Third progress report on Cooperative Agreement NA08OAR4320751

1 April 2010 – 31 March 2011

CIFAR
Cooperative Institute For Alaska Research

UAF
UNIVERSITY OF ALASKA FAIRBANKS

Third report from CIFAR to NOAA on Cooperative Agreement *NA08OAR4320751*

(and incorporating shadow award NA08OAR4320870)

1 April 2010–31 March 2011

Cooperative Institute for Alaska Research
P.O. Box 757740
University of Alaska Fairbanks
Fairbanks, AK 99775-7740
www.cifar.uaf.edu

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CIFAR annual reports can be found on the Web at http://www.cifar.uaf.edu/research/reports.php

Overview

Founded in 2008, the Cooperative Institute for Alaska Research (CIFAR) conducts 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. CIFAR continues to facilitate the developed long-term collaboration between NOAA and the University of Alaska (UA) begun under the Cooperative Institute for Arctic Research in 1994, within which targeted research, technology, education and outreach can be developed and sustained. CIFAR plays a central role in communication and coordination between NOAA, researchers, management agencies, non-governmental organizations, Alaska communities, and the general public in collaborative research, education, and outreach efforts.

Research Themes for CIFAR

1. **Ecosystem studies and forecasting**—Gain sufficient knowledge of Alaskan ecosystems to forecast their response to both natural and anthropogenic change.
2. **Coastal hazards**—Improve understanding of coastal hazards, storms, and tsunamis that affect Alaska's population, ecosystems and coast to improve weather forecast and warning accuracy.
3. **Climate change and variability**—Foster climate research targeted at societal needs and advance Arctic climate research to improve predictive capacity of climate variations affecting coastal regions and ecosystems.

CIFAR's research activities assist NOAA in four of its Mission Goals: (1) *Healthy oceans:* Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management; (2) *Climate adaptation & mitigation*: Understand climate variability and change to enhance society's ability to plan and respond; (3) *Weather ready nation:* Serve society's needs for weather and water information; and (4) *Resilient coastal communities & economies:* Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation.

Membership of CIFAR's Advisory Groups

Listed below are the members of the CIFAR Executive Board and CIFAR Fellows who are responsible for advising CIFAR.

The ***CIFAR Executive Board*** members are:
Eddie Bernard, NOAA Pacific Marine Environmental Laboratory (PMEL) Director (*retired in 12/2010; awaiting replacement)*
John Calder, NOAA Arctic Research Office Program Manager
Douglas DeMaster, NOAA National Marine Fisheries Service, Director, Alaska Fisheries Science Center (AFSC)
Philip Hoffman, NOAA Cooperative Institutes (CI) Program Office Director *(effective 3/2011)*
Frank Kelly, NOAA National Weather Service, Alaska Region Director
Mark Myers, University of Alaska Fairbanks, Vice Chancellor for Research *(effective 3/2011)*
James Partain, NOAA Regional Climate Director for Alaska
John Walsh, CIFAR director, ex officio

The ***CIFAR Fellows*** are:

1. Mark Herrmann, Dean, School of Management, UAF, Fairbanks, AK
2. Larry Hinzman, Director, International Arctic Research Center, UAF, Fairbanks, AK
3. Kris Holderied, NOS, NOAA, Homer, AK
4. Anne Hollowed, AFSC, National Marine Fisheries Service, 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, Auke Bay Laboratory, AFSC, NMFS, NOAA, Juneau, AK
10. James Overland, Oceanographer, PMEL, NOAA, Seattle, WA
11. Carven Scott, Chief, Environmental & Scientific Services Division, NWS, NOAA, Anchorage, AK
12. Clarence Pautzke, Executive Director, North Pacific Research Board, Anchorage, AK *(retired 12/2010; awaiting arrival of this successor)*
13. Buck Sharpton, President's Professor of Remote Sensing, Geophysical Institute, UAF, Fairbanks, AK *(stepped down 1/2011)*

14. Terry Whitledge, Director, Institute of Marine Science, School of Fisheries and Ocean Sciences, UAF, Fairbanks, AK

Summary of Projects Funded during Reporting Period

During the third reporting period of the new competitively awarded cooperative agreement, NOAA provided funding for CIFAR administration and 6 research projects totaling $1.51 M as part of the CIFAR institutional cooperative agreement (NA08OAR4320751). All 6 research projects were Task III (projects that generally require only minimal direct collaboration with NOAA scientists). In addition, 5 competitively awarded RUSALCA projects totaling $325,422 (funded under the "shadow" cooperative agreement NA08OAR4320870) and one Climate Program Office (CPO) project (NA10OAR431055) received $87,585 through CIFAR. The CIFAR research portfolio of 12 competitive and non-competitive new awards addresses all three CIFAR research themes and totals $1.9 M. A full list of CIFAR competitive and non-competitive projects awarded during the reporting period is presented in Appendix 1. Annual reports for the RUSALCA and CPO projects appear in Appendix 4 and 5, but were also submitted separately on Grants Online, as requested.

Summaries of CIFAR projects funded during this reporting period by task/theme and funding source are presented in Tables 1 and 2, respectively.

Table 1: Summary of CIFAR Projects Funded 1 April 2010–31 March 2011: By Task and Theme

Theme	Number of Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)	**1**		**$110,000**	**5.7%**
Core Support	1	$110,000		5.7
Research Themes (Task II)	**0**		**$0**	**0.0%**
Research Themes (Task III)	**12**		**$1,822,529**	**94.3%**
Climate Change & Variability	1	$87,585		4.5
Coastal Hazards	3	$914,838		47.3
Ecosystem Studies & Forecasting	8	$820,106		42.4
Total	**13**		**$1,932,529**	**100.0%**

Table 2: Summary of CIFAR Projects Funded 1 April 2010–31 March 2011: By Funding Source

Includes administration

Funding Source	Number of Projects	Total Amount	Percent of Total
OAR	7	$523,007	27.1%
NOS	0	0	
NWS	3	$914,838	47.3%
NMFS	3	$494,684	25.6%
Total	**13**	**$1,932,529**	**100.0%**

Highlights of CIFAR Task I Activities

CIFAR is staffed by four people: John Walsh, director; Susan Sugai, associate director; Sarah Garcia, CIFAR administrator; and Barb Hameister, publications and meetings manager. Through the first three years of our new cooperative agreement, CIFAR has been awarded only $110 K in Task I funding so we have highly leveraged our staff salaries with University and other restricted funds to enable us to still provide important education and outreach support that is discussed below. Figure 1 shows the distribution of these funds for the current reporting period. Task I funds provided funding for 3.4 months of salary for Sarah Garcia, CIFAR administrator. Travel had to be greatly reduced so our annual meeting of CIFAR fellows and executive board was held by teleconference. All administrative travel was associated with annual meetings for CI directors and administrators. Due to circumstances beyond CIFAR's control, the proposal for Romanovsky's State of the Arctic Land Report (2009/2010) was not submitted in time to be funded, so we reallocated $10,000 of our Task I funds to cover this outreach effort. The report appears with other Climate Change and Variability reports.

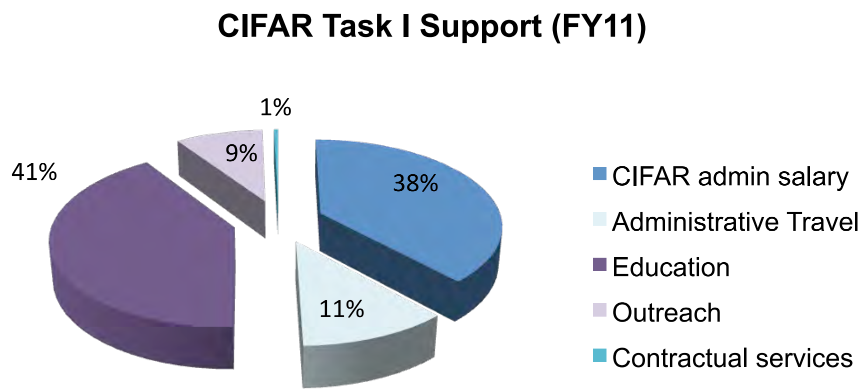

Figure 1. Percentage of funding for various Task I activities during current reporting period

Core Administration

CIFAR Task I funds support 3.4 months of one full-time equivalent (FTE) staff position. UAF 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 responsibilities during the reporting period were as follows:

- John Walsh, CIFAR director, 10% FTE (UA match funds)
- Susan Sugai, CIFAR associate director, 26% FTE (UA match funds)
- Sarah Garcia, CIFAR administrator , 87% FTE (Task I + UA match funds)
- Barb Hameister, publications and meetings manager, 10% FTE (UA match funds)

John Walsh, CIFAR director, represented CIFAR and NOAA in a number of regional, national and international activities during the 12-month period ending 31 March 2011. These activities include the following:

- Coordinated review of 2010 Arctic Report Card by AMAP Climate Expert Group. Provided distillation of review comments to Bulletin of the American Meteorological Society.
- Served as NOAA-supported lead author of Arctic Climate chapter in SWIPA (Snow, Water, Ice and Permafrost in the Arctic) assessment report; attended two SWIPA workshops (July, September 2010); spent full day with SWIPA film crew (February 2011).
- Handled local arrangements for NOAA/NWS Climate Services Workshop, March 2011.
- Wrote white paper (in collaboration with James Partain) on potential storm product for NOAA Climate Services activity.
- Presented overviews of CIFAR activities and attended NOAA/NWS (Alaska Region Headquarters) workshops in August 2010 and March 2011 (two days per workshop)
- Reviewed proposal for NOAA Climate Program.

A joint teleconference meeting of the CIFAR Executive Board (EB) and Fellows was held 20 October 2010 with Bob Shefchik, Interim Vice Chancellor for Research, representing UAF on the EB. Topics of discussion included the draft Memorandum of Agreement (MOA) between UA and NOAA, students funded through the UA contribution to CIFAR's involvement in the Global Change Student Grant Competition, problems associated with NOAA's underfunding of CIFAR's Task 1, update on the Russian-American Long Term Census of the Arctic (RUSALCA) program, changes in funding for the Alaska Tsunami Warning and Environmental Observatory for Alaska (TWEAK), and new collaborations and opportunities.

Looking ahead to NOAA's July 2011 peer-review of CIFAR, it was noted that recent changes in members of CIFAR's EB and Fellows may necessitate more introductory discussion of CIFAR in the early hours of the review.

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Education and 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. Also, the NOAA human resource needs include research scientists with an interdisciplinary training in the physical, environmental, and social sciences. Thus, CIFAR has placed specific emphasis upon competitively supporting graduate and undergraduate students (in addition to those supported on CIFAR research projects) whose research addresses issues critical to both NOAA and the Alaska region. Because CIFAR is positioned within the University of Alaska system, we bring together faculty and students from various departments and campuses to collaborate with NOAA scientists on research and educational efforts.

Global Change Student Research Program (Graduate and Undergraduate Support)

Because of the level of Task I funding provided by NOAA, CIFAR education efforts have focused on opportunities arising from UA and other investments in the Global Change Student Research Grant Competition, established by the UAF Center for Global Change in 1992. The competition provides support to students for research related to global change with a focus on arctic or boreal regions presented in an interdisciplinary context. 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.

During the third year of our new cooperative agreement, the Vice Chancellor for Research made a university contribution of $50,000 toward the Global Change student grant competition that is a voluntary University contribution to CIFAR's cost share. In addition, University of Alaska Anchorage (UAA) made a $50,000 per year contribution. A joint UAF-UAA proposal review panel met on 23 April 2010 and recommended full or partial funding of 18 projects (from a field of 71) for awards running from 1 July 2010 to 30 June 2011. Nine of these awards were funded with CIFAR match or Task 1 education funds. The following students, the degree that they are seeking, and their FY11 CIFAR projects are listed below:

- **Timothy Bartholomaus**, Ph.D. Department of Geology and Geophysics, UAF: Physical oceanography and tidewater glacier dynamics at Yahtse Glacier, Alaska
- **Daniella Della-Giustina**, M.S. Department of Physics, UAF: Regional modeling of Greenland outlet glaciers with the Parallel Ice Sheet Model
- **Michael Garvin**, Ph.D. School of Fisheries and Ocean Sciences, UAF: Whole mitochondrial genome analysis to uncover detailed genetic structure of chum salmon populations and possible historical refugia
- **Samuel Herreid**, B.S. Department of Geology and Geophysics, UAF: Effects of debris cover on glaciers in Alaska
- **Joshua Holbrook**, M.S. Department of Mechanical Engineering, UAF: Determining anisotropic thermal conductivity of snow with needle probe measurements
- **Eunkyoung Hong**, Ph.D. Institute of Northern Engineering, UAF: Estimating damages costs for Alaska infrastructure at risk from climate change
- **Santosh Panda**, Ph.D. Department of Geology and Geophysics, UAF: Modeling permafrost dynamics along the Alaska Highway corridor, Interior Alaska
- **Jill-Marie Seymour**, M.S. School of Fisheries and Ocean Sciences, UAF: Pacific Walrus (*Odobenus rosmarus divergens*) feeding ecology and possible links to Trichinellosis
- **Kyle Wendler**, B.S. Department of Mechanical Engineering, UAF: Preservation of traditional ice cellars in permafrost

In addition, four students selected by the 2009 review panel received their second year award.

In response to the 2011 announcement of funding opportunity, 58 proposals were received, reviewed, and scheduled to be considered by our review panel on 8 April 2011.

Student Support through Individual Awards

As shown in Appendix 2, 19 students (12 undergraduate, 7 graduate) were funded through individual CIFAR projects. Three students seeking Ph.D. degrees associated with RUSALCA projects received more than 50% of their support from NOAA. In addition, many other students benefited from involvement in the research projects, e.g.,

Highlights of CIFAR Research Activities

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

Ecosystem Studies and Forecasting

Rising carbon dioxide (CO_2) levels in the atmosphere have increased CO_2 uptake by the ocean. As a consequence, the marine environment is becoming more acidic (lower pH), a condition termed "ocean acidification" (OA), which has wide ranging implications for organisms like pteropods, foraminifera, and crustaceans that form calcium carbonate ($CaCO_3$) shells. These carbonate-forming organisms are vulnerable to shell thinning or dissolution especially during their larval stage in the cold, productive waters surrounding Alaska because $CaCO_3$ is more soluble in cold waters than in warm waters, meaning that OA could profoundly impact pteropods and foraminifera, which are important food sources for higher marine organisms like salmon, and adversely affect the abundance of commercially important shellfish like crabs and oysters. Fisheries resource managers and Alaska coastal communities need to better understand the effects of OA in order to anticipate and respond to future changes.

Because OA in high latitudes could have major consequences in the highly productive waters of the Gulf of Alaska and Bering Sea, there is an urgent need for OA research and monitoring here. Two new CIFAR projects address those needs. Russell Hopcroft (CIFAR 11-022) will continue multidisciplinary observations of oceanography and lower trophic level productivity in the northern Gulf of Alaska that are critical to long-term monitoring of OA. The two cruises during the past reporting year involved one undergraduate and 12 graduate students. In May 2011, Jeremy Mathis (CIFAR 11-021) and co-workers will deploy, in the southeastern Bering Sea, the first moored surface and deep water measurements of OA in Alaska's marine ecosystems.

In the western Beaufort Sea, an area important to future energy exploration and development, Stephen Okkonen (CIFAR 10-014) and co-workers from Woods Hole Oceanographic Institution and the University of Rhode Island have been investigating how interannual changes in the regional winds influence oceanographic conditions, whale prey abundance, and associated "hotspots" of heavy bowhead whale feeding to refine their conceptual model that can be used as a potential management decision support tool.

Three RUSALCA projects (NA08OAR4320870) continued 2010 field observations, and all five continued sample and data analyses that are increasing NOAA's understanding of the causes and consequences of the reduction in sea ice cover in the northern Bering and Chukchi Seas. Three Ph.D. students, Elizaveta Ershova (CIFAR 11-009), Michael Kong (CIFAR 11-012), and Jonathan Whitefield (CIFAR 11-013) have dissertation research projects funded primarily by this NOAA climate program effort.

Climate Change & Variability

Climate change and variability research at CIFAR is focused upon downscaling climate model outputs to meet local planning needs for site-specific planning needs, and enhancing Alaska research and satellite data services to better meet NOAA user needs.

John Walsh (NA10OAR4310055) is addressing the need for site-specific information about ongoing and projected climate change in Alaska and northern Canada through three activities: 1) identification of optimal subsets of climate models for Alaskan and Canadian downscaling applications; 2) downscaling Alaska and northwestern Canada by the Delta method (whereby global climate mode-derived changes are superimposed on high-resolution climatologies) in order to provide working scenarios; 3) extension of the downscaling to marine ecosystem models and to permafrost simulations.

Tom Heinrichs and Jessica Cherry (CIFAR 10-015) in cooperation with NOAA and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, have been developing next generation scientific products from satellite data. New volcanic ash and SO_2 products as well as cloud and fog products have been introduced into Alaska NWS operations. Production of satellite-derived snow and hydrology products are underway and will be transitioned to operations in the upcoming period. The developments will lead to improved weather, river, and aviation forecasting and warnings.

Coastal Hazards

CIFAR coastal hazards research is focused on observations and modeling efforts to reduce dangers associated with offshore winds and wave states arising from them and from tsunamis.

Atkinson (CIFAR 10-018) plans to deploy a wave and meteorological buoy in the northern Bering Sea that will furnish data about wind and wave state on a near-real time basis that will be fed directly to the forecasters at NWS forecast office in Fairbanks and to the internet for pickup by the following groups: members of the public, the US Coast Guard, and Olgoonik/Fairweather (ocean logistics provider for Shell in the Chukchi lease fields) to improve safety in their day-to-day operations.

Roger Hansen (CIFAR 11-008) heads up the TWEAK (Tsunami Warning and Environmental Observatory for Alaska) effort in collaboration with the Alaska Tsunami Warning Center and the National Tsunami Hazard Mitigation Program through the development of numerical-hydrodynamical models to assist with tsunami warnings and prediction services. Development of community inundation maps, which are utilized for defining evacuation routes for at-risk communities, are currently focusing on three critical areas: the Aleutian Islands, Yakataga region, and southeast Alaska. Efforts are also currently underway (Logan, CIFAR 11-020) to enable the West Coast/Alaska Tsunami Warning Center to run the Alaska Tsunami Forecast Model at the Arctic Region Supercomputing Center. This will enable staff at the West Coast/Alaska Tsunami Warning Center in Palmer to generate tsunami predictions from one to two orders of magnitude more quickly. This will allow for more frequent updates of their pre-computed database, making forecasts more accurate and potentially saving lives in the event of catastrophic tsunamis.

Publications and Presentations

Twenty conference presentations (both national and international) were reported for the period 1 April 2010–31 March 2011. Five peer-reviewed papers were published, with 6 additional papers in press and 1 paper accepted for publication. Many PIs have papers under preparation. In addition, several of the RUSALCA projects and one additional project had papers published (5) or accepted for publication (1) during the reporting period that stemmed from funding to those projects under the previous cooperative agreement NA17RJ1224 (Cooperative Institute for Arctic Research).

Non-competitive projects, by CIFAR theme:

Ecosystem Studies and Forecasting

Climate Change and Variability

Coastal Hazards

ECOSYSTEM STUDIES AND FORECASTING

Oceanography and lower trophic level productivity: the Seward Line 2010

Russell R. Hopcroft, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

NOAA Goals 1 & 2: Healthy Oceans** and **Climate Adaptation & Mitigation

CIFAR 11-022: This project is new.

Line Office NMFS-AFSC, Mike Sigler, Sponsor

Primary objectives

Over the past 50 years the Northern Pacific appears to have undergone at least one clear "regime shift," while the last 12 years have seen multi-year shifts of major atmospheric indices, leaving uncertainty about what regime the coastal Gulf of Alaska is currently in. Concurrently, the warming trend of the last several decades has been followed by three anomalously cold springs. Regime shifts are often expressed as fundamental shifts in ecosystem structure and function, such as the 1976 regime shift that resulted in a change from shrimp-dominated fisheries to one dominated by pollock, salmon and halibut. Given the potential for such profound impacts, this project seeks to continue multidisciplinary observations which began in 1997 along the Seward Line that assess the current state of the Northern Gulf of Alaska, during 2010. Such observations form critical indices of ecosystems status that help us understand some key aspects of the stability or change in upper ecosystems components for both the short and longer-term.

Research accomplishments/highlights/findings

- Cruises were executed 2–9 May, and 12–19 September: All cruise objectives were accomplished on each cruise.
- In May 2010, we saw a return to near "average" surface temperatures, accompanied by a more typical timing of the spring bloom.
- Abundance of the dominant spring zooplankter – the copepod *Neocalanus plumchrus/flemingeri* was significantly above average, although growth was slightly delayed.
- The positive relationship between *Neocalanus* abundance and survival of pink salmon releases that spring continues to hold.
- Summer surface temperatures were slightly above average, but the total heat in the surface 100 m was closer to the climatological mean.
- "Southern" zooplankton species were noticeable with the Alaska Coastal current and Prince William Sound during September 2010.
- The southern-affinity copepod *Calanus pacificus* has become consistently common during recent summers, especially in offshore waters.

NOAA relevance/societal benefits

- Cruises continue to document the physical, chemical and biological status of the coastal Gulf of Alaska, including measurements important for long-term monitoring of ocean acidification.
- Results continue to provide insights into pink salmon returns that can be expect the following year.

Education

- In May, four UAF Institute of Marine Science (IMS) graduate students (Kristen Shake, Jennifer Questel, Imme Rutzen, Michael Kong) collected data that will be used for portions of their thesis/dissertation work. A senior UAF undergraduate student and potential SFOS Masters student (Amy Rath) also gained valuable experience.
- In September, eight IMS graduate students (Kristen Shake, Jennifer Questel, Imme Rutzen, Ayla Doubleday, Amy Rath, Chase Stoudt, Michael Kong, Elena Fernandez) collected data that will generally be used for their thesis/dissertation work.

Outreach

Journalist/writer Nancy Lord joined the September cruise, and has written about our at sea experiences. A work of literary journalism/essay called "My Acid Cruise," about the importance of the research and the issue of ocean acidification is currently under consideration at a literary journal. She is also working on a novel (fiction) that involves oceans, ocean scientists, and ocean acidification and is set in part on a similar cruise.

Publications, conference papers, and presentations

Oral presentations

Hopcroft, R.R. 2010 A decadal view of patterns in zooplankton in the sub-arctic North Pacific. Invited Seminar, October 2010, Technical University of Denmark, Copenhagen.

Poster presentations

Hopcroft, R.R. 2011. Measuring the pulse of the Gulf of Alaska: oceanographic observations along the Seward Line, 1997–2010. Alaska Marine Science Symposium, January 2011, Anchorage, Alaska.

Other products and outcomes

Project website continues to be updated and expanded: http://www.sfos.uaf.edu/sewardline/

Partner organizations and collaborators

North Pacific Research Board
Alaska Ocean Observing System

Characterization of Bering Sea infauna

Stephen Jewett, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Max Hoberg, *University of Alaska Fairbanks*

NOAA Goal: Healthy Oceans *(Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management)*

CIFAR 09-003/10-003: This project is complete.

Line Office NMFS-AFSC, Cynthia Yeung, Sponsor

Primary objectives

We propose to characterize the benthic infaunal community for modeling essential fish habitat in the Eastern Bering Sea in support of the Magnuson-Stevens Sustainable Fisheries Act. Sampling in August 2008 will use a van Veen grab and samples will be collected, sieved in the field on 1.0 mm mesh, fixed in buffered formalin, stained, and transferred to 50% isopropyl alcohol prior to sending them to UAF. We will process each sample, including identification to at least family level of taxonomy, counting, and wet weighting (blotted dry). *Due to unforeseen circumstances 2008 sampling was postponed until 2009.*

Research accomplishments/highlights/findings

NOAA collected the benthic samples 26 July–8 August 2009 and 32 samples were processed by invertebrate taxonomist Max Hoberg and student assistant Kyle Schumann in Jewett's lab at SFOS, UAF. Analyses were completed 17 November 2009. After 100% QA/QC on the data, a draft report was sent on 20 April 2010 to NOAA project coordinator Cynthia Yeung at the Alaska Fisheries Science Center. This report included the History file, Metadata file, Data file, and Benthic taxon list file. In May 2010, Yeung had some questions about the data file, CIFAR09.Data.xls, and these questions were immediately answered, thus our final report to Yeung was complete.

NOAA relevance/societal benefits

This research is an effort to determine essential fish habitat as mandated by the Magnuson-Stevens Sustainable Fisheries Act. Characterization of the benthic infaunal community is necessary for successful modeling of essential fish habitat in the eastern Bering Sea.

Education

Student Assistant Kyle Schumann received a B.S. in Fisheries at UAF May 2010.

Outreach
Nothing to report.

Publications, conference papers, and presentations
See below under "Changes/problems/special reporting requirements."

Other products and outcomes
Nothing to report.

Changes/problems/special reporting requirements
In May 2010, Sathy Naidu (Marine Geologist - sediment component) and Stephen Jewett visited Cynthia Yeung in Seattle to discuss publishing the results in a peer-reviewed journal. Yeung was unable to secure additional funding for Naidu and Jewett to write a draft manuscript. So, Yeung agreed to take the lead and include Naidu and Jewett as coauthors on the paper, although no additional funding would be available to them from NOAA. No timeline was set for a submission to a journal.

Partner organizations and collaborators
Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115-0070 (PI: Cynthia Yeung, Ph.D.).

Infaunal/epifaunal forage base for juvenile flatfish near Kodiak Island

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Stephen Jewett, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Max Hoberg, *University of Alaska Fairbanks*

NOAA Goal: Healthy Oceans *(Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management)*

CIFAR 09-004: This project is complete. Line Office NMFS-AFSC, Clifford Ryer, Sponsor

Primary objectives
We propose to characterize the benthic habitat available to juvenile flatfish in nursery embayments around Kodiak Island in support of the Magnuson-Stevens Sustainable Fisheries Act. Sampling in summer 2008 will use a 0.1 m^2 van Veen grab and samples will be collected at stratified depths at the Holiday and Pillar Cove sites, sieved in the field on 1.0 mm mesh, fixed in buffered formalin, stained, and transferred to 50% isopropyl alcohol prior to sending them to UAF. We will process each sample, including sorting, taxonomy, counting, and wet weighting (blotted dry). All molluskan and crustacean fauna will be taken to family taxonomic levels; annelid fauna will be taken to the finest practical taxonomic level.

Research accomplishments/highlights/findings
Not reported from previous reporting period:
The draft report sent to Clifford Ryer on 7 July 2009 became the final report since no changes were recommended by Ryer. In mid-July 2009, after the final report was submitted, Ryer requested that two reference collections (for Hatfield Marine Center and Kodiak NOAA lab) be compiled from the samples that had been processed. Jewett sent two sets of vials containing the 30 most common taxa in late July 2009.

NOAA relevance/societal benefits
This research is an effort to determine essential fish habitat as mandated by the Magnuson-Stevens Sustainable Fisheries Act and NOAA. Information on quality and quantity of potential benthic invertebrate prey of juvenile flatfishes is critical to understanding essential juvenile flatfish habitat. Thus, this taxonomic study should highlight not only prey availability, but habitat constituents, such as worm tube mats and sediment structure. In the long term, this information may form the basis for determining exclusive no-trawl zones to protect essential fish habitat. Protecting such habitat would be beneficial to the public that utilizes flatfishes in sport, commercial, and subsistence fisheries.

