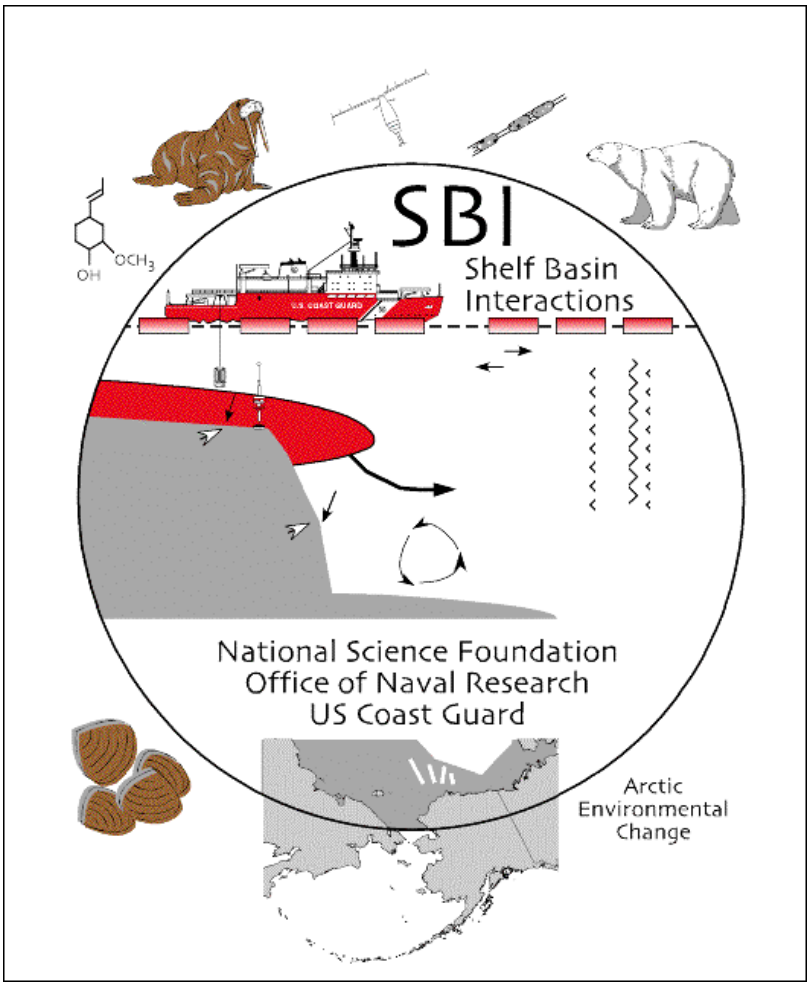
WESTERN ARCTIC SHELF-BASIN INTERACTIONS (SBI)

PHASE 2: PRINCIPAL INVESTIGATORS MEETING



The Rosenstiel School of Marine And Atmospheric Sciences (RSMAS)

University Of Miami. Miami, Florida USA

5-7 March 2003

Sponsored by the U.S. National Science Foundation, Arctic System Science Program

SBI Project Office

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SBI PHASE 2 PRINCIPAL INVESTIGATORS (PI) MEETING

The Rosenstiel School of Marine and Atmospheric Sciences (RSMAS)

University of Miami, 4600 Rickenbaucher Drive, Miami, FL

March 5-7, 2003

The **goal** of the 2002 Western Arctic Shelf-Basin Interactions (SBI) Phase 2 PI meeting is to update the SBI project participants on: 1) the SBI Phase I and II results to date, specifically including the 2002 field season, 2) discuss the 2003 and 2004 field season programs, 3) international collaboration related to SBI goals, and 4) plan for publications and presentations on the SBI project.

AGENDA

Tuesday, 4 March 2003: arrival at hotel

Wednesday, 5 March 2003 (SBI 2 PI Meeting)

0715-0730 Van/car transport from DoubleTree Hotel to RSMAS [meet in lobby near front desk: emergency cell phone contact via Ari Balsom: ph. (+1-865-406-9014]

0730-0830 Continental Breakfast/Registration for SBI PI meeting (RSMAS SA-103, adjacent to Dean's Office)

0830-0845 Opening statements (Grebmeier/Tupas) (RSMAS SA-103)

0845-1000 Session One-*Hydrography, ADCP and Mooring Program and Canadian/ Japanese Collaboration*
(5 speakers; Rapporteur: Knut Aagaard)

- Jim Swift, Upper Halocline Characteristics – What Do the 2002 Data Tell Us About Sources in the Chukchi and Beaufort Seas?
- Lou Codispoti, Jim Swift and Company, Implications of the Biogeochemical Hydrographic Data Collected from the *Healy* in the Chukchi and Beaufort Seas During the 2002 SBI Process Cruises
- Robin Muench, ADCPs, LADCPs, and Boundary Mixing
- Charles Flagg, Maureen Dunn and John Gunn, Status of SBI Shipboard ADCP Data
- Marty Bergmann, Canadian Arctic Science Projects and DFO Coast Guard Elements
- Koji Shimada et al.: Overview of the Joint Western Arctic Climate Studies (JWACS)

1000-1030 Break

1030-1200 Session Two-*Mooring Program, Tracers of Shelf-Basin Exchange,* (6 speakers: Rapporteur: Jim Swift)

- Rebecca Woodgate, A Year in the Physical Oceanography of the Chukchi Sea 1990-1991
- Rebecca Woodgate, The Chukchi Borderland Cruise 2002
- Bob Pickart, Shelfbreak Circulation in the Alaskan Beaufort Sea: Mean Structure and Variability
- Dave Kadko, Radioisotope Evaluation Of Shelf-Basin Transport Processes From The 2002 Field Season
- Lee Cooper, Stable and Radio-isotope Tracers in the SBI Study Area-2002
- Dennis Darby, What the Paleo-Record in the Western Arctic Tells Us About Recent Changes and the Future

1200-1330 Lunch: Patio of the Commons Room

1330-1500 Session Three-*Sea Ice Studies, Organic/Inorganic Carbon Production, and Shelf-Basin Exchange*
(6 speakers: Rapporteur: Lee Cooper)

- Hajo Eicken, Sediment Transport by Chukchi/Beaufort Sea Ice in 2001/2002
- Rolf Gradinger, Biomass and Productivity of Ice Algae in the Chukchi and Beaufort Seas in Spring 2002
- Dennis Hansell: DOC and DON in the SBI System
- Nick Bates: POM and DIC Distributions in the SBI study Region of the Chukchi and Beaufort Seas
- Ron Benner, Is Terrigenous DOC in the Canada Basin Old and Refractory?
- Carin Ashjian, Exchange of Plankton and Particles between the Shelf and Basin

1500-1530 Break

1530-1600 Session Four-*Carbon Transformation and Fate*
(2 speakers: Rapporteur: Glenn Cota

- Rodger Harvey, Molecular Markers of Organic Matter Sources and Cycling in the SBI Study Region
- Brad Moran, POC Export During SBI-II: 2002 Results

1600-1700 Poster Session* (author list below; need to stand by poster)

1700-1900 Reception-Commons Room and Patio (sponsored by the Dean, RSMAS)

1900 Van/car transport to hotel and Dinner on your own

Thursday, 6 March 2003

0715-0730 Van/car transport to RSMAS (0715 and 0730 in hotel lobby)

0730-0830 Continental Breakfast-RSMAS

0830-0835 Meeting updates (Grebmeier)

0835-1005 Session Six –*Trophic Interactions and Benthic Dynamics*
(6 speakers, Rapporteur: Dennis Hansell

- Glenn Cota, Western Arctic Primary Productivity
- Dave Kirchman, Heterotrophic Microbes and the Metabolic Balance of the Arctic Ocean
- Ev and Barry Sherr, Preliminary Results of the Protist Grazing Rate/ Phytoplankton Growth Rate Assays and the Mesozooplankton Grazing Rate Assays
- Bob Campbell, Mesozooplankton Grazing Rates During the 2002 SBI Field season
- Sharon Smith: Biomass of Zooplankton and Molecular Studies in the SBI Study Area
- Devol, Al, Pore-Water Oxygen Distributions in Western Arctic Ocean Margin Sediments

1005-1030 Break

1030-1215 Session Seven-*Benthic Process, Biophysical Coupled Modeling, and SBI Data Management* (6 speakers, Rapporteur: Carin Ashjian

- Ken Dunton, Benthic Faunal Biomass in the Wetsern Arctic: Linkage to Overlying Water Column Process
- Jackie Grebmeier, Benthic Carbon Cycling and Community Structure in the SBI Study Area
- John Walsh and Dwight Dieterle, Decadal Shifts in Biophysical Forcing of Marine Food Webs in the Arctic: Numerical Consequences
- Wieslaw Maslowski, Towards Understanding of Marine Environments in the Western Arctic - Physical Modeling for the SBI Program
- Jim Moore et al., SBI Data Management Support Update
- Greg Stossmeister, SBI Data Archives at JOSS: Status Updates
- Rudy Dichtl, The Metadata Tutorial for SBI

1215-1330 Lunch: outside patio off Commons Room

1330-1400 Session Eight-*Outreach and SBI Cruise 2003* (Rapporteur: Ken Dunton)

- Betty Carvellas, TEA on the SBI 2002 Summer Cruise
- Terry Whitledge, Barrow Outreach

1400-1530 Field Program: 2003 (survey and mooring cruises) Rapporteur: Jackie Grebmeier

- Jim Swift (Chief Scientist survey cruise): survey cruise objectives, plans, data sets needs, participants; service/hydro team components
- Robin Muench: shipboard dissemination of data (e.g., CTD data)
- John Bengston talk, Marine mammals as indicators of Arctic marine Ecosystem Hotspots
- Rebecca Woodgate (Chief Scientist-mooring cruise), with input from Bob Pickart and Knut Aagaard: mooring cruise objectives, plans, data set needs, participants; service/hydro team components
- JOSS activities (Moore)

1530-1545 Break

1545-1730 Field Program: 2004 (process and mooring cruises), with break-out rooms available

- Process cruises on USCGC Healy: dates, spring cruise timing/native issues, cruise plan; chief scientists, participants (Rapporteur: Jackie Grebmeier)
- Bob Pickart (with input from Knut Aagaard and Rebecca Woodgate): mooring cruise on USCGC Healy

1730-2000 Dinner at RSMAS-sponsored by SBI Project Office

2000 Van/car return to hotel: meet outside Commons Room, walk to vans

Friday, 7 March 2003

0715-0730 Van/car transport to RSMAS

0730-0830 Continental breakfast at RSMAS

0830-1000 Field Program: 2004 (cont.) (break-out rooms available)

- Continue 2004 field program discussions (Rapporteur: Jackie Grebmeier)

1000-1020Break

1020-1200 Open Discussion

- Special issue Deep-Sea Research/papers/timetable (Sharon Smith)
- Special sessions Feb. 2004: ASLO and/or AGU (Jackie Grebmeier)
- 3rd SBI Pan-Arctic Meeting, 3-7 Nov 2003, Cadiz, Spain (Jackie Grebmeier)
- Possible Oden 2005 cruise (Jim Swift/Jackie Grebmeier)?

