CIFAR

Cooperative Institute For Alaska Research

Second progress report to NOAA on Cooperative Agreement NA13OAR4320056

1 April 2014 – 31 March 2015

UAF

UNIVERSITY OF ALASKA FAIRBANKS

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to NOAA
on Cooperative Agreement
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Table of Contents

Cover photo taken by UAF graduate student Megan O'Sadnick in Icy Bay near Yakutat, Alaska, with Yahtse Glacier in the background. Report layout and production by Barb Hameister, CIFAR.

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

Overview

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

Research Themes for CIFAR

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

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

Membership of CIFAR's Advisory Groups

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

The ***CIFAR Executive Board*** members are:
Christopher Sabine, NOAA Office of Oceanic & Atmospheric Research (OAR) Pacific Marine Environmental Laboratory (PMEL) Director
Kathy Crane, NOAA OAR Arctic Research Office Program Manager
Douglas DeMaster, NOAA National Marine Fisheries Service (NMFS), Director, Alaska Fisheries Science Center (AFSC)
Aimee Devaris, National Weather Service (NWS) Alaska Division Director
Philip Hoffman, NOAA OAR Cooperative Institutes (CI) Program Office Director
Mark Myers, University of Alaska Fairbanks (UAF), Vice Chancellor for Research
James Partain, NOAA, NWS Regional Climate Director for Alaska
Susan Sugai, CIFAR director, ex officio

The ***CIFAR Fellows*** are:

1. Larry Hinzman, Director, International Arctic Research Center (IARC), UAF, Fairbanks, AK
2. Kris Holderied, National Ocean Service (NOS), NOAA, Homer, AK
3. Anne Hollowed, AFSC, NMFS, NOAA, Seattle, WA
4. Henry Huntington, Huntington Consulting, Eagle River, AK
5. Katrin Iken, Professor of Marine Biology, Institute of Marine Science (IMS), School of Fisheries and Ocean Sciences (SFOS), UAF, Fairbanks, AK
6. Zygmunt Kowalik, Professor Emeritus of Physical Oceanography, IMS, SFOS, UAF, Fairbanks, AK
7. Gordon Kruse, President's Professor of Fisheries, SFOS, UAF, Juneau, AK
8. Denby Lloyd, Executive Director, North Pacific Research Board, Anchorage, AK
9. Molly McCammon, Director, Alaska Ocean Observing System, Anchorage, AK
10. Jeremy Mathis, Supervisory Oceanographer, PMEL, NOAA, Seattle, WA, and Affiliate Professor of Chemical Oceanography, IMS, SFOS, UAF, Fairbanks, AK (*effective 12/10/14*)
11. Phil Mundy, Division director, Auke Bay Laboratory, AFSC, NMFS, NOAA, Juneau, AK

12. James Overland, Oceanographer, PMEL, NOAA, Seattle, WA
13. Carven Scott, Chief, Environmental & Scientific Services Division, NWS, NOAA, Anchorage, AK
14. Terry Whitledge, Professor of Biological Oceanography, IMS, SFOS, UAF, Fairbanks, AK

Summary of Awards Made during Reporting Period

During the second reporting year of our renewal cooperative agreement NA13OAR4320056, NOAA provided 3 amendments to the CIFAR renewal agreement for CIFAR core administration, one Task I education and outreach amendment, one Task II and 14 Task III research awards totaling nearly $1.56M. A full list of CIFAR awards made during the reporting period is presented in Appendix 1.

Summaries of CIFAR awards funded this reporting period by task/theme are shown in Table 1. Table 2 shows the distribution of CIFAR Task II & III projects (percentage of total) by NOAA line office.

Table 1: Summary of CIFAR Awards Funded 1 April 2014–31 March 2015: by Task and Theme

Theme	Number of Awards	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)	**4**		**$198,107**	**12.7%**
Core Support	3	$101,635		6.5
Education & Outreach	1	96,472		6.2
Research Themes (Task II & III)	**15**		**$1,361,646**	**87.3%**
Climate Change & Variability	1	$199,993		12.8
Coastal Hazards	4	$449,305		28.8
Ecosystem Studies & Forecasting	10	$712,348		45.7
Total	**19**		**$1,559,753**	**100.0%**

Table 2: Summary of CIFAR Task II & III Awards Made 1 April 2014–31 March 2015: by Funding Source

Funding Source	Number of Awards	Total Amount	Percent of Total	% of Task I "tax" paid
OAR	6	$481,959	35.4%	73%
NESDIS	4	$461,830	33.9%	27%
NWS	1	$187,468	13.8%	0%
NMFS	4	$230,389	16.9%	0%
Total	**15**	**$1,361,646**	**100.0%**	

During the current reporting year, the funding of Task I core administration support for CIFAR was billed to line offices based upon funding received in Year 1. However, only OAR (amendments 15 and 29 totaling $73,865) and NESDIS (amendment 31 totaling $27,770) contributed to CIFAR's Task I core administration as shown in Appendix 1 resulting in an underfunding compared to previous years. Core administrative support for CIFAR was just 6.5% of funding during the reporting year.

Highlights of CIFAR Task I Activities

Core Administration

The primary role of CIFAR administration is to support research, education, and outreach carried out under the auspices of the Cooperative Institute. CIFAR is currently staffed by three UAF employees who also staff the UAF Center for Global Change & Arctic System Research: Susan Sugai, director; Sarah Garcia, CIFAR administrator working remotely on a 62% FTE basis, and Barb Hameister, publications and meetings manager. This reporting period overlapped with the final 9 months of our original competitive cooperative agreement NA08OAR4320751. CIFAR Task I funds from NA08OAR4320751 supported 843 hours of the CIFAR director who also received 552 hours of CIFAR match funds from UAF (for the current CIFAR renewal NA13OAR4320056) while serving as acting CIFAR administrator for approximately 20% of this reporting period prior to Sarah's hire in mid-May and during Sarah's training period. During this reporting period, the CIFAR staff work load was:

- Susan Sugai, CIFAR director, 67% FTE (Task I and match)
- Sarah Garcia, CIFAR administrator, 49% FTE (Task I and match)
- Barb Hameister, publications and meetings manager, 27% FTE (Task I and match)

Susan Sugai 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 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.

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 4 April 2014 and recommended full or partial funding of 14 projects (from a field of 26) for awards running from 1 July 2014 to 30 June 2015. Eight of these awards were funded with a combination of CIFAR Task 1 from NA08OAR4320751 and match education funds. Because the student award period timing bridges the two CIFAR cooperative agreements, activities prior to 31 December 2014 were covered with Task I funds from NA08OAR4320751 and were reported in the year 7 (final) report for that agreement, while activities in 2015 are covered by UAF match funds associated with our current renewal agreement.

The students, the degree that they are seeking, and their FY15 CIFAR projects are listed below:

- **Kimberly (Tweet) DeGrandpre,** Department of Geology & Geophysics, UAF. *"Relative sea level change in western Alaska as constructed from repeat tide gauge and GPS measurements."*
- **Kyle Dilliplaine**, School of Fisheries & Ocean Sciences (SFOS), UAF. *"Sea ice meiofauna in an ice free Arctic summer; who is present and where will they go?"*
- **Amanda Meyer**, School of Natural Resources and Extension, UAF. *"Exploring community climate change discourses in Nome, Alaska using Q-methodology."*
- **Kelly Overduijn**, Department of Biology & Wildlife, UAF. *"Reproductive success of arctic-breeding shorebirds in a changing climate."*
- **Charlotte Regula-Whitefield**, SFOS, UAF. *"Nutrition and reproduction in the California sea cucumber (Parastichopus californicus)."*
- **Alexander Sacco**, Department of Geology & Geophysics, UAF. *"Sea ice conditions and walrus migration near St. Lawrence Island: Integrating local knowledge for assessing change and interpreting satellite data."*
- **Tanja Schollmeier**, SFOS, UAF. *"Effects of sea ice algal loss on benthic communities using biomarker analysis."*
- **Chris Waigl**, Department of Geology & Geophysics, UAF. *"Boreal forest fire severity and area assessment using mid- and thermal infrared remote sensing and field observations."*

Student Support through Individual Awards

Two graduate students were funded through CIFAR RUSALCA projects, and both received more than 50% of their support from NOAA. In addition, two undergraduate students and 7 other graduate students received salary support through CIFAR.

Other CIFAR Administrative Activities

In July and August 2014, CIFAR worked with CIFAR PI and Fellow Katrin Iken, a professor of marine biology in the School of Fisheries and Ocean Sciences (SFOS) at the University of Alaska Fairbanks to revise and resubmit a successful proposal to lead a five-year, $6 million project to establish the **Arctic Marine Biodiversity Observing Network (AMBON)**, a multi-institutional data collection and integration effort focused on the U.S. Chukchi Sea.

- AMBON was one of three proposals competitively selected under a NOAA initiative to develop a demonstration project through the National Ocean Partnership Program (NOPP) as a first step toward developing an operational Marine Biodiversity Observation Network (BON) in the U.S. In addition to NOAA, funders include the Bureau of Ocean Energy Management (BOEM) and the Shell Exploration and Production Company.
- The AMBON award is associated with CIFAR's renewal cooperative agreement and involves 6 investigators at UAF, 2 collaborators from the University of Maryland, and one each from the University of Washington, U.S. Fish & Wildlife Service, and NOAA. AXIOM (affiliated with the Alaska Ocean Observing Network) will be involved with the project data management as they have for the Russian-American Long-Term Census of the Arctic Program (RUSALCA).

A joint teleconference meeting of the CIFAR Executive Board and Fellows was held 30 October 2014, where new funding opportunities and challenges for CIFAR were discussed.

In November 2014, CIFAR worked with six groups of SFOS investigators to submit full proposals to the NOAA Climate Program Office for continued long-term observations and monitoring in the Pacific Arctic including some of the RUSALCA field locations.

Highlights of CIFAR Research Activities

Although CIFAR has a very modest research portfolio, we have been able to get a high return on our research investment by focusing on student support both with Task I education support and through Task III research projects. Names of students involved in highlighted CIFAR research are shown in **boldface.** Not only have CIFAR-funded students authored peer-reviewed publications in highly regarded journals; their research has also contributed to NOAA operations on a near real-time basis.

Ecosystem Studies and Forecasting

Synthesis and publication efforts from RUSALCA hydrographical and biological field studies from 2004, 2009, and 2012 in the southern Chukchi Sea are well underway. **Elizaveta Ershova**, a Ph.D. marine biology student, is senior author on a paper, "Inter-annual variability of summer mesozooplankton communities in the western Chukchi Sea: 2004–2012" accepted for publication in *Polar Biology.* Two other publications in preparation for the RUSALCA special issue of *Oceanography* involve multiple CIFAR RUSALCA PIs and students. "Patterns of zooplankton and benthic fauna in the Chukchi Sea in relation to physical forcing" involves Iken, **Ershova,** Bluhm, Hopcroft, and Whitledge; while Bluhm, Iken, and **Serratos** are among the authors on "Time-series of benthic community structure and biomass and associated environmental drivers as part of the RUSALCA program."

Climate Change and Variability

Katrina Bennett finished her Ph.D. in December and has begun a post-doc at Los Alamos National Laboratory. She has two publications in revision on "MODIS-derived snow melt timing in boreal warm-permafrost watersheds in Interior Alaska" and "Using MODIS estimates of fractional snow cover extent to improve river forecasting models." Her research has played a key role in operations of NOAA River Forecast Centers (RFC).

PI Jessica Cherry and Ph.D. student **Molly Tedesche** are working with NOAA's NMFS together with the Juneau NWS forecast office and the RFC on determining snow cover and corresponding water resources in southcentral and southeast Alaska.

Coastal Hazards

Sean Egan, a Ph.D. candidate in environmental chemistry is senior author on the paper "WRF-Chem modeling of sulfur dioxide emissions from the 2008 Kasatochi Volcano" that was published in *Annals of Geophysics* earlier this year.

Jonathan Whitefield, a 2013 Global Change Student Research Awardee funded by CIFAR, recently published "A new river discharge and river temperature climatology data set for the pan-Arctic region" in *Ocean Modelling 88(2015)1–15*. His presentation entitled "The importance of accurately reproducing river discharge in models" at a

steering committee meeting of the UAF Center for Global Change (CGC) had immediate relevance to Rick Thoman, NWS climate science and services manager for the Alaska region. Rick requested that Jonathan give his presentation at an Alaska Center for Climate Assessment & Policy webinar attended by eight NWS science and operations officers in Fairbanks, Anchorage, and Silver Spring, MD. Among those participating were Rebecca Heim, NWS Alaska Region Sea Ice Program lead, Renee Tatusko, NWS Alaska Region, International and Arctic Policy Coordinator, Scott Lindsey, NWS Alaska-Pacific River Forecast Center, and Judy Koepsell, NWS Climate Services Branch in Silver Spring. Jonathan's research has clear relevance for NWS decision support for navigation and other coastal operational needs.

Publications and Presentations

At this early stage of the renewal cooperative agreement, there are four publications to report, of which two have students as senior author. Twenty-five conference presentations (both national and international) were reported for the period 1 April 2014–31 March 2015. All other publications by PIs on awards that are continuing from CIFAR's prior cooperative agreement are listed in Appendix 3 of the Year 7 report on NA08OAR4320751.

Task I: AMBON Traineeships

Arctic Marine Biodiversity Observing Network (AMBON) student traineeships

Katrin Iken, PI ***CIFAR theme: Ecosystem studies and forecasting***
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

Amendment 30. This project is new. NOAA Office NOS; Gabrielle Canonico, Sponsor

Primary objectives

This proposal is for funding two Ph.D. graduate students whose research will be aligned with the Arctic Marine Biodiversity Observing Network (AMBON) for a period of 4 years. One student will be working on benthic communities and also will provide program management for AMBON. The other PhD student will work on the genetic analysis of microbes, small plankton and meiofauna.

Both of these students will be receiving education, research, and outreach experience in this NOAA initiative to develop a demonstration project through the National Ocean Partnership Program (NOPP) as a first step toward developing an operational Marine Biodiversity Observation Network (BON) in the U.S. These students will be mentored by the multi-national, multi-institutional, multi-agency collaborators who form the AMBON principal investigators.

This effort, led by Katrin Iken at UAF, will provide these students with a unique opportunity to acquire research training as part of a 5-year research program covering three field seasons in an understudied marine environment that is subject to rapid climatic and resource management challenges. As a part of the AMBON/CIFAR graduate student traineeships, these students will gain education and training that will be valuable to NOAA's strategic needs in both climate services and ocean resource management, and continues CIFAR's priority on graduate student education and outreach.

Research accomplishments/highlights/findings

This project will provide student training stipends and tuition for two students who have been accepted in the graduate program at UAF and will be beginning their research training during the next reporting period.

NOAA relevance/societal benefits

AMBON will provide information on ecosystem components that are currently not part of long-term observation programs in the Chukchi Sea, namely the microbial and other small size fractions, the epifauna and fish components, and functional diversity through food webs. Through integration with other programs such as the Distributed Biological Observatory (DBO; http://www.arctic.noaa.gov/dbo/), this benefits our larger Arctic ecosystem understanding and will improve our detection of biodiversity trends and changes. The AMBON will increase our ability to forecast possible changes, which will be useful to inform the various audiences, from managers to scientists. Through this educational effort, two students will develop their dissertation research with direct involvement of multi-national, multi-institutional, multi-agency researchers.

Partner organizations and collaborators

In addition to NOAA, funders include the Bureau of Ocean Energy Management (BOEM) and the Shell Exploration and Production Company. Besides UAF, AMBON collaborators are from the University of Maryland Center for Environmental Science, the University of Washington Applied Physics Lab, the U.S. Fish and Wildlife Service, NOAA, and the Alaska Ocean Observing System.

Impact

This project will accomplish two major impacts: (1) training for two graduate students, (2) innovative thesis research that will improve our knowledge of the biodiversity of the U.S. Chukchi Sea continental shelf.

Non-competitive projects, by CIFAR theme:

Ecosystem Studies and Forecasting
Including RUSALCA (Russian-American Long-term Census of the Arctic) projects

Climate Change and Variability

Coastal Hazards

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

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

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

During the reporting period, RUSALCA efforts were focused primarily on data analysis and synthesis with limited analyses of additional samples collected from mooring cruises.

Goals of the overall RUSALCA program

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

Project reports for CIFAR awards associated with the RUSALCA program follow this overview, and reflect current synthesis efforts.

A synthesis of long-term observations of Pacific-Arctic zooplankton communities

Russell R. Hopcroft, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

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

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

Amendments 4 & 14 NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
Continues research from NA08OAR4320870

Primary objectives
Conduct a synthesis of recent zooplankton observations in the Chukchi Sea and over the past 30–50 years, specifically tackling the question: Can a climate change signal be detected for zooplankton in terms of major species or community structure? A key component of this analysis will be observations collected by the Russian-American Long-term Census of the Arctic (RUSALCA) program, and its precursor, the Bering Pacific (BERPAC) program. Additional information will be drawn from agencies, industry, and international scientists working in the Chukchi region.

Research accomplishments/highlights
The paper summarizing the zooplankton communities of the 3 primary RUSALCA cruises (plus a mooring cruise) is now accepted for publication. Hopcroft, Kosobokova and Ershova contributed to a paper submitted by Pisareva et al. for the Oceanography RUSALCA special issue (Pisareva, M.N., R.S. Pickart, K. Iken, E. Ershova, J. Grebmeier, L. Cooper, B.A. Bluhm, R. Hopcroft, T.E. Whitledge, C. Ashjian, K. Kosobokova. Patterns of zooplankton and benthic fauna in the Chukchi Sea in relation to the physical forcing). Ershova is now preparing a manuscript for the same special issue where we are exploring long-term changes in the distribution of zooplankton species/communities in the Chukchi Sea over the last 60 years – analysis is more or less completed and we are currently drafting the text. Hopcroft is acting as a guest editor on the special issue. Once these manuscripts are completed we will begin drafting a third manuscript on *Pseudocalanus* copepods in the Chukchi Sea to be submitted to Journal of Plankton Research.

Work continues on consolidating and unifying existing planktonic data sets throughout the arctic. Hopcroft attended an Experts group meeting in Greenland for the Circumpolar Biodiversity Monitoring Program (CBMP) during October 2014 and will attend a writing workshop to this purpose in Iceland the second week of April 2015. He will present some preliminary analysis of patterns on arctic shelves at Arctic Science Summit Week in Toyama Japan in late April. Kosobokova and Ershova attended the Gordon Research conference in Italy during March 2015 and presented aspects of the project.

NOAA relevance/societal benefits
This project examines the potential impacts of climate change in the Pacific–Arctic gateway.

Education
Elizaveta Ershova continues her Ph.D. under this project – she remains jointly supervised by Hopcroft and Kosobokova, and splits her time between UAF and Shirshov Institute, Moscow. She expects to complete her degree in late 2015.

Outreach
Hopcroft, through ArcOD (Arctic Ocean Biodiversity Project) website, continues to develop webpages providing information on Arctic zooplankton and access to historical datasets: see http://www.arcodiv.org/. The species page concept has been expanded upon through a related fellowship by the Encyclopedia of Life to Ershova, that will be merged with ArcOD content over time. The ArcOD website has received ~1 million page loads since its development in 2008.

Publications and presentations

Accepted for publication

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. Inter-annual variability of summer mesozooplankton communities of the western Chukchi Sea: 2004–2012. Accepted for publication in *Polar Biology*.

Wassmann, P., K.N. Kosobokova, D. Slagstad, K. Drinkwater, R.R. Hopcroft, S.E. Moore, I. Ellingsen, R.J. Nelson, E. Popova, J. Berge and E. Carmack. The contiguous domains of Arctic Ocean advection: trails of life and death. Accepted for publication in *Progress in Oceanography.*

Oral presentation

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. 2015. Inter-annual variability of summer mesozooplankton communities of the western Chukchi Sea: 2004–2012. Gordon Research conference, Lucca, Italy, March 15–20, 2015.

