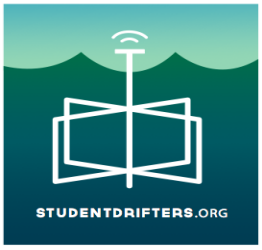
# Student-built, fishermen-deployed, satellite-tracked drifters validating numerical coastal ocean models





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## Project Summary

When there is a spill of toxic substance, oil, or any other pollutant in our coastal waters, how well can we predict the transport of this material on a time scale of days? How well can we assess transient biological hotspots where forage and predatory fishes aggregate, attracting flocks and herds of marine mammals and birds? How well do we understand the larval dispersal of commercially significant species such as lobster? Most importantly, how can such investigations contribute to better understanding of biophysical ocean processes and evidence-based conservation planning? As we begin the process of marine spatial planning of Canadian coastal waters, do we have the tools and expertise to address these **issues/problems**? Since the perceptions of "risk" and information gaps vary widely among stakeholders, a discussion among various sectors of the marine-related communities is essential. We propose to address **MEOPAR's vision** by having schools around the country (primarily eastern Canada but also at least one on the West Coast) build satellite-tracked drifters with the help of scientists and graduate students, and then bring these to local offshore fishermen to be deployed at "specified times and places" AND in a "fast-response mode" in cases of emergency. Results will be presented at the end to local emergency response teams, harbor masters, ferry operators, coast guard personnel, fishermen, coastal community town councils, the marine transportation industry, aquaculturists, tidal power companies, offshore oil and gas operators, and ocean modelers.

The **primary purpose** of the data is to help local numerical circulation modelers (**"end users"**) validate their simulations and predict transport of free-drifting particles. Our assessment work will include, but will not be limited to, the NEMO model (Nucleus for European Modeling of the Ocean), around which much of the MEOPAR Predictive Core centers, as well as data derived from High Frequency Radar installations along the coast. In addition, close coordination with MEOPAR's Observation Core is obviously needed to maximize the usefulness of data and its exposure to all sectors of society. Given our numerous connections with fishermen as well as government and university scientists in Canada and the US (IOOS, NERACOOS, FSRS, eMOLT, GOMLF, ESIP, NSERC CFRN), we can make a significant contribution to MEOPAR's vision of building partnerships outside the traditional academic circles. The **secondary purpose** is to provide experiential learning opportunities in oceanography and numerical literacy, both at the high school and graduate levels. The graduate students (HQPs), in collaboration with the scientists, will introduce school children to oceanography, geographic information systems, as well as particle tracking, and they will teach them how to process data collected by their real and simulated drifters (plus a variety of other ocean observing system data). HQPs will participate in a multi-day workshop in Woods Hole, MA, where they will be trained in particle tracking using Python as programming language. They will all produce graduate theses involving modeling and validation of ocean circulation, in different contexts. We will provide a real-world Science Technology Engineering and Math (STEM) experience and an introduction to ocean literacy.

## Alignment with MEOPAR Strategic Objectives

As noted in the summary above, we plan to develop and test "*new tools for rapid environmental assessment and forecasting of the marine environment during emergencies*", to fill key "*information gaps*" and "*train highly qualified personnel … in addressing real-world concerns related to the coastal marine environment*". We hope to expose hundreds or perhaps thousands of students to the principles of **ocean literacy** and, in particular, the discipline of physical oceanography and computer modeling. We introduce these students to the fishermen along their coast, other mariners whose livelihood depends on the sea, and the local scientists who attempt to simulate a very complex marine environment.

Our goal is to combine our efforts with **existing projects** already underway. We do not intend to coordinate another independent initiative. We also hope to build on work previously funded by MEOPAR and other federal funding programs (e.g., NSERC Strategic Networks) and enhance those projects. There are also a set of operational systems around the country that we intend to connect with including, for example, the Canadian Operational Network of Coupled Environmental Prediction Systems (CONCEPTS) and the Canadian Coast Guard Environmental Response Program. We imagine the end products of our work being highly applicable to a variety of investigations beyond response to emergency situations and filling key biophysical oceanographic knowledge gaps relevant to fishers and resource managers. The modeling outputs can be applied to the movements of larvae, forage fishes and large marine predators, search and rescue, assessing aquaculture sites, tidal kinetic energy potential, sediment transport and erosion, and much more.

A number of **scientific investigations** that are related to MEOPAR's mission, and where surface current study is needed, are underway in 5 "coastal regions" of the country. 1) **In New Brunswick** and throughout Eastern Canada, the "Lobster Node" of the NSERC Canadian Fisheries Research Network uses an individual-based biophysical model to assess connectivity and stock structure of American lobster "sub-populations" throughout the specie's range in Canadian waters. There is also interest in using ocean circulation models to study and predict the range expansion of invasive species and the distribution and movement patterns of plankton-feeding seabirds in the North Atlantic. 2) In **Newfoundland** there are projects related to capelin and lobster larval drift as well as a case of a chronic oil spill from a sunken vessel. This proposal also aligns well with a Citizen Science Project being developed at Memorial University. 3) **In Nova Scotia** there are regions of "bifurcations" where the coastal current splits into two independent currents and repeated deployments upstream can document the variability in circulation under different weather and seasonal conditions. 4) **In Quebec**, Dumont and collaborators are assessing and testing the capacity of ocean circulation models and high-frequency RADAR to reproduce in real-time the trajectories of various floating objects and substances within operational, environmental emergency and search & rescue frameworks. 5) In **British Columbia**, investigators want to increase our understanding of the surface circulation in the waterways of the central coast, validate a circulation model they are developing, and improve understanding of the linkages between the circulation and the whale habitat in the area. Some additional details on these different "applications" can be found below and in letters of support.

## Research Plan, Approach & Outcomes

Coastal circulation modeling has made tremendous advances in the last few decades so that there are now a variety of gridded fields available for most regions off our coasts in both hindcast and forecast modes. There is still much work to be done however to quantify the uncertainty in these products and help refine them in the future. The validation process requires substantial measurements to be made in different years, throughout different seasons, weather conditions, areas of the grid, and layers of the water column. In some cases, these observations can be assimilated into the model in real-time to improve accuracy. Since the Canadian coastline is so vast and topographically complicated, it is essentially impossible and certainly cost prohibitive to deploy enough of Eulerian moorings to restrain the model flow field. Deployment of low-cost drifters on a regular basis together with the existing array of HF Radar provides an alternative.

