Marginal Ice Zone: Biogeochemical Sampling with Gliders

Mary Jane Perry
School of Marine Sciences
University of Maine
Ira C. Darling Marine Center
193 Clark's Cove Road
Walpole, ME 04573-3307
phone: (207) 592-0317 fax: (207) 563-3119 email: perrymj@maine.edu

Ivona Cetinic
School of Marine Sciences
University of Maine
Ira C. Darling Marine Center
193 Clark's Cove Road
Walpole, ME 04573-3307
phone: 626-200-9374 fax: (207) 563-3119 email: icetinic@gmail.com

Award Number: N00014131080
http://www.apl.washington.edu/project/project.php?id=miz

LONG-TERM GOALS

The long-term goal is to understand the distribution of phytoplankton and particulate organic carbon in the Arctic under the ice and in the marginal ice zone, as well as to understand feedbacks between phytoplankton and ice melt. The project specific goals are to develop biogeochemical and optical proxies for glider optics; to use the proxies to project biogeochemical and optical measurements from the ship to the larger spatial scales sampled by the gliders in open water, in the marginal ice zone, and under the ice; and to build collaborations with Arctic scientists at KOPRI.

OBJECTIVES

The scientific objectives are to:

1. Calibrate the biogeochemical sensors on the MIZ Seagliders deployed during the ONR Marginal Ice Zone DRI with from shipboard measurements taken on the Korean icebreaker *IBRV Araon* and to develop optical proxies for phytoplankton concentration and particulate organic carbon.
2. Characterize the development and spatial extent of blooms of phytoplankton under full ice cover, in the MIZ, and in open ice-free water through analysis of calibrated glider data and other shipboard data.
3. Determine how upper ocean vertical structure and turbulent mixing rates affect development of blooms in the MIZ and open ice-free water, and the role of entrainment of nutrient rich waters into the euphotic zone in supporting these blooms.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2014**	2. REPORT TYPE	3. DATES COVERED **00-00-2014 to 00-00-2014**
4. TITLE AND SUBTITLE **Marginal Ice Zone: Biogeochemical Sampling with Gliders**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Maine,School of Marine Sciences,193 Clark???s Cove Road,Wadpole,ME,04573**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

4. Apply a light and chlorophyll primary productivity model to estimate and compare phytoplankton productivity under full ice cover, in the MIZ, and in open ice-free water.

APPROACH

Four MIZ Seagliders were deployed by Craig Lee's team in 2014 during the late July *R/V Ukpik* cruise out of Prudhoe Bay. As of 29 September, the gliders and still operating but will be retrieved in early October from the *R/V Norseman*. All gliders carried sensors for chlorophyll fluorescence, optical backscatter, and irradiance. For all cruises (*Araon, Ukpik,* and *Norseman*) the calibration protocol described below was followed. In the coming year the glider and ship data will be analyzed by Perry and Cetinic (UMaine) in collaboration with Dr. Craig Lee of the University of Washington and Korean scientists Dr. Eun Jin Yang, Dr. Sung-Ho Kang and colleagues from KOPRI.

Calibration of glider biogeochemical sensors and development of optical proxies
The protocol for calibrating glider sensors are based on those developed during the 2008 North Atlantic bloom program, with modification for local conditions. The specific protocols for each sensor – backscatter and chlorophyll fluorescence – are described in sensor specific calibration reports available at the BCO DMO website <http://osprey.bcodmo.org/dataset.cfm?id=13820&flag=view>.

