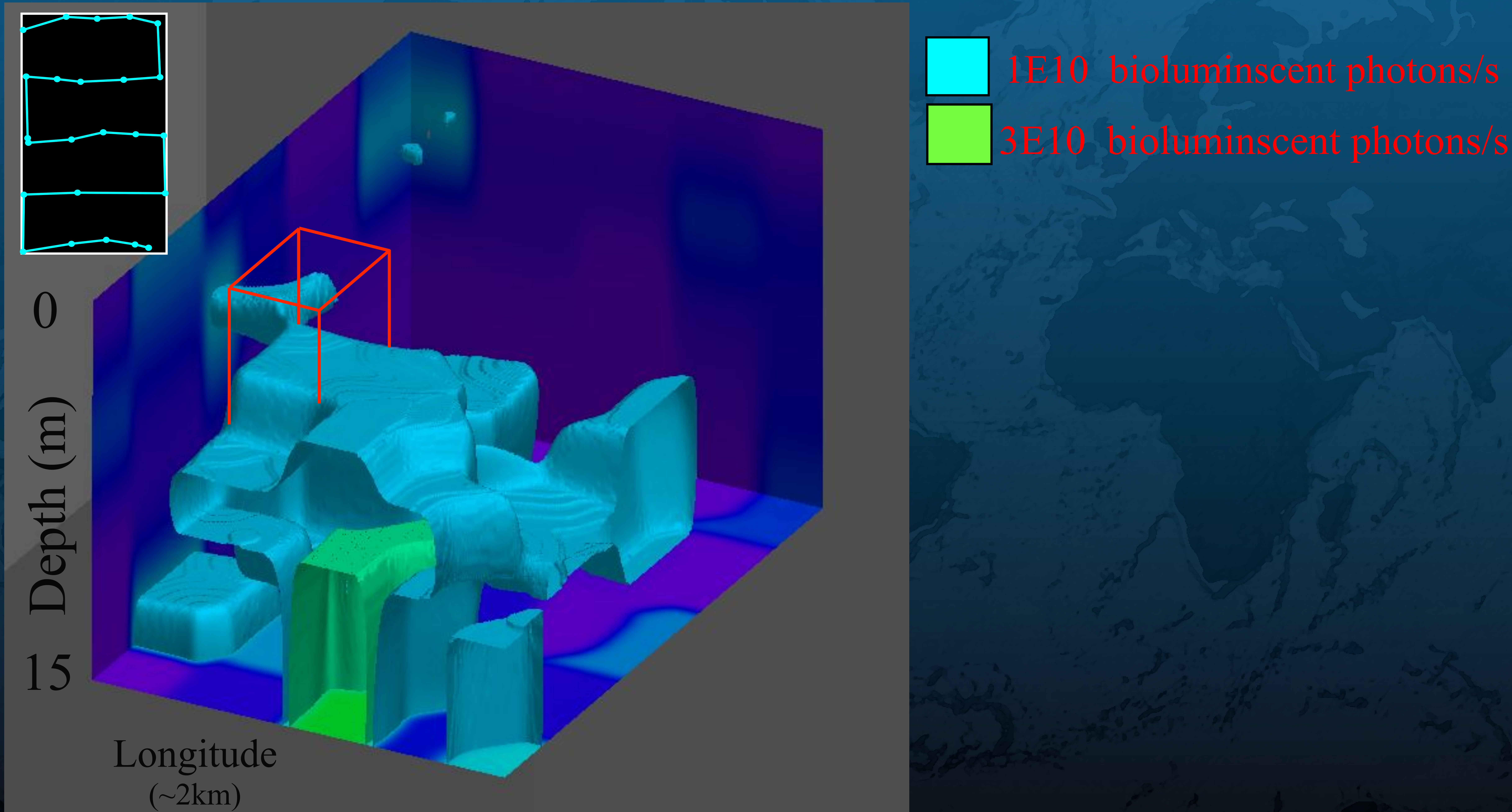
C-Scout

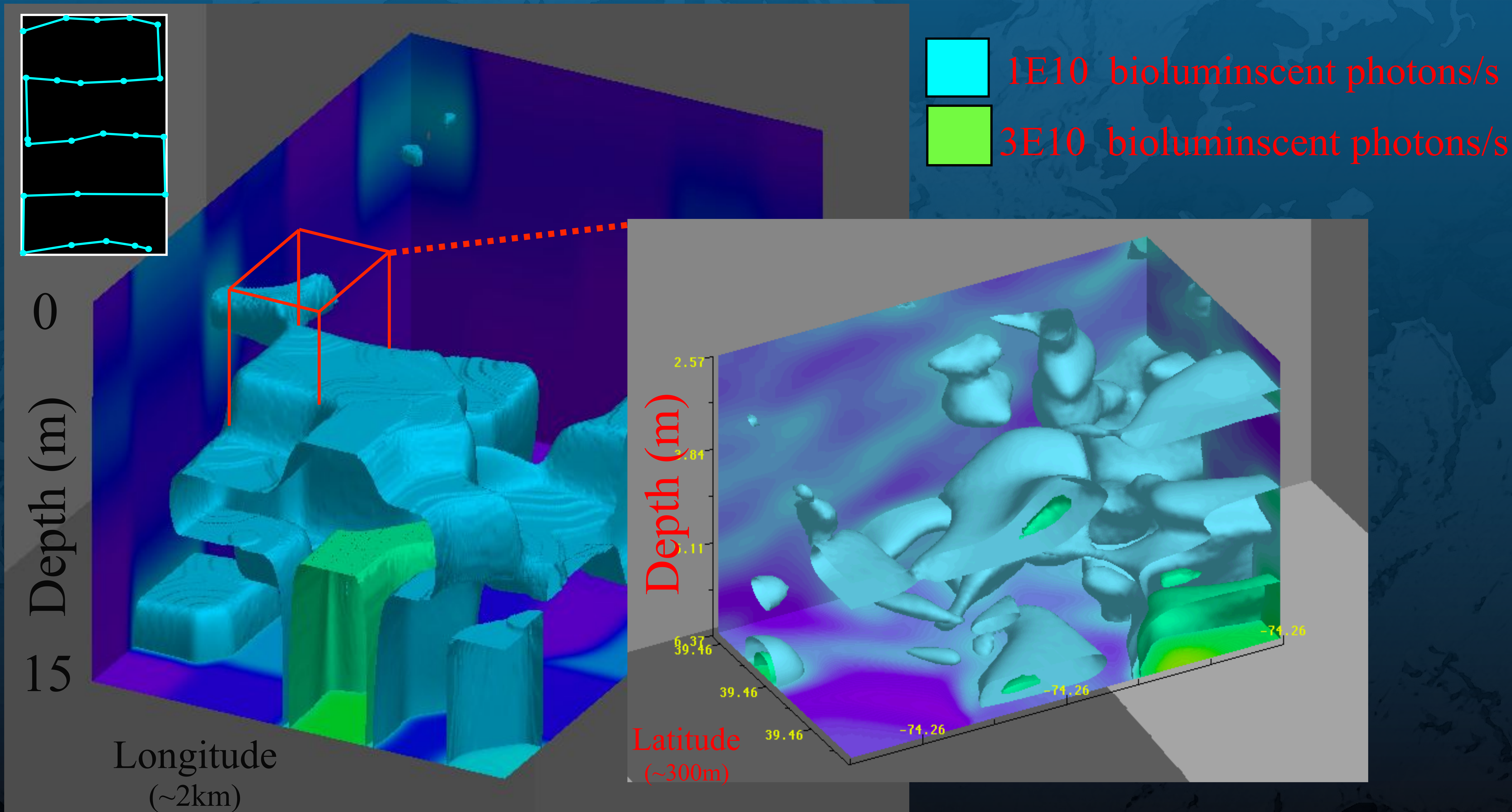
Gavia

Thanks to Gwynn Griffiths

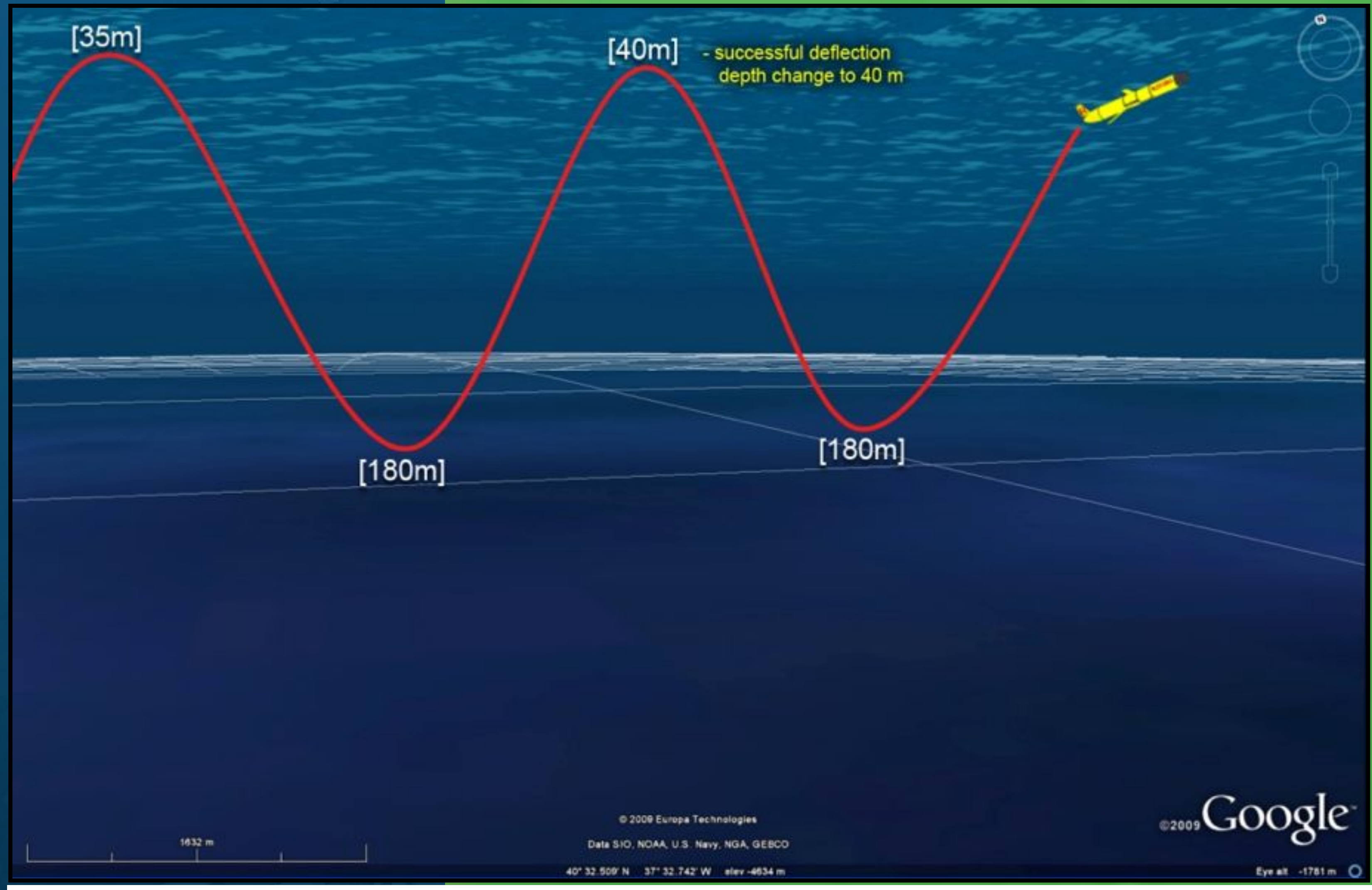

Maximum Horizontal Distance (km)
10000
1000
100
10
1
Slocum
Spray
Seaglider
THESEUS
REMUS-600
Fetch
Autosub
Bluefin-12
HUGIN
REMUS-100
ARCS
ABE
CETUS
ARIES
0.1
1
10
100
1000
Duration (days)

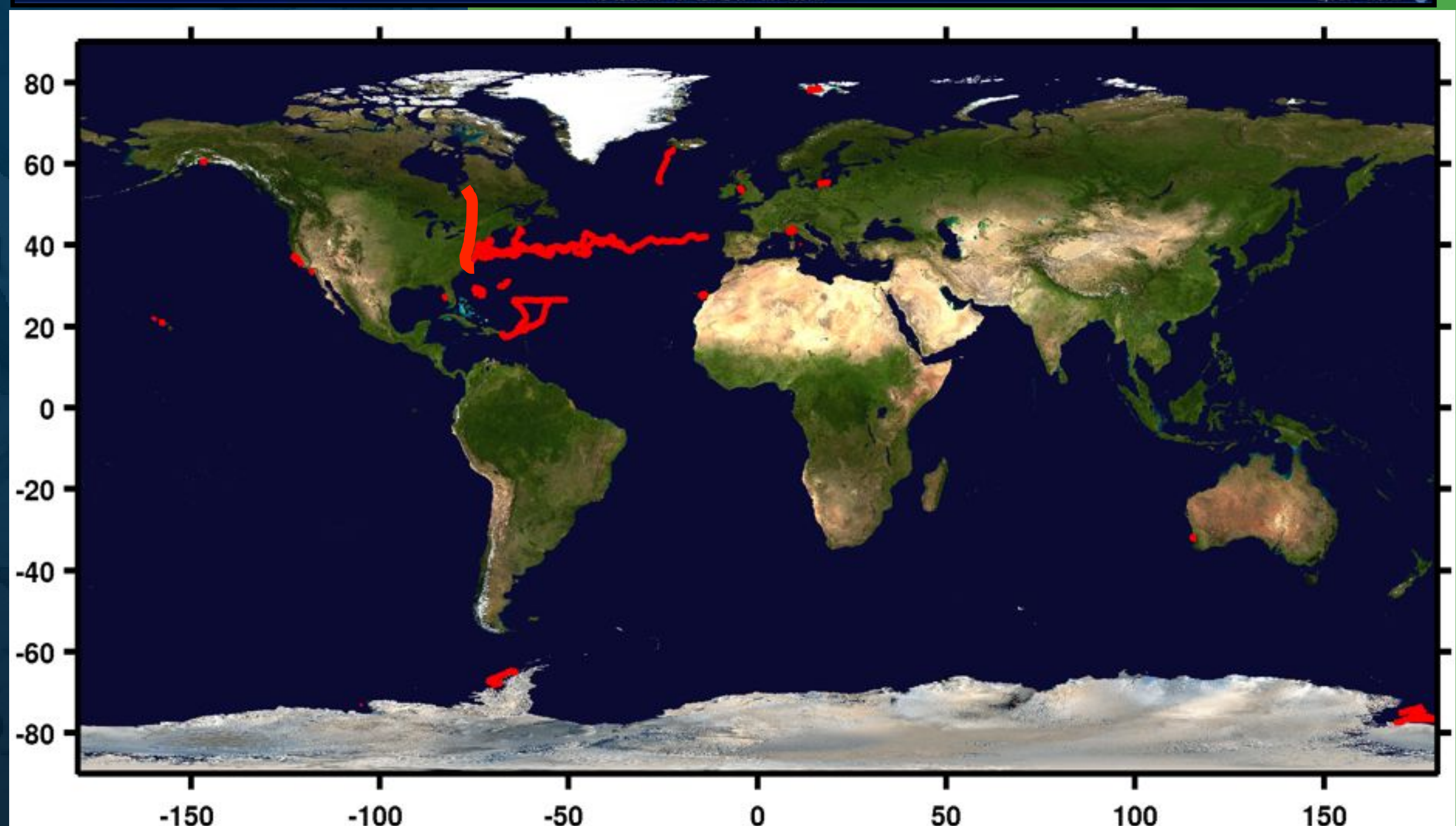

0
15
Depth (m)
Longitude
(~2km)
1E10 bioluminscent photons/s
3E10 bioluminscent photons/s

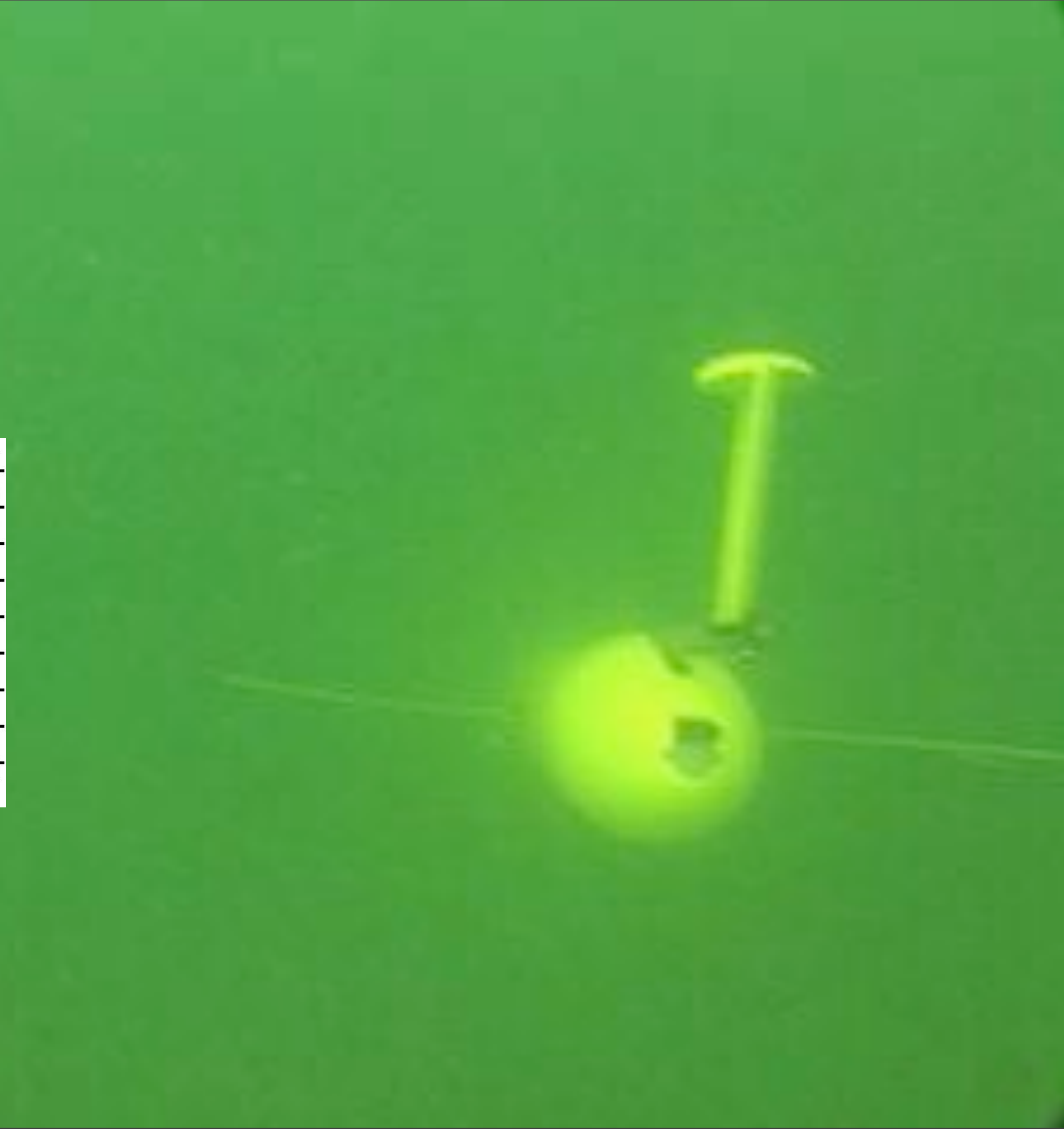

0
Depth (m)
15
Longitude
(~2km)
1E10 bioluminscent photons/s
3E10 bioluminscent photons/s



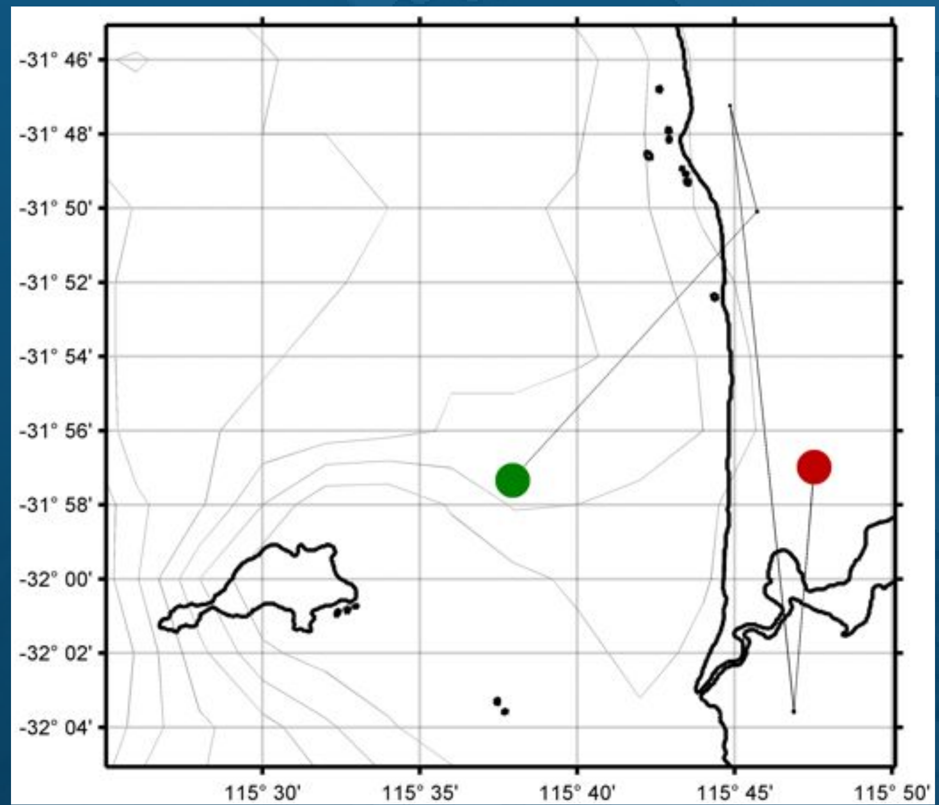
1E10 bioluminscent photons/s
3E10 bioluminscent photons/s
0
Depth (m)
15
Longitude
(~2km)
2.57
3.84
5.11
6.37
Depth (m)
39.46
39.46
39.46
-74.26
-74.26
-74.26
Latitude
(~300m)

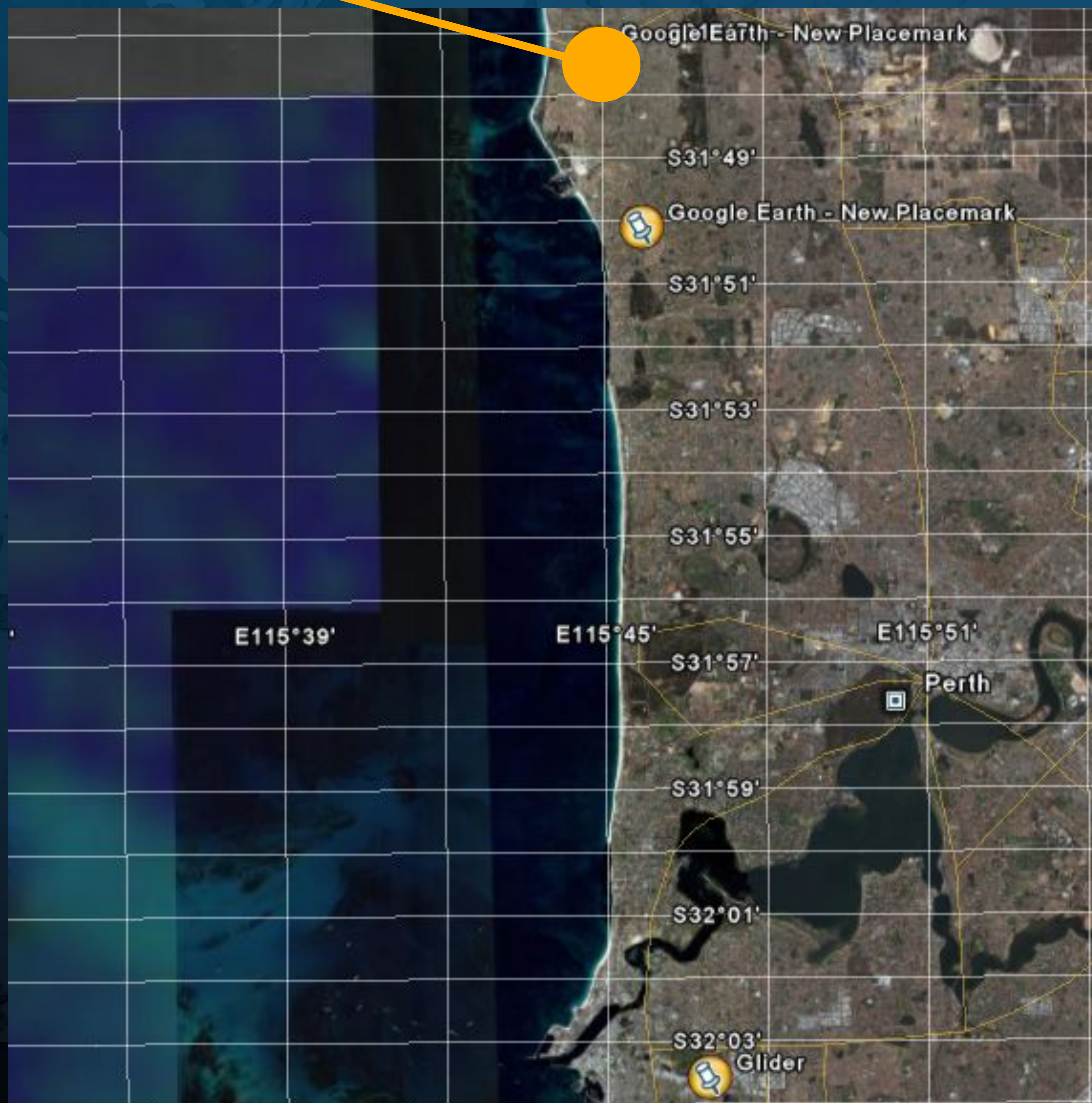

[35m]
[40m]
- successful deflection
depth change to 40 m
[180m]
[180m]
Google


80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150

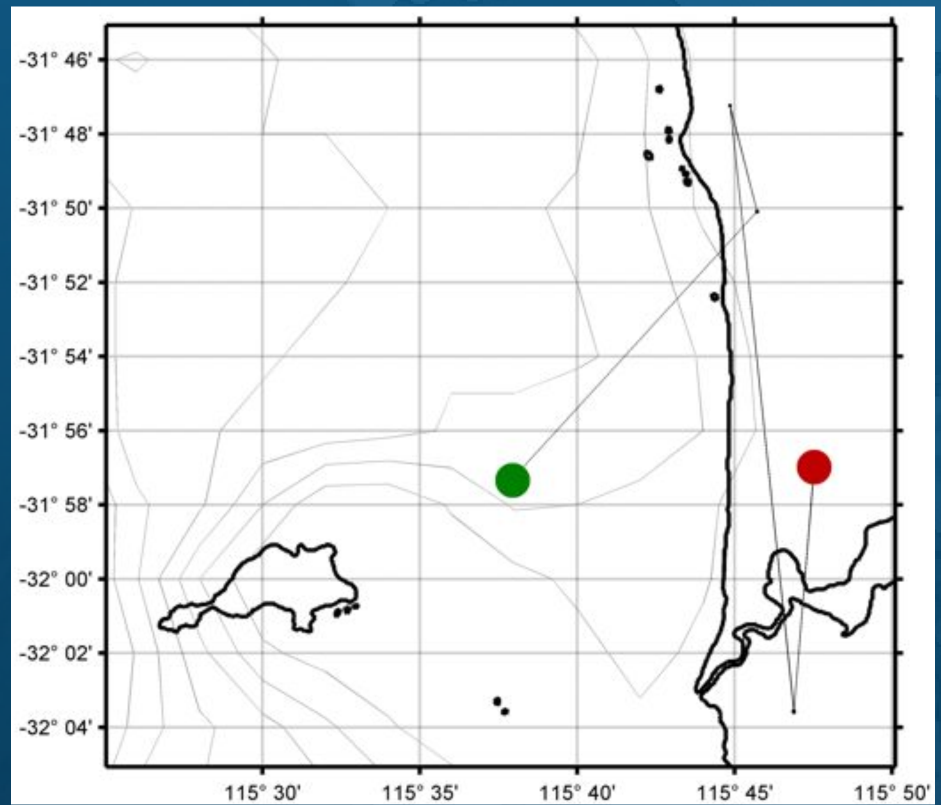


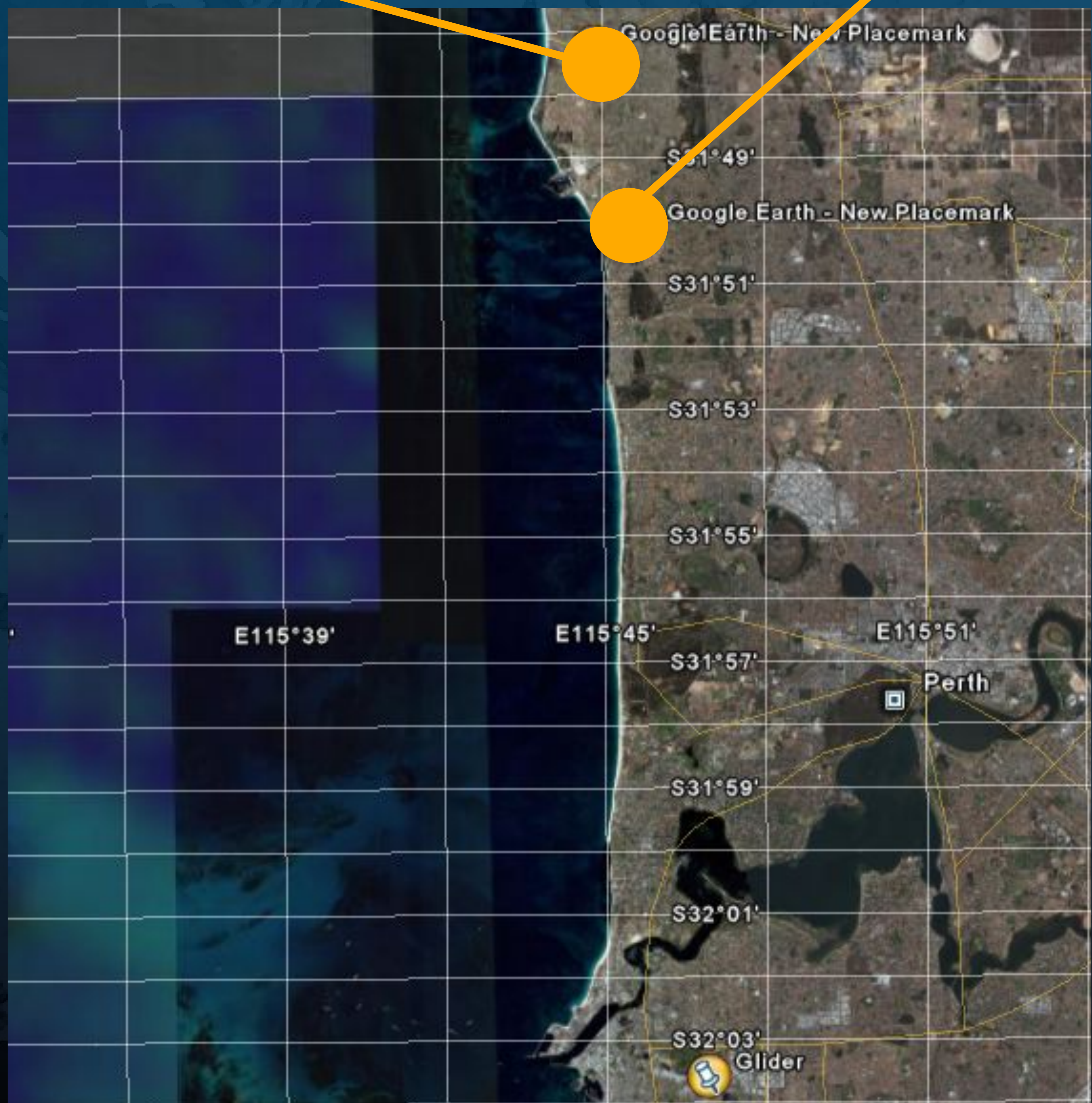
The Communication Revolution
Darwin's Odyssey



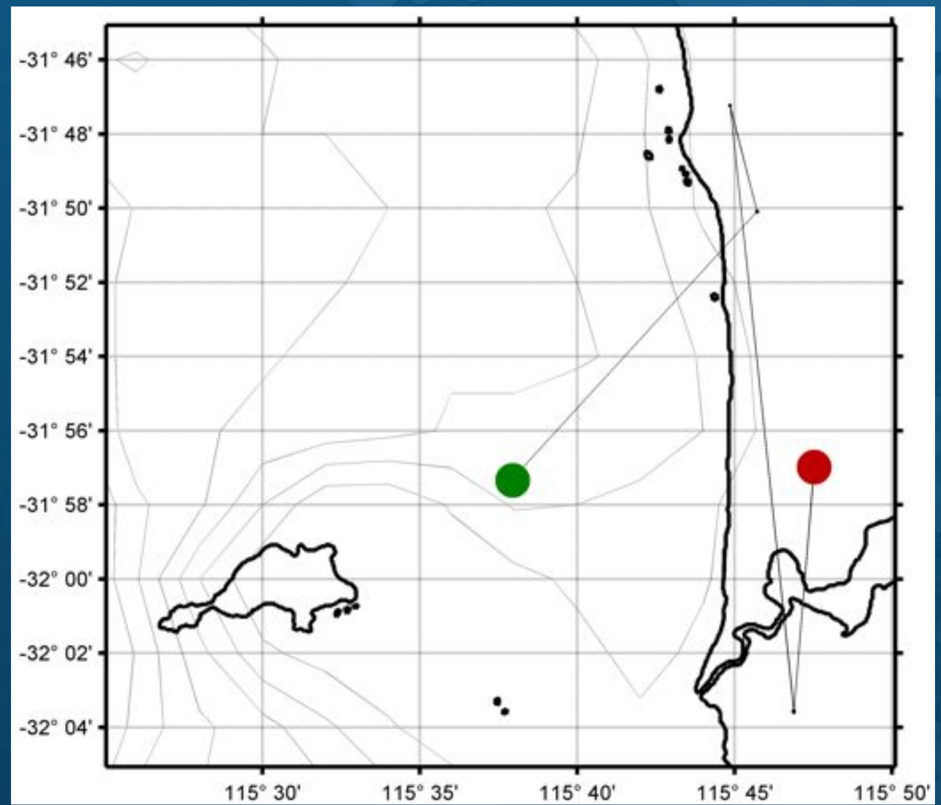


The Communication Revolution
Darwin’s Odyssey

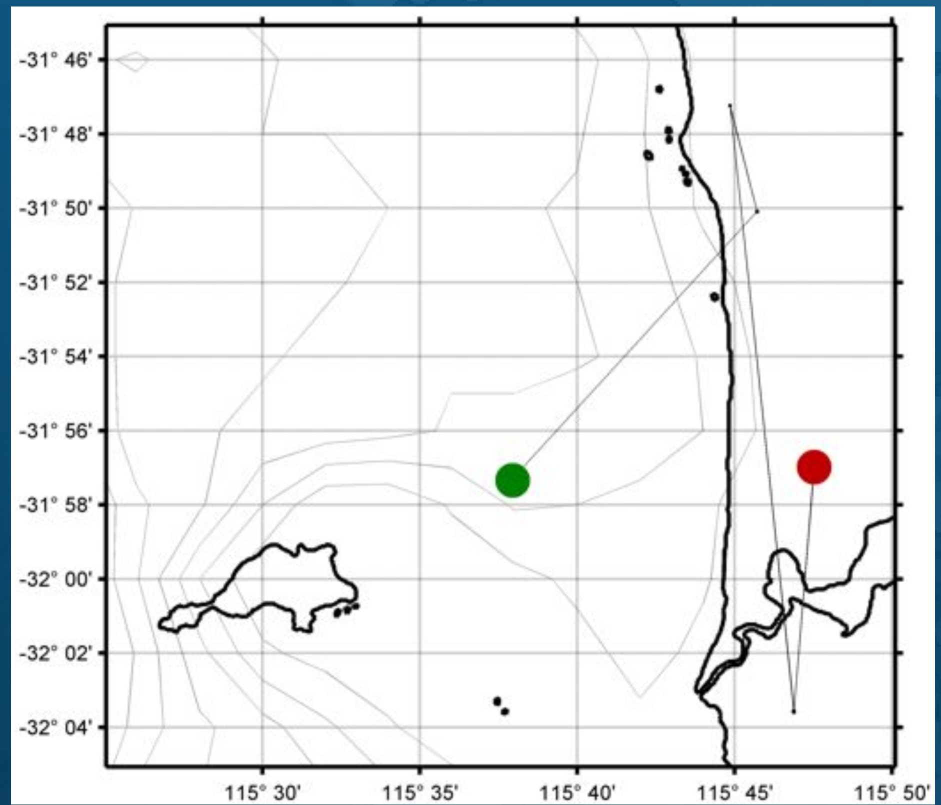


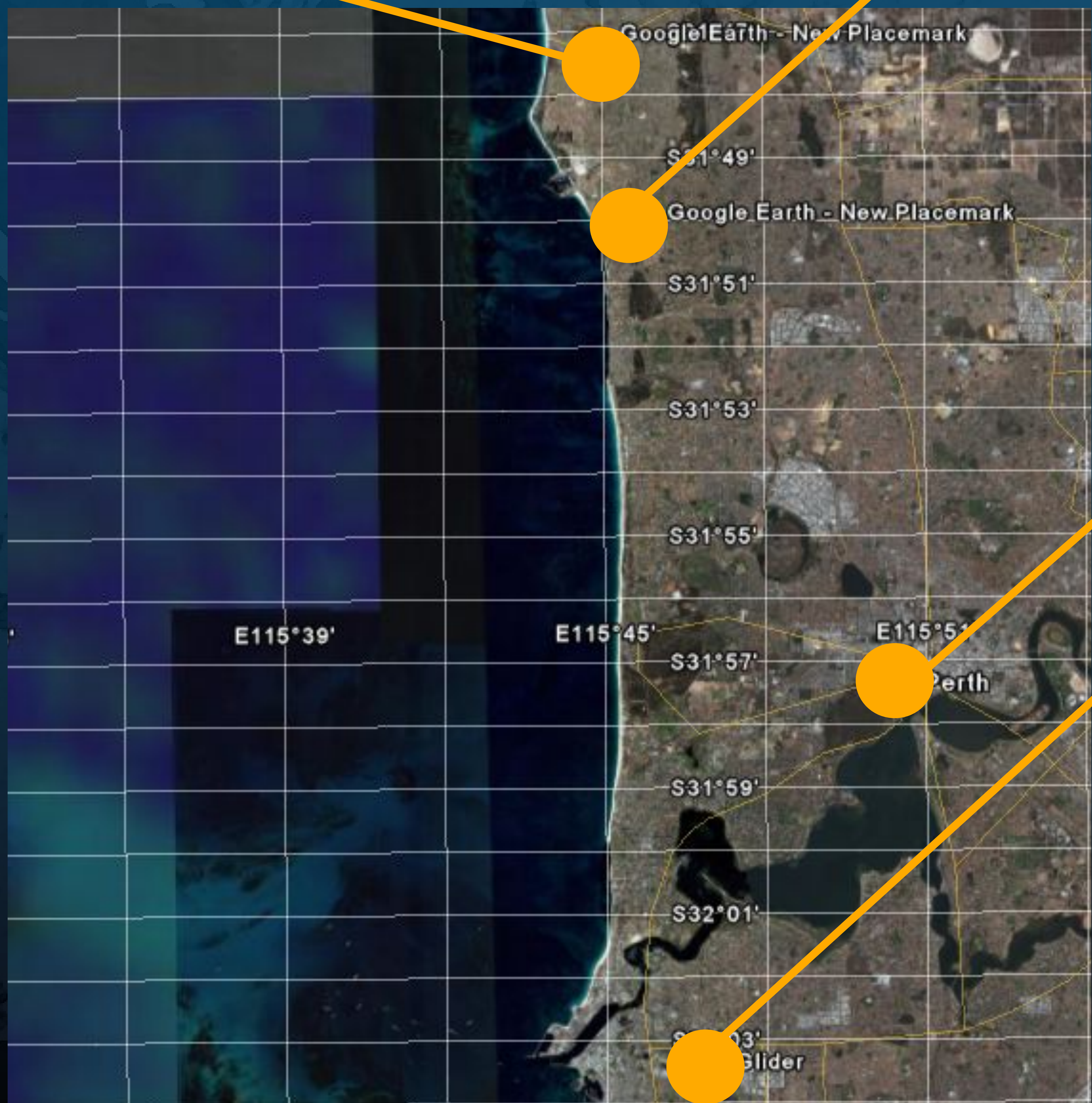


The Communication Revolution
Darwin’s Odyssey

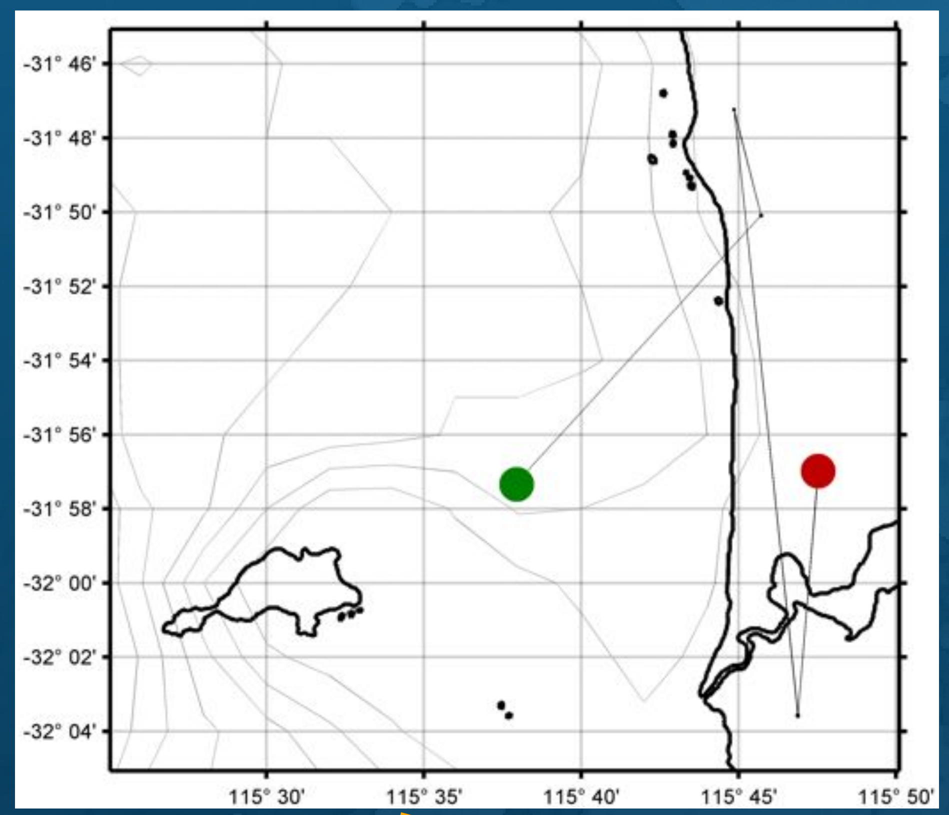


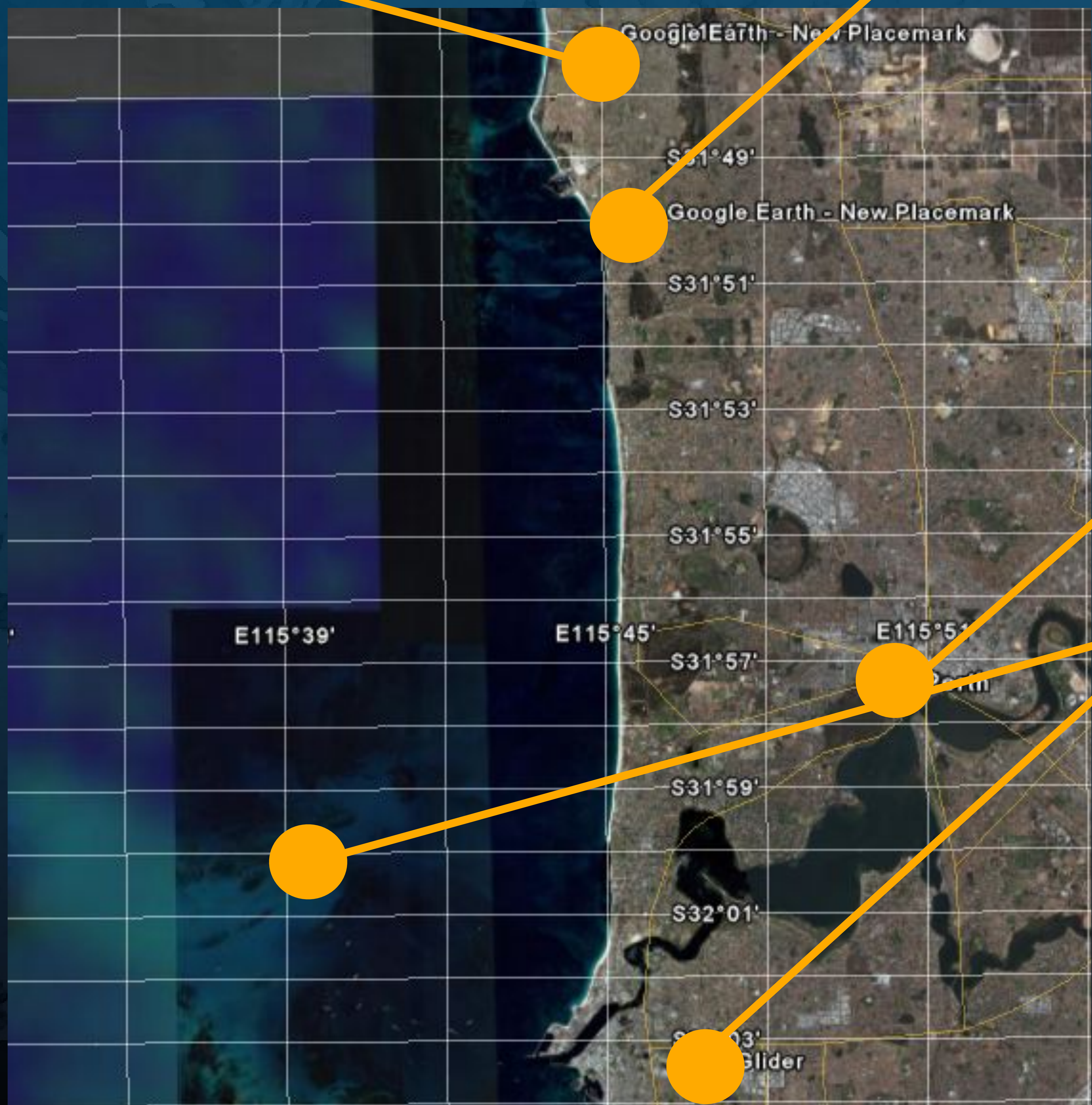
The Communication Revolution
Darwin's Odyssey

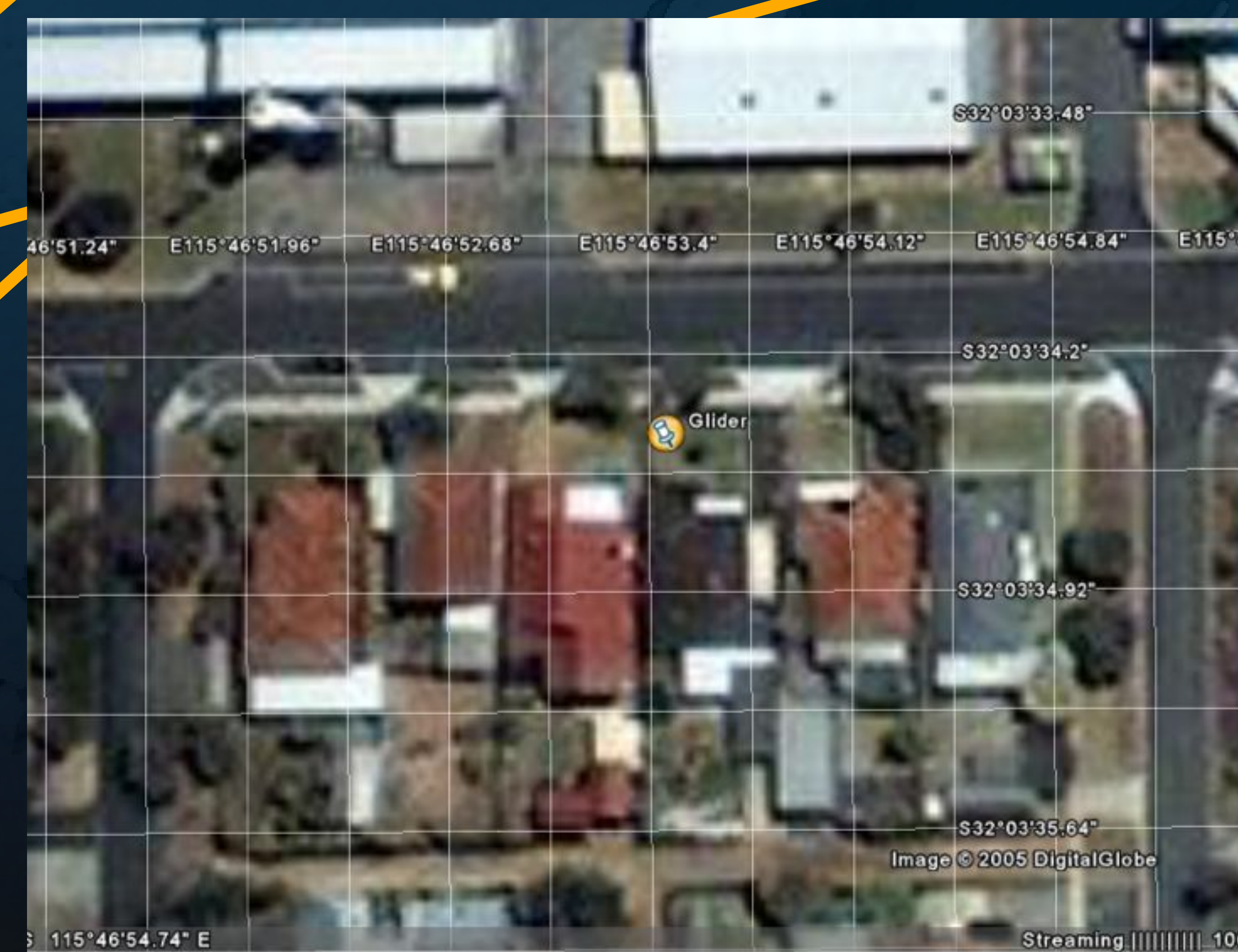


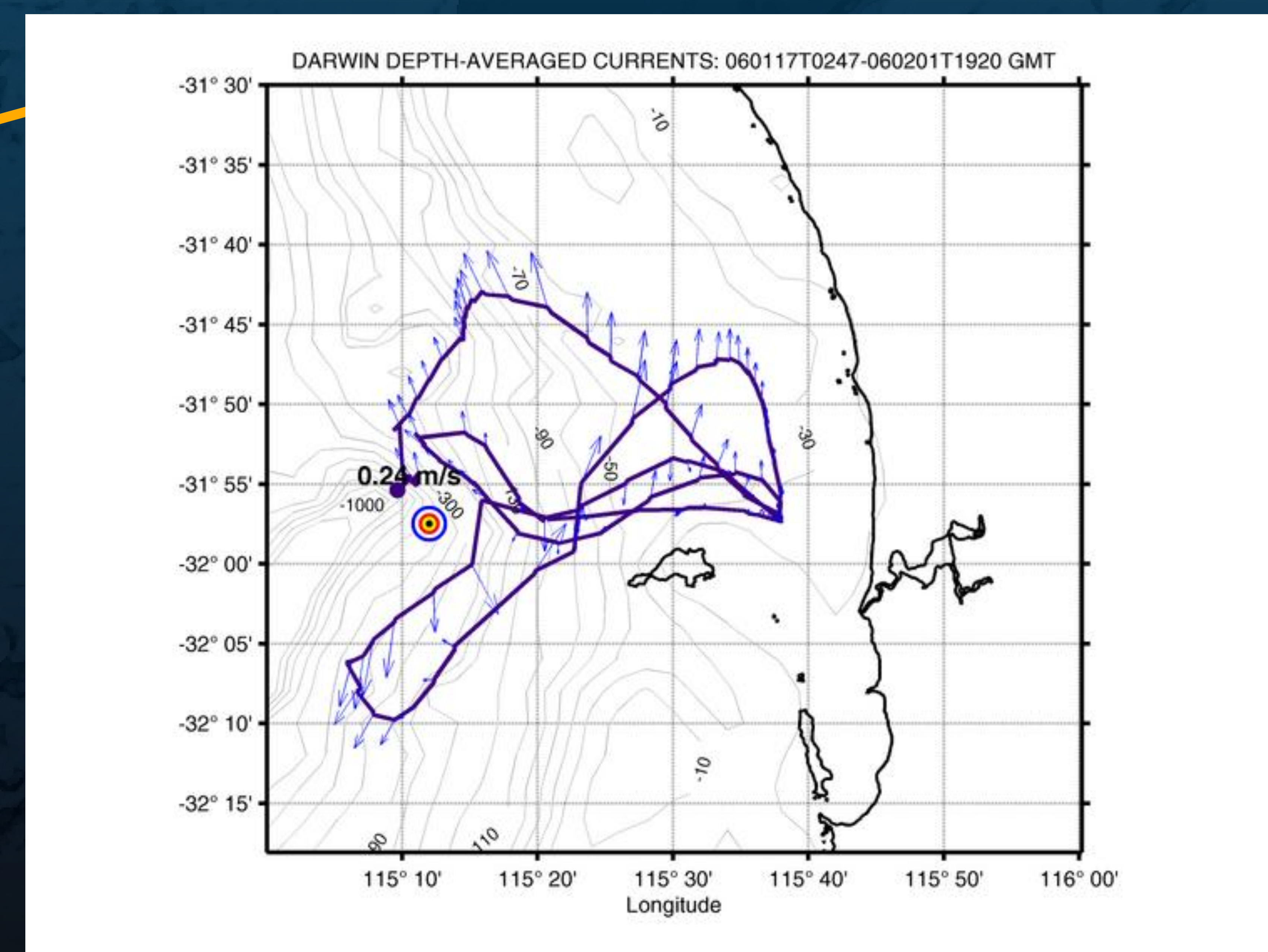


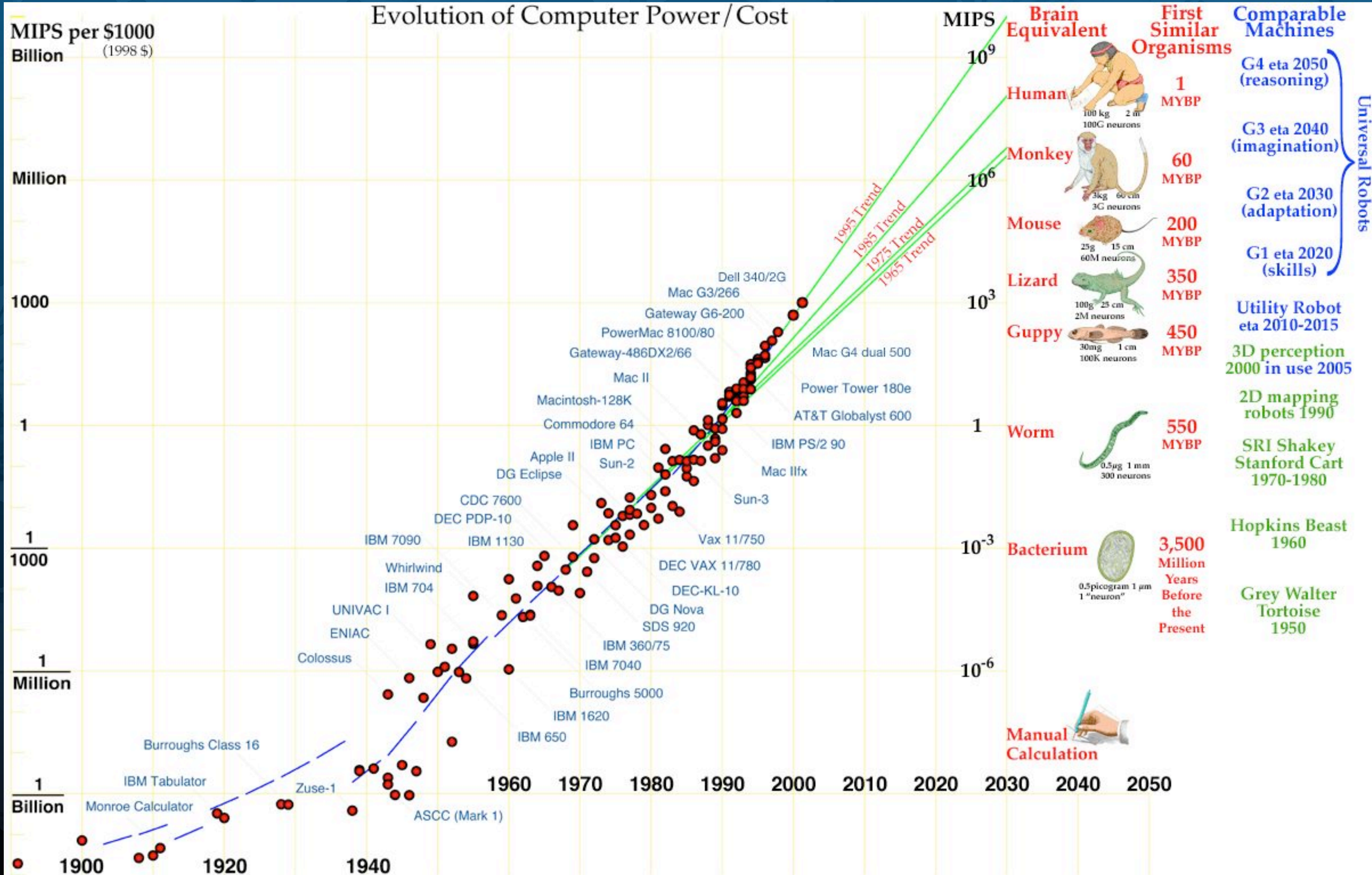
The Communication Revolution
Darwin's Odyssey



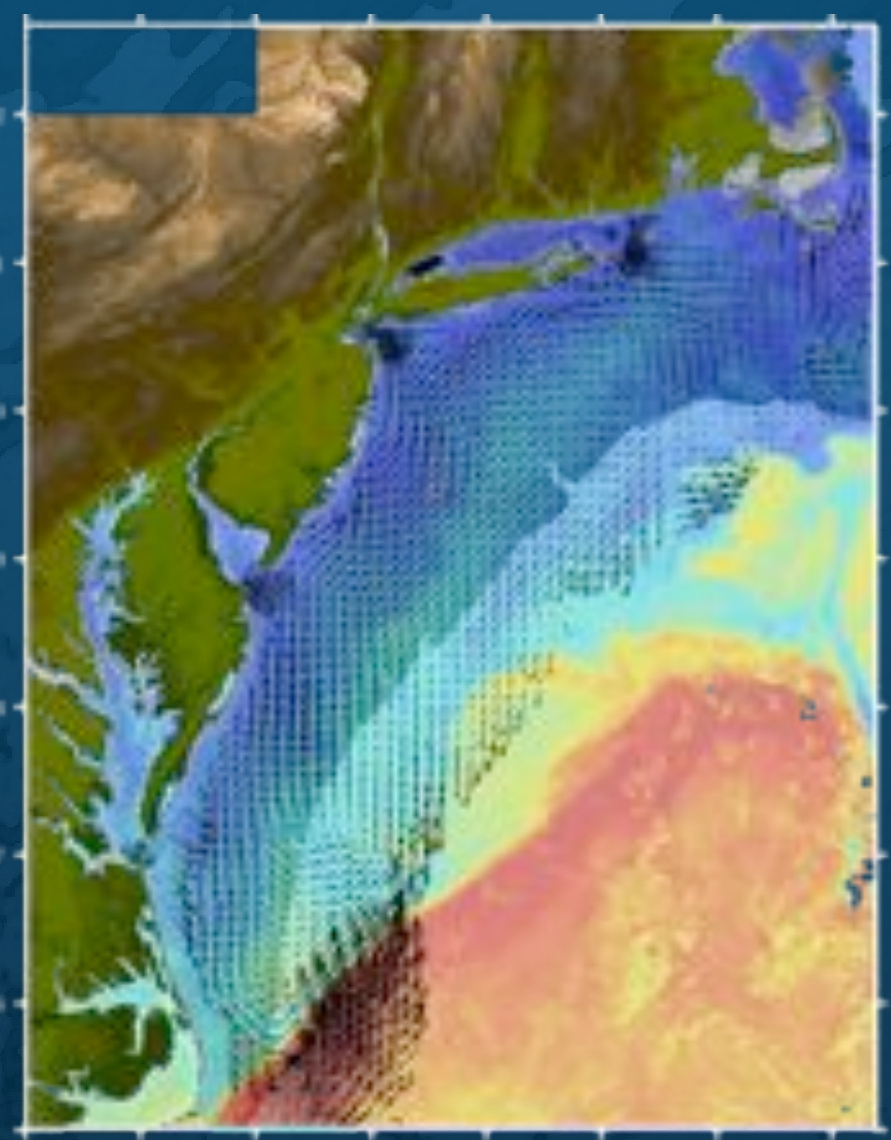




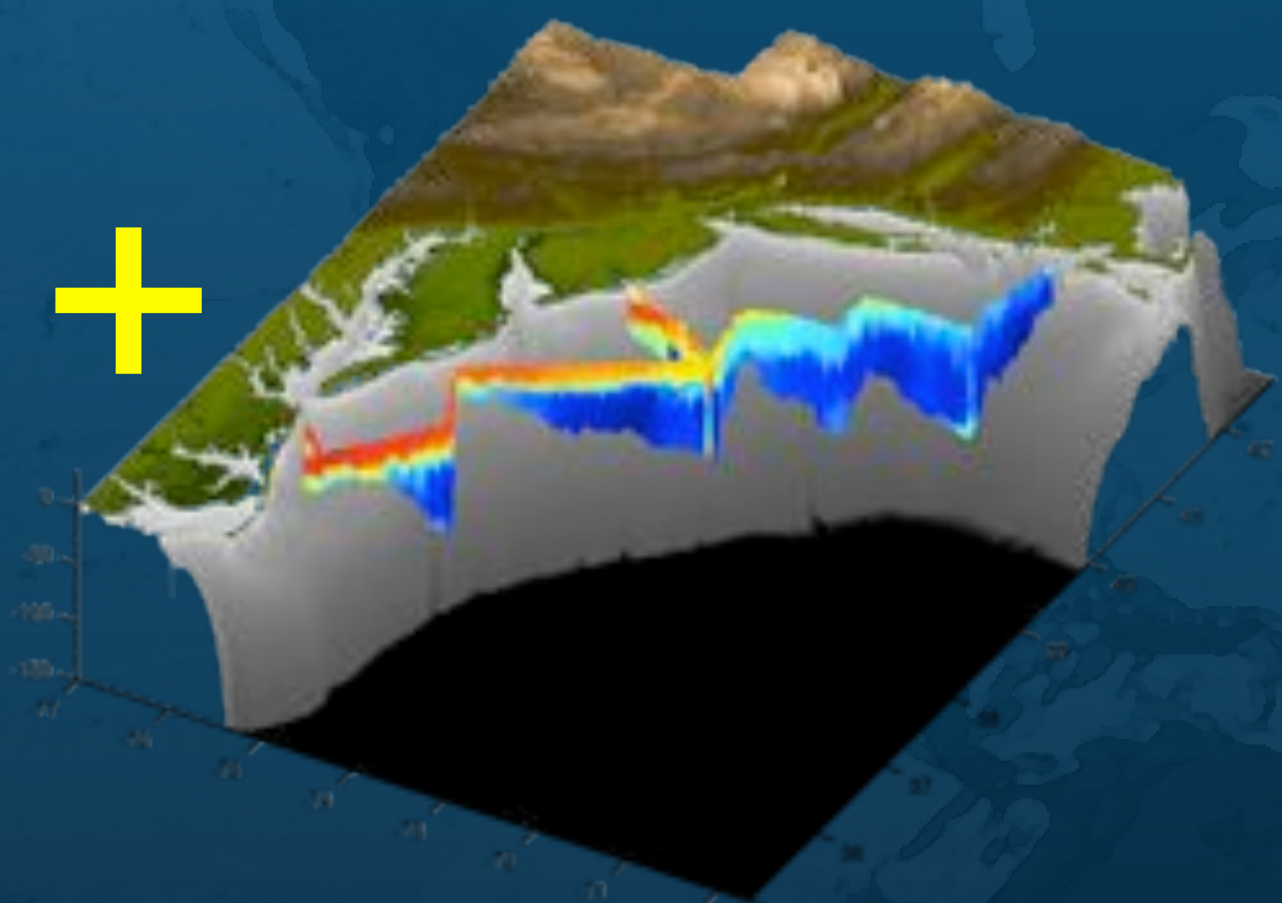




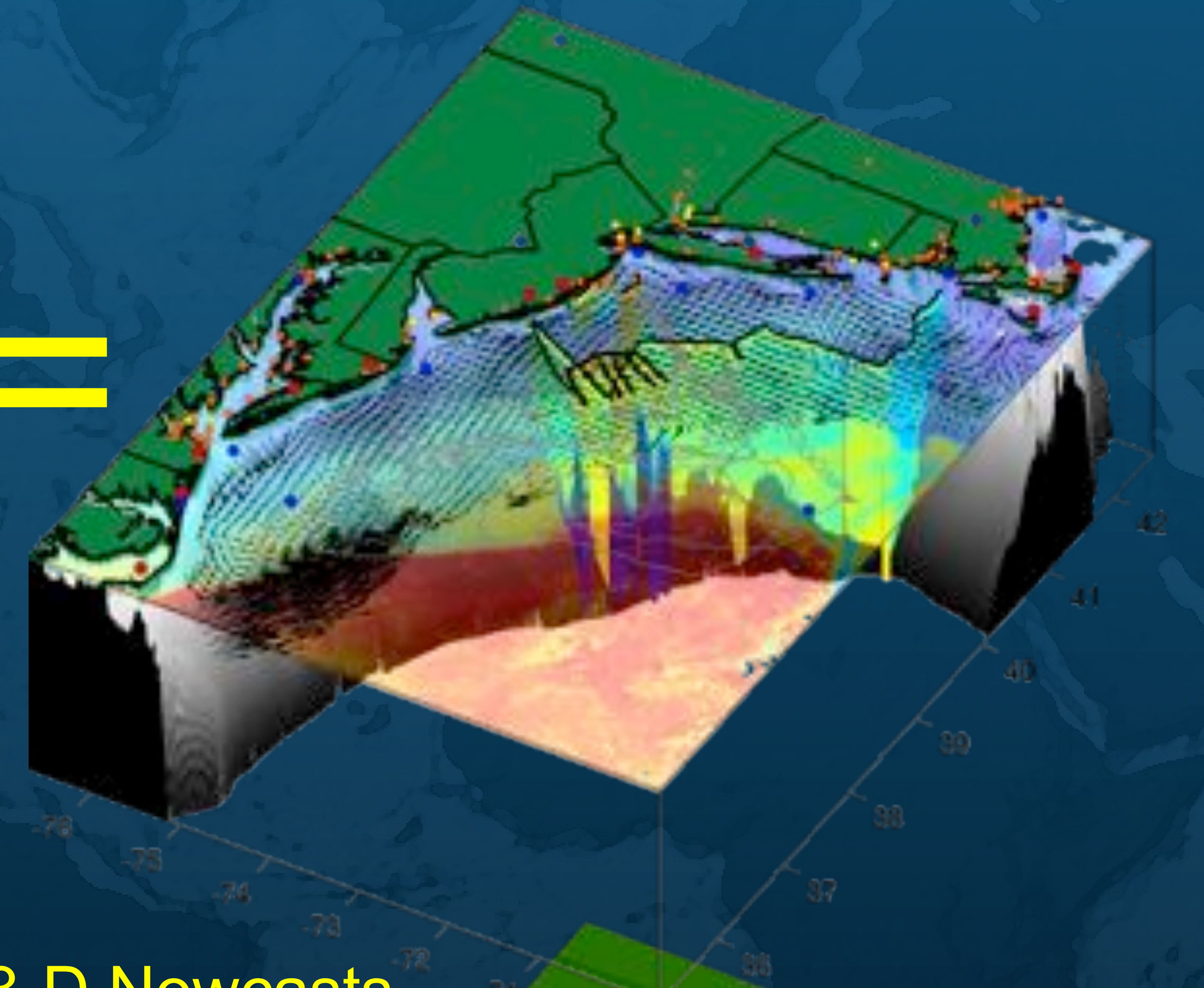
Sunday, July 1, 12



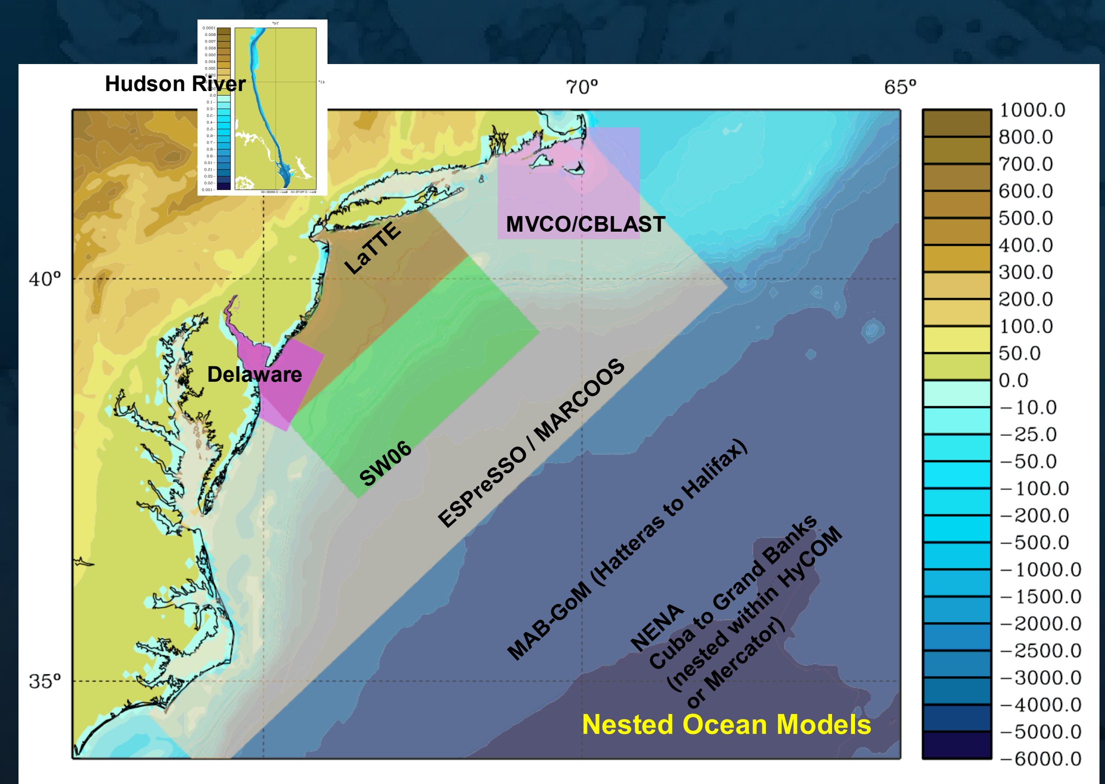
Remote Sensing



Robots



3-D Nowcasts



Nested Models

S4DVAR procedure

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

Lagrange multiplier $\ddot{\mathbf{e}}_i \equiv \ddot{\mathbf{e}}(t_i) \equiv \ddot{\mathbf{e}}(i\Delta t)$