Education

Nothing to report.

Outreach

Nothing to report.

Publications, conference papers, and presentations

A joint (Ryer and Jewett) publication on this data is planned after Ryer analyzes the data. As of April 2011, Ryer was still trying to find time to work on a draft manuscript for submission to a peer-reviewed journal.

Other products and outcomes

Nothing to report.

Changes/problems/special reporting requirements

None.

Partner organizations and collaborators

Fisheries Behavioral Ecology Program, Alaska Fisheries Science Center, Hatfield Marine Science Center, Newport, OR (PI: Clifford H. Ryer, Ph.D.)

Moored observations of ocean acidification in high latitude seas

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Jeremy Mathis, PI — ***CIFAR theme: Ecosystem Studies & Forecasting***

University of Alaska Fairbanks

NOAA Goals 1 & 2: Healthy Oceans *and* ***Climate Adaptation & Mitigation***

CIFAR 11-021: This project is new. — Line Office NMFS-AFSC, Mike Sigler, Sponsor

Primary objectives

Rising carbon dioxide (CO_2) levels in the atmosphere are driving increased uptake of CO_2 by the ocean, thereby causing the marine environment to become more acidic. This phenomenon has been termed "ocean acidification" (OA) and it could have far reaching consequences for pelagic and benthic calcifying organisms, particularly in the cold, productive waters surrounding Alaska. Recent field observations have shown that the shelves of the northern Gulf of Alaska and the Bering Sea are currently experiencing seasonal manifestations of OA, including decreased pH as well as suppressed carbonate mineral saturation states (Ω). Here, we propose to install OA sensors on fixed, autonomous moorings in either the Gulf of Alaska (near Kodiak Island) or Bering Sea (historical M2 mooring). Sensors at the surface would measure the partial pressure of CO_2 (pCO_2) in the air and water along with pH, while a second set of sensors would measure pCO_2 and pH near the bottom. Without a high-resolution understanding of the seasonal cycles and controls on OA, it will be difficult to forecast the impacts this process could have on the local ecosystem and fisheries.

Research accomplishments/highlights/findings

- During the past six months, we have been preparing to deploy a high latitude ocean acidification mooring in the Bering Sea at the M2 location as proposed. We have purchased all of the necessary equipment and hardware for the deployment and have coordinated with the mooring group at the Pacific Marine Environmental Laboratory (PMEL). The mooring is set to be deployed in May 2011 from the research vessel *Oscar Dyson* during a 21-day cruise to the Bering Sea. Mathis' lab manager, Natalie Monacci, will participate in the cruise to ensure that the mooring is deployed properly. If all goes as planned, the mooring should start transmitting surface data including pCO_2 (air and water), pH, temperature, salinity, chlorophyll, and dissolved oxygen immediately after deployment. The mooring will also contain a bottom package with identical sensors as the surface, but without the ability to transmit in real-time. These data will be recovered once per year (May 2012) during mooring turnarounds. The project is on schedule and progressing well.
- The subaward portion of the project to the Byrne group at University of Southern Florida (USF) is also proceeding as planned. This will involve Professor Robert Byrne and his group participating in an Arctic cruise in October of 2011 to collect pH data in the Chukchi and Beaufort Seas.

NOAA relevance/societal benefits

This mooring deployment and subsequent cruise fit well within NOAA's mission to monitor and better understand the controls on OA in coastal seas. The Bering Sea mooring will be the northernmost OA mooring.

Education

Nothing to report.

Outreach

None at this time, but once real-time data is being returned we will work to provide this data to the community and classrooms for educational and instructional purposes.

Publications, conference papers, and presentations

None at this time.

Other products and outcomes

None at this time.

Changes/problems/special reporting requirements

None.

Partner organizations and collaborators

Prof. Robert Byrne (USF) – subaward.

Analyses of sediment samples for organic carbon, nitrogen, and their isotopes ($\partial^{13}C$ and $\partial^{15}N$), phosphorus and chlorophyll a in Bering Sea sediments

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Sathy A. Naidu, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Dean Stockwell, *University of Alaska Fairbanks*

NOAA Goal: Healthy Oceans *(Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management)*

CIFAR 09-002/10-002: This project is complete.

Line Office NMFS-AFSC, Cynthia Yeung, Sponsor

Primary objectives

In collaboration with the NOAA Alaska Fisheries Center (AFSC), Seattle project on "Characterization of the Benthic Infauna Community for Modeling Essential Fish Habitat in the Eastern Bering Sea" in support of the Magnuson-Stevens Sustainable Fisheries Act. The specific objective of the project is to establish a sedimentary granulometric and geochemical database to characterize the benthic habitat.

Research accomplishments/highlights/findings

Thirty-two marine sediment samples were collected by the AFSC in August 2009 from the southeast Bering Sea. These samples were delivered in September 2009 to PI Naidu for laboratory processing and analysis to establish the substrate and geochemical properties of the benthic habitat. During this reporting period the geochemical analyses were completed and the data have been tabulated in an Excel format. The database and final report were submitted to Dr. Cynthia Yeung of NOAA/NMFS for statistical analysis in February 2011.

NOAA relevance/societal benefits

This research is an effort to determine essential fish habitat as mandated by the Magnuson-Stevens Sustainable Fisheries Act. Characterization of the geochemical properties of the benthic habitat is necessary for successful modeling of essential fish habitat in the eastern Bering Sea.

Education
Out of scope of the contract.

Outreach
Out of scope of the contract.

Publications, conference papers, and presentations
In May 2010, Stephen Jewett (Marine Biologist- infauna/epifaunal component) and Sathy Naidu visited Cynthia Yeung in Seattle to discuss publishing the results in a peer-reviewed journal. Yeung was unable to secure additional funding for Naidu and Jewett to write a draft manuscript. So, Yeung agreed to take the lead and include Naidu and Jewett as coauthors on the paper, although no additional funding would be available to them from NOAA. No timeline was set for a submission to a journal.

Other products and outcomes
Nothing to report.

Changes/problems/special reporting requirements
None.

Bowhead whale feeding in the western Beaufort Sea: Oceanographic conditions, whale prey distributions, and whale feeding and foraging behavior

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Stephen Okkonen, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

NOAA Goal: Healthy Oceans *(Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management)*

CIFAR 10-014: This project is ongoing.

Line Office NMFS-AFSC, David Rugh, Sponsor

General objectives
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.

Research accomplishments/highlights/findings
Preliminary investigations of interannual changes in the meteorology and oceanography of the Chukchi-Beaufort domain suggest that when a high pressure system resides over the Beaufort Sea in late summer, associated regional winds are from the southern quadrant, ocean temperatures in Norton Sound and along the Alaskan Chukchi coast are relatively warm, and sea ice is generally absent from the eastern Chukchi Sea. How these conditions influence the biology of the marine environment near Barrow is presently being studied.

NOAA relevance/societal benefits
We have proposed a predictive conceptual model relating changes in potential zooplankton abundance (and the likelihood of observing whale groups, as opposed to observing individual whales) on the western Beaufort shelf to changes in the local wind field. The predictive nature of the conceptual model makes it a potential management decision support tool.

Education
Nothing to report.

Outreach

Rozell, Ned, 2010. Autumn waters north of Barrow heavy with whales. Alaska Science Forum. Fairbanks Daily News-Miner. 9/26/2010. Column appears online at: http://www2.gi.alaska.edu/ScienceForum/ASF20/2030.html

Publications, conference papers, and presentations

Accepted (*peer-reviewed*)

Okkonen, S.R., C.A. Ashjian, R.G. Campbell, J.T Clarke, S.E. Moore and K.D. Taylor. Satellite observations of circulation features associated with a bowhead whale feeding 'hotspot' near Barrow, Alaska. Accepted for publication in *Remote Sensing of Environment.*

Poster presentations

Okkonen, S.R., C.A. Ashjian and R.G. Campbell. 2010. Sea ice as a tracer for circulation features associated with the Barrow area bowhead whale feeding hotspot. American Geophysical Union Fall Meeting, 13–17 December 2010, San Francisco, California.

Okkonen, S.R., C.A. Ashjian and R.G. Campbell. 2011. Does the Alaska Current carry krill to the Arctic? Alaska Marine Science Symposium, 17–20 January 2011, Anchorage, Alaska.

Other products and outcomes

Nothing to report.

Partner organizations and collaborators

Woods Hole Oceanographic Institution – collaborative research
Univ. of Rhode Island – collaborative research
NOAA National Marine Mammal Laboratory – collaborative research
North Slope Borough (Alaska) Dept. of Wildlife Management – collaborative research

Impact

Data from CIFAR-funded current meter moorings have helped refine the conceptual model that relates changes in local winds to changes in potential zooplankton abundance and likelihood of whale group observations. These results are discussed in the Okkonen et al. manuscript accepted by *Remote Sensing of Environment* (above).

Changes/problems/special reporting requirements

None.

Publications related to this project as funded under NA17RJ1224 (previous cooperative agreement)

Okkonen, S.R., C.J. Ashjian, R.G. Campbell, W. Maslowski, J.L. Clement-Kinney and R. Potter. 2010. Intrusion of warm Bering/Chukchi waters onto the western Beaufort Shelf. *Journal of Geophysical Research*, 115, C00A11, doi.10.1029/2008JC004870

Arctic small Unmanned Aircraft System experimentation in support of NOAA Arctic objectives

Gregory Walker, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Donald Hampton, Kathe Rich, *University of Alaska Fairbanks*

NOAA Goal: Healthy Oceans *(Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management)*

CIFAR 09-005:
This project is complete and last year's report should be considered final. Expected additional NOAA funds were not forthcoming.

Line Office: NMFS-NMML, Robyn Angliss, Sponsor

Primary objectives

We propose to use the University of Alaska Fairbanks (UAF) owned Unmanned Aircraft System (UAS), the Insitu ScanEagle A-20 to further test the UAS for use in support of NOAA missions in the Bering, Beaufort, and Chukchi seas to monitor marine mammals in ice-covered waters.

The primary concerns for using UASs in the arctic are: 1) the ability of the sensors to record the presence of seals on the ice, 2) the combined ability of sensors and aircraft to provide sufficient areal coverage within time constraints imposed by seal life history events and seasonal melting of ice, 3) the ability of the aircraft to operate in the extreme weather conditions of the north, and 4) the ability to carry out frequent, long-range missions over pack ice in hard-to-access portions of the Arctic and North Pacific Oceans

We intend to evaluate the aircraft (a UAS designed for launching and recovering from a ship) for surveying off of the NOAA vessel *McArthur II* in the Bering Sea pack ice. Digital and infrared cameras mounted on the UAS will record geo-referenced images of the sea ice and seals below. These images will be analyzed for seals and relevant measures of sea ice. Concurrently, the flight characteristics (e.g., stability, speed, duration, payload, effects of icing, communications, telemetry, tasking) of the UAS will be evaluated for use in the Arctic and sub-arctic environments.

Marine fish survey in the Beaufort Sea outer continental shelf planning area

Thomas Weingartner, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals funded by this project:
Bodil Bluhm, *co-PI*, ***Ken Coyle,*** *co-PI*, ***Seth Danielson, Heloise Chenelot,*** *University of Alaska Fairbanks*

NOAA Goal: Healthy Oceans *(Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management)*

CIFAR 09-007: This project is complete.

Line Office NMFS-AFSC, Elizabeth Logerwell, Sponsor

Primary objectives

- Field measurements of four target fish species representative of Beaufort Sea species, habitats and offshore development issues.
- Deploy active in-situ trawl gear of a variety of types as a primary sampling method.
- Collect concurrent physical, biological, and other environmental data.
- Conduct multivariate analyses to determine the relationships between fish species and between fish and environmental characteristics (such as water column properties, phytoplankton biomass or zooplankton distribution).

Research accomplishments/highlights/findings

We submitted and revised two papers on the project during this reporting period.

NOAA relevance/societal benefits

1. 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 and so that it can be well-managed in the face of anticipated marine development activities.
2. 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-sensitive sector of the US Arctic.
3. 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.*

Education

Nothing to report.

Outreach

Nothing to report.

Publications, conference papers, and presentations

In press (peer-reviewed)

Logerwell, E., K. Rand and T. Weingartner. Oceanographic characteristics of the habitat of benthic fish and invertebrates in the Beaufort Sea. *Polar Biology*, in press.

Parker-Stetter, S., J.K. Horne and T. Weingartner. Distribution of Arctic cod and age-0 fish in the U.S. Beaufort Sea. *Polar Biology*, in press.

Other products and outcomes

Nothing to report.

Partner organizations and collaborators

This is a joint project with researchers at NOAA-NMFS-Alaska Fisheries Science Center and the University of Washington. The physical oceanographic data collected on this project are also being merged with another Beaufort Sea physical oceanography program headed by Weingartner in this region.

We also blended some physical oceanographic inferences drawn from data collected under the auspices of the National Ocean Partnership Program (NOPP) led by Weingartner (UAF) into our final report and manuscripts.

CLIMATE CHANGE AND VARIABILITY

Cooperative Alaska research and satellite data services

Thomas Heinrichs, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

Other investigators/professionals funded by this project:
Jessica Cherry, co-PI, *University of Alaska Fairbanks*

NOAA Goal: Climate Adaptation & Mitigation *(Understand climate variability and change to enhance society's ability to plan and respond)*

CIFAR 10-015: This project is ongoing.

Line Office NWS-NWS AK; Gary Hufford, Sponsor

Primary objectives

- Enhance existing Alaska research and satellite data services and develop new services and applications in cooperation with NOAA personnel.
- Develop next generation scientific products from satellite data.
- Improve near-real-time and forecast snow products as a pilot application using Alaska's North Slope as the test area.

Project accomplishments and status of 4 deliverables

This project is implemented through the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) Alaska Proving Ground program in cooperation with the NOAA National Weather Service (NWS). Goals include enhancing the operational interactions between the University of Alaska Fairbanks and the National Weather Service and NOAA-NESDIS, deploying risk reduction products in preparation for the NOAA-NESDIS GOES-R mission, and demonstrating new near-real-time and forecast snow products derived from satellite data. The Geostationary Operational Environmental Satellite Program (GOES) is a joint effort of NASA and the National Oceanic and Atmospheric Administration (NOAA). Good progress has been made on all goals:

- A robust satellite data processing and distribution hardware configuration has been deployed at the NESDIS Fairbanks Command and Data Acquisition Station (FCDAS).
- Satellite product data flow between UAF's Geographic Information Network of Alaska (GINA) and the Alaska NWS has been streamlined and the number of products reaching forecasters' desks increased.
- Risk reduction products for volcanic ash, sulfur dioxide (SO_2), and low cloud and fog products are being delivered to the Alaska Weather Forecast Offices and the Alaska Aviation Weather Unit.
- Implementation of the River Forecast Center's modeling framework at UAF and model development using remote sensing–derived snow products.
- Training has been performed on new products and feedback received.

Solidified flow of operational data from NESDIS Fairbanks Command and Data Acquisition Station and GINA to NWS and other users. *[Deliverable 1]*

Data flow has been solidified through both software and hardware improvements. A new high availability hardware configuration has been built at the NESDIS Fairbanks Command and Data Acquisition Station (FCDAS) in cooperation with FCDAS staff. These high-performing systems will allow rapid, flexible product generation and have redundant components to enable the continuous operations and reliable data distribution required by NWS users. The hardware is configured and in place at FCDAS. FCDAS is in the process of moving to a newly constructed operations building. Following the move of this hardware to the new building, it will be put into operations.

A Unidata Local Data Manager (LDM) server has been deployed on the UAF campus and been configured to provide data to NWS forecast offices over the Alaska NOAA network. Data from the UAF-GINA LDM is pulled by the Alaska NWS LDM and distributed from there to the forecasters' desktops. The NWS forecasters run the Advanced Weather Interactive Processing System (AWIPS) software which allows them to visualize satellite data products created through this project. It requires considerable effort and coordination on the part of Information Technology NWS and UAF staff to have data flow from UAF-GINA to the NWS and be visualized effectively in AWIPS by forecasters.

Risk reduction products*. *Working closely with colleagues at other NOAA Cooperative Institutes, evaluate and produce analog products from currently operational satellites that will support future GOES-R and NPOESS (*National Polar-orbiting Operational Environmental Satellite System is the next generation of low earth orbiting environmental satellites) *product delivery and application. *[Deliverable 2]*

A suite of nine products was selected to perform GOES-R algorithm evaluation with. These products are:

Volcanic Ash	
1.	MODIS Ash Mass Loading AK
2.	MODIS Ash Height AK
3.	MODIS Ash Effective Radius AK
Volcanic Sulfur Dioxide (SO2)	
4.	GEOCAT MODIS SO2 Detection AK
5.	GEOCAT MODIS SO2 Loading AK
Fog and Cloud	
6.	GEOCAT MODIS Fog Probability AK
7.	GEOCAT MODIS Fog Mask AK
8.	GEOCAT MODIS Fog Depth AK
9.	GEOCAT MODIS Cloud Type AK

(Where GEOCAT is GEOstationary Cloud Algorithm Test-bed and MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard satellites that captures terrestrial, atmospheric, and ocean phenomenology for a wide and diverse community of users throughout the world.)

These products are fully deployed in the Fairbanks Weather Forecast Office and Alaska Aviation Weather Unit in Anchorage. A sample of the volcanic ash products in use is shown in Figure 1. Status of the deployment across the Alaska Region is shown in Figure 2.

These products are produced in cooperation with NOAA and University of Wisconsin staff, faculty, and students in Madison. The lead algorithm developers at NOAA Center for Satellite Applications & Research (STAR) work closely with co-located students and faculty at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) to generate the products, package them for visualization in AWIPS, and distribute them to Alaska.

The flow of data is currently:

1. MODIS satellite data captured in Fairbanks by UAF-GINA in real-time.
2. MODIS data is transmitted to University of Wisconsin Madison CIMSS/STAR.
3. CIMSS/STAR generates products.
4. CIMSS/STAR transfers data to UAF-GINA via LDM.
5. UAF-GINA transfers data to Alaska NWS via LDM.
6. Alaska NWS provides data to forecasters' AWIPS desktops for use in operations.

Products are being used in NWS operations in some NWS Alaska offices. Products will be deployed across all offices within a few months.

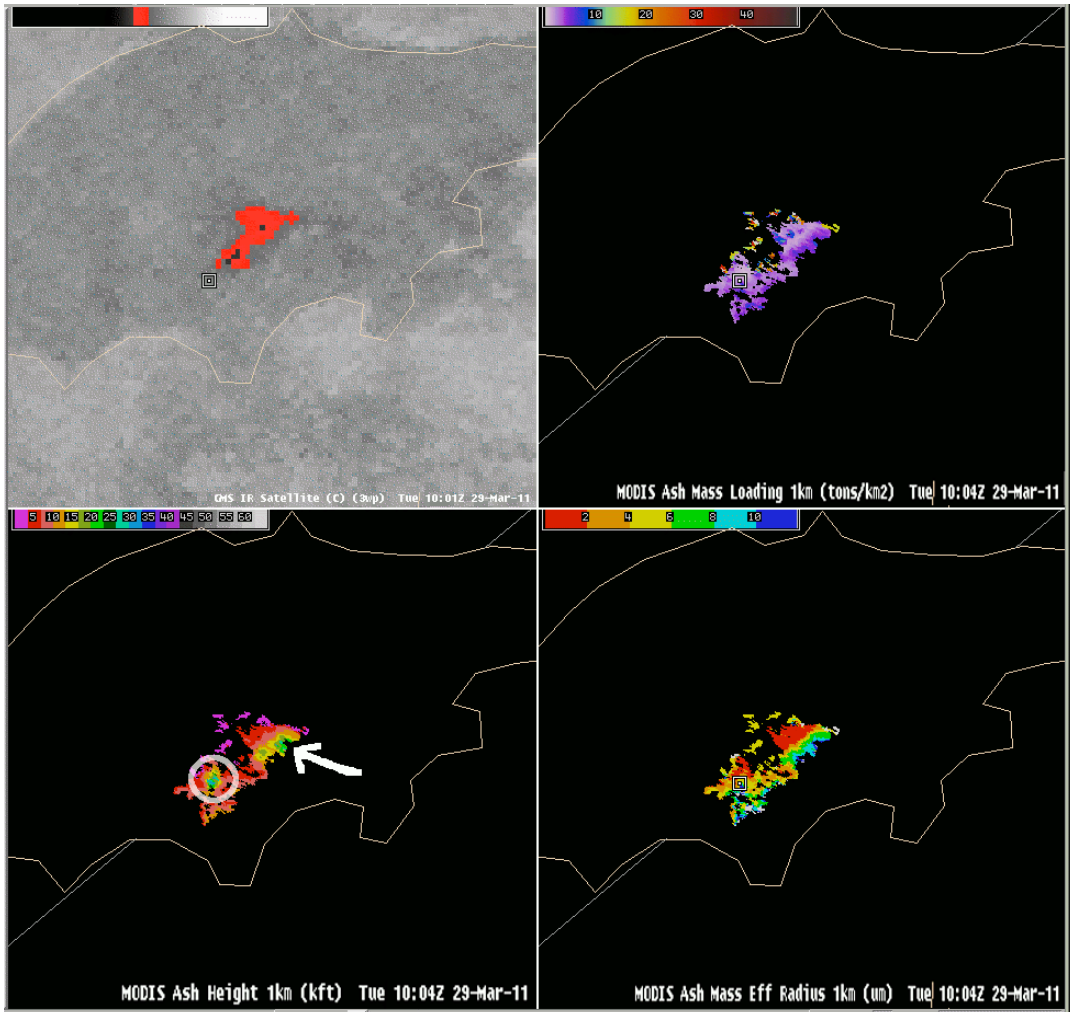


Figure 1. A four-panel layout from AWIPS (clockwise from the top-left) MT-SAT 11-12 split window, Ash Mass Loading, Mass Effective Radius, Ash Height. Note that Kizimen volcano is circled and an arrow pointing to detected ash heights with variable explanation. (Courtesy of Nathan Eckstein, Science Operations Officer, Alaska Aviation Weather Unit.)

Alaska Proving Ground Product Status

Date: April 12, 2011

	Product	UAF-GINA LDM	Fairbanks WFO	Juneau WFO	Anchorage WFO	Alaska Aviation Wx Unit	River Forecast Center	Source of MODIS	Processing Location	Product POC
	MIC	*Tom Heinrichs*	*Jon Dragomir*	*Tom Ainsworth*	*Bob Hopkins*	*Tony Hall*	*Robin Radlein*	-	-	-
	SOO	*Jiang Zhu*	*Eric Stevens*	*Carl Dierking*	*James Nelson*	*Nathan Eckstein*	*Scott Linsey*	-	-	-
	IT	*Greg Wirth*	*Jay Smith*	*Paul Shannon*	*Craig Searcy*	*LJ Miller*		-	-	-
1	MODIS Ash Mass Loading AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
2	MODIS Ash Height AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
3	MODIS Ash Effective Radius AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
4	GEOCAT MODIS SO2 Detection AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
5	GEOCAT MODIS SO2 Loading AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
6	GEOCAT MODIS Fog Probability AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
7	GEOCAT MODIS Fog Mask AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
8	GEOCAT MODIS Fog Depth AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis
9	GEOCAT MODIS Cloud Type AK	LDM	LDM, AWIPS	LDM,AWIPS	LDM,AWIPS	LDM, AWIPS	TBD	UAF-GINA	CIMSS	Mike Pavolonis

Legend

LDM = in office's LDM; available for use

AWIPS = in office's AWIPS; available to forecasters

Figure 2. Status of Proving Ground products being delivered to Alaska National Weather Service.

Strategic planning and implementation white paper and a proof of concept demonstration project on Alaska's North Slope for improved near-real-time and forecast snow products for high latitudes. *[Deliverable 3]*

Work with the Anchorage-based River Forecast Center and the UAF graduate student, Katrina Bennett, has led to implementation of a copy of the new Flood Early Warning System (FEWS) forecasting framework at UAF on the Arctic Region Supercomputing Center's PACMAN system. This makes it possible for UAF to develop capacity in the model and then port it back to the River Forecast Center for operational usage. The first development is to use the MODIS snow products (MOD10, Hall and others) computed from direct readout MODIS data captured at UAF-GINA as input to the model framework. This has now been tested successfully. The second step will be to work with GINA and algorithm developers to develop and implement improved MODIS-based snow products, including those identified by the GOES-R Proving Ground project.

NOAA training, general outreach, and feedback. *[Deliverable 4]*

Extensive training, outreach, and feedback have been performed.

- At least five formal product training sessions for Alaska NWS forecasters have been performed.
- UAF-GINA staff have performed job shadows of forecasters in the Alaska Weather Forecast Office.
- Outreach and coordination with NOAA staff at the NWS and NESDIS has been extensive through presentations and work sessions at: Proving Ground in-person and web-based meetings; Proving Ground workshops; Numerous informal meetings between UAF, NWS, and NESDIS faculty, staff, and students regarding products, network and software configuration, and operations coordination.
- Feedback has been received during training and during subsequent operations. A formal solicitation of feedback will be performed after several months of operational use of products by NWS forecasters.

Summary

All deliverables have been successfully accomplished. The cooperative work between the University of Alaska Fairbanks and NOAA units in Alaska has been successful and has led to greater collaboration between Alaska academic and NOAA operational users. Satellite data products are flowing operationally to the National Weather Service from UAF-GINA and UW-Madison. New snow products and data-model integration are being developed while a Ph.D. student is undergoing her education. Training, outreach, and feedback loops are underway and will continue into the future.

Acknowledgements

This work was the result of the efforts of many at UAF, NOAA, and the University of Wisconsin Madison. We gratefully acknowledge the contributions of NOAA staff at the NWS, especially the Science Operations Officers at all Alaska units and Gary Hufford, Alaska Region Chief Scientist, and staff at the NESDIS Fairbanks ground receiving station. NOAA NESDIS and NWS managers in Alaska have been extremely supportive of this project and their contributions and enthusiasm invaluable. The NOAA and university scientists at the University of Wisconsin Cooperative Institute for Meteorological Satellite Studies (CIMSS) and NOAA Center for Satellite Applications & Research (STAR) in Madison provided the algorithms, training, and software configuration. Many contributed but Mike Pavolonis of NOAA STAR has been the primary interface to the Alaska community of users. At UAF, staff and students at GINA and the International Arctic Research Center performed much of the work and provided many ideas and solutions. Special recognition goes to the late Kevin Engle, GINA research programmer and ground station engineer, whose initiative, energy, and skill with satellite data got this whole project started in the first place.

NOAA relevance/societal benefits

This project has the potential for huge impacts on Alaskan communities because it specifically focuses on developing satellite products to overcome data gaps for applications like flood forecasting and aviation safety. Because of Alaska's large size and sparse ground-based observations, satellites have the potential to provide information that may never be available from in situ networks. Another component of this project is to train forecasters to become more familiar with qualitative and quantitative use of remote sensing in Alaska.

Education

Katrina Bennett, a Ph.D. student, began working on this project in August 2010. Funding for partial support for her work will be requested in the upcoming budget.

