Dawn in a new age of ocean science: A data management perspective

Ocean technology is undergoing a revolution. We will review our lessons learned, science findings, and future directions

-Oceans are changing, changes will be very large on continental shelves in the coming years

-Ocean Observatories will be key to understanding changes giving scientist a 24:7 365 day/year presence in the sea

-Enhanced understanding will directly impact humans today

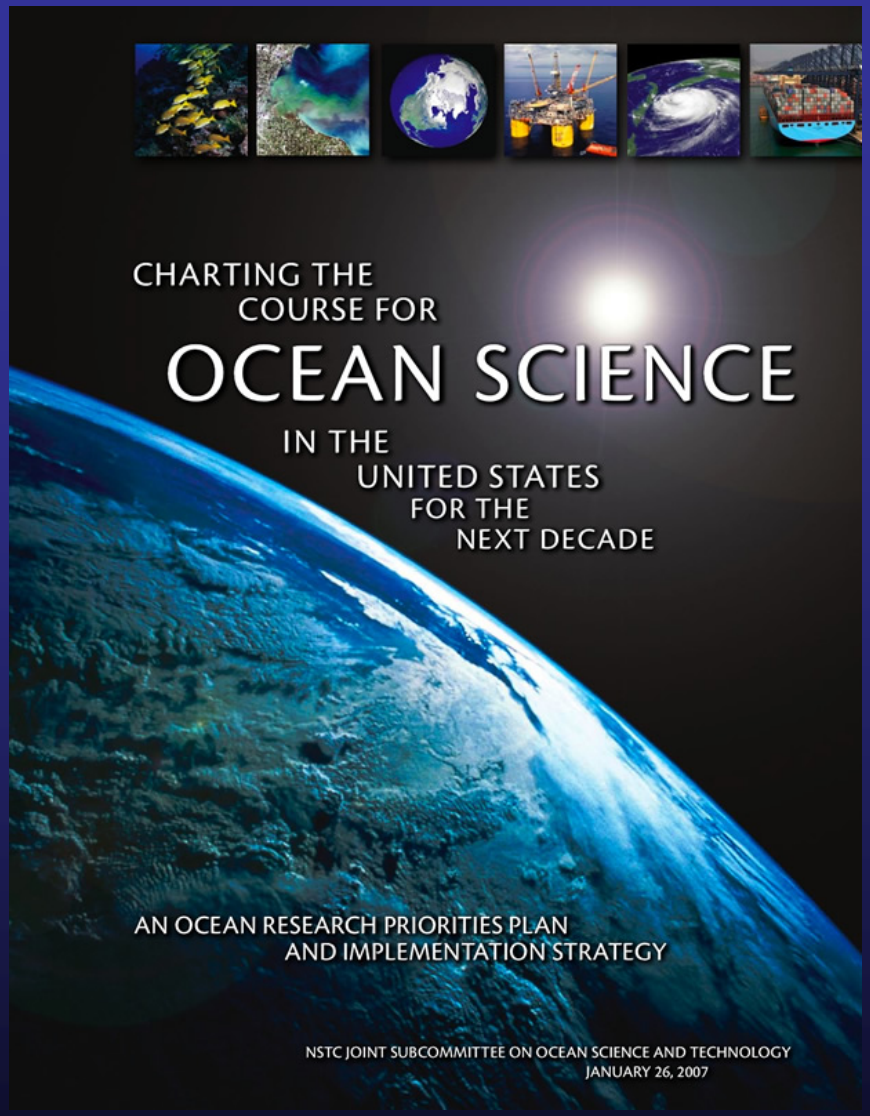
Josh Kohut, Rutgers/IMCS

NJWMCC Meeting

September 12, 2008

Coastal Observation and Prediction Sponsors:

"A Framework for Research Investments in Ocean Science for the coming Decade"



http://ocean.ceq.gov/about/sup_jsost_prioritiesplan.html

- Theme 1: Stewardship of Natural and Cultural Resources
- Theme 2: Increasing Resilience to Natural Hazards
- Theme 3: Enabling Marine Operations
- Theme 4: The Ocean's Role in Climate Change
- Theme 5: Improving Ecosystem Health
- Theme 6: Enhancing Human Health

Three Central Elements:

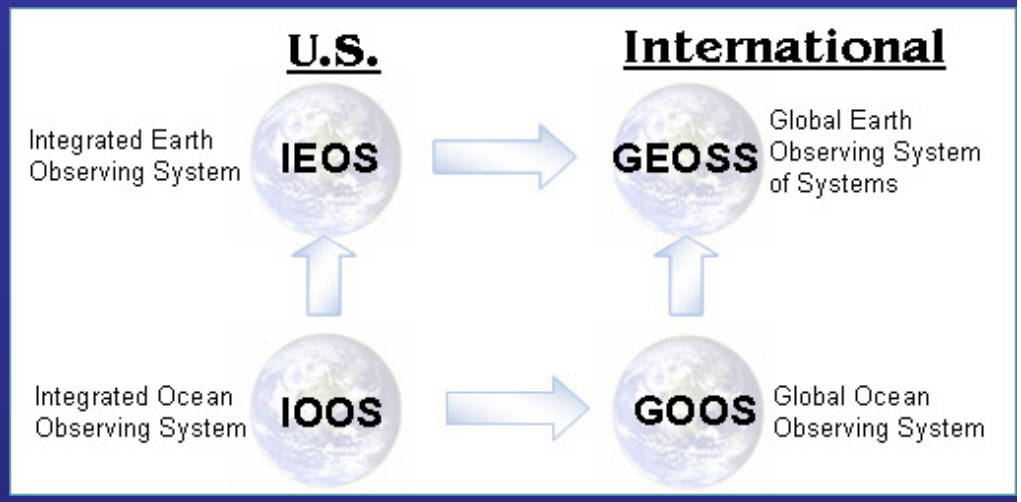
1) *Ocean Observing System*
2) *Forecast Models for Key Ocean and Ocean-Influenced Processes*
3) *Scientific Support for Ecosystem Based Management*

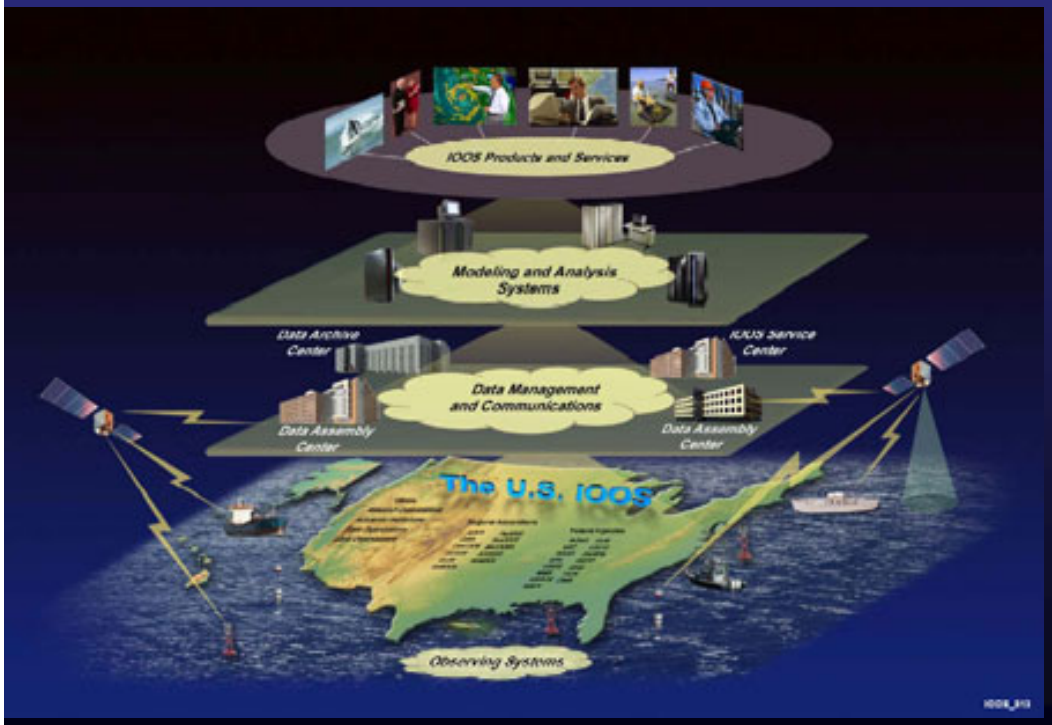
"Deploying an ocean-observation system will revolutionize the access to and view of the ocean and increase the pace, efficiency, and scope of ocean research."

U.S. Integrated Ocean Observing System (IOOS)

US IOOS Components

1) **International Component**
2) **National Component**
   a) **17 Federal Agencies**
   b) **11 Regional Associations**



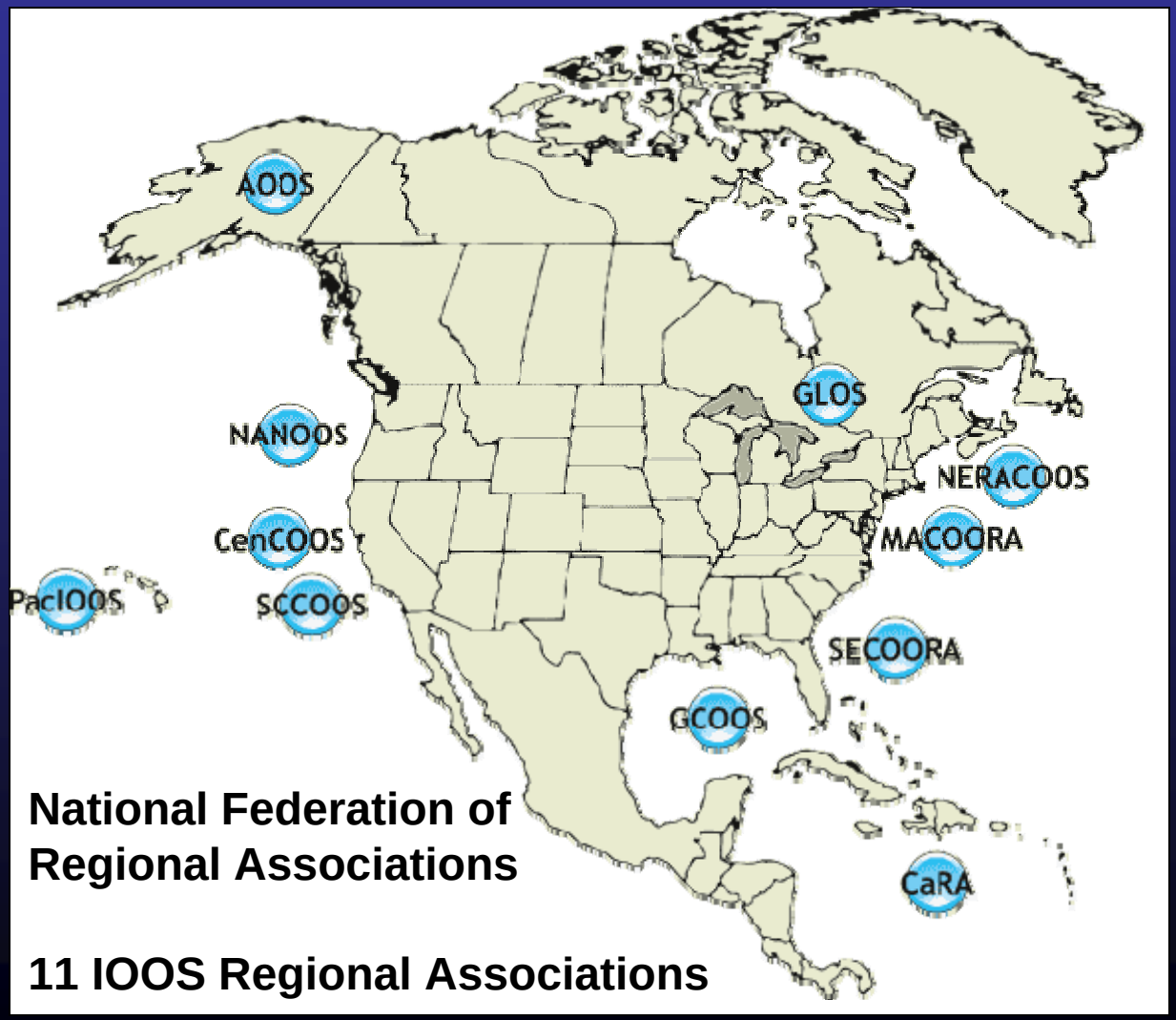


Observing, Data Management, Modeling

Regional Components

National Federation of Regional Associations for Coastal and Ocean Observing

A non-profit representative of the interests of the Regional Associations formed in support of the Integrated Ocean Observing System (IOOS)



National Federation of Regional Associations

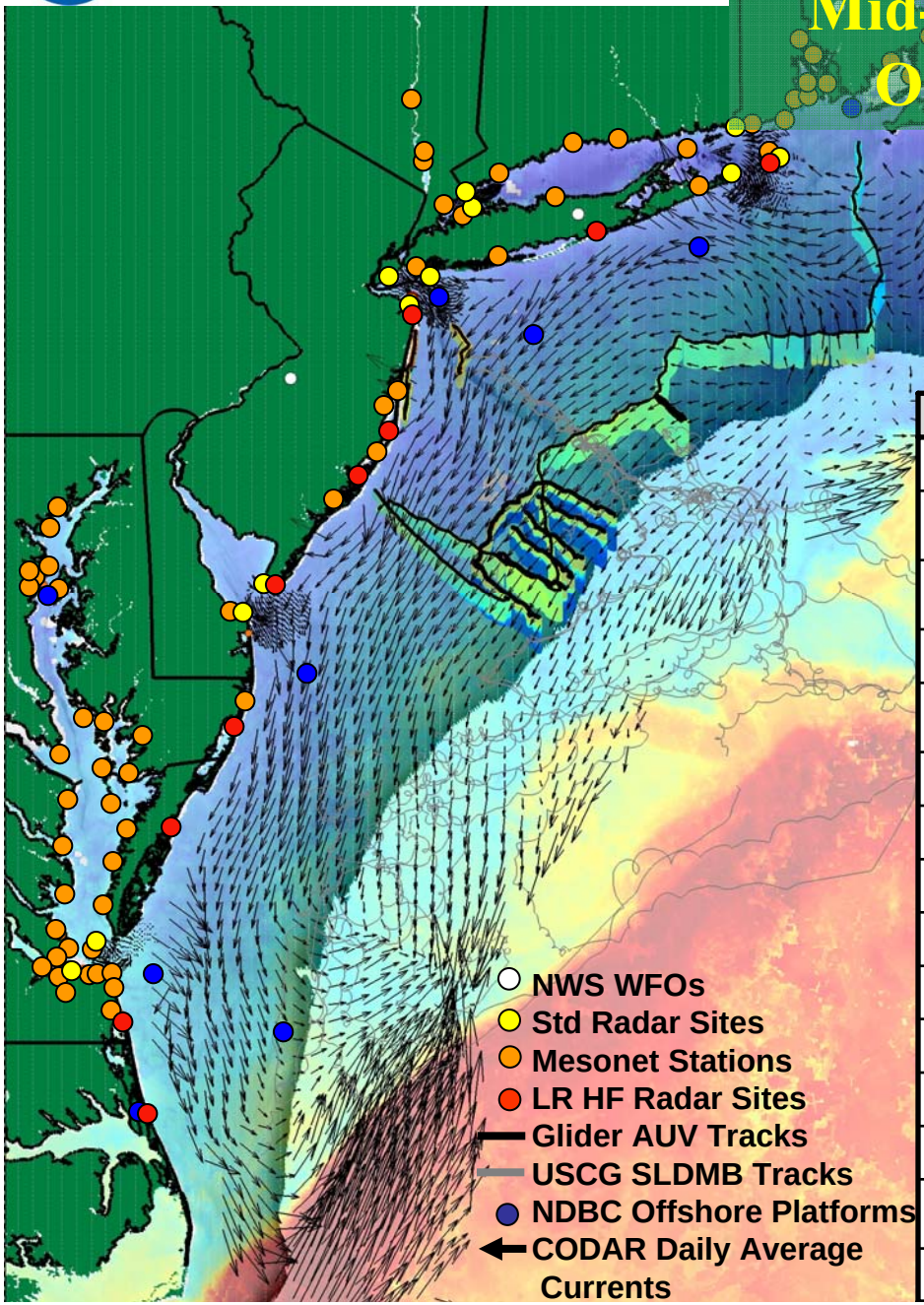
11 IOOS Regional Associations

Regional Associations (RAs) Building IOOS Partnerships - 480 and Growing….

- Business and Industry (66)
- Shipping (18)
- Researchers and Universities (149)
- State agencies (59)
- NGOs (58)
- International Organizations (11)
- Local and Tribal Governments (8)
- Federal Agencies (106)

MACOORA
Mid-Atlantic Coastal Ocean Observing Regional Association

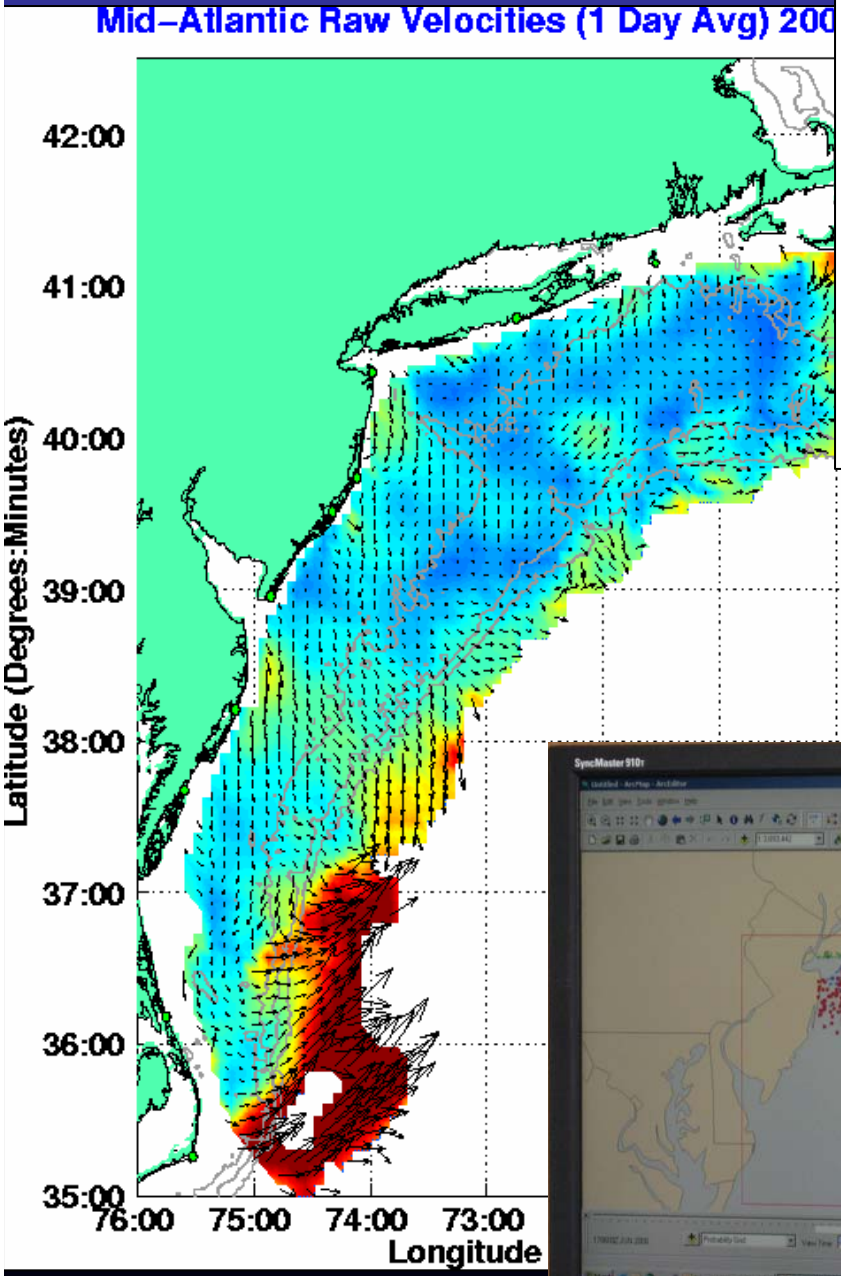
Phased Deployment and Operation of the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS)

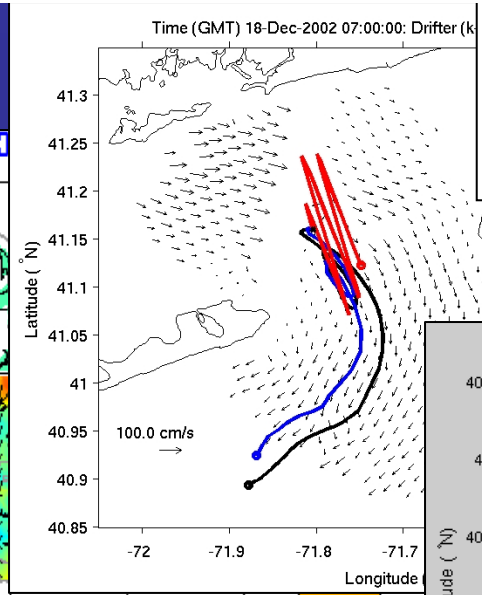


30 Co-PIs, 20 Institutions

Investigator	Affiliation	Investigator	Affiliation
A. Allen	U.S. Coast Guard	L. Atkinson	Old Dominion University
A. F. Blumberg	Stevens Institute of Technology	W. Boicourt	University of Maryland
W. Brown	University of Massachusetts	M. Bruno	Stevens Institute of Technology
D. Chapman	University of Delaware	A. Cope	NOAA Mount Holly WFO
A.Gangopadhyay	University of Massachusetts	T. Herrington	Stevens Institute of Technology
D. Holloway	OPeNDAP	E. Howlett	Applied Science Associates
D. King	University of Maryland	J. Kohut	Rutgers University
B. Lipphardt	University of Delaware	A.MacDonald	Monmouth University
J. McDonnell	Rutgers University	J. Moisan	NASA Wallops
J. O'Donnell	University of Connecticut	M. Oliver	Rutgers University
O. Schofield	Rutgers University	H. Seim	University of North Carolina
J. Titlow	WeatherFlow Inc.	D. Ullman	University of Rhode Island
J. Wilkin	Rutgers University	R. Wilson	SUNY, Stony Brook
W. Wittman	Public Service Electric & Gas	M. Yarosh	CIT
A. Voros	NY/NJ COAST	S. Glenn	Rutgers University

