Sixth progress report on Cooperative Agreement NA08OAR4320751

1 April 2013 – 31 March 2014

CIFAR
Cooperative Institute For Alaska Research

UAF
UNIVERSITY OF ALASKA FAIRBANKS

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

1 April 2013–31 March 2014

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Images in the cover design are from the report on TWEAK Task 2 in this document. Report layout and production by Barb Hameister, CIFAR.

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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
Kathy Crane, NOAA OAR Arctic Research Office Program Manager *(effective 12/3/2013*)
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 (*retired*)
Susan Sugai, CIFAR director, ex officio (*effective 7/1/2013*)

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 Emeritus 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, Division director, 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. Denby Lloyd, Executive Director, North Pacific Research Board, Anchorage, AK (*effective 12/2/2013*)
12. Terry Whitledge, Director, IMS, SFOS, UAF, Fairbanks, AK
13. Katrin Iken, IMS, SFOS, UAF, Fairbanks, AK (*added 11/26/13*)

Summary of Projects Funded during Reporting Period

During the sixth reporting period of the new competitively awarded cooperative agreement NA08OAR4320751, we began our no-cost extension year where many of the CIFAR projects involving graduate students are actively producing research and operational outcomes that are highlighted below. During this same time period, our renewal cooperative agreement NA13OAR4320056 was established. NOAA provided funding for CIFAR administration and 10 research, education, and outreach projects that will be reported in a separate report. Some NA08OAR4320751 projects have received new increments of funding under NA13OAR4320056 so the progress reports for these continuing projects are identical in the two reports.

Highlights of CIFAR Task I Activities

CIFAR is currently staffed by two people: Susan Sugai, director and acting CIFAR administrator; and Barb Hameister, publications and meetings manager. This situation is less-than-optimal for CIFAR, but given declining funds from both NOAA and UAF, recruiting a part-time fiscal manager to act as CIFAR administrator has proven difficult. However, it is hoped that Sarah Garcia, who served as CIFAR administrator from March 2010 to August 2011, can be soon hired to fill this role on a 62% FTE basis. Sarah has assisted on a limited basis during this reporting year.

Core Administration

With tightening state appropriated funds and delay in implementing changes in CIFAR Task I support, we have experienced problems in recruiting new staff for CIFAR while planning for a leadership transition in 2016. For this reporting period CIFAR Task I funds (NA08OAR4320870) supported 823 hours of the CIFAR director, while University match funds (for year 1 of NA13OAR4320056) provided the remainder of core administrative labor costs. Because CIFAR has been without a CIFAR administrator for the current reporting year, Garcia has been assisting Sugai with these responsibilities on “as available” status (~3% FTE), and Sugai’s efforts have increased from 45% in year 5 to 54% effort during this transition between expiring shadow and core cooperative agreements and our renewal cooperative agreement.

- Susan Sugai, CIFAR director, 54% FTE (UA match funds + Task I)
- Sarah Garcia, temporary assistance, 3% FTE (Task I + UA match funds)
- Barb Hameister, publications and meetings manager, 18% FTE (Task I + UA match funds)

John Walsh, CIFAR director prior to his retirement in July 2013, provided CIFAR overview and participated in the NWS Alaska and the OCONUS (Outside (the) contiguous United States) Satellite Proving Ground meeting hosted by UAF Geographic Information Network for Alaska (GINA) in Fairbanks on June 20, 2013.

Susan Sugai, current CIFAR director (former associate director), provides overall CIFAR programmatic guidance, oversees daily operations and serves on the 25-member NOAA Alaska regional collaboration team. She is responsible for submitting all CIFAR proposals, setting up post-award budgets, and overseeing reporting obligations.

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 in 2011 to continue supporting young scientists in quantitative fisheries sciences, including population dynamics, management, and stock assessment (CIFAR 12-024).

Karson Coutre (M.S. student) and Anne Beaudreau (CIFAR 12-025) have finished five sampling trips over two years in St. John the Baptist Bay, where they tagged and collected stomach contents from juvenile sablefish. Coutre has processed stomach contents and analyzed the data collected, and begun preliminary analysis of available acoustic tagging data for St John the Baptist Bay sablefish. Coutre's key findings in St. John the Baptist Bay are that juvenile sablefish are opportunistic predators feeding on a diverse diet composed of more than 50 fish and invertebrate taxa and that the diet composition of juvenile sablefish varies significantly among sampling periods and years. The occurrence and biomass of Pacific herring, euphausiids, and adult spawning salmon in the sablefish diets drive temporal differences that suggest that these seasonally abundant, high energy resources may be important for juvenile sablefish to achieve the body condition necessary for overwinter survival.

Because sablefish in the north Pacific is thought to be one stock, whose movement is life-cycle driven, while an existing single-area assessment model and abundance indices from surveys and the fishery are currently used to apportion harvest in this individually-based quota fishery, **Kari Fenske** (Ph.D. student), is working to develop more biologically realistic and accurate estimates of sablefish abundance and population dynamics. She has been using 27 years of sablefish mark-capture data to estimate movement rates that will be used to add spatial dynamics to the sablefish stock assessment model. Using age-specific movement estimates based upon tagged and recovered fish, catch and catch-per-unit effort data, and age and length compositions, Fenske's spatially-explicit, age-structured stock assessment model will lead to better management strategies. Her research will allow managers to maximize the harvest without depleting local abundance while also examining the social and economic effects of potential harvest strategies.

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 proposal review panel met on 5 April 2013 and recommended full or partial funding of 13 projects (from a field of 26) for awards running from 1 July 2013 to 30 June 2014. The reduction in proposal numbers compared to previous years 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.

Six of these awards were funded with CIFAR Task 1 education funds. The students, the degree that they are seeking, and their FY14 CIFAR projects are listed below:

- **Lauren Bell**, School of Fisheries & Ocean Sciences, UAF. *"Lower trophic level food web structure on the Beaufort Sea slope."*
- **Gregory Deemer**, Atmospheric Sciences, UAF. *"Towards improving operational sea-ice forecasts: Serving commercial and societal needs in the North Pacific."*
- **Carlos Serratos**, School of Fisheries & Ocean Sciences, UAF. *"Temporal comparison of epibenthic community and food web structure in the southern Chukchi Sea between 2004–2012."*
- **Anna Szymanski**, School of Fisheries & Ocean Sciences, UAF. *"Sinking or seeding: the spring fate of ice algae along the Bering Sea shelf."*
- **Sarah Traiger**, School of Fisheries & Ocean Sciences, UAF. *"Effects of glacial discharge on recruitment and succession on coastal rock communities."*
- **Jonathan Whitefield**, School of Fisheries & Ocean Sciences, UAF. *"Analysis of freshwater and heat pathways between the Pacific, Arctic and North Atlantic Oceans."*

In addition, **Elizaveta Ershova**, a Ph.D. student selected by the 2012 review panel, received second-year funding for her project "*Residents vs. expatriates in the Pacific-Arctic gateway: unraveling the summer distribution of sibling copepod species in the Chukchi Sea*".

In response to the 2014 announcement of funding opportunity, 26 proposals were received, reviewed, and considered by our review panel on 4 April 2014.

Student Support through Individual Awards
As shown in Appendix 1, 15 students (4 undergraduate, 11 graduate) were funded through individual CIFAR projects. Two graduate students being supported by Stock Assessment Training Stipends and one graduate student (**Torge Steensen**) 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 25 November 2013, where new funding opportunities and the current plan for CIFAR succession were discussed.

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
CIFAR funding in this theme is primarily from small NOAA investments that have focused on important ecosystem habitats and components ranging from Bering Sea benthic infauna (CIFAR13-033) to moored observations of ocean acidification in the southern Bering Sea shelf and coastal Gulf of Alaska (CIFAR 13-021) to bowhead whale prey in the western Beaufort Sea (CIFAR 13-014) and sablefish ecology and population dynamics in the North Pacific (CIFAR12-025).

In response to a critical need identified in the 2011 review of CIFAR conducted by a NOAA Science Advisory Board–appointed team, four Synthesis of Arctic Research (SOAR) projects led by CIFAR PIs are integrating information from completed and ongoing research in the Pacific Arctic Region (CIFAR 13-34 to 13-37) and are approaching completion. These studies will increase our understanding of the relationships among oceanographic conditions, benthic organisms, low trophic pelagic species and higher trophic species with specific emphasis on the Chukchi Sea Lease Sale Areas, and will allow NOAA to better focus future research funding on the most critical research needs.

Climate Change & Variability
NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) has invested in two CIFAR projects addressing climate change and variability (CIFAR 13-015 and CIFAR13-030) needs for developing specific satellite products to be used for NWS operational needs in high latitudes. Jessie Cherry and Ph.D. student, **Katrina Bennett**, have been developing a near-real-time snow and hydrology forecast products with the Anchorage River Forecast Center in support of spring breakup needs. Cherry and Ph.D. student, **Molly Tedesche,** are working with NMFS, the Juneau NWS forecast office, and the River Forecast Center to determine snow cover and water resources for existing and proposed hydroelectric facilities in southeast Alaska.

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

Dmitry Brazhnikov, Ph.D. student under Zygmunt Kowalik, has assisted in refinements to the global tsunami model to be utilized for tsunami warnings and prediction. Brazhnikov has been working toward incorporating submarine landslide into the existing three dimensional model of tsunami waves by comparing numerical solutions with known analytical viscous flows and with results of verified numerical solutions (CIFAR 12-008, Task 1). His research also involves examining the role of directional properties of submarine seamounts on the propagation of tsunamis in the North Pacific.

Throughout the entire year, storms represent the most important high-impact weather events over Alaska and its adjacent seas. The ability to forecast these events with longer lead times will significantly reduce hazards to coastal residents, vessels, and industries that live and work in these vulnerable areas. **Norman Shippee**, a Ph.D. student at University of Victoria, working with David Atkinson (CIFAR 13-032), has been developing a seasonal extratropical cyclone activity outlook for the North Pacific, Bering Sea, and Alaska using statistical modeling techniques to reproduce storm activity in sub-regions of the study area. Development of an experimental forecast product in a "hindcast" mode has provided reasonably good fit to the storm activity in winter months in the Gulf of Alaska.

Two Ph.D. students have had major roles in the validation of satellite-derived volcanic ash retrievals from Geostationary Operational Environmental Satellite-R series (GOES-R) products (CIFAR 13-028). Volcanic ash clouds are a severe (and relatively frequent) event in Alaska and can cause serious damage to aircraft, cause airport closures, and affect human health. **Torge Steensen**, who finished in August 2013, determined volcanic ash retrievals and compared them to the Weather Research & Forecasting (WRF)-Chem and Puff Volcanic ash models. He built a tool to compare satellite data to the modeled three-dimensional ash cloud. **Sean Egan** is comparing WRF-Chem sulfur dioxide simulations to satellite-based retrievals using UV and thermal infrared data.

Publications and Presentations

Thirty conference presentations (both national and international) were reported for the period 1 April 2013–31 March 2014. Twelve peer-reviewed papers were published, with 4 additional papers in press or accepted for publication; several more have been submitted or are in review. Many PIs also have papers under preparation.

Besides this activity for projects funded directly by NOAA through CIFAR, 6 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
University of Alaska Fairbanks

CIFAR theme: Ecosystem studies and forecasting

NOAA Goals: Healthy Oceans

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

Primary objectives

This project continues 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 CIFAR program has been in place since 2002 as a collaboration 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 professors Anne Beaudreau and Terrance Quinn as co-PI's. As described below, two graduate students are making good progress in both their education and research.

Karson Coutre (M.S. Fisheries) started the graduate program in July 2012. Coutre worked closely with her committee chair (Beaudreau) and in consultation with NOAA collaborators to develop a thesis project structured as two chapters: (1) Temporal and ontogenetic patterns in the diet of juvenile sablefish; and (2) Movement patterns and habitat use of juvenile sablefish in Southeast Alaska.

Coutre and Beaudreau completed five sampling trips over two years (July & September 2012; May, July, & September 2013) in St. John the Baptist Bay, Baranof Island, Alaska, to tag and collect stomach contents from juvenile sablefish. Coutre finished processing stomach content samples and entering data during fall 2013. She has presented results, describing growth and food habits of juvenile sablefish, at three professional meetings (two during this reporting period, see below). She is currently writing her first chapter and has begun preliminary analysis of available acoustic tagging data for St. John the Baptist Bay sablefish.

Briefly, key findings related to Coutre's first thesis chapter are as follows: (1) juvenile sablefish are opportunistic predators with a diverse diet composed of more than 50 fish and invertebrate taxa; (2) based on the results of a multivariate analysis, diet composition of juvenile sablefish differs significantly among sampling periods and years; (3) the occurrence and biomass of Pacific herring, euphausiids, and adult spawning salmon in sablefish diets drive the major differences observed across sampling periods. The findings suggest that these seasonally abundant, high energy resources may be important for juvenile sablefish to achieve the body condition necessary for overwinter survival.

Kari Fenske (Ph.D. Fisheries) is in her 4th semester at UAF, having started in fall 2012, and is supervised by Quinn. The work is being prepared as three chapters of a PhD dissertation, each of which is a manuscript for publication. Chapter 1 is 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). Fenske was a volunteer on the NMFS longline survey in August 2013 to learn about survey data collection firsthand. A major part of this work is to disaggregate data into appropriate regions. Through a careful review of sample sizes and data quality, it has been decided that three regions will be used (Bering Sea/ Aleutians Islands/ Western Gulf of Alaska [GOA], Central GOA, and Eastern GOA). The disaggregation is near completion. A principal finding is that there appear to be appreciable differences in biological data among regions.

Chapter 2 will use the spatially-explicit model as a basis for data simulations to explore management strategy evaluations. The goal is 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. Various scenarios have been developed and are being finalized. Fenske attended the Groundfish Plan Team meeting in November 2013. She observed the discussions about the current single-area sablefish stock assessment and gained a better understanding of the issues surrounding sablefish management.

A third chapter will examine environmental and climate change effects on the management strategy evaluation in Chapter 2. Further elaboration of this chapter is forthcoming.

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. Two former Ph.D. students funded by these traineeships have already become members of Plan Teams of the North Pacific Fishery Management Council.

Education

Coutre successfully defended her thesis proposal to the committee (Beaudreau, UAF-Fisheries; Franz Mueter, UAF-Fisheries; Pat Malecha, NOAA-TSMRI) in November 2013 and advanced to Master's candidacy in spring 2014. She has completed all coursework on her Graduate Study Plan and is on track to defend her thesis in summer 2014 and graduate in fall 2014.

Fenske presented a clear and concise Powerpoint presentation on her research progress at her annual graduate committee meeting in March 2014. Her committee members are Terrance Quinn (chair), Anne Beaudreau, Keith Criddle, and Dana Hanselman (TSMRI, affiliate professor). Fenske received approval of her thesis proposal in March 2013 and will revise it to provide further elaboration about chapter 3. She has completed all coursework for her program. She will take the comprehensive exam in summer 2014.

Outreach

Coutre and Fenske presented their research on sablefish at the event "How to Make a Black Cod Lose its Lunch, and Other Ocean Science Stories from University of Alaska Fairbanks Graduate Students," organized by Beaudreau. On December 5, 2013, Beaudreau and six graduate students, including Coutre, designed and held a science day for the Big Brothers/Big Sisters organization of Juneau, AK titled "Sampling Science with Fish Fanatics!" The half-day event, attended by more than 20 people, was designed to introduce K-6 students to fisheries science through hands-on activities. A particular highlight was a diet detective game that Coutre designed, in which the students had to identify "prey items" constructed out of craft materials using a simple dichotomous key.

Fenske served as liason to the Alaska Chapter of the American Fisheries Society (AFS), representing both Juneau and Fairbanks students; her term ended October 2013. She helped coordinate and attended the Alaska Chapter AFS annual meeting in Fairbanks (October 2013). Coutre was the Juneau student AFS subunit leader from January 2013 until April 2014. Both students were on the organizing committee for the 2014 UAF Fisheries Graduate Student Symposium.

Presentations (all made by the student first author)

Oral presentations

Coutre, K.M., A.H. Beaudreau and P. Malecha. 2013. Seasonal and ontogenetic patterns of resource use by juvenile sablefish, *Anoplopoma fimbria*, in southeast Alaska. AFS Alaska Chapter meeting, Fairbanks, Alaska, October 2013. Oral presentation.

Coutre, K.M., A.H. Beaudreau and P. Malecha. 2014. Seasonal and ontogenetic patterns of resource use by juvenile sablefish, *Anoplopoma fimbria*, in southeast Alaska. Western Groundfish Conference, Victoria, B.C., February 2014.

Fenske, K.H., D.H. Hanselman and T.J. Quinn II. 2014. Slicing the (data) pie: Initial results from dividing data and moving towards a spatial stock assessment for North Pacific sablefish. Western Groundfish conference, Victoria, B.C., February 2014.

Poster presentation

Fenske, K.H., D.H. Hanselman and T.J. Quinn II. 2013. A spatially-explicit, age-structured stock assessment model of north Pacific sablefish, *Anaplopoma fimbria*. International Council for the Exploration of the Sea (ICES) World Conference on Stock Assessment Methods, Boston, Massachusetts, July 2013.

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 and is currently funded through FY14. We are requesting an extension for the Stock Assessment Training stipends to continue funding for Karson Coutre (expected completion date: fall 2014) and Kari Fenske (expected completion date: fall 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: NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
This award is complete under NA08OAR4320751.
The project continues under NA13OAR4320056.

Primary objectives

In support of the Russian-American Long-term Census of the Arctic (RUSALCA) research projects, 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

Representatives from Axiom attended the RUSALCA PI meeting in February 2014, where they demonstrated the workplace and beta versions of several data exploration tools. A number of datasets were secured from the PIs at that time.

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.

Bering Sea benthic habitat & ecosystem infauna

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

NOAA Goals: Healthy Oceans

CIFAR 13-033: This project is complete. — Line Office NMFS; Cynthia Yeung/Bob McConnaughey, Sponsor

Primary objectives
In collaboration with the NMFS Alaska Fisheries Science Center 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 $4100 was requested for sorting these samples. Processing commenced immediately on the 1-jar samples, while awaiting approval for additional funds.

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 of all 25 samples (55 jars) is complete. The history, meta, and data files were submitted electronically to McConnaughey and Yeung on April 3, 2014.

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.

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 complete. — 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

As of February 2014 we have had great success with four ocean acidification moorings sites around Alaska. These include the two original sites (GAK 1 and M2) as well as additional locations (SE Alaska and Kodiak). All of the information and mooring data can be found at http://www.pmel.noaa.gov/co2/story/Coastal+Moorings.

Synthesis of this mooring data has led to a considerable increase in our understanding of the biogeochemistry of high-latitude shelf regions. To date, the data has been used in two publications whose abstracts are listed below. Full citations are listed in the publication section.

Evidence of prolonged aragonite undersaturations in the bottom waters of the southern Bering Sea shelf from autonomous sensors

The southeastern shelf of the Bering Sea is a dynamic area that experiences seasonal variability in primary production and remineralization of organic matter that largely controls the carbon biogeochemistry of the water column. Surface water partial pressure of carbon dioxide (pCO_2) is greatly reduced in summer by biological production, which increases carbonate mineral saturation states (Ω). In contrast, the export of large quantities of organic matter from surface blooms drives an active remineralization loop that sharply increases pCO_2 near the bottom, while lowering pH and suppressing Ω. New observations from moored biogeochemical sensors at the surface showed that seasonal net community production lowers surface water pCO_2, causing large gradients between the ocean and atmosphere that are sustained throughout the summer, confirming that surface waters likely remain supersaturated with respect to aragonite throughout the open water season. On the other hand, moored sensors deployed near the bottom showed that pCO_2 levels exceed 500 µatm by early June and remain at these high levels well into the autumn months indicating that the bottom waters are likely continuously undersaturated in aragonite for at least several months during each year. However, only a small fraction of the increased pCO_2 can currently be attributed to the intrusion of anthropogenic CO_2 from the atmosphere, while the majority is due to natural respiration processes. Therefore, the timing and duration of these undersaturation events are likely critical in the development of larval and juvenile calcifiers in the region and will change as anthropogenic CO_2 concentrations continue to rise.

The Gulf of Alaska coastal ocean as an atmospheric CO_2 sink

A new data set of directly measured surface seawater carbon dioxide partial pressures (pCO_2) was compiled for the Gulf of Alaska (GOA) coastal ocean. Using this information, along with reconstructed atmospheric pCO2 data, we calculate sea–air CO_2 fluxes over two interconnected domains: the coastal ocean defined by the Surface Ocean CO_2 Atlas (SOCAT) Continental Margin Mask, and the continental margin shoreward of the 1500 m isobath. The continental margin in this region lies within the coastal ocean. Climatological sea–air CO_2 fluxes were calculated by constructing monthly climatologies of sea–air pCO_2 difference (ΔpCO_2), sea surface temperature, salinity, and CO_2 solubility, coupled with the monthly second moment of wind speeds from the Scatterometer Climatology of Ocean Winds (SCOW; http://cioss.coas.oregonstate.edu/scow). Climatological sea–air CO_2 fluxes showed instances of atmospheric CO_2 uptake and outgassing in both domains for nearly all months; however, uptake dominated from April through November, with distinct spring and autumn peaks that coincided with periods of strong winds and undersaturated surface seawater pCO_2 with respect to atmospheric levels. Atmospheric CO_2 uptake during the spring and autumn peaks was stronger on the continental margin compared with the coastal ocean. Annual mean area-weighted fluxes for the coastal ocean and continental margin were −2.5 and −4 mmol CO_2 m^{-2} d^{-1}, respectively. Scaling these annual means by the respective surface areas of each domain resulted in estimates of substantial atmospheric CO_2 uptake between 34 and 14 Tg C yr^{-1}. This region is a large sink for atmospheric CO_2, which impacts the current view of weak net CO_2 emission from coastal waters surrounding North America.

NOAA relevance/societal benefits

These 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 and continues to provide a rich dataset for this commercially important region.

Outreach

In 2014, Mathis gave a talk at the Alaska Marine Science Symposium that incorporated data from this project (see below for details) and held an ocean acidification town hall meeting in Anchorage that was attended by over 100 people.

Publications, conference papers, and presentations

Peer-reviewed publication

Evans, W. and J.T. Mathis. 2013. The Gulf of Alaska coastal ocean as an atmospheric CO_2 sink. *Continental Shelf Research* 65:52–63, doi: 10.1016/j.csr.2013.06.013.

Publication in press

Mathis, J.T., J.N. Cross, N. Monacci, R.A. Feely and P. Stabeno. Evidence of prolonged aragonite undersaturations in the bottom waters of the southern Bering Sea shelf from autonomous sensors. *Deep Sea Research II*, http://dx.doi.org/10.1016/j.dsr2.2013.07.019, in press (corrected proof available online).

Oral presentation

Mathis, J. 2014. Ocean Acidification: Perceptions, risks, and uncertainties. Alaska Marine Science Symposium, Anchorage, Alaska, 22 January 2014.

Changes/problems/special reporting requirements

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,
Kim Shelden, 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 is being expanded to accommodate additional statistical analyses. This manuscript will 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.

Education

Heather McEachen, a Ph.D. student at UAF, is supported in part by this CIFAR project. Ms. McEachen is preparing for her oral exam scheduled for fall 2014.