Other products and outcomes

Hopcroft continues to work with NOAA and the Circumpolar Biodiversity Monitoring Program (CBMP) under the International Arctic Council within which the RUSALCA program will represent a significant component from the USA. Hopcroft also provides oversight on the RUSALCA data management project that is aggregating data at pan-arctic scales.

Partner organizations and collaborators

Arctic Ocean Biodiversity Project (ArcOD)

Publications related to this project, funded under previous CIFAR cooperative agreements

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. 2014. Biodiversity and biogeography of lower trophic fauna of the Pacific Arctic Region—Sensitivities to climate change (Chapter 10). In: J.M. Grebmeier and W. Maslowski, Eds. The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment. Springer Science+Business Media Dordrecht, pp. 269–336.

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

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

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

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

Amendments 3 & 27 NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
Continues research from NA08OAR4320870

Primary objectives

- Synthesize information on food web structure and epibenthic faunal assemblages in the Chukchi Sea including their links to the physical and chemical properties of water mass characteristics. This synthesis will build on data collected during RUSALCA cruises in 2004, 2009, and 2012.
- Provide an assessment of the temporal variability in the benthic food web and epibenthic community structure in relation to climatic variability.

Research accomplishments/highlights/findings

Work during the reporting period was mostly associated with comprehensive data analysis of the 2009 and 2012 epifaunal community and food web data across the study region, and a temporal analysis of epifaunal communities and food webs along repeat stations (2004, 2009, 2012) in the southern Chukchi Sea. Both food web and epibenthic community structure data are part of M.S. student Carlos Serratos' thesis, and this report is based mostly on his analyses. We previously reported separately on the 2009 and 2012 data, and we focus the present report on the

temporal comparisons of epibenthic communities and food web structure. In addition, we have worked on several synthesis efforts of the overall, decadal RUSALCA program.

Temporal trends in food web structure

Stations sampled for food web structure in the southern Chukchi Sea were divided by their association with three water masses, the Alaska Coastal Water (ACW), the central Bering Shelf–Anadyr Water (BSAW) and the Russian Coast (RC), which is under the occasional influence of the Siberian Coastal Current as well as under the freshwater outflow of the large Kolyuchin Lagoon. Trophic level (TL) of organisms was determined using their $\delta^{15}N$ stable isotope ratio in relation to particulate organic matter as a reference in all three sampling years. $\delta^{13}C$ of organisms was determined to constrain food source end members.

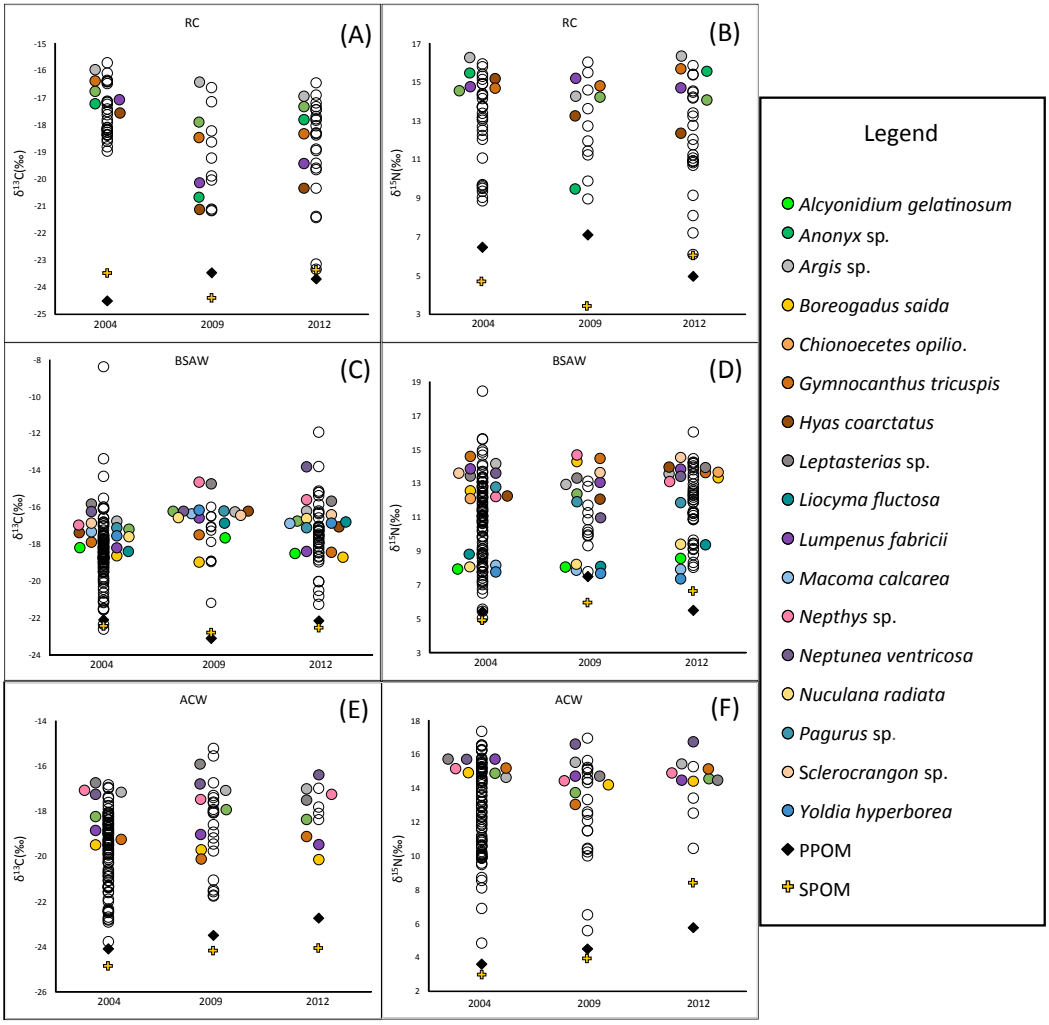

Figure 1. Temporal comparison of $\delta^{13}C$ and $\delta^{15}N$ values of organisms and particulate organic matter (POM) sampled repeatedly in 2004, 2009 and 2012 within water masses in the southern Chukchi Sea. Colored circles refer to the same taxa investigated across various water masses and years, while unfilled circles refer to other taxa (not repeatedly sampled). RC = Russian Coast; BSAW = Bering Shelf–Anadyr Water; ACW = Alaska Coastal Water.

Neither stable carbon nor nitrogen isotope ratios of pelagic particulate organic matter (PPOM) or of sediment particulate organic matter (SPOM) food sources significantly differed among years within any of the three water masses, likely due to high variability within each water mass. Carbon isotope values of the same taxa differed significantly among years within RC (ANOVA, $p = 0.028$), with significantly higher values in 2004 than 2009 ($p = 0.015$) and 2012 ($p = 0.025$) (Figure 1A). Nitrogen isotope values in RC, however, did not differ among years (ANOVA, $p = 0.18$) (Figure 1B). In ACW and BSAW, carbon and nitrogen isotope values of the same organisms did not differ significantly among years (ANOVA, $p > 0.05$ for all comparisons) (Figure 1C-F). In all years in

ACW, there was a noticeable gap in $\delta^{15}N$ values between PPOM and epibenthic consumers (Figure 1F) that was only occupied by very few taxa. This indicates that the majority of consumers in this water mass was not consuming the PPOM food source directly and suggests a consistently missed trophic link not sampled. This gap was not present (BSAW) or not as pronounced (RC) in the other water masses.

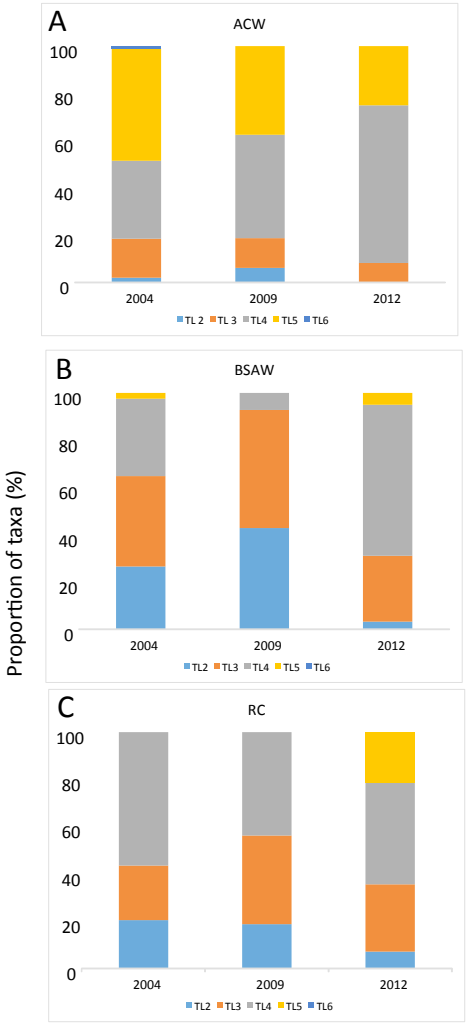

Figure 2. Proportional distribution of taxa among trophic levels in the southern Chukchi Sea in 2004, 2009 and 2012. Comparison among years by dominant water masses in the system. RC = Russian Coast; BSAW = Bering Shelf–Anadyr Water; ACW = Alaska Coastal Water; TL = Trophic Level.

Taking all sampled taxa into account, the food web in ACW was longest with six TL (although only one taxon in TL 6) in 2004 and five TL in 2009 and 2012 (Figure 2A). In BSAW, the food web was the shortest in 2009 (four TL), while food web lengths were similar in 2004 and 2012 with five TL (Figure 2B). In RC, the food web was longer in 2012 (five TL) than in previous sample years (four TL). In ACW, over 80% of all taxa analyzed for food web structure were in TL 4 and 5 in all years, with the remaining taxa mostly within TL 3 and very few in TL 2 (Figure 2A). In contrast, the majority of the taxa in BSAW were TL 2-4 in all years; however, proportionally much fewer taxa were at TL 4 in 2009 than the other two sampling years, especially in 2012 (Figure 2B). Similar to BSAW, most taxa in RC were within TL 2-4, and only in 2012 about 20% of the taxa were at TL 5 (Figure 2C).

The high variability of the POM sources within and among the three water masses likely reflects the high short-term variability in hydrographic properties. In general, however, the slightly lower $\delta^{13}C$ values in the coastal water masses (ACW and RC, Figure 1) may indicate terrestrial matter contributions from river inflow. In contrast to high variability in POM, relatively stable food web structure over time suggests that the benthic consumers integrated the high POM variability and reflected the averaged hydrographic conditions in the area. These benthic food webs should then also be good indicators of potential ecosystem shifts in energy flow on the southern Chukchi shelf, as deriving from long-term climatic changes. The trophic gap between POM sources and consumers, specifically the ACW region, may be a microbial step, or consumers not represented in this study. If a microbial link was the explanation, it seems to have a greater influence on coastal water masses with higher terrestrial carbon input. This concurs with higher microbial activity documented for the ACW than BSAW, where a smaller portion of the primary production is processed by the microbial loop. Climate warming may increase terrestrial matter influx into the coastal Chukchi Sea and may also lead to higher microbial activity, which may alter benthic food web structure in the long term.

Temporal trends in epifaunal community composition

The number of taxa when standardized to the same taxonomic resolution for all three sampling years differed among years, with 52 taxa in 2004, 49 in 2009, and 72 in 2012. The large increase in 2012 was due to a higher number of suspension feeding taxa. Total abundance per station was relatively constant over the three sampling years (Figure 3A). Echinoderms dominated total abundance in 2004 with 64 %, mostly by the holothuroid *Myriotrochus rinkii* and the brittle star *Ophiura sarsii*. Echinoderm abundance decreased in 2009 and 2012. In contrast, arthropod abundance increased from 2004 to 2012, mostly because of high abundances of the snow crab *Chionoecetes opilio* in 2009 and increases in amphipod and hippolytid shrimp abundances in 2012. Mollusk abundance peaked in 2009 because of higher numbers of the moon snail *Cryptonatica affinis* in that year compared with other sampling years. Total

biomass was significantly higher in 2009 than 2012 (ANOVA, p = 0.02) and higher, though not significantly, in 2009 than 2004 (p = 0.06) (Figure 3B). The lower biomass in 2012 was reflected in reduced biomass in all major phyla, except mollusks. Similar to abundance patterns, echinoderm biomass decreased from 2004 to 2012, mostly due to lower biomass of *O. sarsii* and *M. rinkii*. Arthropod and mollusk biomass both peaked in 2009 due to high biomass of the snow crab *C. opilio* and the moon snail *C. affinis*.

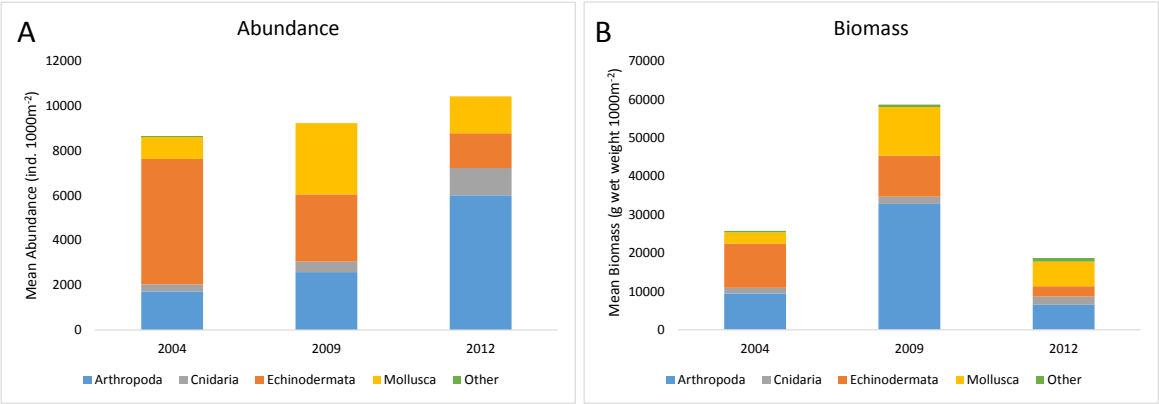

Figure 3. Temporal comparison of relative mean abundance (A) and biomass (B) per phylum across all stations and water masses in the southern Chukchi Sea.

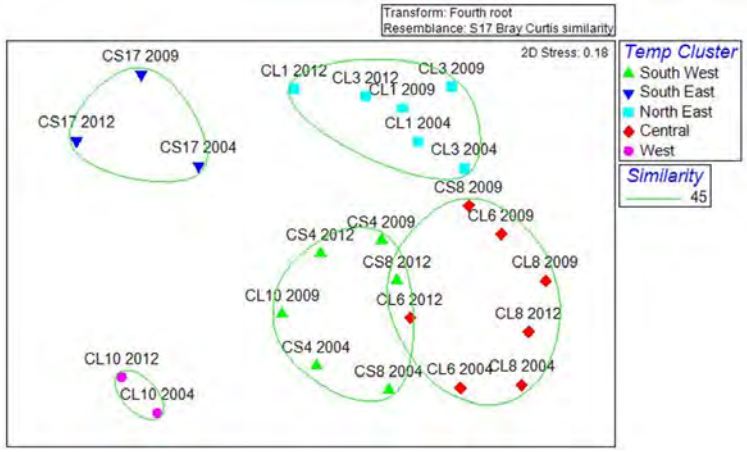

Figure 4. Non-metric multidimensional scaling (nMDS) ordination of repeat (2004, 2009, 2012) stations groups, with groups outlined at the 45% similarity level as determined by hierarchical clustering.

Stations across years grouped into five distinct epifaunal community clusters at 45% cluster similarity (Figure 4). Multivariate analysis showed that stations grouped by geographical proximity rather than by sampling year (the Analysis Of SIMilarity (ANOSIM)) with repeat station as factor: Global R = 0.8, p = 0.001; ANOSIM with factor year: Global R = 0.1, p = 0.06). This pattern suggests that regions retained relatively consistent epibenthic community composition across the sampling years, despite the at times drastic temporal variability in abundance and biomass. Across all years, substrate category was the most consistent driver of epibenthic community structure of seven variables measured. In contrast, dynamic variables such as hydrographic or food supply measures were less influential.

In summary, despite considerable temporal variability in abundance and biomass of dominant phyla across study years, overall epibenthic community composition in the southern Chukchi Sea stayed relatively consistent over time. The main explanation for this community stability may be the relative stability of relevant time-integrated environmental conditions on decadal time scales. For example, the presence of hard substrates typically fosters the occurrence of sessile suspension feeders, while depositional areas dominated by soft sediments and high organic matter content are typically preferred habitat for deposit feeders. It is possible that no detectable response to dynamic environmental variables occurred in epibenthic community structure during the study period, because the high longevity (years to decades) of these arctic invertebrates enables them to integrate temporal variability in environmental conditions. Only drastic and persistent change may affect community composition. Some measures of

food supply (e.g., infaunal biomass, chlorophyll, etc.) were correlated either to community composition or to bulk estimates of abundance and biomass in different sampling years. This may be a response – though inconsistent – to variable food supply over the sampling decade.

Synthesis of decadal RUSALCA work

We are working on two main synthesis efforts, to be published in a special RUSALCA issue of *Oceanography*. One paper combines hydrographic data on the Chukchi shelf with biological data on zooplankton, infauna and epifauna to discern whether the distribution of specific feeding types agrees with and can inform average current velocity fields. The premise is that the functional composition of especially benthic invertebrates is strongly influenced by hydrographic conditions. Specifically, suspension-feeding taxa are more commonly found in fast-flowing hydrographic regimes that foster both resuspension and continuous advective particle transport while deposit feeding taxa are more prevalent in slow flow regimes where food particles can settle. This synthetic RUSALCA effort investigates this concept in two ways; first, we analyze if feeding type distribution matches with what we know about the velocity fields on the shelf; and second, if the distribution of benthic, long-lived feeding types can inform about persistent hydrographic features in the region. Hydrographic measurements are, for the most part, restricted to synoptic point measurements and it is unclear if and how strongly some of the measured features prevail over an annual cycle. The feeding types of long-lived benthic organisms can be considered long-term recorders of prevailing conditions that reflect persistent or recurrent hydrographic features, but are relatively immune to the short-term variation that may be captured during single-season hydrographic measurements. In contrast, zooplankton organisms are expected to respond more immediately to hydrographic conditions and changes and correlate strongly with hydrographic conditions at any given time. Work on this project is progressing well and the team members have met at various times to discuss data needs and conceptual context. Maps are currently being created. The publication stemming from this research is envisioned as:

Pisareva, M.N., R.S. Pickart, K. Iken, E. Ershova, J. Grebmeier, L. Cooper, B.A. Bluhm, R. Hopcroft, T.E. Whitledge, C. Ashjian, K. Kosobokova (in preparation). Patterns of zooplankton and benthic fauna in the Chukchi Sea in relation to the physical forcing. *Oceanography*, RUSALCA Special Issue.

We also are contributing to a second synthesis effort that evaluates environmental drivers of benthic community structure and biomass in the RUSALCA study region, including sediment grain size, food supply and hydrographic factors. We evaluate the key drives for benthic population structure, including export production as food supply, sediment parameters, and predation impacts. The paper includes mapping benthic biomass and broadly covered community descriptions. It will also include RUSALCA efforts within the Distributed Biological Observatory (DBO) international network and discussion of future direction. The spatial coverage will include data from RUSALCA, the first joint USA/USSR Central Pacific Expedition (BERPAC), and other US and Russian data sets. Case studies of time series studies will be a key element of this synthesis, with focus on the time series in the southern Chukchi Sea. We will provide epibenthic abundance, biomass and community composition data to this effort as well as their correlations with environmental drivers. The publication stemming from this research is envisioned as:

Grebmeier, J.M., S. Denisenko, B.A. Bluhm, L.W. Cooper, K. Iken, C. Serratos, M. Kedra, A. Bosun (in preparation). Time-series of benthic community structure and biomass and associated environmental drivers as part of the RUSALCA program. *Oceanography*, RUSALCA Special Issue.

