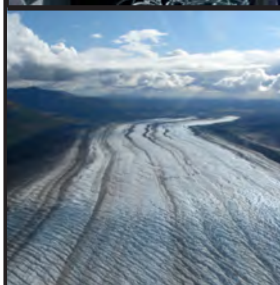
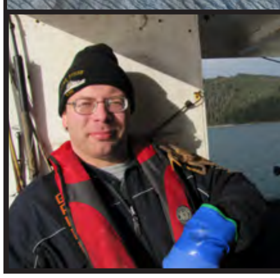
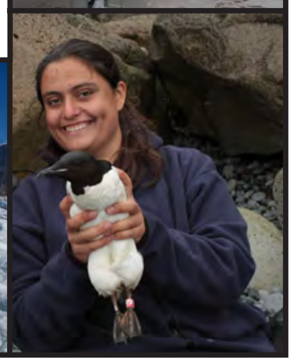


Fourth progress report on Cooperative Agreement NA08OAR4320751

1 April 2011 – 31 March 2012



CIFAR
Cooperative Institute For Alaska Research

UAF
UNIVERSITY OF ALASKA FAIRBANKS

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

1 April 2011–31 March 2012

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

Table of Contents

Overview .... *i*

Progress Reports on Individual Projects
- Task I 1
- Non-competitive projects (NA08OAR4320751), by CIFAR theme
  - Ecosystem Studies and Forecasting 5
  - Climate Change and Variability 15
  - Coastal Hazards 25

Appendices
1. Projects Awarded 1 April 2011–31 March 2012 61
2. Personnel 63
3. Publications 65
4. RUSALCA overview and project reports (NA08OAR4320870) 69
5. Report on J. Walsh project *Downscaling of climate model output for Alaska and Northern Canada* (NA10OAR4310055) 83
6. PI Index 87

Cover images courtesy of CIFAR-funded students (clockwise from upper left: Tim Bartholomaus, Joanna Young, Shiway Wang, Tim Bartholomaus, Rebecca Young, Joanna Young, Jonathan Richar, Joanna Young). Report layout and production by Barb Hameister, CIFAR.

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:
Christopher Sabine, NOAA Office of Oceanic & Atmospheric Research (OAR) Pacific Marine Environmental Laboratory (PMEL) Director (*effective November 2011*)
John Calder, NOAA OAR Arctic Research Office Program Manager
Douglas DeMaster, NOAA National Marine Fisheries Service (NMFS), Director, Alaska Fisheries Science Center (AFSC)
Philip Hoffman, NOAA OAR Cooperative Institutes (CI) Program Office Director
Mark Myers, University of Alaska Fairbanks (UAF), Vice Chancellor for Research
James Partain, NOAA, National Weather Service (NWS) Regional Climate Director for Alaska
John Walsh, CIFAR director, ex officio

The ***CIFAR Fellows*** are:

1. Larry Hinzman, Director, International Arctic Research Center (IARC), UAF, Fairbanks, AK
2. Kris Holderied, National Ocean Service, NOAA, Homer, AK
3. Anne Hollowed, AFSC, NMFS, NOAA, Seattle, WA
4. Henry Huntington, Huntington Consulting, Eagle River, AK
5. Zygmunt Kowalik, Professor of Physical Oceanography, Institute of Marine Science (IMS), School of Fisheries and Ocean Sciences (SFOS), UAF, Fairbanks, AK
6. Gordon Kruse, President's Professor of Fisheries, SFOS, UAF, Juneau, AK
7. Molly McCammon, Director, Alaska Ocean Observing System, Anchorage, AK
8. Phil Mundy, Auke Bay Laboratory, AFSC, NMFS, NOAA, Juneau, AK
9. James Overland, Oceanographer, PMEL, NOAA, Seattle, WA
10. Carven Scott, Chief, Environmental & Scientific Services Division, NWS, NOAA, Anchorage, AK
11. Cynthia Suchman, Executive Director, North Pacific Research Board, Anchorage, AK
12. Terry Whitledge, Director, IMS, SFOS, UAF, Fairbanks, AK

Summary of Projects Funded during Reporting Period

During the fourth reporting period of the new competitively awarded cooperative agreement, NOAA provided funding for CIFAR administration and 12 research, education, and outreach projects totaling $2.72 M as part of the CIFAR institutional cooperative agreement (NA08OAR4320751). The 9 research projects were Task III (projects that generally require only minimal direct collaboration with NOAA scientists). In addition, 4 competitively awarded RUSALCA projects totaling $253,551 (funded under the "shadow" cooperative agreement NA08OAR4320870) and one Climate Program Office (CPO) project (NA10OAR431055) received $89,414 through CIFAR. Two Task I education projects and one outreach effort were funded during this reporting period. The CIFAR research portfolio of 17 competitive and non-competitive new awards addresses all three CIFAR research themes and totals $3.06 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. During this reporting period for the first time in this cooperative agreement, CIFAR received funds from the National Environmental Satellite, Data, and Information Service (NESDIS) for three new satellite research projects.

Table 1: Summary of CIFAR Projects Funded 1 April 2011–31 March 2012: By Task and Theme

Theme	Number of Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)	**4**		**$439,482**	**14.3%**
Core Support	1	$110,000		3.6
Education and outreach	3	329,482		10.7
Research Themes (Task II)	**0**		**$0**	**0.0%**
Research Themes (Task III)	**14**		**$2,625,361**	**85.7%**
Climate Change & Variability	4	$782,759		24.9
Coastal Hazards	3	$1,218,781		39.8
Ecosystem Studies & Forecasting	7	$643,821		21.0
Total	**18**		**$3,064,843**	**100.0%**

Table 2: Summary of CIFAR Projects Funded 1 April 2011–31 March 2012: By Funding Source
Includes administration

Funding Source	Number of Projects	Total Amount	Percent of Total
OAR	9	$855,135	27.9%
NESDIS	3	$730,252	23.8%
NWS	2	$978,781	31.9%
NMFS	4	$500,675	16.3%
Total	**18**	**$3,064,843**	**100.0%**

Highlights of CIFAR Task I Activities

CIFAR is staffed by four people: John Walsh, director; Susan Sugai, associate director; Susan Carson, CIFAR administrator; and Barb Hameister, publications and meetings manager. Through the first four 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 provide funding for 3.2 months of one full-time equivalent (FTE) salary for our CIFAR administrator, roughly equivalent to the previous reporting period. However, because Sarah Garcia left in August 2011 and Susie Carson was not hired to replace her until October, less match funds were needed for this position during this reporting period. 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 Sugai and Carson attending the annual spring meeting for CI directors and administrators.

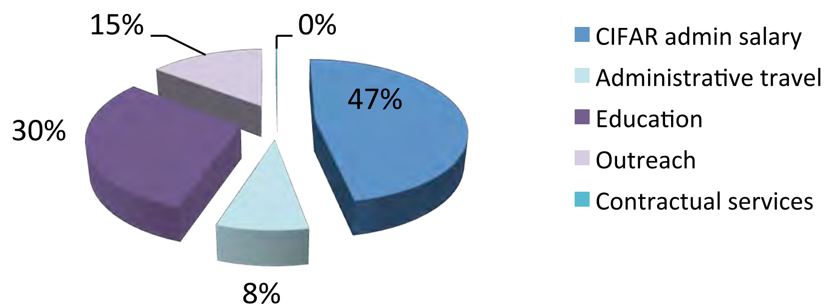


Figure 1. Percentage of funding for various Task I activities during current reporting period.

Core Administration

For this reporting period CIFAR Task I funds supported 3.2 months of one FTE staff position, the CIFAR administrator, while University match funds provided the remainder of core administrative labor costs. Because additional staff time was required in preparation for CIFAR's 4-year review, the actual staff time spent on CIFAR responsibilities during the reporting period were as follows:

- John Walsh, CIFAR director, 6% FTE (UA match funds)
- Susan Sugai, CIFAR associate director, 35% FTE (UA match funds)
- Sarah Garcia/Susan Carson, CIFAR administrator, 62% FTE (Task I + UA match funds)
- Barb Hameister, publications and meetings manager, 24% 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 2012. These activities include the following:

- Participated in CIFAR review, July 27–28, 2011
- Worked on SWIPA (Snow, Water, Ice and Permafrost in the Arctic) papers and Ambio publication based on SWIPA.
- Handled local arrangements for and participated in NOAA/NWS Workshop led by Gary Hufford, September 2011.
- Participated in Arctic Monitoring and Assessment Program (AMAP) Climate Expert Group meeting in Victoria, British Columbia (January 30–February 1, 2012)
- Worked on National Climate Assessment Alaska paper and participated in teleconferences.

Susan Sugai, CIFAR associate director, oversees CIFAR daily operations and serves on the 25-member NOAA Alaska regional collaboration team. She was responsible for preparing briefing materials and coordinating presentations for the NOAA Science Advisory Board peer-review of CIFAR held July 26–28, 2011.

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. Names of students involved in CIFAR research and education projects are given in **bold face** in the summary below.

Stock Assessment Traineeships

Building upon the success of the Stock Assessment Traineeships initiated in 2002 as part of the prior cooperative agreement, the Ted Stevens Marine Research Institute (TSMRI), AFSC, has provided $293,984 during this reporting period, to prepare young scientists for careers in quantitative fisheries sciences, including population dynamics, management, and stock assessment. Training students in quantitative fisheries science is critical to NOAA and the state of Alaska. This represents the same collaboration between TSMRI and SFOS scientists that has proven to be so successful in recruiting five research fishery biologists for TSMRI, 4 with UAF Ph.D. degrees, one with a M.S. Two additional quantitative fisheries professionals who received Ph.D. degrees with support from this program are actively involved in fisheries management and research in Alaska. Four prior recipients are still working on completing their Ph.D. research and degree requirements.

Karson Coutre will work on a juvenile sablefish study under Anne Beaudreau beginning in summer 2012 and Terry Quinn has recruited **Kari Fenske,** who is scheduled to begin on her Ph.D. fisheries project analyzing harvest strategies for sablefish during fall 2012.

Global Change Student Research Program (Graduate and Undergraduate Support)
Because of the low 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.

A joint UAF-UAA proposal review panel met on 23 April 2011 and recommended full or partial funding of 16 projects (from a field of 58) for awards running from 1 July 2011 to 30 June 2012. Five of these awards were funded with CIFAR match or Task 1 education funds. The following students, the degree that they are seeking, and their FY12 CIFAR projects are listed below:

- **Jason Geck**, Geology & Geophysics, UAF: *Future climate impacts on mass balance and discharge from Eklutna Glacier, Alaska.*
- **Jonathan Richar**, School of Fisheries & Ocean Sciences, UAF: *Recruitment mechanisms of Tanner crab in the eastern Bering Sea.*
- **Shiway Wang**, School of Fisheries & Ocean Sciences, UAF: *Tracking the contribution of ice algal fatty acids to ice seals in the Bering Sea from 2003 – 2010.*
- **Joanna Young**, Geology & Geophysics, UAF: *Improving mass change estimates for the Kahiltna Glacier through an expanded high elevation observation network.*
- **Rebecca Young**, Biology & Wildlife, UAF: *Environmental determination of life-expectancy in long-lived seabirds: an inter-ocean comparison of kittiwake chicks' responses to environmental stressors.*

In addition, **Sam Herreid** undergraduate and **Timothy Bartholomaus** and **Daniella Della-Giustina**, graduate students selected by the 2010 review panel received second-year funding.

In response to the 2012 announcement of funding opportunity, 52 proposals were received, reviewed, and scheduled to be considered by our review panel on 6 April 2012.

Student Support through Individual Awards
Walleye pollock are among the most abundant and commercially important species in the Eastern Bering Sea (EBS), where fish communities are undergoing major shifts in response to climate warming. Obtaining critical information on growth of larval and juvenile pollock will aid in stock assessments. **Ashwin Sreenivasan** received summer support through a Task I project to measure whole-body RNA/DNA ratios in larval walleye pollock from different habitats, and utilized these ratios to compare instantaneous growth rates for these fish as part of his Ph.D. that was awarded in fall 2012. He currently has a post-doctorate position at TSMRI where he is continuing his research on genetics of larval pollock.

As shown in Appendix 2, 12 students (3 undergraduate, 9 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. This does not include individuals who are employed as research support staff while also working on advanced degrees. In addition, many other students benefited from involvement in the research projects, e.g., through sample/data collection and data analysis, even though they did not receive direct salary support through CIFAR.

Other CIFAR Administrative Activities

In July, the NOAA Science Advisory Board (SAB) convened an external panel of scientists to conduct a 4th year review of CIFAR management, research, and education/outreach that was submitted to NOAA in March 2012. We will be responding to the recommendations made by the review panel shortly. Overall, the panel felt that "CIFAR is performing outstandingly, taking full scientific advantage of its location in the state that is essentially 'on point' for the nation when it comes to climate change." The panel took special note of "the extraordinary return on investments from CIFAR-funded students" both "because of the quality of the science and the relevance of the science to important practical issues."

A joint teleconference meeting of the CIFAR Executive Board and Fellows was held 11 October 2011. Topics of discussion included two of the SAB review panel recommendations for CIFAR: 1) Incorporation of social science research; 2) need for RUSALCA integration and synthesis.

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

In addition to the major role of ecosystem studies and forecasting inherent in our Task I education efforts, two CIFAR efforts have provided funding for continuation of shipboard and moored observations at long-term monitoring sites in the Gulf of Alaska and Bering Sea for key variables like ocean acidification (CIFAR 11-021) and oceanography and lower trophic level productivity (CIFAR 11-022). Interdisciplinary ecosystem studies are also continuing in the northern Bering and Chukchi Seas as well as the western Beaufort Sea.

Three RUSALCA projects (NA08OAR4320870) continued 2011 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. Two Ph.D. students, **Elizaveta Ershova** (CIFAR 12-009) and **Michael Kong** (CIFAR 12-012) have dissertation research projects funded primarily by this NOAA climate program effort.

In the western Beaufort Sea area, Steve Okkonen (CIFAR 12-014) has found that interannual variability in krill (the principal prey of bowhead whales in the study area) is a function of the local wind field. To visually demonstrate the seasonal oceanographic conditions and how they influence bowhead whale feeding and migration, Steve has produced a calendar for 2013 that shows "A year in the life of the bowhead whale." With funds from the Bureau of Ocean Energy Management through the UAF Coastal Marine Institute with matching funds provided by the UAF Center for Global Change, Okkonen and Roger Tapp, UA Museum of the North, were awarded funds for "A year in the life of the bowhead whale: an animated film" that will build upon the CIFAR-funded calendar and provide broader outreach of this research to a statewide and national audience.

Climate Change & Variability

Climate change and variability research at CIFAR is focused upon downscaling climate model outputs to meet local planning needs, improving sea ice forecasting, and enhancing Alaska research and satellite data services to better meet NOAA user needs.

In the current reporting period, John Walsh (NA10OAR4310055) extended his downscaling in Alaska and northwestern Canada by the Delta method (whereby global climate model-derived changes are superimposed on high-resolution climatologies) in order to derive variables aligned with user needs including break-up and freeze-up dates, soil wetness/dryness, and offshore variables including sea ice.

An enhanced international cooperative network for improving existing methods of sea-ice forecasts is being developed through collaboration between researchers at the Arctic and Antarctic Research Institute (AARI), St.-Petersburg, Russia, IARC at UAF, and the Canadian Ice Service. This effort led by Igor Polyakov and Adrienne Tivy (CIFAR 12-029) performed initial tests earlier this year of the predictive method to be used for seasonal ice forecasts, which become increasingly important with the already diminishing Arctic ice cover.

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, from volcanic ash clouds, and from tsunamis.

David Atkinson (CIFAR 10-018) deployed a wave and meteorological buoy in the northern Bering Sea in mid-July 2011 and retrieved it in mid-October. The buoy provided data about wind and wave state on a near-real time basis 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. During the three month deployment, four events produced winds exceeding 5 m in height, including the one 8.5 m event that was generated by winds from the southeast (meaning the storm was positioned near Russia's Kamchatka Peninsula). New partnerships with the Alaska Ocean Observing System and the Western Alaska Landscape Conservation Cooperative will permit redeployment of this buoy in summer 2012.

Roger Hansen (CIFAR 12-008) 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. During this reporting period, development of community inundation maps including work on quality control of digital elevation models (DEM), which are utilized for defining evacuation routes for at-risk communities, focused on three areas: the Aleutian Islands (Akutan, Dutch Harbor/Unalaska, and Sand Point), Prince William Sound (Port Valdez and Whittier), and southeast Alaska (Sitka).

In a new NESDIS project (CIFAR 12-028), Peter Webley, Martin Steufer and co-workers will improve volcanic ash cloud transport models to be used to test Geostationary Operational Environmental Satellite-R Series (GOES-R) derived ash cloud detection images and heights. This project will assist in developing an improved operational volcanic ash tracking product to NWS for use in Alaska and other regions where volcanic eruptions can disrupt air travel.

Publications and Presentations

Thirty-four conference presentations (both national and international) were reported for the period 1 April 2011–31 March 2012. Eight peer-reviewed papers were published, with 4 additional papers in press and at least 6 submitted or in review. Many PIs have papers under preparation. In addition, several of the RUSALCA projects had papers published (4) or accepted for publication (2) during the reporting period that stemmed from funding to those projects under the previous cooperative agreement NA17RJ1224 (Cooperative Institute for Arctic Research).

Besides this activity for projects funded directly by NOAA through CIFAR, 4 peer-reviewed papers were published by students who have received CIFAR Task I or match funding through the Global Change Student Research Grant Competition during the current cooperative agreement. Many of these students also made presentations at national and international meetings.

Task I: Stock Assessment Training Stipends

Stock assessment training stipends

Terrance Quinn II, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem studies and forecasting

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

CIFAR 12-024: This project is ongoing. Line Office NMFS-AFSC; Dana Hanselman, Sponsor

Primary objectives

This project continues the program initiated in the previous cooperative agreement to prepare young scientists for careers in quantitative fisheries sciences, including population dynamics, management, and stock assessment. Training students in quantitative fisheries science is critical to NOAA and the state of Alaska. This program has been in place since 2002 between the University of Alaska and Alaska Fisheries Science Center (ASFC), NOAA Fisheries. This support is provided through CIFAR to Terrance Quinn II at the University of Alaska Fairbanks, School of Fisheries and Ocean Sciences (SFOS). A committee of AFSC (Dana Hanselman) and SFOS scientists (Terrance Quinn, Franz Mueter) evaluates graduate student applications and decides on disbursement of funds. AFSC continues to be highly supportive of this program and its Auke Bay Lab unit (Ted Stevens Marine Research Institute, TSMRI) has contributed $293,984 to graduate student research about sablefish stock assessment.

Research accomplishments/highlights/findings

Megan Peterson, a fisheries Ph.D. student in Juneau supervised by Franz Mueter, participated in a sablefish longline fishing trip in the Bering Sea during May 2011. Anne Beaudreau, new SFOS faculty member and co-PI with Terry Quinn on the “Cooperative research on sablefish between Ted Stevens Marine Research Institute (TSMRI) and UAF fisheries” project (see the Ecosystem Studies and Forecasting section of this report), selected prospective student Karson Coutre to work on her juvenile sablefish field study, which will commence this summer. Terry Quinn gathered paperwork from five prospective quantitative graduate students and convened the student selection committee on March 14, 2012. The committee selected Kari Fenske as the top choice to work on a study to evaluate alternate harvest strategies for sablefish. Quinn is assisting Fenske in getting her graduate school application approved so she can start Fall 2012.

NOAA relevance/societal benefits

This joint program between UAF and NOAA/NMFS/AFSC is designed to prepare young scientists for careers in fish stock assessment, a field that requires strong quantitative skills. The NMFS Stock Assessment Improvement Plan requires such scientists for its implementation, and the available pool of qualified applicants is shrinking. Under the previous cooperative agreement, thirteen students were supported on these competitive fellowships and five of these students are current NOAA fisheries research biologists at the Ted Stevens Marine Research Institute. Of those five students, two Ph.D. and one M.S. quantitative fisheries professionals were hired by NOAA after graduation and two Ph.D. students were hired before completing their dissertations. One Ph.D. student formed a consulting company, is studying fish distributions in the Aleutians (funding from US Fish and Wildlife Service) and Bering Sea tanner crab (funding by Bering Sea Fisherman's Research Foundation), and continues to serve on the Crab Plan Team of the North Pacific Fishery Management Council.

Education

Megan Peterson is partially funded through the project, but currently receives salary support from the Rasmuson Fisheries Research Center.

Outreach

None yet.

Publications, Conference Papers, and Presentations

In November 2011, Megan Peterson attended the Lowell Wakefield Fisheries Symposium in Anchorage, AK to present the poster, "An Interdisciplinary Investigation of Whale Depredation on Alaskan Longline Fisheries." The presentation discussed quantitative and social research investigating spatial and temporal trends in sperm whale and killer whale depredation in the Gulf of Alaska. This poster presentation won the "Best Student Poster" award.

Other Products and Outcomes

In May 2011, CIFAR fellowship funds were also used to support Megan Peterson's travel to Dutch Harbor, AK to participate in a sablefish longline fishing trip in the Bering Sea. While on the fishing trip, the student conducted research on killer whale depredation, whale depredation impacts on catch rates, and the use of potential deterrent devices. Analyses are in progress. This research will be relevant to future analyses using NOAA Fishery Observer data to assess the impact of killer whale depredation on the sablefish longline fishery.

Partner organizations and collaborators

Ted Stevens Marine Research Institute (Dana Hanselman, Chris Lunsford), Alaska Fisheries Science Center, Juneau, Alaska.

Impact

This project will accomplish two major impacts: (1) training for at least three graduate students who may be recruited by TSMRI when done, (2) innovative thesis research that will improve the stock assessment for sablefish in the North Pacific.

Changes/problems/special reporting requirements

There has been a delay in starting this project because there were no suitable graduate students available until this year and also Beaudreau did not start until January of this year. Thus two of the three students will not start until summer 2012 at the earliest.

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 **CIFAR theme: *Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

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

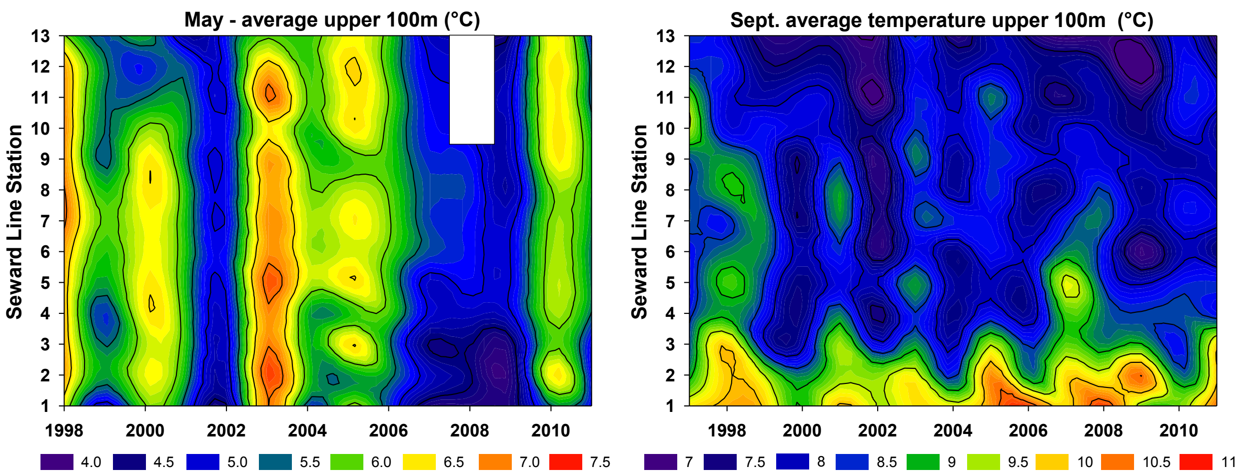
CIFAR 11-022: This project is complete. Line Office NMFS-AFSC, Mike Sigler, Sponsor

Primary objectives

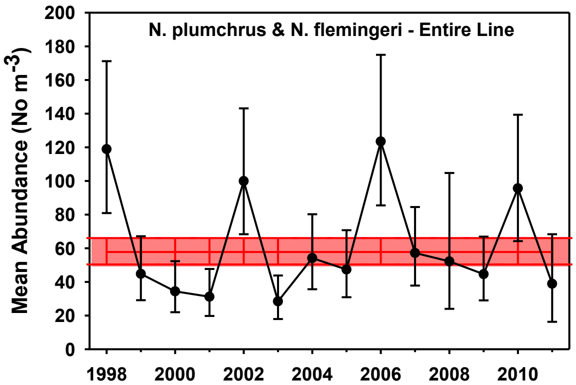
Over the past 50 years, the North Pacific appears to have undergone at least one clear "regime shift," while the last 12 years have seen multi-year shifts of major atmospheric indices, leaving uncertainty about what regime the coastal Gulf of Alaska is currently in. Concurrently, the warming trend of 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.

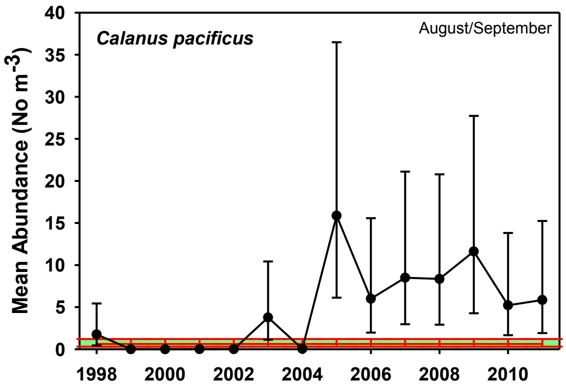
Research accomplishments/highlights/findings

- Cruises were executed April 26–May 11, and September 14–21, 2012. A winch breakdown late on the May cruise prevented Multinet sampling (i.e. macrozooplankton), but all other objectives were accomplished on each cruise.
- In May 2011, surface temperatures were slightly below normal, nutrients still moderate and some build up of chlorophyll was beginning along the middle-shelf domain – overall suggesting a "late year". Related work funded by the North Pacific Research Board (NPRB) has completed a broad-scale survey of the Gulf of Alaska shelf over this period.



- Abundance of the dominant spring zooplankter – the copepod *Neocalanus plumchrus/flemingeri* was below normal with growth rate noticeably delayed.
- The positive relationship between *Neocalanus* abundance and survival of pink salmon releases that spring continues to hold.
- Summer surface temperatures were typical of this period, as was zooplankton species composition.
- The southern-affinity copepod *Calanus pacificus* has become consistently common during recent summers, especially in offshore waters.





NOAA relevance/societal benefits

- These cruises have provided a critical link in the long-term monitoring and documentation of 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 expected the following year.

Education

- In May 2011, seven Institute of Marine Science (IMS) graduate students (Kristen Shake, Jennifer Questel, Imme Rutzen, Amy Tippery, Heather McEachen, Liza Ershova, Jonathan Whitefield) participated in the cruise and some collected data that will be used for portions of their thesis/dissertation work.
- In September, four IMS graduate students (Chase Stout, Heather McEachen, Imme Rutzen, Kristen Shake), and 2 undergraduate students (Moritz Schmidt, Chelsey Smith) participated in the cruise and some collected data that will be used for portions of their thesis/dissertation work.

Outreach

Hopcroft participated in a Gulf of Alaska teacher workshop co-hosted by NPRB, EARTH/MBARI (Monterey Bay Aquarium Research Institute/ Education and Research: Testing Hypotheses), COSEE (Centers for Ocean Sciences Education Excellence) Alaska, and Alaska Ocean Observing System (AOOS) in July 2011. It was attended by 23 educators from Alaska and around the nation.

Publications, conference papers, and presentations

Oral presentations

Doubleday, A. and R.R. Hopcroft. 2012. Estimates of the composition, abundance, and biomass of pteropods and larvaceans in the coastal Gulf of Alaska. ASLO/AGU Ocean Sciences Meeting, February 2012, Salt Lake City, Utah.

Moss, J., S. Hinckley, R.R. Hopcroft and O. Ormseth. 2012. The Gulf of Alaska Project: an Integrated Ecosystem Research Program. Keynote, Alaska Marine Science Symposium, January 2012, Anchorage, Alaska.