Theme 1: Maritime Safety

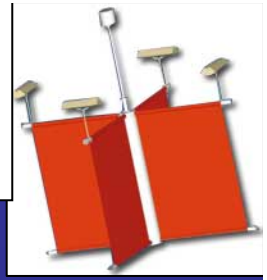


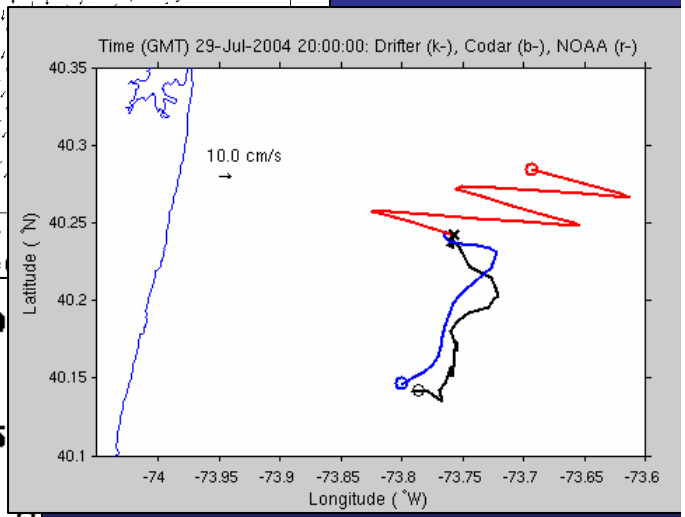


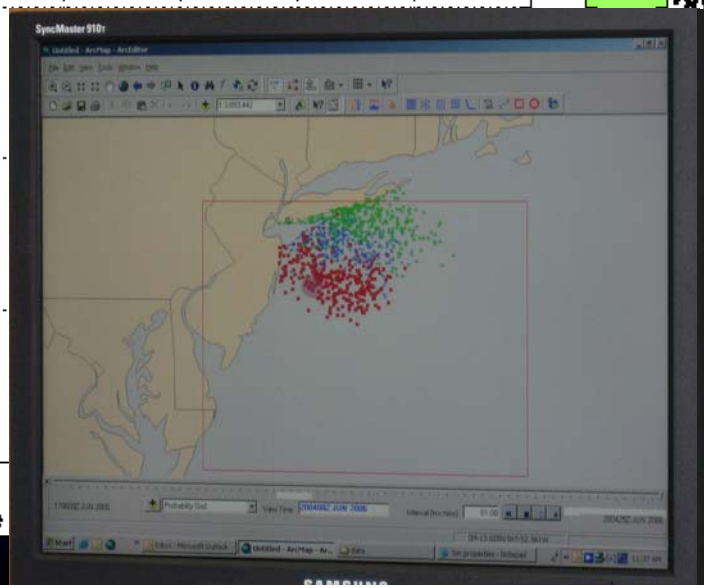
NOAA Coastal Site

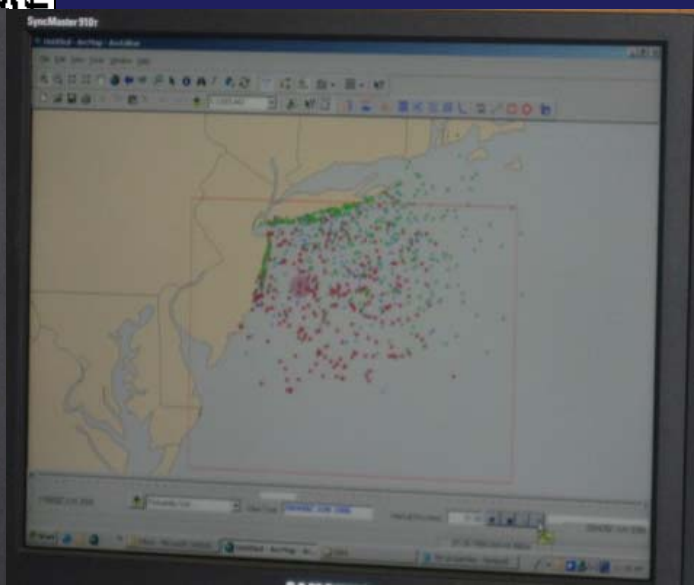
CODAR Currents

SLDMB Drifter

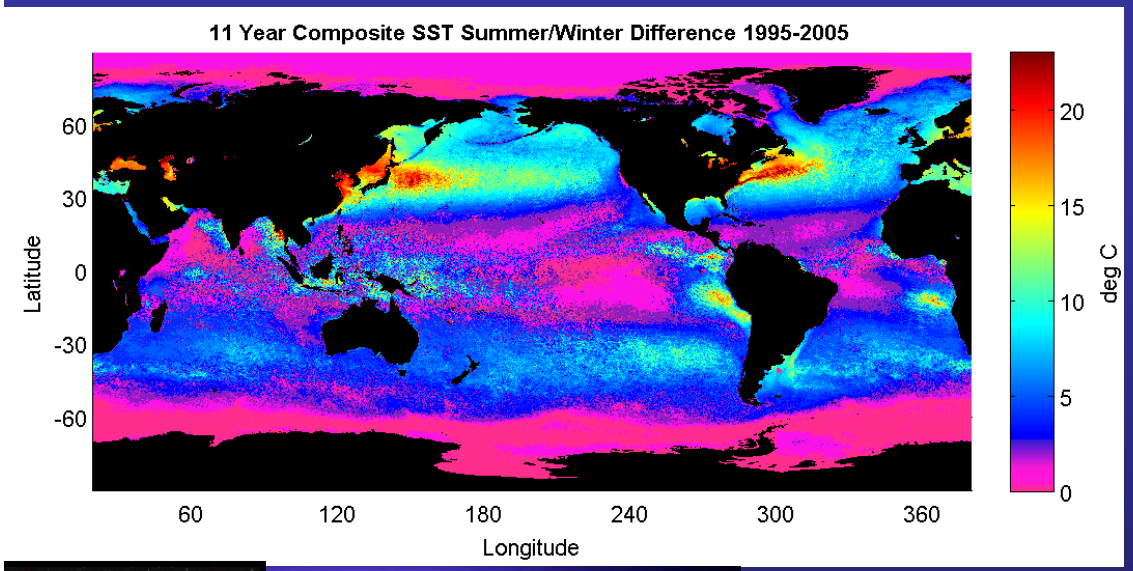


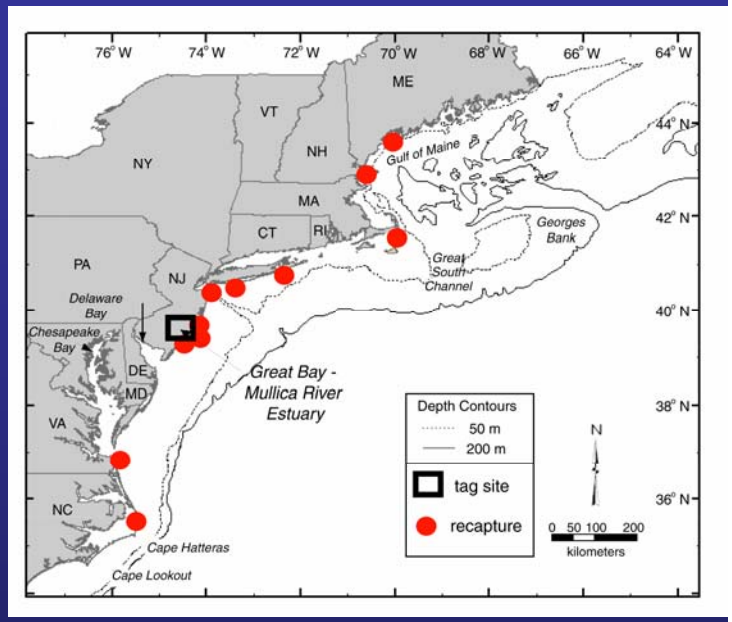


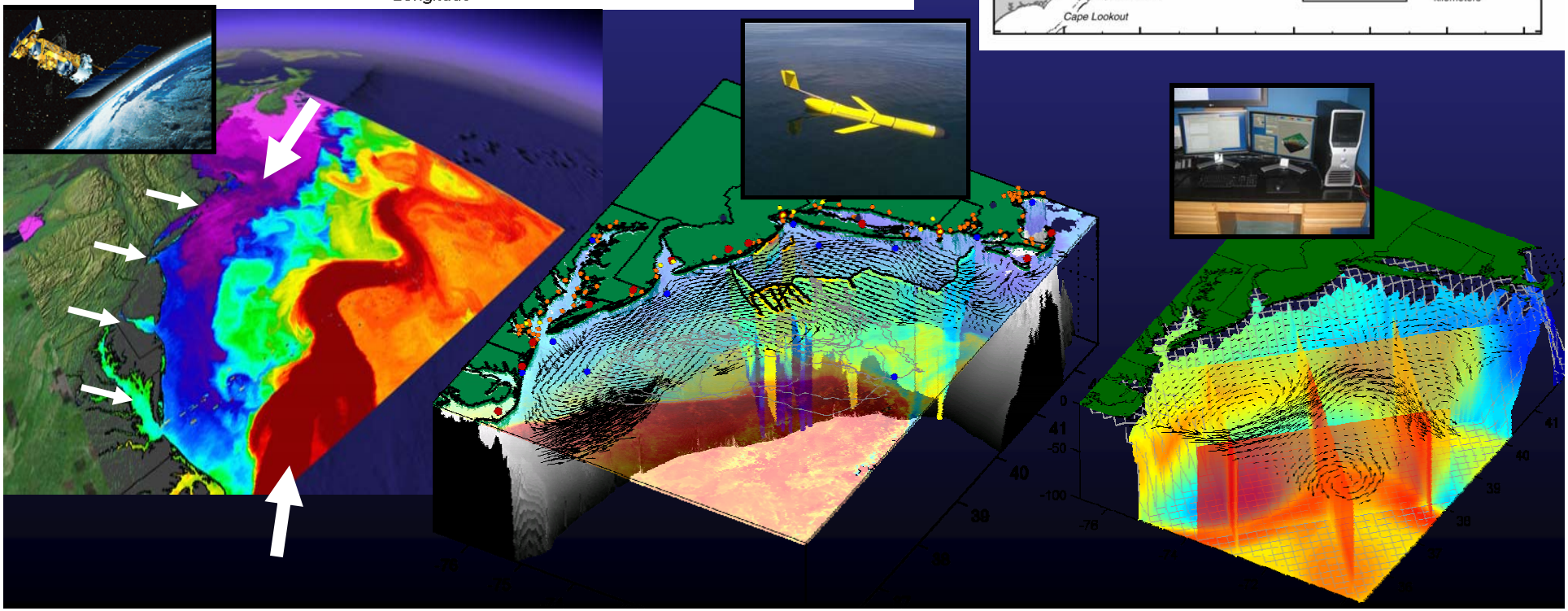




Regional Theme 2: Ecological Decision Support - Fisheries

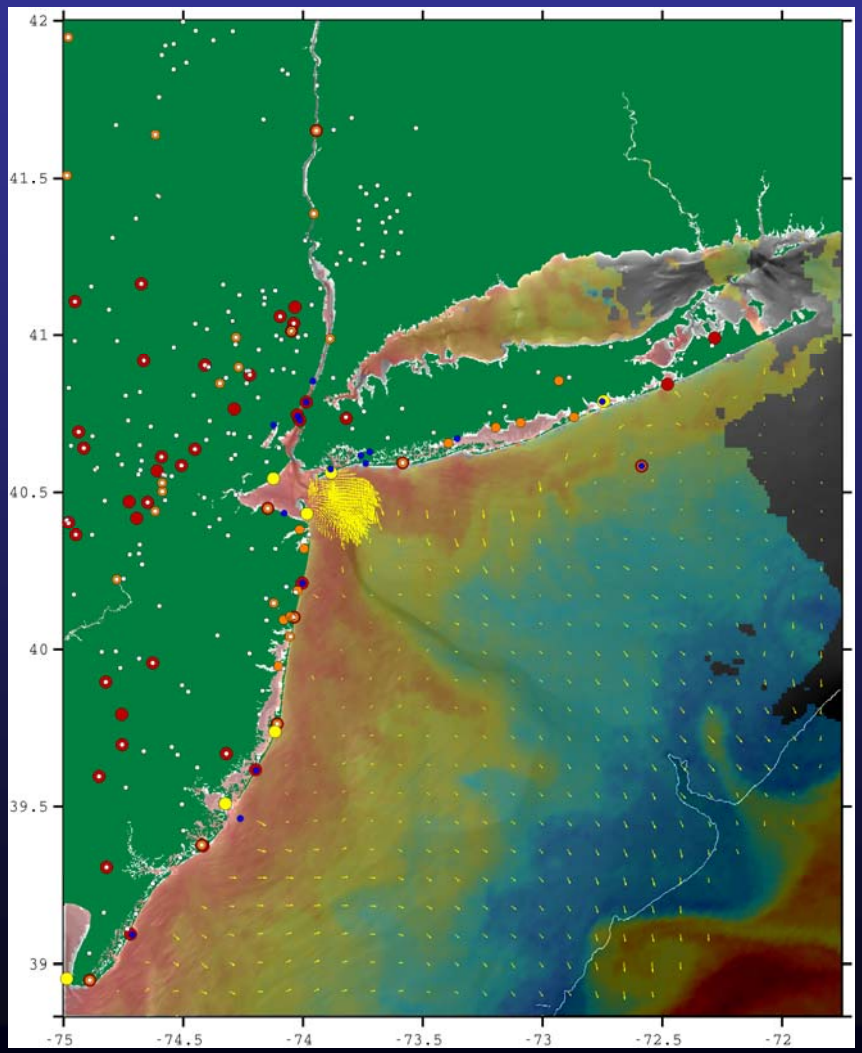




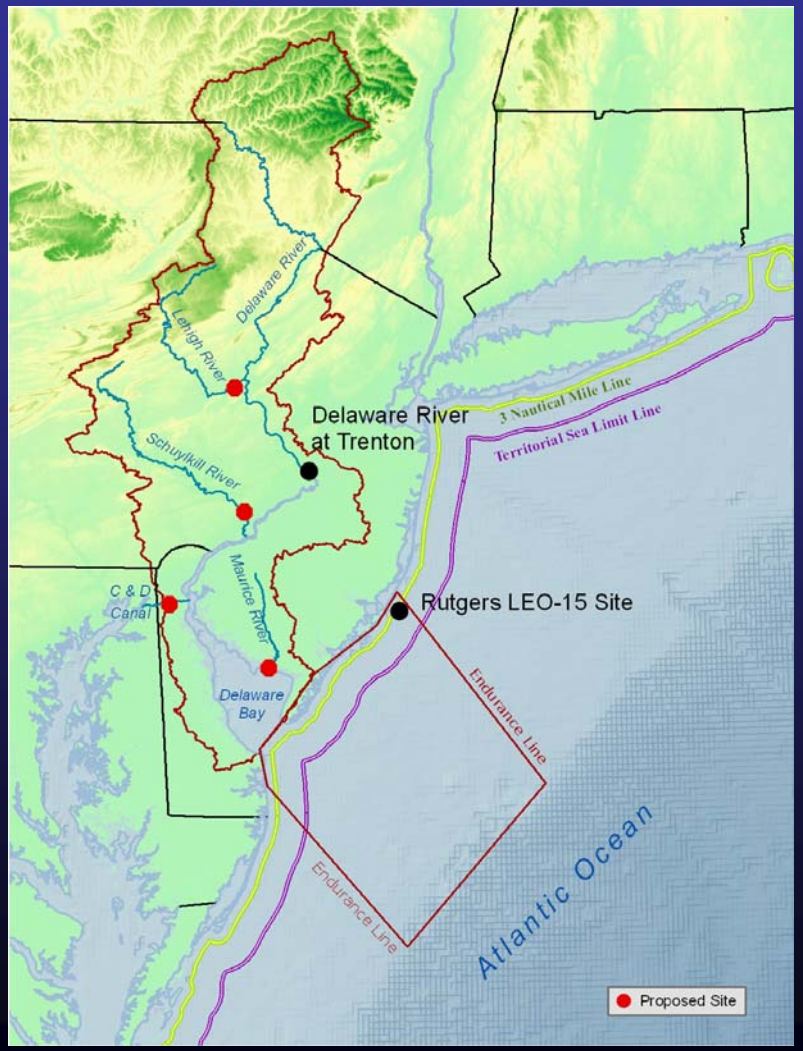


Sub-regional Themes: Coastal Inundation and Water Quality

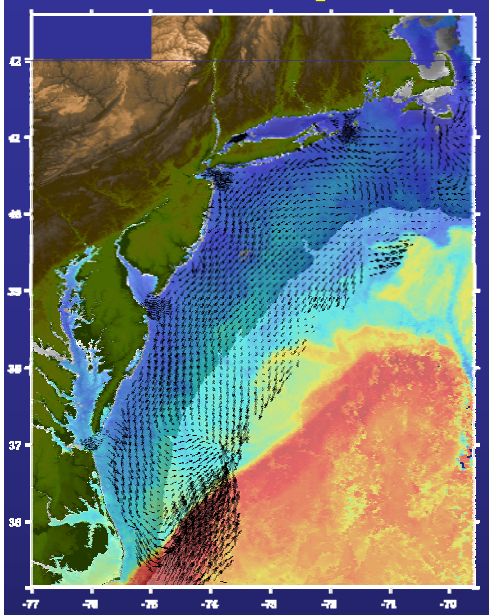
New York Bight



Delaware Bay

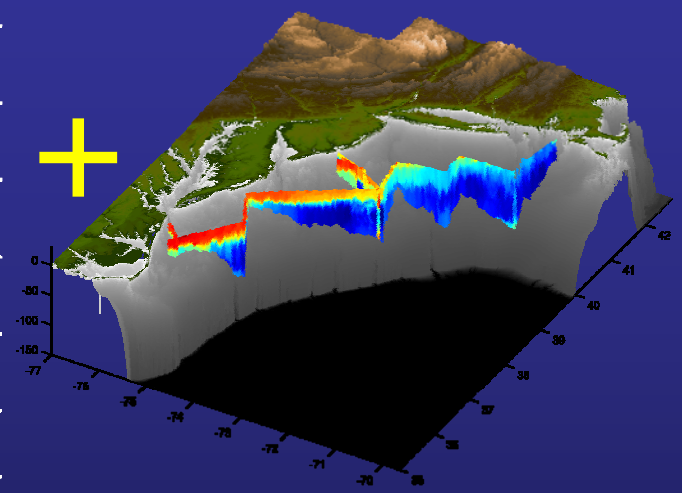


Composite Data & Forecast Products



Remote Sensing

+



Gliders

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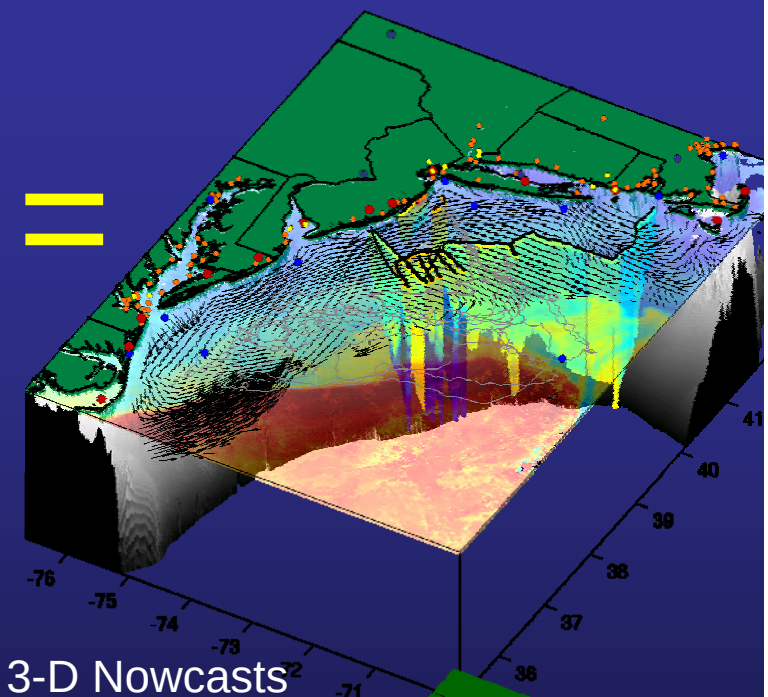
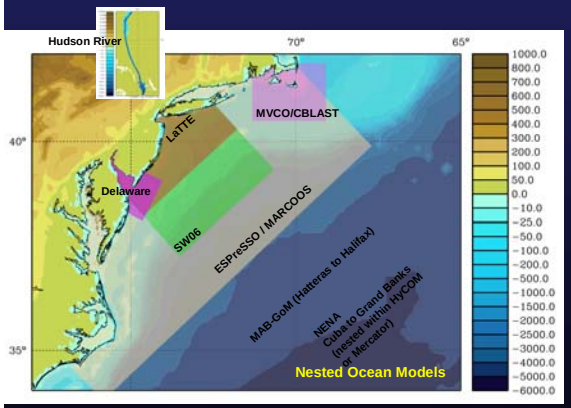


3-D Nowcasts



Nested Models

+

S4DVAR procedure

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

Lagrange multiplier $\boldsymbol{\lambda}_i = \boldsymbol{\lambda}(t_i) \equiv \boldsymbol{\lambda}(i\Delta t)$

At extrema of L, we require:

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

<u>S4DVAR procedure:</u>

(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 $\boldsymbol{\lambda}(0)$

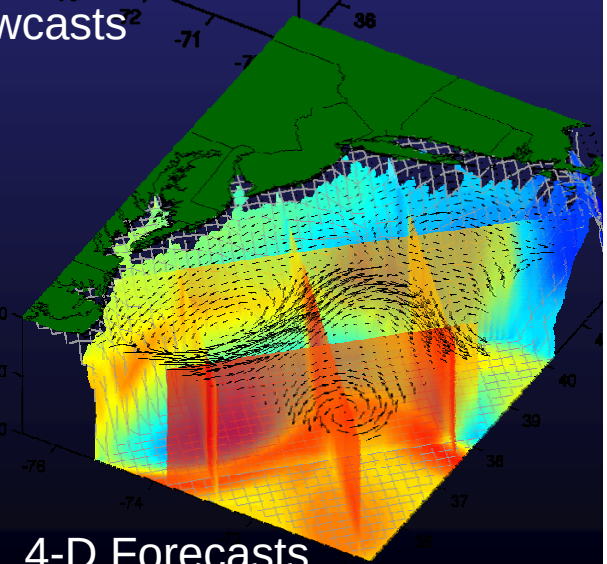
(4) Compute $\frac{\partial J}{\partial \mathbf{x}(0)} = \mathbf{B}^{-1}(\mathbf{x}(0) - \mathbf{x}_b) - \boldsymbol{\lambda}(0)$