There are a variety of drifters commercially available, but the vast majority of these fall into one of two categories, the standard surface drifter (Davis, 1985) or the holey-sock drogue (Niiler, 1995). The transmitters for these devices are generally made by the drifter manufacturers and typically use an expensive electronic package and satellite system. Given the explosion of GPS technology in the last decade, it is now possible to construct a relatively low-cost drifter according to oceanographic standards in the classroom. This process has been underway in the US for more than a decade and is documented at studentdrifters.org. Construction manuals are posted along with lesson plans on what to do with the data. Teachers are finding that students are curious and excited to watch the progress of their drifters each morning on the googlemap displays. They are learning some basic facts about oceanography. The ocean moves. The water off our coast is often not the same water it was the day before, there is interconnectedness of the global oceans.

Given the advances in model and data interoperability, it is now possible to access a variety of model output stored remotely in standard formats. Model **users** can now download the gridded fields and visualize the 3-D flow fields on their desktops. Due largely to the efforts of the US IOOS, the protocols for posting model and data products have been well developed. The software to extract and investigate the terabytes of information, however, is still largely under development. We need to train the next generation of oceanographers to digest the model output, refine the metrics for evaluating its uncertainty, and generate products that help explain the various processes governing the current fields off our coast.

Just as modelers are posting simulated flow fields, observationalists are also serving quality-controlled data according to ocean observing system standards. We post the drifter data in two stages and formats, the first being raw positions within minutes of each transmission and the second being a processed form after the drifter completes its track. The processing involves a series of quality-control steps including range and delta checks on position, velocity, and acceleration. The GPS accuracies on the order of meters are generally sufficient for model validation purposes. These QA/QC routines will be further developed and passed on to the students.

A major part of the software development is the **particle tracking code.** To advect a numerical particle through a 3-D model flow field is not a simple task given the need to parameterize the subgrid processes

that occur, the effects of waves, the processes at the boundaries, vertical behavior of larvae, etc. Just as circulation modelers need to join together as research **communities**, we envision a subgroup of particle trackers combining their code and expertise in a nationwide effort to tackle this project. The process begins, however, in recruiting some of our video-gaming youth into the field of real world coding and visualization. See training and HQP section below.

*Project timeline:* To get started, one-day **workshops** will be held at each location listed in Table 1 in both the first and second years of the project. These will be held at a school and will include a combination of high school and university age students. The workshops will be divided into 3 periods:

1. learning how to build drifters from locally available materials according to oceanographic standards (Manning, 2012; Manning et al., 2009) using eco-friendly materials (bamboo, cotton cloth, wood, and aluminum) that minimize the plastic entering the ocean;
2. addressing the social science aspects of the project, discussing the local applications, marine-debris, and other ecological aspects including how the project contributes to ocean observing systems;
3. getting started with open-source software programs (nefsc.noaa.gov/drifter/particles.html) designed to visualize both observed and modeled drifter tracks and overlay other oceanographic parameters. Students will learn basic coding techniques and some basic ideas about mapping and GIS (Hochstaedter and Sullivan, 2012).

We are proposing, therefore, a total of five **workshops** each of the first two years with one located in four provinces in Atlantic Canada and one on the west coast. Furthermore, one multi-day workshop will be held in Woods Hole MA where Canadian graduate students will be trained in Python particle tracking. In the third year, a series of five **conferences** will held at the same five sites as the workshops where students, teachers, and scientific advisers present their results to community officials, fishermen, the local emergency response teams, harbor masters, ferry operators, coast guard personnel, the marine transportation industry, aquaculturists, tidal power companies, offshore oil and gas operators, and ocean modelers. Some of these conferences may be coordinated around particular MEOPAR Expert Forum events in order maximize the attendance and include some international participation.

The project involves significant training exercises in order to bring the next generation of students into the fields of physical oceanography and computer modeling. Since it has both an observational and predictive mode, it requires multiple steps to develop.

- Fall 2014: particle-tracking training and drifter-building workshop for graduate students in Woods Hole
- Spring 2015: a set of drifter-building, motivational, and software-training workshops at several high school locations
- Spring 2015 through Fall 2015: repeat drifter deployments by fishermen at both fixed locations/times and in any emergency
- Fall 2015: follow-up workshop at the five high school or university locations to examine the data and learn more coding
- Spring 2016: a set of local conferences to present results to all interested parties

In order to reduce the costs of travel for participants, some of the proposed workshops and conferences will be connected with already scheduled annual meetings (Coastal Zone Canada, Ocean Sciences, FSRS).

The "five workshops per year" will each be associated with particular applications or scientific investigations, many of which involve graduate student thesis projects. These include real-world studies of actual processes already fully or partially funded in some way, so that we will be adding to an existing set of observations, analyses and research projects. We consider these workshops "pilot demonstrations" of the operation and hope to spawn more like them in the future. The five applications have different spatial scales but are all associated with time scales of days to weeks. As noted above, in the table below, and in the letters-of-support, they are located in different provinces.

Table 1. Applications (scientific investigations) associated with the workshop-conference series.

| **Application** | **Lead Partners** | **Location** | **Institutions** |
|---|---|---|---|
| Lobster Demography | Remy Rochette* | Eastern Canada | University of New Brunswick |
| Seabird Ecology | Bill Montevecchi, Heather Major* | Newfoundland New Brunswick | Memorial University, University of New Brunswick |
| Model Validations | John Terry, Dave Greenberg | Nova Scotia | Gulf of Maine Institute, DFO |
| Model Validations | Fred Page* | New Brunswick | St Andrews Biol. Station, DFO |
| Whale Habitat | Charles Hannah, Svein Vagle | British Columbia | Institute Ocean Sciences, DFO |
| Improving Drift Forecast | Dany Dumont | Quebec | Université Québec à Rimouski |
| Invasive species | Heather Hunt* | New Brunswick | University of New Brunswick |

*Four applications will combine for workshops in New Brunswick.

