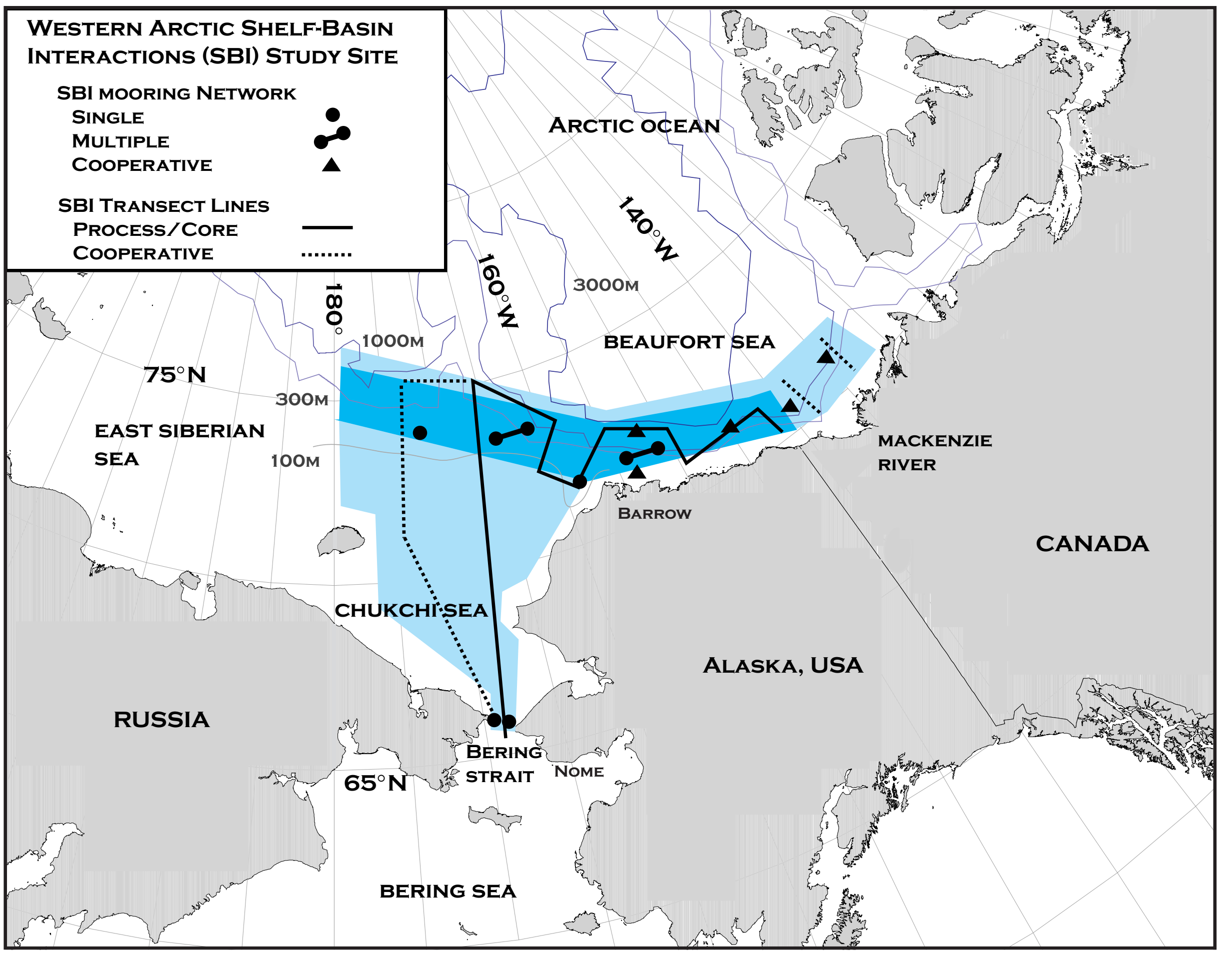
ARCTIC SYSTEM SCIENCE•OCEAN-ATMOSPHERE-ICE INTERACTIONS

WESTERN ARCTIC SHELF-BASIN INTERACTIONS (SBI)

PHASE II FIELD STUDIES IMPLEMENTATION PLAN



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Additional copies of this report may be downloaded as a pdf file from the SBi webpage <http://utk-biogw.bio.utk.edu/SBI.nsf> or contacting the SBI Project Office (jgrebmei@utk.edu) for a hardcopy.

EXECUTIVE SUMMARY

The Western Arctic Shelf-Basin Interactions (SBI) project is a contribution of the Ocean-Atmosphere-Ice Interactions (OAII) component of the National Science Foundation's (NSF) Arctic System Science (ARCSS) global change program. The overarching rationale for the Western Arctic SBI project is that global change will especially influence physical and biological linkages between arctic shelves and their adjacent ocean basins. As such, SBI field efforts will converge on the zone comprised of the outer shelf, shelf break and slope, where key processes control water mass exchange and biogeochemical cycles, and where the greatest responses to warming and altered arctic ice cover are expected. The Western Arctic SBI study area covers the Chukchi and Beaufort seas. It is anticipated that the understanding obtained will permit extrapolation to a Pan-Arctic perspective.

Arctic shelves partition fresh and saline water mass components that impact the ocean's stratification and thermohaline circulation. They also efficiently receive the raw materials of inorganic carbon and nutrients, and fix these for consumption in the food chain and export to the deep ocean. In anticipation of global warming, we expect that the Arctic's shelf domain will experience longer and more extensive ice-free conditions, with attendant changes to underwater light climate and wind forcing that will have cascading effects through the Arctic ecosystem.

The SBI Phase II Field Implementation Plan described in this report outlines seasonal survey and process studies, including a time series mooring component as well as modeling efforts, all at appropriate time and space scales. A special concern is that physical and biogeochemical process studies be well coordinated. "In-place" moored arrays in Bering Strait and the Chukchi/Beaufort outer shelf/slope region as part of the SBI "mooring network" will allow the addition of biochemical instrumentation that will enhance interdisciplinary investigations of the flow into the study area through Bering Strait as well as the exchanges at the shelf-slope interface to document the influence of this highly productive region on the Arctic ecosystem. Additional moorings coincident with process studies are recommended for the outer shelf and slope of the Chukchi and Beaufort seas. Mesoscale, interdisciplinary survey and process studies conducted across the shelf and slope regions within the SBI study area during various seasons will be critical to understanding biogeochemical processes occurring over time and space scales relevant to interpreting annual and interannual changes.

SBI Phase II (2002-2006) will constitute the core regional field investigations in the Chukchi and Beaufort Seas, along with continued regional modeling efforts. The Phase II timeline includes an Announcement of Opportunity for proposals in late February 2001, with the first field program being initiated in spring 2002. Further information on the SBI project and updates can be found on the SBI web page <http://utk-biogw.bio.utk.edu/SBI.nsf>.

TABLE OF CONTENTS

1. INTRODUCTION

The Western Arctic Shelf-Basin Interactions (SBI) project is a contribution of the Ocean-Atmosphere-Ice Interactions (OAII) component of the National Science Foundation's (NSF) Arctic System Science (ARCSS) program. SBI is investigating the Arctic marine ecosystem in an effort to improve our capacity to predict environmental change (OAII, 1992). The overarching rationale for the SBI project is the premise that global changes influencing biological and physical linkages between the shelf and basin have amplified effects in the Arctic ecosystem. The SBI project is focused on the critical zone comprised of the shelf, shelf break and slope, where many important biological, chemical and physical processes result in significant changes and modifications of the system. The SBI project will focus on the outer shelf/slope water mass modification and exchange processes and biogeochemical cycles in the Chukchi and Beaufort Seas. While the program is geographically restricted, a major goal is to understand processes that occur in many Arctic shelf seas. These topics are particularly important because they profoundly influence the thermohaline and biogeochemical structure of the Arctic Ocean.

The SBI project will contribute toward the ARCSS program goal of understanding the role of the Arctic Ocean in the global climate system and the response of this ocean to global change (Moritz et al., 1990; ARCUS, 1997a). These issues are unresolved for two reasons. First, many Arctic processes that potentially affect global climate are not well studied and associated mechanisms are not well understood. Second, observational climatologies for the Arctic are incomplete in comparison to other parts of the global ocean. Certain regions of the Arctic Ocean, including its shelves, have a minimal description of the circulation, hydrography, and seasonal variability. Likewise, the few data pertaining to biological productivity and the fate of this production are so broadly distributed in time and space that it is difficult to distinguish temporal from spatial variability.

The SBI project includes retrospective, laboratory, field and modeling studies directed at elucidating the underlying physical and biological shelf and slope processes that influence the structure and functioning of the Arctic Ocean, as outlined in the community-developed SBI Science Plan (Grebmeier et al. 1998; background text presented in Appendix A). The SBI project is going forward in three phases. Currently Phase I is in progress (1998-2001) and involves regional historical data analysis, opportunistic field investigations, and modeling. Phase II (2002-2006) will constitute the core regional field investigations in the Chukchi and Beaufort Seas, along with continued regional modeling efforts. Phase III (2007-2009) will investigate global change consequences for the ecosystems of the Arctic shelves and basin. This phase will involve development of a Pan-Arctic model (including embedded regional submodels) suitable for exploring "what-if scenario" studies related to global change.

