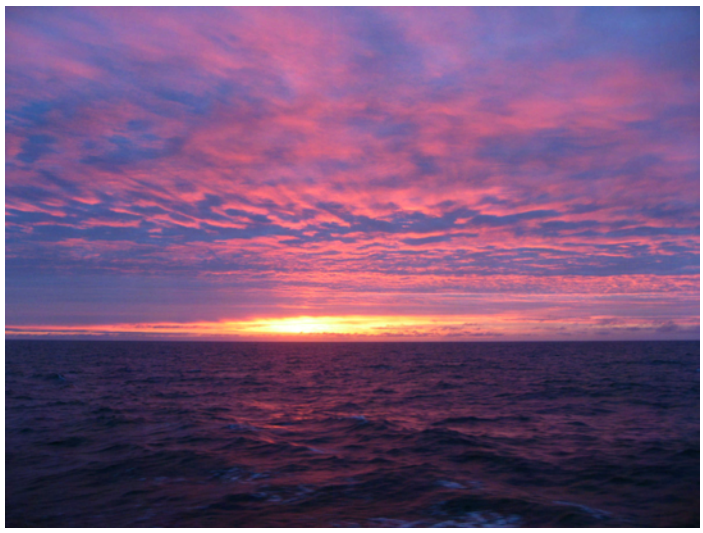
Annual Report

1 July 2007–30 June 2008

Year 7 of Cooperative Agreement NA17RJ1224



Cooperative Institute for Arctic Research
University of Alaska Fairbanks

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

1 July 2007–30 June 2008

Progress reported during Fiscal Year 2008

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

September 2008
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Cover photo taken by CIFAR IPY student Dominic Hondolero during the August 2007 Oshoru Maru *cruise.*

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 (ABL).

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 2007 to 30 June 2008, funding for CIFAR administration and 9 research or education projects totaled $1.49 M. All 8 research projects are CIFAR Task III, i.e., projects funded individually by NOAA. 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 six years of the CIFAR cooperative agreement.

Table 1: Summary of Projects Funded 1 July 2007–30 June 2008: By Task and Theme

Theme	Number of Research Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)			$151,378	**10.1%**
Core Support		$110,000		7.4
Stock Assessment Training & Improvement		$41,378		2.8
Research Themes (Task II)			$0	**0.0%**
Research Themes (Task III)			$1,343,122	**89.9%**
Atmospheric and Climate Research	2	$133,970		9.0%
Climate Modeling				
Contaminant Effects				
Fisheries Oceanography	1	$25,000		1.7%
Hydrographic and Sea Ice Studies	1	$66,699		4.5%
Marine Ecosystem Studies	3	$183,903		12.3%
Tsunami Research	1	$933,550		62.5%
Total			**$1,494,500**	**100.0%**

Table 2: Summary of Projects Funded 1 July 2007–30 June 2008: By Funding Source
Includes administration + student traineeships

Funding Source	Number of Projects	Total Amount	Percent of Total
OAR	3	$251,699*	16.8%
NOS	0	0	
NWS	2	$1,057,520	70.8%
NMFS	4	$185,281	12.4%
Total		**$1,494,500**	

**OAR funding includes $110,000 in Task I, core administrative support*

Highlights of CIFAR Task I Activities

The CIFAR fellows continuing through 2008 are:

1. Mark Herrmann, Dean and 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. Kris Holderied, Director, NOAA Kasitsna Bay Laboratory, NOS, NOAA, Homer, AK
4. Anne Hollowed, Alaska Fisheries Science Center (AFSC), NMFS, NOAA, Seattle, WA
5. Henry Huntington, Huntington Consulting, Eagle River, AK
6. Zygmunt Kowalik, Professor of Physical Oceanography, Institute of Marine Science, School of Fisheries and Ocean Sciences, UAF, Fairbanks, AK
7. Gordon Kruse, President's Professor of Fisheries, School of Fisheries and Ocean Sciences, UAF, Juneau, AK

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

The Fellows provided their perspectives on means by which CIFAR can strengthen or redefine NOAA–University connections. A vision statement and definition of our role in NOAA's mission was part of our successful proposal to NOAA to be the new Alaska regional cooperative institute:

> *The Alaska regional cooperative institute (CI) will contribute to the NOAA mission by developing and disseminating knowledge about Alaska's atmospheric and oceanic systems, weather, and climate. As a center for coordination and communication of research, education, and two-way outreach between scientists, managers, communities, local stakeholders, and funding agencies, the Alaska CI will increase understanding of Alaskan marine ecosystems and coastal zones to better forecast their response to change. The major objectives of the CI 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 this knowledge in education, research and outreach activities; (5) work with regional scientists, managers, and stakeholders to improve the utility and relevancy of NOAA operational products.*

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 2007 to 30 June 2008 were as follows:

- John Walsh, CIFAR director, 10% FTE (both CIFAR Task I and Task III)
- Susan Sugai, CIFAR associate director: 70% FTE (CIFAR Task I)
- Sherry Lynch, CIFAR fiscal administrator: 80% FTE (CIFAR Task I)
- Barb Hameister, publications and meetings manager: 23% FTE (CIFAR Task I).

The greater amount of time spent on CIFAR functions by the associate director in this reporting period compared to previous years is due to CIFAR's response to the NOAA announcement for the new Alaska and related arctic regions CI.

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 impacting 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.

To highlight the important role that students play in fulfilling NOAA's mission goals, we have boldfaced the names of students in this overview of CIFAR accomplishments.

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. 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. **Cindy Tribuzio**, a Ph.D. candidate who has been funded on this project, was hired this year as a Research Fishery Biologist at the Auke Bay Laboratory.

Because of the success of the "Stock Assessment Training and Improvement" project, in FY07 we 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)."

International Polar Year Student Traineeship Awards

In late 2006, following a competitive review process, seventeen CIFAR IPY student projects were selected for funding. Recipients are students at the three major University of Alaska units—UAF, University of Alaska Anchorage (UAA), and University of Alaska Southeast (UAS)—working on a wide variety of NOAA polar issues in the physical, biological, and social sciences during the current IPY. Fourteen graduate students and 10 undergraduate students have been supported on IPY fellowships to date. Some highlights of these student awards are:

- As part of her IPY award, **Yiming Wang**, a Ph.D. candidate at UAF, has developed a stable oxygen isotope technique for analyzing fossil remains of aquatic insects preserved in lake sediments. This new approach has allowed reconstruction of historical atmospheric circulation patterns in southwest Alaska, a key to better understanding Holocene climate variability in Alaska.
- **Dominic Hondolero** received a CIFAR IPY award while an undergraduate student at UAF and determined the nutritional content of common benthic invertebrates collected from the northern Bering Sea in 2004 and 2007 to compare with values obtained 30 years ago in the same area. He found that food availability and assimilation of body energy stores have increased for benthic organisms in the sampling area over the last 30 years (see Iken, Bluhm, and Hondolero, IPY report CIPY-03). Hondolero, an Alaska Native who earned his B.S. in biological sciences in May 2008, has received a 3-year NOAA Graduate Fellowship for M.S. studies at San Diego State University, where he will study the effects of climate change on kelp forests in California. Upon completion of his graduate studies, Hondolero will return to Alaska and will be employed by NOAA to work at the Kachemak Bay Research Reserve in Homer.
- **Jason Amundson**, a Ph.D. student at UAF, has been examining the iceberg calving processes at the Jakobshavn Isbræ, a large ocean-terminating outlet glacier in West Greenland. New observations include that calving events occur once every few days in summer, produce ocean waves that can be detected 50 km away, and cause the glacier retreat to accelerate. Amundson was interviewed by ABC's *World News Tonight* and while in Illulissat, briefed German Chancellor Angela Merkel and Danish Prime Minister Anders Fogh Rasmussen on his Jakobshavn Isbræ research.
- **Jason Addison**, a Ph.D. student at UAF has been examining multiple paleoclimate proxies in sediment cores from the Gulf of Alaska. He has found that high-frequency changes in concentrations of marine and terrestrial organic matter and stable isotopes of carbon and nitrogen are important proxies for the Aleutian Low (AL) pressure system (the principal driver for the Pacific Decadal Oscillation) that dramatically influences North

Pacific ecosystems. Addison has found that marine productivity has been highly variable over the entire Holocene, and amplitude shifts correspond closely to the AL.

- Using simulations performed with the Weather and Research Forecasting model with data obtained from the Alaska Volcano Observatory, **Morgan Brown**, an M.S. student in atmospheric sciences at UAF, examined how volcanic eruptions impact regional weather. She found that release of aerosols, water vapor, and heat all significantly influenced regional weather following a volcano eruption, as did interactions between water vapor and aerosol release, heat and aerosol release, aerosol release and ash fall, and heat and water vapor release.
- **Micaela Ponce**, an undergraduate student at UAS working on a B.S. in biology and math, has made two presentations at national meetings on her studies of ringed seals showing large amounts of gene flow among populations. This suggests that high rates of movement of these sea-ice-dependent seals among populations may help maintain genetic diversity within populations and thus, provide resilience for ringed seals in the face of future sea ice loss.
- **Martha Raynolds**, a Ph.D. student at UAF, has been examining how land-surface temperatures and sea ice patterns influence vegetation patterns and the normalized difference vegetation index (NDVI) across the pan-Arctic. Among her many research findings, Raynolds determined that when added to a model that included climate and lake cover, permafrost characteristics accounted for an additional 11% of the variation in NDVI. During the reporting period, Raynolds published 3 peer-reviewed papers as first author and submitted an additional paper. Four of her seven presentations during the same period were at international forums in Moscow and St. Petersburg, Russia; Whitehorse, Yukon Territory; and Fairbanks, Alaska.
- As part of his IPY project on sea-ice system services, UAF Ph.D. student **Matt Druckenmiller** has been conducting sea-ice thickness surveys of landfast ice off Barrow and Wales, Alaska using an electromagnetic induction sounding devise while also documenting Barrow whaling trails using differential GPS data and local interviews with hunters. Education and outreach are significant components of Druckenmiller's project: he has assisted in instructing the international course, GEOS 693 "Field techniques in interdisciplinary sea-ice research," has given presentations at Kingikmiut School, a K–12 school in Wales, and two workshops in Fairbanks.

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 2008 competition in May; the newly funded CIFAR projects are:

- **Grant Shimer**, Department of Geology & Geophysics: A paleoenvironmental analysis of lake sediments from Canyon Lake, Copper River basin, Alaska
- **Matthew Klick**, Department of Resource Economics: Corporate social responsibility and community resilience: a case study of Norway's Snohvit gas complex

Continuing support for 2-year awards made in 2007 with CIFAR funds:

- **Jason Amundson**, Department of Geology & Geophysics: Investigating the climatic parameters influencing calving rates of Jakobshavn Isbræ, West Greenland

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

This year, as in 2004 and 2006, CIFAR provided travel support for the international, interdisciplinary graduate sea-ice course (jointly listed through Geology and Geophysics and Marine Science and Limnology Departments) that Hajo Eicken and Rolf Gradinger from UAF and Kunio Shirasawa and colleagues from Hokkaido University offer every two years. This year students from UAF and Hokkaido University and over a dozen international instructors met in Barrow for this 12-day course that involved 10 field modules.

Development of Climate Change Course for K–12 Teachers at Kasitsna Bay Laboratory (MSL 495/695)

In summer 2008, CIFAR researchers created a novel, hands-on intensive course on climate change held at the NOAA Kasitsna Bay Laboratory. The course (jointed listed through Marine Science and Limnology and Atmospheric Sciences Departments), was instructed by Susan Sugai and John Walsh (CIFAR), Reid Brewer (Alaska Sea Grant Marine Advisory Program), and David Atkinson (International Arctic Research Center). Students learned how to use NOAA and other websites to obtain climate and weather data specific to their location of interest,

acquired hands-on experience setting up monitoring transects, and developed their own classroom project that was presented to the class and the NOAA laboratory director, Kris Holderied.

Student Support through Individual Awards

Many of the proposals funded through CIFAR involve graduate and undergraduate students. Twenty-nine students (23 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 involvement in the research projects, e.g., through sample/data collection and data analysis, even though they did not receive direct salary support through CIFAR.

Other CIFAR Administrative Activities

On 24 October 2007, NOAA OAR released an announcement of a federal funding opportunity for the establishment of a cooperative institute to conduct ecosystem and environmental research related to Alaska and its associated Arctic regions, including the Gulf of Alaska, Bering Sea, Chukchi/Beaufort Seas, and Arctic Ocean, with a deadline of 24 December 2007. CIFAR responded with a proposal for "The new regional Alaska cooperative institute 2008–2013." In March 2008, CIFAR received the proposal reviews and was asked to provide response to reviewer comments and submit a revised Task I work plan and budget to reflect a budget reduced from $300K to $110K. This was done, and in May NOAA OAR announced that the new regional Alaska CI was awarded to CIFAR. We immediately began processing projects in both the main CIFAR grant and the CIFAR grant for "shadow awards" (competitively selected projects, initially including the RUSALCA projects) prior to the 1 July 2008 start date.

Highlights of CIFAR Research Activities and Results

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

Arctic Research Initiative—RUSALCA, Russian–American Long-term Census of the Arctic

- In the Bering Strait region, isotopic values of particulate organic material (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. POM in ACW is likely to be influenced strongly by freshwater and terrestrial contributions that unlike ice algae do not provide significant food for benthic organisms.
- Iken, Bluhm and Dunton suggest that their findings indicate that AW benthos receives fresher POM than ACW benthos, i.e., higher quality and likely higher quantity, through tighter pelagic–benthic coupling. They predict that an expected weakening of the Anadyr Water productivity (with retreat of the sea ice and associated ice algae) will reduce the currently tight pelagic–benthic coupling resulting in less benthic biomass. This will have consequences for higher trophic levels such as bottom-feeding marine mammals and diving birds.

Atmospheric and Climate Research

In two related Pacific Region Integrated Data Enterprise (PRIDE) projects, David Atkinson and co-workers seek to improve publicly available NOAA products across a range of temporal and spatial scales to provide coastal stakeholder groups with short- and long-term forecasting information needed for improving emergency response, damage prevention, community planning, and coastal zone management activities. These projects also provide a linkage between NOAA activities and needs in the Alaska region with those in Hawaii and other U.S. Pacific interests. Some results to date include:

- In October 2007, Atkinson briefed the U.S. Department of Agriculture in Anchorage on the frequency of strong wind events in support of a relief funding decision for Newtok, a village on the southwest Bering Sea coast that has been subject to extreme coastal erosion. Using data from the Japan Meteorological Agency 25-year Re-Analysis (JRA-25), Atkinson found that several of the storms considered "strong" by local inhabitants had not individually exceeded a "once in 2 year event" in terms of winds. However, an analysis of the number of times that the strong wind threshold was exceeded for the month showed that September 2007 ranked as the second windiest month in the 30-year record. This is because Bering Sea storms with strong winds are extremely common events so that severe coastal erosion experienced in Newtok during September 2007 was the result of fairly continuously high winds rather than a single exceptionally windy storm event.

- **Oceana Francis-Chythlook**, a Ph.D. student working with Atkinson on the PRIDE project, has prepared strong wind return frequency plots that have been delivered to John Marra at the NOAA Integrated Data and Environmental Applications (IDEA) Center in Honolulu.
- **Michel dos Santos Mesquita**, a Ph.D. student working with Atkinson, has a publication on North Pacific storm tracks that has been accepted for publication and is currently "in press." Mesquita found that summer storms have a long life-span relative to storms in any other season.

Climate Modeling

John Walsh and co-workers have examined four reanalysis models: (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).

- A comparison between a one-year experimental Arctic reanalysis system (EARS) and global reanalyses (ERA-40 and NCEP/NCAR) has recently been completed. The EARS reanalysis results, as well as the ERA-40 and NCEP/NCAR reanalyses, were verified against station observations. The results showed that the ERA-40 reanalysis is significantly better than the NCEP/NCAR reanalysis on the basis of root-mean-square error and bias. The EARS produces significantly better wind reanalyses than both ERA-40 and NCEP/NCAR. For the surface air temperature, dewpoint temperature, relative humidity and sea level pressure, the yearly average of the EARS results lies in between those of the ERA-40 and NCEP/NCAR reanalyses.

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 and Gulf of Alaska:

- Growth and maturity schedules for specific target fisheries are used in stock assessments to project the biomass of reproductively active fish that would remain after commercial harvest. **Katy Howard**'s M.S. research, guided by Milo Adkison, updated the growth and maturity parameters for Alaskan sablefish, *Anoplopoma fimbria*, that had not been updated for stock assessment purposes for 20 years, even though many more sablefish have been aged. Her research showed that in recent years, sablefish are growing larger and maturing later and that growth and maturity differ somewhat among regions. These updated and improved estimates of sablefish growth and maturity help ensure the continued proper management of this commercially important species in Alaskan waters.
- **Katie Palof**'s M.S. thesis research with Tony Garrett on the genetic population structure of Alaskan Pacific Ocean Perch (POP), *Sebastes alutus*, showed that all life stages of POP have limited lifetime movement and this dispersal range is generally less than 400 km, a scale that is much smaller than the scale of management areas. This information suggests that current management may be suboptimal to avoid productivity declines.
- **Sean Rooney**, an M.S. fisheries student working with Jennifer Reynolds and Brenda Norcross, did a habitat analysis of two study areas at the outer edge of the Kodiak continental shelf, in a region of major fishing grounds. Albatross Bank had more diverse benthic habitats than Portlock Bank, with overall harder substrate, less soft sediments, and stronger bottom currents. In both sites, rockfishes were the most abundant group. Several important fish–habitat associations observed on Albatross and Portlock Bank (e.g., juvenile rockfishes in shallow bedrock and boulder substrates) agreed with previous studies on the Oregon and California continental margins. However, because the associations of fish communities and individual fish species with substrates change with spatial scale, to understand the habitat requirement of demersal fishes may require examination of fish–habitat associations across a range of scales.

Hydrographic and Sea Ice Studies

- The analyses of Daqing Yang and co-workers using microwave maps of remotely sensed snow indicate the general response of river discharge to seasonal snowcover changes over the Yukon River, i.e., an association of low streamflow with high basin snow cover extent (SCE) and water equivalent (SWE) during the cold season,

and an increase in discharge associated with a decrease of the basin SCE and 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. There is a discrepancy between basin snowcover and streamflow variations perhaps due to the limitations of Special Sensor Microwave/Imager (SSM/I) SWE algorithm.

- Data analyses conducted by Yang and co-workers show that both the snowfall and rainfall days increase with air temperature during winter in northern Eurasia under current climatic conditions. Snowfall days suddenly decrease when the mean winter air temperature increases to -8ºC and above. So the snowfall days are found to decrease with air temperature in both spring and fall. Although rainfall days show increases with air temperature in fall, they decrease in spring due to the fact that rainfall days will decrease in regions where monthly air temperature is above 6ºC.

Tsunami Research

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

- Zygmunt Kowalik and co-workers continued research on the application of energy balance in the Kuril Island Tsunami of 15 November 2006 with a goal of constructing a simple tool to be used at the West Coast/Alaska Tsunami Warning Center. Extensive application of the energy balance equation to the Indian Ocean Tsunami of 24 December 2004 and to the Kuril Island Tsunami of 15 November 2006 allowed them to formulate a new method for prediction of the late arriving tsunamis. The sea levels recorded in the wake of the Indian Ocean Tsunami of December 2004 and of the Kuril Island Tsunami of November 2006 show strong tsunami signal enhancement of the late arriving secondary waves. A series of numerical experiments defined in an explicit way the bathymetric features which scatter tsunami signal towards ports, like Crescent City, California. The main task of this research is to construct models for tsunami warning and prediction services with wider scope of physical processes by incorporating the energy balance equation into presently used tools.

Publications and Presentations

During the current reporting period, 37 peer-reviewed publications and 10 non-peer-reviewed publications (including three Ph.D. dissertations and four Master's theses) were reported from projects funded through CIFAR under cooperative agreement NA17RJ1224. An additional 22 papers were reported as accepted or in press, while another 23 were submitted for publication. Nearly 60 manuscripts were reported as under preparation. Approximately 75 conference presentations (both national and international) and seminars were also reported. Half of these presentations were from the CIFAR IPY student projects.

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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Task I

Education / Outreach

Support for UAF–Hokkaido University Interdisciplinary Sea Ice Field Course

Main Organizers:
Hajo Eicken, Instructor
Rolf Gradinger, co-Instructor
University of Alaska Fairbanks
***Kunio Shirasawa**, Hokkaido University*
With instructors from several other U.S. and Canadian institutions

NOAA Goal: Understand Climate Variability and Change

This project is complete.

Primary objectives

This instructional support provided travel assistance for students and instructors participating in a course on "Field techniques in interdisciplinary sea-ice research" in Barrow, Alaska in May 2008. Kunio Shirasawa (Hokkaido University), Hajo Eicken and Rolf Gradinger (both University of Alaska Fairbanks) were the main course organizers with additional instructors from UAF and other institutions in the U.S. and Canada. They introduced the students to the principal field techniques employed in sea-ice studies of an interdisciplinary (geophysical–biogeochemical) nature. The course focused on sea ice as an instructive example of the close intertwining between ocean, ice and biosphere processes in the polar regions and the trans-disciplinary importance of the ice cover in the climate system. The principal aims and outcomes of the effort included the following:

- Design a sea-ice field research plan that integrates different methods and disciplinary approaches to address scientific or stakeholder needs.
- Understand the role of remote-sensing data and models in the context of field study design and interpret and utilize such data sets for the purpose of integration or upscaling.
- Gain insight into the different services sea ice performs in the context of polar geophysical and socio-ecological systems and be able to draw on different disciplinary methods (including perspectives on indigenous and local knowledge) to provide information in the context of scientific, engineering, planning, or resource management studies.
- Obtain hands-on, immersive experience in the key methods of collecting and analyzing sea-ice data in a field setting.
- Incorporate field safety concerns into the design and execution of the field research.
- Synthesize the methodological and scientific knowledge gained in the context of designing an integrated observing system that aims to answer specific scientific or stakeholder-formulated questions.

Figure 1. Instructors and students of the Interdisciplinary Sea Ice Field Course 2008.

Approach/methodology

The field course was offered at Barrow, Alaska in May 2008 over a period of 12 days. The course comprised 10 course modules that were completed by small teams of students (4 in each team) under the guidance of a designated instructor. All students participated in a 1.5-day opening session that introduced key aspects of field safety, both in general and as they applied to the class; provided theoretical background on the role of sea ice in geophysical and socio-ecological systems; introduced the concept of sea-ice system services; and the use of remote sensing in the design and upscaling of field measurements. The actual field work was preceded by a joint, half-day field trip to allow students to familiarize themselves with the sea-ice environment, cold-weather gear, safety regulations and sampling equipment. The field modules were spread out over Days 3 to 11 of the course with teams of 4 students each rotating between different modules. Modules 1, 9 and 10 were half-day modules that included presentations, a field trip and group discussions.

Research accomplishments/highlights/findings

- Analysis of a wide range of sea ice parameters in an interdisciplinary context.
- Students learned to measure and analyze a wide range of variables, ranging from remote sensing, ice thickness, water current, and light measurements (Figures 2–3), to the photophysiology and abundance of sea ice algae.
- Cross-cultural exchange between students and instructors from different countries and educating the future generation of sea ice scientists.

Figure 2. Students conducting measurements of ice strength with borehole jack tests.

Figure 3. Students analyzing snow properties.

NOAA relevance/societal benefits

The course proved to be not only a broad and hands-on learning experience in sea-ice research, but also an opportunity to establish lasting professional relationships with international scientists and establish connections with students from other countries interested in sea ice research in the broadest context. Understanding the state of Barrow fast ice is important because of its relevance for the ecosystem, its use by local populations and potential impact by changed uses of the Arctic.

Research linkages/partnerships/collaborators and networking

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

Education/outreach

Maya Salganek, an assistant professor in Digital Performance Media at UAF, along with a group of undergraduate and graduate students from her course "Visual Anthropology and Science Documentary Research" spent several days in Barrow to capture on tape about 50 hours' worth of footage of various aspects of the sea-ice field course and sea-ice research. This documentary footage will be used in a supplemental DVD to accompany a textbook about sea ice. It will also be available in a public archive at UAF. An article about the filming appeared in the 16 June 2008 edition of the Fairbanks Daily News-Miner.

Intensive Course on Climate Change for K–12 Teachers at Kasitsna Bay Laboratory

Main Organizers:
Susan Sugai, Instructor
John Walsh, co-Instructor
David Atkinson, co-Instructor
Reid Brewer, co-Instructor
University of Alaska Fairbanks

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

This project is ongoing.

Primary objectives

This project provided travel assistance for three of the instructors participating in a new course on "Climate Change in Alaskan Estuaries," an intensive cross-disciplinary "hands-on" field and laboratory summer course on climate change for K–12 teachers and other interested students at NOAA's Kasitsna Bay Laboratory (KBL) in Seldovia, Alaska. Susan Sugai and John Walsh (CIFAR), Dave Atkinson (International Arctic Research Center), and Reid Brewer (Alaska Sea Grant/Marine Advisory Program) were instructors. The course was offered through both UAF and UAA, was cross listed in marine science and limnology (MSL) and atmospheric sciences (ATM), and offered stacked (495/695) to allow students the choice of registering for graduate or undergraduate credit.
Course goals were to:

- Introduce the students to climate change influences (physical, chemical, and biological) on Alaskan estuarine and coastal environments. A class CD with resource materials and all instructors' presentations was distributed to all the students.
- Familiarize students with the NOAA operational products that are publicly available such as National Centers for Environment Prediction/Marine Prediction Center (NCEP/MPC) reanalysis data, National Climatic Data Center (NCDC) archived observational data (e.g., temperature, precipitation, wind speed/direction), Alaska Region National Weather Service sea ice forecasts and recent observations, National Ocean Service coastal water level and temperature data.
- Demonstrate the processes and ecosystem components undergoing climate-related changes, and techniques for designing transects for community-based monitoring programs.
- Show students how to access available weather, climate, and ecosystem data, and how to "down-scale" observational and reanalysis data for their area of interest.
- Students were then tasked to design a community-based monitoring program or develop a climate-related instructional module appropriate for use in their school's location and grade-level of students taught.

Approach/methodology

The pilot field and laboratory course was offered at KBL from 23–27 June 2008. All students participated in an all-day opening session that introduced key aspects of climate change in the Arctic, with emphasis on Alaskan marine ecosystems. Students were then broken up into two small groups for three field and lab modules: intertidal monitoring; using NOAA reanalysis and archival data; using climate data to track spruce bark beetle infestations. The class modules (all roughly 3 hours in duration) were spread out over a day and half with two teams of 3–4 students rotating between different modules each led by a different instructor. Students worked on their class projects during the afternoon of the third day and for most of the following day in the residential facility with access to all the instructors. All students and instructors (even the modelers) took a mid afternoon break in the non-structured project work day for a boat excursion to explore intertidal regions of Elephant Island. Class presentations were made on the final day.

Research accomplishments/highlights/findings

- Class participants included three Alaskan teachers from small K–12 schools in Kiana (120 students, Northwest Arctic Borough School District), Kenny Lake (121 students, Copper River School District), and St. George (22 students, Pribilof School District); one teacher from Thomas Jefferson High School for Science & Technology in Alexandria, VA with 1800 students selected as freshmen; one teacher from Irmo High School in Columbia, SC with 1500 students; a Cordova, AK resident employed by a non-profit organization tasked with setting up a citizen environmental monitoring program for Prince William Sound.

- All three Alaska teachers completed projects that incorporated modules presented in the class and tracked lesson plans to Alaska Content and Performance Standards; the Virginia teacher presented a research project related to her state standards.
- On the final day of the course, all students presented their class projects (many of them with "hands-on" activities) to the course instructors, students, and NOAA laboratory director, Kris Holderied.
- Because of the residential aspect of the class where all instructors and students lived together and shared in meal preparation and clean-up, there was considerable "out-of-class" formal and informal interactions. This resulted in valuable personal and professional connections being made between researchers (instructors) and teachers and between teachers from within and outside Alaska, to better communicate the effects of observed and anticipated climate change. Especially for the two teachers from the lower 48, discussions with their colleagues from Alaska provided them with valuable human dimension perspectives of these climate and ecosystem change issues that they will carry forth into their own classrooms.

NOAA relevance/societal benefits

The students benefited not only from the broad hands-on learning experience in climate change research as it affects Alaskan estuaries and coastal areas, but also from the opportunity to establish lasting professional relationships with scientists and connections with teachers from Alaska and the nation interested in climate change research in general and in arctic and subarctic marine ecosystems in particular. The teachers learned about NOAA research and operational products (ranging from archived observational data to reanalysis data to regional forecasts) and utilized NOAA products and services in their class projects. Thus, each class participant was expanding the knowledge of NOAA research and services to numerous students and/or stakeholders throughout Alaska and the nation who would not have been otherwise reached.

Research linkages/partnerships/collaborators and networking

In addition to the educational perspective, this course strengthens the ties between UAF and NOAA's Kasitsna Bay Laboratory.

Education/outreach

Course instructors were contacted by several teachers who expressed interest but who were unable to attend without travel support. A proposal will be submitted to NOAA to provide travel and tuition support for this course to allow more teachers from rural communities in Alaska to take advantage of the unique learning environment provided by the NOAA KBL.

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, John Moran, and Cindy Tribuzio 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 graduate stipends.
- The Auke Bay Lab (ABL) of AFSC contributed about $40K for graduate student research into Pacific ocean perch dynamics.
- Peter Hulson developed age-structured assessment models for herring in Prince William Sound and Sitka Sound and finished his M.S. degree in December 2007. He has started a Ph.D. degree at UAF to extend his models. One of the extensions is the modeling of Pacific ocean perch with support from the ABL funding.

Peter Hulson

Haixue Shen

- Haixue Shen is analyzing hydroacoustic data of walleye pollock schools in the Eastern Bering Sea to examine changes in the dynamics of schools. She has completed three chapters of her dissertation and presented two posters at meetings this year.
- Travel support has been provided to several students to attend fishery conferences, including the Alaska Marine Science Symposium and meetings of the American Fisheries Society. Rebudgeting has been accomplished to provide student travel support in the final year of this grant.

NOAA relevance/societal benefits

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, and one Ph.D. student who was hired before completing her dissertation.

Research linkages/partnerships/collaborators and networking

The Alaska Fisheries Science Center continues to support this program with help from Anne Hollowed and Pat Livingston. Martin Dorn serves on Haixue Shen's Ph.D. committee. Jim Ianelli continues to help quantitative students with programming issues related to computer modeling and analysis.

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.), Cindy Tribuzio (Ph.D.), Dana Hanselman (Ph.D.), Kalei Shotwell (Ph.D.), William Bechtol (Ph.D.), Peter-John Hulson (M.S., finished this year), and Haixue Shen (Ph.D.). Williams, Moran, Hanselman, Shotwell, Miller, and Hulson have completed their graduate degrees; Bechtol, Tribuzio, Miller (Ph.D.), Hulson (Ph.D), and Shen are currently pursuing their graduate degrees. Josh Robins (M.S., finished 2006) and Xinxian Zhang (Ph.D.) have received tuition support. Shen received travel support to present a poster at the ICES Symposium in June 2008. For this year, Hulson and Shen received salary support for 12 and 3 months, respectively. Kray Van Kirk will receive a fellowship in Fall 2008 to continue his multispecies modeling work in a new Ph.D. program.

Presentations

Shen, H. 2008. Using acoustic data to study the searching behavior of harvesters in eastern Bering Sea pollock fishery. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2008.

Shen, H. 2008. Schooling pattern of eastern Bering Sea walleye pollock in relation to fishing pattern. Poster presentation at the ICES International SEAFACTS Symposium, Bergen, Norway, June 2008.

Publications

Theses

Hulson, P.-J.F. 2007. Analysis and Comparison of Age-structured Assessment Models for Two Pacific Herring Populations. M.S. Thesis, University of Alaska Fairbanks.

Peer-reviewed

Shen, H., T.J. Quinn II, V. Wespestad, M.W. Dorn and M. Kookesh, M. 2008. Using acoustics to evaluate the effect of fishing on school characteristics of walleye pollock. In: G.H. Kruse, K. Drinkwater, J.N. Ianelli, J.S. Link, D.L. Stram, V. Wespestad and D. Woodby, Eds., *Resiliency of Gadid Stocks to Fishing and Climate Change.* Alaska Sea Grant College Publication AK-SG-08-01, University of Alaska Fairbanks, pp. 125–140.

Miller, S.E., T.J. Quinn II and J.N. Ianelli. 2008. Estimation of age-specific migration in an age-structured model. In: G.H. Kruse, K. Drinkwater, J.N. Ianelli, J.S. Link, D.L. Stram, V. Wespestad and D. Woodby, Eds., *Resiliency of Gadid Stocks to Fishing and Climate Change.* Alaska Sea Grant College Publication AK-SG-08-01, University of Alaska Fairbanks, pp. 161–178.

Hulson, P.-J.F., **S.E. Miller,** T.J. Quinn II, G.D. Marty, S.D. Moffitt and F. Funk. 2008. Data conflicts in fishery models: incorporating hydroacoustic data into the Prince William Sound Pacific herring assessment model. *ICES Journal of Marine Science*, 65:25–43.

Submitted

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. Submitted to *Alaska Dept. of Fish and Game, Research Report Series*.

Shen, H., M.W. Dorn, V. Wespestad and T.J. Quinn II. Schooling pattern of eastern Bering Sea walleye pollock in relation to fishing patterns. Submitted to *ICES Journal of Marine Science*.

In preparation

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*.

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. Individual project reports follow this introduction.

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 aligned with 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 initially funded 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. Final and/or progress reports for CIFAR IPY student projects follow this introduction.

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 fourteen 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.), Joel Gottschalk (M.S.), David Gustine (Ph.D.), Jennifer Newton (Ph.D.), Martha Raynolds (Ph.D.), Theresa Rzeczycki (M.S.), Allison Sayer (M.S.), Kalb Stevenson (Ph.D.), and Yiming Wang (Ph.D.).

Ten undergraduate students have been supported: Amina Ashraf, Melanie Bakker, Jon Barton, Brenda Bruggeman, Dominic Hondolero, Brandon Howard, Micaela Ponce, Cortney Pylant, Jeff Mayfield, and Alice Smith.

International Polar Year (IPY) Student Traineeships:
Late Quaternary climate dynamics inferred using stable oxygen isotope composition of aquatic insects (Chironomidae: Diptera) from Idavain Lake, Southwest Alaska

Matthew J. Wooller, UA faculty member, PI
Yiming Wang, UA graduate student
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIPY-01: This project is ongoing.

Primary objectives
This project contributes one component to a larger scale IPY project which will aid the Arctic paleoclimate science community in understanding of Holocene climate variability in Alaska derived from lake downcore sediments. This research aims to further develop and apply the stable oxygen isotope analyses of chironomid head capsules preserved in lake sediments (Wooller et al. 2004) from Lake Idavain, southwest Alaska, and attempts to extend the record of temperature changes beyond the instrumental record. This new approach could: 1) add significantly to the relatively small database of quantitative temperature reconstructions from terrestrial sites in polar regions, 2) help to establish a more cohesive climate model, and therefore 3) enhance understanding of the paleoclimate and paleoenvironmental changes since the Last Glacial Maximum and make a better prediction of climate change in the future.

Approach/methodology
1. Develop the protocols for preparing subfossil chironomid head capsules for stable oxygen isotope analyses.
2. Apply stable isotope techniques on chironomid fossil heads preserved in the lake sediments.
3. Study modern chironomid isotopic fractionations using laboratory-based growth experiments to compare with the fossil records.
4. In addition to the original plan, stable isotope oxygen and hydrogen analyses on bulk sediments have been added to the methods. We wish to use a suite of stable isotope proxies to provide robust information for the past environment change in southwest Alaska.

Research accomplishments/highlights/findings
- All sample analyses on subfossil chironomid head capsules have been conducted and the paper has been written into Yiming Wang's Ph.D. dissertation as a chapter. The paper will be submitted to a peer-reviewed journal.
- The growth experiment of culturing chironomids has been completed successfully. This research has also been written as an individual paper into Yiming Wang's Ph.D. thesis and soon will be submitted to a peer-reviewed journal.

NOAA relevance/societal benefits
This work supports NOAA's goal to "Understand climate variability and change" by contributing to existing knowledge about past climatic changes in Alaska, which in turn will make possible better predictions of climate changes in the future.

Research linkages/partnerships/collaborators and networking
- Bruce Finney from the Institute of Marine Science, UAF, has supplied core materials.
- U.S. Environmental Protection Agency (EPA) provided advice on the growth experiment and provided organisms.
- NOAA National Weather Service at King Salmon in Alaska collected precipitation samples.
- Amanda Booth, a University of Alaska IPY postdoctoral scholar, is working on a closely related project. Wang has assisted in training Booth in the use of the techniques she has developed for the analysis of chironomids from lake sediments.

Education/outreach

Student participation

Yiming Wang successfully defended her Ph.D. in June 2008 and is currently revising the dissertation. This CIFAR traineeship has given Wang a valuable opportunity to practice writing research grants as a Ph.D. student. It will allow her to participate in international meetings, e.g., the Isotope Ecology (ISOECOL) international conference in August 2008, where she will make an oral presentation of her research. She will benefit greatly from this conference, with the opportunity to connect with other scientists and experts in the field of stable isotope ecology. The CIFAR grant has also allowed Wang to work very intensively on this very challenging research topic using stable isotope analyses of subfossil chironomid head capsules derived from lake sediments. She has reconstructed the history of atmospheric circulation patterns in southwest Alaska by applying this method, which will aid the Arctic paleoclimate science community in understanding Holocene climate variability in Alaska.

Outreach

Yiming Wang is involved with the Alaska Statewide High School Student Symposium and has designed science projects for high school students to participate in.

Publications

In preparation

Wang, Y. The Development and Application of Stable Oxygen and Hydrogen Isotope Analyses of Chironomidae (Diptera) as Indicators of Past Environmental Changes. Ph.D. dissertation (will be submitted in August 2008)

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., B. Finney, A. Krumhardt, B. Cohn and M.J. Wooller. Isotope evidence for shifts in atmospheric circulation patterns during the late Quaternary in Southwest Alaska. In preparation.