1200 SBI 2 PI Meeting adjourns; van/car transport to hotel

***Poster Titles**

1. Arianne Balsom et al.: Sediment Bacterial and Viral Abundances in the Chukchi and Beaufort Seas

2. Laura Belicka et al.: Biochemical Tracers of Marine and Terrestrial Organic Carbon Near the East Barrow Canyon, Arctic Ocean

3. Mark Benfield et al: Calibration of Broadband Acoustic Doppler Current Profilers for Use as Scientific Echosounders

4. Jaclyn Clement et al.: Upstream Environment for SBI-Modeled and Observed Biophysical Conditions in the Northern Bering Sea

5. Glenn Cota et al.: Arctic Productivity

6. Glenn Cota et al.: Arctic Ocean Color

7. Dennis Darby et al.: A millennial-scale Paleoclimate record from the Western Arctic Ocean

8. Jeffrey Dixon et al.: Circulation and Variability in the Western Arctic Ocean from a High-Resolution Ice-Ocean Model

9. Jackie Grebmeier et al.: The Western Arctic Shelf-Basin Interactions (SBI) Project (poster, powerpoint presentation, video clips and movies)

10. Catherine Lalande et al.: Vertical Export of Biogenic Matter in the SBI Study Region

11. Igor Melnikov: Biologically-Oriented Processes in the Coastal Sea Ice Zone: Long-Term Observations in the White Sea.

12. Jim Moore et al. TBD (seabeam maps, etc)

13. Igor Melnikov: Biologically-Oriented Processes in the Coastal Sea Ice Zone: Long-Term Observations in the White Sea

14. Stephane Plourde et al: Poster: Egg Production and Hatching Success of *Calanus glacialis/marshallae*: a Dominant Copepod in the SBI Study Region during 2002

15. Lori Roth and Rodger Harvey: Degradation and Modifications of Dissolved Protein by Natural Bacterial Assemblages in Arctic Waters

16. Waldema Walczowski and Wieslaw Maslowski, SBI-II modeled Versus Observed Hydrography and Currents of the Chukchi and Beaufort Seas

17. Sang H. Lee and Terry E. Whitledge, The Nutrient Dynamics and Physical Structures in Bering Strait and the southern Chukchi sea, June 2002

TABLE OF ABSTRACTS FOR TALKS AND POSTERS

TABLE OF ABSTRACTS FOR TALKS AND POSTERS (cont.)

Exchange of Plankton and Particles Between the Shelf and Basin

Carin Ashjian[1], Mark Benfield[2], Scott Gallager[1], Stéphane Plourde[1]

[1]Woods Hole Oceanographic Institution, Department of Biology
[2]Louisiana State University, Department of Oceanography and Coastal Sciences

The purpose of this project is to document shelf-basin exchange of plankton and particles. The project is composed of two components: shipboard estimates of plankton and particle abundance and vertical distribution from a Video Plankton Recorder(VPR) during the two process cruises and long-term observations of particle/plankton abundance from moored acoustic Doppler current profilers (ADCPs) that were deployed by R. Pickart. The ADCPs were calibrated prior to the cruise so that estimates of absolute backscatter could be obtained (see poster by M. Benfield); data will be retrieved during fall 2003. The VPR was deployed on the CTD rosette during the first process cruise and off the stern from the 3/8" hydro wire using a stainless steel cage during the second process cruise. Typically, the VPR was deployed to 10 m off the bottom or to 350 m, depending on the bottom depth. The VPR was deployed successfully for 13 casts during the first process cruise and 32 casts during the second process cruise, covering most station locations north of the Bering Strait. Analysis to date has concentrated on the second process cruise. The VPR images were dominated by marine snow. Copepods also were observed in the images. Image analysis and an automated image identification program are being used to determine the vertical distributions of the taxa specific plankton and type specific particle concentration and coincident hydrography for each tow. These data then will be merged with ADCP velocity records obtained by the ship's hull mounted ADCPs to obtain estimates of instantaneous flux (magnitude and direction). Preliminary results indicate that Barrow Canyon in particular is a site of high particle concentration and high flux of material between shelf and basin.

Sediment Bacterial and Viral Abundances in the Chukchi and Beaufort Seas

Arianne L. Balsom[1], Jacqueline M. Grebmeier[1], Lee W. Cooper[1], Steven W. Wilhelm[2]

[1]Dept. of Ecology and Evolutionary Biology, University of Tennessee, 10515 Research Drive, Suite 100, Bldg. A, Knoxville TN 37932, USA

[2] Dept. of Microbiology, University of Tennessee, 633 Science and Engineering Research Facility, Knoxville, TN 37996, USA

Recent studies have demonstrated that viruses can cause a significant proportion of bacterial mortality in marine systems and that this mortality can be an important factor affecting microbial community composition, nutrient cycling, and mineralization rates. Benthic viral densities range from one-to-three orders of magnitude higher than in the overlying water column. These viruses may be bacteriophages, or viruses that infect benthic microalgae. By inducing the mortality of bacterial populations, viral activity directly impacts the availability of carbon to higher trophic levels (i.e. microbial grazers) by reducing total bacterial abundance. The sediment abundance and geographical distribution of this important marine trophic food web component has previously been unstudied in most Arctic regions. During the summer of 2002 we investigated the interaction of benthic microbial communities with macroinfaunal communities and the resulting impacts on large scale biogeochemical cycling patterns. Surface sediment aliquots were taken from 0.1 m^2 Van Veen benthic grabs obtained during the SBI Phase II Summer 2002 cruise (HLY-02-03) aboard the USCGC Healy. Samples were prepared for the enumeration of both bacteria and virus-like particles (VLPs) utilizing epifluorescent techniques. Initial results show that the abundance of both sediment bacteria and VLPs were higher on the continental shelf, that at basin stations. These results are consistent with the predominance of many other benthic processes on the shallow productive shelves.

POM and DIC Distributions in the SBI Study Region of the Chukchi and Beaufort Seas

Nicholas R. Bates[1] and Dennis A. Hansell[2]

[1]Bermuda Biological Station For Research, 17 Biological Station Lane, Ferry Reach, GE01, Bermuda
[2]Rosenstiel School of Marine and Atmospheric Science, University of Miami,
4600 Rickenbacker Causeway, Miami, FL 33149

POM and DIC distributions in the SBI study region of the Chukchi and Beaufort Seas will be discussed in relation to water mass properties and preliminary estimates of net community production (NCP). Large increases in near surface concentrations of POC and PON between the spring and summer cruises were observed over the shelf, coincident with high rates of NCP estimated from nutrient changes and drawdown of DIC (50-150 μmoles kg-1). High concentrations of POC (>500 μmoles kg-1) and PON (>80 μmoles kg-1) were observed to extend offshelf in the subsurface upper halocline waters during the summer cruise. In contrast, in the near surface layer of the shelf-break and offshelf region of the West and East Hanna Shoals (e.g., where nitrate concentrations were below 1 μmoles kg-1), POM contents remained low and DIC did not change significantly between spring and summer cruises, suggesting low rates of NCP in this region.

Biochemical Tracers of Marine and Terrestrial Organic Carbon Near the East Barrow Canyon, Arctic Ocean

Laura Belicka[1], Rodger Harvey[1], Robie Macdonald[2], and Mark Yunker[1]

[1]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD
[2]Ocean Chemistry Division, Institute of Ocean Sciences, Sidney, B.C., Canada

We used a subset of samples collected during the 2002 field season to examine lipid biomarkers in particles and sediments. Initial analyses have focused on the Kokolik and Ikpikpuk Rivers and the East Barrow Canyon area of the Arctic Ocean to compare sources and shelf to basin transport of organic carbon. Samples included particles from the chlorophyll maximum and the maximum fluorescence of colored dissolved organic matter and surface sediments from a box core at three stations in near the East Barrow Canyon. Particles from near-surface waters, rafted debris, and surface sediments from the Ikpikpuk and Kokolik Rivers were also analyzed.

Among the suite of compounds observed, biomarkers specific for terrestrial carbon (long-chain saturated and monounsaturated fatty acids, β-amyrin, and β-sitosterol) demonstrated the abundance of terrestrial input from Arctic rivers and the importance of the transport of terrigenous material to the interior of the western Arctic basin. In addition to these terrestrial markers, sediments from the continental shelf near the East Barrow Canyon also contained a large proportion of sterols indicative of diatoms (24-methylcholesta-5,24(28)-dienol and 24-ethylcholesta-5,24(28)Z-dienol) together with algal polyunsaturated fatty acids (18:4, 20:5 and 22:6) and high phytol concentrations, suggesting that despite considerable riverine input, phytoplankton production strongly influences carbon dynamics on the shelf.

A 92-day degradation experiment using ice alga collected from the bottom of a passing floe was performed during HLY02-01 and HLY02-03 to determine the kinetics of loss and changes in biomarker distributions that would occur during water column degradation. Total fatty acids degraded exponentially over the time course of the experiment, with an average rate constant of 0.0433 day^{-1}, less than half the rate seen for temperate diatoms (Harvey and Macko, 1997). These slow degradation rates, coupled with high spring production rates, suggest that ice algal carbon can comprise a significant fraction of the organic carbon pool in Arctic surface sediments. Surprisingly, rate constants for saturated fatty acids were slightly higher than those for mono- and polyunsaturates (0.0466 day^{-1}, 0.0385 day^{-1}, and 0.0445 day^{-1}, respectively). Degradation rates of individual lipids varied, however, implying that chemical structure and saturation state may not be the dominant control of fatty acid degradation.

Calibration of Broadband Acoustic Doppler Current Profilers For Use as Scientific Echosounders

Mark C. Benfield[1], Robert Stokes[2], Charles Greenlaw[2], Duncan McGehee[2], D.Van Holliday[2], Carin Ashjian[3], and Dan Torres[4]

[1]Louisiana State University, Department of Oceanography and Coastal Sciences
[2]BAE Systems Inc
[3]Woods Hole Oceanographic Institution, Department of Biology
[4]Woods Hole Oceanographic Institution, Physical Oceanography Department.

ADCPs are widely used for measurement of current velocity and direction. These instruments also record the intensity of the received backscatter signal and they are increasingly used to provide a qualitative measure of acoustical scattering. In theory, ADCPs could be used as quantitative scientific echosounders provided that a variety of system characteristics are known. We undertook the calibration of broadband ADCPs (RD Instruments 300 kHz and 75 kHz) by measuring their source levels, receive sensitivities, the relationship between received signal strength intensity (RSSI) and applied sound pressure, and beam patterns. These measurements when combined with an estimation of spreading and absorption losses will allow us to convert RSSI data from ADCPs into volume scattering strength measurements (dB).

