Fifth progress report on Cooperative Agreement NA08OAR4320751

1 April 2012 – 31 March 2013

CIFAR

Cooperative Institute For Alaska Research

UAF UNIVERSITY OF ALASKA FAIRBANKS

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

1 April 2012–31 March 2013

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

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Images in the cover montage are from photos taken in summer 2012 by Bill Kopplin, during CIFAR PI Steve Okkonen's field season. 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
John Calder, NOAA OAR Arctic Research Office Program Manager (*retired 7/2012*)
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 (*left NPRB 1/2013*)
12. Terry Whitledge, Director, IMS, SFOS, UAF, Fairbanks, AK

Summary of Projects Funded during Reporting Period

During the fifth reporting period of the new competitively awarded cooperative agreement, NOAA provided funding for CIFAR administration and 14 research, education, and outreach projects totaling $1.36 M as part of the CIFAR institutional cooperative agreement (NA08OAR4320751). The 14 research projects were Task III (projects that generally require only minimal direct collaboration with NOAA scientists). In addition, 3 competitively awarded RUSALCA projects totaling $244,316 (funded under the "shadow" cooperative agreement NA08OAR4320870) were funded. The CIFAR research portfolio of 17 competitive and non-competitive new awards (plus Task I) addresses all three CIFAR research themes and totals $1.60 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 Climate Program Office projects appear in Appendix 4 and 5, but were also submitted separately on Grants Online, as requested.

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

Table 1: Summary of CIFAR Projects Funded 1 April 2012–31 March 2013: By Task and Theme

Theme	Number of Projects	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)	**1**		**$110,000**	**8.1%**
Core Support	1	$110,000		8.1
Research Themes (Task II)	**0**		**$0**	**0.0%**
Research Themes (Task III)	**14**		**$1,250,940**	**91.9%**
Climate Change & Variability	4	$422,268		31.0
Coastal Hazards	3	$623,953		45.9
Ecosystem Studies & Forecasting	7	$204,719		15.0
Total	**15**		**$1,360,940**	**100.0%**

Table 2: Summary of CIFAR Projects Funded 1 April 2012–31 March 2013: By Funding Source
Includes administration

Funding Source	Number of Projects	Total Amount	Percent of Total
OAR	6	$376,322	27.6%
NESDIS	3	$579,769	42.6%
NWS	3	$314,262	23.1%
NMFS	3	$90,587	6.7%
Total	**15**	**$1,360,940**	**100.0%**

Highlights of CIFAR Task I Activities

CIFAR is currently staffed by three people: John Walsh, director; Susan Sugai, associate director; and Barb Hameister, publications and meetings manager. Through the first five 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. Normally, Task I funds provide funding for 3.2 months of one full-time equivalent (FTE) salary for our CIFAR administrator. However, because Susie Carson left in July 2012, and we have been unable to hire a replacement, less Task I and match funds were needed for this position during this reporting period. Travel funds have been greatly reduced so our annual meeting of CIFAR fellows and executive board was held by teleconference. The only administrative travel during this reporting period was Sugai attending the annual spring meeting for CI directors and administrators.

Core Administration
With tightening state appropriated funds and delay in implementing changes in CIFAR Task I support, problems in recruiting new staff for CIFAR outlined in CIFAR's year 4 review by the NOAA Science Advisory Board team have already surfaced. For this reporting period CIFAR Task I funds supported 13 hours of the CIFAR associate director, while University match funds provided the remainder of core administrative labor costs. Because CIFAR has been without an administrator for 9 months of the current reporting year, Carson has been assisting Sugai with these responsibilities on "as available" status (~6% FTE) from her position as fiscal professional for the Vice Chancellor for Research, and Sugai's efforts have increased from 35% in year 4 (when CIFAR was undergoing our year 4 review) to 45% effort in year 5 (when we were submitting our renewal proposal without an administrator).

- John Walsh, CIFAR director, 0.5% FTE (UA match funds)
- Susan Sugai, CIFAR associate director, 45% FTE (UA match funds + Task I)
- Susan Carson, CIFAR administrator, 29% FTE (UA match funds)
- Barb Hameister, publications and meetings manager, 14% FTE (UA match funds)

John Walsh, CIFAR director, represented CIFAR and NOAA at several local, national and international activities during the 12-month period ending 31 March 2013. These activities include the following:

- Hosted visit by, and one-day workshop for, Timothy Brown, Director of Western Region Climate Center (WRCC). Workshop was held in July 2012 and addressed collaborative activities involving WRCC and UAF.
- Co-authored report of Arctic Monitoring and Assessment Program (AMAP) Climate Expert Group meeting on climate scenarios for an Integrated Arctic Assessment. Report was submitted to AMAP in October 2012.
- Co-authored National Climate Assessment Alaska paper "Climate of Alaska"; report was published in January 2013.
- Served as reviewer for NOAA's 2012 Arctic Report Card prior to its release; co-authored atmospheric section.
- Made presentation entitled "Alaskan weather and climate highlights of 2012" at American Meteorological Society's Annual Meeting, Austin, TX (January 2013).

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 the CIFAR renewal proposal and budgets as well as covering most of the CIFAR administrator duties while that position has been vacant.

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, provided $293,984 last year to continue supporting young scientists in quantitative fisheries sciences, including population dynamics, management, and stock assessment (CIFAR 12-024).

Working with Anne Beaudreau (CIFAR 12-025), **Karson Coutre** has finished one field season in St. John the Baptist Bay, where she tagged and collected stomach contents from juvenile sablefish and began initial analyses on their growth and food habits. **Kari Fenske**, who is mentored by Terry Quinn (CIFAR 12-025), will partner with James Murphy, who developed an age-structured movement model at TSMRI to learn more about his approach as she undertakes her Ph.D. research to use a spatially-explicit model as a basis for data simulations to explore management strategy evaluations for sablefish.

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 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 6 April 2012 and recommended full or partial funding of 16 projects (from a field of 52) for awards running from 1 July 2012 to 30 June 2013. Six of these awards were funded with CIFAR match or Task 1 education funds. The students, the degree that they are seeking, and their FY13 CIFAR projects are listed below:

- **Adrian Bender**, B.S., Geology, UAA: *Spatial and temporal variance of great earthquakes along the Alaska-Aleutian megathrust.*
- **Elizaveta Ershova**, Ph.D., Marine Biology, UAF: *Residents vs. expatriates in the Pacific-Arctic gateway: unraveling the summer distribution of sibling copepod species in the Chukchi Sea.*
- **Yuning Fu**, Ph.D., Geology & Geophysics, UAF: *Measuring seasonal hydrological effects in Alaska and accelerating mass loss in southeast Alaska with GRACE and GPS measurements.*
- **Marijke Habermann**, Ph.D., Geology & Geophysics, UAF: *Changing basal conditions during the rapid disintegration of Jakobshavn Isbrae's floating ice tongue.*
- **Vijay Patil**, Ph.D., Biology & Wildlife, UAF: *Modeling interactions between climate change, lake change and boreal ecosystem dynamics in the Yukon Flats National Wildlife Refuge.*
- **Michelle Shero**, M.S., Biological Sciences, UAA: *Weddell seal (Leptonychotes weddellii) physiological plasticity: mechanisms to meet the demands of a changing world?*

In addition, **Shiway Wang** and **Rebecca Young**, graduate students selected by the 2011 review panel, received second-year funding.

In response to the 2013 announcement of funding opportunity, 26 proposals were received, reviewed, and scheduled to be considered by our review panel on 5 April 2013. The reduction in proposal numbers was the result of UAA students no longer being eligible (since all CIFAR match funds are now provided by UAF for the CIFAR renewal and not by UA Statewide as had been the case in 2008) and changes made in the funding eligibility and limits to reflect current fiscal climate.

Student Support through Individual Awards
As shown in Appendix 2, 20 students (6 undergraduate, 14 graduate) were funded through individual CIFAR projects. Two graduate students associated with RUSALCA projects, two graduate students being supported by Stock Assessment Training Stipends, and two graduate students supported by the Webley GOES-R project received more than 50% of their support from NOAA. 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
A joint teleconference meeting of the CIFAR Executive Board and Fellows was held 28 November 2012. Topics of discussion included two of the SAB review panel recommendations: 1) need for a CIFAR successional plan (with John Walsh planning to retire in August 2013); 2) need for integration and synthesis of arctic marine studies.

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
This theme has the largest number of individual projects funded through CIFAR although funding amounts are modest and the anticipated outcomes very specifically defined. In most cases, the field-based studies were completed during the present reporting year so lab analyses and synthesis activities are underway.

As part of the Russian-U.S. Long-term Census of the Arctic (RUSALCA) Program, two research cruises on the Russian R/V Professor *Khromov* were successfully completed in 2012. A mooring cruise took place from 10 to 20 July, and the interdisciplinary cruise from 27 August to 16 September. One Ph.D. student, **Elizaveta Ershova** (CIFAR 12-009) and M.S. student **Carlos Serratos** (CIFAR 12-010) have research projects funded primarily by this NOAA climate program effort. In September, **Ershova** conducted experiments at 18 stations to examine the influence of temperature on zooplankton egg production rates. As part of his M.S. thesis, **Serratos** is examining changes in the epibenthic community and food web structure of the Chukchi Sea that were sampled during 2004, 2009, and 2012 RUSALCA cruises. The efforts of both students contribute to understanding ecosystem responses to the most rapidly changing region of the world's ocean.

Four CIFAR projects contribute to the Bureau of Ocean Energy Management (BOEM)- and NOAA-sponsored Synthesis of Arctic Research (SOAR) program that brings together a multidisciplinary group of Arctic scientists and residents to synthesize scientific information and local observations to better understand the relationships among oceanographic conditions, benthic organisms, lower trophic prey species (forage fish and zooplankton), seabirds, and marine mammal distribution and behavior for the Pacific Arctic region. The aim of SOAR is to develop detailed syntheses to inform management decision-makers and to guide future research studies. This aligns closely with one of the key concerns raised by the NOAA Science Advisory Board review of CIFAR, specifically, that "the RUSALCA efforts would benefit from immediate attention to synthesis and generation of specific hypotheses or models that could enhance the data already collected and to be collected in the future." The CIFAR projects include: "Influence of sea ice and oceanographic conditions and prey availability on the timing of fall bowhead whale migration" (CIFAR 13-034), "Oceanographic factors associated with bowhead whale hotspots and variations in the migration path" (CIFAR 13-035), "Factors maintaining sea bird and mammal benthic hotspots" (CIFAR 13-036), and "An ocean acidification sensitivity index for the Pacific Arctic region" (CIFAR 13-037).

Climate Change & Variability

Climate change and variability research at CIFAR is focused on downscaling climate model outputs to meet local planning needs, improving sea ice forecasting (CIFAR-029), enhancing Alaska research and satellite data services to better meet NOAA user needs (CIFAR 12-015), and producing the Alaska Region Quarterly Climate Impacts and Outlook Product (CIFAR 13-038).

In response to need for regional sea ice projections to provide higher resolution information relevant to national, state and local planners, **Tracy Rogers**, John Walsh (NA10OAR4310055) and co-workers have recently had a paper published on "Arctic sea ice: satellite observations and sea surface temperatures, global climate model analysis and evaluation, and future projects toward Arctic marine accessibility" in which projected increases in arctic marine access in the 21st century range from one month for the northern Bering Sea (Bering Strait) to 2–3 months for the Northern Sea Route and Northwest Passage.

Jessie Cherry and Ph.D. student **Katrina Bennett** have been working with the NWS River Forecast Center (RFC) to identify critical time periods for validating snow-related satellite products into their hydrology forecasts in high latitude areas like Alaska. **Bennett** has been working with the RFC to design means for incorporating remote sensing measurements of snow-covered area into the operational model framework. She began by focusing on re-projected Moderate Resolution Imaging Spectroradiometer (MODIS) products in Interior Alaska, where there are in situ sites for validation, and hopes to test her developed technique on new GOES-R algorithms with the MODIS dataset for Alaska in the upcoming year.

Coastal Hazards

CIFAR coastal hazards research is focused on observations and modeling efforts to reduce dangers associated with offshore storms, from tsunamis, and from volcanic ash clouds.

David Atkinson (CIFAR 13-032) and Ph.D. student **Norman Shippee** have been working on development of a 90-day monthly storm outlook for Alaska, North Pacific, and Hawaii. **Shippee** has conducted a comprehensive review of extra-tropical cyclone (ETC) storm tracks and activity that dominate the North Pacific as well as an overview and assessment of storm identification and tracking methods. He is currently working on means of linking storm track activity to major modes of climatic variability (El Niño-Southern Oscillation, the Pacific Decadal Oscillation, and the Arctic Oscillation) in hopes of developing an experimental forecast model that can be tested in the hindcast mode.

Natalia Ruppert has assumed principal investigator status for the TWEAK (Tsunami Warning and Environmental Observatory for Alaska) effort following the retirement of Roger Hansen. Working in collaboration with the Alaska Tsunami Warning Center and the National Tsunami Hazard Mitigation Program, TWEAK (CIFAR 12-008) is developing numerical-hydrodynamical models to assist with tsunami warnings and prediction services. During this reporting period, tsunami inundation modeling and mapping has focused on Valdez, Chenega Bay, Cordova and Tatitlek in Prince William Sound, and Sitka in southeast Alaska. Work on the quality control of digital elevation models (DEMs) for the tsunami inundation mapping was completed for the communities of Hoonah, Gustavus, Elfin Cove, and Unalaska/Dutch Harbor.

Peter Webley, Martin Stuefer and co-workers (CIFAR 12-028) continued their comparisons of satellite-derived volcanic ash cloud detection images using Geostationary Operational Environmental Satellite-R Series (GOES-R) like products with the Weather Research & Forecasting (WRF)-Chem Puff model simulations. As part of her M.S. thesis, **Angela Ekstrand** compared the Multi-angle Imaging Spectro-Radiometer (MISR) data for different volcanic events with thermal infrared (TIR) plume and cloud top measurements leading to a publication in press "A Multisensor Plume Height Analysis of the 2009 Redoubt Eruption." **Torge Steensen**, a Ph.D. student has been comparing volcanic ash retrievals from satellite data with WRF-Chem model simulations from two events during the 2009 Redoubt eruptions in Alaska and during the eruption from Sarychev Peak, Kuriles in June 2009, leading to senior authorship of a publication in press and one in preparation. These efforts 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-one conference presentations (both national and international) were reported for the period 1 April 2012–31 March 2013. Eleven peer-reviewed papers were published, with 7 additional papers in press or accepted for publication; several more have been submitted or are in review. Many PIs also have papers under preparation. In addition, one RUSALCA project had a paper published during the reporting period that stemmed from funding to that project under the previous cooperative agreement NA17RJ1224 (Cooperative Institute for Arctic Research).

Besides this activity for projects funded directly by NOAA through CIFAR, 2 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, and many students have papers that have been submitted or are now in review. 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 ***CIFAR theme: Ecosystem studies and forecasting***
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans

CIFAR 12-024: This project is ongoing. NOAA 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) contributed $293,984 to graduate student research about sablefish stock assessment.

Research accomplishments/highlights/findings

This project provides student training stipends and travel to quantitative students in conjunction with the research project "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) with Anne Beaudreau and Terry Quinn as co-PI's. As described below, two graduate students have been recruited during this reporting period and are making good progress in both teaching and research.

Karson Coutre (M.S. student) started the graduate program in Fisheries in July 2012 and is supervised by Anne Beaudreau. Coutre has worked closely with her committee chair (Beaudreau) and in consultation with NOAA collaborators to develop a thesis project structured as two chapters, which meets the objectives: (1) investigate temporal and ontogenetic patterns in the diet of juvenile sablefish; and (2) investigate movement patterns and habitat use of juvenile sablefish in Southeast Alaska.

She completed a well-structured, substantive first draft of her thesis proposal in February 2013 and made revisions based on comments from her committee chair. To date, we have completed two sampling periods (July 2012, September 2012) in St. John Baptist Bay to tag and collect stomach contents from juvenile sablefish. We are currently planning logistics for three final trips (May, July, & September 2013). Coutre has nearly completed processing samples collected in July and September. She participated in hiring and took the lead on training an undergraduate research technician who is helping analyze samples. She has begun preliminary analysis of available acoustic tagging data for St. John Baptist Bay sablefish.

Kari Fenske is in her second semester of a Ph.D. Fisheries program at UAF, having started in Fall 2012. Fenske presented a well-developed and well-written initial thesis proposal that contained background information, the objectives of the thesis, and details about two main chapters in her thesis to her graduate committee in March 2013.

Chapter 1 will be the development of a spatially explicit assessment model for sablefish that includes estimated movement between the management regions (Aleutian Islands, Bering Sea, and four Gulf of Alaska sub-regions). This model will be used to develop estimates of fishing mortality, biomass, and spawning biomass and compare these regional and total estimates to the existing single-area population model. The expectation is that the spatially-explicit model will produce more biologically realistic and accurate estimates of sablefish abundance and population dynamics. Chapter 2 will use the spatially-explicit model as a basis for data simulations to explore management strategy evaluations. The goal will be to develop a strategy or suite of harvest strategies that will optimize the harvest of sablefish in Alaska in a sustainable manner, while also examining the social and economic effects of potential harvest strategies.

To help expedite the development of the research for Chapter 1, Fenske will partner with James Murphy, who developed an age-structured movement model before leaving TSMRI for the private sector last year. He was delighted that we were interested in his work and realized he would never have time to complete it himself. He had done sufficient work to produce two draft manuscripts with movement estimates and it was only fair that he remain

the main author. However, we will help him, in that Kari will complete the manuscript and learn more about his approach. This will then be an appendix to Kari's thesis.

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 training stipends 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

Coutre established a graduate advisory committee (Beaudreau, UAF-Fisheries; Franz Mueter, UAF-Fisheries; Pat Malecha, NOAA TSMRI) and completed her first committee meeting in February 2013. Her committee reported that she has been making excellent progress in her coursework and research. Karson has received high marks in her courses to date. She completed three courses in Fall 2012 (9 credits total) and received an A in FISH 627 Statistical Computing with R, an A in FISH/MSL 693 Aquatic Food Web Ecology, and a B+ in STAT 401 Regression and Analysis of Variance. She is currently enrolled in three courses in which she will continue to develop her analytical skills (FISH 631 Data Analysis in Community Ecology, FISH 622 Quantitative Fish Population Dynamics) and communication skills (FISH 692 Communicating Science).

Fenske presented a draft of her graduate study plan to her graduate committee in March 2013, showing coursework taken in Fall 2012 and Spring 2013 and proposed coursework for later semesters. In Fall 2012, she received A's in her two graded courses (FISH 621 Estimation of Fish Abundance and FISH 627 Statistical Computing with R). In Spring 2013, she is taking FISH 622 Quantitative Fish Population Dynamics, FISH 670 Quantitative Analyses for Marine Policy Decisions, and a seminar FISH 692 Communicating Science. She is proposing taking the minimum of 18 credits of mostly quantitative coursework. Her graduate committee [Terry Quinn (chair), Anne Beaudreau, Keith Criddle (all with UAF-Fisheries), and Dana Hanselman (TSMRI)] reviewed her proposal and asked about her M.S. coursework. It turned out that she had a good background in fish ecology and biology, so the committee accepted the proposed coursework. The committee also decided on the areas in which the student will be examined on comprehensive examination and agreed with the schedule she proposed, although noting that it was ambitious.

Outreach

Fenske presented a seminar in the departmental seminar series on her previous work with the South Atlantic Fishery Management Council as a stock assessment coordinator.

Publications, Conference Papers, and Presentations

Oral presentation

Coutre, K.M., A.H. Beaudreau and P.W. Malecha. 2012. Seasonal and ontogenetic patterns of resource use by juvenile sablefish, *Anoplopoma fimbria*, in southeast Alaska. American Fisheries Society, Alaska Chapter meeting, October 2012, Kodiak, AK.

Partner organizations and collaborators

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

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

This project is fully in operation. As previously reported, there was a delay in starting this project because there were no suitable graduate students available until summer 2012 and because Beaudreau did not start until January 2012. Due to this delayed start, we will need to extend the length of the sablefish research grant to cover our final sampling periods in July and September 2013 (and related analysis thereafter) and to provide sufficient time for completing the stock assessment modeling (currently, August 2015).

Non-competitive projects, by CIFAR theme:

Ecosystem Studies and Forecasting
Including four SOAR (Synthesis of Arctic Research) projects

Climate Change and Variability

Coastal Hazards

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; Climate Adaptation & Mitigation

CIFAR 12-027: This project is ongoing. NOAA 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 digitally archiving data from all disciplines to be 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

The Alaska Ocean Observing System (AOOS) was chosen to provide data management services for the RUSALCA data archive. AOOS has established a dedicated research workspace group to facilitate data submission and metadata generation. Data transfer has commenced from investigators and information is flowing into the system along with metadata generation. AOOS data management staff have pulled data sets out of the research workspace and integrated those data into a web-based visualization portal which provides a data catalog in addition to web-based interactive mapping systems. The workspace group instance is secure and reserved for project team members but the web-based visualization tools are available from the AOOS website:
http://data.aoos.org/maps/search/rusalca.php

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.

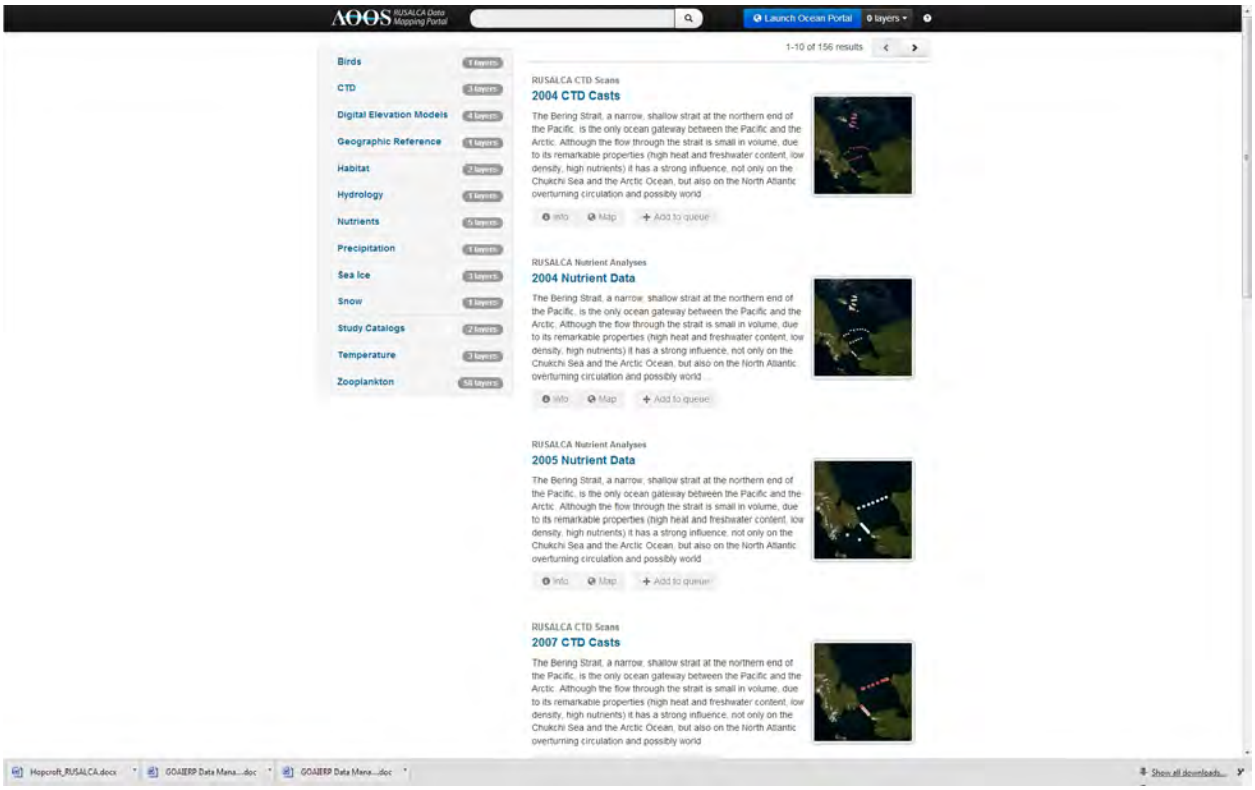


Figure 1. Example of the RUSALCA catalogue on AOOS website (http://dev.axiomalaska.com/maps/search/rusalca.html#search)

Figure 2. Example of a RUSALCA CTD dataset mapped on the AOOS website. The profiles appeared when a location was selected.

Outreach
The Alaska Ocean Observing System (AOOS) has developed several outreach and visualization products based upon data collected during the RUSALCA sampling program. These can be accessed from the AOOS website: http://data.aoos.org/maps/search/rusalca.php

Changes/problems/special reporting requirements
The persistent problem has been getting PIs to put datasets into the workspace, along with appropriate metadata.

Bering Sea benthic habitat & ecosystem infauna

Stephen Jewett, PI ***CIFAR theme: Ecosystem studies and forecasting***
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

CIFAR 13-033: This project is new. NOAA Office NMFS: Cynthia Yeung/Bob McConnaughey, Sponsor

Primary objectives
In collaboration with the NMFS Alaska Fisheries Science Center (AFSC) to characterize the benthic infaunal community for modeling essential fish habitat in the eastern Bering Sea, we will process samples collected by the AFSC that have been sieved in the field on 1.0 mm mesh, fixed in buffered formalin, stained, and transferred to 50% isopropyl alcohol prior to shipping to UAF. We will identify organisms to at least the family level of taxonomy, count, and wet weigh (blotted dry). The 1990 NODC code will be used for all taxonomic data.

Research accomplishments/highlights/findings
Twenty-five 0.1 m^2 samples (55 jars) were collected by Van veen grab and sent to UAF on 26 October 2012 for processing. The original budget was based on processing (sorting and taxonomy) one jar of material per sample. Out of 25 samples received three had multiple jars to sort; 13-3 (16 jars), A06 (9 jars), and 14-3 (8 jars). Therefore, an additional $4,100 was requested for sorting these samples. Processing commenced immediately on the 1-jar samples, while awaiting approval for additional funds. The additional funds were approved, but funds have not yet been received.

All samples were washed on a 1.00 mm mesh screen. Invertebrate material from the replicates were preserved in 10% buffered formalin, transferred to 50% isopropanol in the laboratory and identified to the lowest taxonomic level. All replicates were 100% sorted, i.e., no subsampling occurred. Specimens were blotted damp for a wet weight determination to the nearest (0.001g). The QA/QC process is underway and submission of data to NMFS should occur in May 2013.

NOAA relevance/societal benefits
This research is in support of an effort to determine essential fish habitat as mandated by the Magnuson-Stevens Sustainable Fisheries Act.

Partner organizations and collaborators
Alaska Fisheries Science Center

Impact
This project continues collaborative work done by NMFS and UAF in 1997, 1999, 2001, 2002, and 2009 to address trawling impact on the benthos of the Bering Sea.

Changes/problems/special reporting requirements
Supplemental funds for this project have been delayed for several months by changes in project sponsor, inadvertent errors in processing this award, and effects of the sequester.

Moored observations of ocean acidification in high latitude seas

Jeremy Mathis, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

CIFAR 11-021/13-021: This project is ongoing. NOAA 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 aspects of this project. We have started to synthesize the data from our 2011 moorings at two long-term monitoring sites, GAK 1 (Gulf of Alaska) and M2 (southeast Bering Sea) and at the BS3 site in the Arctic.

GAK 1 – Due to technical difficulties (faulty valves that did not work in cold weather), GAK 1 spent 2012 out of the water, but was redeployed in March 2013. We are working on several papers from the 2010/11 dataset.

M2 – M2 also had valve issues in 2012 that prevented the collection of data. We are working on the 2011 dataset with several pending publications. The mooring will be deployed in May 2013.

NOAA relevance/societal benefits

This mooring deployments and synthesis efforts 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

Mathis gave a keynote presentation on ocean acidification at the Alaska Marine Science Symposium, where over 1,000 scientists, stakeholders and Alaskan residents were present (see below for details). Mathis also conducted town hall style meetings in Dillingham, Homer and Seward.

Publications, conference papers, and presentations

Peer-reviewed publication

Mathis, J.T., R.P. Pickart, R.H. Byrne, C.L. McNeil, G.W.K. Moore, L.W. Juranek, X. Liu, J. Ma, R.A. Easley, M.W. Elliot, J.N. Cross, S.C. Reisdorph, F. Bahr, J. Morison, T. Lichendorph and R.A. Feely. 2012. 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* 39, L07606, doi:10.1029/2012GL051574.

(Three additional papers have been submitted or are in review.)

Oral presentation

Mathis, J. 2013. Preparing for the challenges of ocean acidification in Alaska. Keynote presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, 21 January 2013.

Changes/problems/special reporting requirements

We had issues with valves on the MAP CO_2 systems failing in temperatures below 10°C (pretty much all the time in Alaska). The manufacturer changed valve suppliers and the new valves were not properly tested. We were unaware of this change until the moorings were already in the water. We have fixed the problem.

Since the awarding of this project, PI Jeremy Mathis was hired by NOAA and is now at PMEL. He continues to be affiliated with the School of Fisheries and Ocean Sciences at UAF.

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

CIFAR 10-014/12-014/13-014: This project is ongoing.

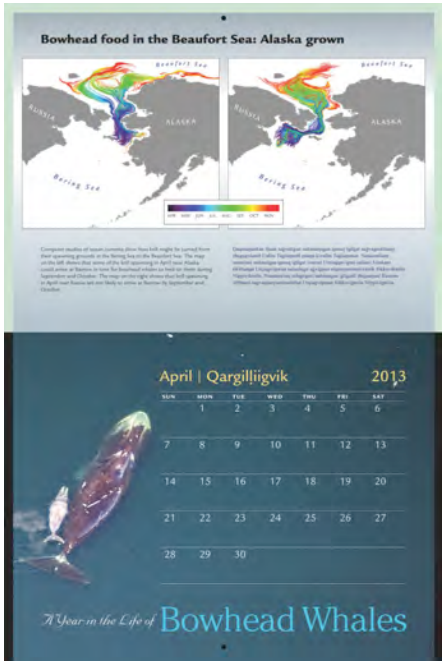
NOAA Office: NMFS-AFSC,
David Rugh/Kim Sheldon, Sponsor

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. A draft manuscript summarizing observations from CIFAR-funded current meter moorings as they relate to wind-driven circulation and the Barrow area bowhead whale feeding hotspot will soon be submitted to a peer-review journal. Another manuscript on relationships between krill and characteristic water masses in the Chukchi Sea is being prepared by Heather McEachen, a Ph.D. student supported, in part, by this CIFAR 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

More than 900 CIFAR-funded "A year in the life of Bowhead whales" 2013 calendars (*right*) were distributed in November and December 2012. Of these, more than 600 were distributed to classrooms, organizations, and individuals in coastal Alaskan villages from Nome to Kaktovik.