Wang, Y., D.M. O'Brien, J. Jenson, D. Francis and M.J. Wooller. The influence of diet and water on the stable oxygen and hydrogen isotope composition of aquatic organisms (Chironomidae: Diptera) with paleoecological implications. In preparation for submission to *Oecologia*.

Reference

Wooller, M.J., D. Francis, M.L. Fogel, G.H. Miller, I.R. Walker and A.P. Wolfe. 2004. Quantitative paleotemperature estimates from $\delta^{18}O$ in chironomid head capsules from arctic lake sediment. *Journal of Paleolimnology*, 31:267–274.

International Polar Year (IPY) Student Traineeships:

Russian–American Long-term Census of the Arctic: Adding caloric content and spatial resolution of Arctic seafloor communities

Katrin Iken, UA faculty member, PI
Bodil Bluhm, UA faculty member, co-PI
Dominic Hondolero, UA undergraduate student
University of Alaska Fairbanks

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

CIPY-03. This is the final report of the project.

Primary objectives

1. Analyze caloric content of common benthic invertebrates and compare with caloric values established 30 years ago, and
2. Expand the spatial scale of epibenthic community structure of the RUSALCA (Russian–American Long-term Census of the Arctic) region.

Caloric content is a measure of the nutritional content and status of an organism and gives information about its value as a food item for higher trophic levels. In the context of climate change, energy content of an individual

species may change because of shifts in the character and amount of its food sources, either due to changes in primary production or due to changes in competitive interactions after a shift in community composition. Based on energy content of species, energy content of communities, and changes thereof, can be calculated if species composition is known. This project also offered the possibility to sample epibenthic communities in Bering Strait and eastern Chukchi Sea to complement the ongoing RUSALCA project (see final report CIFAR 10-069).

Approach/methodology

Samples for caloric content analysis were collected in August 2004 during the RUSALCA cruise (Iken and Bluhm, CIFAR 10-069 project) and in August 2007 during the *Oshoro Maru* cruise (Hondolero, this project). In addition, some samples were obtained from an *Alpha Helix* cruise in 2002 (Bluhm) and a *Healy* cruise in 2008 (Iken, Bluhm) to the northern Bering Sea. Undamaged individuals were preserved by freezing or in a buffered formalin solution. In most cases, formalin-preserved individuals were later transferred into 50% isopropanol for long-term storage. Preservation method was noted (frozen, formalin, formalin/alcohol) and the effect of preservation on caloric content can be compared for those species where several preservation methods were used for caloric content analysis of different individuals (e.g., *Chionoecetes opilio*, *Gersemia rubiformis*).

The procedure for sample preparation was the same for all three preservation treatments. We removed eggs from gravid females and also removed shells from mollusks. Individuals were blotted dry with paper towels and wet weight was determined. Samples were then dried to a constant weight at 60°C for 24–48 h, dry weight determined, and the wet weight–dry weight ratio calculated. Dry samples were then homogenized by grinding them to a powder using mortar and pestle or a Scienceware Micro-Mill. Calcium carbonate from crustaceans and echinoderms was removed by the slow addition of 10% HCl solution to the dried and ground sample until bubbling ceased, and samples were re-dried.

Samples were then measured on an oxygen bomb calorimeter (Parr model 6200). Homogeneous samples were pelletized and pellet weight was recorded before being placed in the oxygen bomb. Energy density was determined as calories (cal/g dry weight and cal/g wet weight based on the wet weight–dry weight ratio determined for each sample). In addition, measured energy content was corrected for the fuse wire used for analysis and for water added to create pellets.

Caloric data obtained here are compared to data on the same species recorded by Stoker (1978) from the same region on formalin-preserved samples. Since Stoker (1978) only reported means without any variance, no statistical comparison between the historic and recent data could be done. As an approximation, we examined Stoker's values within the standard deviation range of our own measurements, i.e., values were considered different if the historic data were outside the standard deviation range of our recent data.

Research accomplishments/highlights/findings

- Caloric content in recent samples was either similar to or higher (i.e., Stoker's values were below the standard variation range of our recent data) than those reported by Stoker (1978). In only two measurements (*Anthozoa* sp. frozen and formalin-preserved) caloric content was lower than that in 1978 reported for this taxon, although this also may be due to differing species. These differences were more pronounced in caloric content referring to wet weight (ww) than dry weight (dw) but this may be because of the large variability associated with wet weight measurements and we recommend using caloric content per dry weight whenever possible.
- Preservation method of samples did have an effect on caloric content (Figure 1). Overall, frozen samples had lower caloric content than formalin-preserved samples, which again were lower in caloric content than formalin/alcohol-preserved samples. Caloric differences between frozen and formalin-preserved samples ranged from about 330–1290 cal/g dw, except for *Neptunea* sp., where frozen material was about 80 cal/g dw higher than formalin-preserved material. Differences between formalin and formalin/alcohol-preserved samples also were relatively large with formalin/alcohol-preserved samples having between 160–920 cal/g dw more calories. These results indicate that caloric content calculations for benthic organisms need to be corrected for preservation method.
- Our results indicate that food availability and assimilation of body energy stores have, if anything, increased for benthic organisms in the sampling area over the last 30 years. This may be related to an earlier ice retreat in the region, which may bear the potential for longer periods of primary production. We consider a methodological cause of the differences between time periods unlikely, because one would expect a consistent trend in all sampled taxa in this case. Alternatively, the sampled taxa could have been in different reproductive stages, although most sampling roughly occurred at a similar time of year.
- Epifaunal abundances at the *Oshoru Maru* stations ranged from 2237 to 71,055 ind 1000 m^{-2} and biomass ranged from 15.8 to 72.7 kg ww 1000 m^{-2} (Figure 2). Echinoderms clearly dominated the epifaunal

communities at all stations although composition was quite variable among stations. These results will be combined with other epifaunal sampling efforts in the region (see CIFAR 10-069 final report for details).

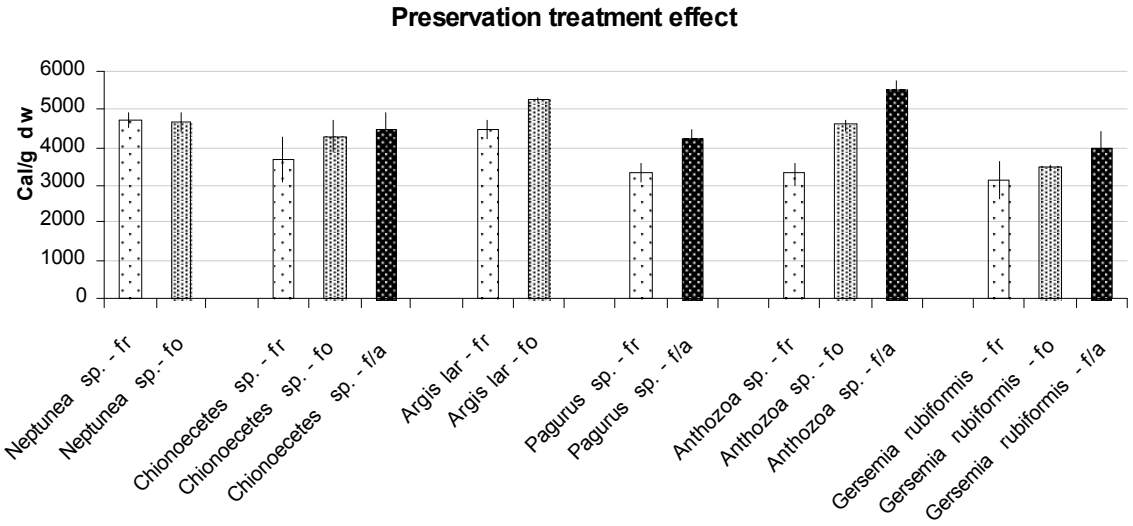

Figure 1. Caloric content of taxa with various preservation treatments. Fr = frozen, fo = formalin-preserved, f/a = formalin/alcohol-preserved. For details see text.

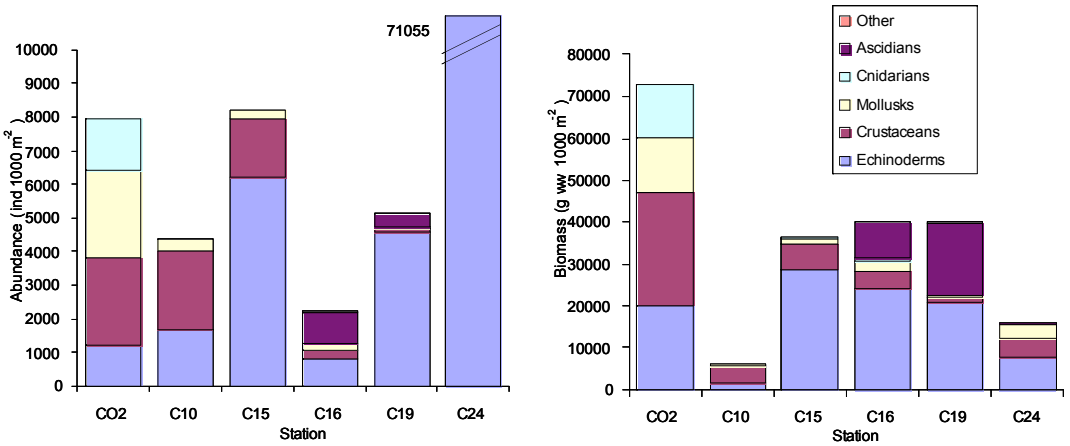

Figure 2. Epibenthic community structure collected during Oshoro Maru cruise in August 2007. Left panel represents abundance and right panel represents biomass.

NOAA relevance/societal benefits

This project supports NOAA's mission to "understand and predict the consequences of climate variability and change on marine ecosystems" by analyzing a variety of ecosystem parameters that will be valuable to detect ecosystem responses to climate change.

IPY linkages/partnerships/ collaborators and networking

This project has established collaboration with S. Saitoh (Hokkaido University) who provided berth space during the *Oshoro Maru* cruise. During the cruise, the student also collaborated with B. Norcross and B. Holladay for epibenthic trawling and with S. Mincks, a University of Alaska IPY postdoc who also participated in the benthic work during the *Oshoro Maru* cruise.

Education/outreach

Student Participation

This project involves a UAF minority (Alaska Native) undergraduate student, Dominic Hondolero. The student received his Bachelor's degree in Biology in May 2008. The project gave the student the opportunity to learn state-

of-the-art lab techniques, and to participate in an oceanographic sampling cruise to the Chukchi Sea, where he also was involved in international collaboration with Japanese scientists onboard the *Oshoro Maru*. D. Hondolero has recently been accepted into the Masters Program at San Diego State University where he will work on climate change effects on kelp forests in California. For his M.S. work, he also has received a 3-year NOAA Graduate Fellowship, which involves employment at a NOAA facility after the degree is completed. For this NOAA employment, D. Hondolero will return to Alaska to work at the Kachemak Bay Research Reserve in Homer. We believe that the experiences gained in this CIFAR-funded project have contributed to this success in being accepted into a Master's program and to receive a highly competitive fellowship.

Publications

None at this point. A publication is planned once all data have been completely analyzed. Results may also be presented at the next Alaska Science Symposium in Anchorage in 2009.

Reference

Stoker, S.W. 1978. Benthic Invertebrate Macrofauna of the Eastern Bering and Chukchi Seas. Ph.D. Dissertation, Institute of Marine Science, University of Alaska Fairbanks, 259 pp.

International Polar Year (IPY) Student Traineeships:
Understanding the causes and future direction of the present rapid thinning of Jakobshavn Isbræ

Martin Truffer, UA faculty member, PI
Jason Amundson, UA graduate student
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIPY-04: This project is ongoing.

Primary objectives

Jakobshavn Isbræ, a large ocean-terminating outlet glacier in West Greenland, has recently undergone a major retreat that coincides with accelerated flow and thinning. This project is attempting to understand the causes and future direction of this retreat, with an emphasis on glacier–ocean and glacier–climate interactions.

Approach/methodology

1. Collect and analyze several different types of field data, including surface velocities (from GPS and optical surveys), seismic data, weather station data, time-lapse photos, iceberg motion (from land-based radar and GPS), tidal stage, and audio recordings.
2. Use these data, along with remotely-sensed ice velocities and surface and bed profiles, to drive numerical models.

Research accomplishments/highlights/findings

- Collected field data discussed in #1 above, and analyzed data regarding iceberg calving processes. New observations include that calving events: (1) occur once every few days in summer, (2) produce ocean waves that can be detected over 50 km away, (3) emit unique seismic signals, and (4) cause the glacier to speed up.
- Have begun processing and analyzing a lengthy time-series of GPS ice motion data. This data is expected to reveal the extent to which the Greenland Ice Sheet responds to melting and precipitation.

NOAA relevance/societal benefits

It is expected that this work will enable researchers to better predict the contribution of sea level rise from retreating glaciers, which directly addresses NOAA's second mission goal: "Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond."

IPY linkages/partnerships/collaborators and networking

This project is a part of the IPY initiative #339: "Measurement and Attribution of Recent Greenland Ice sheet chaNgeS (MARGINS)." Collaborators include Mark Fahnestock at the University of New Hampshire and Martin Lüthi at ETH Zürich, Switzerland.

Education/outreach

Student participation

Jason Amundson is a Ph.D. student in Geophysics at the University of Alaska Fairbanks.

Outreach

Amundson was interviewed for a clip that aired on ABC's *World News Tonight*, for a newspaper article that appeared in Sweden's *Aftonsbladet*, and for an article that will appear in an upcoming issue of *Scientific American*. He has also given two lectures in a school in Ilulissat, Greenland, and organized a public meeting in Ilulissat. These lectures focused on the recent changes to the Greenland Ice Sheet. While in Ilulissat he also had the opportunity to brief German Chancellor Angela Merkel and Danish Prime Minister Anders Fogh Rasmussen on research being done in Greenland.

Presentations

Amundson, J., M. Truffer, M. Fahnestock, M. Lüthi, R. Motyka and I. Joughin. 2008. Large calving events, Jakobshavn Isbræ, Greenland. Talk presented at the Pan-Arctic Regional Climate Assessment (PARCA) meeting in Boulder, Colorado, 4 February 2008.

Amundson, J., M. Truffer, M. Fahnestock, M. Lüthi, R. Motyka and J. Brown. 2007. Large calving events and associated seismicity and ice motion at Ilulissat Glacier (Jakobshavn Isbræ), Greenland. Talk presented at the Northwest Glaciology Meeting in Portland, Oregon, 26 October 2007.

Publications

Submitted

Amundson, J., M. Truffer, M. Lüthi, M. Fahnestock, R. Motyka and M. West. Changing calving dynamics due to loss of terminus stability at the rapidly flowing Jakobshavn Isbræ, Greenland. Submitted to *Geophysical Research Letters*.

International Polar Year (IPY) Student Traineeships:
Assembling the Pan-Arctic distribution of sea ice fauna in relation to algal biomass, a contribution to the Arctic Ocean Diversity (ArcOD) project

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Rolf Gradinger and Falk Huettmann, UA faculty members, PIs
Melanie Bakker and Cortney Pylant, UA undergraduate students
University of Alaska Fairbanks

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

CIPY-05: This is the final report for this project.

Primary objectives

The ice-associated flora and fauna are likely the groups of organisms most challenged by the observed and predicted changes in the Arctic ice regime. Several hundred species have been described inhabiting the Arctic sea ice; however, to date no systematic inventory has been made of all information published in peer-reviewed literature, agency reports and other non-peer-reviewed media into one consistent format. The two undergraduate students are responsible for locating information on the biomass and diversity of sea ice flora and fauna using various UAF library resources (e.g., Aquatic Sciences and Fisheries Abstracts (ASFA), Web of Science).

Approach/methodology

Bakker and Pylant participated in one field expedition in 2006 to Barrow, Alaska, to become familiar with sampling the sea ice environment with different techniques (including ice coring, water sampling, microscopic analysis). In the following year, Bakker and Pylant conducted extensive literature surveys and selected data on occurrence and biomass of sea ice algae and under-ice amphipods, which were compiled into two Excel data sheets for the Arctic Ocean Diversity (ArcOD) project. These data were then used for GIS-based modeling based on other environmental

parameters (e.g., March sea ice extent, sea water salinity, sea water temperature). Different GIS modeling approaches have been applied. The databases produced by the two students contain several hundred observations of either ice algal biomass or sea ice amphipod groups.

Research accomplishments/highlights/findings

- Four under-ice amphipod taxa occur on a Pan-Arctic scale: *Apherusa glacialis*, *Onisimus nanseni*, *Onisimus glacialis*, *Gammarus wilkiztkii*.
- Models were developed for each of the four species (see Figure 1). For all four species, the models predicted the occurrence of these species mainly for the regions where samples have been available, while for other regions (like the more central Arctic Ocean), no predictions could be made (as indicated by the green color code in Figure 1).
- Not only the scarcity of data but also the low number of confirmed absences (i.e., studies that clearly show that these species do not occur) reduced the regions for which predictions could be made.
- Most valuable additions in the near future would be additional studies in the offshore deep Arctic plus information on the occurrence or absence of these species in sub-Arctic and boreal seas.

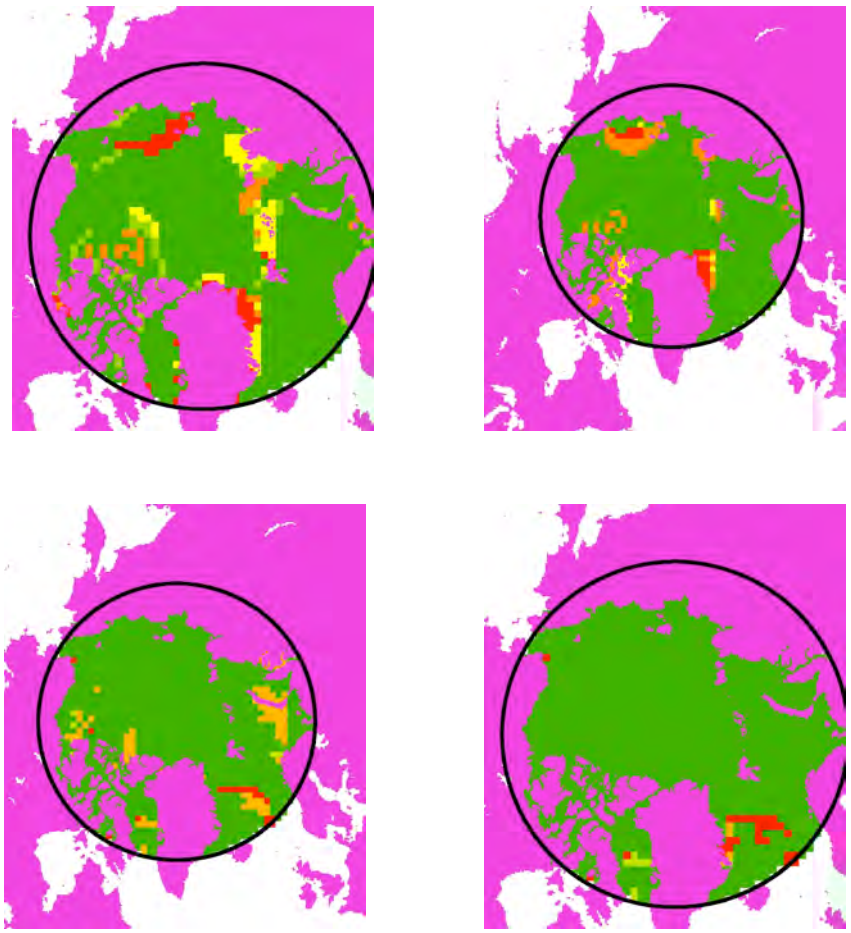


Figure 1. Predicted distribution of the under-ice amphipods Apherusa glacialis (upper left), Gammarus wilkitzkii (upper right), Onismus glacialis (lower left), and Onismus nanseni (lower right). The color code provides information regarding the certainty with which this species is found at a certain location (green – unknown, red – high certainty).

NOAA relevance/societal benefits

The Excel spreadsheets that have been produced within this effort are valuable assets for the Russian–American Long-term Census of the Arctic (RUSALCA) project of the NOAA Arctic Research Office. In addition, the

developed GIS layers and methodology will provide a backbone for future GIS-based ecosystem modeling in the Arctic including Arctic pelagic and benthic invertebrates and marine mammals.

IPY linkages/partnerships/collaborators and networking

This work is linked to the Arctic Ocean Diversity (ArcOD) project, an ICSU-approved IPY project (with R. Gradinger, UAF as cluster lead) (http://www.sfos.uaf.edu/research/arcdiv; http://www.ipy.org/development/eoi/proposal-details.php?id=333) that is part of the Census of Marine Life (CoML, http://www.coml.org). The occurrence and absence of data collected in this project will be posted on the ArcOD web site with free public access through the OBIS data node (http://www.iobis.org).

Education/outreach

Student participation

Funding from this grant was used exclusively to support student travel and work on the project. The two students participated in one field sampling expedition to Barrow, Alaska for six days, where they learned techniques to quantitatively sample the sea ice environment. Melanie Bakker and Cortney Pylant were trained in using online informational systems (like ASFA and Web of Science) to search for publications and retrieve relevant information on sea ice flora and fauna. Cortney Pylant was trained and successfully mastered the GIS modeling part of this study.

Publications

None so far. Gradinger and Huettmann will work jointly with Pylant to produce a short note for publication in an international peer-reviewed journal.

International Polar Year (IPY) Student Traineeships:
Late Quaternary environmental change in the Gulf of Alaska

Bruce P. Finney, UA faculty member, PI
Jason A. Addison, UA graduate student
University of Alaska Fairbanks

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

CIPY-06: This project is ongoing.

Primary objectives

Reconstructions of past climate are a vital component for understanding modern climate variability. The subpolar North Pacific Ocean has been identified through both field studies and modeling efforts as a primary driver for global climate. This project focuses on developing paleoclimate proxies over decadal to millennial timescales using high-resolution marine sediment cores recovered from the Gulf of Alaska. Oceanic and atmospheric circulation in the Gulf of Alaska is strongly dependent on the interactions between the Aleutian Low and Siberian High pressure systems, which in turn influence regional marine ecosystems via associated upwelling and advection of nutrient-rich water from the Alaska Gyre. As a result of these teleconnections, it is possible to quantify the effects of both short-term regime shifts in the Aleutian Low and sub-Milankovitch orbital modulations using techniques that measure primary paleoproduction preserved in the marine sedimentary record because it integrates atmospheric, oceanic, and biological systems through the biogeochemical composition of its constituent sediments.

Approach/methodology

- Develop an accurate age model for each sedimentary core using ^{210}Pb and ^{14}C dating, secular variations of the paleomagnetic record, foraminiferal $\delta^{18}O$ stratigraphy and tephrochronology.
- Measure multiple independent biogeochemical proxies including $\delta^{13}C$ and $\delta^{15}N$ isotopes, biogenic silica, total organic carbon, excess barium, and redox-sensitive transition metal concentrations.
- Apply statistical time-series analyses to determine the significance and frequency of proxy data.
- Correlate with regional and global datasets of climate change.

Research accomplishments/highlights/findings

- High-frequency changes in concentrations of marine and terrestrial organic matter, and stable isotopes of carbon and nitrogen, are important proxies for the Aleutian Low (AL) pressure system (the principal driver for the Pacific Decadal Oscillation) that has influenced climate across the Northern Hemisphere.
- Marine productivity has been highly variable over the entire Holocene, and amplitude shifts correspond closely to the AL.
- Variable concentrations of redox-sensitive trace elements indicate a complex history of bottom water anoxia and biogenic/terrestrial sedimentation.
- Time-series and wavelet analyses of proxies have found significant periodicities of both 40- and 80-yr frequencies, corresponding to AL regime shifts.
- First marine evidence for significant changes in the north Pacific Ocean ecosystem related to the Younger Dryas and Bølling-Ållerød rapid climate perturbations at the end of the Last Glacial Maximum (LGM).
- Strong correspondence between organic proxies and trace element data suggest strong linkages between surface productivity and biogeochemical cycling at the sediment–water interface in the Gulf of Alaska.
- Evidence for a glacial forebulge that exposed parts of the modern continental shelf along the southeast Alaska margin.
- LGM marine productivity in the Gulf of Alaska was significantly lower than at any time during the succeeding Holocene Epoch.
- Comparison to published terrestrial & marine records of climate indicates a strong regional and hemispheric atmosphere–ocean linkage active in the Gulf of Alaska sector of the north Pacific Ocean.

NOAA relevance/societal benefits

This project is focused on reconstructing past marine ecosystem change, as well as investigating teleconnections between the northeast Pacific Ocean and global datasets of climate change. Results will also prove to be an important component of future modeling attempts due to the importance of Aleutian Low dynamics to northern hemisphere climate.

IPY linkages/partnerships/collaborators and networking

This project has benefited from collaborations with researchers at Oregon State University (Joe Stoner and his Ph.D. student Maureen Davies; Alan Mix and Fred Prahl), the U.S.G.S. (Tom Ager, John Barron and Walt Dean), the University of Florida (John Jaeger and his Ph.D. student Gillian Rosen), as well as the Advanced Instrumentation Laboratory (Ken Severin) and the Alaska Stable Isotope Facility (Mat Wooller) at UAF.

Education/outreach

Student participation

Jason Addison – Ph.D. student, Department of Geology and Geophysics, UAF

Presentations

Finney, B.P. and J.A. Addison. 2006. Climatic change and marine ecosystems in the NE Pacific: A Holocene perspective. Oral presentation at the American Geophysical Union, Fall Meeting, San Francisco, California, 11–15 December 2006. (abstract #PP53B-04) [not reported in FY07]

Finney, B.P. and J.A. Addison. 2007. Paleoceanography of the Northeast Pacific Ocean. UAF Department of Geology and Geophysics seminar, 16 February 2007. [not reported in FY07]

Addison, J.A. and B.P. Finney. 2007. High-resolution paleoceanographic records from the Gulf of Alaska, Northeast Pacific Ocean: Inferring Holocene changes in the Aleutian Low Pressure System. Poster presentation at the XVII Congress of the International Quaternary Association in Cairns, Australia, 28 July–3 August 2007.

Addison, J.A. and B.P. Finney. 2007. Understanding past changes in the Aleutian Low Pressure System of the North Pacific Ocean using marine, terrestrial, and ice proxy records. Oral presentation at American Association for the Advancement of Science, Arctic Science Conference, Anchorage, Alaska, 24–26 September 2007.

Publications

In preparation

Addison, J.A., J.E. Beget, B.P. Finney and T.A. Ager. Marine tephrochronology of the Mt. Edgecumbe Volcanic Field, Southeast Alaska. Manuscript under preparation for the journal *Quaternary Science*.

Addison, J.A. and B.P. Finney. Understanding past changes in the Aleutian Low Pressure System of the North Pacific Ocean using marine, terrestrial, and ice proxy records. Manuscript under preparation for proceedings of the 2007 AAAS Arctic Science Conference.

Addison, J.A., B.P. Finney and W.E. Dean. High-resolution paleoproductivity evidence for Holocene evolution of the Aleutian Low Pressure System from coastal fjords in the subarctic North Pacific Ocean. Manuscript under preparation for the journal *Paleoceanography*.

International Polar Year (IPY) Student Traineeships:
Monitoring winter body condition of barren ground caribou from the Bering Sea to the Hudson Bay

Perry Barboza, UA faculty member, PI
David Gustine, UA graduate student
University of Alaska Fairbanks

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

CIPY-10: This project is ongoing.

Primary objectives

We are investigating the relationship between winter diet and nitrogen (N) balance within and between wild caribou (*Rangifer tarandus*) herds. Our "hands off" method for evaluating N balance will be used to assess the body condition of each herd in winter. The project is cooperating with communities and local, state, national, and international wildlife agencies to sample wild caribou across North America.

Approach/methodology

- We are using a new isotopic method to assess nitrogen balance from $^{15}N/^{14}N$ ratios in compounds isolated from urine, feces, and blood. This method determines the proportion of urea N from body tissue (*p*-UN), which is an index of body protein loss and thus body condition.
- Samples of snow urine, feces, and blood have been collected from 5 wintering caribou herds across 3 years (2006–2008).
- We are examining the effects of year, herd, reproductive condition, diet, physiography, and winter severity on our index of body condition.

Photo by Brad Shults, National Park Service

Research accomplishments/highlights/findings

- In collaboration with wildlife agencies in Alaska and Canada, we collected over 1800 snow urine and fecal samples (approx. 915 snow urines and 915 fecals) from 2006–2008. In the past 2 years, we have collected sets of snow urine and fecal samples from the following herds: the Western Arctic Herd in northwest Alaska, Teshekpuk Caribou Herd in northwest Alaska, Central Arctic Herd in northcentral Alaska, Denali Caribou Herd in central Alaska, Bluenose East Caribou Herd in northcentral Canada, and Chisana Caribou Herd in southeastern Alaska and Yukon, Canada.
- We have completed field sampling (2006–2008) and are moving towards completion of the laboratory component of this project. In summer 2007 we validated our technique to estimate the isotopic signature of dietary nitrogen using fractions of plant fiber in feces and developed a simulation model to incorporate known sources of variation in the estimation of the body condition index *p*-UN. The model used parameters from a range of values for $\delta^{15}N$ in urea, diet

and body to estimate mean *p*-UN and confidence intervals around that estimate. The model demonstrated that the accuracy of estimating *p*-UN increases with the difference in isotopic enrichment between the body and the diet. Consequently, this index of body condition is well suited to wintering caribou because body N is highly enriched in comparison with their diet of lichen. We have completed 85% of the lengthy process for isolating urinary N metabolites (urinary creatinine and urea nitrogen) from all samples collected in 2006–2008. We have preliminary results from the Chisana Caribou Herd from samples that were acquired in the late winter 2006.

- Woodland caribou (*R. t. caribou*) in the Wrangell St. Elias–Kluane National Park complex have recently been involved in a captive calf-rearing program. The population was thought to be <150 animals in 2004 and appeared to be limited by low neonatal survival due to predation. To increase calf survival, pregnant female adults were captured in early April 2005 and 2006 (approx. 45–60 days before calving) and moved into a temporary enclosure where they were fed a pelleted ration, protected from predators by a fence, and eventually calved. The fencing eliminated predation on neonates, and, subsequently, early calf survival was high for neonates born in captivity. Although the goal of the project was to stimulate growth of the herd by increasing calf survival, no assessment of body condition for females in captivity and in the wild has been made. We took advantage of this unique opportunity to evaluate the effectiveness of using our isotopic index of body condition to estimate the body condition of this wild population of caribou as well as provide an index of nutritional condition for a small herd in the Wrangell St. Elias and Kluane National Parks in the late winter (April–May) 2006.
- Fifty adult female pregnant caribou were captured in late winter (29 March–2 April 2006) and moved to a remote, temporary enclosure in Kluane National Park and Reserve in Yukon, Canada. Snow urine samples (n = 30) from the penned animals were collected 3 weeks after the animals were captured (25–26 April 2006). Excreta samples were not identified to specific individuals, rather, collections were made as quickly as possible from fresh and discrete excreta. Estimates of body condition, therefore, represent the protein status of the captive group of caribou. Regarding sampling for the "wild" component of the Chisana herd, snow urine and fecal samples were collected at 2 points in late winter: 1–2 April and 1–2 May 2006. Due to the small size of the herd, sampling points for snow urine and fecal collections were distributed over the extent of the wintering area. Twenty-nine urine and 30 fecal samples were collected from the winter range on 1–2 April and 27 and 26 urines and fecals, respectively, were collected on 1–2 May. The $\delta^{15}N$ of the diet for captive caribou was estimated directly from pelleted rations, while the $\delta^{15}N$ of wild diets was assessed by collection period (1–2 April and 1–2 May) using fractions of fecal fiber.
- We used ANOVA to examine the effects of collection time and class (wild and captive caribou) on *p*-UN in the Chisana herd. We used estimates of *p*-UN for animals at zero N balance (i.e., 0.47; Barboza and Parker 2006) as a reference for caribou in the wild and captive groups of the Chisana herd. We predicted that the *p*-UN would decrease from winter to spring in the wild as animals consumed emerging plants and entered positive N balances in spring. We also predicted that the *p*-UN for captive animals fed a formulated diet will be lower than wild animals in both collection periods. We expected that animals from the wild would be in worse condition during May (high *p*-UN) while captive animals would be in the better condition and condition estimates for animals from the wild group in April would fall between these two estimates.
- The mean estimates of *p*-UN by date and group indicated that all animals were in positive N balance and similar among groups (Figure 1). The percentage of each group that was in negative nitrogen balance, however, did correspond more closely to predictions: the sample collected from wild animals in late winter

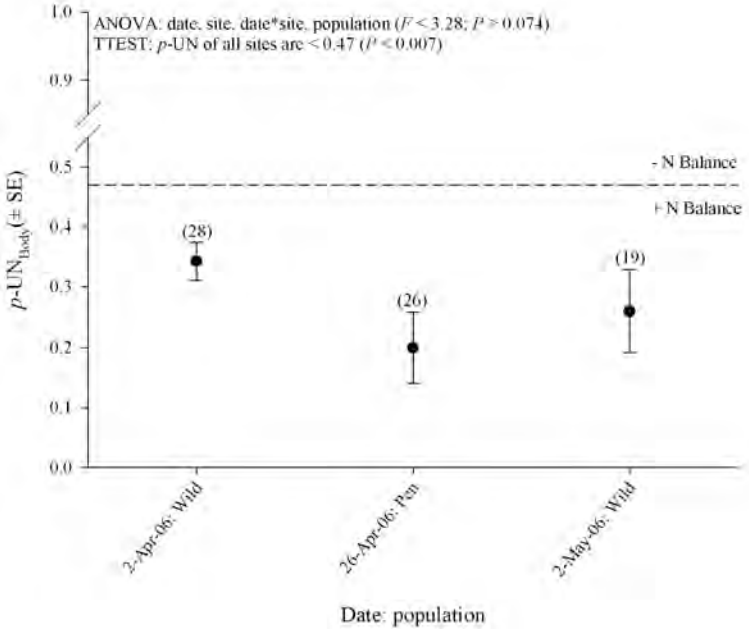


Figure 1. The proportion of urea nitrogen derived from body tissue (p-UN ± SE) for wild and captive caribou from the Chisana herd in the Wrangell St. Elias and Kluane National Parks, 2006. Sample sizes are in parentheses.

(1 May 06) appeared to have more individuals (%) in negative balance than the other groups (wild, 1 May 06 = 44.4% vs. wild, 2 Apr 06 = 25.0%; captive, 26 Apr 06 = 23.1%). We will be better able to interpret these data in relation to large scale factors such as diet, winter severity and physiography as we gather the data from other herds and years.

NOAA relevance/societal benefits

This research addresses the central mission of NOAA "to understand and predict changes in Earth's environment… to meet our Nation's economic, social, and environmental needs." This project will use physiological approaches to improve our ability to predict responses of caribou to changes in their environment.

IPY linkages, partnerships, collaborators and networking

Jim Lawler, Brad Shults, and Tom Leibscher, National Park Service; Jim Dau and Steve Arthur, Alaska Department of Fish and Game; Layne Adams, U.S. Geological Survey; Brian Person, North Slope Borough; Don Russell and Wendy Nixon, Canadian Wildlife Service; Mathieu Dumond, Nunavut Wildlife Division.

Education/outreach

Student participation

This project is part of the doctoral research of David D. Gustine, which is scheduled to be completed in Summer 2010. Funds from National Parks Service and U.S. Geological Survey were used to support Jennifer Addison (B.S. Wildlife Biology, 2007) and Keely Moon (enrolled in nursing school preparatory courses) as undergraduate technical assistants in the laboratory. Renee Parsley completed parts of the validation work as a project supported by the Murdock Foundation for providing research experience to high school science teachers.

Presentations

Gustine, D.D., P.S. Barboza, L.G. Adams, J.P. Lawler and S.M. Arthur. 2008. Developing and evaluating a "hands off" approach to monitoring body condition of caribou in late winter. Unit Review for Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks, Alaska, 26 March 2007.

Barboza, P.S., D.D. Gustine and K.L. Parker. 2007. Tracking nitrogen and metabolism in *Rangifer*. Presentation at the Fourth Circum-Arctic Rangifer Monitoring and Assessment Network meeting in Vancouver, British Columbia, Canada, 27–29 November 2007.

Publications

None to date.

Reference

Barboza, P.S. and K.L. Parker. 2006. Body protein stores and isotopic indicators of N balance in female reindeer (*Rangifer tarandus*) during winter. *Physiological and Biochemical Zoology*, 79:628–644.

International Polar Year (IPY) Student Traineeships:
Effects of an arctic biological pollutant on rare Alaskan habitats

Matthew Carlson, UA faculty member, PI
Theresa Rzeczycki, Allison Sayer,
Joel Gottschalk, UA graduate students
University of Alaska Anchorage

NOAA Goal: Ecosystem-based Management

CIPY-11: This project is ongoing.

Primary objectives

The primary objective of this project is to test how susceptible steppe–bluff habitat, adjacent woodland, and glacier river habitat are to the invasion of *Melilotus alba* (white sweet clover) and investigate how establishment may impact nutrient cycling. An *ex-situ* experiment is being conducted to determine how successfully *M. alba* seeds collected from central Alaska germinate and reproduce in plug samples taken from four different habitat sites (river, road, steppe–bluff and spruce–birch forest) along river and roadsides in the Matanuska River Basin. Physical, biological, and chemical characteristics of each plug sample and each seed genotype are being monitored over a

two-year period. Germination, establishment, growth and reproduction of each genotype are being measured to understand how populations across the state differ in their performance on these four habitats.

Approach/methodology

- Sample plugs from four different sites collected in the same geographic area: river, roadside, steppe–bluff, woodland
- 20 square plugs taken from each site, including controls
- Plugs moved to control site in Anchorage, randomly arranged on south-facing slope
- *Melilotus alba* seeds from 53 individuals collected from along Matanuska River/Glenn Hwy and No Name Creek/Dalton Hwy
- One seed from each plant randomly sown into each flat, with exception of controls
- Soil carbon and nitrogen content, and pH of each plug analyzed at seeding, end of first season, and end of second season
- Germination success, growth, death, flowers and seed set measured over two seasons

Research accomplishments/highlights/findings

- Sample plugs collected from field and moved to study site
- *M. alba* seeds collected, flats seeded, and maintained for 1.5 seasons
- First season germination measurements show river and roadside more successful than steppe–bluff and woodland
- First season growth measurements show woodland growth robust relative to others
- First season heavy insect damage to leaves, cause of mortality of new germs
- Second season additional germination in steppe–bluff and woodland
- Second season growth measurements show very high mortality in river and roadside and relatively robust growth in woodland
- Second season flowering seen in roadside and woodland samples; the largest number of flowers and seed heads found in woodland; seeds developing
- Second season insect damage still occurring, less than prior year
- Soil samples for pH taken at seeding, processed, and analyzed. No significant differences within soil type; significant difference in pH among the four soil types.
- Soil samples for pH taken at end of first season, partially processed. Still need to be analyzed.