Initial pre-cruise and final post-cruise calibration of the glider and ship CTD sensors are done *en masse* at the factory. The field calibration is a two-step procedure, which can be carried out in tandem or separately: 1) calibration of CTD sensor to glider sensor from close proximity, simultaneous profiles; and 2) building of proxy libraries, where a biogeochemical measurement is mapped to a CTD sensor. The ideal protocol entails putting an individual glider into a shallow pre-calibration dive sequence, bringing the ship to the projected surfacing site, and navigating to within 100 m of the surfaced glider. A ship CTD profile is made simultaneously with a glider dive. Sensor data from the ship's CTD downcast is interpolated in density coordinate space to align with the glider profile. Water samples for chlorophyll concentration and particulate organic carbon are taken on the CTD upcast. The ship's downcast optical data is paired with upcast water samples, again using density to align measurements. However, by separating the two steps, more data can be collected for building the biogeochemical proxies (i.e., optical backscatter to particulate organic carbon, Fig. 1, and chlorophyll fluorescence to chlorophyll, Fig. 2), particularly for the more challenging small vessel operations. Any close encounters of gliders will allow for additional glider-glider cross calibration.

Characterization of phytoplankton blooms under the ice, in the MIZ and open water
The Seaglider lines will allow characterization of the distribution of phytoplankton and particulate organic under full ice cover, in the MIZ, and in open ice-free water. Glider measurements of spectral irradiance and turbulent dissipation rates will help in understanding the controlling mechanisms of phytoplankton abundance in the various regimes. Irradiance under the ice primarily depends on ice thickness and presence of melt ponds and leads, and hence will be expected to vary spatially; this is expected to change as melting progresses. The variable nature of light transmission under the ice may give rise to patchy blooms, and the MIZ gliders should provide some insight. In the Chukchi Sea continental shelf, Arrigo et al. (2012) observed the presence of large phytoplankton blooms under the ice, which they attributed to higher light transmission through the relatively thinner (0.5 – 1.8 m) one-year ice. However, their measurements under the ice were sufficiently sparse to prevent them from assessing spatial patchiness. We will be able to determine patchiness of phytoplankton and particulate organic carbon concentrations on the ~ 4 – 5 km scale from the glider transects.

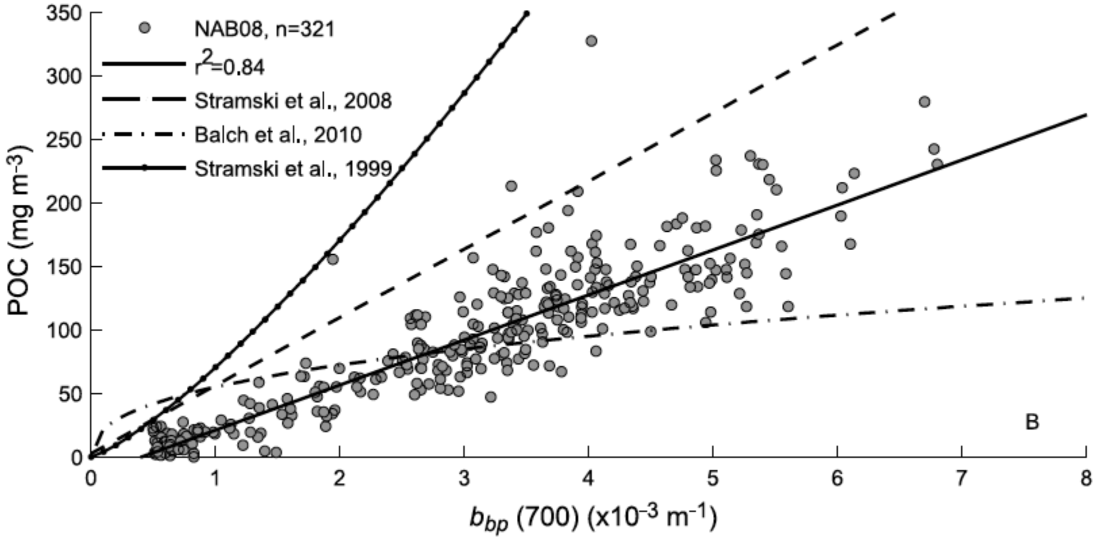

Figure 1. Example of anticipated proxy relationship between particulate organic carbon and optical backscatter, from subpolar North Atlantic (solid line, from Cetinic et al., 2012).

