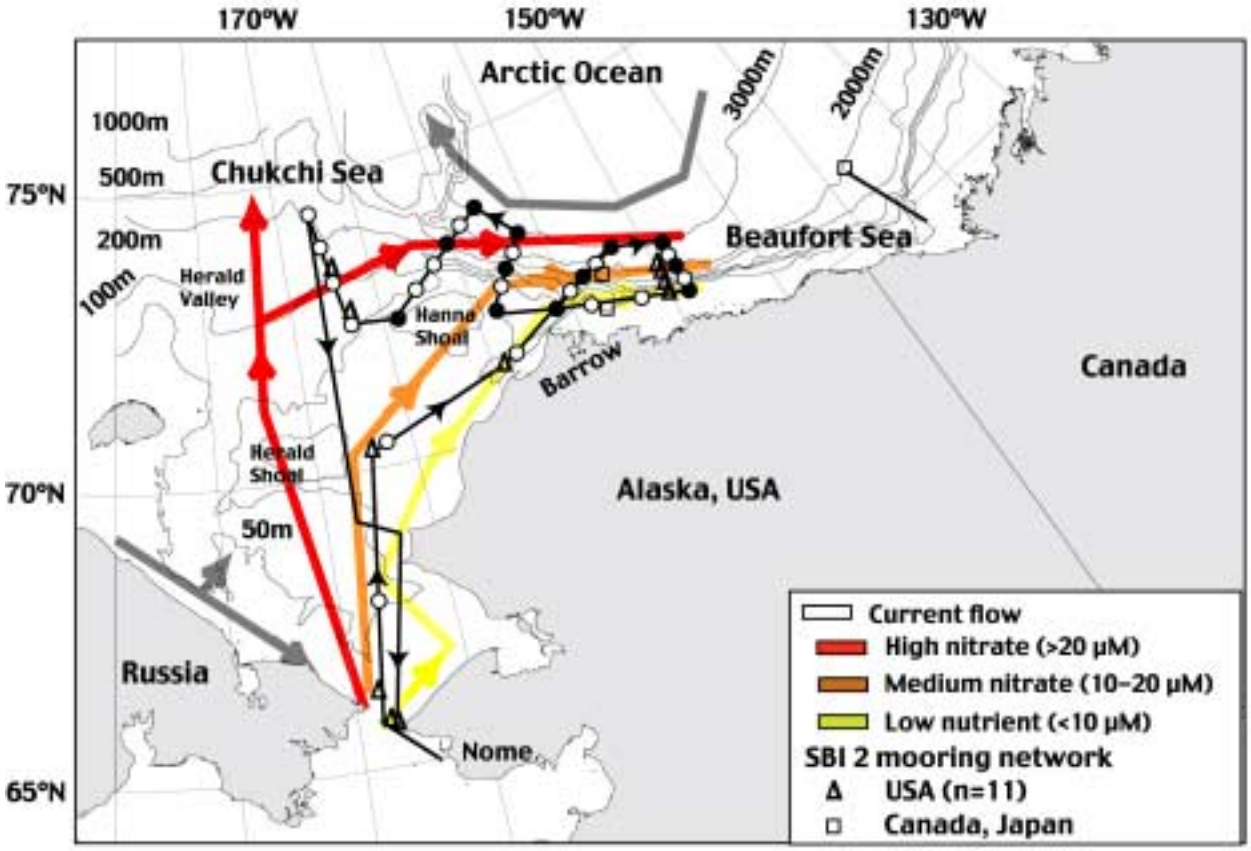

Western Arctic Shelf-Basin Interactions (SBI)

Phase 2 Principal Investigators Meeting

January 29-30, 2002

US Coast Guard Cutter Healy

Seattle, Washington

Sponsored by the National Science Foundation and Office of Naval Research

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AGENDA-SBI 2 PI MEETING (Healy Science Lounge)

Tues. 29 January 2002

0800-0830 General introductions (Grebmeier and USCG personnel)

0830-0900 Overview of SBI science operations during cruises (Grebmeier)

0900-0930 General group discussion (SBI PIs and USCG personnel)

0930-0950 Logistics overview (Andy Heiberg)

0950-1000 Bottle sampling/CTD cast overview (Codispoti)

1000-1010 Marine mammal observations (Webber)

1010-1030 Coffee break

1030-1130 Healy tours

1130-1230 Lunch on the USCG base (ISC)-[~32 SBI people]

1230-1500 Break-out working groups to discuss process cruise specifics on Healy with all MSTs (MSTCS Hendrickson, MST1 Kuhn, MST2 Cullers, and MST3 Schriven) and other USCG groups [SBI leads in ( ) below]. Note, we'll start out in 3 groups (#1-3), then group #1 can break out into smaller groups after that, and groups #2 and 3 can come back into other groups later in day [meeting room].

Break-out groups:
#1: water sampling: service (Swift) and process studies (Cota); zooplankton (Ashjian et al), benthic (Christensen/Grebmeier et al.) sampling w/MST reps [Science Conf. Rm]

#2: data management (Moore et al.) w/MST and USCG computer people [MST1 Kuhn will be main contact; Officers Lounge 2 decks above Science Conf. Rm]

#3: off-ship sampling (Devol/Christensen and Gradinger/Eicken) [CWO Tim Malcolm will represent Deck Division in this discussion; science space)

1500-1515 Coffee break

1515-1600 Continued breakout discussions

1600-1700 General group discussion, overlap questions, issues still pending

1900 Group dinner [F.X.McRory's Steak, Chop & Oyster House (ph. 623-4800)]

Wed. 30 January 2002

0800-1000	Revised break out groups decided previous day
1000-1030	Coffee break
1030-1130	Continued SBI/USCG interactions
1130-1230	Lunch
1300-1500	General SBI group discussions, finalize cruise plan, field needs, outline lab set-up for each cruise, info on teachers, media
1500-1530	Break
1530-1700	Finalize cruise plan, other outstanding field items
1700	Meeting ends

Thurs. 31 January 2002 SBI/Keigwin meeting (Science Conference Room-Healy)

0800-0830	Welcome. Intro Science Party and key USCG personnel
0830-0930	Science Party provide overview of operations as they envision them, and define what successful mission will be.
0930-0945	Break
0945-1115	Further group discussion and/or breakdown into smaller groups. One major issue to resolve is port call logistics.
1115-1215	Lunch
1230-1600	Tour of the ship (berthing, applicable science spaces, aft working decks, etc.)

