Annual Report

1 July 2006–30 June 2007

Year 6 of Cooperative Agreement NA17RJ1224

Cooperative Institute for Arctic Research
University of Alaska Fairbanks

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

1 July 2006–30 June 2007

Progress reported during Fiscal Year 2007

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

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Table of Contents

Cover photo (courtesy of Daniel Pringle): CIFAR IPY fellowship recipient Matthew Druckenmiller and his faculty advisor Hajo Eicken survey sea ice conditions from a large upthrust block at Barrow, Alaska. On the right, polar bear prints lead to the melt pond in the foreground.

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, Office of Oceanic and Atmospheric Research (OAR)–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 Laboratories. 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: John Walsh, director; Susan Sugai, associate director; Sherry Lynch, financial administrator; and Barb Hameister, publications and meetings manager. 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

Under cooperative agreement NA17RJ1224, 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 2006 to 30 June 2007, funding for CIFAR administration and 13 research or education projects was provided in Amendments 38–52 for a total of $3.17 M. All 11 research projects are CIFAR Task III, i.e., projects funded individually by NOAA. These research projects funded in the current year address 5 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 five years of the CIFAR cooperative agreement.

Table 1: Summary of Projects Funded 1 July 2006–30 June 2007: By Task and Theme

Theme	Number of Research Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)			$465,000	**14.7%**
Core Support		$110,000		
IPY Student Traineeships		$330,000		
Stock Assessment Training & Improvement		$25,000		
Research Themes (Task II)			$0	**0.0%**
Research Themes (Task III)			$2,702,037	**85.3%**
Atmospheric and Climate Research	2	$108,455		3.4%
Climate Modeling				
Contaminant Effects				
Fisheries Oceanography	3	$44,075		1.4%
Hydrographic and Sea Ice Studies	2	$255,656		8.1%
Marine Ecosystem Studies	1	$40,000		1.2%
Tsunami Research	3	$2,253,851		71.2%
Total	**11**	**$3,167,037**	**$3,167,037**	**100.0%**

Table 2: Summary of Projects Funded 1 July 2006–30 June 2007: By Funding Source

Funding Source	Number of Projects	Total Amount
OAR	8	$1,178,149
NOS	0	0
NWS	3	$1,919,813
NMFS	4	$69,075
Total		**$3,167,037**

Highlights of CIFAR Task I Activities

The CIFAR fellows for 2005 to 2008 are:

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

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

Because of the uncertainty regarding the timing of the recompetition process and restrictions precluding discussion of it with our NOAA fellows, we did not have a CIFAR fellows meeting this year. However, we added one CIFAR fellow, Phil Mundy, Director of the Auke Bay Laboratories, Alaska Fisheries Science Center, NMFS, Juneau, AK. Carl Schoch has left the CIFAR Fellows because of an employment move.

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.*

As of September 21, 2007, no notice of the availability of funds for the establishment of an Arctic Cooperative Institute has been announced, although under the NOAA Cooperative Institutes transition plan, our continuation funds end June 30, 2008.

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 2006 to 30 June 2007 were as follows:

- John Walsh, CIFAR director, 15% FTE (both CIFAR Task I and Task III)
- Patricia Anderson, CIFAR past associate director: 5% FTE (all ACIA)
- Susan Sugai, CIFAR associate director: 50% FTE (CIFAR Task I)
- Sherry Lynch, CIFAR fiscal administrator: 80% FTE (CIFAR Task I)
- Barb Hameister, publications and meetings manager: 28% FTE (CIFAR Task I).

Education/Outreach

All four of the NOAA mission goals require highly trained scientists and managers, and many retirements from the U.S. labor force are impending over the next decade. Twenty-nine percent of all science and engineering degree holders in the labor force are 50 years old or older. Among science and engineering doctorate holders in the labor forces, 44% are age 50 or over (National Science Board, 2006). Comparing the first half of this decade (2001 to 2004) with the preceding one (1991 to 1995), NSF (2006) found that although 11% more bachelor's degrees were

awarded in the earth, atmospheric, and ocean sciences in the most recent period, the number of doctorate degrees in these fields fell by 11%. With climate change effects dramatically affecting Arctic coastal communities and with half of the nation's seafood volume being caught in the waters off Alaska, these human resource issues are critical to both NOAA and Alaska.

Thus, CIFAR has placed specific emphasis upon competitively supporting graduate and undergraduate students (in addition to those students supported on CIFAR research projects) whose research addresses issues that may not be limited to one NOAA line office or one academic program or unit. Because CIFAR is positioned within the University of Alaska system, we can bring together faculty and students from various departments and campuses to collaborate with NOAA scientists on research and educational efforts.

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 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, ten students have been supported on competitive fellowships under this award and two students have received tuition support. Sara Miller and Josh Robins completed M.S. Fisheries degrees this year. Sara has begun Ph.D. fisheries studies with Milo Adkison and Josh is preparing for a career as a teacher in Washington state. This project has already produced two Ph.D. level and one M.S. quantitative fisheries professionals who have been hired by NOAA's Alaska Fisheries Science Center.

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)."

CIFAR Funds 17 International Polar Year Student Traineeship Awards

In early September 2006, an announcement was released soliciting proposals for IPY Graduate and Undergraduate Research Support, and we received 35 proposals from all three University of Alaska campuses. Following a competitive review process, 17 CIFAR International Polar Year (IPY) projects totaling $330,031 were funded. These IPY student traineeship awards support 10 undergraduate and 13 graduate students working on a wide variety of NOAA polar issues in the physical, biological, and social sciences during the current IPY. As part of the IPY legacy, these CIFAR student traineeships support students doing research in areas important to NOAA missions and for capacity building in Alaska. Students seeking degrees at all major University of Alaska units were funded. Listed below are faculty members, University campus, students, and project titles.

Awards to faculty to support undergraduate students:

- Robert Boeckmann (UAA); Alice Smith: Cultural identity, geographical attachment, and indicators of behavioral health among Alaska Native students
- Rolf Gradinger and Falk Huettmann (UAF); Melanie Bakker and Cortney Pylant: Assembling the pan-Arctic distribution of sea ice fauna in relation to ice algal biomass, a contribution to the Arctic Ocean Diversity (ArcOD) project
- Katrin Iken and Bodil Bluhm (UAF); Dominic Hondolero: Russian–American Long-term Census of the Arctic: Adding caloric content and spatial resolution of seafloor communities
- David Tallmon (UAS); Micaela Ponce, Amina Ashraf, Brenda Bruggeman and two students TBD: Undergraduate involvement in studies of adaptive and neutral genetic variation in Alaskan species sensitive to global climate change

Award to faculty to support an undergraduate and a graduate student:

- Brian Barnes (UAF) and Ian van Tets (UAA); Jeff Mayfield and Kalb Stevenson: Do arctic vertebrates defend bone mineral stores during hibernation?

Awards to faculty to support graduate students:

- Perry Barboza (UAF); David Gustine: Monitoring winter body condition of barren ground caribou from the Bering Sea to the Hudson Bay
- Matthew Carlson (UAA); Theresa Rzeczycki: Effects of an arctic biological pollutant on rare Alaskan habitats
- Hajo Eicken (UAF); Matthew Druckenmiller: Sea-ice use during IPY 2007–2008: Exploring past and present local activities through research and education and outreach in Barrow and Wales, Alaska
- Bruce Finney (UAF); Jason Addison: Late Quaternary environmental change in the Gulf of Alaska
- Nicole Molders (UAF); Morgan Brown: Investigation of the impact of western Arctic volcanic eruption on weather and climate
- Maribeth Murray (UAF); Jennifer Newton: Retrospective study of sea ice, marine and human system interactions in the North Pacific and Western North American Arctic
- Bill Simpson (UAF); Dan Carlson: Role of sea salts in catalyzing the deposition of mercury in Arctic spring
- Martin Truffer (UAF); Jason Amundson: Understanding the causes and future direction of the present rapid thinning of Jakobshavns Isbrae
- Donald Walker (UAF); Martha Raynolds: Greening of the Arctic: Synthesis and models to examine pan-Arctic vegetation change: climate, sea-ice, and terrain linkages
- Matthew Wooller (UAF); Yiming Wang: Late Quaternary climate dynamics inferred using the stable oxygen isotope composition of aquatic insects (Chironomidae: Diptera) from Idavain Lake, southwest Alaska
- Diana Wolf (UAF); Jessica Beecher: Adaptation to cold in the far north
- David Yesner (UAA); Kristin Scheidt: Zooarchaeology and climate change: Implications of high-resolution faunal records from the outer Kenai Peninsula coast, southcentral Alaska

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 2007 competition in May; the newly funded CIFAR projects are:

- Jason Amundson, Department of Geology & Geophysics: Investigating the climatic parameters influencing calving rates of Jakobshavn Isbrae, West Greenland
- Stefanie Bourne, Atmospheric Science Program: Dynamical downscaling over Alaska and its applications
- Cody Strathe, Department of Anthropology: Variability in marine ecosystem productivity and effects on seal abundance, morphology, and subsistence hunting throughout the Holocene in Shelikof Strait, Alaska

Continuing support for 2-year awards made in 2006 with CIFAR funds:

- Jason Addison, Department of Geology & Geophysics: Late Quaternary environmental change in the Gulf of Alaska
- Blaine Spellman, Department of Forest Sciences: White sweetclover in Alaska: can this invasive affect the floodplain vegetative community?

Student Support through Individual Awards

Many of the proposals funded through CIFAR involve graduate and undergraduate students. Twenty-six students (20 graduate; 6 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.

Arctic Climate Impact Assessment

The Arctic Climate Impact Assessment (ACIA), 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. The detailed, peer-reviewed scientific volume totaling 1042 pages was published in October 2005.

The International Arctic Research Center (IARC), 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, 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. This index is available as a freely downloadable PDF at: http://www.acia.uaf.edu/PDFs/ACIA_Science_Chapters_Final/ACIA_index.pdf

Other CIFAR Administrative Activities

In December 2005, 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 2006, 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. The proposal review panel also asked the PI on an ocean carbon measurements proposal to submit a revised 5-year proposal. The revised ocean carbon proposal and 4 proposals submitted to the second targeted announcement were reviewed by reviewers from the original panel. The ocean carbon proposal, a modeling proposal, and a primary productivity proposal were added to the 10 RUSALCA proposals already recommended for funding.

Because Congress failed to pass an FY07 appropriation for federal agencies, funding was not provided for RUSALCA projects beginning in FY07. Principal Investigators of proposals "recommended for funding" by the CIFAR RUSALCA panel have been directed to submit their proposals to the NOAA Climate Program broad area announcement for FY08 with deadline of September 24, 2007.

Highlights of CIFAR Research Activities and Results

Below are highlights from selected projects reported in this document with a focus on the role CIFAR is playing in supporting graduate student education and training in CIFAR research theme areas.

Atmospheric and Climate Research

In two related Pacific Region Integrated Date Enterprise (PRIDE) projects, David Atkinson and co-workers seek an improvement of available end-user products across a range of temporal and spatial scales, which for Alaska are leading to 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. These projects also represent an opportunity for linkage and interface between activities and needs in the Alaska region with those in Hawaii and other U.S. Pacific interests. Some results to date include:

- Oceana Francis-Chythlook, a Ph.D. student working with Atkinson on the PRIDE project, has developed a high-wind return algorithm that is being applied to stations throughout Alaska and the Pacific region to develop end-user data layers.
- Master's student Jennifer March rescued (transferred to digital media and quality controlled) three International Geophysical Year coastal weather data sets for the North Slope. For this data-sparse region, representing one of the pilot PRIDE locations (south of Barrow, AK), additional sources of data are critical. These data have not been utilized in 45 years and for the first time will be brought to bear in this project to assist with local climate and extreme-event impact studies.
- Michel dos Santos Mesquita, a Ph.D. student working with Atkinson, has identified the importance of interpreting individual storm events within a broader climatic context, e.g., the phase of El Niño or the Pacific Decadal Oscillation must be considered when interpreting storm track positions. He has also identified, for the first time, important differences between summer and winter storms, that is, that winter storms are more severe but summer storms last longer—a fact which has important precipitation accumulation implications.
- An extreme event database was initiated for the Alaska district—10 severe storms were identified for more detailed impacts analysis. This represents the initial Alaska contribution to this Hawaii-based Pacific effort that

helps to lay the groundwork for a major Pacific Region Integrated Climatology Products (PRICIP) activity, the development of a large severe events database with impacts and case histories that users can examine.

Climate Modeling

John Walsh and co-workers conducted an intercomparison of the cloudiness and radiative fluxes in four large-scale atmospheric reanalyses (Walsh et al. 2007, JGR, submitted). Arctic radiative fluxes, clouds and cloud-radiative forcing were evaluated from four currently available reanalysis models using data from the North Slope of Alaska (NSA) Barrow site of the Atmospheric Radiation Measurement (ARM) program. The four reanalysis models used in this study were (a) NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) global reanalysis; (b) ERA-40 global reanalysis by the European Center for Medium-Range Weather Forecasts; (c) NCEP/NCAR North American Regional Reanalysis (NARR) and (d) Japan Meteorological Agency 25-year reanalysis (JRA-25).

- The results indicate that these reanalysis models are able to simulate the radiative fluxes *if* the clouds are simulated correctly. However, the systematic errors of climatological cloud fractions simulated by the reanalyses are substantial. The large seasonal cloud biases have significant impacts on the surface energy budget.
- The ERA-40 was found to be the best performer in both shortwave and longwave flux seasonal representations at Barrow, largely because its simulation of the cloud coverage is the most realistic of the four reanalyses. Similar biases of the cloud fraction means and seasonal cycles at Barrow were also detected over the Arctic Ocean in the reanalyses.
- Evaluations of variable cloud radiative forcing (VCRF) show the reanalyses capture the transition from negative to positive cloud radiative forcing for two to three months during the summer, although the dependence of the VCRF on cloud fraction differs widely between the reanalyses and observational data.

Fisheries Oceanography

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 mandates improving the science guiding management with new regional programs for ecosystem research. The North Pacific Fisheries Management Council has long embraced a precautionary approach to management supported by sound science like the fisheries oceanography projects funded through CIFAR and presented at national and international meetings. Some key findings of the graduate students and research supported by CIFAR and the Alaska Fisheries Science Center (AFSC) increase our understanding of several important components of the marine ecosystem in the Bering Sea:

- Using hydroacoustic data collected in winter 2003 for walleye pollock (*Theragra chalcogramma*), target of one of the world's largest fisheries and an important prey species in the eastern Bering Sea (EBS) ecosystem, Haixue Shen, a Ph.D. student working with Terry Quinn, found that pollock aggregate into schools during the daytime and disperse at night during the spawning season. After about two weeks of fishing, the aggregation pattern changes both at the school scale and the scale larger than 1 nautical mile. Pollock aggregate in smaller but denser schools that have a patchier distribution in space.
- Olav Ormseth, a Ph.D. candidate working with Brenda Norcross, who was hired as a Research Fishery Biologist during the past year at the AFSC, found that Pacific cod increase their reproductive potential by maximizing the number, not size or quality, of eggs they produce. Reproductive potential was reduced in the EBS in 2003, and this may have resulted from changes in ocean temperature and prey availability that limited the ability of females to store energy during the previous summer.
- Ed Farley, a mathematical statistician with the AFSC, Auke Bay Laboratory and a Ph.D. student working with Milo Adkison, found that variation in size, relative abundance, and marine-stage survival rate of juvenile Bristol Bay sockeye salmon are likely related to ocean conditions affecting their early marine migratory pathways along the EBS shelf (Farley et al. 2006).
- Farley also found that the relative abundances of age-0 pollock and juvenile Bristol Bay sockeye salmon were higher during warm years and lower during cool years. The primary prey for juvenile sockeye salmon were Pacific sand lance during cool years and age-0 pollock during warmer ones. In cool years, juvenile salmon were found in nearshore waters where sand lance are most abundant, whereas in warmer years, both the juvenile sockeye salmon and their age-0 pollock prey were found further offshore in the middle domain region of the Bering Sea shelf.

- Katy Howard, an M.S. fisheries student working with Adkison, has been examining whether sablefish size-at-age and maturity-at-age have shifted between the period 1981–1993 and 1996–2004. She found that significant differences exist between growth curves fit to the two time periods in Bering, Kodiak, and Southeast Slope regions.

Hydrographic and Sea Ice Studies

Analyses of field and passive microwave satellite data for the Siberian arctic have yielded important new findings published this year on the hydrography of Siberian Arctic shelf and streamflow characteristics of the surrounding watersheds.

- New measurements made in summer 2005 beneath the sea ice in the Central Basin of the Arctic Ocean show relatively high values of pCO_2 ranging from 425 μatm and 475 μatm, values that are larger than the mean atmospheric value in the Arctic in summertime. The sources of those high values are proposed to be: high rates of bacterial respiration, import of the Upper Halocline Water from the Chukchi Sea where values of pCO_2 range between 400 and 600 μatm, a contribution from the Lena River plume, or any combination of these sources (Semiletov et al. 2007).
- The observed distribution of dissolved methane and possible mechanisms of methane release in connection with observed dynamics of the coastal environment suggest that the East Siberian Arctic shelf (ESAS), the broadest and shallowest shelf in the World Ocean, is an important natural source of methane to the atmosphere. Although the ESAS represents only 13% of the total world coastal seas area, Natalia Shakhova and Igor Semiletov (2007) calculate that the ESAS produces up to 50% of the total marine methane emission to the atmosphere.
- Daqing Yang et al. (2007) showed that remotely sensed snow cover data are useful in understanding streamflow characteristics and changes in arctic regions with very sparse observational networks. Comparative analyses of weekly basin snow water equivalence (SWE) data versus snow cover extent (SCE), peak snowmelt floods, and climatic variables (temperature, precipitation) for the large Siberian watersheds (the Ob, Yenisei, and Lena basins) indicate consistency among basin SWE, SCE, and temperature but incompatibility between SWE and winter precipitation, particularly for the Lena watershed.

Tsunami Research

Although much of the tsunami research (Roger Hansen and co-investigators) focuses on the assessment of tsunami and seismic hazards to Alaska coastal communities and to transportation networks, modeling development and research are globally important. Parallel code development has accompanied research-derived refinements of the global tsunami model. After testing, this model described below has been transferred to NOAA's National Tsunami Hazard Mitigation Program to be used for prediction and warning purposes.

- A numerical model for global tsunami computation constructed by Zygmunt Kowalik et al. (2005, 2007), was applied to the tsunami generated near the Kuril Islands on November 15, 2006 by a magnitude 8.3 earthquake. Numerical results were compared to sea level disturbance data collected by Pacific DART (Deep-ocean Assessment & Reporting of Tsunamis) buoys. The model (Kowalik et al., accepted) explained the amplification observed at Crescent City, CA through tsunami refocusing by the distant topographic features. An energy flux function allowed the model to show the key role played by two bathymetric features thousands of kilometers distant from Crescent City (Koko Guyot and the Hess Rise) in enhancing and refocusing the tsunami signal toward Crescent City. The sea level initially surged up to 40–60 cm and 2–3 hours later, the highest wave of about 90 cm amplitude was measured. From their studies of the Kuril tsunami impact at Crescent City, Kowalik et al. concluded that energy flux and energy balance can be important tsunami hazard mitigation tools for predicting and understanding the delayed tsunami signal.

Publications and Presentations

During the current reporting period, 32 peer-reviewed publications and 12 non-peer-reviewed publications (including two Master's theses) were reported from projects receiving their funding through CIFAR under cooperative agreement NA17RJ1224. An additional 21 papers were reported as accepted or in press and 20 had been submitted. Over 60 manuscripts were reported to be under preparation. Approximately 75 conference presentations (both national and international) and seminars were also reported.

In addition to these FY07 numbers, we received information on one non-peer-reviewed publication from FY06 that had not been reported previously. The publication matrix in Appendix 3 reflects this addition.

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.

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Walsh, J.E., W.L. Chapman and D.H. Portis. 2007. Arctic clouds and radiative fluxes in atmospheric reanalyses. Submitted to *Journal of Geophysical Research–Atmospheres*.

Yang, D., Y. Zhao, R. Armstrong, D. Robinson and M.-J. Brodzik. 2007. Streamflow response to seasonal snow cover mass changes over large Siberian watershed. *Journal of Geophysical Research*, 112, F02S22, doi:10.1029/2006JF00518.

Task I

Education / Outreach

Some of CIFAR's IPY Fellowship recipients, clockwise from top left: Matthew Druckenmiller and his advisor, Hajo Eicken; Dominic Hondolero; Kalb Stevenson; Alice Smith

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

- Dana Hanselman, Kalei Shotwell, and John Moran currently work as Research Fishery Biologists with NOAA/NMFS, Auke Bay Laboratory, Alaska Fisheries Science Center, Juneau, AK, demonstrating the success of this project in providing critical new employees to NOAA.
- During the past year, two students received tuition support and three received graduate stipends.
- Travel support has been provided to over five students to attend fishery conferences, including the Alaska Marine Science Symposium and meetings of the American Fisheries Society.
- Sara Miller and Josh Robins completed M.S. Fisheries degrees this year. Sara's work involved a spatial and temporal stock assessment model for walleye pollock in the eastern Bering Sea. Josh's work identified factors associated with the marine growth and survival of coho salmon in Auke Creek.
- Peter Hulson is developing age-structured assessment models for herring in Prince William Sound and Sitka Sound and his M.S. defense is scheduled for August 17, 2007. Haixue Shen is analyzing hydroacoustic data of walleye pollock schools in the Eastern Bering Sea to examine changes in the dynamics of schools. Xinxian Zhang is developing salmon escapement models.