Outreach

Engle and Jiang Zhu, GINA satellite data liaison, performed “job shadows” in the Fairbanks NWS Forecast Office. They learned the daily routines of forecasters and were able to explain and promote additional satellite products being provided through the Proving Ground. Heinrichs, Dayne Broderson (GINA system analyst), and Zhu visited the NWS forecast offices in Fairbanks and Anchorage, and the Alaska Aviation Weather Unit. They discussed the development of the satellite products with the forecasters, who are not typically involved in remote sensing research.

Publications, conference papers, and presentations

Oral presentations

Cherry, J., T. Heinrichs and G. Hufford. 2010. A high latitude and arctic satellite proving ground for next-generation hydrometeorological products. Cold Regions Hydrology Meeting, 28–30 April 2010, Innsbruck, Austria.

Heinrichs, T., J. Zhu and K. Engle. 2011. UAF Geographic Information Network of Alaska joint proving ground program with NWS and NESDIS. Alaska Surveying and Mapping Conference, 21–25 February 2011, Anchorage, Alaska.

Other products and outcomes

- Improved products put into production in NWS offices.
- Improved collaboration between Alaska NWS and university researchers at UAF and University of Wisconsin Madison.
- Transfer of knowledge regarding experimental product data distribution and forecaster visualization from University of Wisconsin Madison CIMSS to UAF CIFAR and Alaska Region NWS.
- Hundreds of Alaska- and Arctic-specific data products derived from NOAA, NASA, and Air Force satellites have been inserted into a Unidata Local Disk Manager (LDM) data feed in Fairbanks. They are available for incorporation into AWIPS (Advanced Weather Interactive Processing System) for Alaska Region forecasters. UAF and NWS staff are working together to introduce these products to forecasters in the Alaska Regional and Field offices.

Partner organizations and collaborators

NOAA National Weather Service: Collaborative research, Facilities

NOAA NESDIS, Fairbanks Command and Data Acquisition Station: In-kind support, Facilities, Collaborative Research

NASA-Cryosphere Group: Collaborative research

UW-Madison CIMSS: In-kind support, Collaborative research, Personnel exchanges

UW-Madison Space Science and Engineering Center (SSEC): In-kind support, Collaborative research, Personnel exchanges

Impact

New volcanic ash and SO_2 products and cloud and fog products have been introduced into operation in Alaska NWS operations. NWS forecasters and Science Operations Officers (SOOs) have provided feedback to the NOAA algorithm developers. Production of satellite derived snow and hydrology products is underway and will be transitioned into operations in the upcoming period. The impact will be improved weather, river, and aviation forecasting and warnings. Products entered operations this period; training is well underway and NWS operators are becoming familiar with the new product lines.

Changes/problems/special reporting requirements

This project was in startup mode in year one and spending was delayed while the data liaison was hired. Progress improved substantially when that hire was accomplished.

Moving products into operations from the University into the NWS network was initially a challenge. University and NWS IT staff have met the challenge and data is fully in operations.

This activity is one of the first GOES-R Proving Grounds and pioneering the protocols for the activity has been a learning experience for both University and NOAA staff. The outcomes of the planning effort are being received well and will provide a good template for future Proving Ground activities.

State of the Arctic Land Report (2009/2010)

Vladimir Romanovsky, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

NOAA Goal: Climate Adaptation & Mitigation *(Understand climate variability & change to enhance Society's ability to plan & respond.*

Funded through Task I; see "Highlights of CIFAR Task 1 Activities" in the Overview section.

Line Office OAR-CPO, John Calder, Sponsor

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.

Research accomplishments/highlights/findings

Most of the permafrost observatories in Alaska show a substantial warming during the 1980s and especially in the 1990s. The magnitude and nature of the warming varies between locations, but is typically from 0.5 to 2°C at the depth of zero seasonal temperature variations. However, during the 2000s, permafrost temperature has been relatively stable on the North Slope of Alaska, and there was even a slight decrease (from 0.1 to 0.3°C) in the Alaskan Interior during the last three years. Only coastal sites in Alaska still show continuous warming, especially during the last four to five years. The data from the 2010 field season may indicate that, in Alaska, the observed warming trend along the coast has begun to propagate south towards the northern foothills of the Brooks Range, where a noticeable warming in the upper 20 m of permafrost has become evident since 2008. A common feature at Alaskan, Canadian and Russian sites is more significant warming in relatively cold permafrost than in warm permafrost in the same geographical area.

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 also contributes to International Polar Year (IPY) activities involving NOAA, NASA, and NSF.

Education

During the last year, Romanovsky was involved in the International Arctic Research Center (IARC) Summer School and in the Program Unite US.

Outreach

During the last year, Romanovsky was interviewed by a Svalbard magazine; by radio station KDLG, Dillingham, Alaska; by *The Arctic Sounder*, North Slope and North West Boroughs, Alaska; by Media & Democracy Group; by weekly radio program *If You Love This Planet* on Pacifica Radio and community stations in the US, Canada and Australia; by the International Polar Foundation; by the *National Geographic* and *On Earth* magazines; by 590 Films; and by Norwegian TV. On 18 September, Romanovsky presented a public lecture for the Barrow community at the BEO Schoolyard Lectures series and on 1 February, he presented a lecture in the Science for Alaska series for the Fairbanks community.

Publications, conference papers, and presentations

Peer-reviewed

Romanovsky, V., N. Oberman, D. Drozdov, G. Malkova, A. Kholodov and S. Marchenko. 2010. Permafrost. In: State of the Climate in 2009. Special Supplement to the *Bulletin of the American Meteorological Society*, 91(6): S92.

Other products and outcomes

- Web site: http://www.permafrostwatch.org/
- Richter-Menge, J. and J.E. Overland, Eds. 2010. Arctic Report Card: Update for 2010. http://www.arctic.noaa.gov/reportcard.

Partner organizations and collaborators

None.

COASTAL HAZARDS

Northern Bering Sea improved hazard monitoring in the marine and coastal environments

David Atkinson, PI **CIFAR theme: Coastal Hazards**
University of Alaska Fairbanks

NOAA Goal: Weather Ready Nation *(Serve Society's needs for weather and water information)*

CIFAR 10-018: This project is ongoing. Line Office NWS-NWS AK, Carven Scott, Sponsor

Primary objectives

- Deploy autonomous wind and wave buoys into the central/northern Bering Sea;
- Establish near-real time delivery of wind and wave data to the internet;
- Establish working community partnerships;
- Develop reporting metrics to determine the ways in which the data ultimately come to be utilized by the community;
- Assessment of data utility for National Weather Service forecasting activities;
- Use data to verify NOAA wave models, and other modeled/remotely sensed data, in the areas of buoy deployment in a research mode.

Changes in proposed wind and wave buoys for the Bering Sea

- Initial specifications called for free-floating wave instrument that would be deployed and recovered by community members from Gambell on St. Lawrence Island. However, this was reconsidered for two reasons: 1) Instruments may float too far for local boats to safely recover, and 2) There was concern that instruments may float into Russian waters, again representing a security/safety issue for local participants.
- From discussions with other researchers to realistically estimate how far the proposed free-floating unit could drift during a protracted storm event, Atkinson decided to substitute a single, moored buoy system for the free-floating unit and utilize "ships-of-opportunity" for buoy deployment and recovery. His discussions with the ship operators indicated that time could realistically be spared to deal with no more than a single buoy, without incurring ship retasking costs (~$30,000 per day). Obtaining wind, air and sea temperature data from this ocean location, in addition to wave data, was deemed of interest. A 1.8-meter buoy was the smallest that will fit the requirements of a meteorological platform, yet is much smaller than the standard, larger 3-meter weather buoys in the interests of facilitating ship-board handling and keeping costs down.
- As the result of discussions with the Canadian and US Coast Guards (CG) in January 2011, Atkinson determined that there was the possibility of deploying the buoy during a science cruise of the Canadian CG vessel *Sir Wilfred Laurier*, which will be transiting the vicinity of interest (St. Lawrence Island in the northern Bering Sea) in mid-July, and the possibility of retrieving the buoy during the fall science cruise of the USCG vessel *Healy*, which will be transiting the vicinity of interest in mid-October.

Research accomplishments

- An order has been placed with Axys Technologies Inc. of Victoria, British Columbia, a proven marine science instrumentation provider, to build a wave and meteorological buoy (Figure 1) tailored for use in the northern Bering Sea. The main modification consists of a twinned anemometer installation to detect the occurrence of icing events. The unit will transmit live data every three hours to all interested parties (NOAA, communities, industry, USCG).
- The Canadian Coast Guard Icebreaker *Sir Wilfred Laurier* has agreed to deploy the unit in early July. The US Coast Guard Icebreaker *Healy* has agreed to pick up the unit in October if weather permits. To ensure recovery, discussions are also ongoing with the Shell Oil logistics shipping contractor (Olgoonik/Fairweather) and will commence with the operators of an NSF research vessel (R/V *Marcus Langseth*) that will also be operating in the vicinity.
- A preferred location for the mooring has been determined – just south of the Bering Strait (Figure 2). This location could change depending on weather and logistical requirements. Two backup locations were also determined.

NOAA relevance/societal benefits

Short term

- The buoy will furnish data about wind and wave state on a near-real time basis that will be fed directly to the forecasters at WFO-Fairbanks. Given the lack of reliable data points in this area, an addition of even one data source is important.
- The buoy will furnish data about wind and wave state on a near-real time basis that will also be fed to the internet for pickup by the following groups: members of the public, the US Coast Guard, and Olgoonik/Fairweather (ocean logistics provider for Shell in the Chukchi lease fields). This will improve safety in their day-to-day operations.
- Although local hire from the northern communities was not utilized, they will still benefit from real-time wave data that this project would make available to them.

Long term

- The information from the buoy will be important to help validate wave models run for the area; this in turn will help with the forecast process for sea-state. From a broader research perspective, the rationale for selecting the location south of the Bering Strait is it will allow monitoring of wave energy that propagates through the strait in either a north or a south direction. If the winds are suitably arranged, wave energy moving north through the strait has the potential to increase wave loading experienced in the southern Chukchi Sea.
- Benefits from the improvement to the sea-state forecast process.

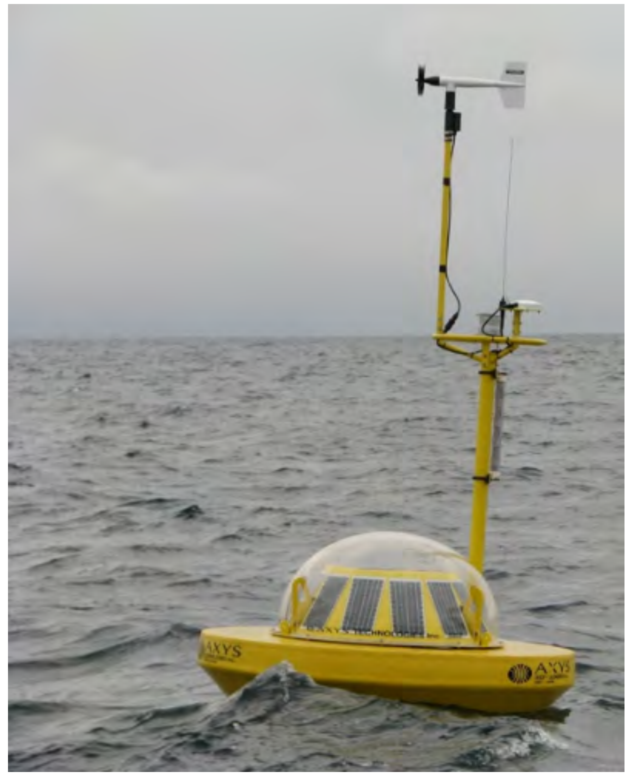


Figure 1. Axys "Watchmate" buoy. This unit measures wind, waves, and air/water temperature. The unit for the Bering Strait will be modified to include "twinned" wind sensors, a precaution against the possibility of icing.

Education

This project will furnish field data for a new Ph.D. student that will start with Atkinson in September 2011, Norman Shippee (current terminal degree is a Masters in meteorology from Plymouth State University).

Data from this instrument will also assist with the WAve prediction Model (WAM) modeling effort currently being undertaken by Atkinson's Ph.D. student Oceana Francis. She has recently successfully implemented the WAM model for experimental use in the Bering and Chukchi Seas.

Outreach

Outreach activities are important for this project and will consist of establishing contact with town and tribal councils in the communities surrounding the area of deployment, including Nome, Teller, Wales, Savoonga, and Gambell. The reason for the contact will be to raise awareness that an offshore wave and wind data feed is available to local residents. This will improve their safety when hunting or traveling north of St. Lawrence Island.

Publications, conference papers, and presentations

Oral presentations

Atkinson will discuss this project at the NOAA-NWS/Meteorological Service of Canada joint Marine Workshop in Seattle 26–29 April 2011, and at the general activities briefing to be held at NWS-Alaska region headquarters in early May 2011.

Partner organizations and collaborators

University of Victoria; Canadian and U.S. Coast Guards; Olgoonik/Fairweather

Changes/problems/special reporting requirements
See the second subsection of this report, "Changes in proposed wind and wave buoys for the Bering Sea."

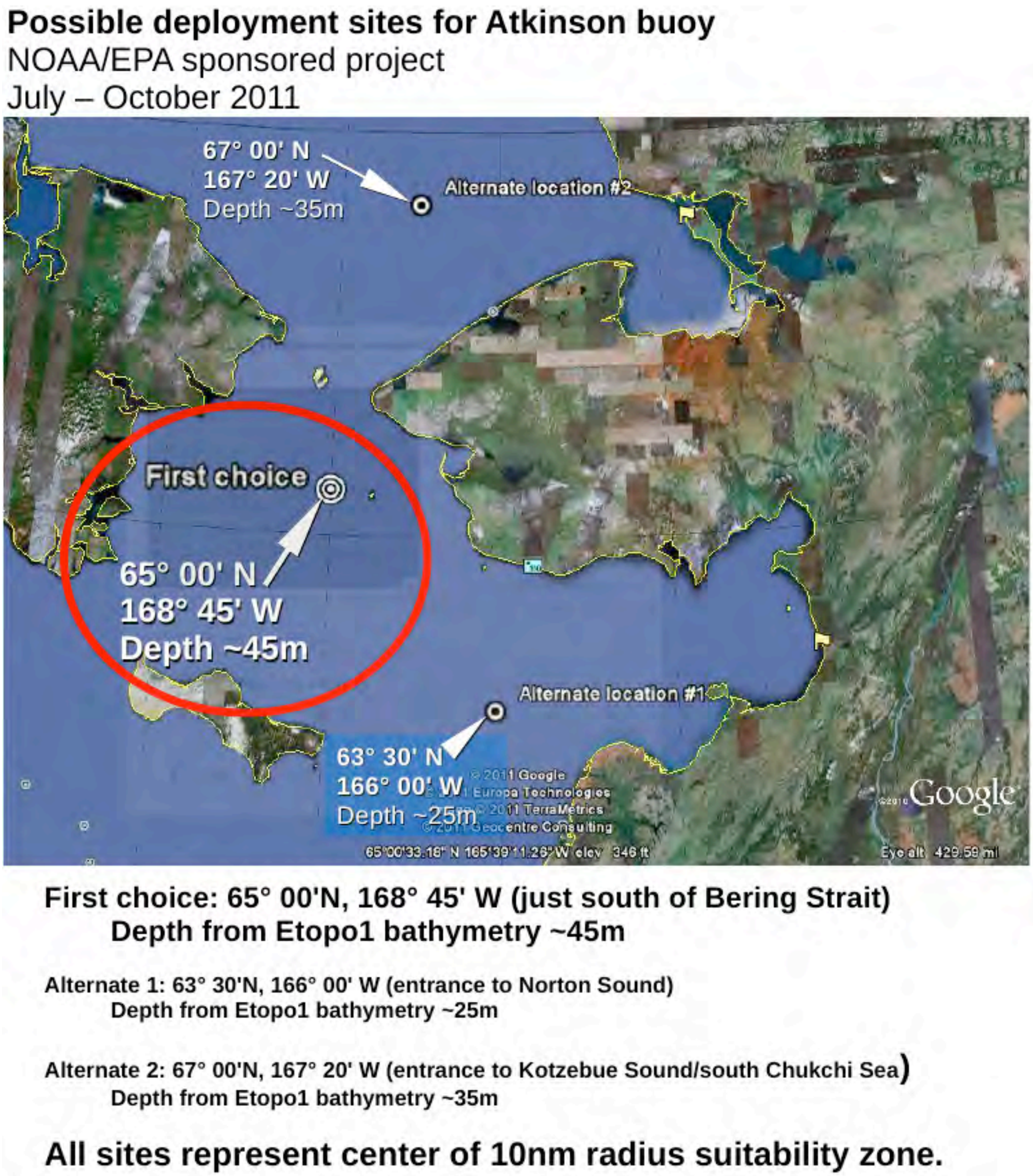


Figure 2. Proposed buoy locations. Preferred site is just south of the Bering Strait.

TWEAK: Tsunami Warning and Environmental Observatory for Alaska

Roger Hansen, PI
University of Alaska Fairbanks

CIFAR theme: Coastal Hazards

NOAA Goal: Weather Ready Nation *(Serve Society's needs for weather and water information)*

CIFAR 09-008/10-008/11-008: This project is ongoing. Line Office NWS-NWS AK, Carven Scott, Sponsor

The University of Alaska Fairbanks (UAF) tsunami studies center called the Alaska Tsunami Center and Observatory (ATCO) combines the strengths of the UAF Institute of Marine Science (IMS), the Geophysical Institute (GI) and the Arctic Region Supercomputing Center (ARSC). By forming one organized group, ATCO allows a single point of contact to our partners and collaborators.

The proposed tasks for TWEAK are:

1. Tsunami code development and specification of non-seismic sources
2. Super computer support for tsunami codes
3. Seismic source function specification
4. Earthquake detection and warning with seismology
5. Assessment of tsunami hazard and wave run-up
6. Education and outreach in Alaska
7. Project management

Because this project continues on-going TWEAK efforts under the previous CIFAR cooperative agreement, this report will be limited to efforts begun or continued with this new award. Beginning in FY10, "TWEAK Task 3: Seismic network component" was funded as a separate CRESTnet (Consolidated Reporting of Earthquakes and Tsunamis) award entitled "Alaska Earthquake Information Center (AEIC) Seismic Station Operations and Maintenance." For continuity with our previous awards, we have included this report within the TWEAK umbrella, but with reference to the separate award.

Partner organizations and collaborators

The University of Alaska has State and Federal partners in the tsunami program. These include the NOAA/NWS West Coast and Alaska Tsunami Warning Center (WC/ATWC), the Department of Homeland Security and Emergency Management (DHS&EM), and the Alaska Division of Geological and Geophysical Surveys (ADGGS). ATCO will continue to support the National Tsunami Hazard Mitigation Program (NTHMP) through improvements and enhancements in monitoring, modeling, and education and outreach.

TWEAK Task 1: Development of new tsunami hazard mitigation tools

Roger Hansen, PI
Zygmunt Kowalik, co-PI and Project Lead
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
J. Beget, T. Logan, *University of Alaska Fairbanks;* ***J. Horrillo,*** *Texas A&M University at Galveston;*
Y. Yamazaki, *University of Hawaii*

Primary objectives

The main task of the UAF IMS research is to assist with tsunami warnings and prediction services by developing numerical-hydrodynamical models. An important result of this work has been the construction of a global tsunami model (GTM). Our primary objectives during this reporting period were associated with further developing and testing of different components of the GTM. Three levels of models with progressively improved physics were used. These are: the Nonlinear Shallow Water models, dispersive Boussinesq type models, and 3D Navier-Stokes.

Research accomplishments/highlights/findings

Z. Kowalik, J. Horrillo and W. Knight continued cooperation with Tom Logan (ARSC) to develop a high performance parallel numerical tool that includes nesting capability and tides-tsunami interactions for inundation maps. For this development we used the Kurile Island tsunami of 15 November 2006, to validate the numerical code. The first step completed was parallelization in one domain. The North Pacific bathymetry data were taken on 1 arcmin space step generating close to 21 million grid points. Preliminary results suggest that the computation time can be diminished about 50 times. Our plan is to solve the same problem on the 15 arcsec space step which will bring the number of the grid points to 330 million.

- The research into dispersive processes based on the constructed depth-integrated, non-hydrostatic model. The formulation builds on the nonlinear shallow-water equations and utilizes a non-hydrostatic pressure term to describe weakly dispersive waves (Yamazaki et al., 2008). The model was extended to include grid nesting for tsunami generation, propagation, and runup (Yamazaki et al., 2010). During this reporting period the hydrostatic and non-hydrostatic tsunami physics were compared through the energy fluxes. For this purpose the energy fluxes were formulated for the dispersive and non-dispersive waves, therefore this tool can be further used to compare differences in both approaches. Separating the pressure field into two parts, i.e., hydrostatic and non-hydrostatic, shows that dispersive waves extract energy from the main wave directing the dispersive energy flux away from the wave front propagation.

Z. Kowalik and J. Horrillo have continued to develop realistic models and landslide source functions. This task was pursued by comparing numerical results with laboratory data obtained by Synolakis and Raichlen (2003) and Raichlen and Synolakis (2003). A series of landslide experiments was carried out in a tank. A solid wedge was used to represent the submarine landslide. The horizontal surface of the wedge was positioned in two different small distances below the still water level (Δ = 0.025 m and Δ= 0.10 m) to reproduce submarine landslides. For description of the experiment refer to the tsunami benchmark "Tsunami Generation and Runup Due to Three-dimensional Landslide," Synolakis et al. (2007). Two numerical models were compared against experimental data: the two-dimensional, vertically integrated shallow water approach and the three-dimensional model based on the full Navier-Stokes equations.

- The three-dimensional model was validated and compared against the experimental results as indicated in Figures 1 and 2. Numerical results agreed very well as accumulative errors are kept reasonably low. Computer parallel instructions were further implemented in the 3D model sub-codes demanding higher CPU time. Most of the computational cost was directed to solve the set of linear equations for the pressure field. The cooperation provided by ARSC was indispensable to complete this work.

The next comparison, using the 2D vertically integrated shallow water approach, was carried out with the help of two models: the nonlinear shallow water model, which is based on the hydrostatic approximation, and the non-hydrostatic with dispersive module. The dispersive terms were constructed using the non-hydrostatic pressure caused by the vertical velocity. With the linear profile of the vertical velocity, the weakly dispersive wave physics is brought into scope of the two-dimensional vertically integrated equations.

The time history of the water level recorded in the lab experiments for case Δ=0.10 m and the results of the hydrostatic model (HM) and non-hydrostatic model (NHM) are plotted in Figure 3. The hydrostatic model produced short period surface waves, which do not reproduce the observed sea level at the tide gage locations. The obvious reason for the discrepancy is the lack of the bottom vertical velocity, which is generated by the sharp edge of the triangular landslide wedge. The NHM model, although it is based on the linear approximation of the vertical velocity, reproduces quite well the sea level changes along the main path of the landslide generated wave.

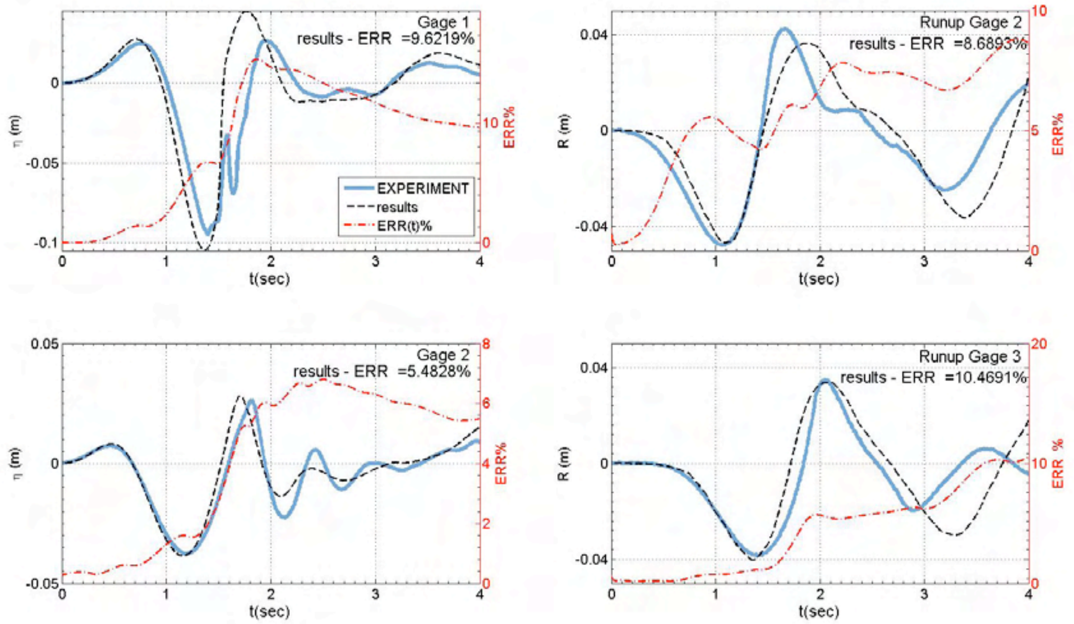


Figure 1. Comparison of 3D numerical result (black broken line) against experiment (blue solid line) for Δ=0.025 m. Red line is the normalized error plotted in time.

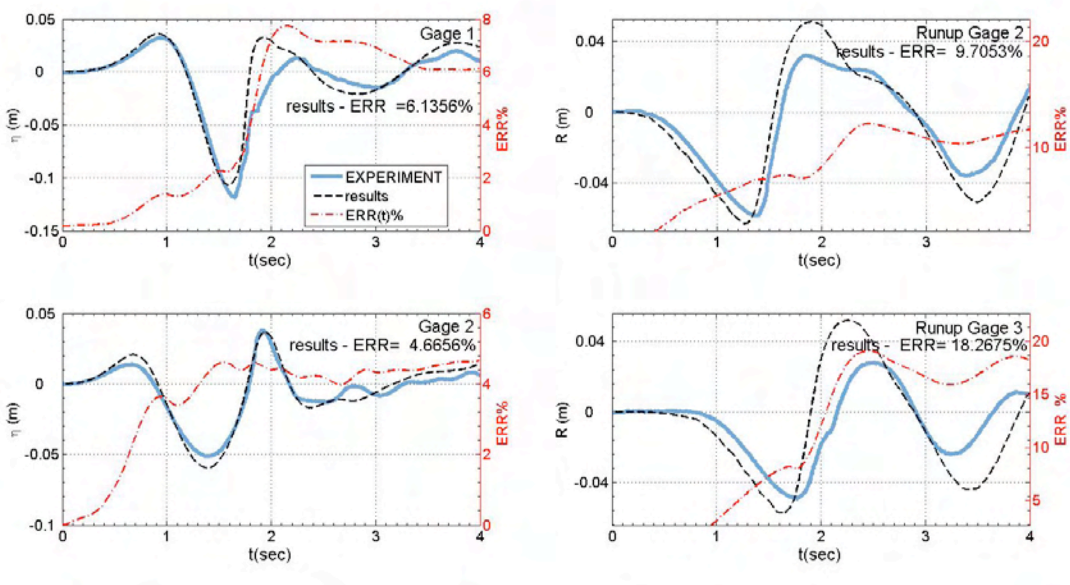


Figure 2. Comparison of 3D numerical result (black broken line) against experiment (blue solid line) for Δ=0.10 m. Red line is the normalized error plotted in time.