NOAA relevance/societal benefits

The ability of *Melilotus* to spread downstream and establish on river gravel bars threatens numerous coastal resources. Gathering baseline information about susceptibility of invasion in different habitats found along river systems can be used to model the behavior of this species under various global climate change scenarios to reduce environmental and economic consequences. Data from this project will be archived at the state's non-native plant database at the Alaska Natural Heritage Program.

IPY linkages/partnerships/collaborators and networking

Research is being performed at UAA, with support of the Environment and Natural Resources Institute (ENRI), The Alaska Natural Heritage Program, the ENRI Isotope & Applied Science, Engineering, and Technology (ASET) Labs, and the UAF Palmer Research Center Lab, Norman Harris of the UAF Palmer Research Center and Trish Wurtz of the USDA Forest Service Research Lab. Additional seed collection support from Jeff Conn and Erin Carr of the USDA Fairbanks Agriculture and Research Service, and Blaine Spellman, UAF Master's student.

Education/outreach

Student participation

Allison Sayer, M.S. Biology 2008, assisted in first season soil analyses. Joel Gottschalk, M.S. Biology candidate, will be assisting for second season analyses.

Presentations

Rzeczycki, T.A. and M.L. Carlson. 2007. The invasibility of critical habitats and effects of *Melilotus alba* on nitrogen availability. Poster presented at the Annual Committee for Noxious and Invasive Plant Management meeting, Fairbanks, Alaska, 10 October 2007.

Rzeczycki, T.A. and M.L. Carlson. 2008. The invasibility of critical habitats and effects of *Melilotus alba* on nitrogen availability. Poster presented at the Graduate Studies and Research Symposium in the UAA Student Union, organized by the UAA Graduate Student Association, 27 March 2008.

Publications
None to date.

International Polar Year (IPY) Student Traineeships:
Role of sea salts in catalyzing the deposition of mercury in Arctic spring

William Simpson, UA faculty member, PI
Daniel Carlson, UA graduate student
University of Alaska Fairbanks

NOAA Goal: Understand Climate Variability and Change

CIPY-12: This is the final report on this project.

Primary objectives
This project focuses on the role of sea salts in catalyzing ozone depletion chemistry and mercury deposition in the Arctic. We have discovered that air contact with first-year sea ice is correlated with reactive bromine (which comes from sea salt) in the atmosphere. This reactive bromine is known to be the key player in ozone depletion and mercury deposition chemistry. Therefore, sea ice properties, which are currently undergoing drastic changes in the Arctic, affect pollutant deposition to the Arctic. However, not enough is currently known about the mechanism of this chemistry to make meaningful predictions of how climate change will impact pollutant deposition. We plan to study the mechanism by which bromine becomes atmospherically accessible and is converted to reactive halogen species during field campaigns in Barrow, Alaska, and at an ice camp on the Arctic Ocean north of Prudhoe Bay, Alaska, in order to determine how changing sea ice conditions will affect atmospheric chemistry and mercury deposition in the Arctic.

Approach/methodology
1. Ion Chromatography was performed on snow/ice samples taken from various areas near Barrow and on the sea ice. The resulting chemical composition data will help us to determine which frozen surfaces (ice, snow, frost flowers, etc.) have the potential to source bromine to the atmosphere.
2. Data from Differential Optical Absorption Spectroscopy, which measures the atmospheric concentration of reactive gas-phase bromine monoxide (BrO), was analyzed to gain insight into the source and mechanisms of release.
3. Portable X-Ray Fluorescence (XRF) was found to be not sensitive enough for these studies and will not be used.

Research accomplishments/highlights/findings
- In spring 2007 at Barrow, AK and at the Applied Physics Laboratory Ice Station (APLIS) in the Beaufort Sea, Carlson made measurements of atmospheric and snowpack bromine
- BrO data was taken at Barrow, AK during spring 2007 (detailed analysis in progress)
- Carlson made one presentation at the American Geophysical Union meeting in December 2007 and contributed to two manuscripts in preparation for submission

NOAA relevance/societal benefits
An understanding of bromine chemistry in the Arctic will bring us one step closer to being able to understand and predict the deposition of toxic mercury, depletions of surface ozone, which affect atmospheric pollutant deposition, and other oxidizing reactions in the Polar Regions. The impacts of this bromine chemistry are of concern to the economy, health of the citizens, and health of the ecosystem.

IPY linkages/partnerships/collaborators and networking
Tom Douglas, Matthew Sturm, Bruce Elder and Jackie Richter-Menge (U.S. Army Cold Regions Research and Engineering Laboratory, CRREL); Joel Blum (University of Michigan); UAF IPY Young Researchers Network; Laura Alvarez-Aviles (University of Alaska Fairbanks); Barrow Arctic Science Consortium.

Education/outreach

Student participation

Daniel Carlson is a Ph.D. candidate in Environmental Chemistry at the University of Alaska Fairbanks.

Presentation

Carlson, D., L. Alvarez-Aviles and W. Simpson. 2007. Salt distributions in the sea-ice snowpack and implications for Arctic halogen activation. Poster # A53B-1150, American Geophysical Union Annual Meeting, San Francisco, California, 10–14 December 2007.

Publications

In preparation

Alvarez-Aviles, L., W.R. Simpson, D. Carlson, M. Sturm, T.A. Douglas and A. Laskin. Multiphase study of the chemical composition of air, aerosol particles, snow, and ice forms collected near Barrow, Alaska provides information on bromine activation. In preparation.

Alvarez-Aviles, L., W.R. Simpson, D. Carlson, T.A. Douglas and M. Sturm. Correlation plots of ions in Arctic surface snow show unique patterns between ions and sea-salt tracer and provide evidence of snow-air interactions. In preparation.

International Polar Year (IPY) Student Traineeships:
Investigation of the impact of western arctic volcanic eruption on weather and climate

Nicole Mölders, UA faculty member, PI
Morgan E. Brown, UA graduate student
University of Alaska Fairbanks

NOAA Goals: Serve Society's Needs for Weather and Water Information; Safe, Efficient and Environmentally Sound Transportation

CIPY-16. This project is ongoing.

Primary objectives

Large volcanic eruptions have been shown to alter large-scale dynamical and physical processes, which impact climate regionally and globally. Alaska has a plethora of active volcanoes, which may impact small-scale, short-term atmospheric processes even if the eruptions are not very large. Four aspects of volcanic eruptions on local weather will be explored: 1) heat released, 2) water vapor addition, 3) change in surface radiation due to plume cover, and 4) addition of aerosols. Statistical methods will be used to determine which of the four aspects has the greatest impact on local weather during an eruption.

Approach/methodology

- Sixteen simulations are performed using the Weather Research and Forecasting (WRF) model.
- The WRF simulations without consideration of any volcanic eruption aspects (called CTR hereafter) serve as reference simulations and for model evaluation.
- The 16 simulations combining the variety of volcanic influences (i.e., heat, water vapor, radiation, and aerosols) are analyzed using ANalysis Of VAriance (ANOVA) to identify which of the four or combination thereof have the most impact on local weather.

Research accomplishments/highlights/findings

- WRF simulations have been performed. All possible combinations of the four volcano influences were simulated, totaling 16 simulations (including the CTR run).
- Evaluation of the reference simulation for the region around Mount Augustine showed that WRF produces excellent weather forecasts for the 2006 Augustine eruption. Currently, a paper reporting these results is in preparation.
- Running WRF one day at a time produces more accurate simulations than five days at a time.
- Satellite-derived surface temperatures were used to include the volcanic heat release in a second simulation.
- Based on the temporal evolution of heat release, scenarios for aerosol release and water vapor release were created using estimates from previous volcano eruptions.
- A scenario for surface albedo impacted from ash fall data was established based on data provided by the Alaska Volcano Observatory (AVO).

- We evaluated the differences from the first simulation and found an impact of volcanic heat release on local weather.
- All simulations are currently analyzed using ANOVA. First results show that independent consideration of aerosol release, water vapor release, and heat release significantly impacted the weather for the region during the volcano eruption. Interactions between water vapor and aerosol release, heat and aerosol release, aerosol release and ash fall, and heat and water vapor release significantly impacted the weather for the region during the volcano eruption.

NOAA relevance/societal benefits

The work is relevant to NOAA's goals and missions of improving weather forecasts. During volcanic eruptions Lagrangian models are driven by operational forecasts. It has to be examined how the unknown and unpredictable external forcing from volcanic eruptions may impact the weather forecasts and hence simulations of ash transport.

It is relevant for NOAA and CIFAR as it investigates the impact of volcanic eruptions in the western Arctic on weather and climate, and contributes to assessing uncertainty in numerical weather prediction. Large volcanic eruptions have an overwhelming impact on society (closure of airports, vog (volcanic smog), evacuation, limitations of surface traffic, etc.) and the atmosphere (additional cloud condensation nuclei, radiative effects, acid precipitation, etc.). Though large eruptions are rare, small eruptions occur frequently all over the world.

Preliminary results show that local changes in the microphysics may lead to significant (at the 95% confidence level) short-term changes in the weather downwind of an active volcano. Thus, our activities will permit assessment of the impact of an eruption on atmospheric measurements if one occurs in the Arctic during the International Polar Year (IPY). Some volcanic eruptions already have occurred since IPY started in March 2007. The work helps to evaluate and synthesize knowledge on weather prediction and volcanic eruptions that may enhance our understanding of climate variability, climate change, and aerosol–radiation feedback and their consequences. Furthermore, the project helps to educate the next generation of scientists by supporting a graduate student.

IPY linkages/partnerships/collaborators and networking

The AVO gave access to the satellite data required to include heat release realistically. The Arctic Region Supercomputing Center (ARSC) provided computational resources. Further networking exists within the Geophysical Institute (GI) and International Arctic Research Center (IARC) with colleagues who either work with WRF or on IPY-related projects, aerosol or volcanic research. Faculty from the College of Natural Sciences and Mathematics (CNSM), Department of Atmospheric Sciences (DAS) are involved as members of the graduate student's committee (C. Cahill, U.S. Bhatt). Using the WRF model also fosters connections with colleagues at the National Weather Service (NWS) and National Center for Atmospheric Research (NCAR). The bi-weekly Atmospheric Science Informal Seminar organized by Mölders featured results of this research and is announced campus-wide and at NWS.

Education/outreach

Student participation

The project provides Morgan E. Brown, a graduate student in the Atmospheric Science M.S. program with experience in atmospheric numerical modeling. This work will be part of her M.S. thesis and another student's thesis. Brown presented posters of her first results at the Great Alaska Weather Modeling Symposium in Fairbanks in March 2007 and the WRF Users' Workshop in Boulder, Colorado, in June 2007, at the Dynamics in Complex Systems (DCS) workshop in Fairbanks in July 2007, and at the American Meteorological Society (AMS) Annual Meeting in New Orleans in January 2008. Also at the AMS meeting, she orally presented the findings of these results at the conference of Atmospheric Science Librarians International (IASLI) with emphasis on the resources used to perform this research project. Lastly, she gave an oral presentation of the project at the Little Alaska Weather Symposium (LAWS) in Fairbanks in May 2008. Brown has finished her class work and is currently working on her thesis.

Stacy E. Porter will work on sensitivity studies related to interesting aspects that came up in the analysis and by recent eruptions. Thus, this project will provide her experience with atmospheric numerical modelling and analysis techniques.

Nicole Mölders organizes a bi-weekly Atmospheric Science Informal Seminar where results from this project were also presented. This seminar is well attended by students from DAS. She presented some aspects of this work within the framework of the Geophysical Institute's Research Experience for Undergraduates (REU) outreach activities and at the Science Teacher Education Program (STEP).

Presentations

Mölders, N. 2007. Wildfire impacts on air quality, weather and climate. REU seminar, Fairbanks, Alaska, 9 July 2007.

Brown, M.E. and N. Mölders. 2007. Analysis of volcanic heat release and local weather interaction: A case study for the 2006 Augustine volcano eruption. Poster presentation at the Dynamics of Complex Systems Workshop, Fairbanks, Alaska, 25–27 July 2007.

Mölders, N. 2007. Key considerations for simulating Arctic weather and climate with limited area models. Arctic System Model workshop, Fairbanks, Alaska, 6–7 August 2007.

Brown, M.E. and N. Mölders. 2008. Using climate-scale resources for mesoscale modeling. Invited oral presentation at the American Meteorological Society Annual Meeting, New Orleans, Louisiana, 20–24 January 2008.

Brown, M.E. and N. Mölders. 2008. Impact of the 2006 Augustine volcano eruption on local weather. Poster presentation at the American Meteorological Society Annual Meeting, New Orleans, Louisiana, 20–24 January 2008.

Brown, M.E. and N. Mölders. 2008. External forcing of the 2006 Augustine volcano eruption on local weather. Oral presentation at the Little Alaska Weather Symposium, Fairbanks, Alaska, 12–13 May 2008.

Publications

In preparation

Brown, M.E. and N. Mölders. Evaluation of the Weather Research and Forecasting (WRF) Model for the period of the 2006 Augustine volcano eruption. In preparation for submission to *Meteorology and Atmospheric Physics*.

Brown, M.E. and N. Mölders. Impact of the 2006 Augustine volcano eruption on daily weather. In preparation for submission to *Special Issue of Atmospheric Research: Polar Weather*.

International Polar Year (IPY) Student Traineeships:
Adaptation to cold in the far north

Diana Wolf, UA faculty member, PI
Jessica Beecher, UA graduate student
University of Alaska Fairbanks

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

CIPY-20: This project is ongoing.

Primary objectives

The student, Jessica Beecher, is looking for latitudinal differences in cold tolerance within *Arabidopsis lyrata kamchatica* using genetic as well as physiological tools. This may allow a better understanding of the overall differences within this species, which ranges from 35°N to 65°N latitude. This comprehensive approach should allow the student to address the following questions: 1) Is there a latitudinal cline in cold tolerance in *A. l. kamchatica*? 2) Is there a latitudinal cline in CBF (C-repeat binding factor) expression? 3) Does a change in the expression of the CBF gene play a role in allowing plants to adapt to extreme cold?

Approach/methodology

1. DNA sequencing of CBF genes in *A. l. kamchatica*
2. Comparison of CBF gene sequences to neutrally evolving genes to look for patterns of selection
3. Measure gene expression levels for CBF genes in populations using quantitative PCR (polymerase chain reaction)
4. Comparison of damage due to cold exposure using electrolyte leakage measurements (a non-lethal assay of freeze damage) for different populations
5. Common garden experiment in Fairbanks to determine if populations are locally adapted by comparing year-long survival, growth, and seed production

Changes to the original proposal:

- The reciprocal transplant experiment will be replaced with a Fairbanks over-winter common garden with 3 populations and, depending on germination, 180 plants per population in 2008.

Research accomplishments/highlights/findings

- Seeds were collected and planted from natural populations in populations in British Columbia and Alaska
- Plants from Southern Canadian and Alaskan populations were grown for the common garden experiment and over-wintered August 2007–April 2008. There were no significant differences in over-winter survival but the sample size was small and therefore this may be inconclusive. We plan to repeat the common garden with larger sample sizes in winter 2008–2009.
- Electrolyte leakage assays have been completed for plants before and after cold acclimation
- Before acclimation there were significant differences between populations in freeze damage ($p=0.023$)
- There may be genetic variation in freeze tolerance within these populations (seen as a family effect $p=0.035$)
- After acclimation, the temperature range chosen (-6 to -11ºC) did not elicit significant differences between populations ($p=0.493$), and only achieved about 20% leakage on average at -11ºC compared to the approximately 80% leakage before acclimation
- Electrolyte leakage will be retested on acclimated plants using a much colder range of temperatures (-10 to -30ºC)
- Thermal analysis has been completed for plants before and after acclimation; neither had significant differences
- Electrolyte leakage and thermal analysis will be repeated with larger sample sizes in 2008–2009
- Sequencing of the CBF genes has begun; this must be completed prior to any other genetic work
- Student has received training on how to operate QPCR software in DNA Core Lab from visiting scientist, Helena Storchova

NOAA relevance/societal benefits

In the face of changing global climates, plants must be able to adapt to new conditions or suffer extinction. This work may be helpful for determining the potential of this and other cold-adapted species to withstand the rapid climate changes which are currently occurring in Alaska and other northern regions.

IPY linkages/partnerships/collaborators and networking

No linkages established yet.

Education/outreach

Student participation

Master's student Jessica Beecher is working on this project.

Outreach

Beecher has been involved in mentoring for the Rural Alaskan Honors Institute program and study groups for the Alaskan Native Science and Engineering Program (ANSEP) in 2007 and continues her involvement with ANSEP in 2008. This has allowed her to develop mentoring skills as well as sparking an interest in a career in science in young students.

Presentations

Beecher, J., D. Wolf and N. Takebayashi. 2008. Is there a latitudinal cline in cold tolerance in *Arabidopsis lyrata* subspecies *kamchatica*? Poster presentation at the EPSCoR All Hands Meeting, Fairbanks, Alaska, 27–30 May 2008.

Publications

None to date.

International Polar Year (IPY) Student Traineeships:
Undergraduate involvement in studies of adaptive and neutral genetic variation in Alaskan species sensitive to global climate change

David Tallmon, UA faculty member, PI
Brenda Bruggeman, Amina Ashraf, Micaela Ponce, UA undergraduate students
University of Alaska Southeast

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

CIPY-23: This project is ongoing.

Primary objectives
Among the most critically important and least understood aspects of rapid climate change is how it will alter the biological diversity upon which all human societies depend for food, shelter, and economic well-being. Biodiversity in polar regions will change due to rapid warming, but determining which species will go extinct or adapt is fraught with uncertainty. An important component of within-species biodiversity—the very essence of what allows a species to persist—is the distribution of neutral and adaptive genetic variation. My collaborators and I seek to engage undergraduates in genetic investigations of Alaskan species likely to be impacted by global climate change.

Approach/methodology
We are actively engaging undergraduates in the field, lab, and analytical research. Primarily, students have been involved in the lab generating genotypes from species likely to be affected by global climate change. So far, three students have been involved in genetics lab projects. However, we have also given students opportunities to work on research projects in the field, including three students who have worked with us in Glacier Bay National Park and Auke Creek.

Research accomplishments/highlights/findings
Our best result comes from the study of ringed seals, which is an important subsistence species and largely dependent upon Arctic ice for breeding. We have found evidence that ringed seal populations are not genetically subdivided, but, rather, appear to have large amounts of gene flow among populations. This suggests that high rates of movement of seals among populations will help maintain genetic diversity within populations and provide resilience to these populations in the face of future sea ice loss.

We have also begun to quantify the adaptive value of substrate matching and predator avoidance behaviors by coastrange sculpins that successfully colonize recently deglaciated habitats, using mark-recapture and lab experiments. This will provide insights into the importance of phenotypic plasticity in the adaptation of organisms to recently deglaciated habitats.

NOAA relevance/societal benefits
Our research will improve our ability to predict responses of organisms in a wide range of coastal marine and terrestrial environments to global climate change.

IPY linkages/partnerships/collaborators and networking
We have forged collaborative research partnerships with Brad Swanson, Central Michigan University and with Glacier Bay National Park.

Education/outreach
Student participation
Micaela Ponce is pursuing a B.S. in Biology and Math
Amina Ashraf graduated in December 2008 with a B.S. in Biology
Brenda Bruggeman graduated in June 2007 with a B.S. in Marine Biology
Brandon Howard is pursuing a B.S. in Marine Biology
Jon Barton is pursuing a B.S. in Marine Biology

Presentations

Ponce, M.E. (UAS Undergrad), B.P. Kelly and D. Tallmon. 2007. Ringed seal population structure; impacts of diminishing snow cover. North Slope Borough Fish & Wildlife Management Annual Meeting, Barrow, Alaska, 4 December 2007.

Howard, B. (UAS Undergrad), A.R. Whiteley and D.A. Tallmon. 2008. Capture-mark-recapture based estimates of the fitness consequences of color plasticity in a freshwater fish. Pacific Ecology and Evolution Conference at Bamfield Marine Sciences Center, Vancouver Island, British Columbia, 22–24 February 2008.

Ponce, M.E. (UAS Undergrad), B.P. Kelly and D. Tallmon. 2008. Breeding site fidelity and philopatry in ringed seals (*Phoca hispida*). West Coast Biological Sciences Annual Undergraduate Research Conference, San Diego, California, 12 April 2008.

Ponce, M.E. (UAS Undergrad), B.P. Kelly, C. Hay-Jahans and D. Tallmon. 2008. Seasonal haulout patterns of ringed seals and the possible impacts of climate change. American Institute of Biological Sciences Annual Conference: Climate, Environment, & Infectious Diseases, Washington, DC, 12 May 2008.

Publications

None to date.

International Polar Year (IPY) Student Traineeships:

Greening of the Arctic: Synthesis and models to examine pan-Arctic vegetation change: climate, sea-ice, and terrain linkages

Donald A. Walker, UA faculty member, PI
Martha K. Raynolds, UA graduate student
University of Alaska Fairbanks

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

CIPY-28.This is the final report for this project.

Primary objectives

The objective of this project is to understand how land-surface temperatures and sea ice patterns influence vegetation patterns and normalized difference vegetation index (NDVI) across the pan-Arctic.

Approach/methodology

1. Synthesize NDVI and temperature data
2. Analyze relationships between climate, ice, and vegetation in different parts of the Arctic
3. Integrate the results of this analysis with the input and output of vegetation change models
4. Changes: Uma Bhatt is doing much of the ice analysis described in Step 2, so Martha Raynolds is focusing on the spatial distribution of arctic NDVI and its relationship to temperature.

Research accomplishments/highlights/findings

- For the whole Arctic, a 5 ^{o}C increase in summer warmth index (SWI) along the climate gradient corresponded to an increase in NDVI of approximately 0.07. This result supports and is of similar magnitude as temporal studies showing increases of arctic NDVI corresponding to increases in growing season temperatures over the length of the satellite record. The strongest positive relationship between NDVI and SWI occurred in partially vegetated and graminoid vegetation types. Recently de-glaciated areas, areas with many water bodies, carbonate soil areas, and high mountains had lower NDVI values than predicted by SWI. (Raynolds et al. 2008a)
- When added to a model that included climate and lake cover, permafrost characteristics accounted for an additional 11% of the variation in NDVI. High ice content in permafrost had the strongest effect, lowering NDVI. Over 65% of areas with thin overburden are vegetated by low-stature, low-cover, low-biomass vegetation types that have little impact on thermal regimes. This climbs to > 82% for areas that also have high ice content permafrost. Over 83% of areas with thick overburden have vegetation types with denser, taller vegetation, which alters the interaction between climate and permafrost. Including vegetation characteristics in permafrost models will be particularly important in areas with thick overburden and medium or high ice content. (Raynolds and Walker 2008)

- Biomass maps along a North American Arctic transect showed lower biomass in the centers of patterned-ground features than in areas between features, and increasing biomass from north to south. Thaw-depth maps showed deeper thaw in the centers of features than between features, and shallow thaw on the north and south ends of the transect. Snow depth maps showed less snow on patterned-ground features subject to differential frost heave compared to areas between features which did not heave, and a north–south gradient of increasing snow depth. The maps also documented the change from small nonsorted polygons to larger nonsorted circles from north to south, and increasing pattern size with moisture. Principal components analysis revealed underlying relationships between patterned-ground landscapes and measured vegetation and environmental variables. Climate in combination with the vegetation was the most important factor affecting patterned ground on zonal sites, but soil moisture, texture and chemistry were also important. (Raynolds et al. 2008b)
- Yamal Peninsula (Northwest Siberia) bioclimate subzones are warmer than average for the Arctic, with coldest areas along the coast and in areas with many lakes. The main trend in NDVI values is an increase from north to south, a gradient along with both temperature and elevation increase. NDVI increases about 0.0036 units for every degree of SWI, which is less than the response of the Arctic as a whole. There was no evidence of differences in NDVI due to age of surfaces as mapped by Quaternary geology, but NDVI of marine sediments were lower than NDVI of glacial and glacio-fluvial deposits (0.46 vs. 0.49). General linear model (GLM) analysis showed that landscape (as mapped by "landschaft") and elevation together accounted for 49% of the variation in NDVI among Circumpolar Arctic Vegetation Mapping (CAVM) polygons. Lithology, vegetation type, SWI and percent lake area together accounted for an additional 13% of the variation. (Raynolds 2008 presentation at Land Cover Land Use Change in Yamal).
- Most of the older arctic landscapes in the circumpolar arctic occur east of the Taimyr Peninsula in Russia and west of the Mackenzie River in Canada. The vegetation types most commonly associated with the oldest landscapes include tussock-sedge, dwarf-shrub, moss tundra and sedge-shrub wetlands. Most of the Arctic, including most bioclimate zones and most vegetation types, showed increasing NDVI with landscape age up to around 20,000 years, after which NDVI leveled off. Landscape age accounted for 34% of the variation in NDVI for landscapes younger than 900,000 years. The coldest parts of the Arctic (Subzone A) and vegetation types that grow primarily in these areas did not show any trend with landscape age. (Raynolds and Walker, submitted)

NOAA relevance/societal benefits

This research is using data derived from Advanced Very High Resolution Radiometer (AVHRR) sensors aboard NOAA's satellites (land surface temperature, sea ice extent and NDVI data) to analyze the relationship between environmental characteristics such as temperature, and vegetation of the Arctic. The results will improve our knowledge of the interactions between climate, sea ice, and vegetation that can be detected from space, and will be applicable for a wide variety of conservation and management purposes—for example, predicting which coastal tundra vegetation types will become more or less common, and which are likely to become rare. This research will also be important for calibrating models of arctic vegetation under different climate conditions (paleoclimate and GCM predictions).

IPY linkages/partnerships/collaborators and networking

Martha Raynolds is working with Donald Walker, Uma Bhatt, Josefino Comiso, Gensuo Jia, and Howard Epstein, all IPY researchers.

Education/outreach

Student Participation

Martha Raynolds, Ph.D. student

Presentations

Raynolds, M.K. 2007. The relationship between permafrost characteristics and the distribution of arctic vegetation types. Poster presented at American Association for the Advancement of Science, Arctic Science Conference, Anchorage, Alaska, 24–26 September 2007.

Raynolds, M.K., D.A. Walker and J.C. Comiso. 2008. Spatial patterns of land surface temperature and NDVI, and their relation to vegetation distribution on the Yamal Peninsula. Presentation at Land Cover–Land Use Change in Yamal, Moscow, Russia, 28–30 January 2008.

Raynolds, M.K. 2008. Circumpolar AVHRR surface temperature and its relationship to bioclimate zones and NDVI. Talk presented to researchers at the Komarov Botanical Institute, St. Petersburg, Russia, 5 February 2008.

Raynolds, M.K., D.A. Walker and J.C. Comiso. 2008. Spatial patterns of land surface temperature and NDVI and their relation to vegetation distribution on the Yamal Peninsula. Poster presentation at NASA Land Cover Land Use Change conference, Baltimore, Maryland, 30 April–2 May 2008.

Raynolds, M.K., D.A. Walker and J.C. Comiso. 2008. Spatial patterns of land-surface temperature and NDVI, and their relation to vegetation distribution on the Yamal Peninsula, Russia. Poster presented at the 2008 NASA Carbon Cycle and Ecosystems Joint Science Workshop, Baltimore, Maryland, 1–3 May 2008.

Raynolds, M.K. and D.A. Walker. 2008. The effects of deglaciation on circumpolar distribution of arctic vegetation. Presented at Circumpolar Remote Sensing Symposium, Whitehorse, Yukon Territory, 2–5 June 2008.

Raynolds, M.K. and D.A. Walker. 2008. Circumpolar relationships between permafrost characteristics, NDVI, and arctic vegetation types. Poster presentation at the Ninth International Conference on Permafrost, Fairbanks, Alaska, 29 June–3 July 2008.

Publications

Peer-reviewed

Raynolds, M.K., J.J. Comiso, D.A. Walker and D. Verbyla. 2008a. Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. *Remote Sensing of Environment,* 112:1884–1894.

Raynolds, M.K., D.A. Walker, C.A. Munger, C.M. Vonlanthen and A.N. Kade. 2008b. A map analysis of patterned-ground along a North American Arctic Transect. *Journal of Geophysical Research–Biogeosciences*, 113:G03S03, doi:10.1029/2007JG000512

Raynolds, M.K. and D.A. Walker. 2008. Circumpolar relationships between permafrost characteristics, NDVI, and arctic vegetation types. Proceedings of the Ninth International Conference on Permafrost (Vol. 2), 29 June–3 July 2008, Fairbanks, Alaska, pp. 1469–1474.

Submitted

Raynolds, M.K. and D.A. Walker. The effects of deglaciation on circumpolar distribution of arctic vegetation. Submitted to a special issue of *Canadian Journal of Remote Sensing*, focused on the Circumpolar Remote Sensing Symposium.

International Polar Year (IPY) Student Traineeships:
Cultural identity, geographical attachment, and indicators of behavioral health among Alaska Native students

Robert J. Boeckmann, UA faculty member, PI
Alice Smith, UA undergraduate student
University of Alaska Anchorage

NOAA Goal: Understand Climate Variability and Change

CIPY-31.This project is ongoing.

Primary objectives

We have aimed to develop a better understanding of how Alaska Native people are responding to cultural changes in their communities. Because of the intimate connection between Alaska Native cultural practice and the geography of Alaska we aimed to examine interrelations between their sense of connection to the land, sense of identity, cultural practice, social dynamics in their communities and indicators of behavioral health. IPY funding was used in part to add to and clean an existing data set examining these variables. To facilitate communication and collaboration between scholars with similar objectives, we sought to present the findings of our research at a national conference. We also sought to design a follow up survey that would include measures of resiliency and suicide risk indicators in addition to a selection of the promising variables from the first study. Finally we planned to collect data from Alaska Native students using this revised survey and analyze it with the goal of presenting the research and publishing it at a later date. The long term aim and application of these research projects is to contribute to better interventions to aid individuals and communities in developing and maintaining resilient responses to rapid cultural changes brought about by contact with other cultures as well as the ongoing and profound climatic and ecological changes going on throughout the Arctic region. Finally, through this project an Alaska Native student, Alice Smith, was mentored into engagement in graduate level scholarship.

Approach/methodology

- Survey One: Developed self report survey consisting primarily of the following variables: demographics, Alaska Native heritage (e.g., Yupik, Tlingit, etc.), strength of identity, strength of connection to land, importance and frequency of interaction with role models, cultural practice indicators, and self esteem.
- Recruited Alaska Native students to add to existing data set and replace incomplete data records.
- Use SPSS to evaluate inter-correlations between measured variables.
- Present findings at a conference using PowerPoint and summary provided by Microsoft Word document.
- Survey Two: In development / refinement. Reviewed research literature on construct of resilience and worked on conceptualizing this variable in terms of social dynamics and community functioning/adaptation. Reviewed research literature and consulted with academics on assessing suicide risk in culturally appropriate ways. Developed draft of survey incorporating aspects of survey one and new variables and drafted Institutional Review Board (IRB) proposal.
- Consulted with director of Native Student Services about developing a random sample of all Alaska Native students at UAA for recruitment.

Research accomplishments/highlights/findings

- Collected additional data for survey one.
- Reanalyzed expanded and cleaned data set.
- Prepared conference presentation "Correlates of Alaska Native Identity and Self Esteem" for presentation at "What's next for Native American and Indigenous Studies?: An International Scholarly Meeting," May 2007 in Norman, Oklahoma (University of Oklahoma). Alice Smith made the presentation and Boeckmann received very positive feedback about her participation at the conference from the symposium chair. Smith also presented this research at UAA.
- Designed new survey measure and submitted the research protocol for approval with the UAA IRB. The IRB gave conditional approval and requested revisions to the protocol. Unfortunately, due to serious illness in her family, Smith was unable to complete the required revisions to the research protocol or do significant additional work on preparing the survey for launch. Boeckmann hopes to make progress on these tasks in the coming year.

NOAA relevance/societal benefits

By elucidating the important role of cultural practice (including subsistence fishing) in Alaska Native identity and behavioral health we believe we can draw attention to the role stewardship of the coastal environment and maintenance of traditional ways can play in aiding Alaska Native communities in maintaining and enhancing behavioral health.

IPY linkages/partnerships/collaborators and networking

In May 2007, Alice Smith met with researchers at the Indigenous Studies conference in Norman who are interested in research with Canadian Indigenous / First Nations groups. She established informal ties with these researchers. Smith also collaborated with Kathy Graves and Boeckmann on examining the Social Transitions of the North (STN) data set. Graves is now the director of behavioral health for the Alaska Native Tribal Health Consortium. At the time of the collaboration she was a University of Alaska IPY postdoctoral fellow at UAA.

Education/outreach

Student participation

Alice Smith completed her B.A. in Psychology in Fall 2007. She is now working but intends to apply to the UAF / UAA joint Ph.D. program in Clinical and Community Psychology with a Rural and Indigenous emphasis.

K–12 outreach

Smith returned to her village of Scammon Bay and presented her research project and described research engagement at UAA for students at the elementary school and the high school. We hope that this presentation will help to inspire other children from the village to consider higher education.

Publications

None to date. In May 2007 Smith presented "Correlates of Alaska Native Identity and Self Esteem: Tradition and Place in Times of Change" at the "What's next for Native American and Indigenous Studies?: An International Scholarly Meeting" at the University of Oklahoma, Norman. There are plans to write up this research for publication.

International Polar Year (IPY) Student Traineeships:
Do arctic vertebrates defend bone mineral stores during hibernation?

Brian Barnes (UAF) and Ian van Tets (UAA),
UA faculty members, PIs
Kalb Stevenson, (UAF/UAA graduate student) and
Jeffery Mayfield (UAF undergraduate student)
University of Alaska Fairbanks/Anchorage

NOAA Goal: Understand Climate Variability and Change

CIPY-33: This project is ongoing.

Primary objectives

In arctic and subarctic Alaska, several species of vertebrate animals must hibernate to survive the winter months. Hibernation is a 5–7 month period of inactivity during which an animal's metabolic rate is severely decreased and no food is consumed. Therefore, maintenance of energy, nutrient, and mineral levels in hibernators is very important. As climate changes in arctic and subarctic regions, nutrients and minerals may change in their availability or accessibility immediately prior to or following hibernation seasons, which could affect the survival and breeding strategies of different hibernating populations. Prolonged inactivity could lead to a loss of minerals from bone or, alternatively, hibernators may have active processes that protect bone mineral density (BMD). There are conflicting reports about whether composition changes during hibernation among various vertebrate species. Our aim is to measure changes in the BMD of captive hibernating and non-hibernating arctic ground squirrels (*Spermophilus parryii*) using dual-energy X-ray absorptiometry (DXA). We will also measure the BMD of captive hibernating black bears across their hibernation season and compare these results with seasonal changes in non-hibernating voles in Alaska, which restrict, but do not eliminate, movement in winter. It has recently been shown that the long bones (femur and humerus) of voles undergo osteopenia from summer to late winter—likely the result of reductions in body mass, activity, and baseline reproductive hormones (Stevenson et al., in press). Our research on hibernators will improve the current understanding of fluctuations (if any) in their bone density levels, will provide a comparison of overwintering strategies of different Alaskan mammals as it relates to mineral storage, and may ultimately contribute some new and valuable information to the study of disuse osteoporosis in humans.

Approach/methodology

All of our study animals were primarily the subjects of other studies in hibernation physiology at UAF. We were allowed by these researchers to carry out our study on BMD on the research subjects they observed.

Arctic Ground Squirrels

- Arctic ground squirrels (*Spermophilus parryii*) were captured in interior Alaska and were held in UAF animal quarters.
- These squirrels (approximately 50) were anesthetized in August 2007 to obtain pre-hibernation measurements of mass and femur BMD using DXA.
- Squirrels were then euthanized after either 30, 60, 90, or 120 days into hibernation, and a second mass and femur BMD measurement taken.
- Changes in mass and femur BMD were compared between groups.
- Non-hibernating squirrels were used as a control and scanned accordingly.

Other hibernators

- Four black bears (*Ursus americanus*) in captivity at UAF were anesthetized in October/November 2007 towards the beginning of hibernation. At this time, a BMD measurement of the first middle phalanx of the right forepaw was recorded using DXA.
- Bears were euthanized in Spring 2008 to obtain a final BMD measurement.

Non-hibernating voles

- A related study on the seasonal changes in the BMD of non-hibernating voles was completed in August 2007 and is currently in press (Stevenson et al.).
- The study concluded that voles undergo dramatic seasonal change in bone density. Vole BMD levels increase rapidly in spring, peak in early summer, and gradually reduce from late summer to their lowest point in late winter. This is likely the result of reduced movement, reduced body size, and reduced levels of reproductive hormones, all of which can affect bone density.

- This study introduces the need for related studies and comparisons with hibernating rodents, such as the arctic ground squirrel.

Research accomplishments/highlights/findings

- A pilot study showed no change in the BMD of three ground squirrels that hibernated during winter 2006/2007. However, the BMD of a fourth squirrel increased dramatically just 1 week after arousal.
- Initial Institutional Animal Care and Use Committee (IACUC) documents and logistical planning were approved, and live animal work began in August 2007 for this project on hibernators.
- In September 2007, final results for related non-hibernators and preliminary work for hibernators were presented at the American Society for Bone and Mineral Research (ASBMR) meeting in Honolulu, Hawaii.
- All captive animal work was complete in May 2008.

NOAA relevance/societal benefits

This research aligns with some of NOAA's major goals in that it applies relatively new technology to document natural variability. It explains the natural ecological process of hibernating animals, and will provide new information about vertebrate hibernation strategies in a changing arctic environment. This research is relevant to the CIFAR themes in that it will assess a critical part of arctic wildlife survival (hibernation) in an attempt to understand the impact climate change might have upon animal physiology and life-history stages.