*Longer-term perspectives (i.e. beyond lifetime of the project, if any)*

The entire project will be documented both on the web, in annual and final reports, and in peer-reviewed scientific journals. The website will include real-time maps of drifter tracks and their modeled counterparts, individual pages for each of the participating school districts, and a complete description and posting of the open source programming tools. An assessment of the local circulation model's ability to forecast trajectories will be made. Collaborations between teachers, scientists, fishermen, response teams, coastal zone managers, aquaculturists, and many other disciplines will be developed. While it is already documented at multiple sites, including for example studentdrifters.org, nefsc.noaa.gov/drifter, and neracoos.org/drifters, we plan to expand that list to the oceanviewer.org and DFO's drifting buoy site in order to maximize exposure to multiple communities. Lesson plans are under development and will be expanded upon with special focus on Python programming techniques to process and visualize physical oceanographic data. Ultimately, the project aims to develop an "operational network" of multiple parties associated with monitoring, modeling, and assessing the transport pathways of coastal waters around the region and stimulating the next generation of scientists to build on the existing tools. As a first effort to introduce this project and expand the network we plan to present the project at the OCEANS 14 Conference that is being held at the Marine Institute of Memorial University in September 2014, which is focused on *Youth and the Ocean*.

The ultimate objective of the drifter deployments is to validate ocean models. This is already underway (Li et al., 2013 and Manning et al., 2009) for the Northeast Continental Shelf and the same methods can be applied elsewhere. Given repeated deployments in particular water bodies (Fig. 1), statistical quantities of the flow fields can be derived (Fig 2).

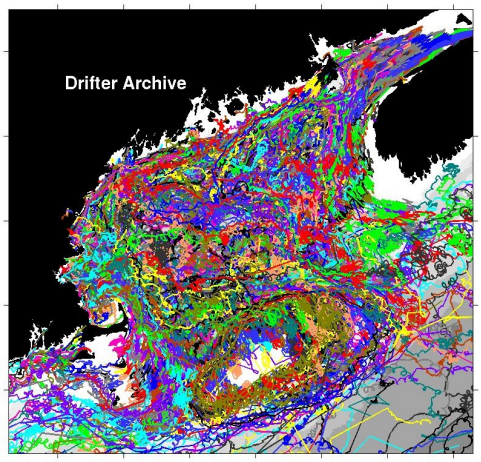


Figure 1. Example of tracks made by drifters deployed since 2003 in as part of the student-drifter project led by James Mannings at NOAA.

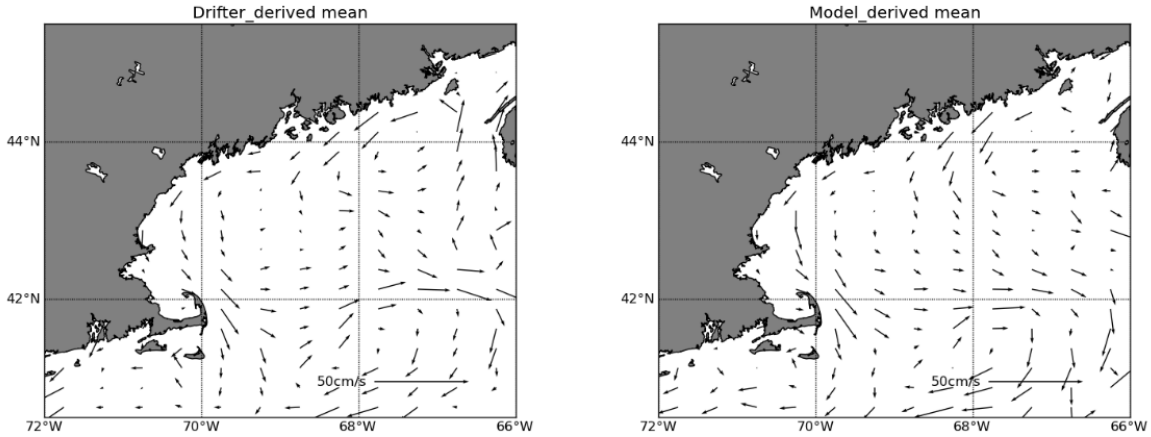


Figure 2. Comparison of observed (left panel) and modeled (right panel) flow fields resulting from deployment of student drifters in the Gulf of Maine.

Also, as noted above, we are proposing to demonstrate the operation with at least one application on the West Coast with the help of our colleagues at the Institute of Ocean Sciences in British Columbia. Given the complexity of the British Columbian coasts, we do not expect to resolve much of the flow field with a relatively small set of drifter deployments but hope to provide an example of the operation and express the potential to expand around the province through various school districts. We similarly expect to expand the east coast applications to Prince Edward Island, likely by coordinating with our CFRN Lobster Node collaborators from industry and government.

## Excellence & Interdisciplinary Balance of the Research Team

**Project Lead PI**: **Rémy Rochette** (University of New Brunswick) is the lead PI and overarching project manager; day-to-day operations will be the responsibility of the project coordinators. Dr. Rochette has been a faculty member at UNB (Saint John) since July 2001, and is currently Chair of the Biology Department. His research is on the ecology, evolution and conservation of coastal marine habitats and organisms. He has 35 publications in peer-reviewed journals and a strong track record of HQP training (currently supervising or co-supervising 5 PhD, 5 MSc and 3 Honours students). He was recently lead PI of two NSERC Strategic project grants, one aiming to develop a program and tool to quantify biodiversity of shallow rocky-bottom coastal habitats and the second to validate a technique to directly assess the age of decapod crustaceans. Since 2011 he is the lead PI of the NSERC Canadian Fisheries Research Network's *Lobster Node*, which is a large tri-partite collaboration between academics (UNB, Université Laval in Québec, Université de Moncton in NB, Université Sainte-Anne in NS), government scientists (lobster biologists from four different DFO labs) and lobster fishermen from 16 different associations throughout eastern Canada. The project aims to identify lobster biological units, or stocks, to enhance the scientific foundation of discussions concerning the placement and size of lobster fisheries management areas. One pillar of the collaboration with DFO scientists and lobster fishermen is a bio-physical model of the dispersal of lobster larvae throughout the species' range. Considerable efforts and resources are being invested in constructing and populating this model, and the present proposal to MEOPAR will make an important contribution to its validation.

Our project team consists of two major groups/categories. Aside from the project PI, we have a set of "Project Coordinators" as well as several "Research Partners/Collaborators". The coordinators, who are already familiar with the student-drifter project, will be responsible for organizing the materials and conducting the student workshops. The research partners/collaborators will be responsible for organizing the workshops in their respective communities and they will support at least one graduate student, who will both contribute to and benefit from the education and research planned through this project.