Publications, conference papers, and presentations

Oral Presentations

Okkonen, S. 2014. A conceptual model of a bowhead whale feeding hotspot near Barrow, Alaska. UAF Institute of Marine Science departmental seminar, 12 February 2014, Fairbanks, Alaska

Okkonen, S., C. Ashjian, R. Campbell, K. Stafford, J. Clarke, F. Bahr and R. Suydam. 2014. Variability of late summer conditions in Barrow Canyon. Ocean Sciences Meeting, 24–28 February 2014, Honolulu, Hawaii.

Poster presentation

Okkonen, S.R. 2014. A statistical summary of current velocities in Barrow Canyon and on the western Beaufort Shelf. Alaska Marine Science Symposium, 20–24 January 2014, Anchorage, 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 2013 calendar (see last year's report), is well underway and scheduled for release in October 2014 at the Alaska Federation of Natives meeting in Anchorage. Periodic updates on the progress of this film are posted on the blog site http://arcticcurrents.wordpress.com/. Clips from the film have been shown during a presentation on the Arctic ecosystem to PolarTrec teachers (10 February 2014, Fairbanks) and during the Institute of Marine Science departmental seminar given by Okkonen (12 February 2014, Fairbanks).

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
Anne Beaudreau, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem studies and forecasting

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 the Alaska Fisheries Science Center (AFSC)/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)

Karson Coutre (M.S. student) continued her research on: (1) Temporal and ontogenetic patterns in the diet of juvenile sablefish; and (2) Movement patterns and habitat use of juvenile sablefish in Southeast Alaska.

During this reporting period, Coutre and Beaudreau completed the final three of five sampling trips (July & September 2012; May, July, & September 2013) in St. John the Baptist Bay, Baranof Island, Alaska, to tag and collect stomach contents from juvenile sablefish. Coutre finished processing stomach content samples and entering data during fall 2013. She has presented results, describing growth and food habits of juvenile sablefish, at three professional meetings (two this reporting period; one reported last year). Coutre has begun preliminary analysis of available acoustic tagging data for St. John the Baptist Bay sablefish.

Briefly, Coutre's key findings are as follows: (1) juvenile sablefish are opportunistic predators with a diverse diet composed of more than 50 fish and invertebrate taxa; (2) based on the results of a multivariate analysis, diet composition of juvenile sablefish differs significantly among sampling periods and years; (3) the occurrence and biomass of Pacific herring, euphausiids, and adult spawning salmon in sablefish diets drive the major differences observed across sampling periods. Research findings suggest that these seasonally abundant, high energy resources may be important for juvenile sablefish to achieve the body condition necessary for overwinter survival.

Apportionment and population dynamics (Quinn)

The research of Kari Fenske (Ph.D. student) has 3 objectives that will ultimately be dissertation chapters and published manuscripts.

(1) **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).** A major part of this work is to disaggregate data into appropriate regions. Through a careful review of sample sizes and data quality, it has been decided that three regions will be used (Bering Sea/ Aleutians Islands/ Western Gulf of Alaska [GOA], Central GOA, and Eastern GOA). The disaggregation is near completion.

This work is in conjunction with James Murphy, who developed an age-structured movement model before leaving TSMRI for the private sector. This collaborative work will be prepared with Quinn taking the lead in converting this earlier work into a scientific manuscript for publication in a leading journal.

(2) **Use the spatially-explicit model as a basis for data simulations to explore management strategy evaluations**. The goal is 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. Various scenarios have been developed and are being finalized.

(3) **Examine environmental and climate change effects on the management strategy evaluation** in objective 2.

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

Education

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

Presentations

For a list of the four presentations made during the reporting period, see companion project "Stock assessment training stipends" in the Task I section of this report.

Outreach
Beaudreau organized an outreach event for the public that featured presentations and a panel discussion by six UAF graduate students at the Alaska State Museum on 27 April 2013. Coutre and Fenske presented 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."

On December 5, 2013, Beaudreau and six graduate students, including Coutre, designed and held a science day for the Big Brothers/Big Sisters organization of Juneau, AK titled "Sampling Science with Fish Fanatics!" The half-day event, attended by more than 20 people, was designed to introduce K-6 students to fisheries science through hands-on activities. A particular highlight was a diet detective game that Coutre designed, in which the students had to identify "prey items" constructed out of craft materials using a simple dichotomous key.

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 two 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.

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. The SOAR projects from CIFAR are:

- *Factors maintaining sea bird and mammal benthic hotspots: a latitudinal analysis*, PI Bodil Bluhm
- *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
- *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
Arny Blanchard, co-PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

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 ongoing.

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

During the reporting period, the lead team of this effort, Grebmeier and Bluhm have been working on compiling a draft manuscript that forms the deliverable of this project. All contributors received a matrix last year that outlined the data needs by variable and statistical metric and provided the geographic bounding boxes for the identified regions of high macrobenthic biomass. These areas are located south of St. Lawrence Island, in the Chirikov Basin, the Hope Basin in the southern Chukchi Sea and in the northeastern Chukchi Sea (shown as boxes, bottom to top, respectively, in Figure 1). We decided to omit the Barrow Canyon area, as a whole separate paper by Pickart et al. is dedicated to that area under the SOAR umbrella.

Our current draft contains an integrated introduction, a composite brief methods section for each of the disciplines involved, followed by a results section that currently contains about 10 composite figures and 6 tables and is organized by discipline from physics to biology and from lower to higher trophic levels. We are working on an outline of the discussion. A draft to all co-authors will be circulated shortly for their comments and corrections.

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 list of authors for the planned paper will be close to the following:
Grebmeier, J.[1], B.A. Bluhm[2], K. Arrigo[3], A. Blanchard[2], J. Clarke[4], L. Cooper[1], S. Danielson[2], R. Day[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], B. Norcross[2], S. Okkonen[2], T. Weingartner[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]Leidos, Buckley WA, [5]Alaska Biological Research, Inc., Fairbanks, AK, [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,

Grebmeier and Bluhm are co-leading the effort, are conducting the majority of the writing and all of the organizing with Grebmeier serving as the lead author. All co-authors contribute data, paragraphs describing their data, and comments on the complete manuscript.

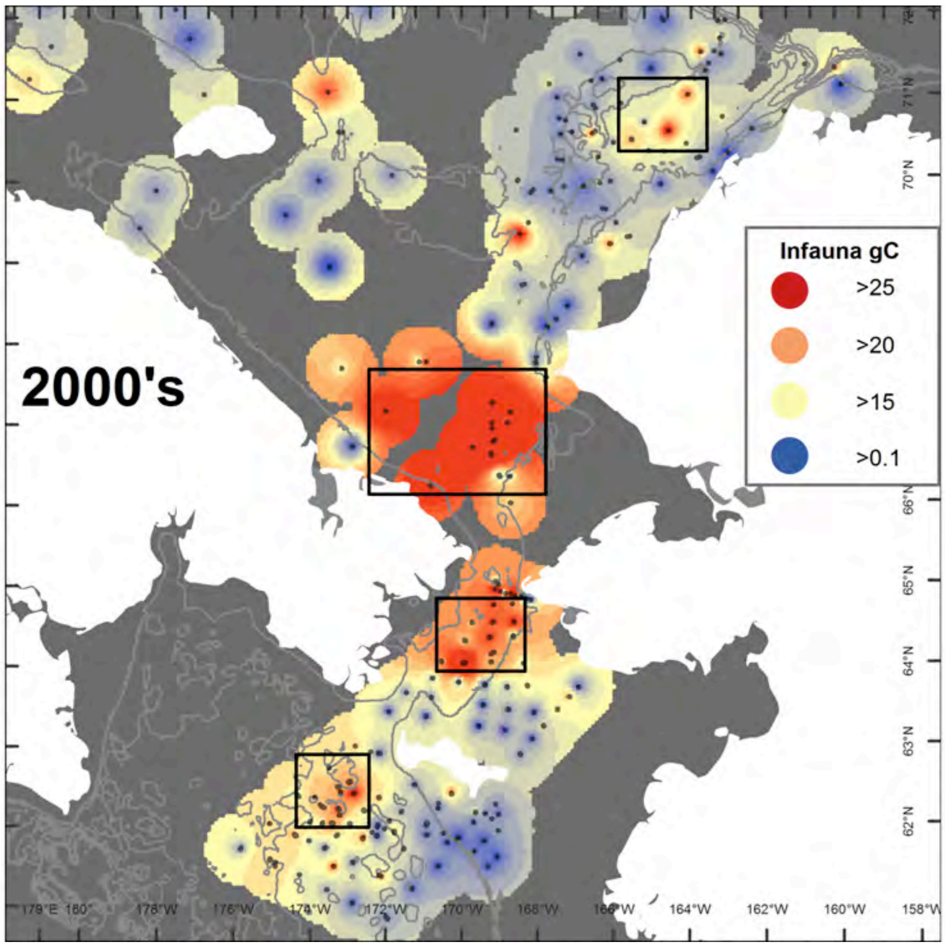

Figure 1. Highlighted boxes show locations of persistent, high benthic macrofaunal biomass in the northern Bering and Chukchi seas. The project is focused on characterizing those boxed areas in an interdisciplinary fashion. We concentrate on the 2000+ time period.

Presentations/Outreach

The project was presented as part of a poster by Sheffield Guy, Moore and Stabeno about the entire SOAR project at the Alaska Marine Science Symposium in Anchorage in January of 2014. PI Grebmeier also reported on the status of the effort to the SOAR steering group at their meeting in Anchorage in January 2014.

Changes/problems/special reporting requirements

The original 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. Most of the originally listed co-authors, however, have contributed sections to the current draft.

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
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

CIFAR 13-034: This project is ongoing.

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 traveled to Monterey, California in May 2013 where he acquired Naval Postgraduate School numerical model output from colleagues Wieslaw Maslowski and Jackie Clement-Kinney. While in Monterey, Okkonen developed custom programs to analyze and visualize the numerical model output.

We have developed a straw man hypothesis suggesting that the cue for the onset of the fall westward migration of bowhead whales from the eastern Beaufort Sea is some threshold availability of zooplankton prey. In the eastern Arctic, these zooplankton prey are believed to be primarily copepods. Greater residence depths associated with diapause, imply stronger and more persistent easterly winds as being necessary to upwell the copepods onto the shallow shelf in the eastern Beaufort Sea whereupon they can be efficiently grazed by bowhead whales. Of the nine seasons (mid-August to mid-September 2005-2013) in which we have been conducting oceanographic field work in the Barrow area, there were two years (2007 and 2011) in which we did not see bowhead whales near Barrow. Both of these years were characterized by unusually strong and persistent easterly winds in the southern Beaufort Sea and late arrivals (October) of whales at Barrow. At present, we are awaiting analyses of passive acoustic recordings of marine mammal vocalizations acquired by hydrophone arrays deployed on the Alaskan Beaufort shelf east of Prudhoe Bay in support of this hypothesis.

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): Oceanographic factors associated with bowhead whale hotspots and variations in the migration path

Stephen Okkonen, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

CIFAR 13-035: This project is ongoing.

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 traveled to Monterey, California in May 2013 where he acquired Naval Postgraduate School numerical model output from colleagues Wieslaw Maslowski and Jackie Clement-Kinney. While in Monterey, Okkonen developed custom programs to analyze and visualize the numerical model output. Selected model products were incorporated into a manuscript which was submitted to *Progress in Oceanography* in December 2013. The manuscript is currently under review. Portions of this manuscript were presented by Okkonen at the Institute of Marine Science departmental seminar on 12 February 2014 in Fairbanks.

A second manuscript comparing migratory paths of tagged bowheads with modeled oceanographic features will be started this spring.

The model output acquired for this project is also being shared with Robert Suydam (North Slope Borough Department of Wildlife Management), John Citta (Alaska Department of Fish and Game), and Donna Hauser (Ph.D. candidate, University of Washington) for preparation of manuscripts on beluga whale dive behavior in Barrow Canyon and beluga dive behavior in the Beaufort Sea.

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

Publication submitted

Citta, J.J., L.T. Quakenbush, S.R. Okkonen, M.L. Druckenmiller, W. Maslowski, J.C. George, H. Brower, R.J. Small, L.A. Harwood, and M-P. Heide-Jørgensen. Core use areas of western Arctic bowhead whales and their ecological characteristics. Submitted to *Progress in Oceanography*.

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): An ocean acidification sensitivity index for the Pacific Arctic Region

Tom Weingartner, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Studies & Forecasting

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 complete.

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

The synthesis is complete and the manuscript is submitted to *Progress in Oceanography*. The main reseach highlights and paper abstract are shown below.

Highlights:

- The coastal oceans around Alaska are sensitive to further changes in carbonate chemistry due to ocean acidification.
- The vast commercial fisheries in Alaska are co-located in regions that have already undergone significant changes in carbonate chemistry due to ocean acidification and the intensity, extent and duration of ocean acidification will increase as atmospheric CO_2 levels continue to rise.
- Regions in southeast and southwest Alaska are highly reliant on fishery harvests and have relatively lower income and employment alternatives and these locations face the highest risk from ocean acidification.

Abstract:
Highly productive Alaskan commercial and subsistence fisheries are located in seas projected to experience rapid transitions in temperature, pH, and other chemical parameters caused by global change, especially ocean acidification (OA). Many of the marine organisms that are most intensely affected by OA, such as mollusks, are native to Alaska and contribute substantially to the state's highly productive commercial fisheries and traditional subsistence way of life. Prior studies of OA's potential impacts on human communities have focused on possible economic losses from specific scenarios of human dependence on harvests and damages to marine species. However, non-economic impacts due to global change are likely to also manifest, such as changes in food security or shifts in livelihoods, owing to the intrinsic characteristics of the affected human communities. This study assesses current patterns of dependence on marine resources within Alaska that could be negatively impacted by OA and current community characteristics to assess the risk to the fishery sector from OA. The study uses a risk assessment framework based on one developed by the Intergovernmental Panel on Climate Change to analyze earth-system global ocean model hindcasts and forecasts of ocean chemistry, commercial and subsistence fisheries harvest data, and demographic information. An index incorporating all of these data compares overall risk among Alaska's federally designated census areas and boroughs. The analysis showed that regions in southeast and southwest Alaska that are highly reliant on fishery harvests and have relatively lower income and employment alternatives face the highest risk from OA. Results presented here suggest that OA merits consideration in policy and adaptation planning, as it may represent yet another challenge to Alaskan communities, some of which are already at socio-economic risk.

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

Publication submitted

Mathis, J.T., S.R. Cooley, N. Lucey, C. Hauri, J. Ekstrom, T. Hurst, S. Colt, W. Evans, J.N. Cross, and R.A. Feely. Ocean acidification risk assessment for Alaska's fishery sector. Submitted to *Progress in Oceanography*.

Oral presentations

Mathis, J. 2014. Ocean acidification: Risks and uncertainties. Presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, 22 January 2014.

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

Steve Colt, University of Alaska Anchorage – Alaska fisheries economic analysis

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:
Eric Stevens and 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.*

The University of Alaska worked with NASA Short-term Prediction Research and Transition Center (SPoRT) to deliver products to the NWS in Alaska for use in forecasting and issuing warnings. GINA built virtual machines to run SPoRT software and produce satellite imagery locally in Alaska, with the motivation of maximizing the speed of delivering the imagery to the NWS in Alaska. GINA and SPoRT collaborated to deliver "Red, Green, Blue (RGB) Night-Time Microphysics" imagery to the NWS beginning in the winter of 2013–2014. (Figure 1)

GINA continues to deliver imagery to the NWS for use by the "Ice Desk" in analyzing and forecasting the extent of sea ice over the ocean surrounding Alaska. In addition to accessing Proving Ground imagery via Advanced Weather Interactive Processing System (AWIPS), the NWS Ice Desk makes consistent use of GINA's "Puffin Feeder" website to access imagery. (Figure 2)

GINA staff have met several times with NWS forecasters and managers from Anchorage, Juneau, and Fairbanks to gather feedback concerning the utility of Proving Ground imagery in the forecast process. GINA Science Liaison Eric Stevens has represented GINA during workshops held at NASA/SPoRT and Cooperative Institute for Meteorological Satellite Studies (CIMSS) and also recorded three editions of "Alaska Weather Facts" on the topic of satellite imagery for use on the NWS television show "Alaska Weather." GINA also collaborated with NOAA and the National Weather Service to coordinate the Proving Ground's OCONUS (Outside the Contiguous U.S.) Meeting in June 2013.

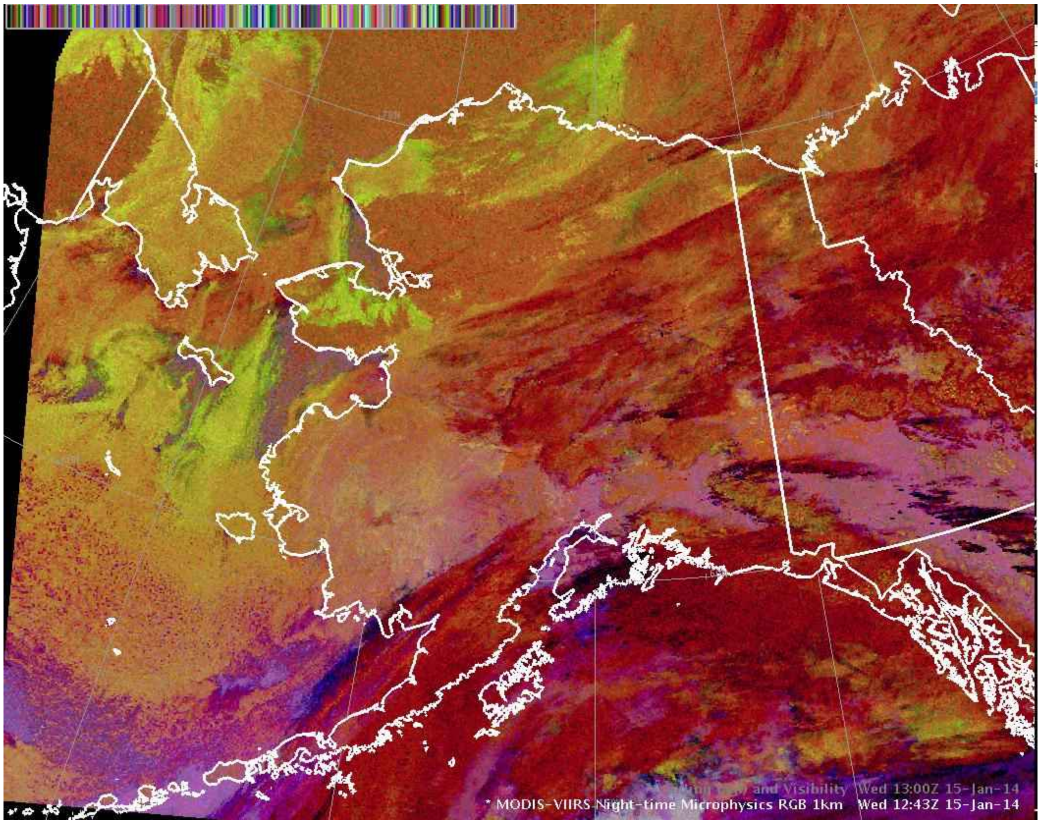

Figure 1. Screen capture from the operational Advanced Weather Interactive Processing System (AWIPS) at NWS Fairbanks showing the MODIS-VIIRS Night-Time Microphysics product generated by GINA using data received by direct broadcast and processed by virtual machines running SPoRT software

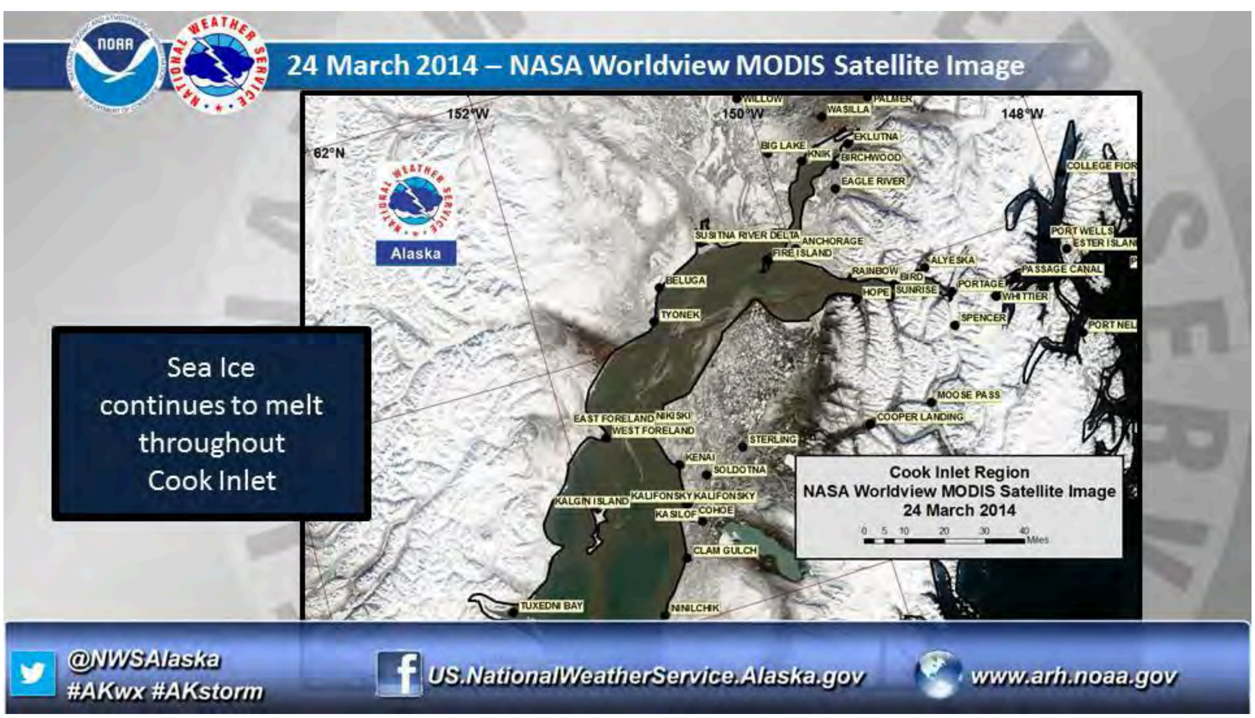

Figure 2. The National Weather Service in Alaska makes extensive use of social media. Here is an example from the NWS Ice Desk highlighting MODIS imagery delivered to the NWS by GINA.

Through leveraged funds, Cherry has also co-located *in-situ* instrumentation with 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 Acquisitions Station (FCDAS) facility near Fox, Alaska, 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 Joint Polar Satellite System (JPSS) 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 Alaska Pacific River Forecast Center (APRFC) to develop improved forecast models for the snowmelt season using Moderate Resolution Imaging Spectrometer (MODIS)-derived imagery. This will be described in more detail below.

A second identifiable product has been probability of blowing snow for transportation risk. Initial work has been completed suggesting a blowing snow algorithm applied to model fields yields accurate results compared to *in situ* measures of visibility. A follow-on proposal will focus on use of remote sensing to verify and refine the algorithm.