Poster presentations

Doubleday, A. and R.R. Hopcroft. 2012. Decadal estimates of productivity by pteropods and larvaceans in the coastal Gulf of Alaska. Alaska Marine Science Symposium, January 2012, Anchorage, Alaska.

Hopcroft, R.R., M. Doyle, A. Matarese, C. Mordy, J. Napp, P. Stabeno and S. Strom. 2012. A broad-scale look at physics through plankton in the coastal Gulf of Alaska. Alaska Marine Science Symposium, January 2012, Anchorage, Alaska.

Sousa, L., K. Coyle, T. Weingartner and R.R. Hopcroft. 2012. Climate-related variability in abundance of mesozooplankton in the Northern Gulf of Alaska 1998–2009. Alaska Marine Science Symposium, January 2012, Anchorage, Alaska.

Other products and outcomes

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

Partner organizations and collaborators

The overall monitoring effort to which this project has contributed is now funded by a consortium of agencies:

- North Pacific Research Board
- Alaska Ocean Observing System
- Exxon Valdez Oil Spill Trustee Council

RUSALCA data management: a proposal for full featured functionality FY11-12

Russell Hopcroft, PI **CIFAR theme: Ecosystem studies and forecasting**

University of Alaska Fairbanks

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

CIFAR 12-027: This project is ongoing. Line Office OAR-CPO; Kathleen Crane, Sponsor

Primary objectives

In support of the Russian-American Long-term Census of the Arctic (RUSALCA) research projects (see Appendix 4), NOAA has provided support for data from all disciplines to be digitally archived and made available to the public and principal investigators via a web based interface. Data will come from biological, physical oceanography, geological, meteorological, and possibly sea ice researchers. Subsets of these data will need to be restricted to access only by principal investigators for certain periods of time.

The project objectives are:

Data Consolidation - Collection of raw data from principal investigators and the ingestion of this data and associated metadata into a University-National Oceanographic Laboratory System (UNOLS) Rolling Deck to Repository (R2R) compatible data format.

Web Interface - An advanced web interface that allows users to browse existing data sets, search for data based on a fully cross referenced set of metadata selection criteria including graphical geo-location bases search will be created. The ability to restrict access of specific data sets to principal investigators via a web based users logging on a per user basis will be pursued.

Data Distribution - Users browsing datasets need the ability to download "folders" or multiple selected datasets of data with a single download action that does not require installation of software beyond the web browser on the client side. Automated dataset distribution by remote computers with authentication will be a product of this project.

Research accomplishments/highlights/findings

Project commenced fall of 2011, no results to report at present. See Changes section.

NOAA relevance/societal benefits

- This project provides the data infrastructure to examine the potential impacts of climate change in the Pacific–Arctic gateway.
- It will place RUSALCA data into public domain, as well as distribute to major data repositories.

Partner organizations and collaborators

Alaska Ocean Observing System (AOOS)
Axiom Consultants

Impact

This project will place this data into the same cyber-infrastructure as the AOOS. AOOS is becoming the major repository for many other datasets for the Pacific-Arctic region from agencies, industry and academia.

Changes/problems/special reporting requirements

Two months after data professional Debi-Lee Wilkinson was hired at UAF, she left for another position. At that point, limited progress had made beyond data consolidation and assimilation. This forced a strategic reconsideration of the vulnerability of the project to loss of its key data position. Several options were considered, with the final resolution that a sub-award to a larger data group would be in the best long-term interests of the program. We have leveraged resources with AOOS to subcontract Axiom Consultants. Rebudgeting and contracting for the sub-award are currently underway, and will ultimately require a no-cost extension to complete the primary objectives of the project.

Moored observations of ocean acidification in high latitude seas

Jeremy Mathis, 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 11-021: This project is ongoing.

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

We had a successful year in multiple areas regarding this project. We deployed and recovered the moorings at two long-term monitoring sites, GAK 1 (Gulf of Alaska) and M2 (southeast Bering Sea) and conducted a very broad survey cruise in the western Arctic with Robert Byrne (subaward) onboard the U.S. Coast Guard Cutter *Healy* in October 2011. Moorings are being redeployed in 2012 and another cruise on the *Healy* is scheduled for October 2012.

GAK 1 – We had a successful GAK 1 mooring deployment in 2011/2012 and recovered data at the surface (Figure 1) and near the bottom. The mooring has been redeployed and we are currently working on several manuscripts (at least 3) using the data from year 1. As expected, there are some very interesting features in both CO_2 fluxes and carbonate mineral saturation states to be discussed.

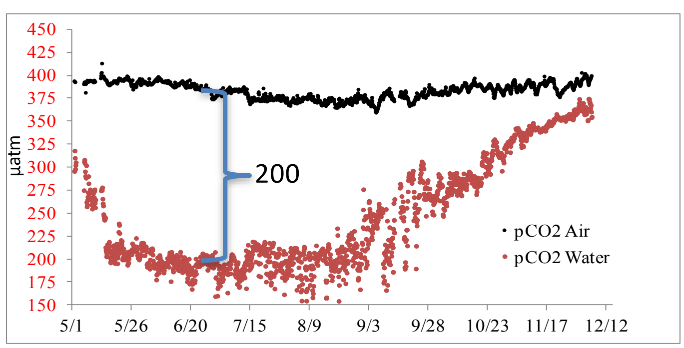


Figure 1. Preliminary surface and atmospheric CO_2 data from the GAK 1 mooring.

M2 – We successfully deployed the surface buoy at M2 during the summer of 2011 and collected pCO_2 (Figure 2) and other hydrographic data. The bottom package on the mooring was left in over winter and will be recovered in May 2012. It should have a full year's worth of data.

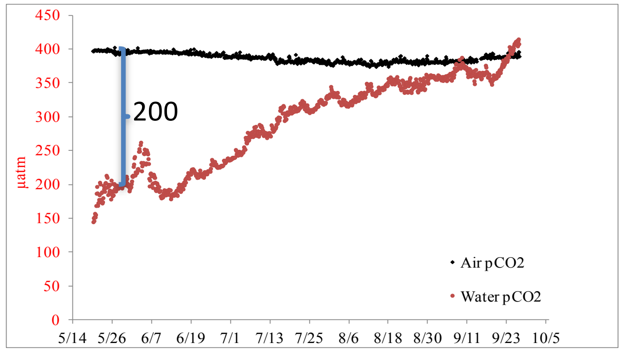
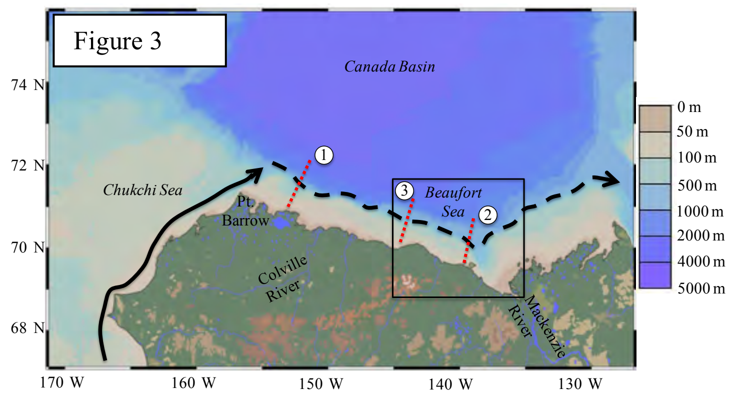


Figure 2. Preliminary surface and atmospheric CO_2 data from the M2 mooring.

Western Arctic *Healy* Cruise – We conducted a broad survey cruise of the eastern Chukchi and Beaufort Sea in October 2011 (Figure 3). During this cruise we made thousands of measurements (many of them for the first time) of pCO_2, pH, DIC (dissolved inorganic carbon) and TA (total alkalinity). This is first time that all four carbonate parameters have been directly measured in the Arctic Ocean and will be critical in improving our understanding of ocean acidification in the region. Mathis has already had a manuscript accepted in *Geophysical Research Letters* for publication using some of these data. Several more publications are now underway.



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 sub-arctic and arctic coastal seas. The Bering Sea mooring is now the northernmost OA mooring.

Outreach

None at this time, but once data is fully processed we will work to provide it to the community and classrooms for educational and instructional purposes.

Publications, conference papers, and presentations

Publications in press

Mathis, J.T., R.H. Byrne, C.L. McNeil, R.P. Pickart, L. Juranek, S. Liu, J. Ma, R.A. Easley, M.W. Elliot, J.N. Cross, S.C. Reisdorph, J. Morison, T. Lichendorph and R.A. Feely. Storm-induced upwelling of high pCO_2 waters onto the continental shelf of the western Arctic Ocean and implications for carbonate mineral saturation states. *Geophysical Research Letters*, in press.

Oral presentations

Mathis, J.T., J.N. Cross and N.R. Bates. 2012. Ocean acidification and the suppression and undersaturation of carbonate mineral saturation states in the Pacific–Arctic region. ASLO/AGU Ocean Sciences Meeting, February 2012, Salt Lake City, Utah.

Monacci, N., J.T. Mathis, W. Evans, N.R. Bates, C. Sabine, L.W. Juranek and T. Takahashi. 2012. Constraining CO_2 budgets in the continental shelf seas of Alaska: New insights from moorings and ocean time-series. ASLO/AGU Ocean Sciences Meeting, February 2012, Salt Lake City, Utah.
Hales, B., S. Alin, W.J. Cai, P. Coble, S. Lohrenz, J. Mathis, G. Mckinley and R. Najjar. 2012. Carbon cycling in ocean margins: A tutorial. ASLO/AGU Ocean Sciences Meeting, February 2012, Salt Lake City, Utah.

Changes/problems/special reporting requirements

We had a few issues with the SAMI II pH sensors. About 50% of the time (3 out of 6 sensors), they did not fully record data for the entire mooring deployment or experienced some mechanical failure. We have been working with the manufacturer to resolve these issues, which are to be expected given the new technology and harsh arctic conditions.

Partner organizations and collaborators

Robert Byrne, University of South Florida (subaward)

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

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 10-014/12-014: 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

CIFAR-funded research has refined our understanding of the conditions that create a late summer-early autumn foraging hotspot for bowhead whales on the western Beaufort shelf near Barrow. In most years, the principal prey associated with this foraging hotspot is krill. Recent comparative analyses of acoustic measurements acquired by CIFAR-funded oceanographic moorings deployed in Barrow Canyon and on the western Beaufort shelf indicate that the numbers of krill arriving at Barrow in late summer from the Bering Sea were greatest in 2009 and least in 2011. Whale groups were observed foraging in shelf waters near Barrow by boat-based and/or aerial observers on multiple days in September 2009 and 2010, but not at all in September 2011. Bowhead whales did eventually appear near Barrow in late October, although animals harvested during the fall 2011 hunt had very few krill in their stomachs. These estimates of krill abundance suggest that there might be a minimum threshold krill abundance on the shelf below which groups of whales are not going to initiate migration to the Barrow area to forage. If there is such a krill abundance threshold and meeting the threshold depends primarily on the numbers of krill being carried northward across the Chukchi Sea, then interannual variability in the times at which bowheads arrive at Barrow is a function of upstream conditions (e.g., krill brood strength, transit time, survival during transit). However, if meeting the krill abundance threshold on the shelf depends on the efficacy of the krill trap mechanism, then interannual variability is a function of the local wind field. The questions of krill abundance thresholds will be investigated further in the upcoming summary year of the overall BOWFEST (Bowhead Whale Feeding in the Western Beaufort Sea) project.

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.

Outreach

In production

2013 Calendar: A Year in the Life of Bowhead Whales

Publications, conference papers, and presentations

Peer-reviewed publication

Okkonen, S.R., C. Ashjian, R.G. Campbell, J.T. Clarke, S.E. Moore and K.D. Taylor. 2011. Satellite observations of circulation features associated with a bowhead whale feeding 'hotspot' near Barrow, Alaska. *Remote Sensing of Environment,* 115:2168–2174.

Poster presentation

Okkonen, S.R., D.J. Jones, P. Alatalo, C.A. Ashjian, M. Baumgartner, S. Brower Sr., J.L. Clement-Kinney, R.G. Campbell, J. Citta, J.C. George, K. Goetz, L. Horstmann, W. Maslowski, J. Mocklin, D. Rugh, L. Quakenbush, K. Stafford and L. Vate Brattstrom. 2012. A year in the life of the bowhead whale: an educational outreach product in calendar format. Alaska Marine Science Symposium, 16–20 January 2012, Anchorage, Alaska.

Newsletter article (accepted)

Okkonen, S.R., C. Ashjian, R.G. Campbell, J.T. Clarke, S.E. Moore and K.D. Taylor. Radarsat observations of circulation features associated with a bowhead whale feeding 'hotspot' near Barrow, Alaska. Alaska Satellite Facility, News and Notes.

Other products and outcomes

With funding from the Bureau of Ocean Energy Management (BOEM) through the UAF Coastal Marine Institute (CMI) with matching funds provided by the UAF Center for Global Change, Okkonen and Roger Tapp, UA Museum of the North, principal investigators, were awarded funds for "A year in the life of the bowhead whale: an animated film" that will build upon the CIFAR-funded calendar and provide outreach of the CIFAR BOWFEST research to a statewide and national audience.

Partner organizations and collaborators

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

Impact

Programs that were written to analyze oceanographic, meteorological, and aerial observational data related to bowhead whale distribution and behavior have recently been adapted for similar analyses of beluga whale distribution and behavior in the Barrow area.

Cooperative research on sablefish between Ted Stevens Marine Research Institute (TSMRI) and UAF Fisheries

Terrance Quinn II, PI
Anne Beaudreau, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem studies and forecasting

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

CIFAR 12-025: This project is ongoing. Line Office NMFS-AFSC; Dana Hanselman, Sponsor

Primary objectives

This project provides support for UAF fisheries faculty supervising graduate student research on sablefish stock assessment in collaboration with TSMRI. Areas of interest to TSMRI are:

Apportionment and population dynamics (Quinn): This graduate research project will focus on analyzing harvest strategies for sablefish. This will include examining different strategies of regional apportionment with the primary goal of optimizing the harvest with respect to maintaining adequate female spawning biomass. Consideration of the socioeconomic aspects of regional apportionment will also be included. This will involve working directly with TSMRI staff on the development of a spatially explicit model to simulate test apportionment strategies including recent updates to movement parameters.

Juvenile sablefish ecology (Beaudreau): This project will collect 2 years of oceanographic, benthic, food habits, and growth data and make use of the available movement data available for St. John the Baptist Bay. The study will occur in the vicinity of St. John the Baptist Bay, where juvenile sablefish are found consistently. The goal is to examine what makes this good habitat for sablefish juveniles. The study will be done in conjunction with TSMRI scientists and the student will be supervised by Anne Beaudreau, a marine fish ecologist. Quantitative analysis and potentially some habitat modeling will be undertaken in this study, similar to a study by Beaudreau that used field-based and quantitative analytical tools to address ecological questions relevant to rocky reef ecosystems in relation to lingcod.

Research accomplishments/highlights/findings

Beaudreau has been meeting with TSMRI scientists to plan field research for this summer. The research protocol for this study has been reviewed and approved by the UAF Institutional Animal Care and Use Committee. Quinn has been meeting with Dana Hanselman and Jon Heifetz of TSMRI to plan alternative harvest strategy evaluations.

NOAA relevance/societal benefits

This joint program between UAF and AFSC/TSMRI is to provide research support to UAF SFOS faculty for mentoring graduate students receiving stock assessment training stipends related to sablefish in the North Pacific.

Education

Kari Fenski, PhD Fisheries, Advisor: Terry Quinn
Karson Coutre, MS Fisheries, Advisor: Anne Beaudreau

Outreach

None yet. Research on these two studies will commence Summer–Fall 2012. Principal efforts so far have been to find qualified graduate students and to work on research designs.

Partner organizations and collaborators

Ted Stevens Marine Research Institute (Dana Hanselman, Chris Lunsford, Pat Malecha), Alaska Fisheries Science Center, Juneau, Alaska.

Impact

This project will accomplish two major impacts: (1) training for at least three graduate students who may be recruited by TSMRI when done, (2) innovative thesis research that will improve the stock assessment for sablefish in the North Pacific.

Changes/problems/special reporting requirements

There has been a delay in starting this project because there were no suitable graduate students available until this year and also Beaudreau did not start until January of this year. Thus two of the three students will not start until summer 2012 at the earliest.

Influence of habitat on early growth of walleye pollock (*Theragra chalcogramma*) in the Eastern Bering Sea

William Smoker, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem studies and forecasting

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

CIFAR 12-026: This project is complete.
Funded through Task I; see "Highlights of CIFAR Task I Activities" in the Overview section

Line Office NMFS-AFSC; Ron Heintz, Sponsor

Primary objectives

This work will contribute to understanding the relationship between early growth of walleye pollock (*Theragra chalcogramma*) and their environment. Walleye pollock are among the most abundant and commercially important species in the Eastern Bering Sea (EBS). Fish communities of the Bering Sea are undergoing major shifts in response to climate warming (Mueter and Litzow 2008.) Careful assessment of pollock stocks, necessary to a sustainable fishery in an era of changing climate, requires understanding the factors controlling pollock survival, particularly growth. Most data currently available is limited to the sub-adult or adult stages of pollock; there is a lack of critical information on growth of gadid fish during larval and juvenile stages (Koedijk et al. 2010).

Growth is determined largely by prey availability. Age 0+ walleye pollock migrate daily over depth (Swartzman et al. 2002), a behavior thought to result from an interplay of prey availability and predator avoidance (Schabetsberger et al. 2000). Dietary changes in age 0+ pollock are possibly related to diel migration, in turn affecting growth. Larger larval pollock have a greater chance of surviving winter and contributing to year-class abundance (Sogard and Olla 1996). Migration patterns, habitat occupied, and consequent growth rate can be a prime determinant of survival and year-class success.

The objectives of this proposal are to a) determine if instantaneous growth rates vary between age 0+ fish collected from different habitats, i.e., above and below the pycnocline in the EBS, b) relate any differences in growth rates to habitat characteristics and c) determine possible reasons for habitat selection between fish of the same age class.

References

Koedijk, R.M., N.R. Le Francois, P.U. Blier, A. Foss, A. Folkvord, D. Ditlecadet, S.G. Lamarre, S.O. Stefansson, and A.K. Imsland. 2010. Ontogenetic effects of diet during early development on growth performance, myosin mRNA expression and metabolic enzyme activity in Atlantic cod juveniles reared at different salinities. *Comparative Biochemistry and Physiology A*, 156:102–109.

Mueter, F.J. and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. *Ecological Applications*, 18:309–320.

Schabetsberger, R., R.D. Brodeur, L. Ciannelli, J.M. Napp and G.L. Swartzman. 2000. Diel vertical migration and interaction of zooplankton and juvenile walleye pollock (*Theragra chalcogramma*) at a frontal region near the Pribilof Islands, Bering Sea. *ICES Journal of Marine Science*, 57:1283–1295.

Sogard, S.M. and B.L. Olla. 1996. Diel patterns of behavior in juvenile walleye pollock, *Theragra chalcogramma*. *Environmental Biology of Fishes*, 47:379–386.

Swartzman, G., J. Napp, R. Brodeur, A. Winter and L. Ciannelli. 2002. Spatial patterns of pollock and zooplankton distribution in the Pribilof Islands, Alaska nursery area and their relationship to pollock recruitment. *ICES Journal of Marine Science*, 59:1167–1186.

Research accomplishments/highlights/findings

RNA/DNA ratios did not indicate any differences in instantaneous growth rates between larval walleye pollock sampled above and below the pycnocline in the EBS, as part of BASIS (Bering–Aleutian Salmon International Survey). These surveys began as surface trawl surveys for juvenile walleye pollock, in order to predict pollock recruitment. However, the addition of an acoustical component in 2008 indicated large numbers of larval/juvenile walleye pollock below the pycnocline, which were not sampled during the surface trawl. This led to the question of whether these fish were different from fish sampled in the surface trawl, especially in the context of growth. This also had implications for the scope of the surface trawl, i.e., if surface trawls were adequate to predict pollock growth and survival, or if fish had to be sampled from below the pycnocline as well. When fish sampled above and below the pycnocline are compared over a larger geographical area (comparing different stations), fish below the pycnocline are generally healthier and larger. However, there is a spatial bias introduced since these fish are sampled in different habitats from different stations. This study showed that when fish were sampled in different habitats (above and below the pycnocline) in the same stations, there were no instantaneous growth rate differences detected.

NOAA relevance/societal benefits

Walleye pollock are among the most abundant and commercially important species in the Eastern Bering Sea. Careful assessments of pollock stocks are vital to sustaining this fishery. This requires understanding the factors controlling pollock survival, particularly growth. Most data currently available is limited to the sub-adult or adult stages of pollock; there is a lack of critical information on growth and physiology of gadid fish during larval and juvenile stages, which this project helped address. Larger larval pollock have a greater chance of surviving winter and contributing to year-class abundance. This work will contribute to understanding the relationship between early growth of walleye pollock and their environment, aiding in stock assessments in the Eastern Bering Sea.

Education

Under a research assistantship with his advisor William Smoker, Ashwin measured whole-body RNA/DNA ratios in larval walleye pollock from different habitats, and utilized these ratios to compare instantaneous growth rates between these fish. Ashwin was pursuing his Ph.D. in fisheries at the University of Alaska Fairbanks, and successfully graduated in Fall 2011.

Publications, conference papers, and presentations

Doctoral dissertation

Sreenivasan, A. 2011. Nucleic Acid Ratios as an Index of Growth and Nutritional Ecology in Pacific cod (*Gadus macrocephalus*), Walleye pollock (*Theragra chalcogramma*), and Pacific herring (*Clupea pallasii*). Ph.D. Dissertation, University of Alaska Fairbanks, 112 pp.

Oral presentation

Sreenivasan, A. 2011. Early larval growth-RNA/DNA analyses. Presented as part of a workshop on “Modeling Walleye Pollock Growth and Bioenergetics in the Eastern Bering Sea, and Comparisons between Atlantic Cod and Walleye Pollock” held at the School of Fisheries and Ocean Sciences, 14–16 September 2011, University of Alaska Fairbanks.

Poster presentation

Sreenivasan, A., R. Heintz and E. Siddon. 2012. Integration of larval pollock growth with modeled oceanographic parameters. Presented at 2012 BEST-BSIERP P.I. Meeting, 28–30 March 2012, Anchorage, Alaska.

Impact

Ashwin Sreenivasan obtained his Ph.D. (fisheries) in Fall 2011, and currently holds a post-doctorate position at NOAA Ted Stevens Marine Research Institute.

Cooperative Alaska research and satellite data services

Thomas Heinrichs, PI **_CIFAR theme: Climate Change & Variability_**
University of Alaska Fairbanks

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 10-015/12-015: This project is ongoing. Line Office NESDIS/GOES-R; Steve Goodman, Sponsor

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 Geographic Information Network of Alaska (GINA) at 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 (GOES) Program is a joint effort of NASA and NOAA.

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

1) ***Enhanced and stabilized flow of operational data*** *from NESDIS Fairbanks Command and Data Acquisition Station and GINA to NWS and other users.*

Data flow has been enhanced and stabilized through both software and hardware improvements. As noted in the previous report, a new high availability hardware configuration was built at the NESDIS Fairbanks Command and Data Acquisition Station (FCDAS) in cooperation with FCDAS staff, and the hardware is now configured and in at FCDAS's newly constructed operations building. We are working with NOAA and University of Wisconsin Madison staff to implement local processing of GOES-R products. A site visit is planned for May 2012, during which this should be addressed.

The Unidata Local Data Manager (LDM) server deployed on the UAF campus and configured to provide data to NWS forecast offices over the Alaska NOAA network has been working well. 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. NWS IT staff and GINA staff have been coordinating deployment of products and all planned products are currently available to forecasters.

2) ***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.*

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 IFR AK
7.	GEOCAT MODIS MVFR 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. MVFR and IFR refer to modified visual flight rules and instrument flight rules, which are regulations governing civil aviation aircraft operation under different visibility conditions.

These products are fully deployed in the Fairbanks Weather Forecast Office and Alaska Aviation Weather Unit in Anchorage. A sample of the IFR/MVFR, cloud and fog products in use is shown in Figure 1.

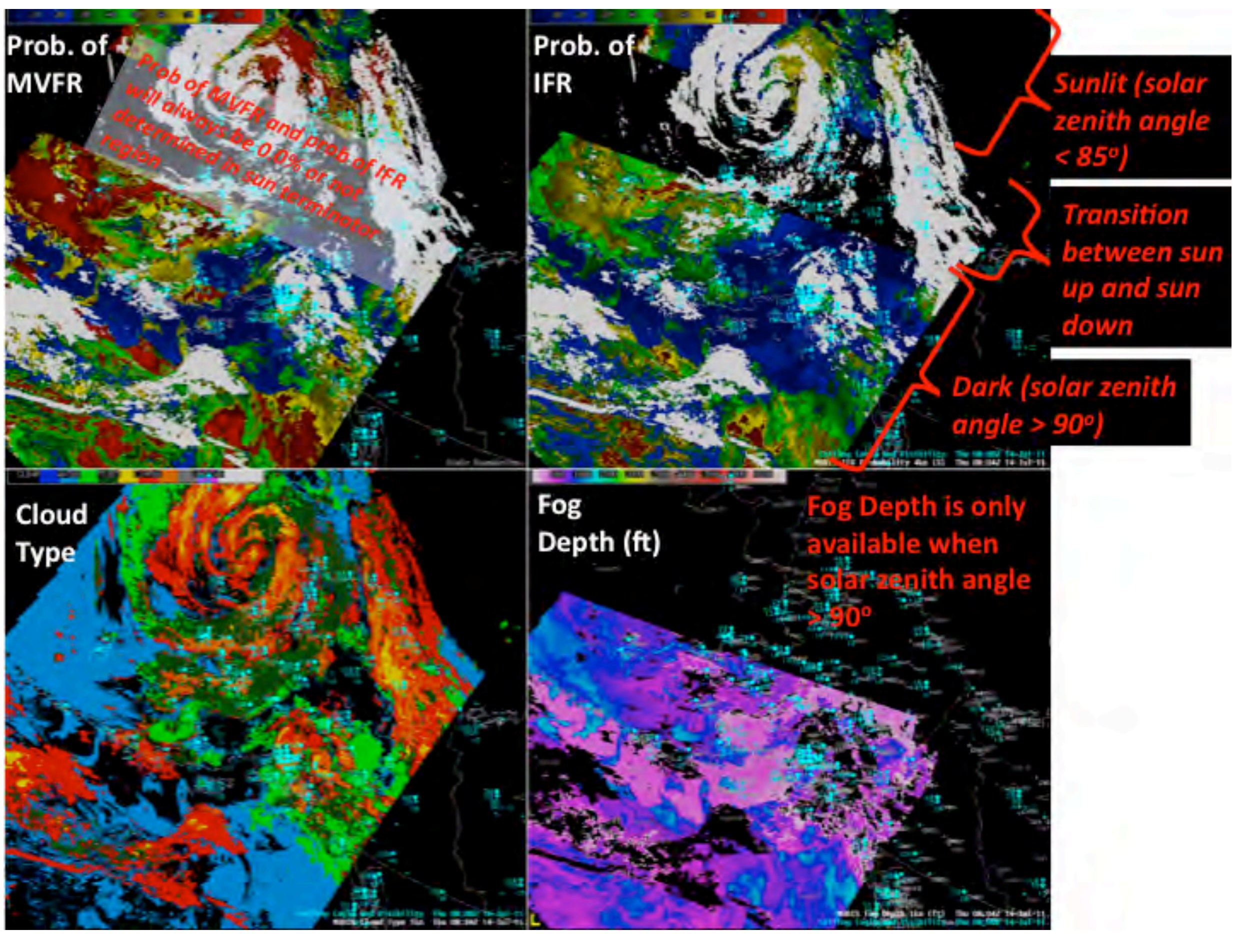


Figure 1. A four-panel layout from AWIPS (clockwise from the top-left): Probability of modified visual flight rules (MVFR), probability of instrument flight rules (IFR), fog depth in feet, and cloud type. (Courtesy of Jordan Gerth and Mike Pavolonis.)

