Annual Report

1 July 2005–30 June 2006

Year 5 of Cooperative Agreement NA17RJ1224

CIFAR

Cooperative Institute for Arctic Research
University of Alaska Fairbanks

Report from CIFAR to NOAA on the fifth year of Cooperative Agreement No. NA17RJ1224

1 July 2005–30 June 2006

Progress reported during Fiscal Year 2006

(including some activity that occurred in but was not reported during previous periods)

September 2006
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Cover photo courtesy of Sean C. Rooney: A kelp greenling (Hexagrammos decagrammus) among hydrocoral on Albatross Bank, southeast of Kodiak Island. The photo was taken from the Delta submersible at 180 m as part of the CIFAR-funded project "Habitat analysis of major fishing grounds on the Kodiak Shelf." The study combines habitat classifications based on high-resolution multibeam mapping, with data from in situ observations and fishery, oceanographic, and geological surveys to characterize the geological substrate and biological composition of commercially important fishing grounds. (Delta submersible time was funded by NOAA's Alaska Fisheries Science Center – Auke Bay Lab)

Report layout and production by Barb Hameister, CIFAR.

Overview

The Cooperative Institute for Arctic Research (CIFAR) was established through a Memorandum of Understanding between NOAA and the University of Alaska in April 1994. It is one of thirteen national NOAA–University cooperative institutes. CIFAR is designed to foster collaboration between NOAA, the University of Alaska and others working in the Western Arctic (Alaska and the Bering, Chukchi and Beaufort Seas) and to conduct research relevant to NOAA's mission as encompassed in our research themes. CIFAR is the only cooperative institute exclusively concerned with arctic research and cooperates with NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle, the NOAA Arctic Research Office, the National Weather Service (NWS), and Alaska Fisheries Science Center (NOAA/National Marine Fisheries Service, NMFS) through the Auke Bay Laboratory. Future plans include expanding our collaborations with NOAA through new integrated initiatives addressing regional needs as prioritized by the CIFAR Fellows.

CIFAR is staffed by four people: Dr. John Walsh, director; Dr. Susan Sugai, associate director; Sherry Lynch, financial administrator; and Barb Hameister, publications and meetings manager. The institute does not have its own scientists, post-doctoral fellows or graduate students. Since we are very distant from the closest NOAA lab and do not have in-house scientific staff, we conduct research in a different manner from other cooperative institutes. A primary mechanism is to involve researchers through a competitive process involving announcements of opportunity to the entire scientific community and to select projects by peer review. As a consequence, CIFAR research is conducted not only by the faculty and staff at the University of Alaska, but also at several other U.S. universities. CIFAR also provides an important mechanism for facilitating research collaboration between University of Alaska Fairbanks (UAF) scientists and other NOAA line offices, such as National Ocean Service (NOS), NWS, and NMFS.

Research Themes

Research supported by CIFAR falls under several general research themes that characterize the scope of interest of the Institute. Thematic emphasis has changed somewhat from year to year but the themes have remained focused on the big problems of arctic research.

Atmospheric and Climate Research • *Arctic Oscillation* • *Arctic clouds and energy balance* • *Paleoclimates* Marine Ecosystem Studies • *Southeast Bering Sea Carrying Capacity (SEBSCC)* • *Bering Sea productivity* Tsunami Research	Climate Modeling • *Coupled models* • *Model inter-comparisons* Fisheries Oceanography • *Global Ocean Ecosystem Dynamics Program (GLOBEC)* • *Fisheries studies* Contaminant Effects • *Arctic pollution* • *Effects on indicator species*	UV and Arctic Haze Studies • *Ozone and UV radiation* • *Arctic Haze* Hydrographic and Sea Ice Studies • *Sea ice research* • *Tides and currents* • *Ocean fluxes and circulation* Data Archiving and Support

NOAA Mission Goals

CIFAR research addresses all four of NOAA's mission goals enumerated in the NOAA Strategic Plan. Each individual project report identifies which NOAA goal(s) are addressed, as well as a brief statement on societal benefits and/or the relevance of the research results to the needs of NOAA.

1. Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management
2. Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond
3. Serve Society's Needs for Weather and Water Information
4. Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation

Summary of Projects Funded during Reporting Period

During the period 1 July 2005 to 30 June 2006, funding for CIFAR administration and 21 research projects was provided in Amendments 11–36 for a total of $5.30 M. All 21 research projects are CIFAR Task III, i.e., projects funded individually by NOAA. These research projects funded in the current year address 7 of the 9 CIFAR research themes. A full list of these projects is presented in Appendix 1, and summaries by task/theme and funding source are presented in Tables 1 and 2, respectively. In this annual submission, we present reports from these projects as well as from ongoing projects funded in the first four years of the CIFAR cooperative agreement. Note that a report is not included for the continuing ship support for GLOBEC (PI Weingartner), a cooperative effort between the National Science Foundation (NSF) and NOAA.

Table 1: Summary of Projects Funded 1 July 2005–30 June 2006: By Task and Theme

Theme	Number of Research Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)			$110,000	**2.1%**
Core Support		$110,000		
Research Themes (Task II)			$0	**0.0%**
Research Themes (Task III)			$5,198,025	**97.9%**
Atmospheric and Climate Research	3	$116,387		2.2%
Climate Modeling	1	$70,000		1.3%
Contaminant Effects	1	$40,000		0.8%
Fisheries Oceanography	8	$369,380		7.0%
Hydrographic and Sea Ice Studies*	3	$2,151,222		40.5%
Marine Ecosystem Studies	2	$179,800		3.4%
Tsunami Research	3	$2,271,236		42.8%
Total	**21**	**$5,308,025**	**$5,308,025**	**100.0%**

*Although funds came as 3 separate awards, IARC FFY2005 is considered one project.

Table 2: Summary of Projects Funded 1 July 2005–30 June 2006: By Funding Source

Funding Source	Number of Projects	Total Amount
OAR*	12	$2,987,718
NOS	2	$173,368
NWS	2	$1,870,127
NMFS	7	$276,812
Total		**$5,308,025**

*Although funds came as 3 separate awards, IARC FFY2005 is considered one project.

Highlights of CIFAR Task I Activities

Meeting of CIFAR Fellows

The CIFAR fellows for 2005 to 2008 are:

1. Dr. Mark Herrmann, Professor of Economics, School of Management, University of Alaska Fairbanks (UAF), Fairbanks, AK
2. Dr. Larry Hinzman, Deputy Director, International Arctic Research Center, UAF, Fairbanks, AK
3. Dr. Anne Hollowed, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA
4. Dr. Henry Huntington, Huntington Consulting, Eagle River, AK

5. Dr. Zygmunt Kowalik, Professor of Physical Oceanography, Institute of Marine Science, School of Fisheries and Ocean Sciences, UAF, Fairbanks, AK
6. Dr. Gordon Kruse, President's Professor of Fisheries, School of Fisheries and Ocean Sciences, UAF, Juneau, AK
7. Ms. Molly McCammon, Director, Alaska Ocean Observing System, Anchorage, AK
8. Dr. James E. Overland, Coastal and Arctic Research Division, Pacific Marine Environmental Laboratory, NOAA, Seattle, WA
9. Mr. James Partain, Chief, Environmental & Scientific Services Division, National Weather Service, NOAA, Anchorage, AK
10. Dr. Clarence Pautzke, Executive Director, North Pacific Research Board (NPRB), Anchorage, AK
11. Dr. Carl Schoch, Gulf of Alaska Program Manager, NPRB, Anchorage, AK
12. Dr. Buck Sharpton, Vice Chancellor for Research and President's Professor of Remote Sensing, Geophysical Institute, UAF, Fairbanks, AK
13. Dr. Terry Whitledge, Director and Professor of Biological Oceanography, Institute of Marine Science, School of Fisheries and Ocean Sciences, UAF, Fairbanks, AK

The first meeting of the CIFAR fellows was held in Anchorage on November 18, 2005. Twelve of the fellows were present in Anchorage and Anne Hollowed participated via teleconference from Seattle. At that meeting the CIFAR Council of Fellows was selected and consists of: Jim Overland, James Partain, Anne Hollowed, Molly McCammon, Clarence Pautzke, Terry Whitledge and John Walsh.

The Fellows provided their perspectives on means by which CIFAR can strengthen or redefine the program's research themes and NOAA–University connections. A mission statement for CIFAR was drafted pending specifics to be released in the Federal Register announcement of the competition for a NOAA cooperative institute in the Arctic:

> *CIFAR will contribute to the NOAA mission by developing and disseminating knowledge about the atmospheric and oceanic systems of the western Arctic. The major objectives of CIFAR are to (1) administer research and education programs on behalf of and in cooperation with NOAA; (2) identify additional high-priority research and education needs and opportunities to be developed by NOAA, including collaborative activities involving NOAA; (3) facilitate and conduct cross-disciplinary, cross-program synthesis activities; (4) involve stakeholders and other users of Arctic knowledge in education, research and outreach activities.*

Arctic Climate Impact Assessment

The Arctic Climate Impact Assessment, a project implemented under the auspices of the Arctic Council and the International Arctic Science Committee, evaluated and synthesized knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences in the Arctic. The assessment was prepared over the period 2000–2005 by an international team of over 300 scientists, other experts and members of the indigenous communities. Two of its reports were completed in November 2004: a synthesis document entitled *Impacts of a Warming Arctic* and a policy document providing recommendations for mitigation, adaptation, research and outreach. The detailed, peer-reviewed scientific volume was published in October 2005. All of the reports can be accessed through the ACIA web site: http://www.acia.uaf.edu.

The International Arctic Research Center, University of Alaska Fairbanks, hosted the ACIA Secretariat and the CIFAR staff was appointed to operate it. Funding from NOAA's Arctic Research Office supported some of the Secretariat activities during this reporting period. (The primary funding for ACIA was from the National Science Foundation). During the past year, a major activity of the Secretariat staff was to coordinate the work of the technical editors, production manager, lead authors, and members of the ACIA Executive in finalizing the content of the report and preparing it for delivery to Cambridge University Press. Following publication of the report in October 2005, the Secretariat developed and coordinated a distribution plan for the science report to ensure that copies were widely distributed as soon as possible. A continuing activity of the Secretariat staff has been to respond to numerous inquiries regarding access to ACIA reports and to requests from various organizations for interviews, scientific clarifications and copyright permissions. Finally, since the timetable for publication of the ACIA science report did not allow for the production of an index, the Secretariat staff pursued the means to produce, and make available on-line, an index for the report which will make it much more useful to the communities it serves.

Education/Outreach

Stock Assessment Training and Improvement

In 2001, the National Marine Fisheries Service completed a Marine Fisheries Stock Assessment Improvement Plan, a comprehensive evaluation of resource needs and strategies for improving the quality and quantity of fisheries assessments nationwide. A central element of this plan was the development of collaborative research programs between NMFS and universities to ensure the training of students and the encouragement of innovative research. Responding to this report, the Alaska Fisheries Science Center in 2002 initiated collaboration with the University of Alaska through the Task III CIFAR project "Graduate Student Stipend Support for Stock Assessment Training and Improvement." Recently, the mandate for ecosystem-based management of the nation's marine fisheries has further increased the critical need to both NOAA and the state of Alaska to enhance the pool of young scientists trained in quantitative fisheries sciences, including population dynamics, management, and stock assessment. Therefore, beginning in FY06, we have transferred this project from Task III to Task I, effectively providing 50% more graduate student support for the same NOAA/NMFS investment dollars.

To date, eight students have been supported on competitive fellowships under this award and one student has received tuition support. All four students who have completed their graduate degrees (two at the Ph.D. level, two at the M.S.) are employed in quantitative fisheries science in Alaska, three of them with NOAA. (Quinn)

Because of the success of the "Stock Assessment Training and Improvement" project, in FY07, we have used it as a model for the NOAA investment in the "Enhancement of the University of Alaska's Contribution to the International Polar Year (IPY)." In early September 2006, an announcement was released soliciting proposals for IPY Graduate and Undergraduate Research Support.

Student Research Grant Program (Graduate and Undergraduate Support)

CIFAR is a major partner in the Global Change Student Research Grant Competition, established by the UAF Center for Global Change in 1992. The competition provides support to UAF students for research on global change presented in an interdisciplinary context, with an arctic or subarctic focus. The work may involve the social, biological, and physical sciences and engineering. This competition is designed to give students experience with proposal writing and the peer review system as practiced by science funding agencies.

CIFAR supports students both through indirect cost recovery, and through Task I direct support of projects of relevance to CIFAR's mission. We completed the 2006 competition in May; the newly funded CIFAR projects are:

- Jason Addison, Department of Geology & Geophysics: Late Quaternary environmental change in the Gulf of Alaska
- Nathan Coutsoubos, Department of Biology & Wildlife/Resilience and Adaptation (RAP) Program: Tundra-nesting shorebirds in relation to landscape transformation and climate change
- Dawn Magness, Department of Biology & Wildlife/RAP: A survey of management strategies linking global change to decision-making in the National Wildlife Refuge System
- Shannon McNeeley, Department of Anthropology/RAP: Climate change and variability in interior Alaska: an interdisciplinary approach to data integration and synthesis for establishing regional patterns relevant to stakeholders
- Blaine Spellman, Department of Forest Sciences: White sweetclover in Alaska: can this invasive affect the floodplain vegetative community?
- Katie Villano, Department of Biology & Wildlife: Assessing wildfire burn susceptibility to invasive plant colonization in black spruce forests of interior Alaska

Continuing support for a 2-year award made in 2005 with CIFAR funds:

- Hannah Clilverd, Institute of Arctic Biology: Surface–subsurface hydrologic exchange and nitrogen transformations in the hyporheic zone of the Tanana River in interior Alaska.

Support for International, Interdisciplinary Sea-Ice Field Course (GEOS/MSL 693)

Once again as in 2004, CIFAR provided support for the international, interdisciplinary graduate sea-ice course (jointly listed through Geology and Geophysics and Marine Science and Limnology Departments) that Drs. Hajo Eicken and Rolf Gradinger from UAF and Dr. Kunio Shirasawa and colleagues from Hokkaido University offer every two years. This year students from UAF and Hokkaido University collected and analyzed samples at a field station in northern Hokkaido, and gave presentations on their research projects at the 21st International Symposium on Okhotsk Sea & Sea Ice.

Other CIFAR Administrative Activities

In December 2005, Dr. John Calder of NOAA Arctic Research requested that CIFAR administer the announcement of opportunity for the Joint Russian–American Long-term Census of the Arctic (RUSALCA) Research Program in the Bering and Chukchi Seas for work to begin in 2007 or 2008 for a period of up to five years. Seventeen collaborative proposals were received and reviewed by peer and panel reviewers. In June, ten proposals were recommended to be held for a funding decision pending FY2007 and beyond appropriations. Because no proposals were recommended in two critical areas, a solicitation for proposals in two targeted areas was issued in July 2006: 1) primary productivity and related hydrographic indicators of ecosystem status, and 2) development of a model-based analysis and synthesis capability.

In response to a specific request made during the 2004 CIFAR review, we track staff time spent on CIFAR functions. Currently, CIFAR core support funds one full-time staff position and one month of the CIFAR director's salary. However, University of Alaska funds support 9 months of the associate director's time and a second full-time staff position to meet combined CIFAR and Center for Global Change responsibilities. The actual time spent on CIFAR Task I and CIFAR project functions during the period 1 July 2005 to 30 June 2006 were as follows:

- John Walsh, CIFAR director, 10% FTE (both CIFAR Task I and Task III)
- Patricia Anderson, CIFAR past associate director: 21% FTE (all ACIA)
- Susan Sugai, CIFAR associate director: 50% FTE (CIFAR Task I)
- Sherry Lynch, CIFAR fiscal administrator: 90% FTE (CIFAR Task I)
- Barb Hameister, publications and meetings manager: 53% FTE (CIFAR 31% and ACIA 22%).

Highlights of CIFAR Research Activities and Results

Each individual report includes a list of accomplishments and findings. Below we present highlights from selected projects reported on in this document. Not surprisingly, the majority of the findings listed are for those projects for which funding began prior to this reporting period.

Arctic Research Initiative – RUSALCA, Russian–American Long-term Census of the Arctic (1-year to 21-month awards funded in 2004)

The Arctic Research Initiative is a competitive grant program begun in 1997 that addresses research topics of national interest in the Arctic and is managed by CIFAR. An announcement of opportunity (AO) under the Arctic Research Initiative was released in July 2003 that addressed a joint U.S.–Russia research cruise to the Bering and Chukchi Seas, the first activity under the Russian–American Long-term Census of the Arctic (RUSALCA) (http://www.arctic.noaa.gov/aro/russian-american/). Ten U.S. projects were selected and 7 were funded through CIFAR. Of the remaining successful proposals, one was funded through CICOR, one was funded directly through NOAA, and one requested no funding, only logistics. The cruise objectives were to support the U.S. interagency Study of Environmental Arctic Change (SEARCH) Program and the NOAA Ocean Exploration Program, including the Census of Marine Life. One project, "Bering Strait: The Pacific–Arctic Ocean Connection," was funded as part of the RUSALCA AO, however, additional funding for retrieval and redeployment of the mooring was made available through a Task III project, "Bering Strait: The Pacific–Arctic Ocean Connection: RUSALCA 2005" and is reported under "Hydrographic and Sea Ice Studies."

The primary study area was the Northern Bering Sea (north of 60°N) and the Chukchi Sea to the extent that ice conditions permitted. The cruise took place 23 July–24 August 2004 on the R/V *Khromov*, a Russian ice-strengthened research ship. Hydrographic, biochemical and productivity data were collected from the northern Bering and Chukchi Seas to be combined with data from RUSALCA investigators (both in the U.S. and Russia) to assess nutrient and productivity processes. Research findings on the spatial and temporal trends and relationships observed in various components of the marine ecosystem in the RUSALCA study area include:

- For the western channel of Bering Strait, the data suggest an increase in temperature and heat flux in summer and early fall compared to measurements obtained in the early 1990s. There is no apparent change in salinity or the freshwater flux. (Weingartner)
- Nutrient distributions in the RUSALCA study area show strong west-to-east gradients of decreasing nutrients. Extremely low nutrient concentrations were observed in the Alaska Coastal Water and much higher levels in Bering Shelf Water and Anadyr Water. The nutrient concentrations decreased progressively from Bering Strait northward. (Whitledge)
- Chlorophyll concentrations increased rapidly north of Bering Strait, and the Herald Canyon transects exhibited high subsurface chlorophyll concentrations. Primary production rates were maximal north of Bering Strait in the

central Chukchi Sea. Primary production rates decline northward of the central area probably as the result of limited nutrient concentrations in surface waters. (Whitledge)

- For zooplankton, clear and persistent patterns in species composition of *Pseudocalanus* exist in the study area tied to the different water masses, but there was no obvious pattern in weight-specific egg production despite strong chlorophyll gradients associated with these water masses. Future increased penetration of Pacific water will lead to increased penetration of the subarctic *Pseudocalanus newmani*, but all other things being equal, secondary production may not change significantly other than that expected from temperature-dependent rate increases alone. (Hopcroft & Kosobokova)
- Stable carbon isotope ratios in surface sediments in the Chukchi Sea are coupled with water column processes. Less negative $\delta^{13}C$ values in the surface sediments occur under the more productive regions of the Chukchi Sea and indicate a marine phytoplankton source for the carbon in these sediments. (Grebmeier & Cooper)
- The biomass of macrobenthic infauna (organisms living within the sediment) in the southcentral Chukchi Sea stations ranged from 500–1400 g wet wt. m^{-2} (24–59 g C m^{-2}), exceeding 3000 g wet wt. m^{-2} (117 g C m^{-2}) in the hot spot region, which is extremely high on the global ocean scale. This region in the southeastern and southcentral Chukchi Sea included an infaunal community composition dominated by the bivalves *Macoma calcarea* and *Nucula belloiti* and it does not appear to have changed dramatically in community composition from previous sampling in this productive area during the late 1980s through mid 1990s. By contrast, benthic infaunal biomass in the northwest region of the RUSALCA study area shows a reduction in benthic biomass to 95–254 g wet wt. m^{-2} (6–7 g C m^{-2}). The northernmost transect line in Herald Trough and its vicinity was dominated by polychaetes, brittle stars, and sipunculids, with a benthic biomass ranging from 113–588 g wet wt. m^{-2} (5–26 g C m^{-2}). (Grebmeier, Cooper, Sirenko & Gagaev)
- For epibenthic invertebrates (those bottom-dwelling organisms living on the surface of the sediments), highest species richness was found at sites with hard bottom, hence, substrate type was a driving force for overall species richness. Range extensions into the Arctic were seen for some crab (e.g., the crab *Telmessus cheiragonus*) and mollusk species. (Iken, Bluhm & Dunton)
- Ichthyoplankton (fish eggs and larvae) and juvenile demersal (bottom) fishes were collected at approximately 18 sites in conjunction with CTD (conductivity, temperature, depth) data. Ichthyoplankton samples contained 23 taxa representing eight families; they were dominated by Arctic cod *Boreogadus saida*, yellowfin sole *Limanda aspera*, and Bering flounder *Hippoglossoides robustus*. Juvenile demersal fish collections were composed of 32 taxa in nine families. Catches were dominated by Arctic staghorn sculpin *Gymnocanthus tricuspis*, shorthorn sculpin *Myoxocephalus scorpius*, and hamecon *Artediellus scaber*. (Norcross, Holladay & Busby)
- Small demersal fishes consisting of 1310 individuals from 17 stations were classified into assemblages using cluster analysis. Four clusters had spatial distributions comparable to the water masses: coastal fish (CF), South Central Chukchi Fish (SCCF), North Central Chukchi Fish (NCCF), and Western Chukchi Fish (WCF). The most important factor affecting habitat selection by juvenile demersal fish was sediment classification, with bottom salinity and bottom temperature having less influence. (Norcross, Holladay & Busby)
- Larval or juvenile fishes were captured at all ichthyoplankton stations and eggs were found at 8 of 18 stations. Three assemblages were produced from cluster analyses of ichthyoplankton abundances that were comparable to demersal assemblages except that the North and South Central Chukchi Fish were combined into one group. Water column temperature was the most important factor determining ichthyoplankton species composition, with salinity having much less influence. (Norcross, Holladay & Busby)

Climate Modeling

- A workshop on high-latitude reanalysis (synthesis of observational data by a mathematical model of the atmosphere) was held in April 2006 in Cambridge, UK. CIFAR PI David Bromwich was a workshop co-organizer; he, along with CIFAR PI John Walsh and their collaborator Mark Serreze, made presentations at the workshop and at the European Centre for Medium-Range Weather Forecasts. These presentations have been synthesized into a review of the high-latitude performance of global reanalyses, submitted to *Journal of Geophysical Research* (Bromwich et al., submitted). (Bromwich, Hines & Bai; Walsh & Fan)
- On the basis of evaluations and workshops, the decision has been made to employ the Weather Research and Forecasting (WRF) model in an Arctic System Reanalysis (ASR). Bromwich, Serreze and Walsh, in collaboration with National Center for Atmospheric Research (NCAR), have submitted a proposal to the National Science Foundation (May 2006) to carry out ASR with WRF, building on the results of Walsh's NOAA-supported pilot project. (Walsh & Fan)

- Full-year forecasts with MM5 (Mesoscale Model version 5) have been completed for a pan-Arctic domain, using a scheme for data assimilation (ingestion of observations) known as 3DVAR, which adjusts variables in three dimensions to fit model constraints as well as the observational values. The simulations have been performed with and without the assimilation of vertical temperature profiles from TOVS (TIROS Operational Vertical Sounder). The results show that the MM5 captures light-to-moderate precipitation events more skillfully than do the reanalyses performed using global models. The assimilation of the TOVS profiles results in small improvements of the MM5-derived precipitation. Results are described by Fan et al. (submitted). (Walsh & Fan)
- The implementation into WRF of high-latitude parameterizations (implicit treatment of process not formulated explicitly) used in Polar-MM5 has been initiated by Bromwich and colleagues at Ohio State. These parameterizations will be critical to capturing the variations of the polar boundary layer (the lowest several hundred meters), clouds, precipitation and fluxes of radiation in an Arctic System Reanalysis. (Bromwich, Hines & Bai)

Fisheries Oceanography

- Retrospective analysis of Bristol Bay juvenile sockeye salmon showed that their primary prey was Pacific sand lance during 2000–2001 and age-0 pollock during 2002–2005. The relative abundance of age-0 pollock increased each year from 2000–2003 as did the size of juvenile sockeye salmon during the same time period. (Adkison)
- Fecundity of Pacific cod is highly dependent on the length ($R^2 = 0.86$) and body weight ($R^2 = 0.89$) of the female cod. The relationship between female size and reproductive output (gonad weight) varies significantly among some regions and years. (Norcross)
- During the course of winter 2005 and early spring 2006, adult female Tanner crabs fitted with sonic transmitters (tags) within two major tagging areas in the East Arm of Glacier Bay concentrated at several locations of approximately 100 m depth. From the reproductive condition of female crabs captured in pots during each tracking trip, it was determined that the crabs were most highly aggregated before or during hatching. After concentrating at depths of 100 m, many tagged crabs made rapid movements to shallow (7–40 m depth) waters, some moving up to 2 km between tracking trips. The movement of crabs to shallow waters coincided with extrusion of a new clutch of eggs in captured crabs. Video footage of many female Tanner crabs in shallow (50 m) water, together with observations of Tanner crab appendages on the surface of the substrate, suggest that mating may be occurring in shallow waters. Following hatching and extrusion of new clutches, tagged crabs began to spread out and move to deeper waters. (Shirley)

Hydrographic and Sea Ice Studies

- During the 2005 NABOS/CABOS cruise, a new warm anomaly found in the Arctic Ocean demonstrating that over the last decade, the North Atlantic supply of warm water into the Arctic Ocean has increased. New pulses of anomalously warm water, including unprecedented warmth at some locations, are on the doorsteps of the Arctic Ocean. These anomalies promise to make the polar basin even warmer, with implications for decaying sea ice. (Polyakov, Dmitrenko & Ivanov)
- Ice at a mooring site in the northern Chukchi Sea reached 2.5-m average draft (about 2.9-m average thickness) in late winter 2004–05. This is about 1 m less than the value mapped by Bourke and Garrett based on submarine sonar data prior to 1985. (Melling)
- Concentration of dissolved CH_4 in estuaries of the great Siberian rivers are supersaturated, with CH_4 up to 200 times more than the atmosphere content. The lowest concentrations of CH_4 were found in the Ob River, which drains the region primarily covered by non-permafrost soils. Modest concentrations were found in the estuary of the Yenisey River, a watershed underlain primarily with discontinuous permafrost. The highest concentrations were found in the estuary of the Lena River, located primarily in the continuous permafrost zone. This west–east trend in CH_4 coincides with the increase in the wideness and the thickness of the permafrost zone in the Siberian region, and with an increase in organic matter freshness. (Semiletov & Shakhova)

Marine Ecosystem Studies

- The cold Arctic shelf ecosystem of the northern Bering Sea is giving way to more a pelagic-dominated subarctic ecosystem, which may have profound impacts on the Arctic marine mammal and diving seabird populations as well as commercial and subsistence fisheries. (Grebmeier)

- Archaeological and anthropological data show three major collapses of the Steller sea lion in the past 1000 years, AD 1200, AD 1870, and AD 1977, that are, in the first two cases the synergistic interactions of warming climates and human hunting pressure, and in the last case, the byproduct of changing climate regimes (oceanic warming), and a period of unprecedented population increase in the absence of traditional harvesting pressures. Aleut people have been harvesting the north Pacific ecosystem for over 10,000 years and the ecosystem cannot be understood without making reference to this relationship. (Maschner & Reedy-Maschner)

Tsunami Research

- The 3-D numerical model for the waves generated by underwater landslides was expanded to calculate inundation of dry land (runup) caused by the slide-generated tsunami waves. This model was applied to the major underwater slide in upper Resurrection Bay that was triggered by the 1964 earthquake and destroyed the Seward waterfront, and calculated runup caused by this slide. The runup caused by the local landslide tsunami will be combined with the runup from the major tectonic tsunami for inundation mapping. (Hansen, Suleimani & Combellick)
- Numerical modeling has been used to calculate the characteristics of a tsunami generated by a landslide into Cook Inlet from Augustine Volcano. Paleotsunami deposits were found at sites along the coast near Mt. Iliamna, Nanwelak, and Homer, consistent with numerical modeling results, indicating significant tsunami wave amplification occurs in these areas. The landslide generated waves of about 20 m high in the island proximity. The application of different numerical schemes to this case demonstrated importance of the nonlinear terms in the tsunami generation domain. (Hansen & Kowalik)

Student and Postdoctorate Support through Individual Awards

Many of the proposals funded through CIFAR involve graduate and undergraduate students. Sixteen students (13 graduate; 3 undergraduate) were supported in full or in part by the research projects covered in this report or by Task I funds (Appendix 2). In addition, many other students benefited from being involved in the research projects, e.g., through sample/data collection and data analysis, even though they did not receive direct salary support through CIFAR.

During summer 2006, CIFAR hosted a NOAA Hollings Scholar (Caroline Larsen, North Carolina State University), who worked with CIFAR, IARC and NWS scientists on a diagnosis of Pacific and Arctic storms associated with flooding and coastal erosion in Alaska.

Publications and Presentations

During the current reporting period, 30 peer-reviewed publications and 17 non-peer-reviewed publications (including three Ph.D. dissertations and one Master's thesis) were reported from projects receiving their funding through CIFAR under cooperative agreement NA17RJ1224. An additional 29 papers were reported as accepted or in press and 22 were described as submitted or in revision. Over 55 manuscripts were reported to be under preparation. Approximately 115 conference presentations (both national and international) and seminars were also reported.

In addition to these FY06 numbers, we received information on four peer-reviewed publications from earlier years that had not been reported previously (one from FY03, two from FY04 and one from FY05). The publication matrix in Appendix 3 reflects these additions.

Note: These numbers do not include presentations or publications from Arctic Research Initiative and Steller sea lion projects funded at NOAA laboratories, other federal agencies, or through other cooperative institutes.

See also Appendix 3.

Task I

Education / Outreach

University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement

Terrance J. Quinn II, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

This project is ongoing.

Primary objectives

This fellowship, funded by the Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service (NMFS), supports the training of M.S. and Ph.D. students in quantitative fisheries science, including population dynamics, management and stock assessment. This fellowship is open to M.S. and Ph.D. graduate students with solid quantitative ability and achievement. Generally, a student's research focus is related to the mandate of the AFSC, which includes marine and anadromous waters of the Alaska region. However, other interesting projects are considered. A committee of AFSC and School of Fisheries and Ocean Sciences (SFOS) quantitative scientists evaluates applications. Up to three fellowships per year can be awarded. Also, "gap" funding is available to support quantitative students without other financial support to help them complete their research programs.

Approach/methodology

Applications are made to the AFSC Scholarship Committee, Fisheries Division, School of Fisheries and Ocean Sciences, 11120 Glacier Highway, Juneau, AK 99801-8677, e-mail: fisheries@uaf.edu. The applicant is either a UAF professor or a student with sponsorship from a UAF professor. The applicant details research in a quantitative arena of fisheries science, such as mathematics, statistics, or modeling. Applications are evaluated as they are received; there is no formal date of application.

Research accomplishments/highlights/findings

- John Moran was hired as a Research Fishery Biologist, NOAA/NMFS, Auke Bay Laboratory, Alaska Fisheries Science Center, Juneau, AK
- Travel support was provided to quantitative fisheries students Haixue Shen, Sara Miller, Jason Gasper, Kray Van Kirk, and Peter-John Hulson to attend the national meeting of the American Fisheries Society.

NOAA relevance/payoff

This joint program between UAF and NOAA/NMFS/AFSC is designed to prepare young scientists for careers in fish stock assessment, a field that requires strong quantitative skills. The NMFS Stock Assessment Improvement Plan requires such scientists for its implementation, and the available pool of qualified applicants is shrinking. This project has already produced two Ph.D. level quantitative fisheries professionals, who were immediately hired by NOAA after graduation.

Describe research linkages/partnerships/collaborators and networking

The Alaska Fisheries Science Center continues to support this program; Anne Hollowed has provided an additional $25,000 in FY07 for future activities. Sara Miller worked with Jim Ianelli at the Alaska Fisheries Science Center in Seattle for one week in summer 2005.

Education/outreach

Graduate student support

The following eight UAF fisheries graduate students have been supported on fellowships under this award in previous years: Ben Williams (M.S.), Colin Schmitz (M.S.), John Moran (M.S.), Sara Miller (M.S.), Cindy Tribuzio (Ph.D.), Dana Hanselman (Ph.D.), Kalei Shotwell (Ph.D.) and William Bechtol (Ph.D.). Williams, Moran, Hanselman, and Shotwell have completed their graduate degrees; Bechtol, Miller and Tribuzio are currently pursuing their graduate degrees.

Josh Robins (M.S.) received tuition support during this year and is expected to defend in August 2006.

Five students received travel support for educational enhancement this year (see above).

Peter-John Hulson will receive a fellowship beginning September 2006.

K–12 outreach

Tribuzio, C. 2005. The green-eyed survivor: Dogfish shark life history and populations in the Gulf of Alaska. Oral presentation given at a community forum in Cordova, September 2005.

Tribuzio, C. 2006. Jaws in Alaska. Oral presentation given as part of "Yakutat Sea Week," May 2006. Presented to high school and elementary audiences (two versions).

Presentations

Bechtol, W. 2006. Historical harvest distribution for red king crab around Kodiak Island, Alaska. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2006.

Miller, S. 2006. Feasibility of estimating movement within a spatially-explicit stock assessment model of eastern Bering Sea walleye pollock. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2006.

Tribuzio, C.A. and G.H. Kruse. 2005. Are dogfish really everywhere? Progress report of an investigation into the dogfish populations in the Gulf of Alaska. Oral presentation at the 135th Annual Meeting of the American Fisheries Society, Anchorage, Alaska, September 2005.

Tribuzio, C. 2006. Progress report of an ecological investigation of spiny dogfish in the Gulf of Alaska. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2006.

Van Kirk, K., T. Quinn II and J. Collie. 2005. Preliminary results from a three-species model of the Gulf of Alaska. Poster presentation at the 135th Annual Meeting of the American Fisheries Society, Anchorage, Alaska, September 2005.

Publications

Non-peer-reviewed

Courtney, D., **C. Tribuzio**, S. Gaichas and K. Goldman. 2005. BSAI Sharks. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, Alaska.

In preparation or submitted

Hanselman, D.H. and T.J. Quinn. Are modern age-structured stock assessments reliable in the presence of large survey measurement errors? In revision.

Hulson, P.J., **S.E. Miller**, T.J. Quinn II, G.D. Marty, S.D. Moffitt and F. Funk. Incorporating hydroacoustic data into the Prince William Sound Pacific herring assessment model. In review.

Moran, J.R., M.D. Adkison and B.P. Kelly. Counting seals: estimating the unseen fraction using a photographic capture–recapture and covariate model. In preparation for submission to *Canadian Journal of Zoology*.

Williams, B.C., T.J. Quinn II and L.J. Haldorson. Influence of year and year-class effects on growth of juvenile yellowfin sole and northern rock sole in the eastern Bering Sea. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.

Williams, B.C., T.J. Quinn II and L.J. Haldorson. Relationships among biomass, recruitment, environmental variation, and growth of juvenile yellowfin sole and northern rock sole in the eastern Bering Sea. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.

Support for UAF–Hokkaido University Interdisciplinary Sea Ice Field Course

Hajo Eicken, Instructor
Rolf Gradinger, co-Instructor
University of Alaska Fairbanks

Other instructors:
***Kunio Shirasawa**, Hokkaido University*

NOAA Goal: Understand Climate Variability and Change

This project is complete.

Primary objectives

This instructional support provided travel assistance for UAF students participating in a course on "Field techniques in interdisciplinary sea-ice research" in Hokkaido, Japan in February of 2006. Drs. Kunio Shirasawa (Hokkaido University), Hajo Eicken and Rolf Gradinger (both University of Alaska Fairbanks) introduced the students to the principal field techniques employed in sea-ice studies of an interdisciplinary (geophysical-biogeochemical) nature. The course focused on sea ice as an instructive example of the close intertwining between ocean, ice and biosphere processes in the polar regions and the trans-disciplinary importance of the ice cover in the climate system. Four

students registered for the class at UAF and participated from the U.S. side, while the Japanese contingent included up to 4 students and a junior researcher.

Figure 1. Sea-ice sampling at Saroma Lagoon.

Approach/methodology

The long-term goal is to offer the class every 2 years, alternating between northern Hokkaido (near the southernmost limit of sea ice in the northern hemisphere) and northern Alaska. This was the second time this course was offered after a successful first offering of the class in Barrow, AK during spring 2004.

The three objectives of the class are: (1) provide students with an in-depth field-based introduction to modern, interdisciplinary sea-ice research methods and topics, (2) expose Japanese and U.S. graduate students to a collaborative, international research environment as part of small, international class teams, and (3) emphasize the importance of research in a broader societal setting.

Research accomplishments/highlights/findings

- The collection and analysis of the field samples were conducted at a field station in northern Hokkaido, near the southernmost limit of sea ice in the Northern hemisphere during 12–19 February 2006 (Figure 1).
- Students learned to measure and analyze a wide range of variables, ranging from ice thickness and light measurements (Figure 2) to the photophysiology and abundance of sea ice algae.
- After completion of the field work, the students from Hokkaido University and UAF participated in the 21st International Symposium on Okhotsk Sea & Sea Ice in Mombetsu, Hokkaido, Japan from 19–24 February 2006. The participating students gave well-received presentations on their interdisciplinary research projects conducted during the class in a special session at the Symposium that focused on the Russian, Japanese, and Korean activities in the Sea of Okhotsk, a major center of oil and gas development activity, providing an opportunity for students to place their acquired knowledge into a broader context.

Figure 2. Light measurements in the field.

NOAA relevance/societal benefits

The students' experience proved not only to be a broad and hands-on learning experience in sea-ice research, but also an opportunity to establish lasting professional relationships with international scientists. Understanding the state of the Okhotsk Sea and its coastal estuaries is important as these may serve as models of arctic relevance for environmental, economic, and geopolitical change driven by a warming climate.

Research linkages/partnerships/collaborators and networking

In addition to the educational perspective, this course strengthens the ties between UAF and Hokkaido University, building on the Memorandum of Understanding on Student Exchange between the University of Alaska Fairbanks and Hokkaido University of 2001.

Task II

Russian–American Long-term Census of the Arctic (RUSALCA)

Atmospheric Aerosols over the Bering and Chukchi Seas

Catherine F. Cahill, PI
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIFAR 10-066: This project is complete.

Primary objectives

This project aims to measure the concentrations and compositions of atmospheric aerosols above the Bering and Chukchi Seas during the Joint Russian–American Long-term Census of the Arctic (RUSALCA) cruise in summer 2004. The information collected during this cruise will assist scientists in understanding the sources, types and sizes of aerosols present over the Bering and Chukchi Seas during the Arctic summer. This information will help quantify the atmospheric deposition of specific trace metals and other elemental species to the seas and provide a measure of the influence of the aerosols on the radiative balance over the seas.

Approach/methodology

Average size-fractionated aerosol mass and trace elemental composition, including mercury concentrations, were determined for every 3 hours during the duration of the cruise. The samples were collected using a rotating drum cascade impactor and analyzed by β-gauge and Synchrotron X-Ray Fluorescence (S-XRF) techniques to determine aerosol mass and elemental composition. These techniques provided 3-hour average concentrations of mass and 42 elements from sodium through uranium, including particulate mercury, that are comparable with previous measurements made during summer 2003 in the Bering and Chukchi Seas on the Chinese research vessel, the *Xue Long*, and existing ground-based measurements in Alaska. These techniques have been used to successfully follow the international transport of specific elemental species from their source regions to the Arctic.

Research accomplishments/highlights/findings *(overall summary of project)*

Figure 1 shows a time series of selected elements in the 0.34 to 1.15 micron size fraction during the period of the RUSALCA cruise. The selected elements represent different aerosol types: sodium for sea salt, potassium for wildfire smoke, zinc for metal smelting, calcium for soil and sulfur for anthropogenic sources. Several periods of interest occur in the graph:

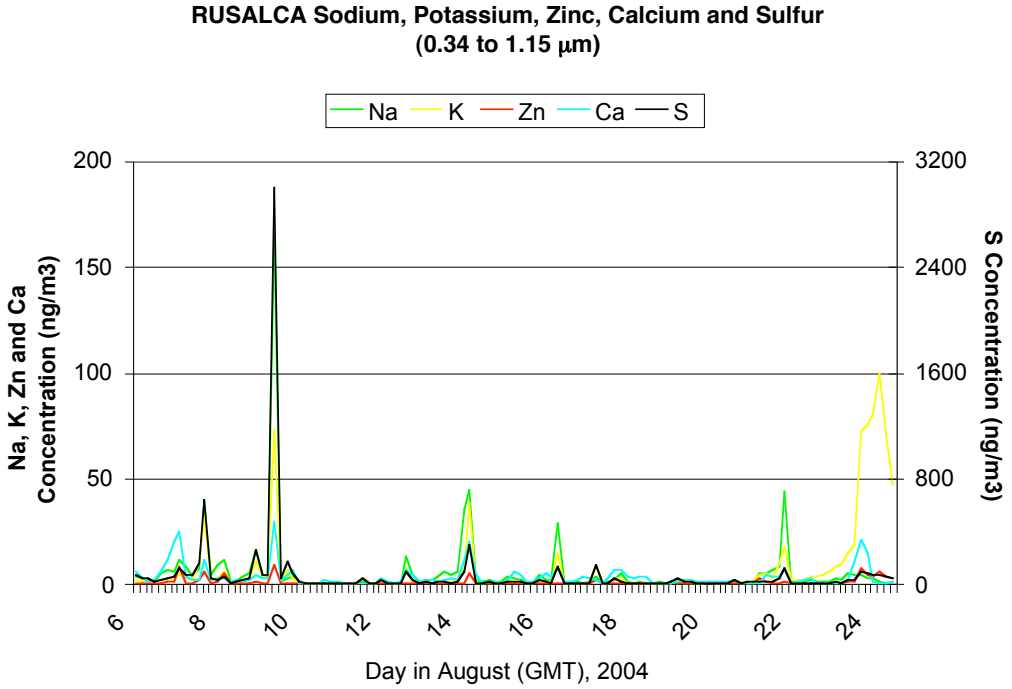

Figure 1. Time series for sodium, potassium, zinc, calcium and sulfur for the entire period of the RUSALCA cruise.

- The period prior to August 10th coincides with the ship being in port or near Nome so anthropogenic and ship exhaust emissions dominate the aerosol.
- The elevated potassium, a tracer of biomass burning, observed during the period from August 23rd through August 24th shows the impact of the Alaskan wildfires on the aerosol composition and concentration when the ship neared the coast of Alaska during an east-to-west wildfire smoke transport event.
- The elevated calcium on August 13th corresponds to either soils transported from southeastern Russia over the Sea of Okhotsk and Kamchatka or, potentially, volcanic ash from Sheveluch volcano in Kamchatka.
- Peaks in anthropogenic components on August 14th and 16th correspond to air coming from Russian industrial regions, such as Norilsk. This was confirmed using meteorological back-trajectories (NOAA Air Resources Laboratory HYSPLIT transport and dispersion model [http://www.arl.noaa.gov/ready/hysplit4.html]).
- Most of the cruise encountered clean, marine air characterized by low aerosol mass concentrations and sea salt.

Overall, the aerosols occurring over the Bering and Chukchi Seas come from a wide variety of local and distant sources, contain both pollutants and nutrients and will have an effect on the radiative balance over the seas.

NOAA relevance/societal benefits

The information collected during this cruise will assist scientists in understanding the sources, types and sizes of aerosols present over the Bering and Chukchi Seas during the Arctic summer. This information will help quantify the atmospheric deposition of specific trace metals and other elemental species to the seas (where they can be either pollutants or nutrients) and provide a measure of the influence of the aerosols on the radiative balance over the seas. The impact of the aerosols on the radiative balance could influence the effectiveness of atmospheric models for calculating climate changes.

Research linkages/partnerships/collaborators and networking

The measurements made during this research cruise are comparable to measurements made during summer 2003 in the Bering and Chukchi Seas on the Chinese research vessel, the *Xue Long*. A comparison of the two data sets, representing two different years in the same region, will be prepared for publication. The author list on this paper will include Chinese, Russian and American scientists. The RUSALCA data synthesis meeting in Kotor, Serbia and Montenegro, in October 2005, provided an excellent networking opportunity and has led to contacts with Vladimir Komchatov and Anton Syroeshkin of the Federal Service of Russia for Hydrometeorology and Environmental Monitoring, State Oceanographic Institute.

Education/outreach

The information gained during this project was presented to NSF REU (Research Experiences for Undergraduates) students from across the U.S. during a lecture on June 5, 2006 and used as an example of international transport in Chemistry 631 (Environmental Fate and Transport), a graduate environmental chemistry course at the University of Alaska Fairbanks.

Publications

A paper comparing the aerosol data sets collected on research vessels during RUSALCA and CHINARE II, which occurred in the same region during two consecutive years, is being prepared for the *Journal of Geophysical Research (Atmospheres)*.

Benthic Processes and Ecosystem Change in the Northern Bering and Chukchi Seas

Jackie M. Grebmeier, PI
Lee Cooper, co-PI
University of Tennessee, Knoxville

Boris Sirenko, co-PI
Sergey Gagaev, co-PI
Zoological Institute, St. Petersburg, Russia

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 10-067: This project is ongoing.

Primary objectives

Our participation in the 2004 U.S.–Russia cruise as the first activity under the Russian–American Long-term Census of the Arctic (RUSALCA) provided a strategic opportunity to continue previous studies in both U.S. and Russian waters, as well as link the RUSALCA program with currently funded work of the Shelf–Basin Interactions project and the Bering Strait Environmental Observatory, all of which will be critical to understanding the impacts of environmental change in the Arctic. Past studies in the region over multiple U.S.–Russian expeditions as part of the BERPAC program (Long-term Ecological Investigations of the Bering Sea and Other Pacific Ocean Ecosystems) allow a time-series comparison of the results from the RUSALCA cruise with these past data sets (1988 *Akademik Korolev*, 1993 *Okean*, and 1995 RV *Alpha Helix*) and allow determination of long-term observation sites for evaluation of climatic impacts on this sensitive northern ecosystem. The PIs on this project are Drs. Jackie Grebmeier and Lee Cooper from the University of Tennessee Knoxville (UTK), USA and Drs. Boris Sirenko and Sergey Gagaev from the Zoological Institute, St. Petersburg, Russia.

Approach/methodology

During the 2004 RUSALCA cruise quantitative sediment samples were collected at 14 stations using a 0.1 m^2 van Veen grab from a depth range of 53–73 m. Five replicate grabs were taken at each station for UTK. The first grab was used for surface sediment sampling of total organic carbon and nitrogen, sediment grain size, sediment chlorophyll *a* content, ^{13}C, and ^{7}Be. These surface sub-samples were collected and frozen for land-based analyses at the UTK laboratory. A sediment sub-sample was also collected for trace metal analysis at the University of Alaska Fairbanks, and another for the Zoological Institute, St. Petersburg for meiofaunal analysis. The remaining four van Veen grabs were sieved separately through a 1 mm stainless steel mesh screen, preserved in 10% buffered formalin, and analyzed at the University of Tennessee. Additional van Veen grabs (three for the Zoological Institute, and 1–2 additional for Russian geologists and microbiologists) were also collected. At three stations, only three van Veen samples for Boris Sirenko (Zoological Institute) were taken, and Ocean grabs were taken for the Zoological Institute at one station. Dredge samples were collected by the University of Alaska Fairbanks and the Zoological Institute at three stations in Bering Strait. In addition, water samples were collected for ^{18}O at sixty-six stations for land-based analyses at UTK.

Research accomplishments/highlights/findings

- Macrobenthic infaunal biomass in the southcentral Chukchi Sea stations ranged from 500–1400 g wet wt. m^{-2} (24–59 g C m^{-2}), exceeding 3000 g wet wt. m^{-2} (117 g C m^{-2}) in the hot spot region, which is extremely high on the global ocean scale.
- Benthic infaunal biomass in the northwest region of the RUSALCA study area shows a reduction in benthic biomass to 95–254 g wet wt. m^{-2} (6–7 g C m^{-2}). The northernmost transect line (Stns 58B, 62B, 73B, 85B, 106 and 107) in Herald Trough and its vicinity was dominated by polychaetes, brittle stars, and sipunculids, with a benthic biomass ranging from 113–588 g wet wt. m^{-2} (5–26 g C m^{-2}).
- The benthic infaunal biomass gradient, ranging from high to low values moving from the southern Chukchi Sea to the northwest, respectively, indicates a variable carbon load moving downstream from the productive southeast Chukchi shelf to the continental margin through Herald Trough.
- The majority of benthic sediment collected during RUSALCA was composed of silt and clay grain size fractions, although stations along the coast were dominated by coarse sediments (gravel and pebbles).
- Sediments collected during RUSALCA and the U.S. Shelf–Basin Interactions project in the Chukchi Sea in 2004 indicate deposition of total organic carbon (TOC) in the southern Chukchi and downstream in Herald Trough, which is associated with the finer silt and clay fraction indicative of reduced current regimes. These data also indicate a significant relationship between surface sediment TOC and silt and clay fraction in the sediments.
- Stable carbon isotope ratios in surface sediments in the Chukchi Sea are coupled with water column processes. Less negative $\delta^{13}C$ values in the surface sediments occur under the more productive regions of the Chukchi Sea and indicate a marine phytoplankton source for the carbon in these sediments.
- Plotting carbon isotope composition of sediment organic matter against C/N ratios in the same sediments from the RUSALCA cruise shows that less refractory, unprocessed organic carbon is more prevalent on the Russian side of the Chukchi Sea, reflecting ungrazed organic carbon produced in nutrient-rich waters that is quickly deposited to the benthos.

NOAA relevance/societal benefits

Monitoring and assessing the current status and potential change in the Bering Strait region and into the Chukchi Sea ecosystem in response to climate change is directly relevant to the goals of the NOAA-supported SEARCH: Study of Environmental Arctic Change multi-agency global change project and similar efforts of the NOAA Arctic Research Office. In addition, RUSALCA is part of the Census of Marine Life project and the benthic faunal collections from the RUSALCA cruise are important samples for this world-wide effort.

Research linkages/partnerships/collaborators and networking

Collaboration with the other U.S. participants in the RUSALCA group, specifically Drs. Bodil Bluhm and Katrin Iken for benthic epifaunal data, has been valuable. This project is also a collaborative effort with Drs. Boris Sirenko and Sergey Gagaev at the Zoological Institute in St. Petersburg, Russia. The ecosystem direction of this project suggests potential coauthored synthesis papers. This joint project is directly related to the SEARCH project to investigate potential impacts of climate change on the marine ecosystem and goals of the international Pacific Arctic Group (PAG).

Education/outreach

Student participation

- Adam Humphrey, an undergraduate student, completed a B.S. in May 2006 (*not in 2005 as was reported last year)* in Ecology and Evolutionary Biology. He assisted in infaunal sorting and general laboratory operations related to this project.
- Rebecca Pirtle-Levy completed an M.S. degree in Ecology and Evolutionary Biology in May 2006 and was responsible for processing sediments for total organic carbon content and sediment grain size.