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. candidate) have developed several key features of the Community Hydrologic Prediction System (CHPS)/Flood Early Warning System (FEWS) forecasting system in offline-mode to support the integration of MODIS (MOD10A1 version 5 from the Terra satellite) 500m pixel daily satellite imagery of snow cover fraction (SCF) in the Snow-17 snow model as an observed variable for the time period 2000–2010. The initial stages of the work included validation of the MODIS data against climate stations (SNOTEL and GHCD) across the Interior of Alaska, and a non-linear modeling approach to identify key melt metrics, such as the date of minimum and maximum melt, melt rate and duration of melt period. These statistics may be useful to ecological managers or analysts attempting to understand and characterize biological responses to melt conditions in Alaskan watersheds. The study focuses on 38 Interior Alaskan locations and comparisons of melt indices based on MOD10A1 models, and then uses the modeling framework to reproduce the non-linear curves using ancillary data, in this case the North American Regional Reanalysis is the basis for this analysis. This information can be used to extend the MOD10A1 temporally, and thus will provide a means to extend the MODIS data for validation and testing of new products as they come online, such as the Visible Infrared Imaging Radiometer Suite (VIIRS) remote sensing product and other GOES-R supported update products.

The APRFC, which provides forecasts for all of Alaska, uses Snow-17, along with the Sacramento Soil Moisture accounting model as the main tool for their main hydrological modeling and prediction of sub-daily streamflow. This project study area comprises four sub-watersheds (Chatanika, Chena, Salcha and Goodpaster basins) of the Tanana River basin located nearby Fairbanks, Alaska. The project focuses primarily on the adaptation of the software to a) ingest preprocessed (clipped and reprojected to Alaska) MODIS imagery as grids of fractional snow cover extent, b) clip the grids and calculate areal averages for each sub-basin in the study area, c) replace the conceptual snow cover depletion curve with the observed areal extent of snow cover, d) run the model with these new observations and, e) calibrate the model to this new simulation. The last step in the project will involve comparing the two products and determining the differences and similarities between the two streamflow predictions. Additional features have been added to CHPS, including a tool to spatially display the raw MOD10A1 daily SCF grids for validation purposes, differencing maps to measure anomalies in modeling vs observed snow cover areal extent, and calibration-based statistics of mean volume bias, Nash Sutcliff model efficiency coefficient, and RMSE (root mean square error) of flow for monthly, seasonal and annual time scales over the period of study (2000–2010).

The second stage of this work had been to develop a parallel workflow for the MODIS Snow Covered Area and Grain Size (MODSCAG) data, which was made available to Cherry in February 2014. MODSCAG builds on the MOD09A1 and utilizes the spectral reflectance of snow varies with grain size to estimate the snow cover fractional area of a pixel (463m). The data set has been noted by some to be a significant improvement from the MOD10A1 product in studies in the western US and in the Himalayan mountain ranges. MODSCSAG data was downloaded, clipped and then pre-processed using the same approach developed for the MOD10A1 product. A similar workflow will be developed in CHPS and will allow for intercomparison of the two MODIS data sets to determine if improvements in the streamflow simulation can be achieved using the MODSCAG data set.

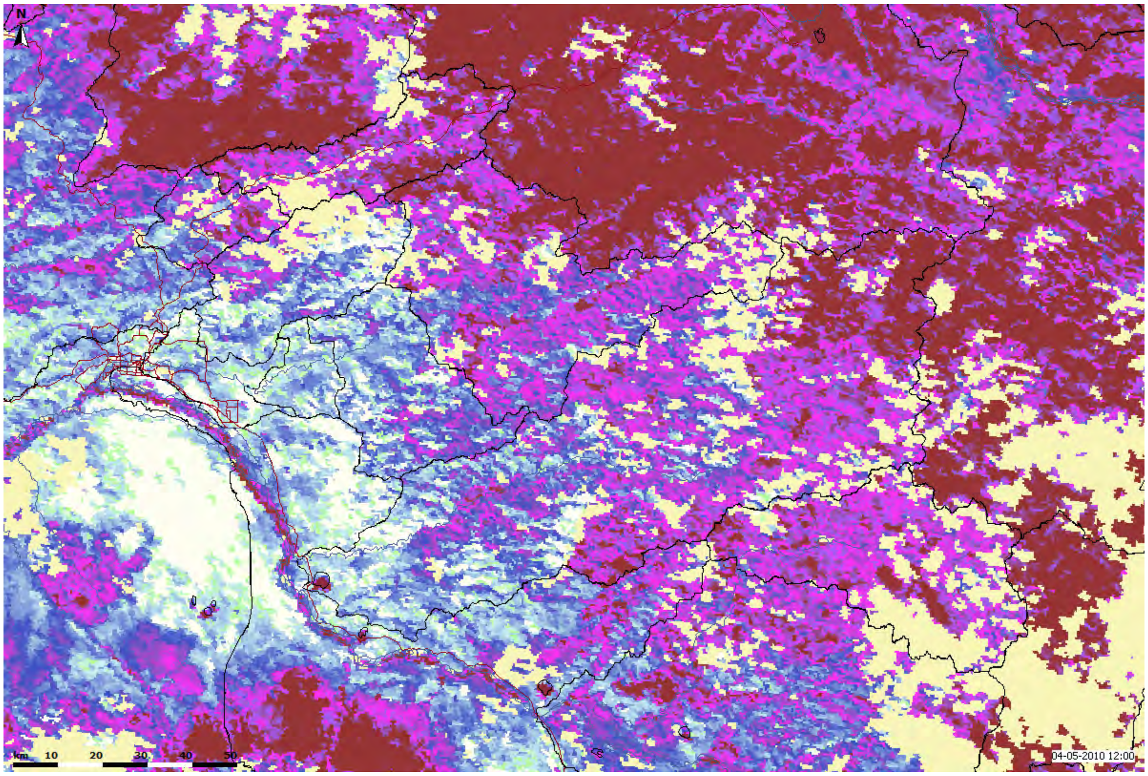

Figure 3. MODIS gridded areal extent of snow cover (AESC) data ingested in CHPS prior to serial and spatial clipping. White represents no snow, green/blue/purple/brick red represents snow covered in increasing snow cover fractions (1–100%). Pale yellow is cloud covered.

The techniques to import MODIS gridded snow cover fractions could be implemented operationally for use in forecasting mode, and this is being discussed by GINA and the AKRFC. In order to carry out this project, a live-data feed of MODIS data would be required. CHPS may be set up to ingest the raw Hierarchical Data Format (HDF) MODIS swath data tiles, and preprocessing tools currently undertaken in ArcGIS would be replicated in CHPS. The process would require initial testing and development in the offline version of CHPS, and then the workflow could be developed in the operational version of CHPS. Alternatively, the import of MODIS data on-the-fly for short periods (1–10 days, for example) could be implemented in CHPS via what is referred to by operational forecasters as a MOD (or modification). The MOD could serve to import the MODIS areal extent of snow cover (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 River Forecast Center (RFC) with a direct means of utilizing the live MODIS satellite imagery for forecasting applications.

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.

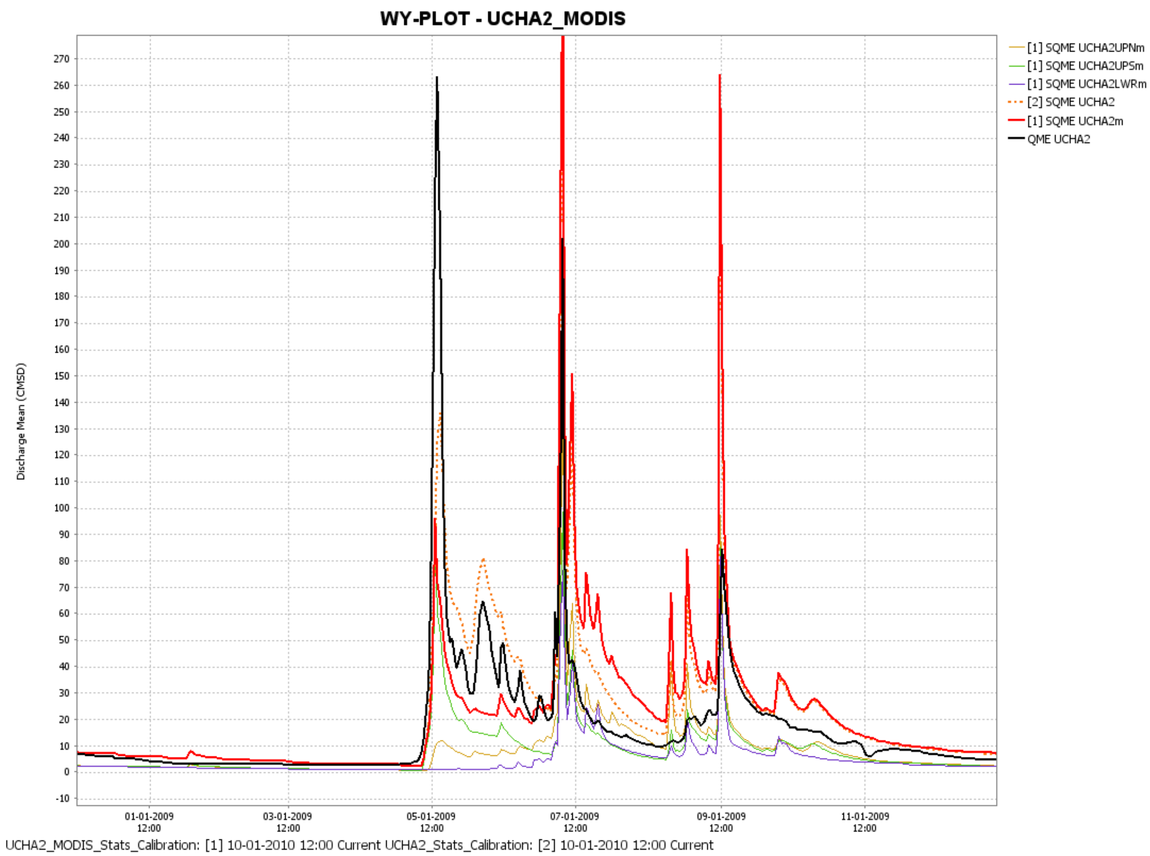

Figure 4. CHPS modeled streamflow for the Upper Chena River basin with and without MODIS AESC (prior to re-calibration). The red line represents the streamflow with AESC observed from MODIS, the dashed orange line represents modeled streamflow using the SNOW-17 areal depletion curve. Observed streamflow is shown in black. The green, blue and brown lines designate the upper south and north basins, and the lower basin, respectively.

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. candidate, began working on this project in August 2010 and continues to be supported in part through this project through to summer 2014.
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, Anchorage, and Juneau, the Alaska Aviation Weather Unit, the River Forecast Center, and the Center Weather Service 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 primarily in support of spring breakup, and Tedesche, Stevens, and Cherry are working with the NWS forecast office in Juneau with an emphasis on hydropower.

Publications, conference papers, and presentations

Submitted for publication

Bennett, K.E., J.E. Cherry, C.A. Hiemstra, L.D. Hinzman and K. Semmens. MODIS-derived snow melt timing in boreal warm-permafrost watersheds of Interior Alaska: validation, modeling and comparison.

Oral presentations

Cherry, J.E., K.E. Bennett and M. Tedesche. 2013. Hydrology, hydropower, and remote sensing in Alaska. OCONUS NESDIS Proving Ground Meeting, 17–21 June 2013.

Stevens, E. 2013. Alaska Region satellite products and data needs. OCONUS NESDIS Proving Ground Meeting, 17–21 June 2013.

Bennett, K.E., J.E. Cherry, C. Hiemstra and W.R. Bolton. 2013. Comparison of snow melt properties across multiple spatial scales and landscape units in Interior Alaska. American Geophysical Union meeting, San Francisco, California, December 2013.

Cherry, J.E., K.E. Bennett, D. Morton and V. Alexeev. 2014. Selected results: Snow research supporting NOAA's mission in Alaska. NOAA Satellite Science Week, virtual meeting, 10–14 March 2014.

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

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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

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Thomas Heinrichs, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

Other investigators/professionals funded by this project:
Eric Stevens, Jiang Zhu, Jay Cable, Scott Macfarlane, Will Fisher, Dayne Broderson *University of Alaska Fairbanks*

NOAA Goal: Climate Adaptation & Mitigation

CIFAR 12-030/13-030:
This award is complete under NA08OAR4320751.
The project continues under NA13OAR4320056.

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. Other NOAA cooperative institute partners include the University of Wisconsin

Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) and the Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA).

In Alaska, the primary focus will be on the atmosphere and cloud products that can be used to address forecasting 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. *GINA Puffin Feeder provides Visible Infrared Imaging Radiometer Suite* (*VIIRS*) *products for use by the Alaska NWS Ice Program.* VIIRS products are being produced in near-real-time in Geographic Tagged Image File Format (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. Examples are shown below (Figures 1 and 2)

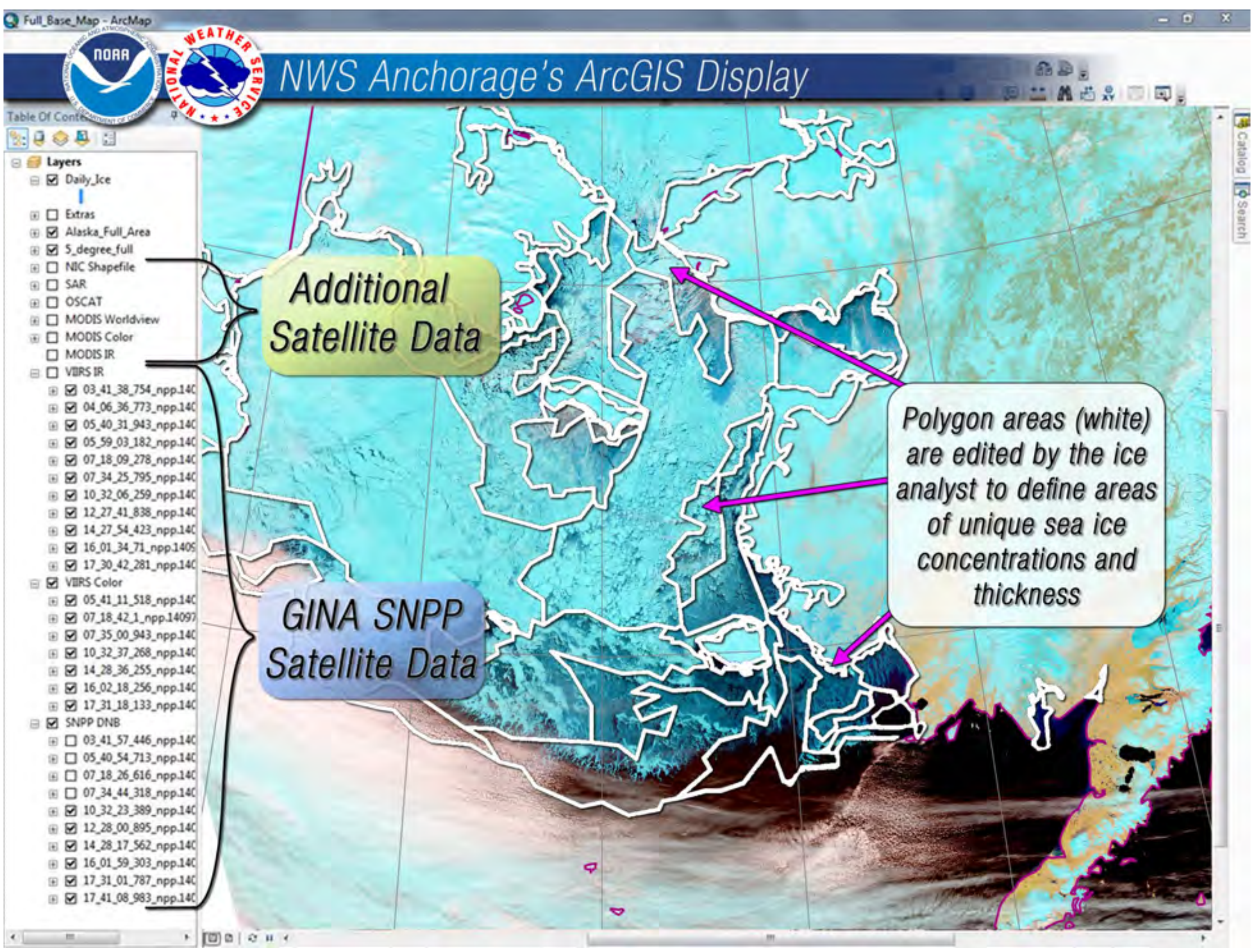

*Figure 1. An example screen shot of a NWS Alaska sea ice analyst's work environment. VIIRS imagery is a key information input from the Suomi National Polar-Orbiting Partnership (*SNPP*).*

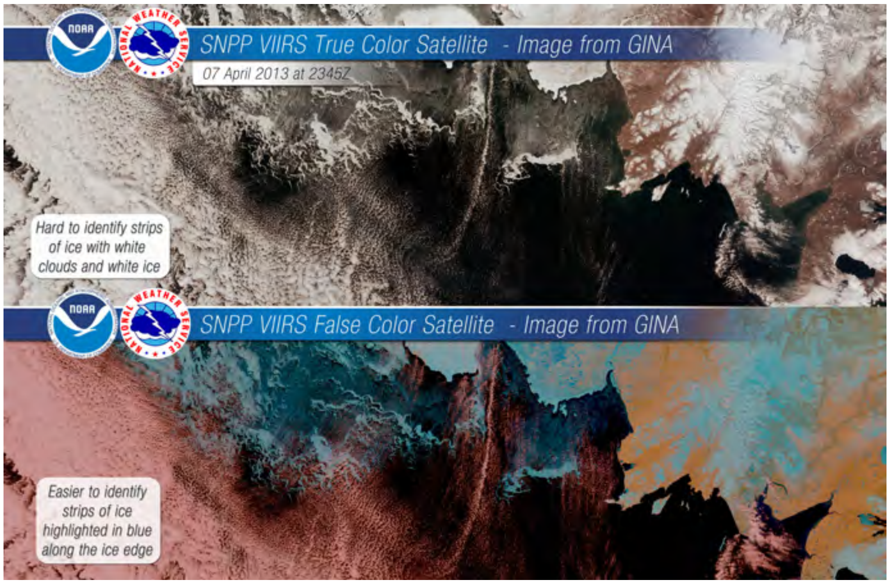

Figure 2. Special VIIRS band combinations that help NWS Alaska sea ice analysts by creating contrast among clouds, snow, and sea ice.

2. *Supplied 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 3)

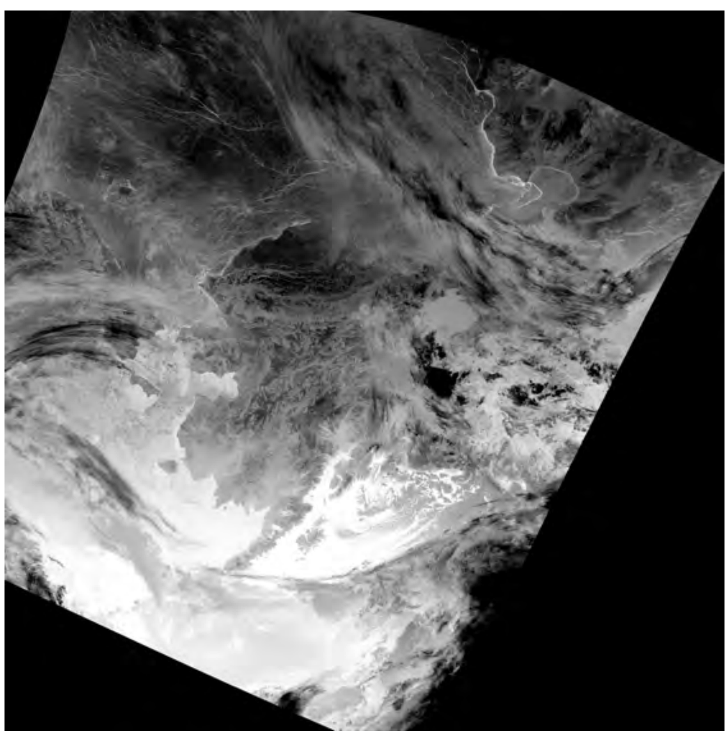

Figure 3. Sample of VIIRS I05 longwave infrared imagery provided in near real time to the NOAA National Ice Center and Alaska NWS Sea Ice Program.

The GINA-WRF (Weather Research & Forecasting) model was configured to include two domains. The coarse domain with 18 km resolution covers the whole Alaska region and a nested domain with 6 km resolution covers the Fairbanks area. The GSI (gridpoint statistical interpolation) 3d-var data assimilation scheme was used in the experiments. GFS forecast were used as initial condition. Only the best quality AIRS/CrIS (Atmospheric Infrared Sounder / Cross-track Infrared Sounder) sounder profile data were assimilated. The model runs in cycling mode with 12-hour spin-up time. Satellite sounder profile data was brought in every 6 hours. Many case studies and a one-month continuous run were done. The initial conclusions were: while the sounder profile data does improve the initial conditions for the GINA-WRF model, the positive impact to forecast is localized and short-term. The degree of impact changes with variables.

We want to continue this research in the following two directions: 1. Bring more satellite data into the cycling WRF model run. 2. Test different data assimilation schemes to further improve the weather forecast accuracy.

3. *Participated in 2013 NOAA Satellite Conference.*
   Tom Heinrichs and Eric Stevens represented GINA at the 2013 NOAA Satellite Conference in College Park, Maryland in April 2013. Eric was lead author and presented a poster on the topic, "Suomi NPP VIIRS Imagery and the Grounding of the Oil Platform Kulluk in Alaska." Tom Heinrichs presented a poster, "Use of GOES-R Imagery in the Detection Volcanic Ash and the Production of Aviation Warnings in Alaska."

4. *Participated in CSPP/IMAPP Users Group Meeting*
   Scott Macfarlane and Eric Stevens represented GINA at the CSPP/IMAPP Users Group Meeting in Madison, Wisconsin in May, 2013, where CSPP is the Community Satellite Processing Package and IMAPP is the International MODIS (or Moderate-resolution Imaging Spectroradiometer)/AIRS Processing Package (IMAPP). Scott gave a presentation on the topic, "CSPP and IMAPP Real-Time Processing in Alaska."

5. *Helped organize and hosted OCONUS meeting*
   GINA staff, in collaboration with NWS Alaska and the Satellite Proving Ground, organized and hosted the OCONUS (Outside (the) contiguous United States) meeting held in Anchorage and Fairbanks in June 2013. Representatives of CIMSS, CIRA, and SPoRT attended, as well as program managers from the satellite proving grounds. GINA staff gave several presentations during the conference.

6. *Began producing NASA SPoRT's RGB (red, green, blue color model) Night-Time Microphysics products from VIIRS and MODIS data on virtual machines at GINA for use by National Weather Service offices in Alaska.*
   With the motivation to deliver SPoRT's RGB NT-Micro product to Alaskan NWS offices with minimal latency, it was proposed that GINA host virtual machines (VMs), thereby eliminating the delay incurred in shipping the products from Alabama to Alaska. The hoped-for improvements in latency have only been partially realized, however, due to the slowness of the VMs at GINA. Work is ongoing to make the VMs run as efficiently as possible. SPoRT staff involved in this effort includes Kevin Fuell, Matt Smith, and Kevin McGrath.