OVERVIEW WESTERN ARCTIC SHELF-BASIN INTERACTIONS (SBI) PHASE II FIELD PROJECT

The National Science Foundation and Office of Naval Research are supporting five years of funding under Phase II of the Western Arctic Shelf-Basin Interactions (SBI) project. This project is part of the Ocean-Atmosphere-Ice Interactions component of NSF's Arctic System Science Program. The goal of the SBI project is the improvement of our ability to assess impacts of global change on the physical and biogeochemical connections among the western Arctic shelves, slopes, and deep basins.

The SBI project focuses on shelf, shelf break and upper slope water mass and ecosystem modifications, material fluxes and biogeochemical cycles. The geographical focus is on the Chukchi and Beaufort seas and adjacent upper slopes. An accumulated body of research indicates that climate change will significantly impact the physical and biological linkages between the Arctic shelves and adjacent ocean basins. SBI will therefore focus on the outer shelf, shelf break and upper slope, where it is believed that key processes control water mass exchange and biogeochemical cycles, and where the greatest responses to climate changer are expected to occur.

The SBI project is progressing in three phases over a 10-year period. Phase I (1998-2001) was just completed and involved analyses of historical data, opportunistic field investigations, and modeling of specific regions and processes. SBI Phase II will constitute the field program, which will take place in the Bering Strait region and over the outer shelf, shelf break and upper slope of the Chukchi and Beaufort seas. A planned Phase III will focus on development of Pan-Arctic models suitable for simulating scenarios of the impacts of climate change on shelf-basin interactions.

The SBI field program will focus on:

- Physical modifications of North Pacific and other waters on the Chukchi shelf and slope, and exchanges of these waters across the shelf and slope.

- 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 the suite of trophic levels.

- Comparative studies over the wide Chukchi and narrow Beaufort shelves and adjacent slopes to facilitate extrapolation and integration of the Western Arctic work to a Pan-Arctic perspective. Integrated process and modeling studies of shelf-basin exchange processes and their sensitivity to global change will be an important methodology in this extrapolation. A physical-biological coupled model will be undertaken for the SBI study region.

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 investigating:

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

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

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;

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

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.

More details on specific physical, biogeochemical and biological hypotheses are outlined in the SBI Science and Implementation plans available on the SBI web page (http://utk-biogw.bio.utk.edu/SBI.nsf).

THE SBI PHASE 2 FIELD PLAN

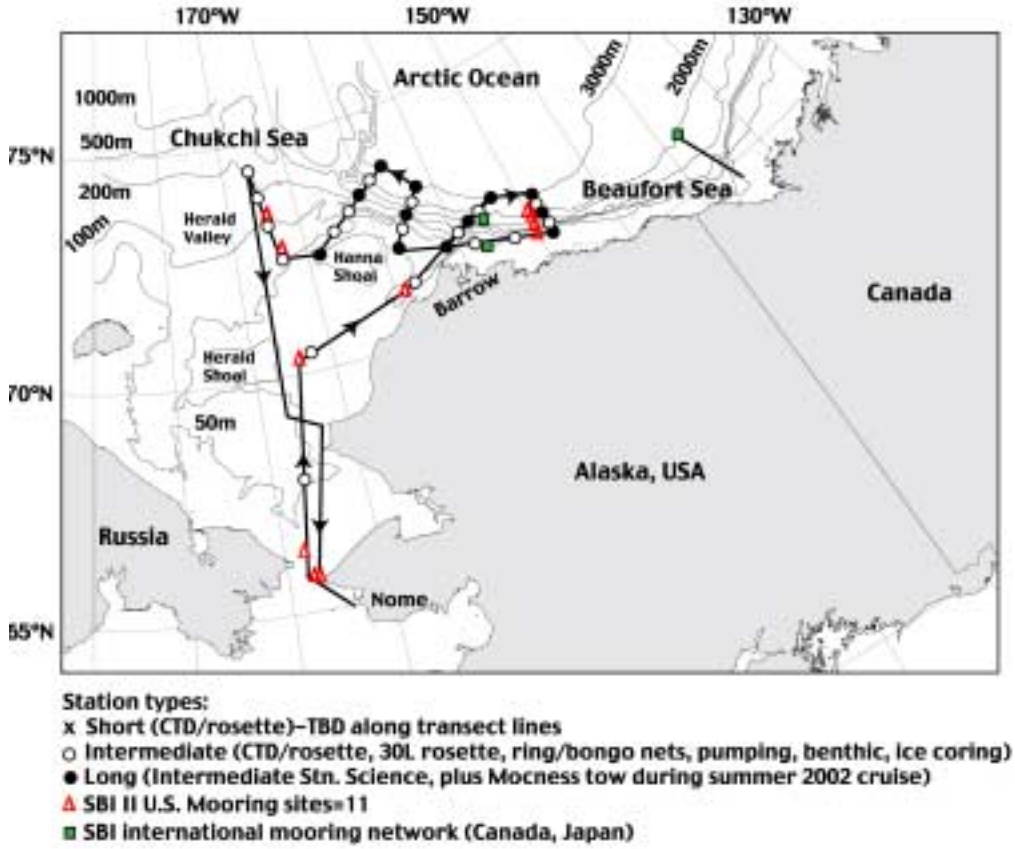
The SBI Phase II Field Implementation Plan (http://utk-biogw.bio.utk.edu/SBI.nsf) outlines a combination of seasonal hydrobiochemical surveys in support of major biogeochemical, biological and physical process studies as well as modeling efforts, at appropriate time and space scales. Mesoscale, interdisciplinary survey and process studies conducted across the outer 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. 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 new SBI moorings as part of Phase 2, constitute the "SBI mooring network".