Publications, conference papers, and presentations

Poster presentation

Okkonen, S.R. 2013. Late summer near-shore circulation on the western Beaufort shelf and exchange with Elson Lagoon. Alaska Marine Science Symposium, 21–25 January 2013, Anchorage, Alaska.

Newsletter article

Okkonen, S.R., C. Ashjian, R.G. Campbell, J.T. Clarke, S.E. Moore and K.D. Taylor. 2012. Radarsat observations of circulation features associated with a bowhead whale feeding 'hotspot' near Barrow, Alaska. Alaska Satellite Facility, News and Notes, vol. 8:1. http://www.asf.alaska.edu/news_notes/8-1/bowhead-whale-feeding-hotspot-barrow-alaska

Other products and outcomes

Production of the animated film "Arctic Currents: A year in the life of the bowhead whale" based in large part on the CIFAR-funded calendar is well underway. Periodic updates on the progress of this film are posted on the blog site http://arcticcurrents.wordpress.com/.

Okkonen is a co-investigator on a recent proposal submitted to NASA that, among its goals, seeks to identify the impact of extreme/anomalous Arctic weather events on the feeding environment for bowhead whales in the Beaufort Sea. Background material for the NASA proposal was based on CIFAR-funded research.

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 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 ***CIFAR theme: Ecosystem studies and forecasting***
Anne Beaudreau, PI
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

CIFAR 12-025: This project is ongoing. NOAA 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

Juvenile sablefish ecology (Beaudreau), 1 April 2012—31 March 2013:
Karson Coutre (M.S. student) started the graduate program in Fisheries in July 2012 and is supervised by Beaudreau. Coutre has worked closely with her committee chair (Beaudreau) and in consultation with NOAA collaborators to develop a thesis project structured as two chapters, which meets the research focus described above: (1) Temporal and ontogenetic patterns in the diet of juvenile sablefish; and (2) Movement patterns and habitat use of juvenile sablefish in Southeast Alaska. She completed a well-structured, substantive first draft of her thesis proposal in February 2013 and made revisions based on comments from her committee chair. Coutre established a graduate advisory committee (Beaudreau, UAF-Fisheries; Franz Mueter, UAF-Fisheries; Pat Malecha, NOAA TSMRI) and completed her first committee meeting in February 2013.

To date, we have completed two sampling periods (July 2012, September 2012) in St. John the Baptist Bay to tag and collect stomach contents from juvenile sablefish. We are currently planning logistics for three final trips (May, July, & September 2013). Coutre has nearly completed processing samples collected in July and September. She participated in hiring and took the lead on training an undergraduate research technician who is helping analyze samples. Coutre presented preliminary results, describing growth and food habits of juvenile sablefish, at the American Fisheries Society Alaska Chapter meeting in October 2012 (Kodiak, AK). She has begun preliminary analysis of available acoustic tagging data for St. John the Baptist Bay sablefish.

Apportionment and population dynamics (Quinn), 1 April 2012—31 March 2013:
Kari Fenske is in her second semester of a Ph.D. Fisheries program at UAF, having started in Fall 2012. Quinn has met extensively with Fenske to explore options for research and to do preliminary work to get her acquainted with the sablefish data. Fenske presented a well-developed and well-written initial thesis proposal that contained background information, the objectives of the thesis, and details about two main chapters in her thesis to her graduate committee [Terry Quinn (chair), Anne Beaudreau, Keith Criddle (all with UAF-Fisheries), and Dana Hanselman (TSMRI)] in March 2013, who provided comments but were pleased overall with the direction of the research.

Chapter 1 will be the development of a spatially explicit assessment model for sablefish that includes estimated movement between the management regions (Aleutian Islands, Bering Sea, and four Gulf of Alaska sub-regions). This model will be used to develop estimates of fishing mortality, biomass, and spawning biomass and compare these regional and total estimates to the existing single-area population model. The expectation is that the spatially-explicit model will produce more biologically realistic and accurate estimates of sablefish abundance and population dynamics. Chapter 2 will use the spatially-explicit model as a basis for data simulations to explore management strategy evaluations. The goal will be to develop a strategy or suite of harvest strategies that will optimize the harvest of sablefish in Alaska in a sustainable manner, while also examining the social and economic effects of potential harvest strategies.

To help expedite the development of the research for Chapter 1, Fenske and Quinn will partner with James Murphy, who developed an age-structured movement model before leaving TSMRI for the private sector last year. He was delighted that we were interested in his work and realized he would never have time to complete it himself. He had done sufficient work to produce two draft manuscripts with movement estimates and it was only fair that he remain the main author. However, Fenske and Quinn will help him, in that Fenske will complete the manuscript and learn more about his approach and Quinn will help with editing. This will then be an appendix to Fenske's thesis.

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 under the CIFAR project "Stock assessment training stipends" related to sablefish in the North Pacific.

Education

Kari Fenske, Ph.D. Fisheries, Advisor: Terry Quinn
Karson Coutre, M.S. Fisheries, Advisor: Anne Beaudreau

Outreach
Beaudreau organized an outreach event for the public that will feature presentations and a panel discussion by six UAF graduate students at the Alaska State Museum on 27 April 2013. Coutre and Fenske will be presenting their research on sablefish at this event, which is titled "How to Make a Black Cod Lose its Lunch, and Other Ocean Science Stories from University of Alaska Fairbanks Graduate Students."

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
This project is fully in operation. As previously reported, there was a delay in starting this project because there were no suitable graduate students available until summer 2012 and because Beaudreau did not start until January 2012. Due to this delayed start, we will need to extend the length of the sablefish research grant to cover our final sampling periods in July and September 2013 (and related analysis thereafter) and to provide sufficient time for completing the stock assessment modeling (currently, August 2015).

Synthesis of Arctic Research (SOAR): Overview

The Synthesis of Arctic Research (SOAR) aims to bring together a multidisciplinary group of Arctic scientists and Alaskan coastal community representatives to explore and integrate information from completed and ongoing marine research in the Pacific Arctic Region. The goal of SOAR is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic pelagic species (forage fish and zooplankton), and higher trophic species (seabirds and marine mammals) in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas. SOAR is supported by the Bureau of Ocean Energy Management (BOEM) and NOAA, and led by Sue Moore (NOAA/NMFS Marine Ecosystem Division, Office of Science & Technology (S&T)), Phyllis Stabeno (NOAA/PMEL), and an 11-member Science Steering Committee.

The major product of SOAR will be a collection of peer-reviewed scientific publications in a special issue or theme section of an appropriate journal. Science themes and questions appropriate for synthesis were developed at a science workshop, held in Anchorage, Alaska from 14–16 March 2012. The SOAR projects from CIFAR are:

- *Influence of sea ice and oceanographic conditions and prey availability on the timing of the fall bowhead whale migration*, PI Stephen Okkonen
- *Oceanographic factors associated with bowhead whale hotspots and variation in the migration path*, PI Stephen Okkonen
- *Factors maintaining sea bird and mammal benthic hotspots: a latitudinal analysis*, PI Bodil Bluhm
- *An ocean acidification sensitivity index for the Pacific Arctic region*, PI Tom Weingartner.

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

Synthesis of Arctic Research (SOAR): Factors maintaining sea bird and mammal benthic hotspots: a latitudinal analysis

Bodil Bluhm, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
Arny Blanchard, co-PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Jacqueline Grebmeier, PI, *University of Maryland*

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

CIFAR 13-036: This project is new.

NOAA Offices: NMFS-S&T, OAR/PMEL: Sue Moore & Phyllis Stabeno, Sponsors

Primary objectives

The proposed synthesis activity and resulting manuscript will evaluate the biological and environmental factors that support a productive benthic prey base with a focus on four infaunal biomass "hotspots" that help maintain seabird and marine mammal populations in the northern Bering and Chukchi Seas in the Pacific Arctic.

Approach

1. Define benthic "hotspots" as regions of persistent high biomass and intense higher trophic use.
2. Synthesize data from currently identified hotspots (with characteristic benthivores).
3. Determine environmental and biological factors driving and maintaining marine mammal and seabird benthic hotspots.
4. Make spatial comparisons of hotspots over latitudinal gradients.
5. Build conceptual analysis of spatial, hydrographic, and biogeochemical controls on benthic hotspots.
6. Involve local Alaskan communities with subsistence hunting efforts that use or benefit from these hotspots.

Synthesis accomplishments/highlights

The lead team of this effort, Grebmeier and Bluhm, held a lunch meeting with about a third of the authors at the Alaska Marine Science Symposium in Anchorage in January 2013. We outlined the planned approach for the synthesis and received some input from the co-authors on the strategy and scope of the manuscript. As the lead team, Bluhm and Grebmeier followed up with defining the regions of interest using a threshold value for benthic infaunal biomass. We also compiled a data matrix containing relevant variables and team members who hold relevant data sets. On March 25, 2013, before the Wakefield Symposium, we brought together all available co-authors in Anchorage for an all-day workshop. All co-authors were tasked with preparing PowerPoint slides that should illustrate what data they can contribute for the regions of interest, how and when they were collected and what the major findings were. Bluhm and Grebmeier presented for the co-authors not present at that meeting. The active engaging discussion evolved around defining hot spot areas, identifying available data sets, the challenges associated with integrating data sets from different time periods, investigators and gear types, and focusing the scope of the paper. In a follow-up lunch meeting a few days later, Bluhm and Grebmeier discussed action items resulting from the workshop and came up with a tentative list of figures and tables that we anticipate to form the core of the manuscript. An email is in preparation that outlines the expectations and tasks for all co-authors for the coming weeks.

NOAA relevance/societal benefits

The goal of the entire SOAR project is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic pelagic species (forage fish and zooplankton) and higher trophic species (seabirds and marine mammals) in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas.

Partners and collaborators

The current list of authors for the planned paper is as follows:
Grebmeier, J.[1], B.A. Bluhm[2], K. Arrigo[3], A. Blanchard[2], L. Cooper[1], S. Danielson[2], R. Day[4], K. Dunton[5], K. Frey[6], R. Gradinger[2], C. Jay[7], M. Kedra[1], B. Konar[2], K. Kuletz[8], S. Lee[9], J. Lovvorn[10], S. Moore[11], B. Norcross[2], S. Okkonen[2], S. Schonberg[5], T. Weingartner[2], T. Whitledge[2]

[1]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD, [2]School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK, [3]Stanford University, CA, [4]Alaska Biological Research, Inc., Fairbanks, AK, [5]Marine Science Institute, University of Texas at Austin, Port Aransas, TX, [6]Graduate School of Geography, Clark University, Worcester, MA, [7]USGS Alaska Science Center, Anchorage, AK, [8]US Fish and Wildlife Service, Anchorage, [9]Pusan National University, Pusan, S. Korea, [10]Southern Illinois University, Carbondale, IL,[11]NOAA NMFS - Science & Technology, Seattle, WA

Grebmeier and Bluhm are co-leading the efforts involved in this project and will conduct the majority of the writing with Grebmeier serving as the lead author. All co-authors are expected to contribute data, paragraphs describing their data, and comments on the complete manuscript.

Changes/problems/special reporting requirements

No problems have occurred. The author list of the manuscript has changed some in the course of the discussions of the paper focus and content relative to the originally submitted author list. Local community representatives were not present at the meetings held so far, but we will continue to consider community involvement.

Synthesis of Arctic Research (SOAR): Oceanographic factors associated with bowhead whale hotspots and variations in the migration path

Stephen Okkonen, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

CIFAR 13-035: This project is new.

NOAA Offices: NMFS-S&T, OAR/PMEL: Sue Moore & Phyllis Stabeno, Sponsors

Primary objectives

1) Describe areas that bowhead whales consistently use (i.e., "hotspots") and summarize what is known about those areas regarding oceanography, sea ice, and zooplankton. The primary question to be addressed is: Can bowhead whale seasonal presence and behavior at these locations be explained by oceanographic processes (i.e. currents, winds, fronts) that concentrate zooplankton?

2) Develop a mechanistic model that, based on relevant meteorological, oceanographic, cryospheric, and/or acoustic conditions, identifies likely trajectories for bowhead whales crossing the Chukchi Sea, and then relate model predictions to the actual paths of bowhead whales with satellite tags.

Synthesis accomplishments/highlights

Okkonen will be traveling to Monterey, California (5–15 May 2013) to compare *in situ* data acquired during his CIFAR-funded component of the BOWFEST project (2007–2012) with Naval Postgraduate School numerical model results. Scheduling conflicts did not allow an earlier visit.

NOAA relevance/societal benefits

The goal of the SOAR project is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic pelagic species (forage fish and zooplankton) and higher trophic species (seabirds and marine mammals) in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas.

Partners and collaborators

Lori Quakenbush, Alaska Department of Fish and Game
John Citta, Alaska Department of Fish and Game
Matt Druckenmiller, National Snow and Ice Data Center
Wieslaw Maslowski, Naval Postgraduate School

Synthesis of Arctic Research (SOAR): Influence of sea ice and oceanographic conditions and prey availability on the timing of fall bowhead whale migration

Stephen Okkonen, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

CIFAR 13-034: This project is new.

NOAA Offices: NMFS-S&T, OAR/PMEL: Sue Moore & Phyllis Stabeno, Sponsors

Primary objectives

The timing of bowhead whale migrations from the Canadian Arctic along the Beaufort Shelf to Barrow AK in the fall varies interannually. Our hypothesis is that bowhead whales "linger" in the Canadian Arctic when prey is plentiful, ice is minimal, and/or ocean temperature is warm. Our objective is to identify how environmental conditions (sea ice, hydrography, prey availability) in the Canadian Arctic (Amundsen Gulf and to the west) and on the Beaufort Shelf are associated with bowhead whale distributions on the shelf and the timing of their fall migration.

Synthesis accomplishments/highlights/

Okkonen will be traveling to Monterey, California (5–15 May 2013) to compare *in situ* data acquired during his CIFAR-funded component of the BOWFEST project (2007–2012) with Naval Postgraduate School numerical model results. Scheduling conflicts did not allow an earlier visit.

NOAA relevance/societal benefits

The goal of the SOAR project is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic pelagic species (forage fish and zooplankton) and higher trophic species (seabirds and marine mammals) in the Pacific Arctic, with particular emphasis on the Chukchi Sea Lease Sale Areas.

Partners and collaborators

Carin Ashjian, Woods Hole Oceanographic Institute (WHOI)
Bob Campbell, University of Rhode Island
Susanna Blackwell, Greeneridge Sciences
George Divoky, Friends of Cooper Island
Craig George, North Slope Borough Department of Wildlife Management
Lois Harwood, Department of Fisheries and Ocean Sciences, Canada
Kate Stafford, University of Washington
Matt Druckenmiller, National Snow and Ice Data Center
Wieslaw Maslowski, Naval Postgraduate School
Robert Pickart, WHOI
Tom Weingartner, UAF

Synthesis of Arctic Research (SOAR): An Ocean Acidification Sensitivity Index for the Pacific Arctic Region

Tom Weingartner, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Claudine Hauri *and* ***Noelle Lucey,*** *University of Alaska Fairbanks*

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

CIFAR 13-037: This project is new.

NOAA Offices: NMFS-S&T, OAR/PMEL: Sue Moore & Phyllis Stabeno, Sponsors

Primary objectives

Our primary objectives of this synthesis activity and resulting manuscript(s) will be an ocean acidification (OA) sensitivity index for the Pacific Arctic Region. This sensitivity index will combine recent data on carbonate mineral saturation states with benthic and pelagic species distribution maps, we will be able to assign each sub-region an OA sensitivity index (OASI) number between 1 and 7 based on the extent and degree of carbonate mineral under saturations, the duration of undersaturations, and the susceptibility of keystone species to OA, as well as their connection to upper trophic levels including humans. It will be possible to determine how physical forcing (i.e. mixing, upwelling, terrestrial inputs) and biological responses (i.e. primary production and respiration) exert fundamentally different controls on OA in the varying sub-regions of the differing shelf environments, and thus determine which areas will be impacted first and to what degree.

Synthesis accomplishments/highlights

- Acquired and analyzed all necessary socio-economic data and created resiliency index
- Model and observational data were analysed to describe current and potential future status of ocean acidification in the waters around Alaska
- We are now in the process of writing up the results in a scientific article

NOAA relevance/societal benefits

The goal of the SOAR project is to increase scientific understanding of the relationships among oceanographic conditions, benthic organisms, lower trophic pelagic species (forage fish and zooplankton) and higher trophic species (seabirds and marine mammals in the Pacific Arctic), with particular emphasis on the Chukchi Sea Lease Sale Areas.

Publications, conference papers, and presentations

Oral presentations

Mathis, J. 2013. Preparing for the challenges of ocean acidification in Alaska. Keynote presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, 21 January 2013.

Mathis, J. 2013. Ocean acidification and the suppression of carbonate mineral saturation states in the Pacific–Arctic region. Gordon Research Conference on Polar Marine Science, Ventura, California, 14 March 2013.

Partners and collaborators

Jeremy Mathis, PMEL-NOAA, USA; School of Fisheries & Ocean Sciences, UAF - lead author

Noelle Lucey, (now at) WHOI, USA/Pavia University, Italy/University of Plymouth, Great Britain – socio-economic data acquisition – analysis - interpretation– manuscript preparation

Sarah Cooley, WHOI - socio-economic data analysis - interpretation – manuscript preparation

Cooperative Alaska research and satellite data services

Thomas Heinrichs, PI ***CIFAR theme: Climate Change & Variability***
Jessica Cherry, co-PI
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
Jiang Zhu, *University of Alaska Fairbanks*

NOAA Goal: Climate Adaptation & Mitigation

CIFAR 10-015/12-015/13-015: This project is ongoing. NOAA Office NESDIS/GOES-R, Steve J. 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 the National Aeronautics & Space Administration (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.*

Through leveraged funds, Cherry has also co-located *in-situ* instrumentation with current and proposed NOAA Climate Reference Network sites and made these data available through near-real time data feeds on a public webpage (http://ine.uaf.edu/werc/projects/atpn/index.html). These sites include the NESDIS Fairbanks Command and Data Acquitions Station (FCDAS) facility near Fox, AK, and the NOAA Earth System Monitoring Laboratory in Barrow, Alaska.

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.*

Flood forecasting has been identified as another candidate for risk reduction through research applications. Our UAF team has partnered with the NWS River Forecast Center to develop improved forecast models for the snowmelt season using MODIS-derived imagery. This will be described in more detail below.

3) Strategic planning and ***implementation white paper*** *and a proof of concept* ***demonstration project*** *in Alaska's Interior for improved near-real-time snow and hydrology forecast products for high latitudes.*

Cherry and Katrina Bennett (Ph.D. 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.

Snow cover extent is a difficult parameter to model during the dynamic and variable snow melt period. The Moderate Resolution Imaging Spectrometer (MODIS MOD10A1 version 5) 500 m pixel daily areal extent of snow cover (AESC) data was integrated into the River Forecast Center's Community Hydrologic Prediction System (CHPS) to improve the model representation of snow cover extent in select Interior basins of sub-Arctic Alaska. Grids were downloaded, converted to GEoTIFFs, and re-projected in ArcGIS to the projection that CHPS is programmed to read. Then, the data was clipped for the Interior region of study, and exported from ArcGIS as an ArcInfo ASCII grid. The XML framework was altered to allow for ingestion of the gridded clipped data for the watersheds nearby Fairbanks, Alaska including the Chatanika, Chena, Salcha and Goodpaster basins from 2000-2012. Then the data was interpreted as a time series both serially and spatially and imported into the SNOW-17 model as an observed snow cover extent variable. This effectively replaced the areal depletion curves that are built in to SNOW-17 to represent the change in areal snow cover extent through the snowmelt period.

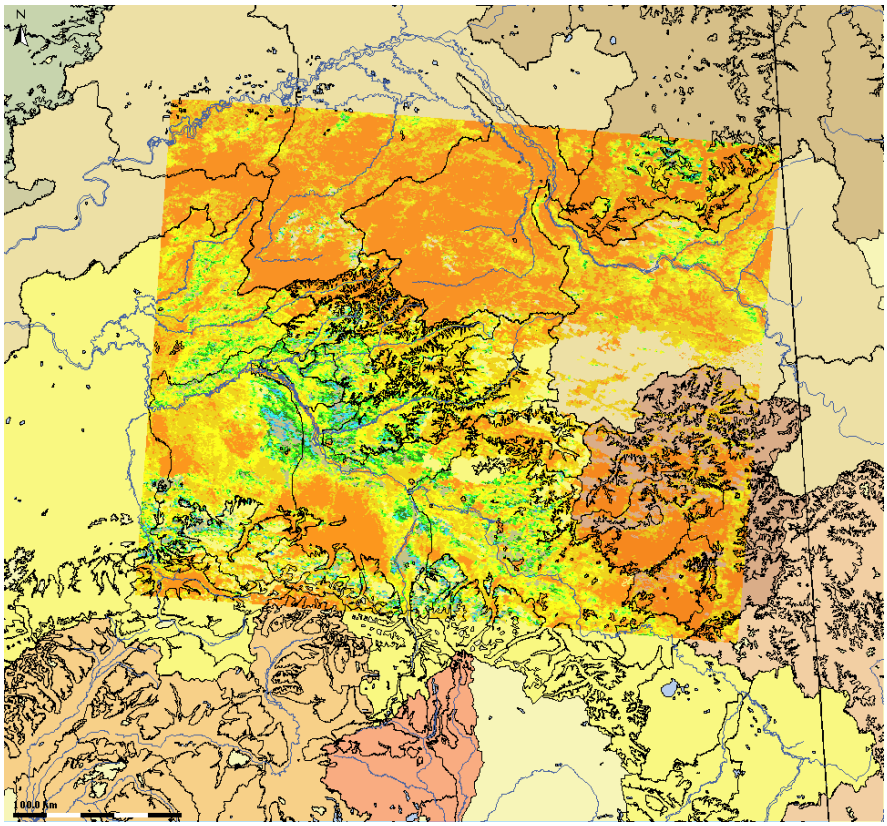


Figure 1. MODIS gridded AESC data ingesting into CHPS prior to serial and spatial clipping. Yellow/orange represents no snow, green/blue represents snow covered. Pale yellow is cloud covered.

The use of this technique to import MODIS gridded snow cover could be implemented operationally for use in forecasting mode. A live-data feed of MODIS data would be required. CHPS may be set up to ingest the raw HDF MODIS swath data, which would remove the extra step of importing the grids into ArcGIS, re-projecting and converting the data to ASCII grids. Once this process has been tested, then the import functions could be built in and a separate workflow could be developed in the operational version of CHPS that could allow for MODIS AESC import. Calibration of the basins would have to be undertaken to realize any improvement, as the SNOW-17 model is currently calibrated to match the existing areal depletion curve. Alternatively, the import of MODIS data on-the-fly for short periods (1-10 days, for example) could be implemented in the software via what is referred to by operational forecasters as a MOD (or modification). The MOD could serve to import the MODIS AESC data and then additional 'calibration' MODs could follow that would shift the model to run using the observed areal extent of snow cover, while adjusting other parameters that previously relied upon the depletion curve. This methodological

approach would require testing but would provide the RFC with a direct means of utilizing the live MODIS satellite imagery in their forecasting modes.

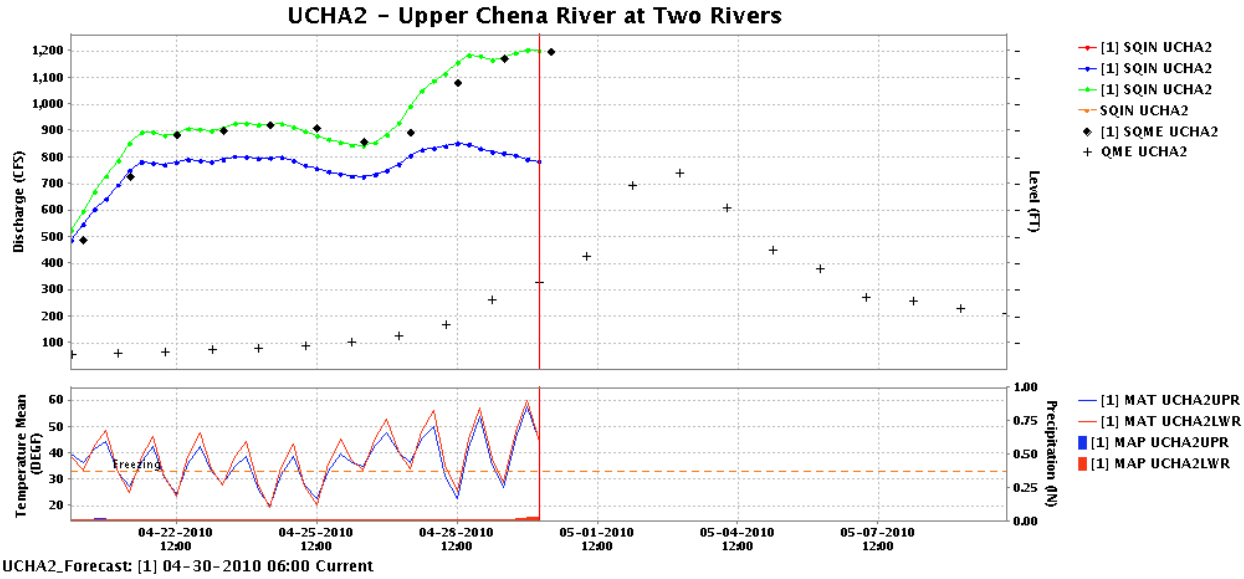


Figure 2. CHPS modeled streamflow for the Upper Chena River basin with and without MODIS AESC. The blue line represented the streamflow with AESC observed from MODIS, the green line represents modeled streamflow using the SNOW-17 areal depletion curve.

Ph.D. student Molly Tedesche is involved in the project with a focus on south central and southeast Alaska. Cherry and Tedesche are working with NOAA's National Marine Fisheries Service on determining snow cover and corresponding water resources for existing and proposed hydroelectric facilities. The Juneau NWS forecast office and the RFC are also partners in this effort.

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.
Molly Tedesche, a Ph.D. student, began working on this project in April 2012 and continues to be supported in part through this project.

Outreach

Heinrichs, Dayne Broderson (GINA Technical Services Manager), Eric Stevens (GINA-NWS liaison), and Jiang 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. Bennett and Cherry are working with the RFC in Anchorage and Tedesche, Stevens, and Cherry are working with the NWS forecast office in Juneau.

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 National Marine Fisheries Service

NOAA National Operational Hydrology Remote Sensing Center
NOAA Climate Reference Network
NOAA Environmental System Research Laboratory (Barrow)
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

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 ***CIFAR theme: Climate Change & Variability***
University of Alaska Fairbanks

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

NOAA Goal: Climate Adaptation & Mitigation

CIFAR 12-030/13-030: This project is ongoing. NOAA 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. *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.
2. *Hosted visit from Kathy Strababa and Jordan Gerth of Cooperative Institute for Meteorological Satellite Studies (CIMSS).* Installed latest version of Community Satellite Processing Package (CSPP). Set up data flow of Visible Infrared Imager Radiometer Suite (VIIRS) data in Advanced Weather Interactive Processing System

(AWIPS-1) compatible data formats through the Unidata Local Data Manager (LDM) to Fairbanks Weather Forecast Office (WFO). Visited Anchorage NWS's Alaska River Forecast Office, Weather Forecast Office, and Aviation Weather Unit; configured NPP products in their AWIPS-1 systems and presented products to forecasters and managers.

3. *CIRA visit 2–4 Oct 2013.* Steve Miller, of the Cooperative Institute for Research in the Atmosphere (CIRA), visited Fairbanks in October 2012. The objectives of this visit were 1) to install and operationalize VIIRS Day/Night Band imagery software, including implementing a raw data format converter and lunar irradiance model, and 2) to meet with various research and operational groups focused on the Alaska Region to introduce low-light visible capabilities in general and the specific capabilities of the VIIRS Day/Night Band. Both of these objectives were met, and the collaboration is off to an outstanding start as we head into the winter months when low-light products will take center stage.

