PROPOSAL COVER SHEET

Project Title: Validating coastal ocean circulation models with student-built, fishermen-deployed, satellite-tracked drifters

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Budget Request: $90K

Brief project description:

We propose to address a variety of issues related to water mass origin and fate with a small pilot project using a combination of observations and circulation model runs. In a multi-phase implementation, we propose to 1) develop and 2) deploy new drifter technology and use the results to 3) validate numerical simulations of the flow fields associated with each deployment. We propose to conduct this demonstration project by focusing our efforts on **Casco Bay**. This area is chosen a) for following-up on other recent studies in this area, b) documenting a complex system of water exchange between the river plumes, estuarine, and shelf systems, c) demonstrating the advantages of finite-element modeling strategy given a complex geography of islands and channels, d) investigating the enhancement of Harmful Algal Blooms and the depletion of oxygen in this area, and e), logistically, so that many of the local colleges in the area (Southern Maine Community, Bowdoin, St. Josephs, and the University of New England) and lobstermen (Gulf of Maine Lobster Foundation) can assist in the project.

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Rationale

Given the recent explosion of data gathering and monitoring efforts around the Gulf of Maine, we propose to assimilate these observations into numerical models. As our nations' regional ocean observing systems develop, there is a need to incorporate the increasingly large volumes of data in a modeling perspective and to develop computerized applications that can digest data for purposes of characterizing the entire physical ecosystem. Here we are proposing to not only implement coastal circulation models but to **validate** the results with the design and deployment of low-cost GPS drifters.

A properly-validated numerical model can be a valuable tool for management to address a whole range of questions concerning the coastal oceans. This proposal does not focus on a particular application. We recognize these models are relevant to multiple issues. While we are most interested in the transport and dispersion of harmful algal blooms and lobster larvae, we see other **applications** in the worlds of aquaculture, tidal power, sewage outfall sightings, and oil spill response. While we do not expect to resolve all the complexities of the current field in a project such as this, we hope to demonstrate these complexities with multiple model runs and deployments of low-cost drifters under a variety of forcing mechanisms.

We propose to address a variety of issues related to water mass origin and fate with a small pilot project using a combination of observations and model simulations. In a multi-phase implementation, we propose to 1) develop and 2) deploy new drifter technology and 3) model the flow fields associated with each deployment. We propose to conduct this demonstration project by focusing our efforts on **Casco Bay**. This area is chosen a) to follow-up on other recent studies in this area, b) it is an ideal location to understand the complex system of water exchange between the river plumes, estuarine, and shelf systems, c) the complex geometry (multiple islands and channels) in the system is ideal for demonstrating the advantages of finite-element modeling strategy, d) to be pertinent to a nascent study concerning the initiation of Harmful Algal Blooms in this area, and e), logistically, so that many students (Southern Maine Community , Bowdoin, and St. Josephs) and lobstermen (Gulf of Maine Lobster Foundation) can assist in the project.

Our objectives fit perfectly within **NEC's mission** of fostering collaboration between academia, science and industry. We propose to compile a set of instrumentation, data, and software that would eventually allow managers to test various scenarios as they occur in the coastal environment. Once this methodology is established, it will be available for real-time response to environmental events and disturbances.

Review of previous work

Casco Bay has been the focus of a variety of research in recent years. The Maine Oil Spill Advisory Committee and the Maine Department of Environmental Protection, for example, has worked with the Maine Sea Grant in the last few years to fund studies in the bay. The one most relevant to our interest is the project on "Observations of Tidal, Sub-tidal, and Seasonal Variability in Casco Bay Circulation". Led by UMaine physical oceanographer, Dr. Carol **Janzen,** they have examined the exchange processes in and out of the Bay using a set of moorings in the major channels. These records provide valuable data on the transport in and out of the bay at multiple depths in those fixed locations. They demonstrated, for example, the vertical shear in the water column where the deep flow can often be opposite that of the surface. Figures of their work can be viewed at http://gyre.umeocn.maine.edu/cjanzen/Dep-MOSAC.html and manuscripts are in preparation.

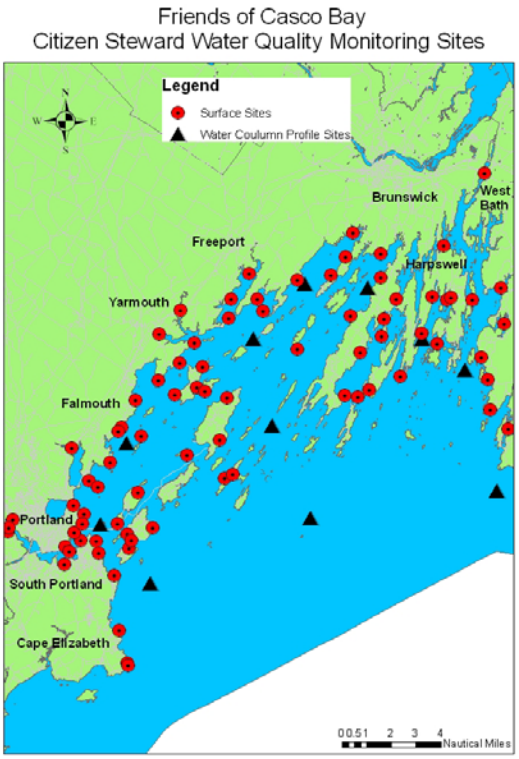

Figure 1. Sampling stations occupied by the Friends of Casco Bay. Black triangles have near-monthly water column readings of temperature and salinity.

Another group that has done extensive work in Casco Bay in the last few years is the **Friends of Casco Bay**. As depicted in Figure 1, they conduct water quality monitoring throughout the Bay during the spring and summer periods. This group has recently been funded by the Casco Bay Estuary Partnership to purchase an Acoustic Doppler Current Profiler. This will provide velocity observations throughout the water column as part of their routine.

The water property sampling by FOCB has been helpful to Dr. **Ernie True**, retired chairman of the Norwich University Math Department, who has been working on model simulations of Casco Bay. He has a manuscript in preparation where he uses the Dartmouth College models to simulate flow scenarios given a variety of initialization and forcings.