**Project Coordinators: Cassie Stymiest** (Program Manager of Northeastern Regional Association for Coastal Ocean Observing Systems) has been coordinating drifter workshops for the past two years as part of her responsibilities as Program Manager where she leads other educational programs and organizational projects. **Shannon Scott-Tibbetts** (Fishermen and Scientists Research Society) is the Research Biologist for the FSRS. She helps coordinate the various research projects and has been involved in fisheries science for 15 years. **Christine Tilburg** is the Program Manager for the Gulf of Maine Council on the Marine Environment's EcoSystem Indicator Partnership (ESIP), which is a bi-national partnership between academics, governmental employees and non-governmental individuals brought together to assess the health of the Gulf of Maine through ecosystem indicators. ESIP uses several different information channels to broadcast information about the Gulf of Maine/Bay of Fundy including fact sheets and webtools, both of which might be useful with the proposed work. **Jim Manning** (Oceanographer at National Oceanic Atmospheric Association) founded the drifter project in the US over a decade ago and has been primarily responsible for processing and posting the data. He works with a variety of teachers, fishermen, and numerical modelers. **Erin Pelletier** (Executive Director of Gulf of Maine Lobster Foundation) has been coordinating much of the drifter project since its inception in 2004. She works with the schools and serves as a liaison with the satellite service providers.

**Maria Recchia:** (Executive Director of Fundy North Fishermen Association) has helped many projects like this one connect with fishermen in the Bay of Fundy.

**Research Partners/Collaborators: Dave Greenberg, Charles Hannah, and Fred Page** (BIO/DFO, IOS) have been involved with both modeling and observations of Canadian coastal waters for decades (see letter of support). **John Terry** (President of Gulf of Maine Institute) has been conducting student "summits" concerning the marine environment on both sides of the US-Canadian border (see letter of support). **Bill Montevecchi:** (Seabird Biologist from Memorial University) directs a research program focused on seabirds as bio-indicators in marine ecosystems and is involved with a variety of MEOPAR-like projects off the coast of Newfoundland (see letter-of-support). **Dany Dumont** is an early-career physical oceanographer at ISMER-UQAR specialized in coupled wave-ice-ocean numerical modeling. He is the leader of a project recently funded by MEOPAR titled *Improving marine drift and dispersion forecasts* (see letter of support). **Heather Hunt** is a marine ecologist who has been a faculty member at UNB (Saint John) since 2002. Her research is on the ecology of coastal marine ecosystems, with particular interests in recruitment of benthic marine invertebrates, marine biodiversity, and climate change. She has been involved in two recent NSERC Strategic Projects, one on kelp-urchin dynamics in the St. Lawrence and another aiming to develop a program and tool to quantify biodiversity of shallow rocky-bottom coastal habitats. She is the author/co-author of 31 peer-reviewed journal publications and she has a strong track record of HQP training. **Heather Major** is a recent faculty member at UNB (Saint John) whose research program focuses on seabird habitat selection, population dynamics and conservation. She has over 10 years of experience working with seabirds in both the Pacific and Atlantic oceans, including projects using radio and geolocation tags to assess seabird movements between ocean basins as well as between and within colonies. She uses a wide variety of analysis and statistical techniques, including relating large-scale oceanographic indices with seabird demography, geographical information systems, population modeling, stable isotope analysis, and linear, mixed, and hierarchical statistical analyses. **Melanie Wiber** is an Anthropologist/Social Scientist at UNB (Fredericton). For more than 15 years she has conducted participatory, community-based, fisheries research in the Maritime Provinces. From 2006-2012, she was co-applicant on the Coastal CURA (Community and University Research Alliance), funded by the Social Sciences and Humanities Research Council of Canada (SSHRC), where she collaborated with Dr. Tony Charles (SMU) and other team members, on integrated coastal management (see www.coastalcura.ca). She has led a Working Group on the Socio-Economics of Integrated Management for the Oceans Management Research Network (OMRN) that was collaboratively funded by SSHRC and Fisheries and Oceans Canada (DFO) (see letter of support).

At least one coordinator will be on hand at each of the workshops and will share the responsibility of training the students with research partners and their graduate students. Pelletier will continue to act as the liaison with the satellite-service providers, and Manning will continue to act as the data processor and technical consultant. Terry will act as a consultant and participant in conducting student summits as he has for years. Hannah, Greenberg, and Page will provide a link to the Canadian Government. Pelletier, Recchia, and Scott-Tibbetts provide a link to the fishermen. Stymiest and Tilburg provide a link to observing system organizations. Wiber brings the social science aspect of the project to the table, having over 15 years of experience working with multiple stakeholders on ocean management issues, primarily in the fisheries.

## Multi Sectorial Structure and Support

Given more than 10 years of experience with the student-built drifters program, we have developed a large and diverse network of partners. More than 50 schools in the US have been exposed to the drifters at some level, from building the units to sponsoring the deployment and following their tracks in the classroom. Since approximately half of the 1000+ ocean-going drifters have eventually come ashore or been recovered, we now have a database of hundreds of beachwalkers and mariners who have reported their findings. In many cases these individuals get interested in the project and subsequently get involved with refurbishments, redeployments, and actually bring the idea to their local schools. It is a project that grows on itself, and through this proposal to MEOPAR we wish to expand it to high schools and universities in Canada.

As an example of how this project can work, take the case of early May 2010 where the Center for Student Coastal Research (an after school program for high school students in Cohasset, Massachusetts) built a dozen drifters for the Massachusetts Division of Marine Fisheries Lobster Larvae Drift project in exchange for a few drifters of their own. When word came of the BP oil spill, however, these units were all shipped to the Gulf Coast where they were loaded on research ships and subsequently deployed. Another NOAA-funded drifter building session was conducted the following weekend with a dozen students involved to provide more drifters to be shipped south. In the end, we contributed dozens of drifters to the concerted effort to track the spill. These drifters were deployed by at least four different research vessels leaving from docks in Lousianna and Florida.

Another example of MEOPAR-like activity occurred the following year, when the US Coast Guard was conducting oil-spill response training exercises off the coast of Portland, Maine, one of the biggest shipping terminals on the east coast of the US. The students at the Southern Maine Community College loaded a drifter they had built on to the Coast Guard Cutter, and this drifter was subsequently deployed during the drill alongside other units. Back at the lab, computer simulations were run to estimate the path of the drifters. Animations of the experimental results were produced with multiple email exchanges. The US Coast Guard has been our partner in a variety of occasions like this. They have been involved with a number of deployments and recoveries. We share data with them and they share their air-deployed drifter data with us.

