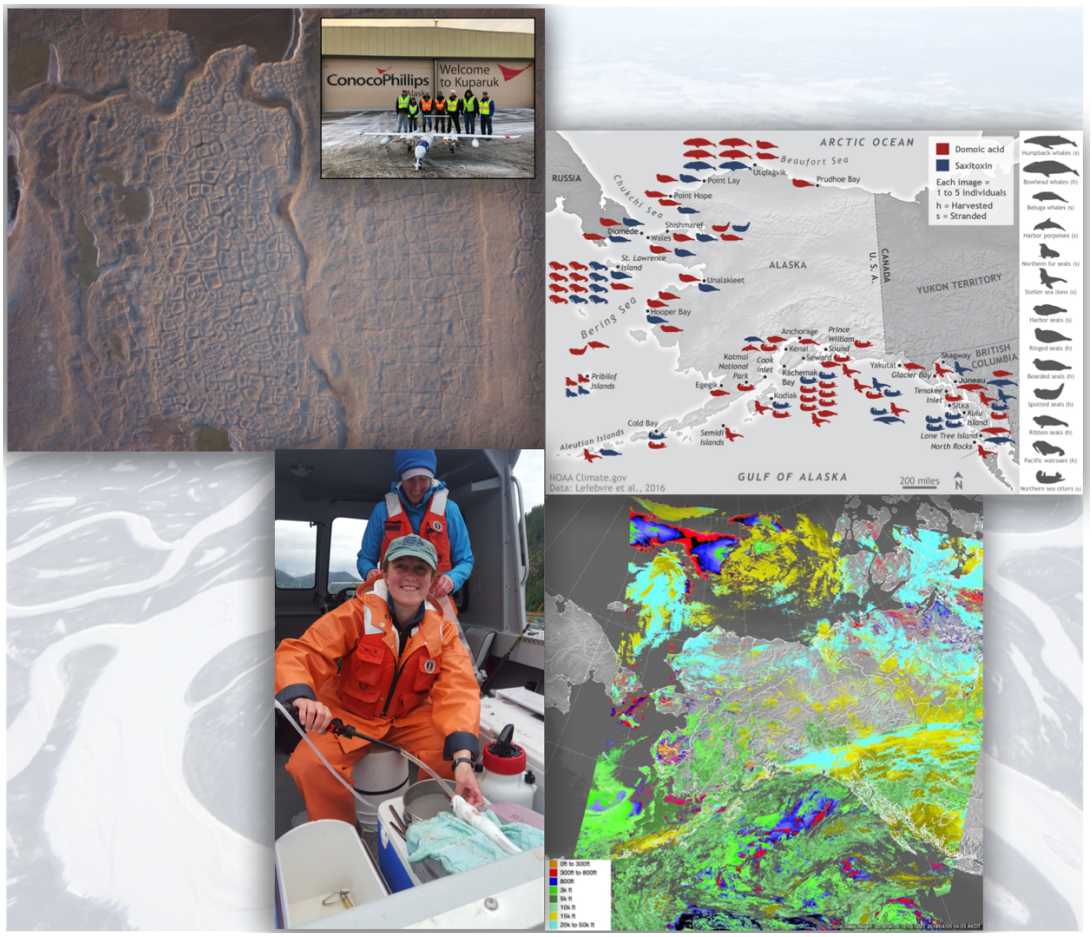
Cooperative Institute For Alaska Research

Sixth Report to NOAA on Cooperative Agreement NA13OAR4320056

1 April 2018 - 31 March 2019



UNIVERSITY OF ALASKA FAIRBANKS

Sixth report from the Cooperative Institute for Alaska Research (CIFAR) to NOAA, regarding Cooperative Agreement *NA13OAR4320056*

1 April 2018-31 March 2019

Cooperative Institute for Alaska Research

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Cover graphic credits. (*Top Left*) Imagery of ice wedge polygons near Kuparuk collected using SeaHunter Unmanned Aerial System by ACUASI and colleagues (inset photo shows team UAF/NOAA/CU team with SeaHunter) from *Regional Rapid Response for Weather and Sea Ice Mapping* project led by Dr. Cahill. (*Top Right*) The graphic created by NOAA.gov for the 2018 Arctic Report Card press conference held at the 2018 Fall AGU meeting highlights the increasing occurrence of paralytic shellfish poisoning cases in Alaska due to warming ocean waters. This is from the project *NOAA State of the Arctic* led by Ms. J Richter-Menge. (*Bottom Right*) Prototype CLAVR-x Cloud Base Altitude product created at GINA for NWS and other aviation representatives in Alaska. This is from project *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* led by Mr. Pace. (*Bottom Left*) NOAA Hollings Scholar senior Willa Johnson learns how to perform gastric lavage on a juvenile sablefish with mentor Dr. Anne Beaudreau, who leads the project titled *Evaluating the effects of habitat quality on YOY sablefish physiological condition to inform estimates of recruitment in the stock assessment*.

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 ended as of June 30, 2018 and this report covers research conducted under a no-cost extension (NCE) until June 30, 2019, which was granted for most of the projects in this report. Two projects have been granted a NCE until June 30, 2020 because they fall under research-to-operations, which typically needs extra time for a solid transition. During this first NCE year, CIFAR has continued to facilitate the well-developed long-term collaboration between NOAA and the University of Alaska (UA) that started under the Cooperative Institute for Arctic Research in 1994. CIFAR continues to play a central role in communication and coordination between NOAA (Alaska and Silver Spring), researchers, management agencies, non-governmental organizations, Alaska communities, and the general public in collaborative research, education, and outreach efforts. During this NCE year when no new monies could be obtained through CIFAR for research activities, CIFAR staff has served to facilitate temporary mechanisms for University of Alaska researchers to access NOAA funding to continue numerous critical activities.

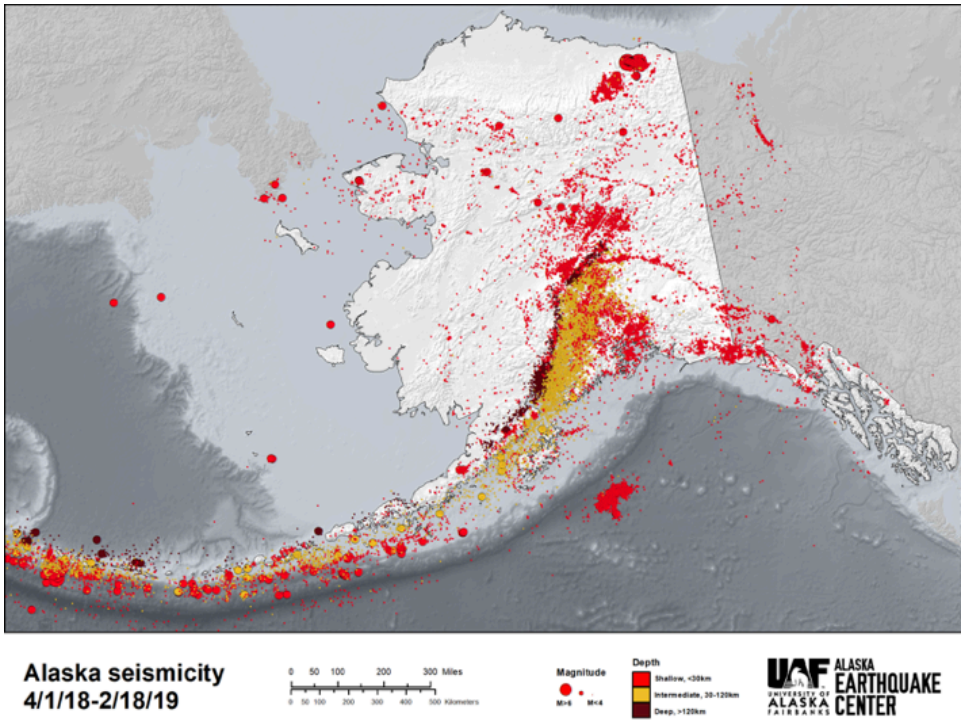

Figure 1. Map of seismicity from April 1, 2018 through February 18, 2019. Maintaining and upgrading the Alaska Seismic Network provides much needed data for a Weather Ready Nation.

Vision, Mission, and Research Themes for CIFAR

The CIFAR Vision is:

Understand the Alaska environment for the protection of society.

The CIFAR Mission is:

Fostering collaboration between NOAA, the University of Alaska, and others doing research in Alaska and its associated Arctic regions.

The CIFAR Research Themes are:

- Ecosystem studies and forecasting—Gain sufficient knowledge of Alaskan ecosystems to forecast their response to both natural and anthropogenic change.
- 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.
- 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 Executive Board and Fellows did not meet in FY19. Since CIFAR is sunsetting, updates to the Executive Board and Fellows based on numerous personnel changes from retirements and promotions have been postponed to a later date when and if a new CI is established. The following provides a list of advisory members that was updated based on conversations that took place in FY18.

The CIFAR Executive Board members are:

1. Chidong Zhang, NOAA Office of Oceanic & Atmospheric Research (OAR) Pacific Marine Environmental Laboratory (PMEL) Acting Director
2. Sandy Starkweather, NOAA OAR Arctic Research Office Program Manager
3. Douglas DeMaster, NOAA National Marine Fisheries Service (NMFS), Director, Alaska Fisheries Science Center (AFSC)
4. Carven Scott, Director NWS Alaska Region
5. Robert McCoy, Director of Geophysical Institute, University of Alaska Fairbanks
6. Bradley Moran, Dean of the College of Fisheries and Ocean Sciences (CFOS), University of Alaska Fairbanks
7. James Partain, NOAA Regional Climate Services Director, Alaska Region
8. Uma Bhatt, CIFAR director, ex officio

The CIFAR Fellows are:

1. Larry Hinzman, Vice Chancellor for Research, University of Alaska Fairbanks (UAF), Fairbanks, AK
2. Kris Holderied, Director NOAA/NOS Kasitsna Bay Laboratory, 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), CFOS, UAF, Fairbanks, AK
6. Seth Danielson, Research Associate Professor of Physical Oceanography, CFOS, UAF, Fairbanks, AK
7. Gordon Kruse, President's Professor of Fisheries, SFOS, UAF, Juneau, AK
8. Betsy Baker, Executive Director, North Pacific Research Board, Anchorage, AK
9. Molly McCammon, Director, Alaska Ocean Observing System, Anchorage, AK
10. Phil Mundy, Division director, Auke Bay Laboratory, AFSC, NMFS, NOAA, Juneau, AK
11. James Overland, Oceanographer, PMEL, NOAA, Seattle, WA

Summary of Awards Made during Reporting Period

During the sixth reporting year of our renewal cooperative agreement NA13OAR4320056, NOAA provided 6 amendments to the CIFAR renewal agreement for Task III research awards/ Task 1 recovery totaling over $360k. 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 I & III projects (percentage of total) by NOAA line office. Each of the amendments provided funding for Task 1 Core Support, including the amendment received for the Education and Outreach project. CIFAR did not receive any Task II funds this reporting period.

Table 1. Summary of CIFAR Awards Funded 1 April 2018-31 March 2019: by Task and Theme.

Theme	Number of Awards	Total Amount	Subtotals by Task	Percent of Total (rounded)
Administration (Task I)	**6**		**$24,699**	**6.80%**
Core Support	6	$24,699		6.80%
Education & Outreach	0	$0		0.00%
Research Themes (Task II & III)	**6**		**$338,340**	**93.2%**
Climate Change & Variability	0	$0		0.00%
Coastal Hazards	1	$3,600		0.99%
Ecosystem Studies & Forecasting	5	$334,740		92.20%
Total	**6**		**$363,039**	**100.00%**

Table 2. Summary of CIFAR Task I III Awards Made 1 April 2018-31 March 2019: by Funding Source.

Funding Source	Number of Awards	Total Project Amount	Percent of Total	Total Task 1 Recovery Amount	% of Task I Recovery paid
NESDIS	1	$3,600	1.06%	$263	1.06%
OAR	0	$0	0.00%	$0	0.00%
NWS	0	$0	0.00%	$0	0.00%
NMFS	5	$337,740	98.94%	$24,436	98.94%
NOS	0	$0	0.00%	$	0.00%
Total	**6**	**$338,340**	**100.00%**	**$24,699**	**100.00%**

During the current reporting year, the funding of Task I core administration support for CIFAR was billed to line offices based upon the NOAA's implementation of the Task 1 recovery 'pay as you go' policy. CIFAR's Task 1 recovery fee was 7.3%.

Highlights from 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, two of whom also staff various other departments: Uma Bhatt, director, working on a 1.0 FTE; Nancy Fresco, associate director, working on a 0.75 FTE; and Sarah Garcia, CIFAR administrator, working remotely on a 0.75 FTE. During this reporting period, the CIFAR staff dedicated work load was:

1. Uma Bhatt, CIFAR director, 25.1% FTE (Task I and match)
2. Nancy Fresco, CIFAR associate director, 15.3% FTE (Task I and match)
3. Sarah Garcia, CIFAR administrator, 52.3% FTE (Task I and match)

Uma Bhatt provides overall CIFAR programmatic guidance and oversees daily operations. She is responsible for approving all CIFAR proposals and overseeing reporting obligations. Nancy Fresco provides support for CIFAR activities and scientific content to the CIFAR web page.

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, NOAA human resource needs include research scientists with an interdisciplinary training in the physical, environmental, and social sciences. Thus, CIFAR continues to emphasize 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 link 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 shown in bold face in the summary below.

A proposal submission and review process took place between June and July 2019 and resulted in the recommendation of full or partial funding of eleven projects for awards running from 1 August 2018 to 30 June 2019. These awards were funded with CIFAR Task 1 education funds.

The students and their FY19 CIFAR projects are listed here:

1. **Marta Ree**, College of Fisheries and Ocean Sciences, UAF, "Linking marine and freshwater ecosystems through growth and survival of Alaska sockeye salmon."
2. **Reyce Bogardus**, College of Natural Sciences and Mathematics, UAF, "Utilizing Multidimensional Hydro-morphodynamic Numerical Models to Predict Coastal Flooding and Erosion under Changing Climate Conditions at Alaska Communities."
3. **Casey Clark**, Institute of Northern Engineering, UAF, "Biogeochemical tracers of change in Pacific walruses past and present."
4. **Marina Washburn**, College of Fisheries and Ocean Sciences, UAF, "Impact of elevated, variable pCO2 on the Pacific razor clam (Siliqua patula) in Alaska."
5. **Danielle Siegert**, College of Fisheries and Ocean Sciences, UAF, "Nearshore food web structure in two environmentally contrasting regions in Cook Inlet."

6. **Jenell Larsen**, College of Fisheries and Ocean Sciences, UAF, "Change and resiliency in the Bering Sea ecosystem: assessing changing distributions of marine resources and effects on subsistence communities."
7. **Nicole Laroche**, College of Fisheries and Ocean Sciences, UAF, "Sea otter foraging behavior along a density gradient in southern southeast Alaska."
8. **Jennifer Marsh**, College of Fisheries and Ocean Sciences, UAF, "Environmental and biological influences on the distribution of Arctic cod (Boreogadus saida)."
9. **Rachel Lekanoff**, College of Fisheries and Ocean Sciences, UAF, "Characterizing particle-associated and free-living microbes and their roles in the carbon cycle of the Bering and Chukchi seas."
10. **Till Baumann**, International Arctic Research Center, UAF, "Pan Arctic Tidal Current Atlas."
11. **Tracie Curry**, School of Natural Resources and Extension, UAF, "Integrating Local Context: Supporting adaptation to climatic and socio-economic change in Arctic communities."

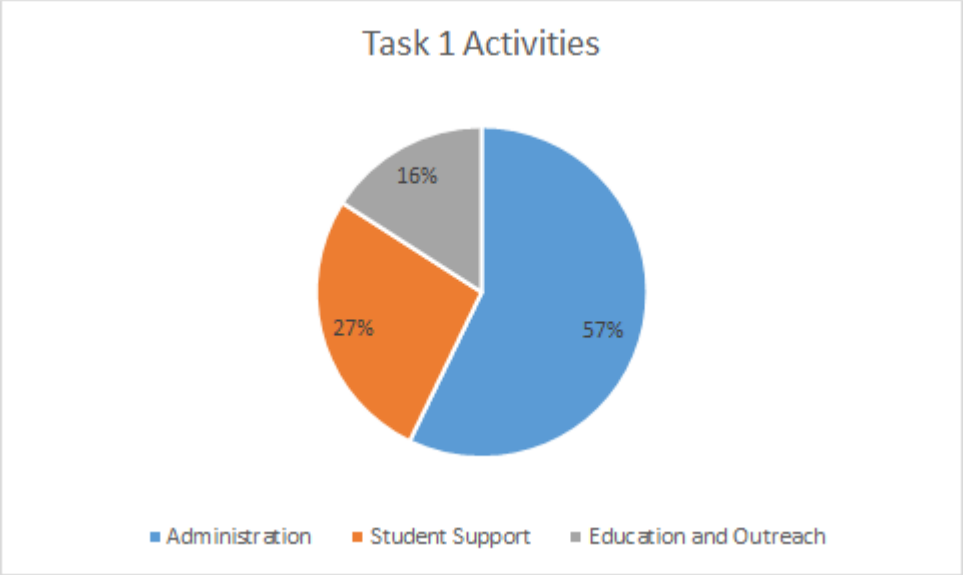

Figure 2: Pie chart displaying TASK 1 breakdown over period 1 April 2018-31 March 2019.

Other CIFAR Administrative Activities

Administrator Sarah Garcia attend the annual CI/JI administrators meeting in Madison, Wisconsin in September 2018. Administrators traveled from almost all of the CI/JIs. The meeting covered challenges as well as solutions for managing the CIs effectively.

This year, CIFAR entered its sunset period. Most the projects funded through CIFAR are/were multi-year projects that are incrementally funded. Seven continuing projects and five would have been new projects had to be re-routed, which was not an easy task. The CIFAR administrative team took immediate and appropriate action to assist the project PIs in finding and securing alternative means for getting their projects funded. The CIFAR administrative team explored multiple ways and identified which ways would be most appropriate for each project. Some of the mechanisms included contracts issued directly from NOAA and awards issued through Sea Grant.

Our team meets in person or virtually with NOAA and CI personnel whenever opportunities arise. The administrative team of Uma Bhatt, Nancy Fresco, and Sarah Garcia attended the annual CI Directors meeting on April 3-4, 2018 in Silver Spring. Uma Bhatt met with CI directors and Craig McLean at AGU in Washington DC in December 2018. Bhatt participated in the September 2018 Arctic All-Hands meeting organized by Dr. Emily Osborne that is used to keep NOAA Arctic researchers informed about ongoing activities. Bhatt and Fresco represented CIFAR in various meetings in Fairbanks: Dr. Jeremy Mathis (May 2018), Dr. Ben Friedman (June 2018), and Dr. H. Tolman (November 2018). Each of these information exchanges helps to strengthen collaborations and to better define priorities.

Highlights of CIFAR Research Activities

CIFAR's modest but diverse research portfolio covers a breadth of activities from observational monitoring of key environmental parameters to the development of operational products to serve NOAA. Training students continues to be a focus of CIFAR in order to serve NOAAs need for workforce development. Students and postdoctoral researchers are bolded and underlined in the highlights section. CIFAR-funded students and postdoctoral researchers have been well-trained to solve complex problems and are poised to contribute to NOAAs mission.

Ecosystem Studies and Forecasting

PI Gordon Kruse is working with collaborators at NMFS on a project that will provide strategic guidance on the management of federally managed fisheries in the Gulf of Alaska (GOA) to support advancing ecosystem-based fisheries management. Judith Rosellon Druker is the post-doctoral researcher for this project and she is developing a conceptual model that emulates the major ecological functions of the GOA to inform planning for a GOA-wide Alaska Integrated Ecosystem Assessment (IEA) Program. A unique aspect of this work is the development of the IEA framework in Southeast Alaska through stakeholder engagement. Workshops in Sitka led to co-production of knowledge between scientists and Sitka stakeholders and allowed integration of Local Ecological Knowledge (LEK) into the scientific process to better understand the local ecosystem. During these workshops, linkages between focal fisheries and community well-being in Sitka (as defined by people in the community) were also identified. This study serves as a fine example of how scientific progress can be made through incorporation of stakeholder input to better serve the stakeholders.

PI Anne Beaudreau investigates the habitat of sablefish, which are among the highest valued commercial species in Alaska. This research aims to link habitat conditions to sablefish overwinter survival by modeling the relationship between habitat condition (temperature, resource availability and quality) and sablefish growth during their first year of life. Determining factors affecting early life survival as it relates to subsequent recruitment is a key question for the sablefish stock assessment in Alaska. Joe Krieger was a postdoctoral researcher on this project and has now moved to a position at the NOAA Regional Office in Juneau, Alaska as a Fishery Management Specialist. Their results fill a gap in knowledge about the ecological and environmental factors affecting overwinter energy depletion and, ultimately, survival of juvenile sablefish. This is essential to improving NOAA's understanding of the factors affecting recruitment success and

identification of environmental indicators that could explain recruitment variation. The research also addresses, information that is of interest and value to the fishing industry and as well as the broader research community.

Climate Change and Variability

PI John Pace and the Geographic Information Network of Alaska (GINA) team at the University of Alaska Fairbanks enhance existing satellite data services and research to develop the next generation scientific products from satellite data that are Alaska-specific. GINA operates direct readout antennas in Fairbanks and captures and processes satellite data in near-real-time; many products are generated within minutes of capture. GINA serves the National Weather Service and other operators such as the Alaska Fire Service with near-real-time imagery and information products. They collaborate with the NWS Weather Forecast Offices (WFOs), the Alaska Pacific River Forecast Center (APRFC), the Alaska Aviation Weather Unit (AAWU), and the Alaska Sea Ice Program (SIP), and NOAA research partners: Cooperative Institute for Meteorological Satellite Studies--CIMSS, Cooperative Institute for Research in the Atmosphere—CIRA, NOAA Center for Satellite Applications and Research--STAR, Short-term Prediction Research and Transition and Center--SPoRT, and the NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC). GINA's work extracts value from the multi-billion-dollar satellite programs by working with operators to solve problems that only polar orbiting satellites can address. The focal areas of sea ice, river ice/flood, fire/smoke, and aviation weather were directly targeted at weather and environmental hazards to people and property in Alaska. Improvements to forecasting these hazards have a significant benefit here in our state by providing products in short order so they can be utilized in preparing forecasts.

PI Richter-Menge leads the annual publication of the NOAA Arctic Report Card (ARC), a web-based resource, and the Arctic chapter in the State of the Climate report, which appears in the Bulletin of the American Meteorological Society (BAMS). Both products provide a timely and peer-reviewed source for clear, reliable and concise environmental information on the state of the Arctic. The content is prepared in a way that is accessible to a wide audience, including scientists, students, teachers, decision-makers and the general public interested in Arctic environment and science. ARC 2018 was prepared by an international team of 78 scientists from 12 different countries. The ARC undergoes a rigorous peer-reporting process, organized by the Arctic Monitoring and Assessment Programme (AMAP) of the Arctic Council to create a synthesis of the current state of the Arctic system.

Coastal Hazards

CIFAR funded student Til Baumann to synthesize the first Arctic atlas of tidal velocities. In a changing global climate, the Arctic Ocean sea ice is experiencing a significant and persistent decay. There is on-going debate about the relative role of atmospheric and oceanic forcing shaping recent dramatic sea-ice changes. Among the mechanisms causing upward heat transport through the ocean is internal mixing driven by tidal dynamics. An Arctic-wide analysis of all available tidal current observations (Figure 3) is an important step towards quantifying the role of tidal currents in a changing Arctic Ocean. Furthermore, a publicly accessible atlas of tidal currents can be used to improve the representation of baroclinic tides in numerical models.

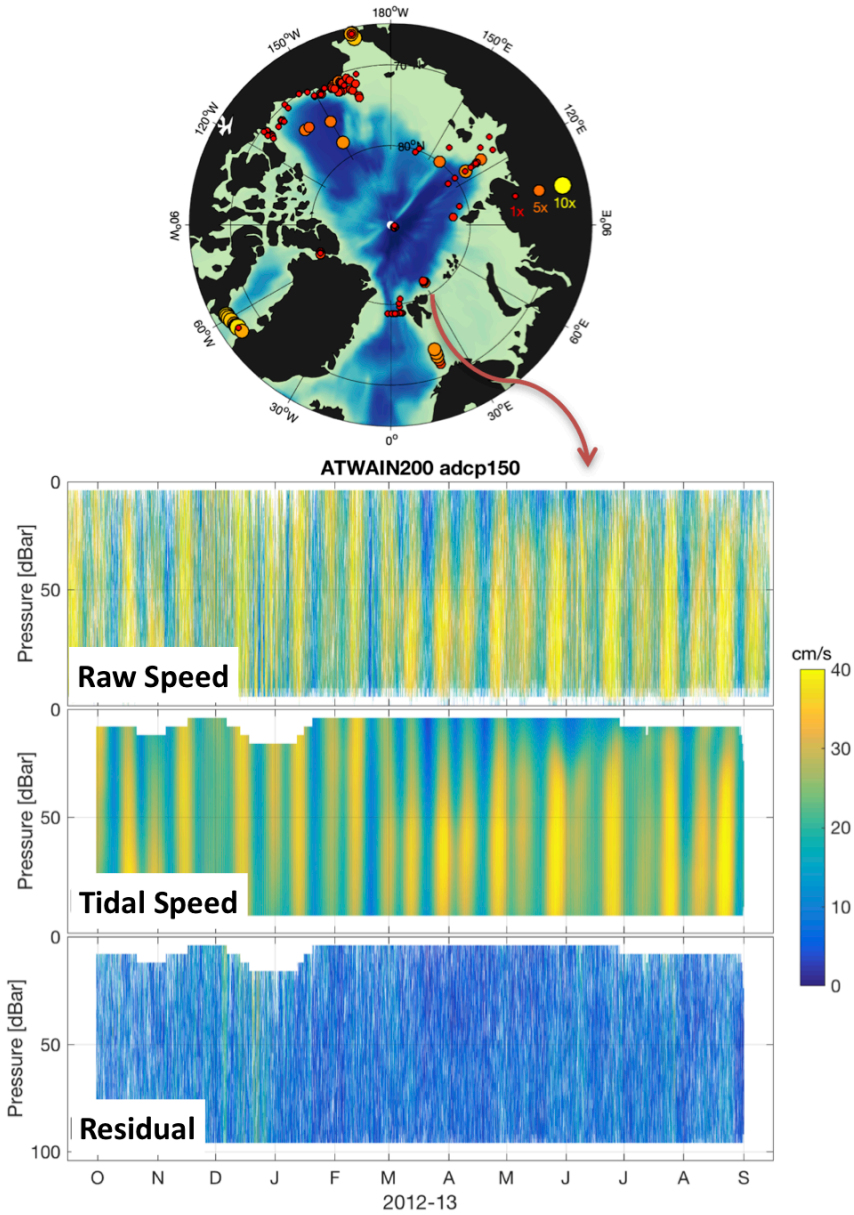

Figure 3. Top: Map showing the location of the current meter records used in the atlas. Large yellow dots indicate greater number of repeat deployments at the same location. Bottom: Example record northeast of Svalbard showing vigorous tidal currents that are extracted from the observed raw-velocities for further analysis.

PI Martin Stuefer and Co-I Peter Webley conduct simulations using WRF-Chem to provide timely decision support to reduce risk related to the spread of volcanic ash plumes to reduce risk. The GOES-R Advanced Baseline Imager Volcanic Ash Algorithm (ABI-VAA) data are used to initialize the WRF-Chem model. The modelled ash plumes improve understanding and help to verify eruption source parameters. The goal is to derive realistic eruption source parameters and provide a useful volcanic ash hazard mitigation tool. The model is run automatically whenever a volcanic eruption alert is received. Automated routines to ingest volcanic ash alerts within the WRF-Chem and

NOAA's Rapid Refresh (HRRR) modelling environments have been developed by their team. Their team provides confirmation, validation and assessment of one of the GOES-R baseline products and also provides tools to better understand the outputs of effective particle size, volcanic ash mass and height from the volcanic ash cloud detection and height algorithm. The GOES-R high temporal resolution in combination with the Rapid Refresh (RAP) model will allow for a timely volcanic ash hazard awareness and dissemination of volcanic warnings. Volcanic ash clouds are a severe event and can cause serious damage to aircraft, cause airport closures and affect human health.

Publications and Presentations

In this last reporting period, there are a total of 26 peer-reviewed publications, 13 have been published, four publications were under review or in revision, four are in press and five are in various stages of preparation. There was a total of 15 conference presentations reported for the period 1 April 2018–31 March 2019.

PROGRESS REPORTS ON INDIVIDUAL PROJECTS

TASK I: AMBON TRAINEESHIPS

Arctic Marine Biodiversity Observing Network (AMBON) student traineeships

Katrin Iken, PI
University of Alaska Fairbanks

CIFAR theme(s): Ecosystem Studies and Forecasting

NOAA Goal(s): Healthy Oceans

Amendments 30, 35, 52, 70

NOAA Office: NOS, Gabrielle Canonico, Sponsor

Budget Amounts: Cumulative $296,013, This year $0

This project is on extension and set to end 06/30/2019.

Primary objectives

This project provides funding to train graduate students whose research will be aligned with the Arctic Marine Biodiversity Observing Network (AMBON) for a period of 4 years. Students will be trained in the fields of benthic ecology, diversity estimates, food web ecology, microbial ecology, molecular techniques, and metagenomics analyses.

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 two 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

One PhD student (Ann-Christine Zinkann) is working on the benthic community and food web portion of the project. She is using amino-acid specific stable isotope analyses to identify trophic linkages between different carbon sources (microbial, terrestrial, marine photosynthetic) and benthic invertebrates. She helped implementing these new techniques here at the University of Alaska Stable Isotope Facility and has since been involved in guiding other students in the technique. She analyzed depth-stratified sediment cores (0-5 cm depth) for the proportional distribution of various carbon producers (endmembers). Endmembers considered were marine microalgae, bacterial production, and terrestrial matter. In addition, she ran an incubation experiment that investigated bacterial production at 0°C and 5°C water temperature. Carbon sources were mostly homogeneously distributed across sediment layers, probably a result of the strong bioturbation activity of benthic fauna. Surprisingly, terrestrial carbon was the most abundant source across all sediment layers, possibly related to the slow degradation processes of

this material and subsequent accumulation in sediments, which microalgal and bacterial carbon sources are more readily utilized by fauna. Bacterial production increased at higher temperatures by about 2-3 times for the first 24 h of incubation, after which production across the two temperature regimes equaled out. Possibly, substrate limitation after that time reduced overall production.

The student learned much of the analytical techniques of sediment analyses since this particular method has been applied to organic tissue but less so to sediments. She needed to troubleshoot and develop new approaches of sample purification. She also developed collaborations with microbial ecologists for the incubation experiment on bacterial production. Again, she explored new analytical tools in a realm (microbes) that is probably going to be the first and fastest-responding to the climatic changes the Arctic is experiencing. The student is currently in the process of writing up this sediment-related work for publication and is delving into the literature to put her own data into context.

In addition, the student presented her work at the Alaska Marine Science Symposium in Anchorage in January 2019 (oral presentation) and will also be presenting at the Benthic Ecology Meeting in Canada in April 2019 (also oral presentation). This has been an excellent venue for the student to receive feedback on her work (and some interpretation has changed based on this feedback from expert peers) and allowed the student to develop deeper collaborations with other scientists in the field. The student's exposure to relevant topics in Arctic ecosystem functioning and diversity has fostered a strong interest in this student to get more engaged in the political decision-making processes; in consequence, she applied to the NOAA Sea Grant Knauss Fellowship and has been invited for a first interview the last week of March 2019. Should she be afforded this opportunity, she will be able to take the lessons learned through this traineeship and apply in-depth knowledge on ecological processes and ocean observing to the political arena.

An MS student (Lauren Sutton) was funded under this traineeship to use benthic community data to explore approaches to functional diversity in addition, and in comparison to taxonomic diversity. Biological traits analysis (BTA) is an emerging field that is believed to be more informative about ecosystem functioning and resilience than the traditionally applied taxonomic biodiversity measures. The student had to code biological traits for 247 epibenthic taxa through a combination of qualitative traits based on observations (e.g., morphological traits) and traits derived from extensive literature research (e.g., life history traits, behavioral traits). BTA included nine traits related to morphology (body form, fragility, sociability), behavior (living habit, adult movement, feeding habit), and life history (size, reproductive strategy, larval development). These data will be entered into an "Arctic Traits Database" (http://www.univie.ac.at/arctictraits). This database is an international collaboration in which the student got engaged at its inception and to which she contributed to the conceptual development (represented by co-authorship in a publication: Degen R, Aune M, Bluhm BA, Cassidy C, Kędra M, Kraan C, Vandepitte L, Włodarska-Kowalczuk M, Zhulay I, Albano PG, Bremner J, Grebmeier JM, Link H, Morata N, Nordtsröm MC, Shojaei MG, Sutton L, Zuschin M. 2018. Trait-based approaches in rapidly changing ecosystems: A roadmap to the future polar oceans. Ecological Indicators 91:722-36). The student was able to present her work at the World Conference on Marine Biodiversity in May 2018 in Montreal Canada (oral presentation) and connect with other scientists developing the functional traits approach. She also presented her work in an oral presentation at the Alaska Marine Science Symposium in Anchorage in January 2019. She is currently working on a first chapter (manuscript) of her thesis, comparing functional

diversity to traditional diversity measures on the Chukchi shelf based on 2015 AMBON data. A second manuscript will follow with an analysis of spatial patterns in functional diversity and their relation to environmental conditions on the Chukchi shelf. That work will include physical and chemical data collected by AMBON collaborators.

An MS student (Rachel Lekanoff) has been working on samples from the AMBON 2017 cruise. She collected water samples to study microbes (phytoplankton, bacteria, etc.) using state-of-the-art metabarcoding techniques. These samples, in conjunction with other samples from a spring 2017 cruise to the study region, are being used to study phytoplankton community structure and the biological and environmental drivers that shape them. During the AMBON cruise, the student was able to meet researchers from other research institutions and establish new professional relationships. The student also learned new techniques pertaining to the study of particle flux (POC and SPM analyses). She presented her work at the Alaska Marine Science Symposium in Anchorage in January 2019 (poster presentation), which afforded an opportunity to share her work and receive important feedback from other scientists in the field.

NOAA relevance/societal benefits

AMBON provides 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. All students in this traineeship program are deeply involved with these novel aspects of the AMBON project. Through integration with other programs such as the Distributed Biological Observatory (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, students are gaining invaluable research experience and complete their thesis research with direct involvement of multi-national, multi-institutional, multi-agency researchers. This traineeship is producing the next generation of scientists with a focus on new and emerging approaches and technologies, who will be important to continue and bring forward biodiversity observations in the ocean.

Partner organizations and collaborators

In addition to NOAA, funders include the Bureau of Ocean Energy Management (BOEM) and the Shell Exploration and Production Company, and the National Science Foundation (NSF). Shell has withdrawn its support after the first year because they ceased operations in the Arctic, but we were able to garner some support from the National Science Foundation for additional support for ship time in summer 2017, which will also benefit further the student education and training. NASA has recently become a partner through funding an associated scientist to involve Seascapes into the AMBON framework. 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 graduate students in novel research approaches and in working with a multi-discipline research team, and (2) innovative thesis research that improves 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

ECOSYSTEM STUDIES AND FORECASTING

RUSALCA Overview: 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 multidisciplinary 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 multidisciplinary 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.

Continuation of RUSALCA fish ecology research

Brenda L. Norcross, PI
Brenda A. Holladay, Co-PI
University of Alaska Fairbanks

CIFAR theme(s): Ecosystem Studies and Forecasting

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation

Amendments 1, 24

NOAA Office: OAR, Jeremy Mathis, Sponsor

Continues research from NA08OAR4320870

Budget Amount: Cumulative $144,833, This year $0

This project is complete.

Primary objectives

To synthesize and publish results of the fish ecology investigations of larval 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 species associations in the present-day Chukchi Sea.

Research accomplishments/highlights/findings

In the last year, a manuscript was submitted to *Polar Biology.* It is titled Ichthyoplankton of the Chukchi Sea 2004-2012: Russian-American Long-Term Census of the Arctic, authors are Busby, Holladay, Meir, Norcross. It provides baseline information on species composition and spatial and temporal distributions of ichthyoplankton and presents new illustrations and photographs of fish larvae. The manuscript was reviewed and returned to the first author, Morgan Busby at NOAA Alaska Fisheries Science Center on 8 January 2019. While the findings were deemed to have merit, a total revision of the manuscript is required. The first author states that he is uncertain when he will revise this manuscript.

The most common fish eggs encountered in the Chukchi Sea were the flatfishes *Limanda* spp. and *Hippoglossoides robustus* (Bering flounder), whereas *Boreogadus saida* (Arctic cod) was the most abundant species of ichthyoplankton. *B. saida* accounted for 61% of the total planktonic catch of larval and juvenile fishes from the surveys in 2004, 2009 and 2012, and were distributed throughout the Chukchi Sea and in the East Siberian Sea. Overall, catch of this species was greatest in 2004 and lowest in 2012. Diversity of ichthyoplankton was greater in 2004 than 2009. Cluster analysis of ichthyoplankton abundance revealed three distinct assemblages: one dominated by *B. saida*, *Liparis* spp. (snailfishes), and the family Stichaeidae (pricklebacks); the second, by *Limanda aspera* (yellowfin sole) and *H. robustus;* and the third by *Gadus chalcogrammus* (walleye pollock).

This manuscript presents new illustrations and photographs that will assist in identification of early life stages of Arctic fishes. We present illustrations of five species from the cod family, including Arctic cod and walleye pollock, and photographs of cleared and stained Limanda proboscidea (longhead dab) and Stichaeus punctatus (Arctic shanny).

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.

Partner organizations and collaborators

None to report at this time.

Impact

Because early life history stages of marine fishes are vulnerable to both gradual environmental changes and episodic perturbations, the data obtained from this project are fundamental to understanding the dynamics of fish communities in the Pacific-Arctic ecosystem.

The new illustrations help to complete developmental series of Arctic fishes, which will assist in future identifications.

Education

None this reporting period.

Outreach

None this reporting period.

Publications

None this reporting period.

Conference presentations

None this reporting period.

Other products and outcomes

None this reporting period.

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

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

CIFAR theme(s): Ecosystem Studies and Forecasting

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation

Amendments 2, 22
NOAA Office: OAR, Jeremy Mathis, Sponsor
Continues research from NA08OAR4320870
Budget Amount: Cumulative $214,169, This year $0
This project is complete.

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
- Prior RUSALCA nutrient/chlorophyll data from mooring cruises were calculated edited and quality checked
- Data for nutrients, chlorophyll and primary production will be sent to designated archive for inclusion in RUSALCA database.
- Data products are planned for presentation at a national meeting.
- 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 an additional manuscript will be prepared that emphasize physical-nutrient processes, nutrient primary productivity processes and nutrient-primary production-microbial processes.

Research Accomplishments/highlights

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.

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

A Ph.D. student has been previously employed to process, collate, aid in the analysis of nutrient data obtained during RUSALCA cruises and place nutrient data with accessible data bases.

Publications and presentations

Sadanandan Bhavya, P., J.H. Lee, H.W. Lee, J.J. Kang, J.H. Lee, D. Lee, S.H. An, D.A. Stockwell, T.E. Whitledge and S.H. Lee. 2018. First in situ estimations of small phytoplankton carbon and nitrogen uptake rates in the Kara Laptev, and East Siberian seas. Biogeosciences, 15:5503-5517.

Shen, Y., R. Benner, K. Kaiser, C. Fichot and Terry E. Whitledge. 2018. Pan-Arctic distribution of bioavailable dissolved organic matter and linkages with productivity in ocean margins. Geophysical Research Letters, 45. https//doi.org/10.1002/2017GL076647.

Ahn, S.H., S.H. Lee, T.E. Whitledge, D.A. Stockwell, J.H. Lee and H.W. Lee. Submitted.Biochemical composition of phytoplankton in the Laptev and East Siberian seas during the summer, 2013. Journal of Geophysical Research Oceans.