Another modeling effort of this sort was recently conducted on the Sheepscot River Estuary (Hess, et al. 2005) where Jim Churchill, a physical oceanographer from the Woods Hole Oceanographic Institute, generated simulations and compared them to the tracks of SMCC-constructed drifters in the vicinity of the **Maine Yankee** Power Plant. This study was in response a suit filed by the Friends of the Coast.

Finally, the ECOHAB programs in the last decade have examined the processes that drive the concentrations of **harmful algal blooms** in the Gulf of Maine. Much of the work, published in a recent special volume of Deep Sea Research, has focused on the waters just upstream and in the vicinity of Casco Bay where the toxic algae is often concentrated (Janzen et al. 2005; Keafer, et al., 2005; He et al, 2005). These recent investigations follow-up on earlier publications on

modeling in the area (Lynch et al, 1997; Fong et al, 1997; Incze and Naimie, 2000; Xue et al, 2000).

Project objectives and scientific hypothesis

The project objectives clearly fit under the two headings "scientific" and "engineering". The scientific objective includes **understanding the processes** that regulate the transport in and out of Casco Bay and delineating the relative importance of wind, river, and tidal forcing. One hypothesis is that volumes of water pass in one channel and out another rather than there being a more traditional estuarine structure where there is a two-layer flow in each channel.

The purpose of having several short (3-4 days each, see project design below) drifter deployments is to document a **variety of scenarios** under different conditions. Since it is unrealistic and too expensive to maintain instrumentation in Casco Bay over an entire season, we plan to deploy at least once per month throughout the summer. In the first set of deployments, for example, we will deploy during calm conditions and under different tidal conditions. We will react (at least a few times) to environmental events such as northeasters and extensive rainfall periods. In these cases, we would deploy a day or so prior to those times relying heavily on NOAA/NCEP weather forecast models. Our hypothesis is that the primary forces that govern the longterm redistribution of water masses in this area are episodic weather related events. In other words, we suspect the residual flow in and around Casco Bay is insignificant compared to the effect of storms. We also suspect a major component of the flow is driven by remote forcing from the Gulf of Maine so that the seasurface elevations at the mouth of the bay will be the most important input variable to successful simulations.

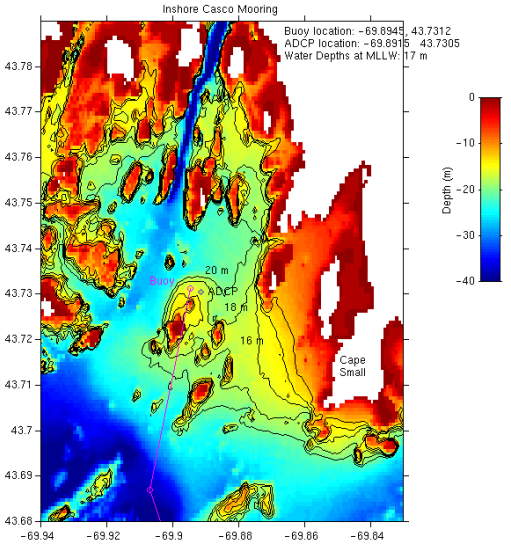

Figure 2. Bottom depth contour of the eastern side of Casco Bay depicting the complexity of the system including multiple ledges and deep channels. Illustration taken from ECOHAB website.

We will follow up on the hypothesis (Kistner and Pettigrew. 1999; Janzen et al, 2005) that the area just to the west of Cape Small (Figure 2) is a **reversed** situation where the fresher Kennebec Plume often sits offshore of the relatively salty New Meadows Estuary. While working in this eastern side of Casco Bay we will help resolve the questions of a) depleted dissolved **oxygen** levels in Quahog Bay (FOCB and CBEP, 2005) and b) why there tends to be an enhanced concentration of **toxic algae** in this area.

Another hypothesis we will be testing is that the flow in Casco Bay is sensitive to small scale details in the underlying bathymetry. Like most of the coast of Maine, Casco Bay is ridden with very complicated topography which needs to be understood in both the field and model

simulations. The most important input to the model initialization is a **detail bathymetry** as contoured in Figure 2.

Finally, there is the complexity of the 3-d fields of temperature and salinity. While we do not expect to resolve all the structure associated with **small eddy fields** throughout the bay, we can address some of this difficulty by a) asking our partners (FOCB and Bowdoin College) to conduct casts with their conductivity, temperature and depth profilers in the area while drifters are in the water, b) making maximum use of the satellite image data available through the UMO, and c) asking local lobstermen to deploy temperature sensors on the fixed gear. Some of the Casco Bay lobsterman are already involved with this activity are willing to expand their deployment of probes on not only the traps but up in the water column as well.

In summary, we are interested in multiple scientific questions related to:

- 2-d or 3-d exchange flow
- Effects of wind, river, and tide
- Effects of offshore forcing
- Reversed New Meadows Estuary
- Oxygen depletion in Quahog Bay
- Enhanced HABs
- Effects of small scale bathymetry
- Effects of small scale features in the temperature and salinity fields

Figure 3. Paul Hodder, SMCC student, and the drifter he designed for shallow water estuarine studies.

While we do not expect to definitively answer all these "scientific" questions, we hope to make a significant contribution in a **cooperative-research** sense. In the end, we hope to help management answer perplexing questions such as "What might be the consequence of a large oil spill 5 kms outside Portland Harbor followed by a two day northeaster?" or "How long would it take to advect *Alexamdrium* cysts into Lumbos Hole following a period of higher-than-normal Kennebec River discharge?"

The other aspect of our work is in the form of an "engineering" project. Our goal is to devise a set of inexpensive drifters using the most **up-to-date technology** while minimizing the cost. The challenge is to make a unit that will be inexpensive but that can withstand an occasional beaching on the rocky coast of Maine (Figure 3). This work actually got underway this past year as Paul Hodder, a student at SMCC, completed his semester project in the marine science program. He devised a drifter for estuarine deployments and tested

it against a more traditional Davis-style surface drifter in Casco Bay. His design was actually more efficient in that a) it was lower in the water column away from the effects of the wind and b) it had a more rugged base that allowed the unit to beach during low tide with little effect on the unit itself. The unit pictured is less than half the size we normally deploy and can therefore travel in much shallower regimes. With each new design, however, water following characteristics need to be well documented and compared with other drifter configurations. Multiple units of different configurations will be deployed together at the same locations to test their relative movements. Repeated experiments are needed to distinguish the variability in tracks from dispersion due to natural processes (Manning and Churchill, 2006).