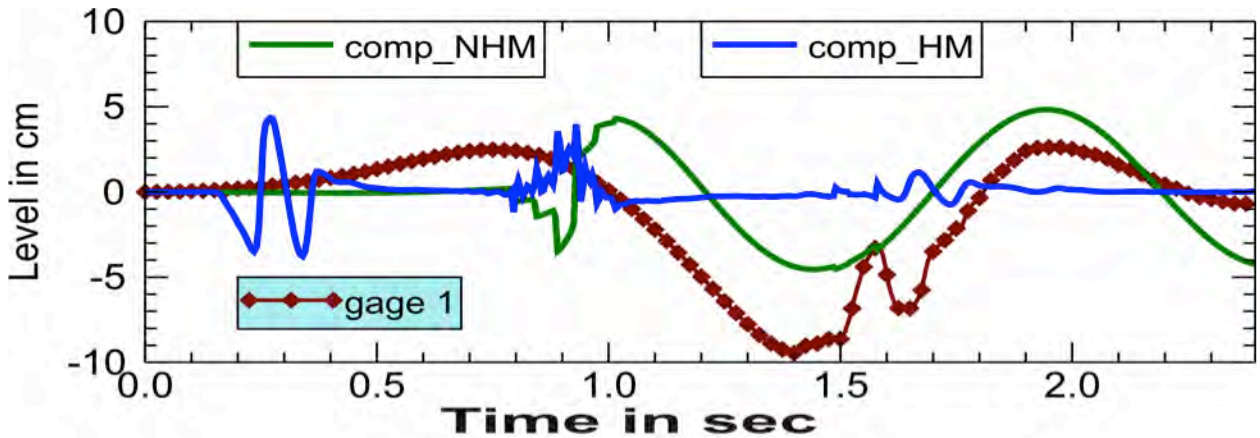


Figure 3. The water level generated by submerged landslide and recorded in the water tank experiment gage 1 (red diamond and solid line). Numerical computation: blue – hydrostatic model (HM); green – non-hydrostatic model (NHM).

- Beget and his collaborator Cristian Montanaro at the University of Roma La Sapienza integrated analysis of marine and terrestrial data resulting in the identification and characterization of 17 extensive submarine debris avalanche deposits from 11 volcanoes. Volume calculations for each volcanic debris avalanche show the amount of material deposited in debris avalanches on the sea floor is as much as three times larger than the amount of material initially involved in the collapse event at the volcanic edifice, suggesting the incorporation of large amounts of submarine material occurred during transport. The orientation of the collapse events was influenced by regional fault systems underlying the volcanoes. Our work demonstrates that the western Aleutian Arc has a significant tsunamigenic potential and communities within the Aleutian Islands and surrounding areas of the North Pacific be at risk during future eruptions. Simple numerical models suggest that the giant volcanic landslides (> 1 cubic kilometer in volume) can generate local tsunami waves larger than those typical of earthquake generated tsunamis.

References

Raichlen, F. and C.E. Synolakis. 2003. Runup from three dimensional sliding mass. In: M. Briggs and C. Coutitas, Eds., *Proceedings of the Long Wave Symposium 2003*. XXX IAHR Congress Proceedings, ISBN-960-243-593-3, pp. 247–256.

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 Tech. Memo. OAR PMEL-135, NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 55 pp.

Synolakis, C.E. and F. Raichlen. 2003. Waves and runup generated by a three dimensional sliding mass. In: J. Locat and J. Mienert, Eds.), *Submarine Mass Movements and Their Consequences*. Kluwer Academic Publishers, pp. 113–119.

Yamazaki, Y., Z. Kowalik and K.F. Cheung. 2008. Depth-integrated, non-hydrostatic model for wave breaking and runup. *International Journal for Numerical Methods in Fluids*, doi: 10.1002/fld.1952.

Yamazaki, Y., K.F. Cheung and Z. Kowalik. 2010. Depth-integrated, non-hydrostatic model with grid nesting for tsunami generation, propagation, and runup. *International Journal for Numerical Methods in Fluids*, doi: 10.1002/fld.2485. Published online in Wiley Online Library (wileyonlinelibrary.com).

Education

Gyeong-Bo is a graduate student at Texas A&M University at Galveston (TAMUG). He has contributed to several submarine landslide numerical simulations for model validation; J. Horrillo chairs his advisory committee.
Joseph Maharrey began graduate study at UAF in September 2010. His graduate work involves investigations of volcanic tsunami deposits in Alaska, especially in the Cook Inlet area.
Ashwin Parambath is a graduate student at TAMUG. He has contributed to several submarine landslide numerical simulations and parallel computation for model validation; J. Horrillo chairs his advisory committee.

Publications
Nothing to report except as below.

Other products and outcomes
Horillo and Knight provided input to model development described in the following publication:

Yamazaki, Y., K.F. Cheung and Z. Kowalik. 2010. Depth-integrated, non-hydrostatic model with grid nesting for tsunami generation, propagation, and runup. *International Journal for Numerical Methods in Fluids*, doi:10.1002-fld.2485. Published online in Wiley Online Library (wileyonlinelibrary.com).

Kowalik provided critical review of the following publication:

Montanaro, C. and J. Beget. 2011. Volcano collapse along the Aleutian Ridge (western Aleutian Arc). *Natural Hazards and Earth System Sciences*, 11:715–730.

TWEAK Task 2: Parallelization of the Global Tsunami Model (GTM) [Formerly Tsunami computational portal work]

Roger Hansen, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Thomas Logan
University of Alaska Fairbanks

Primary objectives
ARSC will parallelize, optimize, and parameterize the multi-gridded Global Tsunami Model (GTM). More specifically, the code will be parallelized, converted to use dynamic memory allocation, and driven by parameter files. This will allow future users of the code to dynamically change the number of grids in a run and/or to configure individual runs without the need for code recompilation. As a result, the code will be simpler to use and, thus, more easily accessible to a larger community of researchers.

Research accomplishments/highlights/findings
ARSC's effort during this reporting period has focused on the optimization, parallelization, and memory management of the newest version of the multi-gridded Global Tsunami Model (GTM).

- The newest version of the GTM was ported to a Unix system
- The code was simplified to work with single grids to ease parallel development work
- Many serial optimizations were performed on the code
- A single gridded parallel version of the code was created and verified to be correct on 4, 16, and 32 processors of ARSC's Cray Opteron cluster
- Dynamic memory allocation was implemented in the parallel code
- The parallel code was optimized for communication patterns
- Code was ported from the Department of Defense (DoD) Cray system Pingo to the academic system PACMAN

Overall, the serial run time for a short run was reduced from 8486 seconds to 3010 seconds, while the partially optimized parallel code ran the same short scenario in just 131 seconds on 32 processors.

NOAA relevance/societal benefits
The advanced numerical models help to solve issues related to saving lives in the event of catastrophic tsunamis. Unfortunately, the highly accurate models, especially when used with high-resolution bathymetry data, tend to be very computationally intensive. As such, flexible optimized parallel versions of these codes help accelerate the advancement of tsunami science.

Education
Nothing to report.

Outreach
Nothing to report.

Publications, conference papers, and presentations
Nothing to report.

Other products and outcomes
The experiences and lessons in this project will be directly relevant to the parallelization of the Alaska Tsunami Forecast Model covered under the CIFAR project 11-020 "Parallelization and Porting of the Alaska Tsunami Forecast Model to Arctic Region Supercomputing Center."

Partner organizations and collaborators
Zygmunt Kowalik (IMS) developed the GTM and has been instrumental in describing the code and answering questions throughout the development process.

Changes/problems/special reporting requirements
The intent is to have a verified multi-gridded parallel implementation of the GTM completed by the end of the fiscal year (30 June 2011). The main tasks remaining are implementing the communication routines to allow sub-grid and parent grid interactions during a simulation, thus allowing the code to once again process multi-gridded scenarios, and conversion of the code to using existing parameter file libraries already developed at ARSC.

TWEAK Task 3: Seismic network component (Alaska CRESTnet)

Roger Hansen, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
S. Estes, J. Sandru, J. Stachnik, T. Viggato, *University of Alaska Fairbanks*

CIFAR 10-017: This project is ongoing. Line Office NWS-NWS AK, Carven Scott, Sponsor
Alaska CRESTnet (Consolidated Reporting of Earthquakes and Tsunamis): Alaska earthquake information center seismic station operations & maintenance.

Primary objectives
- Maintain ATCO- and CREST-funded seismic stations in the integrated Alaska Seismic Network (Figure 1)
- Upgrade analog stations to Advanced National Seismic System (ANSS) standards of Modern broadband equipment.
- Locate seismic events occurring in Alaska and produce alarms and warnings to the West Coast and Alaska Tsunami Warning Center (WC/ATWC) and Emergency Managers.
- Maintain data flow of selected stations to ATWC.

Research accomplishments/highlights/findings
- We continued to upgrade and expand our integrated seismic network, including the following work on ATCO- and CREST-funded stations:
  - At ATKA, we installed a Q330 digitizer and Trillium 240 sensor, improved telemetry to a T1 line, and installed a UPS to regulate power.
  - At BESE (Besse Mt. near Juneau), we replaced older Guralp instruments with a Q330 digitizer and Trillium 240 sensor, removed bear-damaged cables, and installed a new Ethernet cable in buried conduit.
  - At BMR (Bremner River—east of Valdez), we did routine maintenance and repairs.
  - At DCPH (Deception Hills seismic station south of Yakutat), we added 10 batteries to improve backup power, installed new radios, and set up the radio shot to our new receive site at the Coast Guard tower in Yakutat. We also scouted new vault locations in anticipation of our co-location with the new Coast Guard Rescue 21 tower at Deception Hills.

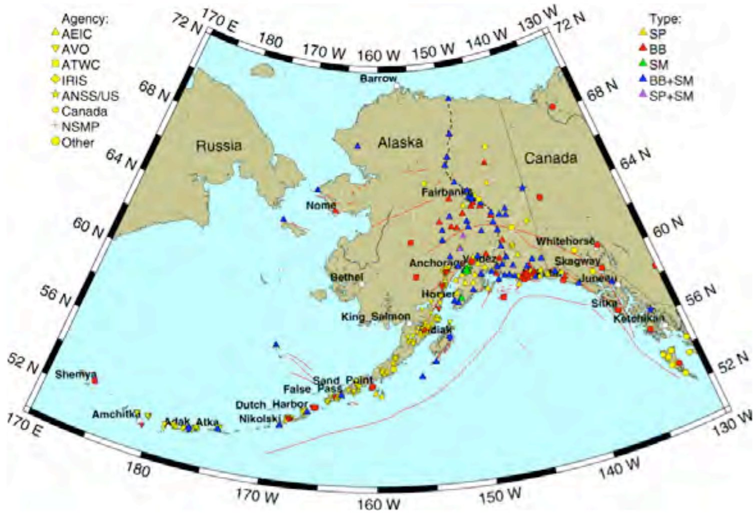


Figure 1. AEIC stations as of April 2011.

- At DOT (Dot Lake), we replaced a faulty digitizer and installed a new power converter.
- At PIN (Pinnacle—north of Yakutat), we added ten batteries to improve backup power, installed a new Q330 digitizer, and set up the radio shot to the new receive site in Yakutat.
- At SMY(Shemya), we added a strong motion instrument.
- At UNV (Unalaska), we replaced the modem and backup power supply.
- We installed a new receive site on the Coast Guard tower in Yakutat. This will improve reliability of data telemetry from DCPH, PIN, and seven other sites in the integrated seismic network.

- Between 1 April 2010 and 31 March 2011, we located 30,895 events, with magnitudes ranging between -0.4 and 6.7 and depths down to 260 km (Figure 2). The largest earthquake, magnitude 6.7, occurred on 18 July 2010, in the Fox Islands region.

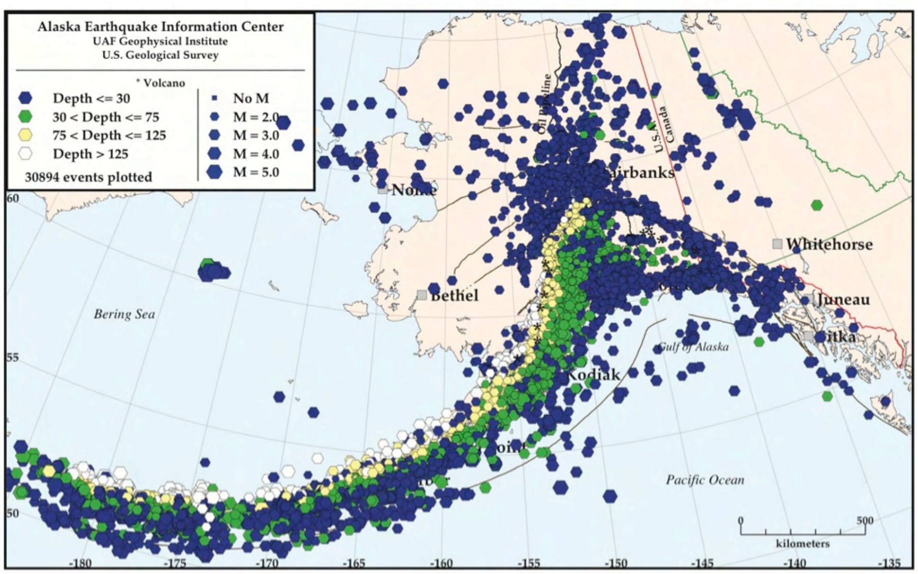


Figure 2. AEIC Seismicity Report for 1 April 2010 – 31 March 2011.

NOAA relevance/societal benefits
Improved detection of tsunamigenic earthquakes by AEIC and NOAA tsunami warning centers.

Education
Nothing to report.

Outreach
AEIC continues to provide real-time and reviewed earthquake information to local Emergency Services offices through monitoring systems installed in the following population centers in the state: Fairbanks, Anchorage, Valdez, Seward, Soldotna, and Kodiak. The system resides on a stand-alone MAC computer that displays real time earthquakes on a state map with audio announcements of earthquake locations and magnitudes.

Publications, conference papers, and presentations
Nothing to report.

Other products and outcomes
Nothing to report.

Partner organizations and collaborators
None.

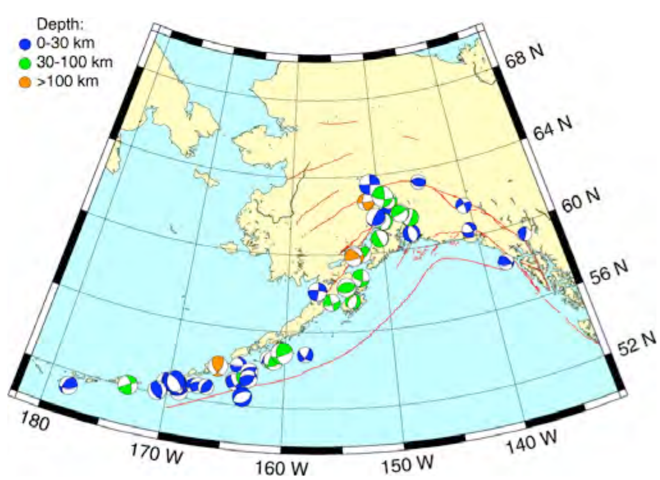
TWEAK Task 4: Earthquake detection and warning with seismology

Roger Hansen, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Natalia Ruppert, Anna Bulanova, *University of Alaska Fairbanks;* ***Aurélie Guilhem***, ***Douglas S. Dreger***, *Berkeley Seismological Laboratory*

Primary objectives
Implementation of the near-real-time moment tensor inversion and extended earthquake source inversion procedures at the Alaska Earthquake Information Center (AEIC).

Research accomplishments/highlights/findings
- A total of 71 regional moment tensor solutions were calculated (moment magnitudes Mw between 3.8 and 5.8) between 1 April 2010 and 31 March 2011 in Alaska and Aleutians:



- Continued expansion of the AEIC broadband network has allowed for more reliable calculations of the earthquake source parameters through inclusion of more waveform data into inversion.
- Worked on inclusion of calculated moment magnitude Mw values into the real-time earthquake database at AEIC. This is important for larger events when ML values get saturated.
- Worked on development of the following two tsunami early warning systems:

Part One: Development and Implementation of Continuous Moment Tensor Scanning for Offshore Seismicity and Tsunami Early Warning (Aurélie Guilhem and Douglas S. Dreger, Berkeley Seismological Laboratory)

Research Objectives

To more effectively monitor the offshore region of Alaska for large possibly tsunamigenic earthquakes, we are implementing an approach for the automatic continuous scanning of long-period (100 to 200 sec) seismic records based on the GridMT method proposed by Kawakatsu (1998) and implemented by Tsuruoka et al (2009). For great earthquakes regional network stations are in the nearfield and to fully recover the source process a finite-source inversion is required. Such inversions however are relatively slow and cannot be done in realtime on streaming data. Thus we are using a modified GridMT concept to account for finite-rupture. We aim to accomplish this by developing composite quasi-finite-source Green's functions using a method being developed as part of a Northern California U.S. Geological Survey (USGS) National Earthquake Hazard Reduction Program (NEHRP) research project. These quasi-finite-source Green's functions are constructed by combining point-source Green's functions distributed spatially, but which can still be treated as point-source Green's functions in the GridMT method. They account for nearfield source-receiver geometry as well as rupture directivity.

Approach

The continuous seismic scanning algorithm proposed by Kawakatsu (1998) and implemented by Tsuruoka et al. (2009) at the University of Tokyo Earthquake Research Institute (ERI) allows for the analysis of events ranging in size from 3.5 to 8+. Briefly, this method recognizes that the linear moment tensor inversion is composed of the autocorrelation of Green's functions and cross correlations of Green's functions with observed waveforms. This cross correlation may be obtained continuously on a streaming data set given adequate computational resources. The autocorrelation only needs to be done once, in advance, saving computation time. Equation 1 gives the linear relationship between the Green's functions (G), the moment tensor (M), and observed seismic waveforms (d):

$$GM = d \qquad (1)$$

The solution to (1) is,

$$M = \left[(G^T G)^{-1} G^T\right] d \qquad (2)$$

The $\left[(G^T G)^{-1} G^T\right]$ matrix is constructed for a predefined grid of virtual sources and seismic stations that are used in the analysis. The Green's functions are for point-sources computed for each source point in a spatially extensive grid. Figure 1 shows the extent of the grid being used for the Mendocino region. The Green's functions and the $\left[(G^T G)^{-1} G^T\right]$matrix may be precomputed and stored in computer memory thereby reducing processing time. The right hand side of equation 2 is essentially the convolution of the Green's functions with the data, and in GridMT (Tsuruoka et al., 2009) this convolution is performed every 2 seconds on the streaming data field considering several thousand source locations. The fit for all source locations is monitored at each time step, and when the fit rises to a defined level the algorithm has automatically detected, located, and determined the scalar seismic moment and focal mechanism of the event.

We are implementing two parallel running algorithms: one focusing on M<8 earthquakes by scanning data filtered between 20 and 50 seconds period and another on large, potentially tsunamigenic events (M>8) with data filtered between 100 and 200 sec period. The onshore, regional distance stations are effectively in the nearfield of great earthquakes, and finite-source effects will be considerable in the recorded seismograms. Two things are done to minimize this in the processing. The first is to consider a longer period passband, 100 to 200 second period, so that the fast point-source assumption is more valid. The second is to use quasi-finite-source Green's functions which are obtained by combining the Green's functions from spatially distributed source points. These Green's functions account for differences in the back azimuth and the effective radiation pattern for a distributed source rupture, yet allows us to maintain the point-source inversion scheme that enables fast continuous processing. Line-source or planar finite-source inversions, while more appropriate for the study of great earthquake source processes, are too slow for a realtime processing environment needed for tsunami early warning.

Accomplishments

We have developed the core software that performs recursive filtering on waveform data and the continuous determination of seismic moment tensors using the GridMT approach for the Mendocino region. This same software is now being applied to Alaska network data.

We have tested large magnitude earthquake continuous moment tensor scanning by using synthetic data sets from three different spatially-variable finite-source kinematic models. These models are for Mw 8.2 earthquakes. Figure 1 shows the map of the Mendocino region, the extent of the Mw 8.2 finite-source model to construct synthetic data, and the locations of source points and stations used in the inversion. The scanning algorithm results show a strong correlation with the region of large fault slip. They also identify the spatial extent of the Mw 8.2 synthetic earthquake. The GridMT inversion of 100 to 200 seconds period waves, using a single point-source Green's function, recovers the correct scalar moment and focal mechanism with a fit of 66.5% (variance reduction measure). In Figure 2 the waveform fit and moment tensor solution obtained using quasi-finite-source Green's functions for three spatially distinct point-sources is shown. The fit to the synthetic data increases to 75% using the quasi-finite-source Green's functions. The spatial extent of the quasi-finite-source Green's functions is shown in Figure 1 (circles with black dots).

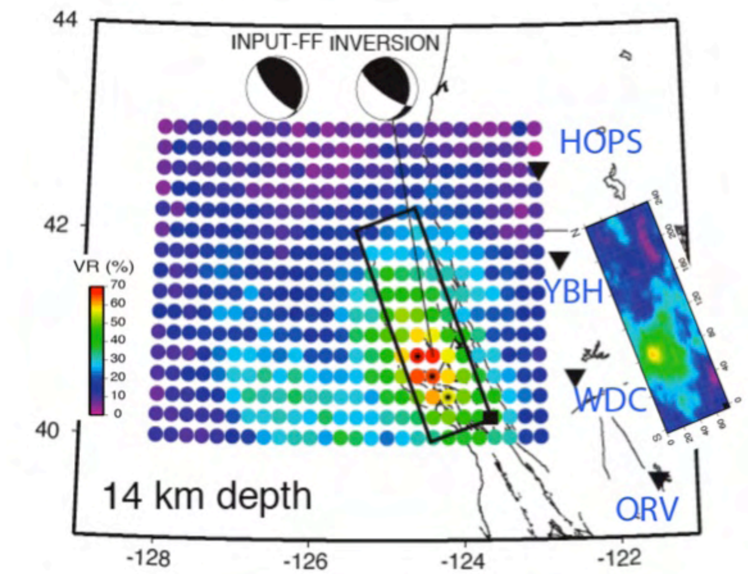


Figure 1. Map showing input mechanism, inversion result, extent of finite-source model (rectangle), stations (triangles), input variable slip model, and point-source solution results (circles, color showing variance reduction measure of fit). The solution circles with a black dot at the center identify the three point-sources used to construct the quasi-finite-source Green's functions.

We are in the process of examining different source-point offsets and configurations of point-source Green's functions to improve the quasi-finite-source Green's function performance in modeling large extended ruptures.

This work was performed as part of a National Earthquake Hazards Reduction Program (NEHRP) Northern California Panel research project. These results have been submitted for publication (Guilhem and Dreger, submitted).

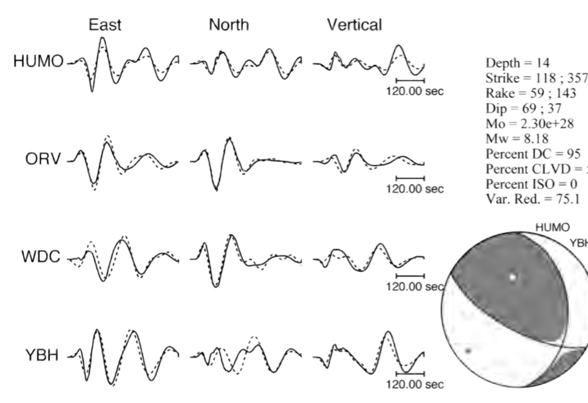


Figure 2. GridMT inversion result using three point-source quasi-finite-source Green's functions. Finite-source synthetic data is shown as solid lines and quasi-finite-source synthetics are shown as dashed lines. The level of fit increases from 66.5% to 75% using the quasi-finite-source Green's functions. The correct scalar seismic moment and focal mechanism are obtained by the inversion.

VERIFICATION OF LOW-FREQUENCY ACCELERATION RECORDINGS

On 11 March 2011 a devastating Mw 9.0 earthquake and tsunami struck the Tohoku region of Japan. This is precisely the type of event that we are developing our system to consider. Tide gauges showed that the damaging tsunami waves arrived between 20 to 30 minutes following the occurrence of the earthquake at the coastal regions immediately to the west of the offshore earthquake rupture. Given the proposed processing time of 8 minutes to determine the event location, seismic moment tensor and Mw this system could provide on the order of 10 to 20 minutes of warning that a potentially tsunamigenic event has occurred.

One uncertainty in the development of this system, however, has been the capability of accelerometers in recording very low frequency (0.005 to 0.01 Hz) motions, and being able to process those motions to velocity or even displacement. Since weak motion instruments will be off scale, and double integration to displacement at low frequency is difficult, we are choosing to use the filtered acceleration data directly. The extensive Japanese seismic networks recorded the 11 March 2011 Mw 9.0 event with exceptional fidelity, and those data demonstrate that such strong motion systems are capable of recording the very low frequency accelerations in the near-field of the earthquake. Figure 3 compares three-component broadband acceleration waveforms with causally filtered accelerations in the 0.005 to 0.01 Hz passband, and shows that long-period waves were well recorded, and stable.

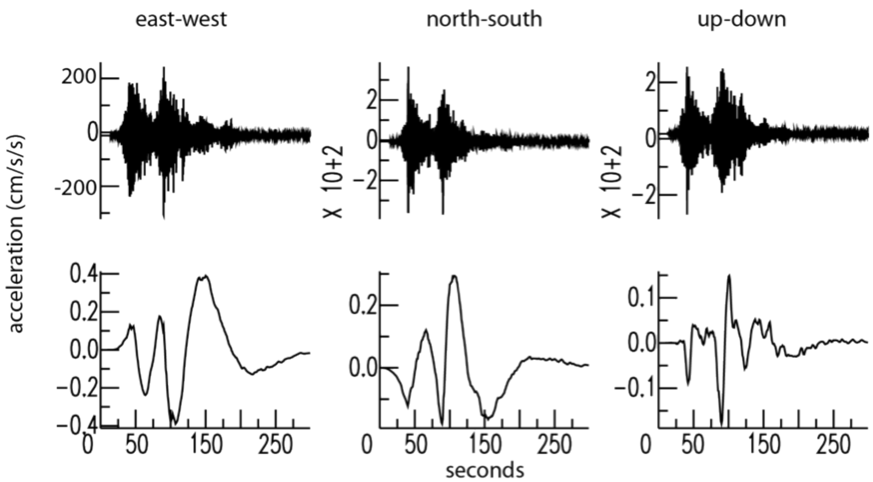


Figure 3. (top row) Unfiltered, three-component acceleration recorded at National Research Institute for Earth Science & Disaster Prevention (NIED) station MYG008 (located at Lat: 38.5769; Lon: 141.4514; 52.4 km from epicenter). The record is 5 minutes long, and shows two wave packets each about 50 seconds in duration. The peak acceleration on the north-south component is 37.9%g. (bottom row) The same seismograms have been bandpass filtered between 0.005 to 0.01 Hz with a causal Butterworth filter.

In Figure 4 we show the slip model obtained by Shao, Ji, and Hayes (2011, Chen Ji's large earthquake website, U.C. Santa Barbara, http://www.geol.ucsb.edu/faculty/ji/) for the 11 March 2011 event. The peak slip in this model is approximately 58 m, and if this holds it represents the largest slip ever observed in an earthquake. The slip model is shown plotted in our Mendocino test region. We used this model to simulate seismograms for the Mw 9.0 earthquake (the Shao model gives Mw 9.1). The GridMT results show the location of the event, and the level of fit that was obtained. This result uses simple point-source Green's functions, and a reverse mechanism and Mw of 9.2 were obtained. It is expected that the fit to the synthetic data and the solution will improve when the quasi-finite-source Green's functions are considered, which is the focus of ongoing work.