*End user involvement*

While the project is designed with young students in mind, it is often the parents, the teachers, and the various mariners who are most interested in the results. With this in mind, we have proposed a series of "conferences" during the final year of the project where students will present their results to a wide audience including all sectors of society. This exposure often leads to additional projects and spawns new funding alliances. In recent years, we have been approaching and been approached by a variety of charitable foundations whose primary mission is related to STEM education.

*External partnerships (business, government, other academia, non governmental organizations)*

A number of partnerships have arisen over the years due to a variety of applications. This past fall, for example, the Mass Audubon Society wanted to document the surface currents in Cape Cod Bay to explain the path of the many "cold stun" turtles that were coming ashore. They organized an after school

program with the local high school, built some drifters, and with the help of a local fisherman, deployed them in the bay on multiple occasions. The Town of Eastham's Department of Natural Resources got involved recovering some of the units. The Cape Cod Natural History Museum had the students make a presentation on the project at a local symposium. Plans are already underway to extend this work next fall.

We now wish to expand the student-drifter project to high schools and universities in Canada, and we have assembled here a strong and multi-sectorial team of collaborators to do this and do it well. Our team comprises the US scientists and coordinators that have designed and delivered the student-drifter project in the US, in addition to an existing and successful network of Canadian scientists and industry collaborators. For example, the lead PI is currently leading within the NSERC Canadian Fisheries Research Network a large project called the *Lobster Node,* which aims to elucidate stock structure and connectivity of lobsters throughout coastal waters of eastern Canada. The *Lobster Node* provides a strong and large tri-partite collaboration between academics, government scientists and fishermen (from 16 different fishermen associations) that will help develop, deliver and uptake the products of this project (see letter of support from *Lobster Node*). Also, Dany Dumont is currently leading a project funded by MEOPAR titled *Improving marine drift and dispersion forecasts* (see letter of support), and through this project we will be able to enhance the training experience of at least two of his graduate students by involving them in the student training workshops in Quebec and having them attend the multi-day Python workshop in Woods Hole Massachusetts (see HQP training section). Similarly, Bill Montevecchi is involved in a variety of MEOPAR-like projects off the coast of Newfoundland and will readily be able to make necessarily linkages with schools and government bodies to deliver the workshops. Importantly, we have included a social scientist in this project, Melanie Wiber, who has considerable experience working with multiple stakeholders on ocean management issues, primarily in the fisheries. This project is unique in that it ties together nearly all sectors of the marine community and provides an opportunity for the co-construction of knowledge. The social science contribution is described in Wiber's letter of support.

## HQP Focus

This project will contribute to the training of a *minimum of 6 graduate students*, 4 of which are already working on their thesis project with their academic supervisors: i- larval dispersal, connectivity and stock structure of lobster in eastern Canada (1 PhD student at UNB with Rochette), ii- search and rescue-like operations in the Gulf of St Lawrence (1 MSc + 1 PhD student at UQAR with Dumont), and iii- seabird movement ecology, biological hotspots and forage fish dynamics off Newfoundland (1 PhD student at MUN under Montevecchi). *We seek no stipend funding for these graduate students*.

In addition to these 4 students, we plan to train an additional 2 HQPs whose salary would be partly covered by this grant; other expenses related the students' project would be covered by the supervisors' operating grants. We provide a brief description of these two projects here. (1) *Dispersal and changes in distribution of invasive species of marine invertebrates as a function of climate change* (PhD student with Hunt at UNB). Ocean circulation modeling can provide predictions about the dispersal of invasive species with a planktonic larval phase as well as the potential effect of climate change on their spread. Research on organismal responses to temperature changes has mainly focused on the acute effects of increases in temperature on species living close to their maximum thermal tolerances (e.g. review by Harley et al., 2006), but for species of warm-water evolutionary origin, changes in and sensitivity to minimum temperatures may be as important, if not more important, in driving distributional changes. This PhD student project would model the potential for dispersal of the invasive Asian shore crab *Hemigrapsus sanguineus*, which was first introduced to eastern North America near Delaware Bay in 1988 and whose current northern limit of distribution is in eastern Maine (Epifanio 2013). Larval dispersal and survival would be modeled using a particle tracking model and projections of changes in water temperature in the Gulf of Maine/Bay of Fundy, coupled with laboratory experiments to test larval temperature tolerances and development functions. (2) *Relation between ocean circulation and annual marine distributions and movement patterns of plankton-feeding seabirds in the North Atlantic* (MSc student at UNB with Major). Knowledge of annual movement patterns and distributions of many pelagic seabirds, especially small plankton-feeding species, remains limited outside of the breeding season. The rapid development of small, light tags capable of storing location information is enabling the study of annual distributions and movement patterns of many seabird species (e.g., Cleeland et al. 2014). Recent geolocation work with Dovekies (*Alle alle*) in the North Atlantic has revealed important marine areas during both the breeding and non-breeding seasons (Fort et al. 2013) and has linked Dovekie distributions to key environmental parameters such as prey abundance and air and sea surface temperature (Fort et al. 2012). Dovekies feed mainly on planktonic *Calanus* copepods (Montevecchi and Stenhouse 2002), which drift with ocean currents. This project will involve the tagging of Dovekies to evaluate the effect of ocean circulation in their annual distributions in the North Atlantic. This type of information is required to assess important feeding areas of planktonic seabirds and to fill an important gap in our knowledge of Dovekie annual movement and distribution patterns.

All HQPs involved in this project will obtain unique training pertaining to ocean circulation modeling, in three concrete ways: (1) the drifter release and model validation work will be designed in part to support the different HQP research projects, (2) all HQPs will be involved in the delivery of the high school workshops in their respective provinces, providing valuable experience in teaching and communication, and (3) all HQPs will attend a **special multi-day ocean circulation modeling workshop** in Woods Hole MA.

**Multi-day workshop in Woods Hole MA**: The primary topic of this training will be "particle tracking", the routines that numerically advect particles through a 3-D fluid field with time-varying estimates of velocity (as well as many other parameters such as temperature, salinity, and diffusion). Scientists from UMASS Dartmouth, Woods Hole Oceanographic Institute, and NOAA will organize and deliver this workshop for the HQPs. Note that to minimize the travel cost of this training, visiting students will be housed and fed by Woods Hole scientists, which will also increase opportunities for HQP to interact with the workshop scientists. During the workshop the HQPs will also be instructed on building drifters, so that they can help organize and conduct the high school workshops back in their respective provinces.