(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

A ship on campus

Mission Planning

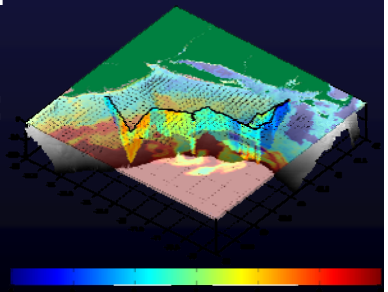
CODAR Network

L-Band & X-Band Satellite Systems

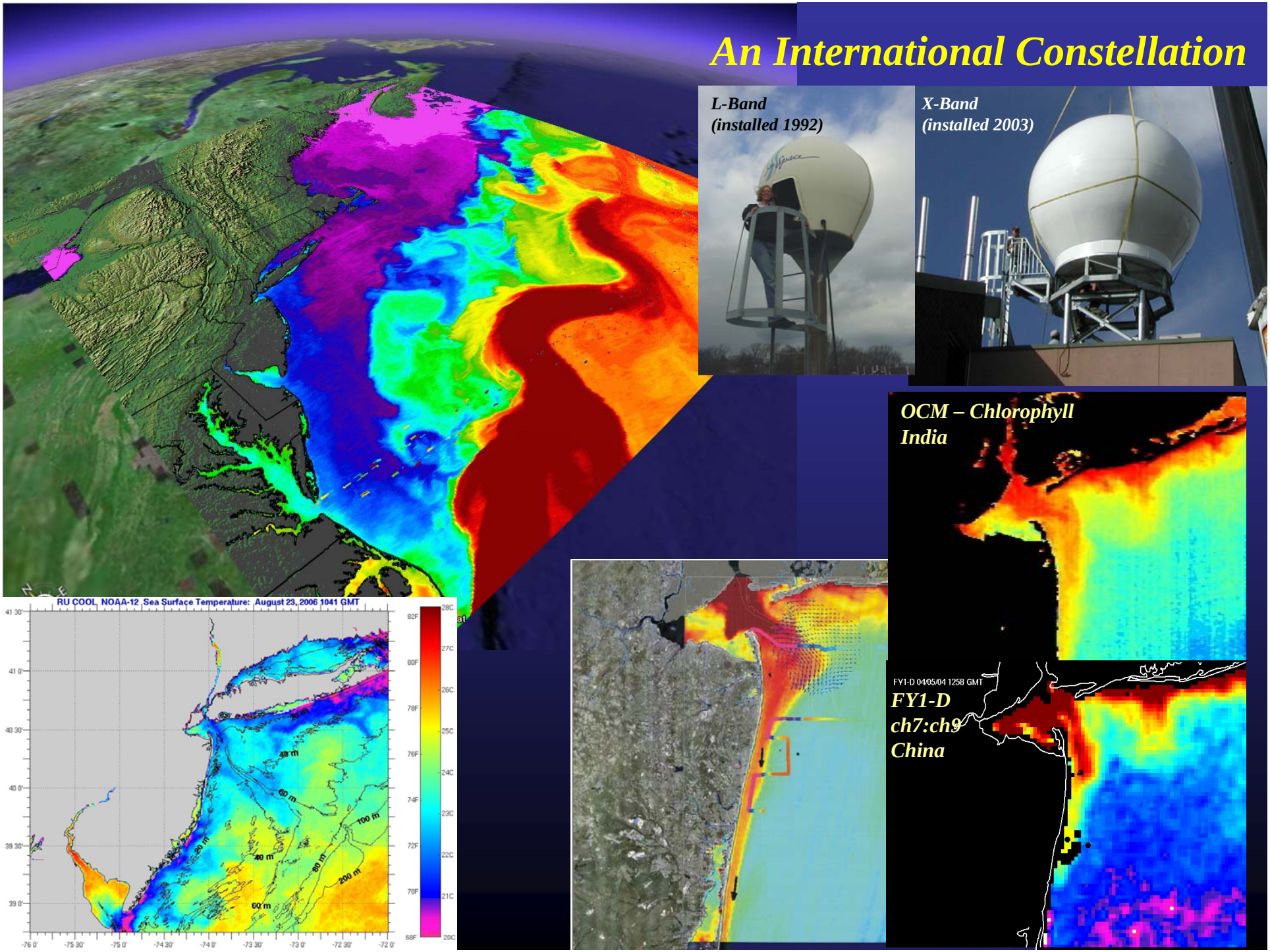
Operations & Communications Station

A "Stommel" View of the Ocean: WWW & Interactive 3-D

Glider Fleet

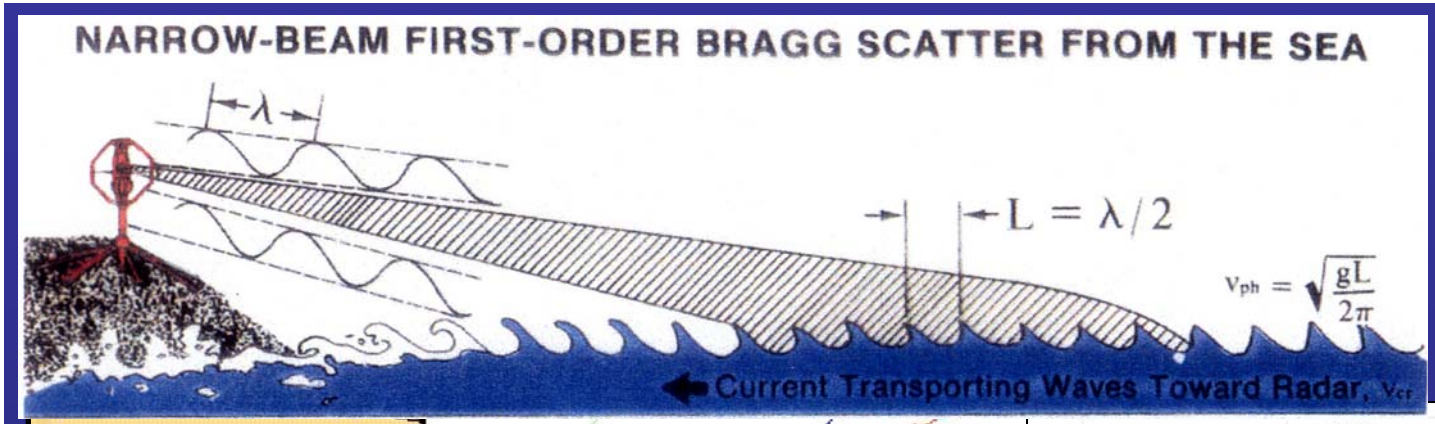


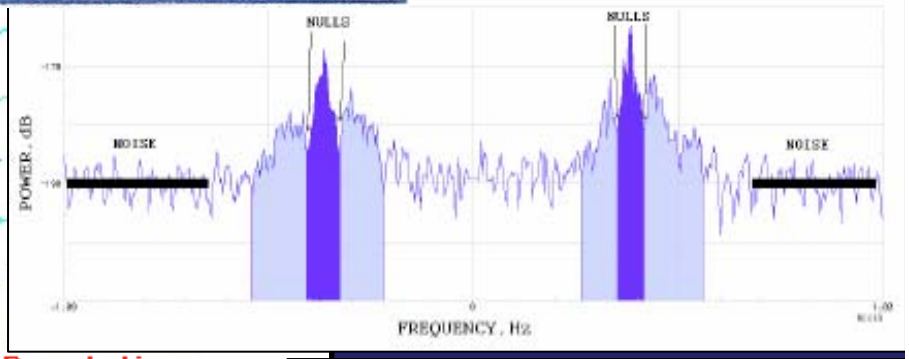
An International Constellation

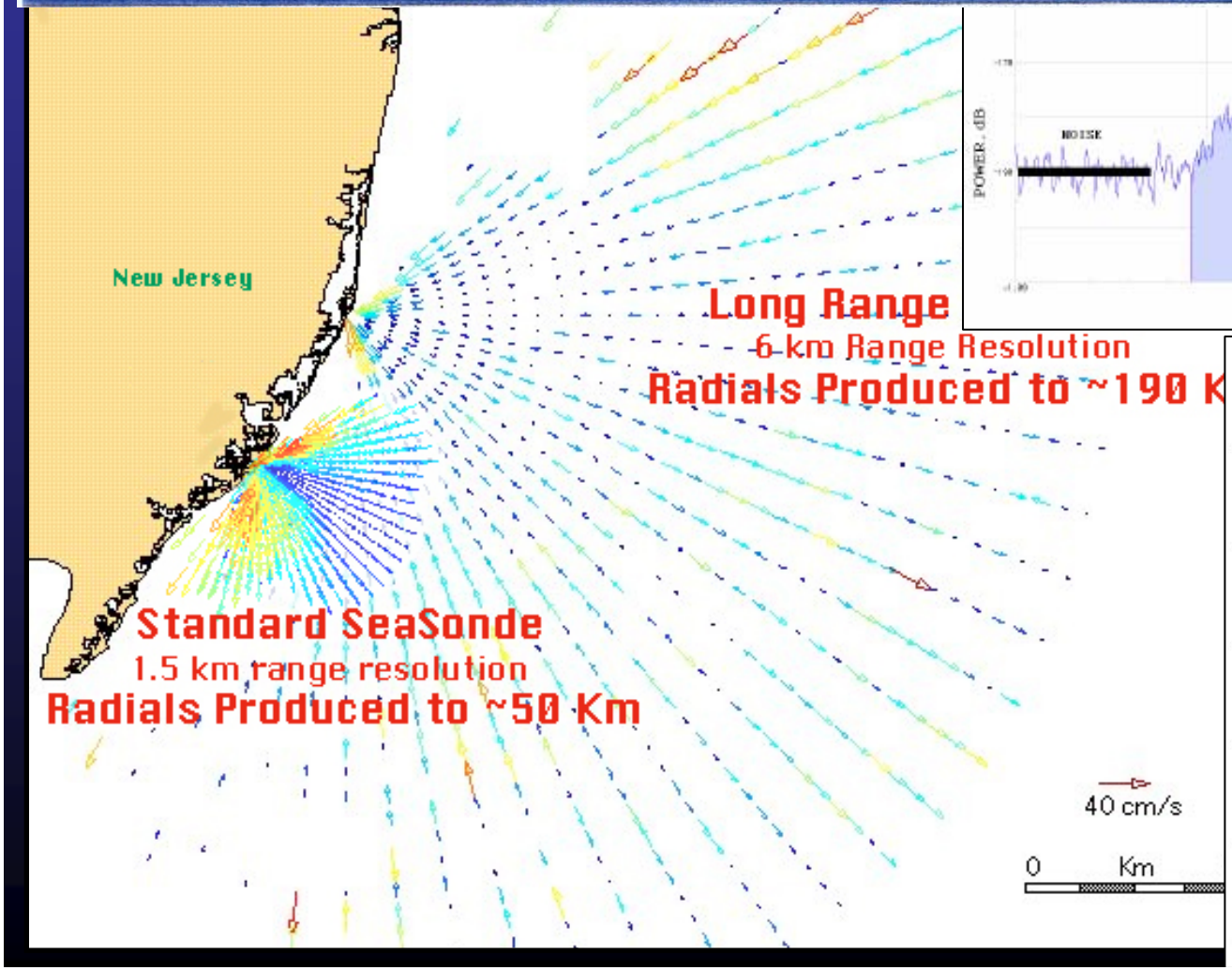


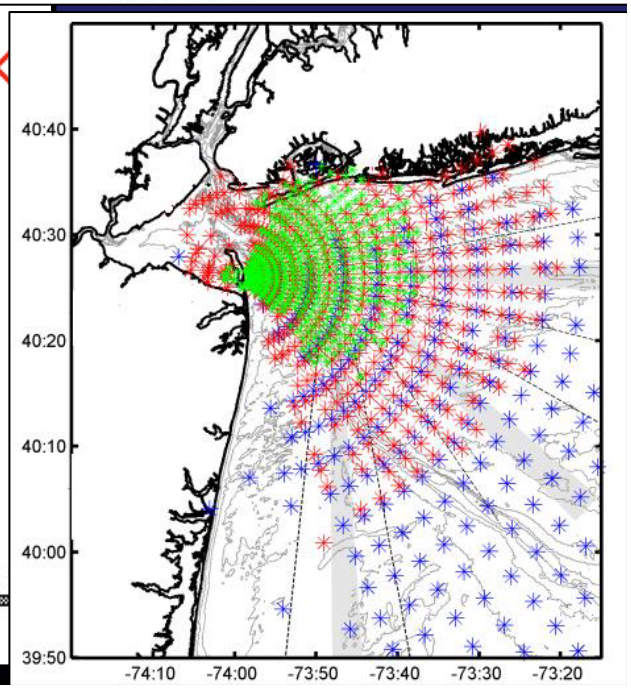
CODAR System Antennas

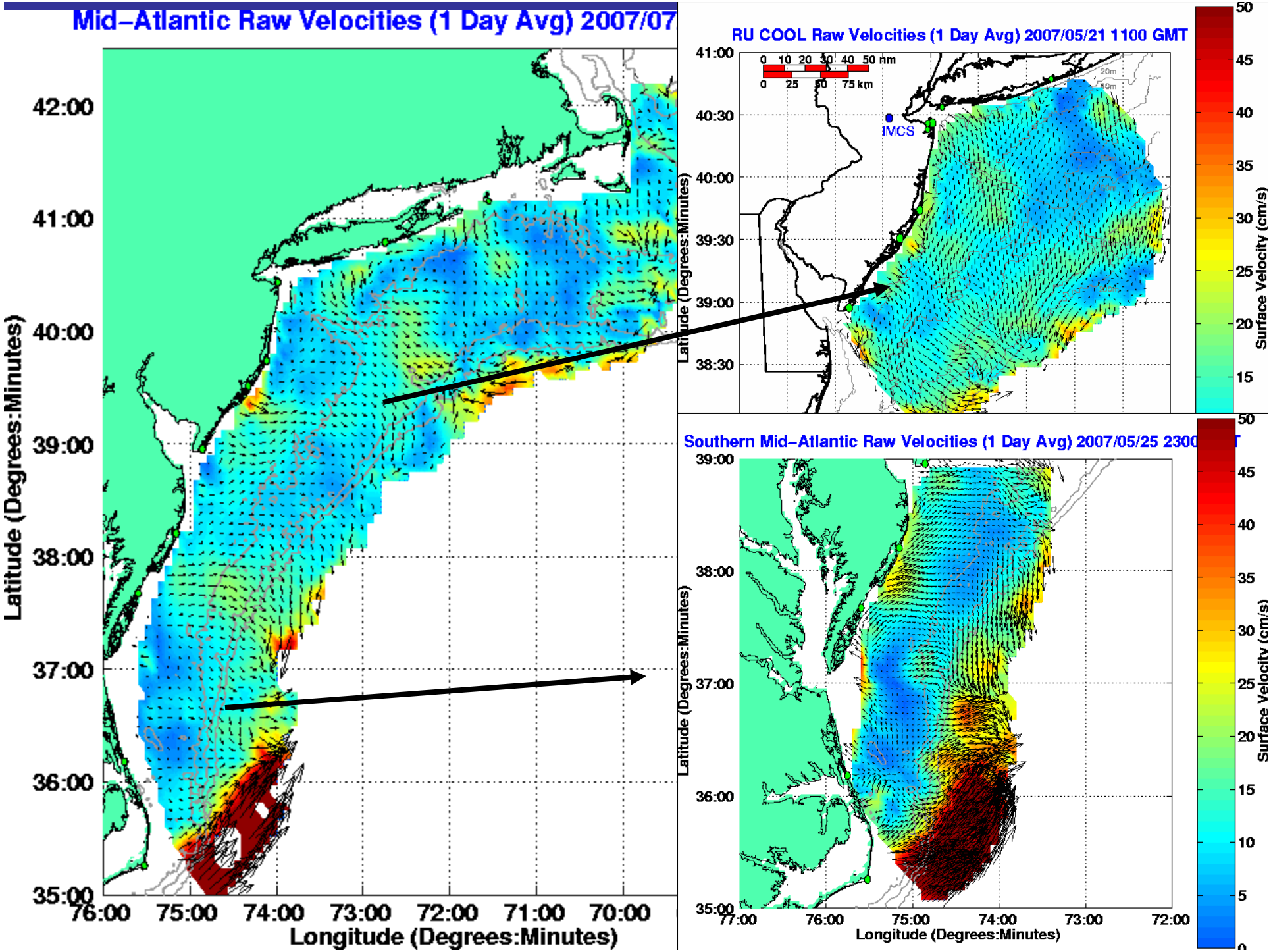
Transmit Antenna

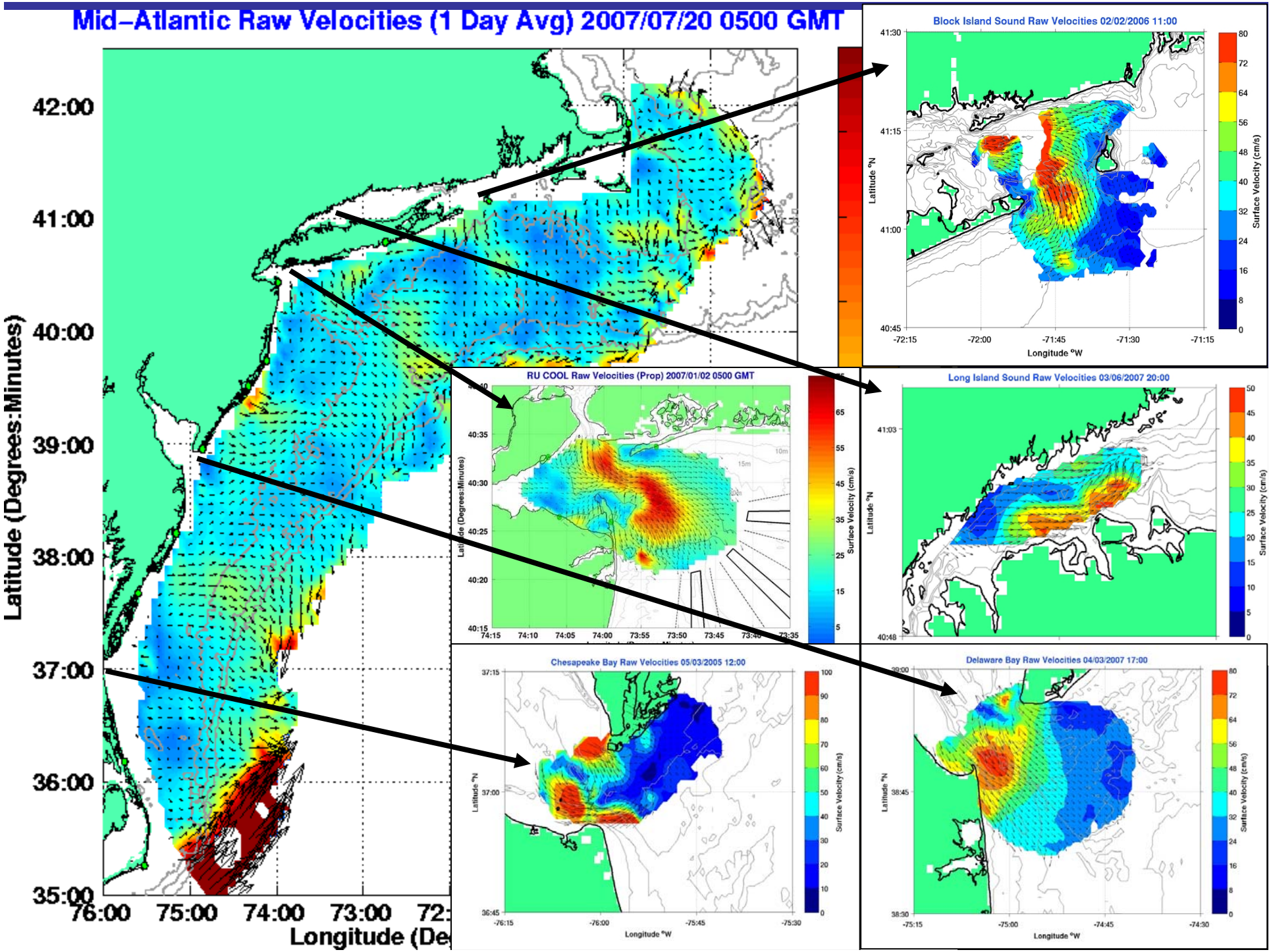

NARROW-BEAM FIRST-ORDER BRAGG SCATTER FROM THE SEA
λ
L = λ/2
$v_{ph} = \sqrt{\frac{gL}{2\pi}}$
Current Transporting Waves Toward Radar, v_{cr}


NULLS
NULLS
NOISE
NOISE
POWER, dB
FREQUENCY, Hz

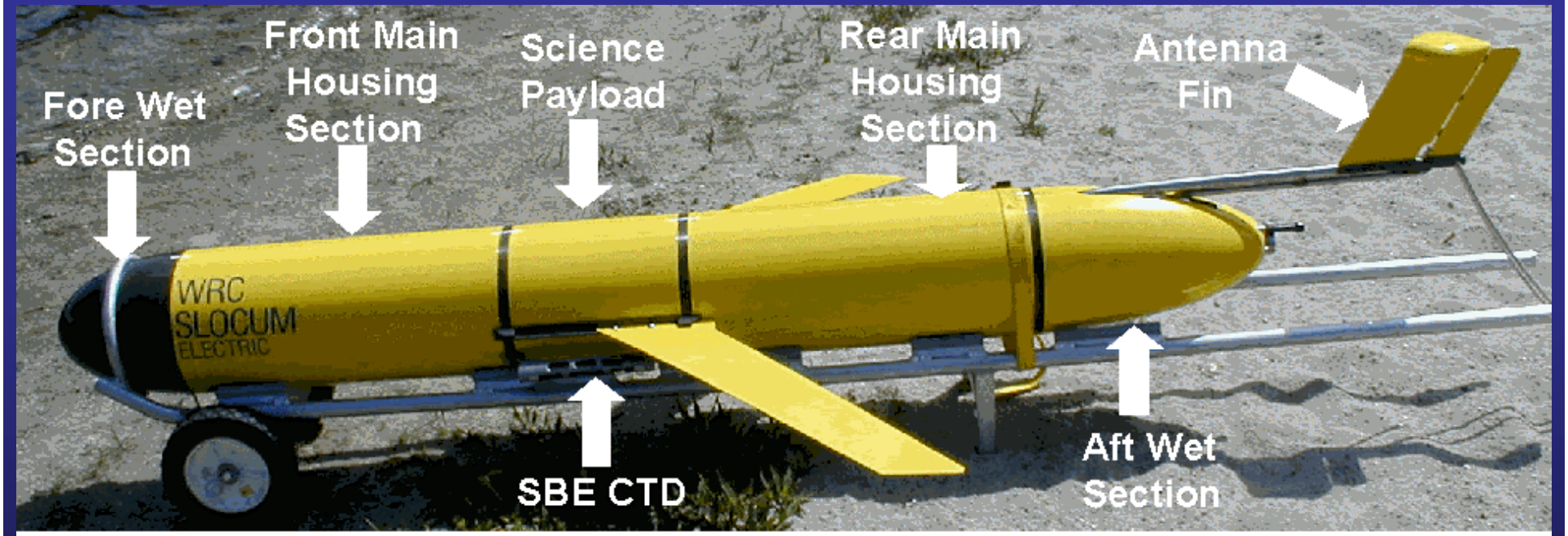

New Jersey
Long Range
6 km Range Resolution
Radials Produced to ~190 K
Standard SeaSonde
1.5 km range resolution
Radials Produced to ~50 Km
40 cm/s
0
Km


40:40
40:30
40:20
40:10
40:00
39:50
-74:10
-74:00
-73:50
-73:40
-73:30
-73:20


Mid–Atlantic Raw Velocities (1 Day Avg) 2007/07
Latitude (Degrees:Minutes)
Longitude (Degrees:Minutes)
42:00
41:00
40:00
39:00
38:00
37:00
36:00
35:00
76:00
75:00
74:00
73:00
72:00
71:00
70:00
RU COOL Raw Velocities (1 Day Avg) 2007/05/21 1100 GMT
0 10 20 30 40 50 nm
0 25 50 75 km
MCS
41:00
40:30
40:00
39:30
39:00
38:30
Surface Velocity (cm/s)
50
45
40
35
30
25
20
15
Southern Mid–Atlantic Raw Velocities (1 Day Avg) 2007/05/25 2300
39:00
38:00
37:00
36:00
35:00
77:00
76:00
75:00
74:00
73:00
72:00
Surface Velocity (cm/s)
50
45
40
35
30
25
20
15
10
5
0


Mid–Atlantic Raw Velocities (1 Day Avg) 2007/07/20 0500 GMT
Latitude (Degrees:Minutes)
Longitude (De
Block Island Sound Raw Velocities 02/02/2006 11:00
Latitude °N
Longitude °W
Surface Velocity (cm/s)
RU COOL Raw Velocities (Prop) 2007/01/02 0500 GMT
Latitude (Degrees:Minutes)
Surface Velocity (cm/s)
Long Island Sound Raw Velocities 03/06/2007 20:00
Latitude °N
Surface Velocity (cm/s)
Chesapeake Bay Raw Velocities 05/03/2005 12:00
Latitude °N
Longitude °W
Surface Velocity (cm/s)
Delaware Bay Raw Velocities 04/03/2007 17:00
Latitude °N
Longitude °W
Surface Velocity (cm/s)

Slocum Coastal Glider



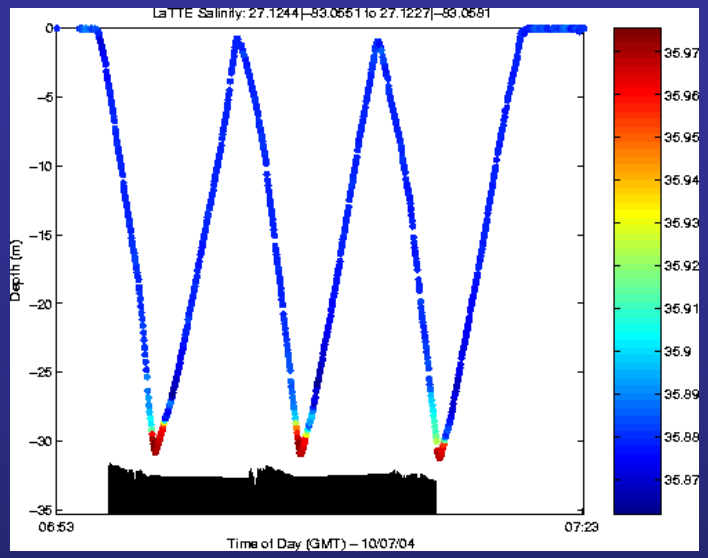
Glider Specs.

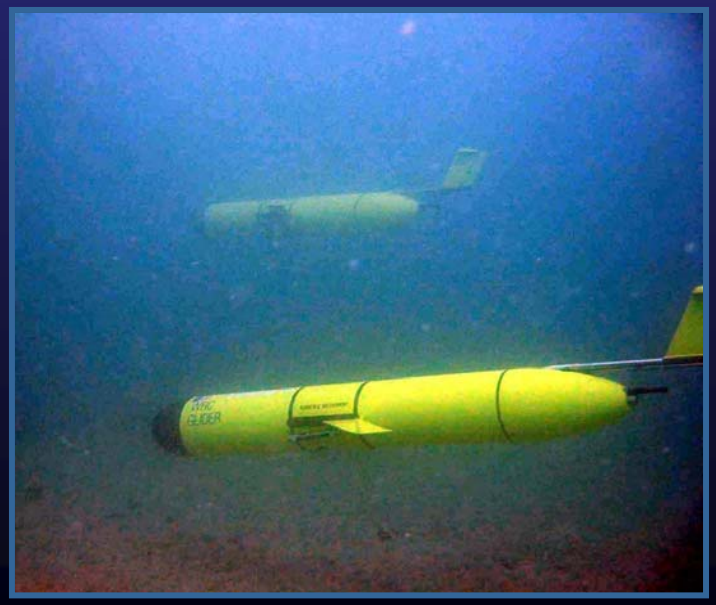
Length: 1.5 m Hull Diameter: 21.3 cm
Weight: 52 kg

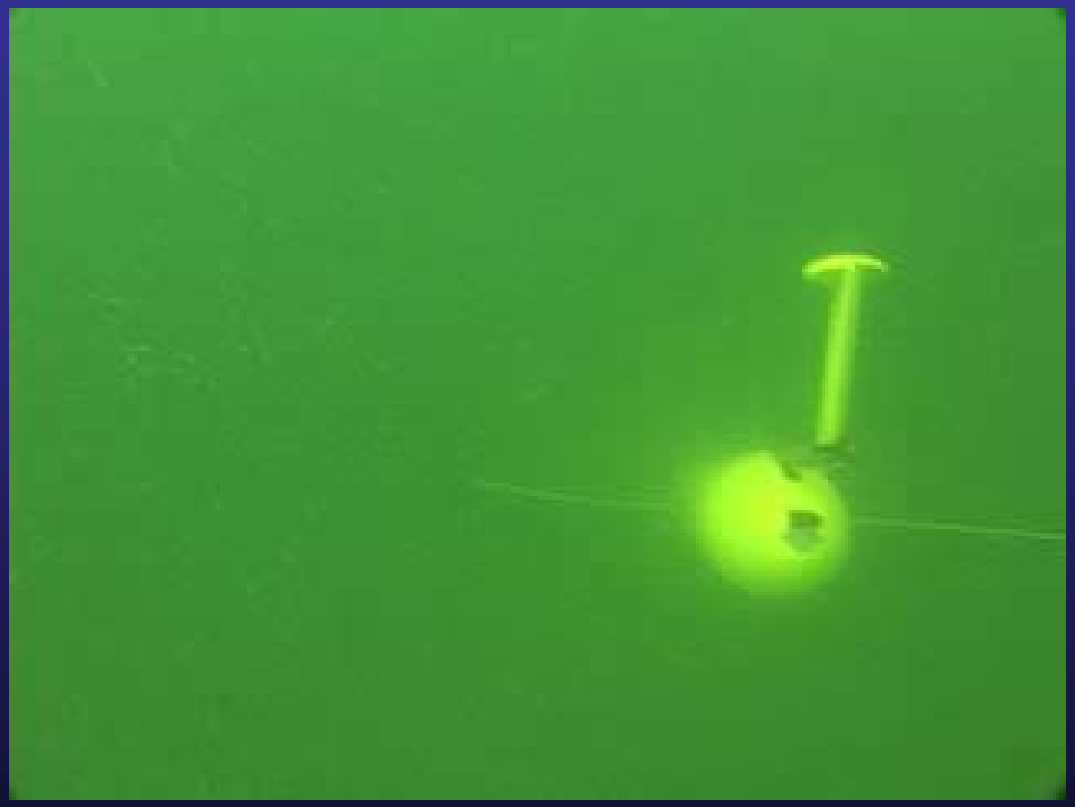
Science Bay Specs.

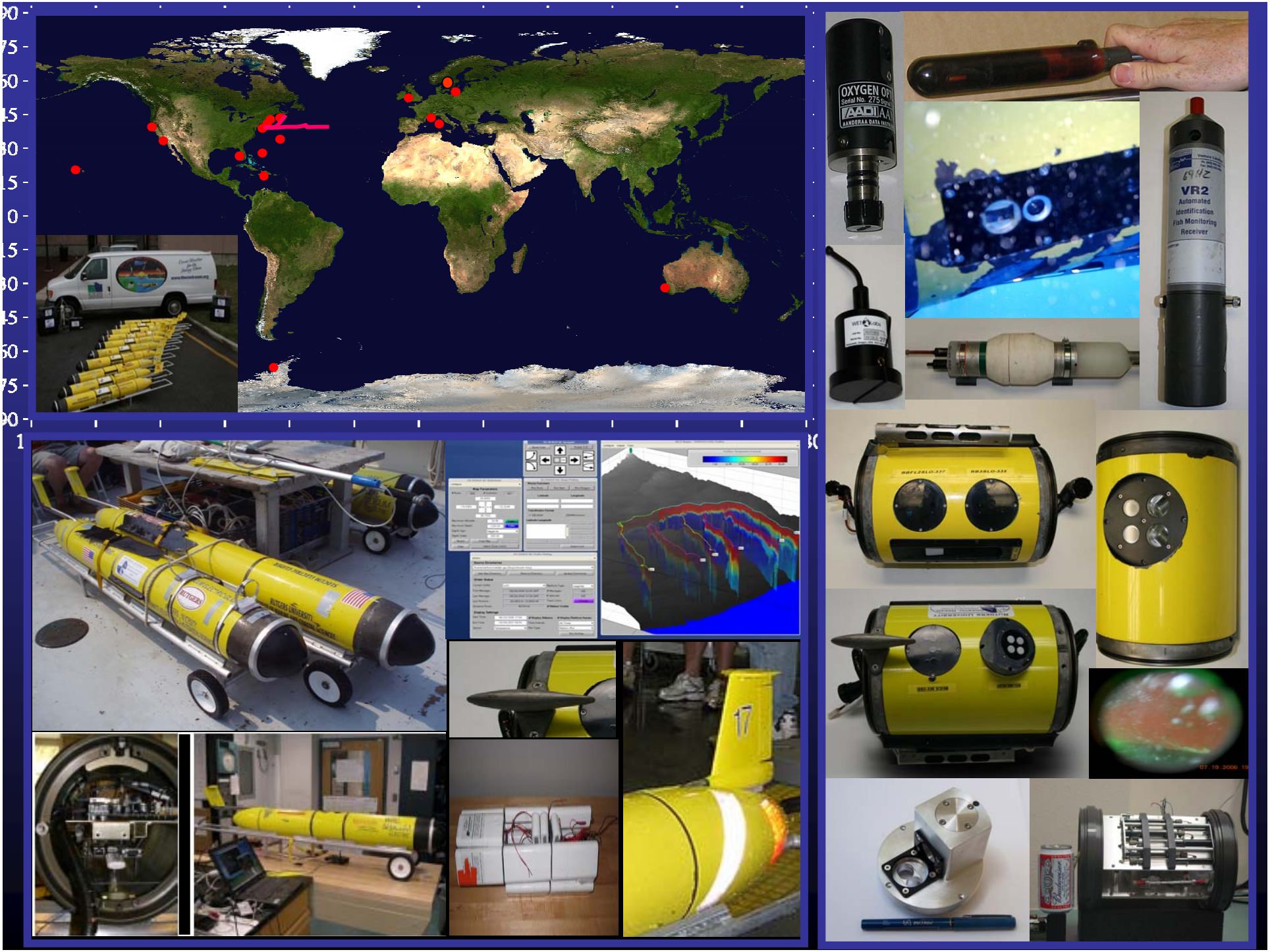
Length: 30 cm Diameter: 21.3 cm
Max. Payload Weight: 4 kg

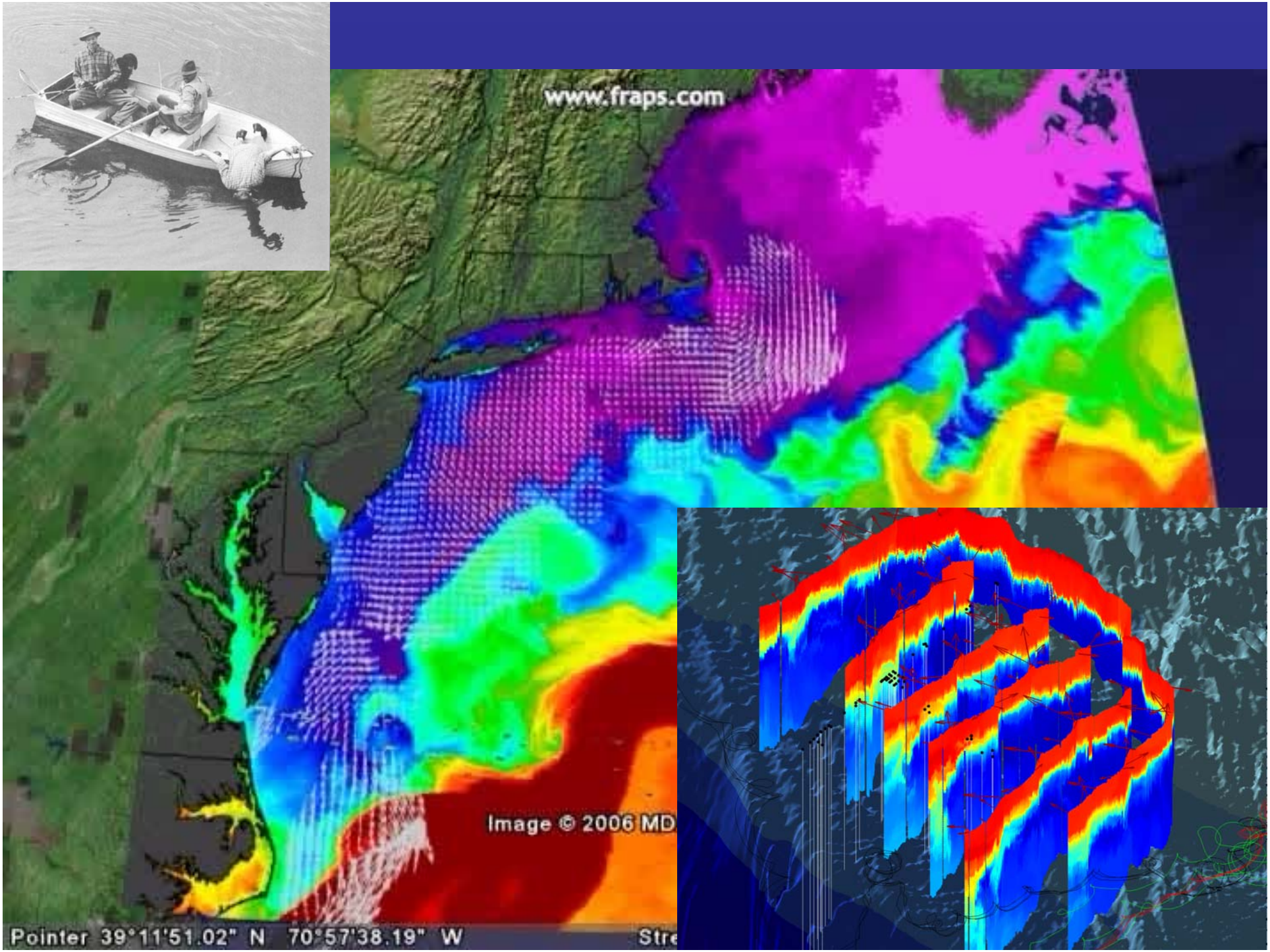
The Glider “Flight”