The SBI II field program will include four process-oriented cruises in May/June and July/August 2002 and 2004. In the alternate years (2003) it will include a reduced survey-only cruise for critical time-dependent measurements essential for interpreting processes relevant to shelf-basin interactions and ecosystem response. Annual mooring cruises will occur in July 2002 and in September 2003 and 2004, which will provide an opportunity for emplacement of new SBI time series moorings into the SBI mooring network. A final two synthesis years will round out the 5-year Phase II project. The following section outlines the SBI field project, both survey and

process studies, and more complete information can be found in the SBI Implementation Plan posted on the SBI web page (http://utk-biogw.bio.utk.edu/SBI.nsf).

The sampling plans listed below for the SBI field program are based on the following parameters within the proposed sampling area (Figure 1):

- estimated 10 day transit time form Nome, Alaska to study area and return, inclusive of scientist change-out in Nome, Alaska
- 30 day process sampling in the operating area indicated by the transects over on the outer shelf and slope of the Chukchi and Beaufort seas (Figure 1)
- station depths from 50-3000 m, with core outer shelf-slope area being at 100-3000 m
- average station spacing of 10 nm in the intensive study area
- possible inclusion of brief single cast stations at 30 nm intervals on the transect from Bering Strait to core SBI sampling region
- estimated 4 stations/d (survey) or 2 stations/d (process), inclusive of between station transit times for each cruise
- average one hr station time (survey) or 12 hr station time (process)
- process, mooring and survey cruises include core hydrobiochemical measurements



SHIP SUPPORT

The 5 year SBI II field program will undertake ship operations in 2002-2004, using the USCGC *Healy* in even years (2002 and 2004) and USCG polar class vessels (*Polar Star or Polar Sea*), or equivalent, for the annual mooring cruises and survey cruise in 2003. Additional ship of opportunity platforms, such as Japan's ice-strengthened ship *Mirai,* Canada's icebreakers *Sir Wilfrid Laurier* and *Louis St. Laurent,* and possible Russian ship use may also be available to support the goals of the SBI project. Process cruises include both core and process measurements. The planned ship use schedule is:

May-June 2002:
- 6 May-15 June (process cruise: 6 weeks, Nome to Nome)-USCGC Healy

July-August 2002:
- 23-29 June (Bering Strait mooring cruise)-RV Alpha Helix
- 13 July-22 August (process cruise: 6 weeks, Nome to Nome)-USCGC Healy
- July (outer shelf/slope mooring cruise: 4 weeks, Dutch Harbor to Nome)-USCGC Polar Star or equivalent

2003:
- June (Bering Strait mooring cruise)-RV Alpha Helix
- July (survey cruise, 6 weeks; exact date and ship to be determined (TBD)
- September/October (mooring cruise, 4 weeks, ship and date TBD).

2004:
- May-June (process cruise: 6 weeks)-USCGC Healy
- June (Bering Strait mooring cruise)-RV Alpha Helix
- July-August (process cruise: 6 weeks)-USCGC Healy
- September/October (mooring cruise: 4 weeks)-USCGC Polar class icebreaker

A winter measurement project will be undertaken on the US Navy-built ice camp in 2003 in the Canada Basin NE of Barrow, Alaska. In addition, a planned helicopter survey will occur in late winter during the SBI Phase II project.

Time Series Moorings

The "SBI mooring network" includes three Bering Strait moorings that will be maintained under separate ONR funding as an "in-place" program. In addition, four 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.

Time series moorings will provide coincident physical and biochemical measurements, including ice-thickness, current velocity, temperature, salinity, and ideally, light transmission, chlorophyll and nutrient sensors. These moorings will have the capability of accepting other samplers and sensors as well. The proposed location of these moorings include the major transport pathways for shelf-basin interactions under study: shelf-slope exchange, eddy formation, and off/on shelf exchange via canyons.

CATEGORIES OF RESEARCH PROJECTS

Two categories of scientific projects have been funded: 1) process-oriented research projects to address the key SBI objectives outlined in the SBI Implementation Plan, and 2) a "service-oriented" hydrobiochemical measurements program,

Category 1 projects include process-oriented research activities that utilize the cruises listed previously, along with appropriate modeling, mooring, underway surveys, and remote sensing activities, to address the program objectives. These measurements include:

a. Biological Rate Measurements

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

b. Biogeochemical and Physical Measurements

Additional biogeochemical and physical measurements for cruises 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.

Category 2 projects address the acquisition of a consistent suite of data from the SBI cruises. The core shipboard measurements will be standard for every cruise and be made available in draft form to PIs at the end of each cruise. Basic data collection will include CTD measurements, in-situ fluorescence and transmissivity, photosynthetic active radiation (PAR), and a rosette for discrete water sampling and determination of inorganic nutrients (nitrate, phosphate, silica,

ammonia), chlorophyll-a, bottle salinity determinatiions, and dissolved oxygen measurements. Underway temperature, salinity, and meteorological data, along with ADCP measurements, will be made.

Remote Sensing and Modeling Efforts

Remote sensing and modeling efforts support the seasonal and interannual objectives of the SBI project. 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. Further details are provided in the SBI Science and Implementation plans.

Additional Measurements

Seabird and marine mammal surveys are encouraged, both of which should include synthesis and interpretation coincident with SBI interdisciplinary data collection and goals. Currently the US Fish and Wildlife Service in Anchorage, Alaska (spring 2002) and the National Marine Mammal Laboratory/NOAA in Seattle are planning to collaborate in marine mammal and seabird shipboard observations.

Limited winter measurements are planned using an ice camp for March-April 2003. Paleoceanography within SBI Phase II will be in collaboration with on-going NSF projects, such as with Dr. Lloyd Keigwin's (WHOI) project in 2002.