Finally, the further development of a limited-area circulation model for Casco Bay, while another step in a scientific research endeavor, is primarily **an engineering challenge**. The goal is to develop a system that can be implemented by other users, with alternative questions, as a management tool. The long-term objective, of course, is to devise a system that can forecast specific oceanographic events days beforehand. Our intention with the project proposed here is to work in parallel with more extensive efforts throughout the Gulf of Maine. It is hoped that the system developed for the Casco Bay region can be applied to other regions as well such that the tool is **portable** to other limited-area grids.

Project plan and experimental design

We envision a four phase implementation of the project to address the objectives above with the bulk of the field work during early summer 2007:

1. Winter 2006-2007: building first draft a) drifters and b) model system
2. April 2007: deploy first set of drifters w/ many students involved
3. early summer 2007: 3-4 day deployments w/approximately one cluster/month
4. late summer 2007: downstream collection of escapees

The first phase will entail the development of at least two new drifter designs. Unlike the standard surface drifters (Davis et al, 1985) and drogued drifters we have used in the offshore environments successfully in the past, the new units will have the estuarine environment in mind where units will likely end up on mud flats, marshes, or rocky shores. Since they may often be advected into shallow areas, a traditional “holey sock” drogue will not be appropriate. In addition to using Paul Hodder’s design mentioned above, we plan to rig a modified Davis drifter where the sails are hung deeper in the water column as a compromise between the deep drogue design and the near-surface design. The new dock facilities at SMCC and the vessels available to the faculty, will allow **initial testing** of these units in the water.

The **first simulations** of Casco Bay’s climatological conditions will also be developed during this winter period. The primary steps to this phase include generation of a) a high resolution mesh of Casco Bay with grid size on the order of tens of meters, b) compiling historical archive of temperature and salinity profiles in order to generate a 3-d density field for early summer periods, and c) devising methods to estimate offshore elevations (Bogden et al, 1996; He et al, 2005). This last step, probably the most difficult and challenging, may involve using a larger gulf-wide model (such as the existing GoMOOS real-time model) to provide the information at the boundaries.

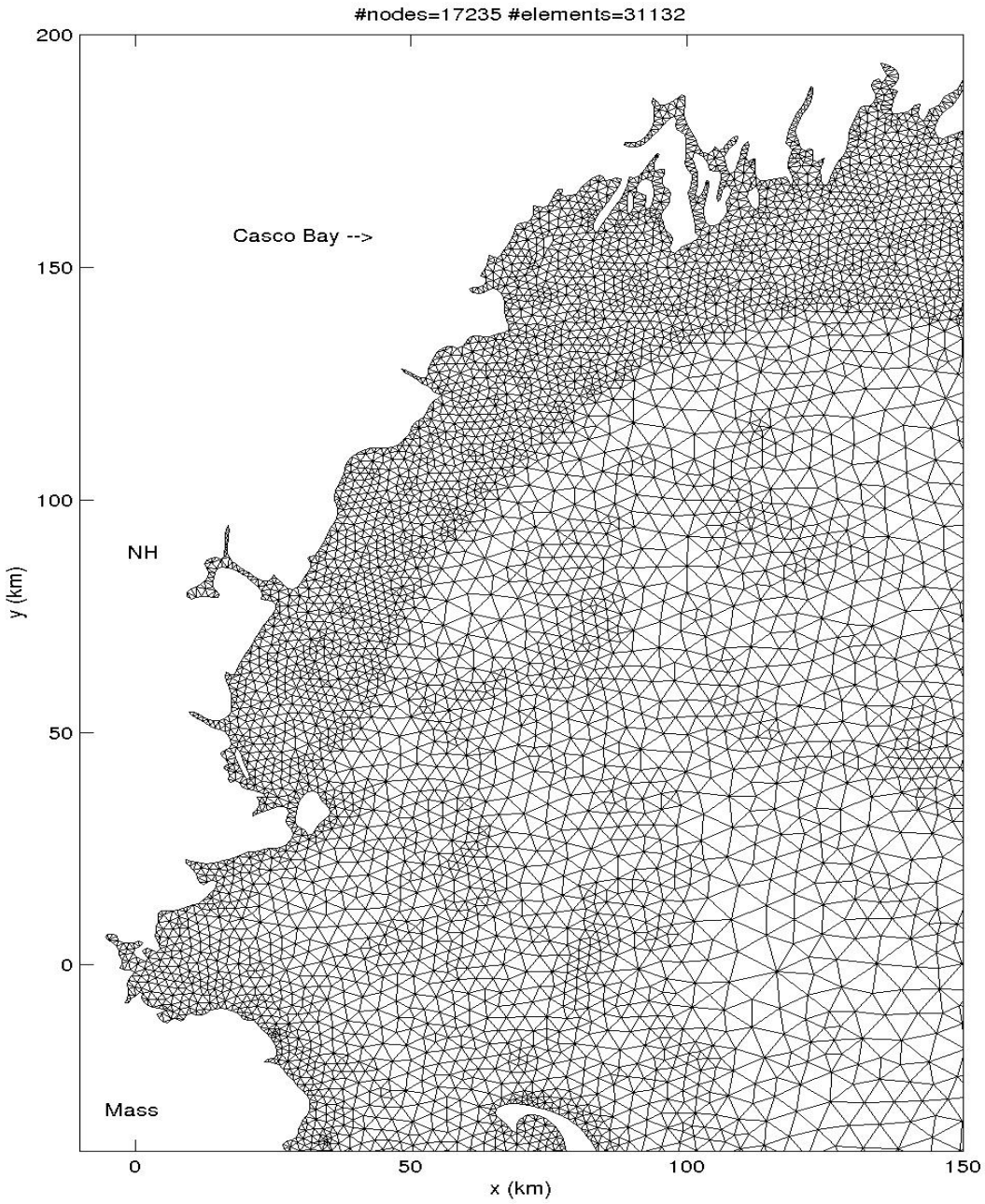

Figure 4. Existing model grid developed by Dartmouth College to examine the Western Gulf of Maine circulation zoomed into the Southern Maine region. A grid with nearly the same number of nodes will be generated for the Casco Bay area.

