The New Jersey shelf Observing System (NJ SOS): Tracking plumes, particulates, and people in the coastal ocean

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Over the next 50 years, coastal oceans throughout the world will undergo changes associated with the increased flux of nutrients resulting from the increasing human population living along the coasts. The potential coastal eutrophication may alter microbial community diversity and productivity, leading to change in the oxidation state of continental shelves. A change in the redox state of a coastal system can be catastrophic, leading to loss of fisheries, increased production of green house gases, altered food webs and potentially the loss of marine biodiversity. While scientific efforts have developed some qualitative understanding of the processes underlying the redox state of continental shelves, we do not quantitatively understand which continental shelves will be the most susceptible to catastrophic change, which might be more resilient, and why. Fundamentally limiting our understanding is our inability to sample the ocean on relevant scales in both space and time. For example, fixed-point sampling grids conducted from ships do not resolve the fractal variability in the physics, chemistry, and biology of the coastal ocean. In addition, very few temporal measurements are sufficiently sustained to resolve the characteristics of episodic events or multi-year trends that play a large role in structuring marine ecosystems.

This lack of understanding fuels the motivation to build regional integrated coastal ocean observing networks. Like many others, we were motivated at Rutgers University's Coastal Ocean Observation Lab (RU COOL) to effectively sample the biogeochemically relevant space and time scales in the Mid-Atlantic Bight. This paper will review the general design of the New Jersey Shelf Observing System (NJ SOS), which provides sustained measurements from a shore based control center known as the COOL room. We will also review how NJ SOS started as a regional research effort, but is developing into an international consortium providing a framework to exchange technology, sensors, and that will be used to compare and contrast a many continental shelves in coming decade.

What is the COOL room?

The COOL room is a shore-based laboratory that controls the ocean observatory. It provides scientists control over remote assets collecting data in the field. The data is collected from an international constellation of satellites (SeaSpace X-band and L-band receiving satellite dishes), a triple nested mulistatic array of HF radars spanning the northeast United States (CODAR, 25 MHz-40 km range, 1km resolution, 13 MHz-70 km range, 3 km resolution, 5 MHz-200 km, 6 km resolution), a propeller-driven autonomous underwater vehicle (Hydroid Inc. REMUS vehicle), an electro-optic fiber optic cable outfitted with a two-way shore-based communication and power delivery system (WETSAT), and a fleet of autonomous Webb Slocum gliders (Webb Research). Data is delivered in near real-time, analyzed, and posted to the world-wide-web through a series of web sites. The data enables adaptive sampling by ships, planes, and other field platforms. Adaptive sampling requires the data acquired in the field to be successfully analyzed in the COOL room and be reliably distributed to people or robotic assets in the field. This requires a robust two-way communication network. The COOL room uses a redundant communication network that allows for graceful degradation of the data stream as assets often operate outside the high bandwidth communication networks. The network consists of high speed radio modems, broadband wireless networks, cell phone networks, and global satellite networks. The availability of the iridium network gives the COOL room a global footprint, allowing assets to be deployed all over Earth and be controlled remotely from the COOL room. The COOL room allows any land locked scientist to be at sea under all conditions at any time of day. For example, the system routinely allows a person to sit at home, cold beer in hand, during large storms (hurricanes and Nor'Easters) and monitor the oceans response in real time. This remote interaction is one of the hallmarks of coastal ocean observing networks and is a transformational step for oceanographic research. More importantly, these observatories will change how human society interacts and manages the oceans. Many of the current scientific research questions also have broad applicability to many in applied maritime community. Two such examples of the many projects being addressed by NJ SOS are material transport and search and rescue.

Buoyant plumes and material transport from the land to the deep sea

Buoyant coastal currents extend along much of the US east coast and are fed by numerous rivers generally characterized by moderate flow rates. Despite these moderate flows, these buoyant plumes appear to dominate the transport of nutrients and chemical contaminants to the coastal ocean. This is especially true for the New York and New Jersey Harbor which arguably hold the distinction of being one of the most contaminated estuaries on the east coast. Therefore, understanding the transport of sediment and the associated material from the harbor to the coastal ocean is a fundamental problem for state and federal water quality managers, a difficult task considering how dynamic these plumes are in space and time. These plumes are modified by bottom topography, shoreline geometry, atmospheric forcing, tides, and river outflow. This makes sampling a plume using moorings or fixed sampling grids impractical.