Marine Mammals as Indicators of Arctic Marine Ecosystem Hotspots

John L. Bengtson[1] and Sue E. Moore[1]
[1]National Marine Mammal Laboratory, NOAA, 7600 Sand Point Way NE Seattle, WA 98115
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The shelf, slope and basin zones of the western arctic provide productive habitats for polar marine mammals. Determining the seasonal patterns of seal and whale abundance and distribution is key to understanding the ecological interactions involving these apex predators and the ecosystem "hotspots" where they are often found. The central hypotheses to be investigated by this project are: 1) marine mammals reflect bottom-up structuring in the Western Arctic ecosystem, and 2) gray whales and bearded seals exert a top-down impact on benthic communities. Although abundance and distribution data on all marine mammal species will be recorded, five will act as bio-samplers across a suite of trophic scales to test these hypotheses: bowhead whales (water column zooplankton feeders); gray whales and bearded seals (benthic foragers); and beluga and ringed seals (fish and crustacean predators). Each species will integrate the environment across variable spatial and temporal scales, with the composite result reflecting oceanographic primary and secondary productivity derived from transport processes and mesoscale oceanographic features.

Incorporating marine mammal visual and acoustic surveys within the framework of the SBI Phase II is vital if these top predators are to be accurately represented in ecosystem models. While we anticipate that all species will be found in highest abundance at productive zones in the Western Arctic (i.e., that they will reflect bottom-up processes), it is unclear what role marine mammals may play (if any) in structuring the food web (i.e. if they control top-down processes). The proposed project suggests a novel use of marine mammals as bio-indicators of the marine environment. Standard visual survey techniques will be applied as well as satellite telemetry and passive acoustic recorders for year-round detection of calling animals. Specific research objectives of the proposed project are to:

- Determine marine mammal distribution, relative abundance and habitat associations via visual and passive acoustic surveys.

- Describe ringed and bearded seal habitat selection, haulout behavior and foraging behavior via satellite tags deployed on captured animals.

- Estimate seasonal abundance of vocal mammals via two paired autonomous acoustic recorders deployed near SBI Phase II mooring sites planned near Herald Canyon and Barrow Canyon.

- Integrate measures of marine mammal relative abundance and habitat use derived from visual surveys and remote sensing (passive acoustics and satellite tags) with measures of oceanographic structure and prey availability.

Is Terrigenous DOC in the Canada Basin Old and Refractory?

Ronald Benner

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Columbia, SC 29208, benner@biol.sc.edu

Arctic rivers discharge about 2.2 Tg C as dissolved organic matter (DOM) annually to shelf and basin waters of the Arctic Ocean. The biological and photochemical reactivity of this material in the Arctic Ocean is largely unknown, but this terrigenous DOM is generally considered to be old and refractory. Arctic rivers drain organic-rich soils (peats) that commonly have old 14C-ages, and recent studies have suggested that the export of old DOM from peat soils could be increasing as temperatures increase due to global warming.

The abundance and distribution of terrigenous DOM was determined in samples collected during the May-June and July-August 2002 cruises on the USCGC Healy. Dissolved lignin phenols, unique biomarkers of terrigenous DOM, were measured in shelf and basin waters, and the 14C ages of 15 DOM samples was determined. In addition, samples from two Alaskan rivers that discharge into the Chukchi and Beaufort Seas, the Ikpikpuk and Kokolik, were also collected and analyzed. High and variable concentrations of dissolved lignin phenols were found throughout shelf and polar surface waters. Relatively low concentrations of lignin phenols, indicative of Atlantic water, were found in deep slope and Canada Basin waters. The 14C age of DOM in both rivers was modern, indicating the discharge of predominantly young and freshly-produced terrigenous DOM. A strong negative correlation was found between lignin phenol concentrations and the 14C age of DOM in basin waters, indicating that the terrigenous component of the DOM was young relative to marine DOM. The 14C age (3765 ybp) of deep water DOM from the Canada Basin was similar to that in deep water from the Atlantic. These results indicate that terrigenous DOM in surface waters of the Canada Basin is relatively young and could be of greater biological and photochemical reactivity than previously recognized.

Canadian Arctic Science Projects and DFO Coast Guard Elements

Martin Bergmann

Arctic Science Program Development, Fisheries and Oceans Canada | 501 University Crescent, Winnipeg, Manitoba R3T 2N6 (204) 983-3776 | facsimile / télécopieur (204) 984-2401, bergmannm@dfo-mpo.gc.ca

Prior to 1994 and before the merger between Department of Fisheries and Oceans (DFO) and the Canadian Coast Guard (CCG), Arctic research aboard CCG icebreakers consisted of a few days of opportunity research once every few years. Over the past 9 years, CCG icebreaker supported oceanographic research has grown to include such research initiatives as the Joint Ocean Ice Studies (JOIS – 1997-ongoing), the Surface Heat Budget of the Arctic Ocean (SHEBA –1997-1998), Tundra Northwest (1999), the Northwater Polynya Project (NOW – 1997-1999), the Nares Strait Project (2001), and the Joint Western Arctic Climate Study (JWACS – 2002-2007).

The need for Arctic research in Canada has increased substantially, and the political climate surrounding this research has also changed. Shaping these developments in Canada are the new governance models in northern Canada, and increased interest nationally and internationally in climate change, now even more importantly under the Kyoto ratification.

Now and in the future, the main principals that must work to accomplish Arctic research aboard CCG icebreakers include cooperation between governmental departments/sectors, partnerships with Canadian universities and international organizations, cost leveraging of infrastructure and equipment, and continued support, promotion and communication between stakeholders**.**

In support of the Arctic Science marine operations by Canadian researchers and their partners, new funds have been made available to in Canada the Canadian Foundation of Innovation (CFI) and DFO to convert a CCG icebreaker to a state-of-the-art research platform for multi-disciplinary science. This initiative is a joint government/university initiative led by Université Laval.

Mesozooplankton Grazing Rates During the 2002 SBI Field Season

Robert Campbell[1], Carin Ashjian[2], Stéphane Plourde[2], Mari Butler[3]

[1]University of Rhode Island, Graduate School of Oceanography
[2]Woods Hole Oceanographic Institution, Department of Biology
[3]University of Rhode Island, Department of Plant Sciences

Grazing experiments were conducted with the dominant mesozooplankton from the Beaufort and Chukchi Seas during the spring and summer 2002 SBI process cruises in order to assess their role and importance in carbon cycling in this region. A total of about 250 grazing measurements were obtained, using up to 5 life stages from 6 different copepod species. Preliminary results indicate that in the spring, feeding activity, as indicated by clearance rates, was highest in the shallow regions of the shelf and decreased with depth. During the summer, feeding activity in the deeper basin regions increased, while those on the shelf remained high. Ingestion rates tended to be higher on the shelf compared to the basin and during the summer compared to the spring because of higher chlorophyll *a* concentrations. Clearance rates declined and ingestion rates increased with increasing chlorophyll *a* concentration, although these relationships were not as strong as expected. In addition, interspecific differences were observed. *Calanus glacialis / marshallae*, the most important inshore copepods, were actively feeding in both spring and summer with highest feeding rates on the shelf, while the offshore dominant, *C. hyperboreus*, was more active in the summer with highest feeding rates in the basin.

TEA on the SBI 2002 Summer Cruise

Betty Carvellas

Essex High School, Essex Junction, VT

Through the Teachers Experiencing Antarctica and the Arctic (TEA) program, teachers take part in on-going scientific research in the polar regions. The goals of the program include: immerse teachers in a research experience as a component of their continuing professional development, inform teaching practices through research experience, bring polar research into classrooms in engaging and innovative ways to underscore the relevance of science to society, and build on the research experience to establish a growing, collaborative Polar Learning Community of teachers, students, administrators, researchers, and the public. Betty Carvellas, a science teacher from Essex High School in Essex Junction, VT worked as a TEA with Dr. Jackie Grebmeier on the SBI 2002 summer cruise. Through her research experience and follow up in her district, she has begun to implement the goals of the TEA program.

Upstream Environment for SBI – Modeled and Observed Biophysical Conditions in the Northern Bering Sea

Jaclyn Clement[1], Wieslaw Maslowski[1], Lee Cooper[2], Jacqueline Grebmeier[2], Waldemar Walczowski[3], Jeff Dixon[1]

[1]Naval Postgraduate School, Department of Oceanography, 833 Dyer Road, Monterey, CA 93943, USA
[2]University of Tennessee, Department of Ecology and Evolutionary Biology, 10515 Research Dr, Suite 100, Bldg A, Knoxville, TN 37932, USA
[3]Institute of Oceanology, Polish Academy of Sciences, ul. Powstańców Warszawy 55, PL-81-712 Sopot, Poland

Using a high-resolution Pan-Arctic ice-ocean model, circulation of the northern Bering Sea and transport through Bering Strait are investigated and discussed in relation to downstream conditions in the Chukchi and Beaufort Seas. Model results are compared to observational data including nutrient concentrations in the Bering Sea and transport measurements in Bering Strait. The high resolution (1/12° or ~9km) and large domain of the model allow for realistic representation of flow through Anadyr, Shapenberg, and Bering Straits and calculation of transport estimates.

A long-term model estimated mean transport through Bering Strait is 0.65 Sv. The modeled seasonal pattern of transport is comparable to observational data collected from moorings in Bering Strait, with lower monthly mean transports during winter and higher transports in July and August. Monthly mean transport through Bering Strait is highly correlated with transport through Anadyr Strait over the model integration time period (r=0.89), while the correlation between Bering and Shapenberg Straits is somewhat lower (r=0.50).

Observational data in the northern Bering Sea from late spring through summer and fall indicate an east-to-west increase in nitrate concentration, silicate concentration, and salinity. Model results show a similar salinity pattern across the Bering shelf, which represents the characteristics of Alaska Coastal Water to the east and Anadyr Water to the west. Using salinity as a proxy for nutrient concentration, the model can be used to determine the biologically-relevant characteristics of water moving north through Bering Strait and across the Chukchi shelf.

Upstream conditions in the northern Bering Sea are important for developing hypotheses regarding the Shelf-Basin Interaction study region in the Chukchi and Beaufort Seas. The model's ability to cross political boundaries and examine high-resolution results over a large scale and long time period is critical for understanding the role of Pacific Water in shelf-basin exchanges, in the arctic circulation, and in climate change.

Implications of the Biogeochemical Hydrographic Data Collected from the *Healy* in the Chukchi and Beaufort Seas During the 2002 SBI Process Cruises

Codispoti, LA[1], J. Swift[2] and Company

[1]Horns Point Laboratory, 2020 Horns Point Road, Cambridge, MD 21613
[2]UCSD/SIO, 0214, 9500 Gilman Drive, La Jolla, CA 92093-0214

The biogeochemical hydrographic data collected on the SBI *Healy* cruises during May-June and July-August 2002, clearly indicated the importance of the inflow of nutrient rich waters *via* Bering Strait and the near-ubiquitous presence of plumes of biogenic material originating over the shelf and penetrating into the interior of the Arctic Ocean. An interesting aspect of the biogenic plumes was the uniformly high ammonium concentrartions but generally low urea and nitrite concentrations. Plumes of silicate, phosphate, nitrate and the parameter N** were well-developed, and the silicate plumes, in particular, provided evidence for nutrient regeneration over the shelves as the blooms progressed.