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 provided an additional $25,000 in FY07 for future activities. Auke Bay Lab will provide about $40,000 in FY08.

Education/outreach

Graduate student support

The following ten UAF fisheries graduate students have been supported on fellowships under this award: Ben Williams (M.S.), Colin Schmitz (M.S.), John Moran (M.S.), Sara Miller (M.S., finished this year), Cindy Tribuzio (Ph.D.), Dana Hanselman (Ph.D.), Kalei Shotwell (Ph.D.), William Bechtol (Ph.D.), Peter-John Hulson (M.S.), and Haixue Shen (Ph.D.). Williams, Moran, Hanselman, Shotwell, and Miller have completed their graduate degrees; Bechtol, Tribuzio, Miller (Ph.D.), Hulson, and Shen are currently pursuing their graduate degrees. Josh Robins (M.S., finished this year) and Xinxian Zhang (Ph.D.) have received tuition support. Hulson received travel support to present a poster at the Marine Science Symposium in January 2007. For this year, Miller, Hulson, and Shen received salary support for 2, 8, and 5 months, respectively.

Presentations

Shen, H. 2006. Schooling changes of EBS walleye pollock during fishing. Oral presentation at the Lowell Wakefield Symposium on Resiliency of Gadid Stocks to Fishing and Climate Change, Anchorage, Alaska, 31 October–3 November 2006.

Miller, S. 2006. Estimation of age-specific migration in an age-structured model. Oral presentation at the Lowell Wakefield Symposium on Resiliency of Gadid Stocks to Fishing and Climate Change, Anchorage, Alaska, 31 October–3 November 2006.

Bechtol, W. 2007. Three-stage catch survey analysis of Kodiak red king crab. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2007.

Hulson, P. 2007. Estimation of temporal variation in maturity-at-age of Pacific herring (*Clupea pallasi*) in Sitka Sound, Alaska. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2007.

Miller, S. 2007. Estimation of migration in an age-structured population dynamics model of Eastern Bering Sea walleye pollock (*Theragra chalcogramma*). Oral presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2007.

Tribuzio, C. 2007. Preliminary results of a demographic analysis of spiny dogfish in the Gulf of Alaska. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2007.

Shen, H.,T.J. Quinn II, V. Wespestad, M.W. Dorn and M. Kookesh. 2007. Using EDSU to investigate the spatial structure of walleye pollock (*Theragra chalcogramma*) schools in the eastern Bering Sea. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2007.

Miller, S. 2007. Estimation of migration in an age-structured population dynamics model of Eastern Bering Sea walleye pollock. Oral presentation at the American Fisheries Society Student Symposium, University of Alaska Southeast, Juneau, Alaska, 4 April 2007.

Miller, S. 2007. Simulation of an Eastern Bering Sea walleye pollock (*Theragra chalcogramma*) spatially-explicit stock assessment model with and without tagging data. Poster presentation at the ICES/PICES Conference for Early Career Scientists, Baltimore, Maryland, June 2007.

Publications

Theses

Robins, J.B. 2006. Biophysical Factors Associated with the Marine Growth and Survival of Auke Creek, Alaska Coho Salmon. M.S. Thesis, University of Alaska Fairbanks.

Miller, S.E. 2007. Estimating Movement with a Spatially Explicit Stock Assessment Model of Eastern Bering Sea Walleye Pollock, *Theragra chalcogramma*. M.S. Thesis, University of Alaska Fairbanks.

In preparation or submitted

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. *ICES Journal of Marine Science*, in review.

Hulson, P.J., T.J. Quinn II and S. Dressel. Estimation of temporal variation in maturity-at-age of Pacific herring (*Clupea pallasi*) in Sitka Sound, Alaska. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.

Miller, S.E., T.J. Quinn II and J.N. Ianelli. Estimation of age-specific migration in an age-structured model. Proceedings of the 2006 Lowell Wakefield Symposium, Alaska Sea Grant College Program, Fairbanks, Alaska. [Manuscript submitted in November 2006, peer-reviewed, revision submitted August 2007.]

Miller, S.E., P.J. Hulson, J.N. Ianelli and T.J. Quinn II. Simulation of an Eastern Bering Sea walleye pollock (*Theragra chalcogramma*) spatially-explicit stock assessment model with and without tagging data. In preparation for submission to *Canadian Journal of Fisheries and Aquatic Sciences*.

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*.

Shen, H., T.J. Quinn II, V. Wespestad, M.W. Dorn and M. Kookesh. Schooling changes of EBS walleye pollock during fishing. Proceedings of the 2006 Lowell Wakefield Symposium, Alaska Sea Grant College Program, Fairbanks, Alaska. [Manuscript submitted in November 2006, peer-reviewed, revision submitted July 2007.]

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*.

Enhancement of the University of Alaska's Contribution to the International Polar Year (IPY): Building a "human legacy" of Arctic scholars

John E. Walsh, PI
University of Alaska Fairbanks

NOAA Goals: Understand Climate Variability and Change; Ecosystem-based Management; Serve Society's Needs for Weather and Water Information

This project is ongoing.

Primary objectives

This competitive undergraduate scholarship and graduate fellowship supports the participation of B.A., B.S., M.S. and Ph.D. students in International Polar Year (IPY) projects in areas oriented towards NOAA's strategic interests in the Arctic. This fellowship is open to degree-seeking undergraduate and graduate students at any University of Alaska campus working with UA faculty on IPY projects oriented towards understanding climate variability and change, enhancing our knowledge of weather and water, providing information for safe transportation and commerce, and moving toward an ecosystem-based approach to management of coastal ocean resources. A committee of University of Alaska Research Advisory Council designees and CIFAR administrators evaluates applications.

Approach/methodology

Applications are made to CIFAR in response to an announcement of opportunity. The applicants are UA professors or student(s) with sponsorship from one or more UA professor(s). The announcement provides submission deadline and application details.

Research accomplishments/highlights/findings

In late 2006, following a competitive review process, seventeen CIFAR IPY student projects were funded including students seeking degrees at the three major University of Alaska units: UAF, University of Alaska Anchorage (UAA), and University of Alaska Southeast (UAS). These IPY awards fund 10 undergraduate and 13 graduate students working on a wide variety of polar issues supporting NOAA mission goals in the physical, biological, and social sciences. As part of the IPY legacy, these awards will help to train the next generation of polar researchers. Listed below are faculty members, University campus, students, and project titles for each award.

Awards to faculty to support undergraduate students:

- Robert Boeckmann (UAA); Alice Smith: Cultural identity, geographical attachment, and indicators of behavioral health among Alaska Native students
- Rolf Gradinger and Falk Huettmann (UAF); Melanie Bakker and Cortney Pylant: Assembling the pan-Arctic distribution of sea ice fauna in relation to ice algal biomass, a contribution to the Arctic Ocean Diversity (ArcOD) project

- Katrin Iken and Bodil Bluhm (UAF); Dominic Hondolero: Russian–American Long-term Census of the Arctic: Adding caloric content and spatial resolution of seafloor communities
- David Tallmon (UAS); Micaela Ponce, Amina Ashraf, Brenda Bruggeman and two students TBD: Undergraduate involvement in studies of adaptive and neutral genetic variation in Alaskan species sensitive to global climate change

Award to faculty to support an undergraduate and a graduate student:

- Brian Barnes (UAF) and Ian van Tets (UAA); Jeff Mayfield and Kalb Stevenson: Do arctic vertebrates defend bone mineral stores during hibernation?

Awards to faculty to support graduate students:

- Perry Barboza (UAF); David Gustine: Monitoring winter body condition of barren ground caribou from the Bering Sea to the Hudson Bay
- Matthew Carlson (UAA); Theresa Rzeczycki: Effects of an arctic biological pollutant on rare Alaskan habitats
- Hajo Eicken (UAF); Matthew Druckenmiller: Sea-ice use during IPY 2007–2008: Exploring past and present local activities through research and education and outreach in Barrow and Wales, Alaska
- Bruce Finney (UAF); Jason Addison: Late Quaternary environmental change in the Gulf of Alaska
- Nicole Mölders (UAF); Morgan Brown: Investigation of the impact of western Arctic volcanic eruption on weather and climate
- Maribeth Murray (UAF); Jennifer Newton: Retrospective study of sea ice, marine and human system interactions in the North Pacific and Western North American Arctic
- Bill Simpson (UAF); Dan Carlson: Role of sea salts in catalyzing the deposition of mercury in Arctic spring
- Martin Truffer (UAF); Jason Amundson: Understanding the causes and future direction of the present rapid thinning of Jakobshavns Isbrae
- Donald Walker (UAF); Martha Raynolds: Greening of the Arctic: Synthesis and models to examine pan-Arctic vegetation change: climate, sea-ice, and terrain linkages
- Matthew Wooller (UAF); Yiming Wang: Late Quaternary climate dynamics inferred using the stable oxygen isotope composition of aquatic insects (Chironomidae: Diptera) from Idavain Lake, southwest Alaska
- Diana Wolf (UAF); Jessica Beecher: Adaptation to cold in the far north
- David Yesner (UAA); Kristin Scheidt: Zooarchaeology and climate change: Implications of high-resolution faunal records from the outer Kenai Peninsula coast, southcentral Alaska

NOAA relevance/societal benefits

This joint program between UAF and NOAA is designed to prepare young scientists for careers in areas supporting all four of NOAA's strategic goals.

Research linkages/partnerships/collaborators and networking

The IPY projects involve linkages with the Environmental Protection Agency, NOAA National Weather Service, U.S. Geological Survey, National Park Service, North Slope Borough, Canadian Wildlife Service, Nunavut Wildlife Division, U.S. Army Cold Regions Research and Engineering Laboratory, National Center for Atmospheric Research, National Aeronautics and Space Administration, Smithsonian Institution, UA IPY postdoctoral scholars, and investigators at University of Tennessee, Hokkaido University, University of New Hampshire, ETH Zürich, Switzerland, Oregon State University, University of Florida, University of Michigan, University of Virginia, Charles Drew University, and University of Hawaii.

Education/outreach

Graduate and undergraduate student support

The following thirteen graduate students have been supported on fellowships under this award to date: Jason Addison (Ph.D.), Jason Amundson (Ph.D.), Jessica Beecher (M.S.), Morgan Brown (Ph.D.), Daniel Carlson (Ph.D.), Matthew Druckenmiller (Ph.D.), David Gustine (Ph.D.), Jennifer Newton (Ph.D.), Martha Raynolds (Ph.D.), Theresa Rzeczycki (M.S.), Kristin Scheidt (M.A.), Kalb Stevenson (Ph.D.), Yiming Wang (Ph.D.).
Eight undergraduate students have been supported: Dominic Hondolero, Melanie Bakker, Cortney Pylant, Brenda Bruggeman, Amina Ashraf, Micaela Ponce, Alice Smith, and Jeff Mayfield.

K–12 outreach

- **Y. Wang** is involved with the Alaska Statewide High School Student Symposium and has designed science projects for high school participants.

- **J. Beecher** has served as a mentor in the Rural Alaskan Honors Institute (RAHI) Program, a high school bridge program held on the UAF campus during summer.
- On 6 April 2007, **M. Druckenmiller** participated in an interview with two high school students from Kingikmiut School in Wales, Alaska as part of the Bering Strait School District's pod-cast interview series. Students asked questions about sea-ice research by Druckenmiller and his faculty advisor Hajo Eicken in the Bering Strait and filmed the drilling of a sea-ice core.

Public outreach

- **J. Amundson** was interviewed for a Greenlandic television program to be aired in late 2007. He also produced a time-lapse video of a glacier calving event that will be shown on a segment of the *NewsHour with Jim Lehrer* (PBS) in late July or early August 2007.
- **M. Druckenmiller** gave a presentation to the Barrow, Alaska community entitled "Sea-ice research during the International Polar Year: Designing studies to meet the needs of communities and other stakeholders" as part of the National Science Foundation's Schoolyard Project, run by the Barrow Arctic Science Consortium (BASC), 31 March 2007.
- **M. Raynolds** gave a presentation entitled "Arctic vegetation: its distribution and characteristics" at a Global Learning and Observations to Benefit the Environment (GLOBE) teacher training workshop, Fairbanks, Alaska, 23 March 2007.
- **M. Raynolds** gave a talk called "Searching for the effects of climate change on arctic vegetation" at IPY Science Café (a series of informal public presentations on IPY topics), Fairbanks, Alaska, 29 May 2007.

Presentations

Addison, J.A., B.P. Finney and J.R. Coon. 2006. Biogeochemical and isotopic records of Holocene climate change in the Gulf of Alaska, Northeast Pacific Ocean. Oral presentation at the American Geophysical Union, Fall Meeting, San Francisco, California, 11–15 December 2006. (abstract #PP53B-07)

Brown, M.E. and N. Molders. 2007. Evaluation of the Weather Research & Forecasting (WRF) model for the time of the 2006 Augustine Volcano eruption. Poster presentation at the Great Alaska Weather Modeling Symposium, Fairbanks, Alaska, 13–15 March 2007.

Brown, M.E. and N. Molders. 2007. Impact of volcanic heat release on local weather for the 2006 Augustine Volcano eruption. Poster presentation at the 8th WRF Users' Workshop, Boulder, Colorado, 11–15 June 2007.

Ponce, M., B.P. Kelly and D. Tallmon. 2007. Breeding site fidelity and philopatry in ringed seals (*Phoca hispida*). Oral presentation at Alaska State Wildlife Society Chapter Meeting, Juneau, Alaska, 16–19 April 2007.

Raynolds, M.K. and D.A. Walker. 2006. Arctic patterned ground. Poster at American Geophysical Union, Fall Meeting, San Francisco, California, 11–15 December 2006.

Smith, A., R. Boeckmann, R. Morales and A. Pearson. 2007. Correlates of Alaska Native identity and self esteem: Tradition and place in times of change. Oral presentation at "What's Next for Native American and Indigenous Studies? An International Scholarly Meeting," Native American & Indigenous Studies Conference, University of Oklahoma, Norman, Oklahoma, 3–5 May 2007.

Publications

In preparation or submitted

Addison, J.A., J.E. Beget, B.P. Finney and T.A. Ager. Southeast Alaska marine tephrochronology. *In preparation.*

Raynolds, M.K., C.A. Munger, D.A. Walker, C.M. Vonlanthen and A.N. Kade. Vegetation, biomass, thaw depth and snow depth maps along the North American Arctic Transect. Submitted to *Journal of Geophysical Research–Biogeosciences*.

Raynolds, M.K., J.J. Comiso, D.A. Walker and D. Verbyla. Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. Under revision for *Remote Sensing of Environment*.

Wang, Y., D. O'Brien, D. Francis and M.J. Wooller. A laboratory based growth experiment examining the influence of diet and water on the stable oxygen and hydrogen isotope composition of chironomids (Chironomidae: Diptera). *In preparation.*

Wang, Y., D. Francis, D. O'Brien and M.J. Wooller. A review of protocols related to preparing subfossil Chironomid (Diptera: Chironomidae) head capsules for stable isotope analysis for paleoclimate reconstruction. *In preparation*.

Task II

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

Steller Sea Lion Projects

Arctic Research Initiative Projects

RUSALCA

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 complete. See previous annual reports for research activity under this award. Activity for this reporting period is described below in the Education/outreach and Publication sections.

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 Jackie Grebmeier and Lee Cooper from the University of Tennessee Knoxville (UTK), USA and 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.

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 Bodil Bluhm and Katrin Iken for benthic epifaunal data, has been valuable. This project is also a collaborative effort with 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

Public awareness

Jackie Grebmeier was featured on program #5183 of the Earth & Sky Radio Series entitled "Major Ecosystem Shift in Arctic Seas," which aired on National Public Radio on April 24, 2007. (http://www.earthsky.org/radioshows/51235/major-ecosystem-shift-in-arctic-sea)

K–12 outreach

- PIs Grebmeier and Cooper presented RUSALCA data to students at Oak Wood Middle School in Greenville, North Carolina in September 2006 as well as at Union Vale middle school in LaGrangeville, New York in January 2007.

Publications

Peer-reviewed

Grebmeier, J.M., L.W. Cooper, H.M. Feder and B.I Sirenko. 2006. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. *Progress in Oceanography*, 71:331–361.

Grebmeier, J.M. and J.P. Barry. 2007. Benthic processes in polynyas. In: W.O. Smith, Jr. and D.G. Barber, Eds., *Polynyas: Windows to the World*, Elsevier Oceanography Series, Volume 74, pp. 363–390.

Accepted

Crane, K. and J.M. Grebmeier. The Pacific Arctic Group, October 11–12, 2006, Shanghai, China meeting report. Accepted for publication in *EOS, Transactions, American Geophysical Union*.

Submitted

Cooper, L.W., C. Lalande, R. Pirtle-Levy, I.L. Larsen and J.M. Grebmeier. Seasonal and decadal shifts in particulate organic matter processing and sedimentation in the Bering Strait Shelf region. In revision. Submitted to the 2nd SBI Special Issue, *Deep-Sea Research II*.

Grebmeier, J.M., L.W. Cooper, R. Pirtle-Levy and R. Brown. Benthic community structure, carbon cycling and shelf–basin exchange in the Chukchi and Beaufort seas during 2002 and 2004. Submitted to the 2nd SBI Special Issue, *Deep-Sea Research II*.

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 and most of the sample processing and data analysis were completed during previous reporting periods. Final processing and data analysis and preparation of manuscripts are 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.

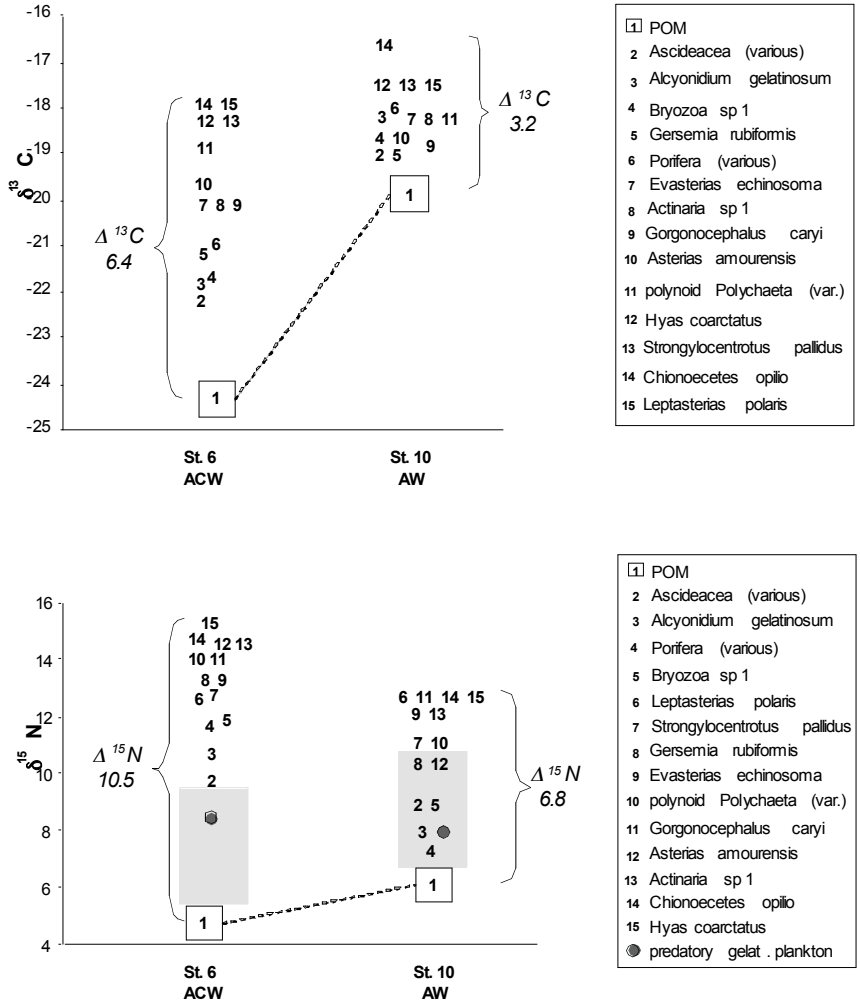

Figure 1. Carbon and nitrogen stable isotopes of taxa in relation to POM food source at two stations in Bering Strait, 70 km apart. Grey box in nitrogen plot marks the first trophic level (3.8‰ enrichment, mean POM at each station as base of food web), showing that more benthic organisms occupy the first trophic level under AW than under ACW conditions. Overall, food web was shorter under AW than ACW.

Research accomplishments/highlights/findings

- Range extensions into the Arctic were seen for some crab and mollusk species (e.g., the crab *Telmessus cheiragonus,* the bivalve *Pododesmus macrochisma,* several chiton species).
- Food web structure and length were significantly different among sampled stations and coincided with water masses.
- In the Bering Strait, isotopic values of POM as the primary food source were generally depleted at the eastern stations influenced by Alaska Coastal Water (ACW) compared to POM found at western stations within the Anadyr Water (AW) mass (Figure 1). Food webs were longer at eastern stations under ACW influence and shorter under the western AW influence.
- Comparison of trophic positions of the same species at two stations under AW and ACW in Bering Strait, separated only by 70 km, revealed that benthic species were feeding on a higher trophic level under ACW than their AW counterparts (Figure 1).This same pattern as seen here for organism 14, *Chionoecetes opilio*, snow crab that is commercially fished in the Bering Sea, was observed at a series of nine stations in the Chukchi Sea. We suggest that this indicates that AW benthos receives fresher POM than ACW benthos, i.e., higher quality and possibly higher quantity, through tighter pelagic–benthic coupling. Changes in physical conditions due to climate change will influence the amount, composition and timing of phytoplankton produced in the water column. These changes in food for benthos will, over time, influence food web structure in the benthos.
- We predict that an expected weakening of the Anadyr Water productivity will lead to a relaxation of the currently tight pelagic–benthic coupling and thus longer food webs (i.e., less efficient energy transfer to higher trophic levels) in the eastern Chukchi Sea.