In Figure 5 raw accelerograms, and bandpass filtered (0.005 to 0.01 Hz) velocity integrated from acceleration observed at NIED site MYG004 (Lat: 38.7292; Lon: 141.0217; 75.1 km from epicenter) are compared to a velocity synthetic obtained from the kinematic simulation using the Shao et al. (2011) slip model for the Tohoku earthquake. We did not simulate the actual source receiver geometry, but rather used the northern California geometry as discussed above (e.g. Figure 4). Nevertheless the synthetics for station YBH compare well with the observations from MYG004 in terms of the frequency content and the amplitudes. This test of GridMT and the waveform comparisons indicate that the method and our choice for filter parameters is appropriate for analyzing great earthquakes in the Mendocino and the Alaska regions.

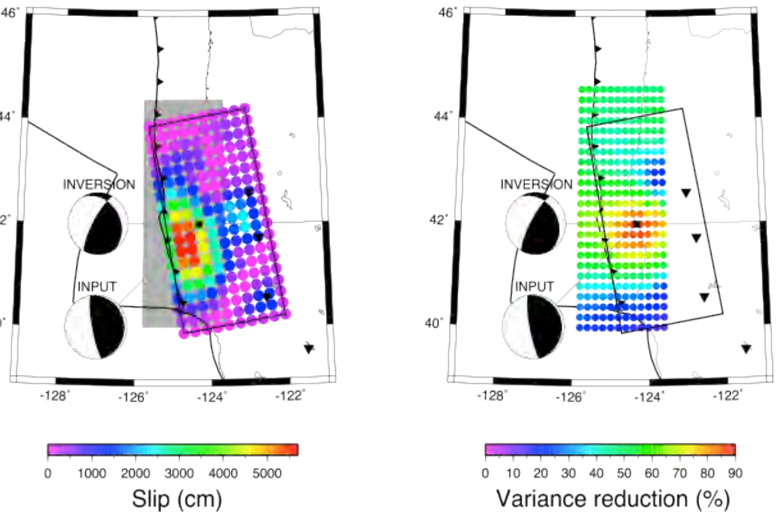


Figure 4. (left) The Shao, Ji and Hayes slip model for the 11 March 2011 Tohoku, Japan earthquake plotted in the Cape Mendocino setting. Onshore stations are shown as inverted triangles. (right) Results of the GridMT analysis of the synthetic Mw 9.0 data and the four BDSN stations. The input and recovered focal mechanisms are also compared.

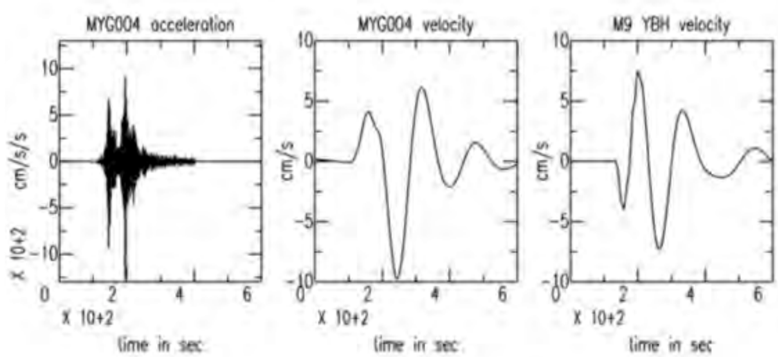


Figure 5. Raw vertical component acceleration from NIED station MYG004. (middle)

Conference presentations

Oral presentations

Guilhem, A., D.S. Dreger and R. Uhrhammer. 2010. A continuous moment tensor analysis in the region of the Mendocino triple junction, California. Seismological Society of America Annual Meeting, 21–23 April, Portland, Oregon.

Work toward implementation in Alaska

The scripts developed for the Mendocino project to compute the Green's functions at a grid of points as well as to construct the $\left[(G^T G)^{-1} G^T\right]$ matrix have been completed and are being used to set up the example processing systems for the Alaska region.

In Figure 6 we show the processing test grid for M<8 earthquakes. In this grid there are 5,520 grid points (345 horizontal x 16 depth locations). Source depths of 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100, 120, 140, 160, 180 and 200 are considered. Green's functions were computed for each source point to the five stations that will be used. The stations BRLK, KDAK, RC01, SII, and VMT were chosen to give good coverage for the region. Three velocity models, obtained from Roger Hansen, for the Aleutian Islands region east, Central Alaska (north of 62.5N latitude) and Southern Alaska (south of 62.5N latitude and east of 157W longitude) are used to compute Green's functions. The test region shown in Figure 6 utilizes the Southern Alaska model.

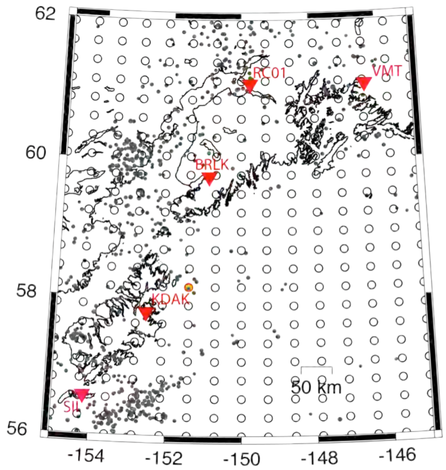


Figure 6. Stations are shown as red triangles, virtual source locations as unfilled circles, and the location of a synthetic test event is shown as the orange circle. Seismicity is shown as gray dots.

To test the software synthetic velocity data was constructed for a source located at the (5,8) grid point (orange circle, Figure 3) at a depth of 30 km. The data and Green's functions were filtered using a causal bandpass filter with corners of 0.02 to and 0.045 Hz. Figure 7 shows the results of the gridMT calculation. All of the source parameters, location, depth, origin time, scalar seismic moment, and focal mechanism were correctly determined.

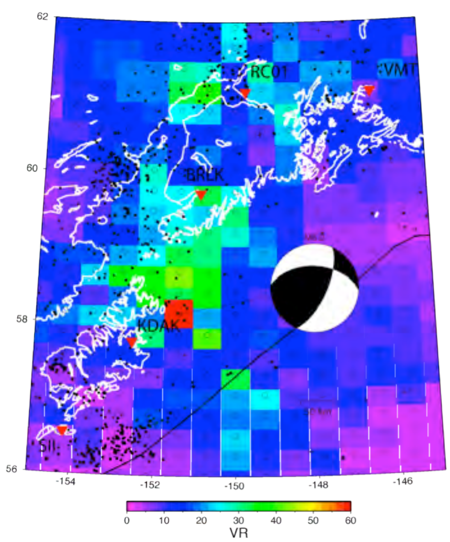


Figure 7. Data fit for a synthetic data test case. The location, depth, origin time and focal parameters were all correctly determined. The best fit was found to be 91%.

We are now in the process of testing the system for several real events within the test region with magnitude between 4 and 7. We will evaluate the performance of the system for recovery of location and focal parameters under varying noise conditions. Since station outages and telemetry interruptions are possible we will test the system for missing data cases.

The second region will extend southwest from the western end of Kodiak Island to Dutch Harbor (Figure 8). In this 1000 km long monitoring region we will set up a system for the scanning of 100 to 200 seconds period data using quasi-finite-source Green's functions to monitor for large M>8, located on the subduction contact zone. The total number of virtual sources in this model space will also be limited by a maximum number of 5000, and will be focused on sampling the contact region of the subduction zone. We will test the method for synthetic M>8 events and evaluate the performance for different configurations of quasi-finite-source Green's functions.

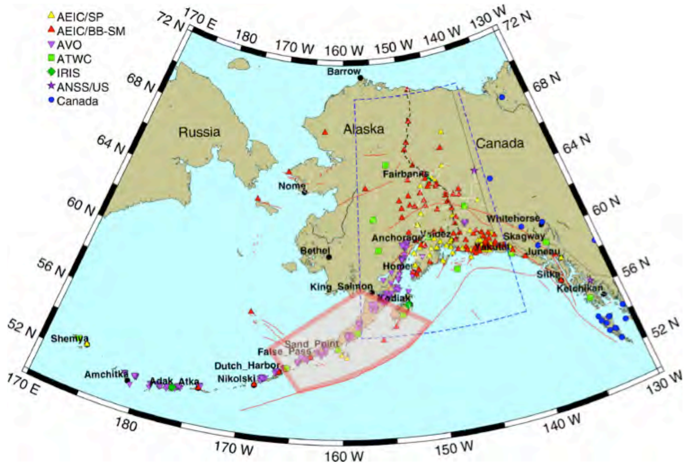


Figure 8. Map showing the location of the Aleutian arc. Stations from various networks are shown. The light red polygon shows the proposed test region for the M>8 earthquakes.

References

Guilhem, A. and D.S. Dreger. Rapid detection and characterization of large earthquakes using quasi-finite source Green's functions in continuous moment tensor inversion. Submitted to *Geophysical Research Letters.*

Kawakatsu, H. 1998. On the realtime monitoring of the long-period seismic wavefield. *Bulletin of the Earthquake Research Institute*, 7:267–274.

Tsuruoka, H., H. Kawakatsu and T. Urabe. 2009. GRiD MT (Grid-based Realtime Determination of Moment Tensors) monitoring the long-period seismic wavefield. *Physics of the Earth and Planetary Interiors*, 175:8–16. doi:10.1016/j.pepi.2008.02.014.

Part 2: Development of GPS Shield Technique for Tsunami Early Warning (Natalia Ruppert and Anna Bulanova, University of Alaska Fairbanks)

Research Objectives

We have also been working towards implementing Sobolev and Babeyko's (Sobolev et al., 2007; Heochner et al., 2008) "GPS Shield" approach for using near-real-time GPS static displacement data to rapidly estimate the tsunamigenic potential of large earthquakes near Alaska.

In the event of a significant undersea earthquake, evaluating the potential for destructive tsunami waves requires quickly estimating moment magnitude along with faulting parameters such as length, width and slip. Accurate estimation of moment magnitude using seismic data might take more than a day, which is unacceptable for early warning. Our project is concerned with using near-real-time GPS static displacement data to determine an earthquake's tsunamigenic potential within minutes.

Approach

Our approach estimates moment magnitude and faulting parameters by comparing an event's GPS displacement data to earthquake scenarios stored in a large database. For each scenario, the database includes its epicenter, moment magnitude, and GPS displacement data. The parameters of a new earthquake can be estimated quickly by matching it to the database scenario that best fits its GPS displacement data. The database approach is much faster than optimization techniques, which are preferable for scientific analysis but take too long for tsunami forecasting. In the case of a database containing about 14,000 earthquakes, the inversion time is under 3 seconds on a Sparc SunBlade 1500 workstation.

Accomplishments

Last year, we determined the sensitivity of our existing array of GPS sites in the Prince William Sound region and coastal areas of southern Alaska and Kodiak Island. This year's goal was to extend the testing area to the Aleutian arc.

At the first stage we created a digital fault model of the Aleutian megathrust extending from the Prince William Sound region in the east to Shemya Island in the west, based on the data from USGS http://earthquake.usgs.gov/research/data/slab/

and the RUM (Regionalized Upper Mantle seismic model of the earth) project http://rses.anu.edu.au/seismology/projects/RUM/rum_download.html .
The discretized interface is composed of 2000 rectangular subfaults (20 down dip and 100 along the strike of the interface) and extends down to 100 km depth (Figure 1).

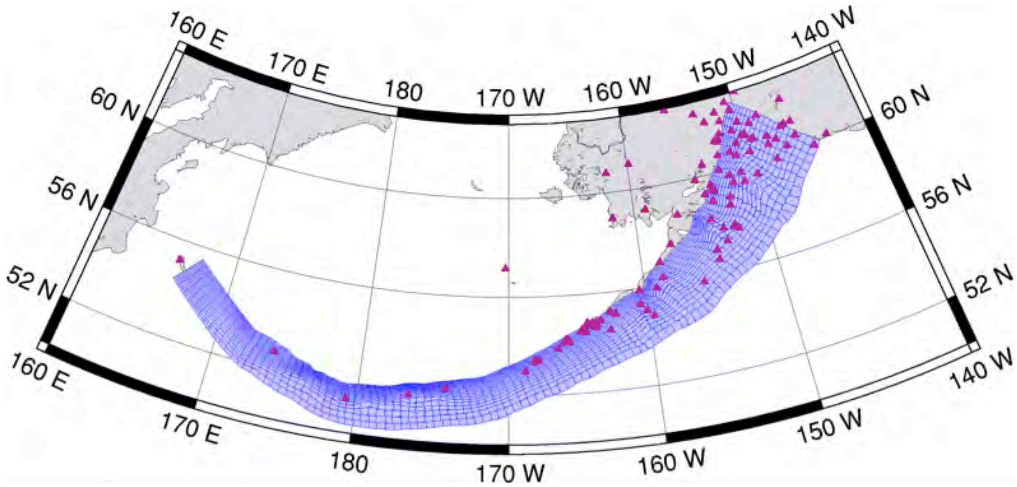


Figure 1. Digital fault model of the Aleutian megathrust.

Next, we created a database of 15,393 earthquake scenarios with magnitudes ranging from 7.0 to 9.6 with a step of 0.2. Each scenario contains information about magnitude, epicenter, and surface displacements at a given set of GPS sites. Scenarios were created using the IASP 91 velocity model. For each epicenter and magnitude, rupture dimensions were set to length=2*width, with slip distribution symmetrical along the rupture width and uniform along the rupture length (Geist and Dmowska, 1999).

The next goal was to determine the sensitivity of the existing distribution of GPS sites in the Aleutian arc and southern Alaska. We took each scenario, added random errors (up to 2 cm) to the surface displacements and searched which scenario fitted this displacement the best. This was done 100 times (with different errors) for each scenario. Recovery was judged successful when magnitude discrepancies were no greater than 0.2 and location errors were no greater than 1 degree in at least 90 cases out of 100 (Figure 2).

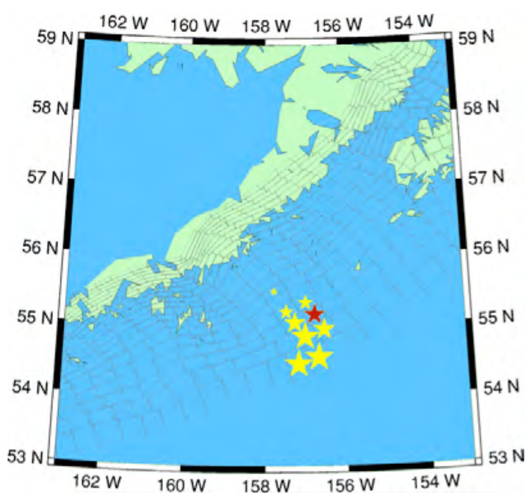


Figure 2. Resulting best fit scenarios are shown by yellow stars (M7.2-7.8). Red star shows the true location.

We found that we could successfully recover earthquakes with magnitudes as low as 7 when they occurred close to GPS sites (e.g., southern Alaska). For earthquakes without near-field GPS sites, minimum magnitude for successful recovery is 8 or greater (e.g., central and western Aleutians) (Figure 3).

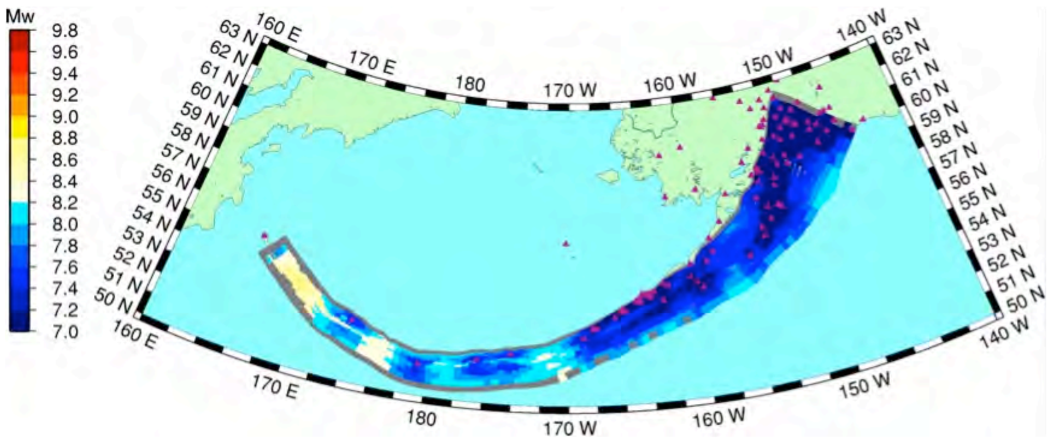


Figure 3. Successful recovery of earthquake scenarios by Mw.

For example, in the case of a large earthquake (M>=8) in an area with dense GPS coverage, magnitude and location of the earthquake is recovered with required misfits of no more than 0.2 magnitude and 1 degree in epicenter (Figure 4).

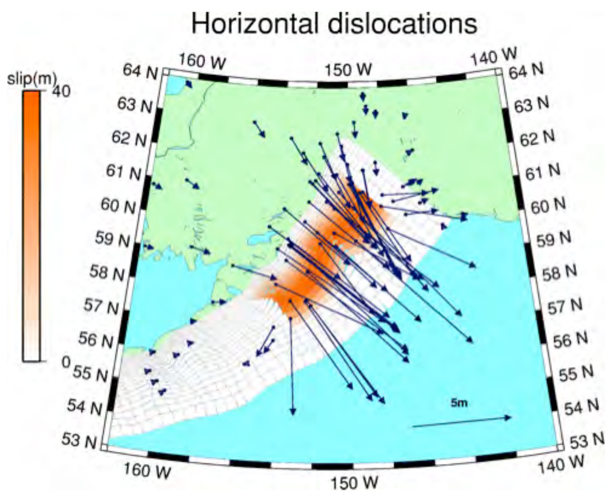


Figure 4. Mw 9.2, epicenter 152W, 59N. Orange shows amount of slip on the fault. Blue arrows are horizontal surface displacements.

The network is sparser on the Alaska Peninsula and across the Aleutian Arc. It is, however, adequate to constrain earthquakes that produce surface displacements on the order of several meters (Figure 5).

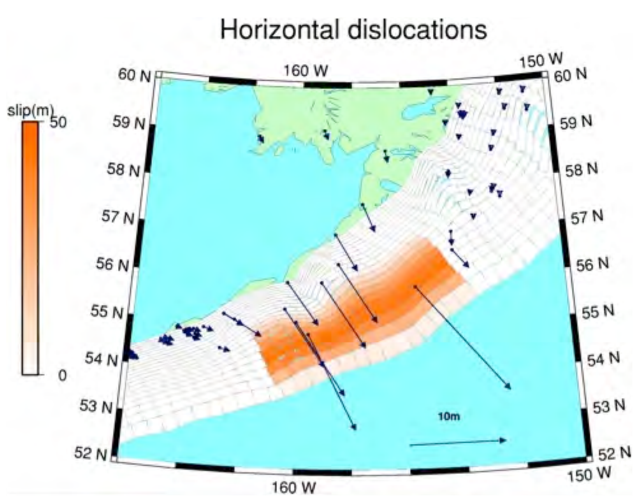


Figure 5. Successfully recovered Alaska Peninsula event with Mw 9.2 and epicenter at 157W, 55N.

Although GPS coverage is sparsest in the Aleutian Arc, we were still able to successfully recover large events (Figure 6). However, magnitude and location may be poorly constrained with misfits of more than 0.2 in magnitude and 1 degree in epicenter.

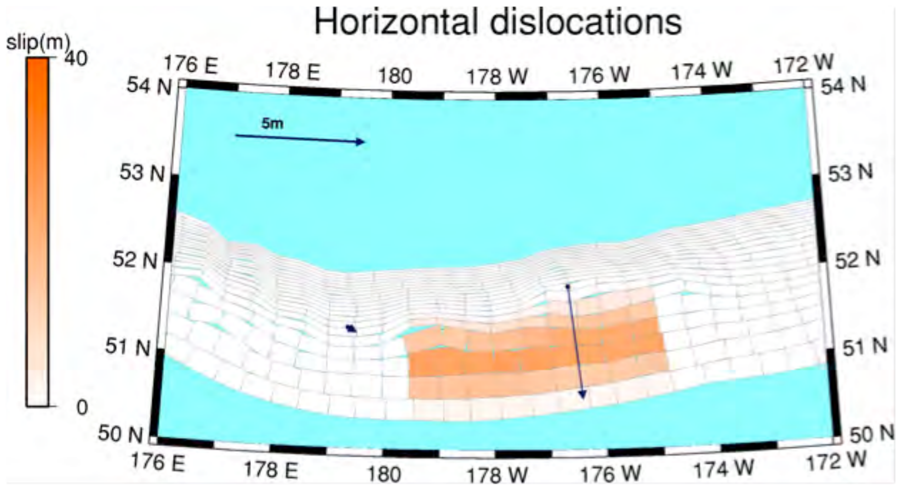


Figure 6. Mw 8.8, epicenter at 177W, 51N. Despite the sparseness of the network, this scenario was recovered in 90% of test runs.

Future directions

Create a prototype real time warning system and run tests with actual data (double integrated strong motion recordings may be used as a proxy for displacements). The system will use the following process:

1) A major earthquake (M>=7) is detected by the real-time system at AEIC and/or recorded surface displacements or acceleration exceed a set threshold
2) Assemble all available surface deformation data. Surface displacement data may come from GPS measurements, or from double integrated strong motion data.
3) Search for an earthquake scenario that fits recorded data best in a least-squares rms sense.
4) Output magnitude and location of the best fit scenario earthquake.
5) If Mw > threshold, initiate further procedures (for example: find the corresponding event in an appropriate database and update it; initiate alarms).

Integrated acceleration data may be used for testing purposes instead of GPS displacement data, but it is not very reliable. To actually use this system for real time warning, we will need to upgrade as many of our GPS stations as possible to provide near-real-time data.

We also plan to calculate more database scenarios for alternative rupture models. The options we are considering now are: using scaling law from Wells and Coppersmith (1994), using asymmetrical slip along rupture width, using non-uniform (tapered) slip along rupture length, or using uniform slip.

References

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Hoechner, A., A. Babeyko, and S. Sobolev. 2008. Enhanced GPS inversion technique applied to the 2004 Sumatra earthquake and tsunami. *Geophysical Research Letters*, 35, L08310.

Sobolev, S., A. Babeyko, R. Wang, A. Hoechner, R. Galas, M. Rothacher, D. Sein, J. Schroter, J. Lauterjung and C. Subarya. 2007. Tsunami early warning using GPS-Shield arrays. *Journal of Geophysical Research*, 112, B08415.

Wells, D. and K. Coppersmith. 1994. New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacements. *Bulletin of the Seismological Society of America*, 84(4):974–1002.

NOAA relevance/societal benefits

Rapid calculation of earthquake source parameters through the moment tensor inversion allows scientists to determine sense of motion along the ruptured fault. While many other conditions determine whether an earthquake is capable of generating potentially destructive tsunamis, the foremost condition is the type of earthquake source (underthrusting vs. normal or strike-slip) and size.

Education

Nothing to report.

Publications, conference papers, and presentations

Peer-reviewed

Ruppert, N.A., S. Prejean and R.A. Hansen. 2011. Seismic swarm associated with the 2008 eruption of Kasotochi Volcano, Alaska: Earthquake locations and source parameters. *Journal of Geophysical Research*, 116, B00B07, doi:10.1029/2010JB007435.

Ruppert, N.A. and R. A. Hansen. 2010. Temporal and spatial variations of local magnitudes in Alaska and Aleutians and comparison with body-wave and moment magnitudes. *Bulletin of the Seismological Society of America*, 100(3):1174–1183, doi:10.1785/0120090172.

Other products and outcomes

Nothing to report.

Partner organizations and collaborators

Nothing to report.

TWEAK Task 5: Assessment of tsunami hazard and wave run-up

Roger Hansen, PI

University of Alaska Fairbanks

Other investigators/professionals associated with this project:

Elena Suleimani, Dmitry Nicolsky, Dave West, *University of Alaska Fairbanks;* ***Rod Combellick,*** *State of Alaska Division of Geological and Geophysical Surveys*

Primary objectives

This task is a continuation of the original TWEAK initiative to complete hazard and risk assessment through inundation modeling in more than 70 Alaskan communities. Bathymetry and topography for these communities are needed as necessary input for creating community inundation maps, which are utilized for defining evacuation routes for the at-risk communities.

Research accomplishments/highlights/findings

The AEIC's numerical model for tsunami propagation and runup is now officially benchmarked and validated (Nicolsky et al., in press). We are in the process of finalizing the high-resolution (15-meter) grid of Sitka, Alaska that will be used in the Sitka tsunami inundation mapping project (Figure 1). Sitka is a community in southeastern Alaska that is exposed to tsunami risk from both local and distant trans-Pacific tsunamis. A number of data sources were used to compile a seamless Sitka Digital Elevation Model (DEM) that includes both topography and bathymetry data. Topography data sets used in the DEM construction are Shuttle Radar Topography Mission (SRTM) data, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data, and the 2005 DEM of the town of Sitka compiled by Delta Aerial Surveys, LTD. The bathymetric data came from the US Army Corps of Engineers (USACE) surveys, National Ocean Service Bathymetric Attributed Grid (NOS BAG) surveys, NOS hydrographic surveys, National Geographic Data Center (NGDC) multi-beam surveys, and NGDC Trackline and NOAA Electronic Navigational Chart soundings. The third input data component is the coastline, placement of which is of great importance to this project because the final DEM will be used to model the extent of tsunami inundation. The source of the coastline data was the Digital Terrain Model (DTM) used by Delta Aerial Surveys, LTD to ortho-rectify the stereo photography provided by the City of Sitka. The evaluation process entailed visual inspection of the coastline over high-resolution digital ortho-photography of the study area. Figure 2 shows the resulting Sitka digital elevation model (DEM) derived from the data sets described above.

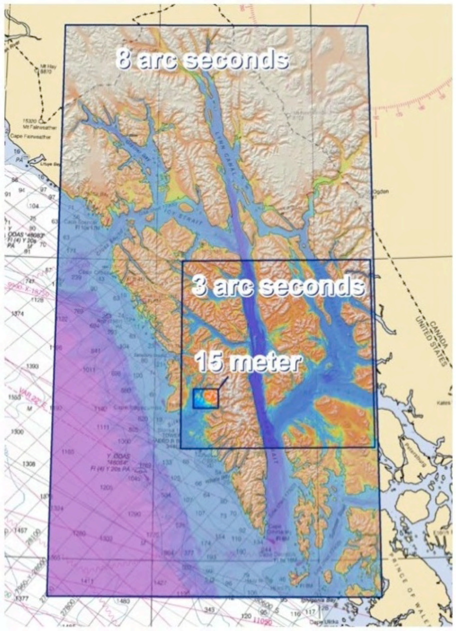


Figure 1. Location of the 15-m resolution grid of Sitka inside the 3-arc second and 8-arc second resolution grids, which were provided to AEIC by the National Geographic Data Center of NOAA.