In combination with data collected by colleagues our results also indicate that:

1.The offshore bloom (at least in the surface layer) was well underway or over by the time of the May-June cruise (*Healy* 02-01).
2. The shelf bloom was starting during *Healy* 02-01.
3. The shelf bloom was well underway or over by the July-August cruise (*Healy*-02-03).
4. Subsurface oxygen supersaturations were common during *Healy* 02-03 suggesting the end of the surface layer bloom and penetration of the blooms into the upper halocline as water clarity increased.
5. High biological activity was present over the shelf and in tongues extending from the shelf, but largely restricted to the upper 200-250 m with the exception of Barrow Canyon..
6. Deep water biological rates may be extremely low.
7. Because of 5 and 6, sedimentary metabolism gradients going from shallow to deep sediments may be unusually high.

Stable and Radio-Isotope Tracers in the SBI Study Area, 2002

Lee W. Cooper[1] and Jacqueline M. Grebmeier[1]

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Our fieldwork in the Shelf-Basin Interactions field area in 2002 included sampling in the water column, on sea ice and in the benthos.

Water column analyses of $^{18}O/^{16}O$ ratios indicate that during the early season cruise in May-June, freshwater associated with runoff was restricted well offshore on several of the transects. This pattern was maintained during the July-August cruise, although contributions of brine-injected waters into Barrow Canyon and the horizontal advection of freshwater associated with melted sea ice were also observed. Relative to other chemical parameter data provided by the Hydrographic Measurements Group, the $^{18}O/^{16}O$ ratio data indicate that Haardt fluorescence decreased in waters with the same oxygen isotope composition between the spring and summer cruises, and that the N* denitrification proxy showed a much wider range of values in Bering Strait and Chukchi summer shelf waters transiting northward than in waters already in place at the shelf-basin boundary at the end of the winter.

Gamma spectroscopy of snow samples indicates that the inventories of the short-lived, natural radionuclide ^{7}Be ($_{t1/2}$ = 53 d) ranged from 41 to 122 Bq cm^{-2} during the May-June cruise. No ^{7}Be deposition was observed on the first cruise in surface sediments, but surface sediment inventories ranged from 1 to 61 Bq cm^{-2} by July-August. Because precipitation fluxes during the second cruise were two-orders of magnitude lower than the inventories already present in snow on the sea ice surface, indications are that a very high proportion of this radionuclide present on the sea ice surface during the spring cruise was deposited to bottom sediments within two months. The radionuclide was detected in sediments >900 m in depth, with strong particle focusing at shelf and slope stations on the East Barrow and Barrow Canyon lines and at productive benthic locations just north of Bering Strait. Many of these locations were also associated with high inventories of sediment chlorophyll deposited to surface sediments.

Additional gamma spectroscopy is underway at this time to ascertain the depths of deposition in the sediments of the anthropogenic radionuclide ^{137}Cs, which will be helpful in identifying regions of high sedimentation.

Arctic Productivity

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Panarctic distributions of remotely-sensed chlorophyll are compared with productivity maps derived from oceanographic property profiles. Direct comparisons are limited to open water areas with useful imagery. There are striking similarities in regional and seasonal patterns, but there .are also large regional differences between years in the five-year SeaWiFS record. Global SeaWiFS chlorophyll has been transformed with our arctic algorithm. Monthly chlorophyll climatologies show that the most intense phytoplankton blooms are found in coastal waters and along retreating ice edges. There is a general northward progression from May to August. Energetic areas, such as the Bering Strait, support prolonged blooms, while more transient features in most regions indicate that nutrient depletion is common.

A circum-arctic BIOgeochemical PROperty Database (BIOPROD) has been assembled. These oceanographic data are highly biased in space (e.g. accessible shelf waters) and time (i.e. summers >1970), but with n > 10,000 profiles they represent the broadest coverage available for the Arctic. Mixing and respiration in fall and winter are assumed to replenish nutrients and draw down oxygen, "resetting" seasonal conditions in the upper 30-70m. Local "seasonality" migrates with ice cover. Property distributions for physical (temperature and salinity), chemical (oxygen and nutrients), and biological (chlorophyll) parameters were used to estimate productivity. The upper layer, where autotrophs dominate biogenic activities, was functionally defined as a "modified" layer depth (MLz). It is roughly equivalent to the euphotic zone, depth of nutrient draw down, and/or oxygen supersaturation. Spring and summer values for chlorophyll concentration, nitrate depletion, and oxygen saturation were used as indicators of seasonal primary production and net trophic status. The later two are the first, nearly panarctic estimates of new production and net community production with regional patterns. Chlorophyll data is more restricted spatially, and column concentrations are presented as areal standing stocks of carbon to illustrate patterns and dynamics. Temporal units are omitted, since the time frames are not well-defined. Seasonal progression and spatial patterns can be masked by combining data seasonally. Nevertheless, the patterns of abundance are qualitatively consistent in many locations with each other and the ocean color imagery.

Assumptions about "seasonal reset" are suspect for certain locations, particularly deep basins where there may be highly muted seasonality. If surface waters are not reset seasonally, artefactual "hot spots" result. The spring 2002 SBI cruise found very low nitrogen levels in basin waters and supersaturation of oxygen in May (Codispoti, pers. comm.) under continuous ice cover. A rare time-series from the early 1970s in largely ice-covered waters of the Canada Basin north of Ellesmere Island reveal that surface layer nitrate was not replenished nor did respiration lead to undersaturation in fall-winter for at least two years. Nutrient data from SHEBA also show very low winter levels of nitrate (Siferd, pers. comm..). Data are available via JOSS/NSIDC with summaries at http://www.ccpo.odu.edu/~orca/sbi.htm. Sponsored by NSF and NASA

Arctic Ocean Color

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Subtle variations in ocean color are detectable from space. When free of ice and clouds, visible radiation emitted from the surface yields "true color" and ocean color images. High latitude waters have unique bio-optical properties, which we have examined on 14 cruises including three in the Chukchi and Beaufort Seas. Phytoplankton are the dominant source of marine primary productivity and optical variability in most regions. However, optically active constituents include water, phytoplankton, nonalgal particulates, and soluble materials. Other constituents may interfere with retrievals of phytoplankton biomass, especially in waters with significant runoff or resuspension. Light is absorbed or scattered by the various constituents, and a small fraction is backscattered by particles out of the ocean. The ratio of particulate backscattering (b_b) to total scattering (b) is higher than at lower latitudes. Absorption (a) and scattering are inherent optical properties (IOPs) that are independent of the ambient light field, and can be determined actively at any time.

Visible remote sensing is a passive measurement of the bio-optical signature of a water mass. Remote sensing reflectance (R_{rs}) can be approximated by the ratio of backscattering to absorption:

$$R_{rs} \approx b_b/a$$

with scaling factors for the radiance distribution. However, R_{rs} is defined by:

$$R_{rs} = L_w/E_d$$

where L_w is water-leaving radiance and E_d is downwelling irradiance. Both radiance and irradiance are apparent optical properties (AOPs), which depend on the ambient conditions when measured. Measured spectra of R_{rs} for several biomass bins compare well with modeled spectra derived from the observed IOPs. The good agreement indicates that the dominant constituents have been considered. Blue-green band ratios of R_{rs} can be related to chlorophyll concentration and net daily primary production. The global SeaWiFS algorithm overestimates low chlorophyll concentrations but underestimates higher levels compared to our current arctic algorithm. Bloom concentrations are often about twice those predicted by SeaWiFS. Phytoplankton productivity can also be estimated with semi-empirical models and simple empirical relationships. When properly tuned with regional data, bio-optical models and satellite remote sensing provide an unprecedented view of polar processes. Sponsored by NASA, NASDA, and NSF.

Western Arctic Primary Productivity

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Primary productivity should be assessed over many scales with multiple techniques. These scales range from instantaneous and microscales (e.g. fluorescence) to seasonal and basin scales (e.g. remote sensing). Productivity observations from a variety of scales will be considered for the Western Arctic Shelf-Basin Interactions study area to better understand the seasonal progression, local differences, and magnitudes of productivity. Sponsored by NASA, NASDA, and NSF.

What the Paleo-Record in the Western Arctic Tells Us About Recent Changes and the Future

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The paleo-record from several cores along a transect near 160° W (Long.) from the shelf edge down into the Northwind Basin (200 to 2100 meters water depth) have important implications for SBI investigations. Modern sedimentation rates (last few millennium) dramatically decrease from the upper slope, northward into the basin (>45cm/kyr to 1 cm/kyr). Thus the dominant flux of sediments is due to poorly understood lateral contour currents or melt-out from sea ice and not down slope transport. The sea surface temperature in August at the shelf edge (~74°N), was warmer than today by 5°C throughout most of the Holocene and plunged 300- 500 years ago near the beginning of the Little Ice Age. Several peaks in SST and salinity occurred during the Holocene. The best explanation for these temperature and salinity increases is an incursion of North Atlantic Intermediate Water into the western Arctic and possible shallowing of this water mass, similar to what is observed during the last decade, but more pronounced.

Periodic expansion of the Trans Polar Drift (TPD) into this area is noted throughout the Holocene by ice-rafted Russian sand grains in Chukchi Slope cores (e.g., originating from the Laptev and Kara Seas). Similar changes in the TPD are predicted during strong positive Arctic Oscillation (AO) anomalies. The presence of large amounts of Russian grains occurs approximately every 55 years during the last millennium, but large amounts of these grains occur about once every 200 years. These TPD changes do not appear to be in sync with SST and salinity changes. During the last half century of Arctic observations, we have not experienced such a pronounced shift in the TPD, but we may be overdue for one. The consequences are not well understood but may include increased flushing of western Arctic packice through Fram Strait.

A Millennial-Scale Paleoclimate Record From the Western Arctic Ocean

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Rapid changes in ice-rafted sources and paleoceanographic conditions such as surface temperature and ice cover during the Holocene are recognized in several cores from the western Arctic Ocean. Some of these changes occur on the century scale and perhaps even shorter time periods. The changes are similar to those caused by the North Atlantic/Arctic Oscillation, but on a longer period. These changes include reversals in the short-term circulation pattern of the Beaufort Gyre and displacement of the Trans-Polar Drift system. These in turn influence changes in local and perhaps global climate. The recent discovery of this atmospheric induced oscillation has raised the question of whether it operated in the more distant past and, if so, at what scale and periodicity. The data from the piston and box cores studied thus far from the continental slope off the Chukchi Sea northwest of Alaska suggest that drift reversals in the past few centuries may have been much larger than those observed over the past 50 years. This area of the Arctic seems to record changes that are much larger than those seen in the Greenland ice core record for the Holocene.