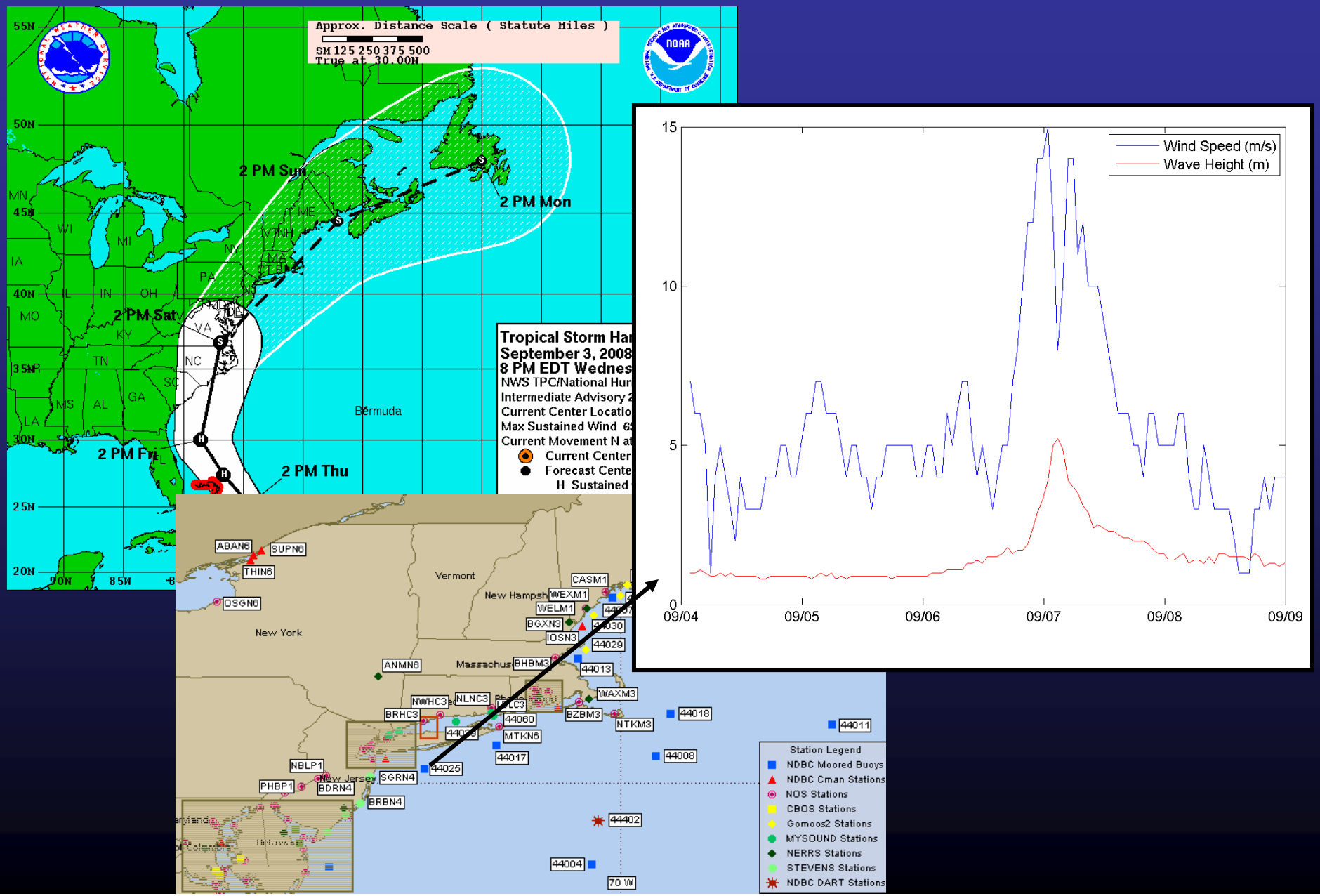



OXYGEN OPT
AANDERAA DATA INSTR
VR2
Automated
Identification
Fish Monitoring
Receiver