7. *Collaborated with SPoRT to evaluate RGB Night-Time Microphysics product by NWS offices in Alaska from December 2013 through February 2014.*
   Kevin Fuell and staff at NASA SPoRT produced a "Quick Guide" document and an "Articulate Presentations" module as training resources for use by NWS in Alaska. Eric Stevens of GINA provided input to SPoRT during the development of these training materials and traveled to NWS Anchorage in early December to speak with forecasters and NWS management about the evaluation. Links to the training materials area available on SPoRT's web site at http://weather.msfc.nasa.gov/sport/training

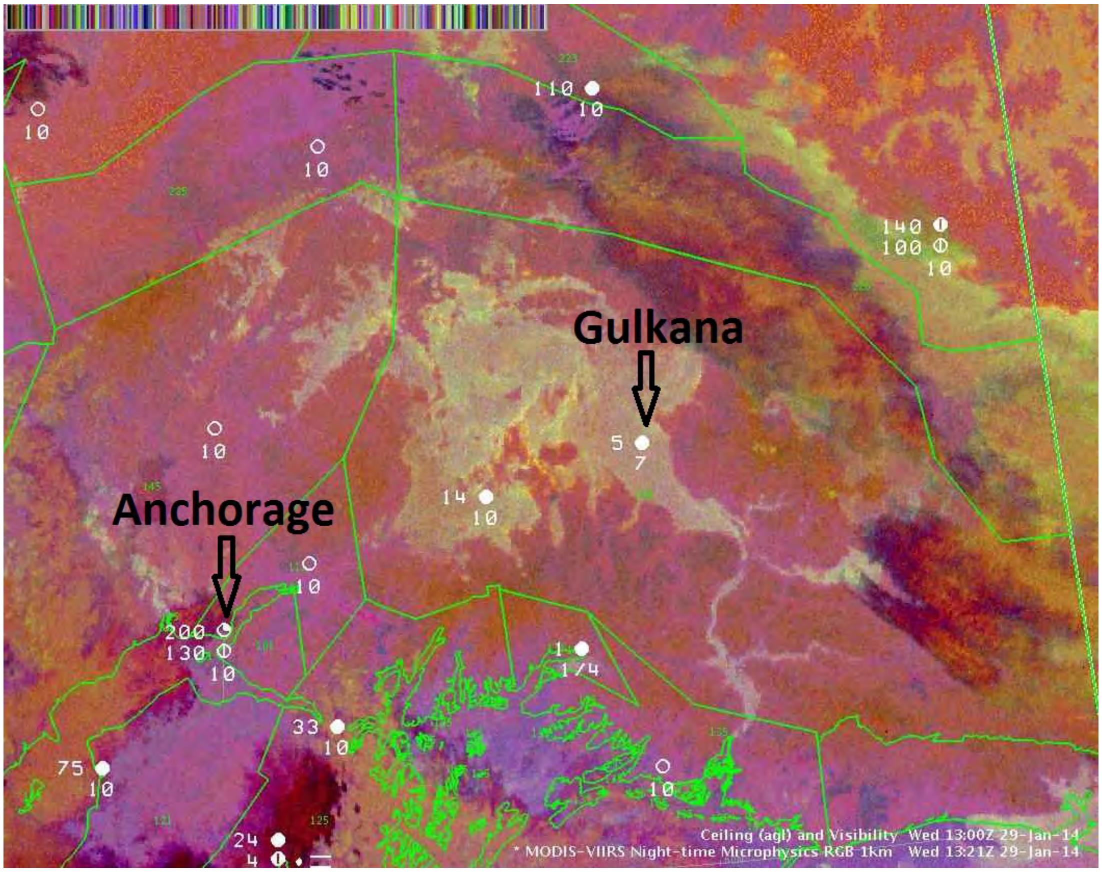

Figure 4. Screen capture from AWIPS2 at WFO Fairbanks showing the RGB Night-Time Microphysics product generated from SPoRT software run on virtual machines at GINA and delivered via LDM from GINA to NWS Alaska

8. *Worked with CIMSS on CrIS update to CSPP Polar2Grid.*
   GINA's Scott Macfarlane collaborated with staff at CIMSS on the pending update to the CSPP code which will allow production of products from CrIS data. Staff involved at CIMSS includes Kathy Strabala, Elisabeth Weiss, and David Hose. Implementation of this update is expected in second quarter 2014.

9. *Participated in the SNPP SDR review in December*
   Eric Stevens of GINA gave a presentation, "Use of VIIRS by the National Weather Service in Alaska" at the "Suomi NPP Science Data Record (SDR) Science and Products Review" held in College Park, Maryland.

10. *Recorded a segment for the "Alaska Weather" television program on the topic of the VIIRS Day-Night Band*
    In December, staff at the National Weather Service in Anchorage recorded an interview with Eric Stevens of GINA on the topic of the VIIRS Day-Night Band and its use in weather forecasting in Alaska. This segment was broadcast state-wide in Alaska in February 2014 as part of the public television program, "Alaska Weather" produced by studio KAKM in Anchorage. This segment is also available on the JPSS web site at www.jpss.noaa.gov/video_gallery.html

11. *Began participation in a project to develop and use VIIRS imagery during flood events in the spring "breakup" period.*
    GINA, under the leadership of the JPSS Program Office and in collaboration with George Mason University, the City College of New York, the National Weather Service's North-Central River Forecast Center and Alaska-Pacific River Forecast Center, contributed to the development of new products to be produced from VIIRS data and used by the River Forecast Centers (RFCs) to identify areas of over-land flooding during floods in the spring "breakup" period along the Red River of the North and the Yukon River. It is expected that the resulting products will be available to the NWS in Alaska during the breakup period of 2014 beginning in April.

12. *GINA staff presented JPSS work at the annual meeting of the American Meteorological Society.* Jiang Zhu and Eric Stevens of GINA attended the annual meeting of the American Meteorological Society (AMS) in Atlanta, Georgia in February 2014. Jiang was lead author and presented a poster, “Satellite Sounder Data Assimilation for Improving Alaska Region Weather Forecast.” Eric Stevens gave an oral presentation on the topic, “Use of VIIRS Imagery by the National Weather Service in Alaska.”
13. *Met NOAA Satellite Liaisons and CIMSS staff.* Eric Stevens traveled to Madison, Wisconsin in March 2014 to meet with the NOAA Satellite Liaisons and staff at CIMSS. Eric gave a PowerPoint presentation on Proving Ground activities at GINA and in NWS Alaska Region and also had several one-on-one meetings with CIMSS staff to discuss projects relevant to Alaska.

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 presentations

Stevens, E. 2013. Alaska Region satellite product and data needs – Near-term and longer term future needs. NOAA-NESDIS OCONUS meeting, Anchorage and Fairbanks, Alaska, 17–21 June 2013.

Stevens, E. 2013. Use of VIIRS by the National Weather Service in Alaska. Suomi NPP SDR Science and Products Review, College Park, Maryland, 18–20 December 2013.

Stevens, E. 2014. Use of VIIRS imagery by the National Weather Service in Alaska. American Meteorological Society meeting, Atlanta, Georgia, 2–6 February 2014.

Poster presentations

Stevens, E. and J. Nelson. 2013. Suomi NPP VIIRS imagery and the grounding of the oil platform Kulluk in Alaska. NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, College Park, Maryland, 8–12 April 2013.

Heinrichs, T., E. Stevens and N. Eckstein. 2013. Use of GOES-R imagery in the detection of volcanic ash and the production of aviation warnings in Alaska. NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, College Park, Maryland, 8–12 April 2013.

Zhu, J., E. Stevens, B.T. Zavodsky, X. Zhang, T. Heinrichs and D. Broderson. 2014. Satellite sounder data assimilation for improving Alaska Region weather forecast. American Meteorological Society meeting, Atlanta, Georgia, 2–6 February 2014.

Outreach

Stevens, Eric. Video segment recorded for Alaska Weather news show regarding SNPP VIIRS Day-Night Band. Broadcast in February 2014. www.jpss.noaa.gov/video_gallery.html

Other products and outcomes

GINA staff worked with NASA Direct Readout Laboratory personnel and the Alaska Volcano Observatory (AVO) to process SNPP OMPS (Ozone Mapping and Profiler Suite) instrument and derive ozone, aerosol, SO_2, and volcanic ash products to support AVO and the Alaska NWS Aviation Weather Unit.

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

Colorado State University CIRA: In-kind support, Collaborative research, Personnel exchanges

NASA Direct Readout Laboratory: In-kind support, Collaborative research, Personnel exchanges

Improving predictive capabilities for the Arctic ice: international cooperative network

Igor Polyakov, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

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

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

CIFAR 12-029: This project is complete. Line Office OAR-CPO; 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.

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

Following the project goal and objectives, the project team (including V. Ivanov and V. Smolyanitsky, both AARI; I. Polyakov and A. Pnyushkov, both IARC; and A. Tivy, now Canadian Ice Service) in year 1, succeeded in building ice concentration climatology (described in CIFAR's year 4 report). The following year, we focused on using ice climatology for ice predictions (described in CIFAR's year 5 report). This year's efforts were on using ice climatology for analysis of causes for long-term Arctic sea-ice change.

Using ice climatology for analysis of causes for long-term Arctic sea-ice change (year 3)

Satellite observations of Arctic sea ice extent since 1979 show a dramatic decrease, and this decrease has been attributed to anthropogenic influence (Min et al., 2008; Kay et al., 2011). Some reconstructions and individual records suggest that sea ice extent may have exhibited an upward trend for several decades prior to the 1970s, but this trend has previously been interpreted as internal climate variability (Mysak et al., 1990; Johannessen et al., 2004). Moreover, the in-filled observational datasets (Rayner et al., 2003; Walsh and Chapman, 2001) shown in the recent Intergovernmental Panel on Climate Change Assessment (IPCC, 2013), and used in other comparisons with climate model simulations (Min et al., 2008; Kay et al., 2011), exhibit almost constant annual mean Arctic sea ice extent throughout the period prior to 1970. In our analysis (to be submitted to *Nature*) we present a new dataset based on in situ observations without infilling, which shows widespread increases in annual mean Arctic sea ice concentration between 1940 and 1970, and we show that this increase is consistent with climate model simulations of an aerosol-driven increase in Arctic sea ice extent over this period (Figure 1). This behavior is consistent with a well-documented Arctic cooling over the 1940–1970 period (Johannessen et al., 2004; Gillett et al., 2008; Fyfe et al., 2013), itself largely driven by aerosol increases (Fyfe et al., 2013). These results challenge the perception that Arctic sea ice extent was unperturbed by human influence until the 1970s, showing instead that it has exhibited forced multi-decadal variations through the 20th century, with implications for our understanding of impacts and adaptation in human and natural Arctic systems (Hamilton et al., 2004).

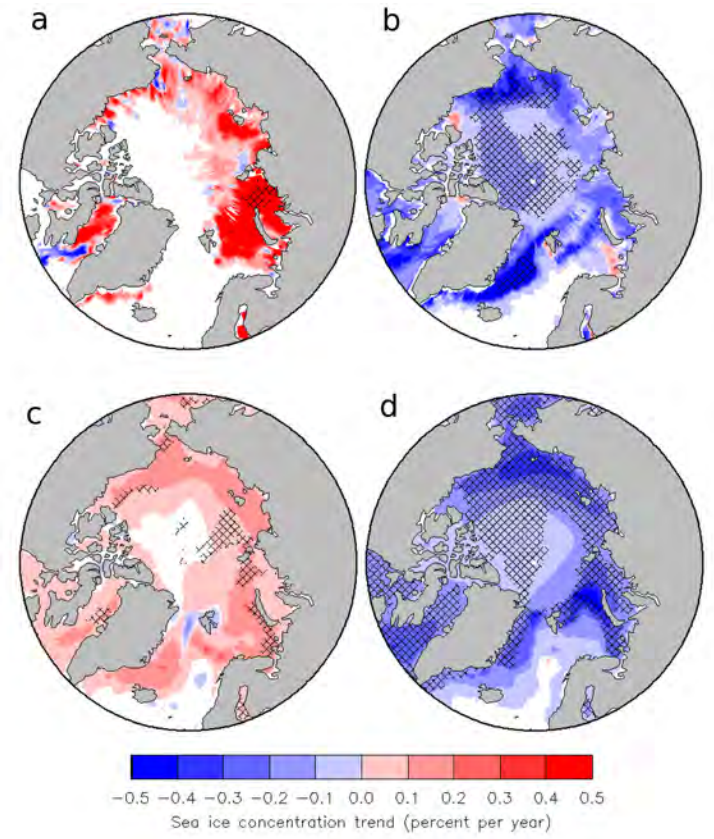

Figure 1. Trends in annual mean sea ice concentration. a. and b. Observed trends for 1940–1970 and 1970–2005, respectively. Observed trends are based on annual averages where at least 6 months of data are available, and these annual average trends are plotted only at locations with at least ten years of data between 1940 and 1970, and with at least fifteen years of data between 1970 and 2005. Hatching indicates where the observed trends are significant at the 95% level. c. and d. Model-mean trends for 1940–1970 and 1970–2005, respectively, with hatching indicating where the model mean trends are significant at the 95% level based on the inter-model spread. From Gagné et al. (submitted).

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Rayner, N.A. et al. 2003. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *Journal of Geophysical Research*, 108, doi: 10.1029/2002JD002670.

Walsh, J.E. and W.L. Chapman. 2001. 20^{th}-century sea-ice variations from observational data. *Annals of Glaciology*, 33:444–448.

Publications and presentations

Peer-reviewed publications

Polyakov, I.V., U.S. Bhatt, J.E. Walsh, E.P. Abrahamsen and P.F. Wassmann. 2013. Recent oceanic changes in the Arctic in the context of long-term observations. Ecological Applications, 23(8):1745–1764. doi: http://dx.doi.org/10.1891/11-0902.1

Polyakov, I.V., A.V. Pnyushkov, R. Rember, L. Padman, E.C. Carmack and J.M. Jackson. 2013. Winter convection transports Atlantic Water heat to the surface layer in the eastern Arctic Ocean. *Journal of Physical Oceanography*, 43(10):2142–2155. doi: 10.1175/JPO-D-12-0169.1

Submitted for publication

Gagné, M.-E., J.C. Fyfe, N.P. Gillett, I.V. Polyakov and G.M. Flato. Aerosol-driven increase in Arctic sea ice from 1940 to 1970. Submitted to *Nature*.

Oral presentation

Ivanov, V., et al. 2013. Ocean heat effect on the observed and predicted reduction of the Arctic sea ice. European Geophysical Union General Assembly, Vienna, 7–12 April 2013.

Poster presentations

Tivy, A. 2013. Skill of persistence forecasts of arctic sea ice concentration, area and extent on monthly to seasonal time-scales. International Workshop on Seasonal to Decadal Prediction, Toulouse France, 13–16 May 2013.

Tivy, A. and T. Carrieres. 2013. A preliminary assessment of seasonal forecast skill for sea ice in the Beaufort Sea, 22nd International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), Espoo, Finland, 2–13 June 2013.

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. Our ongoing work with modelers greatly enhanced our ability to address the project objectives.

Quarterly Alaska climate seasonal overview and impacts

Sarah Trainor, PI
John Walsh, PI
University of Alaska Fairbanks

CIFAR theme: Climate Change & Variability

NOAA Goal: Climate Adaptation & Mitigation

CIFAR 13-038: This project is complete.

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.

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. As of this reporting period it is available on the National Integrated Drought Information Center (NIDIS) website (http://www.drought.gov/media/pgfiles/AK%20Sept2012%20Outlook.pdf).

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

Natalia Ruppert, PI ***CIFAR theme: Coastal Hazards***
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 (UAF)

Other investigators/professionals associated with this project:
J. Horrillo*, Texas A&M University at Galveston (TAMUG);* ***W. Knight****, West Coast and Alaska Tsunami Warning Center (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, Kowalik et al., 2005, 2008; Horrillo et al., 2012). 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 past year, chapter III of this book has been revised and sections on the landslide generated tsunami were enlarged to include our latest experiments on submarine debris movements.

In this reporting period the tsunami code development proceeded along two directions: modeling of the large scale tsunami dynamics and development of models for the land-slide generated tsunami.

The main contribution to this project contains Task 1 of the plan: *Tsunami program optimization and physics enhancement by dispersive processes*. The task was accomplished by cooperation of Z. Kowalik and D. Brazhnikov (UAF), J. Horrillo (TAMUG), W. Knight (WC/ATWC). We have based our research on the previously developed and tested Global Tsunami Model (GTM). The model domain covered the entire World Ocean extending from 80S to 69N. The model spatial resolution was 1 minute and its domain included approximately 200 million grid points. The model was applied to test its skill in the simulation of the Indian Ocean tsunami (IOT) case of 26 December 2004 and Kuril Islands of November 15, 2006. To elucidate the physics of the dispersive processes for the trans-oceanic propagation we compared the energy fluxes for both the dispersive and non-dispersive waves. 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 (Horrillo et al., 2012) and for the laboratory experiments by Yamazaki et al. (2010). Numerical experiments defined bathymetric features which scatter the tsunami energy towards the West Coast via the Mendocino Escarpment. This escarpment seems to be efficient in delivering enhanced tsunami energy if the approaching tsunami signal travels from the west along the escarpment. To pinpoint the sources of the strong tsunami signal occurring often at Crescent City the energy flux was examined. The results are quite surprising; showing the key role in refocusing tsunami signal towards Crescent City played by the two bathymetric features Koko Guyot and the Hess Rise located thousands of kilometers from Crescent City. Our main effort in this reporting period was directed towards understanding directional/focusing properties of the Koko Guyot.

To test the idea of directivity the numerical experiments with prescribed wave forcing were performed. A tsunami wave train was sent towards the Koko Guyot from major directions. The waves were prescribed to arrive either from the West, resembling the generation area of Japan or the North, partially corresponding to the Kuril source region. At the same time to investigate resonance properties of the sea mount the wave periods were spanning from short waves of 2 minutes to long waves with period of 1 hour. Such wave trains were sent independently to study scattering properties of the Koko Guyot.

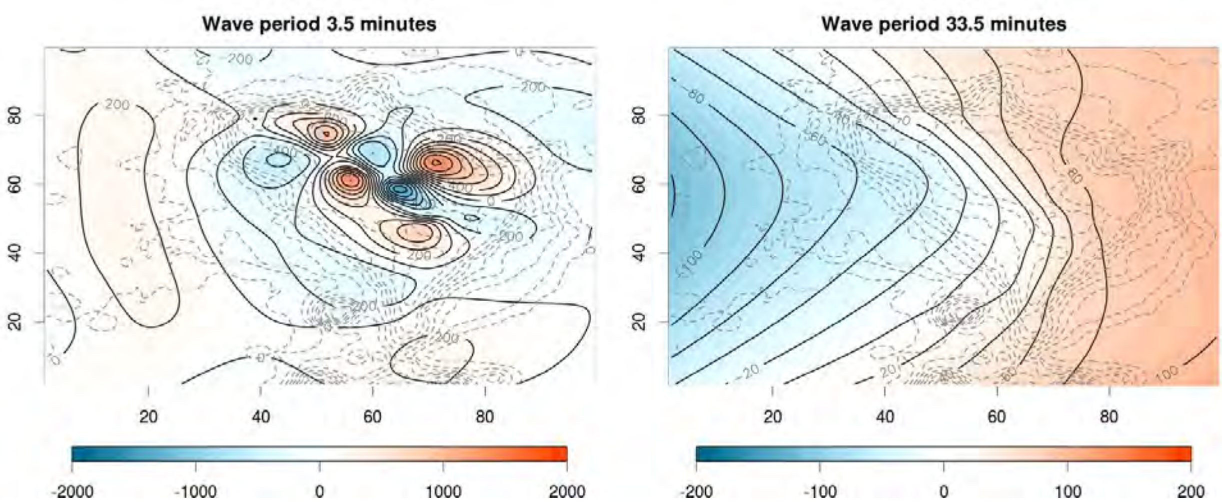

Figure 1. Change of wave field due to interaction with the Koko Guyot. Left panel - incident wave period 3.5 minutes, Right panel - 33.5 minutes. Colormap and black lines give wave amplitude in cm and grey dashed lines denote bathymetry. The far field amplitude is taken as 1m.

The experiments have proved initial hypothesis of the strong enhancement of short period tsunami waves (Figure 1, left panel). As the waves encountered small scale features of the sea mount relief the dipole resonant features were excited. These wave patterns tended to be trapped and further scattered in directions different from the initial. The longer periods were almost unaltered; their propagation was described by changes in the phase speed over shallow regions and consequent wave refraction (Figure 1, right panel).

The directivity experiments have shown the same type of resonance for both direction of incidence. Nevertheless, the scattering towards the NE was more pronounced for the experiments of the North arriving waves. Similar results were obtained from analysis of the model output for two tsunami cases (Figure 2). During the 2006 Kuril event, the tsunami wave arrived from the NW direction. The first arriving waves with the long periods were not influenced by the seamount (Figure 2a, results for 2.62 hours), the later shorter waves were highly scattered primarily towards the NE. Such a scattering pattern was not found for the 2011 Tohoku tsunami. While the waves were mainly arriving from the West, their wave field was largely influenced by refraction so that the maximum of energy flux was directed to the West and South. This was applicable both for the long and short periods. Nevertheless, the energy of secondary waves was also scattered towards the NE with much smaller portion of the overall incident energy than it was for the case of the 2006 Kuril tsunami. However, the flux deflected by the Koko Guyot towards the NE was an order of magnitude larger for the latter case since the Tohoku earthquake and tsunami had higher magnitude.