IPY linkages/partnerships/collaborators and networking

K. Stevenson mentored a National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)/National Institutes of Health (NIH) student, Don Chon, during the summer 2007 to assess seasonal changes in non-hibernating voles to compare with hibernating animals. This was part of the Short-Term Education Program for Underrepresented Persons (STEP-UP) that helps students of underrepresented people groups gain experience in medical research through a partnership between UAA, Charles Drew University, and the University of Hawaii. An oral and poster presentation of this research was presented at the annual NIDDK/NIH STEP-UP meeting in Washington, DC in August 2007. These results will also be published in a future issue of "Ethnicity and Disease," which features the research projects of these mentored students.

Education/outreach

Student participation

Kalb Stevenson—Ph.D. student (UAA/UAF)

Jeff Mayfield—Undergraduate student (UAF)

Trixie Lee, collaborator/participant – Ph.D. student (UAF)

Don Chon, collaborator/participant – (NIDDK/NIH STEP-UP, graduate of East Anchorage High School; UAA)

Presentations

Chon, D.Y., K.T. Stevenson and I.G. van Tets. 2007. Seasonal changes in the bone mineral density of a non-hibernating Alaskan rodent, the northern redbacked vole (*Clethrionomys rutilus*). NIDDK STEP-UP National Conference, Washington, D.C., 14–19 August 2007.

Stevenson, K.T., J.D. Mayfield, B.M. Barnes and I.G. van Tets. 2007. Seasonal changes in the bone mineral density of a non-hibernating arctic rodent species: the northern red-backed vole, *Clethrionomys rutilus*. *Journal of Bone and Mineral Research* 22(1):S227 (M515). Presented at the American Society for Bone and Mineral Research Annual Meeting, Honolulu Convention Center, Honolulu, Hawaii, 15–19 September 2007.

Publications

In press

Stevenson, K.T., I.G. van Tets and D.Y. Chon. Making no bones about it: Bone mineral density changes seasonally in a non-hibernating, high-latitude rodent, the northern red-backed vole (*Myodes rutilus*). *Journal of Mammalogy*, in press.

International Polar Year (IPY) Student Traineeships:
Sea-ice use during IPY 2007–2008: Exploring past and present local activities through research and education and outreach in Barrow and Wales, Alaska

Hajo Eicken, UA faculty member, PI
Matthew Druckenmiller, UA graduate student
University of Alaska Fairbanks

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

CIPY-34: This project is ongoing.

Primary objectives
This project is funding Druckenmiller's contribution to a component of an IPY project led by Eicken, entitled "The State of the Arctic Sea Ice Cover: An Integrated Seasonal Ice Zone Observing Network (SIZONET)." In addition to sampling sea-ice state variables, this work is guided by the concept of sea-ice system services (SISS). By assessing the nature and extent of SISS, an integrated observation network can be built that leads to prediction of key trends in a changing Arctic in a way that provides maximum benefit to stakeholders. Druckenmiller's role is to explore the two-way connection between local and traditional knowledge (LTK) and observations of Iñupiat sea-ice experts and western scientific studies of the sea ice.

Approach/methodology
1. Document the Barrow spring whaling trail networks using differential GPS and local interviews and perform analysis in the context of satellite imagery, coastal radar data, thickness surveys, and photography.
2. Compile information about past ice, weather, and whaling conditions from previous studies, historical text, and local interviews.
3. Compile Inupiaq words for sea-ice and conduct a comparative sea-ice photography project in Wales using present day photos and historical photos from the Alfred Bailey Collection taken in the 1920s.

Research accomplishments/highlights/findings
- Collected GPS data for the 2007 and 2008 Barrow whaling trails and performed relevant interviews with hunters.
- Performed sea-ice thickness surveys of the landfast ice off both Barrow and Wales in 2008 using an electromagnetic induction sounding device.
- Coordinated with and interviewed local sea-ice observers in both Barrow and Wales.
- Performed the interview component for the comparative sea-ice photography project in Wales and assisted with the editing of the Wales Inupiaq Sea Ice Dictionary.

NOAA relevance/societal benefits
This project addresses the following NOAA mission goals: (1) understand climate variability and change to enhance society's ability to plan and respond, and (2) serve society's needs for weather and water information. The particular value of Druckenmiller's approach to these goals lies in his comprehensive examination of both LTK and western science to provide information relevant to stakeholders.

IPY linkages/partnerships/collaborators and networking
The majority of the research conducted thus far in regards to LTK and whaling trail documentation has been done in close collaboration with Igor Krupnik (cultural anthropologist, Smithsonian Institution) and his IPY project "Sea-Ice Knowledge and Use (SIKU)" and Craig George (wildlife biologist, North Slope Borough Department of Wildlife Management), respectively.

Education/outreach
Student participation
Druckenmiller is pursuing a Ph.D. in Geophysics at the University of Alaska Fairbanks.
- In May 2008, Druckenmiller was an assistant instructor for GEOS 693 "Field techniques in interdisciplinary sea-ice research"—a two week graduate course that exposed an international group over twenty students to sea-ice measurements techniques on the landfast ice off Barrow, Alaska. Eicken was one of three lead instructors.

K–12 outreach

Druckenmiller, M.L. 2008. Sea-ice science at Wales, Alaska. Presentations to elementary, middle and high school students, Kingikmiut School, Wales, Alaska, 27–28 February 2008.

Presentations

Druckenmiller, M.L. 2007. Arctic coastal regions and environmental change. Upward Bound Climate Change Workshop, University of Alaska Fairbanks, Fairbanks, Alaska, 18 July 2007.

Druckenmiller, M.L. 2007. Alaska's coastal sea ice: why is it important? Arctic Climate Modeling Program STM Workshop, Fairbanks, Alaska, 17 November 2007.

Publications and Products

Non-peer-reviewed

Druckenmiller, M.L., J.C. George and L. Brower. 2008. Spring 2008 Ice Trails – Barrow, Alaska. *Map posted at* www.sizonet.org/barrowicetrails.

In press

Weyapuk, W. Jr. and I. Krupnik (compilers); Anungazuk, H., I. Krupnik and M. Druckenmiller (editors). Kinikmi Sigum Qanuq Ilitaavut – Wales Inupiaq Sea Ice Dictionary. Arctic Studies Center, Smithsonian Institution, Washington, D.C., in press.

In preparation

Druckenmiller, M.L., H. Eicken, D. Pringle, M. Johnson and C. Williams. Towards an integrated coastal sea-ice observatory: System components and a case study at Barrow, Alaska. In preparation for submission to *Arctic*.

Eicken, H. et al. Handbook on Field Techniques in Sea-ice Research: A Sea-ice System Services Approach. In preparation for publication by the University of Alaska Press, Fairbanks, Alaska. (Druckenmiller is a contributing author to three different chapters.)

Task II

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

Steller Sea Lion Projects

Arctic Research Initiative Projects

RUSALCA

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 is the final report of the project. Final data analyses are largely completed and preparation of manuscripts are at an advanced stage and expected to be completed by the end of the year.

Primary objectives

The first 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, the goal was to analyze 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.

Approach/methodology

Epibenthic communities were sampled at 17 stations using a beam trawl, otter trawl and 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 was performed using PRIMER software.

In addition to the 17 trawl stations sampled during the RUSALCA 2004 expedition, six stations were sampled from 6–10 August 2007 onboard the Japanese vessel *Oshoru Maru* at depths of 25–50 m and another six stations were sampled from 4–14 September 2007 onboard the American vessel *Oscar Dyson* at depths of 31–60 m. These additional stations were collected to obtain better coverage of the Chukchi Sea for a more solid assessment of benthic epifauna. The gear and protocol used were identical to the ones used during the RUSALCA expedition. Sampling was conducted by Sarah Mincks, SFOS/UAF IPY post-doc, Dominic Hondolero, CIFAR-IPY undergraduate student, and Brenda Holladay, SFOS/UAF, who operated the trawl gear. Currently, the species identifications from the three expeditions are unified and quality-controlled and a few last taxa are being sent out for identification to experts. All three data sets will be combined into a single manuscript on Chukchi Sea benthic epifauna that is in progress.

For stable isotope analysis, benthic epifaunal and infaunal organisms as well as water column particulate organic matter (POM) and pelagic invertebrates were collected during the RUSALCA cruise. 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 Alaska Stable Isotope Facility at UAF.

Research accomplishments/highlights/findings

- Abundances at the *Oscar Dyson* and *Oshoru Maru* stations ranged from 371 to 1776 individuals (ind) 1000 m^{-2} and from 2237 to 71,055 ind 1000 m^{-2}, respectively (Figure 1 top panel). Biomass at the *Oscar Dyson* and *Oshoru Maru* stations ranged from 4.2 to 48.5 kg wet weight (ww) 1000 m^{-2} and from 15.8 to 72.7 kg wet weight 1000 m^{-2}, respectively (Figure 1 bottom panel). For comparison, abundance and biomass at RUSALCA stations ranged from 800 to 40,000 ind 1000 m^{-2} and from 1.6–69 kg wet weight 1000 m^{-2}, respectively. Variability between stations was clearly very large and high values were typically driven by the high abundance

of a single species, usually an echinoderm. In many cases during all three cruises the dominant taxon was *Ophiuroidea* (brittle stars), which also is the dominant epifauna taxon on Arctic shelves on a pan-Arctic scale.

- Comparison of trophic positions of the same species at two stations under the Anadyr Water mass (AW) and Alaska Coastal Water (ACW) in Bering Strait, separated only by 70 km, revealed that benthic species under ACW had higher $\delta^{15}N$ values than their AW counterparts. This translates into longer food webs in ACW compared to AW when POM is considered as the baseline food source. However, if primary consumers are used as the baseline for food-web length to account for the typically high variability in POM, food web structures under the different water masses were fairly similar, with AW food webs being slightly longer. This indicates that POM needs to be considered with care in terms of its role as a food source, at least in the ACW. POM in ACW is likely to be influenced strongly by freshwater and terrestrial material, which is measured in the POM source but does not provide significant food for benthic organisms. This coincides with food web theory that predicts higher productivity waters such as the AW to result in longer food webs.
- We suggest that the findings indicate that AW benthos receives fresher POM than ACW benthos, i.e., higher quality and likely 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. This would lead to shorter food webs in the western Chukchi Sea (AW) and will likely result in less benthic biomass. This will have consequences for higher trophic levels such as bottom-feeding mammals and diving birds.

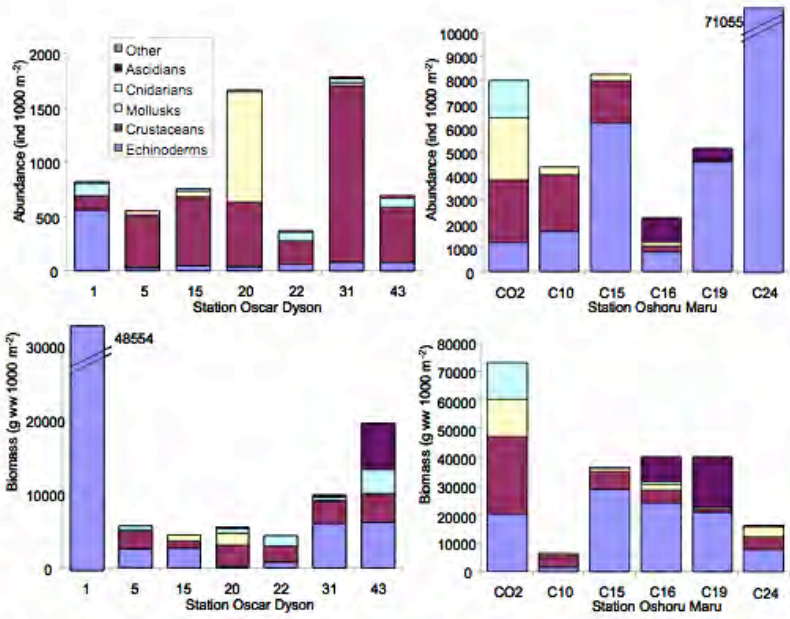


Figure 1. Abundance and biomass of benthic epifauna collected at 12 stations in 2007 during Oshoro Maru *and* Oscar Dyson *cruises to complement RUSALCA sampling. Note the different scales on the y-axis.*

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 water column processes over longer time periods than lower trophic levels, 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. A new initiative that is building on the RUSALCA efforts is a proposal submitted to the Minerals Management Service (MMS) to monitor benthic communities and food web structure in the eastern Chukchi Sea Lease Sale areas (Iken and Bluhm are both among the PIs on this proposal). The PIs' network allows them to interpret the RUSALCA data in a broader context.

The area coverage and the scope of our RUSALCA project were extended by the participation in the Japanese *Oshoro Maru* cruise covering stations in the eastern Chukchi Sea and the *Oscar Dyson* cruise in 2007. An undergraduate student, funded through the CIFAR-IPY student opportunity, participated in the *Oshoro Maru* cruise taking samples for benthic community structure and for measuring caloric content of benthic invertebrates (CIFAR-IPY undergraduate project). One of the University of Alaska Presidential IPY post-docs participated in both these cruises and is not only participating in data analysis and manuscript preparation but will also conduct reproductive studies of common invertebrates and genetic analyses to decipher gene flow in the region. These opportunities expanded our RUSALCA dataset spatially, temporally and conceptually.

Education/outreach

Public awareness

Iken, K. 2008. Presentation of results during guest lecture on "IPY Research" (UAF seminar course taught by Brenda Konar), 27 February 2008.

Professional presentations

Iken, K., B. Bluhm, B. Norcross and B. Holladay. 2007. RUSALCA epibenthic and demersal fish communities. Presentation during RUSALCA PI planning meeting in Moscow, Russia, December 2007.

Crane, K., J. Calder, T. Whitledge, M. Zdhanov and the RUSALCA scientific party. RUSALCA – Russian–American Long-Term Census of the Arctic: physical and ecosystem observations in the Pacific Arctic. NOAA Climate Observations Review, Washington DC, May 2007. [not previously reported]

Publications

Several publications are expected from this project. One manuscript has been submitted to *Deep-Sea Research II* to be part of a special issue on research findings of the RUSALCA cruise and others on the Chukchi Sea shelf and adjacent basins. Both Iken and Blum are guest editors of this special volume. The manuscript was recommended for publication after minor revisions. Revisions are in progress and a revised version will be submitted to the journal in early Fall 2008.

Submitted

Iken, K., B. Bluhm and K. Dunton. Benthic food web structure serves as indicator of water mass properties in the southern Chukchi Sea. In revision at *Deep-Sea Research II*. Recommended for publication after minor revisions.

In preparation

Bluhm, B., K. Iken, S. Mincks and B. Sirenko. Chukchi Sea epibenthic community structure. In preparation*.

* assembly of this manuscript has been delayed because the RUSALCA dataset was combined with data sets from two cruises of the *Oscar Dyson* and the *Oshoro Maru* to provide a larger data set for analysis. Currently, species lists from all cruises are being combined and QA/QC is ongoing. Manuscript for submission expected by the end of 2008.

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 complete. The work will continue with North Pacific Research Board (NPRB) funding as a component of the Bering Sea Integrated Ecosystem Research Program (BSIERP). See previous annual reports for research activity under this award.

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.

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.

Publications

Peer-reviewed

Lee, S.H., T.E. Whitledge and S.-H. Kang. 2007. Recent carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. *Continental Shelf Research*, 27:2231–2249.

In press

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. *Marine Ecology Progress Series*, in press.

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

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 ***NOAA Goal: Ecosystem-based Management***
University of Alaska Anchorage

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

CIFAR 01-005: This project is complete. We are working on the final 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 were published in previous reporting periods.
- Sea lion data was also included in a manuscript on general physiological developmental patterns, published in the *Journal of Comparative Physiology* in 2007.
- As reported in FY07, 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 otariids, 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. Details are also included in a manuscript that was submitted for publication in 2008.
- The interplay between diving physiology and diving behavior are discussed in two manuscripts – 1 published in 2008 in *Canadian Journal of Zoology*, and one currently accepted with revisions at *Oecologia.*
- We are currently working on a manuscript that details the pattern and biochemistry of muscle development. We had hoped to complete this manuscript by Spring 2008, but lead author J. Richmond was working on her Ph.D.

at the University of Connecticut, and progress was slower than anticipated. However, Richmond just completed her Ph.D. and may now have time to finalize the manuscript. If not, Burns is on sabbatical 2008, and will take over as lead author and finalize the manuscript.

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 (ADL). 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	*Completed in FY08*

Presentations

Burns, J.M. 2008. Invited Seminar: Physiological development in pinniped pups: pattern, cause, and consequence. School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 4–6 February 2008.

Publications (over the life of the project to date)

Theses

Prewitt, J.W. 2008. Developmental and Environmental Effects on the Metabolic Characteristics of Harbor Seal (*Phoca vitulina*) Muscle. M.S. Thesis, University of Alaska Anchorage, May 2008, 102 pp. [FY08]

Richmond, J.P. 2004. Ontogeny of Total Body Oxygen Stores and Aerobic Dive Potential in Steller Sea Lions (*Eumetopias jubatus*). M.S. Thesis, University of Alaska Anchorage. [FY04]

Peer-reviewed

Rehberg, M.J. and J.M. Burns. 2008. Differences in diving and swimming behavior in pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. *Canadian Journal of Zoology*, 86:539–553. [FY08]

Burns, J.M., K.C. Lestyk, L.P. Folkow, M.O. Hammill and A.S. Blix. 2007. Size and distribution of oxygen stores in harp and hooded seals from birth to maturity. *Journal of Comparative Physiology B*, 177:687–700. DOI: 10.1007/s00360-007-0167-2 [FY08]

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. [FY07]

Richmond, J.P., J.M. Burns, L.D. Rea and K. Mashburn. 2005. Postnatal ontogeny of erythropoietin and hematology in free-ranging Steller sea lions (*Eumetopias jubatus*). *General and Comparative Endocrinology*, 141:240–247. [FY05]

Burns, J.M., C.A. Clark and J.P. Richmond. 2004. The impact of lactation strategy on physiological development of juvenile marine mammals: Implications for the transition to independent foraging. *Comparative Physiology and Biochemistry, International Congress Series*, 1275:341–350. [FY05]

Submitted

Burns, J.M. and M.O. Hammill. Does iron availability limit oxygen store development in seal pups? Submitted to *Comparative Physiology and Biochemistry*, International Congress Series.

Frid, A., J.M. Burns, G. Baker and R. Thorne. Predicting synergistic effects of resources and predators on foraging decisions by juvenile Steller sea lions. Accepted with revisions for *Oecologia*.

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.

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 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

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 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.

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.

Education/outreach

Presentations

Budge, S.M., M.J. Wooller, A.M. Springer, S.J. Iverson, C.P. McRoy and G.J. Divoky. 2008. Tracing carbon flow in an arctic marine food web using fatty acid–stable isotope analysis. Invited tutorial. American Society of Limnology and Oceanography Summer Meeting, St. John's, Newfoundland, 9–13 June 2008.

Publications (over the life of the project to date)

Peer-reviewed

Budge, S.M., A.M. Springer, S.J. Iverson, G. Sheffield and C. Rosa. 2008. Blubber fatty acid composition of bowhead whales, *Balaena mysticetus*: implications for diet assessment and ecosystem monitoring. *Journal of Experimental Marine Biology and Ecology*, 359:40–46. [FY08]

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. [FY07]

In press

Budge, S.M., M.J. Wooller, A.M. Springer, S.J. Iverson, C.P. McRoy and G.J. Divoky. Tracing carbon flow in an arctic marine food web using fatty acid-stable isotope analysis. *Oecologia*, in press.

Submitted

Cooper, M.H., S.M. Budge, A.M. Springer and G. Sheffield. Blubber fatty acid compositions of pagophilic seals near Little Diomede Island, Alaska—Spring 2003. Submitted to *Polar Biology*.

References

Folch, J., M. Lees and G.H. Sloane-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
Fisheries Oceanography
Hydrographic and Sea Ice Studies
Marine Ecosystem Studies
Tsunami Research

Pacific Region Integrated Data Enterprise (PRIDE) projects: *Collaborative Research: Alaska PRIDE FY07* *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 62-090a (new; a continuation of 39-090 [PRIDE FY06] and 19-086) and CIFAR 40-091: These projects are ongoing.

Primary objectives

Funding received under the NOAA Pacific Region Integrated Data Enterprise (PRIDE) project has been directed towards two main efforts. The first, which involves working closely with NOAA/NWS Alaska Region Headquarters, has been focusing on improving NOAA's forecasting capacity in the coastal regions of Alaska. Work to date has involved improving wave models, building contacts throughout Alaska, and beginning to work directly with coastal erosion in a reconnaissance mode. The second effort concerns developing and improving end-user products for extreme winds in the Pacific region (the "Pacific Region Integrated Climatology Products – PRICIP"). This effort, led by John Marra and Eileen Shea of the NOAA Integrated Data and Environmental Applications (IDEA) Center in Honolulu, translates observational data into summary plots that are tailored to non-technical (in a meteorological sense) end-user groups, such as planning or insurance, and develops cross-sections of specific events of particular note (e.g., Hurricane Iniki).

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.

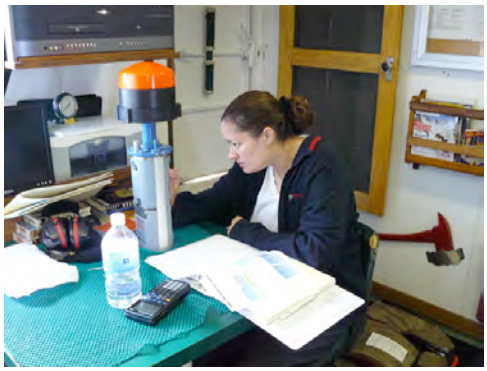
For the PRICIP project, the approaches were similar to those needed for the long-term elements of the PRIDE project, and included:

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).

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

- Atkinson prepared a strong wind return interval briefing for the U.S. Department of Agriculture in Anchorage to support a relief funding decision for the village of Newtok in October 2007. Using data from the Japan Meteorological Agency 25-year Reanalysis (JRA-25), Atkinson found that several of the storms considered "strong" by local inhabitants had not individually exceeded a "once in 2 year event" in terms of winds. However, an analysis of the number of times that the strong wind threshold was exceeded for the month showed that September 2007 ranked as the second-windiest month in the 30-year record. This is because Bering Sea storms with strong winds are extremely common events so that severe coastal erosion experienced in Newtok during September 2007 was the result of fairly continuously high winds rather than a single exceptionally windy storm event.



Oceana Francis-Chythlook prepares the Aandera Recording Doppler Current Profiler for deployment into the Chukchi Sea.

- Closer links forged with Fairbanks WFO – two Student Career Experience Program (SCEP) students hired (Cross – September 2007, Malingowski – January 2008).
- Strong wind return frequency plots prepared and delivered to Marra at NOAA IDEA center (student: Francis-Chythlook).
- Strong wind event/water level surge event comparison and analysis performed for Nome. It was found that locally observed winds are not always adequate predictors of ocean level state, e.g., surges can be present when wind direction is from the land and a strong on-shore flow does not necessarily mean a surge will occur.
- Surge model experiments initiated (student: Cross) to improve operational surge guidance.
- Field work on inversions commenced (student: Malingowski) to improve model (WRF) operational representation of marine and radiation inversions.
- Paper on North Pacific storm tracks accepted for publication; now "in print": (student: dos Santos Mesquita). An important finding here concerned the long life-spans of summer storms relative to storms in any other season.
- Organized a coastal erosion modeling meeting, 28 June 2008. Erosion modelers from Russia, Canada and the U.S. were present. NOAA representatives Aimee Fish (NOAA NOS) and Richard Thoman (NOAA NWS) were present.

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.

- John Jensen, NOAA National Climatic Data Center
- Carven Scott, NOAA NWS Alaska Region Headquarters
- Amy Holman, NOAA NWS Alaska Region Headquarters
- Aimee Fish, NOAA NOS Alaska Region Headquarters
- Sarah Trainor, Alaska Center for Climate Adaptation and Policy (administrator of ACCAP – NOAA RISA – Alaska)
- 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
- 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

Student participation

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

- Oceana Francis-Chythlook (Ph.D. student)
- Michel Mesquita (Ph.D. student)
- Austin Cross (M.S. student attached to WFO Fairbanks as a NOAA SCEP student)
- Julie Malingowski (M.S. student attached to WFO Fairbanks as a NOAA SCEP student)
- Jennifer March (M.S. student)

K–12 Outreach

- Bering Strait School District annual teacher's retreat, Unalakleet, November 2007: Delivered coastal erosion education talk and taught two "mini-courses" about using National Weather Service webpage
- International Polar Year presentation in Nome, January 2008: Delivered talks via live video link to several community schools (Heidi Herter, UAF/Alaska Sea Grant Marine Advisory Agent, Nome); presentation is on Bering Strait School District website at: http://blog.bssd.org/2008/01/30/international-polar-year-speaker-series/

Public Outreach

Atkinson, D.E. 2007. Understanding coastal erosion in Alaska. Oral presentation delivered over statewide teleconference for the Alaska Center for Climate Assessment and Policy (Alaska NOAA – RISA), 9 October 2007.

Atkinson, D.E. 2007. Climate change in the Arctic: observed changes and construction implications. Keynote address delivered to the "Sustainable Northern Shelter in a world of diminishing resources" forum organized the Cold Climate Housing Research Center at the University of Alaska Fairbanks, 28–30 October 2007.

Atkinson, D.E. 2007. Storms, winds, and erosion in the Kotzebue area. Oral presentation delivered to the public during a forum sponsored by the Alaska Center for Climate Assessment and Policy (Alaska NOAA – RISA), Kotzebue, November 2007.

Atkinson, D.E. 2007. Alaska health implications of coastal and riverbank erosion and other hazards. Alaska Health Summit, Anchorage, December 2007.

Atkinson, D.E., T. Jorgensen and B. Jones. 2008. Coastal erosion, ice, and climate change. Alaska Forum on the Environment, Anchorage, February 2008.

Atkinson, D.E. and C. Gerlach. 2008. Climate change and Alaska communities: Infrastructure and food security issues. Talk delivered to Alaska Municipal League meeting, Anchorage, 28 May 2008.

Professional presentations

Atkinson, D.E., M. dos Santos Mesquita, S. Danielson, K. Taylor and T. Weingartner. 2007. An eulerian view of storm events and their relationship to storm surge along the coast of Alaska. Talk A24A-10, American Geophysical Union Fall Meeting, San Francisco, December 2007.

Francis-Chythlook, O. and D.E. Atkinson. 2007. Investigating methods of wave-ice interactions. Poster OS43B-1235, American Geophysical Union Fall Meeting, San Francisco, December 2007.
Dos Santos Mesquita, M., M. King and D.E. Atkinson. 2007. The effect of sea-ice extent on storm activity in the North Pacific/Western Arctic. Poster A13E-1608, American Geophysical Union Fall Meeting, San Francisco, December 2007.

Publications

Peer-reviewed

Atkinson, D.E. and L. Hinzman. 2008. Impact of the August 2000 storm on the soil thermal regime, Alaska North Slope. Proceedings of the Ninth International Conference on Permafrost (Vol. 1), 29 June–3 July 2008, Fairbanks, Alaska, pp. 65–70.
Mesquita, M., N.G. Kvamsto, A. Sorteberg and D.E. Atkinson. 2008. Climatological properties of summertime extra-tropical storm tracks in the Northern Hemisphere. *Tellus*, 60A:557–569.

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 the National Environmental Satellite, Data, and Information Service (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 research program director at NOAA, has since approved a no-cost extension as a result of these delays.

Research accomplishments/highlights/findings

- Cloud detection tests to identify cloud-contaminated radiances have been refined.
- It was determined that only night-time collocations will be used, as contamination by solar radiation in the near-infrared channels is difficult to remove satisfactorily owing to insufficient accuracy in albedo information.
- Pixels with mixed land/ocean scenes will not be used owing to inhomogeneous emissivity values.
- Forward radiative transfer calculations to match observed radiances with expected values based on radiosondes revealed that further errors in the collocation files exist. A. Schweiger has alerted the personnel at NOAA of these ongoing problems that have caused Schweiger and Francis to waste inordinate amounts of time searching for physical reasons for differences between the radiances, when in fact the collocation files were the source of the inconsistencies. This situation continues to be a major source of delay and frustration. While the system to calculate radiances from radiosondes and determine differences from observations has been ready for some time, we have yet to receive a "clean" collocation data set from NOAA, thus the "deltas," or corrections to TOVS radiances that we seek, cannot be completed.

NOAA relevance/societal benefits

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

Research linkages/partnerships/collaborators and networking

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

State of the Arctic (Land) Report

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

CIFAR 54-087a: This project is ongoing.

Primary objectives

The overall goal of the proposed task is to produce an annual, peer-reviewed report fully assessing the state of the Arctic. Specific objectives include:

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

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. Snow cover extent over the landmasses and changes in terrestrial hydrology
4. Thermal state of permafrost and active layer thickness
5. Changes in terrestrial ecosystems.

The University of Alaska Fairbanks (UAF, PI: V. Romanovsky) part of this report will include three components listed above, namely: changes in terrestrial hydrology, thermal state of permafrost and active layer thickness, and changes in terrestrial ecosystems.

The final 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.

The primary products of this effort will be a comprehensive baseline report describing the state of the Arctic Land. The information in this report will be disseminated in several ways. It will be presented as a peer-reviewed article as part of the American Meteorological Society annual climate summary. We will also contribute to the NOAA Web site http://www.arctic.noaa.gov/soa2006/ and an electronic version of the report plus an easily accessible, complete representation of all of the reporting activities. Highlights from the annual assessment will also be presented at major conferences.

Research accomplishments/highlights/findings

We continue our efforts to record and archive the data on active layer and permafrost dynamics at our sites within Alaska. We processed all data we collected from these sites during 2004–2007, performed quality control and converted them to a standard format for submission to the Joint Office for Science Support (JOSS) and the National Snow and Ice Data Center (NSIDC) for archiving. Data were submitted to NSIDC and to the Cooperative Arctic Data and Information Service (CADIS)/NCAR. Results of these activities contributed to a chapter in the *Bulletin of the American Meteorological Society* State of the Arctic Report 2007 (Richter-Menge et al., in press), and in many presentations during this reporting period. Within a framework of the IPY International project "Thermal State of Permafrost," we started a collaborative work with our Russian, Kazakh, and Mongolian partners to update their national Permafrost Monitoring Networks.

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

The observations highlighted in this report indicate that many of the trends documented in the Arctic Climate Impact Assessment (ACIA) Report (2005) continued during the period 2000–2006 and suggest a sustained period of warming in the Arctic region. Convincing evidence includes widespread changes in Arctic vegetation, with the tundra experiencing an increase in greenness and the boreal forest regions showing a decrease in greenness. Permafrost temperatures continued to rise within most of the permafrost-affected areas but with a noticeably slower rate than in the 1990s. Changes in the active layer thickness (the relatively thin layer of ground between the surface and permafrost that undergoes seasonal freezing and thawing) are inconsistent. While some of the monitored sites show a slightly increasing trend in the thickness of the active layer, most of them do not. Permafrost is actively thawing from the top down in the southern regions of permafrost distribution in the European North of Russia, in West Siberia, in Kazakhstan and in Alaska.

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). We developed a network of researchers from Northern Eurasia to monitor changes in permafrost in a framework of the IPY Project #50, the Thermal State of Permafrost (TSP). Eleven institutions from Russia, one from Kazakhstan and one from Mongolia are participating in this project.

Education/outreach

- During the past year, V. Romanovsky was interviewed by TV reporters from the U.S., Japan, United Kingdom, Russia, Australia, and by many news reporters.
- V. Romanovsky worked with high school students and teachers. He gave a Mentor Lecture on Permafrost and IPY research for teachers. This lecture was a part of the ACMP (Arctic Climate Modeling Program) Mentor Lectures Program.
- In October 2007, V. Romanovsky was invited to present a talk at the ConocoPhillips Arctic Environmental Knowledge Sharing Seminar, Kananaskis, Alberta, Canada.
- In January 2008, V. Romanovsky participated in a Winter Cities Conference in Nuuk, Greenland and delivered a presentation there. He also presented a public lecture at the Danish Polar Center.
- In May 2008, V. Romanovsky made presentation at the Woods Hole Oceanographic Institution as a part of the seminar series "Arctic future under influence of summer ice free ocean."
- 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.

- Richter-Menge, J., J. Overland, E. Hanna, M.J.J.E. Loonen, A. Proshutinsky, V. Romanovsky, D. Russell, R. Van Bogaert, R. Armstrong, L. Bengtsson, J. Box, T.V. Callaghan, M. De Dapper, B. Ebbinge, O. Grau, M. Hallinger, L.D. Hinzman, P. Huybrechts, G.J. Jia, C. Jonasson, J. Morison, S. Nghiem, N. Oberman, D. Perovich, R. Przybylak, I. Rigor, A. Shiklomanov, D. Walker, J. Walsh and C. Zöckler. 2007. Arctic Report Card 2007. http://www.arctic.noaa.gov/reportcard (October 2007)

Presentations

Romanovsky, V.E., A.L. Kholodov, S.S. Marchenko, N.G. Oberman, D.S. Drozdov, G.V. Malkova, N.G. Moskalenko, A.A. Vasiliev, D.O. Sergeev and M.N. Zheleznyak. 2008. Thermal state and fate of permafrost in Russia: First results of IPY. Plenary presentation, Ninth International Conference on Permafrost, Fairbanks, Alaska, 29 June–3 July 2008.

Romanovsky, V.E., S.S. Marchenko, R. Daanen, D.O. Sergeev and D.A. Walker. 2008. Soil climate and frost heave along the permafrost/ecological North American Arctic Transect. Oral presentation at the Ninth International Conference on Permafrost, Fairbanks, Alaska, 29 June–3 July 2008.

Publications

Peer-reviewed

Romanovsky, V.E., A.L. Kholodov, S.S. Marchenko, N.G. Oberman, D.S. Drozdov, G.V. Malkova, N.G. Moskalenko, A.A. Vasiliev, D.O. Sergeev and M.N. Zheleznyak. 2008. Thermal state and fate of permafrost in Russia: First results of IPY. Plenary paper. Proceedings of the Ninth International Conference on Permafrost (Vol. 2), 29 June–3 July 2008, Fairbanks, Alaska, pp. 1511–1518.

Romanovsky, V.E., S.S. Marchenko, R. Daanen, D.O. Sergeev and D.A. Walker. 2008. Soil climate and frost heave along the permafrost/ecological North American Arctic Transect. Proceedings of the Ninth International Conference on Permafrost (Vol. 2), 29 June–3 July 2008, Fairbanks, Alaska, pp. 1519–1524.

In press

Richter-Menge, J., Ed. The Poles: Arctic. In: D.H. Levinson and J.H. Lawrimore, Eds., State of the Climate in 2007. Special Supplement to the *Bulletin of the American Meteorological Society*, in press. (July 2008)

References

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

Climate Modeling

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, 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 a journal publication and conference poster presentation listed below.

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 reports for previous years by collaborator D. Bromwich, funded through a separate award.)

Research accomplishments/highlights/findings

- As a contribution to the International Polar Year Open Science Conference, a paper based on a conference keynote presentation has been submitted to and is now under review at the journal *Antarctic Science*. This paper addresses the apparent paradox between recent changes in the Arctic and Antarctic, particularly in terms of air temperature and sea ice. In contrast to the large warming and loss of sea ice in the Arctic in recent decades, Antarctic temperatures and sea ice show little change except for the Antarctic Peninsula. However, model simulations indicate that the Arctic changes have been shaped largely by low-frequency variations of the atmospheric circulation, superimposed on a greenhouse warming that is apparent in model simulations when ensemble averages smooth out the circulation-driven variability of the late 20th century. By contrast, the Antarctic changes of recent decades appear to be shaped by ozone depletion and an associated strengthening of the southern annular mode of the atmospheric circulation. While the signature of greenhouse-driven change is projected to emerge from the natural variability during the present century, the emergence of a statistically significant greenhouse signal may be slower here than in other regions. Models suggest that feedbacks from retreating sea ice will make autumn and winter the seasons of the earliest emergence of the greenhouse signal in both polar regions. Priorities identified in the paper for enhancing robustness of the Antarctic climate simulations are the inclusion of ozone chemistry and the realistic simulation of water vapor over the Antarctic ice sheet.
- A one-year experimental Arctic reanalysis and comparisons with global reanalyses (ERA-40 and NCEP/NCAR) have recently been completed. The one-year Arctic reanalysis was produced using an experimental Arctic reanalysis system (EARS), which utilized the MM5 model and a 3DVAR data assimilation, implemented in combination with an intermittent nudging scheme. TOVS retrieval data and conventional surface and upper-air sounding data were assimilated by EARS, which was driven by the ERA-40 global reanalysis. The domain was pan-Arctic at a horizontal resolution of 30 km. The EARS reanalysis results, as well as the ERA-40 and NCEP/NCAR reanalyses, were verified against station observations. The results showed that the ERA-40 reanalysis is significantly better than the NCEP/NCAR reanalysis on the basis of root-mean-square error and

bias. The EARS produces significantly better wind reanalyses than both ERA-40 and NCEP/NCAR. For the surface air temperature, dewpoint temperature, relative humidity and sea level pressure, the yearly average of the EARS results lies in between those of the ERA-40 and NCEP/NCAR reanalyses.

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 project reports from previous years) and Mark Serreze, University of Colorado/CIRES. More recently, the group has been joined by W. H. Kuo, D. Barker and several other NCAR scientists as the project has transitioned to an Arctic System Reanalysis (see following).

Two workshops in Boulder, Colorado, were held to initiate a continuation of an Arctic System Reanalysis activity, which was seeded by the present project. Co-investigators Walsh, Bromwich and Serreze, together with a group of NCAR scientists, obtained funding from NSF's Office of Polar Programs for a continuation of the Arctic System Reanalysis activity through 2010.

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 and conferences in other venues.

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

Walsh, J.E., W.L. Chapman and D.H. Portis. 2008. Use of ARM/NSA data for validation of cloud and radiative fluxes in atmospheric models. DOE/ARM Science Meeting, Norfolk, Virginia, 27–31 March 2008.

Oral presentations

Walsh, J.E., W.L. Chapman and D.H. Portis. 2008. Arctic clouds and radiative fluxes in large-scale reanalyses. World Climate Research Programme Third Symposium on Reanalysis, Tokyo, Japan, 29 January 2008.