FURTHER INFORMATION

Data management requirements are mandatory following the ARCSS/OAII guidelines that are listed in the SBI Implementation Plan as well as on the SBI web page. Explicit data management and submission planning are being coordinated with the Joint Office of Science Support (JOSS; (http://www.joss.ucar.edu) and posted on the SBI web page (http://utk-biogw.bio.utk.edu/SBI.nsf). The coordination with JOSS will allow streamlined PI data management, with ultimate long-term data archiving through the ARCSS Data Coordination Center (ADCC) and National Snow and Ice Data Center (NSIDC). The SBI Implementation Plan, SBI Science Plan and SBI Data Policy are available on the SBI web page [http://utk-biogw.bio.utk.edu/SBI.nsf]. Further information on this project is available through Dr. Jackie Grebmeier, Director and SBI Project Chief Scientist (ph.+1-865-974-2592, fax: +1-865-974-7896; email: jgrebmei@utk.edu), SBI Project Office, Department of Ecology and Evolutionary Biology, 10515 Research Drive, Bldg. A, Suite 100, The University of Tennessee, Knoxville, TN 37932, USA.

SBI 2 PROJECT SUMMARIES

Carin J. Ashjian and Scott M. Gallager (Woods Hole Oceanographic Institution) and Mark C. Benfield (Louisiana State University)

Proposal Title: Shelf-Basin Exchange of Plankton and Biogenic Material between the Chukchi and Beaufort Seas

Transfer of organic material and organisms from Arctic shelves to the deep Arctic basin may impact significantly the biogeochemical characteristics, and ecosystem function and structure, of both Arctic basin and the Arctic shelf ecosystems. However, the physical and biological processes influencing both the distribution of organisms and biological material on the Arctic shelves and the potential input of these materials into the Arctic Ocean and basin presently are poorly understood. It is critical to increase our understanding of the biological-physical coupling in the shelf-slope region in order to better predict the potential impact of large-scale changes in climate on the Arctic ecosystem.

Multiple physical processes along the shelf break may promote the transfer of water and biogenic material between the shelf and the basin. These include mesoscale processes such as wind-forced upwelling/downwelling, bottom boundary layer secondary circulations, instability and eddy formation, and canyon exchange flows. Smaller scale processes include interleaving of water masses at the conjunction of opposing currents and internal waves. To date, little work has been done relating the influence of these processes on biological distributions and the potential cross-shelf transport of organic material in the Arctic Ocean.

We hypothesize that transport of biogenic material and organisms between the two regions by mesoscale processes is a dominant mode of exchange between shelf and basin. This cannot be verified through the study of physics alone; we must describe and explain what is found in the advecting water. For zooplankton, physical processes and features interact with biological processes, such as behavior, to produce the observed abundances and distributions. Plankton may congregate in fine-scale vertical layers which are associated with physical features and transports but which may not be observed using plankton nets. We propose to describe the role of mesoscale physical processes in the exchange or transport of biogenic material and plankton populations between the Chukchi Shelf and neighboring Beaufort Sea as part of the Shelf Basin Interactions Phase II field program (SBI). The proposed work has two distinct yet interrelated components. For the first component, we propose to describe the abundance, fine-scale vertical distribution, taxonomic and size composition of plankton and particles and aspects of behavior (e.g., orientation) of plankton across the SBI study region, encompassing shelf, basin, and transition regions, during the 2002 and 2004 process cruises using a self-contained Video Plankton Recorder mounted on the CTD rosette during all CTD casts. In the second component, we propose to describe the abundance of zooplankton on the outer shelf and upper slope and in mesoscale physical features that exchange water and biogenic materials between the two regions over two annual cycles using the absolute backscatter intensity data from an array of moored calibrated acoustic Doppler current profilers.

John Christensen (Bigelow Laboratory) and Humfrey Melling (Institute of Ocean Sciences/DFO, Canada)

Mesoscale Nutrient Structures in the Northern Chukchi and Beaufort Seas in Several Seasons

This study will examine the late winter (March-April) hydrographic, nutrient, and tracer distributions in the northeastern Chukchi Sea and western Beaufort Sea. Full sea-surface to sea-floor profiles of T,S, nutrients, O-18 H2O, and other possible tracers will be collected along transect lines sampled from helicopters. Three possible transect lines include one traveling due west from Point Barrow to about 165 deg. W, one perpendicular to the shelf-slope break at 161 deg. W, and one extending east from Point Barrow and crossing the shelf-slope break at 151 deg. W. The shelf portions of these transects will tell what water types occur at various depths on the shelf. The cross-shelf portions will capture the boundary currents and the halocline waters, telling about their composition. The results will help define the strength of winter water exchange across the shelf slope region and will allow estimates of the magnitude of the spring bloom.

The original proposal also included placing chemical and/or photochemical nutrient sensors on the current meter moorings along the shelf-slope break. Although eliminated by the panel, these moorings would help define the seasonal changes in nutrient composition of waters at the mooring depths (> 40 m to avoid ice keels) and would help to define the seasonal changes in nutrients in the SBI region.

John Christensen (Bigelow Laboratory) and Al Devol (University of Washington)

Collaborative Proposal: Denitrification and Sediment Nutrient Dynamics in the Chukchi and Beaufort Seas

This study will focus on a detailed study of denitrification and sedimentary nutrient dynamics in the Chukchi and Beaufort shelf-slope area. The study will include benthic flux measurements of dissolved oxygen, N2, carbon dioxide, nitrate, ammonium, phosphate, silicate, Ca^{+2}, DON, and DOP. These fluxes will be determined both by in situ benthic flux chambers and on-deck core incubations. In addition, bottom water irrigation will be evaluated by radon measurements, by conservative tracer influxes, and by modeling dissolved silicate profiles. We will also measure downcore pore-water profiles of the solutes listed above and of radon (its porewater and equilibrium concentrations), Mn^{+2}, and Fe^{+2}. By using carbon oxidation rate as a proxy for the rain rate to the sediments we will model the response of denitrification to the various controlling drivers, rain rate, bioirrigation, dissolved oxygen, and bottom water nitrate. Our goal is a predictive understanding of the dynamics of denitrification and sediment nutrient regeneration and how they might be altered in response to Arctic change.