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 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 (Canada Basin adjacent to RUSALCA study area), the NSF-funded BEST Program (Bering Sea Ecosystem Studies) 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.

The scope of our RUSALCA project is currently extended by the participation in the Japanese *Oshoro Maru* cruise covering stations in the eastern Chukchi Sea. One undergraduate student, funded through the CIFAR IPY student opportunity, is taking samples for benthic community structure and for measuring caloric content of benthic invertebrates. One of the UAF Presidential IPY post-docs will contribute with reproductive studies of common invertebrates and genetic analyses to decipher gene flow in the region. This opportunity expands our available RUSALCA dataset spatially, temporally and conceptually.

Education/outreach

Public awareness

- Presentation of results during guest lecture at "Stable isotope techniques in environmental research" (UAF course MSL 661, taught by Matthew Wooller)

Oral presentations

Iken, K. and B.A. Bluhm. 2006. Ecological resilience in a changing Arctic. Helge Ingstad Symposium, Fairbanks, Alaska, 9 September 2006.

Iken, K., J. Grebmeier, B. Bluhm, B. Norcross, B. Sirenko, L. Cooper, K. Dunton, S. Gagaev and B. Holladay. 2007. RUSALCA: Benthic studies in the Chukchi Sea. Arctic Frontiers Meeting, Tromso, Norway, 23–27 January 2007.

Hopcroft, R., R. Gradinger, B. Bluhm, K. Iken and X. Kosobokova et al. 2007. Russian–American Long-Term Census of the Arctic. 1st Arctic Marine Biodiversity International Polar Year Cluster Meeting. Frankfurt, Germany, 20–22 February 2007.

Publications

Several publications are expected from this project. One is in the advanced stages of preparation and a first draft is nearly completed. The others are in data analysis and results preparation stage.

Iken, K., B. Bluhm, K. Dunton, B. Sirenko and S. Gagaev. Benthic food web structure as indicator of changing water mass properties in the Chukchi Sea. Draft near completion. Submission expected in September 2007. Anticipated journal is *Limnology and Oceanography*.

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.

Sirenko, B., B. Bluhm, K. Iken, K. Crane and V. Gladish. Preliminary results of composition and quantitative distribution of epifauna in the Chukchi Sea. In preparation.

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 new combined NOAA/NSF mooring program “Gateway to the Arctic” now includes 8 moorings that span the entire Bering Strait that includes both Russian and U.S. Exclusive Economic Zones (EEZs). This new integrated approach will increase greatly the spatial resolution of currents and fluxes that are being measured across this important gateway.

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 and completed his Ph.D. studies at the end of Fall semester 2005. During this reporting period, Hui Liu was supported as a Postdoctoral Fellow to further analyze nutrient and primary production data for presentation at a national meeting and a future publication.

Publications

In press

Lee, S.H., T.E. Whitledge and S.-H. Kang. Recent carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. Corrected Proof, available online 24 May 2007, *Continental Shelf Research*.

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. 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.

STELLER SEA LIONS

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

- Two manuscripts on the development of total body oxygen stores and hematology in Steller sea lions have now been published.
- As reported in FY06, we 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. Some of these details were published in 2004, and additional detail was provided in a presentation in October, 2006.
- 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, 2007, 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.

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., J.P. Richmond and K. Lestyk. 2006. Hematology of pinniped pups: implications for developing divers. American Physiological Society Meeting, Virginia Beach, Virginia, 8–12 October 2006.

Burns, J.M., M.J. Rehberg and J.P. Richmond. 2006. Winter diving and foraging patterns in juvenile Steller sea lions. The Wildlife Society Meetings, Anchorage, Alaska, 23–27 September 2006.

Publications

Peer-reviewed

Richmond, J.P, J.M. Burns and L.D. Rea. 2006. Ontogeny of total body oxygen stores and aerobic dive potential in the Steller sea lion (*Eumetopias jubatus*). *Journal of Comparative Physiology B*, 176:535–545.

Submitted

Rehberg, M.J. and J.M. Burns. Differences in diving and swimming behavior in pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. Submitted to *Journal of Animal Ecology*.

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.

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 complete.

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

- Analysis of sediment cores recovered from two marine bays around Unalaska Island, in the Aleutian Island region of Alaska, indicates that reconstructions of past oceanographic conditions at decadal-scale temporal resolution are possible. Such cores can be dated using ^{210}Pb and radiocarbon techniques, and contain materials suitable for reconstructing changes in temperature/salinity, primary productivity, and nutrient availability. Preservation of scales of forage fish, however, is rare, and only one site has been identified to date containing such materials.
- A multi-proxy approach was used to reconstruct marine primary productivity (organic carbon, biogenic opal, and δ^{13}C of organic matter). Results indicate significant changes over decadal and longer timescales. Recent productivity appears to be unique relative to most of the previous ~800 years. Data suggests that productivity is either currently relatively low or possibly reflects a different phytoplankton assemblage.
- Productivity trends in this region appear to be different than those to the east in the central Gulf of Alaska. This may be due to different physical/biological changes resulting from the same broad-scale climatic forcing (i.e., the post-1976 Pacific Decadal Oscillation (PDO) shift and climate warming trends).
- Results from the stable isotope analysis (δ^{13}C and δ^{15}N) of Steller sea lion bone collagen spanning the last ~1000 years are generally consistent with previous results spanning the period from about 1950–2000 AD. There is little significant change in δ^{15}N, which could indicate little change in their trophic position. There is, however, a significant decline in δ^{13}C over the past ~50 years, unprecedented over the past 1000 years. Some of this change could be due to incorporation of carbon from anthropogenic sources into the marine system (i.e., the oceanic Suess effect), but a significant decline is inferred even when this effect is accounted for. Such a change is consistent with a recent decline in primary productivity.
- Based on fish scales preserved in sediment cores, forage fish abundance has fluctuated over both decadal and century timescales during the past 800 years. The main scale preserved in the Skan Bay cores is from prickleback, and recent trends from box cores show a decline in prickleback scales following the 1976 regime shift, consistent with regional trawl data. The long-term sediment data is of lower time-resolution required to detect decadal-scale shifts because of the amount of sediment needed to obtain adequate scales. This long-term, lower-resolution data indicates fluctuations over multi-century timescales; at least one previous shift of the magnitude of the 1976 shift occurred during the past 800 years.
- δ^{18}O and δ^{13}C analyses of Skan Bay foraminifera samples (*E. excavatum*) suggest modification by sediment diagenetic processes. Further work is needed to assess such effects, and thus the reliability of this data for paleoceanographic reconstructions.
- Comparison of results with historical and paleoclimate and oceanographic data is limited due to the dating accuracy of the sediment record. In general, it is clear that significant changes in productivity occurred over decade to century timescales during the previous 800 years. This period includes both the Little Ice Age and the period of 20th century warming, and analyses of paleo and historical climate data indicate changes over similar timescales. The late 20th century period also appears to be unique, from both the perspective of published paleoclimate data, and the paleoceanographic data developed as part of this study.

NOAA relevance/societal benefits

In a pilot study effort to reconstruct the paleoproductivity 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 past ~800 years. 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 through 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.
- Nicole Misarti, Interdisciplinary Ph.D. student—preparation of bone samples for stable isotope analysis.
- Jamie Coon, undergraduate chemistry student, graduated UAF Spring 2007—preparation of sediment samples for stable isotope and other analyses.

Publications

Peer-reviewed

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. 2007. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, 16 46–67.

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.*

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. Additional samples from animals harvested in 2003–2006 were obtained to extend the time series of these analyses to 10 years.
- Compound-specific stable isotope analysis was completed and confirms preliminary results indicating ice algal carbon represents approximately 25% of total carbon present at higher trophic levels, including zooplankton, fish, birds, whales and seals in the nearshore Beaufort Sea. 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.
- We completed the analyses of 101 ice associated seals from Bering Strait to examine trophic dependencies and resource partitioning among them.

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. George Divoky of UAF provided essential samples of seabirds, forage fishes and invertebrates from the Beaufort Sea for fatty acid–stable isotope analysis.

Publications

Peer-reviewed

Budge, S.M., A.M. Springer, S.J. Iverson and G. Sheffield. 2007. Fatty acid biomarkers reveal niche separation in an Arctic benthic food web. *Marine Ecology Progress Series,* 336:305–309.

In preparation

Budge, S.M., M. Wooller, A.M. Springer, S.J. Iverson, C.P. McRoy and G.J. Divoky. Ice algae contribution to Arctic marine food web productivity: estimates using fatty acid–stable isotope analysis. In preparation for submission to *Oecologia*.

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*.

Cooper, M.H., S.M. Budge, A.M. Springer, S.J. Iverson and G. Sheffield. Resource partitioning by sympatric pagophilic seals in Alaska revealed by fatty acid analysis. In preparation for submission to *Polar Biology*.

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

Pacific Region Integrated Data Enterprise (PRIDE) projects: *Collaborative Research: Alaska PRIDE FY06* *Integrated Pacific Coastal Climatology Data and Information Products* (Pacific Region Integrated Climatology Products; PRICIP)

David Atkinson, PI
University of Alaska Fairbanks

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

CIFAR 39-090 (new; a continuation of 19-086) and CIFAR 40-091 (new): These projects are ongoing.

Primary objectives

This write-up encompasses two projects that benefited from NOAA Pacific Regional Integrated Data Enterprise (PRIDE) initiative source funding.

CIFAR 39-090, "Collaborative Research: Alaska PRIDE FY06," is a continuation of an Alaskan sector contribution to the PRIDE FY05 effort entitled, "Towards an Alaskan Wind/Wave Climatology" (CIFAR 19-086). The overarching objective of this ongoing effort is to further the initial objectives outlined in the FY05 project, which consist of undertaking activities leading to an actual FY07–08 demonstration project as NOAA's contribution to the International Polar Year (IPY). The specific objectives for CIFAR 39-090 include identification of a consulting team, selection of project pilot sites, initiation of supporting wave model activity, and development of initial data layers and products for a geographic information system.

CIFAR 40-091, entitled "Pacific Region Integrated Climatology Products (PRICIP)" is a new award. Led by John Marra and Eileen Shea of the NOAA Integrated Data and Environmental Applications (IDEA) Center in Honolulu, its objectives focus on development of detailed climatologies of extreme events that are tailored to and driven by end-user needs. Specific requirements include compilation of a list of the most severe historical events and determination of extreme event return intervals. Atkinson was tasked with the "High Winds" theme of this project.

Both of these efforts are supporting an improvement of available end-user products across a range of temporal and spatial scales, which for Alaska are leading to 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. These projects also represent an opportunity for linkage and interface between activities and needs in the Alaska region with those in Hawaii and other U.S. Pacific interests.

Approach/methodology

For the Alaska PRIDE FY06 project the initial approach gathered together experts from a wide array of disciplines and research/operational groups in a workshop that was run as part of Atkinson's PRIDE FY05 activities. Based on results from this workshop a series of project steps were identified:

1. Identify a wave model.
2. Identify an expert group; determine end-user requirements.
3. Identify project sites.
4. Begin implementation of a wave model.
5. Secure observational and model data (storm, wind).
6. Develop climatologies.
7. Determine extreme event return frequencies.
8. Operationally implement wave model (Weather Forecast Office (WFO)-level access via NOAAPORT data stream).

Via this approach the current situation of both short-term prediction and long-term management in the Alaska coastal zone will be at least partially improved. Alaska PRIDE FY06 partially supported one Ph.D. student, Oceana Francis-Chythlook and one Master's student, Jennifer March.

For the PRICIP project, the approaches were similar to those needed for the long-term elements of the PRIDE project, and included:

1. Identify end user needs.
2. Acquire necessary data.
3. Identify historical severe events for a database.
4. Build tailored climatology layers.
5. Incorporate into display system.

The tasks for both PRIDE projects are complementary, however in practice the return frequency algorithm development work was discharged exclusively with the PRICIP funding. The results will go to satisfy requirements in both projects, however (the PRICIP mandate is primarily Hawaii and the U.S. Pacific Flag Territories). The PRICIP project partially supported a second Ph.D. student, Michel Mesquita, whose work focused more on this project.

Research accomplishments/highlights/findings (student contributions mentioned by name)

- Pilot project sites identified: Barrow, the Kotzebue Sound region, and the Dillingham region. This was based on a series of selection criteria established at the 2005 workshop that included, among other things, considerations such as public impact, available data, and economic impact.
- Expert team identified (this is not fixed and can be expanded as the need/opportunity arises). These represent a cross-section of regional experts who can provide input on technical matters and end-user needs and delivery formats:

Person	Affiliation	Capacity
Orson Smith	Dept. of Engineering, University of Alaska Anchorage	Technical: coastal defense structural engineer
Christy Miller	Former Alaska State Flood Control Planner	End user: Coastal flooding return intervals for planning and insurance
Torre Jorgensen	Senior Scientist with ABR Alaska, Inc.	Technical: permafrost and erosion specialist
Scott Simmons	Alaska Emergency Preparedness (Dept. Homeland Security)	End user: Emergency planning needs
Hendrik Tolman	NOAA – National Centers for Environmental Prediction (NCEP)/Climate Diagnostics Center (CDC)	Technical: wave model expert
Ken Stenek	Bering Strait School District	End user: community needs
John Dragomir	NOAA – NWS: WFO Fairbanks Meteorologist in Charge	End user: operational alignment

- Rescued (transferred to digital media and quality controlled) three International Geophysical Year coastal weather data sets for the North Slope. For this data-sparse region, representing one of the pilot locations (south of Barrow, AK), additional sources of data are critical. These data, recovered by Jennifer March, have not been utilized in 45 years and for the first time will be brought to bear in this project to assist with local climate and extreme-event impact studies.
- A return interval algorithm developed. Using a Gumbel distribution function and an inversion routine to extract return intervals, Francis-Chythlook has developed a high-wind return interval algorithm that is now being applied to stations throughout Alaska and the Pacific region to develop end-user data layers.
- Characteristics of North Pacific storm tracks better elucidated. In this work Mesquita has identified the importance of interpreting storm parameters within a broader climatic context, e.g., the phase of El Niño or the Pacific Decadal Oscillation must be considered when interpreting storm track positions. He has also identified, for the first time, important differences between summer and winter storms, that is, that winter storms are more severe but summer storms last longer—a fact which has important precipitation accumulation implications.
- Extreme event database initiated for the Alaska district—10 severe storms identified for more detailed impacts analysis. This represents the initial Alaska contribution to this Hawaii-based Pacific effort that helps to lay the groundwork for a major PRICIP activity, the development of a large severe events database with impacts and case histories that users can examine.

- Next-generation coastal wave model developed for the Alaska region (NOAA-NCEP/CDC WaveWatch III). In response to this project's needs, Hendrik Tolman at NCEP has developed a more sophisticated version of WaveWatch that will better account for the complex Alaska coastline and the influence of the Aleutian Islands.
- On-line storm tracking and plotting database established (NOAA-NCEP/CDC). Also in response to this project, Jon Gottschalck at NCEP has expanded his on-line storm tracking system to include a specific Alaska focus page < http://www.cpc.noaa.gov/products/precip/CWlink/stormtracks/strack_alaska.shtml>.
- Submitted a major proposal submitted (still pending) to the National Science Foundation for one of their International Polar Year solicitations: "Collaborative Research: IPY: Integrated Management Tools for Arctic Coastal Zone Resiliency." In an effort to secure funding necessary to see some of the end-user tools fully developed, Atkinson assembled a large expert team and built this proposal. The team represents the following diverse group:
  - International Arctic Research Center, University of Alaska Fairbanks
  - Department of Engineering, University of Alaska Anchorage
  - Marine Advisory Program, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks
  - NOAA Coastal Services Center
  - NOAA National Weather Service
  - ABR Alaska Inc. (Environmental Research and Services Consulting Firm)
  - Aleut International Association
  - A visual artist from Canada to coordinate outreach activities
  - State of Alaska Department of Commerce, Community and Economic Development
- Internal proposal submitted (successful) to the Environmental Protection Agency

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

In many cases linkages within the U.S. translate into direct project collaboration. The following are directly involved in NOAA-based or NOAA-related research as listed project collaborators under PRIDE or projects submitted to NSF or elsewhere in NOAA.

- James Partain, National Weather Service, Alaska Region Headquarters
- John Jensen, NOAA National Climatic Data Center
- John Marra, NOAA IDEA Center, Honolulu
- Rosanne Lorenzana, Environmental Protection Agency Region 10
- John Lyon, Environmental Protection Agency, Environmental Sciences Division Director
- Reid Brewer, Marine Advisory Program, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks
- David Levinson, NOAA National Climatic Data Center (NCDC), Asheville
- Mark Merrifield, University of Hawaii
- Victoria Gofman, Aleut International Association
- Nicole Bauberger, Visual Artist from Whitehorse, Canada
- Christy Miller (ret.), Keith Jost, Ruth St. Amour – Alaska Department of Commerce, Community and Economic Development
- Orson Smith, School of Engineering, University of Alaska Anchorage
- Stephanie Fauver, NOAA Coastal Services Center
- Tom Weingartner, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks
- Torre Jorgensen, ABR Alaska Inc.

Other research linkages with international groups are maintained. This serves as a broader knowledge base of coastal impacts from which to draw.

Arctic Coastal Dynamics Project

- Nicole Couture, McGill University, Montreal, Canada
- Paul Overduin, Alfred Wegener Institute, Potsdam, Germany
- Stanislav Ogorodov, Moscow State University, Russia
- Volker Rachold, Executive Secretary, International Arctic Science Committee (IASC) Secretariat, Stockholm, Sweden
- Dmitry Drozdov, Earth Cryosphere Institute, Russia
- Steve Solomon and Will Perrie, Bedford Institute of Oceanography, Halifax, Canada
- Nils Kvamsto and Asgeir Sorteberg, Bjerknes Climate Center, Bergen, Norway.

Education/outreach

Public awareness

D. Atkinson was interviewed for an article in the February 2007 issue of *Alaska Business Monthly* entitled "Erosion threatens coastal Alaska villages."

Student participation

This funding provided partial salary and tuition support for the following students:

Oceana Francis-Chythlook (Ph.D. student)
Michel Mesquita (Ph.D. student)
Jennifer March (M.S. student)

K–12 Outreach

- Lectured about coastal forcing to high school students in the Upward Bound program

Oral presentations

Atkinson, D.E. 2006. Coastal threats: understanding the forcings. Preventing and Responding to Coastal Flooding and Erosion—Sea Grant workshop, Dillingham, Alaska, 7 August 2006.

Atkinson, D.E. 2006. Coastal threats in Alaska. International Arctic Research Center 2006 Summer School, Fairbanks, Alaska, 5 August 2006.

Atkinson, D.E. 2006. Alaska coastal communities: profiles and threats. Presented to UAF IARC/GI "NSF Research Experience for Undergraduates" program participants, 25 July 2006.

Atkinson, D.E., M. Mesquita, J. Gottschalck and A. Sorteberg. 2006. Chukchi sea storm densities derived from various algorithms. Talk A24A-04, American Geophysical Union Fall Meeting, San Francisco, December 2006.

Atkinson, D.E. and J. Partain. 2006. Alaska PRIDE 2006: status and opportunities. Talk given to NOAA National Climatic Data Center senior personnel, Asheville, North Carolina, 14 September 2006.

Atkinson, D.E., J. Marra, O. Francis-Chythlook, J. Partain, D. Levinson and J. Jensen. 2006. Improving coastal zone emergency response: a pathway from research to human benefits. American Association for the Advancement of Science Arctic Division Annual Meeting, Fairbanks, Alaska, 2–4 October 2006.

Poster presentation

Francis-Chythlook, O. and D.E. Atkinson. 2006. Extreme value wind analysis in Alaska. Poster A21A-0828, American Geophysical Union Fall Meeting, San Francisco, December 2006.

Publications

Accepted

Mesquita, M., N. Kvamsto, A. Sorteberg and D.E. Atkinson. Climatological properties of summertime extra-tropical storm tracks in the Northern Hemisphere. Accepted for publication in *Tellus*.

In preparation

Francis-Chythlook, O. and D.E. Atkinson. Strong wind return intervals for coastal Alaska, Hawaii and the U.S. Pacific Flag Territories. In preparation.

March, J. and D.E. Atkinson. Synoptic events on the Alaska North Slope during the International Geophysical Year. In preparation.

Mesquita, M. and D.E. Atkinson. Characteristics and variability of storm tracks in Alaska. In preparation.

Reference

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 (T. Reale), University of Washington (A. Schweiger), and Rutgers University (J. Francis). 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 follows 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 Tony 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. John Calder, Arctic program director at NOAA, has since approved a no-cost extension as a result of these delays.

Research accomplishments/highlights/findings

- Assisted with cloud-detection strategies and provided validation data from the Barrow ARM site for 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. This work is ongoing.
- Errors and inconsistencies in data set of collocated radiosondes and satellite radiances have been identified and rectified. This procedure is ongoing.
- Schweiger developed a suite of programming modules in Interactive Data Language (IDL) to detect errors in data processing. These modules were delivered to NOAA personnel and are now in use not only for this project, but for a larger global effort to collocate radiosondes with satellite radiances.
- Collocation datasets for 1985 to 1999 now complete.
- Funding acquired by Reale (NOAA) to extend and expand collocation data base globally and into the Advanced TOVS (ATOVS) era and for Geostationary Operational Environmental Satellite (GOES) radiances.
- Sensitivity studies of radiative transfer models underway.
- Sensitivity studies of spectral response functions underway.