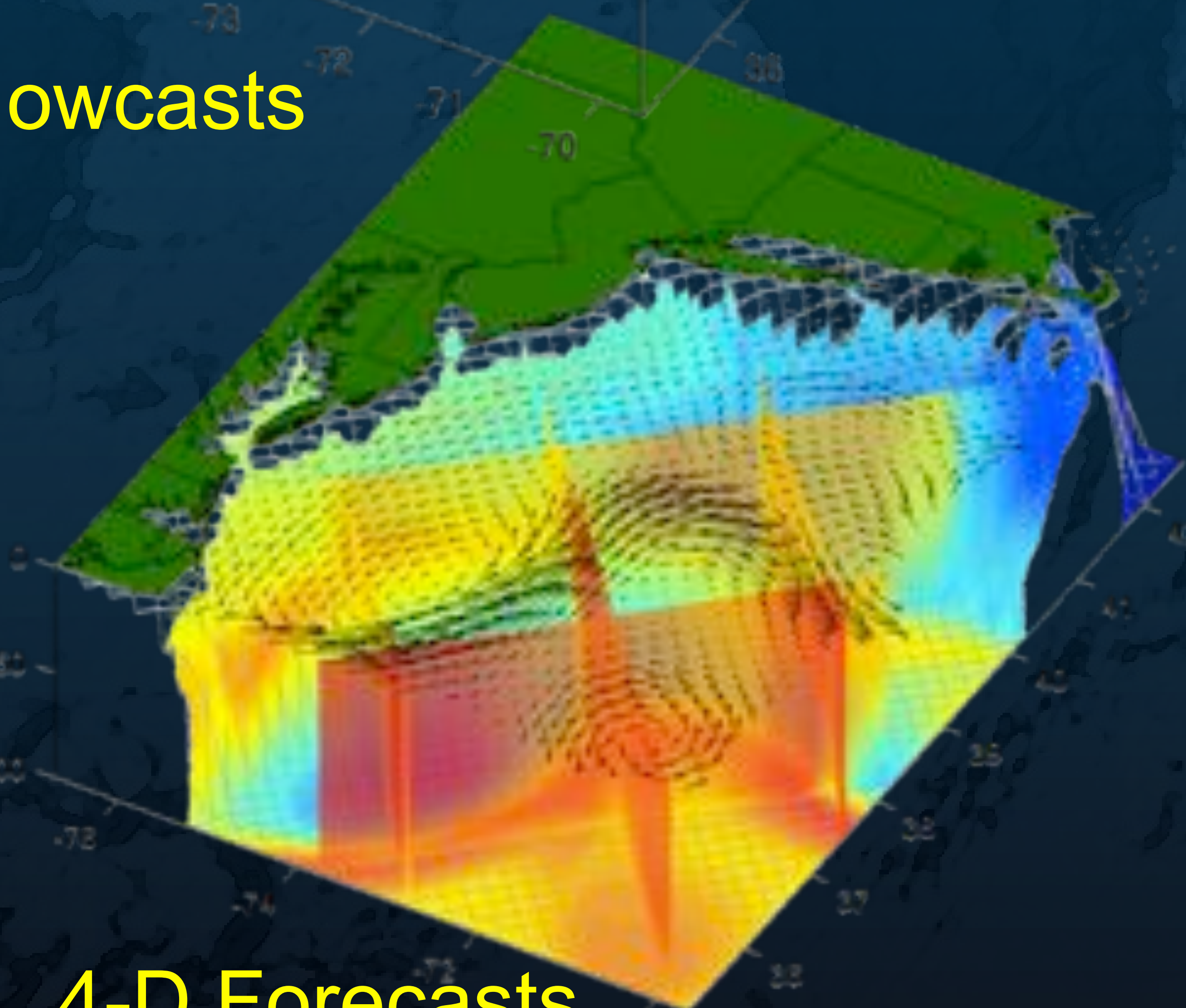
At extrema of L, we require:

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

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

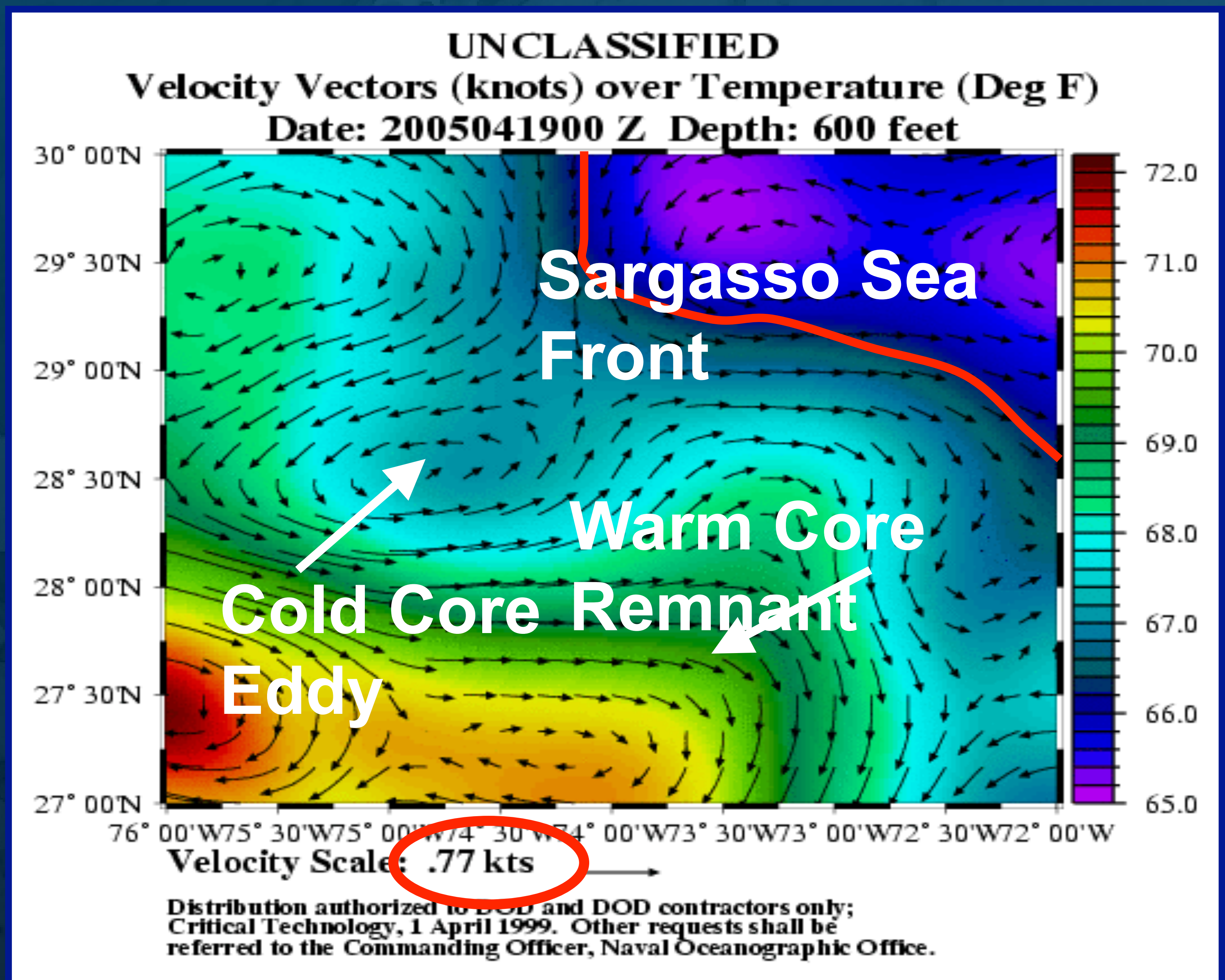
Data Assimilation



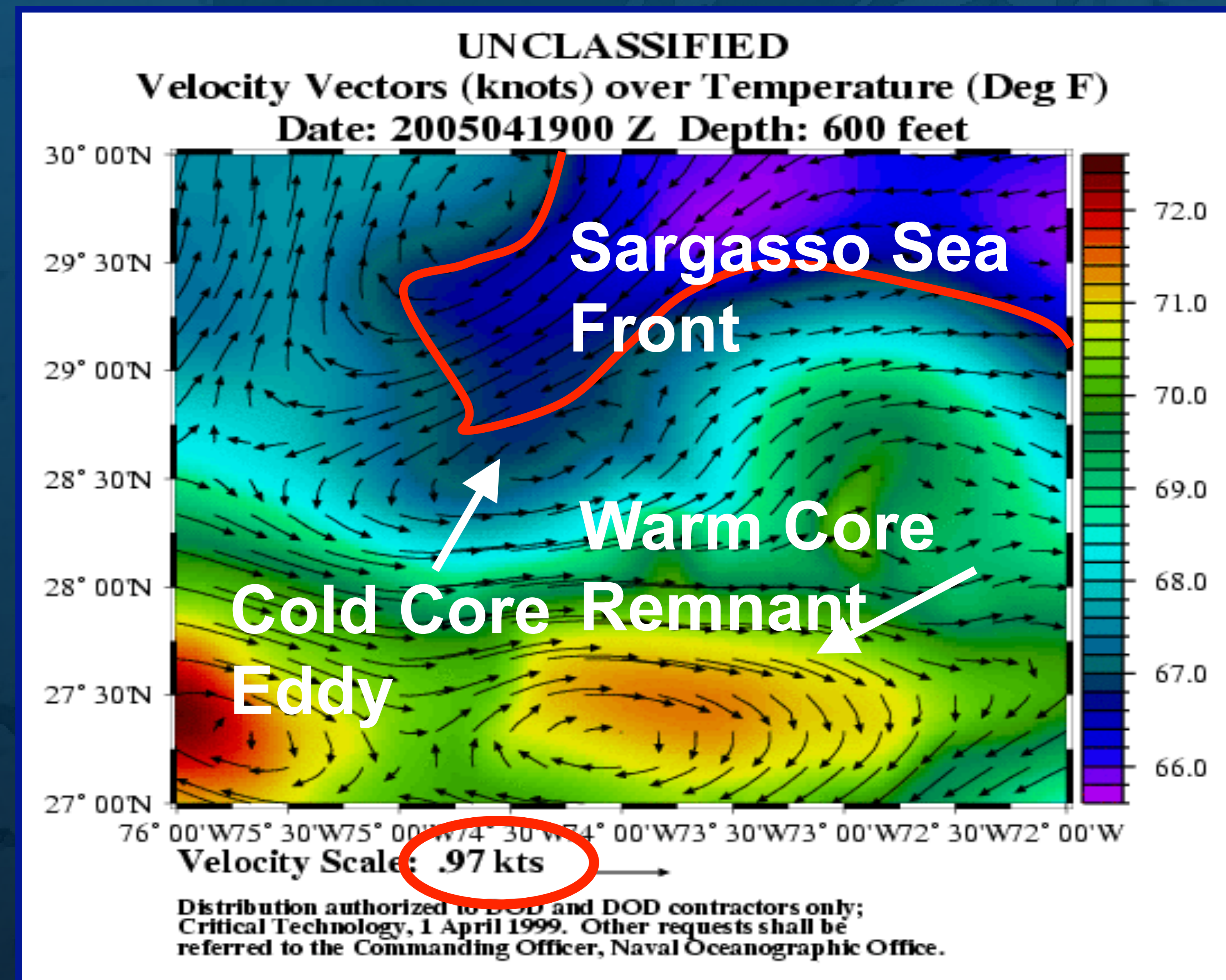
4-D Forecasts

Lets say you are hunting “whales”

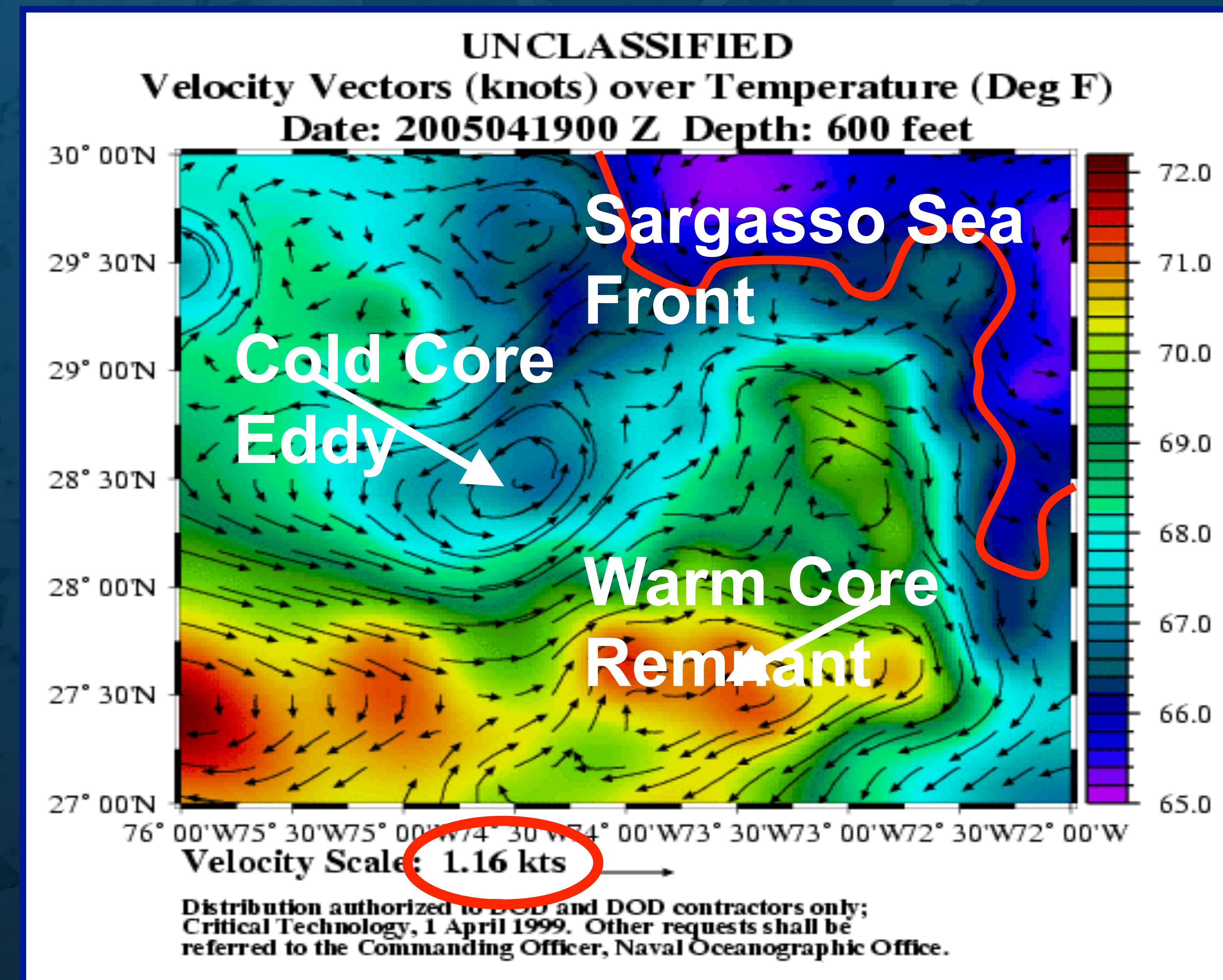
Knowledge of the environment will give you a tactical advantage
Knowledge of future environment will give you a bigger tactical advantage



No in situ data
into the model

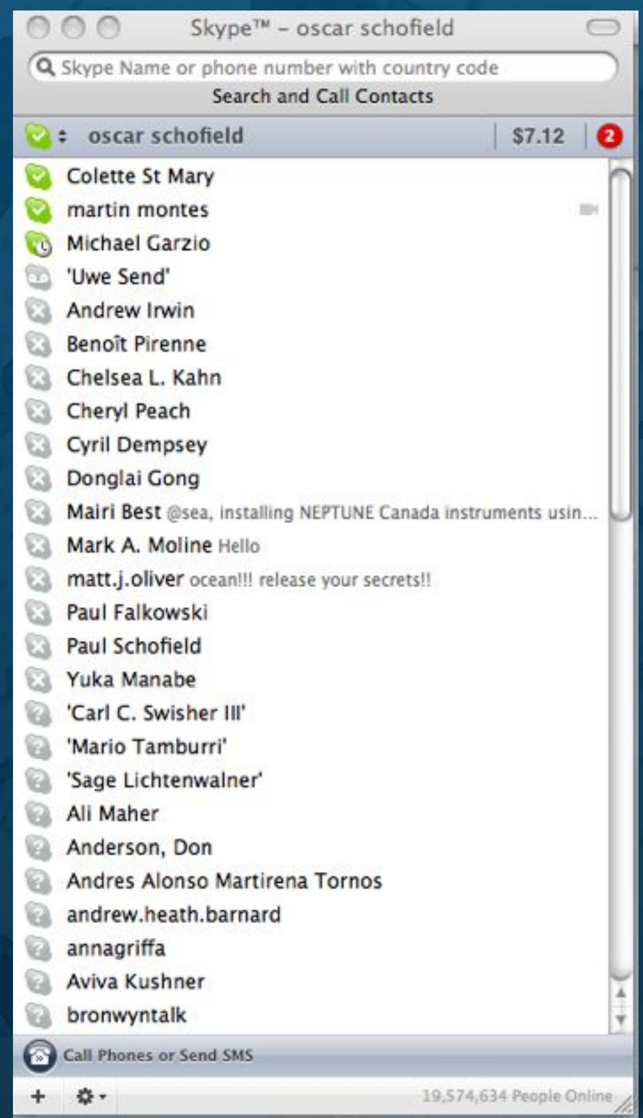


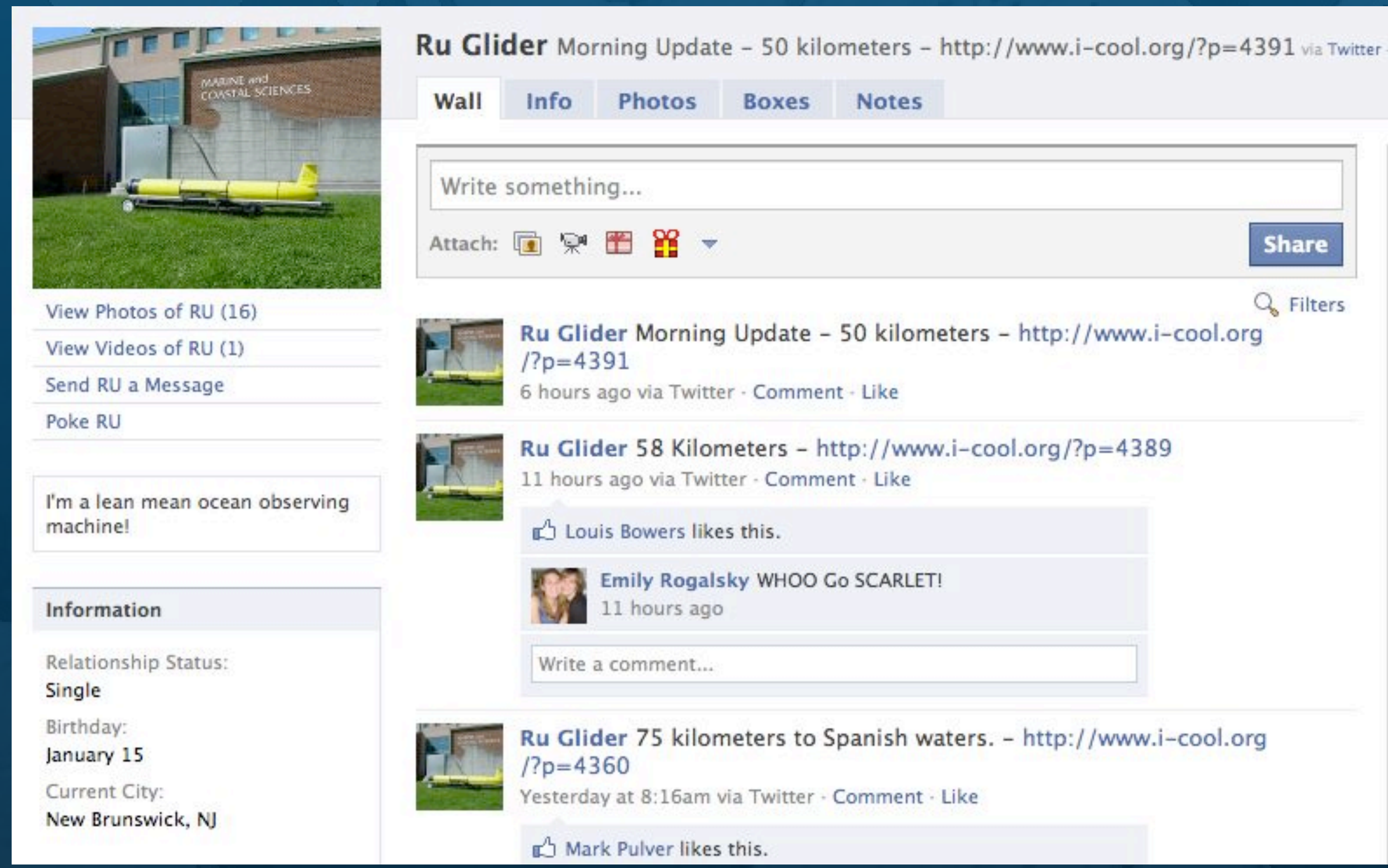
BSP in situ data
into the model

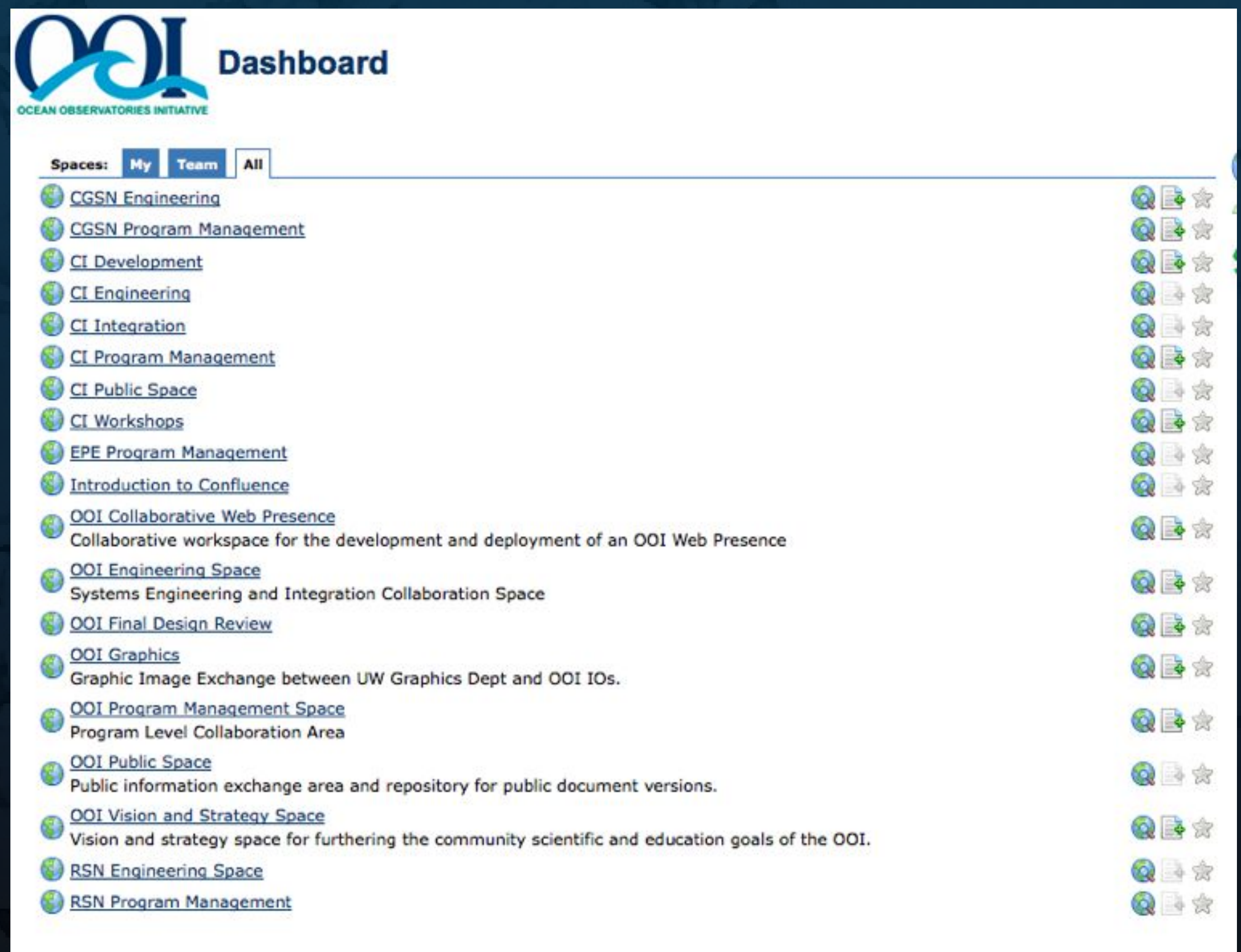


Gliders (4) in situ data
into the model

Science enabled by social networking



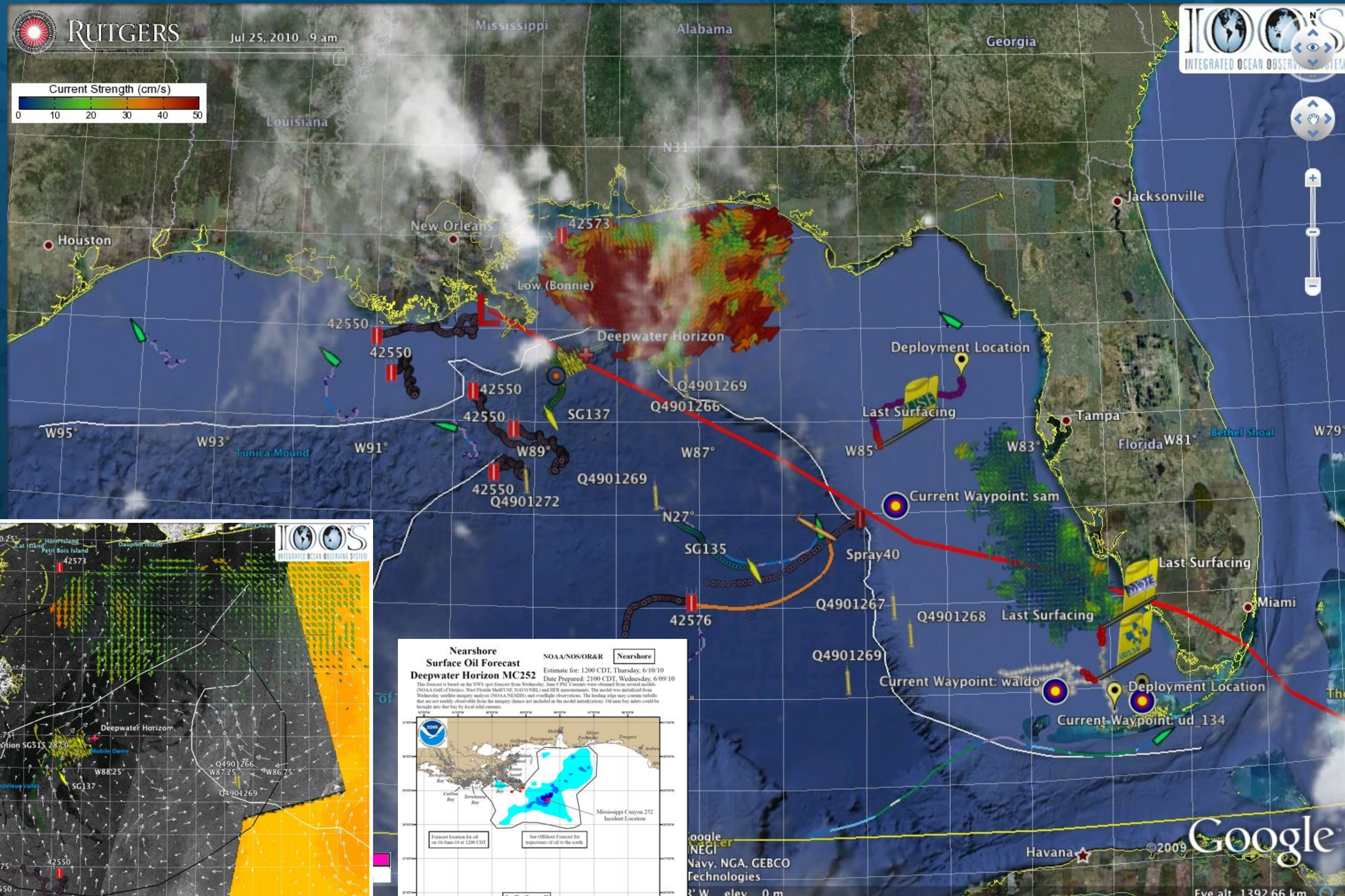


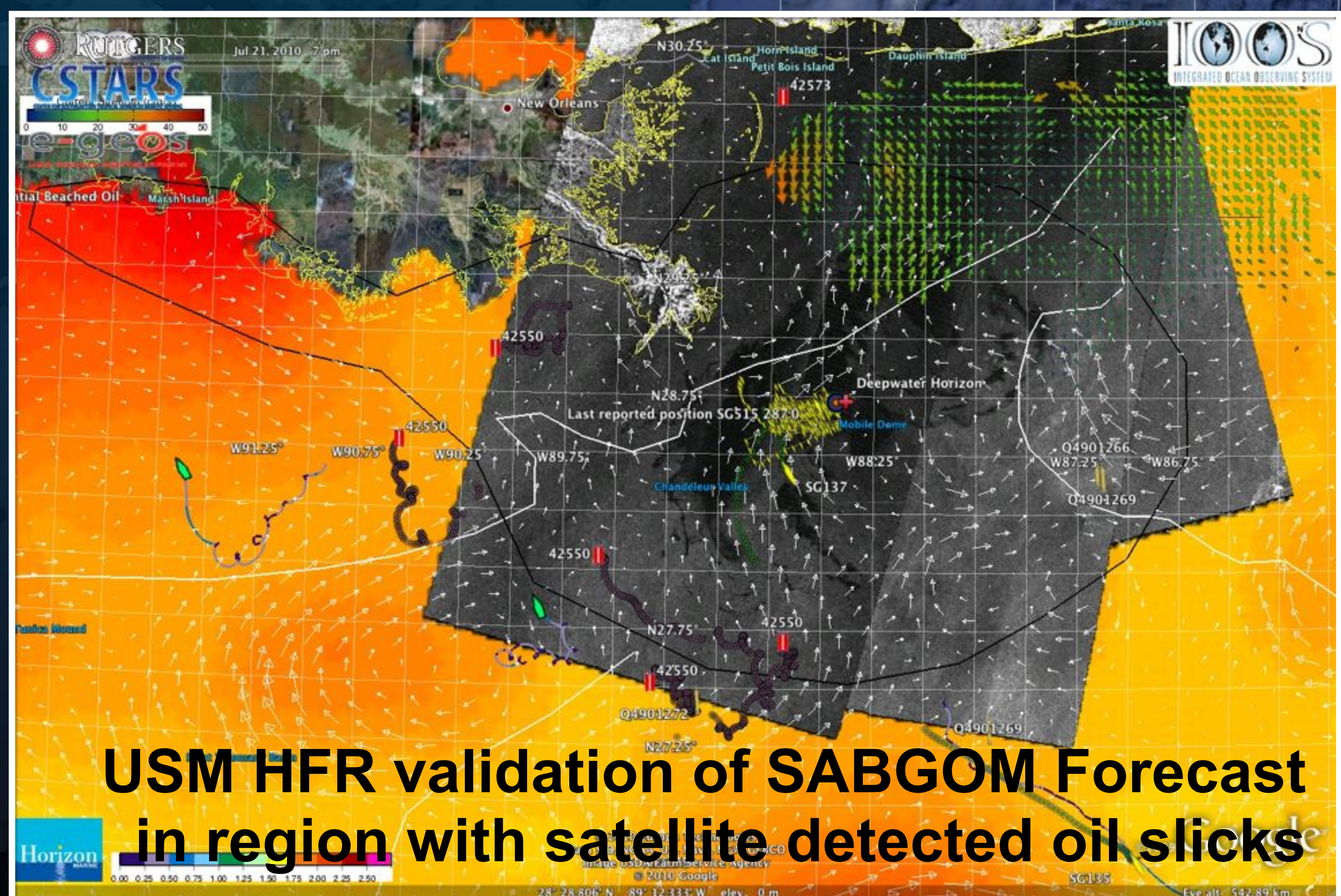


Network allows for construction of ad hoc networks when needed

Contributed Assets:

HF Radar Networks
USF, USM
Gliders
iRobot, Mote, Rutgers, SIO, UDel, USF, Navy
Drifters & Profilers
Horizon Marine, Navy
Satellite Imagery
CSTARS, UDel
Ocean Forecasts
Navy, NCSU
Data/Web Services
ASA, Rutgers, SIO





USM HFR validation of SABGOM Forecast in region with satellite detected oil slicks

Data and models for situations where the University does not allow me to send graduate students

Hurricane Irene
August 2011

The Miami Herald > Weather >

Hurricanes

Sunday, 02.19.12 Welcome Guest •

HOME NEWS SPORTS ENTE

Miami-Dade | Broward | Keys |

Posted on Friday, 09.02.11

HURRICANE SEASON

Intensity remain

Like 1

The National Hurricane Ce
it wasn't the first time — bu
the increasing standards of

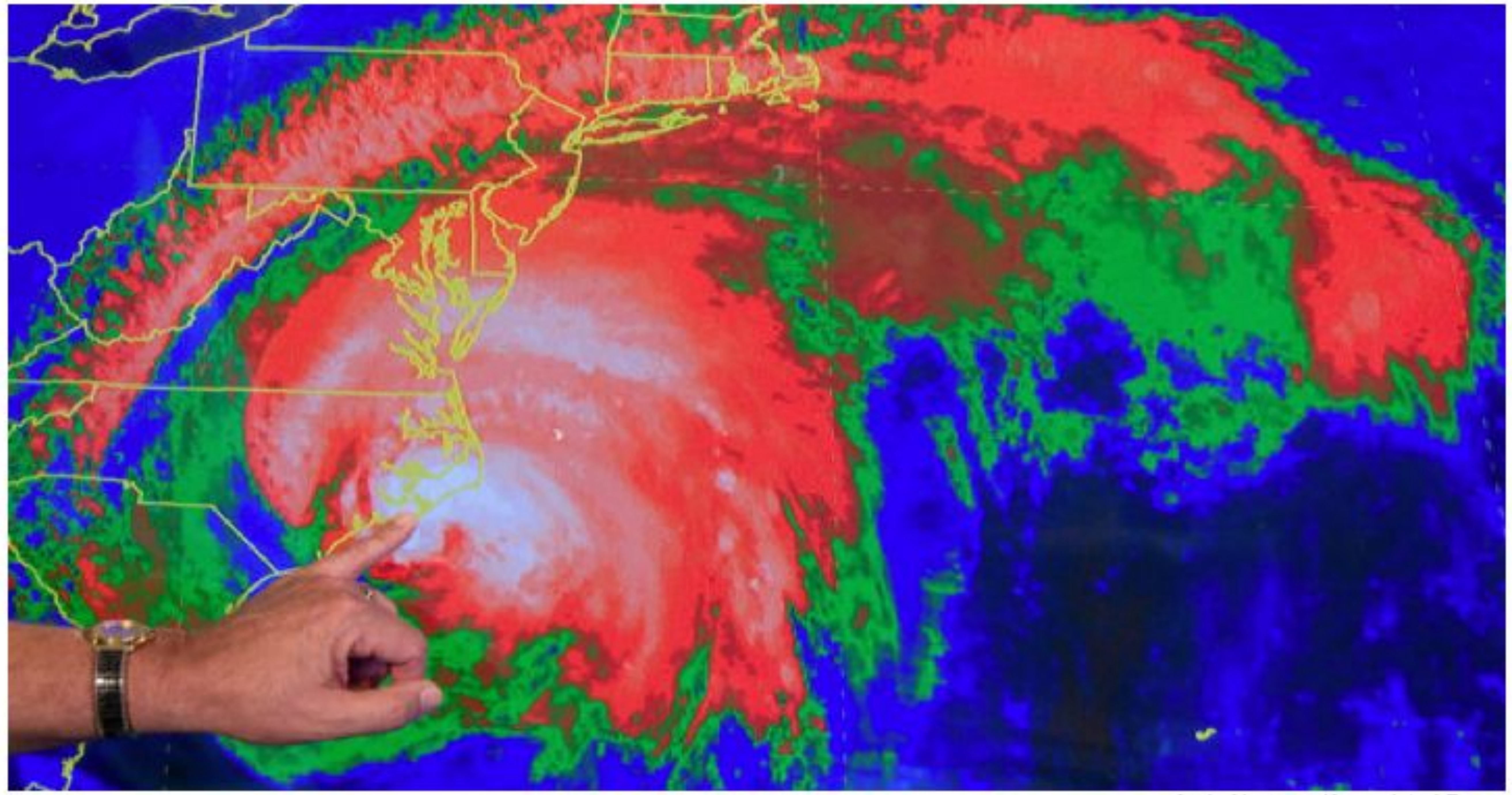
The New York Times

U.S.

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

POLITICS EDUCATION BAY AREA CHICAGO TEXAS

Challenges in Predicting the Intensity of Storms



Andy Newman/Associated Press

Scientists say that it is much easier to accurately predict what path a hurricane will take.

By HENRY FOUNTAIN
Published: August 27, 2011

The Miami Herald > Weather >

Hurricanes

Sunday, 02.19.12 Welcome Guest •

HOME | NEWS | SPORTS | ENTE

Miami-Dade | Broward | Keys |

Posted on Friday, 09.02.11

HURRICANE SEASON

Intensity remain

Like 1

The National Hurricane C
it wasn't the first time —
the increasing standards

Get off the damn beach!!

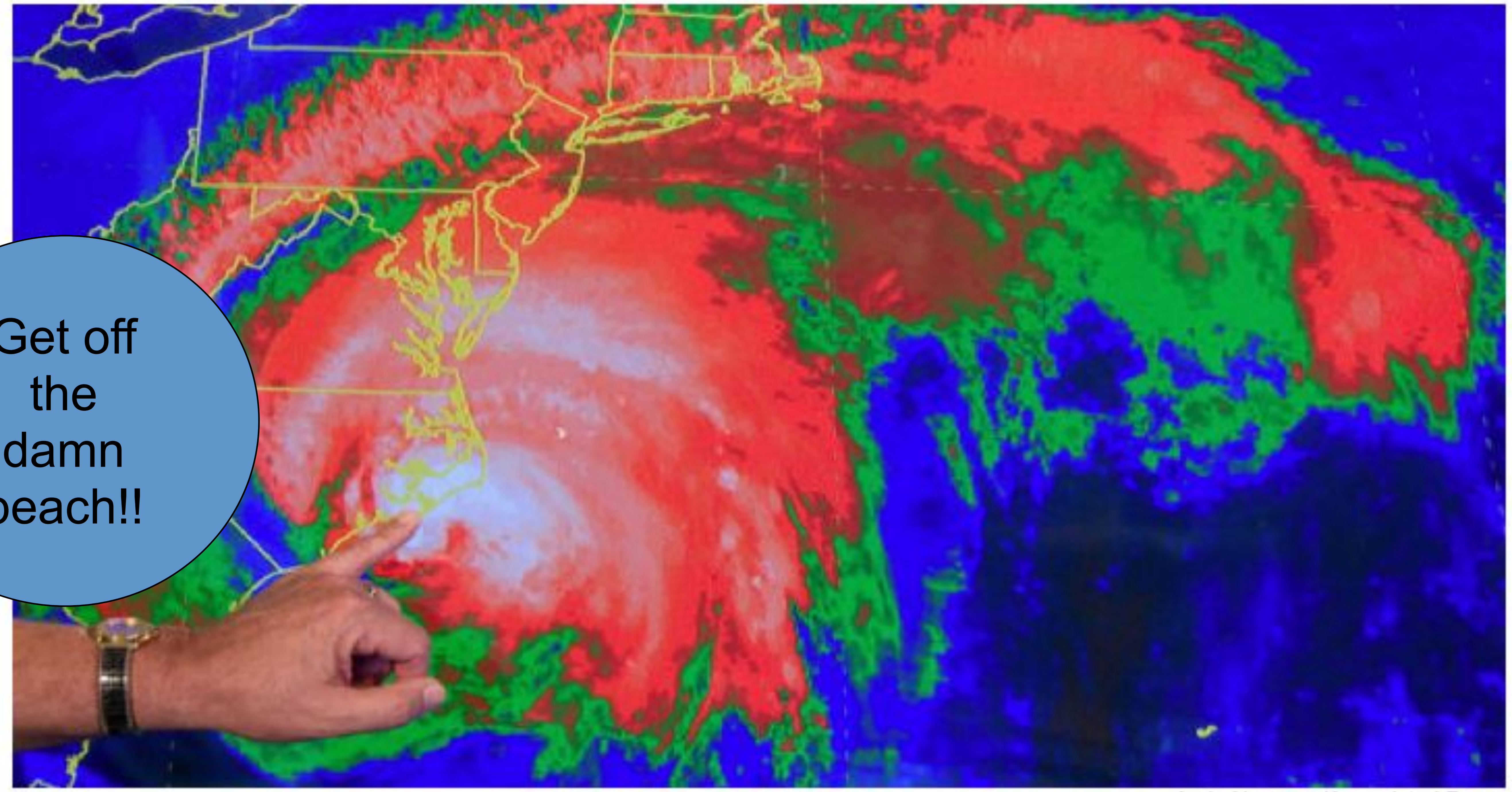
The New York Times

U.S.

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

POLITICS | EDUCATION | BAY AREA | CHICAGO | TEXAS

Challenges in Predicting the Intensity of Storms



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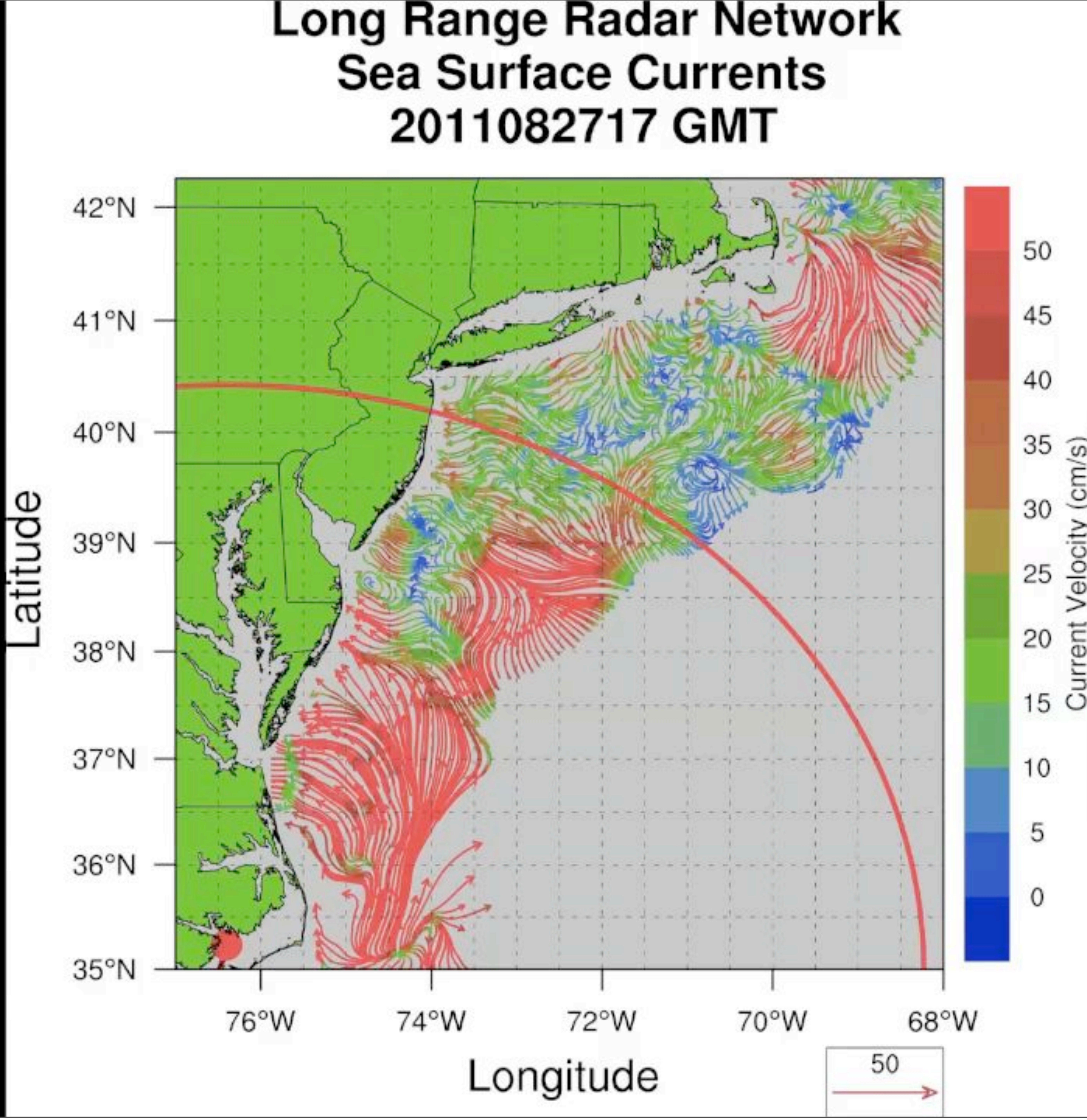
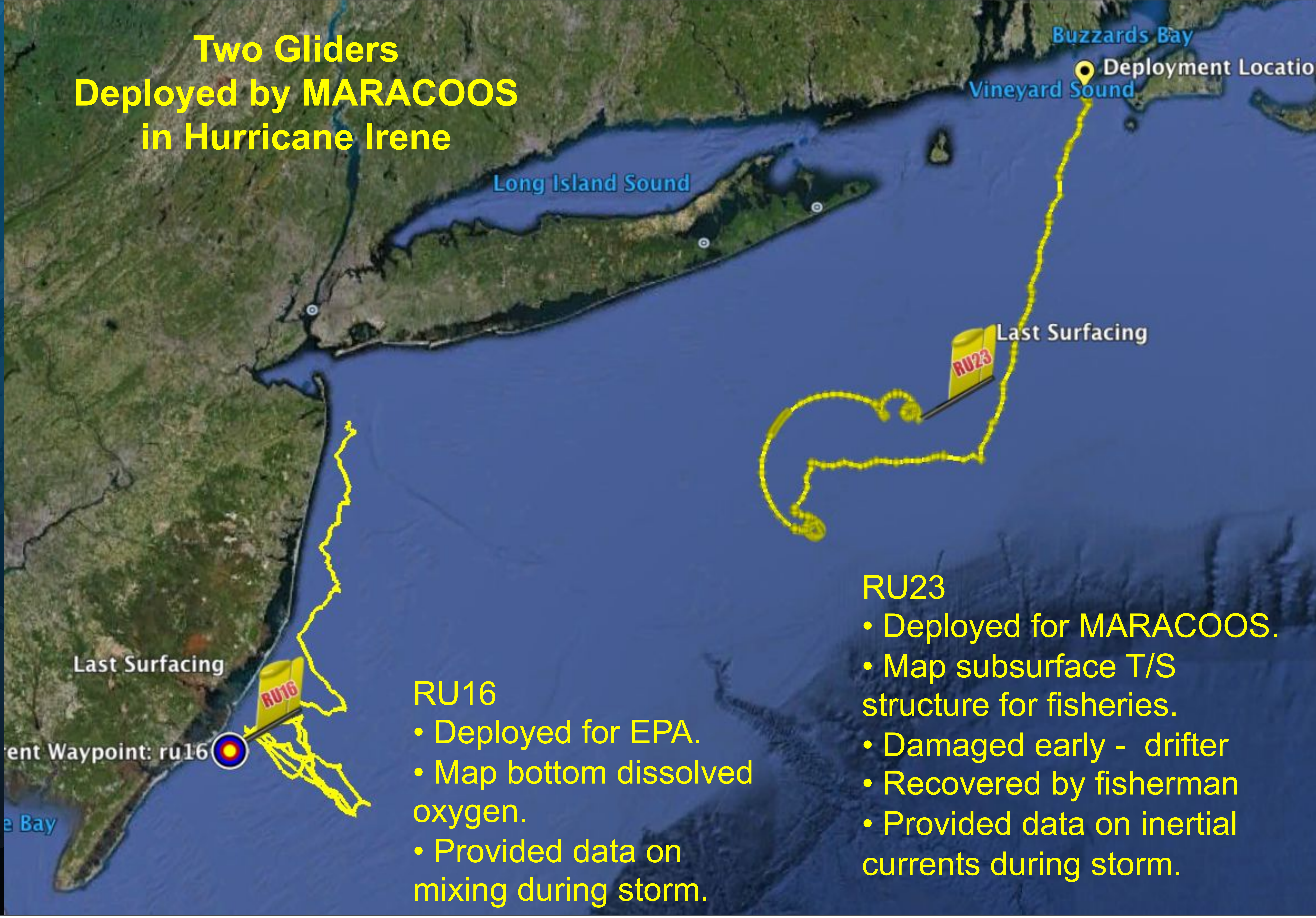
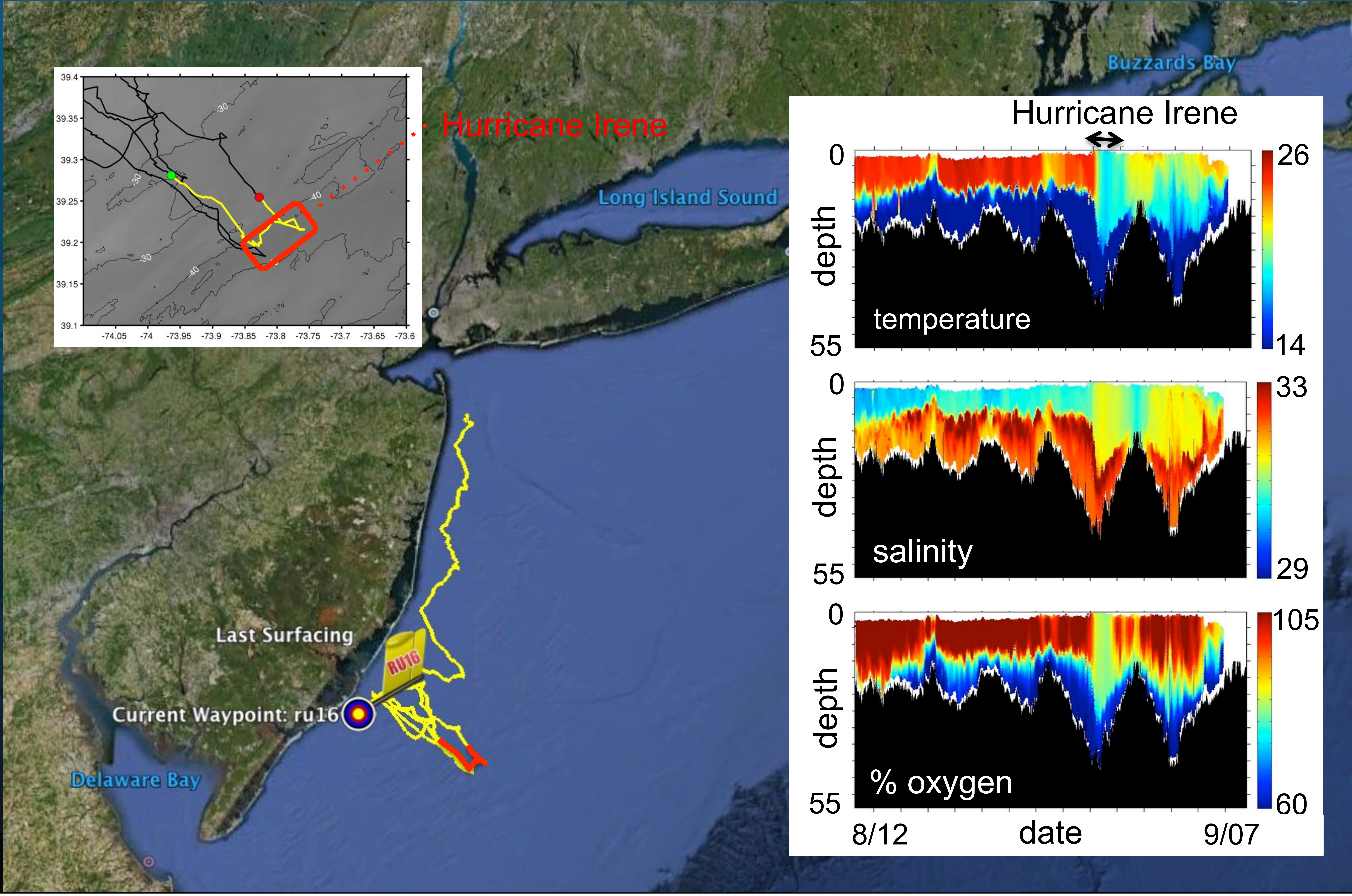

Long Range Radar Network
Sea Surface Currents
2011082717 GMT
42°N
41°N
40°N
39°N
38°N
37°N
36°N
35°N
Latitude
76°W
74°W
72°W
70°W
68°W
Longitude
50
50
45
40
35
30
25
20
15
10
5
0
Current Velocity (cm/s)

Two Gliders Deployed by MARACOOS in Hurricane Irene

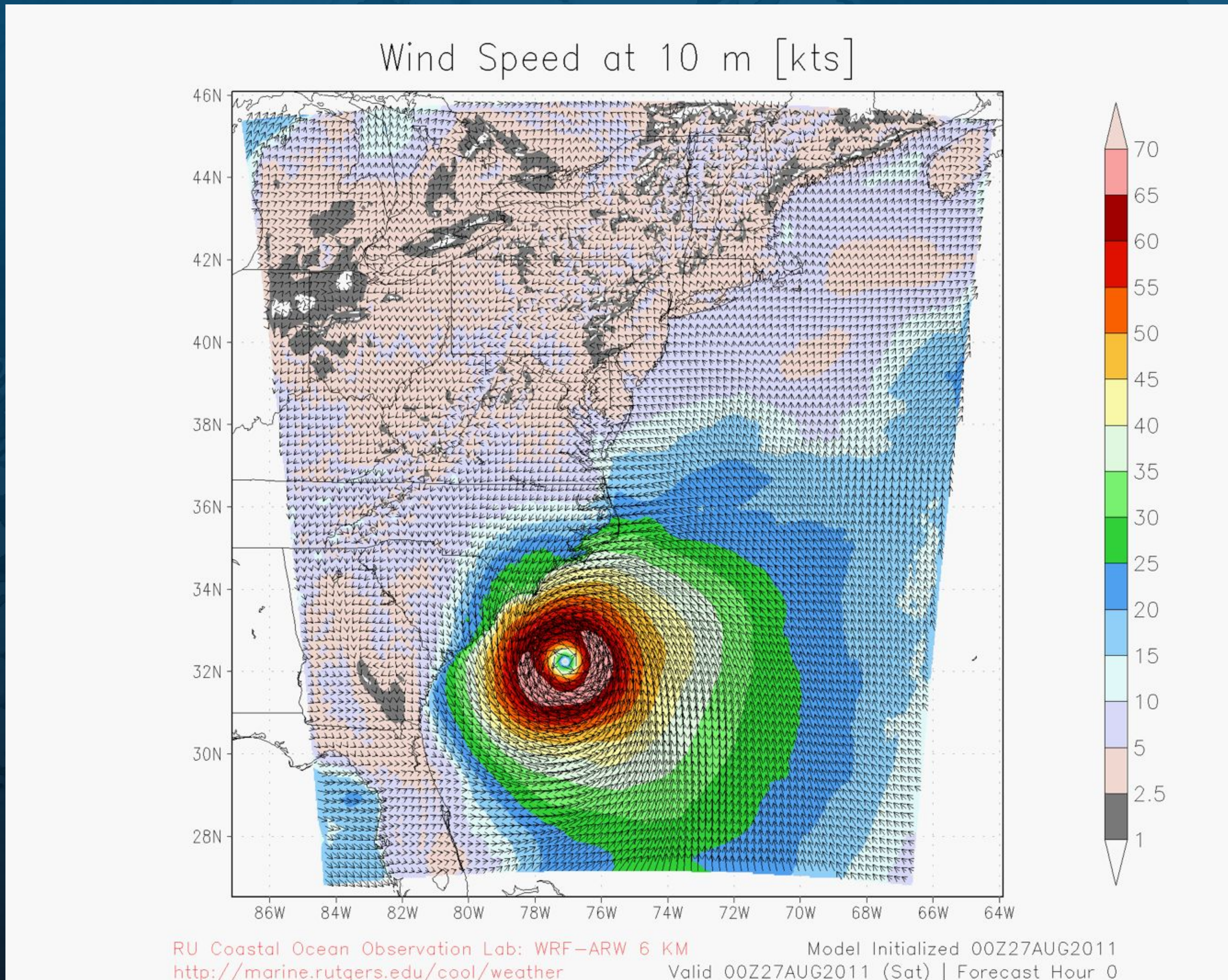


RU16
- Deployed for EPA.
- Map bottom dissolved oxygen.
- Provided data on mixing during storm.

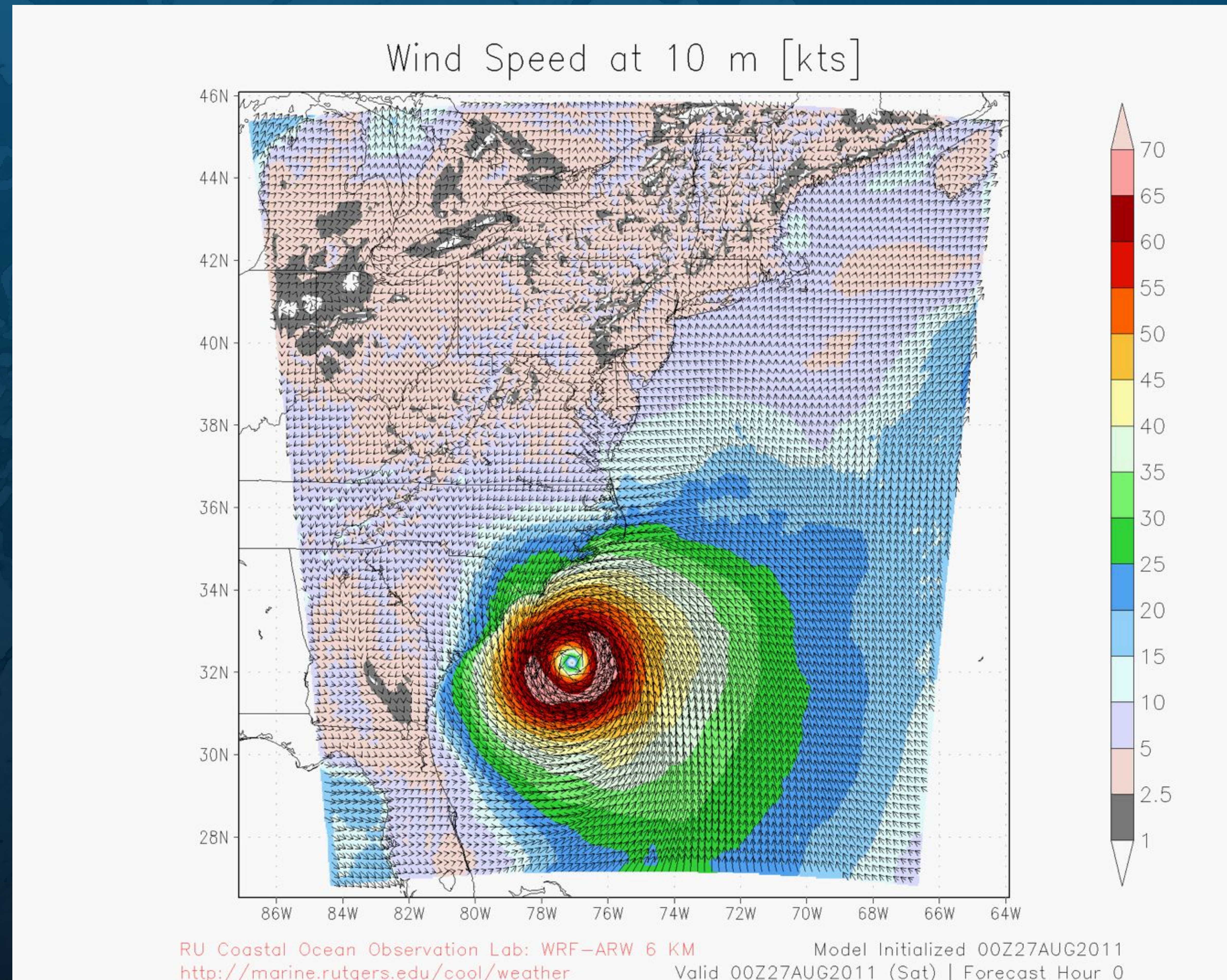
RU23
- Deployed for MARACOOS.
- Map subsurface T/S structure for fisheries.
- Damaged early - drifter
- Recovered by fisherman
- Provided data on inertial currents during storm.