We will make use of both the NOAA/NOS tidal gauges in the area as well as the GoMOOS mooring buoys just offshore. There is a variety of real-time wind (NOAA/National Center for Environmental Prediction, GoMOOS, NOAA buoys, etc) and river guage (USGS) data available that can be used to force the model.

On a calm day in April 2007, we imagine the first deployment of drifters with **many students** involved. This will involve multiple universities in the area including Bowdoin College, University of New England, and St. Josephs College as well as SMCC. All institutions have a marine science program and are interested in exposing their students to physical oceanographic observations. The Bowdoin group, for example, is planning a pilot study of this sort in Quahog Bay in the fall of 2006 with a separate source of funding they have acquired for building and using SMCC drifters. Our first deployment in April 2007 will be a short demonstration of the units lasting no more than a tidal cycle. After a short leg on board to witness deployment and recovery operations, students will be lectured in groups back at the lab on the a) methods to track the units and b) on the history of Gulf of Maine drifter studies including a set of animations for the last five years of deployments (2002-2006).

The bulk of the **actual field study** will entail deployments in each month May-August. Three to four days of drift per deployment will allow sufficient time to document the subtidal features and provide a good chance of recovering the majority before they are either damaged by waves on shore or they are advected from the study area. We will employ local lobstermen to deploy and recover the equipment. Lobstermen will allocate a few hours one day for deploying instruments and then another full day for recovering the units a few days later. The goal is to deploy approximately a dozen drifters per cluster. A month between deployments of this kind will allow time for adjusting both the drifter construction and model parameters between experiments.

The actual **deployment sites** will be determined based on a) preliminary model simulations, b) satellite seasurface temperature imagery, and c) suggestions from the Bowdoin College HABs investigation. At least one of the deployments will investigate the flow in the vicinity of the major channels and at least one of the deployments will be made just west of Cape Small. Each of these deployments will be repeated under different environmental conditions to demonstrate the contrasting fate of drifters in, for example, an upwelling vs downwelling scenario. Both drifter tracks and the associated model simulations for each experiment will be posted on NOAA/NEFSC website in realtime during each experiment. Forecasts of drifter trajectories will be posted as well.

Each deployment will investigate **multiple hypothesis** concerning 1) vertical shear within the water column, 2) horizontal shear across channels, 3) horizontal dispersion, and 4) the water following characteristics of different drifter design. To address the first three items, drifters with the same configuration will be deployed at 1) multiple depths, 2) multiple cross-channel locations and 3) a single location and depth, respectively. To address the 4^{th} item, drifters of different configurations will be deployed at the same location and depth.

By late summer 2007, it is expected that the majority of the drifters will be recovered but that a small fraction of those deployed, especially those near the mouth of the bay, will escape the system and be entrained in the Maine Coastal Current. In these cases, we expect to have reasonable chance of **recovering** them with the help of the Mass Lobstermen Association on the downstream end of the study area. Historical tracks demonstrate that nearly all the units from the coast of Maine pass close to the east side of Cape Cod and often travel in the vicinity of lobstermen in that area who will be contracted to recover the units. Students will help the lobstermen by providing them with fixes every 30 minutes via cell phone.

Personnel and available resources

All the PIs on this proposal have worked together for several years on the Environmental Monitors on Lobster Traps (eMOLT) project. While the proposed project is not directly related, it is obviously an offshoot of eMOLT: Phase IV where we conducted a similar study to investigate the entire Maine Coastal Current. Having had these years of working together we know each other and what to expect from each other. **Patrice and Erin** work well together in the administrative aspects of the program. They are both well connected with the lobstermen in the area and now have years of experience conducting cooperative research. Their activities have recently expanded to other ventures (such as the ventless trap programs) which continue to overlap with each other. There are a number of ventless trap program participants in the vicinity of Casco Bay, for example, who are willing and able to participate in more than one research project. We have worked with many Casco Bay lobstermen in the past including Ed Hunt, David Johnson, and Elliot Thomas but there are dozens more to choose from.

Tom Long has managed the marine science/aquaculture lab at Southern Maine Community College for several years and has seen dozens of students through the system many who go on to university-level studies. His lab is ideal for the kind of work we are proposing here in that it is very much a "hands-on" approach to science where students often get out in the field and conduct actual research. He and his colleague **Brian Tarbox**, a lobsterman himself and actively involved in previous eMOLT drifter design, are the primary webmasters at www.mainemarineeducation.org. Tom has taught courses in, among other things, GIS applications where eMOLT drifter data was used as primary test cases.

Keston Smith has been involved with simulating the coastal ocean of Northern New England waters for several years and is actively involved with a project to forecast Alexandrium fundyense transport along the coast. He has conducted on-board data assimilation projects while at sea several times and is most familiar with the suite of state-of-the-art models developed at Dartmouth College over the course of the last few decades. He has worked closely with Manning on more than one project in the past (Schlitz et al, 2001; He et al, 2004; Lynch et al, 2001; and Aretxabaleta, 2004, and Anderson et al, 2005).

Jim Manning has been primarily involved with observations/data collection in his 20 years as a physical oceanographer at the NOAA lab in Woods Hole but has recently diverted much of his effort towards the organization of this data in the form of web-based data mapping utilities. Posting the wealth of observations collected at the NOAA lab on a public site in a user-friendly environment has become a priority step towards operational oceanography. His primary purpose in serving data is to support the effort of local numerical modelers who need this information for initialization and validation of their simulations. He has convened local ocean modelers for one day meetings on a semi-annual basis for several years in an attempt to coordinate the various efforts.

In addition to the PIs listed on the cover page, there are several individuals who will be involved with this project to some extent. **Ed Laine, Collin Roesler, and Greg Teegarden** who are all involved with marine education/science at Bowdoin College, Bigelow Laboratories, and St Joseph's College will be instrumental in experiments on the eastern portion of the bay. They may suggest relevant times and places to deploy drifters with respect to the Harmful Algal Bloom dynamics in that area. They have been recently funded in real-time monitoring of HABs and are interested in the processes that deliver and concentrate toxic algae in these waters. **Ernie True**

(Norwich University) is interested in all aspects of the program. He first deployed drifters in this area many years ago and now simulating the circulation in Casco Bay with shellfish aquaculture in mind. **Peter Milholland**, director of the Friends of Casco Bay, resides next door to SMCC and is also interested in partnering our efforts. We also hope to collaborate with oceanographers Townsend, Pettigrew, and Xue at U Maine Orono who have interest in nutrients, currents, and modeling, respectively, in this area and Incze and Wolff at USM Portland who we have worked with in the past. Oceanographers (Losier, Page) at the St. Andrews Biological Station have expressed interest in this work and may actually join some of the experiments with drifters of their own. They use a "CAST" drifter (Figure 5) in studies of dispersion around aquaculture sites in the Bay of Fundy and have wondered how these units might respond differently from ours.