2. OVERVIEW OF THE SHELF-BASIN INTERACTIONS (SBI) PROJECT

The fundamental goal of the Shelf-Basin Interactions (SBI) project is to understand the physical and biogeochemical processes that link the arctic shelves, slopes, and deep basins within the context of global change. These processes strongly influence the biology, chemistry, and physics of the Arctic Ocean and its associated ecosystems. The Arctic marine system has, in turn, important links to the global ocean and atmosphere. For example, outflows from the Arctic have a major impact on North Atlantic deep convection which, in turn, exerts a major influence on the thermohaline circulation of the world ocean. Arctic Ocean waters are strongly influenced by biogeochemical processes occurring over the arctic shelves and an improved understanding of these processes is essential for predicting, anticipating and ameliorating the impacts of climate change. Arctic shelves are important sites for the cycling and deposition of carbon, nitrogen and other biogenic materials and for enhanced rates of biological processes relative to the Arctic Ocean Basin. One example is that carbon dioxide fluxes from sources or sinks on Arctic shelves may have direct impacts on air temperatures and sea ice coverage, with negative ramifications for local marine resources and human populations that are dependent upon them for subsistence. The recent mass mortality of short-tailed shearwaters in the Bering Sea may be a consequence of changes in the phytoplankton community influenced by changes in shelf processes, ultimately resulting in regional resource limitations. Changes in Arctic shelf processes could also have globally significant impacts in the cases of changes in denitrification and the possible mobilization of clathrate deposits. One goal of the SBI project will be to identify processes that are sentinel indicators of global change, including alteration of current biogeochemical cycles.

The initial focus of the SBI project is the Western Arctic, particularly where North Pacific waters are modified by shelf processes that exert significant influences on the biology and physics of the Arctic Ocean. Prior carbon cycling work indicates that the southern Chukchi Shelf is the most biologically productive region in the marine Arctic, and that biogeochemical processes in both the water column and sediments control the use and recycling of organic carbon prior to advection into the deeper polar basins. Carbon cycling influences Arctic marine ecosystems, depending upon whether carbon enters: 1) the mixed layer (where it is available for further production), 2) the halocline (where it may be transported long lateral distances), or 3) the abyssal ocean (where it is sequestered for very long times). Since precipitation, temperature, runoff, ocean circulation, ice cover, and other physical factors directly impact the cycling of nutrients and carbon on Arctic shelves, expected global change will likely alter the biogeochemical pathways that determine the fate of shelf production. Evaluating such developments requires a significantly improved understanding of the transformations of carbon over the shelf and slope, particularly as they influence either carbon throughflow to the deep basins or deposition on the continental slopes.

From a physical oceanographic perspective, northward flowing Pacific waters are substantially modified over the shelves before entering the deeper Arctic Ocean. This has consequences for the stability of Arctic sea ice cover, vertical and horizontal mixing, internal wave dynamics, and the accessibility of inorganic nutrients to the euphotic zone. Changes in shelf-basin exchange will influence Arctic Ocean climate through feedbacks to the surface heat budget and freshwater cycling. The injection of shelf-modified waters into the Arctic Ocean appears to be controlled by a number of physical processes occurring over the outer shelf and the continental slope, most of which are poorly understood and some of which may have been neglected altogether by previous work. Changes in either the balance of shelf processes that modify Pacific waters, or in the slope processes that control exchange with the deep basin would likely result in major alterations of the Arctic marine environment. As examples, biological production and physical transformations on the Chukchi Sea shelf and slope likely depend in part on the quantity of freshwater transported through Bering Strait. This freshwater flux is in turn directly related to the North Pacific climatology and hydrology, and probably inversely related to nutrient concentrations. Atmospheric conditions over the Chukchi shelf have further effects upon ice and dense water production, which in turn provide a control on marine organism distributions and abundance, on materials exported from the shelf, and on the evolution of the thermohaline structure of the Arctic Ocean. Alterations in these patterns would have significant consequences upon U.S. marine transportation and resource exploitation, as well as more locally critical impacts upon Arctic residents who rely on the marine ecosystem for subsistence; other impacts may be possible on regional or even global scales.

Sensitivity of the Western Arctic to climate change has direct consequences for human society. Higher trophic-level animals, particularly marine mammals and seabirds, migrate between the Pacific and the Arctic, and Native Iñupiat communities have traditionally depended on harvests from these migrations. These activities are highly dependent on factors such as ice cover and lower trophic level processes which we know have undergone significant recent change. Prior work indicates that a large fraction of the carbon, nutrients, and lower trophic-level organisms on the Western Arctic shelves is exported offshore to the central Arctic Ocean. This export of carbon and nutrients is important to the Arctic Ocean ecosystem, where heterotrophic production (including marine mammals) may exceed autotrophic production. Organic matter added by runoff and by recently accelerated coastal erosion is also involved in the shelf-basin exchange. Hence the present Arctic Ocean ecosystem and its cycling of organic matter depends upon export fluxes from the surrounding shelves, which in turn receive some organic matter from the surrounding land. The Chukchi shelf imports massive quantities of nutrients via the Bering Strait inflow and the biological production there ranks amongst the highest in the world.

Recent paleoceanographic studies under SBI Phase I suggest that the Chukchi Sea has been subjected to large temperature variations during the last 6 kyrs, which were not recorded in the GISP/Vostok ice cores. Contemporary studies are demonstrating declining faunal biomass and changing community structure on the Bering and Chukchi shelves. This variability suggests that the Western Arctic is a region with considerable sensitivity to large-scale biological and climatic change. We note that high-resolution paleo-records can provide an important understanding of this interactive system and its variability by indicating which important variables change during dramatic past climatic events and how they are related to global climate recorded elsewhere. In addition, better understanding of the modern environment will aid the interpretation of the paleo-record, thereby adding to our understanding of the past. An additional benefit will be to provide a paradigm for a changing world by linking the paleoclimate proxy-record with contemporary knowledge of seasonal and interannual process variability in the Arctic.

The SBI project will focus on:

- Physical modifications of North Pacific and other waters on the Chukchi shelf and slope, since these modifications subsequently affect both exchange across the continental slope and the thermohaline structure and circulation of the Arctic Ocean.

- Biogeochemical modifications of North Pacific and other waters over the Chukchi and Beaufort shelf and slope areas, with an emphasis on carbon, nutrients, and key organisms that represent a suite of trophic levels.

- Comparative studies over the wide Chukchi and narrow Beaufort shelves and adjacent slopes to facilitate extrapolation of the Western Arctic work to a Pan-Arctic perspective. Modeling of shelf-basin exchange processes and their sensitivity to global change will be an important methodology in this extrapolation.

Because of the markedly different summer and winter regimes in the Arctic, as well as the remarkable year-to-year variability, seasonal and interannual time series are required to identify the processes that control the functioning of the Arctic ecosystem. Therefore SBI will undertake time series studies to:

- Quantify the major physical processes over the shelf and slope and their variability, including resolution of smaller scale (< 10 km) physical exchange processes along the shelf break and slope, since these appear critical to the disposition within the Arctic Ocean of mass, heat, salt, carbon and nutrients, from the shelves.

- Quantify the major biological and chemical processes over the shelf and slope and their variability since the timing of biological rate processes relative to physical transport processes is critical to understanding ecosystem dynamics.

- Quantify the export of mass, heat, salt, carbon and nutrients into the Arctic Ocean and their variability.

In summary, the goal of the SBI project is to provide a better understanding of the physical and biogeochemical connections between the Arctic shelves, slopes, and deep basins that could be influenced by global change. The physical and chemical nature of seawater transiting the Western Arctic and entering the world ocean is defined by the physical and biogeochemical processes occurring over the Western Arctic shelves. The current Arctic Ocean system and the cycling of carbon depends upon carbon export fluxes from the surrounding shelves. Changes in either the balance of shelf processes that modify the Pacific waters, or in the slope processes that control exchange with the deep basin, will likely result in major alterations of the Arctic marine environment. These alterations would also have significant societal consequences on local, regional, and national levels in areas as diverse as marine transportation, resource use, and climatic change. An understanding of these processes is therefore essential. This new understanding will in turn facilitate assessment of the potential responses of the Arctic system to global change, and the role of these interactive processes on the global climate system.

3. SBI PHASE II FIELD IMPLEMENTATION PLAN

The Western Arctic SBI project is being undertaken using analysis of historical data, modeling, development of a Phase II sampling program (with required platforms) and integration with both national and international programs. The core program will include regional investigations, regional models, Pan-Arctic data synthesis and international comparison of regional models, and development of a "Pan-Arctic" model (or embedded regional submodels) suitable for "what-if" global change scenario studies. The purpose of the SBI Science Plan (Grebmeier et al. 1998) was to summarize the goals and disciplinary objectives of the program and to propose a broad outline for an implementation plan. The current SBI Phase II Implementation Plan outlines priority measurements and appropriate time and space scales for coordinating physical and biogeochemical process studies to address the goals of the SBI project.