K–12 outreach

- PIs Grebmeier and Cooper presented scientific results for 5th grade students at St. John Neumann School in Farragut, Tennessee, in April 2006.

Poster presentation

Grebmeier, J.M., R. Pirtle-Levy, R. Brown and L.W. Cooper. 2006. Benthic community structure, carbon cycling and shelf–basin exchange on the Arctic margins of the Chukchi and Beaufort Seas. Joint AGU/ASLO/TOS Oceans Meeting, Honolulu, Hawaii, February 2006.

Publications

Peer-reviewed

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. *Science*, 311:1461–1464.

In press or in preparation

Grebmeier, J.M. and J.P. Barry. 2006. Benthic processes in polynyas. In: W.O. Smith and D. Barber, Eds., Polynyas: Windows into Polar Oceans, Elsevier Oceanography Series, in press.

Grebmeier, J.M., L.W. Cooper, H.M. Feder and B.I. Sirenko. 2006. Pelagic–benthic coupling and ecosystem dynamics of the Pacific-influenced western Amerasian Arctic. Submitted to *Progress in Oceanography*.

A Census of Arctic Zooplankton Communities

Russell R. Hopcroft, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Ksenia Kosobokova, *Russian Academy of Sciences, Moscow*

CIFAR 10-068: This project is complete.

Primary objectives

Establish critical baseline information on the abundance, biomass, and composition of the zooplankton from the Bering Strait northward throughout the Chukchi Sea, because we expect the Arctic to be more sensitive to ongoing and future climate shifts than elsewhere on the globe. Determine the rate of secondary production for dominant zooplankton species (i.e., copepods).

Approach/methodology

Zooplankton were collected by a package of 4 plankton nets, consisting of two 150-µm and two 53-µm mesh nets equipped with flow meters at 32 stations. Formalin-preserved samples are being processed for composition and biomass. Ethanol samples are being scanned for representatives of the species present in each of the major water masses, and sent to the ZooGene program for determination of the Cytochrome Oxidase I sequence.

At 20 stations, additional nets were employed to collect live zooplankton for digital images of all common species. The productivity of the dominant copepod species was examined by means of egg production rates. During the cruise only *Pseudocalanus* spp. appeared in sufficient numbers for egg production experiments, and depending on abundance, 40–120 individuals were incubated in 70-ml flasks for 48 hours. Rates of egg production have been compared across the sampling region with respect to temperature, the local productivity, and the water mass types in which they occur.

Research accomplishments/highlights/findings *(overall summary of project)*

- Clear and persistent patterns in species composition of *Pseudocalanus* exist in the study area tied to the different water masses, but there was no obvious pattern in weight-specific egg production despite strong chlorophyll gradients associated with these water masses.
- Future increased penetration of Pacific water will lead to increased penetration of *Pseudocalanus newmani*, BUT all other things being equal, secondary production may not change significantly other than that expected from temperature-dependent rate increases alone.
- Biomass of the larvacean community was comparable to the copepods at many stations, and their production at times is estimated to have exceeded that of the copepods.

NOAA relevance/societal benefits

We have established critical baseline information on the abundance, biomass, and composition and production of the zooplankton in an area sensitive to climate-related shifts, such that future changes can be monitored.

Research linkages/partnerships/collaborators and networking

This research has begun a continuing collaborative effort between Hopcroft and Kosobokova.
The RUSALCA program figures prominently in a report to the North Pacific Research Board, "Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research."

Education/outreach

Student participation

Two graduate students have been partially funded by this CIFAR project: Alexei Pinchuk, Ph.D. candidate, Biological Oceanography, expected to graduate Fall 2006; Amanda Byrd, M.S. candidate, Marine Biology, expected to graduate Spring 2007. An undergraduate student, Raymund Hawley, worked on making images from the cruise available through the ArcOD website.

Presentations/public awareness

An overview of Arctic Ocean ecosystems. Presented at Marine Mammal Commission meeting, Anchorage, Alaska, 14 October 2005.

Chukchi Sea zooplankton community patterns. Presented at RUSALCA Joint U.S.–Russian Arctic workshop, Kotar, Montenegro, 26 October 2005.

The consequences of climate change on Alaskan marine life. Presented at the Alaska Forum, Anchorage, Alaska, 6 February 2006.

RUSALCA: Zooplankton. Presented at special session, Arctic Science Summit Week, Potsdam, Germany, 28 March 2006.

A Web site with images of zooplankton species can be found at
http://www.sfos.uaf.edu/research/arcdiv/watercolumn/index.html

Publications

In preparation

Hopcroft, R.R. and K.N. Kosobokova. Production of *Pseudocalanus* species in the Chukchi Sea.

Hopcroft, R.R., K.N. Kosobokova and A.I. Pinchuk. Patterns of zooplankton distribution in the Chukchi Sea.

Arctic Epibenthic Community Structure and Benthic Food Web Structure

Katrin Iken, PI
Bodil Bluhm, co-PI
University of Alaska Fairbanks
Kenneth Dunton, co-PI
University of Texas at Austin

NOAA Goal: Understand Climate Variability and Change

CIFAR 10-069: This project is ongoing. Field work as well as most of sample processing was completed during the previous reporting period. Data analysis and preparation of manuscripts are ongoing and in progress.

Primary objectives

The main objective of the project is to analyze epibenthic community structure in the Chukchi Sea to create a baseline of species composition, abundance and biomass. Epibenthic organisms are good long-term indicators of changes in oceanographic conditions, which may be caused by global climate change. Secondly, we focused on the food web structure of the benthic community and their connection to water column primary production. Benthic food web structure and distribution of feeding types are likely to change with shifts in water column processes due to global climate change.

Approach/methodology

Epibenthic communities were sampled at 17 stations using a beam trawl, otter trawl or dredge. Invertebrate species from these trawls were sorted into species or higher taxonomic groups, weighed and individuals were counted. Abundance and biomass were normalized to the trawled area as catch per unit effort (CPUE). Vouchers were preserved in 4% formalin–seawater solution buffered with hexamethylenetetramine. Size–weight frequency distributions have been measured for dominant members of the epibenthic communities. Community analysis is performed using PRIMER software.

Benthic epifaunal and infaunal organisms as well as water column particulate organic matter (POM) and pelagic invertebrates were collected for stable isotope analysis. A total of 62 water samples, 40 surface sediment samples, 143 plankton samples and 2165 tissue samples of infaunal and epibenthic organisms were taken for stable isotope analysis at 15 stations. Tissue pieces were collected and dried on board the vessel and then prepared and measured for stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) at the UAF Stable Isotope Facility.

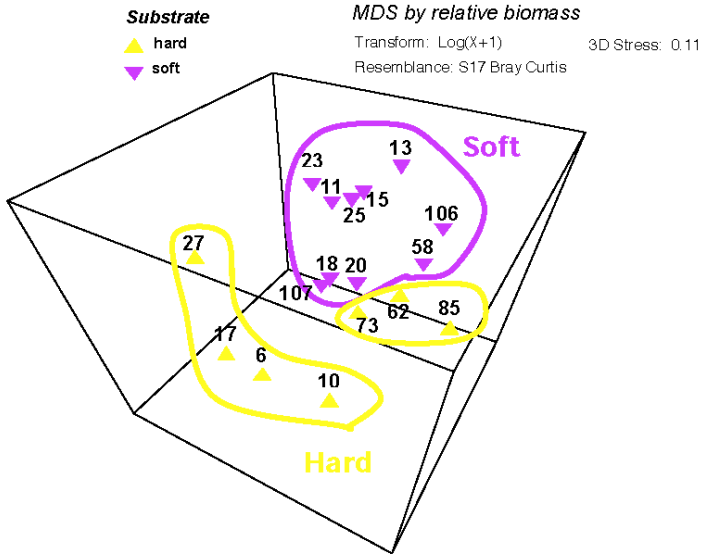

Figure 1. MDS plot of epibenthos by station based on relative biomass. Hard bottom and soft bottom fauna, respectively, cluster together. Some hard bottom Herald Canyon stations cluster with soft bottom group (62–85).

Research accomplishments/highlights/findings

- Approximately 180 epibenthic invertebrate species were collected, representing very different community structures. Indices of community structure are summarized as follows:
  - Species richness: 18–53 species per station, with mollusks and crustaceans being the dominant groups overall

    - Abundance: 800–40,000 individuals 1000 m^{-2}
    - Gross biomass: 1.6–69 kg wet weight 1000 m^{-2}
- Highest species richness was found at sites with hard bottom (clustered in multivariate analysis), hence substrate type appears to be a driving force for overall species richness (Figure 1).
- Range extensions into the Arctic were seen for some crab and mollusk species (e.g., the crab *Telmessus cheiragonus*).
- POM isotopic values in benthic communities differed along an east–west gradient, with the same species feeding on higher trophic levels in the east compared to the west (Figure 2). We suggest that this indicates a stronger pelagic link in the food web in eastern areas (Alaska Coastal Water, ACW) where pelagic primary production is limited. In western areas (Anadyr Water, AW) the higher primary production results in a significant amount of fresh phytodetritus reaching the seafloor and feeding benthic communities directly.

NOAA relevance/societal benefits

This project assisted in NOAA's goal to create baseline data of ecosystem components that are valuable indicators of climate change effects. Benthic communities integrate processes over long time periods rendering them suitable long-term indicators of changes related to climatic effects on oceanographic conditions. Food web structure is highly influenced by water mass characteristics and thus a good indicator of oceanographic conditions that may be impacted by climate change.

Research linkages/partnerships/collaborators and networking

All objectives were strongly based on conceptual and logistical cooperation with other projects within and outside RUSALCA and with other programs. The PIs are also involved in other large-scale Arctic programs, such as the NSF-funded SBI Program (Western Arctic Shelf–Basin Interactions), NOAA Ocean Exploration's Hidden Ocean projects and the Census of Marine Life's Arctic Ocean Diversity project, as well as in cooperation with Russian colleagues. Their network allows them to interpret the data in a broader context.

Education/outreach

Public awareness

- Presentation of results at an Institute of Marine Science seminar at UAF in November 2005.

Presentations

Poster presentations

- Oral presentation of benthic community composition and food web structure data during RUSALCA project meeting in Montenegro (October 2005), extended abstracts to be published
- Bluhm, B.A., K. Iken, K.H. Dunton, B. Sirenko and S. Gagaev. 2006. Chukchi Sea food web structure and epibenthic community composition. 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.
- Dunton, K., S.V. Schonberg, B.A. Bluhm, K. Iken and L. Cooper. 2006. Trophic structure on the Western Arctic shelf: a new paradigm for benthic–pelagic coupling and ultimate carbon sources? 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.
- Sirenko, B., B.A. Bluhm and K. Iken. 2006. New evidence of invertebrate invasion in the Chukchi Sea from the Northern Pacific. 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.

Oral presentations

- Bluhm, B.A., K. Iken, K.H. Dunton, B. Sirenko and S. Gagaev. 2006. Chukchi Sea food web structure and epibenthic community composition. Alaska Marine Science Symposium, Anchorage, Alaska, 23–26 January 2006.

Publications

A minimum of two publications are expected from this project. They are in preparation. Data analyses for both publications are nearly complete and writing of the manuscripts is anticipated this fall:

Bluhm, B., K. Iken, B. Sirenko, S. Gagaev, B. Holladay and B. Norcross. Chukchi Sea epibenthic community composition in relation to oceanographic conditions. In preparation.

Iken, K., B. Bluhm, B. Sirenko, S. Gagaev and K. Dunton. Chukchi Sea food web structure in relation to oceanographic conditions. In preparation.

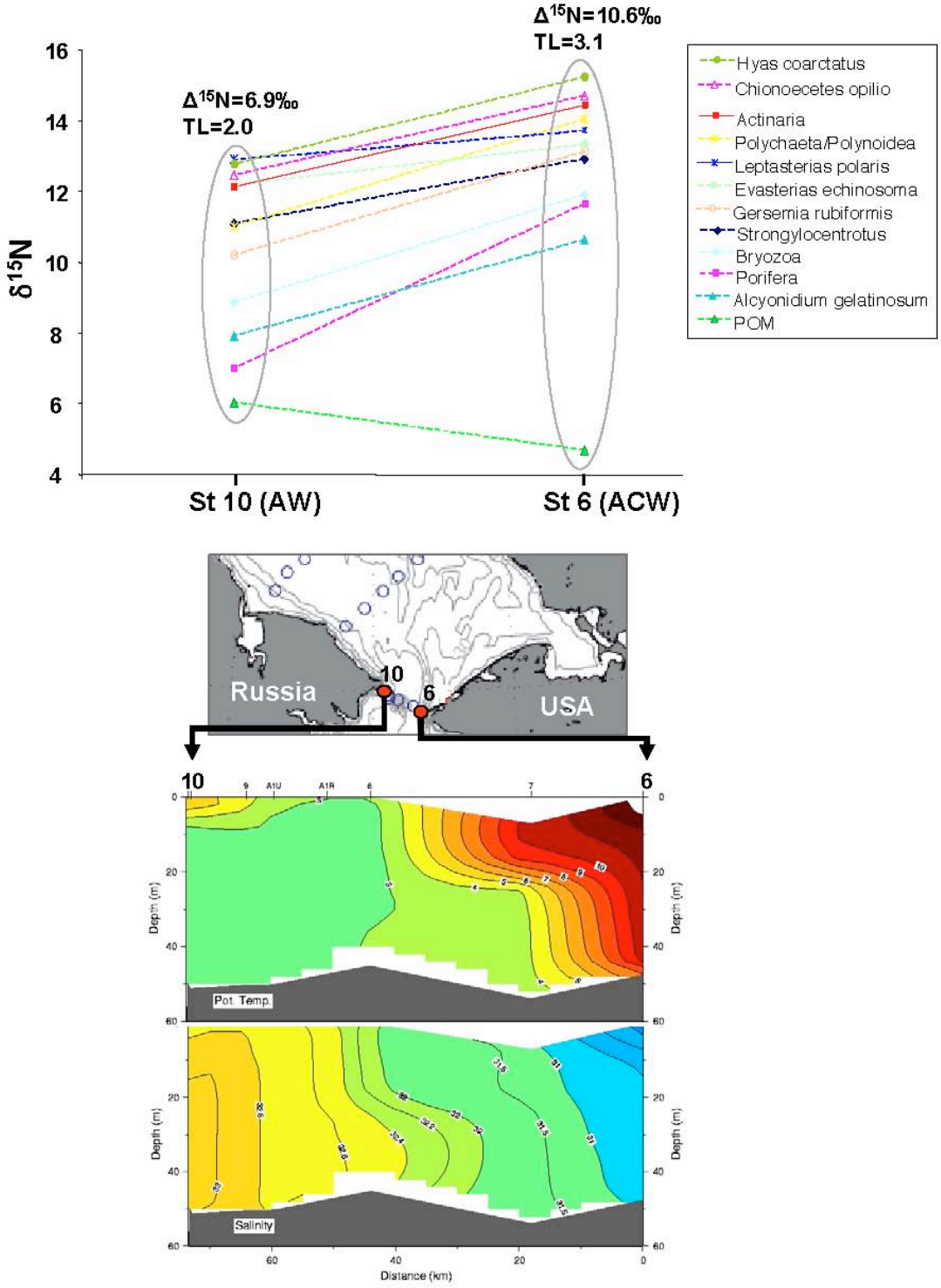

Figure 2. Food web structure of benthic community with respect to POM source as measured by stable isotope analysis. Consumers of the same species show larger difference in isotopic values ($\Delta^{15}N$) with respect to their POM food source under ACW influence (St. 6) than under AW influence (St. 10). Similarly, food web length (trophic levels, TL) is longer under ACW than under AW when the same organisms are considered. Lower panels show temperature and salinity across the Bering Strait transect, indicating warmer temperature and lower salinity for ACW St. 6. Reference values corresponding to colors for temperature and salinity are given within upper and lower panel, respectively.

Fisheries Ecology of the Bering and Chukchi Seas

Brenda L. Norcross, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
***Brenda A. Holladay**, University of Alaska Fairbanks*
***Morgan Busby**, NOAA/NMFS/AFSC*

CIFAR 10-070: This project is complete.

Primary objectives

Our overall goal is to document the fish species in the study area to provide a baseline from which to measure future changes.

(1) Collect larval and juvenile fishes in specific water masses to estimate relative fish abundance and distribution.
(2) Relate ichthyoplankton assemblages (species composition) to oceanographic features (water masses).
(3) Determine the physical characteristics that define juvenile groundfish communities and habitat.
(4) Compare ichthyoplankton, juvenile fish and adult fish distributions and communities among oceanographic domains.

Objective 4 has changed to only compare ichthyoplankton and juvenile fish because adult fish distributions are to be included in a product by David Stein et al.

Approach/methodology

Our focus is the effect of physical and lower trophic level perturbations on fishes. To this end, we collected ichthyoplankton using a 60-cm Bongo net and juvenile groundfishes using a 3-m plumb staff beam trawl. Estimates of species abundance have been developed from these collections and were evaluated with respect to the physical and biological data collected by other researchers.

Research accomplishments/highlights/findings (overall summary of project)

- Ichthyoplankton and juvenile demersal fishes were collected at approximately 18 sites in conjunction with CTD (conductivity, temperature, depth) data. Ichthyoplankton samples contained 23 taxa representing eight families; they were dominated by Arctic cod *Boreogadus saida*, yellowfin sole *Limanda aspera*, and Bering flounder *Hippoglossoides robustus*. Juvenile demersal fish collections were composed of 32 taxa in nine families. Catches were dominated by Arctic staghorn sculpin *Gymnocanthus tricuspis*, shorthorn sculpin *Myoxocephalus scorpius*, and hamecon *Artediellus scaber*.
- Cluster analyses from all stations at which a CTD was taken identified five bottom water masses in the Chukchi Sea (Figure 1). We used results of the cluster analyses and the vertical sections of temperature and salinity at each transect obtained from Bob Pickart to interpret water mass composition. Our water mass determination was confirmed with Bob Pickart (pers. comm.) and agreed in part with Weingartner (1997). The Alaska Coastal Water (ACW), Bering Shelf Water (BSW) and Anadyr Water (AW) flowed northward from Bering Strait. The ACW, which originates in the Gulf of Alaska, passed through the Bering Sea and into the Chukchi Sea, was clearly isolated from the rest of the Chukchi Sea (Figure 1) by a well-defined front ~50 km from the coast that extends northward from Bering Strait to the Lisburne Peninsula (Weingartner 1997). BSW originates on the eastern Bering Shelf and can be seen as a distinct water mass northward into the Chukchi Sea. AW is colder and fresher and originates in the western Bering Sea in the Gulf of Anadyr and moves northward through the western side of the Bering Strait. The Resident Chukchi Water (RCW) is derived from the upper layers of the Arctic Ocean or shelf water left from the previous winter (Weingartner 1997) and is found offshore in the northern Chukchi Sea. Another water mass that we called the Siberian Sea Polynya Water (SSPW) was most likely derived from waters to the west that were being transported into the Chukchi from south of Wrangell Island (Pickart, pers. comm.) The Siberian Coastal Current (SCC), which was expected to flow southeastward along the coast of Russia (Weingartner 1997, Weingartner et al. 1999), was not detected in 2004. Station 27, which may or may not be the SCC, had anomalous results that did not cluster with any other station and was not included in water mass analysis.

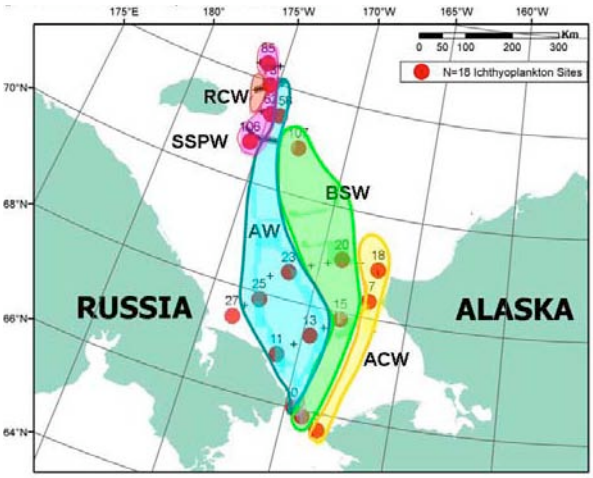

Figure 1. Bottom depth water masses.

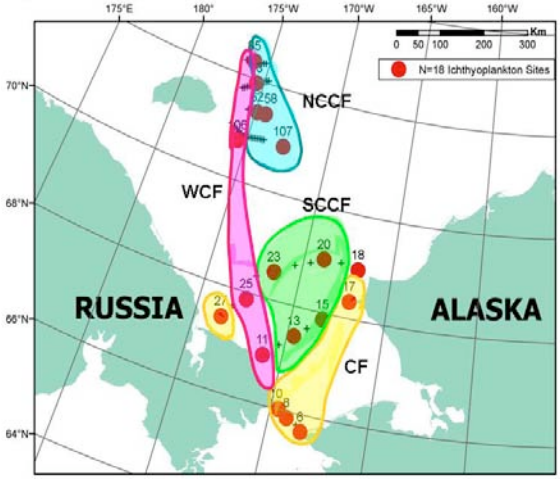

Figure 2. Groups of bottom fishes

- Small demersal fishes consisting of 1310 individuals were classified into assemblages using cluster analysis of species present or absent. Four clusters of small bottom fishes from 17 stations (Figure 2) had spatial distributions comparable to those of the water masses: Coastal Fish (CF), South Central Chukchi Fish (SCCF), North Central Chukchi Fish (NCCF), and Western Chukchi Fish (WCF). An Analysis of Similarity (ANOSIM, Primer) calculated based on presence/absence indicated significant differences in species composition in the assemblages found in ACW and BSW ($p=0.036$). Subsequent Similarity Percentages (SIMPER, Primer) analysis found that contribution to observed differences was similar among all species. A significant difference was also found between species assemblages in ACW and SSPW ($p=0.029$). However, as with ACW and BSW, contribution to observed differences was very similar among all species. There were no significant differences between other water masses. According to Biota and/or Environmental Matching (BIOENV, Primer), which is similar to multivariate analysis, the most important factor affecting habitat selection by juvenile demersal fish was sediment classification ($R_s = 0.54$), with bottom salinity ($R_s = 0.38$) and bottom temperature having less influence ($R_s = 0.37$).

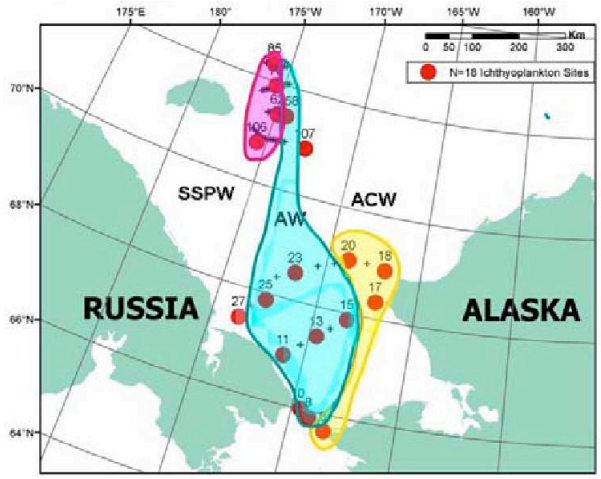

Figure 3. Integrated bongo depth water masses.

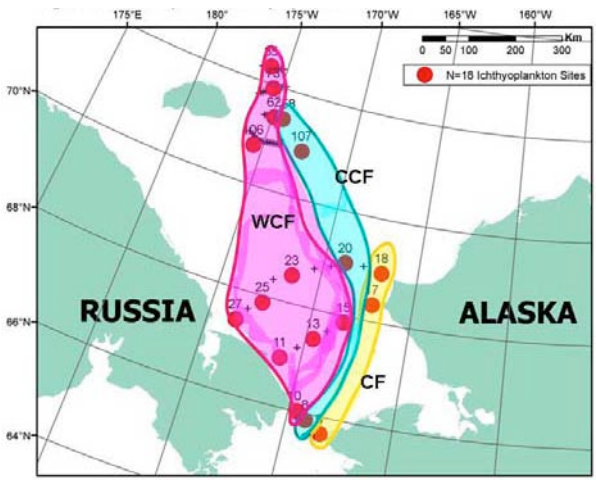

Figure 4. Groups of ichthyoplankton.

- Larval or juvenile fishes were successfully captured at all ichthyoplankton stations, and eggs were found at eight of the 18 stations. A total of 111 eggs and 498 larval fishes were collected in bongo tows. Oblique towing of bongos provide depth-integrated information, i.e., ichthyoplankton are likely derived from more than one water mass. We clustered depth-integrated temperature and salinity to derive three water masses analogous to those found in bottom waters (Figure 3). Three assemblages were produced from cluster analyses of ichthyoplankton abundance (Figure 4). These are comparable to the bottom assemblages (CF, WCF), except the Central Chukchi Fish (CCF) are combined into one group. An ANOSIM indicated significant differences in species composition in the assemblages found in ACW and AW ($p=0.008$). SIMPER analysis determined that

Limanda aspera, Liparis gibbus, Boreogadus saida, and *Liparis spp.* accounted for over 58% of the observed difference. A significant difference was also found between species assemblages in ACW and SSPW (p=0.029). Again, SIMPER analysis showed that *Boreogadus saida, Limanda aspera*, and *Liparis gibbus* account for over 55% of the observed difference. There was no difference between assemblages in AW and SSPW. Water column temperature contributed the most (R_s = 0.42) to determining ichthyoplankton species composition (BIOENV, Primer). Salinity contributed only a small amount (R_s = 0.26).

NOAA relevance/societal benefits

This study identified physical mechanisms that affect fisheries species composition and distribution in the northern Bering and Chukchi Seas. This directly supports the RUSALCA objective of providing a method to identify ecosystem change. Physical characteristics can be measured and analyzed more quickly than fish can be collected and processed; yet, a well-integrated combination of physical and biological studies yields a more meaningful synthesis of the ecosystem. Indications of changes in the physical oceanography that could occur with climate change, e.g., movement or removal of frontal systems or changes in water masses characteristics, may indicate effects on the broader ecosystem. Knowledge of the baseline relationship among fishes and water masses provides the background to monitor changes in the northern Bering and Chukchi Sea ecosystem.

Research linkages/partnerships/collaborators and networking

This project provided fish and invertebrate tissues for other RUSALCA projects: Iken, Hopcroft, and Stein. Water/fish samples were provided for non-RUSALCA research for trace elements (Nate Bickford, UAF/SFOS), and for fatty acid (Alan Springer, UAF/SFOS). The NOAA/NMFS/AFSC laboratory in Seattle received voucher specimens of juvenile fishes and fish larvae and eggs.

Ichthyoplankton identification and some statistical analysis, to be reported in the manuscript by Norcross et al., were performed in the NOAA/NMFS/AFSC laboratory.

Education/outreach

Presentation

Norcross, B.L., B.A. Holladay, M. Busby and K. Mier. 2005. Oceanography, ichthyoplankton, and bottom fishes of Bering Strait and Chukchi Sea. RUSALCA investigators meeting, Kotor, Montenegro, October 2005.

Publications

In preparation

Manuscript in preparation to analyze ichthyoplankton and juvenile fish assemblages and abundance in relation to oceanography of the Bering and Chukchi Seas. The primary author is Brenda Norcross, and additional authors include Brenda Holladay, Morgan Busby and Kathryn Mier.

Manuscript in preparation to describe juvenile and adult fish taxonomy and occurrence. The primary author is Catherine Mecklenburg, and additional authors include Brenda Norcross, Brenda Holladay, Morgan Busby, David Stein, Natalia Chernova, and Boris Sheiko.

References

Weingartner, T.J. 1997. A review of the physical oceanography of the northeastern Chukchi Sea. Pp. 40–59 in: J. Reynolds, Ed., Fish Ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, Maryland.

Weingartner, T.J., S. Danielson, Y. Sasaki, V. Pavlov and M. Kulakov. 1999. The Siberian Coastal Current: A wind- and buoyancy-forced Arctic coastal current. *Journal of Geophysical Research*, 104(C12):29,697–29,713.

Bering Strait: The Pacific–Arctic Ocean Connection

Thomas Weingartner, PI
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIFAR 10-071: This project is complete. A related project, 26-082, is ongoing (see report under the *Hydrographic and Sea Ice Studies* theme).

Primary objectives

Deploy a current meter mooring in the western channel (Russian EEZ) of Bering Strait.

Approach/methodology
Deploy 1 current meter mooring (with 1 current meter and 1 SeaCat temperature/conductivity recorder).

Research accomplishments/highlights/findings
- Mooring that was deployed in 8/2004 was recovered 8/20/2005.

NOAA relevance/societal benefits
Bering Strait is the sole connection between the Pacific and Arctic oceans. As such it provides an efficient environmental monitoring location able to detect integrated changes in the Bering Sea ecosystem. The flux of nutrients, salinity, and heat from the Bering to the Arctic Ocean has important influences on this ecosystem and on climate.

Research linkages/partnerships/collaborators and networking
This project is part of NOAA's RUSALCA program—a multi-investigator, interdisciplinary program to conduct marine research in Bering Strait and the Chukchi Sea. The RUSALCA program afforded the first opportunity since the early 1990s for U.S. scientists to work in the Chukchi Sea.

The work conducted in the western channel is being performed in collaboration with Rebecca Woodgate of the University of Washington. She is making complementary measurements in the U.S. EEZ under support from NSF and the Alaska Ocean Observing System.

Education/outreach
Presentation

Weingartner, T., R. Woodgate and K. Aagaard. Bering Strait: The Pacific–Arctic connection. Oral presentation given at the RUSALCA Meeting, Montenegro, November 2005.

Publications
In press

Aagaard, K., T.J. Weingartner, S.L. Danielson, R.A. Woodgate, G.C. Johnson and T.E. Whitledge. What controls flow and salinity in Bering Strait? *Geophysical Research Letters*, in press.

Woodgate, R.A., K. Aagaard and T.J. Weingartner. Changes in the Bering Strait fluxes of volume, heat and freshwater between 1991 and 2004. *Geophysical Research Letters*, in press.

Interactions of Productivity and Nutrient Processes in the Northern Bering and Chukchi Seas

Terry Whitledge, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 10-072: This project is ongoing.

Primary objectives
The goal of this research is to collect nutrient, carbon/nitrogen productivity data to assess the nutrient uptake and growth of major phytoplankton populations in the northern Bering and Chukchi Seas in relation to ambient light fields. A series of hydrographic transects were collected to allow sampling of all water masses during this late summer period. A high priority of the hydrographic survey was to collect samples across Bering Strait in support of the physical biochemical mooring(s) in western Bering Strait. The long-term goal is to obtain continuous and comprehensive monitoring within Bering Strait for several years which would require routine access to the eastern and western portions of the study area for scientific operations. The hydrographic, biochemical and productivity data from this project is being combined with other U.S. and Russian collaborators for the joint assessment of nutrient/productivity processes.

Approach/methodology
Nutrient (nitrate, nitrite, phosphate, silicate and ammonium) and phytoplankton pigment analyses were determined in all CTD/rosette samples collected on the cruise. University of Alaska Fairbanks (UAF) AutoAnalyzer equipment was placed on the ship for analysis of samples without freezing. All productivity measurement equipment and

fluorometer(s) were supplied by UAF. Daily primary production rate measurements were made by the $^{13}C/^{15}N$ isotope dual enrichment techniques (Bury et al. 1995). Primary production estimates were made daily at mid-day at six light depths. All transect lines had productivity stations in representative locations as time permitted. Water samples, inoculated with 20 µm ^{13}C-labeled Na_2CO_3 or 10% additions of ^{15}N-NO_3 or ^{15}N-NH_4 were incubated in 1-liter polycarbonate bottles under natural light on-deck. After incubation, light and dark samples were filtered and stored for isotope ratio analysis by mass spectrometry.

Research accomplishments/highlights/findings

- The combined U.S.–Russia mooring program recovered one mooring in western Bering Strait which had been in place for one year. The mooring contained good data for currents, temperature, salinity and fluorescence. The Russian mooring was not recovered and after searching and dragging, it was determined to be lost.
- Nutrient distributions in the RUSALCA study area show strong west-to-east gradients of decreasing nutrients. Extremely low nutrient concentrations were observed in the Alaska Coastal Water and much higher levels in Bering Strait Water and Anadyr Water.
- The nutrient concentrations decreased progressively from Bering Strait northward.
- Chlorophyll concentrations increased rapidly north of Bering Strait, and the Herald Canyon transects exhibited high subsurface chlorophyll concentrations.
- Primary production rates were maximal north of Bering Strait in the central Chukchi Sea. Primary production rates decline northward of the central area probably as the result of limited nutrient concentrations in surface waters.

NOAA relevance/societal benefits

The objectives of this project are central to the SEARCH program goals. Our proposal represents a step toward implementation of a long-term observation program in the Bering/Chukchi Seas. Thus, this project will directly contribute to the NOAA goals of detecting and monitoring arctic environmental changes, especially those related to climate change.

Education/outreach

Student participation

Sang Heon Lee was partially supported as a graduate research assistant in Chemical Oceanography during his Ph.D. studies by this project at an estimated 15% during this reporting period. Dr. Lee completed his Ph.D. studies at the end of Fall semester 2005.

A PI meeting was attended in Montenegro to organize additional data analysis and to plan for possible International Polar Year (IPY) cruise(s).

Presentations

Jin, M., C. Dean, J. Wang, K. Shin, N. Tanaka, T. Whitledge, S. Lee and R.R. Gradinger. 2006. Observations and modeling of the ice ecosystem off the Barrow coast. Presented at AGU-ASLO-TOS 2006 Ocean Sciences Meeting, Honolulu, 19–24 February 2006.

Lee, S.H. and T.E. Whitledge. 2006. Ecological significance of ice algae and phytoplankton under decreasing ice thickness and ice extent in the nearshore Arctic Ocean. Presented at AGU-ASLO-TOS 2006 Ocean Sciences Meeting, Honolulu, 19–24 February 2006.

Whitledge, T.E., S.H. Lee, T. Weingartner, R. Woodgate, R. Pickart and R. Benner. 2006. Russian–American Long Term Census of the Arctic (RUSALCA): Preliminary mooring results and hydrographic-nutrient relationships in the western Chukchi Sea. Presented at AGU-ASLO-TOS 2006 Ocean Sciences Meeting, Honolulu, 19–24 February 2006.

Lee, S.H. and T.E. Whitledge. 2006. Ecological significance of ice algae and phytoplankton primary production under decreasing ice thickness and extent in the Arctic Ocean. Presented at From Molecules to Ecosystem in Polar Science: Toward IPY 2007–2008, the 13th International Symposium on Polar Sciences, Incheon, Korea, 9–12 May 2006.

Lee, S.H. and T.E. Whitledge. 2006. Current primary production rate of phytoplankton in Bering Strait and the Chukchi Sea. Presented at From Molecules to Ecosystem in Polar Science: Toward IPY 2007–2008, the 13th International Symposium on Polar Sciences, Incheon, Korea, 9–12 May 2006.

Saitoh, S., T. Hirawake, A. Matsuoka, Y. Sakurai, K. Kuma and T.E. Whitledge. 2006. Collaborative research cruises in the Arctic Sea and subarctic marginal seas for IPY cooperation. Presented at From Molecules to

Ecosystem in Polar Science: Toward IPY 2007–2008, the 13th International Symposium on Polar Sciences, Incheon, Korea, 9–12 May 2006.

Deal, C.J., M. Jin, J. Wang, T.E. Whitledge and S. Lee. 2006. Environmental factors affecting primary production and sea ice algal biomass accumulation in the Chukchi Sea land–fast ice–ocean ecosystem. Presented at Frontier Science Conference for Young Researchers for Climate Change, Nynashamn, Sweden, 24–29 June 2006.

Publications

Non-peer-reviewed

Lee, S.H. 2005. Current Primary Production Rates of the Western Arctic Ocean Estimated by Stable Carbon and Nitrogen Isotope Tracers. Ph.D. Dissertation, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

Submitted

Lee, S.H. and T.E. Whitledge. Spring time productivities of sea ice algae and pelagic phytoplankton in the land fast ice zone at Barrow, Alaska. Submitted to *Marine Ecology Progress Series*.

Lee, S.H. and T.E. Whitledge. Current carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. Submitted to *Continental Shelf Research*.

Lee, S.H. and T.E. Whitledge. Productivities and macromolecular compositions of sea ice algae and phytoplankton under different sea ice thicknesses. Submitted to *Polar Biology*.

In preparation

Whitledge, T.E. and others. New results in U.S.–Russian collaborative program in the western Arctic. In final stages of preparation for submission to *EOS*.

References

Bury, S.J., N.J.P. Owens and T. Preston. 1995. ^{13}C and ^{15}N uptake by phytoplankton in the Marginal Ice Zone of the Bellingshausen Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 42:1225–1252.

Task II

Steller Sea Lion Projects

Arctic Research Initiative Projects

Decision-Making under Uncertainty: Management of Commercial Fisheries and Marine Mammals

Matt Berman, PI ***NOAA Goal: Ecosystem-based management***
University of Alaska Anchorage
Jerry McBeath, PI
University of Alaska Fairbanks

CIFAR 01-015 and 01-004: Work initiated by McBeath (01-015) was completed in FY05. Research for Berman's work (01-004) was completed in FY06, except for revision of manuscripts as needed to obtain peer-reviewed publication. This will be the last annual report for these projects.

Primary objectives (combined projects)

- Examination of the structure of decision-making concerning Steller sea lions (SSL) and commercial fisheries management, with a focus on the National Marine Fisheries Service (NMFS) Alaska Region (legal and regulatory bases and affected interests);
- Etiology of the SSL crisis, based on available sources;
- Policy analysis of scientific literature of SSL decline since the Endangered Species Act (ESA) listing in 1990;
- Analysis of the political, socio-economic, and environmental risks of management failure; analysis of court, congressional, and agency use of science and certainty thresholds before taking action; and
- Analysis of the degree to which science research can respond quickly to provide knowledge that could increase certainty regarding effects of management decisions and thereby reduce risks associated with management actions.

Approach/methodology (combined projects)

The approach of the project involves collection of both primary and secondary data, with both quantitative and qualitative dimensions. The secondary data are of four types: a) the four court orders of *Greenpeace v. National Marine Fisheries Service*, the briefs of plaintiffs, defendants, and defendant-intervenors and the voluminous (20,000 plus pages) administrative record, b) the published scientific literature on the causes of SSL decline, the SSL controversy itself, and its ramifications—in books, journal articles, M.S. and doctoral theses, and agency/interest group reports, c) environmental impact statements and biological opinions on the SSL and its critical habitat, and d) recent and current research projects in the NOAA-funded SSL science program.

Primary data collection consists of nearly 100 mostly qualitative interviews on fisheries and endangered species management with officials of NMFS (past/present), NOAA general counsel office, North Pacific Fishery Management Council, Alaska Department of Fish and Game (ADFG), and the U.S. Environmental Protection Agency (EPA); political leaders (federal, state, local) active in fisheries and endangered species issues, including staff; interest group representatives (industry, environmental, Native organizations), and marine scientists.

Research accomplishments/highlights/findings (Berman)

- Interdisciplinary, policy-relevant research is necessary but difficult.
- But also part of the problem is the gap in understanding between academically oriented researchers, who aim to create new knowledge, and agency researchers, who are called upon for direct decision support. Different types of science organizations have different strengths, collaboration across different types of organizations beneficial.
- Science can be more helpful for avoiding environmental crises than resolving them as they unfold.

NOAA relevance/societal benefits (combined projects)

This research demonstrates that, so far as endangered species law and policy are concerned, requirements of the courts are minimal but logically rigorous. NMFS was never required to establish the definitive causes of SSL decline. It was required to base its hypotheses on the best available scientific information, and then to establish a record of decision-making logically consistent with its hypotheses.

Research linkages/partnerships/collaborators and networking (Berman)

The research has contributed to the development of the human dimensions aspects of the Implementation Plan for the interagency research program Study of Environmental Change (SEARCH) and the proposed Bering Sea Ecosystem Study (BEST) plan. The research led to collaboration with NOAA personnel at the Pacific Marine

Environmental Lab (PMEL) in a proposal (unsuccessful) to create a Regional Integrated Sciences and Assessments (RISA) program in Alaska. The research has also led to new partnerships with marine mammal and fishery researchers at the University of British Columbia, leading to three proposals, two of which were funded, with work started in August 2005. The two ongoing funded projects are: *Valuation of Critical Habitat Closures* (North Pacific Research Board, $61,194), which estimates net economic costs of specific fisheries closures in Steller sea lion critical habitat; and *Estimating the Cost to Fisheries of Marine Mammal Habitat Designations* (North Pacific Universities Marine Mammal Consortium, $60,643), which links outputs and data from spatial ecological models to economic models of fisheries harvest.

NOAA personnel participated as key informants in interviews by both McBeath and Berman. Berman would like to acknowledge specifically the assistance of Lowell Fritz, Doug DeMaster, Joe Terry, and Allan Haynie (Alaska Fisheries Science Center); Phyllis Stabeno (Pacific Marine Environmental Laboratory), and Pete Jones (NOAA Alaska Region).

Education/outreach (combined projects)

Public awareness

McBeath, J. 2005. Decision-making in marine mammal conservation. Oral presentation at the 135th Annual American Fisheries Society Meeting, Anchorage, Alaska, September 2005.

Berman, M. 2006. Endangered species, threatened fisheries, science to the rescue! Evaluating the Congressionally designated Steller sea lion research program. University of Alaska Anchorage Institute of Social and Economic Research Public Policy Seminar Series, 1 August 2006.

Publications (combined projects)

Peer-reviewed

Berman, M. and U.R. Sumaila. Discounting and amenity values in ecosystem restoration. *Marine Resource Economics*, 21(2):211–219.

Non-peer-reviewed

McBeath, J. and J. Rosenberg. 2006. Case studies included in Chapter 4 (Political institutions and the environment) and Chapter 6 (National responses to global environmental problems) in: J. McBeath and J. Rosenberg, Eds., *Comparative Environmental Politics* (Vol. 25 in the series *Advances in Global Change Research*). Springer Science+Business Media, Dordrecht, the Netherlands. 193 pp.

In press

McBeath, J. Science and politics in marine mammal conservation. *Journal of Wildlife Law and Policy*, in press.

Berman, M. Modeling effects of habitat closures in ocean fisheries. *Proceedings of the North American Association of Fisheries Economists (NAAFE) Forum 2005: Fisheries Benefits for All Generations*, Vancouver, BC, in press.

In preparation

Berman, M. The Congressionally designated Steller sea lion research program. In preparation.

Berman, M. Endangered species, threatened fisheries, science to the rescue! Evaluating the Congressionally designated Steller sea lion research program. In preparation.

The Role of Physiological Constraint in the Acquisition of Foraging Ability: Development of Diving Capacity in Juvenile Steller Sea Lions

Jennifer M. Burns, PI *University of Alaska Anchorage*

NOAA Goal: Ecosystem-based Management

Other investigators/professionals funded by this project:
David C. Pfeiffer, *University of Alaska Anchorage*

CIFAR 01-005: This project is ongoing. Data collection is complete; we are working on the final two manuscripts.

Primary objectives

By studying the development of Steller sea lion physiological status, and then linking it with diving behavior (determined as part of other, ongoing studies), this project will identify if physiological limitations in the rate of development might influence activity patterns and foraging strategies. This research may also reveal whether rates of physiological development are tailored to meet specific life history patterns or instead limit them. Data obtained

from sea lions will be compared with that from other pinnipeds to determine physiological maturity relative to timing of independence. Ultimately, this research may offer insight into those factors that influence juvenile survival and recruitment.

Approach/methodology

The development of dive capacity in juvenile Steller sea lions was investigated by measuring blood and muscle oxygen stores. Erythropoietin (EPO), a hormone stimulated in response to tissue hypoxia, was analyzed to investigate a possible mechanism for oxygen stores development. EPO was analyzed using a Radioimmunoassay kit from Diagnostic Systems Laboratories. Biochemical and histochemical characteristics of muscle were studied to determine how these criteria may change with development and how they influence dive ability. Muscle biochemical profiles of three enzymes (lactate dehydrogenase, citrate synthase and β-Hydroxyacyl-CoA dehydrogenase) in various age categories and two muscle types (primary swimming and non-swimming) were determined using kinetic assay. Histochemical analysis of muscle was investigated using immunohistochemical techniques validated with traditional histochemical staining techniques. Juvenile animals ranging in age from 5 to 22 months (n=46) in Southeast Alaska, Prince William Sound, and the Aleutian Islands were captured by the Alaska Department of Fish and Game (ADF&G) and the National Marine Mammal Laboratory (NMML) and sampled for this study.

Research accomplishments/highlights/findings

- The second manuscript from this study, which details the development of total body oxygen stores, was accepted for publication during the reporting period.
- We are currently working on a manuscript that details the pattern and biochemistry of muscle development. We had hoped to complete this manuscript by summer, 2006, but lead author J. Richmond is in a Ph.D. program at the University of Connecticut, and progress has been slower than anticipated. However, the manuscript should be submitted by the end of the year.
- We have analyzed sea lion sera for iron, transferrin, and total iron binding capacity, and compared patterns of hematological development to iron status in Steller sea lions and three phocid species. At this point, it appears that there are very different patterns between phocids and otarrids, and that, while iron might be limiting for hematological development in phocids, it is not for sea lions. This work will be presented in October, 2006.
- We have combined dive data with cADL (calculated aerobic dive limit) estimates to model foraging efficiency and patch quality. In these analyses, the changes in dive duration and post-dive surface intervals are used to predict habitat quality. Without knowledge of the aerobic dive limit of the animals, the analyses can not be conducted. Preliminary data were presented in December 2005 (Testa and Burns 2005).

NOAA relevance/societal benefits

We have demonstrated that the oxygen storage capacity of juveniles > 1 year is only slightly lower than that of adults, and shown that most dives made by juveniles are within their aerobic dive capacity. This suggests that the physiological status of juveniles > 1 year is sufficient to allow independent foraging. However, the deep and long diving patterns observed during winter months result in a large fraction of bout dives that approach or exceed the calculated ADL. This suggests that the winter prior to the second summer of life is a critical period for young Steller sea lions.

Research linkages/partnerships/collaborators and networking

This research would not have been possible without tremendous collaborative efforts. Alaska Department of Fish & Game and NOAA/NMML supplied logistical support for fieldwork and provided samples. Samples were also provided by the Alaska SeaLife Center and the Aleut Community of St. Paul, Alaska.

Education/outreach

Student participation

Julie P. Richmond	Master of Science Degree	*Completed in FY04*
Jill Prewitt	Master of Science Degree	*In progress*

Presentations

Burns, J.M., M.J. Rehberg and J.P. Richmond. 2006. Working harder in the dark: Winter diving and foraging patterns in juvenile Steller sea lions. Talk presented at Marine Sciences in Alaska, Anchorage, Alaska, 22–25 January 2006.

Testa, J.W. and J.M. Burns. 2005. Index to patch quality (IPQ) applied to yearling Steller sea lions in Alaska. Poster presented at the 16th Biennial Conference of the Society for Marine Mammalogy, San Diego, California, 12–17 December 2005.

Publications

In press

Richmond, J.P., J.M. Burns and L.D. Rea. Ontogeny of total body oxygen stores and aerobic dive potential in Steller sea lions (*Eumetopias jubatus*). *Journal of Comparative Physiology B*, in press.

In preparation

Richmond, J.P., J.M. Burns and L. Polasek. Skeletal muscle myoglobin and select oxidative and glycolytic enzyme profiles throughout development in free-ranging Steller sea lions (*Eumetopias jubatus*). In preparation for submission to *Journal of Experimental Biology*.

Burns, J.M., C.A. Clark and J.P. Richmond. The influence of dietary iron on hematological development in juvenile pinnipeds. In preparation.

Climate-driven Bottom-up Processes and Killer Whale Abundance as Factors in Steller Sea Lion Population Trends in the Aleutian Islands: Zooplankton and Acoustic Component

Kenneth Coyle, PI ***NOAA Goal: Ecosystem-based management***
University of Alaska Fairbanks

CIFAR 01-007: This project is complete. See previous annual reports for research activity under this award. Activity for this reporting period is described below in the Publication section.

Primary objectives

The western population of Steller sea lions, extending from Kodiak Island through the western Aleutian Islands, has undergone a steady decline since the mid 1970s. Current working hypotheses for the declines are:

1) Commercial fisheries are out-competing the Steller sea lions for the supply of available forage fish in the western part of the range.
2) Predation by killer whales on sea lions has increased mortality and lowered the survival of sea lion pups and juveniles.
3) Climate cycles in the North Pacific and southern Bering Sea have resulted in substantial declines in ecosystem productivity, thus lowering the overall food base for the Steller sea lions.

This research tests the second and third hypotheses by measuring production indices and whale populations in the Akutan–Unimak area, where sea lion populations are steady or increasing, and in the Seguam–Amukta area, where the populations are in rapid decline.

Approach/methodology

Two cruises were completed in 2001–2002. Large zooplankton and micronekton were collected with a 1-m^2 MOCNESS equipped with 500 μm mesh nets. Small zooplankton were collected with a 9 cm diameter CalVET net system. Acoustic surveys were done through each pass to document large-scale distributional patterns of zooplankton and micronekton. Acoustic data were collected with a Hydroacoustic Technology Inc. (HTI) model 244 split-beam digital system. The simultaneous collection of acoustic and net data will aid in the interpretation and scaling of the acoustic transect data.

NOAA relevance/societal benefits

Due to the declines in Steller sea lion populations and the resulting fishing restrictions on the commercial fleet in the vicinity of sea lion rookeries, NOAA was tasked to provide information on the biology and habitat of sea lions to aid in determining potential causes for the declines. This research addresses two hypotheses of interest to NOAA.

- Predation by killer whales on sea lions has increased mortality and lowered the survival of sea lion pups and juveniles.
- Climate cycles in the North Pacific and southern Bering Sea have resulted in substantial declines in ecosystem productivity, thus lowering the overall food base for the Steller sea lions.

Research linkages/partnerships/collaborators and networking

This research is done in collaboration with four principal investigators funded under separate contracts from various agencies: George L. Hunt, University of California Irvine; Sue Moore, NMML; Steve Zeeman, University of New England; and Phyllis Stabeno, PMEL.

Information from this research was also used by Beth Sinclair and Tom Loughlin of the NMML in their research on Steller sea lion biology.

Publications

Peer-reviewed

Coyle, K.O. 2005. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. *Fisheries Oceanography*, 14 (Suppl. 1):178–195.

Jahncke, J., K.O. Coyle and G.L. Hunt Jr. 2005. Seabird distribution, abundance and diets in the eastern and central Aleutian Islands. *Fisheries Oceanography*, 14 (Suppl. 1):160–177.

Ladd, C., J. Jahncke, G.L. Hunt Jr., K.O. Coyle and P.J. Stabeno. 2005. Hydrographic features and seabird foraging in Aleutian Passes. *Fisheries Oceanography*, 14 (Suppl. 1):77–92.

Impacts of Climate Change on the Bering Sea Ecosystem over the Past 500 Years

Bruce P. Finney, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
Amy C. Hirons and Alan M. Springer, *University of Alaska Fairbanks*

CIFAR 01-010: This project is ongoing.