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.

An evaluation survey of forecasters was performed and feedback on the products solicited through a written survey form and face-to-face interviews. This feedback was captured and reported to the algorithm developers and NOAA program managers. The report is in its final review prior to submission and posting to the GOES-R proving ground website.

*3) 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.*

Cherry and Bennett (PhD student) have worked with the NWS end users to identify critical time periods for validating snow-related remote sensing products in the state. Cherry is working on assembling validation datasets. Bennett is working directly with the NWS River Forecast Center (RFC) to design a mechanism to ingest remote sensing measurements of snow covered area into the operational model framework. The initial work is focusing on re-projected MODIS products in Interior Alaska, where there are a number of in situ sites for validation. However, the technique lays the foundation for moving the new GOES-R algorithms into the RFC's model workflow. The focus of this upcoming year will be to test GOES-R algorithms on the MODIS dataset for Alaska. A second PhD student (Molly Tedesche) will be involved in the project during this upcoming year with a focus on south central and southeast Alaska.

4) NOAA training, general outreach, and feedback.

Extensive training, outreach, and feedback have been performed.

- Formal product training sessions for Alaska NWS forecasters have been performed.
- Extensive outreach and coordination with NOAA staff at the NWS and NESDIS continues via 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.
- A formal solicitation of feedback was performed after several months of operational use of products by NWS forecasters (described above).

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 and continues to be supported in part through this project.
Zhang Zhu completed his Ph.D in Atmospheric Science during the period he was working on this project.

Outreach

Heinrichs, Dayne Broderson (GINA Technical Services Manager), 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. Product evaluations were gathered and a feedback loop established.

Publications, conference papers, and presentations

Oral presentations

Bennett, K.E. 2011. Hydro-climatology of a discontinuous permafrost watershed in Interior Alaska. American Geophysical Union Annual Meeting, December 2011, San Francisco, California.

Cherry, J.E. 2011. Remote sensing of snow and hydrologic modeling with the NWS. NOAA-NASA GOES-R Proving Ground Meeting, Juneau, Alaska.

Heinrichs, T., D. Broderson and J. Zhu. 2011. Overview: Alaska Region specific product satellite data activities and impacts to NWS Alaska Operations and GINA perspective. GOES-R OCONUS Meeting, July 2011, Juneau, Alaska.

Heinrichs, T., D. Broderson and J. Zhu. 2011. X-band DRO Reception in Support of OCONUS Proving Grounds. GOES-R OCONUS Meeting, July 2011, Juneau, Alaska.

Heinrichs, T. and J. Walsh. 2011. CIFAR - Cooperative Institute for Alaska Research. NOAA Satellite Science Week Meeting, September 2011, Huntsville, Alabama.

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

Changes/problems/special reporting requirements

- It took longer than expected to gather feedback from NWS forecast offices.
- Forecasters have a number of new products to evaluate at any given time and getting their attention to use GOES-R products in their operational forecast routine can be a challenge.
- Hiring a person to perform some of the work our late colleague Kevin Engle performed was a challenge, but Scott Macfarlane was hired and is performing well.

High latitude proving ground—improving forecasts and warnings by leveraging GOES-R investment to deliver and test NPP/JPSS data in support of operational forecasters

Thomas Heinrichs, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

Other investigators/professionals funded by this project:
Jay Cable, *University of Alaska Fairbanks*

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

CIFAR 12-030: This project is ongoing. Line Office NESDIS; Ingrid Guch, Sponsor

Primary objectives

The objective of this activity is to build upon the already established collaborative team of National Aeronautics and Space Administration (NASA) Short-term Prediction and Research Transition (SPoRT), NOAA National Weather Service (NWS) Alaska Region, University of Alaska Fairbanks Geographic Information Network of Alaska (GINA), and NOAA National Environmental Satellite, Data, and Information Service (NESDIS) to improve readiness of forecasters to use the Suomi National Polar-orbiting Partnership (NPP) and Joint Polar Satellite System (JPSS) Environmental Data Records (EDRs, http://jointmission.gsfc.nasa.gov/science/DataProducts.html) in a real-time operational forecast environment. Additional partners to the proving ground team could be included based on interest and capabilities, such as the Naval Research Laboratory (NRL), based on their long term work with polar orbiting environmental satellites (POES).

In Alaska, the primary focus will be on the atmosphere and cloud products that can be used to address nowcasting issues. Additional emphasis will be placed on products such as sea surface temperatures (SST), ocean color, sea ice characterization, snow cover, low light visibility, and red-green-blue composites. Results on the test and evaluation of the NPP/JPSS products will be shared with other NWS Regions. Forecaster feedback will be shared with algorithm developers and this feedback loop will result in enhanced utility of polar EDRs.

The overall goal for this project: Alaska NWS weather, aviation, and river forecasters have adopted NPP data products within a year of launch, leading to improved warnings and forecasts, and forecasters are eagerly anticipating JPSS launch and future products.

1. Rapid adoption of NPP/JPSS EDRs into Alaska NWS operations.
2. Delivery of customized, high-latitude-specific products to NWS operations.

Project accomplishments/highlights/findings

1. *Installed on GINA processing cluster. Tested CSPP VIIRS SDR Beta software on test data captured at Madison.*
   Working with Kathy Strabala and Liam Gumley of University of Wisconsin Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS), secured and installed a beta version of the Community Satellite Processing Package (CSPP). Successfully ran the CSPP on Level 0 data to produce Level 1 suites of data.
2. *Completed hardware installation of a new down converter, receiver, and receiving system computer on GINA's X-band receiving station to receive Suomi NPP data by direct broadcast.*
   A technician from SeaSpace traveled to Fairbanks and installed hardware and software upgrades to GINA's X-band receiving station. A new down converter was installed in the dish pedestal, the dish tuned, and a new receiver and capture computer were installed in GINA's operation center on campus. The new hardware allows captures of additional missions beyond NPP and MODIS, including Aura and Feng Yun 3. The scheduling priorities have been set to prioritize captures by: 1. NPP, 2. Terra MODIS, 3. Aura 4. Others to be determined.
3. *Captured Suomi NPP data on upgraded system.*
   Data was captured from Suomi NPP starting on April 5, 2012. First pass taken: Thu Apr 05 09:27 AM, GMT. It has been being captured ever since at a rate of about nine passes per day.

4. *Provided Suomi NPP data to CSPP team to test.*
   Data was transmitted to CSSP team in Madison for evaluation and product generation. CIMSS/STAR staff also projected some sample imagery captured in Fairbanks and ingested it into Advanced Weather Interactive Processing System (AWIPS).
5. *Captured Aura data on upgraded system.*
   Aura data was captured on the X-band system and provided to the Finnish Meteorological Institute for processing. This is outside the scope of this NPP project, but is an exciting ancillary benefit of the X-band hardware upgrade that will likely be of use to the NWS in the future.

NOAA relevance/societal benefits

The National Weather Service, Alaska Region, is the largest operational forecasting user of polar orbiting satellite data in NOAA because of its unique high latitude location and forecasting and warning domains. In addition to polar orbiting data, geostationary satellite data is used effectively in southeast Alaska and the Aleutians and as a synoptic tool for the rest of the state. Effective use of polar orbiting data is essential for accurate forecasting and warning at high latitudes.

Other products and outcomes

The X-band receiving station upgrade is a significant capacity increase at UAF-GINA for capturing satellite data that leads to products of use to the National Weather Service.

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
NOAA NESDIS Center for Satellite Applications and Research (STAR), In-kind support, 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

Improving predictive capabilities for the Arctic ice: international cooperative network

Igor Polyakov, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

Other investigators/professionals funded by this project:
Adrienne Tivy, *co-I, University of Alaska Fairbanks/Canadian Ice Service*
Vladimir Ivanov, *Arctic & Antarctic Research Institute, St. Petersburg*
Andrey Pnyushkov, *University of Alaska Fairbanks*

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

CIFAR 12-029: This project is ongoing. Line Office OAR-CPO; John Calder, Sponsor

Primary objectives

The overarching goal of the proposed study is to develop an enhanced capability for now-casting and forecasting of the state of Arctic sea ice through innovative international collaboration utilizing diverse capabilities of all participating institutions including the Arctic and Antarctic Research Institute (AARI), St.-Petersburg, Russia, the International Arctic Research Center (IARC) at the University of Alaska Fairbanks (UAF), and the Canadian Ice Service, beginning this reporting period.

The project objectives are:

1. Compare performance of the existing methods of sea-ice forecasts utilizing hardware/software capabilities provided by the partnership organizations including the US Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA).
2. Define limitations of the methods and improve them.
3. Develop user-friendly output through improved integration and visualization of existing data streams provided by the arctic sea-ice now-cast and forecast.
4. Enhance international partnerships that enlist resources and commitments within and across institutions.

Research accomplishments/highlights/findings

To address objectives 1, 2 and 4, the project team (including V. Ivanov and V. Smolyanitsky, both AARI, Polyakov and Pnyushkov, both IARC, and A. Tivy, now Canadian Ice Service) had a one-week meeting at UAF in March 2012 to share the method of seasonal ice forecast developed by Tivy to IARC and AARI teams. Simple tests were performed in order to educate the teams and to get basic understanding of capabilities of the method. Using the same prognostic tool and a set of predictors, both teams independently obtained the same results as Tivy. This ensures that in the future both AARI and IARC will be able to independently run the predictive tool.

This set of simple tests with synthetic external forcings was very useful for understanding the method. For example, Figure 1 shows results of two test experiments (upper and lower panels) with two sets of synthetic external forcing (Forcing-1, left column, Forcing-2, central column) and ice response (right column). Each forcing (red line) is a combination of simple functions. For example, left top panel shows that Forcing-1 for this experiment is represented by random noise (blue) and linear trend (green). Forcing-2 for this experiment (red) is produced by a combination of a constant (blue) and a polynomial function (green). The response of ice is assumed as a combination of a linear trend and a cosine function. The method was trained using the first 30 years and the forecast is shown by black line. For the first experiment the prediction was mostly determined by the behavior of Forcing-2 with polynomial sharp increase during the latest period. The model successfully "ignored" noise added to Forcing-1, which is a good feature for the method. The lower panels (experiment #2) demonstrate that the forecast missed low-frequency mode of variability introduced by Forcing-2. That places strong requirement to the external forcing for the future experiments with realistic forcing: it should resolve the major modes of variability.

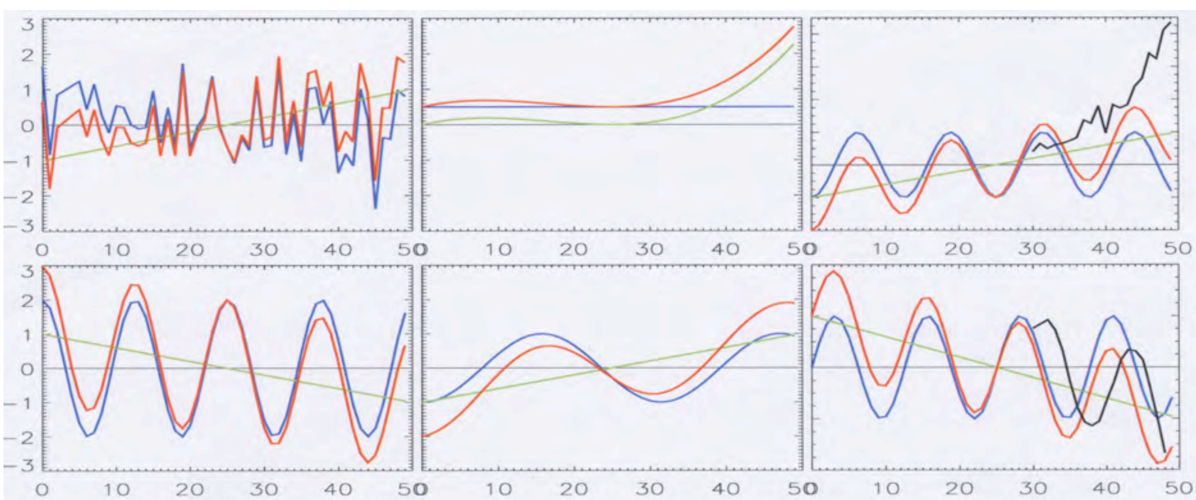


Figure 1. Results of tests of ice prediction method. Two experiments (upper and lower panels) were performed. In both experiments two externals forcings were used (left and central columns). Each forcing (red) was a combination of simple functions. The method was trained using the first 30 years. Prediction was made for the following 20 years (black line). Horizontal axis is time (years).

Another direction of efforts includes preparation of data, which will be used in future ice predictions as predictors. We plan to use various external forcings for testing. Two of them (just synthesized) are shown in Figure 2. These are oceanographic long-term time series of intermediate Atlantic Water core temperature (AWCT) anomalies and freshwater content (FWC) anomalies.

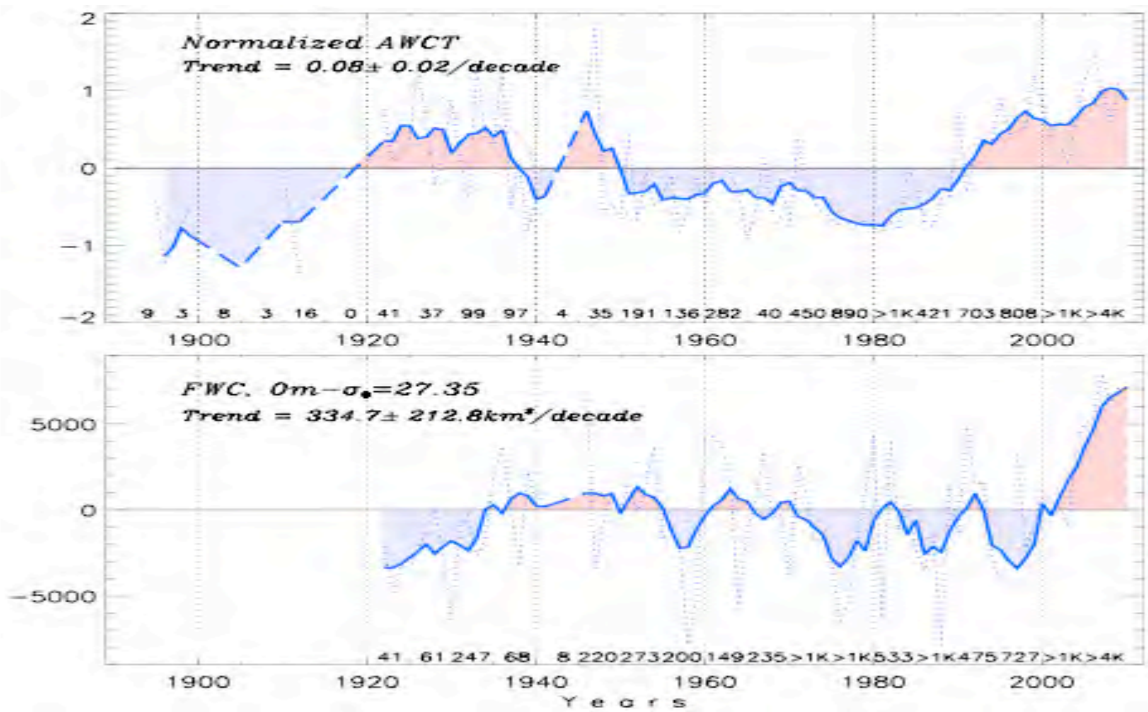


Figure 2. The Arctic Ocean normalized AWCT anomalies and upper σθ layer FWC anomalies (km3). Annual anomalies are shown by blue dotted lines, 7-yr running means are shown by blue thick lines (dashed segments represent gaps in the records), and red dotted lines show their confidence intervals defined by standard errors. Numbers at the bottom denote the 5-yr averaged number of stations used in the data analysis.

The predictive method selected for this project will follow Tivy et al. (2007, 2011). It includes several approaches which may better suit for specific purposes of the forecast. The method has been passed to AARI and IARC for future independent use. Limited tests of the method have been performed. The team has good progress in preparation of updated long-term oceanographic time series to be tested as predictors for ice predictions.

References

Tivy, A., B. Alt, S. Howell, K. Wilson and J. Yackel. 2007. Long-range prediction of the shipping season in Hudson Bay: A statistical approach. *Weather and Forecasting*, 22, doi:10.11/WAF1038.1

Tivy, A., S.E.L. Howell, B. Alt, J. Yackel and T. Carrieres. 2011. Origins and levels of seasonal forecast skill for sea ice in Hudson Bay using Canonical Correlation Analysis. *Journal of Climate*. doi:10.1175/2010JCLI3527.1

NOAA relevance/societal benefits

This strongly international program will provide improved methodology for Arctic sea-ice forecasting. It will foster international collaborations and synergy, which is vital for providing a reliable tool for the future prediction of the state of already diminishing Arctic ice cover.

Outreach

- We are preparing a web page that will highlight the project achievements.
- Tivy presented her method to a participant of an international meeting held in Norwegian Consulate.

Partner organizations and collaborators

AARI (Russia) and Canadian Ice Service

Impact

The project impact to NOAA and to the region is manifold. The seasonal ice forecast is of high demand both nationally and internationally. Our team's work satisfies this demand.

Changes/problems/special reporting requirements

Despite the fact that Tivy has left IARC, we continue our close collaboration. Efforts by A. Pnyushkov are instrumental to the project success because of his advanced computer and data preparation knowledge and his understanding of the method of the seasonal ice forecast necessary for implementing this method in both IARC and AARI.

State of the Arctic Land Report (2011)

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.*

CIFAR 12-006: This project in ongoing. Line Office OAR-CPO, John Calder, Sponsor
Funded through Task I

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 four years. In 2011, new record high temperatures at 20 m depth were measured at all observatories on the North Slope, where measurements began in the late 1970s. Although these distinct patterns of permafrost warming on the North Slope and a slight cooling in Interior Alaska are in good agreement with the air temperature patterns between the Arctic and the sub-Arctic, snow distribution variability may also be responsible. 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 Unite US curriculum (uniteusforclimate.org/index/html). Data collected during this project were immediately used in the unique graduate-level permafrost class that Romanovsky is teaching at UAF.

Outreach

During the last year, Romanovsky was interviewed by NBC Learn, NBC Universal, with NBC Learn Producer Norman Cohen, by live environmental radio show "The Paradise Parking Lot", by the radio station in Kotzebue, Alaska, by Frontier Scientists, by Justin Gillis, Environmental Science Writer for The New York Times, by Seth Borenstein, Science Writer, The Associated Press, and by Umair Irfan, a reporter with ClimateWire. On May 11, 2011, Romanovsky presented a public lecture at the staff training of the Arctic Interagency Visitor Center (AIVC) and on May 24, he presented a lecture for the community of Kivalina sponsored by NANA Regional Corporation.

Publications, conference papers, and presentations

Peer-reviewed

Romanovsky, V., N. Oberman, D. Drozdov, G. Malkova, A. Kholodov and S. Marchenko. 2011. Permafrost [in "State of the Climate in 2010"]. *Bulletin of the American Meteorological Soc*iety, 92(6):S152–S153.

Other products and outcomes

- Web site: http://www.permafrostwatch.org/
- Richter-Menge, J., M.O. Jeffries and J.E. Overland, Eds. 2011. Arctic Report Card 2011, http://www.arctic.noaa.gov/reportcard. (Romanovsky, V.E., S.L. Smith, H.H. Christiansen, N.I. Shiklomanov, D.S. Drozdov, N.G. Oberman, A.L. Kholodov and S.S. Marchenko: Permafrost)

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

David Atkinson, PI ***CIFAR theme: Coastal Hazards***
University of Alaska Fairbanks (currently at University of Victoria)

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

CIFAR 10-018: This project is complete. 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.

Project highlights and findings

- In May 2011, the buoy was tested and Atkinson attended a 3-day training workshop on all buoy systems, post-recovery maintenance, remote and local programming control, and the various data and status messages sent out by the unit.
- In late June, the buoy was loaded onto the Canadian Coast Guard Icebreaker *Sir Wilfred Laurier*. This 4000 ton vessel is an Arctic Class 2 light icebreaker and has made dozens of trips to the Arctic since entering service in 1987. The crew have launched hundreds of buoys and are very familiar with this particular type of buoy. On June 28, 2011 Atkinson went aboard and made sure all was in order.
- The buoy was successfully deployed on July 15, 2011, by the *Laurier*. Conditions were very favorable and the buoy was deployed without incident (Figure 1) to its designated location in the northern Bering Sea (Figure 2).

Figure 1. Buoy on station in the northern Bering Sea.

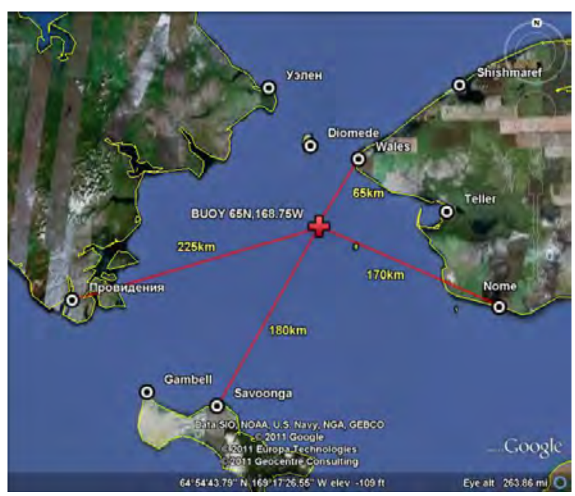


Figure 2. Buoy final location for duration of the deployment.

- To satisfy project requirements that data be available to end-users in a near real-time mode, a series of automated computer processing steps was developed by Atkinson that made possible viewing on an open website maintained at the International Arctic Research Center (IARC)/University of Alaska Fairbanks (UAF).

- The webpage (http://people.iarc.uaf.edu/~datkinson/Bering_Strait_buoy/) has 5 main elements:
  1. Introductory material with location map
  2. Current readings – yellow text on black box
  3. Vector plots which show the last 8 hours. Arrow coloring is designed to show a progressively changing/worsening/improving wave situation.
  4. Line plots of all buoy parameters that show the last three days of data.
  5. NOAA WaveWatch III wave forecast model output for locations just offshore important regional centers.
- The buoy was recovered on October 14, 2011, in good working order, by the NOAA contract ship *Westward Wind* (contractor Olgoonik/Fairweather LLC in Anchorage). Unit was transported to the NOAA facility at Sand Point in Seattle where it is currently stored.
- On December 22, 2011, Atkinson visited the facility to recover the data cards and to examine the buoy to determine what equipment needed to be replaced. During the inspection it was apparent that the unit had taken on some water, indicative that a seal had failed. Moisture ingestion and contamination of internal wiring could have been the source for the instrument reading problems. This was documented photographically and is being taken up with the company. Another visit will take place in June to replace the damaged seal and attend to any wiring the company feels needs replacing.
- Overall the buoy worked very well and provided an uninterrupted stream of wave and wind information. This was despite enduring three large storm events during the deployment period, one of which generated maximum wave heights of almost 9 meters (the buoy height is ~2.5 meters). One wind sensor was damaged during a storm. This was not unanticipated and is the primary reason a second sensor was procured. The output feed was switched over to the second wind sensor which continued to function until recovery. Air temperature data functioned reliably. The sea surface temperature sensor was damaged during a storm and was taken offline.

Research accomplishments

In addition to its real-time hazard mitigation role, the data collected by the buoy increased understanding of the storm-wave linkages in this under-sampled region. The data indicated several aspects to waves in this region.

1. There is a regular, almost weekly, progression of storm events into the greater vicinity (including the northern Gulf of Alaska), that are capable of generating waves that can be problematic for smaller craft (> 2 meter maximum wave height).
2. Most of the storm events that affected the Bering Strait were not positioned over the Bering Sea but were situated farther to the southeast, over or just south of the Alaska Peninsula. This was indicated by the frequency with which elevated wave states were driven by northerly winds; that is, winds coming from the north through the Strait.
3. The buoy has indicated that there is the potential for waves of 9 meters to be observed in this region. Getting real data like this can feed into future design considerations as well as the safety issue for users.
4. Of the four events that produced waves exceeding 5 meters in height, two of these were generated by winds from the north, including the largest 8.5 meter event, one was generated by winds from the southeast (meaning the storm was positioned near Russia's Kamchatka Peninsula), and one recorded a transition from south to northerly winds, representing a storm that traversed from the west Bering Sea over to the Alaska Peninsula (Fig. 3). These results have been presented at the American Geophysical Union meeting in San Francisco (December 2011) and are being readied for publication in a peer-reviewed journal.

NOAA relevance/societal benefits

Short term

- The buoy furnished data about wind and wave state on a near-real time basis that was easily accessed by 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 furnished data about wind and wave state on a near-real time basis that was also 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 improved safety in their day-to-day operations.
- Although local hire from the northern communities was not utilized, they still benefited from real-time wave data from this project.

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.

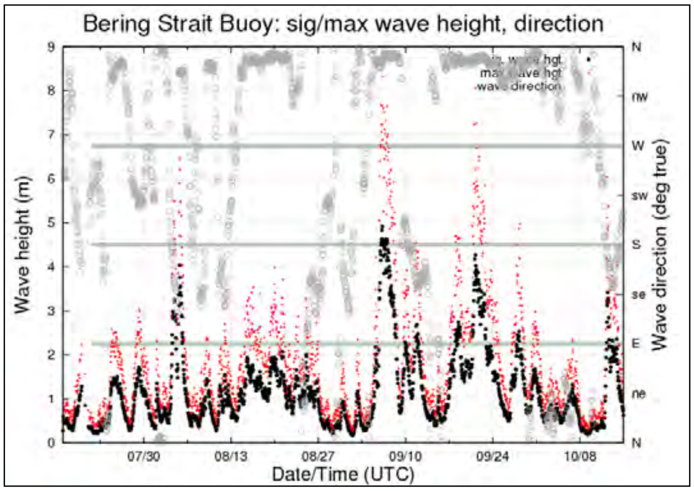


Figure 3. Full wave height and direction record from the buoy. Black dots represent significant wave height, which is an average of the highest 1/3 of wave observations. Red dots represent the maximum wave height, which is the highest wave observed in the 20 minute measuring period leading up to the hour. Grey circles indicate the direction the waves were coming from.

Education

- This project provided field data for Norman Shippee, a new PhD student who began work with Atkinson in September 2011.

Outreach

In order to monitor and track access to observe the extent to which local users accessed the site, web-site tracking software was set up ("StatCounter"). This inexpensive service provides a lot of information about timings and sources of hits to the website. The analyses that follow are drawn largely from this information. The project was a great success in terms of the breadth and frequency of user group access for safety purposes. Anticipated major groups made extensive use of the real-time data provided on the project website. Total number of hits to the website exceeded 700. Awareness-raising for the site was conducted by Atkinson in the form of advising target user groups that it existed. The site has now been picked up by Google and is the first hit when "Bering Strait buoy" is searched.

Publications, conference papers, and presentations

Oral presentation

Atkinson, D. 2011. Synoptic drivers of Bering Strait wave states, fall 2011. American Geophysical Union Annual Meeting, December 2011, San Francisco, California.

Other products and outcomes

- The buoy has been acquired and it makes sense to continue using it in the region of interest, both to continue providing safety information to local users as per the original intent of the project, and to enhance scientific understanding of storms and waves in the region, which also improves safety, albeit with a longer lead time. To that end Atkinson has initiated efforts or worked on partnerships to bring about the two main required elements to get the buoy re-deployed: funds and ship time. See section ***Leveraging of NOAA support through new partnerships*** below.
- The first phase of this project saw improvements made to the Alaska implementation of NOAA's WaveWatch III blue-water wave forecast model. That work is directly harnessed here by including WaveWatch III output specifically targeted at communities and infrastructure loci. Under funding from another NOAA project, Atkinson has employed a research programmer at IARC/UAF who has implemented the WaveWatch III model on the Arctic Region Supercomputing Center, where it will be used to develop wave climatologies and to perform experiments using different storm scenarios. The ultimate aim is to improve community and infrastructure security. This would be less effective if WaveWatch III had not had Alaska-specific upgrades and modifications conducted using the first part of the funding for this project.