NOAA relevance/societal benefits

This work will contribute to NOAA's strategic plan objective "to describe and understand the state of the climate system through integrated observations" of the biological components and the associated water mass characteristics. Increased knowledge of food web connections and epibenthic communities will be essential information to "understand the consequences of climate variability and changes" in the Chukchi Sea marine ecosystem. This work will provide NOAA with a product that can assist to "improve society's ability to plan and respond to climate variability." Knowledge gained during the RUSALCA work has contributed to the development of the Circumpolar Biodiversity Monitoring Program (CBMP) Implementation Plan.

Education

Carlos Serratos has been working on this project as a M.S. student in Marine Biology since fall semester 2012. His thesis objective is to compare epifaunal community and food web structure for the southern and central Chukchi Sea

from 2004, 2009 and 2012. He has completed all analyses and is currently in the advanced stages of writing his thesis. We expect a summer graduation.

Outreach

Photographs from the RUSALCA expeditions have been used in a variety of educational and scientific materials.

Publications and presentations

Publications

No publications were produced during the reporting period, but several manuscripts are in active preparation at this time.

Oral presentations

Bluhm, B.A., P. Archambault, K.H. Dunton, J.M. Grebmeier, F. Huettmann, K. Iken, B.L. Norcross, D. Piepenburg, P.E. Renaud and B.I. Sirenko. 2014. Arctic marine seafloor fauna: biodiversity, community distribution and food webs on regional to pan-Arctic scales. US-IALE Cumulative Impacts and Landscape Initiatives: A Sustainability Check During Climate Change, 2014 Annual Symposium, Anchorage, Alaska, 18-22 May 2014 (invited talk).

Bluhm, B.A., P. Archambault, K.H. Dunton, J.M. Grebmeier, F. Huettmann, K. Iken, B.L. Norcross, D. Piepenburg, P.E. Renaud and B.I. Sirenko. 2014. Arctic marine seafloor fauna in a time of environmental change: biodiversity, community distribution and food webs on regional to pan-Arctic scales. ISTAS: Integrating spatial and temporal scales in the changing Arctic System, Brest, France, 21-24 October 2014 (invited talk).

Iken, K., B.A. Bluhm and L. Divine. 2015. Snow crabs in the Chukchi and Beaufort seas. Coastal Marine Institute Annual Review, Anchorage, Alaska, 24 January 2015 (this presentation included data from RUSALCA project).

Divine, L.M., K. Iken, B.A. Bluhm, R. Foy, B. Lauth, B.L. Norcross, K. Aydin and A. Whitehouse. 2015. Snow crab (*Chionoecetes opilio*) ecology in the Alaska Arctic. Alaska Marine Science Symposium, Anchorage, Alaska, 19-23 January 2015 (this presentation included data from RUSALCA project).

Bluhm, B.A. (with input from many collaborators). 2015. Arctic marine seafloor fauna: biodiversity, community distribution and food webs on regional to pan-Arctic scales. Polar Marine Science Gordon Research Conference, Lucca, Italy, 20-25 March 2015 (invited talk).

Poster presentations

Foster, N., B. Bluhm and K. Iken. 2014. Diversity and distribution of marine mollusks along the Chukchi and Beaufort Sea shelf and slope. Mollusca 2014, The Meeting of the Americas, Mexico City, 22-27 June 2014.

Serratos, C., K. Iken and B. Bluhm. 2015. Food web structure in the southern Chukchi Sea. Alaska Marine Science Symposium, Anchorage, Alaska, 19-23 January 2015.

Partner organizations and collaborators

Bluhm and Iken were both co-PIs of the NSF-sponsored Bering Sea Ecosystem Studies (BEST) project, which investigated pelagic-benthic coupling in the Bering Sea in relation to sea ice cover. The BEST project related to the RUSALCA objectives through the common focus on climate change research on Arctic shelf systems. Both PIs are part of the newly funded AMBON (Arctic Marine Biodiversity Observing Network) project, which builds heavily on RUSALCA and aims to maintain the time series stations in the southern Chukchi Sea (US side only) and adds to the RUSALCA coverage by adding investigations on the northeastern Chukchi shelf. Both PIs are currently involved with snow crab population and reproductive dynamics work in the Chukchi and Beaufort Seas (CMI-funded), which ties together with RUSALCA epifaunal community and food web structure objectives and sampling. Both PIs also are engaged in analyzing the food web structure on the Beaufort Sea shelf, and that of snow crab on the Chukchi shelf through isotope and stomach content analysis by advising a Ph.D. student funded through the NSF-Integrative Graduate Education and Research Traineeship (IGERT) program MESAS (Marine Ecosystem Sustainability in the Arctic and Subarctic). This effort links intrinsically to the food web studies performed within the RUSALCA project on the Chukchi shelf. The continued funding for this Ph.D. student will be from the BOEM-funded Arctic Environmental Impact Study (Arctic EIS) project (Iken and Bluhm co-PIs) that focuses on fish and lower trophic level communities in the northern Bering and Chukchi Seas. Both PIs also are part of the US-Canada Transboundary project funded through BOEM that investigates epifaunal community and benthic food web structure in the Beaufort Sea in an effort paralleling our RUSALCA objectives. Bluhm was also a co-PI on the recent NPRB-funded Pacific Arctic Marine Regional Synthesis (PacMARS) project that aggregated and synthesized research across multiple disciplines in the northern Bering, Chukchi and Beaufort Seas including RUSALCA efforts.

Iken and Bluhm also are members of the Marine Expert Monitoring Group of the Circumpolar Biodiversity Monitoring Program, one of the programs under the directive of CAFF (Arctic Council Conservation of Arctic Flora and Fauna), where the RUSALCA program features strongly in monitoring the Chukchi Sea region. Iken and Bluhm are both involved in the Benthic Marine Ecosystem Expert Group of the CBMP. Under North Pacific Research Board (NPRB) and Norwegian funding, Bluhm is working with Russian collaborators (several of which are involved in RUSALCA) on editing English versions of Russian-authored taxonomic identification keys for Arctic fauna in an effort to both provide better access to identification material and uniform identifications between Russian and western Arctic researchers.

Continuation of RUSALCA fish ecology research

Brenda L. Norcross, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Brenda A. Holladay, Co-PI, *University of Alaska Fairbanks*
Morgan S. Busby, *Senior Investigator, Alaska Fisheries Science Center (AFSC), Seattle*

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

Amendments 1 & 24 NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
Continues research from NA08OAR4320870

Primary objectives

- To synthesize and publish results of the fish ecology investigations of larval and demersal fishes during the 2004, 2009, and 2012 cruises of the Russian-American Long-term Census of the Arctic (RUSALCA) to provide for better understanding of fish distribution, abundance, and demersal species associations in the present-day Chukchi Sea.
- Planned publications will also incorporate data from the extensive fish surveys we have conducted in the eastern Chukchi Sea from 2007 to 2010 under non-RUSALCA funding.

Research accomplishments/highlights/findings

During the past year, we have made progress on five manuscripts described below, one of which has been submitted for publication. We also made progress working with our Russian colleagues to flesh out an outline for the synthesis publication (Norcross lead author with American and Russian co-authors), with a new tentative title "Why are fish where they are?" Christine Gleason, who received her M.S. Fisheries Oceanography degree under Norcross in 2012, developed her thesis research based on specimens she collected during the 2009 RUSALCA cruise, thus is a lead author on two publications.

1. Gleason, Norcross (submitted February 2015) Otolith chemistry discriminates water mass occupancy of Arctic fishes in the Chukchi Sea. *Marine and Freshwater Research.*

The significant findings are as follows: Microchemistry of otoliths can be used to reconstruct fish movement patterns and habitat use between environmentally different habitats. We tested the relationship between water mass from which a fish was collected and microchemistry of the most recent growth edge of the fish's otolith using Mg, Sr, Ba and Ca. Two abundant western demersal Arctic marine fishes, Arctic cod (*Boreogadus saida*) and Arctic staghorn sculpin (*Gymnocanthus tricuspis*) were classified in up to three bottom water masses in the Chukchi Sea. The Mg:Ca ratio was the most distinguished for both species between water masses and was influenced by temperature and fish age, but not salinity. A discriminant function *post-hoc* analysis of fish occupying bottom water masses resulted in 76% correct classification of Arctic cod and 82% for Arctic staghorn sculpin into bottom water masses of capture when ages were pooled. By separating age classes, correct classifications into water masses of capture were as high as 87% for Arctic cod (three water masses) and 90% for Arctic staghorn sculpin (two water masses). Use of otolith microchemistry to determine occupancy of water masses over time is most promising for Arctic cod, which is widespread and occupies environmentally diverse habitats in Arctic waters.

2. Gleason, Norcross. Title: Physical environmental and biological correlates of otolith chemistry of arctic marine fishes in the Chukchi Sea. This includes trace element chemistry of fish otoliths and water samples collected

throughout the Chukchi Sea during RUSALCA-2009. This manuscript has gone through several iterations since last year. We expect to submit to *Fisheries Research* in May 2015.

As noted in the previous report, the significant findings are as follows. Environmental variables and fish age correlated with Arctic cod and Arctic staghorn sculpin otolith signatures, while only environmental variables correlated with Bering flounder signatures. Elemental chemistries were different for Arctic cod captured from three bottom water masses and were correlated to temperature (Sr/Ca and Ba/Ca) and fish age (Mg/Ca and Sr/Ca). Elemental correlations were not always consistent for the variables tested among fish species. The complexity of this multi-element tool suggests otolith chemistry may not be useful to determine life history movement patterns of these demersal Arctic fishes in offshore waters unless sampled over a larger magnitude of environmental variables, e.g., a greater temperature range.

3. Busby, Holladay, Norcross, Mier. Title: Ichthyoplankton of the Chukchi Sea 2004–2012: Russian-American Long-Term Census of the Arctic. This includes 2004, 2009, and 2012 RUSALCA cruises. Several iterations of this paper have been shared among the investigators, and we expect to submit this to *Polar Biology* concurrently with the following paper, Holladay et al.

The significant findings are as follows: Larval fish species, number, size and location are strongly related to timing of cruise as well as cruise track. The timing of the cruises ranged from early August in 2004 to late September in 2009, with the 2012 occurring between those times. More larval/juvenile fish were captured in bongo plankton nets when sampling was early in the ice-free season. For example, abundance of Arctic cod was greatest in 2004 and lowest in 2009; mean standard length was greater in September 2009 than in August 2004 or late August 2012. Diversity of ichthyoplankton was significantly greater in 2004 than 2009. We conclude that most larval fish grew beyond the size normally captured in bongo nets or may have settled out of the water column. Because we now know what to expect, more than one gear type may be needed in future to be appropriate to size of ichthyoplankton anticipated.

4. Holladay, Chernova, Mecklenburg, Norcross, Voronina. Working title: Spatial and temporal variability in fish communities of the Chukchi Sea, 2004–2012. This includes 2004, 2009, and 2012 RUSALCA cruises. A draft has been circulated among the authors. We expect to submit this to *Polar Biology* concurrently with the previous paper, Busby et al.

Significant findings include: The basic content of dominant species in communities was stable. The list of five most common and numerous fishes was not changed. No dramatic changes in fish fauna of the Chukchi Sea were detected during the years 2004–2012.

5. Bluhm, Holladay, Huettmann, Iken, Norcross, Sirenko. Working title: Interactions of epibenthic invertebrates and fish community structure in the Chukchi Sea. This includes field collections from 2004, 2009 and 2012 RUSALCA cruises, 2007 and 2008 Japanese R/V *Oshoro-Maru* cruises and a 2007 NOAA Bering-Aleutian Salmon International Survey (BASIS) cruise. A preliminary draft of this manuscript was completed in December 2013. Several iterations were passed among the authors in the last year. We expect to submit to a journal by summer 2015.

The significant findings include: fish to epifauna biomass ratios may be a useful indicator of carbon flow patterns and ecosystem conditions that is worth monitoring over time.

NOAA relevance/societal benefits

This project adds to the coordinated RUSALCA effort of identifying factors that underlie ecosystem change in the Arctic. Our research develops a broad-scale baseline of abundance and distribution of larval and demersal fishes throughout the Chukchi Sea and identifies the physical mechanisms affecting fish distribution, thereby directly supporting the RUSALCA objective of developing methods of identifying ecosystem change. Also through this research we tested methods to use trace elements to determine association of fish and their environment, with the potential for determining movement of fish in the Chukchi Sea.

Publications and presentations

Oral presentations

Norcross, B.L. and C. Gleason. 2014. Otolith chemistry discriminates water mass occupancy of Arctic fishes in the Chukchi Sea. 5th International Otolith Symposium, Mallorca, Spain, October 2014.

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

Terry E. Whitledge, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
Dean A. Stockwell, co-PI
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

Amendments 2 & 22 NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
Continues research from NA08OAR4320870

Primary objectives

Investigate whether measurable changes have occurred in nutrient properties, biomass of phytoplankton and photosynthetic production of organic matter in the Bering Strait/Chukchi Sea using the nine years of RUSALCA data.

- Analysis of nutrient, chlorophyll, and primary production samples.
- Data for nutrients, chlorophyll and primary production will be sent to designated archive for inclusion in the RUSALCA database.
- Data products will be prepared for presentation at one or two planned RUSALCA workshops.
- Collaborative manuscripts will be prepared with physical, chemical, biological, and microbiological groups either as lead author or contributing author. It is expected that at least three manuscripts will be prepared that emphasize physical-nutrient processes, nutrient-primary productivity processes, and nutrient-primary production-microbial processes.

Research accomplishments/highlights/findings

- Primary production rate measurements using carbon and nitrogen isotopes were analyzed and combined with nutrient data for inclusion in a joint publication of the journal *Oceanography*. (See "In preparation" publication below.)
- Collaborated with RUSALCA investigators in preparation of a RUSALCA joint publication. (See "Submitted" publication below.)

NOAA relevance/societal benefits

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

Education

As reported previously, the Ph.D. student formerly supported by this grant withdrew from his degree program due to medical reasons. The analysis plan for the project was reorganized, with some work being done by technical and research staff. During this reporting period a different graduate student has been able to work part time on the project.

Changes/problems/special reporting requirements

We have completed the nutrient analyses from the multi-disciplinary cruises as originally proposed and the data have been sent to RUSALCA colleagues. Nutrient analyses of samples collected during the 2011 mooring cruise, requested by previous program manager John Calder, remain to be finished. Primary production samples collected on the mooring cruise are presently in the mass spectrometer queue and will be integrated with the chlorophyll data which are already complete. During the next reporting period we should complete the requested analyses and subsequent organization and distribution of the data.

Publications

Submitted

Pisareva, M.N., R.S. Pickart, M.A. Spall, C. Nobre, D.J. Torres, G.W.K. Moore and T.E. Whitledge. Flow of Pacific water in the western Chukchi Sea: Results from the 2009 RUSALCA Expedition. Submitted to *Deep-Sea Research I.*

In Preparation

Lee, S.H. and T.E. Whitledge. Recent field-measured primary production rates of phytoplankton in the Chukchi Sea. In preparation for submission to *Oceanography*.

Program for innovative technology for Arctic exploration (PITAE)

Jessica Cross, PI ***CIFAR theme: Ecosystem studies and forecasting***
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

Amendment 13. This project is new. NOAA Office: OAR-PMEL, Chris Sabine, Sponsor

Primary objectives

A primary NOAA OAR mission requirement is to understand and predict changes in climate, weather, ocean, and coasts. However, NOAA has few programs that address this goal in the Arctic environment, and the Arctic presents unique technical challenges that limit the agency's capacity to conduct regional science and stewardship operations. The Program for Innovative Technology for Arctic Exploration (PITAE) will utilize and develop new and innovative sensors and platforms to address this gap in NOAA's present scientific capabilities.

In order to leverage diverse engineering expertise, infrastructure, and technological assets necessary to advance this technological development, implementation of this program was directed primarily by NOAA Cooperative Institutes. By funding salary support and some travel through CIFAR, Cross will apply her expertise in the Arctic environment and the marine carbon system in order to integrate new and innovative carbon sensors with appropriate platforms and to extend the utility of the data collected through the development of some basic proxies.
The main deliverables of this project are as follows:

(1) To purchase and integrate $MAPCO_2$ and pH systems with a Saildrone hull, and to conduct preliminary design tests. Currently, the unique capabilities of the new Saildrone autonomous platform to move quickly (2-3x as fast as gliders) and to cover a large spatial area, in addition to its easily adaptable design, make it ideal for short-term development.
(2) To examine the effects of lower temperatures and high-energy environments on carbon Prawler operations. The carbon Prawler is a new moored device that uses wave energy to winch itself along a mooring line in order to make carbon measurements throughout the water column, rather than at single depths.
(3) To begin development of skills, expertise, and software necessary for the operation of new sensors on new platforms. Presently, the capabilities of the $MAPCO_2$ system, even when coupled with a cutting-edge pH sensor, cannot fully resolve the carbon system. Existing data can be used to develop proxies that may enable the estimation of other carbon system factors when applied to the datasets from these new moorings.

Research accomplishments/highlights/findings

During this year, we have leased two vehicles from Saildrone, Inc. These two platforms will be deployed on April 21, 2015 from Dutch Harbor. This mission is designed to test the operating capacity of the baseline Saildrone vehicles to operate in low-sunlight conditions typical of this area, as well as to overcome the large currents and navigate the intense shipping traffic we expect to see in the region. During this test deployment, the Saildrones will coordinate some work with the research vessel *Oscar Dyson*. Surface data from the *Dyson*'s underway measurements will provide a baseline for comparison with the Saildrone's sensor readouts, which will allow us to confirm the operability of the sensors and pinpoint operational nuances in the Saildrone's sensor feed. The integration of the $MAPCO_2$ system will proceed after this initial test mission.

This year, we also continued development of the carbon Prawler. Several tests were conducted in Puget Sound this past summer. Our primary challenge was to work to resolve lag in the Prawler's oxygen sensor. These tests are helping to refine how fast the Prawler can proceed up and down through the water column. An initial deployment of the Prawler will be made in summer 2015 in the Chukchi Sea.

Outreach

In order to plan the test deployments for the Saildrones, we generated a number of types of public outreach. Firstly, we developed a document that lists some of the primary information about the PITAE project and the Saildrones as a platform, otherwise known as a NOAA fact sheet. This document is used when we are discussing this project both with the public and with other scientists. Based on this document, we were also asked to develop and submit variations of this report both for the NOAA OAR outreach program, as well as Cabinet Affairs (a White House

document). Secondly, we also developed a document that we shared with a variety of marine research and maritime institutions in Alaska, including the Aleutian Pribiloff Islands Association and the large company fishing fleet in Alaska. This document describes the purpose of the Saildrones and the operating area. The goal is to educate local mariners and residences about research being conducted along the coast.

Publications and presentations

Oral presentations

Cross, J.N. 2015. Carbon biogeochemistry and ocean acidification in the Pacific Arctic Region. Seminar, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, March 2015.

Cross, J.N., J.T. Mathis, W. Evans, R.S. Pickart and R.A. Feely. 2014. Formation and transport of corrosive water in the Pacific Arctic Region. Integrated Marine Biogeochemistry and Integrated Ecosystem Research (IMBER) Open Science Conferences.

Partner organizations and collaborators

The PITAE grant is conducted with the assistance of several NOAA cooperative institutes and labs, including the Pacific Marine Environmental Laboratory (PMEL) Engineering Group, the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington, and the Cooperative Institute for Marine Resources Studies (CIMRS) at Oregon State University.

NOAA relevance/societal benefits

- Addresses the NOAA OAR mission goal to understand oceanographic changes
- In line with the NOAA Arctic Action Plan, to develop better capabilities to observe and monitor changes in the Arctic Ocean
- Full delivery of these ecosystem-capable research vehicles will provide new capabilities in all NOAA mission environments, not just the Arctic, and will help to monitor and sustain important ecosystems and fisheries.

