

INTERNATIONAL ARCTIC SHELF-BASIN EXCHANGE OBSERVATIONS: AN “ARCTIC SNAPSHOT” PROPOSAL FOR IPY07/08

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ABSTRACT

The rapid changes that are being observed in the Arctic at the start of the 21st century may well be a bell-weather of a global climatic change (e.g., warming in some regions, cooling in others). In the fall of 2002 we had the furthest northern retreat of sea ice in the western Arctic off Alaska since satellite observations were initiated and 2003 looks to be approaching that record. Variation in ice extent and thickness are intimately tied to the world climate via ocean-atmosphere interactions and associated heat transfer dynamics. With a reduction of ice in the Arctic, more heat is absorbed by the ocean, which positively feedbacks to enhanced ice melt. Coincident with these physical ocean-air dynamics are biological systems, such as sea ice algae, which are intimately tied to ice. The timing of ice edge production is critical to initiating food chain development and the uncertainties associated with an earlier ice retreat in the Arctic and delayed southern expansion in the fall directly impact water column plant and animal production, water column and sediment carbon cycling, and associated ecosystem structure. Based on these changes the International Arctic Shelf-Basin Exchange (SBE) working group of the Arctic Ocean Sciences Board is proposing an “ARCTIC SNAPSHOT” of key parameters at the shelf break for the International Polar Year in 2007/2008 through development of a synoptic network of collaborative international studies of shelf-basin exchange over a pan-Arctic scale. This concept was also supported by participant consensus at the 3rd International Shelf-Basin Interactions Pan-Arctic Meeting held in Cádiz, Spain in November 2003.

BACKGROUND

In a larger perspective most of the marine waters exiting the Arctic Ocean have had its properties modified over the enormous shelves, which themselves make up 25% of the world's shelf regions. About half of the inflowing Atlantic water entering the Arctic Ocean flows over the wide Barents Sea shelf, where it is cooled and large biological production occurs. Both these processes favor a flux of carbon dioxide from the atmosphere into the surface water. By comparison, a large amount of river runoff enters the Siberian shelf seas, mainly to the Kara and Laptev Seas. This runoff brings particulate matter, nutrients, dissolved inorganic and organic carbon, plus metals and pollutants on to the shelves where some gets buried in the sediments while parts enters the deep central Arctic Ocean. Most of the runoff flows off the shelf in the region between the Gakkel and Lomonosov Ridges. The Pacific water entering through Bering Strait, although not fully fresh water, also brings a large volume of low-salinity water into the Arctic Basin (about 30% volume), adding to the vertical stratification of this ocean.

The Pacific water, with its high nutrient content, flows over the Bering and Chukchi Seas and mixes with river runoff from both the Yukon and Anadyr rivers. Extensive biological production

takes place during its flow to the north, resulting in among other factors, high microbial and macrofaunal activity in the upper sediment, which gives this water a specific nutrient signature observable into the Arctic Basin. In addition, high macrofaunal biomass and carbon cycling over these shallow shelves increases the nutrient content of the water through releasing pools of microbially-recycled carbon, both inorganic and organic forms.

In addition, at different locations of the Arctic shelves polynyas are present, either through most of the year or during part of it. Winter polynyas are significant producers of sea ice, leading to the formation of brine that increases the density of the underlying waters. This high-density water formation is an important contribution to the ventilation of the Arctic Ocean and also facilitates air – sea flux of gases. Polynyas are also areas of large biological production that can support a wide range of biological life.

Different chemical signatures stemming from the shelf seas are useful tools to trace water masses in the central Arctic Ocean, all from the surface down to the bottom, both with regard to their circulation pattern, residence times and formation process. Investigations performed during the last decade have shown a considerable variability in the circulation pattern of the top ~500 m of the central Arctic Ocean, especially with the shift in the runoff front that has exposed a much larger area of the sea ice to the underlying relatively warm Atlantic Layer water. Furthermore, there are signs of variable amounts of the fresh surface water exiting through the Canadian Arctic Archipelago relative to through Fram Strait. Both of these changes have a direct coupling to climate.