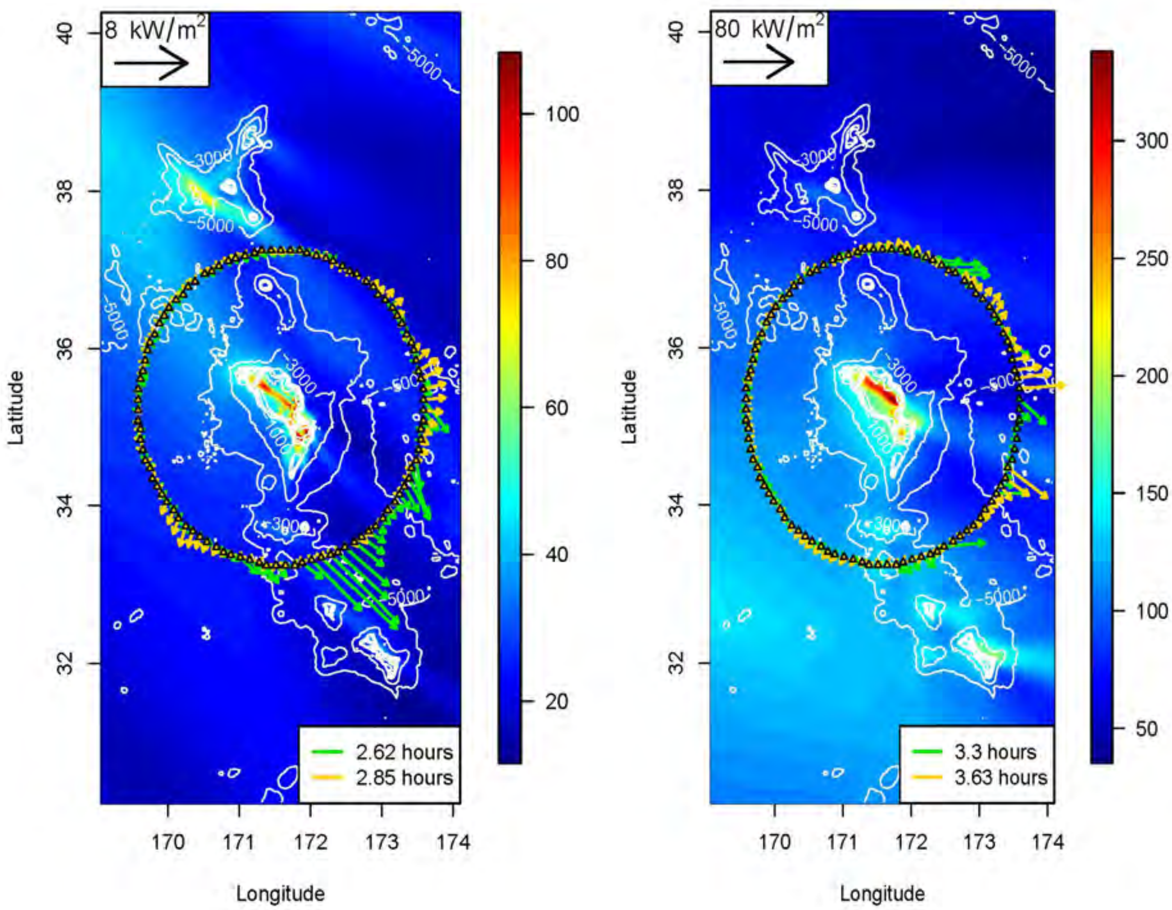

Figure 2. Characteristic distribution of energy flux around the Koko Guyot for Kuril tsunami of 2006 (left panel) and Japan tsunami of 2011 (right panel). Colormap gives maximum amplitude and time is given from the tsunami onset.

These results suggest that due to interference with the Koko Guyot the short period waves experience large changes in their propagation. It leads to deflection from the initial direction such that it can amplify the energy flux in quite specific directions. The numerical experiments have shown that the NE direction is one of them. As well, some incidence directions are prone to higher scattering. Both of these facts can be connected with the elliptical shape of the sea mount plateau with semi-major axis directed towards the NW and semi-minor axis towards the NE. Such orientation results in smaller propagation time along the semi-minor axis and thus can lead to higher scattering. Such increase of scattered wave energy will contribute to the tsunami wave field observed on the West Coast as large secondary waves that were found in sea level records for both tsunami events.

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 led by Juan Horrillo.

J. Horrillo 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). The existing model efficiently solves three dimensional Navier-Stokes equations with explicit time integration method and finite difference representation of spatial derivatives. The physics of the coupled system of water and landslide can be considered as a motion of highly viscous Newtonian fluid. Such an approach introduces variable and often extremely large kinematic viscosity into momentum equations. With further adjusting of viscosity governed by deformations of the mudflow it will be possible to model motion of Bingham fluid. The main effort was directed to incorporating such description of submarine landslide into the existing three dimensional model of tsunami waves.

Current numerical solutions are based on the explicit (in time) integration of the viscous terms. As Newtonian fluid is expressed by the high viscosity, the explicit numerical scheme has limited application due to severe stability criteria; therefore to avoid these limitations we aimed to develop an implicit form of the frictional term in the momentum equations.

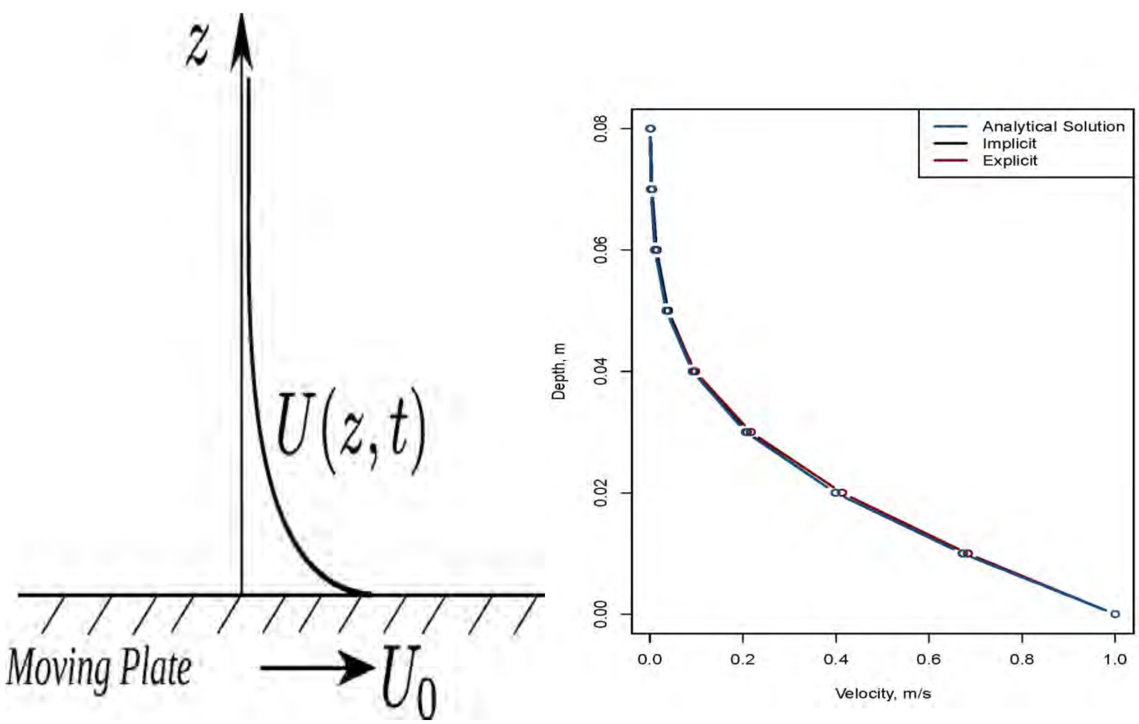

Figure 3. Flow generation by the moving plate, U_0 the plate speed, $U(z,t)$ velocity induced in the fluid. Left panel: schematic view of the test case. Right panel shows comparison of the explicit and implicit numerical solutions with the analytical solution.

For these purposes the Crank-Nicholson scheme for temporal discretization (Ferziger and Peric, 1996) was applied. Analysis of the semi-implicit method was proven to be unconditionally stable with no restrictions on the time step and magnitude of viscosity coefficients.

Several simple numerical experiments were carried out to test validity of the developed scheme. It included comparison of the numerical solution with known analytical viscous flows and with results of verified numerical solutions. The first validation problem, the Stokes problem (Kundu, 1990), considered initiation of flow by the moving plate (Figure 3, left panel). Here the analytical solution was compared to the existing explicit scheme and the developed semi-implicit numerical scheme (Figure 3, right panel). In most experiments the semi-implicit scheme was more accurate and was even stable for the large time steps when the old scheme had shown unstable behavior. The longer time steps and the large space steps in the new scheme also did not introduce the errors in the solutions.

In general, the semi-implicit scheme was achieving the same order of accuracy as the explicit scheme with time steps larger by an order of magnitude.

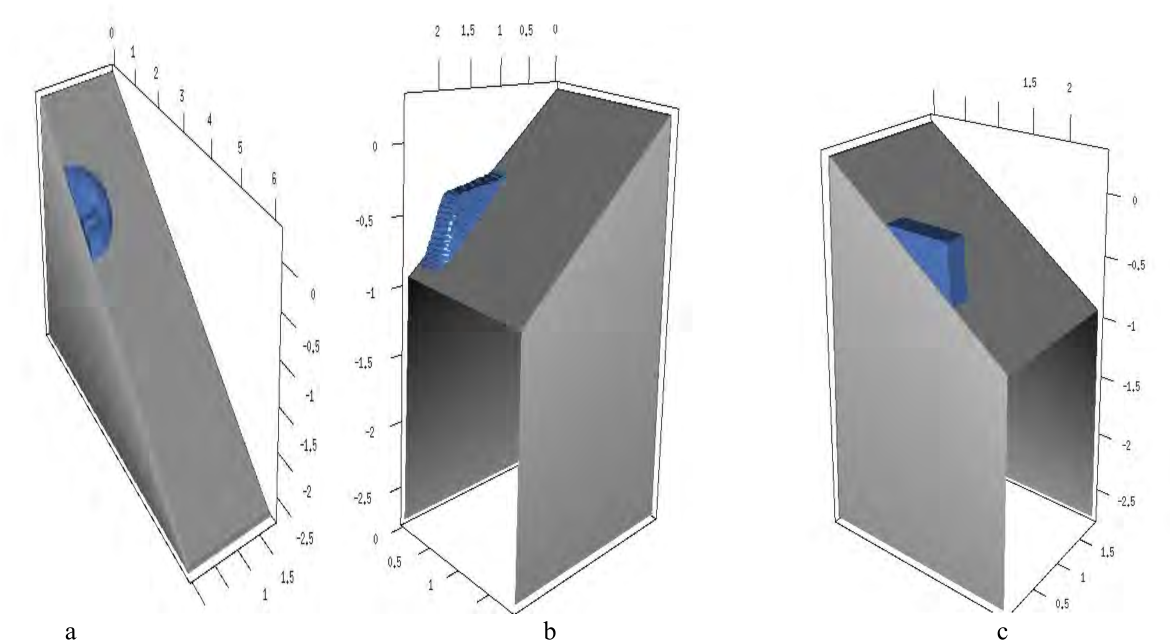

Figure 4. The wedge shape at t = 0.9 s of the wedge slide experiment (total duration of the laboratory experiment 4 seconds). Computation for the different viscosity coefficient a) $v=2.5x10^{-2}$ m^2/s; b) $v=2.5$ m^2/s ; c) $v=250$ m^2/s .

Current efforts are directed towards carrying out numerical simulations of a laboratory experiment. The major test deals with a sliding triangular wedge in a water tank. Previously, tsunami 3D model (Horrillo, 2006) had shown good results in predicting the generated wave patterns and comparison of computed and measured sea level. But in the previous numerical experiments the motion and shape of the wedge were prescribed; now a more sophisticated approach is taken where the motion is governed by the balance between gravitational and frictional forces.

The numerical experiment consists of viscous wedge-shaped fluid sliding on the slope. The heavy incompressible fluid is located along the bottom and it does not mix with the lighter upper layer. The slide motion, the runout distance and the final geometry when the motion is stopped will strongly depend on the fluid rheology.

A critical part of the landslide modeling is the choice of the frictional forces. The slide parameters such as velocity and runout distance are in the direct dependence on frictional forces. Its motion is dissipated by the two stresses a) basal stress along the lower surface of the landslide and b) upper surface stress between the water and the landslide, and by the internal friction expressed by the coefficient of friction.

The developed numerical scheme had shown satisfactory results in solving these problems for the small and large viscosity coefficients (Figure 4). The wedge shape depends on the fluid viscosity. For the small friction coefficients the wedge is deformed strongly (Figure 4, a) but for the large coefficients the wedge shape remained almost constant (Figure 4, c). The performed experiments had shown the importance of developing new numerical tools for the fluid flow with large frictional coefficients.

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 defined bathymetric features which scatter the tsunami energy towards the West Coast via the Mendocino Escarpment. Obtained results suggest that due to interference with the Koko Guyot the short period waves experience large changes in their propagation. This has important consequences for accurate tsunami prediction and warnings.

Education/outreach

Student participation: Dmitry Brazhnikov is a Ph.D. graduate student under the guidance of Zygmunt Kowalik. He has been working towards incorporating of submarine landslide into the existing three dimensional model of tsunami waves. This included comparison of the numerical solution with known analytical viscous flows and with results of verified numerical solutions. He was also researching the role of directional properties of the major seamounts on tsunami propagation in the Northern Pacific. Mr. Brazhnikov was sponsored by this award and successfully finished two years of graduate study. 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.

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Horrillo, J. 2006. Numerical method for tsunami calculation using full Navier-Stokes equations and the volume of fluid method. Ph.D. Dissertation, University of Alaska Fairbanks, 180pp.

Horrillo, J., W. Knight and Z. Kowalik. 2012. Tsunami propagation over the North Pacific: dispersive and nondispersive models. *Journal of Tsunami Society International*, 31(3):154–177.

Kowalik, Z., W. Knight, T. Logan and P. Whitmore. 2005. Numerical modeling of the global tsunami: Indonesian Tsunami of 26 December 2004. *Science of Tsunami Hazards*, 23(1):40–56.

Kowalik, Z., J. Horrillo, W. Knight and T. Logan. 2008. Kuril Islands tsunami of November 2006: 1. Impact at Crescent City by distant scattering. *Journal of Geophysical Research*, C01020, doi:10.1029/2007JC004402.

Kundu, P.K. 1990. Fluid Mechanics. Academic Press, 638 pp.

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

Other products and outcomes

Kowalik, Z. 2012/2013. Introduction to Numerical Modeling of Tsunami Waves, 196 pp.
http://www.sfos.uaf.edu/directory/faculty/kowalik/Tsunami_Book/book_sum.pdf [updated since last report]

TWEAK Task 2: ARSC Computational Support for Tsunami Simulations

Natalia Ruppert, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Sergei Maurits*, University of Alaska Fairbanks*

Primary objectives

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

Research accomplishments/highlights/findings

ARSC's effort from April 1, 2013 – March 31, 2014 has been split into support and development for two related but separate tsunami projects that require computational, visualization, and programming expertise:

(1) Alaska Tsunami Inundation and Mapping Project (ATOM) web portal (Dmitry Nicolsky)
(2) Estimates of potential landslide sources and computing the scope of local tsunamis they can generate in the vicinity of Juneau, Alaska

ARSC High Performance Computing (HPC) Specialist Sergei Maurits has been contributing to these two efforts. The ATOM sub-project was active during the entire period of performance, while computational analysis of the tsunami threat in Juneau, AK started in late January 2014.

The ATOM project was a continuation of efforts of the previous year. Preparation for the transition of the GIS-engine of the ATOM portal (http://atom.giseis.alaska.edu) from Google Map (GMap) API v.2 to Google Map API v.3 during the previous year facilitated a smooth start of the portal operation under Google Map API v.3 in spring of 2013.

In May 2013, the test and development version of the ATOM portal (ATOM-test) was launched in parallel (http://atom.giseis.alaska.edu/index_test.html) with the production portal. The goal was an inclusion of the Keyhole Markup Language (KML)-information into the portal functionality without disruption of the production portal (ATOM-production). The current plan is to merge the ATOM-test and the ATOM-production versions together when the KML-part will be completely finished. Another future task is to launch a separate portal version, based on the KML-section only. This second version will be oriented for the general public's and local decision makers' needs. It will be stripped of unnecessary functionality such as advanced computational and the grid-generating capabilities of the ATOM-production portal. However, an enhanced graphical and GIS-capability of this public portal will be a major advantage for the decision-making process as well as for general public orientation. As soon as this new information about communities of public interest is ready and published at the Alaska Division of Geological and Geophysical Surveys site, it will be added to the ATOM-test portal.

Juneau, Alaska and other areas' computations. The second area of the ARSC activity in the project is providing computational capabilities for high-performance computing of the tsunami-generating effects of the landslides and earthquakes, propagating the resulting tsunami waves in realistic water basins near communities of interest using high-resolution bathymetry data, and, finally, processes of run ups to the shores. ARSC provides to the project participants long (up to 240 hours) computational queues for these goals with massive CPU allocations (up to 512 CPUs), massive short-term and long-term storage, and fast networking capabilities. Maurits also contributes through computational study of the Juneau, AK area for potential tsunami sources. Figure 1 below shows the locations of interest in the vicinity.

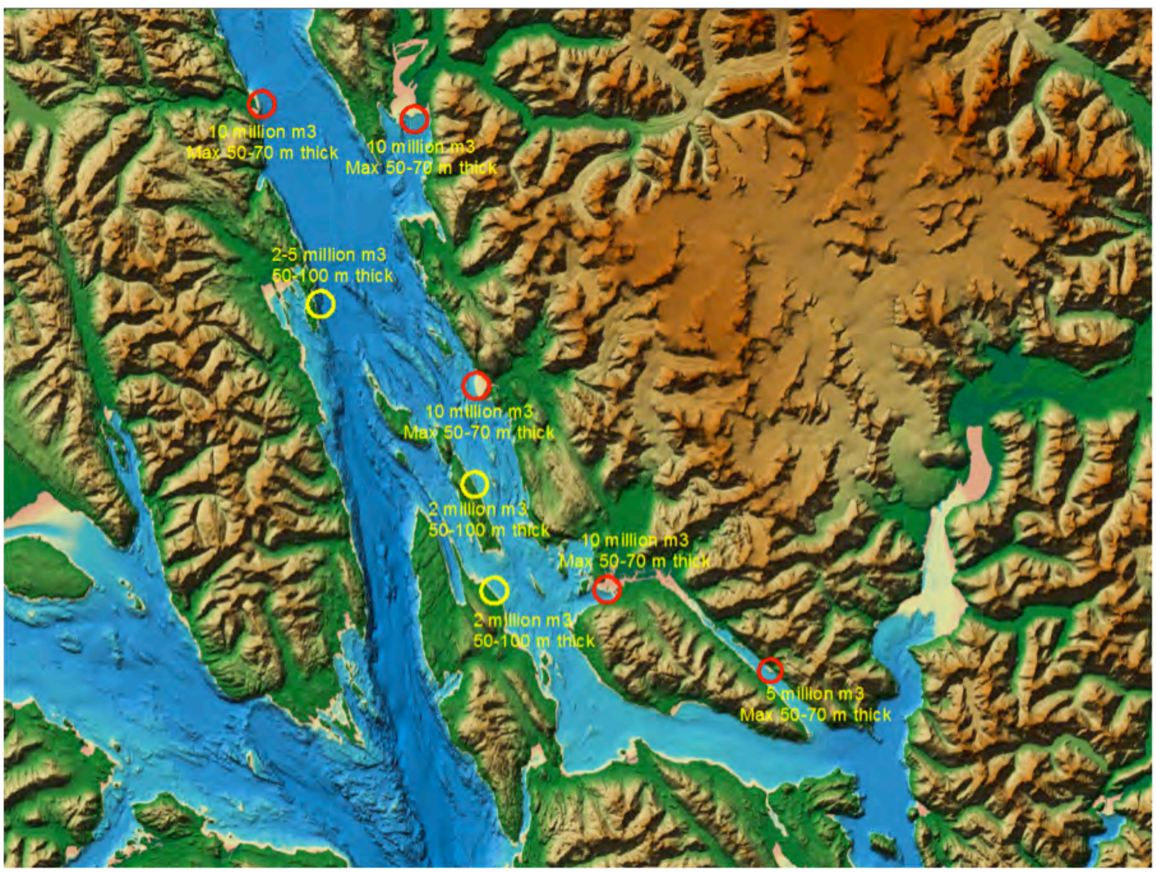

Figure 1. Juneau, Alaska area with markings of potential landslides, their volume, and thickness. Red circles represent accumulation of sediments in the mouth of the local streams, the subject of the current study.

Locations marked by the red circles are investigated for potential landslides' volume and thickness as well as for the intensity of the tsunami wave they can generate. Long runs (50-60 hours) of the propagation code at 15x15 grids (typical problem size is ~1500x~1500 or 2M nodes) require of about 200 CPUs to cover the first ten minutes

(600 sec) of the wave's propagation. This stage of the computational study targets determination if potential tsunamis can be of a danger for populated areas. Based on established findings, the locations of special interest will be covered by a more detailed computational model (generation → propagation → runup). The computational investigation will be continued in the next year with a goal of developing an Inundation Line and Flow Depth map for Juneau area.

TWEAK Task 3: Seismic network component (Alaska CRESTnet)

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

Other investigators/professionals associated with this project:
Christopher Bruton, Scott Dalton, Ian Dickson, Sharon Hansen, Dara Merz, Sara Meyer, Natalia Kozyreva *University of Alaska Fairbanks*

CIFAR 10-017/11-017/12-017/13-017: This project is ongoing. It continues under NA13OAR4320056.

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
- Upgrade analog stations to Advanced National Seismic System (ANSS) standards of modern broadband equipment.
- Locate seismic events occurring in Alaska and produce alarms and warnings to the West Coast and Alaska Tsunami Warning Center (WC/ATWC) and Emergency Managers.
- Maintain data flow of selected stations to ATWC.

Research accomplishments/highlights/findings

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

- At ATKA, we replaced the compromised seismic vault with a new, sealed vault coupled to bedrock.
- At COLD (Coldfoot), we swapped in new batteries and made other improvements to the power system.
- At DCPH (Deception Hills, south of Yakutat), we installed new broadband and strong motion sensors and swapped in new backup batteries.
- At DIV (Divide Microwave, on Richardson Highway, 15-20 miles north of Valdez), we upgraded to digital telemetry and installed a Q330 datalogger, replaced antenna cabling, swapped in a new broadband sensor, and connected the site to state internet. However, we still have networking issues to resolve with the state, so we are not receiving data from DIV.
- At PAX (Paxson), we swapped in a new broadband sensor and removed trash and old batteries.
- At PIN (Pinnacle), we replaced two solar panels and removed trash from the site.
- At PPLA (Purkeypile, south of Denali National Park), we swapped in new broadband and strong motion sensors and replaced all batteries.

Between 1 April 2013 and 20 March 2014, Alaska Earthquake Center reported 28,955 events, with magnitudes ranging between -0.4 and 7.0 and depths between 0 and 290 km (Figure 1). Six earthquakes had magnitudes 6 or greater. The largest earthquake, of magnitude 7.0, occurred on 30 August 2013, in the Andreanof Islands region of Alaska.

NOAA relevance/societal benefits

Improved detection of tsunamigenic earthquakes by Alaska Earthquake Information Center (AEIC) and NOAA tsunami warning centers.

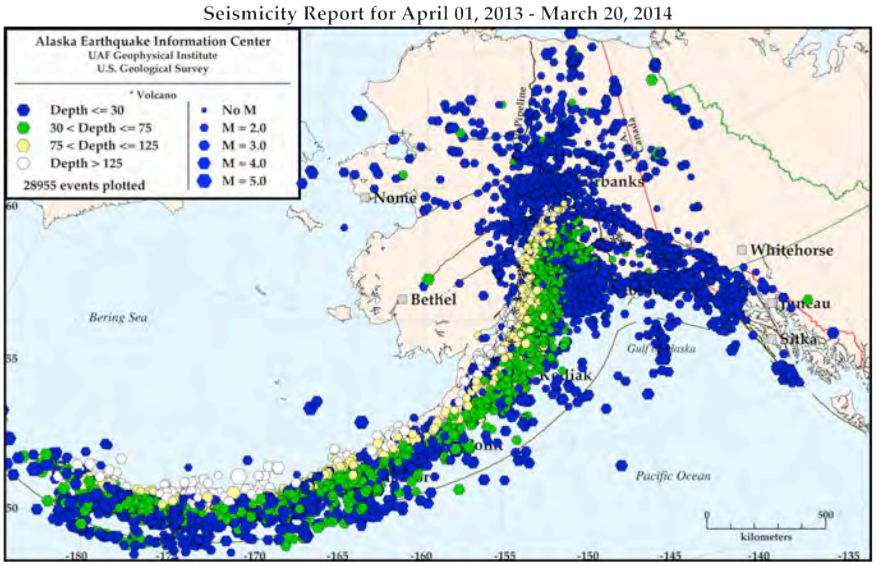

Figure 1. AEIC Seismicity Report for 1 April 2013 – 31 March 2014.