Impact

The PITAE project is developing new and innovative carbon sensors and platforms to address the gap in NOAA's present scientific capabilities in the Arctic, especially regarding ecosystem and carbon related research, greatly expanding the agency's capacity to conduct regional science and stewardship operations. The complexity of this environment requires small vehicles that can capture—without disturbing—small gradients in ocean chemistry and physics, as well as be responsive to continuously changing weather and climate conditions. As an example, one key project we are pursuing with the Saildrone test deployments is the description of ice melt pools. Melt pools may represent a significant heat and salt flux signal for the coastal seas around the Arctic Ocean, but are primarily unknown. The Saildrone vehicle is a perfect platform for examining these fine areas over extended areas and periods of time.

RUSALCA data management

Russell Hopcroft, PI ***CIFAR theme: Ecosystem studies and forecasting***
University of Alaska Fairbanks

NOAA Goals: Healthy Oceans; Climate Adaptation & Mitigation

Amendments 10 & 23 NOAA Office: OAR-CPO, Kathleen Crane, Sponsor
Continues research from NA08OAR4320751

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 (PIs) 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

Investigators have facilitated the data management component for the RUSALCA program during the reporting period, which included participation in RUSALCA planning and strategic meetings. The project team has been focused on supporting the existing RUSALCA data portal, facilitating the use of the dedicated RUSALCA Research Work space group and continued cultivation and data integration of RUSALCA produced data sets (specifically the Arctic Zooplankton Synthesis data set). These activities have greatly increased the transparency of data and sampling/analysis efforts for the entire RUSALCA program. Axiom staff continued to follow up with PIs and facilitate delivery and ingestion of historical RUSALCA data. Organization of files into more logical hierarchies is also ongoing and iterative with PIs.

The Research Workspace has been utilized as the primary vehicle for consolidating, organization and documenting data sets produced from the RUSALCA effort. The increase in use by PIs over the past year is represented in Figures 1 and 2.

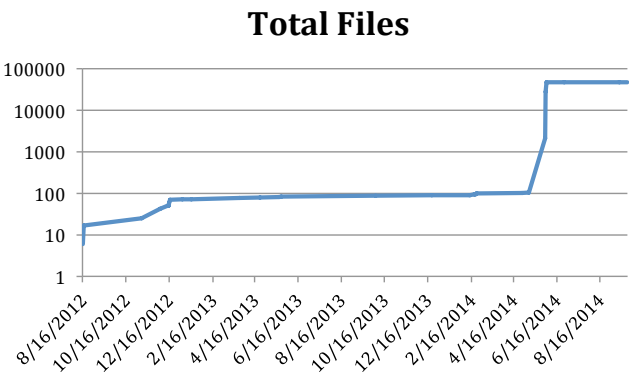

Figure 1. Total storage (in Gb) used by RUSALCA team members.

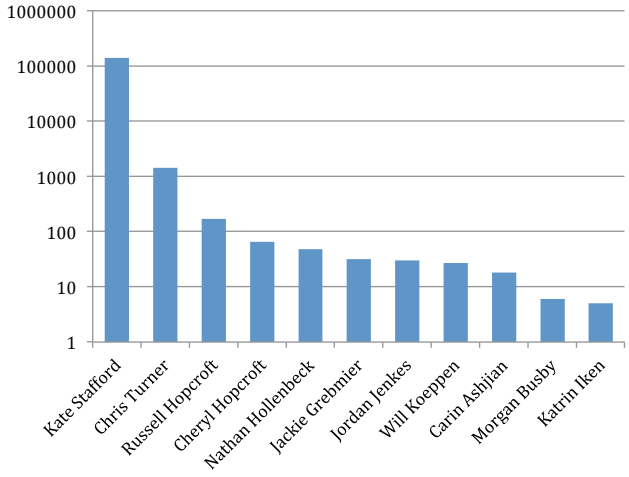

Figure 2. Distribution of file uploads by RUSALCA users.

Previous reports showed a more distributed number of files by users, whereas this reporting period was dominated by the addition of a large passive acoustics dataset: Offshore (Kate Stafford, 14,400 files at ~ 1TB total) uploaded in June 2014. These data were large enough that they were collected on a hard drive and uploaded manually by Axiom staff.

Axiom data management staff have pulled data sets out of the research workspace and integrated those data into a web based visualization portal which provides a data catalog in addition to web based interactive mapping systems. First, CTD, nutrient sampling and zooplankton abundance by species datasets were integrated into geospatial visualizations. Secondly, biological datasets which described abundance and distribution were integrated into map based visualization which could be filtered and summarized by taxonomic hierarchy.

Several enhancements have been made to the RUSALCA data portal including grouping of logical layers in thematic modules, implementing advanced filtering capabilities (spatial and temporal) in addition to the integration of additional RUSALCA resources (RUSALCA Arctic Zooplankton Synthesis). The current RUSALCA data portal can be accessed at http://portal.aoos.org/rusalca.php.

The dedicated RUSALCA Research Workspace contains approximately 1 TB of project data spread across 24 distinct projects. Investigators have uploaded approximately 50,000 files with a majority of the files being within the Marine Mammal Passive Acoustic project. During this reporting period, Axiom data curators have been working to better organize and document project level data sets within the research workspace so that they may be submitted to national archives (NODC), publicly exposed through the RUSALCA data portal and integrated into more advanced visualization systems.

Besides supporting the core data management component of the RUSALCA program, Axiom data analysts have made substantial progress integrating additional zooplankton observational data into the RUSALCA Arctic Zooplankton Synthesis time series (Figure 3). The integrated time series amalgamates numerous zooplankton sampling efforts and enables users to visualize trends and apply filters for spatial, temporal, sampling mesh size, seasonality and collection gear. The Portal and this product were demonstrated at the October 2014 CBMP meeting in Nuuk, Greenland. The Zooplankton Synthesis layer can be accessed here - http://portal.aoos.org/rusalca.php#map?page=1&tagId=75&q=&lg=f48be264-49a9-11e4-be04-00219bfe5678&z=4&ll=83.56294%2C-111.84404

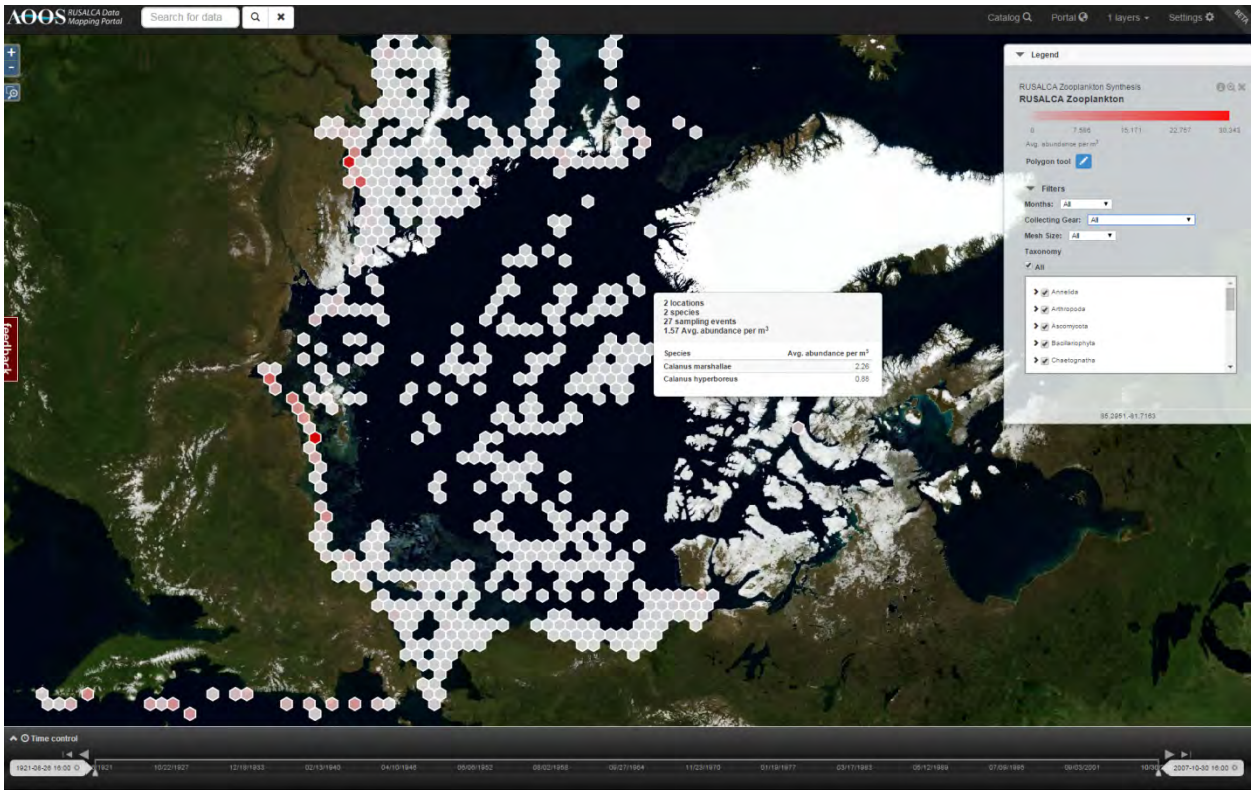

Figure 3. RUSALCA Zooplankton Synthesis Data Layer

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 it to major data repositories.

Partner organizations and collaborators

Alaska Ocean Observing System (AOOS)
Axiom Data Science LLC

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 and ecosystem - infauna

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

NOAA Goals: Healthy Oceans

Amendment 16. This project is complete. NOAA Office: NMFS-AFSC, Cynthia Yeung, Sponsor

Primary objectives

To characterize the benthic infauna community from 2012 for modeling essential fish habitat in the Eastern Bering Sea in support of the Magnuson-Stevens Sustainable Fisheries Act.

Sampling in 2012 used a van Veen grab, and samples were collected, sieved in the field on a 1.0 mm mesh, fixed in buffered formalin, stained and transferred to 50% isopropyl alcohol prior to sending to UAF for processing. We propose to process samples from 25 stations including identification to at least family level of taxonomy, counting, and wet weighing (blotted dry) to 0.001 g. Data will be prepared for community analysis and interpretation. All work will be compatible with previous CIFAR awards made to Jewett on NA08OAR4320751 for sampling in 2009.

We will provide the Alaska Fisheries Science Center with additional support to resolve possible questions on the infauna dataset and provide clarification on the processing that may be necessary before it is subjected to statistical analyses. For example, some taxonomic names have recently changed, so clarification on the name change can be provided together with the appropriate reference.

Research accomplishments/highlights/findings

During this reporting period, UAF marine invertebrate taxonomist Max Hoberg sought to resolve a taxonomic question on the 2012 Bering Sea infauna dataset, namely, have there been any recent taxonomic name changes? After reviewing all taxa he determined that all names were current. Thus, no changes to the infauna dataset were necessary.

NOAA relevance/societal benefits

This project provides information on the benthic infauna community from 2012 for modeling essential fish habitat in the Eastern Bering Sea in support of the Magnuson-Stevens Sustainable Fisheries Act.

Time-varying natural mortality: random versus covariate effects

Terrance Quinn II, PI ***CIFAR theme: Ecosystem studies and forecasting***
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

Amendment 28: This project is new. NOAA Office: NMFS-AFSC, Peter-John F. Hulson, Sponsor

Primary objectives

As part of the Stock Assessment Improvement Program, our first objective is to determine the circumstances under which time-varying natural mortality, *M* is estimable in an age-structured assessment model. We hypothesize that the precision of datasets is most important, especially survey data. The second objective is to compare the performance of estimating *M* with random effects versus using covariates. We hypothesize that using covariates increases precision unless *M* is misspecified. Thus, this proposal is responsive to two objectives of the Assessment Methods Working Group to conduct "investigations to develop best practices for addressing specific topics in stock assessments" and "investigations of the performance of assessment methods across a range of data availability and quality". Furthermore, this proposal is "oriented to the broadly applicable theme" of the feasibility of estimating natural mortality, a topic that comes up in discussion of almost all stock assessments.

We will conduct a typical simulation-estimation exercise (as in Fu and Quinn 2000) with a master's level graduate student in which a true population is created, simulated datasets are generated, and parameters are estimated with an age-structured assessment model. The true population will be modeled after a generic temperate

North Pacific population with parameters that, in addition to time-varying *M*, include time-dependent recruitment and fishing mortality, time-invariant asymptotic fishery and survey selectivity, and time-invariant survey catchability less than 1. With these parameters measurement error will then be generated in fishery age composition data, total catch data, and survey biomass and age composition. Two scenarios for the operating model to evaluate estimability of *M* will be examined: (1) time-variable *M* is a linear function between 0.1 and 0.3, and (2) time-variable *M* is a sinusoidal function between 0.1 and 0.3. We will not have a scenario with constant *M*, because it is already known that misspecification leads to bias. We have tried to keep the number of operating models small, so the study is appropriate for a master's thesis.

Research accomplishments/highlights/findings

- We have conducted a literature review of the body of existing knowledge relevant to fisheries stock assessment in the treatment of natural mortality.
- Ganz has gained proficiency both in R and in AD Model Builder (ADMB) software, to be used in project analysis.
- We have chosen Gulf of Alaska sablefish and Eastern Bering Sea pollock stock assessments that will be used to construct the operating models for this project; these two represent a relatively slow-growing and a fast-growing population, respectively.
- We have obtained code for Gulf of Alaska sablefish stock assessment that will be used as a starting point for incorporating time-varying natural mortality.
- We have decided on three operating models to be used for the deterministic component of natural mortality *M*: constant *M*, a linear increase in *M* over time, and sinusoidal variation in *M* over time. These models will contain two different levels of stochastic variation. A covariate will be constructed following these trends, also with two levels of variation to represent measurement error.
- Four estimation models will be used: stock assessment with (1) *M* constant and fixed, (2) *M* constant and estimated, (3) *M* estimated with random effects, and (4) *M* estimated with the covariate.

NOAA relevance/societal benefits

The primary benefit for the Stock Assessment Improvement Program (SAIP) will be better information about what circumstances allow *M* to be estimated, particularly across time and age. This study will determine if random and correlated effects are sufficient to estimate *M*. If only limited circumstances exist, covariates may make estimating time-varying *M* possible; efforts should then be increased in the real world to find covariates, such as predator biomass, predator consumption, and disease incidence that are related to *M*. There is currently a trend to use more and more random effects to improve the realism of assessment models. But if this use compromises estimability through parameter confounding, this use may be misguided.

Education

Quinn hired graduate student Philip Ganz to work on this project for his M.S Fisheries degree.

In November 2014, Quinn and Ganz attended a conference held by the Center for the Advancement of Population Assessment Methodology on growth modeling, which also provided state-of-the-art information on stock assessment modeling and the treatment of natural mortality.

Partner organizations and collaborators

Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, Juneau, Alaska (Peter-John Hulson).

Impact

This project accomplishes two major impacts: (1) training of a master's level fisheries graduate student in simulation-estimation exercises with an age-structure assessment model, (2) innovative thesis research that will improve estimates of time-varying natural mortality for Gulf of Alaska sablefish and Bering Sea pollock stock assessments.

References

Fu, C. and T.J. Quinn II. 2000. Estimability of natural mortality and other population parameters in a length-based model: *Pandalus borealis* in Kachemak Bay, AK. *Can. J. Fish. Aquat. Sci*. 55:2420–2432.

Regional, seasonal and species differences in trophic feeding ecology of western and central Aleutian Steller sea lions (*Eumetopias jubatus*) prey

Lorrie Rea, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
Todd O'Hara, PI
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

Amendment 20: This project is new. NOAA Office: NMFS-AFSC, Elizabeth Logerwell, Sponsor

Primary objectives

Stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) are being determined in at least 11 marine finfish and 2 cephalopod species thought to contribute to Steller sea lion (*Eumetopias jubatus*) diet in the Aleutian Islands to better understand the trophic position of these potential prey species. Stable isotope data generated by this study will contribute to ongoing stable isotope diet modeling efforts for Steller sea lions to build a better understanding of what prey species are important to sea lions in the western (WAI) and central Aleutian Islands (CAI). We have validated mixing models to predict the percent composition of Steller sea lion diet using $\delta^{13}C$ and $\delta^{15}N$ measured in the whisker tissues of young Steller sea lion pups and $\delta^{13}C$ and $\delta^{15}N$ values from the published literature for marine fish which are potential prey species for sea lions in the Gulf of Alaska and eastern Aleutian Islands (Stricker et al. 2015, Rea et al. 2015, Scherer et al. *in press*). While these models are promising, they are currently limited in regional scope by the lack of published stable isotope data for marine fishes in the WAI and CAI. Samples of known and potential Steller sea lion finfish prey species and some non-finfish bycatch species, have been collected and donated by fishermen on Ocean Peace Inc. vessels during customary commercial fishing practices in the Aleutian Islands and additional WAI fish collections have been facilitated through Alaska Fisheries Science Center (AFSC) researchers on scheduled research cruises in 2014 to target collection of potential prey from regions in the proximity of Steller sea lion breeding rookeries.

Feeding ecology of marine fishes has the potential to change seasonally due to changes in prey availability and in primary productivity that could impact $\delta^{13}C$ and $\delta^{15}N$ values throughout the food web. Ocean Peace Inc. summer trawls (May – July) allowed us to collect samples of potential prey relevant to animals foraging in both the WAI and CAI. In addition to summer trawls in fisheries management areas 542 (July 2014) and 543 (July 2013), Ocean Peace Inc. have provided fish collected in fisheries management area 542 in the winter (March 2013) allowing us to test for seasonal differences in $\delta^{13}C$ and $\delta^{15}N$ within sampled prey species in the CAI. Our AFSC partners have also provided predominantly Atka mackerel, Pacific cod and squid samples collected near Steller sea lions haulouts in the WAI in May 2014 and October 2014 and a research cruise is underway (April 2015) from which we hope to secure additional samples in this area to address seasonal changes in isotopes of Steller sea lion prey. Once our analyses are completed, these data will also be made available to AFSC researchers studying the diet of killer whales (*Orca orca*) in the Aleutian Islands. These isotope data will also help us interpret differences in total mercury concentrations in Aleutian groundfish (analyses currently funded through Alaska Department of Environmental Conservation [ADEC]) based on the trophic level of feeding of each fish species.

Research accomplishments/highlights/findings

Approximately 830 individuals, representing at least 11 species of finfish and 2 species of cephalopod have been collected from the CAI and WAI (Table 1). Sampling has been extremely successful and includes approximately 20 individuals for each species (in some cases genera or family) from each region/season grouping which will allow seasonal comparisons within each region, and comparison between WAI and CAI during both the summer and winter.

Sample processing in the Wildlife Toxicology Lab at UAF includes collection of morphometric data from whole fish (length, mass) followed by subsampling of muscle for stable isotopes. We have also subsampled and archived muscle, liver, eggs (when available) and bone for contaminants and stable isotope analyses funded through other sources. Otoliths were also archived for aging (not included in this award). Concurrent funding from ADEC to analyze total mercury concentration in groundfish muscle tissues has significantly increased the number of samples that could be processed for both studies, since the most costly aspect of these studies (time for subsampling of whole fish and freeze drying of samples) was shared between the two studies.

Muscle samples were weighed (to calculate % water content for contaminants analyses), freeze dried and homogenized using a stainless steel mill. Dried and homogenized muscle samples were weighed into tin capsules for stable isotope analysis and submitted to the Alaska Stable Isotope Facility for analysis. As of the end of this reporting period, 587 individuals have been fully processed and analyzed for stable isotope data ($\delta^{15}N$ and $\delta^{13}C$). Stable isotope data were entered into an Access database with associated capture and morphometric data. Some preliminary analysis has occurred, but most analysis will be conducted after all samples have been processed and data quality evaluated (screened for outliers for potential re-analysis). The majority of effort for PI O'Hara and research associate J.M. Castellini will be focused during data analysis and while O'Hara is off his academic contract.