Partner organizations and collaborators

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

Leveraging of NOAA support through new partnerships

Two new partnerships have been established over the last several months. The first is with the Alaska Ocean Observing System (AOOS http://www.aoos.org). They have a mandate to ingest and provide all manner of data relevant to the region covered by Alaska waters. As such, they are interested in data provided by the buoy and are interested in seeing it deployed again. Discussions with AOOS culminated with Atkinson helping to write a proposal that AOOS submitted to the recent proposal call from the Western Alaska Landscape Conservation Cooperative (West AK LCC), the second organization with whom new linkages have been forged to provide for future buoy deployments. The proposal in large measure was asking for funds for the buoy to:

- Purchase a new mooring chain
- Purchase an acoustic release
- Pay for iridium telemetry monitoring
- Purchase a new anemometer.

[Word was received in mid-April that this proposal was successful, thus funds will be available to re-provision the buoy for re-deployment in summer 2012.]

Atkinson has also submitted a request to transport and deploy the buoy with Olgoonik/Fairweather LLC. They make the most sense for this work because they are contracted by NOAA to deploy and retrieve buoys. Thus they stop at the NOAA Sand Point dock facility, which would save on trying to transport the buoy to the US Coast Guard docks.

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 09-008/10-008/11-008/12-008: 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:
T. Logan, *University of Alaska Fairbanks;* ***J. Horrillo,*** *Texas A&M University at Galveston;* ***W. Knight (WC/ATWC)***

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

During the reporting period Z. Kowalik, J.W. Knight (WC/ATWC) and Tom Logan (ARSC) continued cooperation in performing Task 1 of the plan*: Tsunami program optimization and physics enhancement by dispersive processes.* We have formulated the energy fluxes for both the dispersive and non-dispersive waves, and this tool was used to investigate the long distance tsunami energy transformation in the Japan (2011) and Kurile (2006) tsunamis. The main task was construction of the source function for the Japan tsunami. The rupture length for the Tohoku quake was relatively short for a magnitude 9, but the slip and deformations were very big. We have performed a series of numerical experiments to understand how such strong deformation influences the far and near field tsunami distribution. The preliminary results have been plotted in Fig. 1 as a maximum sea surface height (ssh). Model computations using the above source were made for 10 hrs of propagation, allowing the tsunami signal to travel over the entire North Pacific. During this computation the maximum of ssh in every grid point was recorded. Computations presented in the figure were carried out for the hydrostatic global tsunami model. The main lobe of energy depicts strong directional properties. The maximum at the northern tip of the main energy lobe resulted from interaction with the Emperor Seamount Chain and especially with two bathymetric features namely Koko Guyot and Hess Rise located at the southern tip of the chain. Smaller spikes of energy are due to the interactions with the Hawaiian Ridge. It is interesting to see that prime sources for the larger fluxes at Crescent City are interactions with Koko Guyot and Hess Rise for both Kurile and Japan tsunamis.

In the future experiments we intend to compare the results of the dispersive and non-dispersive computation for the same source function. These experiments will elucidate the importance of dispersive processes in the large-scale propagations.

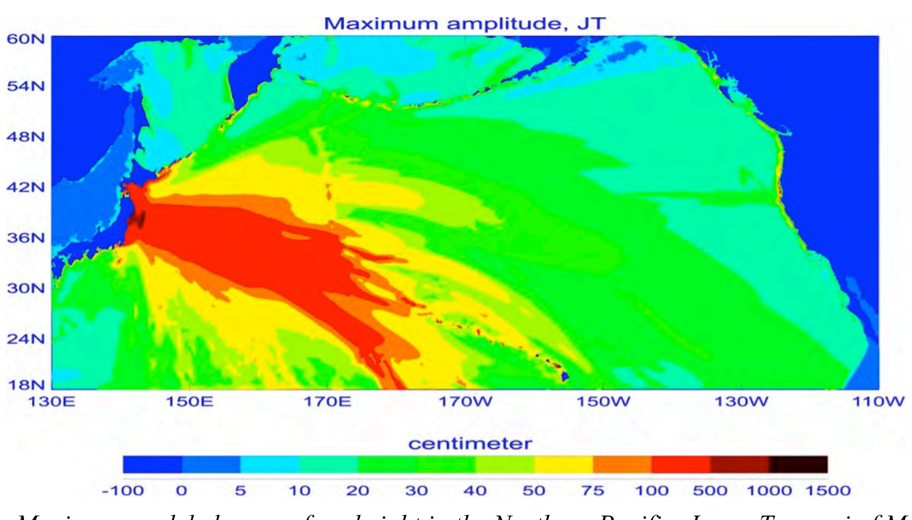


Figure 1. Maximum modeled sea surface height in the Northern Pacific. Japan Tsunami of March 2011.

In Task 2 of the plan (*development of realistic models and landslide source functions*) the three-dimensional tsunami numerical simulations have been carried out with collaboration of Texas A&M University at Galveston tsunami team, Juan Horrillo and co-worker Amanda Wood and Gyeong-Bo Kim (graduate student). The main task effort was directed into improving model capability to simulate 3D submarine landslide. To circumvent computer overload in practical 3D tsunami numerical simulations, a relatively low resolution is required to reproduce a real submarine landslide scenario. Nonetheless, a reasonable convergence and efficient solution is expected. Physical properties tend to diffuse faster in low resolution, especially in the interface of mud and water. The diffusion problem might affect the initial tsunami wave configuration due to the net energy transfer from the moving slide mass to the water. To prove this assertion, a 2D large scale numerical experiment (xz, horizontal and vertical axes) is carried out using the 3D model and compared with the commercial package, FLOW3D. The commercial package will use a diffusive interface between mud and water; our 3D model will be using a sharp interface approach. The experiment will give an indication of the 3D model performance and validation with respect to the commercial packages considering the large scale of the case. To determine the effect of assuming a sharp versus a diffusive water-mud interface, a 2D numerical experiment (x-z axes) was carried out and compared with a commercial package FLOW3D (Figure 2). Observations derived from experiment are: a) choosing a sharp or diffusive interface seems to have no remarkable effect on the early stage of the wave evolution; b) the tsunami initial wave configuration is mainly controlled by the early landslide kinematic characteristic (initial slide acceleration, shape/volume and slope) and not to the posterior slide evolution or deformation. By the time such deformation occurs, the slide has reached deeper water and the effects of the slide evolution only provide small changes to the main tsunami characteristic. Computer parallel instructions were further implemented using OpenMP® and Message Passive Interface (MPI) directives in those subroutines demanding higher Central Processing Unit (CPU) time. Most of the computational cost was directed to solve the set of linear equations for the solution of the non-hydrostatic pressure field.

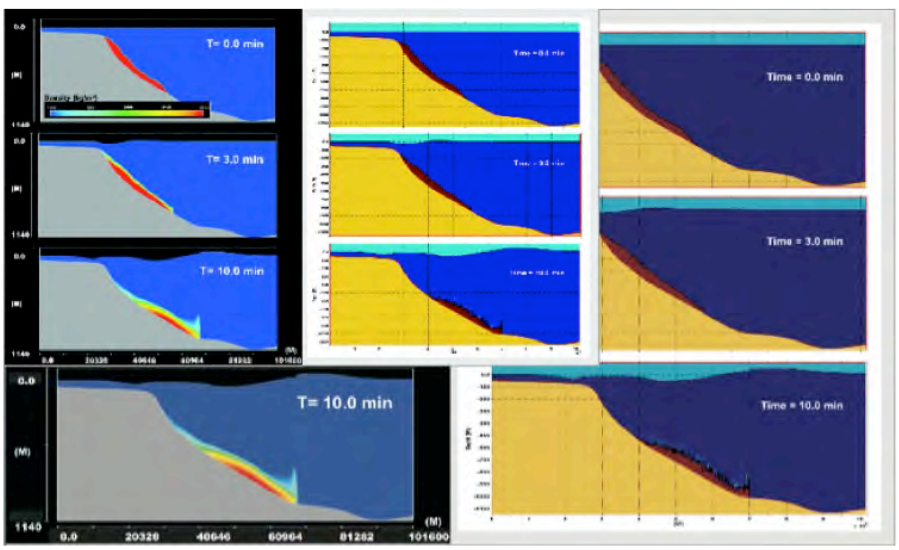


Figure 2. Snapshots comparison for the 2D mud diffusion experiment. Left side, FLOW3D results; right side, our 3D model results.

Education

- Dymitry Brazhnikov is a graduate (Ph.D.) student at the School of Fisheries and Ocean Science (SFOS). He began graduate study at UAF in September 2011. He contributed to numerical simulation of the Japan tsunami. Z. Kowalik chairs his advisory committee.
- Gyeong-Bo Kim 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.

Publications, conference papers, and presentations

Conference publications

Horrillo, J., A. Wood, G-B. Kim, A. Parambath and Z. Kowalik. 2011. TSUNAMI3D (Tsunami Simulation Using Navier-Stokes Approach for Multiple Interfaces). In: Proceedings, National Tsunami Hazard Mitigation Program (NTHMP) Model Benchmark Validation Workshop, 31 March–1 April 2011, Galveston, Texas.

Kowalik, Z. 2011. Application of the energy flux to study landslide and earthquake generated tsunami. In: Proceedings, Tsunami Generation by Subsea/Subaerial Landslides Workshop, 1–3 April 2011, Galveston, Texas, 6pp.

Other products and outcomes

Z. Kowalik and P. Whitmore provided critical review of the following publication:

Knight, W. 2011. Solution of the benchmark problems defined by NOAA using Alaska Tsunami Forecast Model (ATFM). Report to WC/ATWC.

TWEAK Task 2: ARSC Computational Support for Tsunami Simulations

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Roger Hansen, PI

University of Alaska Fairbanks

Other investigators/professionals associated this project:

Thomas Logan

University of Alaska Fairbanks

Primary objectives (modified by need)

Arctic Region Supercomputing Center (ARSC) will support tsunami research at UAF by providing parallel programming expertise, consulting expertise and support, and compute cycles as required by the UAF tsunami researchers and TWEAK participants.

(It was originally proposed that ARSC would work exclusively with Zygmunt Kowalik's Global Tsunami Model, but circumstances dictated a broader support approach from ARSC over the last year.)

Research accomplishments/highlights/findings

ARSC's effort during this reporting period has been split into support and development for three separate tsunami projects – (1) development of Zygmunt Kowalik's Global Tsunami Model (GTM), (2) support and development for Dmitry Nikolsky's Alaska Tsunami On-line and Mapping Project (ATOM) web portal system, and (3) development of a parallelized version of the West Coast Alaska Tsunami Warning Center's (WC/ATWC) Alaska Tsunami Forecast Model (ATFM) Rev12.

1) GTM Work – This work focused on the parallel Global Tsunami Model implementation

- Finished minimized memory model implementation
- Debugged multi-node runs
- Preparing global simulation of the 3/11 Japanese tsunami at 1-minute resolution

2) ATOM Work – This work focused on porting the ATOM system and code modifications

- All ATOM codes were ported from the Midnight cluster to the PACMAN cluster
- During the port, many important code modifications were implemented that will aid in future ports, further code development, and code sustainability:
    - Instantiated environment variables to remove all hard coded paths
    - Reconfigured entire system of scripts to run from a centralized BIN directory
    - Significant reduction in the number of files required by the system (removed unneeded temporary files, removed the need to copy code to each directory, removed duplicate copies of input files, etc.)
- Archived all 1.6 TB of historical data in bulk
- Implemented archiving scripts that will allow individual jobs to be archived in the future; archived several of the oldest jobs to test this new code.

- Implemented "job array" functionality. This added several important features including: automatic resubmission of long running jobs that did not complete, multiple jobs running simultaneously, and better tracking of job metadata (log files, pbs output files, etc.).

3) ATFM Work – This work focused on parallel implementation of Rev12 of the ATFM

- Input routines modified to use new control.dat file and to read in all 8 sub-grids
- All computational routines modified to match Rev12 serial code
- Single grid run has been validated against serial code running at ARSC (less than 1 mm of error was found).
- Multi-gridded runs have been implemented and tested. The code is running to completion, but is showing sea level errors at larger than acceptable levels.
- Parallel model is more than an order of magnitude faster than the serial code
- Communication with Tsunami Warning Center personnel is still ongoing, with a tentative date of June 2012 for final validation of the parallel Rev12 ATFM code.

NOAA relevance/societal benefits

All of these 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.

Partner organizations and collaborators

- Institute of Marine Science: Zygmunt Kowalik developed the GTM and has been instrumental in describing the code and answering questions throughout the development process.
- Geophysical Institute: Dmitry Nicolsky developed the ATOM code and worked closely with ARSC to make sure that all modifications made were as desired.
- 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. Kara Sterling has been the point of contact at the WC/ATWC and has been an invaluable resource in furthering this project.

Changes/problems/special reporting requirements

The remainder of ARSC's TWEAK funding will be spent as before – supporting tsunami computational science. Specifically, the parallel Rev12 ATFM code is still being debugged, and, a simulation of the Japanese tsunami using the parallel GTM is currently underway.

TWEAK Task 3: Seismic network component (Alaska CRESTnet)

Roger Hansen, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Ian Dickson, Sharon Hansen, John Sandru, Josh Stachnik, *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.

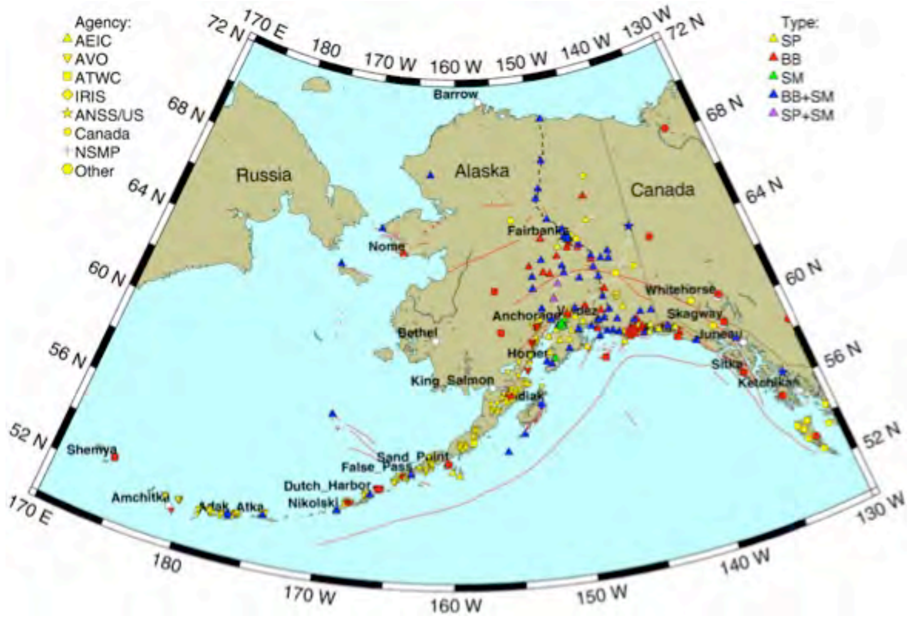


Figure 1. AEIC stations as of April 2012.

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 TNA (Tin City) and SPIA (St. Paul Island), we have worked with USGS and several telecom companies to upgrade the old analog circuits to 56k data circuits. These upgrades will provide more robust telemetry while allowing us to upgrade the digitizers at both sites. Site visits are scheduled for this fall.
- At PAX (Paxton), we improved the lightning protection.
- We performed routine maintenance at DIV (Divide Microwave, station on Richardson Highway 15-20 miles north of Valdez)
- At ATKA, we visited the site, diagnosed the problem, and provided the necessary information to GCI for them to repair their circuit. Apart from GCI's failed wireless link to their earth station, the site was in good condition and working properly.
- At DCPH (Deception Hills, south of Yakutat), we replaced 10 batteries.
- At BESE (Bessie Mountain near Juneau), we returned the site to service by removing the strong motion sensor, which was the source of the power problem. We hope to revisit the site this fall to re-install a strong motion sensor.
- At FALS (False Pass), we did a full battery swap, repaired wind-damaged radio equipment, and cleared brush to improve solar panel performance.
- At DOT (Dot Lake), we restored telemetry by replacing a non-functioning UPS.
- At COLD (Cold Bay), we restored telemetry and upgraded the radios.
- We also addressed outages at FALS (False Pass), GAMB (Gambell), SWD (Seward) and UNV (Unalaska Valley) through remote access and assistance from local contacts.
- Planned April field trips to address outages at FALS and NIKH (Nicolski High Hill).
- Between 1 April 2011 and 31 March 2012, we located 25,787 events, with magnitudes ranging between -0.5 and 7.3 and depths down to 270 km (Figure 2). The largest earthquake, magnitude 7.3, occurred on 24 June 2011, in the Fox Islands region.

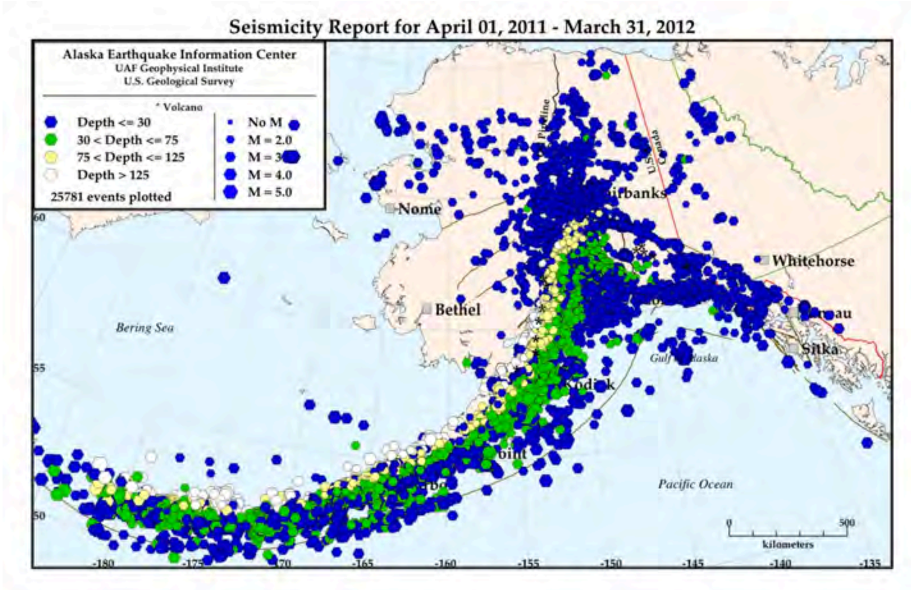


Figure 2. AEIC Seismicity Report for 1 April 2011 – 31 March 2012.

NOAA relevance/societal benefits

Improved detection of tsunamigenic earthquakes by AEIC and NOAA tsunami warning centers.

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.

TWEAK Task 4: Earthquake detection and warning with seismology

Roger Hansen, PI
University of Alaska Fairbanks

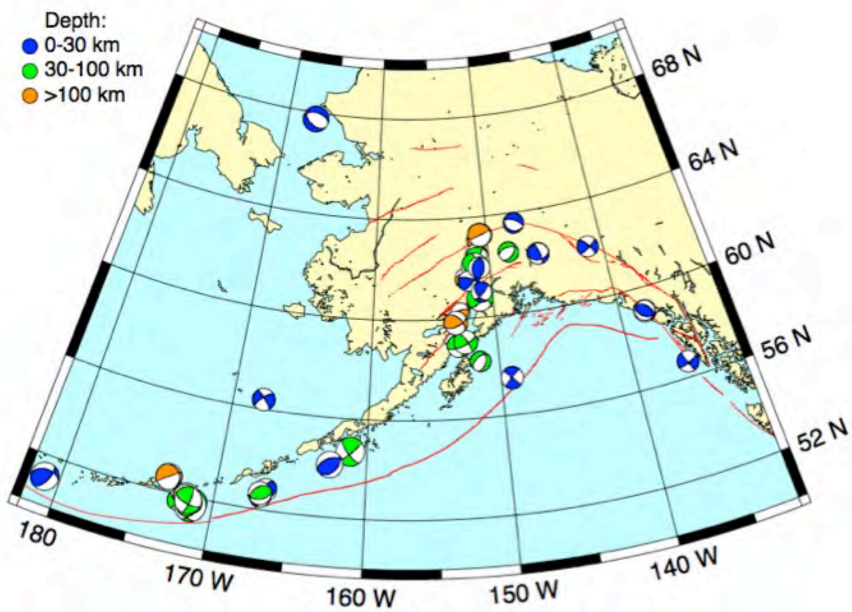
Other investigators/professionals associated with this project:
Natalia Ruppert, Anna Bulanova, Josh Stachnik, *University of Alaska Fairbanks;* ***Aurélie Guilhem****,* ***Douglas S. Dreger****, Berkeley Seismological Laboratory*

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 43 regional moment tensor solutions were calculated (moment magnitudes MW between 3.9 and 7.0) between 1 April 2011 and 31 March 2012 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 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.

Accomplishments

In our previous report we 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. The Mendocino applications, funded under a separate contract (NEHRP Northern California Panel research project), were published in Guilhem and Dreger (2011).

Over the past year we have further tested the algorithms and applied them to the strong motion waveform data recorded in Japan for the March 11, 2011 Mw9.1 Tohoku-oki megathrust earthquake. This work involved examining very low frequency acceleration records, finding a suitable passband for the analysis of megathrust events, and testing the sensitivity of solutions to various network geometries. While this work has focused on the Tohoku-oki earthquake data the lessons learned are directly relevant to the implementation of this method in Alaska. The results of the Tohoku-oki earthquake analysis have been submitted for publication in *Bulletin of the Seismological Society of America*, and the manuscript is presently under revision. The analysis shows that stable moment tensors, with correct estimates of scalar seismic moment may be obtained in the 8 minute time frame using streaming data from 4 three-component stations (Figure 1). In the 20 to 50 seconds period passband commonly employed in regional distance seismic moment tensor analysis the magnitude is under predicted at Mw7.8, and the focal mechanism is incorrect. On the other hand in the 100 to 200 seconds passband the correct moment magnitude and focal mechanism are obtained. Results are compared for both velocity and acceleration data streams. The K-NET strong motion records show stable long-period acceleration signals in the 100 to 200 second passband. These long-period records are effectively modeled with frequency wavenumber synthetics for both point-source and quasi-finite-source (Guilhem and Dreger 2011) representations. We found that by using the quasi-finite-source parameterization the number of virtual source locations could be reduced allowing the testing of more rise time and rupture directivity models.

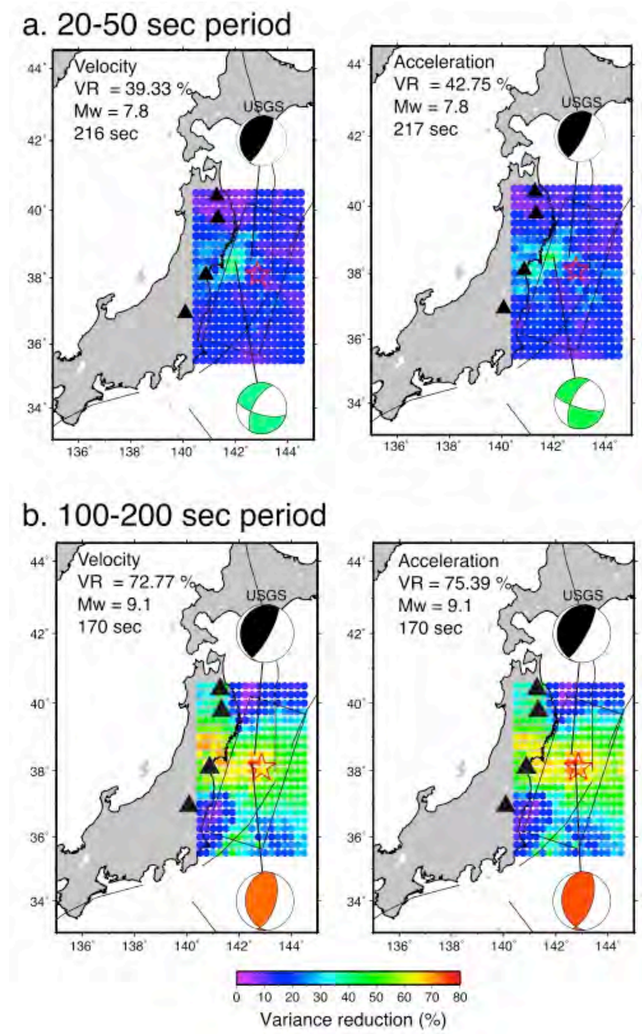


Figure 1. Maps of the best variance reductions per grid points (dots) obtained +/- 5 km from the slab depth using the data of four strong motion stations (triangles) integrated to velocity (left) and let as acceleration (right). a) Inversions using data filtered between 20 and 50 sec period. b) Inversions using data filtered between about 100 and 200 sec. The best double-couple solution is shown by the colored beach-ball diagram and is compared with the USGS CMT mechanism (black). The red star shows the JMA epicenter. Origin time is given with respect to the starting time of the inversion: 05:44:02 UTC.

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 2 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 3 utilizes the Southern Alaska model.

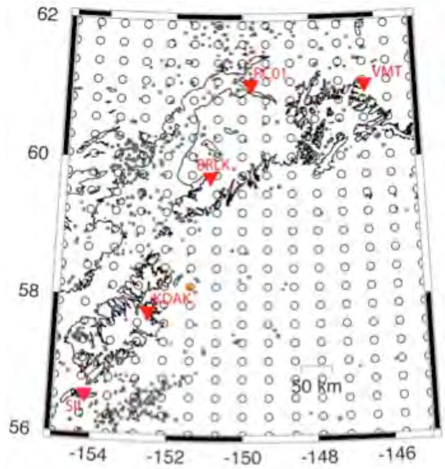


Figure 2. Stations are shown as red triangles, virtual source locations as unfilled circles, and the location of a synthetic test event is shown as the orange circle. Seismicity is shown as gray dots.

To test the software synthetic velocity data was constructed for a source located at the (5,8) grid point (orange circle, Figure 2) 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 3 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.

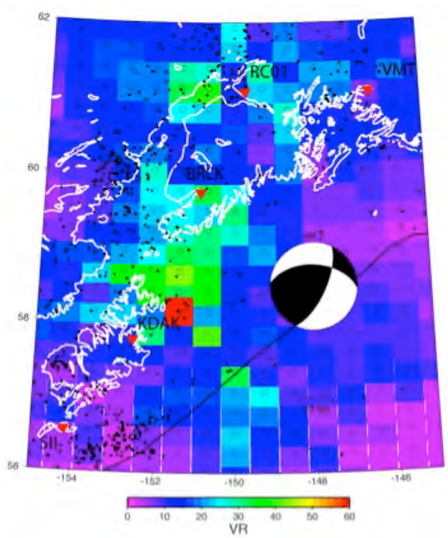


Figure 3. Data fit for a synthetic data test case. The location, depth, origin time and focal parameters were all correctly determined. The best fit was found to be 91%.

We searched the IRIS (Incorporated Research Institutions for Seismology) holdings for the Alaska Network, from 2008 through August 2011, and of the stations we used in the test case (Figure 3) we found a M_L 5.6 event that occurred on July 28, 2011 at 14:00:0.0 UTC that was recorded by three of the stations, BRLK (Bradley Lake), KDAK (Kodiak Island) and RC01 (Rabbit Creek). This is the only event in the catalog during this time period where data was available for all three stations.

The event was located at 62.0485N and 151.3030W at a depth of 86.5 km (Advanced National Seismic System composite catalog), just north of the northern most edge of the processing region. The original reported depth was 65.5 km. Robert Herrmann of Saint Louis University (SLU) has computed a USGS/SLU moment tensor solution for the event locating it at 62.05N, 151.29W, 81 km depth with a Mw 5.3. The USGS/SLU focal mechanism is shown in Figure 4. We found a Mw 5.2 and depth of 80 km for the event, and a focal mechanism consistent with Herrmann's result obtained using data from 42 stations (Figure 4). Figure 4 shows the distribution of the goodness of fit parameter where the bestfit nodes are the two closest to the reported location. This is a very positive result, however it is necessary to test the algorithm with additional events. Considering that this was the only event with complete data for the three stations, we will also need to test capabilities with fewer observations, or find other stations with more complete records that are also low noise in the 0.02 to 0.05 Hz passband.