Publications

Peer-reviewed

Slater, A.G., T.J. Bohn, J.L. McCreight, M.C. Serreze and D.P. Lettenmaier. 2007. A multimodel simulation of pan-Arctic hydrology. *Journal of Geophysical Research–Biogeosciences, 112(G4),* G04S45, doi:10.1029/2006JG000303.

Non-peer-reviewed

Walsh, J.E., W.L. Chapman and D.H. Portis. 2008. Arctic clouds and radiative fluxes in large-scale atmospheric reanalyses. Extended abstract, World Climate Research Programme Third Symposium on Reanalysis, Tokyo, Japan, 28 January–1 February 2008.

In press

Walsh, J.E., W.L. Chapman and D.H. Portis. Arctic clouds and radiative fluxes in atmospheric reanalyses. *Journal of Climate,* in press.

Submitted

Fan, X., J.E. Walsh and J.R. Krieger. 2008. A one-year experimental Arctic reanalysis and comparisons with ERA-40 and NCEP/NCAR reanalyses. Submitted to *Geophysical Research Lett*ers.

Walsh, J.E. A comparison of Arctic and Antarctic climate change, present and future. Submitted to *Antarctic Science*.

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 will be submitted to a peer-reviewed journal in a few months.

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 were 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

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.

References

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

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

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

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

Early Marine Growth and Survival of Bristol Bay Sockeye Salmon Smolt

Milo Adkison, PI ***NOAA Goal: Ecosystem-based Management***

University of Alaska Fairbanks

CIFAR 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

E. Farley dissertation abstract. Smaller sockeye salmon are less likely to survive during their first summer at sea. Body size, fatness, and growth potential are controlled by the physics of the eastern Bering Sea ecosystem. Spring and summer sea temperatures play a key role in marine productivity and sockeye salmon growth and survival.

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 (ABL). Ed Farley, employed at ABL, was a graduate student leading this study. Jack Helle is also involved.

Education/outreach

Student participation

Ed Farley successfully defended his dissertation in Fall 2007 and graduated in May 2008. In recent years Farley has presented his research results in local, statewide, and international scientific symposia. Adkison presented this work at the Western Alaska Interdisciplinary Science Conference in Dillingham in April 2008.

Presentations

Farley, E.V. Jr. and M.D. Adkison. 2008. Studies of juvenile sockeye salmon in the marine waters of Bristol Bay. Western Alaska Interdisciplinary Science Conference, Dillingham, Alaska, 4–6 April 2008.

Publications

Dissertation

Farley, E.V. Jr. 2008. Juvenile Bristol Bay Sockeye Salmon Ecology. Ph.D. Dissertation, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

Peer-reviewed

Farley, E.V. Jr., J.M. Murphy, M.D. Adkison and L.B. Eisner. 2007. Juvenile sockeye salmon distribution, size, condition and diet during years with warm and cool spring sea temperatures along the eastern Bering Sea shelf. *Journal of Fish Biology*, 71:1145–1158.

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.

References

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

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

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

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

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

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

Mason, D.M., A. Goyke and S.B. Brandt. 1995. A spatially explicit bioenergetics measure of habitat quality for adult salmonines: comparison between Lakes Michigan and Ontario. *Canadian Journal of Fisheries and Aquatic Sciences*, 52:1572–1583.

Nislow, K.H., C.L. Folt and D.L. Parrish. 2000. Spatially explicit bioenergetic analysis of habitat quality for age-0 Atlantic salmon. *Transactions of the American Fisheries Society,* 129:1067–1081.
Wei, W.W.S. 1990. *Time Series Analysis: Univariate and Multivariate Methods*. Addison-Wesley Publishing Company, Redwood City, California. 478 pp.

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

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

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

K. Howard thesis abstract. Growth and maturity schedules are used in stock assessments to project the biomass of reproductively active fish that would remain after commercial harvest. Errors in growth and maturity estimates can result in biased estimates of the optimal catch quotas. Growth and maturity parameters for Alaskan sablefish, *Anoplopoma fimbria*, have not been updated for stock assessment purposes for 20 years, even though many more sablefish have been aged. In this study, the old length-stratified data set (1981–1993) was updated and corrected for bias; newer, randomly collected samples (1996–2004) were analyzed; and new length-at-age, weight-at-age, and maturity-at-age and length curves were estimated. The analyses showed that in recent years, sablefish are growing larger and maturing later, and that growth and maturity differ somewhat among regions. The updated growth information improves data fits in the sablefish stock assessment model and also provides results that are biologically reasonable. These updated and improved estimates of sablefish growth and maturity help ensure the continued proper management of this commercially important species in Alaskan waters.

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. Some changes were found, and the updated growth and maturity schedules have been incorporated into NOAA's latest sablefish stock assessment (Hanselman et al. 2007).

Research linkages/partnerships/collaborators and networking

The principal linkages are between the University of Alaska Fairbanks and personnel at NOAA's Auke Bay Laboratory.

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 successfully defended her thesis in May 2008 and is preparing a manuscript for submission within a few months to a peer-reviewed journal.

Publications

In preparation

Howard, K. and co-authors. Inter-decadal change in sablefish, *Anoplopoma fimbria*, growth and maturity in the northeast Pacific Ocean.

References

Clark, W.G. 1991. Groundfish exploitation rates based on life history parameters. *Canadian Journal of Fisheries and Aquatic Sciences*, 48:734–750.

Hanselman, D.H., C.R. Lunsford, J.T. Fujioka and C. Rodgveller. 2007. Alaska sablefish assessment for 2008. In: NPFMC Bering Sea, Aleutian Islands and Gulf of Alaska SAFE.

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

Population Structure in Alaskan Pacific Ocean Perch (*Sebastes alutus*)
and
Species Composition and Spatial Distribution of GOA and BS Young-of-the-Year Rockfish Species

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A.J. Gharrett, PI ***NOAA Goal: Ecosystem-based Management***

University of Alaska Fairbanks

Final report for CIFAR 09-045a and CIFAR 10-062a.
K. Palof (UAF) and J. Heifetz (NOAA Fisheries) are coauthors

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 was 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. Early on we concluded that that there was too little mitochondrial variation to warrant continuation of that approach. Consequently, variation in microsatellite markers was the focus of our study.

Approach/methodology

We studied the variation at microsatellite loci to examine the genetic compositions of collections of POP. The collections (from NOAA stock assessment surveys) were sampled about every 400 km along the continental slope from the Queen Charlotte Islands, British Columbia, to the end of the Aleutian Islands; we also examined two composite collections from the Bering Sea. Our samples represent most of the Alaskan geographic range. We analyzed the data with standard population genetics programs to evaluate the quality of the data and nature of variation within collections of the data (Hardy-Weinberg equilibrium, inbreeding coefficients, estimates of effective population size, etc.). We also examined the divergence among collections (homogeneity tests, partitioning the

variation into fixation indices, correlations between geographic and genetic distances, and individual assignment tests).

In anticipation of continuation and refinement of this work, we thoroughly sampled from the region between Yakutat and Kodiak in summer 2007. 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 that has been supported by the North Pacific Research Board (NPRB) as discussed in *Research linkages* section below.

Research accomplishments/highlights/findings

- We tested 30 microsatellite loci for suitability (amplification, repeatability, variation, absence of null alleles) and selected 14 loci for this study.
- We used the microsatellite loci to survey 11 composite collections (that included more than 1000 fish) from geographically distinct areas in Alaskan waters (Figure 1). We observed genetic divergence that correlated with geographic separation of the collections (Figure 2). This demonstrates that the dispersal range of POP is generally less than 400 km. Moreover, every collection was distinct from every other collection (at nearly every locus), even after adjusting probability levels for multiple testing. However, assignment tests indicate that individuals within a collection are most closely related to individuals in nearby collections.
- Estimates of effective population size demonstrated that all collections were relatively large. Most point estimates were in the 1000s. This observation coupled with the correlation of genetic and geographic distances suggests that the divergence among collections is not an artifact of divergence among cohorts.
- There is a biogeographic break in the distribution of POP that occurs between Yakutat and Kodiak. This break, although much weaker, was also detected in studies of rougheye (*S. aleutianus*) and shortraker (*S. borealis*) rockfishes.
- Graduate student Katie Palof completed her master's thesis in spring 2008 and is now in the UAF doctoral program.

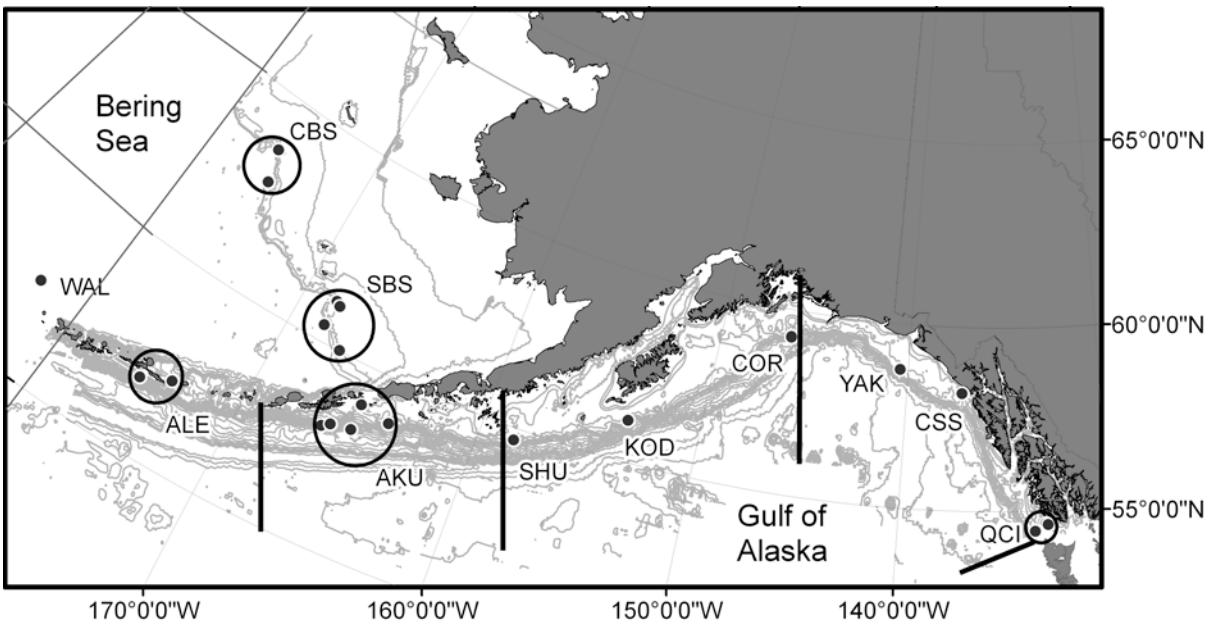

Figure 1. Map of collection sites and geographic groupings. Geographic groupings are: Queen Charlotte Islands (QCI), Cross Sound (CSS), Yakutat (YAK), Cordova (COR), Kodiak (KOD), Shumagins (SHU), Akutan (AKU), Central Aleutians (ALE), Western Aleutians (WAL), Southern Bering Sea (SBS), and Central Bering Sea (CBS). Solid black lines represent management areas.

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 that we are examining to learn about dispersion of young fish. Most

importantly, we determined that the scale of population structure of POP is smaller than the sampling scale (400 km between collections) and much smaller than scale of management areas. These results were confirmed by our study of young-of-the-year POP.

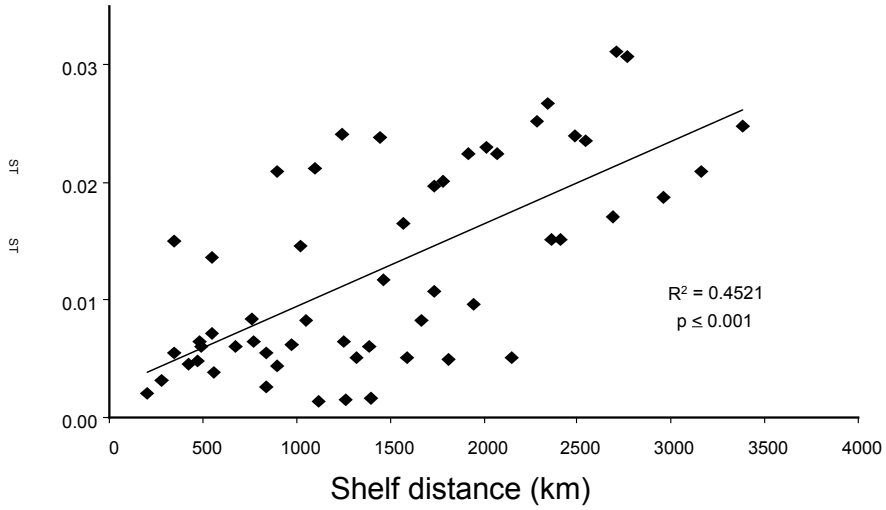

Figure 2. Isolation-by-distance of genetic (FST) and geographic (km) distances. Genetic distance, represented as standardized pairwise FSTs (FST/(1- FST)), regressed on geographic shelf distance (km) ($y = 7.034 \times 10^{-6}x + 0.0024$).

Research linkages/partnerships/collaborators and networking

Funding for this project comes through collaboration with the National Marine Fisheries Service Auke Bay Laboratory, who were also responsible for providing samples. The NOAA investment in CIFAR 09-045a and CIFAR 10-062a provided baseline data that has leveraged funding through NPRB projects F0420 and F0512, *Interannual and spatial variation in population genetic composition of northeastern Gulf of Alaska young-of-year POP* $105,000, 9/1/2004 to 8/31/2005 and F0512, *Juvenile POP genetics, Phase 2*, 9/1/2005 to 2/28/2007, $116,830 that examined the dispersion of juvenile POP.

Education/outreach

Graduate student Katie Palof has completed her Master's degree. The preliminary funding for this project enabled her to obtain a Rasmuson fisheries fellowship through the University of Alaska Fairbanks for both the 2004–2005 and 2005–2006 academic years. She is continuing quantitative and modeling aspects of this project in her doctoral research.

Presentations

Kamin, L., K. Palof, C. Kondzela, J. Heifetz and A.J. Gharrett. 2008. Interannual and spatial variation in the population genetic structure of young-of-the-year Alaskan Pacific ocean perch (*Sebastes alutus*). Alaska Marine Science Symposium, Anchorage, Alaska, 20–24 January 2008.

Palof, K.J., A.J. Gharrett and J. Heifetz. 2008. Genetic population structure of Alaskan Pacific ocean perch, *Sebastes alutus*. Alaska Marine Science Symposium, Anchorage, Alaska, 20–24 January 2008.

Palof, K.J., A.J. Gharrett and J. Heifetz. 2008. Genetic population structure of Alaskan Pacific ocean perch, *Sebastes alutus*. Western Groundfish Conference, Santa Cruz, California, 4–8 February 2008.

Honors and Awards

Best Student Presentation at a Master's Level, Alaska Marine Science Symposium, Anchorage, Alaska, January 2008.

Best Student Presentation, Western Groundfish Conference, Santa Cruz, California, February 2008.

Publications (over the life of the two projects to date)

Thesis

Palof, K.J. 2008. Population Genetic Structure of Alaskan Pacific Ocean Perch, *Sebastes alutus*. M.S. thesis, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks. [Project 09-045a, FY08]

Peer-reviewed
Kendall, A.W. Jr., C. Kondzela, Z. Li, D. Clausen and A.J. Gharrett. 2007. Genetic and Morphological Identification of Pelagic Juvenile Rockfish Collected from the Gulf of Alaska. NOAA Professional Paper NMFS 9, 26 pp. [Project 10-062a, FY08]
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. [Project 10-062a, FY07]
Non-peer-reviewed
Kondzela, C.M., A.W. Kendall, Z. Li, D. Clausen and A.J. Gharrett. 2003. Preliminary evaluation of the rockfish (Sebastes spp.) species collected during ABL-OCC cruises in the Gulf of Alaska in 1998–2002. Section 2, Chapter 7 in Final Report: The Ecological Role of Natural Reefs and Oil and Gas Production Platforms on Rocky Reef Fish of Southern California: Genetics subsection, to L.K. Thorsteinson, U.S. Geological Survey, Biological Resources Division. [Project 10-062a, FY04]
In preparation
We will submit a paper to a peer reviewed journal that is based on Palof's thesis work in the near future.

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 species 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 Single Nucleotide Polymorphism (SNP) assay, but have not yet tested it. We designed primers that will enable us to identify the other diagnostic restriction site difference and used them to determine the species of about 150 specimens.
- 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. That SNP was used to identify fish that were not POP in collections of young-of-the-year Pacific ocean perch in a sample of more than 2000 fish, which was a part of a North Pacific Research Board project and a sample of about 300 that was provided by the Auke Bay laboratory.
- We used 11 microsatellite loci to analyze four collections of 100 northern rockfish. We observed a significant isolation-by-distance signal that indicates that northern rockfish in the Bering Sea and Aleutian Islands are not a single panmictic population.

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 (ABL). The scientists from ABL 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.

Education/Outreach

Lisa Kamin has been supported in part by this CIFAR project. She is working on an M.S. in Fisheries.
Robert Marcotte, who completed a B.S. in Biology at Whitman College (2008), was supported during summer 2007 by this CIFAR project.

Publications

None to date.

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.

Characterizing Movement Patterns of Atka Mackerel Using Ultrasonic Telemetry: A Pilot Study

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

CIFAR 59-096 (new): This project is ongoing.

Primary objectives

Atka mackerel (*Pleurogrammus monopterygius*) is an important groundfish resource in the Aleutian Islands. This species supports a major commercial fishery in addition to serving as a key food source for many species of birds, fish, and marine mammals. Recent efforts to balance fishery removals with requirements for a healthy ecosystem were enacted in response to the listing of the western population of Steller sea lions (*Eumetopias jubatus*) as an Endangered Species in 1990.

Information on abundance and spatial distribution is typically obtained through trawl surveys and the distribution of the commercial fishery, and is confounded by high variance in catch as well as the inability to survey untrawlable areas. In addition, Atka mackerel can undergo daily vertical migrations that may exclude them from trawl surveys conducted during the day. Also, acoustical methods for estimating abundance are precluded because Atka mackerel do not possess a swim bladder. Thus, tagging studies may provide a viable alternative to trawl survey methods for determining distribution and abundance.

Ultrasonic tagging techniques offer an approach that can complement the knowledge gained by conventional tags. Ultrasonic telemetry can provide spatial information at much finer temporal scales and in all habitat types, which will make it possible to study small-scale movement of Atka mackerel across harvest boundaries, in areas not available to trawl gear, and on a temporal scale that reflects their daily behavioral patterns. Recent developments in ultrasonic telemetry technology now allow large numbers of sonic tags to be deployed and detected simultaneously. The objectives of this pilot study are:

1. Assess the feasibility of conducting a telemetry project in the Aleutian Islands.
2. Determine optimal techniques for tag attachment.
3. Ensure that the SYNAPS (Synthetic Aperture Positioning System) program will work for faster-moving fish.

Approach/methodology

An Atka mackerel tag recovery cruise (recovering conventional tagged fish) will be conducted in the Aleutian Islands in October 2007 and will provide a platform of opportunity to test different hydrophone configurations and tag ranges in realistic environmental conditions using moored test tags. The 220' *Seafisher* vessel will be used as a platform. Tasks to be completed on this cruise include:

1. Determining the optimal hydrophone configuration. Different hydrophone configurations will be developed and tested with the support of the *Seafisher* crew.
2. Determining the reception range in local environmental conditions, using the optimal hydrophone configuration, for tags of different power and size. This involves navigating by the test tag and determining the locations where the test tag is received first and last.
3. Determining the feasibility of vessel maneuvers necessary for gathering optimal data for input into the SYNAPS program. The program works by creating a synthetic array of hydrophones comprised of the location of hydrophones in the water when a signal is detected. The position of the tag is then calculated by subtracting the burst interval from the time the signal was first received and determining the time of arrival of the signal at each hydrophone on the array.

Tests for optimal tag attachment will be conducted at the Alaska SeaLife Center (Seward, Alaska), where Atka mackerel can be handled under controlled conditions and observed to quantify tagging effects.

The SYNAPS algorithm works well for slow-moving crabs but has not been tested on faster moving fish. Tests will be conducted out of Juneau, Alaska to determine the effectiveness of this program for estimating locations of mobile animals and modifications to the algorithm can be made by Lotek Wireless if necessary.

Research accomplishments/highlights/findings

The Atka mackerel tag recovery cruise in October 2007 provided valuable insights on the logistics necessary to conduct active tracking from a large vessel in the Aleutian Islands. A line fitted with four test tags of varying signal strengths was deployed at 52° 03.525' N, 177° 07.964' E at a depth of 96 m. A hydrophone was deployed over the bow of the vessel on a weighted line. The vessel circled the test tags at speeds ranging from 3 kts under power to less than 1 kt while drifting. The detection range was much smaller than expected, largely due to the unsatisfactory placement of the hydrophone in the water column. Detection experiments were conducted at wind speeds of 10–15 kts and relatively calm seas; even on these days the swell was 2–3 meters, which occasionally lifted the hydrophone out of the water. For future tracking studies, an extremely robust hydrophone attachment method must be developed prior to active tracking with a large vessel in the open waters of the Aleutian Islands. We also discovered that the rolling motion of the vessel in the ocean swells affects the accuracy of GPS data. Because the GPS antenna is mounted above the vessel, it moves in an arc from side to side in response to swells, while the hydrophone, which is

located near the vessel pivot point, experiences little corresponding side to side motion. Corrections for the location of the GPS antenna relative to location of hydrophones in swells will need to be developed prior to the use of GPS data in the SYNAPS calculations.

Tag attachment studies are being conducted at the Ted Stevens Marine Research Institute in Juneau. Kelp greenling (*Hexagrammos decagrammus*), a locally available species that is closely related to Atka mackerel and is of similar size and weight, is being used as a surrogate species for these experiments. The start date for the laboratory research was delayed due to unanticipated time needed to obtain permits for the fish surgery component and difficulties collecting a sufficient number of fish for the study. Currently, seven kelp greenlings that were collected in early May are being held in 1,200-gallon tanks with circulating seawater at temperatures ranging between 5.3° and 6.1° C. Preliminary fish surgeries were conducted on 29 May in order to acquire surgical training as required for IACUC approval of the study (Figure 1). Lotek MAP11_4 dummy tags (11 mm diameter, 55 mm length and weighing 10.0 g in air and 5.1 g in water) were inserted in the abdominal cavity of three fish (Table 1). Dummy tag weights were within recommended guidelines for the ratio of tag weight to fish weight (2% maximum, Concerted Action for Tagging of Fishes, European Commission). As of 23 June 2008 all tagged fish appear to be healthy and are behaving similarly to control animals (two untagged males and two females). We are in the process of obtaining more fish to complete the study.

Figure 1. Closing incision with sutures after insertion of dummy transmitter.

Tests for applying SYNAPS to moving animals have not yet begun.

Table 1. Sex, length, and weight of fish tagged in initial surgeries, 29 May 2008.

Fish ID	Gender	Fork length [cm]	Wet weight [kg]
2977	male	37.8	0.774
2978	male	35.8	0.68
2979	male	40.0	0.88

NOAA relevance/societal benefits

New telemetry techniques hold great potential for answering important questions about Atka mackerel small-scale distribution and movement patterns by complementing the results obtained through a multi-year study using conventional tags. The Aleutian Islands present a challenge for all field work due to their remoteness and often inclement weather conditions. In addition, Atka mackerel inhabit areas of high currents which pose additional problems when working with high technology underwater acoustic equipment. Therefore this pilot study will test these telemetry techniques before they can be employed in a large-scale study in the Aleutian Islands.

Research linkages/partnerships/collaborators and networking

This pilot project represents a collaboration between NOAA, the University of Alaska Fairbanks, School of Fisheries and Ocean Sciences (UAF, SFOS), and commercial fishers (F/V *Seafisher*). Development of tracking methods for Atka mackerel in the waters of the Aleutian Islands could also facilitate movement studies of other commercially important fish, such as Pacific cod (*Gadus macrocephalus*) or walleye pollock (*Theragra chalcogramma*) in this area.

Education/outreach

Presentations

A poster and display of telemetry equipment was presented to the Juneau public at NOAA Ted Stevens Marine Research Institute during World Ocean Day, 14 June 2008.

Publications

No publications have been prepared yet.

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 complete and this report summarizes the entire project.

Primary objectives

The goal of this research has been to understand the distribution and habitat associations of commercially important species on fishing grounds along the continental shelf east of Kodiak Island, and how these are 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.

This study's original plan was to analyze and compare three study areas at the outer edge of the continental shelf: Portlock Bank, Albatross Bank, and southwest of Chirikof Island. The primary data sets were to be habitat classification maps based primarily on geological interpretation of multibeam sonar data; biological and physical data from fishery surveys and commercial fisheries; and existing oceanographic and geological data. Integration and interpretation of these data was to be conducted primarily by Sean Rooney under the supervision of Jennifer Reynolds and Brenda Norcross, and would serve as Rooney's graduate thesis research for the M.S. degree in Fisheries at the University of Alaska Fairbanks.

This plan evolved over the course of the study. At the end of the first year, NOAA's Auke Bay Lab (ABL) conducted a series of *Delta* manned submersible dives at Portlock and Albatross Banks. This dive program provided a valuable opportunity to groundtruth the habitat classification maps and to collect data on fish and invertebrates observed in direct association with those habitats. As a result, the focus of the study shifted from analysis and integration of existing, regional data sets to analysis of the submersible dive data combined with the habitat classification maps. It was not possible to complete both, due to the time-consuming nature of submersible video analysis. While data sets for NOAA fishery surveys and commercial fisheries were examined and subsets of suitable trawl data were identified for analysis, the research reported here emphasizes the submersible dive results. It is complementary to a study of Portlock Bank fishery surveys and submersible dives by Kalei Shotwell and others at ABL in 2007 as part of their Marine Ecology & Stock Assessment (MESA) program.

Research accomplishments/highlights/findings

Research activities

- *Delta* submersible dive cruise to Albatross Bank, 23 June–2 July 2005 (funded separately by NOAA), which conducted 22 submersible dives and 29 CTD (conductivity, temperature, depth) casts. Sean Rooney assisted in planning the dive program and participated as one of three biologists diving on behalf of NOAA.
- Acquired fisheries data from RACEBASE and NORPAC databases, and conducted quality control analysis to select trawl data suitable for this research. From the Albatross, Portlock and Chirikof sites, a total of 76 RACE (Resource Assessment and Conservation Engineering) trawls and 1,125 NORPAC trawls meet the criteria. Metadata will be delivered to collaborators at ABL.
- Established video analysis methods and conducted preliminary review of video data using C-Map Systems Video Ruler DVD software (version 7.3.4). This included troubleshooting the software version that had been customized for ABL.
- Completed analysis of video data from 28 *Delta* submersible dives conducted by ABL on the Albatross Bank and Portlock Bank sites. This analysis included the 22 dives in 2005, five dives on Portlock Bank in 2001, and one dive on 8-Fathom Pinnacle (Albatross Bank) in 1999. The standard dive length in 2005 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 from 42.5 linear kilometers of dive transects were analyzed. This analysis included fish species, invertebrate classes, invertebrate coverage and relief, substrate type, and seafloor

slope and vertical relief. Audio recordings of diver observations were used to check and refine the video analysis.
- Groundtruthed multibeam-sonar-based habitat maps of Albatross Bank and Portlock Bank, using video from the *Delta* submersible dives. The original maps had been created by H. Gary Greene, Moss Landing Marine Laboratories prior to the dive program.
- Conducted statistical analysis to define fish assemblages, distributions, and habitat associations at each site, using PRIMER and ArcGIS software. Examined associations of fish communities and benthic macrofauna with benthic habitats and depth. This analysis utilized the submersible observations and the habitat classification maps. The data were analyzed at three discrete scales, from tens of centimeters to tens of kilometers. The habitat classification was also examined at several resolutions.

Research findings
- Albatross Bank had more diverse benthic habitats than Portlock Bank, with overall harder substrate, less soft sediment, and stronger bottom currents. Albatross Bank also had much higher densities of fishes (number of fishes per video frame), associated with the hard and mixed substrate. In both sites, rockfishes were the most abundant group.
- At Albatross Bank, seven distinct fish communities were defined. At Portlock Bank, two fish communities were defined; the lower sampling effort, lower density of fishes, and less diversity in benthic habitats at this probably contributed to this result.
- Depth accounted for 40% of the variance in fish community distributions at Albatross Bank, and 32% of the variance at Portlock Bank. This analysis was conducted at a scale of one to several tens of kilometers.
- Results indicate that the presence of hard substrate is very important to the distribution of rockfishes at all depths, and perhaps rivals depth as a controlling factor. This analysis was conducted at a scale of tens to hundreds of meters.
- Associations of fish communities and individual fish species with substrates change with spatial scale. This complicates efforts to define fish–habitat associations and the importance of specific habitat characteristics.
- Several important fish–habitat associations observed on Albatross and Portlock Banks (e.g., juvenile rockfishes in shallow bedrock and boulder substrates) matched results from previous studies on the Oregon and California continental margins. As specific fish–habitat associations are identified, and latitudinal gradients are taken into account, it may be possible to map the distribution of species and communities at the scale of fish populations.
- This study concludes that to understand the habitat requirements of demersal fishes, it may be necessary to examine fish–habitat associations across a range of scales.

NOAA relevance/societal benefits
This research will lead to improved understanding of the natural environment and its relationship to fishery resources. In particular, it is a step toward ecosystem-based management of marine resources in a major fishing ground. This research is also part of the graduate education of a new fisheries scientist. The student, Sean Rooney, has successfully defended his Master's thesis at UAF and will enroll in the Ph.D. program at Washington State University, Vancouver, where he will continue his studies in benthic habitat research.

Research linkages/partnerships/collaborators and networking
This is a collaborative effort between marine scientists at the University of Alaska Fairbanks (Brenda Norcross, Jennifer Reynolds), an M.S. graduate student in UAF's Fisheries program (Sean Rooney), and biologists at NOAA's Auke Bay Laboratory in Juneau, Alaska (Jon Heifetz and others). Research has been conducted at NOAA/NMFS Alaska Fisheries Science Center, Auke Bay Laboratory. This project also incorporates habitat classification maps by Gary Greene at Moss Landing Marine Laboratories. In addition, Rooney's successful progress on this project enabled him to secure a graduate fellowship from the Rasmuson Fisheries Research Center and a student research grant from the Groundfish Forum.

Graduate students supported
The CIFAR funds have supported M.S. thesis research by a UAF graduate student, in collaboration with NOAA biologists at the ABL. Sean C. Rooney, M.S. Fisheries, University of Alaska Fairbanks (Fisheries Division in Juneau), was supported for 12 months per year (100%) in FY05 and FY06.

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

During FY07 and FY08, Rooney's stipend and tuition were no longer supported by CIFAR, but the progress he had made under the CIFAR award enabled him to win a graduate fellowship for stipend and tuition from the Rasmuson Fisheries Research Center (http://www.sfos.uaf.edu/rasmuson/). A no-cost extension of modest funds remaining in the CIFAR award supported his research activities during this period.

Sean Rooney successfully defended his thesis in June 2008 and will graduate from UAF with an M.S. degree in Fisheries in December 2008.

Education/outreach

This award supported Sean Rooney's travel to several professional meetings. During FY06, Rooney attended the biennial 14th Western Groundfish Conference. In FY07, at the Western Society of Naturalists 87th Annual Meeting he presented a poster on kelp forest research conducted at NOAA's Kasitsna Bay Lab. In FY08, he attended the Western Society of Naturalists 88th Annual Meeting and presented a poster on this study. Finally, he gave an oral presentation on this research at GeoHab 2008 (Sitka, Alaska). GeoHab is an international organization for marine geological and biological habitat mapping.

Oral presentations

Rooney, S., J.R. Reynolds, B.L. Norcross, J. Heifetz and H.G. Greene. 2008. A multi-scale analysis of demersal fishes and their associated habitats on a Gulf of Alaska fishing ground. Presented at GeoHab 2008, Sitka, Alaska, 29 April–2 May 2008.

Greene, H.G., C.K. Brylinsky, V.M. O'Connell, J. Reynolds, S. Rooney and J. Heifetz. 2008. Geology as a surrogate to ecology—Is this possible? Examples from Alaska. Presented at GeoHab 2008, Sitka, Alaska, 29 April–2 May 2008.

Poster presentations

Rooney, S., B.L. Norcross and J.R. Reynolds. 2007. Associations among demersal fishes and their associated habitats on a Gulf of Alaska fishing ground. Poster presentation at the Western Society of Naturalists 88th Annual Meeting, Ventura, California, 8–11 November 2007.

Rooney, S.C. 2006. Patterns of macroinvertebrate distribution within *Nereocystis luetkeana* holdfasts. Poster presentation at the Western Society of Naturalists 87th Annual Meeting, Redmond, Washington, 9–12 November 2006. [FY07]

Publications

Submitted

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

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 complete.

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 2003.

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

Last 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. These efforts led to the in press publication listed below.

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. A new Ph.D. student, Katherine Trahnovsky, starting in the fall 2008 will carry out additional data analysis as a part of her graduate research program.

Publications

In press

Janout, M.A., T.J. Weingartner, S.R. Okkonen, T.E. Whitledge and D.L. Musgrave. Some characteristics of Yakutat Eddies propagating along the continental slope of the northern Gulf of Alaska. *Deep-Sea Research*, In press.

Hydrographic and Sea Ice Studies

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 of the Bering Sea (Russian Exclusive Economic Zone, EEZ) in August 2007,
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 2006 were recovered in August 2007 and three moorings were deployed on this cruise. These will be recovered in October 2008.
- 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.

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 Russian waters of 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 fourth-year physics major and has participated in the cruise to Bering Strait and assisted in the mooring preparation and the hydrographic data collection.

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

Publications

None this year.

References

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 56-081b: 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 major tasks in Year 3 include snowcover dataset development and analyses of arctic regional climatic/hydrologic changes over the large arctic rivers. We have focused our effort on data analyses and cross-validations. Snowcover data are the key for this project; we have updated remotely sensed snow data, including visible snow cover extent (SCE) and Special Sensor Microwave/Imager (SSM/I)/snow water equivalent (SWE).

A new climate data record (CDR) for Northern Hemisphere snow extent will be completed this coming fall. Reasons for this effort include the need to standardize land masks and address inconsistencies in the definition of what constitutes a snow-covered cell. This includes eliminating cells considered snow-covered during the first half of the satellite era when mapped as "patchy" and accounting for a major change in the late 1990s from the weekly NOAA visible map product to the daily Ice Mapping System (IMS) product (this project has been in conjunction with another NOAA grant of co-PI Robinson). We suspect that a more liberal early-era interpretation of what constitutes a snow-covered cell resulted in an over-mapping of SCE in some mountainous regions in Eurasia and North America during the early era. Comparisons of the lower-resolution older NOAA product and the newer IMS product that were mapped independently between 1997 and 1999 and climatologies of snow extent for the early era compared to the last almost 10 years of the IMS era are being employed to generate adjustment factors. These will be applied back in time (pre–June 1999: the standard being IMS).

Microwave maps of snow extent and depth over Northern Hemisphere lands are being produced from SSM/I and Scanning Multichannel Microwave Radiometer (SMMR) data. 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.

Research accomplishments/highlights/findings

Our analyses indicate a general response of river discharge to seasonal snowcover changes over the Yukon River, i.e., an association of low streamflow with high basin SCE and SWE during the cold season, and an increase in discharge associated with a decrease of the basin SCE and 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. There is a discrepancy between basin snowcover and streamflow variations perhaps due to the limitations of SSM/I SWE algorithm.

Regional hydrology analyses include the Kolyma and Yana watersheds. The Kolyma River is regulated by large dams and the Yana River without any dams is the best for studying climate impact on basin hydrology changes. Our analysis of monthly discharge data over the Yana River revealed the typical permafrost and snow hydrograph, with a peak flood due to snowmelt in late spring and early summer, and the minimum flows from November to April. Statistical analysis of monthly discharge showed a mixed trend over the basin. There is no significant trend for winter months, as annual discharge increased for some stations and decreased for others over the basin. Temperature and precipitation did not show a significant long-term trend. Correlation between discharge, precipitation and temperature shows that higher precipitation and temperature produce higher annual discharge. Monthly temperature

and discharge relationships have the inverse correlations for June, July and August, when evaporation is significant. Precipitation has a positive correlation with discharge during June, July and August.

We have obtained the historical (in-situ) snow records for 1881–1995 over the Serbian regions. We compiled the gridded monthly snow depth data over northern Eurasia using the all stations for the time period 1966–1995. This data will be very useful for the climate and hydrology community and already has been used by the University of Delaware for their research projects. In addition, 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 the Carbon Dioxide Information Analysis Center (CDIAC), Oak Ridge National Laboratory, Oak Ridge, Tennessee (ORNL/CDIAC-180, NDP-048/R1). Each station record consists 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 types and fog events and study its changes associated with the air temperature at 80 stations for the time period 1936–1989.

We analyzed rain-on-snow events over northern Eurasia. We found that most rain-on-snow events occur over European Russia during winter and increase significantly as air temperature increases. The rain-on-snow events spread into Siberia during spring and fall. Due to the extreme low temperature environment, the rain-on-snow's impact on river discharge is small in winter and potentially significant only during extreme conditions of heavy rain-on-snow events.

Our analyses of the data show that both the snowfall and rainfall days increase with air temperature during winter in northern Eurasia under current climatic conditions. Snowfall days suddenly decrease when the mean winter air temperature increases to -8ºC and above. So the snowfall days are found to decrease with air temperature in both spring and fall. Although rainfall days show increases with air temperature in fall, they decrease in spring due to the fact that rainfall days will decrease in regions where monthly air temperature is above 6ºC.

NOAA relevance/societal benefits

By developing 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. 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, as well as Jakob Theurich and Shaoqing Ge, M.S. students in civil and environmental engineering, have been supported by this project.

Presentations

Yang, D., I. Majhi, D. Kane and T. Zhang. 2008. Impact of frozen ground change on streamflow hydrology over the Lena watershed in Siberia: a preliminary analysis. Ninth International Conference on Permafrost, Fairbanks, Alaska, 27 June–3 July 2008.