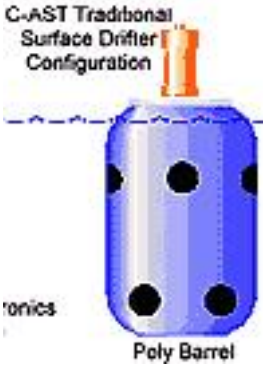

Figure 5. Schematic of the surface drifters used by the Dept. of Fisheries and Oceans in Canada. Do they have the same water following characteristics as the Davis-style units we use?

Dissemination of results, impacts and end-users

As implied earlier, the dissemination of oceanographic data has recently shifted from publications in obscure technical journals to more publicly-available **websites**. Oceanographers are now asked to provide their data in a real-time fashion to be used by multiple parties. Many efforts are underway around the region such as the "Gulf of Maine Ocean Data Partnership" where labs agree to post their data in a distributed fashion so that it can be easily accessed elsewhere. In addition to posting actual data, we have recently implemented MapServer, an open-source internet mapping software, that allows users to select data according to time and space and makes maps. This allows an individual to query several databases stored at NOAA's Northeast Fisheries Science Center and elsewhere, overlay multiple GIS layers (using "Web Mapping Services"), and generate customized views of the data. We plan therefore to mine various GIS layers available from Casco Bay to be included as background shape files.

The results of the study will be presented to **oceanography classes** in the Fall of 2007 at all colleges mentioned above and at meetings of lobstermen associations, ECOHAB researchers, and the Maine Fishermen Forum. These presentation will include animations of each experiment and comparisons of model vs observed tracks.

Given appropriate funding in the future, we imagine the real-time model system developed for this demonstration project **could become** operational such that a mariner could access a website to view forecast current fields for Casco Bay in the same way that one can do with the GoMOOS operational models of the Gulf of Maine. These services would benefit a variety of local user groups including the commercial shipping industry, pleasure boaters/kayakers, and USCG search and rescue units.

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Budget and budget justification

There are at least six parties involve with the project:

1. Administration: Gulf of Maine Lobster Foundation (GOMLF)
2. Drifter Construction: Southern Maine Community College (SMCC)
3. Drifter Deployments: Casco Bay Lobstermen
4. Drifter Recovery: Maine Lobstermen Assoc. and Massachusetts Lobstermen Assoc.
5. Model simulations: Dartmouth College
6. Data management/web services: Northeast Fisheries Science Center (NEFSC)

All administrators will attend 1-day meetings at least four times over the course of the project which may require overnight travel.

GOMLF is lead the organization responsible for general accounting including:

- ordering drifter supplies
- contracting student labor
- outreach to Casco Bay maritime community to alert them of the project
- compensating the lobstermen and lobstermen associations

Southern Maine Community College designs and constructs drifters

- build 18 drifters total in three different configurations
- compiles list of materials and suppliers used in construction
- float test in March 2007
- host drifter deployment workshop in April 2007
- delivers, assembles, and secure units on lobster boat once per month May-Aug
- assist lobstermen recovering still-floating units via cell phone
- primarily responsible for recovering beached units
- refurbishes all units for future use
- enters lobsterman's deployment & recovery logs in spreadsheet

Lobstermen Associations are responsible for conducting the following outreach work:

- select individuals in their organization to deploy/recover drifters
- select individuals in their organization to deploy/recover temperature probes
- ensure the lobstermen properly complete deployment & recovery logs
- initialize, distribute, collect, download, and document temperature probe deployments
- help lobstermen make arrangements with students on deployment and recovery days

Lobstermen conduct drifter deployment and recovery

- provide feedback on the feasibility and logic behind proposed dropsites
- provide USCG-approved license if and when taking on student passengers
- fill out deployment and recovery logsheets
- prepared to substitute fishing days with project activity on 2-3 days over the summer
- respond to problems associated with drifters getting hungup on fishing gear
- deploy array of temperature probes at multiple depths and multiple locations

NOAA/NEFSC will be responsible for:

- assisting students in the drifter design process
- participate in day-long drifter deployment workshop in April 2007
- determines drifter deployment sites
- processing and posting the realtime data within minutes of each sample
- providing up-to-date online analysis of the data
- execute model runs and forecast trajectories
- process temperature data from probes and satellite sensors and compare with model hindcasts initialized with climatology
- managing data including
    - storing data in Oracle tables
    - generating meta data
    - registering the data with national clearing houses
- make presentation of results at:
    - all 3 colleges mentioned above
    - Maine Fishermen Forum & Mass Lobstermen Weekend in 2008

Dartmouth College modeler will build a ready-to-be-executed model system by**:**

- generating a high resolution grid (10's meter per grid cell)
- generating 3d initialization fields from historical data
- assimilate NOAA/NOS tidal elevations and GoMOOS mooring velocities
- include wind, river, and offshore elevations as forcing
- suggest interesting deployment sites based on model runs (testable hypothesis)

Budget

ERIN L. PELLETIER

Gulf of Maine Lobster Foundation
PO Box 523 * Kennebunk, ME 04043
207-985-8088 * erin@gomlf.org

Experience

Gulf of Maine Lobster Foundation, Kennebunk, Maine
Office Manager and Project Coordinator 2003 to present

- Manage all aspects of several cooperative research projects with the lobster industry including eMOLT temperature probe project, eMOLT drifter project and Ventless Trap Survey

The Environmental Schools, Ocean Park, Maine
Associate Director 1998-2003

- Oversee daily operation of 4 residential environmental education sites in New England.
- Hire, train and supervise 25-30 seasonal teaching staff members
- Manage main office, communication among sites and with incoming schools

Controller 1999-2003

- Responsible for all financial records, budgets, accounts payable and receivable.
- Run weekly payroll and quarterly taxes
- Utilize Quickbooks

Program Director, Ocean Park site 1997-1998

- Directed the teaching staff, classroom teachers and students in daily program needs.
- Organized all activities and assisted with medical and teaching.