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).

Education/outreach

Presentations

Reale, A.L. 2006. Evolving reference networks and integrated satellite data (product) validation. Oral presentation at 15th ITOVS Study Conference, Maratea, Italy, 4–10 October 2006.

Reale, A.L. and E.G. Dutton. 2007. A candidate GCOS atmospheric reference observations network (GARON) consisting of ARM, BSRN and WMO reporting sites and satellite/in-situ data collection strategies. Oral presentation at the 14th Symposium on Meteorological Observation and Instrumentation, San Antonio, Texas, January 2007.

Reale also presented information on this work at the NOAA-STAR 07 Projects Review, Camp Springs, Maryland, February 2007.

State of the Arctic Report

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

CIFAR 23-087: 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

- The first NOAA State of the Arctic report was published in October 2006 and distributed widely. It appears on the NOAA Arctic website at: http://www.arctic.noaa.gov/soa2006/
- Taken collectively, the observations presented in the report show convincing evidence of a sustained period of warm temperature anomalies in the Arctic, supported by continued reduction in sea ice extent, observed at both the winter maximum and summer minimum, and widespread changes in arctic vegetation. The warming trend is tempered somewhat by shifts in the spatial patterns of land temperatures and ocean salinity and temperature. While there are still large region-to-region and multiyear shifts in the arctic climate, the large spatial extent of recent changes in air temperature, sea ice, and vegetation is greater than observed in the 20th century.

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 in FY06 convened a workshop with a working group of 16 scientists from national and international universities and governmental laboratories studying the Arctic.

Education/outreach

- During this reporting period, V. Romanovsky was interviewed by Russian TV channel NTV; twice by German TV company DOCUVISTA and Japanese TV Idea Network LA Inc.; South Korean TV program SBS; and by many news reporters.
- V. Romanovsky worked with high school students and teachers. He made a presentation on Permafrost and IPY Plans for teachers and students of the Alaska Lake Ice and Snow Observatory Network (ALISON).
- V. Romanovsky was invited to present this work at the Arctic Science Summit Week 2007, Science Day, in Hanover, NH.
- V. Romanovsky also gave Mentor Lectures, which were broadcast through the Internet to several schools in western and northwestern Alaska. These lectures were a part of the ACMP (Arctic Climate Modeling Program) Mentor Lectures Program.
- Materials collected during the project were included in the graduate-level Permafrost class that V. Romanovsky teaches every semester at the University of Alaska Fairbanks.

Oral presentations

Romanovsky, V., S. Marchenko, D. Sergeev, D. Nicolsky and R. Daanen. 2006. State of permafrost in Alaska. AAAS Arctic Science Conference, Fairbanks, Alaska, 2–4 October 2006.

Romanovsky, V.E. 2006. Permafrost temperature reanalysis as a valuable tool in paleo-environmental studies. Global Environmental Change: Regional Challenges, ESSP Open Science Conference, Beijing, China, 9–12 November 2006.

Romanovsky, V.E., S.S. Marchenko, R. Daanen, D. Nikolsky, D.O. Sergeev and D.A. Walker. 2006. Soil climate and frost heave along the Permafrost/Ecological North American Arctic Transect. Annual meeting of the American Geophysical Union, San Francisco, California, December 2006.

Romanovsky, V.E. 2007. State and fate of permafrost in a warming world. Invited presentation at Arctic Science Summit Week 2007, Science Day, Hanover, New Hampshire, 15 March 2007.

Publications

Peer-reviewed

Richter-Menge, J., J. Overland, A. Proshutinsky, V. Romanovsky, L. Bengtsson, L. Brigham, M. Dyurgerov, J.C. Gascard, S. Gerland, R. Graversen, C. Haas, M. Karcher, P. Kuhry, J. Maslanik, H. Melling, W. Maslowski, J.

Morison, D. Perovich, R. Przybylak, V. Rachold, I. Rigor, A. Shiklomanov, J. Stroeve, D. Walker and J. Walsh. 2006. State of the Arctic Report. NOAA OAR Special Report, NOAA/OAR/PMEL, Seattle, Washington, 36 pp.

Romanovsky, V.E., S. Gruber, A. Instanes, H. Jin, S.S. Marchenko, S.L. Smith, D. Trombotto and K.M. Walter. 2007. Chapter 7: Frozen Ground. In: Global Outlook for Ice and Snow, Earthprint, UNEP/GRID, Arendal, Norway, pp. 181–200.

Non-peer-reviewed

Romanovsky, V.E., S.S. Marchenko, R. Daanen, D.J. Nicolsky, D.O. Sergeev and D.A. Walker. 2007. Air and soil temperatures and frost heave along the Permafrost/Ecological North American Arctic Transect. In: Proceedings of the International Conference: Cryogenic Resources of Polar Regions, Salekhard, Russia, 17–20 June 2007.

Richter-Menge, J., J. Overland, A. Proshutinsky, V. Romanovsky, R. Armstrong, J. Morison, S. Nghiem, N. Oberman, D. Perovich, I. Rigor, L. Bengtsson, R. Przybylak, A. Shiklomanov, D. Walker and J. Walsh. 2007. The Poles: Arctic. In: A. Arguez, Ed., State of the Climate in 2006. *Bulletin of the American Meteorological Society*, 88(6):S62–S71.

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 complete. See previous annual reports for research activity under this award. Activity for this reporting period is described below in the Education/outreach and Publications sections.

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.

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

High-latitude weather and climate research in the polar meteorology group. Presented at the Global Climate Change Summit for Undergraduate Students at the Ohio State University, 26 January 2007.

Hines, K.M. 2007. The polar WRF. Invited presentation at the Great Alaska Weather Modeling Symposium, University of Alaska Fairbanks, 13 March 2007.

Hines, K.M., D.H. Bromwich and L.-S. Bai. 2007. Arctic development of a polar-optimized WRF. Canadian Meteorological and Oceanographical Society/Canadian Geophysical Union/American Meteorological Society Congress, St. John's, Newfoundland, Canada, 29 May 2007.

Hines, K.M., D.H. Bromwich and L.-S. Bai. 2007. Polar-optimized WRF. Presented at the 8th WRF User's Workshop, Boulder, Colorado, 14 June 2007.

Publications

Peer-reviewed

Bromwich, D.H., R.L. Fogt, K.I. Hodges and J.E. Walsh. 2007. A tropospheric assessment of the ERA-40, NCEP, and JRA-25 global reanalyses in the polar regions. *Journal of Geophysical Research*, 112(D10):D10111, doi:10.1029/2006JD007859.

Non-peer-reviewed

Hines, K.M., D.H. Bromwich and L.-S. Bai. 2007. Polar-optimized WRF. Preprints, 8th Annual WRF User's Workshop, Boulder, Colorado.

In press

Hines, K.M. and D.H. Bromwich. Development and testing of Polar WRF. Part I. Greenland ice sheet meteorology. *Monthly Weather Review*, in press.

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 ongoing, and was extended beyond its original ending date because (1) the departure of participant Jeff Tilley from the project left funds available for FY 2007, and (2) collaboration with an ongoing DOE project made available the arctic cloud/radiation data used for validation of the reanalyses. This collaboration led directly to the journal submission discussed below under "Research Accomplishments."

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) and the Japanese 25-year Re-Analysis (JRA-25)) 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. During the past year, the NCEP's North American Regional Reanalysis (NARR) was included with the three global models in a UAF-coordinated diagnosis of cloud-radiative interactions in the reanalyses.

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

- An intercomparison of the cloudiness and radiative fluxes in four large-scale atmospheric reanalyses was completed and submitted for publication (Walsh et al. 2007, JGR, submitted). Arctic radiative fluxes, clouds and cloud-radiative forcing were evaluated from four currently-available reanalysis models using data from the North Slope of Alaska (NSA) Barrow site of the Atmospheric Radiation Measurement (ARM) program. The four reanalysis models used in this study were (a) NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) global reanalysis; (b) ERA-40 global reanalysis by the European Center for Medium-Range Weather Forecasts; (c) NCEP/NCAR North American Regional Reanalysis (NARR) and (d) Japan Meteorological Agency 25-year reanalysis (JRA-25). The results indicate that these reanalysis models are able to simulate the radiative fluxes *if* the clouds are simulated correctly. However, the systematic errors of climatological cloud fractions simulated by the reanalyses are substantial. The large seasonal cloud biases have significant impacts on the surface energy budget. The ERA-40 was found to be the best performer in both shortwave and longwave flux seasonal representations at Barrow, largely because its simulation of the cloud coverage is the most realistic of the four reanalyses. Similar biases of the cloud fraction means and seasonal cycles at Barrow were also detected over the Arctic Ocean in the reanalyses. Evaluations of variable cloud radiative forcing (VCRF) show the reanalyses capture the transition from negative to positive cloud radiative forcing for two to three months during the summer, although the dependence of the VCRF on cloud fraction differs widely between the reanalyses and observational data.

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. The findings concerning the Arctic output of existing NCEP reanalyses, including the global NCEP reanalysis and the North American Regional Reanalysis, will guide future reanalyses at NCEP or elsewhere within NOAA.

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 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 (March 2007), 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 presentations

Fan, X., D. Yang, J.E. Walsh and J.R. Krieger. 2006. Cloud cover and surface air temperature correlations over the northern high latitudes. 2006 Arctic Science Conference, Arctic Division, American Association for the Advancement of Science (AAAS), Fairbanks, Alaska, 2–4 October 2006. P24.

Chapman, W.L. and J.E. Walsh. 2007. Evaluation of high-latitude simulations by atmospheric reanalyses and climate models. PCMDI Workshop on Model Evaluation, San Francisco, 14–16 February 2007.

Walsh, J.E., W.L. Chapman and D.H. Portis. 2007. Evaluation of atmospheric reanalysis products at the Barrow NSA ARM site. DOE/ARM Science Meeting, Monterey, California, 26–30 March 2007.

Oral presentations

Fan, X., J.R. Krieger, D.J. Morton, J. Zhang, M.D. Shulski and A.E. Klenne. 2007. Simulating Beaufort Sea coastal wind events using MM5 and WRF. Great Alaska Weather Modeling Symposium, Fairbanks, Alaska, 13–15 March 2007.

Walsh, J. 2007. Simulation of clouds and radiative fluxes in atmospheric reanalyses. Arctic Monitoring and Assessment Program, Workshop on Arctic Modeling, Oslo, Norway, 12–14 June 2007.

Publications

Peer-reviewed

Serreze, M.C., A.P. Barrett, A.G. Slater, R.A. Woodgate, K. Aagaard, R.B. Lammers, M. Steele, R. Moritz, M. Meredith and C.M. Lee. 2006. The large-scale freshwater cycle of the Arctic. *Journal of Geophysical Research*, 111(C11), doi:10.1029/2005JC003424.

Bromwich, D.H., R.L. Fogt, K.I. Hodges and J.E. Walsh. 2007. A tropospheric assessment of the ERA-40, NCEP, and JRA-25 global reanalyses in the polar regions. *Journal of Geophysical Research*, 112(D10), D1011110.1029/2006JD007859.

Serreze, M.C., A.P. Barrett, A.G. Slater, M. Steele, J. Zhang and K.E. Trenberth. 2007. The large-scale energy budget of the Arctic. *Journal of Geophysical Research*, 112(D11), D1112, doi:10.1029/2006JD008230.

Non-peer-reviewed

Fan, X., J.E. Walsh and J.R. Krieger. 2007. A one-year experimental Arctic reanalysis and comparisons with ERA-40 and NCEP/NCAR reanalyses. Proceedings of the 7th International Conference on Global Climate: Connections to Arctic (GCCA-7), Fairbanks, Alaska, 19–20 February 2007, pp. 37–40.

Submitted

Slater, A.G., T.J. Bohn, J.L. McCreight, M.C. Serreze and D.P. Lettenmaier. A multi-model ensemble of pan-Arctic hydrology. Submitted to *Journal of Geophysical Research–Biogeosciences*.

Walsh, J.E., W.L. Chapman and D.H. Portis. Arctic clouds and radiative fluxes in atmospheric reanalyses. Submitted to *Journal of Geophysical Research–Atmospheres*.

In preparation

Fan, X. Impacts of soil module characteristics on simulated ground heat flux, surface temperature, and other variables. In preparation.

Contaminant Effects

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: This project is complete. The support to the AMAP project has funded 7 sub-projects. Five of these sub-projects (numbers 1, 4, 5, 6 and 7) were essentially completed in the previous reporting period; sub-projects 2 and 3 are now complete.

2. Arctic Council joint assessment on Oil and Gas.

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.

Publications
The costs of producing the Arctic Council Oil and Gas Assessment are considerably higher than originally anticipated because of the extended scope of the assessment and large volume of material being assessed. Even with substantial in-kind and financial support during this reporting period, further financial support will be needed to finalize the production.

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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 complete. 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
Both the popular (non-technical) and scientific reports were released in 2006 and are available as hard copies or can be downloaded from the AMAP website (http://www.amap.no/) as PDF documents.

Arctic Pollution 2006, the third AMAP State of the Arctic Environment Report, updating the 1997 AMAP assessment on Acidification and Arctic Haze has been released as a 28 page document for the general public. Information is presented in a clear and readable manner for the non-scientific audience; richly illustrated and prefaced by an Executive Summary with recommendations specifically addressed to Ministers of the eight Arctic countries.

The 2006 Acidification and Arctic Haze Scientific Report was also released in 2006. AMAP, 2006. ***AMAP Assessment 2006: Acidifying Pollutants, Arctic Haze, and Acidification in the Arctic***. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+112 pp.

Fisheries Oceanography

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

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

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

Josh Robins, a Master's student supported by this project, graduated in Fall 2006. His thesis title was "Biophysical factors affecting marine growth and survival of Auke Creek, Alaska coho salmon." A manuscript based on his work is in preparation.

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 has been most heavily involved in the CIFAR-supported studies, having served on the committees of the graduate students supported by this funding. 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

Student support

Two graduate students have been fully supported for Master's theses on this research project. The first, Ryan Briscoe, currently works for the Alaska Department of Fish & Game. The second, Josh Robins, is preparing for a career as a teacher in the state of Washington.

Publications

Non-peer-reviewed

Robins, J. 2006. Biophysical Factors Affecting Marine Growth and Survival of Auke Creek, Alaska Coho Salmon. M.S. Thesis, University of Alaska Fairbanks.

In preparation

Robins, J., R.J. Briscoe, M.D. Adkison, A. Wertheimer and S.G. Taylor. Biophysical factors associated with the marine growth and survival of Auke Creek, Alaska coho salmon. In preparation.

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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.

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
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 50-040d: 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

- Sea temperatures were cool during 2000 and 2001, warm during 2002 to 2005, then cool during 2006.
- Juvenile sockeye salmon primary prey was Pacific sand lance during 2000–2001, age-0 pollock during 2002–2005 and Pacific sand lance during 2006.
- The relative abundance of age-0 pollock and juvenile Bristol Bay sockeye salmon increased each year from 2000–2003; declined during 2006.
- A manuscript titled "Early marine growth in relation to marine stage survival rate for Alaska sockeye salmon (*Oncorhynchus nerka*)" was published in *Fishery Bulletin* 105(1):121–130.
- A manuscript titled "Juvenile sockeye salmon distribution, size, feeding, condition, and diet during years with warm and cool spring sea temperatures along the eastern Bering Sea shelf" is in press in the *Journal of Fish Biology*.
- A manuscript titled "Growth potential of juvenile sockeye salmon in relation to warm and cool spring sea temperatures along the eastern Bering Sea shelf" is in preparation.
- A manuscript titled "Research on juvenile Bristol Bay sockeye salmon in the eastern Bering Sea: a historical perspective" is in preparation.

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

Student participation

One graduate student, Ed Farley, is basing his Ph.D. on this research and will defend in September 2007. Farley has presented his research results in local, statewide, and international scientific symposia including one presentation during this reporting period.

Presentation

Farley, E. 2007. Juvenile western Alaska salmon research along the eastern Bering Sea shelf, August–October (2002–2006). Arctic–Yukon–Kuskokwim Sustainable Salmon Initiative (AYK SSI) Symposium, Anchorage, Alaska, February 2007.

Publications

Peer-reviewed

Farley, E.V. Jr., J.M. Murphy, M.D. Adkison, L.B. Eisner, J.H. Helle, J.H. Moss and J. Nielsen. 2007. Early marine growth in relation to marine stage survival rate for Alaska sockeye salmon (*Oncorhynchus nerka*). *Fishery Bulletin,* 105(1):121–130.

In press

Farley, E.V. Jr., J.M. Murphy, M. Adkison and L. Eisner. Juvenile sockeye salmon distribution, size, condition, and diet during years with warm and cool spring temperatures along the eastern Bering Sea shelf. *Journal of Fish Biology*, in press.

In preparation

Farley, E.V. Jr. Growth potential of juvenile sockeye salmon in relation to warm and cool spring sea temperatures along the eastern Bering Sea shelf. In preparation.

Farley, E.V. Jr. Research on juvenile Bristol Bay sockeye salmon in the eastern Bering Sea: a historical perspective. In preparation.

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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.

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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

Milo Adkison, PI *University of Alaska Fairbanks*

NOAA Goal: Ecosystem-based Management

CIFAR 52-084a: 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

Length at Age Analysis: Summary statistics have been calculated to characterize fish population by location and date. The chief complication so far has been overcoming the change in sampling methodology over time; age–length data 1981 to 1993 were sampled using length stratification, while age–length data from 1996 to 2004 consist of a random sample.

Estimates produced from length-stratified data create biased estimates of mean length at age, resulting in individuals smaller than the mean size of the first ages and larger than the mean size of the older ages (Goodyear 1995; Sigler et al. 1997). The length data for all years is a random sample from the longline survey and can be used with the age–length samples to create bias-corrected age–length samples of the 1981–1993 data (Sigler et al. 1997), using the following method:

$$\hat{L}_a = \frac{\sum_s LC_s O_{s,a}}{\sum_s C_s O_{s,a}}$$

where L_a is the average length at age a, L is the length of size category s, C_s is the total catch of size category s, and $O_{s,a}$ is the number of age a fish in the length-stratified age-sample from size category s. Bias-corrected mean length at age from 1981–1993 and 1996–2004 age–length data were then fit to the von Bertalanffy (LVB) age–length model (Kimura 1980; Kimura et al. 1993; Sigler et al. 1997; Quinn and Deriso 1999; Hanselman et al. 2006) by non-linear least squares. LVB growth curves were further fit to data by area/sex stratum, to look for differences in growth from the time of 1981–1993 in comparison to the time of 1996–2004 among different areas, as well by sex stratum and year, to look for any patterns in changes of growth over time among all areas combined.

Following the methods found in Quinn and Deriso's (1999) *Quantitative Fish Dynamics*, individual parameters of growth models have been compared between different data sets using the univariate Fisher–Behrens test, in which variance isn't assumed to be constant.

Hotelling T^2 multiparameter tests have been carried out to compare growth curves from different data sets. These tests follow the Cerrato method in which variance isn't assumed to be equal, found in Quinn and Deriso's (1999) *Quantitative Fish Dynamics*.

Results from the comparison of LVB growth curves fit to 1981–1993 data against 1996–2004 data for all Alaskan waters give similar outcomes for both male and female sablefish: older (1981–1993) data fish display smaller asymptotic lengths (L_∞), slower growth rates (k), and smaller t_o estimates. Results of the univariate Fisher–Behrens test on the male data show that only the L_∞ parameter is significantly different (p=0.00) between the old (1981–1993) and new (1996–2004) data, and according to the multiparameter Hotelling T^2 statistical test, the two growth curves are significantly different (p=0.00). Test results on the female data show that the L_∞ (p=0.00) and t_o (p=0.00) parameter estimates are significantly different, and that the two growth curves (p=0.00) are significantly different as well.

Current average maximum length estimates used in the 2007 Alaska Sablefish Stock Assessment are 69 cm for males and 83 cm for females (Hanselman et al. 2006), which are both larger than average maximum length estimates found in this study: Males (1981–1993) = 65.8 cm, Males (1993–2004) = 67.8 cm, Females (1981–1993) = 75.6 cm, and Females (1996–2004) = 80.2 cm.

Results from the comparison of LVB growth curves fit to 1981–1993 data against 1996–2004 data for each sampled region show no particular pattern among male sablefish. Male asymptotic lengths range from 65.7 to 70.9 cm in older (1981–1993) data fish, the smallest maximum lengths being found in the Shumagin Slope region and largest in the Chirikof Slope region. In the newer (1996–2004) male data, asymptotic lengths range from 66.6 (Kodiak Slope) cm to 70.1 (Shumagin Slope) cm. The Chirikof, Kodiak, and Southeast Slope regions all displayed larger asymptotic lengths (L_∞) and slower growth rates (k) in the older data (1981–1993) fish. The older (1981–

1993) data fish from Shumagin Slope had a smaller asymptotic length (L_∞) and a faster growth rate (k) however, while older (1981–1993) data fish from the Bering Slope also had a smaller asymptotic length (L_∞) but a slower growth rate (k). All of the sampled regions had smaller t_o estimates in the 1981–1993 data, except in the Shumagin Slope region.