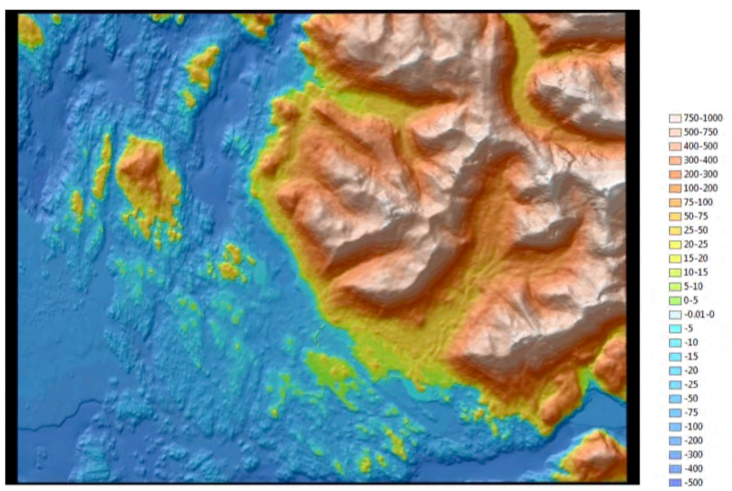


Figure 2. The resulting Sitka DEM of 15-meter resolution. The scale indicates elevations in meters.

In the Alaska Tsunami Inundation Mapping project, we are shifting our efforts to model the communities located in the regions for which we do not have defined hypothetical scenarios. The three critical areas are:

- Aleutian Islands (Akutan, Unalaska, Dutch Harbor, Sand Point, Nikolski)
- Yakataga region (Cordova, Yakutat)
- Southeast Alaska (Sitka, Elfin Cove, Gustavus, Hoonah, Juneau)

In order to conduct tsunami inundation mapping of these regions, we will have to create defendable tsunami scenarios. Our goal is to construct tsunami source functions with prescribed fault geometry and slip distribution. One of the potentially tsunamigenic earthquakes that will affect the Alaska coast as well as the west coast of the US and Canada is shown in Figure 3. This scenario includes the rupture areas of the 1788, 1938, 1946 earthquakes and the eastern end of the 1957 rupture area. This event has a moment magnitude of 8.9. We are in the process of constructing the tsunami source function for this earthquake and defining potential tsunami sources for other segments of the Alaska-Aleutian subduction zone and the Queen Charlotte Islands - Alaska Panhandle margin.

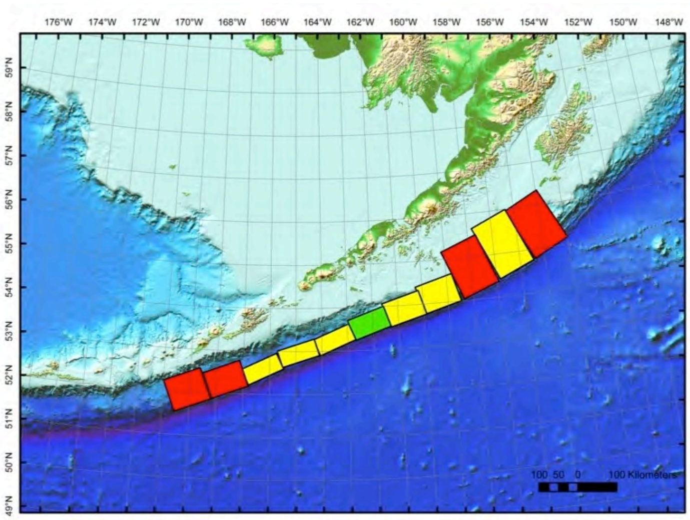


Figure 3. A tsunamigenic earthquake source from Ryan et al. (2010). Red color indicates subfaults with 8-10 m of slip, yellow color – subfaults with 6 m of slip, and green color – subfaults with 1 m of slip.

We have performed inundation modeling and mapping for the city of Valdez, Alaska, and compiled preliminary inundation maps. We used numerical modeling to estimate the extent of inundation due to tsunami waves generated by tectonic sources. Our tsunami scenarios included a repeat of the tsunami triggered by the 1964 Great Alaska Earthquake represented by 2 different source functions, as well as tsunami waves generated by a hypothetically extended 1964 rupture, a hypothetical Yakataga Gap earthquake in northeast Gulf of Alaska, a Cascadia subduction zone rupture, and hypothetical earthquakes in Prince William Sound and Kodiak asperities of the 1964 rupture. Results of numerical modeling combined with historical observations in the region are intended to help local emergency officials with evacuation planning and public education for reducing future tsunami hazard. Figure 4 shows the maximum composite calculated extent of inundation for all scenarios, and the maximum composite flow depths over dry land. Figure 5 illustrates the difference in inundation areas caused by the repeat of the 1964 scenario and the distant tsunami event originated in the Cascadia subduction zone.

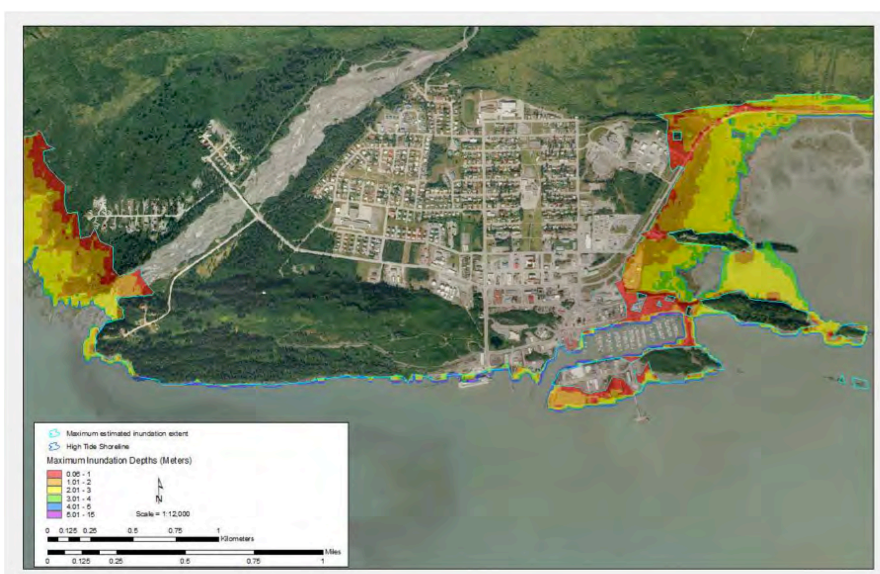


Figure 4. The maximum composite calculated extent of tsunami inundation for all tectonic scenarios, and the maximum composite flow depths over dry land in the town of Valdez.

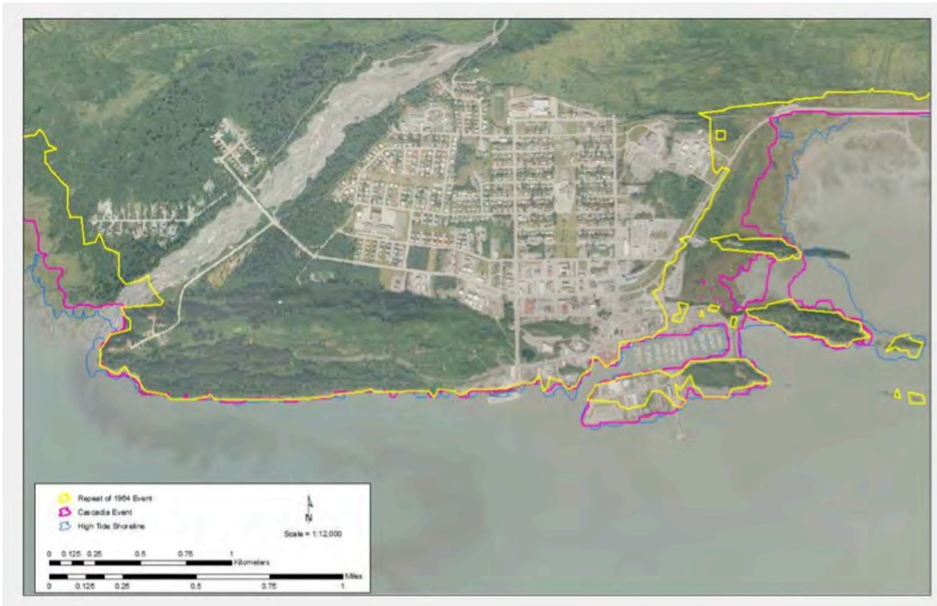


Figure 5. Calculated extent of tsunami inundation of Valdez for two tectonic scenarios, a repeat of the 1964 earthquake and a scenario with a distant tsunami source in the Cascadia subduction zone. Calculations were performed using a numerical grid with MHHW vertical datum.

Accuracy of the high-resolution DEMs developed by NOAA is determined by the topographic datasets with vertical accuracy of 10–15 meters. Since the DEMs can possess large vertical errors near the shoreline, prediction of the potential tsunami inundation can be invalid. Hence, under TWEAK funding that covers travel to communities for verification of DEMs for tsunami inundation mapping, we have conducted quality control of tsunami inundation grids for Cordova, Tatitlek, and Chenega. The surveys were conducted in May, October and November 2010. Locations of the GPS measurements in Tatitlek are shown as black crosses in Figure 6.

The collected GPS data allowed scientists at the National Geographic Data Center (NGDC) to check the quality of different topographic elevation datasets (e.g., ASTER, NED, SPOT, SRTM) for the above-mentioned locations. SPOT data was found to have the most representative elevations for the region. Therefore, the SPOT data were employed by NGDC to develop the Chenega Bay DEM for the Alaska Tsunami Mapping Program. Based on the developed DEM, we started to estimate potential inundation in Tatitlek and Chenega.

Our numerical modeling studies were conducted using a recently developed model of tsunami propagation and runup that simulates tsunami waves in the framework of non-linear shallow water theory (Nicolsky et al., in press). The code adopts a staggered leapfrog finite-difference scheme to solve the shallow water equations formulated for depth-averaged water fluxes in spherical coordinates. A temporal position of the shoreline is calculated using a free-surface moving boundary algorithm. For large-scale problems, the developed algorithm is efficiently parallelized employing a domain decomposition technique. The developed numerical model is benchmarked in an exhaustive series of tests suggested by NOAA. We conducted analytical and laboratory benchmarking for the cases of solitary wave runup on simple beaches, runup of a solitary wave on a conically-shaped island, and the runup in the Monai Valley, Okushiri Island, Japan, during the 1993 Hokkaido-Nansei-Oki tsunami. In all conducted tests the calculated numerical solution is within an accuracy recommended by NOAA standards. The developed model was presented at the 2011 NTHMP Model Validation Workshop in Galveston, Texas, where a group of experts approved the developed model for modeling potential tsunami inundation. The results are published in *Pure and Applied Geophysics*.

Results of our preliminary modeling for Chenega and Tatitlek are shown in Figure 7 and 8.

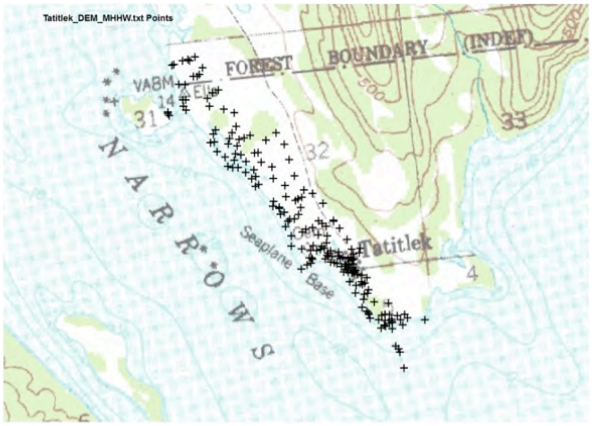


Figure 6. Location of RTK GPS measurements in the near-shore areas of Tatitlek.

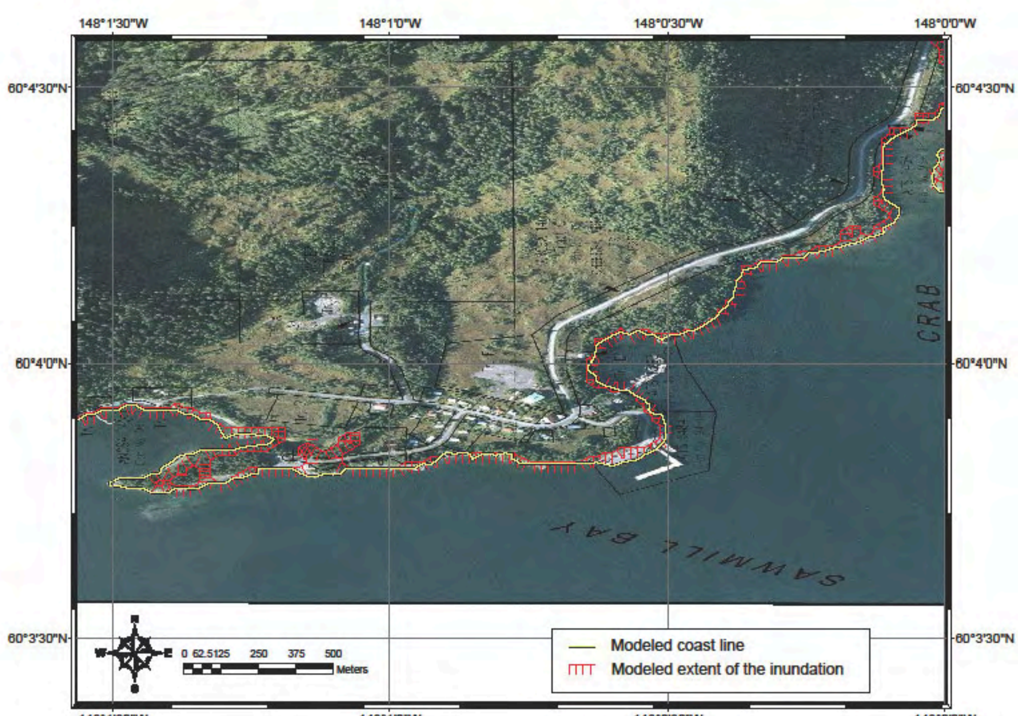


Figure 7. Preliminary modeling of the potential inundation of Chenega.

Figure 8. Preliminary modeling of the potential inundation of Tatitlek.

We have also completed a thorough numerical model of the wave dynamics in Passage Canal, Alaska during the M_W 9.2 megathrust earthquake. During the earthquake, several types of waves were identified at the city of Whittier, located at the head of Passage Canal. The first wave was thought to have been a seiche, while the other two waves were probably triggered by submarine landslides. We modeled the seiche wave, landslide-generated tsunami, and tectonic tsunami in Passage Canal and computed inundation by each type of wave during the 1964 event. The simulated inundation by the seiche, landslide-generated tsunami, and tectonic tsunami (see Figure 9) can help to mitigate tsunami hazards and prepare Whittier for a potential tsunami. The obtained results were presented at the 2010 Meeting of the European Geophysical Union in Vienna, Austria and later published in *Natural Hazards and Earth System Sciences*.

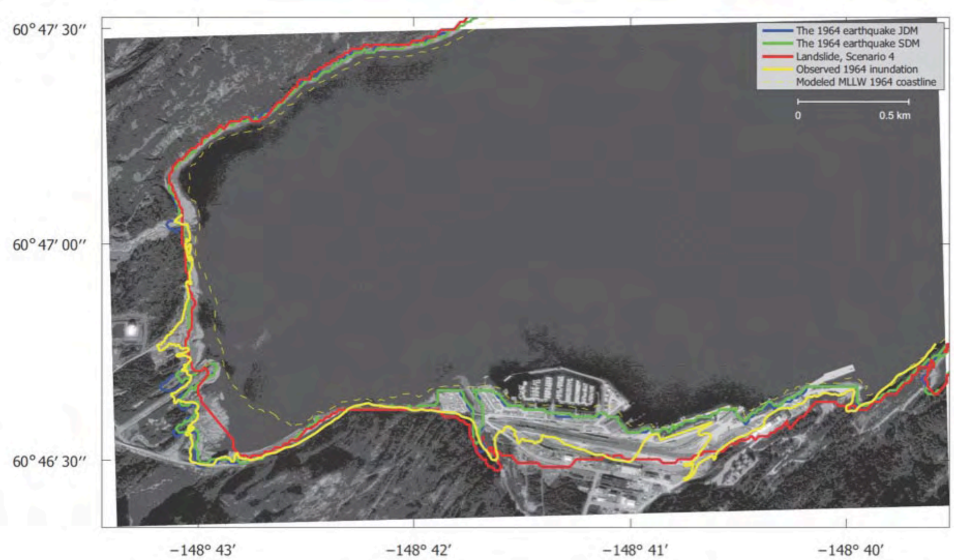


Figure 9. Observed and modeled 1964 inundation of Whittier caused by tectonic and landslide-generated waves. The yellow line represents the observed inundation after the 1964 tsunami. The modeled MLLW shoreline before the earthquake is shown by a dashed yellow line. The DEM height corresponds to the pre-earthquake sea level datum. Earthquake JDM and SDM represent two possible coseismic deformation models of the 1964 event.

Education and outreach

The new Science On a Sphere (SOS) project called "Tsunami" was produced by NOAA in partnership with NTHMP (http://sos.noaa.gov/datasets/extras/tsunami.html). This narrated production commemorates the 5th anniversary of the 2004 Indian Ocean tsunami and uses the tsunami animations of tectonic and landslide-generated waves produced by AEIC in cooperation with ARSC. We provided high-resolution imagery and graphics to the Geophysical Institute Information Office to be used in updating the backlit display boards in the Globe Room. The boards will show results of recent tsunami studies of tectonic and landslide-generated tsunamis in Seward, Alaska, during the 1964 Great Alaska Earthquake. We have delivered 11 tsunami animations, which were produced by AEIC in cooperation with ARSC, to the Tsunami Museum in Hilo, Hawaii to be used in their new interactive displays.

Publications, conference papers, and presentations

Peer-reviewed publications

Nicolsky, D.J., E.N. Suleimani and R.A. Hansen. 2010. Numerical modeling of the 1964 Alaska tsunami in western Passage Canal and Whittier, Alaska. *Natural Hazards and Earth System Sciences*, 10:2489–2505, doi:10.5194/nhess-10-1-2010.

In press (peer-reviewed)

Suleimani, E., D.J. Nicolsky, P.J. Haeussler and R. Hansen. Combined effects of tectonic and landslide-generated tsunami runup at Seward, Alaska, during the Mw 9.2 1964 earthquake. *Pure and Applied Geophysics*, doi:10.1007/s00024-010-0228-4, *in press*. [available online 30 November 2010]

Nicolsky, D.J., E.N. Suleimani and R.A. Hansen. Validation and verification of a numerical model for tsunami propagation and runup. *Pure and Applied Geophysics*, doi:10.1007/s00024-010-0231-9, *in press*. [available online 10 November 2010]

Oral presentations

Nicolsky D., E. Suleimani and R. Hansen. 2010. Numerical modeling of tectonic and submarine landslide-generated tsunamis in Whittier, Alaska. EGU General Assembly 2010, 2–7 May 2010, Vienna, Austria. (*Geophysical Research Abstracts*, vol 12, EGU2010-3780, 2010)

References

Ryan, H., R. Blakely, S. Kirby, D. Scholl, R. von Huene and R. Wells. 2010. USGS multi-hazard demonstration project tsunami scenario: selecting a scientifically defensible Aleutian megathrust earthquake source. Poster presented at the American Geophysical Union Fall Meeting, December 2010, San Francisco, California (abstract #NH33A=1376).

Other products and outcomes

Nothing to report.

Partner organizations and collaborators

None.

TWEAK Task 6: Education and outreach

Roger Hansen, PI

University of Alaska Fairbanks

Other investigators/professionals associated with this project:

S. Hansen, E. Veenstra, T. Viggato, J. Sandru, *University of Alaska Fairbanks*

Primary objectives

To provide tsunami and earthquake mitigation and education and outreach activities for the communities and public in Alaska.

Education and outreach
Throughout the reporting period we distributed information releases after notable events, spoke with news organizations on request, and answered telephone and email queries from the public. We were especially busy with media requests in the two weeks following the 11 March earthquake and tsunami in Japan.

Additionally, AEIC presented earthquake and tsunami education to 21 adults and 98 K-12 students through lab tours and visits from school classes. AEIC also operated booths at the Tanana Valley State Fair and the "Science Potpourri" (held on the UAF campus), where we provide information and demonstrations to an estimated 350 adults and 400 K-12 students. Outreach activities focused on Alaska seismicity, tectonics, and tsunami overviews as well as advice on earthquake and tsunami preparedness.

Publications, conference papers, and presentations
Nothing to report.

Other products and outcomes
Nothing to report.

Partner organizations and collaborators
None.

Parallelization and porting of the Alaska Tsunami Forecast Model to the Arctic Region Supercomputing Center (ARSC)

Thomas Logan, PI
University of Alaska Fairbanks

CIFAR theme: Coastal Hazards

NOAA Goal: Weather Ready Nation *(Serve Society's needs for weather and water information)*

CIFAR 11-020: This project is new.

Line Office NWS-NWS AK, Carven Scott, Sponsor

Primary objectives
This project will enable the West Coast/Alaska Tsunami Warning Center (WCATWC) to run the Alaska Tsunami Forecast Model (ATFM) at the Arctic Region Supercomputing Center (ARSC) using multiple processors. The source code will be re-written for parallel execution and will be ported to ARSC for creation of the ATFM pre-computed tsunami forecast model database.

Research accomplishments/highlights/findings
- Serial code ported to Unix platforms (initially a Cray system, then a Penguin Opteron Cluster)
- Serial code optimized for I/O to reduce runtime
- Serial code converted to work only with uniform rectangular grids, removing the ability to use variable spacing in the input datasets. This was done to speed the code up and because non-uniform grids are not used in production runs.
- Serial code streamlined to reduce computations (e.g. look-up tables created for trig functions)
- All loops in the serial code were rewritten to allow for parallel distribution of the work
- First parallel implementation for a single grid is running and results are verified with the original serial model output.

Overall, the serial code run time for a short run was reduced from 3308 seconds to around 1200 seconds, while the parallel code ran the same short scenario in just 318 seconds on 8 processors.

NOAA relevance/societal benefits
Once the ATFM is fully parallelized and verified, staff at the West Coast/Alaska Tsunami Warning Center in Palmer will be able to generate tsunami predictions far more quickly (at least an order of magnitude, possibly closer to two orders of magnitude). This will allow for more frequent updates of their pre-computed database, which will, in turn, make tsunami forecasts more accurate, potentially saving lives in the event of catastrophic tsunamis.

Education
Nothing to report.

Outreach
Nothing to report.

Publications, conference papers, and presentations
Nothing to report.

Other products and outcomes
The experiences and lessons in this project will be directly relevant to the parallelization of the Global Tsunami Model covered under the TWEAK CIFAR grant.

Partner organizations and collaborators
West Coast/Alaska Tsunami Warning Center: William Knight developed the ATFM and has been instrumental in describing the code and answering questions throughout the development process.

Changes/problems/special reporting requirements
This project will continue until 30 June 2011. The intent is to have a verified multi-gridded parallel implementation of the ATFM completed by then. The main task remaining is implementing the communication routines to allow sub-grid and parent grid interactions during a simulation, thus allowing the code to once again process multi-gridded scenarios.

Appendices

Appendix 1
CIFAR Projects Awarded in Cooperative Agreement NA08OAR4320751, NA08OAR4320870, & NA10OAR4310055
1 April 2010 to 31 March 2011

Last	First	Proposal Title	Project Budget	Theme Description	Funding Source
Task 1 Activities: CI Administration and Education & Outreach					
Walsh	**John**	Regional Alaska Cooperative Institute (2010-11)	$110,000	Administration	OAR
NOAA Non-Competitive Projects (NA08OAR4320751)					
Hansen	**Roger**	TWEAK: Tsunami Warning & Environmental Observatory for Alaska	$554,600	Coastal Hazards	NWS
Hansen	**Roger**	Alaska Earthquake Information Center seismic station operations and maintenance (Alaska CRESTnet, year 2)	$290,000	Coastal Hazards	NWS
Hopcroft	**Russell**	Oceanography and lower trophic level productivity: the Seward Line 2010	$100,000	Ecosystem Studies & Forecasting	NMFS
Logan	**Tom**	Parallelization and porting of the Alaska Tsunami Forecast Model to ARSC.	$70,238	Coastal Hazards	NWS
Mathis	**Jeremy**	Moored observations of ocean acidification in high latitude seas.	$315,000	Ecosystem Studies & Forecasting	NMFS
Okkonen	**Stephen**	Bowhead whale feeding behavior in the western Beaufort Sea: Oceanographic conditions, whale prey distributions, and whale feeding and foraging behavior	$79,684	Ecosystem Studies & Forecasting	NMFS
Competitively Awarded RUSALCA Projects (NA08OAR4320870)					
Hopcroft	**Russell**	A Long Term Census of Arctic Zooplankton Communities	$12,441	Ecosystem Studies & Forecasting	OAR
Iken	**Katrin**	RUSALCA: Arctic Food Web Structure & Epibenthic Communities in a Climate Change Context	$38,582	Ecosystem Studies & Forecasting	OAR
Norcross	**Brenda**	Fish Ecology & Oceanography: RUSALCA 2008 and 2012	$65,121	Ecosystem Studies & Forecasting	OAR
Weingartner	**Tom**	The Pacific gateway to the Arctic--Quantifying and understanding Bering Strait oceanic fluxes	$174,316	Ecosystem Studies & Forecasting	OAR
Whitledge	**Terry**	Global change in the Arctic: Interactions of productivity and nutrient processes in the northern Bering and Chuckchi Seas	$34,962	Ecosystem Studies & Forecasting	OAR
Competitively Awarded Climate Program Project (NA10OAR4310055)					
Walsh	**John**	Downscaling of climate model output for Alaska and northern Canada	$87,585	Climate Change & Variability	OAR
		Total projects funded (including CI administration)	**$1,932,529**		
		Competitively awarded projects (including CI administration)	$523,007		
		Non-competitive projects	$1,409,522		

Appendix 2. Summary of CIFAR-funded Personnel and their Terminal Degree

Category	Number	B.A./B.S. or unknown	M.A./ M.S. or M.B.A.	Ph.D.
Research Scientist	15		2	13
Visiting Scientist	0			
Postdoctoral Fellow	0			
Research Support Staff	24	11	12	1
Administrative	2	1	1	
Total (≥ 50% NOAA Support)	**3**	**1**	**2**	
Undergraduate Students	12	12		
Graduate Students	7		3	4
Total Students	**19**	12	3	4
Employees (< 50% NOAA Support)	38	11	11	14
Located in NOAA Lab	0			
Obtained NOAA employment within last year	0		0	

Appendix 3. Publication Activity

Summary table of publications during the current cooperative agreement

	Institute Lead Author			NOAA Lead Author			Other Lead Author		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Peer-reviewed	0	1	4	0	0	1	0	1	0
Non Peer-reviewed	0	0	0	0	0	0	0	0	0
In press			3			2			1
Accepted			1			0			0

All "in press" and "accepted" are peer-reviewed.