Our assumption is that there are model outputs now available for most of the Canadian coastal waters and that these fields are accessible in a standard format. Model output is often archived in "NetCDF" format and then posted via the "Opensource Network Data Access Protocol (OPeNDAP)" such that users can query for specific times and places and bring the model variables into their working environment. This activity was not possible in most cases until recent years when most modelers complied with the community standards to post their output. Particle tracking is a discipline in itself. There are multiple complications that can be coded including the processes at the boundaries (surface, bottom, and the beach), parameterizing sub-grid processes associated with natural dispersion, imparting larval behavior like vertical migrations, adjusting the time-step depending on the underlying grid structure and velocity fields, consideration of the chemically active properties of the planktonic particles (pe oil), accounting for Langrangian coherent structures, and much more (Lynch et al, 2014; Brickman et al, 2009). The details of the model applications will differ between HQP research projects, and the workshop will enable detailed training to individuals on their research topic as well as an opportunity to expose all HQPs to some of the diversity of applications, through the sharing of case scenarios. As more realistic flow fields are generated in the future, the call to track particles accurately through these fields and to demonstrate the uncertainties of the tracks will be called for but we need to train the next generation of programmers to take this challenge.

There are a variety of open source tools now available but one of the most popular in the oceanographic community is "Python". It is a programming language that has caught on recently that essentially replaces the popular commercial MATLAB packages. In the Fall of 2013, we organized a two-day workshop in Woods Hole to introduce Python to 30+ mid-level scientist. The classroom was filled with individuals from NOAA, WHOI, Marine Biological Lab, US Geological Survey, and a few other labs. There were more people on the waiting list to get in than there were in the room. Instructors were brought in from Dalhousie and Univ of Chicago, representing the "Software Carpentry" organization, a grass-root group of professional programmers who travel the world to share their love of coding. Our proposal here is to give some form of these "boot camps" to our HQPs. Our goal is to introduce them to the beauty of well-written code that is readable, reusable, and well documented. We struggle ourselves to produce such code and we wish we had more training in this discipline as younger scientists.

One of the topics to be covered is the idea of **community code** posted on public repositories such as GitHUB. The idea is that code is shared over the web in the same way as data. Users can access others' code, make modifications, suggest changes, and, in this way, actively be involved in the evolution of the particle tracking community (see http://nefsc.noaa.gov/drifter/particles.html).

## Budget

Our total ask to MEOPAR is **$307,000** over three years (Table 2), and the majority (66%) of this amount is for salary or financial compensation: (1) 33% for the partial salary of 1 PhD student (2 years x $21K/year = $42K) and 1 MSc student (1 year x $17.5K/year = $17.5K) at UNB and salary for graduate and undergraduate students that will assist with the drifter deployments and workshops in Newfoundland (2 years x $20,000K/year = $40K), (2) 29% ($90K) for part-time salary of project coordinators, who are essential to the delivery of the workshops, website management and overall project coordination, and (3) 4% as partial compensation for fishermen that will assist with the deployment of drifters.

Table 2. Detailed budgetary requests to MEOPAR over the three years of this project.

| | | Year 1 | | Year 2 | | Year 3 | | |
|---|---|---|---|---|---|---|---|---|
| | **ind. cost** | **#** | **$** | **#** | **$** | **#** | **$** | **TOTAL** |
| **PERSONNEL** | | | | | | | | |
| university students | | | $58,500 | | $41,000 | | | $99,500 |
| coordinator admin (weeks) | $1,500 | 15 | $22,500 | 10 | $15,000 | 5 | $7,500 | $45,000 |
| website manager (1/day week) | $15,000 | 1 | $15,000 | 1 | $15,000 | 1 | $15,000 | $45,000 |
| fishermen | | ≈20 | $6,000 | ≈20 | $6,000 | 0 | $0 | $12,000 |
| **MATERIALS** | | | | | | | | |
| transmitters | $300 | 50 | $15,000 | 50 | $15,000 | 0 | $0 | $30,000 |
| drifter materials | $60 | 50 | $3,000 | 50 | $3,000 | 0 | $0 | $6,000 |
| satellite fees (1.3K fixes/each) | $240 | 50 | $12,000 | 50 | $12,000 | 0 | $0 | $24,000 |
| **TRAVEL** | | | | | | | | |
| east coast (coordinators) | $1,000 | 4 | $4,000 | 4 | $4,000 | 4 | $4,000 | $12,000 |
| west coast (coordinator) | $3,000 | 1 | $3,000 | 1 | $3,000 | | $3,000 | $9,000 |
| students | | | $5,000 | | $5,000 | 1 | $1,000 | $11,000 |
| **TRAINING** | | | | | | | | |
| Workshops/conferences | $600 | 5 | $3,000 | 5 | $3,000 | 5 | $3,000 | $9,000 |
| Woods Hole (grad students) | $750 | 6 | $4,500 | 0 | $0 | 0 | $0 | $4,500 |
| **TOTAL** | | | $151,500 | | $122,000 | | $33,500 | **$307,000** |

The second principal cost of our proposal is the construction of drifters and satellite uptake of their data. These costs are estimated at $60K, or 20% of our budget request to MEOPAR. This money will allow us to deploy 10 drifters from each of our 5 study regions in years 1 and 2 of the project.

We ask $21K (7% of total) for the travel of coordinators to both the east and the west coats of Canada to deliver the workshops in years 1 and 2 of the project and to participate in the conference in year 3.

We ask $11K (3.5%) for student travel. Most of this will be for travel to and from study sites by students

in Newfoundland, and includes money for accommodation, as the study areas are remote.

We ask $9K to plan and deliver the 10 workshops (5 regions in years 1 and 2) and 5 conferences (5 regions in year 3), and $4.5K for the HQP workshop in Woods Hole in year 1.