Preliminary stable isotope data from Atka mackerel, Pacific cod, and walleye pollock from CAI and WAI were presented at the Alaska Marine Science Symposium (AMSS) in Anchorage, AK in January 2015 (see Opp et al., 2015 in Publications/Presentations; travel funded with the support of the UAF Undergraduate Research and Scholarly Activities program). Initial findings indicate that there are differences in $\delta^{15}N$ and $\delta^{13}C$ among key Steller sea lion prey species, but that temporal and regional effects must be considered when modelling Steller sea lion diet or any other trophic relationships in the Aleutian Islands.

Table 1. Fish muscle samples processed for stable isotope analysis (analyzed and pending) by season in the central (CAI) and western Aleutian Islands (WAI).

		Winter 2013		Summer 2013		Summer 2014			Winter 2014
		Analyzed	Pending	Analyzed		Analyzed	Pending		Pending
Aleutian squid Class Cephalopoda	CAI		13			20			
	WAI			20					27
Arrowtooth flounder *Atheresthes stomias*	CAI	21				14			
	WAI			22					10
Atka mackerel *Pleurogrammus monopterygius*	CAI	17	1			22	9		
	WAI			20			48		60
Darkfin sculpin family Cottidae	CAI		21			14			
	WAI			19					
Kamchatka flounder *Atheresthes evermanni*	CAI	20		22					
	WAI								5
Northern rockfish *Sebastes* spp.	CAI	18				21			
	WAI			21					
Pacific cod *Gadus macrocephalus*	CAI	18	1	4		21			
	WAI					20	16		10
Pacific Ocean perch *Sebastes alutus*	CAI	20				19			
	WAI					20			
Pacific Octopus *Enteroctopus dofleini*	CAI			6		2			
	WAI			11					
Rock Sole *Lepidopsetta bilineata*	CAI	20		20		20			
	WAI			1					
Snailfish family Leparidae	CAI	5				4			
	WAI								
Walleye Pollock *Theragra chalcogramma*	CAI	20				20			
	WAI			21					10
Yellow Irish Lord *Hemilepidotus* spp.	CAI			6		18			
	WAI								10
TOTAL	***CAI***	***159***	***36***	***58***		***195***	***9***		
	WAI			***135***		***40***	***64***		***132***

NOAA relevance/societal benefits

The stable isotope data generated by this study are currently being used to model seasonal changes in the diet of adult and subadult Steller sea lions in the Aleutian Islands, and will be available for future modeling of diet composition of adult female Steller sea lions during late gestation using stable isotope data from the whiskers of

their young pups. Understanding diet of this endangered species will help NOAA develop sound fisheries management policy for the Aleutian Islands. These data will also help us to interpret total mercury concentrations in groundfish (funded separately by ADEC), and consequently understand which prey species may be contributing to high total mercury concentrations measured in some Steller sea lions in the western and central Aleutian Islands.

Education

A large part of initial sample processing was carried out as a group effort in the Wildlife Toxicology Lab, involving several graduate and undergraduate students, providing an excellent opportunity to teach/learn comparative anatomy of fish and cephalopods. Processing and data management has continued under the mentorship of a graduate student who has been working directly with 3 undergraduate students, including an intern completing a University of Alaska Southeast (UAS) Fisheries Technology Associates degree (internship is a degree requirement). One undergraduate student summarized preliminary data, competed for a UAF undergraduate research travel grant and presented a poster at the AMSS (see Publications/Presentations),

Outreach

Preliminary data was presented to the Alaska scientific community at the 2015 Alaska Marine Science Symposium. No additional outreach activities this reporting period.

Publications and presentations

Poster presentation

Opp, K.R., T.M. O'Hara, J.M. Castellini, A.P. Cyr, S. Mcdermott, T.M. Loomis and L.D. Rea. 2015. Variations in carbon and nitrogen stable isotope ratios of Atka mackerel, Pacific cod and walleye pollock in the central and western Aleutian Islands. Alaska Marine Science Symposium, Anchorage, AK, 19–23 January, 2015.

Partner organizations and collaborators

NMFS collaborators: Libby Logerwell (AFSC), Susanne Mcdermott (AFSC)
Industry partner: Ocean Peace Inc. (contact: Todd Loomis)

Literature Cited

Rea, L.D., A.M. Christ, A.B. Hayden, V.K. Stegall, S.D. Farley, C.A. Stricker, J.E. Mellish, J.M. Maniscalco, J.N. Waite, V. Burkanov and K.W. Pitcher. 2015. Age-specific vibrissae growth rates: A tool for determining the timing of ecologically important events in Steller sea lions. *Marine Mammal Science* DOI: 10.1111/mms.12221

Stricker, C.A., A.M. Christ, M.B. Wunder, A.C. Doll, S.D. Farley, L.D. Rea, D.A.S. Rosen, R.D. Scherer and D.J. Tollit. 2015. Carbon and nitrogen isotope discrimination for Steller sea lion (*Eumetopias jubatus*) vibrissae relative to milk and fish/invertebrate diets. *Marine Ecology Progress Series* 523:255-266.

Scherer, R.D., A.C. Doll, L.D. Rea, A.M. Christ, C.A. Stricker, B. Witteveen, T.C. Kline, C.M. Kurle and M.B. Wunder. Isotope values in pup whiskers reveal geographic variation in diets of gestating Steller sea lions (*Eumetopias jubatus*). *Marine Ecology Progress Series*, in press. [Accepted 12 February 2015]

Geological substrate and potential habitat map for deep sea corals and sponges in the Gulf of Alaska margin and the Aleutian shelf and slope regions

Jennifer R. Reynolds, PI ***CIFAR theme: Ecosystem Studies & Forecasting***
University of Alaska Fairbanks

NOAA Goal: Healthy Oceans

Amendments 6 & 25 NOAA Office: NMFS-AFSC, Chris Rooper, Sponsor

Primary objectives

The Alaska Deep Sea Coral and Sponge Initiative (AKCSI) is funded by NOAA's Deep Sea Coral Research and Technology Program to better understand the location, distribution, ecosystem role, and status of deep-sea coral and sponge habitats. This CIFAR project addresses the need to characterize and map seafloor habitats, and particularly seafloor substrates, in order to predict distribution of deep sea corals and sponges.

Geologists Jennifer Reynolds and Gary Greene, funded separately, will collaborate with AKCSI researchers from NOAA and US Geological Survey (USGS) to construct interpreted (from geology) substrate and potential habitat maps for deep-sea corals and sponges in Gulf of Alaska and Aleutian Islands waters. The potential habitat maps will be based on the compiled and georeferenced bathymetry, sonar and sediment data layers from AKCSI collaborators; groundtruth from any available seafloor video and still photo imagery; and geological interpretation that takes into account the bedrock and tectonic patterns, sediment type and depth, oceanography, and seafloor morphology at the highest resolution available. Geologic interpretation is used to understand a suite of seabed characteristics in terms of the processes that create them, and to use this understanding to extrapolate seabed characteristics in poorly sampled areas. These maps may then be combined with other types of information, e.g., bycatch in bottom trawls, for predictive modeling of species distribution.

Research accomplishments/highlights/findings

Jennifer Reynolds worked with the other PIs on this project to prepare for a ROV (remotely operated vehicle) cruise scheduled for summer 2015. The cruise would serve as groundtruthing for interpretation of seafloor data that will be incorporated into the regional substrate and potential habitat maps. That cruise and the contract were canceled at the last minute due to logistical problems with the ROV. The PIs, including Reynolds, prepared a new Statement of Work for a combined ship and ROV contract for a cruise in summer 2015. Jennifer Reynolds participated in the annual AKCSI meeting September 22-23, 2014 where PIs reviewed progress on the Alaska Coral and Sponge Initiative and planned for the upcoming year. The group is now preparing for a cruise in June 2015.

NOAA relevance/societal benefits

The goal of NOAA's exploration and research on deep-sea coral and sponge ecosystems is to provide decision-makers with sound scientific information that will enable effective ecosystem-based management decisions. Research activities in Alaska will provide a better understanding on the location, distribution, ecosystem role, and status of deep-sea coral and sponge habitats.

Deep sea coral and sponge ecosystems are widespread throughout most of Alaska's marine waters. In some places, such as the western Aleutian Islands, these may be the most abundant cold-water coral and sponge communities in the world. Deep sea coral and sponge communities are associated with many different species of fishes and invertebrates in Alaska. For example, the consistent association of sponges and corals with juvenile Pacific ocean perch (*Sebastes alutus*) may imply better growth or survival in these habitats. The challenges facing management of deep coral and sponge ecosystems in Alaska begin with the lack of knowledge of where these organisms occur in high abundance and diversity.

Two critical information needs developed by stakeholder participants at the NOAA Deep-Sea Coral and Sponge Ecosystems Exploration and Research Priorities Workshop for Alaska (September 2010):

- Mine existing knowledge to expand our understanding of deep-sea coral and sponge distribution.
- Implement a regional rather than "postage stamp" approach to deep-sea coral studies.

This project uses existing, archived data as well as new data collected through the Alaska Coral and Sponge Initiative, to determine which areas may contain valuable and potentially vulnerable deep-sea corals and sponges. The product, a regional-scale benthic habitat map, will be the first such map covering large areas of Alaskan waters and will be specifically developed to identify potential locations of deep-sea corals and sponges.

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

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

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

NOAA Goal: Climate Adaptation & Mitigation

Amendments 8 & 19 NOAA Office: NESDIS, Christopher W. Brown, Sponsor
Continues research from NA08OAR4320751

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 (RGB) 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. *New Visible Infrared Imaging Radiometer Suite (VIIRS) hydrology products were used by the National Weather Service in Alaska during "spring breakup."* New VIIRS products developed by researchers at George Mason University and City College of New York were generated by GINA using the updated CSPP code from the University of Wisconsin and delivered routinely to the National Weather Service in Alaska for use during the "spring breakup" flooding period. The 2014 breakup in Alaska turned out to be quite tame, especially compared to the devastating breakup flooding at Galena, Alaska in 2013. Thus it was difficult to assess the utility of these products during a flood event. GINA has continued to generate and deliver these products to the NWS into the summer even after the breakup period has ended, with the intention of evaluating whether these products are useful during non-breakup summer flooding. Figure 1 show the data as seen in AWIPS II (the weather forecasting display and analysis package being developed by the National Weather Service and Raytheon) in the Fairbanks Weather Forecast Office.

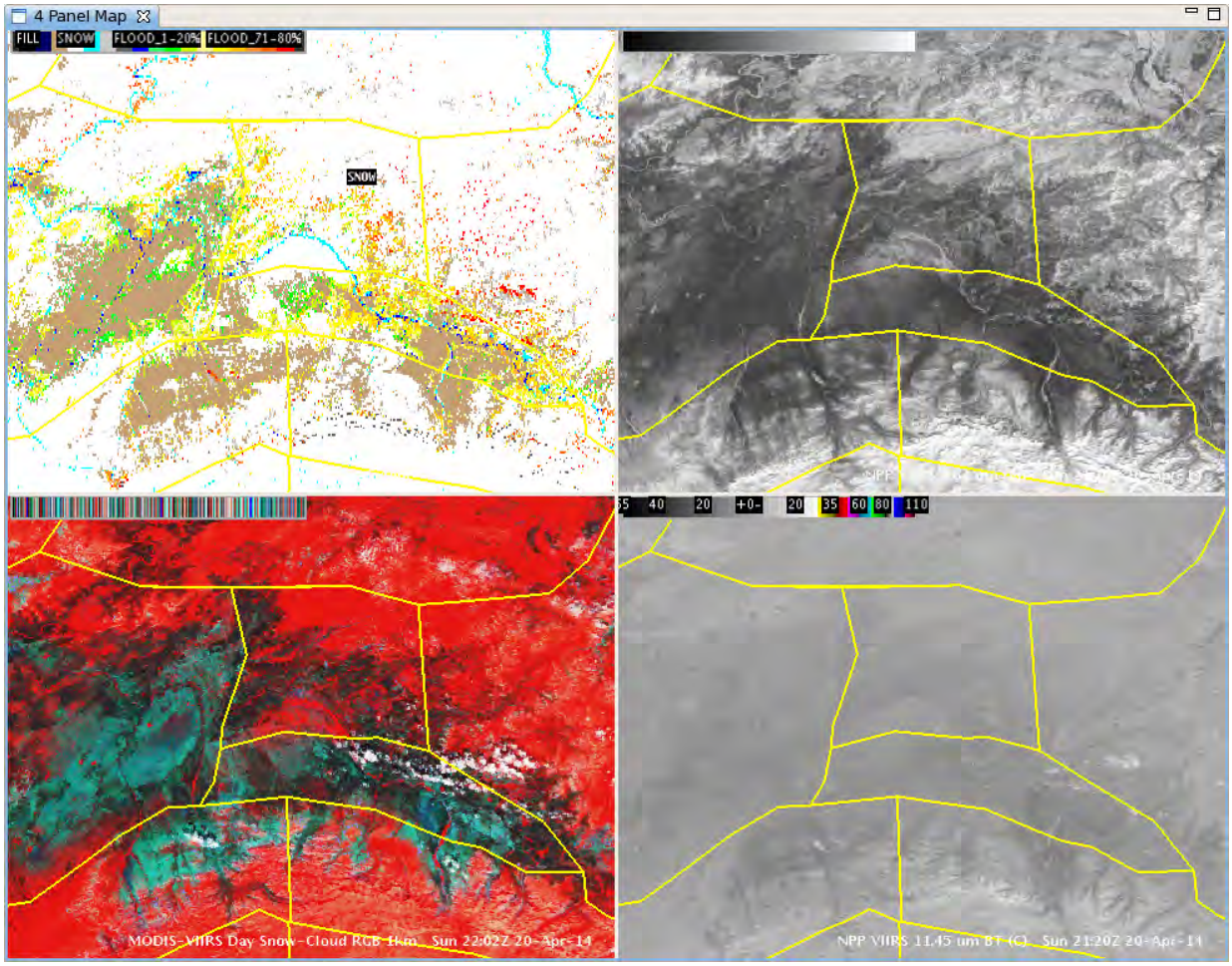

Figure 1. A screen capture from the AWIPS II workstation at the Fairbanks office of the National Weather Service from April 20, 2014, during the spring "breakup" season. No significant flooding was occurring during the time of this screen capture, and spring 2014 breakup was overall quite tame. The screen capture does show four different Proving Ground products. In the upper-left panel is the "river flooding areal extent" product based on VIIRS data, developed by George Mason University, and generated by GINA. The upper-right panel is a VIIRS visible image, the lower-right panel is a VIIRS long-wave infrared (IR) image, and the lower-left image is a Snow-Cloud RGB image developed by NASA/SPoRT and generated on a "virtual machine" at GINA, where snow-covered ground appears red, and snow-free ground appears bluish-green. The Snow-Cloud RGB illustrates a condition typical during the early stages of breakup: the snow is melting first at the lowest elevations and on the lee side of the Alaska Range in areas prone to warm Chinook winds.

2. *Ran an Alaskan Weather Research and Forecasting (WRF) model using hyperspectral sounders in the data assimilation.* Jiang Zhu took data from the Atmospheric Infrared Sounder (AIRS) and incorporated this data into the data assimilation process to see if a local WRF run can show improved performance in modeling a "cold air aloft" outbreak over Alaska that occurred in February 2014. Collaborators on this initiative include Kristine Nelson of the NWS in Anchorage and Elisabeth Weiss of the University of Wisconsin.

3. *Suomi National Polar-Orbiting Partnership (SNPP) imagery used by NWS Ice Desk to facilitate US Coast Guard rescue effort.* VIIRS imagery produced by GINA from direct broadcast data was used by the US Coast Guard in its successful effort to rescue a mariner attempting to sail the Northwest Passage in a one-person sailboat. The mariner had become trapped in the sea ice north of Barrow, Alaska and called upon the Coast Guard for assistance. The Coast Guard in turn called upon the NWS Ice Desk in Anchorage to provide guidance concerning ice conditions. VIIRS false-color imagery generated and delivered to the NWS by GINA was a vital tool used by the Ice Desk, and after the event Coast Guard Rear Admiral Dan Able lauded this imagery as "phenomenal weather products" in a thank-you note to the NWS. An example of this imagery is shown in Figure 2.

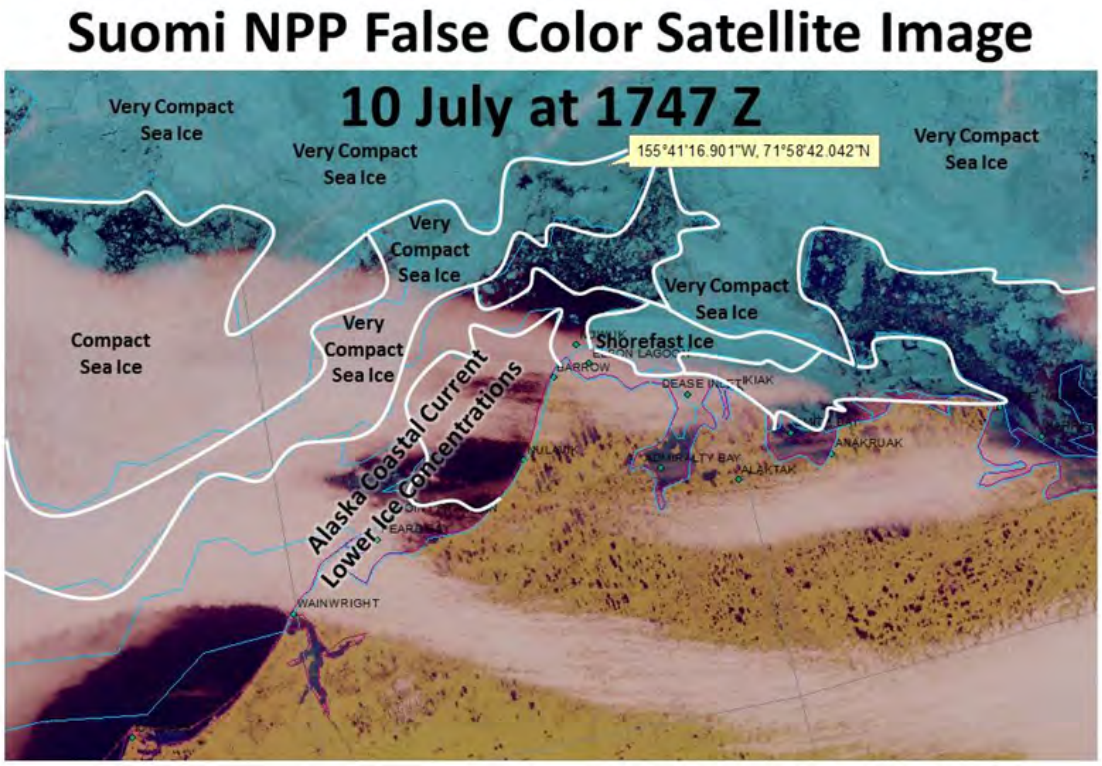

Figure 2. VIIRS false color image produced by GINA using direct broadcast data and then delivered to the National Weather Service Ice Desk in Anchorage. This image was used by the Ice Desk to provide guidance to the US Coast Guard in their effort to rescue a mariner attempting a solo sailboat crossing of the Northwest Passage in July. The latitude/longitude of the mariner is noted near the top of the image. Annotations provided by the NWS Ice Desk.

4. *Organized Sea Ice Analysis Workshop in Anchorage.* GINA Director Tom Heinrichs organized and led a Sea Ice Analysis workshop in Anchorage in August. Participants, both in-person and remote, included representatives of the academic community, NWS, Environment Canada, and private industry. The use of satellite data, including SNPP imagery, in the analysis and forecasting of sea ice was a frequent topic of discussion. Eric Stevens also provided a briefing on the High Latitude Proving Ground and its associated imagery used by the NWS Ice Desk.