4. *Set up GINA Puffin Feeder for VIIRS products for use by the Alaska NWS Ice Program.* VIIRS products are being produced in near-real-time in GeoTIFF formats to support NWS sea ice forecasting. This product format is what is needed by the Geographic Information Systems (GIS) used by the ice forecasters to chart ice. Adoption of the VIIRS imagery products has been strong by the ice desk. http://feeder.gina.alaska.edu (Figure 1)

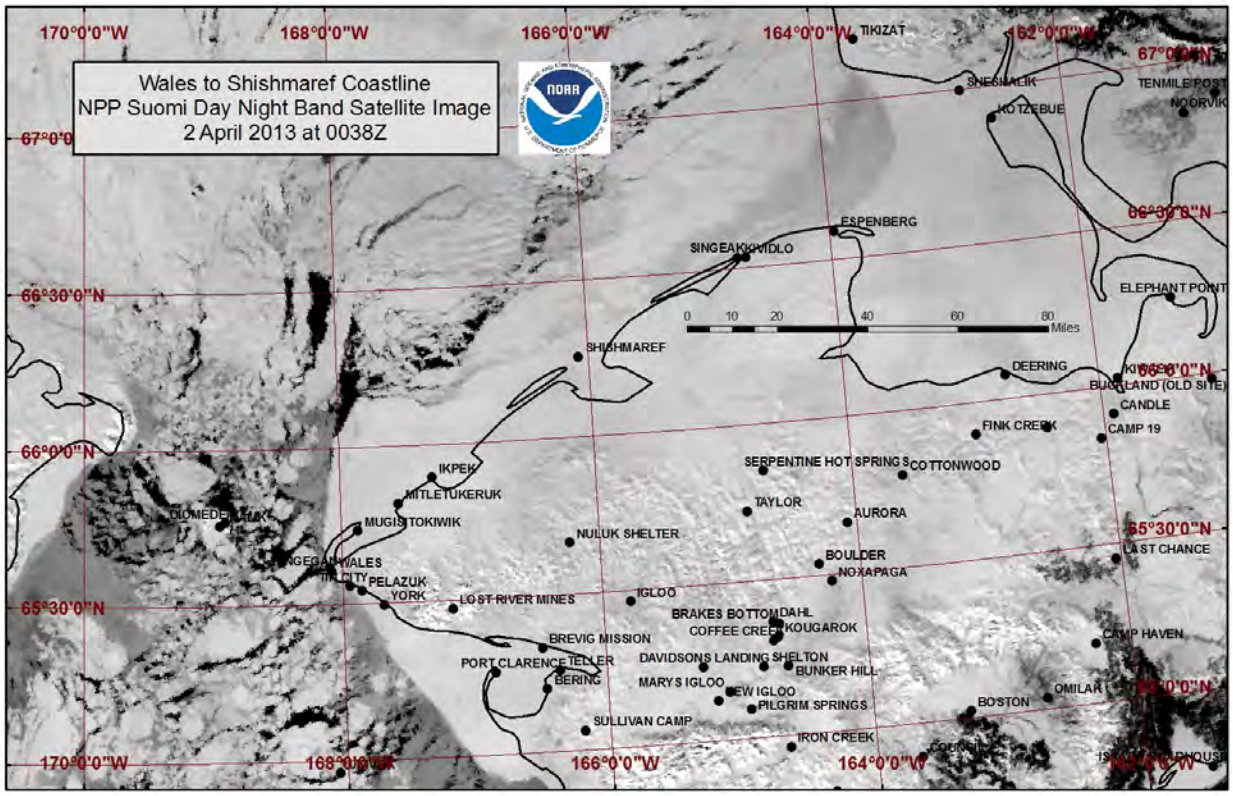


Figure 1. Image published on public website of Alaska NWS Sea Ice Program. http://pafc.arh.noaa.gov/icegraphics.php

5. *Added VIIRS I05 longwave infrared band for NOAA National Ice Center (NIC).* GINA received a request from the NOAA National Ice Center to add the VIIRS I05 longwave infrared channel to the GINA Puffin Feeder. The NIC had been using other georeferenced satellite imagery from the Feeder and requested the enhancement to the service to support ice forecasting at the National center. (Figure 2)

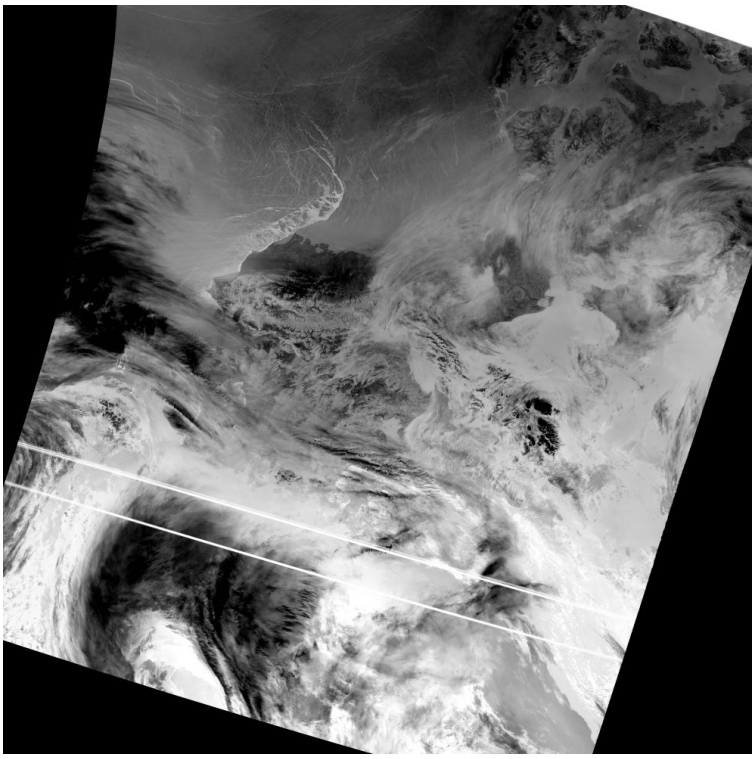


Figure 2. Sample of VIIRS I05 longwave infrared imagery provided in near real time to the NOAA National Ice Center.

6. *Presented polar orbiting satellite data products, including Suomi NPP, at the US-Canada Oil and Gas Forum.* Tom Heinrichs presented to this large audience and advocated the benefits of Suomi NPP data. Many oil and gas industry members were in attendance; this is not a group that is easy to reach.

7. *Presented NPP VIIRS work in Alaska at the JPSS Science Seminar in January 2013.* A successful presentation via webinar to a large audience of primarily NOAA scientists about VIIRS work in Alaska.

8. *Bill Smith visit.* Smith is a renowned atmospheric scientist who visited Fairbanks in February 2013 to perform field work and satellite data validation. Eric Stevens organized his interactions with the Alaska NWS. Much interest in the Suomi NPP Cross track Infrared Sounder (CrIS) was generated within the Alaska NWS.

9. *Outreach visit to Juneau.* On 28–29 March, Eric Stevens and Molly Tedesche visited several NOAA offices in Juneau, Alaska to promote and train on satellite data, with an emphasis on Suomi NPP data. They presented at and interviewed users at the Juneau WFO, NOAA's National Marine Fisheries Service (NMFS) Auke Bay Lab, and University of Southeast faculty hydrologists and ecologists.

10. *Installed CSPP on GINA processing cluster. Tested CSPP VIIRS SDR 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), installed several versions of the Community Satellite Processing Package (CSPP). Successfully ran the CSPP on Level 0 data to produce Level 1 suites of data. This data is distributed to the Alaska NWS through LDM and AWIPS-1. It is also distributed to many other users as georeferenced imagery via the GINA Puffin Feeder.

11. *Captured Suomi NPP data on upgraded system.*
    Data was captured from Suomi NPP starting on 5 April 2012. First pass taken: Thu Apr 05 09:27 AM, GMT. It has been captured ever since at a rate of about nine passes per day.

12. *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. Work is ongoing to operationalize this and transfer the responsibility to another antenna at UAF.

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.

Publications and presentations

Oral presentation

Stevens, E. 2013. The High-Latitude Proving Ground and the utility of Suomi NPP VIIRS imagery in the forecast process. Alaska Weather Symposium, 12–13 March 2012, Fairbanks, Alaska.

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 ***CIFAR theme: Climate Change & Variability***
University of Alaska Fairbanks

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. NOAA Office: OAR-CPO, John Calder/Kathleen Crane, 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 AARI team has worked on development and improvement of the AARI ice product: monthly ice concentration charts of the Arctic Ocean covering the period from January 1901 through September 2012. This data set combines data from several sources including the national ice services of Russia, the USA and Canada (plus several additional data sets). This is the first attempt to create such a data set. The output is monthly gridded data using a 25x25^{o} grid. Figure 1 shows ice concentration maps for 2010, 2011 and 2012. We find reasonable spatial distribution of the parameter in time and in space.

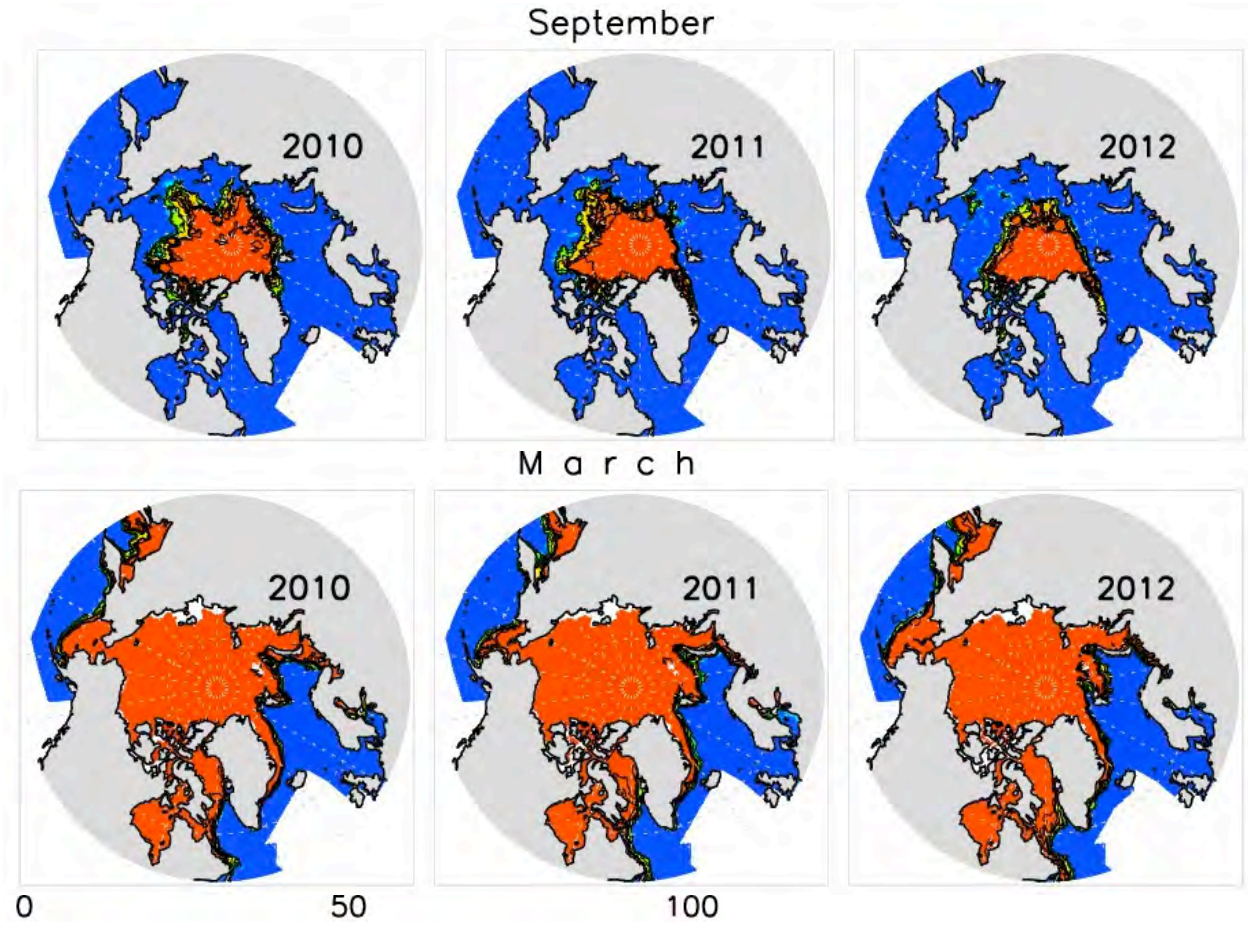


Figure 1. AARI monthly sea-ice concentration for September and March 2010, 2011 and 2012.

However, summer ice concentrations demonstrate some problems with the data set including gaps and discontinuities (Figure 2). Despite these problems, the data set shows data coverage even during those years when one cannot expect to find them. For example, we found some data from the WWII period (Figure 3).

Adrienne Tivy worked on the Canonical Correlation Analysis (CCA) as a method for statistical forecasting of seasonal Arctic ice coverage. The training period used for the experiments was 1951–2010 and September ice concentration was used as a predictant. The metrics to assess skill were percentage of grid points with a significant correlation between the actual and forecast time-series. The model shows reasonably high predictive skill for original (Table 1) and de-trended data (Table 2).

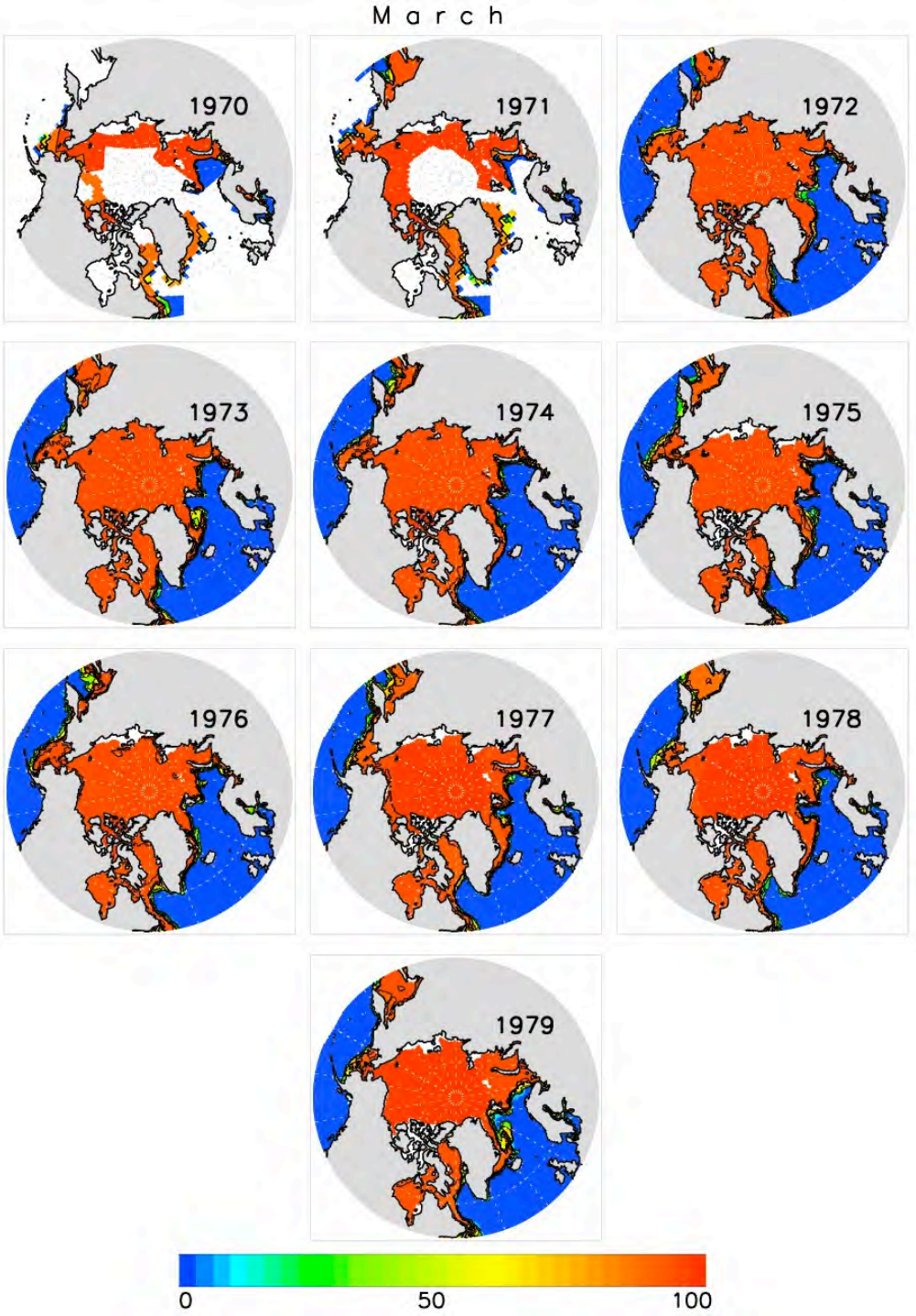


Figure 2. AARI monthly sea-ice concentration for March in the 1970s: gaps in data coverage are evident.

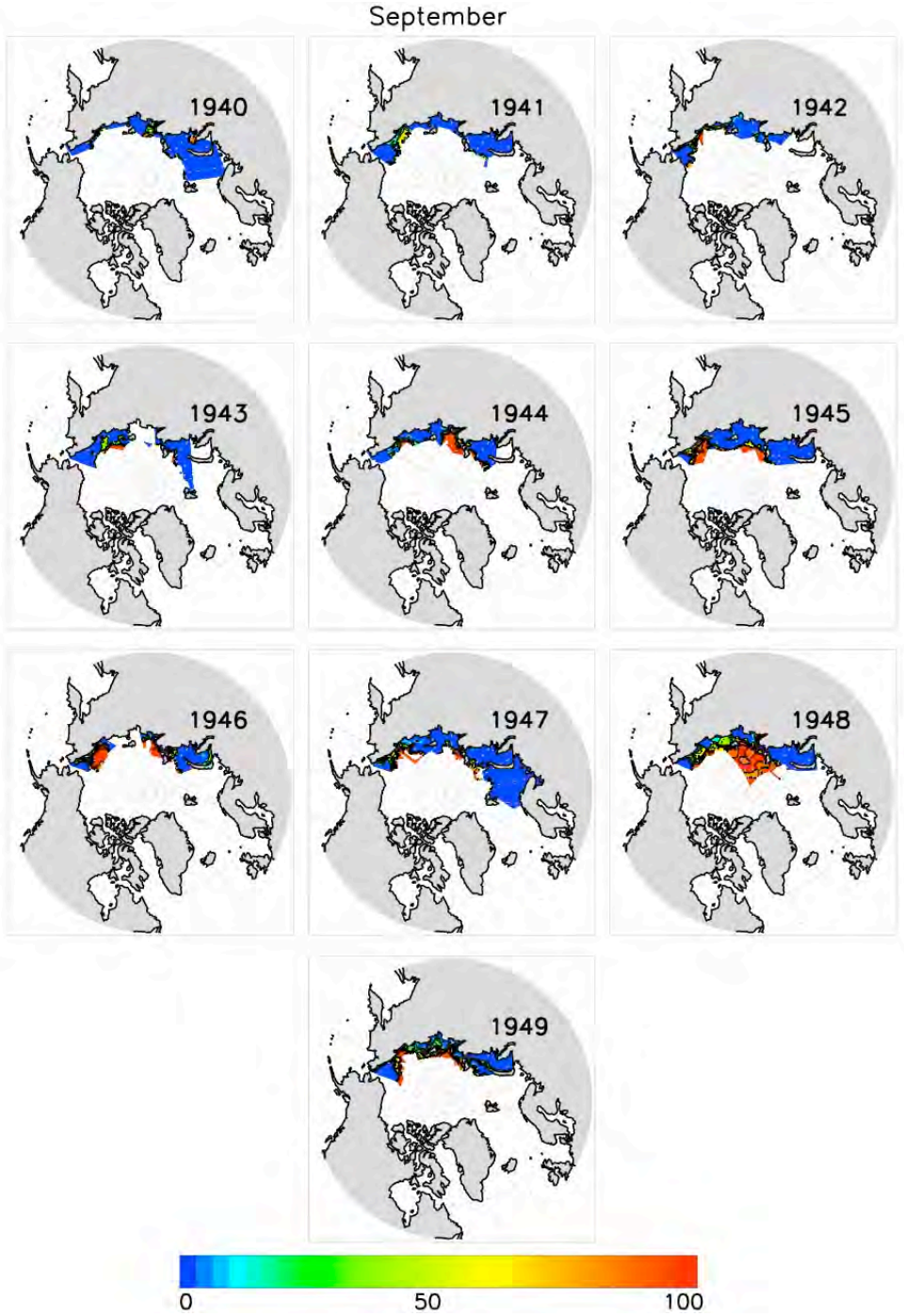


Figure 3. AARI monthly sea-ice concentration for September in the 1940s: despite WWII, data exists.

Tables 1 and 2 show the cross-validated forecast skill for September ice concentration from statistical models based on CCA. The training period is 1951–2010 and September ice concentration is from the AARI dataset. The metric used to measure skill is the percentage of grid points with a significant correlation ($p < 0.05$) between the actual and forecast ice concentration time-series. Surface air temperature (SAT), sea level pressure (SLP), and 500 mb geopotential height (z500) data is from the NCEP/NCAR Reanalysis. Global (SST), North Atlantic (SNA) and North Pacific (SNP) sea surface temperature data is from the Hadley dataset. The analysis was run with raw data (Table 1) and with the long-term trend in both the predictant (ice concentration) and predictor (atmosphere/ocean) data removed (Table 2). If less than 10% of the grid points had a significant correlation coefficient the results were not considered; a 10% threshold is based on results from a Monte Carlo simulation.

The skill of persistence forecasts is high at 1 to 3 months lead, skill drops during the winter months when the area is completely ice covered and there is some skill at 9 to 12 months lead (Table 1). For all of the climate predictors tested, forecast skill does not beat persistence. However at 3 to 9 months lead when persistence forecasts are not possible, there is some skill from sea surface temperatures and local air temperature (Table 1). When trends in the data are removed, there is a drop in the skill of persistence and forecasts based on air temperature. These preliminary results suggest that statistical models may be useful at lead times beyond 3-months when the forecast skill of persistence forecasts (Table 1, 2) and forecasts from coupled dynamical forecast systems declines.

*Table 1. Skill of persistence and CCA models (**trend left in**); the numbers in each column are the percentage of grid points with a significant (95%) correlation between the actual and forecast timeseries*

LEAD	% sig. corr: Persis	SAT (local)	SLP (NH)	Z500 (NH)	SST (global)	SNA N. Atl	SNP N.Pac
0 - Sep	100						
1 - Aug	**98.9**	**39.9**	0	0	6	**12.3**	6.5
2 - Jul	**91.4**	**25.0**	0	1.5	5.2	8.0	7.8
3 - Jun	**54.8**	**19.1**	0	1.6	4.6	**10.2**	6.3
4 - May	7.4	**11.4**	0	1	3.3	**13.1**	6.2
5 - Apr	2.7	0.2	0	0.7	2.3	**13.6**	3.8
6 - Mar	6.1	0	0	0.2	3.7	**14.9**	9.7
7 - Feb	7.7	0	0	0.6	3.3	4.3	**11.2**
8 - Jan	0	1.1	0	1.1	3.0	0.7	6.4
9 - Dec	0	**15.3**	0.3	1.3	5.5	6.7	**11.2**
10 - Nov	**14.9**	8	0	0	6.4	6.6	8.2
11 - Oct	**33.4**	7.8	0	0.2	7.1	**10.6**	6.9
12 - Sep	**22.4**	0	0	0.4	6.3	8.3	6.3

*Table 2. Skill of persistence and CCA models (**trend removed**); the numbers in each column are the percentage of grid points with a significant (95%) correlation between the actual and forecast time series.*

LEAD	% sig. corr: Persist	SAT (local)	SLP (NH)	Z500 (NH)	SST (global)	SNA N. Atl	SNP N.Pac
0 - Sep	100						
1 - Aug	**98.9**	**32.3**	0	0.3	6.0	**12.3**	6.4
2 - Jul	**89.0**	**17.4**	0	0	5.2	8.0	6.3
3 - Jun	**45.8**	5.4	0.2	0	4.6	**10.3**	6.2
4 - May	3.1	1.8	0.9	0.2	3.3	**13.2**	3.8
5 - Apr	1.1	0	0	0	2.3	**13.6**	9.7
6 - Mar	0.9	0	0	0	3.7	**14.9**	**11.2**
7 - Feb	4.6	0	0	0	3.3	4.3	6.4
8 - Jan	0	0	0	0	3.0	0.7	**11.2**
9 - Dec	0	5.0	0	0	5.5	6.7	8.2
10 - Nov	0	5.2	0	0	6.4	6.6	6.9
11 - Oct	**16.4**	1.9	0	0			
12 - Sep	**17.4**	0	0.4	0	6.3	8.3	6.3

Publications and conference presentations

Publications in press

Polyakov, I.V., U.S. Bhatt, J.E. Walsh, E.P. Abrahamsen and P.F. Wassmann. Recent oceanic changes in the Arctic in the context of long-term observations. *Ecological Applications*, in press.

Hinzman, L., C. Deal, A.D. McGuire, I.V. Polyakov and J.E. Walsh. Trajectory of the Arctic as an integrated system. *Ecological Applications,* in press.

Several more papers are under preparation.

Oral presentation

Polyakov, I. 2013. Monitoring warming in the Eurasian Basin of the Arctic Ocean. Invited speaker, ISAR-3, January 14–17, Tokyo, Japan.

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.

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.

Problems with the AARI gridded sea-ice concentrations are inherited and impossible to overcome. We are currently investigating limitations of the data set for future use in our seasonal ice predictions.

Quarterly Alaska climate seasonal overview and impacts

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

NOAA Goal: Climate Adaptation & Mitigation

CIFAR 13-038: This project is new. NOAA Office: NWS, James Partain, Sponsor

Primary objectives

The Alaska Center for Climate Assessment and Policy (ACCAP), the Regional Integrated Science and Assessment (RISA) program in Alaska proposes to make the following contributions to the planned NOAA Alaska Region Quarterly Climate Impacts and Outlook Product.

- **Overview of seasonal extreme events in Alaska for June, July, and August 2012**. This product will include daily and monthly records broken for high and low temperatures, precipitation events, storm events, sea ice, wildfires, and flooding, and will build on a product previously compiled by ACCAP in collaboration with the National Weather Service Fairbanks Forecast Office (WFO), and the Alaska Climate Research Center. Our product will be an Alaska map depicting these events in a format compatible with the national map shown in the template for NOAA's Quarterly Climate Impacts and Outlooks Product.
- **Highlight of social, economic, and environmental impacts of the extreme events**. The product will be a bulleted text summary of the major impacts of climate- and weather-related events as well as a map showing the location of the impacts.

Research accomplishments/highlights/findings

- Map with icons and brief text depicting seasonal highlights of extreme events in Alaska
- Narrative text to accompany the map describing social, economic and environmental impacts of seasonal extreme events
- Color-metric maps showing seasonal departure from normal for both temperature and precipitation
- Maps and narrative text describing seasonal record retreat of Arctic sea ice

NOAA relevance/societal benefits

This project is directly relevant to the focus areas of: a) changes in the extremes of weather and climate, b) climate impacts on water resources and c) coasts and climate resilience identified in the NOAA Next-Generation Strategic Plan (NGSP). Providing a seasonal summary of significant events, societal impacts of these events and departures from temperature and precipitation normal values, this product provides a concise summary for use and application by policy and decision-makers.

The product of this project, the Alaska Region Quarterly Climate Impacts and Outlook Product, was requested and endorsed by the Western Governors Association as a relevant decision-support tool.

Outreach

The product of this project, the Alaska Region Quarterly Climate Impacts and Outlook Product, is a 2-page summary that is widely distributed to stakeholders throughout the region and will be available on the ACCAP website (website revised version scheduled for launch on 1 May 2013).

Partner organizations and collaborators

Alaska Climate Research Center - http://climate.gi.alaska.edu/
Alaska Climate Science Center - http://www.doi.gov/csc/alaska/index.cfmg
Cryosphere Today (University of Illinois) - http://arctic.atmos.uiuc.edu/cryosphere/
NOAA/NWS Weather Forecast Offices in Fairbanks, Anchorage and Juneau
NOAA/NESDIS/NCDC - www.ncdc.noaa.gov
Scenarios Network for Alaska and Arctic Planning – http://snap.uaf.edu/

Impact

This product has the potential to impact decision-making in municipal, regional and state planning and decision-making in areas such as transportation, wildfire, Arctic shipping, agriculture, and water, land and resource management.

COASTAL HAZARDS

TWEAK: Tsunami Warning and Environmental Observatory for Alaska

Roger Hansen, PI ***CIFAR theme: Coastal Hazards***
Natalia Ruppert, co-PI
University of Alaska Fairbanks

NOAA Goal: Weather Ready Nation

CIFAR 09-008/10-008/11-008/12-008: This project is ongoing. NOAA Office: NWS Tsunami Program, Michael Angove, 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

Natalia Ruppert, 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 Institute of Marine Science (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

The main results achieved during the TWEAK project and the models developed for the tsunami warning and prediction have been described in the book, *Introduction to Numerical Modeling of Tsunami Waves* by Z. Kowalik. During the reporting period, the tsunami code development proceeded along the two directions. Two-dimensional models for the dispersive and non-dispersive processes were tested against the Japan and Kurile tsunamis and 3-D models were used for the tsunami generation. We are aiming to connect these two models so that the tsunami generation will be reproduced by the 3-D approach and the long-distance tsunami propagation by the 2-D approach.

Z. Kowalik, 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*. Previously formulated expressions for the energy fluxes for both the dispersive and non-dispersive waves were used to elucidate the physics of the dispersive processes for the trans-oceanic propagation. In numerical experiments the results of the dispersive and non-dispersive computation for the same source function were compared for the Japan Tsunami (JT) of March 2011. To compare the results for the nondispersive and dispersive wave propagation (notice that we compare only positive sea surface height) the maximum sea surface height (ssh) for the dispersive waves is subtracted from the maximum ssh for the nondispersive waves. The difference is given in Figure 1.