Primary objectives

1) To reconstruct changes in primary productivity of the Bering Sea at decadal or better resolution over the past approximately 500 years.
2) To reconstruct relative changes in populations of forage fish at similar resolution to the records produced in objective 1.
3) To determine paleoceanographic changes in factors such as ocean temperature, salinity, and nitrate utilization for the cores discussed above.
4) To determine any changes in the trophic position of Steller sea lions.
5) To synthesize our results with available paleoclimatic, paleoceanographic and paleoecological data, and with retrospective and modern process studies in the North Pacific and Bering Sea.

Approach/methodology

1) We will study cores from two locations to insure that regional changes are determined. We will also use multiple productivity proxies to develop a robust interpretation. We will also measure $\delta^{13}C$ on bone collagen from Steller sea lions to evaluate changes in marine primary production.
2) Piston cores collected in Skan Bay show evidence of some preserved fish scales that provide temporal productivity data for those regions.
3) The combined analysis of the stable isotope of oxygen ($\delta^{18}O$) and Ca/Mg provides data on ocean temperature and salinity. Sequential sampling and analysis along the sediment cores provide information on temporal fluctuations that correspond to climatic changes.
4) The combined analysis of the stable isotope of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) provides information on the productivity of the marine environment and the length of the food web in which the pinnipeds resided. Museum and archaeological remains of these organisms provide information on temporal fluctuations that likely correspond to environmental fluctuations.
5) We are developing a new understanding of natural variability of organisms at several levels of the food web (phytoplankton, zooplankton, forage fish, salmon, marine mammals) in this region, and their relationships to climatic and oceanographic change.

Research accomplishments/highlights/findings

- $\delta^{18}O$ and $\delta^{13}C$ analyses (on *E. excavatum*) for Skan Bay samples are nearly complete, with replication and quality control assessment in progress.
- Foraminifera isotope results are being interpreted and compared with the data from the same core on $\delta^{13}C$ and $\delta^{15}N$ of organic matter, organic carbon and opal. Mg/Ca samples have been prepared and preliminary results have been obtained. These results are part of the M.S. thesis research of Molly Boughan (Graduate Program in Marine Science and Limnology, School of Fisheries and Ocean Sciences, UAF).
- Comparison of results with historical and paleoclimate and oceanographic data is in progress.

NOAA relevance/societal benefits

In a pilot study effort to reconstruct the paleocean productivity of the Bering Sea, we have collected and analyzed sediment cores and skeletal remains from several locations in the Aleutian Islands. These data indicate decadal and century-scale fluctuations in marine productivity took place during the 800-year time period. Information of this kind is useful for addressing management and conservation concerns over recent changes in abundance of several species, such as pollock and sea lions.

Research linkages/partnerships/collaborators and networking

This research has led to additional research and funding though NOAA via the North Pacific Universities Marine Mammal Research Consortium (*Impacts of Climate Change on Steller Sea Lion Populations during the Past Century*, $50,000), NSF Arctic Social Science Collaborative proposal: *Investigating Complex Human-Ecological Relationships over Multidimensional Scales: the Sanak Islands Project*, $100,000), and the Pollock Conservation Cooperative Research Consortium (*Food Web Dynamics of the Bering* Sea, $75,162) on subjects dealing with climatic impact on trophic structure, marine productivity and resource utilization.

Education/outreach

Student participation

- Molly Boughan, M.S.-seeking graduate student, Geological Oceanography – collection, identification and analyses of foraminifera.
- Molly Odell, undergraduate anthropology student, graduated UAF Summer 2005 - preparation of bone samples for stable isotope analysis and studying sedimentation in marine cores.

Publications

In press

Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L. Wang, and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.

In preparation

Finney, B.P., A.M. Springer and A.C. Hirons. Paleoceanographic history of the Eastern Aleutian Island Region, Alaska, over the past 500 years. In preparation for submission to *Paleoceanography.*

Hirons, A.C., B.P. Finney, A.M. Springer and C. Potter. Evidence of environmental fluctuation since the 19th century in Steller sea lions (*Eumetopias jubatus*) using stable isotope ratios. In preparation for submission to *Global Change Biology.*

Ocean Climate Variability as a Potential Influence on Steller Sea Lion Populations

Thomas C. Royer, PI *Old Dominion University*

NOAA Goal: Ecosystem-based Management

Other investigators/professionals funded by this project:
Chester E. Grosch, *Old Dominion University*

CIFAR 01-018: This project is complete. See previous annual reports for research activity under this award. New activity for the reporting period is described below in the Education/outreach and Publications sections.

Primary objectives

We hypothesize that the combination of many of the oceanic-atmospheric forces with bidecadal cycles could lead to the regime shift in the North Pacific that occurred in the late 1970s. Low frequency fluctuations could influence the amount and distribution of biomass in the ecosystem. How are the sea level slopes and ocean circulation related to the coastal freshwater discharge and coastal sea levels in the Gulf of Alaska? Do coastal freshwater discharge, coastal sea level and other long term environmental records contain information on interdecadal changes in the marine ecosystem in the North Pacific and Bering Sea?

NOAA relevance/societal benefits

The Gulf of Alaska and Bering Sea are two of the most productive ecosystems in the United States and contain a majority of U.S. fisheries. A better understanding of the decadal changes in this ecosystem will help us to understand and manage these important marine resources.

Research linkages/partnerships/collaborators and networking

The PIs are also working on other related research programs in this region including Northeast Pacific GLOBEC (NOAA/NSF funding) and the Arctic–Yukon–Kuskokwim Sustained Salmon Initiative (AYK SSI) (See publication list). They are continuing to study the impact of glacial ablation on ocean circulation in the Northeast Pacific.

National Science Foundation, GLOBEC: *Gulf of Alaska Long Term Monitoring Program*, 2000–2005. $339,391

National Science Foundation/National Oceanic and Atmospheric Administration, *GLOBEC Studies in the NE Pacific*, subcontract from the University of Alaska, 1997–2001. $160,610

Education/outreach

Student participation

Isaac Schroeder, a Ph.D. candidate at Old Dominion University, has been supported full time on this grant 2001–2005. The title of his Ph.D. dissertation is "Annual and Interannual Variability in the Wind Field and Hydrography Along the Seward Line in the Northern Gulf of Alaska." Expected completion date December 2006.

Presentations

Royer, T.C. 2005. A maritime window of opportunity for human migration during the last glacial maximum. Presented at the Paths Across the Pacific IV Conference in Sitka, Alaska, 21 July 2005.

Janout, M., S. Okkonen, T. Weingartner, D. Musgrave and T. Royer. 2006. Yakutat eddies and shelf/slope exchange in the Gulf of Alaska. Presented at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2006.

Royer, T.C., C.E. Grosch, T.J. Weingartner and S. Danielson. 2006. Hydrographic changes in the coastal northern Gulf of Alaska during Northeast Pacific GLOBEC (1997–2004), Presented at the Ocean Sciences Meeting, Honolulu, Hawaii, 22 February 2006.

Sarkar, N., T.C. Royer and C.E. Grosch. 2006. Climatology of mixed layer depths along the Seward Line in the northern Gulf of Alaska during the GLOBEC period. Presented at the Ocean Sciences Meeting, Honolulu, Hawaii, 22 February 2006.

Schroeder, I., T.C. Royer and C.E. Grosch. 2006. Hydrographic response to upstream winds along the Seward Line. Presented at the Ocean Sciences Meeting, Honolulu, Hawaii, 22 February 2006.

Royer, T.C. 2006. The North Pacific Ocean climate during the last glacial maximum. Presented at the Paths Across the Pacific V Conference in Sitka, Alaska, 28 July 2006.

Other

Royer, T.C. 2006. Vital ocean monitoring program may be lost. Anchorage Daily News, Compass, 20 July 2006.

Publications (over the life of the project to date)

Peer-reviewed

Okkonen, S.R., D.L. Cutchin and T.C. Royer. 2005. Seasonal variability of near-surface hydrography and frontal features in the northern Gulf of Alaska and Prince William Sound. *Geophysical Research Letters*, 32, L11611, doi:10.1029/2005GL023195 *(FY05; not previously reported)*

Royer, T.C. 2005. Hydrographic responses at a coastal site in the northern Gulf of Alaska to seasonal and interannual forcing. *Deep-Sea Research II*, 52:267–288. doi:10.1016/j.dsr2.2004.09.022 *(FY05; previously reported)*

Weingartner, T.J., S.L. Danielson and T.C. Royer. 2005. Freshwater variability and predictability in the Alaska Coastal Current. *Deep-Sea Research II*, 52:169–191. doi:10.1016/j.dsr2.2004.09.030 *(FY05; previously reported)*

Non-peer-reviewed

Royer, T.C. 2005. Review of *Marine Ecosystems and Climate Variation. The North Atlantic: A Comparative Perspective*. (Edited by N.C. Stenseth, G. Ottersen and J.W. Hurrell. Oxford University Press, ISBN 0-19-850748-8.) *Limnology and Oceanography Bulletin*, 14(3):58–59.

Royer, T.C. et al. 2005. Developing a Research and Restoration Plan for Arctic-Yukon-Kuskokwim (Western Alaska) Salmon. The National Academies Press, Washington, DC. 207 pp. *(FY05; previously reported)*

In press

Royer, T.C. and C.E. Grosch. Ocean warming and freshening in the northern Gulf of Alaska. *Geophysical Research Letters*, in press.

Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L.Wang and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.

Submitted or in preparation

Ebbesmeyer, C.C., W.J. Ingraham, T.C. Royer and C.E. Grosch. Tub toys in orbit. In preparation for submission to *EOS*.

Myers, K.W., N.V. Klovatch, O.F. Gritsenko, S. Urawa and T.C. Royer. Stock-specific distribution of Asian and North American salmon in the open ocean, interannual changes and oceanographic conditions. Under review for *NPAFC-PICES* November 2005 symposium papers.

Schroeder, I., C.E. Grosch and T.C. Royer. NCEP-NCAR Reanalysis: Comparison with observations from the Coast of Alaska and the Gulf of Alaska. Submitted to *Journal of Climate*.

Zhang, B. and T.C. Royer. Freshwater budget estimate for the northern North Pacific Ocean. Submitted to *Geophysical Research Letters*.

ARCTIC RESEARCH INITIATIVE

Trophic Pathways on the Chukchi–Beaufort Shelf: Where do the Ice Algae Go?

Alan M. Springer, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
C. Peter McRoy, *University of Alaska Fairbanks*
Sara J. Iverson and Suzanne Budge, *Dalhousie University*

CIFAR 06-019b: This project is ongoing.

Primary objectives

The goal of this project is to identify trophic pathways of ice algae on the Chukchi–Beaufort continental shelf using fatty acid biomarkers to trace carbon flow through the Arctic food web. Fatty acid biomarkers are used to differentiate between the two types of primary production, ice algae and spring bloom algae, consumed by organisms at higher trophic levels, specifically, Arctic cod, black guillemots, bearded and ringed seals, bowhead whales, walruses and polar bears. This, in turn, will allow us to delineate the trophic pathways of sea ice algae and its importance to those consumers.

Approach/methodology

Plankton samples were collected in May 2002 and 2003 off Barrow, Alaska. Ice algae were obtained from cores, while large volumes of water from under the ice were filtered to obtain algae from the water column. Fauna, including copepods, amphipods, polychaetes, ctenophores and ciliates, were collected with nets deployed under the ice. Amphipods recovered from the stomachs of Arctic cod were also collected in August of 2002. Personnel at the North Slope Borough have also made available to us samples of bowhead whale blubber taken near Barrow from 1997 to the present. Lipid extraction was performed on all sample types with a modified Folch et al. (1957) method (Parrish 1999) using chloroform and methanol, followed by fatty acid methyl ester formation. Individual fatty acids were determined using gas chromatography.

In addition to the samples from Barrow, our collaborator Gay Sheffield of the Alaska Department of Fish and Game, collected adipose from planktivorous seabirds, and blubber samples from walruses and ringed, spotted, ribbon, and bearded seals in May 2003–2005 from Little Diomede Island in the Bering Strait. This data will be compared to data from Barrow to assess geographical/environmental effects on ice algae food webs.

In November 2004, compound-specific isotope analysis was carried out on 10 representative samples of each type, including ice algae, phytoplankton, copepods, fish, sea birds, seals, walruses and whales (n=120). This analysis provides a carbon stable isotope ratio for individual fatty acids and was carried out on those fatty acids that are derived exclusively or predominantly from diatoms.

Research accomplishments/highlights/findings

- Results of our bowhead whale blubber analyses (see FY05 report) were presented at the 16th Biennial Conference on the Biology of Marine Mammals at San Diego in December, 2005.
- Preliminary compound-specific isotope analysis indicates that ice algal carbon represents approximately 25% of total carbon present at higher trophic levels, including zooplankton, fish, birds, whales and seals. The contribution varies from a low of 0% in bowhead whales to a high of 60% in amphipods and euphausiids. These results agree generally with conclusions reached from analysis of the overall fatty acid composition.

NOAA relevance/societal benefits

The study of trophic pathways of ice algae relates directly to NOAA's interests in climate change. Global warming results in the melting of sea ice; it is imperative to understand the impact that the loss of sea ice and associated ice algae may have on consumers at higher trophic levels.

Research linkages/partnerships/collaborators and networking

Gay Sheffield at the Alaska Department of Fish and Game has provided essential samples that we would not otherwise have been able to collect, including walruses and bearded, ringed, ribbon and spotted seals. The Barrow and Kaktovik whaling captains and the North Slope Borough provided blubber samples from bowhead whales.

Publications

In review

Budge, S.M., A.M. Springer, S.J. Iverson and G. Sheffield. Fatty acid biomarkers reveal niche separation in an Arctic benthic food web. In review for *Marine Ecology Progress Series*.

In preparation

Budge, S.M., M. Wooller, A.M. Springer and S.J. Iverson. Examining the contribution of sea ice algae to an Arctic marine ecosystem using stable isotope analyses of fatty acids. In preparation for submission to *Proceedings of Biological Science.*

Budge, S.M., S.J. Iverson, A.M. Springer, G. Sheffield and C.P. McRoy. Blubber fatty acid composition of bowhead whales, *Balaena mysticetus*: implications for diet assessment and ecosystem monitoring. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences.*

References

Folch, J., M. Lees and G.H.S. Stanley. 1957. A simple method for the isolation and purification of total lipides from animal tissues. *Journal of Biological Chemistry*, 226:497–509.

Parrish, C.C. 1999. Determination of total lipid, lipid classes, and fatty acids in aquatic samples. In: Arts, M.T. and B.C. Wainman, Eds., Lipids in Freshwater Ecosystems. Springer-Verlag, New York, pp. 5–20.

Task III

Research Themes

Atmospheric and Climate Research
Climate Modeling
Contaminant Effects
Fisheries Oceanography
Hydrographic and Sea Ice Studies
Marine Ecosystem Studies
Tsunami Research
UV and Arctic Haze Studies

Alaskan Coastal Climatologies Wind and Wave Hindcast Workshop

David Atkinson, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

CIFAR 19-086 (new): This project is complete.

Primary objectives

This project is part of an Alaskan sector contribution to the NOAA Pacific Regional Integrated Data Enterprise (PRIDE) initiative. The objective of this project was to draft a coastal climatology development plan that will lead to an actual FY07-08 demonstration project as NOAA's contribution to the International Polar Year (IPY). The plan will address ocean wind and wave hindcasts (the use of historical wind and wave information to verify simulations of past wave characteristics), combined with sea level changes, permafrost change, coastal erosion rates, and related societal effects in the coastal and near-shore zones of Alaska.

The primary aim of the Damage Prevention in Coastal Regions Project (DPCRP) is to develop a ***multi-scale coastal prediction platform*** to provide coastal stakeholder groups with short- and long-term forecasting products that improve capability of emergency ***response***, damage ***prevention***, and human/ecological coastal zone ***management*** activities. This project for the Alaska zone will interface with corresponding activities in Hawaii in order to identify synergies between corresponding wave modeling activities in the two regions and identify methodological requirements unique to each region.

Approach/methodology

The current funding will be used for two primary activities. First, a workshop will be held to assess agency needs pertaining to Alaskan wind/wave climatologies and forecasts, and to assess the present status of Alaskan coastal wind/wave climatological data, integration, and modeling capabilities. This workshop will entrain representatives from sectors impacted by wave events in coastal Alaska, the National Weather Service, the Alaskan Ocean Observing System (AOOS), Alaskan U.S. Army Corps of Engineers, NOAA and Alaskan climatologists and researchers, and wave modelers from Hawaii and elsewhere. The second activity will involve assessing data sources and assembling climatological databases for the purpose of identifying optimum Alaskan coastal sites for wave model testing and validation.

Research accomplishments/highlights/findings

- A workshop, "Toward an Alaskan Wind/Wave Climatology," was held in Anchorage on 2–3 August 2005, with a half-day retreat for project key personnel on the following day. Forty-five individuals from a wide range of Federal, State, academic and other research organizations attended.
- A workshop report was prepared and delivered to the U.S. Senate Committee on Commerce, Science and Transportation. Items addressed in the report included modeling issues and requirements; pertinent datasets and their readiness; candidate wave models; Alaska/Hawaii integration strategies; identification of stakeholder needs; pilot project site location strategy and selection criteria.
- A draft Science Plan "Damage Prevention in Coastal Regions Project (DPCRP): Phase 1—Alaska zone" has been written and will lead to a demonstration project as part of the IPY.
- A literature review was conducted and a wave model comparison chart has been prepared by Oceana Francis-Chythlook, a Ph.D. student supported by this project. A manuscript on the wave model comparison will be submitted for peer-reviewed publication.
- Existing data and products were identified during the workshop that would provide immediate benefits to emergency planners.

NOAA relevance/societal benefits

Over 80 percent of Alaska's population lives and works in the land/ocean coastal zone. The vulnerability of high latitude coastal communities in the face of decreasing sea ice was a key finding of the Arctic Climate Impact Assessment (2005). Storm surges and heavy wave activity along much of Alaska's coastline have resulted in almost yearly disaster declarations by Alaska governors. Coastal disasters in Alaska are compounded by a lack of infrastructure that hampers immediate relief, and by lack of economic diversity, which slows regional recovery. Thus, an improved applied operational capability to assess the risk of future coastal inundation and erosion events

and their associated effects in Alaska is critical to NOAA's goal to understand climate variability and change to enhance society's ability to plan and respond.

Research linkages/partnerships/collaborators and networking

James Partain, National Weather Service, Alaska Region Headquarters, and John Jensen, NOAA National Climatic Data Center were project collaborators.

This workshop involved three line offices of NOAA (NESDIS, NWS, and NOS), four other federal agencies (U.S. Army Corps of Engineers, U.S. Navy, U.S. Geological Survey and Minerals Management Service), and three State of Alaska departments (Homeland Security and Emergency Preparedness, Community and Economic Development, and Department of Transportation) as well as academic scientists from the University of Alaska Fairbanks, University of Alaska Anchorage, North Carolina State University and the Alfred Wegener Institute for Polar and Marine Research. In addition, participants from the Alaska Ocean Observing System, Kachemak Bay Research Reserve, and U.S. Arctic Research Commission participated.

Education/outreach

Student participation

This funding provided summer salary and tuition support for Oceana Francis-Chythlook, a Ph.D. student.

NOAA Hot Item

This project was featured as a NOAA Hot Item in November 2005 ("Assessment of the Needs for Predicting Coastal Erosion and Flooding in Alaska")

Presentations

The PI has discussed aspects of this project at a variety of venues, including:

Professional scientific conferences

Atkinson, D. 2005. Circum-Arctic high-speed wind event climatology and trends from observational data. American Geophysical Union Fall meeting, San Francisco, California, 6–10 December 2005.

Atkinson, D. 2006. Ice, wind, waves, storminess trends along the Alaskan Coast. 9th Annual University of Alaska Anchorage Science to Technology workshop, "Coastal Erosion Responses for Alaska," Anchorage, Alaska, 4 January 2006.

Workshops or meetings involving research scientists and managers responsible for dealing with risk management in the coastal zone or providing instrumentation for coastal monitoring

- 2nd PRIDE workshop, Honolulu, Hawaii, 9–10 August 2005.
- Alaskan Ocean Observing System Governance Committee meeting, Anchorage, Alaska, 21–22 November 2005.
- Pacific Region Management O'hana meeting, Honolulu, Hawaii, 6–7 December 2005.

Networking with other "impacted" groups from northern coastal communities whose hunting, fishing, and gathering activities need to be considered in a coastal climatology plan

- Alaska Eskimo Whaling Commission, Alaska Federation of Natives conference, Fairbanks, Alaska, October 2005.
- International Conference of Arctic Research Planning, Copenhagen, Denmark, 9–14 November 2005.

References

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press, 1042 pp.

Correction of Systematic Errors in TOVS Radiances

Jennifer Francis, PI
Rutgers University

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

CIFAR 31-056a: This project is ongoing.

Primary objectives

In this collaborative project, we are attempting to identify, quantify, and mitigate errors in radiances measured by the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS). These errors result from changes to satellite orbits, instruments, and/or calibration method. We expect to produce a 26-year (or more) record of TOVS radiances and retrieved products that are as error-free as is practicable, given available resources. Many of the known errors should be regionally and seasonally independent, but we suspect that some may be

peculiar to or exacerbated by Arctic conditions. Thus while our efforts will be global, our focus will be primarily Arctic. The expected product of this investigation will be a data set of tremendous value both for geophysical retrievals, with sufficient accuracy to identify climatic changes since 1979, as well as for direct assimilation by numerical atmospheric models.

Summary of effort

Our approach to removing systematic errors from the TOVS radiances takes several parallel avenues and is a collaborative effort by personnel at NOAA/NESDIS, University of Washington, and Rutgers University. During the past year we have been focused on taking our new database of rawinsondes from high northern-latitude locations, including winter soundings from the Department of Energy's Atmospheric Radiation Measurement Program (ARM) Southern Great Plains site in Oklahoma, and developing software to catalog and quality-check them, identify High-Resolution Infrared Sounder (HIRS) and Microwave Sound Unit (MSU) data at the same location (within 11 HIRS pixels on either side of raob location) and same time (within 6 hours), and create a new database of this collocated information. More detail on the technical aspects of this task follow below. Progress has been significantly slower than expected owing to two unforeseen problems. The first was that NOAA/NESDIS did not have a complete data base of level 1b TOVS radiances. Axel Schweiger purchased additional storage equipment to facilitate the transfer of these data in UW archives to NOAA/NESDIS. As NOAA is supposed to be responsible for archiving and distributing these data, this time-consuming task was not part of the research plan. The second major impediment was that NOAA's funding for this project was inadvertently spent by another project at NOAA, and thus Dr. Reale was left for a few months with no support for his technical staff. A key person had to be let go, which was a major setback in terms of lost knowledge and skill. The funding has since been restored and new technical help hired, but several months were lost owing to this oversight. Dr. Calder, program director at NOAA, has since approved a no-cost extension as a result of these delays.

Research accomplishments/highlights/findings

- Acquired additional rawinsondes from field experiments and ships, reformatted, then sent them to NESDIS to join existing data base.
- Acquired and reformatted additional cloud observations to assist in revising cloud detection algorithm. This is a critical part of the project, as only clear rawinsondes can be used for bias calculations.
- Coordinated frequent teleconferences to discuss problems, solutions, and progress.
- Assisted with cloud-detection strategies and provided validation data from the Barrow ARM site for Dr. Schweiger. New cloud tests and updated thresholds, including a new test using the 7.2 micron channel have increased cloud detection accuracy from 64% to 88%, mainly during nighttime.
- Many legacy modules of code for QC, collocation, indexing, cloud detection, radiance interpolation, scene identification, and a variety of other functions have been completely rewritten and updated for newer sensors.

NOAA relevance/societal benefits

TOVS data can be used both for weather forecasting and climate applications, both of high priority to NOAA.

Research linkages/partnerships/collaborators and networking

Co.-PIs on the overall SEARCH project are Tony Reale, NOAA/NESDIS; Axel Schweiger, University of Washington funded through JISAO.

State of the Arctic Report

Vladimir Romanovsky, PI ***NOAA Goals: Understand Climate Variability and Change***
University of Alaska Fairbanks

CIFAR 23-087 (new): This project is ongoing.

Primary objectives

This project is part of an effort to produce an annual, peer-reviewed report fully assessing the state of the Arctic. Objectives of the overall project include:

1. Hosting a workshop on the state of the Arctic.
2. Preparing a baseline report on the state of the Arctic.
3. Developing a methodology for an annual reassessment.

4. Widely disseminating the report.

This CIFAR funding supports PI Vladimir Romanovsky's participation as one of four members of the team of experts responsible for producing this report (see *Approach/methodology* section).

Approach/methodology

The benchmark assessment will be based on data obtained from U.S. and international sources. It will be a pan-Arctic description of the key atmosphere, ice, ocean and land parameters including:

1. Atmospheric circulation
2. Surface air temperature and barometric pressure
3. Sea ice drift, concentration, thickness concentration, and mass balance
4. Arctic Ocean circulation, thermohaline structure, and heat content
5. Ocean transport of freshwater, heat and nutrients through major Arctic gateways
6. Sea level
7. Biological activity from primary productivity to fish to marine mammals
8. Snow cover extent over the landmasses and changes in terrestrial hydrology
9. Thermal state of permafrost and active layer thickness
10. Changes in terrestrial ecosystems.

The report will be produced by a team of experts led by Jacqueline Richter-Menge (sea ice), James Overland (atmosphere), Andrey Proshutinsky (ocean), and Vladimir Romanovsky (land). The science advisory team will consist of national and international Arctic experts from universities and government laboratories. To assist in formulating the report we will host a workshop on the state of the Arctic, to include ice cover, atmosphere, ocean, and land.

Research accomplishments/highlights/findings

During the fall of 2005, a group of experts was assembled to address the questions related to changes over the Arctic landmass during the last few decades with some special emphasis on very recent changes in terrestrial components of the Arctic system. After collecting and analyzing available information, each member of this group prepared a white paper relevant to his/her expertise topics. These white papers were reworked and presented during the Workshop on the State of the Arctic, which was held in Woods Hole, Massachusetts on 24–26 October 2005. Based on the discussions during this workshop and on additional work after it, an Arctic section for the State of the Climate report that appeared in the June *Bulletin of the American Meteorological Society* (see *Publications* section) was prepared. An extended version of this report is now in a final stage of preparation and will be submitted to NOAA very soon for dissemination within the broader community.

The major findings in this report related to the Arctic land areas are:

The observations highlighted in this report indicate that many of the trends documented in the Arctic Climate Impact Assessment (ACIA) Report (2004, 2005) continued during the period 2000–2005 and suggest a sustained period of warming in the Arctic region. Convincing evidence includes widespread changes in Arctic vegetation, with the tundra experiencing an increase in greenness and the boreal forest regions showing a decrease in greenness. Permafrost temperatures continued to rise within most of the permafrost-affected areas but with a noticeably slower rate than in the 1990s. Changes in the active layer thickness (the relatively thin layer of ground between the surface and permafrost that undergoes seasonal freezing and thawing) are inconsistent. While some of the monitored sites show a slightly increasing trend in the thickness of the active layer, most of them do not.

NOAA relevance/societal benefits

This work is part of NOAA's contribution to the ongoing Study of Environmental Arctic Change (SEARCH) initiative involving close, two-way collaboration with other agencies and research teams studying the changing Arctic. This will also contribute to International Polar Year (IPY) activities involving NOAA, NASA, and NSF.

Research linkages/partnerships/collaborators and networking

The state of the Arctic report is being produced by a team led by Jacqueline Richter-Menge (CRREL), James Overland (NOAA-PMEL), Andrey Proshutinsky (WHOI), and Vladimir Romanovsky (UAF) who convened a workshop with a working group of 16 scientists from national and international universities and governmental laboratories studying the Arctic.

Education/outreach

- During the last year, Romanovsky was interviewed by several TV companies, such as HBO, Japan Broadcasting Corporation, CNN, a Japanese travel/environmental TV program, *USA Today*, *Online Video*, French TV -

France 2, and by news reporters from "The Independent," London; German Radio; Anchorage Daily News; CBC Radio, Yellowknife, Canada; the Associated Press and others.
- Materials collected during the project were included in the graduate-level Permafrost class that V. Romanovsky is teaching every semester at the University of Alaska Fairbanks.

Oral presentations

Romanovsky, V. 2006. Permafrost in a warming world. Invited oral presentation, 8th annual Alaska Forum on the Environment, Anchorage, Alaska, February 2006. This Forum attracted more than 2,000 residents from all regions of Alaska, with emphasis on local communities.

Romanovsky, V.E. 2006. Thermal state of permafrost in Alaska during the last 20 years. International Conference: Earth Cryosphere Assessment: Theory, Applications and Prognosis of Alterations, 29–31 May 2006, Tyumen City, Siberia.

Poster presentations

Romanovsky, V., S. Smith, J. Brown, O. Humlum and S. Marchenko. 2006. The thermal state of permafrost: A contribution to the International Polar Year. Invited poster presented at the European Geosciences Union General Assembly, Vienna, Austria, 2–7 April 2006.

Publications

Non-peer-reviewed

Romanovsky, V.E. 2006. Thermal state of permafrost in Alaska during the last 20 years. In: Proceedings of the International Conference: Earth Cryosphere Assessment: Theory, Applications and Prognosis of Alterations, Vol. 1, pp. 96–101.

Romanovsky, V.E. 2006. Permafrost in Alaska during the last 20 years. National Institute for Environmental Studies, Tsukuba, Japan, *Center for Global Environmental Research Newsletter*, 17(1):9–10 (in Japanese).

Richter-Menge, J., J. Overland, A. Proshutinsky, V. Romanovsky, J.C. Gascard, M. Karcher, J. Maslanik, D. Perovich, A. Shiklomanov and D. Walker. 2006. The Poles: Arctic. In: K.A. Shein, Ed., State of the Climate in 2005. *Bulletin of the American Meteorological Society*, 87:S46–S52.

References

ACIA. 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, 140 pp.

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press, 1042 pp.

Climate Modeling

Initiation of Arctic Reanalysis Activity in SEARCH

David Bromwich, PI
Ohio State University

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

Other investigators/professionals funded by this project:
Keith Hines and Lesheng Bai, *Ohio State University*

CIFAR 13-055a: This project is ongoing.

Primary objectives

The project's two main objectives are (1) the adaptation of the Weather Research and Forecasting (WRF) model for use in the Arctic, and (2) an assessment of the performance of the ERA-40 reanalysis in the Arctic. Both objectives pertain to the design of an Arctic System Reanalysis (ASR), which will be performed for a period of at least several decades and will draw upon all available data for the Arctic atmosphere, sea ice, land surface and upper ocean.

Approach/methodology

Toward objective (1), WRF is tested with high-resolution mesoscale simulations for three different polar land surface types: (i) Permanent ice sheets, (ii) oceans and sea ice, and (iii) Arctic land. We performed simulations over Greenland on a 110×100 grid with 40 km horizontal resolution and 28 levels in the vertical. Previous work comparing MM5 (Mesoscale Model Version 5) with in-situ observations has shown that the Greenland domain

represents an ideal opportunity to test and improve the physical parameterizations for mesoscale polar simulations (Bromwich et al. 2001). The model was tested for the winter month December 2002 and the summer month June 2001. Results were compared to Automatic Weather Station (AWS) data of the Greenland Climate Network (GC-NET), radiation measurements at Summit camp and earlier Polar MM5 simulations for Greenland/Iceland area (Bromwich et al. 2005). Based upon the simulations, several polar-optimizations are included in the 4-layer NOAH (NCEP, Oregon State University, Air Force, Hydrologic Research Lab) land surface model. Simulations to test Polar WRF over the Arctic Ocean in comparison to the observations of the Surface Heat Budget of the Arctic (SHEBA) camp observations for 1997–1998, and over Arctic land in comparison to the Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) observations for the coastal site at Barrow, Alaska and the inland site at Atqasuk, Alaska have begun in collaboration with John Cassano of the University of Colorado.

Toward objective (2), the Polar Meteorology Group has also been examining the Arctic atmospheric circulation diagnosed by ERA-40. Previous research has revealed some significant differences between reanalysis winds from ERA-15 and NCEP-NCAR and those measured by independent rawinsonde observations (CEAREX) from the Atlantic Arctic (e.g., Francis 2002). This comparison has been re-evaluated and extended to ERA-40.

Research accomplishments/highlights/findings

- The NOAH land surface model has been optimized for simulations over ice sheets.
- The new Polar WRF now has similar skill to that of Polar MM5 for simulations over Greenland.
- The skill of atmospheric reanalyses is found to be much higher in the Arctic than the Antarctic, where the reanalyses are only reliable in the summer months prior to the modern satellite era.
- The largest differences between reanalyses in the Arctic are linked to the reanalyses' depiction of clouds and cloud radiative processes. ERA-40 captures the cloud variability much better than NCEP1, but the ERA-40 clouds are too optically thin for shortwave radiation.

NOAA relevance/societal benefits

The effort will lead to a regional atmospheric model optimized for use in the Arctic. When combined with data assimilation strategies developed by other ASR projects, the payoff will be a vehicle for the Arctic regional reanalysis that has been established as a high priority in SEARCH. The ASR will be a high-resolution regional prototype that complements the global reanalyses carried out by NCEP.

Research linkages/partnerships/collaborators and networking

The NOAA funding of the Arctic system reanalysis has supported the following investigators, with whom we have actively collaborated on this project (*see also the project report by J. Walsh*):
J. Tilley, University of North Dakota; M. Serreze, CIRES/University of Colorado; J. Walsh and X. Fan, University of Alaska Fairbanks; K. Manning and J. Powers, National Center for Atmospheric Research.
Additional collaboration with John Cassano, University of Colorado, began in FY06.

Education/outreach

The enhanced WRF model will be made available for general use. The Antarctic version of this model will be used for operational forecasting in support of logistical operations in Antarctica.

Presentations

Bromwich, D.H. and K.M. Hines. 2006. Development and testing of Polar WRF. Antarctic Meteorological Observation, Modeling, and Forecasting Workshop, Boulder, Colorado, 13–15 June 2006.

Hines, K.M. and D.H. Bromwich. 2006. Development and testing of Polar WRF. 7th WRF Users' Workshop, Boulder, Colorado, 19–22 June 2006.

Publications

Peer-reviewed

Bromwich, D.H. and S.-H. Wang. 2005. Evaluation of the NCEP/NCAR and ECMWF 15/40-yr reanalyses using rawinsonde data from two independent Arctic field experiments. *Monthly Weather Review,* 133:3562–3578.

In press

Bromwich, D.H., R.L. Fogt, K.I. Hodges and J.E. Walsh. A tropospheric assessment of the ERA-40, NCEP, and JRA-25 global reanalyses in the polar regions. *Journal of Geophysical Research,* in press.

In preparation

Hines, K.M. and D.H. Bromwich. Development and testing of Polar WRF. Part I. Ice sheet meteorology. In preparation for *Monthly Weather Review*.

References

Bromwich, D.M., J.J. Cassano, T. Klein, G. Heinemann, K.M. Hines, K. Steffen and J.E. Box. 2001. Mesoscale modeling of katabatic winds over Greenland. *Monthly Weather Review*, 129:2290–2309.

Bromwich, D.H., L-S. Bai and G.G. Bjarnason. 2005. High resolution regional climate simulations over Iceland using Polar MM5. *Monthly Weather Review,* 133:3527–3547.

Francis, J.A. 2002. Validation of reanalysis upper-level winds in the Arctic with independent rawinsonde data. *Geophysical Research Letters*, 29. doi: 10.1029/2001GL014578.

Initiation of an Arctic Reanalysis Activity in SEARCH

John E. Walsh, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

Other investigators/professionals funded by this project:
Xingang Fan, *University of Alaska Fairbanks*
Jeff Tilley *(University of North Dakota) [funded prior to FY06]*

Collaborators funded by NOAA:
David Bromwich*, Ohio State University*
Mark Serreze, *CIRES/University of Colorado at Boulder*

CIFAR 09-063: This project is complete.

Primary objectives

The project's main objectives were (1) an assessment of the performance of the atmospheric reanalyses in the Arctic, (2) tests of data assimilation strategies for Arctic regional models, and (3) the adaptation of the Weather Research and Forecasting (WRF) model for use in the Arctic. Work toward these objectivities contributes to the design of an Arctic System Reanalysis (ASR), a NOAA initiative for SEARCH (Study of Environmental Arctic Change). The ASR is intended to integrate all available observations into a consistent framework, providing a vehicle for monitoring and diagnosing changes in the Arctic atmosphere, sea ice, upper ocean and terrestrial components.

Approach/methodology

The Arctic output of global reanalyses (ERA-40, National Center for Atmospheric Research (NCAR)/National Centers for Environmental Prediction (NCEP)) was validated against observational data by the UAF, Colorado and Ohio State groups. Emphasis was placed on precipitation, clouds and radiative fluxes, and upper-air winds. The effects of assimilation of TOVS (TIROS Operational Vertical Sounder) data over sea ice received particular emphasis because the assimilated profiles impact the upper-air winds, thermal structure and cloud distribution. The radiative fluxes and cloud-radiative interactions in ERA-40 were compared with in situ measurements, including those from the Department of Energy's (DoE) intensive observing sites on the North Slope of Alaska.

Three-dimensional variational (3DVAR) data assimilation methodologies were explored with the MM5 (Mesoscale Model Version 5) model in conjunction with experiments addressing sensitivity to resolution. The experiments included assimilation of various combinations of observation types, and were performed on domains of different sizes. The experiments with different nudging and blending strategies were performed for typical synoptic regimes and for extreme events affecting the Arctic in different seasons the past several years. This task involved the North Dakota and UAF groups.

The choice of the land surface module for an Arctic System Reanalysis was addressed through an intercomparison of land surface model performance in cold regions. Particular attention was given to an assessment of the community NOAH (NCEP, Oregon State University, Air Force, Hydrologic Research Lab) land surface model. This task was performed by the Colorado group.

Toward the objectives listed above, the Ohio State group tested Polar-MM5 over a Greenland domain and experimented with parameterizations of Arctic processes. Emphases included topographically affected flows in the Arctic, ice–ocean surface fluxes, Arctic stratus, etc. Variables receiving particular attention were precipitation and winds over Greenland. (See report by collaborator D. Bromwich, funded through a separate award.)

Research accomplishments/highlights/findings

- A workshop on high-latitude reanalysis was held in April 2006 in Cambridge, UK. Three of the present project's investigators (Bromwich—workshop co-organizer, Walsh, Serreze) made presentations at the workshop and at the European Centre for Medium-Range Weather Forecasts. These presentations have been synthesized into a review of the high-latitude performance of global reanalyses, submitted to *Journal of Geophysical Research* (Bromwich et al., submitted).
- On the basis of evaluations and workshops, the decision has been made to employ the WRF model in an Arctic System Reanalysis. Bromwich, Serreze and Walsh, in collaboration with NCAR, have submitted a proposal to carry out ASR with WRF has been submitted to the National Science Foundation (May 2006), building on the results of this NOAA-supported pilot project.
- Full year MM5 forecasts have been completed for a pan-Arctic domain, using a 3DVAR assimilation scheme. The simulations have been performed with and without the assimilation of TOVS (TIROS Operational Vertical Sounder) data. The results show that the MM5 captures low-threshold precipitation events more skillfully than do the global reanalyses, NCEP/NCAR and ERA-40. The TOVS assimilation results in small improvements of the MM5-derived precipitation. Results are described by Fan et al. (submitted). (Work done at UAF).
- The implementation into WRF of high-latitude parameterizations used in Polar-MM5 has been initiated by the Ohio State group. These parameterizations will be critical to capturing the variations of the polar boundary layer, clouds, precipitation and radiative fluxes in an Arctic System Reanalysis. (Work done primarily by project co-investigators at Ohio State).
- Comparisons with in situ measurements at the DoE's Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) site show that ERA-40 captures cloud variability much better than NCEP/NCAR in the Arctic. However, the ERA-40 clouds are too optically thin for shortwave radiation, resulting in unrealistic cloud-radiative forcing, especially with partial cloud fractions. The NCEP/NCAR reanalysis shows more plausible cloud-radiative forcing, although its simulated cloudiness does not vary consistently with observations (Bromwich et al., submitted). (Work done primarily at UAF).
- ERA-40's aerological water budget for the Arctic was found to be quite good. Compared to NCEP/NCAR, the atmospheric and surface budget is well closed. However, ERA-40's precipitation fields over central Arctic were found to be problematic, especially during summer, but much improved in comparison to the NCEP/NCAR reanalysis (Serreze et al. 2005). (Work done primarily by project co-investigators at the University of Colorado).
- The ERA-40 data assimilation scheme for 2-m temperatures was found to provide realistic fields over topographically complex terrain, indicating suitability for the Arctic System reanalysis. (Work done primarily by project co-investigators at the University of Colorado).
- The community NOAH land surface model that will likely be used in the Arctic System Reanalysis was found to suffer from non-conservation of water and energy, and to produce excessive evaporation over snow-covered surfaces. Pilot investigations demonstrate that assimilation of soil temperatures through Kalman filtering approaches could be incorporated as a post-processing step in an Arctic System Reanalysis framework, thereby mitigating this deficiency in NOAH. (Work done by co-investigators at the University of Colorado).
- Output from the ERA-40 reanalysis was used in a synthesis of information on the large-scale freshwater cycle of the Arctic. The freshwater sources, sinks and fluxes in atmosphere, ocean and land components of the Arctic system are presented in a quantitative framework by Serreze et al. (*Journal of Geophysical Research*, accepted). (Work done primarily by co-investigators at the University of Colorado).

NOAA relevance/societal benefits

The ASR, for which this project provides input to the design, will permit the integration of all available observations into a consistent framework, providing a vehicle for monitoring and diagnosing environmental change in the Arctic. As such, it will contribute directly to the NOAA mission goals of (1) documenting and understanding climate variability and change in the Arctic, and (2) serving society's need for weather and water information. More specifically, ASR will be a high-resolution regional prototype that complements the global reanalyses carried out by NCEP.

Research linkages/partnerships/collaborators and networking

In addition to the UAF investigators supported by this award, NOAA funding of the Arctic System Reanalysis also supported David Bromwich, Ohio State University (see separate project report) and Mark Serreze, University of Colorado/CIRES.

Workshops in the U.K. during April 2006 led to plans for continued collaboration with the European Centre for Medium-Range Weather Forecasts (ECMWF) via access to the operational analyses that are serving as updates to ERA-40. This collaboration will extend to our provision to ECMWF of relevant Arctic findings during the planning for ECMWF's next global reanalysis.

The results of the collective effort were reported at the U.S./Sino Workshop on Arctic Climate and discussed with potential Chinese collaborators in Beijing (27–28 July 2004).

The work to evaluate the NOAH land surface model was coordinated with Dr. Ken Mitchell, NOAA/NCEP.

Interaction with the NOAA Boulder Labs (including the NOAA Climate Diagnostics Center) has been ongoing through our participation in workshops in Boulder and conferences in other venues.

A proposal to carry out ASR with WRF has been submitted to the National Science Foundation (May 2006), building on the results of this NOAA-supported pilot project.

Education/outreach

The enhanced WRF model will be made available for general use. The Antarctic version of this model is currently used for operational forecasting in support of logistical operations in Antarctica.

Poster presentation (this reporting period)

Fan, X., J. Krieger and J. Walsh. 2005. Simulation study of an arctic extreme cyclone with 3DVAR assimilation. Poster presentation at American Geophysical Union Annual Meeting, San Francisco, California, 5–9 December 2005.

Oral presentations (this reporting period)

Bromwich, D. 2006. Assessment of the existing reanalyses: the Antarctic. Presentation at Workshop on High-Latitude Reanalysis, British Antarctic Survey, Cambridge, UK, 8–9 April 2006.

Bromwich, D. 2006. Assessment of the existing reanalyses: the Antarctic. Presentation at European Center for Medium-Range Weather Forecasts, Reading, UK, 10 April 2006.

Serreze, M. 2006. Assessment of the existing reanalyses: the Arctic. Presentation at Workshop on High-Latitude Reanalysis, British Antarctic Survey, Cambridge, UK. 8–9 April 2006.

Walsh, J. 2006. Clouds and radiation in atmospheric reanalysis. Presentation at Workshop on High-Latitude Reanalysis, British Antarctic Survey, Cambridge, UK, 8–9 April 2006.

Walsh, J. 2006. Clouds and radiation in atmospheric reanalysis. Presentation at European Center for Medium-Range Weather Forecasts, Reading, UK, 10 April 2006.

Publications (over the life of the project to date)

Peer-reviewed

Bromwich, D.H. and S.-H. Wang. 2005. Evaluation of the NCEP-NCAR and ECMWF 15- and 40-yr reanalyses using rawinsonde data from two independent Arctic field experiments. *Monthly Weather Review, 133*(12):3563–3578.

Fan, X. and J.S. Tilley. 2005. Dynamic assimilation of MODIS-retrieved humidity profiles within a regional model for high latitude forecast applications. *Monthly Weather Review*, 133(12):3450–3480. doi:10.1175/MWR3044.1

Frauenfeld, O.W., T. Zhang and M.C. Serreze. 2005. Climate change and variability using European Centre for Medium Range Weather Forecasts reanalysis (ERA-40) temperatures on the Tibetan Plateau. *Journal of Geophysical Research*, 110, D02101. doi:10.1029/2004JD005230. *(FY05; previously reported)*

Serreze, M.C., A. Barrett and F. Lo. 2005. Northern high latitude precipitation as depicted by atmospheric reanalyses and satellite retrievals. *Monthly Weather Review*, 133(12):3407–3430.

Non-peer-reviewed

Fan, X., J.R. Krieger, X. Meng, R.W. Smith and J.E. Walsh. 2005. Assimilation of MODIS retrievals with the MM5/3DVAR system in an Arctic extreme rain event. Preprints, *Eighth Conference on Polar Meteorology and Oceanography*, AMS, San Diego, California, 9–13 January 2005, P3.19. *(FY05; previously reported)*

Fan, X., J.S. Tilley and J.E. Walsh. 2004. Application of MM5/3DVAR at high latitude: Resolution sensitivity. Preprints, *Fifth WRF/14th MM5 User's Workshop*, NCAR, June 22–25, 2004, Boulder, Colorado, 5.10. *(FY04; previously reported)*

Tilley, J.S., X. Fan and J.E. Walsh. 2005. Application of a mesoscale 3DVAR system at high latitudes as a step towards Arctic reanalysis. Preprints, *Eighth Conference on Polar Meteorology and Oceanography*, AMS, San Diego, California, 9–13 January 2005, JP2.11. *(FY05; previously reported)*

In press or accepted

Bromwich, D.H., R.L. Fogt, K.I. Hodges and J.E. Walsh. A tropospheric assessment of the ERA-40, NCEP, and JRA-25 global reanalyses in the polar regions. *Journal of Geophysical Research*, in press.

Serreze, M.C., A. Barrett, A.J. Slater and 7 others. The large-scale freshwater cycle of the Arctic. *Journal of Geophysical Research,* accepted for publication.

Submitted or in preparation

Fan, X., J.S. Tilley and J.E. Walsh. Application of 3D variational assimilation at high latitudes: Resolution sensitivity. Submitted to *Scientific Online Letters of the Atmosphere (SOLA).*

Serreze, M.C., A.P. Barrett, A.G. Slater, M. Steele, J. Zhang and K.E. Trenberth. The heat budgets of the North Polar Cap and Arctic Ocean as represented by atmospheric reanalyses and other data sources. In final stage for submission to *Journal of Geophysical Research (Atmospheres)*.

Slater, A.G., T.J. Bohn, J.L. McCreight, M.C. Serreze and D.P. Lettenmaier, A multi-model ensemble of pan-Arctic hydrology. In final stage for submission to *Journal of Geophysical Research (Biogeosciences).*

Contaminant Effects

Sources of Mercury Reaching the Arctic – Airborne Particulate Mercury in China

Catherine F. Cahill, PI ***NOAA Goal: Understand Climate Variability and Change***
University of Alaska Fairbanks

CIFAR 06-042: This project is complete.

Primary objectives

The primary objectives of this project are 1) to determine the quantity of mercury in atmospheric aerosols originating in China that is reaching the Arctic and 2) to establish a collaborative working relationship with Chinese scientists.

Approach/methodology

The scientific approach used to reach the goals of this project is to collect and analyze size- and time-resolved aerosol samples from China and the Arctic for their chemical, including mercury, composition. A 3-stage DRUM aerosol impactor collects the aerosol samples which are then analyzed for mass by β-gauge, optical absorption by Ultra-Violet/visible spectroscopy, organic content by proton elastic scattering analysis and selected elements from sodium through uranium by synchrotron X-ray fluorescence. The Chinese research vessel, the *Xue Long*, collected the aerosol samples during the Second Chinese National Arctic Research Expedition (CHINARE II) and the 19th Chinese Antarctic Research Expedition (CHINARE 19). The second goal, establishing collaborative working relationships with Chinese scientists, involved identifying and working with the Chinese scientists best able to collaborate with the U.S. Principal Investigator (PI). Identifying the best scientists in China for the collaborative aspects of this work occurred during NOAA-sponsored meetings in China. Scientists identified during these meetings are now jointly conducting the research described above.

Research accomplishments/highlights/findings

- The aerosols observed during the CHINARE 19 (Antarctic) and CHINARE II (Arctic) cruises demonstrate the difference in aerosol compositions and sources between the Antarctic and Arctic (Figures 1–3). Locally generated aerosols dominate Antarctica's anthropogenic aerosols, while more distant sources produce the anthropogenic aerosols observed in the Arctic.
- The particulate mercury concentrations observed during both CHINARE 19 and CHINARE II were low except during periods of anthropogenic influence, such as near the coast of China and in the Norilsk smelter pollution plume.
- The elements produced by anthropogenic sources, such as fossil fuel power generation (sulfur, some silicon, and nickel), and natural sources, such as soils (most of the silicon), decreased during CHINARE 19 as the ship moved towards Antarctica (Figure 1). However, peaks occurred in these elements when the *Xue Long* was near Antarctic research stations or in port, implying that the stations are producing local pollution.
- Figure 2 shows a high correlation between sulfur, silicon and nickel for much of CHINARE II. This is due to the impact of the *Xue Long*'s exhaust, which contains those elements, on the air sampler. This impact is not observed as often in CHINARE 19 because the ship was underway for most of the cruise and the overall winds caused the ship's exhaust to be blown away from the sampler.

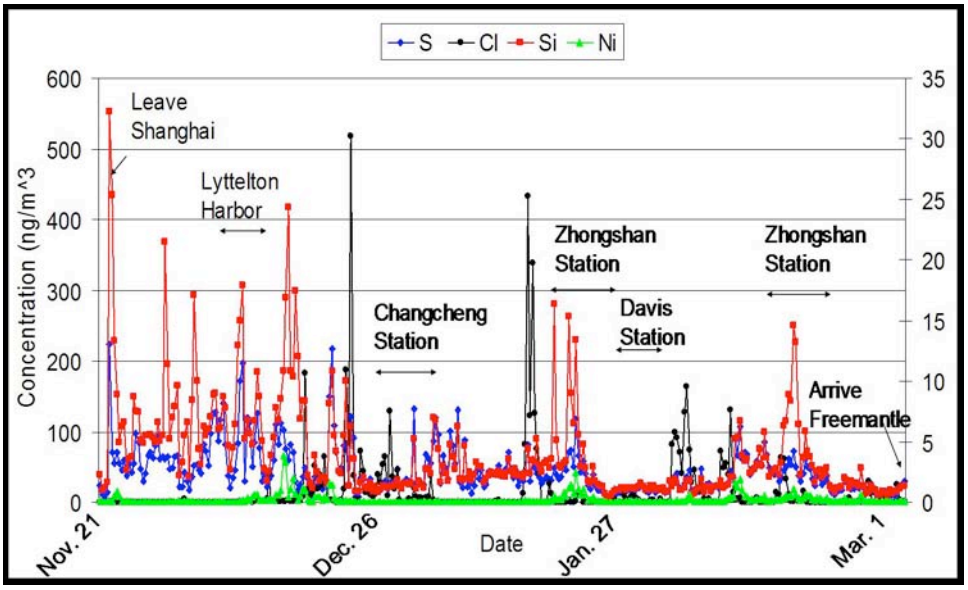

Figure 1. Selected Elements for CHINARE 19 (0.34–1.15 um in aerodynamic diameter. Si and Ni plotted on secondary axis.).