5. *GINA, NASA/SPoRT, and NWS Alaska conducted a formal assessment of SPoRT's 24hr Microphysics RGB as used by NWS Alaska from January 15th through February 28th, 2015.* NASA/SPoRT uses VIIRS data collected via direct broadcast at GINA to produce two multi-spectral composite satellite projects, or "RGBs," on virtual machines at GINA for delivery to the NWS in Alaska. While SPoRT's "Night-Time Microphysics RGB" has been available via this method at NWS Alaska since late 2013, a new companion product, the "24hr Microphysics RGB" was now available for the first time during the fall and winter of 2014-2015. A formal assessment of the 24hr Microphysics RGB was conducted by NWS field offices in Alaska from January 15th through February 28th, 2015. During this assessment, NWS forecasters completed 29 surveys on a web site hosted by SPoRT and documented several cases of the 24hr Microphysics RGB used in forecast operations. SPoRT, NWS Alaska, and GINA held a final wrap-up call to discuss the results of the assessment on March 31st. See Figure 3 for an example of the 24hr Microphysics RGB derived from VIIRS data taken as a screen capture from the NWS Fairbanks office during the assessment. Eric Stevens contributed an entry on this topic to the SPoRT blog at https://nasasport.wordpress.com/2014/12/24/alaskan-sunshine-doesnt-burn-the-24-hour-microphysics-product/

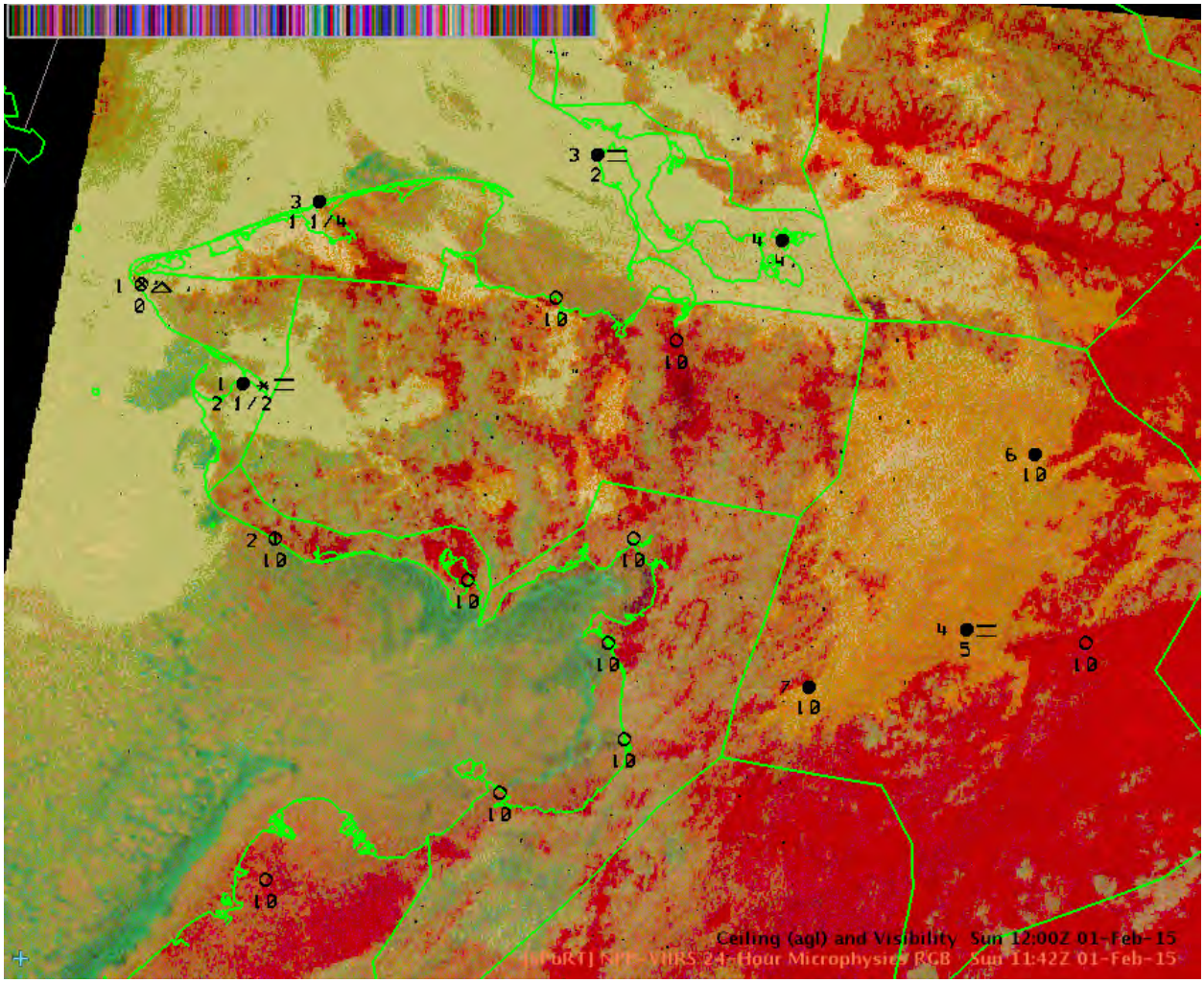

Figure 3. Screen capture from operational AWIPS at WFO Fairbanks showing the "24hr Microphysics" product made from an overlay of VIIRS-based imagery and METAR reports. The data used to generate this imagery was received via direct broadcast at GINA and processed into imagery by SPoRT software hosted on virtual machines at GINA. The resulting imagery was then delivered to the NWS via LDM for display in AWIPS. This example was taken during the formal assessment of the 24hr Microphysics RGB by NWS Alaska from January 15th through February 28th. In this example, the 24hr Micro RGB and METARs indicate the lowest conditions over the Bering Strait and to the north of the Seward Peninsula.

6. *NWS Director visited the University of Alaska Fairbanks.* NWS Director Louis Uccellini visited the University of Alaska Fairbanks during the first week of September and met with, among several UAF staff, Jessie Cherry, Tom Heinrichs, Dayne Broderson, and Eric Stevens. Jessie and Eric provided updates on recent accomplishments of the High Latitude Proving Ground.

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

Publications

Straka, W.C. III, C.J. Seaman, K. Baugh, K. Cole, E. Stevens and S.D. Miller. 2015. Utilization of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band

for Arctic Ship Tracking and Fisheries Management. *Remote Sensing*, 7(1):971-989. doi: 10.3390/rs70100971. *http://www.mdpi.com/2072-4292/7/1/971*

Oral presentations [All presentations were co-reported by a related project under lead PI Cherry]

Stevens, E. 2014. High Latitude Proving Ground Update. JPSS PGRR Project Annual Review, College Park, Maryland, 29 April – 1 May 2014.

Stevens, E. 2014. High Latitude Proving Ground Update. NWS Grid and Science Workshop, Anchorage, Alaska. 1 May 2014.

Stevens, E. 2014. High Latitude Proving Ground Operations Plan 2014/2015. OCONUS Annual Meeting, Honolulu, Hawaii. 29 July – 1 August 2014.

Cherry, J. 2014. High Latitude Proving Ground future plans. OCONUS Annual Meeting, Honolulu, Hawaii. 29 July – 1 August 2014.

Stevens, E. 2014. High Latitude Proving Ground Update. NOAA Liaisons Workshop, Boulder, Colorado. September 2014.

Stevens, E. 2014. VIIRS imagery and products to support fire weather forecasting. Alaska Fire Service seminar. Fairbanks, Alaska. 29 October 2014.

Stevens, E., M. Schreck and J. Key. 2014. The Cold and the Dark: JPSS and the cryosphere. JPSS Science Seminar. Webinar. 15 December 2014

Cherry, J. 2015. Advances in cryospheric prediction in Alaska. NOAA Satellite Science Week. Boulder, Colorado. 23-27 February 2015.

Cherry, J. 2014. High Latitude Proving Ground Update. User Readiness Meeting, Kansas City, June 2014.

Poster presentations [All presentations were co-reported by a related project under lead PI Cherry]

Stevens, E., E. Weisz, K. Nelson and J. Zhu. 2015. Using hyperspectral sounders to detect cold air aloft over Alaska. American Meteorological Society meeting, Phoenix, Arizona, 4-8 January 2015.

Zhu, J., E. Stevens, E. Weisz, K. Nelson, T. Heinrichs, J. Cherry and D. Broderson. 2015. Data assimilation improves model forecast for cold air aloft in Alaska region. American Meteorological Society meeting, Phoenix, Arizona, 4-8 January 2015.

Stevens, E. 2015. VIIRS imagery and the 2014 Funny River Fire in Alaska, and plans for the 2015 fire season. NOAA Satellite Science Week. Boulder, Colorado. 23-27 February 2015.

Outreach

Eric Stevens gave a well-attended public presentation, "Weather Satellites and Alaska" in Fairbanks on 17 February 2015 as part of the Science for Alaska lecture series.
https://www.youtube.com/watch?v=8GM4gqsg8HE&feature=youtu.be

Eric Stevens recorded additional segments for the Alaska Weather television program regarding the use of hyperspectral sounders such as Cross-track Infrared Sounder (CrIS) and AIRS in the data assimilation process for numerical weather prediction models, as well as the detection of volcanic ash by satellite imagery. Broadcast in September 2014 and March 2015.
https://www.youtube.com/playlist?list=PLPTiiC2ZrjNKBbKJ5jdHwxGIXyVjZA0GT

Other products and outcomes

GINA received funding for a second direct readout capture antenna and processor upgrades through the a Sandy supplemental award. Through this project, substantial upgrades have been made to the reception and near-real-time processing of polar orbiting weather satellite data at UAF GINA. Products are delivered within tens of minutes of capture to the NWS Alaska forecast offices in formats that display in their AWIPS and AWIPS2 forecasting software.

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

High latitude proving ground for GOES-R: Advanced data products and applications for Alaska

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

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

NOAA Goal: Climate Adaptation & Mitigation

Amendment 18. This project is new. NOAA Office: NESDIS, Christopher W. Brown, Sponsor
Continues research from NA08OAR4320751

Primary objectives

Based on needs of the National Weather Service, the Geographic Information Network of Alaska (GINA) at the University of Alaska Fairbanks proposes the following research efforts centered on the themes of 1. Cryospheric products; 2. Assimilation of products into models; and 3. Hazardous weather. The primary objectives of the proposed work are to enhance existing satellite data services and research in Alaska and develop next generation scientific products from satellite data. Collaboration will include the Weather Forecast Offices (WFOs), the Alaska Pacific River Forecast Center (APRFC), the Alaska Aviation Weather Unit (AAWU), and the Alaska Sea Ice Program (SIP), the NOAA research partners (Cooperative Institute for Meteorological Satellite Studies--CIMSS, Center for Satellite Applications and Research--STAR, Short-term Prediction Research and Transition and Center--SPoRT, Cooperative Institute for Research in the Atmosphere--CIRA), and the National Operational Hydrologic Remote Sensing Center (NOHRSC).

The primary objectives of the proposed work are to:

- Enhance existing satellite data services and research in Alaska and
- Develop next generation scientific products from satellite data.

Project accomplishments/highlights/findings

Research efforts on Cryosphere products focused on work with the Alaska Pacific River Forecast Center and ongoing efforts to improve the representation of snow melt processes with MODIS imagery. Both NASA Goddard's MODIS/Terra Snow Cover Daily L3 Global 500m Grid (MOD10A1) and JPL's MODIS Snow Covered-Area and Grain size retrieval (MODSCAG) algorithms were tested for interior Alaska watersheds, and resulting model simulations were compared (See Figure 1). These results were presented at the NOAA Satellite Science Week and the graduate student (now post-doc), Bennett, is the lead author on two publications on this topic, which are currently in revision.

Sea ice is an emerging area of interest and several meetings were held between NWS, UAF, and personnel from STAR, CIRA and elsewhere, planning for enhanced ice modeling products in Alaska. Several case studies were also explored wherein RGBs (collaborative between SPoRT and GINA) were used to distinguish sea ice and cloud during a recent marine hazard situation. GINA Director Tom Heinrichs organized and led a Sea Ice Analysis workshop in Anchorage in August 2014. Participants, both in-person and remote, included representatives of the academic community, National Weather Service, Environment Canada, and private industry. The use of satellite data, including Suomi National Polar-orbiting Partnership (SNPP) imagery, in the analysis and forecasting of sea ice was a frequent topic of discussion. Eric Stevens also provided a briefing on the High Latitude Proving Ground and its associated imagery used by the NWS Ice Desk.

Data assimilation to improve the Alaska regional weather forecast is another one of the key foci of this project. The profile and radiance data from Advanced Infrared Sounder (AIRS) and Cross-track Infrared Sounder (CrIS) were assimilated to improve the initial conditions of Alaska regional Weather and Research Forecasting (WRF) model. The experiments show that AIRS profile data and CrIS radiance data assimilation improve the short-term forecast, whereas AIRS radiance and CrIS profile data do not improve the short-term forecast. This conclusion indicates the quality control of the data products matter.

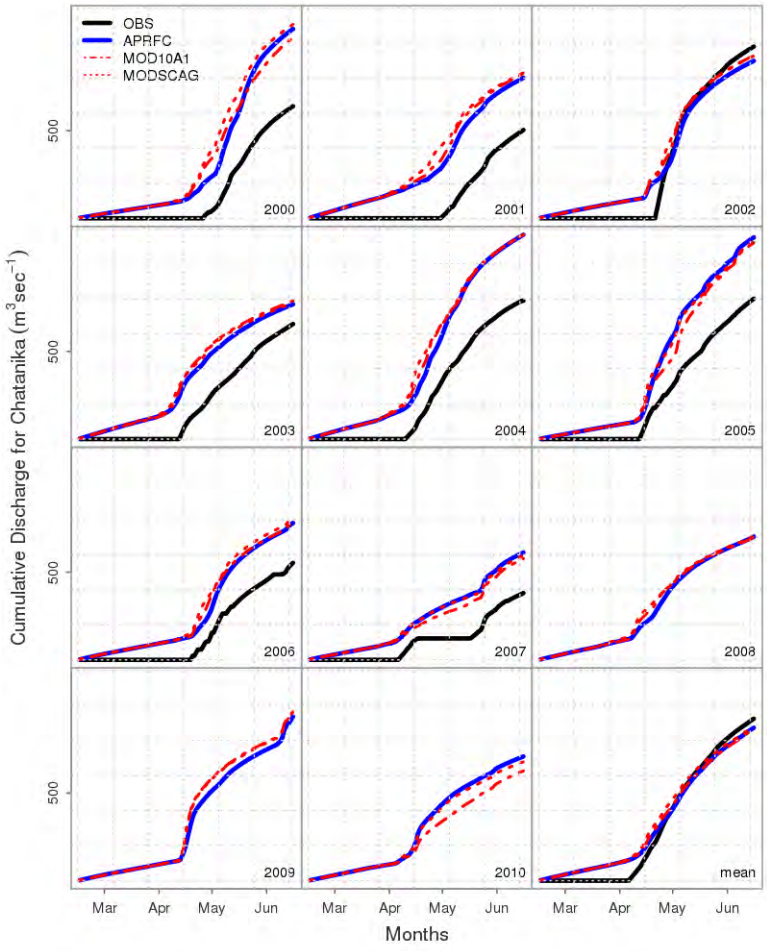

Figure 1. Cumulative discharge during snowmelt for the Chatanika Basin in Interior Alaska, including the observed discharge (Black) and modeled discharge (Blue), and the modeled discharge while updating snow depletion curves with imagery from the MOD10A1 and MODSCAG algorithms.

Hazardous weather is another area of emphasis for this proving ground project and plans are in place for monitoring of spring river breakup in Alaska, including airborne validation of Alaska-Pacific River Forecast Center (APRFC) models and the Joint Polar Satellite System (JPSS) river ice and flood product. Other hazards include fire weather and aviation flight hazards for low cloud and fog. Eric Stevens spent a week-long shift at the Joint Fire Service supporting fire weather prediction in 2014. In the spring of 2015, the group met with the Alaska Aviation Weather Unit (AAWU) to discuss support for case study analysis and forecast verification for flight category and other AAWU products and are planning additional activities in year two of the project, including additional simulations of cold air aloft.

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

Publications

Two peer publications have been written and submitted on this project [as funded under the previous cooperative agreement NA08OAR4320751 and continued under the current agreement] and are under revision. The funding for this GOES-R project was acknowledged:

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 in Interior Alaska. *In revision.*

Bennett, K.E., J.E. Cherry, B. Balk and S. Lindsay. Using MODIS estimates of fractional snow cover extent to improve river forecasting models. *In revision.*

Oral presentations [All presentations were co-reported by a related project under PI Heinrichs]

Stevens, E. 2014. High Latitude Proving Ground Update. JPSS PGRR Project Annual Review, College Park, Maryland, 29 April – 1 May 2014.

Stevens, E. 2014. High Latitude Proving Ground Update. NWS Grid and Science Workshop, Anchorage, Alaska. 1 May 2014.

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Poster presentations [All presentations were co-reported by a related project under PI Heinrichs]

Stevens, E., E. Weisz, K. Nelson and J. Zhu. 2015. Using hyperspectral sounders to detect cold air aloft over Alaska. American Meteorological Society meeting, Phoenix, Arizona, 4-8 January 2015.

Zhu, J., E. Stevens, E. Weisz, K. Nelson, T. Heinrichs, J. Cherry and D. Broderson. 2015. Data assimilation improves model forecast for cold air aloft in Alaska region. American Meteorological Society meeting, Phoenix, Arizona, 4-8 January 2015.

Stevens, E. 2015. VIIRS imagery and the 2014 Funny River Fire in Alaska, and plans for the 2015 fire season. NOAA Satellite Science Week. Boulder, Colorado. 23-27 February 2015.

Education

- Katrina Bennett finished the requirements for her Ph.D. in December and has begun a Post-doc at Los Alamos National Lab. She continues to support the Proving Ground efforts towards operationalizing the assimilation of snow covered area products for the RFCs.
- Ph.D. student Molly Tedesche was 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. The Juneau NWS forecast office and the RFC are also partners in this effort.
- In addition, training at NWS offices took place: A partnership with SPoRT included a winter evaluation of the VIIRS/MODIS Nighttime Microphysics and 24hr Microphysics products to improve fog forecasts included all Alaskan NWS offices. Training was conducted for all NWS offices.

Outreach

- Eric Stevens' service with the Joint Fire Service Weather detail was very useful outreach in that it has made other groups aware of GINA and NWS's capabilities with respect to remote sensing.
- Stevens also made a well-attended public presentation at Fairbanks' Science for Alaska series.

Partner organizations and collaborators

Weather Forecast Offices (WFOs), the Alaska Pacific River Forecast Center (APRFC), the Alaska Aviation Weather Unit (AAWU), and the Alaska Sea Ice Program (SIP), the NOAA research partners (Cooperative Institute for Meteorological Satellite Studies--CIMSS, Center for Satellite Applications and Research--STAR, Short-term Prediction Research and Transition and Center--SPoRT, Cooperative Institute for Research in the Atmosphere--CIRA), and the National Operational Hydrologic Remote Sensing Center (NOHRSC).

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

Marty Rogers, PI
University of Alaska Fairbanks

CIFAR themes: Coastal Hazards; Ecosystem Studies & Forecasting

NOAA Goals: Healthy Oceans; Weather Ready Nation

Amendment 11
This project began under NA08OAR4320751

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. The final mission was conducted in December 2014 (see later in this report), and UAF is currently in discussions with NOAA regarding the potential of using any remaining funding from this effort for the potential use of UAS in river monitoring and/or coastal erosion studies, both of which are directly in support of NOAA's UAS technology goals.

Field Program - Avon Park, FL June, 2014

On June 6th, a demonstration flight for NOAA was performed by ATI personnel in Avon Park, FL. The one day demonstration was to highlight the Resolution Unmanned Aircraft System (UAS). ATI provided a single airframe, two launch systems, a Ground Control Station (GCS) and a UAS field kit. Two flights were performed, showing autonomous flight & control, lost link procedures and sensor package capabilities.