Partner organizations and collaborators

Dr. Sang Heon Lee and four Ph.D. students, Department of Oceanography, Pusan National University, Busan 609-735, South Korea

Publications related to this project, previously reported

Lee, S.H., J.H. Lee, H. Lee, J. H. Lee, D. Lee, S. An, H.T. Joo, D.A. Stockwell and T.E. Whitledge. 2017. Light-limited uptake rates of carbon and nitrogen of phytoplankton in the Laptev and the East Siberian seas. Geophysical Research Letters

Yun, M.S., T.E. Whitledge, D. Stockwell, S.H. Son, J.H. Lee, J.W. Park, D.B. Lee, J. Park and S.H. Lee. 2016. Primary production in the Chukchi Sea with potential effects of freshwater content. Biogeosciences 13:737-749

Lee, S.H., J.H. Lee, H. Lee, J. H. Lee, D. Lee, S. An, H.T. Joo, D.A. Stockwell and T.E. Whitledge. In Prep. Light-limited uptake rates of carbon and nitrogen of phytoplankton in the Laptev and the East Siberian seas. Geophysical Research Letters

Yun, M.S.,T.E. Whitledge, D. Stockwell, J.H. Lee, J.W. Park, D.B. Lee, J. Park, and S.H. Lee.

2015. The potential effects of freshwater content on the primary production in the Chukchi Sea. Biogeosciences Discussions, 12: 13511-13544.

Pisareva, M.N., R... Pickart, M.A. Spall, C. Nobre, D.J. Torres, G.W.K. Moore and T.E. Whitledge. 2015. Flow of Pacific water in the western Chukchi Sea: Results from the 2009 RUSALCA expedition. Deep-Sea Research I 105: 53-73.

Pisareva, M.N., R.S. Pickart, K. Iken, E.A. Ershova, J.M. Grebmeier, L.W. Cooper, B.A. Bluhm, C. Nobre, R.R. Hopcroft, H. Hu, J. Wang, C.J. Ashjian, K.N. Kosobokova, and T.E. Whitledge. 2015. The relationship between patterns of benthic fauna and zooplankton in the Chukchi Sea and physical forcing. Oceanography 28(3):68–83, http://dx.doi.org/10.5670/oceanog.2015.58.

Yun, M.S., T.E. Whitledge, M. Kong, S.H. Lee, 2014. Low primary production in the Chukchi Sea shelf, 2009. Continental Shelf Research 76: 1-11

Lee, S.H., D.A. Stockwell, H.M. Joo, Y.B. Son, C.K. Kang, T.E. Whitledge. 2013. Phytoplankton production from melting ponds on Arctic sea ice. Journal of Geophysical Research.117,

C04030, doi:10.1029/2011JC007717.

C Lee, S.H., M.S. Yun, J.H. Lim, B.K. Kim, E.J. Choy, C.K. Kang, T.E. Whitledge. 2013. Contribution of small phytoplankton to total primary production in the Chukchi Sea. Continental Shelf Research 68:43-50.

Lee, S.H., M.S. Yun, B.K. Kim, S. Saitoh, C.K. Kang, S.H. Kang, T.E. Whitledge. 2013. Latitudinal carbon productivity in the Bering and Chukchi Seas during the summer in 2007. Continental Shelf Research 59:28-36.

AFSC FY 2015 – FY 2017 Alaska Ocean Acidification Research: Autonomous Observations of Ocean Acidification in Alaska Coastal Seas

Brenda Konar, PI (formerly Jessica Cross)
University of Alaska Fairbanks

CIFAR theme(s): Ecosystem Studies and Forecasting, *Climate Change and Variability*

Other investigators/professionals associated with this project:
***Natalie Monacci*, University of Alaska Fairbanks**

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation

Amendments 51, 68 NOAA Office: OAR, Libby Jewett, Sponsor
Budget Amount: Cumulative $137,060, This year $0
This project is complete.

Primary objectives

This project provides support for ongoing monitoring through the GAKOA surface buoy, a time series site in the northern Gulf of Alaska, and the M2 surface buoy (Peggy), a time series site in the southeastern Bering Sea. It also provides support for ongoing subsurface monitoring at the M2 and M8 time series sites in the southeastern Bering Sea.

Research accomplishments/highlights/findings

GAKOA 2018 deployment notes: The GAKOA surface buoy was successfully turned around in March 2018. This site is located in Sunny Cove in Resurrection Bay and is proximal to the long-term monitoring site at GAK1. Seawater carbon dioxide concentrations (pCO_2) show a gradual drawdown in mid-April, coincident with the spring bloom. Seawater pCO_2 was variable through June 2018, relative to other years, but slowly began to recover to atmospheric levels starting in July. Surface seawater temperatures at GAKOA were generally cooler than observations in 2015 and 2016. A plot of the preliminary data is given in Figure 1. Final analysis of the data from the 2017-2018 deployment is ongoing. All final data are uploaded for archival and public access to https://www.nodc.noaa.gov/ocads/oceans/Moorings/GAKOA.html

M2 (Peggy) 2018 deployment notes: The M2 surface buoy was successfully deployed in April 2018. This deployment marked the first time the seawater pCO_2 remained near or above atmospheric levels to the end of May. There were many extraordinary characteristics observed in the southeastern Bering Sea in 2018 including record low sea ice, little to no stratification of the water column along the 70m isobath, and a late spring bloom. A plot of the preliminary data is given in Figure 2. Final analysis of the data from the 2017-2018 deployment is ongoing. All final data are uploaded for archival and public access to https://www.nodc.noaa.gov/ocads/oceans/Moorings/M2_164W_57N.html

M2 and M8: The M2 and M8 subsurface moorings were successfully turned around in 2018. Due to the record low sea ice in the spring of 2018, we were able to visit the M8 site for a calibration

CTD cast for the first time in the history of the M8 mooring. Unfortunately, we continue to have gaps in our continuous records due to sensor failure and malfunction. Our team is currently conducting a study to determine the accuracy and precision of our data at the subsurface locations. We hope to have a group conclusion, including input from sensor reliability at other locations, before 2020.

NOAA relevance/societal benefits

Coastal regions around Alaska are experiencing the most rapid onset of ocean acidification (OA) compared to anywhere else in the U.S. Recent research using OA forecast models as well as species and human impact assessments have shown that Alaska coastal communities and the vast fisheries that support them have a varying degree of vulnerability to OA, ranging from moderate to severe (Mathis et al., 2014). The most vulnerable communities rely heavily on the economic and nutritional value of fisheries and other ecosystem services. OA in Alaska also has the potential to have cascading economic impacts well beyond the state level. Because Alaska fisheries provide over $3 billion annually to the U.S. gross domestic product (GDP), even a relatively small decline in one or more of the fisheries in the Gulf of Alaska or Bering Sea could have a very large net economic impact—large enough to dwarf the combined impacts occurring in other U.S. areas.

Partner organizations and collaborators

This project represents a close collaborative relationship between NOAA's Pacific Marine Environmental Laboratory and the Ocean Acidification Research Center at the University of Alaska, Fairbanks. These mooring data also contribute to the International Ocean Observing System (IOOS) program and the Global Ocean Acidification Observing Network (GOA-ON) and pollock abundance forecasts.

Impact

These monitoring activities support a number of cross-cutting research efforts. Firstly, the time series provides new insights into the seasonal progression of OA events caused by the progressive accumulation of anthropogenic CO_2 into the region's coastal seas. The mooring data can also be used as an early warning system for stakeholders around the state, as well as to provide information for other types of OA research. Other projects within the OAP Alaska Enterprise focus on laboratory-based evaluation of the impact of OA on commercially and ecologically important Alaskan species, especially during the vulnerable larval and juvenile life stages. Our environmental monitoring informs those studies by describing the intensity, duration, and extent of OA events and providing a baseline for projecting future conditions. Finally, this observational data is used to validate new OA models that are currently being developed for the Gulf of Alaska and Bering Sea, and are applied in bio-economic models of crab and pollock abundance forecasts.

Outreach

The Ocean Acidification Research Center (OARC) continues to partner with the Alaska Ocean Acidification Network to engage with scientists and stakeholders to expand the understanding of OA in Alaska. Our surface moorings are highlighted on the AK OA Network's website (https://aoos.org/alaska-ocean-acidification-network/monitoring/moored-sensors/) and our members regularly participate in newsletters, workshops, community seminars, and steering

committees.

Publications

Cross, J.N., Mathis, J.T., W. Evans, and N. Monacci. The Physical and Biogeochemical Influences on Ocean Acidification in the Northern Gulf of Alaska, Journal of Geophysical Research, in preparation.

Pilcher, D.J., D.M. Naiman, J.N. Cross, A.J. Hermann, S.A. Siedlecki, G.A. Gibson, and J.T. Mathis, 2019. Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea. Front. Mar. Sci., 5, 508, doi: 10.3389/fmars.2018.00508.

Sutton, A. J., Feely, R. A., Maenner-Jones, S., Musielwicz, S., Osborne, J., Dietrich, C., Monacci, N., Cross, J., Bott, R., Kozyr, A., Andersson, A. J., Bates, N. R., Cai, W.-J., Cronin, M. F., De Carlo, E. H., Hales, B., Howden, S. D., Lee, C. M., Manzello, D. P., McPhaden, M. J., Meléndez, M., Mickett, J. B., Newton, J. A., Noakes, S. E., Noh, J. H., Olafsdottir, S. R., Salisbury, J. E., Send, U., Trull, T. W., Vandemark, D. C., and Weller, R. A., 2019. Autonomous seawater pCO2 and pH time series from 40 surface buoys and the emergence of anthropogenic trends, Earth Syst. Sci. Data, 11, 421-439, doi.org/10.5194/essd-11-421-2019.

Conference presentations

Monacci, N.M., Musielewicz, S., Cross, J.N., Evans, W., and Mathis, J.T., 2018. An integrated approach to ocean acidification research and monitoring: using observations and models to support the Alaskan blue economy. American Geophysical Union Fall Meeting, Washington, DC.

Monacci, N.M., Cross, J.N., Musielewicz, S., Evans, W., Pilcher, D., and Mathis, J.T., 2019. Ocean Acidification Research: Using Observations and Models to Support Alaska's Blue Economy. Alaska Marine Science Symposium, Anchorage, AK.

Pilcher, D.J., 2019. Impact of local biogeochemical processes and climate variability on ocean acidification in the Bering Sea. Alaska Marine Science Symposium, Anchorage, AK.

Figures

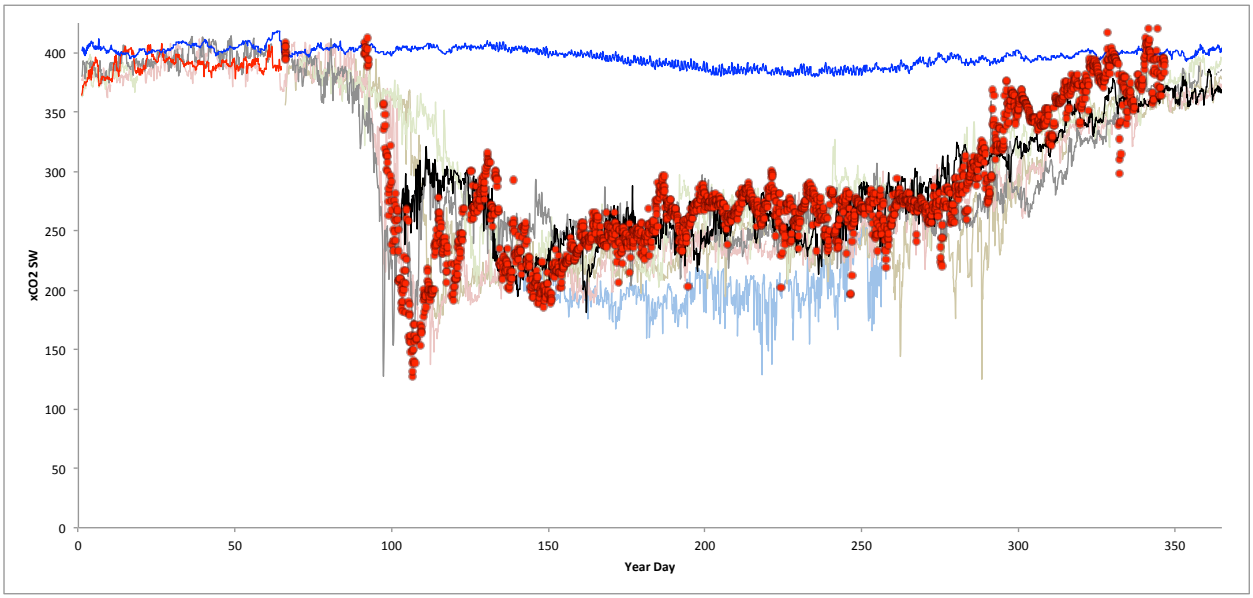

Figure 1. GAKOA is a surface mooring in Sunny Cove in the northern Gulf of Alaska. Preliminary seawater carbon dioxide (xCO_2 SW, µatm) data from 2018 are shown as the red dots. Average atmospheric data are shown as the blue line.

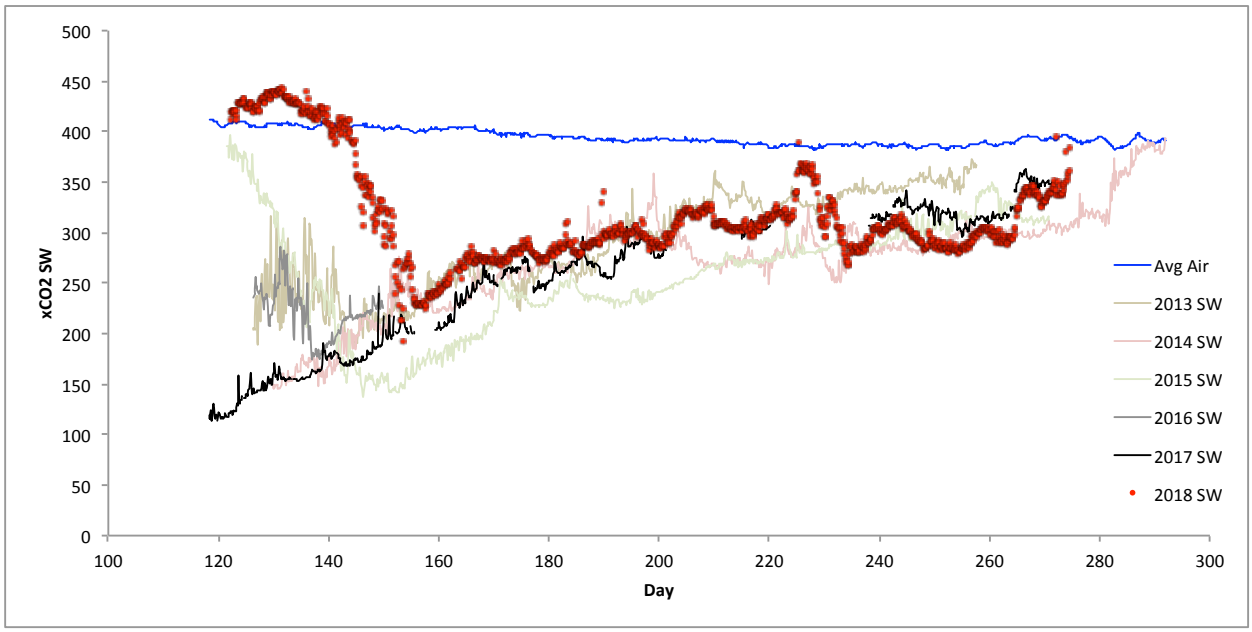

Figure 2. M2 is a seasonal, surface mooring in the southeastern Bering Sea. Preliminary seawater carbon dioxide (xCO_2 SW, µatm) data from 2018 are shown as the red dots. Average atmospheric data are shown as the blue line.

The Stock Varying Assessment Program (SAIP): Time-varying natural mortality: random versus covariate effects

Terrance Quinn II, PI
University of Alaska Fairbanks

CIFAR theme(s): Ecosystem Studies and Forecasting

NOAA Goal(s): Healthy Oceans

Amendments 28, 38 NOAA Office: NMFS-AFSC, Peter-John F. Hulson, Sponsor

Budget Amounts: Cumulative $183,116, This year $0

This project is complete. Due to unforeseen circumstances with the project PI, FY18 was the last year any work on this project was performed.

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.

This is a simulation-estimation study in which a true population is created, simulated datasets are generated, and parameters are estimated with an age-structured assessment model. Estimated parameter values are then compared to the values used to simulate the population, which come from existing stock assessments for the respective species. In this way, the precision and accuracy of estimates can be evaluated. This study models populations after Alaska sablefish (Anoplopoma fimbria) and Eastern Bering Sea pollock (Gadus chalcogrammus), both of which are of commercial importance.

The primary comparison being made in this study is between the performance of covariate and random approaches of estimating time-varying M. Covariate approaches incorporate data on an index that trends with natural mortality (i.e. predation, disease, or environmental conditions) while random approaches make additional assumptions about the error structure of the model so that the assumption of constant natural mortality can be relaxed without necessarily including additional data. Within each of these broad categories of approaches, several sub-scenarios are investigated. Within the covariate approach, we investigate the effect that different levels of observation error in the covariate have on the accuracy and precision of estimates. Within the random approach, we test the performance of models that estimate time-varying M using individual random effects and random walks. Estimation model configurations are tested on three scenarios of time-varying M: (1) linear increase, (2) linear decrease, and (3) sinusoidal fluctuation. The performance of a model that attempts to estimate time-varying M in the case where true M is constant is also evaluated. In addition, we evaluate model performance under low and high

survey biomass variability and both a 1-to-1 and 2-to-1 ratio of fishing mortality to natural mortality. In testing the performance of different model structures under these various data qualities and states of nature, we attempt to broadly characterize the performance of models that attempt to estimate time-variable M, while keeping the size of the study appropriate for a master's thesis.

Research Accomplishments/highlights

1. We conducted a literature review of the body of existing knowledge relevant to fisheries stock assessment in the treatment of natural mortality.
2. Ganz gained proficiency in R and ADMB software, to be used in project analysis.
3. We chose Gulf of Alaska sablefish and Eastern Bering Sea pollock stock assessments that are used to construct the operating models for this project; these two represent a relatively slow- growing and a fast-growing population, respectively.
4. We obtained code for the Gulf of Alaska sablefish and eastern Bering Sea walleye pollock stock assessments that were used as a starting point for incorporating time-varying natural mortality.
5. We 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 contain two different levels of stochastic variation. A covariate is constructed following these trends, also with two levels of variation to represent measurement error.
6. Four estimation models are 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.
7. Ganz completed a draft of a thesis which contains the findings of this study.
8. Ganz successfully defended his thesis in May 2017, turned in his revised thesis, and graduated in Summer 2017.
9. Submitting a manuscript for publication is planned.

NOAA relevance/societal benefits

The primary benefit for the Stock Assessment Improvement Program (SAIP) is better information about what circumstances allow M to be estimated, particularly across time and age. This study determined that a random effects model was sufficient to estimate time-varying M, when a hierarchical model with penalized likelihood was implemented. A mixed effects model that used an integrated likelihood approach performed poorly in comparison. Covariates make estimating time-varying M possible with high precision and accuracy; 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. The Deviance Information Criterion was found to be a useful metric for comparing models.

Education

Quinn hired graduate student Philip Ganz to work on this project for his M.S Fisheries degree. Graduate student Alex Fejer entered the program in Fall 2016 to work on a thesis examining ability

to estimate M for Prince William Sound herring, but funding was not found for him after one semester. Still, some work was accomplished in developing a covariate involving estimation of humpback whale abundance using mark- recapture methods.

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.

In January 2016, Quinn and Ganz gave presentations each at two workshops in Chile.

Outreach

Ganz P.D. Quantifying Death: A Love Story. 2015. Presentation for the general public as part of FISH 692: Communicating Science. Juneau, AK. 25 April 2015.

Publications and presentations

Publications

Ganz, P.D. 2017. Estimability of time-varying natural mortality in groundfishes: covariates and hierarchical models. M.S. Thesis, University of Alaska Fairbanks, Fairbanks AK.

Presentations

Ganz, P.D. and T.J. Quinn II. 2015. Estimability of time-varying natural mortality in exploited groundfishes.

Alaska Chapter of the American Fisheries Society Student Symposium. Juneau, AK. 3 April 2015.

Ganz, P.D., T.J. Quinn II, P.J.F Hulson and D.H. Hanselman. 2015. Estimability of Time-Varying Natural Mortality in Gulf of Alaska Sablefish with a Simulated Covariate. American Fisheries Society National Meeting. Portland, OR. 16-20 August 2015.

Ganz, P.D., T.J. Quinn II and P.J.F Hulson. 2016. The Mathematics of Mortality: How Do We Model Death in Fish Populations? Valparaiso's Math and its Applications Days. Valparaiso, Chile. 7-8 January 2016.

Ganz, P.D., T.J. Quinn II and P.J.F Hulson. 2016. Time of Death: Modeling Time-varying Natural Mortality in Fish Populations. Jornadas de Modelamiento Matematico para la Toma de Decisiones en Evaluaci6n y Gesti6n Pesquera. Valparaiso, Chile. 18-20 January 2016.

Ganz, P.D. 2017. What the heck are random effects? American Fisheries Society Alaska Chapter, Annual Meeting, March 21,2017.

Quinn, T.J., II. 2016. Contemporary Models in Fish Population Dynamics. Valparaiso's Math and its Applications Days. Valparaiso, Chile. 7-8 January 2016.

Quinn, T.J., II. 2016. Contemporary Models in Fish Population Dynamics and Their Application to Fisheries Management. Jornadas de Modelamiento Matematico para la Toma de Decisiones en Evaluaci6n y Gesti6n Pesquera. Valparaiso, Chile. 18-20 January 2016.

Quinn, T.J., II. 2016. Contemporary Models in Fish Population Dynamics and Their Application to Fisheries Management. lnstituto de lnvestigacion Pesquera (INPESCA), Concepcion, Chile. 18-20 January 2016.

Quinn, T.J., II. 2016. Contemporary Models in Fish Population Dynamics and Their Application to

Fisheries Management. Seminario Departamento De Matematica, Universidad Tecnica Federico Santa Marfa, Sala de Seminarios, Edificio F, UTFSM, Valparaiso, Chile. 17 March 2016.

Quinn, T.J., II. 2016. Mathematical, statistical and computational modeling of fish population dynamics remains the core of fisheries stock assessment and management. World Fisheries Congress, Busan, Korea. 24 May 2016.

Gulf of Alaska Integrated Ecosystem Assessment Postdoctoral Research

Gordon H. Kruse, PI **CIFAR theme(s): Ecosystem Studies & Forecasting**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
***Judith Rosellon Druker*, Postdoctoral researcher, University of Alaska Fairbanks**
***Kerim Aydin and Jamal Moss,* National Marine Fisheries Service**

NOAA Goal: Healthy Oceans

Amendments 58, 78, 81, 85 NOAA Office: NMFS, Jamal Moss, Sponsor

Budget Amount: Cumulative $274,553, This year $5,092 (Amendment 85)

This project is on extension and set to end 06/30/2020.

Primary objectives

Primary duties of the post-doctoral researcher involve: (1) developing a conceptual model, or series of models that emulate the major ecological functions of the GOA; (2) an overarching Gulf of Alaska-wide plan for the Alaska Integrated Ecosystem Assessment (IEA) Program; and (3) drafting of a proposal for a regional IEA specific to Southeast Alaska. Additional analyses will focus on determining which data are the most useful for ecosystem indicators.

Research accomplishments/highlights/findings

In this report, we focus on the deliverables associated with these three objectives during this reporting period, 1 April 2018 – 31 March 2019.

Deliverable #1: Conceptual Models for the Gulf of Alaska

- Progress has been reported and discussed during weekly teleconferences with project personnel from UAF, NMFS, and the University of Washington. Judith Rosellon, postdoctoral fellow assigned to the project, distributes a meeting recap shortly after each weekly teleconference.
- The project focused on the development of an Integrated Ecosystem Assessment (IEA) framework in Southeast Alaska, with Sitka as the focal community and halibut, herring, salmon, and sablefish as focal fisheries. The first stage of the IEA loop was completed including the following steps: (1) scoping of the project (definition of a spatiotemporal scale and focal species), (2) identification of local ecosystem components and threats, and (3) conceptualization of the local ecosystem.
- In order to understand the Southeast Alaska ecosystem and the components affecting the focal fisheries, available scientific publications were compiled and synthetized. Excel catalogs including key environmental and biological components were developed as the stepping-stone to build conceptual models of the four focal species. These conceptual models were modified with direct input from Sitka Community members input during workshops held in April and November 2018 at the Sitka Sound Science Center. The goal of this co-production of knowledge between scientist and Sitka stakeholders was to integrate Local Ecological Knowledge (LEK) into the scientific process to better understand

the local ecosystem. During these workshops, linkages between focal fisheries and community well-being in Sitka (as defined by people in the community) were also identified.

- A research paper explaining the development of these co-produced conceptual models was submitted to the journal, Ecology and Society, at the end of October and is currently under review. Key conclusions of this paper are:
- Sitka is a unique fishing community
- Sitka stakeholders have a deep understanding of their local ecosystem
- Conceptual models are a pivotal exercise to capture and integrate LEK into science and to highlight important knowledge gaps in the ecosystem structure
- Incorporation of LEK into science is needed to achieve sustainable, effective, and equitable management of fisheries
- Stakeholder participation in the scientific process leads to a more informed and empowered community in relation to their local ecosystem and resources
- An IEA inherently leads to a more holistic view of fisheries management
- A second research paper is currently being written, and will focus on the operationalization of these conceptual models through the use of Qualitative Network Models. Project outreach tools include the development of iconographic versions of the conceptual models that may be used for teaching or touristic purposes. Methods and results of both Sitka workshops are also featured in the National IEA webpage, under the Gulf of Alaska region.
- Other ongoing activities include the development of a catalog of existing data sources for Sitka Sound on environmental and biological trends and the creation of shiny apps that would allow users to interact with these data.

Deliverable #2: Comprehensive Strategic Plan for the GOA IEA

- Development of a comprehensive strategic plan for the GOA IEA remains an important deliverable. The co-PIs envision this to take the form of a white paper or NOAA Technical Memorandum. NMFS co-PI Jamal Moss intends to take the lead on this deliverable with assistance from the UAF postdoctoral researcher and additional contributions by the UAF-NMFS project collaborators. The time frame to prepare and complete this deliverable is expected to span June-December 2019, with anticipated publication of the white paper or technical memorandum in January 2020.

Deliverable #3 Proposal for Southeast Alaska IEA

- The deliverable "Proposal for the SEAK IEA" has been led by our NOAA partners. Initially, the intention was to draft a formal NMFS proposal to the National IEA program to support activities in Sitka. Instead, our NOAA partners drafted a 3-year plan that addressed future directions for the entire GOA, not just the eastern GOA (Southeast Alaska) where we have been working. Given this, a specific proposal for a Southeast Alaska IEA is no longer needed, as it is encompassed within the 3-year plan for the entire GOA. Given this, NOAA co-PIs Jamal Moss and Kerim Aydin consider this deliverable to be already completed.

NOAA relevance/societal benefits

NOAA Fisheries has identified a need for ecosystem-based management to fully support 21st century stewardship of our oceans and coasts. Integrated Ecosystem Assessments (IEAs) are a next generation tool designed to incorporate ecological processes in decision making and transfer scientific knowledge to managers and stakeholders. When fully implemented, IEAs have the power to quantify ecosystem services and feed into Management Strategy Evaluations (MSEs).

Partner organizations and collaborators

This project involves collaborations with fisheries oceanographers, stock assessment scientists, ecosystem modelers, natural resource economists, commercial fishermen's organizations, tribal entities, and non-profit research organizations. In addition to UAF co-PI Gordon Kruse and postdoctoral researcher Judith Rosellon Druker, primary NMFS partners and collaborators include Jamal Moss (co-PI), Kerim Aydin (co-PI), Curry Cunningham, Ellen Yasumiishi, Marysia Szymkowiak, and Stephen Kasperski. Laura Nelson of the University of Washington is also a regular participant in the weekly meetings. Primary fishery stakeholders in Sitka represent users of the salmon, herring, halibut and sablefish resources, including members of the Native community, fishers, and researchers with the University of Alaska Southeast and non-profit organizations.

Impact

Results from this project will provide strategic guidance on management of federally managed fisheries in the Gulf of Alaska. Since the 1980s, fishery managers have been advised to move away from single-species management toward ecosystem-based fisheries management. Marine resources in the Gulf of Alaska support a wide variety of ecosystem services in addition to provisioning services in the form of fishery landings and seafood products. Integrated ecosystem assessments provide an efficient means to summarize the status of ecosystem components and provide a framework to screen and prioritize potential risks and evaluate alternative management strategies (i.e., management strategy evaluations), including evaluate tradeoffs in ecosystem services.

Education

- N/A.

Outreach

This project involves substantial outreach with commercial fishermen's organizations, tribal entities, non-profit research organizations, other resource agencies, and academic researchers located in the coastal community of Sitka. Alaska. We successfully secured partnerships by hosting two stakeholder workshops. During our first Sitka workshop in April 2018, we coproduced conceptual models for Pacific halibut and Pacific herring, incorporating input from fishery stakeholders. These co-produced models are unique in that they merge scientific research with local knowledge. During our second workshop in Sitka in November 2018, we reported back to the fishery stakeholders on the products of our first workshop (i.e., two conceptual models, website application development, datasets) and we solicited their assistance to coproduce conceptual models for sablefish and salmon (Chinook salmon).

During our workshop in November 2018, Sitka stakeholders strongly voiced their desire for GOA IEA team members to convene a third and final workshop for this project. All co-PIs agreed and

one more workshop in Sitka is planned, likely in fall 2019, during which we will report back to stakeholders on final products from this project to date, including conceptual models for sablefish and salmon, updated website and datasets, and demonstration of user-interactive models and Internet applications, both of which were requested by the stakeholders, so as to allow the public to access and understand IEA data relevant to their fisheries. At this final workshop, at the request of Sitka stakeholders, we also intend to identify other public venues to allow broader dissemination of our results to the public, including presentations in local schools to teachers, students and other community members.

Publications

Rosellon-Druker, J., M. Szymkowiak, C.J. Cunningham, S. Kasperski, G.H. Kruse, J.H. Moss, and E.M. Yasumiishi. In review. Development of socio-ecological conceptual models as the basis for an IEA framework in Southeast Alaska. Ecology and Society, Submitted October 30, 2018.

Conference presentations

None.

Other products and outcomes

We contributed to several other NOAA-UAF products intended largely for the general public. First, we contributed to a NOAA website that describes our place-based integrated ecosystem assessment of the community of Sitka. The website provides an overview of the Sitka project, including the objectives and outcome of the first stakeholder workshop in Sitka in April 2018. The website is:

https://www.integratedecosystemassessment.noaa.gov/regions/alaska/goa-sitka-community

In addition, we also contributed to the development of graphics providing overviews of conceptual models developed for Pacific herring and Pacific halibut. These conceptual model graphics are located here:

https://www.integratedecosystemassessment.noaa.gov/sites/default/files/inline-images/AKIEA%20Herring_proof2.jpg

and

https://www.integratedecosystemassessment.noaa.gov/sites/default/files/inline-images/AKIEA%20Halibut_15AUG18.jpg

Support for US participation in the CBMP Expert Network

Russell R. Hopcroft, PI **CIFAR theme: Ecosystem Studies and Forecasting**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Katrin Iken, University of Alaska Fairbanks
Eric Collins, University of Alaska Fairbanks

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation

Amendments 32, 59 NOAA Office: OAR, Jeremy Mathis, Sponsor

Budget Amount: Cumulative $57,471, This year $0

This project is on extension and set to end 06/30/2019.

Primary objectives

The Arctic Council's Conservation of Arctic Flora and Fauna (CAFF, www.caff.is) working group has developed the multi-national Circumpolar Biodiversity Monitoring Program (CBMP, www.cbmp.is). The CBMP seeks to coordinate pan-Arctic biodiversity monitoring through an international network of scientists working in conjunction with national agency representatives. The overall purpose of the CBMP is to determine the status of, and any changes within, six major components of Arctic biodiversity. These Expert Networks, each with equal representation by all primary participant countries, are tasked with coordination, data integration and data synthesis. Hopcroft and Iken have participated in the development of the implementation plan (Gill et al. 2011), with Hopcroft currently serving as the co-lead of the Pelagic Marine Expert Network, and both Iken and Collins serve as the US members of the Benthic and Sea Ice Biota Marine Expert Network, respectively.

Research accomplishments/highlights/findings

During 2018/19, activities the primary task has remained promoting the State of the Arctic Marine Biodiversity Report (SAMBR) report. Hopcroft presented an overview of the SAMBR plankton report at the World Conference on Marine Biodiversity to be held May 2018 in Montreal, Canada, and additional presentation were made at Polar2018 meeting in Davos, Switzerland, in June. Hopcroft, Iken and Collins we unable to attend the annual CBMP Marine Experts held at the Arctic Biodiversity Congress in Rovaniemi, Finland, October 8 & 12 but participated in pre and post-meeting discussions. Work plans were prepared at that time for the next year for each expert group. Hopcroft and Iken have participated in several planning meeting for the US CBMP meeting in Anchorage, AK to be held May 6-7, 2019.

NOAA relevance/societal benefits

This project documents the state and examines the potential impacts of climate change in circumpolar Arctic domain. It provides interaction between the member countries of the Arctic Council.

Publications, conference papers, and presentations

Lovejoy, C., C. von Quillfeldt, R.R. Hopcroft, M. Poulin, M. Thaler, K. Arendt, H. Debes, Á. Gíslason, K.N. Kosobokova. 2018. State of the Arctic Marine Biodiversity Report: Plankton.

Oral Presentation, World Conference on Marine Biodiversity. Montreal, Canada. May 2018

Lovejoy, C., C. von Quillfeldt, R.R. Hopcroft, M. Poulin, M. Thaler, K. Arendt, H. Debes, Á. Gíslason, K.N. Kosobokova. 2018. State of the Arctic Marine Biodiversity Report: Plankton across sectors. Oral Presentation, POLAR 2018. Davos, Switzerland, June 2018

Partner organizations and collaborators

- Circumpolar Biodiversity Monitoring Program (CBMP)
- Conservation of Arctic Flora and Fauna (CAFF)
- Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, Juneau, Alaska (Peter-John Hulson). Pacific Marine Environmental Laboratory

Acidification in the Distributed Biological Observatory

Brenda Konar, PI (formerly Amanda Kelley) **CIFAR theme(s): Ecosystem Studies and Forecasting**
University of Alaska Fairbanks ***Climate Change and Variability***

Other investigators/professionals associated with this project:
Natalie Monacci, University of Alaska Fairbanks

NOAA Goal(s): Climate Adaptation and Mitigation

Amendment 66 NOAA Office: OAR, Jessica Cross, Sponsor
Budget Amount: Cumulative $37,222, This year $0
This project is complete.

Primary objectives

This project provides support for discrete samples collected as part of the Distributed Biological Observatory (DBO) – Northern Chukchi Integrated Study mission. Discrete samples are collected by NOAA and analyzed by the Ocean Acidification Research Center at the University of Alaska, Fairbanks. This project also provides support for the analysis of data collected by the Saildrones during this mission by the Ocean Acidification Research Center at UAF.

Research accomplishments/highlights/findings

The second year for the DBO field program was led by a carbonate chemistry sampling cruise aboard the USCGC Healy during August 2018. Discrete water samples were collected for analysis of Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA) at the Ocean Acidification Research Center at the University of Alaska Fairbanks. Samples were collected at DBO regions 2, 3, 4, and 5 as well as stations of opportunity and Saildrone calibration locations. Analyses of the carbon chemistry data and correlations with population trends of marine organisms in the DBO are ongoing as of this writing. Importantly, calculation of extended carbon system parameters such as measures of carbonate corrosivity will be corrected for nutrient values before final numbers are submitted.

NOAA relevance/societal benefits

A primary NOAA OAR mission requirement is to understand and predict changes in climate, weather, ocean, and coasts. One of the programs currently supported by the NOAA Arctic Research Program is the Distributed Biological Observatory (DBO), a network of rapidly changing and biologically important sites designed as a change detection array from the northern Bering Sea to the Arctic Basin (Figure 1). Since 2010, the DBO has provided a framework to focus and coordinate sampling and analytical efforts that link biological changes to physical drivers in a rapidly changing Arctic. DBO activities have already connected shifts in benthic community biomass to trends in annual sea ice persistence.

For this project, the NOAA Arctic Research Program partnered with the Innovative Technology for Arctic Exploration (ITAE) testbed with support from the NOAA Ocean Acidification Program to deploy two wind- and solar-powered autonomous surface vehicles (ASV) in conjunction with the DBO-NCIS mission. These ASVs were equipped with new sensing technologies for sea-air carbon dioxide (CO2) flux measurements. Adding this capability to ASVs is key to the NOAA Climate Observation Division's central goal to constraining global anthropogenic CO2 storage. Like ocean heat, increased open water area allows for great exchange of CO2 between the atmosphere and

upper ocean, contributing to accelerating rates of ocean acidification and decreases in ocean pH. Saildrone CO2 flux measurements represent a clear technological breakthrough that could fully survey the regional CO2 sink and constrain the extent, duration, and intensity of ocean acidification events.

Partner organizations and collaborators

This project represents a close collaborative relationship between the Pacific Marine Environmental Laboratory and the Ocean Acidification Research Center at the University of Alaska, Fairbanks. These mooring data also contribute to the International Ocean Observing System (IOOS) program and the Global Ocean Acidification Observing Network (GOA-ON).

Impact

Ultimately, the main mission and deliverable of the overall DBO-NCIS program is to support co-located biological sampling and carbonate chemistry measurements. Adding Ocean Acidification to the DBO 'Change Detection Array' may not only help to identify important ecosystem vulnerabilities, but may also uncover areas of unexpected resilience.

Education

Nothing to report at this time.

Outreach

The researchers involved with this project also work closely with the Alaska Ocean Acidification Observing Network, an impact-driven group designed to connect scientists to stakeholders. Through that group, these monitoring activities support a number of cross-cutting research efforts.

Publications

Cross, J.N., Mathis, J.T., Pickart, R.S., and Bates, N.R., 2018. Formation and transport of corrosive water in the Pacific Arctic Region. Deep Sea Research II, 152, 67-81. doi.org/10.1016/j.dsr2.2018.05.020

Conference presentations

Cross, J.N., Monacci, N.M., Grebmeier, J.M., Pickart, R.S., Mordy, C.W., Meinig, C., Stabeno, P.J., Zhang, D., Pilcher, D., 2018. Building an integrated ocean acidification observing system for the Pacific Arctic Region. American Geophysical Union Fall Meeting, Washington, DC.

Other products and outcomes

- Saildrone mission blog for 2018 available at https://pmel.noaa.gov/itae/follow-saildrone-2018
- DBO main project website at https://www.pmel.noaa.gov/dbo/

Figures

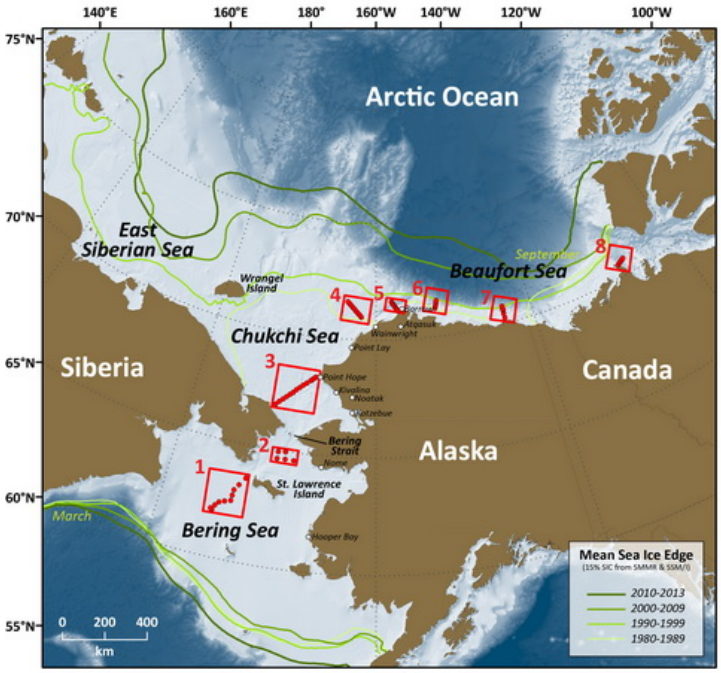

Figure 1. Map of the Distributed Biological Observatory (DBO) sampling locations. The red boxes are regional "hot spots" that exhibit high productivity, biodiversity, and overall rates of change. Provided by NOAA.