Test results showed that significant differences exist between growth curves fit to the two time periods in the Chirikof (p=0.02), Bering (p=0.02), Kodiak (p=0.03), and Southeast (p=0.00) Slope regions. Univariate parameter tests also revealed that Chirikof (p=0.01) and Bering (p=0.00) Slope regions have significantly different asymptotic length (L_∞) estimates, and Kodiak (p=0.02) and Southeast (p=0.00) Slope regions have significantly different growth rates (k) between the older and newer data sets.

LVB growth curves fit to female sablefish data showed more of a pattern than in the male data. Older (1981–1993) data fish from all sampled regions displayed smaller asymptotic lengths (L_∞) than newer (1996–2004) data fish except in the Chirikof Slope region. Chirikof, Aleutian, Kodiak, and Southeast Slope older (1981–1993) data females had slower growth rates than newer (1996–2004) data females, while Shumagin and Bering Slope older (1981–1993) data females displayed faster growth rates. Similar to the males, older (1981–1993) data females from all sampled regions showed smaller t_o estimates, except in the Shumagin Slope region. Female asymptotic lengths range from 69.5 to 78.9 cm in older (1981–1993) data fish, the smallest maximum lengths being found in the Bering Slope region and largest in the Southeast Slope region. In the newer (1996–2004) female data, asymptotic lengths appear much larger, ranging from 76.4 (Bering Slope) cm to 81.3 (Shumagin Slope) cm.

Test results showed that significant differences exist between growth curves fit to the two time periods in the Bering (p=0.00), Aleutian (p=0.01), Kodiak (p=0.02), and Southeast (p=0.00) Slope regions. Univariate parameter tests also revealed that Bering (p=0.00) and Kodiak (p=0.04) Slope regions have significantly different asymptotic length (L_∞) estimates, and Southeast (p=0.01, 0.02) Slope regions have significantly different growth rate (k) and t_o estimates between the older and newer data sets.

Maturity at Age/Length Analysis: Age and length at maturity was estimated by fitting the data to the logistic equations shown in Sasaki (1985), using the method of Quinn and Deriso (1999) by nonlinear least squares.

Updated estimates of fork length and age at 50% maturity for both male and female sablefish during the time period of 1996–2004 in Alaskan waters resulted in larger lengths and older ages at 50% mature in comparison to current values used in the 2007 Alaska Sablefish Stock Assessment. The current estimates used in the 2007 Alaska Sablefish Stock Assessment are the following: $L_{50,m} = 57$ cm, $L_{50,f} = 65$ cm, $A_{50,m} = 5$ yrs, and $A_{50,f} = 6.5$ yrs (Hanselman et al. 2006). Updated estimates during the time period of 1996–2004 found that fifty percent of males mature at 63.1 cm, while 50 percent of females mature at 68.9 cm, corresponding to ages 8.3 years for males and 7.6 years for females.

Calculating estimates of fork length and age at 50% maturity over the time series of 1996 to 2004 for all Alaskan waters combined showed no pattern for either males or females. Fifty percent mature at length estimates ranged from 60 to 63 cm for males and 67.5 to 70 cm for females. Fifty percent mature at age estimates ranged from 6 to 8.6 years for males and 6.5 to 8 years for females.

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, is doing her Master's thesis on this research project. Her stipend and tuition is covered by a Rasmuson fellowship. She has completed all required coursework and is currently in the process of completing the last of the data analysis and is beginning to write her thesis. She expects to complete the program by May 2008.

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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.

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

- Katie Palof has completed a range of genetic analyses to characterize population structure. These included analyses to estimate divergence, to detect past population declines, to determine gene flow, and evaluate the

extent of sibship within collections. She is nearing completion of her M.S. thesis and will continue in our Ph.D. program.

- An observation from Palof's work is that Alaskan POP have highly structured populations relative to many other marine fish species. Consequently, the spatial scale that was sampled is inadequate to determine the fine structure. With an eye to the future to address the fine-scale structure, Palof, along with fellow graduate student Lisa Kamin and UAF technician Rachel Riley, accompanied NOAA trawl surveys in the Gulf of Alaska to sample much more intensively than was done previously. Although the sampling is not yet complete, they have samples from more than 1400 fish that were captured between Kodiak and Yakutat.

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 1/28/2008, $116,830 that examine the dispersion of juvenile POP, which supports graduate student Lisa Kamin.

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 summer 2007. The preliminary funding for this project enabled her to obtain a Rasmuson fisheries fellowship through the University of Alaska Fairbanks for both the 2005/2006 and 2006/2007 academic years. She plans to continue of this project in her doctoral research beginning Fall 2007.

Poster presentations

Kamin, L., K. Palof, J. Heifetz and A.J. Gharrett. 2006. Population structure of adult and young-of-the-year Alaska Pacific ocean perch (*Sebastes alutus*). Poster presented at the 2006 Alaska Marine Science Symposium, Anchorage, Alaska, 23–25 January 2006. (from last reporting period but not included in FY06 report)

Gharrett, A.J., K. Palof, L. Kamin, C. Kondzela and J. Heifetz. 2006. A preliminary look at geographic and cohort variation in the genetic structure of Pacific ocean perch (*Sebastes alutus*). British Isles Fisheries Society Symposium on Fish Population Structure: Implications to Conservation. Aberdeen, Scotland, 10–14 July 2006.

References

Gomez-Uchida, D., E.A. Hoffman, W.R. Ardren and M.A. Banks. 2003. Microsatellite markers for the heavily exploited canary (*Sebastes pinniger*) and other rockfish species. *Molecular Ecology Notes*, 3:387–389.

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

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

- Morphological analysis and species identification have been completed for 200 specimens (Kendall et al. in press).
- A preliminary description of species composition of these fish has been published (Kondzela et al. 2007).
- We are developing single nucleotide polymorphism (SNP) markers to distinguish between Pacific ocean perch (*Sebastes alutus*) and other species from which they cannot be distinguished as young-of-the-year juveniles, namely *S. aleutianus*, *S. ciliatus*, *S. crameri*, *S. reedi*, and *S. polyspinus*. (See report for CIFAR 22-085).

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*, September 2004 to January 2006, $105,000, as well as NPRB project number F0512, *Juvenile POP genetics (Phase II). Pacific ocean perch*, September 2005 to January 2008, $116,000, which supports graduate student Lisa Kamin.

Stephanie Walden, Sharon Hall, and Rachel Riley of the University of Alaska Fairbanks provide laboratory support.

Publications

Peer-reviewed

Kondzela, C.M., A.W. Kendall, Z. Li, D. Clausen and A.J. Gharrett. 2007. Preliminary identification of pelagic juvenile rockfishes collected in the Gulf of Alaska. In: J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell and R.D. Stanley, Eds., *Biology, Assessment, and Management of North Pacific Rockfishes*. Alaska Sea Grant College Publication AK-SG-07-01, University of Alaska Fairbanks, pp. 153–166.

In press

Kendall, A.W. Jr., C. Kondzela, Z. Li, D. Clausen and A.J. Gharrett. Genetic and Morphological Identification of Pelagic Juvenile Rockfish Collected from the Gulf of Alaska. NOAA Professional Paper NMFS.

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: 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. 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 were 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 DNA sequencing, we identified one of the restriction site differences that delineates the two rougheye rockfish species. We designed a SNP assay, but have not yet tested it. We designed primers that will enable us to identify the other diagnostic restriction site difference.
- From DNA sequencing, we identified a diagnostic restriction site difference that will enable us to distinguish *S. alutus* from *S. aleutianus*, *S. ciliatus*, *S. crameri*, *S. reedi*, and *S. polyspinus*, the species that are difficult to distinguish visually as young-of-the-year juveniles. We also characterized a second site that will enable us to distinguish *S. alutus* and *S. aleutianus* from *S. ciliatus*, *S. crameri*, *S. reedi*, and *S. polyspinus*. We designed a SNP assay, but have not yet tested it.

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.

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

Nicola Hillgruber, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 25-083: This project is complete; in February of 2007, Angela M. (Middleton) Feldmann decided to withdraw from the graduate program in fisheries at UAF. See FY06 report for research accomplishments and presentation information.

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.

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 was 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 for 2004 and 2005 at the School of Fisheries and Ocean Sciences (SFOS). Angela's graduate study was conducted at the Auke Bay Lab (NOAA/NMFS/AFSC) in Juneau, Alaska through SFOS, UAF. As of April 2006, Angela had requested a leave of absence from the University and in February 2007 decided to withdraw from the graduate program.

Publications (over the life of the project to date)

Feldmann, A.M., N. Hillgruber and M. Courtney. 2006. Variations in distribution, abundance, diet, and energy density of age-0 walleye pollock, *Theragra chalcogramma*, in the eastern Bering Sea. In: J. Boldt, Ed. Ecosystem Considerations for 2007, NPFMC Bering Sea/Aleutian Island and Gulf of Alaska SAFE, pp. 166–170.

Reproductive Potential of Pacific Cod

Brenda L. Norcross, PI ***NOAA goal: Ecosystem-based Management***
University of Alaska Fairbanks

CIFAR 41-031c: This project is complete.

Primary objectives

The reproductive potential (the number and quality of eggs spawned) of females in a fish population (stock) influences 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 (AI) 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

All analyses have been completed for this project and preliminary drafts of three publications and a Ph.D. dissertation have been prepared.

- Fecundity was related to age and size, and size was an excellent predictor of fecundity. Condition had only a minimal effect on fecundity. Egg size was highly variable among females and this variability was not related to maternal age, size, or condition. Fatty acid analysis suggested that eggs from older Pacific cod may be of slightly lower quality. Differences in reproductive potential among areas and years appeared to be mostly due to variability in egg size. We conclude that Pacific cod increase their reproductive potential by maximizing the number, not size or quality, of eggs they produce.
- Reproductive potential was reduced in the EBS in 2003, and this may have resulted from changes in ocean temperature and prey availability that limited the ability of females to store energy during the previous summer.
- Differences in fatty acid composition between the EBS and AI suggest the possibility of separate stocks within the BSAI management area.
- The biochemical composition of Pacific cod eggs is similar to that of the closely related Atlantic cod (*Gadus morhua*), with specific adaptations to reduce buoyancy and produce demersal eggs.

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 (Olav Ormseth) and NOAA Fisheries personnel (Anne Hollowed and 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 (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.

Education/outreach

Student participation

Olav Ormseth, Ph.D. candidate, Fisheries Oceanography, University of Alaska Fairbanks, has been supported in part by this award. He was a visiting instructor at Alaska Pacific University in the fall of 2006 and is currently employed as a Research Fishery Biologist for the Resource Ecology & Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, National Atmospheric and Oceanic Administration, Seattle, Washington. Ormseth is scheduled to defend his dissertation, "Reproductive Potential of Pacific Cod," on October 10, 2007.

Presentations

Ormseth, O.A. 2006. Life history variation in Pacific cod. Seminar, Alaska Fisheries Science Center, Seattle, Washington, 26 September 2006.

Ormseth, O.A. and B.L. Norcross. 2006. On the reproductive potential of Pacific cod in Alaskan waters. Oral presentation, 24th Lowell Wakefield Fisheries Symposium "Resiliency of Gadid Stocks to Fishing and Climate Change," Anchorage, Alaska, 31 October–3 November 2006.

Ormseth, O.A. and B.L. Norcross. 2006. Cause and consequence of life history variation in North American Pacific cod stocks. Oral presentation, 24th Lowell Wakefield Fisheries Symposium "Resiliency of Gadid Stocks to Fishing and Climate Change," Anchorage, Alaska, 31 October–3 November 2006.

Ormseth, O.A. 2007. Reproductive potential of Pacific cod in Alaska: maternal and area effects. Oral presentation, Pacific cod technical workshop, Alaska Fisheries Science Center, Seattle, Washington, 16–17 April 2007.

Ormseth, O.A. and B.L. Norcross. 2007. Latitude, temperature, and growth: Implications for life history strategies of cod in the Pacific and Atlantic Oceans. ICES/PICES Early Career Scientist Conference, Baltimore, MD, 26–29 June 2007.

Publications

Manuscripts in preparation (first drafts completed)

Ormseth, O.A. and B.L. Norcross. Cause and consequence of life history variation in Pacific cod. Prepared for submission to *ICES Journal of Marine Science*.

Ormseth, O.A. and B.L. Norcross. Biochemical composition of eggs from Pacific cod (*Gadus macrocephalus*). Prepared for submission to *Marine Biology*.

Ormseth, O.A. and B.L. Norcross. Reproductive potential of Pacific cod (*Gadus macrocephalus*) in Alaska: maternal, year, and area effects. Prepared for submission to *Marine Ecology Progress Series*.

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.

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 Martin Dorn and Vidar Wespestad, former AFSC scientist. The scope of 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 Shen presented a poster of her work at the Alaska Marine Science Symposia in Anchorage in January 2007. In November 2006, Shen gave an oral presentation from the first chapter of her dissertation at the Lowell Wakefield Symposium. A manuscript from this work is under peer review. The abstract and major conclusions from the manuscript appear below.

Abstract. Walleye pollock (*Theragra chalcogramma*) is the target of one of the world's largest fisheries and is also an important prey species in the eastern Bering Sea (EBS) ecosystem. Little is known about the potential effects of fishing on the school characteristics and spatial distribution of walleye pollock. Few dedicated research surveys have been conducted during the pollock fishing seasons, so analysis of fishery data is only feasible approach to study these potential effects. We used acoustic data collected continuously by one fishing vessel from January to February 2003, which operated north of Unimak Island. Results from comparisons between early and late fishing periods showed that there were significant changes of pollock distribution at different scales. The schools were smaller and denser in the second period. Furthermore, the spatial distribution of schools became sparser, as evidenced by the lower frequency of occurrence of schools per elementary distance sampling unit and the increase in the averaged next neighbor distances (NNDs). However the average NND between schools within the cluster and the average abundance of a cluster did not change significantly. Variography was used to investigate the changes at the scale larger than 1 nautical mile (nmi). The increased range, nugget effect, and sill in the second period indicated changes of pollock spatial distribution, however it is unclear whether these changes are attributable to fishing or ecological process.

Conclusions. In summary, our results suggest the following operative hypothesis of pollock schooling behavior during the A season. Pollock aggregate into schools in the daytime and disperse at night during the spawning season. After about two weeks of fishing, the aggregation pattern changes both at the school scale and the scale larger than 1 nmi. Pollock aggregate in smaller but denser schools that have a patchier distribution in space. The changed

aggregation pattern may be due to commercial fishing or to biological changes in behavior and movement. It is unknown whether the increased patchiness of pollock is a persistent feature of the A season. This study is a first look at pollock schooling and the affects of fishing on pollock school distribution. The observations are somewhat limited, so it is difficult to draw strong conclusions. However, the results of this study suggest fishing may alter school distribution and density. We recommend further research be undertaken to better understand the relationship between fishing removals and the subsequent reduced spatial extent of the pollock is affecting the foraging ability of Steller sea lions and other predator species dependent on pollock.

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 have presented 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 Fairbanks.

Some work was done at the Alaska Fisheries Science Center (AFSC) in Seattle, Washington (most recently, a one-week visit by Haixue Shen in May 2007). As mentioned above, an AFSC scientist, Martin Dorn, is serving as a member of 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

Haixue Shen, a Ph.D. Fisheries student at UAF, began working on this project in August 2004 under the supervision of Professor Quinn.

Oral presentation

Shen, H., T.J. Quinn II, V. Wespestad, M.W. Dorn and M. Kookesh. 2006. Schooling changes of EBS walleye pollock during fishing. Lowell Wakefield Symposium on Resiliency of Gadid Stocks to Fishing and Climate Change, Anchorage, Alaska, 31 October–3 November 2006.

Poster presentation

Shen, H., T.J. Quinn II, V. Wespestad, M.W. Dorn and M. Kookesh. 2007. Using EDSU to investigate the spatial structure of walleye pollock (*Theragra chalcogramma*) schools in the eastern Bering Sea. Marine Science in Alaska: 2007 Symposium, Anchorage, Alaska, January 2007.

Publications

In review

Shen, H., T.J. Quinn II, V. Wespestad, M.W. Dorn and M. Kookesh. Schooling changes of EBS walleye pollock during fishing. Proceedings of the 2006 Lowell Wakefield Symposium, Alaska Sea Grant College Program, Fairbanks, Alaska. [Manuscript submitted in November 2006, peer-reviewed, revision submitted July 2007.]

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 30 June 2008.

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.

Research accomplishments/highlights/findings

- Completed analysis of video data from 26 Delta submersible dives conducted by NOAA's Auke Bay Laboratory on the Albatross Bank and Portlock Bank sites. The analysis included dives on Albatross Bank in 2005, as described in our FY06 report, five dives on Portlock Bank in 2001, and one dive on 8-Fathom Pinnacle in 1999. The standard dive length was 1800 meters. Video frames were selected by advancing one field of view per frame, to produce continuous coverage of the seafloor. In all, more than 18,000 frames were analyzed. This analysis included fish species, invertebrate classes, invertebrate coverage and relief, substrate type, and seafloor slope and vertical relief. Data were recorded using C-Map Systems Video Ruler DVD software (version 7.3.4) that had been customized for NOAA's Auke Bay Laboratory. Navigation for each dive was edited for quality control.
- Began analysis of the NOAA trawl data (RACEBASE and NORPAC) and submersible video data, using PRIMER software for multivariate statistics. These data are also being compared with substrate habitat maps previously constructed from geologic interpretation of multibeam sonar data.

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 have supported 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 FY05 and FY06. He has completed all coursework toward the degree, and is currently focused on his thesis research (this project).

During FY07 and FY08, 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.

In FY07, Rooney's professional development included formal training in the PRIMER software for multivariate statistical analysis; this software is widely used in fisheries research. He attended the annual meeting of the Western Society of Naturalists (WSN), and the annual community meeting of the Deep Submergence Science Committee (DeSSC) which advises the National Science Foundation and Woods Hole Oceanographic Institution on management and use of the Alvin submersible, Jason ROV, and ABE AUV. Rooney also attended the Marine Habitat Mapping Technology Workshop for Alaska, sponsored by the North Pacific Research Board. Rooney's attendance at this meeting was supported by funds from Alaska Sea Grant.

The presentation and publication listed below, on *Nereocystis luetkeana* holdfasts, were developed from research during a Kelp Forest Ecology dive class at the Kasitsna Bay Laboratory (a NOAA facility operated jointly by NOAA/NOS and UAF). They are listed in this report because they represent part of Rooney's overall professional development, one of the purposes of this CIFAR grant.

Poster presentation

Rooney, S.C. 2006. Patterns of macroinvertebrate distribution within *Nereocystis luetkeana* holdfasts. Presented at the Western Society of Naturalists 87th Annual Meeting, Redmond, Washington, 9–12 November 2006.

Publications

Submitted

Rooney, S.C. and B. Konar. Patterns of macroinvertebrate distribution within *Nereocystis luetkeana* holdfasts. Submitted to *Aquatic Biology*.

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 complete except for travel to present results at the American Fisheries Society annual meeting in September 2007. This will serve as a final report on both projects.

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

- Projects were essentially complete in 2006 except for manuscript and presentation preparation.

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.

Education/outreach

Student participation

Julie Nielsen, 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., S.J. Taggart and T.C. Shirley. 2007. Using a synthetic aperture acoustic telemetry method to determine the location, timing and spatial aggregation of female Tanner crabs during reproductive events. Alaska Marine Science Symposium, Anchorage, January 2007.

Publications (over the life of the project to date)

Non-peer-reviewed

Nielsen, J.K. 2005. Distribution and Movement of Juvenile Tanner Crabs *Chionoecetes bairdi* in Glacier Bay National Park. Master's Thesis, University of Alaska Fairbanks School of Fisheries and Ocean Sciences. *(FY06; previously reported)*

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. Accepted pending revisions, ICES Journal of Marine Science.

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.

Follow-up
Julie Nielsen is currently employed as a Fishery Biologist with the U.S. Geological Survey. She has accepted a position as Research Professional with the University of Alaska Fairbanks School of Fisheries and Ocean Sciences, beginning in October 2007, to work with Nicola Hillgruber on a new CIFAR project "Characterizing Movement Patterns of Atka Mackerel Using Ultrasonic Telemetry: A Pilot Study."

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 year we continued to parse the chemical data into inshore, middle shelf and offshore regions to enable across shelf comparisons. We also spent considerable time to register the data so that the surface underway data could be merged with the towed SeaSoar data.

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.

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.

Publications
No publications were prepared during the reporting period. A presentation is being planned for an upcoming national meeting.

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 34-088and 35-088a: Together these awards support three separate projects. New funding for the current reporting period was through a direct Memorandum of Understanding to IARC rather than through CIFAR. Thus, reports on new field work during the 2007 shipboard field season have been submitted directly to NOAA. This report is for the work done with funds received through CIFAR only and will be the "final" report for these CIFAR projects.

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.

Research accomplishments/highlights/findings

Two papers based on this work were published in Journal of Marine Systems.

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 dissolved organic carbon (DOC) and colored dissolved organic matter (CDOM), particulate matter (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 (four joint U.S.–Russia cruises in the Siberian seas have already been accomplished since 2003). Cooperation with Stockholm University is also in progress.

Publications

Peer-reviewed

Semiletov, I., I.I. Pipko, I.A. Repina and N. Shakhova. 2007. Carbonate dynamics and carbon dioxide fluxes across the atmosphere-ice-water interfaces in the Arctic Ocean Pacific sector of the Arctic. *Journal of Marine Systems*, 66 (1-4):204–226.

Shakhova, N. and I. Semiletov. 2007. Methane release and coastal environment in the East Siberian Arctic shelf. *Journal of Marine Systems*, 66 (1-4):227–243.