Changes in the sea ice cover as well as the magnitude and timing of river runoff have immediate effects on the biological activity. The connectivity of river runoff from land to the shelves as well as air-sea-ice interactions are critical to shelf-basin interactions. The coupling of sea ice melt and river input to stratification and its effect on the light regime and the supply of nutrients, together with possible changes in surface water temperature, will affect the air – sea flux of carbon dioxide. With more open water in the fall (less sea ice cover) there is a potential to form more sea ice during the winter season, increasing the brine production, which will add to both ventilation of deeper waters and to the uptake of atmospheric carbon dioxide. Furthermore, within the Arctic shelves some sediments contain large quantities methane hydrates and methane gas pockets. The fate of these methane pools is unknown in a significant climate change scenario.

Much of our knowledge of the processes and the variability described above has been gained through field activities during the last 10-20 years. However, these field activities have mostly been single studies of different specific regions and processes. Considering all the variability that have been deduced from these investigations there is a need for a synoptic study of critical regions of the Arctic Ocean, together with process-related investigations. An International Polar Year opens a unique opportunity for a coordinated multi-disciplinary, multi-international study of the Arctic Ocean. This could be implemented by utilizing the resources of ships from many nations (~10) at present performing investigations in the Arctic, aircraft to support ice camps and moorings/buoys and other high technologic instrumentation for collecting time series observations. With a true international planning such an investigation could use the right platforms for the right work, in order to get maximum output.

Based on the critical nature of this western Arctic region for shelf-basin transport of nutrients, various carbon forms, as well as in maintaining the upper halocline, it seems timely to set up a pan-Arctic observing system of cross-shelf transect lines to monitor regional changes of shelf-basin exchange processes. An international network of shelf -to-basin transect lines, maintained at key locations throughout the Arctic and coordinated internationally, would move our understanding of possible ecosystem change in this highly sensitive area forward. The use of select, standardized measurements on each of these shelf-basin transect lines would provide the spatial observational grid to assist with scaling up regional studies to a pan-Arctic perspective.

The Proposed “ARCTIC SNAPSHOT” Activities during IPY07/08

The proposed “Arctic Snapshot” for IPY07/08 is focused on the slope region around the Arctic simultaneously to study shelf-basin exchange processes (Figure 1). This study would be a coordinated effort, utilizing ship, aircraft, ice camp, and satellite assets from all countries working on research questions in the Arctic (Canada, China, France, Germany, Japan, Norway, Russia, Sweden, United States, and perhaps Spain). Scaling regional studies to modeling the pan-Arctic, and ultimately then global issues requires a preliminary, internationally-coordinated retrospective study, using both regional and pan-Arctic approaches. We need an interrelated study combining “knowledge, data, processes and understanding” in order to move towards a synthetic understanding of the Arctic shelf seas and connecting slope regions to “scale up” to a pan-Arctic perspective, with the ultimate goal to connect key processes and findings to the global scale.

The SBE working group estimates a two-phase IPY07 program. An initial limited investment (\$0.5-1M) to support 10 internationally coordinated regional retrospective projects would provide the background for emerging scientific questions related to an Arctic system in change to guide the development of 8 circum-arctic shelf-basin regional SBE studies as part of the “snapshot” approach for the IPY07/08 study. The framework of a coordinated, simultaneous study of the Arctic seas (Chukchi, East Siberian, Laptev, Kara, Barents, Canadian Archipelago, and Beaufort), focused at both the shelf-break interface to the Arctic Ocean as well as shelf-shelf connectivity, will provide a comparative baseline to gauge future Arctic change for modeling efforts. Imbedded in this “snapshot” approach is the emplacement of an ocean observing network of moored technology on the slope region to capture seasonal and annual variability in a pan-Arctic framework. Development of Long-Term Observatories (sections and moorings) would provide continuity for scientific measurements and international collaboration during and beyond IPY07/08.

In addition, coordinated circum-arctic projects would also entrain coastal communities by utilizing their community organizations via educational, web-based infrastructure opportunities to bring the research-based project to both the near-field Arctic communities and far-field global communities, thus highlighting the Arctic as a global region of interest.