It is important to note that the project team is bringing a substantial amount of matching funds to the realization of this project, which we conservatively estimate at $285K. In particular, whereas we ask $99.5K from MEOPAR to support university students, this will represent a relatively small portion of the money that will be allocated to the support of undergraduate and graduate students in this project. For example, approximately $196K will be provided to 4 HQPs (2 PhD and 2 MSc) that are involved in the project but already have funding through other sources from their academic supervisors. Similarly, the two graduate students that are outlined in this proposal will receive $38.5K from in salary for the last year of their project from other sources. Furthermore, the costs associated with the research activities of all 6 HQPs involved in this project will also be covered by other funding of their academic supervisors, with the exception of the drifters deployed in this project, the costs of the workshop in Woods Hole and the various travel and accommodation costs directly associated with this project. Similarly, we conservatively estimate at $30K the match provided by project collaborators to the administration and coordination of the project. Furthermore, the HQPs will be housed and fed by Woods Hole scientists, to reduce costs, which we estimate represents an in kind contribution of approximately $2.5K. Finally, we have included $12K in the budget to offset some of the cost of deploying the drifters, but this amount represents a less than half of the actual costs associated with these deployments, and as such the fishermen will be making a significant in kind contribution to this project. Assuming say 5 boat trips to deploy the 10 drifters in each of our five regions (25 trips total), and using a fee of $600/trip (HST not included), as is the case when fishermen perform government sponsored research, we conservatively estimate the in kind contribution (at least $18K) of fishermen to this project at $30K (5 trips/region/year x 5 regions x 2 years x $600/trip). Since the fishermen have a vested interest in the results, they are generally more than willing to help in deployment of the drifters at no cost to us.

It is also important to note that the budget total is significantly more than the planning letter had suggested ($307K instead of $143K). In response to our LOI, the MEOPAR panel review recommended two major changes to our project that affected its budget. The first of these was an expansion of the geographic scope of our project beyond the initial focus on a few locations in the Atlantic Provinces. In response to this comment we now have applications in five different provinces, four on the east coast and one on the west coast of the country. This has led to increases in the money needed to support the project coordinators in the delivery of a greater number of workshops and also for the construction of a greater number of drifters. The second recommendation was that we increase and clarify our contribution to HQP training, which we have done in several ways. First, we now have 6 graduate students involved in the project, two of which would be partially funded by this proposal to MEOPAR and four that are already funded by researchers of the team. All 6 of these HQPs will participate in a multi-day workshop in Woods Hole that was added to our project, where they will learn about particle tracking and will be instructed on the basic steps in building drifters. All HQPs will also play an active role in organizing and conducting the “drifter building/software training” workshops in years 1 and 2.

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Rimouski, April 22nd, 2014

Dr. Rémy Rochette
Department of Biology
University of New Brunswick
P.O. Box 5050, Saint John, NB
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Dear Dr. Rochette,

I would like to express my interest and support for your project proposal to MEOPAR, which was exposed to me by your collaborator Jim Manning. The work you are proposing fits very well with the objectives of our own project aiming at *Improving Marine Drift and Dispersion Forecasts*. During the last year, we spent efforts designing, building and deploying surface drifting buoys that we use to validate and improve numerical models and high frequency radar processing algorithms. What you propose cannot be more helpful to reach our goals because the more data we have the better it is to test our technologies in various conditions, both in the Lower St. Lawrence Estuary and in the Gulf of St. Lawrence.

We thus propose, if both of our initiatives are funded, to be one of your *applications*. We contacted the only senior-high school in Rimouski and have together investigated a few possibilities, the most promising of which would be to engage students in a project to be presented during the annual Science Fair event in Québec (http://expositions.qc.ca/en/). The deployment will easily be done by us (graduate students, researchers), by our partners of the Canadian Coast Guard Auxiliary or by local fishermen. I would strongly encourage our graduate students to attend a multi-day particle-tracking workshop at the Woods Hole Oceanographic Institute during the first year where they would learn how to organize drifter building workshops, which I think would be a strong addition to our HQP and knowledge mobilization strategy.

Sincerely,

Dany Dumont
Professor, Physical Oceanography
Institut des sciences de la mer de Rimouski (ISMER)
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Memorial
University of Newfoundland

16 April 2014

Dr. Remy Rouchette
Department of Biology
University of New Brunswick
Saint John, NB E2L 4L5

Dear Dr. Rouchette:

I look forward to partnering on the MEOPAR Ocean Drifter Project which is highly relevant to our research on seabird ecology, forage fish, oil pollution and fishery studies in Newfoundland, involving fishers, students and government agencies. We offer 4 potential drifter sites aimed at seabird migration, capelin/biodiversity hotspots, lobster fishing and an ongoing chronic leak from a sunken vessel with 500 tons of crude oil aboard.

1) Flightless juvenile Common Murres and their fathers depart Funk Island, the species' largest colony [>1,000,000 birds] in late July/August and move to the edge of Grand Bank near offshore oil platforms. 2) Capelin, the primary forage fish of the NW Atlantic food web and a key component in the recovery of northern cod, was radically reduced by a bottom-up regime shift in the early 1990s. Recent studies on the NE Newfoundland coast have highlighted the significance of demersal spawning as well as their traditional beach spawning. 3) In 1985, the *Manolis L* sank with ~500 t of crude oil aboard between Fogo and Change Islands on the NE Newfoundland coast. Since March 2013, fuel has been surfacing and oiling Arctic eiders and murres. Concerned fishers, hunters and coastal residents have lobbied federal Ministers and MPs to have the oil removed. Coast Guard has installed temporary collecting dams above the leaking ship and monitor the situation. In every instance, however, fishers, hunters and residents have reported slicks and oiled wildlife. We are working with the Shorefast Foundation [Fogo Island] to develop "eyes on the water" citizen science with a dozen fishing crews. 4) Formerly productive lobster sites around the nearby Indian currently yield very low catches. Shorefast is working with fishers to promote a voluntary closed area, and implementation of fisher-supported drifter studies to assess larval movement could enhance efforts for new conservation approaches.

Projects 1 and 2 will involve students at Gill Memorial Academy [Musgrave Harbour] and projects 3 and 4 will engage students from Fogo Island Central High School. With the MEOPAR team, we will facilitate drifter construction and development of oceanography skills and engage fishers to implement drifter releases during July from Funk Island, from 2 capelin beach spawning sites and from a lobster fishery site, while in August releases will be made at 2 deep-water spawning sites; ad hoc releases will be made at the *Manolis L* site when oil slicks are observed.

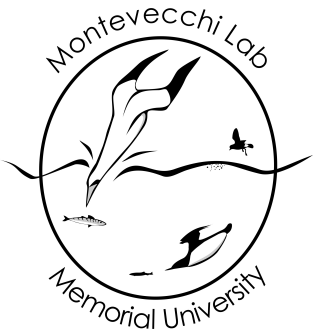
I look forward to sending a graduate students to Woods Hole to learn to make drifters and simulate their tracking. As well, in September, 12th Annual Ocean Innovation Conference is being hosted by the Fisheries and Marine Institute of Memorial University with a focus on 'Youth and the Oceans' providing a potential platform for engaging widespread interest and participation in the MEOPAR Drifter Project.

