The view of the Mid-Atlantic Bight ecosystem from the COOL room

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

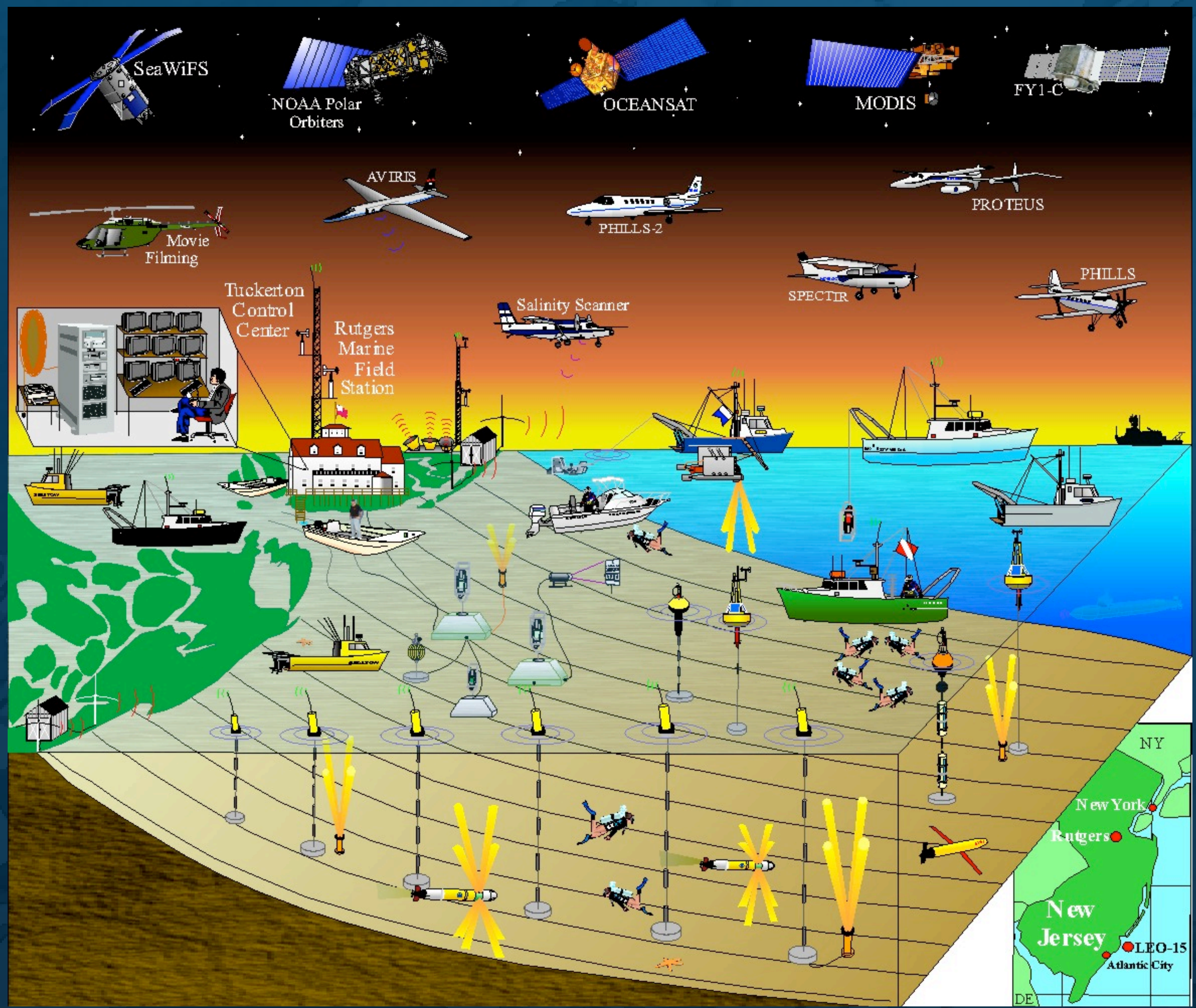
Grad students & Postdocs: Gong, Zhang, Kahl, Gryzmski, Bergmann, Miles, Xu, Durski, Oliver, Sipler, Garzio, Tozzi, Moline, Saba, Montes-Hugo


The Current Team
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

Diverse funding with an evolving suite of questions

Upwelling, hypoxia & coastal predictive skill

Schofield et al 2002
Glenn & Schofield 2003

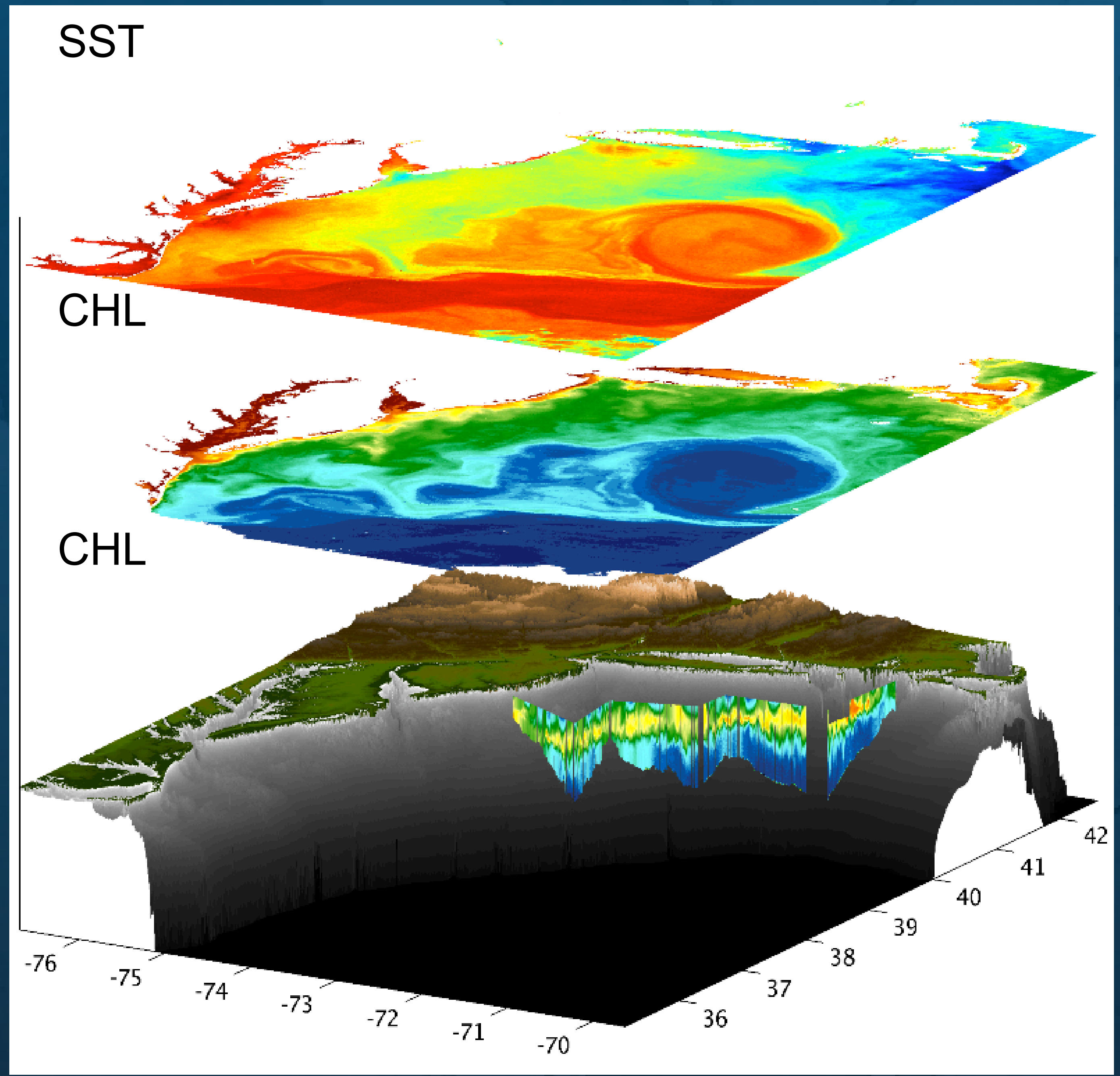


1996-2001
Local scale observatories

→

Shelf transport, land/ocean communication

Glenn & Schofield 2009

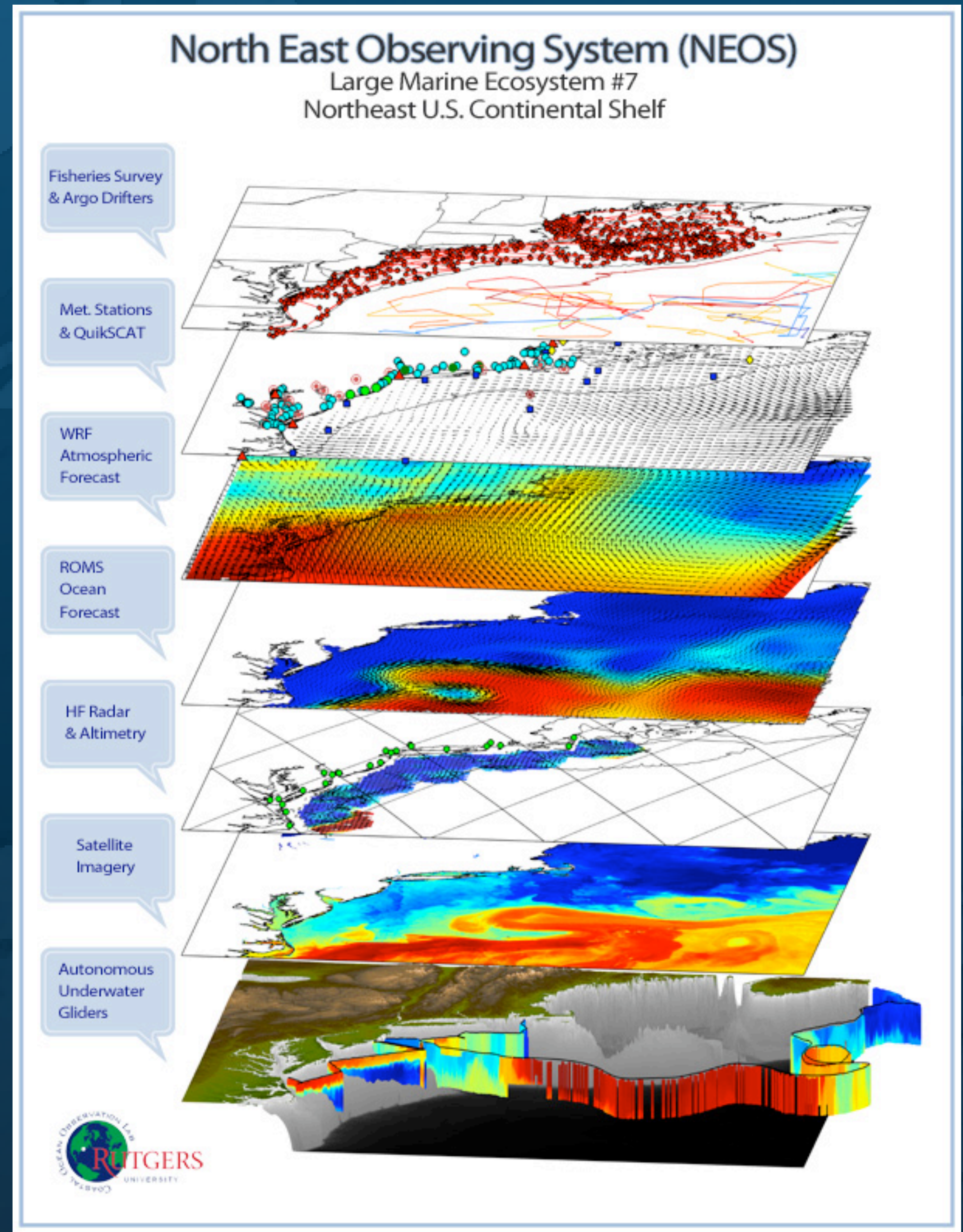


2001-2006
Regional scale observatories

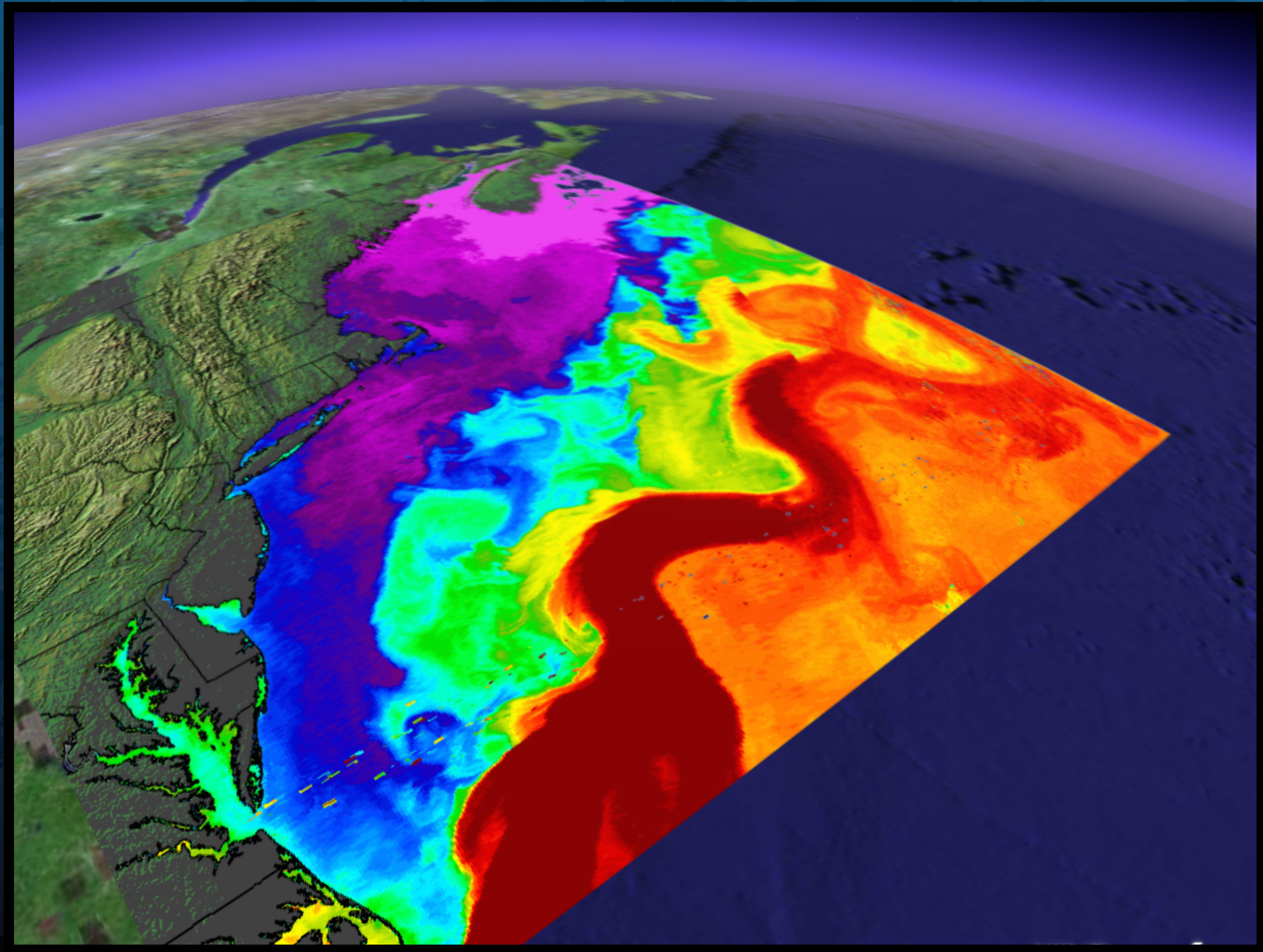
→

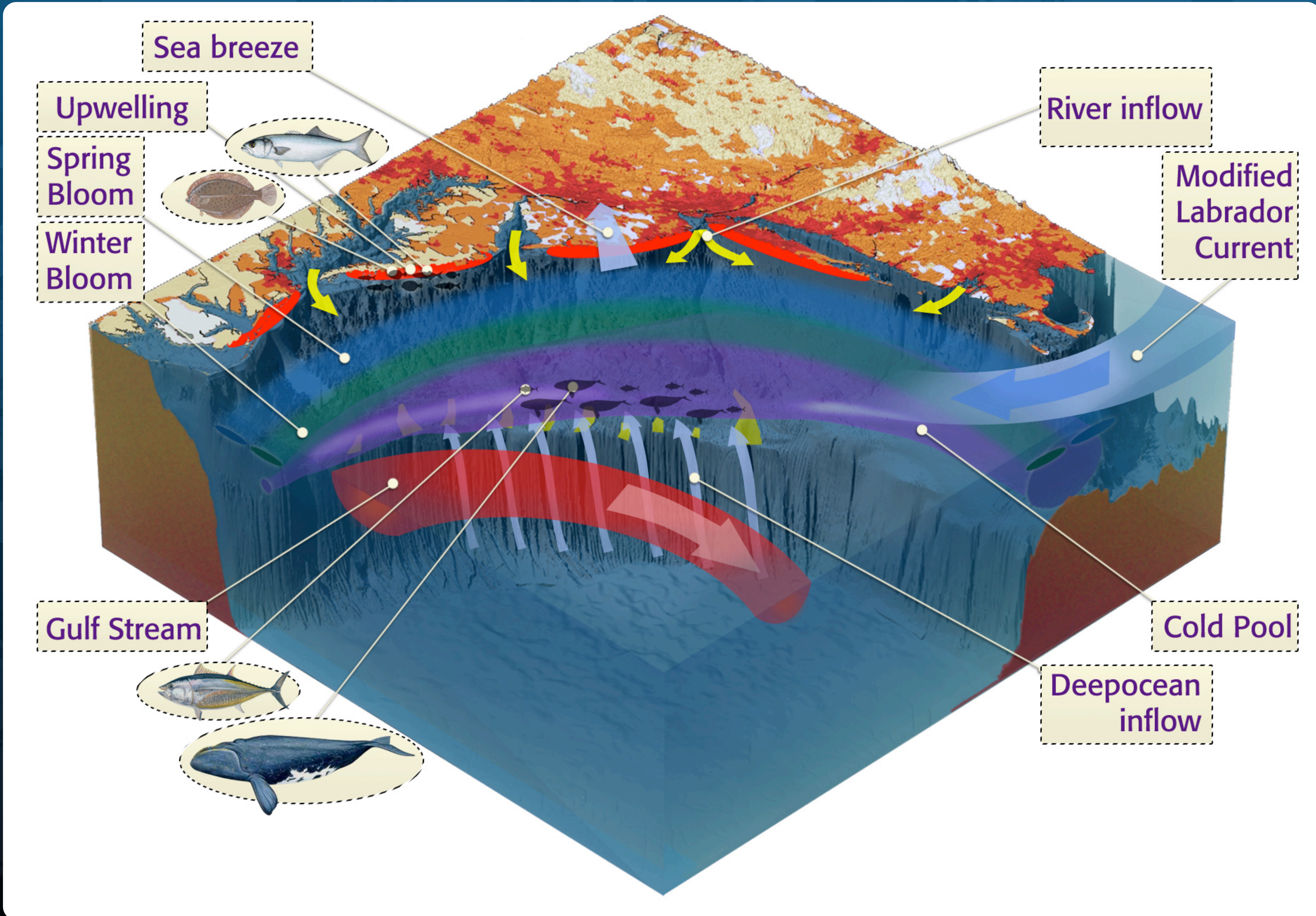
Ecosystem dynamics, climate scale mediated change

Schofield et al. 2011

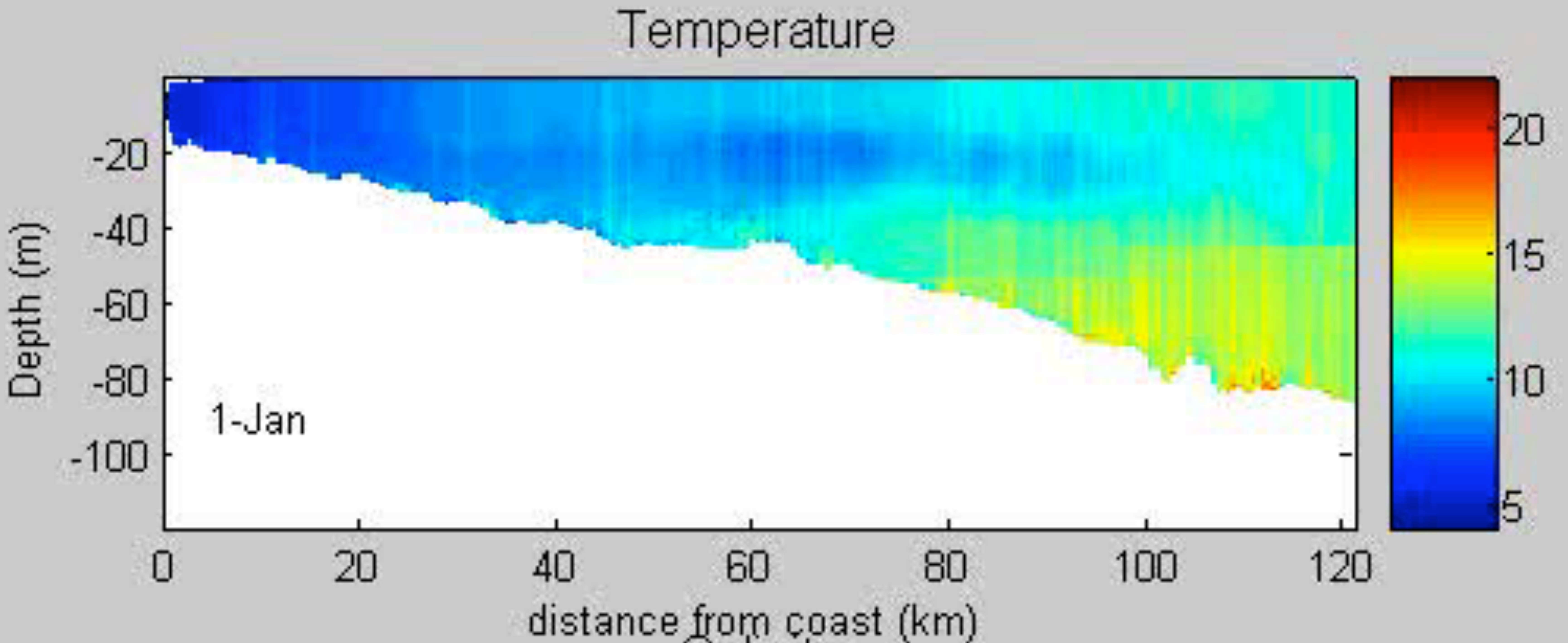


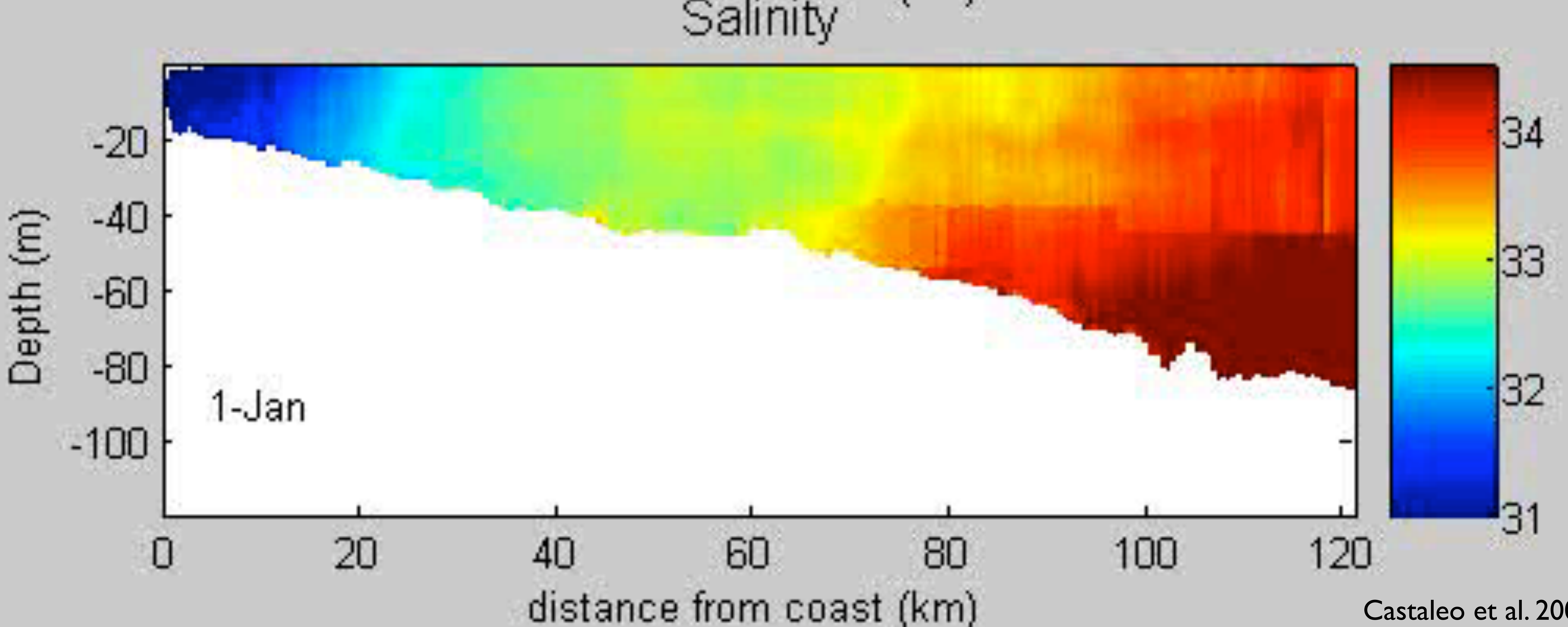
2006-2011
Large marine ecosystem observatories



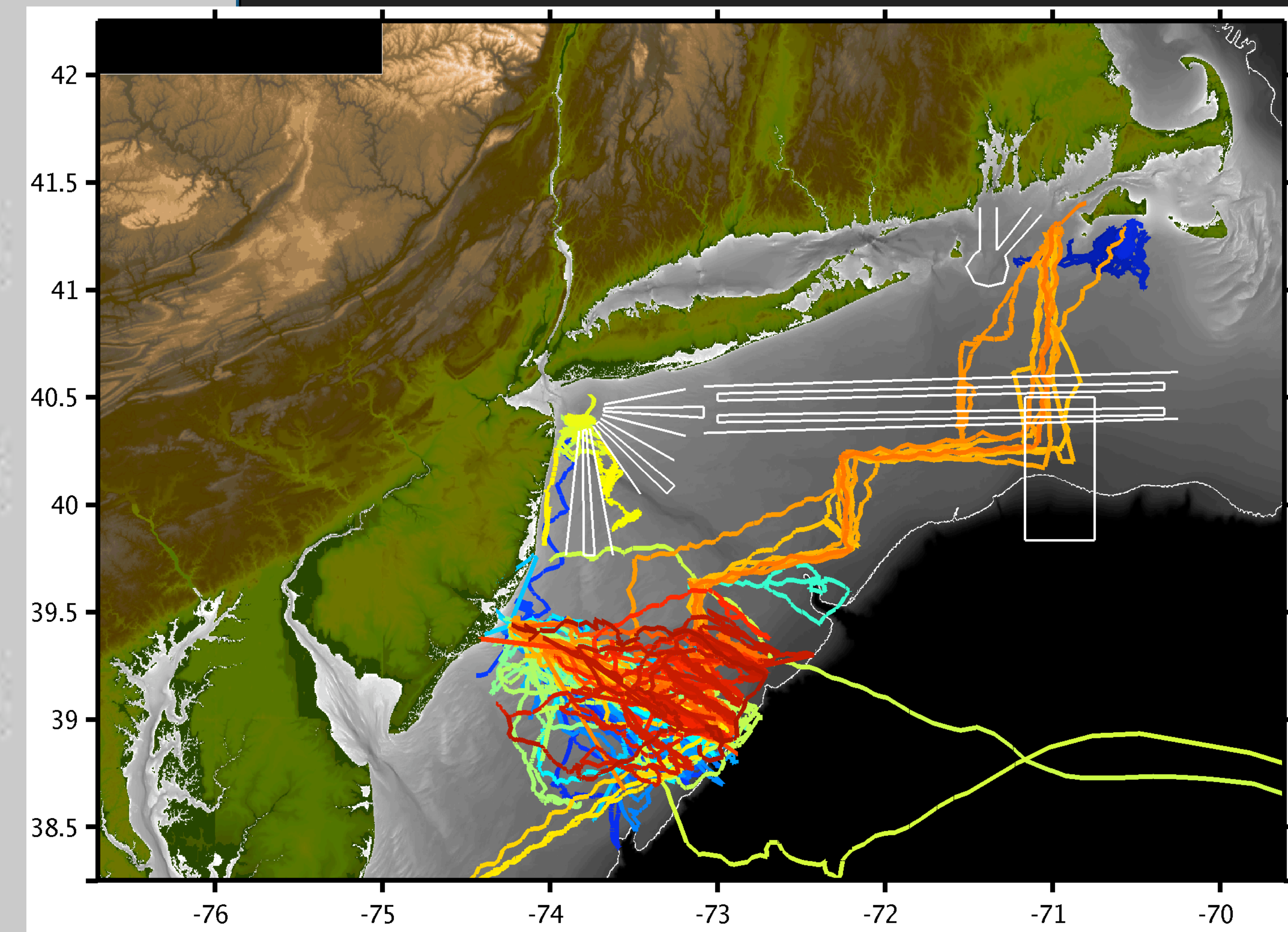


Sea breeze
Upwelling
Spring Bloom
Winter Bloom
River inflow
Modified Labrador Current
Gulf Stream
Cold Pool
Deepocean inflow





Castaleo et al. 2008, 2010

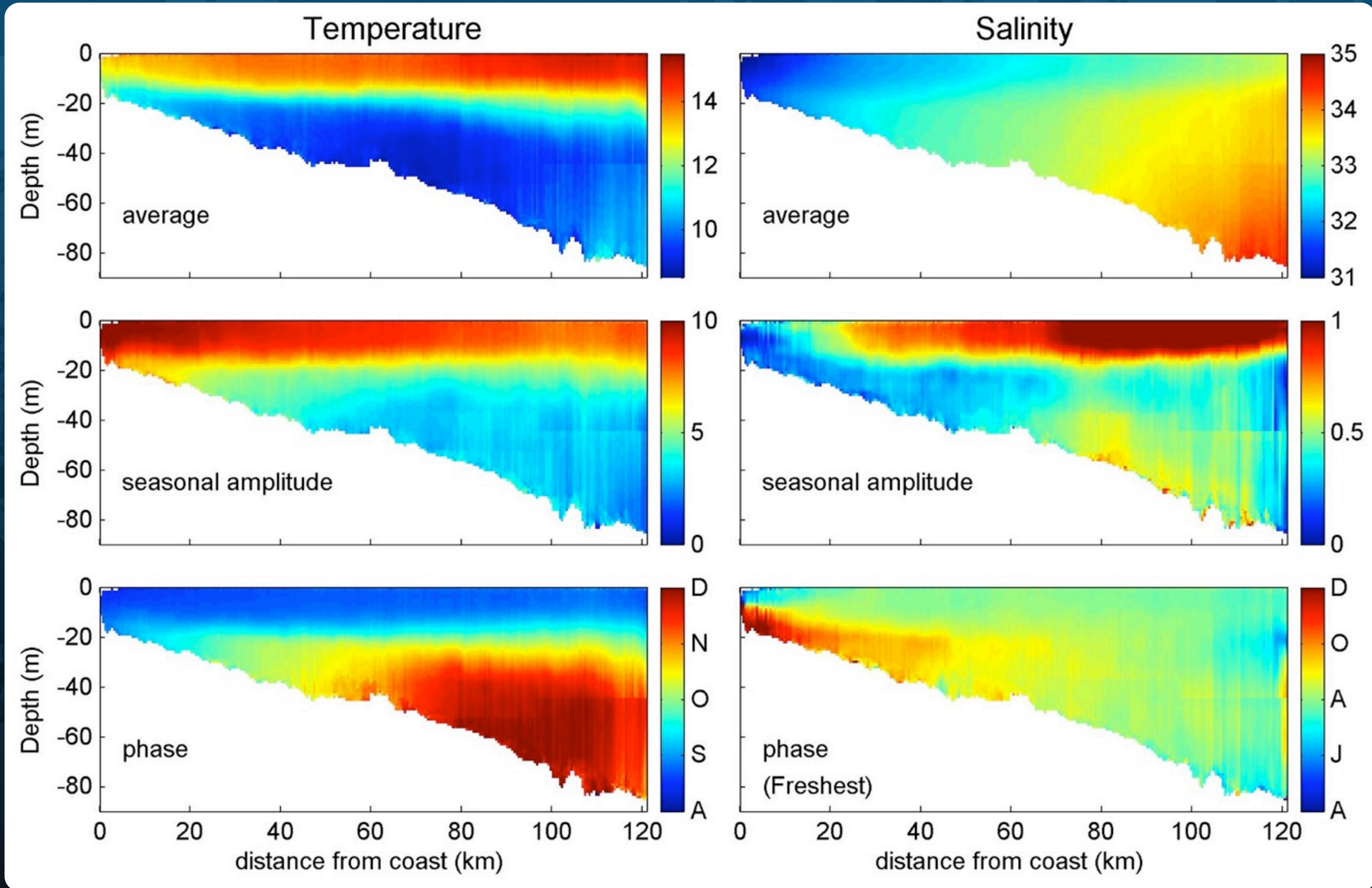


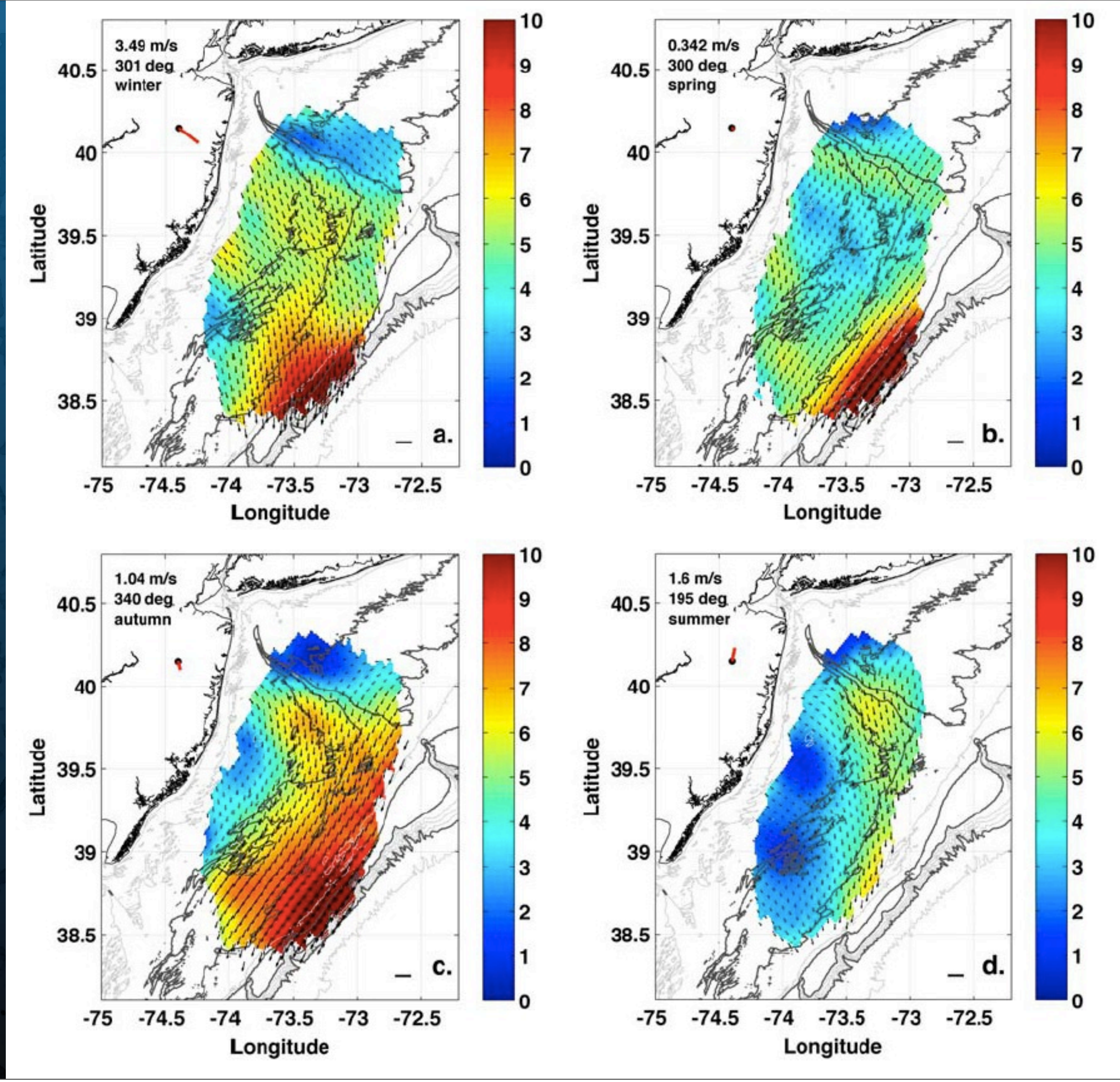
MAB stratification dominates the hydrography of the shelf.