The pan-Arctic shelf-basin exchange transect lines would include standard physical and biogeochemical measurements built on a backbone of standardized measurements on moorings. During a recent meeting of international Arctic experts in Spain, consensus was reached on the

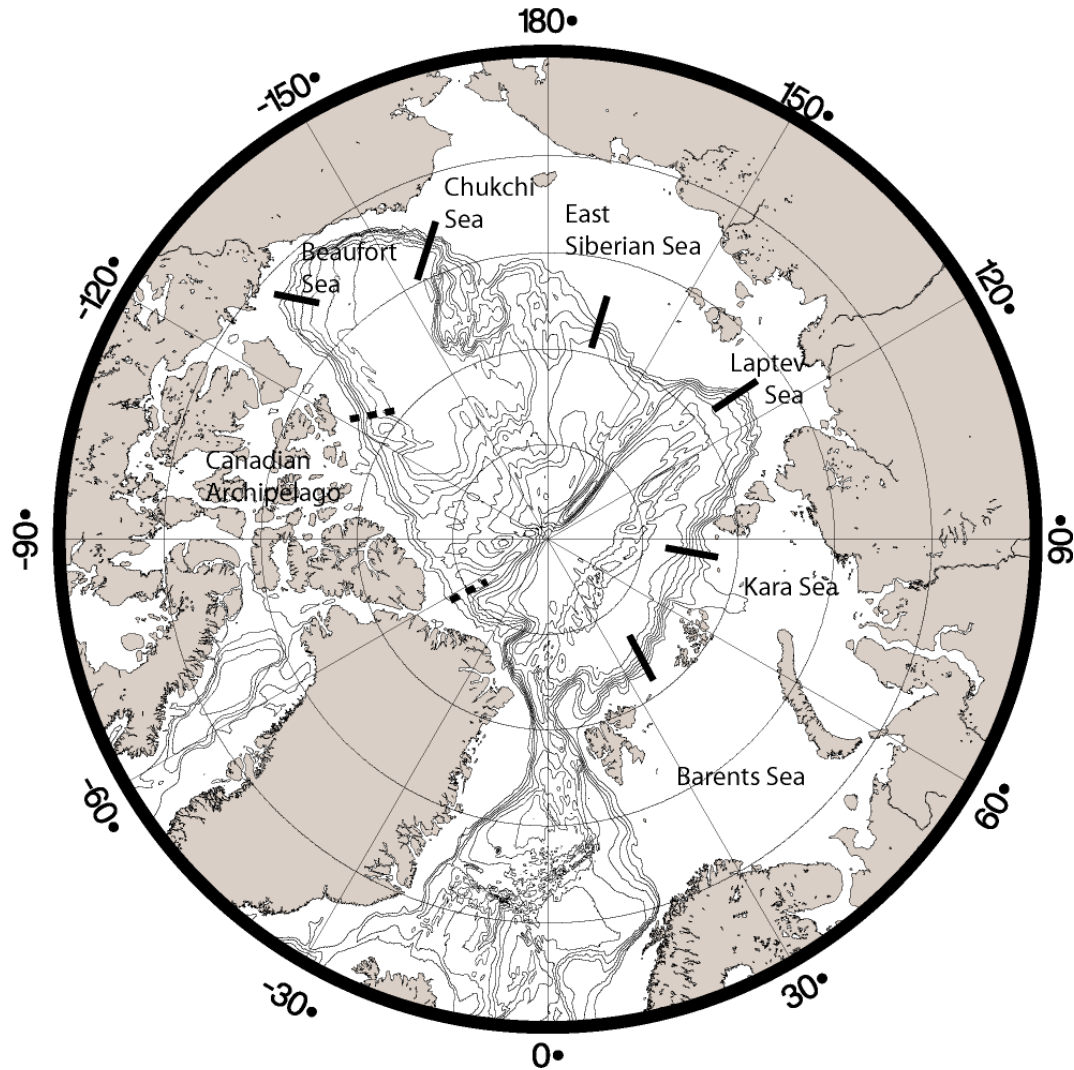


Figure 1. Schematic of international transect lines for synoptic studies of shelf-basin exchange during the proposed IPY07/08 “Arctic Snapshot” project. Each transect line would have an observatory mooring as the backbone at the 600m isobath. The solid lines would be occupied by icebreakers seasonally for standardized measurements and process studies, with the dotted lines only by aircraft. Winter occupation of solid lines would all be by aircraft.

need for focused studies at the Arctic shelf break to investigate potential changes with ice retreat northward over the shelf break. The potential change in the seasonality of shelf dynamics and shelf break upwelling would have a major impact on the total CO₂ budget and shelf-basin fluxes in the Arctic.