Naturalist 1995-1997

- Taught environmental education to 4th to 6th graders. Lessons included astronomy, forest, fresh water ecology, ocean and salt marsh.
- Responsible for a group of 10-12 students at a time.

Shoals Marine Laboratory, Appeldore Island, Maine
Teaching Assistant, Field Marine Science 1998

- Assisted professor in teaching preparation of lessons, field trips and testing for college level marine science class.
- Organized research groups with students and other scientists.

Seacoast Science Center, Rye, NH
Environmental Educator 1997

- Head counselor for kindergarten group at summer camp.
- Taught outdoor education with an emphasis on ocean ecology.

Education

State University of New York at Cortland
BS, Biology and Environmental Science, December 1994

PATRICE MCCARRON
Gulf of Maine Lobster Foundation
PO Box 523, Kennebunk, ME 04043

PROFESSIONAL EXPERIENCE

Executive Director ***November 2001 / Present***
GULF OF MAINE LOBSTER FOUNDATION – Kennebunk, Maine
- Oversee and manage programs for industry-based research organization.

Executive Director ***November 2001 / Present***
Associate Director ***March 2000 / November 2001***
MAINE LOBSTERMEN'S ASSOCIATION – Kennebunk, Maine
- Oversee all aspects of industry association. Serve as industry liaison for issues affecting the lobster industry. Serve on the Board of Directors of organizations including the Maine Fishermen's Forum and Gulf of Maine Ocean Observing System (GOMOOS)

Conservation Associate ***October 1998 / March 2000***
NEW ENGLAND AQUARIUM – Boston, Massachusetts
- Monitor fisheries management, policy and conservation issues through attendance of various and liaisons with fishing industry and other stakeholders.
- Organize multi-stakeholder forums on a variety of issues including lobster stock assessment and electronic information exchange and prepare forum reports.

Resource Center Director ***April 1997 / October 1998***
MARINE ENVIRONMENTAL RESEARCH INSTITUTE – Brooklin, Maine
- Managed all aspects of marine education center (staff, publicity, budget, etc.).
- Developed and managed marine education and community outreach programs.

Planner ***May 1996 / April 1997 and May 1995 / August 1995***
HANCOCK AND WASHINGTON COUNTY PLANNING COMMISION(S) – Ellsworth & Machias, Maine
- Advised coastal municipalities and community groups on coastal planning issues.
- Developed public education programs, coordinated and facilitated public meetings, and wrote proposals, reports and comprehensive planning chapters.

Coastal Outreach Consultant ***May 1995 / September 1995***
MAINE COASTAL PROGRAM – Augusta, Maine
- Coordinated marine debris reduction programs in Stonington and Eastport, Maine.

Education and Outreach Intern ***June 1994 / January 1995***
LAKE CHAMPLAIN BASIN PROGRAM – Grand Isle, Vermont
- Organized celebration of Lake Champlain and established VT natural resources license plate.

Peace Corps Recruiter ***June 1994 / May 1996***
UNITED STATES PEACE CORPS – Burlington, Vermont
- Managed all aspects of Vermont Peace Corps Recruiting office and conducted recruitment campaigns, public presentations, candidate screening and interviewing.

Founder and Manager of Wheelchair Factory (Peace Corps Volunteer) ***July 1991 / August 1993***
UNITED STATES PEACE CORPS, NATIONAL COUNCIL OF THE DISABLED – St. Lucia, Caribbean
- Established and managed wheelchair factory.

EDUCATION

University of Vermont – Burlington, Vermont
Master of Science – Natural Resource Planning ***(pending)***

University of Maine – Orono, Maine; Year abroad in Salzburg, Austria
Bachelor of Arts – International Affairs and German ***May 1991 with Highest Distinction***

Curriculum Vitae

James P. Manning

NOAA National Marine Fisheries Service
166 Water St.
Woods Hole, Ma.02543
Tel: 508-495-2211, email: james.manning@noaa.gov

Education:

B.A. Mathematics, 1979, University of Maine
M.S. Oceanography, 1987, University of Rhode Island

Experience:

1987-present: *Oceanographer* NMFS Woods Hole, Ma.
1987: *Oceanography Instructor* Acadia Institute of Oceanography, Seal Harbor, Me.
1983-1987: *Marine Research Specialist* Graduate School of Oceanography, URI
1982-1983: *Research Assistant* Center for Coastal Studies, Provincetown, Ma.

Selected Committees & Distinctions:

Gulf of Maine Ocean Data Partnership Tech Committee (2003-present)
Northeast Fisheries Science Center Ecosystem Monitoring Task Force (2005-present)
NEFSC Judith Brennan Hoskins Award for Excellence (2003)

Peer-Reviewed, First-Author Publications:

Manning, J.P. and D.R.Watts. 1989. Temperature and Velocity Structure of the Gulf Stream Northeast of Cape Hatteras, Jour. Geophys. Res. 94(C4):4879-4890.

Manning, J.P. 1991. Middles Atlantic Bight Salinity: interannual variability. Cont. Shf. Res. 11(2):123-137.

Manning, J.P.. L.Y. Oey, D. Packer, J. Vitaliano, T.W. Finneran, K.W.You, and S. Fromm. 1994. Observations of Bottom Currents and Estimates of Resuspended Sediment Transport at the New York Bight 12-mile Dumpsite. Jour. Geophys. Res. 99(C5):10,221-10,239.

Manning, J.P., 1996. Oceanographic Conditions of Georges Bank Spawning Grounds: 1992-1994. NAFO Scientific Council Series Doc. No. 24. p.125-141.

Manning, J.P. and R. Beardsley. 1996. Assessment of Georges Bank Recirculation from Eulerian Current Observations in the Great South Channel. Deep Sea ResearchII. Vol. 43(7-8):1575-1600.

Manning, J.P. and G. Strout. 2001. Georges Bank Winds: 1975-1997. Deep Sea Res.II. 48:115-135.

Manning, J.P., R.G. Lough, C.E. Naimie, and J.H. Churchill. 2001. Modeling the effect of a slope water intrusion on advection of fish larvae: May 1995 on Georges Bank. ICES Jour. Mar. Sci. in *Recruitment Dynamics of Exploited Marine Populations: Physical-Biological Interactions* Vol.58(5) 985-993.

