The performance element reporting logs described here represent actions taken for all IARPC Collaboration Teams during FY 2018, presented in order of appearance in Arctic Research Plan 2017-2021

**IARPC Collaboration Teams**

- Health & Well-being Collaboration Team (p. 2)
- Atmosphere Collaboration Team (p. 23)
- Sea Ice Collaboration Team (p. 55)
- Marine Ecosystems Collaboration Team (p. 82)
- Glaciers & Sea Level Collaboration Team (p. 104)
- Permafrost Collaboration Team (p. 127)
- Terrestrial Ecosystems Collaboration Team (p. 153)
- Coastal Resilience Collaboration Team (p. 169)
- Environmental Intelligence Collaboration Team
  *(includes Arctic Observing, Data and Modeling Sub-teams)* (p. 206)

These Federal agencies comprise IARPC: Department of Commerce (DOC), Department of Defense (DOD), Department of Energy (DOE), Department of Health and Human Services (HHS), Department of Homeland Security (DHS), Department of the Interior (DOI), Department of State (DOS), Department of Transportation (DOT), Environmental Protection Agency (EPA), Marine Mammal Commission (MMC), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF, Chair), Office of Management and Budget (OMB), Office of Science and Technology Policy (OSTP), Smithsonian Institution (SI), and United States Department of Agriculture (USDA). Other agencies also contribute to implementation of the Arctic Research Plan.
1.1 Health & Well-being

1.1 Support integrative approaches to human health that recognize the connections among people, wildlife, the environment, and climate.

- **1.1.1 (In progress)** In collaboration with the Alaska Native Tribal Health Consortium (ANTHC), advance and support a regional One Health approach for assessing interactions at the Arctic human-animal-environment interface to enhance understanding of, and response to, the complexities of climate change for Arctic residents; DOI-FWS (Lead), EPA (Lead), HHS-CDC (Lead), NOAA (Lead), USDA-NIFA (Lead), DOI-USGS, DOS, NASA

  o Quarterly Alaska One Health workgroup meetings continue to bring together partners across disciplines to engage on this topic. These workgroup meetings are advertised on the IARPC website and were recorded and archived on the ANTHC LEO Website: [http://www.leonetwork.org/en/leo/hubpage/ALASKA?show=one-health-group](http://www.leonetwork.org/en/leo/hubpage/ALASKA?show=one-health-group). Topics covered during the past year include: surveillance to detect emerging threats, pathogen exposures among polar bears, the State of Alaska report on health impacts of climate change, zoonotic diseases without pandemic potential, harmful algal blooms, antimicrobial resistance among E. coli found in migratory birds. (Oct 10, 2018 - Completed)

  o In May 2018, The US Department of State hosted 10 health experts from five Arctic nations (Canada, Iceland, Norway, Finland, Russia) to visit the US for a One Health study tour under the International Visitor Leadership Program. This include a one-week trip in Alaska to meet with partners engaged in One Health collaborations including from State, Federal, Tribal entities and the University of Alaska. IVLP alumni are eligible to apply for funding support through State Department and it is hoped that this visit stimulates collaborations around Arctic One Health research. (Oct 10, 2018 - Completed)


  o a. The research described by NASA in 2017 regarding its numerous ABoVE projects continues, with several relevant publications produced in FY 18. These projects are assessing how changing wildlife habitat are impacting key wildlife species in the IARPC domain, including caribou habitats in northeastern Alaska, Alaska’s North Slope, and the NWT, nesting habitats in the Yukon-Kuskokwim Delta, and Dall Sheep habitat across its entire range. All this research involves direct interactions with local and regional native organizations, including development and carrying out of research activities and consultation regarding information needs. Mahoney, P.J. et al. (2018) Navigating

b. The research described in 2017 continues. As a general description, ABoVEresearch is being conducted on how changes to ecosystem and environmental conditions caused by wildfires are impacting access to ecosystem services in Interior Alaska. This research involves collaborations with subsistence harvesters.

c. The research described in 2017 continues, see PE 7.3.2. As noted in 2017, ABoVEnormer are supporting a cross-cutting activity (between the Atmospheric, TE, and HWB CTs) to improve information on wildland fire smoke.

d. The research described in 2017 continues, with several relevant publications produced in FY 18. As described in 2017, the ABoVE Science Team is carrying out a synthesis activity focused on a major scientific data and analysis gap that is specific to Arctic and Boreal regions - the role of snow and snow datasets to enable understanding of wildlife movement & human accessibility to ecosystem services. See publications reported in a.) related to snow, as well as: Pan, C.G., et al. 2018. Rain-on-snow events in Alaska, and their frequency and distribution from satellite observations. Environmental Research Letters 13, 075004.

e. The research described in 2017 continues. As first reported in 2017, the ABoVEScience Team has initiated a synthesis activity focused on both the response of wildlife and the availability of ecosystem services to productivity changes (i.e. greening and browning trends) in Arctic and Boreal regions. (Sep 27, 2018 - Completed)

As part of ANTHC’s EPA GAP grant, program staff attended and provided logistical assistance to the quarterly One Health Group meetings held in person and via Adobe Connect. Participants include technical experts from state/territorial and federal agencies, academic institutions, and tribal organizations (U.S. and Canada) on topics related to human, wildlife and ecological health. A quarterly meeting was held in April with a presentation on Zoonotic diseases with pandemic potential by Dr. Jacques Godfroid and a presentation titled Assessment of the Potential Health Impacts of Climate Change in Alaska by Sarah Yoder. One Health Group webinars are archived here: http://www.leonetwork.org/en/leo/hubpage/ALASKA?show=one-health-group. Program staff attended three of ANTHC’s Clinical & Research Services consultation committee meetings to provide feedback and suggestions to improve research that is respectful and culturally sensitive for the Alaska Native community. NOTE: Our colleagues at DOS are the POCs for several activities around the approved One Health Arctic Council project. EPA has not been involved in tabletop preparedness exercise follow-on activities. (Sep 4, 2018 - Completed)
The May HWCT & ACT May 2018 meeting focused on wildfire forecasting—potential tools for community applications (https://www.iarpccollaborations.org/members/events/10564). This meeting sought to answer the questions:

- Are we getting the right tools to the right people?
- What are gaps and what are the next steps to fill those gaps?

The opportunity to reconvene this group and perhaps advise state/regions/borough on how to coordinate different toolsets to help wildfire response was discussed. Presentations: Recap from AOSST/TECT meeting on Observing system applications & gaps for wildfire smoke detection & forecasting (Sandy Starkweather) LEO Network: how to use the network for ground observations and to stand up projects on specific fires and outreach efforts to tribes on smoke preparedness: clean rooms, HEPA filters, identifying at-risk populations- Mike Brubaker (ANTHC) UAF Smoke Project: ongoing work on simulating transport of smoke from Alaskan wildfires- Martin Stuefer (UAF) (Jun 5, 2018 - Completed)

At the April 2018 HWCT/One Health Quarterly Meeting (https://www.iarpccollaborations.org/members/events/10551) there was an involved discussion of brucellosis in marine mammals. Sarah Yoder provided a helpful overview of the Assessment of the Potential Health Impacts of Climate Change in Alaska. Presentations: Zoonotic diseases with pandemic potential, like brucellosis, are in need of innovative One Health approaches. Dr. Jacques Godfroid, DVM, MSc, PhD. University of Tromsø, Norway; Assessment of the Potential Health Impacts of Climate Change in Alaska, Sarah Yoder M.S., Alaska Section of Epidemiology (Apr 17, 2018 - