Environmental Monitors on Lobster Traps Phase VII: Validating Ocean Models

Annual Report June 2011

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Project Objective and scientific hypothesis:

As noted in the original proposal for this work, our primary objective is to engage fishermen, students, and numerical modelers in a joint effort to validate simulations of New England's coastal current. The traditional means of ground truthing ocean circulation models typically involves deploying a few moorings at selected locations within the domain but this leaves much of the complexity of the flow field unresolved. We choose to devise a system where low-cost instrumentation can be built and deployed by students and fishermen, respectively, at more locations. While traditional scientific moorings cost many tens of thousands of dollars to deploy and maintain, our observations cost at least an order of magnitude less, cover a much larger portion of the study area, and involve different sectors of the society beyond the academic scientists.

Given the topographic complexity off our coast, there is considerable spatial variability in the coastal currents which are affected by these bathymetric variations. There are evidently small areas of convergence and divergence that results in varying degrees of retention and dispersion of water parcels. Now that our circulation models have reduced their grid cells down to less than a kilometer resolution, they are capable of depicting some of these small scale features.

One example of a potentially important small scale feature is a small area of relatively stagnant flow at the mouth of Buzzards Bay. While the semi-diurnal tides are fairly strong in this area, the residual means are near zero in contrast to a strong westward coastal current just offshore. Since lobstermen and scientist working together the last few years have found a higher concentration of egging female lobsters in this region, there is some discussion of the consequences. When lobsters release their eggs from the bottom, are they more likely to be caught in the westward coastal current or do they quickly ascend to the surface and then get affected up the bay in a wind-driven northeastward surface current. Given the dozens our drifters that have been deployed in this area in the last few years, we are beginning to understand the details of the mean flow as well as the temporal variability.

Methods and work plan:

As proposed, we expanded on the eMOLT phases that had worked well in the recent past (drifters, current meters). Ten drifters were to be constructed by students and delivered to lobstermen to deploy. Fifty-bottom current meters were to be built and delivered to lobstermen along the coast. Data from the drifters, in particular, was to be shared with the High-Frequency Radar personnel at multiple labs so they could validate the surface currents derived from these systems. Salinity sensors were to be deployed by a few lobstermen in an attempt to correct for the difficulties experienced in eMOLT phase II. Web-based displays of

all of the above were to be built and lobstermen were to be asked to comment on these pages.

As the main components of our outreach effort, we had proposed both a day-long eMOLT event at the Maine Fishermen Forum as well as presentations to students.

Work completed to date:

At the beginning of our project year, in the spring of 2010, our attention was diverted to the Gulf of Mexico. Along with many of the oceanographers around the country, we were ask to address the oil spill. In May of 2010, we called upon some student laborers to help build and ship a few dozen drifters to various ports along the gulf coast. We made arrangements to distribute 25 units between our colleagues at a) Dauphin Island Sea Lab in Alabama, b) Univ. of South Florida at St Petersburg, and c) NOAA's AOML in Miami. We also arranged for deployments off two New England based ships, the R/V ENDEAVOR and R/V DELAWARE, that were headed to the gulf. The tracks of these drifters were posted in realtime and the data shared by multiple modeling groups for the purposes of assimilation and validation. The group at the University of South Florida, for example, used these drifters along with many others to understand the flow patterns throughout the gulf and posted results on their website at http://ocgweb.marine.usf.edu/DrifterMaps/OilDriftersNEFSC.php .

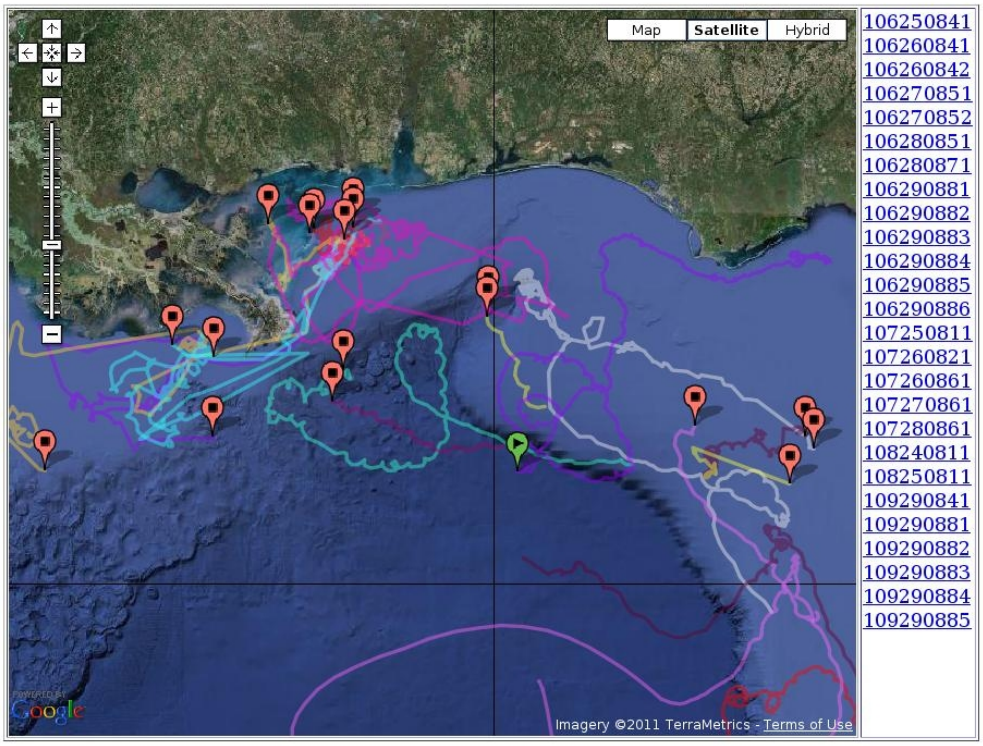

Figure 1. Tracks of drifters in the Gulf of Mexico. All of these drifters were built and subsequently tracks by New England school children.

Now that the tools have been developed (primarily MATLAB and PYTHON routines), we can begin to conduct more quantitative analysis of the models performance. When we deployed drifters early in 2011, we were be able to forecast the drifters path based on circulation model forecast. Particularly in the case of Mass Bay where there are now multiple models resolving some of the detailed complexity of this region, we will be able to simulate the drifter's projected path 2-3 days into the future. Given that we supplied both Quincy High School and UMASS Boston with several of our transmitters in the past year and the Mass Division of Marine Fisheries still have a fleet of drifters from previous years, we expect to conduct more focussed studies within Boston Harbor and the waters immediately outside the harbor during the summer of 2011.

Given the Massachusetts Ocean Partnership (MOP) funding the FVCOM modeling group, we hope to have a complete hindcast of our coastal waters from 1978 to present. As of this writing 1978 through 1981 simulations are available for each hour. When it is complete, we will be better able to conduct a complete analysis of model vs observations and begin to address the inter-annual variations in the transport pathways. In the meantime, we continue to develop the tools and ways to properly evaluate the model's performance.

We have also expended considerable effort in restoring and posted a large set of historical current meter data from 1978 on-ward. While these data have been stored for the last few decades on a few computer disks, they are now accessible via the Open Source Network Data Access Protocol (OPeNDAP) according to the NOAA IOOS standards. The historical data restored to date include those from Great South Channel, the Northeast Channel, and the Southern Flank of Georges Bank and can be used to evaluate the MOP-funded hindcast.

Given some of the drifters funded through this Phase VII project, we have been able to build a close collaboration with the Zephyr Marine Education Foundation in Woods Hole. Beginning in April (and potentially throughout this summer), we have conducted bi-weekly drifter deployments in local waters when groups of primarily high school students go on-board, witness the deployments, and subsequently follow the path of the drifters on a customized googlemap online. From this project alone, approximately 2500 kilometers of ocean has been logged in Southern New England Waters. As these drifters approach other shores, they are picked up by students elsewhere. URI students, for example, have been involved with a few recoveries and Brookdale Community College students are now involved with tracking one of these drifters off the Jersey Shore.

Figure 2. Example of student/teacher groups involved with drifter deployments in the Spring of 2011.

At the time of this writing, another drifter-building workshop is being planned for August 2011 in Monterey California. Leveraging NSF-funding to the "Marine Advanced Technology Education" group, several colleges will be able to send marine science teachers to this 3-day event and allow them to return with a ready-to-deploy drifter. The drifter construction manual we have developed over the last few years will be followed and teachers will then be able to have their students build more drifters. The primary focus here, however, is not to maximize the drifters deployed but to get the most out of the drifter data that is generated. Much of the teaching is associated with the downloading, processing, and visualizing of drifter tracks. Students will learn how to plot the tracks and overlay other information such as the wind fields and the numerical model fields.

The bottom current meter project has succeeded thus far. After our initial deployment on 11 lobster traps in the fall of 2008, another set of 27 were deployed and recovered in fall of 2010. Given these encouraging pilot projects, we then sent out units to 50 different lobstermen in 2011. These will be out for

the entire fishing season so that we should get them back in early 2012. The locations are depicted in the figure below are those for the 2010 deployment.

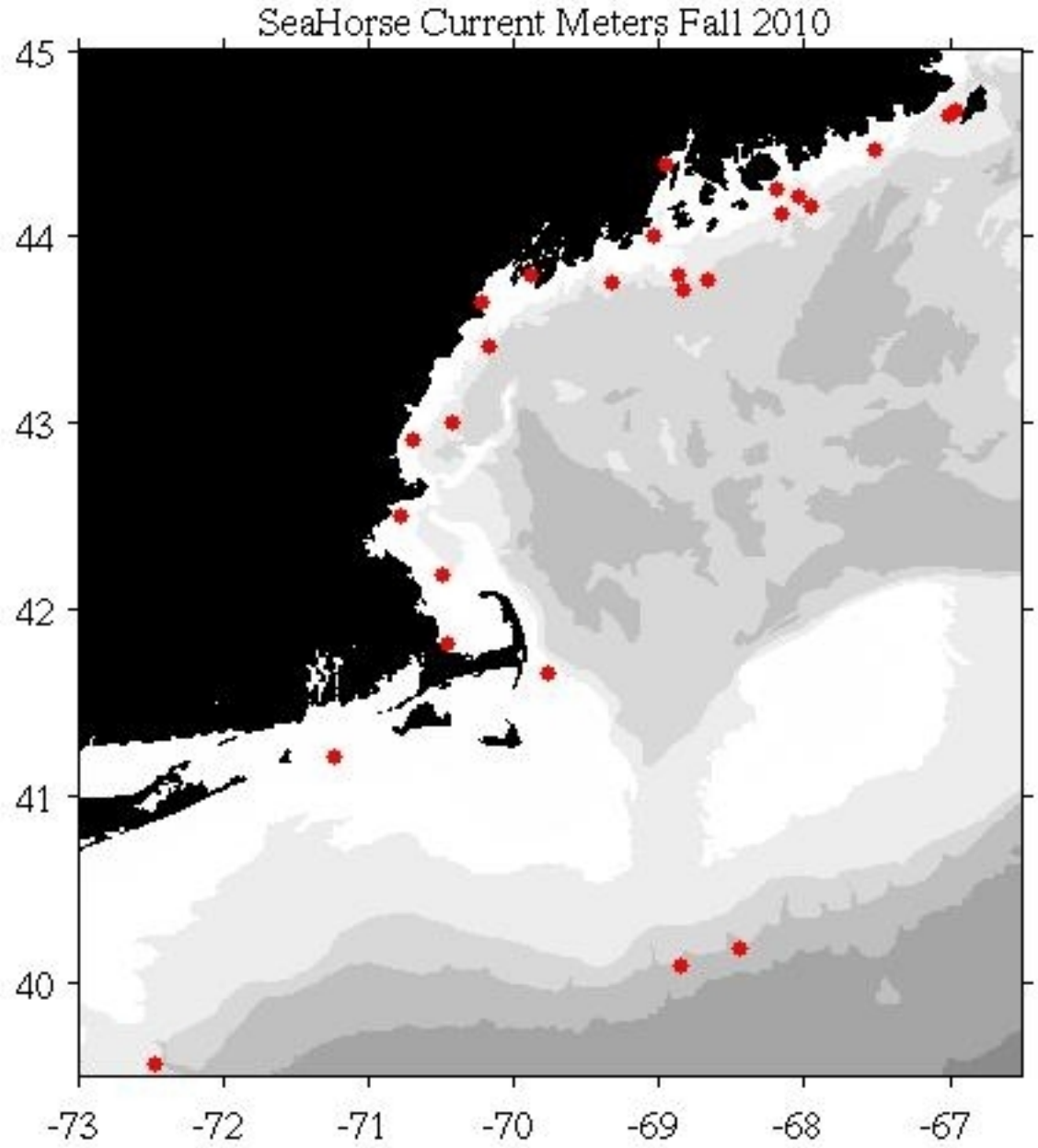

Figure 3. Locations where bottom-current meter records were obtained from lobster traps in the Fall of 2010.

During the summer of 2010, approximately a dozen drifters were built by students at the Cohasset Center for Student Coastal Research. Most of these units were deployed in Mass Bay by local lobstermen. In some cases, local fishermen were recruited to recover units that washed ashore on remote islands.

Finally, the most recent eMOLT-related work in the summer of 2011 is in deploying digital-cameras on lobster traps. Working in collaboration with ocean engineers at Woods Hole Oceanographic Institute, we are preparing several cameras to be sent out to lobstermen in the next few weeks. With the help of NOAA divers, we have tested their waterproofed housings and the light limitations in water depths up to 10 meters off the dock and are curious to find out how they work in the various environments that the fishermen work. While these cameras help us document the performance of our instrumentation (drogued drifters and tilt current meters), the 20+ plus lobstermen who responded to our email are obviously interested in monitoring the activity of their trap so that the collaborative project is a win-win situation. If these cameras do work, lobstermen and scientist alike may obtain a better understanding of the catch dynamics. A example photos obtained in the test deployments are provided below.

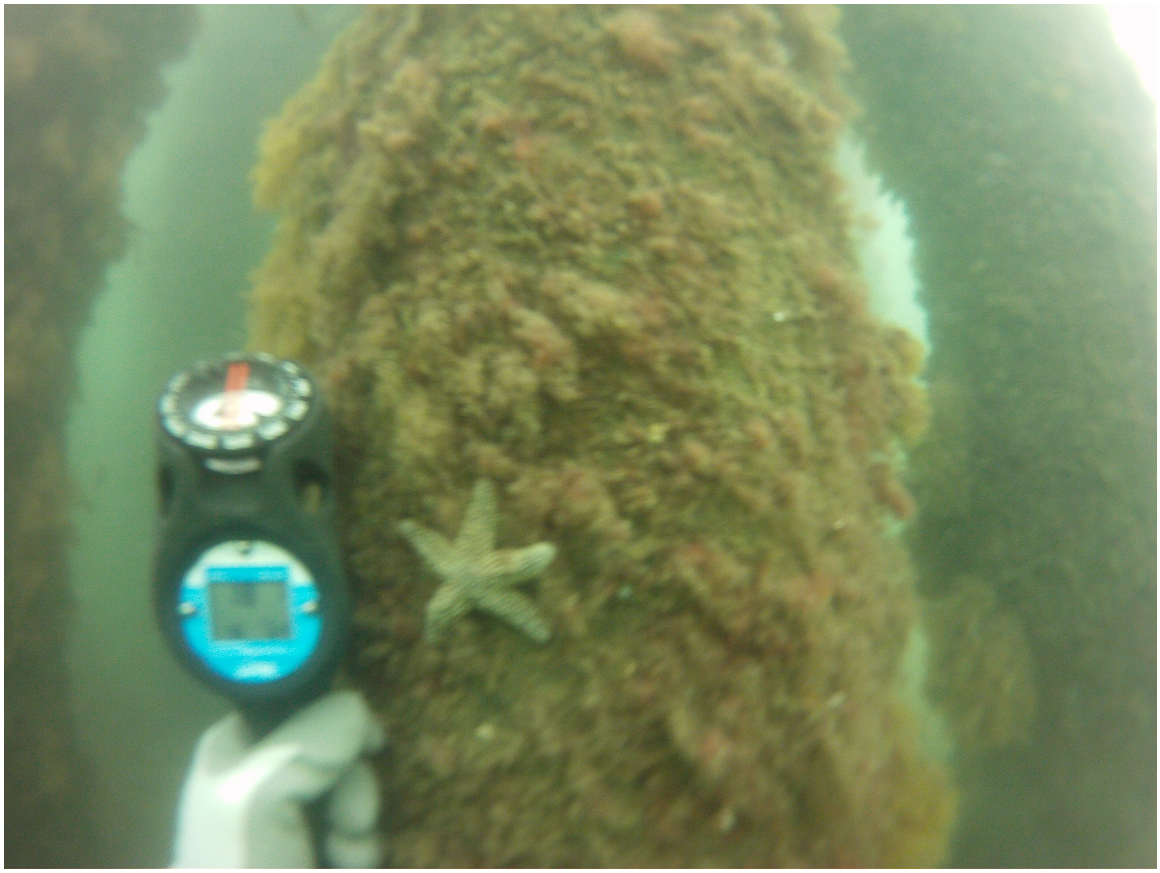

Figure 4. Testing new underwater cameras to be deployed by lobstermen in 2011.

Results to date:

Considerable advances have been made towards the validation of local ocean models in the last few years. Given new utilities that allow investigators to

remotely access a variety of web-served model output, it is now possible to examine these models without needing to bother the modeling teams that generate the output. These are powerful new tools that can be leveraged.

Because of the activity associated with this NEC-funded grant, I was invited to sit on a advisory panel that evaluates UMASSS Dartmouth's FVCOM model operations: the Northeast Coastal Ocean Forecast System. Much of the work that has been done and the tools that have been develop in this grant therefore have addressed the FVCOM model in particular. However, there are multiple models that simulate our coastal waters and these tools have been applied to these other models as well.

The validation of models has progressed along a few fronts associated with different data products. We compare the model output to eMOLT drifters, eMOLT bottom temperatures, and GoMOOS moored current observations. Examples of these comparisons are posted at http://www.nefsc.noaa.gov/epd/ocean/MainPage/circ/necofs_vs_eMOLT.html and are shown below in Figures 1, 2, and 3. While this website is a work in progress and should NOT be linked from any public site, it provides an up-to-date summary of our efforts to date. As of this writing, most of the code has been written to make the comparisons but a quantitative analysis of the models will not be complete for several months from now and the results should appear in the final report of this grant.

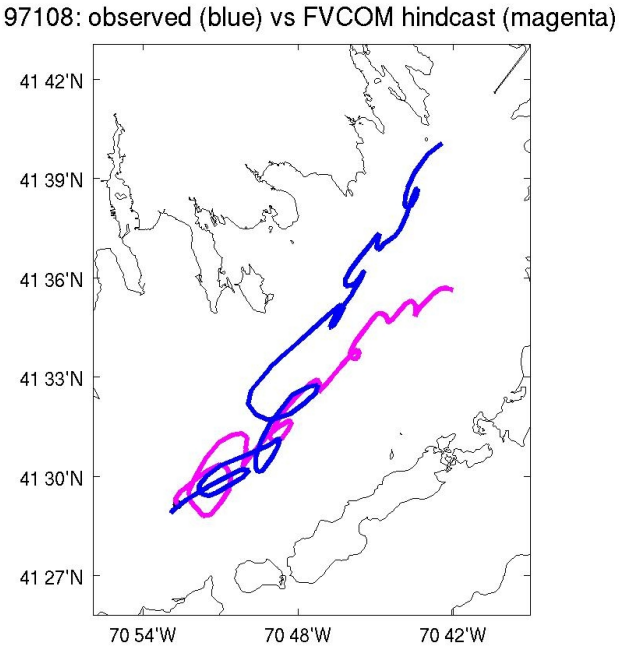

Figure 6. Example of comparing model drifter track vs observed. This case is for one drifter flowing up Buzzards Bay in July 2009 where the model captures the events but not the absolute values.

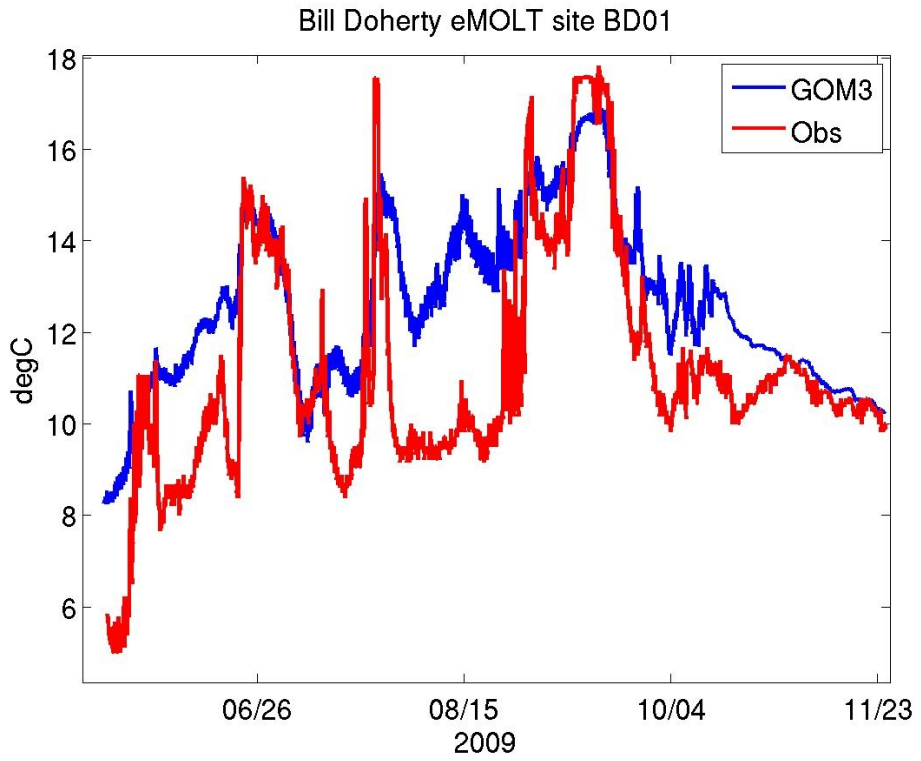

Figure 7. Example of comparing model temperatures to eMOLT bottom temperatures. This case is for Bill Doherty's site off Boston Harbor.

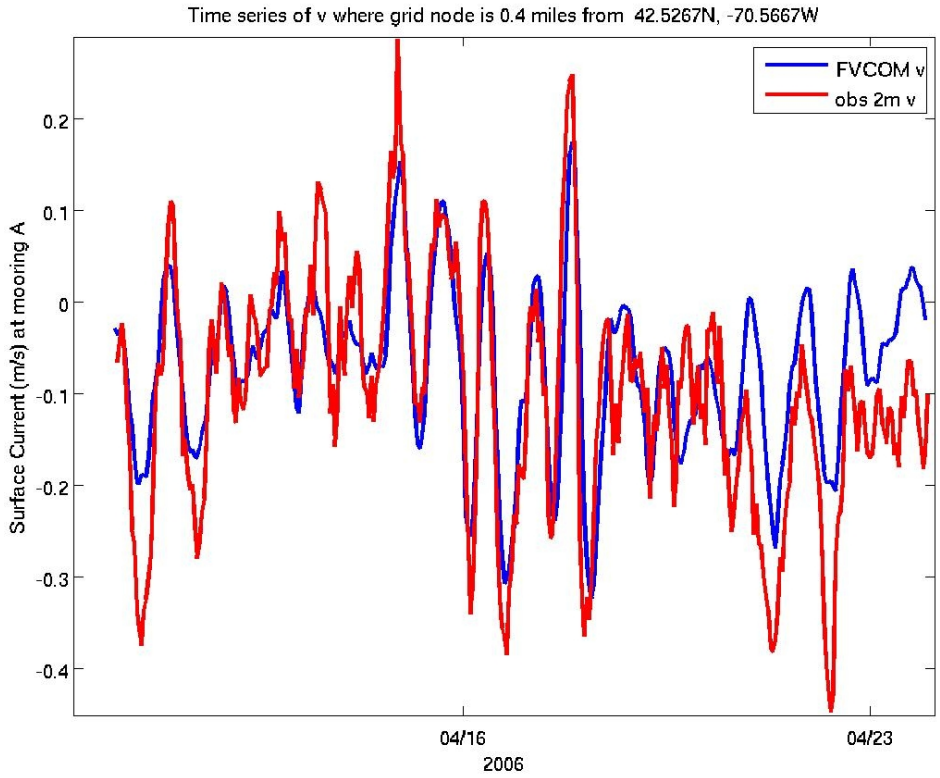

Figure 8. Example of comparing model to GoMOOS mooring time series of northward velocity. This case is for mooring "A" in April 2006 where the model does generally well.

Our drifter data is accessed by other groups for the purposes of validating their models. Other labs (North Carolina State, UMASS Dartmouth, and Rutgers University) have manuscripts underway that describe a model – data comparison using eMOLT data.

In July 2011, our colleagues at Woods Hole Oceanographic Institute will be deploying approximately 80 drifters in a cluster south of Martha's Vineyard. We have been preparing for this event by tracking particles through numerical model fields in order to estimate what will occur (Figures 9 and 10) and help design the deployment. Since the objective is to recover all the drifters a few days after the deployment, the forecast models will help us determine how feasible that plan is and to what extent the drifters will disperse. Some examples of the estimated tracks are presented in the figure below.