The National Science Foundation is currently supporting the Lagrangian Transport and Transformation Experiment (LaTTE) program which is focused on the physical circulation mechanisms that alter the transport and transformation of the chemistry and biology of the harbor plume as it flows into the coastal ocean. To monitor and adaptively sample the plume, this project intimately relies on the ocean observatory. The real-time data from all remote assets are used to direct ship and gliders. Ocean color imagery and sea surface temperature provide maps that help define the spatial extent of the Hudson river plume. These daily composites are then advected through time using the hourly data from the surface current radars. Data is compiled in real-time in the COOL room and transferred to ships at sea, using the nested communication network. This adaptive capacity allows ships to adjust sampling strategies on the fly. Supplementing the ship data are Webb gliders that provide subsurface maps of the river plume. *Here the scientist benefits from having a three dimensional picture of the plume and its contents over a time period sufficiently long to study the transformation of organic material. The environmental managers benefit from a real-time picture of the plume allowing adaptive sampling and increased understanding of potential deposit centers of pollutants, heavy metals, organic and inorganic particulates flowing out of the harbor.*

Shelf circulation and Search and Rescue:

The spatial variability in continental shelf circulation is well known. Until recently, the lack of data forced scientists, the Coast Guard, the Navy, and HazMat response groups to rely on the climatology of circulation patterns to conduct operations. Climatological approaches do a poor job in capturing the true variability of the circulation. CODAR is a High Frequency (HF) radar system that uses radio waves to remotely measure ocean surface currents as far out as 200 km offshore. Surface current maps are now provided hourly which indicate the directions and speeds of the current. These maps have great potential for search and rescue. Demonstration projects are being conducted to provide proof of concept for using these surface current maps in Coast Guard search and rescue operations. This effort uses the existing HF Radar network off the coast of New Jersey (operated by the COOL room) and near the mouth of Long Island Sound (operated by Universities of Connecticut and Rhode Island. Drifting buoys are used to simulate boats adrift at sea and search areas are defined with and without the use of CODAR. The figure shows the predicted of Coast Guard deployed drifters (black) using the current NOAA predicted trajectories (red), and the predicted trajectories using the New Jersey long-range CODAR data (blue) showed that after a 24 hour period, the difference between the drifter location and the NOAA track is 17.76 km, while the incorporation of the CODAR data reduced that distance to 1.35 km. *Here the observatory benefits science by providing continuous spatial circulation data allowing a robust means to understand advection of material on the on the continental shelf while simultaneously providing the potential to greatly improve Coast Guard search and rescue operations.*

Who will build the observatory networks in the United States? Building integrated ocean networks is an active research problem requiring fundamental advances in sensors, cyber-infrastructure, data assimilation models, fixed and mobile platforms. These advances are necessary to improve our ability to uncover when and where the material is found, and to understand why it is there. Without these technological advances, these networks will not reach their full potential for commercial and environmental communities. Over the next decade, the United States will deploy significant infrastructure to enhance the nation's ability to "see" the oceans in all of its dimensions. Currently, the two major systems are the Integrated Ocean Observing System (IOOS) and the Ocean Observatories Initiative (OOI). The National Science Foundation's OOI will develop state-of-the art coastal, regional, and global ocean observation capabilities that will provide the research and engineering advances needed. These systems will complement the applied and mobile integrated networks being developed by Office of Naval Research. As the capabilities mature, the societal benefit will only be realized if the systems are deployed and sustained on an operational basis. This operational network will be is developed by NOAA's Integrated Ocean Observing System (IOOS). These diverse efforts all complement each other and their efforts will provide a capability that will be greater than a sum of the parts.