Evaluating the effects of habitat quality on YOY sablefish physiological condition to inform estimates of recruitment in the stock assessment

Anne Beaudreau, PI **CIFAR theme(s): Ecosystem Studies and Forecasting**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Joe Krieger, NOAA Regional Office, Juneau
Ron Heintz, Sitka Sound Science Center, Juneau

NOAA Goal(s): Healthy Oceans

Amendment 72 NOAA Office: NMFS, Tony Marshak, Sponsor

Budget Amount: Cumulative $15,321, This year $0

This project is complete.

Primary objectives

The overall goal of this research was to link habitat conditions to sablefish overwinter survival by modeling the relationship between habitat condition (temperature, resource availability and quality) and YOY sablefish growth during their first year of life. Determining factors affecting early life survival as it relates to subsequent recruitment is a key question for the sablefish stock assessment in Alaska.

Our objectives were to (1) Conduct laboratory experiments that measure the influence of temperature, ration, and body size on YOY sablefish growth and overwinter energy depletion; (2) Develop a mass balance model for growth and energy depletion that incorporates covariates of size, condition, temperature and ration for YOY sablefish; and (3) Use the model to index habitat conditions for recruiting year classes and to identify environmental parameters likely to be important in determining growth and overwintering success of YOY sablefish.

Research accomplishments/highlights/findings

Joe Krieger started as a postdoc on the project in July 2017 and led the work for all objectives. Joe is now working as a Fishery Management Specialist at the NOAA Regional Office in Juneau, Alaska, and has held his current position since fall 2018.

Dr. Beaudreau contributed to the experimental design and conceptual framework for all objectives, provided advice regarding modeling, provided mentorship to the postdoc, and contributed to writing the manuscript for Objectives 2 & 3. In addition, she is leading a field-based project on sablefish (funded by the North Pacific Research Board) that will contribute diet, energy density, and temperature data to future application of the bioenergetics model.

The laboratory experiments (Objective 1) were completed in 2017 and a manuscript summarizing the results was published in 2019. In addition, a manuscript detailing development and corroboration of the bioenergetics model (Objectives 2 and 3) was submitted in December 2018 and is under review at the Canadian Journal of Fisheries and Aquatic Sciences. Following publication of the bioenergetics model, a third manuscript will be developed that focuses on application of the model to examine scenarios of temperature and prey quality that affect overwinter condition of juvenile sablefish. That manuscript further builds upon Objective 3, but is beyond the scope of the current CIFAR grant and will be completed as part of a related project

funded by NPRB.

Summary of Results for Objective 1

- In our laboratory trials, we measured the effects of temperature on growth and consumption rates of YOY sablefish (218 – 289 mm TL) with fish (n = 420) held over 5 temperature treatments (5°C, 8°C, 12°C, 16°C and 20°C) and maintained on high, medium, or low ration for 7 weeks (5 temperatures x 3 ration treatments x replicate tanks = 30 total tank treatments). Specific growth rate (SGR; % wet weight gain (g) per day) was used to derive a temperature-dependent growth model, and consumption rates were used to derive species specific parameters for the consumption function of a Wisconsin-type bioenergetics model. Daily growth in length varied from 0.13 mm d^{-1} to 1.74 mm d^{-1} and SGR ranged from 0.52 to 2.31. SGR peaked at 15.4°C, remained high at 12°C and 16°C, and steadily declined as temperatures shifted outside this range. Residuals of length-weight regressions showed YOY sablefish condition was positive at 12°C and 16°C, and negative at 5°C, 8°C, and 20°C. Consumption rose sharply with temperature, peaking at 18.6°C. The narrow thermal range of positive condition and optimal SGR indicates YOY sablefish growth and development may be dramatically influenced by relatively small shifts in water temperatures. Further, when compared to similar studies of smaller sized sablefish, we observed a shift with size in thermal performance with larger fish optimizing physiological response at colder temperatures compared to smaller fish (see Figure 1 below). The shift in thermal performance with size is an important consideration for future management initiatives. While traditional recruitment models rely heavily on information from a single life-stage, resource use and physiological requirements often change with development. Given the widespread occurrence of anomalous thermal events in the GOA, a life-stage specific understanding of the effects of varying temperatures is crucial.

Summary of Results for Objective 2

- We measured the effects of temperature on growth, consumption, and respiration of young-of-year (YOY) sablefish (218 – 289 mm TL) in laboratory trials. Physiological response functions were used to outfit a novel, life stage specific bioenergetics model. Average daily growth rates ranged from 46.7 to 122 J g-1d-1 (0.82 to 3.42 g d-1) with optimum growth occurring at 12-16°C, and declining substantially outside of this range. A second growth study was used to corroborate the performance capabilities of our model. Observed growth rates matched well with model estimates. We then demonstrated the importance of including life stage specific physiological response functions by comparing growth estimates from our model to a previous model parameterized with life stage indiscriminate information. Disparities in modeling efficiency and mean absolute percent error indicate superior performance of our life stage specific model. Sensitivity analysis indicated that consumption-related parameters exert the greatest influence on model output. These findings emphasize how the physiological response of an organism changes through ontogeny and advocate the importance of understanding life stage specific species-habitat connectivity.
- In both years of our laboratory trials, we found that temperature had clear effects on growth of YOY Sablefish. Fish held at temperatures outside of the thermal range for optimal growth (12-16°C) grew an average of 25% and 12% less at lower temperatures in

2016 and 2017, respectively, and 22% less at higher temperatures in 2016. While these differences are considerable and could potentially impact overwinter survival and recruitment success, the effect of temperature on growth presented here is probably only a conservative estimate. The laboratory fish were fed ad libitum which likely does not reflect typical prey field scenarios found in the wild and may mask the effect of sub-optimal temperatures on YOY Sablefish growth and development. It can be assumed that wild YOY Sablefish encountering less abundant or lower quality prey would grow slower at a given temperature than those observed in our study. If growth is hindered during the late summer or fall it could prevent YOY fish from reaching a sufficient size or condition to survive the winter. A fruitful area of future inquiry would be to experimentally evaluate the combined effects of prey quality and temperature on sablefish growth and condition.

NOAA relevance/societal benefits

Sablefish are among the highest valued commercial species in Alaska. They were identified as one of the top priority stocks for habitat science through the West Coast Regional Habitat Assessment Prioritization (Blackhart 2014). While Alaskan stocks were not included in this assessment, tagging studies indicate evidence of exchange between Alaska and Pacific Northwest sablefish stocks (Hanselman et al. 2015). Hence, findings from this study will contribute to science and management of sablefish in both the Alaska and the Pacific Northwest regions. Moreover, the approach we describe can be applied to other high latitude Fish Stock Sustainability Index species. This work will also address both areas of emphasis as identified in the National Marine Fisheries Service Habitat Assessment Improvement Plan by reducing habitat-related uncertainty in current sablefish stock assessments and by identifying key species-habitat relationships to better characterize essential fish habitat for successful sablefish recruitment (NMFS 2010).

Our results fill a gap in knowledge about the ecological and environmental factors affecting overwinter energy depletion and, ultimately, survival of YOY and juvenile sablefish. This is essential to improving NOAA's understanding of the factors affecting recruitment success and identification of environmental indicators that could explain recruitment variation. Furthermore, the research addressed fundamental ecological questions about the early life history of sablefish, information that is of interest and value to the fishing industry and research community more broadly.

References

Blackhart, K. 2014. Habitat assessment prioritization for West Coast stocks. Report of the Northwest and Southwest Regional Habitat Assessment Prioritization Working Groups. Internal report, NMFS White Paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 199pp.

Hanselman, D.H., J. Heifetz, K.B. Echave, & S.C. Dressel. 2015. Move it or lose it: Movement and mortality of sablefish tagged in Alaska. Can. J. Fish. Aquat. Sci. 72(2): 238-25.

NMFS. 2010. Marine fisheries habitat assessment improvement plan. Report of the National Marine Fisheries Service Habitat Assessment Improvement Plan Team. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-108, 115 p.

Partner organizations and collaborators

This project is a close collaboration between the Recruitment Energetics and Coastal Assessment

group at NOAA Auke Bay Laboratories (PI Ron Heintz, now retired) and the Coastal Fisheries Ecology Lab at the University of Alaska Fairbanks (PI Anne Beaudreau) in Juneau, Alaska. Beaudreau and Heintz are leads on two complementary projects on juvenile sablefish, funded by NOAA/CIFAR and the North Pacific Research Board (NPRB). Postdoc Joe Krieger (NOAA) and MS student Matt Callahan (UAF) have been involved in all aspects of the research and led components of the work.

Impact

This project has resulted in greater collaboration between NOAA and UAF, including new partnerships among early career scientists (postdoc, MS student, and technicians). Additionally, it addressed priority research needs for sablefish identified by NOAA.

Education

This project has resulted in training and professional development of a postdoctoral researcher. It is also closely tied to a complementary project funded by NPRB (PI Beaudreau) that involves a Master's student (Callahan) and multiple undergraduate student technicians. Beaudreau is providing mentorship and training to the postdoc and students. We also hosted a NOAA Hollings Scholar, Willa Johnson, who contributed to the project in summer 2018.

Outreach

Anne Beaudreau co-led and coordinated *UA Fisheries Days at Lena Point*, which featured two events for the public on April 6-7, 2018—the 22nd Annual Student Research Symposium (90-100 attendees) and the first Fisheries Open House in Juneau (500 attendees). Over the spring of 2018, Anne put in 55 hours of work to plan and participate in the events. Members of her lab, including postdoc Joe Krieger and MS student Matt Callahan, designed and led a "Diet Detectives" station as part of the event. This hands-on activity featured data collected from juvenile sablefish in the field. Anne wrote a blog post about the event here: https://annebeaudreau.com/2018/07/02/ua-fisheries-days/

Anne Beaudreau and Matt Callahan have been collaborating with 7th grade science teacher Jess Cobley (Juneau School District) to develop a Gulf of Alaska ecosystem module that they will co-teach with her during the month of April 2019. Anne and Matt have had several planning sessions with two teachers and NOAA scientist Elizabeth Siddon to develop the 5-week ecosystem module with a focus on sablefish. They have developed learning goals, presentation materials, and hands-on activities and will each spend 4-8 hours in the classroom to help teach four 7th grade classes (>100 students). They have also recruited other NOAA and UAF researchers and a local fisherman to contribute to the weekly lesson plans. At the culmination of the module, the 7th graders will hold a mock scientific panel in which they will present their recommendations regarding NOAA's risk assessment for sablefish in the Gulf of Alaska.

Publications

Manuscripts detailing results for CIFAR-funded project:

Krieger, J.R., A. Sreenivasan, R. Heintz. 2019. Temperature-dependent growth and consumption of young-of-the-year sablefish *Anoplopoma fimbria*: Too hot, too cold or just right? *Fisheries Research* 209: 32-39. (Objective 1)

Krieger, J.R., A.H. Beaudreau, R. Heintz. Development and evaluation of a life stage specific

bioenergetics model for young-of-year Sablefish (*Anoplopoma fimbria*). In review at *Canadian Journal of Fisheries and Aquatic Sciences*. (Objectives 2 & 3)

Additional related manuscript in preparation:

Krieger, J., A. Beaudreau, R. Heintz, M. Callahan. Factors affecting overwinter condition and growth of juvenile sablefish: Application of a bioenergetics model

Conference presentations

We presented a poster at two conferences:

Krieger, J., A. Sreenivasan, R. Heintz, A. Beaudreau. 2018. What came first, the lipid or the length? Effects of Habitat Quality on YOY Sablefish (Anoplopoma fimbria) Physiological Condition. (Poster). Alaska Marine Science Symposium, Anchorage, AK and Western Groundfish Conference, Monterey, CA.

Other products and outcomes

Joe Krieger, Anne Beaudreau, and Ron Heintz organized and facilitated a one-day "Sablefish Summit" workshop with state and federal agency and university researchers on Tuesday, September 26, 2017 at NOAA's Ted Stevens Marine Research Institute in Juneau. The event featured a series of talks in the morning on current sablefish research, including presentations by Beaudreau and Krieger. An afternoon discussion session was held to identify common research goals and potential collaborations, coordinate sampling efforts and resource sharing, and outline data gaps.

Trophic Interactions in Subarctic Pelagic Ecosystems: Fish, Medusae and Zooplankton

Alexei Pinchuk, PI **CIFAR theme(s): Ecosystem Studies and Forecasting**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Kristin Cieciel, NOAA, AFSC

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation

Amendment 74 NOAA Office: NMFS, Kristin Cieciel, Sponsor

Budget Amount: Cumulative $82,695, This year $0

This project is set to end 06/30/2019.

Primary objectives

The scientific objectives of this project are to assess age-0 groundfish, juvenile salmon, zooplankton, and oceanographic conditions in the coastal, shelf, slope, and offshore waters of coastal Alaska. This work improves our understanding of the feeding ecology of major planktivorous predators in Alaskan subarctic pelagic ecosystems of the Northern Bering Sea (NBS), Southern Chukchi Sea (SCS) and Eastern Gulf of Alaska (EGOA). The major goal of this project is to analyze and interpret data on fish diets in relation to zooplankton prey fields collected by NOAA scientists during pelagic trawl surveys in summer 2017. Information obtained from this project is used to describe species distributions, ecosystem processes, marine productivity, and recruitment processes in response to changes in climate patterns and temperature anomalies (i.e., "The Blob", and El Niño).

Research accomplishments/highlights/findings

EGOA: Salinity appeared to be the largest factor influencing distribution and biomass in the mesozooplankton community in the Gulf of Alaska in summer 2017. Additionally, the lack of a distinct frontal structure and the ability of certain species to rapidly react to temperature and salinity differences appeared to have shaped the zooplankton community in July of 2017. Nearshore communities over the northern portion of the grid were shaped by a freshwater plume emanating from the Alsek River, south of Yakutat. The largest proportion of cnidarian biomass was within and bordering this freshwater influence. Total zooplankton biomass had two large peaks, one oceanic and one over the shelf. The oceanic peak was due to a very high biomass of tunicates (doliolids and salps), while the nearshore biomass peak was due to a high number of small (<0.25 mm) juvenile shelled pteropods, *Limacina helicina*, at a single station. Other selected species were influenced by salinity above the pycnocline, with increased biomass in offshore and shelf areas along with intrusions of oceanic water. Some mixing of oceanic and shelf species assemblages occurred during July of 2017, likely resulting from weak horizontal density gradients, and an underdeveloped Alaska Coastal Current.

Approximately 40% of the total zooplankton biomass was attributable to Cnidaria and Tunicata (hydrozoan jellyfish, doliolids, and salps). Above average sea surface temperatures (July) have been observed on this survey since 2014. Asexual and sexual reproduction may increase with temperature in many cnidarian and tunicate species, allowing these zooplanktors to quickly respond to favorable conditions. This is exemplified by the peak in cnidarian biomass centered on

the outflow of the Alsek River. We have observed a large increase in the abundance and prevalence of pelagic tunicates (doliolids and salps) during the summer season in the past few years. The long-term Continous Plankton Recorder data indicated that doliolid blooms in the south-central Gulf of Alaska may have occurred in the past two decades during El-Nino events. In addition to the high proportion of gelatinous biomass, other ecologically important species have markedly declined. As an example in critical species abundance reduction, the average abundance per cubic meter for *Calanus marshallae* in 2012 was nearly 500% more than the average abundance in 2017 (similar survey grid and timing). Abundance in 2012 was regularly above 100 individuals per cubic meter, a level not reached in any of the 2017 samples. In fact, 22 of 32 stations processed from the 2017 survey had an abundance of less than 10 individuals per cubic meter, which is likely a negative temperature response.

The elevated biomass of cnidarians and tunicates suggests the potential for a large proportion of primary production to be consumed by these animals. Trawl samples (and other anecdotal evidence) included pyrosomes in 2017 and increased numbers of gymnosomes since 2014. Both of these are highly efficient filter feeders, likely advected from other areas. Shunting of pelagic production to the benthos occurs via fecal pellets and dead falls. Given the prevalence of these species, there is a high potential for the removal of a large fraction of primary productivity from the pelagic ecosystem. Removal of the base of the food chain may have large implications for zooplankton, forage fishes, age-0 marine groundfishes, juvenile and immature salmon, and other consumers such as seabirds and marine mammals. It is likely that these patterns in zooplankton have existed since the summer of 2014, when the shift to warmer conditions occurred. The catch of juvenile salmon and age-0 marine groundfishes during the July 2017 survey was very low. While some of this difference is possibly attributable to a trawl gear change (summer 2017), it is likely to be the result of this shift in prey fields and primary producers. In contrast, the shunting of pelagic primary production to the benthos may stimulate benthic production and growth in demersal species of fishes.

SCS: Examination of diets of age-0 marine ground and forage fishes in the Southern Chukchi Sea revealed their strong dependence on neritic and brackish water zooplankton, which typically inhabit the Alaska Coastal Current and is advected northward by favourable winds. Few fish were feeding on the cold-water lipid-reach *Calanus glacialis*, indicating that the recent warm phase may have substantially impacted this foundation species on the Chukchi shelf. Generally low number of fish catches may also be interpreted as an evidence of negative impact of the warm conditions on the native ichtyofauna.

NBS: Diets of juvenile salmon, ground and forage fishes from the Northern Bering sea shelf are being analyzed.

NOAA relevance/societal benefits

Commercially harvested salmon, as well as forage fish and jellyfish play a central role in the food web of the southeastern Bering Sea and Gulf of Alaska, where they potentially compete for available zooplankton prey. A better understanding of their feeding ecology and their interactions with different ecosystem components would enhance our ability to success fully model these populations via changing prey and prey quality as they are mediated by changing climatic conditions. The obtained information will substantially increase our knowledge of environmental mechanisms which facilitate biological production in Alaskan waters, and the success of

commercially harvested species.

Partner organizations and collaborators

None

Impact

A lecture on doliolid blooms in the eastern Gulf of Alaska was presented by Dr. Pinchuk to undergraduate students at BIOL S492 Biological Seminar at University of Alaska Southeast on March 26, 2019.

Education

No funds were provided for education

Outreach

No funds were provided for outreach

Publications

Strasburger W.W., Moss J.H., Siwicke K.A., Yasumiishi E.M., Pinchuk A.I, Fenske K.H. 2018. Eastern Gulf of Alaska Ecosystem. Assessment, July through August 2017. NOAA Technical Memorandum NMFS-AFSC-367. doi:10.7289/V5/TM-AFSC-367

Ecosystem Considerations 2017: Status of the Gulf of Alaska Marine Ecosystem. Zador, S., Yasumiishi E. (Eds.) Gulf of Alaska Ecosystem Status Report, North Pacific Fishery Management Council, Anchorage, Alaska, 213 pp.

Conference presentations

Pinchuk A.I., Strasburger W.W. 2019. Summer doliolid blooms in the southeast Gulf of Alaska shelf – potential importance for the offshore ecosystem. Alaska Marine Science Symposium, January 28-31, 2019 Anchorage, Alaska.

Alaska Direct Broadcast – Sandy Sustainment and Bridge to Operations

John Pace, PI (formerly Lisa Wirth) **CIFAR theme(s): Ecosystem Studies and Forecasting**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Oralee Nudson, Jay Cable, Greg Wirth, Carl Dierking, University of Alaska Fairbanks

NOAA Goal(s): Weather Ready Nation

Amendment 77 NOAA Office: NESDIS, Mitch Goldberg, Sponsor

Budget Amount: Cumulative $733,450, This year $0

This project is on extension and set to end 06/30/2020

Primary objectives

- The original objective of this project was to transition equipment ownership of the Sandy Supplemental Alaska Direct Broadcast (DB) systems and services from UAF to NWS, with long-term operation of the Sandy Supplemental DB systems by UAF-GINA in partnership with NWS and NESDIS.
- Due to a number of staff vacancies at GINA since August of 2017, we were unable to complete certain portions of this project, particularly Task 1A and 1B, by the scheduled completion date of June 30, 2018. We applied for and received a no-cost-extension from CIFAR for this project through June 30, 2019.
- In early 2019, GINA met with NWS and determined that Tasks 1A and 1B are no longer required. Also we suggested that NOAA purchase new equipment, rather than transitioning the old existing equipment from GINA to NWS, and NOAA agreed.
- We are proceeding with arrangements to complete the objectives of the project, in coordination with NOAA/NESDIS and NWS. The result will be that the Sandy system will be owned by NWS, and operated by UAF-GINA in partnership with NWS and NESDIS.

Research accomplishments/highlights/findings

Task 1A. Establish FISMA compliance plan with NWS IT security staff (cancelled).

- UAF-GINA received funding for this project in September 2017. On October 4, 2017, GINA staff met with FCDAS and NWS representatives for a project kick-off meeting. GINA staff identified software and online resources to facilitate the writing of the System Security Plan. We also obtained a template Interconnection System Agreement from NOAA.
- GINA continued work on this Task, making good progress, until GINA and NWS determined that a GINA-generated FISMA compliance plan is not required or even useful by NWS. GINA suspended work on this Task and requested to be excused from completing it. NWS will generate its own FISMA compliance documentation.

Task 1B. Migrate system ownership to approved operations procedures (cancelled and changed to supporting acquisition of new system).

- Held project orientation teleconferences with NOAA/NWS Staff to move forward with

transition planning: Brian Gockle, Eugene Petrescu, John Evans, Arron Lyons, Angel Corona, Tom Heinrichs, and Nate in Anchorage. Angel and Carven will become the physical System Owners.

- Initialized efforts to obtain Common Access Cards (CAC) for GINA Staff. Sought guidance from NOAA/NWS staff regarding GINA staff needing to be sponsored by NOAA/NWS in order to obtain CAC cards for accessing the information systems post ownership transition: http://www.cac.mil/Common-Access-Card/Getting-Your-CAC/

Task 2A. Maintain and coordinate the Direct Reception System (antenna and control and capture computer)

- Upgraded the EOS-FES antenna control computer to a newer version of the operating system, and updated it to the latest version of the control software.
- Performed basic maintenance for the long-term health of the antenna system, including replacing vendor warrantied failed data drive.

Task 2B. Patch and upgrade operating systems and maintain system hardware

- Continuing regular system maintenance and security updates on the Near Real Time (NRT) data processing stack as needed.
- Replaced failed OS drive in VM host server.
- Deleted a large and unused storage volume then repurposed that storage space to the production storage space
- Doubled the archival backup spinning disk storage space
- Removed unused network cables
- Began separating test and production VMs onto dedicated hardware to facilitate future server upgrades and updates.
- Responded to and fulfilled vendor warranty parts replacement for a failed power supply unit on an NRT computational server.

Task 2C. Maintain processing software

- Updated several processing tools, including AAPP, MIRS, Polar2grid, CSPP, and NUCAPS.

Task 2D: Maintain processing framework

- GINA staff have continued to update the test and production NRT software stacks. New processors in the form of virtual machines were created to support the incoming data processing needs of the production NRT stack. Specific maintenance tasks included:
- Gathered requirements necessary to host future Alaska Direct Broadcast processing framework at FCDAS facility.
- Gathered vendor quotes to share with NWS in preparation for procurement of hardware necessary to host Alaska Direct Broadcast processing framework
- Working with NWS and FCDAS staff to define and document network design for Alaska Direct Broadcast processing framework

Task 2E: Maintain the data distribution network

- Raw data feeds and products were maintained to the Cooperative Institute for Meteorological Satellite Studies (CIMSS), Cooperative Institute for Research in the Atmosphere (CIRA), the Alaska Fire Service (AFS), NASA Short-term Prediction Research and Transition Center (SPoRT), NOAA Earth System Research Laboratory (ESRL), the National Center for Atmospheric Research, Forest Service Remote Sensing Applications Center (RSAC), George Mason University (GMU), and the general public. Data feeds and products were also maintained to NWS groups: River Forecast Center (RFC), the Alaska Sea Ice Program (ASIP), the Alaska Aviation Weather Unit (AAWU), and the Center Weather Service Units (CWSU)

New Activities:

- Data from VIIRS, MODIS, and AVHRR were distributed to the Alaska Region NWS in SCMI, allowing access to the full resolution of the data.
- distributed NUCAPS soundings from NOAA20 to the Alaska Region NWS
- distributed MIRS passive microwave products from NOAA20 to the Alaska Region
- NWS Distributed Metop-C AVHRR data

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 are 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.

Partner organizations and collaborators

- NOAA National Weather Service
- NOAA NESDIS, Fairbanks Command and Data Acquisition Station
- NOAA NESDIS Center for Satellite Applications and Research (STAR)
- UW-Madison CIMSS
- UW-Madison Space Science and Engineering Center (SSEC)
- Colorado State University CIRA
- NASA Direct Readout Laboratory
- NASA SPoRT
- George Mason University
- Alaska Fire Service

Outreach

- Outreach activities by GINA personnel are described in other annual reports.

Other products and outcomes

- GINA partners with the UAF department Research Computing Systems (RCS) for long-term

archival storage of the raw data received from the Big Dog and Sandy Dog Antennas. This service is provided by a fee of $50/TB/Year (beyond the first 10TB) and our current archive holds 80 TBs.

Development of Increased Capacity for Quantitative Fisheries Education and Training at the UAF College of Fisheries and Ocean Sciences

S. Bradley Moran, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Forecasting and Studies

Other investigators/professionals associated with this project:
Gordon Kruse, University of Alaska Fairbanks

NOAA Goal(s): Healthy Oceans

Amendment 84 NOAA Office: NFMS/ AFSC, Jeremy Russin, Sponsor
Budget Amount: Cumulative $93,197, This year $0
This project is new and complete.

Primary objectives

NOAA Quantitative Ecology and Socioeconomic Training (QUEST) program funds were allocated in FY18 to the University of Alaska Fairbanks (UAF) College of Fisheries and Ocean Sciences (CFOS) to support education and training of the next generation of ecosystem scientists, stock assessment scientists, and economists to work on applied research that contributes to the management of living marine resources. For FY18, QUEST funds covered a portion of the faculty salary and benefits of Dr. Gordon Kruse for student education and training in applied fisheries. For FY19 and beyond, CFOS has an active faculty search to hire a new faculty member with these funds as the new CFOS QUEST professor. This new hire is critical with the recent retirement of Dr. Terrance Quinn II, who taught several advanced quantitative courses including fish stock assessment, and the retirement of Dr. Kruse, who taught several graduate courses in fisheries management, including ecosystem-based fisheries management. We anticipate the new faculty hire starting in Fall 2019. The new faculty member will:

- train the next generation of applied marine scientists that NMFS hires in Alaska and its other regions
- train students, who conduct applied research that contributes to the management of living marine resources, particularly in waters off Alaska
- collaborate with and provide guidance and continuing education to NMFS fishery researchers
- serve on expert committees providing scientific guidance on NMFS management responsibilities, such as the NPFMC's Scientific and Statistical Committee

Year 1 of this proposed multi-year project was funded under the current CIFAR Cooperative Agreement. Remaining years are anticipated to be requested in the form of a supplemental funding request under the new Cooperative Agreement, when and if, it is in place.

Research accomplishments/highlights/findings

As Dr. Kruse retired on August 31, 2018, research conducted during this reporting period focused on mentorship of research by his graduate students. Much of this research activity focused on the following research topics.

Reproductive biology of walleye pollock in the Gulf of Alaska – This research included three objectives: (1) identify annual and spatial patterns in GOA pollock maturity based on samples collected during NMFS acoustic surveys in Shelikof Strait during 1983–2013, (2) examines relations in maturity and fecundity with environmental indices and population abundance to explore variability between several estimates of reproductive potential; and (3) development of an agent-based model to explore the implications of different management strategies between territorial waters and the exclusive economic zone of the Gulf of Alaska, should the state of Alaska choose to develop a state-waters fishery. The NMFS senior stock assessment scientist for Gulf of Alaska pollock was a committee member; results from this research are incorporated into the annual Stock Assessment and Fishery Evaluation report for pollock fishery management. A journal manuscript addressing objective 1 was published in 2016. Manuscripts addressing objectives 2 and 3 are under preparation.

Evaluating potential age structures for three Alaska crustacean species – Objectives of this research are to: (1) describe optimal species-specific methods for producing and evaluating band counts for red king crab, snow crab, and spot shrimp; and (2) use differences in shell condition to test whether band counts indicate age for snow crab. Results describe optimal methods for processing crustacean structures and suggest that the potential age structures may not continue to produce bands after terminal molt in the case of snow crab. Results also indicate that there is no relationship between band count and shell condition for terminally molted snow crab. Two manuscripts are currently being prepared for journal submission.

Factors affecting size-at-age of Pacific halibut – Dr. Kruse collaborated on a NMFS-led project to develop a bioenergetics model for halibut using survey-based diet and temperature data for Alaska to evaluate potential environmental drivers of size-at-age. Results suggest the potential for patterns in size-at-age to arise from trophic and environmental constraints that collectively limit growth in some regions and years. A paper describing these findings was published in 2018. A second paper was published, based on previous research conducted by Dr.Kruse's master's student, Jane Sullivan. In this second paper, hypotheses related to declines in size-at-age were investigated, including the effects of environmental and ecological variability on growth using linear mixed models. Results suggest a negative correlation between arrowtooth flounder and proportional growth, as well as some support for a negative relationship between Pacific halibut biomass and proportional growth. As our best-fitting model explained only 28% of the observed variability in growth, it may be that other factors are more important contributors to variability in size-at-age.

NOAA relevance/societal benefits

The Department of Fisheries at UAF/CFOS is one of the few US institutions training graduate students in fisheries research and management. Over 80 of our alumni have gone on to research and management positions at federal agencies (primarily NOAA Fisheries), and over 100 to similar positions with the state agencies, mainly the Alaska Department of Fish and Game. Our program emphasizes quantitative skills, such as stock assessment and statistical analysis of fisheries data, and many of our alumni hold stock assessment or biometrician positions with the federal and state management agencies. We are one of just three institutions in the Nation that regularly teach nine core courses identified by NMFS as necessary for young stock assessment scientists (see list in Table 5; NOAA Tech. Memorandum NMFS-F/SPO-91).

Partner organizations and collaborators

The Alaska Fisheries Science Center (AFSC) Ted Stevens Marine Research Institute in Juneau, Alaska**;** Alaska Fisheries Science Center (AFSC) in Seattle, Washington.

Impact

CFOS produces a significant fraction of NOAA Fisheries' workforce in Alaskan fisheries-focused institutions, such as the Alaska Fisheries Science Center (AFSC) in Seattle, Washington, and especially the AFSC's Ted Stevens Marine Research Institute in Juneau, Alaska. Our faculty and NOAA scientists and managers interact closely in many other ways. NOAA personnel serve as members on graduate student committees and sometimes co-advise students, guest lecture in our courses, and attend and give seminars. NOAA personnel and CFOS faculty routinely collaborate on research projects, including multimillion dollar integrated ecosystem research programs in the Bering Sea, Gulf of Alaska, and the Arctic. This collaborative research provides training opportunities for graduate students by involving student thesis or dissertation work on various high-priority aspects of federally managed fisheries. Moreover, CFOS faculty routinely serve on management advisory committees with NOAA personnel, such as the Scientific and Statistical Committee (SSC, 3 faculty currently including the current SSC co-chair) and various Plan Teams of the North Pacific Fishery Management Council (NPFMC). Students are exposed to NPFMC management activities by classroom instruction from SSC members, as well as CFOS courses that directly involve student participation at NPFMC meetings.

Education

Students trained at CFOS provide a steady pipeline of highly qualified candidates for project-level positions at NOAA Fisheries and other agencies; in particular CFOS is a major producer of high-demand quantitatively-skilled personnel. The value of these interactions is heavily dependent on the core group of CFOS faculty specializing in quantitative aspects of fisheries. See also above under Impact.

During this reporting period is April 1, 2018 – March 31, 2019, Dr. Kruse taught the following course: FISH 640 Management of Marine Renewable Resources (spring 2018) to 13 students. During this reporting period, he chaired five graduate student committees: Ben Williams (PhD, pollock reproductive biology), Laura Slater (PhD, snow crab reproductive potential), Tadayasu Uchiyama (PhD, groundfish multispecies modeling), April Rebert (MS, crustacean ageing methods), and Kevin McNeel (MS, shortraker rockfish growth chronology). Of these, Ben Williams successfully defended his PhD dissertation in April 2018, titled "The reproductive biology and management of walleye pollock (*Gadus chalcogrammus*) in the Gulf of Alaska," and April Rebert successfully defended her master's dissertation in January 2019, titled "Evaluating potential age structures for three Alaska crustacean species." In addition, Dr. Kruse served as committee member on five additional graduate committees: Fletcher Sewall (PhD, Pacific herring recruitment), Matt Smukall (PhD, shark movement and life history), Jenell Larsen (PhD, Pacific walrus reproductive biology), Dan Michrowski (MS, skate discard mortality), and Laura Junge (MS, Pacific cod in the Aleutian Islands). Of these, Laura Junge successfully defended her master's dissertation in November 2018, titled "Comparing fishery-dependent and fishery-independent data sources of Pacific cod (*Gadus macrocephalus*) in the Aleutian Islands." Nearly all of these

students conducted research on federally managed fisheries in Alaska.

Outreach

Dr. Kruse traveled to St. Paul in the Pribilof Islands during June 29 – July 6, 2018. On June 30, he participated in a town hall/text-in live radio show on KUHB at the St. Paul Council Chambers Conference Room. During this 1 ¾ hr program, he was interviewed by PhD student, Jared Weems, and recent PhD graduate, Lauren Divine (Aleut Community of St. Paul Island), who served as moderators, about his career involvement in fisheries science and management in Alaska. He fielded questions from the mayor, community elders, Trident Seafoods plant manager, and other members of the community on a broad range of fisheries topics including crab population dynamics and restoration, climate-driven ecosystem changes, declines in northern fur seals, trawling effects, halibut bycatch, and a host of other marine ecosystem and fishery topics. During the ensuing week, Dr. Kruse observed and participated in Bering Sea – Pribilof Islands ECO, a marine ecosystem/fisheries summer camp, attended by ~28 students from St. George and St. Paul Islands led by Lauren, Jared, Ph.D. student Veronica Padula, and Alaska Sea Grant MAP Agent Melissa Good. The radio show can be replayed at: https://www.sfos.uaf.edu/research/pribsbluesmuse/\

Publications

Submitted, Under Journal Review

Divine, L.M., F.J. Mueter, G.H. Kruse, BA. Bluhm, S.C. Jewett, and Katrin Iken. In review. New estimates of weight-at-size, maturity-at-size, fecundity, mortality and biomass of snow crab, *Chionoecetes opilio*, in the Arctic Ocean off Alaska. Fisheries Research, revised manuscript under review.

Published or In Press

Uchiyama, T., F.J. Mueter, and G.H. Kruse. In press. Multispecies biomass dynamics models reveal effects of ocean temperature on predation of juvenile pollock in the eastern Bering Sea. Fisheries Oceanography, in press.

Gardner, C., R.A. Watson, A.D. Jayanti, Suadi, M. Al-Husaini, and G.H. Kruse. In press. Crustaceans as fisheries resources: General overview. Chapter 1 in M. Thiel and G. Lovrich, editors. The Natural History of Crustacea, volume 9. Fisheries and Aquaculture, Oxford University Press.

Sullivan, J.Y., G.H. Kruse, and F.J. Mueter. 2018. Do environmental and ecological conditions explain declines in size-at-age of Pacific halibut in the Gulf of Alaska? Pages 103-121 in F.J. Mueter, M.R. Baker, S.C. Dressel, and A.B. Hollowed (eds.). Impacts of a changing environment on the dynamics of high-latitude fish and fisheries. Alaska Sea Grant, University of Alaska Fairbanks. https://doi.org/10.4027/icedhlff.2018.06

Holsman, K.K., K. Aydin, J. Sullivan, T. Hurst, and G.H. Kruse. 2018. Climate effects and bottom-up controls on growth and size-at-age of Pacific halibut (*Hippoglossus stenolepis*) in Alaska (USA). Fisheries Oceanography, https://doi.org/10.1111/fog.12416

Zacher, L.S., G.H. Kruse, and S.M. Hardy. 2018. Autumn distribution of Bristol Bay red king crab using fishery logbooks. PLoS ONE 13(7): e0201190. https://doi.org/10.1371/journal.pone.0201190

Conference presentations

Reproductive biology and fishery management of snow and Tanner crabs in the eastern Bering Sea. Oral presentation, Annual Meeting of the North Pacific Marine Science Organization (PICES), Yokohama, Japan, November 2, 2018.

Reproductive biology informs fishery management of snow (*Chionoecetes opilio*) and Tanner crabs (*C. bairdi*) in the eastern Bering Sea, Alaska. American Fisheries Society, Western Division, Annual Meeting, Anchorage, Alaska, May 23, 2018.

Reproductive biology informs fishery management of snow (*Chionoecetes opilio*) and Tanner crabs (*C. bairdi*) in the eastern Bering Sea, Alaska. National Shellfisheries Association, Annual Meeting, Seattle, Washington, March 22, 2018. [Invited]

Other products and outcomes

Dr. Kruse serves as co-chair of the Scientific and Statistical Committee (SSC) of the North Pacific Fishery Management Council (NPFMC). In this role, he co-chairs five public SSC meetings per year during which the SSC provides advice on overfishing limits (OFLs), acceptable biological catches (ABCs), and other scientific advice for federally managed fisheries in the exclusive economic zone off Alaska. Moreover, in his role as SSC co-chair, in September 2018 he chaired a meeting of a subcommittee of SSC members to provide recommendations to NMFS on the prioritization of stock assessment surveys under alternative reduced budget scenarios for 2019 and 2020. Written reports of all SSC meetings are available online at the NPFMC website (https://www.npfmc.org/meeting-minutes/).

Developing a novel approach to estimate habitat-related survival rates for early life history stages using individual-based models (IBM)

Georgina Gibson, PI
University of Alaska Fairbanks

CIFAR theme: Ecosystem Forecasting and Studies

Other investigators/professionals associated with this project:
Dr. K. Shotwell, National Oceanic and Atmospheric Association, Alaska Fisheries Science Center
Dr. W. Stockhausen, National Oceanic and Atmospheric Association, Alaska Fisheries Science Center
Dr. J. Pirtle, National Marine Fisheries Service
Dr. A. Deary, National Marine Fisheries Service

NOAA Goal(s): Healthy Oceans

Amendments 87 NOAA Office: NMFS; Gerald Hoff, Sponsor

Budget Amount: Cumulative $18,825, This year $18,825 (Amendment 87)

This project is new and set to end 06/30/2019.

Primary objectives

The overall goal of this study is to characterize habitat utilization and productivity; increase the level of information available to describe and identify Essential Fish Habitat (EFH); apply information from EFH studies at regional scales. We will demonstrate the utility of a novel approach to raise the current EFH level from habitat related densities (Level 1) to habitat-related survival rates (Level 3) for the early life history stages (ELHS) of groundfish (larvae, and pelagic juveniles). Existing particle trajectories from previously developed individual-based models (IBMs) for groundfish (Gibson et al., 2016) will be post-processed to identify the spatial domain for survivor trajectories of the larvae and pelagic juvenile stages. A geostatistical model (e.g. Thorson et al., 2015) will be used to first create a smoothed surface of the individual survivor trajectories using model selection for the appropriate error distribution. Following this, a suite of habitat variables from the underlying biophysical forcing models will be tested to select the best model to explain the survivor trajectories for a given early life stage. We will use two case studies on Alaska sablefish and Gulf of Alaska Pacific cod as examples of this new application and will provide survival rate EFH maps for the ELHS stages of these two species. Once established, our new methodology may be explicitly applied to other groundfish species in Alaska where IBMs have been developed (e.g. pollock, arrowtooth flounder, Pacific ocean perch) and used as a starting reference for other co-occurring species during the early life stages.