Accepted

Macdonald, R.W., L.G. Anderson, J.P. Christensen, L.A. Miller, I.P. Semiletov and R. Stein. The Arctic Ocean: budgets and fluxes. Accepted as a chapter to be published in: K.-K. Liu, L. Atkinson, R. Quinones and L. Talaue-McManus, Eds., Springer-Verlag.

Submitted

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.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*.

Reference

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, Vladimir Alexeev
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.

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 *Kapitan Dranitsyn*: The International Arctic Research Center at the University of Alaska (USA), in cooperation with DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies) (Europe), the Russian Foundation for Basic Research, the Russian Ministry of Science and Education and the Obukhov Institute of Atmospheric Physics (Russia), conducted an Arctic expedition for K–12 teachers from August 21 to September 15, 2006. This Arctic Expedition is concurrent with the fifth scientific cruise to the Arctic Ocean of the Nansen Amundsen Basins Observation System (NABOS) program that is funded by NOAA, NSF and JAMSTEC (Japan Agency for Marine-Earth Science and Technology). The Arctic Expedition was offered as University of Alaska course NRM 595/ED595 on "Climate Change in the Arctic Ocean" with instruction and guidance from an international team of experienced polar researchers specializing in disciplines such as oceanography, meteorology, biology, chemistry, and arctic paleoclimate. The pre-college teachers were provided a unique opportunity to learn about and engage in high-latitude Arctic climate change research and to gain a better understanding of how scientific research is done in practice. Vladimir Alexeev, IARC, provided a major role in organizing and instructing in this program. He gave lectures on modeling, worked with K–12 teachers on a modeling project, and participated in marine field work with other scientists and students.

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 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/for_educators/arctic_expedition_2006/

Web sites

http://nabos.iarc.uaf.edu/cruise/2006/

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:
Karen Brewster, *University of Alaska Fairbanks*
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 these rivers and the 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

- Four stands of *Picea glauca* along the Kuskokwim were marked and measured and analysis of these trees are in progress (M.A. student S. Winslow).
- The rate of growth of white spruce is exceptional along the Yukon and Kuskokwim river floodplains. Mean radial growth of all Yukon trees across all years was almost exactly 1 mm/yr (based on measurements of 147 trees from 7 stands cored in 2002). Mean radial growth of all Kuskokwim trees across all years was between 1.14 and 1.47 mm/year (based on 58 trees from 4 stands). This finding shows there is a clear difference between upland and floodplain white spruce growth in interior Alaska.
- A strong common signal is present in the Yukon floodplain sample, with distinctive regional patterns along the length of the river sampled. The common signal was predominately made up of major growth reductions in particular "pointer" years, especially 1827, 1845 or 1846, 1868:69, 1872, 1888, 1912, 1924, 1934:37, 1954, 1969:70, 1978, and 1987. Cell abnormalities consistent with mechanical trauma are present in some of the pointer years.
- Crossdating of driftwood samples is continuing. This allows us to refine crossdating techniques and shows that transit times of drift logs span a relatively large range between 4 and 60 years, which is partly related to how far from their origin logs were collected.
- June 2007, fieldwork expedition on the Tanana and Yukon River:
    - Coring of ten new stands of white spruce (*Picea glauca*) evenly spaced between Fairbanks and Marshall: two on the lower Tanana River and eight on the Yukon between Tanana and Marshall (about 200 trees measured and cored)
    - Sampling of one driftwood accumulation on the Tanana River and three on the Yukon River (about 50 samples)
    - Sampling of driftwood logs from people's firewood piles in Galena, Nulato and Marshall (about 25 samples)
    - Recording Oral History interviews with elders and wood users along the Yukon River (10 individuals for a total of 7 interviews)

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 (Glenn P. Juday, principal collaborator). Traditional carvers from Native Villages of Hooper Bay, Scammon Bay, and Napakiak are local collaborators.

Education/outreach

Student participation

This award supported M.A. student Steve Winslow's travel for summer fieldwork on the Yukon River related to this project.

Public outreach

- Alaska Science Forum article #1855 by Ned Rozell "Scientists to take driftwood expedition this summer" (http://www.gi.alaska.edu/ScienceForum/ASF18/1855.html). This article was also published in local newspapers in Sitka, Anchorage and Fairbanks. May 2007.
- In June 2007, Public presentations were given in villages along the Yukon River by C. Alix, G. Juday and K. Brewster at the Louden Tribal Council in Galena (June 19), at the Community Hall in Grayling (June 26), and at the Annual Meeting of Macerculiq Incorporated in Marshall (June 30).

Presentations

Seminars and workshops

Alix, C. 2006. Conduite des recherches en milieu nordiques et cas particulier du programme Anthropobois (Conducting research in Arctic Settings: the case of "Driftwood and Humans in the North" Project). Graduate

Seminar in Precolumbian Archaeology, University of Paris, 1 Panthéon Sorbonne, Paris, France, 13 November 2006.

Alix, C. 2006. Archaeology of wood remains and tree-ring research in the North American Arctic. 6th International Winter School on Wood Anatomy of Tree-ring. Davos Laret, Switzerland, 19–25 November 2006.

Alix, C., G.P. Juday and K. Brewster. 2007. Tree-ring research on driftwood and ethnoarchaeology of wood use in Alaska. International Arctic Research Center Seminar, 28 February 2007.

Alix, C., G.P. Juday and K. Brewster. 2007. Tree-ring research on driftwood for the study of human use of wood in Alaska. Department of Geology and Geophysics Seminar, University of Alaska Fairbanks, 9 March 2007.

Paper at International Conference

Alix C. 2006. "Wood is Food" Importance du bois et fabrication des instrument de chasse en milieu arctique. (Wood is food – The importance of wood and the making of hunting implements in Arctic environment). Oral presentation at XXVIIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes: Les civilisations du renne d'hier et d'aujourd'hui. Approches ethnohistoriques, archéologiques et anthropologiques. Antibes, France, 19–21 October 2006.

Poster at International Conference

Juday, G. and C. Alix. 2007. Environmental signal focused in pointer years in Yukon River white spruce. Disturbance Dynamics in Boreal Forests VI: International Conference on Climate Change Impacts on Boreal Forest Disturbance Regimes. Fairbanks, Alaska, 30 May–2 June 2007.

Publications

In press

Alix, C. Ethnoarchéologie de la production des object en bois dans l'Arctique.nord-américain (Ethnoarchaeology of the production of wooden objects in the North American Arctic). Les Civilisations du Renne d'Hier et d'Aujourd'hui – Approches Ethnohistoriques, Archéologiques et Anthropologiques. XXVIIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Ed. S. Beyries and V. Vaté. Editions APDCA, Antibes, in press.

In preparation

Alix, C. and G.P. Juday. Use of master chronologies from Alaska rivers to date Arctic Driftwood. In preparation.

Juday, G.P. and C. Alix. Growth and growth history of *Picea glauca* on the Yukon River floodplain. Planned for submission to Canadian Journal of Forest Research.

Bering Strait: The Pacific–Arctic Ocean Connection: RUSALCA 2006

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

CIFAR 42-082a: 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 3 moorings deployed in the western channel (Russian Exclusive Economic Zone, EEZ) in August 2006,
2) replace these moorings with 1 new mooring containing an Acoustic Doppler Current Profiler (ADCP) and temperature-conductivity-fluorometer (T/C) recorder, and an In Situ Ultraviolet Spectrophotometer (ISUS) nitrate analyzer,
3) supplement the two Russian moorings (under the direction of I. Lavrenov of the Arctic and Antarctic Institute) with T/C recorders and ADCP current meters,
4) continue collaborating with Rebecca Woodgate (U. Washington), who is making similar measurements in the U.S. EEZ (eastern channel of Bering Strait) with support from the NSF.

Approach/methodology

Our approach involves making measurements of the salinity, temperature, velocity, fluorescence, and nitrate in the western channel of Bering Strait at hourly intervals for a period of one year. The measurements are and will continue to be made from three moorings deployed across the western channel of Bering Strait. Each 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 in the center of the strait will include a fluorometer and a nitrate sensor. This mooring at about 65 53.8'N, 169 25.9'W is the approximate position of the A1 mooring previously deployed in the western channel under this program and is linked to historical deployments made in the strait in the early 1990s (Roach et al. 1995).

Research accomplishments/highlights/findings

- The moorings that were deployed in August 2005 were recovered in August 2006 and three moorings were deployed on this cruise. These will be recovered in August 2007.
- CTD (conductivity, temperature, depth) profiles and nutrients were collected on a hydrographic transect conducted across the strait.
- We are continuing our processing of the moored and hydrographic (shipboard) data. Aspects of these data along with those collected by R. Woodgate in the eastern channel of the strait were presented in a talk entitled "Bering Strait: The Pacific-Arctic Connection" at the Arctic Frontiers Conference, Tromso, Norway on 23 January 2007.
- We obtained the first year-round record of nitrate concentration in Bering Strait in 2006–2007, which will allow us to better understand variability in nitrate fluxes through the strait.
- Moored fluorescence data suggest that the spring bloom began in late April.
- We published a paper in Geophysical Research Letters addressing: 1) potential interannual variations in steric forcing in Bering Strait and 2) the sources of salt and freshwater for Bering Strait.

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 complement those obtained from moorings in the eastern channel (U.S. 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

Student participation

This project is also providing partial support to an undergraduate student at the University of Alaska. Kevin Taylor is a third-year physics major and has participated in the cruise to Bering Strait and assisted in the mooring preparation and the hydrographic data collection.

Presentation

Lavrenov, I., T. Weingartner, T. Whitledge, R. Woodgate and K. Aagaard. 2007. Bering Strait: The Pacific–Arctic connection. Invited presentation at the Arctic Frontiers Conference, Tromso, Norway, 23 January 2007.

Project website

Our data and findings are being combined with those of Rebecca Woodgate, who is maintaining a joint project website: http://psc.apl.washington.edu/HLD/Bstrait/bstrait.html

Publication

Peer-reviewed

Aagaard, K., T.J. Weingartner, S.L. Danielson, R.A. Woodgate, G.C. Johnson and T.E. Whitledge. 2006. Some controls on flow and salinity in Bering Strait. *Geophysical Research Letters*, 33, L19602, doi:10.1029/2006GL026612.

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 ***NOAA Goal: Understand Climate Variability and Change***
University of Alaska Fairbanks

CIFAR 47-081a: 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 2 include continuations of dataset development and analyses of arctic regional climatic / hydrologic changes. We have made significant progress during the second year. We have focused our effort on dataset developments and analyses. Up to spring 2007, we have acquired long-term records for temperature, precipitation, snowcover, river streamflow for the largest arctic watersheds (i.e., the Ob, Yenisei, Lena, Yukon and Mackenzie basins), and river ice thickness data for large Siberian rivers. Snowcover data are the key for this project; we have updated remotely sensed snow data, including visible snow cover extent and Special Sensor Microwave/Imager (SSM/I)/snow water equivalent (SWE).

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

The seasonal changes of the Lena basin SWE and streamflow in each individual year are shown in Figure 1. They clearly indicate a general response of river discharge to seasonal snowcover changes over the Lena river, 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, Lena river peak flows during the spring melt season were high in 1989 and low 1999, while the maximum basin SWE were

very close to each other (about 110–125 mm) for these two years. This discrepancy between basin snowcover and streamflow variations raises an important question for this research.

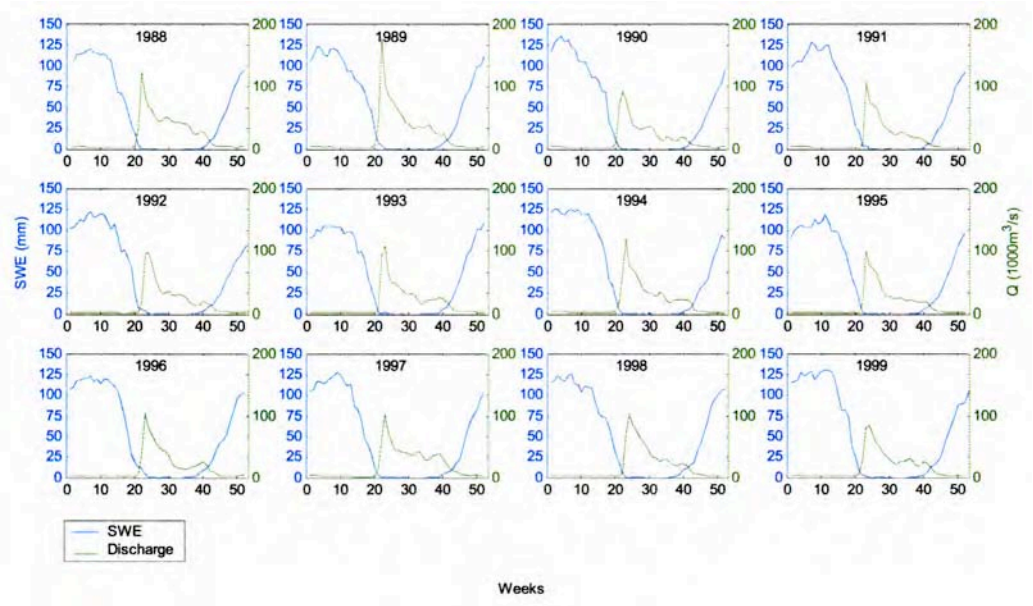

Figure 1. Comparisons of basin snow water equivalent (SWE, mm) with river discharge (Q, m^3/s) for the Lena basin during 1988–1999 (from Yang et al. 2007).

We have also examined interactions of snowfall and river discharge over the northern regions. We want to quantify the impact of rain-on-snow events, changes in rainfall and snowfall days on river discharge variation. With a warming climate, the numbers of both rainfall and snowfall days and rain-on-snow events are expected to change. The directions of these changes depend on the geographical location and the seasons. Changes in these variables have significant impacts on seasonal characteristics of river discharge under a warming climate.

We have acquired historical synoptic weather observations over Siberia. The synoptic weather data are from the Six- and Three-Hourly Meteorological Observations from 223 USSR Stations available at Carbon Dioxide Information Analysis Center (CDIAC), Oak Ridge National Laboratory, Oak Ridge, Tennessee (ORNL/CDIAC-180, NDP-048/R1; ftp from cdiac.esd.ornl.gov). Each station records consist of 6- (1936–1965) and 3-hourly (1966–1990) observations of 24 meteorological variables, including temperature, past and present weather type, precipitation amount, cloud amount and type, sea level pressure, relative humidity, wind direction and speed, plus ground cover condition. This dataset enables us to extract useful information regarding the precipitation conditions and compile the time series of precipitation variables at 80 stations for the time period of 1936–1989.

Our preliminary analyses of the data show that rain-on-snow events mostly concentrated on the European part of Russia—most likely to impact the Ob and Yenisei river basins during spring and fall, and the small river basins over west side of the Ural mountain during winter. The warming air temperatures are found to be associated with increasing rain-on-snow events and total rainfall days over European Russia, while numbers of snowfall days have not been significantly affected by air temperature in this region. We are looking for other sources of data to update meteorological time series to more recent years.

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

Student participation

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

Presentations

Yang, D. 2006. Streamflow response to seasonal snowcover change over the large northern rivers. American Geophysical Union Fall Meeting, San Francisco, California, December 2006.

Ye, H., et al. 2006. AIRS total precipitable water over high latitudes. American Geophysical Union Fall Meeting, San Francisco, California, December 2006.

Robinson, D.A. 2007. Improved monitoring of hemispheric snow cover extent. The 19th Conference on Climate Variability and Change, American Meteorological Society, San Antonio, Texas, January 2007.

Yang, D. 2007. Yukon River streamflow response to seasonal snowcover changes. American Water Resource Association Alaska Annual Meeting, Fairbanks, Alaska, 3–5 April 2007.

Robinson, D.A. 2007. A hemispheric snow cover extent climate data record. Annual Meeting of the Association of American Geographers, San Francisco, California, April 2007.

Yang, D. 2007. Challenges in understanding arctic hydrology system changes. Asia CliC Workshop, Yokohama, Japan, 17–19 May 2007.

Publications

Peer-reviewed

Yang, D., Y. Zhao, R. Armstrong, D. Robinson and M. Brodzik. 2007. Streamflow response to seasonal snowcover mass changes over large Siberian watersheds. *Journal of Geophysical Research–Earth Surface,* 112:F02S22, doi:10.1029/2006JF000518.

In press

Ding, Y., D. Yang, B. Ye and N. Wang. Effects of bias correction on precipitation trend over China. *Journal of Geophysical Research–Atmospheres,* in press.

Majhi, I. and D. Yang. Streamflow characteristics and changes in Kolyma basin in Siberia. *Journal of Hydrometeorology,* in press.

White, D., L. Hinzman, L. Alessa, J. Cassano, M. Chambers, K. Falkner, J. Francis, W. Gutowski, M. Holland, M. Holmes, H. Huntington, D. Kane, A. Kliskey, C. Lee, J. McClelland, B. Peterson, T.S. Rupp, F. Straneo, M. Steele, R. Woodgate, D. Yang, K. Yoshikawa and T. Zhang. The Arctic freshwater system: changes and impacts. *Journal of Geophysical Research–Biogeosciences,* in press.

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 complete. See previous annual reports for research results.

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.

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 has supported the work of an Oceanography Master's degree student, Molly Boughan. She is expected to complete and defend her thesis in the next year.

Presentations

Boughan, M.L. and B.P. Finney. 2006. Understanding paleoclimate shifts in the Gulf of Alaska using foraminiferal-based paleoceanographic methods. 102nd Annual Meeting of the Cordilleran Section, GSA, 81st Annual Meeting of the Pacific Section, AAPG, and the Western Regional Meeting of the Alaska Section, SPE, 8–10 May 2006. *(Not reported in FY06)*

Publications

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. 2007. Bottom-up forcing and the decline of Steller sea lions in Alaska: Assessing the ocean climate hypothesis. *Fisheries Oceanography*, 16(1):46–67.

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 49-060b: 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 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

- A biophysical mooring deployed in fall 2004 southwest of St. Lawrence Island (see previous reports) was successfully retrieved in July 2006 and a new mooring was deployed at the same location. This mooring was again recycled during the fall of 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 Jim Overland at NOAA/PMEL and 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).

Education/outreach

Public awareness

Jackie Grebmeier was featured on program #5183 of the Earth & Sky Radio Series entitled "Major Ecosystem Shift in Arctic Seas," which aired on National Public Radio on April 24, 2007.
(http://www.earthsky.org/radioshows/51235/major-ecosystem-shift-in-arctic-sea)

Student participation

- 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 2003–2007.

K–12 outreach

- Betty Carvellas, a high school science teacher from Essex Junction, Vermont, participated in the 2004–2007 *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 students at Oak Wood Middle School in Greenville, North Carolina in September 2006 as well as at Union Vale middle school in LaGrangeville, New York in January 2007.

Publications

Peer-reviewed

Grebmeier, J.M., L.W. Cooper, H.M. Feder and B.I Sirenko. 2006. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. *Progress in Oceanography*, 71:331–361.

Grebmeier, J.M. and J.P. Barry. 2007. Benthic processes in polynyas. In: W.O. Smith, Jr. and D.G. Barber, Eds., *Polynyas: Windows to the World*, Elsevier Oceanography Series, Volume 74, pp. 363–390.

Accepted

Crane, K. and J.M. Grebmeier. The Pacific Arctic Group, October 11–12, 2006, Shanghai, China meeting report. Accepted for publication in *EOS, Transactions, American Geophysical Union*.

Submitted

Cooper, L.W., C. Lalande, R. Pirtle-Levy, I.L. Larsen and J.M. Grebmeier. Seasonal and decadal shifts in particulate organic matter processing and sedimentation in the Bering Strait Shelf region. In revision. Submitted to the 2nd SBI Special Issue, *Deep-Sea Research II*.

Grebmeier, J.M., L.W. Cooper, R. Pirtle-Levy and R. Brown. Benthic community structure, carbon cycling and shelf–basin exchange in the Chukchi and Beaufort seas during 2002 and 2004. Submitted to the 2nd SBI Special Issue, *Deep-Sea Research II*.

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 30 June 2008.

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 are 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 are to 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

- Large-scale observations based on the multibeam sonar data include the following: A small number of flank vents are observed, but Bogoslof does not have well-developed flank rift zones characteristic of larger submarine volcanoes. Instead, the great majority of volcanic eruptions on Bogoslof occur through vents on the summit platform, where Bogoslof Island and Fire Island are located. These summit eruptions do create hard substrate on the uppermost slopes. For example, a single lava flow crosses the south edge of the summit platform, and short ridges observed on the uppermost slope are either blocky lava flows or piles of blocky debris originating at the summit. Most of the volcanic products that end up on the seafloor are debris of various sizes, rather than intact lava flows. The submarine slopes to 750 m depth are dominated by downslope transport of volcanic debris and erosion of bedrock into knife-edge ridges. Debris fans blanket the seafloor between these ridges, and are expected to include the volcanic products from historical eruptions. Finer-scale interpretation of the seafloor morphology, prediction of benthic habitat, and assessment of seafloor age are ongoing.
- We have acquired video recordings from two Phantom ROV dives on the upper slopes of Bogoslof (90–230 m) conducted by Rick Brodeur in 1995. These videos show clear differences in substrate and invertebrate colonization between the two sites, as well as along-track changes in the second dive. The dive navigation appears to be excellent, as changes in seafloor character observed in the dive video match features in the new multibeam sonar data. These dives provide valuable constraints on geological and habitat interpretation of the new maps.

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 Zimmermann, fisheries biologist at NOAA's Alaska Fisheries Science Center (Seattle), and Jennifer Reynolds, marine geologist at 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.