Pore-Water Oxygen Distributions in Western Arctic Ocean Margin Sediments

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Pore-water oxygen profiles yield information about the rain rate of organic carbon to the sediments. These profiles were determined for four transects across continental margin of the western Arctic Ocean. Each transect covered the water depth interval of 50 to 3,000 m and all were done during July-August, 2002. At all continental shelf stations oxygen concentrations decreased rapidly from overlying water concentrations near saturation to zero in the upper few millimeters. On each section the oxygen penetration depth increased with increasing water depth however, the penetration depth at the deepest station was quite different. At the two easternmost sections the oxygen penetration depth was 20 to 30 mm at the 3,000 m station and the offshore gradient in penetration depth was very similar to that observed previously for the Washington State continental margin. In contrast, at the two western most transects, the penetration depth at 3,000 m was almost an order of magnitude greater, 120 to 220 mm. Shallower penetration depths at the eastern sections may, in part, be due to off-shelf transport of organic matter the through Barrow Canyon.

A Metadata Tutorial for SBI

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The need for accurate and complete metadata is an absolute necessity to insure that SBI data sets are available and useful via a long term archive. The ARCSS Data Coordination Center (ADCC) is the only long term archive for all ARCSS related data. The presentation will discuss the need for metadata and its importance not only to ADCC but also to the SBI principal investigator. The ADCC Metadata Submission Form will be present and explained.

Circulation and Variability in the Western Arctic Ocean from a High-Resolution Ice-Ocean Model

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Interactions of the Atlantic Water circulation with Pacific Water exported from the Chukchi shelves towards the Chukchi Rise and in the southern Canada Basin are not well understood. Comprehensive modeling provides tools to supplement limited observational data and to improve our knowledge of the circulation in the Western Arctic. The Naval Postgraduate School (NPS) Pan-Arctic sea ice and ocean model, developed in part for the SBI program, provides valuable insights into the circulation of the region. One of the main goals of this effort is to more accurately model the circulation in the main SBI region (i.e. shelves and slopes of the Chukchi and Beaufort seas) as well as the upstream conditions for this region.

To address some of the issues related to the circulation in the Western Arctic, the time-mean and interannually variable velocity fields are analyzed. The bases of this investigation are results from the recently completed 24-year model integration for 1979-2002, forced with realistic daily-averaged atmospheric fields from the European Centre for Medium-range Weather Forecast (ECMWF). Velocity output at three separate depth intervals are averaged to present the circulation in the upper ocean, at the halocline depth and in the Atlantic Layer. Decadal variability is analyzed comparing results from the early 1980s, 1990s and 2000s. The Western Arctic Ocean response to the climate regime shifts of the recent decades is estimated by calculating decadal differences of velocity fields at various depths. Property fluxes across the Bering Strait are compared with those downstream across the Chukchi Cap to better understand their variability as well as to quantify the fate of Pacific Water in the region.

Benthic Faunal Biomass in the Western Arctic: Linkage to Overlying Water Column Processes

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The ultimate goal of our research is to link patterns of benthic community structure and biomass in the Chukchi and Beaufort seas to associated physical and biological processes that can be identified as key determinants of global change. Benthic organisms integrate elements in the adjacent water column and therefore can be used as indicators of long-term change. We used Geographical Information Systems (GIS) software as a tool to map the biomass and distribution of benthic organisms for comparison to other features (e.g. ocean depth, seasonal ice extent, currents, water column chlorophyll, etc.). Benthic data were assembled in an Access relational database and analyzed with the GIS program Arc/Info. A Geostatistical Analyst extension to ArcMap was used to interpolate the data with kriging techniques to produce probability estimates of benthic biomass across the study area. Plotted benthic data reveal areas of high biomass (>250 gm^{-2}) north of the Bering Strait in the Chukchi Sea and south of the Bering Strait in Gulf of Anadyr waters. In contrast, benthic biomass along the nearshore Alaskan Beaufort Sea shelf is less than 30 gm^{-2} except along the regions of the western Beaufort and east of the Mackenzie River delta. Areas of high benthic biomass coincide with major outflows from the Bering Strait onto the Chukchi and Beaufort Sea shelves. The significant advection of allocthanous carbon produced on the Bering Shelf to high latitude areas in the western Arctic is supported by the distinct carbon isotopic signatures of benthic (and pelagic) consumers collected west of Pt. Barrow, compared to the areas of the eastern Beaufort Sea Shelf and Arctic Basin. Continued examination of isotopic data is focused on elucidating the linkages between chlorophyll standing stocks and the productivity of overlying shelf waters with the physical forcing processes that regulate the advection of carbon to these benthic communities.

Sediment Transport by Chukchi and Beaufort Sea Ice in 2001/2002

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The Chukchi and Beaufort Sea shelves are receiving organic and inorganic particulate matter from a variety of sources, ranging from input through coastal erosion, river discharge to Bering Strait inflow and local biogenic production. With the shelf width ranging from >500 km in the western Chukchi to <100 km in the eastern Beaufort Sea transfer of this material to the Arctic Ocean can vary considerably. In contrast with marginal seas at lower latitudes, the shelf sediment and carbon budget in Arctic regions can be significantly affected by entrainment and transport of particulates into sea ice. Thus, in a recent effort to arrive at a sediment and organic carbon budget for the Canadian Beaufort Sea shelf, Macdonald et al. (1998) identified the magnitude (as well as the sign) of sediment transport by sea ice as a major unknown. It is commonly believed (e.g., Reimnitz et al., 1994) that owing to the prevailing sea-ice regime with alongshore motion and a predominance of multi-year ice, ice rafting in the Chukchi and particularly the Beaufort Sea are of minor importance on a basin-wide scale, since the total transport is much smaller than that in the Siberian Arctic. Essentially, this view has been confirmed by an analysis of ice transport based on published ice volume fluxes, ice sediment loadings as well as distribution and composition of source sediment areas. Thus, the export of terrestrial organic carbon from the Beaufort and Chukchi shelf by sea ice is $<1 \times 10^9$ g yr^{-1}, compared to roughly 200×10^9 g yr^{-1} for the Laptev and Kara Seas. Recent observations during the Shelf-Basin Interaction (SBI) spring cruise into the Chukchi and Beaufort Sea in May/June 2002 have led us to reexamine these findings. Thus, significant portions (>25 % areal fraction averaged over the study area up to 73.5˚N) of the first-year ice cover were found to contain sediments in multiple layers. Ice core analysis and ancillary information on ice history obtained from buoy data suggests an origin from shallower waters in the Beaufort Sea. At this point it is not clear, whether this observation merely represents an anomaly or is potentially indicative of recent changes in sediment entrainment associated with a changing sea-ice regime.

Biomass and Productivity of Ice Algae in the Chukchi and Beaufort Seas in Spring 2002

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This presentation summarizes our findings on concentrations of algal pigments, and the abundance and activity of ice algae versus phytoplankton (collected in about 5m depth) for the Chukchi and the Beaufort Seas during the spring 2002 SBI expedition. Considerable regional differences were observed with highest ice algal biomass and activity in the Chukchi Sea. Most of the ice samples originated from first-year sea ice. The few samples taken in multi-year ice floes were located at the northernmost stations and were characterized by considerably lower concentrations of ice algae compared to the shelf locations.

Benthic Carbon Cycling and Community Structure in the SBI Study Area

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Sediment samples were collected with a Haps benthic corer and van Veen grab at stations in the SBI study area to trace the deposition of organic matter using sediment metabolism, plant pigment, carbon content, grain size and benthic faunal composition and biomass. Surface sediment chlorophyll values indicate a declining gradient from the shelf to the deep basin. Sediment oxygen uptake and nutrient flux (an indication of carbon supply) were highest on the Chukchi and Beaufort shelves, with rates decreasing from the shelf to deep basin. During spring sediment respiration rates ranged from 19mM O_2 m^{-2} d^{-1} in shallow shelf regions to <1 mmol O_2 m^{-2} d^{-1} in deep slope and basin regions, indicative of a reduction in carbon supply from the shelf to basin transects. By comparison, summer sediment respiration rates increased, with values ranging from 41 mM O_2 m^{-2} d^{-1} on the southern Chukchi shelf, down to <1 mM O_2 m^{-2} d^{-1} in deeper slope and basin stations. The highest carbon supply for the spring cruise was at the historical "hot spot" area just north of Bering Strait in the Chukchi Sea, although the increased value in summer was less than the maximum observed for an upper Barrow Canyon station (BC2) during that cruise. Nutrient flux measurements indicate high levels of silicate and ammonium effluxing from the sediments to the overlying water column on the Chukchi shelf, likely influencing the observed increase in silicate and ammonium concentrations from spring to summer in the plumes moving off the shelf to the deep basin. It is notable that higher sediment uptake rates occurred at deeper depths in Barrow Canyon than the other transect lines, which is likely due to a depositional focusing of organic carbon down the axis of the canyon. Benthic macrofaunal populations and associated benthic carbon biomass follow the high-to-low trend in carbon deposition to the benthos moving from shelf to basin. In spring, benthic biomass was greatest at the 50-100 m stations (25 g C m^{-2}), declining down to the 500 m depth (3 g C m^{-2}), and negligible at water depths of ≥1000 (<1 g C m^{-2}). The species collected from the greater depths were small and limited to foraminifera, clams and marine worms. The upper Barrow Canyon stations had well sorted cobbles and gravel and a greater number of filter feeding animals than other stations, which were dominated by finer-grained sediments where infaunal organisms dominated the community structure.

Overview of the Western Arctic Shelf-Basin Interactions (SBI) Project

Jackie M. Grebmeier[1] and the SBI 2 Principal Investigators

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The goal of the Western Arctic Shelf-Basin Interactions (SBI) project, funded through the National Science Foundation and the Office of Naval Research, is to investigate the production, transformation, and fate of carbon at the shelf-slope interface in the Arctic as a prelude to understanding the impacts of a potential warming of the Arctic. 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. Phase I of SBI used retrospective research and analyses, opportunistic sampling studies, and modeling to prepare for field work in the Chukchi and Beaufort seas. The second phase of the SBI project (2002-2006) involves 40 Principal Investigators on 14 integrated projects working in the Bering Strait region and over the outer shelf, shelf break, and upper slope of the Chukchi and Beaufort seas. The 2002 field season of SBI completed four successful scientific missions to the Arctic using three vessels: the USCGC *Healy* (5 May -15 June and 17 July-26 August), the USCGC *Polar Star* (15 July-13 August) and the RV *Alpha Helix* (20-29 June). During the first-year field program the SBI project applied a broad array of physical, biogeochemical and biological measurements from May through September (and year-round with the moorings), which are almost unprecedented in scope for the Arctic. Plans for the 2003 SBI field season include a March helicopter survey and field sampling project, participation by some SBI PIs in an April ice camp sponsored by the Office of Naval Research, a June Bering Strait mooring project, a July-August hydrographic and sampling survey cruise, and a September-October mooring cruise. The 2004 field season will proceed with four cruises similar to that undertaken in 2004 to provide both seasonal and interannual comparison of processes in the SBI sampling region. The final SBI mooring retrieval will occur in 2004, with SBI Phase II continuing through 2006 with data synthesis. The final SBI Phase III (2007-2009) will focus on development of Pan Arctic models suitable for simulating scenarios of the impacts of climate change on shelf-basin interactions. Further information on the SBI project can be found at the SBI website: http://sbi.utk.edu.