ATI completed the following tasks:

- Sensor Package for demo flight -
  - Samsung NX210 installed for demo flight
  - Trigger hardware/software set for 10% ground coverage overlap on images
  - Automatic "rubber-sheeting" display of image ground coverage location displayed in near-real time on GCS display
  - Post-process integration of flight data and images to geo-reference images and allow for post-process mosaic
- Prepare one airframe for FL demo flight, over land, at Avon Park
- Prepare presentation for NOAA personnel at Avon Park
- Continued testing of autonomous take-off and landing
- Pass private pilot written test for Curt Olson
- Obtain 2nd class FAA medical for Tim Veenstra and Curt Olson

The Samsung NX210 replaced the Mightex SCE-CG04-U camera which had been used on the previous missions.

Demonstration Flight Results

Below are representative images that were taken during the demonstration flights on June 6, 2014. The camera was set in manual mode with 1/1000 sec shutter speed, aperture of 6.3 and ISO at 400. While the images were acceptable with good exposure, results would have been improved with a slight increase in the aperture. The image histograms were skewed slightly to the right which results in washed out highlights. Generally, the settings are adjusted for the ground cover (e.g., water color, vegetation) and objects that you intend to capture. In Figure 1 and 2, the white sun tent and car are slightly washed out.

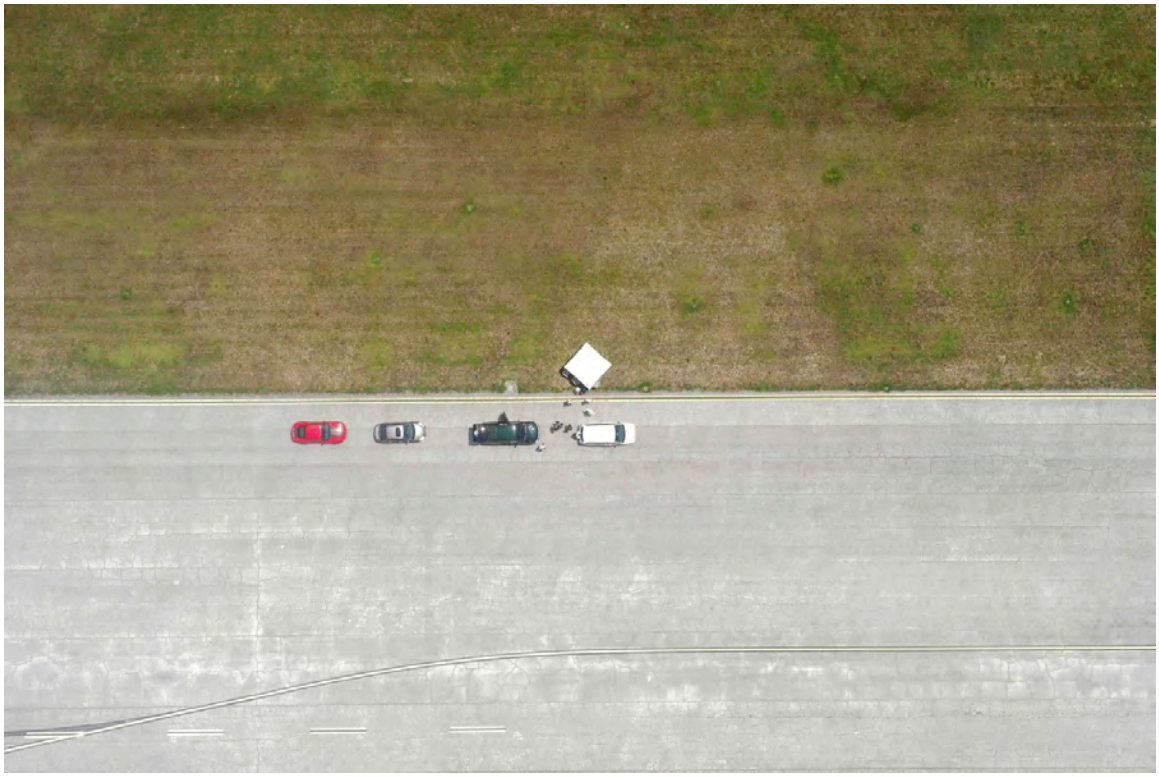

Figure 1. Image #0083 of runway with vehicles and sun shelter

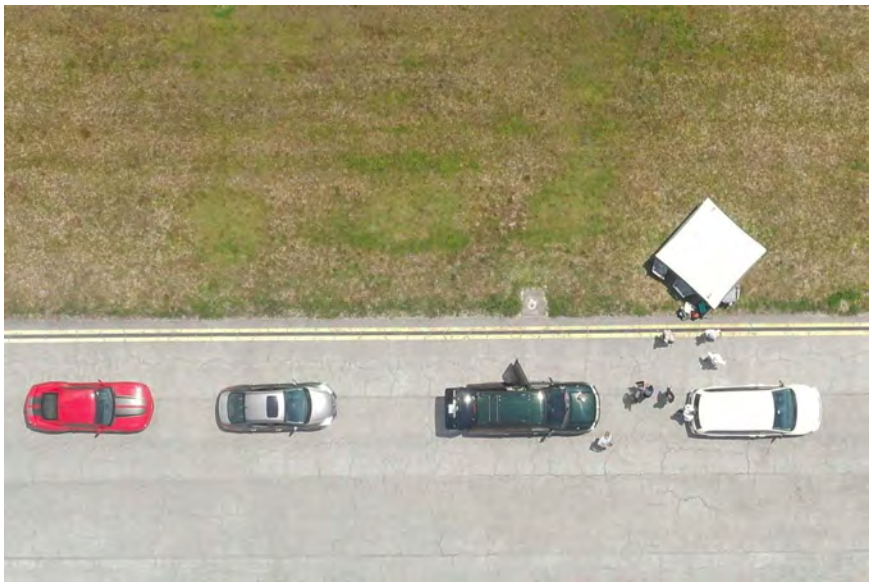

Figure 2. Cropped view of image #0083 with 1.5 cm per pixel ground resolution

Figure 3. In this enhanced crop of image #233, the red bungee cord used for launching the UAS is visible stretching across the grass and coiled up on the runway. The bungee cord is ½ inch in diameter.

Final Field Program - Avon Park, FL December, 2014

Dec 8, 2014: The ATI Resolution launched after a fairly lengthy series of troubleshooting steps--battery change due to not holding power, issue with a position updating process in the software, etc. The launch was normal. During the first few minutes of flight the normal approach is to maintain manual control through a typical RC aircraft controller, and then transition to autopilot operations, and then return to manual control to land. 43 seconds after launch the system was still in manual control when it stopped responding to controller inputs, rolled sharply right, nosed down and flew into the water. The captain motored the Shearwater over to the Resolution and it was retrieved. It incurred significant damage and is not considered to be restorable. There was no risk to crew or the vessel as the planned and actual flights were well clear of the boat. The immediate review of the flight logs indicated the last commands transmitted from the controller were received and acknowledged by the UAS. Post event assessment, to include a review of the telemetry data and testing of the airframe components, indicated the cause of the incident appeared to be the control failure of the left wing elevon caused by a damaged/bad servo, potentially as a result of damage incurred during shipment of the system.

Arctic Ocean and sea ice engineering system development tests – The UAF portion of 2013 MIZOPEX (Marginal Ice Zone Oceans and Ice Observations and Process Experiment) mission has been completed successfully.

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

We believe all three projects have extended the NOAA UAS capabilities and understanding of the sUAS potential for NOAA missions.

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.

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

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

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

NOAA Goal: Weather Ready Nation

Amendments 9 & 17 NOAA Office: NESDIS, Andrew Heidinger, 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 continued building the capability to perform analysis with sulfur dioxide (SO_2) for volcanic eruptions. The aim of our work 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 can now include SO_2 products from WRF-Chem. We: (1) furthered the satellite to model comparisons for Kasatochi 2008 and Sarychev Peak 2009 eruptions; (2) continued the development of WRF-Chem for sulfur dioxide/sulfate (SO_2/ SO_4^{2-}) comparison to satellite data; and (3) improved the WRF-Chem programming code to accept volcanic activity reports without the necessity to recompile the modeling framework. This step is essential for our next step to create an automated scheme for near real-time WRF-Chem model runs. Additionally, we worked on accessing the remote sensing data that is collected locally at UAF for comparison to any WRF-Chem model simulations for the North Pacific volcanoes. This aim is to assess the modeling workflow to be able to compare to any satellite data available from NOAA and NASA satellite sensors and be ready for GOES-R Day 1.

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 by Egan et al. (2015) was submitted to Annals of Geophysics (title: WRF-Chem modeling of sulfur dioxide emissions originating from the 2008 eruption of Kasatochi Volcano). This was from the EGU (European

Geophysical Union) session where the work was presented in April 2014. It has been reviewed and is now back with the lead author and will be sent to press in early 2015.

Figures 1 and 2, from Egan et al. (2015) show examples of the WRF-Chem results versus the satellite data in terms of spatial extent at defined timings, Figure 1, and temporally by examining a cross section through the cloud as the WRF-Chem simulates its movement and the satellite detects the SO_2, Figure 2. Examining the cross section, we see that the model has a close match to the timing of the highest satellite SO_2 column densities and the model provides a good approximation to spatial extent of the cloud. These show how the WRF-Chem model could then be applied for modeling volcanic SO_2 for future eruptions and use the results as a potential proxy to volcanic ash.

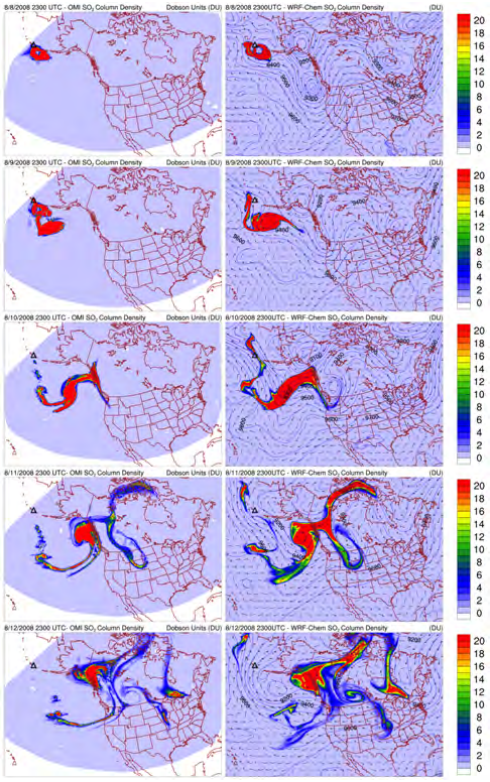

Figure 1. August 8th, 9th, 10th, 11th and 12th 2008 analysis for the Kasatochi eruption showing both from OMI (on left) and WRF (on right) SO_2 column densities. The August 10th image shows a transect, used in Figure 2, along the plume located at 145°W, adapted from Egan et al. (2015).

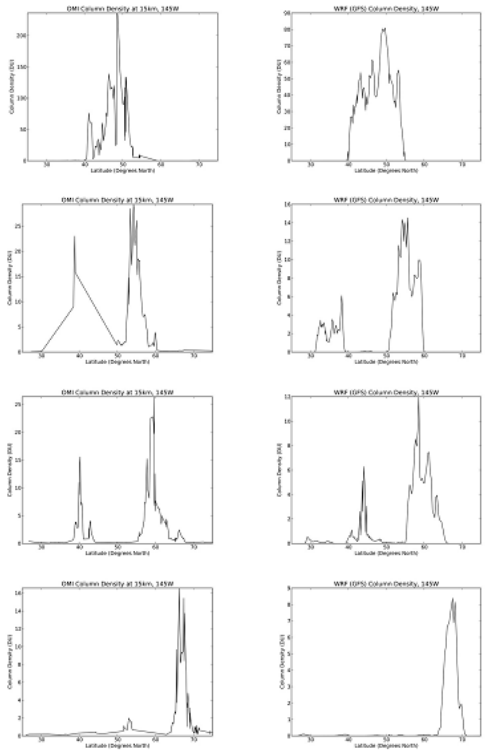

Figure 2. Cross sections on August 10, 11, 12 and 13, 2008 from transect in Figure 1. OMI (left) and WRF-Chem (right) column densities of SO_2 at 145°W from 20 to 30 °N, adapted from Egan et al. (2015).

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

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.

Martin C. Harrild, MSc. Student in Geology and Geophysics. Role on the Project: Early detection of volcanic events in real-time ground observations to instigate WRF-Chem real-time simulations for active volcanoes. Martin is working with ground-based webcams and comparing the data to satellite imagery for the every detection of events. This work leads into the follow-on project [PI Martin Stuefer, GOES-R RAP, amendment 21 to this cooperative agreement] of integrating the WRF-Chem model into the Rapid Refresh (RAP), the continental-scale NOAA hourly-updated assimilation/modeling system operational at the National Center for Environmental Prediction (NCEP).

Publications and presentations

Peer-reviewed publications

Egan, S.D., M. Stuefer, P. Webley and C.F. Cahill. 2015. WRF-Chem modeling of sulfur dioxide emissions from the 2008 Kasatochi Volcano. *Annals of Geophysics*, *57*. DOI: 10.4401/ag-6626 [This publication was supported by both the current cooperative agreement NA13OAR4320056 and the previous agreement, NA08OAR4320751 and is co-reported with the current project led by PI Stuefer.]

Poster presentations

Stuefer, M., S. Egan, P. Webley, G. Grell, S. Freitas, M. Pavolonis and J. Dehn. 2014. Online-coupled modeling of volcanic ash and SO_2 dispersion with WRF-Chem. European Geophysical Union (EGU) General Assembly. Id: EGU2014-16167, 27 April–2 May 2014.

Egan, S., M. Stuefer, P. Webley, G. Grell and S. Freitas. 2014. Modeling and remote sensing of the 2008 Kasatochi eruption. European Geophysical Union (EGU) General Assembly. Id: EGU2014-16308, 27 April–2 May 2014.

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.

GOES-R volcanic ash risk reduction: Operational decision support with NOAA's Rapid Refresh (RAP)

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

NOAA Goal: Weather Ready Nation

Amendment 21: This project is new. NOAA Office: NESDIS, Andrew Heidinger, Sponsor

Primary objectives

- We are working to implement a volcanic eruption model within the Rapid Refresh (RAP) model, and provide pathways for an operational RAP volcanic ash product.
- NOAA's Geostationary Operational Environmental Satellite R-Series (GOES-R) volcanic ash retrievals are tested and verified with case studies using the Weather Research and Forecasting (WRF) model coupled with Chemistry (WRF-Chem) and RAP model simulations. We compare the modeled plume dispersion downwind from well-documented volcanic eruptions with the GOES-R volcanic ash baseline product.

Our project work aims to build an improved volcanic ash decision support capability within NOAA's RAP modelling system. During the previous months, we have provided case studies of volcanic ash dispersion and worked on the pathways for implementation of operational volcanic ash alerts within the RAP modelling environment. The ***model source code*** has been updated within WRF-Chem, and close collaboration with NOAA Earth System Research Laboratory (ESRL) started to initiate the volcanic ash application within the RAP model. Work is in progress to compare Volcanic Ash Advisory (VAA) baseline products to modelled plume dynamics. We collaborate with NOAA NESDIS to implement GOES-R baseline products within the case studies. WRF-Chem ***case studies*** have started for the proposed historic eruptions using different source parameters, and we are in the process of compiling data for model comparison. A detailed WRF-Chem case study for the event of Kasatochi volcano showed promising results for the first days of the event. Absolute numbers of mass loadings are sensitive to the source parameters used for the model setup. Accurate retrievals of initial plume heights and mass loading are most suitable for RAP/WRF-Chem model initialization, and plume characteristics need to be updated for each model run. A work focus is on better estimates of our assumptions for particle size distributions. Based upon observational data from the Redoubt eruption in spring 2009, we are in the process of testing particle aggregation parameterization schemes.

We plan to continue with the ***case studies***, and to collaborate with the RAP developers to implement the volcanic ***source code*** within the RAP model.

Research accomplishments/highlights/findings

- We have evaluated the Advanced Base Imager (ABI) VAA baseline product with WRF-Chem model output with the eruptive event of Kasatochi volcano in 2008. The GOES-R type ash retrieval was discussed with modelled ash loadings, and we also used modelled and observed volcanic sulfur dioxide emissions to test our confidence in the WRF-Chem output as well as the satellite retrieval results.
- WRF-Chem model source code changes have been applied to simplify the setup for volcanic emission model runs. This work directly supports volcanic emission model implementation and adaption of the volcanic emissions driver into RAP.
- Different eruption source parameters were used for the case studies in order to test the plume mass loading sensitivities. The results were compared to GOES-R ash retrievals using MODIS data.
- An aggregation parameterization has been implemented within the WRF-Chem volcanic emissions driver, and tests are in progress to derive best assumptions for particle sizes.

Our current work focus has been on ***model source code*** preparation for operational needs, and on ***case studies*** for WRF-Chem model evaluation.

Model code: The WRF-Chem Prep-Sources-Chem pre-processing software was extended for volcanic emissions with look-up tables defining specific volcano characteristics as well as default eruption source parameters. In order to change parameters such as plume heights or mass fluxes, the emission driver within WRF-Chem source code

needed to be changed, and a model re-compilation was necessary prior to each model run. For model adaptation into the RAP environment, we changed the modelling source code in order to facilitate the flow for operational model runs. A volcanic namelist file including volcanic eruption heights, total mass and changes of eruption source parameters with time was implemented within WRF-Chem; the emission driver reads the file contents removing operational obstacles due to recompilation. The updated code has been tested and will be made available for RAP as a next step.

Case studies:
(1) We tested WRF-Chem for Kasatochi volcano, which erupted August 7–8, 2008. Mike Pavolonis provided MODIS ash products, which were compared to the WRF-Chem model output. The volcanic emissions were dispersed immediately within a strong cyclogenetic development almost overhead Kasatochi accounting for complex plume dynamics. The total column ash mass loading compared well during the first 3 days of the Kasatochi event with slightly higher modelled concentrations probably due to our source parameter assumptions (Fig. 1a and b). Significant differences in the concentrations were found in the subsequent days (Fig. 1c). On August 11, the model shows more distinct plume branches with higher mass loadings. However, there is evidence that the MODIS satellite retrieval is hampered by opaque ash particles; the retrieved ash loading became more and more 'spotty' within the distal plume. In order to evaluate our findings, we also looked into the sulfur dioxide (SO_2) plume (Egan et al., 2015). Significant amounts of SO_2 were emitted during the Kasatochi event, and we investigated the SO_2 plume using Ozone Monitoring Instrument (OMI) retrievals and WRF-Chem. WRF-Chem was initialized with volcanic SO_2 and we included a SO_2 to sulphate conversion parameterization. The satellite retrieved as well as modelled distal SO_2 plume extended well over the contiguous U.S. and to the north into Canada's Arctic (Fig. 2). Changes of SO_2 mass were compared with OMI derived mass loadings. A high degree of correlation resulted between model and OMI retrievals.

(2) A main goal of further case studies is to improve our ash particle size distribution assumptions. We started a detailed analysis of the March 22–April 9, 2009 eruption of Mount Redoubt with WRF-Chem. The Redoubt event has been well documented, and observational data on plume dynamics as well as on particle deposits exist. The Redoubt ash plume dynamics were strongly influenced by ash particle aggregation accounting for a shift of the ash size distribution to larger particles. This shift accounts for increased ash depositional effects near the volcano, and reduced mass loadings within the distal plumes. Based upon the Redoubt findings, we started to test various options to include a particle aggregation parameterization scheme within WRF-Chem. Experimental evidence suggests that the majority of coarse and fine ash settle out of volcanic plumes where liquid water is present. Coarse ash settles quickly due to its density and settling velocity, while fine ash aggregates due to hydrometeor-enhanced aggregation. Experimental testing suggests that this aggregation process is highly dependent on the amount of water present. For example, the size selectivity of the aggregation process decreases with increasing water content, with plume water concentrations greater than 15 wt% leading to less size selective processes.