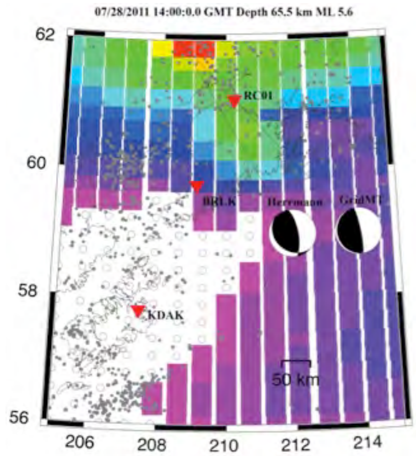


Figure 4. Map showing the locations of three stations that recorded the July 28, 2011 ML 5.6 event at the northern edge of the processing grid. Gray circles show the distribution of back ground seismicity, the USGS/SLU (Herrmann) moment tensor solution is compared to the result obtained with our GridMT implementation. The color shading shows the goodness of fit parameter that ranges from a variance reduction of 10% to a maximum of 60% with the maximum fit region corresponding to the catalog location for the event.

Future work

In the coming year we will test the M<8 implementation (e.g. Figure 3 and 4) with additional events, setup the M>8 implementation as defined in our previous report, and test it using synthetic finite-source data sets. We will transfer the software and supporting scripts to the UAF, and work with University of Alaska personnel toward implementing the test algorithms in their operational system.

References

Guilhem, A. and D.S. Dreger. 2011. Rapid detection and characterization of large earthquakes using quasi-finite-source Green's functions in continuous moment tensor inversion. *Geophysical Research Letters*, 18:L13318, doi:10.1029/2011GL047550.

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Kawakatsu, H. 1998. On the realtime monitoring of the long-period seismic wavefield. *Bulletin of the Earthquake Research Institute*, 73:267–274.

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*, doi:10.1016/j.pepi.2008.02.014.

Part 2: Development of GPS Shield Technique for Tsunami Early Warning (Josh Stachnik 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

During this reporting period we continued working on a prototype real time warning system and transitioning this project to Josh Stachnik (Anna Bulanova has left AEIC as of March 31, 2012). We also created a new event database and ran a new set of tests with a different rupture. The new model follows guidelines for rupture dimensions taken from Wells & Coppersmith (1994), whereas the previous model used rupture dimensions set to length=2*width. We then extensively documented past work, including interface discretization, generation of Green's functions, creating and testing scenario databases, and the details of the prototype real time warning system. After creating the documentation, Anna worked with Josh Stachnik and Natalia Ruppert to ensure continuity of the project after her departure.

References

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.

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

1) Sitka Tsunami Inundation Mapping Project

We have completed the construction of the high-resolution (15-meter) grid of Sitka, Alaska that is now being used in the Sitka tsunami inundation mapping project. Sitka is a community in southeastern Alaska that is exposed to tsunami risk from both local and distant trans-Pacific tsunamis. Tsunami potential from tectonic and submarine landslide sources must be evaluated in this case for comprehensive mapping of areas at risk for inundation. In this area of southern Alaska, the subduction of the Pacific plate beneath the North America plate becomes a transform boundary that continues down the coast as the Fairweather - Queen Charlotte (FW-QC) transform fault system. The Sitka segment of the FW-QC fault system ruptured in large strike-slip earthquakes in 1927 (M_s7.1) and in 1972 (M_s7.6). We have constructed several tectonic tsunami sources and performed numerical modeling of propagation and runup of tsunami waves at Sitka. Tectonic tsunami scenarios include a repeat of the tsunami triggered by the 1964 Great Alaska earthquake, repeat of the tsunami triggered by the 2011 Tohoku earthquake, tsunami waves generated by a hypothetically extended 1964 rupture, a hypothetical Cascadia megathrust earthquake, a hypothetical earthquake in the Izu-Bonin subduction zone, and hypothetical earthquakes along the FW-QC fault system. We performed simulations for each of the scenarios using AEIC's numerical model of tsunami propagation and runup, which was validated through a set of analytical benchmarks and tested against laboratory and field data. Figure 1 shows a hypothetical rupture in the Cascadia subduction zone (a), and the extent of tsunami inundation at Sitka that corresponds to this source function (b). Since the tsunami energy from this source will be directed mostly to the west, the inundation of Sitka is not significant. Figure 2 illustrates a hypothetical earthquake in the 1964 rupture area (a) and the corresponding inundation zone (b). The source is the extended 1964 rupture that includes the Yakataga segment. The inundation zone at Sitka for this scenario is slightly larger than that for the Cascadia scenario, both for the downtown and the airport areas.

Underwater landslide events off the continental shelf along the FW-QC fault zone are also considered as credible tsunamigenic scenarios. USGS geologists from the Alaska Science Center in Anchorage have identified a large scarp on the continental shelf south of Sitka, on the Fairweather fault between Baranof Island and the Dixon Entrance (Figure 3). Analysis of the high-resolution bathymetry data of this area reveals that the slide debris lobes do not appear to be offset on the fault, which indicates that the slide probably postdates the last glacial maximum. We have estimated the volume of this slide at about 200 km^3. We have constructed a hypothetical tsunami scenario that involves an underwater slide off the continental shelf just offshore Kruzof Island, with approximately the same volume as the identified historic slide (Figure 4). Figure 5 shows the inundation of Sitka that corresponds to this scenario. The movement of the slide down the continental slope produces extremely large wave amplitudes, and because of the close proximity to the tsunami source, Sitka is inundated entirely. Future work will focus on modifications of this hypothetical scenario, which include different locations of the slide with respect to Sitka, and different slide volumes.

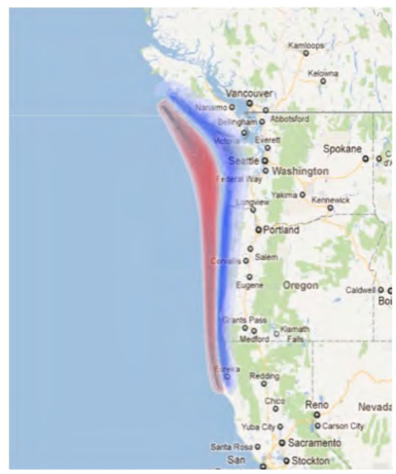

Figure 1a. The snapshot from the Alaska Tsunami Online Mapping interface that shows the pattern of coseismic uplift (pink) and subsidence (blue) for a hypothetical earthquake in the Cascadia subduction zone.

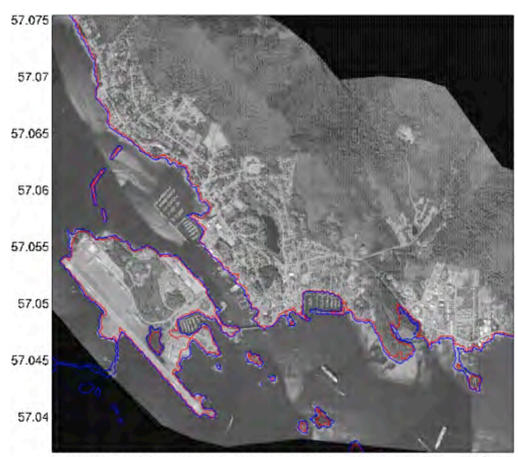

Figure 1b. Tsunami inundation map of Sitka for the Cascadia subduction zone scenario. The blue contour indicates the coastline, and the red contour shows the extent of tsunami inundation.

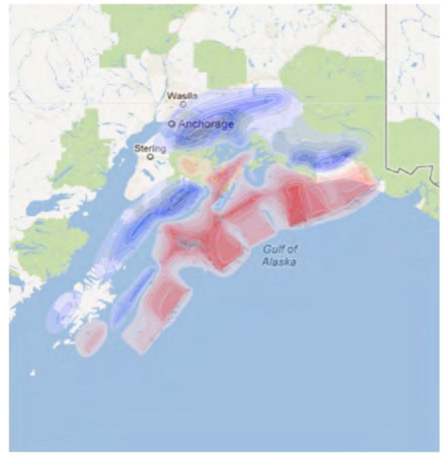

Figure 2a. The snapshot from the Alaska Tsunami Online Mapping interface that shows the pattern of coseismic uplift (pink) and subsidence (blue) for a hypothetical earthquake in the rupture area of the 1964 Great Alaska earthquake.

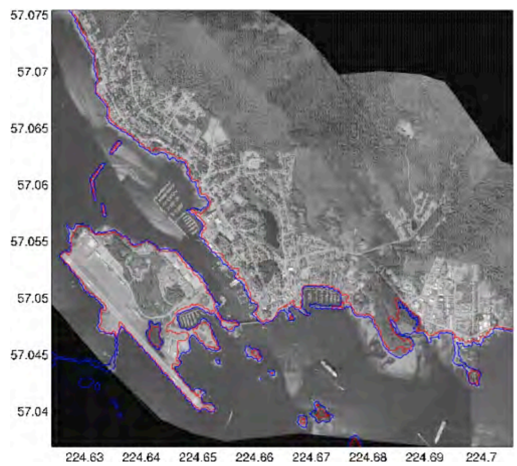

Figure 2b. Tsunami inundation map of Sitka for the modified 1964 source scenario. The blue contour indicates the coastline, and the red contour shows the extent of tsunami inundation.

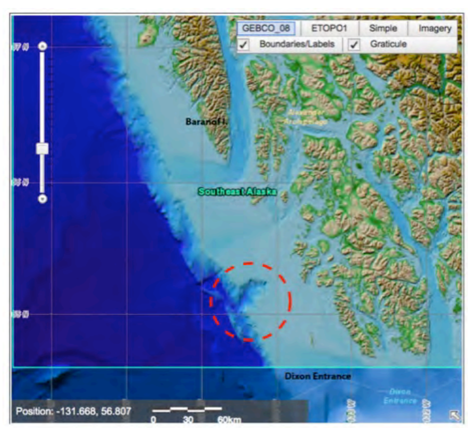

Figure 3. Snapshot of the high-resolution bathymetric image of Southeast Alaska from the Tsunami DEM Portal of the National Geophysical Data Center. The red dashed circle indicates the scarp of a large underwater slide off the continental shelf.

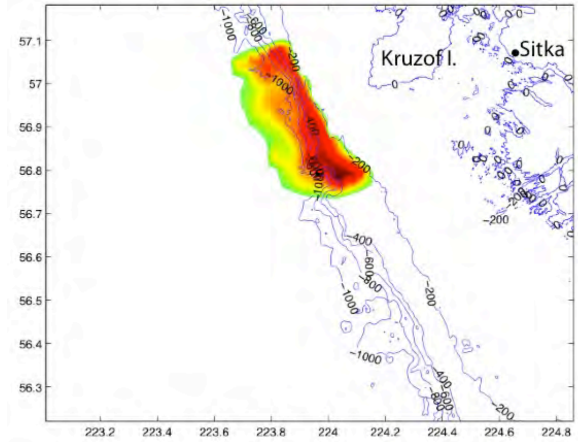

Figure 4. Thickness distribution of a hypothetical underwater slide offshore Kruzof Island. The volume of the slide is approximately the same as the estimated volume of the historic slide shown in Figure 3.

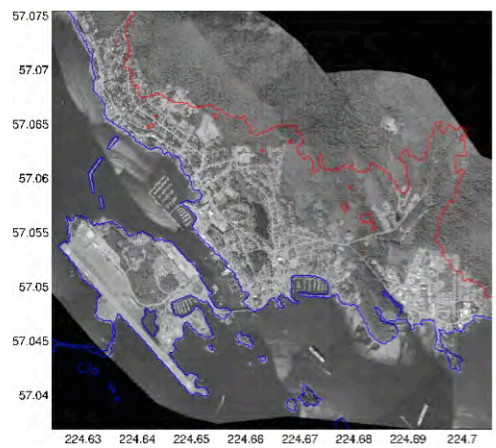

Figure 5. Tsunami inundation map of Sitka for the hypothetical slide scenario. The blue contour indicates the coastline, and the red contour shows the extent of tsunami inundation.

2) Port of Valdez Tsunami Inundation Mapping Project

We reconstructed two submarine landslides in Port Valdez during the 1964 Alaska earthquake. The first slide is thought to be localized at the head of the bay, while the other is at the entrance to Shoup Bay, in the western part of Port Valdez. The landslide configurations and thicknesses are based on the difference of pre-1964 and 1966 bathymetries, provided by P. Haeussler of USGS. Figure 1 shows contours of the landslide thicknesses.

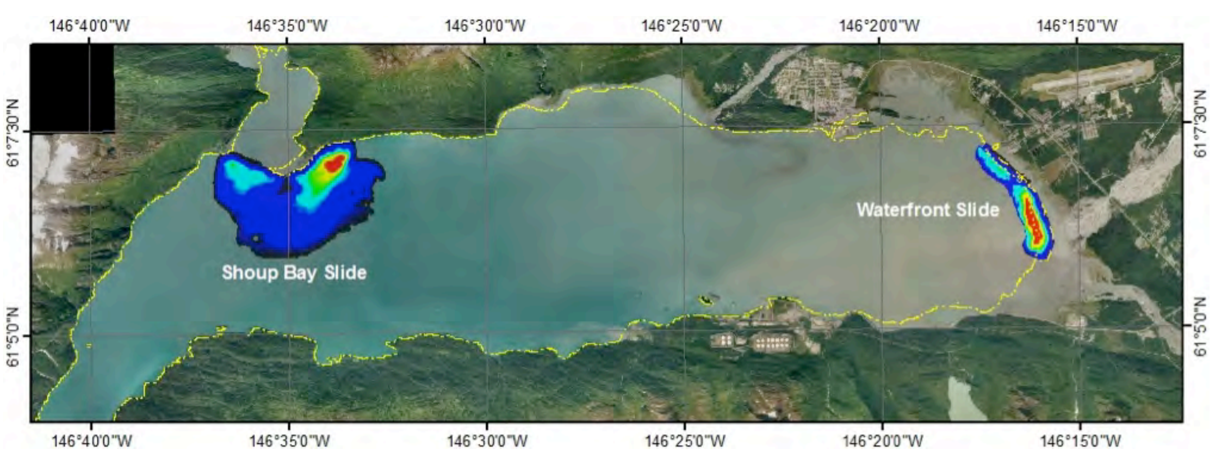

Figure 1. Locations and reconstructed thicknesses of two landslides during the 1964 earthquake.

Figure 2 shows modeled inundation by tsunami waves that are generated by ground failures only at the old city waterfront. The observed extent of inundation after the 1964 earthquake is shown by the solid yellow line. Note that the 1964 tsunami inundated along the streets, but did not flood inside of the city blocks. The dry "islands" are marked by the line with hatched symbols looking into the wet area. The debris line from the first wave is shown by the violet color. Recall that the landslide-generated tsunami during the 1964 earthquake did not flood beyond McKinley St. except for a few locations.

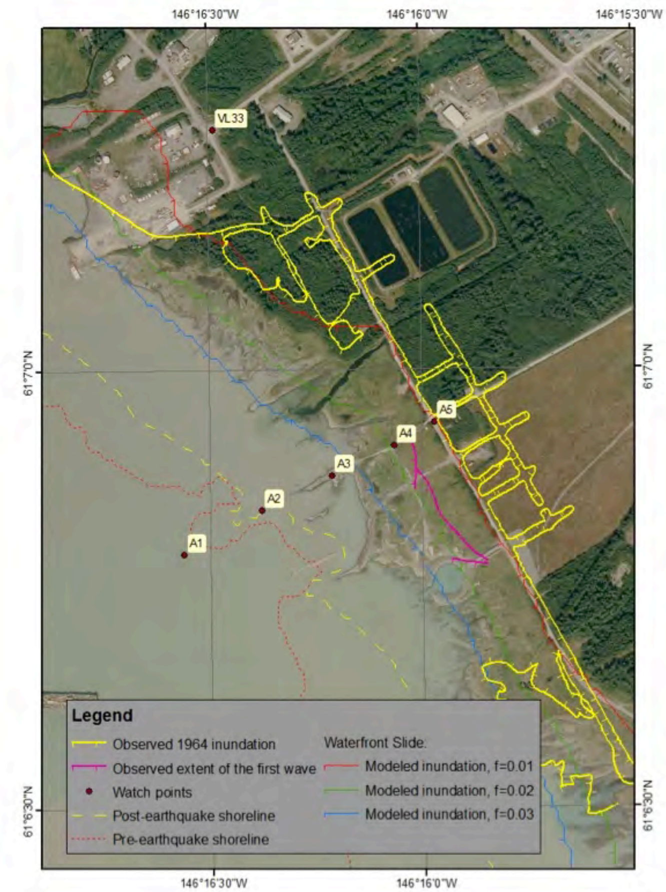

Figure 2. Comparison of the observed and modeled inundation at the old Valdez site due to the Waterfront slide-generated tsunami during the 1964 event.

The presented modeling results show that a limit of the tsunami inundation is sensitive to parameterization of the bottom drag coefficient, i.e. the surface roughness μ in the Manning's formula. The maximum modeled tsunami inundation for three values of the surface roughness μ=0.01, 0.02, and 0.03 are plotted by red, green, and blue lines, respectively. The best comparison with observations is obtained when the roughness μ is equal to 0.01 that corresponds to the roughness of smooth metal. The second good comparison is related to the roughness μ=0.02 that corresponds to firm gravel. We note that the comparison of the modeled and observed extents of the inundations is hindered by existence in the town of high snow berms and a deep snow cover during the earthquake. The berms channeled the water and restricted its distribution (Coulter and Migliaccio 1966).

Coulter and Migliaccio (1966) and Plafker et al. (1969) describe and analyze damage by landslide-generated waves during and after the 1964 earthquake. In addition to this, multiple pieces of evidence by Beget (2007); Lee et al. (2007); Ryan et al. (2010) provide a convincing view that massive submarine landslides in Port Valdez can happen in the future. Since the post-earthquake slopes are practically parallel to the pre-earthquake slope, it is thought that seismic tremor can cause the ground material, constituting the submarine slopes in Port Valdez, to liquefy and then to slide into the bay (Coulter and Migliaccio 1966). In conjunction with P. Haeussler and H. Ryan, we have developed several hypothetical scenarios of major underwater slide failures in Port Valdez (Figure 3).

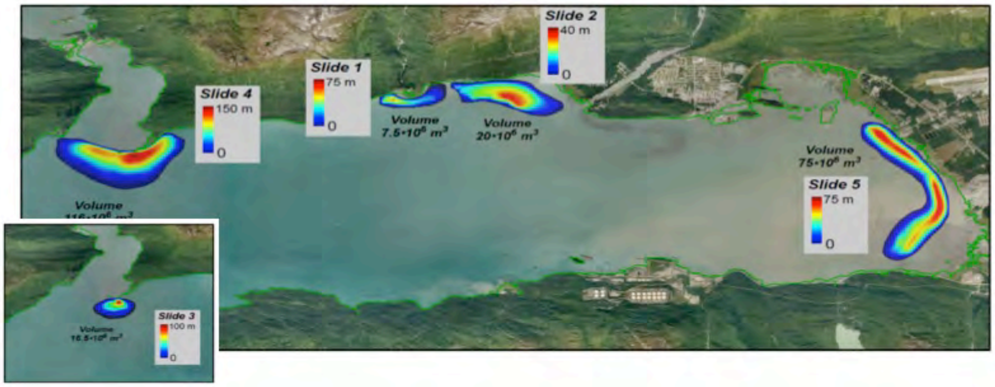

Figure 3. Hypothetical locations of landslides in Port Valdez (personal communication with P. Haeussler).

3) Incorporating horizontal displacements of the ocean bottom into the tsunami generation process

On March 27, 1964, a M_w9.2 megathrust earthquake generated the most destructive tsunami in Alaskan history. The tsunami was extensively studied and good comparison between the modeled and observed tsunami runup was obtained at most locations around the Pacific Ocean. At the same time, a cluster of unexplained runup values still exists in the western Prince William Sound, near the epicenter of the 1964 Alaska earthquake.

Currently, there are two well-known methods to simulate tsunami generation. Kervella et al. (2007) call the first method a passive generation approach, or a piston model. The initial water surface displacement is equal to the vertical seafloor displacement, while the initial water velocity is set to zero. Since the work by Kajiura (1963), who first described the piston model, the horizontal seafloor displacement is not accounted for in the majority of tsunami modeling studies due to its thought-to-be small weight in the initial surface displacement (e.g. Berg et al. 1970). However, recent studies by Tanioka and Satake (1996), Song et al. (2005), and Nagao et al. (2010) provide some basis to re-consider importance of the horizontal displacement to tsunami generation. Contrary to the passive approach, an active approach takes into account not only the vertical displacement but also the entire dynamics of the seafloor during the earthquake. Dutykh et al. (2006) showed in the framework of the linear shallow water theory that the generated tsunamis differ from the one generated by a piston model. The conducted research aimed to check the hypothesis that the horizontal displacement is primarily responsible for the observed destruction in the western Prince William Sound.

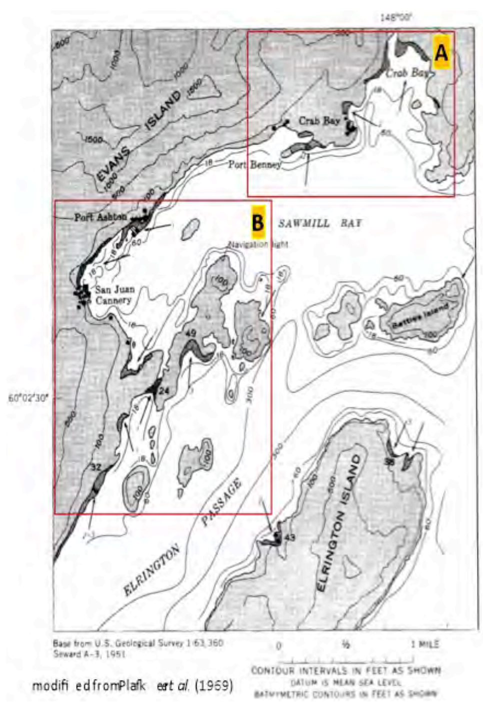

Figure 4. The observed runup in Sawmill Bay during the 1964 tsunami.

We have modified the shallow water equations to account for the dynamic horizontal and vertical displacement of the land during the 1964 event and obtained good comparison between the modeled and observed inundation, for example, in Sawmill Bay. Figure 4 shows the observed runup in Sawmill Bay. The red rectangles A) and B) mark areas where the numerical results (see Figure 5a and 5b) are compared to the observations, respectively. More thorough results and a description of the numerical model are provided in Nicolsky et al. (in press).

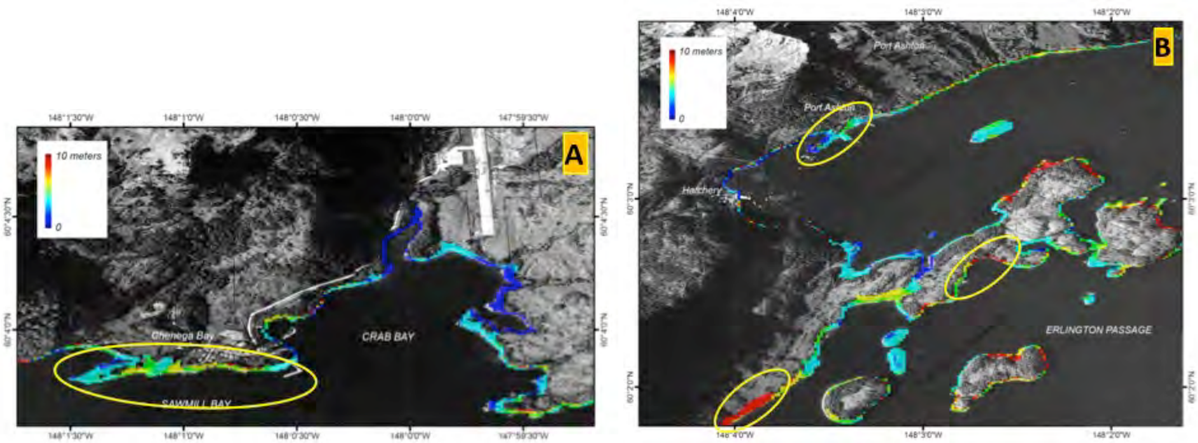

Figure 5. The modeled runup in Sawmill Bay during the 1964 tsunami. The yellow ellipses show locations where good comparison with the observations is obtained.

4) Quality control of the tsunami inundation DEMs

We continued working on the quality control of digital elevation models (DEMs) for the tsunami inundation mapping project. In August 2011, we conducted high resolution Real-time Kinematic GPS surveys in the city of Akutan, Dutch Harbor/Unalaska, and Sand Point. In October 2011, we visited the cities of Gustavus and Hoonah and also conducted similar surveys within the harbor area and along near-shore roads. The collected GPS measurements are post-processed, using the measured tide, and are ready to be sent to National Geophysical Data Center/NOAA, where they will be incorporated with other elevation data to produce realistic DEMs.

5) Modeling of the potential rockfall-generated tsunami in Passage Canal, near Whittier

During summer 2011, Alaska Division of Geological & Geophysical Surveys (DGGS) scientists conducted geologic-hazards fieldwork around Passage Canal and discovered a number of mass movement features, including several rockfalls along the steep slopes of Passage Canal. A large subaerial rockfall entering into Passage Canal has the potential to generate a local tsunami that could impact the community of Whittier and damage critical infrastructure. Thus, the tsunami inundation mapping for the community of Whittier is augmented by a new scenario related to a potential rockfall-generated tsunami.

An aerial view of the rockfall is shown in Figure 6. The red line in this figure marks the hypothesized extent of the potential rockfall. Based on field observations, we assume that the upper limit of the potential rockfall is constrained by the bedrock fracture. The lateral extent of the potential rockfall was assumed based on extension of the arcuate form of the fracture. Note that the upper limit coincides with the surveyed extent of the fracture, the location of which is shown by a series of white triangles representing GPS measurements. The lower boundary of the rockfall is assumed here to be located well below the water surface. The findings are appended to the report of investigation by Nicolsky et al. (2011).

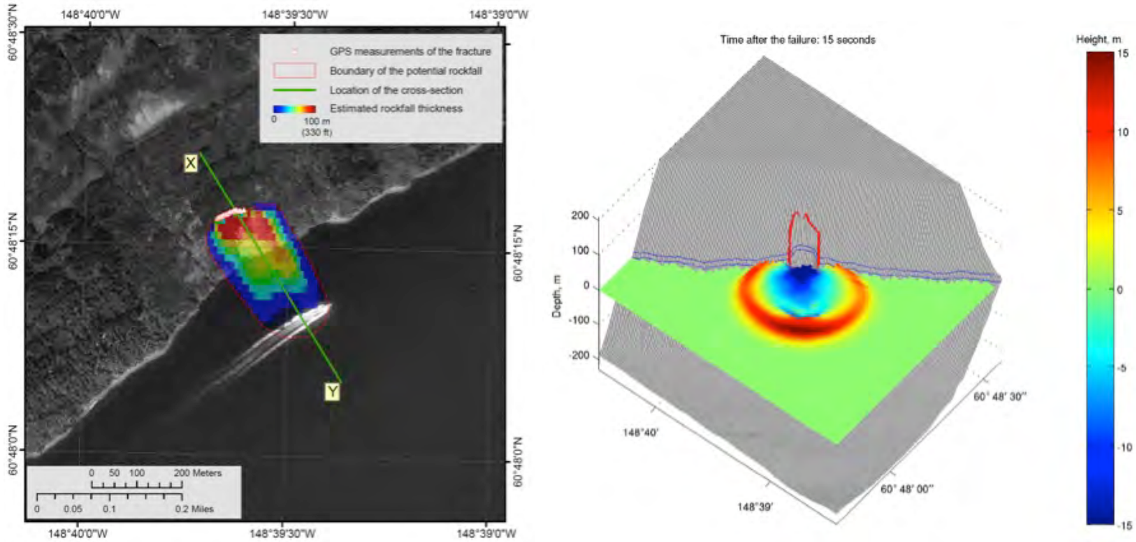

Figure 6. Left plot - Aerial view of the study area with the red line showing an extent of the potential rockfall. GPS locations of a visible part of the fracture are marked by white triangles. Right plot - Numerically modeled wave, leaving the splash zone, 15 seconds after the rockfall failure. The extent of the rockfall is marked by a red line. The blue lines correspond to 0 and 10 m (33 ft) elevations above the sea level. The DEM corresponds to the present-day mean higher high water (MHHW) datum. For the sake of visualization, the elevations are cut at 200 m (660 ft) level.

