An Empirical Test of the Arctic Ocean Sedimentation Hypothesis

Steven J. Manganini and Richard A. Krishfield (G&G)
Jeomshik Hwang (MC&G)

Ocean and Climate Change Institute

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Hypothesis and Project Objective:

According to the current hypothesis to explain Arctic Ocean sediment processes, a major portion of sediment including organic carbon may be supplied to the deep basin from the surrounding large continental shelves that constitute 52% of the Arctic Ocean area. If a major fraction of the carbon is derived from the margin, a key follow-up question is; what proportion of carbon is derived from primary production in the marginal seas (e.g., Chukchi, Beaufort) and from terrigenous inputs via the numerous large rivers that drain into the Arctic? Retreat of sea ice and destabilization of permafrost soils are likely to lead to increases in carbon fluxes from these sources, respectively, as a result of warming of Artic climate.

The main objective of this project has initiated detailed assessments of inputs of biogenic and detrital materials as well as the construction of time-series data sets to help understand potential impacts on Arctic biogeochemical cycles. The funding was specifically used to chemically analyze a suite of sinking particle samples collected from a time-series sediment trap in the deep Canadian Basin (75°N, 150°W, 3,824m water depth) and the resulting key observations were reported in our recent publication: Hwang, J., T. I. Eglinton, R. A. Krishfield, S. J. Manganini, S. Honjo, 2008, Lateral organic carbon supply to the deep Canada Basin, *Geophysical Research Letters*, Vol. 35, L11607. In addition, a more comprehensive proposal (*Export of Particulate Organic Carbon from the North American Margin to the Deep Canada Basin)* is being prepared for submission to NSF.

Motivation:

1. Predicted changes in the hydrological cycle and attendant shifts in sea-ice due to global warming are likely to perturb the carbon cycle in the Arctic Ocean.
2. In order to understand how these changes will impact biogeochemical cycles and Arctic ecosystems it is important to characterize present-day processes, particularly concerning the fixation and sequestration of carbon in the Arctic Ocean.
3. Our understanding of the cycling of carbon in the central Arctic Ocean is particularly limited due to logistical challenges.

Central Question:

What is the flux, composition, and source of organic carbon exported to the deep Canada Basin?

This study:

1. We have analyzed a collection of settling particle samples from the deep Canadian Basin (75°N, 150°W, 3,824m water depth). The 21 samples were collected by a time-series sediment trap that was deployed for one year at 3000m (824m above bottom) on a mooring in the seasonally ice-covered area of the Beaufort Gyre. These samples

constitute the first collection of their kind (Fig. 1 location BGOS-A, Fig. 2c, analyzed sediment trap time-series samples, Fig. 3, sediment trap position on mooring).

2. With information obtained from the elemental (total mass, OC, inorganic carbon , N, P, biogenic Si, lithogenic Si, Al), isotopic ($\delta^{13}C$, $\Delta^{14}C$), and biomarker analyses of these samples, we were able to evaluate our hypotheses concerning Arctic sedimentation. The composition and provenance of sinking particulate matter was evaluated based on elemental and isotopic compositions (Fig. 2).

Key Observations:

1. Photosynthesis and resuspension of sediment appear to control particle flux and radiocarbon values of POC in near surface water (Fig. 2d), (Hwang et al., 2008).
2. Particulate carbon fluxes to the Central Canada Basin are low and maximum flux is in the winter with maximum ice cover and northward current direction (Fig. 2a, b, c)
3. The geochemical composition of particulate organic carbon entering the deep Canada Basin suggests that it is predominantly supplied from the margins as opposed to overlying surface waters (Fig. 2c), (Hwang et al., 2008).
4. Radiocarbon serves as a sensitive tracer of organic carbon supply to the deep basins (Fig. 2d), (Hwang et al. 2008).

Unresolved questions:

1. What is the mechanism of supply of carbon from the margins?
2. Was this organic carbon derived from marine productivity over the shelves and marginal seas, or does it reflect terrestrial inputs?
3. How will this situation change in the future?

