Magnetically attractive particles; 10^9 reasons for collecting data during studies of dispersion
Letter of Intent for the MEOPAR Centre of Excellence first call for proposals

Introduction

Typically, dispersion of marine particles is studied using either fluorescent dyes, GPS based drifters, or models; these models are often validated by using measurements of water velocity. These methods suffer from the following limitations:

- concentrations of dyes drop below measurable levels in less than one day
- GPS based drifters are typically large (O(0.5 m)) and are made with drogues.
- instrument cost prohibits the number of locations at which current measurements which can be collected
- ship mounted measurements of marine currents are costly, and suffer time/space convolution
- model's used to predict particle movement are tailored using a random walk parameter (K) that simulates the effects of sub-grid scale dispersion not included in the models, and is also required to correctly simulate dispersion of chemical species.

In contrast to these limitations, Dr.'s Chris Taggart and Barry Ruddick have spent the past decade validating the scientific application of magnetically attractive particles for use in dispersion studies. Originally created to study connectivity of ecosystems, particularly related to the dispersion of marine organisms at the larval stage, these particle tracers can be used to study the movement of buoyant, negatively buoyant particles in marine systems. These particles are advantageous over other methods of measuring or predicting dispersion for the following reasons:

- particle concentration allow for measurements over long time intervals (7 days) and horizontal (10s km) scales
- particle size (O(10^{-6}m) particles more accurately matches the physical size of material whose dispersive properties are being measured
- magnetic collectors are less expensive than current meters allowing for a larger area of study
- counts of particles in each collector are direct observation of K (in fact, our studies have shown that K is routinely underestimated by a factor of 10).

The use particle tracing system consists of a “batch” of particles, typically suggested to be 10 kg consisting of 10^9 particles, and a series spatially distributed of collectors. The batch size can be varied depending on the horizontal scales over which dispersion is to be studied. The particles are released either from a single or multiple locations, either in one instant in time or over a time interval. Over the course of the study interval, typically days to weeks, the particles accumulate in the magnetic collects moored at a fixed location. At the end of the experiment, the collectors are removed from the study area and analysed in the lab. Lab analysis consists of imaging the collectors, removing, counting and imaging the particles. Numerical results are then processed to give a spatial distribution of particles, and a probability map for dispersion can be calculated.

Current state of the technology

The Magnetically Attractive Particle System (MAPS) has been used by Taggart and Ruddick in five experiments (produced water, Godderich ON; larval distribution, Key Largo FL USA; larval distribution, Belize; Bonne Bay NL; Murray's Harbour, PEI). The flow disturbance and particle collection statistics for the collectors have been well quantified in flume studies and particle toxicity studies have been completed. These experiments have been funded through various sources including NSERC's I2I program and Innovacorp's Early Stage Commercialization Fund (ESCF).

Taggart and Ruddick are currently working with GaleForce Scientific Consulting Ltd. to bring this product to market. This proposal is a collaboration between industry (GaleForce) and academia (Ruddick and Taggart) and meets many of the objectives set out in this call for proposals, and objectives set out in the strategic plan. In particular, this proposal will address the following criteria outlined by MEOPAR:

- Develop new tools and technologies for rapid environmental assessment and forecasting during marine environmental emergencies.
- Link projection of future changes in storms, coastal flooding, waves on local scales considering economic impacts, safety, planning, and policy.
- involve researchers from different disciplines (physical and biological)

as they relate to the focus of "Theme 1:" improving the ability of government and private sector to respond to existing and emerging marine hazards on time scales of hours to seasons.

The experiment

Halifax harbour is well modelled but direct measurements of dispersion of pollutants introduced at the waste-water outputs, storm water runoffs, shipyard and container ports have not been directly measured on time scales of days and distances of kilometres. In consideration of Them 1: improving the ability of government and private sector to respond to existing and emerging marine hazards on time scales of hours to seasons, and topic 1 listed in the call for proposals, Marine Dispersion and Response to Emergencies we propose to measure:

- dispersion from particles released over 1 tidal cycle (12 hours) from the sewage treatment outflows in Halifax Harbour and the Northwest Arm.
- dispersion from land based storm over flow, by releasing particles on city streets prior to a significant predicted rain event.

Taggart and Ruddick will contribute one set of collectors, two more sets will be purchased bring the total number of collectors to 120, 80 or which will be surface mounted 40 bottom mounted

Four 10 kg batches of particles will be purchased, consisting of

- two negatively buoyant, one batch coloured, one non-coloured
- two positively buoyant, one batch coloured, one non-coloured

Two experiments will be conducted, to be separated in time by approximately 1 month (longer than the expected lifetime of the particles). The first experiment will be to release one batch of both the buoyant-coloured and negatively buoyant particles at three sewage out-takes in Halifax Harbour and the Northwest Arm, with a series of collectors spaced in high density in close proximity (1km) of each outtake. The remaining bottom mounted collectors will be spread out throughout the Bedford basin and entrances to the Harbour. Surface collectors will be evenly spaced throughout the harbour, basin, northwest arm and approaches to the harbour. After 1 week the collectors will be recovered and the particles counted.

The collectors will be returned to their positions for the three more weeks, recovered and inspected for particles. If no more particles are found the collectors will be repositioned, and the remaining batch of buoyant and negatively buoyant-coloured particles will be dispersed on the streets of downtown Dartmouth and downtown Halifax on the day of a predicted rain event. After one week, the collectors will be recovered and the particles counted.

In both experiments, measured results will be compared to model results.

Social policies to be addressed

While we do not have a partner to address the social implications of the results, there is certainly room to discuss the impacts of historical use of the harbour, and future plans for the use, specifically related to increased shipping activity and related to the new ship building projected slated for the Irving shipyard.

User involvement and external partnerships.

This proposal represents a significant partnership between GaleForce Scientific Consulting Ltd., who is contributing a significant amount of field work and lab analysis as in-kind.

Specific contributions to MEOPAR's Vision and Strategic Objectives

With regard to Marine Dispersion and Response to Emergencies rapid prediction of dispersion via computer simulated models is critical; however, direct measurements of dispersion for high risk areas are key to validating model output.

Qualifications and expertise of the research team

Taggart: Biological oceanographer expert in fisheries and ecological aspects of larval dispersion

Ruddick: Physical oceanographer expert in ocean mixing and dispersion; co-inventor with Taggart of the tracking technique to be applied.

Schillinger: field technician, project manager, data analyst, consultant.

Timeline

This project will be conducted either prior to hurricane season or late in the hurricane season but before the winter storms increase their frequency. This is to avoid the influence of storm (wind or wave breaking) induced circulation, and to remove any fear of wave induced loss of surface or bottom collectors.

Each experiment is to last one week, although the time between experiments will be at least one month. Lab analysis will take eight weeks total (both experiments combined).

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

The results from this study will become the basis of a sales and marketing strategy for GaleForce Scientific Consulting Ltd. (or subsidiary). Results will be worked into an academic paper, and results will be presented at a conference. Travel and dissemination costs are included in the budget. Data will also be available for honours and masters thesis.

Budget

Item	Year 1	In kind
Personnel: Field	4500	2500
Lab analysis	8000	4000
Materials and dissemination	2500	
Travel	2500	
Ship time	800	
Equipment: MAPS	36000	
Collectors	9000	4500
Total	63300	11000