6) Collaboration with the University of Rhode Island on tsunami modeling code

In January 2012, we visited an east coast tsunami modeling group at the University of Rhode Island (URI). The purpose of the trip was to share expertise and efforts in the tsunami modeling efforts. As a result, URI shared their new non-hydrostatic model (called NHWAVE, for Non HydrostaticWAVE model) based on a Godunov-type scheme. NHWAVE solves the incompressible Navier-Stokes equations in terrain and surface following σ coordinates. Bottom movement is included in order to simulate tsunami generation by three-dimensional underwater landslides. To apply Godunov-type scheme, the velocities are defined at cell centers. The dynamic pressure is defined at vertically-facing cell faces as in the Keller-box method, allowing the pressure boundary condition at the free surface to be precisely imposed. The hydrostatic equations are solved by a well-balanced finite volume method. We plan to use this model to simulate landslide-generated tsunamis in the future.

7) Collaboration with the University of Colorado Boulder on exploring tsunami with non-traditional dataset

Anne Sheehan, Zhaohui Yang, and George Mungov - researchers at the Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder - observed clear tsunami signals generated by the July 15, 2009 magnitude 7.8 Dusky Sound (Fiordland) New Zealand earthquake (Figure 7) on seafloor differential pressure gauges (DPGs). The dataset was collected between 2009 and 2010 during the ocean-bottom seismic experiment, Marine Observations of Anisotropy Near Aotearoa (MOANA). After numerical modeling of the 2009 tsunami, we demonstrated that the DPGs can effectively record open-ocean tsunami signals and the tsunami signals on DPG records can be used for tsunami studies. The arrival times of tsunami signals on DPG recordings can be directly used to constrain tsunami wave propagation models. The numerical tsunami modeling helps to calibrate the DPGs, and hence to obtain better control on the amplitude of the tsunami signals on the DPG records. Calibrations are done over frequency bands of both Rayleigh wave and tidal signals. Synthetic pressure waveforms are calculated to be compared with the DPG recorded signals (Figure 8).

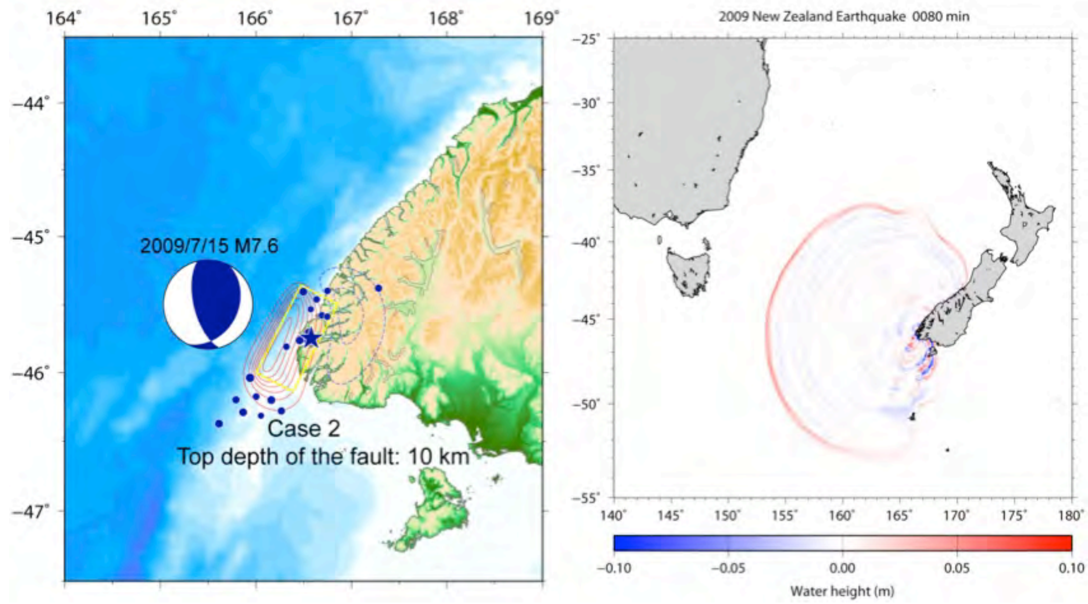

Figure 7. Earthquake and tsunami waves from July 15, 2009 Fiordland New Zealand earthquake recorded on a subset of our ocean bottom pressure. Left plot: earthquake's focal mechanism and source region deformation. From http://iisee.kenken.go.jp/staff/fujii/NZ/tsunami.html. Right plot: Snap shot of water height at 80 minutes after the earthquake.

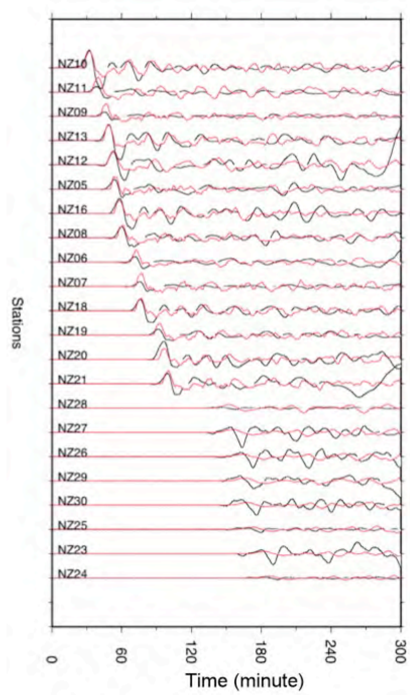

Figure 8. Comparison of synthetic and observed data. Black, DPG records with instrument response removed and converted to water height; red, synthetics normalized to six times of their original values.

8) Collaboration with the California Geological Survey on establishing a partnership

To help mitigate hazards that earthquakes and tsunamis pose to Alaska coastal communities, under the umbrella of the National Tsunami Hazard Mitigation Program, we produce tsunami inundation maps (e.g. Suleimani et al. 2010, Nicolsky et al. 2011) for selected parts of the Alaska coastline. To achieve efficient production of inundation maps, we developed and employ a parallel tsunami modeling algorithm (Nicolsky et al. 2011), executed at a Penguin Cluster at the Arctic Region Supercomputing Center (ARSC). To facilitate execution of the tsunami model, the ATOM (Alaska Tsunami On-line Mapping) interface - a Google Map internet-based interface is also created (Figure 9).

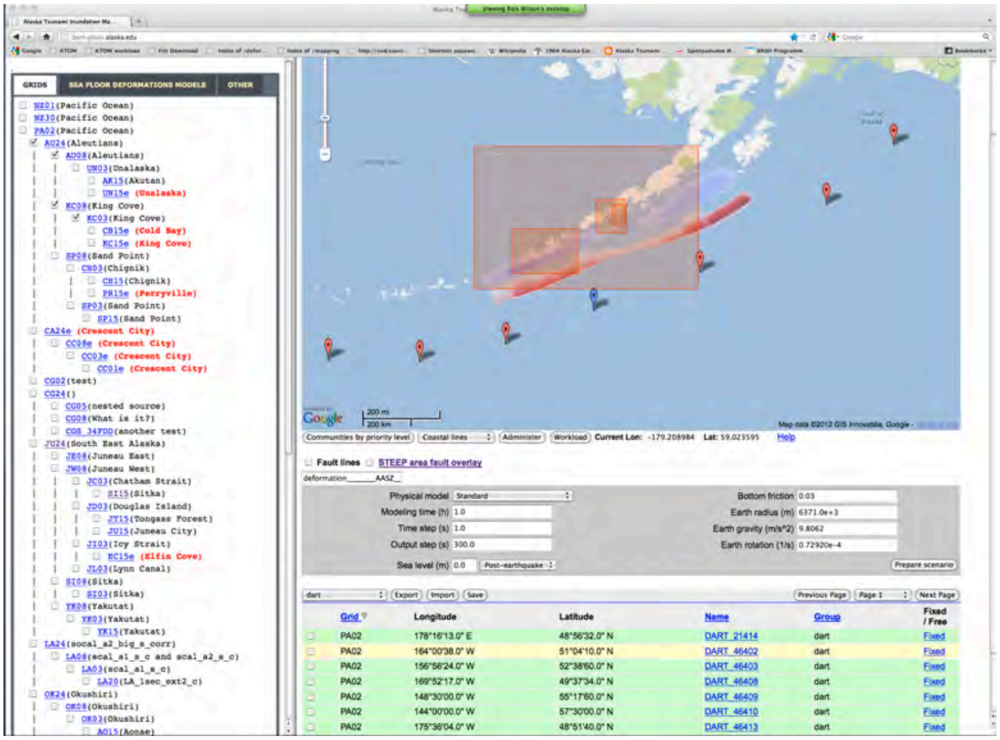

Figure 9. Screenshot of the Alaska Tsunami On-line Mapping Interface http://burn.giseis.alaska.edu/. The available DEMs are listed in the left column and can be selected by marking the check box. The extent of selected grids is marked by red rectangles on the Google Map inset. The locations where the synthetic marigrams are to be save are shown by red pointers. The computational parameters such as the longevity of the computer simulation are set up by a form within the gray rectangle. The green form below shows the geographic locations of the marigram pointers.

In the scope of establishing the partnership between California Geological Survey (CGS) and University of Alaska Fairbanks (UAF), we will maintain the ATOM interface and provide an access for researchers at the CGS to 1) develop specific tsunami scenarios at the ATOM interface, 2) execute the tsunami model on a computing cluster at the ARSC, and 3) retrieve numerical results from the cluster. The Alaska Tsunami Mapping Team (ATMT) will also provide means and expertise to explain the computational results and facilitate comparison of the numerical calculations to previous tsunami observations. In addition, we will train researchers at the CGS to simulate potential tsunamis and to retrieve the computational results.

9) USGS Multi-Hazards Demonstration Project

AEIC staff is participating in the Multi-Hazard Demonstration Project for Southern California by using tsunami numerical models to estimate the inundation of the Los Angeles area for the hypothetical case of a great earthquake in the Alaska Peninsula region. The project was initiated by USGS to demonstrate how hazard science can be used to improve the preparedness and resilience of the region. Some of the goals include developing the best models of tsunami inundation and currents for the event and stimulating research related to Alaska earthquake sources.

The Earthquake Source group (led by Steve Kirby from the USGS in conjunction with the USGS' Tsunami Source Working Group) has decided on a rupture model for the source event that is similar to the March 11, 2011 Tohoku earthquake but set in the Eastern Aleutians instead of Japan. A compact rectilinear source of ~350 km wide and ~210 km downdip was created that reflects the extremely compact nature of the 11 March event in Japan. Another related feature of the Tohoku source is the very large slips recorded approximately updip of the epicenter of the main shock based on seafloor GPS and seafloor pressure gage observations, reaching 85. A maximum slip of 75 m was adopted for the present Alaska model. The Alaska source was subdivided into 56 subfaults with a variable slip distribution. Figure 10 shows the source geometry and coseismic slip distribution for this rupture model.

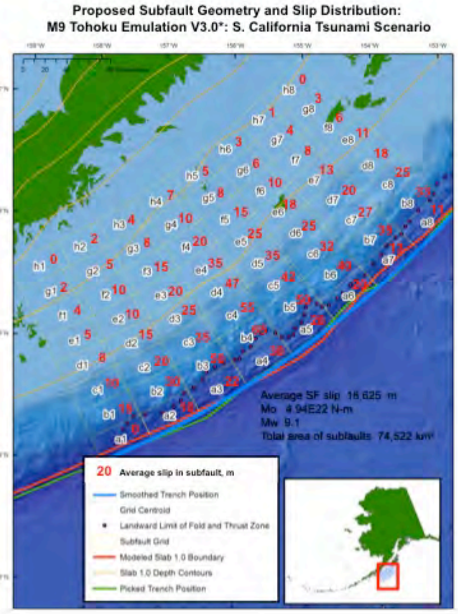

Figure 10. Source geometry and slip distribution for rupture model of hypothetical East Aleutians source event.

Using the Okada algorithm, we calculated vertical coseismic deformation for this scenario. The distribution of uplift and subsidence, which is used as an initial condition in the tsunami model, is shown in Figure 11. Then, we applied the numerical models of tsunami generation, propagation and runup using the Alaska Tsunami Online Mapping interface (http://burn.giseis.alaska.edu) to calculate maximum tsunami amplitudes in the Los Angeles area (Figure 12). We delivered our results to the Tsunami Source Working Group for comparison with other models' results.

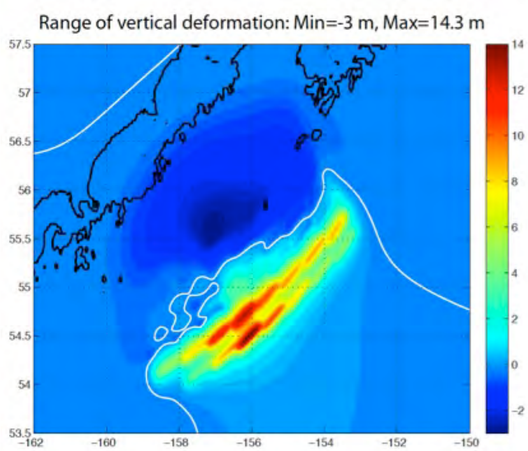

Figure 11. Distribution and uplift of the model source event.

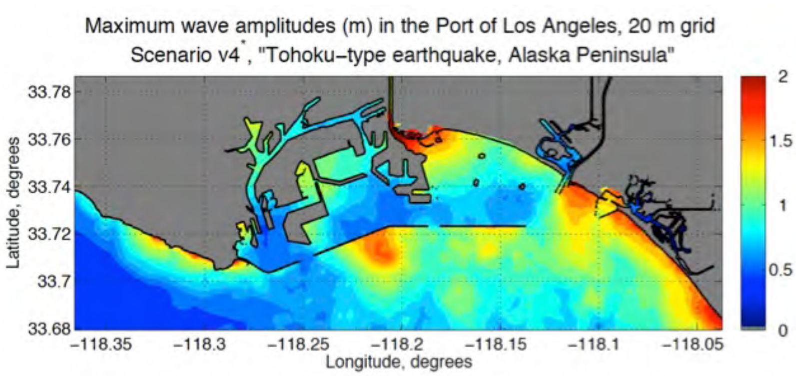

Figure 12. Maximum amplitudes in the Los Angeles area as calculated using the Alaska Tsunami Online Mapping interface.

10) NTHMP Model Benchmarking Workshop
Dmitry Nicolsky participated in a workshop of the NTHMP Mapping and Modeling Subcommittee where participants presented the results of applying benchmark tests to their tsunami propagation models and discussed new and refined benchmark tests for future implementation. Dmitry was substantially responsible for reviewing and editing the proceedings, which are currently in draft form and will be finalized soon. Workshop recommendations include continued use of existing benchmarks in OAR-PMEL-12; building improved, nested coastal digital elevation models (DEMs) of the Okushiri, Japan area to facilitate improved study of the 1993 Hokkaido-Nansei-Oki Tsunami event, which remains one of the most important and thoroughly documented cases of extensive tsunami runup available to the tsunami community; and adoption of the workshop's consensus pass/fail criteria for allowable errors in the three main categories used for benchmarking numerical models.

11) Collaboration with USGS, Menlo Park on computation of sea floor deformation to simulate inundation of Aleutian and Alaska Peninsula communities
During this year, we collaborated with scientists in USGS, Menlo Park to develop credible tsunami scenarios in order to simulate potential inundation at communities located on Aleutian Islands and Alaska Peninsula. The objective was to compute the vertical sea floor deformation, given a hypothetical slip distribution along the Aleutian plate interface. As a starting point, we exploited a coarse parameterization of the plate interface with 100 km wide sub-faults, shown in Figure 13. The computed vertical sea floor deformation is shown by color contours. Areas colored by red and blue are related to uplift and subsidence, respectively. The deformation is computed according to Okada formulae, which require a rectangular sub-fault geometry, slip, rake, strike and other parameters.

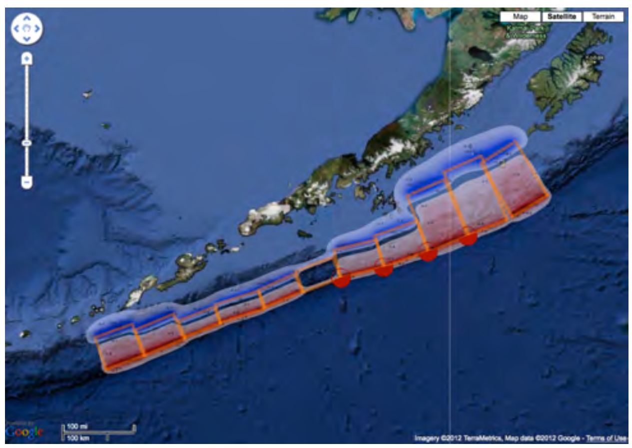

Figure 13. The vertical seafloor deformation computed according to the slip distribution at eleven sub-faults. The sub-fault geometry is courtesy of H. Ryan, USGS, Menlo Park.

Since the geometry of each sub-fault must be consistent with geometry of the plate interface, development of a fine sub-fault parameterization of the hypothetical rupture is a tedious, time-consuming process. Here, we have developed a set of tools to discretize the entire Aleutian plate interface into a set of elementary rectangles, geometry of which follows all bends and curves of the interface in the 3-D space. The elementary rectangles have a length of 50 km and cover 10 km depth variation in the plate interface. A section the discretized interface near Shumagin Islands is shown in Figure 14. The shoreline is plotted by the green line. Each elementary rectangle is further discretized into sub-rectangles: ≈16 km wide and ≈3.5 km deep.

We emphasize that geometry of each sub-elementary rectangle is consistent with the plate interface geometry. This allows computation of the seafloor deformation according to Okada's formulae as follows. For example, the slip on the plate interface can be specified on a surface projection of the interface within one or several polygon-type regions, e.g. shown in the right plot in Figure 14. The developed software tools distribute the slip from these polygons onto certain sub-elementary rectangles. Consequently, a seafloor deformation according to each sub-elementary rectangle is computed by using its slip and Okada's formulae. Finally, all contributions are summarized together to yield the seafloor deformation according to the original polygon-type source. The comparison coarse discretization of "Fox Islands Through Semidi Islands Scenario" according to 27 sub-faults and 1200 sub-faults is shown in Figure 15. Note that the most significant difference between these two discretizations and the related sea floor deformations is at the prediction of the subsidence near the shoreline. The coarse discretization over-predicts the land subsidence at the Aleutian Islands, and hence the tsunami inundation might be biased.

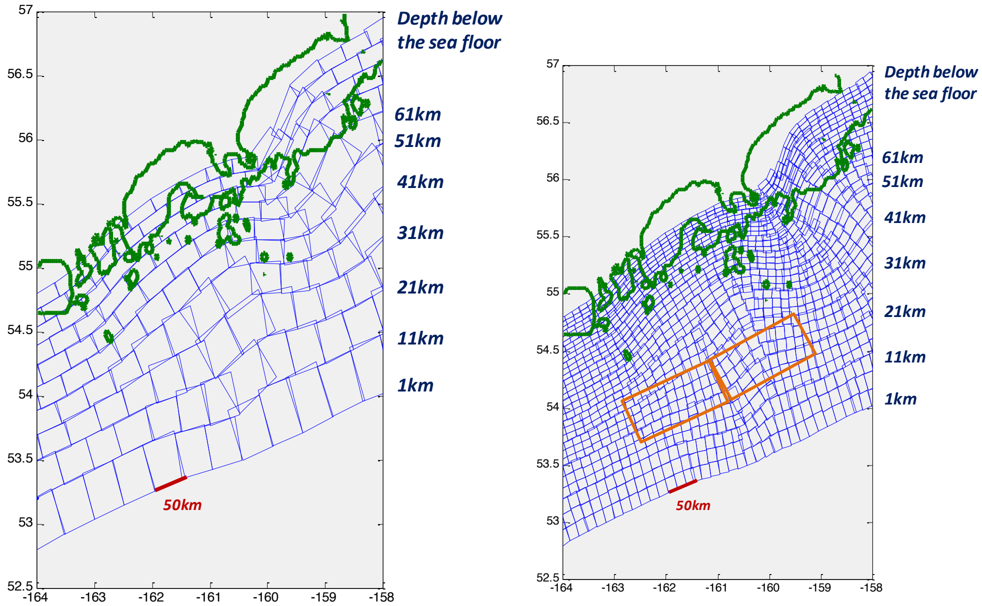

Figure 14. The Aleutian plate interface discretization by elementary (left) and sub-elementary (right) rectangles. Each rectangle has a set of parameters that are necessary to compute the sea floor deformation according to Okada's formulae.

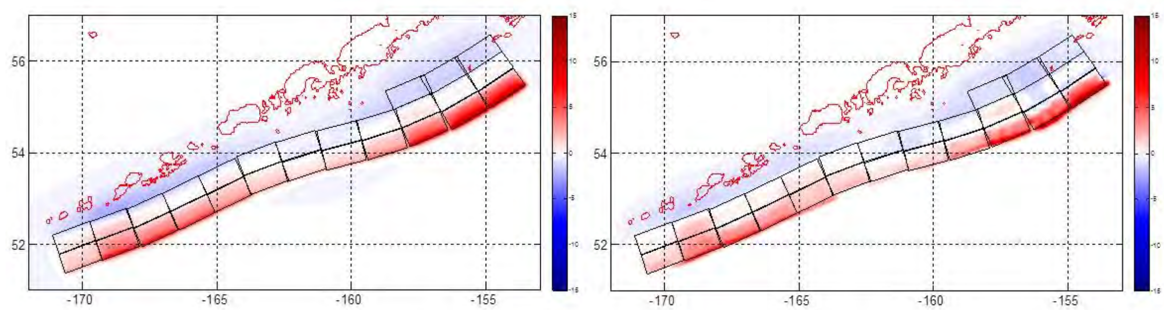

Figure 15. Comparison of the vertical sea floor deformation according to "Fox Islands Through Semidi Islands" Scenario (H. Ryan, USGS). The left plot is the related to the vertical sea floor deformation according to 27 sub-faults, shown by black rectangles. The right plot shows the sea floor deformation according to 1200 sub-rectangles. The slip at each sub-rectangle is computed by redistributing the slip of original 27 sub-faults. The most noteworthy difference is a fine structure of the uplift and differences in the subsidence along the islands, where the plate interface is at the greatest depth.

We continue working on computing the vertical sea-floor deformation with an assumption of the multi-layered elastic crust using EDGRN/EDCMP package developed by (Wang et al., 2003). The vertical sea floor deformation is obtained for each sub-rectangle sub-fault within 20^{o} radius in longitude and latitude of the sub-rectangle center.

References

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Publications and presentations

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Suleimani, E., D.J. Nicolsky, P.J. Haeussler and R. Hansen. 2011. Combined effects of tectonic and landslide-generated tsunami runup at Seward, Alaska, during the Mw 9.2 1964 earthquake. *Pure and Applied Geophysics*, 168:1053–1074, doi:10.1007/s00024-010-0228-4.

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Nicolsky, D.J., E.N. Suleimani and R.A. Hansen. 2011. Validation and verification of a numerical model for tsunami propagation and runup. *Pure and Applied Geophysics*, 168:1199–1222, doi:10.1007/s00024-010-0231-9.

Peer-reviewed, in press

Nicolsky, D.J., E.N. Suleimani and R.A. Hansen. Note on the 1964 Alaska tsunami generation by horizontal displacements of ocean bottom. Numerical modeling of the runup in Chenega Cove, Alaska. *Pure and Applied Geophysics*, doi:10.1007/s00024-012-0483-7, in press.

Oral presentations

Nicolsky D., E. Suleimani and R. Hansen. 2011. Tsunami modeling and inundation mapping in Alaska: The threat of local landslide-generated tsunamis. IUGG (International Union of Geodesy and Geophysics) General Assembly 2011, 28 June–7 July 2011, Melbourne, Australia.

Nicolsky D., E. Suleimani and R. Hansen. 2011. Tsunami modeling and inundation mapping in Alaska: The threat of local landslide-generated tsunamis. AEG (Association of Environmental and Engineering Geologists) annual meeting, 17–22 September, Anchorage, Alaska.

Sheehan, A., Z. Yang, D. Nicolsky, G. Mungov and B. Eakins. 2011. Exploring tsunamis with non-traditional dataset: array recordings from temporary ocean-bottom seismic experiment. American Geophysical Union Fall meeting, December 2011, San Francisco, California.

TWEAK Task 6: Education and outreach

Roger Hansen, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Sharon Hansen and Elizabeth Veenstra, *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. The June 24 M7.3 Aleutian event and its M6.8 aftershock resulted in numerous requests from national as well as state and local media.

Additionally, AEIC presented earthquake and tsunami education through the following activities:

- Tours of the seismology lab including presentations on seismology and earthquake and tsunami safety (10 adults and 40 K-12 students).
- Operated booths at the "Science Potpourri" (held on the UAF campus), where we provided information and demonstrations to an estimated 800 K-12 students and parents (combined) and the Alaska Satellite Facility Open House (250 people).
- Lab tour and presentation on Alaska seismicity and tsunami science for 30 visiting Japanese high school students.
- AEIC personnel hosted 1 high school student as part of a day-long job shadow.
- Currently developing educational fact sheets for display at Denali, Wrangell-St. Elias, and Glacier Bay National Parks.
- Natasha Ruppert gave a talk entitled *Recent Earthquakes That Shook the World* as part of the Science for Alaska lecture series at the Westmark Hotel in Fairbanks. About 180 people attended.
- At the same event, Sharon Hansen gave a pre-talk presentation on earthquake monitoring in Alaska. 35 people attended.

Outreach activities focused on Alaska seismicity, tectonics, and tsunami overviews as well as advice on earthquake and tsunami preparedness.

Parallelization and Porting of the Alaska Tsunami Forecast Model to 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 complete.

Line Office NWS-NWS AK, Carven Scott, Sponsor

Primary objectives

This project will enable the West Coast/Alaska Tsunami Warning Center (WC/ATWC) 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

- Rev10 of the ATFM was fully parallelized, allowing two-grid tsunami propagation simulations.
  - Coarse_to_fine sub-grid connections were implemented using a minimal set of all-to-all communications to pass needed values.
  - Fine_to_coarse sub-grid connections were implemented using a minimal set of all-to-all communications to pass needed values.
- Parallel code was debugged and tested using the single scenario that was delivered with the code.
  - Scenario runs across multiple nodes.
  - Tests on up to 128 processors yielded correct results.
  - Memory utilization was examined thoroughly but never reduced due to the unconventional implementation of the code (i.e. all arrays are stored as 1-D vectors with auxiliary data structures).
- Parallel ATFM Rev10 code results are good
  - Grid file outputs showed only 0.1 mm error when compared to the serial Rev10 code.
  - Marigram files show at most 1 mm error when compared to the serial Rev10 code.
  - On 48 processors, the parallel code required 2.5 hours to complete a 24-hour simulation run (the optimized serial code takes nearly 29 hours).
  - On 96 processors, with reduced outputs, the parallel code completed a 24-hour simulation in a mere 1-½ hours.
- Significant inline documentation was introduced in the code, describing all of the parallelism that was added.

Please note that all of these accomplishments were completed between 1 April 2011 and 15 July 2011, when the funding for this project ran out.

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.

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. Kara Sterling has been the point of contact at the WC/ATWC and has been an invaluable resource in furthering this project.

Changes/problems/special reporting requirements

In early July 2011, ARSC requested the other four scenarios needed to complete the validation phase of this project. In addition, it was requested that Kara (the new contact at the WC/ATWC) plan a visit to ARSC in August to look over the results.