3.1 Study Area/Sampling Sites

The principal study area of the SBI project will be the outer shelf and continental slope area of the Chukchi/Beaufort Seas (Figure 1). The Chukchi Sea study area is a wide throughflow shelf for Pacific waters that have entered through Bering Strait. These waters are known to principally cross the northern shelf via Barrow Canyon, the Hope Sea Valley/Herald Canyon depression, and the gap between Herald and Hannah shoals, but the details of their exit from the shelf are largely unknown. The regional biophysical signal is evident in the formation of the upper halocline waters. By comparison, the western Beaufort Sea shelf is narrow and locally-driven, with a large freshwater input from the Mackenzie River on the wider eastern Beaufort shelf. While many details are not known, the study area has high annual and interannual change in the system.

In a cooperative SBI effort, Canadian colleagues continue to study the area westward of the Mackenzie

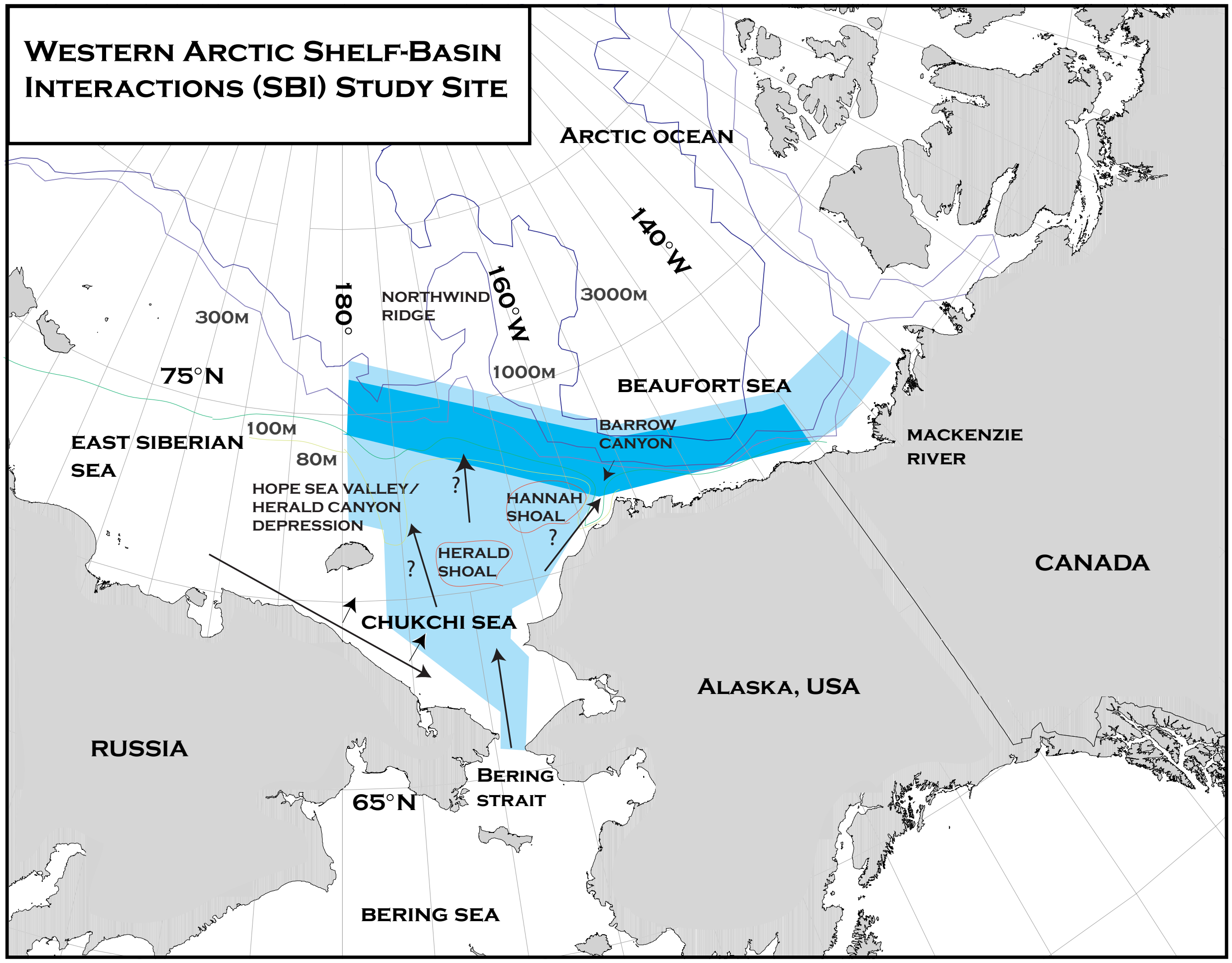

Figure 1. Planned study region for the SBI project in the western Arctic, including schematic of general current flow.

River (current DFO moorings) receiving outflow from the Chukchi shelf (Figure 2). A pending study off the Mackenzie River eastward through the Admunsen Gulf called the "Canadian Arctic Shelf Ecosystem Study (CASES) will complement the goals of the U.S. lead SBI project. In addition to exchanges with the Canadian Basin, this shelf also provides inflow to the Canadian Archipelago, which in turn connects to the North Atlantic Ocean.

The combination of these two study areas permits a general assessment of both wide and narrow shelves. In combination, they include regions dominated by advective inflow, freshwater inflow, shelf-basin exchanges and advective outflow through the Canadian Archipelago. If international circumstances allow and Russian collaborations are established, portions of the western Chukchi Sea and nearby East Siberian shelf/slope will also be included in the study area.

3.2 Goals, Objectives and Hypotheses

The SBI Phase II field project is centered around three research foci in the core study area (Fig. 1) in the Chukchi and Beaufort seas:

- Northward fluxes of water and bioactive elements through the Bering Strait input region