Year 1 = 1 July 2008–31 March 2009
Year 2 = 1 April 2009–31 March 2010
Year 3 = 1 April 2010–31 March 2011

***NOTE**: In addition to these publications, several of the RUSALCA projects and one additional project had papers published (5) or accepted for publication (1) during the reporting period that stemmed from funding to those projects under the previous cooperative agreement NA17RJ1224 (Cooperative Institute for Arctic Research).*

See next page for a spreadsheet of publications (published, in press, and accepted for publication) from the reporting period.

Work from projects funded through CIFAR that was published, in press, or accepted for publication during the reporting period.

CI Name	Authors	Publication Date	Publication Title	Published in	Type of Publication	Citation No. (doi)	Research Support Award No.	CI Lead Author	NOAA Lead Author	Other Lead Author	Peer Reviewed	Non Peer Reviewed
CIFAR	Nicolsky, D.J., E.N. Suleimani and R.A. Hansen	3 Dec 2010	Numerical modeling of the 1964 Alaska tsunami in western Passage Canal and Whittier, Alaska	Natural Hazards and Earth System Sciences, 10:2489–2505	Journal article	10.5194/nhess-10-1-2010	NA08OAR4320751	X			X	
CIFAR	Overland, J.E., M. Wang, N.A. Bond, J.E. Walsh, V.M. Kattsov and W.L. Chapman	March 2011	Considerations in the selection of global climate models for regional climate projections: The Arctic as a case study	Journal of Climate, 24(6):1583–1597	Journal article	10.1175/2010JCLI3462.1	NA08OAR4320870		X		X	
CIFAR	Romanovsky, V., N. Oberman, D. Drozdov, G. Malkova, A. Kholodov and S. Marchenko	July 2010	Permafrost. In: D.S. Arndt, M.O. Baringer and M.R. Johnson, Eds. State of the Climate in 2009	Special Supplement to the Bulletin of the American Meteorological Society, 91(6):S92	Journal article (special supplement)	10.1175/BAMS-91-7-StateoftheClimate	NA08OAR4320751	X			X	
CIFAR	Ruppert, N.A. and R.A. Hansen	June 2010	Temporal and spatial variations of local magnitudes in Alaska and Aleutians and comparison with body-wave and moment magnitudes	Bulletin of the Seismological Society of America, 100(3):1174–1183	Journal article	10.1785/0120090172	NA08OAR4320751	X			X	
CIFAR	Ruppert, N.A., S. Prejean and R.A. Hansen	18 Feb 2011	Seismic swarm associated with the 2008 eruption of Kasatochi Volcano, Alaska: Earthquake locations and source parameters	Journal of Geophysical Research - Solid Earth, 116, B00B07	Journal article	doi:10.1029/2010JB007435	NA08OAR4320751	X			X	
CIFAR	Logerwell, E., K. Rand and T. Weingartner	In press	Oceanographic characteristics of the habitat of benthic fish and invertebrates in the Beaufort Sea	Polar Biology	Journal article		NA08OAR4320751		X			
CIFAR	Nicolsky, D.J., E.N. Suleimani and R.A. Hansen	In press	Validation and verification of a numerical model for tsunami propagation and runup	Pure and Applied Geophysics	Journal article	10.1007/s00024-010-0231-9	NA08OAR4320751	X			X	
CIFAR	Overland, J.E., M. Wang, V.M. Kattsov, J.H. Christensen, W.L. Chapman and J.E. Walsh	In press	Climate model projections for the Arctic. Snow, Water, Ice and Permafrost in the Arctic, Chapter 3	Scientific Report, Arctic Monitoring and Assessment Program	Book chapter		NA08OAR4320870		X		X	
CIFAR	Parker-Stetter, S., J.K. Horne and T. Weingartner	In press	Distribution of Arctic cod and age-0 fish in the U.S. Beaufort Sea	Polar Biology	Journal article		NA08OAR4320751			X	X	
CIFAR	Suleimani, E., D.J. Nicolsky, P.J. Haeussler and R. Hansen	In press	Combined effects of tectonics and landslide-generated tsunami runup at Seward, Alaska, during the Mw 9.2 1964 earthquake	Pure and Applied Geophysics	Journal article	10.1007/s00024-010-2010	NA08OAR4320751	X			X	
CIFAR	Walsh, J.E., J.E. Overland, P. Groisman, J. Christensen and V. Vuglinsky	In press	Arctic climate: Past and Present. Snow, Water, Ice and Permafrost in the Arctic, Chapter 2	Scientific Report, Arctic Monitoring and Assessment Program	Book chapter		NA08OAR4320870	X			X	
CIFAR	Okkonen, S.R., C.A. Ashjian, R.G. Campbell, J.T Clarke, S.E. Moore and K.D. Taylor.	Accepted	Satellite observations of circulation features associated with a bowhead whale feeding 'hotspot' near Barrow, Alaska	Remote Sensing of Environment	Journal article		NA08OAR4320751	X			X	

Note: None of these publications are related to Deep Water Horizon (DWN) projects.

Appendix 4.

RUSALCA: Joint Russian–American Long-term Census of the Arctic research program in the Bering and Chukchi Seas

The Russian–American Long-term Census of the Arctic (RUSALCA), a joint U.S.–Russia research program in the Bering and Chukchi Seas, focuses on sampling and instrument deployment in both U.S. and Russian territorial waters and operates under the auspices of two Memoranda of Understanding between NOAA and, respectively, the Russian Academy of Sciences and Roshydromet. The RUSALCA objectives are to support NOAA's Climate Observation and Analysis Program and the Russian interagency Federal Target Program "World Ocean." It also provides some of the Arctic components of international and national climate observing systems including Global Earth Observation System of Systems (GEOSS), Global Climate Observing System (GCOS), and Integrated Ocean Observing System (IOOS). RUSALCA has also contributed to the U.S. interagency Study of Environmental Arctic Change (SEARCH) Program, NOAA's Office of Ocean Exploration and the Census of Marine Life (CoML).

The RUSALCA program is focused on gathering long-term observations towards understanding the causes and consequences of the reduction in sea ice cover in the northern Bering Sea and the Chukchi Sea in the Arctic Ocean. Models suggest that the expected changes in sea ice and albedo in this area will translate to significant alterations in water column structure and flow and in associated ecosystems. The program began in summer 2004 with a multi-disciplinary cruise on the R/V *Khromov*, a Russian ice-strengthened research ship, to investigate water column physics, nutrient chemistry, and pelagic and benthic biology. Oceanographic moorings were deployed in the western portion of the Bering Strait in 2004, and recovered and redeployed yearly. For 2007 and beyond, the RUSALCA program had planned an annual cruise focused on the physics in the Bering Strait region and more extensive multi-disciplinary cruises in 2009 and 2012 in the northern Bering and Chukchi Seas depending on resources.

During the current funding period, 5 competitively selected RUSALCA projects were funded through CIFAR, and continued analyzing samples and data from the 2009 multidisciplinary Russian–American expedition in the Bering Strait, East Siberian and Chukchi Sea and comparing them with the 2004 cruise. The 2010 RUSALCA Bering Strait mooring and hydrographic cruise involved researchers from three of the CIFAR RUSALCA projects who participated in the mooring recovery and deployments, CTD and water sampling, and zooplankton tows.

http://www.arctic.noaa.gov/aro/russian-american/2010/CruiseReportKhromov2010_verAug10.pdf

Goals of the RUSALCA program

- Make physical, chemical, and ecological observations where Arctic sea ice is diminishing
- Monitor fresh water and nutrient fluxes via long-term moorings in Bering Strait
- Monitor ecosystem indicators of climate change
- Improve international Arctic science collaboration
- Explore the unknown Arctic

Project reports for each CIFAR-funded RUSALCA project follow this overview.

RUSALCA: A long-term census of Arctic zooplankton communities

Russell R. Hopcroft, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Ksenia Kosobokova, *Russian partner****,*** *Russian Academy of Sciences, Moscow*

NOAA Goals 1 & 2: Healthy Oceans; Climate Adaptation & Mitigation

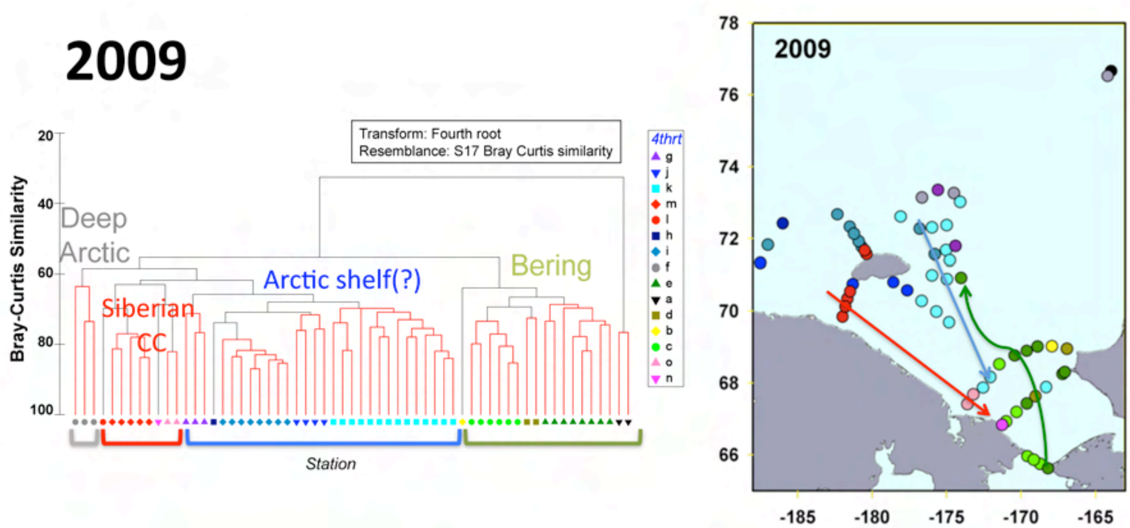
NA08OAR4320870 CIFAR Amendment 1
Line Office OAR-CPO, Ko Barrett, Sponsor
CIFAR 09-009/11-009: This project is ongoing.

Primary objectives

We propose repeated comprehensive surveys of zooplankton communities in the Bering Strait and Chukchi Sea to understand the transport patterns of Pacific zooplankton into the Arctic and build time-series to assess ecosystem change in this climatically sensitive region. The census will involve a combination of traditional taxonomic enumeration and identification, along with continued molecular sequencing and photographic documentation of the species collected by several types of plankton nets. This work will build on similar efforts from RUSALCA-2004, recent work in the Canada Basin under the Ocean Exploration program, and will temporally extend transects occupied by the Shelf-Basin-Interactions program, and tie into efforts by the International Polar Year and Census of Marine Life for a pan-Arctic program.

Research accomplishments/highlights/findings

A fuller analysis of samples from the RUSALCA 2009 expedition has been completed. Cluster analysis and Multidimensional Scaling using the Bray-Curtis community similarity reveals distinct clustering of the stations. Results are shown for the 150 µm mesh nets. Compared to 2004, the Alaska Coastal current is not as distinctly identified, but once again results suggest water from the Bering Sea can be traced as far as Herald Valley using the zooplankton fauna. Water pathways suggested by the clusters are shown by arrows.



A less extensive cruise was completed in 2010, occupying Bering Strait and the line to the north. Sample analysis from 2010 is currently incomplete.

NOAA relevance/societal benefits

This project examines the potential impacts of climate change in the Pacific–Arctic gateway.

Education
Kosobokova's student, Elizaveta Ershova, began a Ph.D. with Hopcroft at UAF in the fall of 2010 focusing on the RUSALCA project – she will be jointly supervised by Hopcroft and Kosobokova, and will split her time between UAF and Shirshov Institute, Moscow.

Outreach
Hopcroft, through ArcOD (Arctic Ocean Biodiversity Project), continues to develop a website that provides information on Arctic zooplankton and access to historical datasets. http://www.arcodiv.org/. The species page concept is being expanded upon through a related fellowship by the Encyclopedia of Life to Ershova.

Publications, conference papers, and presentations
Publications

None so far.

Oral presentations

Hopcroft, R.R,. K.N. Kosobokova and E.A. Ershova. 2010. RUSALCA: Census of the arctic zooplankton. RUSALCA PI meeting. 9–12 October 2010, Kotor, Montenegro.

Poster presentations

Ershova, E.A, R.R. Hopcroft and K.N. Kosobokova. 2011. Broadscale patterns of summer zooplankton communities in the Chukchi Sea during 2004 and 2009. 5th International Zooplankton Production Symposium, March 2011, Pucon, Chile.

Other products and outcomes
Hopcroft is working in conjunction with NOAA toward the development of a Circumpolar Biodiversity Monitoring Program (CBMP) under the International Arctic Council within which the RUSALCA program will represent a significant component from the USA.

Partner organizations and collaborators
Arctic Ocean Biodiversity Project (ArcOD)

Changes/problems/special reporting requirements
The current budget is insufficient to fully support a graduate student. Additional funds are being pursued from other sources.

RUSALCA: Arctic food web structure and epibenthic communities in a climate change context

Katrin Iken, PI
Bodil A. Bluhm, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Ken Dunton, *University of Texas at Austin*

NOAA Goals 1 & 2: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 2
Line Office OAR-CPO, John Calder, Sponsor
CIFAR 09-010/11-010: This project is ongoing.

Primary objectives

Our primary objectives are to contribute to RUSALCA goals by linking physical and chemical observations of water mass characteristics to food web structure and epibenthic faunal assemblages. First, we propose that food web analysis is a meaningful quantitative key variable for long-term climate observations. Benthic ecosystems act as indicators of long-term of change in marine systems because they tend to integrate both seasonal and inter-annual variability in overlying water column processes. Secondly, we propose to analyze epibenthic community structure as an indicator for ocean current regime and sediment patterns. In collaboration with working groups investigating infauna, we propose to monitor epifaunal community trends in the RUSALCA region.

Research accomplishments/highlights/findings

We have started analyzing our samples from the 2009 RUSALCA cruise and have presented the first results and comparisons with our 2004 RUSALCA cruise data at the PI meeting in Montenegro, 9–12 October 2010. Additional data processing and analysis is ongoing.

Our first results for epifaunal community structure show that in 2009, at eight stations that were repeated from 2004, epifaunal biomass had increased at six stations and decreased at the other two. Abundance at these repeat stations had not changed at five sites, was lower at two and higher at one site. Any of these trends need to be considered very carefully, as they are based only on two points in time, and as they are based on one trawl catch per station each year, no information is available on variability. We expect that additional year samples (long-term monitoring) as is the overall goal of the RUSALCA project, will add important information to these first emerging trends. Interestingly, the change in epifauna biomass was mostly related to increases in snow crab (*Chionoecetes opilio*) (six stations). That most biomass increases were connected to one species seems to give support to our observed overall trend of increase. Similarly, when we compare our 2-year trends with historical information from adjacent regions beginning with the 1970s, a similar increase in epifauna has been observed elsewhere. Overall epifaunal composition was related to substrate characteristics, but other environmental drivers are less clear.

Regional benthic food web structure based on carbon stable isotope ratios in 2004 differed, with benthic organisms in the eastern (Alaska Coastal Water, ACW) Chukchi Sea feeding more on terrestrial materials than in the western part (Anadyr Water, AW). Similar patterns were found in 2009, but a $\delta^{13}C$ depleted food source in the AW indicates freshwater influence in that region in 2009 (Figure 1). Possibly, this is due to a strengthened influence of the (ephemeral) Siberian Coastal Current (SCC) during 2009, which transports a large freshwater signal from the Russian shelf eastwards into the western Chukchi Sea. This influence (=depletion) was not noticed in benthic organism $\delta^{13}C$, but we suspect that we will be able to detect this freshwater signal in western Chukchi Sea benthos if the influence of the SCC were to become more permanent as part of the ongoing oceanographic changes in the region. In $\delta^{15}N$, which is representative of the trophic position of an organism, we detected that ACW consumers were slightly enriched compared to AW consumers in 2004. We had related this to the use of fresher, more labile food sources through shorter food chains in the AW. No changes in trophic position based on $\delta^{15}N$ ratios were found between 2004 and 2009 (Figure 1), indicating stable food webs, which may make them particularly good indicators for long-term changes.

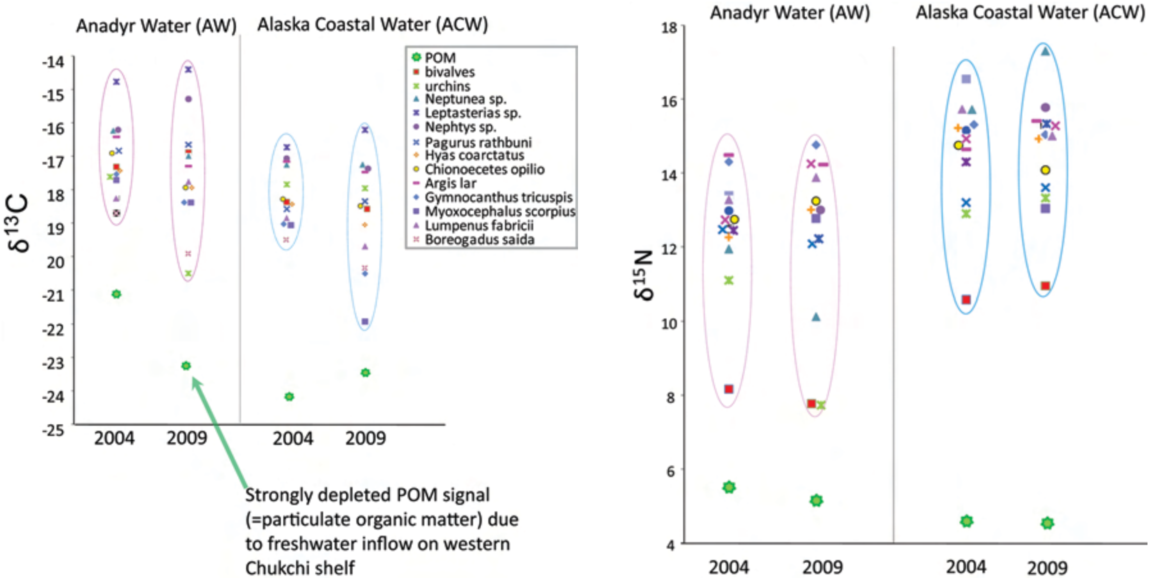


Figure 1. Stable carbon (left) and nitrogen (right) isotope composition of the particulate organic matter (POM) food source and benthic consumers in the two Chukchi Sea regions, the western Anadyr Water (AW) and the eastern Alaska Coastal Water (ACW) in a comparison of samples taken during 2004 and 2009.

NOAA relevance/societal benefits

This work will contribute to NOAA's strategic plan objective "to describe and understand the state of the climate system through integrated observations" of the biological components and the associated water mass characteristics. Increased knowledge of food web connections and epibenthic communities will be essential information to "understand the consequences of climate variability and changes" in the Chukchi Sea marine ecosystem. This work will provide NOAA with a product that can assist to "improve society's ability to plan and respond to climate variability."

Education

No graduate or undergraduate students were supported by the project during the reporting time.

Outreach

We shared pictures taken during the RUSALCA cruises with media and other interested parties.

Publications, conference papers, and presentations

We presented results of a comparison between 2004 and 2009 for the epibenthic community structure and the food web structure at the Alaska Marine Science Symposium, 17–20 January 2011, in Anchorage, Alaska. This meeting attracted more than 1000 attendees, and the Arctic focus of this meeting is increasing. We received much feedback to our presentation from other scientists active in the Arctic as well as other Alaskan waters.

Poster presentations

Iken, K., B. Bluhm, B.I. Sirenko, S.M. Hardy, B.A. Holladay, J. Weems and K. Dunton. 2011. Food web structure and epibenthic megafauna in the Chukchi Sea—a temporal comparison. Alaska Marine Science Symposium, 17–20 January, Anchorage, Alaska.

Other products and outcomes

Nothing to report.

Partner organizations and collaborators

Bluhm is one of the PIs of Arctic Ocean Diversity (ArcOD), the Arctic Ocean field project of the Census of Marine Life. Iken and Bluhm are also co-PIs of a NSF-sponsored Bering Sea Ecosystem Studies (BEST) project, which investigates pelagic-benthic coupling in the Bering Sea in relation to sea ice cover. Iken also is a member of the Marine Expert Monitoring Group of the Circumpolar Biodiversity Monitoring Program (CBMP), one of the programs under the directive of CAFF (Arctic Council Conservation of Arctic Flora and Fauna), where the RUSALCA program features strongly in monitoring the Chukchi Sea region. She has just been nominated as the US Benthic Marine Ecosystem Expert for the implementation of the CBMP.

Changes/problems/special reporting requirements

Other than a 1-year delay in the original plan because of the delay of the interdisciplinary cruise there are no changes to this project.

Publications related to this project as funded under NA17RJ1224 (previous cooperative agreement)

Peer-reviewed

Piepenburg, D., P. Archambault, W.G. Ambrose Jr., A.L. Blanchard, B.A. Bluhm, M.L. Carroll, K.E. Conlan, M. Cusson, H.M. Feder, J.M. Grebmeier, S.C. Jewett, M. Levesque, V.V. Petryashev, M.K. Sejr, B.I. Sirenko and M. Wlodarska-Kowalczuk. 2010. Towards a pan-Arctic inventory of the species diversity of the macro- and megabenthic fauna of the Arctic shelf seas. *Marine Biodiversity,* doi 10.1007/s12526-010-0059-7. (*We contributed biomass, abundance and species diversity data from the Chukchi Shelf from the 2004 RUSALCA cruise to this pan-Arctic synthesis effort.*)

Wei, C.L., G. Rowe, E. Escobar-Briones, A. Boetius, T. Soltwedel, M.J. Caley, Y. Soliman, F. Huettmann, F. Qu, Z. Yu, C.R. Pitcher, R.L. Haedrich, M.K. Wicksten, M.A. Rex, J.G. Baguley, J. Sharma, R. Danovaro, I.R. MacDonald, C.C. Nunnally, J.W. Deming, P. Montagna, M. Lévesque, J.M. Weslawski, M. Wlodarska-Kowalczuk, B. Ingole, B.J. Bett, A. Yool, B.A. Bluhm, K. Iken and B.E. Narayanaswamy. 2010. Global patterns and predictions of seafloor biomass using random forests. *Public Library of Science One,* 5(12): e15323. (*We contributed biomass data from the Chukchi Shelf from the 2004 RUSALCA cruise to this global effort to estimate biomass patterns and to develop predictive models for the global ocean.)*

Submitted

Hondolero, D., B.A. Bluhm and K. Iken. Caloric content of dominant benthic species from the Northern Bering and Chukchi Seas: historical comparisons and the effects of preservation. Submitted to *Polar Biology* (POBI-11-00085). *(This manuscript contains samples from the RUSALCA project that were measured for caloric content. The first author was an undergraduate student performing the work under a NOAA-CIFAR International Polar Year Student Traineeship grant for undergraduate students (CIPY-03).)*

RUSALCA: Fish ecology and oceanography

Brenda L. Norcross, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Brenda A. Holladay, Co-PI, _University of Alaska Fairbanks_
Morgan S. Busby, _Senior Investigator, Alaska Fisheries Science Center (AFSC), Seattle_

NOAA Goals 1 & 2: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 3
Line Office OAR-CPO, John Calder, Sponsor
CIFAR 09-011/11-011: This project is ongoing.

Primary objectives

We hypothesize that climate change, specifically a reduction of sea ice cover in the northern Bering and Chukchi Seas, will alter the species composition, abundance and distribution of fishes. Our objectives are to:

- Collect larval and juvenile fishes in specific water masses to estimate relative fish abundance and distribution.
- Determine ichthyoplankton and juvenile demersal fish assemblages (species composition).
- Determine physical and oceanographic features (water masses) characteristics that define ichthyoplankton and juvenile demersal fish habitat.
- Determine temporal distribution of ichthyoplankton and juvenile demersal fish from trace elements in otoliths.
- Determine the physical characteristics that define juvenile and adult fish communities and compare among collection periods.
- Determine mixed phyla benthic community assemblages, i.e., fish and invertebrates, and compare them among oceanographic feature and collection periods.

Research accomplishments/highlights/findings

Results from RUSALCA-09 collections were included in an evaluation of all fisheries collections in the Chukchi Sea between 1959 and 2009. Diversity of fish communities (Figure 1) appears to be highest in eastern Bering Strait and an area in the northeastern Chukchi Sea. Diversity in the northern Chukchi Sea is relatively low, and an intermediate level of diversity exists in the eastern Siberian Sea, eastern and central Chukchi Sea.

The project moved forward on all aspects. Identifications of the ichthyoplankton samples were verified and they have been entered in ICHBASE, which makes the data publically available. Analysis of combined 2004 and 2009 bottom trawl collections showed that adding more sites provides a clearer picture of fish communities, that the length of fishes is small even with large mesh net, and that the small mesh net yields greater diversity.

NOAA relevance/societal benefits

This project adds to the coordinated RUSALCA effort of identifying factors that underlie ecosystem change in the Arctic. Our research develops a broad-scale baseline of abundance and distribution of larval and juvenile fishes in the Chukchi Sea and identifies the physical mechanisms affecting fish distribution, thereby directly supporting the RUSALCA objective of developing methods of identifying ecosystem change.

Education

Christine Gleason (M.S. student, Fisheries Oceanography) has developed her thesis research based mainly on specimens she collected during the September 2009 cruise. Her thesis will examine the process by which two species of fishes that are common in the Chukchi Sea incorporate trace elements from the environment into their blood, liver and otoliths.

In addition to Gleason, who is not funded under this grant, this RUSALCA research has provided on-the-job training for 11 UAF student technicians. All technicians have assisted with weighing and measuring fishes, removing otoliths and other tissues, recording data, and computer data entry. Some technicians also have performed the more skilled tasks of assigning ages to otoliths and using sophisticated equipment to determine the trace element content of fish tissues.