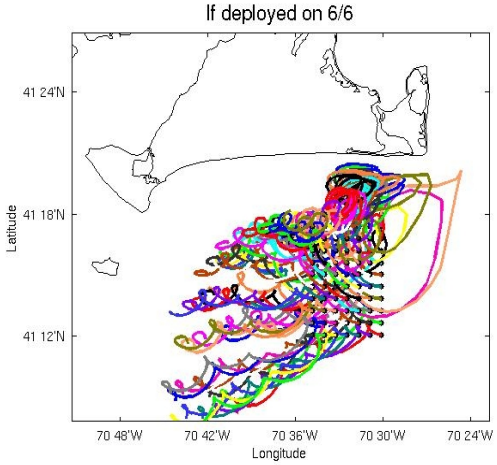

Figure 9. Forecast trajectories from a grid of 80 sites south of Martha's Vineyard if deployed on 6/6/11.

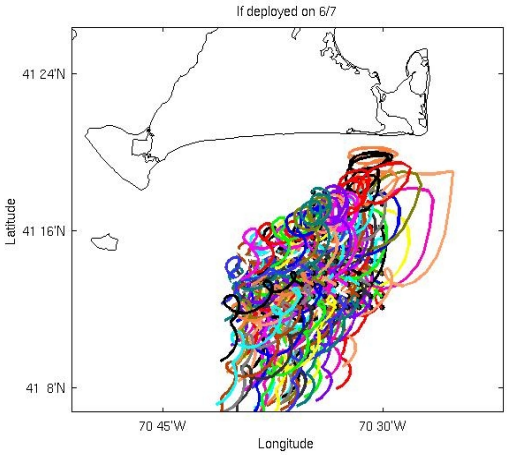

Figure 10. Forecast trajectories from a grid of 80 sites south of Martha's Vineyard if deployed on 6/7/11

Future work:

Given that more drifters were deployed in 2010 than any previous year and that at least as many are scheduled to be deployed in 2011, it is unlikely that the drifter project, first funded by NEC in 2004, is going away. We do not expect additional seed funding from NEC but, given the results thus far, we hope to be able to secure routine operational funding from other NOAA sources such as ECOHAB or IOOS. There is also some chance we may be able to obtain funding indirectly from Ocean Observatory Initiative (OOI). There are indications that our colleagues in the Middle Atlantic Bight may be looking for drifter data for both model and CODAR validation.

In addition to more drifter deployments, we hope to continue the development of the bottom current meter. We have submitted a proposal to NOAA's Advanced Technology Working Group to add a digital compass to the instrument in order to better resolve the direction of current. As noted above, we hope to also distribute more digital cameras to our lobstermen in an effort to monitor our instrument performance as well as the lobster catch activity.

We continue to make improvements to the presentation of our results on the web. The most recent additions are pages that allow teachers and students to document their deployments and enter the necessary metadata in a standardize way. There are also a variety of googlemap presentations of the tracks. The new drifter website is at: http://gisweb.wh.whoi.edu/cgi-bin/ioos/drift/driftTable.cgi Similarly, the results associated with the new bottom-current meter is posted at: http://www.nefsc.noaa.gov/epd/ocean/MainPage/tilt/shtcm.html where there are links to all the time series data collected thus far. Web presentations will continue to evolve as new display methods become available. Flash animations, for example, are now posted and provide far more effective visualization of both modeled and observed drifter tracks.

Impacts and applications:

Hundreds of eMOLT-style drifters have been deployed over the last several years in support of the ECOHAB and GOMTOX programs to study the advection of Harmful Algal Blooms. In 2010, the GOMTOX-funded drifters revealed an unusual offshore veering of the coastal current near Casco Bay that helped explain the lack of toxic cells in the Mass Bay region that year. The realtime plots of these drifters are often watched by shellfish managers as a index of the surface water transport towards or away from their shores. In years like 2005 where there was a series of northeasterly wind events, the drifters could be seen along the coast and advecting shoreward. It was a very different situation in 2010 (Figure 5). A manuscript recently submitted (McGillicuddy et al, 2011) provides the full story of the suppression of HABs in 2010.

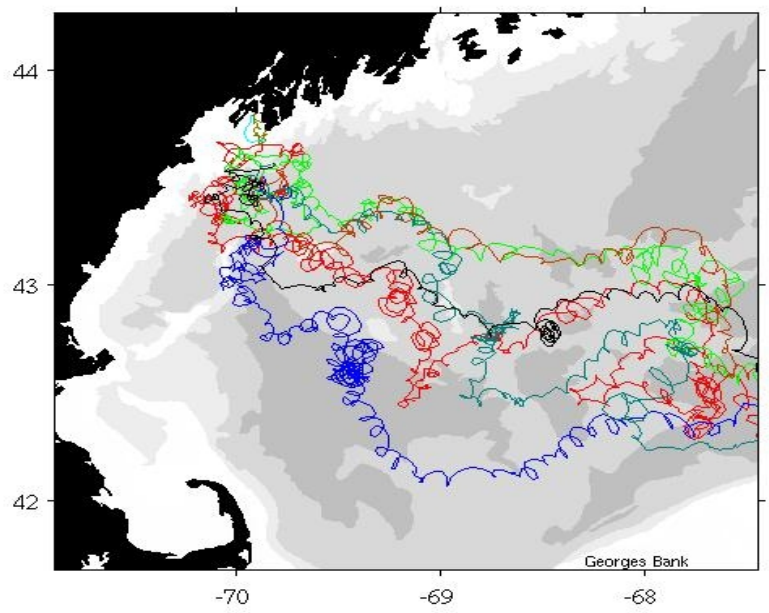

Figure 5. GOMTOX-funded drifters in 2010 tracking offshore from Casco Bay and therefore explaining the lack of toxic cells appearing in MassBay shellfish beds.