International partners with NJ SOS The NJ SOS is not unique as many similar coastal observing networks are being deployed globally. Some are focused exclusively on research problems while others have an applied focus. Success in the future will be measured by how the observatories simultaneously serve both of these needs. This will require efficient and open exchange between all the observatories. In the past, information and technology exchange between systems has largely been informal and facilitated by the desire of scientists to work with each other. In an effort to formalize some of these informal collaborations an ocean observatory consortium was established in spring 2005. The consortium, the International Collaborating Ocean Observing Laboratories (ICOOL), represents partnership between several observatories in the United States (from the Northeast to Alaska), Canada, Norway, and England. The primary goal of these labs is the exchange of technology, models, and experience. Examples of such efforts include the planned deployment of NJ SOS gliders from Liverpool (England), Rostock (Germany), and Bergen (Norway) in Fall 2005 to provide these groups data to facilitate garnering funds to purchase gliders. As the global network of coastal observatories evolve, consortia like ICOOL will allow for interoperability, the efficient integration of rapidly evolving technologies throughout the global network, and the expansion of resources that any community can leverage from.

Acknowledgements. We specifically wish to acknowledge the amazing people of the COOL room, our partners in LATTE and Coast Guard search and rescue programs. Also we thank our ICOOL partners which are one of the best reasons to get into work each morning.

Figure Legends

Figure 1. The lay-out of the COOL room. Each bank of computers is dedicated to a different component of the observatory.

Figure 2. The COOL room facilitates research by providing satellite, radar, and robot data to ships at sea allowing them to sample the oceans adaptively.

Figure 3. Maps of the surface currents measured by the observatory and its ability to improve drifter (and humans) locations at sea.

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Oscar Schofield is an associate professor of biological oceanography at the Institute of Marine and Coastal Sciences at Rutgers University. He is a co-founder of the COOL group with Dr. Scott Glenn. His research is focused on the coupling between physics and its impact on the ecology of the oceans.