Richard Dirks and James Moore (Joint Office for Scientific Support, JOSS), UCAR, Boulder, CO)

Data Management Support for Western Arctic SBI Phase II

Tasks included in the revised JOSS Work Plan as directed by the NSF:

- Preparation and implementation of an SBI data management strategy, including follow-up data questionnaire, preparation of a SBI Data Management Plan and information exchange on data format and documentation guidelines.

- Interim data archival services for SBI Phase 2 datasets, including rapid turn around and availability following receipt using the JOSS data management system, interim data archive access and support for the full duration of SBI, Phase 2, assistance with dataset and documentation submission, perusal and access using the JOSS data management system and coordination with ADCC regarding transfer for SBI datasets.

- Implementation of the JOSS on-line field data products and documentation catalog aboard a single research ship (presumably the USGS Healy) used during the planned multi-year cruises of SBI. This also includes training aboard ship for care and use of the system, submission of products and use of on-line forms.

- Collection of "basic" operationally available datasets to be specified by the investigators and could include regional surface data, soundings, model grids and other map products. These data/products will be archived at JOSS.

Rolf Gradinger and Hajo Eicken (University of Alaska Fairbanks)

Physical-Biological Control of Primary Production in Beaufort and Chukchi Sea Ice: Its Contribution to Shelf-Basin Interactions in the Western Arctic

Arctic shelves in general are highly productive seas, sustaining high biomass of pelagic and benthic biota. The seasonal sea ice cover plays a key role not only as a habitat but also in structuring physical and biological processes in these high-latitude systems. Reduction in sea ice extent is one of the major anticipated consequences of climate change in the Arctic. Arctic marine systems are challenged by a large-scale warming trend and a substantial loss of ice extent recorded over the past decades. The regional focus of the Shelf-Basin Interactions (SBI) program offers a unique opportunity to study the linkages between physical, chemical and biological oceanography in the Chukchi and Beaufort Seas in order to predict the impact of climate variability and change.

This interdisciplinary proposal aims to quantify the sea ice primary production in the Chukchi and Beaufort Seas. The main working hypotheses are that both light and nutrient supply control the magnitude of biomass formation within the sea ice. While irradiance controls the rate of biomass changes in spring and autumn, nutrient advection is dominant during summer as melt water accumulation below the sea ice impedes nutrient supply and hence controls the total integrated biomass build-up in the ice cover. To verify these hypotheses we combine field studies, experimental work, and remote sensing efforts. Through this comprehensive approach we anticipate to quantify the ice-related biogeochemical processes and supply an estimate of carbon production and release from the seasonally varying ice cover. During two ship expeditions (May – August) an extensive data set of physical, chemical and biological parameters will be obtained at sampling locations comprising the prevailing ice types. Ice thickness and morphology will be determined with an indirect measurement technique along transects of several hundreds to thousands of meters in length. Profiles of salinity, temperature, stable isotope concentrations, algal pigments and species composition will be determined over the entire ice thickness based on ice cores. Primary production will be determined by optical and tracer techniques. Our experimental work aims to elucidate the relationships between ice physics, chemistry and algal activity, to extend our estimates to early spring and late summer, when ship-based sampling is difficult. This proposal contributes to the overall aims of SBI in assessing the contribution of ice-associated primary production and biomass build-up and release from the ice to the total carbon flow in the system. It will help in understanding and quantifying the response of ice-algal communities to climate variability and change, and in particular how this impacts the overall system. The work also ties into the pelagic and benthic studies carried out within the framework of SBI, as key physical, chemical and biological ice characteristics will be determined, allowing, e.g., to trace the fate of sea ice production in the pelagic and benthic realms.

Jackie Grebmeier and Lee Cooper (University of Tennessee), Glenn Cota (Old Dominion University), Ken Dunton (University of Texas at Austin/PortAransas), Dave Kirchman (University of Delaware), Wieslaw Maslowski (Naval Postgraduate School), Bradley Moran (University of Rhode Island), John J. Walsh (University of South Florida)

Collaborative Research: Carbon Cycling in the Chukchi and Beaufort Seas-Field and Modeling Studies

The Western Arctic is profoundly influenced by the northward flux (~0.8 Sv) of nutrient and organic-rich, low salinity Pacific Ocean water that enters the basin through the Bering Strait and across the Chukchi shelf and slope. This flow, a key component of the global ocean circulation, transports freshwater from the Pacific to the Atlantic via the Arctic Ocean while also sustaining some of the most productive ecosystems in the world, the Bering and Chukchi Seas. Net transport, sea ice cover and sea surface temperatures are well known to vary greatly over seasonal and interannual time scales, but the experimental, observational, and modeling bases to evaluate the response of Arctic ecosystems to these changes, and to global change in general, are largely lacking.

Our proposed interdisciplinary project will provide the observational and theoretical framework to evaluate carbon fluxes in the Chukchi and Beaufort Seas in response to variable environmental forcing. *A main goal of this project is to determine the impact of decadal-scale environmental regime shifts in the northern high latitudes on carbon cycling in the western Arctic Ocean.* We will examine carbon import from the Bering Sea, local production and transformation, and export from the Chukchi and Beaufort shelves to the basin**.** This project will focus on understanding the influence of physical and biological processes on fluxes of carbon and other key elements (e.g. N, O, Si) in the water column and benthos of the shelves and slope, and subsequent exchange with the basin. Our specific research topics include work in the pelagic zone (production, respiration, other rate processes, standing stocks), the benthos (respiration, sediment composition, nutrient fluxes, standing stocks), and particle and water mass export as measured with tracers (e.g. ^{234}Th, ^{7}Be, ^{210}Pb, ^{18}O, ^{13}C). Coupled bio-physical models will be used to help organize and evaluate observational programs, to identify gaps, important transports and dominant elemental fluxes, and to examine responses of the Arctic ecosystem to global change. To better understand the mechanisms responsible for regional differences in shelf-basin exchange, we will compare the Chukchi (a wide, strongly marine-forced, continental shelf/slope) and Beaufort (narrow, riverine-influenced) seas. This project has been integrated with other research programs and related resources, which are important to our success and that of the entire SBI program. The ultimate goal of this study is to obtain a more complete understanding of shelf-basin exchange processes and biogeochemical cycles, and to establish benchmarks useful for assessing future global change of this sentinel ecosystem.