www.fraps.com
Image © 2006 MD
Pointer 39°11'51.02" N 70°57'38.19" W

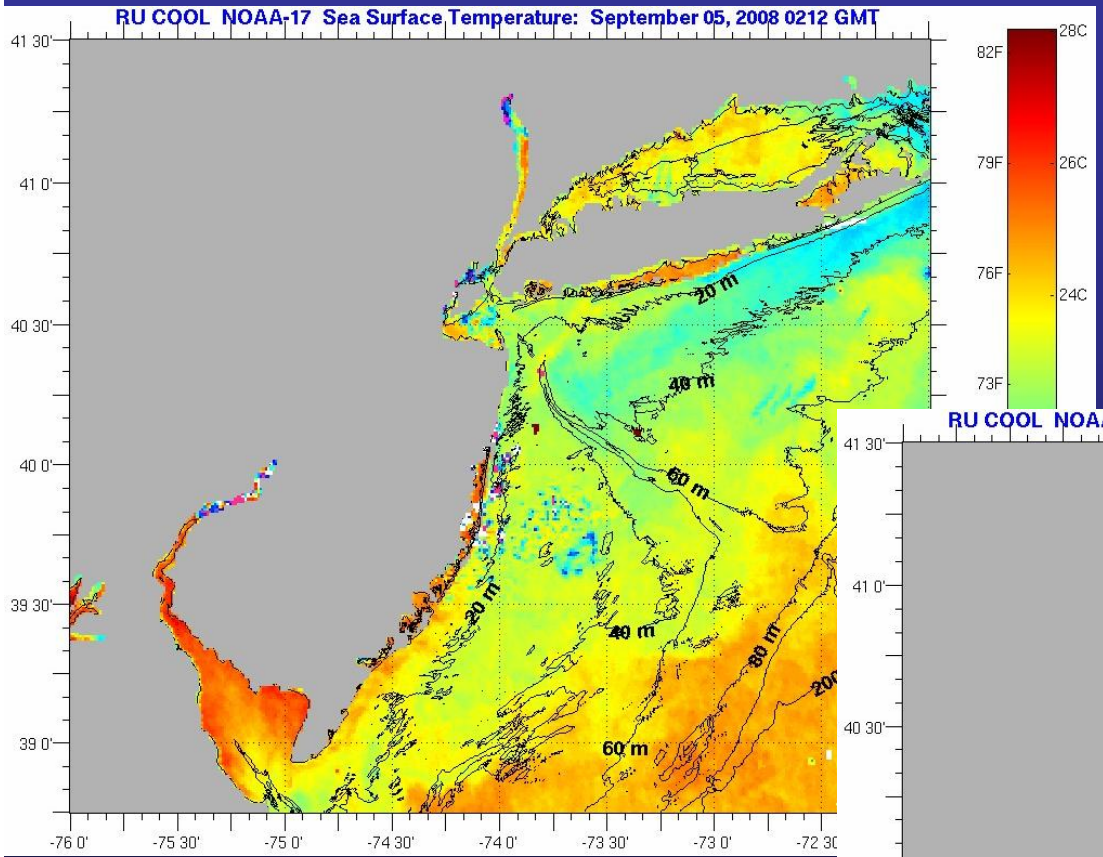
Tropical Storm Hanna

September 2008



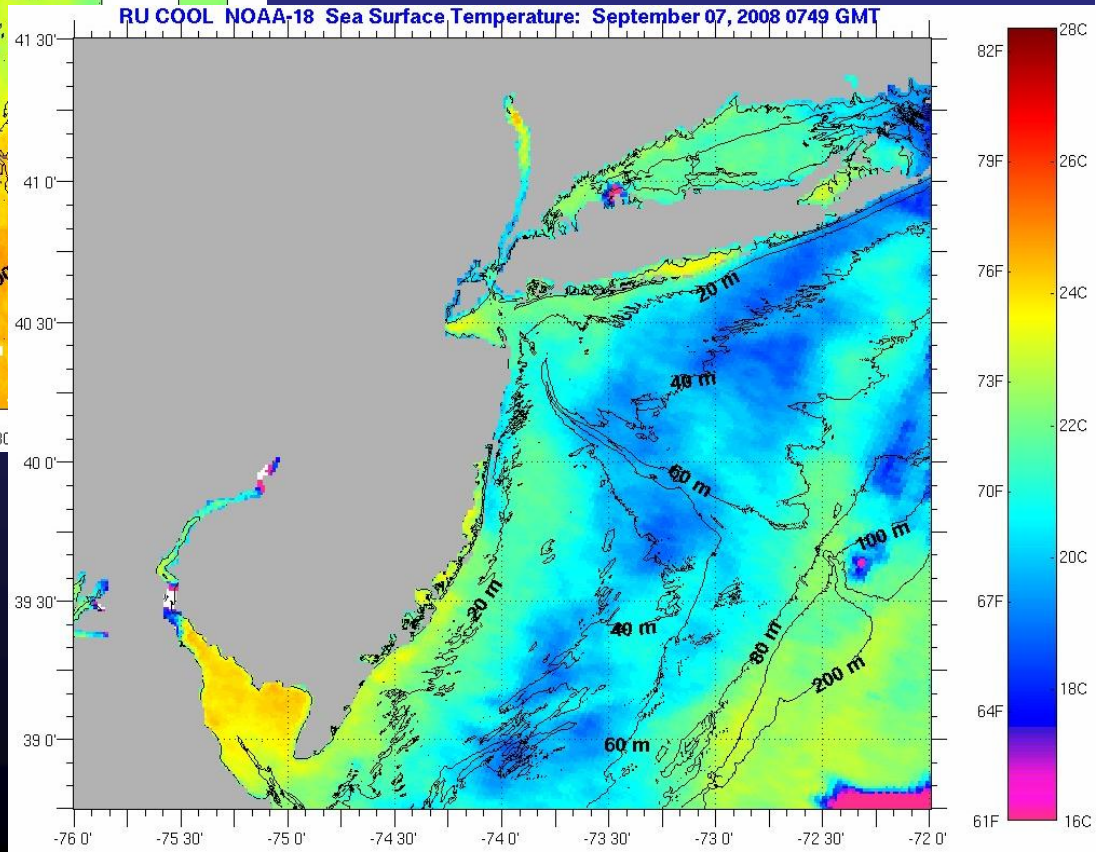
Tropical Storm Hanna

September 2008



Sea Surface Temperature

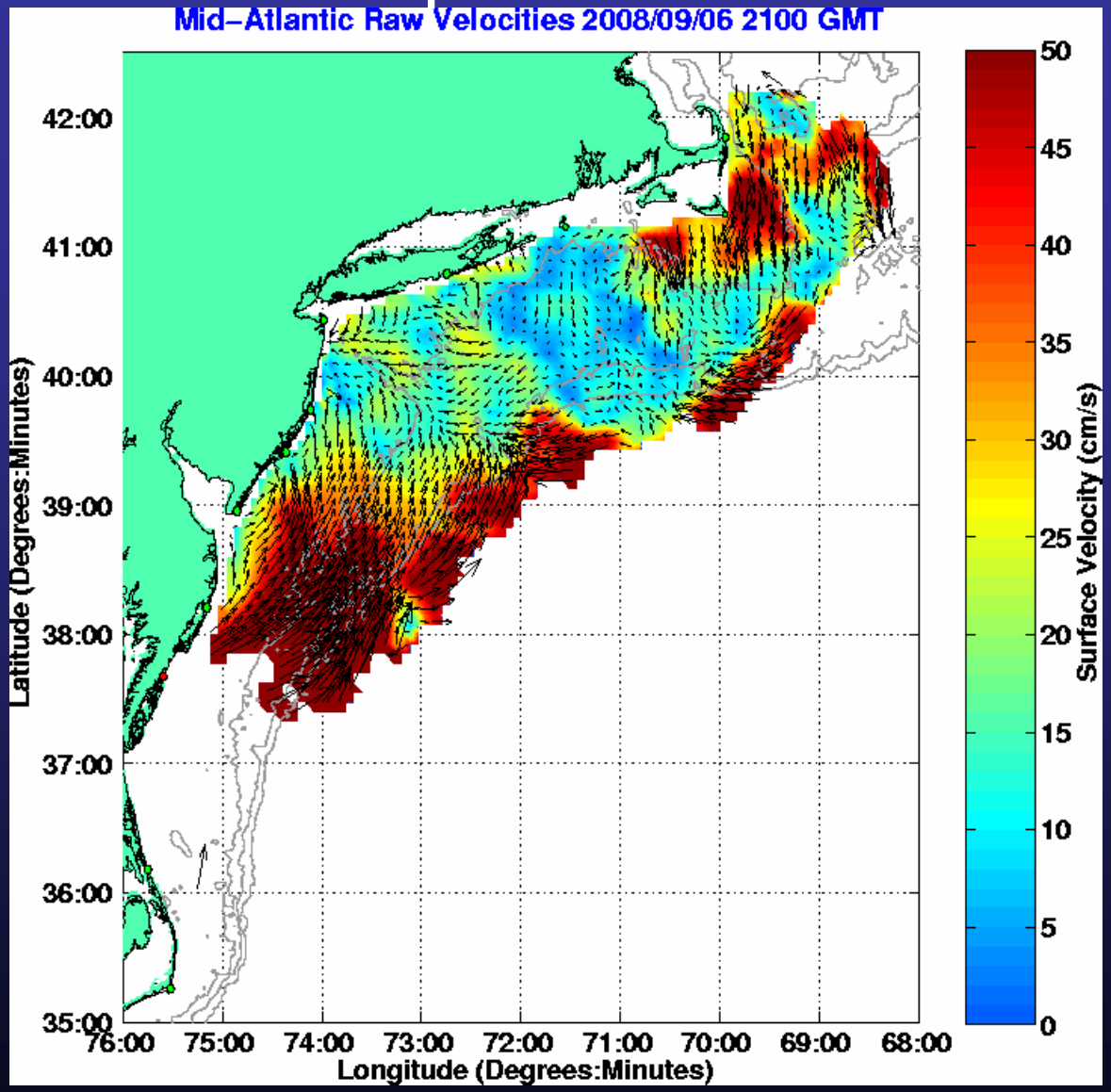
After



Before

Tropical Storm Hanna

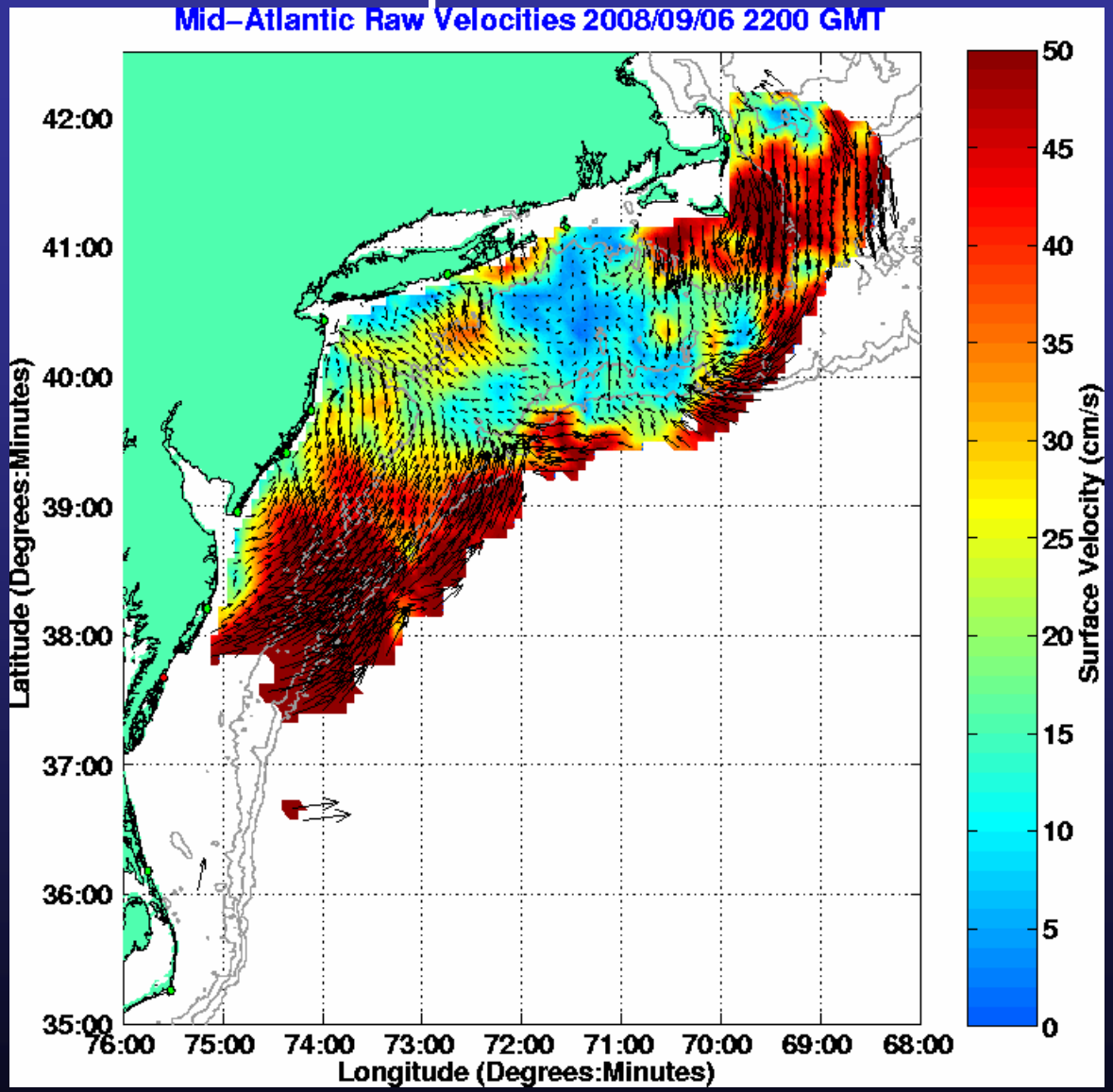
September 2008



Sea Surface Currents

Tropical Storm Hanna

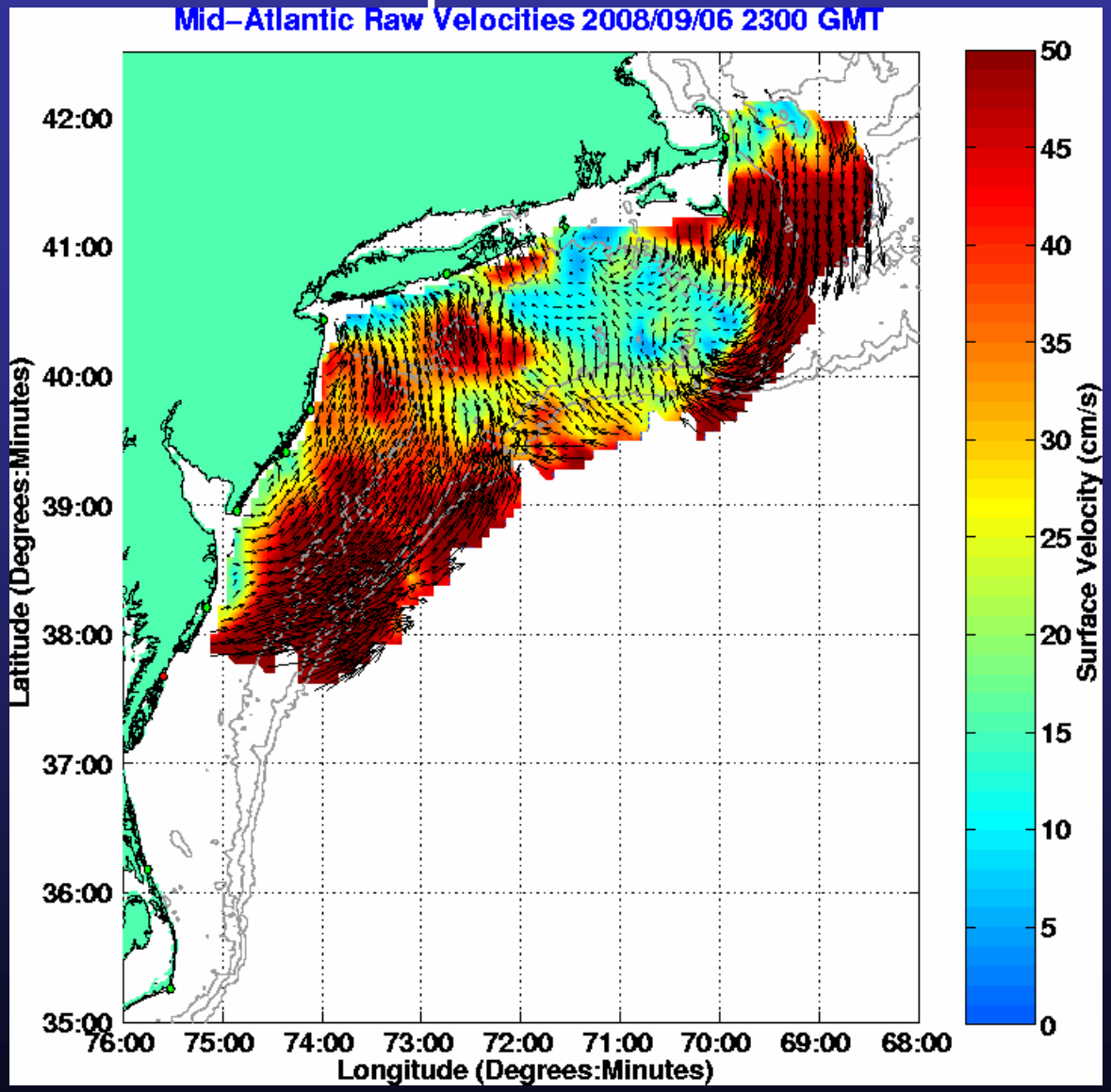
September 2008



Sea Surface Currents

Tropical Storm Hanna

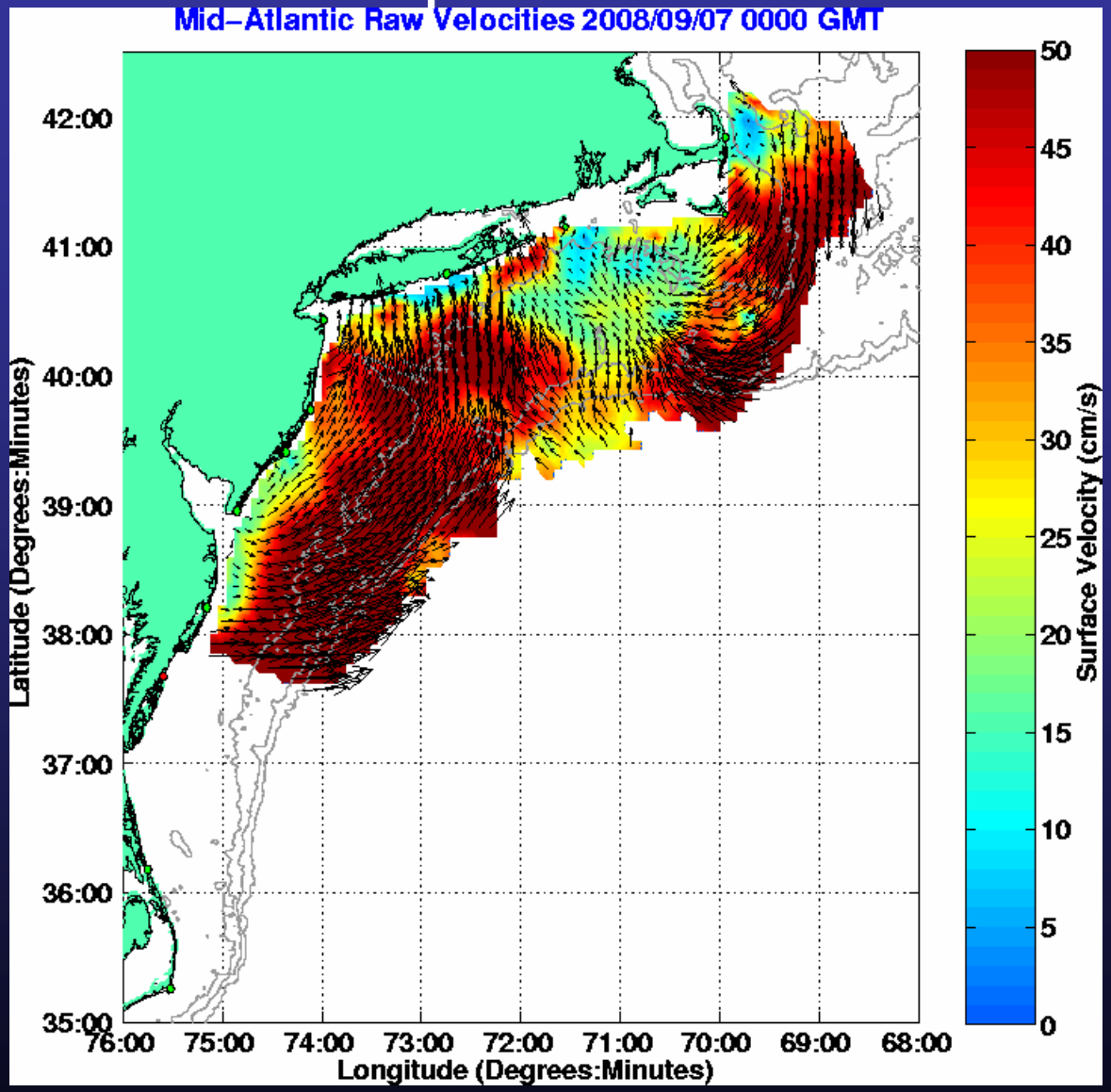
September 2008



Sea Surface Currents

Tropical Storm Hanna

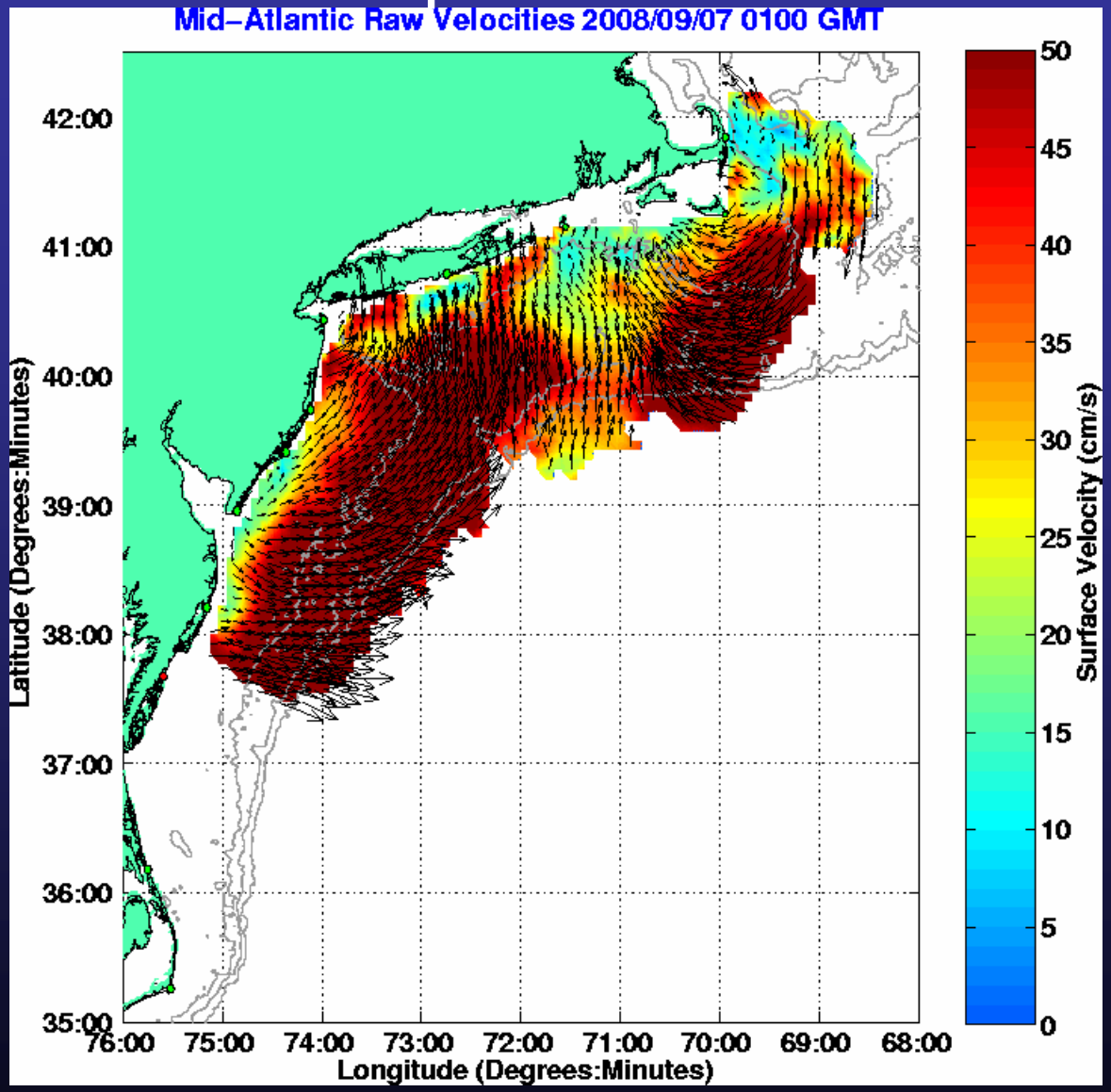
September 2008



Sea Surface Currents

Tropical Storm Hanna

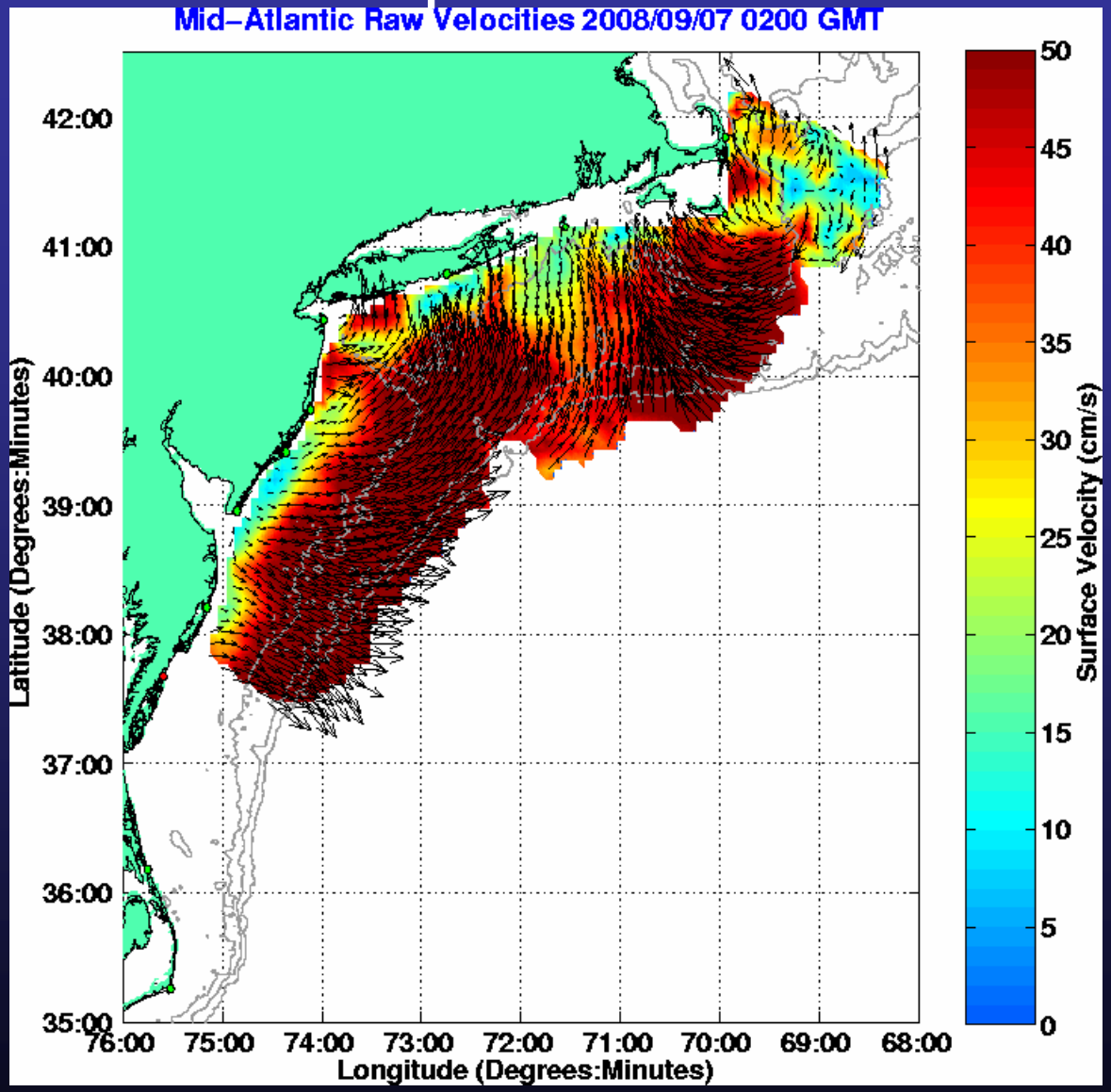
September 2008



Sea Surface Currents

Tropical Storm Hanna

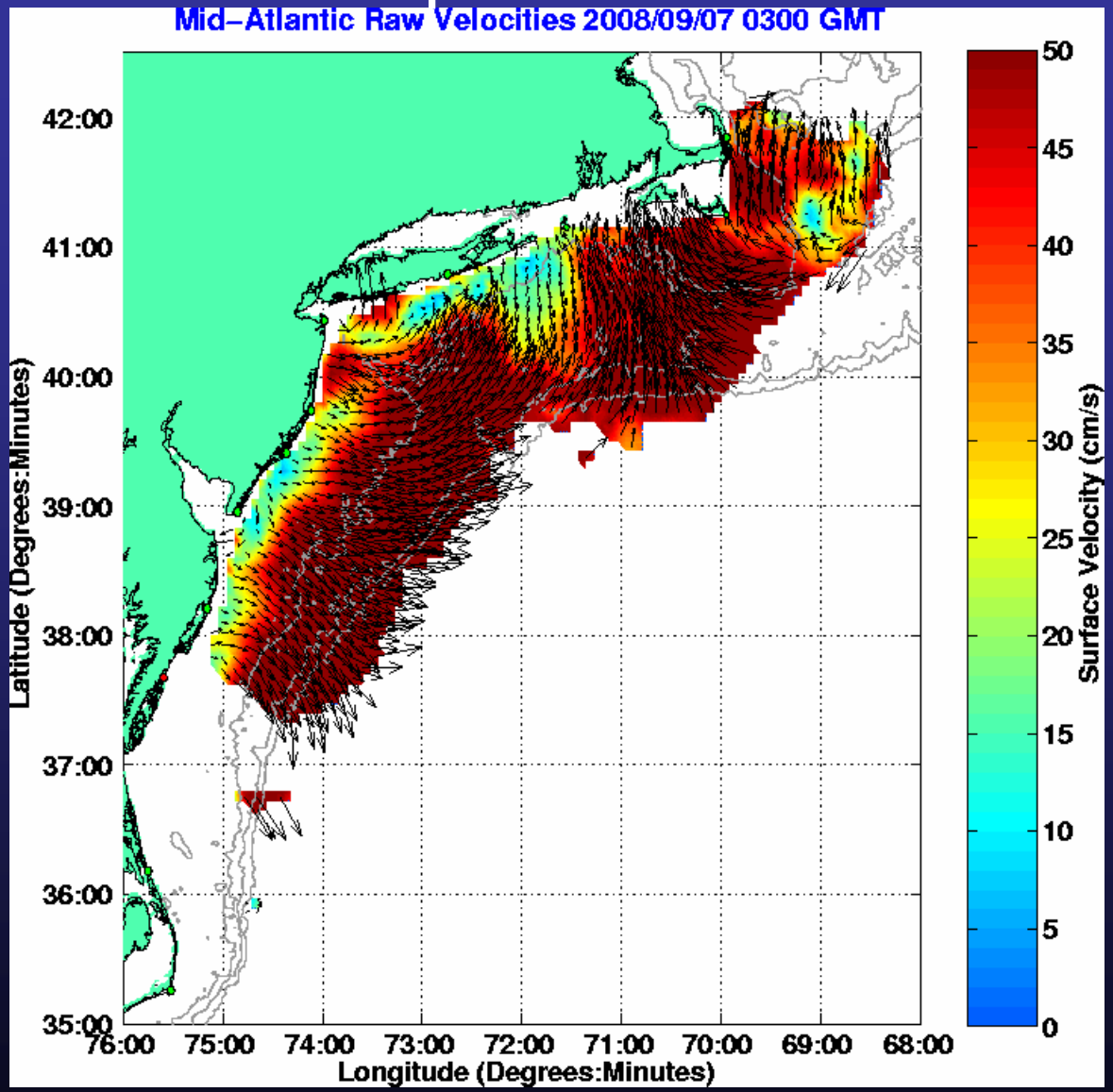
September 2008



Sea Surface Currents

Tropical Storm Hanna

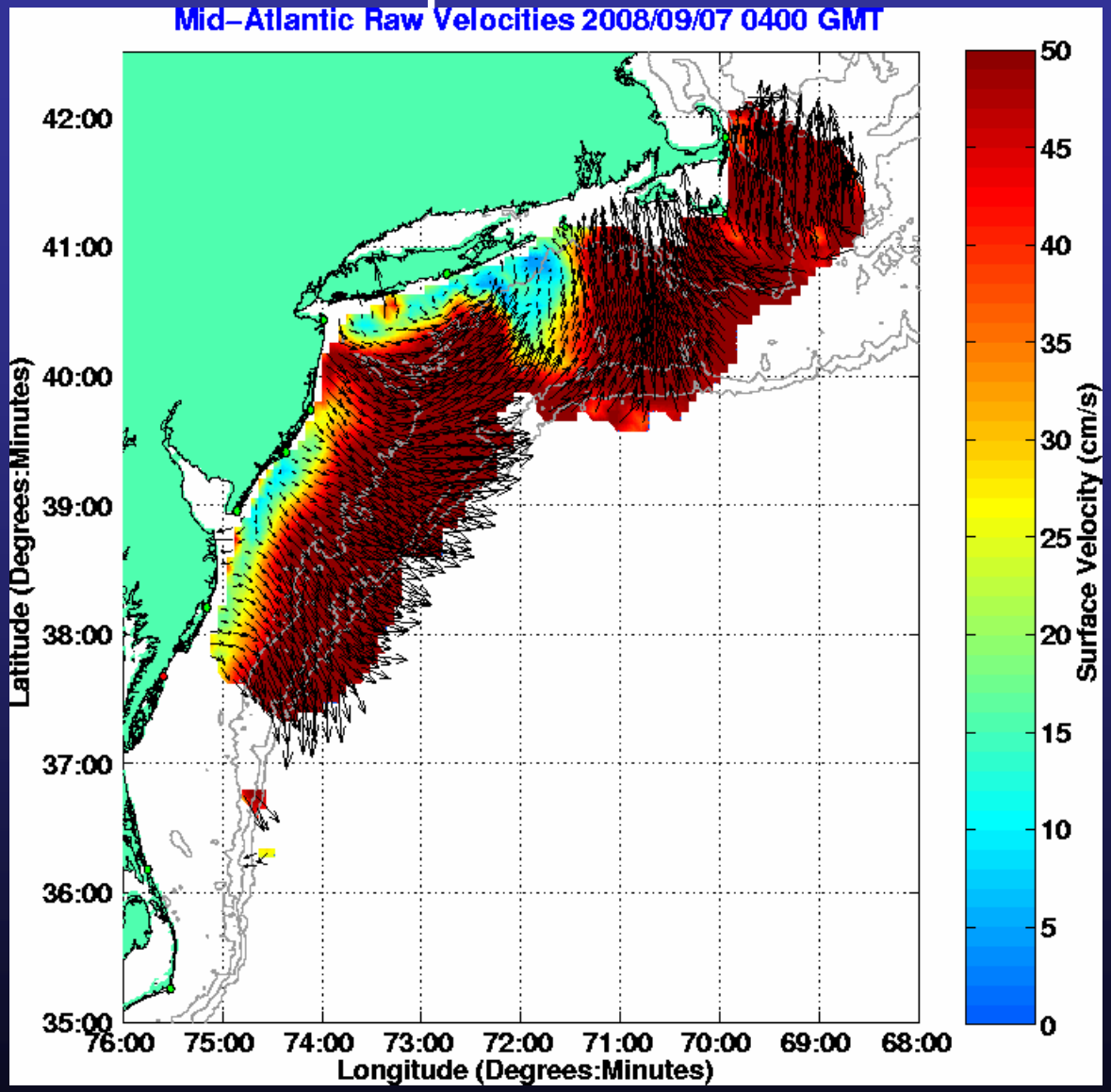
September 2008



Sea Surface Currents

Tropical Storm Hanna

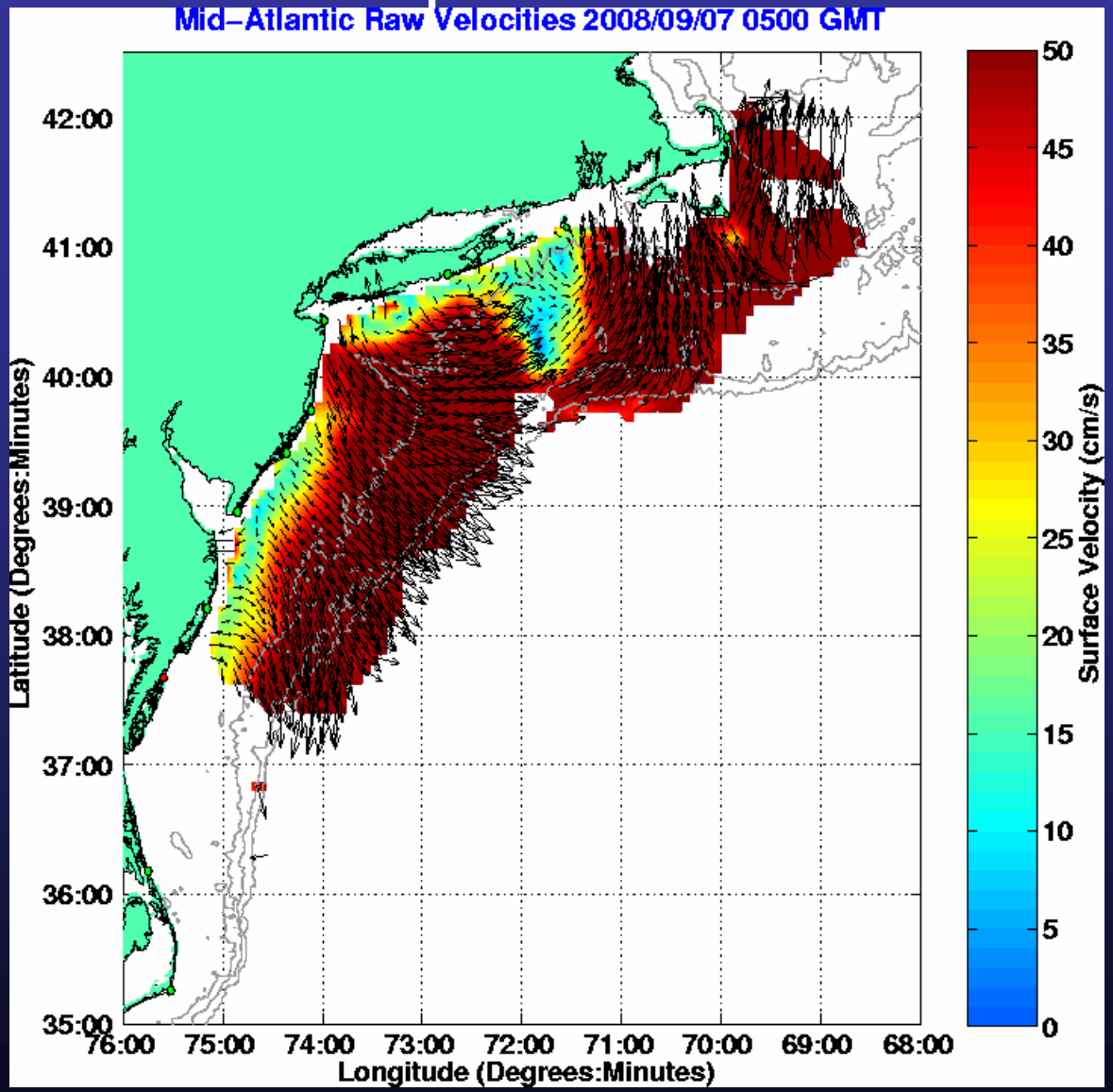
September 2008



Sea Surface Currents