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:
Kenneth Macpherson, *University of Alaska Fairbanks*
***Aurélie Guilhem**, **Douglas S. Dreger**, Berkeley Seismological Laboratory*

Primary objectives

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

Research accomplishments/highlights/findings

Activities during the reporting period were focused on the implementation of the GridMT algorithm. This algorithm monitors a grid of potential earthquake sources by continuously cross-correlating pre-computed Green's functions (synthetic seismograms) with an actual recorded data stream, allowing for the rapid determination of an earthquake's location, mechanism and magnitude (Kawakatsu, 1998; Tsuruoka, 2009; Guilhem et al., 2013).

In June 2013, Kenneth Macpherson had a training session with Douglas Dreger's group at the Berkeley Seismology Laboratory, where he learned about theoretical aspects of the algorithm and obtained operational and research versions of the code as well as scripts for constructing monitoring grids. Since this visit, we have been adapting Berkeley's methods and code for use at the AEIC. In order to verify that we understand the procedure for constructing GridMT monitoring grids, we have reconstructed the original test grid around Anchorage. Using this grid we have been able to duplicate Berkeley's results for several moderate southern Alaska events.

We have constructed an additional grid for south-eastern Alaska centered on the Queen Charlotte – Fairweather Fault in order to test the algorithm on the aftershock sequence from the M_w ~ 7.5 Craig, Alaska earthquake of January 5, 2013 (Figure 1). This has provided an opportunity to test the effectiveness of the algorithm in less than ideal conditions; the source locations are off-shore and the network in the region is sparse. Preliminary results from these tests indicate that GridMT is able to recover accurate moment tensors for aftershocks larger than about M_w~4.0.

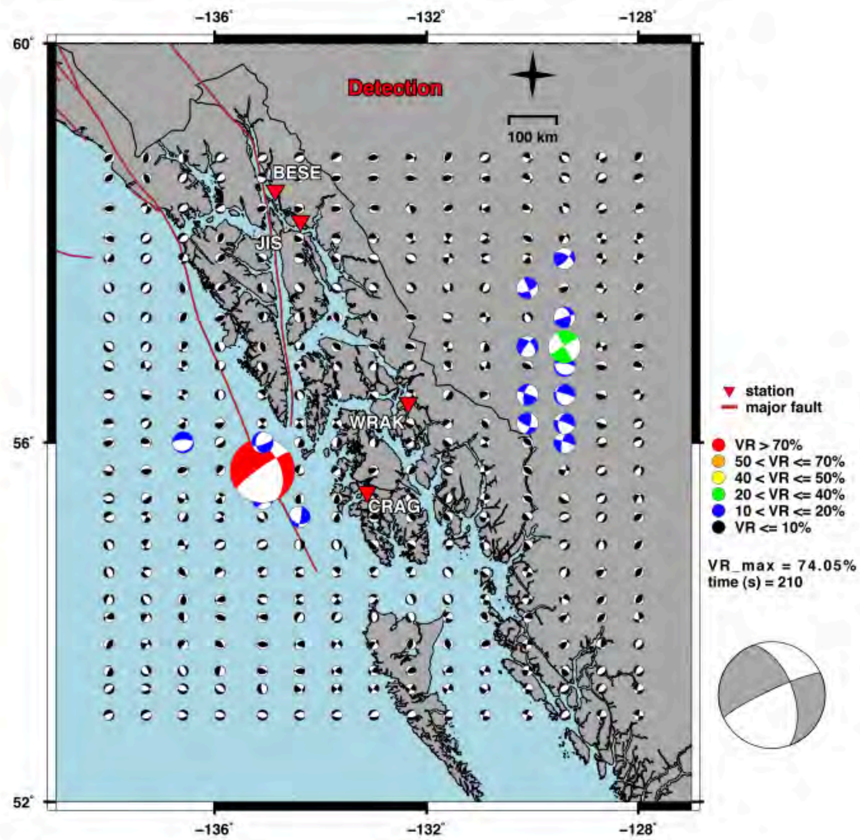

Figure 1. Snapshot of solution grid at the timestep of maximum variance reduction for a M_w~4.4 aftershock of the Craig, Alaska earthquake of January 5, 2013. GridMT grids are 3-dimensional, but here we show a depth slice at 10 kilometers. The mechanism agrees well with that of a solution obtained using a conventional time-domain moment tensor inversion code (grey "beachball" at lower right).

Because one of the fundamental goals of GridMT implementation at AEIC is near-real-time detection and characterization of moderate and large earthquakes in Alaska, the code must be modified to work with the AEIC real-time data processing system. To this end, we have rewritten the code using Antelope libraries (Antelope is AEIC's data processing system). This new code now can work with the archived seismic data. However, the technical crux of running the code in operational mode is developing the ability to read and process data in real time. This phase of the code development is nearing completion.

References

Guilhem, A., D. Dreger, H. Tsuruoka and H. Kawakatsu. 2013. Moment tensors for rapid characterization of megathrust earthquakes: the example of the 2011 M9 Tohoku-oki, Japan earthquake. *Geophysical Journal International*, 192(2):759–772, 2013. Doi:10.1093/gji/gg5045

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, conferences papers and presentations

Poster presentation

Macpherson, K.A., N. Ruppert, D. Dreger, P. Lombard, J. Freymueller, D. Nicolsky and A. Guilhem. 2013. Towards implementation of the GRiD MT algorithm for near real-time calculation of moment tensors at the Alaska Earthquake Center. American Geophysical Union annual meeting, San Francisco, California, December 2013.

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

Natalia Ruppert, 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:

- **Sitka:** We completed the tsunami inundation mapping project for Sitka, Alaska. The tsunami inundation modeling and mapping report is published and available through the Alaska Division of Geological & Geophysical Surveys (ADGGS) web site.
- **Elfin Cove, Gustavus and Hoonah (ECGH):** We continued our tsunami modeling efforts to compute a hypothetical tsunami inundation zone in three communities of Southeast Alaska: Elfin Cove, Gustavus and Hoonah. The ECGH tsunami inundation modeling and mapping report is in review for publication by the ADGGS.
- **Yakutat:** We started the tsunami inundation modeling and mapping project for Yakutat. We identified potential tectonic and landslide tsunami sources that could generate tsunami waves potentially dangerous for Yakutat.

Publications and conference presentations

Peer-reviewed publications

Suleimani, E.N., D.J. Nicolsky and R.D. Koehler. 2013. Tsunami Inundation Maps of Sitka, Alaska. Alaska Division of Geological & Geophysical Surveys Report of Investigation 2013-3, 76 p., 1 sheet, scale 1:250,000.

Nicolsky D.J., E.N. Suleimani, P.J. Haeussler, H.F. Ryan, R.D. Koehler, R.A. Combellick and R.A. Hansen. 2013. Tsunami Inundation Maps of Port Valdez, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation 2013-1, 77 p., 1 sheet, scale 1:12,000.

Ross, S.L., L.M. Jones, K. Miller, K.A. Porter, A. Wein, R.I. Wilson, B. Bahng, A. Barberopoulou, J.C. Borrero, D.M. Brosnan, J.T. Bwarie, E.L. Geist, L.A. Johnson, S.H. Kirby, W.R. Knight, K. Long, P. Lynett, C.E. Mortensen, D.J. Nicolsky, S.C. Perry, G.S. Plumlee, C.R. Real, K. Ryan, E. Suleimani, H.K. Thio, V.V. Titov, P.M. Whitmore and N.J. Wood. 2013. SAFRR (Science Application for Risk Reduction) Tsunami Scenario Executive Summary and Introduction: U.S. Geological Survey Open-File Report 20131170A, in Ross, S.L. and L.M. Jones, eds., The SAFRR (Science Application for Risk Reduction) Tsunami Scenario. U.S. Geological Survey Open-File Report 20131170, 17 p., http://pubs.usgs.gov/of/2013/1170/a/

Nicolsky, D.J. and E.N. Suleimani. 2013. Modeling tsunami dynamics in the Port of Los Angeles, California. Chapter 6 in: Modeling for the SAFRR Tsunami Scenario: Generation, Propagation, Inundation, and Currents in Ports and Harbors. U.S. Geological Survey Open-File Report 20131170D.

Accepted 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.

(Several additional publications have been submitted or are in review.)

Oral presentations

Suleimani E.N., D.J. Nicolsky and R.D. Koehler. 2013. Inundation mapping and hazard assessment of tectonic and landslide tsunamis in Southeast Alaska. 26th International Tsunami Symposium, Gocek, Turkey, September 2013.

Nicolsky, D.J., E.N. Suleimani and R.D. Koehler. 2013. Tsunami modeling and inundation mapping in Southcentral Alaska. 26th International Tsunami Symposium, Gocek, Turkey, September 2013.

Suleimani E.N., D.J. Nicolsky, J.T. Freymueller and R.D. Koehler. 2013. Specification of tectonic tsunami sources along the eastern Aleutian Island Arc and Alaska Peninsula for inundation mapping and hazard assessment. Abstract NH54A-06. Fall Meeting, American Geophysical Union, San Francisco, California, 9–13 December 2013.

Poster presentation

Nicolsky, D.J., E.N. Suleimani, R.D. Koehler and J.T. Freymueller. 2013. Tsunami modeling and inundation mapping in Southcentral Alaska, Abstract NH41B-1721. Fall Meeting, American Geophysical Union, San Francisco, California, 9–13 December 2013.

Education/Outreach

E.N. Suleimani presented the hypothetical tsunami inundation maps to the Sitka City Council, 4 November 2013, Sitka, Alaska.

TWEAK Task 6: Education and outreach

Natalia Ruppert, PI
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Helena Buurman, Ian Dickson, Lea Gardine, Matt Gardine, Sharon Hansen, Amy McPherson, Ken McPherson, Mike West *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. Additionally, the Alaska Earthquake Information Center (AEIC) presented earthquake and tsunami education through the following activities:

- Lab tours and presentations were given to 119 individuals (107 elementary students and 12 adults).
- At the University of Alaska Science Potpourri on 13 April 2013, AEIC presented information on earthquakes and tsunamis to students of all ages. Around 900 people, mostly children, attended the event.
- Six staff members presented earthquake and tsunami information at the Preparedness Expo. There were 836 attendees.
- Sharon Hansen presented a 1-hour workshop to 57 people and then distributed pamphlets to 600 people at the University of Alaska Anchorage Development Day.
- Mike West presented earthquake info to about 50 people in a presentation to the Alaska Miners Association.
- Four staff members presented educational activities for children at the Fairbanks Children's Museum (30 attendees).
- Mike West and Natasha Ruppert gave interviews to the Associated Press and KUCB (Unalaska) about the M7 Adreanof earthquake and its aftershocks.
- Ian Dickson began outreach via social media by establishing a twitter account and a facebook group in late 2013. Both are used to share information about notable earthquakes as well as other earthquake and tsunami-related topics. At the end of the reporting period the combined number of followers for these two platforms was 264, with information posted to both on most days.
- Mike West participated in multiple events related to the 50th anniversary of the 1964 Great Alaska Earthquake.

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

Greg Walker, PI
Marty Rogers, PI *(as of 3/1/14)*
University of Alaska Fairbanks

CIFAR themes: Coastal Hazards; Ecosystem Studies & Forecasting

NOAA Goal: Healthy Oceans; Weather Ready Nation

CIFAR 13-031: This project is ongoing.
It continues under NA13OAR4320056.

NOAA Office: OAR, Robbie Hood, 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, 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, and we supported a field mission on Kodiak Island in September 2013.

The UAF Subcontractor ATI has been developing a suitable imager for this project. The camera that they were working with was the compact USB 2.0 powered Mightex SCE-CG04-U which was controlled by OpenIRiS ("Integrate. Relate. Infer. Share") anomaly detection software. This camera has been replaced by the Samsung NX-210. This is a mirrorless camera with the following specifications:

- 20.3 Mp Image Capture
- 18-55mm (3x) Zoom Lens
- Large (23.5 x 15.7mm) APS-C (Advanced Photo System type C) Image Sensor
- Full HD 1080p Stereo Video Capture
- Instant Sharing via Wi-Fi
- 3.0" VGA AMOLED (Active-Matrix Organic Light-Emitting Diode) Display
- High Speed 8.0 fps Capture
- Smart Auto and Filter 2.0
- 2D/3D Panorama Capable

One of the challenges regarding use of various sensors on UAS is the rapid entry of improved technology into the market. So, in some cases by the time the payload integration process is completed the sensor has been updated/improved and can be perceived as obsolete. ATI is currently reviewing newer sensor technology and plans on settling on a "final" sensor package by mid-2014.

<u>Second Field Program – Kodiak Island September 24-26, 2013</u>

Completed - Resolution test flights in Minnesota and Flight Report – ATI
Completed - Certificate of Operation for Kodiak – UAF

Completed - Operations Plan, CONOPS (concept of operations) Details, and Operational Risk Management Assessment – Bill Pichel (NOAA project PI), UAF, ATI, AOC, ESRL (NOAA Earth System Research Laboratory), Marine Debris Program, NOAA UAS Program Office
Completed - Waiver Request for Supplemental Pilot – Pichel, ATI, UAF
Completed - Flight Readiness Review and Mission Readiness Review 9/18/13 – AOC, Pichel, UAF, ATI, NOAA UAS Program Office
Completed - Puma Enhanced Sensor Tests in Arctic – UAF

Three complications prevented field program on Kodiak Island –

1. Weather did not allow participants to fly to Kodiak from Anchorage and bad weather all week led to cancellation of field program
2. Waiver of FAA Ground School and physical for Curt Olson as Supplemental Pilot was not approved by AOC.
3. Enhanced Puma sensor was not ready to fly on NOAA Puma

Completed - Performance tests for UAS that lands in water were conducted in Wasilla after Kodiak field program was cancelled – ATI
Completed - Kodiak Mission Report on Resolution testing and preparations for Kodiak Field Program – ATI

UPCOMING EFFORTS

<u>Resolution Demonstration at AOC – Dates to be determined</u>

Completed - Subcontract between UAF and ATI for second year of project – UAF, ATI
Completed - FAA Ground School – ATI (Curt Olson)
Complete FAA physical – ATI (Tim Veenstra and Curt Olson)
Arrange for use of range in Florida for demonstration flights – AOC
Preparation of documents required for demonstration flights – AOC, ATI
Travel to Florida for Demonstration Flights – ATI, Pichel
Demonstration Flights – ATI, AOC, Pichel
Flight Report – ATI

<u>Final Field Program for Project – Early June 2014 or September 2014</u>

Completed - Developed and submitted proposal in response to call for proposals for 5 free days at sea on a NOAA ship – Pichel
Completed - Proposal for 5 free days at sea on a NOAA ship was accepted, but ship time was moved from May to September
Decide location for final field program – Kodiak, Channel Islands Sanctuary, NOAA Ship Shimada or elsewhere – UAF, ATI, UAS Program Office
Decide whether field program will be for Resolution only or will include Puma – ATI, UAF, AOC, UAS Program Office
Arrange for airspace use, if necessary – Participants depend on location
Arrange for use of vessel – Participants depend on location
Complete Operations Plan, CONOPS Details, and Operational Risk Management Assessment – Pichel, UAF, ATI, AOC, ESRL, Marine Debris Program, NOAA UAS Program Office
Complete Flight Readiness Review and Mission Readiness Review – AOC, Pichel, UAF, ATI, NOAA UAS Program Office, Marine Debris Program
Compete Field Program – ATI, UAF, Pichel
Analyze UAS data – ATI

Arctic Ocean and sea ice engineering system development tests – The MIZOPEX (Marginal Ice Zone Oceans and Ice Observations and Process Experiment) mission was conducted in August 2013 off of Oliktok Point, Alaska. The main objectives of MIZOPEX were to improve knowledge of how ocean surface and near-surface properties vary and evolve as a function of ice characteristics in and near the marginal ice zone (MIZ), and to quantify the performance of satellite-derived geophysical products and climate models in these areas.
Measurements included: skin temperature, spectral reflectance and albedo, sea ice freeboard and roughness, ice melt pond characteristics, atmospheric state variables, and wave height.

Instruments included: infrared pyrometers, broadband and hyperspectral sensors, synthetic aperture radar, lidar, and electro-optical cameras.

Specific information regarding the results of MIZOPEX 2013 will be provided in the next report.

Augment existing Steller sea lion research project with field time – The Steller sea lion (SSL) project has been completed successfully. (See last year's report.)

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.

Partner organizations and collaborators

Columbia University
University of Colorado
Ball Aerospace
US Air Force 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

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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 ongoing. 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

Experimental forecast products have been developed using statistical modeling techniques such as Generalized Linear Models (GLMs) and "Random Forest" ensemble regression techniques to reproduce storm activity patterns in sub-regions of the study area. These reproductions are driven by teleconnection indices that have been established to be well correlated with storm activity patterns in the region (e.g. PNA, PDO). Breaking the large study area into smaller subdivisions was made necessary by the differences in distribution of storm events with relation to main storminess regions seen in the Empirical Orthogonal Function (EOF) analysis.

GLM hindcasts for the wintertime months (December, January, February, March, DJFM) generated from teleconnection indices with a 1-month lag (i.e. beginning in November) provided reasonably good fit to the storm activity distribution in the Gulf of Alaska with a correlation coefficient of 0.66 (Figure 1). Additionally, a second statistical model was built using "random forest" ensemble regression techniques. This model was trained on 50 years of storm frequency data from 1951–2000 in the Gulf of Alaska using the same teleconnection indices provided in the GLM. The resulting regression ensemble was then used to generate a 10 year hindcast for 2001–2010 (Figure 2), with the resulting correlation coefficient of 0.82. Other statistical techniques such as Canonical Correlation Analysis (CCA) and Generalized Additive Models (GAMs) are currently being evaluated to provide a training dataset with a longer temporal range such as the 20th Century Reanalysis (20CR) (Compo et al., 2006).

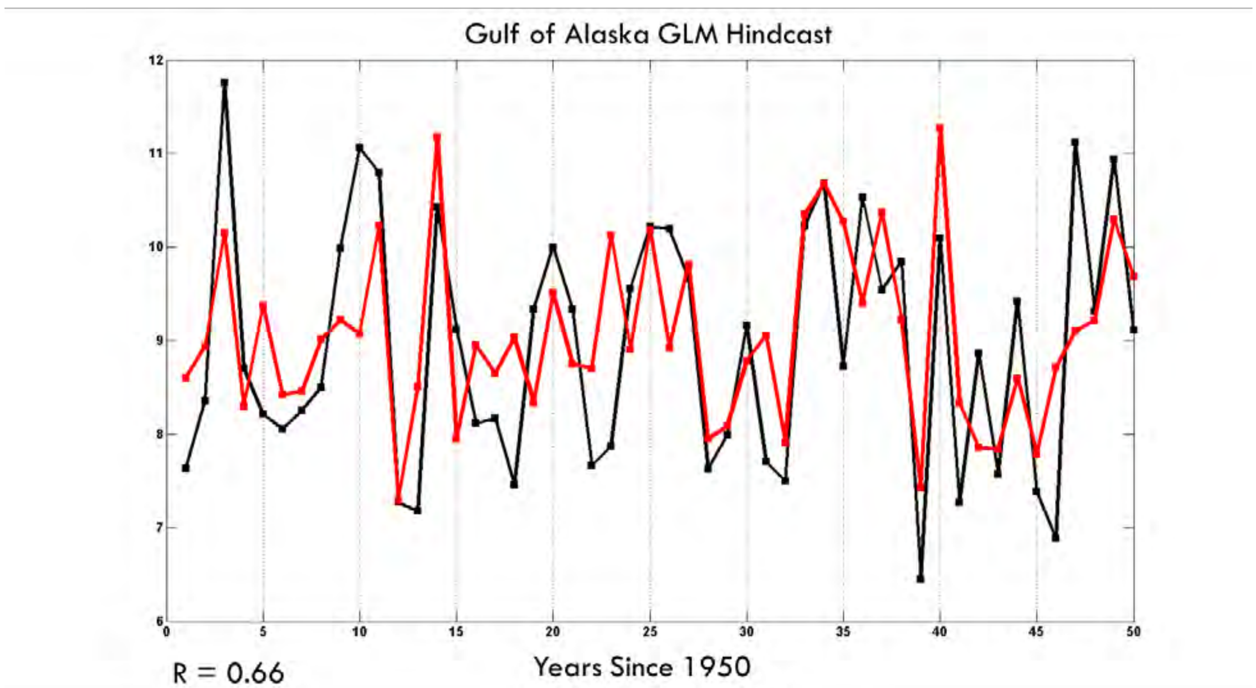
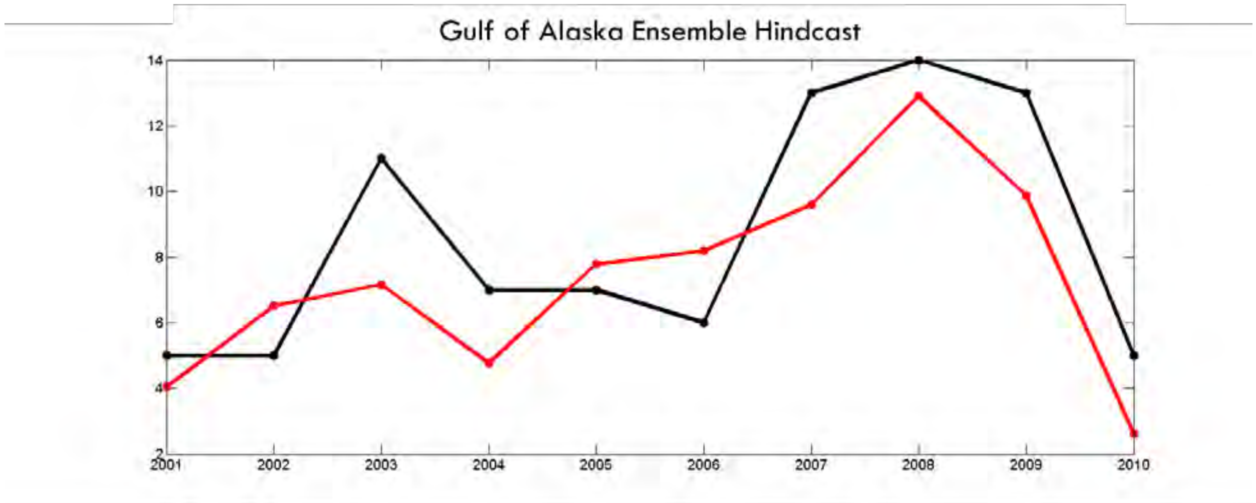


Figure 1. Seasonally predicted wintertime (DJFM) storm activity (red) verified against actual storm activity (black) counts for the Gulf of Alaska region, for the period 1951–2000. This hindcast was created using a Generalized Linear Modeling (GLM) technique.