Publications

Peer-reviewed

Ding, Y., D. Yang, B. Ye and N. Wang. 2007. Effects of bias correction on precipitation trend over China. *Journal of Geophysical Research–Atmospheres*, 112, D13116, doi:10.1029/2006JD007938

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. 2007. The Arctic Freshwater System: Changes and Impacts. *Journal of Geophysical Research—Biogeosciences*, *112*, G04S54, doi:10.1029/2006JG000353.

Majhi, I. and D. Yang. 2008. Streamflow characteristics and changes in Kolyma basin in Siberia. *Journal of Hydrometeorology,* 9:267–279.

Non-peer-reviewed

Ye, H., D. Yang and D. Robinson. 2007. Rain-on-snow events and its relationship to air temperature over northern Eurasia. Proceedings of the 64th Eastern Snow Conference, St. Johns, Canada, May–June 2007.

In press

Ye, H., D. Yang and D. Robinson. Winter rain-on-snow and its association with air temperature in northern Eurasia. *Hydrological Processes*, in press.

Submitted

Yang, D., Y. Zhao, R. Armstrong and D. Robinson. Yukon River streamflow response to seasonal snowcover changes. Submitted to *Hydrological Processes.*

Ye, B., D. Yang and D. Kane. Variation of hydrological regime with permafrost coverage over Lena Basin in Siberia. Submitted to *Journal of Geophysical Research–Atmospheres*.

Marine Ecosystem Studies

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 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

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 Fisheries-Oceanography Coordinated Investigations (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.

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 #5293 of the Earth & Sky Radio Series entitled "Arctic drilling may impact northern ecosystems," which aired on National Public Radio on August 31, 2007. (http://www.earthsky.org/radioshows/51697/drilling-in-the-arctic)

Publications (over the life of the project to date)

Peer-reviewed

Crane, K. and J.M. Grebmeier. 2007. Monitoring the Arctic Ocean north of the Pacific Ocean, Pacific Arctic Group Meeting, Shanghai, China, October 11–12, 2006. *EOS, Transactions, American Geophysical Union*, 88(39):384.

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, doi:10.1016/j.pocean.2006.10.001 [FY07]

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. [FY07]

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. *Science*, 311:1461–1464. [FY06]

Non-peer-reviewed

Grebmeier, J.M. and L.W. Cooper. 2004. Biological implications of arctic change. In: Arctic Climate Impact Assessment, Extended Abstracts. Arctic Monitoring and Assessment Programme, Reykjavik, 2004. ISBN 82-7971-041-8. Also available at www.amap.no. [FY05]

In press

Cooper, L.W., C. Lalande, R. Pirtle-Levy, I.L. Larsen and J.M. Grebmeier. Sedimentation and water column indicators of organic carbon processing in the Bering Strait Shelf region: evidence for seasonal and decadal shifts. 2nd SBI Special Issue, *Deep-Sea Research II*, in press.

Pirtle-Levy, R., J.M. Grebmeier, L.W. Cooper and I.L. Larsen. Seasonal variation of chlorophyll a in Arctic sediments implies long persistence of plant pigments. 2nd SBI Special Issue, *Deep-Sea Research II*, in press.

Bowhead Whale Feeding in the Western Beaufort Sea: Oceanographic Conditions, Whale Prey Distributions, and Whale Feeding and Foraging Behavior

Stephen Okkonen, PI ***NOAA Goal: Ecosystem-based Management***
University of Alaska Fairbanks

Other Collaborators funded by NOAA:
Carin J. Ashjian *and* ***Mark F. Baumgartner****, Woods Hole Oceanographic Institution*
Robert G. Campbell*, University of Rhode Island*

CIFAR 58-095: This project is new.

Primary objectives

The present proposal is part of a larger study to understand "the relationships among bowhead whale prey, oceanographic conditions, and bowhead whale feeding behavior… and to identify predictable aspects in those relationships" (Bowhead Whale Feeding in the Western Beaufort Sea, Draft Study Plan). The goal of the study is to gain a better understanding of the shelf environment in order to develop effective mitigation plans for future oil and gas development. The present proposal addresses three specific objectives of the larger study: (1) Document bowhead whale prey distributions and abundance in the immediate vicinity of feeding bowhead whales as well as in neighboring areas without whales; (2) Document "fine scale" oceanographic and other relevant environmental

conditions both near feeding bowhead whales and in neighboring areas without whales; (3) Characterize oceanographic features on a "coarse scale" relative to the study area.

Approach/methodology

Okkonen will be project leader for the physical oceanographic components, Ashjian and Campbell will be project leaders for the prey sampling components, and Baumgartner will be project leader for the tagging, tracking, and whale proximate physical and biological sampling components.

Methodology:

Sampling will be conducted on the Beaufort Sea shelf from Barrow, AK east to ~152 °E during mid-August to mid-September 2007. High vertical-resolution oceanographic sampling using a 43' boat will be conducted along several shore–shelfbreak transects; whale prey distributions also will be determined along the transects. Finer scale oceanographic and prey sampling adjacent to feeding bowhead whales, and to tagged feeding whales, will be conducted using two boats (43' and 32') following a nested sampling design (whale tracking will be conducted simultaneously using a third, smaller (20') boat). Oceanographic moorings will be deployed to monitor shelf–slope exchange events that are believed to influence the availability of zooplankton on the shelf and lagoon–shelf exchange events that appear to influence the near-shore distribution of zooplankton.

Okkonen will:

1. Prepare, deploy and recover oceanographic moorings,
2. Participate in the acquisition of field data from vessel and mooring platforms,
3. Participate in the analyses of those data, and
4. Provide analyses of ancillary (meteorological and remote sensing) data sets.

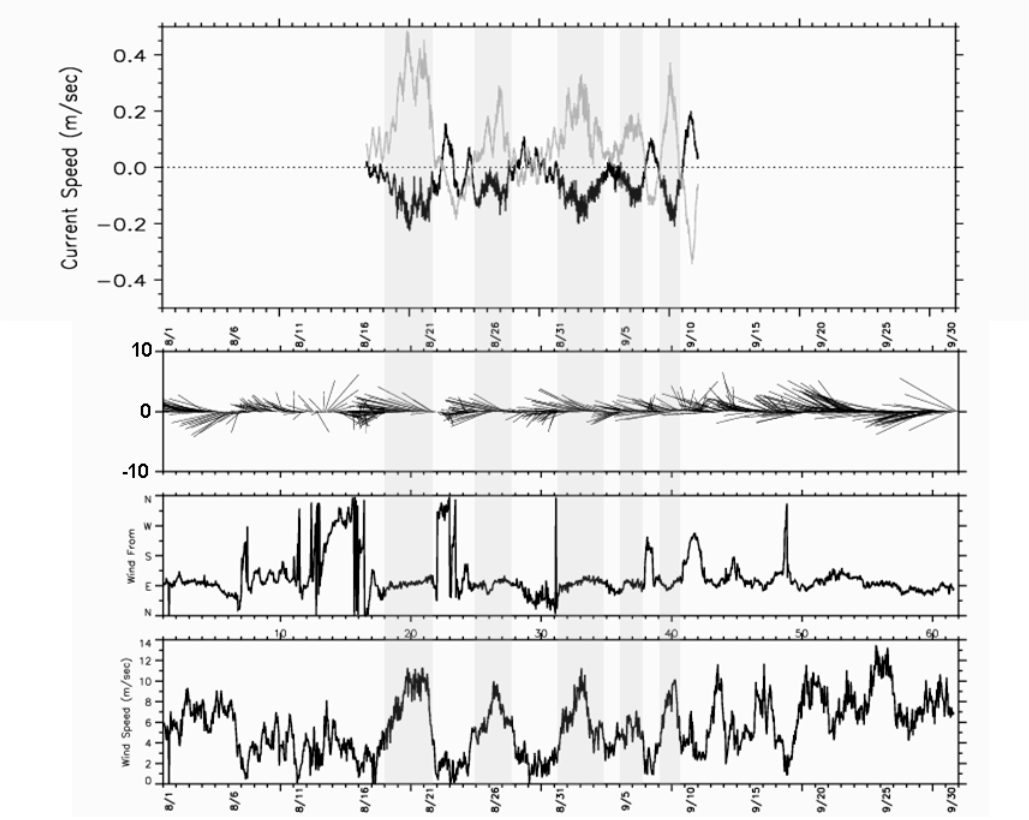

Figure 1. (top panel) Time series of depth-averaged U (black) and V (grey) current components at Cape Halkett. Positive U and V velocities indicate eastward and northward flow, respectively. (bottom panels) Barrow winds: stick plot, wind direction, and wind speed. Grey shading is used to highlight northwestward flowing currents and concurrent winds.

Research accomplishments/highlights/findings

Two oceanographic moorings were deployed between mid-August and mid-September 2007 as part of the BOWFEST project. Each mooring was instrumented with an upward-looking acoustic Doppler current profiler

(ADCP), microcat CT sensor, and AURAL phone. A shelf break mooring deployed ~10 km northeast of Pt. Barrow was not recovered due to the failure of the acoustic release. Divers will attempt to recover this mooring in August 2008. The near-shore mooring (~15 m water depth) deployed near Cape Halkett was recovered in September 2007. Data from the ADCP at the Cape Halkett mooring site are briefly summarized below.

Comparison of winds at Barrow and currents at Cape Halkett (Figure 1) show that northwestward-flowing currents (to 308°T) are well correlated ($R^2 = 0.75$) with east-northeasterly winds (from 78°T). Because easterly winds will promote upwelling onto the Beaufort shelf, we suspect that euphausiids are coincidentally upwelled onto the shelf. We infer that the northwestward-flowing shelf currents would then carry these euphausiids toward Barrow where they would tend to collect at the Barrow Canyon shelf break front (SAR image for 10 Sept 07; Figure 2) when winds weaken or blow from the south or southwest.

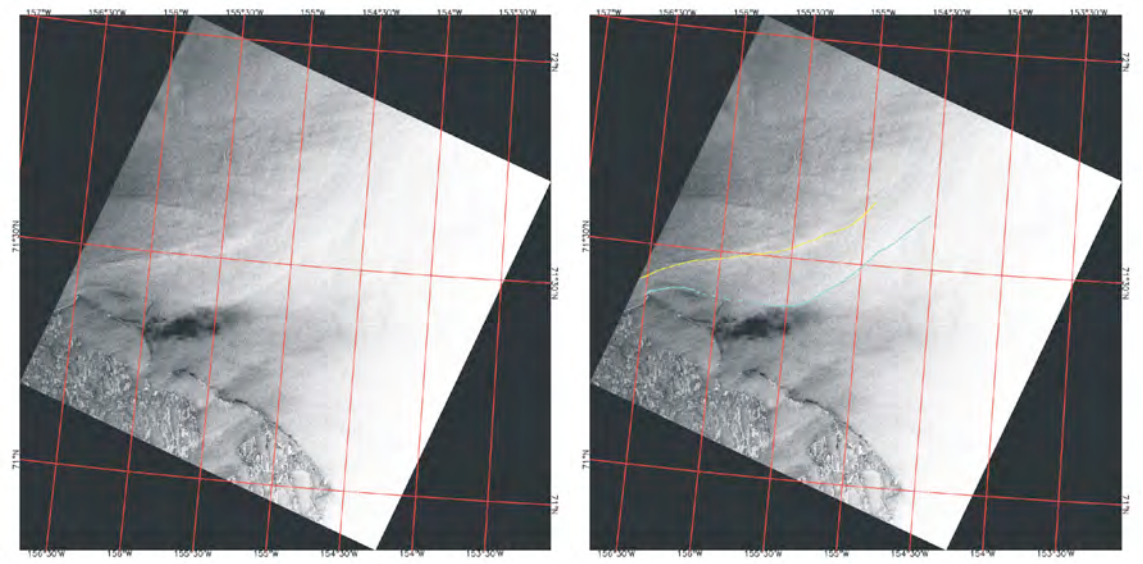

Figure 2. (left) SAR image of Barrow area for 10 September 2007; (right) same image with fronts highlighted in blue and yellow.

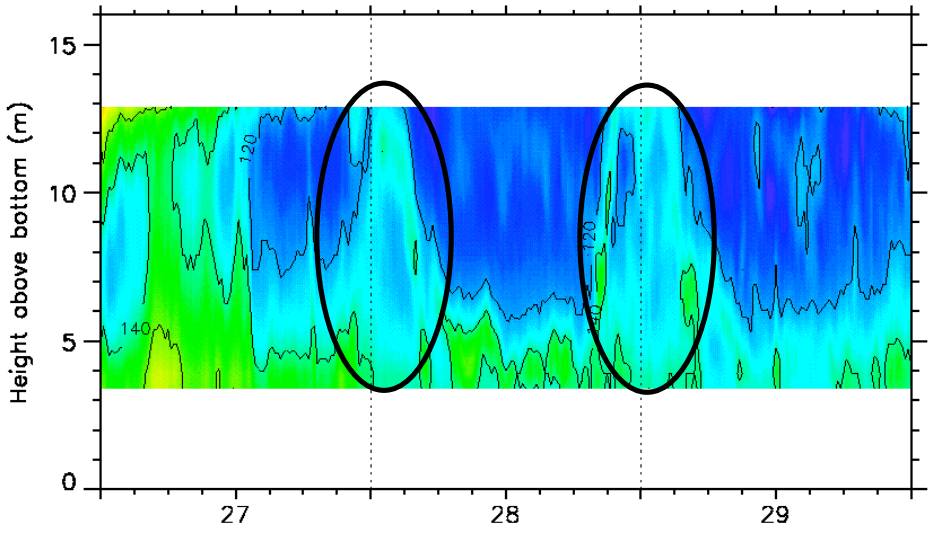

Figure 3. Sub-sampled time series (27–29 August 2007) of ADCP-measured echo intensity within the water column at the Cape Halkett mooring site. Ovals enclose occurrences of suspected diel migration. The vertical dotted lines indicate midnight.

Evidence for the presence of euphausiids on the Beaufort shelf is suggested by the time series of ADCP echo intensity (Figure 3). The elevated echo intensities occurring within a few hours either side of midnight reveal what appears to be diel migration of zooplankton.

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.

Research linkages/partnerships/collaborators and networking

This is a collaborative effort between marine scientists at the University of Alaska Fairbanks, Woods Hole Oceanographic Institution, and the University of Rhode Island.

Education/outreach

Presentation

Okkonen, S., C. Ashjian and R. Campbell. 2008. Intrusion of warm Bering/Chukchi waters onto the shelf in the western Beaufort Sea. Poster presented at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2008.

Publications

Submitted

Okkonen, S., C. Ashjian, R. Campbell, W. Maslowski, J. Clement-Kinney and R. Potter. Intrusion of warm Bering/Chukchi waters onto the shelf in the western Beaufort Sea. Submitted to *Journal of Geophysical Research–Oceans*.

Bogoslof Island Mapping for Invertebrate Colonization Study

Jennifer Reynolds, PI
University of Alaska Fairbanks

NOAA Goal: Ecosystem-based Management

CIFAR 10-079: This project is complete.

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. This project focuses on constructing a preliminary map of the 'seafloor ages' and substrate 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 have been 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 have produced both fragmental volcanic debris and lava ridges that extend hundreds of meters down the slopes of the volcano. Debris fans blanket the seafloor between these ridges, and are expected to include volcanic products from historical eruptions. The lava ridges predate the historical eruptions. Most are eroded, and all have accumulated sediment on relatively flat areas. Below 400–500 m the slopes are dominated by volcaniclastic debris. Relative age relationships can be established both among the lava ridges and the debris fans. There are no signs of major landslides or slope failure on Bogoslof.

- Age predictions can be made with confidence in two locations, and probably in a third. (1) A young debris deposit is present on the uppermost slope north of Fire Island, identifiable to a depth of about 150 m. Fire Island formed in the 1882–1883 eruption, and subsequently went through a period of rapid erosion. Significant erosion may also have occurred during explosive eruptions in 1906–1910. The effective age range for this substrate, then, is 1883–1910, or 125–95 years. (2) The southeast tip of the platform is a large, young debris deposit that extends to at least 450 m depth. The position of this deposit is apparently controlled by southeast-directed waves and currents that sweep the summit platform, rather than proximity to eruption vents. The deposit is interpreted to contain products of the 1927 tephra eruption, with erosion and redeposition by 1935. The surface age of this slope is thus predicted to be 81–73 years. (3) A much smaller debris deposit off the northeast edge of the platform, to about 90 m depth, may be the same age.
- We have acquired video recordings from two Phantom ROV dives on the upper slopes of Bogoslof (90–230 m) conducted by Rick Brodeur (NOAA) in 1995. The first dive is located on the young, southeast debris deposit, and the second crosses an eroded lava ridge and older volcaniclastic debris on the northeast slope. The dive navigation appears to be excellent, as changes in seafloor character observed in the dive video match features in the multibeam bathymetry data. These videos show clear differences in substrate character and invertebrate colonization between the two sites, and lend support to the concept of this study.
- The bathymetry map shows an anomalous cluster of small pinnacles, up to 10 m high, tentatively identified as sponge reefs (bioherms). This cluster is on the south slope of the volcano, at 290–315 m depth. Sponge reefs were first discovered in British Columbia coastal waters in 1988, and were found on the continental slope off Washington in 2007. If confirmed, this would be the first site located in Alaska and would greatly extend their known geographic distribution.

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 and sponges.

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.

Education/Outreach

Presentation

Reynolds, J.R. and M. Zimmermann. 2008. Substrate mapping of Bogoslof Volcano, Alaska for a natural experiment on invertebrate colonization. GeoHab 2008, Sitka, Alaska, 29 April–2 May 2008. (GeoHab Program with Abstracts, Ninth International Symposium, Alaska Department of Fish and Game, Sitka, AK, p. 71; http://geohab.org/)

Publications

None to date.

RUSALCA Preparation for FY08 Multidisciplinary Ocean Climate Observations

Susan Sugai, PI
University of Alaska Fairbanks

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

CIFAR 61-093 (new): This project is ongoing.

Primary objectives

This project provides advance funding to investigators with competitively selected Russian–American Long-term Census of the Arctic (RUSALCA) projects. Specifically, this project funds research and logistical activities necessary in preparation for joint U.S.–Russian multidisciplinary cruise in the northern Bering and Chukchi Seas aboard a Russian icebreaker in late summer 2008.

Approach/methodology

These funds are available to RUSALCA investigators by contacting the PI and describing their specific, time-sensitive need for advance funding. Examples of appropriate use of funds include:

- Support for investigators needing to order specific instrumentation or sampling gear needed for the RUSALCA cruise that require significant lead time for fabrication, testing, and shipping prior to use.
- Support for shipping costs of sampling gear, hazardous chemicals, and isotopes via barge to Nome or other port for field operations.

Research accomplishments/highlights/findings

- Planned joint U.S.–Russian multidisciplinary cruise for late summer 2008 was cancelled in late June 2008 because NOAA funding for intended vessel could not be transferred to Russia in time. NOAA Arctic Research Program managers hope to get the expedition vessel contract finalized this fall for the late summer 2009 field season.
- Plans for reoccupation of the Bering Strait mooring locations and CTD transects are still planned for late October 2008.

NOAA relevance/societal benefits

RUSALCA is supported by the Climate Observations and Analysis Program of NOAA. The primary goal of this program is to develop climate-quality observations, and associated data ingest, archiving, and dissemination systems.

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 Russian waters of the Chukchi Sea.

Marine Fish Survey in the Beaufort Sea Outer Continental Shelf Planning Area

Thomas Weingartner, PI
University of Alaska Fairbanks

NOAA Goals: Ecosystem-based Management; Understand Climate Variability and Change; Safe, Efficient, and Environmentally Sound Transportation

Other investigators/professionals funded by this project:
Bodil Bluhm and Ken Coyle, *co-PIs*
University of Alaska Fairbanks

CIFAR 53-092: This project is new.

Primary objectives

The project's goals are to assess the distribution, abundance, prey resources and oceanographic habitats of marine fish in the Alaskan Beaufort Sea.

Approach/methodology
The field effort involves sampling adult and juvenile fish by trawl and hydroacoustic surveys, larval fish and zooplankton by vertical net tows, and CTD casts from a fishing vessel in the Alaskan Beaufort Sea. This effort is underway in August 2008.

Research accomplishments/highlights/findings
1. Held a workshop on under-ice fish survey techniques.
2. Completed planning and preparation for the survey cruise through numerous teleconferences and at a meeting in Seattle.
3. Developed the 50+ page cruise plan.

NOAA relevance/societal benefits
Protect, Restore, and Manage the Use of Coastal and Ocean Resources through an Ecosystem Approach to Management. This will be achieved by measurements in the Alaskan Beaufort Sea that determine the health and productivity of this marine ecosystem so that it can be well-managed in the face of anticipated marine development activities.
Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond. This survey represents the first comprehensive fisheries survey of the Alaskan Beaufort Sea conducted in more than 20 years. As such it assesses the fish populations in this climate climate-sensitive sector of the U.S. Arctic.
Support the Nation's Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation. If offshore oil development proceeds in this area, it is likely that produced oil will be transported onshore by underwater pipelines. The proposed measurements help define critical biological issues to be addressed in the event of offshore oil development.

Research linkages/partnerships/collaborators and networking
This is a joint project with researchers at NOAA-NMFS-Alaska Fisheries Science Center and the University of Washington.

Education/outreach:
We are planning a presentation on the project to the North Slope Borough in fall 2008.

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 has been completed. The work will continue with NPRB funding as a component of BSIERP.

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;
- Make 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_10m	15 days of data
ISUS#077	April 2007	Miller Freeman	M5_14m	no data
ISUS#124	Sept 2007	Miller Freeman	M2_13.5m	3 mos. of data
ISUS#125	Sept 2007	Miller Freeman	M2_61m	no data
ISUS#041	April 2008	Oscar Dyson	M2_10m	in water
ISUS#036	April 2008	Oscar Dyson	M2_61m	in water
ISUS#077	April 2008	Oscar Dyson	M4_15m	in water
ISUS#021	Sept 2007	Miller Freeman	M5_32m	in water
ISUS#017	Sept 2007	Miller Freeman	M8_22m	in water

ISUS #'s 041, 036, 077, 021 and 017 will be recovered in August and September 2008. ISUS instruments will be placed on M2 and M4 with funding by NPRB for the BSIERP program. 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 (1995–2008) 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.

Publications
Submitted

Stabeno, P.J., C. Mordy, J. Napp and T.E. Whitledge. The influence of seasonal sea ice on the eastern Bering Sea ecosystem: 2005. Submitted to *Continental Shelf Research*.

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 complete.

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 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

Peer-reviewed

Lee, S.H., T.E. Whitledge and S.-H. Kang. 2007. Recent carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. C*ontinental Shelf Research*, 27:2231–2249.

Submitted

Lee, S.H., M. Jin, T.E. Whitledge and S.H. Kang. Comparison of characteristics of bottom sea ice algae at different regions in the Arctic Ocean for their ecological significance. Submitted to *Geophysical Research Letters*.

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.

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. This year we have purchased several digital data loggers for installation at various analog telemetry seismic stations. In many cases the ultimate upgrade of the seismic sensor to broadband will come at a later date.

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. Battery change. All OK.
  - COLD (near Coldfoot) – GPS timing antenna failed, replaced. Due to remodel of telemetry building, equipment to be relocated for better accessibility.
  - DCPH (Deception Hills seismic station south of Yakutat) – Telemetry problems, data intermittent. With trees removed at Yakutat, Internet protocol (IP) freewave radios re-installed. Hit by lightning. Replaced solar panels, digitizer. Only spare seismometer was a single component short period. Needs a revisit to replace short period with a broadband and strong motion seismometers.
  - DIV (Divide – East of Valdez) – Replace bad GPS unit. System functioning.
  - DOT (Dot Lake) – Uninterruptible power supply (UPS) and micro-serial server failure. All replaced, and seismometer re-orientation required.
  - EYAK (near Cordova) – Inspected site. All OK. Re-worked permit through an employee change in Cordova.
  - FALS (near False Pass) – Installed UPS and replaced micro-serial server. Inspected station. New internet service provider locked our IP addresses out. Communication has now been re-established.
  - GAMB (Gambell) – Visited late summer 2007, power cycle and system reset required. 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. Site permit required renewing, now have a ten year permit.
  - SWD (Seward) – Replaced bad modem. Installed UPS. Site visit indicates a potential for a cell phone modem upgrade.
  - TNA (Tin City) – All OK.
  - ATKA (Atka Island) – Phone line for communications is still voice grade. Tried to upgrade to digital through USGS without success. A digital subscriber line (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.
NIKH (Nikolski) – Relocated site currently operating as well as NIKO through donated internet access. Improved response and telemetry over NIKO.
Yakutat – NOAA weather service building site visit. Communications hub at NOAA weather service tower inspected and maintained. Upgraded antennas. Serviced radios and router. Trees to the south were cleared from telemetry paths.

- In the past year we have continued 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 located a second station 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 installation of the station on Chirikof Island. The permitting process was completed, and a radio relay site was established to transmit the data into the Coast Guard facility in Ahkiok. As part of the relay site on Sitkinak Island, a second seismic station was installed. In addition, we now have several new or upgraded sites throughout Alaska. Upgrades consist of a minimum of 24-bit digitizers and digital telemetry from the sites. Broadband seismometers still need to be acquired for many of the stations:
  Akhiok – Wireless telemetry service was established that was not reliable. Now we have established a cooperative very small aperture terminal (VSAT) link with the EarthScope Plate Boundary Observatory for telemetry of SII and Chirikof.
  BGLC (Bering Glacier BLM Camp) – VSAT telemetry system was hardened with additional batteries and wind generator service. System had improved performance throughout winter 2007/2008. Additional work to come late summer 2008. System telemeters 12 broadband seismic stations in real-time.
  BPAW (Bear Paw Mountain) – Telemetry of Broadband Digitial station modified and improved.
  BRLK (Bradley Lake) – Complete re-install of the station to digital broadband and strong motion. Uses cell phone modem for data telemetry.
  CAST (Castle Rocks) – Site visit for strong motion instrument planning, repair of power subsystem wiring.
  CHUM (Lake Minchumina) – Site visit and trouble shooting of receive site for station KTH late summer 2008.
  CHX (Chaix Hills) – Upgraded short period station to local digitizing and digital telemetry. Receive site still problematic. Still needs seismometer upgrade.
  CNP (China Poot) – Upgraded short period station to local 24-bit digitizing and digital telemetry. Uses cell phone modem for data telemetry. Still needs seismometer upgrade.
  DDM (Donnelly Dome) – Upgraded short period station to local 24-bit digitizing and digital telemetry. Uses cell phone modem for data telemetry. Still needs seismometer upgrade.
  DHY (Denali Highway) – Complete upgrade of a short period analog station to 6-component digital broadband and strong motion. Uses cell phone modem for data telemetry.
  HDA (Harding) – Upgrading analog short period station to on-site 24-bit digital acquisition and digital IP telemetry. Still needs seismometer upgrade.
  KLU (Klutina) – Upgrading analog short period station to on-site 24-bit digital acquisition and digital IP telemetry. Still needs seismometer upgrade.
  KTH (Kantishna Hills) – Site visit. Local equipment functions well, requires a receive site visit to Lake Minchumina.
  MDM (Murphy Dome) – Complete upgrade of seismic station to digital broadband and strong motion. Uses IP Freewave radios for telemetry.
  PNL (Peninsula) – Site visit to existing Broadband station. Firmware upgrade to digital radio system.
  CCB (Clear Creek Butte) – Upgrading analog short period station to on-site 24-bit digital acquisition and digital IP telemetry. Still needs seismometer upgrade.
  RAG (Ragged Mountain) – Site visit of existing Broadband and strong motion station. Firmware upgrade to digital IP radio system.
  RC01 (Rabbit Creek) – Site visit of existing Broadband station. Established repeater site for new station at Skwentna (SKN).
  RIDG (Independence Ridge) – New installation of a 24-bit digital broadband and strong motion site. Data telemetry to be established summer of 2008 with digital IP cell phone modem.
  RND (Reindeer) – Complete upgrade of a short period analog station to 6-component digital broadband and strong motion. Uses cell phone modem for data telemetry.
  SCM (Sheep Mountain) – Upgraded short period station to local 24-bit digitizing and digital telemetry. Uses cell phone modem for data telemetry. Still needs seismometer upgrade.

SCRK (Sand Creek) – New installation of a 24-bit digital broadband and strong motion site. Data telemetry to be established summer of 2008 with digital IP cell phone modem.
SII (Sitkinak Island) – Site visit. Hardened power subsystem and swapped out telemetry to a VSAT system located in Ahkiok. Created a repeater capability for new station at Chirikoff to be installed September 2008.
SKN (Skwentna) – Complete upgrade of seismic station to digital broadband and strong motion. Uses IP Freewave radios for telemetry.
SSN (Susitna) – Complete upgrade of seismic station to digital broadband and strong motion. Uses IP Freewave radios for telemetry.
TRF (Thorofare Mountain) – Site visit. Broadband station functioning as new.
Ultima Thule – Site visit. VSAT telemetry site. Functioned well through the winter. Power subsystem upgrade.
MCAR (McCarthy) - Site visit. VSAT telemetry site and broadband seismic station. Functioned well through the winter. Power subsystem upgrade.

- The pilot VSAT project sites that were established during the last few 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 twelve outlying sites during this period were lost. Still it was a marked improvement over the previous year. The system crash was not critical, and only needed a reboot to re-enable the IP interface. Once this happened data immediately began to flow. The on-site data storage was recovered from all twelve sites. Analysis of the data is ongoing. The two additional VSATs in McCarthy and Ultima Thule were quite successful, as they have benefit of local on-site caretakers. An additional improvement is being made to the power system this summer, as well as a remote IP based capability to reboot the field computer through the VSAT system should it hang again. This should go a long way toward solving all problems.

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 continued in this reporting period.

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, Dmitry Nicolsky, and Dave West, *University of Alaska Fairbanks*

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.

Research accomplishments/highlights/findings

1. Validation and verification of the tsunami numerical model

Recently, NOAA published Technical Memorandum OAR PMEL-135 "Standards, criteria and procedures for NOAA evaluation of tsunami numerical models" (Synolakis et al. 2007). This document outlines major requirements for numerical models used for inundation mapping and tsunami forecasting, and describes a procedure for model evaluation. There are two major components in this process. The first one is model validation, which is ensuring that the model solves equations of motion correctly by comparing model results with known solutions. This is achieved through analytical and laboratory benchmarking. The second component is model verification, which is testing the model using observations of real events through field data benchmarking. The Alaska Earthquake Information Center (AEIC) currently employs a numerical model for tsunami inundation mapping that uses nonlinear shallow water equations. We solve this system of equations using a finite-difference method on a staggered grid. To validate the algorithm, we compare numerical results with the analytical solutions for the cases when an analytical solution exists, and test the model against laboratory experiments and field data.

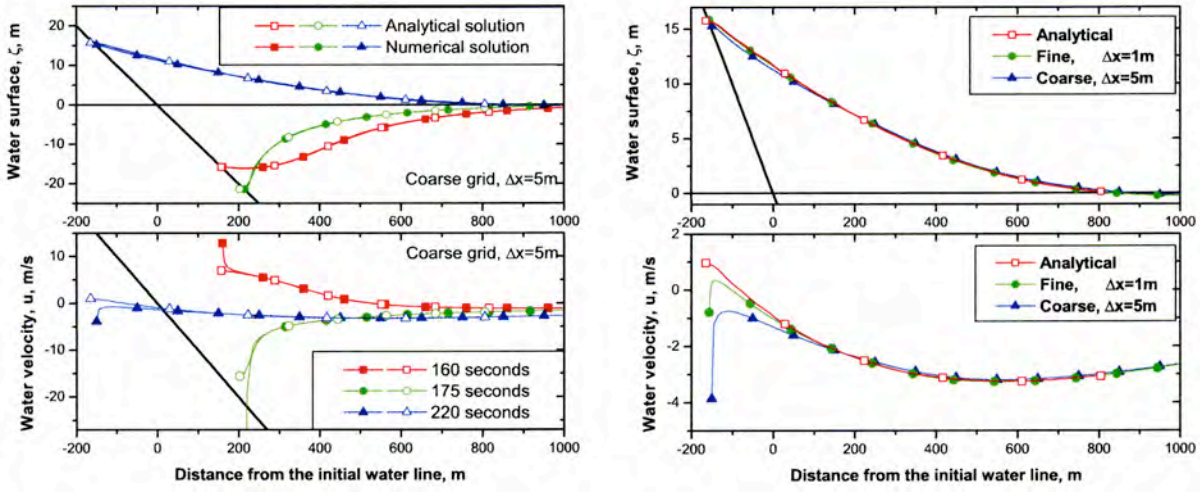

Figure 1. Left: snapshots of the computed (filled symbols) and analytical (hollow symbols) water heights (upper plot) and velocities (lower plot) at 160, 175 and 220 seconds. Right: comparison of analytical solutions for water height (upper plot) and velocity (lower plot) at 220 seconds with the numerical results computed on the fine and coarse grids. Black solid line represents bathymetry.

1.1 Analytical benchmarking: one-dimensional problem of single wave on a simple beach.

During the 3rd International Workshop on Long-Wave Runup Models (http://www.cee.cornell.edu/longwave/) the following standard test for a numerical scheme solving one-dimensional shallow water equations was proposed. In this benchmark, bathymetry is a uniformly sloping beach with a slope of 0.1 and no variation in the lateral direction. Initially water is motionless, and non-zero surface height is specified over the entire domain. At the right side of the domain, we set a non-reflective boundary condition, whereas at the left side of the domain we need to calculate a position of the point that separates dry land from water. We compute this problem first on a coarse grid of 5 m resolution, and then on a fine grid of 1 m resolution. We show that the numerical solution converges to the analytical solution as the computational grid refines. Figure 1 shows that the numerical results are in good agreement with the analytical solution. Also, it demonstrates that as the size of the grid cell decreases the numerical results converge to the analytical values. Figure 2 shows temporal variation of the water height near the beach. The

location of the computed shoreline is given by the boundary between the colored and white areas. The analytical solution for the location of the shoreline is plotted by the dash-dotted line. A discrepancy around t=200 sec is caused by small artifacts in the velocities, however if the grid cell size decreases, the numerical results are in good agreement with the analytical predictions.

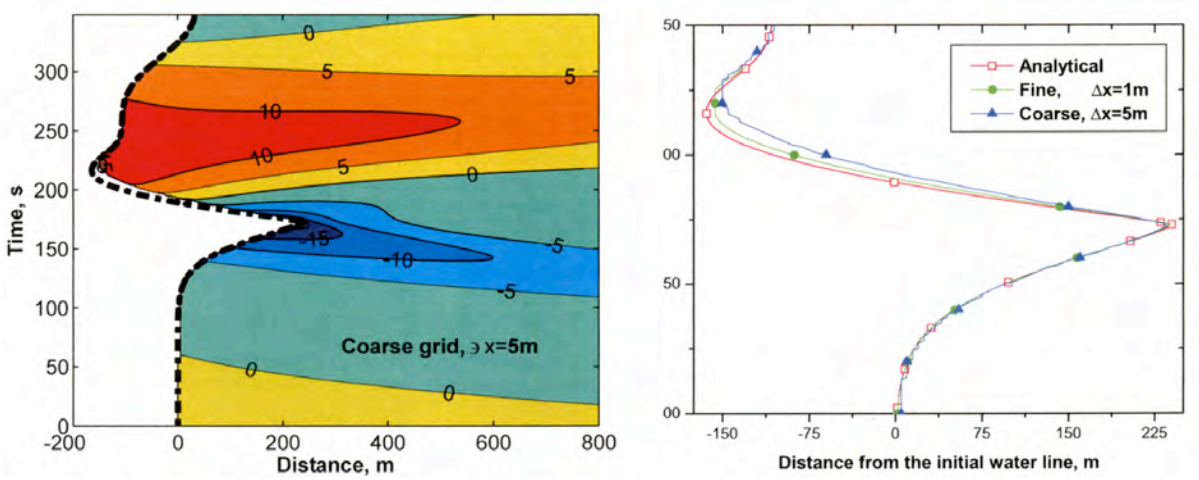

Figure 2. Left: temporal and spatial variation of the computed water surface. The dashed line shows an analytical solution for the location of the shore line. Right: comparison of the shore line dynamics computed on the fine and coarse grids.

1.2 *Analytical benchmarking: two-dimensional nonlinear shallow water problem of oscillatory time-dependent motion in a parabolic basin*

Analytical solutions exist for the problem of time-dependent frictionless oscillatory motions in a two-dimensional parabolic basin. These solutions can be described as nonlinear normal mode oscillations of water. In the first solution, the water surface remains planar as it oscillates, and in the second solution the surface is an oscillating paraboloid. We have tested our model against both analytical solutions. Figure 3 shows calculated water surfaces after the third revolution. We note that numerical dispersion and dissipation become evident in the numerical solution after three revolutions, since the finite difference scheme has only the first order degree of accuracy. Numerical errors decrease if grid resolution increases.

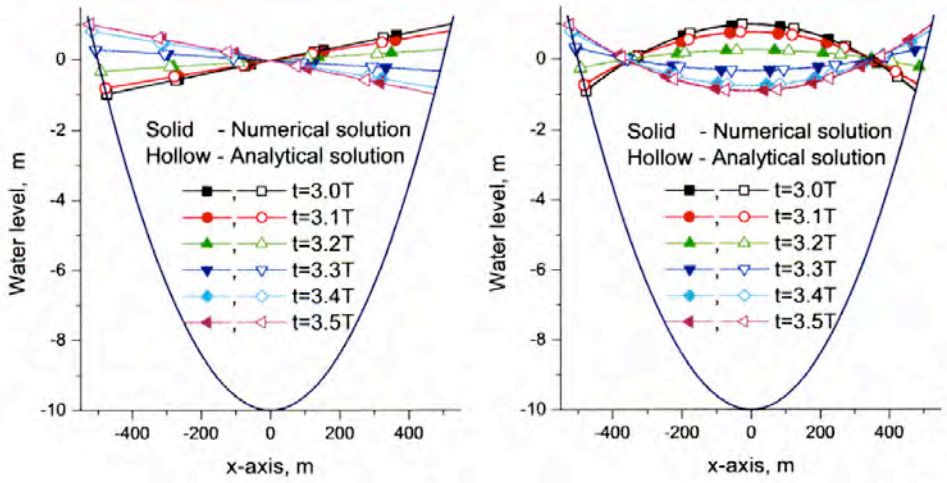

Figure 3. Numerical (solid) and analytical (hollow) solutions of water height profiles at t=3T, 3.1T, 3.2T, 3.3T, 3.4T, and 3.5T, where T is the period of the corresponding oscillatory mode.