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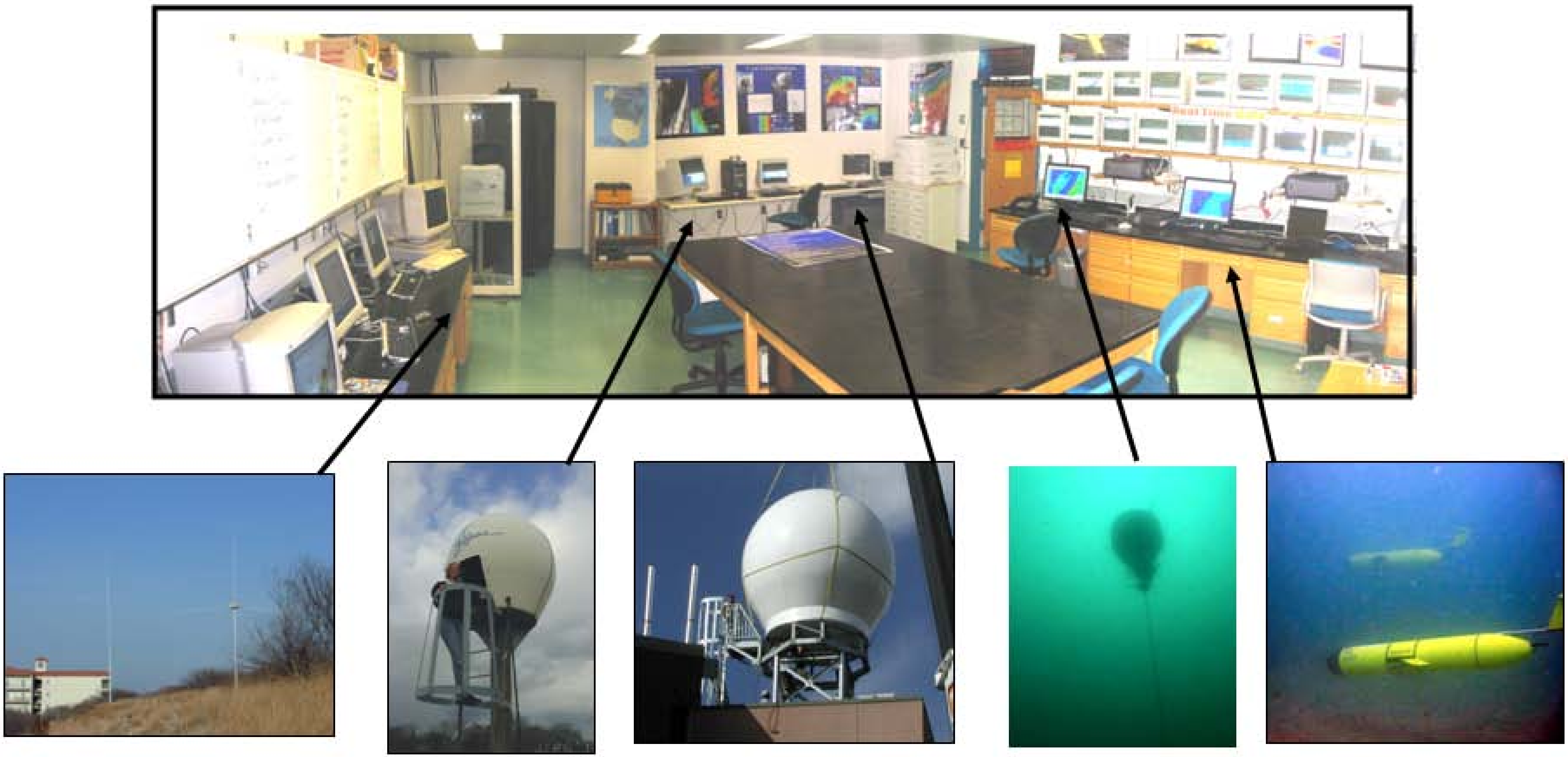
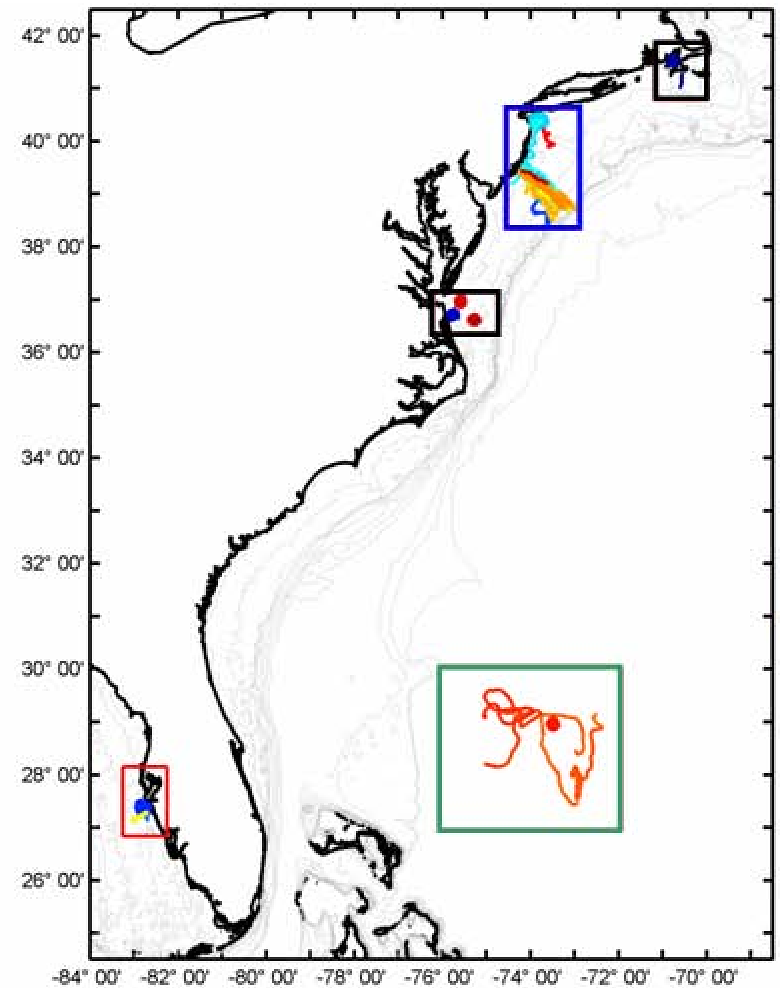