DOC and DON in the SBI System

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DOC and DON concentrations, distributions and seasonality will be viewed in the context of the water masses endemic to the SBI region. Particular focus will be given to Atlantic, Pacific, river, and melt waters. DOC is characteristic to the water masses (i.e., relatively conservative) and thus serves as a water mass tracer, while DON shows greater within water mass variability, particularly near the sediment/water interface. DOM will be considered relative to other tracers of the water masses, as well as to various biogeochemical processes.

Molecular Markers of Organic Matter Sources and Cycling in the SBI Study Region

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As part of our efforts to document the sources and cycling of organic materials under SBI, we are building on initial efforts which identified those specific organic molecules which can help to distinguish marine from terrestrial inputs. From the two cruises in 2002, we have a suite of particles collected from multiple depths at 30 stations as well as sediments from 15 locations collected by boxcore for analysis. A subset of samples from particles and sediments as well as riverine material collected by at the river mouth of the Kokolik and Ikpikpuk Rivers has been completed. This includes a transect across the East Barrow Canyon area to examine the balance of marine verses terrestrial material. Particles from near-surface waters, rafted debris, and surface sediments from the Ikpikpuk and Kokolik Rivers were also analyzed. Among the suite of compounds observed, a number of biomarkers specific for terrestrial carbon (long-chain saturated and monounsaturated fatty acids, §-amyrin, and §-sitosterol) are being used to track the abundance of terrestrial input from Arctic rivers to the interior of the western Arctic basin. Shelf sediments also contained a large proportion of sterols indicative of diatoms (24-methylcholesta-5,24(28)-dienol and 24-ethylcholesta-5,24(28)Z-dienol) together with algal polyunsaturated fatty acids (18:4, 20:5 and 22:6) and high phytol concentrations. In shelf areas it appears that phytoplankton production strongly influences carbon dynamics despite the large input of terrestrial organic matter.

An important issue for biological productivity is the turnover of labile marine carbon which fuels benthic production. In an experiment spanning both cruises (92 days), we conducted a simple degradation experiment to examine organic carbon and biomarker distributions in phytoplankton after cell death. Ice algae collected from the bottom of a passing floe was diluted and degraded in the dark under with the distribution of bulk properties, dissolved markers and organic biomarkers followed over time. Organic carbon degradation rates were about half that seen in similar experiments with temperate species, suggesting that much of the marine derived material arrives at the sediment water interface on shelf waters prior to significant degradation. Detailed structural in formation will be provided on the accompanying poster by Laura Belicka.

Radioisotope Evaluation of Shelf-Basin Transport Processes from the 2002 Field Season

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Modeling results suggest that inflow from the Bering Strait, upon reaching the edge of the Chukchi shelf, is constrained by the earth's rotation to follow local isobaths instead of flowing into deeper water. Resulting strong along-isobath currents lead to sharp lateral velocity and property gradients near the shelfbreak. The SBI PHASE I and PHASE II 228Ra/226Ra results support this notion, where high 228Ra/226Ra ratios are constrained to nearshore stations. Eddy formation via hydrodynamic instability of the boundary current may therefore be an important mechanism for transporting mass and properties offshore in this region. During the Spring 2002 SBI cruise on the USCGC Healy, evidence of such eddy formation was found on the East Hannah Shoal (EHS) transect. Distributions of temperature, salinity (density), radionuclides, nutrients and 18O, as well as geostrophic velocity, suggest the presence of a cyclone adjacent to the boundary current, consistent with the eddy formation process.

Heterotrophic Microbes and the Metabolic Balance of the Arctic Ocean

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Heterotrophic and autotrophic process may be out of balance in some oceanic regimes, including the Arctic Ocean where dissolved organic carbon (DOC) from terrestrial sources may favor the growth of especially heterotrophic bacteria. (Although "bacteria" is used here, our measurements include Archaea, which may be quite abundant in the Arctic even in surface waters.) To examine the metabolic balance of the Arctic Ocean, we measured bacterial production and biomass, community respiration and oxygen production during the SBI process cruises of 2002. Preliminary data indicate that bacterial abundance was about 10^8 cells per liter in the spring, roughly 50% lower than found in low-latitude oceanic waters. Abundance then increased in summer to 10^9 cells per liter at the shelf stations. Because of low activity, total respiration and oxygen production rates were measurable in only about 30% of the samples during the summer cruise. Similar to low-latitude waters, bacteria seem to account about 50% of total respiration, although this percentage varies greatly. In collaboration with Rodger Harvey and Ron Benner, we also conducted various experiments to examine DOC utilization and regulatory mechanisms that control bacterial growth and community structure. These experiments indicated that growth rates of heterotrophic bacteria during the spring SBI cruise were limited by organic carbon, although temperature also impacted growth rates with a Q10 of 2, i.e. rates increasing by a factor of 2 every 10 degrees. Results from these experiments are not consistent with the Pomeroy-Wiebe hypothesis, which states that more DOC is needed to support microbial growth at low than at high temperatures. Bacterial production, respiration and net oxygen production will be compared with 14C-primary production data in order to determine the balance between heterotrophic and autotrophic processes during the SBI cruises.

Vertical Export of Biogenic Matter in the SBI Study Region

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Some of the world highest benthic biomass concentrations are found on the shallow arctic shelves, indicating a tight pelagic-benthic coupling of carbon in these areas. Preliminary results from the May-June 2002 SBI cruise indicate similar distributions of benthic biomass concentrations in the northern Bering and Chukchi Seas, with highest concentrations in the Bering Strait region and upper Barrow Canyon. By comparison, benthic biomass values declined downslope in the Chukchi and Beaufort Seas to the Arctic Ocean. Sediment total organic carbon content also indicates areas of higher quality phytodetrital deposition in the region. The vertical export of biogenic matter is a major link between pelagic and benthic ecosystems. The investigation of factors influencing this export is crucial in the understanding of carbon cycling in the SBI study. Short-term deployments of floating sediment traps are proposed for the SBI 2004 process cruises in order to estimate the vertical flux of POC, PON, Be^7, and select stable- and radio-isotopes.

Towards Understanding of Marine Environments in the Western Arctic - Physical Modeling for the SBI Program

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The ocean circulation and sea ice conditions in the Western Arctic are hard to observe comprehensively for both logistic and political reasons. The multi-year Ice Pack in the basin and seasonal sea ice over the shelves of the Bering through Chukchi and Beaufort seas contribute to the logistic difficulties. The separation of the Chukchi and Bering seas by the International Date Line into eastern and western parts creates the access problem for political reasons. High resolution modeling of the Pan-Arctic region over the range of temporal scales from hours to decades provides fundamental information needed to synthesize limited observations and to explain their observed variability.

The physical modeling component of this SBI II project has been designed to address three main aspects of the SBI program. We utilize coupled ice-ocean models at increasingly high resolutions to:
1) allow focused study of ocean and sea ice processes, including eddies, tides, and boundary currents as well as seasonal ice cycle, leads, and polynyas, controlling the dynamics of the outer shelves and slopes of the Chukchi and Beaufort seas
2) obtain an up-to-date large-scale picture of seasonally and interannually changing physical regimes of the western Arctic as well as its upstream and downstream conditions, and
3) provide high-resolution physical model output for forcing/coupling to ecological models at spatial and temporal scales relevant to biogeochemical studies.

In this talk we summarize progress with the physical modeling of the Pan-Arctic region, focusing on results most relevant to shelf basin interaction in the Western Arctic. Seasonally and interannual variability of sea ice and ocean conditions are emphasized. Examples of spatial and temporal variability and their role in mass and property transfers are discussed. Usefulness of such a model for synthesis and integration of available observations in space and time and a feasibility of model guidance of future field campaigns is also addressed. More detailed analyses are presented in three modeling posters by the co-authors of this talk.

Biologically-Oriented Processes in the Coastal Sea Ice Zone: Long-Term Observations in the White Sea

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Recently well known, that sea ice is an important component of the global climate system controlling miscellaneous natural processes in the polar oceans. However, little is known about the sea-ice impact on the sea floor, the coastline and their habitants, and especially, in the coastal environment with the tidal dynamic. The annual advance and retreat of sea ice may be considered as a major physical determinant of spatial and temporal changes in the structure and function of marine coastal biological communities. In this presentation I go to demonstrate some of data obtained in the tidal zone of Kandalaksha Gulf (White Sea) during the 1996-2002 period. Previous observations in this area were mainly obtained during the ice-free summer season, however, there were not any information on the ice-covered winter season (6-7 months duration), and, especially, on the sea-ice itself. During the winter observations there were conducted series of standard transects along of coastline with sea ice samplings including the under ice observations of the sea ice/bottom floor interactions. Interannual cycles or trends in the annual extent of the sea ice during this period of observations have shown significant effects at all levels of sea ice associated communities - from the winter production of the sea ice algae to breeding success among seabirds in the summer. Habitat conditions of littoral communities depending on the flood duration have been also studied. Three types of sea ice impact on the kelps, balanoides, littorinas and amphipods were distinguished: (i) positive, when the sea ice protects populations from a grinding; (ii) negative, when the ice grids both fauna and flora, and (iii) combined effect, when the fast ice protects but the anchored ice grids plant and animals. It was concluded, that to understand all spectra of the ecological problems caused by pollution on the coastal zone, as well as, the problems of the sea ice melting caused by global warming, it needs an integrated long-term study of the physical, chemical, and biological processes occurring in the coastal-shelf zone in the Russian Arctic.

SBI Data Management Support Update

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JOSS provides data management support to SBI Phase 2 activities. This includes a SBI data support web page at JOSS, archival of Phase 1 and 2 datasets and assistance to the investigators for submission and redistribution of project data. The JOSS SBI Field Catalog was customized for use aboard the *USCGC Healy*. We interfaced directly with the ship's underway data stream to provide real time updates to ship position and track as well as to display a variety of products and reports. Display of polar orbiter satellite data imagery was possible through coordination with the US Coast Guard. A catalog "mirror site" was implemented at UCAR/JOSS in Boulder with information relayed from the ship by satellite so that those not on the cruise could follow the progress of shipboard activities. The complete field catalogs documenting both SBI Healy cruises are available at: http://www.joss.ucar.edu/sbi/
SBI scientific datasets from the 2002 cruises are being submitted to the JOSS Interim archive. As of Early February, 2003, 19 datasets were lodged at JOSS with many more in preparation for submission.