R = 0.82

Figure 2. Seasonally predicted wintertime (DJFM) storm activity (red) verified against actual storm activity (black) counts for the Gulf of Alaska for the years of 2001–2010 using "random forest" ensemble regression techniques.

References

Compo, G.P., J.S. Whitaker, and P.D. Sardeshmukh. 2006. Feasibility of a 100 year reanalysis using only surface pressure data. *Bulletin of the American Meteorological Society*, 87:175–190.

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

Bjerknes Center for Climate Research. Oslo, Norway. November 2013. Supported trip for Norman Shippee to Oslo to present results of this project at the Statistics and Climate Workshop, sponsored in part by the Bjerknes Center and also by the SARMA project (Statistical Approaches to Regional Climate Models for Adaptation).

Publications and conference presentations

Oral presentations

Shippee, N. 2013. Seasonal storminess in the North Pacific, Bering Sea, and Alaska regions. 12th Conference on Polar Meteorology and Oceanography, Seattle, Washington, 1 May 2013.

Shippee, N, 2013. The development of a seasonal extratropical cyclone activity outlook for the North Pacific, Bering Sea, and Alaskan regions. Statistics and Climate Workshop, Oslo, Norway. 12 November 2013.

Poster presentation

Shippee, N.J., D.E. Atkinson, J.W. Walsh, J. Partain, J. Gottschalck and J. Marra. 2013. The development of a seasonal extratropical cyclone activity outlook for the North Pacific, Bering Sea, and Alaskan regions. A43C-0273. American Geophysical Union Fall Meeting, San Francisco, California, 12 December 2013.

Partner organizations and collaborators

- Arctic Region Supercomputing Center
- Kevin Hodges at the National Center for Earth Observation in Britain. Hodges has been providing extensive support for Shippee as he further implements Hodges' TRACK storm track algorithm on NOAA's 20th Century Reanalysis.

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

Peter Webley, PI
Martin Stuefer, PI
University of Alaska Fairbanks

CIFAR theme: Coastal Hazards

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.
It continues under NA13OAR4320056.

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. We added in the capability to perform analysis with sulfur dioxide for volcanic eruptions. 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 (1) completed the Redoubt 2009 and Eyjafjallajökull 2010 analysis for two publications; (2) furthered the satellite to model comparisons for Kasatochi 2008 and Sarychev Peak 2009 eruptions; (3) completed our Multi-angle Imaging Spectro-Radiometer (MISR) analysis (Ekstrand et al. 2013); and (4) continued development of WRF-Chem for sulfur dioxide/sulfate (SO_2/ SO_4^{2-}) comparison to satellite data.

Student Torge Steensen completed his analysis of WRF-Chem as well as the Puff dispersion model as compared to satellite remote sensing for his Ph.D. thesis. The Steensen et al. (2013) publication compared volcanic ash retrievals with WRF-Chem model simulations from two events during the 2009 Redoubt eruptions. In addition, Stuefer et al. (2013) was published as a Geoscientific Model Development (GMD) Discussion paper. The paper provides a technical description of the implementation of volcanic source parameters and a volcanic eruption model in WRF-Chem.

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 continued to develop 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. This is a publication in prep by Steensen et al. for submission to *Journal of Volcanology and Geothermal Research* (working title "Quantitative comparison of volcanic ash observations in satellite-based remote sensing data and WRF-Chem model simulations").

For the SO_2 analysis, we continued WRF-Chem simulations as well as OMI (Ozone Monitoring Instrument) UV satellite retrievals. Our aim was to assess the model's capability to perform SO_2 simulations as well as the sulfur dioxide (SO_2) into sulfate (SO_4^{2-}) 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.

A publication is in preparation by Egan et al. (working title "Modeling and remote sensing of the 2008 Kasatochi sulfur dioxide (SO_2) plume").

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. student in Geophysics (completed August 2013)

Role on project: Determine 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

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 thermal infrared (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 publications

Stuefer, M., S.R. Freitas, G. Grell, P. Webley, S. Peckham, S.A. McKeen and S.D. Egan. 2013. Inclusion of ash and SO_2 emissions from volcanic eruptions in WRF-CHEM: Development and some applications. *Geoscientific Model Development*, 6(2):457–468. doi:10.5194/gmd-6-457-2013

Ekstrand, A., P.W. Webley, M.J. Garay, J. Dehn, A. Prakash, D.L. Nelson, K.G. Dean and T.S. Steensen. 2013. A multi-sensor plume height analysis of the 2009 Redoubt eruption. *Journal of Volcanology and Geothermal Research,* 259:170–184. http://dx.doi.org/10.1016/j.jvolgeores.2012.09.008

Steensen, T., M. Stuefer, P.W. Webley, G. Grell and S. Freitas. 2013. 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,* 259:235–247. 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. 2013. Local seismic and infrasound observations of the 2009 explosive eruptions of Redoubt Volcano, Alaska. *Journal of Volcanology and Geothermal Research*, 259:63–76. http://dx.doi.org/10.1016/j.jvolgeores.2013.03.016

Poster presentations

Egan, S. and M. Stuefer. 2013. Modelling and remote sensing of ash and sulfur dioxide from the 2008 Kasatochi Volcano eruption. American Geophysical Union (AGU) fall meeting, abstract V43B-2886, December 2013.

Stuefer, M., P. Webley, G. Grell, S. Freitas, C.K. Kim and S. Egan. 2013. Volcanic ash transport integrated in the WRF-Chem model: a description of the application and verification results from the 2010 Eyjafjallajökull eruption. European Geophysical Union (EGU) General Assembly. Id: EGU2013-6502, 7–12 April 2013.

Egan, S. and M. Stuefer. 2013. Modeling and remote sensing of volcanic sulfur dioxide. European Geophysical Union (EGU) General Assembly. Id: EGU2013-6533, 7–12 April 2013.

Partner organizations and collaborators

Jeff Osiensky (NWS Volcanic Ash Program Manager), NWS 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, NWS, 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. Summary of CIFAR-funded Personnel and their Terminal Degree (or degree seeking for students)

Category	**Number**	**unknown or none**	**B.A./B.S.**	**M.A./M.S. or M.B.A.**	**Ph.D**
Research Scientist	20			1	19
Visiting Scientist					
Postdoctoral Fellow					
Research Support Staff	30		15	7	7
Administrative	4		1	2	1
Total (≥ 50% NOAA Support)	2			1	**1**
Total	54	0	16	10	27
Employees (< 50% NOAA Support)	52	0	16	9	26
Located in NOAA Lab	0				
Obtained NOAA employment within last year	0				
Undergraduate Students	4		4		
Graduate Students	11			2	9
Total Students	**15**	**0**	**4**	**2**	**9**

Appendix 2. 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 6	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6
Peer-reviewed	0	1	4	6	4	**12**	0	0	1	1	1	**0**	0	1	0	1	6	**1**
Non Peer-reviewed	0	0	0	0	2	**0**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
In press						**2**						**0**						**1**
Accepted						**2**						**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
Year 6 = 1 April 2013–31 March 2014

***NOTE**:*
*Besides this activity for projects funded directly by NOAA through CIFAR, **six** peer-reviewed papers and **one** non-peer-reviewed paper were published during this reporting period by students who have received CIFAR funding through the Global Change Student Research Grant Competition during cooperative agreement NA08OAR4320751. Also, **four** new student papers, all peer-reviewed, were reported belatedly from previous reporting periods.*

See next pages 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	Polyakov, I.V., U.S. Bhatt, J.E. Walsh, E.P. Abrahamsen, A.V. Pnyushkov and P.F. Wassmann	Dec 2013	Recent oceanic changes in the Arctic in the context of long-term observations	Ecological Applications	Journal article	http://dx.doi.org/10.1891/11-0902.1	NA08OAR4320751	X			X	
CIFAR	Suleimani, E.N., D.J. Nicolsky and R.D. Koehler	Nov 2013	Tsunami inundation maps of Sitka, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation 2013-3		Technical report		NA08OAR4320751	X			X	
CIFAR	Polyakov, I.V., A.V. Pnushkov, R. Rember, L. Padman, E.C. Carmack and J.M. Jackson	Oct 2013	Winter convection transports Atlantic Water heat to the surface layer in the eastern Arctic Ocean	Journal of Physical Oceanography	Journal article	doi:10.1175/JPO-D-12-0169.1	NA08OAR4320751	X			X	
CIFAR	Lee, S.H., M.S. Yun, B.K. Kim, H.T. Joo, S-H. Kang C.K. Kang and T. Whitledge	Oct 2013	Contribution of small phytoplankton to total primary production in the Chukchi Sea	Continental Shelf Research	Journal article	http://dx.doi.org/10.1016/j.csr.2013.08.008	NA08OAR4320751/ NA08OAR4320870	X			X	
CIFAR	Ross, S.L. and 27 others including D.J. Nicolsky and E. Suleimani	Sept 2013	SAFRR (Science Application for Risk Reduction) Tsunami Scenario Executive Summary and Introduction	The SAFRR (Science Application for Risk Reduction) Tsunami Scenario. U.S. Geological Survey Open-File Report 20131170	Technical Report		NA08OAR4320751			X	X	
CIFAR	Nicolsky D.J. and E.N. Suleimani	Sept 2013	Modeling tsunami dynamics in the Port of Los Angeles, California. Chapter 6.	Modeling for the SAFRR Tsunami Scenario: Generation, Propagation, Inundation, and Currents in Ports and Harbors: U.S. Geological Survey Open-File Report 20131170D.	Chapter in Technical report		NA08OAR4320751	X			X	
CIFAR	Evans, W. and J.T. Mathis	Aug 2013	The Gulf of Alaska coastal ocean as an atmospheric CO2 sink	Continental Shelf Research	Journal article	http://dx.doi.org/10.1016/j.csr.2013.06.013	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	July 2013	Tsunami Inundation Maps of Port Valdez, Alaska. Alaska Division of Geological & Geophysical Surveys, Report of Investigation 2013-1		Technical report		NA08OAR4320751	X			X	
CIFAR	Ekstrand, A., P.W. Webley, M.J. Garay, J. Dehn, A. Prakash, D.L. Nelson, K.G. Dean and T.S. Steensen	June 2013	A multisensor plume height analysis of the 2009 Redoubt eruption	Journal of Volcanology and Geothermal Research: Special Issue on 2009 Redoubt Eruption	Journal article	http://dx.doi.org/10.1016/j.jvolgeores.2012.09.008	NA08OAR4320751	X			X	

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	McNutt, S.R., G. Thompson, M.E. West, D. Fee, S. Stihler and E. Clark	June 2013	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	http://dx.doi.org/10.1016/j.jvolgeores.2013.03.016	NA08OAR4320751	X			X	
CIFAR	Steensen, T., M. Stuefer, P.W. Webley, G. Grell and S. Freitas	June 2013	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	http://dx.doi.org/10.1016/j.jvolgeores.2012.02.018	NA08OAR4320751	X			X	
CIFAR	Lee, S.H., M.S. Yun, B.K. Kim, S.I. Saitoh, C-K. Kang, S-H. Kang and T. Whitledge	May 2013	Latitudinal carbon productivity in the Bering and Chukchi Seas during the summer in 2007	Continental Shelf Research	Journal article	http://dx.doi.org/10.1016/j.csr.2013.04.004	NA08OAR4320751	X			X	
CIFAR	Stuefer, M., S.R. Freitas, G. Grell, P. Webley, S. Peckham, S.A. McKeen and S.D. Egan	April 2013	Inclusion of ash and SO2 emissions from volcanic eruptions in WRF-Chem: development and some applications	Geoscientific Model Development	Journal article	doi:10.5194/gmd-6-457-2013	NA08OAR4320751	X			X	
CIFAR	Mathis, J.T., J.N. Cross, N. Monacci, R.A. Feely and P. Stabeno	In press	Evidence of prolonged aragonite undersaturations in the bottom waters of the southern Bering Sea shelf from autonomous sensors	Deep Sea Research II	Journal article	http://dx.doi.org/10.1016/j.dsr2.2013.07.019	NA08OAR4320751	X			X	
CIFAR	Bieniek, P., J.E. Walsh, R.L. Thoman and U.S. Bhatt	In press	Using climate divisions to analyze variations and trends in Alaska temperature and precipitation	Journal of Climate	Journal article	doi:10.1175/JCLI-D-13-00342.1	NA10OAR4310055	X			X	
CIFAR	Nelson, R.J., C. Ashjian, B. Bluhm, K. Conlan, R. Gradinger, J. Grebmeier, V. Hill, R. Hopcroft, B. Hunt, H. Joo, D. Kirchman, K. Kosobokova, S. Lee, W. Li, C. Lovejoy, M. Poulin, E. Sherr and K. Young	In press	Biodiversity and biogeography of lower trophic fauna of the Pacific Arctic Region—Sensitivities to climate change (chapter 10)	J.M. Grebmeier and W. Maslowski, Eds. The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment. Springer, New York	Book chapter		NA08OAR4320870			X	X	
CIFAR	Nicolsky D.J., E.N. Suleimani and R.D. Koehler	Accepted	Tsunami Inundation Maps of Cordova and Tatitlek, 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	Shero, M.R., L.E. Pearson, D.P. Costa and J.M. Burns	March 2014	Improving the precision of our ecosystem calipers: A modified morphometric technique for estimating marine mammal mass and body composition	PLoS ONE	Journal article	doi:10.1371/journal.pone.0091233	NA08OAR4320751	X			X	
CIFAR	Wang, S.W., S.M. Budge, R.R. Gradinger, K. Iken and M.J. Wooller	March 2014	Fatty acid and stable isotope characteristics of sea ice and pelagic particulate organic matter in the Bering Sea: Tools for estimating sea ice algal contribution to Arctic food web production	Oecologia	Journal article	doi:10.1007/s00442-013-2832-3	NA08OAR4320751	X			X	

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	Seymour, J., L. Horstmann-Dehn and M.J. Wooller	Feb 2014	Inter-annual variability in the proportional contribution of higher trophic levels to the diet of Pacific walruses.	Polar Biology	Journal article	doi:10.1007/s00300-014-1460-7	NA08OAR4320751	X			X	
CIFAR	Young, J. and A. Arendt	Dec 2013	Assessing the effects of changing climate on the Kahiltna Glacier using field, airborne, and satellite observations	Alaska Park Science	Journal article		NA08OAR4320751	X				X
CIFAR	Habermann, M., M. Truffer and D. Maxwell	Nov 2013	Changing basal conditions during the speed-up of Jacobshavn Isbræ, Greenland	The Cryosphere	Journal article	doi:10.5194/tc-7-1679-2013	NA08OAR4320751	X			X	
CIFAR	Bartholomaus, T.C., C.F. Larsen and S. O'Neel	Oct 2013	Does calving matter? Evidence for significant submarine melt	Earth and Planetary Science Letters	Journal article	http://dx.doi.org/10.1016/j.epsl.2013.08.014	NA08OAR4320751	X			X	
CIFAR	Garvin, M.R., C.M. Kondzela, P.C. Martin, B. Finney, J. Guyon, W.D. Templin, N. DeCovich, S. Gilk-Baumer and A.J. Gharrett	July 2013	Recent physical connections may explain weak genetic structure in western Alaskan chum salmon (*Oncorhynchus keta*) populations	Ecology and Evolution	Journal article	doi:10.1002/ece33.628	NA08OAR4320751	X			X	
CIFAR	Seymour, J., L. Horstmann-Dehn and M.J. Wooller	Accepted	Proportion of higher trophic-level prey in the diet of Pacific walruses (*Odobenus rosmarus divergens*)	Polar Biology	Journal article		NA08OAR4320751	X			X	
CIFAR-funded CGC student grant publications from earlier reporting periods (not previously reported):												
CIFAR	Weems, J., K. Iken, R. Gradinger and M.J. Wooller	Nov 2012	Carbon and nitrogen assimilation in the Bering Sea clams *Nuculana radiata* and *Macoma moesta*	Journal of Experimental Marine Biology and Ecology	Journal article	http://dx.doi.org/10.1016/j.jembe.2012.06.015	NA08OAR4320751	X			X	
CIFAR	Knott, K.K., D. Boyd, G.M. Ylitalo and T.M. O'Hara	Sept 2012	Lactational transfer of mercury and polychlorinated biphenyls in polar bears	Chemosphere	Journal article	http://dx.doi.org/10.1016/j.chemosphere.2012.02.053	NA08OAR4320751	X			X	
CIFAR	Knott, K.K., D. Boyd, G.M. Ylitalo and T.M. O'Hara	Nov 2012	Concentrations of mercury and polychlorinated biphenyls in blood of Southern Beaufort Sea polar bears (*Ursus maritimus*) during spring: variations with lipids and stable isotope (δ15N, δ13C) values	Canadian Journal of Zoology	Journal article	doi: 10.1139/Z11-071	NA08OAR4320751	X			X	
CIFAR	Knott, K.K., P. Schenk, B. Beyerlein, D. Boyd, G.M. Ylitalo and T.M. O'Hara	Nov 2011	Blood-based biomarkers of selenium and thyroid status indicate possible adverse biological effects of mercury and polychlorinated biphenyls in Southern Beaufort Sea polar bears	Environmental Research	Journal article	doi:10.1016/j.envres.2011.08.009	NA08OAR4320751	X			X	

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

Appendix 3.

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 final report was submitted via Grants Online in June 2013. It is included here for the sake of completeness.]

NOAA grant NA10OAR4310055 supported the downscaling of projections of climate change for North American high latitudes, specifically Alaska and northern Canada. Recent and ongoing climate assessments (e.g., the U.S. National Climate Assessment scheduled for release in late 2013) have pointed to 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 activities—Activity (4) 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 project's efforts fell into eight main categories: (1) identification of optimal subsets of climate models for Alaskan and Canadian downscaling applications, (2) downscaling for Alaska and northern Canada by the Delta method in order to provide working scenarios, (3) Extension of the downscaling to marine ecosystem models and to permafrost simulations, (4) provision of downscaled fields for Alaska as part of a regional technical input report for the National Climate Assessment, (5) projections of changes of marine access in Alaskan waters, (6) implementation of a quantile mapping procedure utilizing daily model output to project changes in extreme events, (7) incorporation of the latest generation (CMIP5) of coupled models into our downscaling, and (8) 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 eight activities in more detail.

(1) *Identification of optimal subsets of climate models for Alaskan and Canadian downscaling applications*

While global climate models (GCMs) provide credible quantitative estimates of future climate at continental scales and above, individual model performance varies for different regions, variables, and evaluation metrics: a less-than-satisfying situation. In collaboration with NOAA researchers J. Overland and M. Wang of the Pacific Marine Environmental Laboratory, we have documented and implemented an approach to model selection for various Arctic subregions. Publications describing the approach with the CMIP3 models have appeared in the Journal of Climate (Overland et al., 2011) and the Arctic Council assessment project known as SWIPA (Snow, Water, Ice and Permafrost in the Arctic). Because of the mostly unexplained inconsistencies in model performance under different selection criteria, simple and transparent evaluation methods are favored. Starting with a set of model results obtained from an "ensemble of opportunity, the core of our procedure was to retain a subset of models through comparisons of model simulations with observations at both the continental and regional scale. The continental scale evaluation was a check on the large-scale climate physics of the models, and the regional-scale evaluation emphasizes variables of ecological or societal relevance. In many but not all applications, improved results were obtained from a reduced set of models rather than by relying on the simple mean of all available models. Reliance on a single model proved to be a less-than-optimal strategy. For some applications, no model may be able to provide a suitable regional projection. In the Arctic the top-performing models were found to be more sensitive to greenhouse forcing than the poorer-performing models. The finding of greatest relevance to this project is that the following CMIP3 models showed the greatest skill (integrated over the seasonal cycle) in hindcast simulations of Alaskan and northern Canadian climate: the ECHAM5 model of the Max Planck Institute, Hamburg, Germany; NOAA Geophysical Fluid Dynamics Laboratory model 2.1; the Canadian Center for Climate Modeling and Analysis model CGCM 3.1; the Japanese model MIROC 3.2; and the U.K.'s Hadley Centre model HADCM3.

Publications from Activity (1):

Overland, J.E., M. Wang, N.A. Bond, J.E. Walsh, V.M. Kattsov and W.L. Chapman. 2011. Considerations in the selection of global climate models for regional climate projections: The Arctic as a case study. *Journal of Climate,* 24:1583–1597. doi: 10.1175/2010JCLI3462.1.

Walsh, J.E., J.E. Overland, P.Y. Groisman and B. Rudolf. 2011. Ongoing climate change in the Arctic. *Ambio,* 40:6–16.

Overland, J.E., M. Wang, J.E. Walsh, J.H. Christensen, V.M. Kattsov and W.L. Chapman. 2012. Climate model projections for the Arctic. Snow, Water, Ice and Permafrost in the Arctic. Chapter 3 in Scientific Report, Arctic Monitoring and Assessment Program, 3-1–3-18, http://amap.no/swipa/

Walsh, J.E., J.E. Overland, P. Y. Groisman and B. Rudolf. 2012. Arctic climate: Recent variations. Snow, Water, Ice and Permafrost in the Arctic. Chapter 2 in Scientific Report, Arctic Monitoring and Assessment Program, 2-1–2-13, http:// http://amap.no/swipa/

(2) *Downscaling for Alaska and northern Canada by the Delta method in order to provide working scenarios.*

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

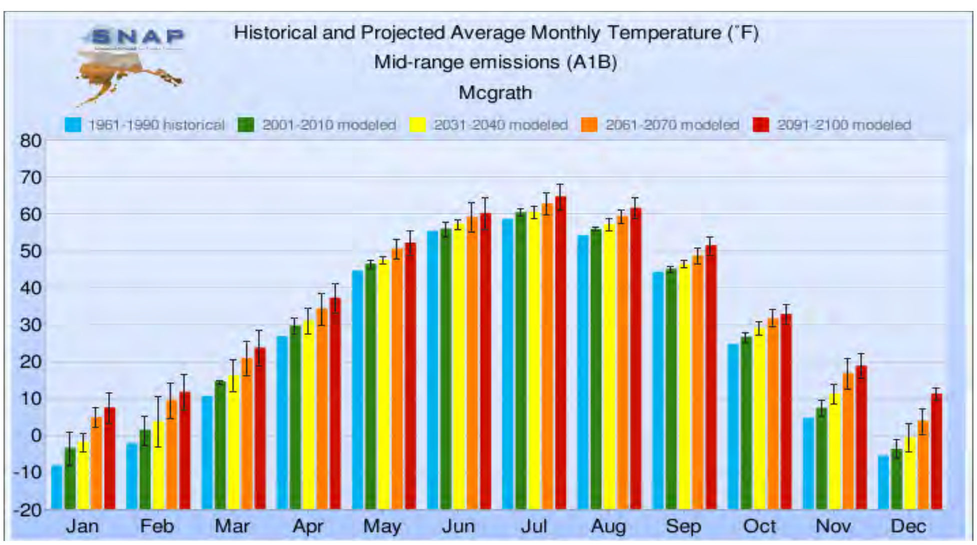


Figure 1. Example of the downscaled temperatures (°F) by decade for a community (McGrath) in the Alaskan Interior. Colors represent different decadal time slices, which are shown for each calendar month (x-axis). Thin black range indicators are uncertainties, for which the metric is the across-model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

(3) *Extension of the downscaling to marine ecosystem models and to permafrost simulations.*

During the project's early phases, it became apparent that the needs of users extend well beyond temperature and precipitation. Examples of needs include evapotranspiration over terrestrial regions where surface drying and/or water levels are user concerns, subsurface temperatures in areas of permafrost and permafrost-affected infrastructure, and the surface forcing of offshore waters where marine ecosystems have value to community and commercial stakeholders. For the evaluations of changes in potential evapotranspiration, we have collaborated with B. O'Brien of The Wilderness Society, who used the downscaled model output to compute changes in surface moisture flux and growing season length; these results were provided to the 2013 National Climate Assessment (see Activity (4) below). For high-resolution projections of permafrost, investigators in the UAF Geophysical Institute's Permafrost Laboratory have used our downscaled model output to drive a state-of-the-art permafrost model at high resolution. The results, a sample of which is shown in Figure 2 below, include maps of future permafrost degradation based on annual mean soil temperatures at a depth of 1 meter. The figure shows that annual mean 1-meter soil temperatures over large areas of interior Alaska increase from below-freezing (blue) to above freezing (red) by 2050, implying thaw and degradation of permafrost, with adverse consequences for overlying infrastructure (roads, buildings, pipelines, etc.). Finally, our output has been used by Georgina Gibson, a postdoctoral scientist supported by this project, to drive a nutrient-phytoplankton-zooplankton (NPZ) model that forms the underpinning of a marine food web model. The NPZ simulations are being applied to the Bering Sea, where high resolution is necessary to capture the details of the coastline, islands and bathymetry.