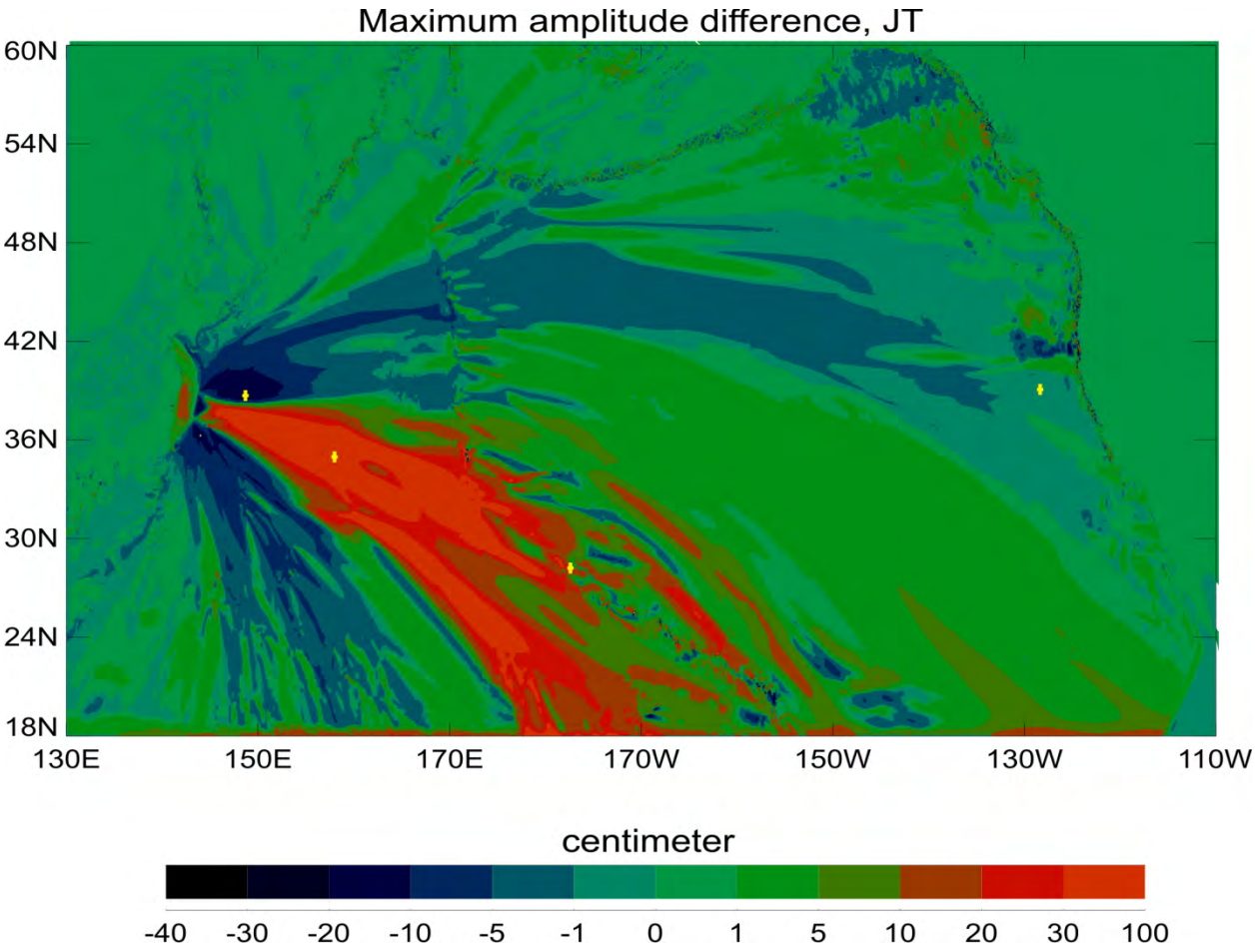


Figure 1. Difference between nondispersive and dispersive maximum ssh, for JT. Red-green: the nondispersive waves dominate; blue: the dispersive waves dominate. Yellow plus markers indicate: Dart Buoy 21418 (148.694 E, 38.711 N), numerical gauge located in main lobe of energy (158.00 E, 35.00 N), Midway Island tide gauge (177.36 W, 28.212 N) and Dart Buoy 46411 (127 W, 39.94 N).

This figure shows the following pattern: in the main energy lobe the hydrostatic solution dominates strongly while at the side lobes, elongated domains dominated by dispersive waves are generated. The strongest differences occur along the main energy lobe where the largest ssh occurs. This observation is well confirmed by the equation of motion since the dispersive component is generated in the areas where either the large gradients of the depth or the sea level occur. The results of these numerical experiments can be summarized as follows: (1) within the main energy lobe there exists a large difference between maximum dispersive and non-dispersive wave amplitudes, (2) in the far-field from the tsunami source the differences are small, (3) the transfer of the tsunami wave energy between the non-dispersive and dispersive modes is well confirmed by the energy flux, (4) temporal series from a few locations confirm the importance of dispersion in the main energy lobe as well.

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).
J. Horrillo, his team and D. Brazhnikov (UAF, graduate student) have continued the numerical work required to improve the landslide capability of our 3-D Navier-Stokes model (VOF3D). Main new features in the model are: (1) the inclusion of a simplified soil rheology and (2) a better treatment of the diffusion term. The three-dimensional model is in the process of being calibrated using lab experiments carried out by H. Fritz (Georgia Institute of Technology). Results of the model against a fjord-like laboratory experiment are shown in Figures 2 and 3.

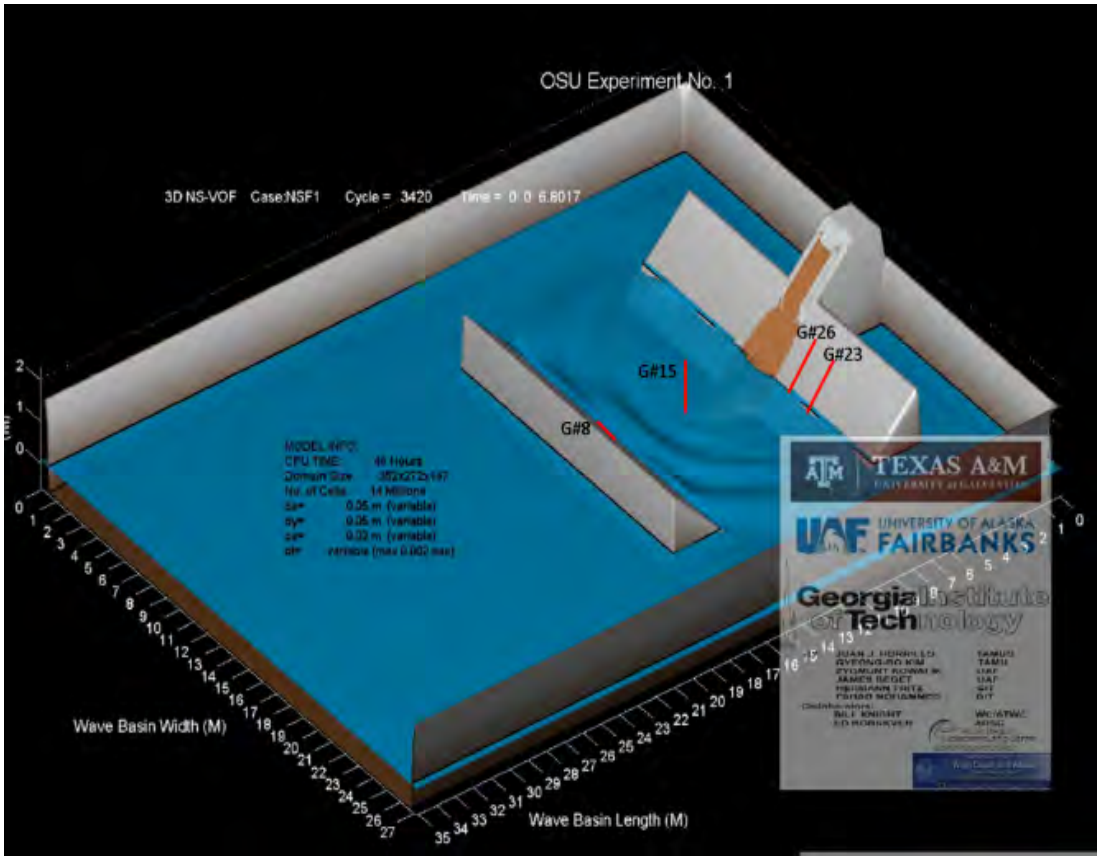


Figure 2. Numerical wave tank configuration. The image captures the landslide-induced tsunami waves and runup at the adjacent and opposite fjord cliffs. Gauge locations are marked in red.

D. Brazhnikov explored common features of the Bingham plastic mudslide and Navier-Stokes 2D model. To increase accuracy in modeling of the moving boundary of the landslide Brazhnikov performed a series of numerical experiments with mesh refinement in front of the landslide.

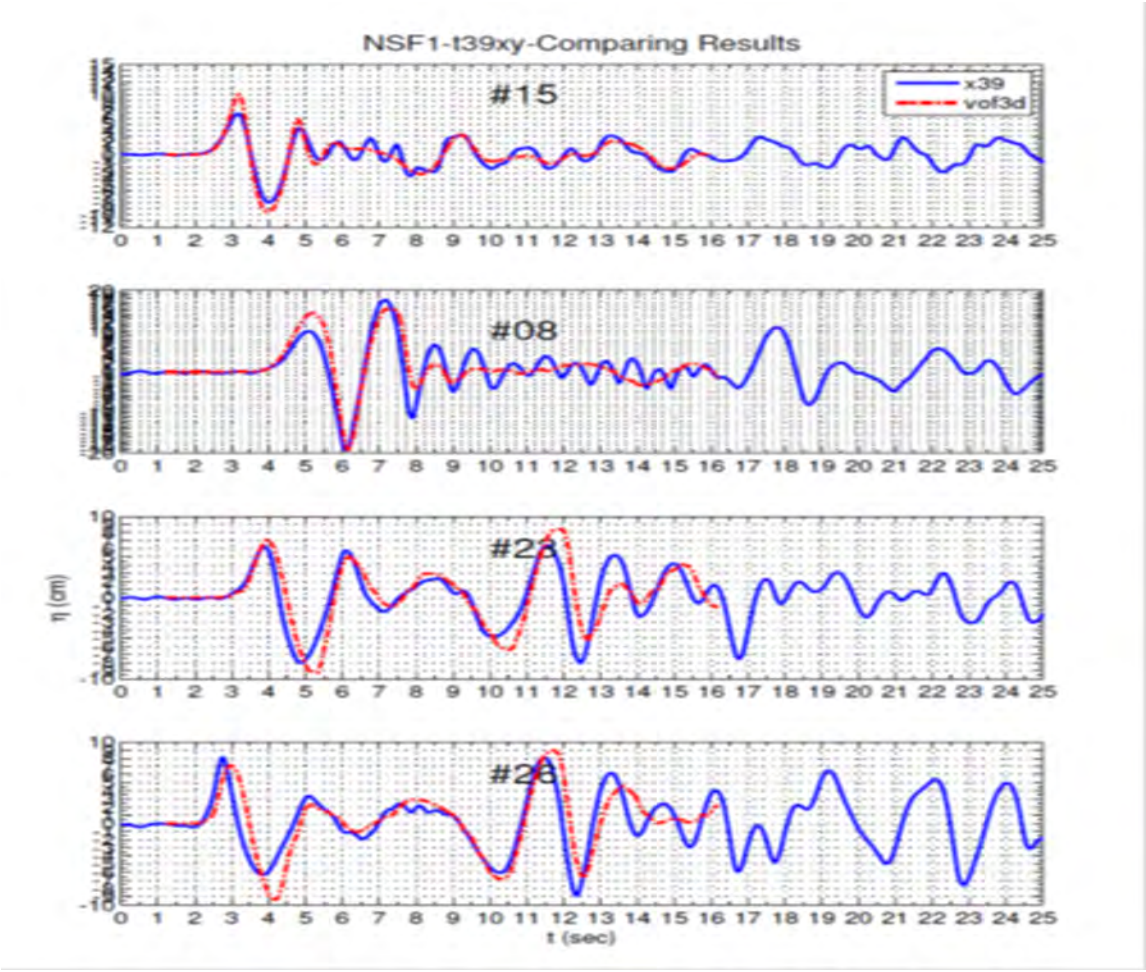


Figure 3. Model results (dashed red) against Fjord lab experiment (solid blue). Free surface fluctuation is recorded on gauge #15. Runups are recorded on gauges # 8, 23, 26. Lab experiments were carried out at Oregon State University.

NOAA relevance/societal benefits

Numerical models are required to assess expected coastal tsunami impact, in amplitude, horizontal inundation distance and velocities, so that proper evacuation decisions can be made during tsunami warnings, as well as for long-term planning of coastal zone development. The new part of the comprehensive tsunami model under development, the dispersive model, was comprehensively tested against the Kuril Island Tsunami of November 2006 and the Japan Tsunami of March 2011. Numerical experiments show that strong differences between non-dispersive and dispersive waves develop along the length of the main energy beam. This has important consequences for accurate tsunami prediction and warnings.

Education/outreach

Student participation: Dmitry Brazhnikov is a graduate (Ph.D.) student at the School of Fisheries and Ocean Sciences (SFOS). He began graduate study at UAF in September 2011. He contributed to numerical comparison of Navier-Stokes model with 2D vertically integrated equations. Z. Kowalik chairs his advisory committee. Gyeong-Bo is a graduate student at Texas A&M University at Galveston (TAMUG). He has contributed to several submarine landslide numerical simulations for model validation; J. Horrillo chairs his advisory committee.

Publications

Peer-reviewed publication

Horrillo, J., W. Knight and Z. Kowalik. 2012. Tsunami propagation over the North Pacific: dispersive and nondispersive models. *Science of Tsunami Hazards* 31(3):154–177. ISSN 8755-6839

Other products and outcomes

Kowalik, Z. 2012. Introduction to Numerical Modeling of Tsunami Waves, 196 pp.
http://www.sfos.uaf.edu/directory/faculty/kowalik/Tsunami_Book/book_sum.pdf

TWEAK Task 2: ARSC Computational Support for Tsunami Simulations

Natalia Ruppert, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Greg Newby, Thomas Logan, Sergei Maurits
ARSC, 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 the period of performance April 1, 2012 – March 31, 2013 has been split into support and development for three separate tsunami projects, which require computational, visualization, and programming expertise. These three projects are as follows

(1) Zygmunt Kowalik's Global Tsunami Model (**GTM**),

(2) West Coast Alaska Tsunami Warning Center's (WCATWC) Alaska Tsunami Forecast Model (**ATFM**) Rev12.

(3) Dmitry Nicolsky's Alaska Tsunami Inundation and Mapping Project (**ATOM**) web portal

ARSC High Performance Computing (HPC) Specialist Tom Logan was contributing to these projects until his departure from ARSC in July 2012. HPC Specialist Sergei Maurits resumed this effort, specifically for project ATOM in November 2012 and is currently working with the ATOM team.

GTM work was focused on such topics as the parallel Global Tsunami Model runs; on developing a "fast" serial version of the GTM; and on training Ph.D. student Dmitry Brazhnikov, who will be working with Zygmunt Kowalik on further code developing and refining.

For full parallel version of GTM a global simulation of the March 2011 Japanese Tsunami was prepared, ran, and post-processed. Time resolution of the run was 1 minute, the run was performed on a grid of 21600x8941 cells. This simulation took 72 hours on 128 processors; its downsampled outputs were saved for analysis, visualization, and animations.

Optimized "FAST" version of the GTM is a stripped down version of the global model GTM to be run in a "real-time" fashion. Serial optimization of the code was performed to achieve real-time capability on low-cost serial platform. Optimization managed to reduce the code runtime from initial 266 CPU seconds down to 46 seconds per single model time step, which is set at 1 model minute. Besides the code optimization, it took thorough debugging of the code to achieve its stability and to sustain the performance gain throughout the entire run. Particularly, several out-of-bounds array references were found and fixed.

Training for Ph.D. student Dmitry Brazhnikov, who recently joined the project, consisted of more than 20 hours of one-on-one training. Such topics as general programming in Message Passing Interface (MPI); architecture and details of the parallel GTM code; running it at the ARSC resources and many others were thoroughly covered during that training. In July 2012 the code was assumed by Dmitry Brazhnikov of SFOS from ARSC HPC Specialist Tom Logan for production runs and for further refining and development.

ATFM work was focused on debugging the parallel implementation of the ATFM Rev 12 code. The stage achieved by July 2012 was such that the parallel code was running, but still was generating unacceptable sea level errors. To

overcome this deficiency, additional output routines and the parallel runup routine were implemented. Joint work with WCATWC employees Kara Sterling and Bill Knight in attempts to determine the cause of the problem included extensive email communications, several on-line distance meetings, and two half-day face-to-face meetings with Bill Knight at UAF. All suggestions from Bill Knight and Kara Sterling were implemented and tested. However, errors of the sea level determination were not affected by the suggested corrections. ARSC requested at least a weeklong joint working session with the code initial developers, but this request was not granted. In the end, the project was handed back to Bill Knight with all parts of the code parallelized and documented. As of July 2012, the code was still giving larger than acceptable errors in the sea level. The code requires major improvements in its numerical and mathematical formulation, which can only be accomplished with the most close and intense interaction with the code initial developers and the original tsunami model creators.

ATOM work first stage was wrapped up in April 2012. The first stage tasks included finishing procedures for archiving and transfer of all modified/updated/tested scripts back to Dmitry Nicolsky, one of the leaders of ATOM project. The second stage of this task was a transition from Google Map (GMap) API v.2 to GMap API v.3 as the Web-portal GIS-engine. The reason for this transition is scheduled deprecation of GMap v.2 by Google, Inc. in May 2013 with complete elimination of its on-line support, including shutting down the servers for GMap v.2 on-line resources. Transition to GMap v.3 requires completely new syntax in the scripts and some more fundamental changes on a deeper level, since GMap v.3 updates several GMap paradigms and modifies the older approaches, which has been proven obsolete. That second part of the task was assigned to ARSC HPC Specialist Sergei Maurits, who started this development as a part-time task in November–December 2012.

The portal GMap-related functionality was divided into elements, a full list of which was comprised jointly with Dmitry Nicolsky. Altogether about 20 basic functions of the portal map interface were singled out and included into this list. Each of these functionalities were represented with a sample GMap v.3-based script, completely tested and documented with the embedded comments. Finalizing this preparatory stage, a static version of the portal work map was created. It combines a number of the key portal GMap-elements (see Figure 1 for example). That stage was accomplished by mid-March 2013, according to the work plan. Transition to the GMap v.3 in the larger parts of the actual portal code is ongoing now. A whole library of relevant scripts developed and tested with GMap v.3 will facilitate full transition to the updated version to meet the May 2013 deadline. Further tasks will include utilization of the updated and improved features of the GMap v.3 to enhance the ATOM portal functionality.

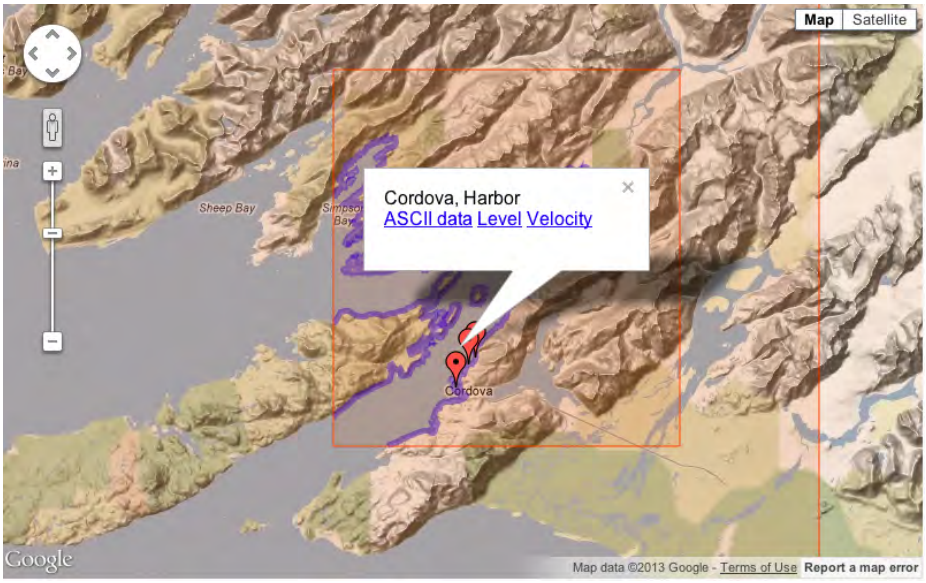


*Figure 1. Alaska Tsunami Inundation and Mapping Project (**ATOM**) web portal. Screen shoot of a sample of the map, generated with new Google Map API v.3-based script at the portal. The map includes clickable overlays, showing the grid boundaries (orange lines); geographic locations of the data (red markers), which provide on-line access to the location-specific data files in ASCII representation (Level and Velocity) at representative locations; and KML overlays (blue ribbon lines), automatically indicating that part of the shoreline, for which run up was computed.*

TWEAK Task 3: Seismic network component (Alaska CRESTnet)

Roger Hansen, PI
Michael West, PI
Natalia Ruppert, Co-PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Christopher Bruton*, *Ian Dickson, Steven Estes*, *Sharon Hansen, Natalia Kozyreva *University of Alaska Fairbanks*

CIFAR 10-017/11-017/12-017/13-017:
This project is ongoing.

NOAA Office: NOAA Tsunami Program,
Michael Angove, Sponsor

Alaska CRESTnet (Consolidated Reporting of Earthquakes and Tsunamis): Alaska earthquake information center seismic station operations & maintenance.

Primary objectives

- Maintain Alaska Tsunami Center and Observatory (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.

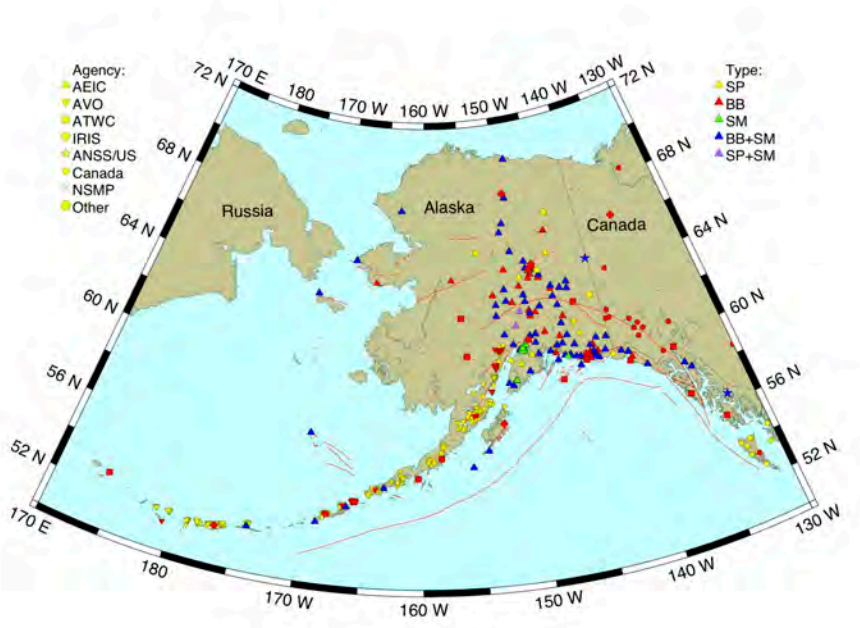


Figure 1. AEIC stations as of April 2013.

Research accomplishments/highlights/findings

We continued to upgrade and expand our integrated seismic network, including the following work on ATCO- and CREST-funded stations:

- At ATKA, replaced a failed power supply with a more rugged unit.
- At BESE (Bessie Mountain near Juneau), installed a Nanometrics Titan accelerometer.

- At COLD (Cold Bay), replaced Guralp 3T with a Nanometrics T240 broadband sensor.
- At DCPH (Deception Hills, south of Yakutat), repaired bear damage that disabled power system.
- At DIV (Divide Microwave, on Richardson Highway, 15-20 miles north of Valdez), swapped in new 5T accelerometer.
- At DOT (Dot Lake), upgraded site with a Q330, T120PH broadband sensor, Nanometrics Titan strong motion sensor, and new radios.
- At EYAK, replaced both sensors (3T and Episensor) and upgraded site with a Q330 telemetering via a new DSL line.
- At GAMB (Gambell), upgraded radios and fixed chronic power issues.
- At NIKH (Nikolski High Hill), upgraded radios.
- At PAX (Paxson), reoriented both sensors to north using a dual-GPS azimuth pointing system.
- At PIN (Pinnacle), installed 20 Celair and 6 rechargeable batteries.
- At SPIA (St. Paul Island), upgraded site with a Q330 datalogger telemetering via a 56K circuit.
- At SWD (Seward CREST station), upgraded site with a Q330 datalogger telemetering via a new DSL line. Also replaced faulty accelerometer.
- At TNA (Tin City), upgraded site to a Q330 datalogger. Telemetry still needs to be established.

Between 1 April 2012 and 31 March 2013, we located 27,581 events, with magnitudes ranging between 0 and 7.5 and depths down to 295 km (Figure 2). Six earthquakes had magnitudes 6 or greater. The largest earthquake, of magnitude 7.5, occurred on 5 January 2013, in southeast Alaska.

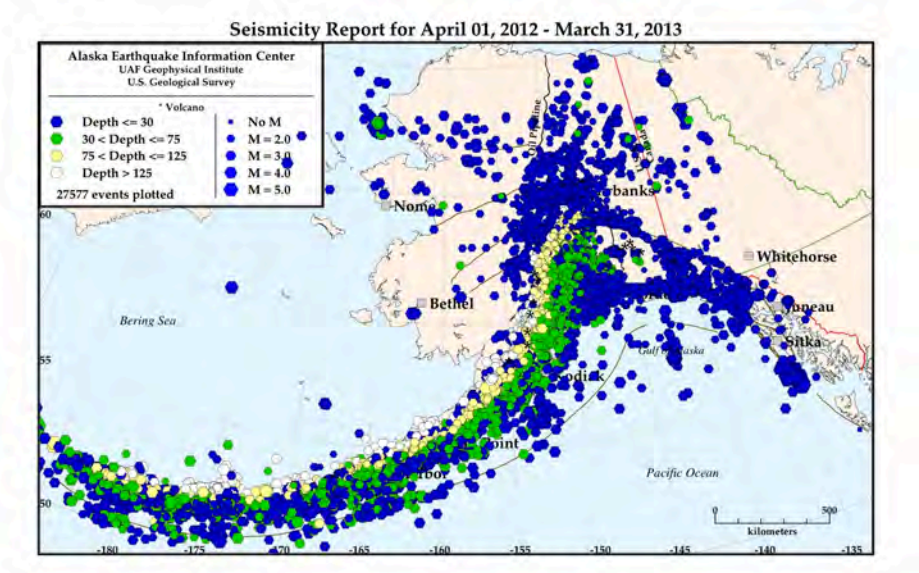


Figure 2. AEIC Seismicity Report for 1 April 2012 – 31 March 2013.

NOAA relevance/societal benefits

Improved detection of tsunamigenic earthquakes by Alaska Earthquake Information Center (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

Natalia Ruppert, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
***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

To more effectively monitor regions of Alaska for possibly tsunamigenic earthquakes, we are implementing an approach for automatic continuous scanning of seismic records based on GridMT method proposed by Kawakatsu (1998) and implemented by Tsuruoka et al. (2009). Implementation of GridMT method is nearly complete at the Berkeley Seismological Laboratory. The next step would be installation of this package at AEIC. So far this algorithm has been tested in the south central region of Alaska only. This needs to be extended to other regions and further tested. Newly hired Postdoctoral Research Fellow Kenneth Macpherson will begin his appointment on 1 April 2013, and will be working full time on implementation of GridMT code at AEIC.

We also began evaluation of various methods to incorporate real time high rate GPS data into extended earthquake source inversions. We submitted a request to the Plate Boundary Observatory (PBO) data management center to upgrade existing continuous GPS sites in Alaska to real time mode.

A total of 42 regional moment tensor solutions were calculated (moment magnitudes M_W between 3.8 and 6.5) between 1 April 2012 and 31 March 2013 in Alaska and the Aleutians.

References

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.

Publications

Peer-reviewed publication

Guilhem, A., D.S. Dreger, H. Tsuruoka and H. Kawakatsu. 2013. Moment tensors for rapid characterization of megathrust earthquakes: the example of the 2011 M 9 Tohoku-oki, Japan earthquake. *Geophysical Journal International* 192(2):759–772. doi:10.1093/gji/ggs045.

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

Roger Hansen, PI
Natalia Ruppert, Co-PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
***Elena Suleimani, Dmitry Nicolsky,** University of Alaska Fairbanks*

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

Tsunami Inundation Modeling and Mapping in selected communities:

- **Valdez:** We continued evaluation of the potential tsunami hazards for the city of Valdez. In the past year, we numerically modeled the extent of inundation in Port Valdez due to tsunamis generated by earthquake and landslide sources. The earthquake sources are developed by discretizing the plate interface and prescribing a slip distribution consistent with the seismologic and geologic constrains. In total more than 20 different scenarios are considered. Tsunami scenarios include a repeat of the tsunami triggered by the 1964 Great Alaska Earthquake, as well as several credible worst-case hypothetical tsunamis generated by a rupture along the Alaska-Aleutian megathrust in the Prince William Sound region, a Cascadia megathrust earthquake, and earthquakes from the Prince William Sound and Kodiak asperities of the 1964 rupture. Local underwater landslide events in Port Valdez are also considered as credible tsunamigenic scenarios. Results of numerical modeling are verified by successfully simulating the tectonic and landslide-generated tsunamis in Port Valdez observed during the 1964 earthquake. We presented results of the inundation mapping to the City of Valdez during a community visit on 11/23/12, and the Valdez City Council provided its comments in December 2012. The Valdez tsunami inundation modeling and mapping report has been accepted for publication by the Alaska Division of Geological & Geophysical Surveys (ADGGS). The potential inundation is illustrated in Figure 1.

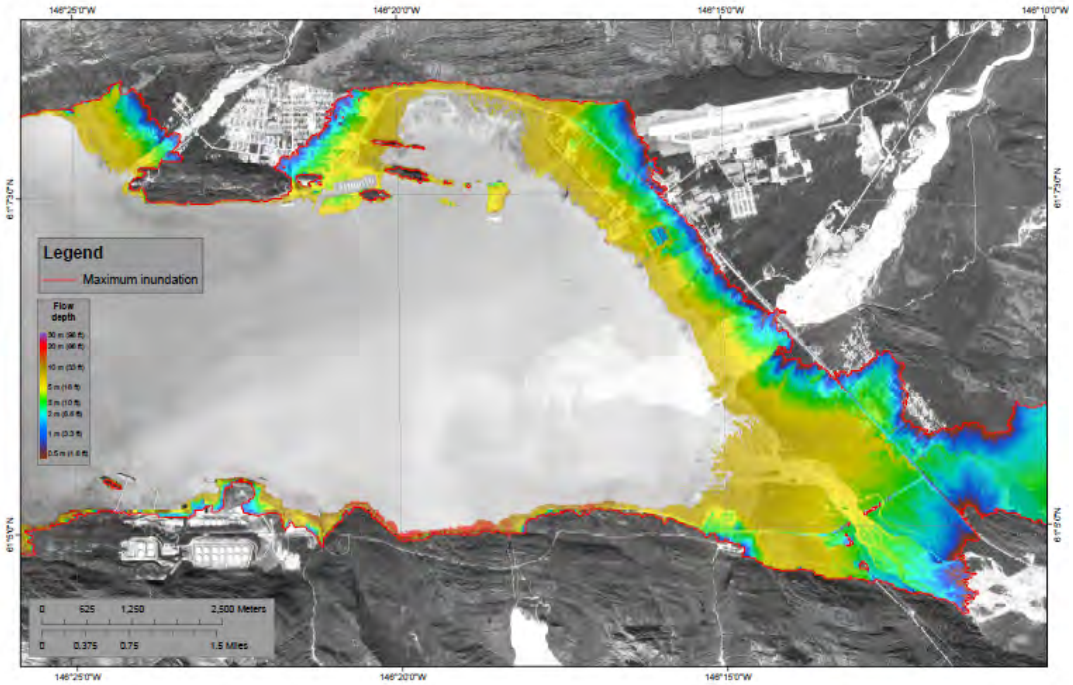


Figure 1. The modeled potential inundation in Port Valdez. This map is an illustration which should not be used for assessing the hypothetical inundation. The interested reader should consult ADGGS.