Dennis Hansell (University of Miami, Rosenstiel School of Marine and Atmospheric Science) and Nick Bates (Bemuda Biological Station)

Collaborative Research: Transport and Transformations of Carbon and Nitrogen in the Western Arctic Ocean: A Contribution to the SBI Project

The Western Arctic Shelf-Basin Interactions (SBI) project focuses on shelf, shelf break and upper-slope water mass and ecosystem modifications, material fluxes and biogeochemical cycles. The geographical focus is on the Chukchi and Beaufort Seas and adjacent upper slopes, with the aim of generalization of the results into Pan Arctic and global models. The overarching goal of the SBI project is to understand the physical and biogeochemical processes that link the Arctic shelves, slopes, and deep basins. Relevant to this proposal, the SBI project will focus on a) biogeochemical modifications of Pacific water over the Beaufort and Chukchi shelf and slope regions, with emphasis on carbon and nitrogen; and b) comparative analysis of the findings over the broad Chukchi shelf and narrow Beaufort shelf and adjacent slopes to facilitate integration of the Western Arctic into a Pan-Arctic perspective.

We will support the goals of SBI by evaluating the processes of carbon and nitrogen transport, exchanges and transformations in the regions of interest. Our specific interests will be: a) determination of mass transport and fate of carbon and nitrogen associated with the volume transports calculated by SBI collaborators; b) interpretation of carbon and nitrogen spatial distributions and temporal variability relative to biological and physical conditions; c) evaluation of partitioning of organic matter between dissolved and particulate phases; d) determination of net community production and it's fate as DOM, suspended POM, and sinking POM; e) determination of C:N stoichiometry as a complement to biological studies, particularly in relation to community structure and seasonal progression of intense phytoplankton blooms in the Chukchi and Beaufort Seas; and f) evaluation of the contribution of DOM vs. POM to apparent oxygen utilization (AOU) development in the Arctic halocline and export from the shelf.

We will measure the full suite of carbon and nitrogen variables in survey mode. These include dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), as well as dissolved organic nitrogen (DON). Dissolved inorganic nitrogen (DIN), a required variable, will be measured by the Category 2 hydrographic team contracted by SBI. We will also measure alkalinity to aid in identification of water masses. DOC, DIC, total alkalinity, and seawater pCO2 will be determined at sea. DON, PON, and POC will be analyzed at our shore labs. We require that 4 individuals from our groups (2 for organic variables and 2 for inorganic variables) join each of two 6-week process cruises each summer (2002 and 2004). Synthesis of data will progress throughout the five year project, culminating in the overarching final year synthesis. We anticipate ongoing synthesis and modeling collaborations with other funded SBI groups, including the physical oceanographic and tracer groups, the service groups and biological studies groups.

Rodger Harvey (University of Maryland) and Ron Benner (University of South Carolina)

Collaborative Research: Biogeochemical Cycling of Particulate and Dissolved Organic Matter in the Arctic Ocean using Molecular Markers

We will investigate marine and terrestrial molecular organic markers in particulate material DOM and surface sediments, its transformation in the water column and sediments, and transport across the shelf-basin boundary. We will analyse 60 samples per cruise to include POC/PN, fatty acids, sterols, alcohols,, alkanes/alkenes, hopanes (bacterial), triterpenes (higher plant markers), neutral sugars and amino sugars. In addition we will include total protein & amino acids for all particulate samples. A companion set of samples (60) will be collected for DOM characterization. These samples will be analyzed for DOC, neutral sugars, amino sugars, amino acids, and lignin-derived phenols. This sample number can be partitioned between survey and experimental work as needed. Our sediment samples are being used for two purposes. The first will be to examine molecular organic markers in upper sediment layers as an integrator of organic fluxes which we will compare with water column samples. This will provide information on both he preservation of organic matter, its processing in surface sediments and variability in the types of organic matter reaching underlying sediments. The second will be the examination of redox-sensitive elements with increasing sediment depth to test the hypothesis that sediments in some areas may have experienced episodic inputs of labile organic matter which are not be reflected in total organic carbon values. Two set of measures requires two cores.

David Kadko (University of Miami, Rosenstiel School of Marine and Atmospheric Science)

Proposal Title: Investigation of the Rate of Shelf-Basin Interaction in the Western Arctic Ocean Using Radium Isotopes: SBI PHASE II

The largely landlocked Arctic Ocean receives input from the Pacific and Atlantic Ocean, and from rivers draining the surrounding continents. These inflows are important sources of salt, heat, nutrients, sediment and organisms to the central basin. With the exception of a portion of the Atlantic contribution, these inputs must cross continental shelves where they are significantly modified by benthic, water column, air/sea and sea/ice interactions. There are therefore significant biogeochemical exchanges between the shelves and basins, but we currently lack the information necessary to quantify these exchanges. To address this issue, as part of the Western Shelf-Basin Interaction (SBI) PHASE II program, we will apply an isotopic tracer technique for elucidating the pathways and rate of exchange between the Arctic shelves and the Arctic Ocean interior. The technique utilizes the measurement of the water column ratio of two naturally occurring radium isotopes 228Ra/226Ra. Because 228Ra (T1/2 = 5.77 y) is derived solely through input from shelf sediments, it is an unambiguous marker of shelf water. Its relative distribution in shelf and basin water is therefore very valuable in assessing the degree of shelf-basin interaction. This technique is mature, having been utilized in shelf-basin exchange investigations elsewhere, and pilot results from SBI PHASE I have clearly indicated this tracer's utility in the western Arctic Ocean study. Tracer data collected by ship transects during the field program will be analyzed within the context of modeling studies by other investigators that are aimed at understanding offshore transport, including the role and formation of eddies in this process. Where appropriate, the short-lived 224Ra (T1/2= 3.64d) will be measured at sea to supplement our data set. Radium tracer data will also be collected autonomously from floating drifters (if available) and moored arrays (if suitable moored instrumentation is made available in SBI) that are designed to study the role of eddies in the western Arctic shelf-basin interaction and time-variability of shelf currents.