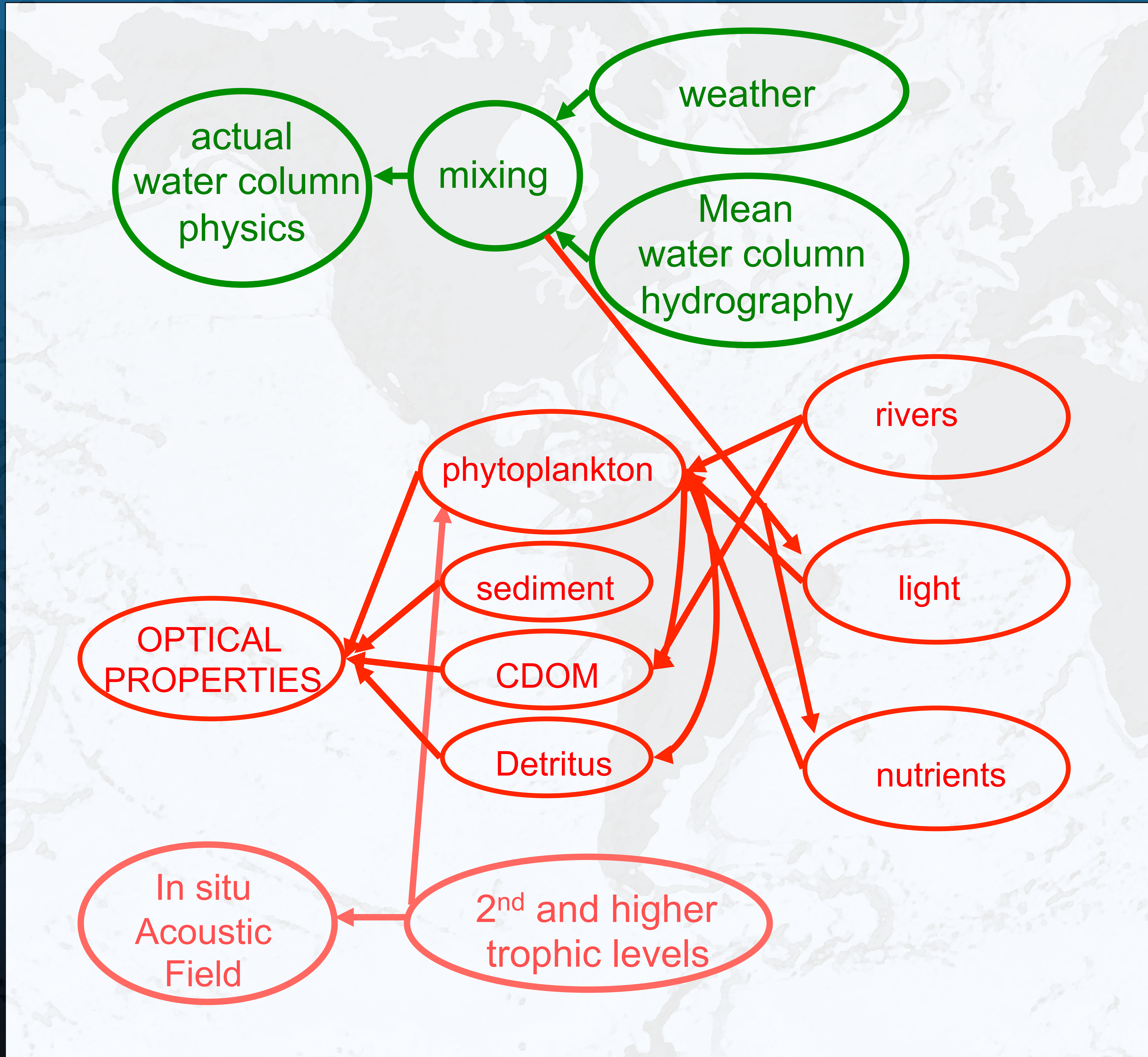

Hurricane Irene
Buzzards Bay
Long Island Sound
Last Surfacing
RU16
Current Waypoint: ru16
Delaware Bay
39.4
39.35
39.3
39.25
39.2
39.15
39.1
-74.05
-74
-73.95
-73.9
-73.85
-73.8
-73.75
-73.7
-73.65
-73.6
-30
-40
Hurricane Irene
0
55
depth
temperature
26
14
salinity
33
29
% oxygen
105
60
8/12
date
9/07

Winds assuming warm temperatures

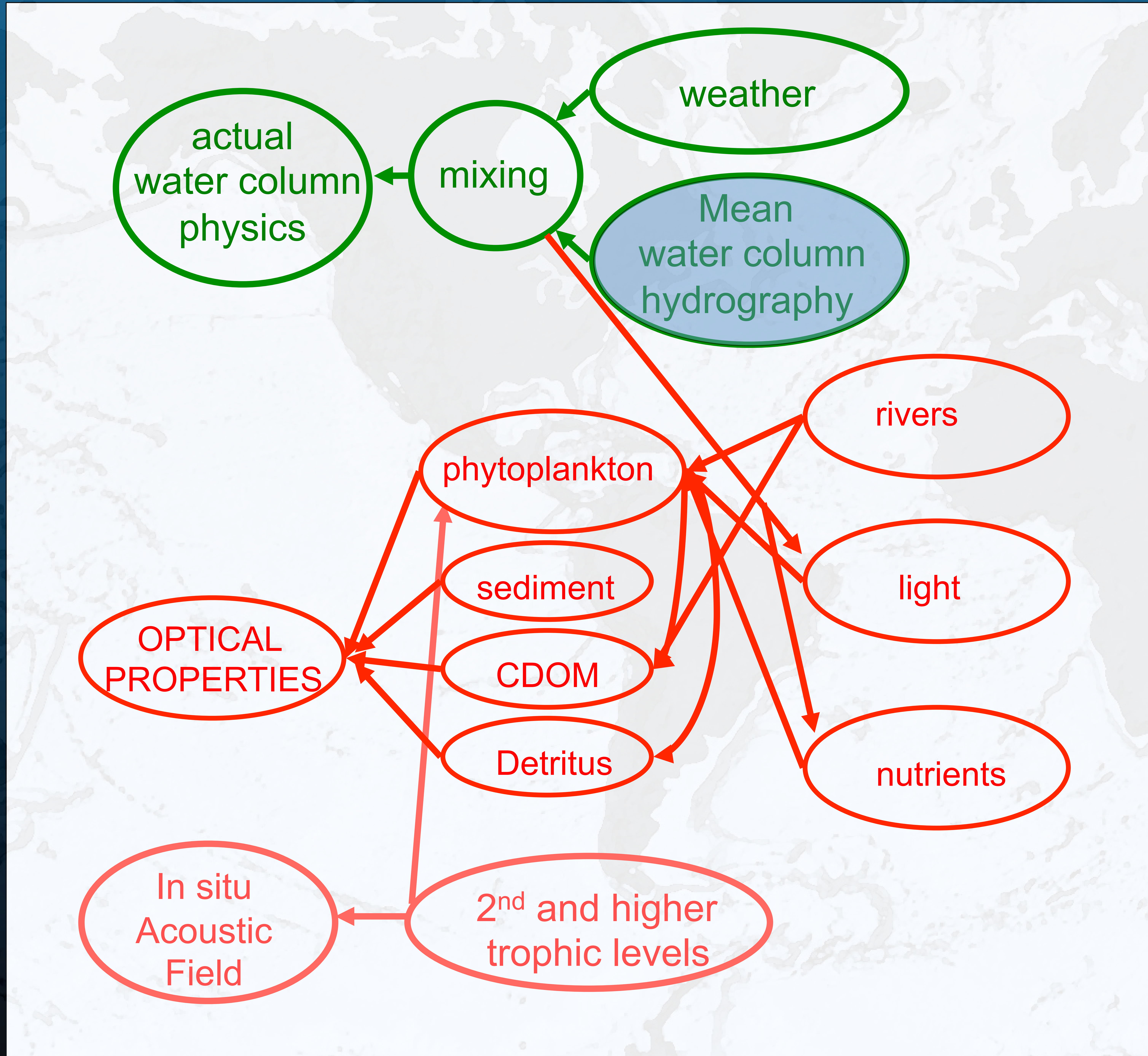


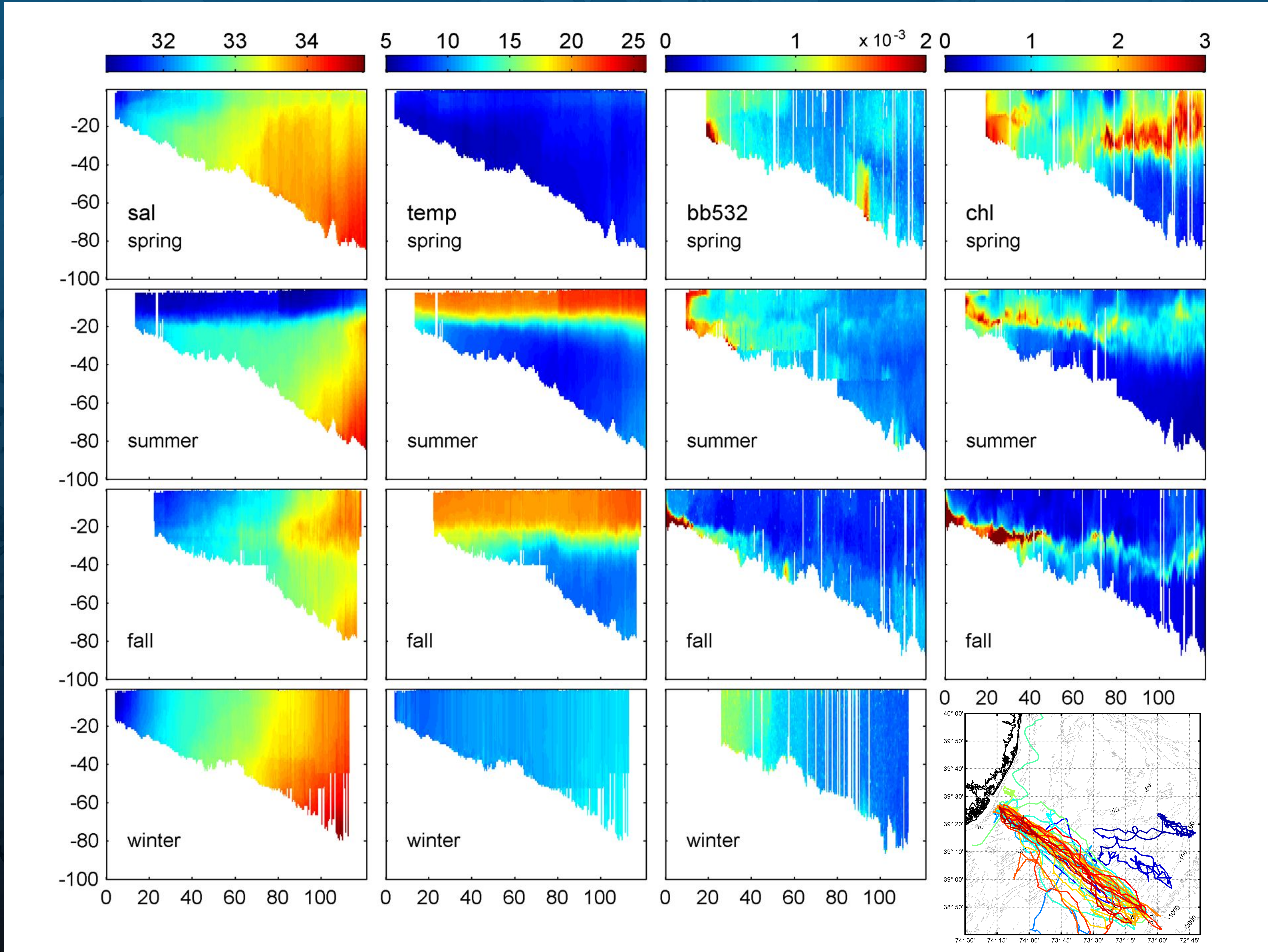
Winds using glider temperatures



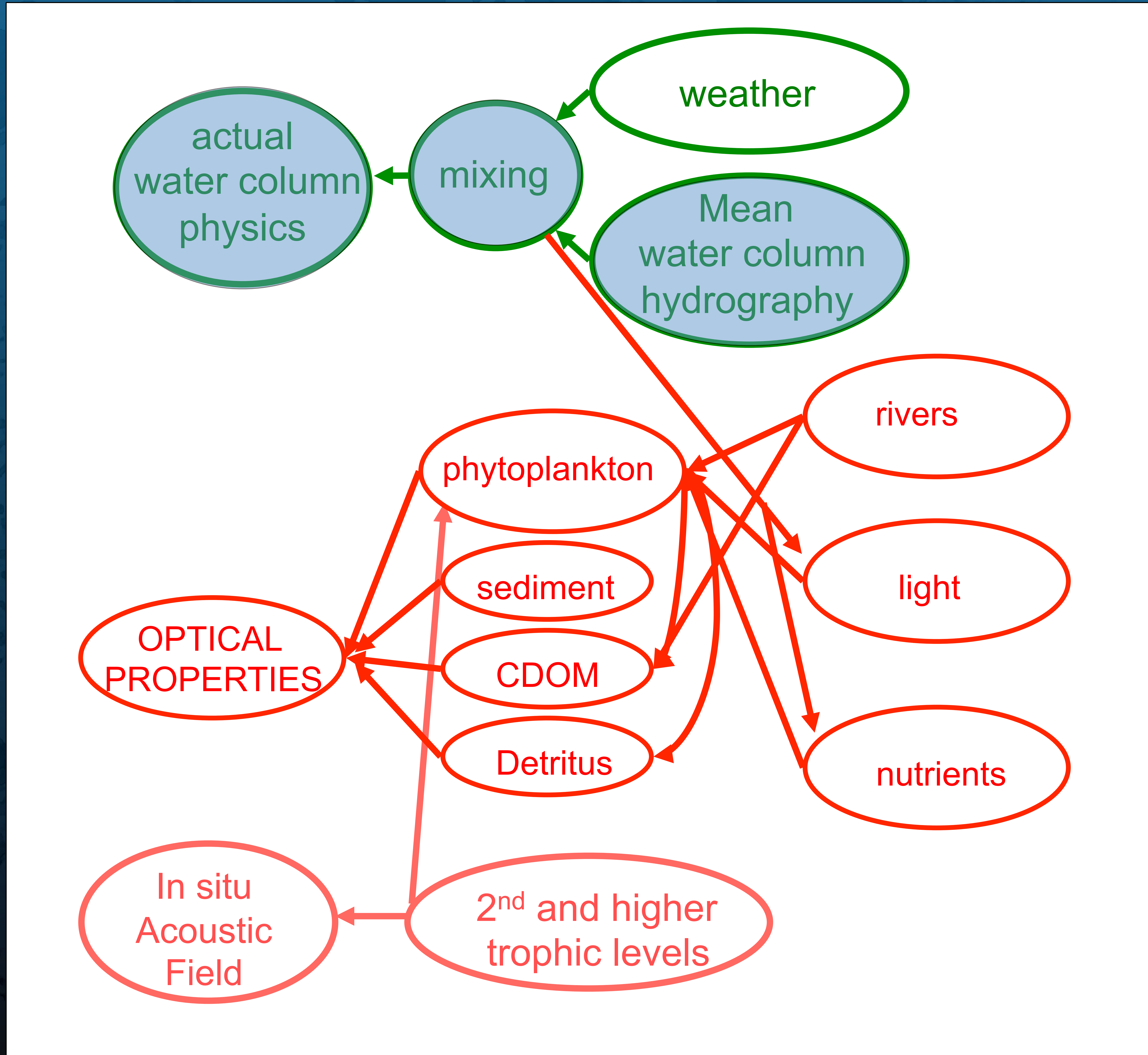


weather
actual water column physics
mixing
Mean water column hydrography
rivers
phytoplankton
light
sediment
OPTICAL PROPERTIES
CDOM
Detritus
nutrients
In situ Acoustic Field
2nd and higher trophic levels

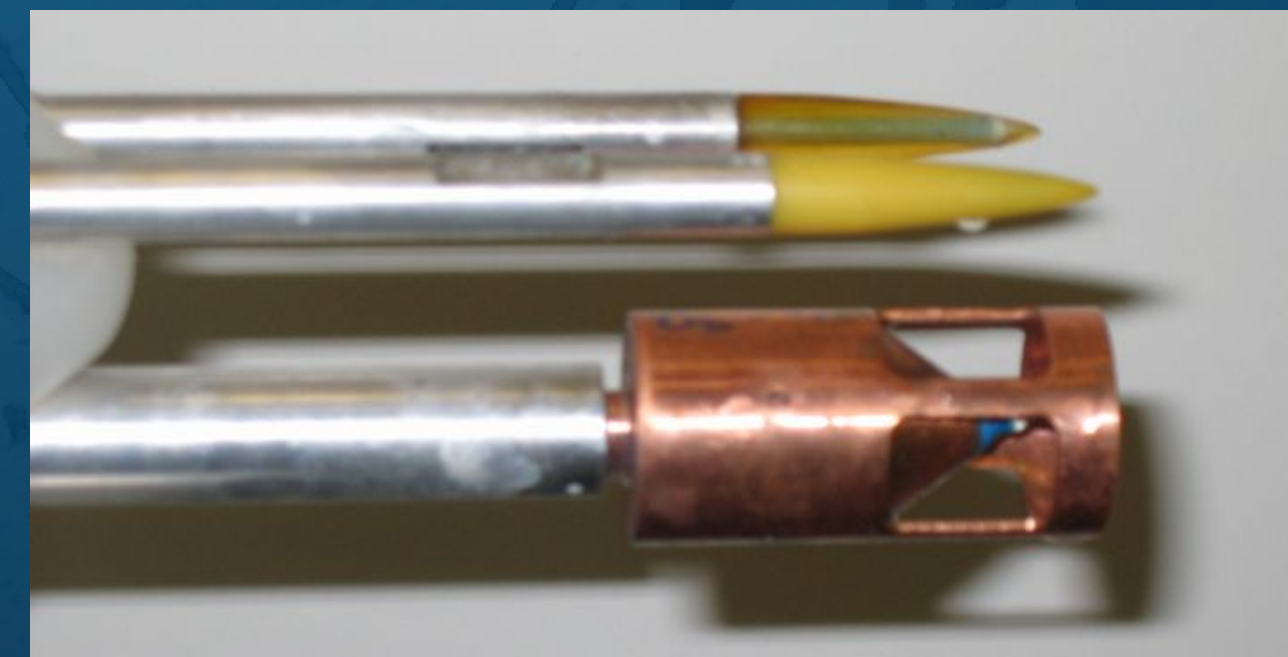

weather
actual water column physics
mixing
Mean water column hydrography
rivers
phytoplankton
light
sediment
OPTICAL PROPERTIES
CDOM
Detritus
nutrients
In situ Acoustic Field
2nd and higher trophic levels

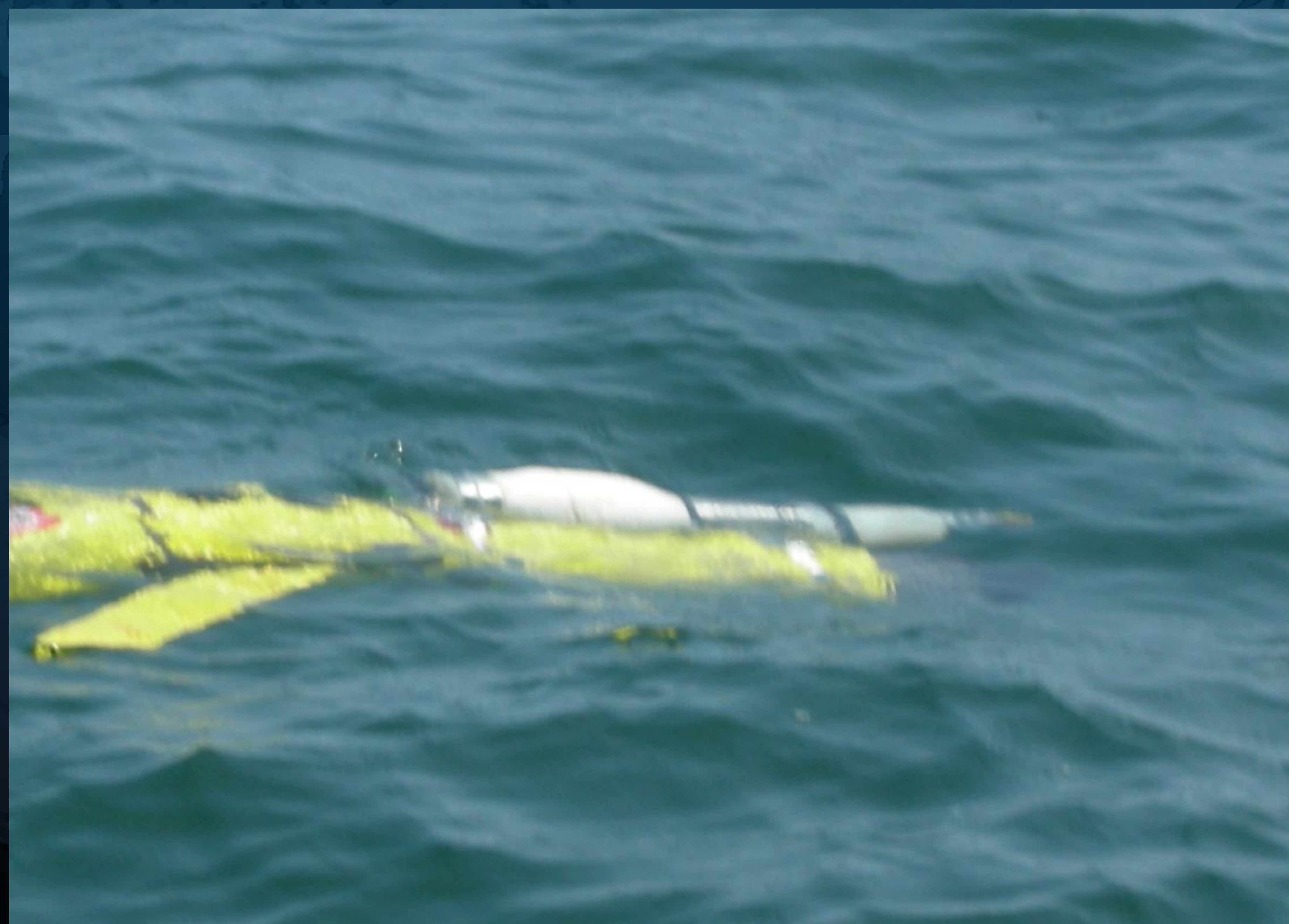


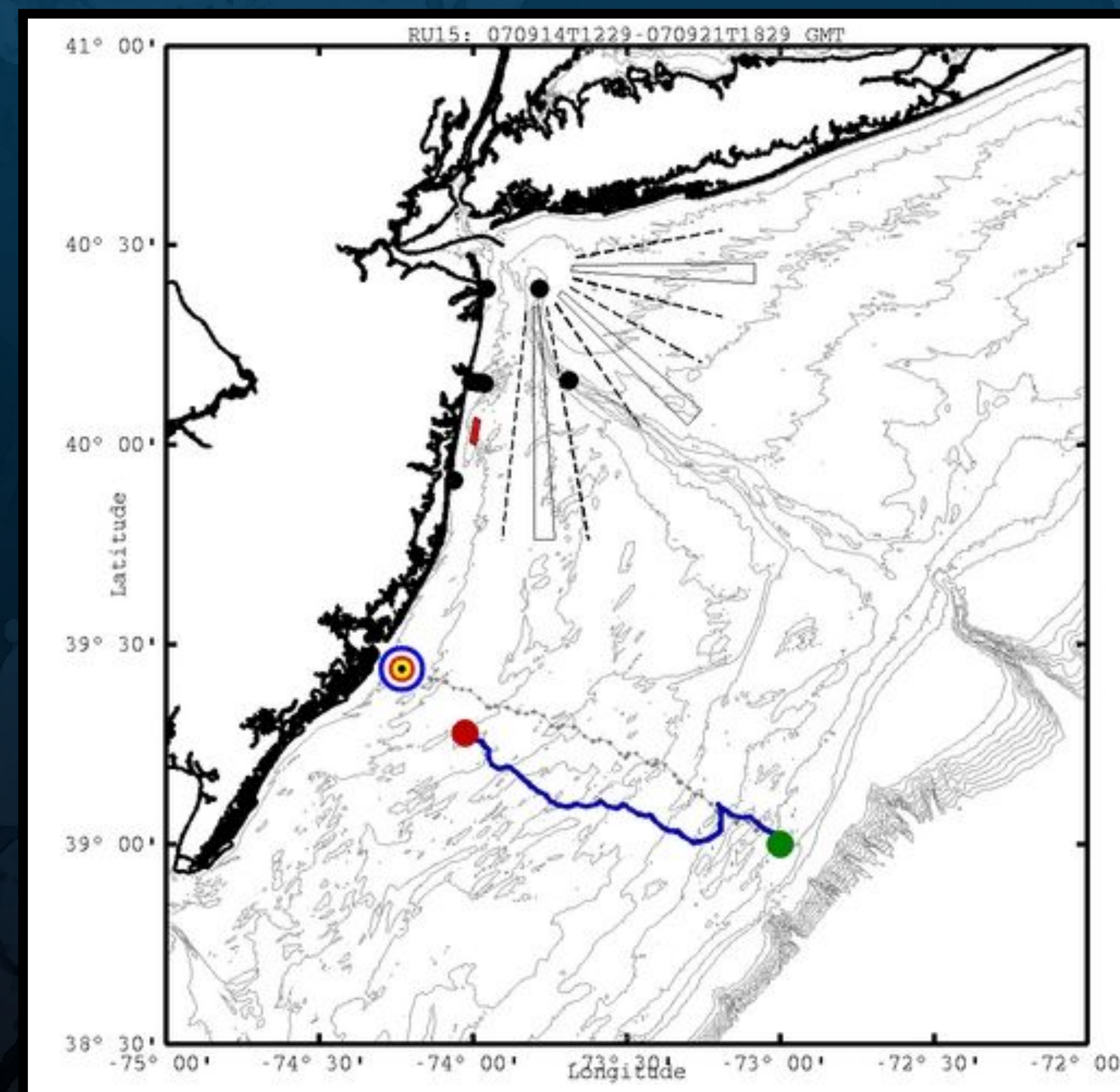
sal
spring
summer
fall
winter
temp
spring
summer
fall
winter
bb532
spring
summer
fall
winter
chl
spring
summer
fall
x 10^-3

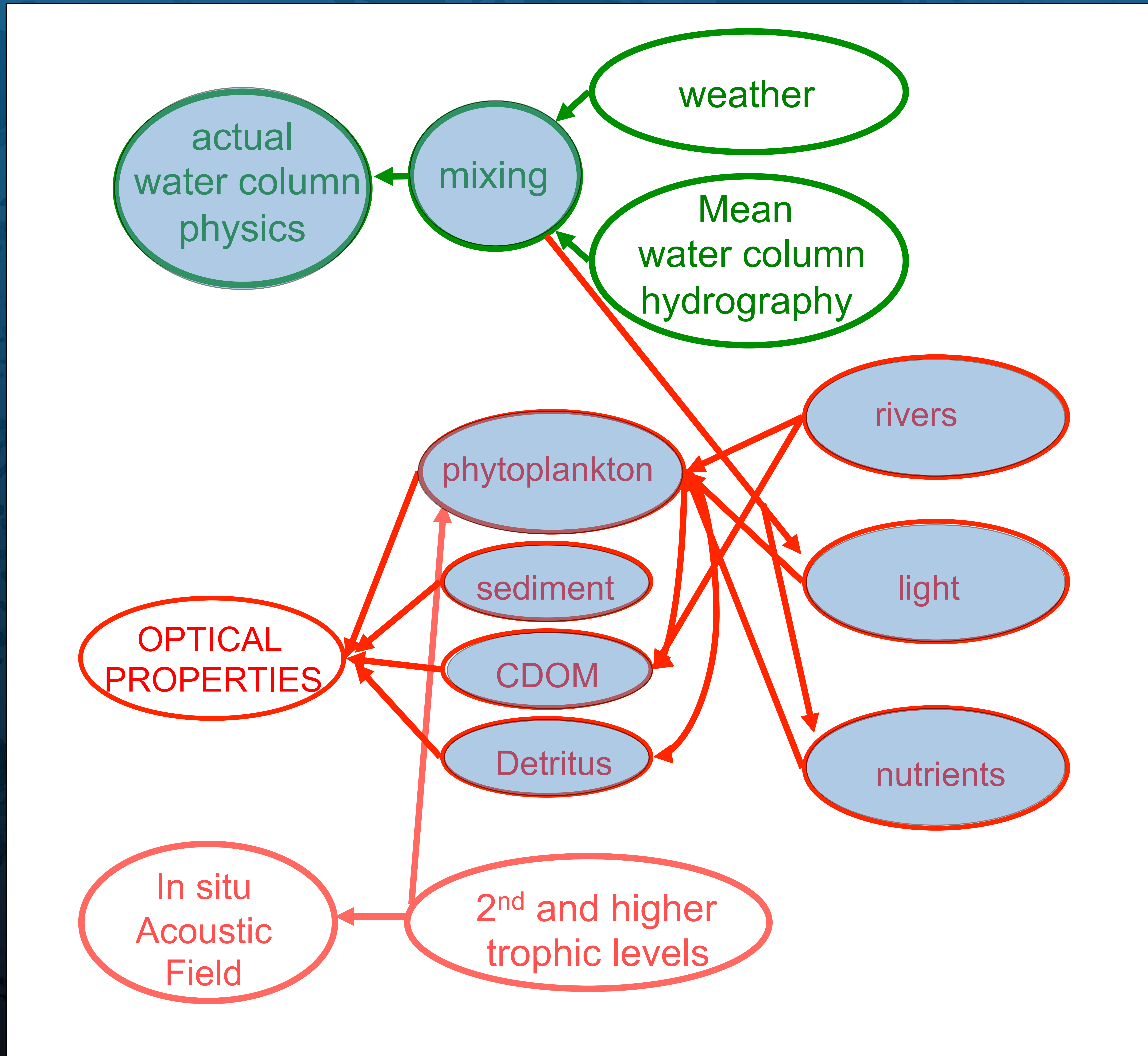

weather
actual
water column
physics
mixing
Mean
water column
hydrography
rivers
phytoplankton
light
sediment
OPTICAL
PROPERTIES
CDOM
Detritus
nutrients
In situ
Acoustic
Field
2nd and higher
trophic levels


RUTGERS UNIVERSITY
COASTAL OCEAN
OBSERVATION
LAB
OPERATIONS CENTER

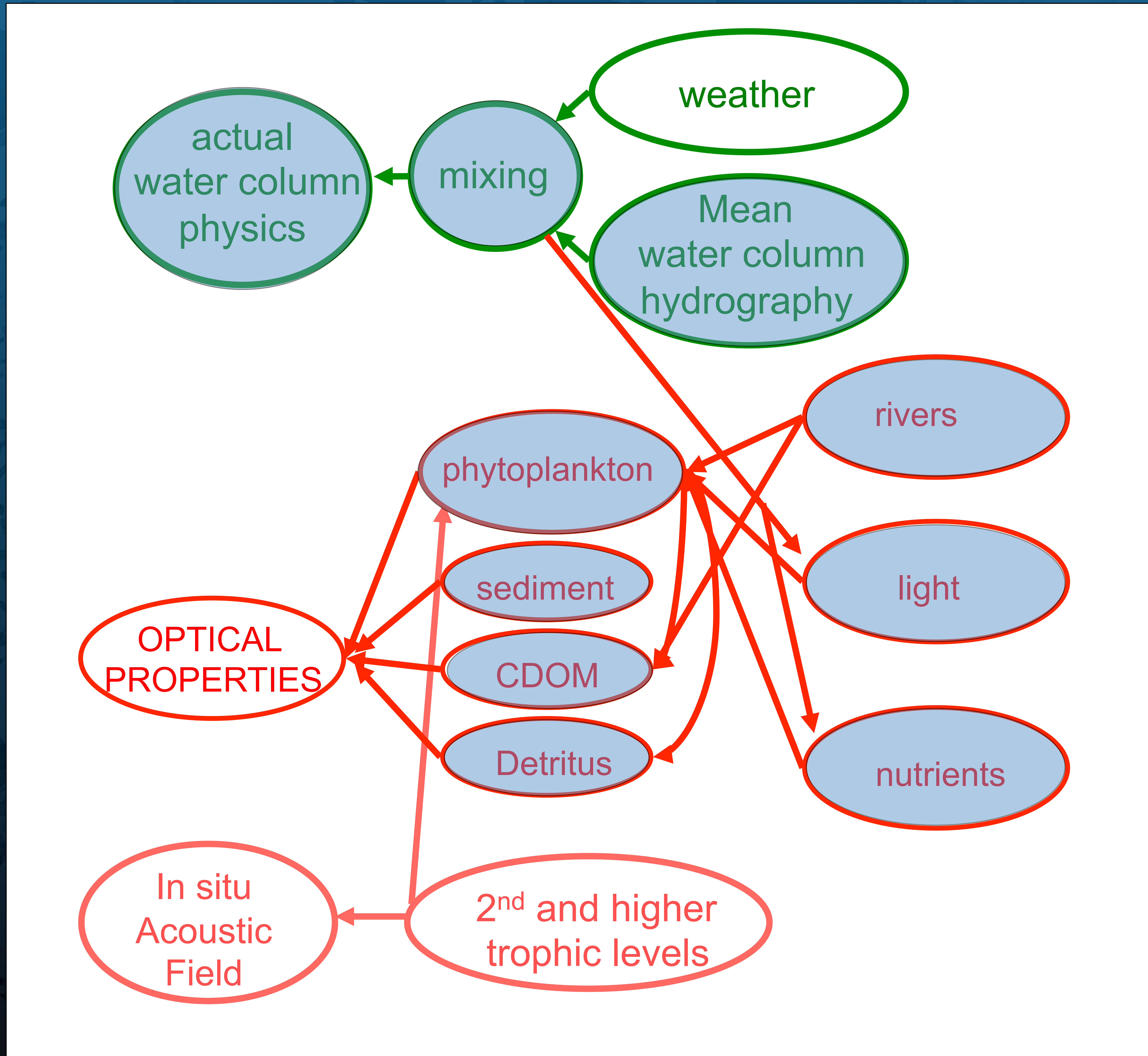




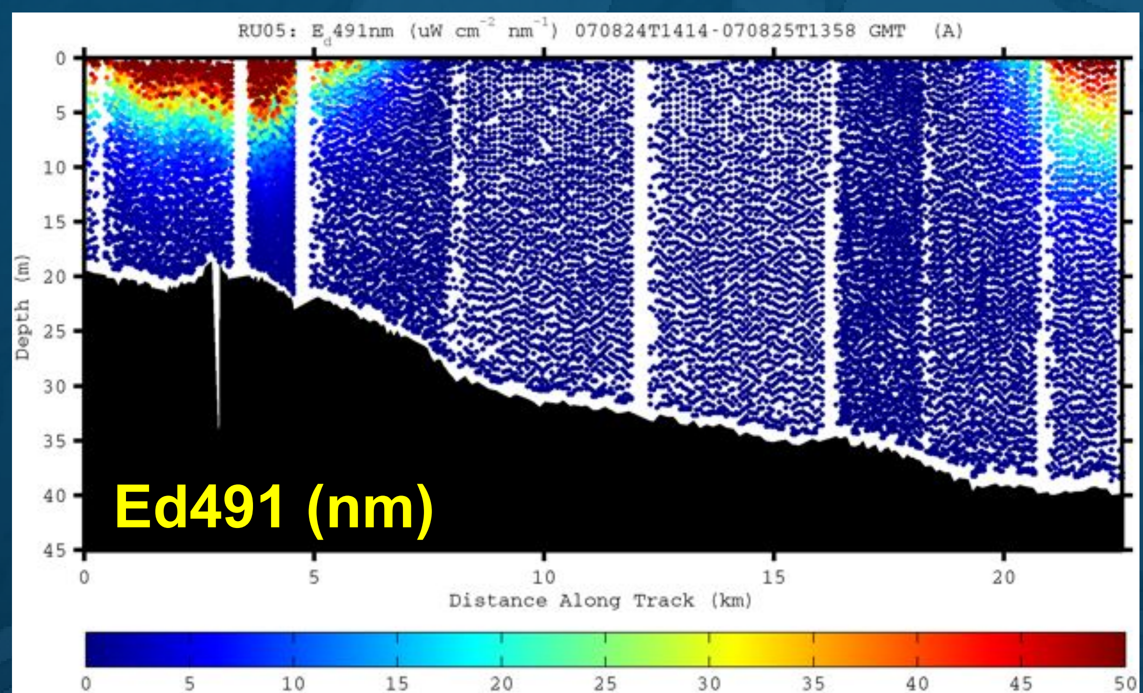

RU15: 070914T1229-070921T1829 GMT
41° 00'
40° 30'
40° 00'
39° 30'
39° 00'
38° 30'
Latitude
-75° 00'
-74° 30'
-74° 00'
-73° 30'
-73° 00'
-72° 30'
-72° 00
Longitude

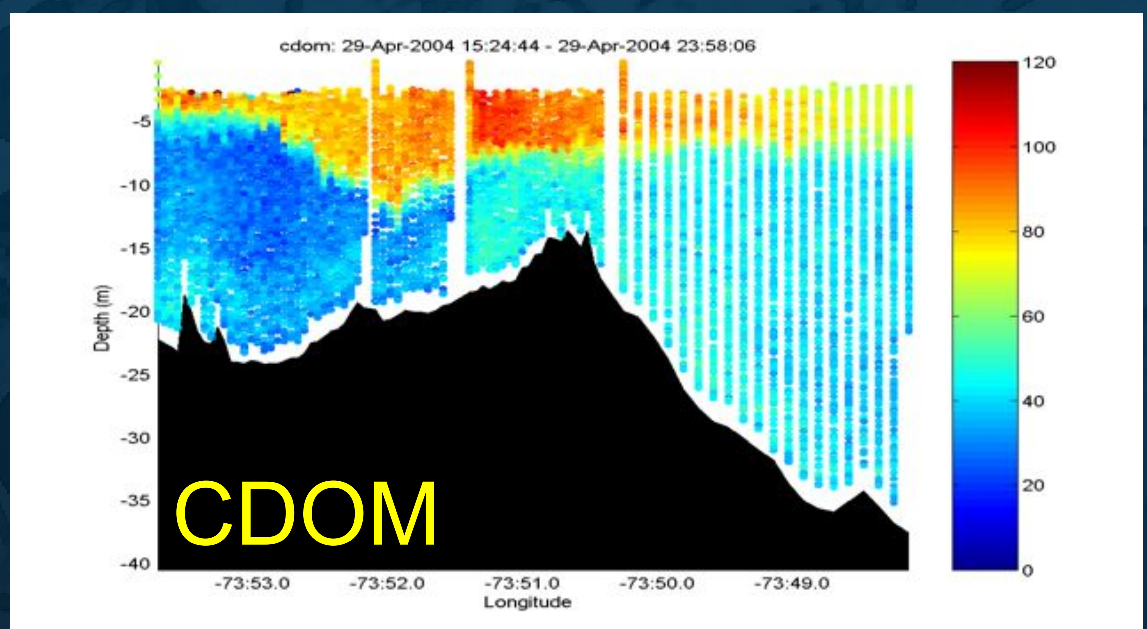


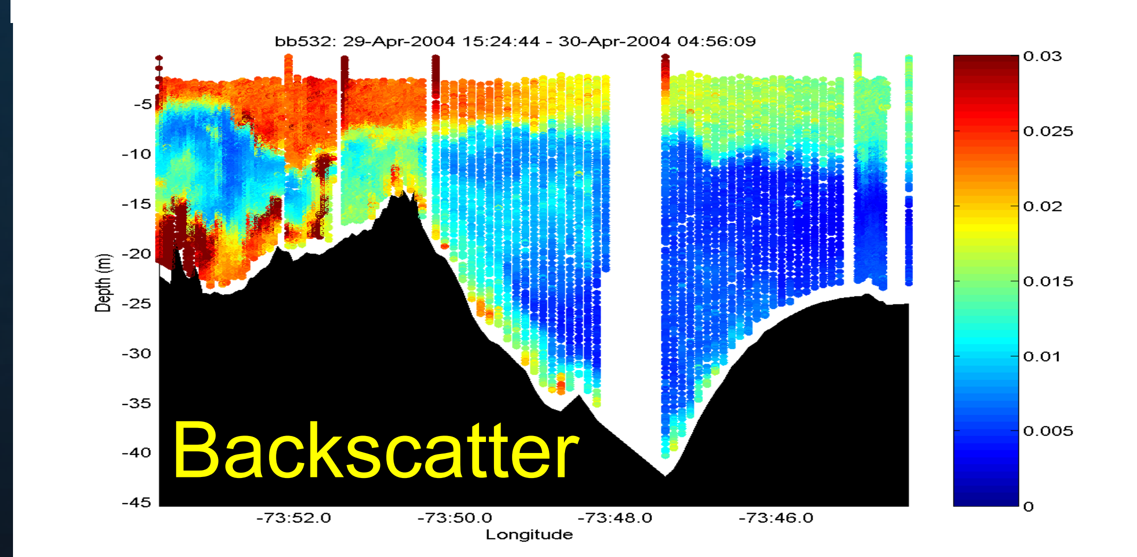
actual water column physics
mixing
weather
Mean water column hydrography
rivers
phytoplankton
light
sediment
OPTICAL PROPERTIES
CDOM
Detritus
nutrients
In situ Acoustic Field
2nd and higher trophic levels

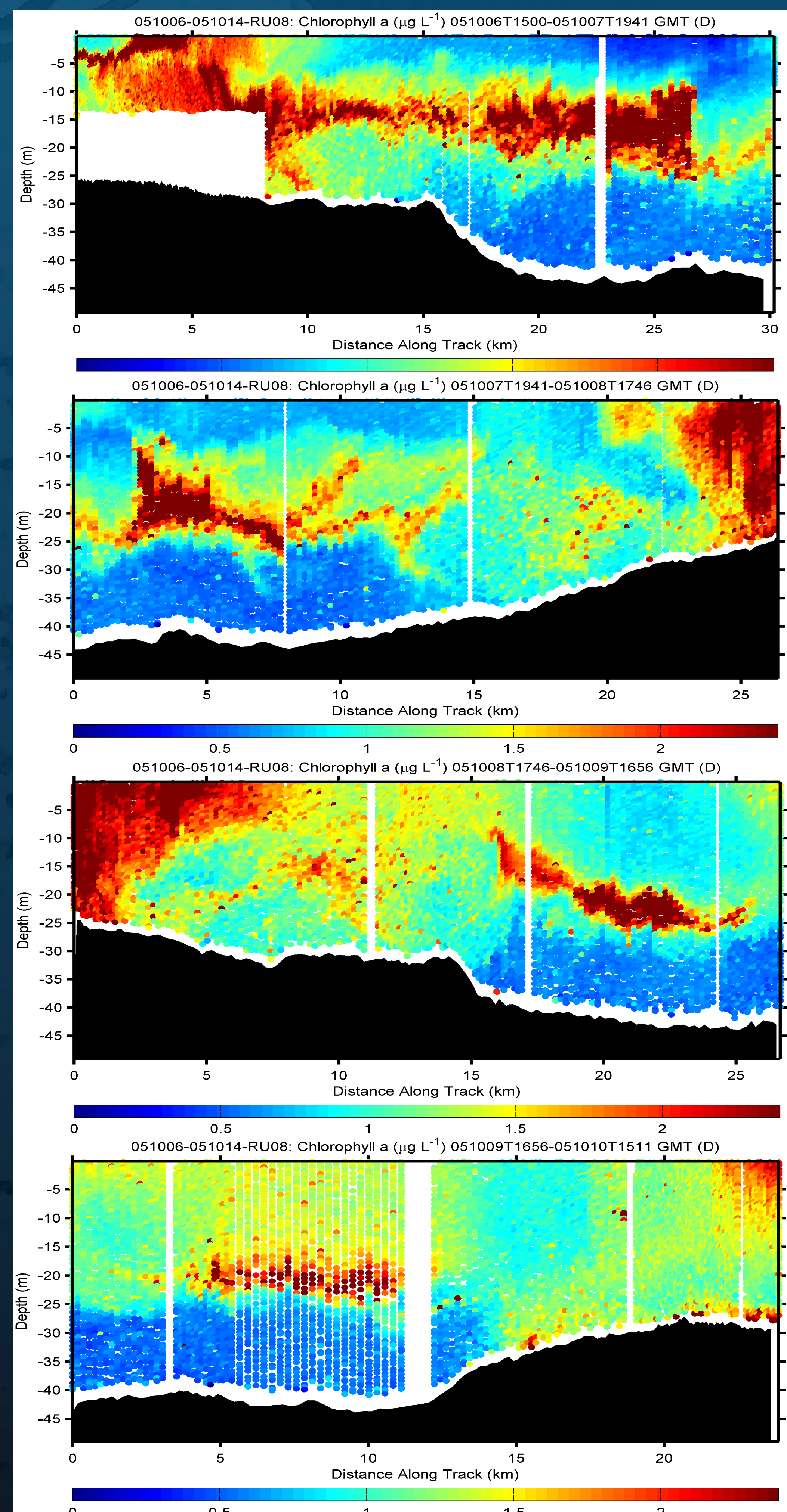

weather
actual
water column
physics
mixing
Mean
water column
hydrography
rivers
phytoplankton
sediment
light
OPTICAL
PROPERTIES
CDOM
Detritus
nutrients
In situ
Acoustic
Field
2nd and higher
trophic levels

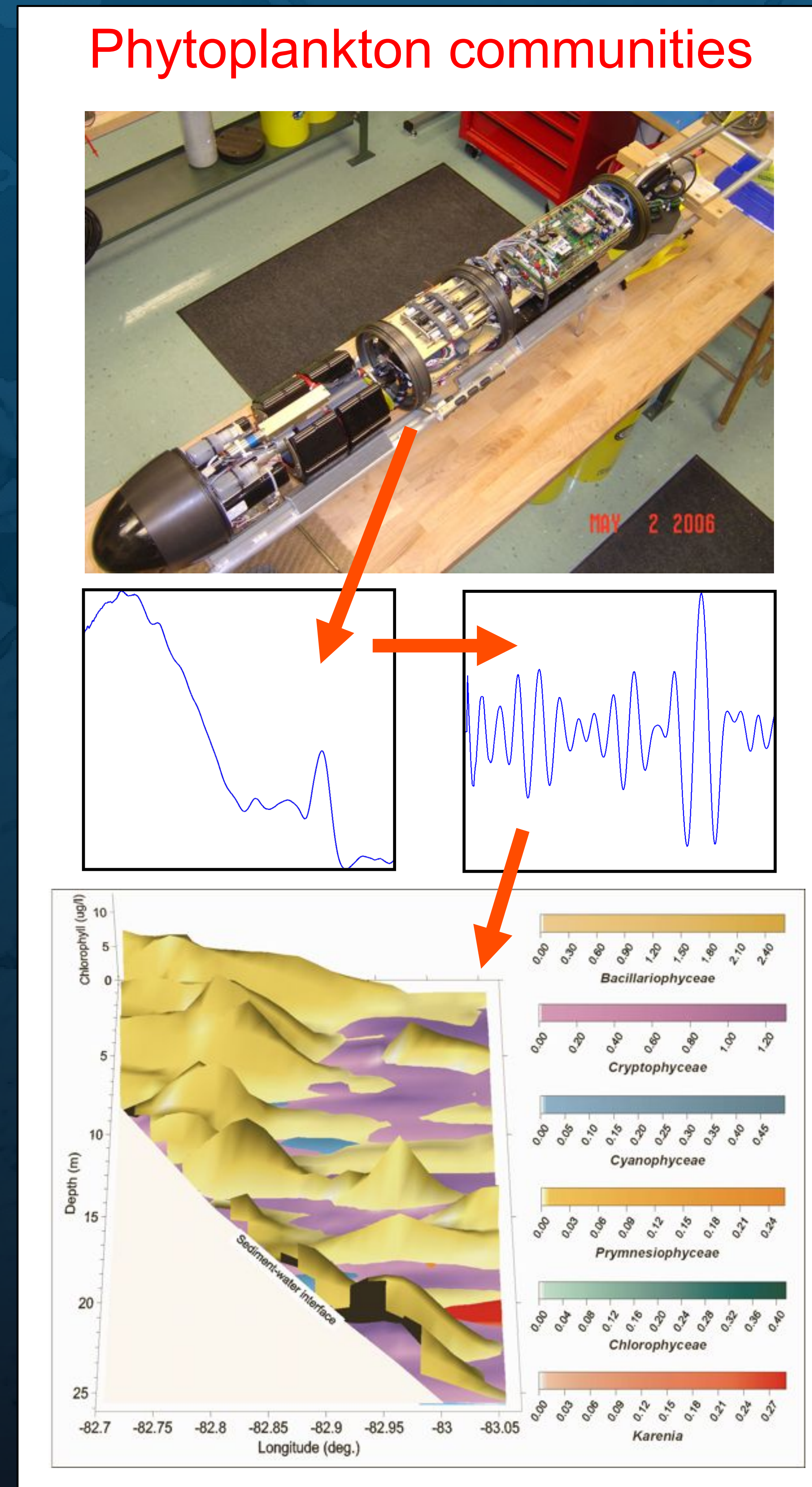
Optical data collected by gliders

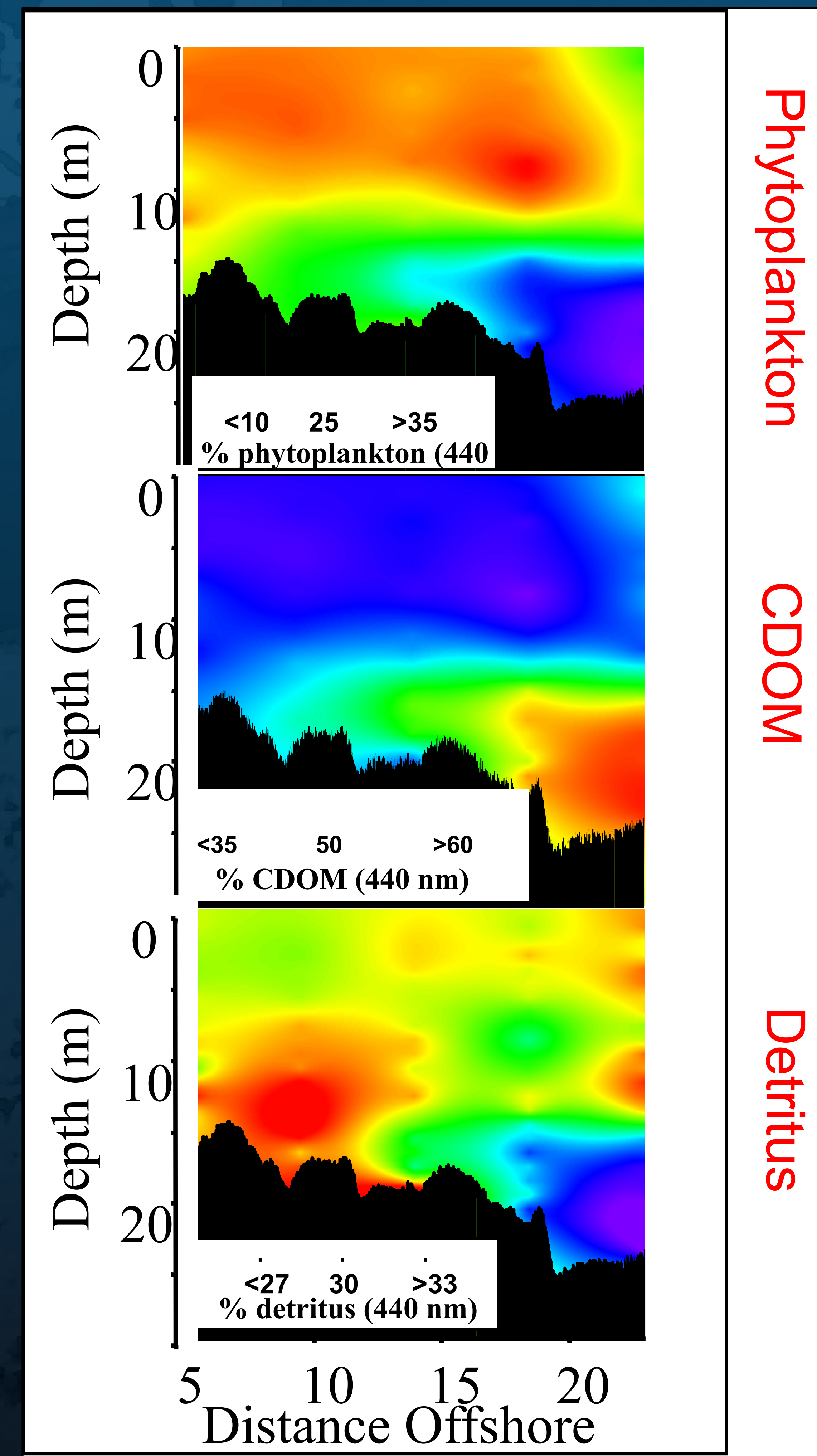


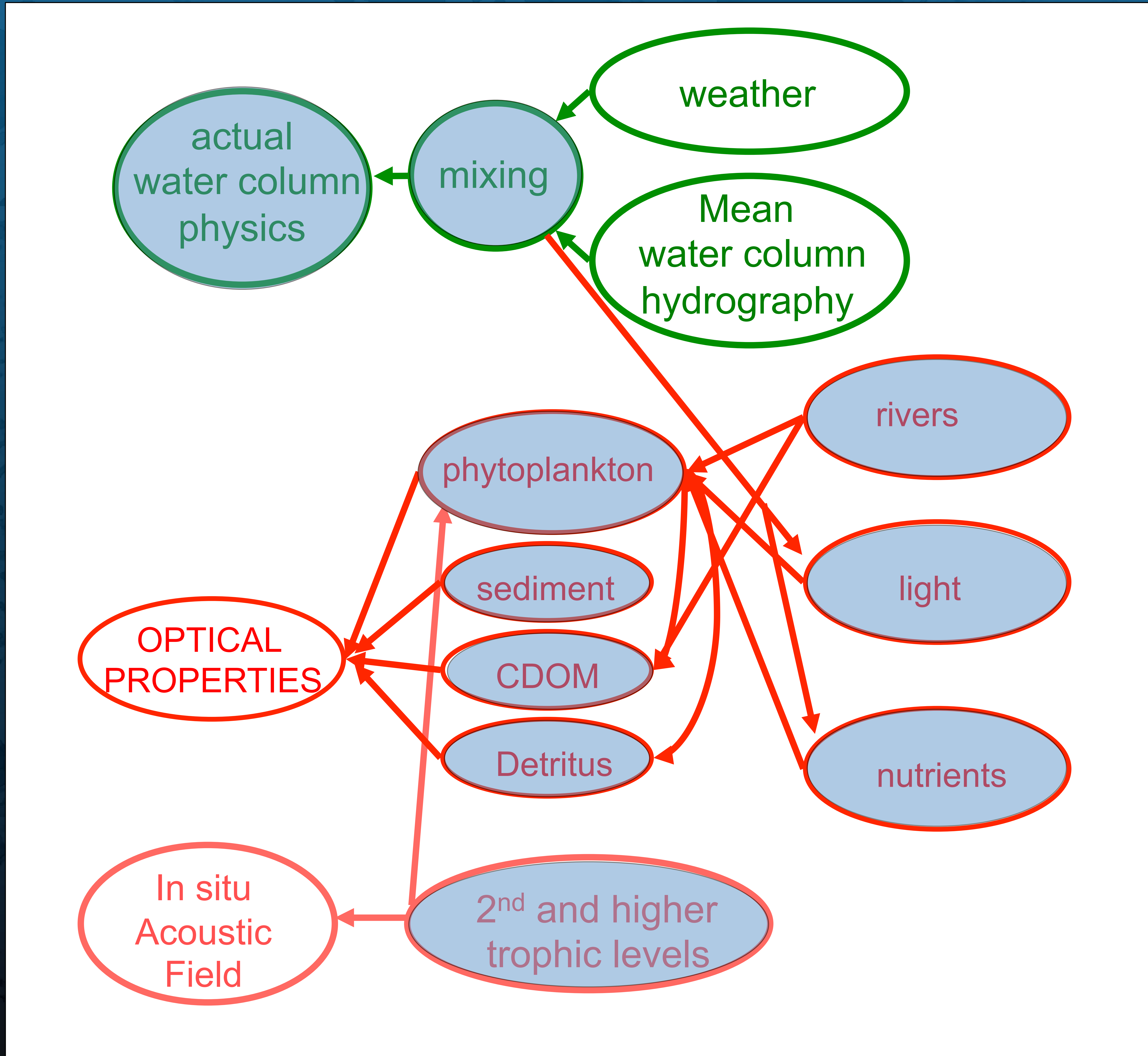












weather
actual
water column
physics
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Mean
water column
hydrography
rivers
phytoplankton
light
sediment
OPTICAL
PROPERTIES
CDOM
Detritus
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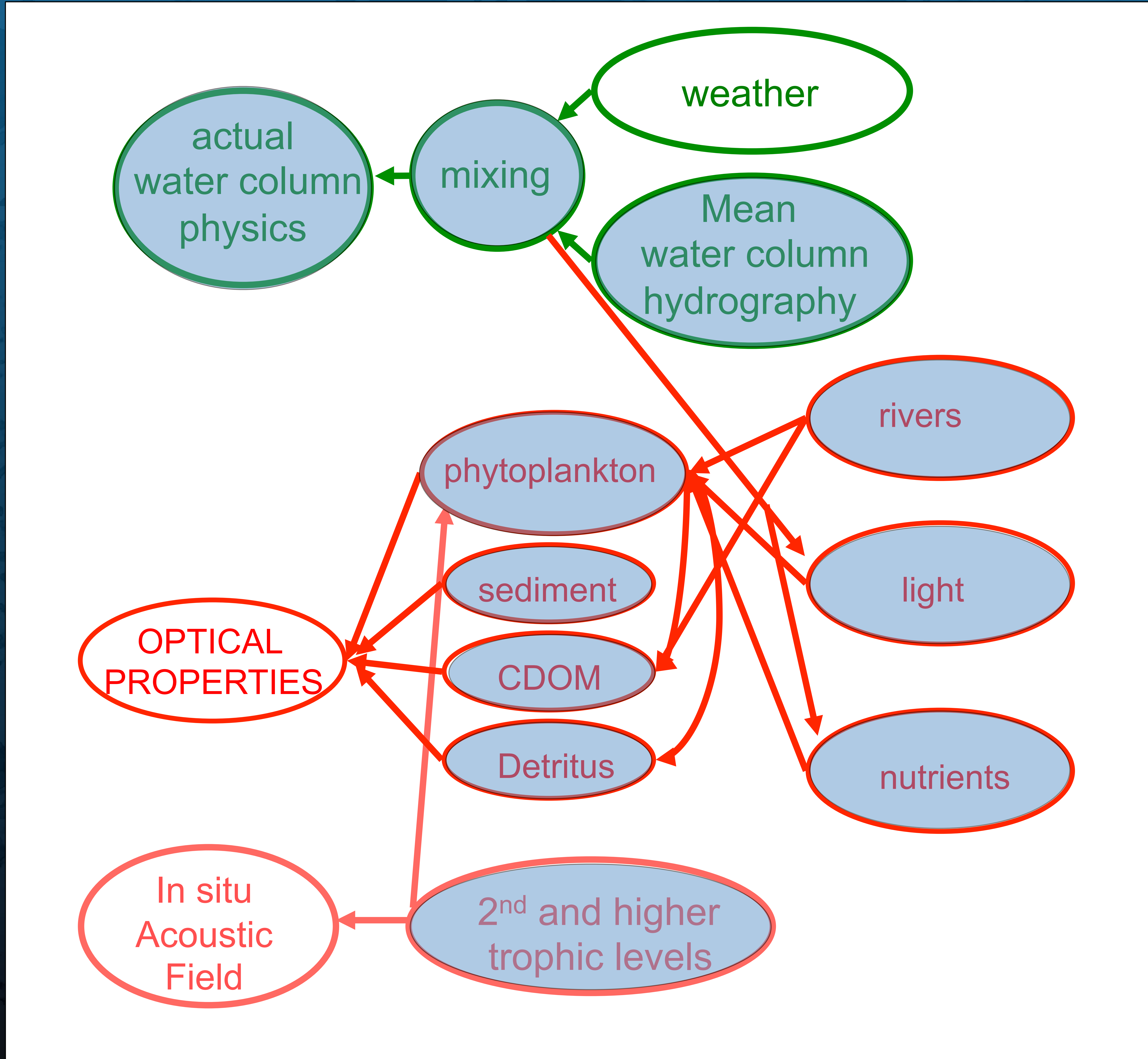
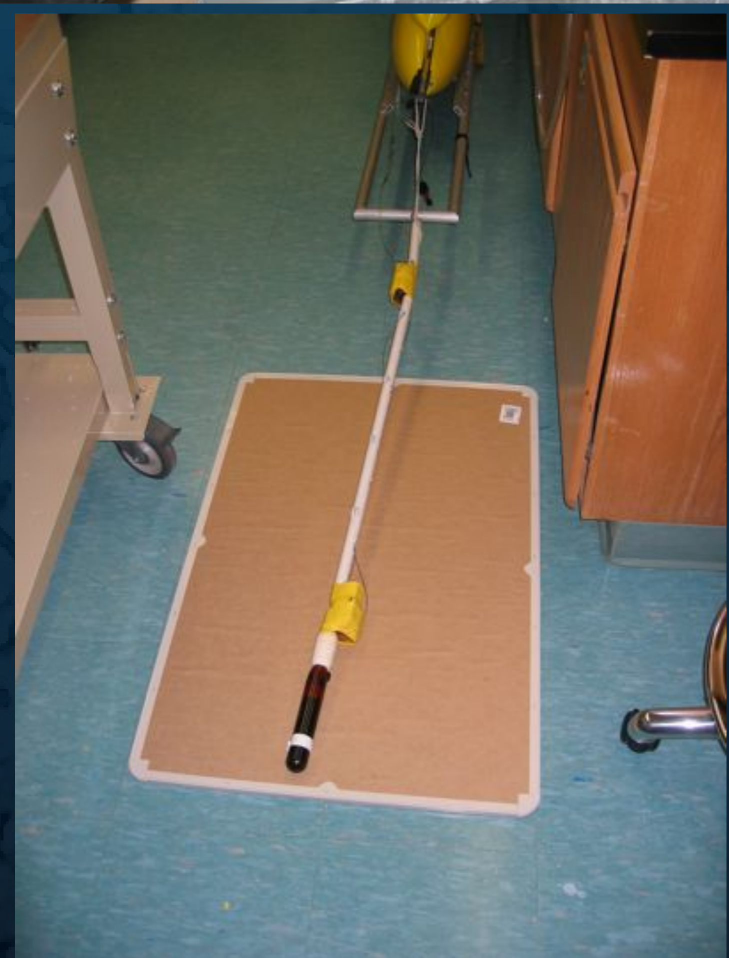
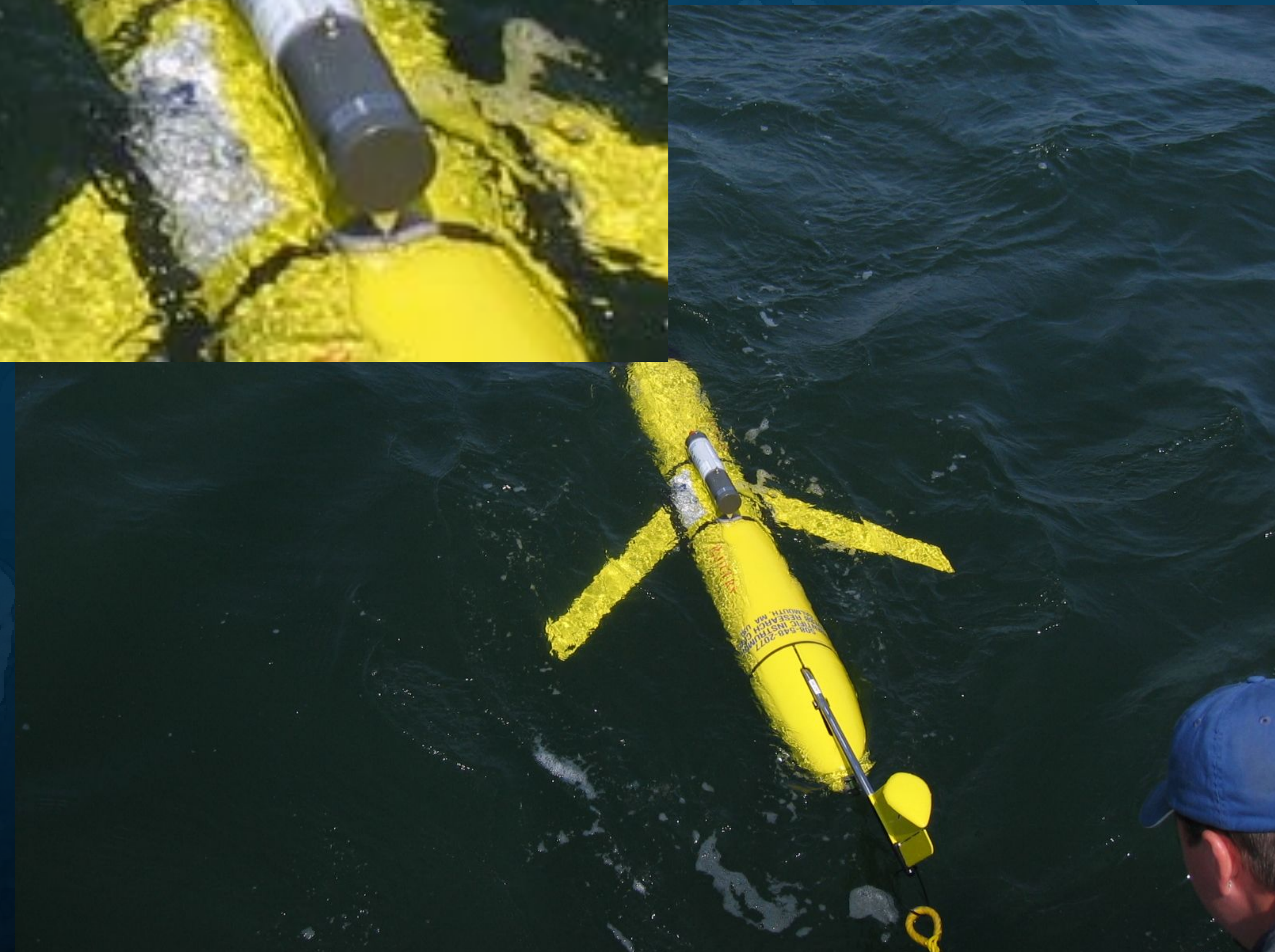


Sunday, July 1, 12


06

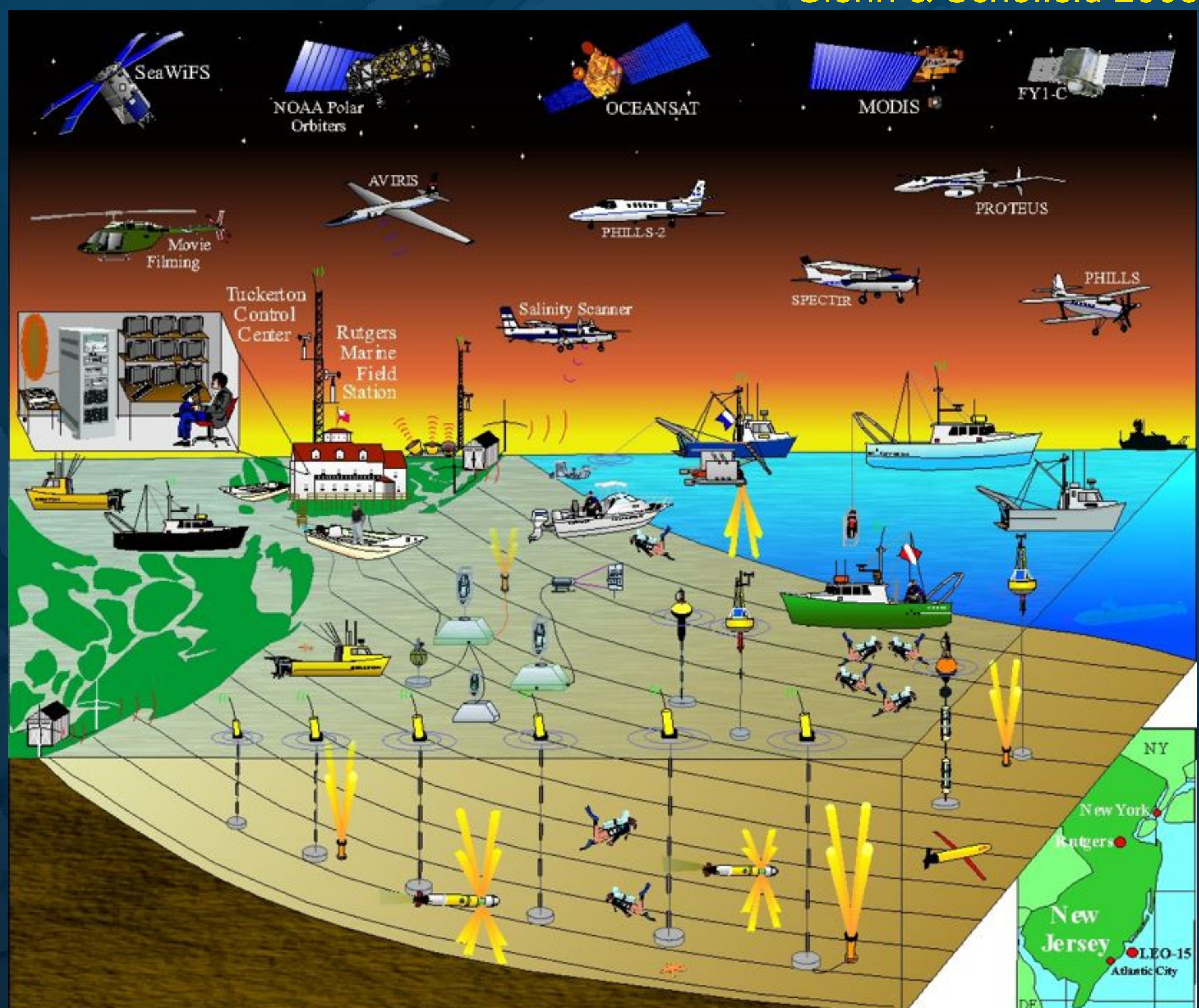




Diverse funding with an evolving suite of questions

Upwelling, hypoxia & coastal predictive skill

Schofield et al 2002
Glenn & Schofield 2003

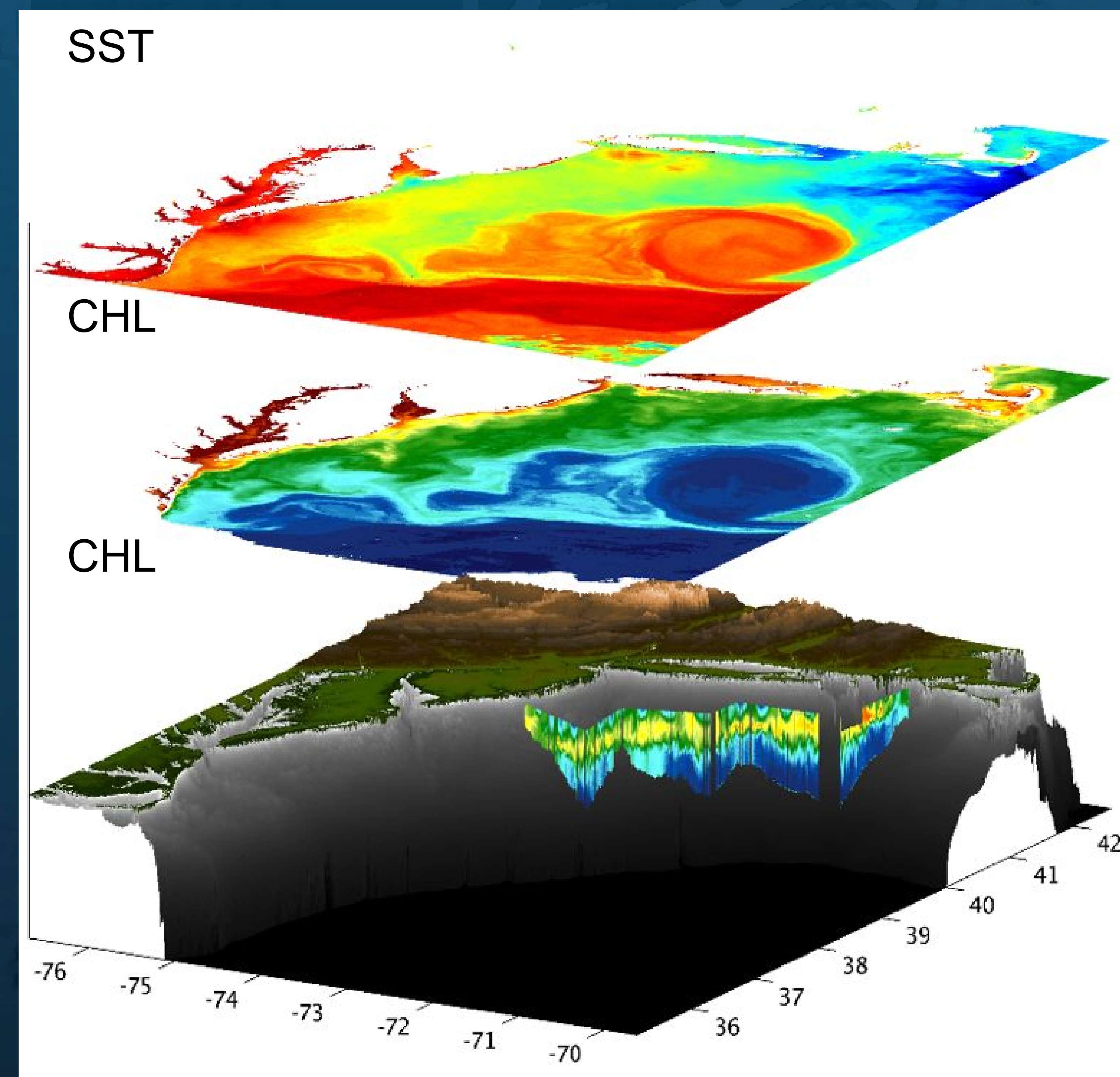


1996-2001
Local scale observatories

→

Shelf transport, land/ocean communication

Glenn & Schofield 2009

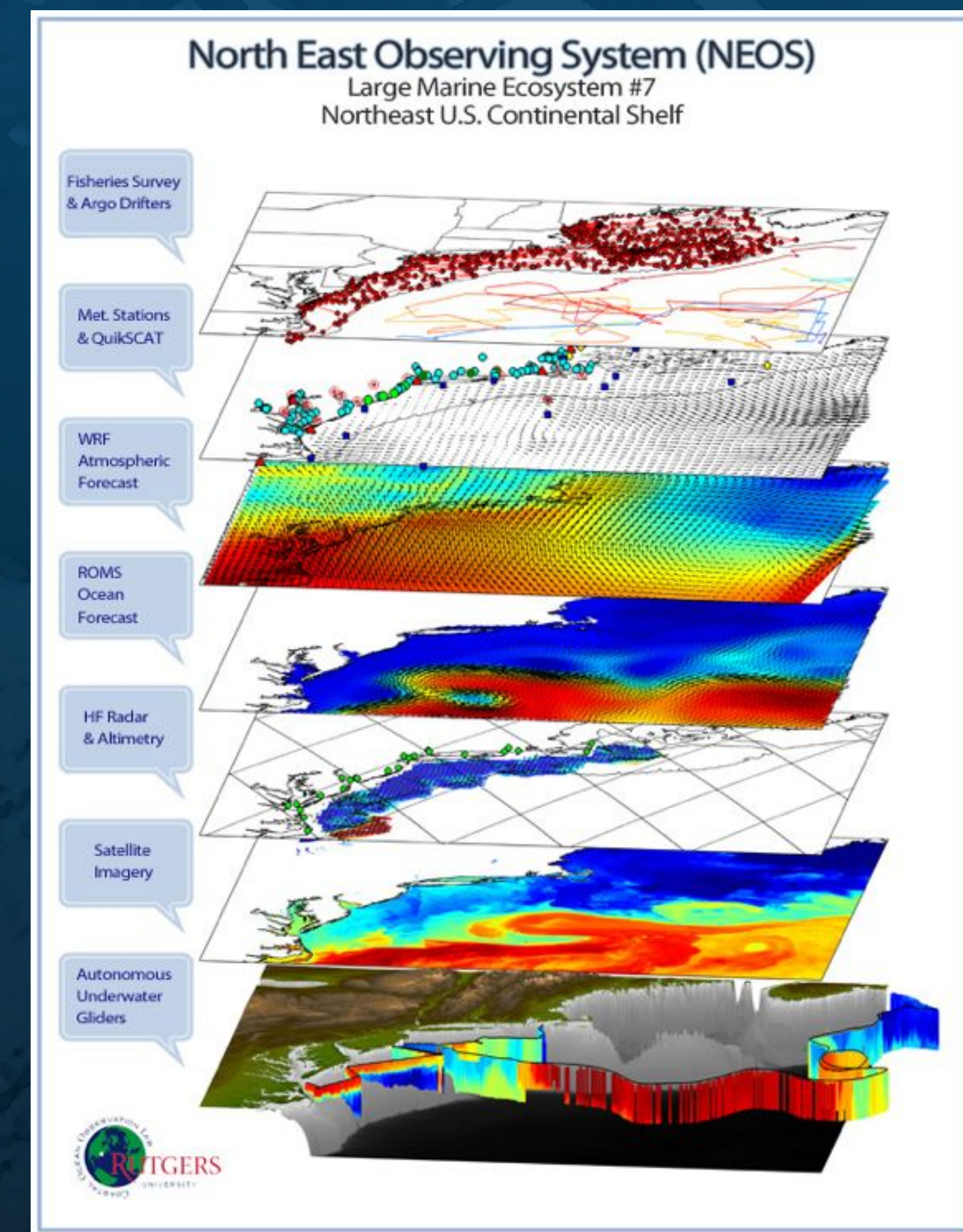


2001-2006
Regional scale observatories

→

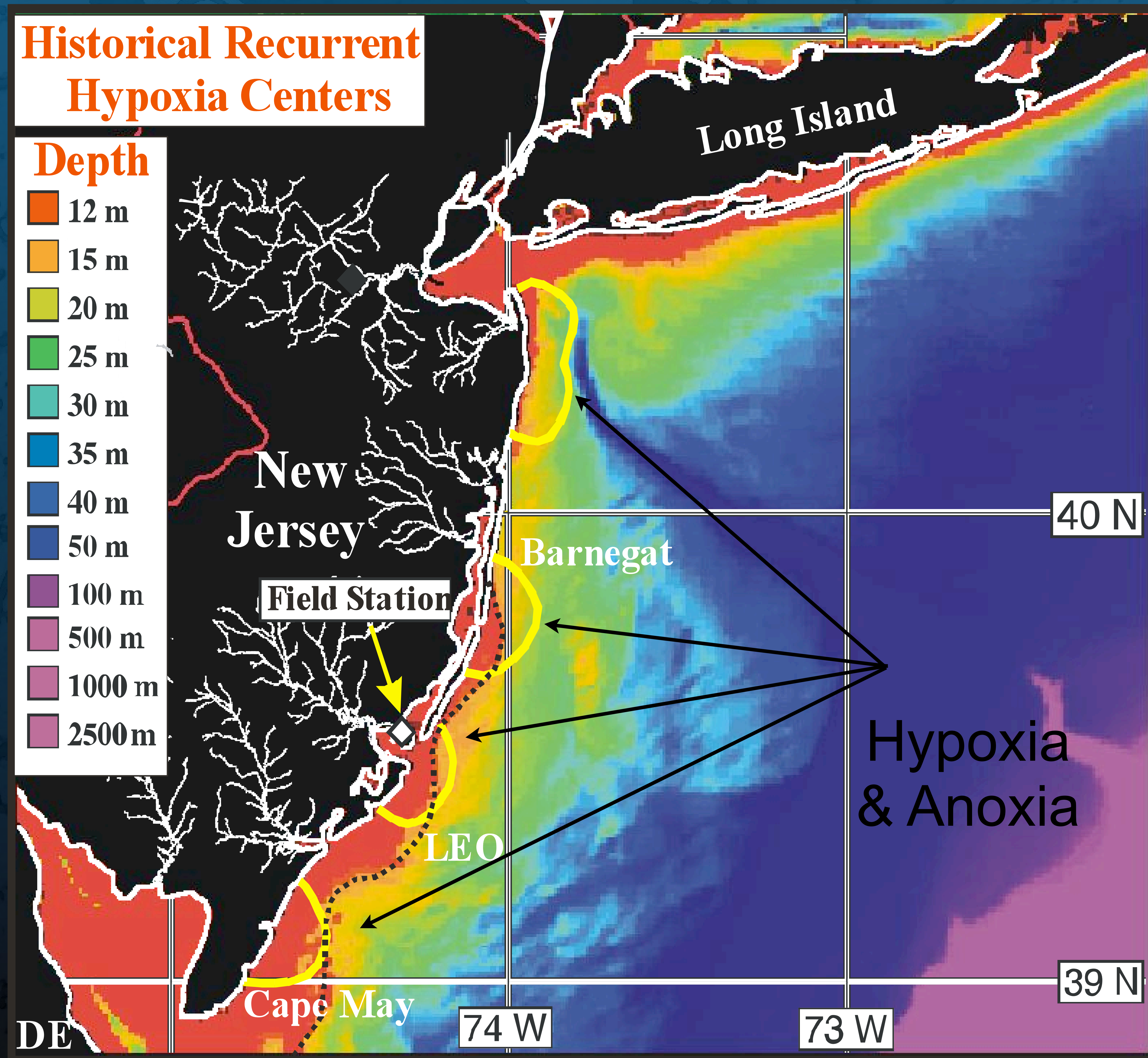
Ecosystem dynamics, climate scale mediated change