- **Chenega Bay:** We continued numerically modeling the extent of inundation due to a hypothetical tsunami in Sawmill Bay. Tsunami scenarios include a repeat of the tsunami triggered by the 1964 Great Alaska Earthquake as well as tsunamis generated by a hypothetically extended 1964 rupture, a hypothetical Cascadia megathrust earthquake, and a hypothetical earthquake in the Kodiak asperity of the 1964 rupture. Additionally, we considered and modeled a hypothetical Tohoku-type scenario in the Gulf of Alaska. The computed inundation shows a significant tsunami-related threat to the community. The tsunami inundation modeling and mapping report has been submitted for peer-review.
- **Sitka:** We continued our tsunami modeling efforts to compute a hypothetical tsunami inundation zone in Sitka. During the past year, we validated the employed tsunami model by calculating wave amplitudes at Sitka due to the recent Haida Gwaii earthquake of October 28, 2012 and comparing them with the tide gauge record at Sitka.

After a close collaboration with staff in ADGGS we developed a set of hypothetical near- and far-field tsunami sources for Sitka inundation mapping. Tsunami scenarios include a repeat of the tsunami triggered by the 1964 Great Alaska earthquake, repeat of the tsunami triggered by the recent 2011 Tohoku and 2012 Haida Gwaii earthquakes, tsunami waves generated by a hypothetically extended 1964 rupture, a hypothetical Cascadia megathrust earthquake, and a hypothetical earthquake in the Queen Charlotte-Fairweather fault zone.

- **Cordova and Tatitlek:** We developed several tectonic tsunami sources for communities of Tatitlek and Cordova. Tsunami scenarios include a repeat of the tsunami triggered by the 1964 Great Alaska Earthquake, several variations of the 1964 rupture, and a hypothetical Cascadia megathrust earthquake. Several additional hypothetical worst-case tectonic sources, which model ruptures at different depths are considered. Some tsunami modeling results show a significant inundation of Cordova and Tatitlek. The tsunami inundation modeling and mapping report has been submitted for peer-review.

Quality control of the tsunami inundation digital elevation models:
We continued working on the quality control of digital elevation models (DEMs) for the tsunami inundation mapping project. In summer 2012, we conducted high resolution RTK (Real Time Kinetic) GPS surveys in the communities of Elfin Cove, Cold Bay, and King Cove. The collected GPS measurements are post-processed, using the measured tide, and are ready to be sent to the National Geophysical Data Center (NGDC) NOAA, where they are incorporated with other elevation data to produce realistic DEMs. We reviewed and edited (based on the collected GPS measurements) tsunami DEMs developed by NGDC for the communities of Hoonah, Gustavus, Elfin Cove, and Unalaska/Dutch Harbor. The reviewed DEMs now support the tsunami inundation mapping needs for the state of Alaska.

Participation in the USGS SAFRR (Science Application for Risk Reduction) Project:
AEIC staff continues to participate 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 M_w 9.0 earthquake in the Alaska Peninsula region. We calculated vertical coseismic deformations for the earthquake source model and completed selected model runs using a set of telescopic grids around the Port of Los Angeles. In addition, we estimated the impact of this tsunami on the Alaska communities in the near-field (Akutan, King Cove, Unalaska, Sand Point), and along the south-eastern coast (Sitka, Elfin Cove, Gustavus, Hoonah).

Collaboration with the University of Rhode Island on tsunami modeling code:
We continue our fruitful collaboration with the east coast tsunami modeling group at the University of Rhode Island (URI). The URI shared their time-stepping Boussinesq model (FUNWAVE) and a new non-hydrostatic model (NHWAVE) based on a Godunov-type scheme. Preliminary modeling of the tsunami using FUNWAVE in Dutch Harbor/Unalaska with a spatial resolution of 4-5 m reveals some hazardous currents forming in narrow passages and near the tip of the narrow peninsulas. The preliminary modeling results were shared with emergency managers tasked with development of a hazard plan for the Dutch Harbor/Unalaska region.

Collaboration with the California Geological Survey on establishing a partnership:
We continue to foster our close working relationship with the California Geological Survey (CGS). Last year, the objective was to upgrade the web-service capabilities of the ATOM (Alaska Tsunami On-line Mapping) interface - a Google Map internet-based interface to the tsunami modeling tools at the Arctic Region Supercomputing Center (ARSC). In the scope of establishing the collaboration, we also obtained a full suite of the scenarios that model a hypothetical rupture along the Cascadia subduction zone. The Cascadia scenarios are used to model the potential inundation at the selected number of locations both in California and in Alaska. The newly developed capabilities of the ATOM interface provide access for researchers both at the CGS and UAF to develop and execute specific tsunami scenarios at the ATOM interface.

Propagation of tsunami-induced acoustic-gravity waves in the atmosphere:
To analyze the possibilities of early tsunami warning in Alaska based on measuring tsunami-induced gravity waves in the atmosphere, we conducted simple test scenarios. In particular, a dynamical core of the atmospheric Global Circulation Model was utilized for assessing the qualitative picture of propagation of atmospheric acoustic-gravity waves in response to perturbations generated by tsunami waves at the surface. Both resting isothermal atmosphere and model-generated atmosphere with realistic stratification and circulation features were considered. Shallow water tsunami model was run in two different configurations: ocean of equal depth of 4 km and ocean with realistic

continents and bottom topography. Amplitude and timing of atmospheric response was analyzed as a function of vertical stratification and configuration of atmospheric jets. We found that this approach has a potential for early tsunami detection by measuring changes in electric properties of the upper atmosphere in response to acoustic-gravity waves generated by tsunami. The results were presented at the 2012 AGU Fall Meeting in the Section "Advances in Tsunami Hazard Mitigation III Posters" (Alexeev and Nicolsky, 2012).

Publications and conference presentations

Peer-reviewed publication

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.

Accepted for publication

Nicolsky D.J., E.N. Suleimani, P.J. Haeussler, H.F. Ryan, R.D. Koehler, R.A. Combellick and R.A. Hansen. Tsunami Inundation Maps of Port Valdez, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation, accepted.

Submitted for publication

Nicolsky D.J., E.N. Suleimani and R.D. Koehler. Tsunami Inundation Maps of Cordova and Tatitlek, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation, submitted.

Nicolsky D.J., E.N. Suleimani and R.A. Combellick. Tsunami Inundation Maps of Chenega Bay, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation, submitted.

(Two additional papers have been submitted for publication, and three are in preparation.)

Poster presentations

Ross S., L.M. Jones, R.I. Wilson, B. Bahng, A. Barberopoulou, J.C. Borrero, D. Brosnan, J.T. Bwarie, E.L. Geist, L.A. Johnson, R.A. Hansen, S.H. Kirby, E. Knight, W.R. Knight, K. Long, P.J. Lynett, K.M. Miller, C.E. Mortensen, D. Nicolsky, D.D. Oglesby, S.C. Perry, K.A. Porter, C.R. Real, K.J. Ryan, E.N. Suleimani, H.K. Thio, V.V. Titov, A.M. Wein, P. Whitmore and N.J. Wood. 2012. USGS SAFRR tsunami scenario: Potential impacts to the U.S. West Coast from a plausible M9 earthquake near the Alaska Peninsula. Abstract NH33A-1639 presented at 2012 Fall Meeting, American Geophysical Union, San Francisco, California, 3–7 December 2012.

Alexeev, V.A. and D.J. Nicolsky. 2012. Propagation of tsunami-induced acoustic-gravity waves in the atmosphere. Abstract NH33A-1649 presented at 2012 Fall Meeting, American Geophysical Union, San Francisco, California, 3–7 December 2012.

Suleimani E.N., D.J. Nicolsky and R.A. Hansen. 2012. Tsunami source specification for southeast Alaska with focus on inundation mapping and hazard risk assessment in Sitka. Abstract NH33A-1646 presented at 2012 Fall Meeting, American Geophysical Union, San Francisco, California, 3–7 December 2012.

Nicolsky, D.J., E.N. Suleimani and R.A. Hansen, Numerical modeling of the 1964 Alaska tsunami runup in Chenega Cove, Alaska; the role of horizontal displacements of ocean bottom. Abstract NH33A-1647 presented at 2012 Fall Meeting, American Geophysical Union, San Francisco, California, 3–7 December 2012.

Education/Outreach:

- Nicolsky, D.J. and E.N. Suleimani, presentation of the hypothetical tsunami inundation maps to the Valdez City Council, 23 November 2012, Valdez, AK.
- Suleimani, E.N., class lecture to the students of the OLLI (Osher Lifelong Learning Institute) class "Alaska Earthquake of 1964" on the subject of tectonic and landslide-generated tsunami waves generated by the 1964 earthquake, 19 March 2013, Fairbanks, AK.

TWEAK Task 6: Education and outreach

Natalia Ruppert, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Sharon Hansen, *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 5 January 2013 M7.5 Southeast Alaska event and its aftershocks resulted in numerous national and local media requests and, more importantly, generated a great deal of concern among the affected communities. Natasha Ruppert traveled to Craig and Sitka in late January to give public talks about the event and its aftershocks. She also appeared on a local radio program.

Additionally, Alaska Earthquake Information Center (AEIC) presented earthquake and tsunami education through the following activities:

- Lab tours and presentations were given to around 80 individuals, including 45 elementary students and 25 university students.
- At the University of Alaska Science Potpourri on 14 April 2012, AEIC presented information on earthquakes and tsunamis to students of all ages. Around 600 people, mostly children, attended the event.
- Natasha Ruppert gave media interviews to the *Alaska Dispatch* on 16 May 2012, about the M4.6 event near Anchorage and to Channel 13 local news on 12 April 2012 about the M3.8 Nenana basin earthquake.
- On 15 October 2012, Natasha Ruppert gave a presentation on earthquake monitoring in Alaska to 30 members of the Rotary Club at the Princess Hotel in Fairbanks.
- Natasha Ruppert and other AEIC staff members responded to media requests after the M7.7 Haida Gwaii event, the M6.4 Gulf of Alaska event, the M5.8 event near Anchorage, and a M3.9 event in Southeast Alaska.
- Jeff Richardson of the Fairbanks Daily News-Miner interviewed Natasha Ruppert for his 10th anniversary article about the 2002 M7.9 Denali Fault earthquake, published on 4 November 2012 under the headline, "Ten years later, researchers still learning from the Denali Fault earthquake" (http://newsminer.com/view/full_story/20711136/article-Ten-years-later--researchers-still-learning-from-Denali-Fault-earthquake).
- Currently developing educational fact sheets for display at Denali, Wrangell-St. Elias, and Glacier Bay National Parks.
- Finally, AEIC staff responded to questions from the public about the hoax earthquake prediction for Anchorage in December 2012 which was propagated by the website earthquakepredictor.com.

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

Supporting NOAA's mission goals using unmanned aircraft systems (UAS) technology

Gregory Walker, PI ***CIFAR themes: Coastal Hazards; Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans; Weather Ready Nation

CIFAR 13-031: This project is new. NOAA Office: OAR, Senita Hill, Sponsor

Primary objectives

The main science objective of this project is to use two different UAS to meet NOAA's mission goals in three areas.

1. **Survey of marine debris generated by the 2011 Japanese tsunami**. We plan to search and map the location, type, distribution and movement of marine debris originating from the tsunami that struck Japan on March 11, 2011.
2. **Arctic Ocean and sea ice engineering system development tests**. In coordination with the NASA funded UAS project "Marginal Ice Zone Observations and Processes Experiment (MIZOPEX)" we plan to conduct UAS field trials from Oliktok Point, Alaska.
3. **Augment existing Steller sea lion research project with field time**. This project will supplement and continue the technology evaluation underway to evaluate augmenting current Steller sea lion surveys with UAS.

Research accomplishments/highlights/findings

Survey of marine debris generated by the 2011 Japanese tsunami - Under this effort, we have evaluated a new payload UAF developed for the AeroVironment Puma All Environment (AE) small unmanned aircraft system (sUAS). We have managed a subcontractor, Airborne Technologies, Inc. (ATI) of Wasilla, Alaska in their preparation of the Resolution sUAS that they have designed and built under a NOAA Small Business Innovation Research (SBIR) contract. Additionally, we have been working with the NOAA Aircraft Operations Center (AOC) to arrange for flight opportunities and for ship opportunities to be used by the NOAA Marine Debris Program for deployment of UAS.

- AeroVironment Puma AE payload. Development of this payload by UAF was not financially supported by NOAA, however, the use of this payload is critical for the mission success. In January 2013, we tested a non-waterproof version of this payload in collaboration with AeroVironment in Simi Valley, California, and waterproof testing is scheduled with the USAF Special Operations Command in May 2013. As part of the NOAA effort a design review was conducted with the NOAA UAS program and NOAA AOC in November 2012. The testing in January validated the design met the program goals of 1-cm spatial resolution imagery with adequate overlap for mapping missions when flying at nominal Puma flight altitudes. To accomplish this, the camera on a simple gimbal is a 24 megapixel Sony "full frame" imager that can be programmed to shoot at 1.3 frames per second.
- The UAF Subcontractor ATI has been developing a suitable imager for this mission. The camera that they are working with is the compact USB 2.0 powered Mightex SCE-CG04-U and is being controlled by OpenIRiS ("Integrate. Relate. Infer. Share") anomaly detection software. The camera is currently being integrated into the Resolution sUAS aircraft system (hardware and software). The camera can now be triggered in hardware from the autopilot board. Flight test changes to autopilot code to move autonomous take-off capabilities forward have also been underway. Currently ATI is building the two airframes that will be used during the upcoming June field season. Weather issues prevented a planned flight session in January and again in February. The March flight session saw the effect of the two missed tests. Since the March flight session, ATI has had a number of opportunities (weather-wise) to fly and confirm code and hardware changes made throughout the sensor package development. Currently, they are awaiting the final autopilot board spin that will integrate the hardware changes made. The original camera (Sony FCB-1X11A) that was chosen for OpenIRiS did not integrate with the onboard sensor package computer. A number of hardware solutions were tried that were expected to work but all proved futile. Finally, ATI switched development paths and decided to try a USB camera. Their choice was a machine vision type camera, the Mightex SCE-CG04-U. Final design and construction of the camera/sensor package mounts has been delayed until ATI can confirm all the hardware is working correctly together. All hardware parts have been drawn up in a 3D modeling program and are awaiting final approval before mounts are built.

Arctic Ocean and sea ice engineering system development tests – Payload arrival in Alaska from the partners on this effort delayed testing in the summer of 2012. In 2012, the ATOM IR payload from Columbia University arrived but was not in a condition to flight test in July 2012. Improvements in the package have it ready for flight test in the spring of 2013. The ARIAL radiometer payload from Spain cannot be flown on a stock ScanEagle due to too much RFI from the avionics. Testing of the ARIAL on a ScanEagle with the Piccolo autopilot is scheduled for the week of 29 April in Oregon. The SSDS payload from University of Colorado arrived in a flyable condition and was launch tested to failure in Oregon in September 2012. Flight-testing of this payload requires that the ScanEagle be modified with the Piccolo autopilot, flight-testing of which was completed on the first two ScanEagle aircraft in March 2013. The BESST payload final integration by Ball Aerospace was completed in February 2013 and flight-testing is being arranged at this time. Logistics and airspace access for this flight operation has been the largest hurdle that has been worked on in the past year. Airspace access to conduct this mission is still not available and ongoing discussions with the FAA are not leading to any realizable solution at this time. Payloads may be ready but without access to the airspace this mission is at risk of not being able to be executed as planned.

Augment existing Steller sea lion research project with field time – The Steller sea lion (SSL) project has been completed successfully. In March 2012, a three-week deployment through the Aleutians resulted in successful deployment of two sUAS. One goal was to familiarize NOAA Fisheries about the potential of the technology to help with their surveillance mission for the SSL population. This was successful as in 2013 NOAA is planning on deploying their own UAS for the missions. This decision was heavily influenced by the successes of the March 2012 deployment. Meanwhile, the University team has identified the shortcomings of the technology deployed in 2012 and has developed advanced solutions to evaluate an enhanced capability. At the present time UAF is seeking opportunities to evaluate these advanced capabilities, which include:

- An improved imager for the Puma AE. The Puma flew in the Aleutians on calm days but the sensor quality was inadequate for the scientific mission. The new sensor improves the payload from the stock 5-megapixel 20-second frame rate to a 24-megapixel 0.75-second frame rate.
- A design of a new aircraft capable of flying in the higher winds found in the Aleutians. The Puma AE could not fly when the winds were in excess of 25 mph, a common occurrence in the Aleutians. The new aircraft, designed in partnership with Embry-Riddle Aeronautical University and Boeing Phantom Works should be able to fly in 50 mph winds although this was accomplished by reducing the greater than 2 hour endurance to less than 45 minutes. The shorter flight endurance should have less effect upon the SSL mission success than the increased operating capabilities provided by higher wind speeds tolerances by the new craft. Fabrication by Boeing Phantom Works and flight-testing of this new aircraft is being planned for the summer 2013.

NOAA relevance/societal benefits

All three projects are extending the NOAA UAS capabilities and understanding of the sUAS potential for NOAA missions. The synergy between these missions and long-term NOAA UAS program objectives is clear. NOAA for example in 2012 acquired their own Puma AE aircraft and with the new payload work and field testing being conducted by UAF are enhancing their systems capabilities and will ultimately help the NOAA scientific utility of these new aircraft. UAF has agreed to fabricate a duplicate Puma AE payload for the NOAA Corps aircraft once the system is operationally ready in the summer of 2013.

Outreach

- Presentation at Association for Unmanned Vehicle Systems International's Unmanned Systems North America Meeting, 6–9 August 2012 in Las Vegas, NV "Testing small UAS for mapping coastal regions with shipped based operations in the harsh conditions of the Aleutian Islands."
- Presentation at Alaska Marine Science Symposium, 21–24 January 2013 in Anchorage, AK "Augmenting Steller sea lion surveys in the western Aleutians with unmanned aircraft."

Partner organizations and collaborators

Columbia University
University of Colorado
Ball Aerospace
USAF Special Operations Command
AeroVironment Inc.
Airborne Technologies Inc.

Impact

The value of low-cost aerial imagery in remote locations in Alaska is profound. From managing endangered species, such as the Steller Sea Lions in the Western Aleutians to understanding the Marginal Ice Zone in the Arctic, this technology affords NOAA many new methods of understanding the environment that they must manage. Alaska is a challenging environment for these platforms and applications, and our research increases the understanding of this technology and identifying the existing limitations to realize fully their potential mission set.

Towards a 90-day monthly storm outlook for Alaska, North Pacific, and Hawaii

John Walsh, PI ***CIFAR theme: Coastal Hazards***
University of Alaska Fairbanks

Other investigators/professionals funded by this project:
David Atkinson, *sub-contractor,* ***University of Victoria***

NOAA Goal: Weather Ready Nation

CIFAR 13-032: This project is new. NOAA Office: NWS, James Partain, Sponsor

Background

In all seasons of the year, storms represent high-impact weather events over Alaska and its adjacent seas. Alaska's extensive coastline and, in many cases, shallow offshore shelves makes the region especially vulnerable to coastal flooding and erosion, particularly where a protective sea ice buffer is absent. Even in the Alaskan Interior, cyclonic systems can produce major floods, ranging from the Fairbanks inundation of 1967 to the recent Eagle/Tok floods in summer 2010. Extensive commercial fishing, oil and gas field development, tourism, and increasing military and Coast Guard interest add to the potential parties impacted by storms in coastal waters. Hawaii can experience considerable coastal impact, including inundation and damage to harbors, during low-press system transits.

Forecasts containing information about storm events are currently issued by the National Weather Service (NWS) out to 7 days; model guidance through Week 2 is also available at a NOAA Climate Prediction Center (CPC) "Storm Tracks" website: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/stormtracks/strack_alaska.shtml. This website currently includes summaries of storm tracks and accumulated precipitation for the past 10-, 30-, and 90-day periods, together with Week-1 and Week-2 forecast storm tracks from the Global Forecast System (GFS) Operational Run and the GFS Ensemble. Given the limits of deterministic predictability, we will extend the window of the storm outlook to 90 days using probabilistic methods, which draw upon the present and CPC-predicted states of El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Arctic Oscillation—three large-scale modes of variability known to affect Alaska.

The envisioned product is a map depicting the likelihood of enhanced (or reduced) storminess relative to the climatological normal.

The project objectives are:

- Objective 1: Literature review summarizing: identification of nature and strength of all modes of variability that affect Alaska, North Pacific, and Hawaii; representation of storms in aggregate and rationales for using different types of storm classification; methodologies for empirically relating climatic indices to storminess or other parameters such as precipitation.
- Objective 2: Development of experimental forecast product in "hindcast" mode.

Research accomplishments/highlights/findings

Objective 1: Literature review

Two literature reviews were prepared by Ph.D. student Norman Shippee, who received support for one academic term. One focuses on different storm classification methods. The other focuses on Pacific storm activity and the nature of some of the primary physical climate controls. As the work progressed it became apparent that this was a more logical way to organize the information. A research paper based on these overviews is in preparation.

Objective 2: Development of hindcast product
Reduction of the NOAA Climate Prediction Center storm data, and implementation of Hodges' TRACK storm track algorithm, took longer than anticipated. Work on Objective 2 got to the point of devising a novel way to link storm track activity to major modes of climatic variability, performed by regressing extracted patterns of variability within the storm data against the climate indices, and using this to demonstrate the extent to which selected modes influence storm track patterns. This work is a direct prelude to establishing the predictive potential of the method. Note that Shippee ran the TRACK algorithm using the Arctic Region Supercomputing Center facility, whose assistance to this project is gratefully acknowledged.

Sample results are presented below.

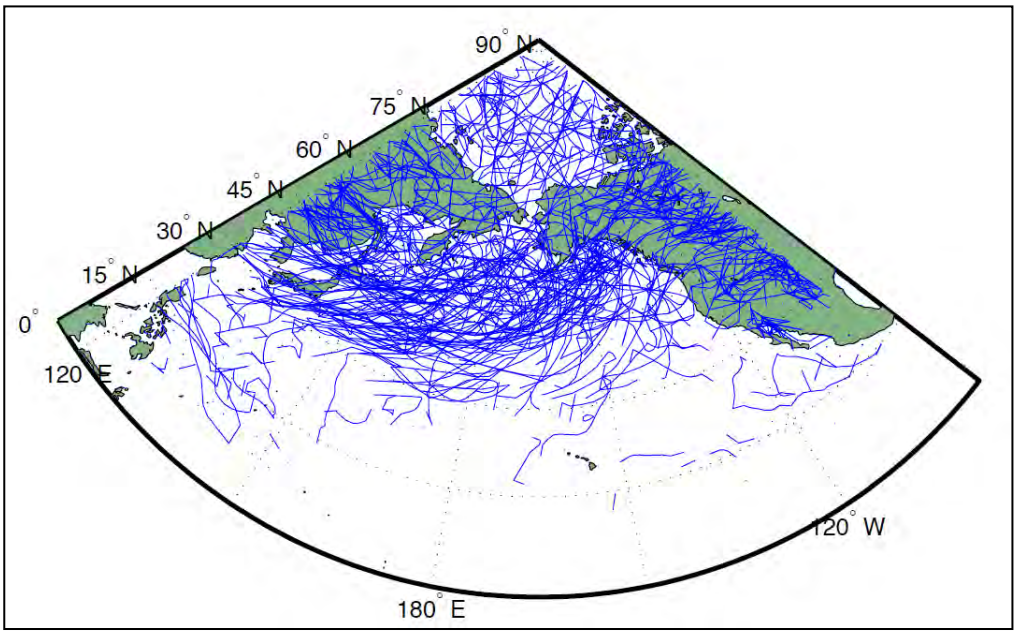


Figure 1. Example of one year of storm tracks extracted from the NOAA CPC database. Method is based on mean sea level pressure parameter. Domain is North Pacific.

NOAA relevance/societal benefits
The project impacts to NOAA and to the region are manifold. There exists a major need for an expanded temporal range of storm outlooks to enable proactive responses by coastal communities and the various industries noted above.

Outreach
- **Network of Expertise on Transportation in Arctic Waters (NEXTAW)**. Churchill, Manitoba, 7-9 September 2012. Invited (and paid for) presentation by Norman Shippee to this focus group of northern transportation sector issues. The group consists of experts from municipal, state, and federal-level government groups. Some academic participation.
- **British Columbia Ministry of Environment**. Victoria, BC, 29 November 2012. Invited talk given by Atkinson on Pacific Storms. Shippee also gave a short presentation on the storminess outlooks project. BC is a natural partner in any Pacific storms initiative.

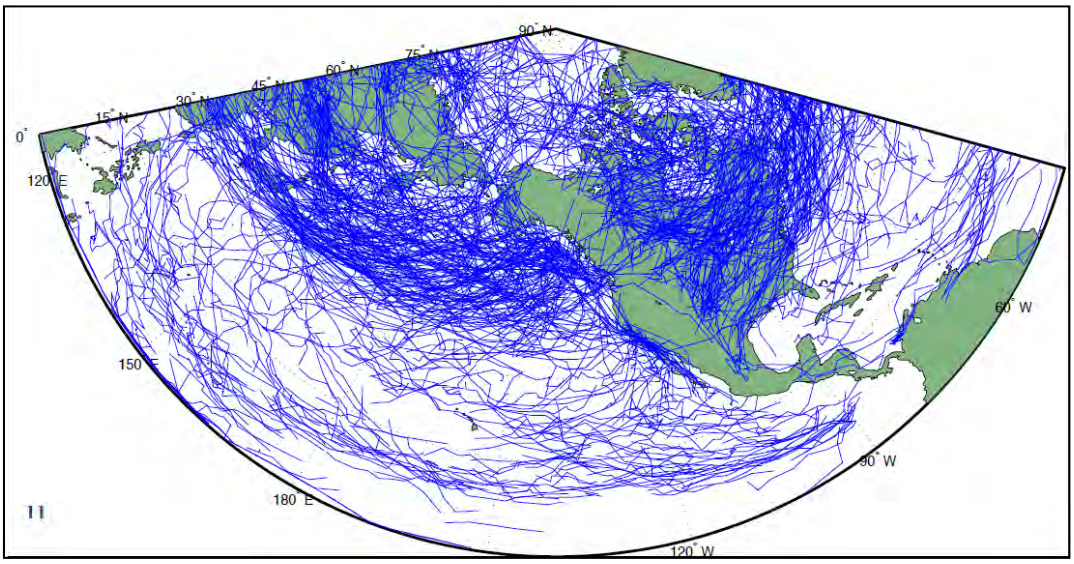


Figure 2. Example of one year of storm tracks generated using the Hodges TRACK method, based on relative vorticity. Domain is Hemispheric. Data set is NOAA Climate Forecast System Reanalysis (CFSR).

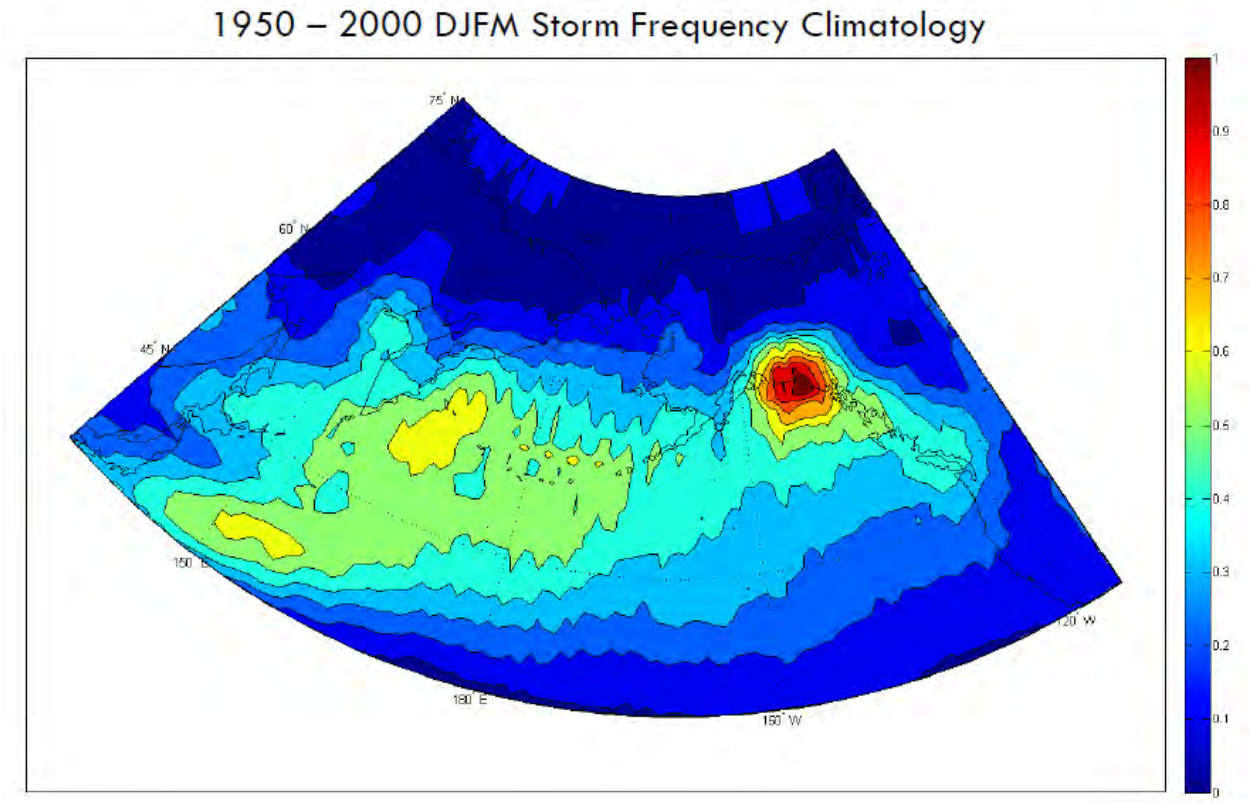


Figure 3. Aggregate storm frequency climatology, 1950–2000, for the December through March (DJFM) period. Units are a standardized relative frequency scaled to range from 0 to 1 to conduct regional spatial intercomparison.