Keegan Birchfield, B.S.
Michael Courtney, student, working toward B.S. in Fisheries
Thomas Foster, student, working toward B.S. in Fisheries
Christine Gleason, B.S. Fisheries, working toward M.S. in Fisheries Oceanography (not financially supported

by this grant)
Benjamin Gray, student, working toward B.S. in Fisheries
Casey McConnell, B.S. Fisheries
Brian Perttu, B.S., student, working toward M.S. in Geology
Casey Peterson, student, working toward B.S. in Petroleum Engineering
Tyler Ray, student, working toward B.S. in Fisheries
Peter Reed, B.A. Accounting
Matthew Robinson, student, working toward B.S. in Fisheries
Andrea Ruby, student, working toward B.S. in Fisheries

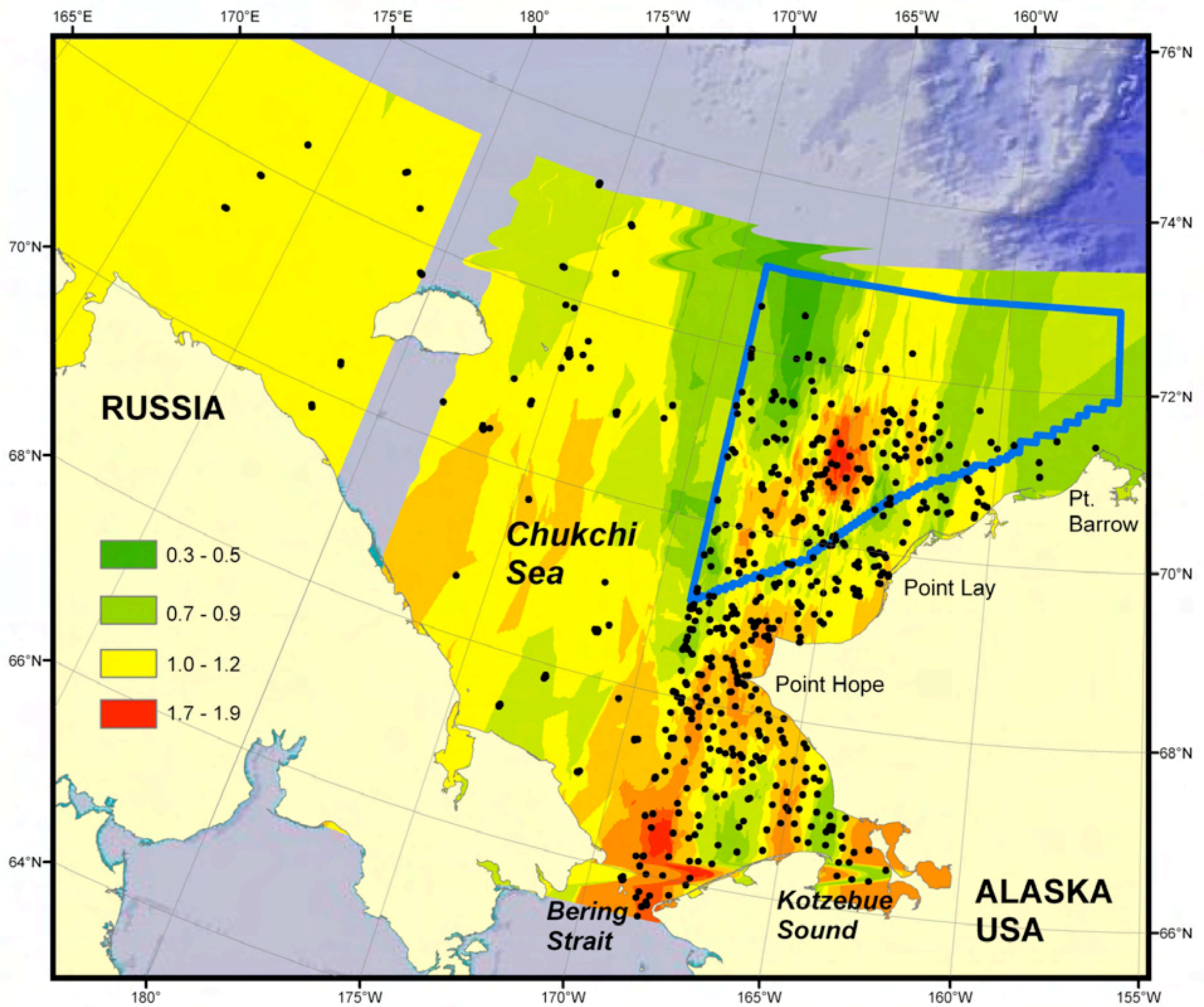


Figure 1. Shannon Diversity Indices incorporate abundance and evenness measures. The higher numbers, and the brighter colors on this map, indicate greater diversity. Results from RUSALCA-09 and RUSALCA-04 bottom fish collections were included in an evaluation of all fisheries collections in the Chukchi Sea between 1959 and 2009 (black dots). Including large quantities of data allowed patterns of diversity to be seen.

Outreach

- We hosted several outreach events for high school students at the Fisheries Oceanography Laboratory at UAF, and guided them in hands-on activities of fish dissection, microscopic examination of otoliths, and assigning ages based on patterns of dark and light bands in the otoliths. These events included UAF's first Campus Research Day, held on 9 April 2010.
- Morgan Busby gave a NOAA laboratory tour with hands-on activities for visiting MIMSUP (Multicultural Initiative in the Marine Science: Undergraduate Participation) students on 10 March 2011.

Outreach presentations

- Norcross, B.L., B.A. Holladay, L. Edenfield and C. Gleason. 2011. Chukchi Sea Environmental Studies Program: Fisheries Ecology, Olgoonik-Fairweather debrief meeting, January 2011, Anchorage, Alaska.
- Gleason, C. 2010. Fisheries as a career in Alaska. Middle and High school presentation, November 2010, Grayling, Alaska.

Publications, conference papers, and presentations

Some of the presentations during the reporting period incorporated work funded through the previous CIFAR cooperative agreement, NA17RJ1224.

Oral presentations

Gleason, C. 2011. Otolith chemistry of Arctic cod and Arctic staghorn sculpin in the Chukchi Sea. Rasmuson Fellows annual meeting, March 2011, Anchorage, Alaska.

Norcross, B.L., B.A. Holladay and C.W. Mecklenburg. 2011. Distribution and ecology of demersal fishes in the Chukchi Sea over 50 years. Arctic Frontiers Conference, January 2011, Tromso, Norway. (Invited talk.)

Carroll, S.S., L. Dehn and B.L. Norcross. 2011. What's in the mix: treatment of ice-seal prey sources within stable isotope mixing models. Alaska Marine Science Symposium, 17–21 January, Anchorage, Alaska.

Norcross, B.L. and B.A. Holladay. 2011. 50 years of demersal fishes in the Chukchi Sea. Alaska Marine Science Symposium, 17–21 January, Anchorage, Alaska.

Norcross, B.L., B.A. Holladay, C.W. Mecklenburg and C. Gleason. 2010. RUSALCA 2004 and 2009: epibenthic fish distribution in the Chukchi Sea. RUSALCA Summit, October 2010, Kotor, Montenegro.

Other products and outcomes

None in this reporting cycle.

Changes/problems/special reporting requirements

None in this reporting cycle.

Publications related to this project as funded under NA17RJ1224 (previous cooperative agreement)

None in this reporting cycle.

The Pacific Gateway to the Arctic—Quantifying and understanding Bering Strait oceanic fluxes

Thomas Weingartner, PI
Terry Whitledge, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

NOAA Goals 1 & 2: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 5 Line Office OAR-CPO, Kathy Crane, Sponsor
CIFAR 10-013/11-013
This project is ongoing. Although this project was reviewed and competitively awarded with the other RUSALCA projects, this project was funded jointly by NSF and NOAA, with NSF covering year 1.

Primary objectives

- Provide mooring instrumentation and flotation for 4 complete moorings and recover the same;
- Provide CTD (conductivity, temperature, depth) data collection and analyses for stations occupied during the mooring deployment and recovery cruises;
- Collect and analyze nutrient data collected for stations occupied during the mooring deployment and recovery cruises;
- Assist in mooring data quality control, archiving and analysis.

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 four moorings deployed across the western channel of Bering Strait. Each mooring contains an RDI 300 kHz upward looking ADCP (Acoustic Doppler Current Profiler) 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 includes a fluorometer and a nitrate sensor. We are also engaged in analyzing the data from these moorings and the CTD section in conjunction with a 4 mooring array deployed in the eastern (US EEZ) channel of Bering Strait with Rebecca Woodgate of the University of Washington.

Research accomplishments/highlights/findings

Work this year included an extensive set of CTD collections (including nutrients) in Bering Strait and the southern Chukchi Sea. It also included the recovery of 8 moorings and the re-deployment of the same moorings in Bering Strait. Data analyses on the CTD and recovered moorings is awaiting arrival of the data. All of the collected data must pass through Russian Customs and military approval before we can begin working on it.

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.

Education

Michael Kong, a Ph.D. student in chemical oceanography, assisted with CTD data collection, nutrient sampling and analyses. Seth Danielson, a Ph.D. student in physical oceanography, analyzed CTD data. Graduate student Chase Stoudt, a M.S. student in physical oceanography, assisted in the work at sea. Jonathan Whitefield, a Ph.D. student in physical oceanography, assisted in the fieldwork and is comparing the observations with model data.

Outreach

None this year.

Publications, conference papers, and presentations

None this year.

Other products and outcomes

We contribute to a project website hosted at the University of Washington: http://psc.apl.washington.edu/HLD/

Partner organizations and collaborators

State Research Navigational Hydrographic Institute of the Russian Federation: Expedition logistics and coordination (In-kind support, facilities)

Group Alliance (Russia): logistics and translation services (In-kind support, facilities)

Arctic and Antarctic Research Institute (Russian Federation): moorings and CTD (Collaborative Research)

Polar Science Center, Applied Physics Lab, University of Washington (Rebecca Woodgate), Co-PI, Co-Chief Scientist, moorings, CTD, physical oceanography (Collaborative Research)

Impact

The narrow, shallow Bering Strait is the only ocean gateway between the Pacific and the Arctic Ocean. Given the significant role of Pacific waters in the Arctic, quantifying the Bering Strait through flow and its properties is essential to understanding the present functioning of the Arctic system, and the causes and prediction of present and future Arctic change.

Changes/problems/special reporting requirements

Other than a 1-year delay in the original plan because of the delay of the interdisciplinary cruise there are no changes to this project.

RUSALCA: Global change in the Arctic: Interactions of productivity and nutrient processes in the northern Bering and Chukchi Seas

Terry E. Whitledge, PI
Dean A. Stockwell, co-PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

Other investigators/professionals associated this project:
Daniel Naber, *University of Alaska Fairbanks*

NOAA Goals 1 & 2: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 4 Line Office OAR-CPO, John Calder, Sponsor
CIFAR 09-012/11-012: This project is ongoing.

Primary objectives

We are using measurements of nutrient and plant pigment distributions, phytoplankton taxonomy, and rates of primary productivity to assess changes in the carbon cycle related to nutrient utilization and primary production that may be driven by variations in the Arctic climate.

Research accomplishments/highlights/findings

- The RUSALCA cruise aboard the R/V *Professor Khromov* in summer 2010 was used to obtain samples in the Bering Strait region to provide data to investigate climate change in the Chukchi Sea.
- Nutrient and chlorophyll samples were collected on hydrography stations during the mooring leg. The nutrient samples were analyzed for nitrate, nitrite, ammonium, phosphate and silicate after freezing and transport to the Fairbanks laboratory. Size fractionated chlorophyll were also filtered at primary production sampling stations.
- Primary production rate measurements using carbon and nitrogen isotopes were determined at six light depths on 4 stations.

NOAA relevance/societal benefits

This project will determine the amount of nutrients that are available to support primary production in the seasonally ice-covered waters of the Chukchi Sea and compare to prior data collected over the prior two decades to assess changes that are related to climate change.

Education

Michael Kong, Ph.D. student, Chemical Oceanography

Outreach

Outreach was attempted with local school children in Nome 2009 but weather conditions and new Transportation Security Administration rules prevented visitation to the vessel. P.I. was not able to participate in the 2010 cruise so follow-up plans for a school visit were not possible.

Publications, conference papers, and presentations

Publications

Publications during the reporting period originated from work funded through the previous CIFAR cooperative agreement, NA17RJ1224. See below.

Oral presentations

Lee, S.H., K.H. Chung and T.E. Whitledge. 2011. Phytoplankton and ice algae communities responding to the environmental changes in the western Arctic Ocean. Presented at Arctic Science Summit Week Symposium, 27 March–1 April 2011, Seoul, Korea.

Longina, E.A., T.V. Matveeva, V.I. Petrova, D.A. Korshunov, V.A. Gladysh, K. Crane, T. Whitledge and G.A. Cherkashov. 2010. Did pockmark-like structures from the Chukchi Sea form due to fluid discharge? Presented at 10th International Conference on Gas in Marine Sediments, 6–12 September 2010, Listvyanka, Russia.

Whitledge, T.E. 2010. RUSALCA program overview. RUSALCA PI Meeting, 9–12 October 2010, Kotor, Montenegro.

Whitledge, T.E. 2010. Nutrients, chlorophyll and primary productivity during the 2009 RUSALCA Cruise. RUSALCA PI Meeting, 9–12 October 2010, Kotor, Montenegro.

Partner organizations and collaborators

A collaborative proposal with Russian colleagues was submitted to the U.S. Civilian Research & Development Foundation to fund additional data analysis and synthesis based on the new cruise data.

Changes/problems/special reporting requirements

Other than a 1-year delay in the original plan because of the delay of the interdisciplinary cruise there are no changes to this project.

Publications related to this project as funded under NA17RJ1224 (previous cooperative agreement)

RUSALCA Publications (with at least partial support from project funds)

Peer-reviewed

Lee, S.H., M. Jin, T.E. Whitledge and S.H. Kang. 2010. Comparison of bottom sea ice algal characteristics from coastal and offshore regions in the Arctic Ocean. *Polar Biology*, 33:1331–1337.

Lee, S.H., D.A. Stockwell and T.E. Whitledge. 2010. Uptake rates of dissolved inorganic carbon and nitrogen by under-ice phytoplankton in the Canada Basin in summer 2005. *Polar Biology*, 33:1027–1036.

Pickart, R.S., L.J. Pratt, D.J. Torres, T.E. Whitledge, A.Y. Proshutinsky, K. Aagaard, T.A. Agnew, G.W.K. Moore and H.J. Dail. 2010. Evolution and dynamics of the flow through Herald Canyon in the western Chukchi Sea. *Deep-Sea Research II*, 57:5–26.

Accepted (peer-reviewed)

Walsh, J.J., D.A. Dieterle, F.R. Chen, W. Masowski, J.L. Clement Kinney, J.J. Cassano, T.E. Whitledge, D.A. Stockwell, J.T. Mathis, M.V. Flint, J. Cristensen, N. Bates and D.A. Hansell. Resetting the winter biological clock of Arctic plankton: A prelude to centenarian simulations of element cycling north of Bering Strait, with emphasis on interannual variations of biotic carbon, oxygen, nitrogen, silicon, and phosphorus fluxes by a six-component phytoplankton community of a marine food web, constrained by three groups of planktonic and benthic herbivores, under changing sea ice cover, vertical mixing, and water transport during 2002–2004. Accepted for publication in *Deep-Sea Research I*.

Submitted (peer-reviewed)

Lee, S.H., C.P. McRoy, H.M. Joo, R. Gradinger, X.H. Cui, M.S. Yun, K.H. Chung, C.K. Kang, E.J. Choy, S.H. Son, E. Carmack and T.E. Whitledge. Holes in progressively thinning Arctic sea ice lead to new ice algae habitat. Submitted to *Science.*

Lee, S.H., H.M. Joo, M.S. Yun and T.E. Whitledge. Recent phytoplankton productivity of the northern Bering Sea in the western Arctic Ocean during early summer in 2007. Submitted to *Polar Biology*.

Publications that utilized RUSALCA data, shiptime, and/or scientific collaboration:

Peer-reviewed

Purcell, J.E., R.R. Hopcroft, K.N. Kosobokova and T.E. Whitledge. 2010. Distribution, abundance, and predation effects of epipelagic ctenophores and jellyfish in the western Arctic Ocean. *Deep-Sea Research II*, 57:127–135.

In press (peer-reviewed)

Walsh, J.J., D.A. Dieterle, F.R. Chen, J.M. Lenes, W. Maslowski, J.J. Cassano, T.E. Whitledge, D. Stockwell, M.V. Flint, I.N. Sukhanova and J. Cristensen. Trophic cascades and future harmful algal blooms within ice-free Arctic Seas north of Bering Strait: A simulation analysis. *Progress in Oceanography*, in press. doi:10.1016/j.pocean.2011.02.001

Appendix 5.

Downscaling of climate model output for Alaska and northern Canada

John E. Walsh, PI ***CIFAR theme: Climate Change & Variability***
University of Alaska Fairbanks

Other investigators/professionals associated this project:
Georgina Gibson, *CIFAR post doc*

NOAA Goal: Climate Adaptation & Mitigation *(Understand climate variability and change to enhance Society's ability to plan and respond)*

NA10OAR4310055 Line Office OAR-CPO, Chris Miller and Bill Murray, Sponsors

NA10OAR4310055 Year 1 Progress Report: Technical Summary

Work under Grant NA10OAR4310055 is directed at high-resolution projections of climate change for North American high latitudes, particularly Alaska and northern Canada. The need for high-resolution projections became apparent in recent activities such as the Arctic Climate Impact Assessment (2005), which noted the absence of the site-specific information needed by local planners. The need for site-specific information about ongoing and projected climate change is one of the main drivers of NOAA's emerging emphasis on climate services.

The effort during Year 1of the present project fell into three main categories: (1) work on the identification of optimal subsets of models for regional projections and downscaling for Alaska and Canada, (2) downscaling of climate projections for Alaska and northwestern Alaska by the Delta method, and (3) extension of the downscaling to marine ecosystem models and to permafrost simulations, both of which require high-resolution fields of climate drivers. These three activities are summarized below.

(1) *Identification of optimal subsets of climate models for Alaskan and Canadian downscaling applications.* While global climate models provide credible quantitative estimates of future climate at continental scales and above, individual model performance varies for different regions, variables, and evaluation metrics: a less than satisfying situation. In collaboration with NOAA researchers J. Overland and M. Wang of the Pacific Marine Environmental Laboratory, we have documented and implemented this approach for various Arctic subregions. Publications have been prepared for the Journal of Climate (2011, accepted) and the Arctic Council assessment project known as SWIPA (Snow, Water, Ice and Permafrost in the Arctic). Because of the mostly unexplained inconsistencies in model performance under different selection criteria, simple and transparent evaluation methods were favored. Starting with a set of model results obtained from an "ensemble of opportunity," the core of our procedure was to retain a subset of models through comparisons of model simulations with observations at both the continental and regional scale. The continental scale evaluation was a check on the large-scale climate physics of the models, and the regional-scale evaluation emphasizes variables of ecological or societal relevance. In many but not all applications, improved results were obtained from a reduced set of models rather than by relying on the simple mean of all available models. The use of model evaluation strategies, as opposed to relying on simple averages of ensembles of opportunity, was recommended to be part of future synthesis activities such as the upcoming Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Reliance on a single model proved to be a less than optimal strategy; for some applications, no model may be able to provide a suitable regional projection. In the Arctic the top-performing models tend to be more sensitive to greenhouse forcing than the poorer-performing models. The finding of greatest relevance to this project is that the following models show the greatest skill (integrated over the seasonal cycle) in hindcast simulations of Alaskan and northern Canadian climate: the ECHAM5 model of the Max Planck Institute, Hamburg, Germany; NOAA Geophysical Fluid Dynamics Laboratory model 2.1; the Canadian Center for Climate Modeling and Analysis model CGCM 3.1; the Japanese model MIROC 3.2; and the U.K.'s Hadley Centre model HADCM3.

Publications from activity (1):

Overland, J. E., M. Wang, N. A. Bond, J. E. Walsh, V. M. Kattsov and W. L. Chapman, 2011: Considerations in the selection of global climate models for regional climate projections: The Arctic as a case study. *J. Climate*, accepted November 2010.

Walsh, J. E., J. E. Overland, P. Groisman, J. Christensen and V. Vuglinsky, 2011: Arctic climate: Past and Present. Snow, Water, Ice and Permafrost in the Arctic, Chapter 2 in Scientific Report, Arctic Monitoring and Assessment Program, in press (publication scheduled for spring 2011).

Overland, J. E., M. Wang, V. M. Kattsov, J. H. Christensen, W. L. Chapman and J. E. Walsh 2011: Climate model projections for the Arctic. Snow, Water, Ice and Permafrost in the Arctic, Chapter 3 in Scientific Report, Arctic Monitoring and Assessment Program, in press (publication scheduled for spring 2011).

(2) *Downscaling for Alaska and northwestern Canada by the Delta method in order to provide working scenarios.* Downscaling by the Delta method, whereby GCM-derived changes are superimposed on high-resolution climatologies, has been implemented for Alaska and northwestern Canada. We have used the coarse-resolution output from the five global models identified in (1) above, together with the high-resolution PRISM (Parameter-elevation Regressions on Independent Slopes Model) climatology at 0.8-km resolution, to downscale temperature and precipitation fields. In addition, in collaboration with the University of Alaska's SNAP (Scenarios Network for Alaska Planning) program, we have derived corresponding fields of potential evapotranspiration in order to map future demands on surface moisture across northwestern North America. For the Alaskan region, we have tabulated the downscaled projections of temperature and precipitation for 353 communities across the state on a decade-by-decade basis through the year 2100. These local projections, which are available online in chart format (http://www.snap.uaf.edu/community-charts), are for three different scenarios of greenhouse gas forcing (A2, A1B, B1). In addition, the local projections are accompanied by estimates of uncertainties, for which the metric is the across-model standard deviation of the projection. An example of the temperature projections by calendar month for an interior Alaskan community, McGrath, is shown in Figure 1 below. In the chart, the different colors of the bars represent different time slices, beginning with the historical climatology for 1961-1990 (blue bars). The uncertainties accompanying the estimates are shown by range indicators at the top of each bar.

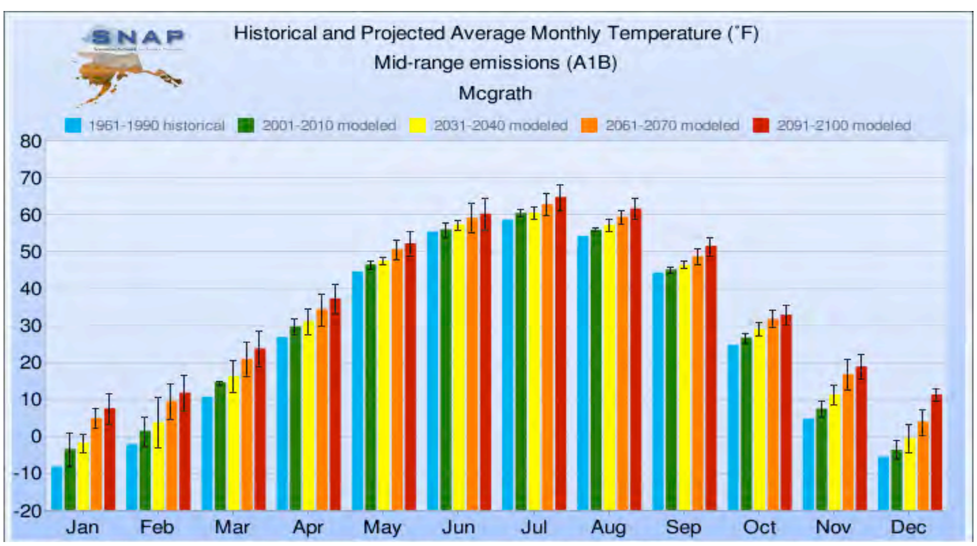


Fig. 1. Example of the downscaled temperatures (°F) by decade for a community (McGrath) in the Alaskan interior. Colors represent different decadal time slices, which are shown for each calendar month (x-axis). Thin black range indicators are uncertainties, for which the metric is the across-model standard deviation.

(3) *Extension of the downscaling to marine ecosystem models and to permafrost simulations.* During the project's first year, it has become apparent that the needs of users extend well beyond temperature and precipitation. Examples of needs include evapotranspiration over terrestrial regions where surface drying and/or water levels are user concerns, subsurface temperatures in areas of permafrost and permafrost-affected infrastructure, and the surface forcing of offshore waters where marine ecosystems have value to community and commercial stakeholders. For the evaluations of changes in potential evapotranspiration, we have collaborated with B. O'Brien of The Wilderness Society, who has used the downscaled model output to compute changes in surface moisture flux and growing season length; a paper on these results is in preparation. For high-resolution projections of permafrost, investigators in the Geophysical Institute's Permafrost Laboratory have used our downscaled model output to drive a state-of-the-art permafrost model at high resolution. The results, a sample of which is shown in Figure 2 below, include maps of future permafrost degradation based on annual mean soil temperatures at a depth of 2 meters. The figure shows that annual mean 2-meter soil temperatures over large areas of interior Alaska increase from below-freezing (blue) to above freezing (red) by 2050, implying thaw and degradation of permafrost, with adverse consequences for overlying infrastructure (roads, buildings, pipelines, etc.). Finally, our output is being used by Georgina Gibson, a postdoctoral scientist supported by this project, to drive a nutrient-phytoplankton-zooplankton (NPZ) model that forms the underpinning of a marine food web model. The NPZ simulations are being applied to the Bering Sea, where high resolution is necessary to capture the details of the coastline, islands and bathymetry. These results will form the basis for a paper to be submitted in the next several months.

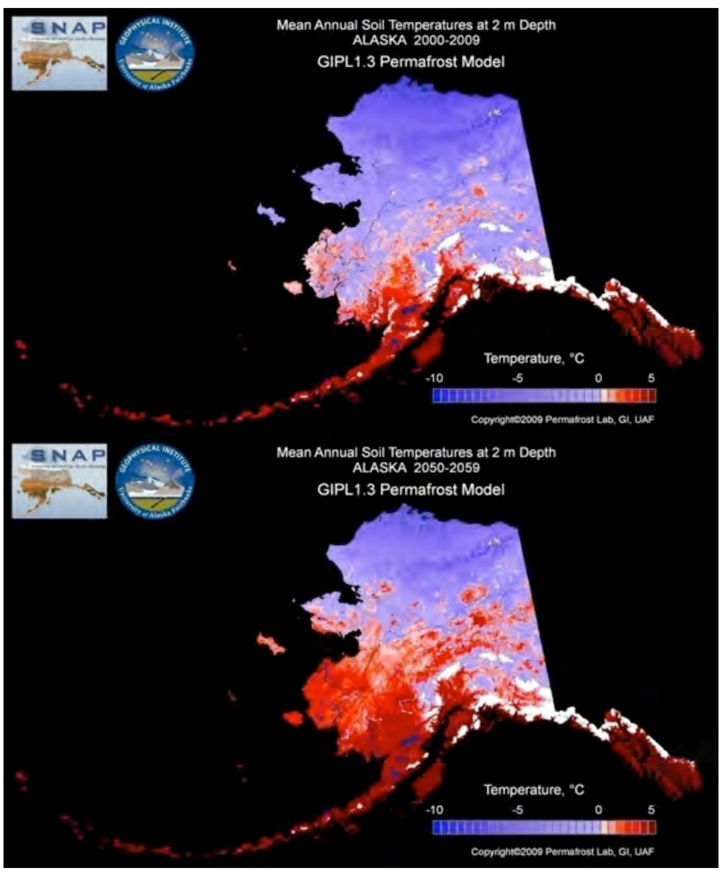


Fig. 2. Soil temperatures (°C) at 2-meter depth as similated by a permafrost model driven by downscaled output from ECHAM5 global climate model for 2000-2009 (upper panel) and 2050-2059 (lower panel). As indicated by color bar, blue and red shades denote below- and above-freezing temperatures, respectively.

Work Plan for Year 2

The Year 1 activity followed the original work plan with two exceptions: (1) effort was added to the project by the contribution to SWIPA, which was not foreseen when the original proposal was prepared; (2) the collaboration with the Scenarios Network for Alaska Planning enabled synergies in the downscaling by the Delta method. For Year 2, we will follow the original work plan with one main difference. Since the Delta-method downscaling has already been implemented with the monthly model output, we will extend the downscaling to include the distributions of daily values, enabling projections of changes in extremes. The downscaled daily distributions will be obtained using the Bias Correction and Spatial Downscaling method. It will be applied to the daily output fields of temperature, precipitation and wind from the five models selected during Year 1. This downscaling will represent the first objectively determined projections of changes in extremes for Alaska and Canada. The present lack of such information for wind events (storms) affecting Alaska's coasts was noted in the recent U.S. National Assessment, Global Climate Change Impacts in the United States.

Appendix 6. Index of Principal Investigators
(key words are in parentheses in cases where one PI has multiple project reports)