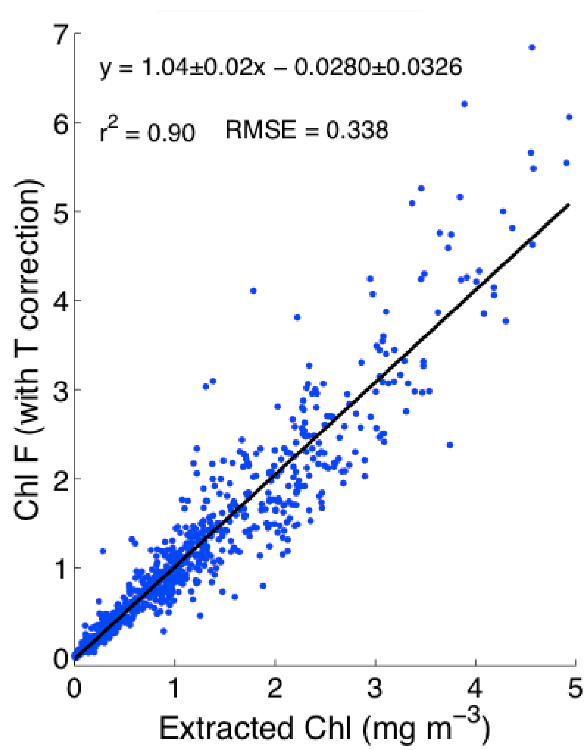

Figure 2. Example of anticipated proxy relationship between extracted chlorophyll concentration and chlorophyll fluorescence, from subpolar North Atlantic (unpublished from N. Briggs draft dissertation, anticipated completion in October 2014).

WORK COMPLETED

In May, Perry attended a planning meeting at KOPRI (Inchon, Korea) with other members of the MIZ team, to plan the August cruise on the Korean ice breaker with Dr. Sung-Ho Kang, Dr. Eun JinYang and other Korean colleagues. Biogeochemical samples were collected on three cruises: a ten day cruise in late July/early August on the *R/V Ukpik*, a small vessel out of Prudhoe Bay; a twenty-six day cruise in August on the *IBRV Araon* from Nome to Barrow, Alaska; and a ten-day glider retrieval cruise in late September-early October. Chlorophyll, particulate organic carbon, and particulate absorption coefficient samples were collected. Completion of chemical and optical analysis of samples is anticipated before December. Additional samples collected by our KOPRI collaborators will be made available when those analyses are completed.

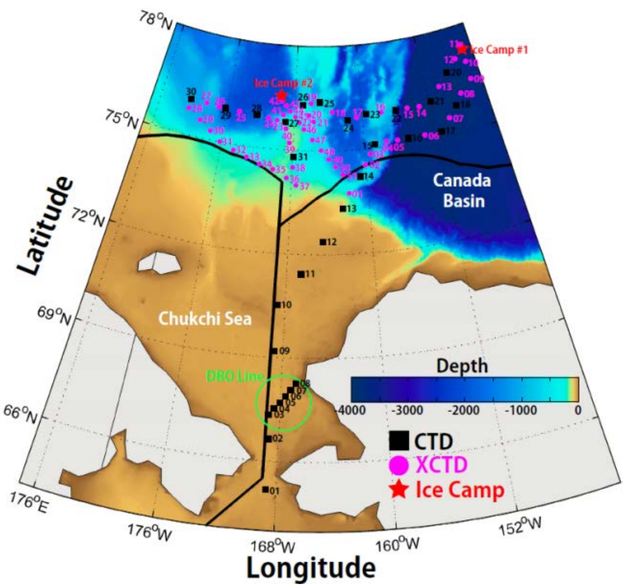

Figure 3. Map of 2014 IBRV Araon Arctic cruise study area, indicating CTD, XCTD, sea-ice caps, and helicopter survey stations.

Two poster abstracts have been submitted to report preliminary results; one to the international Ocean Optics XXII conference in Portland, Maine, in October and the other to AGU in San Francisco, California, in December.

RESULTS

The chemical analyses have not yet been completed. However, the distribution of phytoplankton were characterized by subsurface deep chlorophyll and particle maximum layers (see example in Fig. 4).