1.3 Laboratory benchmarking: tsunami runup onto a complex three-dimensional beach of Monai Valley

We model laboratory observations of long wave run-up on a complex bathymetry, built in a large-scale wave tank. The laboratory experiment is described in the second benchmark of the 3rd International Workshop on Long-Wave Runup Models. The beach in the laboratory tank is a 1:400 scale model of the coastline bathymetry near the village of Monai in Okushiri Island, Japan. In this region during the 1993 Okushiri tsunami, an extreme 32 meter height runup mark was discovered at the tip of a very narrow gully within a small cove. In the laboratory experiment an incoming wave is created by wave paddles approximately 200 meters away from the shore line. This wave is measured at several locations near the shore by gauges. Additionally, dynamics of the shoreline during the run-up is video recorded and is available at http://www.cee.cornell.edu/longwave/. The goal of this benchmark is to numerically simulate temporal and spatial variations of the shoreline, as well as the temporal variations of the water surface at the gauges. In the computational experiment, we model a small portion of the wave tank near the shoreline. The computational domain is shown in Figure 4. The computed water surface elevation at three water gauges, marked as Channel 5, 7, and 9, is shown in Figure 5. The numerical solution is compared to the observations for the first 25 seconds during which the maximal runup occurs. The numerical solution matches the observations at three gauges very well. Additionally, we compared the computed and observed positions of the shoreline at various moments in time (Figure 6). The frames constitute a series of snapshots which are 0.5 seconds apart and are focused on a narrow gully where the highest run-up was observed in 1993. Comparison of the two sets of frames reveals a similarity between the numerical solution and the observations in the area of maximal inundation.

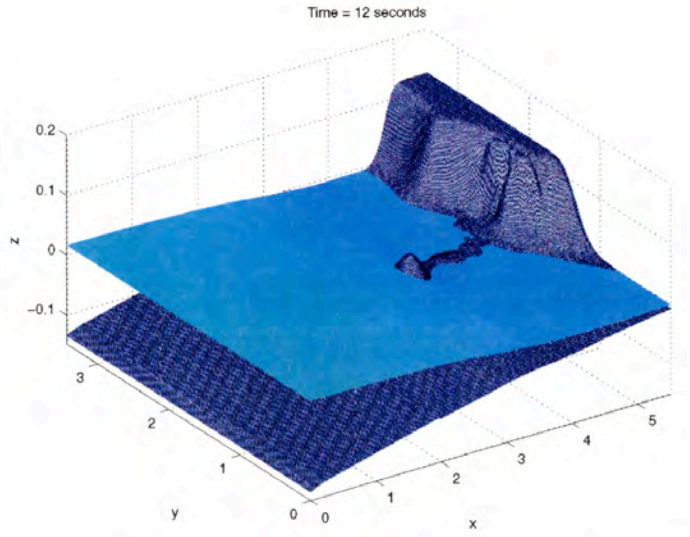

Figure 4. Computational domain and the numerical solution at t=12 seconds. The inlet boundary is modeled at x=0. At x=0, y=0 and x=0, y=3.4 the solid wall boundary condition is specified.

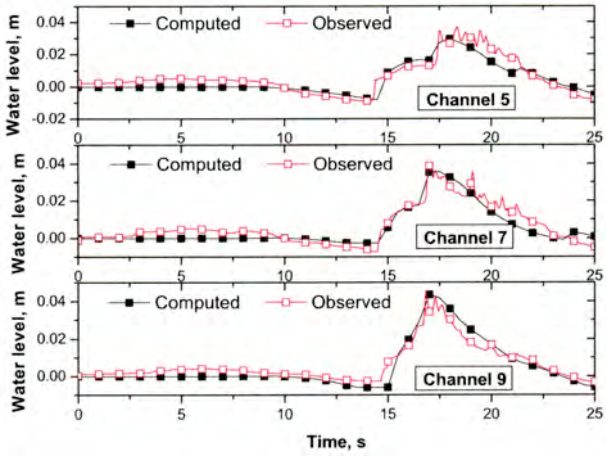

Figure 5. Comparison of the computed water height with the laboratory measurements at water gauges: channel 5, 7, and 9.

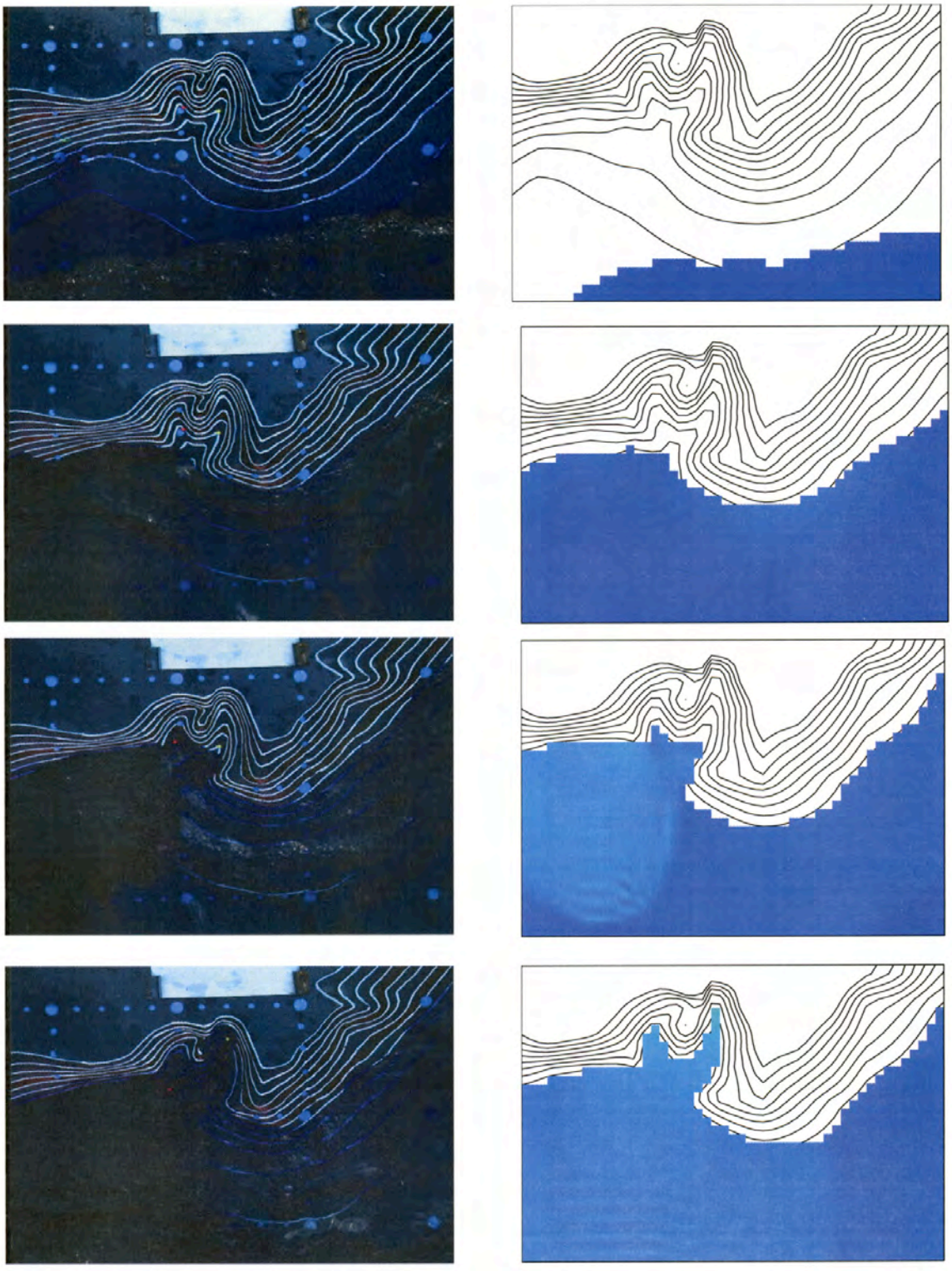

Figure 6. Snapshots from the overhead movie of the laboratory experiment (left) and the corresponding frames from the numerical simulation of the Monai Valley runup (right).

1.4 Field benchmarking: modeling of the Kuril Islands tsunami of 15 November 2006

The M_W8.3 (USGS) earthquake on 15 November 2006 at 11:14:16 (UTC) generated a tsunami on the continental slope of the Central Kuril Islands (Figure 7). The generation mechanism for the Kuril Islands tsunami model is static sea floor displacement. We apply a single fault model to calculate the deformation of the ocean floor resulted from this earthquake. Due to the model assumption that water is incompressible, the initial sea water displacement is equal to the deformation of the ocean floor. We calculate vertical sea floor displacements by Okada's static dislocation formulae using the following parameters: epicenter depth is 13 km, strike is 215°, dip is 15°, fault length is 240 km, fault width is 80 km, the seismic moment $M=3.5 \times 10^{21}$ N·m, and the rigidity is 4.2×10^{10} N/m^2. To simulate propagation of the Kuril Islands tsunami across the Pacific, we use a computational grid that covers the northern part of the Pacific Ocean and includes several Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys, which recorded a tsunami signal (Figure 7). The source of the bathymetry data is the 2-min resolution ETOPO2 seafloor topographic grid. The DART records were filtered to remove tidal components, and the obtained time series were compared with the model computations. The starting time in all our computations is the tsunami onset time. The comparison results are presented in Figure 8. The computed tsunami signals are in a good agreement with the waveforms recorded by the DART stations.

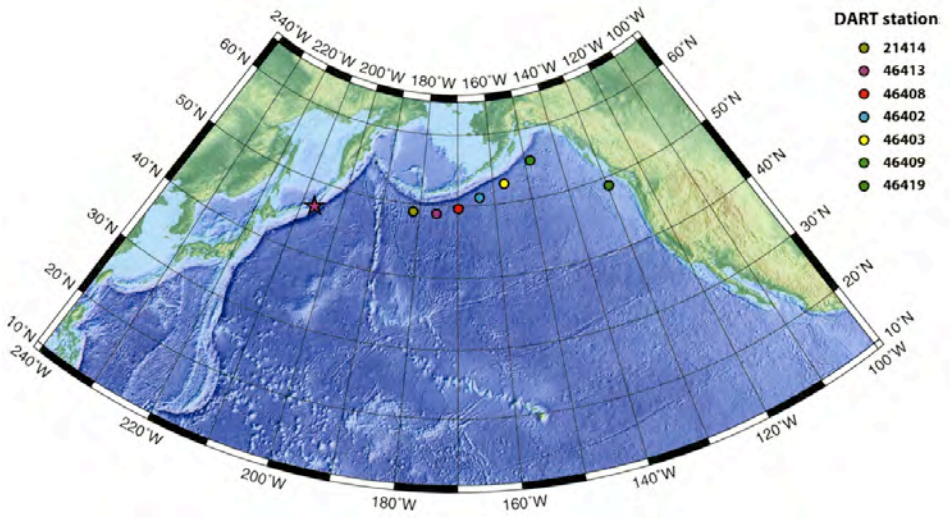

Figure 7. Computational domain with locations of the DART stations. The star indicates the epicenter of the M_w8.3 earthquake of 15 November 2006.

2) Seward inundation mapping project

We are finalizing tsunami inundation maps for Seward, Alaska. This project is a part of the National Tsunami Hazard Mitigation Program. Seward, located at the head of Resurrection Bay, was hit hard by both tectonic and local landslide-generated tsunami waves during the M_W9.2 1964 earthquake. We assess tsunami hazard related to tectonic and landslide-generated tsunamis in Resurrection Bay by performing model simulations for each of the possible earthquake and landslide source scenarios. In order to construct inundation maps for Seward, we use a bathymetry/topography grid of 15-m resolution. The source of the data is the 2001 NOAA high-resolution multibeam survey of Resurrection Bay, a 2006 survey of the Seward harbor and surrounding areas, and the high-resolution LIDAR survey of the Resurrection Bay area. In order to propagate the waves generated by tectonic sources from the generation area to Resurrection Bay, we use nested grids of increasing resolution (Table 1, Figures 9 and 10). We numerically solve shallow water equations using an explicit in time numerical scheme as follows. First, we compute the water flux (WF) in a coarse resolution grid. These values of WF are used to define the WF on a boundary of the fine resolution grid. Consequently, the sea surface height (SSH) and then the WF are calculated in the fine resolution grid. Finally, the SSH computed in the fine resolution grid is used to define the SSH within an area of the coarse resolution grid that coincides with the fine grid. Despite the fact that developed nested grids decrease the number of grid cells and preserve an accuracy of computations within certain regions of interest, real life simulations are still prohibitive if parallel computing is not implemented. We use Portable Extensible Toolkit for Scientific computation (PETSc) that provides sets of tools for the parallel numerical solution of the shallow water equations. In particular, each computational grid listed

in Table 1 can be subdivided between an arbitrary number of processors and the above-mentioned passing of information regarding the WF and SSH can be implemented efficiently using PETSc subroutines.

Table 1. Nested grids used in the model to compute propagation of tsunami waves generated in the Gulf of Alaska to the city of Seward. The 15-meter grid is used to compute the potential inundation.

Resolution	West – East boundaries	North – South boundaries
2'	138°00'W – 169°00'W	52°00'N – 63°00'N
24"	147°00'W – 155°00'W	55°00'N – 62°00'N
8"	149°00'W – 150°00'W	59°30'N – 60°10'N
3"	149°14'W – 149°37'W	59°42'N – 60°10'N
15 meters	149°16'W – 149°27'W	59°57'N – 60°09'N

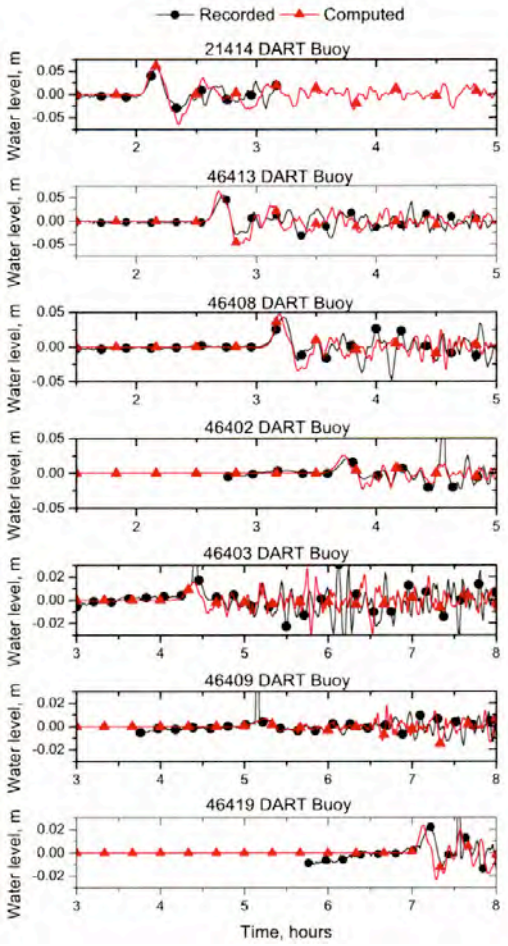

Figure 8. Measured and computed tsunami waveforms of the 15 November 2006 Kuril Islands tsunami.

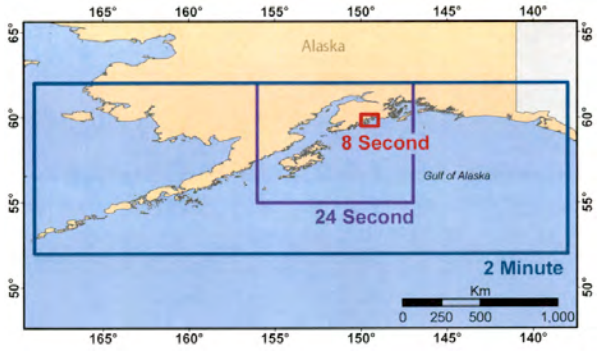

Figure 9. Coarse-resolution telescopic grids for Seward inundation mapping.

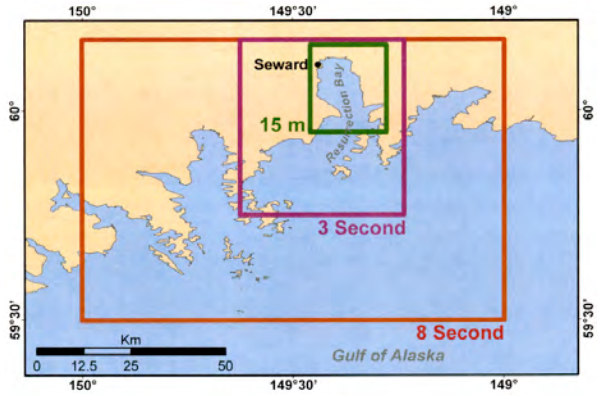

Figure 10. Fine-resolution telescopic grids for Seward inundation mapping.

To create tsunami inundation maps for Seward, we use an approach that combines modeling of the historical tsunami events of 1964 in Resurrection Bay for model verification, and assessing the landslide tsunami hazard by simulating hypothetical landslide scenarios and performing sensitivity analysis. To reconstruct the sequence of waves observed at Seward on 27 March 1964, we model tsunami waves caused by superposition of the local landslide-generated tsunamis and the major tectonic tsunami. Next we create hypothetical landslide scenarios that are based on the underwater sediment accumulation areas derived from the bathymetry difference maps. The following are the tectonic source scenarios:

(1) The M_W9.2 Alaska earthquake of 1964 with the rupture area represented by 17 subfaults.
(2) Modified 1964 event: Prince William Sound asperity of the 1964 rupture.
(3) Modified 1964 event: Kodiak asperity of the 1964 rupture.
(4) Modified 1964 event: Prince William Sound asperity of the 1964 rupture with the additional slip on the Patton bay fault.
(5) Rupture of the transition zone between the Yakutat block and the Pacific Plate.
(6) Rupture of the Pamplona zone between the Yakutat block and the North America Plate.

Figure 11 is an example of one of the inundation map products that will be delivered to Seward for tsunami hazard mitigation and for emergency planning purposes. It shows extent of the flooded area and depth of inundation on dry land calculated for Scenario 4. The observed 1964 inundation is given for comparison. Figure 12 is a similar map constructed for the landslide source scenarios. The scenario "Accumulation Areas" refers to the potential underwater slope failure that involves areas in the upper Resurrection Bay where the data shows accumulated sediment. The second scenario, "Slides 1,2 and 4", refers to three major slide complexes of the 1964 massive slope failure in the upper Resurrection Bay.

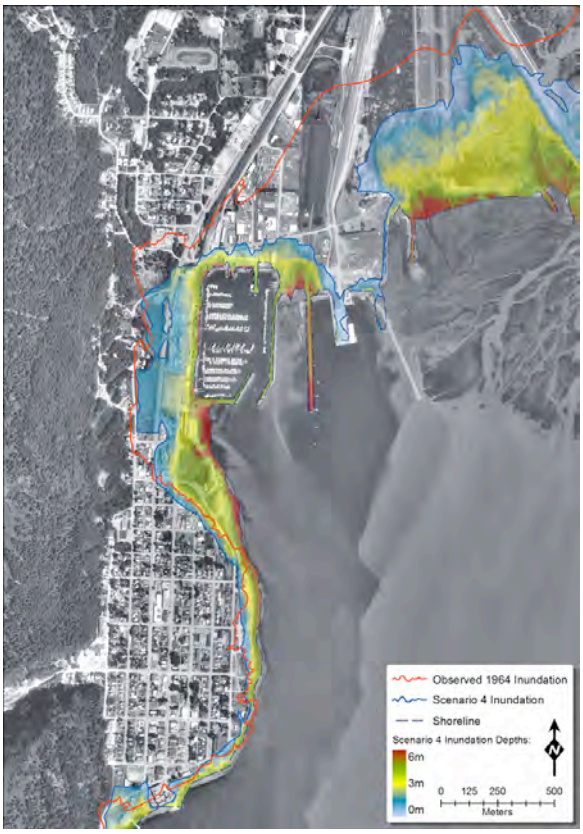

Figure 11. The map of Seward downtown that shows tsunami inundation depths calculated for tectonic scenario 4 (combination of the Prince William Sound asperity of the 1964 rupture area and the slip on the Patton Bay fault).

Figure 12. Tsunami inundation areas for 2 different landslide scenarios.

3) Development of Google Earth interface for visualization of inundation mapping results as a tsunami hazard mitigation tool.

The most vital step in tsunami hazard mitigation is education and outreach. Inhabitants of at-risk communities, who are well informed in recognizing warning signs and know what to do in the case of a tsunami, have a vastly improved chance of surviving an event. Making maps which are easily distributed and can communicate this information effectively is a challenge for any hazard mitigation campaign, particularly when the Geographic Information System (GIS) source data used to derive the information is generally inaccessible to the public.

In order to add to the cadre of tools available for educators and decision makers, the Alaska Earthquake Information Center (AEIC) will soon begin publishing their tsunami maps and models in Keyhole Markup Language (KML) format. Maintained primarily by Google, KML is a widely accepted geo-data format recently accepted by the Open Geospatial Consortium (OGC) as a supported cross-platform format, which ensures reliability and ongoing support. KML is a flexible format which allows the creator to bundle a wide array of map data into one flexible package. It can then be distributed over the web and viewed through a web browser or natively within the Google Earth desktop application itself, available by free download.

While no digital format can hope to supplant the simplicity of the well-designed paper map, digital formats such as KML can extend visualization functionality to include zoom, pan, toggling geo-data layers on and off, viewing information from many angles, as well as using aerial photography and 3D terrain. With the use of web-based KML, dynamic datasets can be posted, which reflect updates and additions from the content creator on a real-time basis. With the addition of these technologies, users have the capability to develop an enhanced sense of their surroundings, helping them to address questions such as where high ground lies and what the most efficient route is to get there from the current location. As a pilot project, a Google Earth data bundle was developed at AEIC for the community of Seward, Alaska.

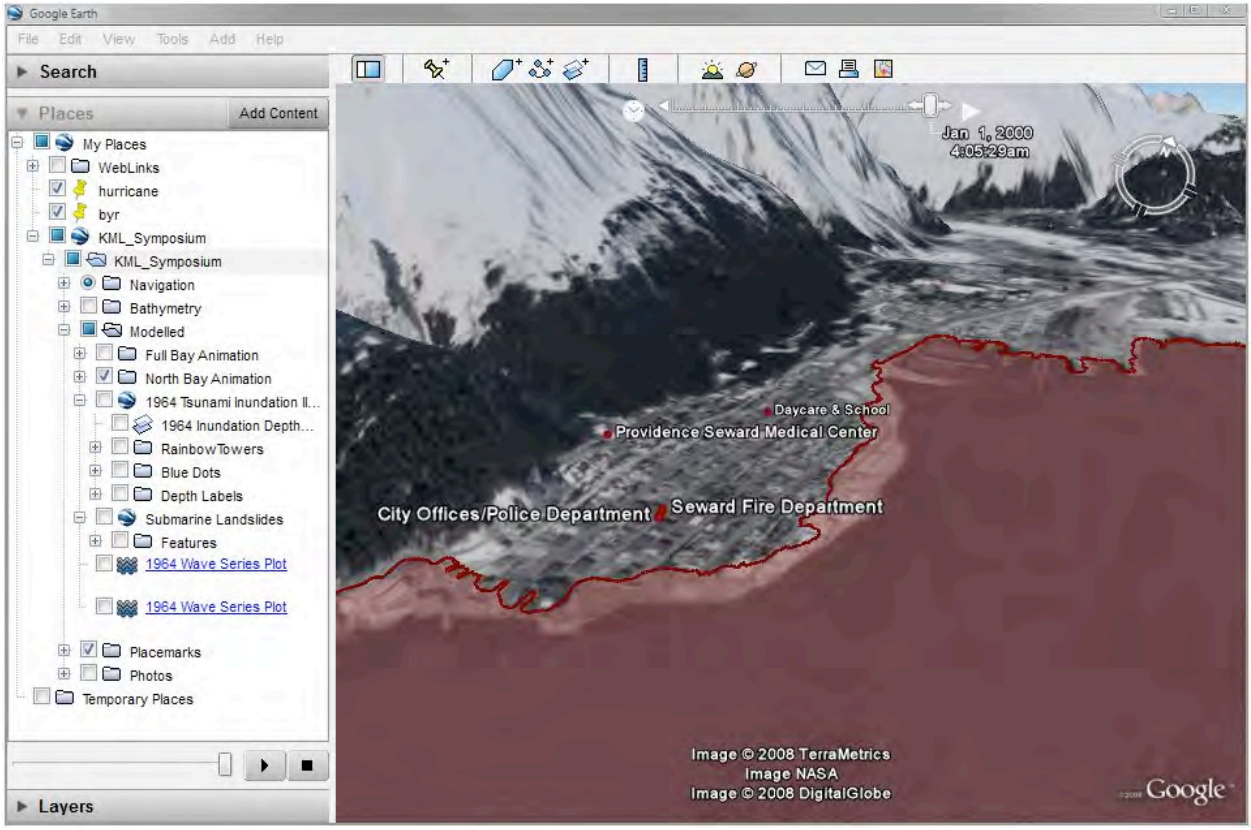

Figure 13. Tsunami inundation lines for Seward, AK and surrounding placemarks, displayed within Google Earth.

Methods

AEIC uses a wide variety of geo-spatial data to create tsunami models, beginning with high resolution bathymetric and topographic datasets, combining this elevation data with expected tsunami scenario source data (primarily seismic activity and submarine landslides). After a process of intensive numerical modeling, GIS data in the form of inundation extents, wave heights, and tsunami animations are generated. Described here are the methods used for converting these existing ESRI datasets to the more portable KML format.

Perhaps the most vital of the generated data are the inundation outlines. These boundaries define the furthest extent of land which will be covered by a tsunami wave in a given scenario. AEIC generally produces several of these for a community in order to define different levels of risk in landslide and tectonic tsunami scenarios. These are generated originally as ASCII text files (.xyz) containing a set of latitude-longitude point locations with Boolean values indicating inundation status in a given location. Using a custom routine in SAFE

Software's "Feature Manipulation Engine" (FME), the inundated point locations are buffered in order to create a smooth outline of inundated areas. FME is then used to export these lines directly into ESRI shapefile and Google .kml formats. Without further editing, the kml files appear in Google Earth as standard grey lines, so colors and labels are added either in the KML code itself, or more intuitively, directly within the Google Earth interface (Figure 13).

AEIC has also been testing "on-earth" tsunami wave animation within Google Earth. This allows for realistic visualizations of tsunami wave propagation, which appear directly on the surface of the map in simulated time. This process takes a bit of processing power and time to develop, but when complete, it allows for an effective user-experience, facilitating views of the animation from angles and perspectives previously available only in high-end animation suites.

Most tsunami modeling codes are able to create a series of hillshade waveform image, which arranged in time act as frames for an animation. KML format manages time using a very simple coding mechanism. Within KML code, time tags specify the period of time a given object (or frame) is active. When the object is active, it is visible. After using internally developed code to georeference each of these images within Google Earth, a time period is assigned to each one. Google Earth recognizes a time-activated layer and by default displays a slider in the top right of the screen, which allows the user to play or drag through the animation onscreen at a chosen speed (Figure 14).

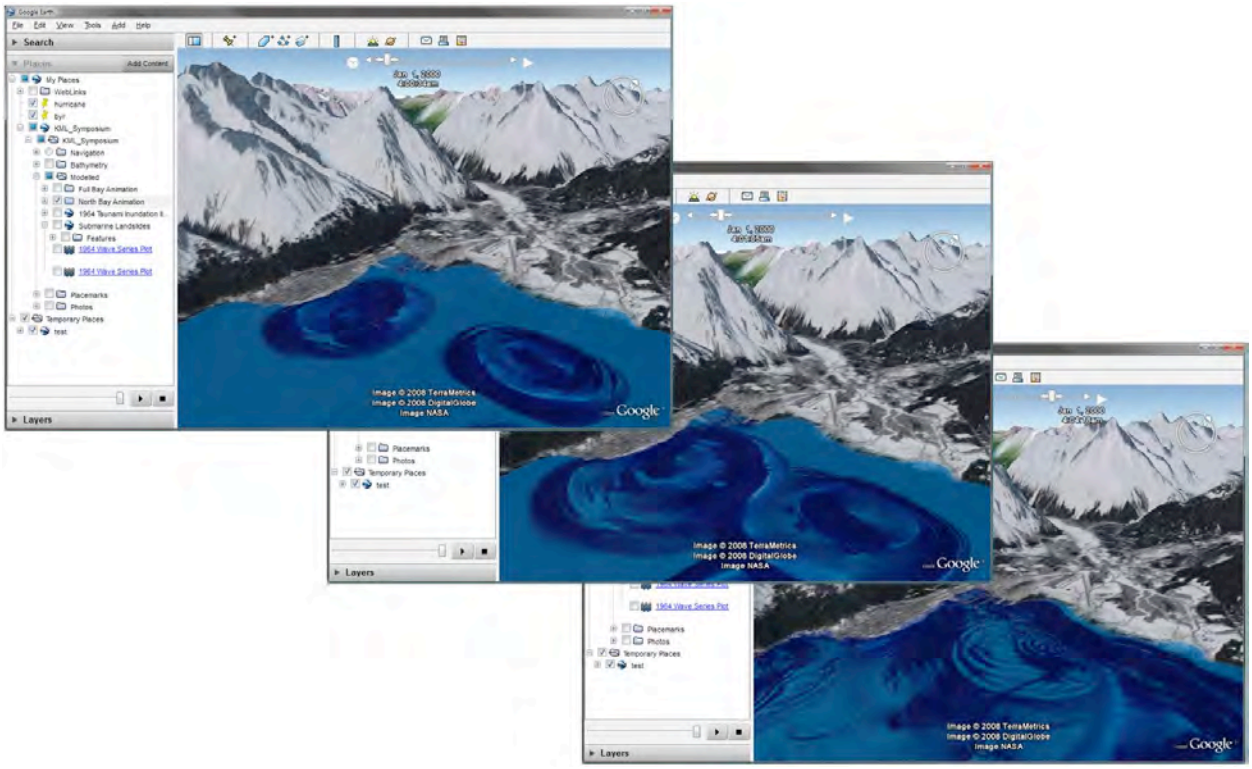

Figure 14. Three frames from a landslide-generated tsunami model animation, displayed within Google Earth.

Other miscellaneous geo-data can be added to the KML file, including placemarks for important infrastructure, popup windows for relevant charts and photos, 3D inundation depth data or buildings, and direct access to webcams or other web video. All of these pieces can then be bundled together into a tutorial or organized reference, and published online.

Unfortunately, within Google Earth there are a number of image registration issues related to data layering. In many locations, including Seward, the provided aerial photography is not registered to the same position on the earth as the more accurate GIS input data. In some cases, the photo has been shown to be off by as much as 50 meters. In order to use tsunami data within Google Earth, a data shift is sometimes required to attain an acceptable spatial match between basemaps. The developer is ultimately at the mercy of available input basedata. For many Alaskan communities high resolution aerial photography does not exist, which can make mapping and displaying this data at the community scale very difficult.

Familiarity with virtual globes and web map programs is another significant barrier to dissemination in this manner. Though web mapping interfaces have seen huge functionality and usability enhancements in the past few years, it is still a challenging interface for much of the less tech-savvy public. For this reason, geo-data should never be a singular solution. A suite of other approaches including paper, in-person, and public space education is required for a successful public safety and education campaign. AEIC therefore intends for distribution of KML to serve as a good solution for those deeply involved citizens and decisions makers who have the required skill and tools as well as an interest in understanding the full tsunami modeling process.

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

In the scope of the "Alaska Tsunami Educational Program" proposal that was funded by the Department of Education, Elena Suleimani and Jamie Roush have contributed to the Tsunami Curriculum by reviewing several class units. Also, Elena Suleimani and Dave West have given teleconference lectures in Google Earth to science teachers and their students in rural Alaska.

Presentations

Suleimani, E., P. Haeussler, K. Labay and R. Hansen. 2007. Numerical study of multiple submarine slope failures and tsunamis near Seward, Alaska, during the M9.2 1964 earthquake. International Union of Geodesy and Geophysics (IUGG) Assembly, Perugia, Italy, 2–14 July 2007.

Suleimani, E., D. West and R. Hansen. 2007. Understanding landslide tsunami hazard in Alaska fjords for tsunami inundation mapping. AGU Fall Meeting, San Francisco, California, December 2007.

West, D., E. Suleimani and R. Hansen. 2008. Tsunami inundation mapping for Seward, Alaska. Alaska Survey and Mapping Conference, Anchorage, Alaska, February 2008.

West, D. and R. Hansen. 2008. Tsunami inundation mapping with KML. "KML in the North" Symposium, Fairbanks, Alaska, April 2008.

Publications

Accepted

Suleimani, E., P. Haeussler and R. Hansen. Numerical study of tsunami generated by multiple submarine slope failures in Resurrection Bay, Alaska, during the M9.2 1964 earthquake. *Accepted for publication in the PAGEOPH topical issue on tsunamis, as Proceedings of the 23rd International Tsunami Symposium, Perugia, Italy, 2–14 July 2007.*

Reference

Synolakis, C.E., E.N. Bernard, V.V. Titov, U. Kânoğlu and F.I. González. 2007. Standards, criteria, and procedures for NOAA evaluation of tsunami numerical models. NOAA Technical Memo Memorandum OAR PMEL-135, NTIS: PB2007-109601, NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 55 pp. (online at http://www.pmel.noaa.gov/publications/search_abstract.php?fmContributionNum=3053)

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, Kate Pyatek, *University of Alaska Fairbanks*

An element of CIFAR 57-047c: 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 2007 and June 2008. Many of our continuing 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.

We have an ongoing partnership with the ADHS&EM 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 was completed 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 contributes to the program by participation in outreach visits and by acquisition of warning sirens for coastal towns. Planning and preparation continued for upcoming outreach trips to the communities of Sand Point and King Cove. Warning sirens were purchased and installed in Valdez and continued assistance provided to ADHS&EM regarding acquisition of sirens for St. Paul in the Pribilof Islands.

Staff from AEIC continue to work 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.

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

Roger Hansen, PI ***NOAA Goals: Serve Society's Needs for Weather and Water Information;***
Zygmunt Kowalik, Co-PI ***Safe, Efficient and Environmentally Sound Transportation***
and task lead
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
James Beget, Juan Horrillo, Tatiana Proshutinsky, *University of Alaska Fairbanks*

An element of CIFAR 57-074c: This project is ongoing.

Primary objectives

The objective of this project 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 these activities 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), J. Horrillo (IMS) and T. Logan (Arctic Region Supercomputing Center; ARSC) (Kowalik et al. 2007a, Kowalik et al. 2007b, Horrillo et al. 2006). Previously this code was tested, calibrated and validated with analytical solutions as well as with laboratory experiments. During this reporting period, the depth-integrated model with non-hydrostatic component was tested to reproduce breaking and runup (Yamazaki et al., accepted).
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), Yoshiki Yamazaki from University of Hawaii 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 2007–2008 were aimed at constructing a simple dispersive set of equations which can be implemented into everyday prediction and warning at WC/ATWC. The formulation decomposes the total pressure into hydrostatic and non-hydrostatic components and introduces a linear vertical velocity in response to the non-hydrostatic pressure (Yamazaki et al., accepted). The hydrostatic component is equivalent to a nonlinear shallow water model with an explicit

scheme and an implicit scheme provides the non-hydrostatic pressure through the three-dimensional continuity equation. The unique feature of the model is the use of an upwind flux approximation in the computation of the continuity equation and the momentum-conserved advection.

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 (Kowalik et al. 2006). 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 2006–2008 the model of tide/tsunami interaction for Port Valdez and Cook Inlet has been run and data are being analyzed. A paper "Tsunami-tide interactions: a case study for Cook Inlet and Port of Valdez" is in preparation. It will be submitted by Z. Kowalik and A. Proshutinsky to a topical issue of Progress in Oceanography on "Tides in the marginal seas" in memory of Professor Alexei Nekrasov by 1 October 2008.
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 (Beget and Kowalik 2006). Subaerial and submarine mass failures are complex phenomena, which involve strong vertical flows, turbulence and slide/water interactions, and sometimes wave breaking. In this context, a 3D Navier-Stokes model will be further implemented and tested using the scenarios mentioned above. The accuracy of the 3D model will be checked against experimental data as well.
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; the main results are described in Kowalik et al. 2005a, 2005b; Kowalik et al. 2007a, 2007b. In 2006–2008, we have used our model to investigate the tsunami generated near the Kuril Islands on 15 November 2006 at 11:14:16 (UTC). Along with the primary source of tsunami, sea level uplift due to earthquake, the secondary sources due to scattering and refocusing complicate the process of tsunami propagation. The secondary ridge-amplified and seamount scattered waves travel more slowly from the primary source and arrive later at distant coastal points. As a result, interactions between wave fronts derived from primary and secondary sources lead to difficulties in predicting the arrival time of the largest amplitude wave. These waves, important for tsunami prediction, warning and hazard mitigation have been investigated and results published in Kowalik 2008; Kowalik et al. 2008; Horrillo et al. 2008.
6. In order to carry out the above simulations and a new development of dispersive model a large portion of time was used for code construction and testing. The addition of non-hydrostatic pressure to the set of the long wave equations resulted in a Poisson-type equation. The key role in the generation and modification of dispersive waves plays the magnitude of the bottom and free surface slopes. The vertical component of the flow, important for sustaining dispersive processes, is imparted through the bottom and surface slopes in terms of the horizontal flow components from the boundary conditions. The matrix associated with the numerical solution of the Poisson equation provides the non-hydrostatic pressure at each time step. It often contains 1 to 200 mln computational cells. The matrix is non-symmetric, which is typically solved by either the bi-conjugate gradient method (BiCG) or the conjugate gradient squared (CGS) algorithm. In this study, we use the conjugate gradient squared stabilized (CGSTAB) algorithm. To test validity of preliminary results from the dispersive model a comparison was made with the full Navier-Stokes model developed by Horrillo (2006).