Schofield et al. 2011

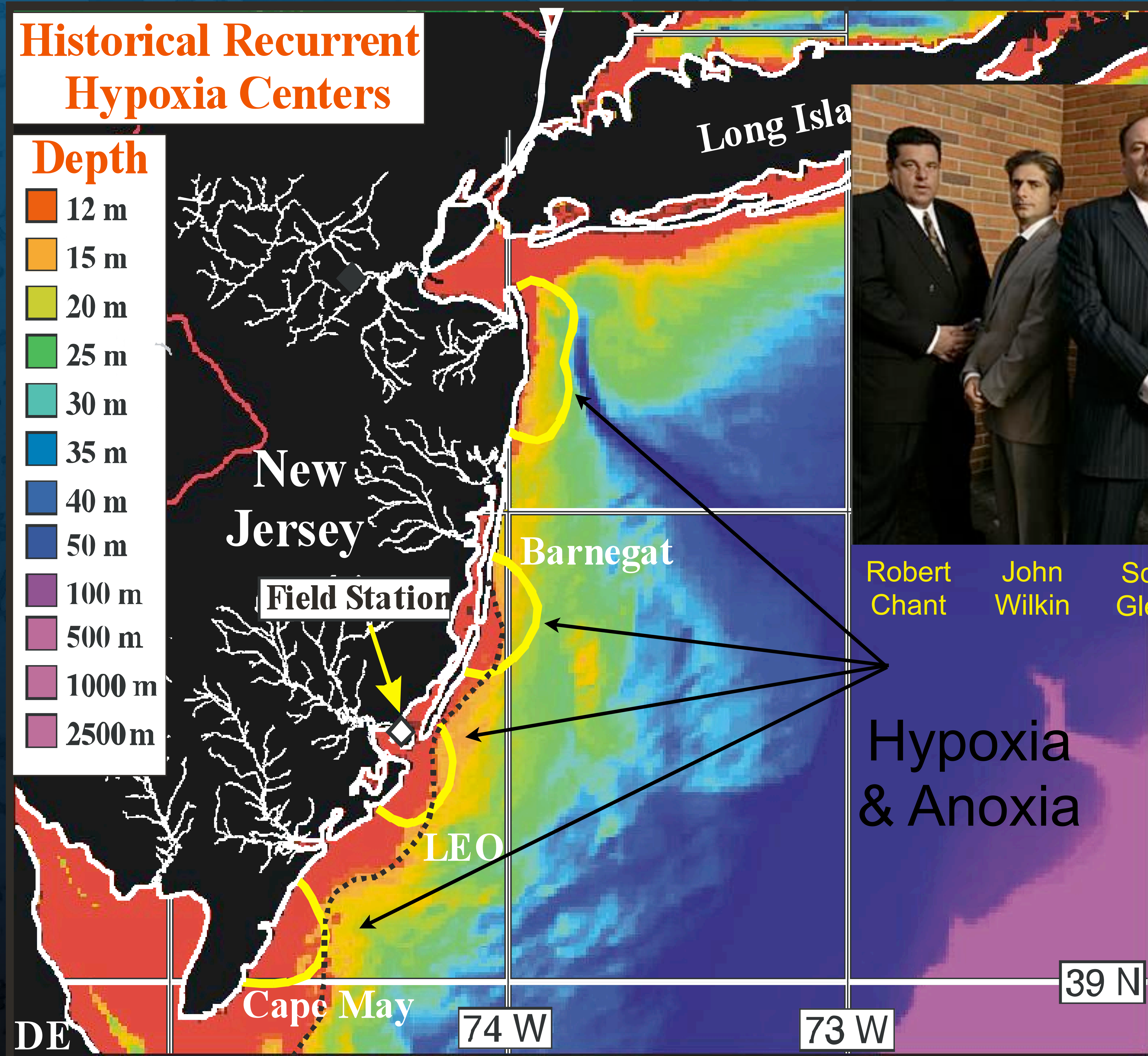


2006-2011
Large marine ecosystem observatories

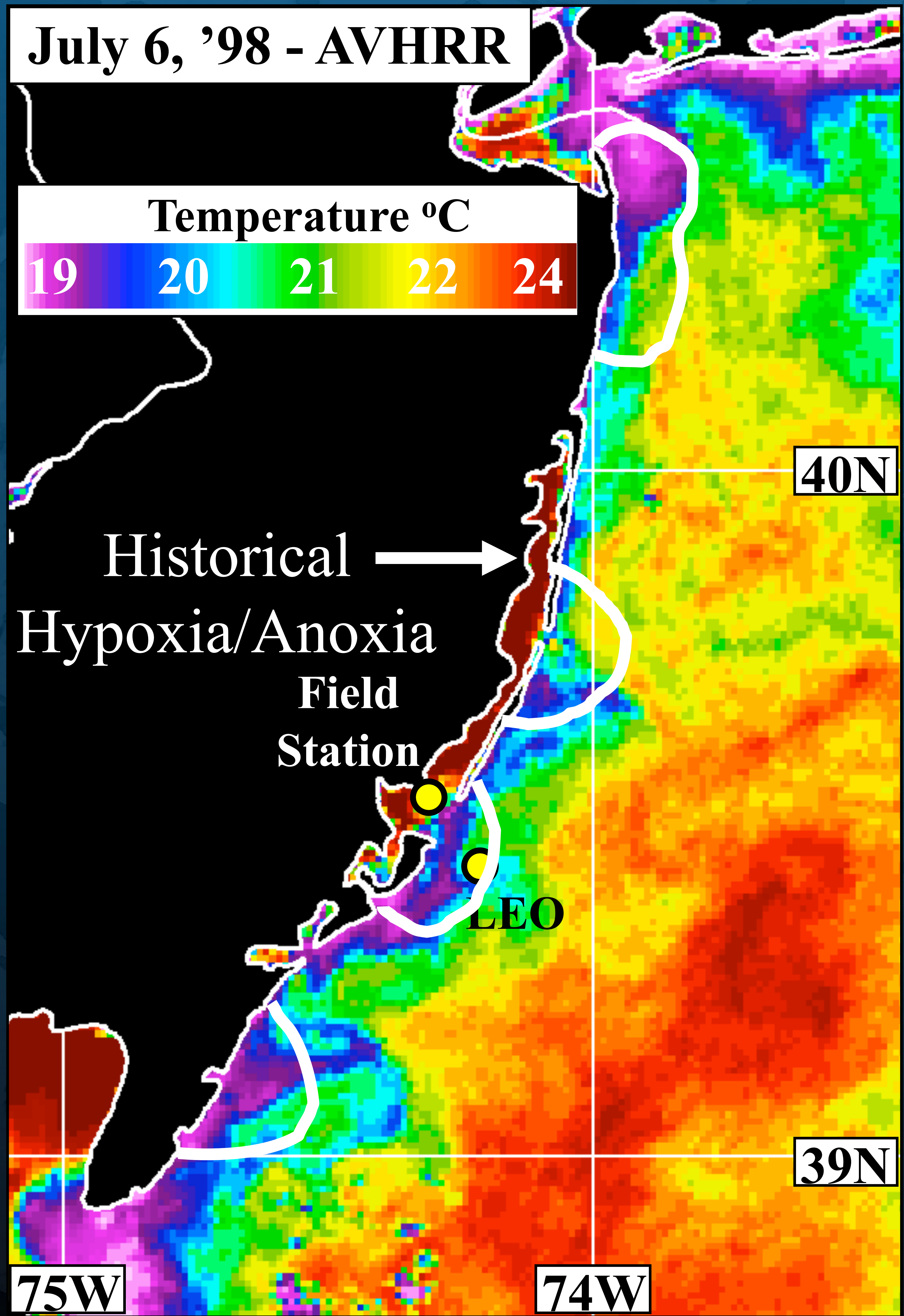
Phase development: The nearshore coastal system
Question driving science deployment: Are humans causing coastal hypoxia?

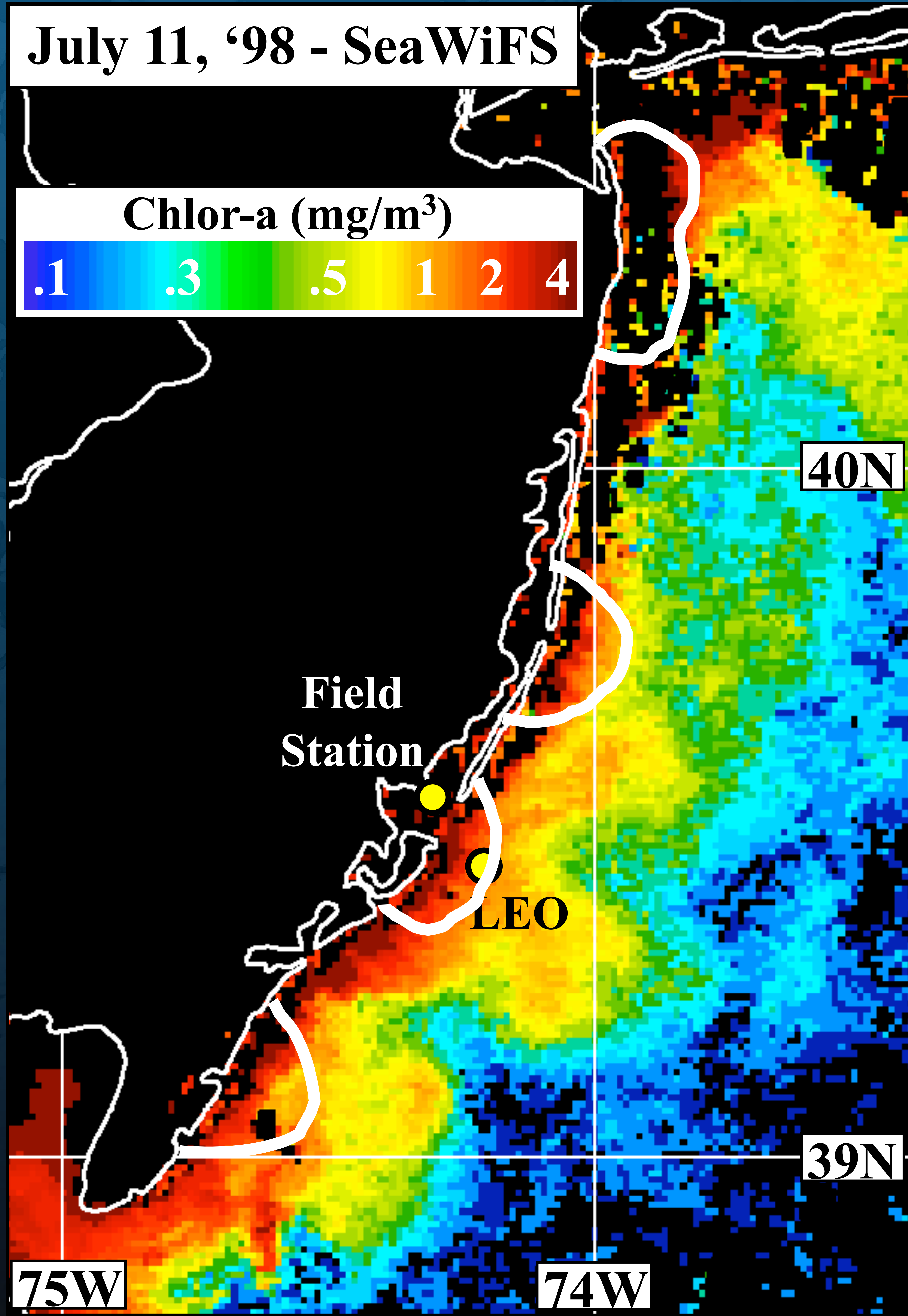


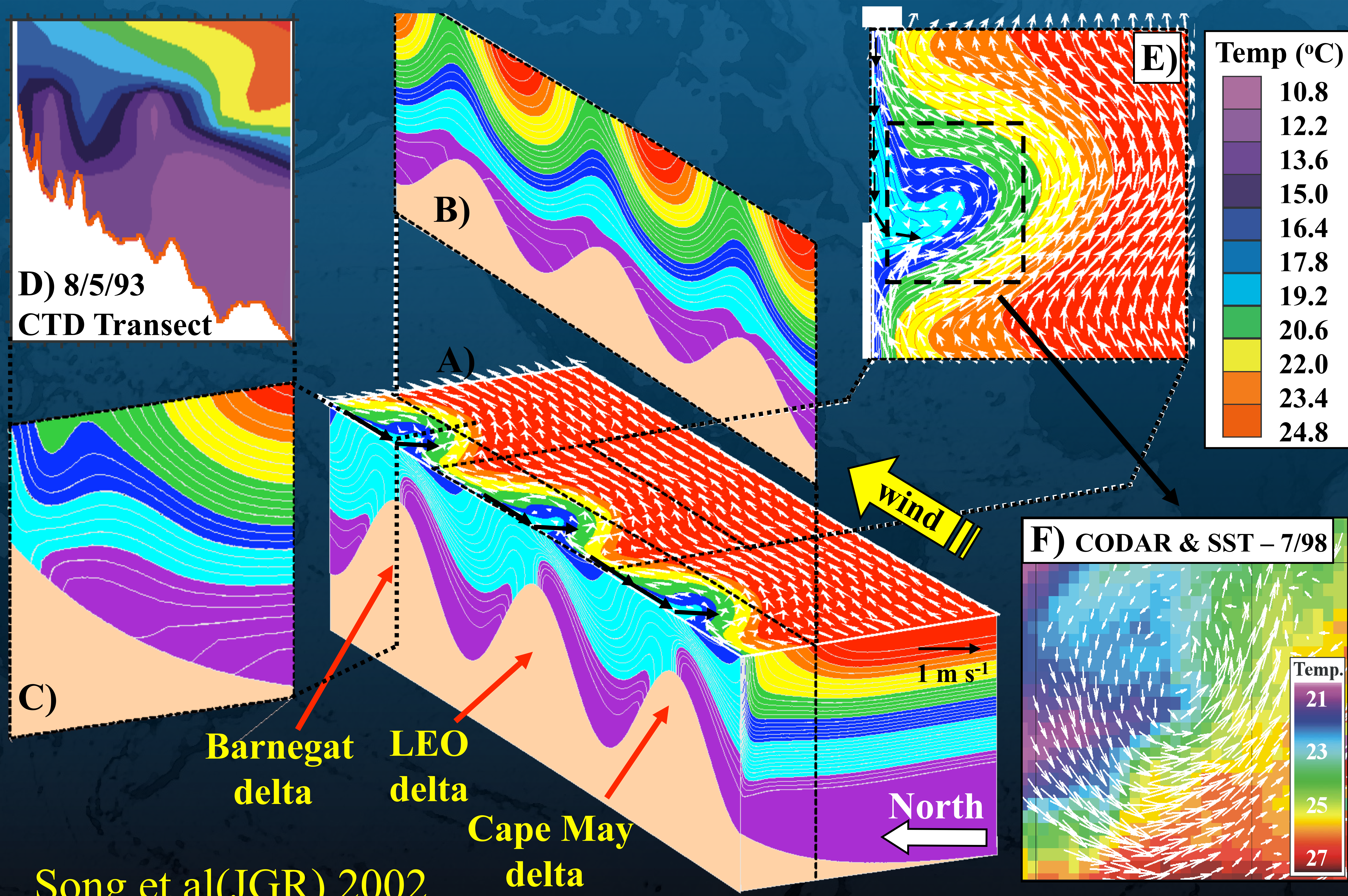
Phase development: The nearshore coastal system
Question driving science deployment: Are humans causing coastal hypoxia?



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

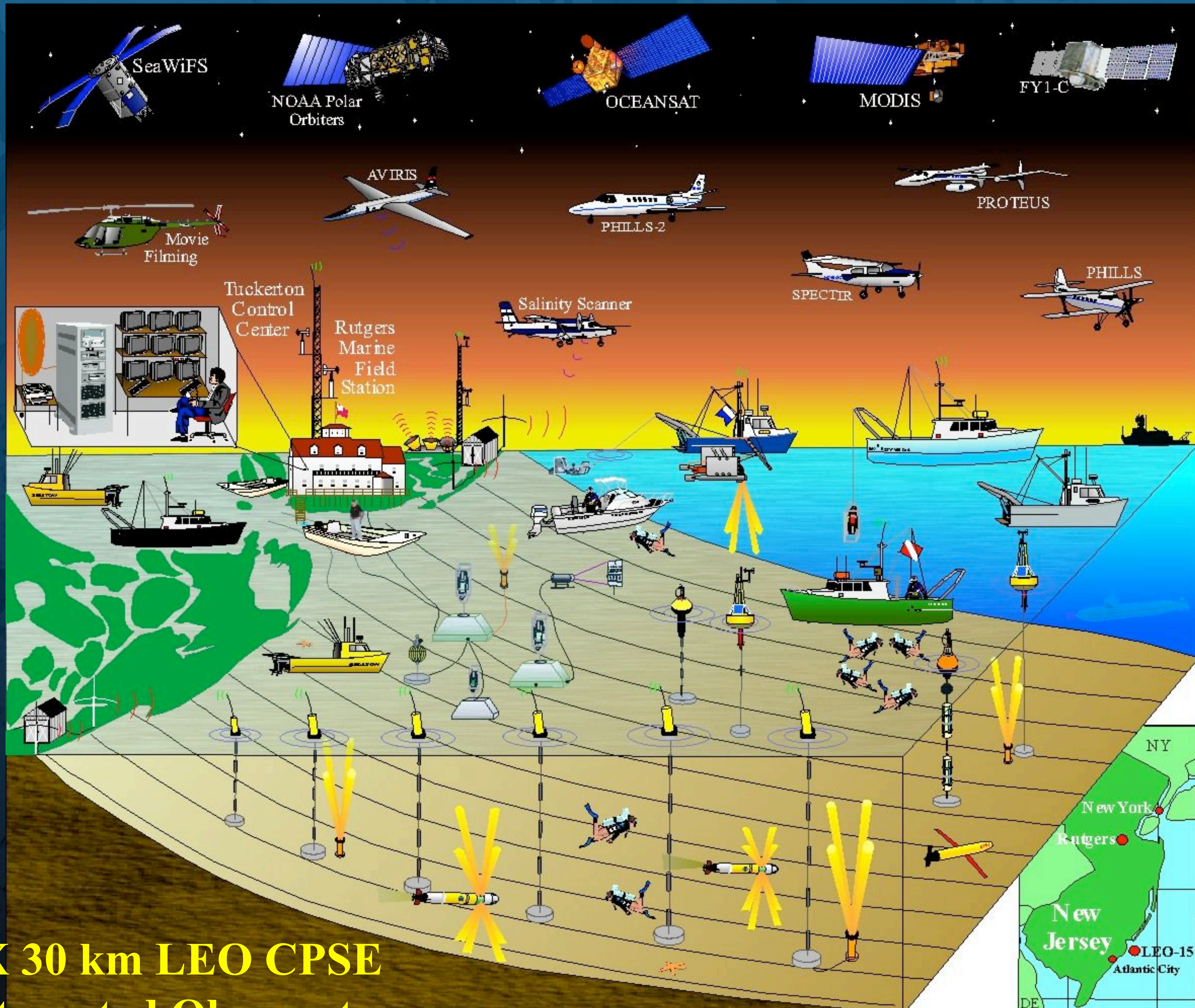

July 6, '98 - AVHRR
Temperature °C
19
20
21
22
24
40N
39N
75W
74W
Historical
Hypoxia/Anoxia
Field
Station
LEO


July 11, '98 - SeaWiFS
Chlor-a (mg/m³)
.1
.3
.5
1
2
4
40N
39N
75W
74W
Field
Station
LEO



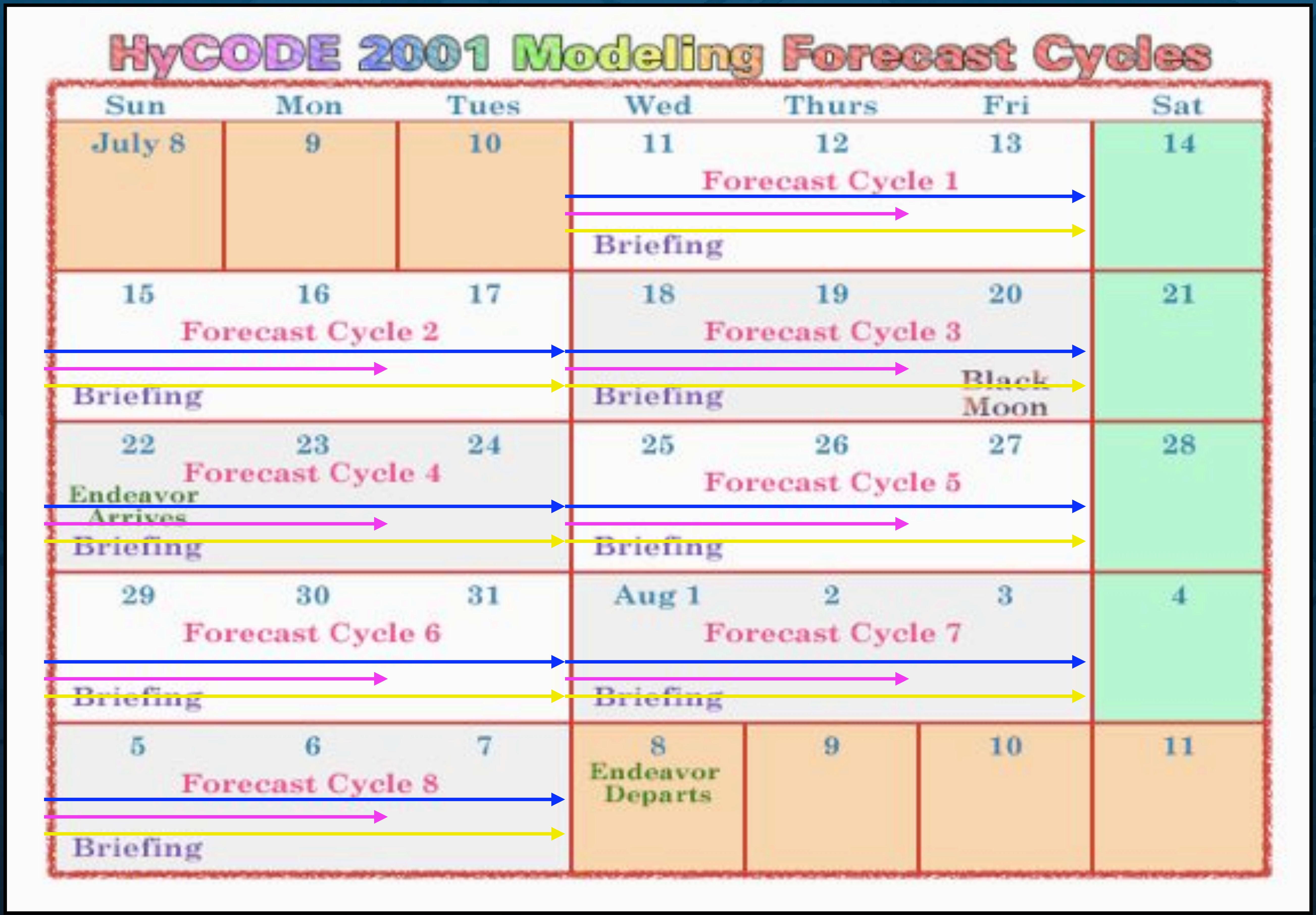
Song et al(JGR) 2002

Figure 6

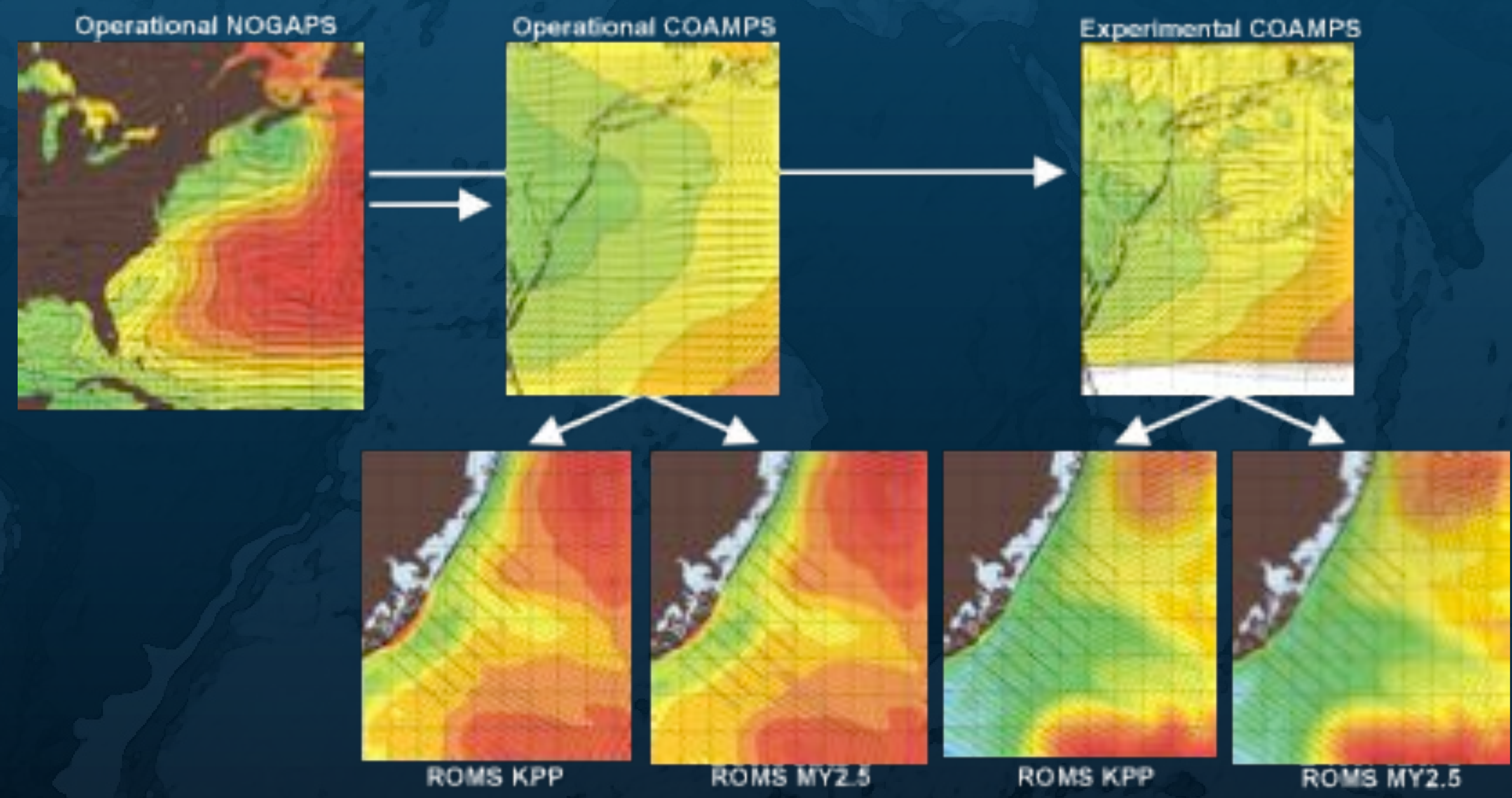


30 X 30 km LEO CPSE
An Integrated Observatory

Month Long Experimental Effort

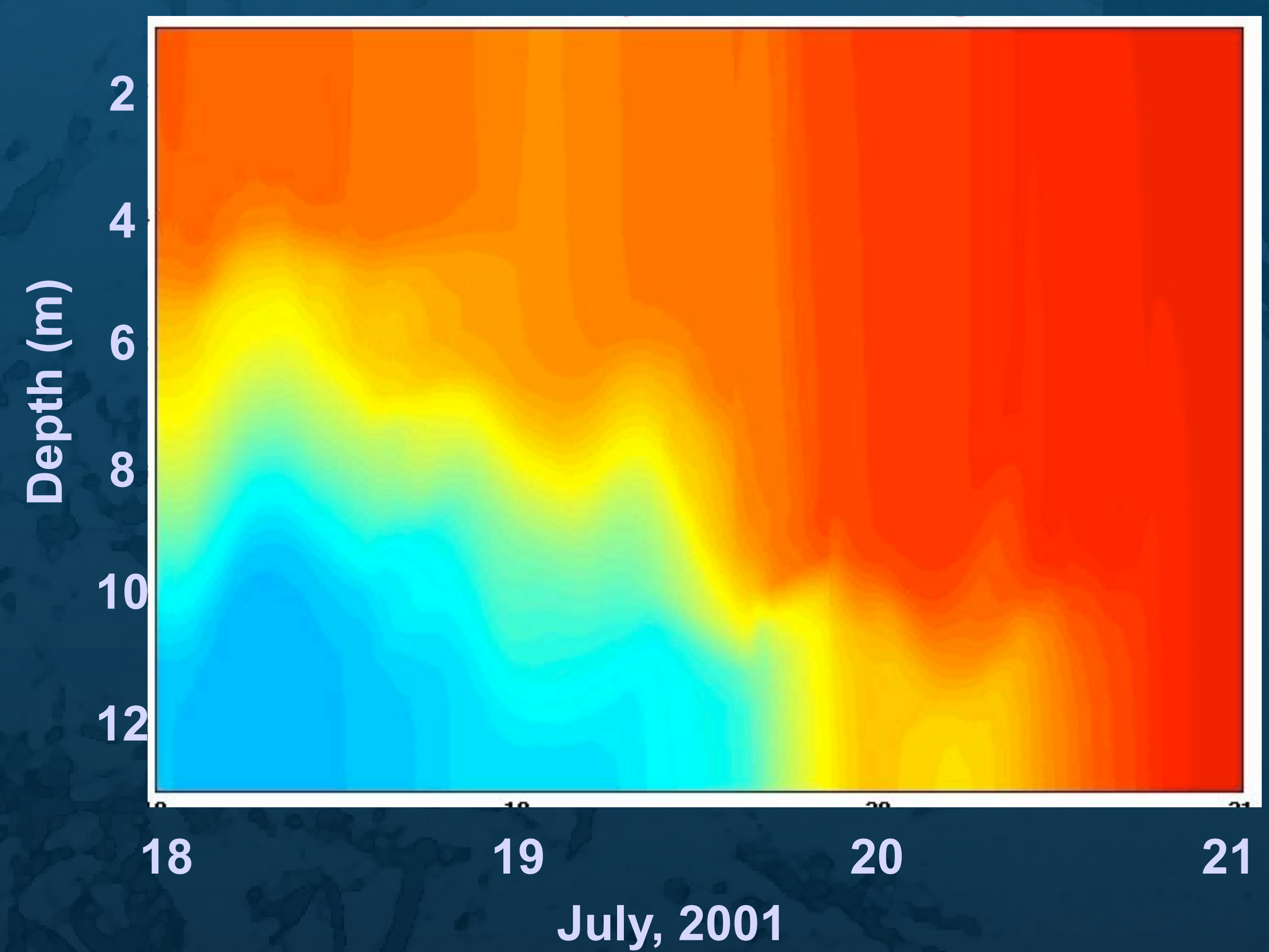


2001 Real-time Ensemble Forecasts

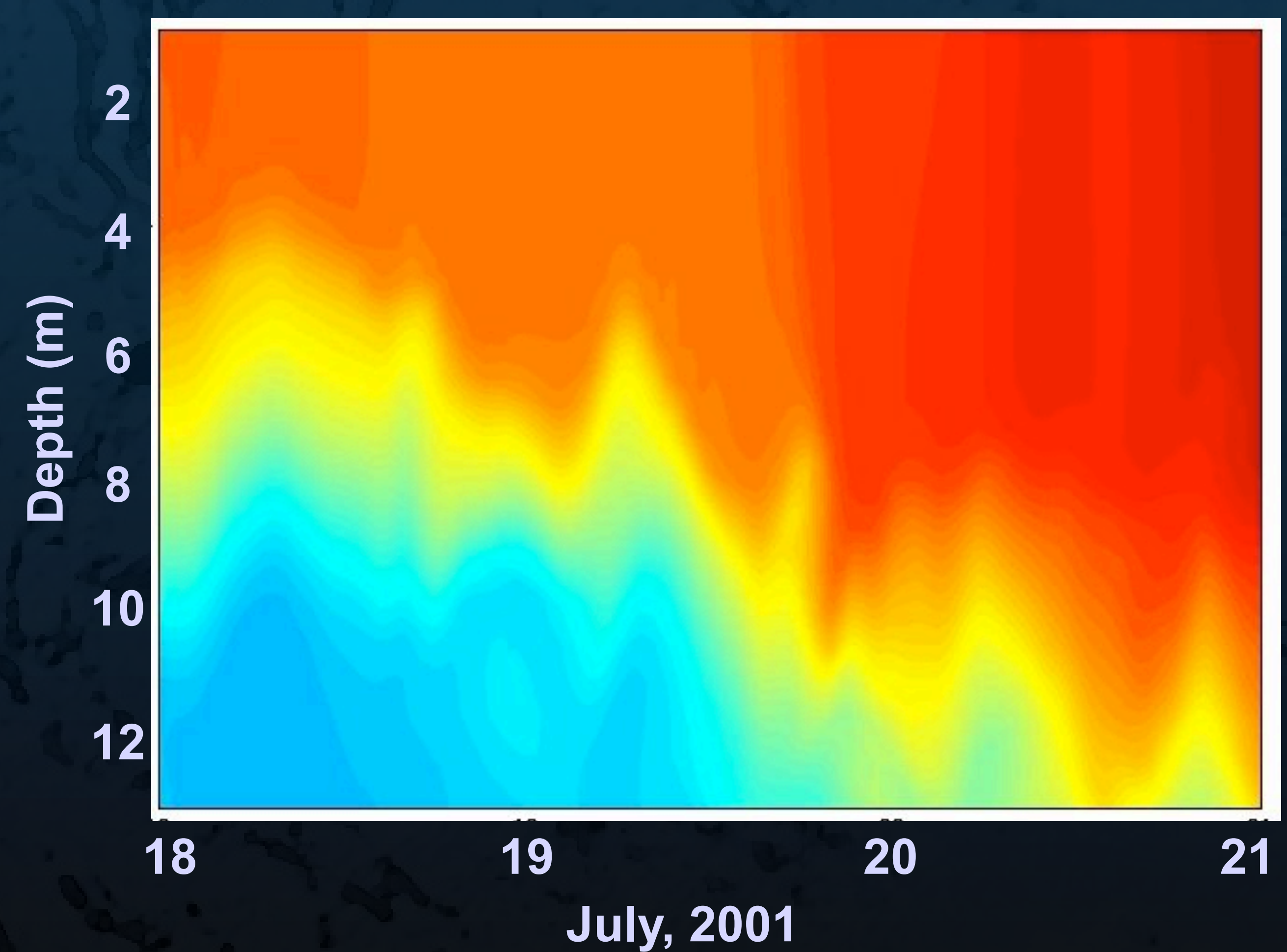


Real-time validation of the ensemble forecasts

HR COAMPS / ROMS

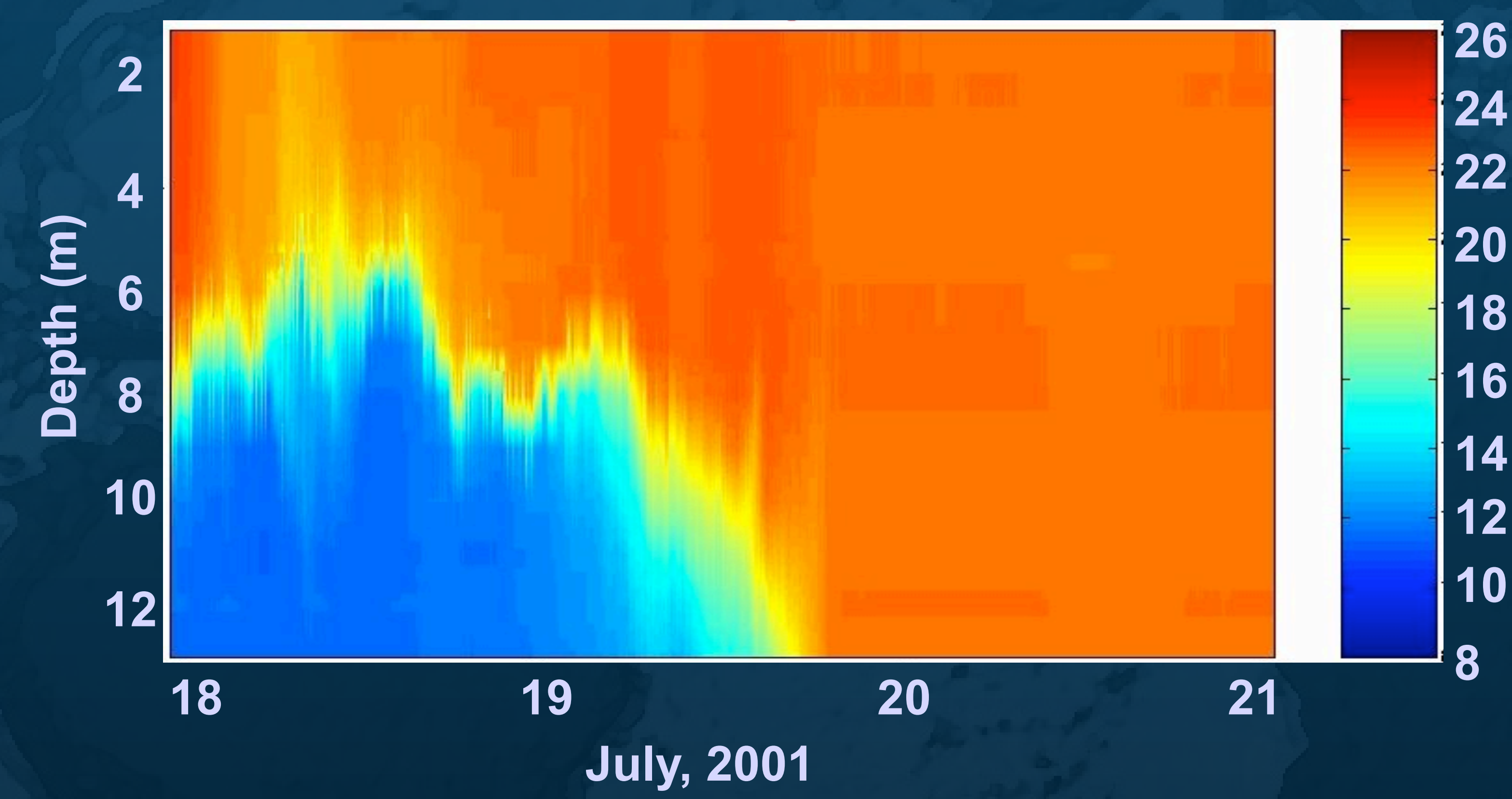


KPP

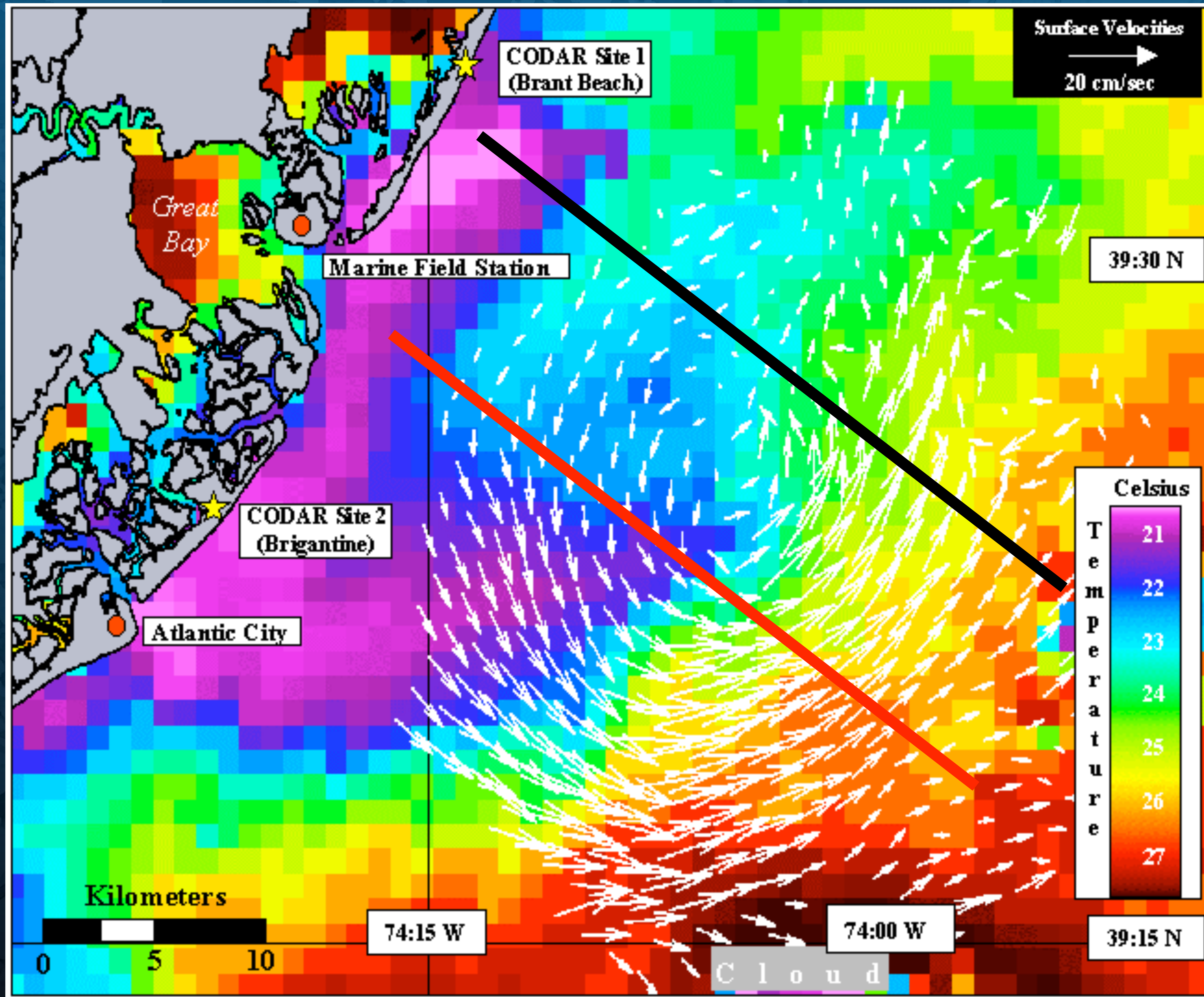


MY2.5

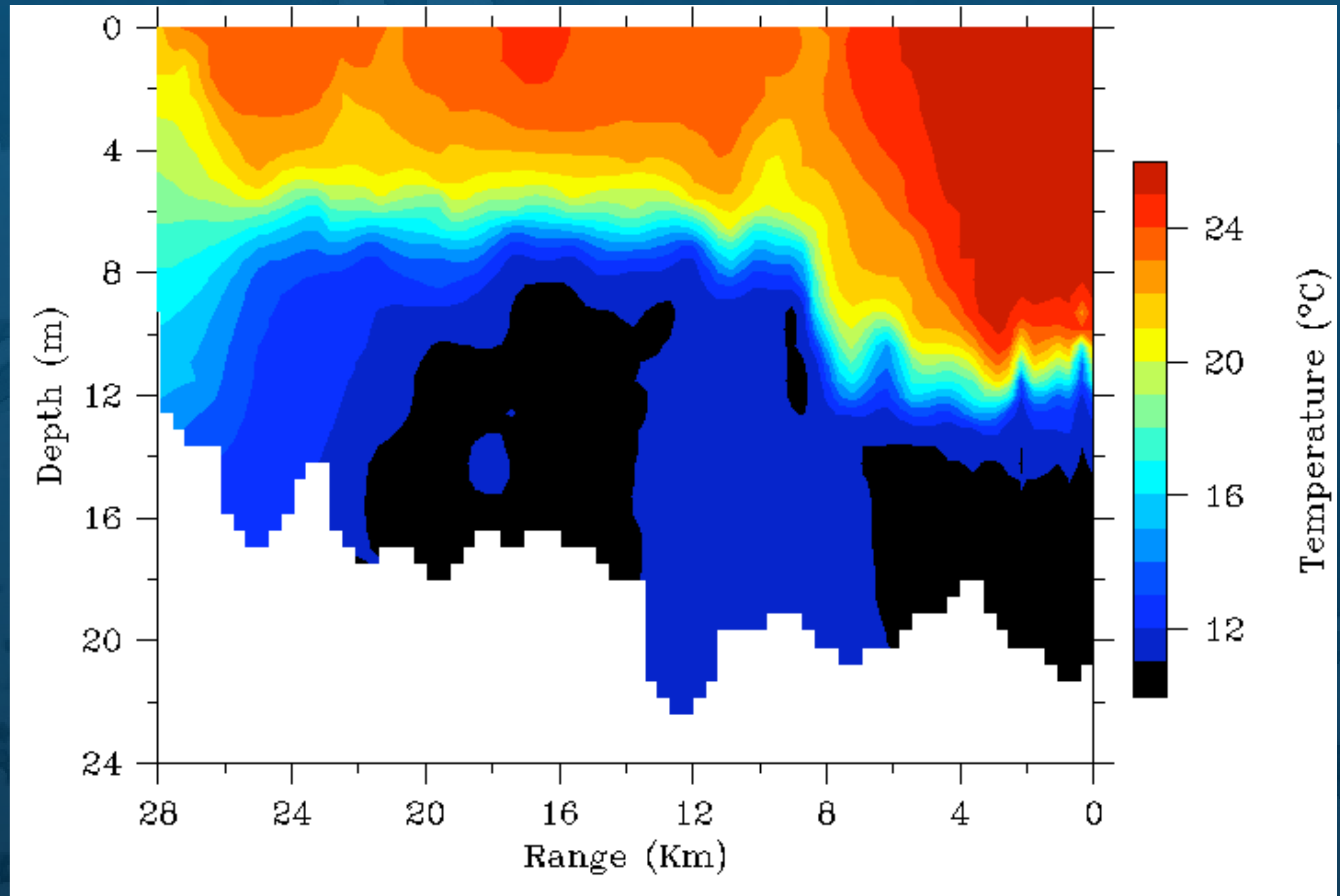
Thermistor



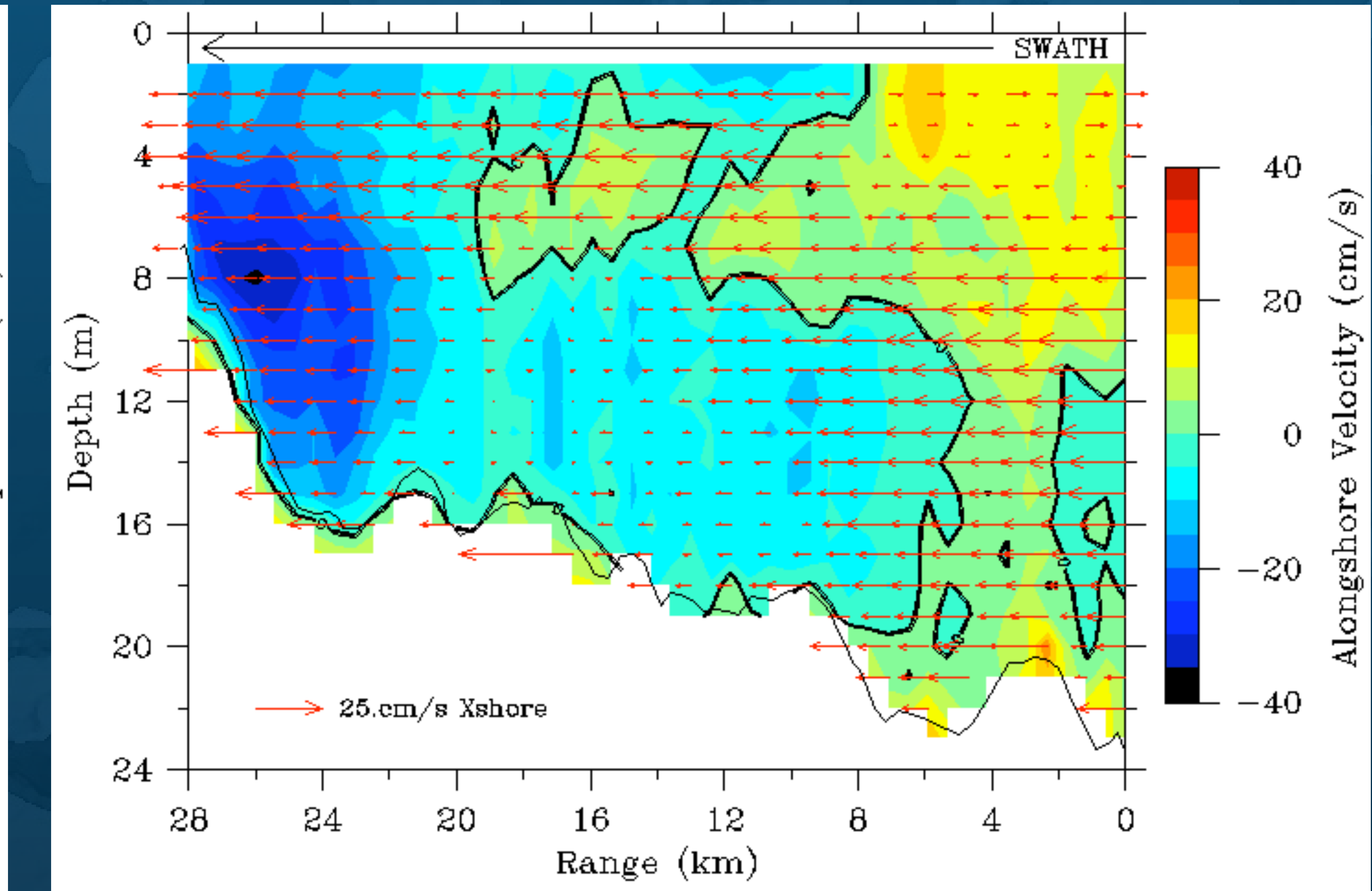
-In an observationally rich environment, ensemble forecasts can be compared to real-time data to assess which model is closer to reality and try to understand why.


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

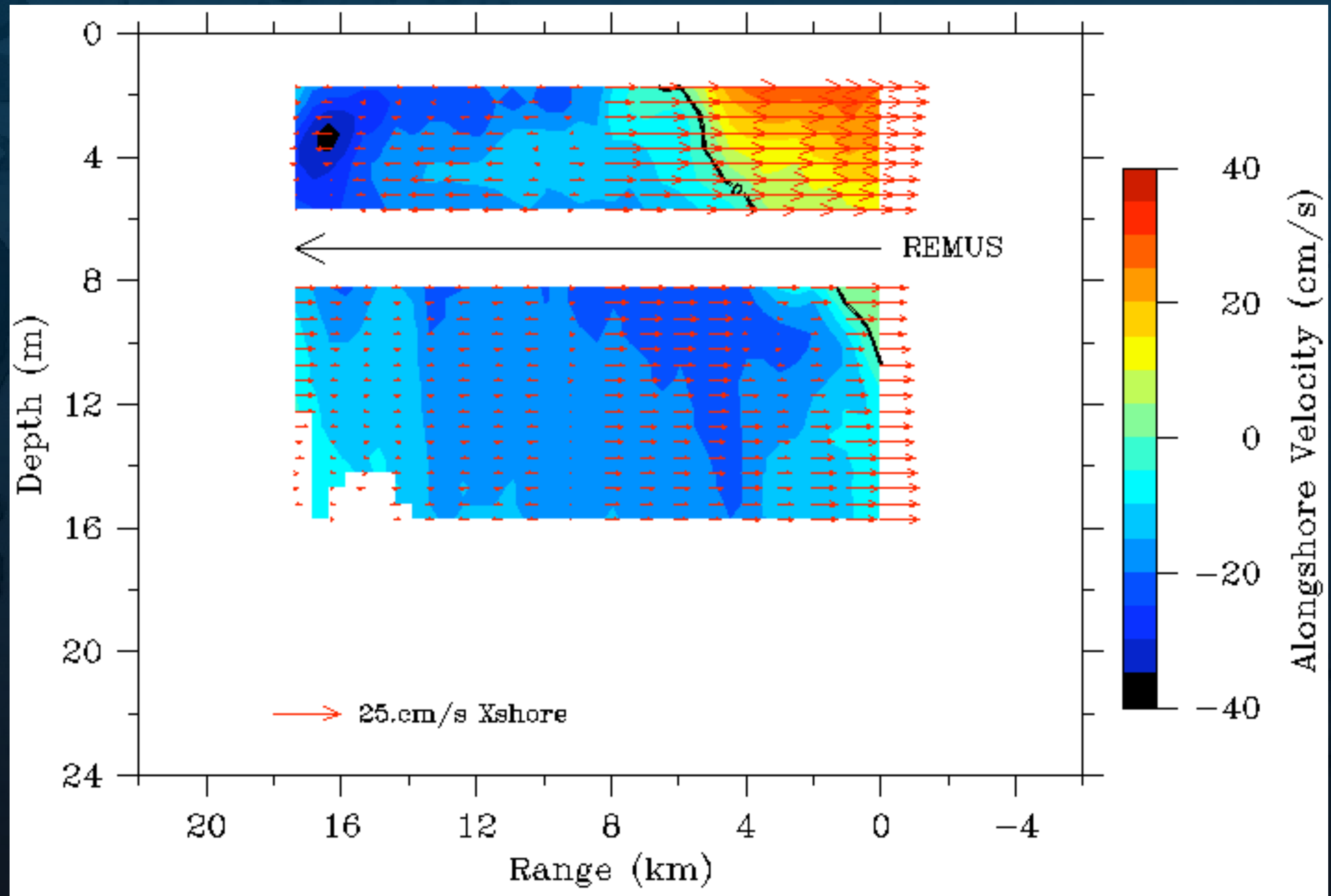
Shipboard surveys



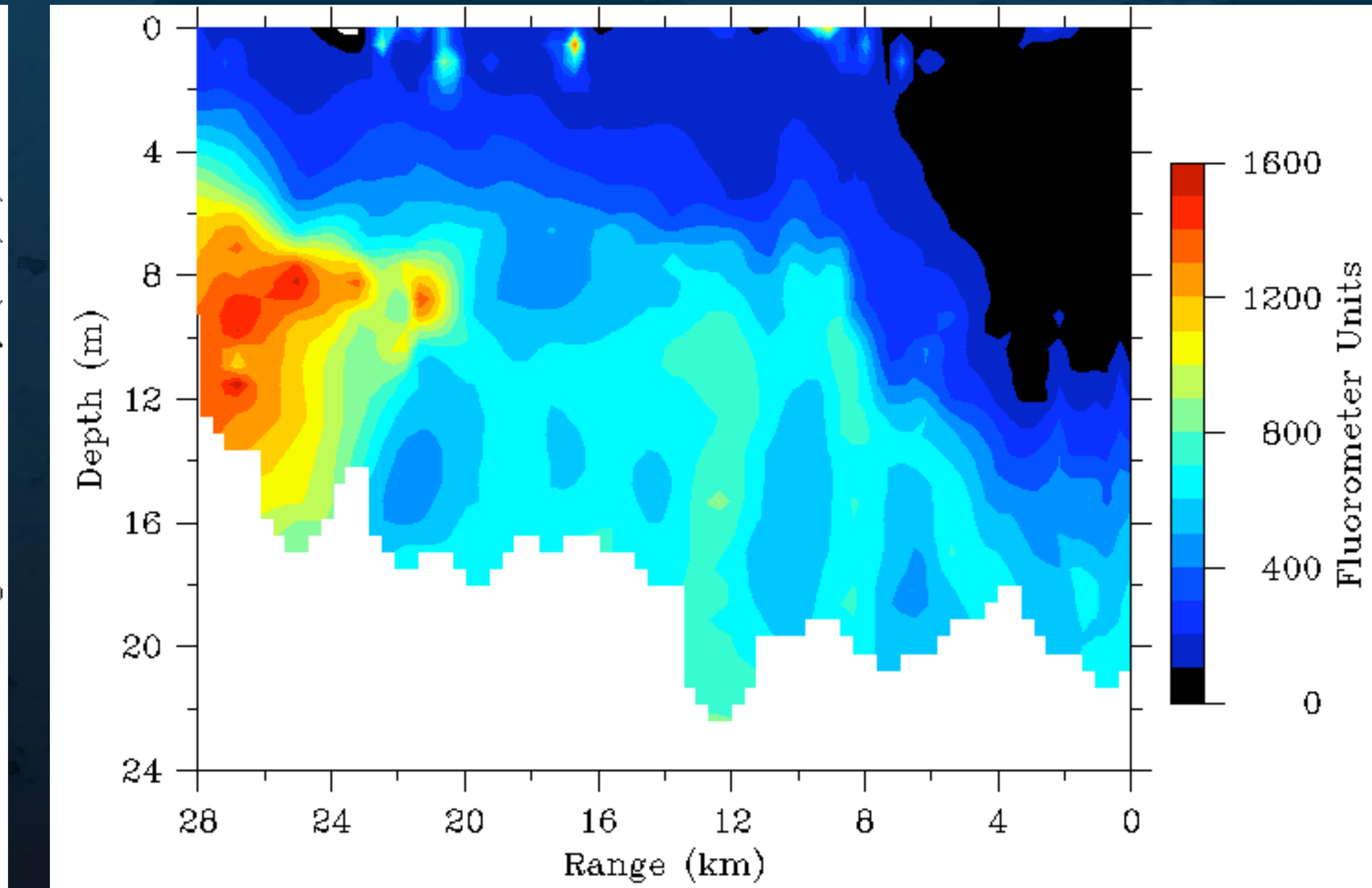
MiniBat Temperature Section: Date: 980723, Leg 3



Surface Towed–ADCP Velocity Section: Date 980723, Leg 03

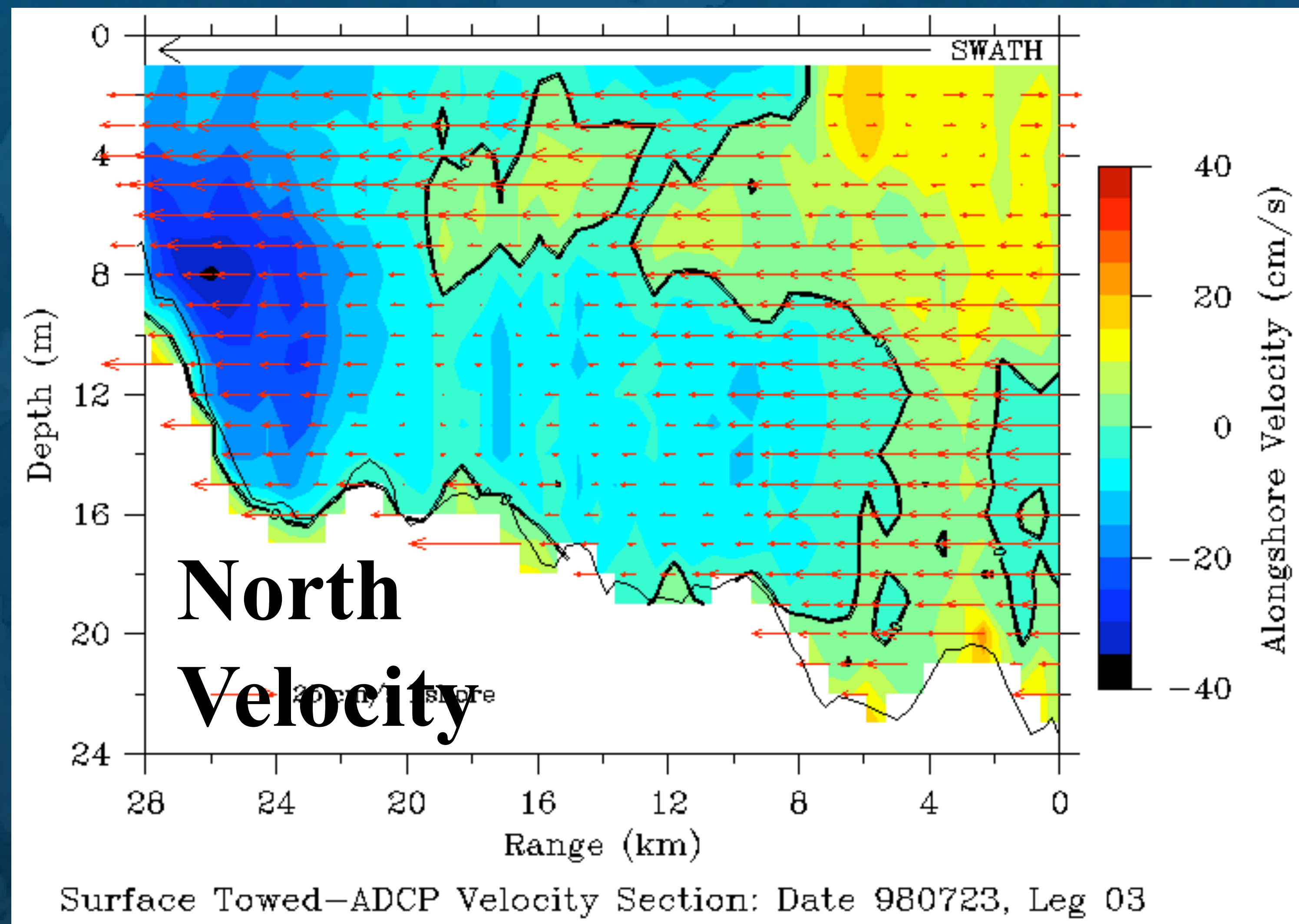


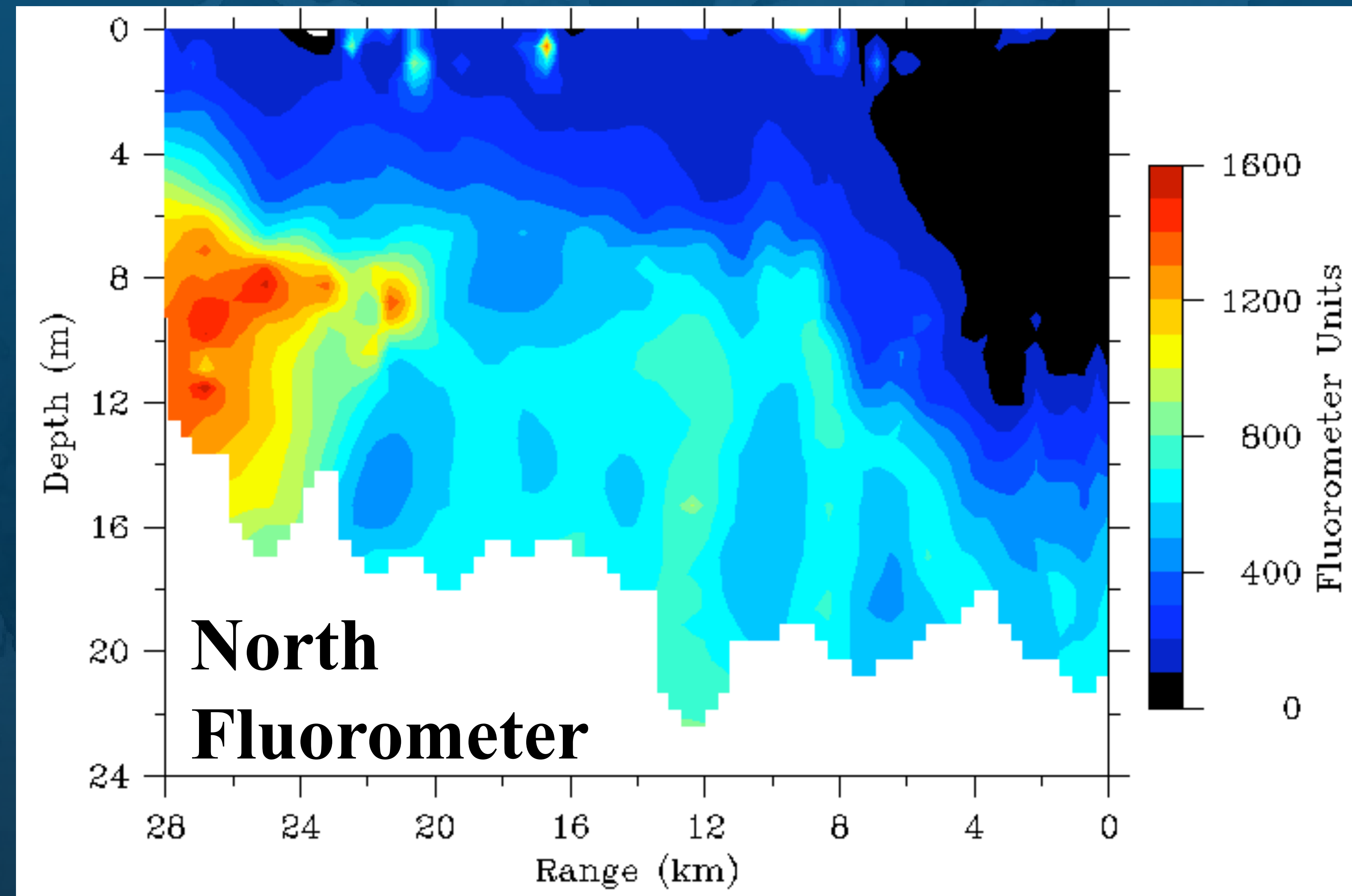
REMUS ADCP Velocity Section: Date 980723