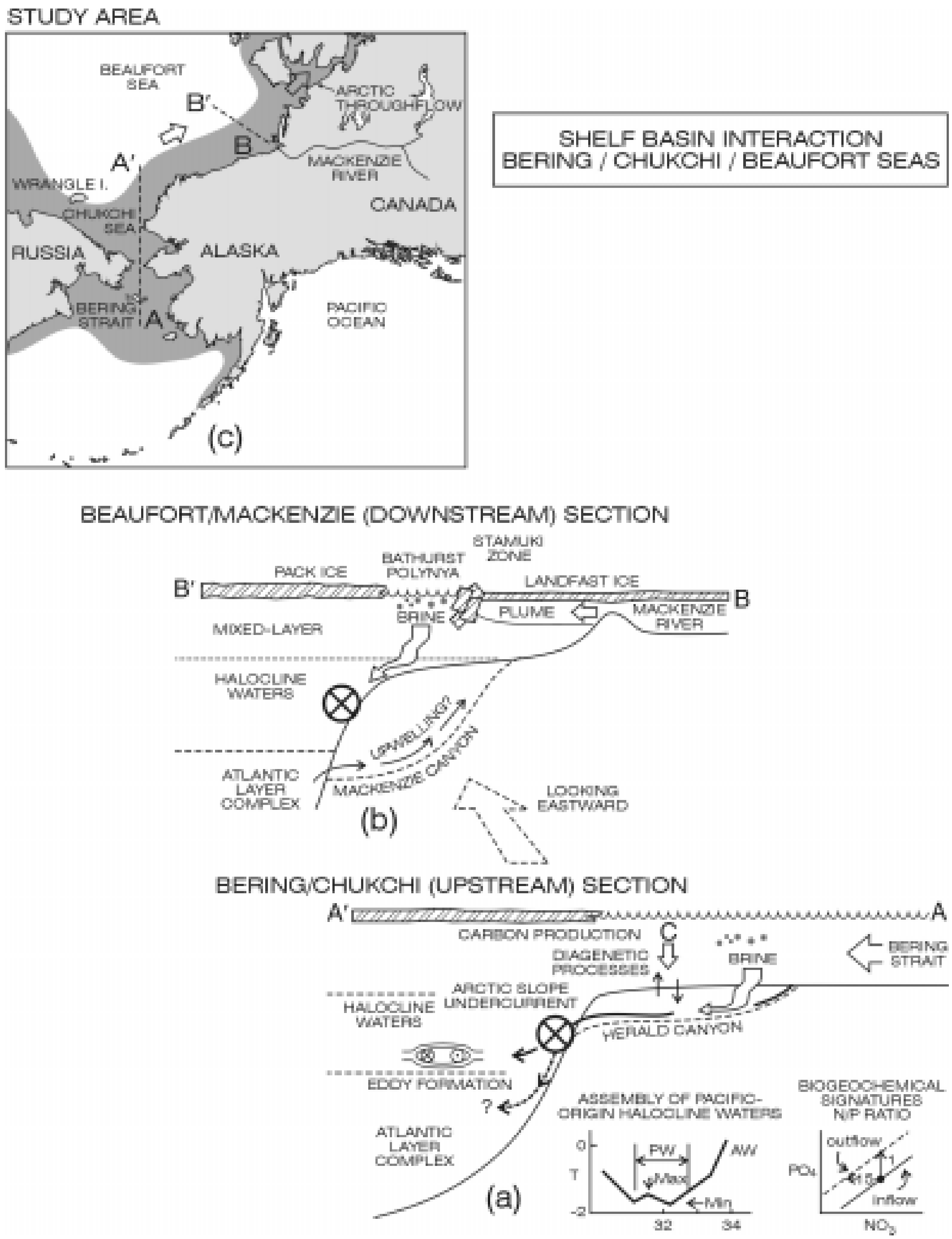

Figure 2. Schematic showing processes affecting shelf/basin interaction in the Western Arctic and linkages between the Bering/Chukchi and the Mackenzie/Beaufort regions. The gray shaded zone is the seasonal ice extent. Central issues for process related work in the Bering/Chukchi region (Figure 2a) include: (1) influx and disposition of Pacific waters (PW) entering through Bering Strait; (2) modification of PW by physical (e.g. cooling, ice formation) and biogeochemical (e.g. productivity, diagenesis) processes during transit of the broad shelf; and (3) efflux of modified PW into the halocline waters of the Arctic basin. Central issues for work in the Mackenzie/Beaufort region (Figure 2b) include: (1) influx and disposition of Mackenzie River (MR) waters; (2) modification of water properties on the Beaufort Shelf with emphasis on the role of particles; (3) exchange processes (e.g upwelling, brine drainage) at the shelf break and in submarine canyons; (4) export of Arctic basin waters into the Canadian Arctic Archipelago by selective withdrawal; and (5) winter oceanography of the Bathurst Polynya.

- Seasonal and spatial variability in the production and recycling of biogenic matter on the shelf-slope area

- Temporal and spatial variability of exchanges across the shelf/slope region into the Canada Basin.

Through integrated field and modeling efforts, the SBI project will investigate the effects of global change on production, cycling and shelf-slope exchange of biogenic matter, both seasonally and spatially. To this end, there are five study objectives deemed both timely and essential to an improved understanding of the effects of global change on productivity as it contributes to shelf-basin interactions within the Arctic Ocean ecosystem, including:

1. Understanding the roles of physical processes in the transport and modification of water and biogenic materials across the shelf and into the interior basin;

2. Identification of mesoscale oceanographic features that support locally elevated concentrations of benthic and pelagic biota;

3. Quantification of upper ocean (water column and sea ice) primary productivity in relation to the biomass and diversity of benthic and pelagic primary and secondary consumers;

4. Assessment of the relative importance of top-down as compared to bottom-up controls over pelagic-benthic coupling, biotic complexity, and carbon partitioning among different trophic levels; and

5. Assessment of food web changes consequent to the impacts of changing ice cover and hydrographic parameters on remineralization of organic matter, recycling efficiency and biogeochemical fluxes.

Specific physical, biochemical and biological hypotheses that can be addressed within the SBI program, through field studies and modeling, are outlined in the SBI Science Plan. Examples of such hypotheses include:

- Ice formation and dense shelf water production contribute to a highly stratified upper layer in the Arctic Ocean. Therefore, changes in the physical processes that affect dense shelf water production directly influence shelf and basin biogeochemical cycles: a cessation of dense water production will lead to increased nutrient concentrations on the shelf and/or a larger nutrient flux into the surface layers of the Arctic Ocean. As a result, alterations in the rates and timing of biological production, and the associated Arctic food chain, will occur.

- Reduction in ice cover and stratification, which may already be occurring and which are the plausible result of any warming trend, will increase total/new production in the Arctic Ocean and its marginal seas. However, even without changes in overall total/new production, a change in ice cover will cause a major shift in the relative contributions of ice algae and phytoplankton to shelf and slope primary production.

- The degree of ice cover will have no effect on total secondary production, but it will instead cause a major shift in the relative importance of the benthic fauna and pelagic zooplankton.

- Reduced ice cover with global change will result in increased carbon sedimentation and carbon storage in the Arctic shelf and slope sediments, thus providing an increased sink for global CO_2.

- At least four species of marine mammals (ringed seal, ribbon seal, bearded seal, polar bear) are obligately ice-associated. Changes in the extent of ice cover will control where these mammals are located and where higher trophic levels will have the most significant impact on lower trophic levels.

The SBI Phase II Field Implementation Plan outlines a combination of seasonal hydrobiochemical surveys in support of major biogeochemical, biological and physical process studies as well as modeling efforts, at appropriate time and space scales. Mesoscale, interdisciplinary survey and process studies conducted across the shelf and slope regions during various seasons will be critical for understanding biogeochemical and physical processes occurring over time and space scales relevant to interpreting annual and interannual change in the system. Standard hydrobiochemical measurements on each cruise will constitute the core measurements program within SBI and is considered a "service program" in support of the biological direction of the SBI project. Interdisciplinary mooring arrays are to be coordinated with process studies.

A special need of the SBI project is for physical and biogeochemical process studies to be well coordinated. A set of "in-place" domestic and foreign mooring arrays, in combination with any proposed moorings as part of this AO, constitute the "SBI mooring network". Moored time-series arrays as part of the SBI mooring network are available for instrumentation proposals to add equipment to the array that will enhance biogeochemical investigations of the flow characteristics into the study area through Bering Strait as well as the exchanges at the shelf-slope interface.

3.3 Phase II SBI Field Project

The main focus area for shipboard work is planned for the outer northern shelf and slope of the Chukchi and Beaufort Seas (Figure 3). The SBI II field program will include four process-oriented cruises in May/June and July/August 2002 and 2004 (Table 1). Alternate years, 2003 and 2005 in both May/June and July/August, will include reduced field programs for critical time-dependent, core measurements essential for interpreting processes relevant to shelf-basin interactions and ecosystem response. Annual fall cruises will occur in September and will provide an opportunity for emplacement of new SBI time series moorings into the SBI mooring network, underway surveys, and opportunities for coring. A final synthesis year will follow the 4-year field program, thus 5-year proposals are suggested.

Previous and on-going studies, including ship-based studies, time series moorings, and modeling suggest a sampling scheme as outlined in Figure 3. The mooring sites are indicative of "in-place" moorings (both national and foreign) and recommended mooring array locations for the current SBI AO. "In-place moorings" in Bering Strait will measure oceanographic parameters in the two channels of Bering Strait which admit the Pacific waters. There are two JAMSTEC (Japan Marine Science and Technology Center) moorings currently in place in the Beaufort Sea maintained as a Japanese contribution to SBI. Two moorings are planned by Canadian colleagues in their sector of the Beaufort Sea. This international combination of moorings forms the initial time series network for the SBI project.

In general, multi-disciplinary time series from moored instrumented arrays, shipborne sampling, and satellite observations covering the seasonal cycle over several years are essential to improving our