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

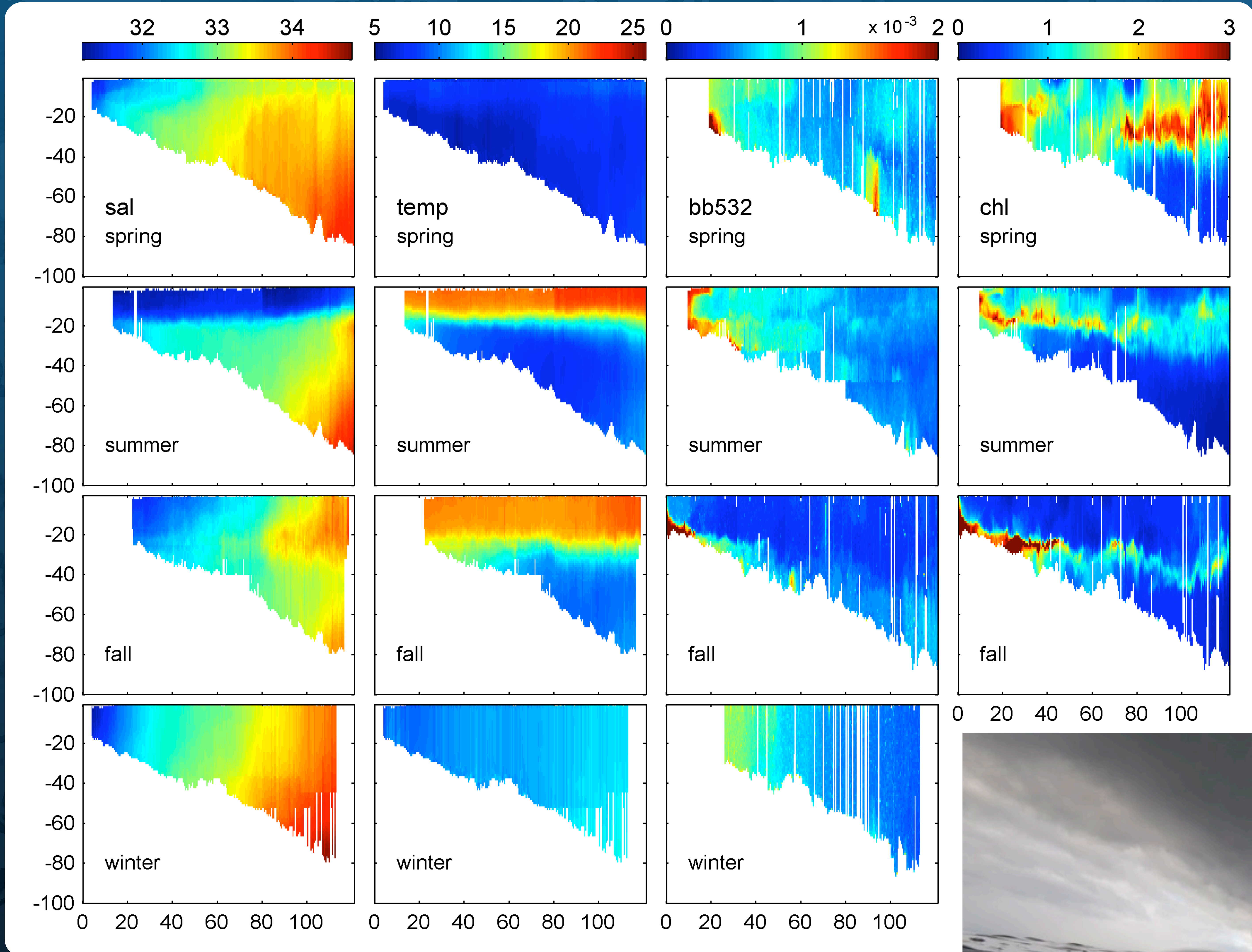
Salinity gradients show inshore and offshore gradients

Seasonal dynamics in the hydrography



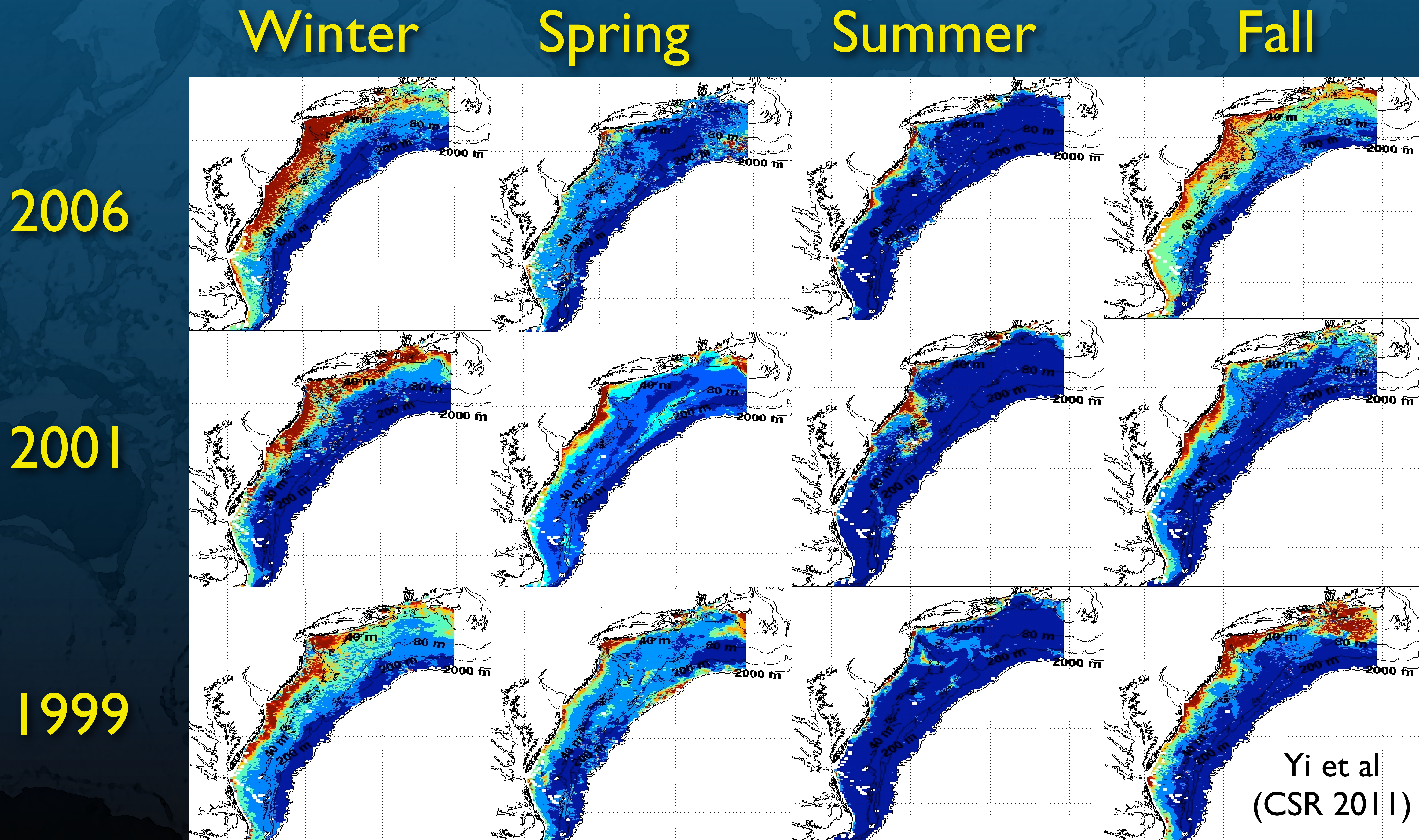


Gong et al 2010

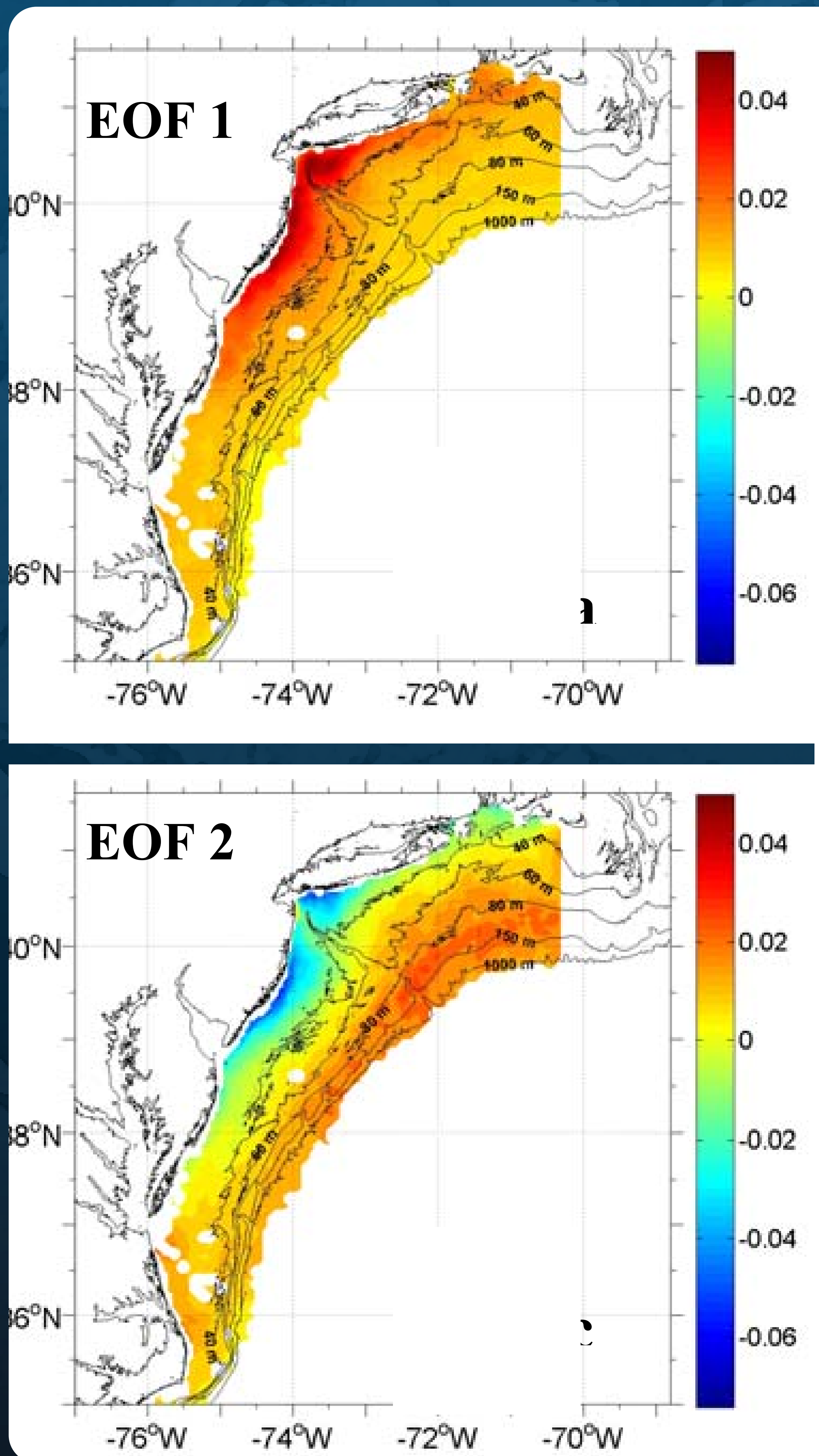

32 33 34
5 10 15 20 25
0 1 x 10^-3 2
0 1 2 3
sal
spring
temp
spring
bb532
spring
chl
spring
summer
summer
summer
summer
fall
fall
fall
fall
winter
winter
winter
-20 -40 -60 -80 -100
0 20 40 60 80 100


©CHRISLINDER

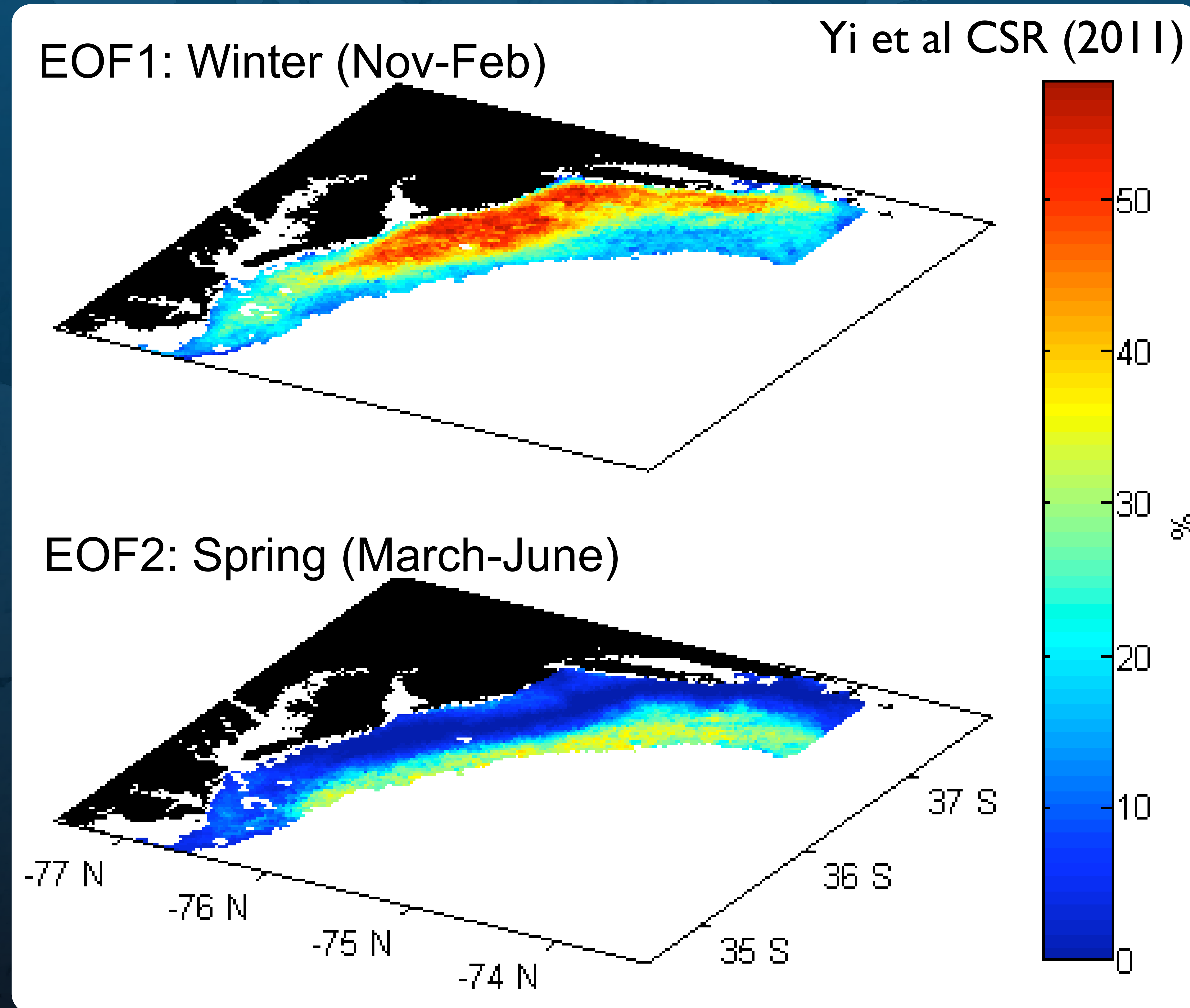
MID-ATLANTIC BIGHT IS A PRODUCTIVE ECOSYSTEM
(decade of satellite imagery)



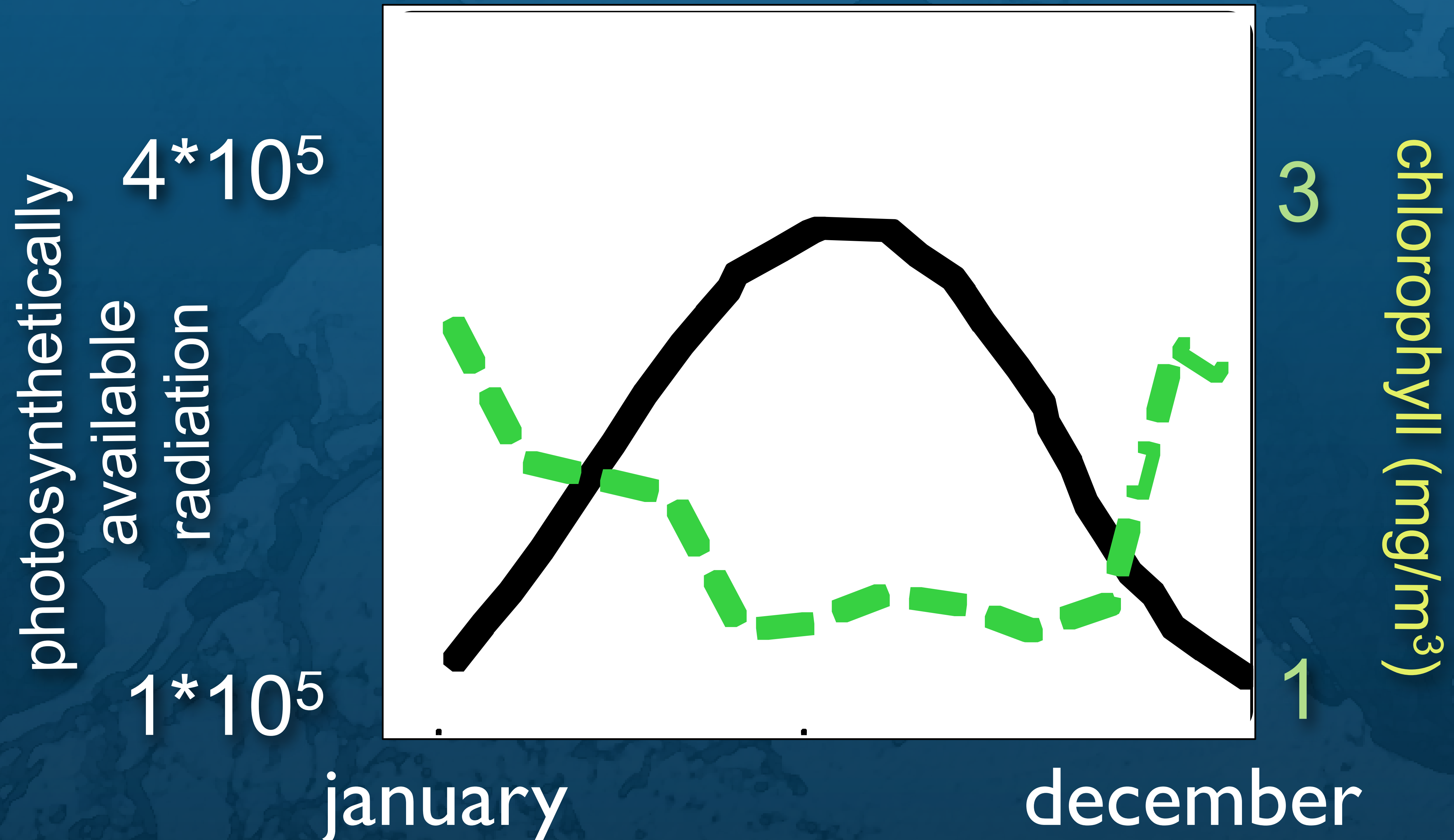
Dynamics in phytoplankton variance is described by 2 modes. Mode 1 occurs in the winter on the inner shelf. Mode 2 occurs in spring on the outer shelf. Summer phytoplankton explain little of the shelf-wide variance however is extremely important to the nearshore coastal ecosystems

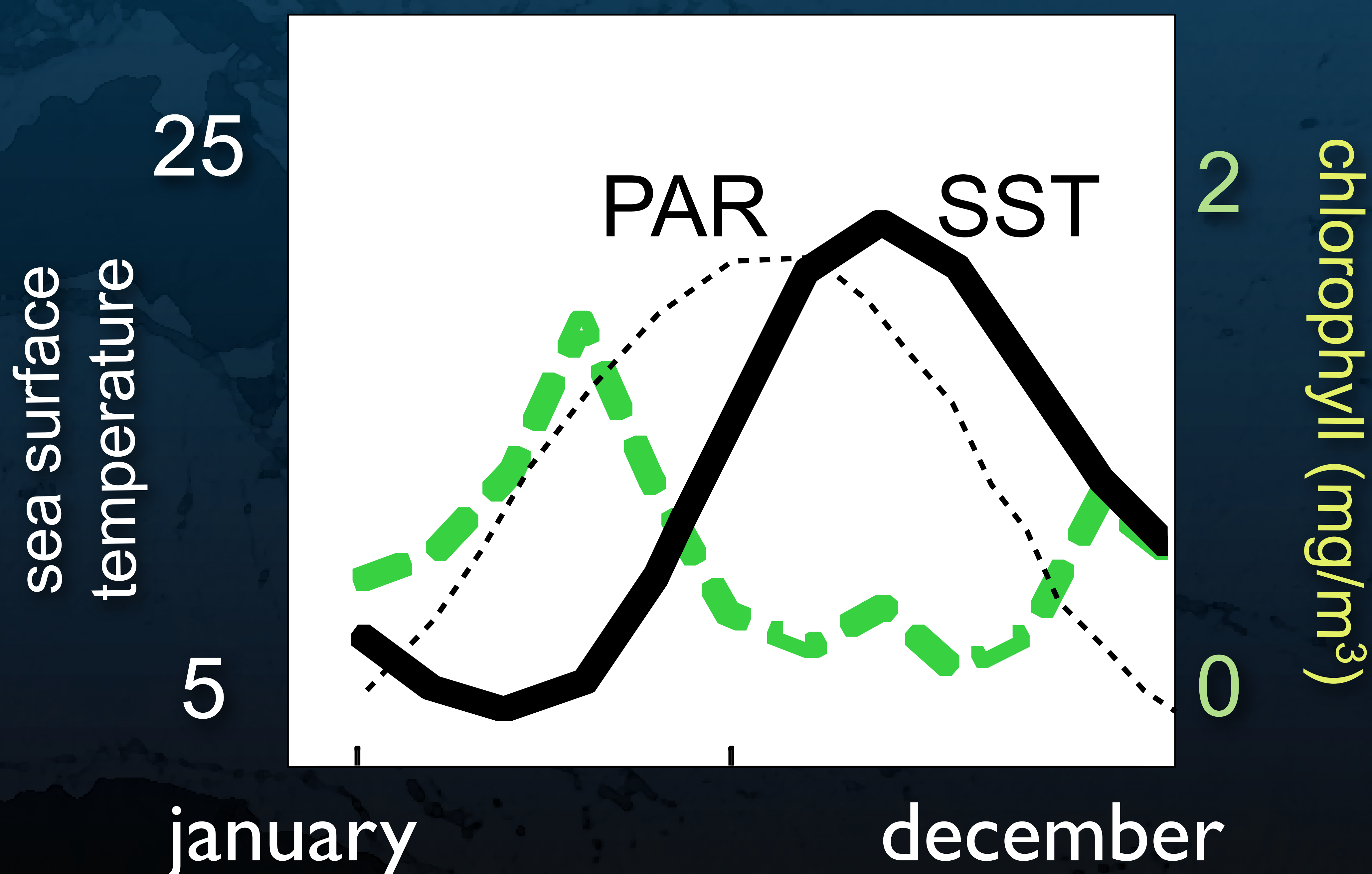


Two major EOF modes



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



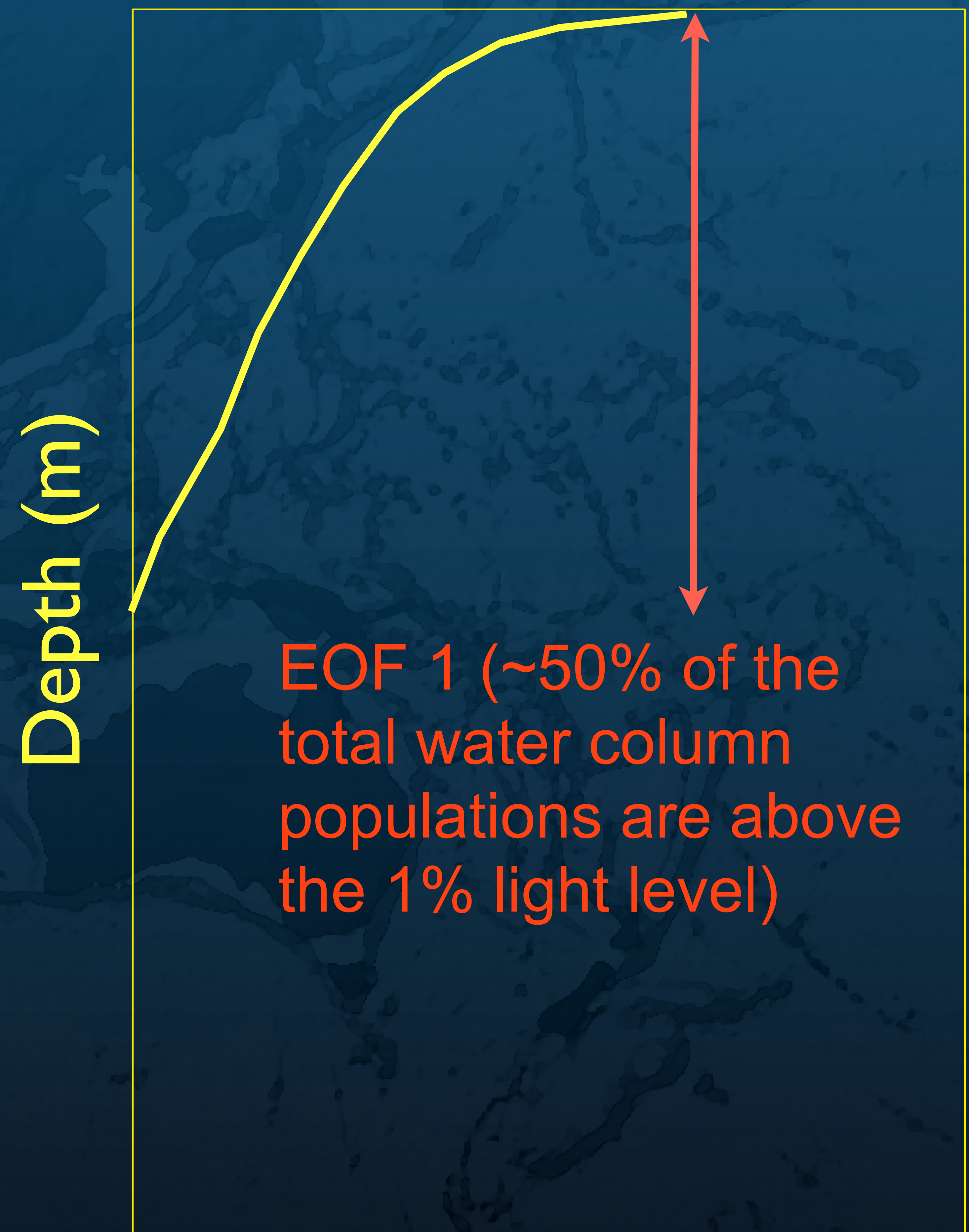


Mode 1: Largest and most recurrent bloom. Occurs during the dimmest months of the year which is interesting.

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

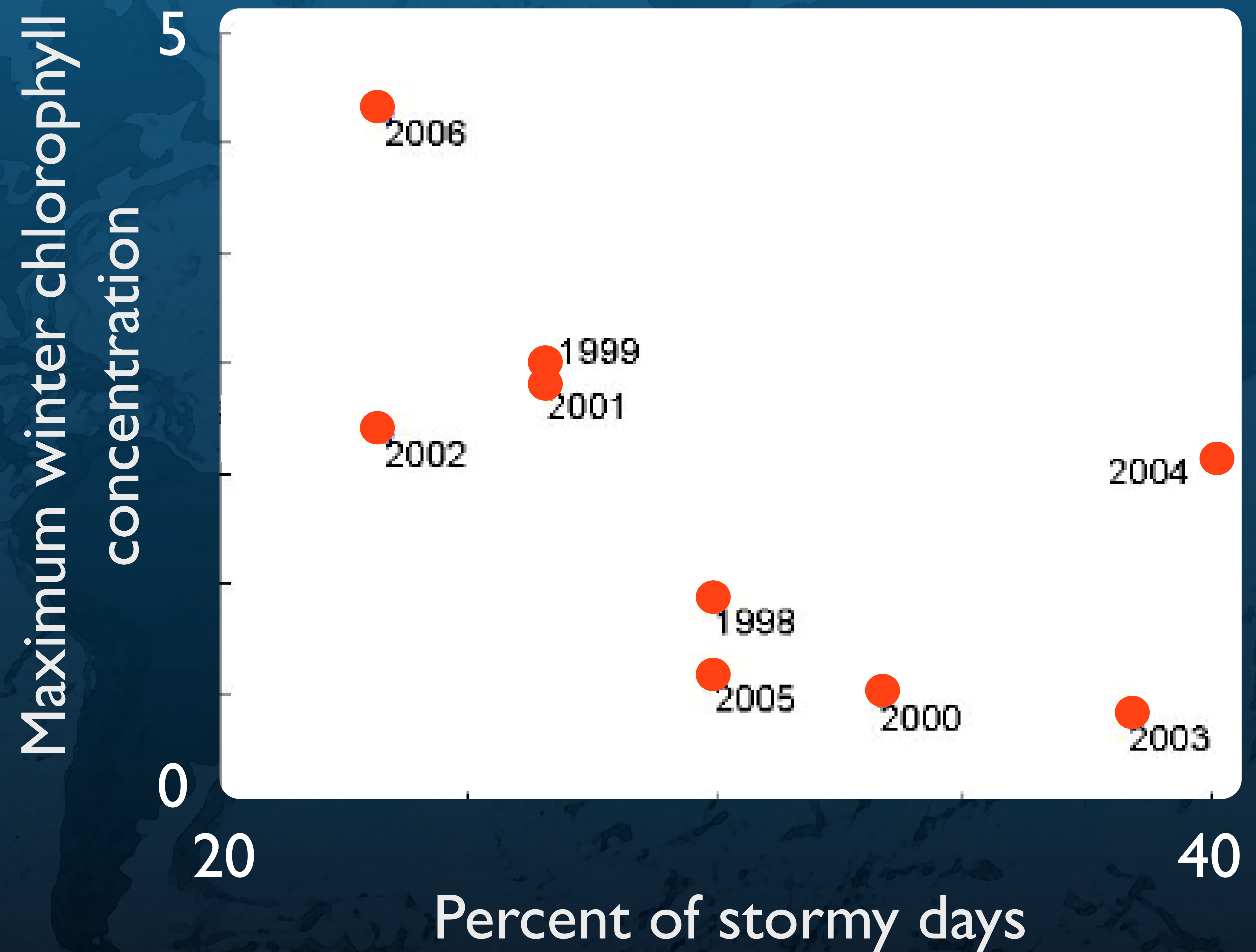
Schofield et al. 2008

Why does the Winter bloom extend to ~50 m depth?



Parameter	EOF 1	EOF 2
Mean Chl a	1.7	0.7
Max Chl a	4.9	2.1
Min Chl a	0.6	0.2
Mean depth Chl a 1% Light Level	20	33
Max Chl a 1% Light Level	12	27
Min Chl a 1% Light Level	36	55
% water column in euphotic zone	49%	17 (5)%

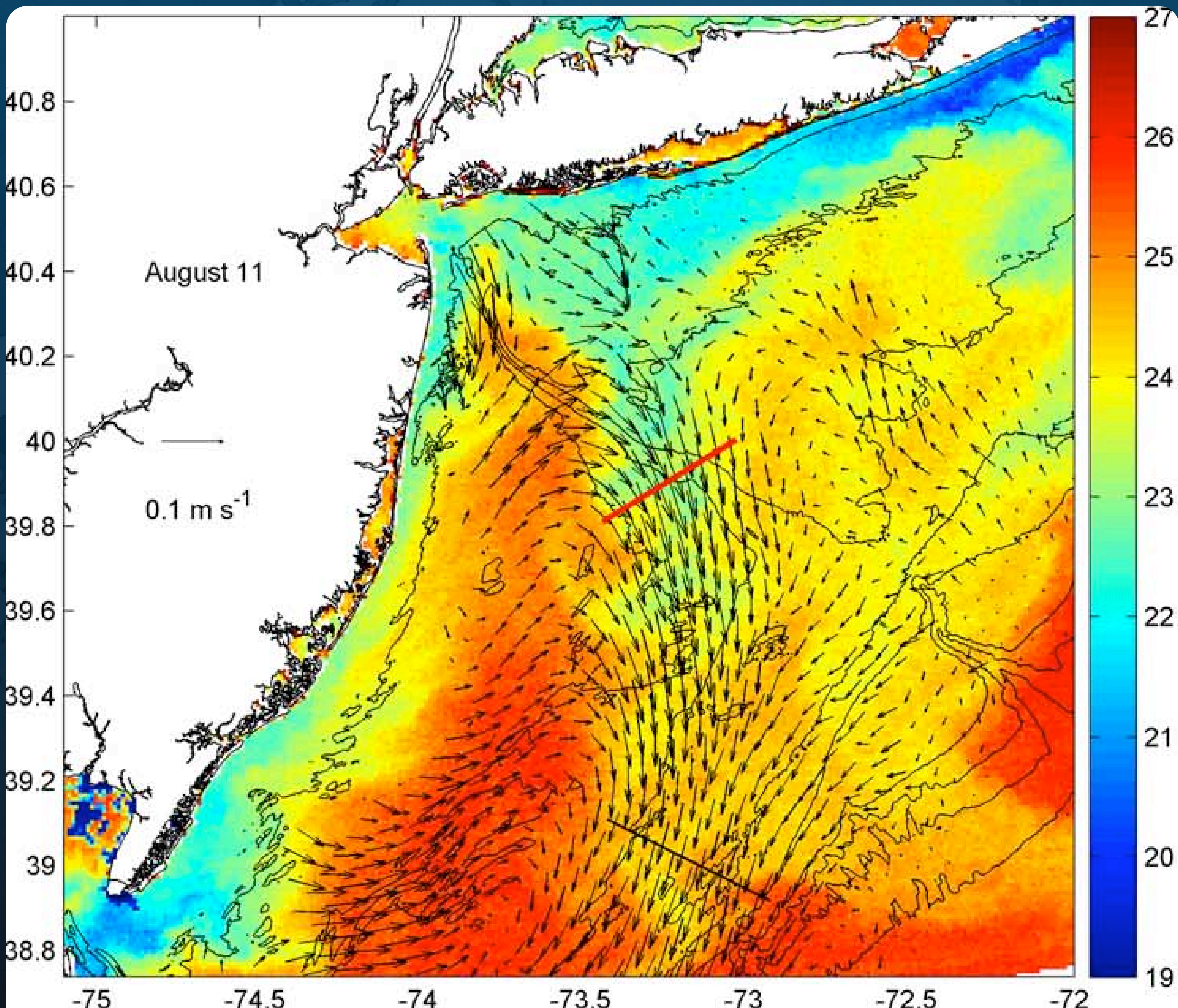
Calculated using the mean chlorophyll concentrations and using Hydrolight radiative transfer equations



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

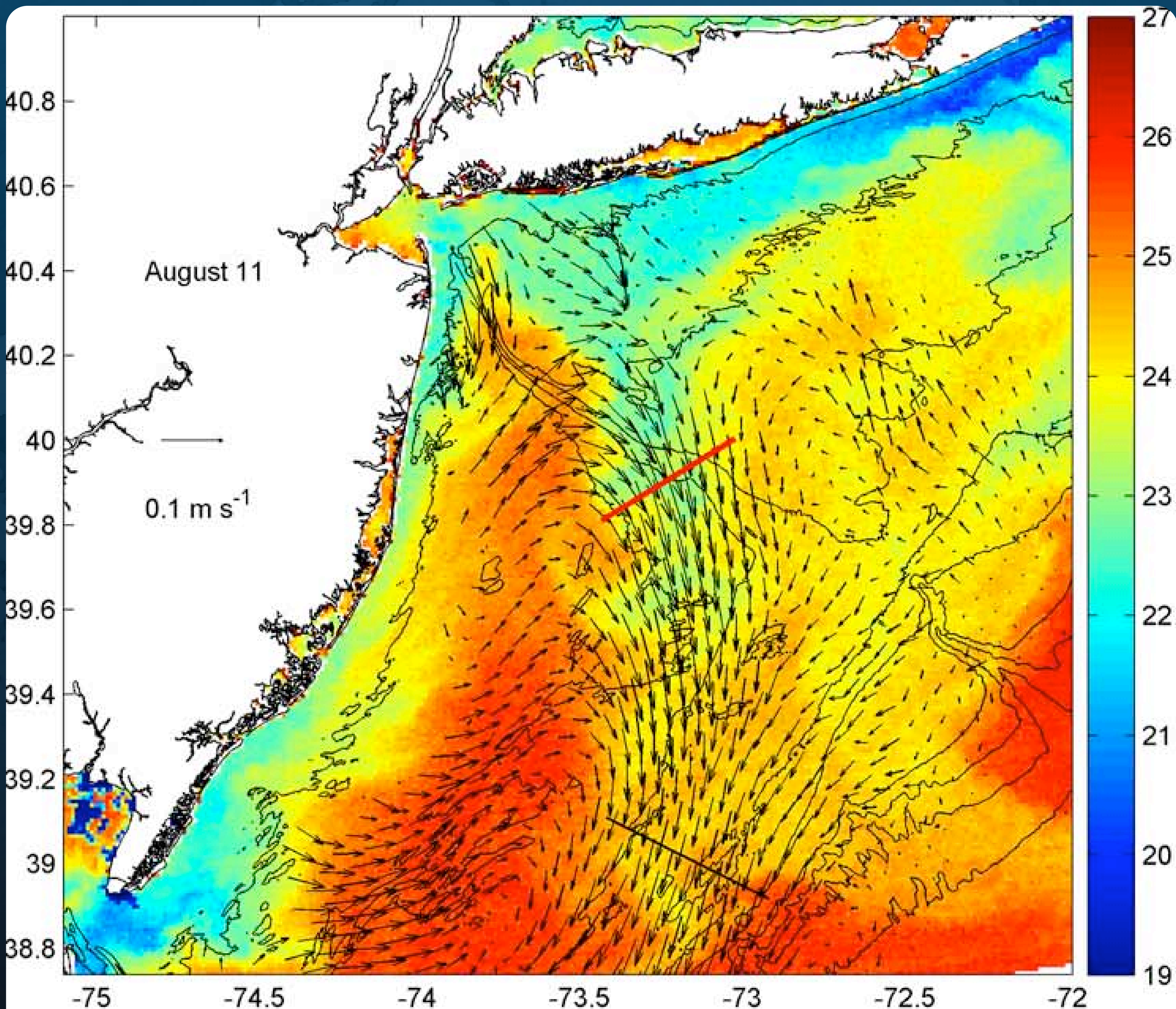
What are the drivers of the winter blooms?