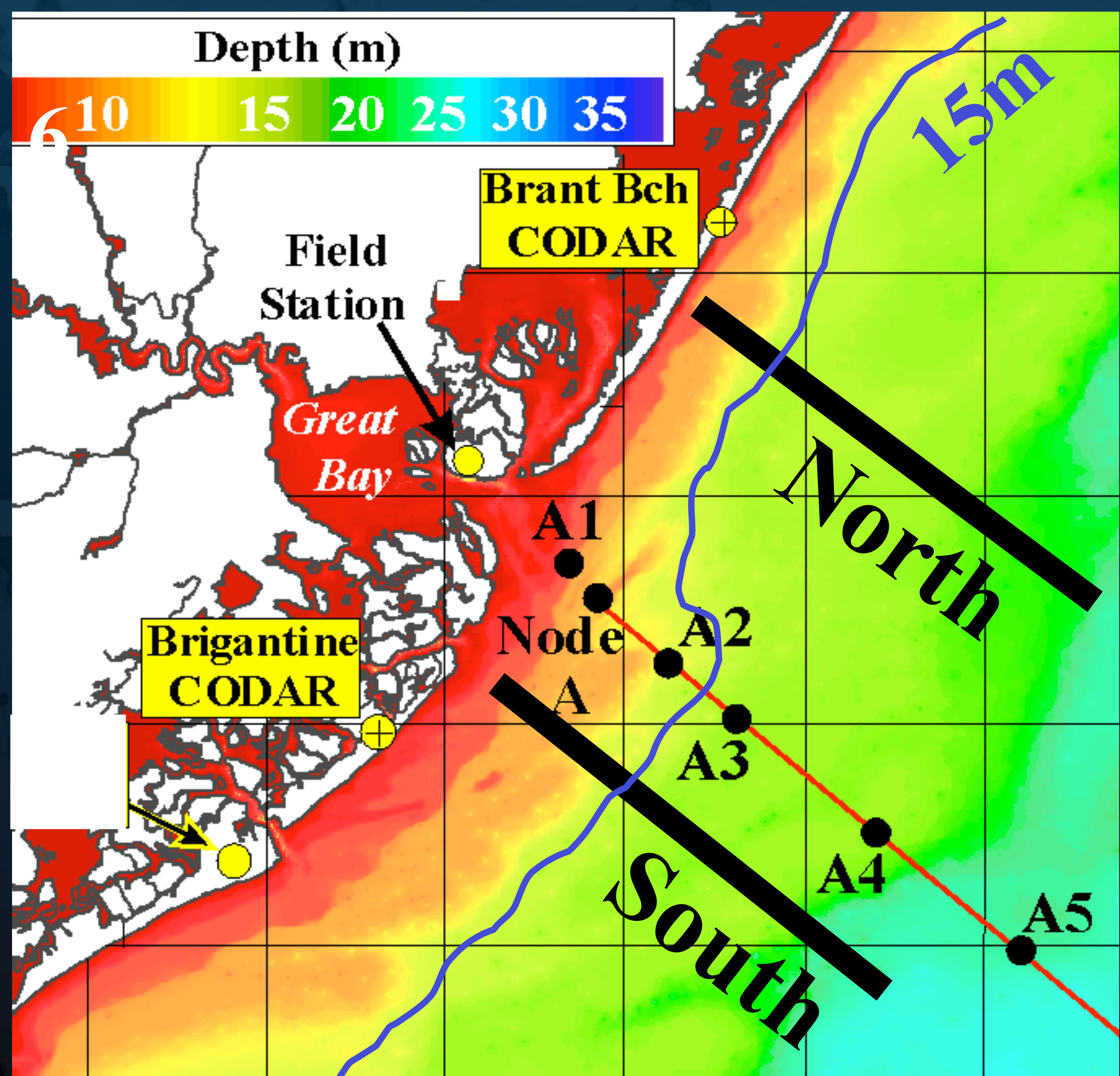


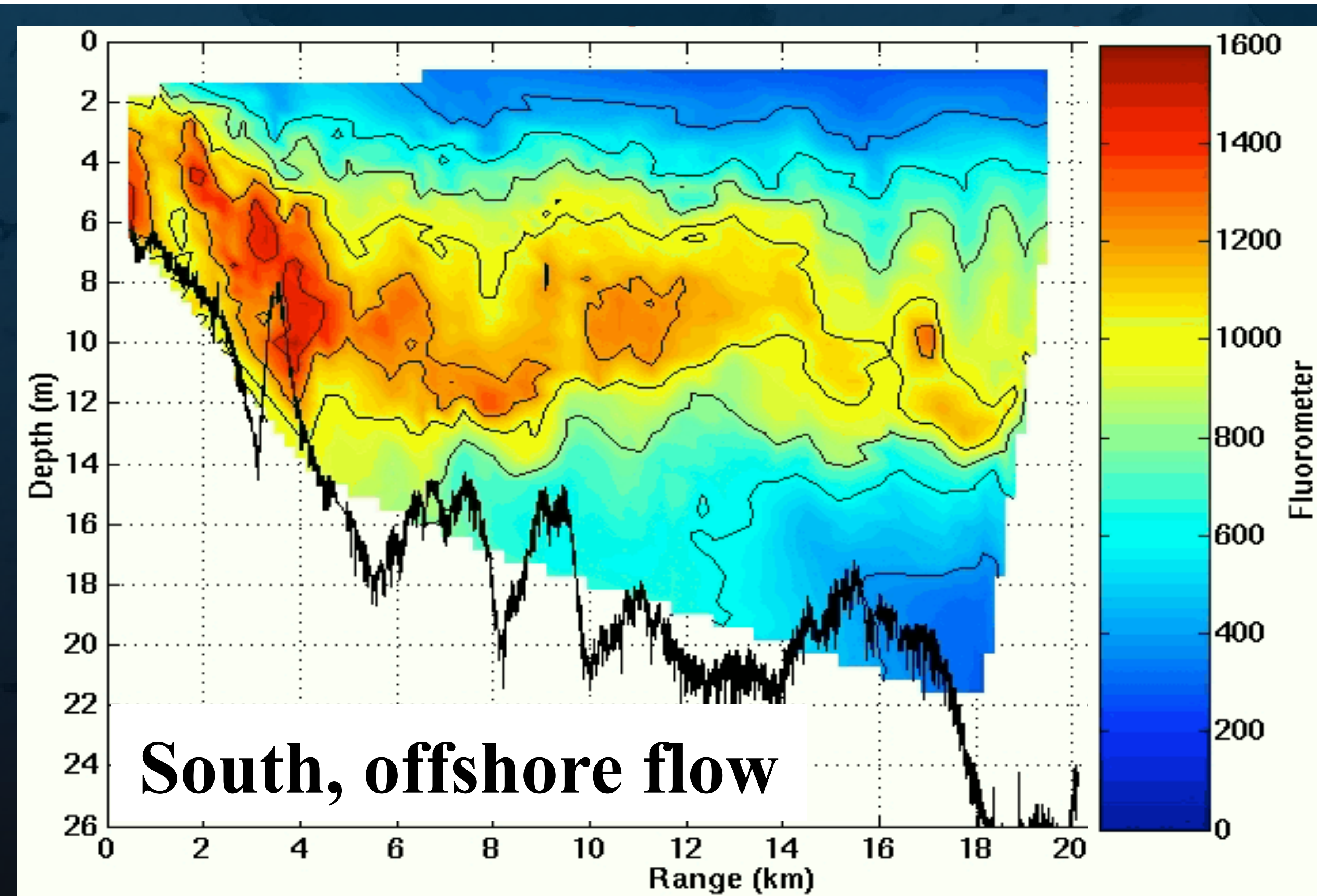
MiniBat Fluorometer Section: Date 980723, Leg 3

Adaptive Sampling of Resolved Scales- Shipboard & AUV surveys

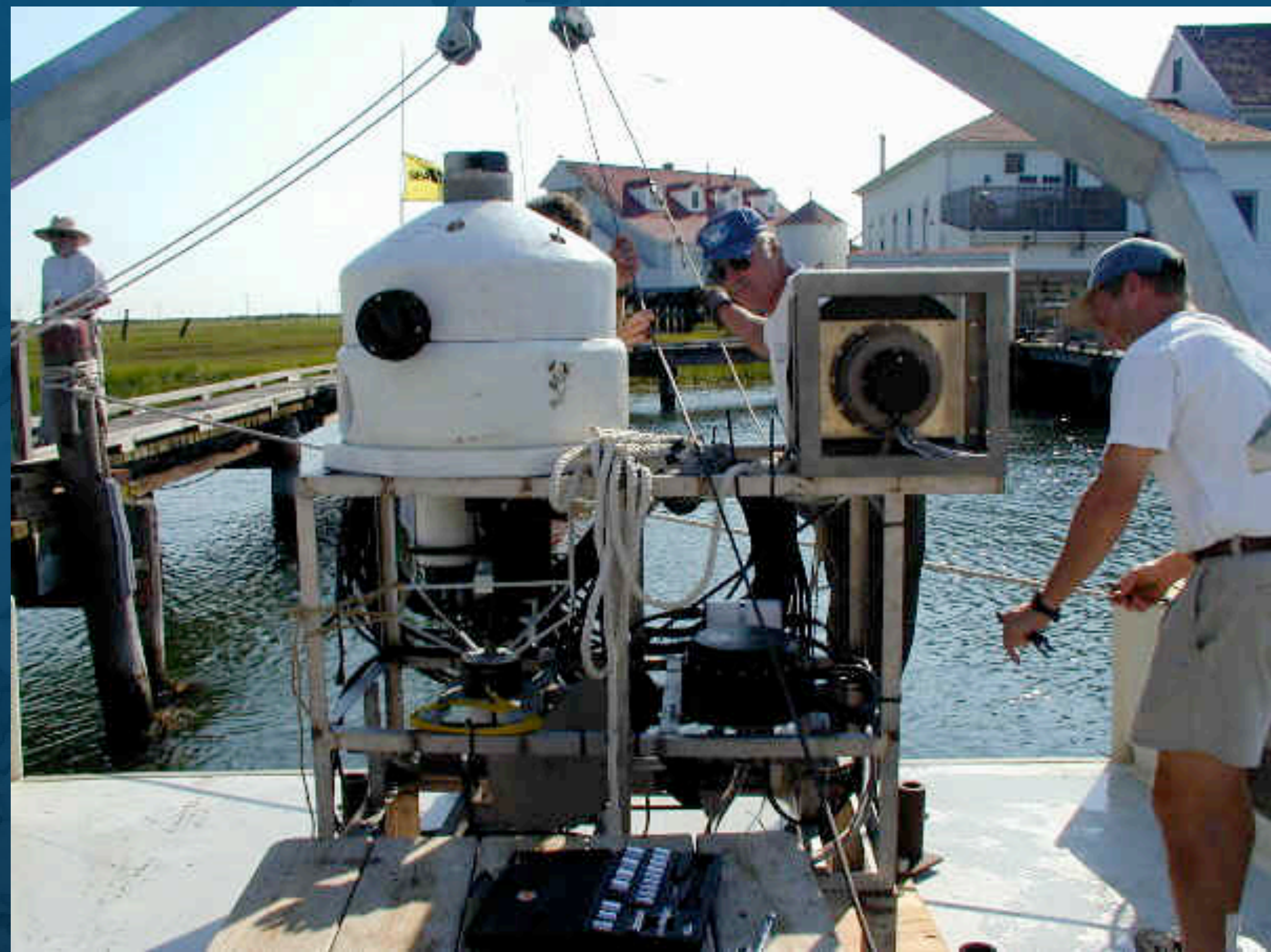




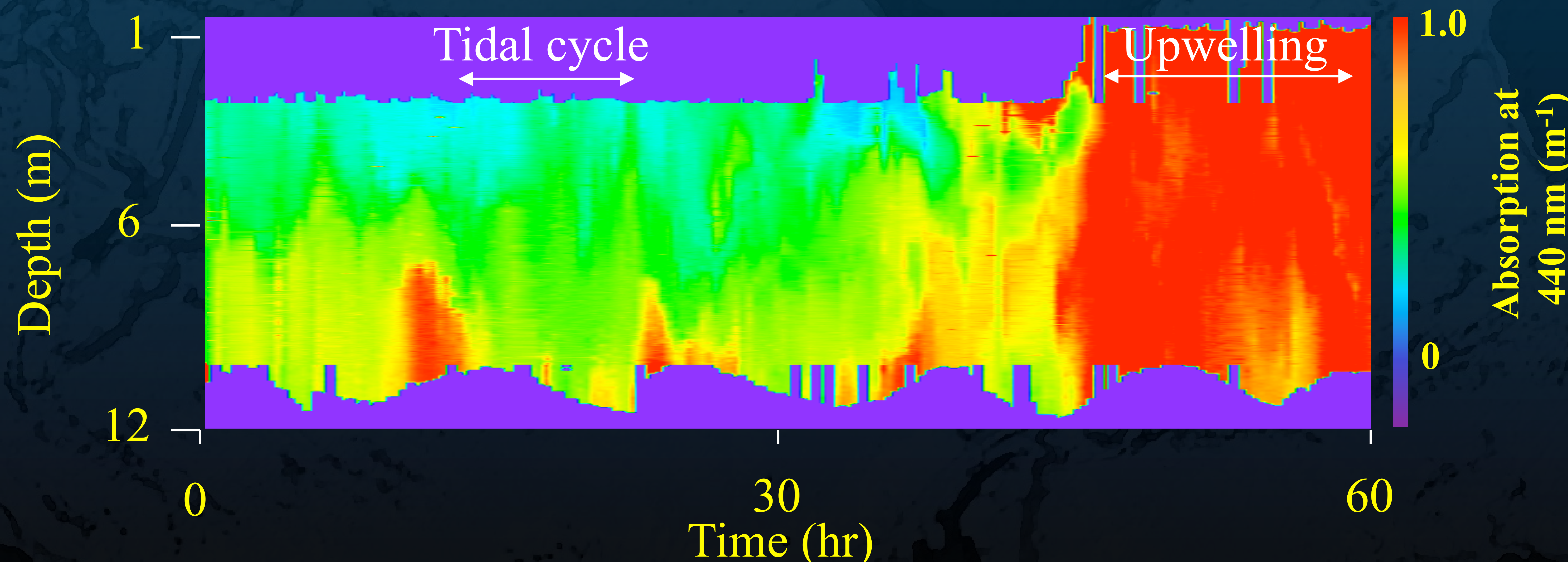




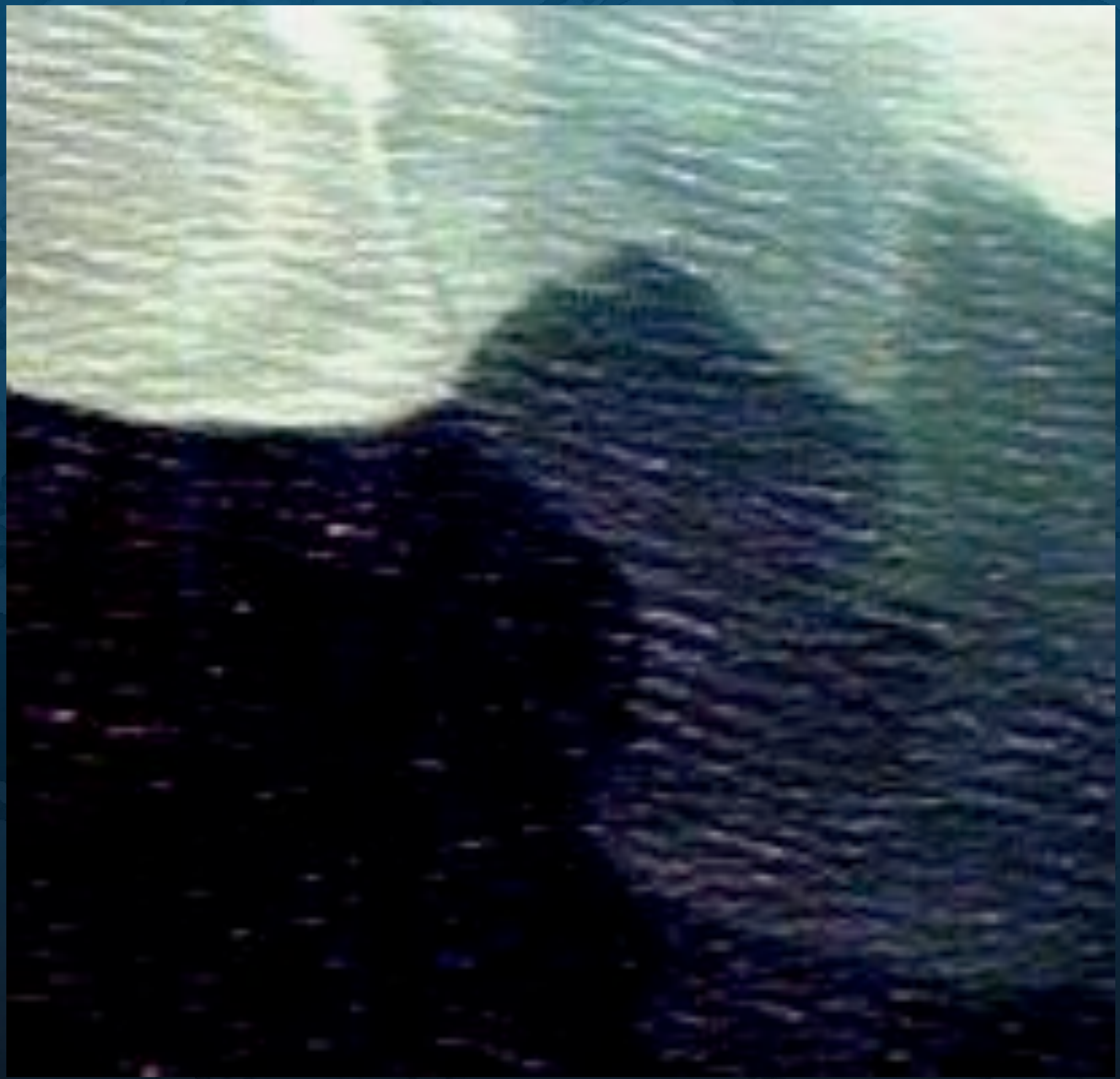
Optical profiler deployed on LEO-15 guest port

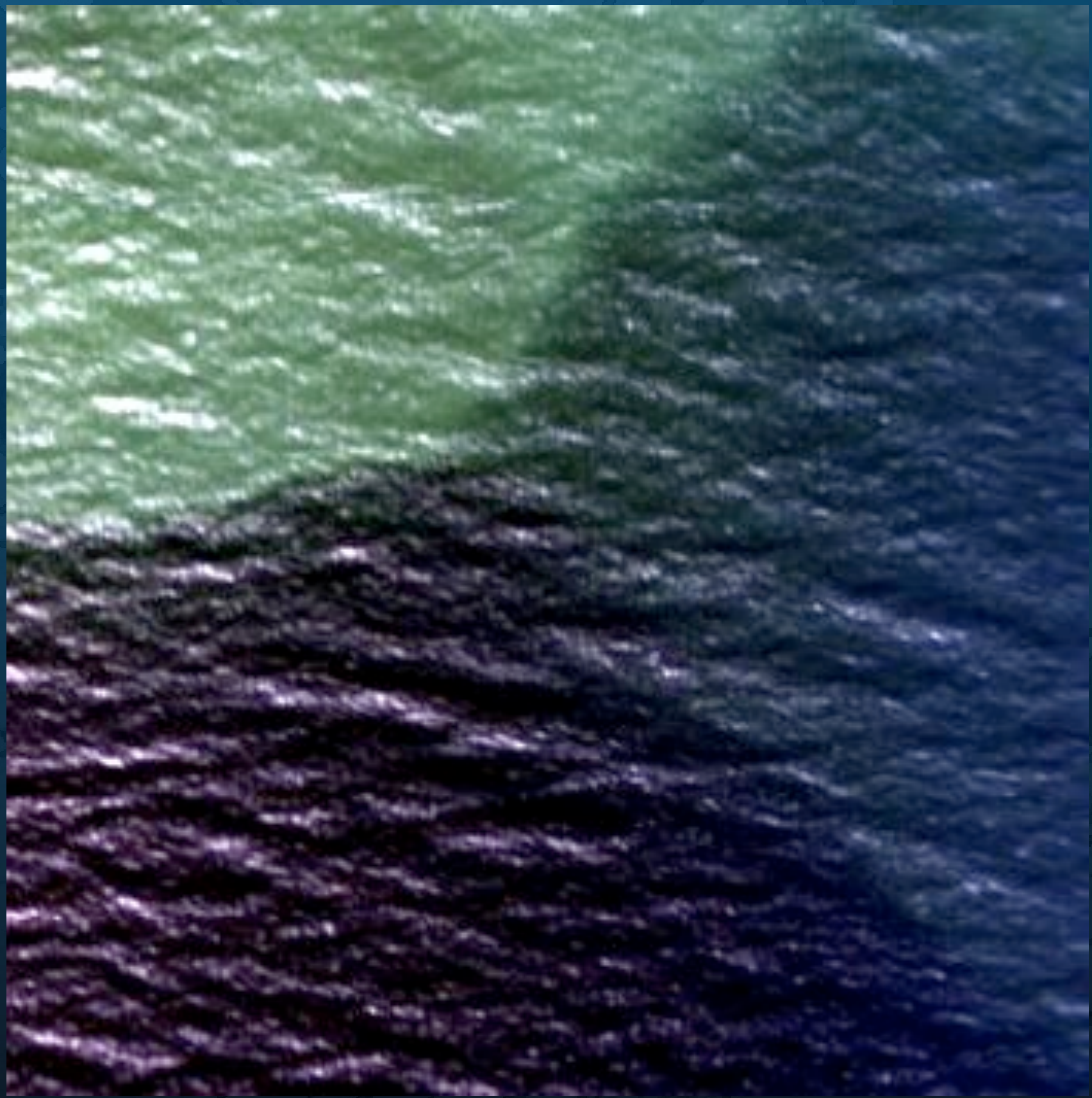


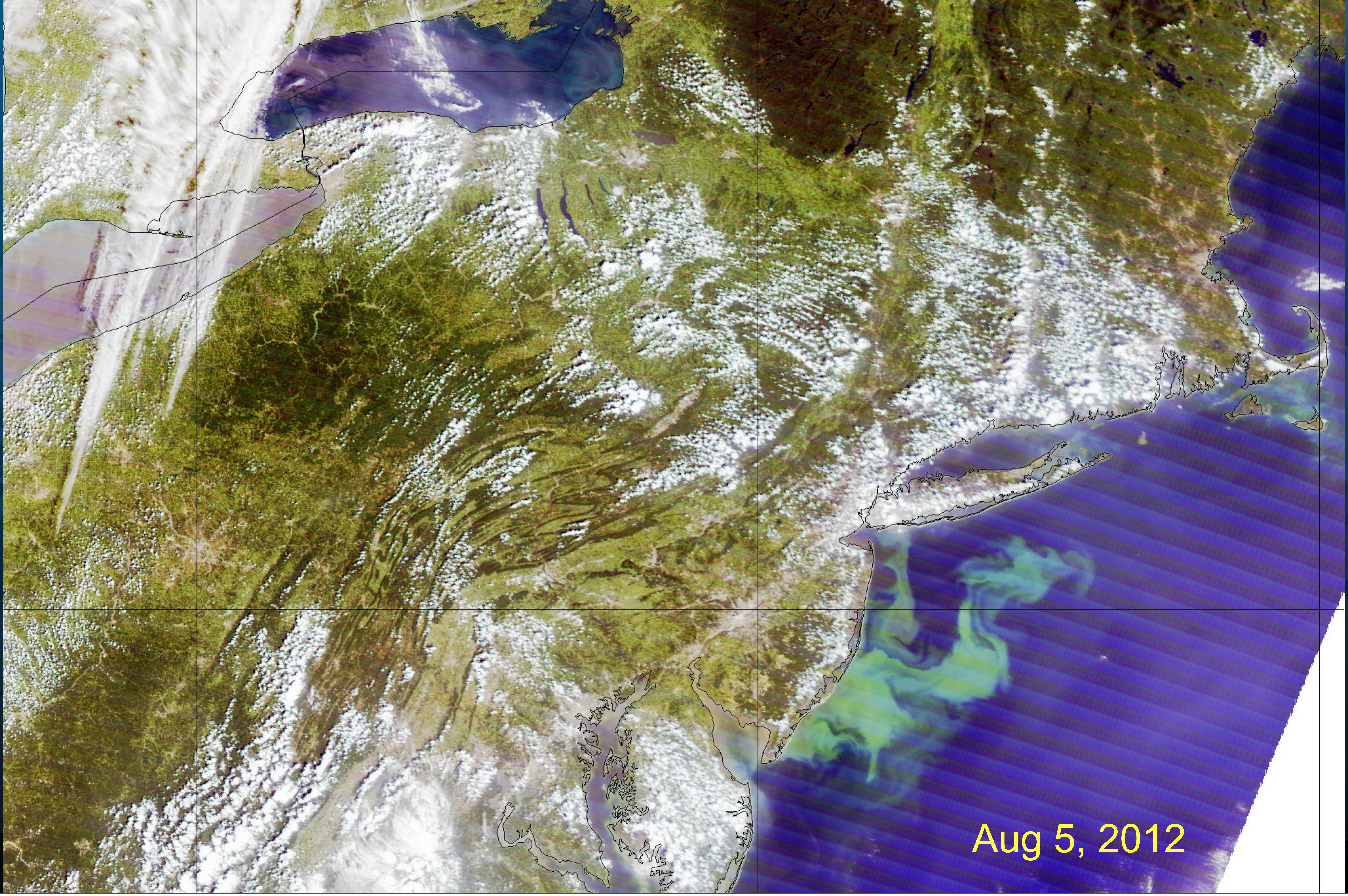
Nerd summer camp

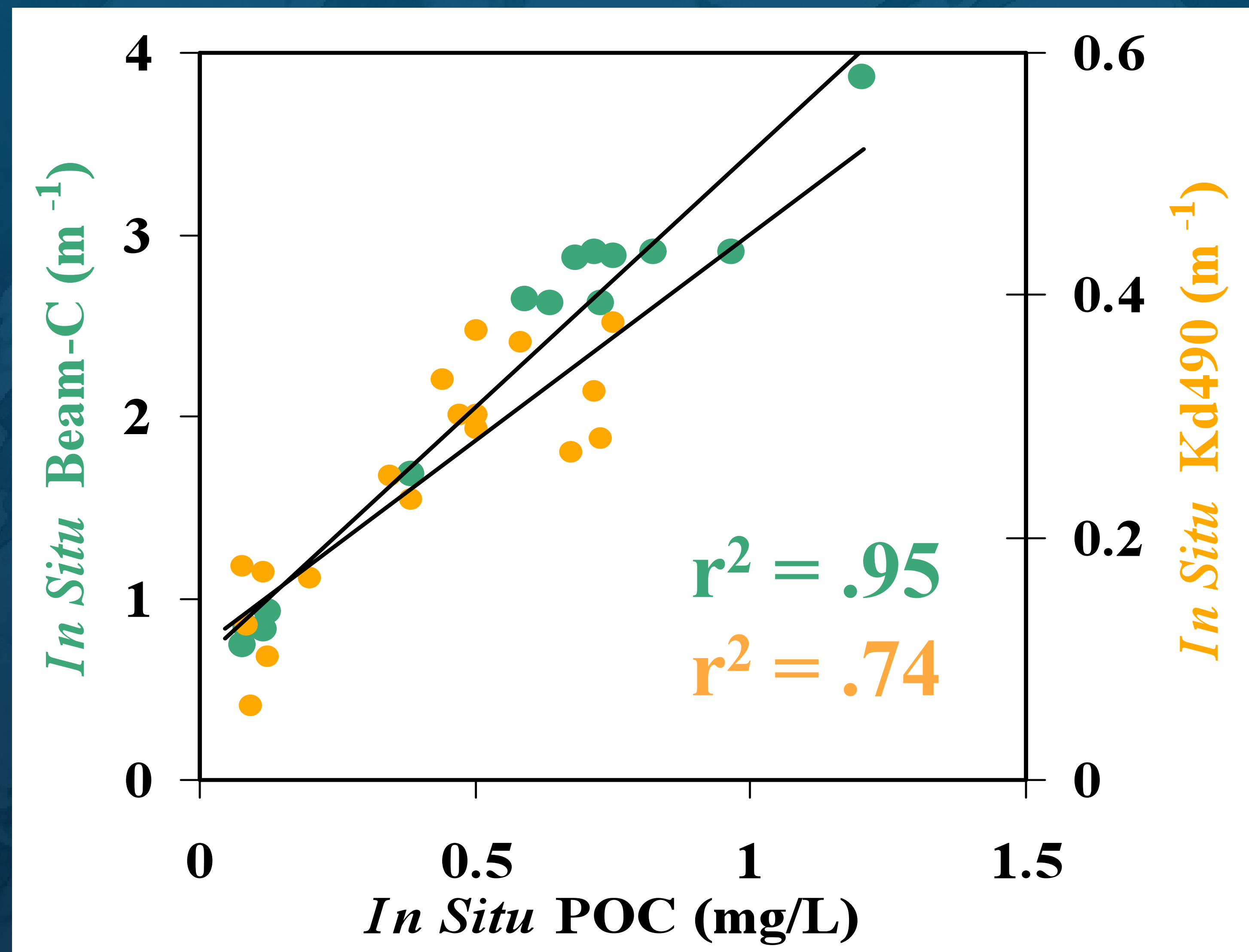


That Pristine Blue NJ Water

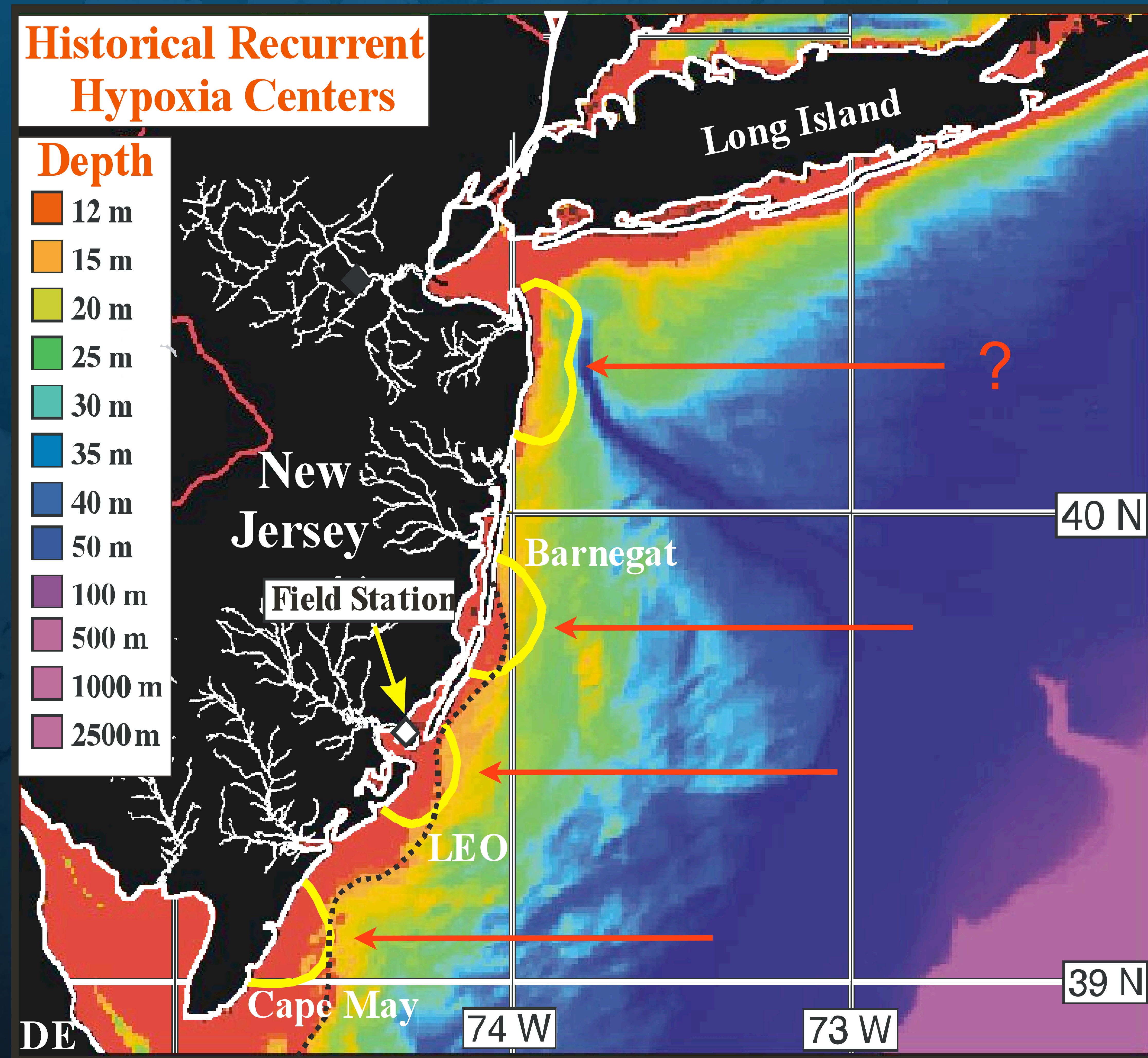




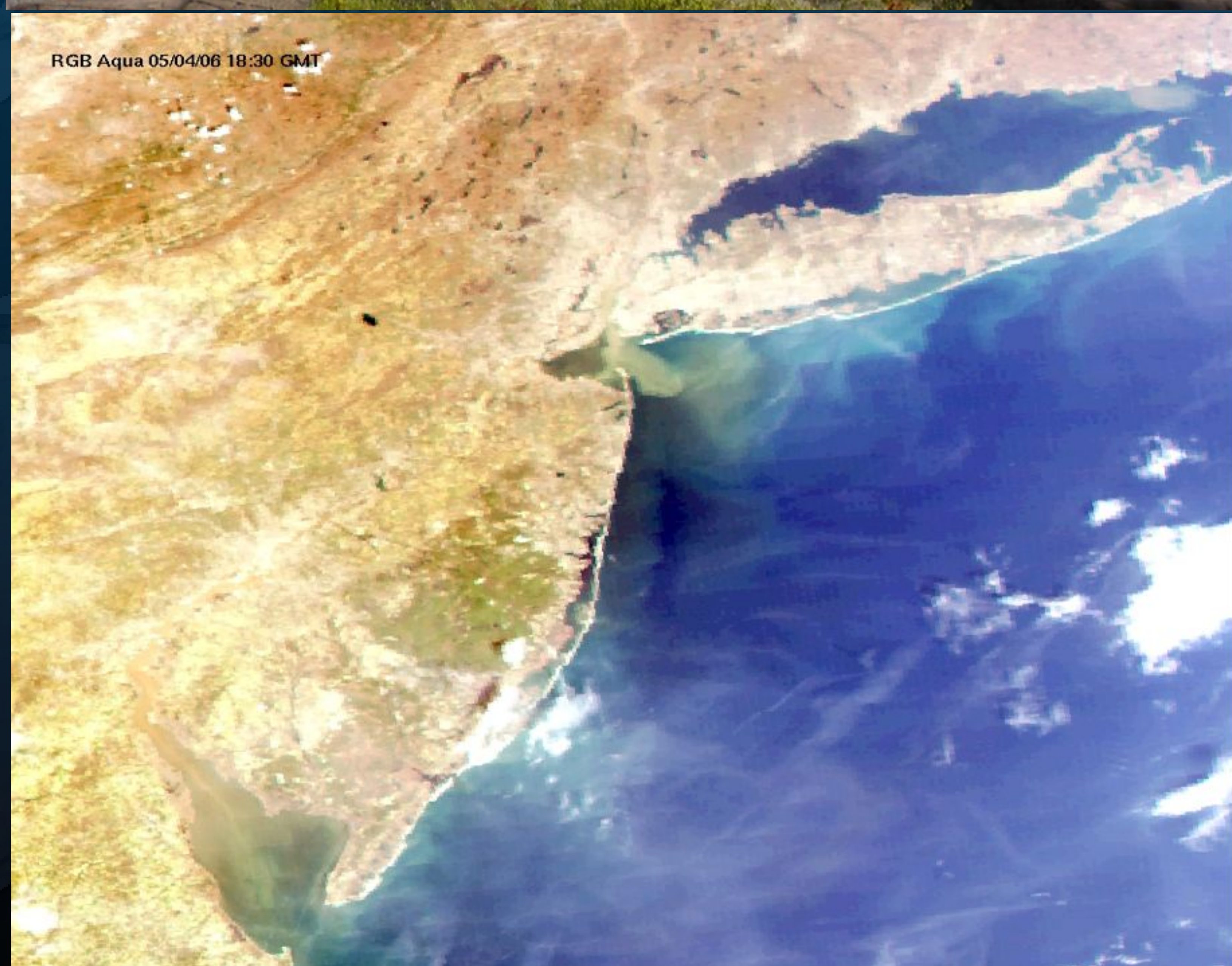

Aug 5, 2012



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

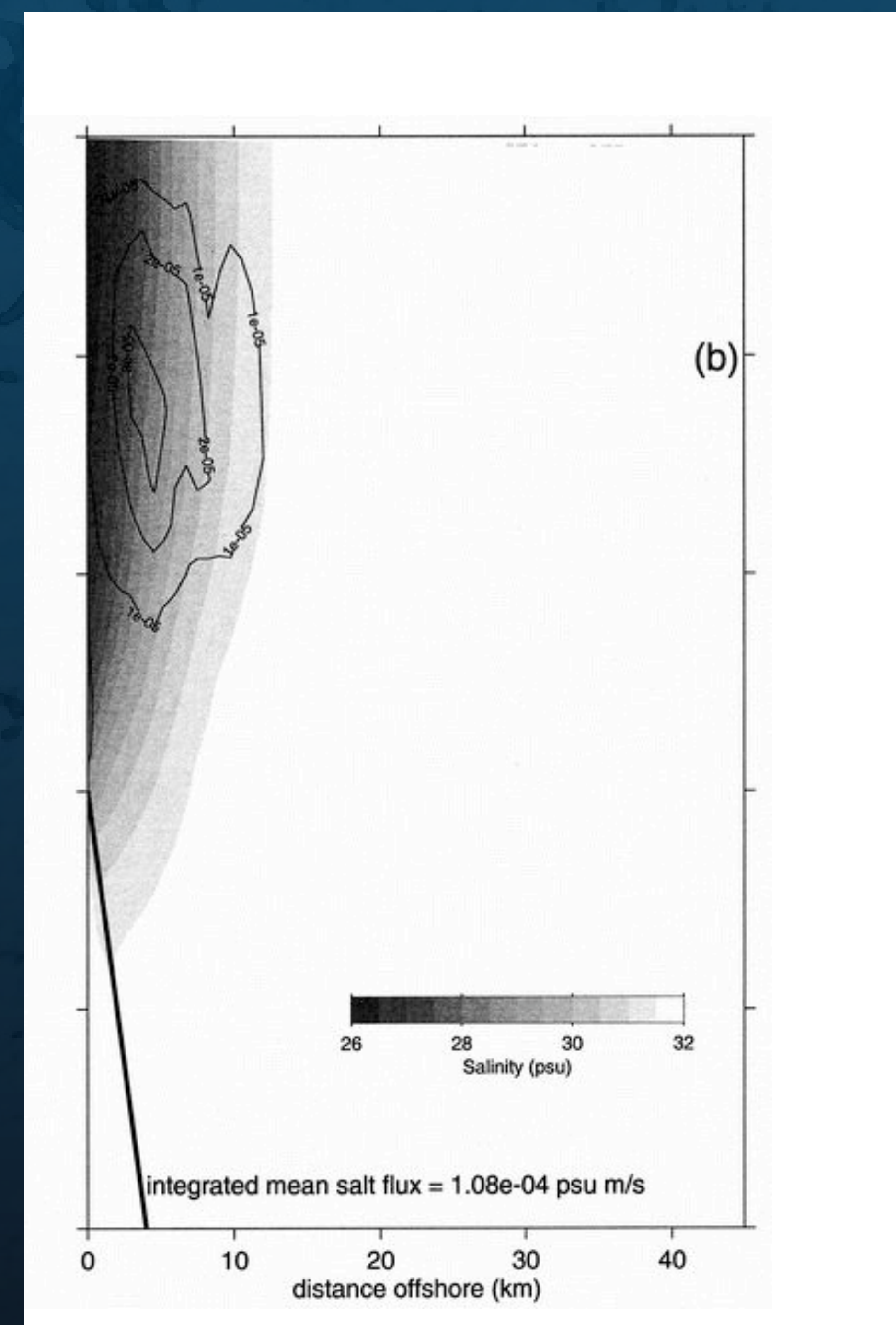


What is happening in the northern zone?



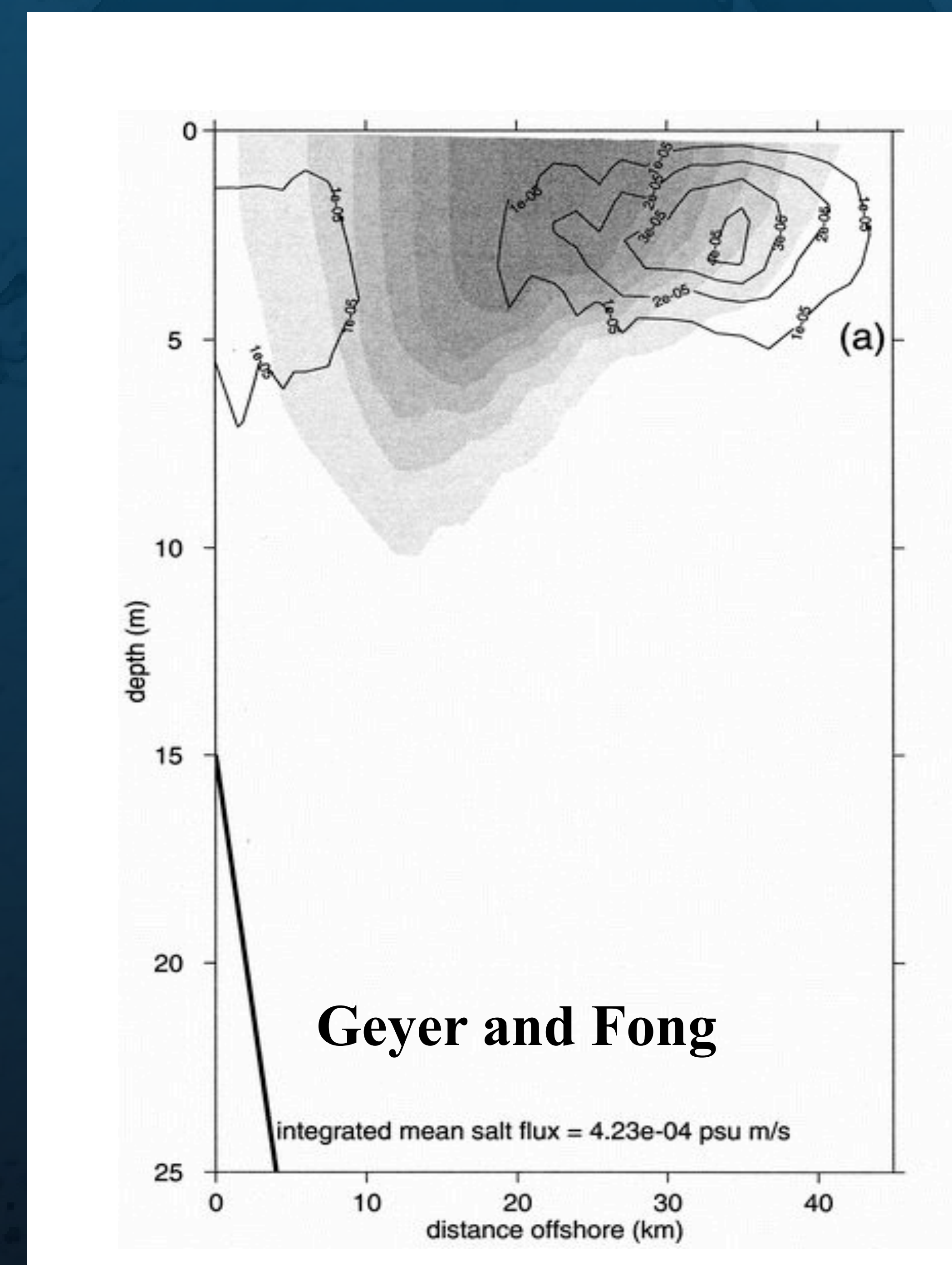
Science focus Land-Ocean: How does the dynamics in the physical oceanography influence the transport and transformation of the particulate and dissolved matter in coastal buoyant plumes?

Downwelling



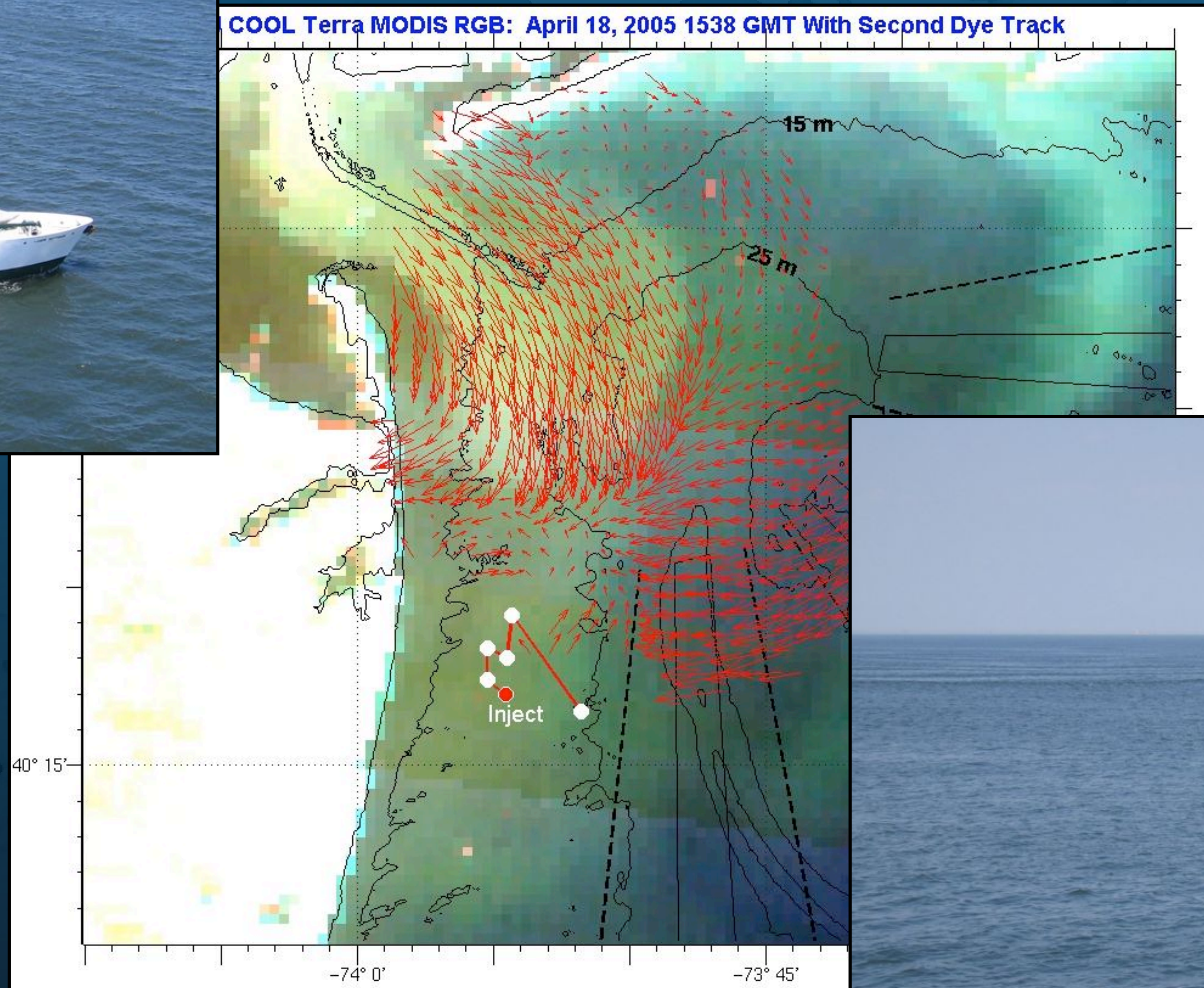
Southern flowing turbid plume

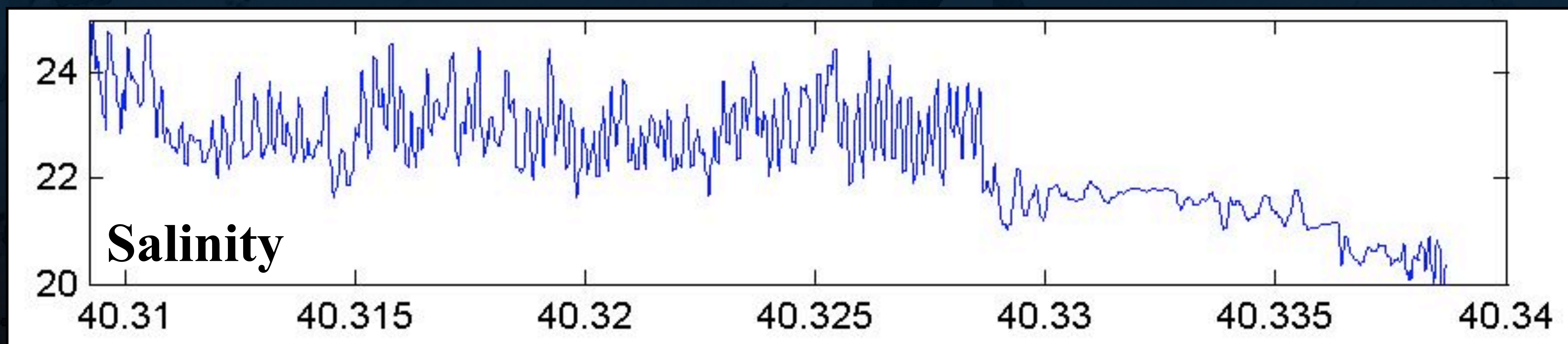
Upwelling



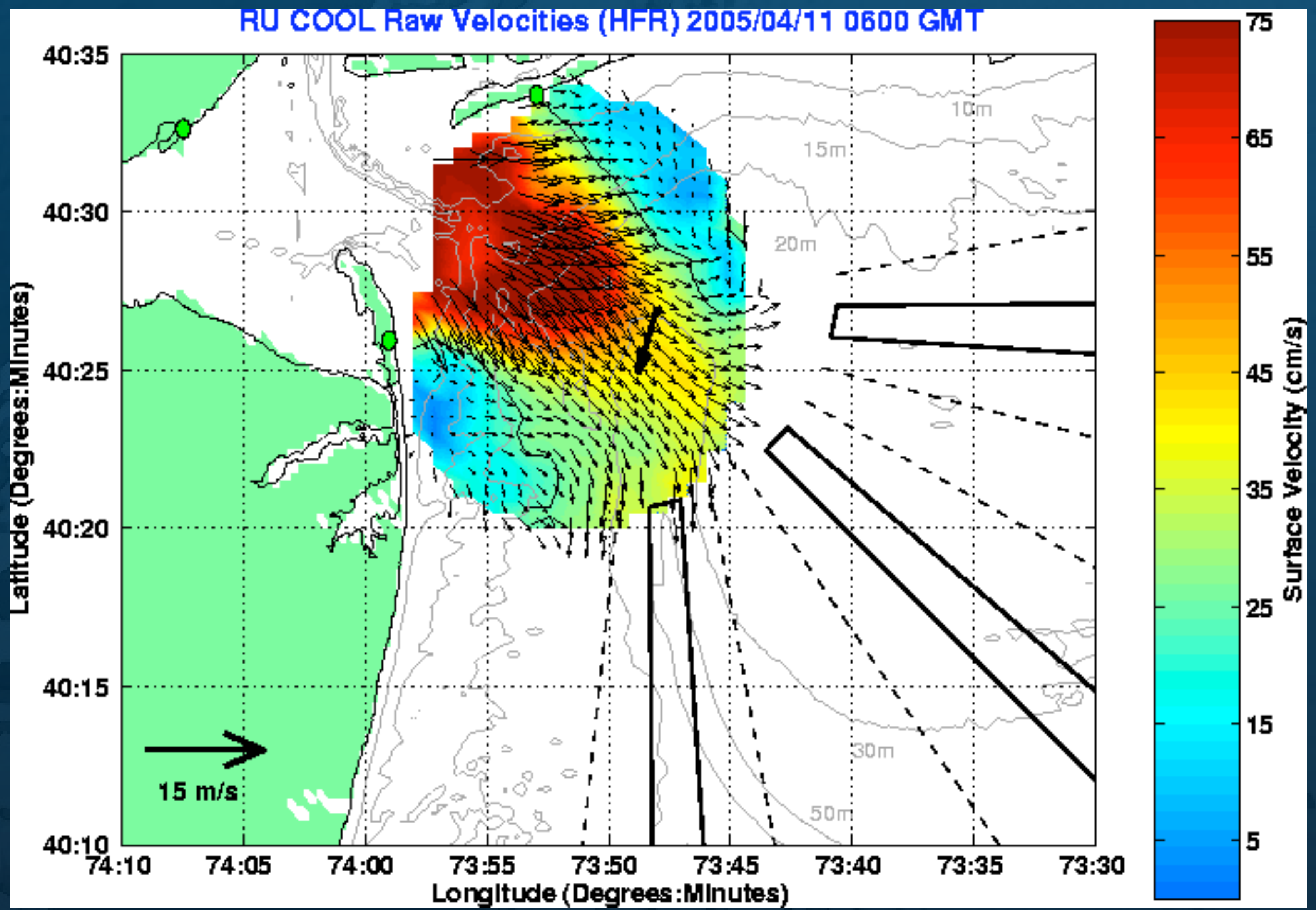
Eastern offshore flowing shallow turbid plume

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



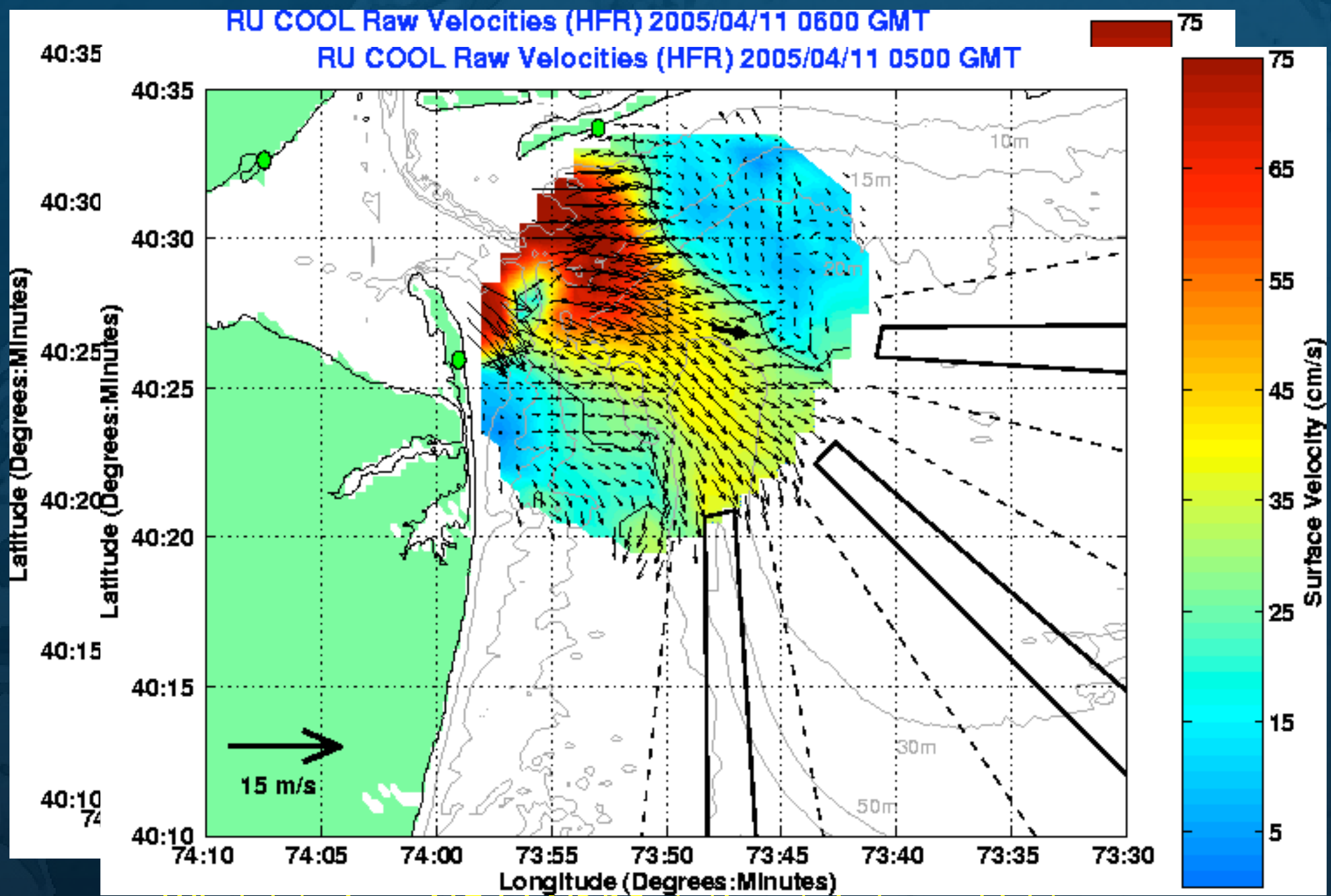


HF RADAR tracking and dye labeling of plume



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

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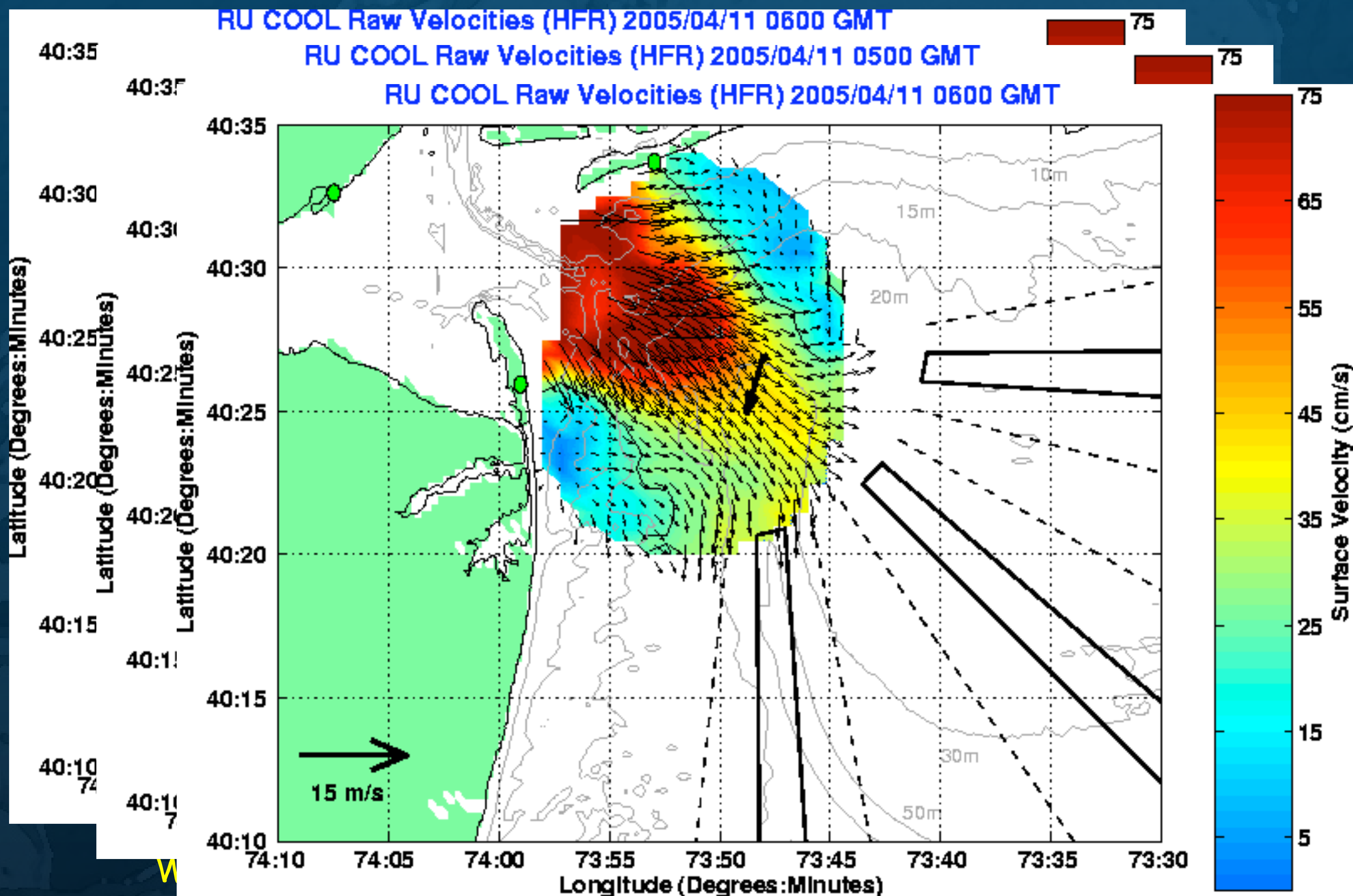
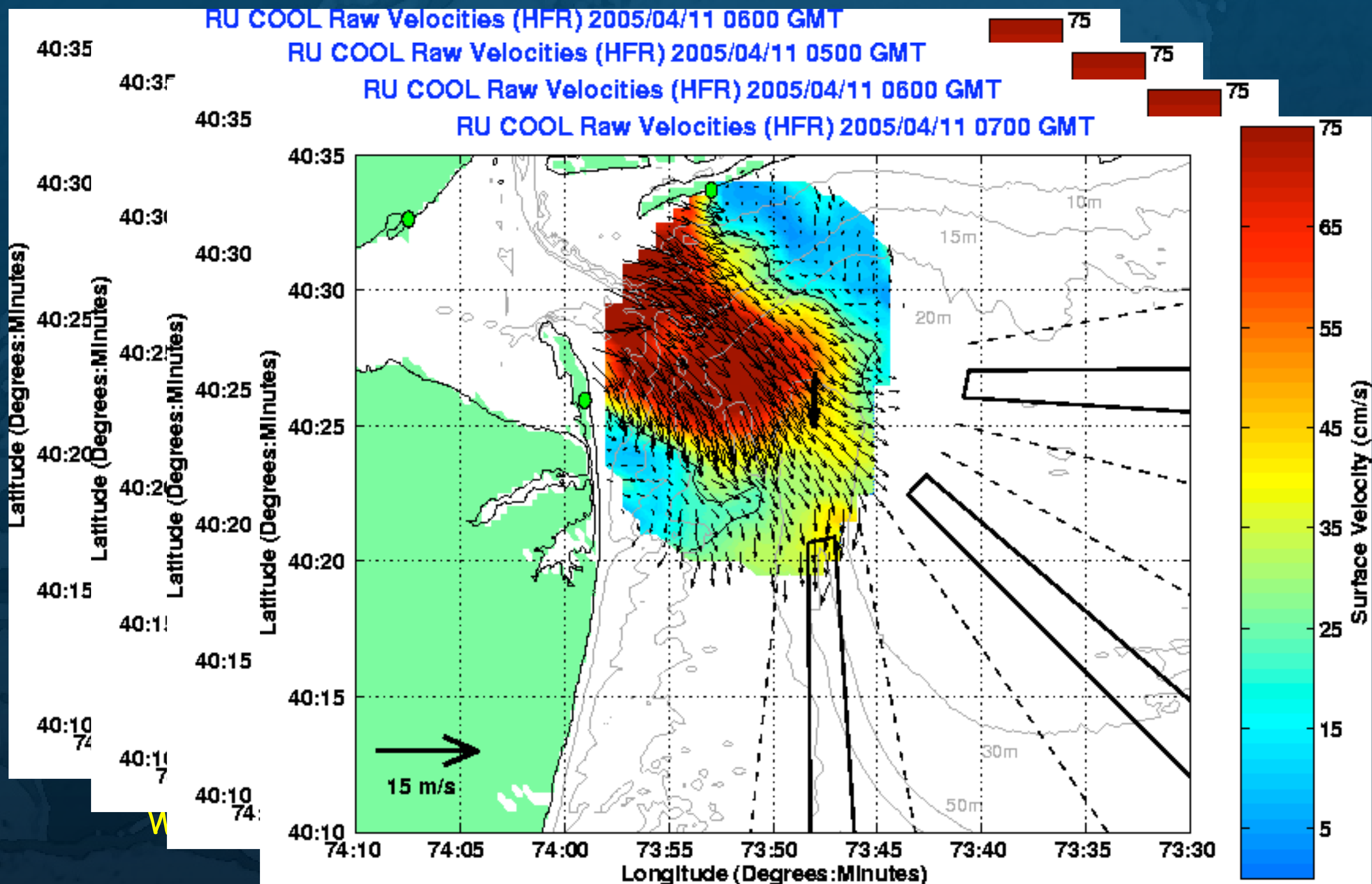
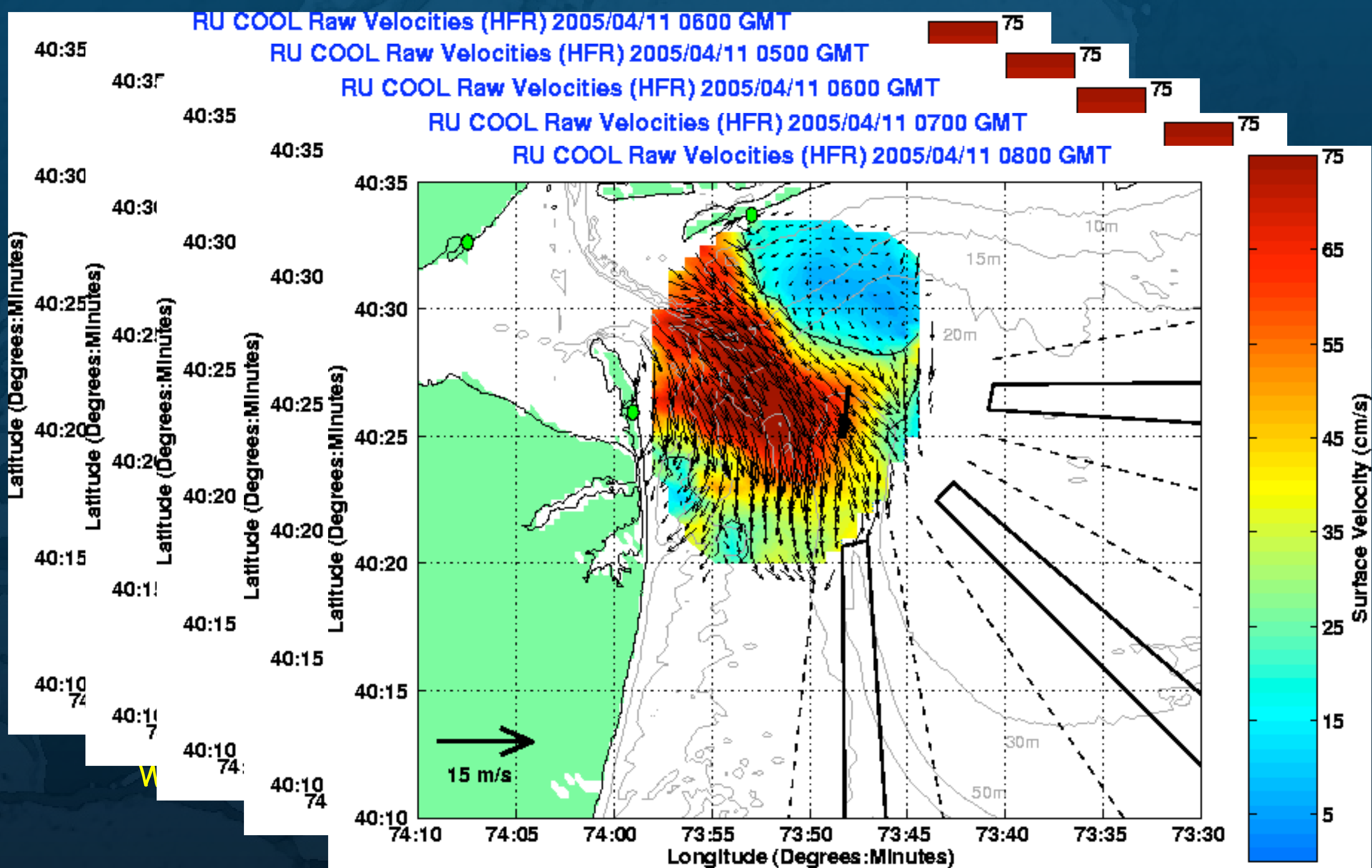