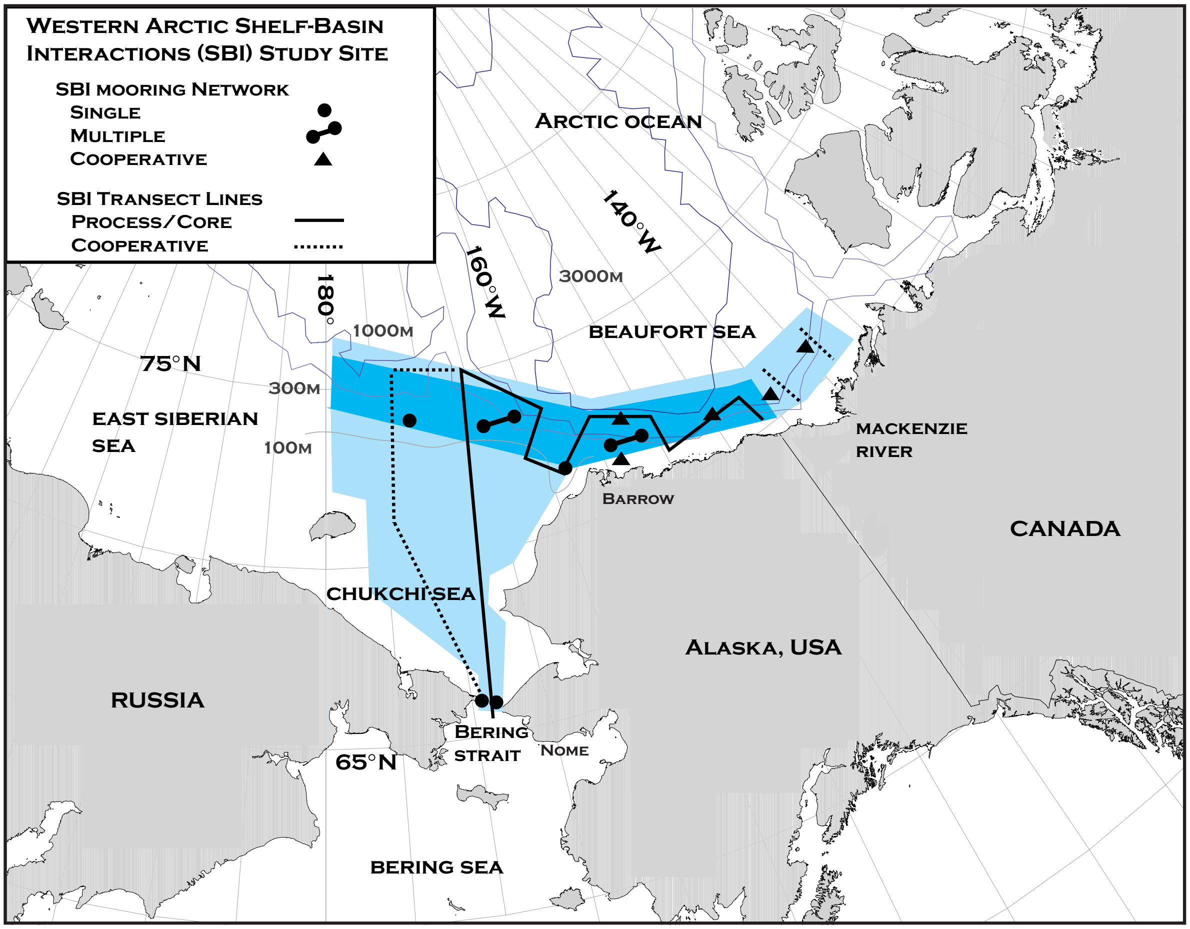

Figure 3. Study region (blue zone) for the SBI project in the western Arctic, with possible U.S. mooring sites indicated which are coincident with current and planned Japanese and Canadian cooperative studies.

understanding of the important processes associated with shelf-basin interactions. Critical seasonal time series measurements must be maintained over a number of annual cycles to assemble adequate and representative time series, for interannual variability on the shelf appears to be large (Sherr and Sherr, 2000). In parallel, seasonally distributed sampling from ships and other platforms (e.g., helicopters operating on the ice) are required for detailed process studies and rate measurements over critical areas not sufficiently sampled from moorings, as well as for mapping the spatial fields of various key variables. This combination of approaches involving multi-disciplinary observations will provide the critical data sets for developing and improving physical-biological coupled models, and will also provide a basis for generating testable hypothese.

Biological field observations are often valuable indicators and integrators of physical and biogeochemical processes over both temporal and spatial time scales. In anticipation of climate change, interdisciplinary sampling efforts are critical to understanding biological events that are dependent on the occurrence of unique physical processes. Investigation of “hotspot” areas, identified by aggregations of higher-trophic species (i.e., seabirds and marine mammals), could augment physical modeling projects. For example, the proposed western SBI study area encompasses key foraging areas for endangered bowhead whales (*Balaena mysticetus*) and gray whales (*Eschrichtius robustus*) Because these species feed on zooplanktonfrom the water column and benthos, respectively, they may function as bio-indicators of specific combinations of physical processes that initiate zooplankton swarming in specific regions.

Table 1. SBI Phase II Field Schedule.

Year	Date	Activities	Length
2002	May-June	Process-oriented cruise; “service measurements”	6 wks
	July-Aug.	Process-oriented cruise; “service measurements”	6 wks
	Sept.	Bering Strait mooring turnaround; emplace new moorings; underway surveys	4 wks
2003	Feb.-Mar.	Possible ice camp measurements	6 wks
	May-June	“Service measurements”; underway survey	4 wks
	July-Aug.	“Service measurements”; underway survey	4 wks
	Sept.	Mooring turn-around; underway surveys; coring	4 wks
2004	Feb.-Mar.	Possible ice camp measurements	6 wks
	May-June	Process-oriented cruise; “service measurements”	6 wks
	July-Aug.	Process-oriented cruise; “service measurements”	6 wks
	Sept.	Mooring turnaround; underway surveys	4 wks
2005	May-June	“Service measurements”; underway survey	4 wks
	July-Aug.	“Service measurements”; underway survey	4 wks
	Sept.	Pull out moorings; underway surveys	4 wks
2006		Synthesis	

3.4 Core Field “Service Measurements”

Selected physical and biochemical measurements will constitute the core “service measurements” program on process cruises indicated in Table 1. Proposals for this category should addresss the acquisition of a consistent suite of data for process cruises in May/June and July/August 2002 and 2004, and note that tthese proposals are considered a “service measurements” function rather than a scientific function. Insofar as possible, data will be provided to scientific participants upon their departure from the vessel at the completion of each cruise leg. Data to be collected include:

- CTD- based temperature, salinity and dissolved oxygen measurements
- In-situ fluorescence and transmissivity
- Photosynthetic active radiation (PAR) measurements
- Rosette for discrete water sampling
- Determination of inorganic nutrients (nitrate, nitrite, phosphate, dissolved silicon, ammonium), chlorophyll-a, salinity and dissolved oxygen
- Underway surface observations, including temperature, salinity and meteorological data.

Note that the process study proposals outlined below should not duplicate measurements to be provided within the “service measurements” program to all participants. However, since “service measurements” will not be provided for the fall cruises, any measurements considered essential to process studies should be justified and budgeted within submitted process proposals.

3.5 Process Studies

Intensive seasonal process studies are planned for May/June and July/August 2002 and 2004, with limited sampling possible in alternate years. The intensiveprocess studies are required for detailed rate measurements over critical spatial domains not sufficiently sampled from moorings, as well as for mapping the spatial fields of various key variables. Any additional mooring arrays identified to be added to the SBI mooring network must be proposed in coordination with SBI process studies.

a. Recommended Rate Measurements for Seasonal Process Cruises

At the minimum, rate measurements recommended for the seasonal process cruises in 2002 and 2004 include:

- New and regenerated primary production
- Bacterial activity/production
- Micro and macro-zooplankton grazing and reproduction
- Benthic faunal production
- Sediment metabolism.

b. Additional Biogeochemical and Physical Measurements

Additional biogeochemical and physical measurements for cruises could include:

- Dissolved inorganic carbon (DIC)
- Chemical (e.g., oxygen-18) and radiochemical ocean tracers
- Phytoplankton species composition and HPLC pigments
- Particulate organic carbon (POC), particulate organic nitrogen (PON), dissolved organic carbon (DOC), and dissolved organic nitrogen (DON)
- Bacterial biomass and/or microbial sensors
- Heterotrophic protist biomass
- Micro-and macro-zooplankton biomass
- Benthic macrofaunal biomass
- Ocean front and frontal process studies
- Eddy formation and slope boundary transport.

c. Time Series Mooring Arrays

Collaboration between scientists interested in deploying time series moorings and those interested in pursuing process studies are encouraged. This collaboration should result in proposals integrating mooring and process activities to justify the placement of the moorings and show how the proposed research will meet SBI objectives. The “SBI mooring network” includes two Bering Strait moorings that will be maintained under separate ONR funding as an “in-place” program, so interested people can propose to place biochemical sensors and sampling devices on these moorings as part of the SBI AO. In addition, four funded, foreign-supported moorings are available for additional biogeochemical instrumentation in the Beaufort Sea as part of the SBI mooring network. These four currently funded moorings include two JAMSTEC (Japan Marine Science and Technology Center)-sponsored moorings and two Canadian-sponsored moorings (DFO: Department of Fisheries and Oceans). Both currently have standard physical oceanographic instrumentation on them. The revised SBI field map within the SBI Implementation Plan provides a schematic of the currently maintained moorings for the SBI mooring network, as well as suggestions of possible SBI Phase II and "in-place" mooring sites. Any proposed time series moorings should provide coincident physical and biochemical measurements, including ice-thickness, current velocity, temperature, salinity, light transmission, chlorophyll and nutrient sensors. These moorings should have the capability of accepting other samplers and sensors as well. The proposed location of these moorings may include the major transport pathways for shelf-basin interactions under study: shelf-slope exchange, eddy formation, and off/on shelf exchange via canyons.

Physical and biogeochemical measurements on all moorings should include, at the minimum:

- Ice-thickness
- Current velocity
- Temperature
- Salinity
- Light transmission
- Chlorophyll sensors
- Nitrogen and phosphate (possibly) sensors.

These moorings must have the capability of accepting other instrumentation, especially biogeochemical samplers and sensors. Additional measurement devices on these moorings could include, but are not limited to:

- Time series collections of water sample (e.g., for oxygen-18 and trace elements)
- Detectors for dissolved organic carbon
- Vertical particulate fluxes
- Passive acoustics detections (marine mammals)
- Active acoustic detections (zooplankton).

d. Additional Measurements

Proposals will be accepted for acoustic doppler current profiling (ADCP) data collections as well as seabird and marine mammal surveys if coordinated with process study proposals. Both these data collection techniques should include synthesis and interpretation coincident with SBI interdisciplinary data collection objectives and goals. Limited winter measurements are suggeseted and specific proposals for such measurements are welcome. There is a possibily for occupation of an ice camp in the northern-most portion of the SBI study area in Feb.-Mar. 2003 or 2004.