Robert Pickart, Principal Investigator (Woods Hole Oceanographic Institution)

Dynamics of Exchange in the Beaufort Sea Boundary Current System: Implications for Interior Ventilation

OBJECTIVES:

- To quantify the mean and seasonally varying transport, structure, and water mass content of the boundary current system downstream of the Chukchi Sea outflow points.

- To determine the nature and cause of the mesoscale variability of the boundary current, and assess the impact of the variability on the cross-stream exchange of mass and properties.

- To identify the dynamics of the secondary circulation.

- To elucidate the source of the interior eddies by comparing the seasonally changing boundary current water to the characteristics of the observed mid-basin eddy field.

We will deploy six moorings across the Beaufort shelfbreak and upper slope, approximately 150 km east of Barrow Canyon. These will be serviced annually during the mooring cruises. Each mooring consists of a bottom-mounted upward-looking ADCP, and a profiling CTD. This will provide vertical profiles of velocity (once per hour) and temperature/salinity (four times daily).

Barry Sherr and Ev Sherr, (Oregon State University) and Carin Ashjian and Robert Campbell (Woods Hole Oceanographic Institution)

Collaborative Research: Mesozooplankton-Microbial Food Web Interactions in the Arctic Ocean

A central goal of the Shelf-Basin Interactions (SBI) program is to understand the processes affecting carbon transformations and fluxes within and between Arctic shelf and basin ecosystems, and how climate change might impact these processes. The cycling of carbon in Arctic shelf and basin habitats depends on the structure and functioning of the food webs of these regions. In the pelagial, both micro- and meso- zooplankton are significant consumers of primary production. The partitioning of primary production between the fractions remaining in the water column or sedimenting to the benthos (where organic matter is less available for export from the shelf) can be greatly affected by the relative grazing rates of microzooplankton versus mesozooplankton herbivores. Microzooplankton grazing dampens export flux, while mesozooplankton grazing enhances it. The primary focus of our proposed collaborative project is an analysis of the impact of microzooplankton and mesozooplankton grazers on the fluxes and exchanges of carbon within the oceanic waters of the Canada Basin and the shelf waters of the Chukchi/Beaufort Seas. We will use standard methods and experimental protocols to determine the standing stocks and size structures of microzooplankton, phytoplankton, and mesozooplankton assemblages, to measure growth (microzooplankton) and reproduction (mesozooplankton) rates, to measure grazing rates of heterotrophic protists and dominant mesozooplankton in the two regions, and to identify mesozooplankton that are sentinel species of Arctic change. Our collaborative study will explicitly address trophic linkages previously unexplored in this region of the Arctic. We hypothesize that changing ecosystem structure, such as might occur during climate change, will alter the role of these trophic interactions in the utilization and cycling of carbon in arctic shelves and basin systems.

We propose participation in the four process cruises of the SBI Phase II program. The planned cruise schedules of May-June and July-August will permit us to work in contrasting scenarios of ice cover, and importance of ice algae versus phytoplankton in primary production, during early summer compared to late summer. Since we plan a comparison of the phytoplankton – microzooplankton – mesozooplankton trophic coupling in shelf versus basin systems, we will carry out a full set of analyses (standing stock determinations and rate measurements) at a number of stations in both basin and shelf regions of the SBI-II study area. Abundances and rate measures will be combined to determine relative mesozooplankton and microzooplankton grazing impacts. The research proposed here addresses major objectives of the SBI-II program: 'Assessment of relative importance of top-down as compared to bottom-up controls over pelagic-benthic coupling and carbon partitioning among different trophic levels' and 'Assessment of food web changes consequent to the impacts of changing ice cover and hydrographic parameters on biogeochemical fluxes.' This project will provide rate measurements for microzooplankton and mesozooplankton grazing and reproduction, parameters that were identified as high priority for the seasonal process cruises in the SBI Phase II Implementation Plan. We will fully collaborate with, and make our data available to, other SBI investigators.

Sharon Smith (University of Miami, Rosenstiel School of Marine and Atmospheric Science)

Shelf-Basin Exchange of Large-Bodied Zooplankton [Copepods] in the Chukchi and Beaufort Seas

Physical forcing in the North Pacific/Western Arctic region exhibits abrupt regime shifts in which several decades (~25-35 years) of relatively cold, icy (2% above average) conditions are replaced in the span of a year or two by decades of warmer, less icy (3% below average) conditions; these cycles of climate in the region can be traced back at least to the late 1700s. The response of the Chukchi/Beaufort shelf ecosystem to warmer climate could follow two quite different pathways. In one scenario, warm periods would reduce ice cover and could create stronger thermal stratification, less mixing, limited nutrient supply, lower primary production, smaller-sized phytoplankton and smaller, coastal-like zooplankton. In a second scenario, also during warm periods with less ice, increased wind could result in shelf-break upwelling and mixing, enhanced nutrient supply, larger-sized phytoplankton and larger, deep-water zooplankton advected onto the shelf. Will global change, particularly warming, result in more large-sized zooplankton which support fish, birds, and mammals over the Chukchi and Beaufort shelves and slopes or smaller-sized zooplankton which will diminish the fish, birds, and mammals and favor sedentary benthic organisms?