Tropical Storm Hanna

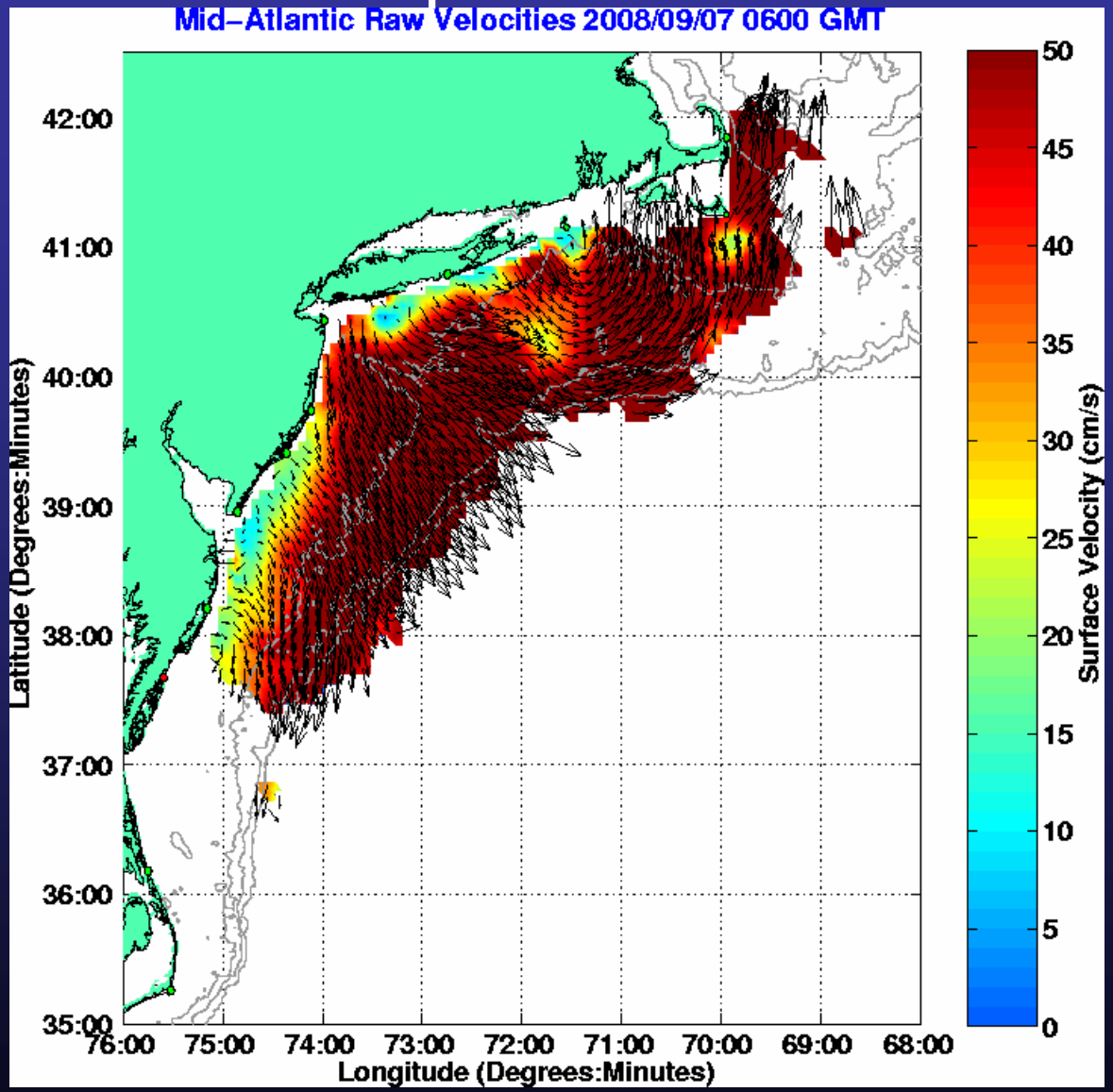
September 2008



Sea Surface Currents

Tropical Storm Hanna

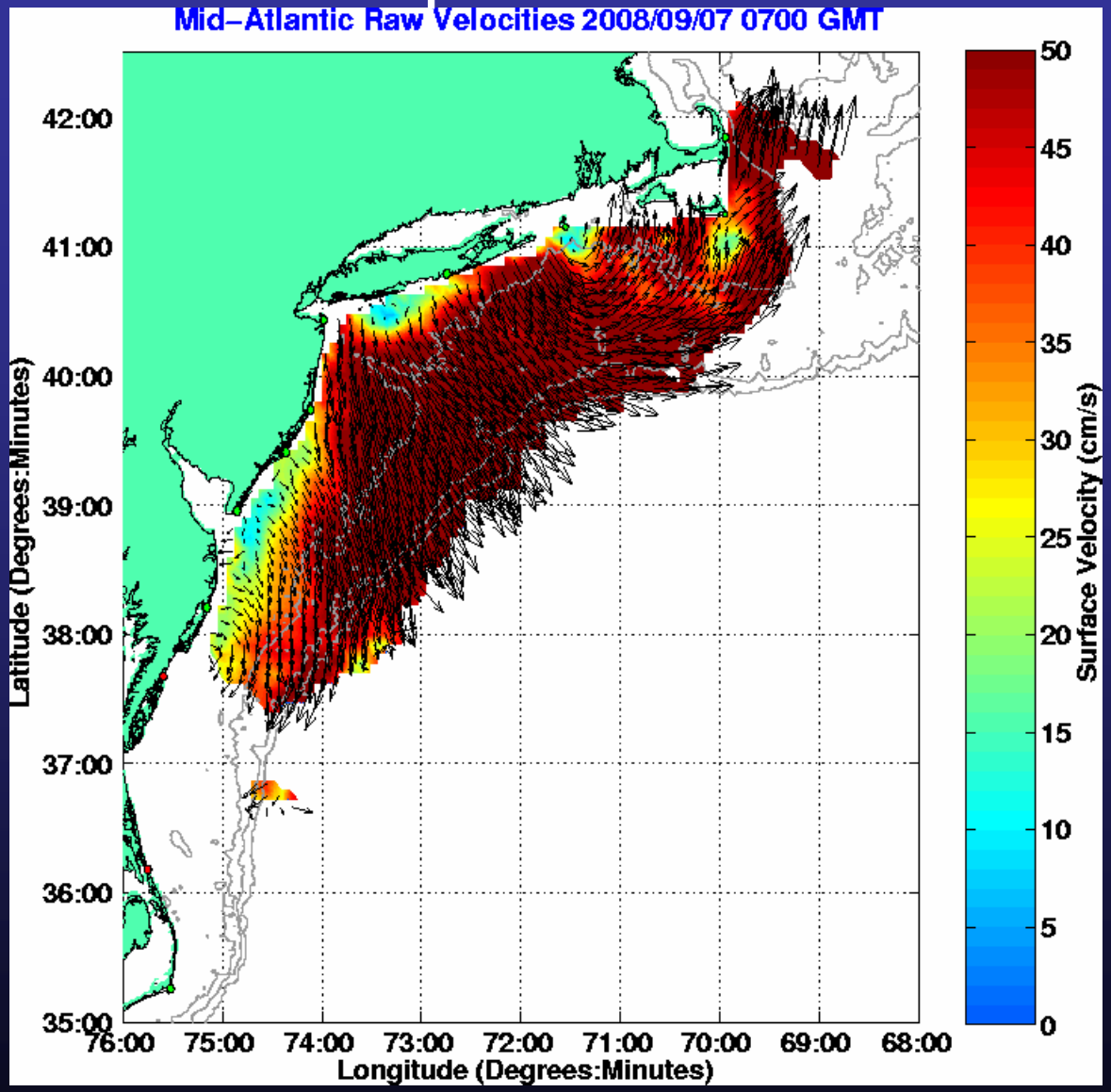
September 2008



Sea Surface Currents

Tropical Storm Hanna

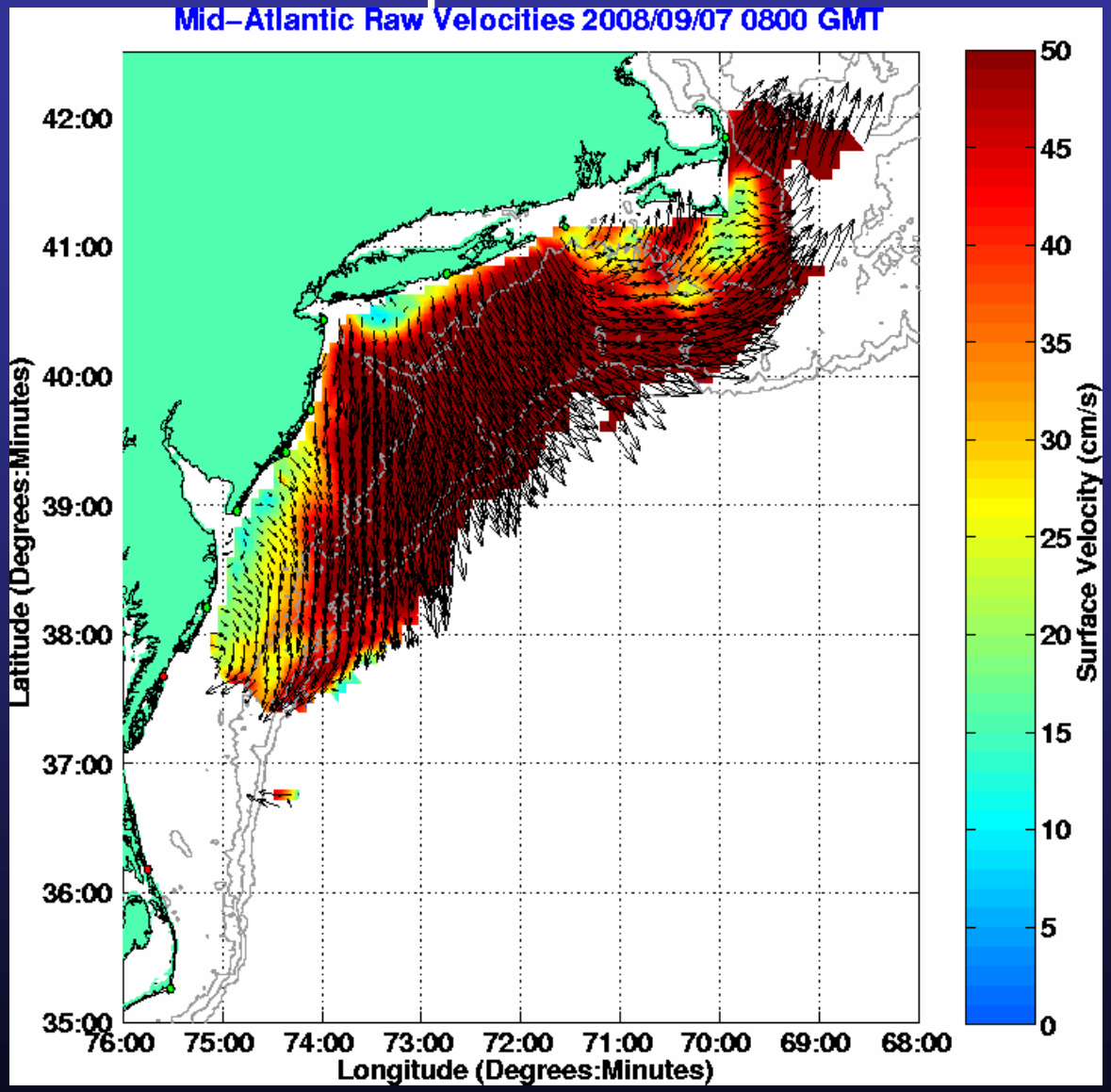
September 2008



Sea Surface Currents

Tropical Storm Hanna

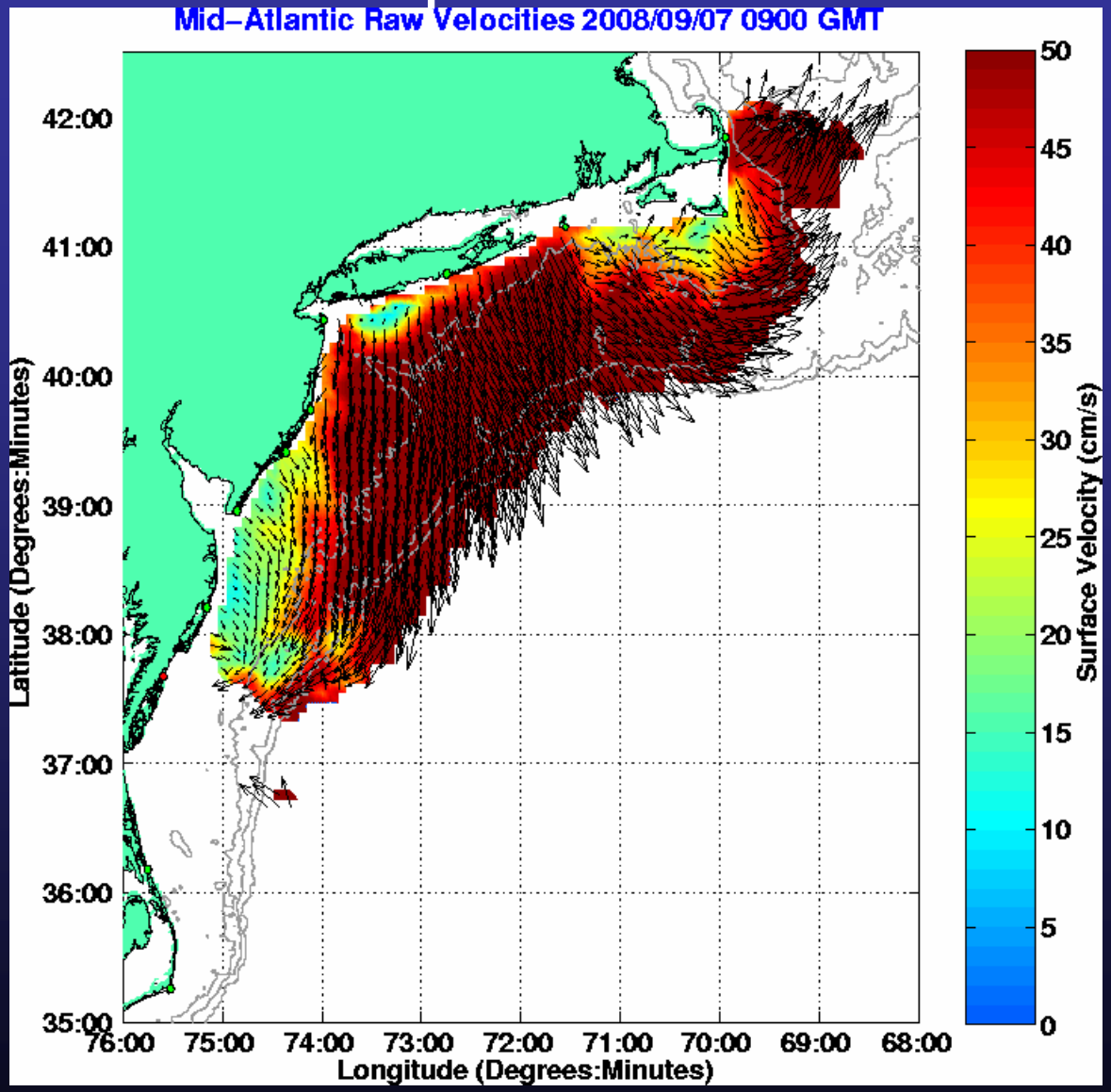
September 2008



Sea Surface Currents

Tropical Storm Hanna

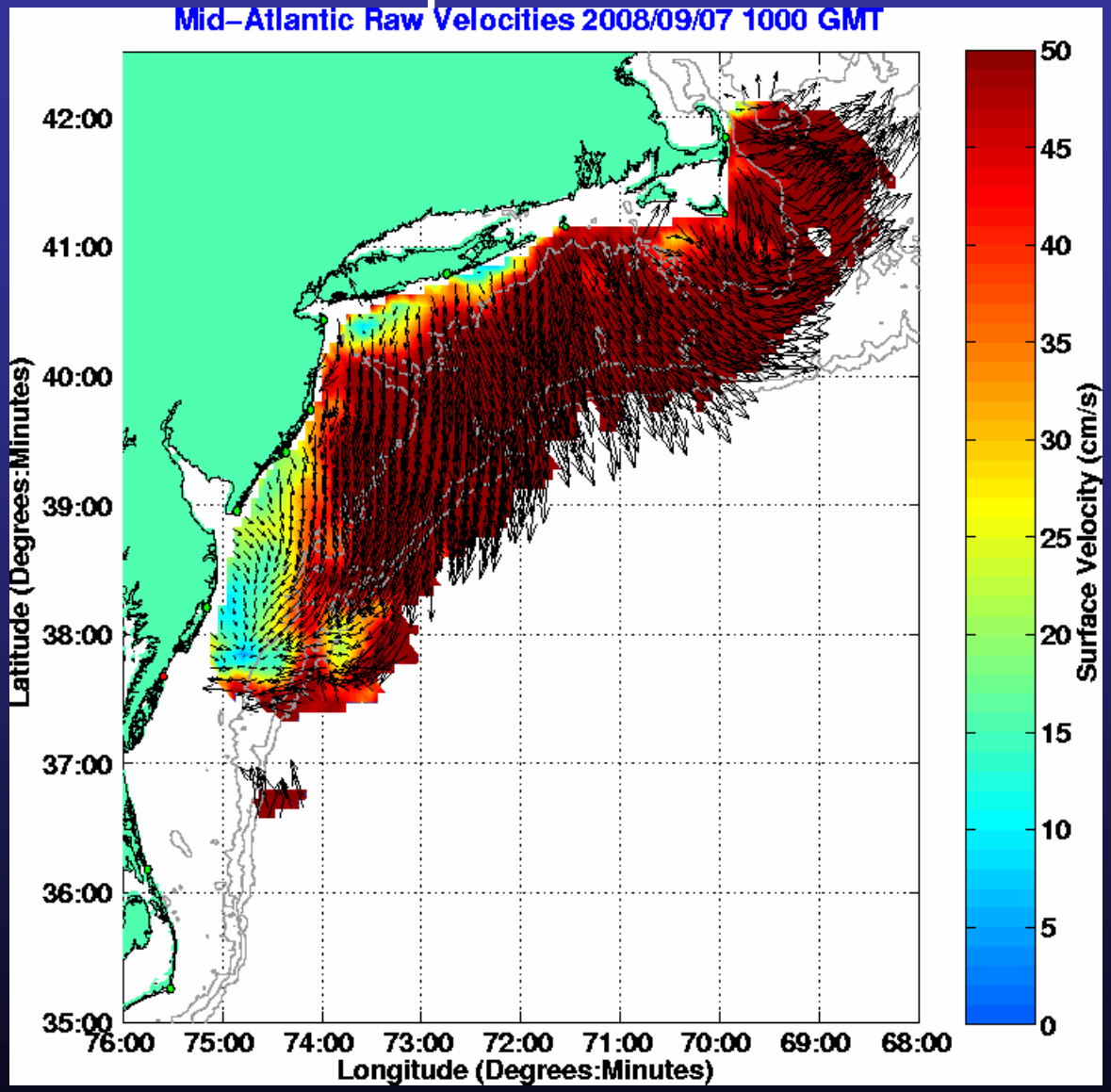
September 2008



Sea Surface Currents

Tropical Storm Hanna

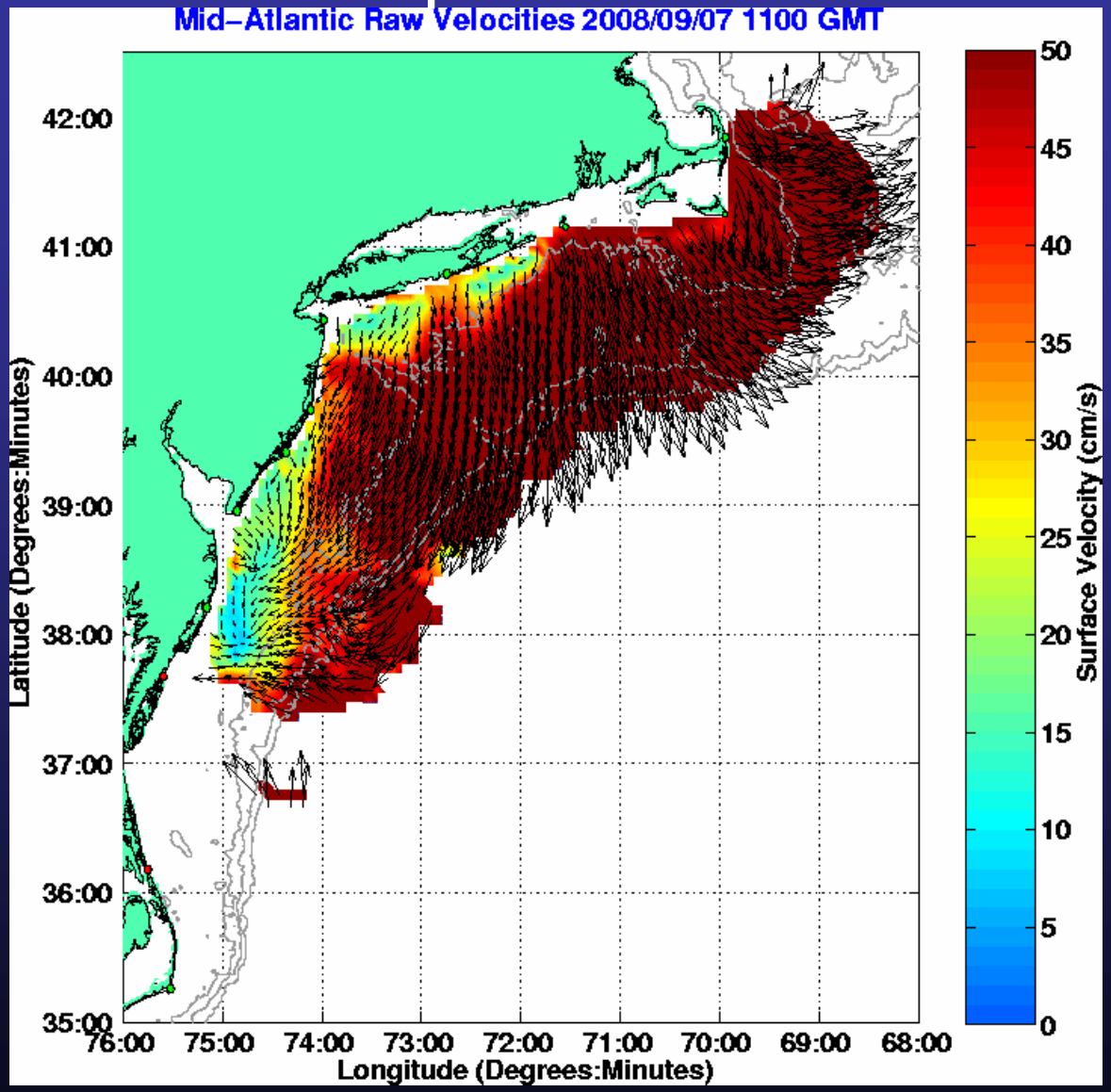
September 2008



Sea Surface Currents

Tropical Storm Hanna

September 2008

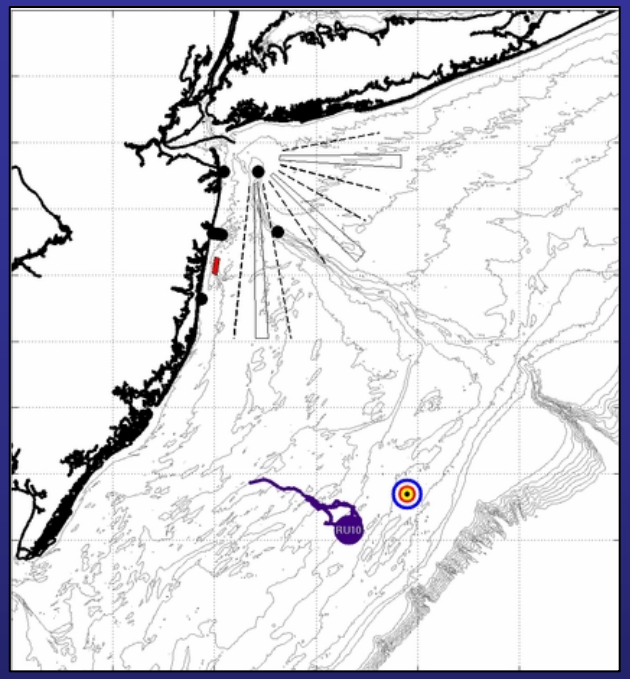


Sea Surface Currents

Tropical Storm Hanna

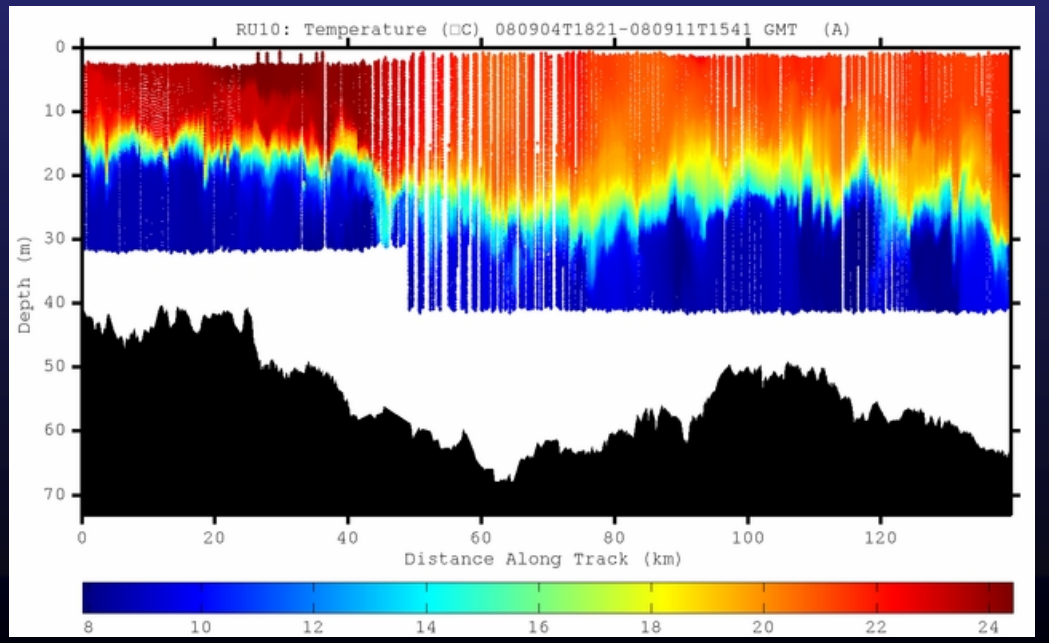
September 2008

Sub-Surface Structure/Mixing

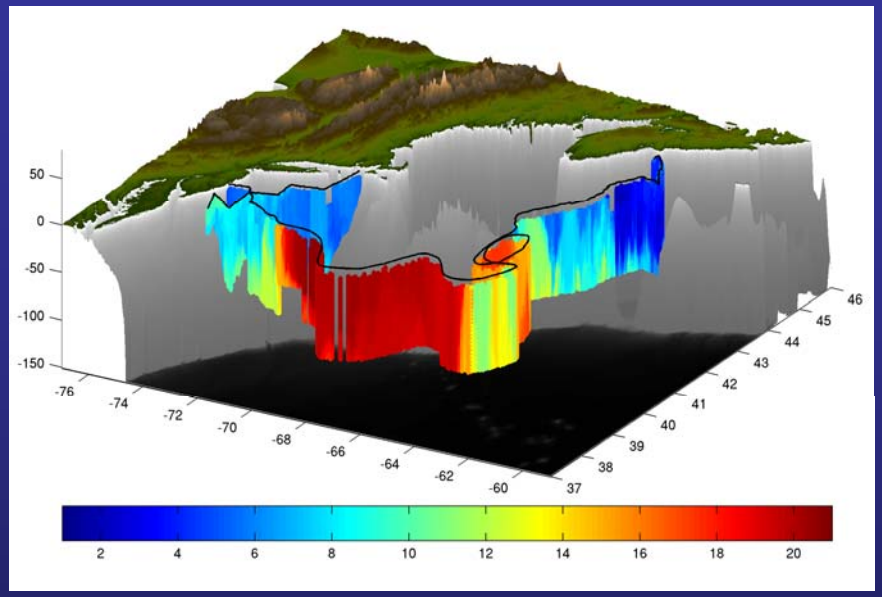


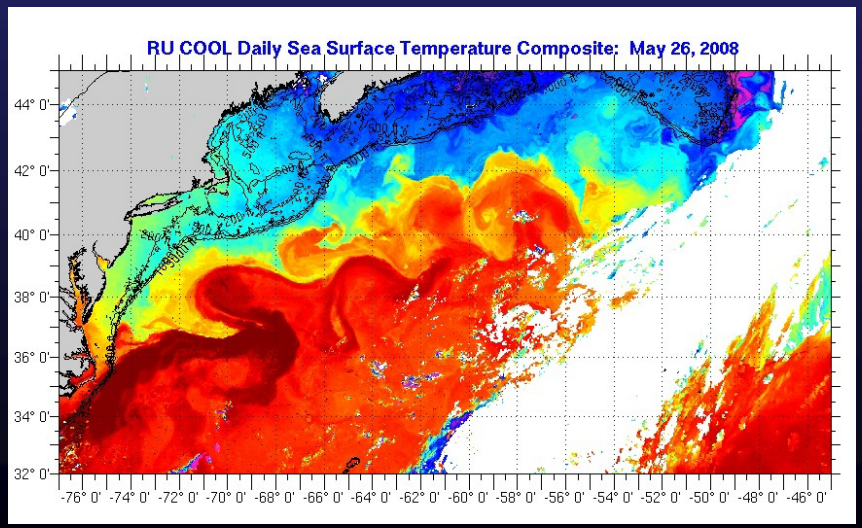
Autonomous Hurricane Hunter:

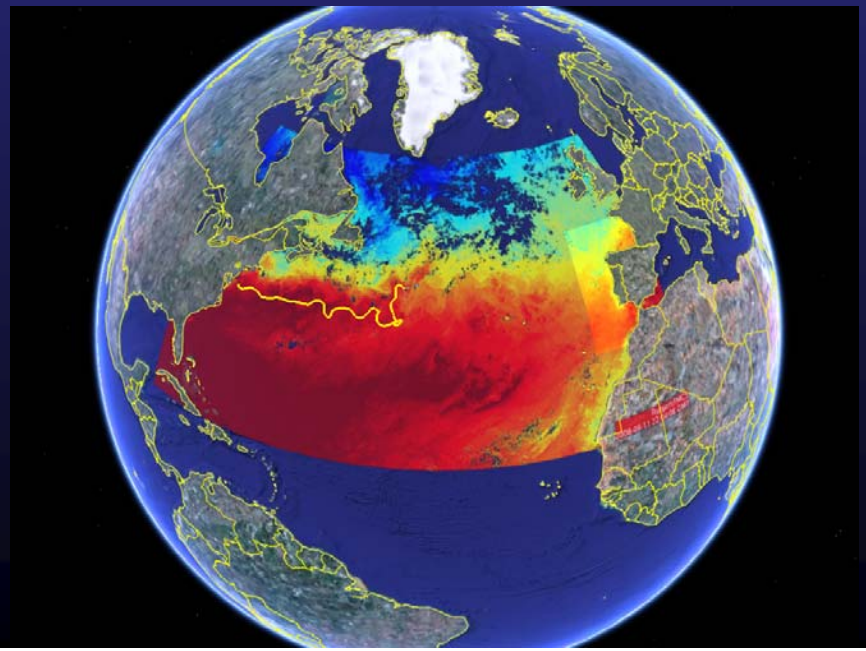
RU10 deployed to rendezvous with Hanna



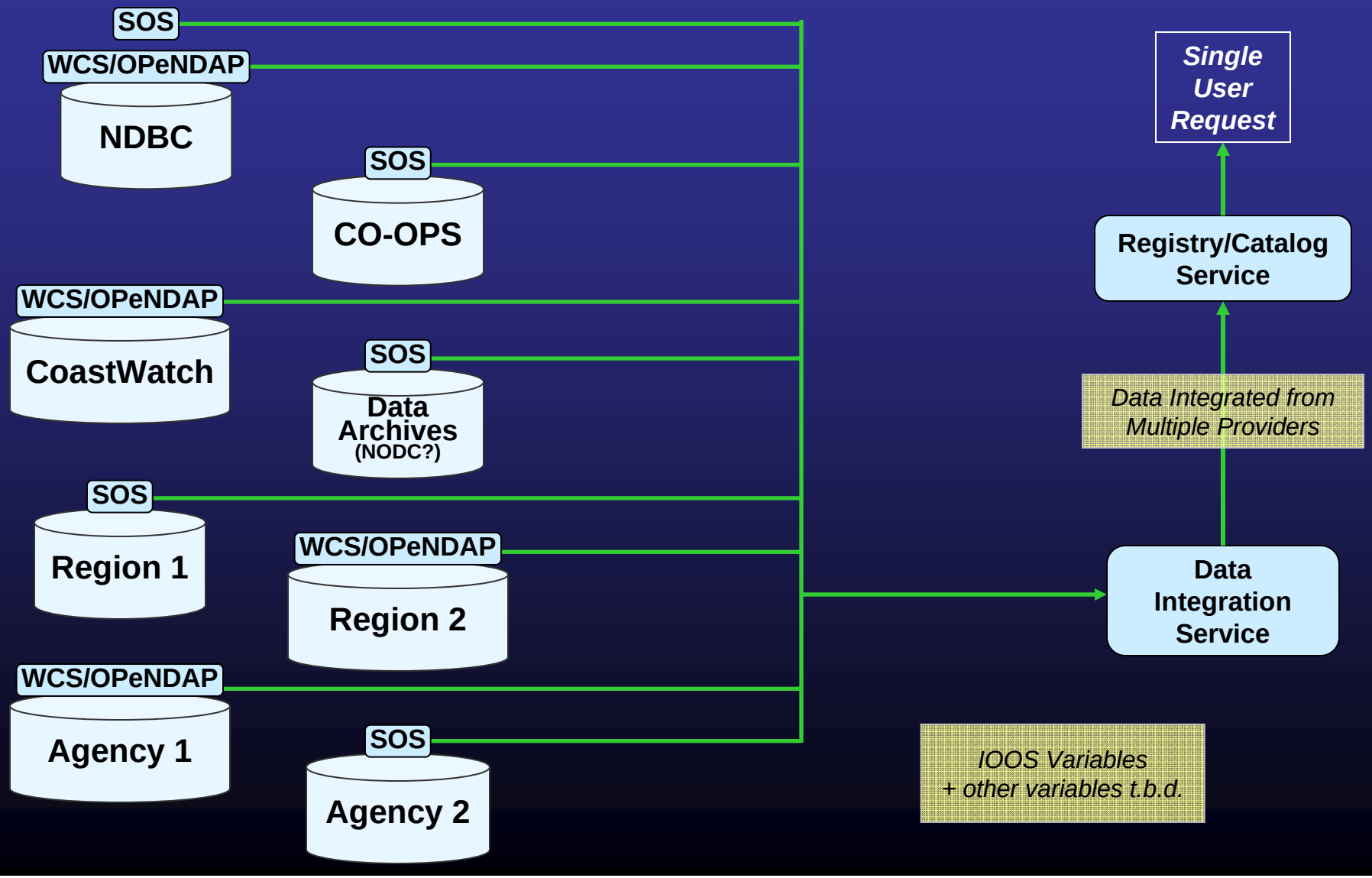
Looking Forward: Halifax & Atlantic Crossing (2008)