3.6 Paleoceanography within SBI

Paleoenvironmental studies provide a unique historical perspective for assessing SBI documentation of present-day conditions. The paleo-record provides an ability to compare many different scenarios that have occurred in the last 50 kyrs in order to obtain an insight into today's shelf-basin interaction processes. Equally important, comparison of Arctic parameters such as productivity, nutrients, water temperature, salinity, and percent ice cover over the last several thousand years with conditions outside of the Arctic during this same times allows for the assessment of the impact of global change on the Arctic and insights into the role of the Arctic in global change. For example, Phase I results of SBI indicate that the sea-surface temperature, salinity, and ice cover have fluctuated over a surprisingly large range in the western Arctic Ocean during the last 7 kyrs. These changes were relatively rapid, switching from lows to highs in less than a few centuries and on a cyclicity similar to Dansgaard-Oeschger cycles of rapid, large temperature changes seen in the ^{18}O record from the Greenland ice core and deep-sea sediments of the North Atlantic. In addition, fluxes of sediment from different sources appear to change on similar, if not higher frequency time scales. These results have important implications for interpreting Phase II results and for informing Phase III analyses and modeling.

The overall goal of the SBI Phase II paleoceanography component is to determine the paleorecord in at least two other high resolution sedimentation cores that are located along the Chukchi-Beaufort continental slope within the SBI study area. Based on the limited availability of high resolution sediment cores from the SBI study area (one core with deposition rates of 25 cm/kyr currently being studied in Phase I), further coring and analysis of such cores is warranted. Because of the importance of predicting change into the future, SBI appreciates the value of the long-term sediment record for informing efforts to model future change. Therefore, the SBI project anticipates providing ship-time, including sea-beam use to obtain these cores, with the main scientific support coming from collaboration with NSF's Earth System History (ESH) program.

3.7 Remote Sensing

Remote-sensing platforms will be important for understanding both physical and biogeochemical processes. They will be helpful in providing regional and basin scale spatial coverage as well as year-round measurements. Data collected during the SBI project, in conjunction with archived satellite data sets, will help quantify ocean and ice variability. That information will be particularly helpful for placing in a historical context the environmental conditions encountered during the SBI field program. Satellite sensors such as the Synthetic Aperture Radar (SAR), the Defense Meteorological Satellite Program Special Sensor Microwave/Imager (DMSP-SSM/I) and the NOAA Advance Very High Resolution Radiometer (AVHRR) can measure ice type, concentration, and displacement, thereby contributing to quantifying freshwater transport and ice production rates. The SAR and AVHRR sensors can provide information on fronts, circulation, and weather. Western Arctic data from these sensors are downloaded to the SAR facility at the University of Alaska, Fairbanks. The recently launched NASA SeaWiFs satellite detects chlorophyll pigments and will therefore be useful in ocean production studies. NASA P3 aircraft could also be equipped with an array of specialized sensors geared for use in conjunction with local field experiments. Under-ice observations, from submersibles, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and divers are also feasible measurement approaches.

3.8 Sampling Plans for the SBI Field Program

The following measurements for the SBI field program are based on the following parameters (refer to Figure 3 for study location):

- estimated two week transit time from Dutch Harbor to Bering Stait and return, inclusive of scientist change-out in Nome or Barrow, Alaska
- either 14 day (survey) or 30 day (process) sampling in the operating area indicated by the transects outlined in the intense study region for the SBI project (see dark blue zone in the schematic SBI map)
- station depths from 50-1000 m
- an average station spacing of 10 nm in the intensive study area
- inclusion of brief single cast stations at 30 nm intervals on the transect from Bering Strait to the

intense blue area each cruise

- estimated 10 stations/d (survey) or 5 stations/d (process), inclusive of between station transit times for each cruise
- average one hr station time (survey) or about 5 hr station time (process) [note process station times likely variable depending on need of funded proposals)
- both process and reduced survey cruises include core hydrobiochemical measurements using a 12 bottle rosette system.

a. Hydrographic sampling planning information during two “service measurement” survey cruises each year in 2003 and 2005

The following sampling plan outlines core hydrographic “service measurements” for two survey cruises each year during spring and summer of 2003 and 2005 (see Table 1):

- 20 brief one cast stations from Bering Strait to primary SBI study region (dark blue region)
- 120 stations/cruise in intensive sampling area
- one CTD rosette cast per station in the intense sampling area
- estimated 10 stations per day
- the average daily sample load in the intensive area, based on 120 core samples/day are:
  - 120 nutrient samples (nitrate, nitrate, phosphate, silica and ammonia)
  - 120 chlorophyll samples
  - 25 bottle salinities
  - 75 dissolved oxygen determinations.

b. Hydrographic sampling planning information during two process cruises each year in 2002 and 2004 (see Table 1):

The following sampling plan outlines activities during process cruises in 2002 and 2004 (see Table 1):

- 20 brief one cast stations from Bering Strait to primary SBI study region
- 120 stations/cruise in intense sampling area
- on average, 4 casts/station in the intensive sampling area, including one CTD rosette cast for core measurements and the other 3 casts for primary productivity and process experiments
- estimated 5 stations per day
- the average daily sample load in the intensive area, based on 60 core samples/day, plus estimated support for primary productivity and process experiments are:
  - 120 nutrient samples (nitrate, nitrate, phosphate, silica and ammonia) [core, plus experimental support samples]
  - 120 chlorophyll samples [core, plus experimental support samples]
  - 25 bottle salinities
  - 75 dissolved oxygen determinations.

c. Water column/sediment sampling plan during process cruises

The following sampling plan relates to water column and sediment sampling during process cruises:

- within the 120 stations/cruise scheme, a subset (20-40) of these stations will be occupied for intense water column and sediment process studies

- the actual number of stations and time per station for experimental studies will vary depending on the type of process studies funded as part of the SBI Phase II AO. However, the estimated extra effort for hydrobiochemical measurements for process studies is included in the 4 casts/ station and the sampling load listed above for hydrographic sampling during process cruises.

4. MODELING

The SBI project has a specific need for physical and biological coupled modeling projects that are contemporaneous with field observations. The individual physical and biological models as well as coupled biological-physical models are needed for feedback into the field sampling program and for a continual assessment of understanding the critical processes associated with ecosystem function and climate change in the Arctic. The field observations cannot by themselves examine the ecosystem holistically or synoptically but an interweaving of process and mass budget circulation models can be used to focus the sampling programs and test concepts of Arctic ecosystem mechanisms. In addition, timely analysis of newly collected field data is vital to stimulate evolution of the SBI project and allow for a continual refinement of the field measurements and understanding of the Arctic ecosystem in the context of global change.

Modeling efforts should address the confounding biological responses of reductions in sea ice cover, increases in land derived nutrient loading, changes in the locations of polynyas and marginal ice zones. An expected warming of the Arctic Ocean is hypothesized to result in higher productivity. Will this increase offset the retreat or loss of the marginal ice zone environment and the associated effects on fauna that rely heavily on these habitats? Secondly, will the transfer of carbon and organisms between shelves and basins decrease, accelerating the impacts of ice loss on higher trophic level organisms? Biological models that incorporate results of field sampling efforts to address such questions will increase our understanding and recognition of the critical biological processes that are key determinants of climate change. Models that try to understand physical processes in support of the SBI objectives are also recommended.

5. SAMPLING PLATFORMS AND LOGISTICS

The 4 year SBI II field program will undertake ship operations in 2002-2005, using the USCGC *Healy* in even years (2002 and 2004) and USCG polar class vessels (*Polar Star or Polar Sea*), or equivalent, in the odd number years (2003 and 2005). Additional ship of opportunity platforms, such as the US's ice-strengthen ship *Alpha Helix*, Japan's ice-strengthened ship *Mirai,* Canada's icebreakers *Sir Wilfrid Laurier* and *Louis St. Laurent,* and possible Russian and Chinese ships may also be available to support the goals of the SBI project. Some of these cruises are possibilities as part of international SBI-relevant collaborative studies jointly being undertaken. Process cruises include both core and process measurements. The reduced cruises consist of a limited suite of core measurements considered essential to address the seasonal and spatial goals of the SBI project. Proposals for limited winter measurements in 2004 will be reviewed. Satellite coverage is anticipated to be an important component of SBI project. Since seasonal time series data and rate process studies are the primary measurement activities, the following sampling schedule on available platforms are anticipated with oceanographic cruises each year proposed during May-June, July-August and September-October. Table 1 outlines the proposed SBI Phase II field program over its 5 year extent.

A limited winter measurement project may be proposed for the 2003/2004 timeframe. Table 2 outlines the planned composite of science platforms over the seasonal cycle.

Table 2. Proposed science sampling platforms for the seasonal and interannual SBI project.

Season	Proposed Science Platforms			
Spring/Early Summer	Moorings	Ice breaker	Satellite	-
Late Summer	Moorings	Ice breaker	Satellite	-
Fall	Moorings	Ice breaker	Satellite	-
Winter	Moorings	-	Satellite	Winter sampling (2003/4)

6. SBI PHASE II TIMELINE

The projected timeline for the SBI Phase II program is outlined in Table 1, including the following key dates:

- February 2001: Announcement of Opportunity for Phase II to scientific community
- May 2001: Proposal deadline to NSF/ONR for SBI Phase II
- October 2001: Initiate funding Phase II
- May 2002: First SBI Phase II field season initiated.