We will provide a summary of our activities and those planned for the remainder of 2003.
Comments will be solicited on ways to improve the catalog and archive structure to better support SBI investigators. JOSS is working on several value added products that will be of use to SBI. They include high-resolution ship tracks overlaid on the Seabeam bathymetry data collected during the cruises, the preparation of GIS format compatible data for ship position and meteorological data and possibilities for basemaps to help integrate results from the various analysis activities.

POC Export During SBI-II: 2002 Results

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As part of the 2002 Shelf-Basin Interaction II field program, measurements of radiochemical tracers (^{234}Th, ^{228}Th, ^{210}Pb, ^{228}Ra, ^{226}Ra, ^{129}I, ^{137}Cs) are being used to quantify the sinking flux of particulate organic carbon (POC) from the surface waters and the exchange of particles and water between the shelf and interior basin of the Chukchi-Beaufort Seas. This talk will discuss the magnitude and variability (spatial and seasonal) of POC exported from the upper ocean based on measurements of ^{234}Th/^{238}U disequilibrium and large particle (>53 μm) POC concentrations. Analysis of these data is nearly complete and posted at the JOIS website. Large volume (~200-1000 L) water samples were collected in-situ from a total of 36 stations and 184 depths during May-June (HYL-02-01) and July-August (HLY-02-03). Particle-reactive ^{234}Th (half-life 24.1 d) was determined both at-sea and in the shore-based lab by gamma spectrometry and beta counting. ^{234}Th/^{238}U disequilibrium was evident at all stations, indicative of particle export occurring on a time-scale of weeks. Results are characterized by: 1) enhanced particle export in the shelf and slope waters; 2) higher particle export in the southeast sections near Barrow Canyon compared to the Chukchi Sea (West of Hanna Shoal), and; 3) a marked increase in particle export at all stations occupied during the summer. Estimates of POC export flux from the upper 50 m were calculated using a 1-D steady-state model and multiplying the observed ^{234}Th deficit by the measured POC/^{234}Th ratio of large particles (>53 μm). POC export fluxes exhibit a marked spatial and seasonal variability, averaging 2.5 mmol m^{-2} d^{-1} (0.03-22 mmol m^{-2} d^{-1}) during the spring and increasing to an average value of 12.5 mmol m^{-2} d^{-1} (2.1-39 mmol m^{-2} d^{-1}) during the summer. These results are within the limited range of data previously reported for the Arctic and adjacent seas. Ongoing analyses include ^{228}Th/^{228}Ra disequilibrium and ^{210}Pb/^{226}Ra disequilibrium in the water column and sediments and water column distributions of the anthropogenic tracers ^{129}I and ^{137}Cs.

ADCPs, LADCPs, and Boundary Mixing

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Oceanic kinetic energy, in the form of boundary currents, internal waves and turbulence, typically is concentrated near shelf break and slope regions. This concentration is amplified at high latitudes, because sloping bottom topography tends to influence the overlying water column more strongly than in temperate oceans. High latitude ocean basins are typically less energetic than temperate oceans, and so energy concentration at the boundaries can be especially striking. The SBI program focuses geographically on the region surrounding the Beaufort Sea shelf break, where we can reasonably expect the foregoing statements to apply. The eastward-flowing slope current that comprises a part of the Arctic Ocean peripheral circulation system adds an energy source to the Beaufort slope. Bottom-trapped density flows may be present as a downstream consequence of dense water production on the adjacent shallow shelves. Barotropic tidal currents are small, but not negligible. Shear associated with these features can generate turbulent mixing either locally or, through generation and propagation of internal waves, remotely. Mixing in turn modifies water masses along the boundary while also impacting the distribution of biogenic materials. The physical manifestations of these several processes can be complex, involving fronts, eddies, filamentous currents and lateral interleaving. Continuous profile sampling such as can be obtained using an ADCP or LADCP are extremely useful in analyzing such regions. Data from these instruments can, when integrated with *T*, *S* and density fields obtained using a CTD, provide us with detailed mesoscale to small-scale information on the physical conditions associated with the ocean boundary. This presentation summarizes some processes of likely interest within a Beaufort Sea context.

Shelfbreak Circulation in the Alaskan Beaufort Sea: Mean Structure and Variability

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While it is well established that a significant amount of Pacific-origin water enters Barrow Canyon from the Chukchi shelf, the fate of this water as it encounters the edge of the Canada Basin is uncertain. Dynamical constraints suggest that much of the transport should skirt the canyon, and continue to the east along the shelfbreak and upper slope of the Beaufort Sea. Here we show that this notion is likely correct, and use historical data to quantify the structure, transport, and variability of the "Beaufort shelfbreak jet".

The available hydrographic sections from the National Oceanographic Data Center, over the period 1959–1987, are transformed into a bathymetric coordinate system and combined to form a mean thermal wind section for the Beaufort shelfbreak/slope. This is referenced using historical current meter data, revealing a jet on the order of 15-20km wide, centered near the 150m isobath. Seasonally, the jet varies between three distinct configurations. In spring/summer it transports cold winter-transformed Bering Sea water as a mid-depth jet. Later in the summer/fall it evolves into a buoyant, surface-trapped jet carrying warm Bering Sea summertime water. Finally, in late-fall and winter—under upwelling favorable winds—the Atlantic water flows eastward at relatively shallow depths along the upper slope. From year to year there can be marked changes in the first of these configurations, whereby the winter-transformed Pacific-origin water ventilates different strata within the halocline.

On shorter timescales, mesoscale processes can lead to shelf-basin exchange of water. One such process is baroclinic instability of the boundary current and subsequent eddy formation. In summer 2002, a high-resolution hydrographic data set was obtained along the southern boundary of the Canada Basin during the Western Arctic Shelf-Basin Interactions (SBI) mooring cruise. Preliminary analysis of these data, within the framework of previous mid-latitude instability modeling, suggests strongly that eddy formation readily occurs along the shelfbreak of the Alaskan Beaufort Sea.

Egg Production and Hatching Success of *Calanus glacialis/marshallae*: A Dominant Copepod in the SBI Study Region During 2002

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Egg production rates may reflect secondary production rates and are indicative of a species ability to survive and sustain itself in different regions. Egg production rates of dominant copepod species were determined during the two 2002 SBI process cruises. *Calanus glacialis*, an Arctic species, and *Calanus marshallae*, a Pacific species, are similar morphometrically and are reproductively active during the spring and summer. These two species were not differentiated. Although *Calanus hyperboreus* is an important species in both regions, the reproductive period for this species was completed prior to the cruises. Egg production rates and egg hatching success for *C. glacialis/marshallae* were determined in both shelf (< 200 m) and basin (> 200 m) regions. Preliminary results suggest that egg production on the shelf may be initiated earlier, reach higher levels, and last longer than in the adjacent basin. Egg production was somewhat correlated with chlorophyll levels in the upper water column. Egg production rates dropped off markedly at the end of the second process cruise because of decreases in both spawning frequency and clutch size suggesting that this was the end of the reproductive season for this species. Hatching was similar in both shelf and basin regions and usually greater than 80%. Egg production rates for *C. glacialis/marshalle* observed on the shelf (< 200 m) exceeded those observed for this species in the adjacent basin (> 200 m) and during 1997-1998 further to the north in the Arctic Basin.

Degradation and Modifications of Dissolved Protein by Natural Bacterial Assemblages in Arctic Waters

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Organic nitrogen is an important part of the nitrogen cycle in the oceans, serving as substrates for bacterial growth and food for benthos. Proteins are the principal organic nitrogen compounds of living biomass. Most proteins are rapidly recycled in seawater, and historically have been quantified by measuring total hydrolyzable amino acids or total combined amino acids. Recent evidence shows that some portion of proteinaceous material can be found in dissolved organic matter pools. There are a number of potential preservation pathways including encapsulation in macromolecular organic matrices, sorption to mineral surfaces, or selective degradation based on structure, but all assume microbial degradation is the major catalyst for alteration in marine waters. The major focus of this research is to determine the degradation and modification of protein, and what factors, including environmental and protein characteristics, influence the rates and alteration of protein. Incubations were run using water from the Arctic Ocean, Delaware Bay, and Patuxent River. These incubations provide a comparison of the degradation rates of protein and/or chemical modifications to the protein by bacterial communities in different aquatic environments. A series of incubations were run using BSA as the model protein in water containing a natural bacterial assemblage. Dissolved protein was collected from the incubations and analyzed using size exclusion chromatography to follow chemical modifications of the protein and separate them into fractions by size. Preliminary results show that over time chemical modifications of BSA lead to a shift to lower molecular weight material. Detailed structural analysis will include the use of LC/MS to more specifically identify the chemical modifications. Further investigation of protein degradation will help to determine what factors, including temperature, hydrophobicity, and the presence of lipid bilayers might influence the rate of bacterial utilization and modifications that occur.

Preliminary Results of the Protist Grazing Rate/Phytoplankton Growth Rate Assays and the Mesozooplankton Grazing Rate Assays

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During the 2002 SBI field year, we carried out 18 dilution assay experiments designed to access microzooplankton grazing rates and phytoplankton growth rates. Based on changes in chlorophyll-a content as a proxy for change in phytoplankton biomass, 2 out of 6 dilution experiments in the spring, and 8 of 12 experiments in summer, showed significant microzooplankton grazing rates. Phytoplankton intrinsic growth rates varied from 0 to 0.4 / day in spring and summer. We also have independently analyzed change in phytoplankton stocks in the dilution experiments via flow cytometric enumeration of small and large phytoplankton size classes for a subset of the dilution experiments. The preliminary results indicate that, for some experiments, over the 3-day incubation period cell-specific fluorescence for smaller phytoplankton cells decreased, resulting in underestimation of phytoplankton growth rates based on chlorophyll. In at least one experiment in the spring, flow cytometry data showed significant grazing loss for large cells, presumably diatoms, but not for smaller cells. Preliminary flow cytometry and inverted microscopy counts made for a subset of the mesozooplankton grazing experiments have shown that, in general, the mesozooplankton appeared to be consuming large phytoplankton cells and heterotrophic protists, but not small phytoplankton cells. Inspection of representative microscope slide preparations made during the two cruises has shown a diverse phytoplankton and protist assemblage.

Overview of the Joint Western Arctic Climate Studies (JWACS)

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JWACS 2002 fieldwork has been conducted by three vessels operation using R/V Mirai, CCGS Louis S. St-Laurent and CCGS Sir Wilfrid Laurier to cover the full span of the southern Canada Basin from the Canadian Beaufort Sea to the Chukchi Borderland (CBL). Here we report the recent hydrographic status of the western Arctic Ocean.