In late July, the other scenarios were made available along with a new serial version of the ATFM (Rev12). It was found that the Rev12 code uses 8 grids (instead of only two used by Rev10), it has modified or changed continuity and runup routines, it has changes to both the fine_to_coarse and the coarse_to_fine subroutines (the hardest to parallelize), has different methods for startup, and has different formats for outputs. At least 7 routines were changed and 10 more routines were brand new. The result was that the version of code ARSC parallelized (rev10) was not usable for comparison with the validation scenarios delivered.

As a result, completion of this project was impossible under this grant because the money was depleted by July 15th, 2011. However, rather than just leave the project in an uncompleted state, work continued on parallelization of the Rev12 ATFM code using funds from the 2011-2012 TWEAK grant. Please see that report for updates on work completed from 15 July 2011–31 March 2012.

Validation of GOES-R volcanic ash products: near real-time operational decision support/hazard analysis

Peter Webley, PI **CIFAR theme: Coastal Hazards**
Martin Stuefer, PI
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
Jonathan Dehn, Stephen McNutt, co-PIs, *University of Alaska Fairbanks*

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

CIFAR 12-028: This project is ongoing. Line Office NESDIS; Ingrid Guch, Sponsor

Primary objectives

- Produce a Weather Research & Forecasting (WRF)-Chem/Puff model-satellite comparison product for operations
- Provide a confirmation and an assessment of Geostationary Operational Environmental Satellite – R Series (GOES-R) derived ash cloud detections and heights
- Determine the full particle size distribution and total mass and relate to retrieved GOES-R products
- Support development of an improved operational volcanic ash tracking product to NWS for use in Alaska and farther afield

Research accomplishments/highlights/findings

We have focused on two aspects: (1) Analysis of thermal infrared remote sensing of cloud top heights and (2) volcanic ash modeling using WRF-Chem and comparison to volcanic ash retrievals. We analyzed three of the major eruptions across the North Pacific: Kasatochi in 2008, Redoubt in 2009, and Sarychev Peak in 2009, as well as the 2010 Eyjafjallajokull events.

With the thermal infrared (TIR) remote sensing, we have shown that the conversion of brightness temperature to cloud height requires knowledge of cloud opacity as well as timing of the measurement relative to the eruption time. Without taking into account the cloud opacity, directly taking the TIR temperature and converting to cloud height can give an underestimation of the true cloud height. When an ash cloud has a positive brightness temperature difference, then it could be partially translucent in the TIR and hence it is not a truly opaque cloud. During these cases, the cloud top temperature will be lower from the TIR than the true cloud top height. We have confirmed this in comparisons to both local radar and multi-angle spectroradiometer data (Ekstrand et al. in review). The timing of the satellite acquisition relative to the eruptive event has been shown to be critical for inferring if the TIR height is from the drifting ash cloud or the erupting column. If the event has ended and then TIR data is available, the cloud height will be measured for the drifting cloud and hence is not a representation of the explosive event's maximum altitude (Webley et al. in review). This is an essential source parameter for the volcanic ash transport and dispersion (VATD) models used for future location information for the ash cloud and downwind concentrations.

For the VATD modeling and comparison to the satellite ash retrievals, we focused on the Puff and Weather Research Forecasting within inline Chemistry (WRF-Chem) models. We have developed model simulations to the three volcanic events from North Pacific and Eyjafjallajokull. This analysis has shown the eruption rate and particle size distribution (PSD) to be the critical parameters to produce downwind concentrations and mass loadings to compare to the GOES-R ash retrievals. We have compared the modeled ash clouds to volcanic ash retrievals from the GOES-R algorithm, on MODIS (Moderate Resolution Imaging Spectroradiometer) and SEVIRI (Spinning Enhanced Visible Infra-Red Imager) data, as well as other volcanic ash retrieval tools (Steensen et al. in review) which can be applied to all TIR data. Most VATD models use a set of default eruption source parameters and this can be applied to the VATD models used in this project. We have assessed the sensitivity of the eruption rate and PSD on the downwind concentrations. We are also developing tools to allow both a spatial and point-to-point comparison between the volcanic ash satellite retrievals and VATD model simulations.

NOAA relevance/societal benefits

GOES-R is a key element in NOAA's ongoing satellite series. We will provide a confirmation, validation and assessment of one of the GOES-R baseline products. We will provide tools to better understand the outputs of effective particle size, volcanic ash mass and height from the volcanic ash cloud detection and height algorithm**.**

Volcanic ash clouds are a severe event and can cause serious damage to aircraft, cause airport closures and affect human health. This project aims to provide improved hazard assessment and reduce the potential risk from volcanic eruptions.

Education

Torge Steensen, Ph.D. candidate student in Geophysics.
Role on project: Determination of volcanic ash retrievals and comparison to the WRF-Chem and Puff Volcanic ash models. Build tool to compare satellite data to the modeled three-dimensional ash cloud.

Angela Ekstrand, M.Sc. candidate student in Geology.
Role on project: Comparison of thermal infrared (TIR) plume and cloud top measurements to multi angle spectroradiometer data. Assessment of the TIR observations to measure true cloud top.

Publications, conference papers, and presentations

Publications in review

Ekstrand, A., P.W. Webley, D.L. Nelson, M.J. Garay, J. Dehn, T.S. Steensen, K.D. Dean and A. Prakash. A multisensor plume height analysis of the 2009 Redoubt eruption. *Journal of Volcanology and Geothermal Research: Special Issue on 2009 Redoubt Eruption* (Eds. Peter Webley and Chris Waythomas), in review.

McNutt, S.R., G. Thompson, M.E. West, D. Fee, S. Stihler and E. Clark. Local seismic and infrasound observations of the 2009 explosive eruptions of Redoubt Volcano, Alaska. *Journal of Volcanology and Geothermal Research: Special Issue on 2009 Redoubt Eruption* (Eds. Peter Webley and Chris Waythomas), in review.

Steensen, T., M. Stuefer, P.W. Webley, G. Grell and S. Freitas, S. Analysis of ash distribution of the Redoubt 2009 Eruption based on satellite observations and model estimates. *Journal of Volcanology and Geothermal Research: Special Issue on 2009 Redoubt Eruption* (Eds. Peter Webley and Chris Waythomas), in review.

Webley, P.W., T. Steensen, M. Stuefer, G. Grell, S. Freitas and M. Pavolonis. Analyzing the Eyjafjallajökull 2010 eruption using satellite remote sensing, lidar and WRF/CHEM dispersion and tracking model. *Special Issue of Journal of Geophysical Research: Eyjafjallajökull 2010 eruption*, in review.

Poster presentations

Webley, P.W., J. Dehn, L.G. Mastin and T. Steensen. 2011. Improvements on the relationship between plume height and mass eruption rate: Implications for volcanic ash cloud forecasting. American Geophysical Union Fall Meeting, December 2011, San Francisco, California.

Steensen, T., P. Webley and J. Dehn. 2011. Sensitivity analysis of input parameters for near-real-time monitoring of volcanic ash emissions - A satellite- and model-based approach. American Geophysical Union Fall Meeting, December 2011, San Francisco, California.

Ekstrand, A.L., P.W. Webley, M.J. Garay, J. Dehn, A. Prakash, D.L. Nelson, K.G. Dean and T. Steensen. 2011. A survey of the utility of the MISR sensor for analyzing volcanic plumes in the North Pacific. American Geophysical Union Fall Meeting, December 2011, San Francisco, California.

Partner organizations and collaborators

Jeff Osiensky (NWS Volcanic Ash Program Manager), National Weather Service Alaska Region,Anchorage, Alaska.

Michael Pavolonis (GOES-R Volcanic Ash Algorithm Developer), NOAA Center for Satellite Applications and Research, Advanced Satellite Products Branch, Madison, Wisconsin.

Kristine Nelson (Meteorologist in Charge), Center Weather Service Unit, National Weather Service, Anchorage, Alaska.

Georg A. Grell (Leads development for inline WRF-chemistry model and WRF-Chem working group), NOAA Earth Systems Research Laboratory, Boulder, Colorado.

Impact

Knowledge of the location and amount of volcanic ash is critical for NOAA and the NWS in their role to maintain the Anchorage and Washington Volcanic Ash Advisory Centers (VAAC). Satellite data from any volcanic ash algorithm, including the GOES-R products, can only determine the ash cloud's location and mass loadings at one instant in time. Our work in this project analyzes the ash products from satellite data with products from volcanic ash transport and dispersion models. We have shown the significance of the input parameters to the downwind concentrations and how this affects the mass loadings that are compared to the volcanic ash products. Additionally, we have shown how the cloud and plume top measurements from satellite data require both knowledge of the timing of the measurement as well as optical depth if they are to be used for the true cloud top height.

Improved tools to compare the volcanic ash products from the satellite data to the VATD models will benefit the NWS in Alaska as they will be able to use those tools in their duties in the VAAC and in the production of their volcanic ash advisories. The tools and analysis in this project can be applied directly to the VAAC office and Alaska Meteorological Watch Office and Alaska Aviation Weather Unit.

Appendices

1. Projects Awarded 1 April 2011–31 March 2012 *(p. 61)*

2. Personnel *(p. 63)*

3. Publications *(p. 65)*

4. RUSALCA overview and project reports *(p. 69)*

5. Report on J. Walsh project NA10OAR4310055 *(p. 83)*

6. Index of PIs *(p. 87)*

Appendix 1: CIFAR Projects Awarded in Cooperative Agreement NA08OAR4320751, NA08OAR4320870, and NA10OAR4310055
1 April 2011 to 31 March 2012

Last	First	Proposal Title	Project Budget	Theme Description
Task 1 Activities: CI Administration and Education & Outreach				
Walsh	**John**	Regional Alaska Cooperative Institute (2011-12)	$110,000	Administration
Romanovsky	**Vladimir**	State of the Arctic 2011/2012	$20,000	Climate Change & Variability
Quinn	**Terrance**	Stock assessment training stipends	$293,984	Ecosystem Studies & Forecasting
Smoker	**William**	Influence on the early growth of walleye pollock (Theragra chalcogramma) in the eastern Bering Sea (Student stipend support)	$15,498	Ecosystem Studies & Forecasting
NOAA Non-Competitive Projects (NA08OAR4320751)				
Hansen	**Roger**	TWEAK: Tsunami Warning & Environmental Observatory for Alaska	$628,781	Coastal Hazards
Hansen	**Roger**	Alaska Earthquake Information Center seismic station operations and maintenance (Alaska CRESTnet, year 3)	$350,000	Coastal Hazards
Heinrichs	**Thomas**	High Latitude Proving Ground--GOES-R	$136,000	Climate Change & Variability
Heinrichs	**Thomas**	NOAA cooperative Alaska research and satellite data services (GOES)	$354,252	Climate Change & Variability
Hopcroft	**Russell**	RUSALCA data management: A proposal for full featured functionality FY11–12	$199,077	Ecosystem Studies & Forecasting
Okkonen	**Stephen**	Bowhead whale feeding behavior in the western Beaufort Sea: Oceanographic conditions, whale prey distributions, and whale feeding and foraging behavior	$96,237	Ecosystem Studies & Forecasting
Polyakov	**Igor**	Improving predictive capabilities for the Arctic ice: International cooperative network	$183,093	Climate Change & Variability
Quinn	**Terrance**	Cooperative research on sablefish between TSMRI and UAF fisheries	$94,956	Ecosystem Studies & Forecasting
Webley	**Peter**	Validation of GOES-R volcanic ash products: Near real-time operational decision support/ hazard analysis	$240,000	Coastal Hazards
Competitively Awarded RUSALCA Projects (NA08OAR4320870)				
Norcross	**Brenda**	Fish ecology & oceanography: RUSALCA 2008 and 2012	$68,715	Ecosystem Studies & Forecasting
Whitledge	**Terry**	Global change in the Arctic: Interactions of productivity and nutrient processes in the northern Bering and Chukchi Seas	$37,949	Ecosystem Studies & Forecasting
Hopcroft	**Russell**	A long term census of Arctic zooplankton communities	$105,367	Ecosystem Studies & Forecasting

Last	First	Proposal Title	Project Budget	Theme Description
Iken	**Katrin**	RUSALCA: Arctic food web structure & epibenthic communities in a climate change context	$41,520	Ecosystem Studies & Forecasting
Competitively Awarded Climate Program Project (NA10OAR4310055)				
Walsh	**John**	Downscaling of climate model output for Alaska and northern Canada	$89,414	Climate Change & Variability
		Total projects funded (including CI administration)	**$3,064,843**	
		Competitively awarded projects (including CI administration)	$452,965	
		Non-competitive projects	$2,611,878	

Appendix 2. Summary of CIFAR-funded Personnel and their Terminal Degree (or degree seeking for students)

Category	Number	B.A./B.S. or unknown	M.A./ M.S. or M.B.A.	Ph.D.
Research Scientist	13		2	11
Visiting Scientist	0			
Postdoctoral Fellow	0			
Research Support Staff	21	10	8	3
Administrative	4	2	2	
Total (≥ 50% NOAA Support)	**1**	**1**		
Undergraduate Students	3	3		
Graduate Students	9		3	6
Total Students	**12**			
Employees (< 50% NOAA Support)	37	14	11	12
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			
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 1	Yr 2	Yr 3	Yr 4	Yr 1	Yr 2	Yr 3	Yr 4
Peer-reviewed	0	1	4	6	0	0	1	1	0	1	0	1
Non Peer-reviewed	0	0	0	0	0	0	0	0	0	0	0	0
In press				3				1				0
Accepted				0				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
Year 4 = 1 April 2011–31 March 2012

NOTE 1:
Besides this activity for projects funded directly by NOAA through CIFAR, 4 peer-reviewed papers were published by students who have received CIFAR funding through the Global Change Student Research Grant Competition during the current cooperative agreement.

NOTE 2:
Several of the RUSALCA projects also had papers published (4) or accepted for publication (2) 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	Logerwell, E., K. Rand and T. Weingartner	Nov 2011	Oceanographic characteristics of the habitat of benthic fish and invertebrates in the Beaufort Sea	Polar Biology 11:1783–1796	Journal article	10.1007/s00300-011-1028-8	NA08OAR4320751		X		X	
CIFAR	Nicolsky, D.J., E.N. Suleimani and R.A. Hansen	June 2011	Validation and verification of a numerical model for tsunami propagation and runup	Pure and Applied Geophysics 168:1199-1222	Journal article	10.1007/s00024-010-0231-9	NA08OAR4320751	X			X	
CIFAR	Parker-Stetter, S., J.K. Horne and T. Weingartner	Oct 2011	Distribution of polar cod and age-0 fish in the U.S. Beaufort Sea	Polar Biology 10:1543–1557	Journal article	10.1007/s00300-011-1014-1	NA08OAR4320751			X	X	
CIFAR	Suleimani, E., D.J. Nicolsky, P.J. Haeussler and R. Hansen	June 2011	Combined effects of tectonics and landslide-generated tsunami runup at Seward, Alaska, during the Mw 9.2 1964 earthquake	Pure and Applied Geophysics 168:1053–1074	Journal article	10.1007/s00024-010-2010	NA08OAR4320751	X			X	
CIFAR	Okkonen, S.R., C.A. Ashjian, R.G. Campbell, J.T Clarke, S.E. Moore and K.D. Taylor.	15 Aug 2011	Satellite observations of circulation features associated with a bowhead whale feeding 'hotspot' near Barrow, Alaska	Remote Sensing of Environment 115:2168–2174	Journal article	10.1016/j.rse.2011.04.024	NA08OAR4320751	X			X	
CIFAR	Romanovsky, V., N. Oberman, D. Drozdov, G. Malkova, A. Kholodov and S. Marchenko	June 2011	Permafrost. [in “State of the Climate 2010”].	Bulletin of the American Meteorological Society, 92(6):S152–S153.	Journal article (special supplement)	10.1175/1520-0477-92.6.S1	NA08OAR4320751	X			X	
CIFAR	Nicolsky, D.J., E.N. Suleimani, R.A. Combellick and R.A. Hansen	Dec 2011	Tsunami Inundation Maps of Whittier and western Passage Canal, Alaska	Alaska Division of Geological & Geophysical Surveys, Report of Investigation 2011-7, 65 p.	Technical report		NA08OAR4320751	X			X	
CIFAR	Walsh, J.E., J.E. Overland, P.Y. Groisman and B. Rudolf	Dec 2011	Ongoing climate change in the Arctic	Ambio, 40(Suppl. 1):6–16	Journal article	0.1007/s13280-011 0211-2	NA08OAR4320870	X			X	
CIFAR	Nicolsky, D.J., E.N. Suleimani and R.A. Hansen	In press	Note on the 1964 Alaska tsunami generation by horizontal displacements of ocean bottom. Numerical modeling of the runup in Chenega Cove, Alaska	Pure and Applied Geophysics	Journal article	10.1007/s00024-012-0483-7	NA08OAR4320751	X			X	

CIFAR	Mathis, J.T., R.H. Byrne, C.L. McNeil, R.P. Pickart, L. Juranek, S. Liu, J. Ma, R.A. Easley, M.W. Elliot, J.N. Cross, S.C. Reisdorph, J. Morison, T. Lichendorph and R.A. Feely	In press	Storm-induced upwelling of high pCO2 waters onto the continental shelf of the western Arctic Ocean and implications for carbonate mineral saturation states	Geophysical Research Letters	Journal article		NA08OAR4320751	X			X	
CIFAR	Overland, J.E., M. Wang, J.E. Walsh, J.H. Christensen, V.M. Kattsov and W.L. Chapman	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	Walsh, J.E., J.E. Overland, P. Groisman and B. Rudolf	In press	Arctic climate: Recent variations. Snow, Water, Ice and Permafrost in the Arctic, Chapter 2	Scientific Report, Arctic Monitoring and Assessment Program	Book chapter		NA08OAR4320870	X			X	
Publications from students funded by CIFAR through the Global Change Student Grant Competition:												
CIFAR	Brosius, L.S., K.M. Walter Anthony, G. Grosse, J.P. Chanton, L.M. Farquharson, P.P. Overduin and H. Meyer	Feb 2012	Using the deuterium isotope composition of permafrost meltwater to constrain thermokarst lake contributions to atmospheric CH4 during the last deglaciation	Journal of Geophysical Research, 117, G01022	Journal article	10.1029/2011JG001810	NA08OAR4320751	X			X	
CIFAR	Barger, C.P. and A.S. Kitaysky	Dec 2011	Isotopic segregation between sympatric seabird species increases with nutritional stress	Biology Letters	Journal article	10.1098/rsbl.2011.1020	NA08OAR4320751	X			X	
CIFAR	Müller-Stoffels, M. and R. Wackerbauer	Mar 28 2011	Regular network model for the sea ice–albedo feedback in the Arctic	Chaos, 21, 013111	Journal article	10.1063/1.3555835	NA08OAR4320751	X			X	
CIFAR	Müller-Stoffels, M. and R. Wackerbauer	Feb 2012	Albedo parameterization and reversibility of sea ice decay	Nonlinear Processes in Geophysics, 19:81–94	Journal article	10.5194/npg-19-81-2012	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, 4 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 2011 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/2011/Khromov2011CruiseReport.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 09-009/11-009/12-009: 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

New samples were collected from the American side of the 2 lower long-term transects in 2011. Analysis of both 2010 and 2011 samples was completed. In both years, east-west patterns were distinct with a clear signal of Alaska Coastal water. Zooplankton abundance and biomass values fall within the range observed on more extensive cruises in 2004 and 2009. Re-analysis of 2009 data with data collected simultaneously in the northeastern Chukchi shows the latter region to have its own distinct community structure.

Planning is underway for participation in both the mooring cruise and more extensive Biology cruise in 2012.

NOAA relevance/societal benefits

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

Education

Elizaveta Ershova continues her Ph.D. under this project – she remains jointly supervised by Hopcroft and Kosobokova, and splits her time between UAF and Shirshov Institute, Moscow.

Outreach

Hopcroft, through ArcOD (Arctic Ocean Biodiversity Project), continues to develop webpages providing information on Arctic zooplankton and access to historical datasets: see http://www.arcodiv.org/. The species page concept is being expanded upon through a related fellowship by the Encyclopedia of Life to Ershova, and will be merged with ArcOD content over the next year.

Publications, conference papers, and presentations

Oral presentations

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2012. A multi-year census of the zooplankton communities in the Pacific Arctic. Alaska Marine Science Symposium, January 2012, Anchorage, Alaska.

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2012. A multi-year census of the zooplankton communities in the Pacific Arctic. ASLO/AGU Ocean Sciences Meeting, February 2012, Salt Lake City, Utah.

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2012. A multi-year census of the zooplankton communities in the Pacific Arctic. RUSALCA PI meeting, March 2012, Miami, Florida.

Other products and outcomes

RUSALCA data was employed in analysis contributing to the following, which has been accepted for publication:

Nelson, R.J., R.R. Hopcroft, K.N. Kosobokova, B.P.V. Hunt and K. Young. Biodiversity and biogeography of metazoan zooplankton of the Pacific Arctic Region – Sensitivities to climate change, In: Grebmeier, J.M., W. Maslowski and J. Zhao, Eds., The Pacific Arctic Sector: Status and Trends. Springer, New York.

An additional paper using RUSALCA data is currently in review.

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

Budget remains tight, but adequate to support activities through 2013. A renewal next year will be required to complete project goals as well as Ershova's Ph.D. degree.

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 09-010/11-010/12-010: 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. Second, 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 benthic community trends in the RUSALCA region.

Research accomplishments/highlights/findings

We have analyzed most of the samples from the 2009 RUSALCA cruise; some more isotope analyses and taxonomic identification of epifauna are still ongoing. Isotope analyses included a comparison of lipid-extracted and non-extracted samples to gauge the impact of lipids on stable isotope ratios. Most of the epifaunal work included matching taxonomic identifications between the 2004 and 2009 samples to create one consistent data matrix for analysis.

We established in comparison of stable isotope data from 2004 and 2009 that overall food web structure in relation to water mass characteristics is relatively stable among years, making this community metric a good indicator of long-term change. Variability was mostly detected in the particulate organic matter (POM), the primary food source for the system. This variability is likely derived from variable influence of freshwater among years (e.g., strength of Alaska Coastal Current and/or Siberian Coastal Current), or by interannually variable influence of ice algae (typically enriched in $\delta 13C$ isotope ratios). These are components that will need to be explored further. In addition, food web structure of the northern extent of the RUSALCA study region, i.e., around Herald Canyon and Wrangel Island, is intermediate between the structures described for the Alaska Coastal Current and the Anadyr Water influenced region. This may reflect the extension of the Bering shelf-modified water northwards.

Epifaunal community comparisons between 2004 and 2009 indicated higher abundance and biomass at several repeat stations. These increases were mostly attributed to crabs (*Chionoecetes opilio*) and seastars (Figure 1). This short-term trend reflects well with possible long-term changes we identified by comparison with historical data. The 2009 sampling extended into the eastern part of the East Siberian Sea and, thereby, added a different benthic assemblage relative to the 2004 sampling regime. This assemblage was, besides the generally very common brittle star *Ophiura sarsi*, dominated by sadurian isopods (Figure 2). This taxon was only found at one of the 2004 stations where crustaceans were otherwise overwhelmingly dominated by snow crab, *Chionoecetes opilio*. The dominance of the latter prompted us to begin to look at the population structure of this species (using additional funds obtained through the Coastal Marine Institute) since it supports a multi-million dollar industry further south and in the Canadian North Atlantic. First results of the snow crab study suggest that Chukchi Sea snow crabs are very small compared to their southern conspecifics (Figure 3).

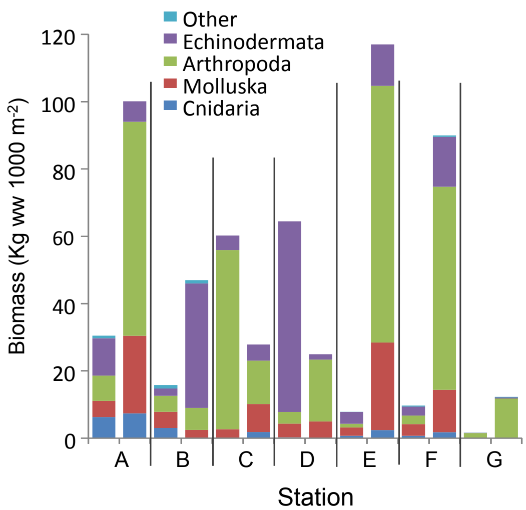

Figure 1: Comparison of epifauna composition by biomass at seven repeat stations between 2004 (first bar for each station) and 2009 (second bar for each station). Most interannual differences were related to Arthropoda (mainly Chionoecetes opilio*) and Echinodermata (mostly Asteroidea).*

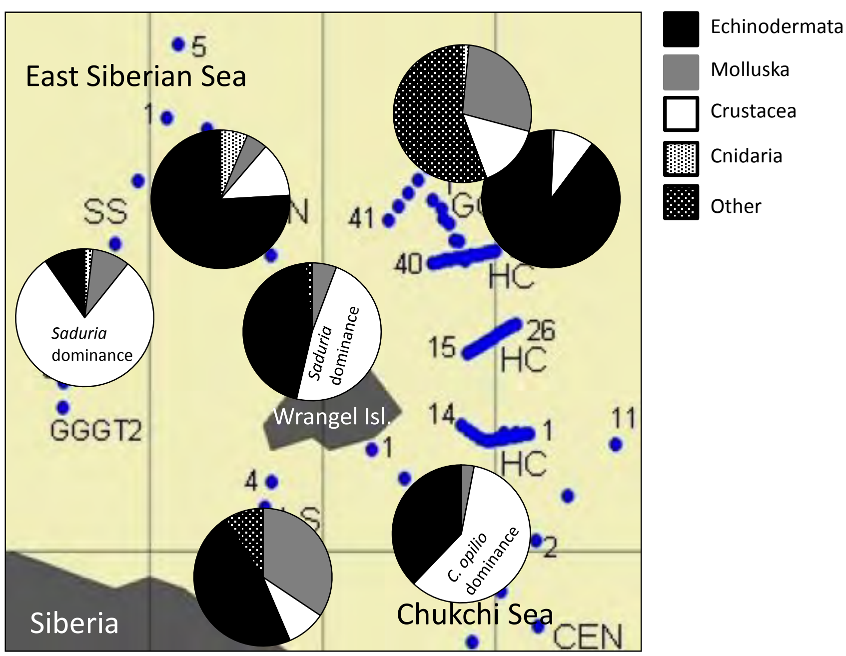

Figure 2: Epifaunal community composition at stations added to RUSALCA sampling grid in 2009.

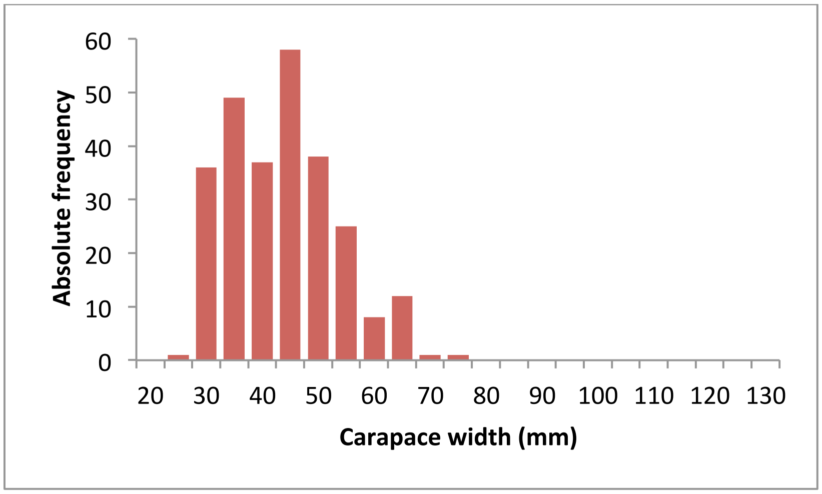

Figure 3: Preliminary size-frequency-distribution (n=268) of snow crab, Chionoecetes opilio, from the Chukchi Sea shows small size of crab stock. The x-axis includes the size range typically found in the southern Bering Sea. (Work funded through Coastal Marine Institute (CMI) using RUSALCA 2004 and 2009 snow crab among others.)

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." Knowledge gained during the RUSALCA work has contributed to the development of the Circumpolar Biodiversity Monitoring Program (CBMP) Implementation Plan.