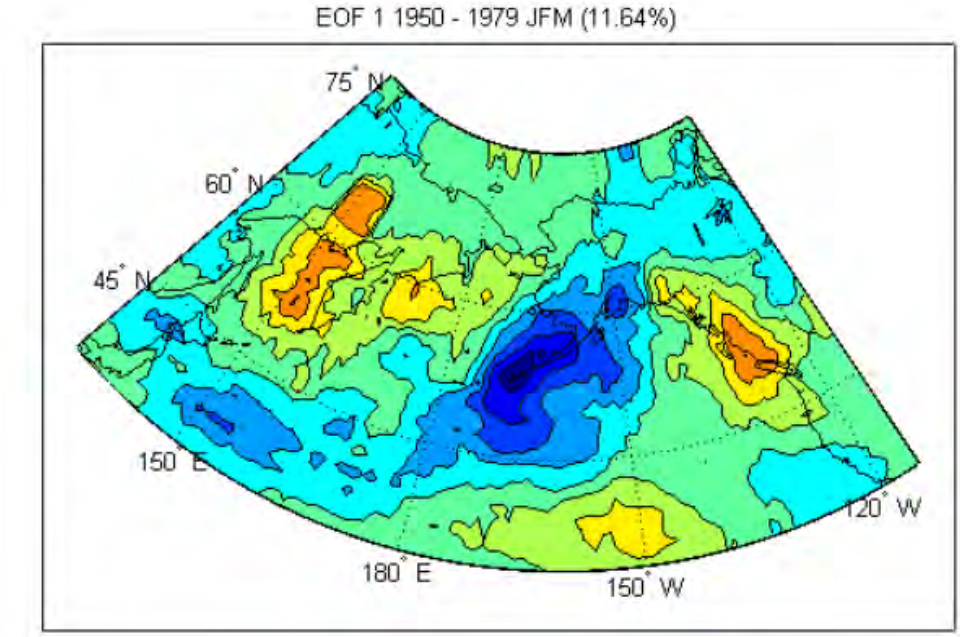


Figure 4. Example first vector of an empirical orthogonal function (EOF) run on storm frequency. Seasonal period is winter (Jan–Mar), time frame is the cool phase of the Pacific Decadal Oscillation (PDO) (pre mid 1970s). Blues indicate relatively fewer storms; oranges indicate more frequent storms.

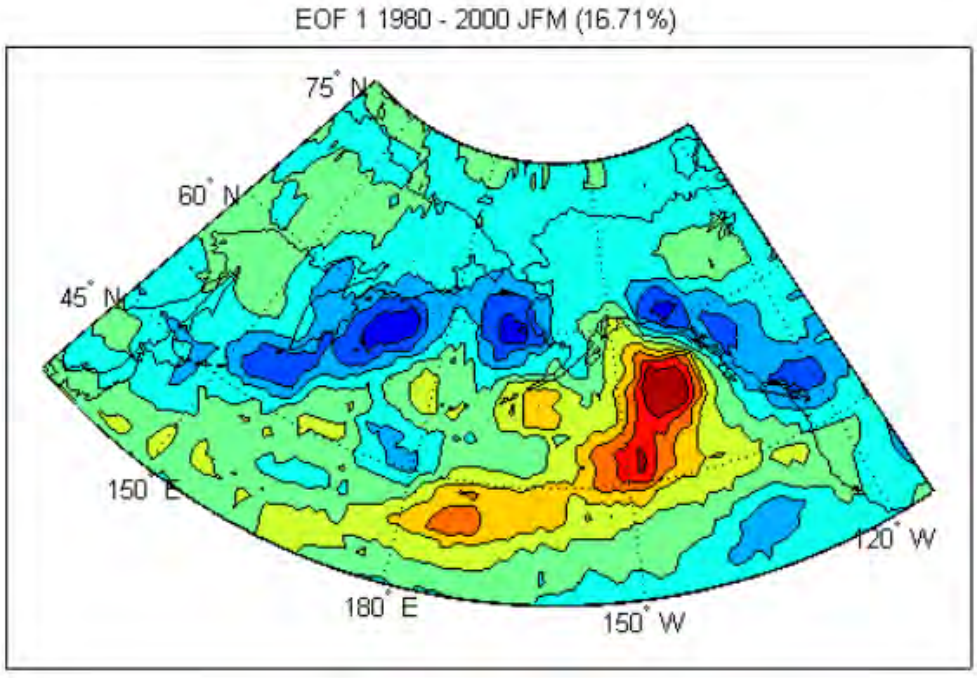


Figure 5. Example first vector of an empirical orthogonal function run on storm frequency. Seasonal period is winter (Jan–Mar), time frame is the warm phase of the PDO (post mid 1970s). Blues indicate relatively fewer storms; oranges indicate more frequent storms.

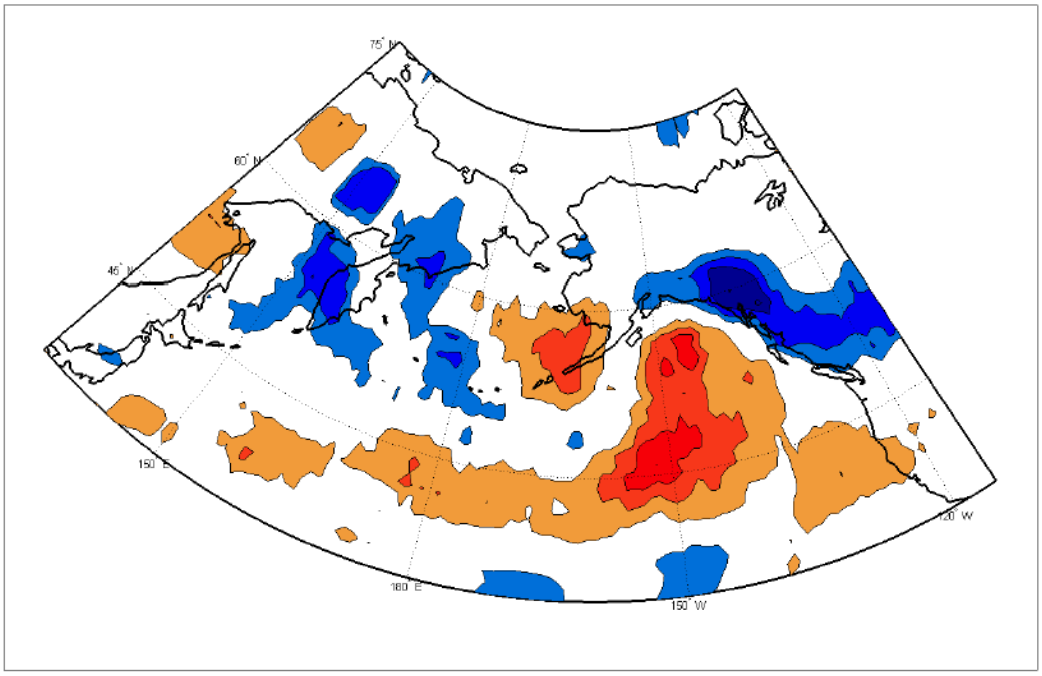


Figure 6. Total storm counts, warm phase PDO minus cool phase PDO. This indicates that climate variability as captured by the PDO index appears to have some influence on storm patterns in the North Pacific.

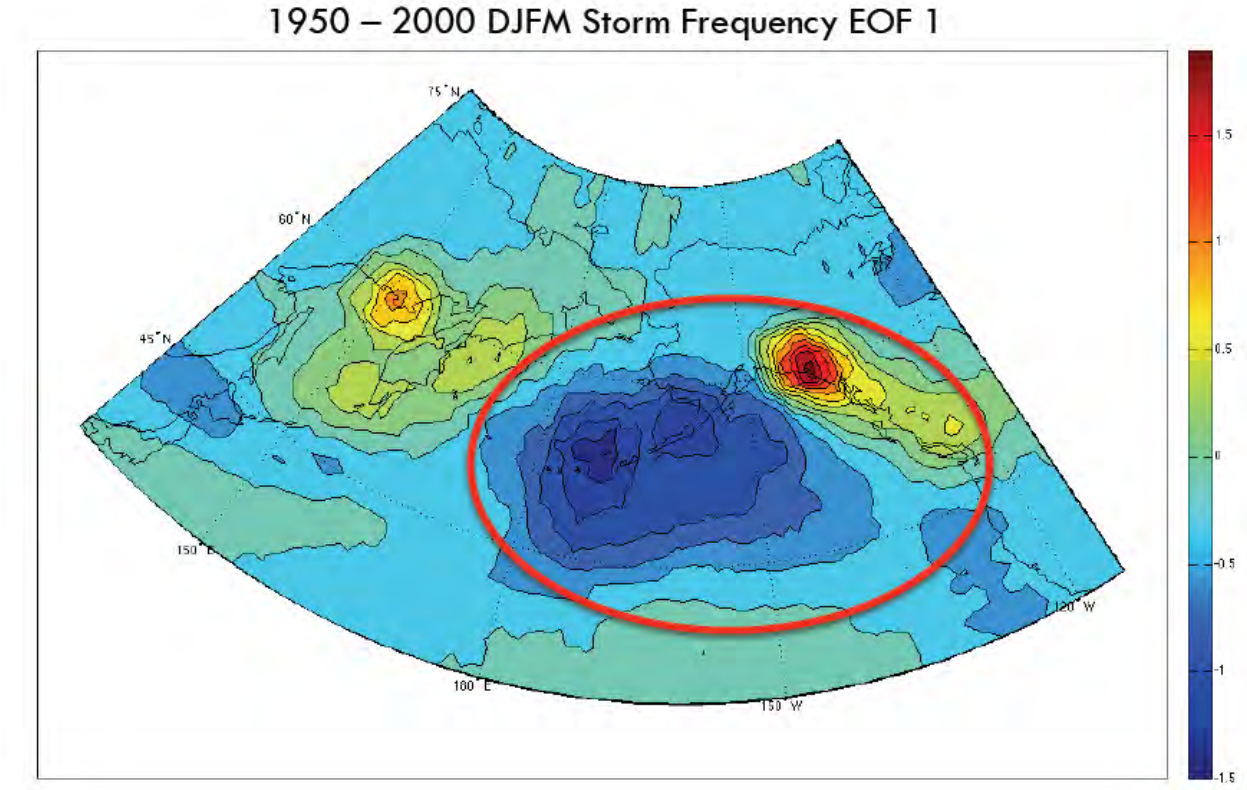


Figure 7. First vector of an empirical orthogonal function run on storm frequency. Seasonal period is winter (Dec–Mar), time frame is the 1950–2000 period. Spatial pattern indicates high levels of storm occurrence in the Alaska panhandle, The Sea of Okhotsk, and coastal southern British Columbia.

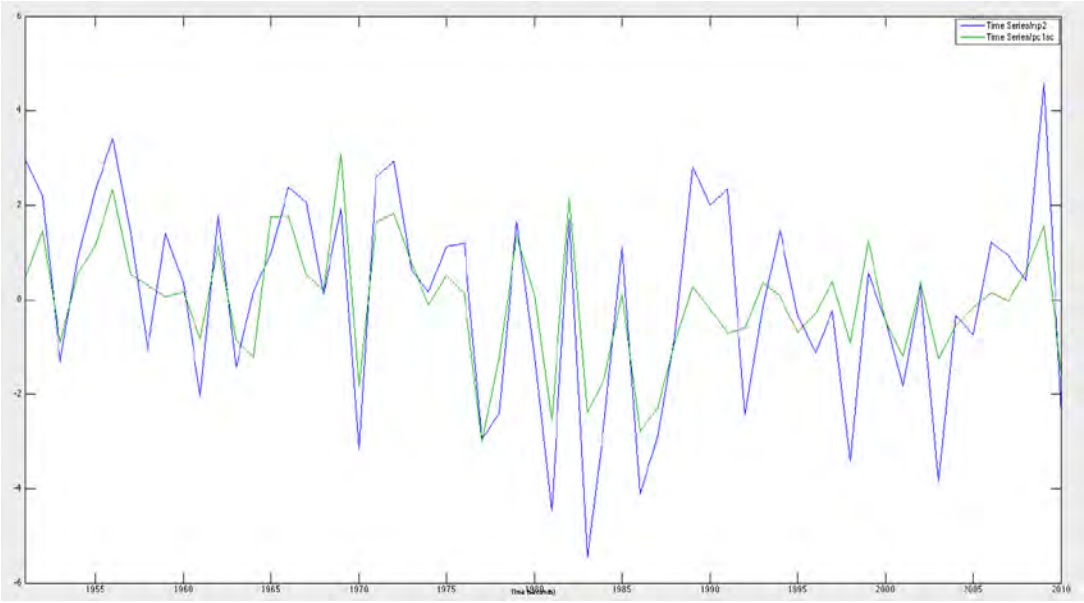


Figure 8. Time series of score strengths for the first vector of the EOF run shown in Figure 7 (blue) plotted alongside the index value for the North Pacific Index (NPI) climate variability mode (green). The value for Pearson's correlation is 0.83. This also suggests that NPI exerts a certain amount of influence over storm patterns in the North Pacific.

Publications and conference presentations

Oral presentations

Shippee, N. 2013. Seasonal storminess in the North Pacific, Bering Sea, and Alaska regions. Alaska Weather Symposium, Fairbanks, Alaska, 12 March 2013.

Walsh, J., D. Atkinson, S. Trainor and N. Shippee. 2013. Coastal and off-shore downscaling for Alaska. Alaska Weather Symposium, Fairbanks, Alaska, 12 March 2013.

Poster presentation

Shippee, N.J., D.E. Atkinson, J.W. Walsh, J. Partain, J. Gottschalck and J. Marra. 2012. Seasonal storminess in the North Pacific, Bering Sea, and Alaskan regions. A33B-0148. American Geophysical Union Fall Meeting, San Francisco, California, 5 December 2012.

Partner organizations and collaborators

Arctic Region Supercomputing Center

Changes/problems/special reporting requirements

Procedural delays in setting up and funding the sub-contract resulted in a postponement of this project's start and the necessity of a request for a no-cost extension for delivering of outcomes.

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

CIFAR 12-028/13-028: This project is ongoing. NOAA 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

For the past year, we continued our comparisons between satellite-derived volcanic ash retrievals and the WRF-Chem volcanic ash transport model. The aim was to provide a systematic assessment of the merit of the volcanic WRF-Chem simulations using GOES-R like products. These methodologies will be applicable operationally where WRF-Chem model simulations for active volcanoes can be evaluated against the GOES-R AWG (Algorithm Working Group) ash retrievals from Day 1 of the GOES-R products. We focused on (1) completing the Redoubt 2009 and Eyjafjallajökull 2010 analysis for two publications; (2) furthering the satellite to model comparisons for Kasatochi 2008 and Sarychev Peak 2009 eruptions; (3) completing our MISR analysis; (4) starting development of WRF-Chem for SO_2/SO^{-2}_4 comparison to satellite and (4) developing flight route tools within WRF-Chem to analyze the May 2010 Eyja results from collaborators in Germany.

Student Angela Ekstrand completed her analysis of the MISR (Multi-angle Imaging Spectro-Radiometer) data for different volcanic events and comparison to TIR (thermal infrared) plume heights. She led a paper on this, along with PI Webley and Co-PI Dehn, see Ekstrand et al. (2012) listed in publications. The Steensen et al. (in press) publication compares volcanic ash retrievals with WRF-Chem model simulations from two events during the 2009 Redoubt eruptions. They showed that the model is able to capture the ash cloud movement and the choice of eruption rate and particle size distribution is critical for ash concentration and mass loading comparisons. In addition, Stuefer et al. (in press) was published as a Geoscientific Model Development (GMD) Discussion paper and has been accepted for final publication in GMD. The paper provides a technical description of the implementation of volcanic source parameters and a volcanic eruption model in WRF-Chem.

Webley et al. (2012) compared the WRF-Chem simulations of the April 2010 period of activity from Eyjafjallajökull volcano with satellite remote sensing of the ash clouds from thermal infrared and LIDAR as well as comparison to the ground based LIDAR measurements. They showed that the WRF-Chem simulation matched well with the observations, and again confirmed the findings of Steensen et al. (in press) that the eruption rate and initial particle size distribution or amount of fine ash versus coarse ash in the model simulations is critical to forecast both ashfall and airborne ash concentrations.

We have furthered our analysis of volcanic eruptions by performing analysis with WRF-Chem of the eruption from Sarychev Peak, Kuriles in June 2009. This had 23 different events as detected in the remote sensing data and we have focused on four of these events. Torge Steensen, Ph.D. student on the project, along with Webley and Stuefer is using the model simulations of these events to build his system to carry out point to point analysis with the satellite retrievals as well as build a spatial comparison tool, or Merit of Space. Here, we ran the simulation with the default eruption source parameters from the known publications as well as varying the initial particle size distribution and eruption rater using empirical models relating plume height and eruption rate and one-dimensional models using local atmospheric models to account for atmospheric stratification on the plume rise. These different

sets of model inputs will assess the sensitivity of the modeled ash concentration from these input datasets and how critical they will be for operations. This is a publication in prep by Steensen et al., see publication list.

The Sarychev Peak ash analysis has shown that the definition of the 'edge' of the ash cloud is a significant parameter. Satellite ash retrievals have a lower limit to the measureable mass loadings possible, given pixel size, local cloud cover and ash dispersal. Volcanic ash modeling will predict the dispersion of the ash cloud and therefore, can forecast ash concentrations and hence mass loadings to lower levels than detectable from the satellite data. A definition of the satellite detection threshold in order to define the 'zero' boundary in the satellite retrievals and the 'zero' boundary in the modeled mass loadings will dramatically affect the match between the two datasets and hence the evaluation of the modeled ash cloud.

For the SO_2 analysis, we have started to perform WRF-Chem simulations as well as OMI (Ozone Monitoring Instrument) UV satellite retrievals. Our aim is to assess the model's capability to perform SO_2 simulations as well as the $SO_2 \rightarrow SO_4^-$ conversion. There is an option 2 GOES-R SO_2 product and although there is no operational required advisory for SO_2, there are cases such as Hawaii where knowledge of the erupting SO_2 and its forecasted location is important for the local NWS office to provide advice upon. WRF-Chem with the inline Numerical Weather Prediction Model (NWP) and chemistry provides a unique tool over other SO_2 forecasting tools. See Egan et al. in preparation, listed below.

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: Determine 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

Completed M.Sc. in Geology (May 2012)

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

Sean Egan

Ph.D. Candidate student in Environmental Chemistry

Role on Project: Comparison of WRF-Chem SO_2 simulations to satellite based retrievals using UV and TIR data, including ASTER (Advanced Spaceborne Thermal Emission & Reflection), MODIS (Moderate Resolution Imaging Spectroradiometer), OMI and AIRS (Atmospheric Infrared Sounder) data.

Publications, conference papers, and presentations

Peer-reviewed

Webley, P.W., T. Steensen, M. Stuefer, G. Grell, S. Freitas and M. Pavolonis. 2012. Analyzing the Eyjafjallajökull 2010 eruption using satellite remote sensing, lidar and WRF/Chem dispersion and tracking model. *Journal of Geophysical Research (Special Issue: Eyjafjallajökull 2010 eruption)* 117, D00U26. doi:10.1029/2011JD016817

Conference paper

Steensen, T. and P. Webley. 2012. Qualitative analysis of input parameter for satellite-based quantification of airborne volcanic ash. *IGARRS 2012*. 4pgs.

In press (peer-reviewed)

Stuefer, M., S.R. Freitas, G. Grell, P. Webley, S. Peckham and S.A. McKeen. Inclusion of ash and SO_2 emissions from volcanic eruptions in WRF-Chem: development and some applications. *Geoscientific Model Development*, in press. doi:10.5194/gmdd-5-2571-2012

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

Steensen, T., M. Stuefer, P.W. Webley, G. Grell and S. Freitas. Qualitative comparison of Mount Redoubt 2009 volcanic clouds using the PUFF and WRF-Chem dispersion models and satellite remote sensing data. *Journal of Volcanology and Geothermal Research: SI on 2009 Redoubt Eruption, eds. Peter Webley and Chris Waythomas,* in press. http://dx.doi.org/10.1016/j.jvolgeores.2012.02.018

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: SI on 2009 Redoubt Eruption, eds. Peter Webley and Chris Waythomas,* in press.

Publications in preparation

Steensen, T., P.W. Webley and M. Stuefer. Quantitative comparison of volcanic ash observations in satellite-based remote sensing data and WRF-Chem model simulations. In preparation for submission to *Journal of Volcanology and Geothermal Research.*

Egan, S.D., M. Stuefer, P.W. Webley, C.K. Kim, G.A. Grell, S. Freitas and S.A. Carn. Modeling and remote sensing of the 2008 Kasatochi sulfur dioxide (SO_2) plume. In preparation.

Oral presentation

Steensen, T. and P. Webley. 2012. Qualitative analysis of input parameter for satellite-based quantification of airborne volcanic ash. IEEE International Geoscience and Remote Sensing Symposium, Munich, Germany, 22–27 July 2012.

Poster presentations

Steensen, T.S., P.W. Webley and M. Stuefer. 2012. Ash emissions and risk management in the Pacific Ocean. American Geophysical Union Fall Conference, San Francisco, California, 3–7 December 2012. NH11A-1548

Stuefer, M., P. Webley, G. Grell and S. Freitas. 2012. A discussion of WRF-Chem volcanic ash particulate simulations of the 2010 Eyjafjallajökull eruption. American Geophysical Union conference on Volcanism and the Earth's Atmosphere, Selfoss, Iceland, 10–15 June 2012.

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.

Saulo Freitas (Development of the plume emission module in WRF-Chem and collaborator on forest fire and volcanic cloud modeling with WRF-Chem), Centro de Previsão de Tempo e Estudos Climáticos (CPTEC – INPE), Brazil

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 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 Volcanic Ash Transport and Dispersion (VATD) models will benefit the NWS in Alaska as they will be able to use them 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

Appendix 1
CIFAR Projects Awarded in Cooperative Agreement NA08OAR4320751 and NA08OAR4320870
1 April 2012 to 31 March 2013

Last	First	Proposal Title	Amend	Project Budget	Theme Description	Funding Source
Task 1 Activities: CI Administration and Education & Outreach						
Walsh	**John**	Regional Alaska Cooperative Institute (2012–2013)	49	$110,000	Administration	OAR
NOAA Non-Competitive Projects (NA08OAR4320751)						
Bluhm	**Bodil**	SOAR: Factors maintaining seabird and mammal benthic hotspots: A latitudinal analysis	54	$31,495	Ecosystem Studies & Forecasting	OAR
Hansen	**Roger**	Alaska Earthquake Information Center seismic station operations and maintenance (Alaska CRESTnet, year 4)	48	$276,763	Coastal Hazards	NWS
Heinrichs	**Thomas**	High Latitude Proving Ground--GOES-R	55	$139,769	Climate Change & Variability	NESDIS
Heinrichs	**Thomas**	NOAA cooperative Alaska research and satellite data services (GOES) Year 2A	45	$260,000	Climate Change & Variability	NESDIS
Jewett	**Stephen**	Bering Sea benthic habitat and ecosystem infauna	44	$22,485	Ecosystem Studies & Forecasting	NMFS
Mathis	**Jeremy**	Moored observations of ocean acidification in high latitude seas (supplemental funds)	40	$15,000	Ecosystem Studies & Forecasting	NMFS
Okkonen	**Stephen**	Bowhead whale feeding behavior in the western Beaufort Sea: Oceanographic conditions, whale prey distributions, and whale feeding and foraging behavior	46	$53,102	Ecosystem Studies & Forecasting	NMFS
Okkonen	**Stephen**	SOAR: Influence of sea ice and oceanographic conditions and prey availability on the timing of the fall bowhead whale migration from the Canadian Arctic along the Beaufort Shelf to Barrow	53	$14,518	Ecosystem Studies & Forecasting	OAR
Okkonen	**Stephen**	SOAR: Oceanographic factors associated with bowhead whale hotspots and variation in the migration path of bowhead whales across the Chukchi Sea during the fall migration	50	$17,006	Ecosystem Studies & Forecasting	OAR
Trainor	**Sarah**	Quarterly Alaska climate seasonal overview	51	$22,499	Climate Change & Variability	NWS
Walker	**Greg**	UAS survey of marine debris generated by 2011 Japanese tsunami (Year 1)	56	$152,190	Coastal Hazards	OAR
Walsh	**John**	Towards a 90-day monthly storm outlook for Alaska, North Pacific and Hawaii	47	$15,000	Coastal Hazards	NWS
Webley	**Peter**	Validation of GOES-R volcanic ash products: Near real-time operational decision support/ hazard analysis (Year 2A)	43	$180,000	Coastal Hazards	NESDIS

Last	First	Proposal Title	Amend	Project Budget	Theme Description	Funding Source
Weingartner	**Tom**	SOAR: An ocean acidfication sensitivity index for the Pacific Arctic region	52	$51,113	Ecosystem Studies & Forecasting	OAR
Competitively Awarded RUSALCA Projects (NA08OAR4320870)						
Norcross	**Brenda**	Fish ecology & oceanography: RUSALCA 2008 and 2012	17	$80,062	Ecosystem Studies & Forecasting	OAR
Whitledge	**Terry**	Global change in the Arctic: Interactions of productivity and nutrient processes in the northern Bering and Chukchi Seas	16	$85,137	Ecosystem Studies & Forecasting	OAR
Iken	**Katrin**	RUSALCA: Arctic food web structure & epibenthic communities in a climate change context	15	$79,117	Ecosystem Studies & Forecasting	OAR
		Total projects funded (including CI administration)		**$1,605,256**		
		Competitively awarded projects (including CI administration)		$354,316		
		Non-competitive projects		$1,250,940		

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

		unk or none	Bachelor's	Master's	Ph.D
Research Scientist	26			3	23
Visiting Scientist					
Postdoctoral Fellow					
Research Support Staff	37	4	14	14	5
Administrative	2			1	1
Total	65	4	14	18	29
Total (≥ 50% NOAA Support)	2		1		1
Employees (< 50% NOAA Support)	63	4	13	18	28
Located in NOAA Lab	0				
Obtained NOAA employment within last year	0				
Undergraduate Students	6		6		
Graduate Students	14			4	10
Total Students	**20**				

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 5	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Peer-reviewed	0	1	4	6	4	0	0	1	1	1	0	1	0	1	6
Non Peer-reviewed	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
In press					5					0					1
Accepted					1					0					0

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

Year 1 = 1 July 2008–31 March 2009
Year 2 = 1 April 2009–31 March 2010
Year 3 = 1 April 2010–31 March 2011
Year 4 = 1 April 2011–31 March 2012
Year 5 = 1 April 2012–31 March 2013

***NOTE 1**:*
Besides this activity for projects funded directly by NOAA through CIFAR, two 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**:*
One RUSALCA project also had a paper published during the reporting period that stemmed from funding 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	Rogers, T.S., J.E. Walsh, T.S. Rupp, L.W. Brigham and M. Sfraga	Feb 2013	Future Arctic marine access: analysis and evaluation of observations, models, and projections of sea ice	The Cryosphere	Journal article	10.5194/tc-7-321-2013	NA10OAR10055			X	X	
CIFAR	Guilhem, A., D.S. Dreger, H. Tsuruoka and H. Kawakatsu	Feb 2013	Moment tensors for rapid characterization of megathrust earthquakes: the example of the 2011 M 9 Tohoku-oki, Japan earthquake	Geophysical Journal International	Journal article	10.1093/gji/ggs045	NA08OAR4320751	X			X	
CIFAR	Hunt, G.L. Jr., A.L. Blanchard, P. Boveng, P. Dalpadado, K.F. Drinkwater, L. Eisner, R.R. Hopcroft, R.R., K.M. Kovacs, B.L. Norcross, P. Renaud, M. Reigstad, M. Renner, H.R. Skjoldal, A. Whitehouse and R.A. Woodgate	Jan 2013	The Barents and Chukchi Seas: Comparison of two Arctic shelf ecosystems	Journal of Marine Systems	Journal article	10.1016/j.marsys.2012.08.003	NA08OAR4320870			X	X	
CIFAR	Woodgate, R.A., T.J. Weingartner and R. Lindsay	Dec 2012	Observed increases in Bering Strait oceanic fluxes from the Pacific to the Arctic from 2001 to 2011 and their impacts on the Arctic Ocean water column	Geophysical Research Letters	Journal article	10.1029/2012GL054092	NA08OAR4320870			X	X	
CIFAR	Webley, P.W., T. Steensen, M. Stuefer, G. Grell, S. Freitas and M. Pavolonis	July 2012	Analyzing the Eyjafjallajökull 2010 eruption using satellite remote sensing, lidar and WRF Chem dispersion and tracking model	Journal of Geophysical Research–Atmospheres	Journal article	10/1029/2011JD016817	NA08OAR4320751	X			X	
CIFAR	Bieniek, P.A., U.S. Bhatt, R.L. Thoman, H. Angeloff, J. Partain, J. Papineau, F. Fritsch, E. Holloway, J.E. Walsh, C. Daly, M. Shulski, G. Hufford, D. Hill, S. Calos and R. Gens	July 2012	Climate divisions for Alaska based on objective methods	Journal of Applied Meteorology and Climatology	Journal article	10.1175/JAMC-D-11-0168	NA10OAR10055			X	X	
CIFAR	Steensen, T. and P. Webley	July 2012	Qualitative analysis of input parameters for satellite-based quantification of airborne volcanic ash	IGARSS 2012	Conference paper	10.1109/IGARSS.2012.6350799	NA08OAR4320751	X			X	
CIFAR	Horrillo, J., W. Knight and Z. Kowalik	July 2012	Tsunami propagation over the North Pacific: dispersive and nondispersive models	Science of Tsunami Hazards	Journal article	ISSN 87556839	NA08OAR4320751	X			X	