Research accomplishments/highlights/findings

An in-person investigator meeting was conducted in Juneau, Alaska on August 6-7, 2018 to set up this project and initiate project tasking. Multiple presentations were provided by the project team to give background on various elements of the project. K. Shotwell reviewed the overall proposal setup and goals, previous examples of Level 3 EFH products, and information from the stock assessments for post processing the IBMs. W. Stockhausen and G. Gibson provided an overview of the Pacific cod and sablefish IBMs, respectively and discussion on relevant model output and predictor variables for use in the project. A. Deary updated the group on new early life data for sablefish from her laboratory projects that will be used in upgrading and updating the sablefish IBM for this project and also provided feedback on the Pacific cod IBM. J. Pirtle (with assistance

from C. Rooper prior to the meeting) reviewed the progression of building the habitat suitability models for these species, the current essential fish habitat status, and covariates available from this effort for modeling applications.

EFH model output including plots of diagnostics, continuous suitability maps, and percentiles maps were collected for all stages of sablefish and Pacific cod. This information was sorted by stage and included in the shared drive. Additional relevant papers, meeting agenda, and meeting minutes were shared for the project team to access.

A table of sizes for the prey fields available in the IBM was created. This information was taken from the Gulf of Alaska Nutrient, Phytoplankton, and Zooplankton (NPZ) model that pairs with the underlying hydrographic Regional Ocean Modeling System (ROMS) to influence the individual trajectories of the IBM. This information has been paired with mouth gape (newly determined from laboratory results by A. Deary) to determine stage specific ingestion abilities and can be used in the post-processing routine. This information will be used to adjust the sablefish IBM hatch size, stage, and duration for feeding pre- and post-flexion within the sablefish IBM. A potential temperature threshold for the yolk-sac larval stage was also reported, implying a clear vulnerability to warm temperatures and potential need for cold static temperatures during this stage and will be incorporated into the model.

Gibson has obtained the most recent version of the ROMS model output for the Gulf of Alaska, and the most up-to-date version of the DiSMELS IBM base code, and is in the process of setting up the sablefish IBM for an updated model run.

NOAA relevance/societal benefits

This project directly addresses two goals of NOAAs Essential Fish Habitat (EFH) Research Plan which describes specific tasks to accomplish over the next five years. The first objective is to develop EFH Level 1 maps where information has not yet been analyzed and the second objective is to raise the EFH Level from Level 1 or 2 to Level 3 (Sigler et al., 2017).

Partner organizations and collaborators

This project is being conducted in collaboration with Kalei Shotwell (NOAA) and William Stockhausen (NOAA). Because of the changes with the CIFAR organization at the time of award funding, other funding for this project was routed through Sea Grant Project Number R/101-17.

Impact

This project is supporting the continuation of a collaboration between NOAA and IARC/UAF and elevating the interest in using ecosystem modeling as a tool to address NOAAs priority research questions related to sablefish recruitment and habitat.

Education

No funds were requested or provide to support student researchers.

Outreach

Gibson presented the findings of her research to date on the Sablefish IBM to the North Pacific Fisheries Management Council (NPFMC) Science and Statistical Committee. This committee is in charge of providing guidance to the NPFMC on stock assessments. The committee was interested in the current status of models and how they can be used to improve stock assessments.

Publications

None to date

Conference presentations

No conference presentations to date but Gibson did present this work to NPFMC SSC, G.A. Gibson, Sablefish Individual Based Model, NPFMC SSC, Portland, Oregon, Feb 2019

Other products and outcomes

Through this project Gibson has begun a new collaboration with a sablefish life history spatial modeling group led by Dan Goethel (NOAA). It is anticipated that by joining these group conversations and sharing the work undertaken as part of this project, opportunities for collaboration and synergy will become apparent.

Measuring the strength of ocean-atmosphere coupling to predict climate forcing of northeast Pacific ecosystems

Michael Litzow, PI **CIFAR theme(s): Ecosystem Forecasting and Studies**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Dr. Mary Hunsicker, NOAA Northwest Fisheries Science Center (NWFSC)
Dr. Nicholas Bond, University of Washington, Joint Institute for the Study of the Atmosphere and Ocean
Dr. Brian Burke, NOAA NWFSC
Dr. Curry Cunningham, Alaska Pacific University
Dr. Jennifer Gosselin, University of Washington
Dr. Chris Harvey, NOAA NWFSC
Dr. Eric Ward, NOAA NWFSC
Dr. Stephani Zador, NOAA Alaska Fisheries Science Center

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation

Amendments 83 NOAA Office: NMFS; Mary Hunsicker, Sponsor

Budget Amount $57,008, This year $57,008 (Amendment 83)

This project is new and set to end 06/30/2019.

Primary objectives

The overall goal of this study is to improve climate indices for ecosystem-based fisheries management in North Pacific ecosystems. Our research seeks to incorporate nonstationarity in the atmosphere-ocean interactions that are leading drivers of North Pacific climate variability in order to produce climate indices that are able to better capture temporal evolution of climate dynamics that are critical for ecosystem function.

Our study pursues the following specific objectives. Objective 1: Test the hypothesis that the strength of SST-SLP correlations can predict biological response to climate anomalies. Objective 2: Create new indices of probable climate forcing strength, based on statistical measures of SST-SLP correlation strength. Objective 3: Apply the SST-SLP index to seasonal forecasts to provide a forecast of the likely strength of climate-biology covariation.

Research accomplishments/highlights/findings

To date, project collaborators have assembled the atmosphere, ocean, and biology time series that are necessary for the study, commenced an initial round of statistical modeling to resolve nonstationary environmental and ecological relationships at regional and basin scales, and submitted the first manuscript from the study.

A major focus of initial statistical modeling has been the use of self-organizing maps (SOMs) to evaluate temporal changes in the spatial expression of atmosphere and ocean variables such as sea surface temperature (SST), sea level pressure (SLP) and related wind stress fields. SOMs have also been employed to evaluate changing relationships among these atmosphere and ocean variables. A notable early finding is that spatial patterns in North Pacific SST changed after 1988/89, which is our *a priori* identified division between eras of contrasting atmosphere-ocean dynamics (Figure 1). Another early focus of our analysis has been the evaluation of evidence for nonstationarity in relationships between existing climate indices (the Pacific Decadal Oscillation

[PDO] and North Pacific Gyre Oscillation [NPGO]) in regional ecosystems, including the Bering Sea, Gulf of Alaska, and northern and southern California Current ecosystem. The manuscript reporting these results is currently in prep. Finally, we have conducted analysis testing the hypothesis of nonstationary responses of salmon productivity to local temperatures at ocean entry for populations over a basin-wide spatial scale across the northeast Pacific (Figure 2). This analysis is an important test of our central hypothesis that nonstationary environment-biology relationships should exist at a basin spatial scale due to the causal role of nonstationary Aleutian Low dynamics. Results of this analysis have been submitted to the *Canadian Journal of Fisheries and Ocean Sciences.*

NOAA relevance/societal benefits

Ecosystem-based approaches are central to NOAA's role in fisheries management. Recognition that simple statistical summaries of basin-scale climate variability, such as the PDO and NPGO, had predictive skill for ecological variability over very large spatial scales was a tremendous advance in ecosystem-based management. However, this predictive skill of these indices has decayed over time, making them less useful for managers. This project seeks to improve climate indices for management by explicitly accounting for nonstationarity in the atmosphere-ocean interactions that are critical drivers of environmental forcing in marine ecosystems. These improved indices are expected to improve the ability of managers to account for accelerating volatility in environmental forcing under climate change.

Partner organizations and collaborators

This project is a close collaboration among a large interdisciplinary group, consisting of PIs at UAF, the NOAA Northwest and Alaska Fisheries Science Centers, the University of Washington, and the Joint Institute for the Study of the Atmosphere and Ocean.

Impact

This project is adopting emerging concepts from basic research on the ecological importance of temporal nonstationarity in atmosphere-ocean interactions and applying them to derive a new suite of ecosystem indicators for management. By highlighting a poorly recognized phenomenon with potentially outsized consequences for ecosystem understanding and management, and aiming to produce improved tools for responding to this problem, the study stands to contribute to ecosystem-based fisheries management throughout the North Pacific.

Education

None to report.

Outreach

None to date.

Publications

Litzow, M. A., L. Ciannelli, C. Cunningham, B. Johnson, and P. Puerta. Nonstationary effects of ocean temperature on Pacific salmon survival. In review, *Canadian Journal of Fisheries and Aquatic Sciences*.

Conference presentations

None to report.

Other products and outcomes

None to report.

Figures

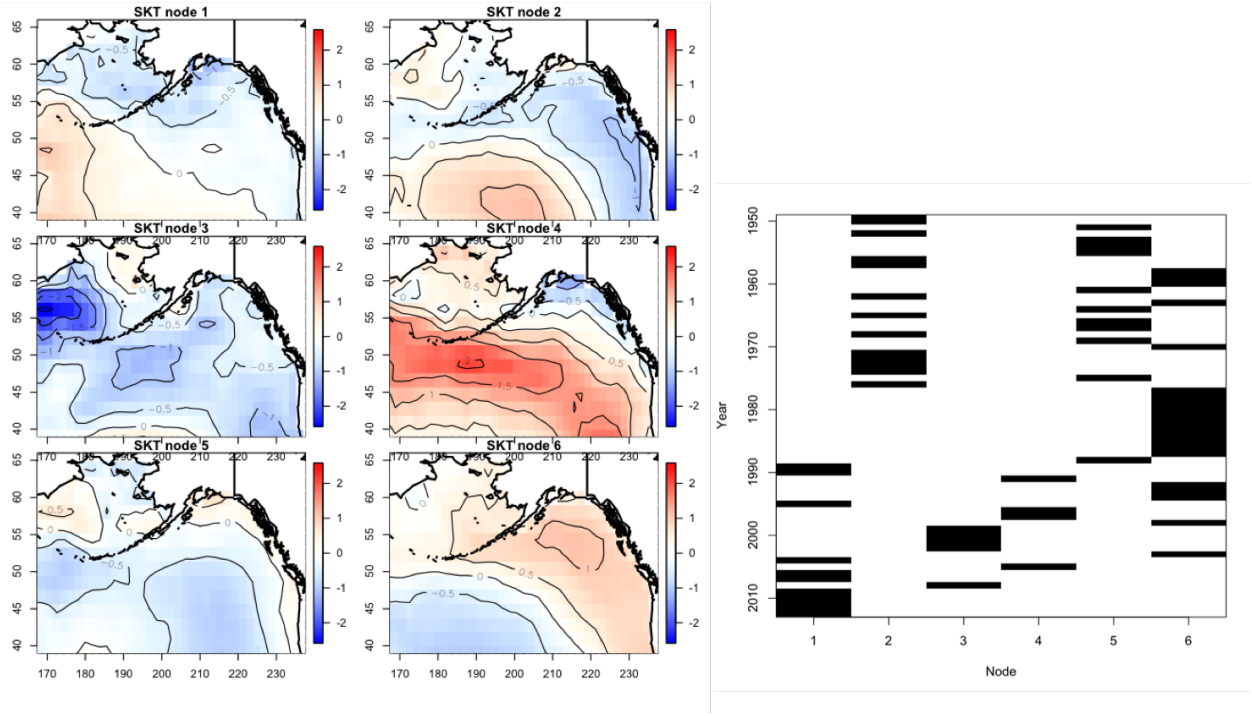

Figure 1. Self organizing map results for North Pacific sea surface temperature variability, 1950-2012. Left hand panels identify the leading spatial patterns (nodes), and the right-hand panels identify their incidence through time. Note the break in incidence of nodes before and after the late 1980s.

Understanding post-settlement survival for juvenile Pacific cod in the Gulf of Alaska (Yr1)

Michael Litzow, PI ***CIFAR theme: Ecosystem Studies & Forecasting***

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Alisa Abookire, University of Alaska Fairbanks

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation; Weather Ready Nation

Amendments 82 NOAA Office: AFSC; Paul McCluskey, Sponsor

Budget Amount: Cumulative $160,619, This year $160,619 (Amendment 82)

This project is new and set to end 06/30/2019.

Primary objectives

The goal of this project is improved understanding of the factors regulating the growth, condition, and survival of juvenile Pacific cod in the western Gulf of Alaska under continued heatwave conditions. Specific objectives are:

1. Conduct broad spatial scale beach seine sampling across the western Gulf of Alaska in summer 2018 to define the scales at which juvenile growth and abundance and relevant physical processes vary, and to estimate age-0/age-1 abundance at a scale relevant to stock management.
2. Conduct seasonal beach seine sampling at long-term Kodiak sites during March-May 2018 to collect basic information concerning winter habitat associations, bioenergetics, diet, and survival.

Research accomplishments/highlights/findings

Field sampling for Objective 1 occurred from the 14m vessel *Galactic* between 3 July and 31 August, 2018. Beach seines were the primary sampling method. A total of 130 beach seine sets were made in 14 different bays on Kodiak Island, the Alaska Peninsula, and the Shumagin Islands (Figure 1). Sampling occurred both during the outbound leg from Kodiak to the Shumagins, and on the return leg to Kodiak. In accordance with our protocol, sites in most bays were sampled on each leg in order to resolve seasonal patterns of abundance, growth, condition, and diet. The only bays not resampled were those in the Shumagins, which could not be resampled over time given their position, and one other bay (Kujulik) in which suitable cod habitat could not be seined. For each set, habitat information, temperature, and salinity were recorded. In addition, a CTD cast was made during each visit to each study bay to record temperature, salinity, and fluorescence profiles.

A total of 46,141 individuals of 53 fish species were captured in beach seines. Pacific cod were the most abundant species, and juveniles of several other commercially important species were also well sampled (Figure 2). We froze 2,156 Pacific cod for laboratory analysis, and retained fin clips from 345 Pacific cod for genetic analysis. Total length was measured for a subset of 8,626 fish, including 4,337 Pacific cod. The large majority of measured Pacific cod were < 120 mm TL, with a handful of individuals > 120 mm. We also conducted a pilot survey of age-1 Pacific cod abundance using baited cameras. This effort resulted in 27 individual sets comprising a combined total of ~9 hours of camera sampling (Figure 3). Comparison of catch per unit effort data from our broad-scale summer sampling with long-term data at a restricted number of Kodiak sites suggests that

the 2018 cohort showed above average abundance as age-0 across the western Gulf of Alaska (Figure 4).

Seasonal beach seine sampling at long-term Kodiak sites occurred during February-June and September-December of 2018. Regular summer sampling was conducted by NOAA at the same sites in July and August. Sampling occurred biweekly or monthly, as day length, tide stage, and weather conditions allowed. This work sampled age-0 cod from settlement through the critical first summer of nearshore occupancy, until offshore migration at the onset of winter. Laboratory analysis of body condition for all fishes retained during this study has been completed. Diet identification through stomach content analysis is ongoing.

NOAA relevance/societal benefits

The collapse of the Gulf of Alaska stock of Pacific cod is the leading crisis in contemporary Alaskan fisheries management. The 2017 bottom trawl survey found the lowest abundance of Pacific cod ever observed, more than 70 % lower than the 2015 value. The recommended allowable biological catch for 2018 and 2019 was reduced more than 75% from recommendation in the 2016 stock assessment. Very weak recruitment that contributed to the stock collapse coincided with the 2014-16 marine heatwave, which was the largest warm anomaly ever observed in the North Pacific. However, the actual links between climate anomalies and reduced recruitment remain unknown. Better understanding of climate effects on recruitment are critically needed to anticipate future harvest quotas, evaluate alternative management actions and prepare for socio-economic consequences of recruitment failure under continuing climate change.

A particularly important knowledge gap is the effect of climate conditions on age 0-1 Pacific cod survival, condition, and growth. Very little is known about the ecology of that life history stage in the Gulf of Alaska, particularly during winter. This study aims to fill that knowledge gap.

Partner organizations and collaborators

This project is a close collaboration with Dr. Ben Laurel, Hatfield Marine Science Center, Alaska Fisheries Science Center, NOAA. Dr. Laurel is the PI on the long-term Kodiak sampling and also provides expert input concerning thermal impacts on juvenile cod condition and bioenergetics.

Impact, Other products and outcomes

The first year of the western Gulf of Alaska sampling effort demonstrated the ability of this project to provide a unique source of early information concerning the strength of incoming cohorts to the Pacific cod stock. Prior to the start of this project, the earliest qualitative index of juvenile adult abundance was obtained from the occurrence of age-2 Pacific cod in the Shelikof Strait walleye pollock fishery, and the earliest quantitative information came when age-3 cod recruited to the biannual bottom trawl survey. Information from our first summer field season was included in the 2018 Pacific cod stock assessment report. Repeat sampling in future years will allow overwinter survival to be estimated through comparison of the relative abundance of cohorts at age-0 (before first winter of life) and age-1 (after first winter of life), which will increase the value of this information for stock assessment and monitoring of potential stock rebuilding. This sampling will also allow a suite of specific hypotheses to be tested to improve understanding of the effects of continuing warm anomalies on juvenile Pacific cod growth, condition, and survival.

Education

None to report.

Publications and Presentations

Abookire, A.A., M.A Litzow, and B.J Laurel. 2019. Abundance, condition, and diet of age-0 Pacific cod in the western Gulf of Alaska. Poster presentation, Alaska Marine Science Symposium, Anchorage.

Figures:

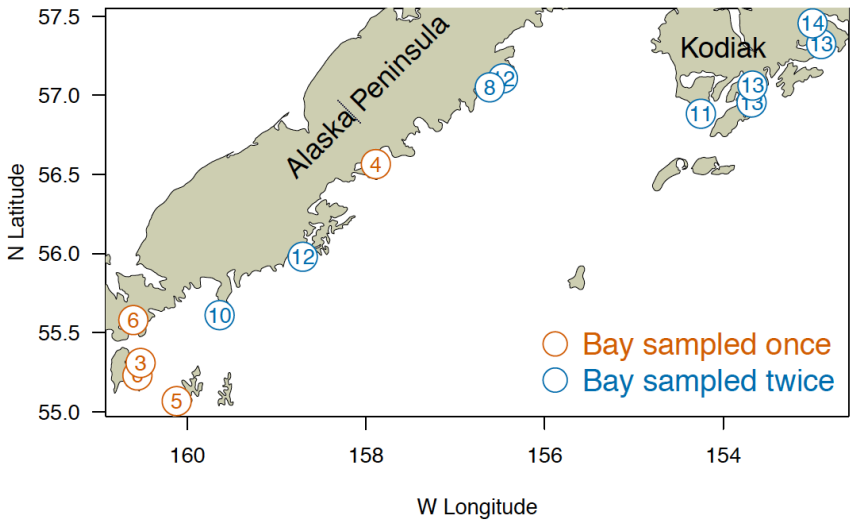

Figure 1. Western Gulf of Alaska beach seine sampling effort. Number within the circles indicate the number of sets within each bay.

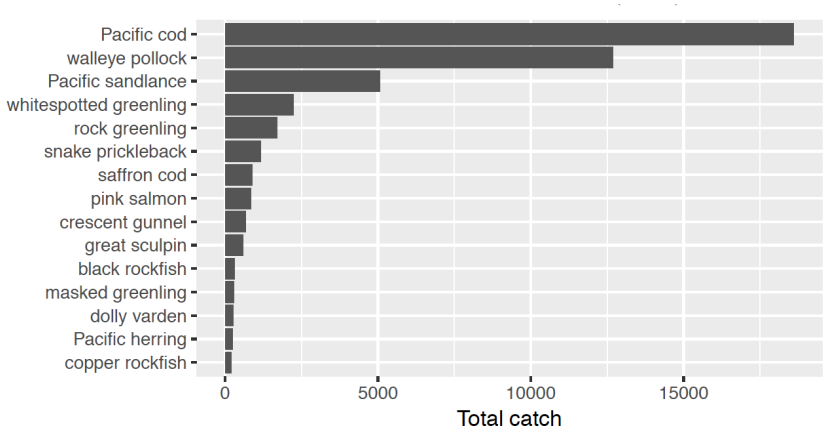

Figure 2. Total catch (# of fish) for the 15 most abundant species captured in summer western Gulf of Alaska beach seines.

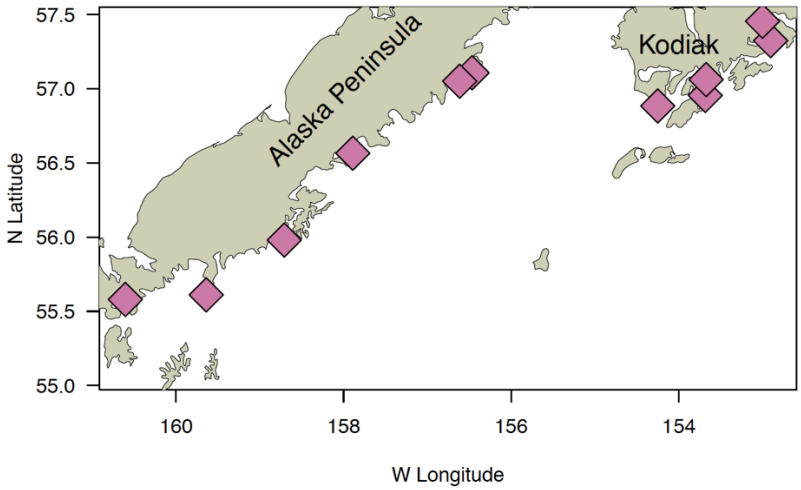

Figure 3. Bays sampled with baited camera to assess age-1 Pacific cod abundance.

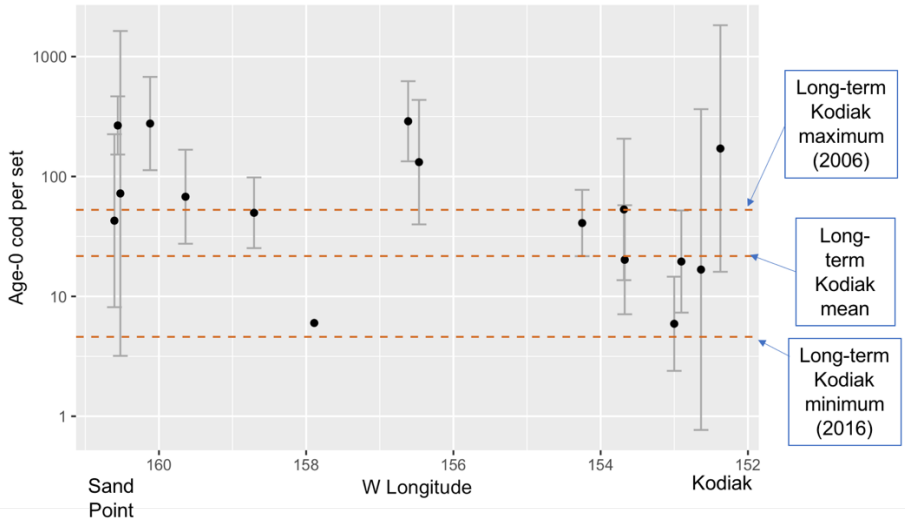

Figure 4. Catch per unit effort (CPUE; fish per set, where present) for age-0 Pacific cod from 2018 summer sampling, compared with the range of values observed during long term (2006-2018) sampling around Kodiak. Error bars =95% CI.

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

John Pace, PI **(formerly Thomas Heinrichs)**
University of Alaska Fairbanks

CIFAR theme(s): Climate Change and Variability
Coastal Hazards

Other investigators/professionals associated with this project:
Oralee Nudson, Eric Stevens (former Liaison), Carl Dierking, Jiang Zhu, Jay Cable, University of Alaska Fairbanks

NOAA Goal(s): Climate Adaptation and Mitigation

Amendments 8, 19, 42, 50, 62 NOAA Office: NESDIS, Greg Mandt, Sponsor
Continues research from NA08OAR4320751
Budget Amounts: Cumulative $1,016,547, This year $0
This project is on extension and set to end 06/30/2019.

Primary objectives

The objective of this activity is to build upon the already established collaborative team of National Weather Service (NWS) Alaska Region, University of Alaska Fairbanks-Geographic Information Network of Alaska (UAF-GINA), National Environmental Satellite, Data, and Information Service (NESDIS), and Cooperative Institute for Meteorological Satellite Studies (CIMSS), Cooperative Institute for Research in the Atmosphere (CIRA), and Short-term Prediction Research and Transition Center (SPoRT) to improve the near real-time distribution of the Suomi National Polar-orbiting Partnership (SNPP)/Joint Polar Satellite System (JPSS) data to algorithm developers, science users, and the operational NWS forecast offices.

In cooperation with University of Wisconsin, Colorado State, and National Oceanic and Atmospheric Administration (NOAA) Center for Satellite Applications and Research (STAR) algorithm developers and direct broadcast application developers, UAF-GINA will provide an operational environment to run the Community Satellite Processing Project (CSPP) SNPP sensor processor. Both the stable and pre-release development processors for the SNPP sensors will be generating products in near real-time for distribution to the Alaska NWS and algorithm developers at other university and NOAA research sites. These products delivered to the Alaska NWS will initially include natural color and infrared imagery in near-real-time. GINA staff will work closely with NOAA and Cooperative Institutes to train, deploy, and evaluate products in Alaska Region forecast offices and river, aviation, and sea ice units.

Research accomplishments/highlights/findings

- GINA assisted with logistical planning and support of the JPSS Arctic Summit in Anchorage and Fairbanks, May 1-8 2018
- The JPSS Arctic Summit was a very successful exchange between Alaskan users of polar satellite data and product developers. Special sessions focused on Aviation, Hydrology, Coastal Marine, and the Cryosphere were held in Anchorage May 1-4 2018. That was

followed by sessions on Fire Weather and Direct Broadcast in Fairbanks May 7-8 2018. GINA was represented at all sessions.

- GINA began distribution of new SCMI formatted products to NWS.
- The SCMI "tile" format is a relatively new capability provided by CIMSS polar2grid developers that creates products in instrument native resolution and precision. Products in this format were evaluated internally at GINA for some time and before beginning distribution to the NWS in Alaska due to the significant increase in data volume and concerns about impact on bandwidth. These impacts were not found to be significant however, so GINA plans to fully convert all products to the new format in the coming year.
- GINA provided new GLSL configurations for client-side RGBs.
- Science Liaison Carl Dierking provided NWS-Alaska new GLSL configurations for creating AWIPS client-side RGBs from SCMI formatted files. GLSL is a new method for creating client-side RGBs developed by Jordan Gerth and the NESDIS-NWS Satellite Enhancement Team. This, combined with the new SCMI format in the full native resolution and precision, allows forecasters to use the sample tool to determine BTs and reflectance percentages from each band that is a component of the RGB
- As a member of the JPSS Aviation Initiative, GINA began producing and distributing CLAVR-x cloud products as part of an assessment project Dec-Mar.
- Developer Jay Cable and Science Liaison Carl Dierking led an effort wherein GINA generated and made available prototype CLAVR-x cloud products (Figure 1) to members of the Aviation Initiative team that included NWS and other aviation representatives in Alaska. Tom George (Aircraft Owners & Pilots Assn) and Adam White (Alaska Airmen Assn) visited GINA to provide guidance on the best online presentation of cloud products for the Alaska aviation community.

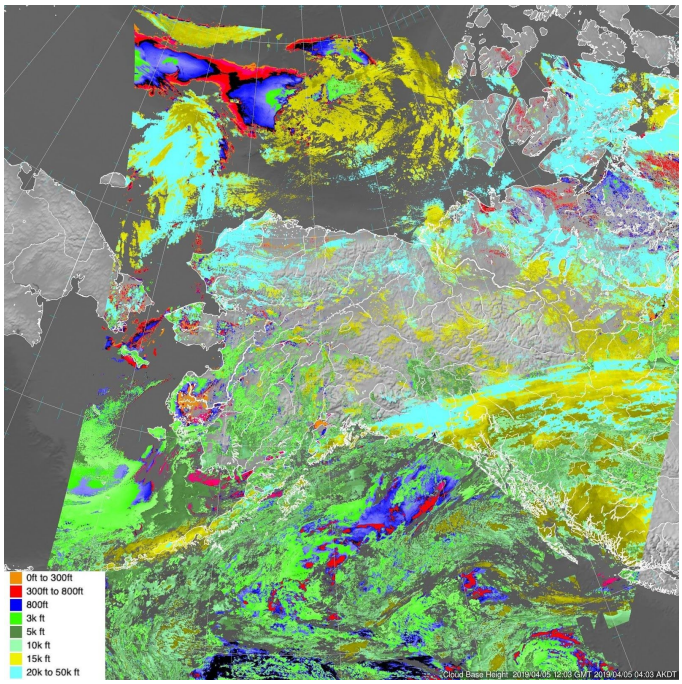

Figure 1. CLAVR-x Cloud Base Altitude.

Other methods of viewing the cloud output, such as cross-sections, are under consideration. The assessment project is still ongoing.

As a member of the JPSS Arctic Initiative, GINA began producing and distributing experimental Sea Ice products as part of an assessment project that ran from Nov 19, 2018 to Jan 31, 2019.

Developer Jay Cable and Science Liaison Carl Dierking were members of a team that provided experimental sea ice products from GINA Direct Broadcast data by using algorithms developed by Jeff Key and his development team at CIMSS. Products developed include: Ice Age/Thickness, Ice Concentration, Ice Surface Temperature, Ice Motion, Ice Characterization, Sea Surface Temperature, and a Cloud Mask. These ice products were made available to the Alaska Sea Ice Program (ASIP) and others for evaluation with assistance on how to use them.

Participation in other JPSS Initiatives include: River Ice and Flood, Fire and Smoke, and NUCAPS.

In addition to the JPSS Arctic and Aviation Initiatives, GINA is an active participant in many other JPSS initiatives such as River Ice and Flood, Fire and Smoke, and NUCAPS. The Initiative team members collaborate to identify existing product problems, enhancements, or uses, as well as potential new developments or user groups.

Performed infrastructure maintenance and upgrades to improve receptions of Direct Broadcast data.

In May 2018, a snow rope was installed on the UAF housed antenna in hopes of improving winter-time reception of SNPP data. At the same time, maintenance of the housing was completed by caulking all the panels to ensure it was weatherproof. Spinning disk capacity was also expanded for raw satellite data backups. The "pancake" server for hosting products was deployed for the sea ice and aviation product evaluations. The feeder data distribution tool database was successfully migrated from old infrastructure onto new hardware and Postgres database versions were updated during migration.

- New server for River Flood products placed into service and old server retired.
- A new, faster server “riverflood” was installed and has replaced the old server “riverice” for producing VIIRS river ice and flood products. Also, on the new server, software was updated to produce river products from NOAA20. Two software packages were ported to the new hardware by Jay Hoffman from CIMSS, the River Flood Areal Extent software developed by Sanmei Li at George Mason University and the River Ice Extent software developed by CCNY. Evaluations are ongoing to determine if there are problems or product differences between SNPP and NOAA20.
- Continued collaboration with the Alaska Fire Service
- GINA provided NOAA20 VIIRS fire detections to the Alaska Fire Service for evaluation purposes and produced NOAA20 VIIRS fire color and fire temperature RGBs in addition to SNPP. GINA Researchers Lisa Wirth and Jay Cable examined the performance of the active fire-detection and characterization algorithm using VIIRS and Landsat imagery from 2015. Overall, the algorithm performs well but there are documented areas where the algorithm missed fire pixels due to pixel folding or on-board averaging (Figures 3-5). The pixels that were not corrected using the algorithm appear to be due to the I5 brightness temperature below the threshold of 325K, possibly making Chris Waigl's work completed for improved fire products for high latitudes more applicable.

- Staff from CIMSS visited Alaska in March 2019 to review technical collaboration topics.
- Jordan Gerth and Kathy Strabala of CIMSS traveled to Fairbanks to meet with GINA staff in March 2019. Discussions were focused on identifying and resolving problems with current CSPP and Polar2grid software; reviewing development efforts that are currently underway at CIMSS, and collecting requests for future enhancements.
- Development of improved data assimilation in short-term WRF modeling of Alaska's weather continues to advance.
- GINA research scientist Jiang Zhu continues to study how to improve the WRF short-term forecast for Alaska by using satellite data assimilation. NUCAPS profile data and ACARS aircraft data have been included in the assimilation scheme previously, with preliminary results indicating that these profiles improve the short-term forecast. Most recent efforts focused on how satellite wind-product assimilation impacts the WRF short-term forecast. Forecasts for 24-hours were produced 4 times a day for one month, followed by statistical analyses on all simulations.
- GINA completed work to make ATMS microwave imagery from NOAA-20 available to NWS Alaska via LDM.
- In coordination with the JPSS Program Office, the CSPP developers at University of Wisconsin, and officials at NWS Alaska, GINA is now routinely processing NOAA-20 data and generating ATMS microwave products in AWIPS-ready formats and making these products available to the NWS via LDM.
- Began production and distribution of MIRS Snowfall Rate product
- As a result of new capabilities in MIRS and CSPP software, GINA began production of MIRS Snowfall Rate (SFR) products from ATMS and AMUS-A/MHS microwave data. See Figure 2. The Snowfall rate product provides an instantaneous estimate of the liquid equivalent 1-hr rate of snowfall during at time time of the satellite pass.

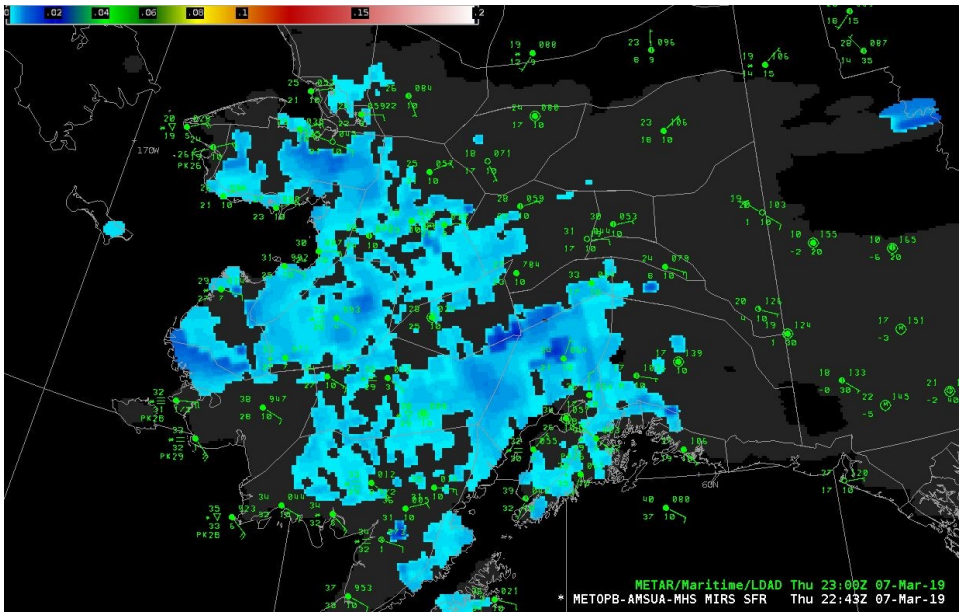

Figure 2. MIRS Snowfall Rate (SFR) product for 07 Mar 2019. This imagery is now available in near

real time via LDM in AWIPS-ready formats for use by NWS Alaska.

- Began reception, processing, and delivery of Metop-C data
- GINA began reception of Metop-C AVHRR and AMUS-A/MHS Direct Broadcast data and updated tools to process the data into products and distribute to NWS and other users.
- Began processing and testing IASI satellite sounding products.
- IASI satsoundings are now being received and produced experimentally at GINA. Development is underway for conversion to AWIPS-ready products for potential distribution to NWS in Alaska.

NOAA relevance/societal benefits

- GINA operates direct readout antennas in Fairbanks and captures and processes satellite data in near-real-time; many products are generated within minutes of capture. GINA serves the National Weather Service and other operators such as the Alaska Fire Service with near-real-time imagery and information products. GINA is the best, most effective conduit between scientists and operators in Alaska. GINA's work extracts value from the multi-billion-dollar satellite programs by working with operators to solve problems that only polar orbiting satellites can address.
- 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. Effective use of polar orbiting data is essential for accurate forecasting and warning at high latitudes.

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
- NASA SPoRT: In-kind support, Collaborative research, Personnel exchanges

Education

- Science Liaison Carl Dierking represented GINA at the JPSS Satellite Training Advisory Team workshop in
- Boulder, CO September 10-14. The purpose of the meeting was to finalize the roadmap for

completion of the JPSS Satellite Training due in 2019. GINA has committed to produce some of the training videos and quick guides for the training series.

- As part of the JPSS Satellite Training Advisory Team requirements, a proof of concept training video, entitled "Mosaics and Time Delta: Tracking and Overlaying Passes", was completed by Eric Stevens, Jill Shipman and Carl Dierking. Also Carl and Jill completed a video illustrating the benefits of Direct Broadcast for Monitoring Natural Hazards in Alaska. In addition, Quick Guides for the "Day Land Cloud RGB", "MIRS Total Precipitable Water", "MIRS Rain Rates", and "MIRS Sea Ice Concentration" products were completed for the JPSS Satellite Training Advisory Team (STAT).
- GINA continued the partnership with Alaska Center for Climate and Policy (ACCAP) hosting webinars for the Virtual Alaska Weather Symposium (VAWS). For the monthly VAWS series, guest speakers are invited to give a virtual presentation about a topic of interest to operational meteorologists in Alaska. Speakers this past year included: Huan Meng (NESDIS STAR), Wes Atkins (NWS), Jordan Gerth (CIMSS), Christopher Grassotti (NESDIS STAR), Steve Miller (CIRA), Mike Pavalonis (SSEC) Rodney Viereck (NOAA), Kristin Timm (George Mason), Jeff Key (CIMSS), and Jessy Cherry (APRFC). Recordings of these and previous webinars are available at: https://accap.uaf.edu/webinars/virtual-alaska-weather-symposium

Outreach

GINA assisted with planning and support of the JPSS Arctic Summit in Anchorage and Fairbanks, May 1-8, 2018. The JPSS Arctic Summit was a very successful exchange between Alaskan users of polar satellite data and product developers. Special sessions focused on Aviation, Hydrology, Coastal Marine, and the Cryosphere were held in Anchorage May 1-4, 2018. That was followed by sessions on Fire Weather and Direct Broadcast in Fairbanks May 7-8, 2018. GINA was represented at all sessions.

Conference presentations

Science Liaison Carl Dierking attended the NWA Annual Meeting in St. Louis to present a poster on Fire Weather Satellite Products. The poster gave examples of two Fire Weather RGBs, The DayLandCloudFire RGB (also called NaturalFireColor) and the FireTemperature RGB. The DayLandCloudFire RGB in particular is being used extensively by the Alaska Fire Service for monitoring fire perimeter changes.

GINA Director John Pace, along with Jill Shipman and Carl Dierking, attended the American Geophysical Union (AGU) fall meeting in Washington D.C. in December. John Pace and Jill Shipman presented "flash talks" at the UAF Geophysical Institute vender booth at the conference to review GINA activities and to showcase a recent video about the benefits of Direct Broadcast in Alaska.

Research Scientist Jiang Zhu presented a post on assimilation of satellite winds at the Annual Meeting of the American Meteorological Society in Phoenix, AZ in January.

GINA Director John Pace gave an oral presentation on the value of Direct Broadcast in Alaska at the American Meteorological Society in Phoenix, AZ in January.

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

John Pace, PI (formerly Lisa Wirth) **CIFAR theme: Climate Change and Variability, Coastal Hazards**
University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Carl Dierking, Eric Stevens (former Liaison), Jiang Zhu, Jay Cable, **University of Alaska Fairbanks**

NOAA Goal(s): Climate Adaptation and Mitigation

Amendments 18, 33, 48, 64 NOAA Office: NESDIS, Dan Lindsey,Sponsor
Continues research from NA08OAR4320751
Budget Amounts: Cumulative $761,416, This year $0
This project is on extension and set to end 06/30/2019.

Primary objectives

Based on needs of the National Weather Service, the Geographic Information Network of Alaska (GINA) at the University of Alaska Fairbanks, performs the following research efforts centered on the themes of 1. Cryospheric products; 2. Fire Weather products, 3. Volcanic Ash products, 4. Assimilation of products into models; and 5. 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. Collaborators include the NWS Weather Forecast Offices (WFOs), the Alaska Pacific River Forecast Center (APRFC), the Alaska Aviation Weather Unit (AAWU), and the Alaska Sea Ice Program (SIP), and the NOAA research partners: Cooperative Institute for Meteorological Satellite Studies--CIMSS, Cooperative Institute for Research in the Atmosphere—CIRA, NOAA Center for Satellite Applications and Research--STAR, Short-term Prediction Research and Transition and Center--SPoRT, and the NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC).