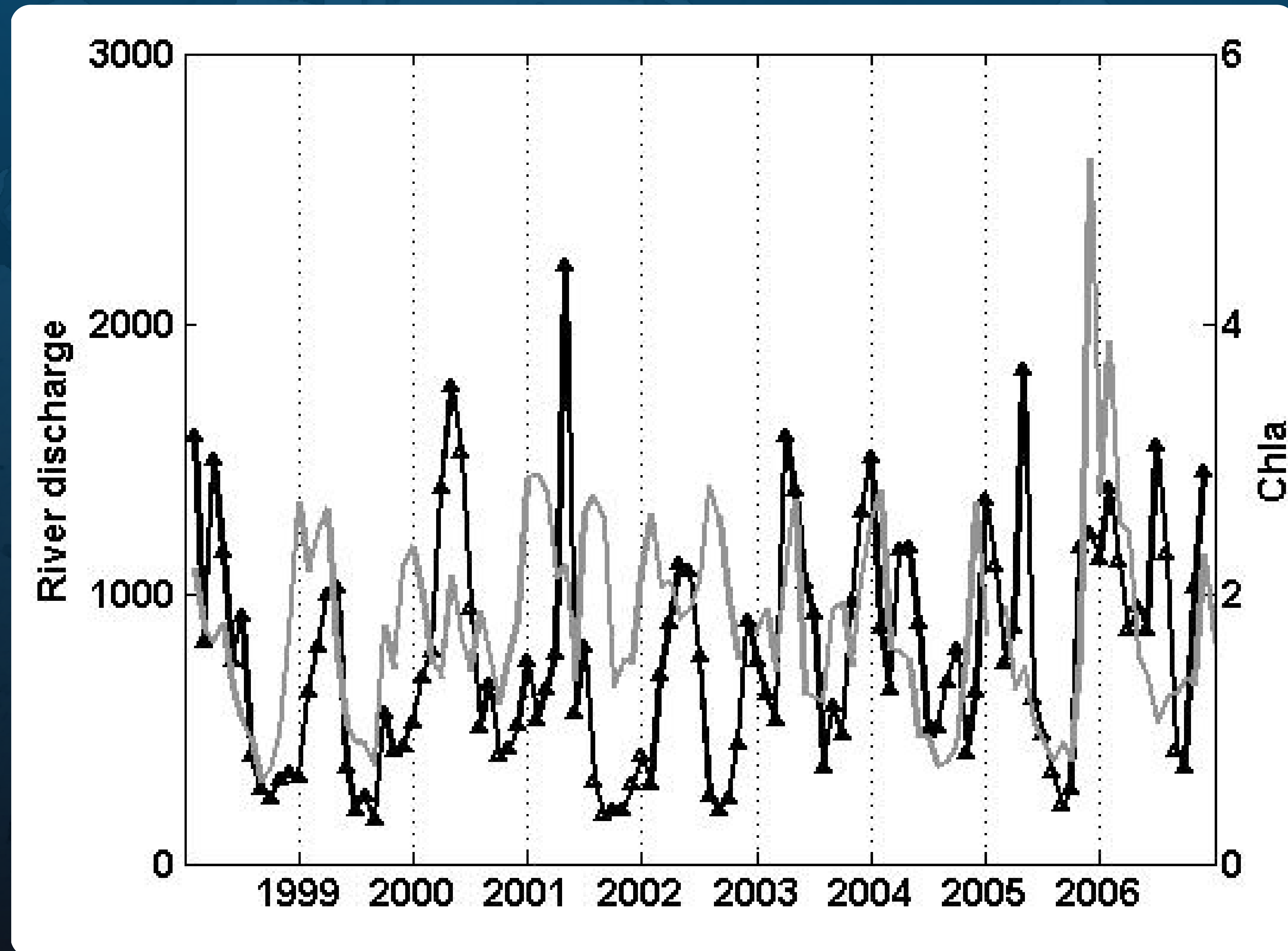
Rivers can contribute chlorophyll biomass shelves



What are the drivers of the winter blooms?

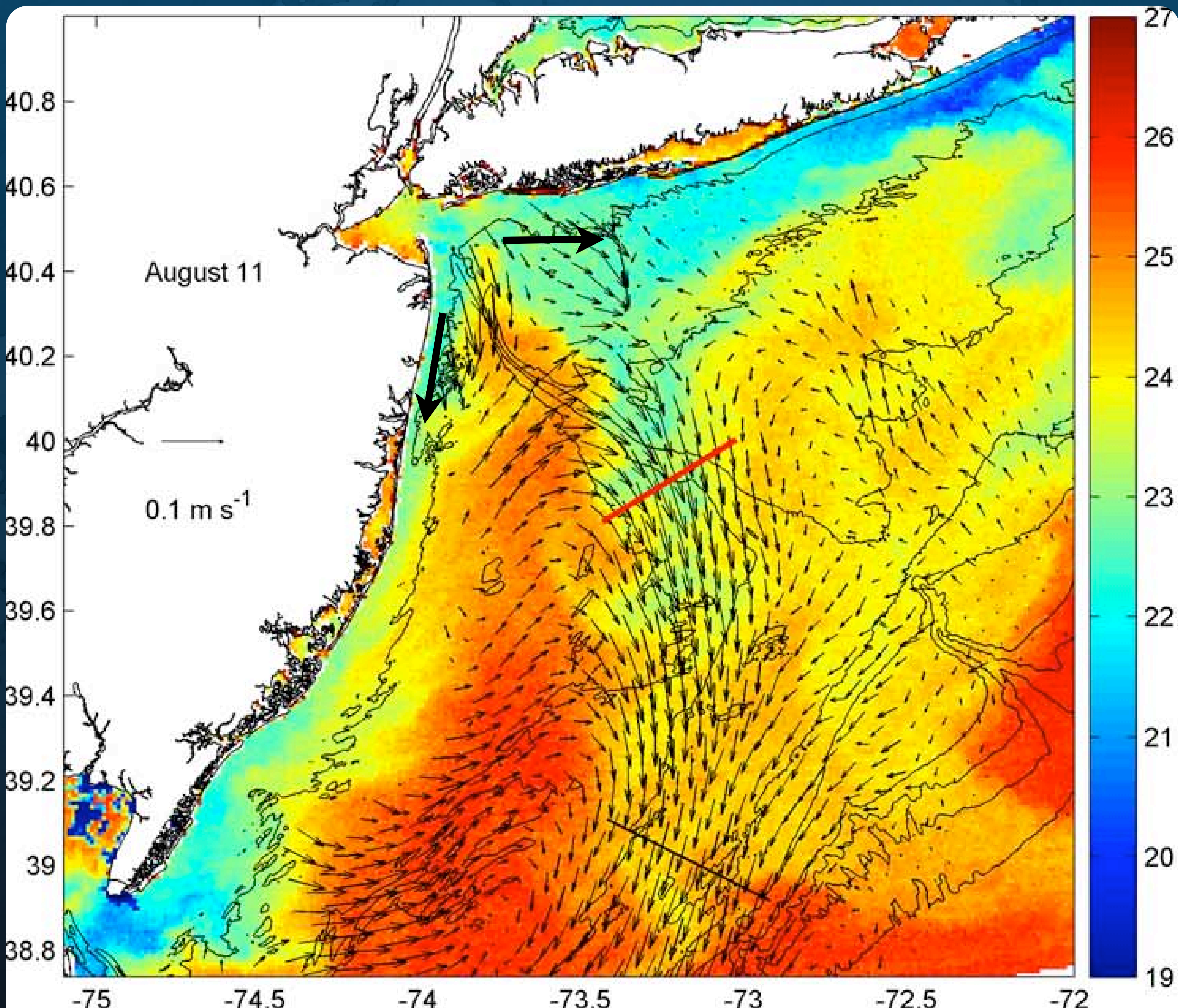
Rivers can contribute chlorophyll biomass shelves

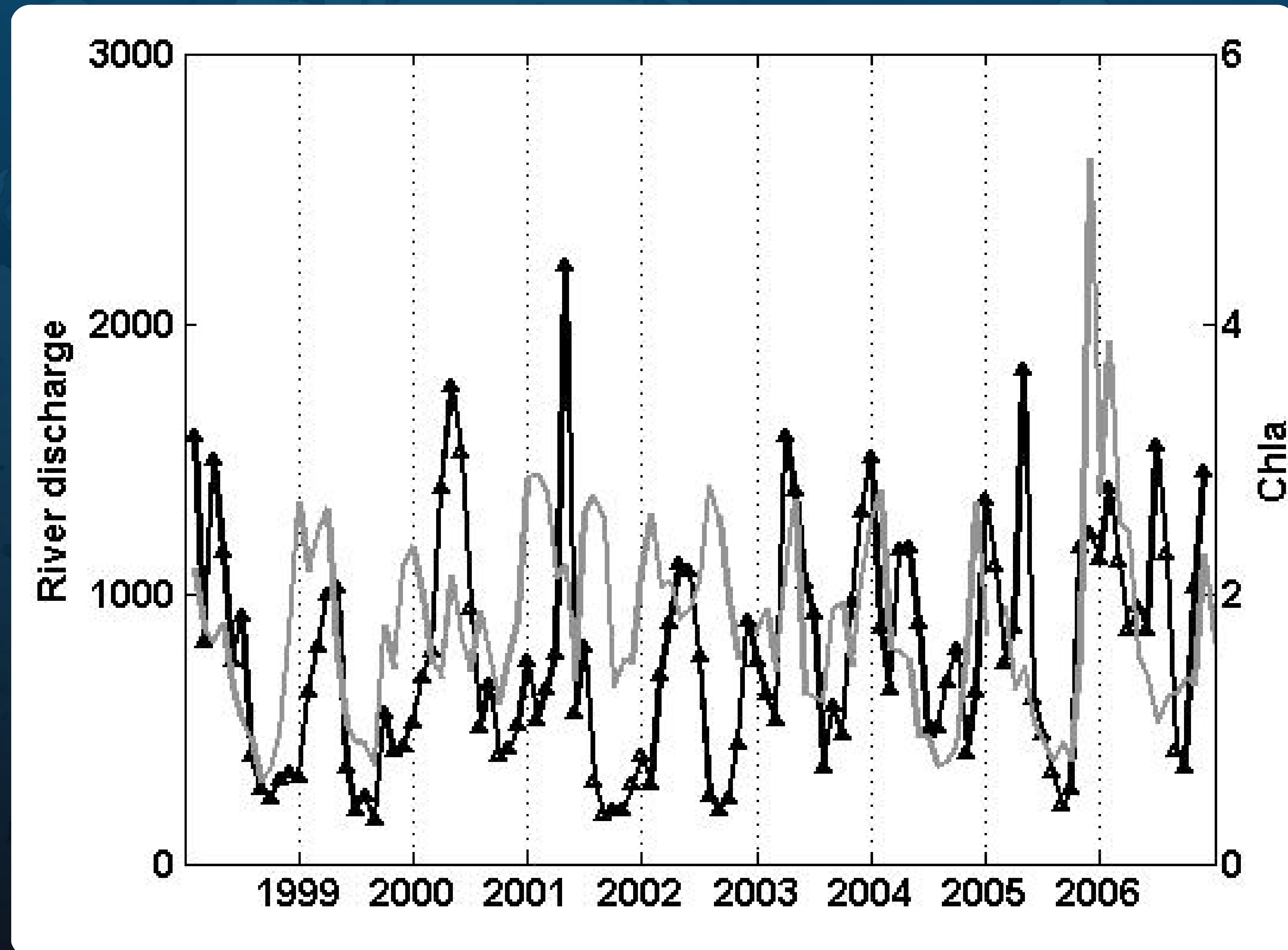




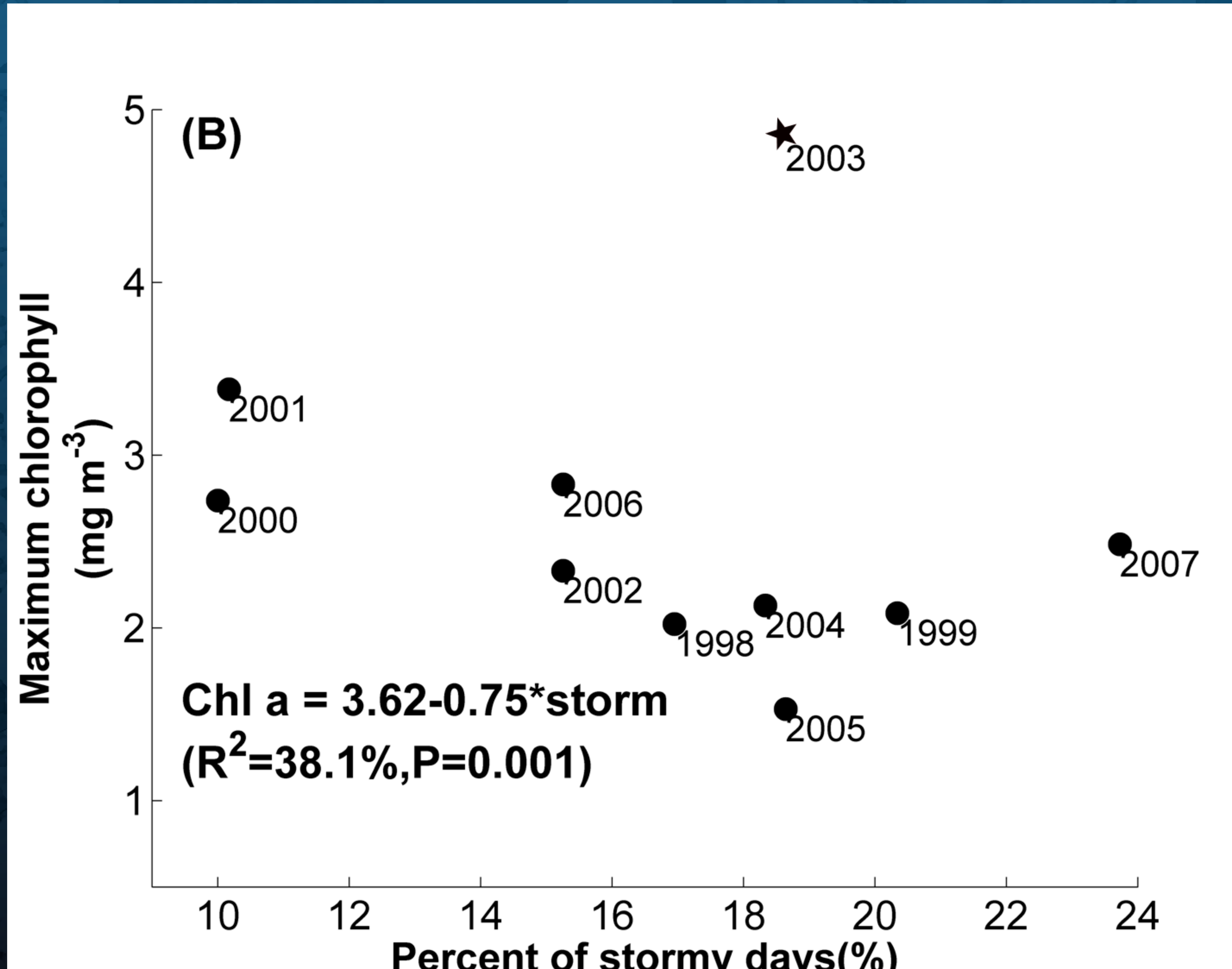
What are the drivers of the winter blooms?

Rivers can contribute chlorophyll biomass shelves





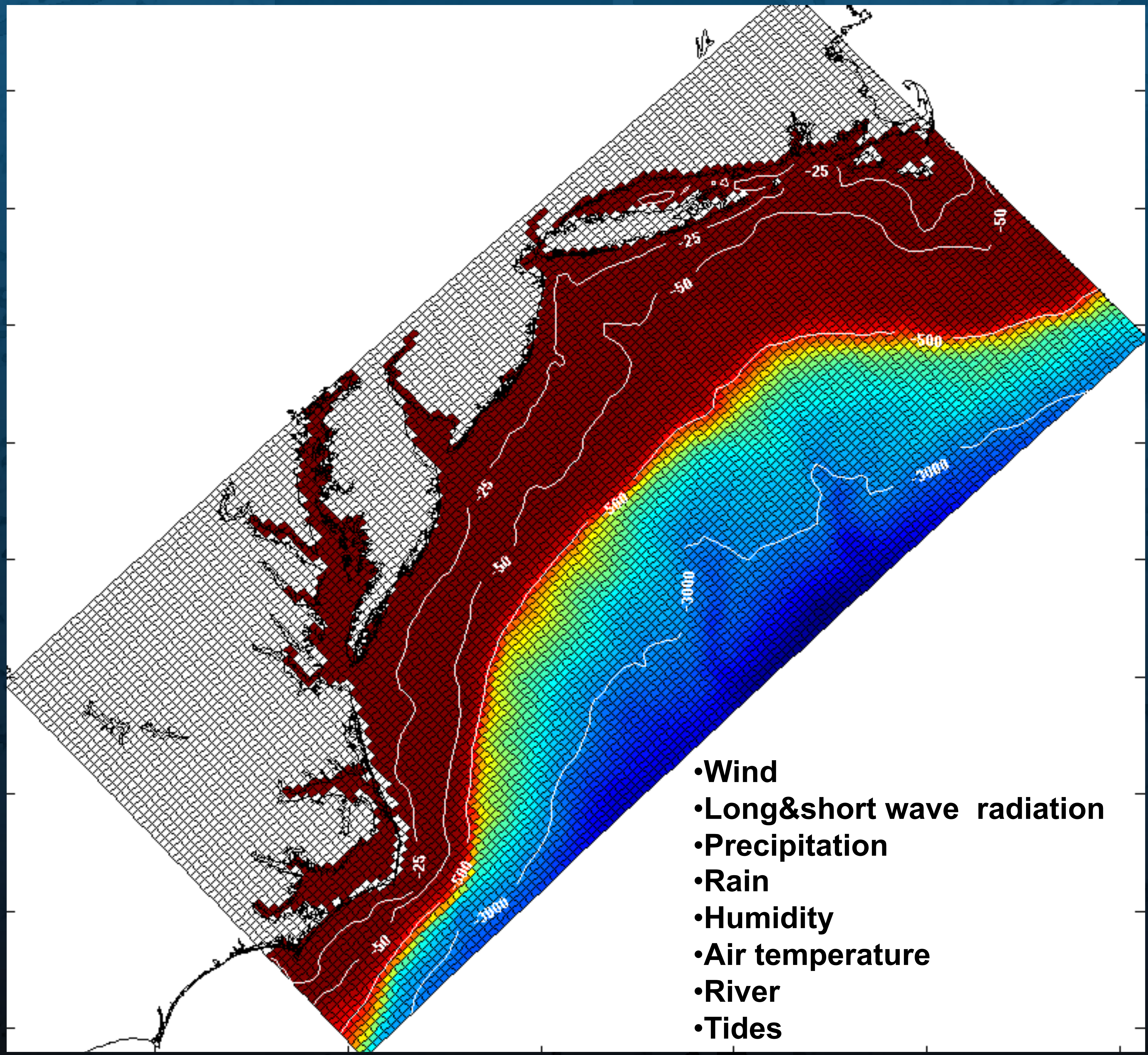
Spring Bloom Magnitude



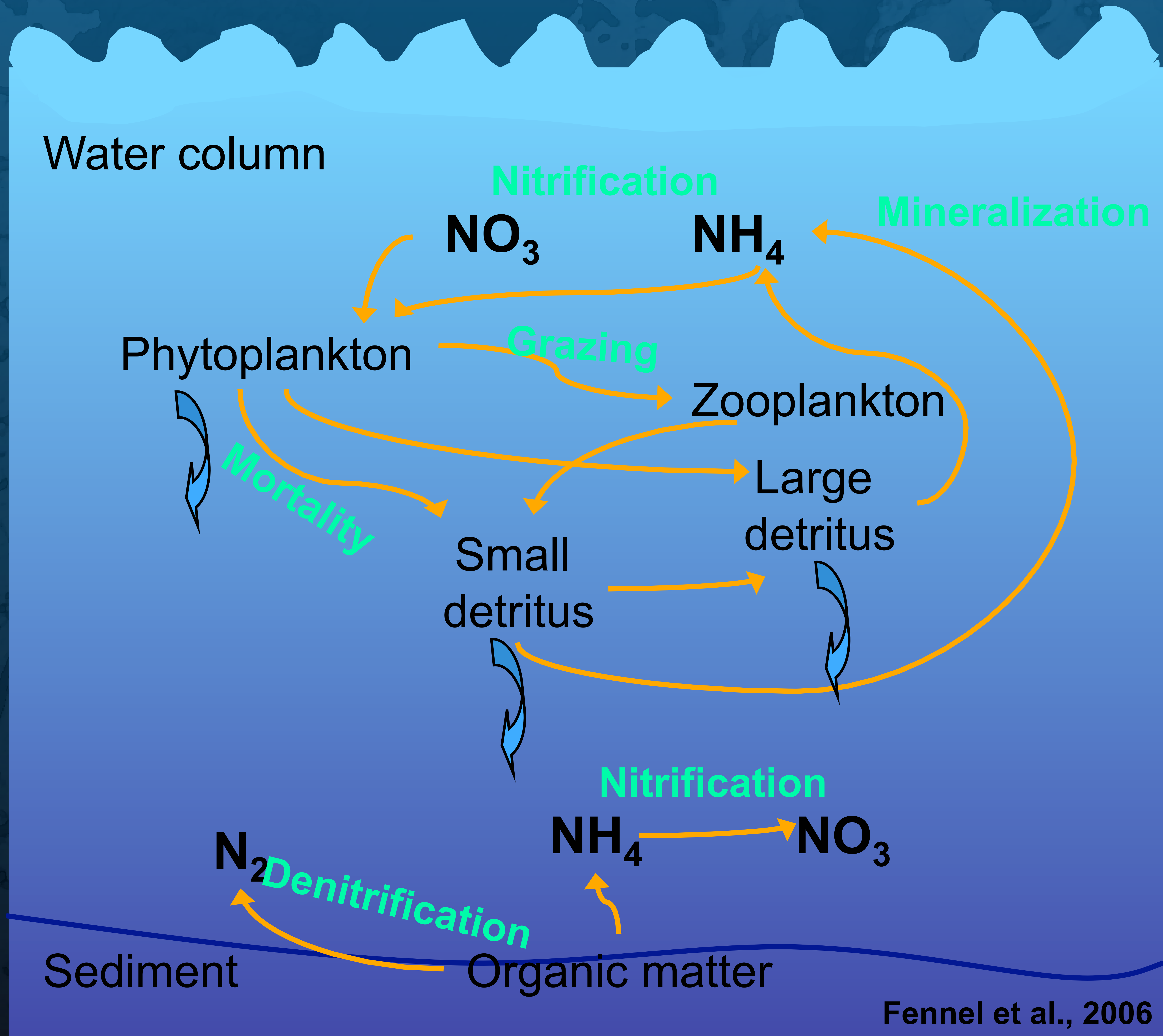
Regional Ocean Modeling System

5 km grid resolution, 36 vertical layers

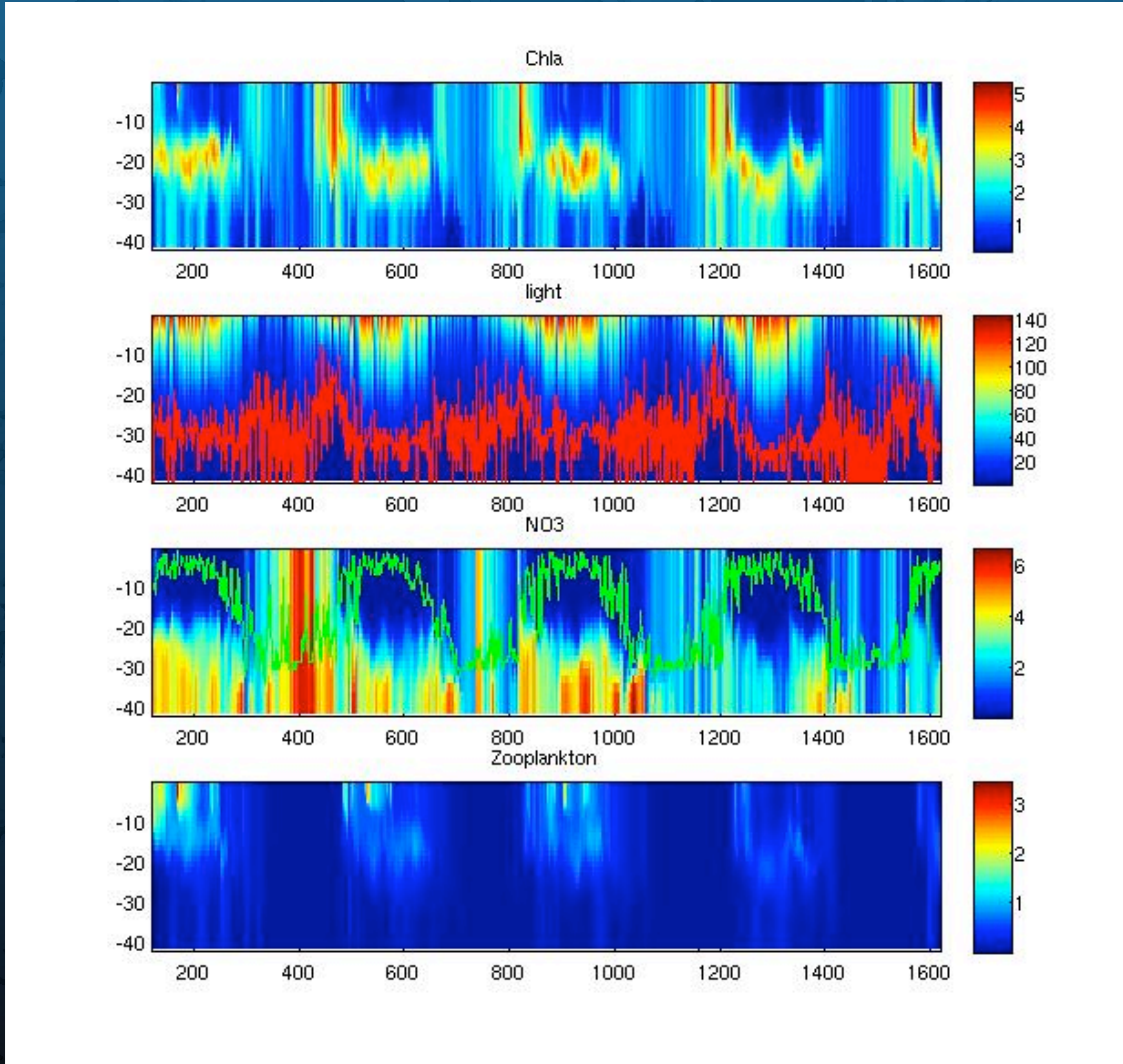
Model run in Hindcast run (4 year run 2004-2008)



Biological Modeling System

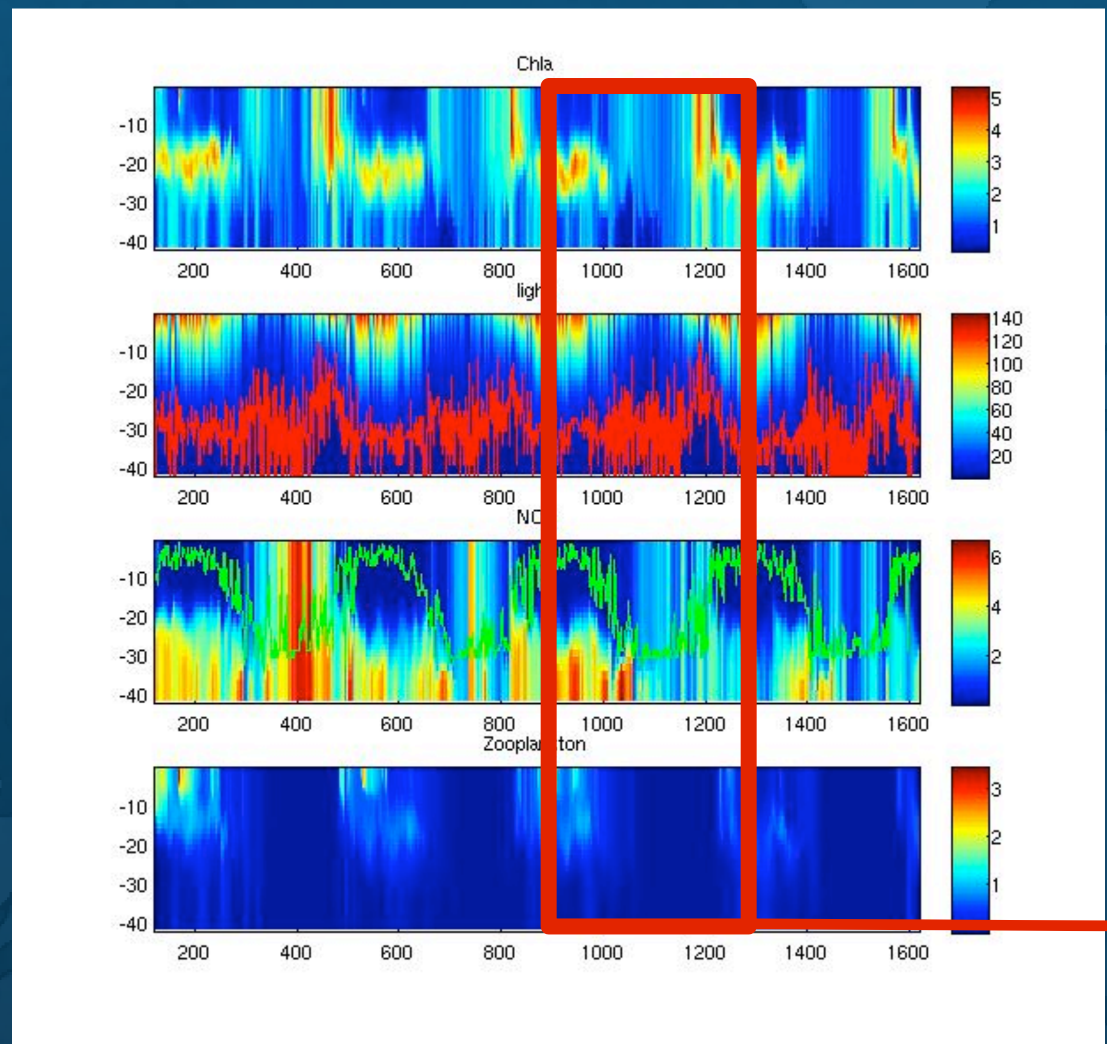


Model assumes N is the main limiting



Chla
-10
-20
-30
-40
200
400
600
800
1000
1200
1400
1600
5
4
3
2
1
light
-10
-20
-30
-40
200
400
600
800
1000
1200
1400
1600
140
120
100
80
60
40
20
NO3
-10
-20
-30
-40
200
400
600
800
1000
1200
1400
1600
6
4
2
Zooplankton
-10
-20
-30
-40
200
400
600
800
1000
1200
1400
1600
3
2
1