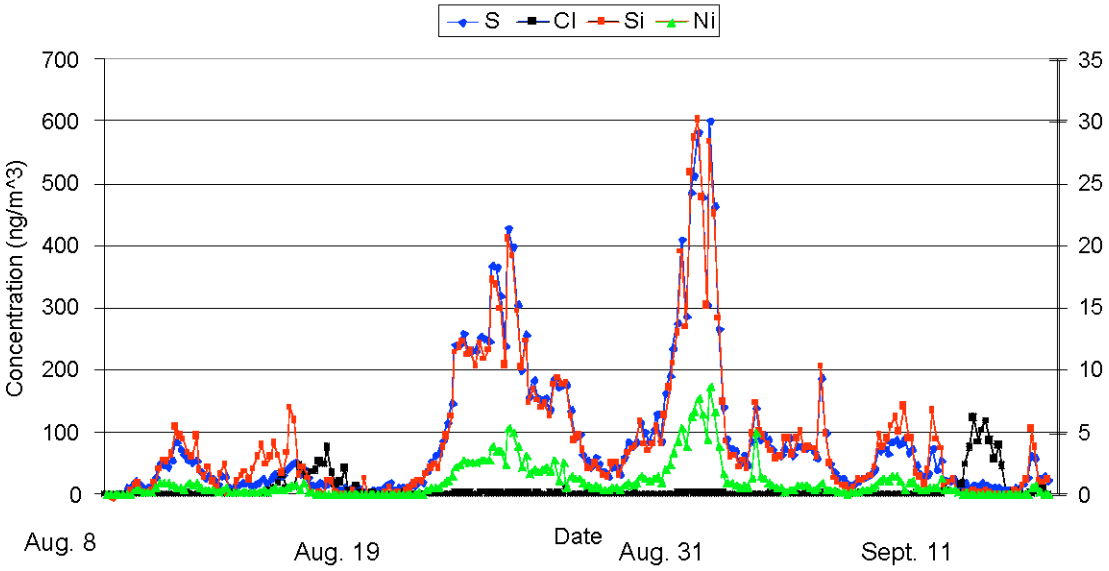

Figure 2. The same selected 0.34–1.15 um aerodynamic diameter aerosol elements as in Figure 1 except during CHINARE II.

- A comparison of Figure 2 and Figure 3 shows that copper does not correlate with ship exhaust impact periods during CHINARE II. This, and the episodic nature of the copper plumes, implies that some other source, probably anthropogenic, is impacting the aerosol composition during these periods. Meteorological back trajectories from the NOAA Air Resources Laboratory (ARL) HYSPLIT transport and dispersion model and the composition of the aerosols during these periods suggest that the emissions are coming from Norilsk, Russia.
- The good relationship between the PI and Chinese scientists led to the collection of aerosols during August 2004 at the new, established in 2004, Chinese Yellow River Station in Ny Alesund. These samples have undergone chemical analyses and the final data analysis is almost complete.

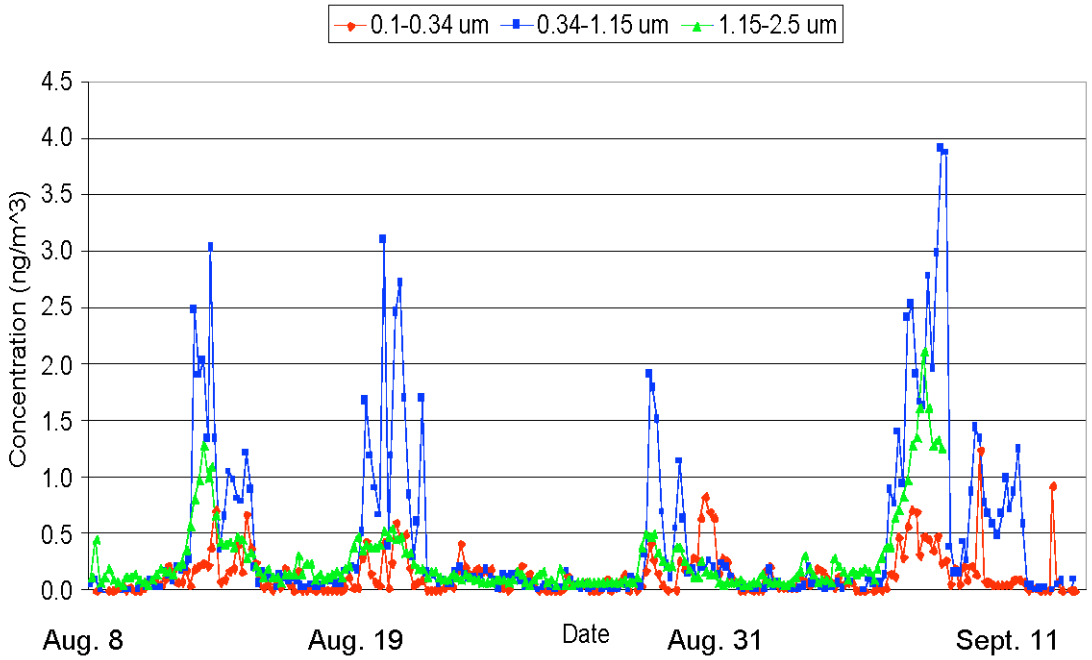

Figure 3. Copper in three different aerosol size bins during CHINARE II.

NOAA relevance/societal benefits

This research advances NOAA's goals of understanding the sources of aerosols, particularly mercury, impacting the peoples and ecosystems of the Arctic. The data obtained during this project will be used to determine potential aerosol deposition fluxes into and radiative impacts over the Bering and Chukchi Seas. It also fulfills the NOAA goals outlined by the U.S.–China Polar Science Panel by developing working relationships with Chinese scientists conducting Arctic research.

Research linkages/partnerships/collaborators and networking

This project was successful in developing relationships between the PI and scientists from the Chinese Arctic and Antarctic Administration, the Polar Research Institute of China and the Third Institute of Oceanography. These relationships have led to funding from outside sources (John Hopkins University–Applied Physics Laboratory Grant. *University Partnering for Operational Support—China Dust Aerosol Measurement and Model Validation.* 10/01/02–10/30/04. $65,000; National Park Service. *Relocation of Interagency Arctic Air Quality Monitoring Site.* 5/31/06–5/30/07. $9,575) and will lead to additional joint research between the participants. The papers resulting from this project will also include Russian authors so the networking resulting from this project will reach beyond China and the United States. In addition, the PI is contemplating visiting the Chinese Arctic and Antarctic Administration personnel during her next sabbatical.

A forthcoming Department of Defense project by the PI is a result of the proof of principle demonstrated using the samplers on mobile platforms like the R/V *Xue Long* and the method sensitivities demonstrated in this NOAA-funded project. The Chinese Arctic and Antarctic Administration now own an unmanned aerial vehicle (UAV) and I will propose testing some of the equipment developed on the earmark project on the Chinese UAV. Army Research Laboratory. "Airborne Sensors for Airborne Threats." 10/1/06–9/30/09. $3,000,000

Education/outreach

Data obtained from this research was used as an example of transport from Asia into Alaska and the Arctic during an NSF-sponsored Arctic Climate Monitoring Program videoconference to schools throughout the Bering School District. The students asked questions relating to the transport and its potential impacts on them, the climate around the Bering Sea and their subsistence foods. It was also used as a part of Aerosol Transport to the Arctic, a lecture given by the PI in an NSF-sponsored Research Experiences for Undergraduates Program.

Publications

No journal publications have been submitted yet, but three papers are in preparation. The first is a paper to the *Journal of Geophysical Research* on the transport of aerosols, especially mercury, to the Arctic from China. The

paper will include results from CHINARE II and the 2004 RUSALCA research cruise. The Ny Alesund and CHINARE II aerosol samples are being included in a paper on the impacts of Norilsk, Russia, on Arctic aerosol compositions and effects. Also, a comparison of the transport of Chinese emissions into the Antarctic and Arctic is being prepared for the *Journal of Geophysical Research*. As reported last year, the work also appeared in the proceedings of the 2005 American Meteorological Society Annual Meeting.

Arctic Monitoring and Assessment Programme (AMAP)

Lars-Otto Reiersen, PI
Executive Secretary, AMAP

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 21-052c: The support to the AMAP project has funded 7 sub-projects; Five of these sub-projects (numbers 1, 4, 5, 6 and 7) have been essentially completed; sub-projects 2 and 3 are due to be completed during the Fall of 2006. A status of all 7 sub-projects is presented below.

1. Analysis and modelling of new mercury data and support to an intensive field project on mercury at Barrow, Alaska.

Primary objectives
To study the "Sunrise phenomena" in more detail to understand the mechanisms and the size of the phenomena.

Approach/methodology
Different methods have been used to study the washout of mercury from the atmosphere and its relation to changes in ozone, UV and climate.

Research accomplishments/highlights/findings
- Data was collected during the winter and spring of 2004 at Barrow.
- A workshop was held in December 2004 in Tennessee, USA. Scientists from several Arctic countries participated, e.g., Canada, Denmark, Norway and USA.
- The data has been analyzed and will be reported in a special AMAP report when ready.
- Follow-up projects in connection with the International Polar Year (IPY) have also been prepared.

NOAA relevance/societal benefits
The study is highly relevant to NOAA and work related to atmospheric processes linked to climate change, UV/ozone and pollution.

Research linkages/partnerships/collaborators and networking
Scientists from National Atmospheric Research Institutes in Canada, Denmark, Norway, Russia and USA engaged in this study and are continuing to work closely on the issue of concern. This includes preparation of proposals for work under the IPY.

Publications
Papers for the scientific literature are under preparation and the results of the work will be incorporated in the next AMAP update report on this issue.

2. Arctic Council joint assessment on Oil and Gas, to be presented in 2006.

Primary objectives
To assess the situation related to oil and gas activities within the Arctic region, including ongoing and future plans for activities, the effects these activities might have on social life and the economy within the region, and the pollution situation and future threats.

Approach/methodology
Expert groups have been established for each of the main topics. Different assessment methods have been applied by scientists and experts from the eight Arctic countries. The work is to a far extent based on existing data.

Research accomplishments/highlights/findings

- An International Symposium was arranged in St. Petersburg, Russia in September 2005 as part of the assessment process. International workshops to prepare the assessment have been held in Washington, DC, USA, in January 2004; Oslo, Norway, in September 2004; Helsinki, Finland, in February 2005; Washington, DC, USA, in June 2005; Copenhagen, Denmark, in April 2006; and The Hague, Netherlands, in July 2006. The next meeting is planned for Victoria, Canada, in September 2006.
- A baseline survey to document the levels of hydrocarbons in Arctic Seas and Adjacent Seas has been performed and results are under evaluation.

NOAA relevance/societal benefits

This project is highly relevant to NOAA in relation to issues such as pollution of the marine environment.

Research linkages/partnerships/collaborators and networking

Links have been established to scientists and research institutes in the eight Arctic countries.

Education/outreach

The activity has been presented to the Arctic Council and the Barents Council.

Publications

Under preparation for release in 2006/2007.

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3. AMAP assessment on acidification and effects of acidifying substances, to be presented in 2006.

Primary objectives

To assess the situation related to acidification of Arctic areas, and Arctic haze, to document any trends and effects at hot spot sites and on a circumpolar level.

Approach/methodology

Expert groups have been established for each of the main topics. Different assessment methods have been applied by scientists and experts from the eight Arctic countries. The work is to a far extent based on existing data.

Research accomplishments/highlights/findings

The assessment work has been completed and assessment products are under preparation. International workshops were held in Helsinki, Finland, January 2004 in Kilpisjärvi, Finland, March 2005, and in Tromsø, Norway, October 2005.

NOAA relevance/societal benefits

This project is highly relevant to NOAA's work with atmospheric pollution, and climate change.

Research linkages/partnerships/collaborators and networking

Links have been established to scientists and research institutes in the eight Arctic countries.

Education/outreach

The activity has been presented to the Arctic Council and the Barents Council.

Publications

Under preparation for release in October 2006 as hard copy and as an electronic document from www.amap.no

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4. Production of the ACIA reports.

Primary objectives

The primary objective of ACIA (Arctic Climate Impact Assessment) is to assess changes in climate and UV/ozone and its effects on Arctic environment and human life.

Approach/methodology
Expert groups have been working with the main topics over the last several years. Different assessment methods have been applied by scientists and experts from the eight Arctic countries. Based on selected scenarios from IPCC models have been used as a core part of the assessment work. The work has been based on existing data.

Research accomplishments/highlights/findings
The assessment work has been completed. The ACIA Overview report, *Impacts of a Warming Arctic*, was published in November 2004 and the full scientific report was published in October 2005. A close cooperation has been established among scientists in the eight Arctic countries and some countries that are involved in Arctic climate and UV research. There will be several additional publications in international journals over the years to come.

NOAA relevance/societal benefits
This project is highly relevant to NOAA and its work related to climate change and ozone/UV.

Research linkages/partnerships/collaborators and networking
Links have been established to scientists and research institutes in the eight Arctic countries.

Education/Outreach
- The ACIA Overview report has been presented to the Arctic Council, the Barents Council, the IPCC process and at several international meetings and organizations. The scientific background report should be very useful as a textbook at schools and Universities.
- A special film/video presenting the ACIA results was prepared and has been widely distributed.

Publications
Arctic Climate Impact Assessment. 2004. Impacts of A Warming Arctic. Cambridge University Press, 139 pp. This report has also been translated to German, Dutch, Russian, Norwegian and Saami languages, and a French language version is currently under preparation. All these reports are available as electronic documents from www.amap.no/acia

Arctic Climate Impact Assessment. 2005. Cambridge University Press, 1042 pp. (English Version only). The report can also be downloaded from www.acia.uaf.edu

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5. The 2004 ACIA climate and UV conference.

Primary objectives
To present the results from the ACIA assessment and the latest results related to changes in Arctic climate and ozone/UV from ongoing research and monitoring.

Approach/methodology
Standard procedure to call for an International conference was followed.

Research accomplishments/highlights/findings
The ACIA Symposium was arranged 9–12 November 2004 in Reykjavik, Iceland. More than 300 experts participated.

NOAA relevance/societal benefits
The Symposium was highly relevant to the work of NOAA; latest results from research and monitoring were presented and discussed.

Research linkages/partnerships/collaborators and networking
Not relevant for the practical arrangement of the symposium.

Education/Outreach
Special grants for young investigators were arranged.

Publications
A special Proceeding of all extended abstracts was prepared and is available from AMAP web site, www.amap.no

6. ICES symposium in Bergen.

Primary objectives
To bring forward the latest results from research and monitoring related to the issue of concern.

Approach/methodology
Standard procedure to call for an International conference was followed.

Research accomplishments/highlights/findings
The symposium "Influence of Climate Change on North Atlantic Fish Stocks" took place 11–14 May 2004 in Bergen, Norway, and a special proceedings volume has been prepared.

NOAA relevance/societal benefits
The Symposium was highly relevant to the work of NOAA, and its work with marine systems and climate change.

Research linkages/partnerships/collaborators and networking
Not relevant for the practical arrangement of the symposium.

Publications
A special Proceeding of all presentations has been prepared and is available from ICES (www.ices.dk).

7. The Second International Conference on Arctic Research and Planning (ICARPII).

Primary objectives
The goal of ICARP II was to evaluate Arctic research priorities to guide international cooperation over the next 10–15 years.

Approach/methodology
Standard procedure to call for an International conference was followed.

Research accomplishments/highlights/findings
The Second International Conference on Arctic Research and Planning was arranged 10–13 November 2005 in Copenhagen, Denmark. More than 450 experts participated.

NOAA relevance/societal benefits
The Conference was highly relevant to the work of NOAA; latest results from research and monitoring were presented and discussed and plans for future work, including IPY proposals, were developed.

Research linkages/partnerships/collaborators and networking
Not relevant for the practical arrangement of the Conference, but the outcome is highly relevant for Arctic scientists.

Education/Outreach
Special grants for young investigators were arranged.

Publications
A special Proceeding for all extended abstracts was prepared and is available from ICARP web site, www.icarp.dk

Relationship between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska

Milo Adkison, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 30-027d: This project is ongoing.

Primary objectives

This study will use archived scales from both adult and juvenile coho salmon to examine the relationships between growth during specific marine phases and subsequent survival to adult and size at maturity, and to evaluate how these parameters vary in relation to biophysical data sets. As a bonus, we contemplate making comparisons among growth and survival rates of female, male jack, and male hooknose fish to examine the costs and benefits of alternative life history choices.

Approach/methodology

Digitizing and analysis of Auke Creek scale collections. Archived scales taken from adult and jack coho salmon returning to Auke Creek weir are being digitized and analyzed to determine interannual growth patterns. Marine growth will be evaluated for three phases: juvenile nearshore/coastal; juvenile Gulf of Alaska; and adult.
Data management, analysis, and reporting. A data base of scale data will be created and linked to biological data on Auke Creek coho salmon and environmental data for nearshore waters of southeast Alaska and for the GOA. Relationships between scale growth, marine survival, size at return, and environmental data sets will be analyzed using appropriate statistical methodology.
Life history tradeoffs. Results to date were based on digitized images of juvenile coho captured in nearshore marine waters, and on scales of adult female coho returning to Auke Creek. In the next stage of the project, we will incorporate two additional data sets: (1) scale growth increments from adult males, both jacks (one summer at sea) and hooknose (one year plus a summer at sea), and (2) the sex ratio and characteristics of smolts emigrating from freshwater to saltwater. The literature provides both theoretical and empirical bases for expecting differences in growth and survival between the sexes (Holtby and Healey 1990) and between males employing the jack and hooknose reproductive strategies (Gross 1985, 1991; Young 1999). These new data will allow us to examine these differences in the Auke Creek stock and their implications for the interaction of coho salmon and the marine environment.

Research accomplishments/highlights/findings

- A manuscript describing patterns of survival has been published in a major fisheries journal. An additional manuscript describing growth patterns is in preparation.
- Josh Robins, a master's student supported by this project, will defend his thesis, "Factors affecting marine growth and survival of Auke Creek, Alaska coho salmon (*Oncorhynchus kisutch*): Phase II" in August 2006.

NOAA relevance/societal benefits

These studies will increase our understanding of the mechanisms by which processes in the Gulf of Alaska affect coho salmon population responses, and may lead to enhanced predictability of the response of the resource to changing climate conditions. Such information is important in developing robust management approaches that can respond to both times of high survival and abundance that have occurred recently in much of Alaska, as well as for conservation and maintenance of coho salmon populations when climatic conditions shift.

Research linkages/partnerships/collaborators and networking

The principal linkages are between the University of Alaska Fairbanks and personnel at NOAA's Auke Bay Laboratory pursuing complementary research projects funded by US GLOBEC. Alex Wertheimer is most heavily involved in the CIFAR-supported studies, serving on the committees of the graduate student research assistants. Other associated NOAA personnel include Gerri Taylor, Joe Orsi, and William Heard. Wertheimer and Taylor are co-authors (along with Adkison and Briscoe) of the two journal manuscripts prepared to date.

Education/outreach

Two graduate students have been fully supported for master's theses on this research project. The first, Ryan Briscoe, graduated in December 2004 after 2.5 years of support. The second, Josh Robins, started his research two year ago and will make a public thesis defense in early August.

Publications

Peer-reviewed

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. 2005. Biophysical factors associated with the marine survival of Auke Creek, Alaska coho salmon. *Transactions of the American Fisheries Society*, 134:817–828.

In preparation

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. Factors influencing marine growth of Auke Creek, Alaska coho salmon. In preparation.

References

Gross, M.R. 1985. Disruptive selection for alternative life histories in salmon. *Nature*, 313:47–48.

Gross, M.R. 1991. Salmon breeding behavior and life history evolution in changing environments. *Ecology*, 72:1180–1186.

Holtby, L.B. and M.C. Healey. 1990. Sex-specific life history tactics and risk-taking in coho salmon. *Ecology,* 71:678–690.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society*, 78:1069–1080.

Young, K.A. 1999. Environmental correlates of male life history variation among coho salmon populations from two Oregon coastal basins. *Transactions of the American Fisheries Society*, 128:1–16.

Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt

Milo Adkison, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 24-040c: This project is ongoing.

Primary objectives

- To determine if Bristol Bay sockeye salmon production is influenced by early marine growth rates.
- To identify the relationship between environmental conditions and early marine growth of juvenile sockeye salmon in the eastern Bering Sea.

Approach/methodology

The approach to analyzing early marine growth of Bristol Bay sockeye salmon will be broken into two parts: 1) a retrospective analysis, relating early marine growth of Bristol Bay sockeye salmon to adult salmon production and changes in the marine environment using time series analyses; and 2) a model of growth potential relating environmental characteristics (forage density and water temperature) to juvenile sockeye salmon biological characteristics (growth, distribution, diet, and thermal experience) to make relative comparisons of juvenile sockeye salmon growth rate potential between oceanographic habitats (coastal, middle, and outer domains; see Kinder and Schumacher (1981) for description of physical habitat in the eastern Bering Sea) and years.

Data for the retrospective analysis of early marine growth are from previously digitized (annulus and circuli growth) sockeye salmon scales (1959–2000) from the Kvichak (age classes 1.2, 1.3, 2.2, and 2.3) and Egegik (age classes 1.3, 2.2, and 2.3) River systems. Early marine growth rates of juvenile sockeye salmon taken from the first marine growth year, adult survival, and changes in the environment will be modeled using univariate and multivariate Time Series Analysis (Wei 1990). Factors affecting early marine growth rate potential will be analyzed using data from annual fall surveys (1999 to 2003) of juvenile sockeye salmon in the eastern Bering Sea conducted by the Ocean Carrying Capacity program (Farley et al. 1999; 2000; 2001) and explored using a spatially explicit model of growth potential (Brandt et al. 1992; Brandt and Kirsch 1993; Mason et al. 1995; Nislow et al. 2000).

Research accomplishments/highlights/findings

- Juvenile sockeye salmon primary prey was Pacific sand lance during 2000–2001 and age-0 pollock during 2002–2005.

- The relative abundance of age-0 pollock increased each year from 2000–2003.
- The size of juvenile sockeye salmon increased each year from 2000–2003.
- A manuscript titled "Early marine growth in relation to marine stage survival rate for Alaska sockeye salmon (*Oncorhynchus nerka*)" is in press with *Fishery Bulletin*.
- A manuscript is in preparation titled "Annual variability in distribution, size, feeding, condition, and habitat associations of juvenile Bristol Bay Sockeye salmon along the eastern Bering Sea shelf."

NOAA relevance/societal benefits

These studies will increase our understanding of the mechanisms by which smolt growth as a function of nearshore processes affects sockeye salmon population responses, and may lead to enhanced predictability of the response of the resource to changing climate conditions. Such information is important in developing robust management approaches that can respond to both times of high survival and abundance that have occurred recently in much of Alaska, as well as for conservation and maintenance of sockeye salmon populations when climatic conditions shift.

Research linkages/partnerships/collaborators and networking

The principal linkages are between the University of Alaska Fairbanks and personnel at NOAA's Auke Bay Laboratory. Ed Farley, employed at the Auke Bay lab, is a graduate student leading this study. Jack Helle is also involved.

Education/outreach

One graduate student, Ed Farley, is basing his Ph.D. on this research. Farley has presented his research results in local, statewide, and international scientific symposia including:

- October 2005: A review of the critical size, critical period hypothesis for juvenile Pacific salmon. NPAFC/PICES Symposium, Jeju, South Korea
- October 2005: Interannual and spatial variations in water mass properties, plankton, nutrients, juvenile salmon and age-0 pollock during fall in the eastern Bering Sea. NPAFC/PICES Symposium, Jeju, South Korea
- April 2006: A summary of juvenile salmon research along the eastern Bering Sea shelf, August–September 2001–2005. NPAFC juvenile salmon workshop, Sapporo, Japan.
- April 2006: Spatial patterns in consumption demand and growth potential of juvenile pink salmon (*Oncorhynchus gorbuscha*) in the Gulf of Alaska. NPAFC juvenile salmon workshop, Sapporo, Japan.

Publications

In press or in preparation

Farley, E.V. Jr., J.M. Murphy, M.D. Adkison, L.B. Eisner, J.H. Helle, J.H. Moss and J. Nielsen. Early marine growth in relation to marine stage survival rate for Alaska sockeye salmon (*Oncorhynchus nerka*). *Fishery Bulletin*, in press.

Annual variability in distribution, size, feeding, condition, and habitat associations of juvenile Bristol Bay sockeye salmon along the eastern Bering Sea shelf. In preparation.

References

Brandt, S.B. and J. Kirsch. 1993. Spatially explicit models of striped bass growth potential in Chesapeake Bay. *Transactions of the American Fisheries Society*, 122:845–869.

Brandt, S.B., D.M. Mason and E.V. Patrick. 1992. Spatially-explicit models of fish growth rate. *Fisheries*, 17(2):23–31, 34–35.

Farley, E.V. Jr., J.M. Murphy, R.E. Haight, C.M. Guthrie III, C.T. Baier, M.D. Adkison, V.I. Radchenko and F.R. Satterfield. 1999. *Eastern Bering Sea (Bristol Bay) Coastal Research on Bristol Bay Juvenile Sockeye Salmon, July and September 1999*. (NPAFC Doc. 448) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626. 22 pp.

Farley, E.V. Jr., R.E. Haight, C.M. Guthrie and J.E. Pohl. 2000. *Eastern Bering Sea (Bristol Bay) Coastal Research on Juvenile Salmon, August 2000*. (NPAFC Doc. 499) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626. 18 pp.

Farley, E.V. Jr., C.M. Guthrie III, S. Katakura and M. Koval. 2001. *Eastern Bering Sea (Bristol Bay) Coastal Research (August and September 2001) on Juvenile Salmon*. (NPAFC Doc. 560) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626. 19 pp.

Kinder, T. and J.D. Schumacher. 1981. Hydrographic structure over the continental shelf of the southeastern Bering Sea. In: D.W. Hood and J.A Calder (Eds.). *The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. 1*. OMPA/NOAA, distributed by University of Washington Press, Seattle, pp. 31–52.

Mason, D.M., A. Goyke and S.B. Brandt. 1995. A spatially explicit bioenergetics measure of habitat quality for adult salmonines: comparison between Lakes Michigan and Ontario. *Canadian Journal of Fisheries and Aquatic Sciences*, 52:1572–1583.
Nislow, K.H., C.L. Folt and D.L. Parrish. 2000. Spatially explicit bioenergetic analysis of habitat quality for age-0 Atlantic salmon. *Transactions of the American Fisheries Society,* 129:1067–1081.
Wei, W.W.S. 1990. *Time Series Analysis: Univariate and Multivariate Methods*. Addison-Wesley Publishing Company, Redwood City, California. 478 pp.

Inter-decadal Change in Sablefish Growth and Maturity in the Northeast Pacific Ocean: Year 1

Milo Adkison, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 16-084: This project is ongoing.

Primary objectives
- Assemble data on size-at-age and maturity-at-age.
- Determine how to account for confounding factors such as location, season, and method of capture.
- Determine if sablefish size-at-age and maturity-at-age have shifted over the period 1981 to 2003.

Approach/methodology
Data - Data available for analysis span 1981 to 2003 and include age, length, weight, and maturity data. Age and length data are available every other year from 1981 to 1993. Age, length, weight, and maturity data are available every year from 1996 to 2003. Environmental indices are available from sources such as the National Climate Data Center and NOAA's Pacific Marine Environmental Laboratory, among other places.
Analysis of change in growth and maturity at age - Size distributions and percent mature at age will be examined for temporal trends using graphical and statistical analyses. Where they exist, differences due to confounding factors such as depth or region (Sigler et al. 1997) will be incorporated in the analyses.
Relationship between trends and environmental indices - If temporal patterns in growth and age at maturity are observed, we will search for environmental correlates. Statistical significance of relationships will be tested. If strong temporal autocorrelation exists in the biological or environmental data, time series methodology will be employed.
Implications of trends on harvest rates - If temporal patterns are found in growth or maturity rates, we will examine optimal harvest rates for the current stock characteristics. We will construct simulation models employing various harvest policies on a stock with the characteristics estimated for sablefish at present (*sensu* Clark 1991). We will undertake a sensitivity analysis, looking at simulated stocks with plausible alternative growth and maturity patterns.

Research accomplishments/highlights/findings
Data have been assembled for the entire period. Summary statistics are being prepared to characterize fish population by location, depth, and date. The chief complication so far is accounting for sampling methodology that has changed over time. We have not yet looked at time series of size and maturity at age, but expect to in the next few months.

NOAA relevance/societal benefits
Any evolution over time in size or age at maturity could affect the stock assessment and the allowable harvest, as such changes did for Pacific halibut stocks.

Research linkages/partnerships/collaborators and networking
The principal linkages are between the University of Alaska Fairbanks and personnel at NOAA's Auke Bay Laboratory. The graduate research assistant is participating in a NOAA sablefish survey cruise to more fully understand the particulars of these data.

Education/outreach
One graduate student, Katy Howard, has been fully supported for a master's thesis on this research project.

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Sigler, M.F., S.A. Lowe and C. Kastelle. 1997. Area and depth differences in the age-length relationship of sablefish *Anoplopoma fimbria* in the Gulf of Alaska. In: M. Saunders and M. Wilkens (Eds.), Proceedings of the International Symposium on the Biology and Management of Sablefish. NOAA Technical Report 130, pp. 55–63.

Population Structure in Alaskan Pacific Ocean Perch (*Sebastes alutus*)

A.J. Gharrett, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 09-045a: This project is ongoing and continues CIFAR 06-045. Phase 1 was in previous cooperative agreement. It will be extended until June 2007 at which time K. Palof will have finished her thesis work.

Primary objectives

The population structure of a species underlies the basis of its production and provides crucial information for its effective management and conservation. Genetic studies can provide information on population structure. The objective of this project is to characterize the population genetic structure of Pacific ocean perch (POP) in Alaskan waters of the Gulf of Alaska and Bering Sea, and to evaluate the structure in the context of geographic and oceanographic features and the life history of POP. Both mitochondrial and microsatellite markers will be used in the study.

Approach/methodology

In the early stages of this study, we examined the mtDNA variation in POP and concluded that there was too little variation to warrant continuation of that work. Preliminary analyses of microsatellite variation, however, revealed genetic divergence among geographically distinct samples and encouraged us to continue the microsatellite analysis. We are using approximately fourteen microsatellite loci to quantify the variation within and among the Alaskan POP populations. Our samples now represent most of the Alaskan geographic range. Last summer, additional samples were collected from areas around the Gulf of Alaska to complete the range of POP in Alaskan waters. Allele frequencies and distributions will be compared between and among populations to determine if genetic structure exists. These data should be able to characterize the genetic structure of POP in Alaskan waters. Additionally, the mitochondrial work performed on these samples will be linked with the microsatellite analysis. We plan to analyze more than one thousand fish in this study. These data also form a framework for evaluating young-of-the-year samples of POP collected in the northern Gulf of Alaska and Bering Sea supported by the North Pacific Research Board (NPRB) as discussed in *Research linkages* below.

Research accomplishments/highlights/findings

- For the current analysis, we are using microsatellite loci *Sal1*, *Sal2, Sal3, Sal4*, and *Sal6* (Miller et al. 2000); *SR7-2, SR7-7* (Westerman et al. 2005); *Sma7* and *Sma5* (Wimburger et al. 1999); Spi4, Spi6, Spi10, and Spi12 (Gomez-Uchida et al. 2003); Sth3B (Sekino et al. 2000).
- We have evaluated 1000 fish from 12 geographically distinct areas at each of the fourteen loci and these genotypes are currently being analyzed.
- A range of genetic analyses are underway to characterize population structure. These include analyses to estimate divergence, to detect past population declines, to determine gene flow, and evaluate the extent of sibship within collections.

NOAA relevance/societal benefits

Effective management and conservation of a species requires knowledge of its population structure. Knowledge of sub-populations will yield information on POP movement between birth and reproduction and aid in preventing depletion of these smaller populations. More research into POP population structure and basic biological development would aid in understanding population distribution, the location of critical habitats throughout this distribution, and the times of the year when these habitats are necessary for survival. These data will also provide a reference for the young-of-the-year POP which we are examining to learn about dispersion of young fish.

Research linkages/partnerships/collaborators and networking

Funding for this project comes through collaboration with the National Marine Fisheries Service Auke Bay Laboratory. International collaboration with the Department of Fisheries and Oceans, Canada has also resulted from this project. The NOAA investment in CIFAR 09-045a and CIFAR 10-062a: *Species Composition and Spatial Distribution of Gulf of Alaska and Bering Sea Young-of-the Year Rockfish Species* provided baseline data that has leveraged funding through NPRB projects F0420, *Interannual and spatial variation in population genetic composition of northeastern Gulf of Alaska young-of-year POP*, $105,000, 9/1/2004 to 8/31/2005 and F0512, *Juvenile POP genetics, Phase 2*, 9/1/2005 to 2/28/2007, $116,830 that examine the dispersion of juvenile POP.

Education/outreach

Student participation

Graduate student Katie Palof has completed her third year of Master's work and is expected to complete her thesis during the 2006/2007 academic year. The preliminary funding for this project enabled her to obtain a Rasmuson fisheries fellowship through the University of Alaska Fairbanks for both the 2004/2005 and 2005/2006 academic years. She plans to continue of this project in her doctoral research beginning Spring 2007.

Poster presentations

Palof, K., A.J. Gharrett and J. Heifetz. 2005. Population structure of Alaska Pacific ocean perch (*Sebastes alutus*). Biology, Assessment, and Management of North Pacific Rockfishes, 23rd Lowell Wakefield Fisheries Symposium, September 2005.

Palof, K.J., L. Kamin, A.J. Gharrett, C.K. Kondzela and J. Heifetz. 2006. Genetic population structure of adult and young-of-the-year Alaskan Pacific ocean perch *(Sebastes alutus)*. Western Groundfish Conference, Newport, Oregon, February 2006.

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Miller, K.M., A.D. Schultze and R.E. Withler. 2000. Characterization of microsatellite loci in *Sebastes alutus* and their conservation in congeneric rockfish species. *Molecular Ecology*, 9:240–242.

Sekino, M., N. Takagi, M. Hara and H. Takahashi. 2000. Microsatellites in rockfish *Sebastes thompsoni* (Scorpaenidae). *Molecular Ecology*, 9:629–644.

Westerman, M.E., V.P. Buonaccorsi, J.A. Stannard, L. Galver, C. Taylor, E.A. Lynn, C.A. Kimbrell and R.D. Vetter. 2005. Cloning and characterization of novel microsatellite DNA markers for the grass rockfish, *Sebastes rastrelligeri*, and cross-species amplification in 10 related *Sebastes* spp. *Molecular Ecology Notes*, 5:74–76.

Wimberger, P., J. Burr, A. Gray, A. Lopez and P.P Bentzen. 1999. Isolation and characterization of twelve microsatellite loci for rockfish (Sebastes). *Marine Biotechnology*, 1:311–315.

Species Composition and Spatial Distribution of GOA and BS Young-of-the-Year Rockfish Species

A.J. Gharrett, PI — ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks
C.M. Kondzela, cooperator
NOAA Fisheries, AFSC, Auke Bay Laboratory

Other investigators/professionals funded by this project:
Arthur Kendall III
AJALA Enterprises, La Conner, Washington
Z. Li, S. Walden, R. Riley
University of Alaska Fairbanks

CIFAR 10-062a: This project is ongoing.

Primary objectives

Young-of-the-year (YOY) *Sebastes* rockfish were collected as "bycatch" during NOAA Ocean Carrying Capacity (OCC) surveys of salmon juveniles in the Gulf of Alaska (GOA) and the Bering Sea (BS) in 1998, 2000, 2001, 2002, and 2003. The capture of the rockfish was serendipitous, and the first time that such large concentrations of

juvenile rockfish have been observed in the GOA. YOY rockfish were caught along several different transects in the GOA in the same year and there is some coincidence of sample locations between years. From genetic studies supplemented by morphological analysis, we identified thirteen different species, the most abundant of which is the Pacific ocean perch (*S. alutus*; POP). These collections provide an unparalleled opportunity to: 1) fill in some of the gaps in knowledge of the early life histories of several Alaskan rockfish species and 2) explore the possibility of developing morphological methods for species identification.

Approach/methodology

One focus of this project is to examine the variation in the temporal and spatial distribution of rockfish species in the eastern GOA at different locations within a year and between years. The second focus is the extent of genetic divergence that occurs between year classes of a species. There are three distinct but parallel questions we will ask in both facets of this study. Questions for the species distribution focus are: 1) Is there interannual variation in the relative abundances of YOY rockfish species at a location within the GOA? 2) Do the relative abundances and distributions of species vary across the region sampled in the GOA within a year? and 3) Does the composition vary along a transect within a year?

Because morphological distinctions among species often fail, we are taking an alternative approach. We developed a scheme to delineate species based on mtDNA markers (Gharrett et al. 2001). Recently, we (Li et al. 2006) extended the study to more than 70 *Sebastes* species, including all the species reported in the GOA (Kendall 2000; Love et al. 2002).

Research accomplishments/highlights/findings

- Dr. Kendall completed morphological analysis of an additional 200 specimens.

NOAA relevance/societal benefits

Effective management and conservation of a species requires knowledge of the life histories of the species being managed and of their predators and prey. At present virtually nothing is known about the early life histories of Alaskan rockfish species or the habitat that is critical to their success at different stages of their life histories.

Research linkages/partnerships/collaborators and networking

Funding for this project comes through collaboration with an independent contractor (A. Kendall) and use of laboratory facilities at the National Marine Fisheries Service, Auke Bay Laboratory. Most of the rockfish obtained in this study are Pacific ocean perch. Support for investigation of the population genetic structure of those fish at our UAF laboratory was provided by NPRB project number F0420, *Interannual and spatial variation in population genetic composition of northeastern Gulf of Alaska young-of-the-year Pacific ocean perch*, 1 year September 2004 to August 2005, $105,000.

Stephanie Walden and Rachel Riley of the University of Alaska Fairbanks provided laboratory support.

Education/outreach

Poster presentation

Kondzela, C., A. Kendall, Z. Li, D. Clausen and A.J. Gharrett. 2005. Species of juvenile rockfish collected in the Gulf of Alaska, 1998–2002. 23rd Lowell Wakefield Symposium: Biology, Assessment, and Management of North Pacific Rockfishes, Anchorage, Alaska, 12–15 September 2005.

Publications

In press

Kondzela, C.M., A.W. Kendall, Z. Li, D. Clausen and A.J. Gharrett. Preliminary identification of pelagic juvenile rockfishes collected in the Gulf of Alaska. Proceedings of the 23rd Lowell Wakefield Symposium: Biology, Assessment, and Management of North Pacific Rockfishes, Anchorage, Alaska, 12–15 September 2005, in press.

In preparation

Kendall, A.W. Jr., C.M. Kondzela, Z. Li, D. Clausen and A.J. Gharrett. Genetic and morphological identification of pelagic juvenile rockfishes collected from the Gulf of Alaska. In preparation.

References

Gharrett, A.J., A.K. Gray and H. Heifetz. 2001. Identification of rockfish (Sebastes spp.) by restriction site analysis of the mitochondrial ND-3/ND-4 and 12S/16S rRNA gene regions. *Fishery Bulletin*, 99:49–62.

Kendall, A.W. Jr. 2000. A historic review of *Sebastes* taxonomy and systematics. *Marine Fisheries Review*, 62:1–23.
Li, Z., A. Gray, M. Love, A. Goto, T. Asahida and A. Gharrett. 2006. A key to selected rockfishes (*Sebastes* spp.) based on mitochondrial DNA restriction fragment analysis. *Fishery Bulletin*, 104:182–196.
Love, M.S., M. Yoklavich and L. Thorsteinson. 2002. The Rockfishes of the Northeast Pacific. University of California Press, Berkeley, California.

Genetic Studies of Rockfishes (Phase I)

A.J. Gharrett, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 22-085 (new): This project is ongoing.

Primary objectives

The *Sebastes* rockfishes are an important component of the marine food web and are also economically important. There are more than 100 worldwide and more than 60 along the Pacific Coast of North America. In addition, they are morphologically similar; and during their embryological development, they pass through several morphological transformations. Consequently, many adults of some are difficult and many larvae impossible to identify from their morphologies. Genetics provides tools that can be used to learn about population structure and the underlying demographic structures and markers that can be used to delineate species. This project will address three questions:

1. Is there detectable population structure in Alaskan northern rockfish (*S. polyspinis*)?
2. Are there morphological differences between the sibling species of rougheye rockfish (*S. aleutianus* types I and II) (Gharrett et al. 2005)?
3. Are there additional mtDNA markers that will allow us to resolve (thus far) genetically indistinguishable species of rockfish (Li et al. 2006)?

Approach/methodology

The methodologies below correspond to the points under Primary Objectives.

1. The genetic structure of five spatially distinct collections that represent the Bering Sea/Aleutian Island species range are being analyzed by using data from microsatellite loci. We anticipate using 10 loci in this analysis of about 500 fish. Standard population genetics analyses will include tests of (a) Hardy-Weinberg proportions, (b) homogeneity, and (c) correlation between geographic and genetic distances (Mantel tests).
2. Dr. J. Orr (NOAA/NMFS Alaska Fisheries Science Center, personal communication) suggests differences in spotting patterns between the two rougheye rockfish sibling species. We compared identifications of specimens collected in 2005 based on spotting pattern with identifications based on both mitochondrial and microsatellite markers, which are diagnostic for the two types. In 2006, additional fish will be sampled, identified from spotting patterns, and digitally photographed; tissue samples will be analyzed blindly for the genetic markers to determine species.
3. It would be useful to develop single nucleotide polymorphism (SNP) markers to identify the two rougheye rockfish types. Restriction digests of mtDNA regions that we have not yet analyzed will be examined for variation in two groups of rockfishes: (a) *Sebastes polyspinis*, *S. cilatus*, *S. variabilis*, and *S. crameri*; and (b) *S. variegatus*, *S. emphaeus*, *S. zacentrus*, and *S. wilsoni*.

Research accomplishments/highlights/findings

- From data from five collections (n = 100 in each) of northern rockfish for seven microsatellite loci, we observed divergence at one locus (*Sal*6: P = 0.029) and overall for the seven loci (P = 0.008). Correlation between genetic and geographic distances was nearly significant (P = 0.08).
- Poor correspondence was observed between identifications of the two rougheye rockfish species based on spotting patterns and based on genetic markers.
- Amplification of small fragments of DNA from formalin-fixed rockfish samples was moderately successful. If we develop SNP markers, we should be able to delineate between the two rougheye rockfish sibling species.

NOAA relevance/societal benefits

As part of their stewardship of Alaska's living marine resources, the NOAA/NMFS Alaska Fisheries Science Center (AFSC) is responsible for conducting research that will lead to effective conservation and management. Genetics

provides tools that can be used to learn about population structure and the underlying demographic structures and markers that can be used to delineate species, knowledge critical for effective management and conservation of a species. More research into rockfish population structure and basic biological development will aid in understanding population distributions, the locations of critical habitats throughout this distribution, and the times of the year when these habitats are necessary for survival.

Research linkages/partnerships/collaborators and networking

Funding for this project comes through collaboration with the National Marine Fisheries Service Auke Bay Laboratory. The scientists from Auke Bay Laboratory collected all of the specimens used in this analysis during stock assessment surveys. Although it is not possible to estimate the effort expended, it has been substantial. In addition, considerable vessel time was involved. Principal ABL personnel were J. Heifetz, C. Lunsford, and D. Clausen. K. and T. Mecklenburg (on subcontract) conducted the visual inspection of the rougheye rockfish to identify species based on spotting patterns.

References

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray and J. Heifetz. 2005. Two genetically distinct forms of rougheye rockfish (*Sebastes aleutianus*) are different species. *Transactions of the American Fisheries Society*, 134:242–250.

Li, Z., A.K. Gray, M.S. Love, A. Goto, T. Asahida and A.J. Gharrett. 2006. A key to selected rockfishes (*Sebastes* spp.) based on mitochondrial DNA restriction fragment analysis. *Fishery Bulletin*, 104(2):182–196.

Energy, Diet, and Condition of Juvenile Pink Salmon, *Oncorhynchus gorbuscha*, in the Gulf of Alaska

Nicola Hillgruber, PI — ***NOAA Goal: Ecosystem-based Management***

University of Alaska Fairbanks

CIFAR 10-076: The research portion of this project was completed during the previous reporting period. This final report covers the Education/Outreach and Publication activity over the life of the award.

Primary objectives

Juvenile pink salmon (*Oncorhynchus gorbuscha*) are most vulnerable to mortality during their first months at sea, when prey abundance, competition, predation, and environmental changes can impact their growth and survival. Because early marine growth is critical for survival, it is important to understand juvenile energy requirements. Whole body energy content (WBEC) can indicate overall condition and growth potential. WBEC of juvenile pink salmon from three Prince William Sound hatcheries (Armin F. Koernig, Wally Noerenberg, and Solomon Gulch) was compared to wild juveniles in the Gulf of Alaska. WBEC and condition factor were used to determine and compare condition for these four groups.

Approach/methodology

Juvenile pink salmon were collected during Ocean Carrying Capacity (OCC)/GLOBEC Gulf of Alaska (GOA) research cruises on 34 stations along three transects: Gore Point (GP), Seward Line (GAK), and Cape Cleare (CCL). The cruises were conducted in July–August, 2001–2002 on board the F/V *Great Pacific* using a 198-m-long midwater rope trawl with hexagonal mesh wings and body, and 1.2-cm mesh liner in the codend. Fork length and body weight were measured for up to 50 juvenile pink salmon per haul. Fish were frozen and returned to the lab for further analyses. Hatchery origin was determined by identifying the otolith thermal marks; fish lacking thermal marks were considered wild. From each transect a subsample of 30 fish per origin was selected and whole body energy content, the composition of protein, fat, and water content in somatic tissue, was determined using a Parr 1425 semi micro bomb calorimeter. LeCren's condition factor was calculated for each fish using length and weight data. Analysis of variance was used to test for significant differences in WBEC by year, transect, and origin of the pink salmon juveniles. Pairwise differences between transects and hatcheries were identified using a multiple comparison Tukey Kramer HSD test.

Relationships between WEBC and length, weight, condition factor and percent dry weight were also examined.

NOAA relevance/societal benefits

Since the mid 1980s wild pink salmon returns to Prince William Sound have noticeably declined. Early marine growth, which is critical for survival, is a function of the juvenile's condition. This study is aimed to better understand energy requirements of wild and hatchery-reared juvenile pink salmon during their early marine life.

Research linkages/partnerships/collaborators and networking

The funded project is part of a graduate study conducted by Angela M. (Middleton) Feldmann, NOAA research fisheries biologist, who is pursuing an M.S. degree in Fisheries. CIFAR funding supported 0.75 months of the graduate student's committee chair at the University of Alaska Fairbanks (UAF), School of Fisheries and Ocean Sciences and Angela's graduate study conducted at the Auke Bay Lab (NOAA/NMFS/AFSC) in Juneau, Alaska through the UAF School of Fisheries and Ocean Sciences.

Education/outreach

Presentations

Rodgveller, C., A.M. Middleton and J.H. Moss. 2005. Energy density of juvenile pink salmon (*Oncorhynchus gorbuscha*) in the Gulf of Alaska. 22nd Northeast Pacific Pink and Chum Salmon Workshop, Ketchikan, Alaska, 23–24 February 2005. (oral presentation) [not reported last year]

Publications

Non-peer-reviewed

Rodgveller, C., A.M. Middleton and J.H. Moss. 2005. Energy density of juvenile pink salmon, *Oncorhynchus gorbuscha*, in the Gulf of Alaska. Proceedings of the 22nd Northeast Pacific Pink and Chum Salmon Workshop in Ketchikan, Alaska, 15 pp.

In preparation

A manuscript detailing the results of the present study is currently being revised by C. Rodgveller, J. Moss and A. (Middleton) Feldmann of the Auke Bay Lab, Juneau, Alaska. The manuscript will be submitted to the *Alaska Fishery Research Bulletin*.

Relationships between Pollock (*Theragra chalcogramma*) Distribution and Biomass, Zooplankton Biomass, and Oceanographic Conditions in the Bering and Chukchi Seas, Alaska

Nicola Hillgruber, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 25-083 (new): This project is in progress; however, Angela (Middleton) Feldmann will be on a leave of absence until September 2007.

Primary objectives

The objectives of this project are to describe the distribution of age-0 walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea and Chukchi Sea; determine any spatial or oceanographic relationships that may exist between pollock biomass and zooplankton biomass in the eastern Bering Sea and Chukchi Sea using sea surface temperature, salinity, and chlorophyll-a for oceanographic parameters; describe regional differences in energy density of age-0 pollock in the eastern Bering Sea and Chukchi Sea; and describe regional differences in diet of age-0 pollock in the eastern Bering Sea and Chukchi Sea.

Approach/methodology

Age-0 pollock, zooplankton, and oceanographic data were collected during the Ocean Carrying Capacity (OCC) U.S. BASIS (Bering–Aleutian Salmon International Survey) surveys aboard the F/V *Sea Storm*. These cruises were conducted in August–October, 2001–2004, and a total of 467 stations were sampled. At each station age-0 pollock were caught with a midwater rope trawl, fished at the surface. Stomach contents were analyzed at sea, to examine feeding patterns in response to physical and biological factors.

Condition of pollock was measured as energy density using a Parr 1425 semi micro bomb calorimeter. Energy density of juvenile pollock caught in different regions of the Bering and Chukchi Seas was compared to determine the potential effect of region on juvenile pollock condition.

To estimate prey biomass, zooplankton samples were collected using a 60-cm-diameter bongo net fitted with one 505 µm and one 335 µm net. Zooplankton samples collected along each transect were sorted into taxonomic groups and enumerated. Zooplankton biomass was calculated using the displacement volume of the zooplankton sample.

To test the effects of oceanographic conditions on pollock distribution, diet, and condition, vertical profiles of temperature, salinity, and fluorescence were measured at each sample station. Casts were taken at each station from surface to near-bottom (10 m off the bottom) depths.