Manning, J.P. and J.H. Churchill, 2006, Estimates of dispersion from clustered-drifter deployments on the southern flank of Georges Bank. In Press Deep Sea Research II..

Manning, J.P., D.J. McGillicuddy, W.R. Geyer, J.H. Churchill, and L. Incze, 2006, Observations of Maine Coastal Current Drift. (in Prep).

Peer Reviewed Co-Authored Publications

Anderson, D.M., D.J. McGillicuddy, B.A. Keafer, M. Michelson, K. Keay, P.S. Libby, J. Manning, C. Mayo, D. Whittaker, J.M. Hickey, R. He, D. Lynch, K. Smith, 2006. Initial Observations of the 2005 Alexandrium fundyense bloom in southern New England. Deep Sea Research II.

Aretxabaleta, A., J.P. Manning, F.E. Werner, K. Smith, B. Blanton, and D.R. Lynch, 2004. Hindcasting May 1999 on the Southern Flank of Georges Bank: frontal circulation and implications. *Cont. Shelf Res.* 25 (7/8), 849-874.

Bisagni, J.J., R.C. Beardsley, C.M. Rusham, J.P. Manning, and W.J. Williams. 1996. Historical and recent evidence of Scotian Shelf Water on southern Georges Bank. Deep Sea ResearchII (7-8):1439-1472.

Chen, C., R. Schlitz, K. Smith, R.C. Beardsley, J.P. Manning, and R.G. Lough, 2003, Wind-Induced, Cross-frontal water exchange on Georges Bank: A Mechanism for the early summer on-bank larval transport. Jour. of Geophys. Res., VOL. 108, NO. C11, 8011, doi:10.1029/2002JC001358.

Churchill, J.H., J.P. Manning, and R.C. Beardsley, 2003, Slope water intrusions onto Georges Bank, Jour. Geophys. Res. Vol.108, No.C11.

He, Ruoying, D. McGillicuddy, D.R. Lynch, K.W.Smith, C.A.Stock, and J.P.Manning, 2005. Adjoint Assimilation Model Hindcast of the Gulf of Maine Coastal Current. Jour. Geophys. Res. Vol. 110(C10011) doi:10,1029/2004JC002807.

Lentz, S., R.C. Beardsley, J.P.Manning, J.Irish, K. Brink, and P.C. Smith, 2003. Temperature and salt balances on Georges Bank February - August 1995. Jour. Geophys. Res. Vol. 108(C11):8006, doi:10.1029/2001JC001220.

Lough, R.G. and J.P. Manning. 2001. Tidal-front entrainment and retention of fish larvae on Georges Bank. Deep Sea Res II. 48:631-644.

Lynch, D.R., C.E. Naimie, J.T. Ip, C.V. Lewis, F.E. Werner, R. Luettich, B.O. Blanton, J.A. Quinlan, D.J. McGillicuddy, J.R. Ledwell, J. Churchill, V. Kosnyrev, C.S. Davis, S.M. Gallager, C.J. Ashjian, R.G. Lough, J. Manning, C.N. Flagg, C.G. Hannah, R.C. Groman. 2001. Real-time assimilative modeling on Georges Bank. Oceanography. 14(1):65-77.

Mountain, D.G. and J.P. Manning. 1992. Seasonal and Interannual Variability in the Properties of the surface waters of the Gulf of Maine. Cont.Shf.Res. 14(13/14):1555-1581.

Pershing, A.J., P.H. Wiebe, J.P. Manning, and N.J. Copley. 2001. Evidence for vertical circulation cells in the well-mixed area of Georges Bank and their biological implications. Deep Sea Research II. 48:283-310.

Oey, L.Y., J. Manning, H.T. Jo, and K.W. You. A plume and wind driven circulation model of the New York Bight. 1995. Quantitative Skill Assessment for Coastal Ocean Models. D.R. Lynch and A.M. Davies. American Geophysical Union. Coastal and Estuarine Studies Volume 47. p.329-347.

Schlitz, R., J.P. Manning, and K. Smith. 2001. Structure and transport of Alongshelf currents across the Southern Flank of Georges Bank during late summer. Deep Sea Res. II. 48:341-372.

David Casoni

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Plymouth, Massachusetts
508-224-3038
lobsterteacher@hotmail.com

Education:

Masters in Biology

Past Experience:

34 years teaching school in Hanover, Massachusetts.
37 years commercial lobstermen

Current Positions:

Secretary/Treasurer for the Massachusetts Lobstermen's Association
Executive Board of the Shore Shore Lobstermen's Association
Executive Board of the East Boat Basin Commercial Fisheries Association
Massachusetts Ocean Management Task Force

Tom Long
Southern Maine Community College Marine Science
2 Fort Road
South Portland, Maine 04106
207 741-5641
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2000 – Present

Laboratory Manager – Science Department – SMCC
Responsible for all Lab oversight, materials and equipment acquisition and maintenance and management of student labor and internships.

Past Experience

Twenty-seven years owning, operating, and managing several small businesses.

Education

A.S. in Applied Marine Biology and Oceanography – Southern Maine Technical College.

Description of prior cooperative research results and impacts

As noted earlier, this proposal is a natural descendant of eMOLT phase IV project, conducted duirng the summer of 2004, when nearly 100 drifters were deployed in the Maine Coastal Current. This year's proposal is very similar to its predecessor except we have now shifted our focus on a smaller time and space scale. The 2004 study investigated the larger scale (~100km) processes of the coastal current system on seasonal time scales (~months) while this new proposal intends to investigate processes in a limited area (1-10km) on shorter time scales (~days).

The 2004 study has been documented completely in the final report to NEC and the analysis is underway in Manning et al. 2006. The analysis provides statistics on various sub-regions of the gulf such as residence times and the percentage of units advecting inshore or offshore within a specified box. One example is depicted in Figure which shows units crossing the 69W longitude near Cape Small being generally advected by Casco Bay with very little entering. One is left wondering, therefore how and under what conditions do coastal current water parcels enter the Casco Bay system?