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



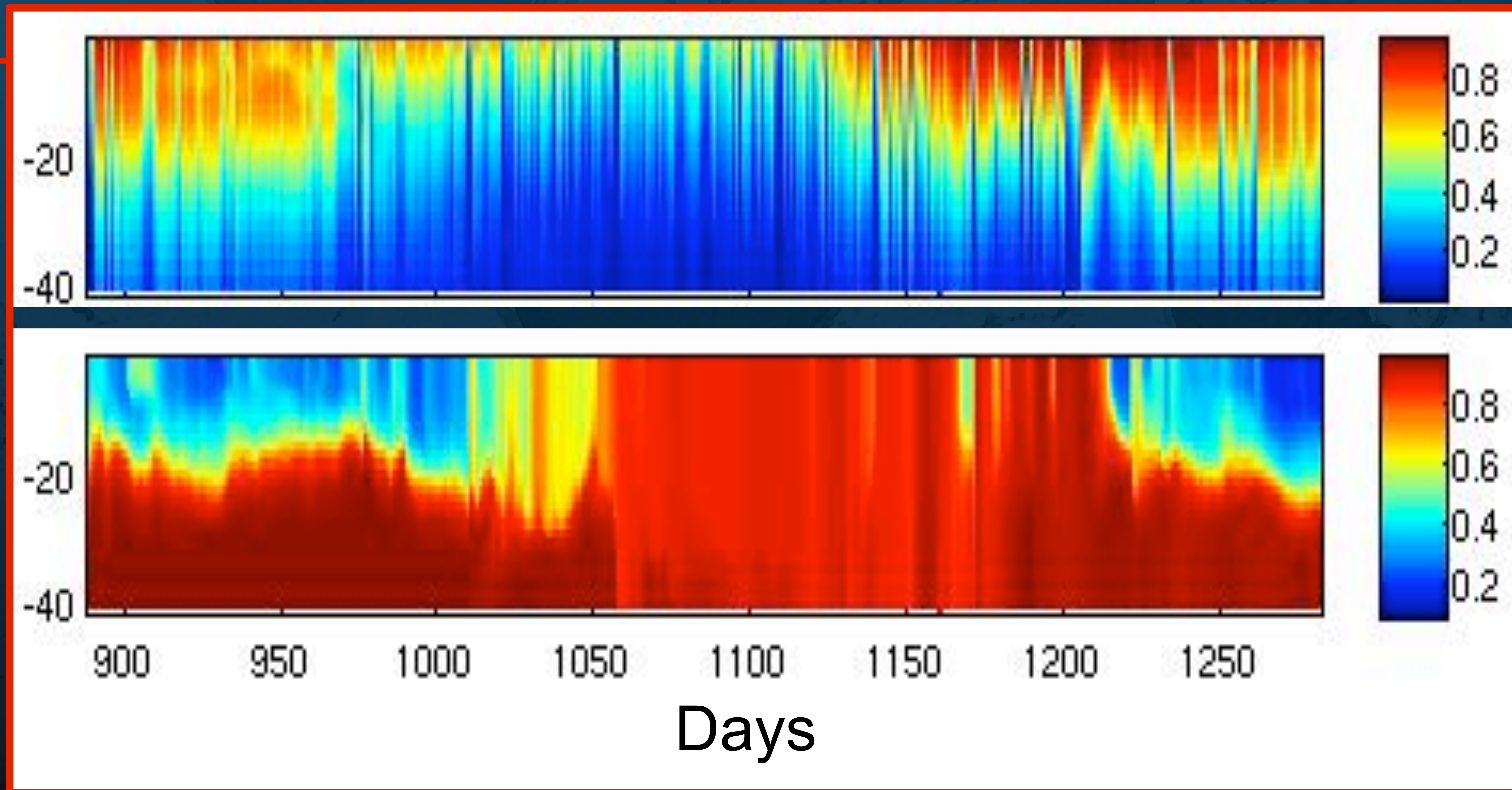
Light limitation

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

Nutrient limitation

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

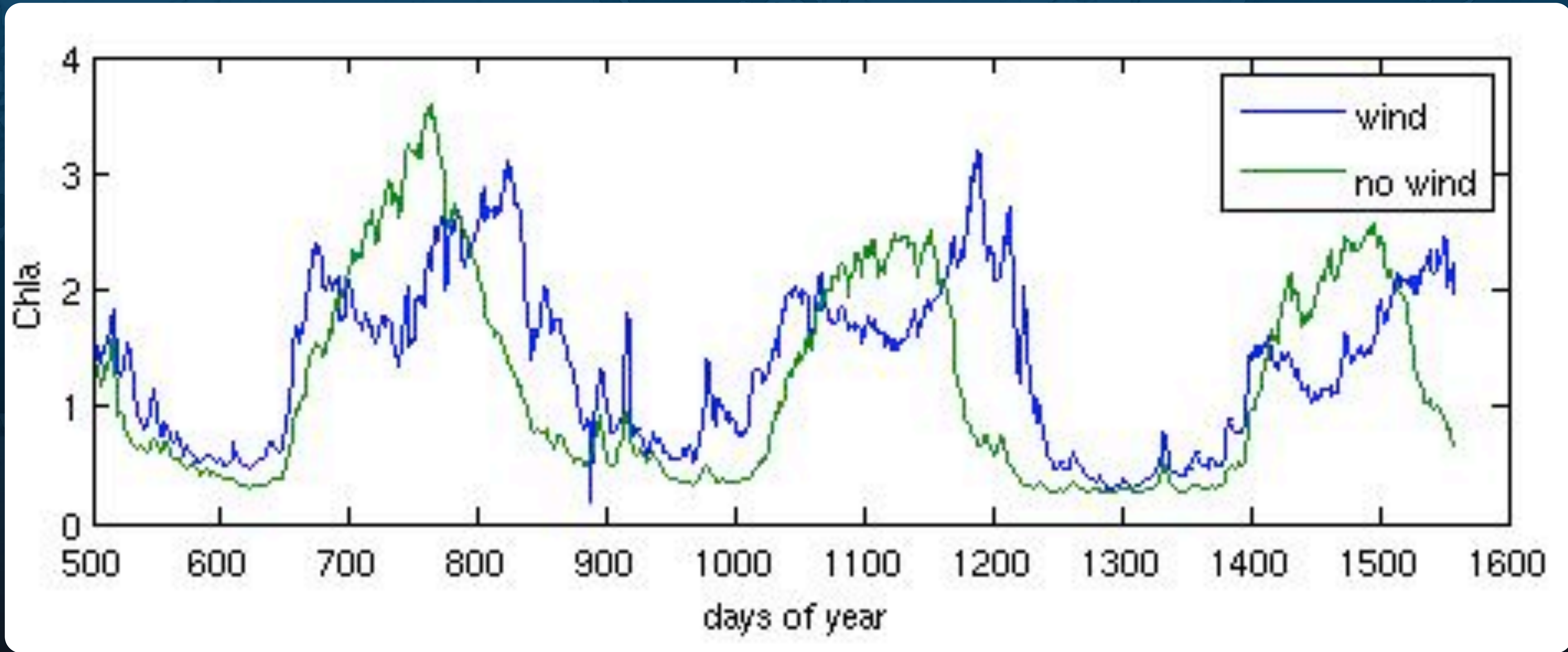
$$L_{NH4} = \frac{NH4}{K_{NH4} + NH4}$$

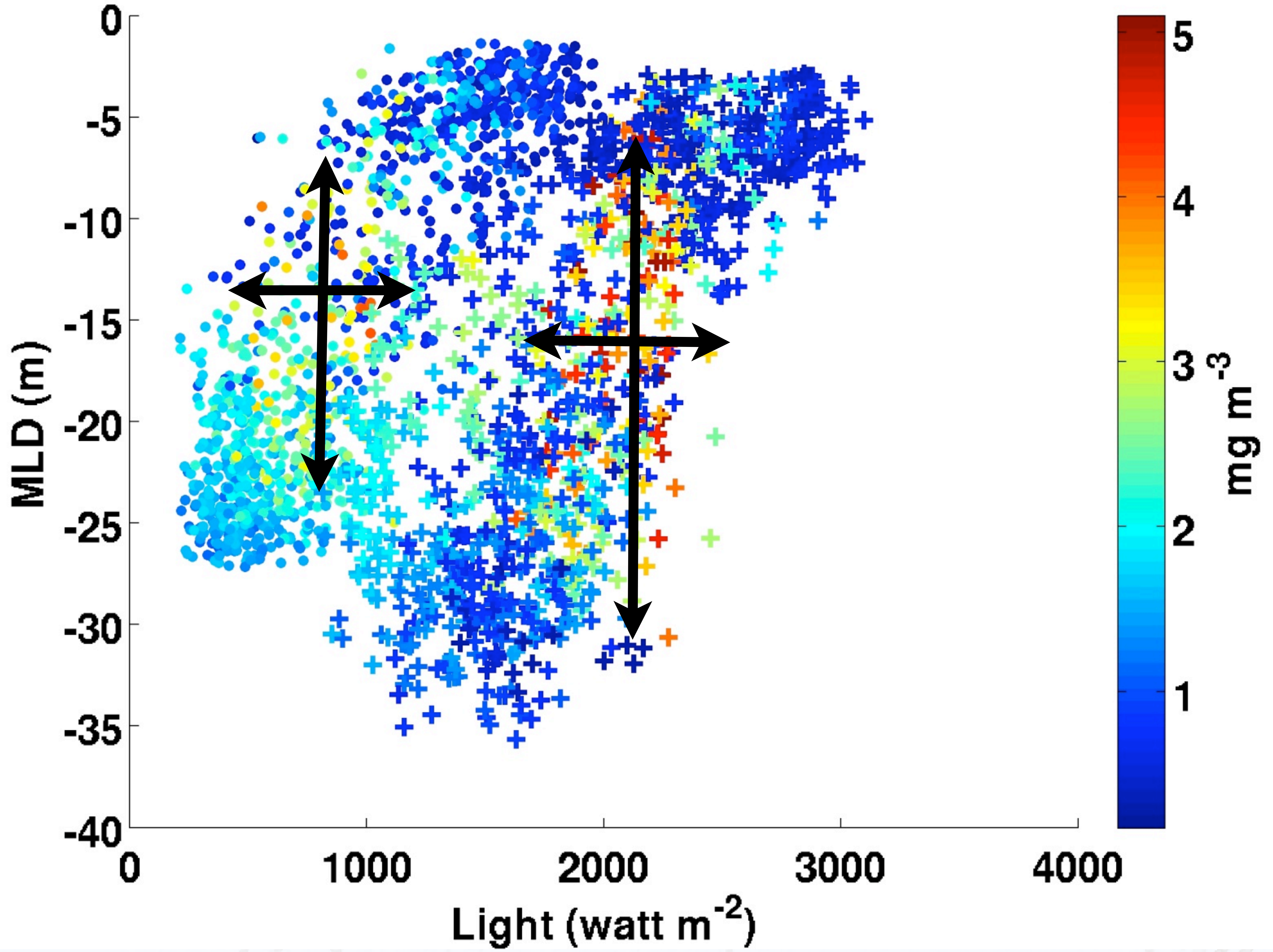


Numerical experiment: Measured wind and no wind in Zone 1

No wind condition, later bloom, larger bloom during darkest winter months, but integrated productivity over the winter is small by XXX%

Yi et al submitted



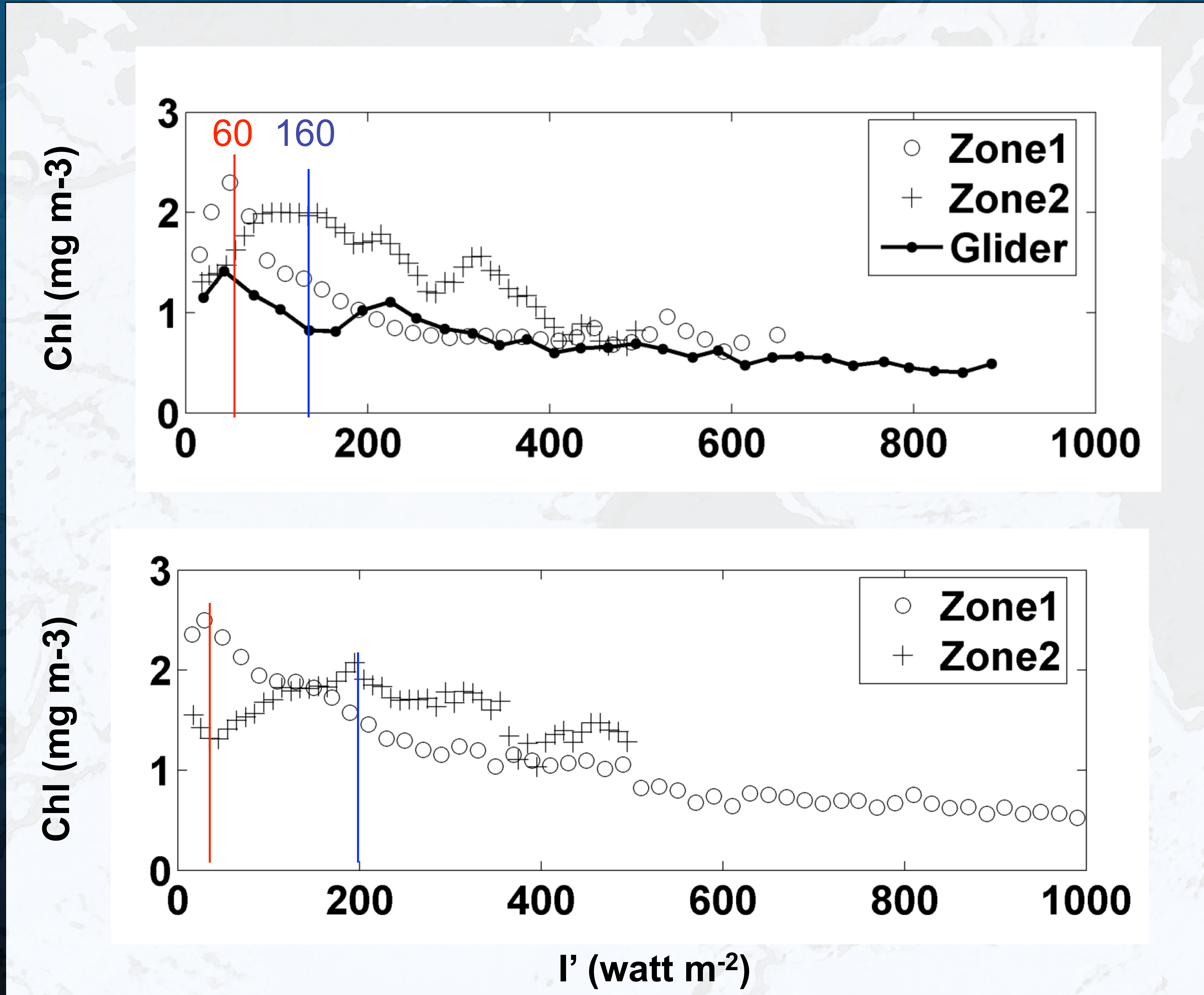


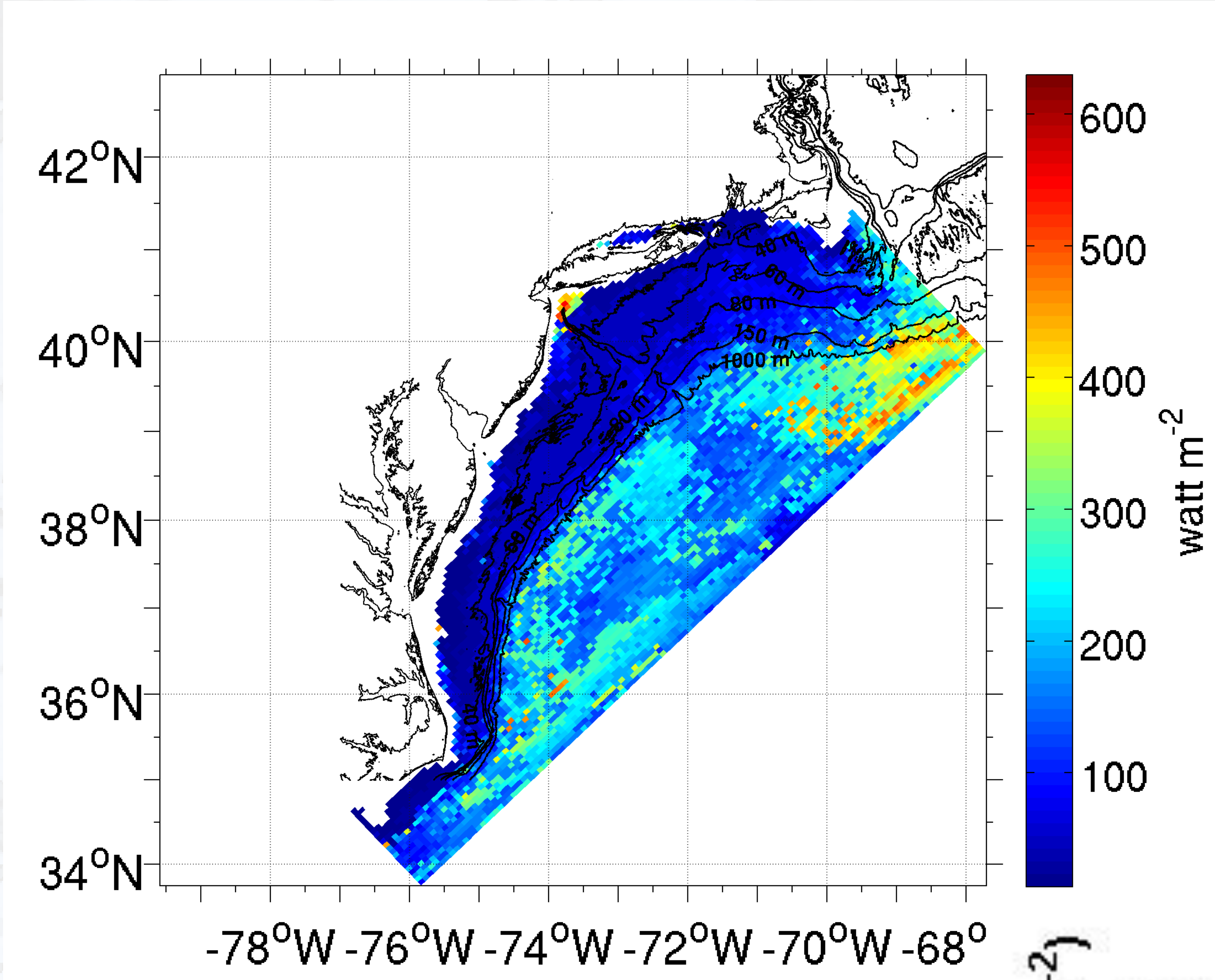
Mixing-light (I')

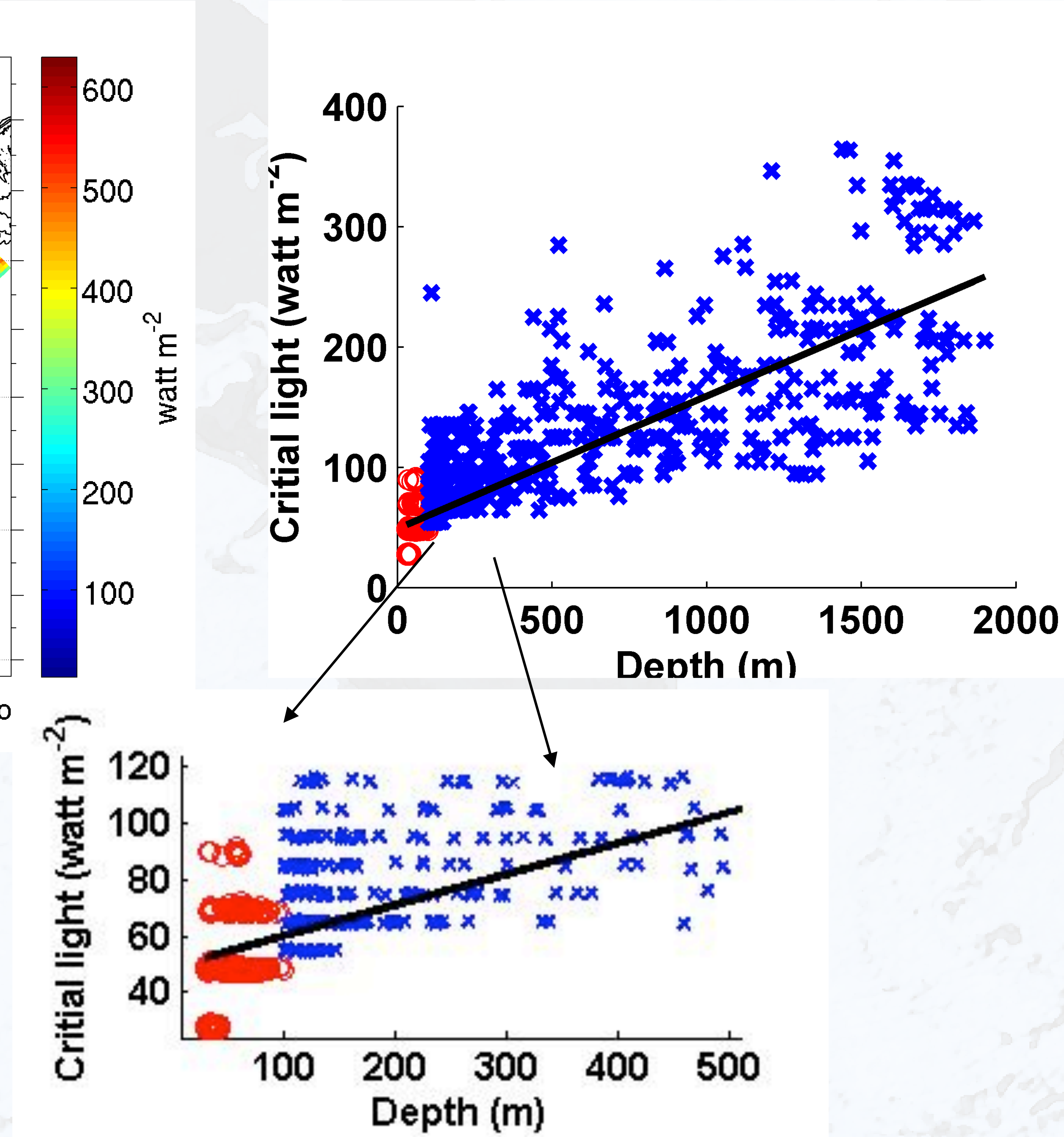
$$I' = \int_{-Z_{eu}}^{0} I(z) * dz \Big/ Z_{mld}$$

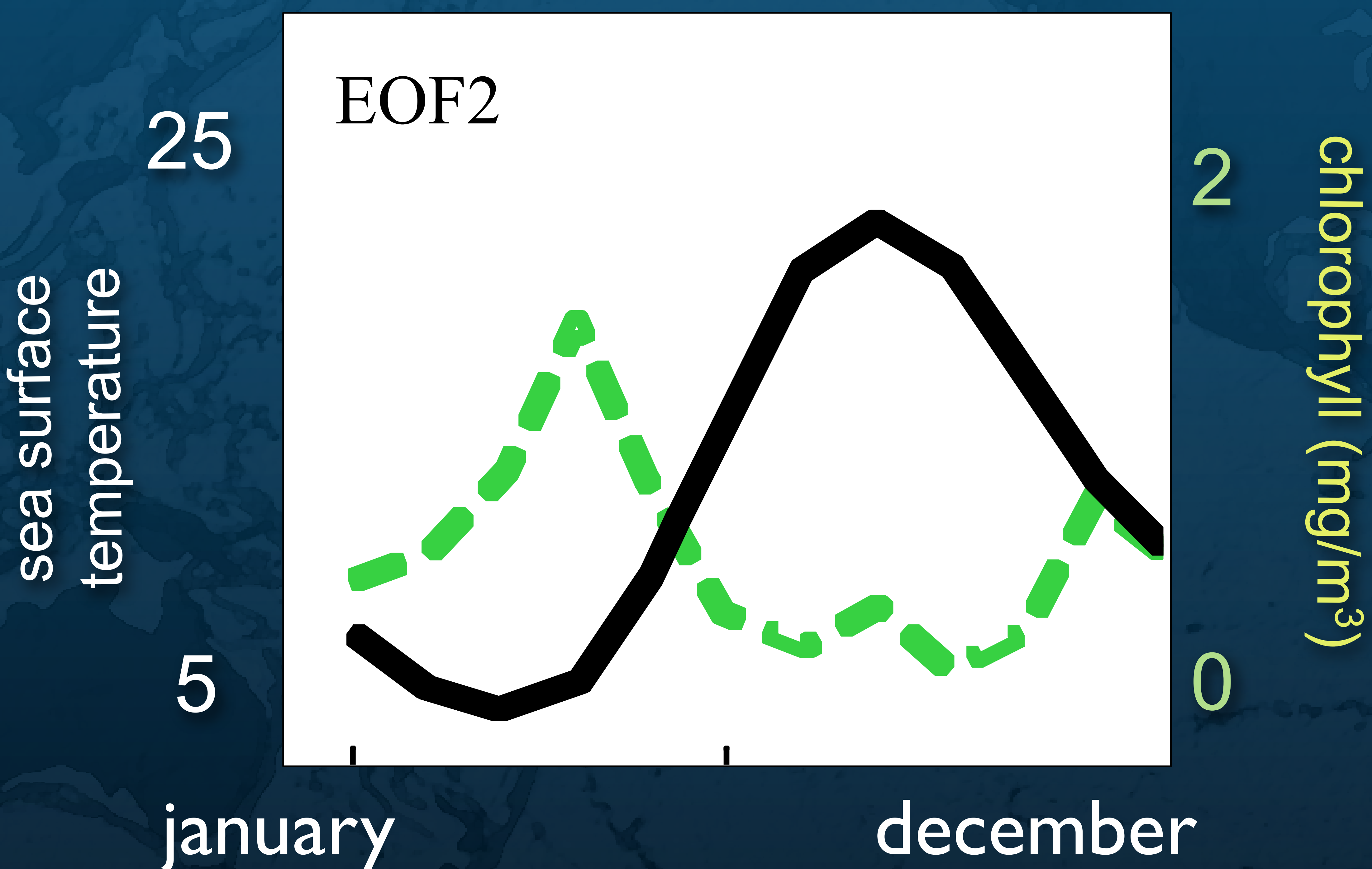
Low I' ⟶ **Light limitation**

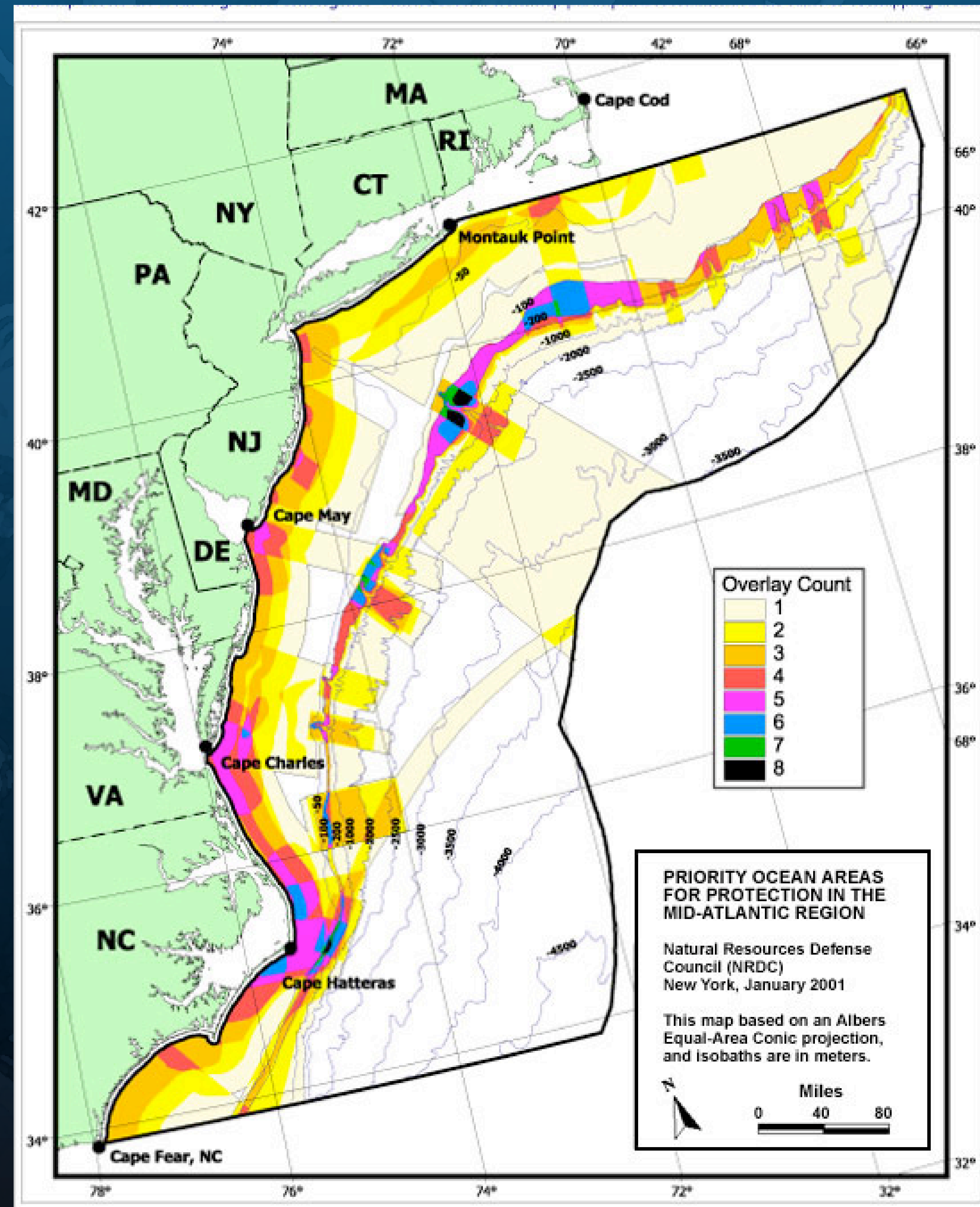
High I' ⟶ **Nutrient limitation**


60
160
Zone1
Zone2
Glider
Chl (mg m-3)
0
1
2
3
0
200
400
600
800
1000
Zone1
Zone2
Chl (mg m-3)
I' (watt m-2)

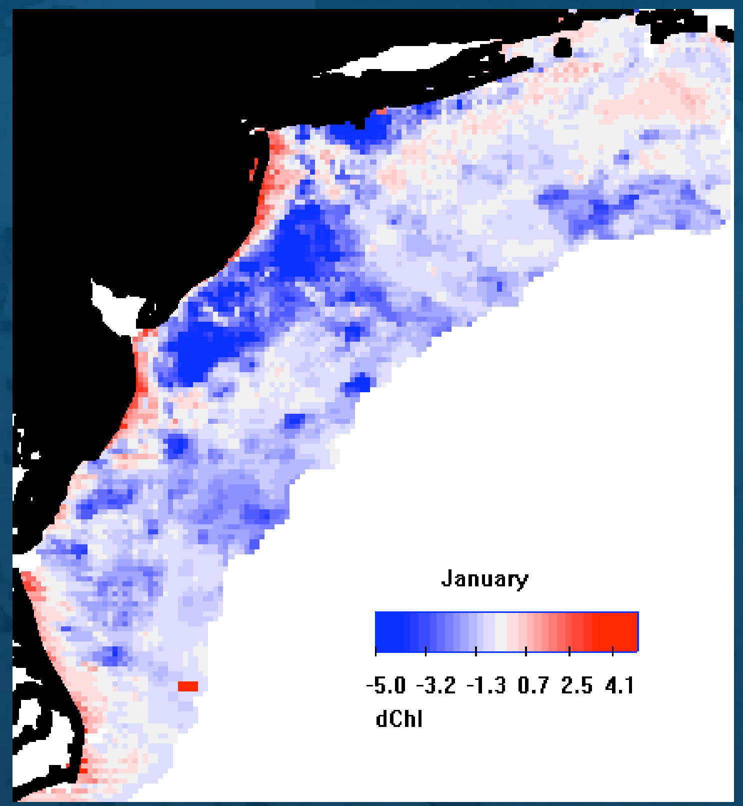

42°N
40°N
38°N
36°N
34°N
-78°W -76°W -74°W -72°W -70°W -68°
600
500
400
300
200
100
watt m^-2


Critial light (watt m^-2)
400
300
200
100
0
0 500 1000 1500 2000
Depth (m)
Critial light (watt m^-2)
120
100
80
60
40
100 200 300 400 500
Depth (m)

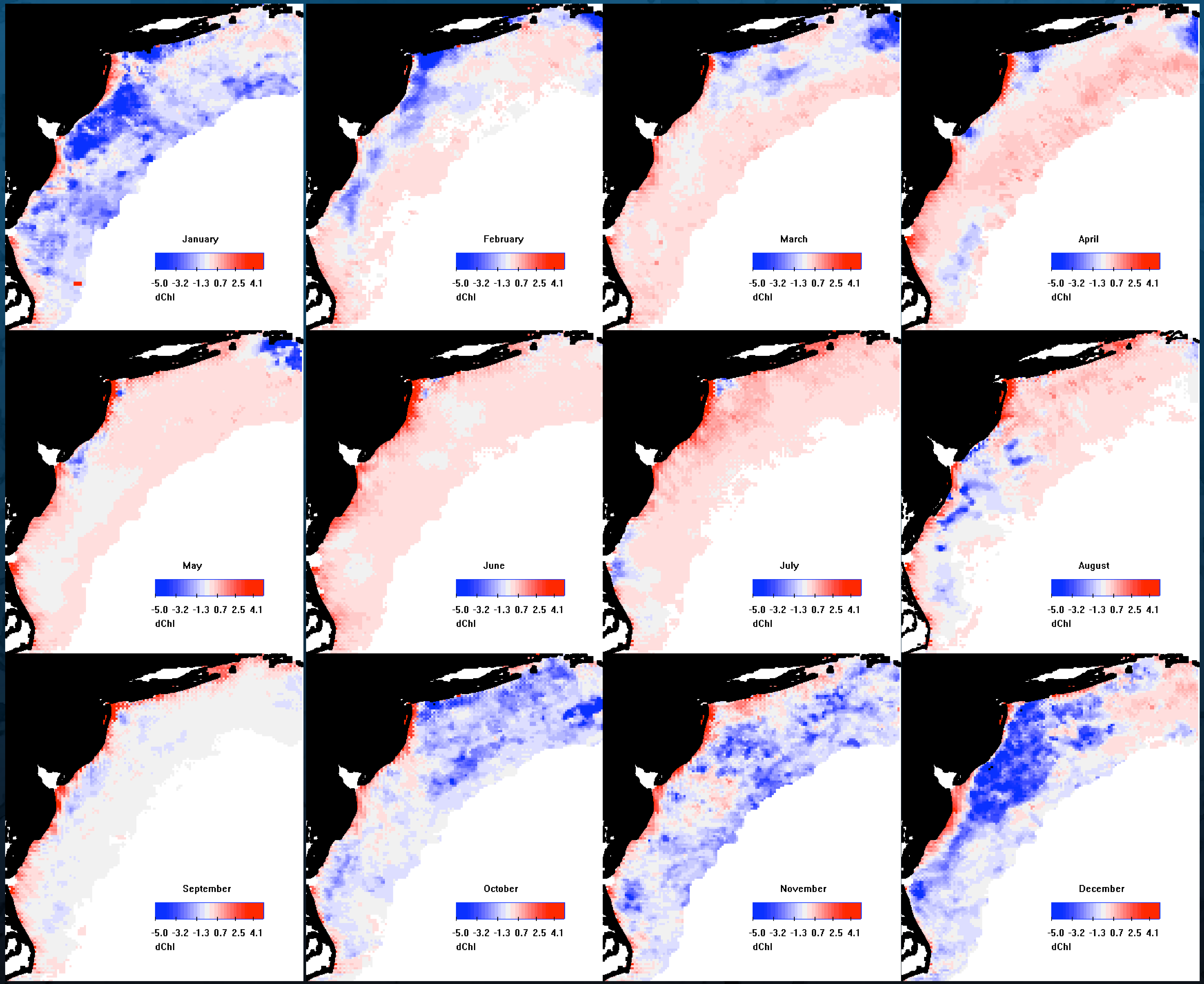

EOF2
25
5
sea surface temperature
2
0
chlorophyll (mg/m^3)
january
december


MA
RI
CT
NY
PA
NJ
MD
DE
VA
NC
Cape Cod
Montauk Point
Cape May
Cape Charles
Cape Hatteras
Cape Fear, NC
Overlay Count
1
2
3
4
5
6
7
8
PRIORITY OCEAN AREAS FOR PROTECTION IN THE MID-ATLANTIC REGION
Natural Resources Defense Council (NRDC)
New York, January 2001
This map based on an Albers Equal-Area Conic projection, and isobaths are in meters.
Miles
0 40 80

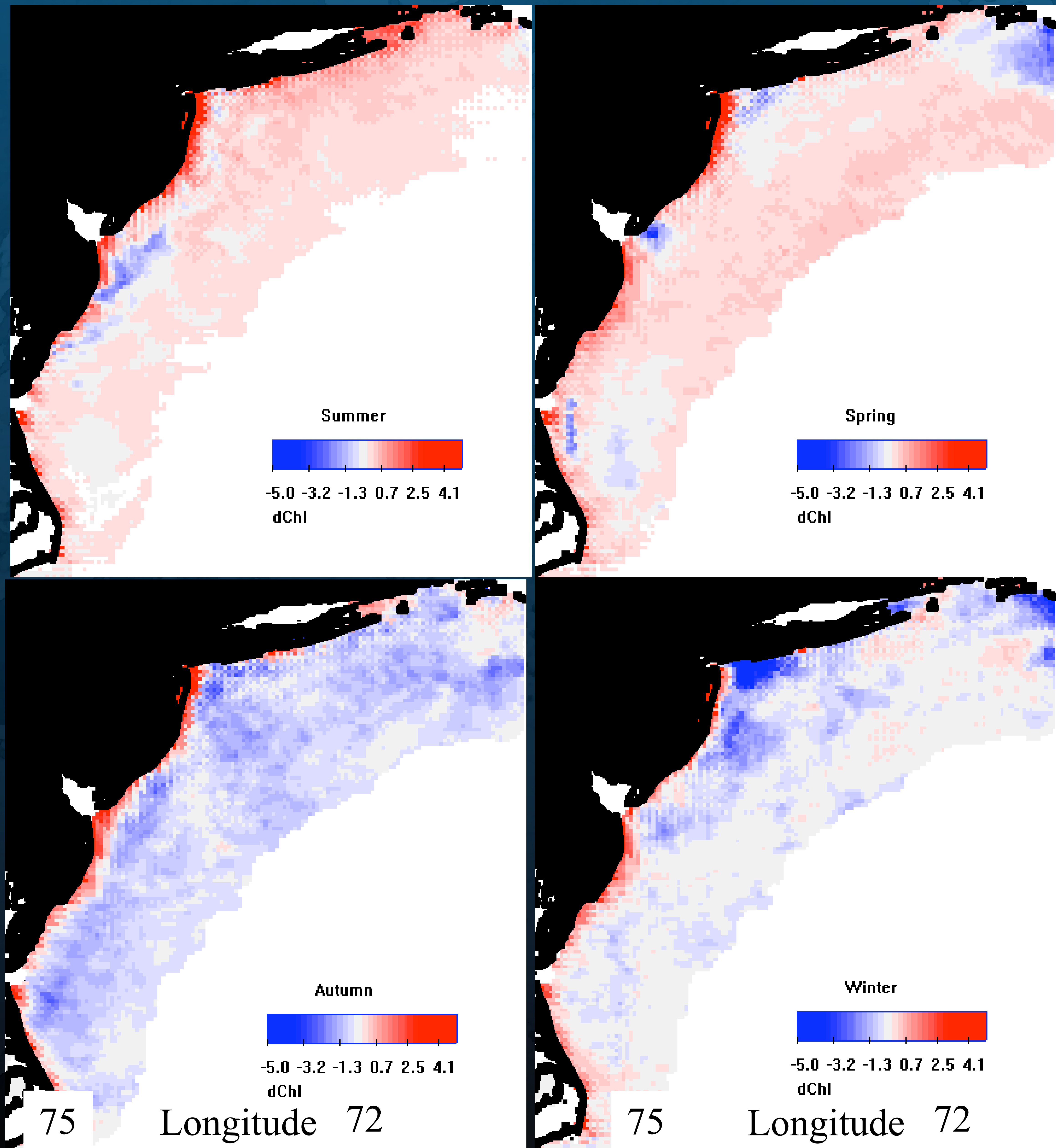
CZCS (1978-1986) and SeaWiFs (1998-2007)