There are many other recent examples of why these models are useful. Last year, there was the question of why a sudden rise in the toxic Alexandrium cells in Nauset Inlet occurred in June 2009. We were ask to evaluate the circulation pattern of the coastal current just prior to that event to determine if there was an influx of surface waters into the inlet. The combination of modeled and observed paths (Figure 6) depicts the real possibility.

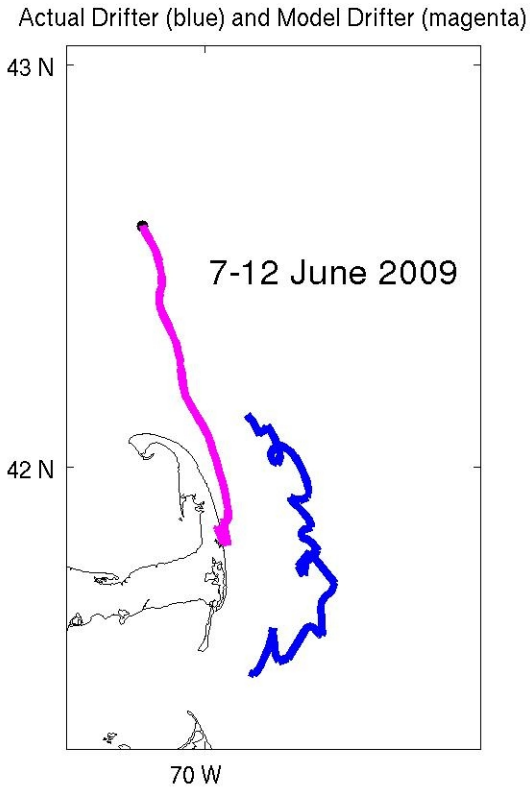

Figure 6. Trajectory of both actual and simulated drifter paths prior to the June 2009 toxic Alexandria outbreak in Nauset Inlet depicting the numerical results of a particle released in the model fields just east of Stellwagen Bank on June 7 (magenta).

This past year we were asked to simulate the path of a drifter that unfortunately lost its GPS transmissions but subsequently records tagged animals on the acoustic receiver that was attached to the drifter (Figure 7). The model in this case was the “simple” model as described by Manning et al 2009.