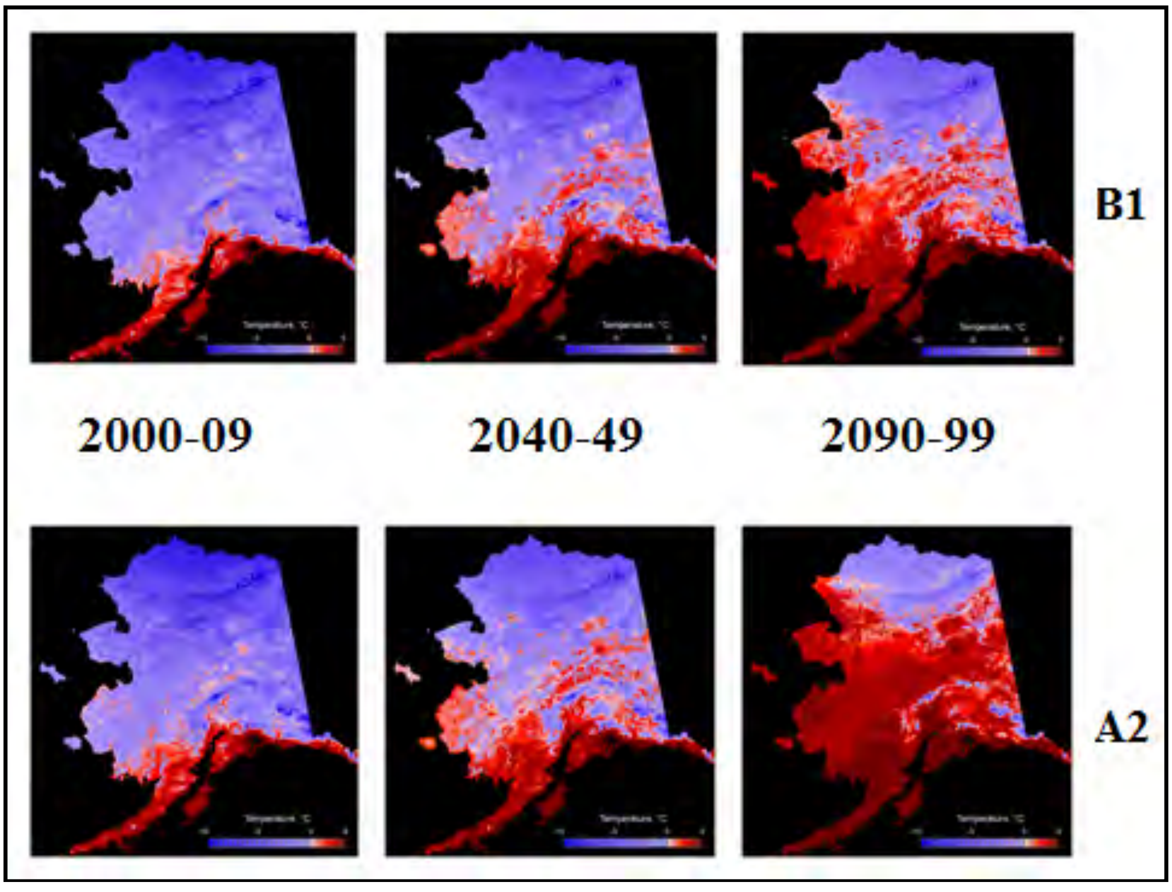


Figure 2. Annual mean ground temperatures at 1-meter depth for 2000–09, 2040–49, and 2090–99. Fields are from permafrost model simulations driven by downscaled CMIP3 climate model output for the B1 (upper panels) and A2 (lower panels) scenarios. As indicated by color bars, blue shades represent temperatures below 0°C and red shades represent temperatures above 0°C.

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

Our contributions to the Alaska Technical Input Report for the NCA included downscaled fields of historical and projected fields of the primary variables (temperature, precipitation) as well as downscaled fields of two key derived variables described above under Activity (3): (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 (see Figure 2 above) are projected to occur by the end of the century. Because of their potential impacts on 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 (4):

Stewart, B.C., K.E. Kunkel, L.E. Stevens, L. Sun and J.E. Walsh. 2013. Climate of Alaska. Technical Input Report for U.S. National Climate Assessment, U.S. Global Change Research Program, 60 pp.

(5) *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 was recently published (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 3 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. (Note: Partial support for this activity was also provided by NOAA award NA11OAR4310172, "An integrated sea ice database for century-scale reanalyses and diagnostic studies").

Publication from Activity (5):

Rogers, T.S., J.E. Walsh, T.S. Rupp, L.W. Brigham and M. Sfraga. 2013. Future Arctic marine access: Analysis and evaluation of observations, models, and projections of sea ice. *The Cryosphere*, 7:321–332.

(6) *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 earlier progress report were based on the CMIP3 models. With the release of the CMIP5 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 or Canada facilitates exchanges of information with the modeling centers.

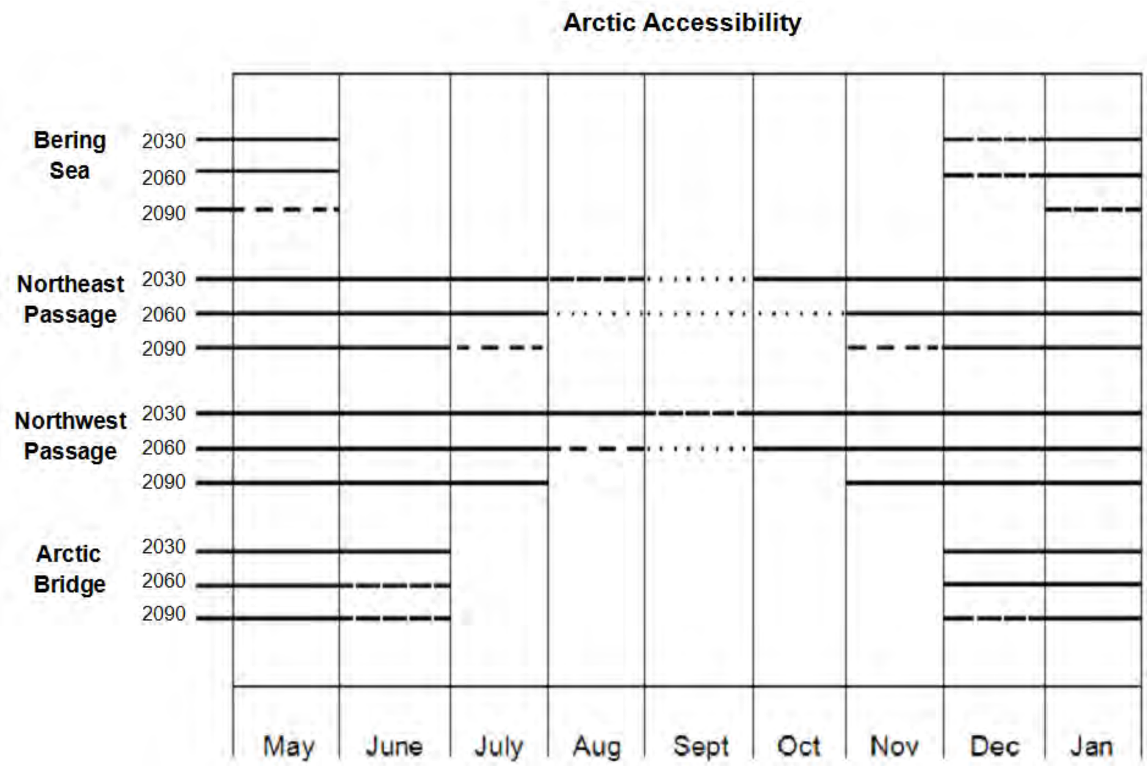


Figure 3. Projected changes in arctic marine access as a result of changes in sea ice cover projected by a set of four CMIP3 models. A solid line indicates that no model projects accessibility (defined as open water along entire navigation corridor) in a calendar month (x-axis). Dotted and dashed lines indicate that one and two models, respectively, project accessibility. Absence of any line indicates that all four models project accessibility. (From Rogers et al., 2013).

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. et al., 2011, Journal of Climate, 24:1583–1597). The selected CMIP5 models 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.

Building on this model selection, Walsh and UAF graduate student Katrina Bennett examined extreme temperature and precipitation events in Alaska in an ensemble of the top-performing CMIP5 and an atmospheric reanalysis. The evaluations included a 30-year historical period and two 30-year future timeslices centered on the 2050s and the 2080s. The metrics were the extreme daily maximum and minimum temperature of each month, and the maximum 5-day precipitation amount of each month. Although some biases exist, the models were found to capture the spatial pattern and seasonality of the extremes depicted by the ERA-40 reanalysis. Discrepancies between station data (Anchorage, Fairbanks, Barrow) and both the models and reanalysis are larger than the model-reanalysis differences and are consistent with (1) elevation differences arising from the models' resolution and topography, and (2) gauge undercatch of precipitation in the station data. For the future timeslices, the projected changes are two to four times larger than the across-model standard deviations. Projected changes in extreme minimum temperature and extreme 5-day precipitation amounts are much larger than the projected changes in the corresponding means, although the converse is true for extreme maximum temperature. The extreme minimum temperatures are projected to increase two to three times as much as the extreme maximum temperatures in all seasons except summer. Increases of cold-season extreme minimum temperatures are larger in coastal regions than inland. By the 2080s, the increases in the indices of all three extremes are approximately twice as large in the RCP 8.5 scenario as in the RCP 4.5 scenario. The magnitude of the increase of maximum 5-day precipitation is largest in inland areas and in the south, although the percentage increase is largest in the north. Especially in the RCP 8.5 simulations, the models' ranges of extreme temperatures in particular grid cells converge by the end of the century, most notably in autumn. The linearity of the relationship between increases of maximum 5-day precipitation and extreme temperatures is strongest in autumn. Record 5-day precipitation events become noticeably more common in the RCP 8.5 than in the RCP 4.5 scenario.

<u>Paper submitted from Activity (6):</u>

Bennett, K.E. and J.E. Walsh: Spatial and temporal changes in indices of extreme temperature and precipitation for Alaska. *Journal of Climate*, submitted.

(7) *Implementation of a quantile mapping procedure utilizing daily model output*

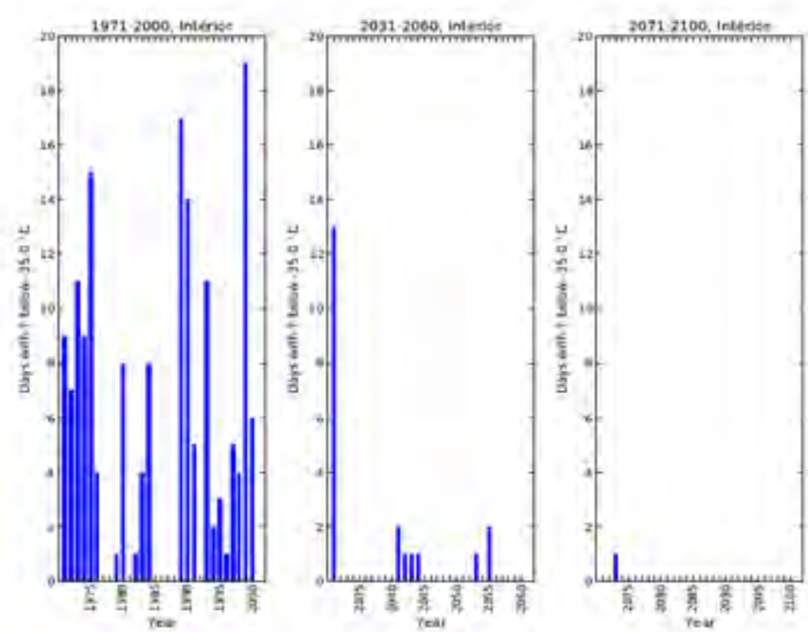
The downscaling made publicly available (Activity 2) has been based on the Delta method applied to monthly fields of CMIP3 output and superimposed on a 2-km PRISM climatology. In order to extend the downscaling to extreme events and the daily fields required for such an extension, we have implemented 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 (a high-performing CMIP5 model), and applied the mapping to a number of locations in Alaska and over the offshore seas. An example is shown in Figure 4, 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 6 above) 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, have enabled 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 models' 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.

<u>Paper submitted under Activity (7):</u>

Leonawicz, M., and J.E. Walsh: Quantile mapping strategies: An Alaskan case study. *Journal of Applied Meteorology and Climatology*, submitted.

Bettles: Days below -35C



Bettles: Days above 23ºC

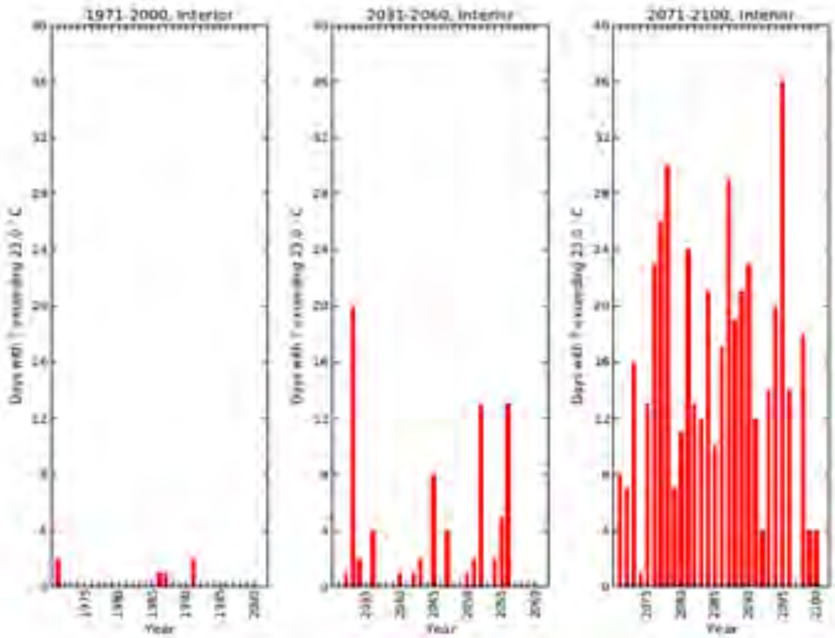


Figure 4. Example of BCSD quantile mapping: Yearly number of temperature threshold exceedances (below -35ºC, above +23ºC) at Bettles, Alaska in CCSM4 model simulation.

(8) *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 became 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 hired a postdoctoral scientist (Peter Bieniek) under this project. Dr. Bieniek used his recently computed set of Alaska climate divisions (Figure 5) as a basis for enhancing the time series of station data back to 1920 in order to document regional variations and trends of temperature and precipitation over Alaska from 1920–2012.

The divisional time series of temperature are characterized by large interannual variability superimposed upon low-frequency variability, as well as by an underlying trend. As shown in Figure 6, low-frequency variability corresponding to the Pacific Decadal Oscillation includes Alaska's generally warm period of the 1920s and 1930s, a cold period from the late 1940s through the mid-1970s, a warm period from the late 1970s through the early 2000s, and a cooler period in the most recent decade. An exception to the cooling of the past decade is the North Slope climate division, which has continued to warm. There has been a gradual upward trend of Alaskan temperatures relative to the PDO since 1920, resulting in a statewide average warming of about 1ºC and providing evidence of an externally forced warming.

In contrast to temperature, variations of precipitation are generally limited to one or two climate divisions and have much less multidecadal character. 30-year trends of both variables are highly sensitive to the choice of the subperiod within the overall 93-year period. The trends also vary seasonally, with winter and spring making the greatest contributions to the annual trends. Even within a season, adjacent calendar months can have widely different trends in a 30-year subperiod.

<u>Publications from Activity (8):</u>

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. Climate divisions for Alaska based on objective methods. *Journal of Applied Meteorology and Climatology*, 51:1276–1289.

Bieniek, P., J.E. Walsh, R.L. Thoman and U.S. Bhatt: Using climate divisions to analyze variations and trends in Alaska temperature and precipitation. *Journal of Climate*, submitted. [In press as of 3-13-2014. doi:10.1175/JCLI-D-13-00342.1 An "early online release" version available from AMS website]

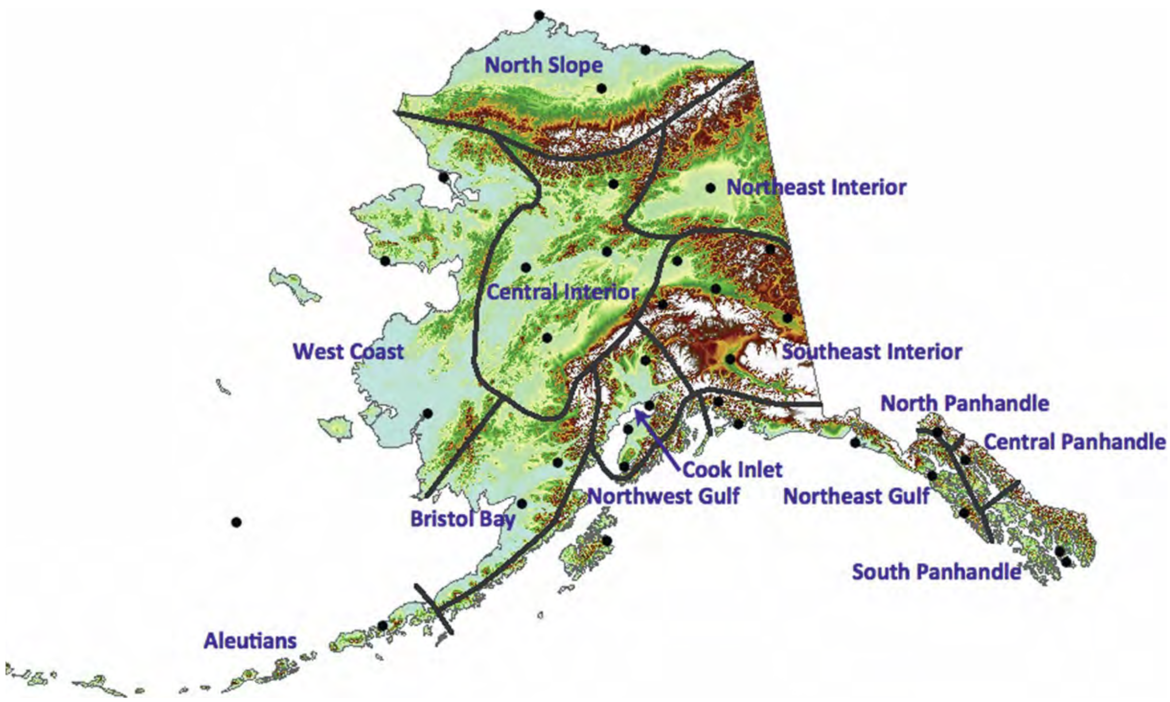


Figure 5. Objectively determined climate divisions for Alaska (from Bieniek et al. 2012). The divisional temperature and precipitation values are the basis for our extension of the historical record of station data to include the 93-year period, 1920–2012.

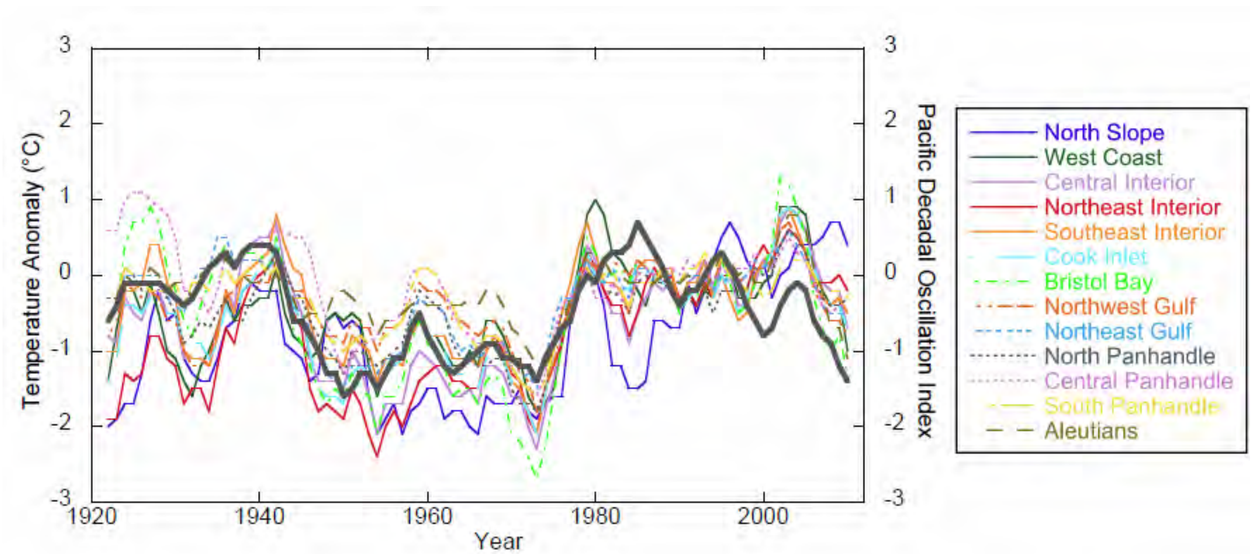


Figure 6. Temperatures for Alaskan climate divisions (colored lines, legend at right) for the period 1920–2012. Also shown (thick black line) is the Pacific Decadal Oscillation (PDO) index. All quantities are 5-year running averages, expressed as normalized departures from the corresponding means for the entire period. [From Bieniek et al., submitted]

Appendix 4. Index of Principal Investigators

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