CIFAR	Overland, J.E., M. Wang, J.E. Walsh, J.H. Christensen, V.M. Kattsov and W.L. Chapman	May 2012	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		NA10OAR10055*		X		X	
CIFAR	Walsh, J.E., J.E. Overland, P. Groisman and B. Rudolf	May 2012	Arctic climate: Recent variations. Snow, Water, Ice and Permafrost in the Arctic, Chapter 2	Scientific Report, Arctic Monitoring and Assessment Program	Book chapter		NA10OAR10055*	X			X	
CIFAR	Norcross, B.L., B.A. Holladay and C.W. Mecklenburg	May 2012	Recent and Historical Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area. Final Report to the Coastal Marine Institute		Technical report		NA08OAR4320870	X				X
CIFAR	Nicolsky, D.J., E.N. Suleimani and R.A. Hansen	April 2012	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.P. Pickart, R.H. Byrne, C.L. McNeil, G.W.K. Moore, L.W. Juranek, X. Liu, J. Ma, R.A. Easley, M.W. Elliot, J.N. Cross, S.C. Reisdorph, F. Bahr, J. Morison, T. Lichendorph and R.A. Feely	April 2012	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	10.1029/2012GL051574	NA08OAR4320751	X			X	
CIFAR	Ekstrand, A., P.W. Webley, M.J. Garay, J. Dehn, A. Prakash, D.L. Nelson, K.D. Dean and T.S. Steensen	In press	A multisensor plume height analysis of the 2009 Redoubt eruption	Journal of Volcanology and Geothermal Research: Special Issue on 2009 Redoubt Eruption	Journal article		NA08OAR4320751	X			X	
CIFAR	McNutt, S.R., G. Thompson, M.E. West, D. Fee, S. Stihler and E. Clark	In press	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	Journal article		NA08OAR4320751	X			X	
CIFAR	Steensen, T., M. Stuefer, P.W. Webley, G. Grell and S. Freitas	In press	Analysis of ash distribution of the Redoubt 2009 Qualitative comparison of Mount Redoubt 2009 volcanic ash clouds using the PUFF and WRF-Chem dispersion models and satellite remote sensing data	Journal of Volcanology and Geothermal Research: Special Issue on 2009 Redoubt Eruption	Journal article	doi:http://dx.doi.org/10.1016/j.jvolgeores.2012.02.018	NA08OAR4320751	X			X	
CIFAR	Stuefer, M., S.R. Freitas, G. Grell, P. Webley, S. Peckham, S.A. McKeen and S.D. Egan	In press	Inclusion of ash and SO2 emissions from volcanic eruptions in WRF-Chem: development and some applications	Geoscientific Model Development	Journal article		NA08OAR4320751	X			X	

CIFAR	Hinzman, L., C. Deal, A.D. McGuire, I.V. Polyakov and J.E. Walsh	In press	Trajectory of the Arctic as an integrated system	Ecological Applications	Journal article		NA08OAR4320751			X	X	
CIFAR	Polyakov, I.V., U.S. Bhatt, J.E. Walsh, E.P. Abrahamsen and P.F. Wassmann	In press	Recent oceanic changes in the Arctic in the context of long-term observations	Ecological Applications	Journal article		NA08OAR4320751	X			X	
CIFAR	Nicolsky D.J., E.N. Suleimani, P.J. Haeussler, H.F. Ryan, R.D. Koehler, R.A. Combellick and R.A. Hansen	Accepted	Tsunami Inundation Maps of Port Valdez, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation		Technical report		NA08OAR4320751	X			X	
Publications from students funded by CIFAR through the Global Change Student Grant Competition:												
CIFAR	Fu, Y., J.T. Freymueller and T. Jensen		Seasonal hydrological loading in southern Alaska observed by GPS and GRACE	Geophysical Research Letters	Journal article	10.1029/2012GL052453	NA08OAR4320751	X			X	
CIFAR	McNabb, R.W., R. Hock, S. O'Neel, L.A. Rasmussen, Y. Ahn, M. Braun, H. Conway, S. Herreid, I. Joughin, W.T. Pfeffer, B.E. Smith and M. Truffer		Using surface velocities to calculate ice thickness and bed topography: a case study at Columbia Glacier, Alaska, USA	Journal of Glaciology	Journal article	10.3189/2012JoG11J249	NA08OAR4320751	X			X	

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

**incorrectly reported in RY12 as NA08OAR4320870*

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, 3 competitively selected RUSALCA projects received additional funding through CIFAR. The 2012 RUSALCA Bering Strait mooring and hydrographic cruise followed by the 2012 interdisciplinary cruise involved researchers from all five CIFAR RUSALCA projects who participated in the mooring recovery and deployments, CTD (conductivity, temperature, depth) and water sampling, and sampling of the biomass and distribution of benthic and water column invertebrates, plankton, and fish to better understand the consequences of climate change on the Arctic ecosystems in the region where sea ice thawing has been at a maximum.

http://psc.apl.washington.edu/HLD/Bstrait/Khromov2012CruiseReport_vers6thAug2012.pdf

http://www.arctic.noaa.gov/aro/russian-american/2012/documents/Initial_Leg_2_Cruise_Report_RUSALCA_2012.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 ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

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

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 1 NOAA Office: OAR-CPO, Ko Barrett, Sponsor
CIFAR 09-009/11-009/12-009/13-009: This project is complete.

Primary objectives

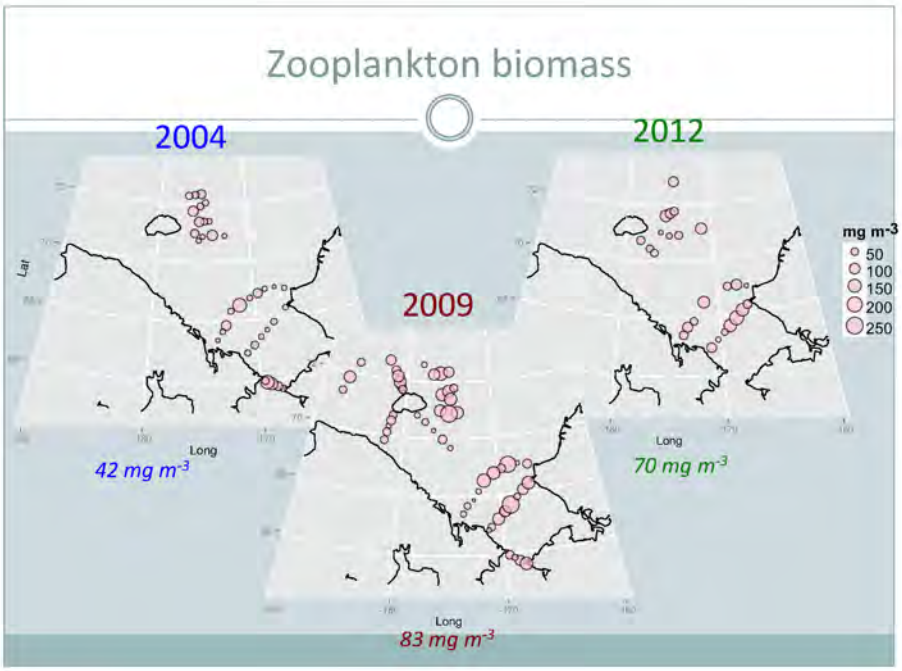
We propose repeated comprehensive surveys of zooplankton communities in the Bering Strait and Chukchi Sea to understand the transport patterns of Pacific zooplankton into the Arctic and build time-series to assess ecosystem change in this climatically sensitive region. The census will involve a combination 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

Zooplankton samples were collected during the September 2012 cruise. Egg production experiments were successfully executed at 18 stations. Incubations were performed at several of these stations to more directly explore the influence of temperature on egg production. One of the types of plankton nets employed for collection is now analyzed, the other is still being processed. Clear east-west patterns were distinct with a signal of Alaska Coastal water, Bering Water and Siberian Coast water. Zooplankton abundance and biomass values are more similar to 2009 than those observed in 2004.

Ershova has already begun drafting her first two manuscripts.

Planning is underway for a PI data synthesis meeting in May.



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 has been expanded upon through a related fellowship by the Encyclopedia of Life to Ershova, that will be merged with ArcOD content over time.

Publications, conference papers, and presentations

Peer-reviewed publication

Hunt, G.L. Jr., A.L. Blanchard, P. Boveng, P. Dalpadado, K.F. Drinkwater, L. Eisner, R.R. Hopcroft, K.M. Kovacs, B.L. Norcross, P. Renaud, M. Reigstad, M. Renner, H.R. Skjoldal, A. Whitehouse and R.A. Woodgate. 2013. The Barents and Chukchi Seas: Comparison of two Arctic shelf ecosystems. Journal of Marine Systems 109–110:43–68. doi:10.1016/j.marsys.2012.08.003

Oral presentation

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2012. A multi-year census of the zooplankton communities in the Pacific Arctic. Wakefield Symposium, March 2013, Anchorage, Alaska.

Poster presentation

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2013. Inter-annual variation in the spatial patterns of *Pseudocalanus* species distribution and egg production. Alaska Marine Science Symposium, January 2013, Anchorage, Alaska.

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2013. Spatial patterns of *Pseudocalanus* species distribution and egg production in the Pacific Arctic. ASLO Meeting, February 2013, New Orleans, Louisiana.

Other products and outcomes

Hopcroft is working in conjunction with NOAA toward the development of a Circumpolar Biodiversity Monitoring Program (CBMP) under the International Arctic Council within which the RUSALCA program will represent a significant component from the USA. Hopcroft also provides oversight on the RUSALCA data management project.

Partner organizations and collaborators

Arctic Ocean Biodiversity Project (ArcOD)

Changes/problems/special reporting requirements

Assuming the RUSALCA synthesis proposal is funded, we have a 3 month funding gap for Ershova's stipend.

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

Katrin Iken, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
Bodil A. Bluhm, PI
University of Alaska Fairbanks

Other investigators/professionals associated this project:
Ken Dunton, *University of Texas at Austin*
NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 2 NOAA Office: OAR-CPO, John Calder/Kathleen Crane, 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

During the reporting period, we participated with 3 people in the RUSALCA 2012 interdisciplinary research cruise on the R/V *Khromov* in August/September 2012. Samples for epifaunal community structure and food web investigations were collected at 20 stations, using collections from the CTD rosette (water samples for particulate organic matter, POM), van Veen grabs (for infauna and surface sediments for food web structure), and the plumb-staff beam trawl (epifaunal collections for community and food web structure). The epifaunal community was sampled from 16 stations. The entire or a representative fraction of the haul was sorted to species or lowest identifiable taxon, solitary taxa were counted, and wet biomass of all taxa (solitary and colonial) weighed on board with spring or digital hanging scales. Voucher specimens of all taxa were preserved in 10% formaldehyde-seawater solution. A total of 175 taxa were separated on board but final numbers will depend on species verifications from taxonomic specialists.

For species verification, we mailed out voucher specimens to the following taxonomists: G. Hendler (Ophiuroidea (brittle stars), Natural History Museum of Los Angeles County), C. Mah (Asteroidea (sea stars), Smithsonian Institution), M. Kedra (Sipuncula (sipunculid worms), Institute of Oceanology Polish Academy of Sciences), P. Kuklinski (Bryozoa (moss animals), Institute of Oceanology Polish Academy of Sciences), Dr. A. Rogacheva (Holothuroidea (sea cucumbers), Shirshov Institute of Oceanology Moscow), L. Cole (Ascideacea (tunicates), Smithsonian Institution), E. Rodriguez (Actinaria (sea anemones), New York Museum of Natural History). We also consulted the following local taxonomic experts: K. Coyle (Amphipoda, University of Alaska Fairbanks), M. Hoberg (Polychaeta, UAF) and N. Foster (Bivalvia and Gastropoda, NF Consulting). Mailing voucher specimens with sufficient documentation is time consuming because it requires careful labeling and packaging according to U.S. Postal Service and Federal Aviation Administration regulations of hazardous materials since these specimens are preserved in chemicals. Clear and redundant labeling is needed to ensure that expert identifications can later be matched up with the correct specimens. The PIs themselves verified identifications of shrimps and hermit crabs. We still need to identify a sponge taxonomist. Only a few groups will remain identified on the phylum level including nemertean and echiuran worms, because they are rare, do not add much to total biomass and diversity, and few taxonomists worldwide have expertise in their species identification. Several taxonomists have already returned their identifications. In most cases, the species had previously been recorded for the study area, but several species are new records for the region. Even for the taxonomists, several genera remain difficult to identify, either because of subtle differences or because of ongoing disputes of phylogenetic relationships. We are currently in the process of matching expert identifications with our field identifications.

The student working on the project (see below) has worked towards matching taxa among cruises for a temporal (2004–2012) comparison of epibenthic community structure at seven stations sampled in all three sampling years (Figure 1). At the level for which taxonomic identifications are currently confirmed for the three years, 94 taxa match among the three years. Mean epibenthic abundance increased from 2004 (8,491 individuals (ind) 1000 m^{-2}) to 2012 (11,533 ind. 1000 m^{-2}) across the seven compared stations in the southern Chukchi Sea; however, individual stations did not reflect a linear increase in abundance over this time and exhibited much variability in patterns of abundance and relative contribution to total abundance (Figure 2). Particularly the large abundance increase at station B in 2009 and at station G in 2012 (Figure 2) contributed much to the overall pattern. Much of this overall abundance increase can be attributed to arthropods. Mean epibenthic biomass increased from 2004 (27,162 g wet weight 1000 m^{-2}) to 2009 (59,890 g wet weight 1000 m^{-2}) and declined in 2012 (18,442 g wet weight 1000 m^{-2}), yet again with much variability across the seven stations (Figure 3). The overall pattern in total biomass is mainly driven by a strong increase in total biomass at stations B, C and G between 2004 and 2009, followed by a sharp decline in 2012, a trend that was again mainly driven by arthropods. The similarity between stations in hierarchical clustering analysis was primarily driven by sampling year rather than by station location (Figure 4). The

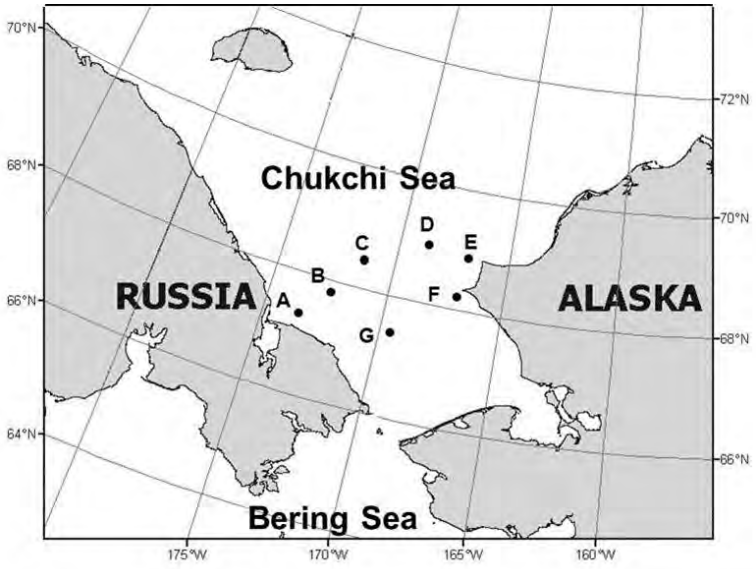


Figure 1. Map of the southern Chukchi Sea study region showing station locations A-F sampled in all three study years (2004, 2009, 2012) for interannual comparisons.

only site that was consistently dissimilar from all other locations between years was site F, a location with hard substrate that influences the taxon composition compared to soft bottom locations. The Pielou's evenness index and the Shannon diversity index were slightly higher in 2012 than in 2004 at six of the seven time series stations. Data analysis for this for 2009 is in progress. As soon as the environmental variables measured in 2012 become available, an environmental matrix will be compiled for all years and be used to identify the most important drivers of epifaunal community structure.

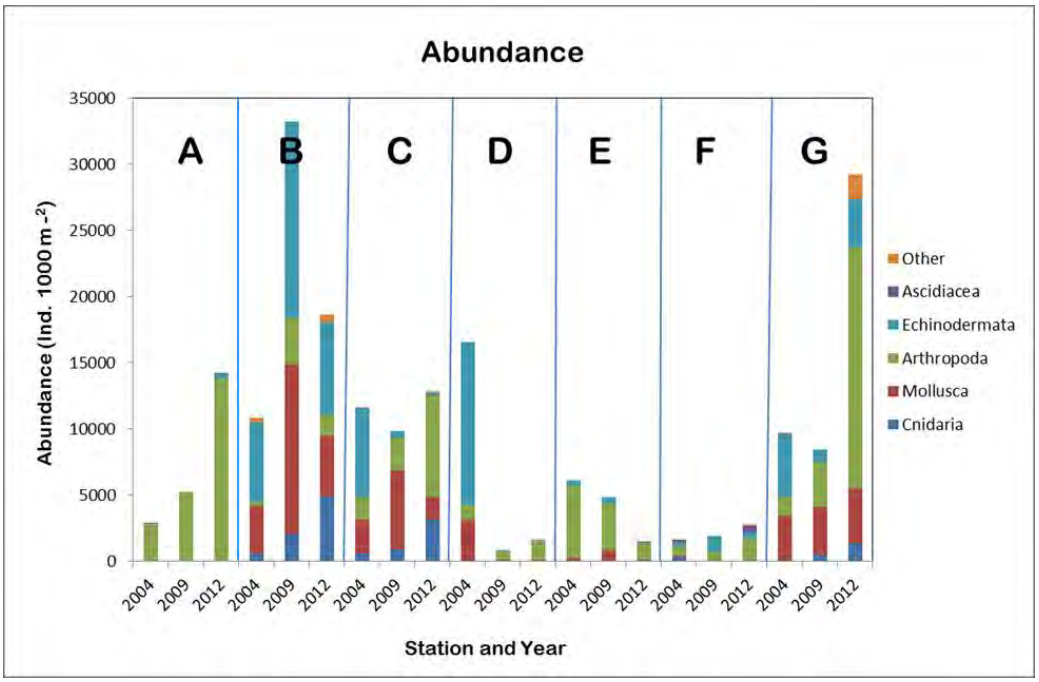


Figure 2. Epibenthos abundance (number of individuals 1000 m^{-2}) with absolute contributions of major taxa at seven repeat sampling stations over the three study years (2004, 2009, 2012). Station names as in Figure 1.

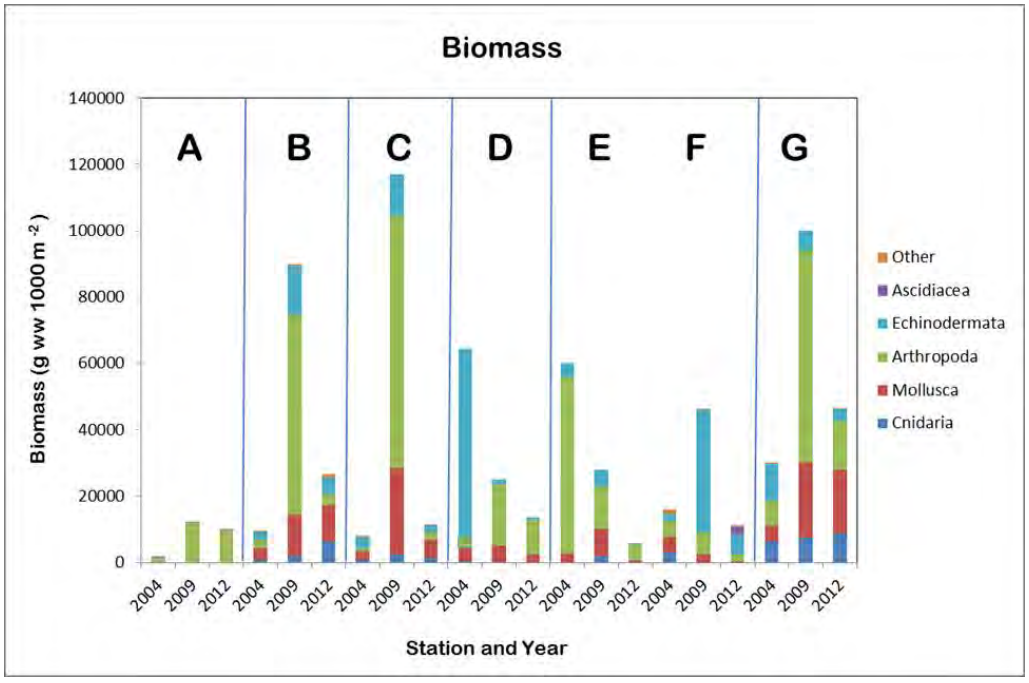


Figure 3. Epibenthos wet biomass (gram wet weight 1000 m^{-2}) with absolute contributions of major taxa at seven repeat sampling stations over the three study years (2004, 2009, 2012). Station names as in Figure 1.

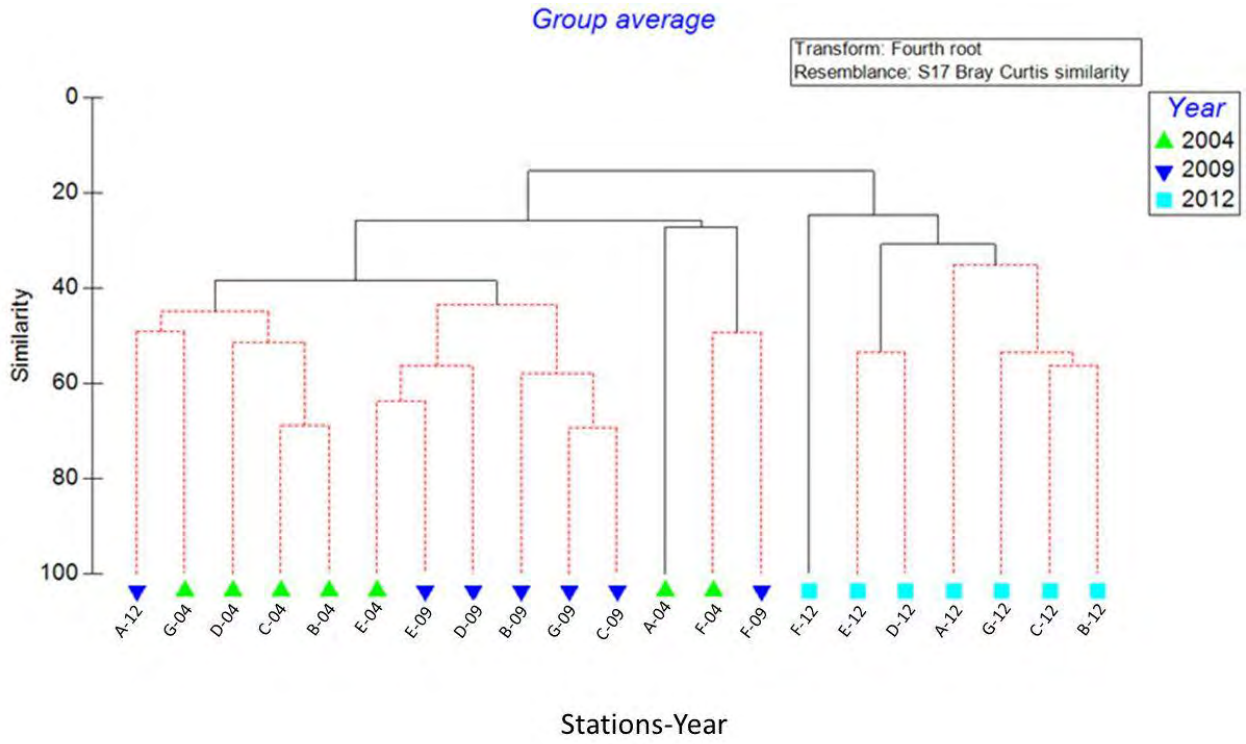


Figure 4. Hierarchical cluster analysis of epibenthos community composition based on abundance among the three sampling years (2004, 2009, 2012). Similarity based on Bray-Curtis resemblance matrix. Station names as in Figure 1.

During the cruise, we took the opportunity to analyze population dynamic parameters of snow crab (*Chionoecetes opilio*). These data contribute to our Bureau of Ocean Energy Management (BOEM), Coastal Marine Institute (CMI)-funded project on the population dynamics and reproductive ecology of Arctic snow crab. Snow crabs were collected at 14 stations and were measured on board for individual wet weight, carapace width, shell condition, and chela height. Spermathecae were dissected from mature females and clutch fullness and ovary color were determined. These data will be entered into our growing database on snow crab from the Chukchi and Beaufort shelves.

All particulate organic matter (POM) samples collected in 2012 were measured for carbon and nitrogen stable isotope ratios at the Alaska Stable Isotope Facility. Invertebrate and fish tissue samples are in the process of being prepared for analysis (i.e., lipid extraction) and will be completed in the next several weeks. We selected taxa that were also analyzed in previous years at the same stations in the southern Chukchi Sea for comparison.

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

Carlos Serratos began as a M.S. student in Marine Biology in the Fall semester 2012. His thesis objective is to compare epifaunal community and food web structure for the southern and central Chukchi Sea from 2004–2012. He has taken several of the required courses in the degree program and has done very well. In the fall he also worked on data management of epifaunal community data for the three years to match taxa, identify taxa that needed to be voucher identified, and proof data entry from field notebooks into electronic format. He has assisted in the voucher packaging and sending to taxonomic experts. He prepared epifaunal data currently available for analysis

with the software program Primer, for which he just completed a training workshop in March 2012 in Plymouth, UK. Carlos also has selected and started preparing stable isotope samples for the 2012 (and some additional 2009) collections.

Carlos has presented his preliminary results on epifaunal community structure in a poster at the Alaska Marine Science Symposium in January 2013 (see below). He also submitted a proposal to the Center for Global Change Student Research Competition to request some bridge funding for summer salary.

Outreach

During the 2012 cruise, we contributed to the cruise webpage with a background piece on Marine Biodiversity (http://oceanexplorer.noaa.gov/explorations/12arctic/background/biodiversity/biodiversity.html) and a cruise log on seafloor communities (http://oceanexplorer.noaa.gov/explorations/12arctic/logs/sept2/sept2.html). We also provided pictures to illustrate this website as well as NOAA's RUSALCA web site http://www.arctic.noaa.gov/aro/russian-american/2012/photos4.html. We also contributed to the teacher-at-sea's blog on the Polar Trec web site: http://www.polartrec.com/expeditions/russian-american-long-term-census-of-the-arctic.

Publications, conference papers, and presentations

Publications

No publications were produced during the reporting period, but the ongoing research will form the basis for (at least) two publications that will form the core tasks of the new RUSALCA grant.

Oral presentation

Bluhm, B. and K. Iken. 2013. Population assessment of snow crab, *Chionoecetes opilio*, in the Chukchi and Beaufort Seas: Preliminary findings. 28th Lowell Wakefield Symposium, 26–29 March 2013, Anchorage AK. [This presentation included data on snow crab collected during the 2004-2012 RUSALCA cruises]

Poster presentations

Serratos, C., B. Bluhm and K. Iken. 2013. A preliminary temporal comparison of epibenthic community structure in the southern Chukchi Sea from 2004–2012. Alaska Marine Science Symposium, 21–25 January 2013, Anchorage AK.

Bluhm, B. and K. Iken. 2013. Population assessment of snow crab, *Chionoecetes opilio*, in the Chukchi Sea. Alaska Marine Science Symposium, 21–25 January 2013, Anchorage AK.

Divine, L., K. Iken and B. Bluhm. 2013. Can you stomach it?: preliminary diet and stable isotope analysis of snow crab (*Chionoecetes opilio*) in the Alaskan Arctic. 28th Lowell Wakefield Symposium, 26–29 March 2013, Anchorage AK. [This presentation included data on snow crab collected during the 2012 RUSALCA cruise]

Partner organizations and collaborators

Bluhm and Iken are both 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. The project relates to the RUSALCA objectives through the common focus on climate change research on Arctic shelf systems. 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 epifaunal community and food web structure objectives and sampling. Both PIs also are engaged in analyzing the food web structure on the Beaufort Sea shelf, and that of snow crab on the Chukchi shelf through isotope and stomach content analysis by advising a PhD student funded through the NSF-Integrative Graduate Education and Research Traineeship (IGERT) program MESAS (Marine Ecosystem Sustainability in the Arctic and Subarctic). This effort links intrinsically to the food web studies performed within the RUSALCA project on the Chukchi shelf. The continued funding for this student will be from the BOEM-funded Arctic Environmental Impact Study (EIS) project (Iken and Bluhm co-PIs) that focuses on fish and lower trophic level communities in the northern Bering and Chukchi Seas. Both PIs also are part of the US-Canada Transboundary project funded through BOEM that investigates epifaunal community and benthic food web structure in the Beaufort Sea in an effort paralleling our RUSALCA objectives. Bluhm is funded through the Oil Spill Recovery Institute (OSRI) to rescue historic unpublished data from epifaunal trawl hauls in the Beaufort Sea. Bluhm is also a co-PI on the NPRB-funded Pacific Arctic Marine Regional Synthesis (PacMARS) project that aggregates and synthesizes research across multiple disciplines in the northern Bering, Chukchi and Beaufort Seas including RUSALCA efforts.

Iken and Bluhm also are members of the Marine Expert Monitoring Group of the Circumpolar Biodiversity Monitoring Program, 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. Iken is the US Benthic Marine Ecosystem Expert and Bluhm is the US Sea Ice Marine Ecosystem Expert for the implementation phase of the CBMP. 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. A no-cost extension of the project has been requested, approved and is in the process of being administratively implemented.

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: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 3 NOAA Office: OAR-CPO, John Calder/Kathleen Crane, Sponsor
CIFAR 09-011/12-011/13-011: 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 RUSALCA-2012 cruise provided a good complement to the larval and small demersal fishes sampled during the 2004 and 2009 cruises. At time-series stations we had sampled during the earlier cruises, and at stations we first examined in 2012, we collected fish data that can be quantified by volume (bongo net: plankton in water column) or area (beam trawl: sea floor). Quantitative samples are necessary for long-term comparisons of abundance.

Demersal fishes: It is notable that this beam trawl has become the most used bottom trawl gear in the Chukchi Sea, with relatively dense sampling in the eastern Chukchi and U.S. Beaufort seas, and broad geographic coverage of samples in the Russian western Chukchi. Survey continuity over this large geographic area is an excellent baseline for long-term abundance analyses.