In the case of Redoubt, Doppler radar measurements indicated that the plume height of the 23 March eruption decreased from 15 km to 10 km within the first 30 minutes of the eruption. We hypothesize that this decrease in plume height results from a majority of fine ash < 250 μm (95% total fine ash mass) aggregating into heavier lapilli. Field measurements also suggest rapid aggregation with fallout decreasing substantially within 20 km of the vent (A. Eaton, pers. communication).

To test this, we implemented a rapid aggregation scheme into WRF-Chem that is activated upon the presence of liquid water. The presence of liquid water is determined from the Clausius-Clapeyron equation, using pressure and temperature at each grid cell as a selection criteria. If liquid water is present, 95% of the mass of that grid cell is removed and added to the coarse ash-bin over a 30 minute period of time. If ice is present, currently no additional aggregation takes place.

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.

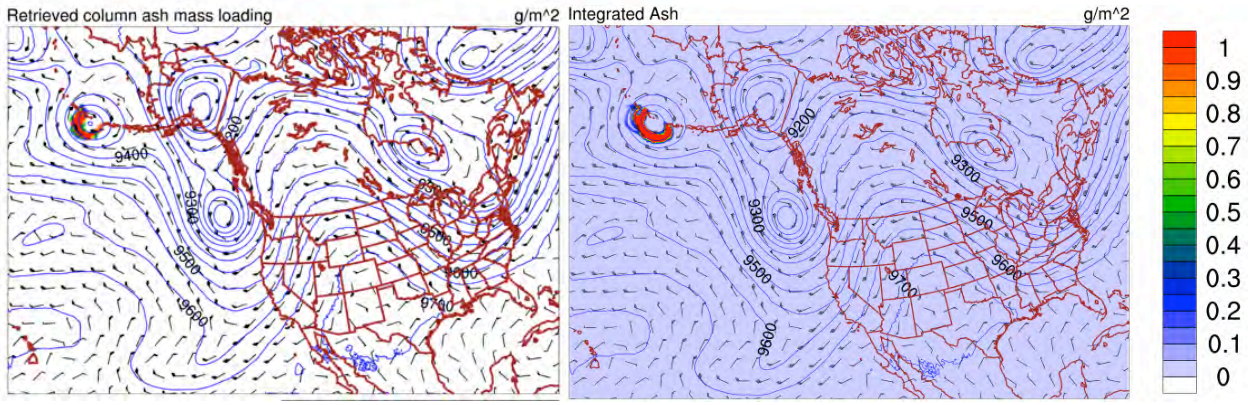

Figure 1a: August 8, 2008

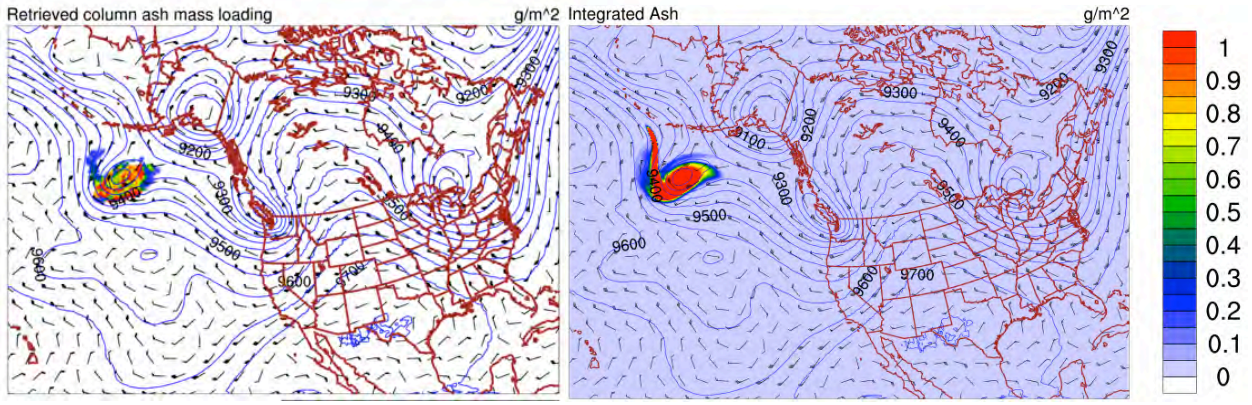

Figure 1b: August 10, 2008

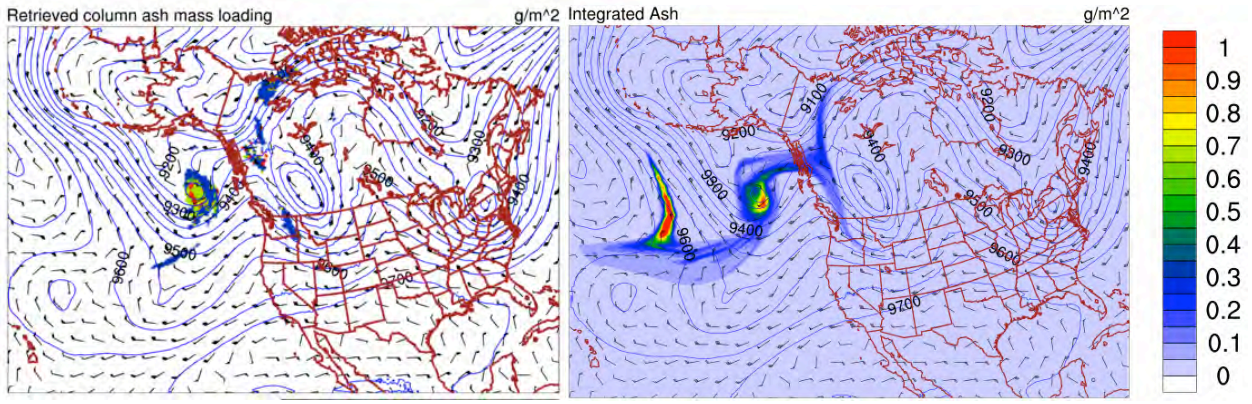

Figure 1c: August 11, 2008

Figure 1. Dispersion of the Kasatochi ash plume as modeled by WRF-Chem (left) and derived from MODIS satellite data (right).

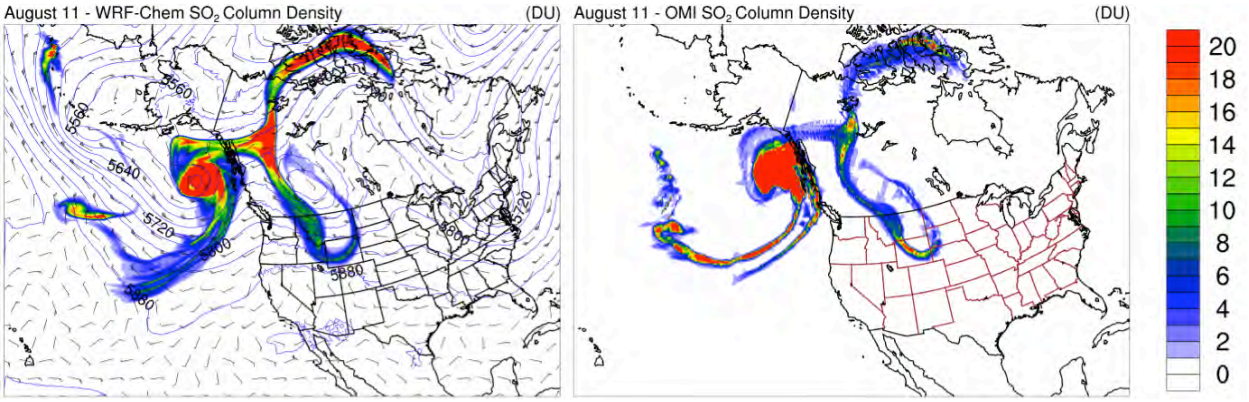

Figure 2. Dispersion of the Kasatochi SO_2 plume as modeled by WRF-Chem (left) and calculated by the NASA Level 2 SO_2 product (ColumnAmountSO2_STL, right).

Education

Sean Egan is a Ph.D. candidate student in Environmental Chemistry working within this project. Sean has completed his written comprehensive exams; his oral thesis proposal defense with the oral comprehensive exam is scheduled this spring. The thesis proposal includes model development elements that directly support this effort.

Partner organizations and collaborators

Georg Grell, NOAA Earth Systems Research Laboratory, georg.a.grell@noaa.gov
Michael J Pavolonis, NOAA/NESDIS Center for Satellite Applications and Research (STAR), mpav@ssec.wisc.edu

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.

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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.

Publications

Peer-reviewed publications

Egan, S.D., M. Stuefer, P. Webley and C.F. Cahill. 2015. WRF-Chem modeling of sulfur dioxide emissions from the 2008 Kasatochi Volcano. *Annals of Geophysics*, *57*. DOI: 10.4401/ag-6626 [This publication was supported by both the current cooperative agreement NA13OAR4320056 and the previous agreement, NA08OAR4320751 and is co-reported with the current project led by PI Webley.]

Alaska Earthquake Center seismic station operations and maintenance (CRESTnet)

Michael West, PI ***CIFAR theme: Coastal Hazards***
Natalia Ruppert, Co-PI
University of Alaska Fairbanks

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

NOAA Goal: Weather Ready Nation

Amendments 7 & 26 NOAA Office: NOAA Tsunami Program, Michael Angove, Sponsor

Alaska CRESTnet (Consolidated Reporting of Earthquakes and Tsunamis): Alaska Earthquake Center (formerly referred to as "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 National Tsunami Warning Center (NTWC) and Emergency Managers.
- Maintain data flow of selected stations to NTWC.

Research accomplishments/highlights/findings

Activity from the first 9 months of the reporting period can be found in the year 7 report for NA08OAR4320751.
Between January 1 and March 31, 2015, the Alaska Earthquake Center reported 8,074 events, with magnitudes ranging between -0.3 and 5.7 and depths between 0 and 243 km (Figure 1). Six earthquakes had magnitudes of 5 or greater. The largest earthquake, with a magnitude of 5.7, occurred on March 7 in the Andreanof Islands region of Alaska. From late January through early February, we recorded an unusual series of moderate earthquakes (M5.3-5.4) in the Pribilof Islands region, followed by over one hundred aftershocks with magnitudes 2.8 and greater.

The CRESTnet stations continue to benefit from the equipment and infrastructure upgrades undertaken over the last several years. During the reporting period, the average data return rate for these stations was 85%, which is satisfactory given the remoteness and challenging monitoring environments.

However, the eight stations still supported by NOAA have an average return rate of 92% while the ten unsupported CRESTnet sites have only a 79% return rate. This gap can be expected to widen as a result of broad funding reductions, which make it impossible for us to commit to ongoing maintenance of unsupported equipment.

During the reporting period, we performed the following work on CRESTnet sites:

- At UNV (Unalaska Valley), investigated options for digital telemetry and began planning for the ANSS broadband upgrade. UNV is the last CRESTnet station with a DM24 digitizer telemetering via a voice grade circuit.
- At GAMB (Gambell), worked with local contacts to replace a failed radio.
- At TNA (Tin City), fixed outage and hardened site after animals damaged the power and data cables.
- At PAX (Paxson), prepared equipment for extracting a 1960s-era sensor from the old borehole. Installing a modern sensor in this borehole will dramatically improve data quality.

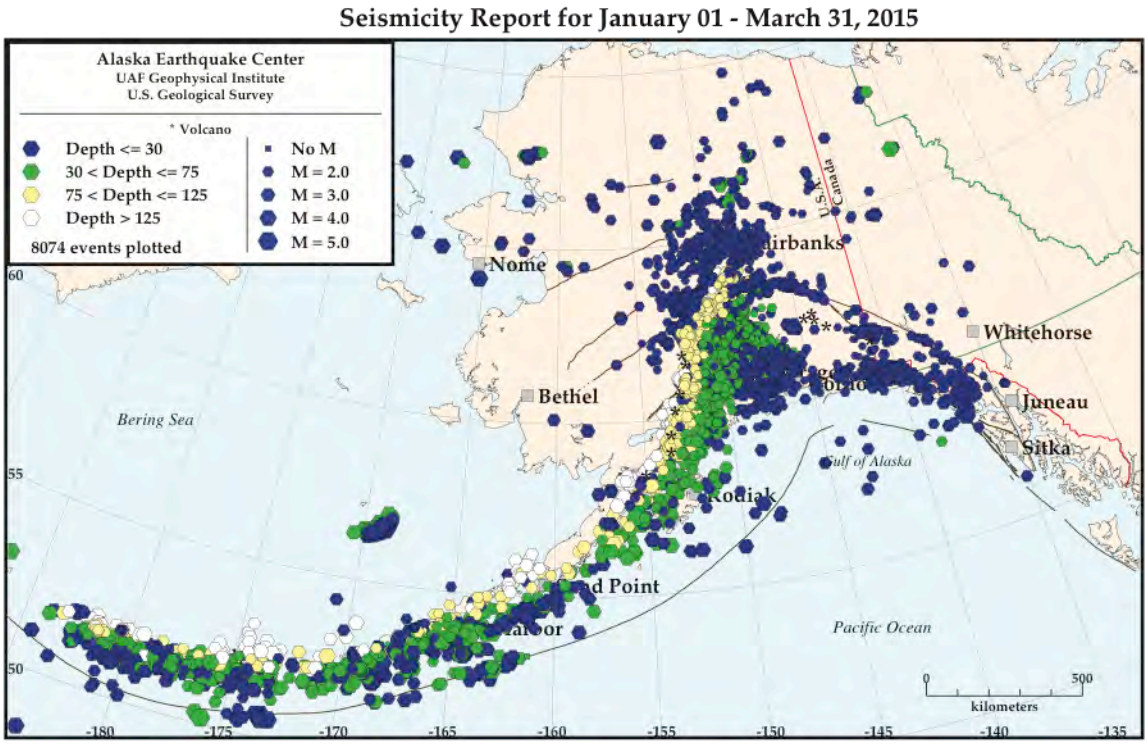

Figure 1. AEC Seismicity Report for 1 January 2015 – 31 March 2015.

NOAA relevance/societal benefits

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

Outreach

AEC 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 systems reside on stand-alone MAC computers that display real time earthquakes on a state map with audio announcements of earthquake locations and magnitudes.

Appendices

Appendix 1
CIFAR Projects Awarded in Cooperative Agreement NA13OAR4320056
1 April 2014 to 31 March 2015

Last	First	Proposal Title	Amend	Project Budget	Theme Description	Funding Source	NOAA PM
Task 1 Activities: CI Administration and Education & Outreach							
Sugai	**Susan**	Cooperative Institute for Alaska Reseach (CIFAR) renewal (2013-2018)	15	$65,000	Administration	OAR	Hoffman
Sugai	**Susan**	Cooperative Institute for Alaska Reseach (CIFAR) renewal (2013-2018)	29	$8,865	Administration	OAR	Hoffman
Sugai	**Susan**	Cooperative Institute for Alaska Reseach (CIFAR) renewal (2013-2018)	31	$27,770	Administration	NESDIS	Hoffman
Iken	**Katrin**	Arctic Marine Biodiversity Observing Network (AMBON) Graduate Student Traineeships (year 1 of 4)	30	$96,472	Education & Outreach	NOS/IOOS	Canonico
NOAA Non-Competitive Projects (NA13OAR4320056)							
Cherry	**Jessica**	High latitude proving ground for GOES-R: Advanced data products and applications for Alaska (year 1 of 3)	18	$199,993	Climate Change & Variability; Coastal Hazards	NESDIS	Goodman
Cross	**Jessica**	Program for innovative technology for Arctic exploration (PITAE)	13	$105,961	Ecosystem Studies & Forecasting	OAR	Sabine
Heinrichs	**Thomas**	FY14 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 (year 2)	19	$130,000	Coastal Hazards	NESDIS	Brown
Hopcroft	**Russell**	RUSALCA: A synthesis of long-term observations of Pacific-Arctic zooplankton communities (year 2)	14	$55,051	Ecosystem Studies & Forecasting	OAR	Crane
Hopcroft	**Russell**	RUSALCA data management (year 2)	23	$165,949	Ecosystem Studies & Forecasting	OAR	Crane
Iken	**Katrin**	RUSALCA: Arctic food web structure and epibenthic communities in a climate change context (synthesis) year 2	27	$55,000	Ecosystem Studies & Forecasting	OAR	Crane
Jewett	**Stephen**	Bering Sea benthic habitat and ecosystem - infauna	16	$4,510	Ecosystem Studies & Forecasting	NMFS	Yeung
Norcross	**Brenda**	RUSALCA Fish ecology research (year 2)	24	$34,998	Ecosystem Studies & Forecasting	OAR	Crane
Quinn	**Terrance**	SAIP: Time-varying natural mortality: random versus covariate effects (year 1 of 2)	28	$91,435	Ecosystem Studies & Forecasting	NMFS	Hulson

Year 2

Last	First	Proposal Title	Amend	Project Budget	Theme Description	Funding Source	NOAA PM
Rea	**Lorrie**	Regional, seasonal and species differences in trophic feeding ecology of western and central Aleutian Steller sea lion (Eumetopias jubatus) prey	20	$112,300	Ecosystem Studies & Forecasting	NMFS	Logerwell
Reynolds	**Jennifer**	Geological substrate and potential habitat map for deep sea corals and sponges in the Gulf of Alaska margin and the Aleutian shelf and slope regions (year 2)	25	$22,144	Ecosystem Studies & Forecasting	NMFS	Rooper
Stuefer	**Martin**	GOES-R Volcanic ash risk reduction: Operational decision support within NOAA's Rapid Refresh (RAP) year 1 of 2	21	$99,590	Coastal Hazards	NESDIS	Heidinger
Webley	**Peter**	Validation of GOES-R volcanic ash products: near real-time operational decision support/hazard analysis (year 2)	17	$32,247	Coastal Hazards	NESDIS	Heidinger
West	**Michael**	Alaska Earthquake Information Center (AEIC) seismic station operations and maintenance (CRESTnet) year 2	26	$187,468	Coastal Hazards	NWS	Angove
Whitledge	**Terry**	RUSALCA: Global change in the Arctic: Interactions of productivity and nutrient processes in the northern Bering and Chukchi Seas (year 2)	22	$65,000	Ecosystem Studies & Forecasting	OAR	Crane
		Total projects funded (including CI administration)		**$1,559,753**			
		Task II & III awards for Task I formula		$1,361,646			

Appendix 2. 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	15			2	13
Visiting Scientist					
Postdoctoral Fellow					
Research Support Staff	21		12	6	3
Administrative				1	
Total (≥ 50% NOAA Support)	0				
Total	36	0	12	9	16
Employees (< 50% NOAA Support)	36				
Located in NOAA Lab	1				
Obtained NOAA employment within last year	0				
Undergraduate Students	2		2		
Graduate Students	9			4	5
Total Students	**11**				

Appendix 3. Publication Activity

Summary table of publications during the current cooperative agreement NA13OAR4320056

	Institute Lead Author		NOAA Lead Author		Other Lead Author	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Peer-reviewed	0	1	0	0	0	1
Non Peer-reviewed	0	0	0	0	0	0
Accepted for publication		1		0		1

The "accepted" publications are peer-reviewed.

Year 1 = 1 July 2013–31 March 2014
Year 2 = 1 April 2014–31 March 2015

***NOTE**: In addition to these publications, four papers were reported as having been submitted, two of which are currently undergoing revision. Another eight were reported as actively in preparation. Many projects are only just getting underway and we anticipate publications from them in the out years.*

Peer-reviewed papers published, in press or accepted for publication during the reporting period

Egan, S.D., M. Stuefer, P. Webley and C.F. Cahill. 2015. WRF-Chem modeling of sulfur dioxide emissions from the 2008 Kasatochi Volcano. *Annals of Geophysics*, *57*. DOI: 10.4401/ag-6626

Ershova, E.A., R.R. Hopcroft and K.N. Kosobokova. Inter-annual variability of summer mesozooplankton communities of the western Chukchi Sea: 2004–2012. Accepted for publication in *Polar Biology*.

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