Education

No graduate or undergraduate students were supported by the project during the reporting time. We do, however, have an undergraduate student (Colton Lipka, fisheries major) processing snow crab collected during the 2004 and 2009 RUSALCA cruises under Coastal Marine Institute (CMI) funding. His lab work satisfies his class requirement for the "Experiential learning" through the UAF undergraduate Fisheries degree.

Outreach

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

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

Bluhm, B.A., K. Iken, B.I. Sirenko, S.M. Hardy, B.A. Holladay and K. Dunton. 2012. Food web structure and epibenthic megafauna in the Chukchi Sea: A comparison between 2004 and 2009. Ocean Sciences Conference, 20–24 February 2012, Salt Lake City, Utah.

Iken, K., B. Bluhm, B. Sirenko, S. Hardy, B. Holladay and K. Dunton. 2012. Temporal trends in epibenthic megafauna and food web structure in the Chukchi Sea. RUSALCA Planning Meeting, 10–12 March 2012, Miami, Florida.

Partner organizations and collaborators

Bluhm and Iken both were involved with the Census of Marine Life Program, specifically the Arctic Ocean Diversity (ArcOD) project that produced biodiversity-related publications in the past few years. Iken and Bluhm are also co-PIs of an ongoing NSF-sponsored Bering Sea Ecosystem Studies (BEST) project, which investigates pelagic-benthic coupling in the Bering Sea in relation to sea ice cover. Both PIs are involved with snow crab population and reproductive dynamics work in the Chukchi and Beaufort Seas (CMI-funded), which ties together with RUSALCA objectives and sampling. By advising a student funded through the NSF-Integrative Graduate Education and Research Traineeship *(*IGERT) program MESAS (Marine Ecosystem Sustainability in the Arctic and Subarctic) both PIs also are engaged in analyzing the food web structure on the Beaufort Sea shelf, which links intrinsically to the food web studies performed within the RUSALCA project on the Chukchi shelf. Iken also is a member of the Marine Expert Monitoring Group of the 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. Bluhm is funded through Oil Spill Recovery Institute (OSRI) to rescue historic unpublished data from epifaunal trawl hauls in the Beaufort Sea. Both PIs have a proposal pending with Bureau of Ocean Energy Management (BOEM) that would investigate epifaunal community and benthic food web structure in the Beaufort Sea in an effort paralleling our RUSALCA objectives. Under North Pacific Research Board (NPRB) and Norwegian funding, Bluhm is working with Russian collaborators (several of which are involved in RUSALCA) on editing English versions of Russian-authored taxonomic identification keys for Arctic fauna in an effort to both provide better access to identification material and uniform identifications between Russian and western Arctic researchers.

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

Hondolero, D., B.A. Bluhm and K. Iken. 2012. Caloric content of dominant benthic species from the Northern Bering and Chukchi Seas: historical comparisons and the effects of preservation. *Polar Biology*, 35:637–644. doi:10.1007/s00300-011-1107-x

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 **_CIFAR theme: Ecosystem Studies & Forecasting_**
University of Alaska Fairbanks

Other investigators/professionals associated with 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

The spatial extent of demersal fish communities in the Chukchi Sea and the taxonomic families that make up four communities are shown (Figure 1). Each station was assigned to a community based on abundances of fish species at that station. Sculpins and pricklebacks were abundant in all four communities, with sculpins being more abundant in the central Chukchi Sea (community l) and pricklebacks being more abundant in communities c, k, and m. Eelpouts were more abundant in the north (community c) than further south. Cods (primarily the Arctic cod *Boreogadus saida*) were most abundant in the north and central Chukchi Sea (communities c and l). Flatfishes were more abundant in the eastern Chukchi Sea (community m) than elsewhere.

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

Two UAF students were supported by this CIFAR grant in the past 12 months. Christine Gleason (M.S. student, Fisheries Oceanography, graduation in summer 2012) developed her thesis research based mainly on specimens she collected during the September 2009 RUSALCA cruise. Her thesis examines the correlation of environmental and physiological variables to trace element signatures recorded in fish otoliths. Although Gleason's graduate stipend was not funded under this CIFAR grant, the grant supported her for four weeks of research specific to the CIFAR project. Tyler Ray (student working toward B.S. in Fisheries) recorded digital images of otoliths and assigned ages.

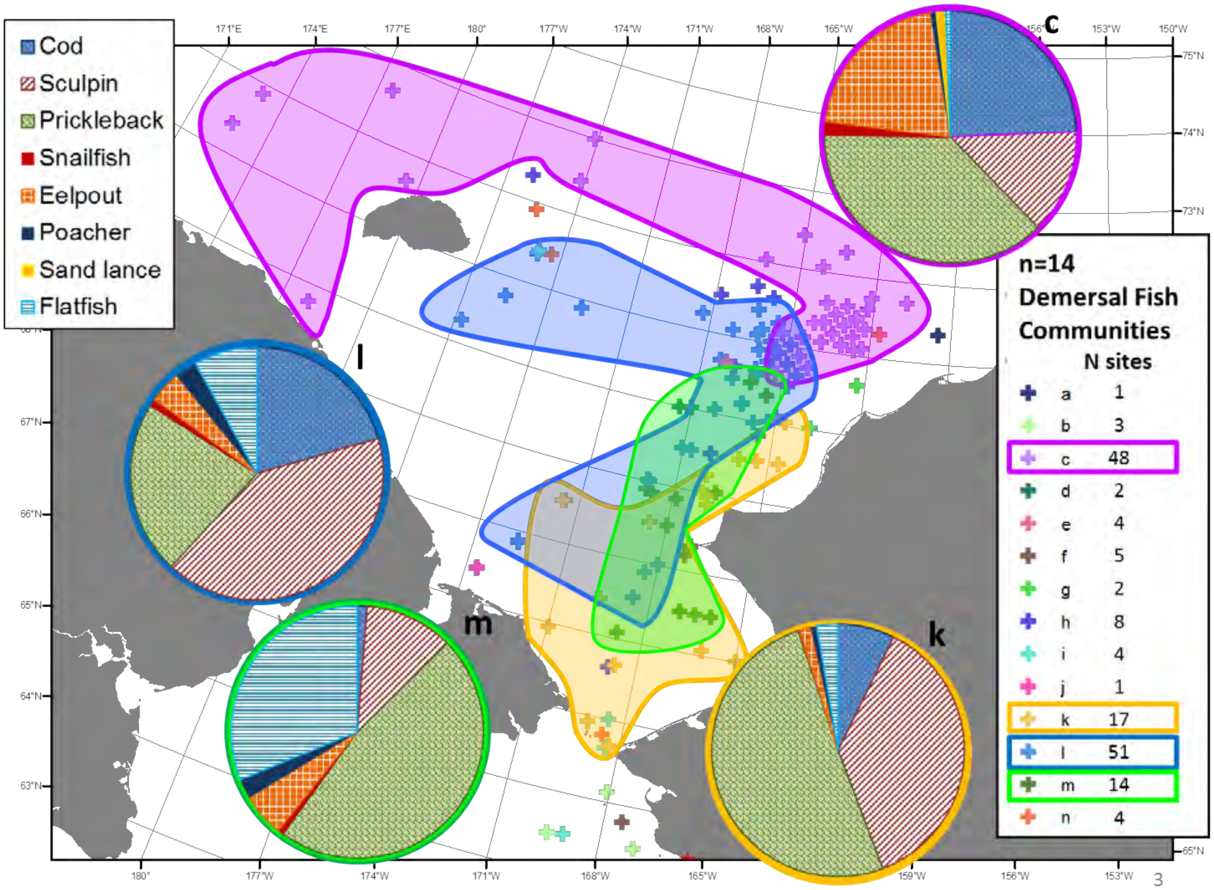

Figure 1. Map of spatial extent of demersal fish communities in the Chukchi Sea, as determined by cluster analysis of fish abundance (p>0.05) sampled 2004–2009. Pie charts indicate the taxonomic families composing four communities that had the largest number of sites.

Publications, conference papers, and presentations

Oral presentations

Gleason, C. and B.L. Norcross. 2011. Otolith chemistry of Arctic cod, Arctic staghorn sculpin, and Bering flounder in the Chukchi Sea. American Fisheries Society Meeting, Alaska Chapter, November 2011, Girdwood, Alaska.

Norcross, B.L., B.A. Holladay and C. Gleason. 2012. Fish ecology – Baseline for assessing effects of climate change on fishes. RUSALCA PI Meeting, March 2012, Miami, Florida.

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
CIFAR 10-013/11-013
Line Office OAR-CPO, Kathy Crane, Sponsor

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 (Conductivity Temperature Depth) section in conjunction with a 4 mooring array deployed in the eastern (US Exclusive Economic Zone, EEZ) channel of Bering Strait with Rebecca Woodgate of the University of Washington.

Research accomplishments/highlights/findings

Work this past year included an extensive set of CTD collections (including nutrients) in Bering Strait and the southern Chukchi Sea. We also planned to recover 8 moorings and re-deploy these in the same locations. However, clearance issues with the Russian government prevented ALL operations in the Russian EEZ in summer 2011. We were thus unable to recover 3 moorings or collect CTDs in the Russian EEZ. These moorings are specifically covered under the Weingartner component of the program. Hence we only deployed moorings in the US EEZ in 2011. We finally received data collected from 2010 that had to pass through Russian government clearance and have thus been delayed in analyzing these data. (All of the collected data must pass through Russian Customs and military approval before we can begin working on it. This process has generally been conducted within the 4 months following the cruise. The 2010 data were only received in fall 2011). We have also been using a regional ocean configuration of the MITgcm (MIT General Circulation Model), and extracting vertical sections (6 horizontal cells, 2-5 vertical layers) that correspond to existing moorings in the Bering Strait. Direct comparison between the model and the moorings show similar seasonality. Calculations of the modeled long term mean velocity across a section including the Alaska Coastal Current (ACC) closely matches previously published data made at a single point (the A3 mooring) that does not include the ACC. The modeled Bering Strait yields an estimated mean annual northward Strait transport of 1.1Sv. This suggests that 33% of the Strait transport is excluded by omitting the ACC.

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. Jonathan Whitefield, a Ph.D. student in physical oceanography, assisted in the fieldwork and is comparing the observations with model data.

Publications, conference papers, and presentations

Oral presentation

Whitefield, J., P. Winsor and T. J. Weingartner. 2012. Bering Strait throughflow from a global ocean model. Alaska Marine Science Symposium, January 2012, Anchorage, Alaska.

Poster presentation

Whitefield, J., P. Winsor and T. J. Weingartner. 2012. Bering Strait throughflow from a global ocean model. AGU-ASLO Ocean Sciences Meeting, February 2012, Salt Lake City, Utah.

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, and clearance issues discussed in the Research Accomplishments section, the project has proceeded as planned.

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 09-012/11-012/12-012: 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 2011 was used to obtain samples in the Bering Strait region to provide data to investigate climate change in the Chukchi Sea but unfortunately problems with clearance into the Russian EEZ prevented the scientists from collecting water samples in Russian waters.
- 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 samples were also collected at primary production sampling stations.
- Primary production rate measurements using carbon and nitrogen isotopes were collected at six light depths on 4 stations. The samples will be analyzed by mass spectrometry when new funding arrives in 2012.

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

Whitledge made a presentation ("Cooperative research programs with Russian scientists and a new research vessel to support field research") to the Northern (Arctic) Federal University, Arkhangelsk, Russia delegation, in Fairbanks on 4 April 2011.

Data from prior RUSALCA sampling has been placed on the SFOS ftp site (ftp://ftp.sfos.edu/terry/rusalca) for use by other project PIs and the RUSALCA data management project.

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

Whitledge, T.E. and Sang H. Lee. 2012. Fluxes and change detection in nutrients, chlorophyll, phytoplankton composition and primary production. RUSALCA PI Meeting, 10–12 March 2012, Miami, Florida.

Changes/problems/special reporting requirements

As noted above the scientific team was denied the usual clearance into the Russian EEZ without entering a Russian port so sampling only occurred in U.S. waters and the moorings in Russian waters were not retrieved/redeployed. The 1-year delay in the original plan because of the delay of the interdisciplinary cruise and request for nutrient, chlorophyll and productivity data on mooring cruises as well as interdisciplinary cruises has resulted in no funds for data synthesis and has hampered production of manuscripts. In addition, the support for a PhD graduate student was insufficient to maintain his stipend during the spring of 2012 thus the progress on his graduate research project has been slowed down significantly. A request for supplemental funding for the graduate student during the upcoming summer and fall semesters has been submitted to NOAA through the CIFAR office.

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

Peer-reviewed

Lee, S.H., C.P. McRoy, H.M. Joo, R. Gradinger, X. Cui, M.S. Yun, K.H. Chung, S.H. Kang, C.K. Kang, E.J. Choy, S. Son, E. Carmack and T.E. Whitledge. 2011. Holes in progressively thinning Arctic sea ice lead to new ice algae habitat. *Oceanography*, 24:302–308.

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. 2011. Trophic cascades and future harmful algal blooms within ice-free Arctic Seas north of Bering Strait: A simulation analysis. Progress in Oceanography, 91:312–343, doi:10.1016/j.pocean.2011.02.001

Lee, S.H., H.M. Joo, M.S. Yun and T.E. Whitledge. 2012. Recent phytoplankton productivity of the northern Bering Sea in the western Arctic Ocean during early summer in 2007. *Polar Biology*, 35:83–98, doi:10.1007/s00300-011-1035-9.

Accepted (peer-reviewed)

Torres-Valdes, S., T. Tsubouchi, S. Bacon, A. Naveira-Garabato, R. Sanders, B. Petrie, G. Kattner, K. Azetsu-Scott and T.E. Whitledge. Export of nutrients from the Arctic Ocean. Accepted for publication in *Journal of Geophysical Research*.

Lee, S.H., D.A. Stockwell, H.M. Joo, Y.B. Son, C.K. Kang and T.E. Whitledge. Phytoplankton production from melting ponds on Arctic sea ice. *Journal of Geophysical Research*, 117, in press, doi:10.1029/2011JC007717.

Appendix 5.

Downscaling of climate model output for Alaska and northern Canada

John E. Walsh, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

Other investigators/professionals associated this project:
Georgina Gibson, *University of Alaska Fairbanks (former 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

The primary goal of Grant NA10OAR4310055 to the University of Alaska is to produce high-resolution projections of climate change for North American high latitudes, particularly Alaska and northern Canada. Recent and ongoing climate assessments (e.g., the U. S. National Climate Assessment scheduled for release in 2013) have shown a need for such downscaling, and a contribution of Alaskan downscaling to the National Climate Assessment has been one of this project's primary activities during Year 2, as described below. More generally, 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 2 of the present project fell into four main categories: (1) extension of Year 1's downscaling for Alaska to include additional user-relevant information such as thaw season length, evapotranspiration, and sea ice in offshore Alaskan waters; (2) provision of downscaled fields for Alaska as part of a regional technical input report for the National Climate Assessment (Stewart et al. 2012); (3) an analysis of trends of recent extremes of temperature and precipitation in Alaska (Stewart et al. submitted), setting the stage for the next phase of downscaling; and (4) preparation of a review paper on ongoing and projected climate changes for the Arctic (Walsh et al. 2011). These four activities are summarized below.

1) Extension of Alaskan downscaling to derived variables of user relevance.

Our Year 1 report described the downscaling of Alaskan temperature and precipitation fields by the Delta-method, utilizing a subset of global climate models selected on the basis of their ability to simulate Alaska's present climate (including its seasonal cycle). Examples of downscaled temperature fields were presented in the Year 1 report. The Delta-method downscaling was expanded in Year 2 to include derived variables that are more directly aligned with user needs: growing season/thaw season length, evapotranspiration (combined with precipitation to provide metrics of surface dryness), and offshore variables including sea ice. An example of downscaled changes in break-up and freeze-up dates, defined by the crossing of the 0°C temperature threshold in spring and autumn, are shown below in Figure 1. Over much of the Alaskan landmass, springtime break-up dates are projected to advance by 10-20 days, while autumn freeze-up is projected to occur 10-20 days later than during the 1971-2000 reference period. However, the delayed freeze-up is especially prominent over the offshore seas north of Alaska, where the longer ice-free season allows for enhanced storage of heat in the upper ocean. The release of this heat occurs sufficiently slowly that an additional 30-60 days of open water and hence above-freezing temperatures characterize the projected seasonal regime of this area. The implications of the earlier ice loss and delayed retreat are a lengthening of the open-water navigation season by 2 to 3 months, with significant opportunities for enhanced offshore access and resource extraction. Because the changes of sea ice are consistent with the projected changes in the duration of above-freezing temperatures, we do not include examples of sea ice here. However, we do note that our results on projected changes of sea ice were presented at a NOAA Sea Ice Forecasting Workshop (Anchorage, AK, September 2011), which was targeted at a new NOAA initiative on sea ice prediction over time scales of days to several decades.

Downscaled projections for 2091-2100 (vs. 1971-2000)

Change in break-up date **Change in freeze-up date**

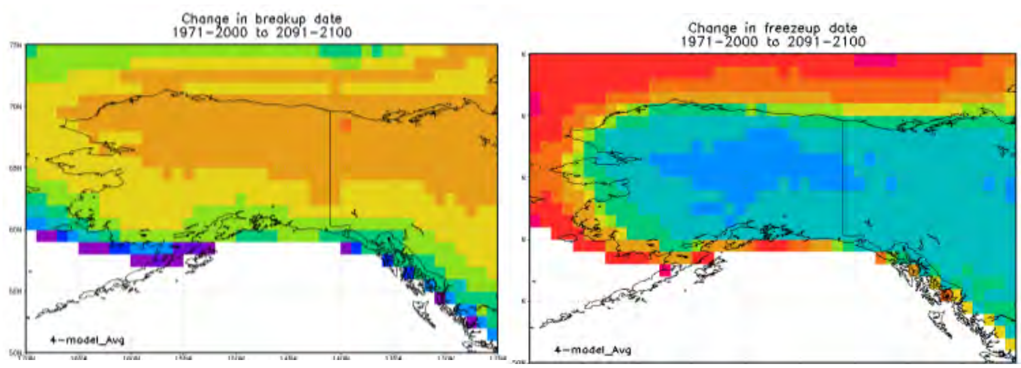

Figure 1. Downscaled projections of changes (days) in calendar dates of spring break-up (left) and autumn freeze-up (right).

As an example of higher resolution downscaling keyed to the 2-km resolution PRISM climatology, Figure 2 shows the projections of the total length of the growing season, defined here as the duration of the period of above-freezing surface air temperatures. The results in Figure 2 are for southern Alaska's Kenai Peninsula for four decadal time slices: 2000-09, 2030-39, 2060-69 and 2090-99. Increases of 50-90 days are projected by the 2090s.

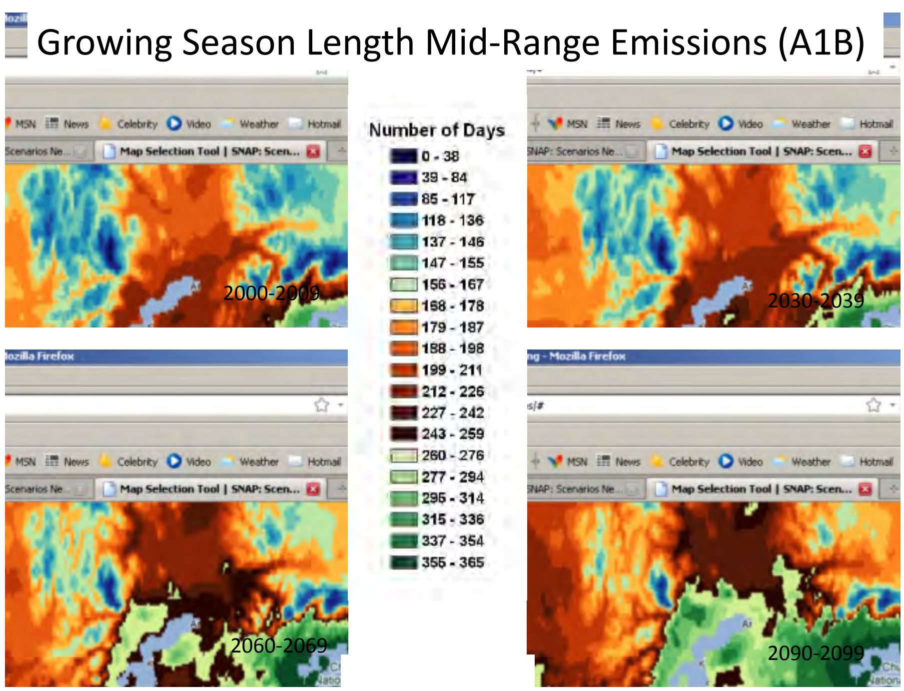

Figure 2. Downscaled projections of growing season lengths over the Kenai Peninsula under the A1B scenario for four time slices: 2000-09, 2030-39, 2060-69 and 2090-99.

Finally, the downscaled projections of evapotranspiration are temperature-based and have been used together with projections of precipitation to drive models of soil wetness/dryness. The soil moisture state, in turn, has been used to drive models of future fire season severity over Alaska. Preliminary results indicate that the effect of increased evapotranspiration during summer will more than offset the projected increase of precipitation, resulting in summer drying and an increase of fire activity in the boreal forest region of interior Alaska.

2) Contribution of downscaled fields as part of the Alaskan regional technical input report for the National Climate Assessment.

As part of the process for preparation of the U. S. National Climate Assessment scheduled for publication in 2013, a series of technical input documents have been prepared to guide the regional and sectoral chapter author teams. At the request of K. Kunkel of the National Climatic Data Center, we contributed downscaled products and associated text for the Alaska regional chapter (Stewart et al. 2012). Our contributed graphics consisted of Alaskan statewide maps of downscaled temperature, precipitation and growing season length (cf. Activity 1, above) for the scenarios and time slices used by regions in the contiguous 48 states; examples of community-specific projections for all calendar months; and downscaled projections of permafrost and sea ice for the Alaskan region. The downscaled products include information on the uncertainty derived from across-model spread and on the uncertainty inherent in natural variability. The interdecadal noise is one measure of the latter.

As with all technical input documents for the National Climate Assessment, our report underwent scientific review, was revised per reviewer comments, and made available to the Assessment author teams in March 2012. It will serve as a basis for the Alaska regional chapter draft due in June 2012. The completion of the assessment is scheduled for early 2013.

3) Analysis of trends of recent extremes of temperature and precipitation in Alaska.

The next step in the downscaling for Alaska is an extension to extreme events. This extension will require more sophisticated downscaling methodologies (e.g., the Bias-Correction Spatial-Disaggregation, or BCSD method), which we are now implementing. Our plan is to apply a quantile-mapping technique such as BCSD to daily fields of temperature, precipitation and wind from global climate models.

In preparation for the downscaling of extreme evens, we have prepared validation information by analyzing temporal distributions of extreme temperatures and precipitation from daily time series of historical station observations in Alaska. Specifically, we used daily data from 26 Alaskan surface weather observing stations from 1950 to 2008. Extremes were defined as the upper one percentile of events. Results indicate an overall increase in frequency of extreme maximum temperature events, a decrease in frequency of extreme minimum temperature events, and an increase in frequency of extreme three-day precipitation totals. Regional and seasonal variation is apparent, with the strongest trends occurring in winter and spring. The winter and spring trends at many of the stations are significant at the 99% level. In spring, all stations in all regions, except the Southeast, display increases in frequency of warm extremes and decreases in frequency of cold extremes with at least 90% significance. Winter had the next greatest increases (decreases) in the frequency of warm (cold) extremes. Precipitation results are more variable than, and generally not as significant as, trends in temperature extremes. Decreases in frequency of extreme three-day heavy precipitation events were found in the Arctic region for winter, spring, and summer, with significance at the 90% level and greater. Decreases of heavy precipitation events also occurred in the Southwest in spring. The greatest increases in frequency of heavy precipitation extremes were found in the Southeast in winter. The results are described in more detail in a recently submitted paper (Stewart et al. submitted).

The analysis of extremes in observational data for Alaska was also input to the historical summary section of the Alaskan Climate technical report for the U.S. National Climate Assessment (see #2 above). The table below is an example from this project that appears in the Alaska Climate report (Stewart et al. 2012).

Region	Warm Extremes	Cold Extremes
Arctic	**100%**	**100%**
West Central	**100%**	**100%**
Interior	**100%**	**100%**
Southwest	**100%**	**100%**
South Central	**100%**	**100%**
Southeast	**71%**	**86%**

Table 1. Percent of stations in each Alaskan region displaying increasing trends in occurrence of warm extremes and decreasing trends in frequency of cold extremes in spring (1950-2008). [From Stewart et al. 2012].

4) Preparation of a review paper on ongoing and projected climate changes for the Arctic

Walsh led the preparation of an invited paper for *Ambio* (Walsh et al. 2011) on recent and projected Arctic climate changes. One of this paper's main points is that extreme events – the target of Activity (3) above – are key elements that have received little attention in the 'story' of ongoing and projected Arctic change.

Among the paper's key points are the following (most of which are from the recent published literature, as this is a review paper): During the past decade, the Arctic has experienced its highest temperatures of the instrumental record, even exceeding the warmth of the 1930s and 1940s. Recent paleo-reconstructions also show that recent Arctic summer temperatures are higher than at any time in the past 2000 years. The geographical distribution of the recent warming points strongly to an influence of sea ice reduction. The spatial pattern of the near-surface warming also shows the signature of the Pacific Decadal Oscillation in the Pacific sector as well as the influence of a dipole-like circulation pattern in the Atlantic sector. Areally-averaged Arctic precipitation over the land areas north of 55°N shows large year-to-year variability, superimposed on an increase of about 5% since 1950. The years since 2000 have been wetter than average according to both precipitation and river discharge data. There are indications of increased cloudiness over the Arctic, especially low clouds during the warm season, consistent with a longer summer and a reduction of summer sea ice. Storm events and extreme high temperature show signs of increases, but conclusions about systematic changes are not firm.

With regard to oceanic changes, the paper points out that the Arctic Ocean has experienced enhanced oceanic heat inflows in recent years from both the North Atlantic and the North Pacific. The Pacific inflows evidently played a role in the retreat of sea ice in the Pacific sector of the Arctic Ocean, while the Atlantic water heat influx has been characterized by increasingly warm pulses. Recent shipboard observations show increased ocean heat storage in newly sea-ice-free ocean areas, with increased influence on autumn atmospheric temperature and wind fields.

Publications

Peer-reviewed

Walsh, J.E., J.E. Overland, P.Y. Groisman and B. Rudolf. 2011. Ongoing climate change in the Arctic. *Ambio,* 40(Suppl. 1):6–16, doi:10.1007/s13280-011-0211-2

In press

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

Walsh, J.E., J.E. Overland, P. Groisman and B. Rudolf. Arctic climate: Recent variations. Chapter 2 in: Snow, Water, Ice and Permafrost in the Arctic, Scientific Report. Arctic Monitoring and Assessment Program. (Hardcopy publication scheduled for 2012)

Submitted

Stewart, B., W.L. Chapman and J.E. Walsh. Changes in frequency of extreme temperature and precipitation events in Alaska. Submitted to *Journal of Climate* (January 2012).

Other products and outcomes

Stewart, B.C., J.E. Walsh, K.E. Kunkel and L.E. Stevens. 2012. Climate of Alaska. Technical Input Report for National Climate Assessment, U.S. Global Change Research Program. March 2012.

Appendix 6. Index of Principal Investigators

(key words are in parentheses in cases where one PI has multiple project reports)

Atkinson, D. 25
Hansen, R. 28
Heinrichs, T. (satellite data services) 15
Heinrichs, T. (GOES-R proving ground) .. 19
Hopcroft, R (RUSALCA). 70
Hopcroft, R. (Seward Line) 5
Hopcroft, R. (RUSALCA data mgmt.) 7
Iken, K. 72
Logan, T. 53
Mathis, J. 8
Norcross, B. 76
Okkonen, S. 10
Polyakov, I. 20
Quinn, T. (training stipends) 1
Quinn, T. (sablefish) 11
Romanovsky, V. 23
Smoker, W. 13
Walsh, J. 83
Webley, P. 55
Weingartner, T. 78
Whitledge, T. 80