Research accomplishments/highlights/findings

In the past year, while GOES-17 went through calibration/validation, moved to its operational orbit position, and transitioned to operations on Feb 12, 2019, GINA participated in training and outreach to promote the advanced use of GOES-17 data in Alaska. In response to the loop heat pipe cooling problem that has affected the quality of some GOES bands for short periods during this past year, GINA promoted alternative polar data sources to mitigate data loss during these seasonal outages. Other GOES-17 related activities include:

1. Science liaison Carl Dierking worked with Unidata to set up an LDM feed of GOES data to GINA. The timely availability of these data allow research into ways that GOES and JPSS products can work synergistically to advance forecast tools in Alaska. This information is being used to prepare training on GOES applications for a variety of user groups in Alaska.

2. Alaska Fire Weather

GINA has promoted the use of new FireTemperature and DayLandCloudFire RGBs for improved fire detection. The ability of GOES-17 to make available these RGB products every 10 minutes, and every 1 minute in a mesoscale domain, provides an enhanced monitoring capability for fires and smoke. GINA also investigated a method for mitigating pixel “roll over” to cold brightness temperatures when a VIIRS 3.7um band sensor saturates in very hot fires. The method, which

could be adapted to GOES-17, uses multiple bands to detect pixel saturation. It works acceptably in the most common cases allowing saturated areas to be displayed as “hot” instead of “cold” in the single-band and fire-related RGBs.

3. Alaska Sea Ice Program

The Day Land Cloud RGB (formerly known as Natural Color) and other Snow vs Cloud identification products from polar data have been refined and used extensively by the Alaska Sea Ice Program desk. The application of these products with the high temporal resolution of GOES-17 enables much more precise measurement of ice movement and evolution. GINA has participated in training efforts to demonstrate the effective use of GOES-17 data in support of the Alaska Sea Ice Program. GINA continues to explore new products that will help to improve Sea Ice analysis and forecasting in Alaska.

4. Alaska-Pacific River Forecast Center

GINA supported efforts by Dr. Sanmei Li of George Mason University to migrate river ice and flooding software to GOES-17 ABI. SNPP/NOAA-20 VIIRS River ice and flooding products from direct broadcast data have been very successful in Alaska, and are heavily used by the Alaska-Pacific River Forecast Center during spring break-up to monitor the potential for river ice flooding. This success has encouraged migration to a GOES-17 ABI version of this product which is now being tested. GINA has supported Dr. Li in evaluation of all aspects of this flood monitoring software.

5. Alaska Aviation Weather Unit

GINA evaluated and promoted specialized satellite products for the purpose of tracking volcanic ash, such as the Ash RGB and the Split Window channel difference. The high frequency of GOES-17 provides accurate details about the movement and evolution of the ash cloud after a volcanic eruption.

NOAA relevance/societal benefits

The focal areas of sea ice, river ice/flood, fire/smoke, and aviation weather were directly targeted at weather and environmental hazards to people and property in Alaska. Improvements to forecasting these hazards have a significant benefit here in our state.

The National Weather Service Alaska Region is much more dependent on satellite data than CONUS NWS regions due to the sparse network of radars, surface observations, and balloon launches. The forecast area of responsibility for the Alaska Region is vast and includes large ocean areas, including the Bering Sea and Strait, North Pacific, and Arctic Ocean. The 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 are used effectively and extensively in southeast Alaska and the Aleutians and as a synoptic tool for the rest of the state. With the much enhanced spatial, spectral, and temporal resolution of ABI data, GOES-West/17 ABI is a critical forecasting support tool in Alaska.

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
- NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC), 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

Outreach

- GINA staff attended two meetings hosted by the Alaska Fire Service, a beginning of the season kick-off meeting and an end of the season wrap-up.
- GINA Director John Pace and GIS Lead Peter Hickman attended the Interagency Spring Fire Operations Meeting in Fairbanks in March 2019.
- Science Liaison Carl Dierking accompanied Jordan Gerth and Scott Lindstrom during their GOES-17 training March at the Weather Service Forecast Office in Juneau.
- GINA and the Alaska Center for Climate Assessment & Policy (ACCAP) at UAF are co-hosts of the Virtual Alaska Weather Symposium (VAWS). VAWS is a monthly series of webinars during which a guest scientist or forecaster is able to present work and lead discussions about a topic of interest to operational meteorologists in Alaska. In the past year, presentations include: "New Capabilities, Opportunities, and Challenges Using GOES-17 in Alaska" by Jordan Gerth, "Volcanic Cloud Monitoring in the North Pacific: The dawning of the GOES-R Era" by Mike Pavalonis, and "CIRA Development of Alaska-relevant satellite applications from JPSS and GOES-R" by Steve Miller. Recordings of these and previous webinars are available at: https://accap.uaf.edu/webinars/virtual-alaska-weather-symposium

Conference presentations

Science Liaison Carl Dierking presented a poster on new Fire Weather RGB products at the National Weather Association Annual Meeting in August 2018.

GINA Director John Pace and Science Liaison Carl Dierking represented GINA at the American Geophysical Union Fall Meeting in December 2018. Mr. Pace gave a flash talk on recent work that GINA has been doing with satellite data.

GINA Director John Pace and Science Liaison Carl Dierking represented GINA at the American Meteorological Society Annual Meeting in January 2019. Mr. Pace gave a presentation reviewing the recent work that GINA has been doing with satellite data.

NOAA State of the Arctic

Jacqueline Richter-Menge, PI
University of Alaska Fairbanks

CIFAR theme(s): Climate Change and Variability, ***Ecosystem Studies and Forecasting***

Other investigators/professionals associated with this project:
J. Overland, E. Osborne, **NOAA**
M. Jeffries, **ONR**

NOAA Goal(s): Climate Adaptation and Mitigation; Resilient Coastal Communities and Economies

Amendments 63, 80 NOAA Office: OAR, Emily Osborne, Sponsor

Budget Amount: Cumulative $55,609, This year $0

This project is complete.

Primary objectives

This project supports the publication of the annual NOAA Arctic Report Card (ARC), a web-based resource, and the Arctic chapter in the State of the Climate report, which appears in the Bulletin of the American Meteorological Society (BAMS). Both products provide a timely and peer-reviewed source for clear, reliable and concise environmental information on the state of the Arctic. The content is prepared in a way that is accessible to a wide audience, including scientists, students, teachers, decision-makers and the general public interested in Arctic environment and science.

Research accomplishments/highlights/findings

Consistent with the work plan, the project has two major accomplishments: the annual publication of (1) the web-based NOAA Arctic Report Card (ARC) and (2) the Arctic chapter in the BAMS State of the Climate Report. The first ARC was produced in 2007. The ARC 2018, released on 11 December 2018 at the 2017 Fall American Geophysical Union meeting, marked the 12th update. The BAMS State of the Climate in 2018 report is currently under production and is scheduled for release in July 2019. Taking advantage of the production timeline of the ARC, much of the content of ARC2017 provides the foundation for the Arctic chapter of the BAMS State of the Climate in 2018 report.

ARC 2018 continues the format adopted during the third major revision of the ARC in its fundamental scope and content organization. This revision, which was initiated with ARC 2014, improved the quality of the content and the efficiency of the fast-paced production schedule. There are three main sections: Vital Signs, Indicators, and Frostbites. *Vital Signs* essays are on topics that are updated annually, including surface air temperature, terrestrial snow cover, Greenland ice sheet, sea ice, sea surface temperature, and ocean primary productivity. *Indicators* essays are on topics that are updated every 3-5 years. *Frostbites* essays are for reports on new and newsworthy items, describing emerging issues, and addressing topics that relate to long-term scientific observations in the Arctic.

ARC2017 successfully expanded the involvement of NOAA researchers and leadership in its production, including the selection of topics for the *Indicators* and *Frostbites* sections and as lead

and co-authors on essays. Reflecting this expanded involvement, ARC 2018 includes *Indicator* essays on recent climate-related trends in river discharge into the Arctic Ocean, reindeer herds, and lake ice formation. *Frostbite* topics include the increasing prevalence of harmful algal blooms and microplastics in the marine environment; changes in land fast sea ice conditions, an important platform for subsistence communities; and progress in understanding Arctic influences on mid-latitude weather.

Highlights from ARC2018 are the following.

- **Surface air temperatures** in the Arctic continued to warm at twice the rate relative to the rest of the globe. Arctic air temperatures for the past five years (2014-18) have exceeded all previous records since 1900.
- In the **terrestrial system**, atmospheric warming continued to drive broad, long-term trends in declining terrestrial **snow cover**, melting of the **Greenland Ice Sheet** and **lake ice**, increasing summertime Arctic **river discharge**, and the expansion and greening of Arctic tundra **vegetation**.
- Despite increase of vegetation available for grazing, herd populations of **caribou and wild reindeer** across the Arctic tundra have declined by nearly 50% over the last two decades.
- In 2018 Arctic **sea ice** remained younger, thinner, and covered less area than in the past. The 12 lowest extents in the satellite record have occurred in the last 12 years.
- Pan-Arctic observations suggest a long-term decline in **coastal landfast sea ice** since measurements began in the 1970s, affecting this important platform for hunting, traveling, and coastal protection for local communities.
- Spatial patterns of late summer **sea surface temperatures** are linked to regional variability in sea-ice retreat, regional air temperature, and advection of waters from the Pacific and Atlantic oceans.
- In the Bering Sea region, **ocean primary productivity** levels in 2018 were sometimes 500% higher than normal levels and linked to a record low sea ice extent in the region for virtually the entire 2017/18 ice season.
- Warming Arctic Ocean conditions are also coinciding with an expansion of **harmful toxic algal blooms** in the Arctic Ocean and threatening food sources.
- **Microplastic contamination** is on the rise in the Arctic, posing a threat to seabirds and marine life that can ingest debris.

ARC 2018 has been prepared by an international team of 78 scientists from 12 different countries. We continue the implementation of a rigorous peer-reporting process, organized by the Arctic Monitoring and Assessment Programme (AMAP) of the Arctic Council.

Taking advantage of the production timeline of the Report Card, much of the content of ARC2017 (Richter-Menge et al., 2017) provided the foundation for the Arctic chapter of the BAMS State of the Climate in 2017 report (Richter-Menge et al., 2018). The BAMS Arctic chapter in the State of the Climate in 2017 report included updates on: surface air temperature, sea surface temperature, sea ice, Greenland ice sheet, glaciers outside of Greenland, tundra greenness, terrestrial permafrost, terrestrial snow cover, and ozone and UV radiation. Sidebars in the chapter included results from paleoceanographic studies, which provide context for current trends in sea ice extent. Another sidebar highlighted wildfires in the North American Arctic. A third addressed the value of

indigenous knowledge and the co-production of knowledge to create a holistic understanding of Arctic change. The BAMS Arctic chapter for State of the Climate 2018 is currently under review.

NOAA relevance/societal benefits

This work directly supports NOAA Climate Program Office objectives to (a) describe and understand the state of the climate and (b) improve society's ability to plan and respond to climate variability and change by providing an integrated summary of the state of the Arctic. This goal also supports the guiding principles of NOAA's Arctic Vision & Strategy.

Partner organizations and collaborators

Both reports are the work of a large international team. The ARC 2018, represents the collective effort of 81 researchers in 12 countries. On the editorial staff, the PI (Richter-Menge) is joined by members of the NOAA (Osborne, OAR) and ONR (Jeffires) staffs.

A full list of collaborators is available at: https://www.arctic.noaa.gov/Report-Card/Report-Card-2018/ArtMID/7878/ArticleID/775/Authors-and-Affiliations.

Impact

Both reports involve a widely-publicized public release, coordinated through NOAA PAO. The release of the ARC2018 took place on 11 December 2018, at the 2018 Fall AGU meeting. Because of the public rollout, highlights from the reports are picked up by key news organizations (e.g. Reuters and AP) and quickly and widely spread to local, regional, national and international news media appearing in hundreds of articles around the world. The Report Card and the BAMS State of the Climate report are featured resources on NOAA Climate.gov.

Education

See 'Outreach'.

Outreach

The primary motivation for NOAA's ongoing support of ARC and BAMS State of the Climate report is outreach and education. The release of the 2018 update took place on 11 December 2018, at the 2018 Fall AGU meeting. As in the past, the release is timed to occur soon after the end of the summer melt season and will be marked by a public rollout event that is being organized by NOAA POA. During the annual public rollout, results from the Report Card are picked up by key news organizations (e.g. Reuters and AP) and quickly and widely spread to local, regional, national and international news media appearing in hundreds of articles around the world. The Report Card is a featured resource on NOAA Climate.gov. ARC2018 is available at: https://arctic.noaa.gov/Report-Card/Report-Card-2018. The BAMS State of the Climate 2017 report was released to the public on 1 August 2018 and featured the Arctic chapter. The full report is available at: https://www.ncdc.noaa.gov/bams/2017.

Publications

Osborne, E., J. Richter-Menge, and M. Jeffries, Eds., 2018: Arctic Report Card 2018, https://www.arctic.noaa.gov/Report-Card.

Richter-Menge, J. A. and J.T. Mathis, Eds., 2017: The Arctic [in "State of the Climate in 2016"]. Bull. Amer. Meteor. Soc., 98 (8), S129–S154, doi:10.1175/2017BAMSStateoftheClimate.1.

Conference presentations

The public rollout of the BAMS State of the Climate in 2017 report took place on 1 August 2018. The slides were presented by Dr. Emily Osborne, NOAA Arctic Research Office. The release of the 2018 update took place on 11 December 2018, at the 2018 Fall AGU meeting.

Other products and outcomes

None to report.

High Latitude Proving Ground – GOES-R River Ice and Flood Product Support

John Pace, (formerly Lisa Wirth)
University of Alaska Fairbanks

CIFAR theme(s): Climate Change and Variability

Other investigators/professionals associated with this project:
Oralee Nudson, Eric Stevens, Jay Cable, Carl Dierking, Greg Wirth, **University of Alaska Fairbanks**

NOAA Goal(s): Weather Ready Nation

Amendment 65 NOAA Office: NESDIS, Dan Lindsey, Sponsor

Budget Amount: Cumulative $18,479, This year $0

This project is complete.

Primary objectives

The production of river ice and flooding products from the SNPP VIIRS sensor direct readout data has been very successful in Alaska. The product is used during spring break-up and floods by the NWS Alaska-Pacific River Forecast Center and has been reviewed favorably by the operational hydrologists and forecasters. The products are generated in near-real-time using direct readout data captured by UAF-GINA in Fairbanks and processed and distributed to the NWS through a collaboration of UAF-GINA, George Mason University, and the University of Wisconsin Madison Space Science and Engineering Center (SSEC).

This project extends and leverages the success of the river ice and flooding initiative VIIRS products (developed under JPSS program sponsorship) by creating systems to generate similar products using GOES-R Advanced Baseline Imager (ABI) data.

Research accomplishments/highlights/findings

1. GINA provided system administration support and monitoring for the physical server processing and supplying data for the river ice and flood products.
2. GINA installed, configured, and deployed a new physical server hosting the programs, libraries, and tools necessary for data generation. The migration of services and CCNY River Products was coordinated with Jay Hoffman from SSEC. Completed the transition of production services to the new hardware in June 2018. Retired the original hardware which had surpassed its end of life.
3. Worked with the NWS APRFC to resolve issues with displaying the River products in the Advanced Weather Interactive Processing System (AWIPS).
4. Coordinated with the NWS APRFC and Jay Hoffman from SSEC to include NOAA-20 data in the River products.

NOAA relevance/societal benefits

Flooding caused by ice jams damming a river during spring break-up is a major hazard for communities along Alaskan rivers. Many of the most destructive floods in Alaska's history were caused by ice jams. The ability to monitor large reaches of river using satellite data gives NWS forecasters and hydrologists valuable information for issuing warnings and forecasts. Without satellite observations, hydrologists must rely upon observations of very limited spatial extent, such as observers on the river bank and small aircraft flights. For scale, more than 1200 miles of the

Yukon River runs through Alaska and it is one of dozens of rivers subject to ice jam flooding.

Partner organizations and collaborators

- NWS Alaska-Pacific River Forecast Center (APRFC)
- George Mason University
- JPSS Program Office
- GOES-R Program Office
- Space Science and Engineering Center (SSEC) at University of Wisconsin-Madison

Regional Rapid Response for Weather and Sea Ice Mapping

Catherine Cahill, PI **CIFAR theme(s): Climate Change and Variability**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
John Coffey, **supporting NOAA UAS Program**
Greg Foscue, **Unmanned Systems Alaska**
Justin Humphries, **Unmanned Systems Alaska**
Robert Parcell, **University of Alaska Fairbanks**
Joseph Rife, **University of Alaska Fairbanks**
Eyal Saiet, **University of Alaska Fairbanks**
Joncy Walden, **Unmanned Systems Alaska**
Andrew Wentworth, **University of Alaska Fairbanks**

NOAA Goal(s): Resilient Coastal Communities and Economies; Climate Adaptation and Mitigation

Amendments 76 NOAA Office: OAR, Phil Hall, Sponsor

Budget Amount: Cumulative $368,652, This year $0

This project is on extension and set to end 06/30/2019

Primary objectives

The Alaska Center for UAS Integration (ACUASI) in the Geophysical Institute at the University of Alaska Fairbanks (UAF) conducted a multi-week flight campaign during fall of 2018 using their Griffon Aerospace Outlaw SeaHunter UAS platform (a UAS with a 16' wingspan, a maximum take-off weight of approximately 300 lbs, and an endurance of up to 10 hours). The campaign was designed to support the Office of Naval Research's Stratified Ocean Dynamics of the Arctic (SODA) experiment by mapping sea ice and collecting meteorological measurements over the Arctic Ocean. The flights were launched from the North Slope of Alaska, specifically ConocoPhillips's airport at Kuparuk, AK. This campaign leveraged ACUASI's 16-year history of flying UAS in Alaska and the Arctic, and included beyond-visual-line-of-sight (BVLOS) operations over the Arctic Ocean in Warning Area 220. One of the purposes of these missions was to create a concept of operations and operational system for collecting information important to NOAA scientists from locations over the Arctic Ocean. The payload for the missions included cameras and a University of Colorado miniFlux meteorological sensor to collect images of surface roughness, albedo, ridging, sea ice motion, percentage of ice covered by water, etc. and meteorological variables needed by sea ice experts and climate scientists to understand ice dynamics, validate or initialize climate models, and validate satellite retrievals of ice surface parameters.

Research accomplishments/highlights/findings

While this research was initiated and concepted at NOAA's Arctic Domain Awareness Workshop in January 2017, the timing of this flight campaign was shifted into 2018 to support the SODA experiment.

Prior to SeaHunter operating over the Arctic Ocean and as a hazardous weather risk mitigator, a portion of a SeaHunter wing was tested in NASA's Glenn Research Center's Icing Research Tunnel to: 1) determine aircraft icing potential and maritime Arctic survivability, 2) test the PEMDAS Atmospheric Sensing and Prediction System's (ASAPS) ability to identify when aircraft are in icing

and cloud conditions, and 3) validate the NASA LEWICE model for predicting aircraft icing. Under severe icing conditions, the ASAPS correctly characterized the conditions, ice formed on the SeaHunter wing, and the ice shapes were scanned for comparison with the LEWICE predictions. The team further tested the PEMDAS Atmospheric Sensing and Prediction System's (ASAPS) ability to identify when the aircraft was in icing and cloud conditions over the Arctic Ocean during the flight campaign. The ASAPS correctly characterized the conditions around the SeaHunter, as observed by the onboard camera and meteorological sensors and predicted by the National Weather Service/NOAA/CU/UAF weather forecasting team, and improved the team's confidence in being able to fly a UAS BVLOS safely over the Arctic Ocean. The results of these tests should help NOAA improve the survivability of their aircraft in the Arctic and under icing conditions.

Figure 1. SeaHunter flying over the North Slope of Alaska in October. Photo courtesy of Jordan W. Murdock and Robert J. Edison.

The UAF/NOAA/CU team successfully integrated the miniFlux package, the sensor sticking out of the nose of the aircraft as shown in Figure 1.

The UAF/NOAA/CU team conducted several SeaHunter flights around and offshore of Kuparuk, AK, during October 2018. Unfortunately the meteorological conditions hindered the team's ability to operate the aircraft in accordance with FAA regulations. The icing and poor visibility conditions that occurred during the field campaign limited the number of days the aircraft had conditions suitable for safe flight. The additional requirement for a chase plane to escort the UAS from the Kuparuk airport to Warning Area 220 further limited the number of days available for flight due to the chase plane coming in from another airport that occasionally had worse conditions than Kuparuk and prevented the chase plane from reaching Kuparuk. These conditions highlighted the need for better anti-icing and deicing technologies for the safe use of UAS in the Arctic.

Figure 2. Sea ice image from the SeaHunter

The miniFlux and camera payloads did acquire meteorological data and sea ice imagery (Figure 2) during the few flights that occurred during the flight campaign. The data is being analyzed and the results are being prepared for conference presentations and journal articles.

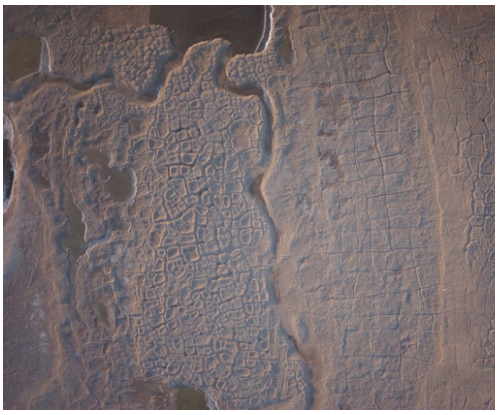

Figure 3. Ice wedge polygons image

The imagery collected around the Kuparuk airport showed many additional permafrost, ice, and snow features that may be of interest to scientists. For example, Figure 3 shows ice wedge polygons near Kuparuk. This imagery shows that UAS could be useful for collecting data for diverse other NOAA efforts.

The results of the flights and the pioneering wind-tunnel testing are being prepared for conference presentations and journal articles.

NOAA relevance/societal benefits

The efforts planned for this project will provide NOAA support to a multi-agency arctic science endeavor. Additionally, the testing of the effectiveness of the unmanned aircraft system, payloads, and concepts of operations under real-world conditions will assist NOAA with developing unmanned aircraft systems as tools for: 1) the collection of NOAA-relevant scientific information in remote or hazardous locations and 2) support of NOAA maritime operations such as oil spill response and marine mammal surveys. The data obtained from these systems will assist in validating weather and climate models and improving weather forecasting.

Partner organizations and collaborators

- NOAA Unmanned Aircraft Systems (UAS) Program
- National Weather Service
- National Sea Ice Data Center
- Gijs de Boer, Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder
- Janet M. Intrieri, NOAA/ESRL Physical Sciences Division
- Robert P. Dahlgren, NASA-Ames

Impact

The impact of this work is to help develop a tool for NOAA capable of supporting NOAA science and operational missions in remote and hazardous locations.

Education

Images from these flights are being incorporated into lectures delivered to students and students assisted with the integration of the payloads onto the SeaHunter.

Outreach

The missions and resulting photographs have been used in multiple presentations to students, the public, and governmental officials to show the potential for unmanned aircraft to conduct scientific missions, marine mammal surveys, and maritime domain awareness for NOAA and other federal agencies.

Publications

Journal articles are being prepared for publication. These will include an article by Gijs de Boer that will focus on the miniFlux sensor package and data obtained during SODA.

Conference presentations

Pictures from the flight campaign and ice tunnel testing have been incorporated into many presentations, but no true conference presentations based solely on the results of this testing have been presented. For example, a briefing to The Office of Science and Technology Policy about SODA included the results from this work, but it was not the primary focus of the presentation.

Other products and outcomes

N/A

Enhanced Tools and Training for Subseasonal to Seasonal Outlooks to Support Decision Makers for Potential High Impact Events at Higher Latitudes

John Walsh, PI **CIFAR theme(s): Climate Change and Variability**

University of Alaska Fairbanks

Other investigators/professionals associated with this project:
Nathan Kettle, Peter Bieniek, Soumik Basu, Richard Thoman, Casey Brown, **University of Alaska Fairbanks**

NOAA Goal(s): Weather Ready Nation; Climate Adaptation and Mitigation

Amendment 79 NOAA Office: NWS, Eugene Petrescu, Sponsor

Budget Amount: Cumulative $147,465, This year $0

This project is complete.

Primary objectives

- Develop a climatology of storm tracks (locations and intensity) in the hindcasts of 1982-2010 by forecast models (CFSv2 and other NMME models if available) based on a sea-level-pressure-based algorithm applied at 6-hourly intervals
- Develop anomalies of storm tracks (location and intensity) in the Alaska sector from forecast models
- For a demonstration set of variables based on services needs and priorities as well as available resources, develop hindcast-based climatologies and bias statistics, together with anomalies and bias-corrected metrics from real-time models (e.g., CFSv2)
- Compile an assessment of Alaska and Arctic user needs, primarily a review of current literature and ongoing projects of the Alaska Center for Climate Assessment and Policy
- Deliver a set of recommended climate tools needed for selected decision support services

Research accomplishments/highlights/findings

Activity 1: Published paper on high-wind events in Alaska

We have published a paper (Basu and Walsh, 2018, *Atmospheric and Climate Sciences*) synthesizing observational data and model simulations of winds over Alaska, with a focus on high-wind events. Eleven first-order stations across different subregions of Alaska provided historical data for the observational climatology and for the calibration of CMIP5 simulations, which in turn provided projections of changes in winds through 2100. From the observational data, winds exceeding 25 and 35 knots were found to be most common in the Bering Sea coastal region of Alaska, followed by northern Alaska coastal areas. Autumn and winter are the seasons of most frequent high-wind occurrences in the coastal sites, while there is no distinct seasonal peak at the interior stations where high-wind events are less frequent. An examination of the sea level pressure pattern associated with the highest-wind event at each station reveals the presence of a strong pressure gradient associated with an extratropical cyclone in most cases. The CMIP5 output showed that the northern coastal regions of Alaska are projected to experience increased frequencies of high-wind events during the cold season, especially late autumn and early winter, when reduced sea ice cover in the late century will leave coastal regions increasingly vulnerable

to flooding and erosion. Figure 1 shows that the projected changes are generally consistent with northward shifts of the wind speed maxim, which are found farthest north during the warm seasons.

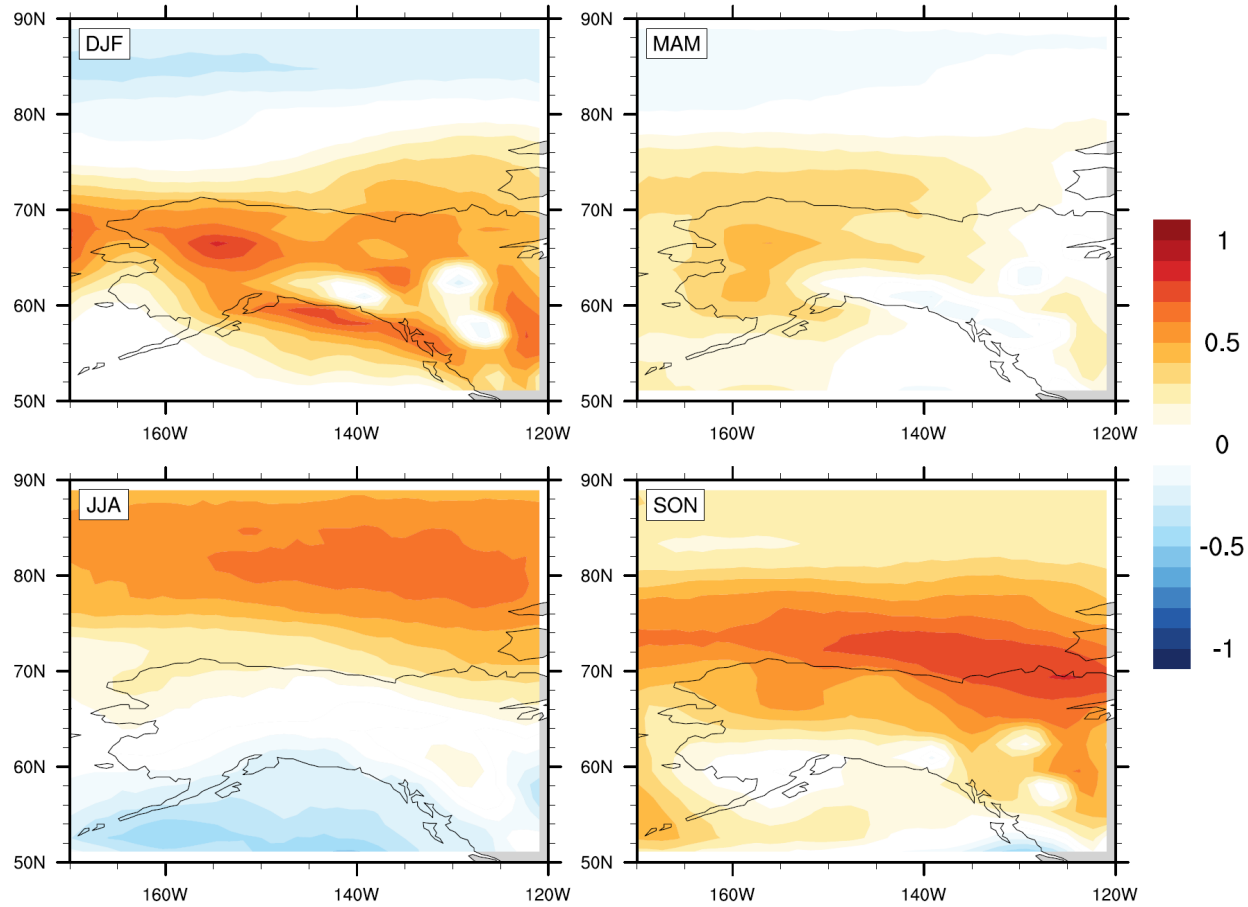

Figure 1. All-model average of seasonal mean wind speed differences (m sec-1), RCP 8.5, 2070-2100 minus Historical (1985-2005). Panels are for winter, Dec-Feb (upper left); spring, Mar-May (upper right); summer, Jun-Aug (lower left); autumn, Sep-Nov (lower right).

Activity 2: Role of storms in the Bering Sea extreme ice minimum of 2018

As part of a paper for the *Bulletin of the American Meteorological Society (BAMS)* annual special issue on extreme events (of 2018, in this case), we are preparing a paper on the extreme sea ice minimum of 2018 in the Bering Sea. The diagnostic analysis of the drivers of this record-breaking minimum includes an evaluation of the Bering Sea's storm activity of 2018 relative to the historical other years. Using the NCEP-NCAR reanalysis for 1949-2018, we evaluated the rank of 2018's southerly wind strength (a proxy for "storminess") relative to all other years in the 60-year record. As shown in Figure 2, the winter of December 2017 - February 2018 ranked among the top several winters by this metric, but it was not the highest-ranking winter of the 60-year period. The implication is that storm activity was a contributing factor to the extreme minimum of sea ice in 2018, but that it was not the sole reason for the record ice minimum. Additional analyses within this study show that anthropogenic forcing also contributed to the extreme minimum. This paper

for the BAMS special issue on extreme events is scheduled to be submitted at the end of April, 2019.

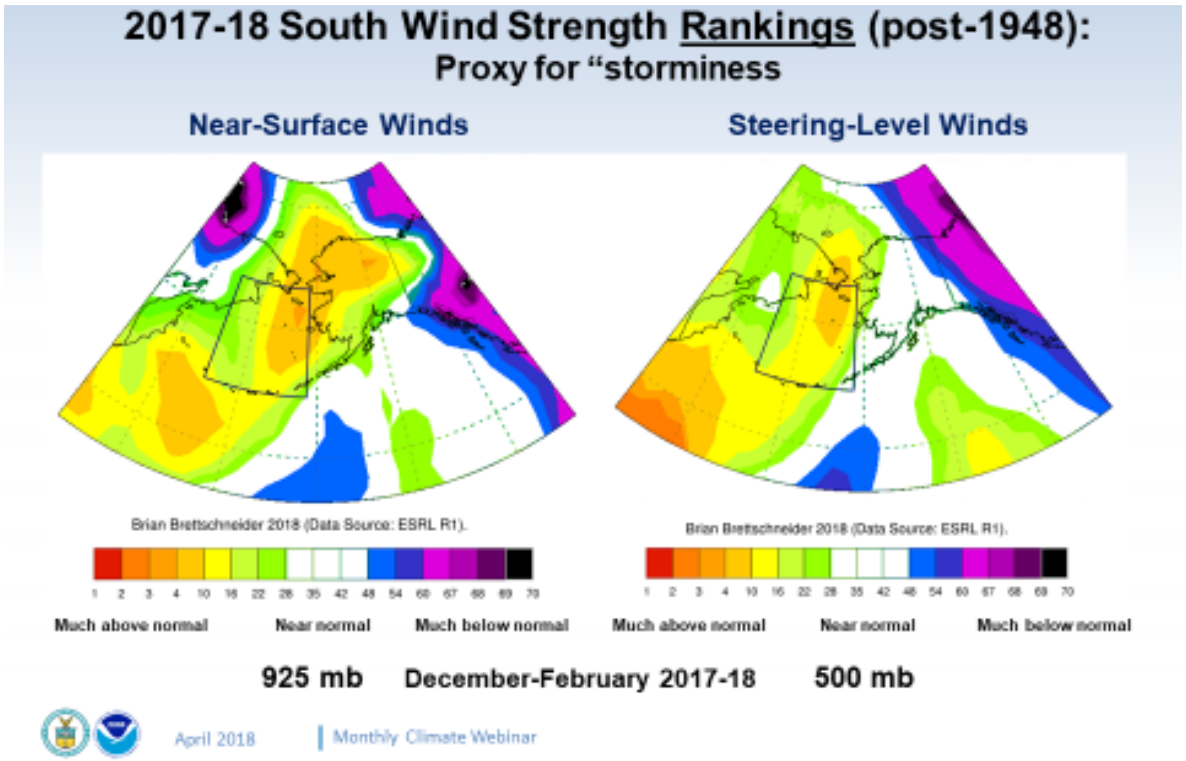

Figure 2. Rank (among 60 winters ending in 1949-2018) of the southerly wind strength over the North Pacific sector. Ranks range from much above normal (orange, yellow) to much below normal (purple, blue). The left panel shows the ranks for near-surface (925 hPa) winds, the right panel shows the ranks for steering-level (500 hPa) winds. Figure provided by Brian Brettschneider, Alaska Center for Climate Assessment and Policy.

Activity 3: Distance learning modules on climate decision support in the Arctic.

- The primary goals of this activity are to (1) compile an assessment of Alaska and Arctic user needs, primarily from a review of current literature and (2) deliver a set of recommended climate tools needed for selected sector decision support services. Two primary datasets are being developed and assessed to achieve these goals: a review of the literature and questionnaires.

Literature Review

- We are a conducting a review and synthesis of climate information needs assessment documents in Alaska. 103 documents have been identified so far via web-based searches and conversations with local experts. A document was included in the analysis if: 1) the document was generated by a stakeholder group, 2) it related to climate change and 3) it identified one or more climate change research needs. Scholarly articles or science plans were not included in the analysis. Coding of existing climate research needs assessments and documents have followed methods outlined in Knapp and Trainor 2013, Knapp and

Trainor 2015. Coding includes specific identifiers for coastal storms and changing weather patterns to help guide future planning efforts for the selection of NWS weather products.

Questionnaires

- Information from the literature review is being supplemented by data gathered from two surveys. One survey targets NWS Alaska Staff. This questionnaire has been developed, will undergo review by UAF's Institutional Review Board (IRB), and is anticipated to be administered in the next 2 months. The questionnaire covers topics related to (1) challenges in data monitoring, analysis and prediction in Alaska; (2) desired tools to carry out tasks more efficiently and effectively; (3) how to improve the customer-interface; and (4) desired trainings. A second survey targets individuals who have attended trainings on tribal climate adaptation planning, sponsored by the Alaska Native Tribal Health Consortium (ANTHC) and Institute for Tribal Environmental Professionals (ITEP). The survey has been developed, is under review by ANTHC and ITEP, will be reviewed by IRB, and is anticipated to be administered in by May.

NOAA relevance/societal benefits

The project is targeting storms and other extreme events that represent environmental hazards to people and property in Alaska. Protection of life and property is a primary mission of NOAA. Storminess outlooks at time scales of weeks to months are frequently requested in Alaska because of the high impacts (flooding, erosion) of coastal storms, especially during the summer and autumn (and increasingly the winter) when sea ice is not present to buffer the coast. Alaska's north and west coasts are especially vulnerable due often to single points of failure of community infrastructure and isolated location, with no road connections to the outside world. These constraints make long lead times necessary for both tactical decisions and strategic planning. Higher storminess than average is understood by core partners as being in some sense proportional to the risk of significant coastal flooding. Preliminary work by the NWS Alaska Region suggests that significant coastal flooding events in the past 60 years have occurred primarily, although not exclusively, in seasons with above-average numbers of storms.

A second benefit of the proposed work is the direct engagement of stakeholders (Activity 3, see above) in guiding the products and methods of communication that will most benefit users of the information. This engagement is already providing guidance on relevant thresholds and metrics for enhanced utility of the forecasts and outlooks.

Partner organizations and collaborators

- NOAA National Weather Service (Alaska Region)
- Alaska Center for Climate Assessment and Policy (ACCAP)
- Alaska Native Tribal Health Consortium (ANTHC
- Institute for Tribal Environmental Professionals (ITEP).

Impact

Utilization of long-lead outlooks for hazards such as storms will enable advance preparation by coastal communities and industries active in Alaska's coastal waters. Planning can include strengthening of coastal protection (e.g., coastal berms), movement of vehicles and other

equipment, and secure storage of provisions. Offshore activities (e.g., barge operations, commercial, resource exploration/extraction, subsistence fishing and hunting) can also be rescheduled by operators to minimize risks to life and property. Finally, longer-term trends in storms and other hazards can be incorporated into adaptation plans by coastal communities and other affected stakeholders.

Education

Products developed here are intended primarily to meet the needs of stakeholders, decision-makers, and planners.

Outreach

A major goal of Activity 3 is to deliver a set of recommended climate tools needed for selected sector decision support services. Our elicitation of user needs via questionnaires and literature reviews represents a key step in bridging NOAA operational activities and user needs.

A second phase of outreach can take place after the products identified in this project have been transitioned to operations. This phase, which will consist of user feedback on the products, is beyond the 9-month timeline of the present project.

Publications

Basu, S., and J. E. Walsh, 2018: Climatological characteristics of historical and high-wind events in Alaska. *Atmospheric and Climate Sciences, 8*, 373-394, https://doi.org/10.4236/acs.2018.84025

Thoman, R. L., P. A. Bieniek, T. T. Lader, Jr., J. E. Walsh, U.S. Bhatt, S. Danielson, W. Meier, Z. Labe, M. Brubaker, and G. Sheffield, 2019: The Bering Sea's record-breaking absence of sea ice durng the winter and spring of 2018. *Bulletin of the American Meteorological Society*, to be submitted May 2019.

Conference presentations

Crouch, J., J. Walsh, and A. Artusa, 2018: NOAA Climate Science and Services Monthly Climate Update. April 17, 2018.

Thoman, R. L., 2018: Winter sea ice in western Alaska (2017-2018): Past, present and future. 2018 Western Alaska Interdisciplinary Science Conference, Nome Alaska, April, 2018.

Other products and outcomes

The high-wind climatology (Activity 1) and CFSv2 forecasts described in our prior annual report were used in support of the U.S. Navy's ICEX field program in the Beaufort Sea during the spring of 2018. This information augmented the short-range forecasts provided to the ICEX project by the National Weather Service. The broad pattern of surface winds forecast by the CFSv2 in early February was found to correspond with the observed March winds (and drift of the ice camp). However, the CFSv2 forecast of March sea ice thickness showed a geographical pattern different from the March sea ice thickness derived from CryoSat measurements: the former had the thickest ice along the northeastern Russian coast, while the thickest ice measured by CryoSat was offshore of the Canadian Archipelago.