7. SBI DATA MANAGEMENT

Data management requirements will be mandatory using the developing JOSS data network coincident with the ARCSS/OAII guidelines that are listed in Appendix A. Inclusion of a specific data management plan is a required component of all submitted research requests as outlined in the OAII management guidelines (Appendix B). An SBI data policy is being developed by the SBI Project Office (see update on SBI web page) and the Joint Office for Scientific Support (JOSS) in Boulder, Colorado [http://www.joss.ucar.edu/] to allow streamlined PI data management which has been successfully undertaken within the OAII SHEBA (Surface Heat Budget of the Arctic Ocean) project. The JOSS personnel will interact with the PIs and SBI Project Office to facilitate identifying and coordinating of data set development and transfer to a web-based interactive system for the SBI PIs, and subsequently, scientific community use. JOSS will also coordinate the ultimate long-term data archiving through the ARCSS Data Coordination Center (http://arcss.colorado.edu) within the National Snow and Ice Data Center (NSIDC), also in Boulder, CO.

8. SBI PROJECT OFFICE MANAGEMENT

The role of the SBI Project Office (PO) includes organizing SBI annual PI meetings and workshops, acting as information liaison for SBI management of science projects, assisting in the timely placement of data summaries from SBI PI's on the Internet-accessible SBI webserver, and facilitating transfer of complete data sets to the ARCSS Data Coordination Center (ADCC) at the National Snow and Ice Data Center (NSIDC) through the JOSS network. The SBI PO is responsible for providing services for the project including science logistics, meeting arrangements and maintaining the SBI web page [http://utk-biogw.bio.utk.edu/SBI.nsf]. Phase II PIs are required to attend annual SBI PI meetings as organized by the SBI PO.

The SBI PO is advised by the SBI Science Steering Committee (SSC) which consists of representatives from the SBI principal investigators, non-SBI Arctic scientists, and international collaborators. The SBI Executive Committee (EC) is a subset of the SSC and includes the Chair, co-Chair, and representatives of each major discipline within the SBI. The SSC is delegated the authority to make timely decisions in the best interests of the SBI project. The SSC will recommend a person(s) to the SBI PI's for the position of SBI Chief Scientist (and co-Chief Scientist) during Phase II. This (these) individual(s) will be requested to lead the program conceptually and to spend a significant amount of their time toward its successful completion. Additional working groups of PI's will be established to assess project progress, provide scientific direction and to make recommendations on project needs.

9. NATIONAL COLLABORATION

Other planned or on-going domestic projects may address SBI objectives or provide the opportunity for synergistic studies addressing SBI goals. Current moorings are deployed in Bering Strait as part of an ongoing US program, and these moorings provide both data and platforms for deployment of additional instrumentation during SBI Phase II.

In addition, NSF has recently funded a limited number of Long-Term Observatories (LTO) in the Arctic, including a land-based observatory on Little Diomede Island in Bering Strait <http://arctic.bio.utk.edu>, which includes an oceanographic sampling component in the Bering Strait region relevant to SBI. Other LTO projects include hydrological, atmospheric and ice thickness programs. The SBI PO will work to interface the SBI project with observatories and other on-going national and international programs that have direct relevancy to the SBI project.

10. INTERNATIONAL COLLABORATION

International collaboration is sought and desired for the success of the SBI project in order to take advantage of special or unique capabilities of foreign scientists and programs. Input from the international Arctic community is also needed to attain a Pan-arctic and Arctic System analysis of global change processes. During the initial planning of SBI, international scientists attended the workshops and SBI was represented at several foreign meetings of Arctic scientists. The SBI Science Steering Committee is also comprised of key foreign scientists in order to maintain close interactions to ongoing and future international science programs in the Arctic. The following international contacts have been completed or are anticipated: Canada*, Japan*, Norway*, Russia*, China, Germany, and Sweden (*members currently serve on the SBI Science Steering Committee).

Examples of foreign projects that may provide opportunities to address SBI goals and objectives include Russian/other foreign projects in the Chukchi Sea and Canadian/other foreign projects in the Beaufort Sea, such as the ongoing JAMSTEC and Canadian Department of Fisheries and Oceans (DFO) projects, and the pending Canadian Arctic Shelf Exchange Study (CASES) project.

Biennial pan-Arctic meetings are part of the SBI overall project format. The first SBI workshop was held in 1997 in Yokohama, Japan.. The second SBI pan-Arctic meeting, sponsored by the NSF, was held November 7-9, 2000, in Pine Mountain, Georgia, USA. The goal of this meeting was to encourage open discussion of Arctic science in a forum that fostered an international network of active people interested in the SBI goal "to provide a clear understanding of the physical and biogeochemical connections between the Arctic shelves, slopes, and deep basin. That understanding will in turn allow realistic assessment both of the potential responses of the Arctic system to global change, and of the role of these interactive processes on the global system". A summary of the workshop agenda and abstracts is posted on the SBI web page.

11. MULTI-AGENCY SUPPORT

Arctic System Science (ARCSS) in the Office of Polar Programs and the Division of Ocean Sciences at the National Science Foundation, along with the Office of Naval Research, have been the primary sponsors of SBI during its genesis. It is anticipated that ARCSS will maintain the central program support, but other federal agencies with Arctic interests are likely to be interested in also providing some support. A partial list of agencies that will/may take part in Phase II of the SBI project are:

- National Science Foundation (NSF)
- Office of Naval Research (ONR)
- National Oceanic and Atmospheric Administration (NOAA)
- Alaska Department of Fish and Game (ADFG)
- Minerals Management Service (MMS)
- National Atmospheric Science Administration (NASA)
- National Ocean Partnership Program (NOPP)
- Department of Energy (DOE)
- United States Coast Guard (USCG)
- United States Fish and Wildlife Service (USFWS)
- United States Geological Survey (USGS)
- United States Navy (USN)
- International Whaling Commission (IWC).

12. OUTREACH ACTIVITIES

It is important to include outreach activities within proposal preparation describing, for example, how indigenous populations would interface with your research project and how resultant data collected through the SBI project will be utilized to disseminate results and findings to the scientific community, indigenous populations, K-12 education programs and the general public. Acceptable plans may include new media outlets, special presentations and direct research experiences. The updated OAII Science Plan (Codispoti et al. 2000) outlines the ARCSS OAII project outreach requirements, including student and public outreach. For example, the NSF Teachers Experiencing Antarctica and Arctic (TEA) program places K-12 science teachers into research teams in the Arctic for mutual interactions and participant enhancement (see http://tea.rice.edu). Also, NSF support for undergraduate assistants in Arctic research programs is available through the Research Experience for Undergraduates (REU) program, as well as support for graduate education through the Graduate Research Fellowships program. Visit the NSF website: <http://www.nsf.gov> for further information.

Interest in the Arctic is growing as issues of global warming and environmental change are discussed in the public forum. For example, the OAII SHEBA program received considerable national press, both radio and TV. Successful SBI Principal Investigators are encouraged to communicate their results to the public. In some cases, NSF can support these efforts though its public relations staff, and PIs are encouraged to work through their own university-affiliated outreach programs. Finally, outreach to indigenous populations is highly encouraged, such as presentations to the local community where research operations will occur and involvement of native people in science operations. The linkages between climate change, sea ice extent and duration, and marine mammal and seabird populations are central to SBI objectives as are interactions with local populations that directly interface with the arctic environment and who will ultimately be mpacted by global change.

13. FURTHER INFORMATION

Further information can be obtained by contacting Jackie Grebmeier, Director of the SBI Project Office (jgreb@utkux.utk.edu; ph. 865-974-2592) and via the SBI web page <http://utk-biogw.bio.utk.edu/SBI.nsf>. The SBI Science Plan as well as this SBI Phase II Implementation Plan are available for downloading from both the SBI web page and the OAII web page <http://arcss-oaii.umces.hpl.edu>.

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APPENDIX A
BACKGROUND DOCUMENT*

[from the SBI Science Plan (Grebmeier et al., 1998)
and the OAII Science Plan Codispoti et al., 2000]

Collectively, these studies imply that changes in sea ice properties could lead to broad scale changes in climate. However, the present day distribution of the permanent ice pack is due to the Arctic Ocean's halocline, a strongly stratified layer that inhibits the vertical flux of heat into the surface layer from the vast pool of warm water found at mid-depths in the Arctic Ocean. Stratification also affects biological production by hindering the upward flux of nutrients into the polar mixed layer. The maintenance of the halocline depends upon lateral advection of source waters from the adjacent shelves into the interior of the Arctic Ocean. The shelves occupy ~35% of the Arctic Ocean's area and they are the primary sites for processing waters received from the Pacific and Atlantic Oceans and the numerous large rivers that drain the circumpolar continents. These inflows affect the formation of halocline source waters which are cold, salty waters formed when salt is rejected during the seasonal growth of sea ice on the shelves. Hence, the thermohaline structure of the Arctic Ocean relies upon ventilation via a horizontal, cross-slope transport of shelf waters whose density is determined by the salt distillation effects of freezing and thawing. Ventilation also depends on mixing between shelf outflows and ambient shelf and slope waters. In contrast, ventilation of mid-latitude oceans is primarily accomplished in the interior of the basin by the subsidence of surface waters whose density depends upon the heating and cooling cycle.