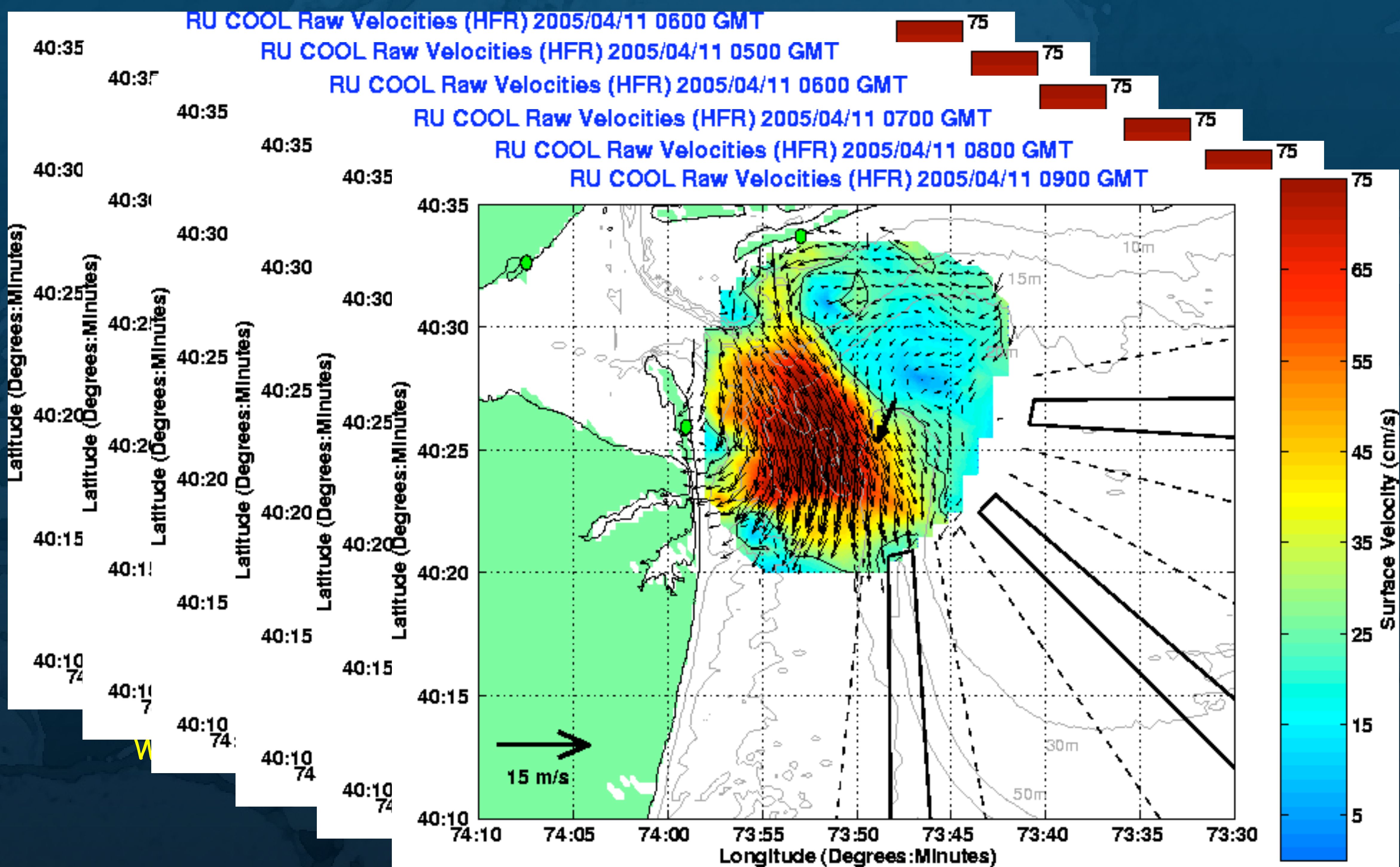
HF RADAR tracking and dye labeling of plume



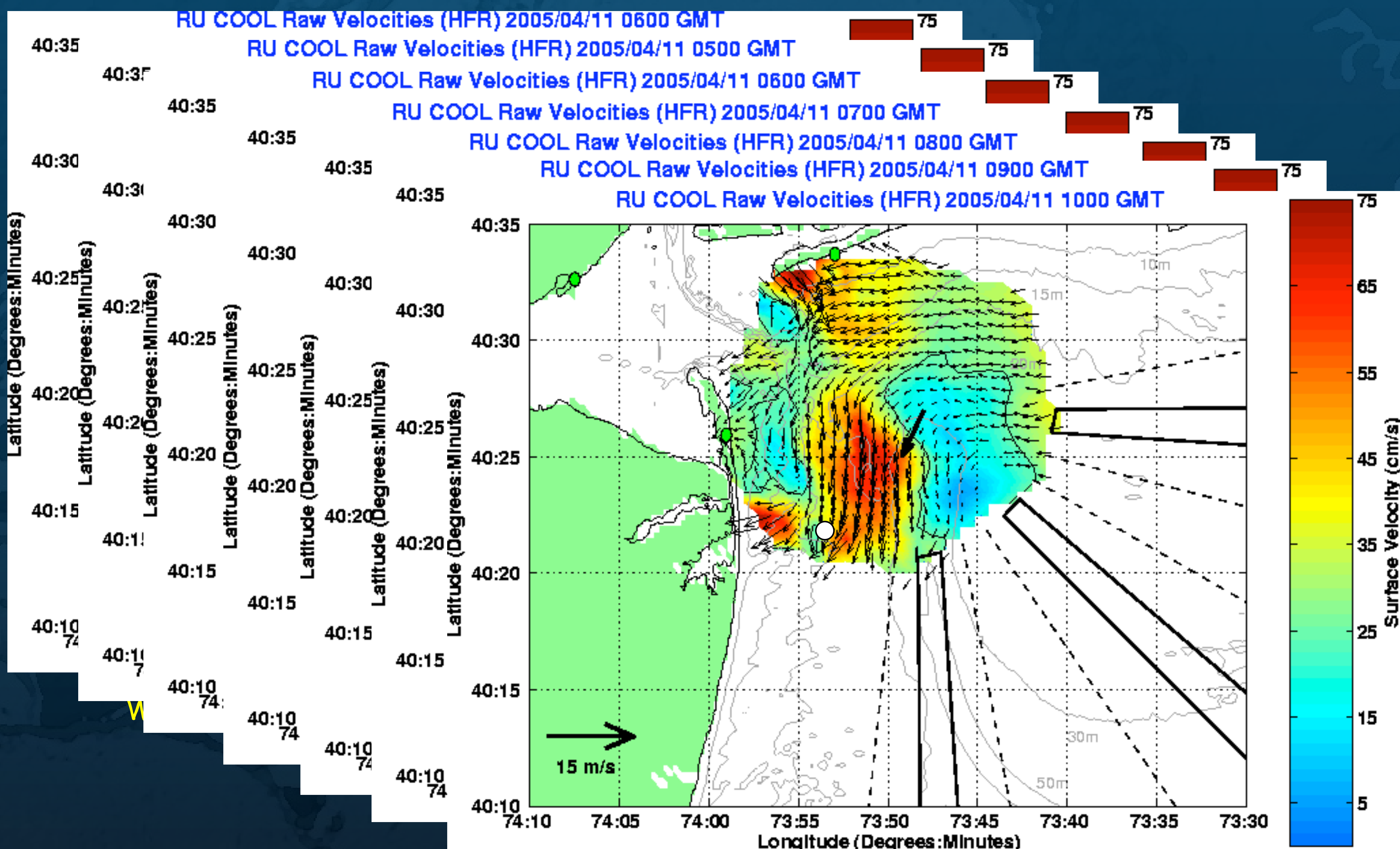
HF RADAR tracking and dye labeling of plume



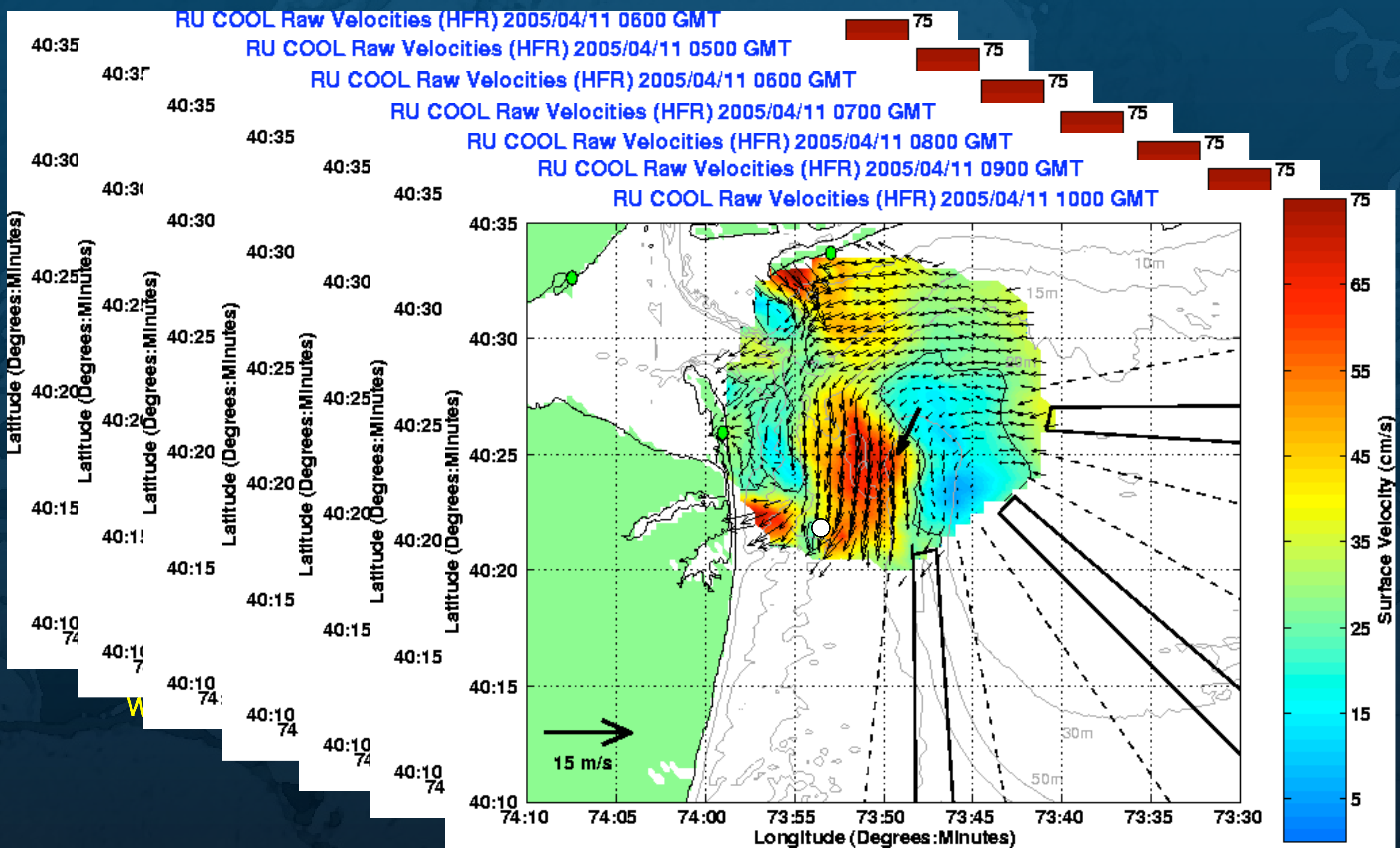
HF RADAR tracking and dye labeling of plume

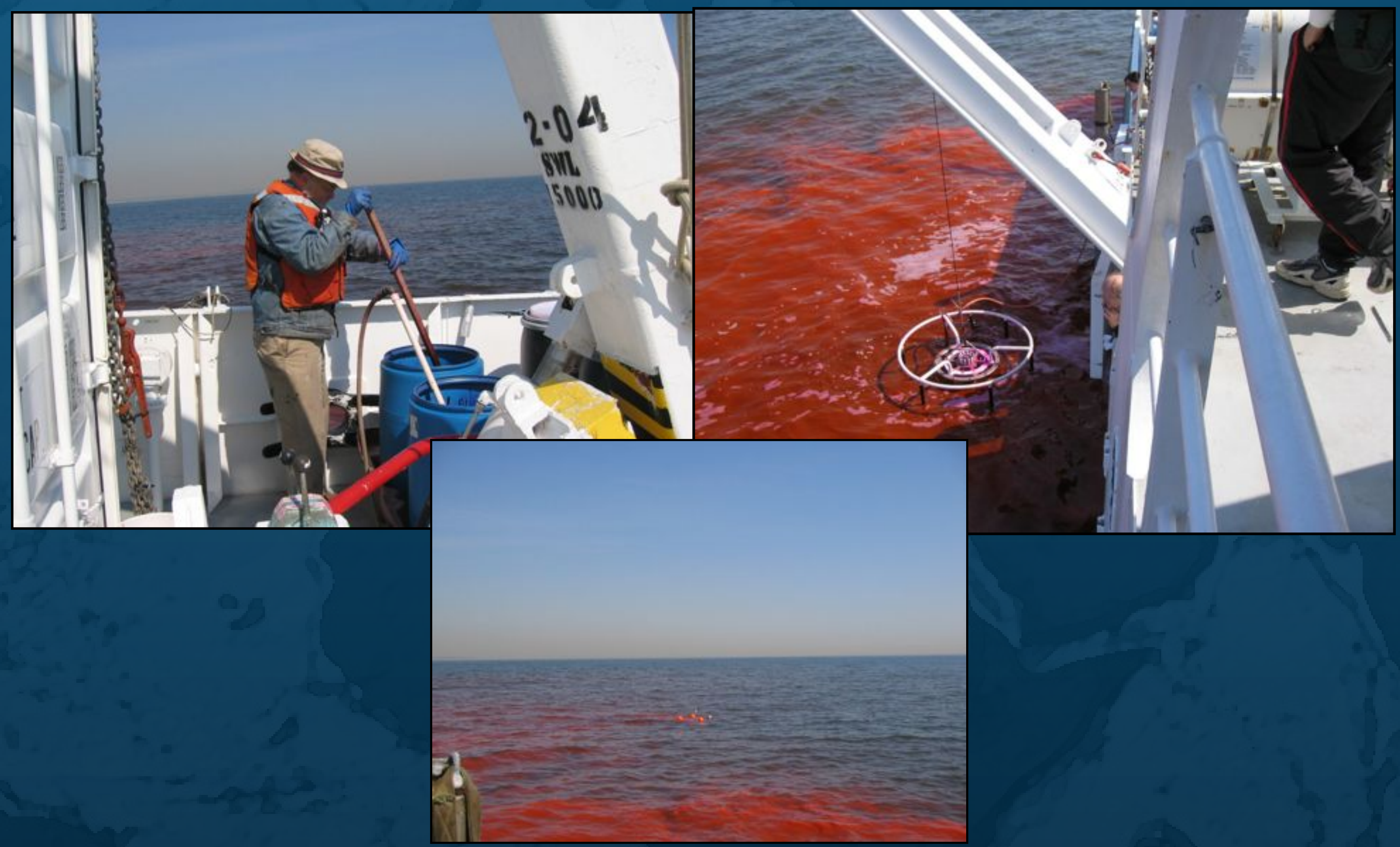


HF RADAR tracking and dye labeling of plume



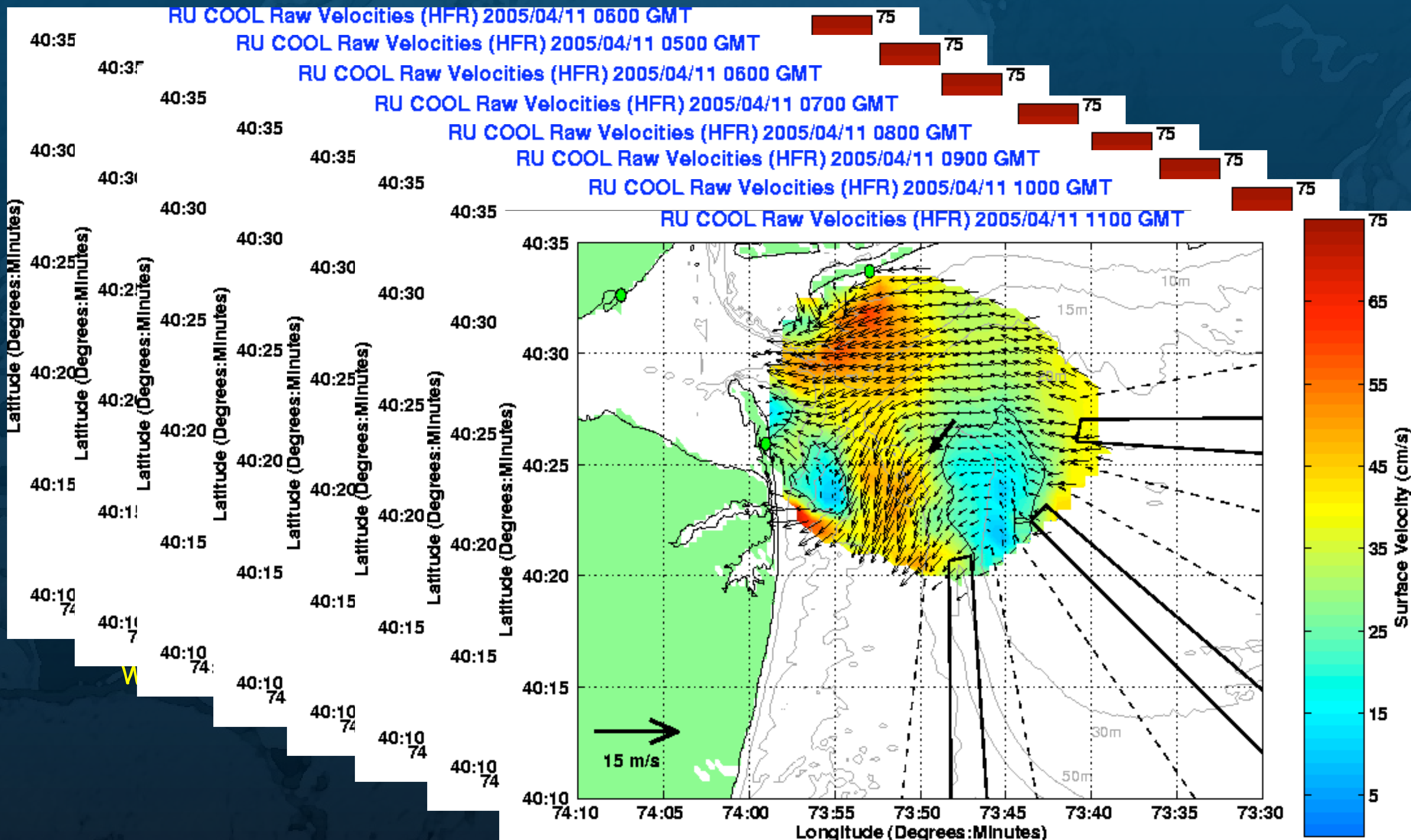
HF RADAR tracking and dye labeling of plume



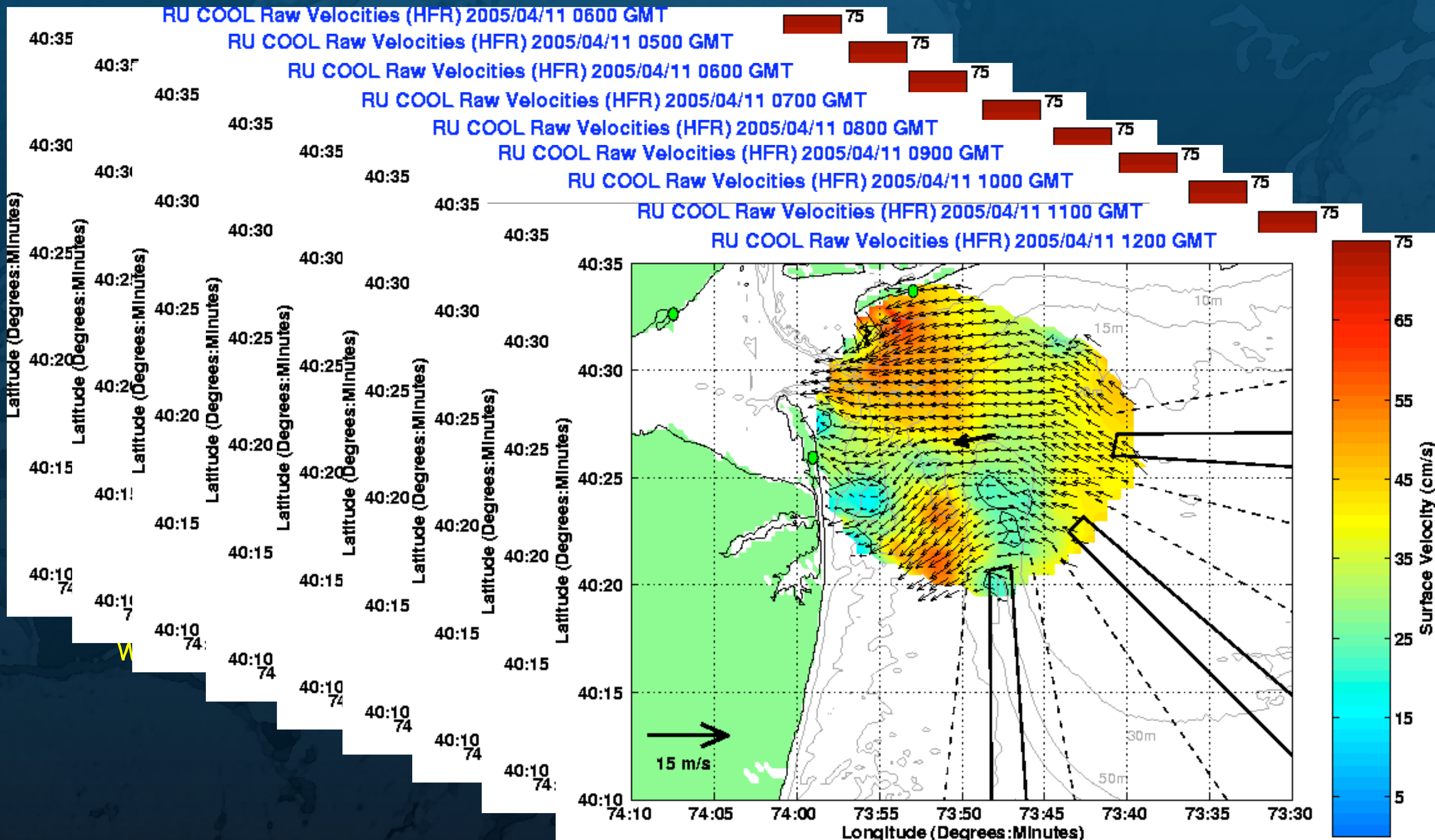


Sunday, July 1, 12

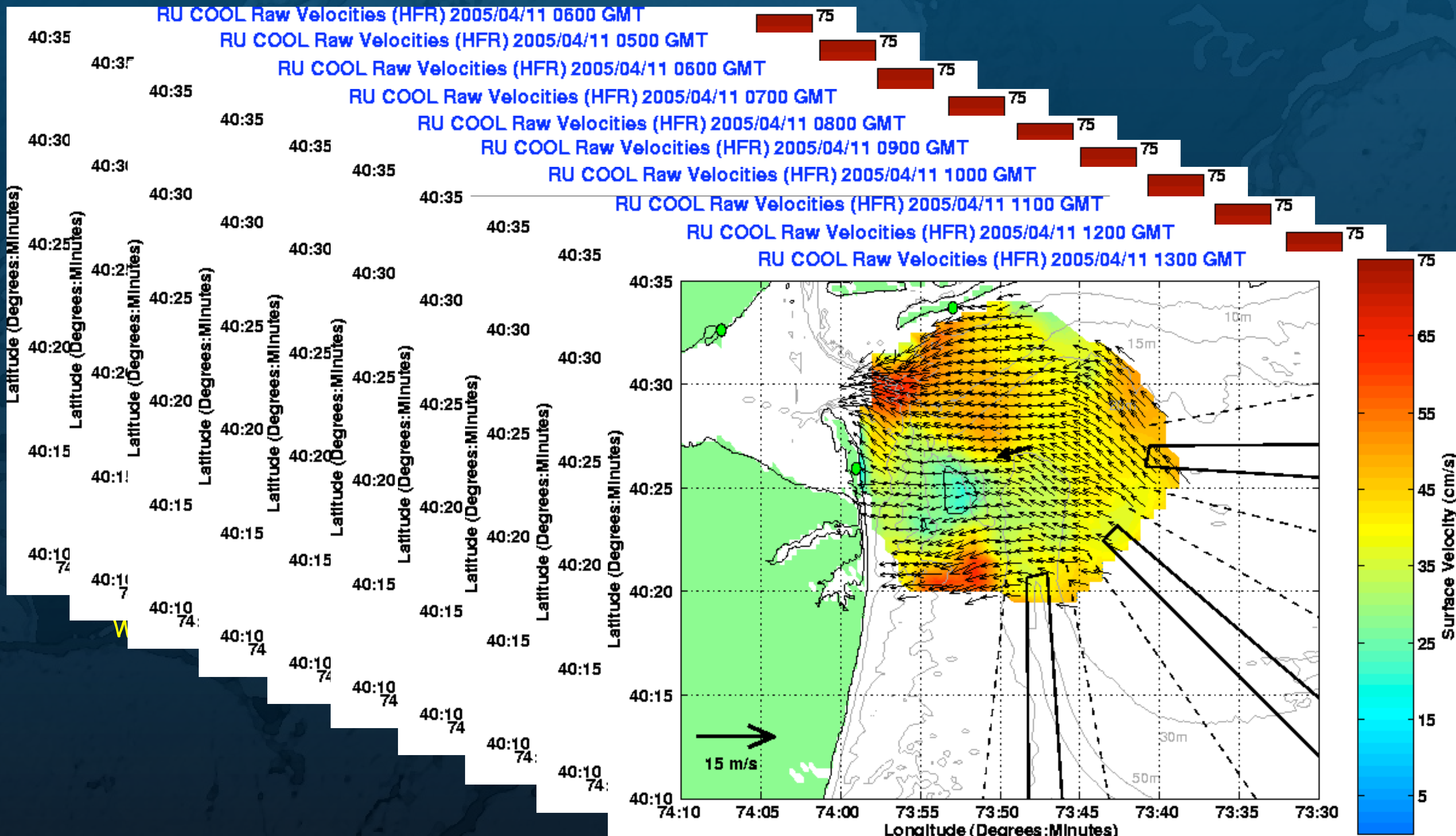
HF RADAR tracking and dye labeling of plume



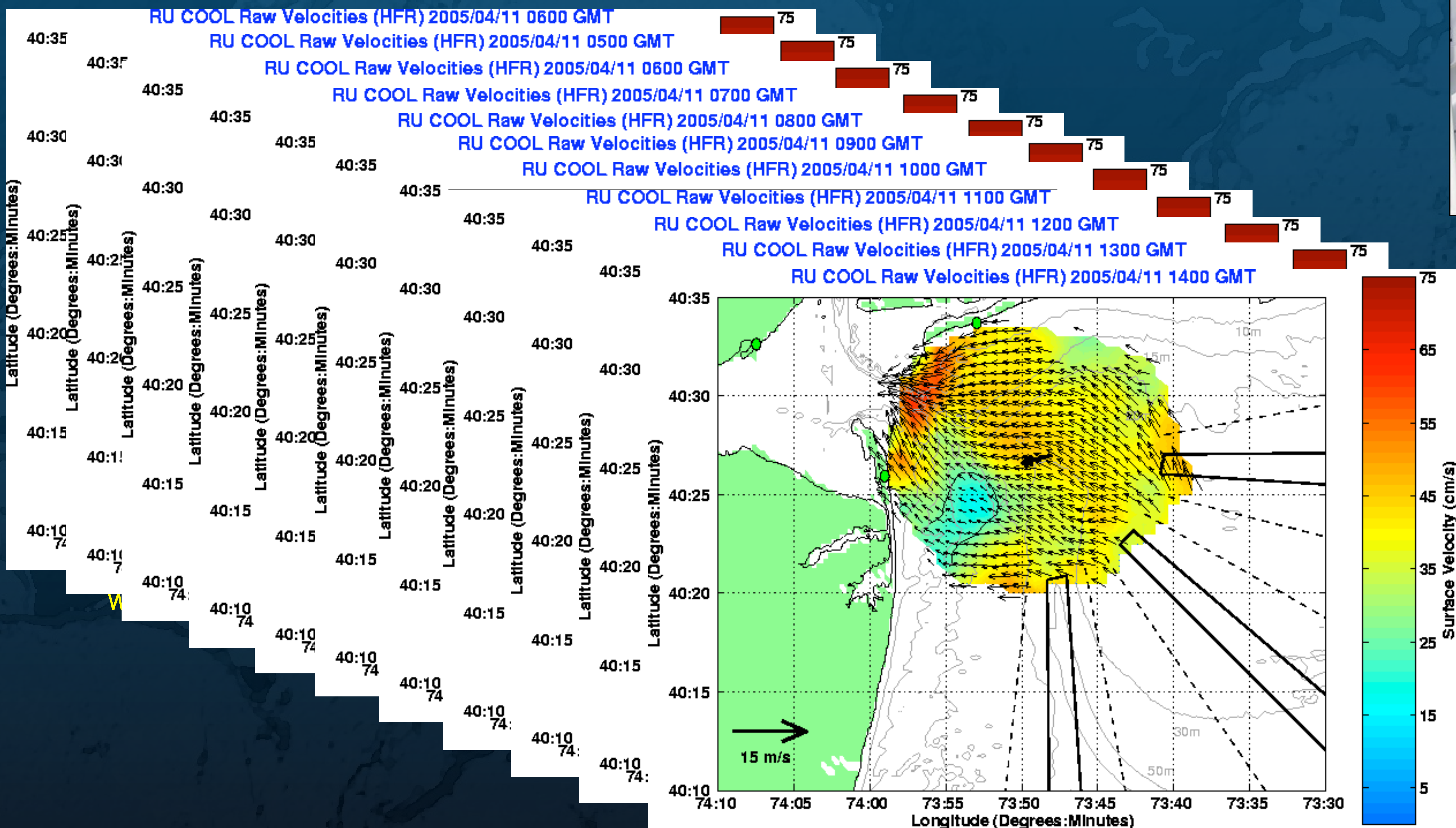
HF RADAR tracking and dye labeling of plume



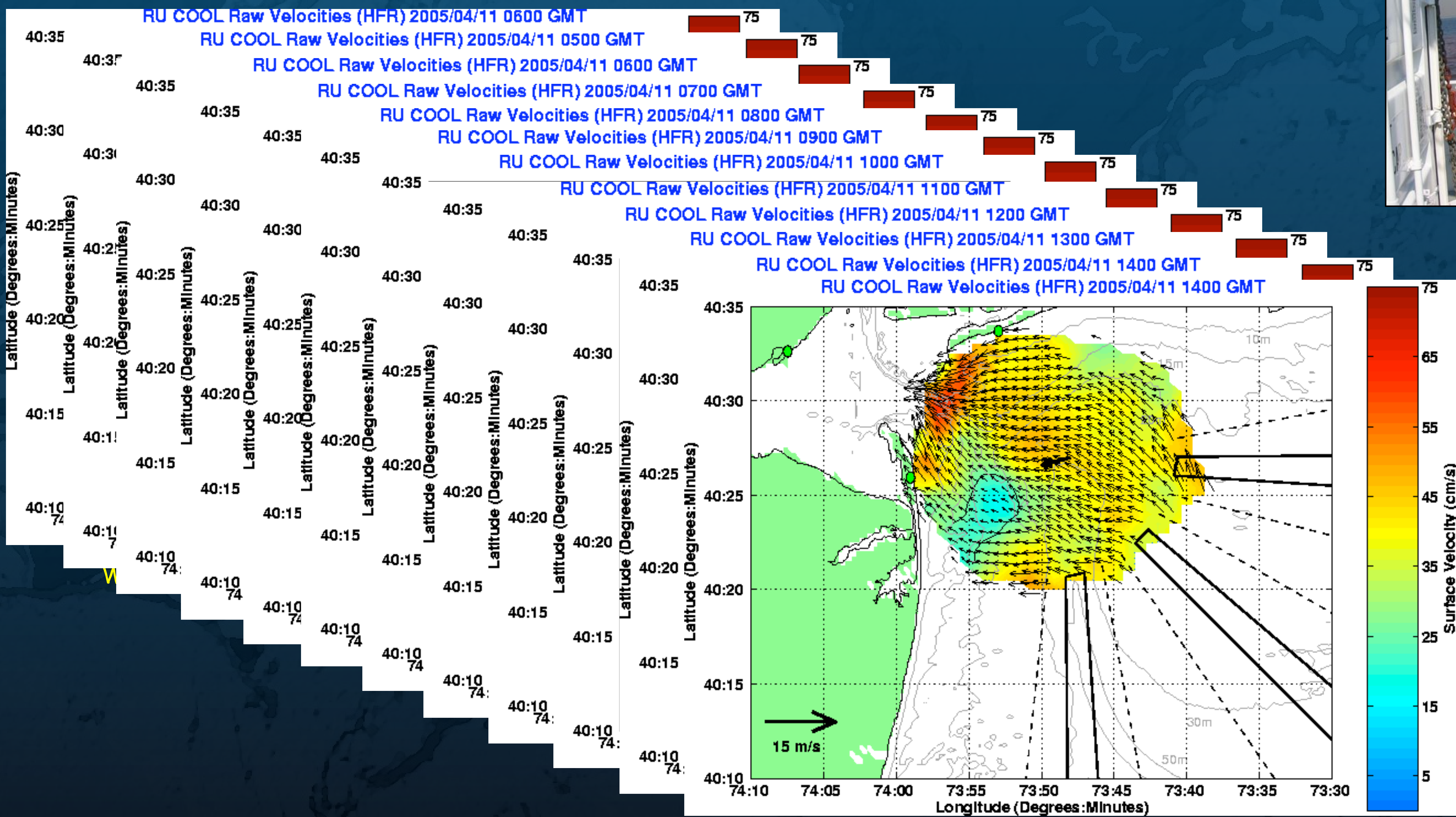
HF RADAR tracking and dye labeling of plume



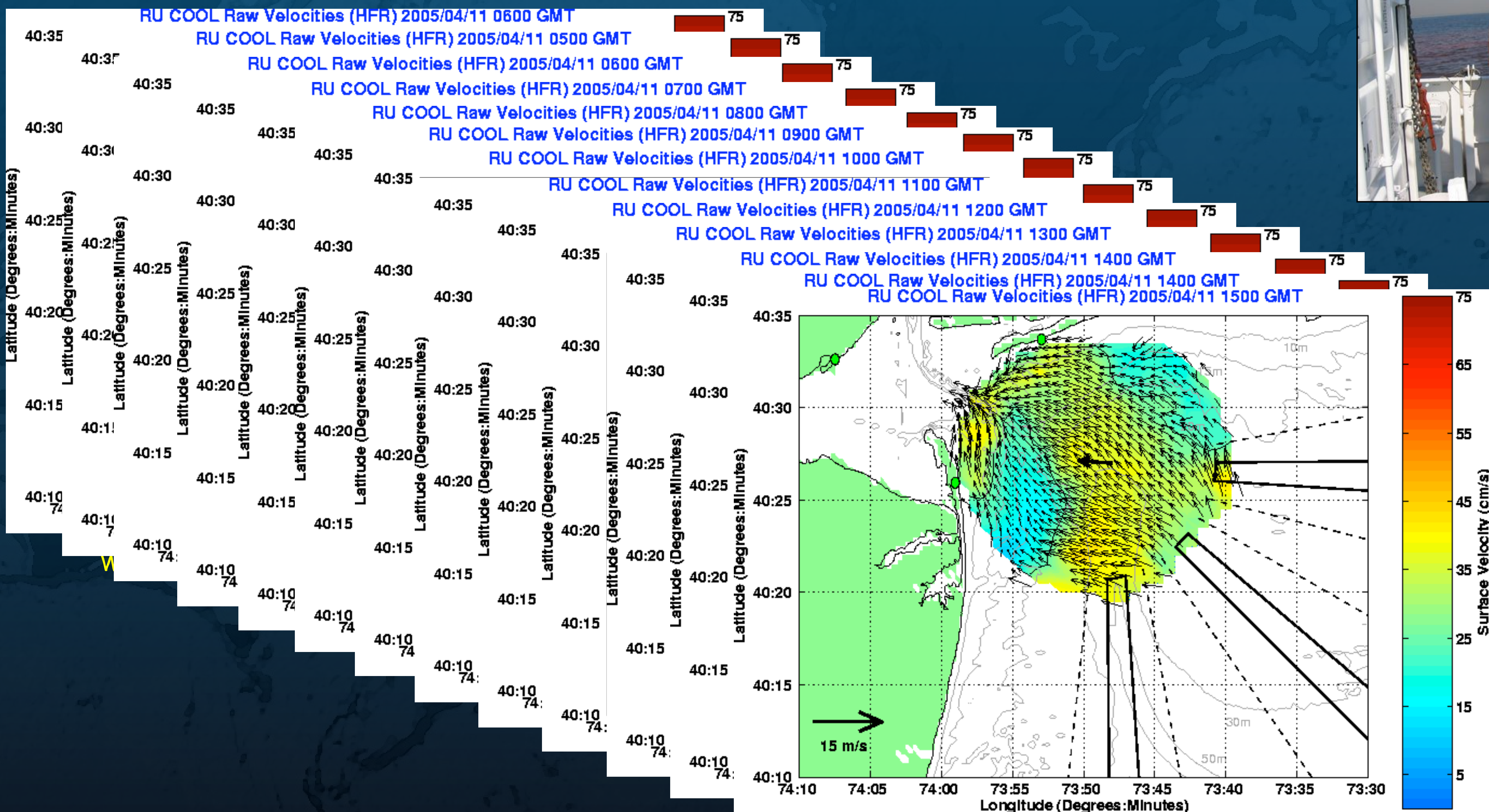
HF RADAR tracking and dye labeling of plume

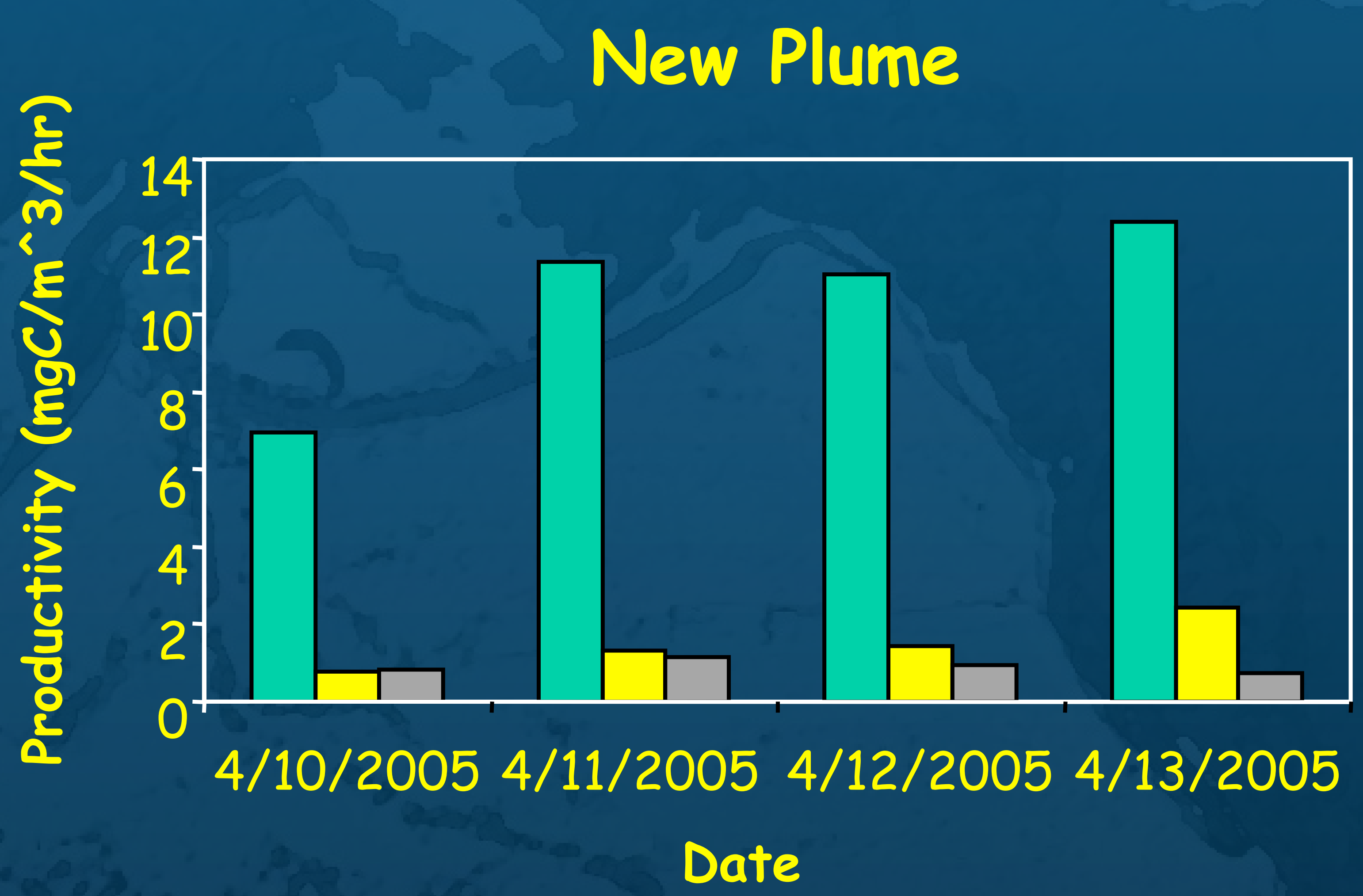


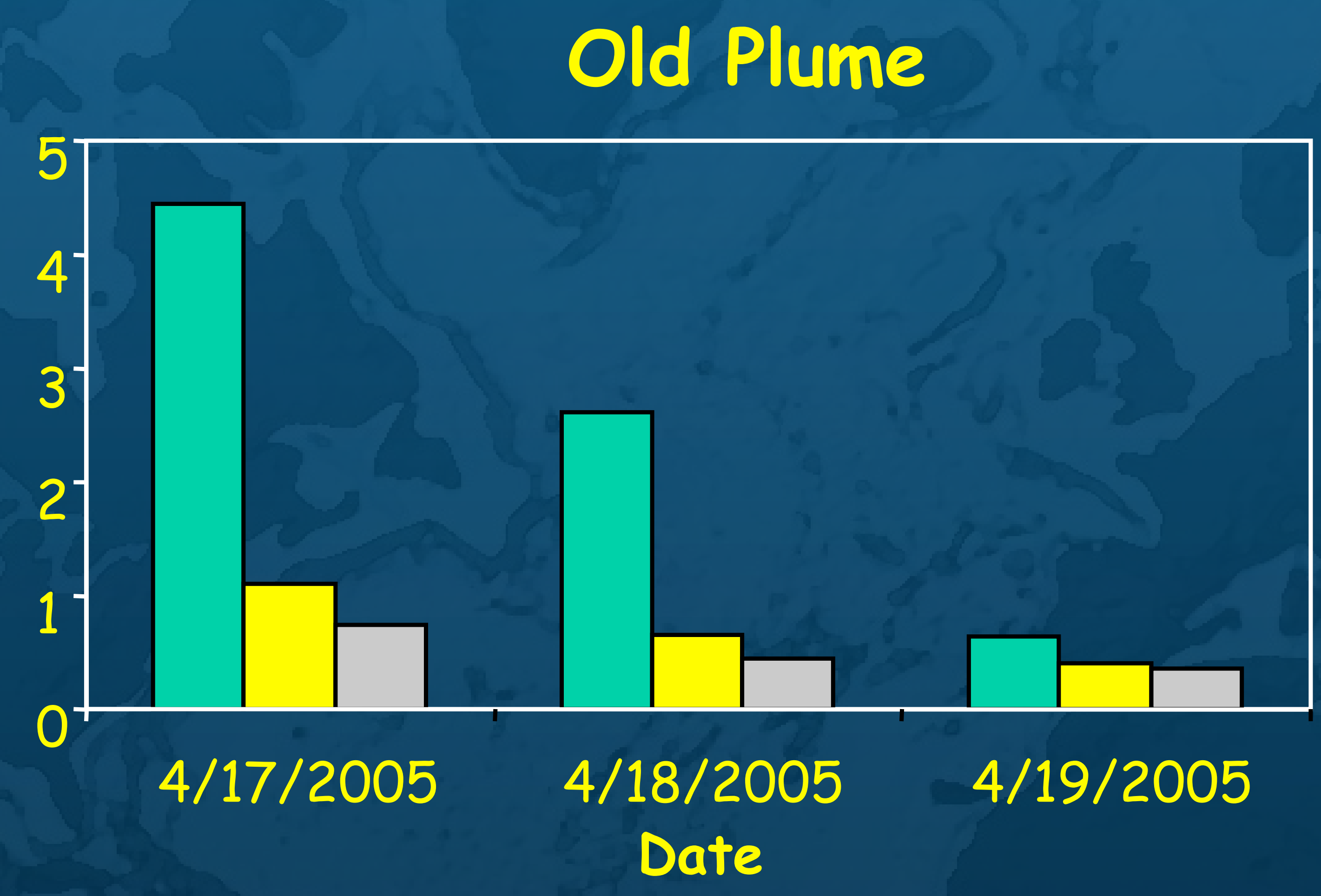
HF RADAR tracking and dye labeling of plume

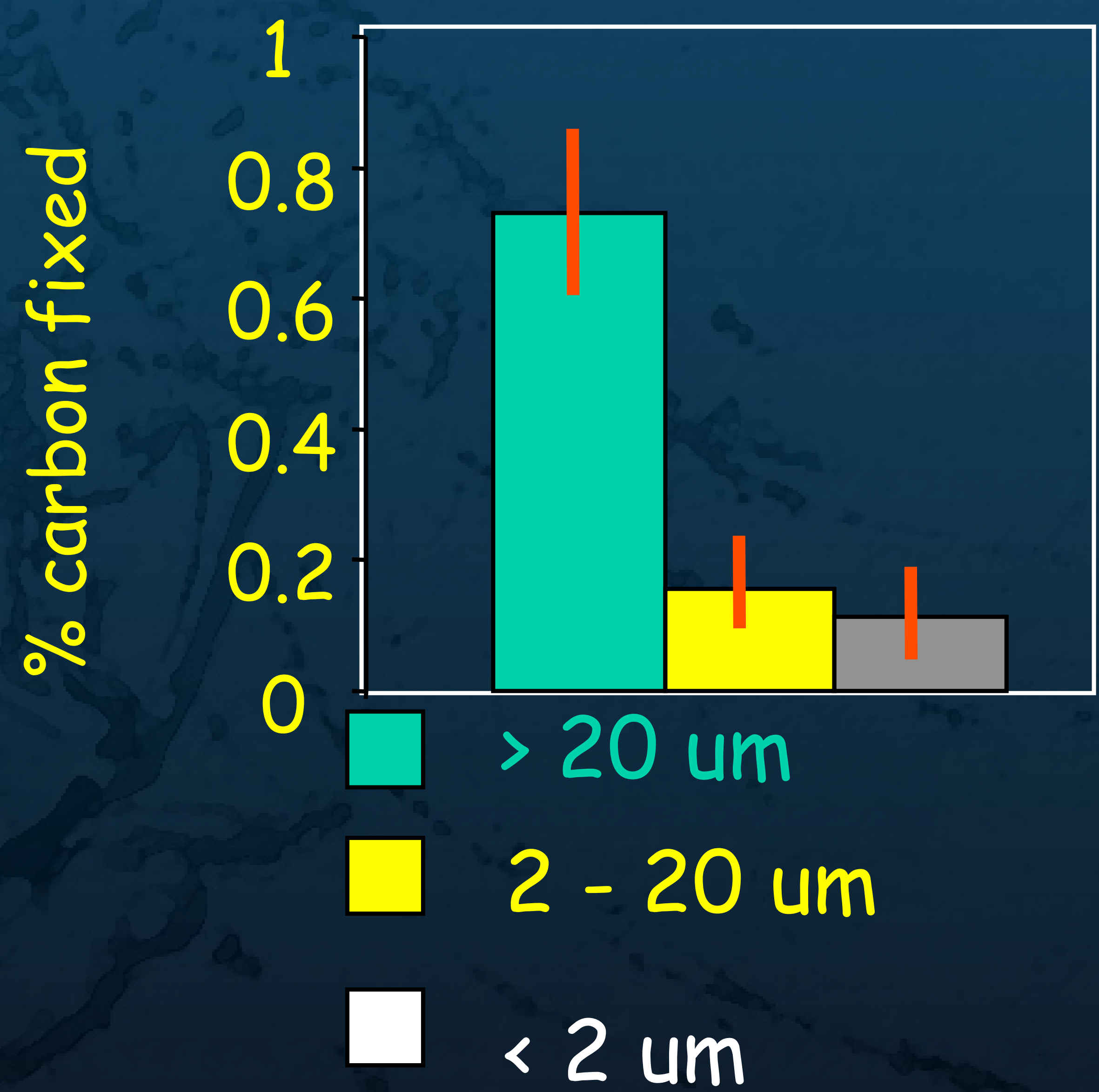


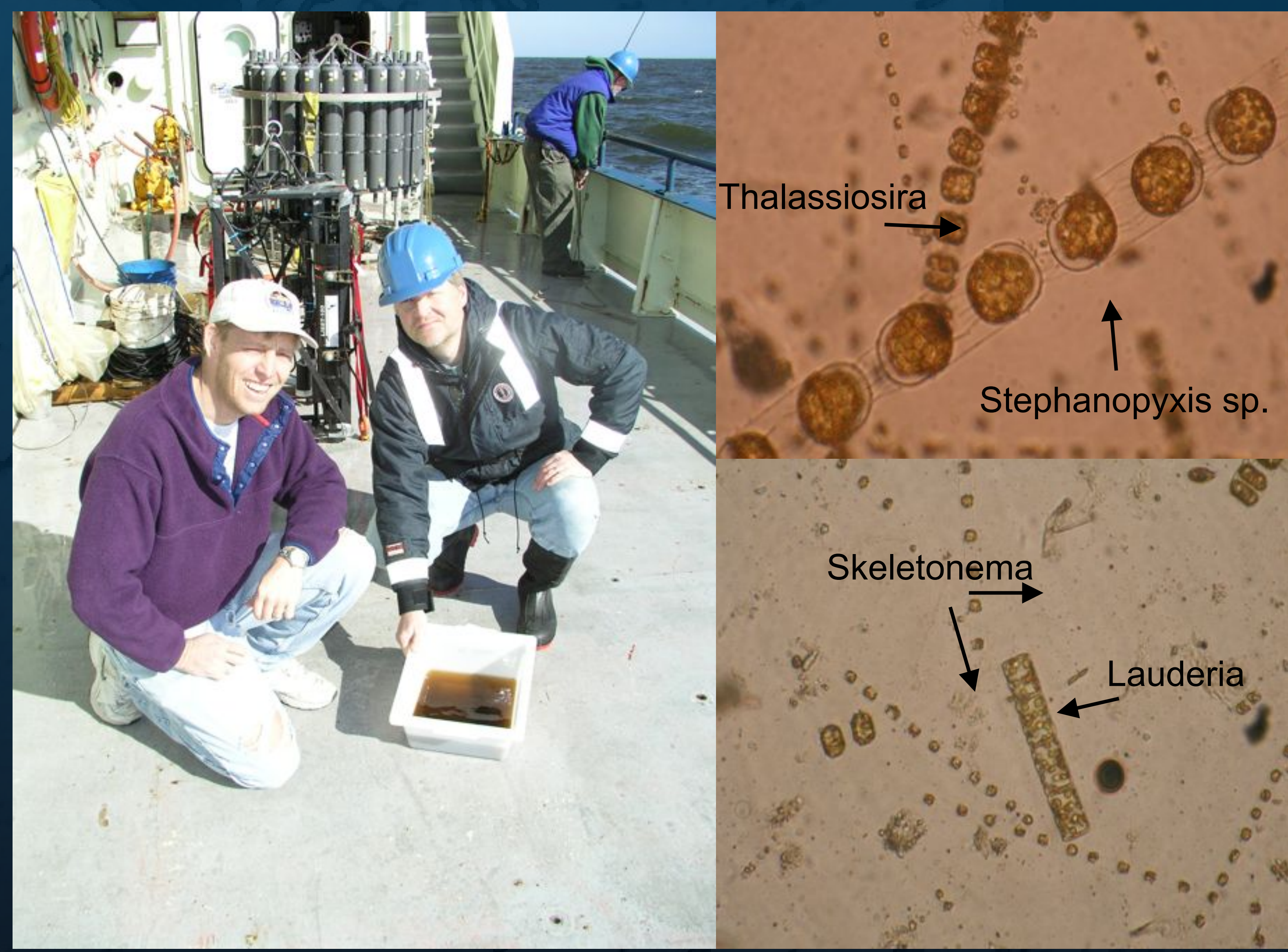
HF RADAR tracking and dye labeling of plume

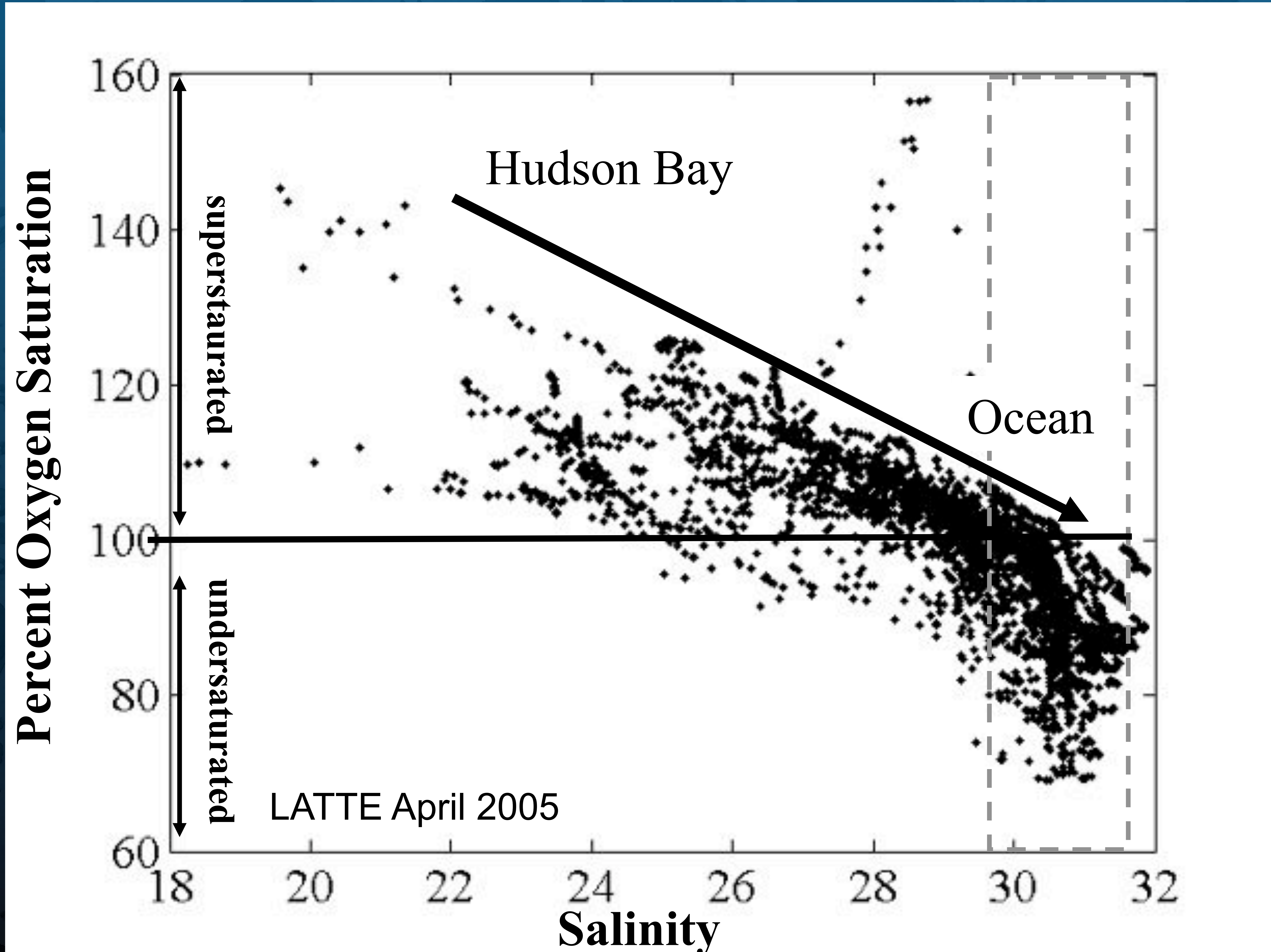



New Plume
Productivity (mgC/m^3/hr)
0
2
4
6
8
10
12
14
4/10/2005
4/11/2005
4/12/2005
4/13/2005
Date

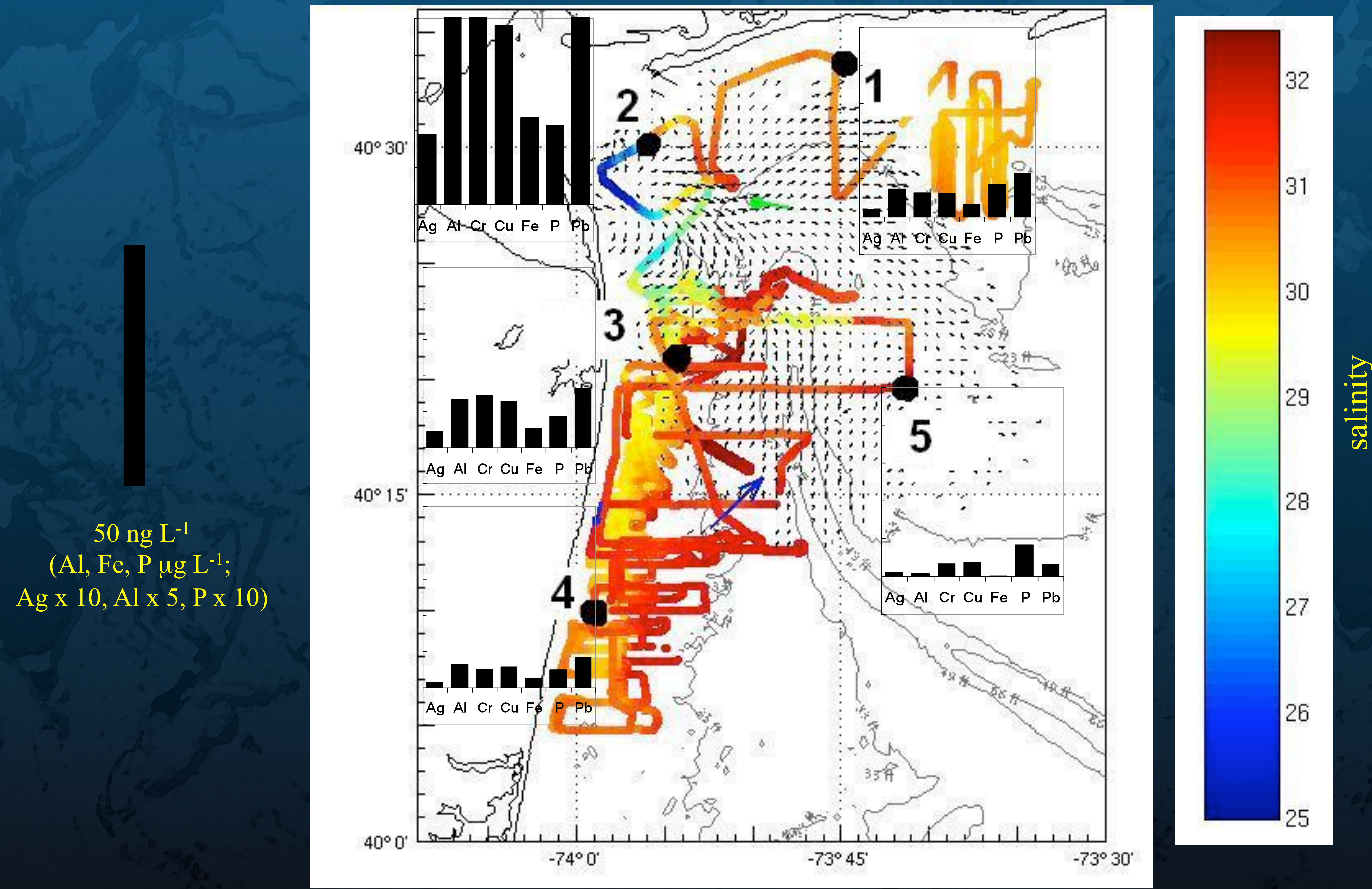

Old Plume
0
1
2
3
4
5
4/17/2005
4/18/2005
4/19/2005
Date


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

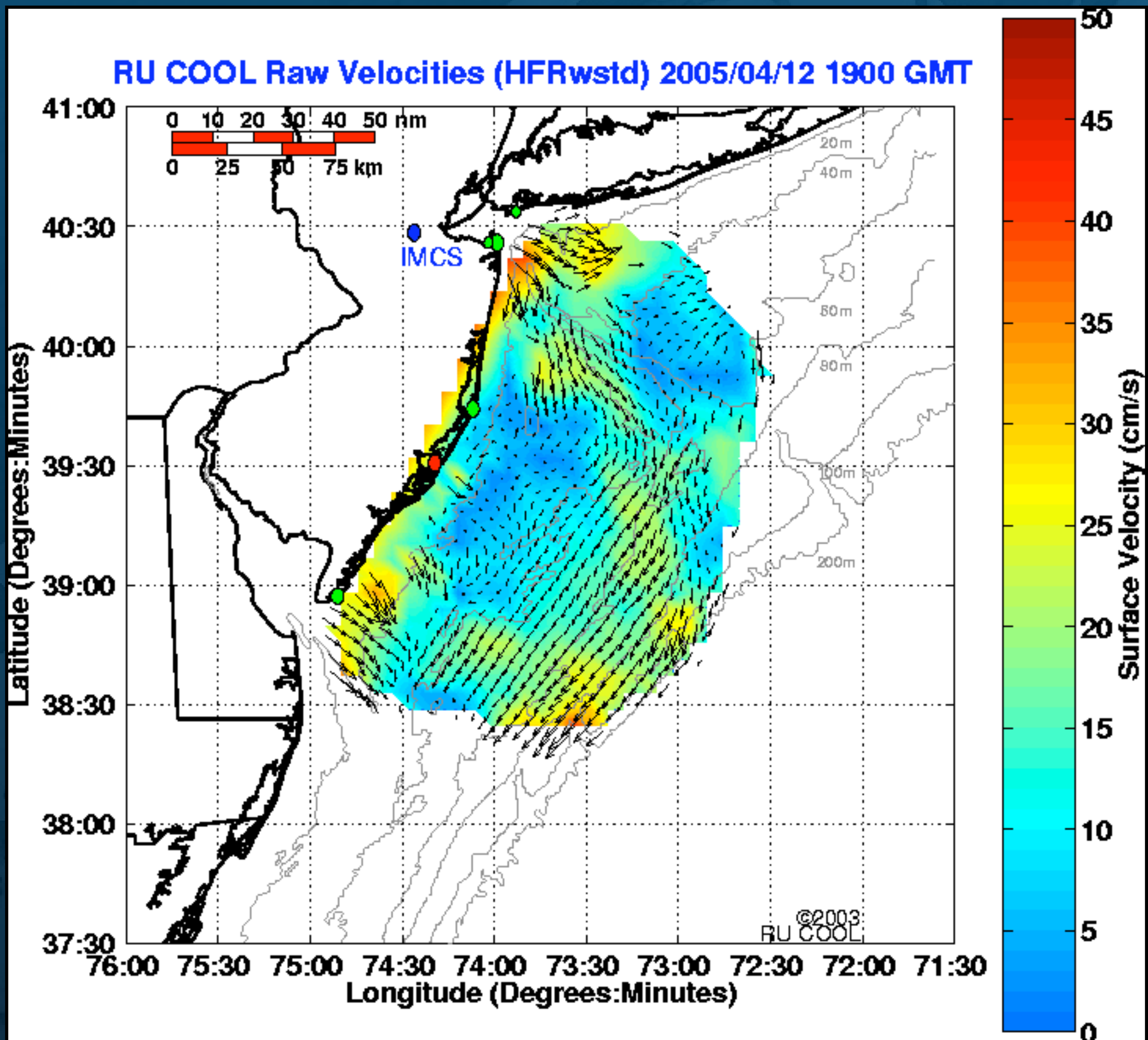

Thalassiosira
Stephanopyxis sp.
Skeletonema
Lauderia

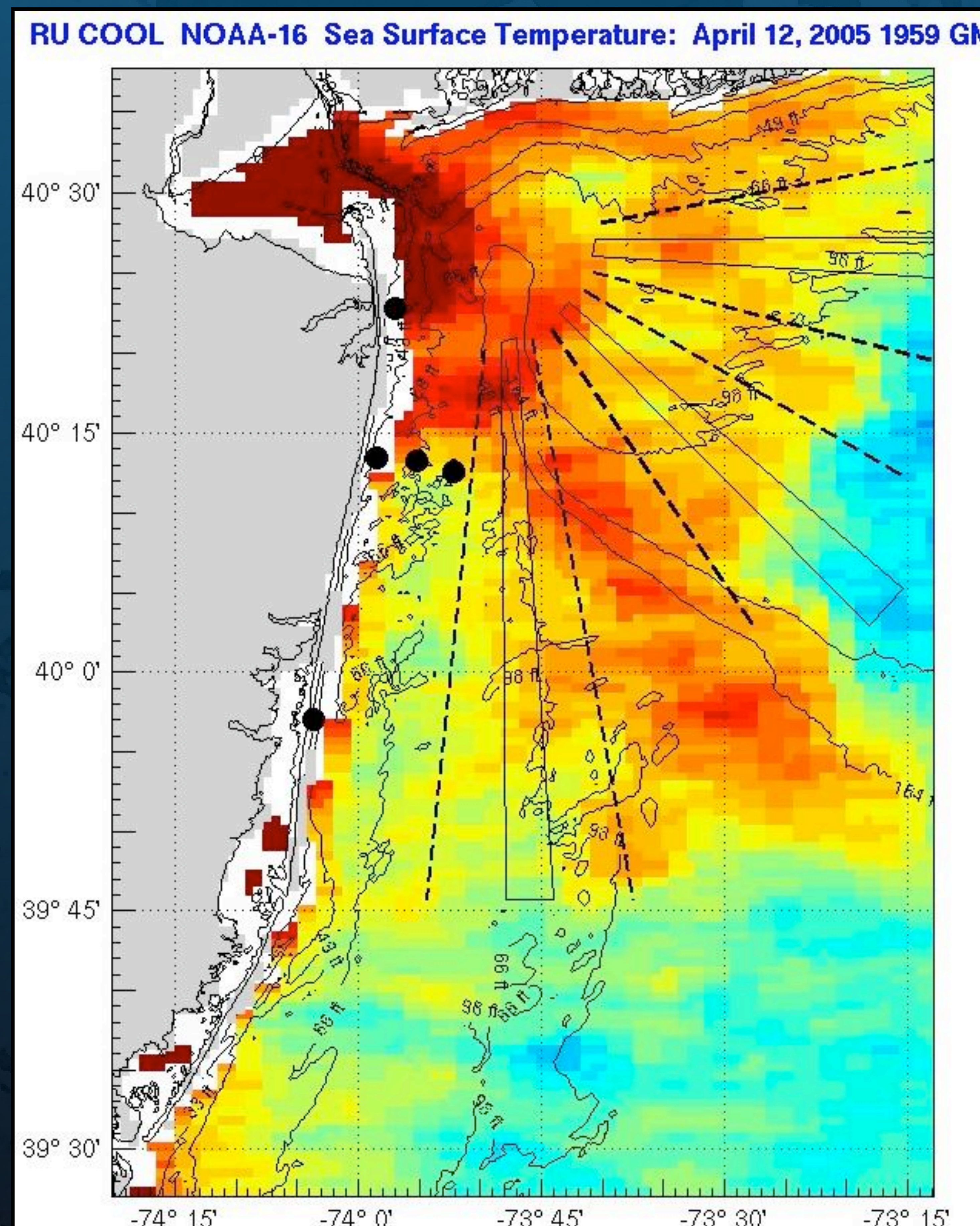

Percent Oxygen Saturation
160
140
120
100
80
60
18
20
22
24
26
28
30
32
Salinity
superstaurated
undersaturated
Hudson Bay
Ocean
LATTE April 2005

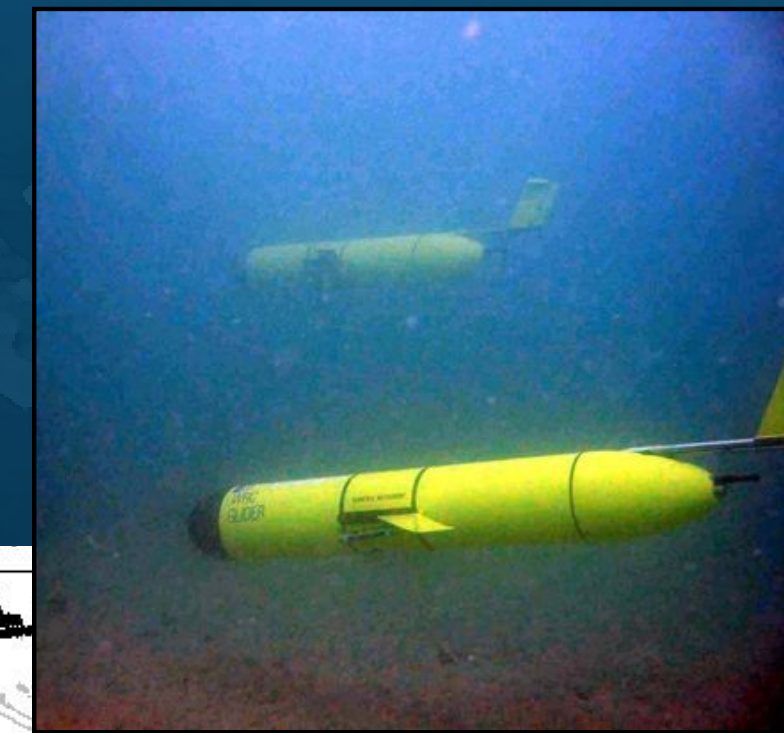
>20 µm particulate trace metals and phosphorus - Ag, Al, Cr, Cu, Fe, P, Pb