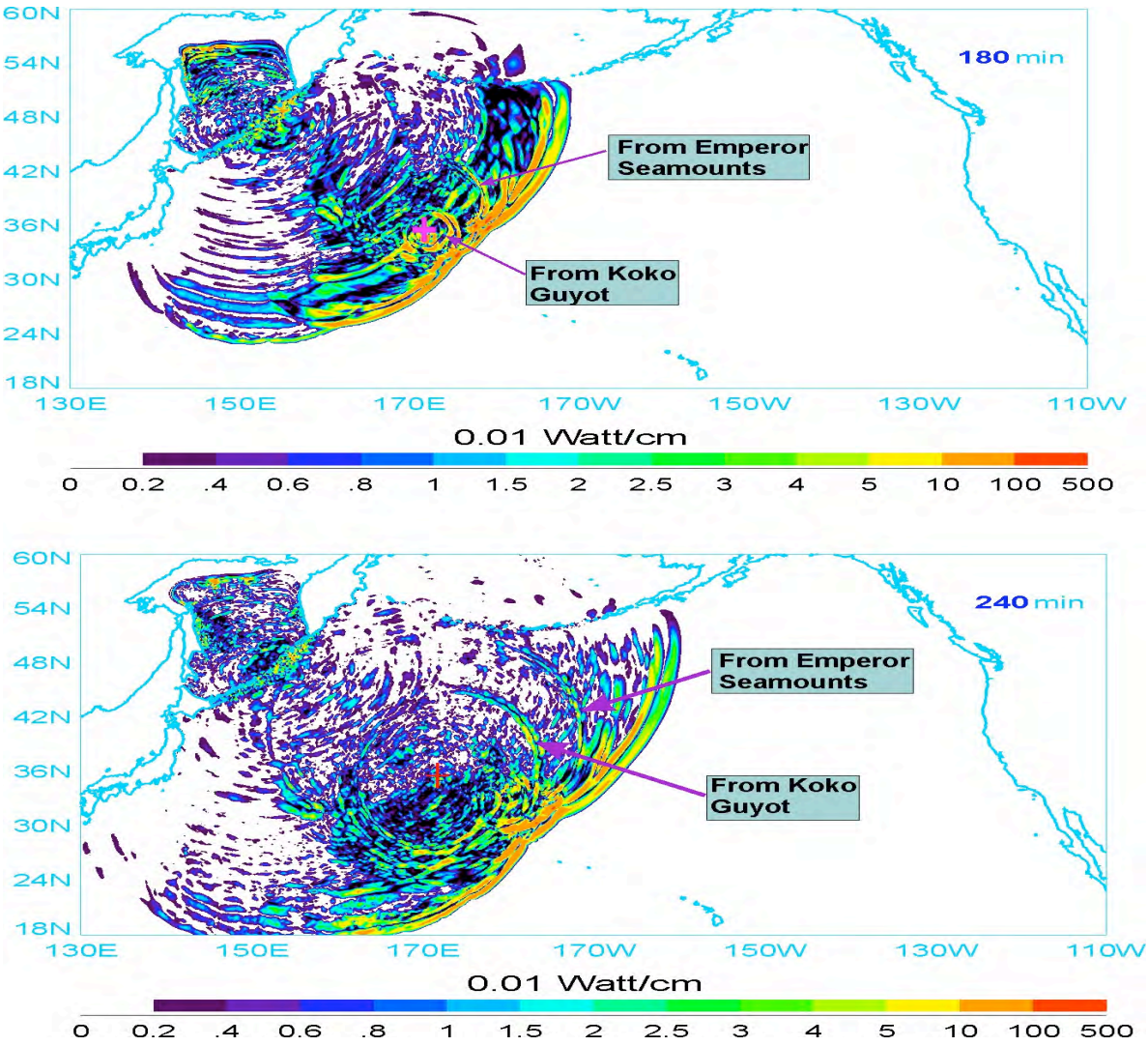

Figure 1. Kuril Tsunami of 15 November 2006. Tracing the high energy scattered tsunami signal by the energy flux. Energy flux contours, 180 min (upper panel) and 240 min (lower panel) after tsunami onset. Two signals of higher energy have been identified as scattered from Emperor Seamounts and Koko Guyot. Note that only the second stronger front is centered on the Koko Guyot. Red plus marker points to location of Koko Guyot seamount.

Research accomplishments/highlights/findings

In 2006–2007, major accomplishments were related to application of the energy balance in the Kuril Island Tsunami of 15 November 2006. We continued this line of research aiming at construction a simple tool to be used in WC/ATWC (Kowalik 2008). 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 24 December 2004 and to the Kuril Island Tsunami of 15 November 2006 allowed us to formulate a new method for prediction of the late arriving tsunamis. The sea levels recorded in the wake of the Indian Ocean Tsunami of December 2004 and of the Kuril Island Tsunami of November 2006 show strong tsunami signal enhancement of the late arriving secondary waves. Using these tsunami events we demonstrate that sudden changes caused by higher energy pulses in the intermittent tsunami wave trains can be assessed by energy fluxes. Therefore, to delineate the regions of tsunami wave amplification and travel time, we propose to use energy flux. A series of numerical experiments defined in an explicit way the bathymetric features which scatter tsunami signal towards ports, like Crescent City. The identification of the distant bathymetric features was achievable since the energy flux vector delineated the energy pathways that coupled with distant bathymetric features to ports located thousands of kilometers apart. Calculations of the energy flux vector involve simple formulas based on two components of velocity and sea level. Since velocity is required and usually it is not recorded at gauges, such calculation can be made only through numerical computations. The maximum of the energy flux

(which has no directional properties) can be evaluated from the sea level amplitude, hence both observed and computed sea level can be used for this purpose. The main task of this research is to construct models for tsunami warning and prediction services with wider scope of physical processes by incorporating the energy balance equation into presently used tools.

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. New numerical models and tools developed and properly tested in our project, are transferred to WC/ATWC and through cooperation with University of Hawaii are used in a tsunami mitigation program. The new tool under development in the past 2 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, University of Ottawa, Department of Civil Engineering, University of Guadalajara, and Centro Universitario de la Costa, Mexico. Last year in cooperation with University of Hawaii and WC/ATWC we started to upgrade the model by a new module for evaluating the dispersion in tsunami waves.

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 and Ed Kornkven, Arctic Region Supercomputing Center (ARSC)), 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 coordinated research activities related to model 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. The development of the efficient tsunami codes relies heavily on ARSC staff (T. Logan and E. Kornkven) and the inclusion of new parallel computational tools. For instance, the pressure Poisson equation is computationally expensive to solve, thus, currently we make use of a variety of tools such as PETSc to solve the pressure field efficiently. Maintaining the codes and applications at ARSC 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

- William Knight is a Ph.D. student at the Institute of Marine Science and he works at WC/ATWC. He continues research towards developing a dispersive tsunami model and fine grid resolution for coastal flooding. These models will 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. He is implementing these new models to Hawaii coastal waters. Z. Kowalik is a member of his advisory committee.

Presentations

Kowalik, Z., J. Horrillo and W. Knight. 2008. Investigating tsunami wave scattering and enhancement using energy fluxes. Presentation and poster at Ocean Sciences Meeting, 2–7 March 2008, Orlando, Florida.

Horrillo, J., Z. Kowalik and W. Knight. 2007. Kuril Islands tsunami of November 2006 (Examination of tsunami enhancement at Crescent City, California). Oral presentation at IUGG, XXIV General Assembly, 2–13 July 2007, Perugia, Italy.

Publications

Peer-reviewed

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In press

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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

Yamazaki, Y., Z. Kowalik and K.F. Cheung. Depth-integrated, non-hydrostatic model for wave breaking and runup. Accepted for publication in *International Journal for Numerical Methods in Fluids*.

In preparation

Kowalik, Z. and A. Proshutinsky. Tsunami–tide interactions: a case study for Cook Inlet and Port of Valdez. In preparation for a topical issue of *Progress in Oceanography*.

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Horrillo, J., Z. Kowalik and Y. Shigihara. 2006. Wave dispersion study in the Indian Ocean Tsunami of December 26, 2004. *Marine Geodesy*, 29:149–166.

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2007a. The tsunami of 26 December 2004: Numerical Modeling and energy considerations-II. 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.

Kowalik, Z., T. Proshutinsky and A. Proshutinsky. 2006. Tide–tsunami interactions. *Science of Tsunami Hazards*, 24(4):242–256.

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2005. The tsunami of 26 December 2004: Numerical Modeling and energy considerations. In: G.A. Papadopoulos and K. Satake, Eds., Proceedings of the International Tsunami Symposium, Chania, Greece, 27–29 June 2005, pp. 140–150.

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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 57-074c: 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 continuous waveform archive for the broadband stations. If waveforms within a certain epicentral distance are available, then the moment tensor inversion is performed. The inversion uses a library of precalculated Green's functions to compute synthetic seismograms for a range of source depths (from 5 to 200 km with 5 km interval). Currently, we use 3 regionalized velocity models: (1) Aleutian Islands region east of 157º W longitude; (2) central Alaska region north of 62.5º N latitude; (3) southern Alaska region south of 62.5 º N latitude and east of 157 º W longitude. Three different frequency ranges are used depending on the magnitude of the earthquake: 0.02–0.1 Hz for magnitude less than 4.0, 0.02–0.05 Hz for magnitudes between 4.0 and 5.4, 0.01–0.05 Hz for magnitudes 5.5 and greater. 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 (Figures 1a–d).

The automatic moment tensor information in three forms is available through the AEIC webpage: http://www.aeic.alaska.edu/html_docs/moment_tensors.html. Automatic moment tensors are reviewed on the following business day.

Research accomplishments/highlights/findings

- A total of 58 regional moment tensor solutions were calculated (magnitudes Mw between 4.0 and 6.6) for this time period (Figure 2).The solutions are based on at least two stations. When possible, the solution is compared with the P-wave first motions for the event. If the moment tensor solution disagrees with a majority of the available first motions, it is discarded.
- Ongoing expansion of the AEIC broadband network allows for more reliable calculations of the earthquake source parameters through inclusion of more waveform data into the inversion. The key to a successful inversion is availability of high quality recordings that are distributed over both azimuth and distance from the epicenter. The uneven broadband coverage outside of the network core area in southern Alaska hinders attempts to obtain successful and reliable inversion results.
- A library of the three basic Green's functions (synthetic seismograms) was expanded over a larger distance range, up to 700 km instead of the former 500 km. This allows more distant stations into the moment tensor inversion, important in areas outside of the network core area (such as the Aleutians and western and northern Alaska). This also may be critical when near-field records go off-scale from a large earthquake.
- Trial (not real time) runs have been performed with the extended earthquake source inversion code.

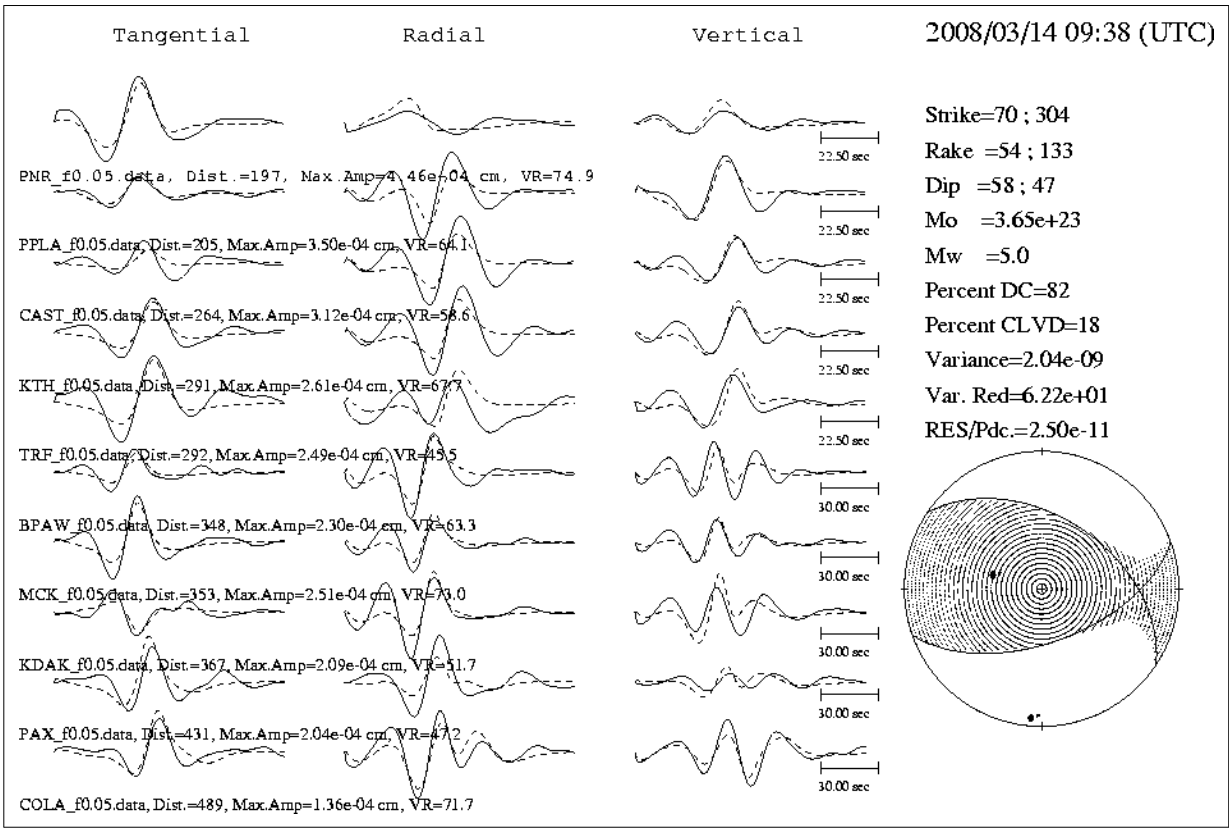
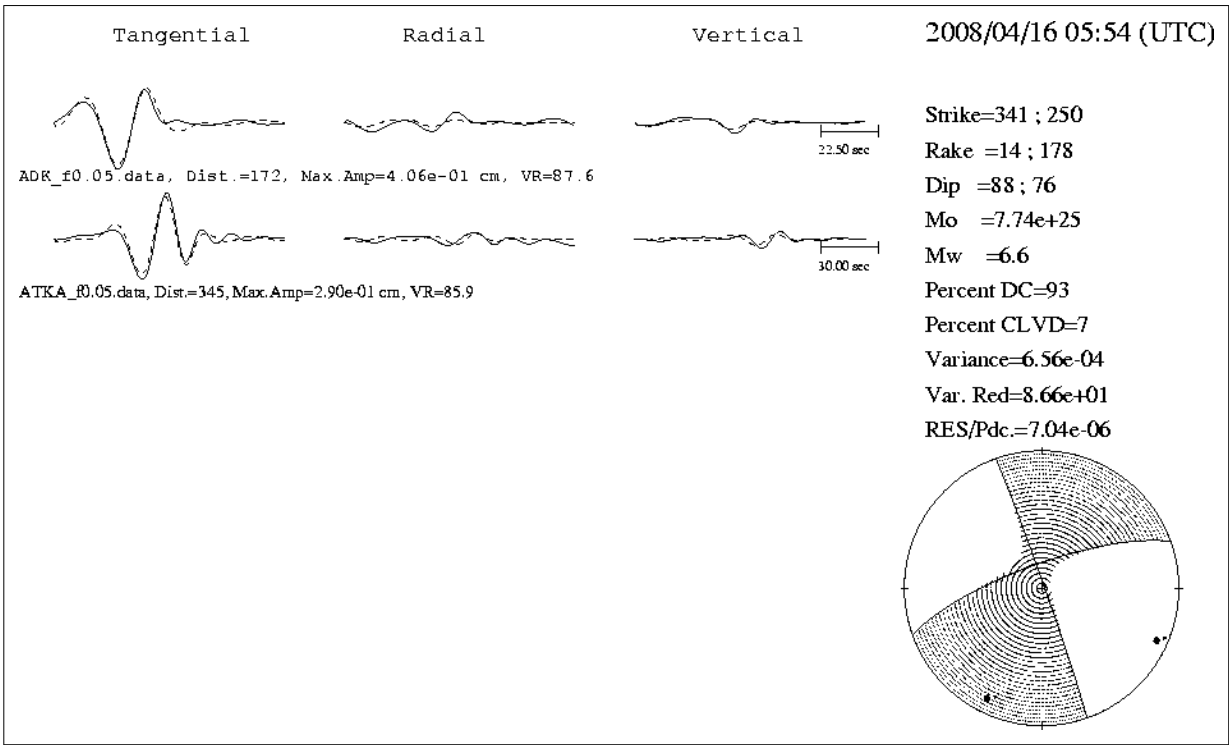


Figure 1a. Example of the moment tensor inversion result for the deepest event (144 km depth) in July 2007–June 2008 catalog. The top panel shows the waveform fit, the bottom panel is location of the event. This event was located in well instrumented area, therefore many stations are available for the inversion.



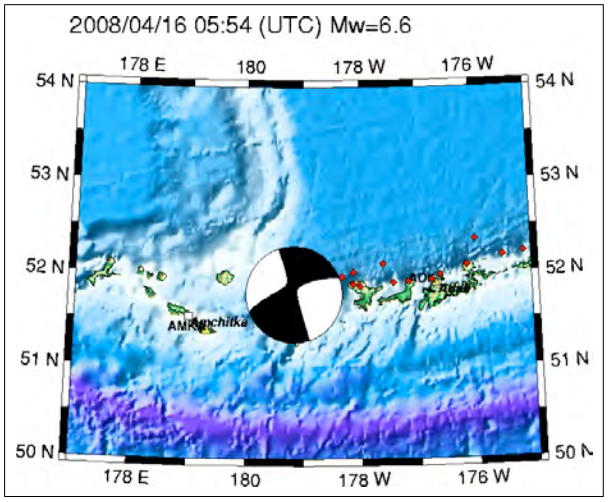
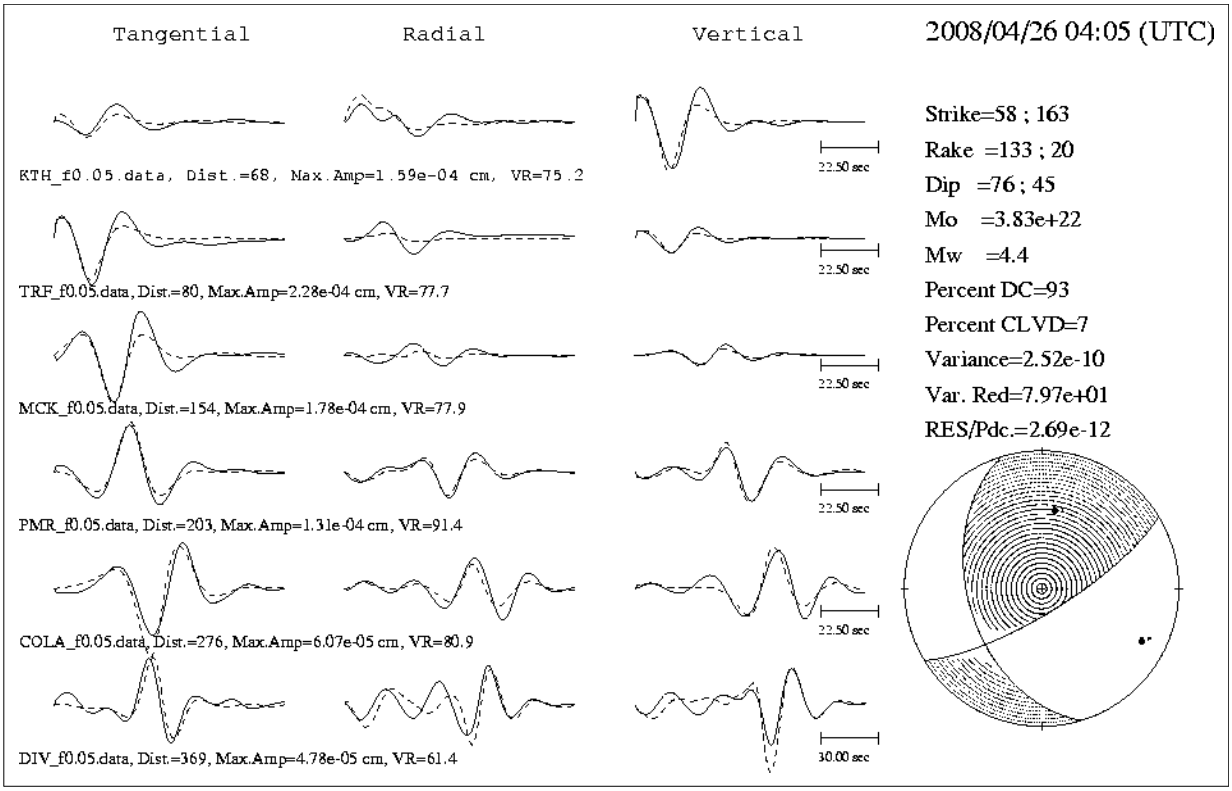


Figure 1b. Example of the moment tensor inversion results for the largest event in July 2007–June 2008 catalog. The top panel shows the waveform fit, the bottom panel is location of the event. This event was located in a poorly instrumented area of central Aleutians, therefore only two stations are available for the inversion. This was a shallow crustal event.



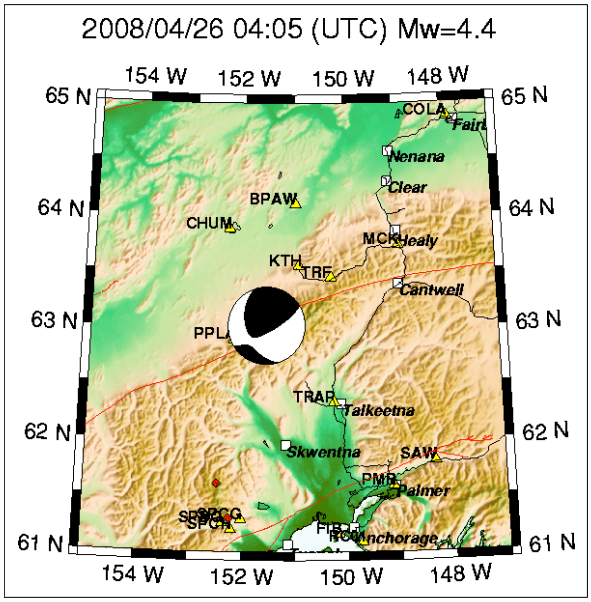
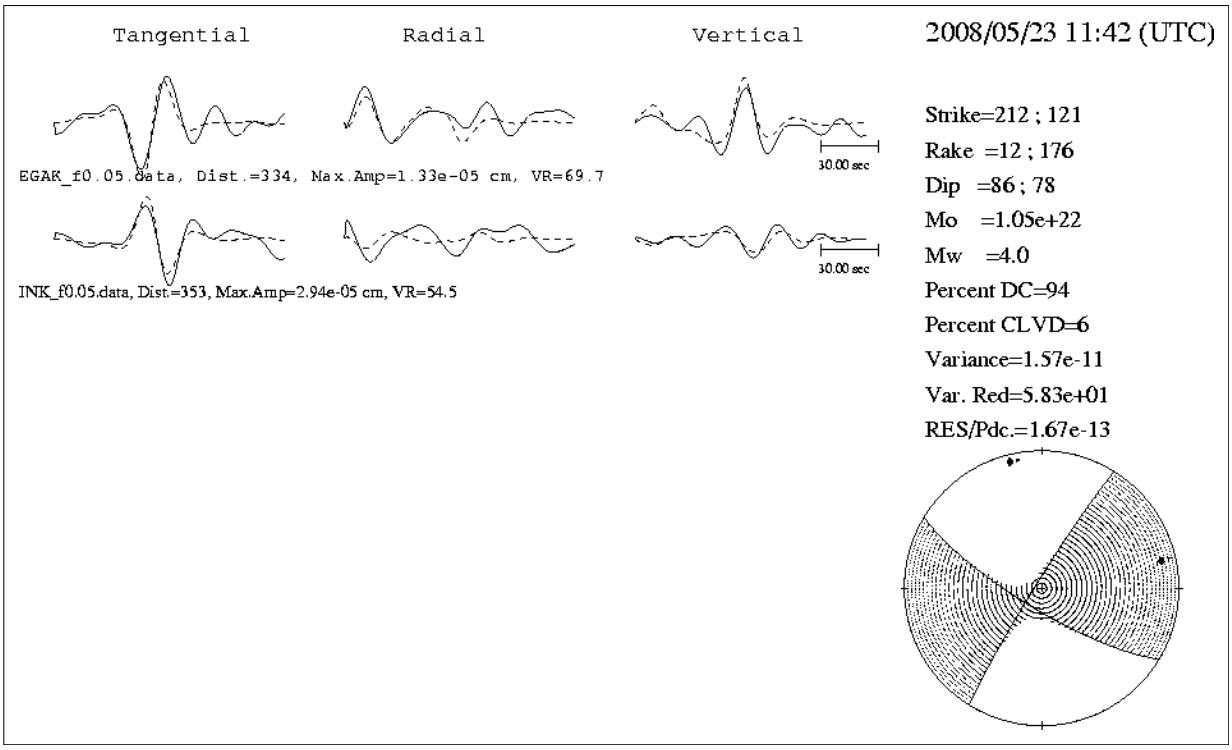


Figure 1c. Example of the moment tensor inversion results for shallow event located on the Denali fault. The top panel shows the waveform fit, the bottom panel is location of the event. This event was located in a well instrumented area, therefore many stations are available for the inversion.



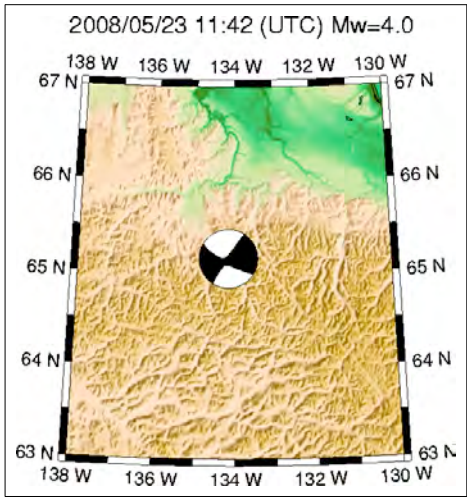


Figure 1d. Example of the moment tensor inversion results for one of the smallest events in July 2007–June 2008 catalog. The top panel shows the waveform fit, the bottom panel is location of the event. This event was located in Canada's poorly instrumented area and too small to be recorded well by more distant stations in the Alaska network core area; therefore only two stations, both located in Canada, are available for the inversion.

- A graphic interface (mt_inversion_tool) has been developed and is now routinely used to review automatic moment tensors and to calculate new inversions for any event within the regional network (see Fig. 2 in 2007 report). This interface allows for subsetting data from the continuous waveform archive for examination prior to inversion. This interface gives the analyst much more control over choosing any number of available stations for the inversion thus allowing only the use of high quality data. It also allows the choice of any available velocity model if the default model does not produce a satisfactory result. Finally, it allows for the examination of the solution through special plots, and then allows the analyst to update the AEIC moment tensor web archive and database.

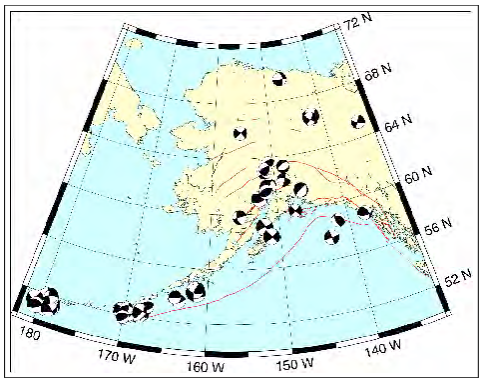


Figure 2. Calculated regional moment tensors for July 2007–June 2008.

NOAA relevance/societal benefits

Rapid calculation of earthquake source parameters through the moment tensor inversion allows scientists to determine the sense of motion along a 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 or normal vs. strike-slip) and size.

Research linkages/partnerships/collaborators and networking

This project is one of several 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. 2008. Five years after the Denali Fault earthquake sequence - data collected, lessons learned: A regional network operator's perspective. Seismological Society of America Meeting, Santa Fe, New Mexico, 16–18 April 2008.

Ruppert, N.A. and R.A. Hansen. 2007. Analysis of 4+ years of aftershock data of the 2002 M7.9 Denali Fault, Alaska, earthquake. International Union of Geodesy and Geophysics (IUGG) Assembly, Perugia, Italy, 2–13 July 2007.

Publications

Peer-reviewed

Ruppert, N.A. 2008. Five years after the 2002 Denali Fault earthquake sequence: A regional network operator's perspective. *Seismological Research Letters*, 79(3):424–425, doi:10.1785/gssrl.79.3.424.

In press

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

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 (NACSE);* ***Harry Yeh,*** *Oregon State University*

An element of CIFAR 57-074c: This project is ongoing.

Primary objectives

The Tsunami Computational Portal (TCP) 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. Once the web portal is functional, the front-end will be migrated to the Arctic Region Supercomputing Center (ARSC) at UAF where the entire portal will be hosted.

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

Portal Migration Work – [The portal is now fully hosted at ARSC]

- Migrated back-end from iceflyer/nanook to midnight/seawolf
- Migrated front-end code, front-end database, and job results to ARSC's web server
- Set up nightly backups of front-end code, front-end database, and job results at ARSC

Portal Modifications by NACSE [Note: Although NACSE was not funded by TWEAK during this fiscal year, their support was invaluable in the migration of the portal to ARSC and the continuing improvement of the system.]

- Automated process of displaying job results on a TCP user's home page once a job is flagged as "have result" in the database.
- Developed scripts to make continued monitoring and maintenance more efficient.
- Developed web-based administration tool for confirming/denying user account requests, and for creating new user accounts.
- Automated backend return messaging so that incoming messages referencing a completed job are now handled automatically (database is updated, user is notified, etc.) and transferred control of message processing to the "ARSC" account at NACSE.
- Fixed bug where nested grids were not being referenced in clipped parent coordinates (they were being referenced in full parent coordinates).
- Fixed bug where dip angle was allowed to be zero, causing errors in the model runs. The portal now enforces the constraint that the value must be greater than zero.
- Fixed bug involving a detail of child-grid alignment that was not readily apparent and was causing great difficulty with integrating some new datasets into the portal (a 5:1 spacing error).
- Modified user request page to add error checking on all fields (i.e., client-side checking for valid email address, maximum character lengths, etc.).
- Generated detailed TCP database schema.
- Held weeklong face-to-face session at NACSE with Craig Stephenson from ARSC, to work on porting the TCP to ARSC's servers.
- Rewrote the random password generator (for establishing user accounts) to ARSC's requested specifications.
- Modified the database schema -- added "requested" and "created" date fields to the users table, to be used for determining when to require password changes.
- Implemented digital signing of emails between ARSC and NACSE, using GnuPG (GNU Privacy Guard), so that it works with a web agent. Tested and moved into production.
- Completed initial implementation of the CLAW model into the TCP front end. Tested against multiple datasets in multiple configurations to ensure that the portal is correctly configuring CLAW jobs.
- Updated metadata information in the database for the CLAW model.

Portal Modifications

- Replaced Smylie fault model with Okada fault model
- Models were ported and optimized for Midnight SUN cluster
- Added SSL (Secure Sockets Layer) encryption to front-end
- Implemented file-based job queue

Debugging

- Fixed off by one errors in UAF tsunami model
- Fixed inconsistent land values in portal database
- Fixed open boundary problems with Comcot model
- Fixed Okada deformation model coordinate calculations

Usage

- Between the last reporting period and the time when the portal was moved to ARSC, 20 new user accounts were created, and approximately 160 new jobs were run.

Error Checking/Robustness

- NAN/INF numerical error checks for all outputs
- NAN/INF filtering in fault generated deformation to fill small gaps resulting from numerical errors

- Filtering of spurious lines generated by numerical side-effects of fault models
- Correction of coordinates for default deformation scenario
- Improved error reporting via more automated emails

CLAW Model
- Fixed-grid format outputs implemented
- Ported this model to Midnight SUN cluster
- Received new version of code with major revisions; modified to portal standards (input formats, configuration file, output formats)
- Included support for the Okada deformation model, and the NAN/INF and smoothing filters

Additional Tsunami Work
- Optimization of the UAF land-slide model for Iceberg (IBM Power4 system)
- Ported landslide model to Midnight (Sun Opteron system)
- Assisted in the addition of Cartesian coordinates to the UAF Tsunami model
- Assisted in coupling of the land-slide model with the UAF Tsunami model

NOAA relevance/societal benefits
The TCP was used by researchers at CIRES (Cooperative Institute for Research in the Environmental Sciences) to examine gridding methodologies for creation of a new 1 arc-second digital elevation model (DEM) of King Cove in the Alaska Peninsula. The resultant dataset was made available in the portal.

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.

Presentations

Logan, T. 2007. MPI-IO and MPI-2 one-sided communication. 2007 IBM Scientific Users Group Conference, Garching, Germany, July 2007.

Pancake, C. 2007. Collaborative efforts to understand and predict the impact of tsunamis. Keynote presentation at Computing in Atmospheric Sciences Workshop 2007, Annecy, France, 9–13 September 2007.

Pancake, C. 2008. Cyberinfrastructure for the tsunami community. Presentation to the Director of Engineering, National Science Foundation, January 2008.

Conference paper

Janik, C., M. Bailey, D. Keon, C. Pancake and H. Yeh. 2007. Web-based tsunami visualization. 9th International Conference on Fluid Control, Measurements and Visualization (FLUCOME), Tallahassee, Florida, 16–19 September 2007.

TWEAK (Tsunami Warning and Environmental Observatory for Alaska) National Academy of Sciences Review of the NOAA Tsunami Program

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, Kate Pyatek, *University of Alaska Fairbanks*

An element of CIFAR 57-047c: 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 Tsunami Warning and Education Act of 2006 states that the National Academy of Sciences (NAS) will "review the tsunami detection, forecast, and warning program established under this Act to assess further modernization and coverage needs, as well as long-term operational reliability issues, taking into account measures implemented under this Act."

Under NOAA direction we used more than 40% of our funding for this past year to fund the above-described study as a subcontract given through the University of Alaska Fairbanks. The review will assess education and outreach efforts to improve tsunami preparedness of the at-risk population and how well these efforts complement and enhance state and local tsunami hazard mitigation programs. The review shall also include an assessment of how well the detection equipment has been integrated into other United States and global ocean and coastal observation systems and the global earth observing system of systems. The goal of the review will be to assess NOAA's efforts to strengthen the Tsunami Program and to identify areas for improvement. The review will also focus on integration with other earth observing systems and will identify promising areas of research that may improve tsunami warning and preparedness both nationally and worldwide.

The first meeting for describing the scope and nature of the review was held 30 June–3 July 2008 in Washington, D.C. Presentations were given by NOAA National Weather Service personnel, the Federal Emergency Management Agency (FEMA), National Science and Technology Council (NSTC), United States Geological Survey (USGS), National Science Foundation (NSF), a reviewer of the NTHMP, and Roger A. Hansen representing this project. The next step is a visit to the Tsunami Warning Center in Alaska for further discussions and evaluation of the program.

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.

Appendices 1–4

1. Projects Awarded 1 July 2007–30 June 2008

2. Personnel

3. Publication Activity

4. Index of PIs

Appendix 1.
CIFAR Projects Awarded in Cooperative Agreement NA17RJ1224
Year 7: 1 July 2007–30 June 2008

Last	First	Proposal Title	Award	Task	Theme Description	Funding Source
Atkinson	**David**	Collaborative Research: Alaska PRIDE FY07	$ 123,970	III	Atmospheric Climate	NWS
Hansen	**Roger**	Tsunami Warning and Environmental Observatory for Alaska - Year 6	$ 933,550	III	Tsunami Research	NWS
Hillgruber	**Nicola**	Characterizing Movement Patterns of Atka Mackerel Using Ultrasonic Telemetry: A Pilot Study	$ 25,000	III	Fisheries Oceanography	NMFS
Okkonen	**Stephen**	Bowhead Whale Feeding in the Western Beaufort Sea: Oceanographic Conditions, Whale Prey Distributions, and Whale Feeding and Foraging Behavior	$ 94,543	III	Marine Ecosystems	NMML / NMFS
Quinn II	**Terrence**	University of Alaska Fairbanks Graduate Student Stipend for Stock Assessment Training and Improvement	$ 41,378	I	Fisheries Oceanography /Admin	NMFS
Romanovsky	**Vladimir**	State of the Arctic (Land) Report	$ 10,000	III	Atmospheric Climate	OAR
Sugai	**Susan**	RUSALCA Preparation for FY'08 Multidisciplinary Ocean Climate Observation	$ 65,000	III	Marine Ecosystems	OAR
Walsh	**John**	CIFAR Task I: Administration & Supplement (Year 7)	$ 110,000	I	Administration	OAR
Weingartner	**Thomas**	Marine Fish Survey in the Beaufort Sea Outer Continental Shelf Planning Area (YR 1)	$ 24,360	III	Marine Ecosystems	NMFS
Yang	**Daqing**	Assessment of Arctic Snowcover Change and its Impact on Large River Runoff	$ 66,699	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	2			2
Visiting Scientist	0			
Postdoctoral Fellow	0			
Research Support Staff	5	2	1	2
Administrative	1	1		
Total (≥ 50% NOAA Support)	**8**	**3**	**1**	**4**
Undergraduate Students	6			
Graduate Students	23	11	12	
Total Students	**29**			
Employees (< 50% NOAA Support)	32	10	7	15
Located in NOAA Lab	0			
Obtained NOAA employment within last year	0		0	

Appendix 3. Publication Activity

Work from projects funded under cooperative agreement NA17RJ1224 that was published, accepted, or in press during the reporting period.

Alix, C. 2008. L'usage du bois en Alaska. Ethno-archeologie et dendrochronologie. *Les nouvelles de l'Archeologie*, 111–112:45–50.

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.

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Summary table of publications from projects funded under NA17RJ1224.

	JI (subgrantee lead)							NOAA lead							Other lead						
	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
P-R	0	10	11	12	17	18	27	0	0	0	0	0	3	2	0	4	5	4	13	11	8
N-P-R	0	1	13	12	12	9	9	1	0	1	1	2	1	0	0	1	0	0	3	2	1

Appendix 4. Index of Principal Investigators
(key words are in parentheses in cases where one PI has multiple project reports)