Research accomplishments/highlights/findings

- Research cruises have been conducted on the eastern Bering Sea (EBS) and Chukchi Sea from 2001–2004.
- Age-0 pollock were distributed throughout the sampling area with the highest catches occurring in the middle domain (between 50 and 100 m bottom depth) of Bristol Bay during each survey year.
- Distinct bi-modal size distribution of age-0 pollock was seen in 2003 and 2004, possibly indicating fish from different hatch dates or breeding populations.
- Age-0 pollock caught in the central Bering Sea were significantly smaller in 2003 than fish caught in 2004.
- Pollock juveniles from Bristol Bay had a larger average energy density in 2003 than in 2004, and had the lowest energy density between regions in 2004.
- Northern Bering Sea/Chukchi Sea pollock consistently had the greatest energy density in 2003 and 2004.
- Age-0 pollock had a highly varied diet in 2003 and 2004; however, calanoid copepods and euphausiids were the predominant prey items in each study year.
- In 2004, pollock in Bristol Bay and the northern Bering Sea had a similar diet composition as 2003, but pollock from the Bering Sea shelf consumed a large proportion of fish (37%), consisting predominantly of larval fish and young-of-the-year (YOY) pollock.
- The increase in piscivory coincided with the larger length frequency of YOY pollock seen in the central Bering Sea region in 2004.
- In 2002, small calanoid copepods (*Acartia longiremis*, *Centropages abdominalis*, and *Pseudocalanus spp*.) made up the greatest proportion of 335 µm bongo samples; in 2003 and 2004, calanoid copepods and echinoderms were the predominant zooplankton found in 335 µm bongo samples.
- Euphausiids did not make up a significant proportion of the zooplankton collected in the 335 µm bongo samples, but they were a component of age-0 pollock diets in all regions in 2003 and 2004.
- The absence of euphausiids in the zooplankton might be due to net avoidance behavior, which could make euphausiids challenging to capture, particularly during daytime. In addition, euphausiids undergo diurnal vertical migration; since zooplankton collection was restricted to daytime sampling, euphausiids might have been underrepresented in our samples.

NOAA relevance/societal benefits

Walleye pollock are important both commercially and ecologically. Understanding the effects of physical and biological factors on the early marine condition, growth and survival of pollock throughout the EBS is essential for making ecosystem-based management decisions. Goals of this project are to describe the distribution of age-0 pollock in the eastern Bering Sea and Chukchi Sea and examine potential relationships between age-0 pollock biomass, zooplankton biomass, and oceanographic parameters, such as sea surface temperature, salinity, and chlorophyll a. A secondary goal is to identify regional differences in energy density and diet of age-0 pollock in the EBS.

Research linkages/partnerships/collaborators and networking

The funded project is part of a graduate study conducted by Angela M. (Middleton) Feldmann, NOAA research fisheries biologist, who is actively pursuing an M.S. degree in Fisheries at the University of Alaska Fairbanks (UAF). CIFAR funding supported 0.75 months of the graduate student's committee chair at the School of Fisheries and Ocean Sciences, UAF, and Angela's graduate study conducted at the Auke Bay Lab (NOAA/NMFS/AFSC) in Juneau, Alaska through the School of Fisheries and Ocean Sciences, UAF.

Education/outreach

Presentations

Middleton, A., N. Hillgruber, L. Eisner and J. Moss. 2005. Effects of biological and physical factors on distribution of age-0 walleye pollock, *Theragra chalcogramma*, in the Eastern Bering Sea, Alaska. 135th Annual Meeting, American Fisheries Society, Anchorage, Alaska, September 2005. (Poster)

Grain Size Distributions, and Concentrations and Stable Isotope Ratios of Organic Carbon and Nitrogen in Marine Sediments Near the Islands of Four Mountains, Aleutian Chain, Southeastern Bering Sea

Sathy A. Naidu, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 10-073: This project is complete.

Primary objectives

This study will determine sediment characteristics from five sites near the Islands of Four Mountains, west of Dutch Harbor on the Aleutian chain, southeastern Bering Sea, to assist in determining the role of sediment substrate as habitat for juvenile rockfish. Each site was mapped using towed side-scan sonar and multi-beam sonar systems. These instruments collected bathymetry and reflectivity data using sound characteristics reflected from the sea floor. Sediment samples were collected from the seafloor using a van Veen grab to groundtruth the acoustic observations. These samples will be used to interpret reflectivity, a measure of seafloor hardness collected using the sidescan sonar system by determining the grain-size of each sediment sample. In addition to sediment grain size distributions, samples will be analyzed for organic carbon (OC), total nitrogen (N), OC/N ratio, and stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of OC and N to provide more insight into the processes controlling fish-habitat relationships.

Approach/methodology

The textural analysis on the sediment samples was by the combined sieve-pipette method, and calculation of the grain size statistical parameters was according to the methods described in Folk (1980). The analyses of the concentrations of organic carbon and nitrogen and determinations of the carbon and nitrogen stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of carbonate-free sediment samples were based on the methods outlined in Naidu et al. (2000), using a Delta Plus XP isotope ratio mass spectrometer interfaced with a Carlo Erba elemental analyzer (Model NC2500). Statistical analysis was restricted to the determination of correlation coefficients between mud % and organic carbon (C), organic carbon and total nitrogen (N), $\delta^{13}C$ and $\delta^{15}N$, and C/N and $\delta^{13}C$.

Research accomplishments/highlights/findings

Seventy-two sediment samples analyzed on this project were integrated into a map of five areas in the Aleutian Islands based on multibeam and sidescan sonar. Specifically, the grain size of the sediments was used to calibrate the acoustic reflections from the seafloor and indicate potential bottom types at the study areas. The sediment data was also integrated into a Gulf of Alaska–wide effort to map existing sediment data, although this database is not yet complete.

NOAA relevance/societal benefits

Early life history is thought to be critical in rockfish recruitment, a slow-growing and long-lived commercial fish. The NOAA fisheries Groundfish Assessment Program is tasked with assessing the value of the Aleutian Islands archipelago habitat to juvenile Pacific ocean perch. Using multi-beam and side-scan sonar, researchers are able to observe how certain habitats affect both survival and growth of rockfish. However, these acoustic mapping techniques need to be groundtruthed through grain-size analyses of collected sediment samples for which reflectivity data has been collected.

Research linkages/partnerships/collaborators and networking

NOAA Fisheries biologists have collected the acoustic and sediment samples with funding from NOAA and the North Pacific Research Board Project F0416: *Determining the value of habitat to juvenile rockfish in the Aleutian Islands* ($163,402).

References

Folk, R.L. 1980. *Petrology of Sedimentary Rocks*. Hemphill Publishing Co., Austin, TX. 182 pp.

Naidu, A.S., L.W. Cooper, B.P. Finney, R.W. Macdonald, C. Alexander and I.P. Semiletov. 2000. Organic carbon isotope ratios ($\delta^{13}C$) of Arctic Amerasian continental shelf sediments. *International Journal of Earth Sciences*, 89:522–532.

Reproductive Potential of Pacific Cod

Brenda L. Norcross, PI *University of Alaska Fairbanks*

NOAA goal: Ecosystem-based Management

CIFAR 17-031b: This project is ongoing.

Primary objectives

The reproductive potential (the number and quality of eggs spawned) of females in a fish population (stock) is a central determinant of the stock's capacity for growth and resilience to fishing. Most stock assessment models predict the reproductive output of a stock with little regard for individual variation in reproduction, despite increasing evidence that such variability may be substantial. This project examines factors that influence the reproductive potential of female Pacific cod (*Gadus macrocephalus*). We hypothesize that reproductive potential varies positively with age, size, and energy reserves (condition) in cod. Because condition is likely to be influenced by the environment, this work will also give us insight into the effect of climate changes on cod reproduction.

Approach/methodology

Adult female Pacific cod were collected during the spawning season for three consecutive years in two regions where cod are managed separately by NOAA Fisheries: the Gulf of Alaska (GOA: 2002–2004) and the eastern Bering Sea (EBS: 2003–2005). An additional collection was made in the western Aleutian Islands in 2005. Fish were collected over a size range of 40–115 cm. From these samples, tissues were dissected out to perform the following laboratory analyses:

- Age determination from otoliths.
- Energy reserves estimated using Fulton's condition factor and hepatosomatic index.
- Fecundity (number of eggs) by counting of subsamples of eggs taken from ovaries.
- Egg quality estimated by measuring egg weight and egg energy content.

In addition, for a subset of the fish sampled in the EBS, we are performing a more detailed analysis of egg quality by quantifying different types of metabolic fuels (i.e., lipid classes, free amino acids, and protein).

Research accomplishments/highlights/findings

1) Age determination has been completed for all samples to be used in this study (n=593). Ages ranged from 2 to 12 years in the GOA, 3 to 12 years in the EBS, and 1 to 14 years in the Aleutian Islands.
2) Fecundity and egg size analyses have been completed for five of the seven datasets (n=410) involved in this study.
3) Preliminary results:
    - Fecundity is highly dependent on the length ($R^2 = 0.86$; Figure 1) and body weight ($R^2 = 0.89$; Figure 2) of female cod.
    - Females in better condition display increased fecundity.
    - Relative fecundity (the number of eggs produced per gram of body weight) shows a slight positive relationship with age, size, and condition.
    - Egg size varies considerably among females and does not appear to be influenced by the age, size, or condition of female cod.
    - The relationship between female size and reproductive output (gonad weight) varies significantly among some regions and years.

NOAA relevance/societal benefits

This research will improve management of Pacific cod in Alaska by enhancing the ability of NOAA Fisheries to assess the reproductive output of Pacific cod stocks, predict future abundance and anticipate the effects of fishery management decisions. This work will also help to clarify differences between GOA and EBS cod stocks and contribute to our knowledge of the effects of climate change on fish.

Research linkages/partnerships/collaborators and networking

This project has resulted in a close working relationship between UAF personnel (Norcross) and a student (Ormseth) and NOAA Fisheries personnel (Dr. Anne Hollowed and Dr. Grant Thompson, NMFS/REFM, Seattle). In addition, during our sampling we have collected tissues for use by other NMFS research projects, including analyses of

population genetics and length-at-maturity. Ormseth is also collaborating with NMFS personnel (Dr. Libby Logerwell and Sandi Neidetcher, NMFS/REFM, Seattle) on a project funded by the North Pacific Research Board in May 2006. We have also employed a UAF Research Associate, Brenda Holladay, to assist with laboratory and data analyses.

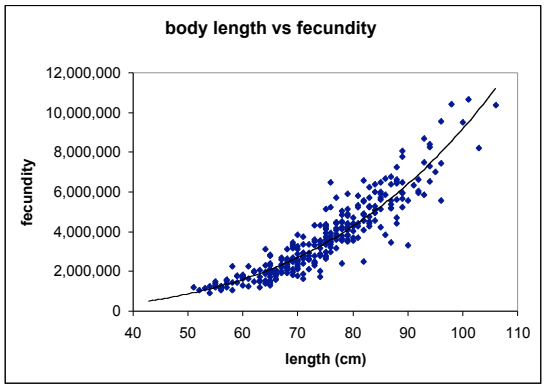


Figure 1. Relationship between length and fecundity in female Pacific cod ($y=1.174x^{3.45}$; $R^2=0.86$).

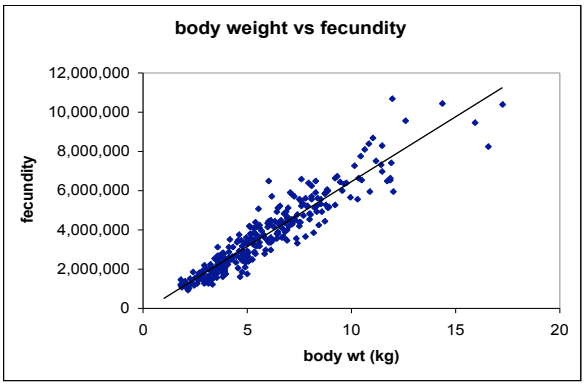


Figure 2. Relationship between body weight and fecundity in female Pacific cod (y=662,164x – 187,109; $R^2=0.89$).

Education/outreach

Student participation

Olav Ormseth, Ph.D. candidate, Fisheries Oceanography, University of Alaska Fairbanks, is supported in part by this award.

Presentations

Ormseth presented preliminary results of this study to a board meeting of the Rasmuson Fisheries Science Center in Anchorage, Alaska in March 2006.

Student Research about Local Pollock Abundance using Hydroacoustic Data

Terrance J. Quinn II, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 06-050: This project is complete (except that one month of Haixue Shen's salary will be paid in FY07).

Primary objectives of the project

This collaborative project between UAF, Alaska Fisheries Science Center (AFSC), and the pollock industry seeks to investigate whether localized depletion of pollock is occurring by the eastern Bering Sea pollock fishery. Acoustic data loggers have been installed on 7 catcher/processors (about half the fleet); each data logger interfaces with the ship's 38 kHz echo sounder and captures the acoustic backscatter. The backscatter data is post-processed and integrated with observer and logbook data. The research goals are to develop variables related to pollock school density, composition, and frequency, and to examine changes in these variables during the course of the fishing season.

Approach/methodology

CIFAR funding provided support for 2 years to Ph.D. graduate student Haixue Shen. Her committee consists of UAF professors Quinn and Smoker and AFSC scientist Dr. Martin Dorn and Dr. Vidar Wespestad, former AFSC scientist. The scope of Ms. Shen's thesis project is as follows:

1. Focus on smaller scale processes, and in particular, on fishing impacts on pollock distributions.
2. Address the localized depletion issue as the primary objective.
3. Use the school descriptor module in Echoview® to evaluate changes in school structure due to fishing impacts.
4. Examine the processed acoustic data in databases put together by AFSC researchers Steve Barbeaux and Matt Kookesh, although the school descriptor algorithm in Echoview® may require raw ping-by-ping data.

5. Classify the searching behavior of the vessels, identify pollock aggregations detected while searching, and evaluate what inferences, if any, can be made concerning the rate at which those aggregations are reduced in abundance or altered in size and shape.

Research accomplishments/highlights/findings

Haixue has made excellent progress in research. She has developed a thesis proposal and has mastered the software tool Echoview® and applied it to pollock hydroacoustic data. She presented a poster of her work at the Alaska Marine Science Symposium in Anchorage in January 2006. In summer 2006 she participated in research aboard the *Oscar Dyson*.

The null hypothesis of this project is that fishing activities do not affect the abundance and spatial distribution of walleye pollock. To investigate this hypothesis, we used the hydroacoustic data of FV *Kodiak Enterprise* in January and February, 2003, which operated north of Unimak Island in the eastern Bering Sea (EBS). To investigate the fishing impact on schools, two separate fishing periods (Jan 22–Feb 5 and Feb 14–Feb 24) were examined because of their similar operating area. Several school morphological descriptors of walleye pollock were evaluated to better understand whether differences at the scale of school occurred in response to fishing. The NND (next-neighbor distance) clustering procedure and variography were also used to quantify walleye pollock spatial patterns. At the school scale, results from echo trace classification (ETC) did not suggest a significant change for most of the descriptors except for the mean thickness (P=0.002). However, results from NND clustering did exhibit some change at a larger scale. Schools and clusters per km decreased significantly during the fishing period. Both NND clustering and variography showed that the spatial distribution of walleye pollock changed at a large scale, presumably due to fishing. A decline in abundance may be inferred based on the sparser distribution of schools. Obviously, a decline in abundance and change in spatial pattern of walleye pollock could affect the prey availability of Steller sea lions.

NOAA relevance/societal benefits

This project employed a novel approach to the study of localized depletion of pollock. There is international interest in the use of hydroacoustics data from commercial fishing vessels. We hope to present our results to the Fisheries Acoustics Science and Technology (FAST) committee of the International Council for Exploration of the Sea (ICES).

Research linkages/partnerships/collaborators and networking

This project has received funding ($251K, 2001–2006) from the Pollock Conservation Cooperative Research Center (PCCRC), a fishing industry-funded program administered by the University of Alaska.

Some work was done at the Alaska Fisheries Science Center (AFSC) in Seattle, Washington. As mentioned above, AFSC scientists are serving as members of Ms. Shen's graduate advisory committee. We are collaborating with a committee housed in the AFSC to provide coordinated databases and analytical methods for processing hydroacoustic data.

Education/outreach

Student Participation

Ms. Haixue Shen, a Ph.D. fisheries student began working on this project in August 2004.

Poster Presentation

Shen, H., M. Kookesh, T.J. Quinn II, V. Wespestad, M. Dorn, J. Ianelli and S. Barbeau. 2006. Interaction between commercial fishing and walleye pollock in Eastern Bering Sea. Marine Science in Alaska: 2006 Symposium, Anchorage, Alaska, January 2006.

Habitat Analysis of Major Fishing Grounds on the Kodiak Shelf, Alaska

Jennifer Reynolds, PI ***NOAA Goal: Ecosystem-based Management***
Brenda Norcross, co-PI
University of Alaska Fairbanks

CIFAR 10-078: This project is ongoing, with a no-cost extension to July 1, 2007.

Primary objectives

The overall goal of this research is to understand the distribution of commercially important species on fishing grounds along the continental shelf east of Kodiak Island, and how it is affected by geological, biological, and oceanographic factors. These locations are known for extensive bottom trawl and longline fisheries for groundfish.

Approach/methodology

An important step in defining essential fish habitat and potential mitigative measures is to understand the relationship between habitat characteristics, fish distribution, and fishing effort. In Alaska, major fisheries occur on the continental shelf and slope, but very few areas of benthic habitat in these regions have been described.

The study will analyze and compare three study areas: Portlock Bank, Albatross Bank, and southwest of Chirikof Island. The study will incorporate habitat classifications of the mapped areas, existing biological and physical data from fishery surveys, commercial fisheries, and oceanographic and geological surveys.

Methodology:

- Ground truth multibeam-sonar-based habitat maps, using submersible video and records of geological grab samples from the literature.
- Map benthic biological assemblages, using submersible video and NOAA fishery databases.
- Examine associations of fish communities and benthic macrofauna with benthic habitats (including biohabitats), depth, and oceanography.
- Examine species richness, composition and relative abundance of fish communities at multiple scales.
- Extrapolate results from groundtruth sites to the full study area, and provide quantitative predictions of community distribution and composition.

Research accomplishments/highlights/findings

- Delta submersible dive cruise to Albatross Bank, June 23–July 2, 2005 (funded separately by NOAA). Participated in cruise planning, conducted 24 submersible dives, and collected 29 CTD casts.
- Acquired fisheries data from RACEBASE and NORPAC databases for this research.
- Conducted exploratory analysis of fisheries and geological data in GIS (ESRI ArcMap).
- Established video analysis methods and conducted preliminary review of video data using Video Ruler software. This included troubleshooting the software version customized for NOAA's Auke Bay Lab.

NOAA relevance/societal benefits

This research will lead to improved understanding of the natural environment and its relationship to fishery resources, and will assist NOAA/NMFS in its mission to manage and conserve the Nation's resources. This research is also part of the graduate education of a new fisheries scientist.

Research linkages/partnerships/collaborators and networking

This is a collaborative effort between marine scientists at the University of Alaska Fairbanks, an M.S. graduate student in UAF's Fisheries program in Juneau, and biologists at NOAA's Auke Bay Laboratory in Juneau, Alaska. Research is conducted at NOAA/NMFS Alaska Fisheries Science Center, Auke Bay Laboratory. This project also incorporates habitat classifications based on multibeam sonar maps, from Moss Landing Marine Laboratory. In addition, the student's successful progress on this project enabled him to secure a graduate fellowship from the Rasmuson Fisheries Research Center.

Education/outreach

The CIFAR funds support M.S. thesis research by a UAF graduate student, in close collaboration with NOAA biologists at the Auke Bay Laboratory. Sean C. Rooney, M.S. Fisheries, University of Alaska Fairbanks (Fisheries Division in Juneau), was supported for 12 months (100%) in FY06. This was his second year in the program. He has completed all coursework toward the degree, and is currently focused on his thesis research (this project). During

FY06, Mr. Rooney was able to attend the biennial 14th Western Groundfish Conference with support from this award; this is a key conference for his research field. He also attended the American Fisheries Society 135th Annual Meeting, in Anchorage, Alaska, with AFS student funding support.

In Fall 2005, Mr. Rooney was awarded $2,815 from the Groundfish Forum, a group of Bering Sea trawling companies, to support his graduate research in groundfish habitat. This reflects commercial fisheries' interest in training researchers in this field, and in Mr. Rooney's research in particular (this project funded by CIFAR).

During FY07, Mr. Rooney's stipend and tuition will no longer be supported by CIFAR, but the progress he has made under the CIFAR award enabled him to win a graduate fellowship from the Rasmuson Fisheries Research Center (http://www.sfos.uaf.edu/rasmuson/). This fellowship will cover his stipend and tuition. A no-cost extension of modest funds remaining in the CIFAR award will support his research activities. Mr. Rooney expects to complete the project by summer, 2007.

Tag Retention in Snow Crabs; Movement of Primiparous Female Tanner Crabs: Spatial Dynamics of Tanner Crab Recruitment

Thomas C. Shirley, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks
(now at Texas A&M University–Corpus Christi)

CIFAR 06-053 and 09-065: These projects are ongoing.

Primary objectives

The initial objective of this research was to develop a tag for snow crabs that is inexpensive in cost and application, has a high retention through molting, and is not detrimental to crabs. The tag must have high visibility to fishers and processors, and be thoroughly tested to ensure that it is not lost because of agonistic interactions or grooming activities of crabs. The ultimate goal of the research is utilization of tags to measure molt increments and movements and other life history of Bering Sea snow crabs.

Approach/methodology

The initial year of the study was laboratory based and used both juvenile snow crabs and Tanner crabs as test subjects. Tanner crabs were used as surrogates because of their similar size and morphology to snow crabs, their local availability, and because of lesser concerns about pathogens and genetic contaminations. Juvenile snow crabs were collected in the Bering Sea in July and August, 2002 in separately funded experiments and transported to the Juneau Center in insulated containers. Juvenile Tanner crabs were collected from Glacier Bay, Alaska in commercial shrimp pots in summer, 2002 and by scuba divers from along the Juneau road system in fall and winter, 2002–2003. Crabs were cultured in a flowing sea water system at the Juneau Center, School of Fisheries and Ocean Sciences. A variety of different tags designs and insertion locations were used in premolting, juvenile crabs; success of tag retention through the molt, and effects upon survival and molting success were compared to control crabs which were untagged. The second phase of the research planned for 2003–2004 was to place digital, ultrasonic tags on crabs and to monitor their movements in Glacier Bay, as a method of tracking cohorts tagged with T-bar tags. The new digital tags were not fully developed until 2005, and sonic tags were attached to adult female Tanner crabs October 2005.

Research accomplishments/highlights/findings

- During the course of winter 2005 and early spring 2006, adult female Tanner crabs fitted with sonic transmitters (tags) within two major tagging areas in the East Arm of Glacier Bay concentrated at several locations of approximately 100 m depth. From the reproductive condition of female crabs captured in pots during each tracking trip, we know that the crabs were most highly aggregated before or during hatching.
- After concentrating at depths of 100 m, many tagged crabs made rapid movements to shallow (7–40 m depth) waters, some moving up to 2 km between tracking trips. The movement of crabs to shallow waters coincided with extrusion of a new clutch of eggs in captured crabs. Video footage of many female Tanner crabs in shallow (50 m) water, together with observations of Tanner crab appendages on the surface of the substrate, suggest that mating may be occurring in shallow waters.
- Following hatching and extrusion of new clutches, tagged crabs began to spread out and move to deeper waters.

NOAA relevance/societal benefits

Movements of Bering Sea snow crabs have been inferred from changes in spatial distribution of different size classes of crabs as recorded in the annual Bering Sea survey. The actual movements of crabs remain unsubstantiated. Development of an effective, inexpensive tag that could be applied quickly to large numbers of crabs could provide data to analyze movements of crabs. Development of a tag and long-term tracking movements of juvenile snow and Tanner crabs could help determine if some areas or habitats serve as 'nursery' areas and whether or not emigration from these areas occurs with growth of the crabs. Although these goals remain largely unrealized as yet, we have made some progress.

Research linkages/partnerships/collaborators and networking

During the current reporting period this project was mostly funded by NURP (West Coast and Polar Regions Undersea Research Center). Funds provided by CIFAR grants were used to purchase sonic tags for adult female crabs and pay for miscellaneous expenditures. We also combined this study with a study of red king crab reproductive habitat where the Alaska Department of Fish & Game contributed funds for king crab sonic tags.

Follow-up

Julie Nielsen received her Master's degree in fisheries in December 2005. She is currently working as a Fishery Biologist for the USGS Alaska Science Center. She, along with principal investigators Tom Shirley and Jim Taggart, have completed fieldwork for a research project funded by the West Coast and Polar Regions Undersea Research Center to search for seasonal aggregations of adult female Tanner crabs in Glacier Bay National Park. Julie has taken the lead in organizing fieldwork, analyzing data, and writing the resulting manuscript(s) for this project. Her salary is being provided by a combination of West Coast and Polar Regions Undersea Research Center and USGS funds. Her goal is to obtain full-time employment as a fisheries researcher in Alaska focusing on spatial and temporal trends in crab distribution and abundance.

Education/outreach

Student participation

Julie Nielsen, Graduate Research Assistant, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks was supported by this award. Julie defended her M.S. thesis entitled "Distribution and movement of juvenile Tanner crabs *Chionoecetes bairdi* in Glacier Bay National Park" in May 2005 and graduated in December 2005.

Presentations

Nielsen, J. Trans-molt Floy tag retention and tagging effects on juvenile Tanner crabs. Interagency Crab Research Meeting, Anchorage, December 2005.

Publications

Non-peer-reviewed

Nielsen, J.K. 2005. Distribution and Movement of Juvenile Tanner Crabs *Chionoecetes bairdi* in Glacier Bay National Park. M.S. Thesis, University of Alaska Fairbanks School of Fisheries and Ocean Sciences.

Submitted or in preparation

Nielsen, J.K., S.J. Taggart, T.C. Shirley and J. Mondragon. Spatial distribution of juvenile and adult female Tanner crabs *Chionoecetes bairdi* in a glacial fjord ecosystem: implications for recruitment processes. Submitted to *Canadian Journal of Fisheries and Aquatic Sciences*.

Nielsen, J.K., T.C. Shirley and S.J. Taggart. Trans-molt retention of Floy tags in Tanner crabs *Chionoecetes bairdi*. In preparation.

Nielsen, J.K., T.C. Shirley and S.J. Taggart. Nursery areas for Tanner crabs in Glacier Bay? In preparation.

GLOBEC-NEP: Topographic Control of Mesoscale Variability in the Gulf of Alaska

Terry Whitledge, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 28-058b: This project is ongoing.

Primary objectives

This research studies the physical and biological distributions and processes and their effect on juvenile salmon recruitment on the Gulf of Alaska shelf. The spatial scope of the study was from Montague Strait to west of the Chiswell Ridge. The overriding theme of the proposal was that along-shelf and cross-shelf mesoscale structures are due to bathymetric control of the currents. Physical and biological oceanographic characteristics associated with the Alaska Coastal Current, its offshore excursions in the Seward Eddy and Seward Counter Eddy, the shelfbreak front, slope eddies and meanders and the deep flow were investigated during both of the 21-day cruises in May and July/August.

Approach/methodology

In May and July/August, 2003, we conducted two to three synoptic surveys (5 days each) of cross-shelf transects spaced every 10 km alongshelf. An undulating, underwater, towed vehicle (SeaSoar) was used to continuously map salinity, temperature, depth (CTD), biooptical parameters, and mesozooplankton (optical plankton counter). Surface samples of the above (minus depth), nutrients, and chlorophyll fluorescence were measured continuously using similar sensors. We used an Acoustic Doppler Current Profiler (ADCP) to measure along- and cross-track velocities to 150 m. We calibrated the above with on-station samples of salinity, temperature, nutrients, and phytoplankton.

Research accomplishments/highlights/findings

This past year was spent editing the surface underway nutrient data that was collected simultaneously with the undulating SeaSoar. This large data set contains approximately 43,000 records for six variables for each of the spring and autumn cruises. The edited version has the bad data records removed and was converted from raw voltages to engineering units for comparison to profiles of the SeaSoar fish sensors. The chemical data records from the surface and SeaSoar mapping of physical, chemical and optical biological measurements will be combined on a common time base for analysis, comparison and preparation of a publication of results.

NOAA relevance/societal benefits

This research is important to building a better understanding of mesoscale variability in the coastal ocean especially in an area that is critical habitat for salmon.

Research linkages/partnerships/collaborators and networking

This project is part of GLOBEC (Global Ocean Ecosystem Dynamics), a large multi-agency effort that is strongly supported by both NOAA and the National Science Foundation. David Musgrave of the University of Alaska Fairbanks is directly collaborating on this project, funded by NSF.

Education/outreach

The broader impacts of this study included the training of two Ph.D. students (Amy Childers and TaeKeun Rho) in multidisciplinary oceanography and a better understanding of the effects of oceanographic effects on salmon variability in the Gulf of Alaska. Amy Childers completed her Ph.D. requirements during this reporting period.

Publications

No publications were prepared during the reporting period. The complex merging of the two underway data sets required a major amount of time during this reporting period. Several are being planned for this next period which will be written after the data base manipulations are completed.

Hydrographic and Sea Ice Studies

NOAA / IARC FFY 2005

Syun Akasofu, PI
International Arctic Research Center (IARC)
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Serve Society's Need for Weather and Water Information

CIFAR 34-088 (new) and 35-088a (new): Together these awards support three separate projects. All are ongoing, and progress reports for each of them appear below.

IARC Project #1: Pacific Arctic Shelf Studies (PASS)

PI: Igor Semiletov
Co-PI: Natalia Shakhova
University of Alaska Fairbanks

Primary objectives

The purpose of this project is to quantify changes occurring in the carbon cycle over the shallow Siberian shelf of the Arctic Ocean in connection with circulation, water mass transformations, and transformation mechanisms. Deep-sea studies are also now underway to trace a riverine carbon signature across the Arctic Ocean.
The major objectives of this project are:

- Estimate the geographic variability of main carbon cycle components within the Arctic land–shelf–basin system with focus on the coastal zone, characteristics of particular sources, and factors affecting water–ice–air methane and carbon dioxide gas exchanges.
- Explore transport and fate of terrestrial particulate organic carbon vs. marine organic carbon and their role in sedimentation processes.

Approach/methodology

- To estimate the geographic variability of sinks and sources of atmospheric carbon dioxide (CO_2) in the Arctic Ocean, we applied both "in situ" and "in lab" measurement techniques. Three vessels (the *Auga, Kapitan Dranitsyn*, and the *Oden*) were utilized (Figure 1). New information on pCO_2 dynamics beneath sea ice was obtained in summer, May–August 2005, in the central arctic basin using the Russian North Pole-33 drifting station as a platform, where ice-tethered pCO_2 observations were executed with the autonomous SAMI-CO_2 device, which is described by DeGrandpre et al. (1999), and is equipped with a LI-193 spherical underwater quantum sensor, which is used to measure photosynthetically active radiation (PAR). The SAMI-CO_2 was installed 1.5 m below the sea-ice bottom and it measured pCO_2 at hourly intervals in quasi-stable water temperature, which ranged between -1.7°C and -1.4°C.
- The surface water was pumped through the second SAMI-CO_2 device on board the *Oden*. Distribution of CO_2 was measured along the *Oden* track from Stockholm to the Bering Strait (Figure 1) at hourly intervals. Initial measurements of the air–sea (air–sea and air–sea ice) turbulent fluxes of CO_2 over the Arctic shelf–shelf slope were made onboard the *Kapitan Dranitsyn* and *Auga* in September 2005 (Figure 1), using the eddy-correlation technique (EC). In September of 2005, we measured the turbulent CO_2 fluxes above the open water and ice at an ice station located near the edge of the multi-year sea ice (Semiletov et al. in press).
- Ship-based sampling onboard the *Auga* includes conductivity/temperature/depth (CTD) and water and particulate material (PM) sample profiles, and surface sediments. Chemical and isotope analyses of water samples are used to infer water-mass origins and mixing history. In situ turbidity and colored dissolved organic matter (CDOM), and hydrochemical data will be used to evaluate the intensity of coastal erosion, which is an integrative indicator of degradation of coastal permafrost. Concentration and isotopic signatures of particulate organic carbon and nitrogen were measured at the University of Alaska Fairbanks, using techniques described elsewhere (Guo et al. 2004).
- Distribution of dissolved methane (CH_4) along the Northern Sea Route, surveying near the mouths of the great Siberian rivers (Ob, Yenisey, and Lena), in September of 2005, was also studied onboard the RV *Auga.* Air methane concentration was measured over the sea surface in the Laptev and East Siberian seas, over 15-minute intervals, using a gas chromatographic technique (Shakhova et al. submitted).

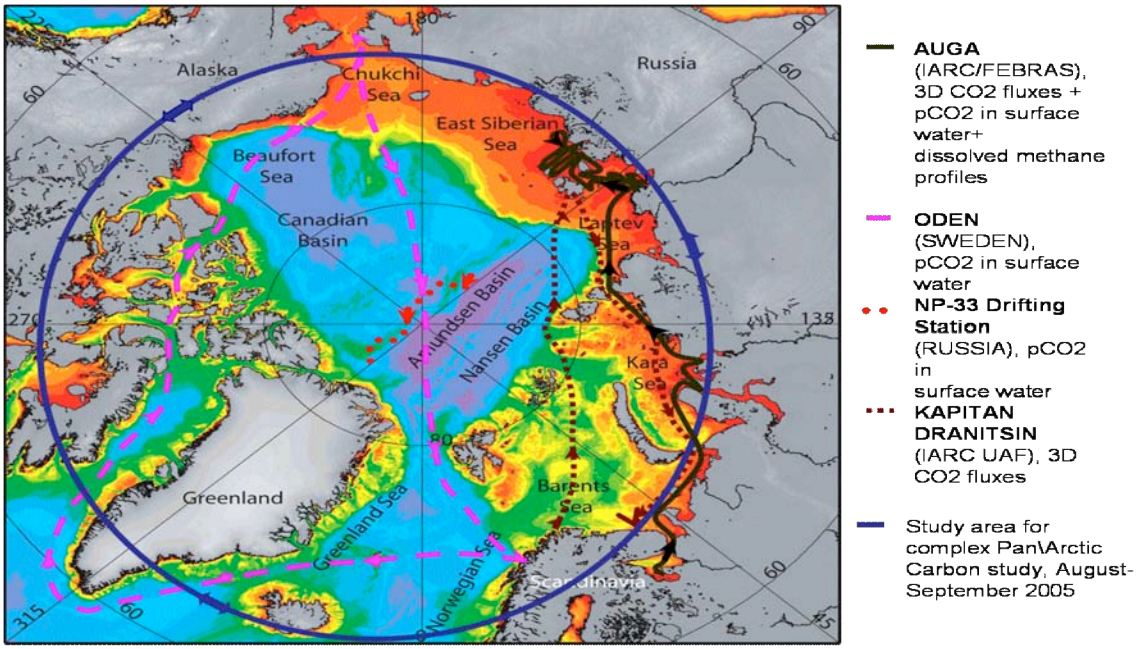


Figure 1. The NOAA-supported Pan-Arctic carbon survey in 2005, with a focus on the shallow Siberian shelf.

- Dynamics of the carbonate system in seawater were also studied using the common pH-total alkalinity technique. We measured pH at 25 ± 0.1°C with an ORION 8103 Ross electrode on the total hydrogen ion concentration scale (pH_T), using tris-buffer prepared according to Goyet and Dickson (DOE 1994). Total alkalinity (A_T) data were obtained by direct indicator titration in an open cell using a 665-Dosimat system with a precision of ± 0.1%. Atmospheric pCO_2 concentration was measured using a Li-Cor-820 non-dispersive infrared analyzer, with precision to within 3% with a 15 cm optical bench. Those data were used to calculate the CO_2 flux between atmosphere and ocean, which was determined by the difference of CO_2 concentration between the sea and atmosphere and by the rate of exchange or transfer velocity.
- Using the ship's Seabird CTD meter, continuous profiles of conductivity, temperature, pressure, light transmission, turbidity, and in situ fluorescence (CDOM) were made on the downcast, with data averaged over 1 dbar intervals. Water samples were taken using Niskin bottles. An Autosal salinometer, which was referenced against IAPSO standard seawater, was also used to test the CTD salinity data. Regional correlations between in situ turbidity and concentration of particulate material (PM), and CDOM-dissolved organic carbon (DOC) were found.

Research accomplishments/highlights/findings

Semiletov and Shakhova organized and coordinated the international (U.S.A., Russia, and Sweden) Pan-Arctic campaign-2005, focusing on the Siberian shelf studies. All the data were integrated, analyzed, and synthesized by the PASS group at IARC.

1. Eddy correlation measurements made above the open water surface of the Laptev Sea ranged between the *negative* (invasion) and *positive* (evasion) values of +1.7 mmol m^{-2} d^{-1} and -1.2 mmol m^{-2} d^{-1}. Comparing the distribution of CO_2 fluxes with surface temperature and salinity shows that warmer and fresher water, which is probably a riverine plume, which is supposed to be the Lena River, acts as a source of CO_2, while relatively colder and saltier water near the ice edge is a sink.
2. Flux measurements made on one-year ice in the Laptev Sea and fast ice near Barrow provide some insights into the influence of sea ice on CO_2 exchange between atmosphere and sea ice surface. We infer that, in early summer, absorption of atmospheric CO_2 by ice-covered ocean dominates; this agrees with data collected using aircraft. Our measurements also suggest the important role of melt ponds and brine channels in gas exchange. The sea-ice melt ponds and open brine channels form an important spring/summer air CO_2 sink that also must be included in any arctic regional CO_2 budget; both the direction and amount of CO_2 transfer between air and sea, during open water season, may be different from transfer during freezing and thawing, or during winter, when CO_2 accumulates beneath Arctic sea ice.

3. Direct measurements beneath the sea ice gave two initial results. First, new measurements made in summer 2005, beneath the sea ice in the Central Basin, show relatively high values of pCO_2 ranging between 425 μatm and 475 μatm, values which are larger than the mean atmospheric value in the Arctic in summertime. The sources of those high values are supposed to be: high rates of bacterial respiration, import of upper halocline water (UHW) from the Chukchi Sea, where values of pCO_2 range between 400–600 μatm, a contribution from the Lena River plume, or any combination of these sources. Second, a drastic pCO_2 decrease from 410 μatm to 288 μatm, which was recorded in February–March, beneath the fast ice near Barrow using the SAMI-CO_2 sensor, may reflect increased photosynthetic activity beneath sea-ice, just after polar sunrise.
4. Concentration of dissolved CH_4 in estuaries of the great Siberian rivers are supersaturated, with CH_4 up to 200 times more than the atmosphere content. The lowest concentrations of CH_4 were found in the Ob River, which drains the region primarily covered by non-permafrost soils. Modest concentrations were found in the estuary of the Yenisey River, a watershed underlain primarily with discontinuous permafrost. The highest concentrations were found in the estuary of the Lena River, located primarily in the continuous permafrost zone. This west–east trend in CH_4 coincides with the increase in the wideness and the thickness of the permafrost zone in the Siberian region, and with an increase in organic matter freshness.
5. Anomalies in dissolved CH_4 distribution and air CH_4, which are above the sea surface, were correlated spatially with fault zones in the Laptev and East Siberian seas. Some geological and modeling results show that this phenomenon may be caused by CH_4 release from sub-sea gas hydrates, destabilized due to the Lena heat effect, and an anomalously high geothermal flux, which thawed the sub sea permafrost through.

NOAA relevance/societal benefits

1. New data obtained within the framework of this project will be crucial for detection of climate changes, since supplemental climate information and atmospheric modeling, which today are our primary weather and climate forecasting tools, will improve future planning both for governments and for individuals, and therefore is highly relevant to and consistent with NOAA's mission to "Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond."
2. Some results obtained in this project are highly relevant to the Study of Environmental Change (SEARCH). The Arctic is linked to the rest of the globe biogeochemically via carbon exchanges (SEARCH 2005). Since the effects of arctic change on the global radiation balance and the carbon cycle are central to the Arctic's role in the broader earth system, we believe that change in air composition caused by CH_4 release from the Siberian shelf can be considered as a sign of gas hydrate decay, though additional studies are required to test this hypothesis.
3. Empirical regional relationships between concentration of DOC and CDOM, PM and turbidity, and salinity and dissolved inorganic carbon (DIC) have been established in the Laptev and East Siberian seas. These relationships may be used for satellite data validation, restoring DOC/DIC, river plume, and PM dynamics over the last three decades, and the development of biogeochemical modeling in the Arctic.

Research Linkages/Partnerships/Collaborators and Networking

Participation of international scientific partners at every stage of this arctic project is crucial to its success. We have established strong ties with scientists from other U.S. and international institutions: primarily with the Institute of Marine Sciences (IMS), University of Alaska Fairbanks; Pacific Oceanological Institute (POI), Far-Eastern Branch of Russian Academy of Sciences (FEBRAS); the Institute of Ocean Sciences (IOS, Canada); Stockholm University (Sweden); University du Quebec a Rimouski (Canada); PP Shirshov Institute of Oceanology (IORAN, Russia); Institute of Atmospheric Physics (IFA RAN, Russia), Ust'-Lensky Reservation (Tiksi, Russia); and the Arctic and Antarctic Research Institute (AARI, Russia). Our strategic partnership with the FEBRAS Headquarters and POI is an example of a stable and mutual collaboration between the U.S. and Russian institutions (three joint U.S.–Russia cruises in the Siberian seas have already been accomplished since 2003). Cooperation with Stockholm University is also in progress.

Education/outreach

Student participation

Two FEBRAS-based graduate students (Alexander Charkin and Denis Kosmach) participated in the field campaign in 2005 onboard the *Auga*. Semiletov is a scientific adviser for both of them.

Oral presentations

Semiletov, I.P. and N.E. Shakhova. 2005. Carbon cycling in the Laptev and east-Siberian Seas. Invited report in the Institute of Applied Environmental Research/Stockholm University, Stockholm, Sweden, 18 November 2005.

Semiletov, I.P. 2005. Carbon cycle in the Arctic Ocean: the east-Siberian region. Plenary report in the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia, 23 November 2005.

Semiletov, I.P. 2006. Results of joint U.S.–Russia cruises in the Siberian Seas (2003–2005). Invited report in the Institute of Marine Geology and Geophysics, Far Eastern Branch, Russian Academy of Sciences, Yuzhno-Sakhalinsk, Russia, 3 April 2006.

Poster presentations

Semiletov, I., O.V. Dudarev, I.I. Pipko, N. Shakhova, O. Gustaffson, I. Repina and A. Makshtas. 2006. Carbon cycling in the atmosphere–sea ice–ocean and land–shelf systems in the Arctic: new data. 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.

Shakhova, N., I. Semiletov, N. Bel'cheva, A. Salyuk, V. Yusupov and D. Kosmach. 2006. Methane anomalies in the Arctic air–sea system. 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.

Makshtas, A., R. Vlasenkov, I. Semiletov, I. Pipko, A. Charkin and N. Belchiva. 2006. Radiation climate of the east-Siberian Sea coastal waters in the present and past. 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.

Shakhova, N., I. Semiletov and V. Ioussoupov. 2005. Dissolved methane in the east-Siberian and Laptev Seas. American Geophysical Union Fall Meeting, San Francisco, California, 5–10 December 2005.

Semiletov, I., N. Shakhova, G. Panteleev and O. Dudarev. 2005. Detection of environmental changes in the Arctic seas: carbon and water masses. American Geophysical Union Fall Meeting, San Francisco, California, 5–10 December 2005.

Publications

Accepted or in press

Dudarev, O.V., I. Semiletov, A. Charkin and A. Botsul. Deposition settings on the continental shelf of the East Siberian Sea. *Transactions of Russian Academy of Sciences*, in press [409(6)] (translated into English from *Doklady Akademii Nauk*).

Semiletov, I.P., I.I. Pipko, I. Repina and N.E. Shakhova. Carbonate chemistry dynamics and carbon dioxide fluxes across the atmosphere–ice–water interfaces in the Arctic Ocean: Pacific sector of the Arctic. *Journal of Marine Systems*, in press.

Shakhova, N. and I. Semiletov. Methane release and coastal environment in the East Siberian Arctic Shelf. *Journal of Marine Systems*, in press.

Macdonald, R.W., L.G. Anderson, J.P. Christensen, L.A. Miller, I.P. Semiletov and R. Stein. The Arctic Ocean: budgets and fluxes. Chapter In: K.-K. Liu, L. Atkinson, R. Quinones and L. Talaue-McManus, Eds., Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis, Springer-Verlag, accepted.

Shakhova, N.E., I.P. Semiletov, A. Salyuk, N. Bel'cheva and D. Kosmack. Anomalies of methane in air above the sea surface in the East-Siberian arctic shelf. *Transactions of Russian Academy of Sciences*, accepted.

Submitted

Semiletov, I.P., C.P. McRoy, I.I. Pipko, O.V. Dudarev, N.E. Shakhova, S.P. Pugach, A.N. Charkin and A.Yu. Gukov. On the chemical signature of the Lena River from the upper stream to the Laptev Sea: interactions with atmospheric circulation, river runoff, and ocean conditions. Submitted to *Journal of Geophysical Research–Biogeosciences*.

Semiletov, I.P., O.V. Dudarev, I.I. Pipko, N.E. Shakhova and A.N. Charkin. Transport and fate of terrestrial organic carbon, dynamics of the carbonate system, and dissolved methane and their fluxes in the East-Siberian Arctic seas. Submitted as a chapter to be published in Arctic Coastal Dynamics, Elsevier Press.

Semiletov, I. and I. Pipko. Sources and sinks of carbon dioxide in the Arctic Ocean: results of direct instrumental measurements. Submitted to *Transactions of Russian Academy of Sciences*.

Shakhova, N., I. Semiletov, A. Salyuk, N. Bel'cheva and D. Kosmach. Anomalies of methane in air above the sea surface in the East-Siberian Arctic Shelf. Submitted to *Transactions of Russian Academy of Sciences*.

Shakhova, N.E., I.P. Semiletov and N. Bel'cheva. The great Siberian Rivers as a source of methane on the Russian arctic shelf. Submitted to *Transactions of Russian Academy of Sciences*.

References

DeGrandpre, M.D., M.M. Baehr and T.R. Hammar. 1999. Calibration-free optical chemical sensors. *Analytical Chemistry*, 71:1152–1159.

Department of Energy (DOE). 2004. Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. A.G. Dickson and C. Goyet, Eds., ORNL/CDIAC-74.

Guo, L., I. Semiletov, O. Gustafsson, J. Ingri, P. Andersson, O. Dudarev and D. White. 2004. Characterization of Siberian Arctic coastal sediments: implications for terrestrial organic carbon export. *Global Biogeochemical Cycles*, 18, GB1036. doi:10.1029/2003GB002087.

Study of Environmental Change (SEARCH). 2005. Study of Environmental Arctic Change: Plans for Implementation During the International Polar Year and Beyond. Arctic Research Consortium of the United States (ARCUS), Fairbanks, Alaska, 104 pp.

IARC Project #2: NABOS/CABOS (Nansen and Amundsen Basins Observational System / Canadian Basin Observational System)

Participants:
Igor Polyakov, Igor Dmitrenko, Vladimir Ivanov, Robert Chadwell
International Arctic Research Center (IARC), Fairbanks, AK, USA
M. Dempsey
Oceanetic Measurement Ltd., Sidney, BC, Canada

Primary objectives

The purpose of this project is to provide a quantitative, observationally based assessment of the circulation, water mass transformations, and transformation mechanisms in the Eurasian Basin of the Arctic Ocean. The major objectives of this project are:

- To quantify the structure and variability of the circulation in the upper, intermediate, and lower layers of the Eurasian Basin;
- To evaluate mechanisms by which the Atlantic Water is transformed on its pathway along the slope of the Eurasian Basin;
- To evaluate the impact of heat transport from the Atlantic Water on ice;
- To investigate the strength and variability of the Fram Strait and Barents Sea branches of the Atlantic Water; and,
- To estimate the rate of exchange between the arctic shelves and the interior in order to clarify mechanisms of the arctic halocline formation.

Approach/methodology

The primary monitoring tool of the NABOS/CABOS program is a series of moorings placed at carefully chosen locations around the Arctic Ocean. Time series obtained from these moorings allow separation of synoptic-scale "noise" (e.g., eddies, shelf waves) from longer term climatic signal. Located along the major pathways of water, heat, and salt transport, such moorings capture climatically important changes in oceanic conditions. The locations of moorings within each cross-section are designed to capture the major near-slope transports within surface, intermediate, and bottom layers, resolve important shelf–basin interaction processes, and document the complex interactions of the Fram Strait and Barents Sea branches of the inflowing Atlantic Water. The NABOS/CABOS moorings operate for one year at a time, with replacement every year. A gradual increase in the number of moorings is planned, from two deployed in summer 2002 to the full-scale monitoring system after several years. In the Canadian Basin, several moorings are planned. Their locations are chosen to best complement existing Canadian, Japanese, and U.S. moorings, so that international coordination is essential. The CABOS moorings will provide detailed information on small-scale processes at the mooring locations, but the primary goal is to resolve large-scale modes of variability. Most NABOS/CABOS moorings are equipped with the "McLane Moored Profiler" (MMP). This instrument is capable of profiling vertically along the mooring line. The MMP is typically equipped with a conductivity/temperature/depth (CTD) sensor and a three-component acoustic velocimeter. The up-and-down motion of the profiler is programmable, making it possible to focus on specific depth ranges and time periods, giving a high degree of flexibility in designing a sampling scheme.

Research accomplishments/highlights/findings

Our observational program successfully follows the roadmap. For example, in 2005, as a part of our multi-disciplinary field program, we maintained seven moorings in accordance to our plans specified for this year. The strong international collaboration of NABOS/CABOS scientists in research and outreach provides strong evidence of the successful path of our program towards its goals.

- *International collaborations (MAOOS/IPY):* Further understanding of the evolving changes in the Arctic Ocean depends strongly on available observational data. That is why, under the stimulus of the International Polar Year (2007–08), we proposed a coordinated large-scale Mooring-based Arctic Ocean Observational System

(MAOOS) as a part of the international Arctic Ocean Observing System (iAOOS). The intention is to make this program a backbone of the future climate-oriented observational activities. Note that Arctic Ocean Model Intercomparison Project (AOMIP) models are planned to be used in the iAOOS, thus these two IARC projects are naturally linked together through their international cooperation. The expected gain is an enhanced predictability of the Arctic climate system. Our Expression of Intent and proposal were approved by the IPY Search Committee. This proposal is well-accepted by the international community. For example, NABOS/MAOOS was mentioned 11 times in the Annex of DAMOCLES which is the leading EU IPY-related program.

- *Science*: *New warm anomaly found in the Arctic Ocean*: This observationally based study provides new insights into Arctic variability. Our findings demonstrate that over the last decade the North Atlantic supply of warm water into the Arctic Ocean has increased. New pulses of anomalously warm water, including unprecedented warmth at some locations, are on the doorsteps of the Arctic Ocean. These anomalies promise to make the polar basin even warmer, with implications for decaying sea ice.

NOAA relevance/societal benefits

This program establishes international cooperation in Arctic research, combining efforts of several nations with strong Arctic interests. New data from Russian waters obtained within the framework of this project are crucial for detection of climate changes, since supplemental climate information and atmospheric modeling, necessary for our primary weather and climate forecasting tools, improve future planning both for governments and for individuals from Arctic nations and therefore are highly relevant to and consistent with NOAA's mission to "*Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond*."

Research linkages/partnerships/collaborators and networking

Funding partnerships

This project was funded primarily by NOAA with major contributions from the National Science Foundation (NSF) and the Japan Agency for Marine–Earth Science and Technology (JAMSTEC), who provided some salary support for the NABOS team. In addition, NSF funds were used for a portion of shipping and publication charges.