Ongoing research:

1. Lipid biomarker and mineralogical and carbon isotopic analyses of Canada Basin POC and surface sediments to constrain the source(s) of old organic carbon (terrestrial vs. marine).
2. An integrated sediment traps/physical oceanographic mooring program in the deep Canada Basin ("The Beaufort Gyre System: Flywheel of the Arctic Climate?" A. Proshutinsky, PI; OPP-0424864)
3. The continuation of sediment traps deployed in the deep Canada Basin to access interannual variability.
4. Proposal submission to NSF-OPP (Office of Polar Programs) in Nov. 2008, *Export of Particulate Organic Carbon from the North American Margin to the Deep Canada Basin,* co-PIs, Tim Eglinton and Roger Francois. Continuation of sediment trap deployments (6 sediment traps) in the deep Canada Basin (Fig. 3).

Publications:

Hwang, J., T. I. Eglinton, R. A. Krishfield, S. J. Manganini, S. Honjo, 2008, Lateral organic carbon supply to the deep Canada Basin, *Geophysical Research Letters*, Vol. 35, L11607.

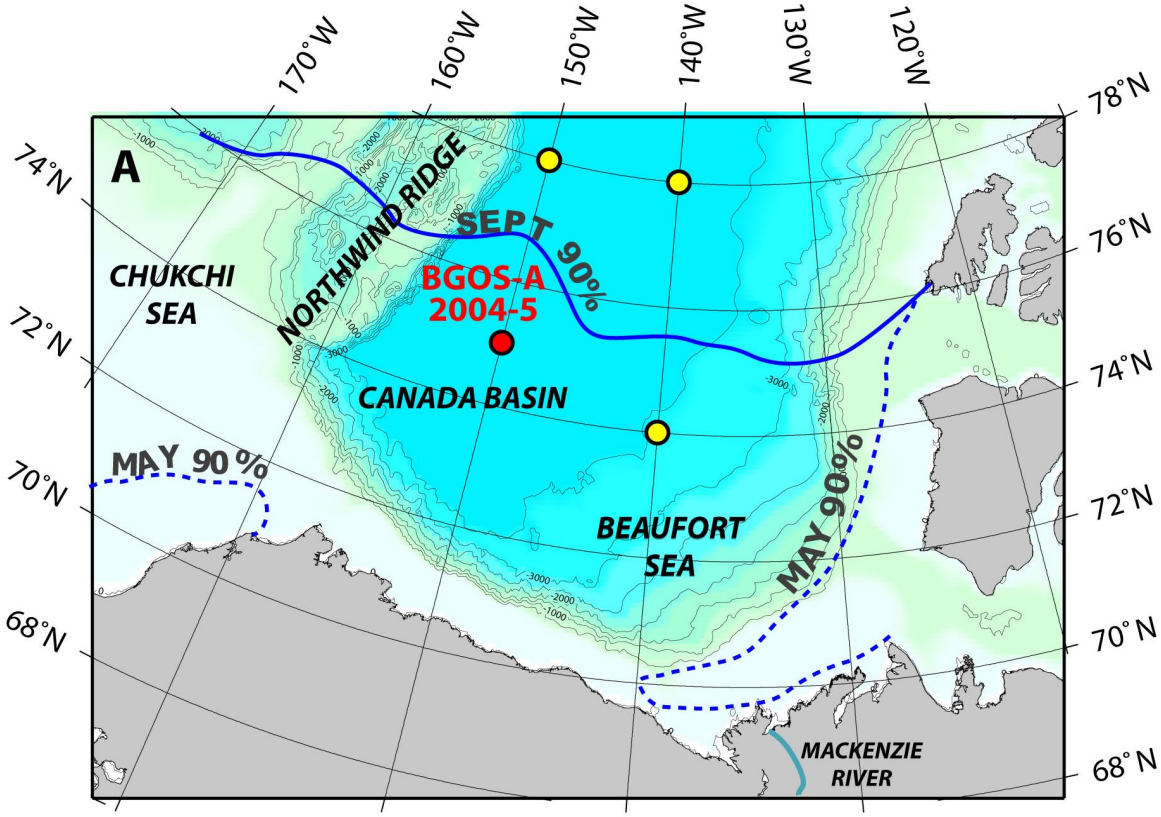

Figure 1. Location of BGOS-A 2004-2005 sediment trap (Red circle) and the proposed sediment trap mooring locations (yellow circles) in a proposal to be submitted Nov. 2008 to NSF-OPP.