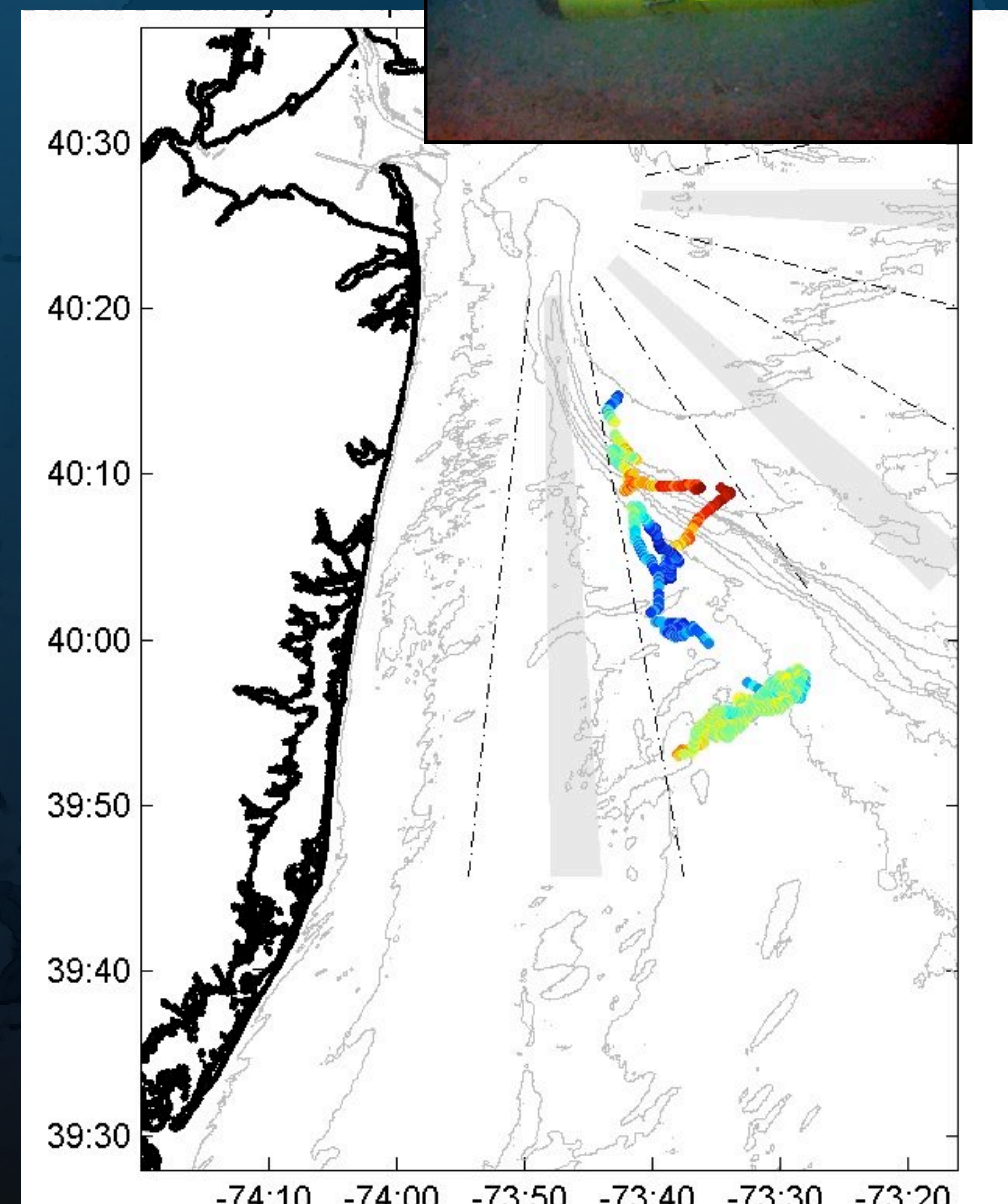


Freshwater Plume Moves Out Across the Shelf: Hudson Shelf Valley







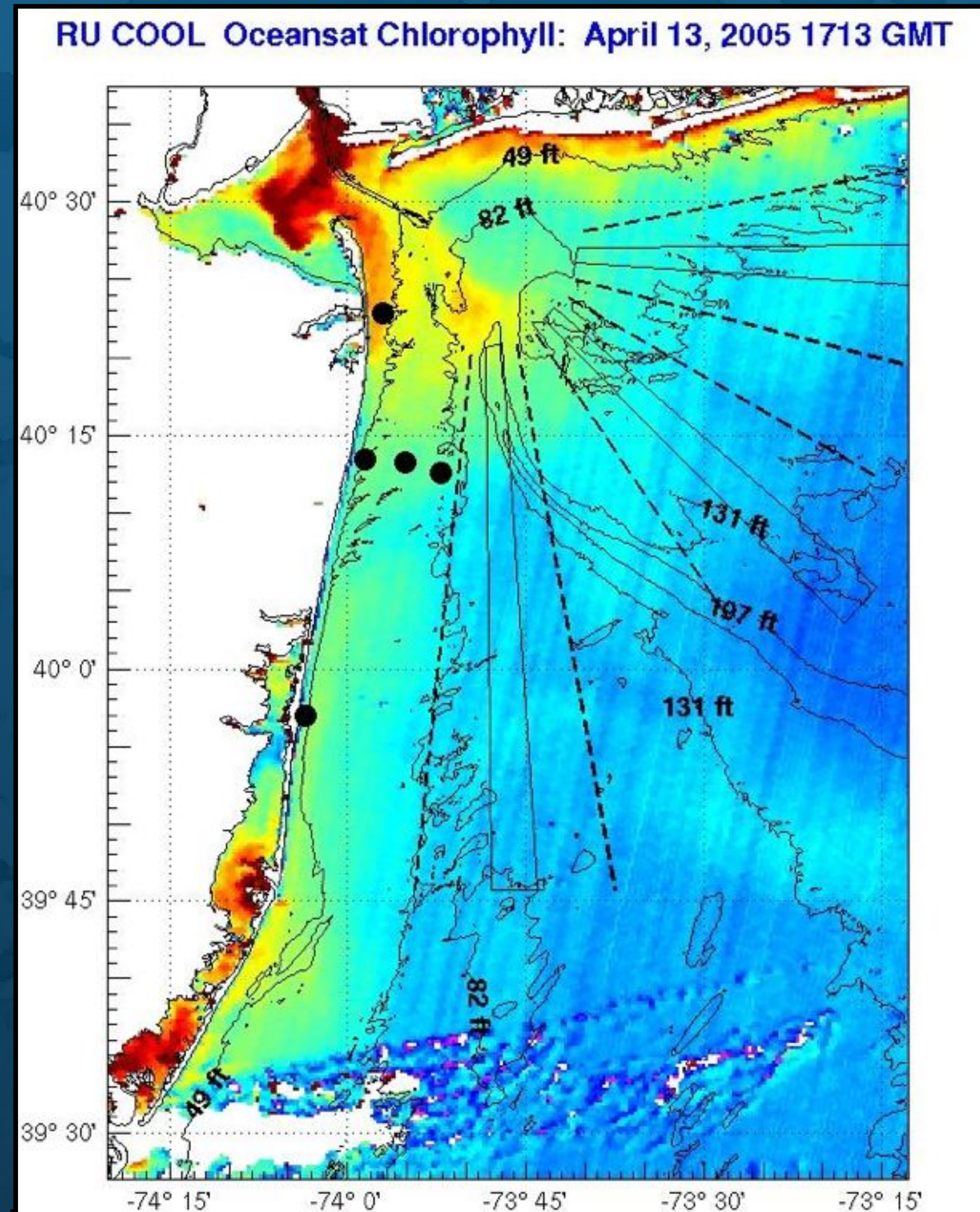


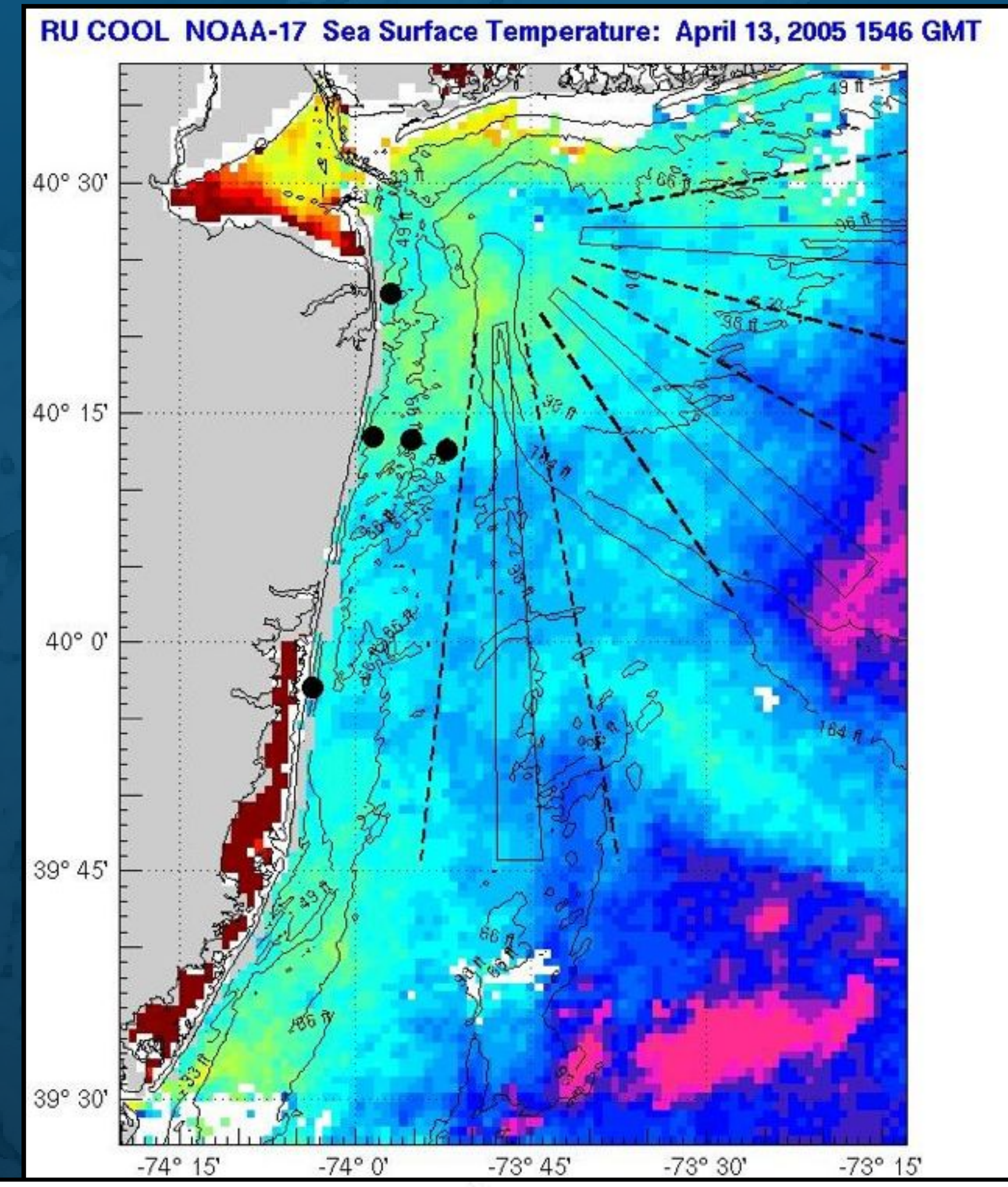
LaTTE 2005 --Post Injection 2 – Final shipboard survey After luring the Cape Hatteras offshore.

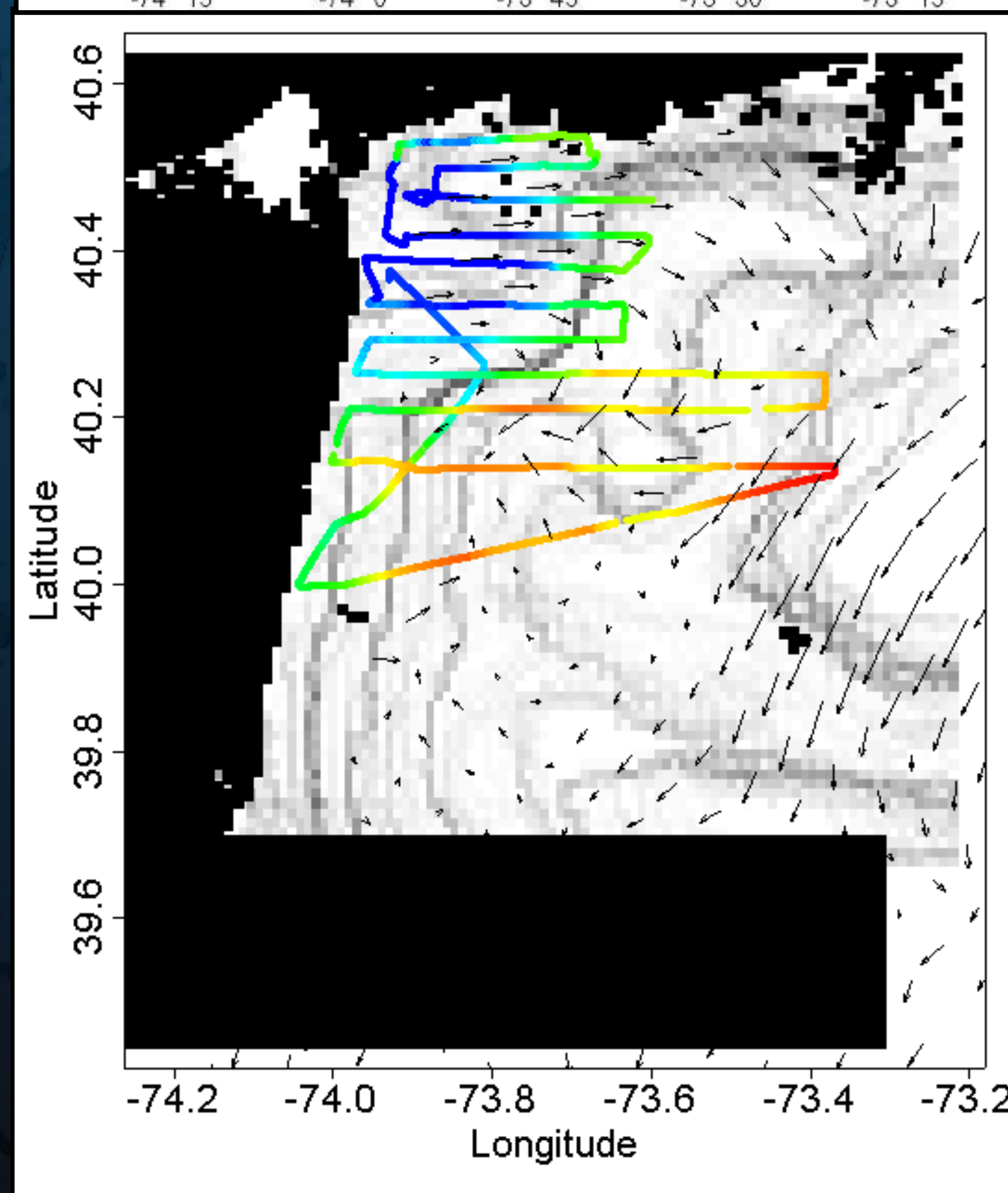
"The survey began on the 'Highway'. We were near the glider when it surfaced. We saw currents ripping southward in a 10 m thick layer of freshwater along the highway -- perhaps the most significant freshwater transport we saw all week."

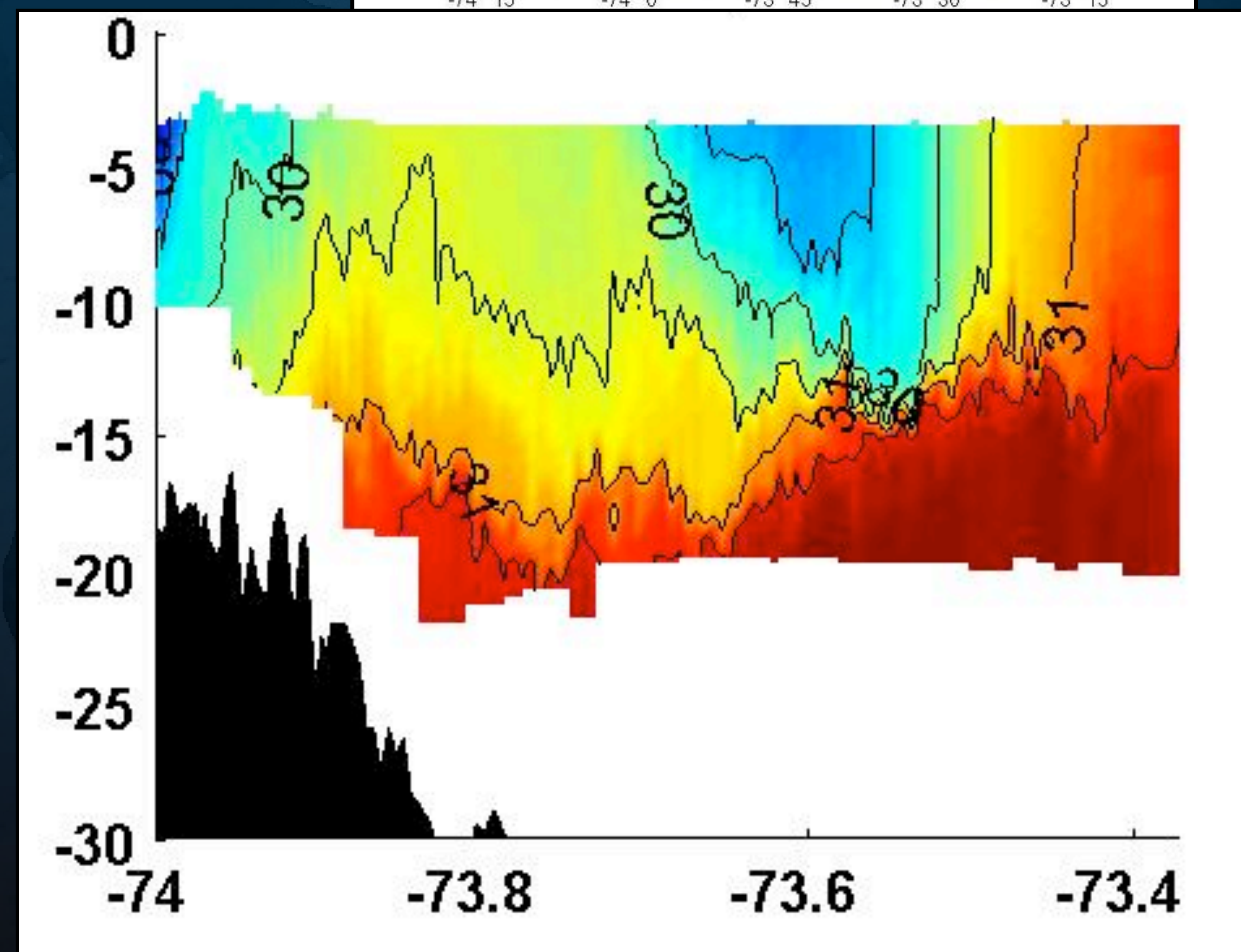
"Perhaps the most perplexing to me is 'the Highway' and why there has been a lack of a strong coastally trapped flow this week."

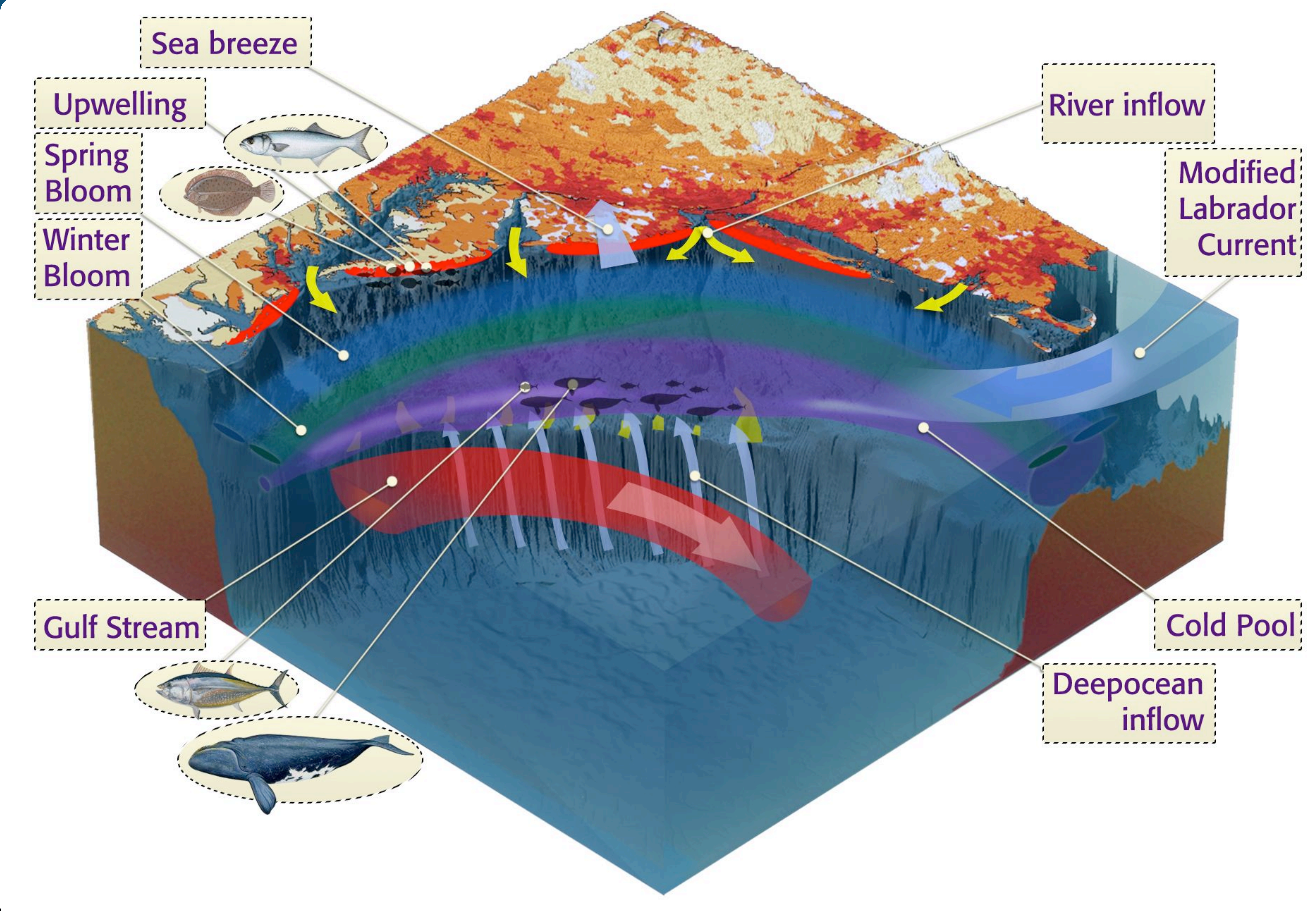
--- Bob Chant aboard the Cape Hatteras, April 21, 2005

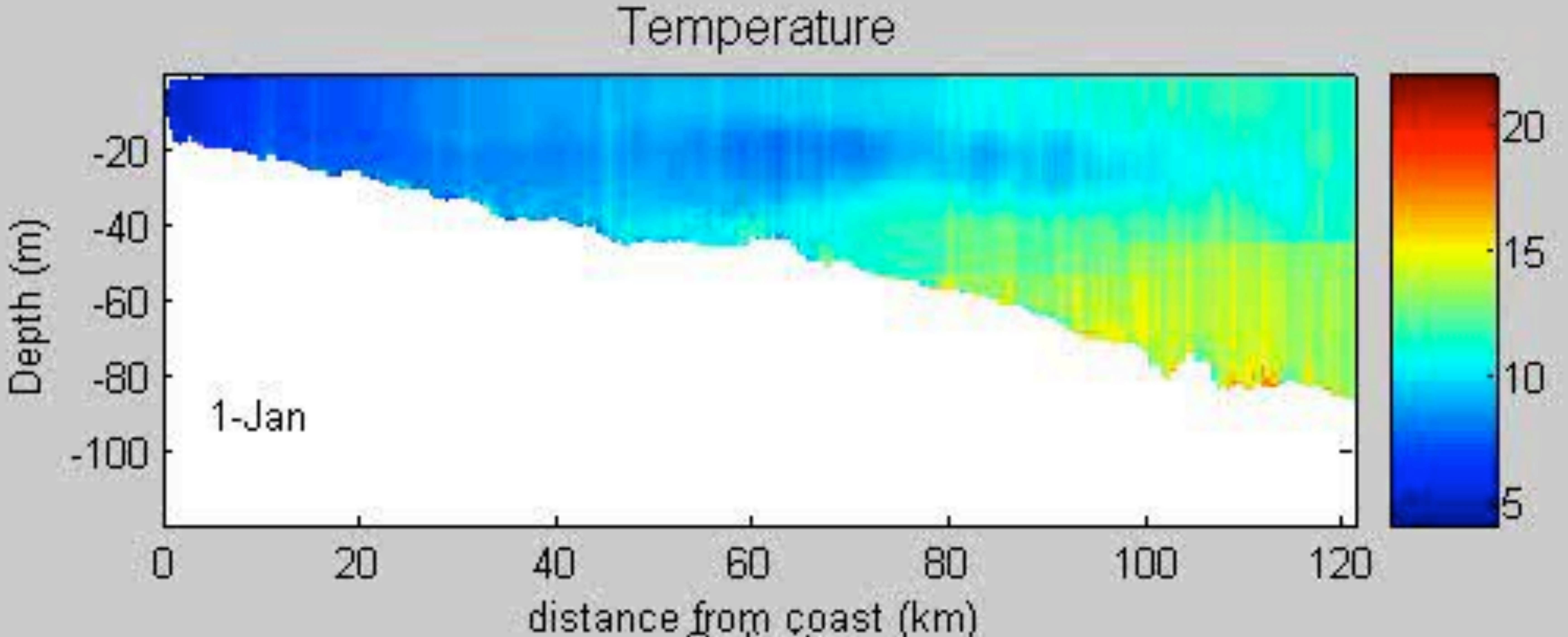

RU COOL Oceansat Chlorophyll: April 13, 2005 1713 GMT
49 ft
82 ft
131 ft
197 ft
131 ft
82 ft
40° 30'
40° 15'
40° 0'
39° 45'
39° 30'
-74° 15'
-74° 0'
-73° 45'
-73° 30'
-73° 15'

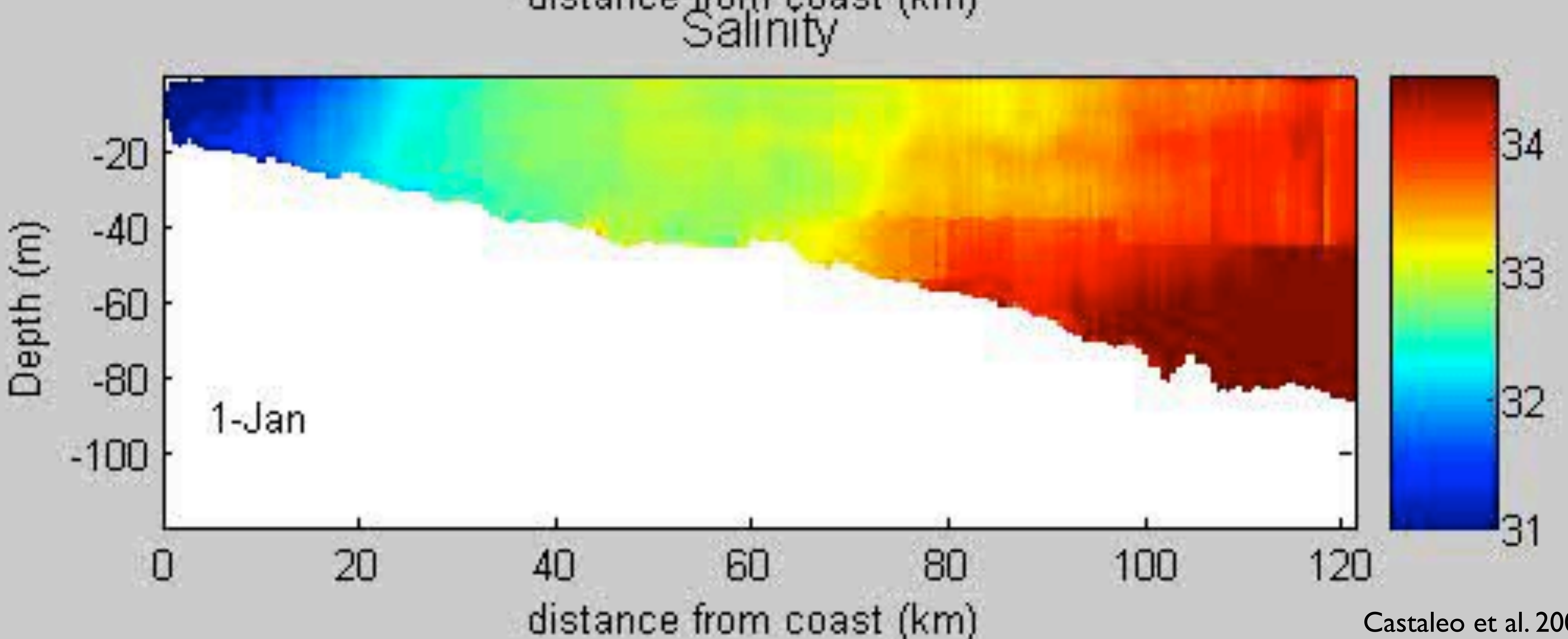

RU COOL NOAA-17 Sea Surface Temperature: April 13, 2005 1546 GMT
40° 30'
40° 15'
40° 0'
39° 45'
39° 30'
-74° 15'
-74° 0'
-73° 45'
-73° 30'
-73° 15'

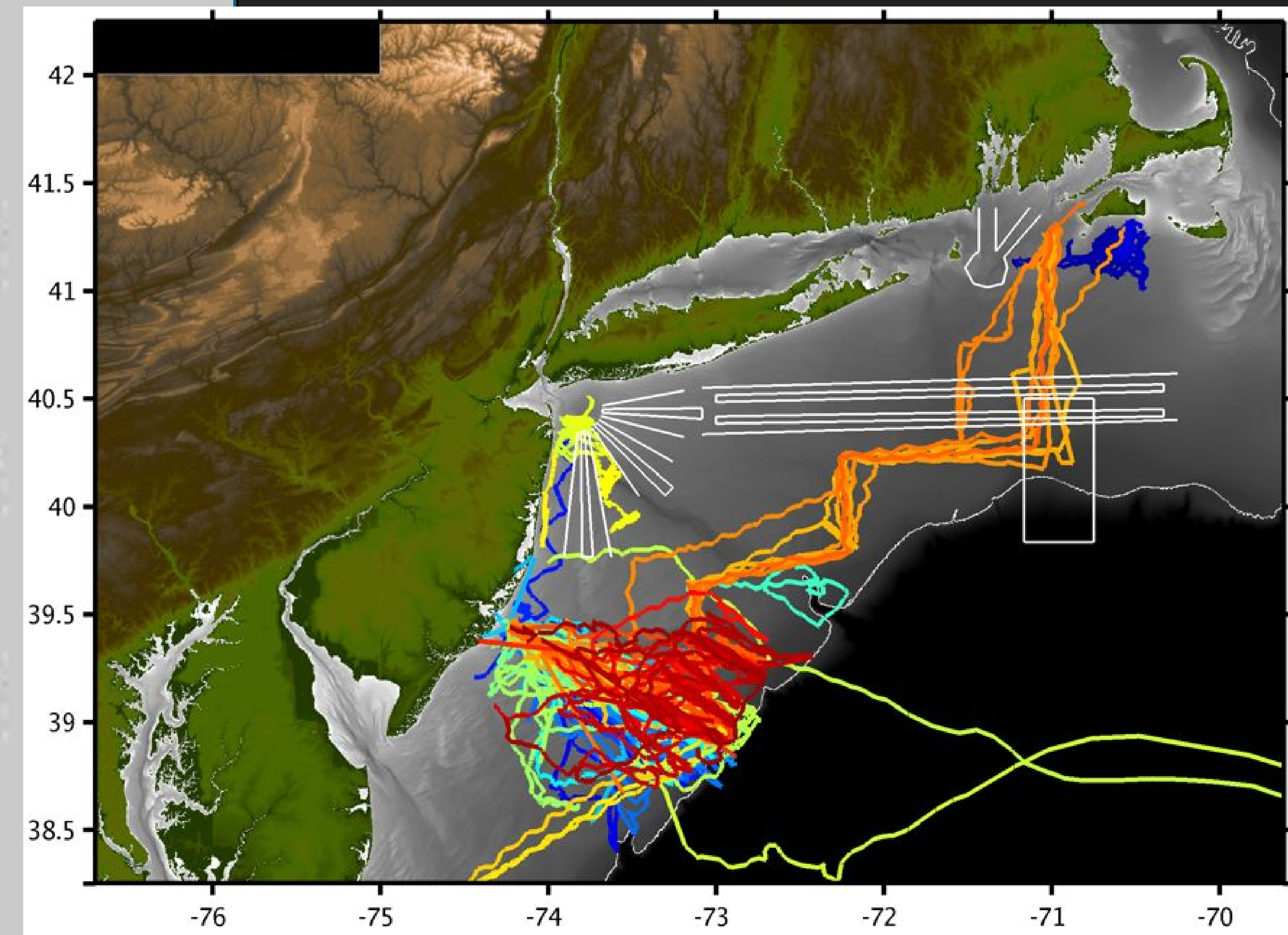

Latitude
40.6
40.4
40.2
40.0
39.8
39.6
-74.2
-74.0
-73.8
-73.6
-73.4
-73.2
Longitude


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


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





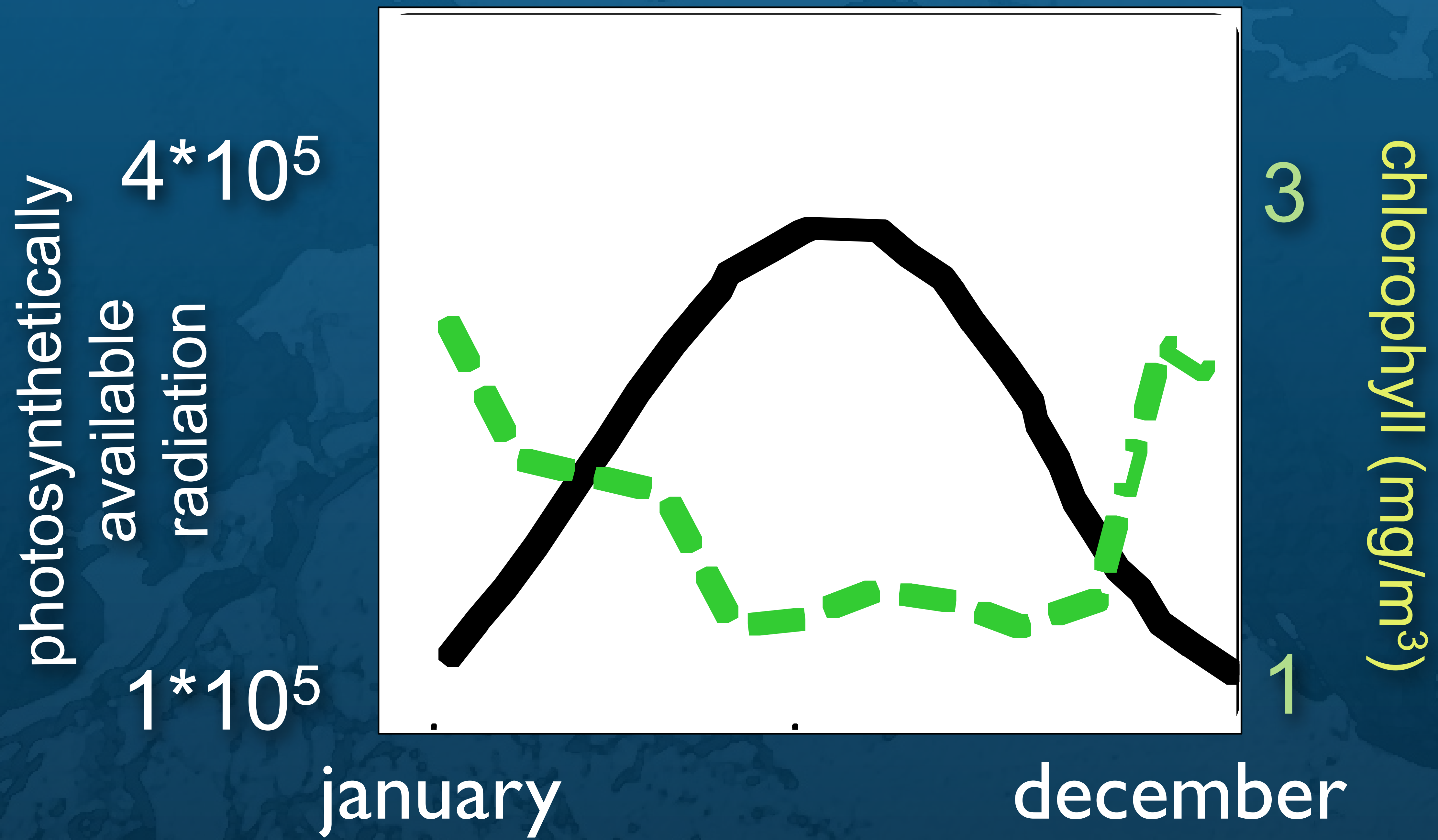


MAB stratification dominates the hydrography of the shelf.

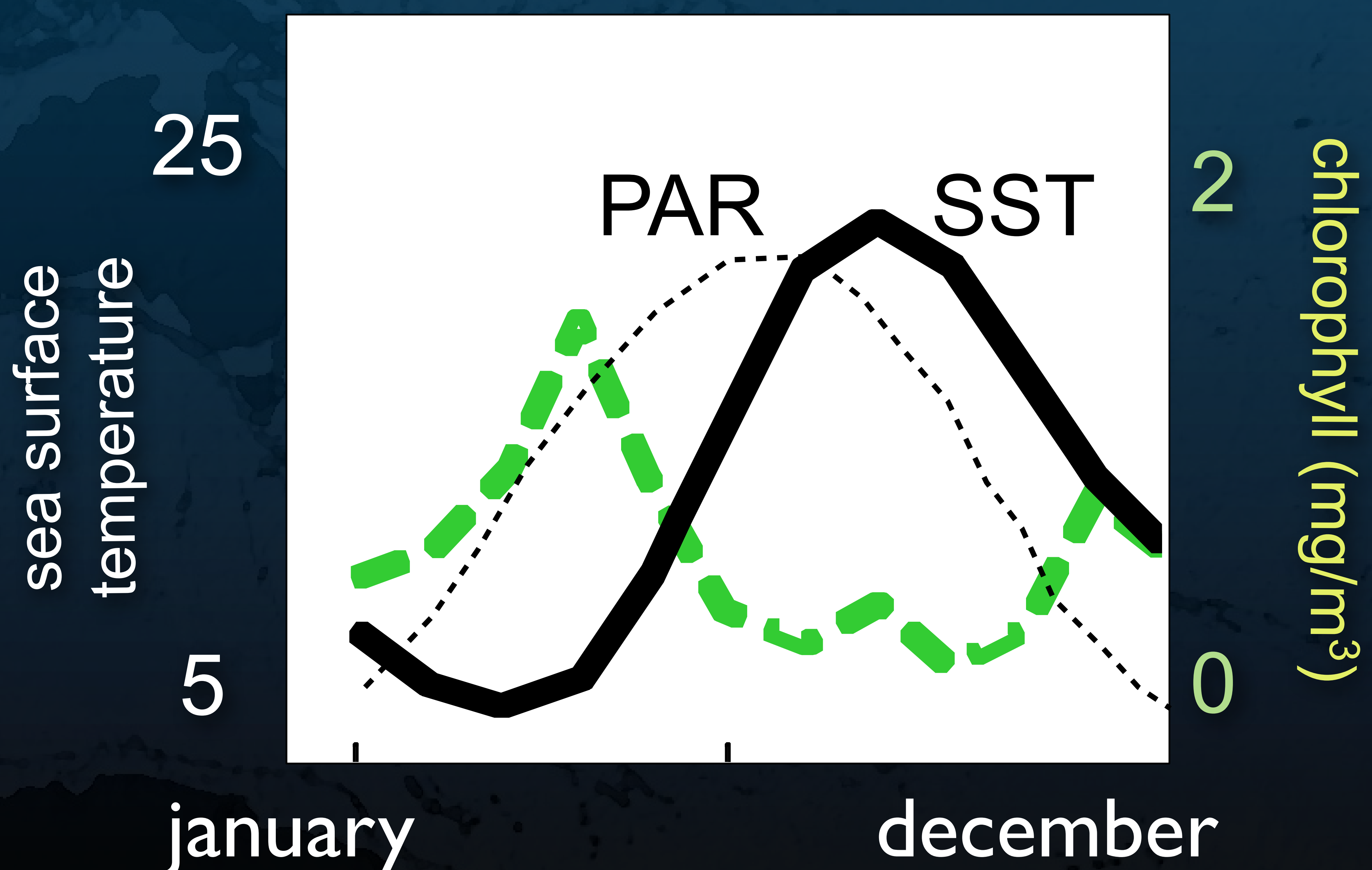
Temperature stratification extreme, 25 to 8 degrees in a only three meters

Salinity gradients show inshore and offshore gradients

Castaleo et al. 2008, 2010



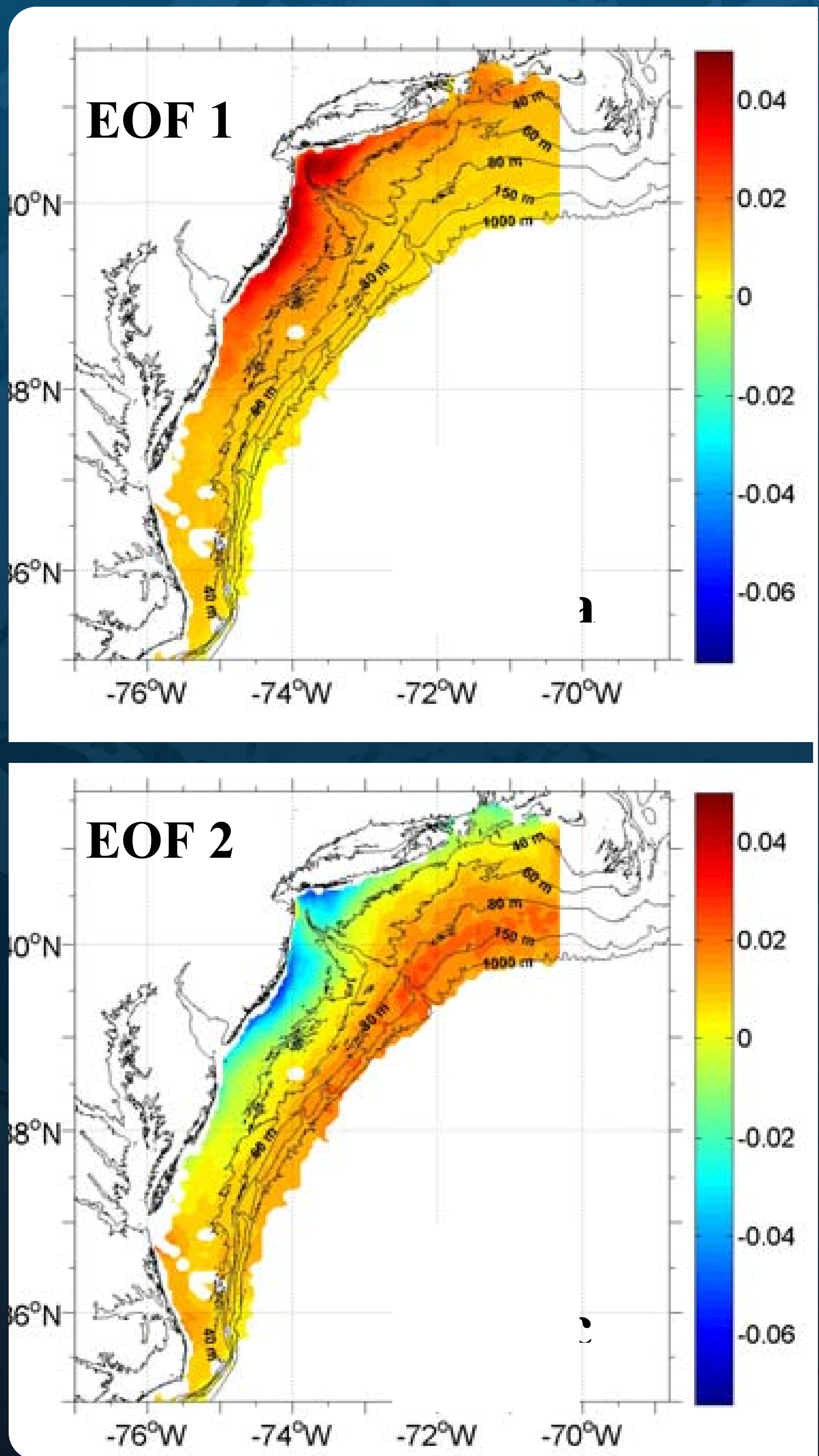
Mode 1: Largest and most recurrent bloom. Occurs during the dimmest months of the year which is interesting.



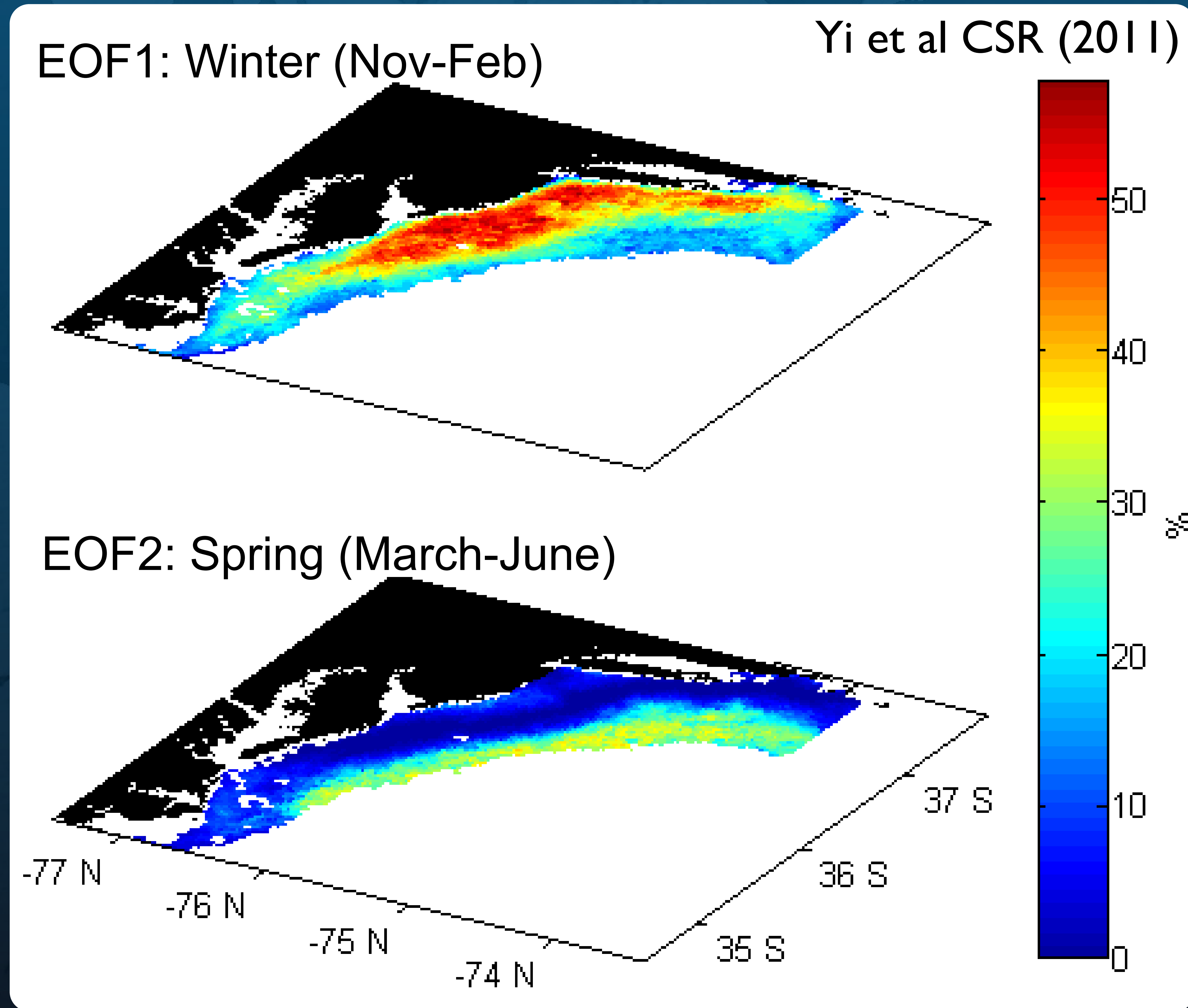
Mode 2: The canonical spring bloom which occurs prior to strong shelf stratification.

Schofield et al. 2008

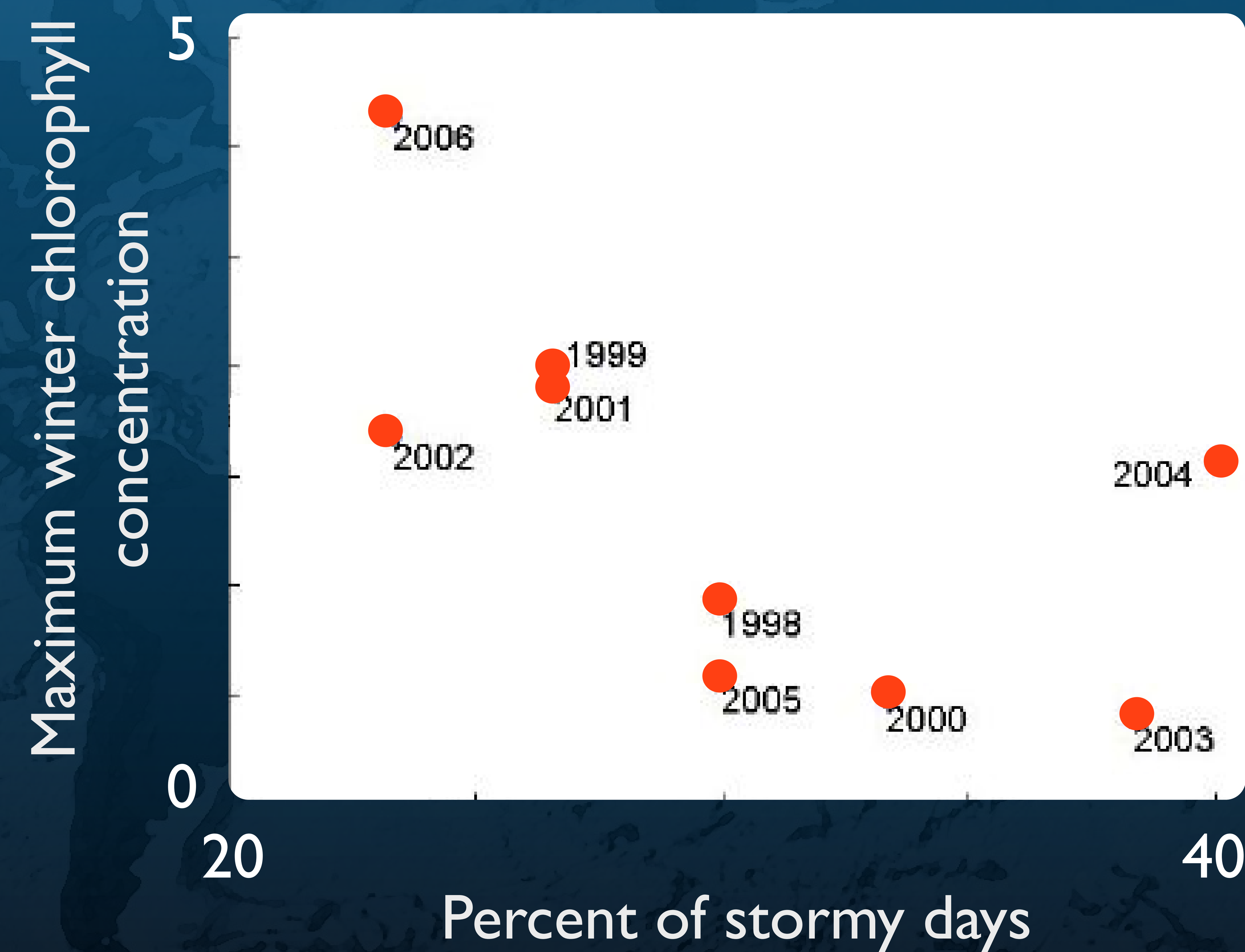
Dynamics in phytoplankton variance is described by 2 modes. Mode 1 occurs in the winter on the inner shelf. Mode 2 occurs in spring on the outer shelf. Summer phytoplankton explain little of the shelf-wide variance however is extremely important to the nearshore coastal ecosystems



Two major EOF modes



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

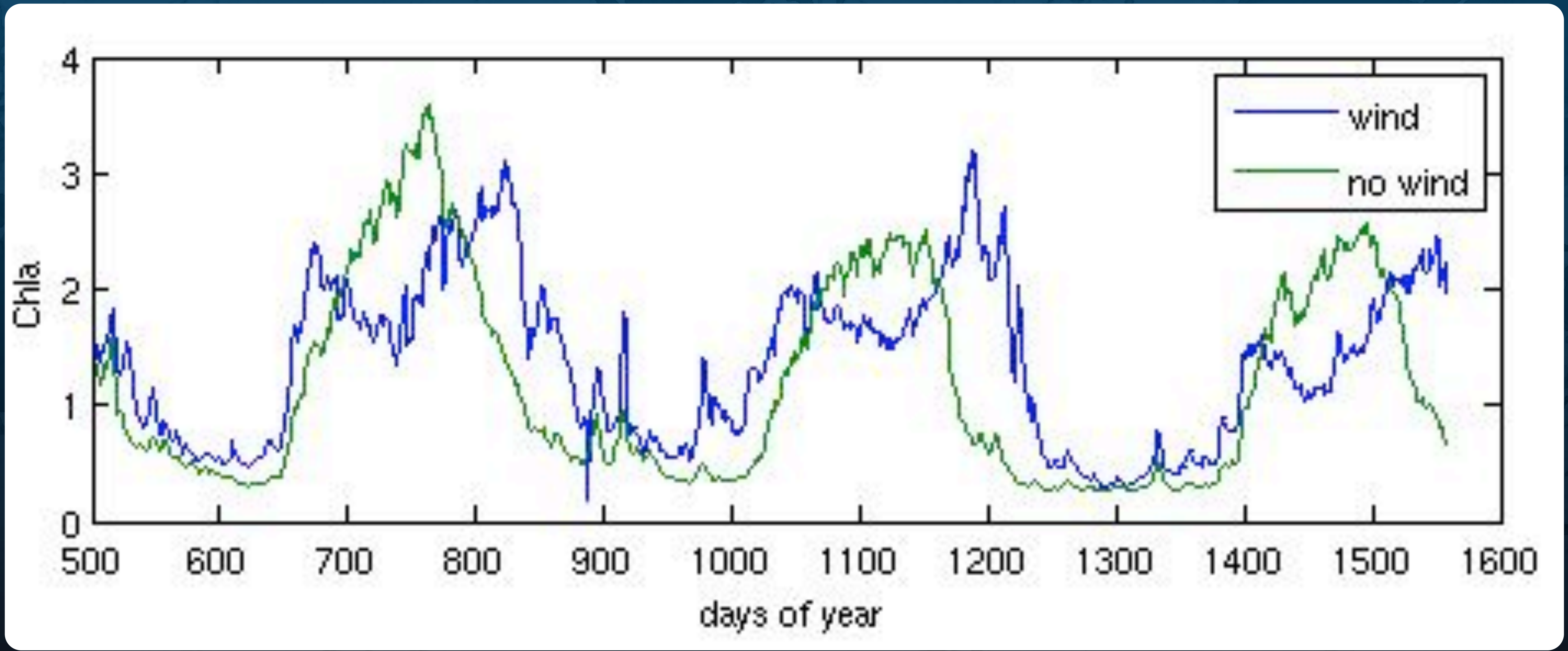


Maximum winter chlorophyll concentration
5
0
20
40
Percent of stormy days
2006
1999
2001
2002
2004
1998
2005
2000
2003

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%

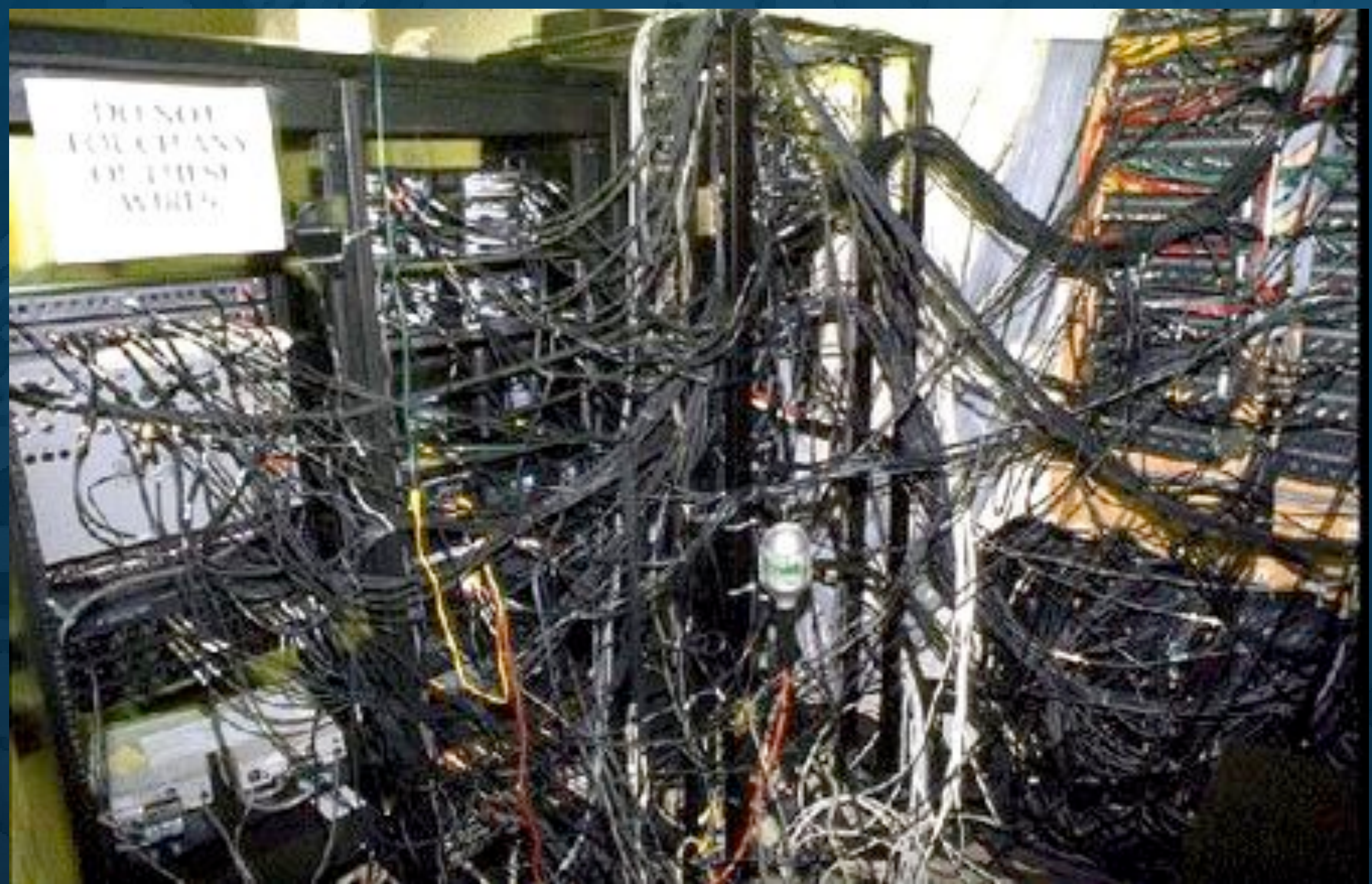
Yi et al submitted



WHERE DO WE GO FROM HERE?

WHERE DO WE GO FROM HERE?

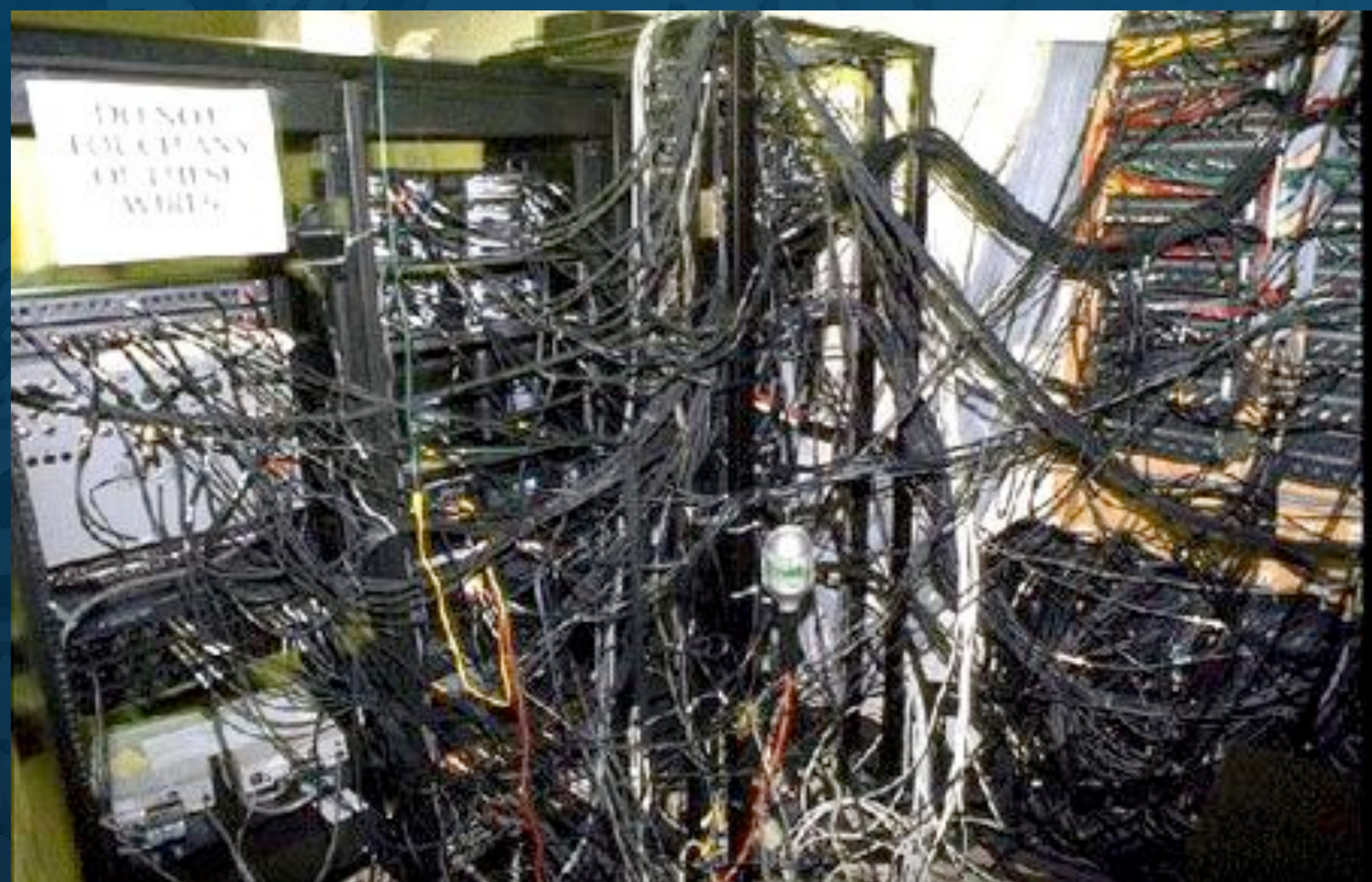
Machines have improved



A technicians solution
in integrating the observatory
components

WHERE DO WE GO FROM HERE?

Machines have improved



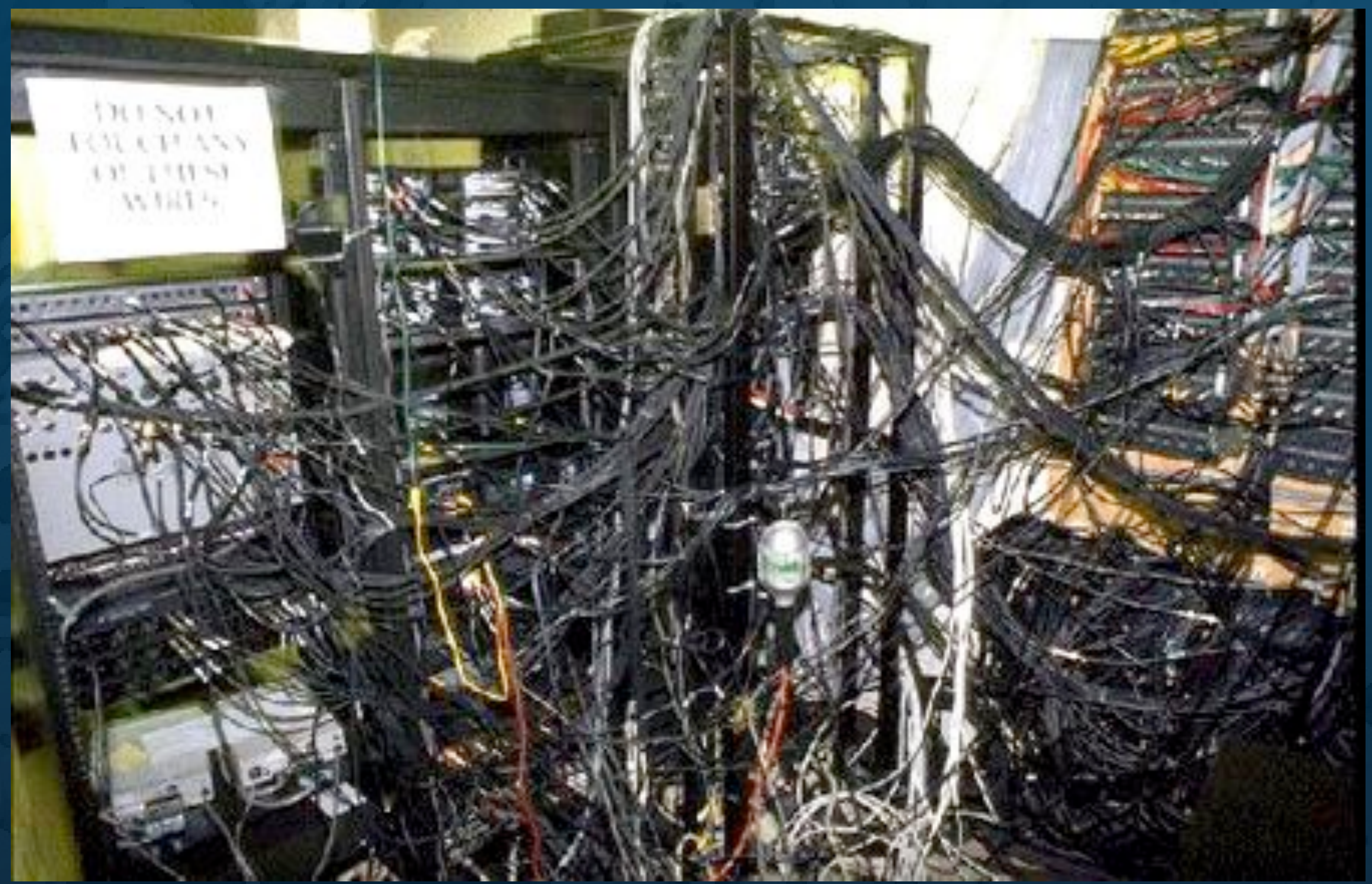
A technicians solution
in integrating the observatory
components

People need to sleep
and are fragile

Humans become the
bottle neck for
collecting data bytes

WHERE DO WE GO FROM HERE?