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



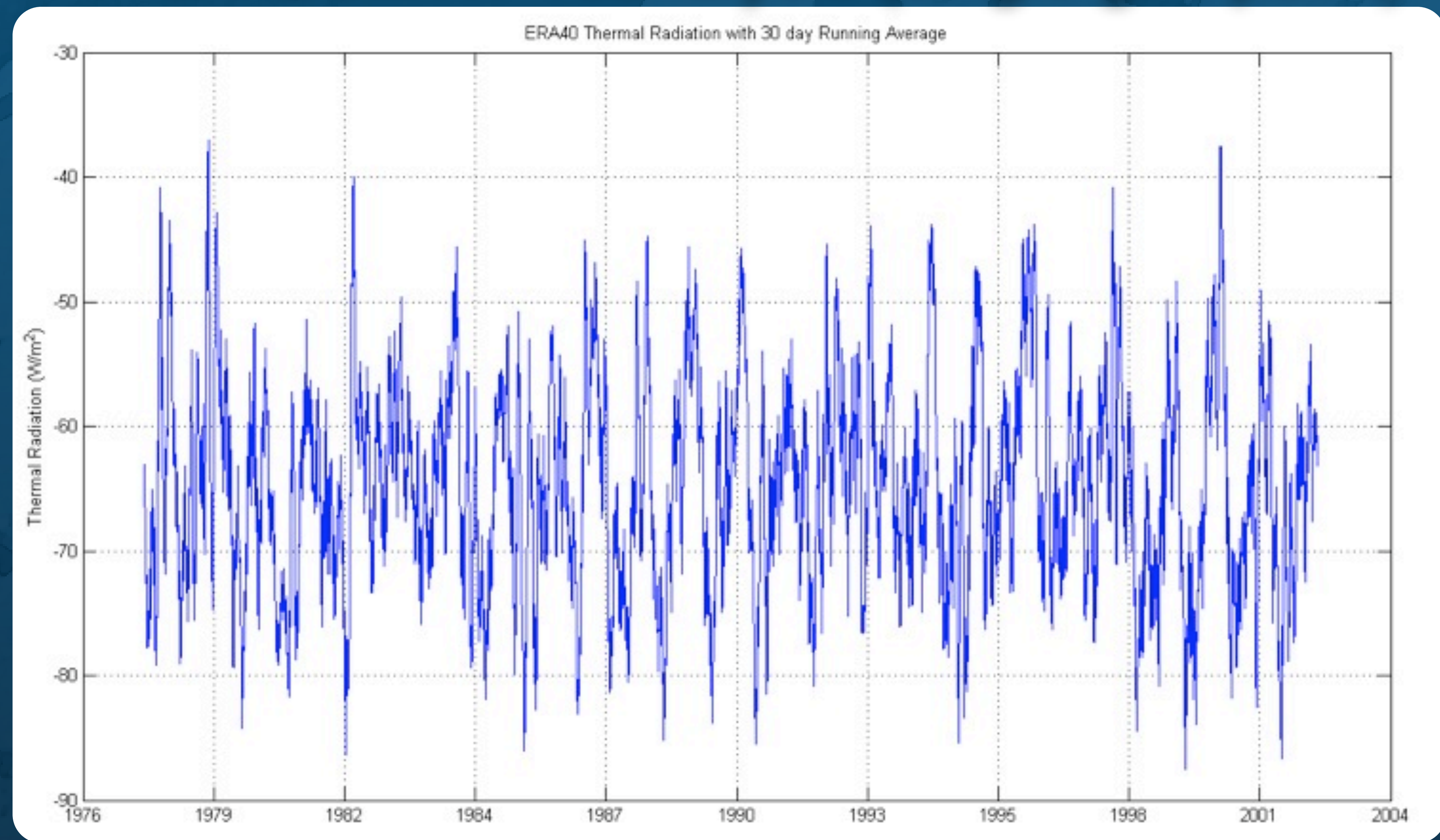
CZCS (1978-1986) and SeaWiFs (1998-2007)

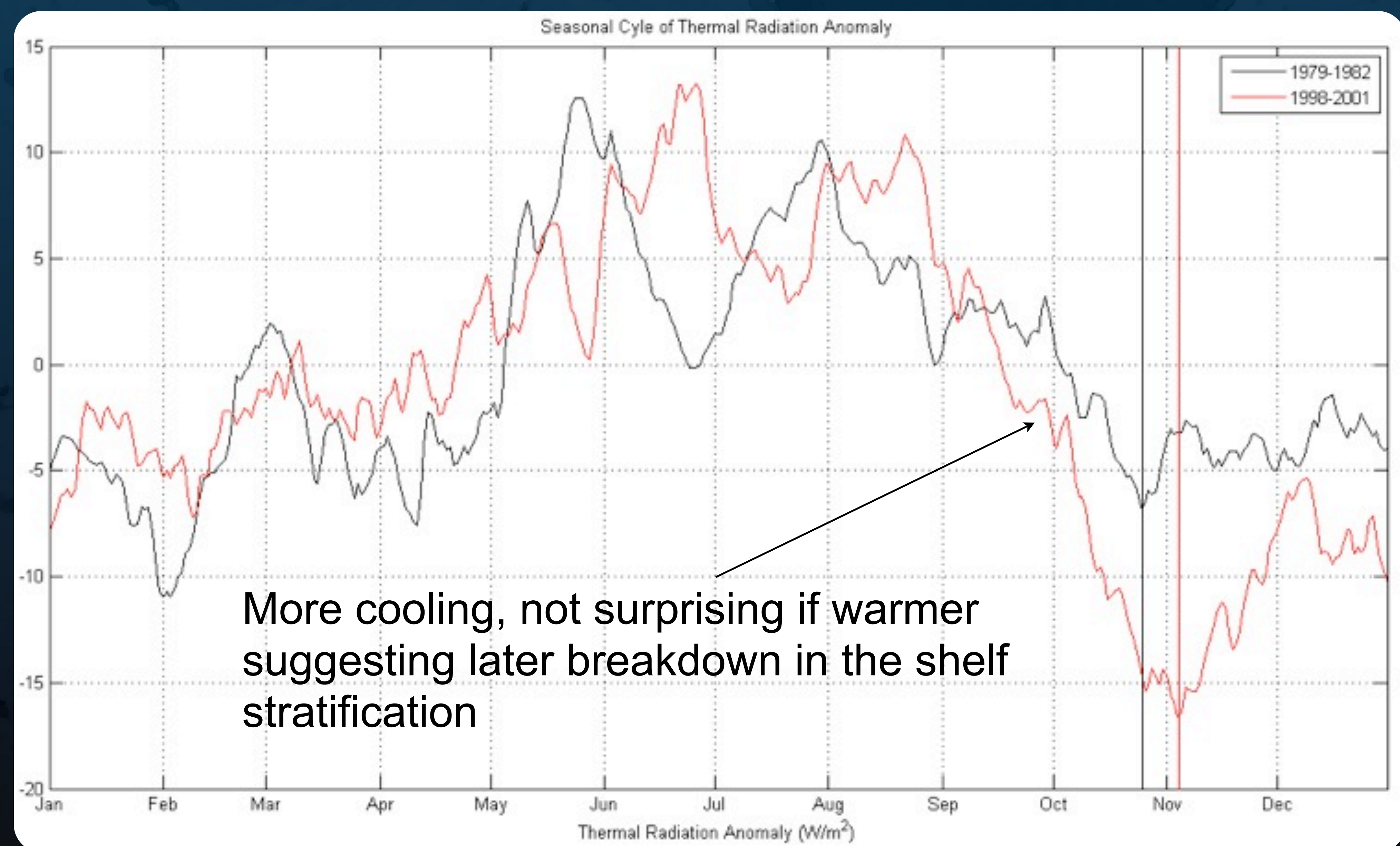


Season	1978–1986	1998–2006	Difference	% Change
Spring	2.52	2.74	0.21	8
Summer	1.73	2.02	0.29	14
Fall	3.89	2.73	-1.16	-43
Winter	3.61	2.80	-0.81	-29
Total	**13.00**	**11.35**	**-1.66**	**-14**

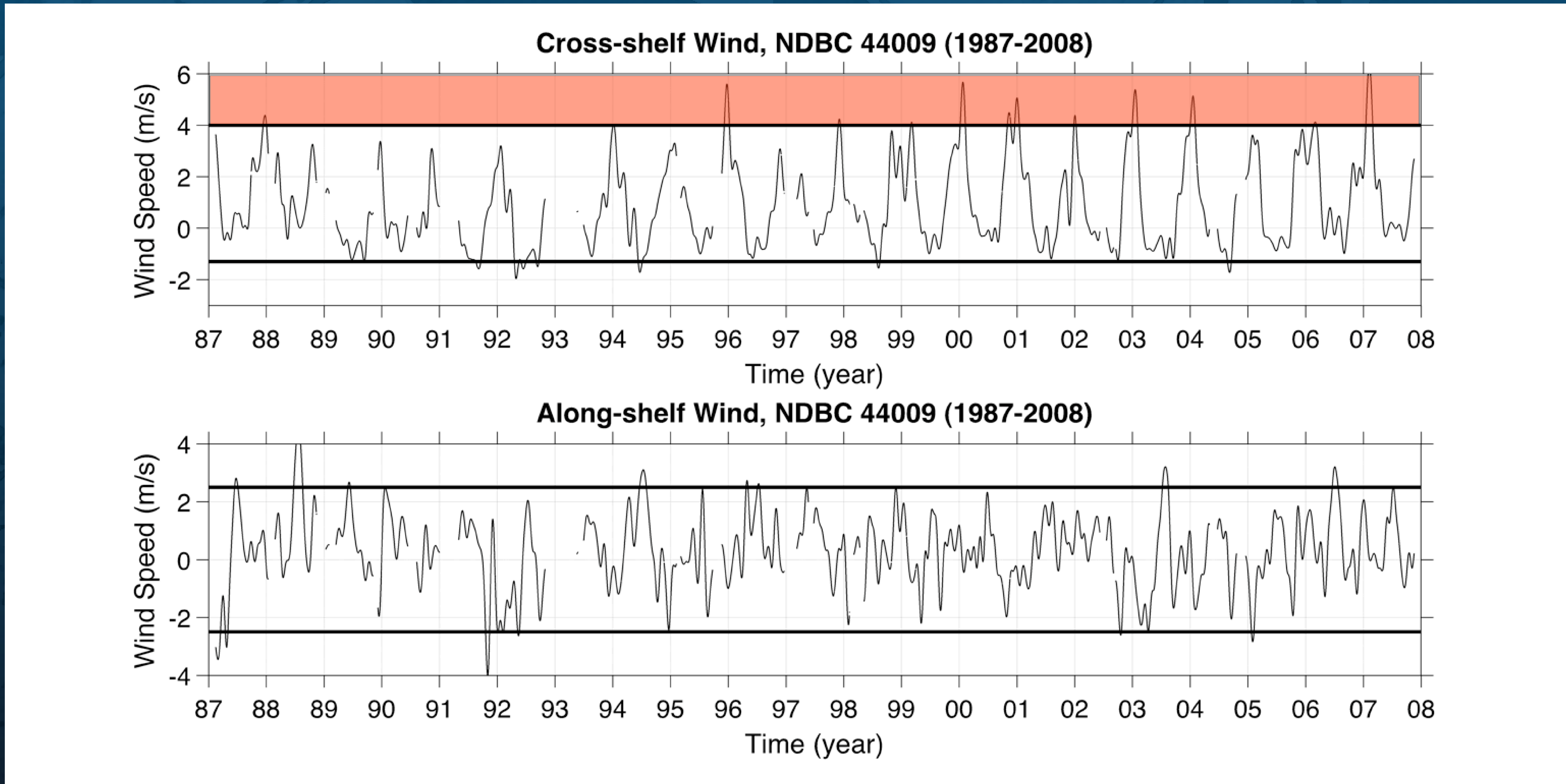
Declines in the Fall Bloom?

From ECMWF reanalysis (single gird point)

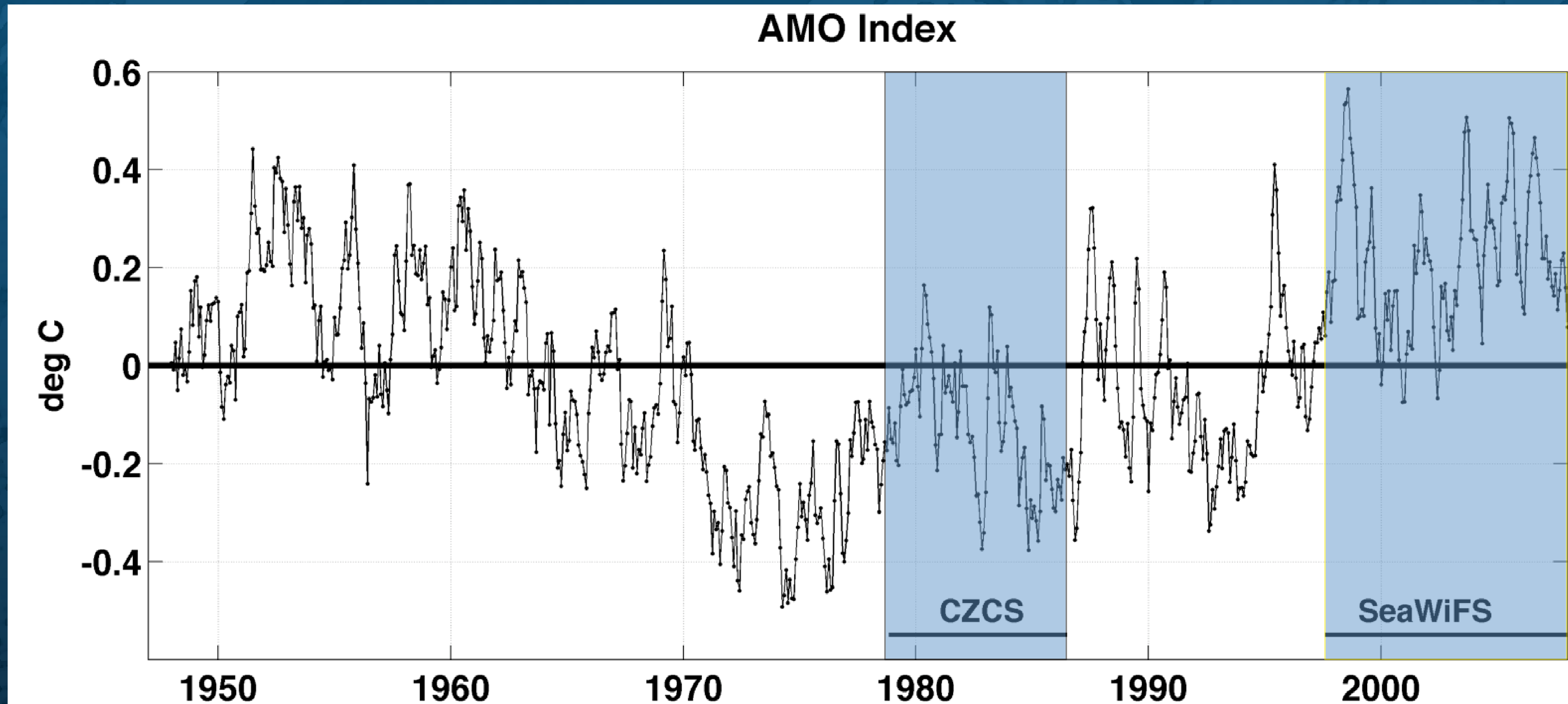




Declines in the Winter Bloom?



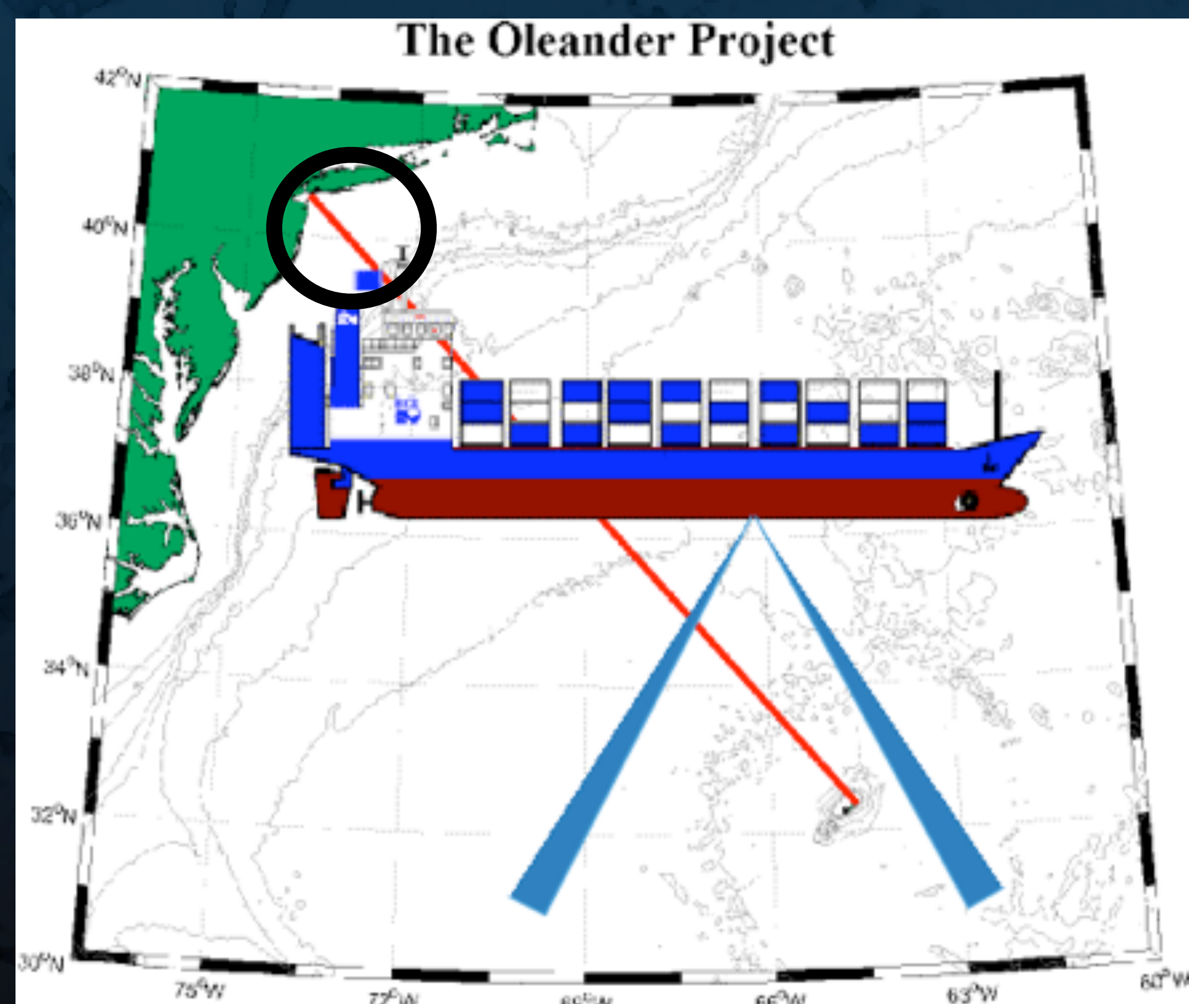
Declines in the Winter Bloom?

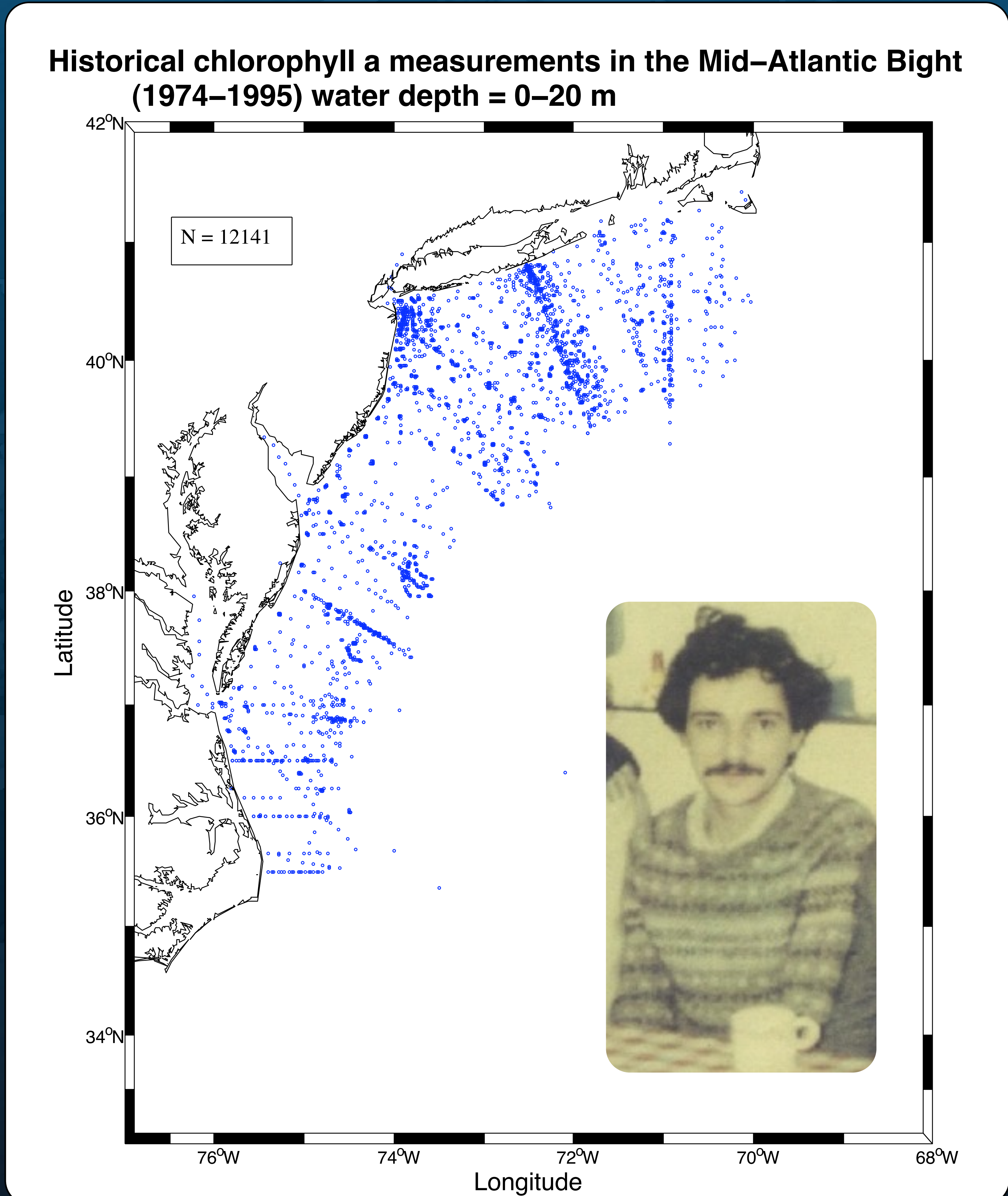


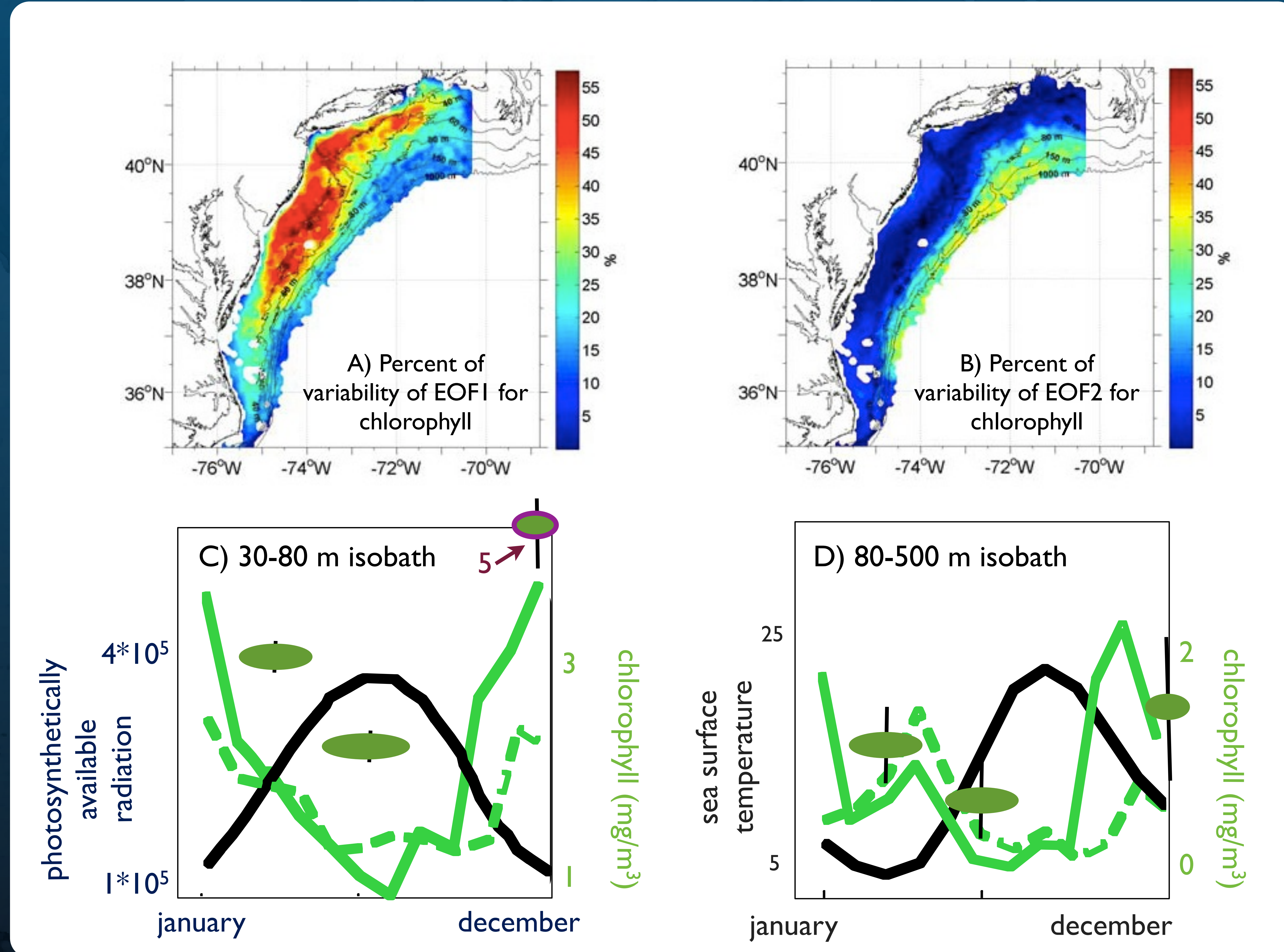
winter winds

duration of shelf stratification

annual phytoplankton biomass



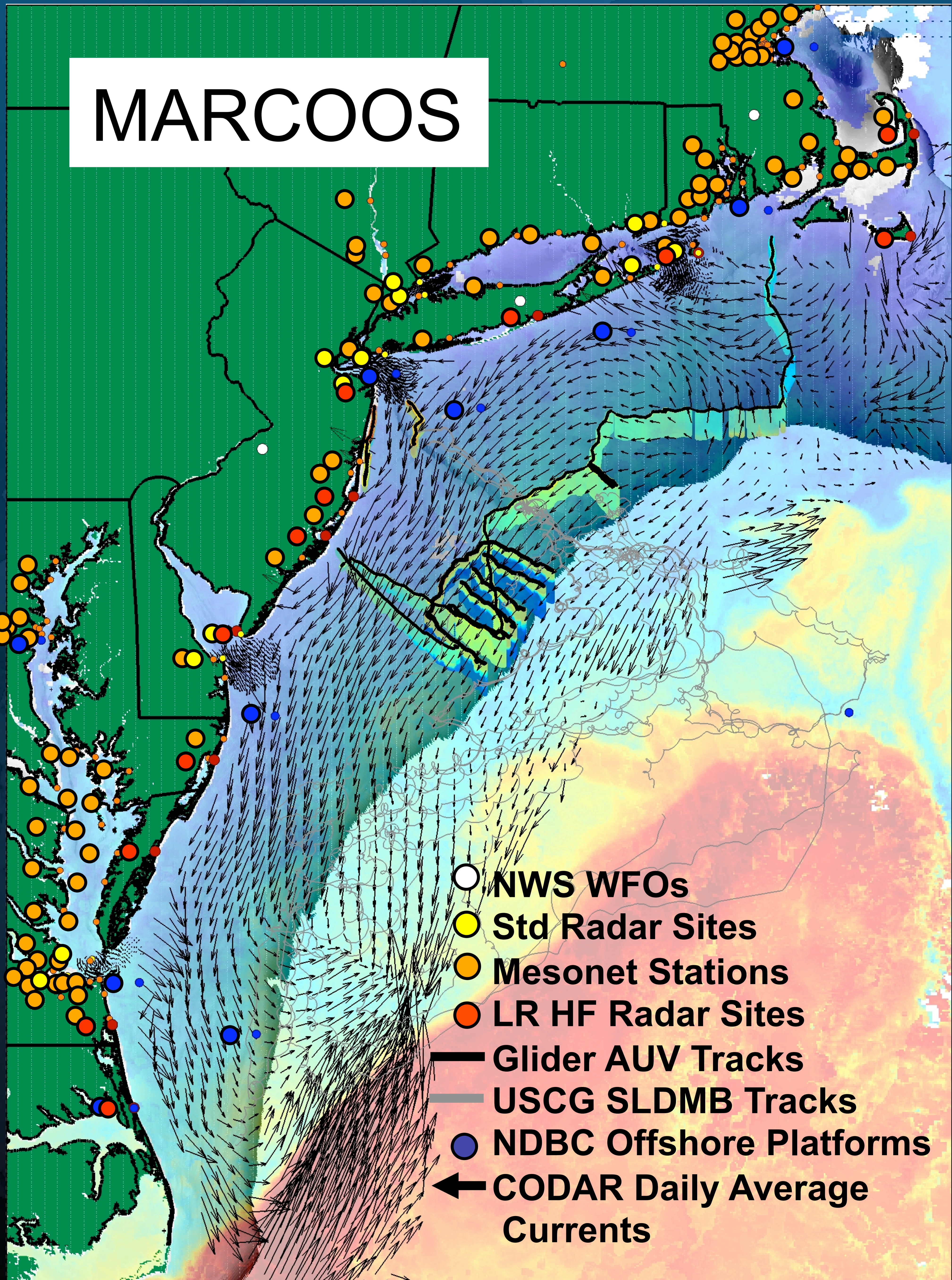

Historical chlorophyll a measurements in the Mid–Atlantic Bight
(1974–1995) water depth = 0–20 m
N = 12141
Latitude
Longitude
42°N
40°N
38°N
36°N
34°N
76°W
74°W
72°W
70°W
68°W


A) Percent of variability of EOF1 for chlorophyll
B) Percent of variability of EOF2 for chlorophyll
40°N
38°N
36°N
-76°W
-74°W
-72°W
-70°W
%
C) 30-80 m isobath
5
photosynthetically available radiation
4*10^5
1*10^5
3
1
chlorophyll (mg/m^3)
january
december
D) 80-500 m isobath
sea surface temperature
25
5
2
0
chlorophyll (mg/m^3)
january
december


Manasquan Inlet, NJ
Star Ledger
1978-1986 CZCS
Stations with water depth = 40-100 m
Winter
Spring
Summer
Fall
0.05
1
30
Chl a (mg m-3)

In Situ Research- 'The Early Years'

NOAA Integrated Ocean Observing System (IOOS)

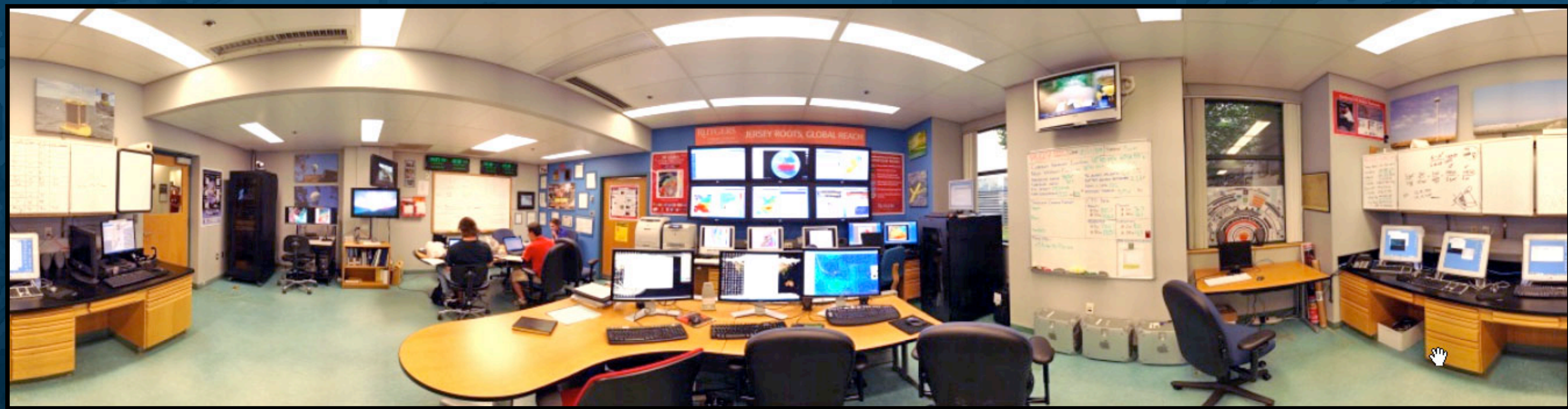


MY INTERESTS: USING THE OOI & IOOS NETWORK (CINAR?) TO DEFINE THE INTERFACE OF MIXING AND SEASONAL LIGHT

To test the software, OOI used an existing ocean network. The test engaged scientists from across the country who used the software to enable their science. For OOI, the network provided an ideal "real world" test

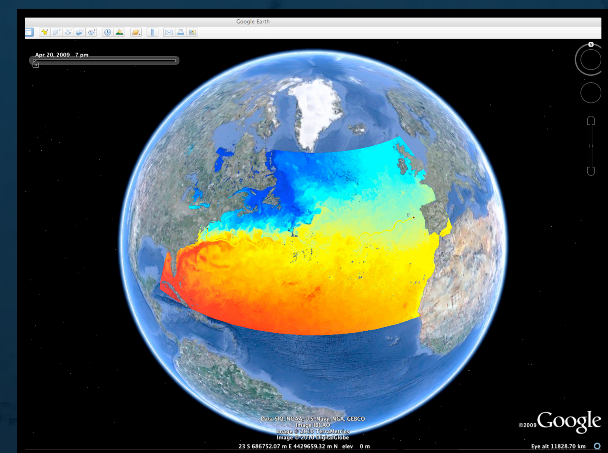
Participating Institutions: Rutgers, MIT, Scripps, Wood Hole, NRL, U Mass, U Maryland, JPL, WHOI, Cal Poly, U Del, Stevens, OSU, USGS, NOAA, NURC, NWS
(~125 scientists & engineers)