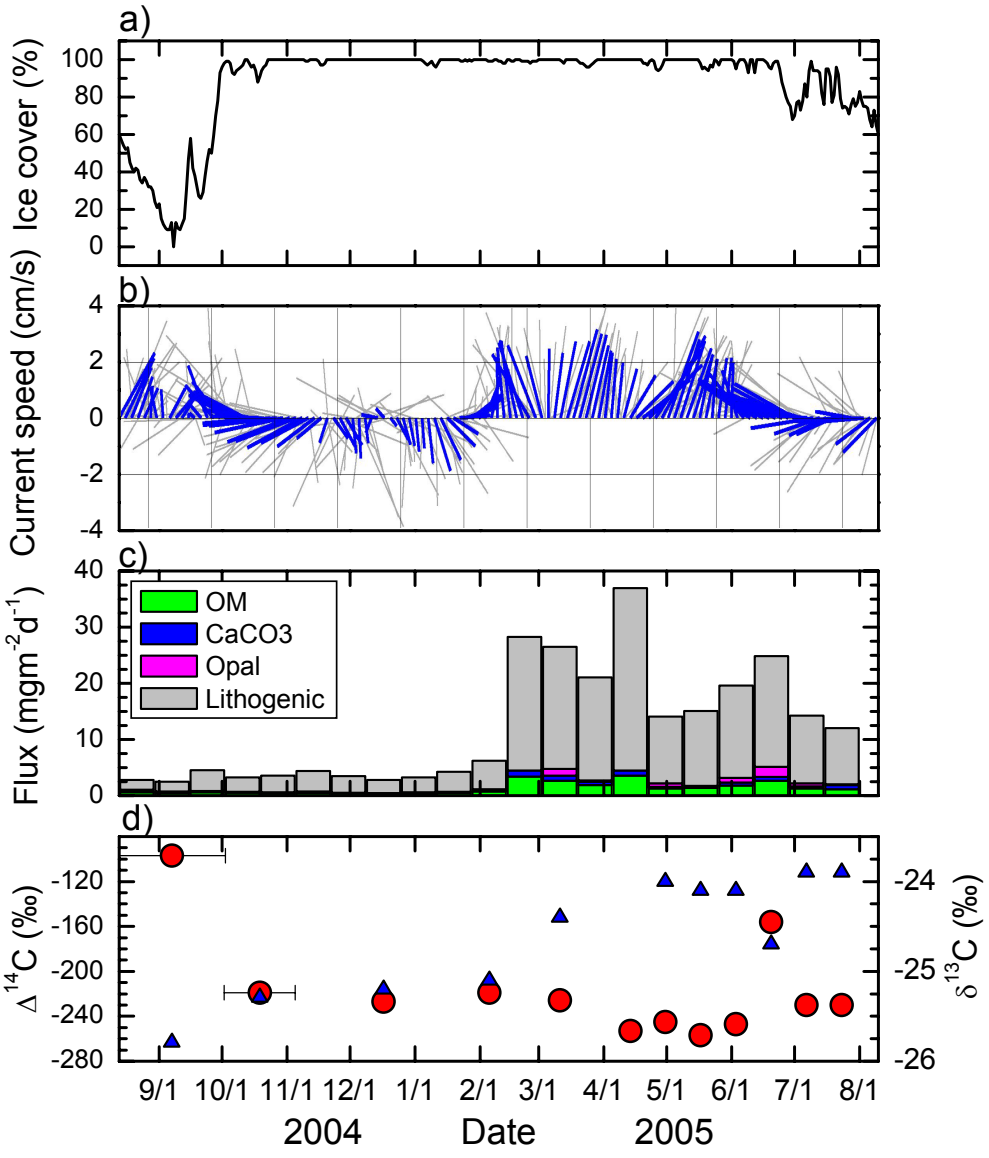

Figure 2. a) ice concentration at the surface, b) current speed and direction at 2000m, c) fluxes of biogenic and lithogenic particles, and d) $\Delta^{13}C$ (blue triangles) and $\Delta^{14}C$ (red circles) values of the organic matter collected in the sediment trap moored at 3067m (757m above the bottom) on BGOS mooring A from August 2004 to July 2005. An abrupt increase in particle flux occurred in February when the sea was completely covered with ice; the period of high flux coincided with the period of northward-flowing current. The $\Delta^{14}C$ values of organic matter are very low compared to modern values of dissolved inorganic carbon (> -50 ‰), implying that laterally transported pre-aged organic matter was the major source of organic matter to the deep Canadian Basin.