Research partnerships

Alfred-Wegener Institute, Bremerhaven, Germany
Applied Physics Laboratory/University of Washington, USA
Arctic and Antarctic Research Institute, St. Petersburg, Russia
Centre for Environment, Fisheries and Aquaculture Science, UK
Ecoshelf, St. Petersburg, Russia
Geophysical Institute, Bergen, Norway
Institute of Marine Sciences, UAF, USA
Institute of Ocean Sciences, BC, Canada
Laboratoire d'Océanographie Dynamique et de Climatologie, France
Laval University, Canada
Naval Research Laboratory, Stennis Space Center, USA
Norwegian Meteorological Office, Norway
Norwegian Polar Institute, Norway
Oceanetic Measurement Ltd., Sidney, BC, Canada
State Research Navigation and Hydrographic Institute, St. Petersburg, Russia
University of Washington, Seattle, USA

Education/outreach

Summer School aboard Russian icebreaker: For graduate students and early career scientists, IARC, in cooperation with Laval University (Canada), the Arctic and Antarctic Research Institute (Russia), and the Obukhov Institute of Atmospheric Physics (Russia) organized the Summer School "Climate Change in the Arctic Ocean" aboard the Russian icebreaker *Kapitan Dranitsyn* during its fourth scientific cruise to the Arctic Ocean in September 2005. Leading invited scientists addressed a wide spectrum of polar disciplines from oceanography and meteorology to biology, chemistry, and Arctic paleoclimate. In addition to the opportunities for learning and professional training that are provided by a traditional onshore educational system, the students from 10 countries aboard the icebreaker had a unique chance to experience arctic exploration to acquire invaluable skills in oceanographic field work under harsh arctic conditions, and to gain a better understanding of how scientific observations are organized in practice. Students learned first-hand about oceanographic, biochemical, ice, and meteorological observations in the

dynamically rich area of the Arctic. Working with the international team of experienced polar researchers provided them an excellent opportunity to learn more about modern methods of high-latitude observations and analysis, and to personally participate in the study of the fast-changing Arctic environment. The Summer School web page is http://www.iarc.uaf.edu/education_outreach/summer/iarc_2005/

Web sites

http://www.nabos.iarc.uaf.edu
http://www.nabos.iarc.uaf.edu/cruise/2005
http://www.iarc.uaf.edu/education_outreach/summer/iarc_2005/
http://www.nabos.iarc.uaf.edu/cruise/reports (past cruise reports)

Publications

In preparation

Walsh, D. et al. High-resolution measurements of thermohaline structure and flow in Mackenzie Canyon, Beaufort Sea. In preparation for submission to *Journal of Marine Systems*.

Walsh, D., I. Polyakov, L. Timokhov and E. Carmack. Thermohaline structure and variability in the Eastern Nansen Basin from historical data. In preparation for submission to *Journal of Geophysical Research.*

IARC Project #3: Driftwood and Humans in the North

PI: Claire Alix
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
Ma Zhifang and Anna Jacobson*, University of Alaska Fairbanks*

Primary objectives

The primary objective of the project is to develop a technique to identify the source of driftwood along major Alaska rivers and its age as it enters the Bering Sea/Arctic ocean system, in order to determine the rate and path of transport and ultimately allow the analysis and dating of well-preserved and abundant archaeological wood remains from coastal sites of the last two thousand years. This work is conducted in conjunction with an analysis of the traditional use and cultural meaning of the driftwood resource both now and in the past to better understand the archaeological record.

Approach/methodology

Our methodological approach combines tree-ring and oral history research:

- Collecting and measuring tree-rings of white and black spruce (*Picea glauca, P. mariana*) from driftwood-producing floodplain environment and driftwood accumulations from coastal Alaska. Several tree-ring master chronologies are being built with samples collected along the Yukon River between Circle and Galena, and on the Tanana and Kuskokwim rivers. Undated chronologies are also being built from driftwood disks collected along Bering Sea and Chukchi Sea coasts, which are then cross-dated with the floodplain master chronologies and other published Alaska tree-ring chronologies. Origin, age and transit time of driftwood samples are then recorded. Tree-ring signals in the samples are compared with climate and other environmental data.
- Analysis of oral history and ethnographic recordings collected in villages of southwestern Alaska and along the Yukon and Kuskokwim rivers. These recordings include information on the annual driftwood transport and delivery, the technological, economical and traditional aspect of driftwood use and on the environmental and climate factors that impact the resource and people's use of the resource record.

Research accomplishments/highlights/findings

- Nine *Picea glauca* floodplain master chronologies have been built representing five stands along the Yukon River and one along the Tanana River (see locations in Figure 1).

  Analysis of the master chronologies shows that some recurrent pointer years are a response to major and widely shared climate and possibly river events. However, growth on the floodplain is not generally limited by climate as is seen on upland and tree-line sites. To date we have not found a significant correlation between floodplain chronologies and climate records of interior Alaska. Other data sets such as river water tables are being examined for possible correlations.
- More than fifty driftwood disk samples have been processed and measured representing eight driftwood collections sites from Hooper Bay to Point Barrow (see locations in Figure 1).

- Driftwood samples are being crossdated with master chronologies.

  First attempts have validated the crossdating technique. A large log collected in 2003 at the north end of Hooper Bay by resident S. Stone has an end date of 1998 (Figure 1). This log was successfully cross-dated with the Beaver area master chronology. It took this log five years to drift down the river, reach Hooper Bay area and be collected. According to S. Stone, the log was fresh and freshly arrived in 2003. We collected it in 2004 from a firewood stock that was intended to last several years.
- Twenty-one hours of oral history recordings on wood and driftwood use and ecology have been transcribed and translated (Yup'ik to English).

  The analysis of these interviews shows the depth of knowledge shared by traditional driftwood carvers. It also shows the similarity of technology and wood type selection between what we observed on archaeological material from Arctic sites and what we recorded from traditional carvers.

  These recordings also reveal the existence of a high quality spruce wood extracted from the lower part of tree trunk that presents quality such as grain straightness, regular growth ring patterns, absence of knots, etc. The description of this wood recalls the description of a highly prized wood called "resonance wood" in western Europe. Growth conditions given for "resonance wood" in Switzerland parallel some of the growth conditions of floodplain white spruce (*Picea glauca*) along major river systems of Alaska (i.e., Yukon River).

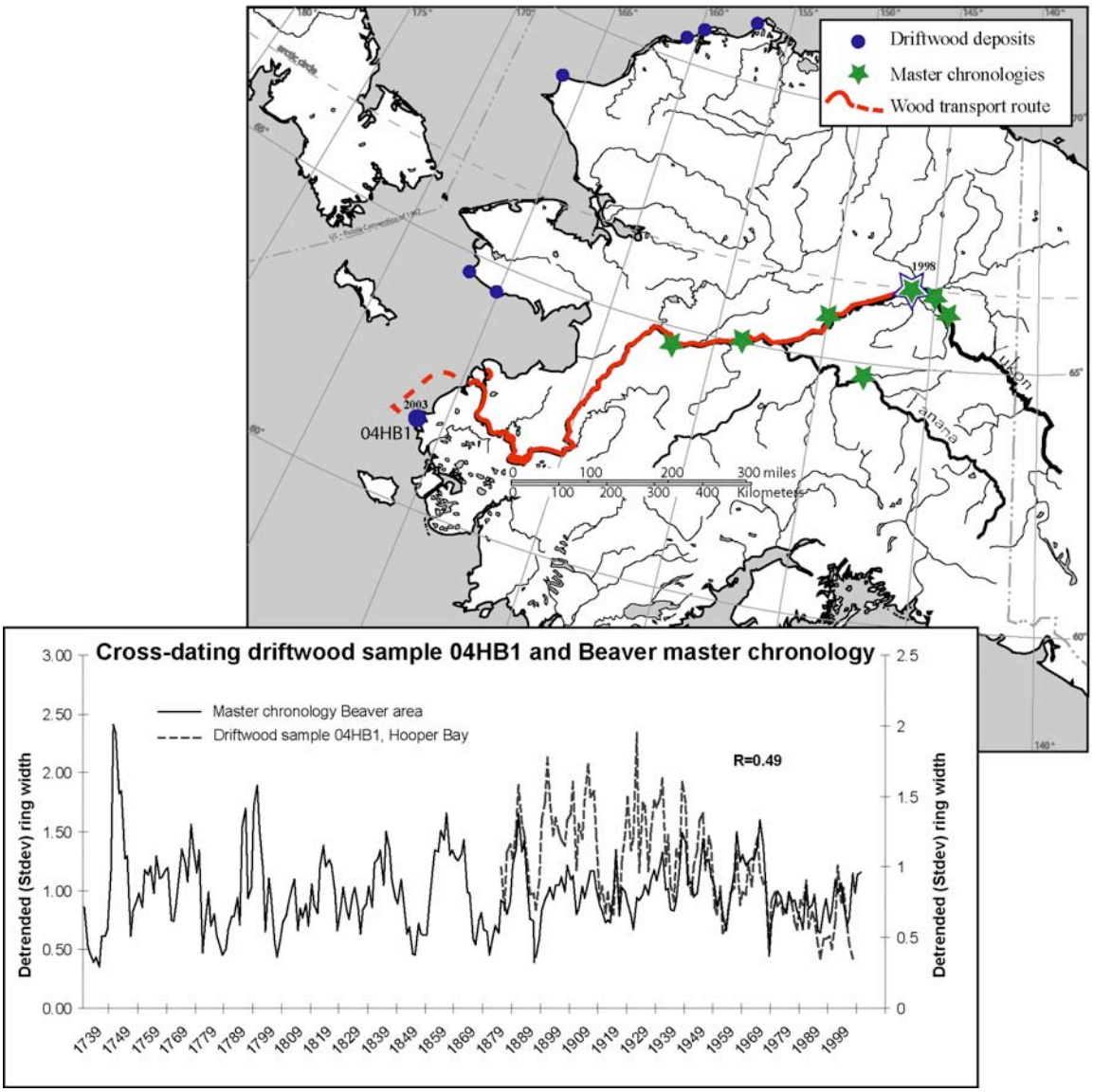


Figure 1. Floodplain tree stands, driftwood deposits and sourcing of driftwood.

NOAA relevance/societal benefits

This research is providing the basis for determining the replenishment rate of a limiting resource (wood) in the treeless Arctic region and the influence of coastal currents and wind in moving it. The identification of traditional uses helps distinguish high value from low value driftwood pieces and contributes to the preservation of this traditional knowledge.

Research linkages/partnerships/collaborators and networking

The Bonanza Creek Long Term Ecological Research (LTER) program (NSF) collaborates through support by the tree-ring laboratory of UAF (Dr. Glenn P. Juday, principal collaborator). The Oral History Program (project Jukebox) at UAF assists with interviews and archives the recordings (K. Brewster, main collaborator). Traditional carvers from Native Villages of Hooper Bay, Scammon Bay, and Napakiak are local collaborators.

Education/outreach

Public outreach

Copies of the oral history interviews have been made and are being sent to the village councils and to the project participants and collaborators.

Alix gave presentations in Whitehorse at the Beringia Interpretative Centre and the Centre de la Francophonie (Invited speaker of the Yukon Science Institute).

Presentations

Alix, C. 2005. "Resonance Wood" in the Arctic? Traditional knowledge and selection of wood among the Yup'ik and Inupiaq Eskimo. 6th Pacific Regional Wood Anatomy Conference, Kyoto, Japan, 1–5 December 2005.

Alix, C. 2006. L'homme et le bois flotté dans l'Arctique. Presentation to the Centre National de la Recherche Scientifique (CNRS) research team "Archéologie des Amérique," Paris, France, 19 May 2006.

Publications

In preparation

Key pointer years in Alaska tree-ring series. (Juday, Alix and others); "Resonance Wood" in the Arctic? Traditional knowledge and selection of wood among the Yup'ik and Inupiaq Eskimo (Alix); Use of master chronologies from Alaska rivers to date Arctic Driftwood (Alix and Juday)

Monitoring Sea Ice Thickness in the Arctic Ocean Using Seafloor-Moored Ice Profiling Sonar

Humfrey Melling, PI
Fisheries and Oceans Canada
Institute of Ocean Sciences, Sidney, BC

NOAA Goals: Understand Climate Variability and Change; Safe, Efficient and Environmentally Sound Transportation

CIFAR 10-077: This project is complete.

Primary objectives

One of the main goals of NOAA's SEARCH initiative is to produce an annual report of the state of and change in the Arctic sea ice cover, which will be widely distributed. Under this CIFAR project, we establish an ice monitoring site in the northern Chukchi Sea, in a key location for describing variability in Arctic sea-ice thickness. From a sub-surface oceanographic mooring, we use ice-profiling and Doppler sonar to measure ice draft, ridging and velocity of drift. The site is part of a larger array with sites in the southeastern Beaufort Sea (Canadian funds), at the North Pole (NSF funds) and in the Canadian Arctic Archipelago.

Approach/methodology

Year 1 (2004–05)

- Identify a platform for initial deployment.
- Fabrication of 2 mooring packages.
- Establishment of mooring site CH01.
- Deployment of ice-mass balance (IMB) buoy in vicinity of CH01.

Year 2 (2005–06)

- Recovery and re-deployment of instruments at mooring site CH01.
- Deployment of IMB buoy in vicinity of CH01.

- Analysis, archiving and reporting of the data collected from the drifting buoys.
- Presentation of results, including development of a webpage.

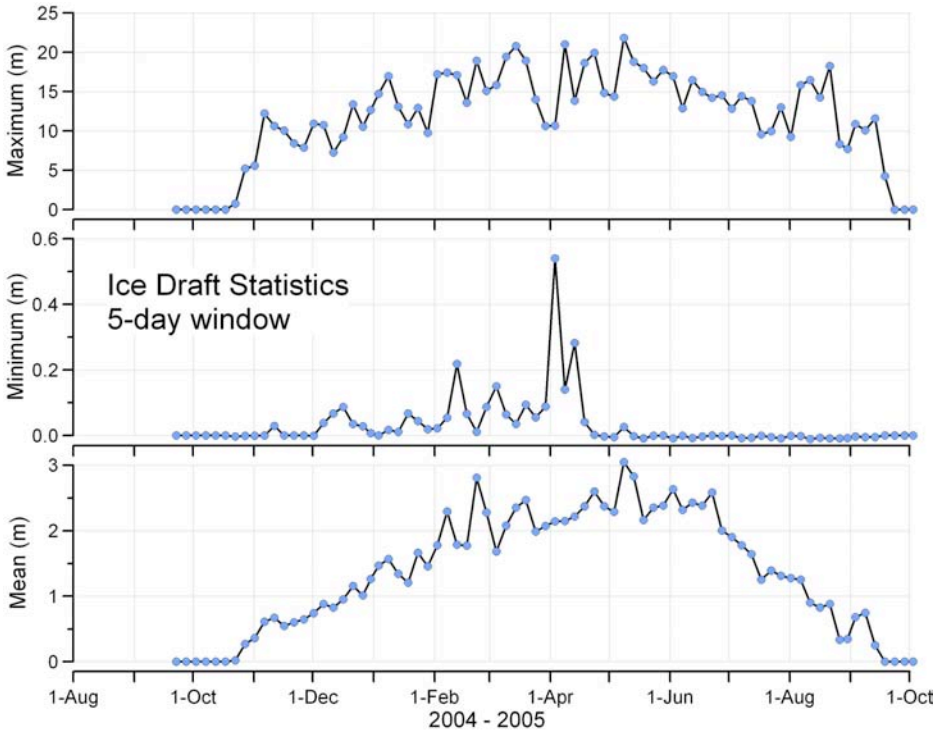
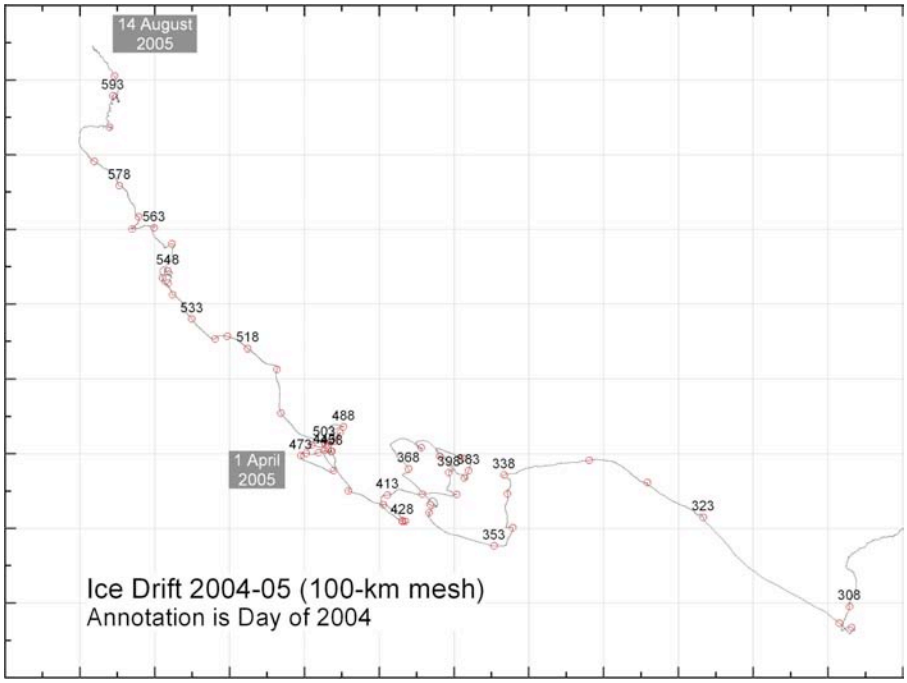


Figure 1. Ice at the mooring reached 2.5-m average draft (about 2.9-m average thickness) in late winter 2004–05. This is about 1 m less than the value mapped by Bourke and Garrett (1987) based on submarine sonar data prior to 1985. The large seasonal range is also unusual for this area, reflecting both the typical thinning and spreading of ice floes in summer and an atypical northward drift of the pack (see below), which placed the site near the ice edge by mid August.



Research accomplishments/highlights/findings

- The mooring site (76.1°N, 168°W) was serviced in October 2005 (*CCGS Sir Wilfrid Laurier*).
- Data recovery from moorings has been 100% – ice draft, ice velocity, upper ocean current, temperature and acoustic backscattering cross-section.
- Data calibration and processing of observations have been completed.
- Ice at the mooring reached 2.5-m average draft (about 2.9-m average thickness) in late winter 2004–05 (Figure 1). This is about 1 m less than the value mapped by Bourke and Garrett (1987) based on submarine sonar data prior to 1985.
- Co-author of NOAA State of the Arctic Report 2006, presently in draft

NOAA relevance/societal benefits

This project is providing information on the impact of changing climate on Arctic ice pack. It will provide the means of assessing the accuracy of numerical forecasts of future Arctic ice conditions. It will permit study of the relative importance of various influences on Arctic ice—air temperature, sea temperature, snow cover, ice circulation and ice deformation. Such information and understanding are essential for appropriate and timely societal adaptation to changing conditions—shipping, offshore oil and gas, traditional lifestyles.

Research linkages/partnerships/collaborators and networking

This project forms a part of an internationally coordinated effort under CliC (the Climate and Cryosphere project of the World Climate Research Programme) to monitor the state of the northern marine cryosphere and its variability (http://nsidc.org/noaa/moored_uls/index.html). In particular it fosters collaborations between the Canadian Department of Fisheries and Oceans, which has monitored ice thickness in the Beaufort Sea since 1990 and recently established sites in the Canadian Arctic Archipelago, the USA agencies NOAA and NSF, and Canadian private-sector partners, IMV Projects of Calgary and ASL Environmental Sciences Inc. of Sidney. Together, we now maintain an observational network that spans a third of the Arctic Ocean. Logistics are provided at incremental cost by icebreakers of the U.S. and Canadian Coast Guards. The moorings can provide a substrate for instrumentation needed for other types of measurement in remote areas of the Arctic Ocean—oceanography and biology.

Education/outreach

- Web site: http://www.crrel.usace.army.mil/sid/IMB/index.htm
- Co-author, Arctic Climate Impact Assessment, Chapter 2
- Panel member, WCRP Arctic Climate Panel for CliC and CliVar
- Member of Northern Panel & contributing author, chapter 4, Canadian Climate Change Impacts & Adaptation Assessment, Natural Resources Canada.
- Contributing author, The IPCC 4th Assessment Report. Observations: Changes in Snow, Ice and Frozen Ground.
- Co-author, NOAA State of the Arctic Report 2006, presently in draft

Presentations

Melling, H. and J.A. Dumas. 2005. Pack ice, stamukhi and the development of fast ice. 6th Annual Canadian Ice Service Sea-Ice Workshop, Victoria, B.C., July 2005.

Melling, H. 2005. Sea ice in relation to offshore development. Oil and Gas Engineering Issues for the Beaufort Sea. PERD workshop with oil industry stakeholders, Calgary, October 2005.

Melling, H. 2005. Sea ice, climate & Beaufort development. Northern Oil & Gas Research & Development in the Beaufort Sea. INAC/PERD workshop with Northern stakeholders, Inuvik, October 2005.

Publications from collaborative activity

Peer-reviewed

Melling, H., D.A. Riedel and Z. Gedalof. 2005. Trends in the draft and extent of seasonal pack ice, Canadian Beaufort Sea. *Geophysical Research Letters,* 32, L24501, doi: 10.1029/2005GL024483

Amundrud, T.L., H. Melling, R.G. Ingram and S.E. Allen. 2006. The effect of structural porosity on the melting of ridge keels in pack ice. *Journal of Geophysical Research,* 111, C06004, doi:10.1029/2005JC002895.

Eicken, H., R. Gradinger, A. Graves, A. Mahoney, I. Rigor and H. Melling. 2005. Sediment transport by sea ice in the Chukchi and Beaufort Seas: Increasing importance due to changing ice conditions? *Deep-Sea Research II*, 52:3281–3302. doi:10.1016/j.dsr2.2005.10.006.

McBean, G.A., G. Alekseev, D. Chen, E. Forland, J. Fyfe, P.Y. Groisman, R. King, H. Melling, R. Vose and P.H. Whitfield. 2005. Chapter 2: Arctic Climate: Past and Present. In: *Arctic Climate Impact Assessment*, Cambridge University Press, pp. 21–60.

Submitted

Dumas, J.A., H. Melling and G.M. Flato. 2006. Late-summer pack ice in the Canadian Archipelago: Thickness observations from a ship in transit. Submitted to *Atmosphere–Ocean*. (manuscript is concerned with development of methods for ship-of-opportunity ice monitoring)

Note that publications emerge from mooring projects with appreciable lag. This project was funded in July 2004. The mooring and instruments were prepared in the initial months, and deployed in September 2004. The mooring was 13 months at sea before recovery in October 2005. Data were queued shortly thereafter and processing was not completed until May 2006, 6 weeks before the formal end of the project. Our focus now is the scientific interpretation and implications of the new observations.

Reference

Bourke, R.H. and R.P. Garrett. 1987. Sea ice thickness distribution in the Arctic Ocean. *Cold Regions Science and Technology*, 13:259–280.

Bering Strait: The Pacific–Arctic Ocean Connection: RUSALCA 2005

Thomas Weingartner, PI ***NOAA Goal: Understand Climate Variability and Change***
Terry Whitledge, Co-PI
University of Alaska Fairbanks

CIFAR 26-082 (new): This project is ongoing and is a continuation of the RUSALCA project, CIFAR 10-071.

Primary objectives

Our goals are to:

1) recover and analyze data from a mooring deployed in the western channel (Russian EEZ) in August 2004,
2) replace this mooring with a new mooring containing an Acoustic Doppler Current Profiler (ADCP) and temperature-conductivity (T/C) recorder, and
3) supplement the two proposed Russian moorings (under the direction of I. Lavrenov of the Arctic and Antarctic Institute) with T/C recorders and (Aanderaa) current meters.

Approach/methodology

Our approach involves making measurements of the salinity, temperature, velocity, in the western channel of Bering Strait at hourly intervals for a period of one year. The measurements will be made from a single mooring deployed in the center of the western channel of Bering Strait. The mooring will contain an RDI 300 kHz upward looking ADCP current meter for measuring velocity and a SeaCat (SBE-16 T/C recorder) for the temperature and salinity measurements. The mooring will be deployed in the center of the channel at about 65 53.8'N, 169 25.9'W, which is the approximate position of the A1 mooring previously deployed in the western channel (Roach et al. 1995).

Research accomplishments/highlights/findings

- Mooring that was deployed in August 2004 (with funding through CIFAR 10-071) was recovered on 8/20/05. Three moorings were deployed 8/21/2005–8/22/2005.
- CTD (conductivity, temperature, depth) profiles and nutrients collected on a hydrographic transect conducted across the strait.
- Preliminary processing of mooring data begun, with preliminary results reported at the RUSALCA meeting held in Montenegro.
- For the western channel of Bering Strait, the data suggest an increase in temperature and heat flux in the summer and early fall compared to measurements obtained in the early 1990s. There is no apparent change in salinity or the freshwater flux.
- Moored fluorescence data suggest that the spring bloom began in late April.

NOAA relevance/societal benefits

Bering Strait is the sole connection between the Pacific and Arctic oceans. As such it provides an efficient environmental monitoring location able to detect integrated changes in the Bering Sea ecosystem. The flux of nutrients, salinity, and heat from the Bering to the Arctic Ocean has important influences on this ecosystem and on climate.

Research linkages/partnerships/collaborators and networking

This project continues work originally funded under NOAA's RUSALCA program—a multi-investigator, interdisciplinary program to conduct marine research in Bering Strait and the Chukchi Sea. The RUSALCA program afforded the first opportunity since the early 1990s for U.S. scientists to work in the Chukchi Sea.

Our measurements will complement those obtained from moorings in the eastern channel (US EEZ) of Bering Strait, which, with the exception of one year, have been maintained since 1990 under NSF, NOAA, and/or ONR support by K. Aagaard and R. Woodgate from the University of Washington. Aagaard, Woodgate, Weingartner, and Whitledge have worked together for over a decade and so collaborative analyses and data sharing are easily facilitated among these PIs.

Education/outreach

Presentation

Weingartner, T., R. Woodgate and K. Aagaard. Bering Strait: The Pacific-Arctic Connection. Oral presentation given at the RUSALCA Meeting, Montenegro, November 2005.

Reference

Roach, A.T., K. Aagaard, C.H. Pease, S.A. Salo, T. Weingartner, V. Pavlov and M. Kulakov. 1995. Direct measurements of transport and water properties through Bering Strait. *Journal of Geophysical Research,* 100:18,443–18,457.

Assessment of Arctic Snowcover Change and its Impact on Large River Runoff

Daqing Yang, PI
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIFAR 14-081 (new): This project is ongoing.

Primary objectives

The primary objective of this research is to determine arctic snowcover change and assess its impact on large river runoff change and variation. Three major aspects of research are designed to accomplish the goals: a) Generation and analysis of weekly snowcover and runoff time-series for all major arctic watersheds; b) Examination of streamflow response to snowcover extent change; and, c) Cross-validation of results.

Approach/methodology

This is a 3-year project. The main tasks in Year 1 include dataset preparation and analyses of arctic regional climatic/hydrologic changes. Up to spring 2006, we have acquired long-term records for temperature, precipitation, snowcover, and river streamflow for the largest arctic watersheds (i.e., the Ob, Yenisei, Lena, Yukon and Mackenzie basins), and river ice thickness data for the Lena basin. Snowcover data are the key for this research; we have updated remotely sensed snow data, including visible snow cover extent and Special Sensor Microwave/Imager (SSM/I)/snow water equivalent. In particular, we have made considerable progress in evaluating the impact of the late 1990s switch from the weekly NOAA visible map product to the daily Interactive Multisensor Snow and Ice Mapping System (IMS) product (in conjunction with another NOAA grant of co-PI Robinson). We are certain that a more liberal early-era interpretation of what constitutes a snow-covered cell resulted in an over-mapping of snow cover extent in some mountainous regions in Eurasia and North America. Comparisons of the lower resolution older NOAA product and the newer IMS product that were mapped independently between 1997 and 1999 are being employed to generate adjustment factors. These will be applied back in time (pre–June 1999: the standard being IMS) and forward in time (post–May 1999: the standard being the older NOAA product). This will provide a range of area coverage that will be useful in accessing error margins. A standard land mask will eliminate differences observed when the mapping change took place in 1999. All of this will soon lead to a definitive Northern Hemisphere snow cover extent climate data record for the late 1966 to present interval.

Microwave maps of snow extent and depth over Northern Hemisphere lands are being produced from SSM/I and Scanning Multichannel Microwave Radiometer (SMMR) data as part of a related NOAA grant of Robinson and T. Mote. A multi-step processing procedure was developed that involves first discriminating land cover type, then eliminating periods with wet snow before assessing snow extent and depth from the microwave data. Daily files and maps of microwave-derived snow extent and depth are being updated for Northern Hemisphere lands. Snow depth and extent for 1988–2003 are available with the exception of some periods between 1989 and November 1991 when the 85GHz channel was unavailable or unreliable on SSM/I. A version of the system used for processing of the microwave data is being developed that does not use the 85GHz channel. This will eventually be necessary for incorporation of SMMR data from 1978–1987. Work is currently underway to produce a comparison with and without the 85GHz channel for 1995–2000. We also obtained the historical (in-situ) snow records during 1881–1995 over the Siberian regions.

Research accomplishments/highlights/findings

We have carried out preliminary analyses to examine the relationship between snowcover and river runoff changes over the large Siberian watersheds. We used daily SSMI data to generate weekly basin-mean snowcover water equivalent (SWE) time-series during 1988–2001. Based on these weekly records, we define the snowcover seasonal cycle, i.e., weekly SWE climatology—the dates of snowcover formation/disappearance and duration of snowcover/snow-free days, and rates of snowcover mass change during the accumulation and melt seasons. We also derive weekly discharge time-series from the daily streamflow data collected at basin outlets, and use the weekly data to describe the seasonal streamflow changes, including discharge regime, rates of streamflow rise and peak flow during the melt period. We calculate the weekly correlation of streamflow with basin SWE, and determine the consistency between SWE and streamflow changes over the seasons.

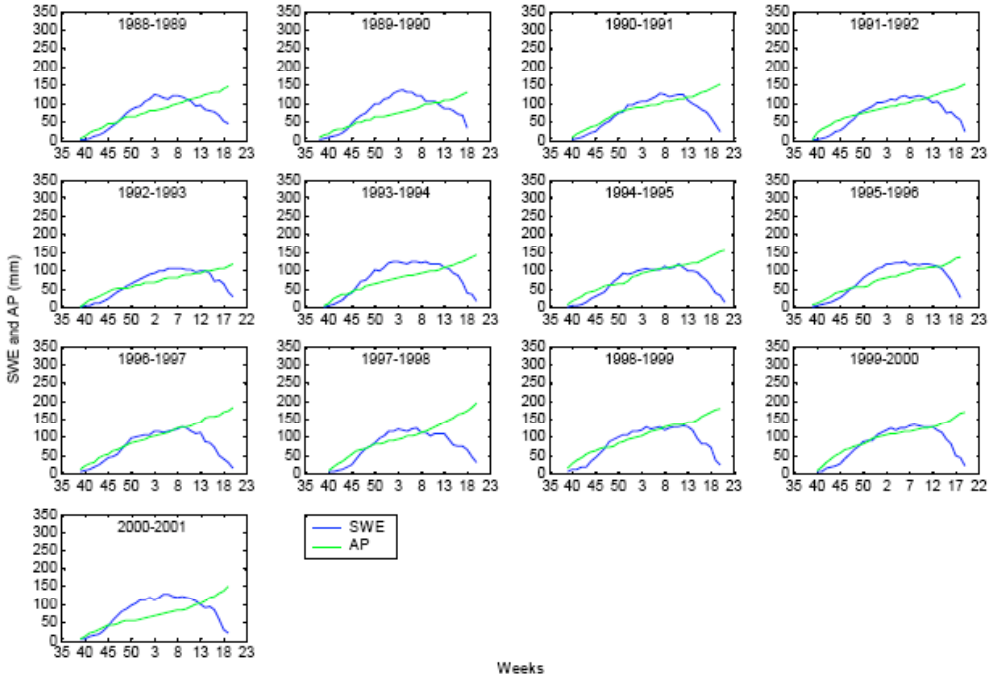


Figure 1. Comparisons of Siberian Lena basin snowcover water equivalent (SWE, mm) with winter accumulated precipitation (AP, mm) during 1988–2001 (from Yang et al. in press).

The seasonal changes of the basin SWE and streamflow in each individual year are displayed in Figure 1 for the three basins in Siberia. They clearly indicate a general response of river discharge to seasonal snowcover changes over the Siberian regions, i.e., an association of low streamflow with high basin SWE during the cold season, and an increase in discharge associated with a decrease of the basin SWE during the melt periods. They also show the inter-annual variations in both SWE and streamflow. Relative to the basin SWE, streamflow varies much more between years. For instance, the Yenisei River peak flows were low (69,000 m^3/s) in 1995 and high (157,000 m^3/s) in 1990, while the maximum basin SWE were very close to each other (about 80–85 mm) for these 2 years. Similar cases

exist in other basins, such as 1989 (high peak flow) vs. 1999 (low peak flow) for the Lena River, and 1992 (low peak flow) vs. 1999 (high peak flow) in the Ob watershed. This discrepancy between basin snowcover and streamflow variations raises an important question for this research.

Our efforts continue to improve the datasets and advance the analyses. We are currently updating the historical (in-situ) snow records to the early 2000s over the Siberian regions and combining them with the North America high latitude snow data to create an arctic regional snow dataset. We are also expanding our analyses to cover all the largest rivers in the Arctic region, i.e., the Ob, Yenisei, Lena, Yukon and Mackenzie watersheds. We are investigating and quantifying the uncertainties in basin SWE data perhaps due to algorithm limitations. The results of our ongoing analyses will directly benefit international research programs, particularly the predictability of the water cycle and its change in the high latitude regions.

Snowcover depletion is a useful indicator of snowmelt processes and streamflow generation. We will use the weekly snowcover maps/data to develop snowcover depletion curves for each melt season. Changes in the timing and pattern of the snowcover melt are sensitive indicators to climate change. This study, based on the long-term snowcover, streamflow, and climatic records, will investigate the spatial and temporal sensitivity of snowmelt runoff to regional climate changes and variations. We will examine the weekly correlation of streamflow with both basin-mean snowcover extent and temperature, and determine the consistency between snowcover and streamflow changes during the snowmelt period. We will also investigate the associations between snowcover and streamflow anomalies, identify extreme snowmelt runoff cases, and examine their correspondence with snowcover and climate conditions. These analyses will define the weekly relationship between snowmelt runoff and snowcover changes over the large arctic watersheds.

NOAA relevance/societal benefits

This project will develop a comprehensive climatic and hydrologic database for the watersheds of the five largest rivers in the Arctic. This project specifically addresses a high priority research topic of the NOAA Climate Change Data and Detection (CCDD) program element, namely climate change detection and attribution. This project is also closely related to the Study of Environmental Arctic Change (SEARCH). The methods and results of this research will improve our understanding of spatial and temporal variability of the high-latitude snowcover, and its contribution and impact on Arctic large river streamflow changes. This work will enhance our capability to predict future changes in the water cycle over the Arctic regions and at the global scale.

Research linkages/partnerships/collaborators and networking

Collaborators on this project are co-PI David Robinson of Rutgers University and co-PI Henchung Ye of California State University Los Angeles.

Education/outreach

Ipshita Majhi, a Ph.D. student in environmental engineering, has been supported by this project.

Presentations

Robinson, D. 2005. Elements of a successful climate data records generation program. American Geophysical Union Fall Meeting, San Francisco, California, December 2005 (invited).

Robinson, D. 2005. Trends and variability of snowfall and snow cover across North America and Eurasia. Part 1: Data quality and homogeneity analysis. American Geophysical Union Fall Meeting, San Francisco, California, December 2005.

Robinson, D. 2005. Trends and variability of snowfall and snow cover across North America and Eurasia. Part 2: What the data say. American Geophysical Union Fall Meeting, San Francisco, California, December 2005.

Robinson, D. 2006. Snow cover studies at the Rutgers Global Snow Lab. NOAA/NESDIS, World Weather Building, Camp Springs, Maryland, January 2006 (invited).

Yang, D. 2005. Streamflow response to seasonal snowcover change over the large northern rivers. American Geophysical Union Fall Meeting, San Francisco, California, December 2005.

Ye, H. 2005. The role of snow indicators in the search for connections between Eurasian snow and south and southeast Asian monsoon. American Geophysical Union Fall Meeting, San Francisco, California, December 2005.

Ye, H., et al. 2006. Arctic atmospheric and climatic information provided by AIRS. American Association of Geographers Annual Meeting, Chicago, Illinois, March 2006.

Publications

Peer-reviewed

Frei, A., R. Brown, J.A. Miller and D.A. Robinson. 2005. Snow mass over North America: observations and results from the second phase of the Atmospheric Model Intercomparison Project. *Journal of Hydrometeorology*, 6:681–695.

In press

Yang, D., Y. Zhao, D. Robinson, R. Armstrong and M. Brodzik. Streamflow response to seasonal snowcover mass changes in large Siberian watersheds. *Journal of Geophysical Research–Earth Surface*, in press.

Non-peer-reviewed

Mote, T.L., J.L. Dyer, A.J. Grundstein, D. Robinson and D.J. Leathers. 2005. Evaluation of new snow depth and mass data sets for North America. Proceedings of the 15th Conference on Applied Climatology, American Meteorological Society, Savannah, Georgia, JP1.10.

Robinson, D.A. and R.R. Heim Jr. 2006. Trends and variability of snowfall and snow cover across North America and Eurasia. Part 2: What the data say. Proceedings of the 18th Conference on Climate Variability and Change, American Meteorological Society, Atlanta, Georgia, paper 1.6, 5pp.

Heim, R.R. and D.A. Robinson. 2006. Trends and variability of snowfall and snow cover across North America and Eurasia. Part 1: Data quality and homogeneity analysis. Proceedings of the 18th Conference on Climate Variability and Change, American Meteorological Society, Atlanta, Georgia, paper P2.18, 3pp.

Marine Ecosystem Studies

Paleoecologic and Paleoceanographic Studies of Marine Bays in Southeast Alaska

Bruce P. Finney, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

CIFAR 06-043: This project is ongoing.

Primary objectives

Many marine bays in southeast Alaska have great potential for high resolution paleoceanographic work due to their fast sedimentation rates and their preservation of a wide variety of paleo-proxies. Based on our previous pilot studies on cores from 18 bays, we have selected several promising bays for detailed work. The overall objective of this project is to reconstruct changes in primary productivity, forage fish populations, oceanographic conditions and climate in several southeast Alaska embayments at decadal or better resolution over the past 500 years. This information will be compared with results from a similar study presently underway in the Bering Sea.

Approach/methodology

1) Sediment cores are being dated using ^{210}Pb and AMS radiocarbon (^{14}C) techniques.
2) To reconstruct primary productivity, we are using a multiproxy approach using standard paleoceanographic tools. Diatoms are generally dominant primary producers in this region, and thus, sedimentary biogenic silica abundance/mass accumulation rate can be determined. We are also reconstructing productivity from analysis of organic carbon mass accumulation rate. The third proxy we are using is the δ^{13}C ratio of organic matter.
3) Downcore changes in salinity and temperature will be determined through analyses of foraminifera for δ^{18}O; changes in nitrate utilization are being assessed by analyses of δ^{15}N of organic matter.
4) Oceanographic conditions will be reconstructed in these cores using analyses of foraminifera δ^{18}O (temperature and salinity), δ^{15}N of organic matter (changes in nitrate utilization), and productivity proxies.
5) Analysis of multiple sites will be synthesized to determine robust regional trends, which will be compared to ongoing research results from similar studies in the Aleutian Islands.

Research accomplishments/highlights/findings

1) Sieving and identification of foraminifera are complete on cores from Bay of Pillars, Eliza Harbor and GAK4. δ^{18}O analyses of the foraminifera are underway.
2) The bulk of the data synthesis and interpretation is part of the M.S. thesis of Molly Boughan. She is in the final stages of labwork, and plans on completing her thesis in Fall 2006.

NOAA relevance/societal benefits

This work comprises the first effort to use paleoceanographic sampling methods to produce high resolution data on decadal to century scale variability in oceanographic and ecological processes in southeast Alaska. Such information is part of that needed to address practical management and conservation concerns over recent changes in marine animal populations. By learning how variable systems have been over both short and long-time scales, we are also developing understanding of fundamental ecological processes and how ecosystems will respond to regional and global climate change.

Research linkages/partnerships/collaborators and networking

This research is collaborative with NOAA personnel at the Auke Bay Lab, Juneau. This CIFAR-funded research has led to additional research and $50,000 funding though NOAA via the North Pacific Universities Marine Mammal Research Consortium for the project *Impacts of Climate Change on Gulf of Alaska Steller Sea Lion Populations During the Past Century*. Also, data from this project helped lead to a 5-PI NSF ocean drilling site survey project entitled *Collaborative Research: Establishing a High-resolution Temporal Record of Quaternary Climate-Glacial-Ocean Linkages in Southern Alaska (and IODP Site Survey)* on subjects dealing with changes in primary productivity, oceanographic conditions and climate. The cruise took place in Sept. 2004. Finney's funding for his involvement in this project was $47,000 plus ship time.

Education/outreach

This project is supporting an Oceanography Masters degree student, Molly Boughan. She is conducting sediment core analyses, collection and analysis of foraminifera and stable isotope analyses of three cores at this time. She has completed her course work, and is finishing up her comprehensive examination, and so completion and defense of her thesis is her final task for graduation.

Publications

In press

Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L. Wang, and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.

Several other publications will result from this project. A paper(s) resulting from M. Boughan's thesis should be submitted following her defense in 2006.

Activity and Diversity of Sea Ice Biota in the Chukchi and Beaufort Seas

Rolf Gradinger, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management

Other investigators/professionals funded by this project:
Bodil Bluhm, *University of Alaska Fairbanks*

CIFAR 08-057: This project is complete.

Primary objectives

Our proposal focused on the structure and dynamics of Arctic sea ice communities. The studies were conducted onboard the Chinese icebreaker *Xue Long* in summer 2003 in close cooperation with U.S. and Chinese scientists. The specific objectives of our study were: (1) to determine the vertical distribution of microalgae, ice meiofauna and dissolved and particulate exopolymeric substances (EPS) in sea ice and the underlying water, (2) to determine the EPS production of sea ice and planktonic communities using short term in situ incubations, and (3) to measure the activity of ice algae using short term in situ incubation and fluorometry.

Approach/methodology

Ice cores were taken using ice augers, and water samples were collected with a Kemmerer sampler. Light was recorded with LICOR light sensors, and a T/S sensor measured temperature and salinity below the ice. Biomass data

(Chlorophyll *a*, POC, PON, $\delta^{13}C$, $\delta^{15}N$), salinity, and nutrient concentrations (N compounds, SiO_4, PO_4) were assessed on melted ice core sections over the entire ice thickness. The ratios of stable isotopes ($\delta^{13}C$, $\delta^{15}N$) of natural communities as well as POC and PON were determined on filtered samples at the stable isotope facility at UAF. Stable isotope techniques were used to determine the ice algal nutrient nitrogen uptake (^{15}N) and carbon assimilation (^{13}C) under *in-situ* conditions using incubations on the floes. P vs. I (production versus irradiance) curves were established using optical techniques (Water Pam fluorometer). Dissolved and particulate EPS were determined using a modified phenol-sulfuric-acid method. Bottom segments of ice cores were melted and subsamples fixed directly for protist counts, while the rest of the sample was concentrated over 20µm gauze, fixed and used for meiofauna abundance determination.

Research accomplishments/highlights/findings *(overall summary of project)*

- Snow covered the summer pack ice and a slush-layer was found in the ice–water interface.
- The vertical distribution of ice algal biomass mostly followed C-shaped curves with elevated concentrations at the bottom and the top of the ice.
- The C-shaped chlorophyll curves are uncommon for the Arctic and could be have resulted from the high snow depth in combination with decreased ice thickness.
- The biomass and activity of the shade-adapted ice algae was at the lower end of typical Arctic ice values.
- The ice meiofauna was mainly constricted to the bottom 10cm of the ice and was dominated by turbellarians, harpacticoid copepods and nematodes.
- Potential meiofaunal ingestion rate was about 1% of published daily algal production rates.

NOAA relevance/societal benefits

The published results will be useful in evaluating the effect of global change on the Arctic ecosystem. This grant facilitated close collaboration with Chinese colleagues, creating a stepping stone to further strengthen the U.S.–Chinese cooperation in Arctic science.

Research linkages/partnerships/collaborators and networking

In addition to the U.S.–Chinese collaboration, the grant supported the cooperation with Dr. Meiners (Yale University). For publication purposes, the collected material was combined with data from the NOAA-funded Ocean Exploration 2002 expedition to a similar area. The materials will further be used to study the diversity of sea ice biota as part of the Arctic Ocean Diversity project of the Census of Marine Life program. (http://www.sfos.uaf.edu/research/arcdiv/).

Education/outreach

Student participation

The collected ice algal material will form the backbone for a thesis of a future graduate student at the School of Fisheries and Ocean Sciences (focus: diatom diversity, funding currently not secured).

Presentations

Gradinger, R., H. Eicken and B.A. Bluhm. 2005. Does sea ice contribute to the biogeochemical cycles of the Bering Sea? Climate Variability and Sub-Arctic Marine Ecosystems Symposium, Victoria, B.C., Canada, 16–20 May 2005 (talk). *(previously reported)*

Publications *(cumulative over the duration of the project)*

Peer-reviewed

Gradinger, R.R., K. Meiners, G. Plumley, Q. Zhang and B.A. Bluhm. 2005. Abundance and composition of the sea-ice meiofauna in off-shore pack ice of the Beaufort Gyre in summer 2002 and 2003. *Polar Biology*, 28:171–181, doi:10.1007/s00300-004-0674-5. *(previously reported)*

In preparation

Meiners, K. and R. Gradinger. Extracellular polymeric substances in sea ice of the Beaufort and Chukchi seas during spring and summer.

Ecosystem Change in the Northern Bering Sea

Jackie M. Grebmeier, PI
University of Tennessee, Knoxville

NOAA Goals: Ecosystem-based Management; Understand Climate Variability and Change

CIFAR 15-060a: This project is ongoing.

Primary objectives

This project is investigating recent changes observed on the northern Bering Sea shelf coincident to decadal-scale atmospheric/sea ice/oceanographic processes, which reflect regime-induced climate changes in the western Arctic. Recent work indicates that there are "hot spots" of biological productivity southwest of Saint Lawrence Island, and that this productivity has been decreasing over the past decade. Recent findings indicate that the Bering Sea is shifting to an earlier spring transition based on changes in ice melt and atmospheric circulation patterns. Since the trend in Arctic Oscillation appears to be a clearly increasing climate signal, the northern Bering Sea is an important location to monitor ecosystem change.

Approach/methodology

Our project is undertaking the following tasks to understanding ecosystem change in the northern Bering Sea: 1) A retrospective analysis of all northern Bering Sea data to put future changes into context and to provide an objective measure for change detection; 2) Establishment of a northwest Bering Sea biophysical oceanographic mooring to document ongoing changes, similar to the successful multiyear FOCI mooring M2 on the southeast Bering Sea shelf; and 3) Process studies of the northern biological hot spots, also funded by non-NOAA sources. Oceanographic logistics are provided in collaboration with Dr. Ed Carmack (Institute of Ocean Sciences, IOS) and the Canadian Coast Guard ship *Sir Wilfrid Laurier* enroute to resupply communities in the Canadian Arctic via NOAA and NSF funding. We are utilizing this platform to reoccupy key sites on the northern Bering Sea shelf for hydrographic, biochemical and sediment collections. A Seabird CTD with rosette is used to collect salinity, temperature and water column collections for measurements of nutrients, chlorophyll and oxygen-18 content. Sediment is collected using grabs and cores for faunal population and biomass analyses, sediment grain size, carbon content, and other sediment tracers to document pelagic–benthic coupling and carbon deposition sites in the benthos.

Research accomplishments/highlights/findings

- Recent analyses indicate a reduction of seasonal sea ice extent in the northern Bering Sea and an earlier retreat of sea ice, as indicated by an earlier atmospheric warming in the spring (Figure 1).

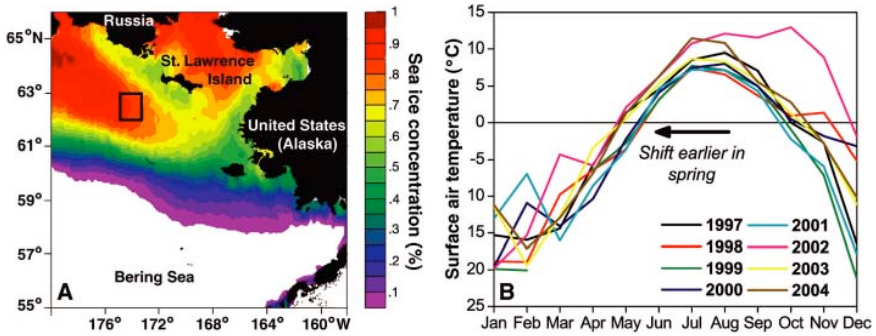


Figure 1. (A) Location map (box indicates location of time-series biological sites) and average April sea ice concentration (1=100% to .1=10% in the northern Bering Sea from 2000–2004. (B) Monthly averaged surface air temperature measured at Savoonga (63.68°N, 170.5°W) on St. Lawrence Island over years 1997–2004 (Grebmeier et al. 2006).

- Supported studies indicate that the cold Arctic shelf ecosystem of the northern Bering Sea is giving way to a more pelagic dominated sub-arctic ecosystem because of a significant reduction in carbon being exported to the underlying sediments (Figure 2). This reduction in carbon export to the sediment and resultant decrease in benthic biomass may have profound impacts on Arctic marine mammal and diving seabird populations as well as commercial and subsistence fisheries.

- A biophysical mooring deployed in fall 2004 southwest of St. Lawrence Island (see previous reports) was successfully retrieved in July 2005 and a new mooring was deployed at the same location, albeit without a nutrient sensor due to equipment limitations. This mooring was again recycled during the fall of 2005 and a new nutrient instrument was deployed, along with the suite of physical sensors and a fluorometer, to be retrieved in 2006.

NOAA relevance/societal benefits

Monitoring and assessing the current status and potential change in the northern Bering Sea ecosystem in response to climate change is directly relevant to the goals of the NOAA-supported SEARCH: Study of Environmental Arctic Change multi-agency global change project and similar efforts of the NOAA Arctic Research Office.

Research linkages/partnerships/collaborators and networking

This project is a collaborative effort with Dr. Jim Overland at NOAA/PMEL and Dr. Terry Whitledge at UAF to investigate the status and change in the northern Bering Sea ecosystem. This project includes deployment of a mooring array coincident with retrospective data analysis and fieldwork. This joint project is directly related to the SEARCH project to investigate potential impacts of climate change on the marine ecosystem and goals of the international Pacific Arctic Group (PAG).