IMPACT/APPLICATIONS

The results of this project will provide improved knowledge of the distribution, magnitude and productivity of phytoplankton under the ice, in the MIZ, and in open water through collection of data with well calibrated and validated autonomous sensors. A new collaboration with Korean scientists at KOPRI was forged with the potential for future collaborative Arctic studies.

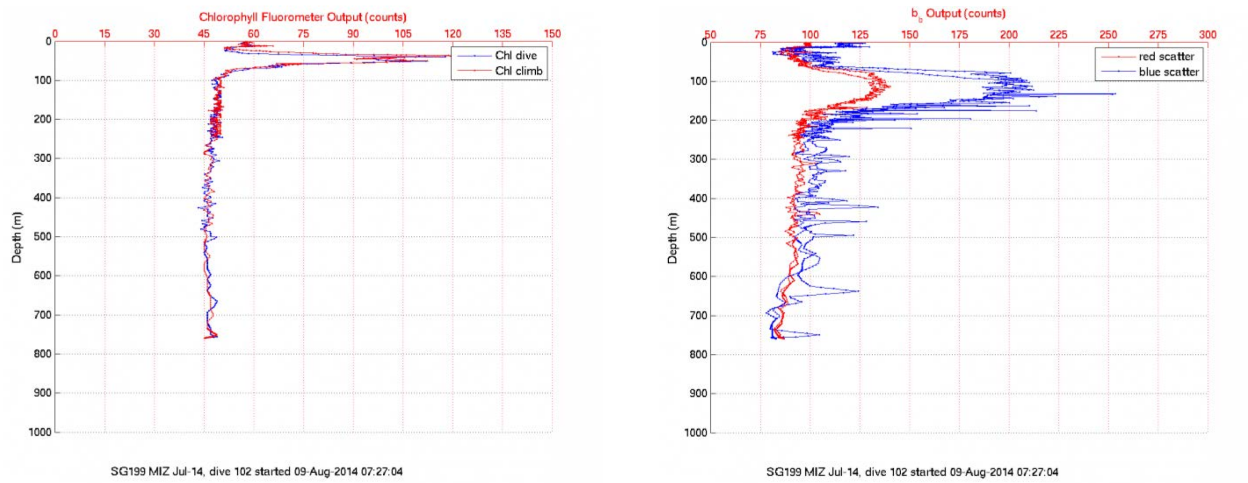

Figure 4. Seaglider 199, dive 102. Left, chlorophyll fluorescence shows a strong deep chlorophyll maximum layer. Right, optical backscatter also shows a strong subsurface maximum layer, but below the chlorophyll maximum layer.

RELATED PROJECTS

This project is a component of the Marginal Ice Zone DRI (MIZ) and is most closely aligned with the project entitled *Evolution of the Marginal Ice Zone: Adaptive Sampling with Autonomous Gliders*, PIs C. Lee, L. Rainville, and J. Gobat. http://www.apl.washington.edu/project/project.php?id=miz. This work will also rely on collaboration with with Korean scientists at KOPRI and with other DRI team members collecting irradiance measurements and measuring entrainment of deeper (nutrient rich) water into the euphotic zone.

REFERENCES

Arrigo, K. R., and thirty others, 2012. Massive phytoplankton blooms under Arctic sea ice. Science 336: 1408. doi: 10.1126/science.1215065.

Briggs, N., 2014. Using temporal variability in optical measurements to quantify phytoplankton production, particle size, and aggregation during the North Atlantic spring bloom from autonomous platforms. Doctoral dissertation, in draft, completion anticipated November 2014, University of Maine.

Cetinić, I., M. J. Perry, N. Briggs, E. Kallin, E. A. D'Asaro, C. M. Lee. 2012. Particulate organic carbon and inherent optical properties during the 2008 North Atlantic Bloom Experiment. *Journal of Geophysical Research* 117, C06028, 18 pp. doi:10.1029/2011JC00777.