Pacific Waters: We conducted the CTD/Rosette sampling to evaluate the seasonality and spreading pathway of the Pacific Water into the western Arctic Ocean. We met a recorded ice reduction in the western Arctic Ocean centered on the Northwind Ridge. The spatial distribution of the ice retreat area was well correlated with the spatial distribution of shallow temperature maximum water originated from the Eastern Chukchi Summer Water (ECSW). This indicated an evidence of an ocean-ice interaction and an inter-ocean interaction between Pacific and Arctic Oceans. The spatial distribution of ECSW was not uniform but a zebra-like pattern. New Pacific Winter Shelf Water with cold and oxygen rich properties was occupied the region where the summer water was rarely found. Thus the seasonality of the Pacific inflow was observed as a spatial distribution of the water masses in the southern Canada Basin. We have already deployed three moorings at the mouth of the Barrow Canyon one year prior to the JWACS 2002 basin-scale survey. The time-series data of the moorings showed not only the seasonality of the water masses but also the seasonality of circulation patterns associated with the seasonality of the Beaufort High.

Atlantic Water (FSB): Based on the direct measurement of the velocity field over the Chukchi Borderland (CBL) using ADCP mounted on the line of drifting buoys, the circulation pathway of the Atlantic Water correlated with the seafloor topography. The advective velocity at 250m deep was in the relation of $(u,v)=80*(dh/dy, -dh/dx)$, where u and v are horizontal velocities, h is total depth, and x, y are zonal and meridional distance respectively. During the late 1990s, the warm temperature anomaly (WTA) of Atlantic Water was observed over the Chukchi Borderland. The warming is now apparent in the southern Canada Basin. At the base of the Canadian Beaufort slope (climate station site A), CFC concentration increases monotonically. However a saw-like feature of interleaving structure is not so clear east of the Barrow Canyon. AW is thicker toward the downstream along the Beaufort Slope. The structural changes near the temperature maximum would be caused by external mechanical and thermal forcing i.e., upwelling/downwelling on the Beaufort Slope and submarine canyons and cooling by winter water ventilation.

Biomass of Zooplankton and Molecular Studies in the SBI Study Area

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(text extracted from HLY-02-03 cruise report)

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Fifty-two successful Bongo tows were made for zooplankton species composition and abundance determinations during the summer 2002 SBI cruise. Detailed underway data collections were made to obtain temperature, salinity, chlorophyll and zooplankton measurements. Underway samples were used to replace vertical one-meter net tows for nauplii while occupying stations. Much of the time the system actually captured subadult stages of the copepod *C. glacialis*, indicating its abundance and distribution in very near-surface layers. These samples will be used for the molecular studies of distribution of copepod nauplii throughout the study area in conjunction with the physical oceanographic determination of transport mechanisms linking the shelf, slope and basin sectors. Results at sea indicated that the deeper tows contained the copepods *Euchaeta* and *Microcalanus* for example, while the 0-100m tows usually contained *Calanus hyperboreus*, *Calanus glacialis* and chaetognatha. The onshore-offshore gradients in taxa were quite confused to the east of Barrow Canyon, with each station often seeming to have an assemblage not fully present at adjacent stations. Coastal species (e.g., *Acartia*) were collected offshore and Arctic Ocean taxa (e.g., *C. hyperboreus*) were collected on the shelf. Many taxa we expected to see were absent; some stations were fairly diverse, others were nearly monocultures. The clearest pattern was the absence of deep Bering Sea copepods in the study area in general. They were collected only at two nearshore stations in the Alaska Coastal Water (ACW). All other stations, including Herald Valley where they were supposed to be found in the Bering Sea inflow to the Chukchi shelf and slope, lacked Bering Sea species totally. The slope stations in the Herald Valley area (western-most part of the study area) contained a zooplankton assemblage that was typical of the deep waters of the Arctic Ocean. Based on earlier zooplankton collections during warm and cold years in this region, this warmest summer on record should have been accompanied by widespread distribution of large-bodied copepods coming from the deep Bering Sea. This was definitely not the case.

Upper Halocline Characteristics - What Do the 2002 Data Tell Us About Sources in the Chukchi and Beaufort Seas?

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The Chukchi and Beaufort Seas substantially influence the characteristics of the upper halocline in the central Arctic Ocean. The characteristics of this layer away from boundaries are contrasted with those at appropriate densities in the 2002 study region with an eye toward elucidating sources and anomalies.

SBI II - Modeled Versus Observed Hydrography and Currents of the Chukchi and Beaufort Seas

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Observational data from the SBI II cruises HLY-02-01 and HLY-02-03 are used for validation of the Naval Postgraduate School (NPS) Pan-Arctic ice-ocean model. Modeled and observed hydrological fields (temperature and salinity) as well as currents, including shipboard ADCP measurements, are compared.

Using model output, circulation of the Chukchi and Beaufort Seas is investigated. The high resolution (1/12° or ~9 km) of the model allows observation of mesoscale meanders and eddies and narrow jet streams. Mesoscale structures appear to be very important to the shelf-basin exchange.

Modeled time series (1979-2002) of volume, heat and fresh water transports across the sections investigated during USCG 'Healy' 2002 SBI cruises are presented. In addition, transports through the Bering Strait and Barrow Canyon are analyzed.

The high temporal (seasonal and interannual) variability characterizes modeled parameters, especially the upper ocean velocities. ADCP measurements at the stations investigated by the USCG 'Healy' indicate non-steady behavior. The investigated environment appears to be much more variable than previously thought. Even at such a high model resolution, one should use caution when comparing model output with measurements, since model results and observations represent different space and time scales. On the other hand they are complementary to each other.

Decadal Shifts in Biophysical Forcing of Marine Food Webs in the Arctic: Numerical Consequences.

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A numerical model of competition by phytoplankton and herbivores with benthic carbon and nutrient exchange is coupled to a numerical model of water motions of the Chukchi and Beaufort shelves to compare carbon and nutrient cycling in the region under different phases of the Arctic Oscillation. The summer of 1980, during a negative phase, is characterized by reduced northward flow through the Bering Strait, colder water temperatures, and extended ice cover compared to the summer of 1989, when a positive phase of the AO prevailed.

In initial case studies the model calculates as much as 70% more total carbon fixed by phytoplankton over the Chukchi-Beaufort shelf for 15 August to 15 September of the later warmer period with a concomitant increase in flux to the sediments. At a point 70 degrees North/170 degrees West, the production is about the same for the two periods, and here we find the advective gains and losses are a large fraction of the carbon and nutrient budgets.

The Nutrient Dynamics and Physical Structures in Bering Strait and the Southern Chukchi Sea, June 2002

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Three different water masses pass northward through Bering Strait; Anadyr Current water, Bering Shelf water (BSW) and Alaskan Coastal water (ACW). These three different water masses in Bering Strait and Chukchi Sea can be structured differently seasonally and inter-annually by environmental conditions. The distribution of the different water structures of the three water masses in June 2002 as a result of light winds and southward direction made different nutrient structures and thus possibly different phytoplankton distributions than normally observed. Basically, the water masses in our study regions had different properties in each section line. It is somewhat typical for the waters coming through Bering Strait to tend to flow discretely side by side (Coachman and Shigaev, 1988). However, low salinity ACW occupied only the top of the eastern part of the Bering Strait line. BSW and Anadyr Current waters were stratified beneath ACW. By contrast, the CHUK line was dominated over the cross section by ACW. The surface salinity diagram showed that low salinity water in the line, which was believed to the ACW, extended to the central Convention line probably as a result of the light winds. We found an anomalous cold water mass in the eastern part of the Point Hope line. Normally, nitrate concentrations were depleted in the water column related to ACW. However, the water column related to Anadyr Current had high concentrations of nitrate which supported high phytoplankton biomass in the water. The surface salinities exhibited about the same salinities range (29.8 ppt < S <32.7 ppt) as the salinities from deeper water samples (29.8 ppt <T< 32.9 ppt), which might suggest that not much river discharge was added to ACW this time of the year. Surface salinity and nitrate distributions show the broad areal coverage of BSW along the CHUK line while north of 67^{o} N Anadyr water is encountered.

The Chukchi Borderland Cruise 2002

Rebecca Woodgate[1], Knut Aagaard[1], Jim Swift[2], Bill Smethie[3], Kelly Falkner[4]

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The most important subsurface Arctic Ocean transport system is an anticlockwise boundary current, which carries Atlantic (warm, salty) waters and Pacific (fresh, nutrient-rich) waters along the continental slopes and major trans-Arctic ridges. The most complex obstacle the boundary current encounters on its circum-Arctic pathway is the Mendeleev Ridge/Chukchi Borderland, north of the Pacific entrance to the Arctic.

This region, some 350nm northwest of Barrow, is the crossroads for Pacific-origin waters from the south and Atlantic waters carried from the west with the boundary current. The sparse existing data suggest that some of the boundary current and some of the Pacific waters are diverted out into the deep basin in this region, and that over the last decade a warming signal is propagating through the area. However, due to complexity of the region and the paucity of data, we have no clear understanding of the processes that determine the fate of the warm Atlantic and the nutrient-rich Pacific waters.

In a changing Arctic Ocean, both issues are highly relevant. The sea-ice is protected from the warmth of the Atlantic layer by a cold, low-salinity layer originating from the Arctic shelves and from the Pacific, and changes in the pathways or quantities of these waters could thin the sea ice. Similarly, the course and final depth of the nutrient-rich Pacific waters affect the local biological productivity, with implications up the food chain. As we view the changes in the Arctic system over the last decades (the thinner ice cover, the generally warmer climate over both land and ocean), we see the importance of gaining a clearer understanding of the general Arctic Ocean circulation, especially in regions such as the Chukchi Borderland.

In autumn 2002, a 35-day expedition aboard the USCGC Polar Star conducted an oceanographic survey of the Mendeleev Ridge and Chukchi Borderland regions. CTD and tracer (CFCs, O18 and barium) measurements allow us to determine the pathways of the Atlantic and Pacific waters, the influence of river waters and the distribution of nutrients. Three moorings, measuring water velocity, temperature and salinity, were deployed in the boundary current for the duration of the cruise. Coupled with the sparse historic data, this survey will elucidate the interactions in the region and the changes observed over the last decade. This information will provide both a better understanding of the Arctic Ocean and quantitative data required to improve the predictive analytical and computational models of the Arctic system.

We present some preliminary results from this cruise, focusing on the pathways of Pacific waters in the region and the progression of the warming signal in the Atlantic layer.

A Year in the Physical Oceanography of the Chukchi Sea 1990-1991

Rebecca Woodgate[1], Knut Aagaard[1], Tom Weingartner[2]

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A set of twelve physical oceanographic moorings were deployed in the Chukchi Sea between autumn 1990 and autumn 1991. The retrieved measurements of deep temperature, salinity, and water velocity allow us to characterize the water mass transformations and transports in the region over an annual cycle.

This talk will discuss the implications of the variations in temperature (T) and salinity (S) observed. Some indicate atmospheric cooling and warming and the formation and melting of sea-ice. Some indicated the temporary presence of Siberian Shelf Waters.

Of the three main outflows to the Arctic Ocean (Herald Canyon, Central Channel, Barrow Canyon), two (Herald Canyon and Barrow Canyon) were instrumented in this experiment. We will also address the combination of velocity and water mass property measurements with a view to quantifying the variability of the outflows and possible fates of these waters in the Arctic Ocean.

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