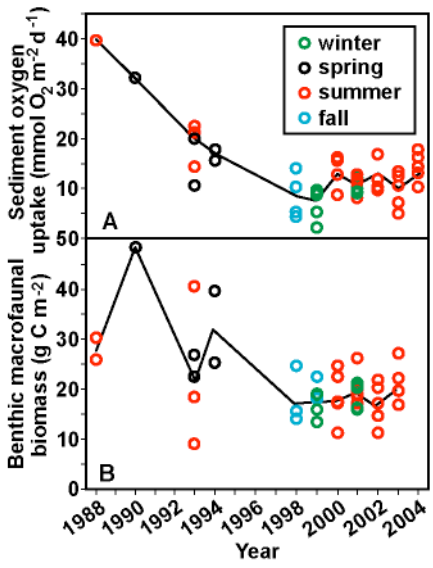


Figure 2. Time series measurements of sediment oxygen uptake (an indicator of carbon supply) and benthic infaunal biomass southwest of St. Lawrence Island, northern Bering Sea (Grebmeier et al. 2006).

Education/outreach

Student participation

- Alicia Clarke, a minority undergraduate student completed a B.S. degree in May 2005 in Ecology and Evolutionary Biology. She was supported to participate in the *Sir Wilfrid Laurier* 2004 cruise and undertake a student project on identifying phytoplankton types in surface sediments coincident with our sediment chlorophyll measurements. Her support continued though July 2005 and she just recently completed a Master's Program in Science Writing at the University of Michigan.
- Adam Humphrey, an undergraduate student, completed a B.S. in May 2006 in Ecology and Evolutionary Biology *(not in 2005 as was reported last year)* and assisted in infaunal sorting and general laboratory operations.
- Rebecca Pirtle-Levy, an M.S. student in Ecology and Evolutionary Biology, processed sediments for total organic carbon content and sediment grain size. Rebecca also participated in all oceanographic cruises associated with this project at sea on the CCGS *Sir Wilfrid Laurier* from 2003–2005.

K–12 outreach

- Betty Carvellas, a high school science teacher from Essex Junction, Vermont, participated in the 2004, 2005 and 2006 *Sir Wilfrid Laurier* cruises as part of the NSF-sponsored Teachers Experiencing the Antarctic and Arctic program (now called the Teachers and Researchers-Exploring and Collaborating (TREC) program; see http://www.arcus.org). Betty maintained a website with daily journals during the cruise that summarized results from the joint NOAA–NSF research in the northern Bering Sea. She also interacted with the public via questions and answers on the website.
- PIs Grebmeier and Cooper presented scientific results for 5th grade students at St. John Neumann School in Farragut, Tennessee, in April 2006.

Public outreach

- PI Grebmeier gave an Arctic environmental change talk for the Knoxville Rotary Club in June 2006.

Oral presentations

Overland, J.E., J.M. Grebmeier, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift observed in the northern Bering Sea. Joint AGU/ASLO/TOS Oceans Meeting, Honolulu, Hawaii, February 2006.

Poster presentations

Grebmeier, J.M., R. Pirtle-Levy, R. Brown and L.W. Cooper. 2006. Benthic community structure, carbon cycling and self–basin exchange on the Arctic margins of the Chukchi and Beaufort Seas. Joint AGU/ASLO/TOS Oceans Meeting, Honolulu, Hawaii, February 2006.

Publications

Peer-reviewed

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. *Science*, 311:1461–1464.

In press or in preparation

Grebmeier, J.M. and J.P. Barry. 2006. Benthic processes in polynyas. In: W.O. Smith and D. Barber, Eds., Polynyas: Windows into Polar Oceans, Elsevier Oceanography Series, in press.

Grebmeier, J.M., L.W. Cooper, H.M. Feder and B.I. Sirenko. 2006. Pelagic-benthic coupling and ecosystem dynamics of the Pacific-influenced western Amerasian Arctic. Submitted to *Progress in Oceanography*.

Traditional Ecological Knowledge, Indigenous Observations, and Spatio-temporal Dynamics of Steller Sea Lion Populations along the Western Alaska Peninsula and Eastern Aleutians

Herbert D.G. Maschner, PI ***NOAA Goal: Ecosystem-based Management***
Katherine L. Reedy-Maschner, co-PI
Idaho State University

Other investigators/professionals funded by this project:
Amber Tews, Jack Nielson, Sharon Plager, Aaron Harker, *Idaho State University*

CIFAR 06-047: This project is complete.

Research problem

The Steller sea lion (SSL) decline witnessed between 1977 and the late 1990s resulted in one of the more spectacular proactive scientific and special interest group actions in the history of modern science. The reactions to this decline and the listing of the SSL as endangered resulted in over $100 million in new research while ushering in sweeping and untested changes in north Pacific fisheries access and management. Left on the sidelines were the indigenous peoples of the north Pacific who had been observing and harvesting those species for thousands of years. Recognizing that we were in a position to add local voices to these problems and issues, the peoples of the eastern Gulf of Alaska asked us to initiate a research program where Aleut history and local knowledge would be used to address some of the key hypotheses being investigated to explain the SSL population crash. It was felt that both archaeological and anthropological data might be useful in testing whether or not local fisheries had an impact on the SSL population and if the new restrictions on groundfish harvesting would have any affect in bolstering the SSL population. In the context of creating this project, we found that six of the seven initial hypotheses (we have no data on containments), that is, fisheries competition, environmental change, predation, anthropogenic effects, disease, and most importantly, the general category of synergies, could all be tested or at least evaluated using anthropological and archaeological data. As will be discussed below, the SSL has gone through at least three major declines in the last 1000 years, and the ultimate cause has probably been climate, but climate change synergistically associated with anthropogenic effects, predation, fisheries, and other factors.

Approach and accomplishments

Interviews: Interviews were conducted with fishermen and others from the communities of Sand Point, King Cove, Nelson Lagoon, and False Pass (several attempts to reach Akutan failed for logistical reasons). Interviews were unstructured and moved in directions the interviewee found most important, but were always focused on SSLs,

environmental change, historical changes and observations, and natural history. These data were recorded in notebooks and summarized.
Historical Analyses: Hundreds of 18th, 19th, and 20th century historic documents were mined for information about the natural history, harvesting, and general observations about SSLs and other marine mammals. These data were catalogued, tabulated, and summarized.
Laboratory Analyses: The analysis of nearly 40,000 sea mammal bones from archaeological sites spanning 4500 years was conducted to identify broad trends in the long-term history of SSL and other species on the north Pacific. Also recorded were skeletal pathologies, age, sex, and other data from the skeletal remains. These data were tabulated and correlated with climatic and other data from the region.
GIS Analyses: A geographic information system of the region was constructed that included all of the archaeological and anthropological data collected on the project. This GIS also incorporates much of the traditional knowledge of SSL on the north Pacific as well as the data prepared by NOAA and other agencies.

Results

The SSL has gone through at least three major declines in the last 1000 years, and the ultimate cause has probably been climate, but climate change synergistically associated with anthropogenic effects, predation, fisheries, and other factors. The first major decline is seen during the warming oceanic regime of the Medieval Warm Period between AD 1100 and 1300. This resulted in a major human population decline in the region and was a byproduct of a severe drop in marine productivity. The Little Ice Age, between AD 1400 and 1800, witnessed major expansion of SSL populations in the region. A slow SSL decline began in the late 18th century as the demand for sea otters forced Aleut hunters to spend much more time in their boats, which required that they replace the SSL kayak skins more often. Since SSLs provide the only usable skins for covering kayaks in this region, and because it takes 4–6 skins per kayak, and because they must be replaced every year under normal hunting conditions, then the SSL must be seen as a fixed cost. The harvest of SSLs then, is a product of the number of adult males with kayaks, not necessarily a product of the need for food. The combined effects of increased demand because of the sea otter hunt and a brief period of warming in the 1870s led to another collapse of SSL populations. Sea lions were so rare on the north Pacific that skins were being imported from California to meet the needs of Aleut kayak builders to have sufficient skins to go hunting and fishing. By the early 1900s, cooler temperatures and the introduction of wooden dories in the region sent SSL populations growing at an exceptional rate so that by the1960s, SSL populations had probably witnessed their first 50-year period in the last 10000 years with little or no harvesting pressure. Thus, when the regime shift of 1975–77 occurred, SSL populations were probably larger than they should have been, resulting in what appeared to be a catastrophic decline, but what was more likely a readjustment to the fact that their entire ecology had changed with the removal of Aleut hunters from their natural history. These data lead us to the conclusion that the entire "natural" behavioral ecology of the SSL is probably a product of human harvesting and the remote, inaccessible haulouts and rookeries that SSL appear so well adapted are probably adaptations to human hunters. We conclude that the three major collapses of the SSL that can be identified at this time, AD 1200, AD 1870, and AD 1977, are, in the first two cases, products of the synergistic interactions of warming climates and human hunting pressure, and in the last case, the byproduct of changing climatic regimes (oceanic warming), and a period of unprecedented population increase in the absence of traditional harvesting pressures. We further conclude that initial Aleut assertions to the importance of orca in the decline of the SSL are probably accurate, but their cause and effect relationship with the other variables addressed here has not been evaluated. In conclusion, cold waters are good for SSLs, warm waters are bad, but the relationship is complicated by the synergistic interactions of human harvesting, a complete lack of human harvesting, and the secondary effects of decreasing marine productivity on orcas, Atka mackerel, sea otters, walrus, and other species in the region. One point is clear, the Aleut people have been harvesting, in fact engineering, the north Pacific ecosystem for over 10,000 years and there are no aspects of the ecosystem that can be understood without first making reference to this relationship.

Research linkages/partnerships/collaborators and networking

Collaborators in this work include the Aleut Marine Mammal Commission; Bruce Finney of the University of Alaska Fairbanks; and Andrew Trites of the University of British Columbia.

Education/outreach

Student participation
Krysta and Krystal Williams, undergraduates, were laboratory assistants for faunal analysis.
Presentations
The results of these research efforts were presented to Tribal and Corporate organizations as well as the Aleut Marine Mammal Commission. Presentations were also done in the schools and community centers of the local

communities. Local comment and further observations were collected in the course of these presentations and added to the database.

Presentations with published abstracts (summarized for total project to date)

Maschner, H.D.G. 2003. Humans within ecosystems: Getting beyond "Human Impacts" along the southern Bering Sea and North Pacific. Paper presented at the NSF HARC Science Meeting, 25–26 October 2003.

Maschner, H.D.G. 2003. The complex dynamic of social and environmental catastrophe: The southern Bering Sea and North Pacific in a dynamic global system. Plenary Keynote Address, Arctic Section, American Association for the Advancement of Science, Fairbanks, Alaska, 22 September 2003.

Maschner, H.D.G., J.W. Jordan, N. Huntly, B.P. Finney and K.L. Reedy-Maschner. 2003. The ecology and paleoecology of human–landscape interactions on the North Pacific and southern Bering Sea: Investigating the role of the Aleut as ecosystem engineers. Paper presented to the First NSF SEARCH Open Science Meeting, Seattle, Washington, 27–30 October 2003.

Maschner, H.D.G., B. Finney and A. Tews. 2004. Did the North Pacific/Bering Sea ecosystem collapse in AD 1150? Paper presented in the symposium: The Northern World AD 1100–1350. Society for American Archaeology Annual Meeting, Montreal, 31 March–4 April 2004.

Tews, A. and H. Maschner. 2004. Seafood: It's what's for dinner (breakfast and lunch). Poster presented at the Society for American Archaeology Annual Meeting, Montreal, 31 March–4 April 2004.

Public presentations (summarized for total project to date)

Maschner, H.D.G. 2002. Steller sea lions, Aleut heritage, and cultural identity on the western Alaska Peninsula. Presentation to the Aleut Marine Mammal Commission, 7 December 2002.

Maschner, H.D.G. 2003. Recent research on the archaeology of North Pacific sea mammals. Presentation to the Aleut Marine Mammal Commission, 4 December 2003.

Maschner, H.D.G. 2004. Salmon, sea lions, and heritage. Departmental Colloquium. Department of Anthropology, Idaho State University, 4 February 2004.

Maschner, H.D.G. 2004. Building an Aleut anthropology and archaeology that matters: Heritage, fisheries, and legacy. Keynote presentation to the annual meeting of the Aleut Corporation, 23 October 2004.

Maschner, H.D.G. 2005. Humans, climate, and the marine ecology of the greater Beringian region. Science Day Presentation. Seventh Arctic Science Summit Week, Kunming, China, 20 April 2005.

Publications (over the life of the project to date)

In press

Maschner, H.D.G., B. Finney, J. Jordan, A. Tews, N. Misarti and G. Knudsen. Did the North Pacific ecosystem collapse in AD 1200? In: H.D.G. Maschner, Ed., The Northern World AD 900 to 1400. University of Utah Press, in press.

Trites, A.W., A.J. Miller, H.D.G. Maschner, M.A. Alexander, S.J. Bograd, J.A. Calder, A. Capotondi, K.O. Coyle, E. Di Lorenzo, B.P. Finney, E.J. Gregr, C.E. Grosch, S.R. Hare, G.L. Hunt, J. Jahncke, N.B. Kachel, H.-J. Kim, C. Ladd, N.J. Mantua, C. Marzban, W. Maslowski, R. Mendelssohn, D.J. Neilson, S.R. Okkonen, J.E. Overland, K.L. Reedy-Maschner, T.C. Royer, F.B. Schwing, J.X.L. Wang and A.J. Winship. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, in press.

In review

Maschner, H.D.G., K.L. Reedy-Maschner, A.M. Tews and M. Livingston. Anthropological investigations on the decline of the Steller sea lion (*Eumetopias jubatus*) in the western Gulf of Alaska and southern Bering Sea. *Marine Mammal Science*, in review.

Reedy-Maschner, K.L. and H.D.G. Maschner. Sea-kings, sea bears and bait: Historic Euro-American perspectives on the Steller sea lion and their implications for a modern recovery. *Arctic Anthropology*, in review.

Bogoslof Island Mapping for Invertebrate Colonization Study

Jennifer Reynolds, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 10-079: This project is ongoing, with a no-cost extension to July 1, 2007.

Primary objectives
The role of benthic invertebrates in marine ecosystems, such as deep corals and sponges, and their vulnerability to disturbance by fishing activity, is a topic of increasing concern. However, little is known about the recovery of these species after disturbance in Alaskan waters except that it probably takes decades. This is the first phase of a study of the colonization process of benthic invertebrates at hard-bottom sites decades old on Bogoslof Volcano, as a proxy for measuring recovery from benthic fishing activities.

Approach/methodology
Bogoslof provides a natural laboratory for this study because lava and tephra from historical eruptions (since 1790) have resurfaced different areas of the shallow seafloor around the island. We first need to construct a preliminary map of the 'seafloor ages' and habitat classification on the upper slopes of the volcano. These maps will guide placement of ROV video/sampling transects in the next phase of the study (to be funded separately).

We have acquired high-resolution multibeam bathymetry and backscatter of the seafloor around Bogoslof Island, through a NOAA contract with Fugro TGPI. This survey was done with a 100 kHz Reson SeaBat 8111, operated as a pole-mounted system for hydrographic charting. The new multibeam sonar data is being used, in combination with the historical eruption record and the geology of the island, to predict areas of seafloor that were resurfaced by specific eruptions and thus would have known surface ages in the range of 10–200 years. Surface ages will be confirmed in the next phase of the study, by matching rock sample compositions from ROV dives to the volcanic products of documented eruptions.

Research accomplishments/highlights/findings
- The project was on hold through FY06, due to the PI taking on temporary administrative duties (January 2005–August 2006) which prevented her from devoting appropriate time to this research. A no-cost extension has been requested and approved, to enable the PI to complete the research after returning to faculty status.

NOAA relevance/societal benefits
This research will provide information needed for fisheries management by defining an upper bound on natural colonization and growth rates for estimating the recovery of sessile hard bottom invertebrates from benthic fishing activities. The research will also complement ongoing studies of the distribution and habitat relationships of deep corals.

Research linkages/partnerships/collaborators and networking
This project is a fully interdisciplinary collaboration between Mark Zimmerman, a biologist from NOAA's Alaska Fisheries Science Center (Seattle), and a marine geologist from the University of Alaska Fairbanks. Interest in the results has also been expressed by the Alaska Volcano Observatory, the National Marine Mammal Laboratory, and the U.S. Fish & Wildlife Service.

Ecosystem Change in the Northern Bering Sea: Nitrate Sensors on the Mooring and Retrospective Nutrient Analyses

Terry Whitledge, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 11-061a: This project is ongoing.

Primary objectives and approach/methodology
This project investigates the hypothesis that recent anomalous spring and summer productivity on the Northern Bering Sea shelf relates to decadal-scale atmospheric/sea ice/oceanographic processes, which reflect regime-induced climate changes in the western Arctic. Recent work (Grebmeier and Dunton 2002; Cooper et al. 2002) shows that there are hot spots of biological productivity southwest of Saint Lawrence Island, and that this productivity has been decreasing over the past decade. Stabeno and Overland (2001) report the Bering Sea is shifting to an earlier spring transition based on ice melt and changes in atmospheric circulation patterns. Since changes in the North Pacific Ocean show little long-term trend while the trend in Arctic Oscillation appears to be a clearly increasing climate signal, the northern Bering Sea is an important location to monitor ecosystem change. The combination of these studies demonstrates the timeliness for increased focus on the ecosystem of the northern Bering Sea. As a result, the following tasks are being undertaken:

- A retrospective analysis of all northern Bering Sea data to put future changes into context and to provide an objective measure for change detection. (Whitledge, Overland and Grebmeier)
- Establishment of a northwest Bering Sea biophysical oceanographic mooring to document continuing changes, similar to the successful multiyear FOCI (Fisheries-Oceanography Coordinated Investigations) mooring, M2, on the southeast Bering Sea shelf. (Whitledge and Overland)
- Process studies of the northern biological hot spots, primarily funded by non-NOAA sources. (Grebmeier)

Research accomplishments/highlights/findings

- Data from four additional cruises from the 1930s was located and entered into electronic format for comparison with the other historical data over a span of five to seven decades. This effort required manual entry of the historical data which was unexpectedly slow and laborious. See Table 1.
- An In situ Ultraviolet Spectrometer (ISUS) instrument was not deployed on the Northern Bering Sea mooring because ice cover will prevent recovery in the early spring and funding for the mooring by NOAA ends near the possible recovery time. Future moorings at M8 are proposed to be supported by the Alaska Ocean Observing System (AOOS).

NOAA relevance/societal benefits

Monitoring and assessing the current status and potential change in the northern Bering Sea ecosystem in response to climate change is directly relevant to the goals of the NOAA-supported SEARCH: Study of Environmental Arctic Change multi-agency global change project and similar efforts of the NOAA Arctic Research Office.

Table 1. Historical Data Compilation

13 July 2006

Cruise	*Ship*	*Dates*	*Sta*	*Area*	*Status*
BERCHUK	Gannet	Jun–Aug 33	34	Bering/Chukchi	1
BERCHUK	Chelan	Jun–Aug 34	125	Bering/Chukchi	1
BERCHUK	Northland	Jun–Sept 37	215	Bering/Chukchi	1
BERCHUK	Northland	Jul–Sept 38	171	Bering/Chukchi	1
BERPAC 77	Volna	Jul–Aug 77	48	N Bering	1
BERPAC 84	Korolev	Jul 84	26	N Bering	2
BERPAC 88	Korolev	Jul–Aug 88	113	N Bering/Chukchi	2
CHOEX/ICE	Khromov	Jul–Aug 90	117	Chukchi	2
CHOEX/ICE	Surveyor	Sept–Oct 90	156	Chukchi	2
CHOEX/ICE	Surveyor	Sept–Oct 91	58	Chukchi	2
BERPAC 93	Okean	Aug–Sept 93	63	N Bering/Chukchi	2
AH235	Alpha Helix	Aug–Sept 00	53	Chukchi*	2
AH250	Alpha Helix	Sept 01	54	Chukchi*	2
AH260	Alpha Helix	June 02	98	Chukchi*	2
AH274	Alpha Helix	Jun–Jul 03	123	Chukchi*	2
RUSALCA	Khromov	Aug 04	77	Chukchi	2
AH290	Alpha Helix	Aug–Sept 04	121	Chukchi*	2
RUSALCA	Sever	Aug 05	22	N Bering/Chukchi	1

* Data collected only in US EEZ
1 Data is in electronic format but needs to be reformatted
2 Data is fully installed into Ocean Data View database

Notes: The data files being compiled contain a mixture of hydrographic, productivity, and other biological measurements. All cruises include nutrients on nearly all stations but chlorophyll and productivity measurements were collected on a reduced number of stations. The ODV files will carry the hydrographic data along with nutrient and chlorophyll concentrations. Other biological data will be available as a separate Excel file. A metadata file will also be included for each cruise to describe measurement protocols.

Research linkages/partnerships/collaborators and networking

This project is a collaborative effort with Dr. Jim Overland at NOAA/PMEL and Dr. Jackie Grebmeier at the University of Tennessee, Knoxville, to investigate the status and change in the northern Bering Sea ecosystem. It is directly related to the SEARCH project to investigate potential impacts of climate change on the marine ecosystem and goals of the international Pacific Arctic Group (PAG).

Education/outreach

This project provided partial support to a graduate student, Sang Lee, to enter historical data into an electronic spreadsheet.

Publications

Submitted

Lee, S.H. and T.E. Whitledge. Current carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. Submitted to *Continental Shelf Research*.

References

Cooper, L.W., J.M. Grebmeier, I.L. Larsen, V.G. Egorov, C. Theodorakis, H.P. Kelly and J.R. Lovvorn. 2002. Seasonal variation in sedimentation of organic materials in the St. Lawrence Island Polynya Region, Bering Sea. *Marine Ecology Progress Series*, 226:13–26.

Grebmeier, J.M. and K.H. Dunton. 2000. Benthic processes in the northern Bering/Chukchi seas: Status and global change. In: H.P. Huntington, Ed., Impacts of Changes in Sea Ice and Other Environmental Parameters in the Arctic. Marine Mammal Commission Workshop, Girdwood, Alaska, 15–17 February 2000, pp. 80–93.

Stabeno, P.J. and J.E. Overland. 2001. Bering Sea shifts toward an earlier spring transition. *EOS, Transactions of the American Geophysical Union*, 82:317,321.

Continuation of Observations on the Bering Sea Shelf: Biophysical Moorings at Site 2

Terry Whitledge, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 09-064: This project is ongoing.

Primary objectives

This research continued biophysical measurements at mooring site 2 and collected samples along the southeast Bering Sea transect. Mooring Site 2 has been maintained almost continually since 1995, and provides the longest near continuous time-series of biophysical variables on the Bering Sea shelf. Long-term observations provide critical data that allow comparisons among habitats and years, characterizations of interannual variability, quantification of regime shifts and climate change, and a database necessary for model simulations. Data from the moorings and transects have provided the basis for a number of advancements in our understanding of how the Bering Sea shelf functions, and resulted in over a dozen publications and many more presentations.

The objectives of our project are twofold:

- to continuously monitor the temporal variability of biophysical properties over the southeast Bering Sea ecosystem using moorings and shipboard measurements;
- making results available via the world wide web for all end users, including scientists, managers, industry, educators, students and the general public.

Approach/methodology

Wet chemical (NAS) and optical (In Situ Ultraviolet Spectrometer; ISUS) sensors are integrated into the PMEL biophysical mooring.

Research accomplishments/highlights/findings

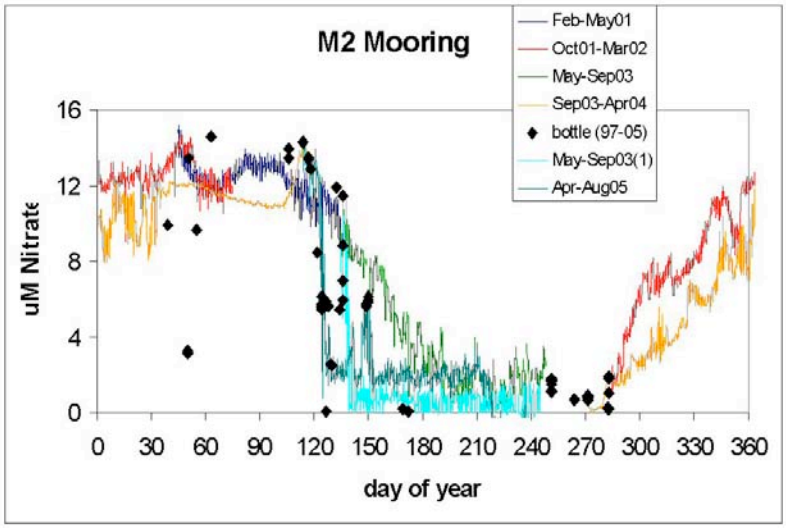
Mooring Deployment and Recovery Cruises

Instrument	Deployment Date	Vessel	Location	Data
ISUS#017	Sept 2005	Miller Freeman	M2	good
ISUS#077	Sept 2005	Miller Freeman	M4	none
ISUS	April 2006	Miller Freeman	M2	in water
ISUS	April 2006	Miller Freeman	M4	in water

ISUS #017 was deployed at the M2 site in September 2005 and was recovered in April 2006. ISUS#077 was deployed at the M4 site in September 2005. The mooring was recovered in pieces in April 2006 because of a possible encounter with a fishing boat. The instrument was retrieved but data was lost. An ISUS was redeployed at M2 and M4.

NOAA relevance/societal benefits

The biophysical moorings at the M2 and M4 sites are the only long term observations (1995–2006) that have been collected continuously in this important fishing area. The data have been provided to numerous scientists and resource managers for use in both applied and basic research studies. Additional sensors are being considered to broaden the range of variables that can be monitored, including large marine mammals.



Composite nitrate concentrations at 13m at mooring site M2 in the SE Bering Sea for February 2001 through August 2005.

Research linkages/partnerships/collaborators and networking

This work is being done in collaboration with Phyllis Stabeno and Jeff Napp, NOAA/PMEL.

Education/outreach

Presentations (partial list of presentations that use the M2/M4 data)

Deal, C., M. Jin, J. Wang and T. Whitledge. 2006. An ecosystem model study of plankton and nutrient dynamics in the Bering Sea shelf with a focus on a nitrogen budget and water column nitrification. Presented at Marine Science in Alaska – 2006 Symposium, Anchorage, 22–25 January 2006.

Stabeno, P., C.M. Mordy, J.M. Napp and T.E. Whitledge. 2006. Spatial and temporal variability over the eastern Bering Sea shelf. Presented at Marine Science in Alaska – 2006 Symposium, Anchorage, 22–25 January 2006.

Rho, T.K., S. Saitoh and T.E. Whitledge. 2006. Temporal and spatial variations of satellite-derived chlorophyll-a concentrations and primary production over the Bering Sea shelf during 1998–2004. Presented at AGU-ASLO-TOS 2006 Ocean Sciences Meeting, Honolulu, 19–24 February 2006.

Rho, T.K., S. Saitoh, and T.E. Whitledge. 2006. Variability of primary production in the southeastern Bering Sea shelf in relation to recent change of sea ice condition using remote sensing and in situ measurement. Presented at From Molecules to Ecosystem in Polar Science: Toward IPY 2007–2008, the 13th International Symposium on Polar Sciences, Incheon, Korea, 9–12 May 2006.

University of Alaska Fairbanks Living Marine Resources Graduate and Postgraduate Fellowship

Denis Wiesenburg, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

Other investigators directly funded by this project:
Pieter deHart, Ph.D. student

CIFAR 06-046: This project is complete. The postgraduate fellowship portion of this project was complete in 2005 and reported then. This report is on the graduate fellowship.

Primary objectives

The goals of NOAA's strategic plan are to build sustainable fisheries, to recover protected species, and to sustain healthy coasts. These goals require the support of sound scientific research to build the knowledge base for maintaining economically viable fisheries and, at the same time, minimize anthropogenic impacts on marine ecosystems. The School of Fisheries and Ocean Sciences (SFOS), University of Alaska Fairbanks, entered into an agreement in Fiscal Year 2003 with NOAA/National Marine Fisheries Service (NMFS)'s Alaska Fisheries Science Center, Seattle to provide training and advanced research on issues affecting the sustainability of the Steller sea lion (SSL) in the northeast Pacific Ocean and Bering Sea.

Research accomplishments/highlights/findings

This project has funded ***Pieter deHart***, a Ph.D. student working with Dr. Matthew Wooller. Pieter deHart successfully defended his doctoral dissertation on "A multi-organismal isotopic study of the North Pacific and Bering Sea marine mammals: responses to a changing environment" on June 19, 2006, a chapter of which was based on his SSL research. The thesis was prepared with each chapter written in the style ready for submission to a peer-reviewed journal.

The dissertation abstract follows: The north Pacific and Arctic marine realm is currently experiencing dramatic environmental changes as a result of global climate change. Stable isotope analysis of western Arctic bowhead whales (WABW, *Balaena mysticetus*) and Steller sea lions (SSL, *Eumetopias jubatus*) were conducted to examine the influence these changes may have had on the life history characteristics (migration and foraging) of these marine mammals. WABW baleen plates were analyzed for their stable oxygen and hydrogen composition ($\delta^{18}O$ and δD) and were compared to the $\delta^{18}O$ and δD in water and zooplankton prey along their seasonal migratory route. The $\delta^{18}O$ and δD varied along the baleen (8 to 18 ‰; -180 to -80 ‰, respectively) and corresponded with stable isotopic differences in zooplankton from the winter (Bering Sea) and summer (eastern Beaufort Sea) WABW habitats. Baleen $\delta^{18}O$ and δD confirmed the seasonal annual migration of WABW and were subsequently compared to historical sea ice concentrations (SIC). This illustrated that WABW migration patterns appeared to have altered concomitant with changes in SIC. Years with a higher SIC (colder climate regimes) correlated with the largest difference in δD between winter and summer in WABW baleen during the period from 1972 to 1988. For a similar time period (1955 to 2000), the feeding ecology of SSL was also examined by analyzing the stable carbon and nitrogen isotope compositions ($\delta^{13}C$ and $\delta^{15}N$, respectively) of SSL bone and tooth collagen. Both $\delta^{15}N$ and $\delta^{13}C$ varied greatly with location and sample year (14.6 to 20.5 ‰; -16.7 to -11.8 ‰, respectively), with a significant change in $\delta^{13}C$ observed at the point of the 1976 regime shift. Bottom-up processes may have limited growth of SSL populations throughout this region over time, with animals focusing their foraging on offshore regions to mitigate this environmental change. Stable isotope analyses of historical samples of WABW (baleen) and SSL (bone and tooth collagen) both illustrated that recent environmental changes influenced the ecology (migration and feeding) of these marine mammals in the recent past.

Pieter also gained access to an aged killer whale tooth. Predation of SSL by killer whales is also being considered as a possible cause of the SSL decline. Pieter conducted a preliminary set of analyses mimicking the methods he has been applying to his set of SSL teeth to examine if a 40-year-old killer whale had systematically changed its feeding ecology during the period of time when SSL have declined. Pieter presented these preliminary findings at the 16th Biennial Conference on the Biology of Marine Mammals (see below).

NOAA relevance/societal benefits

This project has provided training and advanced research on issues affecting the sustainability of the Steller sea lion in the northeast Pacific Ocean and Bering Sea. Using stable isotope mixing models, the new dataset analyzed by this

research will help to isolate specific sources of isotopic depletion, illuminate the importance of nutritional limitation, and ultimately further our understanding of natural population foraging and mammalian reactions to environmental changes.

Research linkages/partnerships/collaborators and networking

Partnerships were established with NOAA/National Marine Mammal Laboratory (NMML) (Jim Thomason, Mike Etnier, and Tom Loughlin), Alaska Department of Fish and Game (ADF&G) (Lorrie Rea, Vicki Stegall, and Jamie King), and the University of California Santa Cruz (Paul Koch). A partnership was established with Lori Quakenbush, ADF&G and Dan Vos at the National Marine Fisheries Service to secure access to a killer whale tooth sample.

Education/outreach (Cumulative list for graduate fellowship portion of the project)

Student participation

- deHart served as a volunteer teaching assistant for the Stable Isotope Techniques in Environmental Research course at UAF in the Spring of 2004.
- During 2005–2006 deHart taught science at a local high school in Fairbanks on a fellowship from the NSF-funded Teaching Alaskans Sharing Knowledge (TASK) program.

Presentations

deHart, P.A.P. and M.J. Wooller. 2005. Historical ecology of Steller sea lions during the recent past. Institute of Marine Science seminar series, University of Alaska Fairbanks, May 2005.

deHart, P.A.P. and M.J. Wooller. 2005. A temporal perspective on pinniped foraging ecology: Stable isotope variations in the teeth and bones of Steller sea lions (*Eumetopias jubatus*). 16th Biennial Conference on the Biology of Marine Mammals, San Diego, California, December 2005.

Wooller, M.J., P.A.P. DeHart, L. Quakenbush and D. Vos. 2005. Coupling stable isotope (C and N) analyses of stomach contents and tooth collagen to elucidate patterns in a transient killer whale's (*Orcinus orca*) diet composition. 16th Biennial Conference on the Biology of Marine Mammals, San Diego, California, December 2005.

deHart, P.A.P. and M.J. Wooller. 2004. Shouldn't we ask where? Stable isotopic evidence of geographical variations in Steller sea lion (*Eumetopias jubatus*) diets. Sea Lions of the World Conference, Anchorage, Alaska, September 2004.

deHart, P.A.P. and M.J. Wooller. 2004. Mammalian responses to a changing environment: an isotopic study of Steller sea lions. American Society of Mammalogy conference, Arcata, California, June 2004.

deHart, P.A.P. and M.J. Wooller. 2004. A multi-organismal isotopic study of north Pacific and Bering Sea marine mammals: responses to a changing environment. Isotopes in Ecological Research Meeting, Wellington, New Zealand, April 2004.

Publications

Non-peer-reviewed

deHart, P.A.P. 2006. A Multi-organismal Isotopic Study of the North Pacific and Bering Sea Marine Mammals: Responses to a Changing Environment. Ph.D. Dissertation, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

In preparation

deHart, P.A.P., M.J. Wooller, V.K. Stegall, B.P. Finney and P.L. Koch. The historical ecology of Steller sea lions: An isotopic study of mammalian responses to a changing environment. In preparation for submission to *Marine Mammal Science*.

Follow-up

Pieter has secured a one-year visiting Assistant Professor position at Mount Ida College in Newton, Massachusetts.

Alaska Earthquake Information Center Seismic Station Upgrade and Installation and TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Seismic Network Expansion and Upgrades

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals directly funded by this project:
Steve Estes, Martin LaFevers, Josh Stachnik, Mitch Robinson, John Sandru, Natalia Ruppert, Lily Wong, Elizabeth Fuerst and Rebecca Sanches, *University of Alaska Fairbanks*

CIFAR 33-013d: This project is ongoing.

Primary objectives

This continuing project is to install new modern digital broadband seismic stations throughout Alaska and to maintain their operation and telemetry.

Installations and maintenance

- Alaska Earthquake Information Center (AEIC) personnel continue to monitor and process data from the combined CREST (Consolidated Reporting of Earthquakes and Tsunamis) network funded by the National Tsunami Hazard Mitigation Program (NTHMP). In the past year, 14 seismic or communication sites needed attention for either routine maintenance or hardening for harsh weather. They are listed below:
  - BESE (Besse Mt. near Juneau, AK) – Repair bear damaged cable.
  - BMR (Bremner River – east of Valdez) – Inspected site. All ok.
  - COLD (near Coldfoot, AK) – Major commercial power outage caused UPS (uninterruptible power supply) battery to freeze. Replaced UPS.
  - DCPH (Deception Hills seismic station south of Yakutat) – Increased transmitter power, repaired wind charger.
  - DIV (Divide – East of Valdez) – Repaired transmission line.
  - DOT (Dot Lake) – Replaced UPS. Replaced lightning damaged seismometer.
  - EYAK (near Cordova) – Inspected site.
  - FALS (near False Pass) – Installed UPS and replaced micro-serial server. Inspected station.
  - GAMB (Gambell AK) – Installed UPS at school, reset ground fault interrupter at site.
  - PAX (Paxson) – Replace lightning damaged power supply and phone circuit.
  - PIN (Pinnacle – north of Yakutat) – Replaced damaged solar panels, repaired wind charger, added batteries.
  - SPIA (St. Paul Island) – Replaced bad modem.
  - SWD (Seward, AK) – Replaced bad modem. Installed UPS.
  - Yakutat – Communications hub at NOAA weather service tower. Upgraded antennas. Installed new UPS and replaced router.
- Additionally, this year's funding included a significant upgrade to the Alaska Tsunami Warning Center (ATWC) seismic network. Three AEIC sites are being upgraded at Reindeer Mountain, Ragged Mountain and Skwentna, with equipment from this project.
- The pilot VSAT (Very Small Aperture Terminal) project sites that were established last year at the Bering Glacier Research Camp worked through January. A power system failure, a subsequent computer crash and the lack of spare parts kept the system down until May. Real-time data from the eight outlying sites during this period were lost. However, the on-site data storage was recovered from all eight sites. Analysis of the data is ongoing. Plans are to install two additional VSAT during the next fiscal year.

NOAA relevance/societal benefits

Improved detection of tsunamigenic earthquakes by AEIC and NOAA tsunami warning centers.

Research linkages/partnerships/collaborators and networking

Partnerships and collaborators include the NOAA tsunami warning centers, the state of Alaska emergency services offices, the USGS, and other regional seismic centers. Improved detection, location, and magnitude are available from large earthquakes in the vicinity of Alaska and the greater tsunamigenic regions of the Pacific Ocean.

Education/outreach

Outreach and collaboration efforts with the Tanana Valley State Fair, the Murie Science and Learning Center in Denali National Park, and the Alaska Department of Homeland Security and Emergency Management reported in FY05 continued in FY06.

Alaska Tsunami Inundation Mapping Project and TWEAK (Tsunami Warning and Environmental Observatory for Alaska) Element I: Accelerated Alaska Inundation Mapping Production

Roger Hansen, PI *University of Alaska Fairbanks*

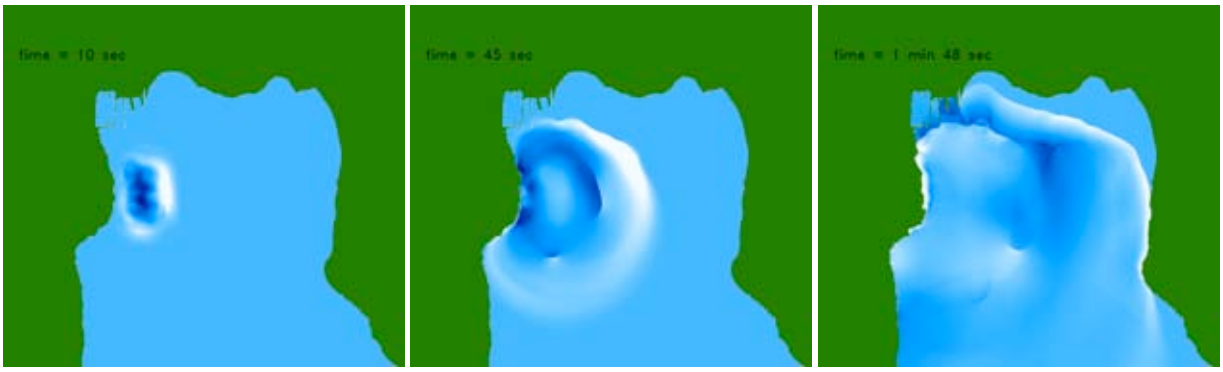
NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals funded by this project:
Elena Suleimani, *University of Alaska Fairbanks*
Rod Combellick, *State of Alaska Division of Geological and Geophysical Surveys*

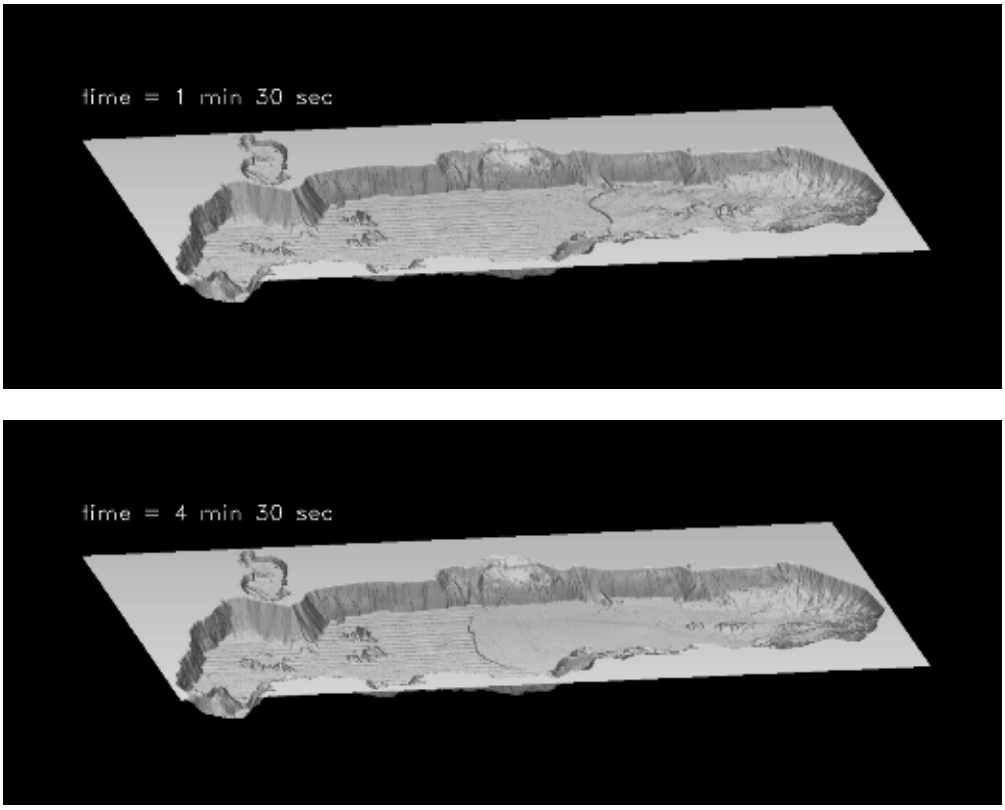
CIFAR 27-014d and 06-028a: These related projects are ongoing.

Primary objectives and approach

The Geophysical Institute/Alaska Earthquake Information Center participates in the National Tsunami Hazard Mitigation Program (NTHMP) by evaluating and mapping potential inundation of selected parts of Alaska coastlines using numerical modeling of tsunami wave dynamics. The communities are selected for inundation modeling in coordination with the Division of Homeland Security and Emergency Management (DHSEM) with consideration to location, infrastructure, availability and quality of bathymetric and topographic data, and community involvement. Kachemak Bay and Prince William Sound are high-priority regions for Alaska inundation mapping. They have several communities with significant population and extensive fishing resources (Homer, Seldovia, Seward, and Valdez). Emergency managers need tsunami evacuation maps for these communities, showing the extent of inundation with respect to human and cultural features, and evacuation routes.



Snapshots from a numerical simulation of tsunami waves and runup generated by the 1964 Seward waterfront slide. The three images show the position of the shoreline at 10, 45, and 108 seconds after the slide was triggered by strong ground shaking of the 1964 earthquake.



Snapshots from a numerical simulation of the 1964 old Valdez waterfront slide. The images show the position of the underwater slide at 1.5 and 4.5 minutes after the slide was triggered by strong ground shaking of the 1964 earthquake.

Research accomplishments/highlights/findings

- We have completed the tsunami inundation maps and report for the communities of Homer and Seldovia in Kachemak Bay, Alaska. The report is published and available from the Alaska Division of Geological and Geophysical Surveys (ADGGS), both in printed form and downloadable from the ADGGS web site.
- We continue to work on the 3-D numerical model for the waves generated by underwater landslides. The model was expanded to calculate inundation of dry land (runup) caused by the slide-generated tsunami waves. We have applied this model to the major underwater slide in upper Resurrection Bay that was triggered by the 1964 earthquake and destroyed the Seward waterfront, and calculated runup caused by this slide. The runup caused by the local landslide tsunami will be combined with the runup from the major tectonic tsunami for inundation mapping.
- We collaborate with a team of scientists from USGS (project leader Dr. Homa J. Lee, USGS Menlo Park, CA) who conducted a number of surveys in Resurrection Bay and Port Valdez in the summer of 2005. They have obtained multi-beam and high-resolution subbottom profile surveys of these areas that provide new information about the morphology of landslide deposits. On the submarine slope adjacent to Seward, the surveys show medium- and large-sized blocks, which we interpret as landslide debris that slid in the 1964 earthquake. In Port Valdez, there are no blocks near the old Valdez townsite, but rather a broad lobe that extends across the fjord bottom, which we interpret as a relatively fluid debris flow deposit. The surveys provide information on the geometry of the slides (areas, runout, and volumes). This information is being used in landslide and tsunami modeling.
- A three-dimensional numerical model of an incompressible 3-D viscous slide with full interaction between the slide and surface waves is used to simulate the slope failure of the old Valdez town site, and the resulting tsunami waves. The long-wave approximation is used for both water waves and slides. The equations of motion and continuity for the slide and for surface waves are solved simultaneously using an explicit finite-difference scheme on a grid of 4.5m x 9m resolution.
- In order to calculate inundation caused by multiple slides in Port Valdez in 1964, we have started working on construction of a seamless bathymetry-topography grid for the town of Valdez. The digital elevation model (DEM) of the Valdez area that was purchased from AeroMap US is now integrated into the high-resolution

multi-beam bathymetry data of Port Valdez. This fine-resolution grid will be connected to a series of embedded grids of increasing resolution that propagate the 1964 tsunami from the Gulf of Alaska to Port Valdez.

NOAA relevance/societal benefits

These activities all pertain to the National Tsunami Hazard Mitigation Program with NOAA's Weather Service.

Research linkages/partnerships/collaborators and networking

Collaborations for this work include the Alaska Division of Geological and Geophysical Surveys, the Alaska Department of Emergency Services, the Alaska Tsunami Warning Center, and the Pacific Marine Environmental Laboratory of NOAA in Seattle.

Education/outreach

Public outreach

- Every year, the Geophysical Institute sponsors the "Science for Alaska" lecture series. University of Alaska scientists give public talks on different subjects related to Alaska climate, environment, wildlife and natural phenomena. In January and February of 2006, Elena Suleimani presented a lecture titled "Surviving a tsunami: is Alaska ready for the next big wave?" in Fairbanks, Anchorage and Juneau. This hour-long lecture consisted of explanation of basic physical characteristics of tsunami waves, summary of tsunami history in Alaska, overview of tsunami preparedness in the United States, and detailed instructions on how to get ready for the next tsunami in Alaska. The lecture stressed the importance of learning more about the tsunami hazard, and of transferring the knowledge about tsunamis to the next generations by creating effective tsunami educational programs for children. The visual effect of the lecture was enhanced by a number of high quality computer animations both illustrative and based on scientific calculations.
- We have provided scientific support and consulting to the Geophysical Institute Information Office in writing a proposal called "Alaska Tsunami Educational Program" that was submitted to the Department of Education. The proposal has been funded, and we plan to participate in the program by contributing to the Tsunami Curriculum and giving live and teleconference lectures to science teachers in rural Alaska.

Presentations

Suleimani, E., R. Hansen and R. Combellick. 2005. Tsunami inundation mapping for Alaska coastal communities. California Tsunami Hazards Workshop, San Francisco, California, 11–12 October 2005.

Suleimani, E., R. Hansen and R. Combellick. 2005. Tsunami inundation mapping and hazard risk assessment for Alaska coastal communities. AGU Fall Meeting, San Francisco, California, 5–9 December 2005.

Suleimani, E., H. Lee, P. Haeussler and R. Hansen. 2006. Assessment of tsunami hazard and landslide potential in Seward and Valdez, Alaska, from numerical modeling and recent multi-beam surveys. Seismological Society of America 2005 Annual Meeting, San Francisco, California, 17–22 April 2006.

Suleimani, E., R. Hansen and R. Combellick. 2006. Tsunami inundation mapping and hazard risk assessment for Alaska coastal communities. AGU Chapman Conference on Active Tectonics and Seismic Potential of Alaska, Alyeska Resort, Girdwood, Alaska, 11–14 May 2006.

Publications

Non-peer-reviewed

Suleimani, E.N., R.A. Combellick, D. Marriott, R.A. Hansen, A.J. Venturato and J.C. Newman. 2005. Tsunami hazard maps of the Homer and Seldovia areas, Alaska. (see http://wwwdggs.dnr.state.ak.us/pubs/pubs). Report of Investigations 2005-2, State of Alaska Department of Natural Resources, Division of Geological & Geophysical Surveys, 28 pp., 2 sheets, scale 1:12,500.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Tsunami Code Development

Roger Hansen, PI ***NOAA Goals: Serve Society's Needs for Weather and Water Information;***
Zygmunt Kowalik, Co-PI and task lead ***Safe, Efficient and Environmentally Sound Transportation***
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
James Beget, Tatiana Proshutinsky, Sathy Naidu, *University of Alaska Fairbanks;*
Galen Gisler, *Los Alamos National Laboratory;* ***Yoshinori Shigihara,*** *National Defense Academy, Japan*

CIFAR 32-074a (Task 3.1): This project is ongoing.

Primary objectives

The objective of the research plan is to improve the present numerical models and afterwards develop a comprehensive numerical model for tsunami generation, propagation and transformation to be used at the West Coast/Alaska Tsunami Warning Center (WC/ATWC). Although the current models have been successfully used, there is a need of actualization using the state-of-the-art approaches. To carry out this plan we closely cooperated with the WC/ATWC in model development, testing and implementation and with external institutions that are in the vanguard in specific fields of tsunami research, Los Alamos National Laboratory and the Tohoku University, amongst others.

Approach/methodology

We have approached the objective by developing particular tasks with the aim to improve the model components:

1) *Tsunami runup:* We have concentrated our efforts on further testing and improving a new runup code. The code was developed by Z. Kowalik (Institute of Marine Science, University of Alaska Fairbanks; IMS) in close cooperation with W. Knight (WC/ATWC) and J. Horrillo (IMS). Previously this code was tested, calibrated and validated with analytical solutions as well as with laboratory experiments. In 2005–2006, various codes based on the full Navier-Stokes equations, long wave equation and dispersive equations were tested for the runup to investigate how different physics may change runup.
2) *2D/3D hybrid tsunami model*: We applied full Navier-Stokes (FNS) equations to test the validity of the fluid dynamics. The results obtained with hydrostatic tsunami model and Boussinesq (dispersive) model were compared against FNS model in order to assess differences caused by vertical acceleration and identify the importance of dispersion for the global propagation model. This investigation is a cooperative effort of J. Horrillo and Z. Kowalik (IMS), Y. Shigihara (National Defense Academy, Japan) and Bill Knight (WC/ATWC and IMS). Last year, model testing was completed using analytical and laboratory cases. Recent investigations have integrated more realistic scenarios. A numerical study which takes into account wave dispersion effects was carried out in the Indian Ocean to reproduce the initial stage of wave propagation of the tsunami event that occurred on 26 December 2004. Three different numerical models mentioned above were used. Numerical model results were compared against each other. General features of the wave propagation agreed very well in all numerical studies. However some important differences were observed in the wave pattern when dispersion is not considered, i.e., the development in time of the wave front is shown to be strongly connected to the dispersion effects.
3) *Interaction of tide and tsunami:* In the real ocean, the short-period tsunami wave rides on the longer-period tides. The question is whether these two waves can be superposed linearly for the purpose of determining the resulting sea level or in the shallow water, do they interact nonlinearly enhancing the total sea level and currents. The constructed model of nonlinear tsunami and tide interaction (preliminarily we use only one tidal constituent) indicates that in Alaska, tsunami runup cannot be computed separately from tides. This investigation is a cooperative effort of A. T. Proshutinsky (WHOI/IMS) and Z. Kowalik (IMS). During the previous reporting period, these assumptions were tested in simple domains like elongated channels. In 2005–2006, we continued these investigations in order to formulate major rules of tsunami/tide interactions as functions of ocean depth, continental slope and ocean shelf characteristics and to identify regions of potentially strong tsunami/tide interactions in the northern Pacific Ocean. The first step was aimed at the investigation of tide/tsunami interactions in two important regions, namely Cook Inlet and Port Valdez. These two regions have very different bottom bathymetries, different coastline configurations and respectively very different natural

modes and resonance conditions. Results of the numerical experiments demonstrated that in locations with a narrow shelf (like Valdez) the time for the tide/tsunami interactions is very short and mainly limited to the large currents in the runup domain. In locations with an extended shallow water region (like Cook Inlet) the nonlinear bottom dissipation of the tide and tsunami leads to strong reduction in tsunami amplitude and tsunami currents.