Larval fishes: Two points were indicated for ichthyoplankton by the inconsistent timing of the three RUSALCA cruises. Because the dates of the three RUSALCA cruises were not the same in each year, we gathered a broader seasonal perspective on ichthyoplankton abundance. The unfortunate consequence of this timing is that interpretation of the interannual aspect of these three ichthyoplankton collections is confounded by differences in date. Distinct ichthyoplankton species assemblages observed during the Aug-2004 cruise were associated with different water masses (n=498 larvae at 18 stations). The few planktonic fishes collected during Sep-2009 (n=22 larvae at 31 stations) were insufficient to make definitive statements about assemblages. Although ichthyoplankton samples from the Aug-Sep 2012 cruise are not yet examined, at-sea observations indicate a much larger number of larval fishes than in 2009. In addition to the RUSALCA cruises, a 60 cm bongo with 0.505 mm mesh net towed at 1.5–2 kts collected ichthyoplankton during other recent surveys of the Chukchi (2007, 2008, 2012) and Beaufort (2008, 2011) seas. We recommend continuing to use this gear as a consistent measure of abundance for a long-term time series. Although survey continuity is highly desirable, we recognize it is not always possible. To successfully

assess species presence and size of fish larvae, we recommend that future surveys of ichthyoplankton during late summer in the Arctic sample not only with bongo gear but also with a larger meshed plankton net, such as a Methot net of 2–3 mm mesh, which can be towed at a faster speed (3 kts). The larger meshed net may be more effective at catching larger planktonic larval and juvenile fish during late summer (September) in the Chukchi Sea.

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

In the past 12 months, one UAF student graduated with an advanced degree, and another student was financially supported by this CIFAR grant. Christine Gleason graduated with a Master's degree in Fisheries Oceanography; her thesis was based on the trace elements detected in fish otoliths and seawater collected during RUALCA-2009. Brandi Larson, undergraduate technician, assisted in preparing otolith samples for analysis of trace elements.

Publications, conference papers, and presentations

Poster presentations

Busby, M.S., B.L. Norcross and B.A. Holladay. 2013. Ichthyoplankton collected on the 2004 and 2009 Russian-American Long-Term Census of the Arctic research cruises. 28th Lowell Wakefield Fisheries Symposium: Responses of Arctic Marine Ecosystems to Climate Change. Anchorage, AK, March 2013.

Norcross, B.L., B.A. Holladay and C.W. Mecklenburg. Richness and diversity of demersal fishes in the eastern Chukchi Sea over 50 years. 28th Lowell Wakefield Fisheries Symposium: Responses of Arctic Marine Ecosystems to Climate Change. Anchorage, AK, March 2013.

Non-peer review publication

Norcross, B.L., B.A. Holladay and C.W. Mecklenburg. 2012. Recent and Historical Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area. Final Report to the Coastal Marine Institute, Task Order M07AC12462, OCS Study BOEM 2012-073, Fairbanks Alaska.

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

Thomas Weingartner, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
Terry Whitledge, PI
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 5 NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
CIFAR 10-013/11-013

This project is ongoing. Although this project was reviewed and competitively awarded with the other RUSALCA projects, this project was funded jointly by NSF and NOAA, with NSF covering year 1.

Primary objectives

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

Approach/methodology

Our approach involves making measurements of the salinity, temperature, velocity, fluorescence, and nitrate in the western channel of Bering Strait at hourly intervals for a period of one year. The measurements are and will

continue to be made from four moorings deployed across the western channel of Bering Strait. Each mooring contains an RDI 300 kHz upward looking ADCP (Acoustic Doppler Current Profiler) current meter for measuring velocity and a SeaCat (SBE-16 T/C recorder) for the temperature and salinity measurements. The mooring in the center of the strait includes a fluorometer and a nitrate sensor. We are also engaged in analyzing the data from these moorings and the CTD (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 collecting ~150 CTD casts (including nutrients on ~ half the casts) in Bering Strait and the southern Chukchi Sea in early July 2012. We had planned to recover 11 moorings (8 in the US EEZ and 3 in the Russian EEZ) and to re-deploy 5 of these in the US EEZ. (These 5 re-deployments were performed by the University of Washington, but included UAF nitrate analyzers.) The 3 moorings in the Russian EEZ were supposed to have been recovered in 2011, however, clearance for vessel operations in the Russian EEZ was not provided by the government of Russia in 2011. In 2012, permission was granted for working in the Russian EEZ, but we were then required to conduct two Russian port calls, for which the vessel did not have time. Hence in 2012, we were unable to recover 3 moorings or collect CTDs in the Russian EEZ as planned. (However, these moorings were subsequently recovered prior to the second leg of the RUSALCA program in late July/early August). As this represents the final year of UAF involvement in the Bering Strait mooring program, we did not re-deploy any moorings. Because of the delay in the arrival of the CTD and ISUS nitrate data from 2010, the processing of these data are behind our anticipated schedule. However, these data will be available shortly. (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.) The 2012 CTD and ISUS nitrate data are now being processed. 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. 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

Peer-reviewed publication

Woodgate, R.A., T.J. Weingartner and R. Lindsay. 2012. Observed increases in Bering Strait oceanic fluxes from the Pacific to the Arctic from 2001 to 2011 and their impacts on the Arctic Ocean water column. *Geophysical Research Letters* 39, L24603, doi:10.1029/2012GL054092.

Oral presentations

Woodgate, R., R. Lindsay, T. Weingartner, T. Whitledge, E. Bondareva, M. Kulakov and V. Golavsky. 2013. Bering Strait, February 2013 Update. Distributed Biological Observatory Meeting, Seattle, WA, February 2013.

Whitefield, J., P. Winsor and T.J. Weingartner. Using in situ observations to validate the performance of a high-resolution global model in the Bering, Beaufort and Chukchi Seas. ECCO2 meeting, NASA/JPL, Pasadena, CA, 31 October–2 November, 2012.

Poster presentations

Whitefield, J., P. Winsor and T.J. Weingartner. 2013. Transport and T/S variability in Bering Strait from a global ocean model and a shipboard survey. Gordon Research Conference on Polar Marine Science, Ventura, CA, 10–15 March 2013.

Whitefield, J., P. Winsor and T.J. Weingartner. 2013. Using in situ observations to validate the performance of a high-resolution global model in the Bering, Beaufort and Chukchi Seas. Alaska Marine Science Symposium, Anchorage, AK, 21–25 January 2013.
Whitefield J., Winsor P., Weingartner T.J. Using in situ observations to validate the performance of a high-resolution global model in the Bering, Beaufort and Chukchi Seas. 16th Arctic Ocean Model Intercomparison Project, Woods Hole, MA, 23–26 October 2012.

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 recovery of moorings within the Russian EEZ due to 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 ***CIFAR theme: Ecosystem Studies & Forecasting***
Dean A. Stockwell, co-PI
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

NA08OAR4320870 CIFAR Amendment 4 NOAA Office: OAR-CPO, John Calder/Kathleen Crane, Sponsor
CIFAR 09-012/11-012/12-012/13-012: 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 2012 was used to obtain samples in the Bering Strait region and the wide scale biological cruise to provide data to investigate climate change in the Chukchi Sea.
- Nutrient and chlorophyll samples were collected on hydrography stations during the mooring and wide scale biological survey legs. 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 21 stations. The samples will be analyzed by mass spectrometry after data is cleared and released by Russian authorities.

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

Changes/problems/special reporting requirements

The 2012 RUSALCA cruise was carried out within both U.S. and Russian EEZ areas of the Chukchi Sea as proposed. Early sampling during the cruise was hampered greatly by high winds and rough seas with an accrued delay of about two days to the sampling program. Subsequently relatively heavy ice cover presented challenging conditions to collect water and plankton, sediment and fish samples in desired locations near Wrangel Island. Irrespective of weather and ice cover delays all long term biological sites were sampled which will provide the necessary information to assess ecosystem changes in the Chukchi Sea. Nutrient and chlorophyll concentrations as well as nitrogen and carbon production rates from approximately 20 productivity stations will be reported at the PI Meeting scheduled in St. Petersburg, Russia in May 2013.

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

Peer-reviewed

Lee, S.H., D.A. Stockwell, H.M. Joo, Y.B. Son, C.K. Kang and T.E. Whitledge. 2012. Phytoplankton production from melting ponds on Arctic sea ice. *Journal of Geophysical Research*, 117, C04030, doi:10.1029/2011JC007717.

Appendix 5.

Downscaling of climate model output for Alaska and northern Canada

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

Other investigators/professionals associated this project:
Peter Bieniek, *University of Alaska Fairbanks (postdoc)*

NOAA Goal: Climate Adaptation & Mitigation

NA10OAR4310055 NOAA Office: OAR-CPO, Chris Miller and Bill Murray, Sponsors
[This report was submitted via Grants Online in January 2013. It is included here for the sake of completeness.]

Research supported by NOAA grant NA10OAR4310055, now in its final months, is focused on 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 high-resolution projections, and a contribution of high-resolution Alaskan climate projections to the National Climate Assessment has been one of this project's primary activities the past year – Activity (1) described below. More generally, the need for site-specific information about ongoing and projected climate change is a key element of NOAA's provision of climate services.

The past year's effort fell into five main categories: (1) provision of downscaled fields for Alaska as part of a regional technical input report for the National Climate Assessment, (2) extension of the high-resolution projections to include sea ice and implications for marine navigation in the Arctic, (3) implementation of a quantile mapping procedure utilizing daily model output to project changes in extreme events, (4) incorporation of the latest generation (CMIP5) of coupled models into our downscaling, and (5) synthesis of Alaskan station data into a homogeneous product spanning 90 years for use in trend assessment and downscaling algorithm development. In the following paragraphs, we describe each of these five activities in more detail.

(1) *High-resolution Alaskan scenario input for the National Climate Assessment (NCA).*

Our previous reports described the downscaling of Alaskan temperature and precipitation, and subsequently 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. The sea ice projections are described in more detail under Activity (2). Our contributions to the Alaska Technical Input Report for the NCA include downscaled fields of historical and projected fields of the primary variables (temperature, precipitation) as well as downscaled fields of two key derived variables (freeze-free season length, permafrost temperatures). The downscaled fields of these variables have horizontal resolution of 2 km. The changes in permafrost represent a major vulnerability to ongoing warming in Alaska, as large areas of subsurface thaw (transition from blue to red in Figure 1) are projected to occur by the end of the century. Because of their potential impacts in infrastructure and ecosystems, these changes are highlighted in both the Climate Science and the Alaska-Arctic chapters of the actual NCA report. In addition, the Alaska Technical Input report contains several figures showing our downscaled projections of decade-by-decade mean temperature and precipitation for specific locations in Alaska (Figs. 14–16 and 24–26 of the report).

Publication from Activity (1):

Stewart, B.C., K.E. Kunkel, L.E. Stevens, L. Sun and J.E. Walsh. Climate of Alaska. 2013. Technical Input Report for U.S. National Climate Assessment, U.S. Global Change Research Program, 60 pp. [This is the same document mentioned in last year's annual report as scheduled for release 3/1/012, but with substantial revisions.]

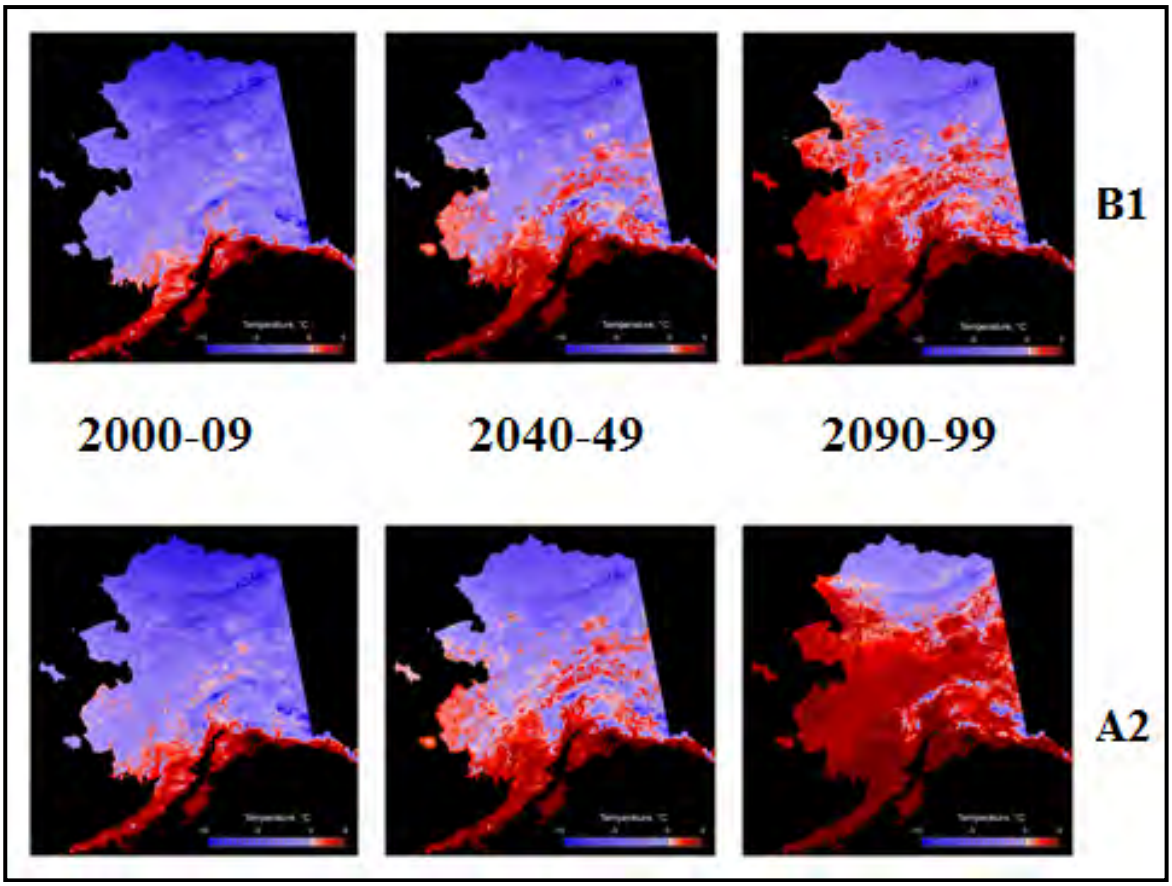


Figure 1. Annual mean ground temperatures at 1-meter depth for 2000–09, 2040–49, and 2090–99. Fields are from permafrost model simulations driven by downscaled CMIP3 climate model output for the B1 (upper panels) and A2 (lower panels) scenarios. As indicated by color bars, blue shades represent temperatures below 0°C and red shades represent temperatures above 0°C.

(2) *Projections of changes in marine access in Alaskan waters.*

In response to an emerging need for regional applications of sea ice projections to provide higher-resolution information relevant to national, state and local planners as well as other stakeholders, we have carried out a prototype of a sea ice assessment that bridges observational data, climate model simulations, and user needs. A paper describing this effort has been accepted for publication (Rogers et al., 2013). The study's first component was an observationally based evaluation of Arctic sea ice trends during 1980–2008, with an emphasis on seasonal and regional differences relative to the overall pan-Arctic trend. The recent loss of sea ice has varied regionally, with a significantly larger decline of the summer minimum north of Alaska and eastern Siberia. By contrast, the decline of the winter maximum (January–March) extent has been largest in the Atlantic region. A lead–lag regression analysis of Atlantic sea ice extent and ocean temperatures indicates that reduced wintertime sea ice extent in the Atlantic sector is associated with increased Atlantic Ocean temperatures. The performance of 13 global climate models was then evaluated using several metrics (overall mean, seasonal amplitude, recent trends) by comparing the model-simulated sea ice with the observed record. The models were ranked over the pan-Arctic domain and regional quadrants, leading to an integrated rank of model performance. The best performing models project reduced ice cover across key marine access routes in the Arctic through 2100, with a lengthening of seasons for marine operations by 1–3 months. Figure 2 shows the increased access for a Polar-Code 7 vessel. The results show that all the routes hold potential for enhanced marine access to the Arctic in the future, including shipping and resource development opportunities. More specifically, the projected 21st-century increases in length of the navigation season range from about one month for the northern Bering Sea (Bering Strait) to 2–3 months for the Northern Sea Route and Northwest Passage.

Paper accepted from Activity (2):

Rogers, T.S., J.E. Walsh, T.S. Rupp, L.W. Brigham and M. Sfraga. 2013. Arctic sea ice: satellite observations and sea surface temperatures, global climate model analysis and evaluation, and future projections towards Arctic marine accessibility. Accepted January 2013 for publication in *The Cryosphere*. [published in February]

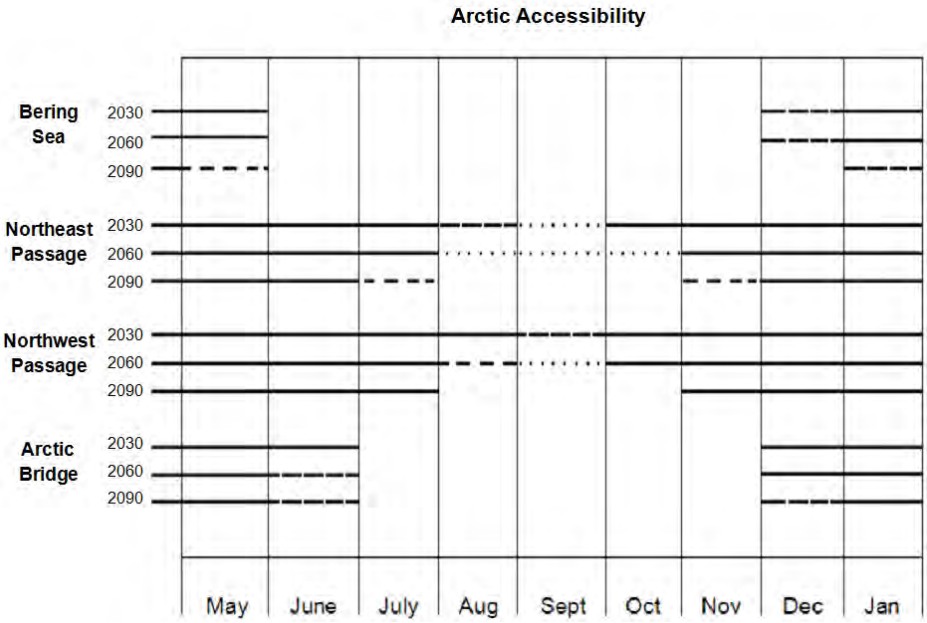


Figure 2. Projected changes in arctic marine access as a result of changes in sea ice cover projected by a set of four CMIP3 models. A solid line indicates that no model projects accessibility (defined as open water along entire navigation corridor) in a calendar month (x-axis). Dotted and dashed lines indicate that one and two models, respectively, project accessibility. Absence of any line indicates that all four models project accessibility. (From Rogers et al.).

(3) *Implementation of a quantile mapping procedure utilizing daily model output to project changes in extreme events.*

The downscaling described in our previous report and thus far in the present report has been based on the Delta method applied to monthly fields and superimposed on a 2-km PRISM climatology. In order to extend the downscaling to extreme events and the daily fields required for such an extension, we have implemented the Bias-Correction Spatial Disaggregation (BCSD) procedure, which falls under the category of downscaling methods known as "quantile mapping". We have tested this method with daily output from the CCSM4 model, and applied the mapping to a number of locations in Alaska and over the offshore seas. An example is shown in Figure 3, which illustrates for Bettles (in northern Interior Alaska) the projected decreases in very cold days (below -35ºC) and the increases in warm days (above 23ºC). Both threshold exceedances are projected to change dramatically over the next nine decades. These and other emerging results confirm the importance of including changes in extremes in assessments of future changes.

We have retrieved daily output from five CMIP5 models (see Activity #4 below) in order to extend the BCSD downscaling to a multi-model ensemble. The retrieved variables include daily maximum and minimum temperature, precipitation and wind speeds. Downscaling of winds, which are typically not included in presentations of model projections, will enable us to assess the changes in the high-wind events that are associated with large waves, coastal flooding and erosion. We are combining this information with the sea ice projections in order to assess the compound effects of changes in high-wind events and changes in sea ice, which has historically buffered large parts of the Alaskan coast from wave-induced flooding. The loss of sea ice increases coastal vulnerability to storms, adding to the need for information on future changes in high-wind events.

Paper in preparation under Activity (3):

Leonawicz, M. and J.E. Walsh. Quantile mapping of projected changes in Alaskan temperature and precipitation. In preparation for submission to *Journal of Climate* (planned March 2013).

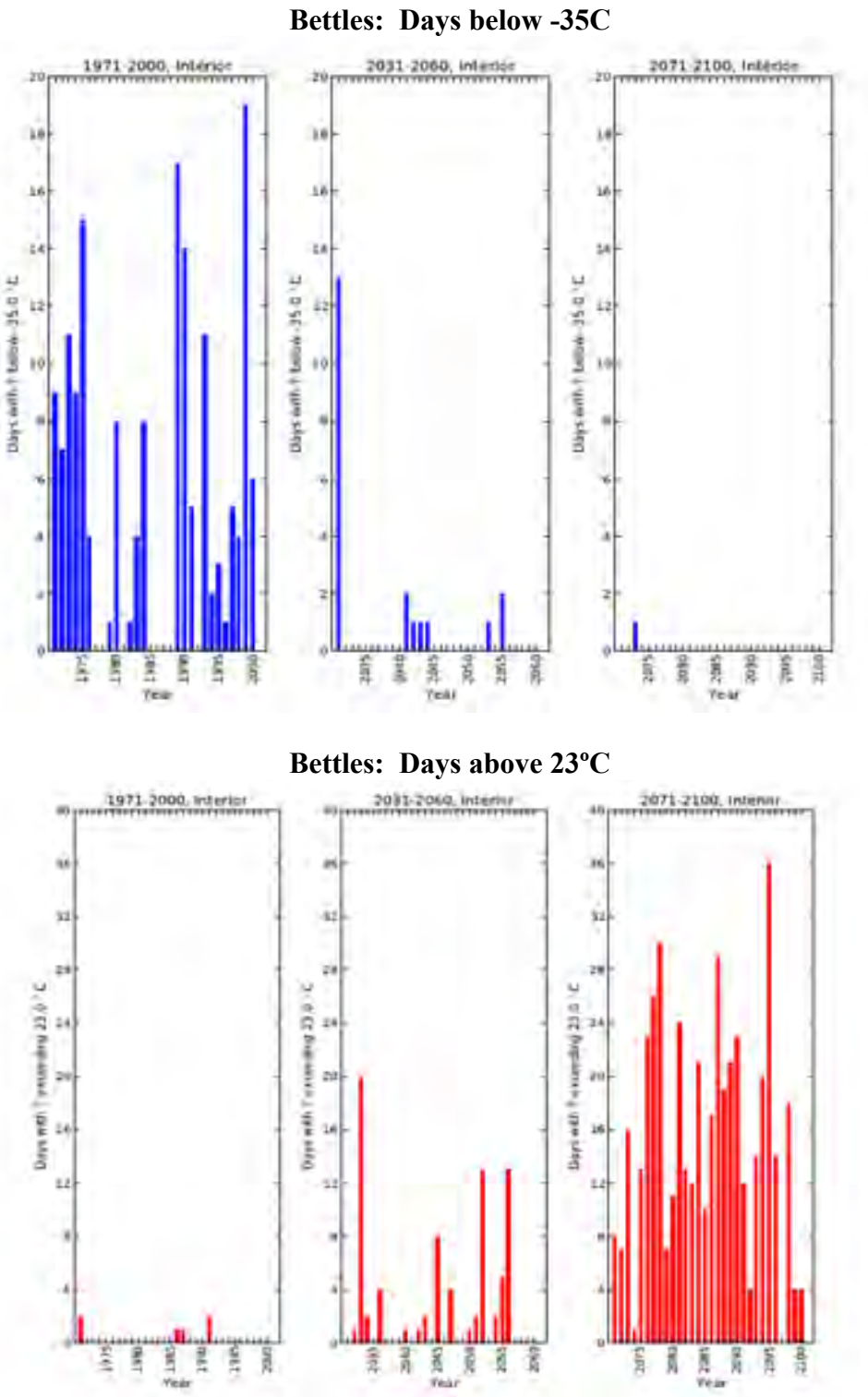


Figure 3. Example of BCSD quantile mapping: Yearly number of temperature threshold exceedances (-35ºC, +23ºC) at Bettles, Alaska in CCSM4 model simulation.

(4) *Extension of model evaluation and downscaling to include CMIP5 models*

The downscaled products provided to the National Climate Assessment and the products described in our previous progress report were based on the CMIP3 models. With the recent release of the CMI5 simulations in conjunction with the IPCC's Fifth Assessment, output from a new generation of models is now available. As well, the forcing scenarios for future projections have changed from the SRES (Special Report on Emission Scenarios) to the RCP (Representative Concentration Pathways) set. We have retrieved the CMIP5 output and repeated the model evaluation process in order to select the model subset that performs best for Alaska and the Arctic. These best-performing CMIP5 models were found to be the MPI-ESM (Germany), the NASA GISS-E2, the CCSM4 (U.S.), the MRI-CGCM3 (Japan) and the GFDL-CM3 (U.S.). While there is some overlap with the CMIP3 best-performers, the NASA GISS and CCSM4 models are new additions to our suite of selected models. The fact that the majority of models are from the United States facilitates exchanges of information with the modeling centers.

We have found that the model evaluation results show some dependence on the error metric, on the selected variable(s), and on the time period used for the validation. We are planning to prepare a journal paper on the topic of model selection, providing a case study of the handling of many of the issues described more generally in our earlier paper on this topic (Overland, J.E., M. Wang, N.A. Bond, J.E. Walsh, V.M. Kattsov and W.L. Chapman. 2011. Considerations in the selection of global climate models for regional climate projections: The Arctic as a case study. *Journal of Climate,* 24:1583–1597).

The selected CMIP5 models will form the basis for a "next-generation" update of our publicly accessible website on downscaled climate scenarios for specific Alaskan locations (presently more than 350 locations): http://www.snap.uaf.edu This website is the project's primary outreach tool.

(5) *Extension of Alaskan station database for downscaling and trend assessment*

In the course of our downscaling project and in preparing the input for the National Climate Assessment, it has become apparent that the Alaskan station database is limited by gaps in both time and space. In order to augment the station database for both downscaling applications and trend analysis, we have hired a postdoctoral scientist (Peter Bieniek) under the present project. Dr. Bieniek is using his recently computed set of Alaska climate divisions (Figure 4) as a basis for enhancing the time series of station data back to 1920. The strategy is to use available station-months to develop regression relations in which the independent variables are divisional temperature and precipitation data based on anomalies for stations that do report in a particular month. The independent variable is the temperature or precipitation value for a particular station. In any year-month for which the particular station's value is missing, the regression equation (developed from all months with data available from the particular station) provides an estimate of the missing value. We have found that the regression-derived and observed values generally correlate at 0.80–0.90 for temperature and 0.70–0.85 for precipitation over all months for which data are available, indicating that the major portion of the variance is captured by this procedure for temporally interpolating missing data for a station. Bieniek et al. (2012) documented the correspondence between station data and corresponding divisional values for the shorter period, 1977–2010, used in determining the climate divisions in Figure 4.

Publication from Activity 5:

Bieniek, P.A., U.S. Bhatt, R.L. Thoman, H. Angeloff, J. Partain, J. Papineau, F. Fritsch, E. Holloway, J.E. Walsh, C. Daly, M. Shulski, G. Hufford, D. Hill, S. Calos and R. Gens. 2012. On revising the climate divisions for Alaska. *Journal of Applied Meteorology and Climatology*, 51:1276–1289.

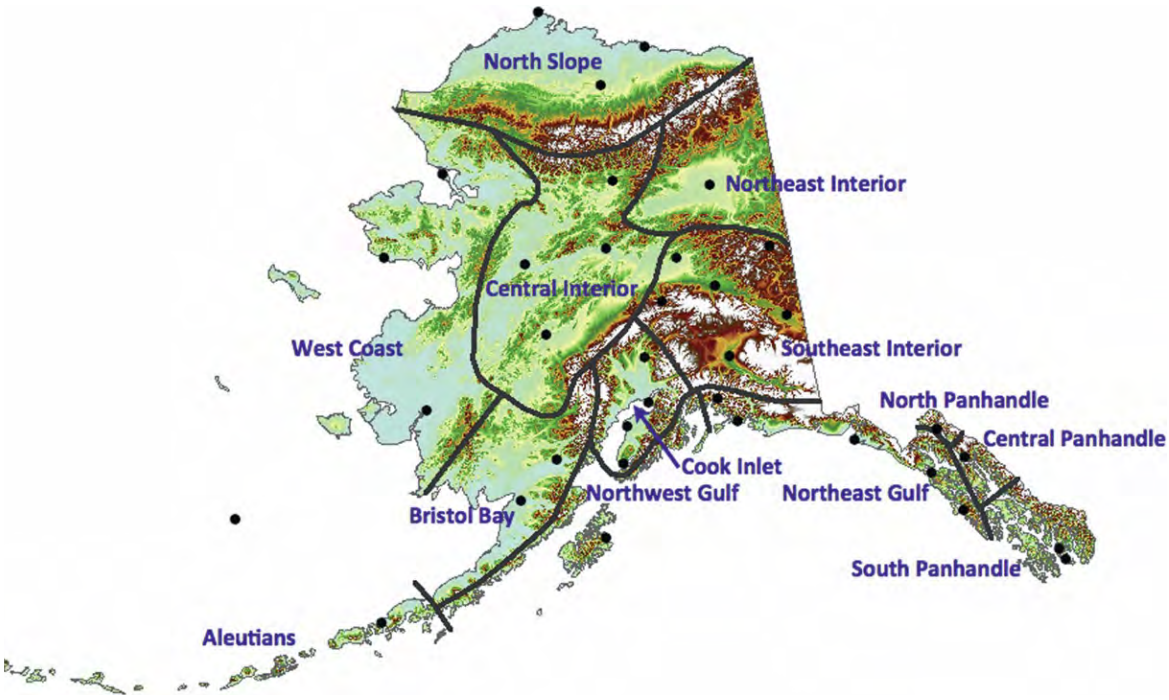


Figure 4. Objectively determined climate divisions for Alaska (from Bieniek et al. 2012). The divisional temperature and precipitation values are the basis for our extension of the historical record of station data to include the 93-year period, 1920–2012.

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