COORDINATE THE EXPERIMENT THROUGH THE COOL ROOM, BUT THE EXPERIMENT INCLUDES A GEOGRAPHICALLY DISTRIBUTED GROUP OF LABS

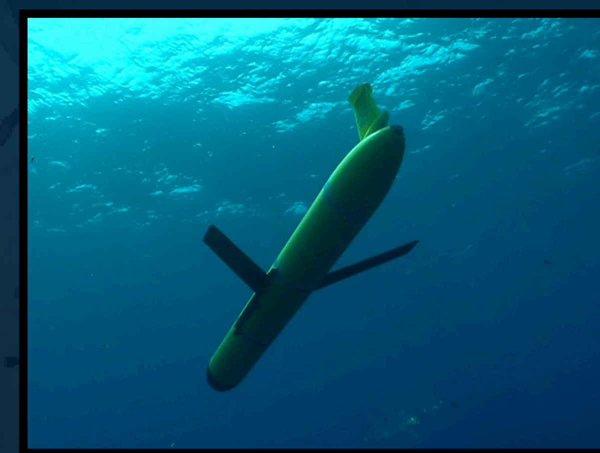


HF Radar

Satellites



3D Now- & Forecasts

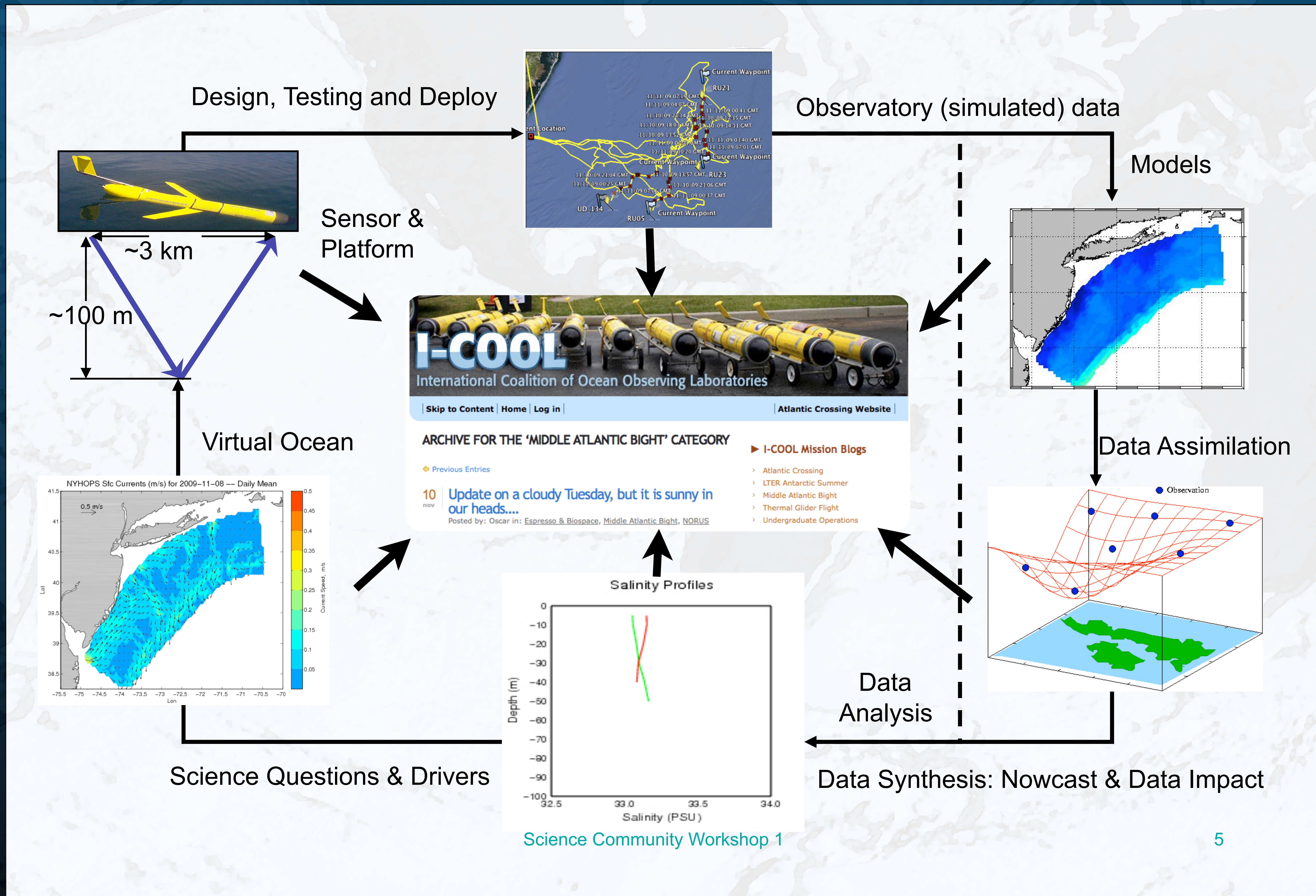


Robots

- **Objective: To provide a real oceanographic test bed in which the designed CI technologies will support field operations of ships and mobile platforms, aggregate data from fixed platforms, shore-based radars, and satellites and offer these data streams to data assimilative forecast models.**
- **Goal: To use multi-model forecasts to guide glider deployment and coordinate satellite observing.**

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)

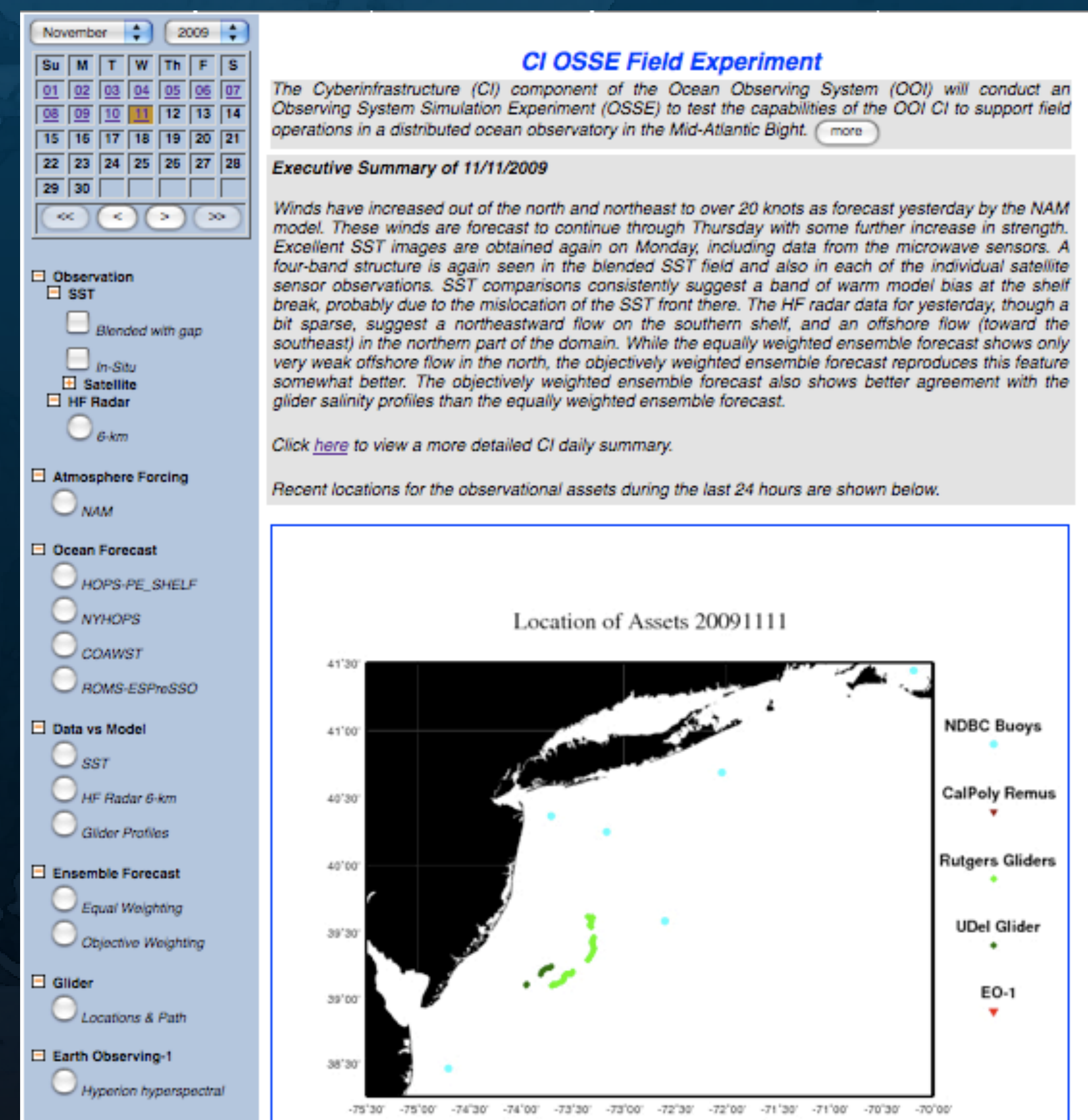


The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

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

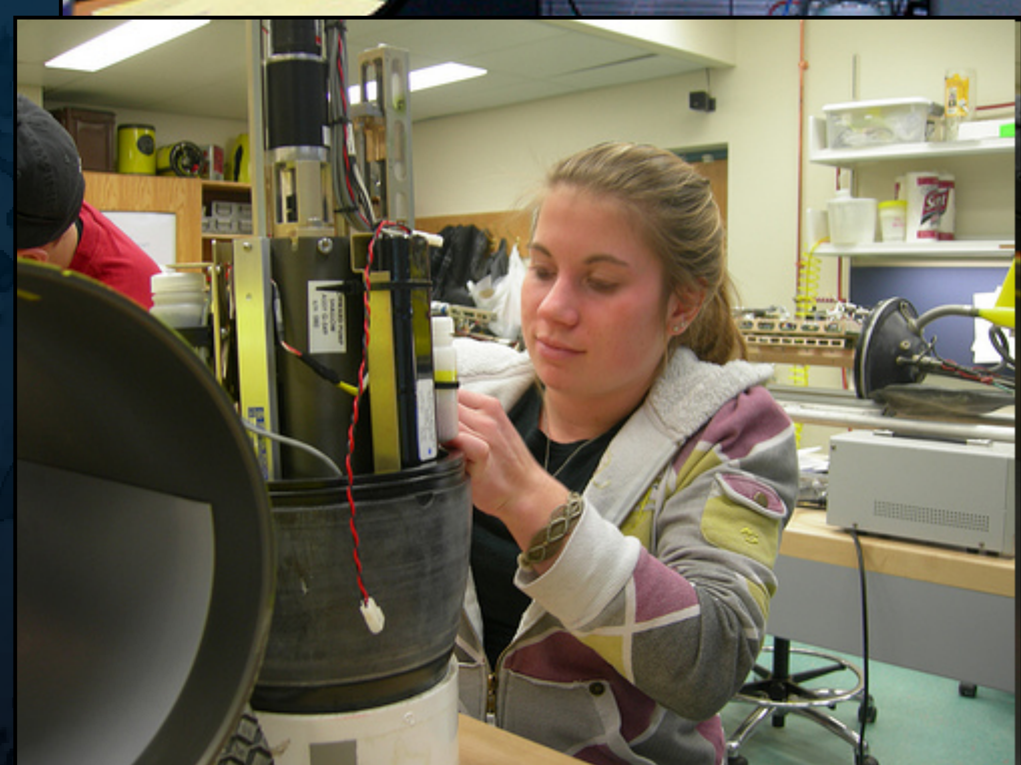
Community Blog

Data Portal



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

Exciting the Next Generation: Data live to undergraduates and students helped deploy the tools

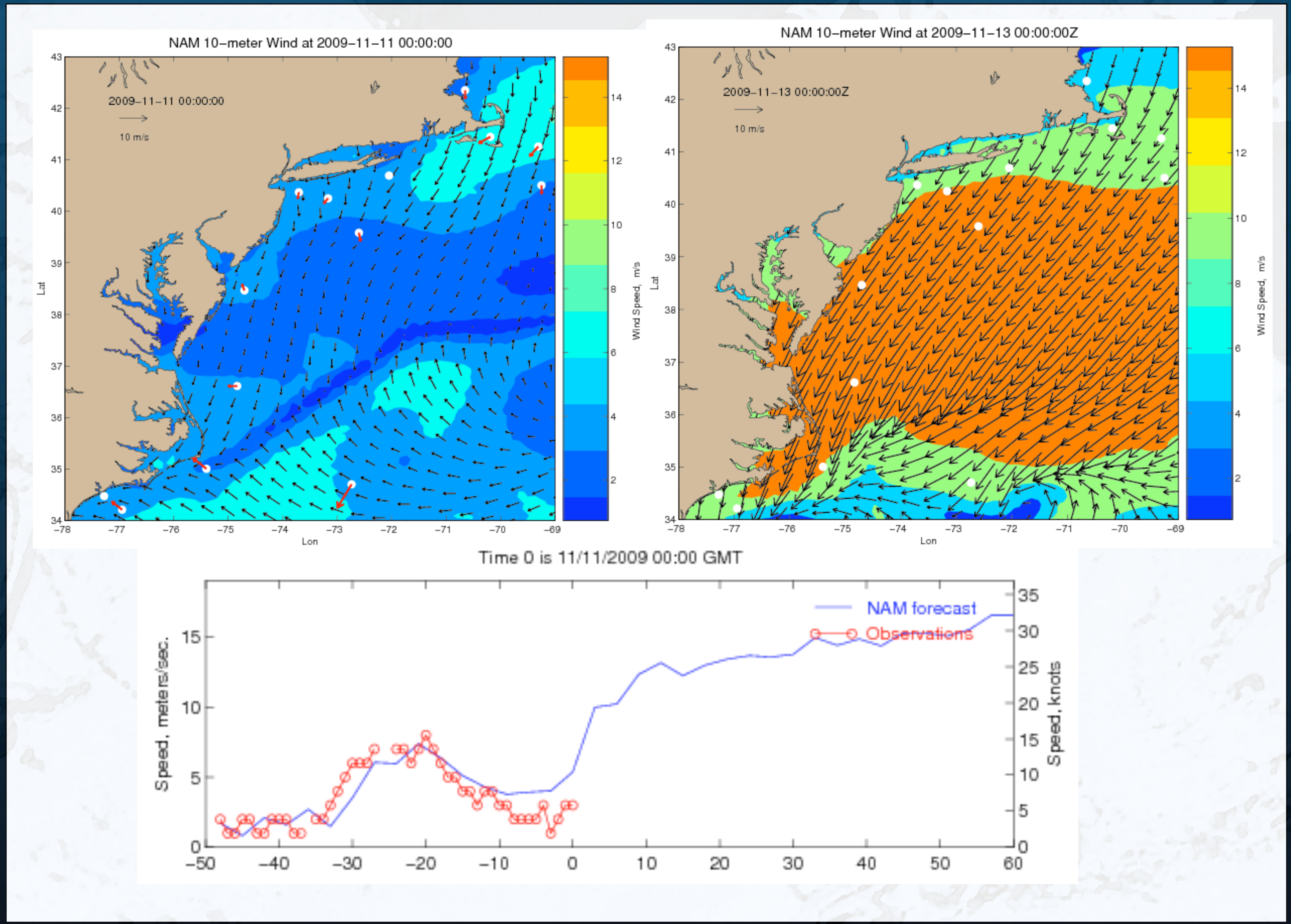


The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

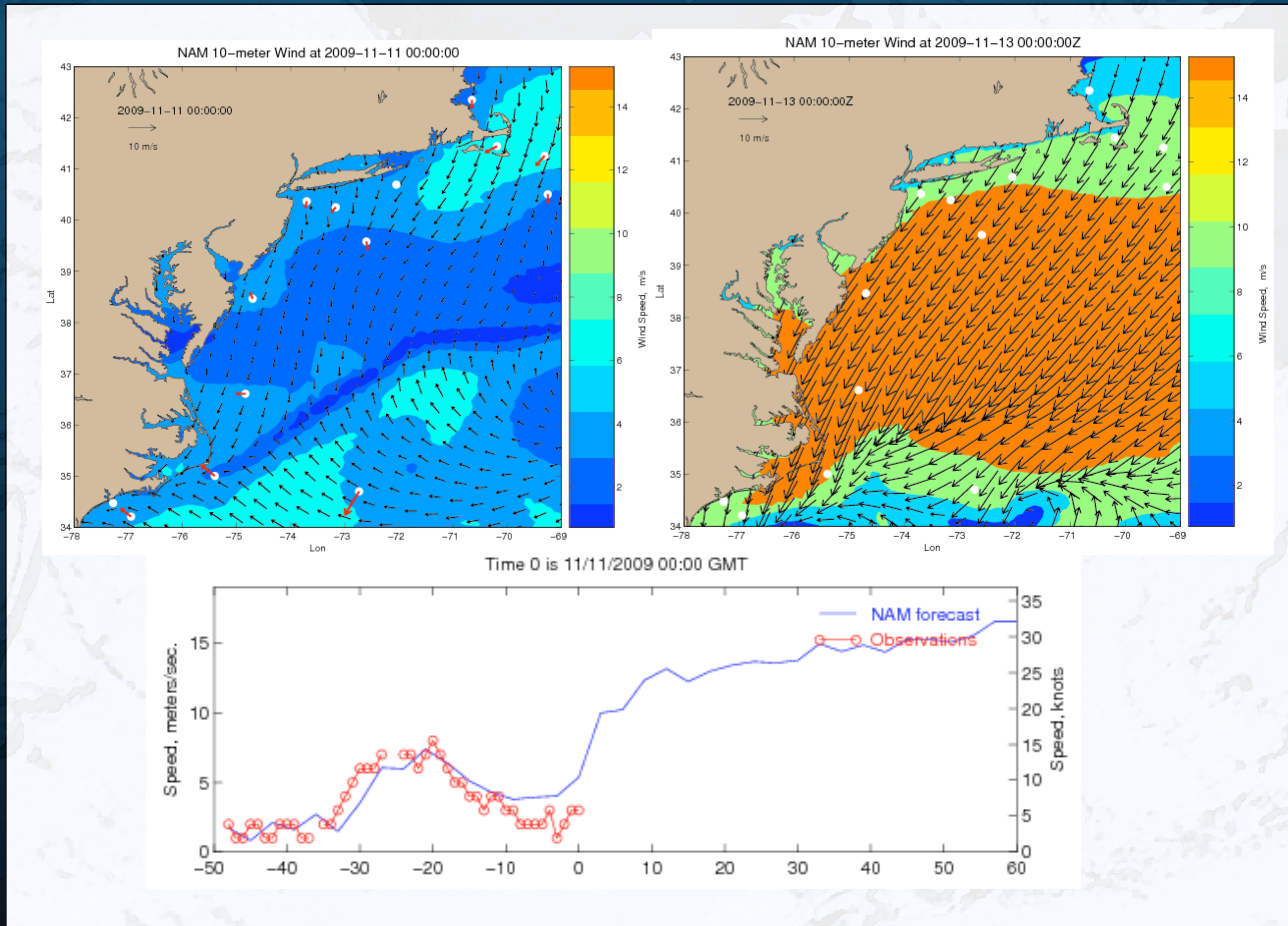
Documenting the efforts: Scripps document the efforts with Rutgers English Students

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

Weather Forecasts



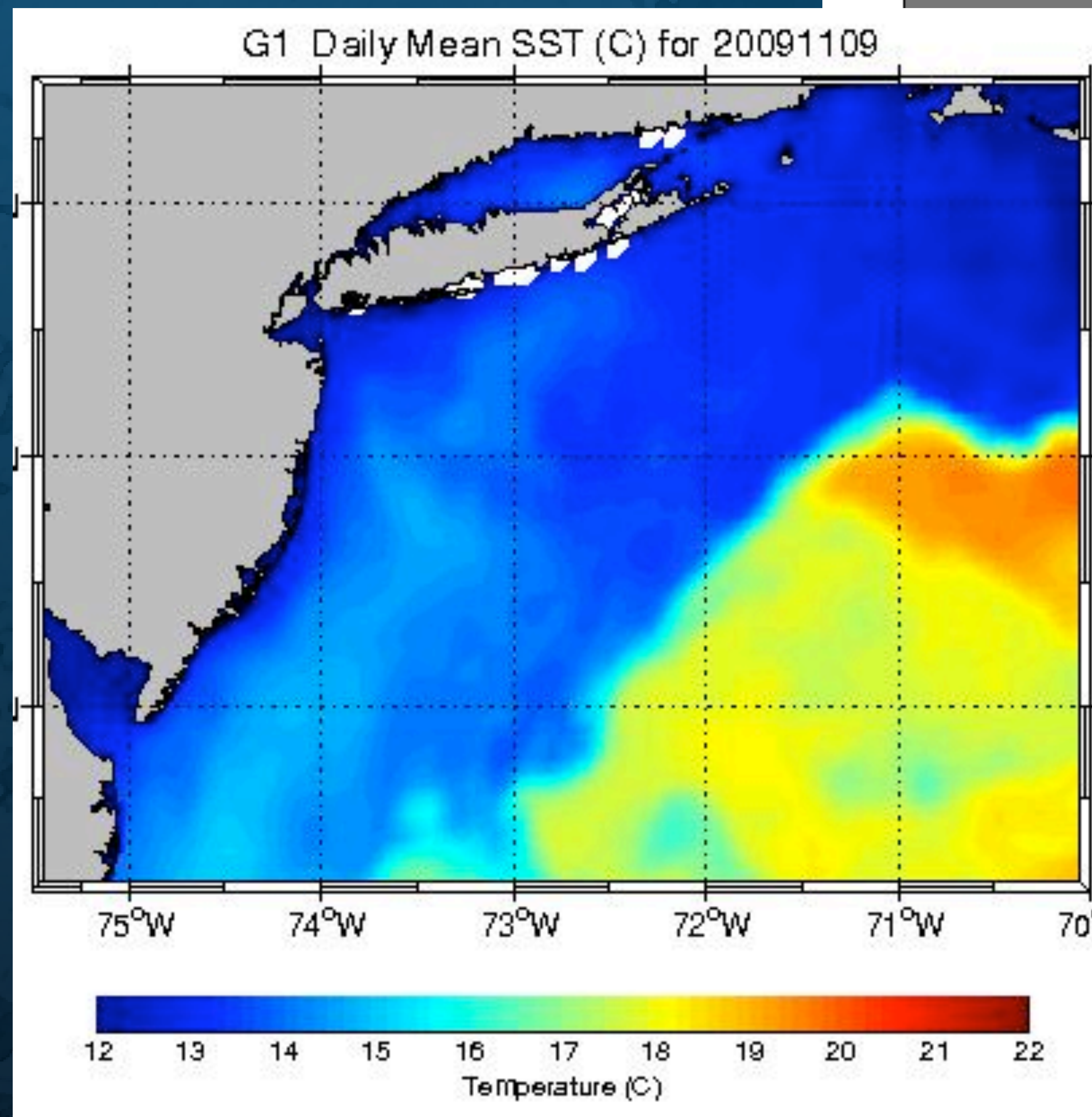
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

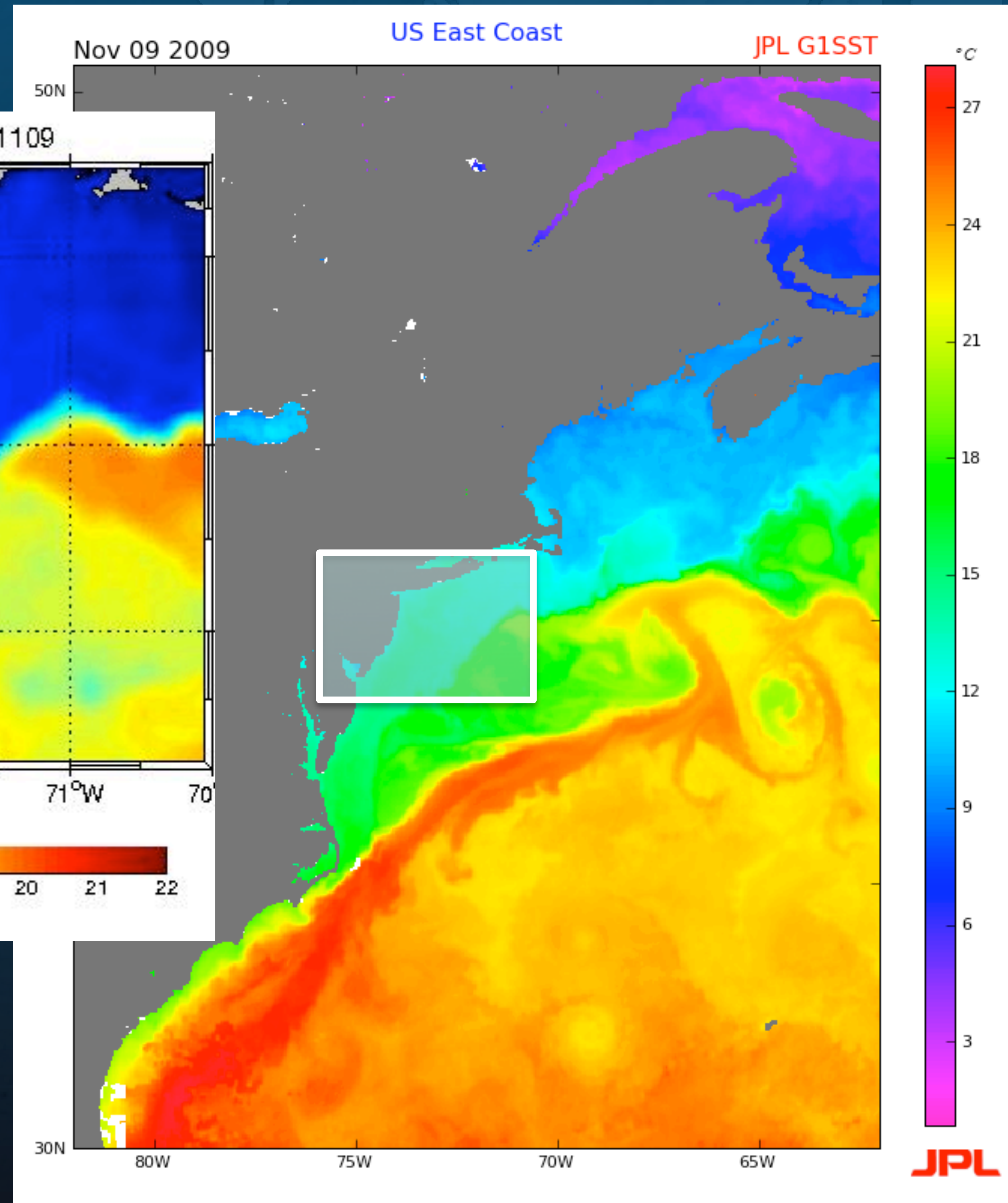


Weather Forecasts

The OOI Observing System Experiment (OSE)

5 different satellite sensors

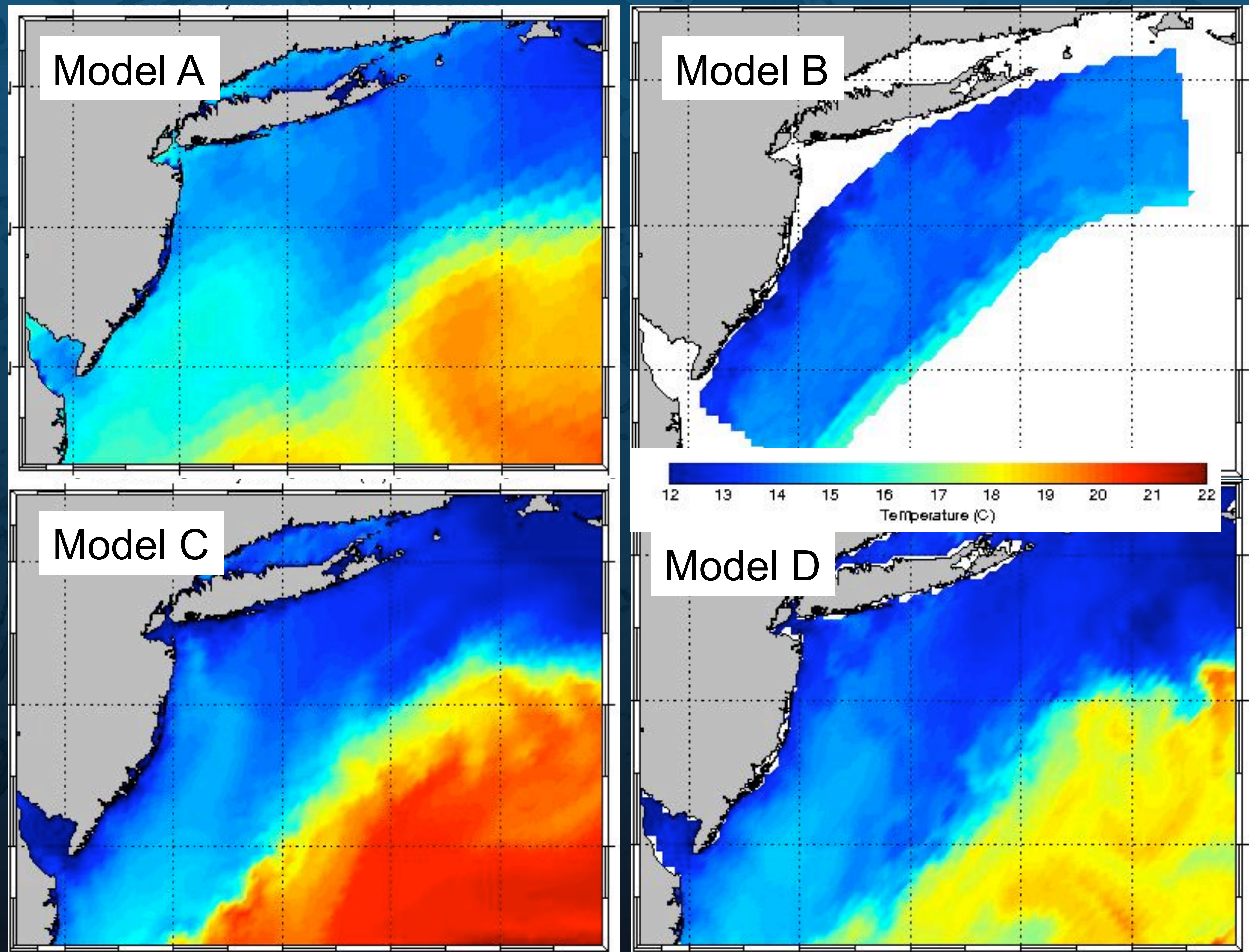




The OOI Observing System Experiment (OSE)

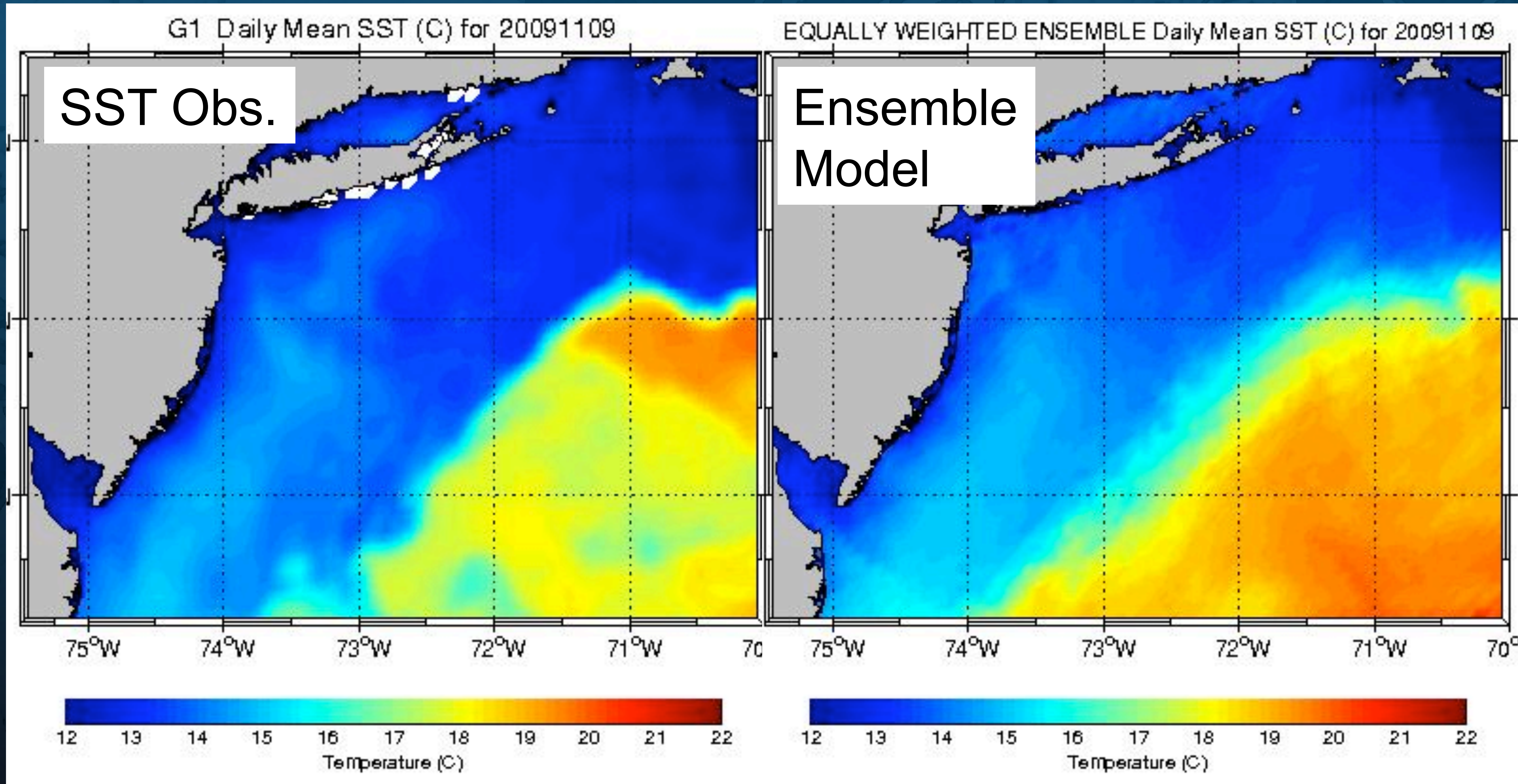
5 ocean numerical models run in forecast mode:

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



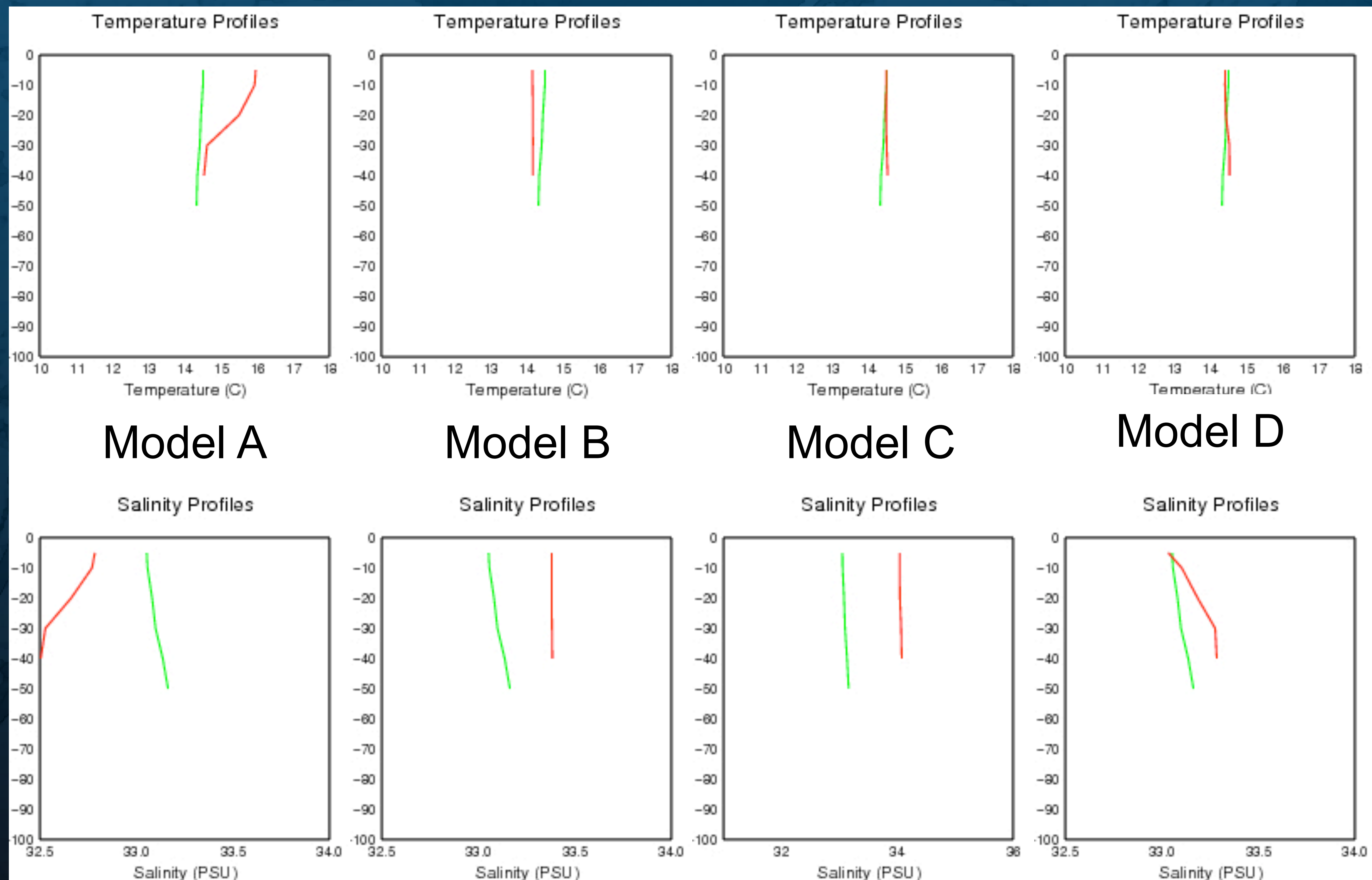
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