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#041	Sept 2006	Miller Freeman	M2_13.5m	good
ISUS#077	Sept 2006	Miller Freeman	M2_61m	good
ISUS#041	April 2007	Miller Freeman	M2	in water
ISUS#077	April 2007	Miller Freeman	M4	in water

ISUS #041 and #077 will be recovered in September 2007. ISUS instruments will be placed on M2, M5 and M8 while a NAS instrument will be placed on M4 by PMEL. If sufficient instruments are available, two ISUS instruments will be placed on M2 mooring.

NOAA relevance/societal benefits

The biophysical moorings at the M2 and M4 sites are the only long term observations (1995–2007) 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.

Research linkages/partnerships/collaborators and networking

This work is being done in collaboration with Phyllis Stabeno and Jeff Napp, NOAA/PMEL.

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

- Three additional data sets from the 1960s were located and they are in the process of being entered manually into electronic format. These data sets will partially fill a rather large three-decade data gap. The manual labor to enter the data is large but the effort will bring these data back for more widespread use.

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 Jim Overland at NOAA/PMEL and 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).

Publications

In press

Lee, S.H., T.E. Whitledge and S.-H. Kang. Recent carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. C*ontinental Shelf Research*, in press.

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.

Tsunami Research

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, Mitch Robinson, John Sandru, Natalia Ruppert, Artak Martirosyan and Morgan Fowler, *University of Alaska Fairbanks*

CIFAR 44-013e: 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, several CREST seismic or communication sites needed attention for either routine maintenance or hardening for harsh weather. Site visits are listed below:
  - BESE (Besse Mt. near Juneau) – Repair bear damaged cable.
  - BMR (Bremner River – east of Valdez) – Inspected site. All OK.
  - COLD (near Coldfoot) – GPS timing antenna failed, replaced.
  - DCPH (Deception Hills seismic station south of Yakutat) – Telemetry problems, data intermittent.
  - DIV (Divide – East of Valdez) – Replace bad GPS unit.
  - DOT (Dot Lake) – UPS and micro-serial server failure.
  - EYAK (near Cordova) – Inspected site.
  - FALS (near False Pass) – Installed UPS and replaced micro-serial server. Inspected station.
  - GAMB (Gambell) – Site currently down, visit scheduled later this summer.
  - PAX (Paxson) – Replace lightning damaged power supply and phone circuit.
  - PIN (Pinnacle – north of Yakutat) – Replaced damaged solar panels, repaired wind charger, added batteries, improved communications link.
  - SPIA (St. Paul Island) – Data telemetering, no visit required.
  - SWD (Seward) – Replaced bad modem. Installed UPS.
  - TNA (Tin City) – All OK.
  - ATKA (Atka Island) – Phone line for communications is out. Tried to upgrade to digital through USGS, not able to. A DSL service may be the answer, to be addressed later this summer.
  - UNV (Unalaska) – Broadband OK, Strong motion noisy on two components.
  - PPLA (Purkeypile) – All OK.
  - NIKO (Nikolski) – Power outage over winter, back up and working. Site relocated summer 2007, waiting comm circuit.
  - Yakutat – NOAA weather service building roof blew off last year. Communications hub at NOAA weather service tower inspected and maintained. Upgraded antennas. Serviced radios and router.
- In the past year we have begun upgrading and expanding the broadband seismic network. NIKO was originally located where the village would allow us, in the vicinity of the town. We now have permission to be located at a bedrock site farther out of town toward the hill of a previously used Air Force facility. This has been installed, and should give much better data with respect to sensitivity, bandwidth, and cultural interference. We have begun the process to install a station on Chirikof Island. The permitting process is begun, and a radio relay site

has been permitted to transmit the data into the Coast Guard facility in Ahkiok. As part of the relay site on Sitkinak Island, a second seismic station will be installed in the next month. In addition, we now have four new sites in the Interior of Alaska: upgraded sites at RAG (Ragged Mountain), and SKN (Skwentna), and 2 new sites at RIDG (Independence Ridge), and SCRK (Sand Creek), all waiting final telemetry connections.

- Additionally, this past year had a significant addition to the Alaska Tsunami Warning Center (ATWC) monitoring network. TWEAK purchased 6 portable underwater pressure sensors to be used for temporary deployment. They were first successfully deployed around the erupting Augustine Island volcano.
- The pilot VSAT (Very Small Aperture Terminal) project sites that were established during the last two years at the Bering Glacier Research Camp, Ultima Thule, and McCarthy worked through the year with some tender care. At Bering Glacier Camp, the power system failure, and a subsequent computer crash kept the system down a couple of months, however, and 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 to install two additional VSAT in McCarthy and Ultima Thule were quite successful. An improvement is being made to the power system this summer.

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 and FY06 continued in FY07.

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 51-014e 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.

a) b)

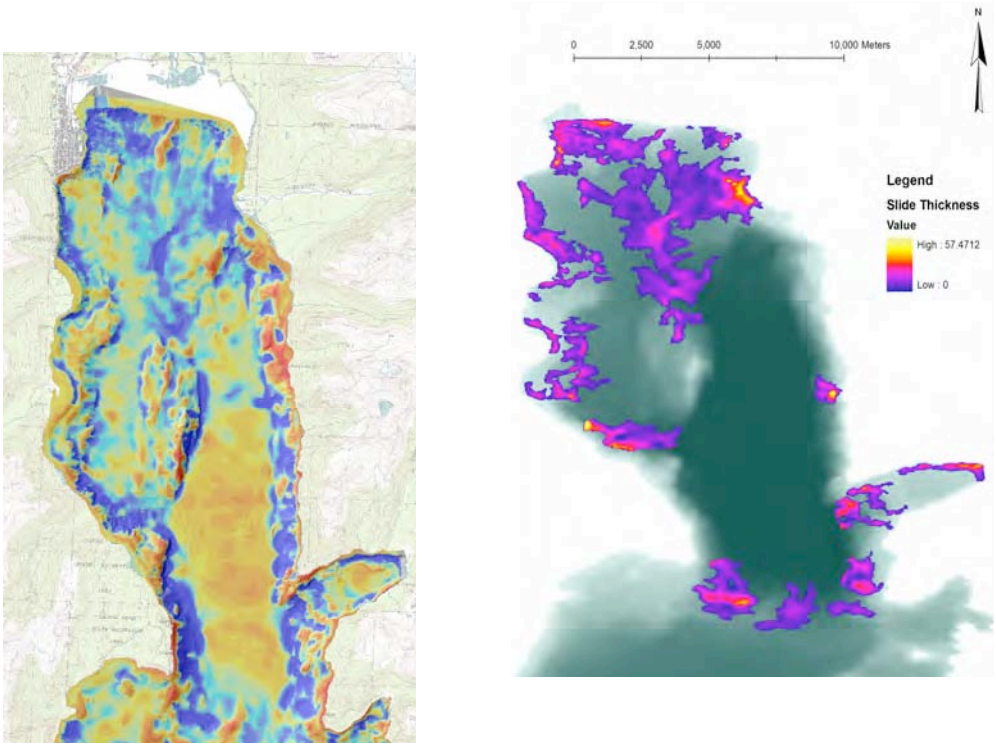

Figure 1. (a) Difference between pre-1964 bathymetric grid and 2001 multibeam survey. Cold colors indicate depth increase (loss of material), and warm colors indicate depth decrease (accumulation of material). (b) The map of initial slide thicknesses derived from bathymetric difference map (a). The minimum thickness of 5 meters was used to outline areas of underwater slope failures and for calculation of landslide volumes.

Research accomplishments/highlights/findings

- We are creating tsunami inundation maps for Seward, Alaska, in the scope of the National Tsunami Hazard Mitigation Program. We constructed a 5-m grid of combined topography and bathymetry for the northern part of Resurrection Bay. The data is of exceptional quality and includes (1) a 2006 LIDAR survey of the entire area of interest, (2) a 2001 multi-beam survey of the bathymetry of all of Resurrection Bay, and (3) a 2006 survey of the Seward harbor and surrounding areas. Gaps between the LIDAR and multi-beam surveys were minimal, with the exception of a shallow tidal area at the head of the bay. Where gaps exist, interpolation was used to create a smooth transition between the surveys.
- We collaborate with scientists from the USGS office in Anchorage, Alaska (Peter Haeussler and Keith Labay), to reconstruct the volumes and locations of underwater slope failures in Resurrection Bay that were triggered by the 1964 earthquake. All pre-1964 (1905 to 1961) bathymetric surveys from NOAA smooth sheets were digitized, with corrections applied for coseismic subsidence, post-seismic uplift, sea level rise, and rounding errors. We then compared these to a 2001 NOAA multi-beam survey to assess the location and size of submarine slides. More than 100 million m^3 of sediment moved during the 1964 earthquake, with much of it flowing about 10 km to the south into a bathtub-shaped depression in the fiord bottom (Figure 1). There were four major slides in the bay with volumes in excess of 14 million m^3. A slide along the Seward waterfront, which is likely responsible for most of the initial damage, has a volume of about 19 million m^3, and left behind a blocky lag deposit.
- We have identified 10 major landslide complexes that failed during the 1964 earthquake and contributed to the tsunami waves observed in Seward downtown and in other locations in Resurrection Bay. To reconstruct the sequence of waves observed at Seward on March 27, 1964, we have modeled tsunami waves caused by multiple slope failures. We have calculated time series of tsunami wave action at Seward. The results for the arrival time and the amplitude of the highest wave are in good agreement with observations. The modeling results show that the entire floor of Resurrection Bay was repaved as a result of massive deposition of sediments as a result of

underwater landsliding. This is in agreement with seismic sub-bottom profile data showing an acoustically transparent unit, which we interpret as a megaturbidite deposited in the 1964 earthquake.
- We have completed the preliminary bathymetry and topography data assessment for inundation modeling of Sitka.

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
See report on TWEAK (Tsunami Warning and Environmental Observatory for Alaska) Education Outreach Activities by AEIC.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska) Education Outreach Activities by AEIC

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, Jamie Roush, Natasha Ruppert, *University of Alaska Fairbanks*

An element of CIFAR 45-047b: This work is ongoing.

Primary objectives and approach
The Geophysical Institute/Alaska Earthquake Information Center (AEIC) participates in the National Tsunami Hazard Mitigation Program (NTHMP) by evaluating and mapping potential inundation of selected parts of Alaska coastlines and providing education and outreach to educate the inhabitants. These efforts are in collaboration with the Division of Homeland Security and Emergency Management (DHSEM) and Alaska Tsunami Warning Center (ATWC), with consideration to local community involvement. Emergency managers need training along with tsunami evacuation maps for these communities, showing the extent of inundation with respect to human and cultural features, and evacuation routes.

Research accomplishments/highlights/findings
The Alaska Earthquake Information center conducted a wide range of education and outreach activities between July 2006 and June 2007. Many of our efforts focused on communicating with the public about tsunami hazards. Funding from the TWEAK program was used to plan visits to Alaskan coastal communities for the National Weather Service's Tsunami Ready outreach program, to develop informational brochures in partnership with the State of Alaska Division of Homeland Security and Emergency Management (ADHS&EM), to provide information to the public during tours of AEIC facilities and visits to local classrooms, to assist in the development of tsunami-related school curricula, and to provide communities with tsunami warning sirens.

A partnership with the ADHS&EM has been undertaken to develop of a series of informational brochures and other printed materials for public distribution. The objective of this work is to create materials that will provide the public with important safety information. Work has begun on a tsunami evacuation map for Kodiak that will also be used as a template for similar brochures in other communities. Evacuation brochures are also planned for Homer, Sand Point, Sitka, and Seward. Other publications that are being designed include "all hazards" brochure, "tsunami country" and "earthquake country" general brochures, and similar pamphlets for young children.

With support from TWEAK, AEIC continued to cooperate with the National Weather Service and the ADHS&EM in the Tsunami Ready community certification program. AEIC contributed to the program by participation in outreach visits and by acquisition of warning sirens for coastal towns. Planning and preparation were undertaken for upcoming outreach trips to the communities of Sand Point and King Cove. Warning sirens were purchased for Valdez and assistance was provided to ADHS&EM in the acquisition of sirens for St. Paul in the Pribilof Islands.

Staff from AEIC have worked with the Information Office at the UAF Geophysical Institute to create tsunami-related educational materials for Alaskan schools. A K–12 science curriculum entitled the Alaska Tsunami Education Program (ATEP) is being developed for the Aleutians-East and the Lake & Peninsula school districts. The curriculum materials will help schools meet content standards in math and science at multiple grade levels and they are being designed to be culturally relevant for Alaska Native peoples. AEIC staff have contributed knowledge and expertise in the development of science lessons and provided critical review of content. AEIC has also provided staff for "mentor lectures" via video teleconference to participating schools.

The most basic and ongoing outreach efforts conducted by AEIC were also supported by TWEAK. This included the conduct of public tours of the Seismology Lab at the UAF Geophysical Institute, the operation of an earthquake information booth at the state fair, and visits to classrooms in Fairbanks area schools. AEIC staff led weekly public tours of our facilities in June, July and August as well as tours by special arrangement for school groups throughout the year. During tours, visitors to AEIC were provided with information about earthquake and tsunami hazards as well as an overview of our operations. Similar information was provided to the public at our information booth at the Tanana Valley State Fair in August. Throughout the year, groups of students from local schools also visited AEIC to participate in demonstrations using our "earthquake machine" and to learn about tectonics, seismicity, and tsunamis.

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.

Conference presentation

Suleimani, E., H. Lee, P. Haeussler and R. Hansen. 2006. Numerical modeling of submarine landslide-generated tsunamis as a component of the Alaska tsunami inundation mapping project. American Geophysical Union Fall Meeting, San Francisco, California, 11–15 December 2006.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska): Tsunami Code Development

Roger Hansen, PI
Zygmunt Kowalik, Co-PI and task lead
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:
James Beget, Juan Horrillo, Tatiana Proshutinsky, Sathy Naidu, *University of Alaska Fairbanks*

An element of CIFAR 45-074b: 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 for the two-dimensional vertically integrated equations of motion and continuity. 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 2005–2007, 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 model and dispersive models were compared against the 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). 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 (Horrillo et al. 2006). Investigations into dispersive models in 2006–2007 were aimed at: a) constructing a simple dispersive set of equations which can be implemented into everyday prediction and warning at WA/ATWC, and, b) constructing 3-D dispersive models based on the vertical equation of motion. In the latter topic our team cooperates with Ph.D. student Y. Yamazaki from the University of Hawaii.
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). 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. During 2006–2007 the model of tide/tsunami interaction for Port Valdez has been run and data are being analyzed.
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. During 2006–2007, we continued modeling submarine slides by implementing 3-D models.
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. 2007a, 2007b). This Global

Tsunami Model (GTM) was applied to test its skill in the simulation of the Indian Ocean tsunami (IOT) case of 26 December 2004, resulting in two publications (Kowalik et al. 2007a, 2007b).

In 2006–2007, we have used our model to investigate the tsunami generated near the Kuril Islands on November 15, 2006 at 11:14:16 (UTC) by an earthquake with a moment magnitude 8.3. Tsunamis propagated over the entire Pacific Ocean. The resulting sea level disturbance was recorded by DART (Deep-ocean Assessment & Reporting of Tsunamis) buoys located in the open ocean and by many coastal tide gauges, thus providing an opportunity to compare the model against an excellent set of data. We directed our effort toward explaining the tsunami record in Crescent City, California (CC). The sea level at CC initially surged up to 40–60 cm and 2–3 hours later the highest wave of about 90 cm amplitude was recorded. No other west coast tidal stations recorded such a high wave. To investigate tsunami behavior, we use energy flux. Energy flux, in contrast to the noisy tsunami sea level data, reveals uniform behavior in time and space. In addition, it contains information about signal direction, which is important for identification of the prominent bathymetric features as potential sources of tsunami wave refocusing. The energy flux function was applied to model investigations of the late arriving tsunami at CC. Simple numerical experiments reveal energy trapping and enhancement by the Mendocino Escarpment. These experiments define bathymetric features which scatter the tsunami signal towards CC via the Mendocino Escarpment. The Mendocino Escarpment serves as a very effective waveguide in delivering enhanced tsunami energy if the approaching tsunami signal travels from the west along the escarpment. To pinpoint the sources of the late arriving signal, a control volume is constructed around CC, and inflowing and outflowing energy fluxes are examined. The results were quite surprising, showing the key role played by two bathymetric features thousands of kilometers distant from CC (Koko Guyot and the Hess Rise) in refocusing tsunami signal towards CC. These prominent bathymetric features scattered, delayed and re-routed the tsunami signal more efficiently toward CC.

The model domain covered the entire Pacific Ocean extending from 80°S to 69°N. The model spatial resolution was 1 arc minute and its domain had approximately 100 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 2006–2007, major accomplishments were related to application of the energy balance in the Kuril Island Tsunami of November 15, 2006. An energy flux function proved to be very useful in defining causes of large tsunamis which arrived at Crescent City, California 2 hours after an initial signal. Extensive application of the energy balance equation to the Indian Ocean Tsunami of December 24, 2004 and to the Kuril Island Tsunami of November 15, 2006 allowed us to formulate a new method for prediction of the late arriving tsunamis.
- Therefore, Kowalik sent the following email message to tsunami researchers in the USA, Japan, Canada, India, Europe and Australia:

> *Dear Colleagues:*
> *Two recent transoceanic tsunamis: the Indian Ocean Tsunami of 12-26-04 (IOT) and the Kuril Tsunami of 11-15-06 (KT) produced late arriving signals often with amplitudes higher than the initial signal. Understanding and predicting these delayed energetic signals is important for tsunami warnings.*
>
> *Together with Juan Horrillo (UAF) and William Knight (WATWC and UAF), I have been analyzing these phenomena through an application of the energy flux - a notion borrowed from the field of tidal research.*
>
> *Our first application of the energy flux was made for the IOT (Kowalik, Z., Knight, W., Logan, T. and P. Whitmore, 2007. The tsunami of 26 December 2004: Numerical Modeling and energy considerations-II. In: Tsunami and Its Hazard in Pacific and Indian Oceans, Eds: Satake, K., Okal, E. A., Borrero, J. C., Pure and Applied Geophysics (PAGEOPH), vol. 164, No. 2/3, 379–393.)*
>
> *We have just finished an examination of the KT by studying its impact at Crescent City and have concluded that energy flux and energy balance can be important tsunami hazard mitigation tools for predicting and understanding the delayed tsunami signal. Although the manuscripts on the Crescent City impact will not be published for several months, application of this approach should not be delayed.*

The two manuscripts submitted for publication are:

Z. Kowalik, J. Horrillo, W. Knight, T. Logan, The Kuril Island Tsunami of November 2006, Part I: Impact at Crescent City by distant scattering.

J. Horrillo, W. Knight and Z. Kowalik, The Kuril Island Tsunami of November 2006 Part II: Impact at Crescent City by local amplification.

The purpose of this note is to spur your interest in the approach. By including energy flux in your models and by performing further testing, we hope to arrive at a comprehensive understanding of the energy flux method as applied to tsunami research. The paper on the IOS and manuscripts on Crescent City can be found on my website:
http://www.sfos.uaf.edu/directory/faculty/kowalik/

With best regards,
Zygmunt Kowalik

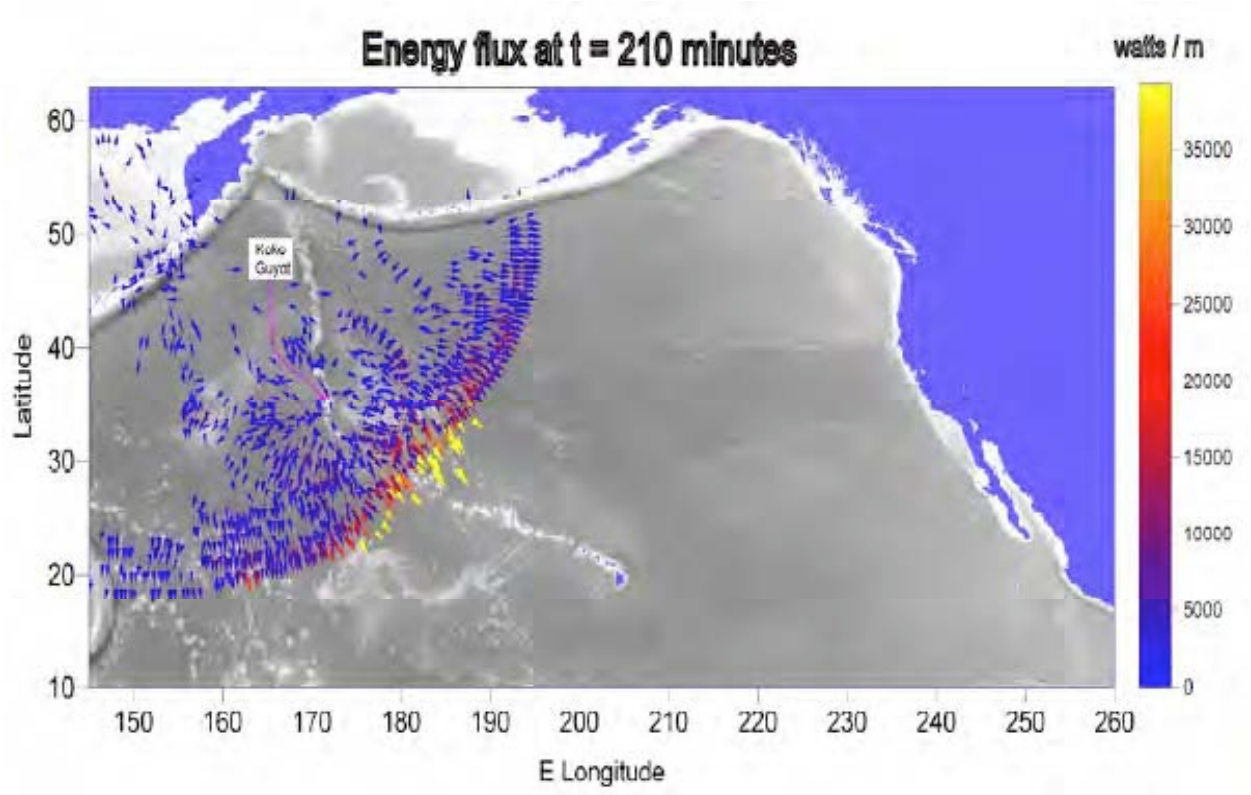

Figure 1. Kuril Tsunami of November 15, 2006. Energy flux vectors 3.5 hours after tsunami onset. Note radially expanding wave front centered on Koko Guyot. (Full explanation of energy flux application is given at http://www.sfos.uaf.edu/directory/faculty/kowalik/)

NOAA relevance/societal benefits

Numerical models are required to assess expected coastal tsunami impact, in amplitude, horizontal inundation distance and velocities, so that proper evacuation decisions can be made during tsunami warnings, as well as for long-term planning of coastal zone development. When a new numerical model or tool is developed and properly tested in our project, it is transferred to WC/ATWC, tested again and finally implemented for prediction and warning. The new tool developed in the past two years, tsunami energy flux, should serve well to examine past and future tsunami events to identify the late arriving high energy tsunami signals.