Large-bodied copepods on the Chukchi and Beaufort shelves must be advected there from the slope waters of the Arctic Ocean or Bering Sea; none of them can complete their life cycles on the shelf itself. Therefore, they are tracers of shelf-basin exchanges. We seek to understand which large-bodied copepods reach the Chukchi (wide) and Beaufort (narrow) shelves, and the physical forcing (upwelling, intrusions, eddies) that might be responsible. Once on the shelves, how do size and reproductive responses of large copepods vary spatially, and what are the roles of physical processes and food supply? These responses define the robustness of the shelf habitat for supporting a pelagic ecosystem. Finally, we wish to determine which copepods are transported off the shelves and the physical processes (eddies, plumes) associated with that. Our investigation will: 1) define the distributions of the major taxa of zooplankton on the shelf, slope and in the open Arctic Ocean in summer, 2) measure copepod body and lipid sac sizes in different habitats, 3) measure female reproductive state, rates of egg production and egg hatching in different habitats, 4) describe the distribution of copepod nauplii and subadults in the region with the aid of molecular identification techniques, and 5) integrate these ecosystem measurements with the physical forcing (both observations and models) to understand how advection shapes the food web in the region.

James Swift (Scripps Institution of Oceanography), Lou Codispoti (University of Maryland/UMCES), Charles Flagg (Brookhaven National Laboratory), Terry Whitledge and Dean Stockwell (University of Alaska Fairbanks), Laurence Padman (ESRI), and Andreas Munchow (University of Delaware)

Collaborative Research: CTD/Hydrographic and Underway Service Measurements for the Shelf-Basin Interactions Phase II Field Project

The 3 year SBI Phase II field program will undertake ship operations in 2002-2004 using the USCGC Healy in 2002 and 2004 and USCG polar class vessels or equivalent, in 2003. This proposal address what National Science Foundation Solicitation 01-78 defines as service measurements on eight cruises during 2002-2005, and includes all service measurements defined in Solicitation 01-78, including CTD-based temperature, salinity, dissolved oxygen concentration, transmissivity, fluorescence and photosynthetically active radiation (PAR); rosette sample data to include inorganic nutrients (nitrate, nitrite, phosphate, silicate and ammonia), chlorophyll-a, salinity and dissolved oxygen concentrations; and underway measurements including (sea chest) temperature and salinity, standard meteorological observations, Acoustic Doppler Current Profiler (velocity and backscatter) on service measurement cruises from vessels which are equipped with ADCP, and various underway measurements made by SBI-designated science programs.

This is a collaborative proposal representing US scientific and technical service support groups from the UCSD Scripps Institution of Oceanography (Swift), Earth & Space Research (Padman), the University of Delaware (Muenchow), and University of Alaska, Fairbanks (Stockwell). Services from the University of Maryland Center for Environmental Science (Codispoti) and from Brookhaven National Laboratory (Flagg) are contained in subcontracts to the UCSD/SIO proposal. The UCSD Scripps Institution of Oceanography leads on the overall collaborative proposal and proposes to lead and coordinate the CTD/hydrographic and non-ADCP underway portion of the service measurements, with PI James H. Swift overall responsible for the service measurement program, except for the shipboard ADCP service measurements and Chl-a measurements. Shipboard technical support groups from the University of Alaska, Fairbanks (chemistry), the University of Maryland Center for Environmental Science (chemistry), the University of Washington (SeaBird CTD and chemistry), Oregon State University (chemistry), Texas A&M University (chemistry), and University of South Florida (chemistry) have indicated to Swift a strong interest in joint participation at sea, which Swift will handle via subcontracts from UCSD/SIO for specific personnel services on specific cruises to be determined after overall consideration of the actual cruise schedules for SBI as well as for other US programs concurrent with SBI which may require high-quality routine chemistry. Earth & Space Research, Brookhaven National Laboratory, and the University of Delaware will be jointly responsible for underway shipboard ADCP service measurement. The University of Alaska, Fairbanks, is responsible for the Chl-a/pigment analyses. The University of Maryland Center for Environmental Science (Dr. Louis Codispoti) is working with Swift in the oversight of the sea program, data quality examination, and data reporting.

All service measurement participants are committed to support a data management plan that fully meets SBI and Solicitation 01-78 specifications. All reportable data resulting from the work

proposed here will be available at sea to all SBI investigators in scientifically useful form and will be placed on-line at a site linked to the UCAR Joint Office for Science Support (JOSS) and/or delivered to JOSS (or other designated official data repository for the SBI Phase II Field Program) via express service shortly after the conclusion of each cruise. Data will be reported in preliminary, interim, and final form as appropriate, and with schedule, form, and format in accord with applicable NSF, ARCSS/OAII, and SBI Project guidelines and requirements.

Tom Weingartner (University of Alaska Fairbanks) and Knut Aagaard and Rebecca Woodgate (University of Washington)

Collaborative Research: The Fate of a Large and Strongly Forced Arctic Shelf Outflow: Physical and Biochemical Process Studies

Objectives:

1. To quantify the characteristics of the shelf outflow from the Chukchi Sea (e.g., transport, temperature, salinity), and to determine which upstream processes are principally responsible for the variability of these characteristics?

2. To quantify the variability of the system on seasonal and interannual timescales, and to assess what might be the connections with a changing climate?

3. To provide the temporal context of the Chukchi shelf water properties and flows useful to other SBI investigators who are addressing the regional biochemical and physical processes.

We will deploy four current meter moorings on the Chukchi continental shelf, with the moorings serviced annually during the mooring cruises. Each mooring will measure vertical profiles of horizontal velocity at hourly intervals using ADCPs. The moorings will also include 1 to 2 SeaCats or MicroCats, which will collect temperature, conductivity (for salinity), and in some cases pressure data. All instruments will sample at hourly intervals.

The mooring locations are:
a) 1 mooring in upper Barrow Canyon (~ 80 m isobath),
b) 1 mooring on the central shelf east of Herald Shoal (~ 50 m isobath),
c) 2 moorings on the outer Chukchi shelf east of the EEZ boundary one on the ~70 m isobath and the other on the ~100 m isobath.

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