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



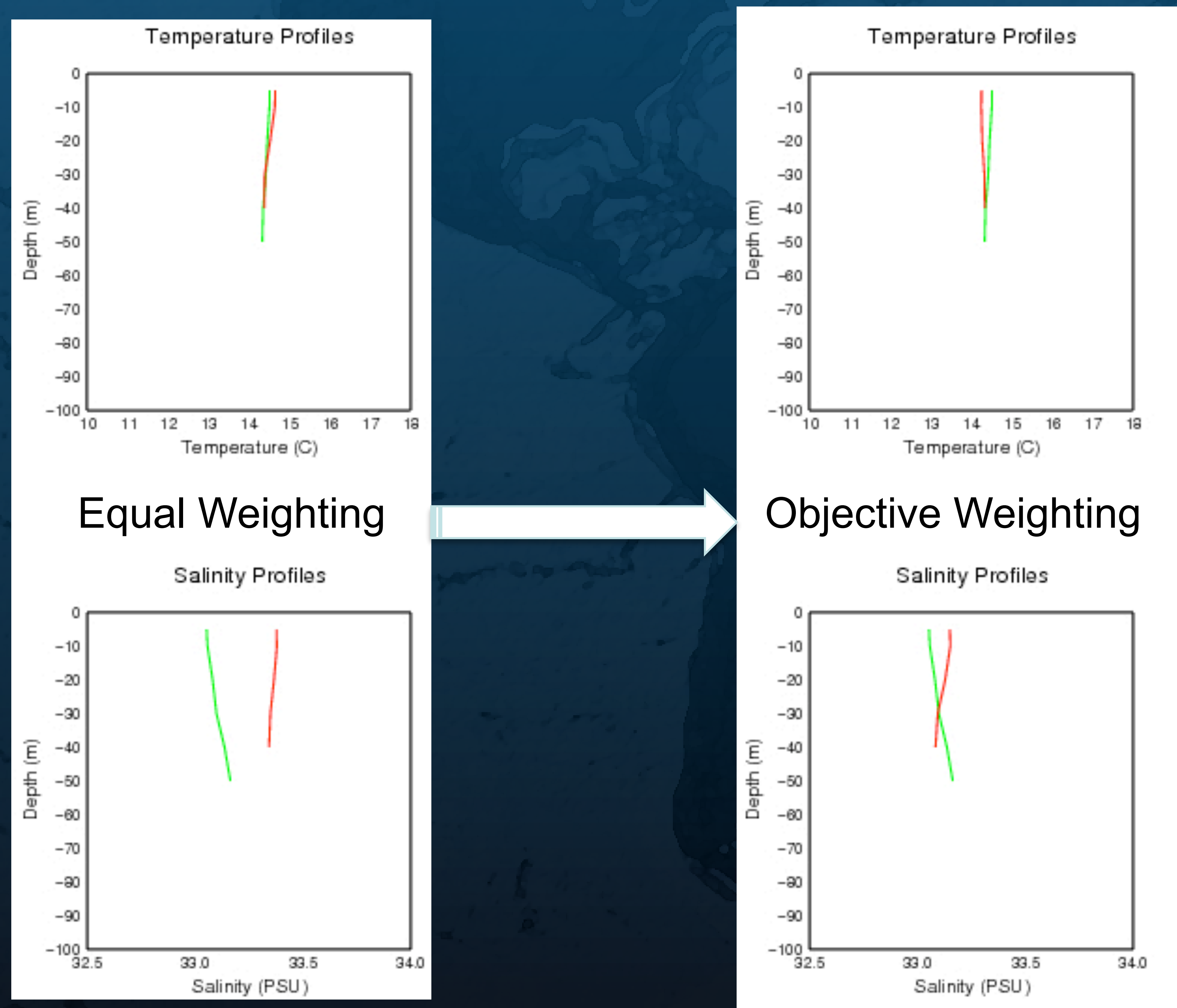
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

The same for *in situ* measurements



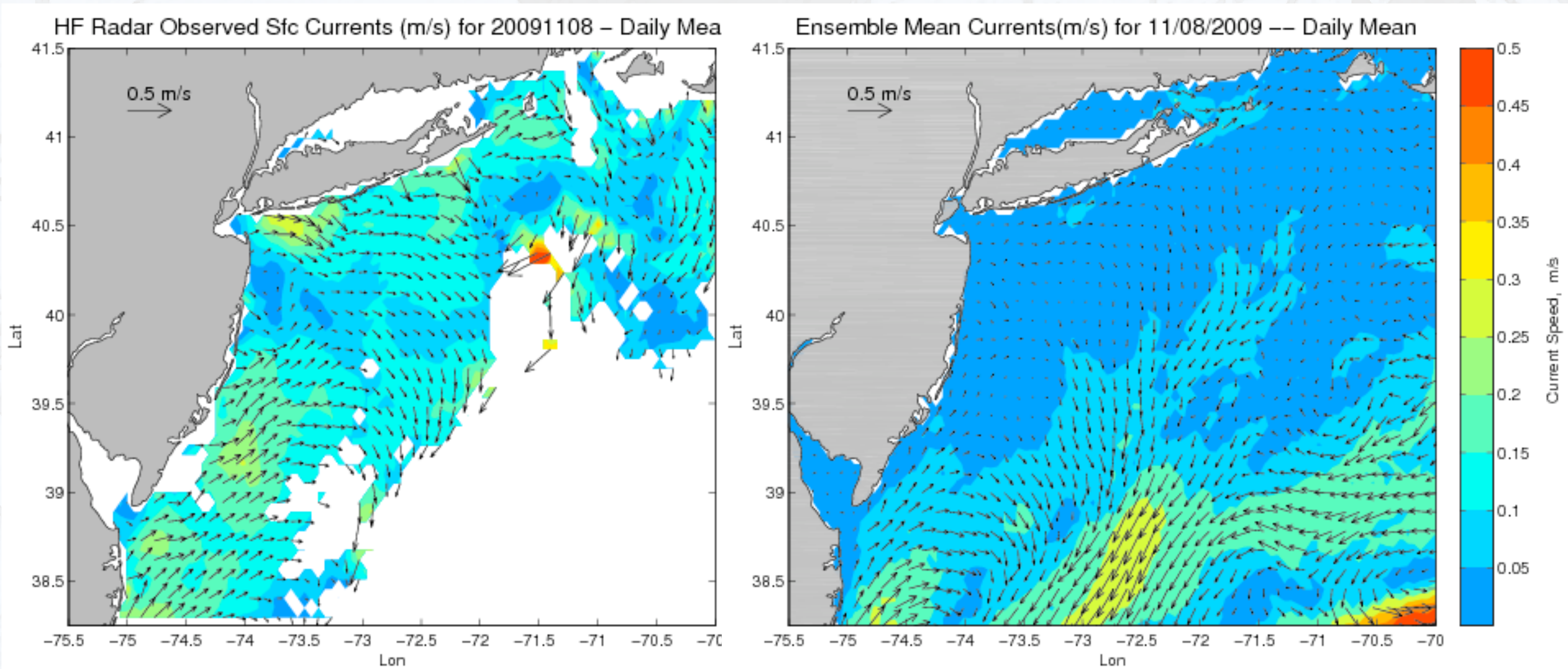
The OOI Observing System Experiment (OSE)
Nov 2 to Nov 13 2009

Discussion during experiment develops new tools during the experiment



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

Observation model comparisons spurred discussion on tools for synthesis

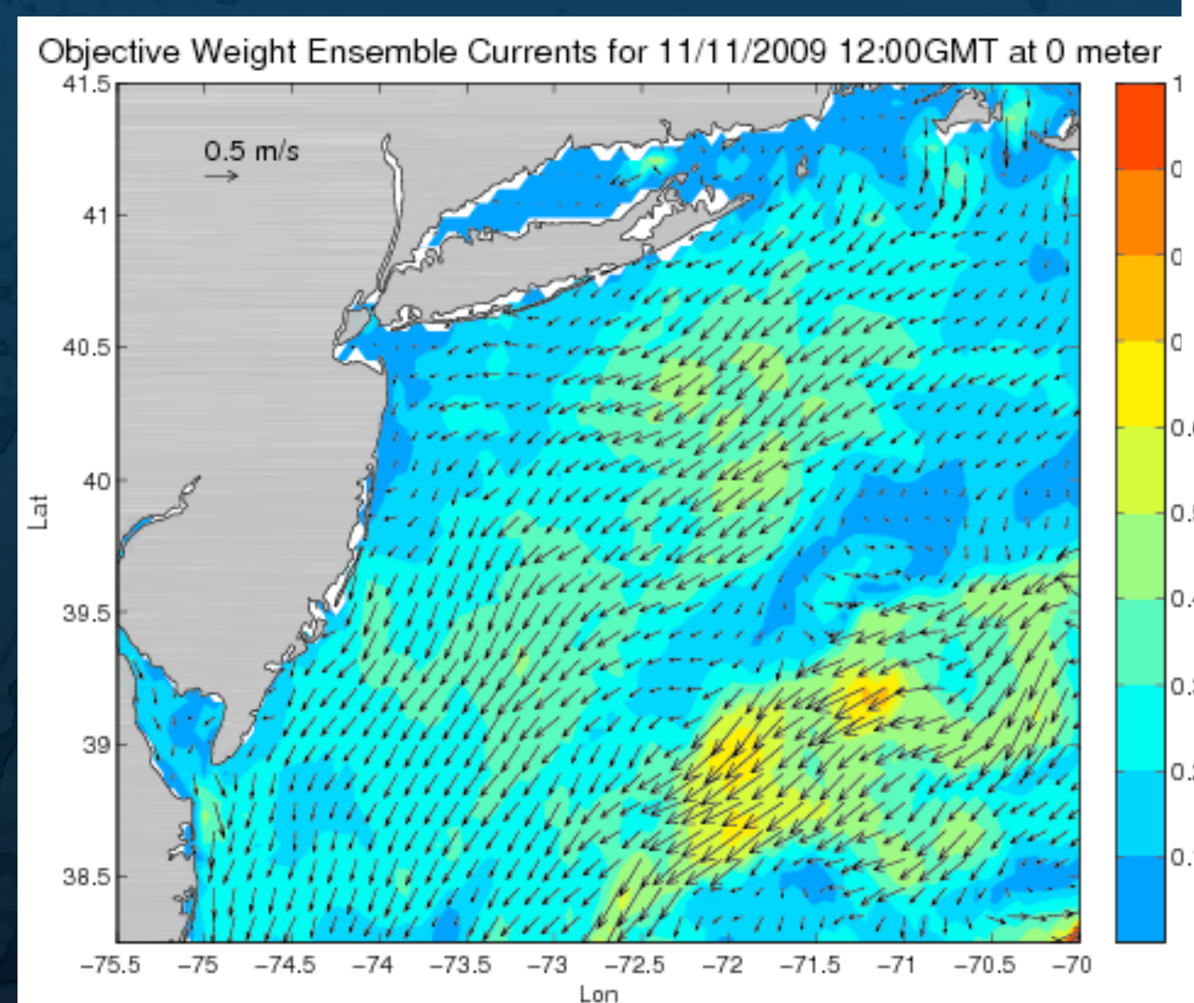


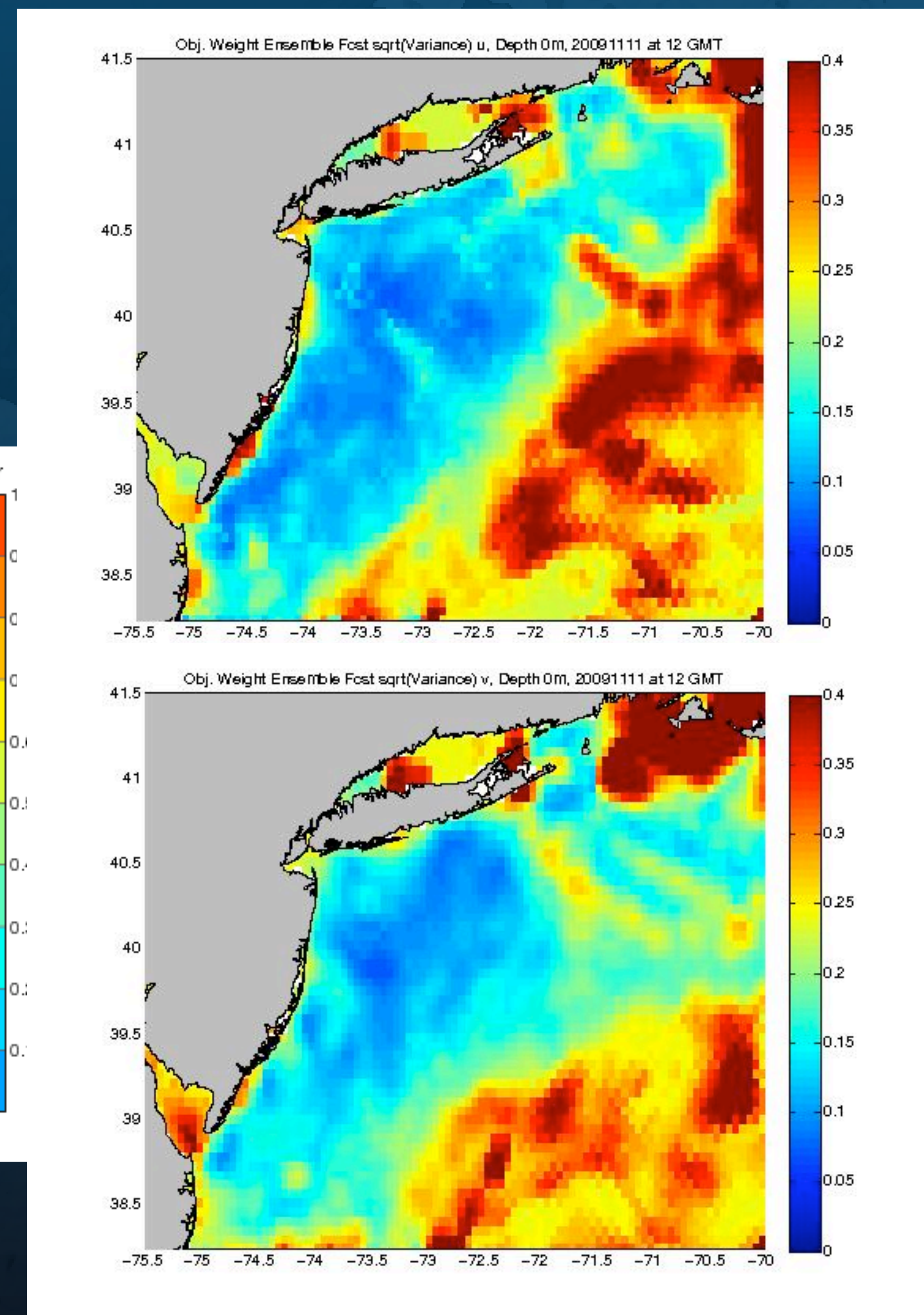
HF Radar Obs

Ensemble Model

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

Ensemble mean model

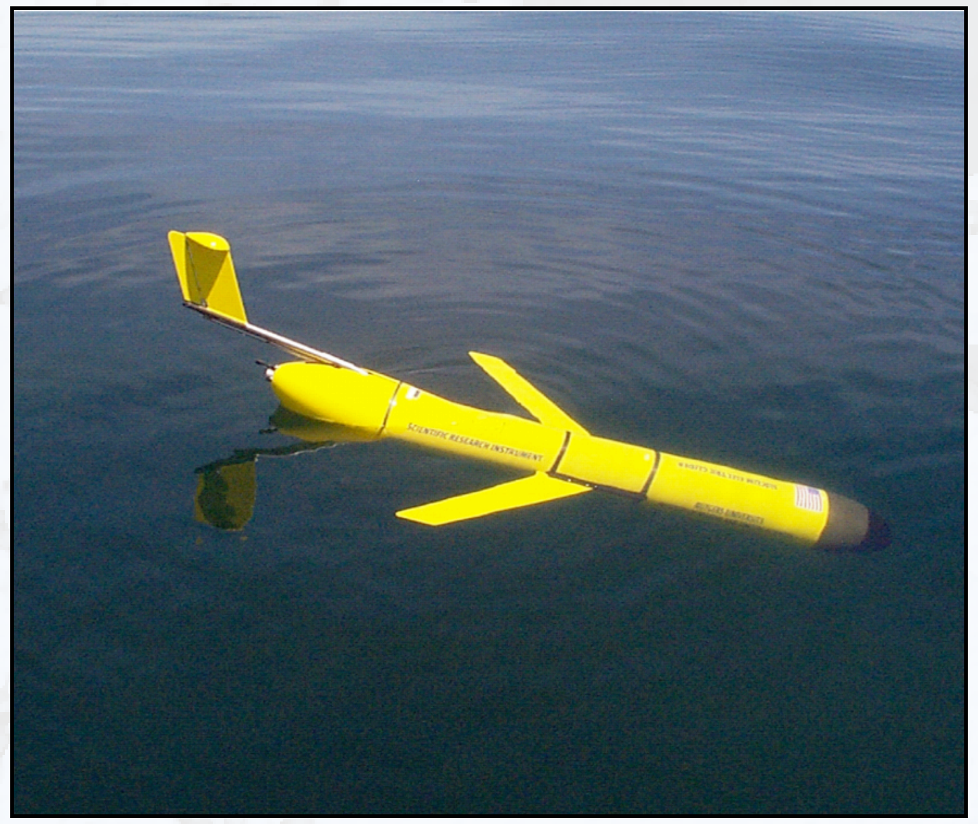




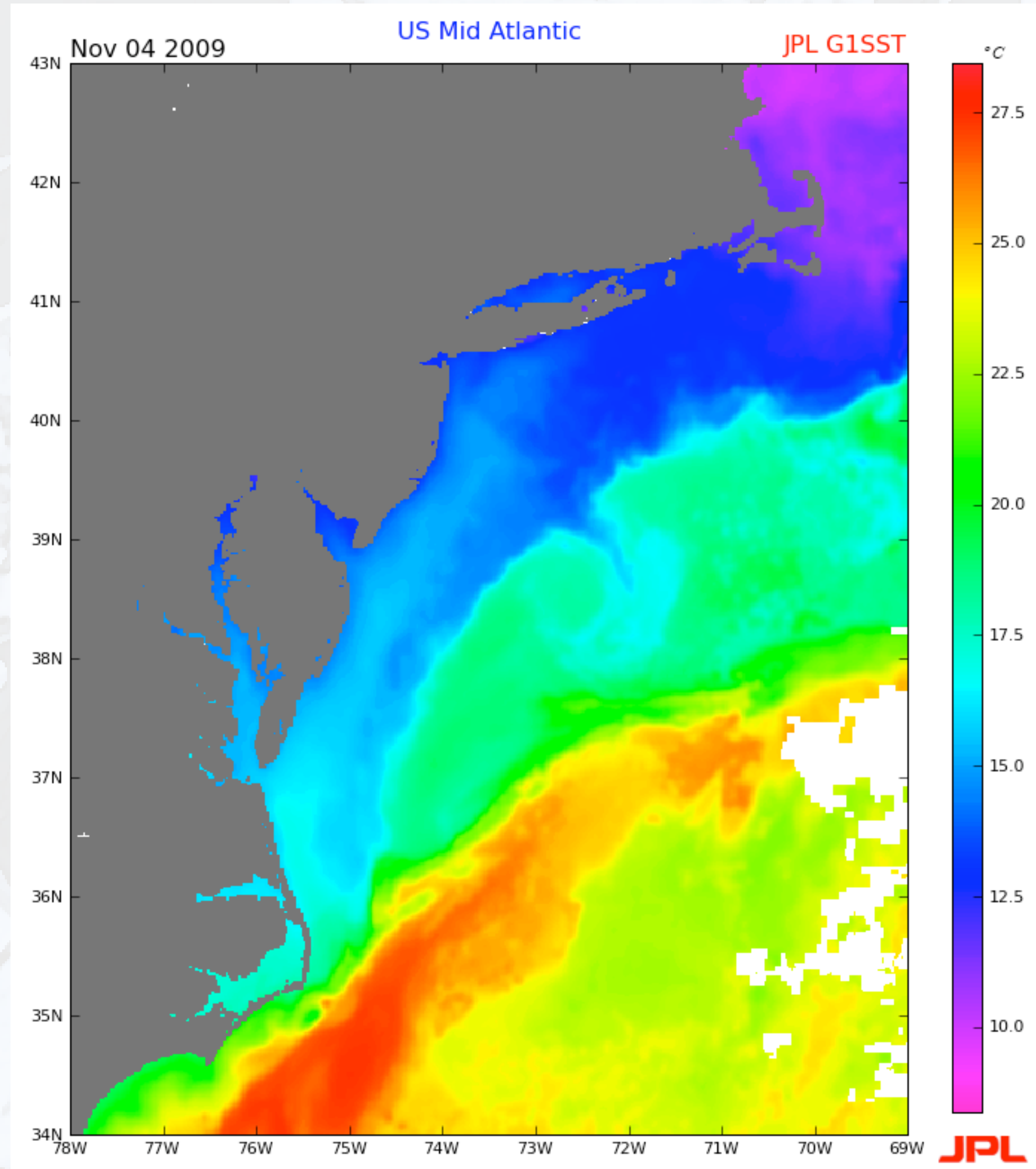
Variance in *u* velocity component

Variance in *v* velocity component

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



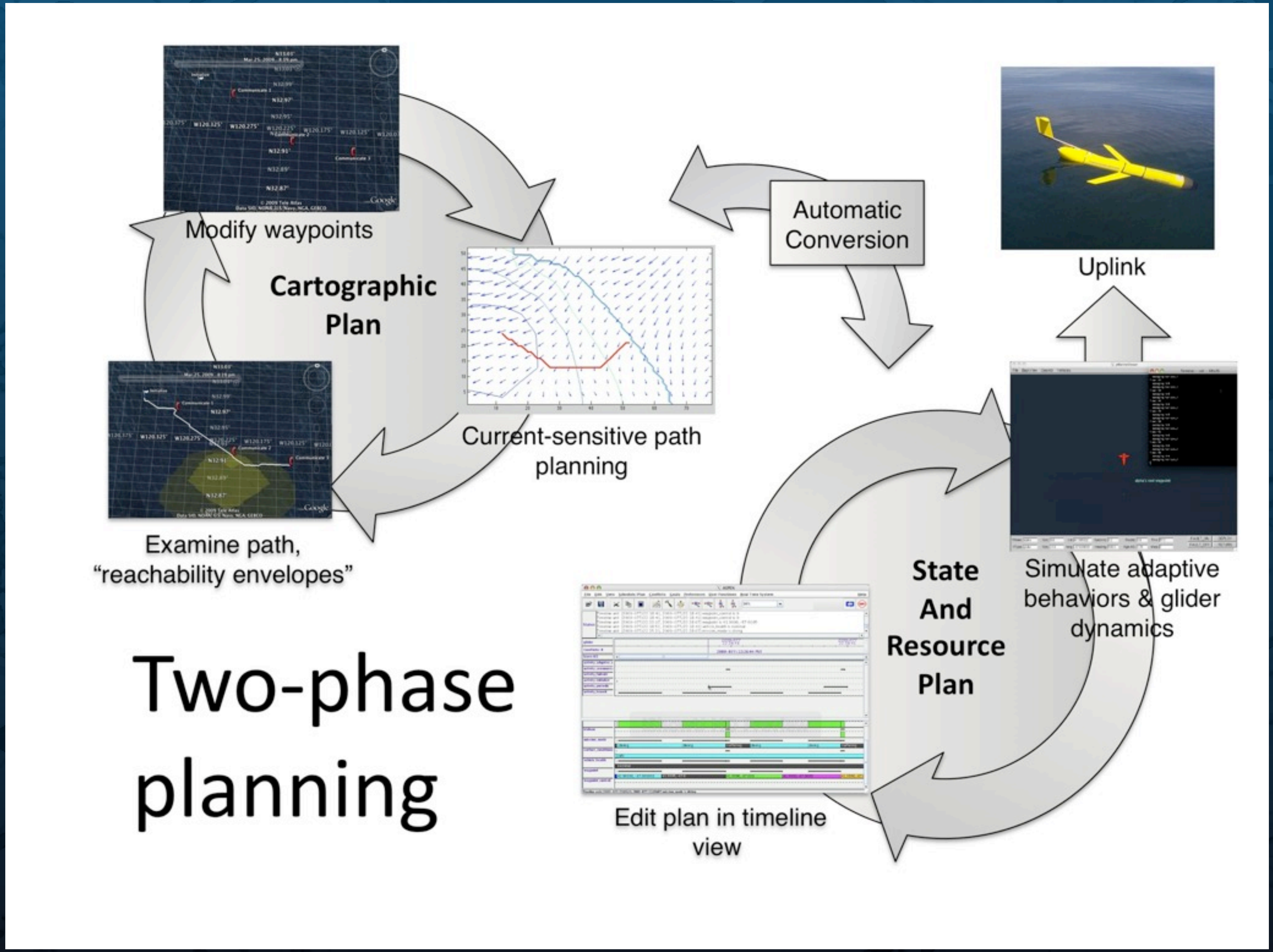
- Known constraints (slow 0.5 knot, Battery, shipping lanes)
- Uncertain constraints (time-varying 3D currents)
- Operate autonomously & re-plan daily



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

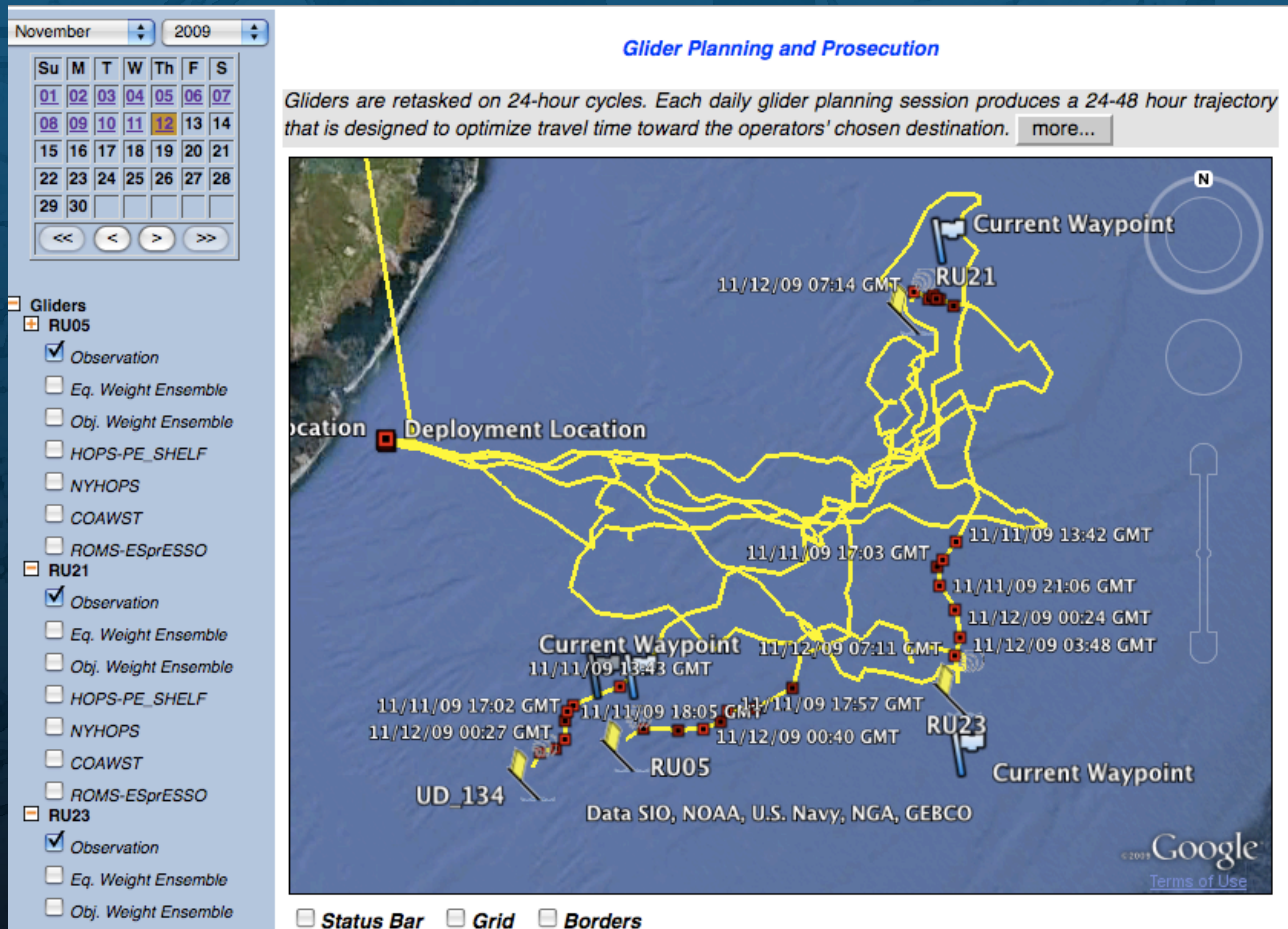
The OOI Observing System Experiment (OSE)

Scientific community



Marine operators

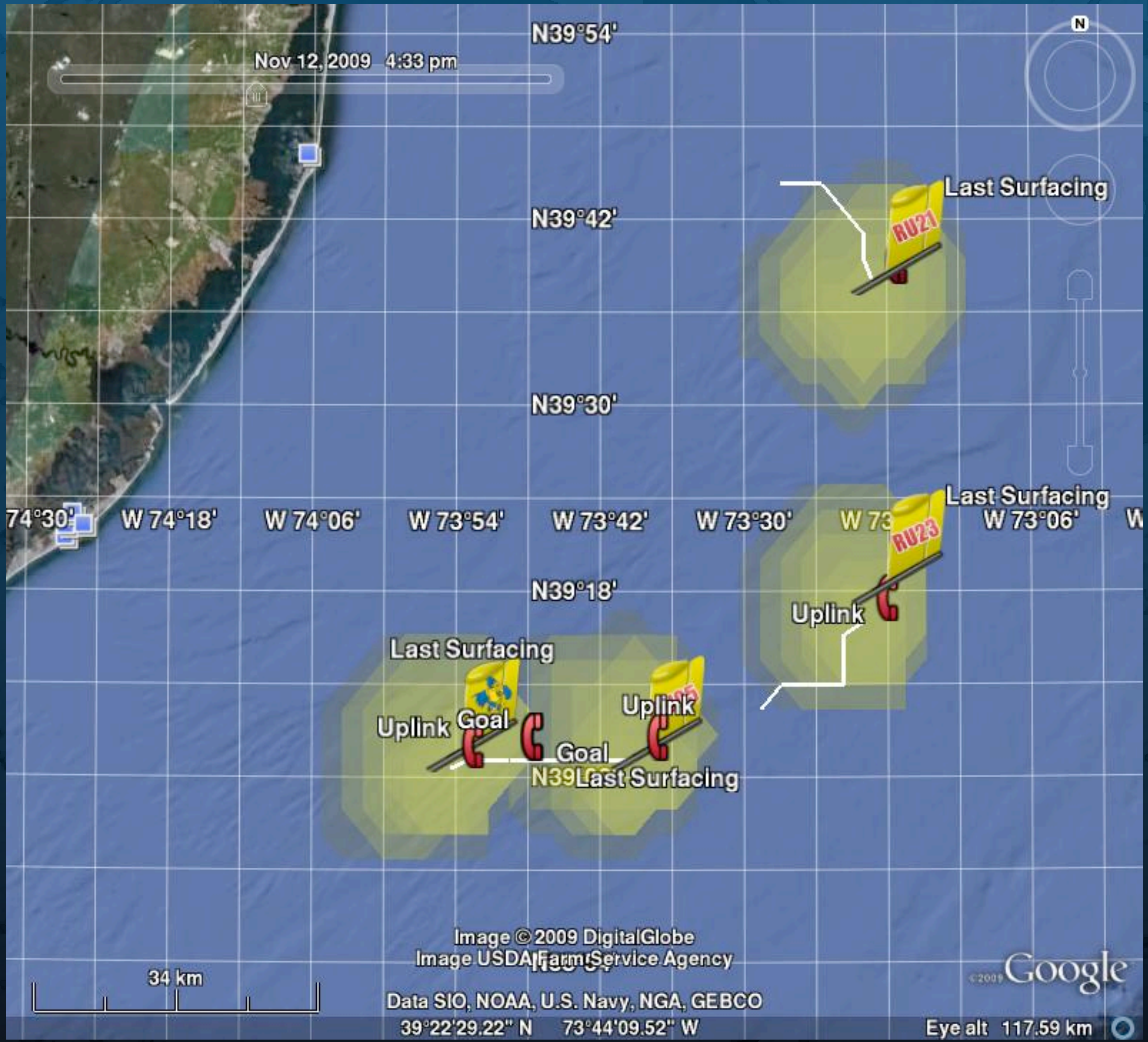
The OOI Observing System Experiment (OSE)



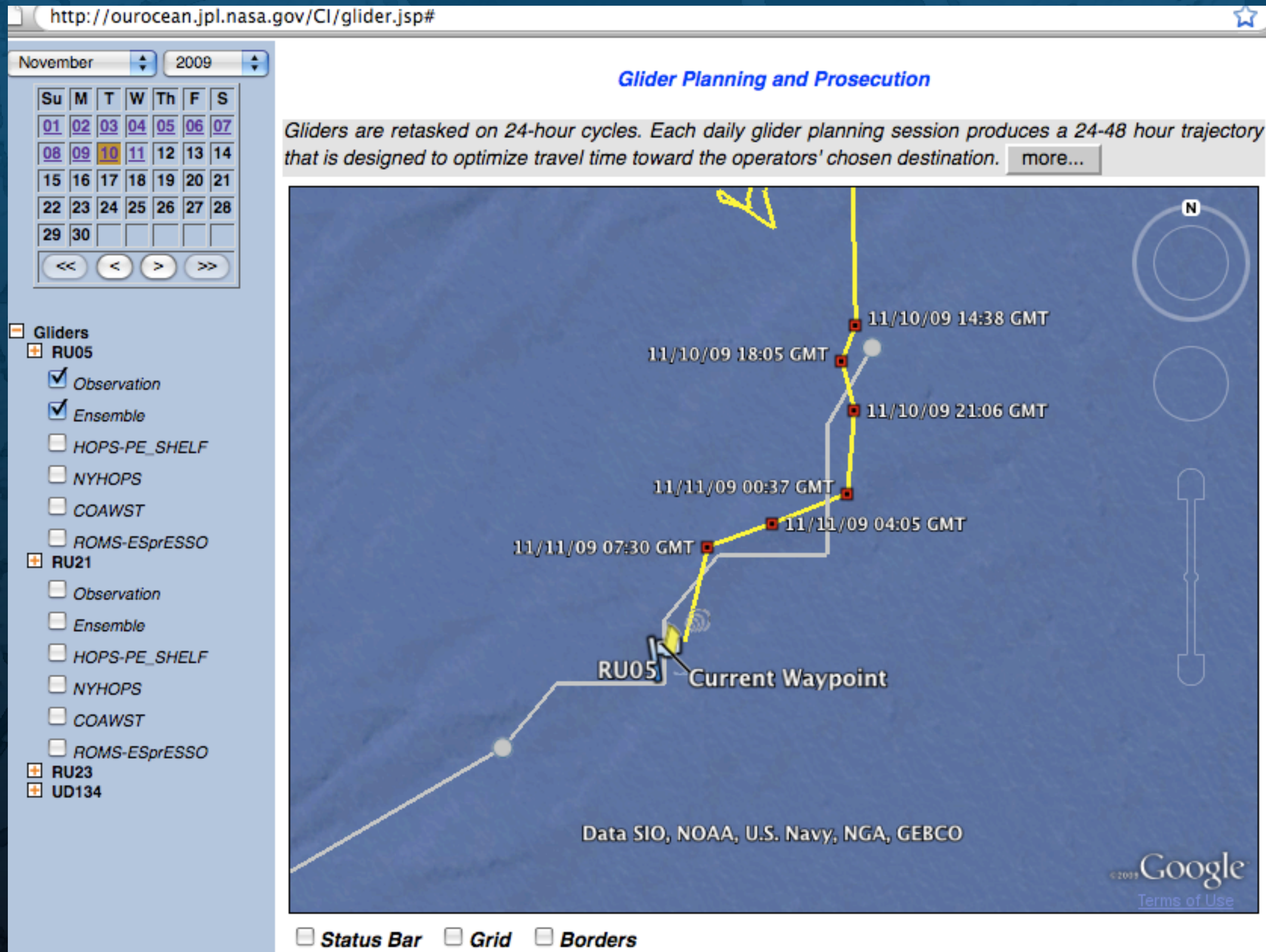
Monday, April 11, 2011

The OOI Observing System Experiment (OSE)

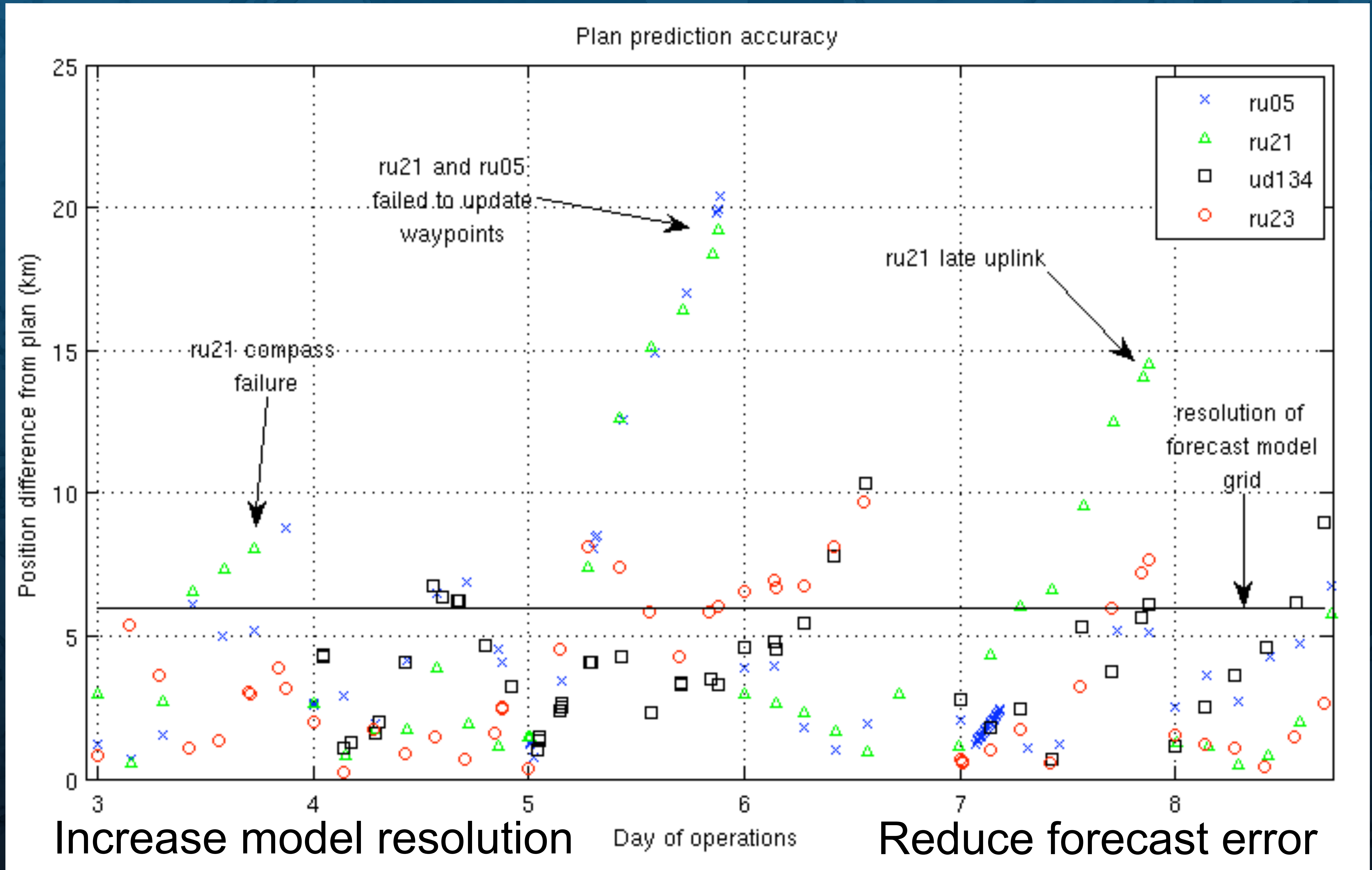
Distributed decision making
using live web service tools