CODAR Network L-Band X-Band Cables Glider Fleet

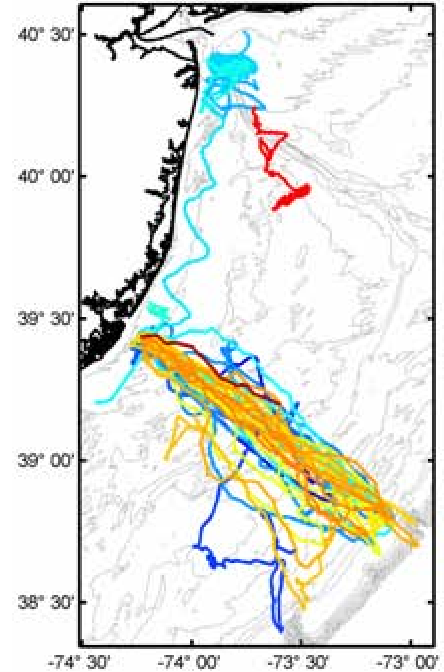
Coastal Ocean Observation Lab – Global Glider Deployments: 8/20/2003 – 6/2/2005
Kilometers Flown: >11,000.   In-Water Calendar Days: 391 of 671.   Glider Days: 522.

Eastern Seaboard

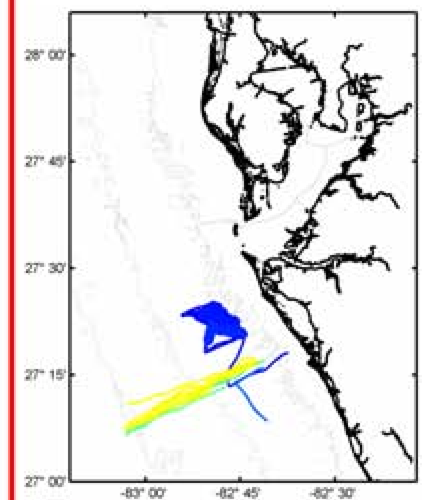


Sites no shown: Martha's Vineyard and Virginia Beach