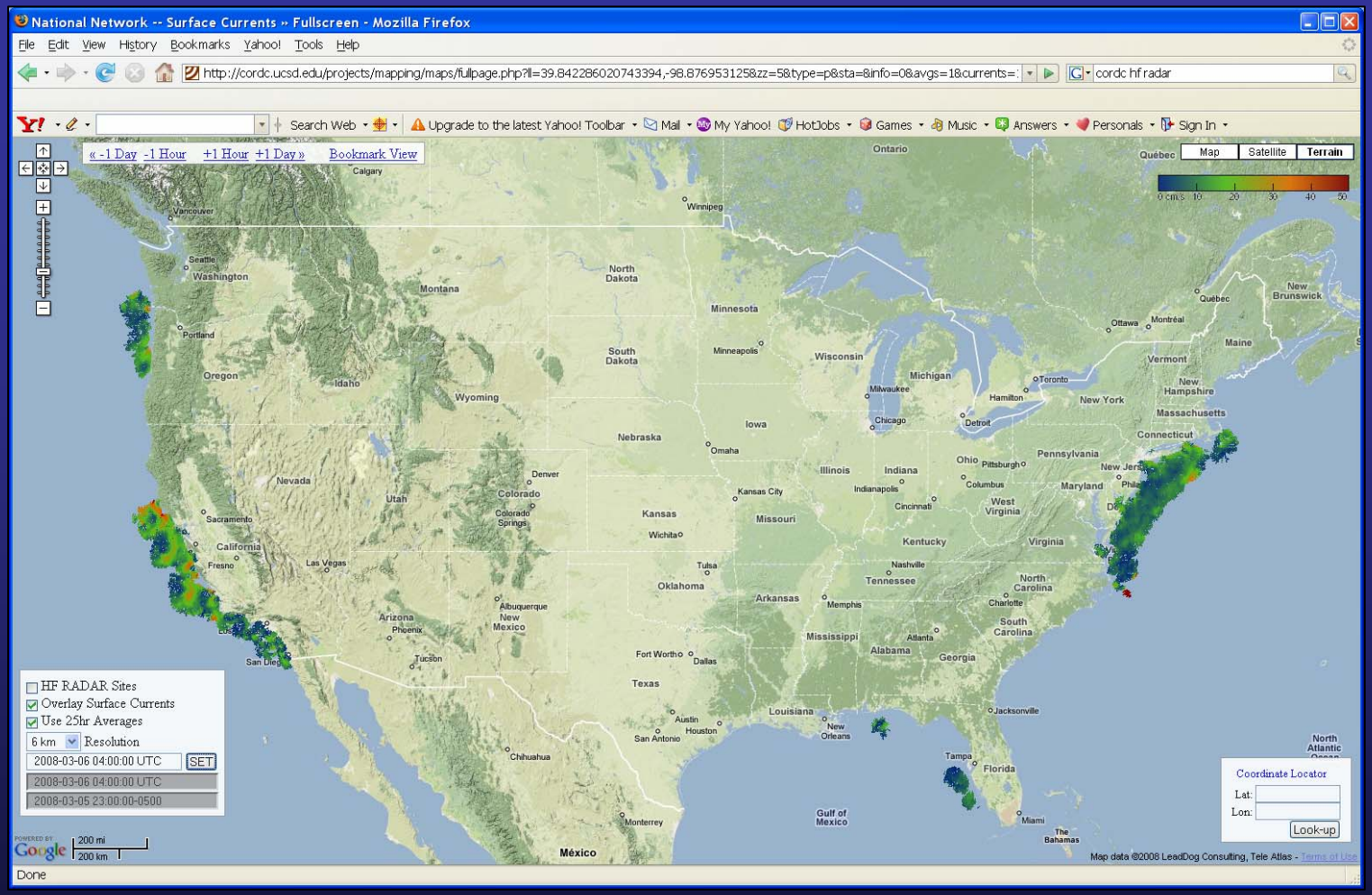




Additional Providers & Services

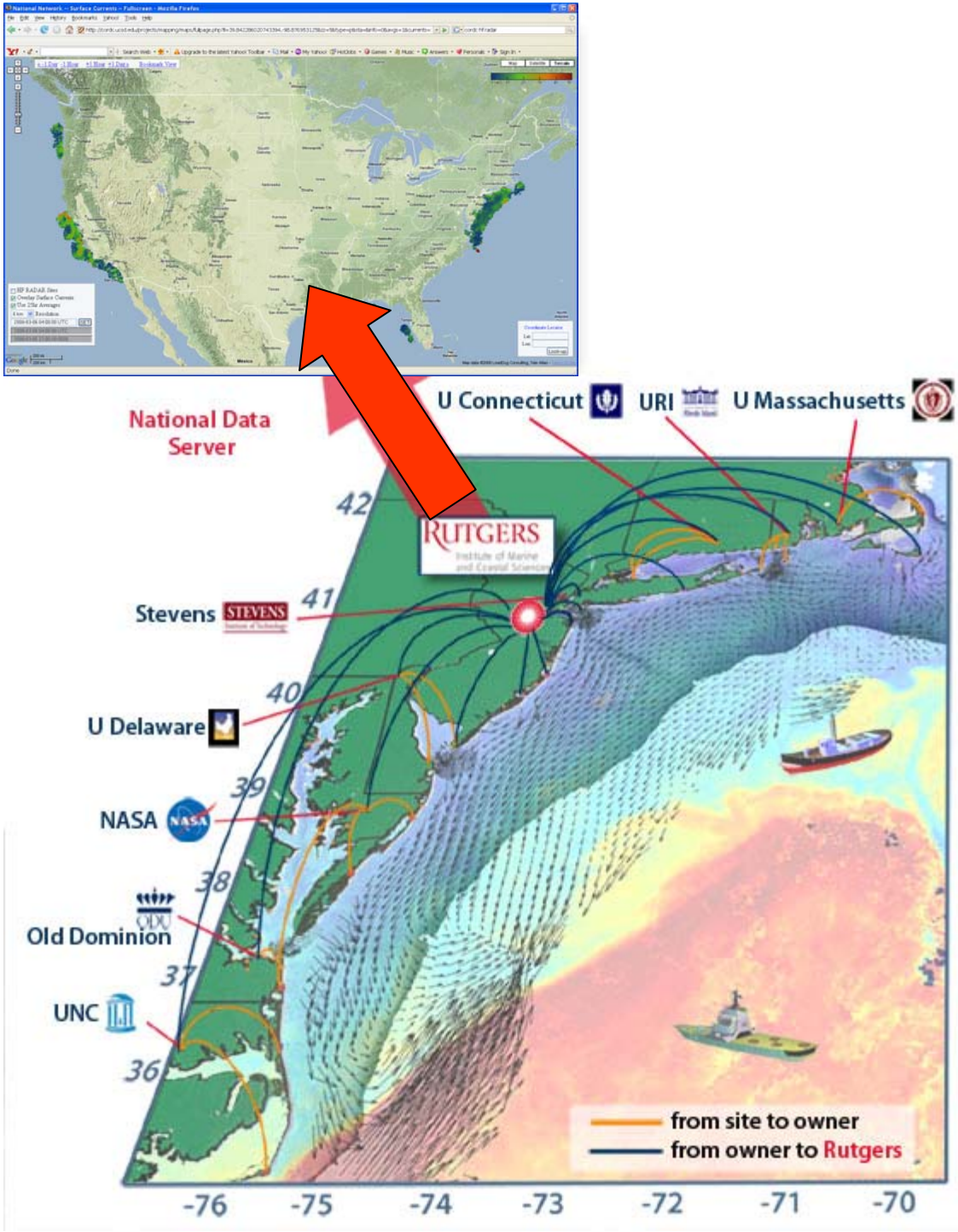


National HF Radar Plan



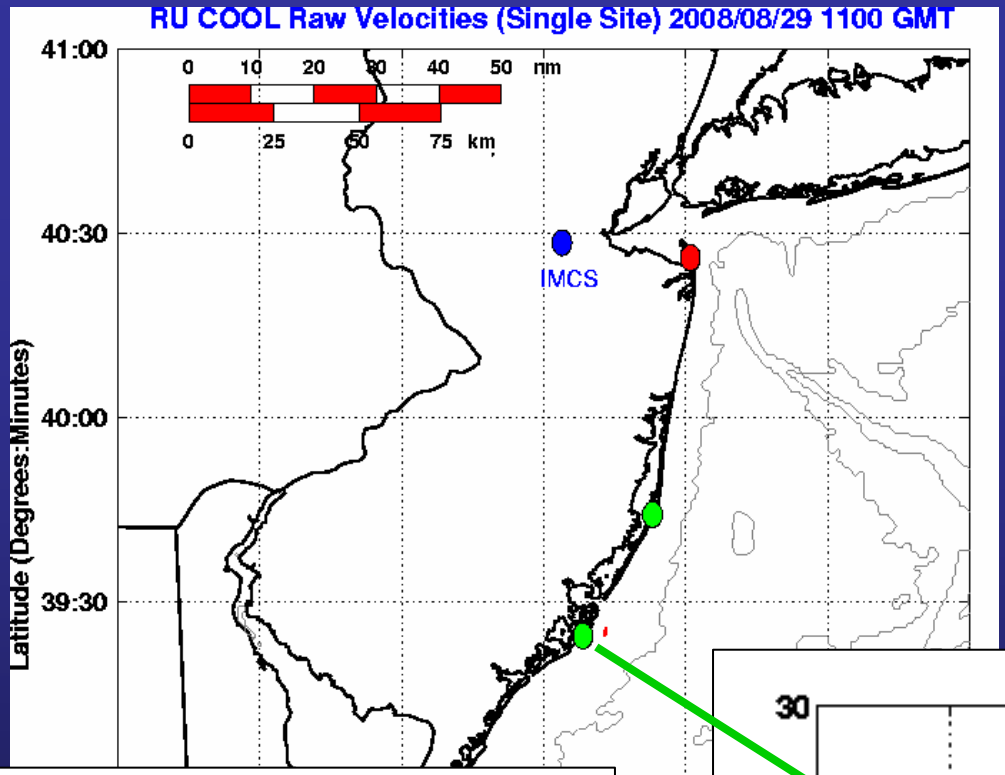
- Over 100 Sites Participating (including all 26 MARCOOS systems)
- 3 Data Nodes (Rutgers, Scripps, NDBC)
- NOAA IOOS to fund development of a National Plan (coordinated through ACT)
  - Design, Budget, Metrics

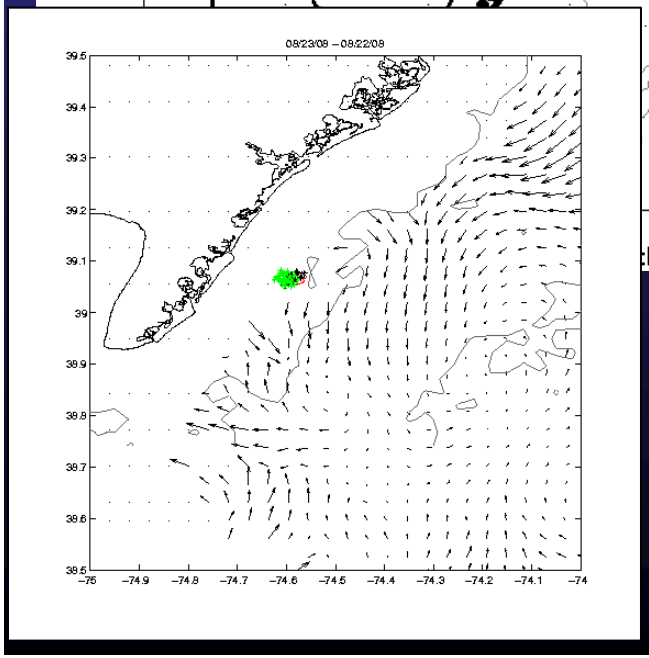
HF Radar Data Flow

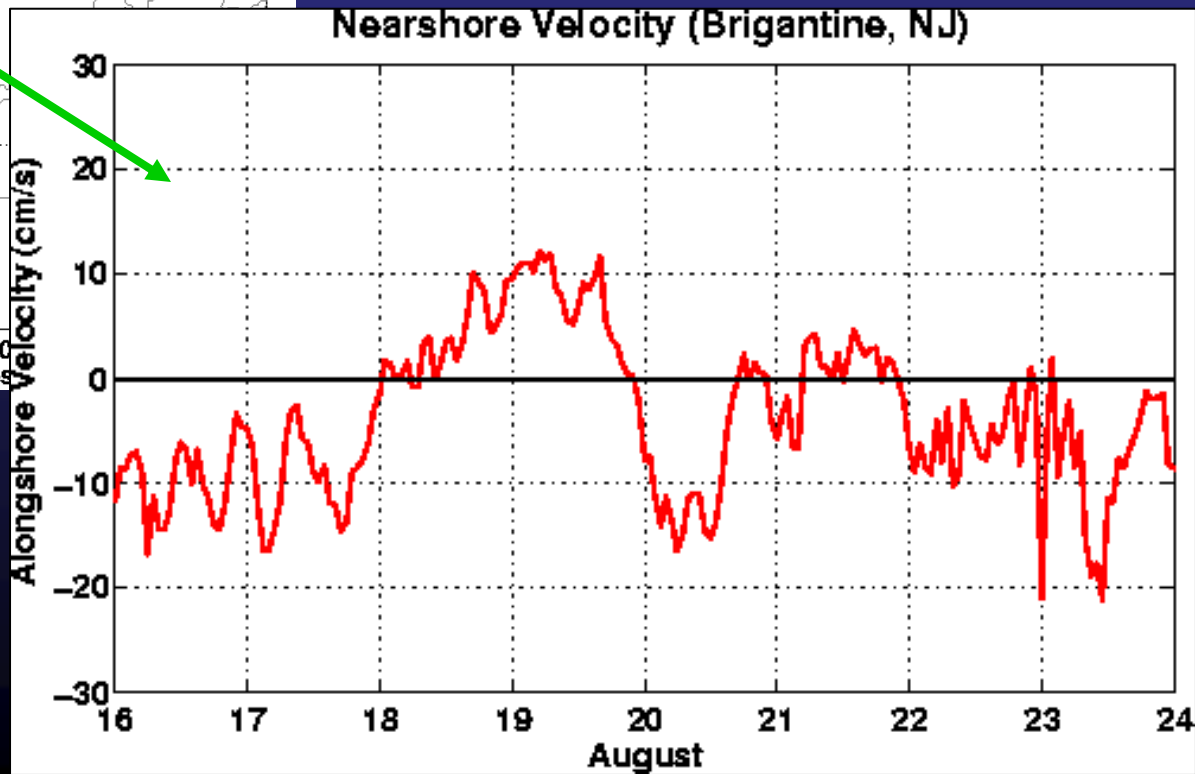


August 23rd, 2008

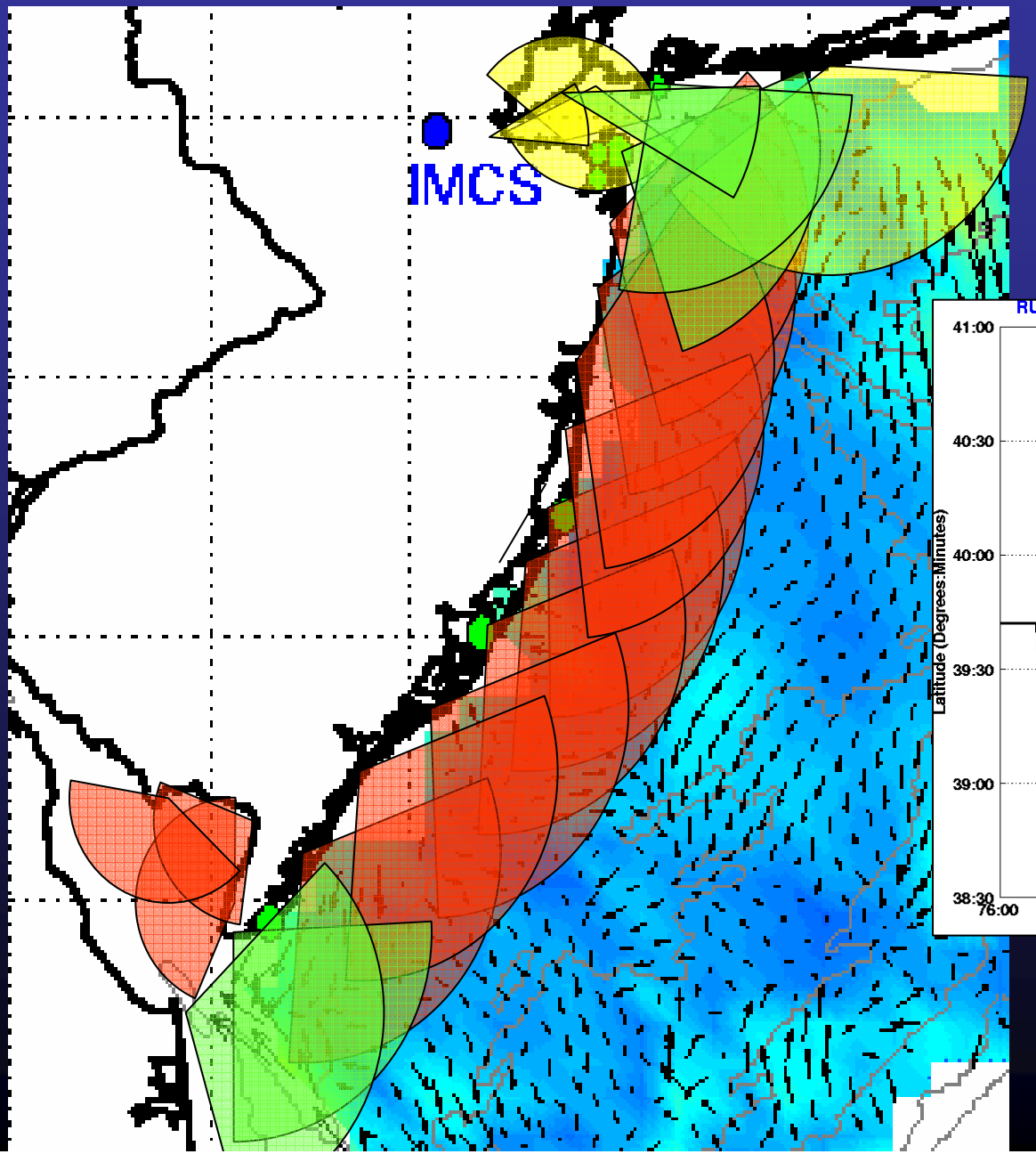
Avalon, NJ

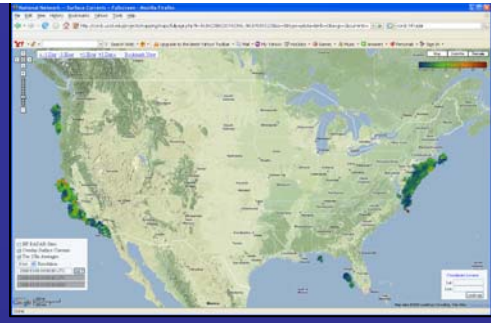




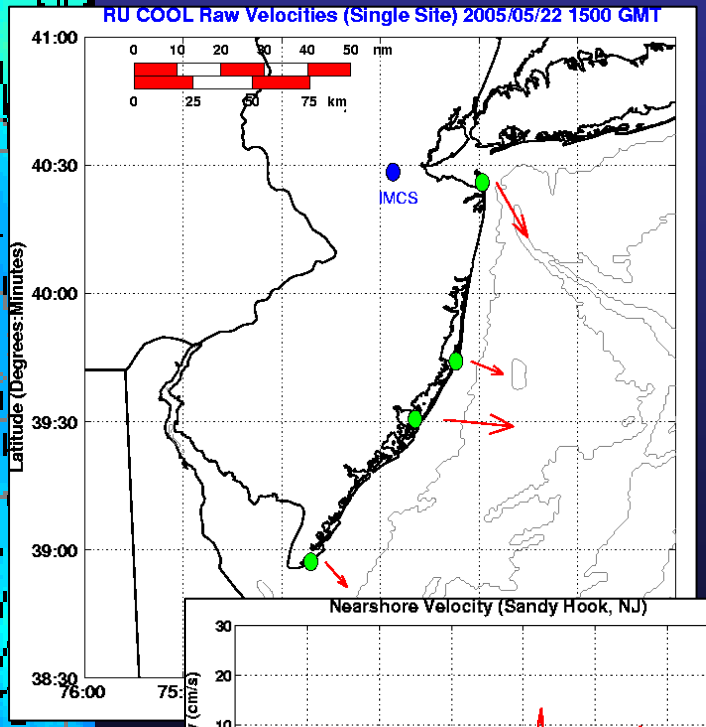


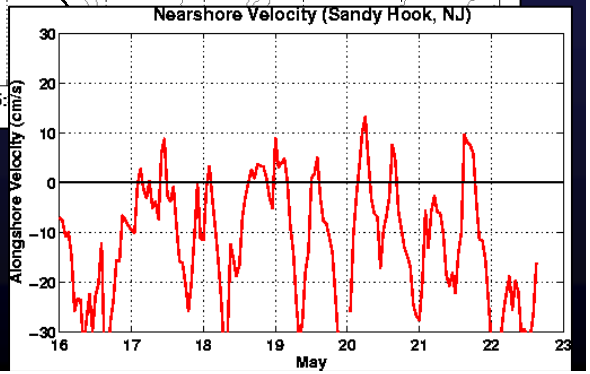
Gap-Filling the National Coverage





Nearshore Currents

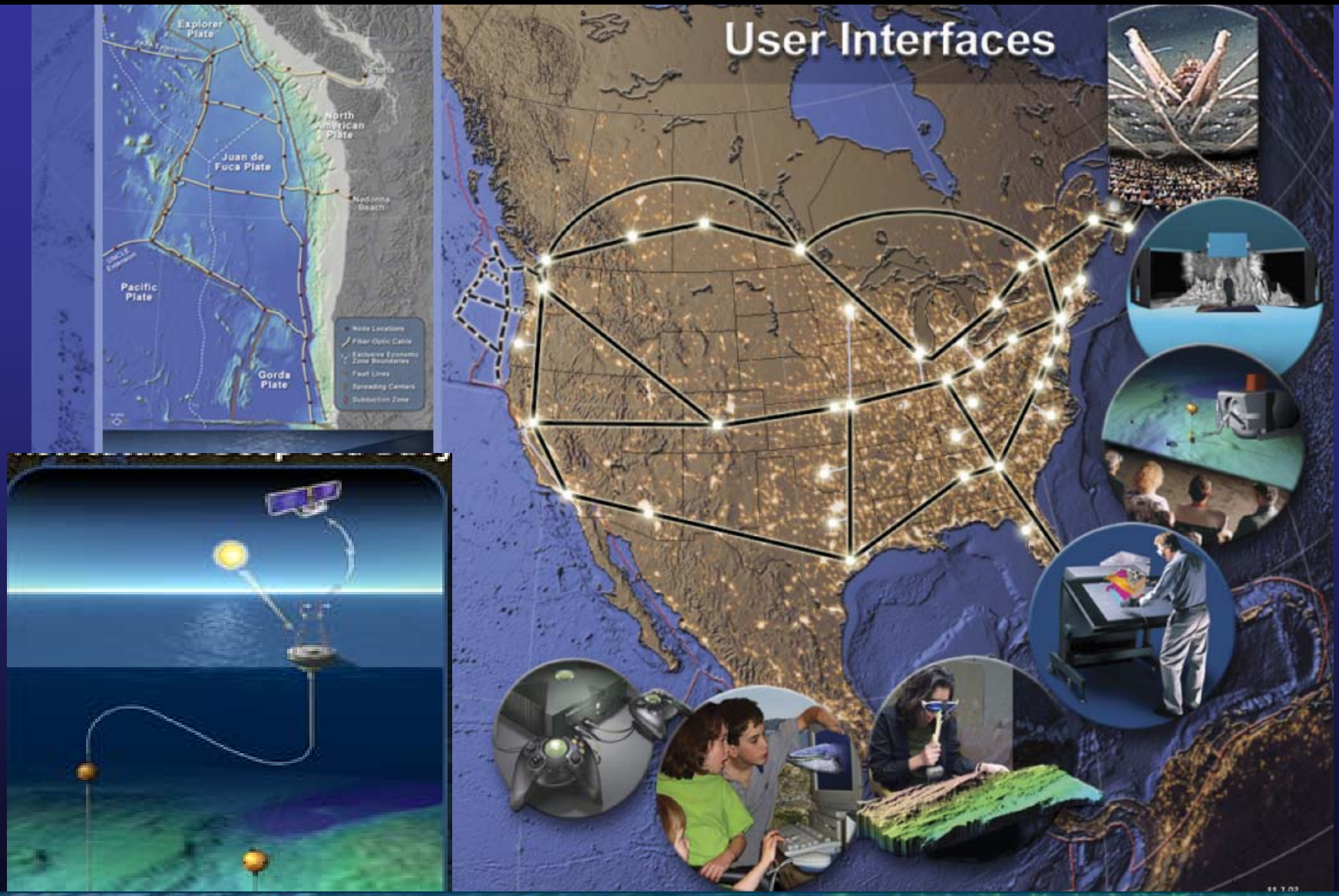




Summary

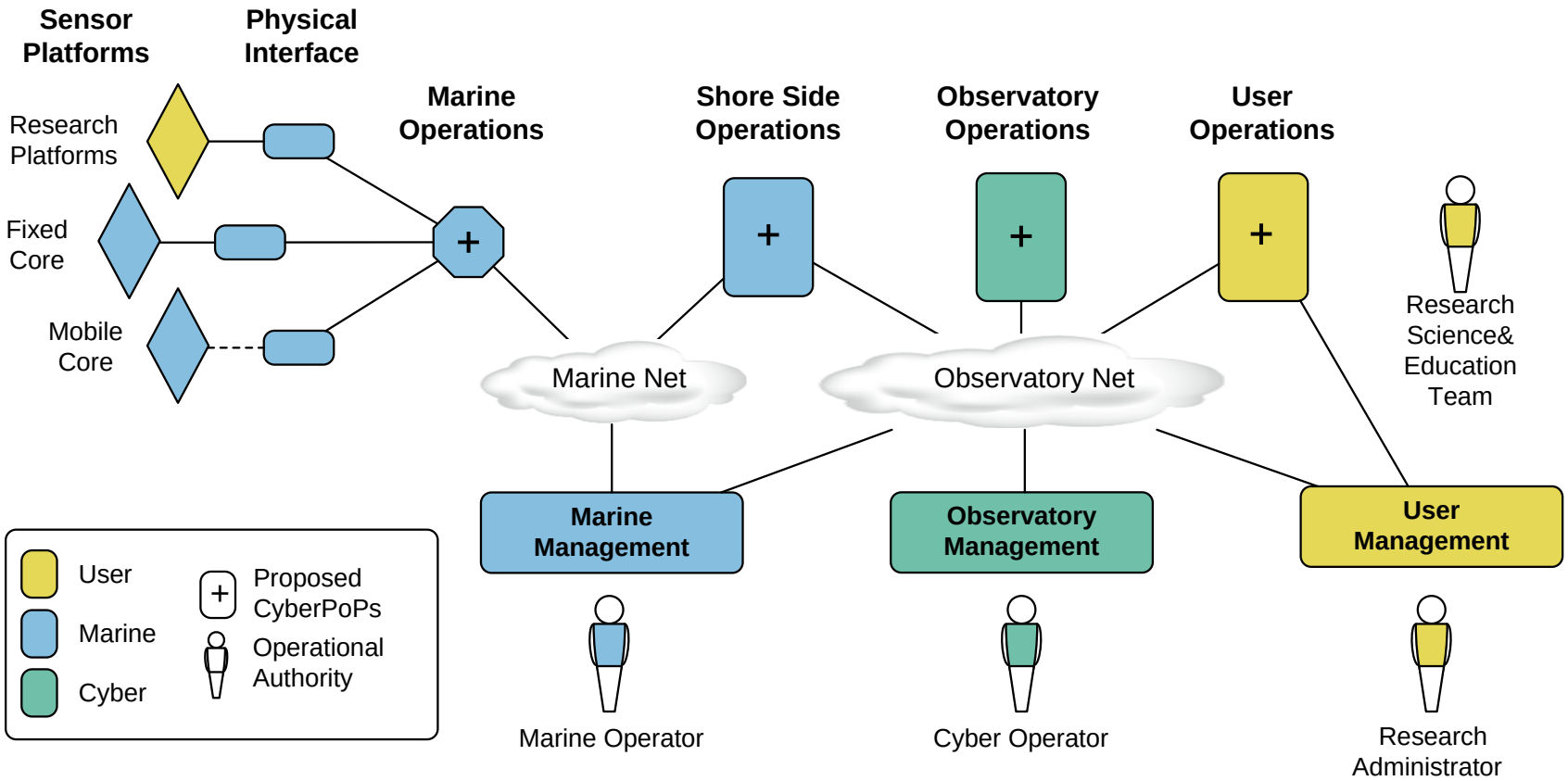
- Coastal ocean observatories are fundamentally changing the way we research and understand the coastal ocean and provide an incredible resource to answer questions that previously could not be answered.
- Data Providers are now working together to link distributed datasets into integrated support tools.
- The Mid-Atlantic (New Jersey) can serve as an example of how local user needs and data sources can feed into a truly national systems with national applications.