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

Martin Stuefer, PI

Peter Webley, co-PI

University of Alaska Fairbanks

CIFAR theme: Coastal Hazards

Other investigators/professionals associated with this project:
Marcus Hirtl, **University of Alaska Fairbanks**
Sean Egan, **University of Alaska Fairbanks**
Georg A Grell, **NOAA-ESRL**
Ravan Ahmadov, **NOAA-ESRL**
Trevor Alcott, **NOAA-ESRL**
Mike J Pavolonis, **NOAA-NESDIS**

NOAA Goal(s): Weather Ready Nation

Amendments 21, 37

NOAA Office NESDIS; Andrew Heidinger, Sponsor

Budget Amount: Cumulative $194,364, This year $0

This project is set to end 06/30/2019.

Primary objectives

The GOES-R Advanced Baseline Imager Volcanic Ash Algorithm (ABI-VAA) data are used to initialize the WRF-Chem model. The modeled ash plumes allow to better understand and to verify eruption source parameters (ESP). The goal is to derive realistic ESP and provide a useful volcanic ash hazard mitigation tool. We updated a newer version of the WRF-Chem model (version 3.9) in order to predict volcanic ash plumes using the latest physics packages. Model runs are executed automatically whenever a volcanic eruption alert is received. Automated routines to ingest volcanic ash alerts within the WRF-Chem and NOAA's Rapid Refresh (HRRR) modelling environments have been developed and are further refined. There were no significant case studies occurring within our modelling domain in 2018. Further simulations of the Eyjafjallajökull eruption in Iceland (April and May 2010) have been performed to verify modeled particle aggregation processes with observations of ash particle microphysics.

Research accomplishments/highlights/findings

Significant progress has been achieved to complete the proposed milestones.

1. Automatic WRF-Chem simulations are produced. We updated the volcanic emission driver and implemented the code into WRF-Chem Version 3.9.
2. Our progress has been discussed during a meeting with our collaboration partners from NOAA ESRL in Boulder, Colorado, in September 2018. The volcanic emission application of WRF-Chem is functional, and with the implementation of the volcanic code into the newer version of WRF-Chem, our alerts could be incorporated into the High Resolution Rapid Refresh (HRRR). The implementation will need a reduction of ash bins from currently 10 bins to one or two bins in order to be less computing intensive. Further discussions were

focused on the reduction of false volcanic activity alerts. The HRRR environment is designed to show solely confirmed volcanic aerosol cases in near real time.

3. Typically, volcanic eruption source parameters (ESP) such as erupted mass, particle size distribution or initial plume heights are not well observed in real time. As a consequence, we use default ESP derived from a database based on historic eruptive cases. To account for a range of possible ESP, we would need a number of volcanic ash model runs with varying ESP in order to build a useful real time tool. Good estimates of the initial plume dimensions are important to predict the atmospheric dispersion of the plume realistically. - We have implemented ensembles of plume heights within one WRF-Chem run in order to have model output available at the moment when satellite observations of the ash plume become available. A superimposition of the plume ensemble also allows to create maps of negative ash, which might be of interest especially for aviation stakeholders.
4. A repository with webpage scripts and a test webpage has been created on Github. Webpage updates with hypothetic ash clouds (from orange coded eruption alerts) and test cases were created at a prototype demonstration webpage was created at http://plume.alaska.edu/index_tmp.html. However, we need a more pronounced distinction between hypothetic plumes and real plumes. Webpage graphics have been removed from the webpage for the moment.
5. Further comparison of modelled ash plumes with particle measurements shows evidence that ash particles mostly tend to aggregate. Work was continued to refine our aggregation parametrization.

We are receiving volcanic activity alerts from the Anchorage Volcanic Ash Advisory Center (VAAC) and from the VOLcanic Cloud Analysis Toolkit (VOLCAT) from M. Pavolonis. Volcanic WRF-Chem runs are automatically executed whenever VAAC or VOLCAT alerts are received, which occurs normally on a daily basis and sometimes multiple times a day. There were no significant events accounting for a case study to evaluate GOES-R volcanic ash alerts during the recent months. However, our work aims to be well prepared for a real-time case. Initial forecast graphics and automatic webpage update scripts have been developed.

We adapted and improved our WRF-Chem modeling environment to use a new version of WRF-Chem (version 3.9), and to create an ensemble of possible volcanic eruption source scenarios within one WRF-Chem run. The ensemble is accomplished by changing ash particle concentrations to account for very fine ash (particles less than 3.9 µm in diameter) and coarse ash (particles with 1-2mm in diameter) and associating the 2 particle sizes with various plume heights. Originally, we introduced a number of 10 ash bins in WRF-Chem (Stuefer et al., 2013) to account for ash particles with a range of different sizes. Reducing this range of sizes to only 2 sizes, and associating these 2 sizes to different plume heights (instead of 1 plume height) allows to create a prognostic tool for near real time volcanic plume prediction. Typically, the eruption source parameters (ESP) are not observed well in real time; volcanic ash advisory centers detect seismic activities near a volcano, or there is a thermal anomaly or a combination of thermal anomalies and predicted atmospheric stability to derive a first guess of a volcanic plume. The WRF-Chem ensemble of fine ash and varying plume heights allows to predict the afar dispersion of the plume and areas of 'negative ash'. Regions of negative ash are of main interest for example for aircraft traffic. The varying plume

heights consist of 5 assumed plumes that include as a 'center plume height' either the plume height detection from the initial VOLCAT or GOES-R volcanic baseline alert, or the default ESP used within WRF-Chem (Stuefer et al., 2013). Additional plume heights are introduced at 30%, 70%, 150% and 300% of the center height. In analogy to fine ash, we set up WRF-Chem with coarse ash particles and the 5 varying plume heights (as above) in order to predict ash fallout in the vicinity of the erupting volcano. The ash fallout prediction is especially important for hazard mitigation to life on the ground and to protect infrastructure.

Progress was achieved implementing a volcanic ash aggregation scheme into WRF-Chem. Microphysical analysis of ash particles showed strong evidence that ash particles typically aggregate to larger particles during the atmospheric dispersion. We used a simplified version of the Smoluchowski Coagulation Equation, which allowed to parameterize and introduce the aggregation process between particles of fine ash into the base chemistry code of WRF-Chem (Von Smoluchowski, 1917). Aggregation depends on various ash particle collision parameters. The aggregation model was compared to remote sensing, field measurements of tephra fallout and in situ observations of the April/May 2010 ash particle dispersion during the eruptions of Eyjafjallajökull Volcano. We compared measured ash particle concentrations with WRF-Chem derived ash concentrations, and found better agreement in concentrations using the aggregation code. In addition, we note a decrease in the lifetime of volcanic fine ash by a factor of three. A publication describing the implementation of the aggregation scheme into WRF-Chem is in progress and will be submitted in late spring/summer 2019.

The WRF-Chem modeled aerosol processes as well as interactions between meteorology and air quality result in realistic prediction of main meteorological variables such as temperature and wind speed. The coupled VOLC WRF-Chem model runs simulates a more realistic atmospheric state and highlights that the current aerosol parameterization within WRF-Chem is both useful and provides equivalent results to observational data. Our evaluation shows that the observed meteorology is regionally affected by the source of the emissions and the initial plume distribution.

Further accomplishments are described in the report for our continuing and overlapping project, GOES-R Volcanic Ash Risk Reduction (R3): New operational GOES-R decision support within NOAA's High Resolution Rapid Refresh.

NOAA relevance/societal benefits

GOES-R is a key element in NOAA's ongoing satellite series. We provide a confirmation, validation and assessment of one of the GOES-R baseline products. We also 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. The GOES-R high temporal resolution in combination with the Rapid Refresh (RAP) model will allow for a timely volcanic ash hazard awareness and dissemination of volcanic warnings.

Partner organizations and collaborators

- Georg Grell, NOAA Earth Systems Research Laboratory
- Michael J Pavolonis, NOAA/NESDIS Center for Satellite Applications and Research (STAR)

Impact, Other products and outcomes

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 derived GOES-R volcanic ash products can only determine the ash cloud location and mass loadings at one instant in time. This project analyzes the ash products from satellite data with products from volcanic ash transport and dispersion models.

We have highlighted 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.

Education

- Sean Egan is a Ph.D. candidate student in Environmental Chemistry at UAF working within this project.
- Marcus Hirtl is a Ph.D. candidate student within the Interdisciplinary Program at UAF working on this project.

Publications and Presentations

S.D. Egan, M. Stuefer, P. Webley, C. F. Cahill, M. Hirtl, G. Grell: Inclusion of volcanic ash aggregation processes in the Weather Research Forecasting with Chemistry model, with impacts on the April/May 2010 eruptions of Eyjafjallajökull, to be submitted to Natural Hazards and Earth *System Sciences* (NHESS) in late spring/summer 2019.

M. Hirtl, D. Arnold, C. Maurer, S. Natali, M. Stuefer, G. Grell, P. Webley, B. Scherlin-Pirscher and others: EUNADICS demonstration exercise for an artificial volcanic eruption scenario in Europe and the impacts on aviation, to be submitted to Natural Hazards and Earth *System Sciences* (NHESS) in summer 2019.

Alaska Earthquake Center seismic station operations and maintenance

Michael West, PI **CIFAR theme(s): Coastal Hazards**

Natalia Ruppert, Co-PI

University of Alaska Fairbanks

Other investigators/professionals associated with this project (w/affiliation):

Miriam Braun, Dan Brazitis, Scott Dalton, Ian Dickson, Dara Merz, Nate Murphy, Natalia Kozyreva, Mitch Robinson, **University of Alaska Fairbanks**

NOAA Goal(s): Weather Ready Nation

Amendments 7, 26, 41, 61, 71 NOAA Office: NWS, Michael Angove, Sponsor

Budget Amount: Cumulative $1,094,981, This year $240,000 (Amendment 71)

This project is complete.

Primary objectives

- Maintain NOAA-sponsored seismic stations in the integrated Alaska Seismic Network
- Upgrade stations to Advanced National Seismic System (ANSS) standards for modern broadband equipment and telemetry. Maintain data flow of selected stations to the National and Pacific Tsunami Warning Centers.
- Detect seismic events occurring in Alaska as a means of seismic data quality control and to support improved knowledge of tsunamigenic earthquake sources.

Research Accomplishments/highlights:

The average return rate for the 17 NOAA-funded stations (minus DCPH) was 95%; 95% for eight sites that are currently supported and 95% for 9 de-scoped sites (not counting DCPH), over the target rate of 90%. DCPH, located in Glacier Bay National Park, remains out of service due to ongoing discussions with USCG regarding site co-location. All required paperwork with USCG is now nearly complete and we are hoping to re-install this site during the coming field season. Three sites had data return rates less than 90%: ATKA, NIKH and PIN. The station in Atka continued to experience outages due to telecommunications and networking issues, but performed much better than in previous reporting period (87% vs 69% overall data return). Station NIKH in Nikolsky suffered a power system component failure which was repaired on February 28, 2019, but the site remains out due to some other reason. The troubleshooting is ongoing. Station PIN near Yakutat has underperforming power system due to heavy snow loads in winter time. It was the worst performing station during the reporting period.

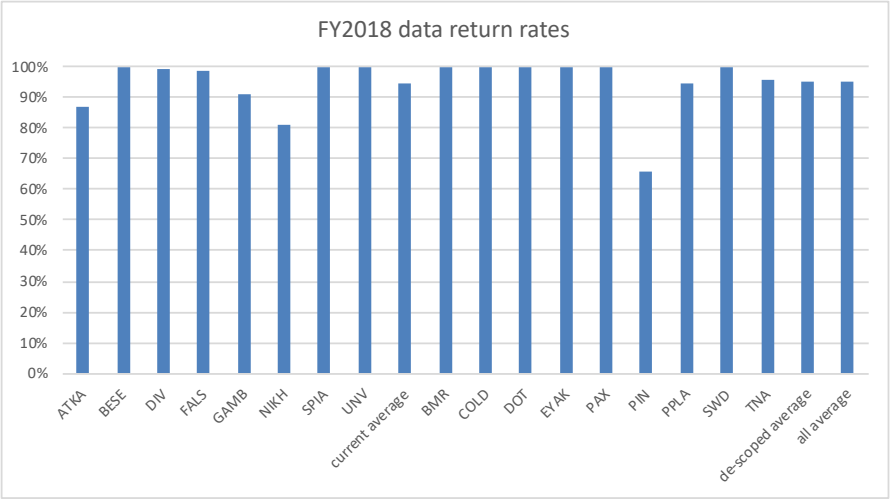

Figure 1. Data return rates for NOAA-funded stations.

During this reporting period we upgraded sites PIN, PNL, BMR and DIV with 9', steel-cased boreholes and installed new strong motion and posthole broadband sensors. This work was conducted with assistance and support of the Earthscope's USArray project.

Between April 1, 2018 and February 23, 2019, the Alaska Earthquake Center reported more than 40,000 events, with magnitudes ranging between -0.35 and 7.1 and depths between 0 and 300 km (Figure 2). Event reporting for the entire reporting period is incomplete due an increased amount of seismic activity and insufficient staff time to process events. The total over the reporting period is predicted to be closer to 50,000 which would be an increase over the previous reporting period. The largest and most notable earthquake, of magnitude 7.1 occurred on November 30, 2018. The earthquake caused widespread damage to Anchorage and surrounding areas. Damage included infrastructure damage, landslides and liquefaction. Nearly 9,000 aftershocks have been recorded to date. Aftershocks continue from the M7.9 offshore Kodiak earthquake that occurred on January 24, 2018 (previous reporting period). These aftershocks are critical to assessing the mechanics of the earthquake. A magnitude 6.4 and subsequent 6.0 aftershock occurred in northeastern Alaska, south of Kaktovik on August 12. This is the largest earthquake ever recorded on the north slope of Alaska. More than 4,000 aftershocks have been recorded to date. August 15-23, three magnitude 6-plus earthquakes occurred off the coast of Tanaga Island in the Aleutians. On October 24, an unusual Magnitude 4.9 event occurred of the coast of Hooper Bay in the Bering Sea. A magnitude 6.1 occurred off coast of the Alaska Peninsula on December 31.

The addition of EarthScope USArray stations throughout Alaska has vastly improved the accuracy and detection thresholds for earthquakes. The distribution and fidelity of USArray stations has significantly improved the ability to quickly determine the tsunamigenic potential of earthquakes occurring offshore Alaska.

With the assistance from the EarthScope USArray program, The Earthquake Center was able to replace broadband sensors at all CRESTNET borehole sites in recent years. However, equipment at other sites, including dataloggers, are approaching fifteen years in the field. Recent budgets do

not cover replacement of sensors and dataloggers. While several sites have benefitted from EarthScope- or state-provided instruments, other NOAA-funded sites will require additional support to replace aging equipment.

During the reporting period, we visited 7 NOAA-funded sites and performed the following work:

- ATKA (Atka) September 30, 2018 – swapped out Q330.
- BMR (Bremner, Chugach Mountains) July 29, 2018 - installation of a new borehole and instruments as part of the EarthScope USArray.
- DIV (Divide) July 28, 2018 - installation of a new borehole and instruments as part of the EarthScope USArray.
- DOT (Dot Lake) May 23, 2018 – swapped out sensors.
- GAMB (Gambell) September 27, 2018 – inspected the site and repaired the antenna mast that had fallen.
- NIKH (Nikolski) February 26-28, 2019 – replaced a single power switch with two newer models.
- PIN (Pinnacle, Yakutat Bay area) September 8, 2018 – installation of a new borehole and instruments as part of the EarthScope USArray and swap out batteries.

NOAA relevance/societal benefits

Faster and more accurate detection of tsunamigenic earthquakes by the NOAA tsunami warning centers and the Alaska Earthquake Center.

Data that support the development of geologically plausible earthquake scenarios for tsunami hazard modeling under NOAA's National Tsunami Hazard Mitigation Program.

Partner organizations and collaborators

N/A

Impact

- AEC continues to provide real-time and reviewed earthquake information to local emergency service offices and to the public. The primary means for this is the Earthquake Center website, earthquake.alaska.edu. The support and collaboration with NOAA is reiterated in several places across the site.
- While not an explicit part of this project, the earthquake catalog shown in Figure 1 is critical information used in the development of the tsunami inundation hazard products.

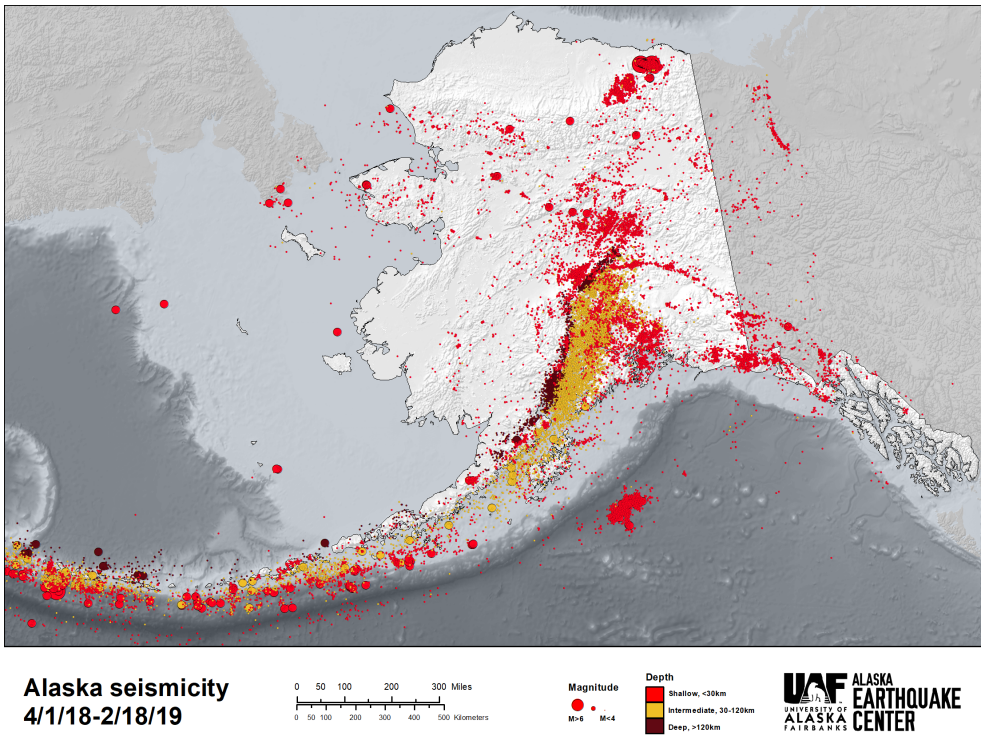

Figure 2. Map of seismicity from April 1, 2018 through February 18, 2019.

Publications

N/A. This award does not support research.

Conference presentations

N/A. This award does not support research.

GOES-R Volcanic Ash Risk Reduction (R3): New operational GOES-R decision support within NOAA's High Resolution Rapid Refresh

Martin Stuefer, PI

Peter Webley, co-PI

University of Alaska Fairbanks

CIFAR theme: Coastal Hazards

Other investigators/professionals associated with this project:
Marcus Hirtl, **University of Alaska Fairbanks**
Sean Egan, **University of Alaska Fairbanks**
Georg A Grell, **NOAA-ESRL**
Ravan Ahmadov, **NOAA-ESRL**
Trevor Alcott**, NOAA-ESRL**
Mike J Pavolonis, **NOAA-NESDIS**

NOAA Goal: Weather Ready Nation; Resilient Coastal Communities and Economics

Amendments 67 NOAA Office NESDIS; Dan Lindsey, Sponsor

Budget Amount: Cumulative $45,657, This year $0

This project is on extension and set to end 06/30/2019.

Primary objectives

We aim to test the ability to use GOES-R Advanced Baseline Imager Volcanic Ash Algorithm (ABI-VAA) data to define volcanic Eruptions Source Parameters (ESP) for volcanic activity. The GOES-R derived ESP data are necessary to initialize the volcanic emission parameterization routine within our fully automated University of Alaska Fairbanks (UAF) based Weather Research Forecast model coupled to Chemistry (WRF-Chem) environment and the modern data assimilation within NOAA's ESRL High Resolution Rapid Refresh (HRRR) modelling system. We have used aerosol aware physics packages within WRF-Chem to simulate volcanic aerosol-radiation-cloud feedback. Case studies have been performed running the model with and without aerosol feedback processes. The potential of aerosols from volcanic eruptions to alter the physical structure of the atmosphere has been evaluated during the reporting period for the well-documented historic case study of Eyjafjallajökull eruption in Iceland in April and May 2010. We showed that inclusion of volcanic aerosol within the numerical weather model improved the weather prediction. Further evaluation follows for GOES- R ABI-VAA ash detections in the future. Initial volcanic ash model initialization routines have been implemented into NOAA's HRRR system. The routines are ready to accept volcanic plume characteristics as derived from the GOES-R ABI-VAA. We are working in close collaboration with our colleagues from NOAA's ESRL, conduct benchmark tests and comparisons of the best ESP to be used by the HRRR - and UAF WRF-Chem models.

We developed a variation of the volcanic emission driver used within the WRF-Chem model, which allows to run an ensemble of varying ESP within one WRF-Chem run. The objective is to create a near real time hazard mitigation tool, and to have the ability to discuss ABI-VAA (or similar) derived volcanic ESP. The superimposition of plumes originating from a possible range of initial plume altitudes allows to predict areas of 'negative ash' with high confidence. Regions of negative ash are of main interest for managing air traffic during an explosive volcanic event. The varying plume heights consist of 5 assumed plumes that include as a 'center plume height' either the plume height detection from the initial VOLCAT or GOES-R volcanic baseline alert, or the default historic

ESP used within WRF-Chem.

Research accomplishments/highlights/findings

Main accomplishments for this period were:

1. Automatic WRF-Chem simulations are produced. We updated the volcanic emission driver and implemented the code into WRF-Chem Version 3.9.
2. Our progress has been discussed during a meeting with our collaboration partners from NOAA ESRL in Boulder, Colorado, in September 2018. The volcanic emission application of WRF-Chem is functional, and with the implementation of the volcanic code into the newer version of WRF-Chem, our alerts could be incorporated into the High Resolution Rapid Refresh (HRRR). The implementation will need a reduction of ash bins from currently 10 bins to one or two bins in order to be less computing intensive. Further discussions were focused on the reduction of false volcanic activity alerts. The HRRR runs should potentially show only real cases in near real time.
3. Typically, volcanic eruption source parameters (ESP) such as erupted mass, particle size distribution or initial plume heights are not well observed in real time. As a consequence, we use default ESP derived from a database based on historic eruptive cases. To account for a range of possible ESP, we would need a number of volcanic ash model runs with varying ESP in order to build a useful real time tool. Good estimates of the initial plume dimensions are important to predict the atmospheric dispersion of the plume realistically. - We have implemented ensembles of plume heights within one WRF-Chem run in order to have model output available at the moment when satellite observations of the ash plume become available. A superimposition of the plume ensemble also allows to create maps of negative ash, which might be of interest especially for aviation stakeholders.
4. A repository with webpage scripts and a test webpage has been created on Github. Webpage updates with hypothetic ash clouds (from orange coded eruption alerts) and test cases were created at a prototype demonstration webpage was created at http://plume.alaska.edu/index_tmp.html. However we need a more pronounced distinction between hypothetic plumes and real plumes. Webpage graphics have been removed from the webpage for the moment.
5. Further comparison of modelled ash plumes with particle measurements shows evidence that ash particles mostly tend to aggregate. Work was continued to refine our aggregation parametrization.

We are receiving volcanic activity alerts from the Anchorage Volcanic Ash Advisory Center (VAAC) and from the VOLcanic Cloud Analysis Toolkit (VOLCAT) from M. Pavolonis. Volcanic WRF-Chem runs are automatically executed whenever VAAC or VOLCAT alerts are received, which occurs normally on a daily basis and sometimes multiple times a day. There were no significant events accounting for a case study to evaluate GOES-R volcanic ash alerts during the recent months. However, our work aims to be well prepared for a real-time case. Initial forecast graphics and automatic webpage update scripts have been developed.

We adapted and improved our WRF-Chem modeling environment to use a new version of WRF-Chem (version 3.9), and to create an ensemble of possible volcanic eruption source scenarios

within one WRF-Chem run. The ensemble is accomplished by changing ash particle concentrations to account for very fine ash (particles less than 3.9 µm in diameter) and coarse ash (particles with 1-2mm in diameter) and associating the 2 particle sizes with various plume heights. Originally, we introduced a number of 10 ash bins in WRF-Chem (Stuefer et al., 2013) to account for ash particles with a range of different sizes. Reducing this range of sizes to only 2 sizes, and associating these 2 sizes to different plume heights (instead of 1 plume height) allows to create a prognostic tool for near real time volcanic plume prediction. Typically, the eruption source parameters (ESP) are not observed well in real time; volcanic ash advisory centers detect seismic activities near a volcano, or there is a thermal anomaly or a combination of thermal anomalies and predicted atmospheric stability to derive a first guess of a volcanic plume. The WRF-Chem ensemble of fine ash and varying plume heights allows to predict the afar dispersion of the plume and areas of 'negative ash'. Regions of negative ash are of main interest for example for aircraft traffic. The varying plume heights consist of 5 assumed plumes that include as a 'center plume height' either the plume height detection from the initial VOLCAT or GOES-R volcanic baseline alert, or the default ESP used within WRF-Chem (Stuefer et al., 2013). Additional plume heights are introduced at 30%, 70%, 150% and 300% of the center height. In analogy to fine ash, we set up WRF-Chem with coarse ash particles and the 5 varying plume heights (as above) in order to predict ash fallout in the vicinity of the erupting volcano. The ash fallout prediction is especially important for hazard mitigation to life on the ground and to protect infrastructure.

Progress was achieved implementing a volcanic ash aggregation scheme into WRF-Chem. Microphysical analysis of ash particles showed strong evidence that ash particles typically aggregate to larger particles during the atmospheric dispersion. We used a simplified version of the Smoluchowski Coagulation Equation, which allowed to parameterize and introduce the aggregation process between particles of fine ash into the base chemistry code of WRF-Chem (Von Smoluchowski, 1917). Aggregation depends on various ash particle collision parameters.

The aggregation model was compared to remote sensing, field measurements of tephra fallout and in situ observations of the April/May 2010 ash particle dispersion during the eruptions of Eyjafjallajökull Volcano in Iceland. We see spatial and temporal agreement between measurements of the plumes and model output, with better agreement in concentrations using the aggregation code. In addition, we note a decrease in the lifetime of volcanic fine ash by a factor of three. A publication describing the implementation of the aggregation scheme into WRF-Chem is in progress and will be submitted later this spring.

NOAA relevance/societal benefits

GOES-R is a key element in NOAA's ongoing satellite series. We are in the process to validate and assess the GOES-R volcanic ash baseline product. We 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. The GOES-R high temporal resolution in combination with the Rapid Refresh (RAP) model will allow for a timely volcanic ash hazard awareness and dissemination of volcanic warnings.

Partner organizations and collaborators

- Georg Grell, NOAA Earth Systems Research Laboratory
- Michael J Pavolonis, NOAA/NESDIS Center for Satellite Applications and Research (STAR)

Impact, Other products and outcomes

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.

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 all VAAC offices and Alaska Meteorological Watch Office and Alaska Aviation Weather Unit.

Education

- Sean Egan is a Ph.D. candidate student in Environmental Chemistry at UAF working within this project.
- Marcus Hirtl is a Ph.D. candidate student within the Interdisciplinary Program at UAF working on this project.

Publications and Presentations

M. Hirtl, M. Stuefer, D. Arnold, C. Maurer, S. Natali, G. Grell, P. Webley, B. Scherlin-Pirscher: The effects of simulating volcanic aerosol radiative feedbacks with WRF-Chem during the Eyjafjallajokull eruption, April and May 2010. Accepted for publication in Elsevier Journal of Atmospheric Environment, October 2018.

Implementing Interdisciplinary Approaches to Solve Societally Relevant Problems in Alaska through Education, Workforce Development and Partnerships

Vladimir Alexeev, PI **CIFAR theme(s): Coastal Hazards**

University of Alaska Fairbanks

Other investigators/professionals associated with this project (w/affiliation):
Megan Hillgartner, Sorina Seeley, **University of Alaska Fairbanks**

NOAA Goal(s): Healthy Oceans; Climate Adaptation and Mitigation; Weather Ready Nation; Resilient Coastal Communities and Economies

Amendment 75 NOAA Office: NMFS, Kaja Brix, Sponsor

Budget Amount: Cumulative $184,222, This year $0

This project is complete.

Primary objectives

The project supports NOAA efforts to improve relationships between the agency and the communities they work in. This project will foster a better fit between decisions being made and the ecological and social processes happening on the ground by integrating the necessary diverse expertise and developing and implementing societally relevant and sustainable solutions to complex socio-ecological problems. It also cultivates a pathway for professional development in Alaska youth and helps expand the knowledge base and working approaches of agency professionals.

Research accomplishments/highlights/findings

The final report "An Analysis of Opportunities and Challenges: Engaging Rural Alaskans and Alaska Natives in NOAA's Workforce" has been submitted to NOAA Fisheries Alaska Regional Office.

A central finding of this analysis is that NOAA Fisheries Alaska Regional Office can do more to address this need for greater representation by further developing its "institutional porosity[1]".

The report provides practical and implementable recommendations under the theme of building NOAA's porosity, falling into six key categories:

1. Creating more internship opportunities for undergraduate and graduate students in Alaska
2. Addressing the federal hiring process
3. Engaging in direct and targeted interaction with undergraduate and graduate students
4. Increasing engagement with middle and high school students
5. Creating and strengthening support structures to build a more inclusive work environment
6. Building a structured and dedicated effort

[1] The means by which an institution creates portals and mechanisms for entry and recruitment into their organization, as well as the means by which an institution builds connection to the communities and people it works with through specific programs or initiatives for increasing engagement, participation, and opportunity.

Each of the key recommendations include courses of action, a justification, and recommendations for implementation. Each of the recommendations of the report are focused on a clear identified gap -- the disconnect between degree seeking or degree holding students in NOAA fields of interest that decide not to pursue a career with NOAA.

Development of the NOAA Diversity Coalition Meeting in Anchorage

In January 2018, a meeting was held in Anchorage, Alaska: *Diversity Brainstorm and Action Planning for the National Oceanic and Atmospheric Administration (NOAA)*. This meeting arose out of the agency's strong need for a diverse workforce equipped to address complex and rapidly changing marine science and resource management challenges. Building off the existing partnership agreement between NOAA Alaska Region and the University of Alaska Fairbanks, agency personnel from NOAA's National Marine Fisheries Service (NMFS) Alaska Region organized a meeting with staff from the University of Alaska Fairbanks to consider ways in which both parties could take more actionable and meaningful steps towards fostering greater diversity in STEM degree tracks and the federal workforce. This meeting led to the development of a transformative diversity STEM academic model: the *Partnership Education Program Alaska for* increasing diversity in the federal workforce and marine science careers. This structured, systematic, and interdisciplinary workforce-development education model for Alaska unites a network of institutions and entities involved in marine resource management and education.

Proposal to NOAA Fisheries AK Region:

The report and Anchorage Diversity Brainstorm Meeting laid the foundation for a proposal to develop a program for Alaska and the West Coast that unites a network of institutions involved in marine resource management and education in a transferable academic and workforce development model. This proposal, "Alaska Partnership for Education Program (PEP)" was submitted and accepted by NOAA's Alaska Regional Office in June 2018. The implementation of the PEP AK program for 2019 is under way as a part of that proposal.

NOAA relevance/societal benefits

Efforts to better understand partnerships between diverse entities have shown that more work is needed to jointly identify issues and priorities. To develop truly sustainable solutions to our shared problems, we must rethink the way we educate and train professionals entering the workforce. We must also consider ways in which we continue and enhance education and learning for the current workforce, to ensure they are equipped to address such challenges. We connect leading scientists with experienced NOAA professionals to develop an education/workforce model connecting science and policy making in education via a classroom model. In action this model will prepare students to be effective members and leaders in multidisciplinary teams that are able to design, evaluate, and implement responses to complex socio-environmental challenges. Such an approach will also help to expand the knowledge base and working approaches of agency professionals and provide ongoing opportunities for professional development.

Partner organizations and collaborators

- NOAA Fisheries AK Region, NOAA Alaska Fisheries Science Center, PEP Woods Hole

Education and outreach

Megan Hillgartner and Sorina Stalla contributed to an NSF REU project conducted at the International Arctic Research Center. The 2018 NSF REU program ws coordinated with the PEP Woods Hole program. One student (Josette McLean) from PEP Woods Hole, supported by NOAA AK Region, participated in the NSF program, along with two NOAA Hollings scholars who conducted their scholarships with NWS in Fairbanks. Josette has recently gone on to receive a fully funded NOAA scholarship to pursue a Master's degree in Marine Science.

Publications

Komatsu, KK, Alexeev, VA, Repina IA and Tachibana Y, 2018. "Poleward upgliding Siberian atmospheric rivers over sea ice heat up Arctic upper air", Scientific Reports, DOI: 10.1038/s41598-018-21159-6

Tachibana Y, Kensuke K, Alexeev V, Cai L, and Ando Y, "Warm hole in Pacific Arctic sea ice cover forced mid-latitude Northern Hemisphere cooling during winter 2017-18", accepted to Nature Scientific Reports.

Conference presentations

February 2017: Alaska Forum on the Environment, Panel on Workforce Challenges in the Emerging Arctic

July 2017: International Arctic Research Center, Seminar: Food Security in a Changing Arctic: Understanding Partnership for Better Natural Resource Management

Aug 2017: 147th American Fisheries Society Meeting as a part of the symposium: Game Changing Solutions for Enhancing Diversity and Inclusion in the Fisheries Profession.

Presentation: Utilizing Partnership for Greater Diversity and Inclusion in Natural Resource Management

June 2018: Ninth International Congress of Arctic Social Sciences: People and Place, *Panel Presentation: Partnerships for Place-based Problem Solving*

March 2018: NOAA EPP/MSI 9th Biennial Education and Science Forum Howard University , *Presentation:* Diversity in Action: Partnership for Education Program (PEP) for Alaska

August 2018: 148th American Fisheries Society Meeting, Presentation: Actionable Steps for Enhancing Diversity and Inclusion in Fisheries Profession

Other products and outcomes:

- Co-Instructor for graduate level UAF Course*: Navigating Interpersonal Interactions in Science Careers.* Fall Semester 2017. Completed.
- 2018 American Fisheries Society. Organizing committee for s symposium on creating actionable steps to increase diversity and inclusion in fisheries professions. Completed.
- Partnership Education Program Alaska proposal. Funded.
- Policy Analysis 2018: An Analysis of Opportunities and Challenges: Engaging Rural Alaskans and Alaska Natives in NOAA's Workforce. Completed.

A JPSS Initiative for Improving Volcanic Hazard Monitoring and Forecasting

Taryn Lopez, PI

University of Alaska Fairbanks

CIFAR theme: Coastal Hazards

Other investigators/professionals associated with this project:
Michael Pavolonis, **NOAA**
Christoph Kern, **USGS**
Simon Carns, **Michigan Technological University**

NOAA Goal(s): Resilient Coastal Communities and Economies

Amendments 86 NOAA Office Mitch Goldberg; NESDIS

Budget Amount: Cumulative $3,600, This Year $3,600 (Amendment 86)

This project is new and set to end 06/30/2019.

Primary objectives

This project aims to integrate multiple JPSS sensors to detect and rapidly characterize volcanic ash and SO_2 clouds, building on the Volcanic Cloud Analysis Toolkit, developed by NOAA project investigator, Michael Pavolonis. PI-Lopez aims to provide airborne SO_2 measurements from Alaska volcanoes to help validate the products developed by Co-I Pavolonis.

Research accomplishments/highlights/findings

This past year PI-Lopez assisted with or led airborne SO_2 measurements from the following Alaska volcanoe: Redoubt, Iliamna, Makushin and Pavlof. These data will be available to compare against the multi-sensor JPSS products developed by Co-I Pavolonis, when available, for validation and testing purposes.

Additionally, PI-Lopez participated in virtual planning meeting led by Co-I Pavolonis to brainstorm initial project steps. She will also participate virtually in the project kick-off meeting to be held on 22 April 2019.

NOAA relevance/societal benefits

This project will help provide near-real time detection and characterization of volcanic plumes. These tools will be available to decision makers and can be used to provide advanced warning of volcanic hazards, such that mitigation efforts can be made. These tools will ultimately help mitigate ash-aviation hazards, which is the primary volcanic hazard in Alaska.

Partner organizations and collaborators

- Michael Pavolonis, NOAA
- Christoph Kern, US Geological Survey
- David Schneider, US Geological Survey
- Simon Carn, Michigan Technological University

APPENDICES

Appendix 1 Awards through CIFAR 1 April 2018-31 March 2019

Table 1.1 CIFAR Projects Awarded in Cooperative Agreement NA13OAR4320056
1 April 2018 to 31 March 2019

Last	First	Proposal Title	Amend	Project Budget	Theme Description	Funding Source	NOAA PM
Task 1 Activities: CI Administration and Education & Outreach							
Bhatt	**Uma**	Task 1 Request for S24822 - Litzow	82	$11,725	Administration	NMFS	Hoff (acting)
Bhatt	**Uma**	Task 1 Request for S24794 - Litzow	83	$4,162	Administration	NMFS	Hunsicker
Bhatt	**Uma**	Task 1 Request for S25387 - Moran	84	$6,803	Administration	NMFS	Rusin
Bhatt	**Uma**	Task 1 Request for S25066 - Kruse	85	$372	Administration	NMFS	Moss
Bhatt	**Uma**	Task 1 Request for S24956 - Lopez	86	$263	Administration	NESDIS	Goldberg
Bhatt	**Uma**	Task 1 Request for S24761 - Gibson	87	$1,374	Administration	NMFS	Hoff (acting)
NOAA Non-Competitive Projects (NA13OAR4320056)							
Litzow	**Michael**	Understanding post-settlement survival for juvenile Pacific cod in the Gulf of Alaska (Yr 1)	82	$160,619	Ecosystem Studies and Forecasting	NMFS	Hoff (acting)
Litzow	**Michael**	Measuring the strength of ocean-atmosphere coupling to predict climate forcing of northeast Pacific ecosystems (Year 1 of 2)	83	$57,008	Ecosystem Studies and Forecasting	NMFS	Hunsicker
Moran	**Brad**	Development OF Increased Capacity for Quanitative Fisheries Education and Training at the UAF College of Fisheries and Ocean Sciences	84	$93,197	Ecosystem Studies and Forecasting	NMFS	Rusin
Kruse	**Gordon**	Gulf of Alaska Integrated Ecosystem Assessment Postdoctoral Research - Travel Supplement	85	$5,092	Ecosystem Studies & Forecasting	NMFS	Moss
Lopez	**Taryn**	A JPSS Initiative for Improving Volcanic Hazard Monitoring and Forecasting (Period 1a of 3)	86	$3,600	Coastal Hazards	NESDIS	Goldberg
Gibson	**Georgina**	Developing a novel approach to estimate habitat-related survival rates for early history stages using individual-based models (Period 1 of 3)	87	$18,824	Ecosystem Studies & Forecasting	NMFS	Hoff (acting)
		Total projects funded (including CI administration)		**$363,039**			
		Task I - Recovery		$24,699			
		Task I - Project Awards		$0			
		Task II & III awards		$338,340			

APPENDIX 2 PERSONNEL

Appendix 2. contains a summary of CIFAR-funded personnel and their terminal degree (or degree seeking for students)

Table 2.1 Summary of CIFAR funded personnel and terminal degree information.

Category	Number	Unknown or none	B.A./B.S.	M.A./M.S. or M.B.A.	Ph.D.
Research Scientist	1	0	0	0	1
Visiting Scientist	0	0	0	0	0
Postdoctoral Fellow	1	0	0	0	1
Research Support Staff	8	0	3	3	2
Administrative	1	0	0	1	0
Total (≥50 % NOAA Support)	**11**	**0**	**3**	**4**	**4**
Undergraduate students	1	0	1	0	0
Graduate students	13	0	6	5	2
Employees that receive < 50 % NOAA Funding (not including students)	40	3	5	9	23
Located in NOAA Lab	0				
Obtained NOAA employment within last year	2				

APPENDIX 3 PUBLICATIONS

Appendix 3 lists publications and presentations and summarizes author affiliation categories.

Table 3.1 Summary table of peer-reviewed (published and accepted) and non-peer-reviewed publications during the current cooperative agreement NA13OAR4320056.