Machines have improved

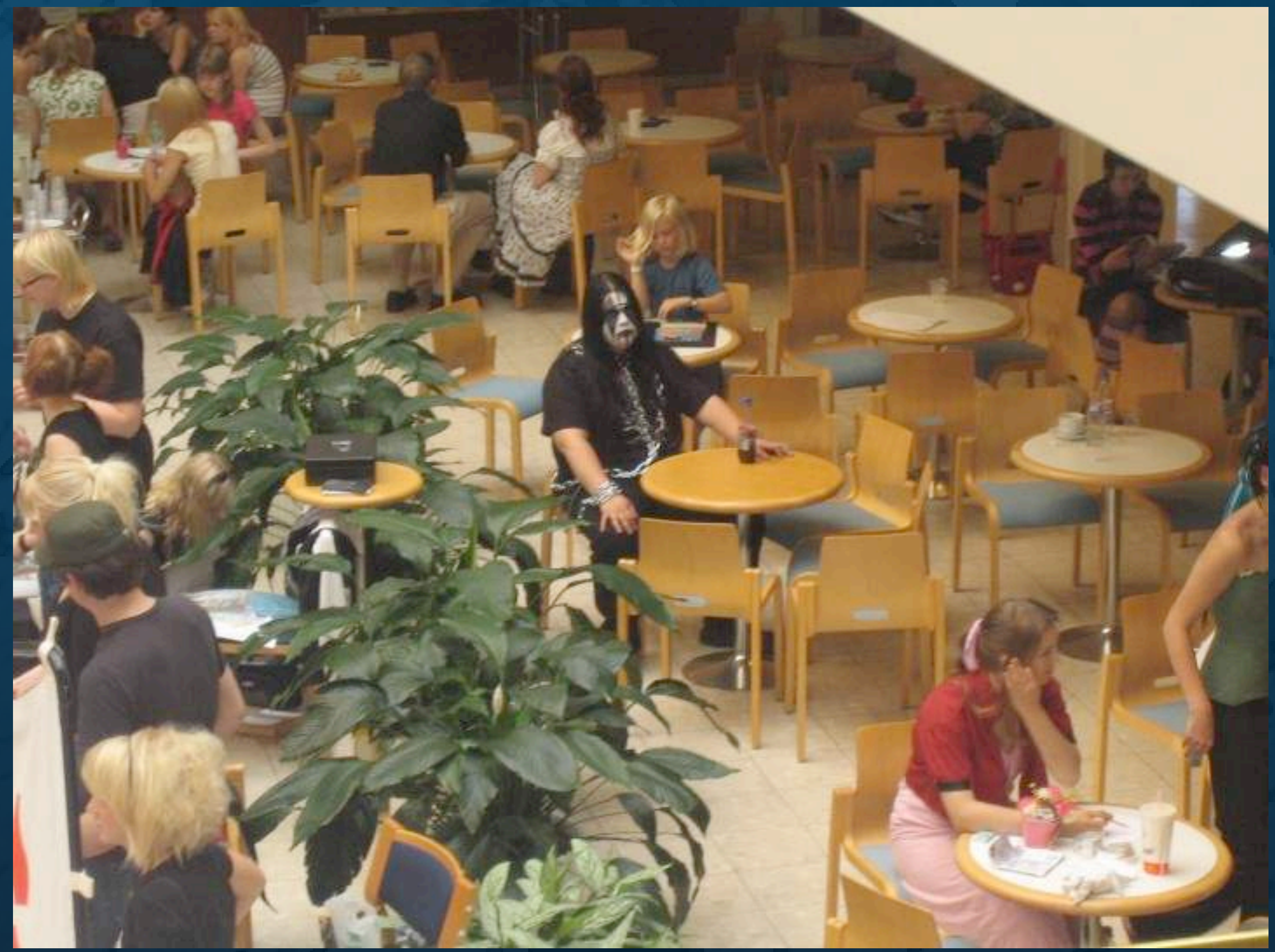


A technicians solution in integrating the observatory components

People need to sleep and are fragile

Humans become the bottle neck for collecting data bytes

Scientists need time to think



Oscar tries to reintegrate into society after the field experiments

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

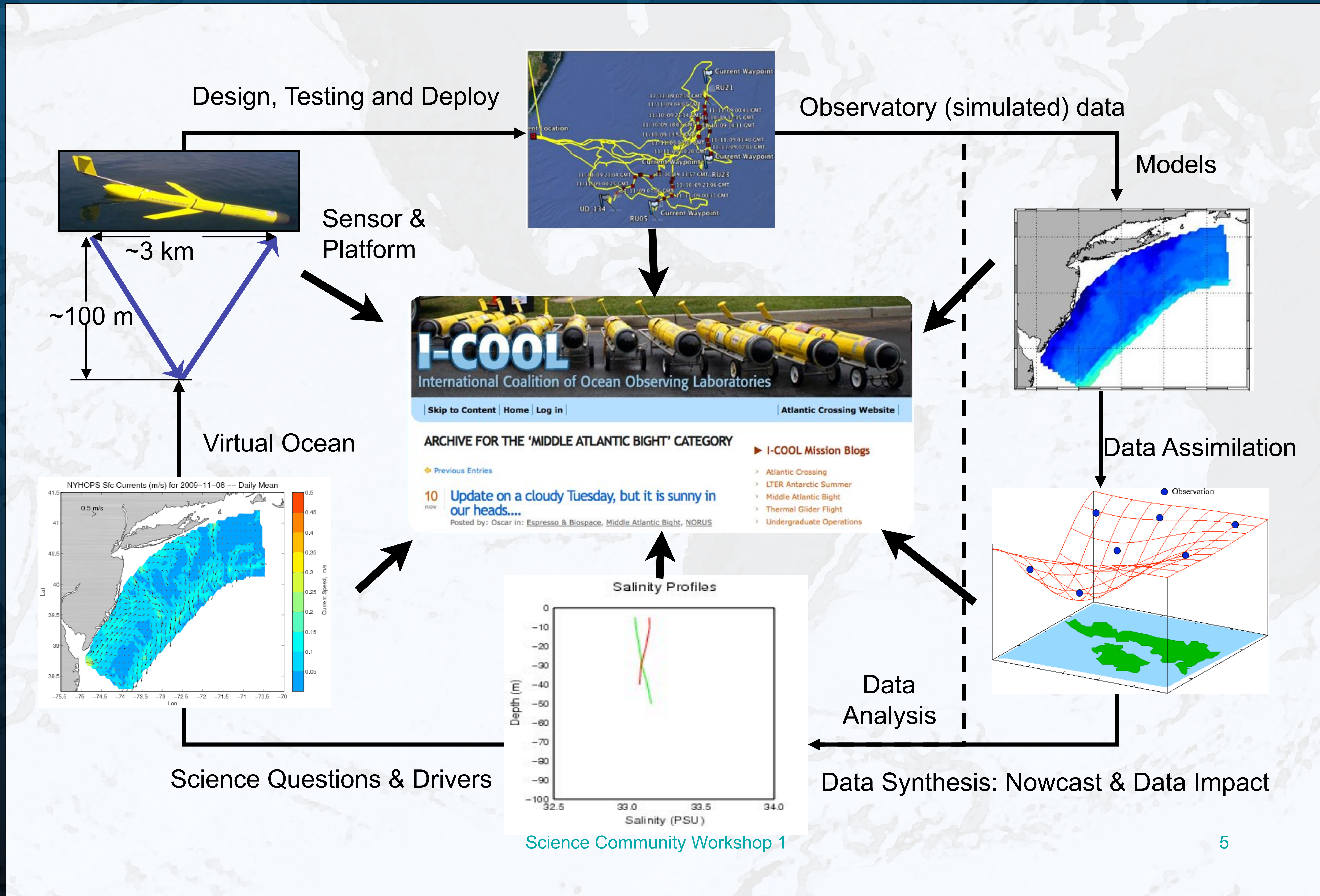
Idea of Test
(May 2009)

↓

Virtual Test
(Sep 2009)

↓

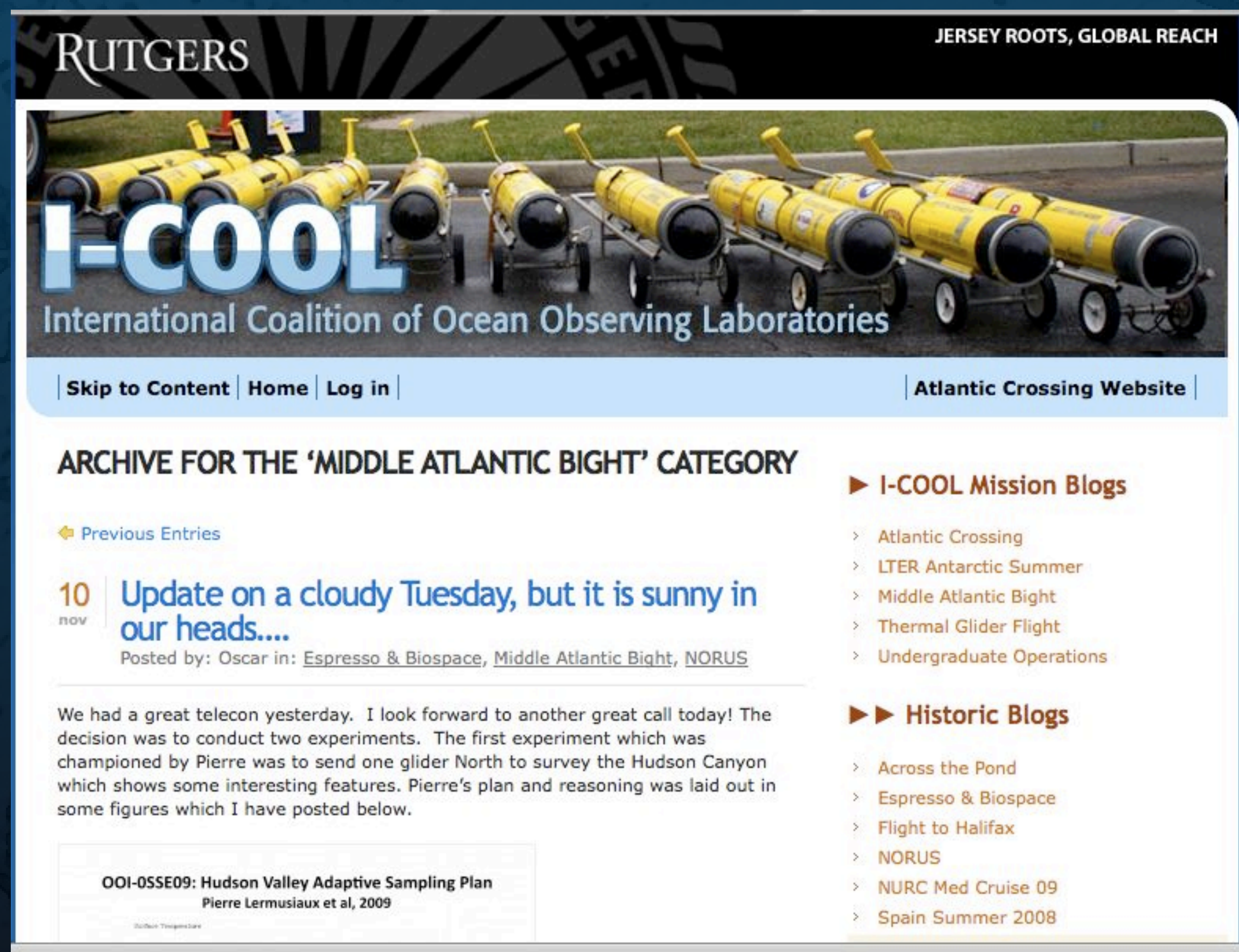
Wet Test
(Nov 2009)



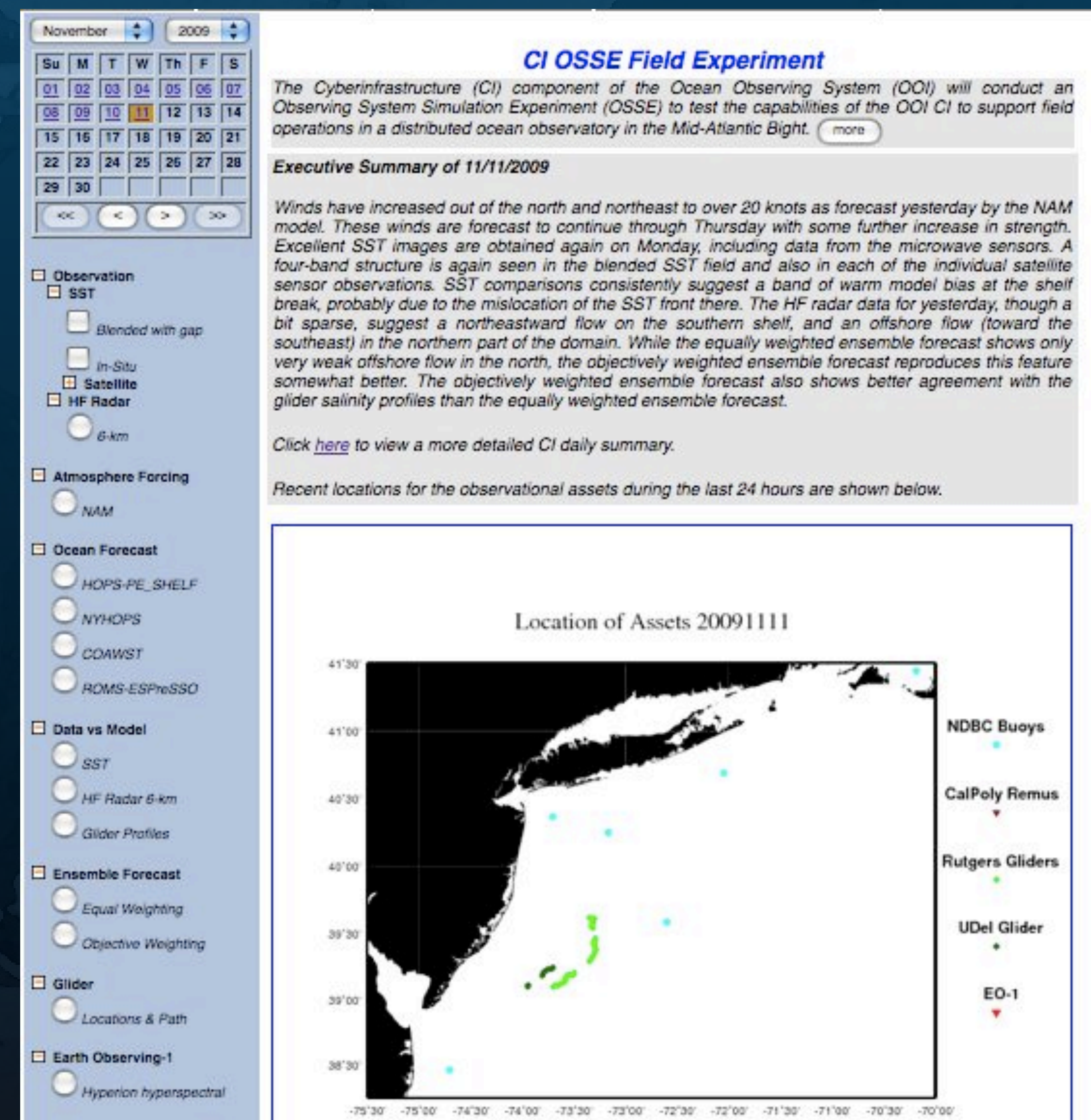
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

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

Community Blog

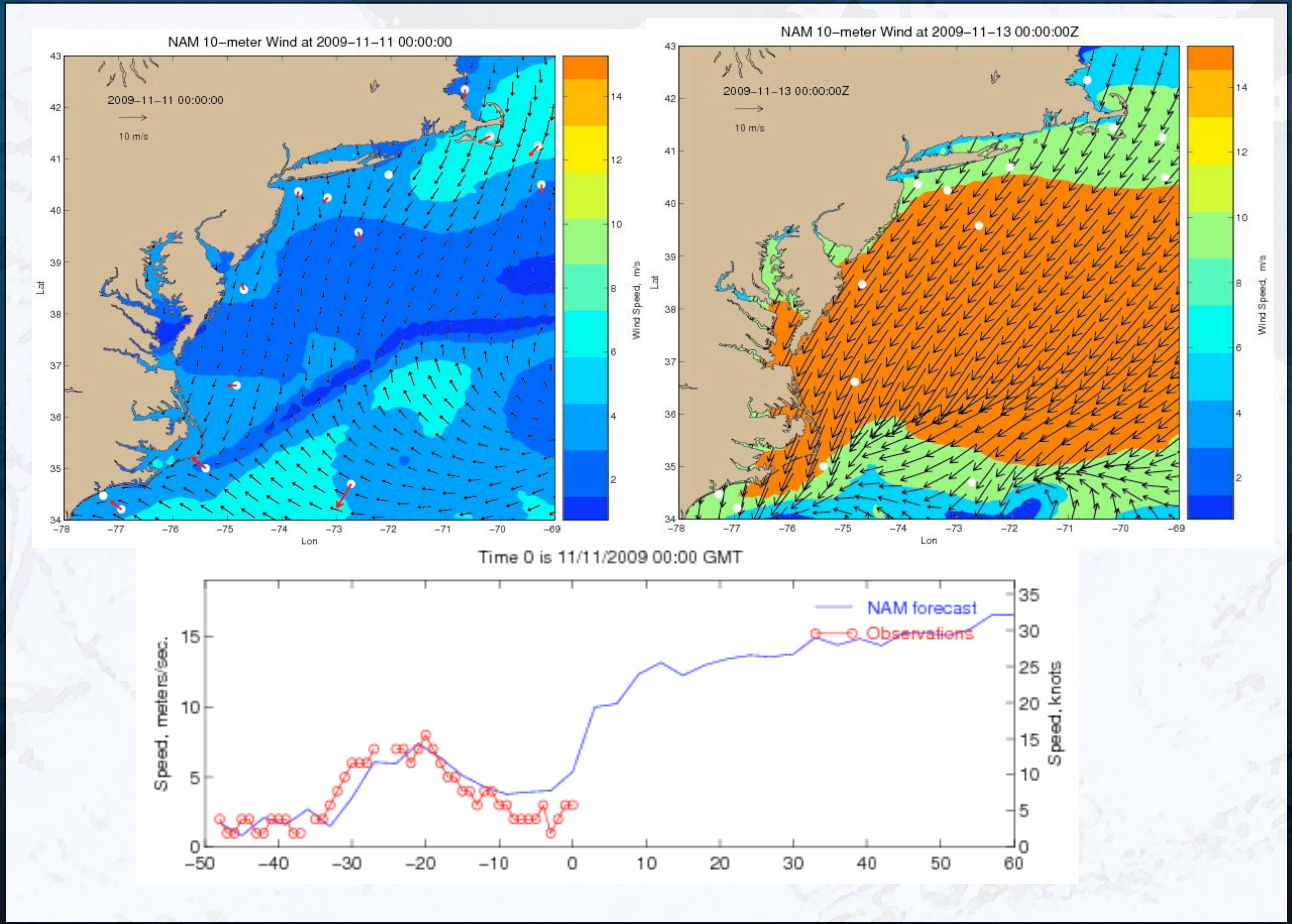


Data Portal



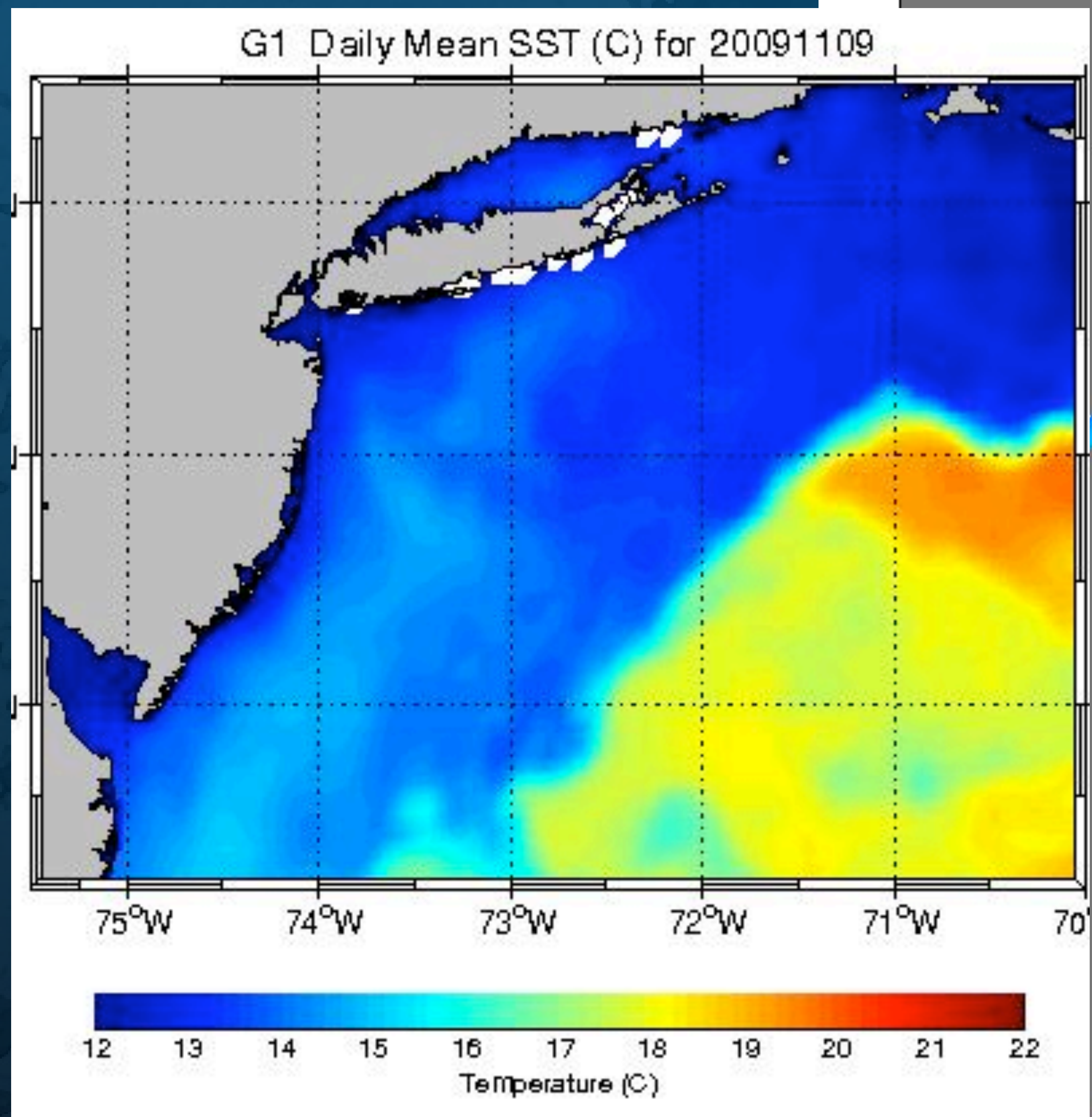
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

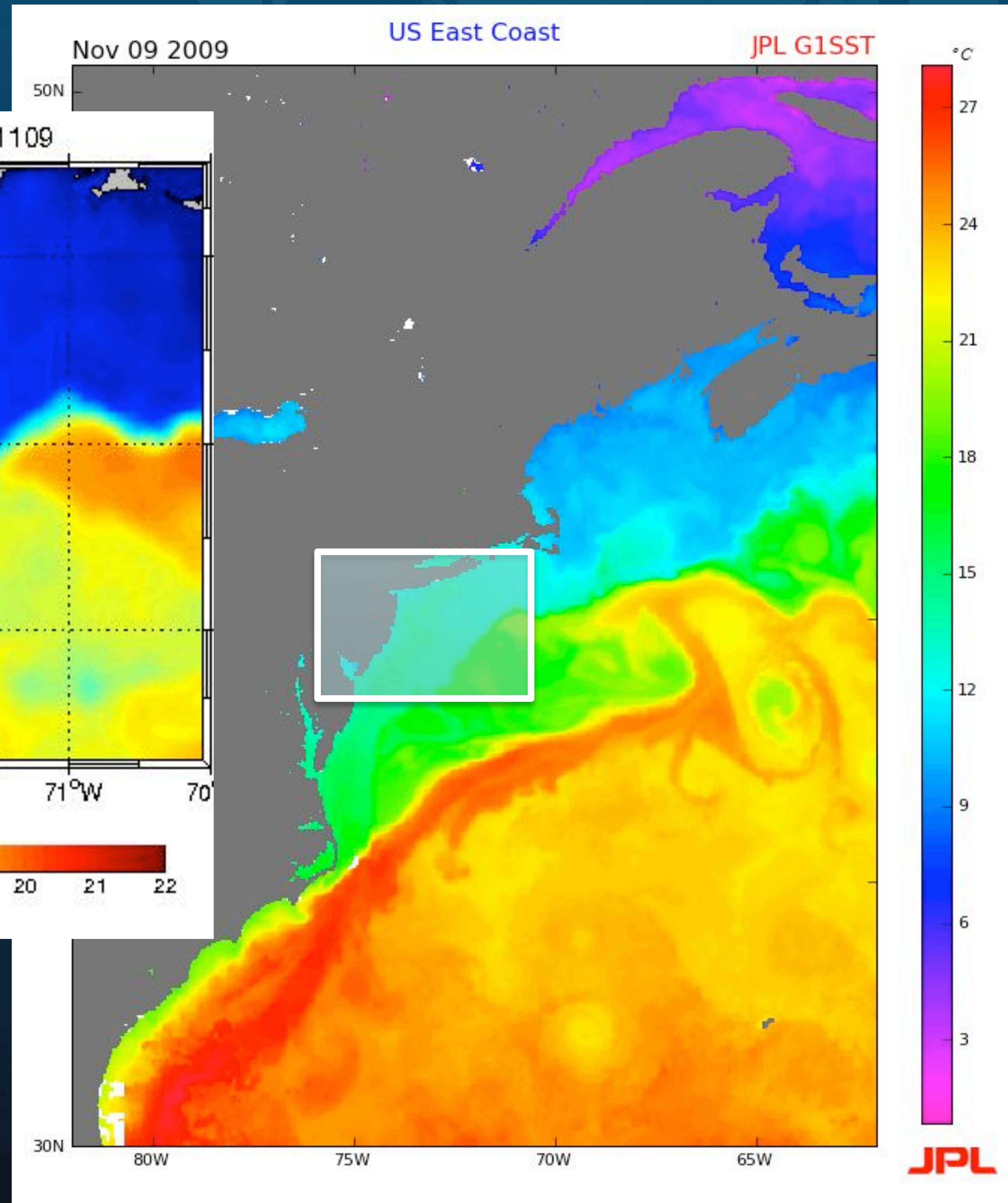
Weather Forecasts



The OOI Observing System Experiment (OSE)

5 different satellite sensors

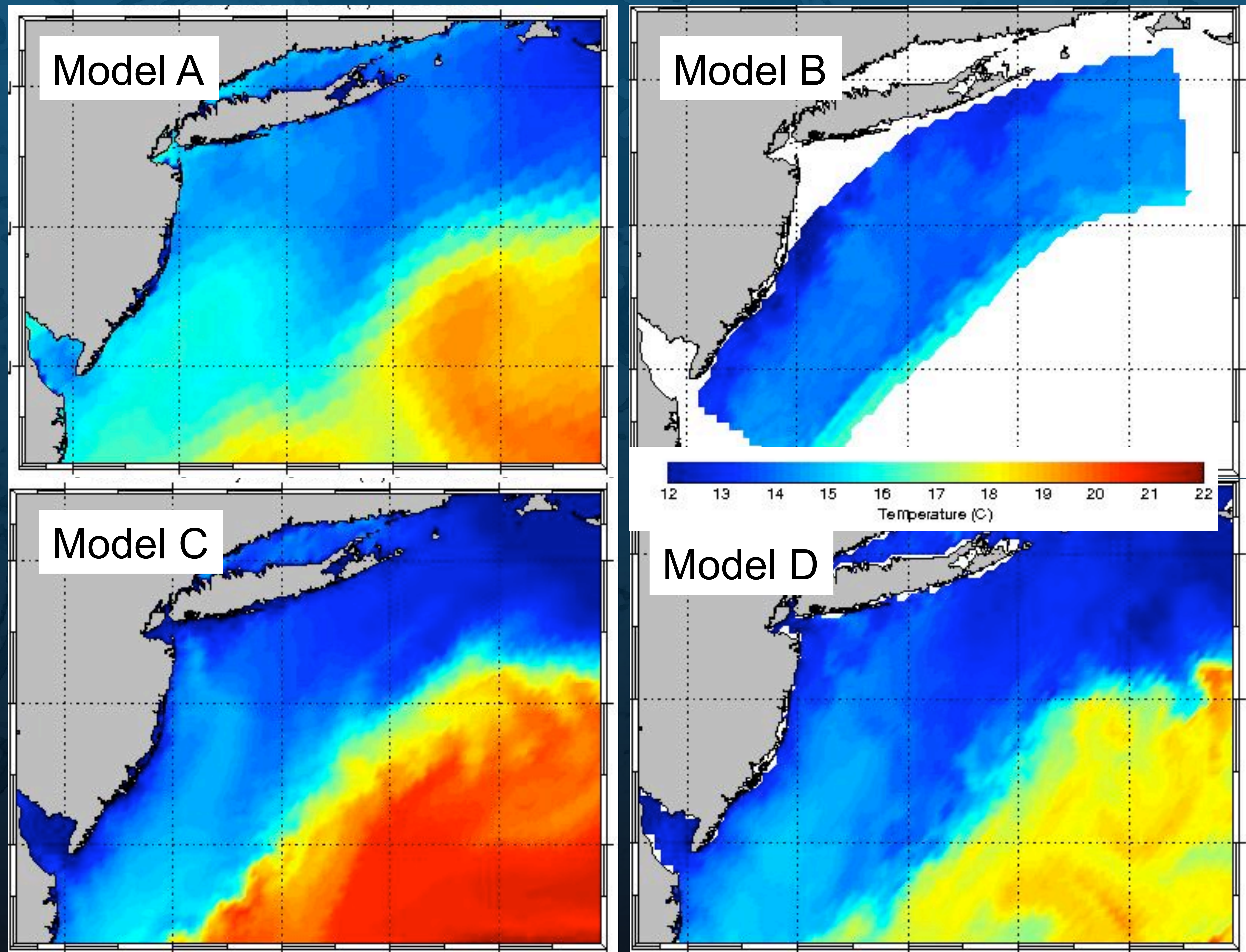




The OOI Observing System Experiment (OSE)

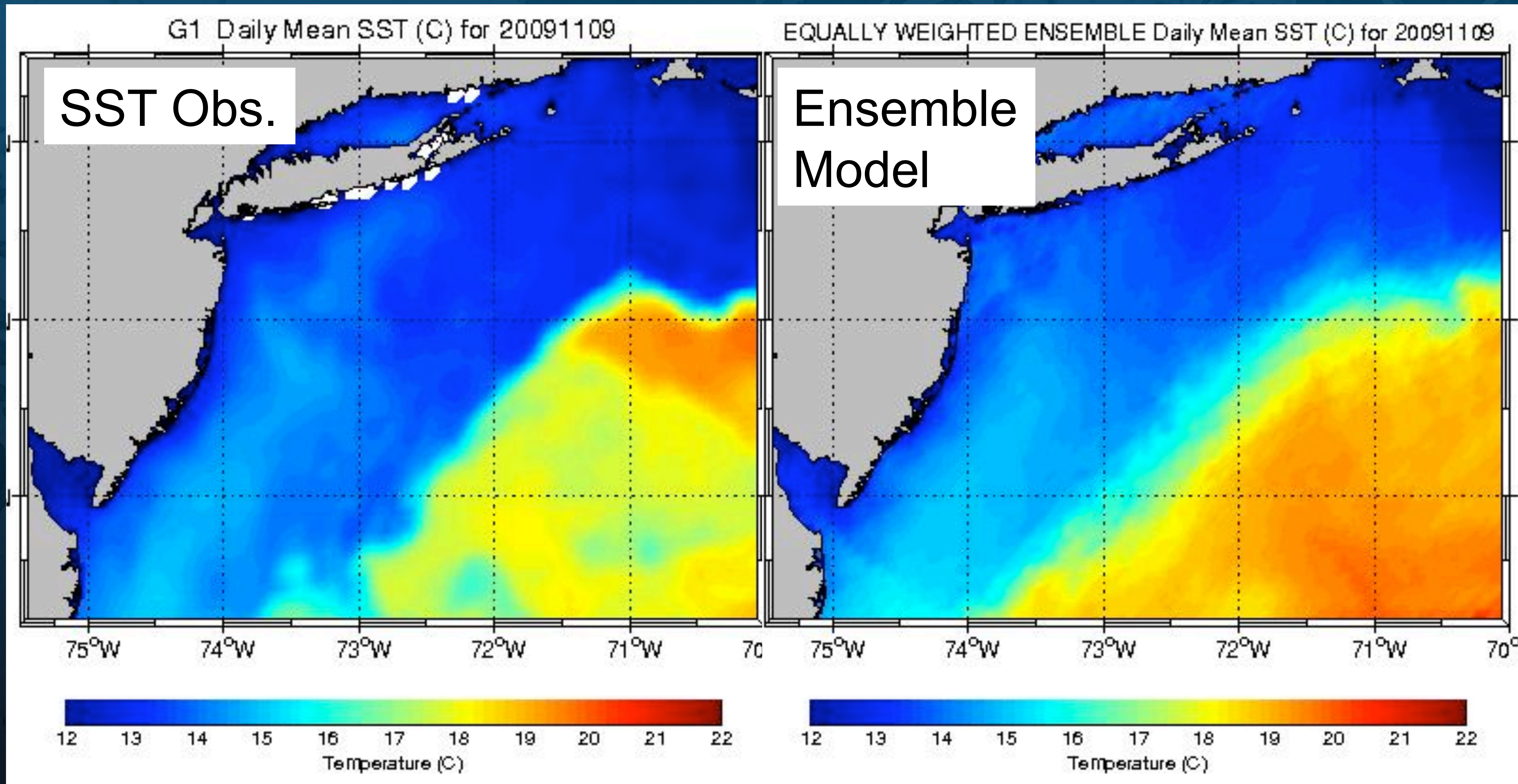
5 ocean numerical models run in forecast mode:

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



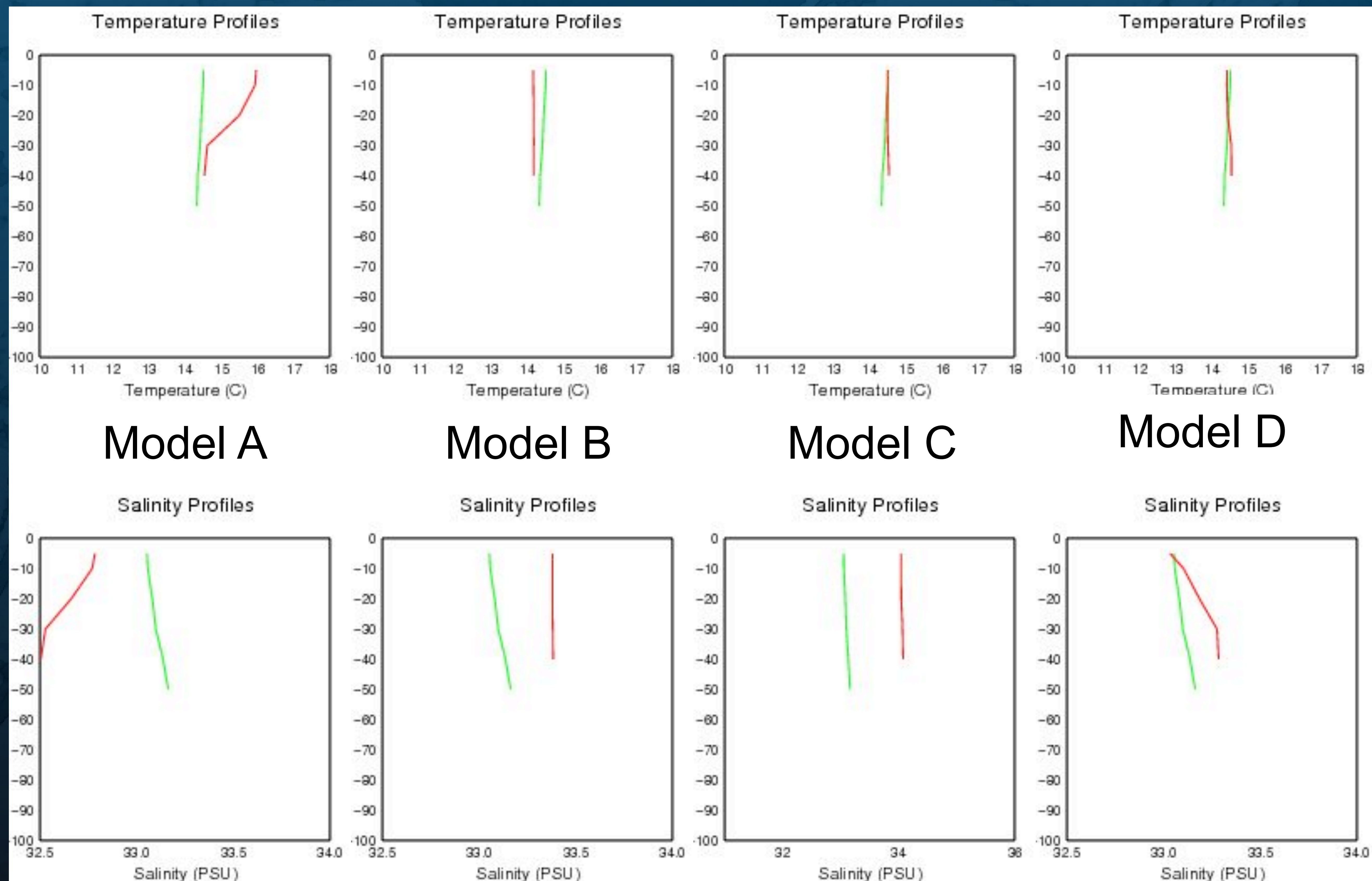
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

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



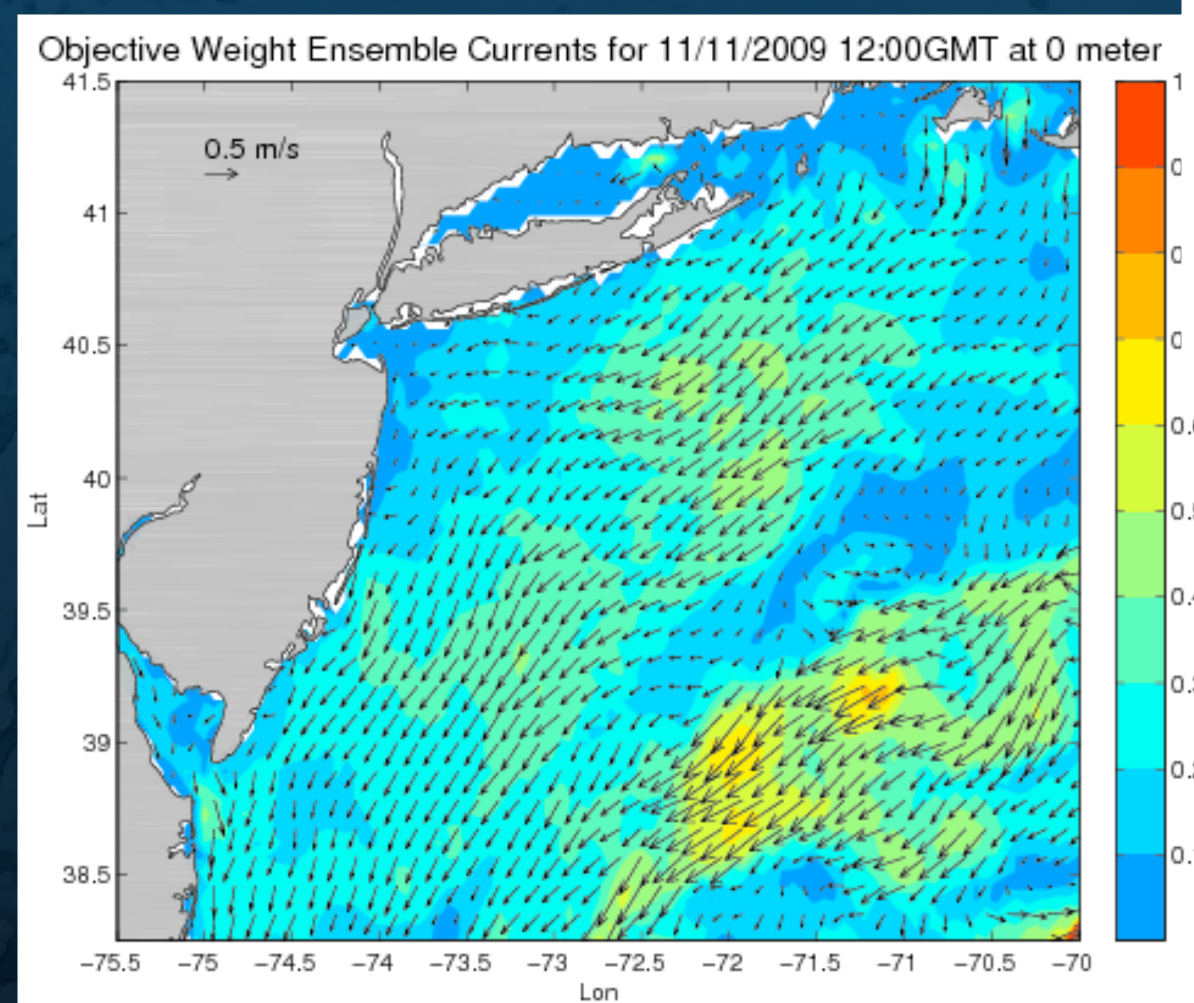
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

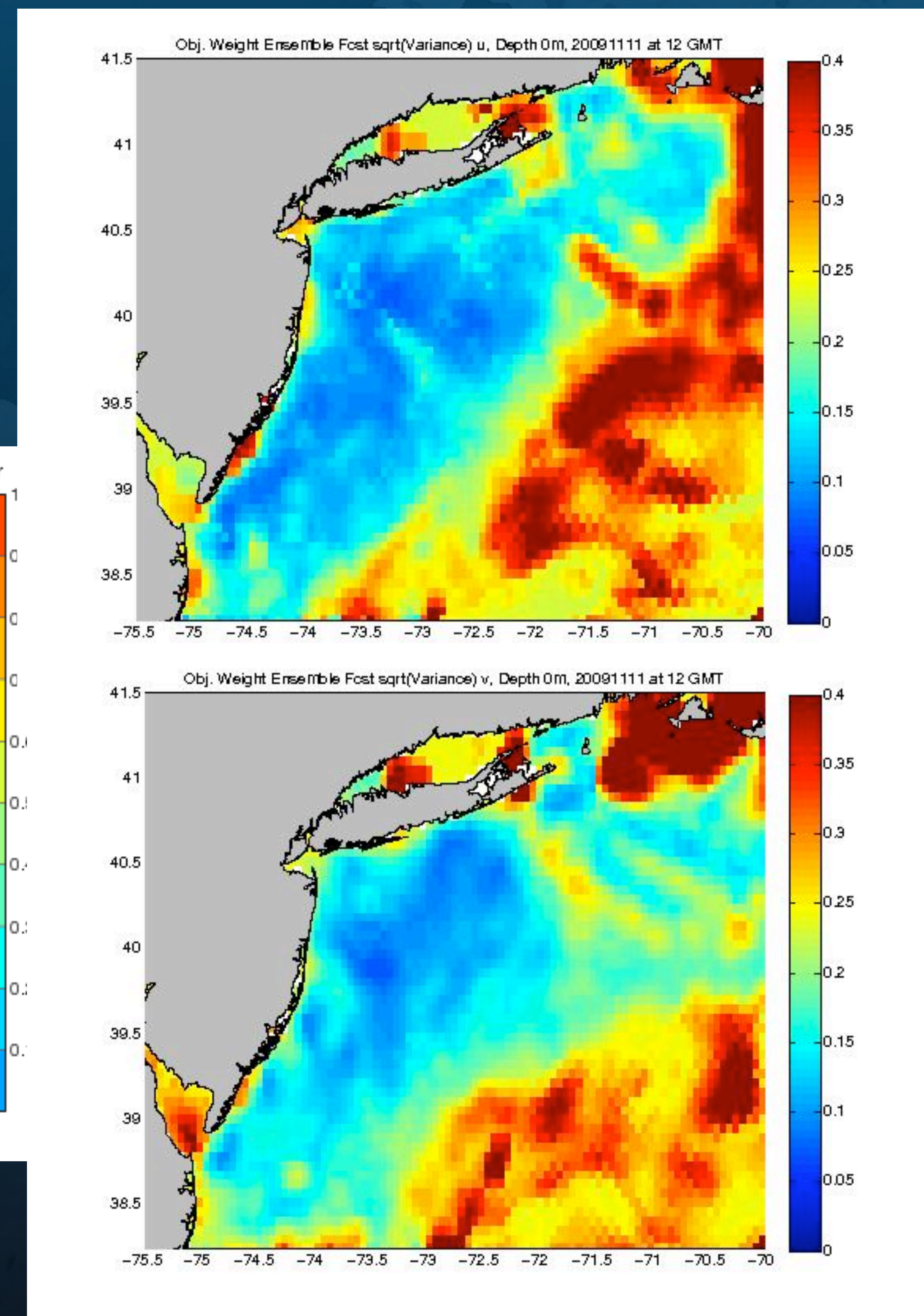
The same for *in situ* measurements



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

Ensemble mean model

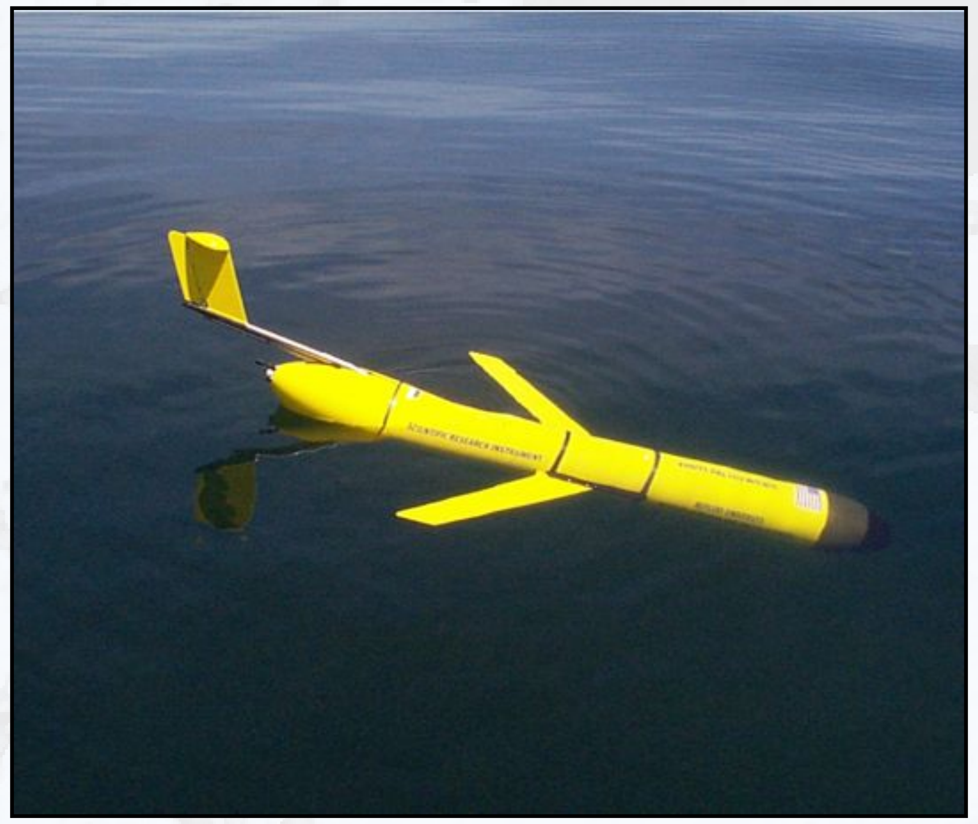




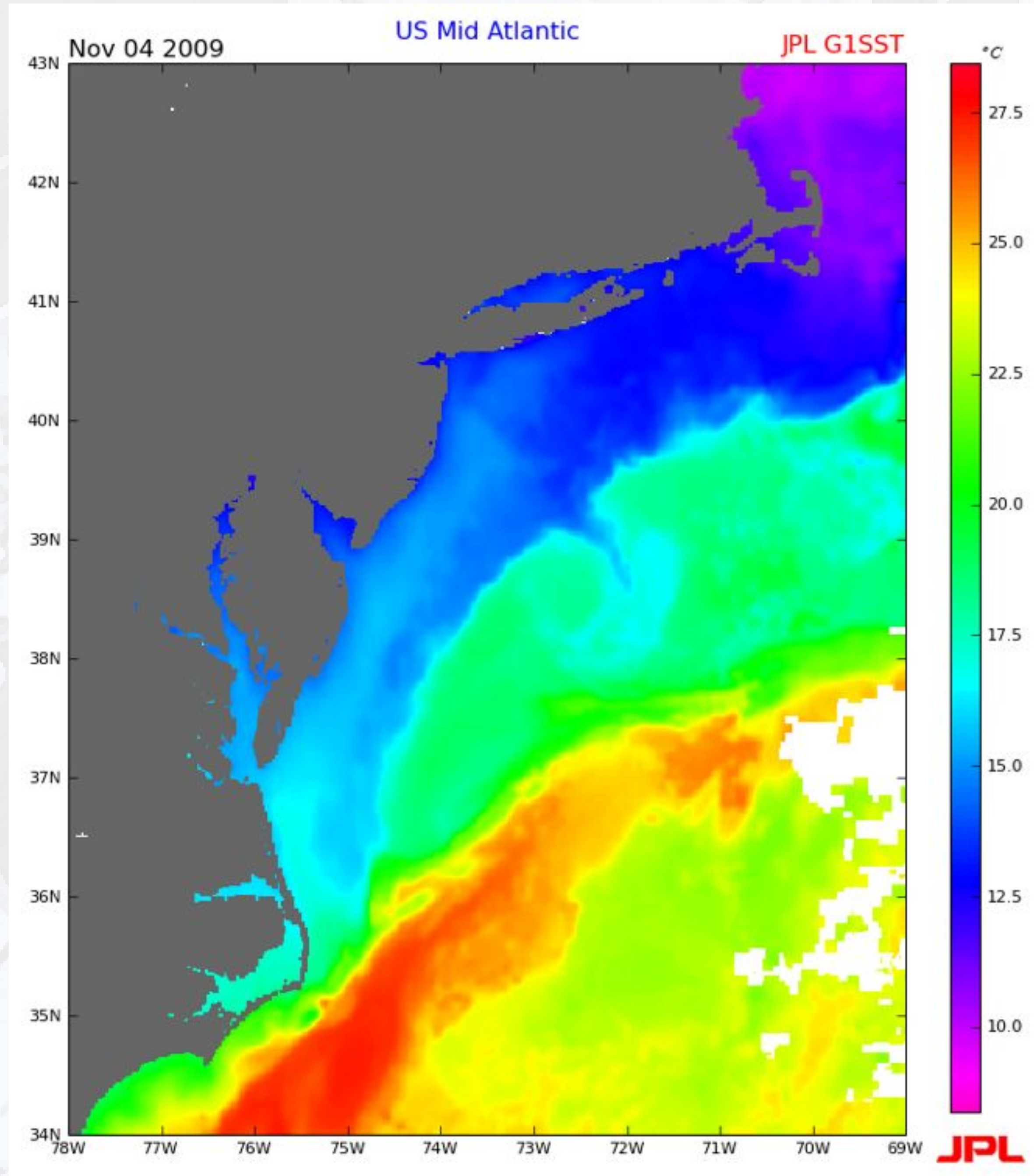
Variance in *u* velocity component

Variance in *v* velocity component

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



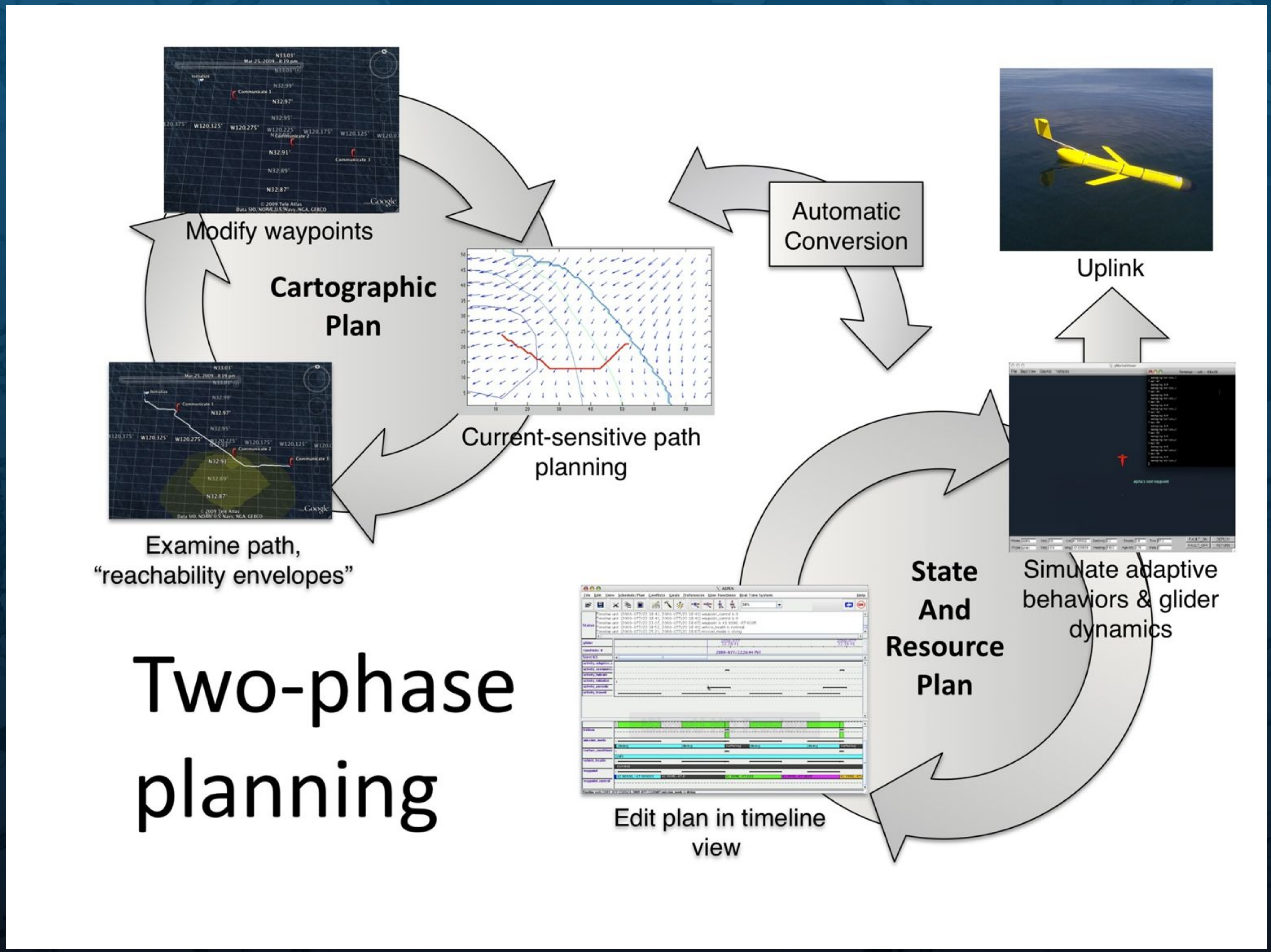
- Known constraints (slow 0.5 knot, Battery, shipping lanes)
- Uncertain constraints (time-varying 3D currents)
- Operate autonomously & re-plan daily



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

The OOI Observing System Experiment (OSE)

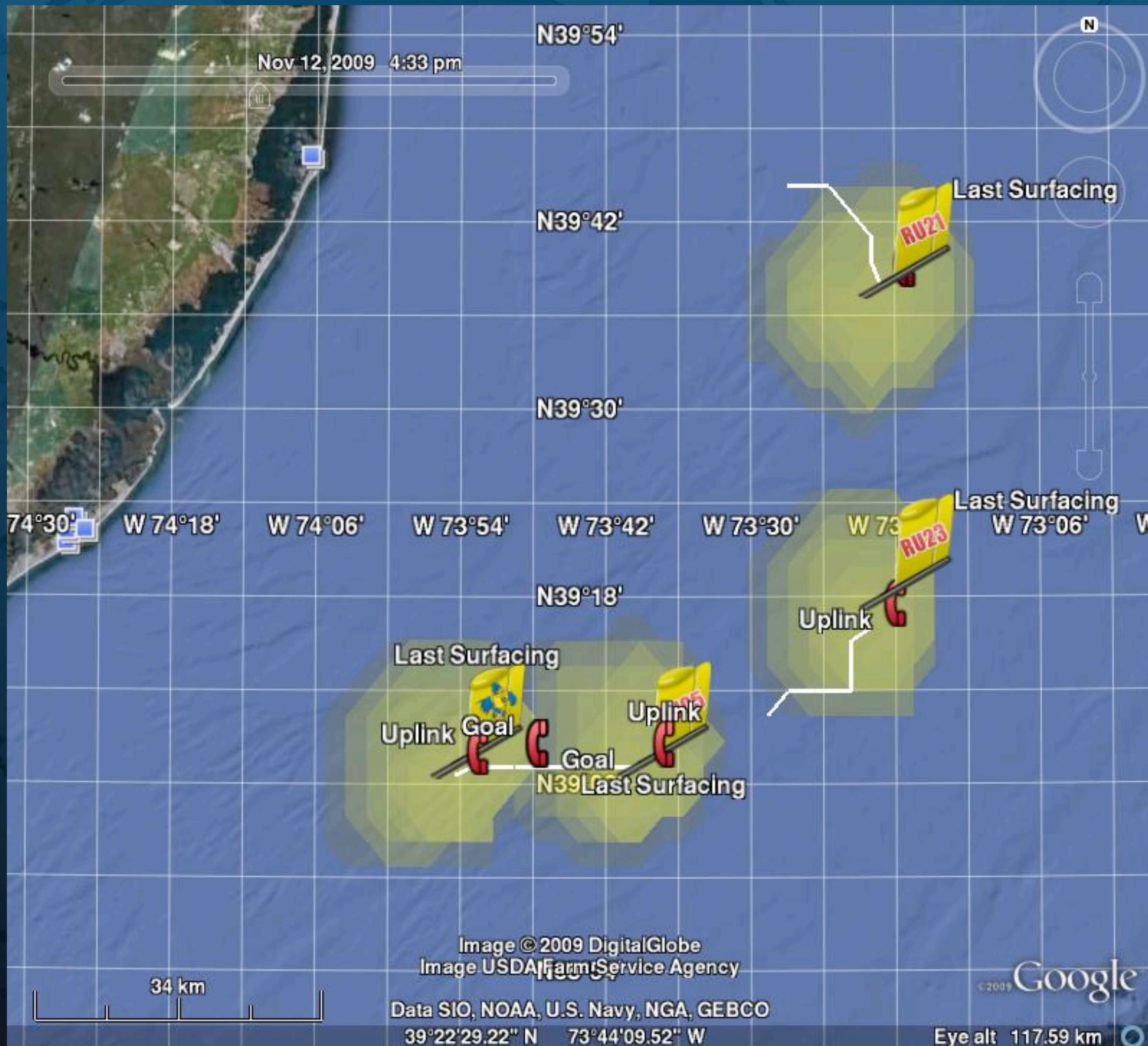
Scientific community



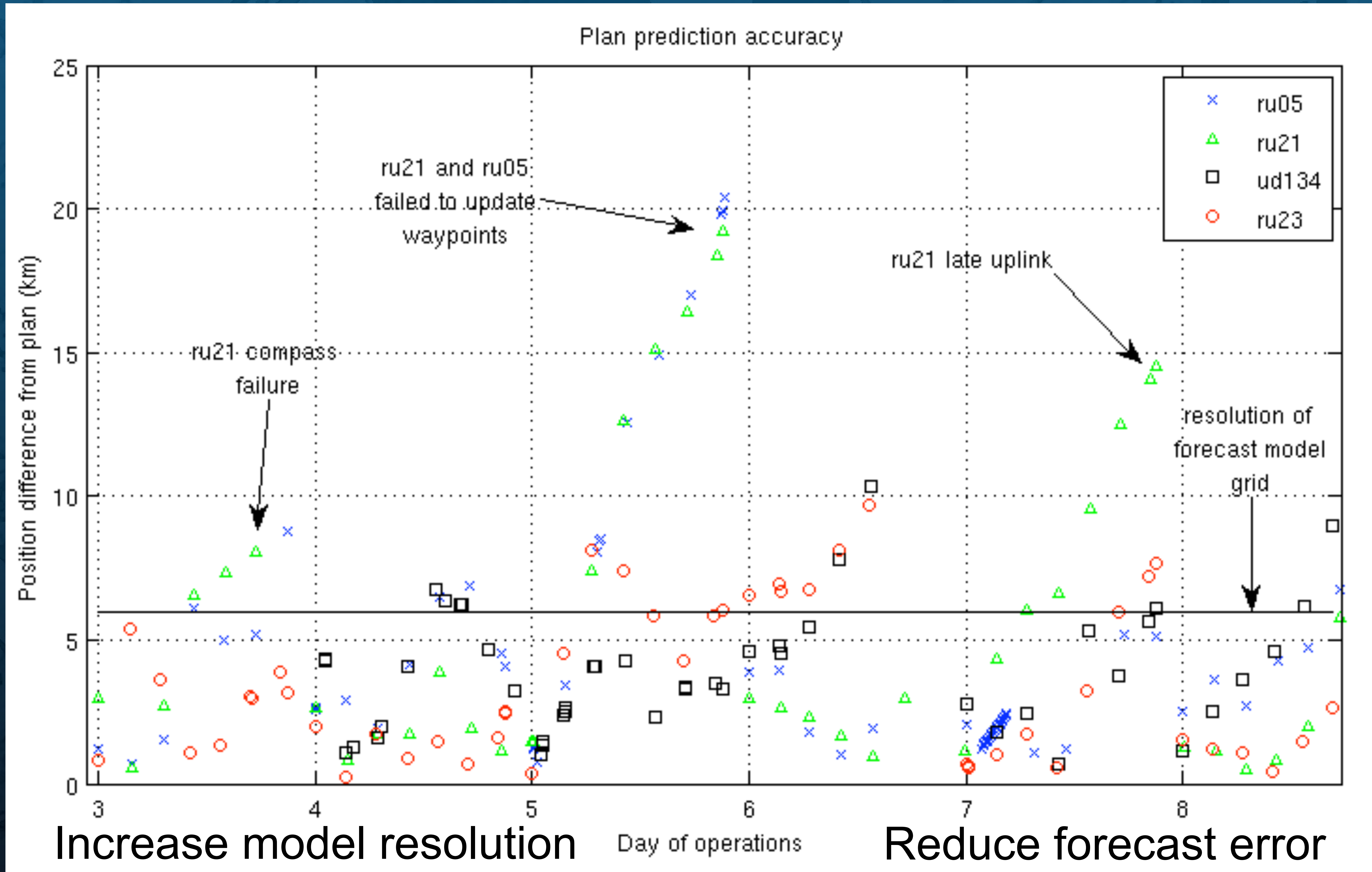
Marine operators

The OOI Observing System Experiment (OSE)

Distributed decision making
using live web service tools

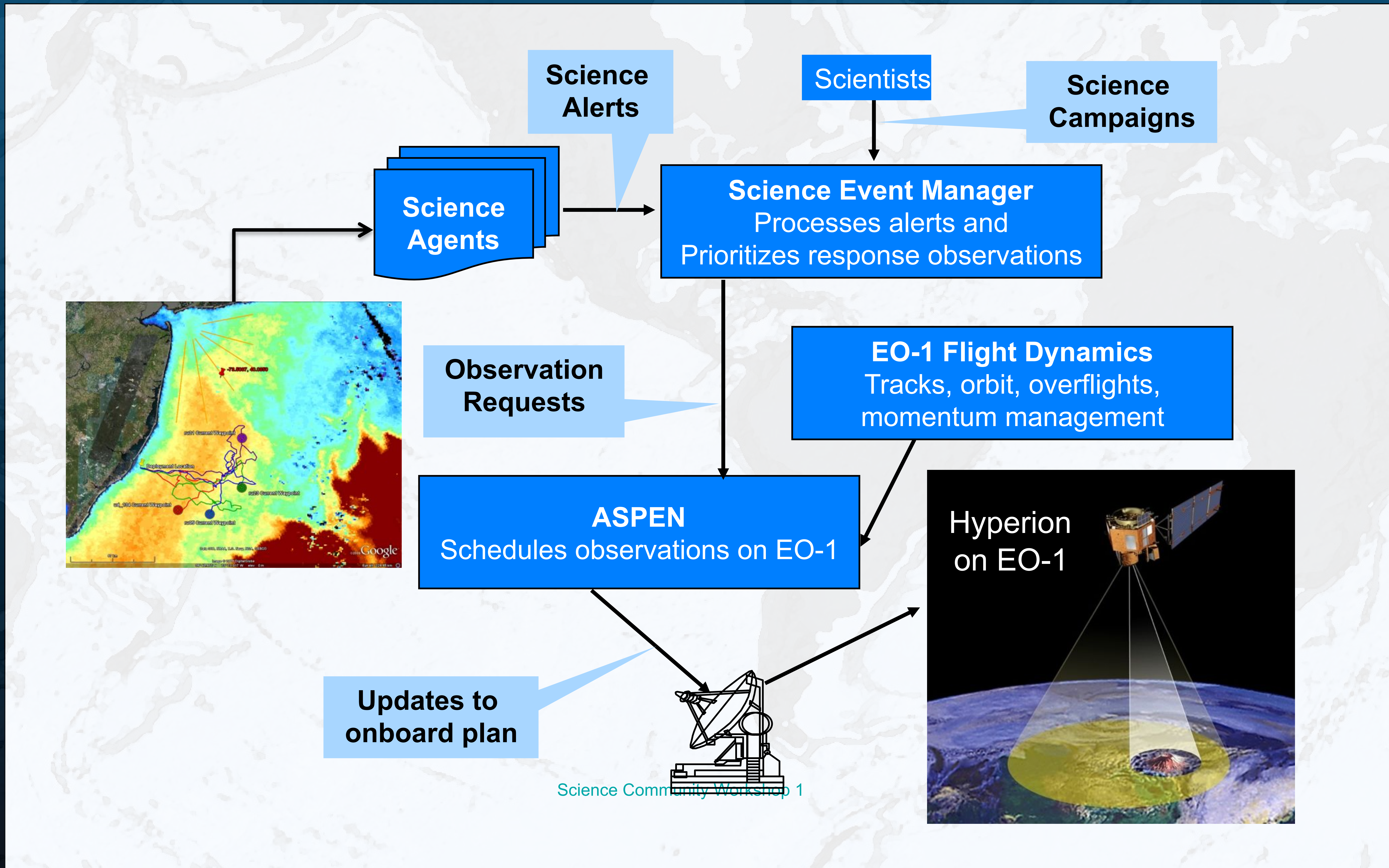


The OOI Observing System Experiment (OSE)



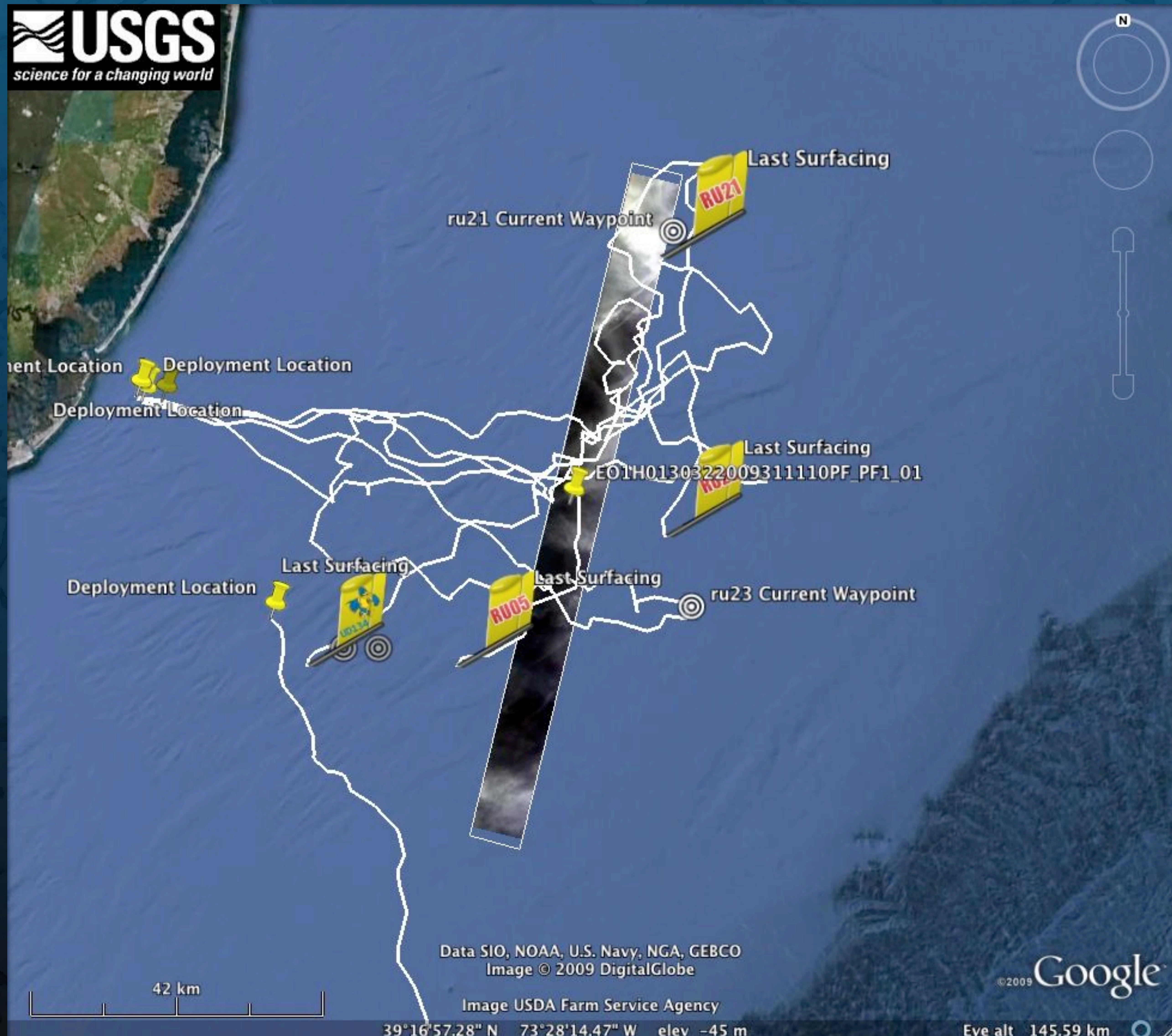
How well did we do?

The OOI Observing System Experiment (OSE)



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)




19 YEARS
CAUTION