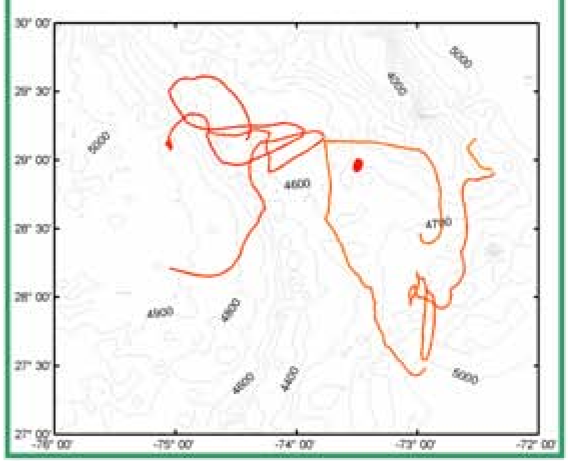
COOL Endurance Line/LATTE



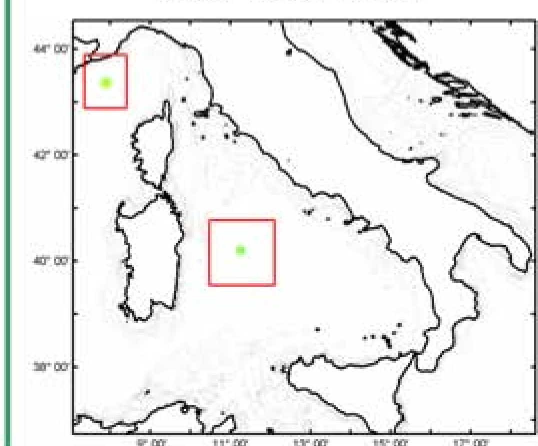
SO-COOL EcoHAB

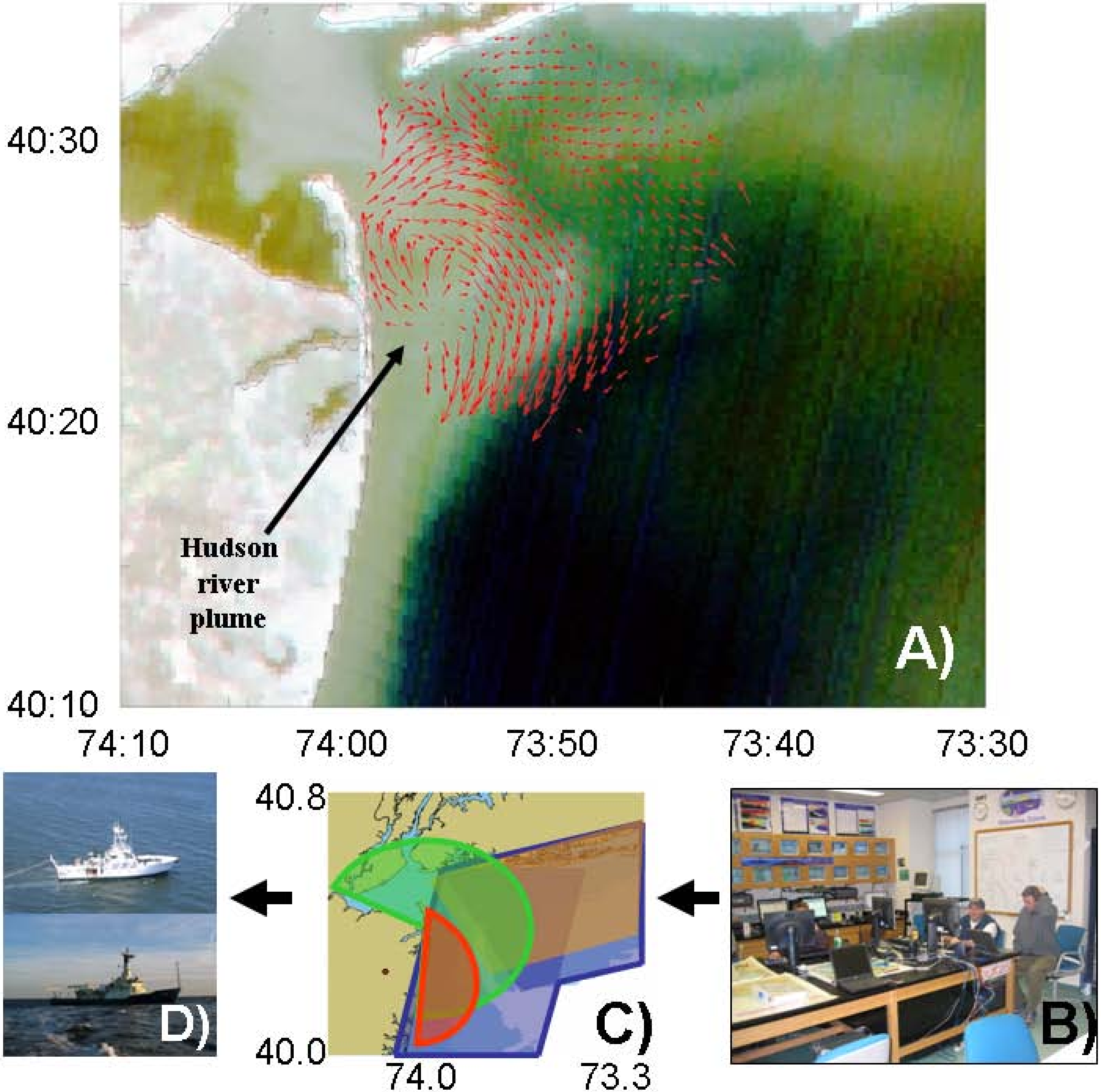


SHAREM 2005

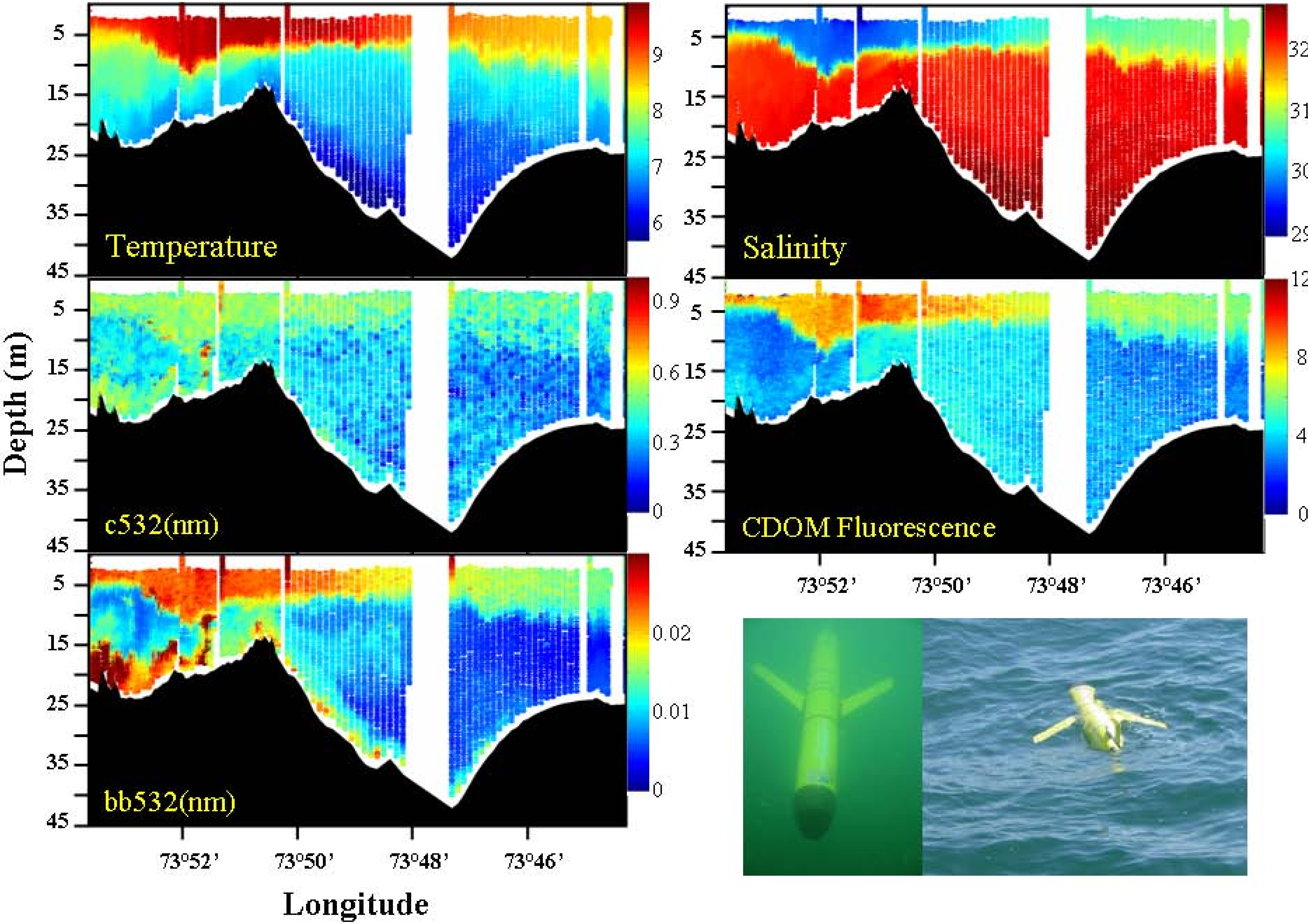


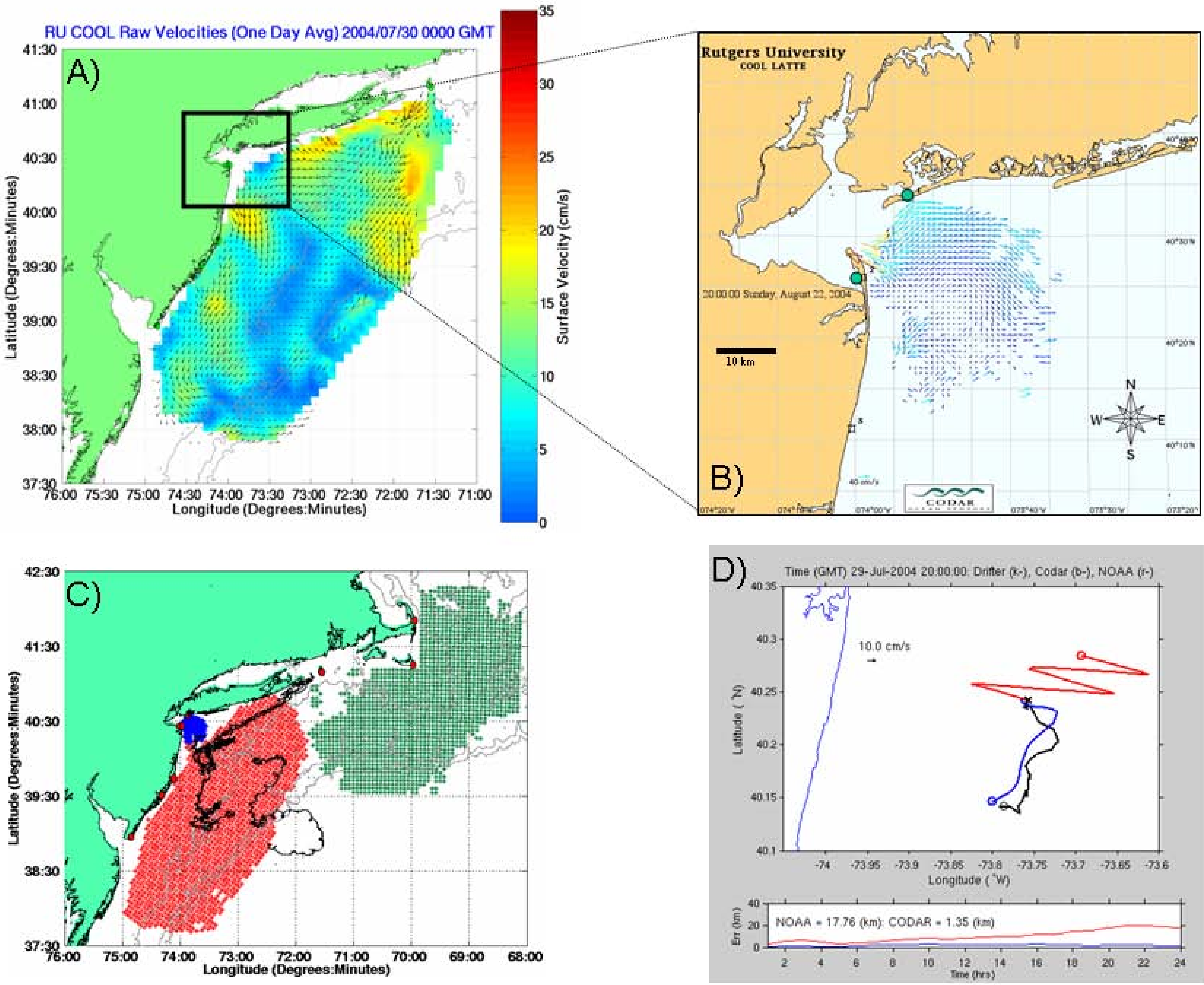
AOPEX 2004





40:30
40:20
40:10
74:10
74:00
73:50
73:40
73:30
Hudson river plume
A)
40.8
40.0
74.0
73.3
C)
B)
D)


Temperature
Salinity
c532(nm)
CDOM Fluorescence
bb532(nm)
Depth (m)
Longitude
73°52'
73°50'
73°48'
73°46'
5
15
25
35
45
9
8
7
6
32
31
30
29
0.9
0.6
0.3
0
120
80
40
0
0.02
0.01
0



RU COOL Raw Velocities (One Day Avg) 2004/07/30 0000 GMT
A)
Latitude (Degrees:Minutes)
Longitude (Degrees:Minutes)
Surface Velocity (cm/s)
B)
Rutgers University
COOL LATTE
20:00:00 Sunday, August 22, 2004
10 km
N
S
W
E
CODAR
C)
Latitude (Degrees:Minutes)
Longitude (Degrees:Minutes)
D)
Time (GMT) 29-Jul-2004 20:00:00: Drifter (k-), Codar (b-), NOAA (r-)
10.0 cm/s
Latitude (˚N)
Longitude (˚W)
NOAA = 17.76 (km): CODAR = 1.35 (km)
Err (km)
Time (hrs)