A Distributed Cyber-Ocean Network
Enabling Process Science, Discovery and Education

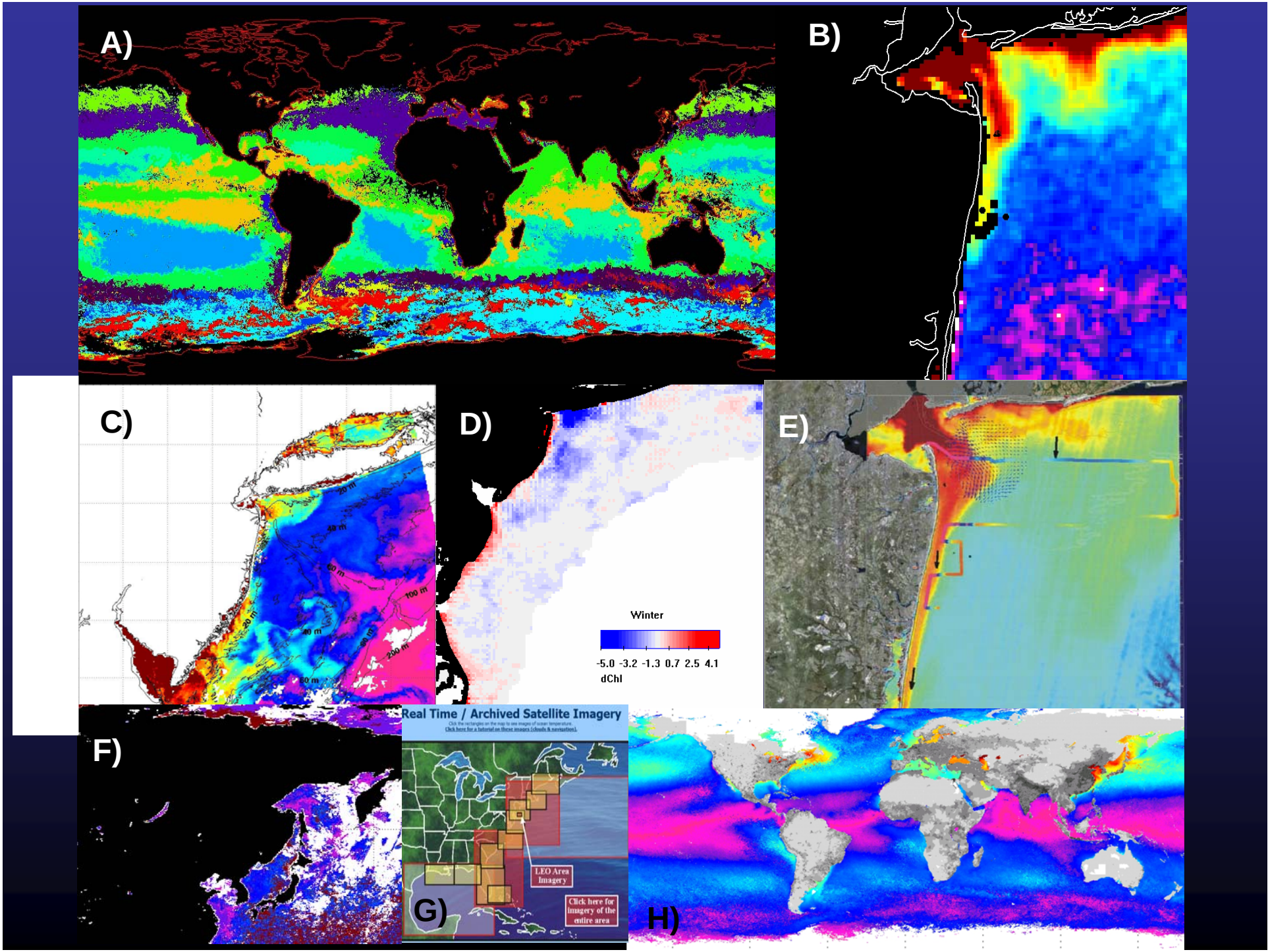


Ocean Research Interactive Observatory Networks

Integrated Observatory Operators and Users

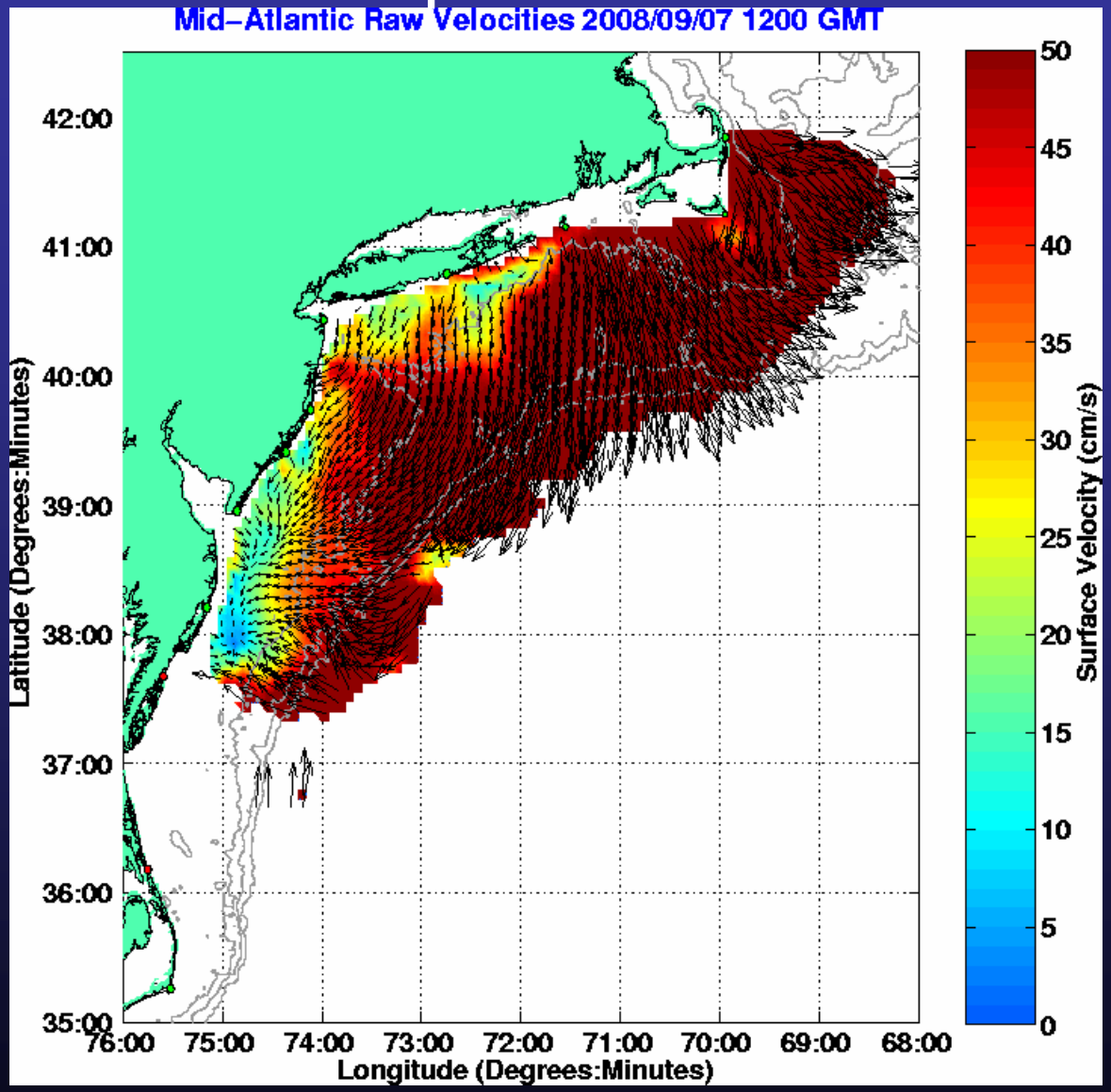


- Users access the OOI through Integrated Observatory interfaces provided by the CI
- Operators have direct access to resources and systems in their domain


A)
B)
C)
D)
Winter
-5.0 -3.2 -1.3 0.7 2.5 4.1
dChl
E)
F)
Real Time / Archived Satellite Imagery
LEO Area Imagery
Click here for imagery of the entire area
G)
H)

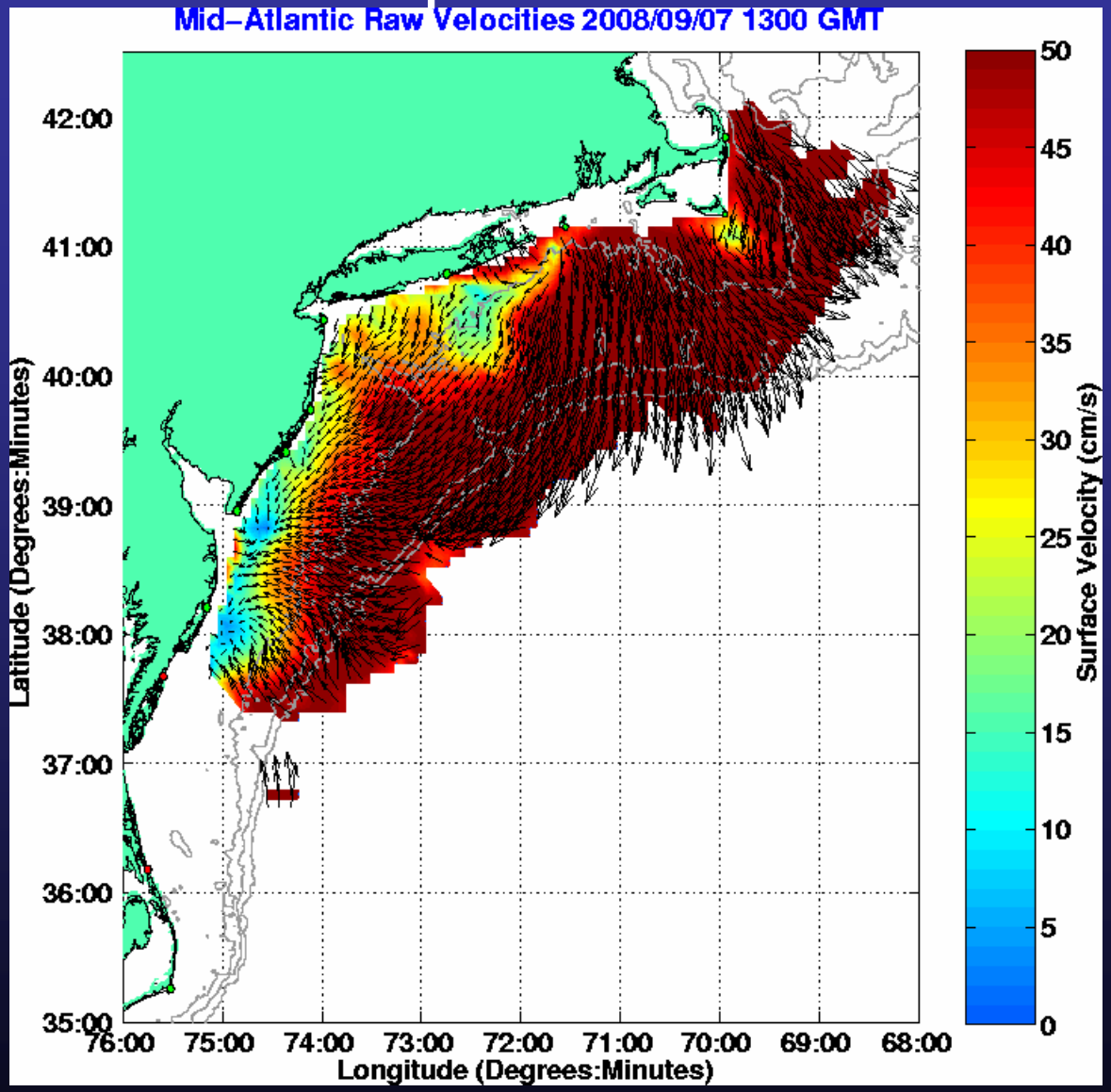
Tropical Storm Hanna

September 2008

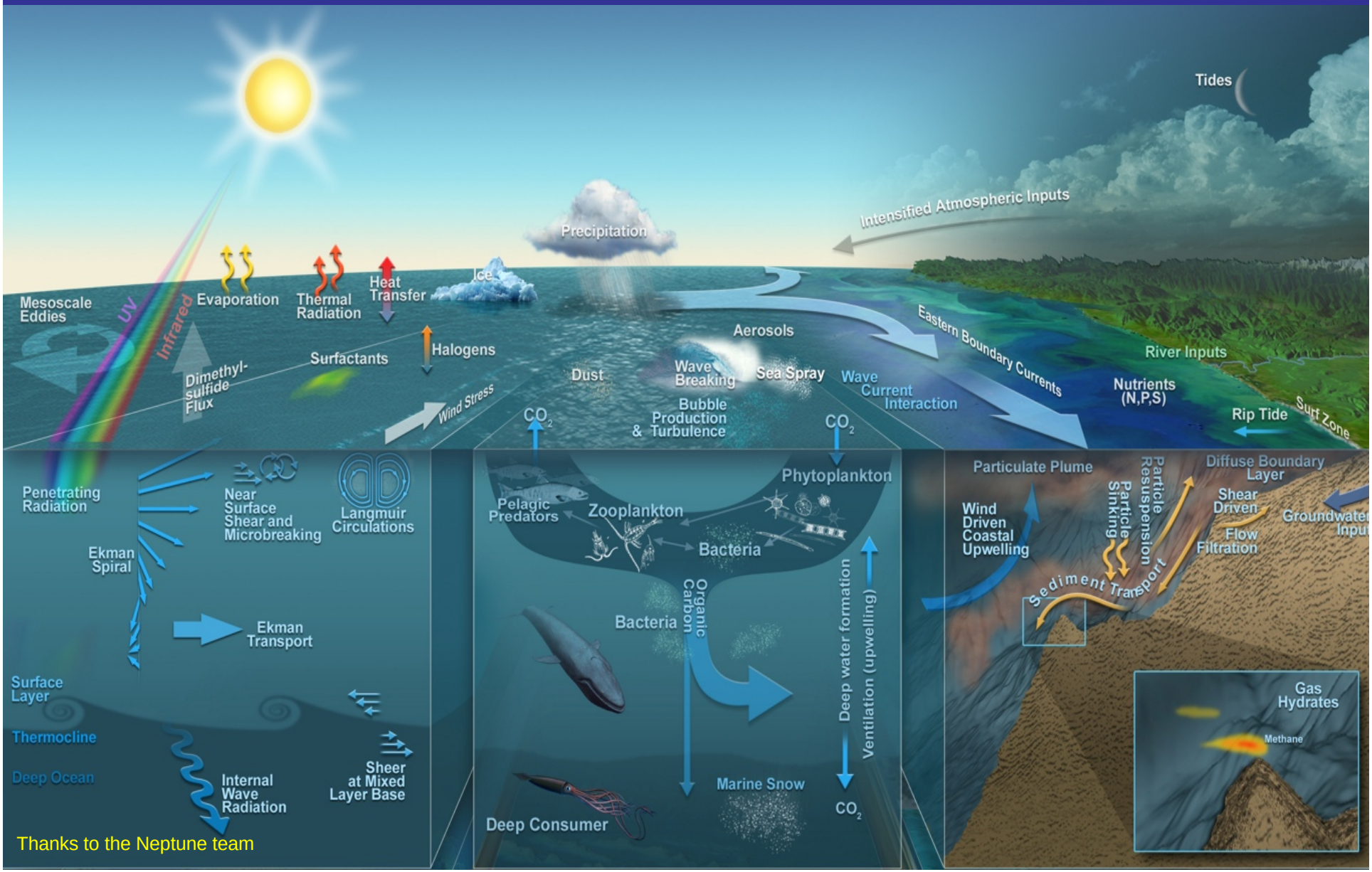


Tropical Storm Hanna

September 2008



Oceans are complex and central to the Earth system

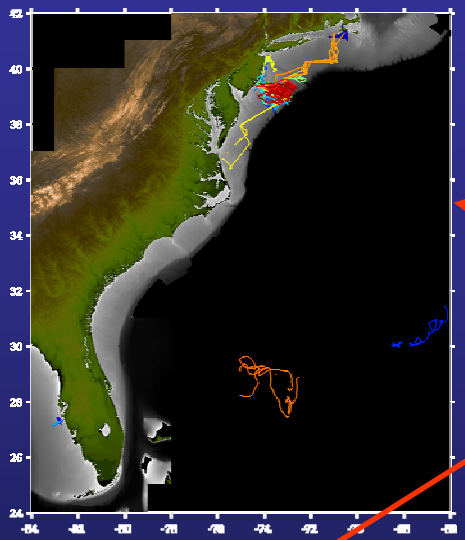


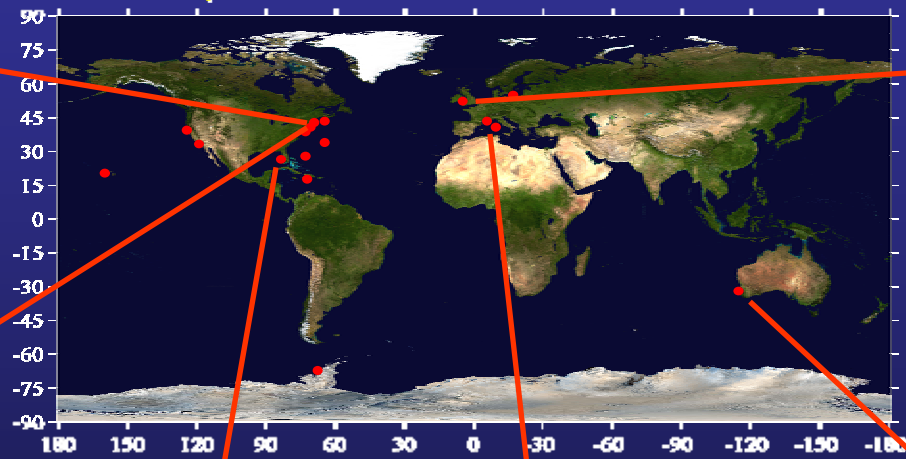
Thanks to the Neptune team

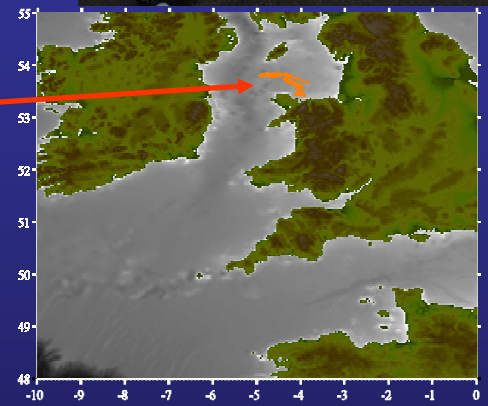
Rutgers Slocum Glider Fleet

140 deployments worldwide (2003 – present)

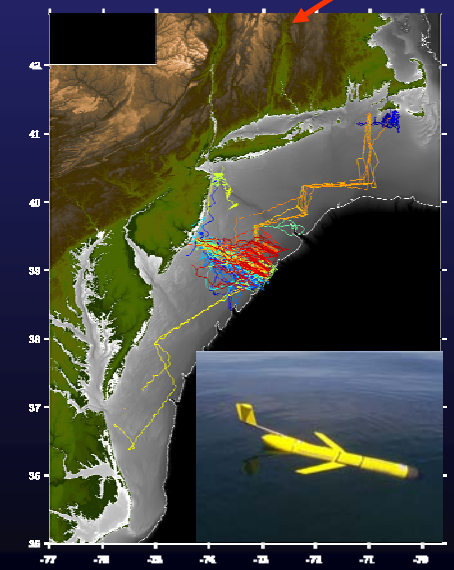
46,153 km flown (Earth's circ. ~ 40,000 km)
2115 days in water
296425 profiles



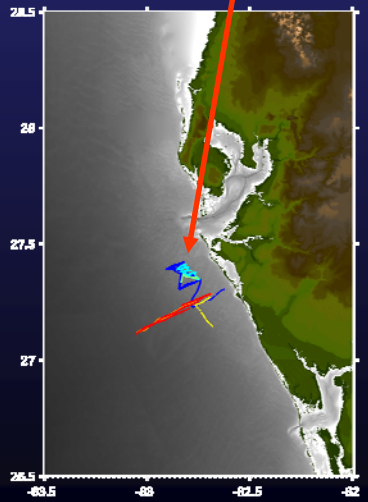




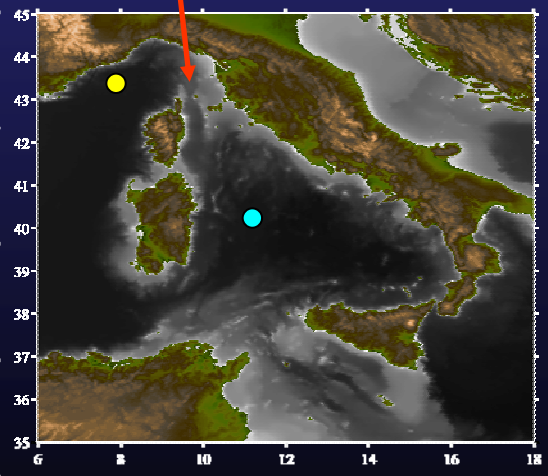
Liverpool Bay
Coastal Observatory



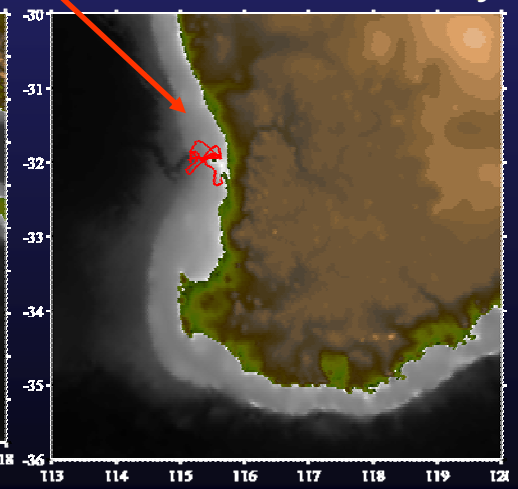
Mid-Atlantic Shelf



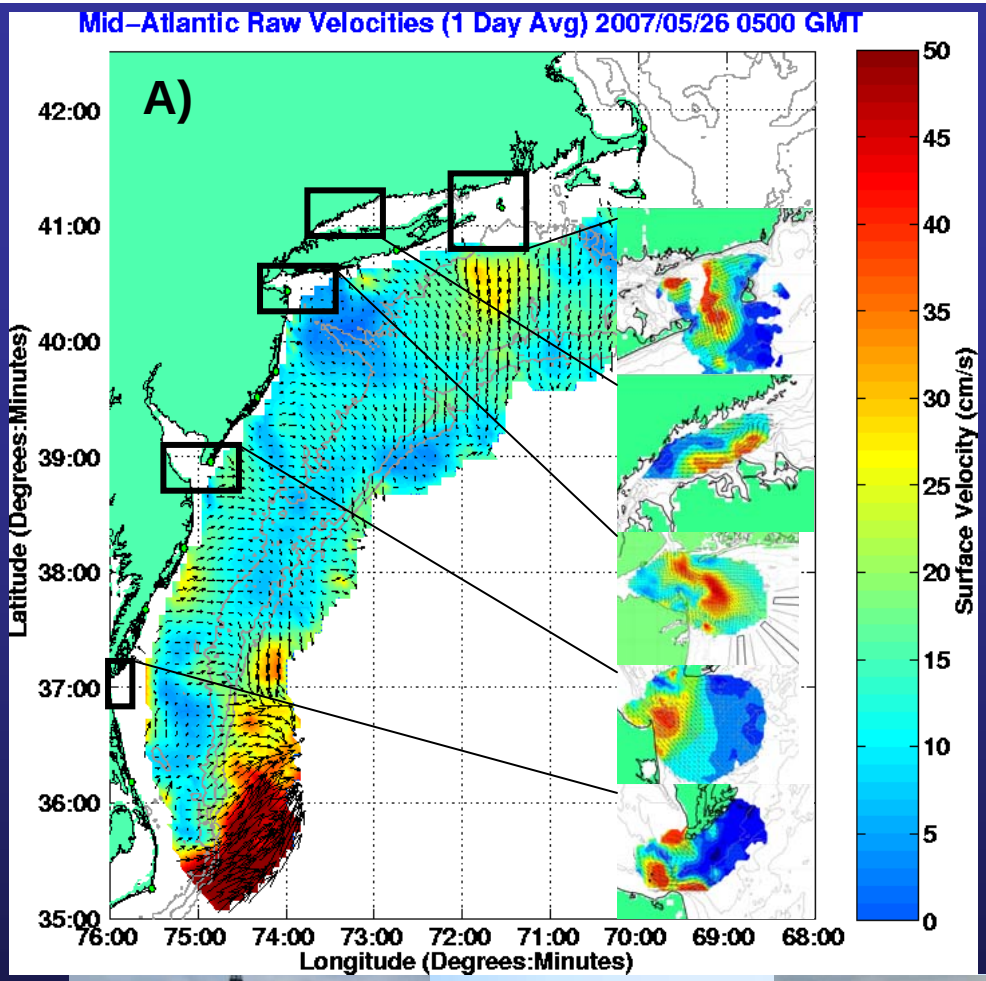
West Florida Shelf

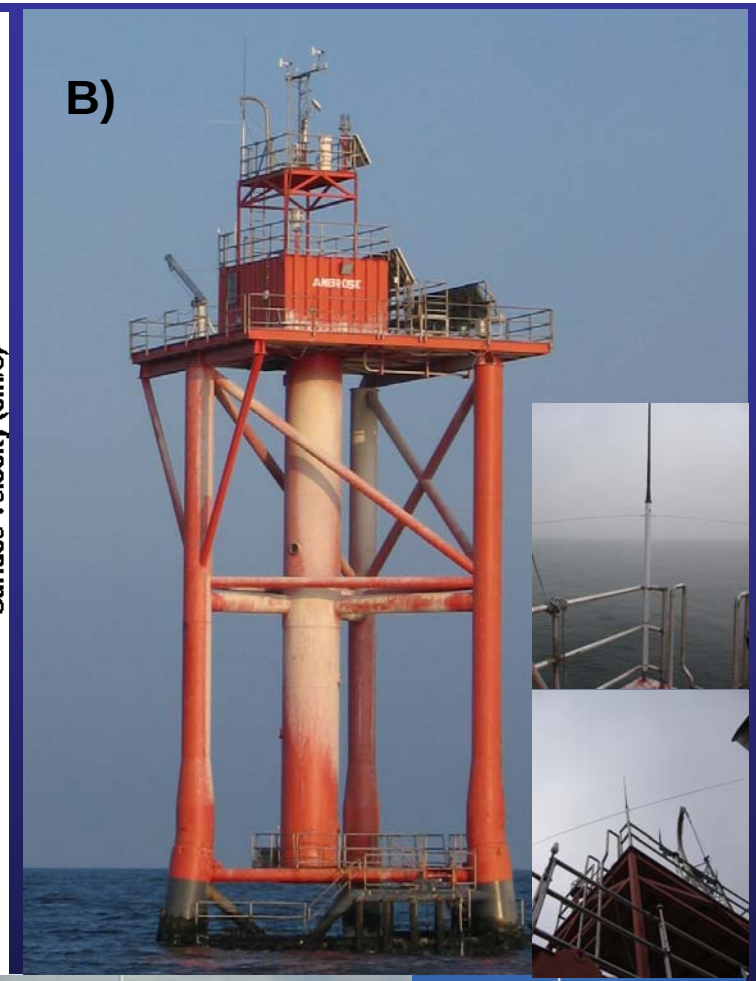


Mediterranean Sea



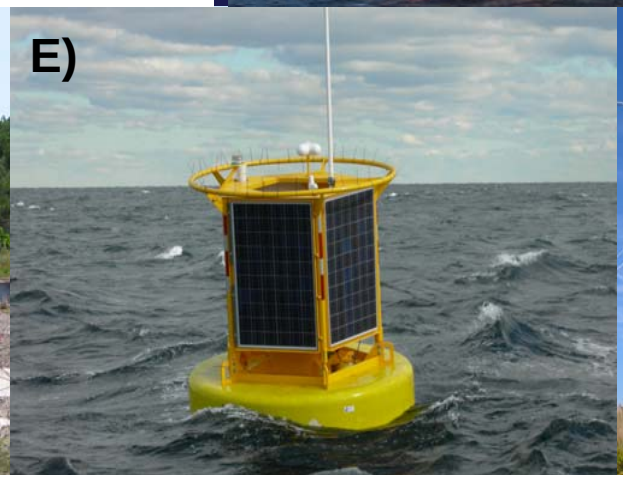
Perth, Australia


Mid–Atlantic Raw Velocities (1 Day Avg) 2007/05/26 0500 GMT
A)
Latitude (Degrees:Minutes)
42:00
41:00
40:00
39:00
38:00
37:00
36:00
35:00
76:00
75:00
74:00
73:00
72:00
71:00
70:00
69:00
68:00
Longitude (Degrees:Minutes)
Surface Velocity (cm/s)
50
45
40
35
30
25
20
15
10
5
0


B)

C)

D)


E)

F)