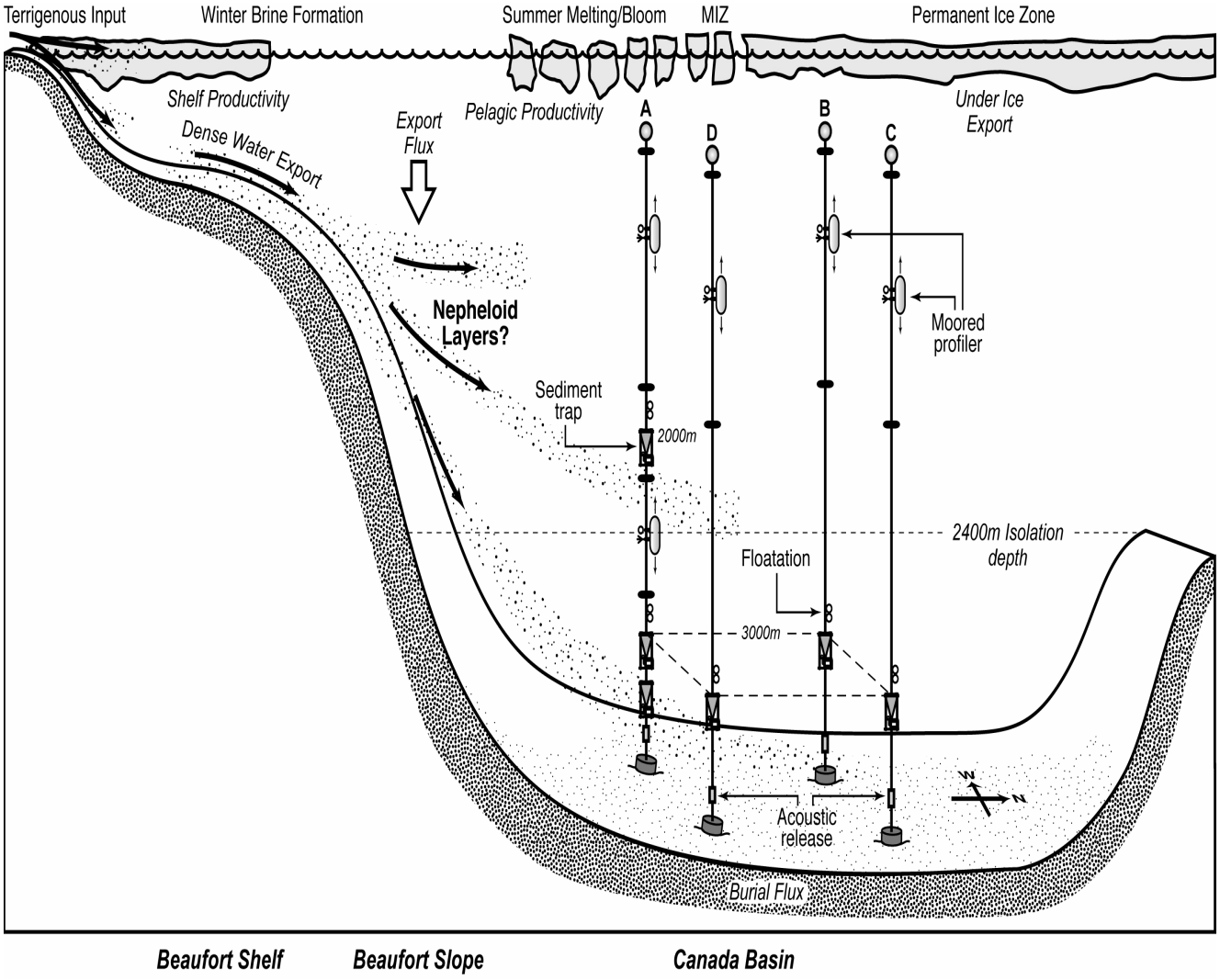

Figure 3: A representation of the current Arctic Ocean sedimentation hypothesis and our future project proposal to be submitted to NSF-OPP. Planned configuration of BGOS moorings (A, B, C, D) including (6) sediment traps to study inter-annual variability in the deep Canada Basin (MIZ = Marginal Ice Zone). In this study the sediment trap samples were collected and analyzed from Mooring A, from the 3000m sediment trap, in 2004-2005.