Sincerely,

W. A. Montevecchi

W. A. Montevecchi, Ph.D.
Psychology, Biology, Ocean Sciences
Memorial University of Newfoundland, St. John's

cc: Dr. G Davoren
R. Gillespie
G. Slade
Dr. Y. Wiersma



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Remy Rouchette
Department of Biology
University of New Brunswick
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E2L 4L5

April 25, 2014

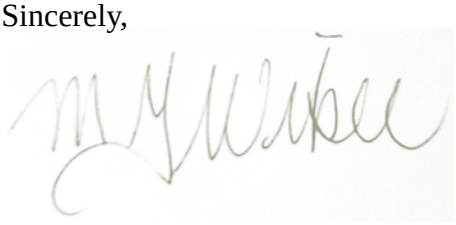
Dear Remy,

As you know, my research has focused on natural resource management, community-based management, local ecological knowledge and property rights. My current research on sustainability indicators is conducted under Project 1.1 of the Canadian Fisheries Research Network, funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). I have many publications focused on property theory, including new forms of property rights in dairy and fishing quota, in genetics, and in cultural property, as well as community-based management and local ecological knowledge in the fisheries. Since 1999, I have served as an executive member for the International Commission on Legal Pluralism and currently serve as Editor-in-Chief for the Journal of Legal Pluralism (see http://www.tandfonline.com/loi/rjlp20). For the past ten years I have been a regular visiting scholar at the Max Planck Institute for Social Anthropology in Halle, Germany. I have received numerous national and international research grants, including SSHRC standard research, conference and workshop grants, and Max Planck Institute funding support. In 2014, I received a SSHRC award to investigate risk perception in the marine environment.

I see a fourfold involvement with the work you are proposing. First, to involve fishermen, who often know more about the processes underway on their grounds than the desktop scientist, especially as relates to temporal patterns and localized variations. Interviews, ocean mapping exercises, and focus groups can all help to obtain from fishermen the information they have collectively gathered after generations of fishing in their respective

grounds. Second, social science can assist fishermen and natural scientists to build collaborative approaches to knowledge construction that will benefit both parties. Third, as the primary mission of the proposed work is to coordinate a network of multiple parties in several communities, social science can facilitate communication across sectors and groups that may not otherwise communicate with each other, to discuss, measure, analyze, and predict the flow fields offshore. Fourth, to train the next generation of scientists so that they can collaborate across disciplinary boundaries, we will develop training modules on issues such as the science to policy nexus and the roadblocks to utilizing scientific evidence in better resource management. By posing real-world example problems in each community, we can address actual situations, answer pressing questions, and, at the same time, build a set of instruments and software tools that will benefit the next generation.

Sincerely,



Melanie Wiber, Ph.D.

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April 25, 2014

Dear members of the MEOPAR Peer Review Committee:

The Lobster Node Inc (LNI) is very pleased to support the research proposal headed by Dr. Rémy Rochette (University of New Brunswick Saint John) entitled: *Student-built, fishermen deployed, satellite-tracked drifters validating numerical coastal ocean models.*

The LNI is a research corporation that groups together 16 different lobster fishermen's organizations from Quebec, the Maritimes and Newfoundland to undertake strategic research on lobster that none of our organizations would be able to undertake independently. Through the LNI the lobster fishing industry has been working under the lead of Dr. Rochette with scientists from academia and the Department of Fisheries and Oceans (DFO) on this approach to lobster research since 2010, under the auspices of the Canadian Fisheries Research Network (CFRN). At the core of much of the sampling of lobster we do within the LNI project is the goal to quantify spatial and temporal variability in larval production, and then predict the dispersal of these larvae using ocean circulation models. It is thus of paramount importance that we rigorously assess the accuracy of these circulation models, and the work proposed in this project proposal to MEOPAR will greatly contribute to this critical exercise. We will be happy to help identify lobster fishermen to assist in the release of drifters made through this project. We also greatly value the education component of this project, and see this as a unique opportunity to engage high school students from our communities in a fun project that will improve their numerical literacy and likely increase their interest in sciences in general. We will be happy to identify fishermen that will be interested in contributing to the training workshops as well as the presentation of the results in the third year of the project.

In closing I would like to say that our research experience with Dr. Rochette and other researchers of the Lobster Node has been, from our perspective, an exemplary collaboration. We have found these researchers to be very conscientious and extremely productive professionals who bring very high ethical standards to their work. They have brought new resources to this research and have gone out of their way, time and again, to do the little things that make the collaboration work. It has truly been a pleasure to work with them.

If you have any questions about the importance of this research to our industry and fleets, please do not hesitate to get in touch with me.

Sincerely,

Virginia A. Boudreau

Virginia Boudreau, President Lobster Node Inc.

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23 April 2014

Dr. Remy Rochette
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Dear Dr. Rochette:

**Subject: DFO support for MEOPAR drifter proposal**

Your proposal to MEOPAR is relevant, as you know, to the work DFO researchers have been doing for many years. Drs. Charles Hannah, Fred Page and Dave Greenberg have worked with your US partners in documenting various tool sets for coastal ocean modellers. This proposal would be an ideal collaboration, and we are particularly interested in projects related to particle transports off the Canadian coasts. Drs. Hannah, Page and Greenberg have been building relationships with some of the local DFO modellers such as Youyu Lu, Svein Vagle, and Susan Haigh, respectively. We also support the idea of recruiting the local fishermen and the students you propose to build the instruments.

We see value in the drifter deployments you are proposing for both here and in west coast waters and, given our connections to Dalhousie and UBC, respectively, would be interested in having some graduate students involved. Our applications will be primarily aimed at addressing drifter performance comparisions and model Lagrangian validations in some coastal and shelf areas adjacent to New Brunswick (Bay of Fundy), Nova Scotia (Cape Sable, St. Mary's Bay, Cape Breton, Shelburne, Bay of Fundy) and the Central Coast of British Columbia.

We would be happy to have graduate students and others help organize a few of your workshops both here in New Brunswick, Nova Scotia and on the West Coast, and would also like to send at least one of the graduate students that we co-supervise to the "multi-day particle tracking training" you have proposed.

Thank you again for the invitation to collaborate in your proposed study.

Yours truly,

Alain F. Vézina
Regional Director of Science
Maritimes Region, Fisheries and Oceans
Canada

cc Dr. Blair Greenan
Dr. Kent Smedbol

Canada