As our GTM includes parallel code and it is the first truly global tsunami model, the importance of our investigations on the IOT was 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 transferred code to the University of Hawaii at Manoa, Department of Ocean & Resources Engineering and University of Ottawa, Department of Civil Engineering.

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), S. Naidu (IMS) and Y. Yamazaki, University of Hawaii; 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. Such re-computation is especially envisioned for application of the energy flux to delineate cases of strong but late arriving tsunamis. With a 3-D visualization laboratory in ARSC, it was a relatively simple task to develop animation techniques that elucidated physics of the global tsunami propagation.

Education/outreach

Student participation

- Juan Horrillo is a postdoctoral researcher in this project at the Institute of Marine Science. Previously, he 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, and continues research towards developing a dispersive tsunami model which can be applied at the Alaska Tsunami Warning Center. Z. Kowalik chairs his advisory committee.
- Yoshiki Yamazaki is a Ph.D. student at the University of Hawaii at Manoa, Department of Ocean & Resources Engineering. He tests dispersive models against laboratory measurements and analytical solutions. Z. Kowalik is a member of his advisory committee.

Presentations

Kowalik, Z., J. Horrillo, W. Knight and T. Logan. 2007. The Kuril Tsunami of November 2006: Impact at the Crescent City. PACON 2007 (Pacific Congress on Marine Science and Technology), Ocean Observing Systems and Marine Environment, Honolulu, Hawaii, 24–27 June 2007.

Proshutinsky, T., Z. Kowalik, M. Johnson and A. Proshutinsky. 2007. Interactions of Cook Inlet tides with wind-driven and tsunami-generated oscillations. Poster presentation at the American Geophysical Union Fall Meeting, San Francisco, December 2006.

Kowalik Z. and A. Proshutinsky. 2006. Tsunami-tide interactions. Presentation and poster at Tsunami Workshop 2006: Interactions Between Tsunamis and Underwater Geological Processes, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 30 October 2006.

Publications

Peer-reviewed

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2007a. The tsunami of 26 December, 2004: numerical modeling and energy considerations. In: K. Satake, E.A. Okal and J.C. Borrero, Eds., *Tsunami and Its Hazard in the Indian and Pacific Oceans*. *Pure and Applied Geophysics*, 164:379–393.

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2007b. Numerical modeling of the Indian Ocean tsunami. In: T.S. Murty, U. Aswathanarayana and N. Nirupama, Eds., *The Indian Ocean Tsunami*. Taylor and Francis, London, pp. 97–122.

Horrillo, J., Z. Kowalik and Y. Shigihara. 2006. Wave dispersion study in the Indian Ocean-Tsunami of December 26, 2004. *Marine Geodesy*, 29(3):149–166, doi:10.1080/01490410600939140

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.
Accepted
Kowalik, Z., J. Horrillo, W. Knight and T. Logan. The Kuril Islands Tsunami of November 2006, Part I: Impact at Crescent City by distant scattering. Accepted for publication in *Journal of Geophysical Research*.
Horrillo, J., W. Knight and Z. Kowalik. The Kuril Islands Tsunami of November 2006, Part II: Impact at Crescent City by local amplification. Accepted for publication in *Journal of Geophysical Research*.

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*

An element of CIFAR 45-074b: 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.

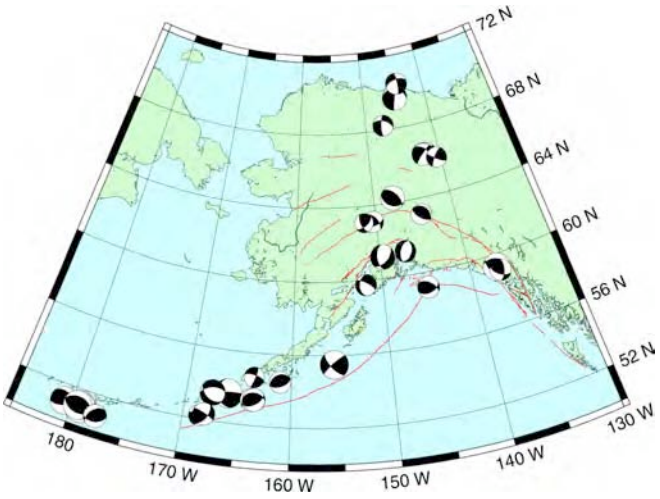

Figure 1. Calculated moment tensors from the regional network stations for July 2006–June 2007.

Research accomplishments/highlights/findings

- A total of 39 regional moment tensor solutions were calculated (Mw=3.8–6.6) 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 22 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.
- A graphic interface (MT_review_tool) is in final stages of testing. It will provide data analysts with a convenient way to review automatic moment tensors and to calculate new inversions for any events within the regional network (Figure 2).

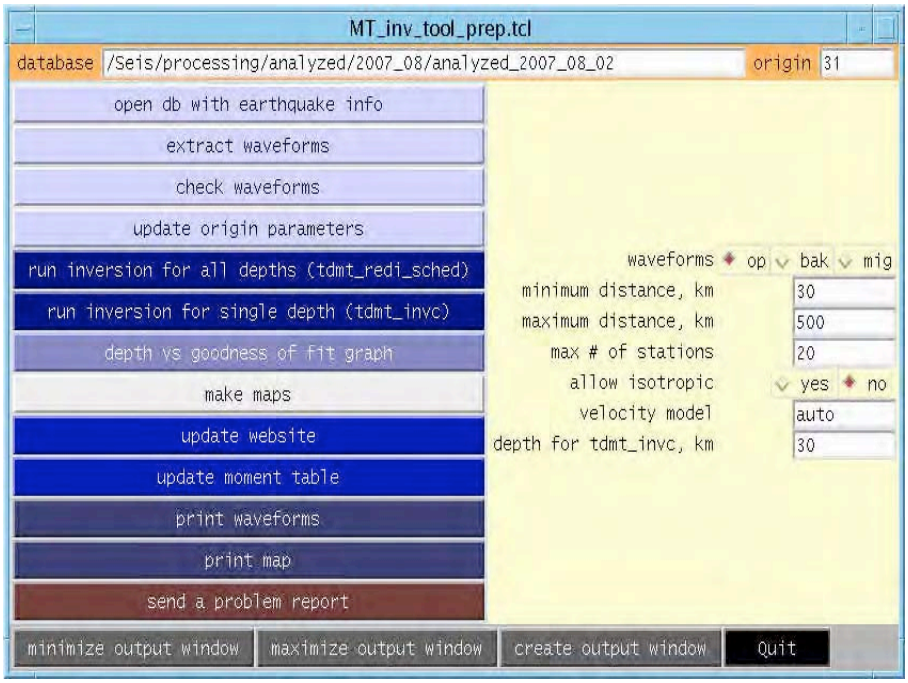

Figure 2. Moment tensor review tool interface.

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 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. and R.A. Hansen. 2007. Real-time data processing systems and products at the Alaska Earthquake Information Center. American Geophysical Union Spring Assembly, Acapulco, Mexico, 22–25 May 2007.

Ruppert, N.A. and R.A. Hansen. 2007. Real-time data processing systems and products at the Alaska Earthquake Information Center. Seismological Society of America Meeting, Kona, Hawaii, 11–13 April 2007.

Ruppert, N.A., R.A. Hansen, S. Estes, M. LaFevers, J. Sandru, G. Pavlis, M. Bauer, M. Gordon, M. Fowler and L. Lowe. 2006. Seismic component of the STEEP project, Alaska: Results of the second field season. American Geophysical Union Fall Meeting, San Francisco, December 2006.

Publications

Submitted

Ruppert, N.A. Stress map for Alaska from earthquake focal mechanisms. Chapter in: P. Haeussler, J. Freymueller and R. Wesson, Eds., Active Tectonics and Seismic Potential in Alaska. *Geophysical Monograph Series*. Submitted.

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, Elena Suleimani,*** *University of Alaska Fairbanks;* ***Cherri Pancake, Chris Janik, Dylan Keon, Ben Steinberg,*** *Northwest Alliance for Computational Science and Engineering;* ***Harry Yeh,*** *Oregon State University*

An element of CIFAR 45-074b: This project is ongoing.

Primary objectives

The Tsunami Computational Portal is a shared web portal for executing computational models of tsunami behavior. Researchers, operational staff and other interested parties are able to input data for different scenarios to run on the available models. They 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 has been built by an outsourced team from the Northwest Alliance for Computational Science and Engineering (NACSE) and

Oregon State University (OrSU), and includes 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 allows 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 provides 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 are 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 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

Front-End Enhancements

- Improved PHP-based framework that drives the portal including adopting a modular, object-oriented approach that facilitates the addition of new models and implementing extensive error checking to ensure proper values are entered.
- Completed automation of job initiation messaging from NACSE to Arctic Region Supercomputing Center (ARSC) and job finalization messaging from ARSC to NACSE.
- Completed the implementation of user "home page" within the portal that allows the user to track the submitted and completed jobs, view configuration files and download model outputs. The home page contains information on all jobs submitted, with links to input data, configuration files and job outputs.
- Through testing, identified and fixed several bugs in the model codes, the bathymetric/topographic datasets, and in the portal front-end.
- Implemented a feature that allows users to pre-load configuration parameters from previous jobs, making it simple to tweak just one parameter and compare outputs with a previous job.
- Implemented more efficient data queries for faster region selection and data extraction.
- Automated packaging of results for download.
- Completed implementation of the TsunamiClaw model parameters into the portal front end.
- Performed extensive testing of the entire processing chain using model runs configured with multiple combinations of models, datasets, and parameterizations.
- Improved extraction and packaging of data. Spatial queries are submitted to database for each grid and sub-grid and a custom C++ tool connects to database and writes out clipped grids in binary format required by ARSC.

- Improved model run parameterization. Parameters displayed are dependent upon the selected model—the portal dynamically populates each page based on the selected model. Sample configurations can be loaded for real events from selected areas. An interactive client side calculator provides realistic estimate of output size.
- The portal front-end is at the point where it is stable enough to move to ARSC in the coming year.

Backend/Model Enhancements

- Portal Automation
  - The portal backend automation was completed, tested and documented.
- TsunamiClaw Model
  - TsunamiClaw developer, David L. George, visited Fairbanks in April 2007 to work with Tom Logan on integration of the model into the portal.
  - The model was analyzed and all necessary parameters were added to the parameter definitions document (unifying these parameters with existing parameters where possible).
  - The model conversion to meet the portal standards is well underway: the model is reading from standard configurations files and the Smylie fault model is integrated.
  - Work commenced to convert the adaptive mesh refinement output so that it matches the output format of the other two models.
  - The initial implementation of TsunamiClaw at ARSC was benchmarked against the original version, and some initial comparisons have been made with the other two models.
  - Additional enhancements to the models have been discussed, including unification of tide gauge functions, addition and unification of run-up capabilities, support for the Okada deformation model, and support for time-varying deformations.
- Portal Opened to Public
  - The portal was opened to the public on 4/3/07.
  - More than 40 user accounts were approved and created.
  - More than 60 model runs have been generated since the portal was released.
  - Minor glitches are being identified and resolved as they arise.
  - Robustness and error checking is improving, but work needs to continue.

Other Accomplishments

- A face-to-face meeting was held in April at Oregon State with personnel from ARSC, NACSE, OrSU, U of Washington.
- Added fine resolution bathymetry and topography datasets that cover Pacific Northwest costal areas.
- The global tsunami model
  - The model was ported from Co-Array FORTRAN to MPI (message-passing interface) communications, making the model easily portable to any system supporting MPI-2 functionality.
  - The model was implemented to allow for a rectangular, as well as the original cylindrical, propagation scheme.
  - The model was used to simulate the Kuril Island event of 15 November 2006 at a 1-minute resolution.
- Completed the TCP Visualizer, a Java-based tool that allows users to visualize and query model outputs from completed jobs. This tool allows quick access and response times even when visualizing multi-gigabyte datasets. It was streamlined for easy installation.

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, IMS/UAF (see report on TWEAK Tsunami Code Development).

Education/outreach

- Multiple tours in the ARSC Discovery Lab highlighted Tsunami Research showing one of two visualizations applications. The first shows a realistic visualization of a tsunami at Kodiak. The second shows an animation of a tsunami created specifically for educational purposes.
- Provided 200 copies of the ARSC Frontier of Discovery DVD to the Alaska Tsunami Education Program (ATEP). The "Tsunami Threat" chapter will serve as a visual aid illustrating wave propagation and as a source of information about current research and developments in tsunami science.

Presentation

Pancake, C. 2007. Keynote Address. Corporation for International Networks and Initiatives in California (CENIC) Annual Conference, San Diego, California, March 2007.

Publications

Peer-reviewed

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2007. The tsunami of 26 December, 2004: numerical modeling and energy considerations. In: K. Satake, E.A. Okal and J.C. Borrero, Eds., *Tsunami and Its Hazard in the Indian and Pacific Oceans. Pure and Applied Geophysics*, 164:379–393.

Non-peer-reviewed

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2007. Numerical modeling of the Indian Ocean tsunami. In: T.S. Murty, U. Aswathanarayana and N. Nirupama, Eds., *The Indian Ocean Tsunami*. Taylor and Francis, London, pp. 97–122.

Accepted

Kowalik, Z., J. Horrillo, W. Knight and T. Logan. The Kuril Islands Tsunami of November 2006, Part I: Impact at Crescent City by distant scattering. Accepted for publication in *Journal of Geophysical Research*.

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 complete.

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

- Cleaned up equipment from Rugged and Middleton Island deployments for storage and backed up collected data into permanent data archive.
- Because inadequate data was collected from the Rugged and Middleton Island deployments, efforts this year were directed to HF radar operations in Prince William Sound for surface current mapping. Results of this work are shown on the **S**ea-**A**ir-**L**and **M**odeling and **O**bserving **N**etwork (**SALMON**) Project website: http://www.ims.uaf.edu/salmon/research/hf_radar/pws/index.html

NOAA relevance/societal benefits
NOAA has long had interest in the physical oceanography and marine ecosystem on the shelf of Alaska. The data and logistical experiences collected during these deployments 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 garnered the interest of the Alaska Ocean Observing System (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.

Publications and Presentations
No publications or presentations due to insufficient data.

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 complete.

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. NOAA funding directly to Shaw (not through CIFAR) to continue this monitoring effort has been secured.

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 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. 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.
- Scott Pegau of the Kachemak Bay Research Reserve and NOAA operates the sampling station at Homer. 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. 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.
- 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.
- 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.
Scott Pegau proposes to use our aerosol sampling instruments as demonstrations to public teaching programs carried out at the Kachemak Bay Research facility.

Publications

Peer-reviewed

Quinn P., B. Andrews, E. Dutton, G. Shaw and T. Ruoho-Airola. 2006. Chapter 4. Arctic haze. In: M. Forsius and M. Nyman, Eds. AMAP Assessment 2006: Acidifying Pollutants, Arctic Haze, and Acidification in the Arctic. Arctic Monitoring and Assessment Program (AMAP), Oslo, Norway, pp. 31–40. ISBN 82-7971-046-9.

Quinn, P.K., G. Shaw, E. Andrews, E.G. Dutton and T. Ruoho-Airola. Arctic Haze: current trends and knowledge gaps. *Tellus*, 59B:99–114.

Appendices 1–4

1. Projects Awarded 1 July 2006–30 June 2007

2. Personnel

3. Publication Activity

4. Index of PIs

Appendix 1.
CIFAR Projects Awarded in Cooperative Agreement NA17RJ1224
Year 6: 1 July 2006–30 June 2007

Last	First	Proposal Title	Start date	Ending date	Total Award	Task	Theme Description	Funding Source
Adkison	Milo	Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt	07/01/06	06/30/07	$ 14,178	III	Fisheries Oceanography	NMFS
Adkison	Milo	Inter-Decadal Change in Sablefish Growth and Maturity in the Northeast Pacific Ocean	09/01/06	08/31/07	$ 16,827	III	Fisheries Oceanography	NMFS
Atkinson	David	Collaborative Research: Alaska PRIDE FY06	05/01/06	04/30/07	$ 58,705	III	Atmospheric Climate	NWS
Atkinson	David	Integrated Pacific Coastal Climatology Data and Information Products	05/01/06	04/30/04	$ 49,750	III	Atmospheric Climate	NWS
Grebmeier	Jackie	Ecosystem Change in the Northern Bering Sea (joint w/ Whitledge)	06/01/06	06/30/07	$ 40,000	III	Marine Ecosystems	OAR
Hansen	Roger	CREST CIFAR-Alaska Earthquake Information Center Seismic Station Upgrade and Installation	07/01/06	06/30/07	$ 268,359	III	Tsunami Research	OAR
Hansen	Roger	Tsunami Warning and Environmental Observatory for Alaska - Year 5	07/01/06	06/30/07	$ 1,811,358	III	Tsunami Research	NWS
Hansen	Roger	RUNUP-CIFAR Alaska Tsunami Inundation Mapping Project	07/01/06	06/30/07	$ 174,134	III	Tsunami Research	OAR
Norcross	Brenda	Reproduction Potential of Pacific Cod	07/01/06	06/30/07	$ 13,070	III	Fisheries Oceanography	NMFS
Quinn II	Terrence	University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement	07/01/06	06/30/08	$ 25,000	I	Admin/Fisheries Oceanography	NMFS
Walsh	John	CIFAR Task I: Administration (Year 6)	07/01/06	06/30/08	$ 100,000	I	Administration	OAR
Walsh	John	CIFAR Task I: Administration Supplement	07/01/06	06/30/08	$ 10,000	I	Administration	OAR
Walsh	John	Enhancement of the University of Alaska's Contribution to the International Polar Year	07/01/06	06/30/08	$ 330,000	I	Administration	OAR
Weingartner	Thomas	Bering Strait: The Pacific-Arctic Ocean Connection, RUSALCA 2006	04/01/06	03/31/07	$ 190,811	III	Hydrographic & Sea Ice Studies	OAR
Yang	Daqing	Assessment of Arctic Snowcover Change and its Impact on Large River Runoff	07/01/06	06/30/08	$ 64,845	III	Hydrographic & Sea Ice Studies	OAR

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	3			3
Visiting Scientist	0			
Postdoctoral Fellow	0			
Research Support Staff	2		2	
Administrative	1	1		
Total (≥ 50% NOAA Support)	**6**	1	2	3
Undergraduate Students	6			
Graduate Students	20	8	12	
Total Students	**26**			
Employees (< 50% NOAA Support)	51	13	10	28
Located in NOAA Lab	1		AFSC	
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. 2006. Some controls on flow and salinity in Bering Strait. *Geophysical Research Letters*, 33(19), L19602. doi: 10.1029/2006GL026612.

Alix, C. Ethnoarchéologie de la production des object en bois dans l'Arctique.nord-américain (Ethnoarchaeology of the production of wooden objects in the North American Arctic). Les Civilisations du Renne d'Hier et d'Aujourd'hui - Approches Ethnohistoriques, Archéologiques et Anthropologiques. XXVIIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Ed. S. Beyries and V. Vaté. Editions APDCA, Antibes, in press.

Andersen, S. and I. Belkin. 2006. Adaptation of Global Frontal Climatologies for Use in the OSISAF Global SST Cloud-masking Scheme. Technical Report 06-14, Danish Meteorological Institute, Copenhagen, 77 pp.

Belkin, I.M. 2005. Oceanic Fronts in Large Marine Ecosystems. Final Report to the United Nations Environmental Program (UNEP), 51 pp. *(not previously reported)*

Belkin, I.M. 2007. Oceanic fronts in large marine ecosystems. In: The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas. UNEP Regional Seas Report and Studies 2007, No. 182.

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	JI (subgrantee lead)						NOAA lead						Other lead					
	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
P-R	0	10	11	12	17	18	0	0	0	0	0	3	0	4	5	4	13	11
N-P-R	0	1	13	12	12	9	1	0	1	1	2	1	0	1	0	0	3	2

Appendix 4. Index of Principal Investigators
(abbreviated project name in parentheses where one PI has multiple project reports in this document)