Since marine productivity and biogeochemical cycles are intimately linked to the physical environment, fundamental uncertainties surround the role of the Arctic Ocean in global biogeochemistry cycles. The timing of physical transport processes relative to biological rate processes is still relatively unknown in the Arctic. During earlier interglacial periods when the climate was warmer and the ice cover reduced or absent, the Arctic Ocean had relatively high biological productivity and was an apparent sink for atmospheric CO_2 (Lundberg and Haugan, 1996). Today it appears that the Arctic Ocean has very recently, once again, become a sink for atmospheric CO_2 (Walsh and Dieterle, 1994; Lundberg and Haugan, 1996). The sediment record holds information to understand shelf basin interactions during the past, particularly processes or events that occurred at very slow or infrequent rates. Proxies for these processes, such as fossil and geochemical records, would provide valuable information for coupling paleoclimate and modern observational records to improve quantitative reconstructions of past conditions. High resolution and good stratigraphic control on archived or sediment cores collected as part of the SBI project would provide valuable insight on these processes recorded in the sediment record.

There are also indications that the present day climate of the Arctic is delicately poised, such that small perturbations to the present day climate system could be dramatically amplified in the Arctic. For example, several general circulation model (GCM) studies predict a "polar amplified" warming response (involving an increase in both air temperature and precipitation) to elevated greenhouse gas concentrations (Sarmiento and Toggweiler, 1984; Broecker and Peng, 1989; Manabe et al., 1992; Miller and Russell, 1992; Intergovernmental Panel on Climate Change (IPCC, 1996). If true, these results imply that the Arctic might serve as a harbinger of global change. Indeed, a consensus is emerging in the scientific community that a change has recently occurred in the Arctic Ocean circulation (Macdonald, 1996). Warming and shallowing of the Atlantic layer was first reported by Aagaard and Carmack (1994) and Carmack et al. (1995). The warming was confirmed by Mikhalevsky et al. (1995) during the Transarctic Acoustic Propagation experiment conducted in April 1994. Other analyses suggest decreasing trends over the past 20-30 years in sea ice extent (Maslanik et al., 1997) which coincides with warming trends (Martin et al., 1997). Thus, the characteristics of the boundary currents along the continental slope regions might also be experiencing changes in density and velocity structure which could affect the mechanics of shelf-basin exchange and influence the biological and physical processes. Preliminary data collected during the OAII Arctic Ocean Section (AOS) and NSF/Office of Naval Research (ONR) Submarine Science Experiment (SCICEX) cruises indicate the transfer of western Arctic shelf-derived carbon to the Canada Basin (Sambrotto, 1996). High total CO_2 water was seen to extend from the shelf edge and enter the upper halocline at about 100 m, suggesting that the Canada Basin could be an important reservoir for oceanic carbon.

The Arctic Ocean and its adjacent and marginal seas while only representing~4-5 % of the surface area of the ocean have the potential to exert a major effect on global climate via deep convection (e.g. Broecker, 1997, Broecker *et al.,* 1999; Stevens, 1999), changes in albedo (Kerr, 1999; Vinnikov *et al.*, 1999), and releases of methane stored in shallow clathrate deposits (Stevens, 1999; Kerr, 1999; Katz *et al.*, 1999; Dickens, 1999;). In addition, we know that since 25% of the global continental shelf lies in the Arctic important biogeochemical processes, such as denitrification that are enhanced in and over continental shelf sediment, could be disproportionately large (e.g. Devol *et al.* 1997).

On a regional scale climate changes could have a number of important consequences for the people living in northern regions. For example, alterations in cloud cover and/or ice distribution could profoundly alter the spatial and temporal patterns of primary production given the sensitive dependency of high-latitude primary production on surface irradiance (Platt and Sathyendranath, 1995). Arctic trophic systems are relatively simple compared to those of lower latitudes and changes in productivity patterns and/or rates could therefore be rapidly reflected in the structure of Arctic marine ecosystems. Most of the primary and secondary production in the Arctic takes place over continental shelves, directly influencing water column and benthic faunal populations. In addition, benthic fauna in certain large shelf regions of the Arctic, such as the Chukchi Sea, directly consume a large proportion of the carbon fixed by microalgae and these benthic organisms sustain huge herds of several marine mammal species that are culturally and economically important to the endemic peoples of the Arctic. Thus, changes in primary productivity over Arctic shelves could impact marine mammal populations through modification of prey populations.

Recent studies indicate increased levels of anthropogenic contaminants (persistent organic contaminants, heavy metals, and radionuclides), along with significant resource development impacts in the Arctic (Arctic Monitoring and Assessment Programme, 1997; Jensen et al., 1997; Nilsson, 1997; Strand, 1997). Changes in trophic pathways and flux rates due to global change may affect the bioamplification and delivery of pollutants to consumers of Arctic fish, mammals, and bird populations that may, in turn, jeopardize the health and/or economic future of traditional indigenous populations. A comprehensive understanding of shelf-basin exchange, including physical and biogeochemical interactions, would assist in analyses of global change impacts on contaminant transport, transformation, and fate in the polar north.

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APPENDIX B-OAII DATA MANAGEMENT GUIDELINES

The National Science Foundation Arctic System Science (ARCSS) program supports a multidisciplinary research effort of the Arctic environment. Within the many different ARCSS data collection efforts, it is vital to facilitate data archival and an easy mechanism for data exchange among researchers interested in the Arctic system. This data protocol is a guideline for OAII/ARCSS investigators to ensure proper data formats, meta data, and efficient data archival. The research programs in the Ocean-Atmosphere-Ice Interactions (OAII) section of ARCSS primarily deal with the oceanographic environment and the surrounding interfaces with the atmosphere, bottom, shoreline and surface ice. It is a common goal to have OAII scientific research use the best scientific methods that are based on standardized and community-accepted measurements.

Data Management

All data collected by ARCSS/OAII projects are required to be submitted to the ARCSS Data Coordination Center maintained at the National Snow and Ice Data Center (NSIDC). It is the responsibility of the Principal Investigator(s) of each funded ARCSS/OAII research project to develop a data management plan that will assure the collection of quality data that will be available to co-PI's, OAII collaborators, ARCSS investigators and the scientific community in general. The NSIDC will request data management plans from all funded research projects. In general, data should be submitted to the NSIDC as soon as possible but all data must be submitted within two years after the collection of the samples or data reduction. Large coordinated programs, e.g. SHEBA, may establish shorter time limits for sharing data within the program.

In general, the data archiving process for a field project will begin with the submission of an "event log" (e.g. ROSCOP form) to the ARCSS data coordination center at NSIDC by the chief scientist or field project leader. This event log must be submitted within three months of the conclusion of a field project and should list the times, locations, and responsible parties for all data collected. All data submitted to the NSIDC must contain a meta data description as detailed in the Data and Information Formats section below. The acceptable data format and media are described in the ARCSS Data Submission Guidelines on the ARCSS webpage at http://arcss.colorado.edu/data/proto.html. Data not recorded on electronic media are also included in the data requirements to be placed in the NSIDC repository.

Data Exchange

All data collected within ARCSS/OAII funded research is considered "community property." Principal Investigators retain exclusive use of the data collected for one year after collection or data reduction. It is highly desirable that basic "core" observations such as hydrographic and meteorological data be distributed in draft form to OAII collaborators as soon as possible. After one year, data will be released to other ARCSS/OAII investigators. Two years after data collection or reduction, the data will be made available to all other science users through the NSIDC. Exceptions to these time frames must be referred to the ARCSS Program Manager and Project Chief Scientist.

Note that the term "data reduction" applies to those types of data that are not produced shortly after sample collection. For example, certain types of isotope analyses typically require several months for processing, depending on availability of instruments, etc.

Data Set Referencing

Citation must be given to the investigators responsible for data collection in any and all publications using OAII data sets. Reference to these data will include:

1. Reference to publications describing the data
2. Reference to the PI(s) if no papers are yet published

Data and Information Formats

In coordination with the National Snow and Ice Data Center, the PI(s) will include the following information (meta data) with each data set archived:

1. Platform(s) name
2. Project title(s)
3. Data collection date(s)
4. Chief Scientist or PI name
5. Data collection method(s)
6. Data analysis method(s)
7. Instrumentation used
8. Standardization or Quality Assurance/Quality Control procedures
9. Data format or spreadsheet name
10. Data collection problems
11. Other related data sets
12. Conditions for use or citation
13. Data qualifications or warnings
14. Appropriate NSF Grant numbers
15. Sample repository locations (cores)