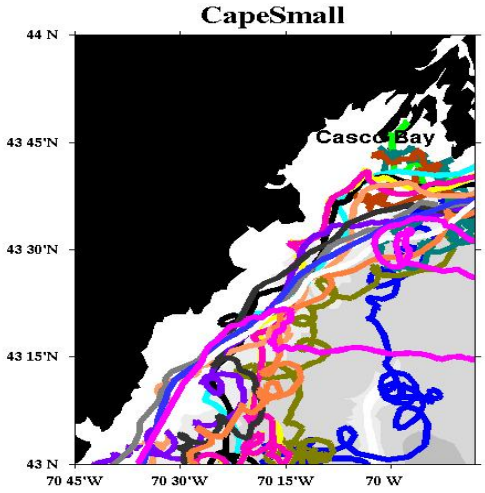

Figure 6. Tracks of eMOLT drifters 2003-2005 demonstrating propensity to by-pass Casco Bay. Only a few drifters entered the bay.

The archive of drifter tracks resulting from a compiling of historical data, the 2004 eMOLT data, and subsequently funded studies is available at both emolt.org (under "drifter study") as well as the NEC website. In both cases, users can query the data by space and time parameters and download actual latitude/longitude records from each track. The system has become an integral component of a new website for "Oceanography at the Northeast Fisheries Science Center" at http://www.nefsc.noaa.gov/epd/ocean/Mainpage .

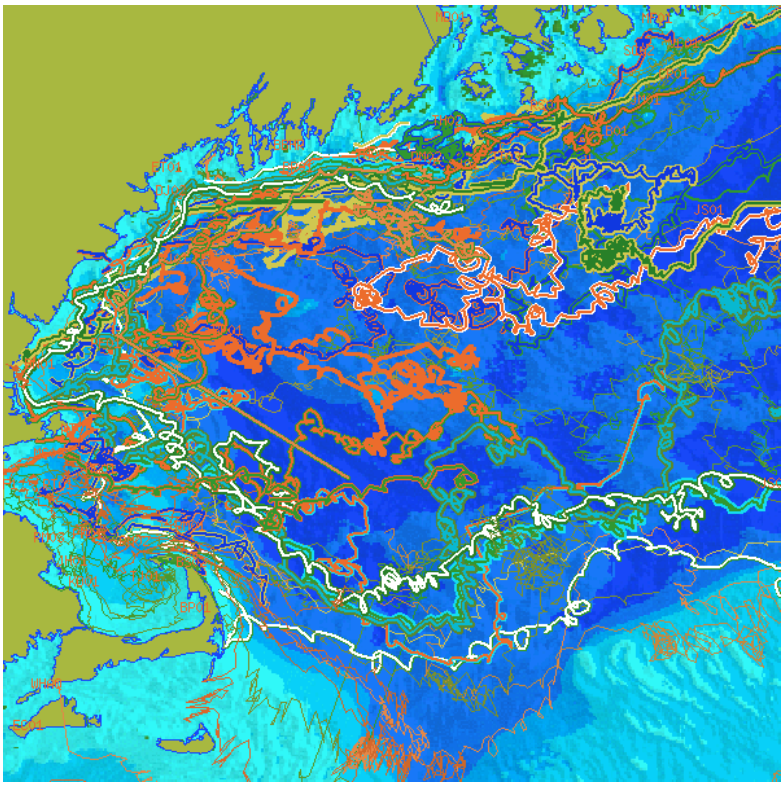

Figure 7. Overlay of all drifters tracks prior to 2006 emanating from Gulf of Maine dropsites.

The drifters developed for the 2004 eMOLT study have now been used by several other research labs (WHOI, UMASS Dartmouth, Mass Water Resource Authority, MIT, NOAA/NEFSC, and the Univ. of S. Maine) to investigate a variety of processes. While the primary use has been in tracking HABs in the Bay of Fundy and GoM, other applications include tracking power plant effluent, sewage outfall effluent, invasive crabs dispersal, and zooplankton advection related to right whale concentrations.

In some ways, this proposal follows up on and is very similar to Lew Incze's NEC-funded project in 2005 where drifters were deployed and allowed to flow for a few days before being recovered for subsequent use (Figure 8). Incze's objective was to study a limited-area of the coastal current system south of Penobscot bay and to document the effects of a well-documented frontal system in that area. Four clusters of four drifters each were deployed in the vicinity of the front.

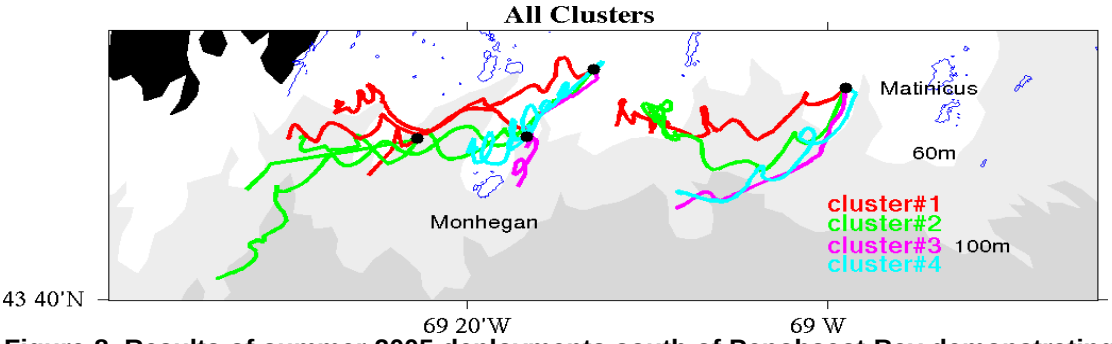

Figure 8. Results of summer 2005 deployments south of Penobscot Bay demonstrating the day to day variability of drifter trajectories. Clusters were deployed over a period of 10 days.

As concluded in Incze et al 2005, the most significant results include a) rapid cross-frontal movement of drifters is possible, b) large day-to-day variability in the fate of drifters emanating from the same drop sites, c) large day-to-day variability in the speed of advection (apparently related to both the drifter's position relative to the front and small wind events), and d) significantly more variable temperature records at 5m relative to 1m. This last observation, resulting from temperature probes on drifters and their sub-surface drogues, supports the notion that the subsurface layer may be subsiding below the thin surface layer. This is important for interpreting sea-surface temperature (SST) data and transport potential for plankton along the coast.