The OOI Observing System Experiment (OSE)



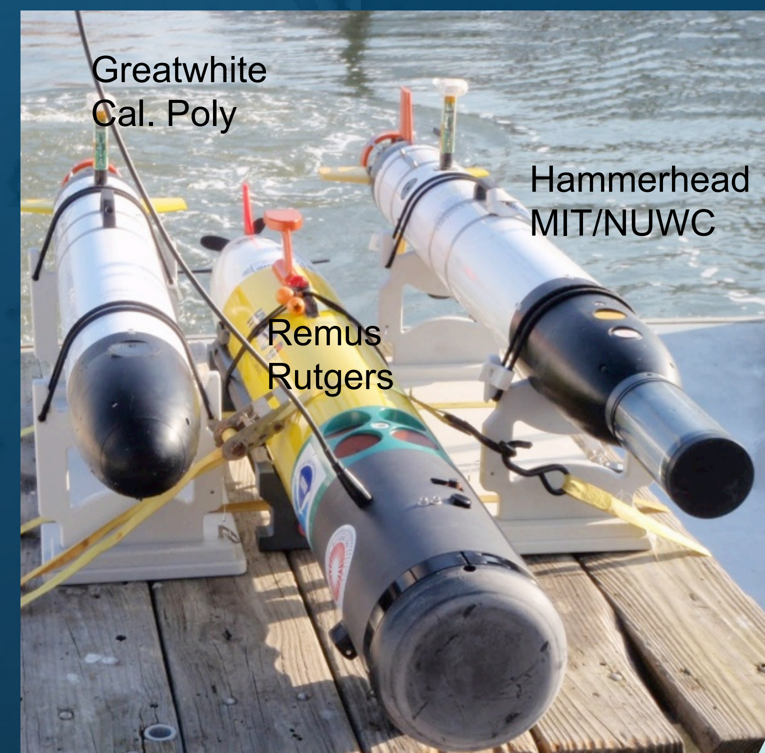
The OOI Observing System Experiment (OSE)

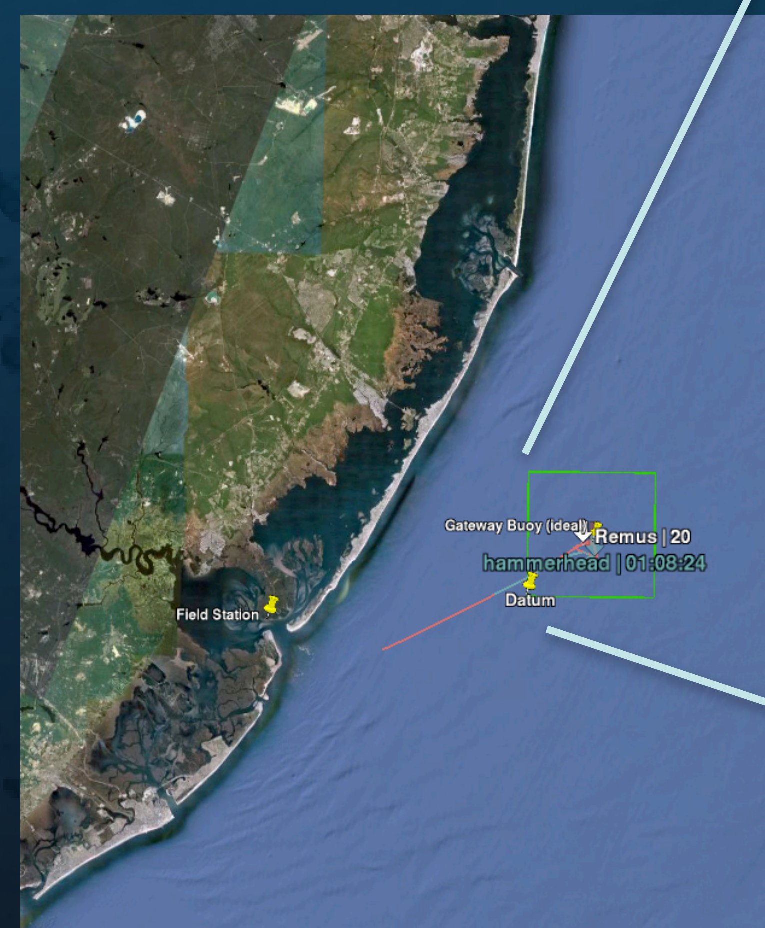


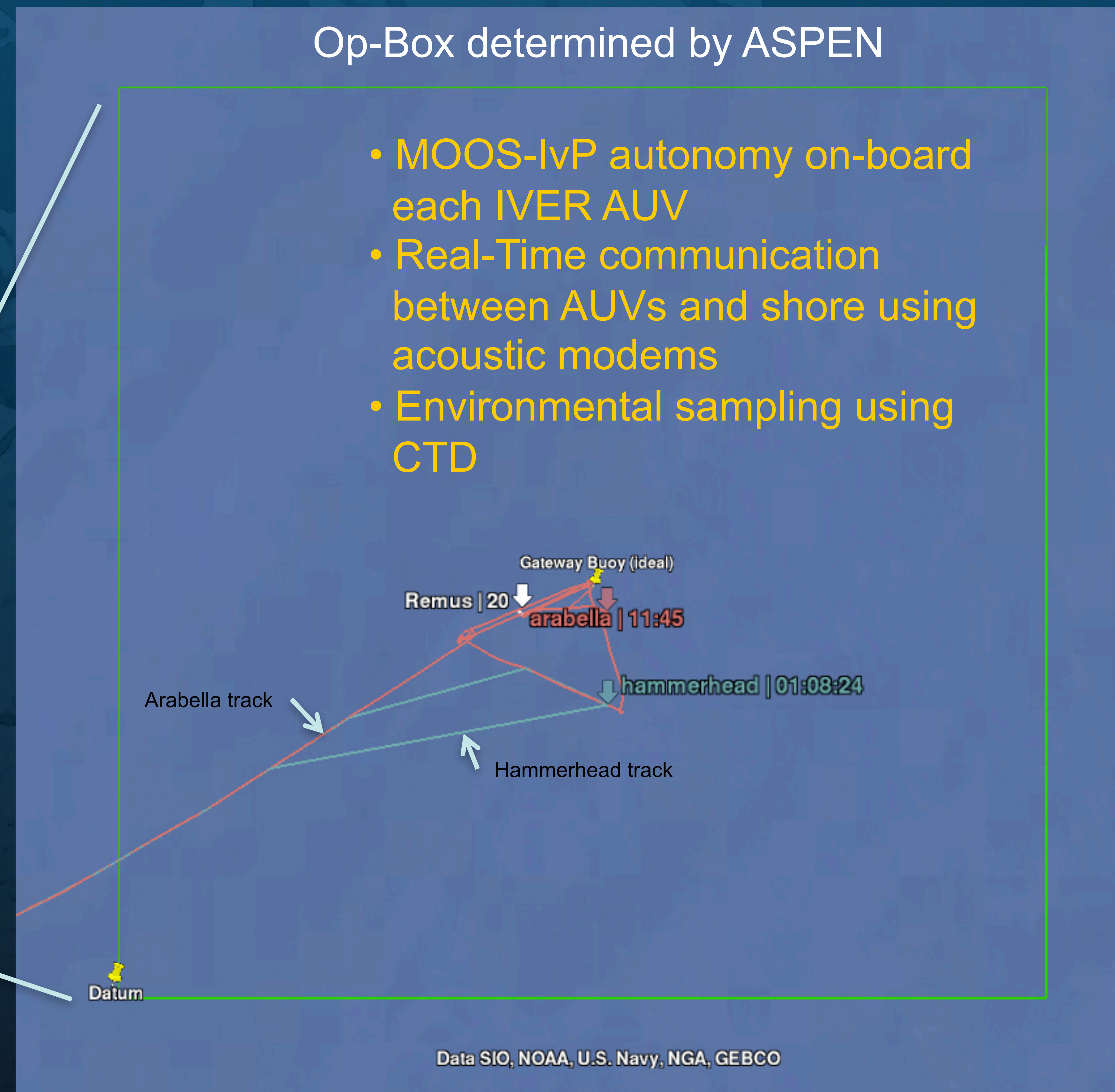
How well did we do?

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

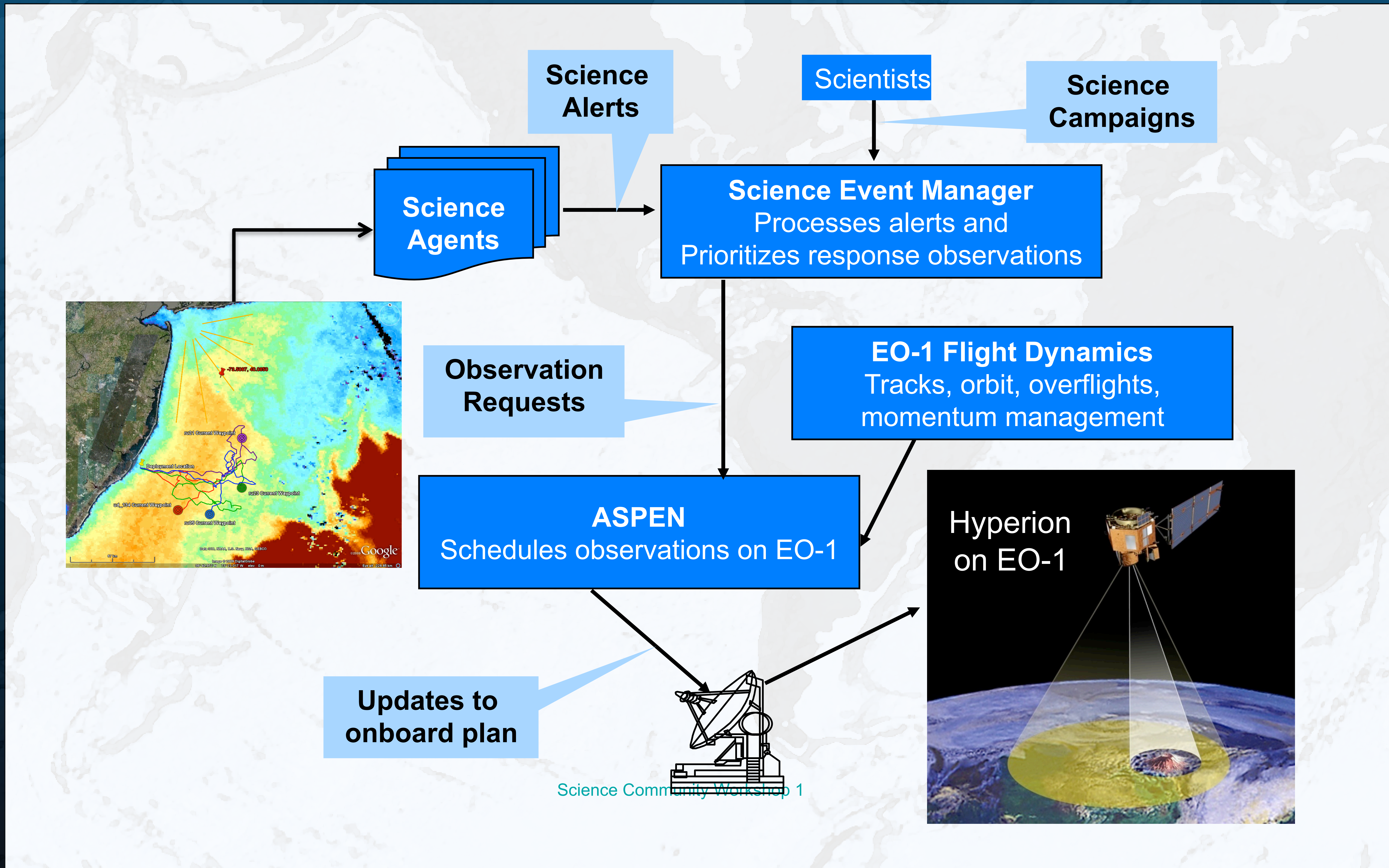
- High resolution underwater planning
- Smart robots
- Distributed control





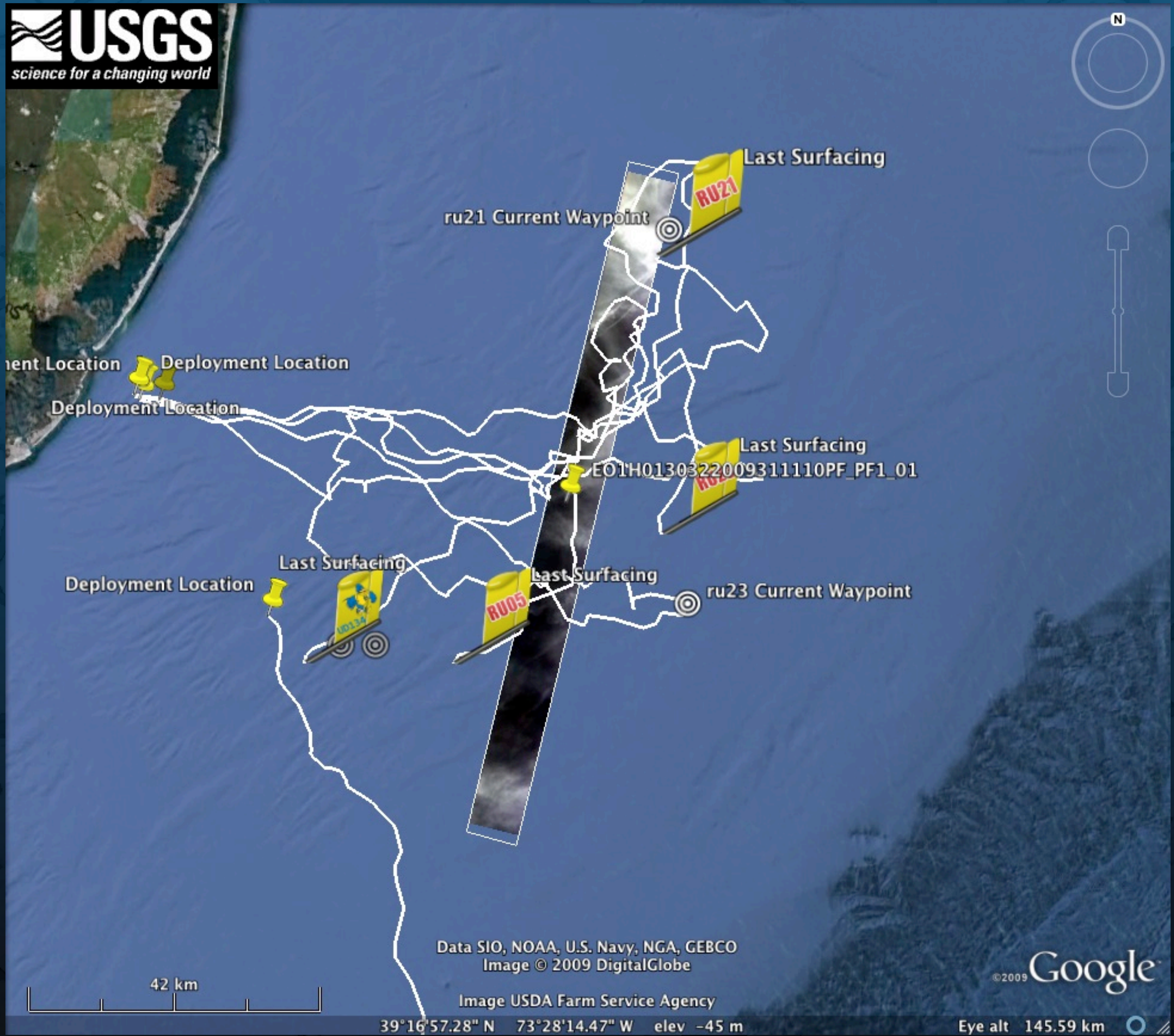


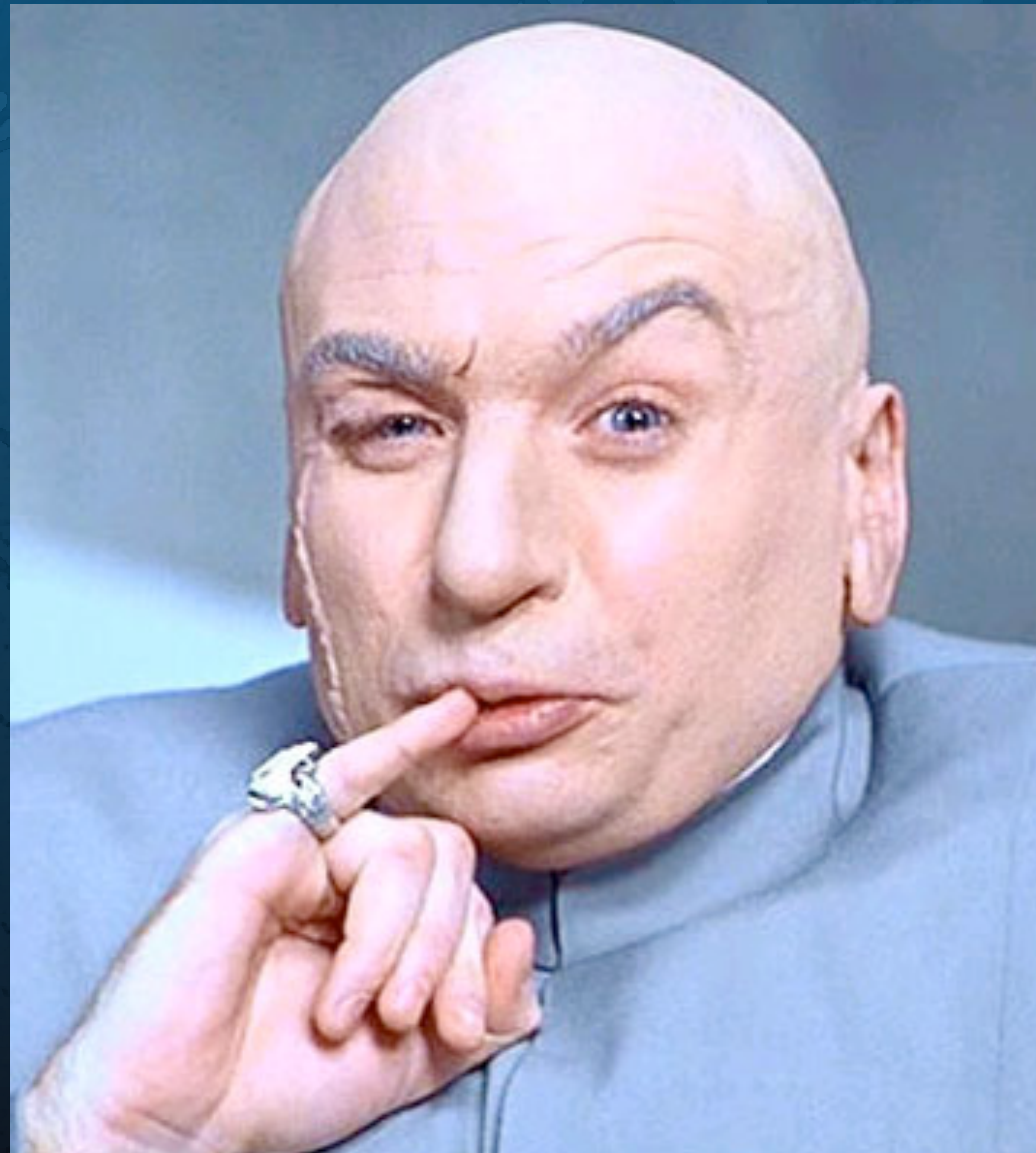
The OOI Observing System Experiment (OSE)



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

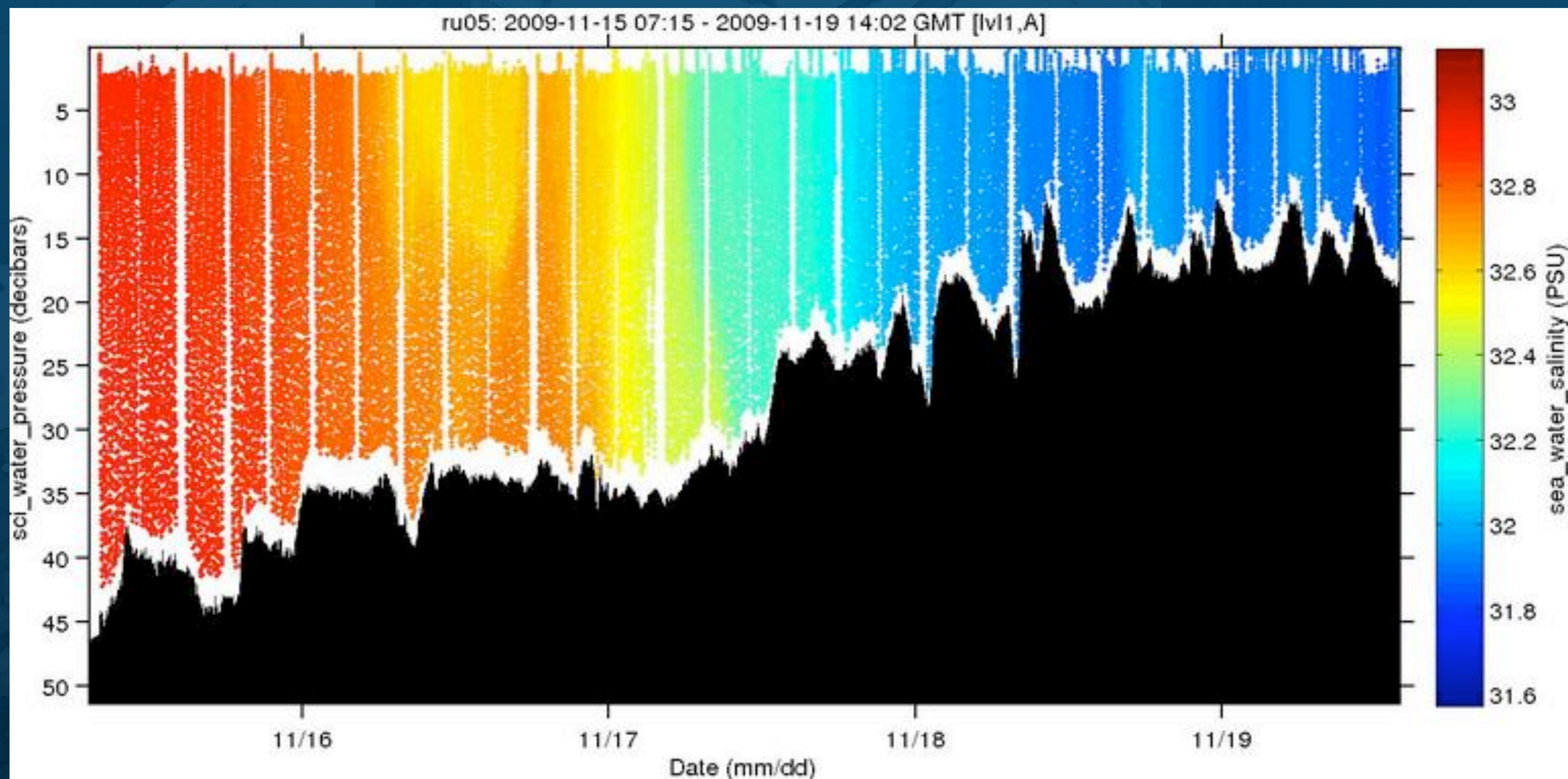
Hyperion on EO-1
7.5 km by 100 km
(30 m resolution)

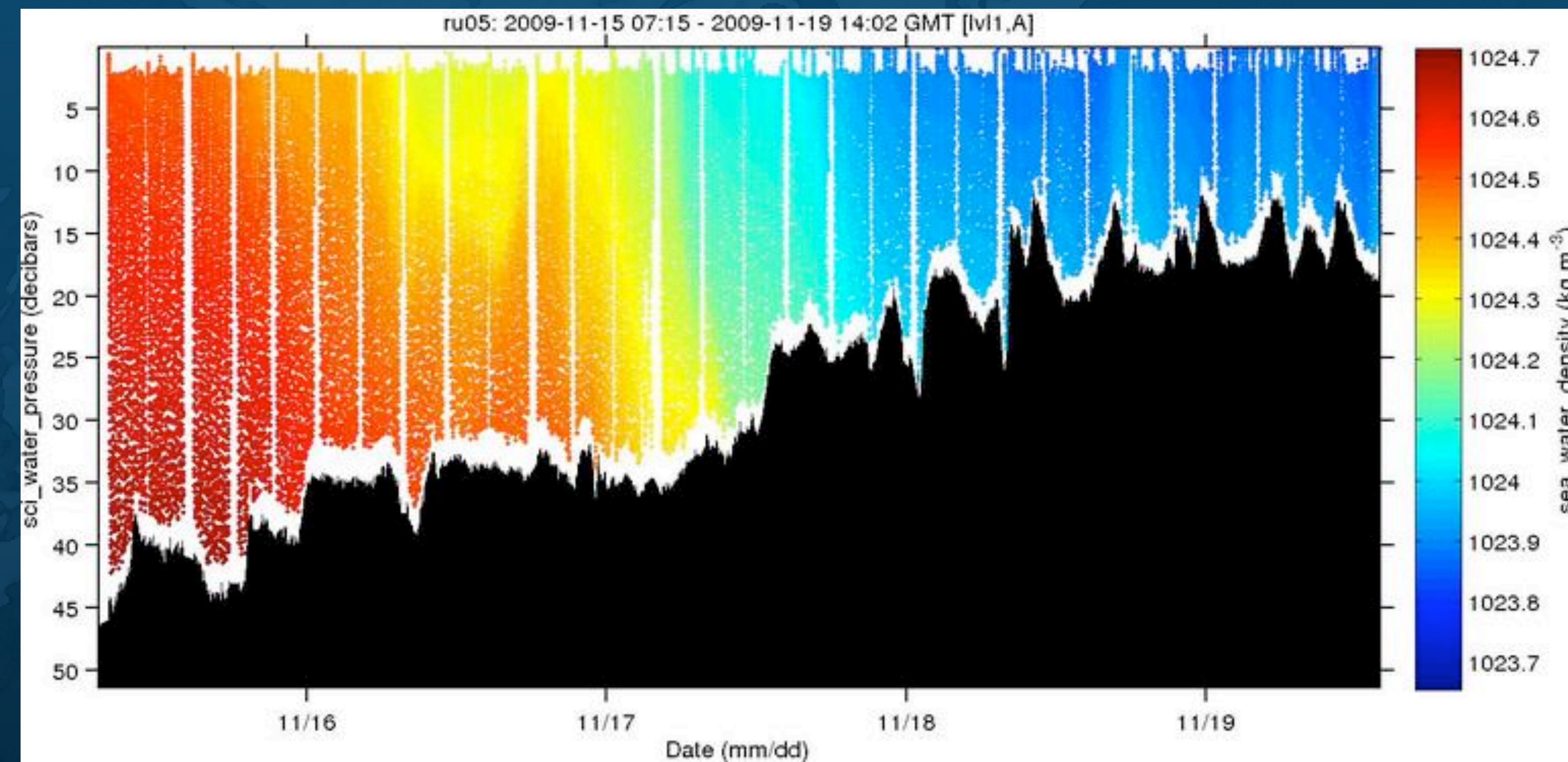


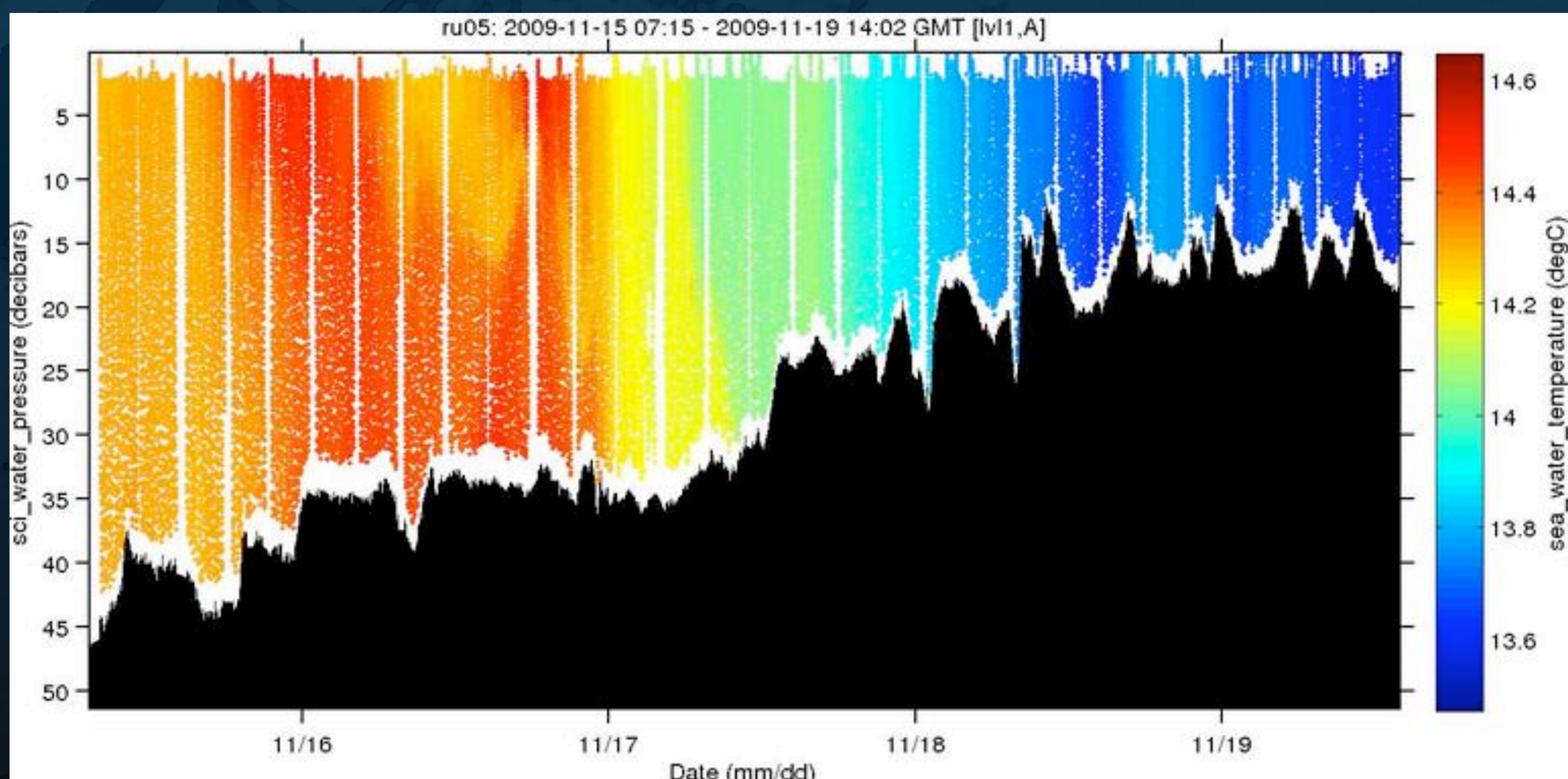


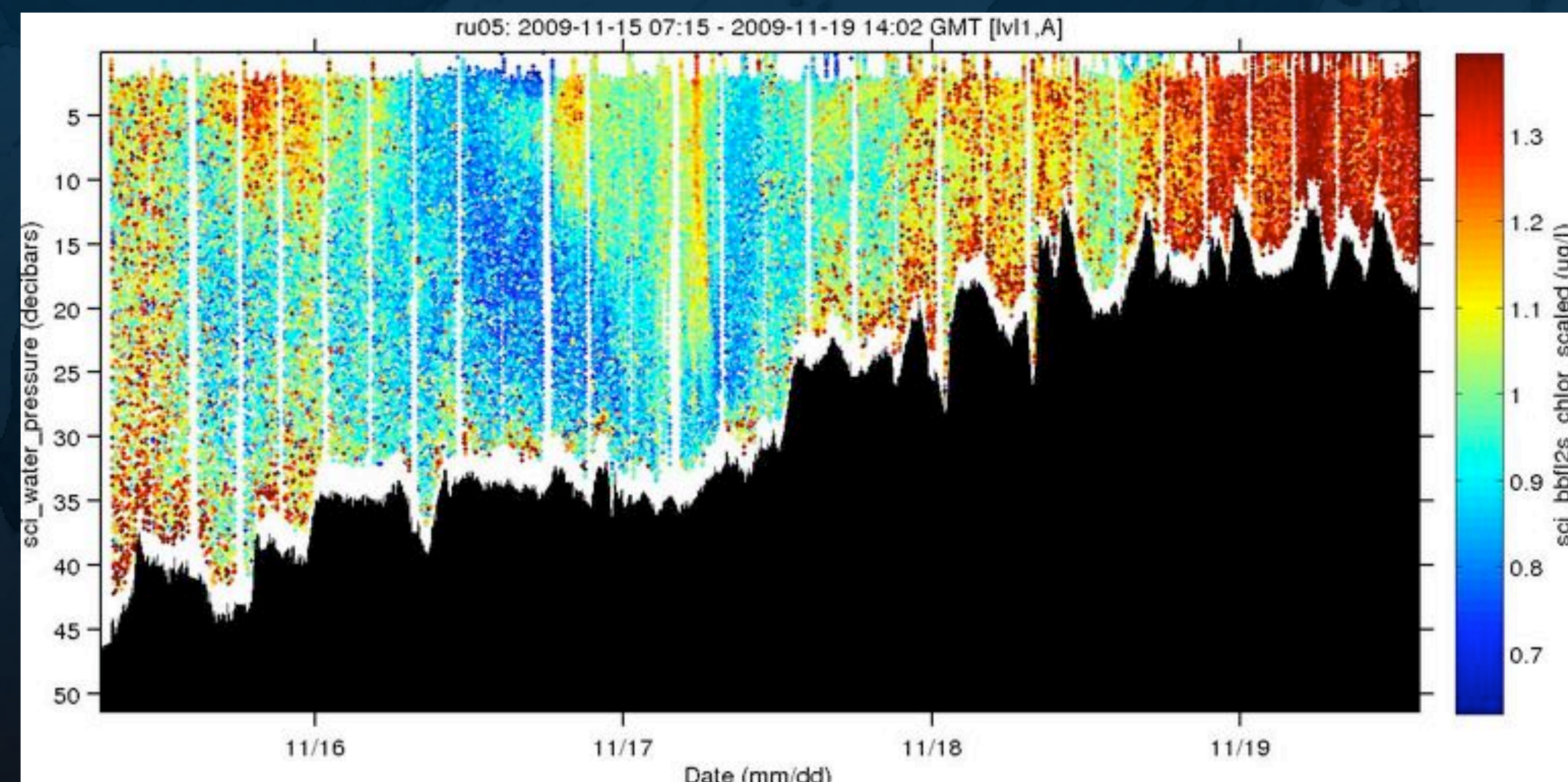
Data from the deployment

Nor' Easter









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

Technical Accomplishments

A closed machine to machine adaptive sensor net spanning satellites to underwater robots

Observation network coupled to ensemble ocean model systems

Improved science and observatory decision making

Science Accomplishments

Special issue of Continental Shelf Research in which 4 publications utilize the OOI OSE data.

OOI OSE data central to two PhD theses (one biologist and one physicist)

OOI OSE data utilized in special issue of Marine technological Society special issue (Nov 2010) and highlighted in EOS (Sep 2010)

Technology will give us a grand new day
Thank you