	Institute Lead Author		NOAA Lead Author		Other Lead Author	
	Yr 1-5	Year 6	Yr 1-5	Year 6	Yr 1-5	Year 6
Peer-reviewed	0/1/1/1/4	6	0/0/2/1/1	5	0/1/12/4/3	3
Non Peer-reviewed	0/0/1/0/10	0	0/0/0/0/5	0	0/0/4/0/3	0
Accepted for publication	0/1/1/0/0	0	0/0/0/1/1	0	0/1/1/0/0	4

Year 1 = 1 July 2013-31 March 2014; Year 2 = 1 April 2014-31 March 2015; Year 3 = 1 April 2015-31 March 201; Year 4 = 1 April 2016 – 31 March 2017; Year 5 = 1 April 2017 – 31 March 2018, Year 6 = 1 April 2018 – 31 March 2019.

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

Publications

In Preparation

Cross, J.N., Mathis, J.T., W. Evans, and N. Monacci. The Physical and Biogeochemical Influences on Ocean Acidification in the Northern Gulf of Alaska, Journal of Geophysical Research, in preparation.

Egan, S.D. M. Stuefer, P. Webley, C. F. Cahill, M. Hirtl, G. Grell: Inclusion of volcanic ash aggregation processes in the Weather Research Forecasting with Chemistry model, with impacts on the April/May 2010 eruptions of Eyjafjallajökull, to be submitted to Natural Hazards and Earth *System Sciences* (NHESS) in late spring/summer 2019.

Hirtl, M. D. Arnold, C. Maurer, S. Natali, M. Stuefer, G. Grell, P. Webley, B. Scherlin-Pirscher and others: EUNADICS demonstration exercise for an artificial volcanic eruption scenario in Europe and the impacts on aviation, to be submitted to Natural Hazards and Earth *System Sciences* (NHESS) in summer 2019.

Krieger, J., A. Beaudreau, R. Heintz, M. Callahan. Factors affecting overwinter condition and growth of juvenile sablefish: Application of a bioenergetics model

Thoman, R. L., P. A. Bieniek, T. T. Lader, Jr., J. E. Walsh, U.S. Bhatt, S. Danielson, W. Meier, Z. Labe, M. Brubaker, and G. Sheffield, 2019: The Bering Sea's record-breaking absence of sea ice durng the winter and spring of 2018. *Bulletin of the American Meteorological Society*, to be submitted May 2019.

In Review

Divine, L.M., F.J. Mueter, G.H. Kruse, BA. Bluhm, S.C. Jewett, and Katrin Iken. In review. New estimates of weight-at-size, maturity-at-size, fecundity, mortality and biomass of snow crab, *Chionoecetes opilio*, in the Arctic Ocean off Alaska. Fisheries Research, revised manuscript under review.

Krieger, J.R., A.H. Beaudreau, R. Heintz. Development and evaluation of a life stage specific bioenergetics model for young-of-year Sablefish (*Anoplopoma fimbria*). In review at *Canadian Journal of Fisheries and Aquatic Sciences*.

Litzow, M. A., L. Ciannelli, C. Cunningham, B. Johnson, and P. Puerta. Nonstationary effects of ocean temperature on Pacific salmon survival. In review, *Canadian Journal of Fisheries and Aquatic Sciences*.

Rosellon-Druker, J., M. Szymkowiak, C.J. Cunningham, S. Kasperski, G.H. Kruse, J.H. Moss, and E.M. Yasumiishi. In review. Development of socio-ecological conceptual models as the basis for an IEA framework in Southeast Alaska. Ecology and Society, Submitted October 30, 2018.

In Press/Accepted

Gardner, C., R.A. Watson, A.D. Jayanti, Suadi, M. Al-Husaini, and G.H. Kruse. In press. Crustaceans as fisheries resources: General overview. Chapter 1 in M. Thiel and G. Lovrich, editors. The Natural History of Crustacea, volume 9. Fisheries and Aquaculture, Oxford University Press.

Hirtl, M, M. Stuefer, D. Arnold, C. Maurer, S. Natali, G. Grell, P. Webley, B. Scherlin-Pirscher: The effects of simulating volcanic aerosol radiative feedbacks with WRF-Chem during the Eyjafjallajokull eruption, April and May 2010. Accepted for publication in Elsevier Journal of Atmospheric Environment, October 2018.

Tachibana Y, Kensuke K, Alexeev V, Cai L, and Ando Y, "Warm hole in Pacific Arctic sea ice cover forced mid-latitude Northern Hemisphere cooling during winter 2017-18", accepted to Nature Scientific Reports.

Uchiyama, T., F.J. Mueter, and G.H. Kruse. In press. Multispecies biomass dynamics models reveal effects of ocean temperature on predation of juvenile pollock in the eastern Bering Sea. Fisheries Oceanography, in press.

Published

Basu, S., and J. E. Walsh, 2018: Climatological characteristics of historical and high-wind events in Alaska. *Atmospheric and Climate Sciences, 8*, 373-394, https://doi.org/10.4236/acs.2018.84025.

Cross, J.N., Mathis, J.T., Pickart, R.S., and Bates, N.R., 2018. Formation and transport of corrosive water in the Pacific Arctic Region. Deep Sea Research II, 152, 67-81. doi.org/10.1016/j.dsr2.2018.05.020.

Holsman, K.K., K. Aydin, J. Sullivan, T. Hurst, and G.H. Kruse. 2018. Climate effects and bottom-up controls on growth and size-at-age of Pacific halibut (*Hippoglossus stenolepis*) in Alaska (USA). Fisheries Oceanography, https://doi.org/10.1111/fog.12416.

Komatsu, KK, Alexeev, VA, Repina IA and Tachibana Y, 2018. "Poleward upgliding Siberian atmospheric rivers over sea ice heat up Arctic upper air", Scientific Reports, DOI:

10.1038/s41598-018-21159-6.

Krieger, J.R., A. Sreenivasan, R. Heintz. 2019. Temperature-dependent growth and consumption of young-of-the-year sablefish *Anoplopoma fimbria*: Too hot, too cold or just right? *Fisheries Research* 209: 32-39.

Osborne, E., J. Richter-Menge, and M. Jeffries, Eds., 2018: Arctic Report Card 2018, https://www.arctic.noaa.gov/Report-Card.

Pilcher, D.J., D.M. Naiman, J.N. Cross, A.J. Hermann, S.A. Siedlecki, G.A. Gibson, and J.T. Mathis, 2019. Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea. Front. Mar. Sci., 5, 508, doi: 10.3389/fmars.2018.00508.

Sutton, A. J., Feely, R. A., Maenner-Jones, S., Musielwicz, S., Osborne, J., Dietrich, C., Monacci, N., Cross, J., Bott, R., Kozyr, A., Andersson, A. J., Bates, N. R., Cai, W.-J., Cronin, M. F., De Carlo, E. H., Hales, B., Howden, S. D., Lee, C. M., Manzello, D. P., McPhaden, M. J., Meléndez, M., Mickett, J. B., Newton, J. A., Noakes, S. E., Noh, J. H., Olafsdottir, S. R., Salisbury, J. E., Send, U., Trull, T. W., Vandemark, D. C., and Weller, R. A., 2019. Autonomous seawater pCO_2 and pH time series from 40 surface buoys and the emergence of anthropogenic trends, Earth Syst. Sci. Data, 11, 421-439, doi.org/10.5194/essd-11-421-2019.

Strasburger W.W., Moss J.H., Siwicke K.A., Yasumiishi E.M., Pinchuk A.I, Fenske K.H. 2018. Eastern Gulf of Alaska Ecosystem. Assessment, July through August 2017. NOAA Technical Memorandum NMFS-AFSC-367. doi:10.7289/V5/TM-AFSC-367.

Sullivan, J.Y., G.H. Kruse, and F.J. Mueter. 2018. Do environmental and ecological conditions explain declines in size-at-age of Pacific halibut in the Gulf of Alaska? Pages 103-121 in F.J. Mueter, M.R. Baker, S.C. Dressel, and A.B. Hollowed (eds.). Impacts of a changing environment on the dynamics of high-latitude fish and fisheries. Alaska Sea Grant, University of Alaska Fairbanks. https://doi.org/10.4027/icedhlff.2018.06.

Richter-Menge, J. A. and J.T. Mathis, Eds., 2017: The Arctic [in "State of the Climate in 2016"]. Bull. Amer. Meteor. Soc., 98 (8), S129–S154, doi:10.1175/2017BAMSStateoftheClimate.1.

Ecosystem Considerations 2017: Status of the Gulf of Alaska Marine Ecosystem. Zador, S., Yasumiishi E. (Eds.) Gulf of Alaska Ecosystem Status Report, North Pacific Fishery Management Council, Anchorage, Alaska, 213 pp.

Zacher, L.S., G.H. Kruse, and S.M. Hardy. 2018. Autumn distribution of Bristol Bay red king crab using fishery logbooks. PLoS ONE 13(7): e0201190. https://doi.org/10.1371/journal.pone.0201190.

Presentations

Abookire, A.A., M.A Litzow, and B.J Laurel. 2019. Abundance, condition, and diet of age-0 Pacific cod in the western Gulf of Alaska. Poster presentation, Alaska Marine Science Symposium, Anchorage.

Cross, J.N., Monacci, N.M., Grebmeier, J.M., Pickart, R.S., Mordy, C.W., Meinig, C., Stabeno, P.J., Zhang, D., Pilcher, D., 2018. Building an integrated ocean acidification observing system for the Pacific Arctic Region. American Geophysical Union Fall Meeting, Washington, DC.

Crouch, J., J. Walsh, and A. Artusa, 2018: NOAA Climate Science and Services Monthly Climate Update. April 17, 2018.

Krieger, J., A. Sreenivasan, R. Heintz, A. Beaudreau. 2018. What came first, the lipid or the length? Effects of Habitat Quality on YOY Sablefish (*Anoplopoma fimbria*) Physiological Condition. (Poster). Alaska Marine Science Symposium, Anchorage, AK and Western Groundfish Conference, Monterey, CA.

Lovejoy, C., C. von Quillfeldt, R.R. Hopcroft, M. Poulin, M. Thaler, K. Arendt, H. Debes, Á. Gíslason, K.N. Kosobokova. 2018. State of the Arctic Marine Biodiversity Report: Plankton. Oral Presentation, World Conference on Marine Biodiversity. Montreal, Canada. May 2018

Lovejoy, C., C. von Quillfeldt, R.R. Hopcroft, M. Poulin, M. Thaler, K. Arendt, H. Debes, Á. Gíslason, K.N. Kosobokova. 2018. State of the Arctic Marine Biodiversity Report: Plankton across sectors. Oral Presentation, POLAR 2018. Davos, Switzerland, June 2018.

Monacci, N.M., Musielewicz, S., Cross, J.N., Evans, W., and Mathis, J.T., 2018. An integrated approach to ocean acidification research and monitoring: using observations and models to support the Alaskan blue economy. American Geophysical Union Fall Meeting, Washington, DC.

Monacci, N.M., Cross, J.N., Musielewicz, S., Evans, W., Pilcher, D., and Mathis, J.T., 2019. Ocean Acidification Research: Using Observations and Models to Support Alaska's Blue Economy. Alaska Marine Science Symposium, Anchorage, AK.

Pilcher, D.J., 2019. Impact of local biogeochemical processes and climate variability on ocean acidification in the Bering Sea. Alaska Marine Science Symposium, Anchorage, AK

Pinchuk A.I., Strasburger W.W. 2019. Summer doliolid blooms in the southeast Gulf of Alaska shelf – potential importance for the offshore ecosystem. Alaska Marine Science Symposium, January 28-31, 2019 Anchorage, Alaska.

Pinchuk, A.I. et al. 2018: Reproductive biology and fishery management of snow and Tanner crabs in the eastern Bering Sea. Oral presentation, Annual Meeting of the North Pacific Marine Science Organization (PICES), Yokohama, Japan, November 2, 2018.

Pinchuk, A.I. et al. 2018: Reproductive biology informs fishery management of snow (*Chionoecetes opilio*) and Tanner crabs (*C. bairdi*) in the eastern Bering Sea, Alaska. American Fisheries Society, Western Division, Annual Meeting, Anchorage, Alaska, May 23, 2018.

Pinchuk, A.I. et al. 2018: Reproductive biology informs fishery management of snow (*Chionoecetes opilio*) and Tanner crabs (*C. bairdi*) in the eastern Bering Sea, Alaska. National Shellfisheries Association, Annual Meeting, Seattle, Washington, March 22, 2018. [Invited]

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Appendix 5 Linked proposals

Table of linked proposals during the current cooperative agreement NA13OAR4320056

Last Name	First Name	Project Title
Bhatt	**Uma**	Seasonal Climate Forecasting Applied to Wildland Fire Management in Alaska
Lovecraft	**Amy**	Arctic Sustainability Research in support of the Arctic Policy and Governance Educational Partnership
Walsh	**John**	Arctic Indicators for Assessment and Enhanced Understanding
Wirth	**Lisa**	Adaptive, High Resolution Modeling for the Arctic Test Bed at NWS Alaska

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Seasonal Climate Forecasting Applied to Wildland Fire Management in Alaska Progress Report

1. General Information

Project Title: Seasonal Climate Forecasting Applied to Wildland Fire Management in Alaska

PI/co-PI names and institutions: Uma Bhatt, Peter Bieniek, Allison York, (University of Alaska) and Peitao Peng (CPC/NOAA)

Report Year: Progress Report Fiscal Year 2 FY17

Grant #: NA16OAR4310142

2. Main goals of the project, as outlined in the funded proposal

The overall project goal is to create, test, and provide specific forecast products that are not currently available for fire managers in Alaska on the 2-week to seasonal time scale.

Increase the forecast lead-time for the Canadian Forest Fire Weather Index System (CFFWIS) in Alaska from the current 48-hours to several months by utilizing state-of-the-art seasonal forecast models (NMME) and sub-seasonal forecasts (GEFS).

Evaluate lightning ignition risk (LIR) in Alaska and its forecast potential.

3. Results and accomplishments

3.1 Stakeholder inputs changes analysis: co-production of information

This study comprises a multi-prong approach to co-producing outputs from seasonal forecasts for use in decision support for fire management in Alaska. This has been an evolving process that involves communicating science capabilities and understanding manager needs. Several things have become apparent as these interactions have evolved.

We needed to use the geographical divisions used by the fire managers in our analysis. These divisions are called Predictive Service Areas (PSAs) and were constructed based primarily on expert knowledge to combine existing fire management zone boundaries and the fire weather forecast zone boundaries. PSA boundaries were drawn based on similar weather patterns but also include respecting boundaries based on management concerns. There are 21 PSAs (Figure 1), they vary in size, and their boundaries align well with Alaska climate divisions (Bieniek et al. 2012).

The UAF team's dynamically downscaled ERA-Interim data set for Alaska (Bieniek et al. 2016) has been used as a proxy for observations for many of our studies (e.g., Lader et al. 2017) but cannot serve as the observational basis for this project. The fire managers are comfortable with station-based meteorological data (2-m Temperature, relative humidity, winds, and sea level pressure) that is averaged for stations within a PSA. There are typically 4-8 stations within a PSA and they generally are located at low altitudes. For example, gridded downscaled reanalysis temperature that is averaged over a PSA has lower values when compared to station-based PSA averages, for

the reasons that are clear to atmospheric scientists (i.e., point measurements versus grid values). However, it was not possible to get the stakeholder community to accept these values as ground truth.

It has become clear that the forecast temperature and precipitation need to be corrected at the PSA level using the station data as ground truth (previous bullet). Consistently for all boreal forest PSAs, early season (May-June) temperatures are too low and the conditions are too wet. We have chosen to apply the method of quantile mapping based on current literature (Bedia et al. 2017) to correct daily temperature and precipitation.

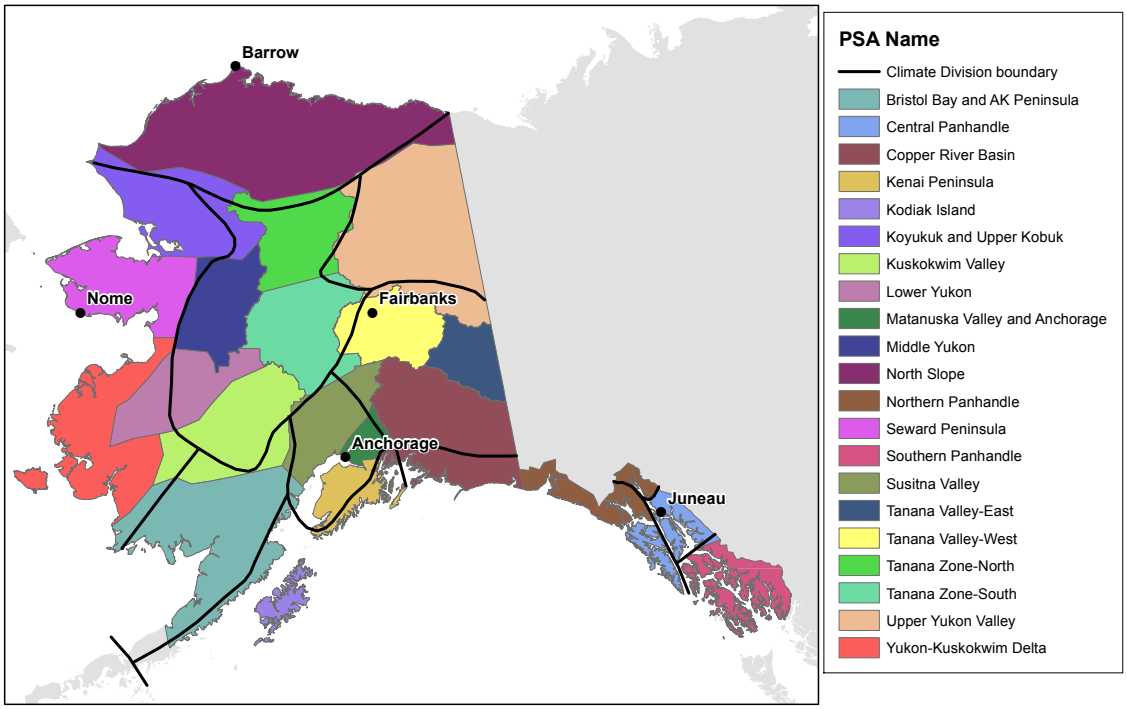

Figure 1. Map delineating the Predictive Service Areas (PSAs) for Alaska by shading and climate divisions by black lines.

3.2 Key scientific findings

3.2.1 CFFWIS from seasonal forecasts

The key index from the CFFWIS that we are investigating is the Buildup Index (BUI; Lawson and Armitage 2008) and represents potential fuel availability and flammability, based on cumulative scoring of daily temperature, relative humidity, and precipitation. High BUI values generally represent periods of high fire danger and BUI is often derived from meteorological station observations but can also be constructed from gridded data (i.e., reanalyses or forecasts). BUI is well suited for describing most fire seasons in northern boreal regions so is widely used by managers in Canada and Alaska. BUI begins to increase after the snowmelt, reaches its peak in June–July, and declines thereafter. BUI is not the complete story because we need to also consider ignition in the form of lightning which has the larger role in acres burned than human ignitions in Alaska.

Biases in temperature and precipitation result in systematic biases in the BUI for Interior

Alaska. Temperatures are generally too low (Figure 2, left panel) particularly in spring and the CFSv2 March forecast is too wet (Figure 2, right panel). The eastern Interior PSAs display a negative temperature bias all summer while the western Interior PSA display a negative bias until mid-May and then have positive biases until mid-August. The larger positive precipitation biases coincide with the eastern Interior PSAs (green lines) while the precipitation biases are smaller in the western Interior PSAs (purple lines) and the Tanana Valley-East (dark grey line) zone. With low temperatures and high precipitation during the early season, the BUI has a negative bias. An example of a BUI with a negative bias is shown for the Upper Yukon Valley in Figure 3 (left panel). The CFSv2 BUI is an order of magnitude smaller than station-based BUI in the Upper Yukon Valley PSA and this tendency is generally shared by the other PSAs.

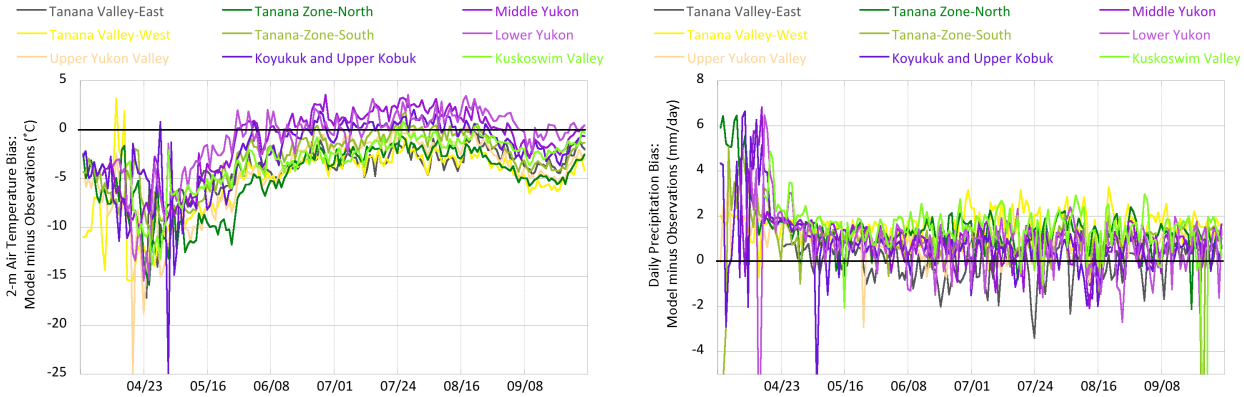

Figure 2. Interior Alaska PSA-averaged daily biases for the March-start forecasts CFSv2 for 2-m temperature (left panel) and total daily precipitation (right panel) over the boreal fire season. These are climatological biases averaged over the period 1994-2010.

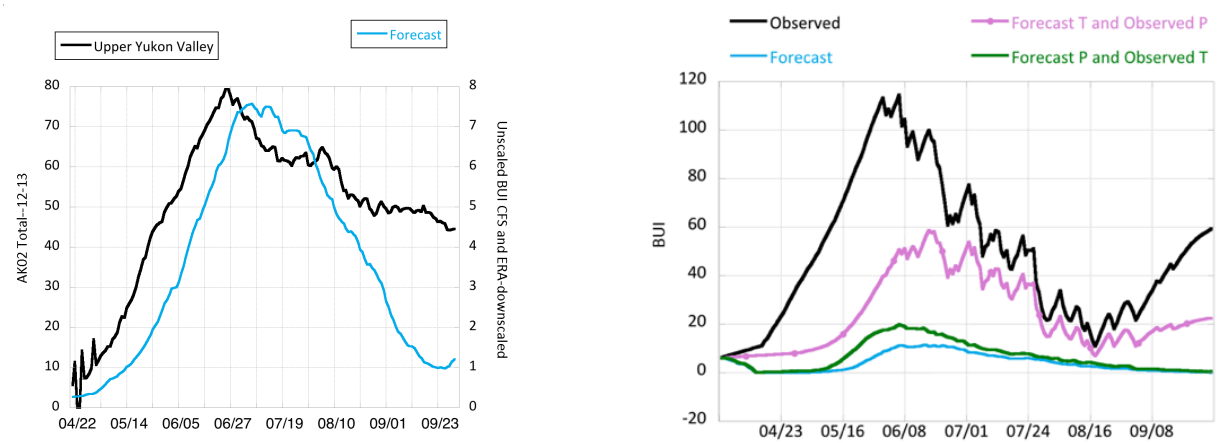

Figure 3. Seasonal cycle of Upper Yukon Valley BUI (left panel) from observations (black line) and CFSv2 forecast (blue line). There is an order of magnitude difference (note gridded data has a different scale) between the observed-based and forecast-based BUI. Seasonal cycle of Tanana Valley-West BUI from observations (black line) and CFSv2 March forecast (sky blue line). In a set of sensitivity experiments, BUI was calculated for 2015 using observed precipitation with forecast temperature (pink line) and observed temperature with forecast precipitation (green line) to indicate that BUI was most sensitive to precipitation.

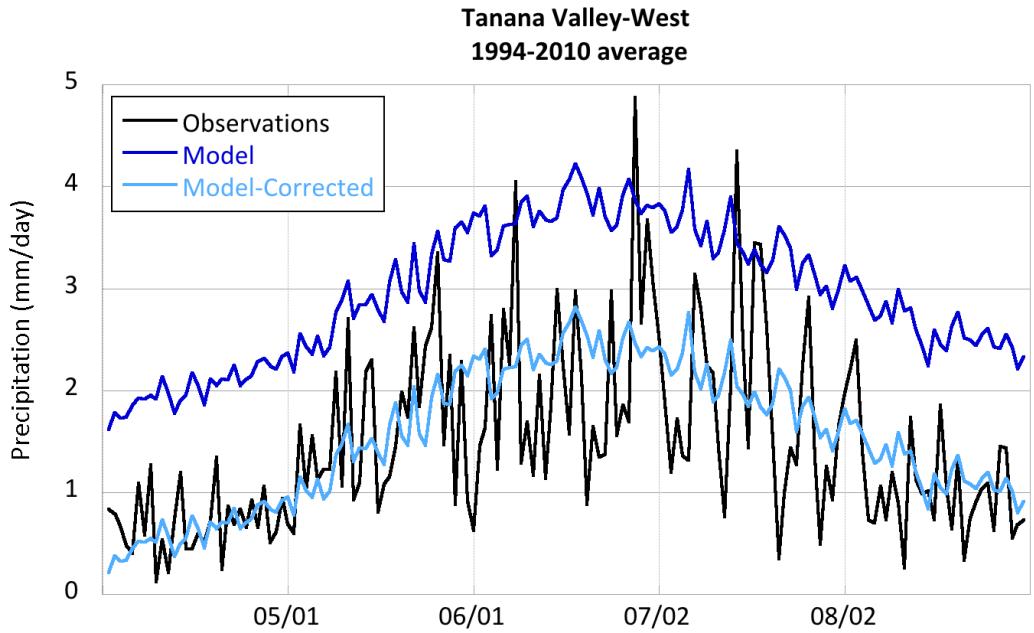

Figure 4. Tanana Valley-West climatological seasonal cycle of daily precipitation from observations (black), raw model forecast (dark blue) and corrected model forecast using quantile mapping (light blue). Plot shows a seasonal cycle averaged over 1994-2010.

The order of magnitude size bias in the forecast-based BUI motivated us to consider correcting the forecast temperature and precipitation. Quantile mapping has been used successfully in other studies for correcting precipitation and temperatures from downscaled climate data and forecasts (e.g., Lader et al. 2017). We followed the method outlined in Bedia et al. (2017) which applied quantile mapping to the Canadian Fire Weather Indices (FWI) to Mediterranean Europe. In order to correct forecasts, one must have reliable ground truth observations as the target. This is a constant issue in Alaska, where first order meteorological stations are sparse and continuous data is problematic. After investigating our options, it was decided that the best observational data would be the PSA-level time series of meteorological data compiled by the Alaska Fire Service that is used to calculate BUI based on observations. These are the operationally-used BUIs. This area averaged index uses all available stations within an area and covers the period 1994-present. The data compiled by the fire scientists begins each spring at the date when the snow goes out, which does not necessarily mean April 1, typically it is later. The data for various stations was missing for April and the first half of May. The PhD student leading the CFSv2 BUI analysis accessed the various station data from the GHCN and filled in the gaps. This is an onerous task for the nearly 200 stations that comprise the PSA level station averages for meteorological data, but it was a necessary step to perform the quantile mapping. Filling the data with climatological data was first attempted and that method did not work. The quantile mapping method shifts the cumulative distribution of the model forecast to match the observed distribution to reduce biases (Figure 4). The variance is lower in the model forecast than observed in part because the observations are based on point stations while the model is an average of multiple grid points in the PSA, making this a comparison of two items at different scales. Both temperature and precipitation have been corrected for all the PSAs. The next step is to recalculate the Canadian Forest Fire Indices, quantify the skill of the FWIs, and develop

products/visuals that fire managers find useful. From discussions, it is clear that fire managers want a measure of uncertainty in any products we provide.

3.2.2 Links between lightning and meteorological fields

Alaska has a reliable record of lightning observations from 1986 to present, over which period sensors have been updated, creating discontinuities in the time series. The current stations are shown in Figure 5 (top left) and provide adequate coverage with a fairly high accuracy of strike location. The major system upgrade in 2012 began counting individual flashes so strike multipliers retained in the historical data 1986-2011 were used to combine the periods (Figure 5, upper right). The monthly strike counts were combined on the 20-km downscaling grid for ease of analysis in conjunction with atmospheric variables.

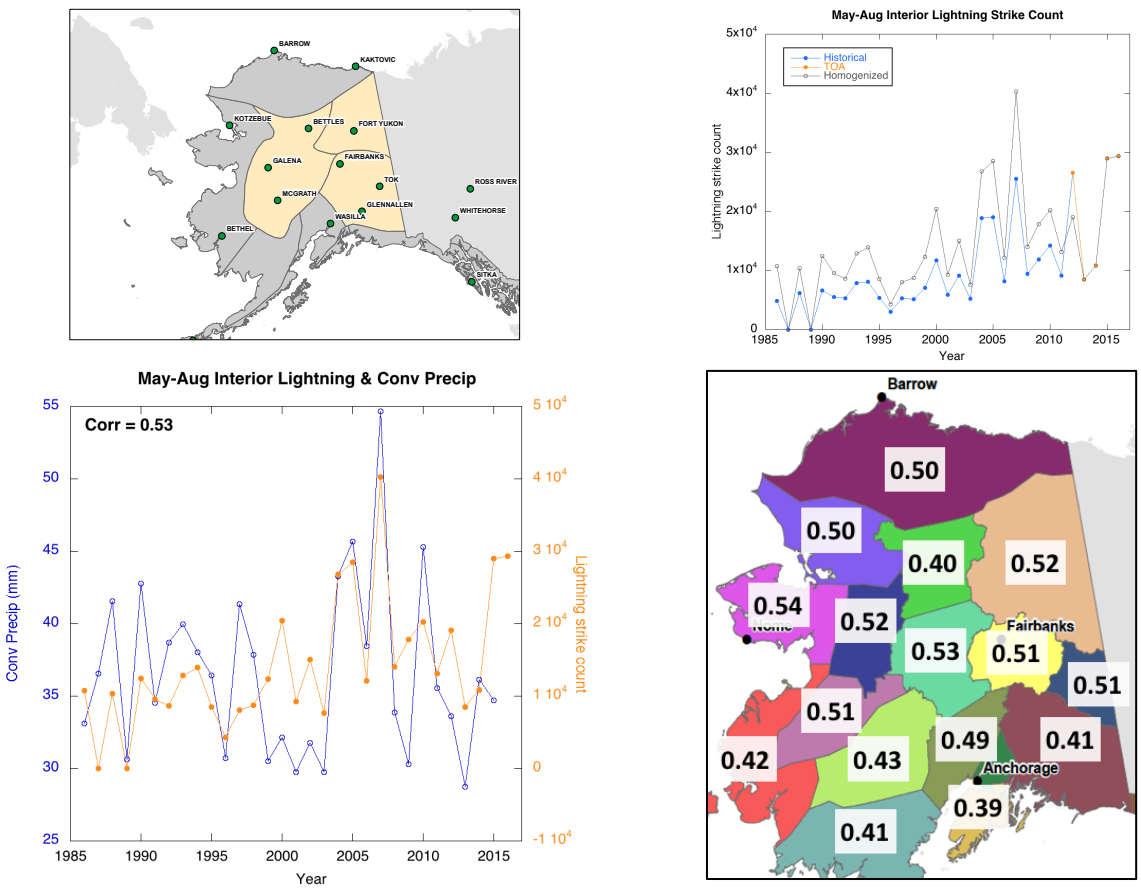

Figure 5. Location of lightning observation system is shown in the top left panel. The time series of lightning strike counts for Alaska is shown in the top right panel. The bottom left panel shows the homogenized lightning strike count (orange) along with convective precipitation. The PSA-level correlations between dynamically downscaled ERA-Interim parameters and observed lightning strikes for May 28-July 16th over the 1982-2015 period is shown in the bottom right panel.

The homogenized lightning strike data compares favorably with the ERA-Interim downscaled convective precipitation (Figure 5, bottom left). More specifically, May-Aug Interior average convective precipitation is correlated at 0.53 with seasonal lightning totals. The years with

highest lightning activity in 2004-5 were also high fire years while 2006 corresponded to high convective precipitation. Next a multivariate regression analysis was conducted using downscaled ERA-Interim convective precipitation, vertical temperature gradient (stability), dew point Temperature, 2m air temperature, and 500-hPa geopotential height to predict lightning strike count. The PSA-based correlations are shown in Figure 5 (bottom right) for the part of the summer season when the relationship is the strongest, May 28-July 16. The relationship is generally stronger in Interior Alaska (R > 0.5) than in PSAs that are south of the Alaska Range (R ~0.4). The multivariate coefficients determined from the observational analysis were applied to the CFSv2 March, April, and May start-time forecasts to predict lightning strikes for June and July. Overall, the skill for this multivariate prediction of lightning strikes over the 1982-2015 period using CFSv2 seasonal forecasts was low. However, further analysis is being conducted at the PSA-scale to better understand the forecast skill for the meteorological parameters used in the multivariate analysis. No clear tendencies are clear at this point and post-processing of forecast data may be needed to improve lightning strike predictions.

3.2.3 Presentations and Meetings

With the continued goal of producing an operationally useful product our team has regularly met with fire managers and presentations are summarized below.

- Interagency Fall Review and Fire Science Workshop, October 2017 (Bieniek), Spring Incident Management Team/Dispatch, March 2018 (Bhatt, Bieniek), Alaska Fire Service Workshop, May 2018 (Strader), and various ad hoc meetings with smaller groups of managers. The Fire Science Consortium linked us through a webinar with a Canadian group (Weather Shield) who have combined analogue forecasting with dynamical to provide higher skill forecasts.

We presented our science results at several meetings, summarized below.

- Bhatt (MAPP PI meeting, August 2017), Bieniek and Sampath (Climate Diagnostics Workshop, October 2017), Bhatt (Graduate Student UAF GI lunch seminar, February 2018; MAPP Fire Webinar, April 2018), Strader (Predictive Services Annual Meeting, January 2018; JPSS Remote Sensing Workshop, May 2018) and Thoman (Climate Prediction Applications Science Workshop (CPASW), May 2018). Visiting NOAA scientist, Kaja Brix presented material about the course Bhatt and Brix co-taught in Spring 2017 (course had a project devoted to fire management) at the NOAA EPP-MSI (Education Partnership Program with Minority Serving Institutions) 9th Biennial Education and Science Forum, in April 2018.

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Bieniek, PA, US Bhatt, RL Thoman, H Angeloff, J Partain, J Papineau, F Fritsch, E Holloway, JE Walsh, C Daly, M Shulski, G Hufford, DF Hill, S Calos, and R Gens, 2012: Climate divisions for Alaska based on objective methods, *J. Applied Meteorology and Climatology*, **51** (7), 1276-1289.

Lader, RT, JE Walsh, US Bhatt, and PA Bieniek, 2017: Projections of 21st century climate extremes for Alaska via dynamical downscaling and quantile mapping. *J. Applied Meteorology and Climatology*, **56** (9), 2393-2409, DOI: 10.1175/JAMC-D-16-0415.1.

4. Highlights of Accomplishments

- Identified the need to bias correct forecasts and applied quantile mapping to correct temperature and precipitation forecasts at the Predictive Service scale (lead: PhD student A. Sampath).
- Multivariate analysis using convective precipitation, vertical temperature gradient, dew point temperature, 2m air temperature, and 500-hPa geopotential height provides some predictive skill of lightning strikes in observational data (lead: P. Bieniek).
- Input from stakeholders made up of fire managers (including predictive services, fire ecologists and fire managers) has guided this project to construct more 'useful' products.

5. Transitions to Applications

In this second year of our project we have worked closely with Alaska fire managers and fire specialists to identify the types of applications they find useful. This has been a very important part of the process of transitioning from research to applications and a component that requires significant time investment as well as thought. We continue to present at the Spring and Fall wildland fire management meetings in Fairbanks and with each presentation, our communication ability improves. We have also strengthened our personal connections with various managers through these interactions. This personal connection helps to improve communications by breaking the barriers to having a dialog rather than information exchange. It becomes more comfortable to ask seemingly 'stupid' questions. For example, I presented an update at the March 2018 fire manager meeting and decided to describe what is meant by an 'ensemble forecast' in some detail. I received many positive comments along the lines of, 'oh, now I know what you mean by ensembles.' Thus, something that we as climate variability researchers take as second nature needs to be viewed with a new lens as we attempt to lead research-to-operations in a successful manner. A more comfortable relationship allows people to ask questions and make requests more freely, which leads to fruitful end products.

Once the quantile mapping process is finished and the CFSv2 results are finalized, we will begin to specifically address how to transition these calculations by working with Dr. P. Peng at CPC to operationalize identified products. The codes and methods can be applied to the new forecast model that is expected at NOAA even though it has been developed for the CFSv2.

6. Publications from the Project

Peer-reviewed Publications (Cumulative)

Partain, JL, S Alden, US Bhatt, PA Bieniek, BR Brettschneider, RT Lader, PQ Olsson, TS Rupp, H Strader, RL Thoman, JE Walsh, AD York, and RH Ziel, 2016: An assessment of the role of anthropogenic climate change in the Alaska fire season of 2015, *Bulletin of the American Meteorological Society Special Report Explaining Extreme Events of 2015 from a Climate Perspective*, S14-S18 pp.

York, A, U Bhatt, R Thoman, and R Ziel, 2017: Wildland Fire in High Latitudes [in Arctic Report

Card 2017], http://www.arctic.noaa.gov/Report-Card.

Submitted/Under Review/Conditionally Accepted

AYork, A, U Bhatt, R Thoman, and R Ziel, 2018: Wildland Fire in Boreal and Arctic North America, [in "State of the Climate in 2017"]. Bull. Amer. Meteor. Soc., 99(8).

In-Prep

Bieniek, PA et al. 2018: Linking Alaska lightning data to large-scale climate drivers and potential for seasonal forecasting. in prep for J. Climate.

Sampath, A et al. 2018: Application of Canadian Fire Indices using NMME to seasonal wildland fire in Alaska. in prep for J. Applied Meteorology and Climatology.

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8. Budget for Coming Year

We have funds of around $50k left in the budget on May 1, 2018 and have requested a no-cost extension of one year on the project to July 31, 2019, which has been approved. The remaining funds will pay the stipend for A. Sampath for summer 2018, travel to the Climate Diagnostics Workshop for P. Bieniek, travel to AMS in 2019 for A. Sampath, publication costs, and salary for Bhatt to finalize project activities.

We are working on leveraging funds to support PhD student Sampath in fall of 2018 during which time she will complete her part of the project and have a paper ready for submission. This work will form one of the three components of her PhD thesis and will result in a publishable paper. Her overall PhD dissertation will focus on seasonal forecasting in the Arctic.

9. Future Work

The next step for creating FWI products is to finish the bias corrections for the full forecast period of 1982-2018, to calculate the FWI, to quantify the skill of fire indices in the CFSv2, and to evaluate the uncertainty in the forecasts. Next, we must evaluate whether the March and May forecasts of the fire weather indices are usable by the fire managers. If the answer is negative, then it will be critical to evaluate what improvements are needed in the seasonal forecasts for the outputs to be usable. There will be a manuscript led by A. Sampath on this component on the CFSv2 seasonal forecasts of the fire weather indices.

The lightning piece of this project, led by P. Bieniek, will explore a few more avenues to see if there is any skill in the seasonal forecasts. At this point the forecasts of the parameters that best link to lightning strike counts are not easy to forecast several months in advance. There is hope

that there could be some predictability based on the relationships between the downscaled reanalysis and observed strikes. There will be a manuscript led by P. Bieniek on the feasibility of developing some lightning guidance based on seasonal forecasts. This work will also articulate needed model improvements in order to be able to develop guidance for lightning for Alaska.

We also plan to expand our analysis to the entire suite of NMME models for the seasonal forecasts. The data access has hampered doing this in parallel with analyzing the CFSv2 (which has the best data availability). With the observational PSA-level data prepared and correction codes in place, the analysis of the other models is expected to be faster. B. Brettschneider has another project investigating analog forecasts for Alaska. He has compared analog forecasts with NMME and his results are relevant for this piece of the seasonal forecasting. U. Bhatt will lead this work and prepare a manuscript.