The use of satellite for remote sensing of ice coverage, thickness and ocean color (chlorophyll) relative to the shelf and shelf break will provide enhanced coverage of the pan-arctic region as well as validation of measurements during the field program.

Specially, the network of SBE measurements would include the following measurements from ships, with a reduced suite of these data for aircraft collections particularly during the spring:

- 1) Standard suite measurements: temperature, salinity, nutrients, oxygen and oxygen-18, carbon measurements (POC, DIC, DOC, pH), atmospheric measurements, including incident light, and chlorophyll;
- 2) International mooring arrays focused at the shelf break band around the Arctic, with standardized measurements as a “backbone” to the pan-Arctic snapshot;
- 2) Process studies around this backbone of key observatory sites located at 300-600 m depth (shelf break region);
- 3) Satellite coverage focused on the polar region;
- 4) Modeling effort, with 1-D, 3-D, and coupled biophysical regional models;
- 5) Technological development to incorporate biochemical sensors to mooring arrays; and
- 6) Outreach component to people since the Arctic is people-relevant due to its harvestable production, resource use, and transportation issues associated with ice retreat from shelves.

Standard measurements from the international mooring arrays located at the SBE band include temperature, salinity, currents, oxygen sensors, ice thickness, nutrients, fluorescence, and transmissivity sensors. If feasible, sediment traps, near-bottom benthic sensors, and profiling mixed layer biochemical measurement sensors are recommended.

Process studies via synoptic transect lines at these observatory sites on the slope would include a variety of physical, biogeochemical and biological studies at the air-sea interface, ice, water column and sediments to compare/contrast key shelf-basin exchange processes at the shelf break around the Arctic. When possible, sediment core collections should be made to study the Holocene short-term variability in siliciclastic and biogenic/organic-carbon fluxes and its relationship to natural environmental/climate change in sedimentary records on transects from the shelf towards the continental slope. Finally, the studies would be coordinated with remote sensing observations to emplace the regional studies into a pan-Arctic framework.

The proposed “Arctic Snapshot” incorporates a variety developing and proposed IPY07/08 –relevant national studies to understand the Arctic as a system. These studies include: 1) SPACE: Synoptic Pan-Arctic Climate and Environment Study” to utilized multi-icebreaker operations in a synoptic fashion to undertake slope to basin sections in the Eurasian Arctic (U.Shauer et al., Germany; 2) “A Study of the Land-Shelf Basin Interaction along the Siberian Shelf Seas” to undertake synoptic studies of the exchange of waters and properties, both terrestrial and marine at the shelf-break from the Laptev Sea to the Russian border of the Chukchi Sea (Leif Anderson et al., Sweden), 3) Phase 3 of the ongoing Shelf-Basin Interactions (SBI) global change project to study the production, transformation and fate of carbon at the shelf break of the Chukchi and Beaufort Sea in relation to global warming (<http://sbi.utk.edu>); and 4) SEARCH: Study of Environmental Arctic Change as it relate to the development of an

observation network of pan-Arctic oceanographic transects (<http://psc.apl.washington.edu/search/>).

Ultimately, the educational outreach component could coordinate with organizations, such as the “Nordic Network”, the Canadian ArcNET, and University of the Arctic to coordinate SBE activities within the scope of this IPY project. Data management would be approached in a coordinated fashion using an agreed upon, web-linked “virtual electronic” data base for linking the “Arctic Snapshot” SBE-relevant data on one web page to the actual data housed in national data archives.

In summary, the International SBE “Arctic Snapshot” would consist of the following coordinated synoptic international activities during IPY07/08:

- Perform transects of the continental slope all around the Arctic Ocean in order to study the boundary current (Figure 1). By examining the change in key physical and biochemical properties along its flow path the interaction with the shelves could be deduced;
- Complement the above with shelf and slope process studies in order to elucidate the water flow pattern, biological activity, and flux of chemical constituents from the sediment surface;
- Studies of several polynyas in a pan-Arctic perspective for as many seasons that are logistically feasible, with the objective to evaluate their role in ventilation of the Arctic Ocean and in the carbon cycle, and
- Compare and contrast slope canyons as mechanism for biogeochemical product transport from the shelves to the deep Arctic basin.