4) *Tsunami generation by land and submarine slides:* A land/submarine slide model is in development by Z. Kowalik and J. Horrillo (IMS) and W. Knight (WC/ATWC) while potential scenarios of generation are constructed by J. Beget (UAF) and S. Naidu (IMS). Our goal for 2005–2006 was: a) evaluation of sites of submarine landslides associated with past eruptions of Augustine Volcano, b) estimation of their extent and volume, and c) estimation of potential hazards from future landslides (volcanic debris avalanches) from Augustine Volcano in the Cook Inlet area of Alaska.
5) *Construction of the comprehensive tsunami model:* The comprehensive model construction includes at the present time generation by earthquake, propagation and runup (Kowalik et al. in press #1 and 2). This model was applied to test its skill in the simulation of the Indian Ocean tsunami (IOT) case of 26 December 2004. In 2005–2006 along with IOT simulation we modeled the tsunami generated by the Mount St. Augustine (MSA) volcano in 1883 when a portion of the volcano collapsed into the shallow water of Cook Inlet. Both IOT and MSA tsunami results were investigated with different numerical schemes (linear and nonlinear). The results show the importance of the nonlinear interactions in the generation and runup domains. The model constructed by Z. Kowalik implemented higher order approximations for the nonlinear terms in equations of motion and continuity. The high particle velocities of a few meters per second which occurred in the generation domain of MSA require that the spatial derivatives be devoid of short wave oscillations. Such schemes were developed in the field of computational gas-dynamics through extensive application of the flux-limiters and we are testing these schemes for tsunami physics. In testing such limiters we intend to delete the numerical short oscillations but to retain physical short oscillations caused by dispersive waves.
6) The model domain covered the entire World Ocean extending from 80°S to 69°N. The model resolution was 1 minute and its domain had approximately 200 million grid points. In order to carry out this simulation, a parallel version of the model code was developed by T. Logan (ARSC) and run on a supercomputer.

Research accomplishments/highlights/findings

- In 2005–2006, major findings in the global tsunami modeling were related to unraveling the energy balance in the Indian Ocean Tsunami. An energy flux function was used to investigate energy transfer from the tsunami source to the Atlantic and Pacific Oceans. Although the first energy input into the Pacific Ocean was the primary (direct) wave, reflections from the Sri Lankan and eastern shores of Maldives were a larger source. The tsunami traveled from Indonesia, around New Zealand, and into the Pacific Ocean by various routes. The direct path through the deep ocean to North America carried minuscule energy, while the stronger signal traveled a much longer distance via South Pacific ridges as these bathymetric features amplified the energy flux vectors. Travel times for these amplified energy fluxes were much longer than the arrival of the first wave. These large fluxes were organized in the wave-like form when propagating between Australia and Antarctica. The sources for the larger fluxes were multiple reflections from the Seychelles, Maldives and a slower direct signal from the Bay of Bengal. The energy flux into the Atlantic Ocean showed a different pattern since the energy was pumped into this domain through the directional properties of the source function. The energy flow into the Pacific Ocean was approximately 75% of the total flow to the Atlantic Ocean. In many locations along the Pacific and Atlantic coasts, the first arriving signal, or forerunner, has lower amplitude than the main signal which often is much delayed. Understanding this temporal distribution is important for an application to tsunami warning and prediction.
- *Basic results on tide/tsunami interaction in Cook Inlet and Valdez fjord*. The nonlinear interaction of the tide with tsunami is important, as it generates stronger sea level change and even stronger changes in tsunami currents, thus the resulting run-up ought to be calculated for the tsunami and tide propagating together. The major difference between tide and tsunami occurs in the runup region. Tide undergoes small changes in the velocity or sea level in the nearshore/runup domain, while for tsunami this is the region of major amplification of the sea level and currents. In water bodies with an extended shallow water region like Cook Inlet, the nonlinear bottom dissipation of the tide and tsunami leads to strong reduction in tsunami amplitude and tsunami currents. In Figure 1, two locations in Cook Inlet, Anchor Point (close to the mouth) and Anchorage (close to the head), are shown. Tsunami/tide interactions for these locations are depicted in Figure 2. Tsunami has been generated close to the mouth and only M2 tide is considered. While tsunami propagates along the Cook Inlet, it is strongly damped. We had estimated this damping both for the case when tsunami travels alone and together with M2 tide. Comparison shows that tidal currents strongly influence tsunami damping.

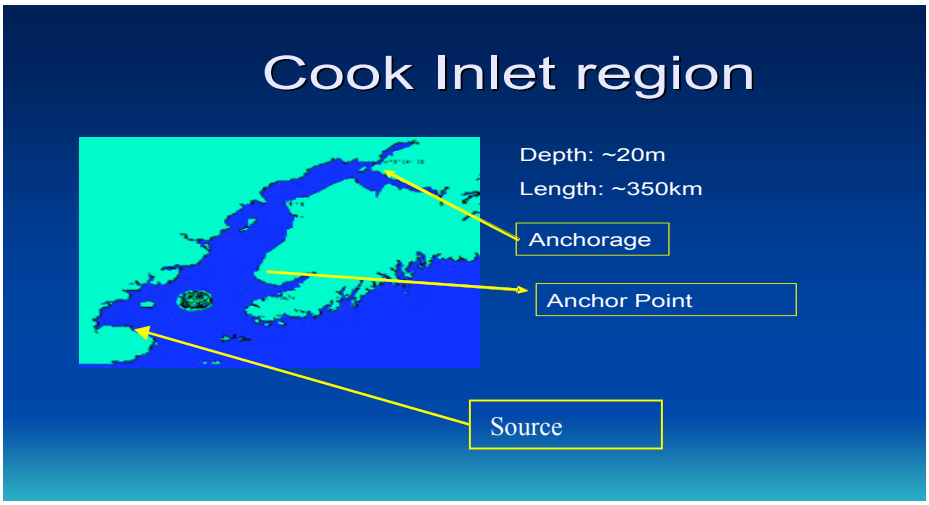


Figure 1. Location of Anchor Point and Anchorage in Cook Inlet.

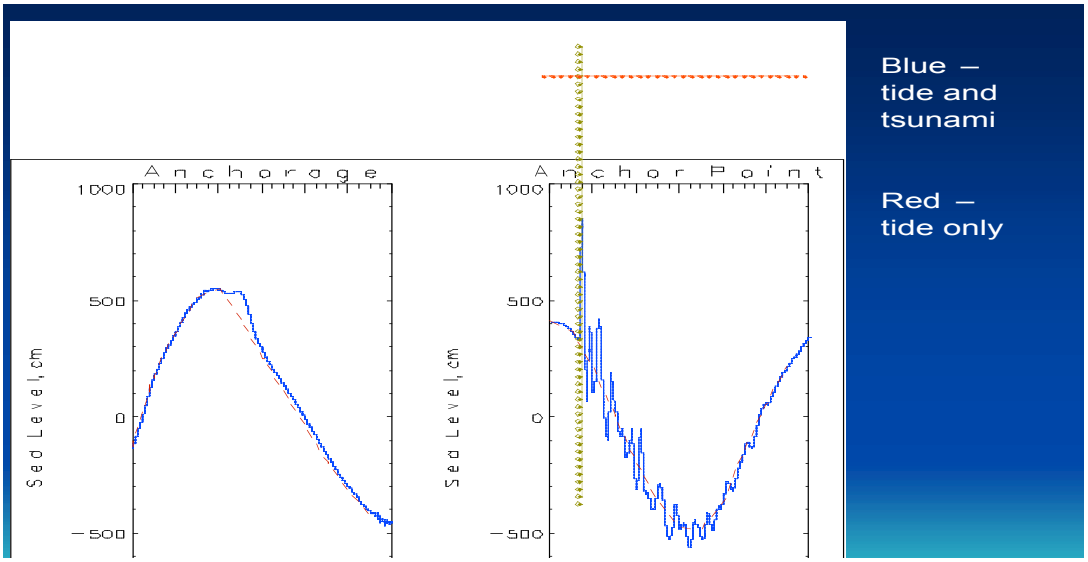


Figure 2. Tide/tsunami interaction in the Cook Inlet while tsunami propagates from the source.

- *Tsunami generation by land and submarine slides.* Numerical modeling has been used to calculate the characteristics of a tsunami generated by a landslide into Cook Inlet from Augustine Volcano. Paleotsunami deposits were found at sites along the coast near Mt. Iliamna, Nanwelak, and Homer, consistent with numerical modeling results, indicating significant tsunami wave amplification occurs in these areas (see Figure 3). The landslide generated waves of about 20 m high in the island proximity. The application of different numerical schemes to this case demonstrated importance of the nonlinear terms in the tsunami generation domain and therefore the high order of numerical approximations is going to be our priority in improving our models.

NOAA relevance/societal benefits

Numerical models are required to assess expected coastal tsunami impact, both in amplitude and horizontal inundation distance, so that proper evacuation decisions can be made during tsunami warnings, as well as for long-term planning of coastal zone development. When the project is completed, the West Coast/Alaska Tsunami Warning Center will have the much-needed tsunami models for use in their warning procedures.

As our model includes parallel code and it is the first truly global tsunami model, the importance of our investigations on the IOT were instantly recognized by the international tsunami community. The model has been already transferred to the Alaska Tsunami Warning Center in Palmer to be used for tsunami warning and prediction

in the Atlantic Ocean, and we have received requests to transfer code to the University of Hawaii at Manoa, University of Ottawa, Canada and Federation of the Indian Chamber of Commerce and Industry.

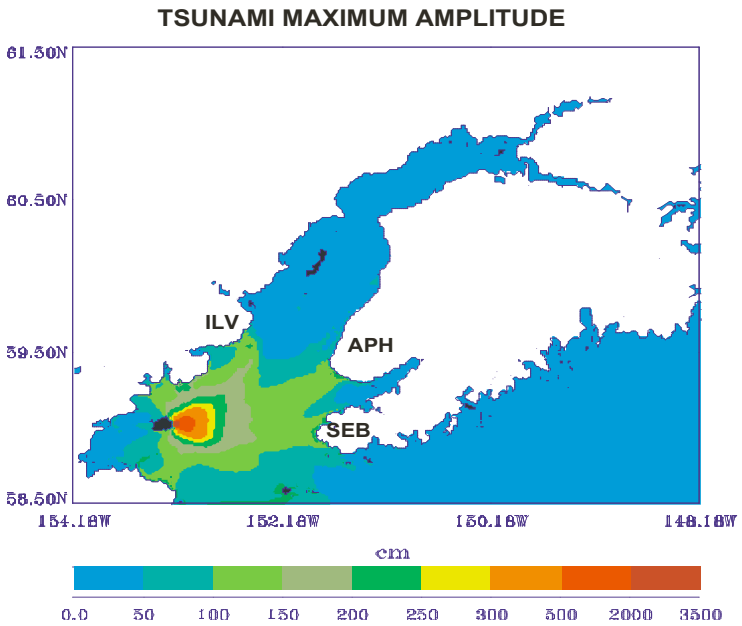


Figure 3. Maximum tsunami amplitudes in centimeters. Abbreviations: APH, Anchor Point–Homer; SEB Seldovia–English Bay; ILV, Iliamna Volcano.

Research linkages/partnerships/collaborators and networking

The numerical modeling technique used by the West Coast/Alaska Tsunami Warning Center (WC/ATWC) which forms the present basis of the U.S. Tsunami Warning System's predictive technique was developed during the period 1984–1990 by the Institute of Marine Science, University of Alaska in cooperation with the Institute of Ocean Sciences, Sidney, BC, Canada through an NSF grant.

Several teams from institutions of the U.S.A. and Japan are involved in this project. For the continuing model development, the responsibility lies with the University of Alaska (Kowalik and Horrillo, Institute of Marine Science; Tom Logan, Arctic Region Supercomputing Center), W. Knight and P. Whitmore (WC/ATWC), Y. Shigihara (National Defense Academy, Japan) and T. and A. Proshutinsky (WHOI/IMS). Input to the project was also made by G. Gisler (Los Alamos), J. Beget (UAF) and S. Naidu (IMS); William Knight of the WC/ATWC coordinated research activities with implementation at the WC/ATWC.

We envision that many of the tsunami algorithms can be most effectively transported to and tested on the UAF supercomputers. Maintaining the codes and applications at UAF will enable the WC/ATWC to quickly generate new database entries as needed or to re-compute the old database entries. With a 3-D visualization laboratory in ARSC, it was a relatively simple task to develop animation techniques (R. Edberg, ARSC) that elucidated physics of the global tsunami propagation.

Education/outreach

Student participation

Juan Horrillo, a Ph.D. graduate student in physical oceanography at the Institute of Marine Science who was previously funded by this project, successfully defended his thesis titled: *Numerical Method for Tsunami Calculation Using Full Navier-Stokes Equations and Volume of Fluid Method.* Z. Kowalik was chair of his advisory committee.

William Knight is a new Ph.D. student at the Institute of Marine Science, to continue tsunami research. Z. Kowalik chairs his advisory committee.

Presentations

Kowalik, Z., J. Horrillo, W. Knight, T. Logan, Y. Shigihara and P. Whitmore. 2006. Numerical modeling of the Indian Ocean Tsunami. Ocean Sciences Meeting, Honolulu, Hawaii, 20–24 February 2006.

Kowalik, Z., T. Proshutinsky and A. Proshutinsky. 2006. Tide–tsunami interactions. Keynote lecture at the Third Tsunami Symposium, Honolulu, Hawaii, 23–26 May 2006.

Horrillo, J., Z. Kowalik and Y. Shigihara. 2006. Wave dispersion study in the Indian Ocean, December 26, 2004. 2006. Third Tsunami Symposium, Honolulu, Hawaii, 23–26 May 2006.

Publications

Peer-reviewed

Beget, J. and Z. Kowalik. 2006. Confirmation and calibration of computer models of the 1883 tsunami produced by Augustine Volcano, Alaska. *Science of Tsunami Hazards*, 24(4):257–266.

Kowalik, Z., T. Proshutinsky and A. Proshutinsky. 2006. Tide–tsunami Interactions. *Science of Tsunami Hazards*, 24(4):242–256.

Non-peer-reviewed

Horrillo, J.J. 2006. Numerical Method for Tsunami Calculation Using Full Navier–Stokes Equations and Volume of Fluid Method. Ph.D. Dissertation, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

In press

Kowalik, Z., J. Horrillo and E. Kornkven. Tsunami runup onto a plane beach. In: P.L.-F. Liu, H. Yeh and C. Synolakis, Eds., Advances in Coastal and Ocean Engineering. Advanced Numerical Models for Simulating Tsunami Waves and Runup. Vol. 10, pp. 79–84. World Scientific. In press.

Kowalik, Z., J. Horrillo and E. Kornkven. Tsunami propagation and runup due to a 2D landslide. In: P.L.-F. Liu, H. Yeh and C. Synolakis, Eds., Advances in Coastal and Ocean Engineering. Advanced Numerical Models for Simulating Tsunami Waves and Runup. Vol. 10, pp. 85–89. World Scientific. In press.

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. Numerical modeling of the Indian Ocean tsunami. In: T.S. Murty, U. Aswathanarayana and N. Nirupama, Eds., The Indian Ocean Tsunami. Balkema, New York, pp. 97–122. In press.

Accepted

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. The tsunami of 26 December 2004: numerical modeling and energy considerations–II. Accepted for inclusion in a book, Tsunami and Its Hazard in Pacific and Indian Oceans, to be published by Pure and Applied Geophysics.

Kowalik, Z., J. Horrillo and Y. Shigihara. Wave dispersion study in the Indian Ocean Tsunami, Dec 26, 2004. Accepted for publication in *Marine Geodesy*.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Earthquake Characteristics and Finite Fault Processes

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals funded by this project:
Natalia Ruppert, *University of Alaska Fairbanks*

CIFAR 32-074a (Task 3.2): This project is ongoing.

Primary objectives

Implementation of the near-real-time moment tensor inversion and extended earthquake source inversion procedures at the Alaska Earthquake Information Center (AEIC).

Approach/methodology

The real-time earthquake detection system at AEIC is based on the Antelope software package from BRTT, Inc. Automatic earthquake locations are searched over a pre-calculated three-dimensional grid. Once an event is located, its magnitude is calculated. Location and magnitude along with the set of associated arrivals and other information are written into the real-time earthquake database. The moment tensor inversion program is triggered by a module that continuously watches the real-time earthquake database. When a new event above a certain magnitude level has been recorded, it triggers the execution of the moment tensor inversion module. The procedure consists of several steps. First, the waveforms are extracted from the broad-band stations. If the waveforms within a certain epicentral distance are available, then the moment tensor inversion is performed. The program generates a series of output files including a postscript graphics file with the actual and synthetic wave forms and the best fit moment tensor parameters, a map with the earthquake location and the focal mechanism obtained, and an ascii file with the moment tensor parametric data.

The automatic moment tensor information is available through the AEIC webpage:
http://www.aeic.alaska.edu/html_docs/moment_tensors.html
in three forms. Automatic moment tensors are reviewed on the following business day.

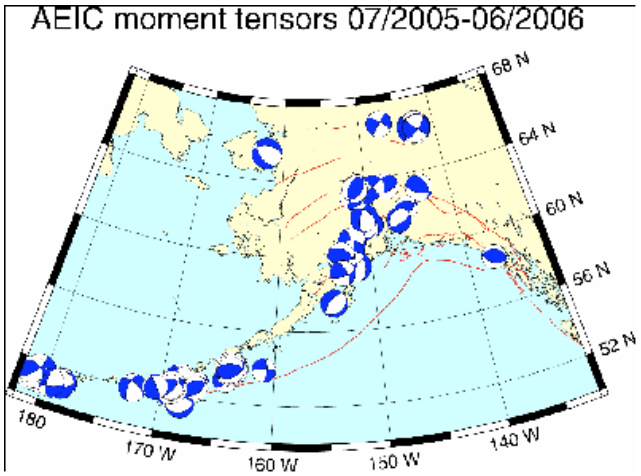


Figure 1. Calculated moment tensors from the regional network stations for July 2005–June 2006.

Research accomplishments/highlights/findings

- A total of 56 regional moment tensor solutions were calculated (Mw=3.8–6.93) for this time period (Figure 1).
- Ongoing expansion of the AEIC broadband network allows for more reliable calculations of the earthquake source parameters through inclusion of more waveform data into inversion. The most recent installation of 14 broadband stations in Wrangell–St. Elias National Park (a part of the ongoing St. Elias Erosion Tectonic Project, or STEEP) greatly expanded our detection capabilities in southern Alaska.
- Trial (not real time) runs have been performed with the extended earthquake source inversion code.

NOAA relevance/societal benefits

Rapid calculation of earthquake source parameters through the moment tensor inversion allows scientists to determine sense of motion along the ruptured fault. While many other conditions determine whether an earthquake is capable of generating potentially destructive tsunamis, the foremost condition is the type of earthquake source (underthrusting vs. normal or strike-slip) and size.

Research linkages/partnerships/collaborators and networking

This project is one of three research tasks identified under TWEAK (Tsunami Warning and Environmental observatory for Alaska) and share the linkages and partnerships outlined under the other tasks.

The moment tensor inversion package at AEIC was installed in close cooperation with Dr. D. Dreger from Berkeley Seismic Laboratory. This cooperation is continuing as part of installation and tuning of the program package for extended source inversion at AEIC. All AEIC earthquake source data is available on-line through open-access web pages. This information is available to scientists at the West Coast/Alaska Tsunami Warning Center (WC/ATWC) as well as many other institutions.

Education/outreach

Presentations

Ruppert, N.A. 2005. Stress map for Alaska from earthquake focal mechanisms. American Geophysical Union Fall Meeting, San Francisco, California, 5–9 December 2005.

Ruppert, N.A., R.A. Hansen and M. Robinson. 2006. Earthquake detection and data processing systems at the Alaska Earthquake Information Center. Seismological Society of America Annual Meeting, San Francisco, California, 17–21 April 2006.

Ruppert, N.A. 2006. Interior Alaska seismicity and the Denali Fault earthquake. Chapman Conference, Girdwood, Alaska, 11–14 May 2006.

Ruppert, N.A. 2006. Stress map for Alaska from earthquake focal mechanisms. Chapman Conference, Girdwood, Alaska, 11–14 May 2006.

Ruppert, N.A. and R.A. Hansen. 2006. Analysis of the aftershock sequence of the 2002 Mw 7.9 Denali Fault, Alaska earthquake. Chapman Conference, Girdwood, Alaska, 11–14 May 2006.
Hansen, R.A., N.A. Ruppert and G. Pavlis. 2006. Relocation studies of the southcentral Alaska seismicity augmented with the STEEP portable seismic network. Chapman Conference, Girdwood, Alaska, 11–14 May 2006.
Hansen, R.A. and N.A. Ruppert. 2006. Seismicity studies along the Alaska-Aleutian Arc. Chapman Conference, Girdwood, Alaska, 11–14 May 2006.
Fisher, M.A., N.A. Ruppert, D.M. Eberhard-Phillips, R.E. Wells, R.J. Blakely and R.W. Sliter. 2006. Active tectonics and deep-crustal structure of the continental margin beneath Prince William Sound and the northernmost Gulf of Alaska. Chapman Conference, Girdwood, Alaska, 11–14 May 2006.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Tsunami Portal for Comparison of Tsunami Code

Roger Hansen, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

Other investigators/professionals funded by this project:
Barbara Horner-Miller (*Task lead****), Craig Stephenson, Thomas Logan, Roger Edberg, Edward Kornkven, Elena Suleimani,*** *University of Alaska Fairbanks;* ***Cherri Pancake, Sara Cole, Tim Holt, Dylan Keon, Leanne Lai, Harry Yeh, Daehyun Yoon, Daphne Kagume, Wilson Mbugua, Javier Moncada, Rob Steiner****, Oregon State University*

CIFAR 32-074a (Task 3.3): This project is ongoing.

Primary objectives

The Tsunami Computational Portal will be a shared web portal for executing computational models of tsunami behavior. Researchers, operational staff and other interested parties will be able to input data for different scenarios to run on the available models. They will specify parameters for explicit scenarios, specify which of the available models to use to create computer runs, submit those runs for execution, access or download the results from the computational systems to the portal, and share comments on their results, issues and recommendations. The web portal will be built by an outsourced team and will include the necessary user interface/infrastructure to initially provide access to two prominent tsunami codes and professionally developed case studies.

Approach/methodology

The Tsunami Computational Portal is a shared website where computer models of tsunami behavior can be executed and compared against a series of benchmark data mimicking real-world coastal communities. The portal will allow researchers to collaboratively refine existing techniques for predicting the occurrence and effects of tsunamis and storm surge waves.

Computational models yielding relevant and useful predictive information about any particular natural hazard are hard to identify, access, or understand. In the case of tsunamis, a number of high-quality simulation and prediction models exist, but are in the hands of individual researchers located at various institutions throughout the world. To obtain critical predictive information (e.g., wave height and propagation estimates, run up effects), each model must be run with particular input data (specific coastline and underwater geography, historical water levels, tidal patterns, etc.). While much of the data is available online, it must be located and gathered from a variety of agencies, then converted to the appropriate formats for each model. Further, the computing resources for executing the models are scattered, with computer architecture, system availability, and access varying from one location to another. Expert computing knowledge is required to install the models, expert geographic information knowledge is required to convert and properly align the input data, and expert tsunami knowledge is required to accurately interpret simulation results. The Tsunami Computational Portal provides a collaborative forum where these areas of expertise come together in support of tsunami research and mitigation.

The Tsunami Computational Portal will provide a unique forum to expedite the development of new and enhanced methods for predicting tsunamis and mitigating their effects. Using the portal, researchers and tsunami warning operations staff will be able to collaboratively execute and analyze model behavior, comparing them to the observed effects of past tsunamis. Researchers who have developed computational models "contribute" them to the portal, where they are fully documented and made available for peer review by other tsunami experts. Portal users

can select individual models and apply them to a variety of "scenarios," or collections of geographical and infrastructure data that mimic a variety of real-world coastal settings. The models are maintained at a supercomputer center (where they are kept up-to-date by IT professionals) and are executed on behalf of portal users; after execution, users can view or download their results. Most importantly, users can compare the results of running different models on the same "scenarios" and can exchange comments about issues and recommendations with the rest of the tsunami research community. This collaborative process of review and analysis will improve both our understanding of tsunami dynamics and the accuracy of tsunami models.

Research accomplishments/highlights/findings

- Continued development, testing and tuning of the UAF Tsunami model.
- Integration of a new model, TsunamiClaw. Testing of the model and initial comparison to the UAF Tsunami model. After analysis of the model, the portal parameter definition document was updated to include it; porting of this model is in the planning stage. (Keon, Logan, Yeh)
- Use of the parameter definition document defined last year was created to define each identified parameter and the models were modified to accept input data as defined in that document. Integration of these parameters with the portal, to enable researchers to specify their model runs.
- Further optimization of the COMCOT model from Cornell has resulted in a near 20 times speed up of this model to allow larger, more lengthy model runs. (Logan)
- Work is underway to port the parallel Global tsunami model from Co-Array FORTRAN to MPI-2. This will make the model far more portable to different architectures. (Logan)
- Work has continued on implementing the system architecture. Automation of the job initiation and finalization has been partially implemented, with work continuing on this aspect of the project. (Stephenson)
- Multiple bench marking and test runs have been made for both the UAF Tsunami and COMCOT models. (Logan, Keon)
- Previously, work on the portal was leveraged to allow UAF to create a Global tsunami model to study the effects of the Sumatra tsunami that occurred in December 2004. During the current reporting period, visualizations of the Sumatra event were created and shared. These visualizations were important for outreach and training, including to non-specialist populations. More importantly, they were useful for tsunami modelers to assess the accuracy of their model runs, as compared to actual measurements of the event. (Edberg)
- Added two large bathymetry data sets to the spatial database and made them available in the Web-based portal. The two data sets are GEBCO (1-minute global bathymetry/topography data) and ETOPO2 (2-minute global bathymetry/topography data). (Keon)
- Updated PostgreSQL/PostGIS installation. Later PostGIS versions store geometries in the LWGEOM format (Lightweight Geometry). This has resulted in about a 40% reduction in disk space required by the spatial database. (Keon, Steiner)
- Optimized spatial database by 1) altering PostgreSQL data types to use most efficient type wherever possible (e.g., smallint vs. int), resulting in a substantial reduction in disk usage for some of the datasets, and 2) building new spatial indexes on the geometry columns using LWGEOM. We have also optimized some of the spatial queries used by the portal frontend. (Keon)
- Completed implementation of COMCOT model parameters in the portal front end. (Steiner)

NOAA relevance/societal benefits

The visualizations of the Indonesian tsunami were used extensively for education and outreach, as described below. Work to integrate the third model (TsunamiClaw) is expected to provide insights into how the three available models differ and agree, and to allow us to identify model strengths and weaknesses. Ease of use for doing such comparisons, as provided by the portal, can help to accelerate model evaluation and comparison.

Research linkages/partnerships/collaborators and networking

This project is leading to better collaborations between the Arctic Region Supercomputing Center and the West Coast and Tsunami Warning Center in Anchorage. William R. Knight, Physical Scientist at the Warning Center is utilizing the computational resources at ARSC working on the project sponsored by Zygmunt Kowalik (see earlier report on TWEAK task 3.1), IMS/UAF.

Education/outreach

Web portal under development: http://tsunamiportal.nacse.org/wizard.php
Formal demonstrations of the portal included the following:

- NEES (Network for Earthquake Engineering and Simulation) Consortium Annual Meeting, Washington, DC, March 2006.
- NSF/NEES Workshop on Tsunami Research and Modeling, Corvallis, Oregon, July 2006.
- NSF/NOAA National Tsunami Research Workshop, Corvallis, Oregon, July 2006.

K–12 outreach

During this reporting period, visualization of results from these models were used in the ARSC Discovery Laboratory to present science to approximately 1000 K–12 students from throughout the state of Alaska, making them more aware of tsunamis and their impacts on the world.

University/research outreach

The visualizations were displayed at several conferences, and added to a widely distributed ARSC DVD. The DVD also featured Drs. Suleimani and Kowalik speaking about their research. Formal presentations included the following:

Pancake, C. 2005. Tsunami—understanding the big wave. Invited talk at SC2005, Seattle, Washington, November 2005.

Pancake, C. 2006. Experiences with e-science: predicting and preparing for tsunamis. Keynote at UK E-Science Conference, Edinburgh, Scotland, January 2006.

Kowalik, Z., J. Horrillo, W. Knight, T. Logan, Y. Shigihara and P. Whitmore. 2006. Numerical modeling of the Indian Ocean Tsunami. 2006 Ocean Sciences Meeting, Honolulu, Hawaii, February 2006.

Pancake, C. 2006. How IT can help mitigate the effects of natural disasters: lessons from the tsunami community. Dessai Lecture, Kansas State University, Manhattan, Kansas, February 2006.

Pancake, C. 2006. Making cyberinfrastructure accessible and appealing to users—lessons from early efforts. Keynote presentation at NSF/EPSCoR Conference on Cyberinfrastructure, Nashville, Tennessee, May 2006.

Publications

In press

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. Numerical modeling of the Indian Ocean tsunami. In: T.S. Murty, U. Aswathanarayana and N. Nirupama, Eds., The Indian Ocean Tsunami. Balkema, New York, pp. 97–122. In press.

Accepted

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. The tsunami of 26 December 2004: numerical modeling and energy considerations–II. Accepted for inclusion in a book, Tsunami and Its Hazard in Pacific and Indian Oceans, to be published by Pure and Applied Geophysics.

TWEAK Element III: Tsunami Warning and Environmental Observatory for Alaska

David L. Musgrave, PI *University of Alaska Fairbanks*

NOAA Goals: Serve Society's Need for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

CIFAR 06-028c: This project is ongoing.

Primary objectives

1) Characterize the mesoscale flow field (kinematics, dynamics, and biological importance).
2) Address mechanisms of cross-shelf exchange, particularly those involving the interaction of a swift western boundary current, interacting with a cross-shelf canyon.
3) Provide an unprecedented opportunity to examine how fluctuations in a boundary current (Alaskan Stream) affect transfer between the shelf and slope.
4) Quantify the temporal (tidal – interannual) variability in the circulation and water mass properties.

Approach/methodology

We proposed to install a high frequency ocean surface current radar system (CODAR Ocean Sensors *SeaSonde*) to map the surface velocity field at a resolution of ~3 km at 3 times/hour. The viewing field would cover approximately 80 km (subject to environmental constraints).

Research accomplishments/highlights/findings

- After the installation of the additional propane tanks at Rugged Island in August 2005, the site was inoperative within one week. A field inspection showed that the propane tanks once again were empty within one week. We

still could not find any leaks in the system. Therefore we decided to mothball both systems for the winter and retrieve them in spring, 2006.

- In April 2006, we were able to demobilize the Middleton Island site and at the end of June we demobilized the Rugged Island site. We will be analyzing the small amount of data that we did obtain in 2005.

NOAA relevance/societal benefits

NOAA has long had interest in the physical oceanography and marine ecosystem on the shelf of Alaska. The data collected in the full deployment will help determine the spatial and temporal variability of the currents in the Gulf of Alaska.

Research linkages/partnerships/collaborators and networking

This work has already garnered the interest of the Alaska Ocean Observing System (AOOS) and we expect that continued operational funds for the maintenance of the systems will be forthcoming from AOOS. Although minimal salary support from the TWEAK project was used, funds provided from a NASA grant from the University of Massachusetts Dartmouth for $50,000 accounted for about half of the total amount spent for the Rugged and Middleton Island deployments.

UV and Arctic Haze Studies

Long-Term Trends and Spatial Variability in Arctic Haze at Four Sites in Western Alaska

Glenn E. Shaw, PI ***NOAA Goal: Understand Climate Variability and Change***
University of Alaska Fairbanks

CIFAR 10-059a: This project is ongoing.

Primary objectives

The main objective of this project is to assess the long-term trends in Arctic Haze and ascertain the cause of the observed trends by continuing measurements of aerosol chemical composition at four Alaskan sites at Barrow, Poker Flat, Denali Park, and Homer in the Gulf of Alaska. In recent years we are seeing evidence of pollution from Asian sources reaching Alaska, around late spring at a time of large dust-storms in China and the Gobi Desert areas.

Our goal is generally to combine the chemical information with meteorological information to determine how sources of the pollution reaching Alaska change on inter-seasonal to inter-annual time scales.

Approach/methodology

In 2001/2002 the network's ability to discriminate different far-away pollution sources was improved by installing impactors to size select submicron aerosols. These fine particles have long residence times in the atmosphere.

At Barrow, the submicron samples are collected daily. At the other three sites, atmospheric samples are collected on a weekly basis. Samples are analyzed for major anions (chloride, nitrate, sulfate, and methanesulfonate) and cations (sodium, ammonium, potassium, magnesium, and calcium).

Information about sources of aerosol to western Alaska can be ascertained from the chemistry. For example, methanesulfonate has a purely biogenic source and follows local biological productivity, peaking strongly in summer. Sulfate and nitrate are primarily produced through anthropogenic combustion processes. Sodium serves as a tracer for sea salt, magnesium and calcium as tracers for dust, and potassium as a tracer for biomass burning.

Research accomplishments/highlights/findings

- Sampling continued at all four sites during the reporting period.
- This project represents the latest installment of a long-term monitoring effort that began in 1997. Earlier results can be found in: P.K. Quinn et al. 2000. Surface submicron aerosol chemical composition: what fraction is not sulfate? *Journal of Geophysical Research*, 105:6785–6806 and P.K. Quinn et al. 2002. A three-year record of simultaneously measured aerosol chemical and optical properties at Barrow, Alaska. *Journal of Geophysical Research*, 107, doi:10.1029/2001JD001248.
- A third paper was been submitted to *Tellus* in June 2006 (see Publications section).

NOAA relevance/societal benefits

Alaska's air is polluted from Arctic Haze and is episodically contaminated from dust mixed with industrial air pollution from the Orient. China's economy and attendant air pollution is rapidly growing. This study assesses long-term trends and ascertains the cause of the observed trends.

Research linkages/partnerships/collaborators and networking

This work is done in collaboration with Dr. Patricia Quinn of NOAA/PMEL, with additional assistance from the following individuals:

- Andrea Blakesley of the National Park Service operates the sampling station at Denali Park. Ms. Blakesley changes the impactor sampler once per week (all the stations impactor films are changed at the same time/date) and arranges for alternate personnel when she is on travel. She has been a loyal, long-term participant in this project and has always taken a high and active interest in the project and insures the highest quality of standards for this sampling program. She is donating approximately two hours per week to this project.
- Dr. Scott Pegau of the Kachemak Bay Research Reserve and NOAA operates the sampling station at Homer. Dr. Pegau has taken a great interest in the project and drives to the sampling location every week to change filters. Since early July, 2005, we have installed additional aerosol equipment to derive the aerosol size distribution spectrum and the optical scattering coefficient. Dr. Pegau is operating the equipment and is active in helping us locate an alternate sampling location for the southern station in the Gulf of Alaska. He is donating several hours a week to this project.
- Dr. John Ray of the National Park Service has helped maintain a meteorological system at the Poker Flat Research Station. The system is now permanently loaned to the University of Alaska and personnel at the Poker Flat Research range maintain this meteorological equipment that records wind direction and speed, temperature and temperature vertical gradient, solar radiation and humidity every 5 minutes.
- Mr. Brian Lawson from the office of Poker Flat Research Range is hired to change the impactor films every week. He has done a thorough and excellent job, spending about two hours per week on the project.

Education/outreach

A number of scientists and students have visited the air sampling site at Poker Flat in the past year.
Dr. Scott Pegau proposes to use our aerosol sampling instruments as demonstrations to public teaching programs carried out at the Kachemak Bay Research facility.

Publications

Submitted

Quinn, P.K., G.E. Shaw, E. Andrews, E.G. Dutton and R. Ruoho-Airola. Arctic Haze: current trends and knowledge gaps. Submitted to *Tellus*.

Appendices 1–3

1. Projects Awarded 1 July 2005–30 June 2006

2. Personnel

3. Publication Activity

Appendix 1
CIFAR Projects Awarded in Cooperative Agreement NA17RJ1224
Year 5: 1 July 2005–30 June 2006

Last	First	Proposal Title	Proposal Budget	Sub F&A	Total Award	Task	Theme Description	Funding Source
Walsh	**John**	CIFAR Task I: Administration (Year 5)	$ 100,000	n/a	$ 100,000	I	Administration	OAR
Walsh	**John**	CIFAR Task I: Administration Supplement	$ 10,000	n/a	$ 10,000	I	Administration	OAR
Adkison	**Milo**	Inter-Decadal Change in Sablefish Growth and Maturity in the Northeast Pacific Ocean: Year 1	$ 57,740	n/a	$ 57,740	III	Fisheries Oceanography	NMFS
Adkison	**Milo**	Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt	$ 10,600	n/a	$ 10,600	III	Fisheries Oceanography	NMFS
Adkison	**Milo**	Relationship Between Growth and Survival of Coho Salmon Utilizing the Coastal Gulf of Alaska	$ 40,612	n/a	$ 40,612	III	Fisheries Oceanography	NMFS
Akasofu	**Syun**	NOAA / IARC FFY2005	$ 750,000	n/a	$ 750,000	III	Hydrographic & Sea Ice Studies	OAR
Akasofu	**Syun**	NOAA / IARC FFY2005	$ 400,000	n/a	$ 400,000	III	Hydrographic & Sea Ice Studies	OAR
Akasofu	**Syun**	NOAA / IARC FFY2005	$ 750,000	n/a	$ 750,000	III	Hydrographic & Sea Ice Studies	OAR
Atkinson	**David**	Alaskan Coastal Climatologies Wind and Wave Hindcast Workshop	$ 40,987	n/a	$ 40,987	III	Atmospheric Climate	NWS
Bromwich	**David**	Initiation of Arctic Reanalysis Activity in SEARCH	$ 70,000	n/a	$ 70,000	III	Climate Modeling	OAR
Francis	**Jennifer**	Correction of Systematic Errors in TOVS Radiances	$ 55,400	n/a	$ 55,400	III	Atmospheric Climate	OAR
Gharrett	**A.J.**	Genetic Studies of Rockfishes (Phase I)	$ 69,000	n/a	$ 69,000	III	Fisheries Oceanography	NMFS
Grebmeier	**Jackie**	Ecosystem Change in the Northern Bering Sea (joint w/ Whitledge)	$ 99,000	n/a	$ 99,000	III	Marine Ecosystems	OAR
Hansen	**Roger**	RUNUP-CIFAR Alaska Tsunami Inundation Mapping Project	$ 174,124	n/a	$ 174,124	III	Tsunami Research	OAR
Hansen	**Roger**	CREST CIFAR-Alaska Earthquake Information Center Seismic Station Upgrade and Installation	$ 267,972	n/a	$ 267,972	III	Tsunami Research	OAR
Hansen	**Roger**	Tsunami Warning and Environmental Observatory for Alaska - Year 4	$ 1,829,140	n/a	$ 1,829,140	III	Tsunami Research	NWS
Hillgruber	**Nicola**	Bering Strait: Relationships between Pollock (Theragra chalcogramma) Distribution and Biomass, Zooplankton Biomass, and Oceanographic Conditions in the Bering and Chukchi Seas, Alaska	$ 8,098	n/a	$ 8,098	III	Fisheries Oceanography	NMFS
Norcross	**Brenda**	Reproduction Potential of Pacific Cod	$ 9,962	n/a	$ 9,962	III	Fisheries Oceanography	NMFS
Reiersen	**Lars-Otto**	Arctic Monitoring and Assessment Programme (AMAP)	$ 40,000	n/a	$ 40,000	III	Contaminant Effects	OAR
Romanovsky	**Vladimir**	State of the Arctic Report	$ 20,000	n/a	$ 20,000	III	Atmospheric Climate	OAR

updated: 9/5/2006

Last	First	Proposal Title	Proposal Budget	Sub F&A	Total Award	Task	Theme Description	Funding Source
Weingartner	**Thomas**	ALPHA HELIX for GLOBEC	$ 62,290	n/a	$ 62,290	III	Fisheries Oceanography	NOS
Weingartner	**Thomas**	Bering Strait: The Pacific-Arctic Ocean Connection, RUSALCA 2005	$ 185,995	n/a	$ 185,995	III	Hydrographic & Sea Ice Studies	OAR
Whitledge	**Terry**	GLOBEC-NEP: Topographic Control of Mesoscale Variability in the Gulf of Alaska	$ 111,078	n/a	$ 111,078	III	Fisheries Oceanography	NOS
Whitledge	**Terry**	Ecosystem Change in the Northern Bering Sea: Nitrate Sensors on the Mooring and Retrospective Nutrient Analysis	$ 80,800	n/a	$ 80,800	III	Marine Ecosystems	NMFS
Yang	**Daqing**	Assessment of Arctic Snowcover Change and its Impact on Large River Runoff	$ 65,227	n/a	$ 65,227	III	Hydrographic & Sea Ice Studies	OAR
			$ 5,308,025		$ 5,308,025			

Appendix 2. Summary of CIFAR-funded Personnel and their Terminal Degree

Category	Number	B.A./B.S. or unknown	M.A./ M.S.	Ph.D.
Research Scientist	6			6
Visiting Scientist	1			1
Postdoctoral Fellow	0			
Research Support Staff	4	1	2	1
Administrative	2	2		
Total (≥ 50% NOAA Support)	**13**	3	2	4
Undergraduate Students	3			
Graduate Students	13	8	5	
Total Students	**16**			
Employees (< 50% NOAA Support)	60	16	12	32
Located in NOAA Lab	1	ABL(1)		
Obtained NOAA employment within last year	1		1	

Appendix 3. Publication Activity

Work from projects funded under the current cooperative agreement (NA17RJ1224) that was published, accepted, or in press during the reporting period (or published during previous reporting periods but not reported earlier).

Aagaard, K., T.J. Weingartner, S.L. Danielson, R.A. Woodgate, G.C. Johnson and T.E. Whitledge. What controls flow and salinity in Bering Strait? *Geophysical Research Letters*, in press.

Amundrud, T.L., H. Melling, R.G. Ingram and S.E. Allen. 2006. The effect of structural porosity on the ablation of sea ice ridges. *Journal of Geophysical Research*, 111, C06004, doi:10.1029/2005JC002895

Beget, J. and Z. Kowalik. 2006. Confirmation and calibration of computer models of the 1883 tsunami produced by Augustine Volcano, Alaska. *Science of Tsunami Hazards*, 24(4):257–266.

Belkin, I. and P. Cornillon. 2003. SST fronts of the Pacific coastal and marginal seas. *Pacific Oceanography*, 1(2):90–113. *(FY03; not previously reported)*

Belkin, I.M. and P.C. Cornillon. 2004. Surface thermal fronts of the Okhotsk Sea. *Pacific Oceanography*, 2(1–2):6–19. *(FY04; not previously reported)*

Belkin, I.M. and P.C. Cornillon. 2005. Bering Sea thermal fronts from Pathfinder data: Seasonal and interannual variability. *Pacific Oceanography*, 3(1):6–20.

Berman, M. and U.R. Sumaila. 2006. Discounting, amenity values, and marine ecosystem restoration. *Marine Resource Economics*, 21(2):211–219.

Berman, M. Modeling effects of habitat closures in ocean fisheries. In: Proceedings of the North American Association of Fisheries Economists (NAAFE) Forum 2005: Fisheries Benefits for All Generations, Vancouver, BC, in press.

Briscoe, R.J., M.D. Adkison, A. Wertheimer and S.G. Taylor. 2005. Biophysical factors associated with the marine survival of Auke Creek, Alaska coho salmon. *Transactions of the American Fisheries Society*, 134:817–828.

Bromwich, D.H. and S.-H. Wang. 2005. Evaluation of the NCEP/NCAR and ECMWF 15- and 40-yr reanalyses using rawinsonde data from two independent Arctic field experiments. *Monthly Weather Review*, 133(12):3562–3578.

Bromwich, D.H., R.L. Fogt, K.I. Hodges and J.E. Walsh. A tropospheric assessment of the ERA-40, NCEP, and JRA-25 global reanalyses in the polar regions. *Journal of Geophysical Research*, in press.

Chen, Y., J.R. Miller, J.A. Francis, G.L. Russell and F. Aires. 2003. Observed and modeled relationships among arctic climate variables. *Journal of Geophysical Research*, 108(D24), 4799, doi:10.1029/2003JD003824 *(FY04; not previously reported)*

Chen, Y., F. Aires, J.A. Francis and J.R. Miller. Observed relationships between arctic longwave cloud forcing and cloud parameters using a neural network. *Journal of Climate*, in press.

Clement, J.L., W. Maslowski, L.W. Cooper, J.M. Grebmeier and W. Walczowski. 2005. Ocean circulation and exchanges through the northern Bering Sea: 1979–2001 model results. *Deep Sea Research II*, 52:3509–3540.

Courtney, D., C. Tribuzio, S. Gaichas and K. Goldman. 2005. BSAI Sharks. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, Alaska.

Coyle, K. 2005. Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. *Fisheries Oceanography*, 14 (Suppl. 1):178–195.

deHart, P.A.P. 2006. A Multi-organismal Isotopic Study of the North Pacific and Bering Sea Marine Mammals: Responses to a Changing Environment. Ph.D. Dissertation, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

Dudarev, O.V., I. Semiletov, A. Charkin and A. Botsul. Deposition settings on the continental shelf of the East Siberian Sea. *Transactions of Russian Academy of Sciences*, in press [409(6)] (translated into English from *Doklady Akademii Nauk*).

Eicken, H., R. Gradinger, A. Graves, A. Mahoney, I. Rigor and H. Melling. 2005. Sediment transport by sea ice in the Chukchi and Beaufort Seas: Increasing importance due to changing ice conditions? *Deep-Sea Research II*, 52:3281–3302.

Fan, X. and J.S. Tilley. 2005. Dynamic assimilation of MODIS-retrieved humidity profiles within a regional model for high-latitude forecast applications. *Monthly Weather Review*, 133(12):3450–3480. doi: 10.1175/MWR3044.1

Farley, E.V. Jr., J.M. Murphy, M.D. Adkison, L.B. Eisner, J.H. Helle, J.H. Moss and J. Nielsen. Early marine growth in relation to marine stage survival rate for Alaska sockeye salmon (*Oncorhynchus nerka*). *Fishery Bulletin*, in press.

Francis, J.A., E. Hunter, J.R. Key and X. Wang. 2005. Clues to variability in Arctic minimum sea ice extent. *Geophysical Research Letters*, 32, L21501, doi:10.1029/2005GL24376

Francis, J.A., E. Hunter and C.-Z. Zou. 2005. Arctic tropospheric winds derived from TOVS satellite retrievals. *Journal of Climate*, 18:2270–2285.
Frei, A., R. Brown, J.A. Miller and D.A. Robinson. 2005. Snow mass over North America: Observations and results from the second phase of the Atmospheric Model Intercomparison Project. *Journal of Hydrometeorology*, 6(5):681–695.
Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. *Science*, 311:1461–1464.
Grebmeier, J.M. and J.P. Barry. Benthic processes in polynyas. In: W.O. Smith and D. Barber, Eds., Polynyas: Windows into Polar Oceans. Elsevier Oceanography Series, in press.
Heim, R.R. and D.A. Robinson. 2006. Trends and variability of snowfall and snow cover across North America and Eurasia. Part 1: Data quality and homogeneity analysis. Proceedings of the 18th Conference on Climate Variability and Change, American Meteorological Society, Atlanta, Georgia, paper P2.18, 3 pp.
Herrmann, M. and J. Greenberg. The demand and allocation of Alaska and Canada snow crab. *Canadian Journal of Agricultural Economics*, in press.
Horrillo, J.J. 2006. Numerical Method for Tsunami Calculation Using Full Navier–Stokes Equations and Volume of Fluid Method. Ph.D. Dissertation, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.
Jahncke, J., K.O. Coyle and G.L. Hunt Jr. 2005. Seabird distribution, abundance and diets in the eastern and central Aleutian Islands. *Fisheries Oceanography*, 14(Suppl. 1):160–177.
Kondzela, C.M., A.W. Kendall, Z. Li, D. Clausen and A.J. Gharrett. Preliminary identification of pelagic juvenile rockfishes collected in the Gulf of Alaska. In: Proceedings of the 23rd Lowell Wakefield Symposium: Biology, Assessment, and Management of North Pacific Rockfishes, Anchorage, Alaska, 12–15 September 2005, in press.
Kowalik, Z., W. Knight, T. Logan and P. Whitmore. Numerical modeling of the Indian Ocean tsunami. In: T.S. Murty, U. Aswathanarayana and N. Nirupama, Eds., The Indian Ocean Tsunami. Balkema, New York, pp. 97–122, in press.
Kowalik, Z., T. Proshutinsky and A. Proshutinsky. 2006. Tide–tsunami interactions. *Science of Tsunami Hazards*, 24(4):242–256.
Kowalik, Z., J. Horrillo and E. Kornkven. Tsunami propagation and runup due to a 2D landslide. In: P.L.-F. Liu, H. Yeh and C. Synolakis, Eds., Advances in Coastal and Ocean Engineering. Advanced Numerical Models for Simulating Tsunami Waves and Runup. Vol. 10, pp. 85–89. World Scientific, in press.
Kowalik, Z., J. Horrillo and E. Kornkven. Tsunami runup onto a plane beach. In: P.L.-F. Liu, H. Yeh and C. Synolakis, Eds., Advances in Coastal and Ocean Engineering. Advanced Numerical Models for Simulating Tsunami Waves and Runup. Vol. 10, pp. 79–84. World Scientific, in press.
Kowalik, Z., J. Horrillo and Y. Shigihara. Wave dispersion study in the Indian Ocean Tsunami, Dec 26, 2004. Accepted for publication in *Marine Geodesy*.
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Summary table of publications during the current cooperative agreement (projects funded under NA17RJ1224).

	JI (subgrantee) lead					NOAA lead					Other lead				
	FY 02	FY 03	FY 04	FY 05	FY 06	FY 02	FY 03	FY 04	FY 05	FY 06	FY 02	FY 03	FY 04	FY 05	FY 06
P-R	0	10	11	12	17	0	0	0	0	0	0	4	5	4	13
N-P-R	0	1	13	12	12	1	0	1	1	2	0	1	0	0	3