A final piece of the proposed work was to prepare the FWI using the GEFS at a two-week time scale. We will reevalute this task through discussions with the fire managers since some products may be now available at that time scale from MesoWest. If this time scale still remains a gap that has a high priority to fill, then we will apply our FWI codes to the GEFS to provide a 2-week outlook on a weekly basis. A deep evaluation and bias correction is not going to be possible due to the time and resources that would entail.

Arctic Sustainability Research in support of the Arctic Policy and Governance Educational Partnership

PI – A. Lovecraft

This project was contracted for professional academic expertise for the development of the Arctic Policy Partnership and no annual report was required. There is a project report in preparation and will be a key product of this project.

Annual Report for Year 1: NOAA Grant NA17OAR4310160

Project title: Arctic Indicators for Assessment and Enhanced Understanding
Principal Investigator: John Walsh, University of Alaska, Fairbanks
Period covered by report: July 1, 2017 - June 30, 2018

The main objective of work under NA17OAR431060 is the development of a set of cryospheric and related climate indicators for the Arctic in support of the National Climate Assessment (NCA) and other uses. The indicators span the key Arctic climate system components: sea ice, snow cover, glaciers, permafrost and vegetation. Storminess was also included in the list of proposed indicators because storms affect other system components (e.g., sea ice) and directly impact people, ecosystems and infrastructure. An additional Arctic indicator, the amount of cold air mass in the Northern Hemisphere, has been added to the project's products through collaboration with our partners from Japan. Several criteria entered into the choice of these indicators: (1) the extent to which changes in the indicator variable impact humans and ecosystems, (2) the potential for this project to add value to existing metrics or indicators, (3) conduciveness to straightforward communication, (4) synergies with NOAA products and datasets and (5) readiness of the key product or information.

Work performed during Year 1 has addressed each of the indicators listed in the proposal, as summarized below. In addition, the project has produced three journal papers describing (1) indicators of cold air mass amount, (2) regional sea ice indicators, and (3) a synthesis of broad-scale Arctic indicators. A fourth manuscript, now in preparation, addresses vegetative indicators based on modern satellite measurements (NDVI) Normalized Difference Vegetative Index) in conjunction with paleo measurements depicting variations of plant type over time since the previous glaciation. The project's PIs also organized a special session on Arctic Indicators at the AGU Fall Meeting in December 2017: GC43J: Indicators of Processes and Feedbacks Contributing to Arctic Change and Their Linkages to Global Change (oral and poster sessions), which is summarized in Section 2b. Finally, the project's PIs are coordinating a special journal issue, "Arctic Climate Change Indicators", for *Environmental Research Letters*, with submissions due in summer 2018 and a publication target of early 2019. This issue is described in more detail in Section 2b below.

1. Arctic indicator research accomplishment

While work was initiated during Year 1 on each of the proposed indicators, the indicator tasks for which the work is most advanced in terms of publications and implementation are those for cold airmass amount, sea ice, and vegetative variations. In the following sections, we

describe the work on these indicators in more detail. We then provide brief updates on the work on permafrost and glacier indicators, together with project-supported publications

1a. Cold air mass amount

A novel indicator for monitoring the Arctic environment is the amount of cold air (defined relative to a threshold) at a particular time. Neither NOAA nor the NCA currently has a metric for cold air amount. Because the Northern Hemisphere's coldest air is generally found in the Arctic, indicators of cold air amount can serve as useful metrics of hemispheric and even global climate change. In collaboration with partners from Japan, we have applied such indicators to an evaluation of trends and variations of the amount of cold air in the Arctic and the Northern Hemisphere over the 60 year period, 1959-2018. The results, presented in detail by Kanno et al. (2018) were based on two key indicators: (1) Polar Cold Air Mass (PCAM), which is the amount (mass) of air below a potential temperature threshold, and (2) Negative Heat Content (NHC), which includes a weighting by coldness. Because the metrics of coldness are based on multiple layers in the atmosphere, they provide a more comprehensive framework for assessment of warming than is provided by surface air temperatures alone. For both metrics, the potential temperature is used rather than the actual temperature in order to allow for the effects of adiabatic compression if the air were brought to 1000 hPa (approximately the surface). The three-dimensional atmospheric fields are obtained from atmospheric reanalyses.

The trends of the cold air mass indicators were found to significantly negative. The negative trends of PCAM and NHC are stronger (as % per decade) when the threshold is 245°K rather than 280°K, indicating that the loss of extremely cold air is happening at a faster rate than the loss of moderately cold air. Figure 1 provides the time series of the metrics for the winter season, December-February, of the 60-year period 1959-2018. Statistical analysis shows that the loss of cold air has accelerated, as the most rapid loss of NHC has occurred over the recent decades (1989-2018). These trends are robust across the two reanalyses (JRA-55 and ERA-Interim) used in the study. The spatial pattern of the trends of PCAM and NHC provide another manifestation of Arctic amplification. Of the various teleconnection indices, the Atlantic Multidecadal Oscillation shows the strongest correlations with the spatially integrated metrics of moderate coldness. Several Pacific indices also correlate significantly with these indicators. However, the amount of extreme cold air mass does not correlate significantly with the indices of internal variability, implicating external forcing as the driver of the loss of extreme cold air mass.

Publication:

Kanno, Y., J.E. Walsh, M.R. Abdullah, J. Yamaguchi and T. Iwasaki, 2018: Indicators and trends of polar cold airmass. *Environmental Research Letters*, submitted (June 2018).

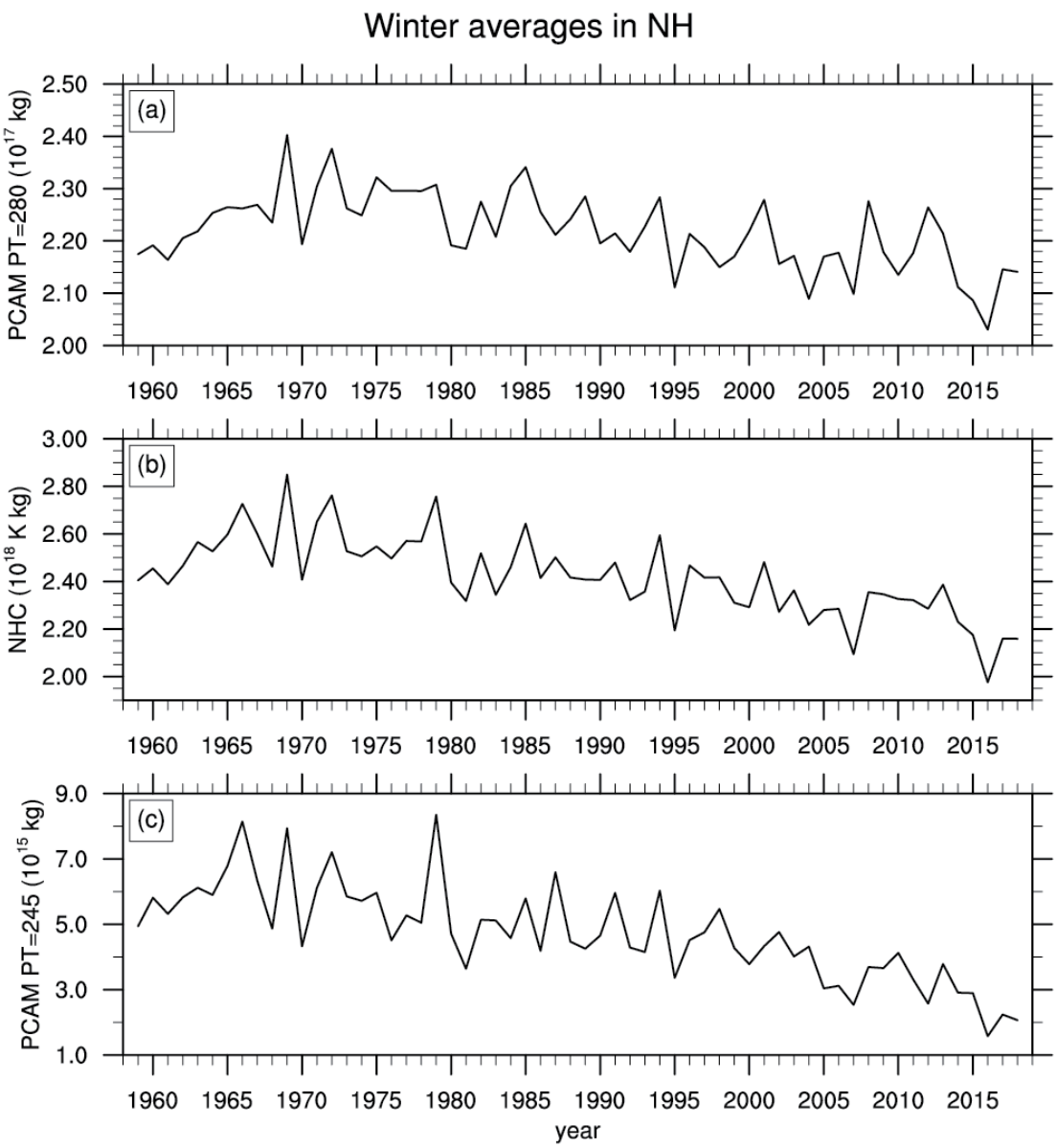

Figure 1. Time series of (a) total hemispheric PCAM amount below 280°K, (b) NHC below 280°K, and (c) PCAM amount below 245°K for the Northern Hemisphere winter. Units are kg for (a) and (c), and °K kg for (b). From Kanno et al. (2018, *Env. Res. Lett.*).

1b. Sea ice

In collaboration with the National Snow and Ice Data Center (F. Fetterer and J. S. Stewart), we have explored the use of regional sea ice indicators. The regional indicators consisted of ice extent and area in the MASIE (Multisensor Analyzed Sea Ice Extent) regions (Figure 2). The study consisted of evaluating the regional indicators for the 1953-present, evaluating lead/lag relationships with total pan-Arctic ice extent, and comparing the regional indices with the

Barnett Severity Index (BSI), a user-driven indicator developed by the National Ice Center to capture variations of navigation conditions in the Beaufort-Chukchi region. As documented in Walsh et al. (2018), we also used these regional indicators to test basic statistical metrics such as autocorrelations and across-region lag correlations of sea ice variations in order to provide benchmarks for the assessments of forecast skill achieved by other methods such as more sophisticated statistical formulations, numerical models, and heuristic approaches.

While the regional indicators are useful for monitoring, their applicability to seasonal forecasting is complicated by the strong negative trend of ice coverage in recent decades. The trends inflate the autocorrelation and cross-correlations of interannual variations of pan-Arctic and regional ice extent. Walsh et al. (2018) provide a quantitative evaluation of the contribution of the trend to the skill of monthly and seasonal ice extent on the pan-Arctic and regional scales. Application of the piecewise linear trend calculation showed an acceleration of the trend during the 1990s in most of the regional indicators. The Barnett Index as well as September pan-Arctic ice extent show significant predictability out to several seasons when the data include the trend. However, this apparent skill largely vanishes when the indicators are detrended. No region showed significant correlation with the detrended September pan-Arctic ice extent at lead times greater than a month or two; the concurrent correlations are strongest with the East Siberian Sea, as shown in Figure 2. The Beaufort Sea's ice extent as far back as July explains about 20% of the variance of the Barnett Severity Index. The Chukchi Sea indicator was the only other region showing a significant association with the Barnett Index, although only at lead times of a month or two.

To further extend this work and develop new pan-Arctic indicators, we have begun to implement an approach to derive the timing of the sea-ice freeze-up and break-up seasons. The approach is based on community expert observations that have been translated to allow derivation of local scale indicators from passive microwave satellite data. With code to process data at the pan-Arctic scale being developed, and remote sensing data being staged, we plan to examine data of these seasonal stage indicators in the autumn of 2018.

Publication:

Walsh, J.E., J.S. Stewart, and F. Fetterer, 2018: Seasonal sea ice prediction based on a regional index approach. *The Cryosphere*, submitted (June 2018).

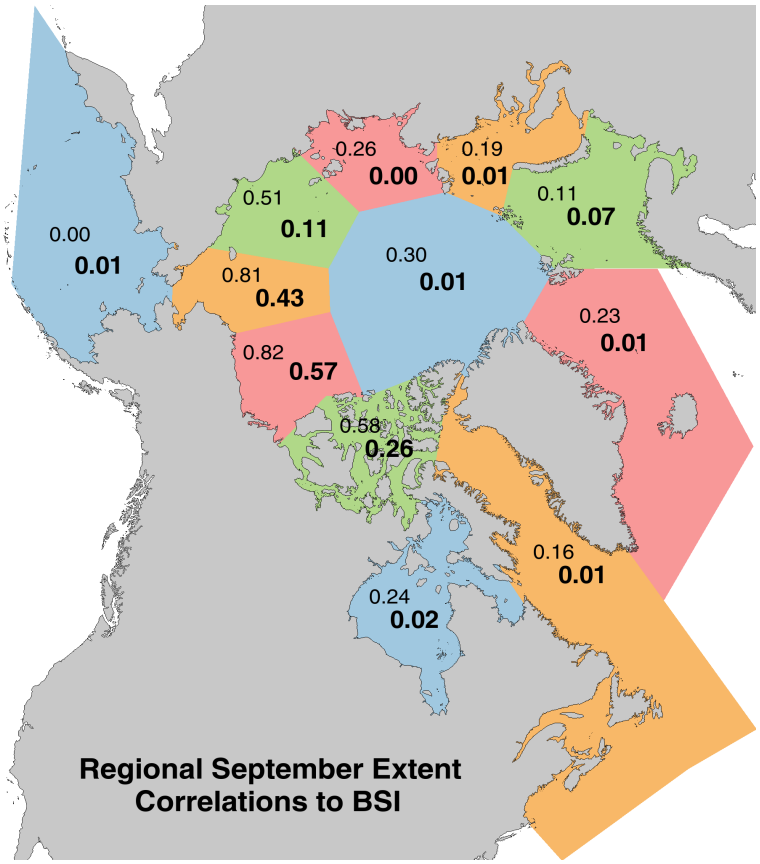

Figure 2. Explained variances (squares of correlations) between the annual Barnett Severity Index for the Beaufort-Chukchi Seas and September regional ice extents based on raw (not detrended) time series (upper numbers, standard font) and detrended time series (lower numbers, bold font). From Walsh et al. (2018, *The Cryosphere*).

1c. Arctic vegetation

Arctic tundra vegetation based on the Maximum Normalized Difference Vegetation Index (maxNDVI) is a well-studied indicator of tundra vegetation productivity increases (Myneni et al. 1997, *Nature*, *386*, 698–702.). The yearly Maximum NDVI (MaxNDVI) generally showed an increase until about 2000 (Bhatt et al. 2013, *Remote Sensing 5*, 4229-4254; doi:10.3390/rs5094229) when parts of the Arctic began to show declines in MaxNDVI. This project is using the recently updated NDVI3g v1.1 (Pinzon et al. 2018 in prep) AVHRR-based data set for NDVI. The new Circumpolar Arctic Vegetation Map (Walker et al. 2018 in prep) provides a timely tool to probe the NDVI analysis further to examine changes to the MaxNDVI for vegetation types. Figure 3 (bottom panel) indicates that there are varying trends in different types of barren landscapes. The greatest NDVI increase is in the B2b vegetation type which includes southern shrubs and supports the notion that NDVI increases are linked to shrubification. The NDVI time series analysis is in progress for other vegetation types from the CAVM, and also for landscape age and other factors, to provide further understanding on NDVI increases and declines.

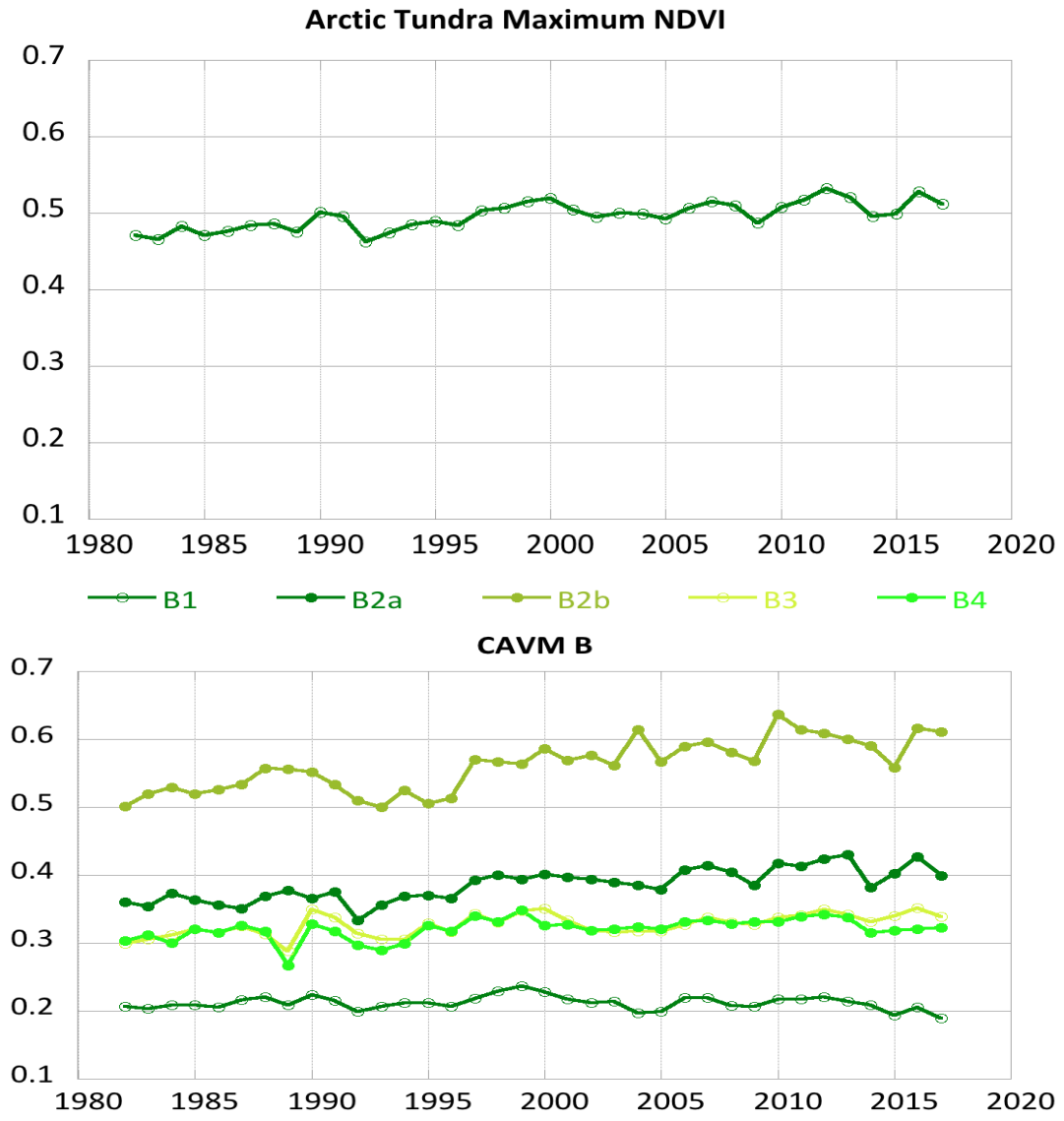

Figure 3. Maximum Normalized Difference Vegetation Index timeseries for Arctic tundra is shown in the top panel. The MaxNDVI has steadily increased since the record began in 1982. The bottom panel shows the timeseries for PanArctic tundra MaxNDVI separated into different vegetation types from the Circumpolar Arctic Vegetation Map (updated from CAVM Team 2003 Map No. 1. U.S. Fish and Wildlife Service, Anchorage, Alaska. ISBN: 0-9767525-0-6, ISBN-13: 978-0-9767525-0-9) for one type of vegetation: Barrons where B1 is Cryptogam, herb barren, B2 is Cryptogam barren complex (bedrock), more specifically B2a is rocky high arctic lichen covered while B2b is southern shrub covered land, B3 is Noncarbonate mountain complex and B4 is Carbonate mountain complex

1d. Permafrost

As described in the original proposal, our permafrost indicator are derived from mean annual air temperature (MAAT), summer air temperature (SAT), and snow duration (i.e. snow-on and snow-off date). Summer air temperature drives the subsurface warming that determines the ground thaw depth (or active layer thickness), while snow cover acts as an insulator that

influence the heat loss to the air during the winter. Late-winter temperatures of the upper soil layers are considerably higher after a winter of deep snow than after a winter with little snow. The novel aspect of the task in this project is the integration of metrics of MMAT and snow cover. More specifically, our permafrost indicator is a weighted sum of the thawing degree days (TDD), mean annual surface air temperature (MAAT), and snow on/off date.

As a first step, we assessed various atmospheric reanalysis products for the Arctic and found that three model products stand out as being more consistent with independent observations: the Climate Forecast System Reanalysis (CFSR), the Modern-Era Retrospective Analysis for Research and Applications (MERRA), and the ECMWF Interim Re-Analysis (ERA Interim) (Lindsay et al., 2014; Lader et al., 2016). Based on further analysis of these climate data products, we chose the 2m air temperature (daily and monthly) product of ERA-Interim (1979 – present) for deriving TDD and MAAT inputs for permafrost indicator. We are in the process of obtaining the ERA-Interim 2m temperature product from the ECMWF Public Dataset page (http://apps.ecmwf.int/datasets/data/interim-full-moda/levtype=sfc/). Figure 4 shows the climatological mean June-August 2-meter air temperature obtained from ERA-Interim, illustrating the highest summer temperatures occur in the discontinuous permafrost zone of the Alaskan Interior. We are using Rutgers University's gridded daily snow product to obtain snow on/off dates (https://climate.rutgers.edu/snowcover/docs.php?target=datareq) for input for permafrost indicator. The yearly permafrost indicator is being evaluated for each year from 1979 onward by comparing it with actual *in situ* temperature observations and active layer thickness measurements from permafrost monitoring sites in Alaska.

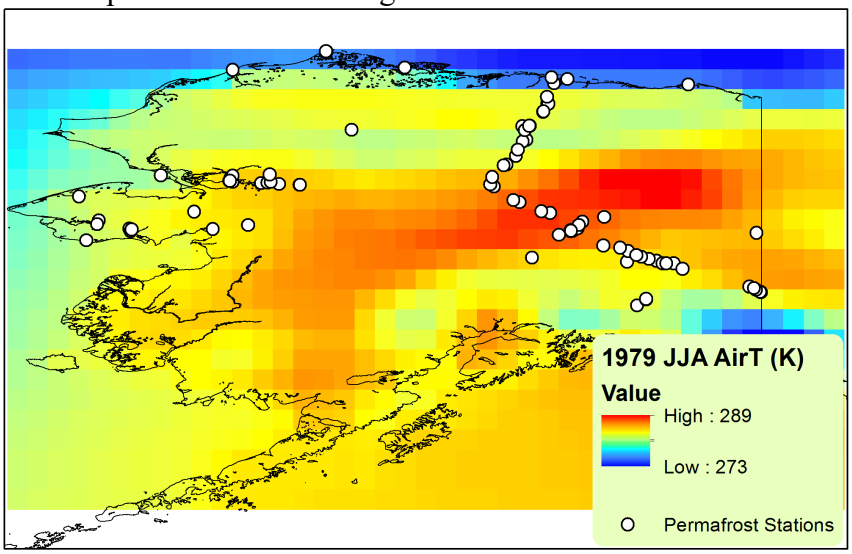

Figure 4. 1979 seasonal average (JJA) air temperature (from ERA-Interim; 0.75 x 0.75 degree grid) for Alaska. The ground temperature and active layer thickness data from the Permafrost Stations across Alaska are being used to evaluate the yearly permafrost indicators.

1e. Glaciers

Annual equilibrium line altitudes (ELAs), i.e. the set of points on the glacier where the surface mass balance is zero at the end of the mass-balance year, has been shown to correlate well with the mass balance of a glacier. As ELAs rise, net mass loss increases. Since increase in air temperature is the main driver for ongoing glacier changes, observations of ELAs may provide a good surrogate for glacier mass change and associated temperature rise. Determining ELAs is considerably less time-consuming than direct glaciological measurements of glacier mass change, since ELAs can be identified from visible remote sensing.

We investigated whether ELAs can be used as a surrogate for glacier mass change in Alaska. We focused on 19 glaciers in the Central Alaska Range, specifically those within the bounds of Denali National Park and Preserve, roughly 3,755 km^2 of ice. Snowlines were determined for each glacier and all years between 1994-2016 with suitable imagery.
Landsat satellite images from years 1994-2016 were selected from USGS Earth Explorer. Landsat 5 and 7 sensors TM and ETM+ respectively, were manually scrutinized for cloud free images. The combination of spectral bands 4, 3, 2 for Landsat TM/ETM+ was used to discriminate snow cover from ice. Scenes were chosen from the end of summer state for Alaska, between August 1 and September 30, when the snow cover is at a minimum and the transient snowlines are at a maxima in high altitudes indicating climatic conditions. Cloud-free images from as late in the summer season as possible were prioritized for each year. Landsat images of viable quality were not available for all years in the time series (1995, 1996, 1997, 1998, 2006, 2008, 2011, 2013, and 2015), since cloud cover was often a problem in the analysis of these satellite images. Results are shown in Table 1.
The glaciers' annual ELAs are now being correlated to climate variables to investigate if ELAs are suitable indicators of climate change.

Table 1: Statistics of ELA and AAR for the 19 glaciers over the period 1994-2016. ELA and Accumulation Area Ratios (AAR) refer to the mean over the time series. The maximum, minimum and median ELAs are also averaged across the time series for each glacier.

Glacier name	ELA (m a.s.l.)	Max ELA (m a.s.l.)	Min ELA (m a.s.l.)	Median ELA (m a.s.l.)	AAR (%)
Calwell	1567	1397	1784	1575	31
Chedotlothna	1720	1572	1999	1677	40
Cul-de-sac	1649	1615	1735	1650	29
Dall	1403	1038	1858	1421	47
Eldridge	1690	1248	2297	1688	43
Foraker	2067	1868	2374	2063	57
Herron	2031	1808	2302	2042	47
Kahiltna	1681	1314	2273	1677	54
Lacuna	1773	1421	2210	1760	33
Muldrow	2091	1627	2860	2043	56
Mystic	1289	1108	1536	1296	40
Peters	2233	1804	2776	2235	67
Ruth	1570	2027	1665	1538	49
Shadows	1537	1388	1744	1520	41
Straightaway	2114	1959	2289	2113	44
Surprise	1492	1388	1688	1471	49
Tatina	1595	1484	1748	1591	37
Tokositna	1699	1340	2233	1681	43
Yenta	1724	1233	2347	1696	40

1. Broader community involvement

2a. Special session on Arctic Indicators at AGU Fall Meeting

The project's PIs also organized a special session on Arctic Indicators at the AGU Fall Meeting in December 2017:

GC43J: Indicators of Processes and Feedbacks Contributing to Arctic Change and Their Linkages to Global Change.

This event consisted of 8 oral presentations, which are listed at

https://agu.confex.com/agu/fm17/meetingapp.cgi/Session/32650

The session also included a poster session in which approximately 15 posters were presented. Various oral and poster presentations addressed processes and feedbacks relevant to indicators, as well as linkages to global change. The broader global connections served to expand the audience beyond the Arctic research community.

2b. Arctic Indicators special issue of Environmental Research Letters

Four of the PIs (Walsh, Bhatt, Eicken, Romanovsky) are coordinating a special journal issue, "Indicators of Arctic Environmental Variability and Change", for *Environmental Research Letters*, with target dates of fall 2018 for submission and early 2019 for publication. Papers have been solicited on a wide range of Arctic indicator-relevant topics, ranging from physical to biological to social. Examples of topics mentioned in the solicitation are:

- Indicators of changes in physical components of the Arctic climate system (ice, atmosphere, ocean)
- Changes to the terrestrial system regarding vegetation or permafrost
- Ocean acidification indicators
- Indicators of biogeochemical changes in the system
- Indicators of human response to climate change
- Specific Arctic indicators that are relevant for global change

A website for the special issue is accessible at

http://iopscience.iop.org/journal/1748-9326/page/Arctic-Environmental-Variability-Change

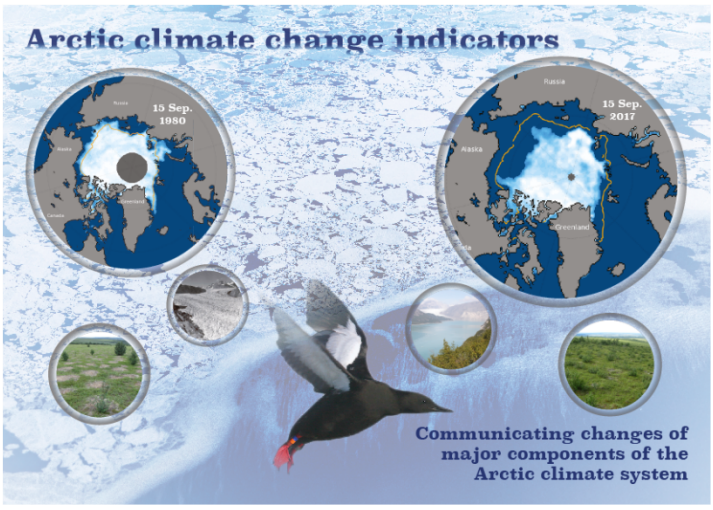

Figure 5. ERL Special Issue logo.

The review process will be coordinated by a team of eight Guest Editors, six from the University of Alaska Fairbanks and two (J. Intrieri and D. Stanitski) from NOAA's Earth Systems Research Laboratory.

A notable contribution to the ERL special issue has had the involvement of two of the project's PIs (Walsh and Romanovsky). This contribution is a synthesis of the Arctic indicators addressed by the Arctic Monitoring and Assessment Programme in its 2018 assessment report, *Snow, Water, Ice and Permafrost in the Arctic (*https://www.amap.no/documents/doc/Snow-Water-Ice-and-Permafrost-in-the-Arctic-SWIPA-2017/1610). The synthesis paper includes indicators of air temperature, precipitation, snow on land, permafrost, sea ice, land ice, freshwater, carbon cycling, wildfire and terrestrial ecosystems. The manuscript submitted to the special issue is keyed to the following figure, which shows the indicators updated through 2017:

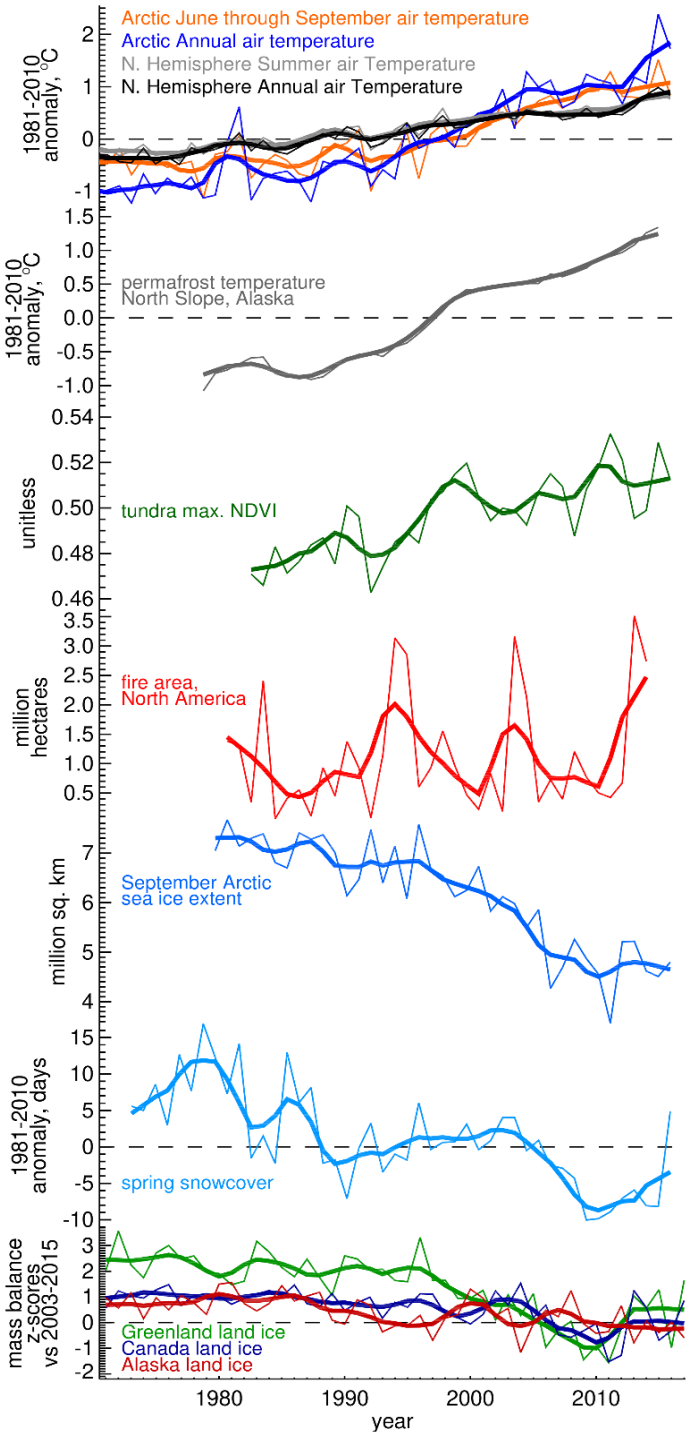

Figure 6. Time series of key Arctic indicators through 2017. From Box et al. (2018, *ERL*)
Publication:
Box, J.E., W.T. Colgan, T.R. Christensen, N.M. Schmidt, M. Lund, R. Brown, J.E. Walsh, J.E. Overland, M. Wang. R. Corell, W.N. Meier, V. Romanovsky, B. Wouters, S. Mernild, J. Mard, J. Pawlak, and M.S. Olsen, 2018: Key Indicators of climate change in the Arctic. *Environmental Research Letters*, submitted June 2018.

CSTAR Progress Report

Adaptive, High Resolution Modeling for the Arctic Test Bed at NWS Alaska

Reporting Period: 01 May 2018 - 31 October 2018
Grant number: NA16NWS4680006

PI: Lisa Wirth (University of Alaska Fairbanks) Co-I's: Don Morton (Boreal Scientific Computing, LLC); Jiang Zhu (UAF)

Highlights

- Moved project emphasis to AWS deployment of verification and simulation activities,
- Began the process of disseminating products and documentation of the project. The URL for this is https://sites.google.com/a/borealscicomp.com/hrrrak/products
- Studied assimilation of VIIRS wind data in HRRRAK-like model

CSTAR Progress Reporting Items

1. Key scientific accomplishments

- The application interface for the HRRRAK verification system has been improved by putting most of the functionality behind two URL endpoints. Through this mechanism, it's possible to perform queries and retrieve raw matched pair (forecast vs observations) for the queries by sending a query as a JSON-encoded payload to a specified URL (an "endpoint"). This matched pair data is

available as a URL for processing by other clients. A second endpoint has been created that facilitates the creation of a plot from the stored output (again, available via URL). This is described in more depth and breadth at https://sites.google.com/a/borealscicomp.com/hrrrak/products/hrrrak-verification-system

- The many technical challenges in deploying the HRRRAK verification system within the AWS cloud translate to more general "meteorology as a service" environments that, because of long processing times and large datasets, don't fit into the more typical software-as-a-service scenarios based on short and small transactions. We have learned that there are numerous "gotchas" in the process that can significantly sidetrack development. This steep learning experience serves as the foundation for the last major project task of deploying "WRF-on-demand" simulations in the AWS cloud, which will be completed in the last months of the project.

- We had experience of assimilation of satellite wind data in a standard WRF model before. We moved the assimilation workflow into a HRRRAK-like model. The HRRRAK-like model has the same similar options and namelist as the operational HRRR-Alaska model. The difference is the HRRRAK-like model does not assimilate all of the observational data ingested into the operational HRRR-Alaska model, rather, it only assimilates satellite wind data in order to evaluate its impact on HRRR-Alaska-like model short term forecasts . Data quality and time window are two critical factors that impact the performance of data assimilation. In original VIIRS wind data, there are two kinds of quality information. The first is called "quality_info", it uses 0-100 to represent the quality of the data with 0 as the worst and 100 the best quality. The second is called "quality_flag". The value indicates the quality control criterion of the data pass. Time window controls data to be assimilated, only data within the time window are assimilated in the initial fields. We experimented multiple combinations of above two factors. The best performance is provided with quality_flag=0 and time window=1 hour. We also had to determine how we choose the "ground true" to compare with forecasts. Normally we use the

GDAS observation as the “ground true”. If we think the satellite wind data are “accurate”, we can use GDAS+wind data as the “ground true”. We evaluated the data assimilation performance with two “ground true”. The results do not show much difference. In both comparisons, GDAS observation assimilation produces better results than GDAS+wind data assimilation.

2. *Any issues delaying current or future progress*

- In the last semiannual report we estimated that we had completed 95% of the HRRRAK verification system task. In retrospect, we were at best 75% complete. Almost every week we thought completion was “just around the corner,” only to face more complexities and limitations in working with AWS Cloud components. However, with each problem encountered, we realized that we were being forced into a high-quality “software as a service” paradigm, and the problems being solved would apply directly to our upcoming “WRF as a service” deployment, and lessons learned would be valuable to the general computational meteorology community.
- We are still working on wind data assimilation with various quality control and time window criteria. We hope to find a better way to improve the data assimilation performance.

3. *Interactions with NOAA scientists at WFO’s, NCEP Centers, Regional Offices, etc.*

- Morton has corresponded informally with personnel at Developmental Testbed Center and NWS Alaska Region HQ concerning current and future work within and beyond the context of this project
- Jiang accomplished his visiting scholar project at DTC. He continues working on the study of satellite wind data assimilation and will consult with personnel from DTC and NWS Alaska Region HQ.

4. *Progress against milestones/schedules in proposal Tasks and outcomes -- status summary*

- [in progress; 100% complete] Decide on and deploy and test any of the computational resources we are going to be using - all resources have been decided on.

- [in progress; 95% complete] Initial deployment of model verification structure - this was estimated at 95% complete in the last semiannual report, but a retrospective estimate for the time is 75%. Now, the prototyping and development is complete and we will not invest time in “perfecting” the prototype. Instead, we will spend remaining time to document the many “gotchas” encountered, and our solutions.

- [pending; 10% complete] Development of additional post-products from the HRRRAK, of interest to Alaska entities - this is Morton’s sole focus for the remaining six months. A “WRF as a service” prototype will be deployed in the AWS Cloud, in consultation with the NWS Alaska Region HQ stakeholders.

- [in progress; 100% complete] Development of a workflow for performing case studies - in particular, data acquisition and storage. The workflow for comparing forecasts with each other and with observations has been documented at https://sites.google.com/a/borealscicomp.com/hrrrak/products/workflow-for-forecast-versus-observation-comparisons

- [in progress; 70% complete] Pre-processing workflow for any potential data to be test-assimilated. By now, we have built the pre-processing workflow to process NUCPAS data and VIIRS wind data. We successfully assimilated both data into HRRRAK-like model. We would like to spend more time on wind data assimilation study. In the last half year of the project, we will investigate assimilation of observational meteorological data from USArray stations, and get conclusions on assimilation of three data sources: NUCAPS, VIIRS wind data, and USArray station meteorological data.

- [in progress; 100% complete] Performance of an initial “ceiling and visibility” case study to understand current strengths and weaknesses for execution of future case studies. Based on the

case study, we are now focusing on assimilation of different data sources to improve the HRRAK model short-term forecast.

5. ***Any previously unreported changes to the execution of the originally submitted proposal None.***

6. ***Any outcomes that could be transitioned or offered to operations (previous outcomes can be repeated)*** To the best of our knowledge, the deployment of an active model verification system, using a number of DTC tools, in a cloud environment, is novel, and has been of interest to Alaska Region ESSD. We have made substantial progress in understanding and prototyping what is needed to deploy key computational meteorological activities in the AWS Cloud, and will be extending this to “WRF as a service” deployment in the next months. DTC leadership has also been notified of this progress, as it leverages their own interests in containerization, virtualization and provisioning.

7. ***Critical budget issues (separate financial forms are required)*** None to report.