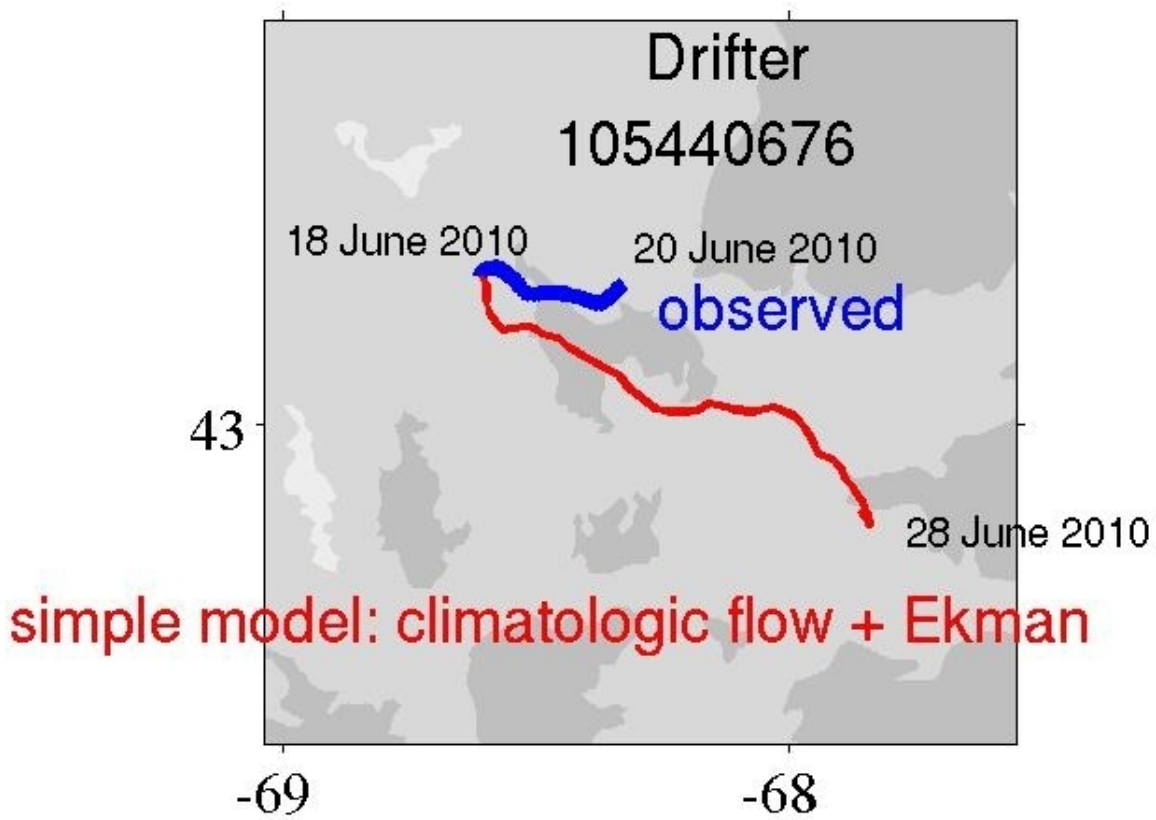

Figure 7. Trajectory of both actual (thick line) and modeled (thin red line) depicting the ESE-ward flow in late June 2010. The simple model is the result of moving a particle through empirically derived drifter climatology and adding a wind-driven Ekman component.

Related projects/partnerships:

The most relevant projects are the Regional Associations of Coastal Observing Systems in both the Mid-Atlantic (MARACOOS) and the Northeast (NERACOOS). As a member of the board of directors on the former and the data management committee on the latter, Manning is actively involved with these initiatives and hopes to promote the eMOLT idea in both organizations.

The Gulf of Maine Toxicity (GOMTOX) project is also very much aligned with eMOLT objectives in the observation and modeling of ecosystem processes over multiple years. The objectives of the Northeast Coastal Ocean Forecast System (NECOFS) also runs parallel to eMOLT directions. We are beginning to exchange ideas with the Northeast Cooperative Research Program in the last few months where, for example, we are attempting to develop a real-time probe for both mobile and fixed-gear applications. The objective is to exchange data, ideas, code, and instrumentation between all of these analogous efforts.

Presentations:

In October 2010, a presentation was made at the Boston Harbor Educators Conference at UMASS Boston. Several teachers from around the commonwealth were provided a history of the eMOLT project and instructed on building drifters.

A presentation on drifter tracks was presented at a meeting of Atlantic Salmon researchers in Portland Maine in January 2011. They are interested in the pathways of smolt transport after they enter the ocean from the rivers in Maine. As documented in Friedland et al (2011), the variability of the coastal current and its potential to change over climatic time scales may significantly affect the ability of salmon to maintain there existing population levels.

A presentation was made to the public at the South Shore Art Center in Feb 2011 where there was a show on "things in motion". The animated drifter tracks provided an interesting discussion among those that attended.

Given this last phase of NEC funding, a full day eMOLT session at the Maine Fishermen Forum occurred on 3 March 2011. Dozens of lobstermen attended this event and were treated to a series of talks including those by Ru Morrison (head of the Northeast Regional Association of Coastal Observing Systems), Diane Cowan (Lobster Conservancy), Lew Inzce (USM lobster biologist), Paul Music (NOAA), and Heather Desse (Island Institute). Lobstermen heard first hand of the efforts underway to provide them with a real-time ocean forecast system as well as the results of the various eMOLT projects by Manning and Sheremet. This session was well attended and exposed many more fishermen to our efforts to monitor and understand the environment.

Figure 8. Active eMOLT participants at the March 2011 10-year anniversary get together.

A presentation was made to colleagues at the Massachusetts Division of Marine Fisheries in June 2011 illustrating the mean flow patterns that are beginning to

emerge from the multiple drifter deployments this group has assisted with in the last few years.

Finally, we are preparing a presentation to be made at the National Marine Educators Annual Conference in Boston, MA on 1 July 2011. The objective is to transfer the drifter technology to teachers around the country. We hope to share the construction manuals, computer code, and lesson plans needed to engage students in both the hands-on activity of building and tracking of drifters.

Published reports and papers:

McGillicuddy, D.J., Jr., D.W. Townsend, R. He, B.A. Keafer, J.L. Kleindinst, Y. Li, J.P. Manning, D.G. Mountain, M.A. Thomas, D.M. Anderson. 2011. Suppression of the 2010 *Alexandrium fundyense* bloom by changes in physical, biological, and chemical properties of the Gulf of Maine. Submitted to Continental Shelf Research.

Manning, J.P., D. McGillicuddy, N. Pettigrew, J. Churchill, L. Incze, 2009, Drifter Observations of Gulf of Maine Coastal Current, Continental Shelf Research. doi:10.1016/j.csr.2008.12.008.

Friedland, K.F., J. Manning, J. Link, A. Gilbert, and A. O'Connell. 2011. Variation in wind and piscivorous predator fields affecting the survival of Atlantic salmon, Salmo salar L., in the Gulf of Maine. Accepted by Fishereis Management and Ecology.

Data:

The eMOLT temperature, drifter, and now moored current meter data is posted at emolt.org and accessible via OPeNDAP as it has been for the last decade. Computer code is now posted on the website that allow users to by-pass the traditional point-and-click web-based methods so that they can access the data directly in from Python or Matlab environments.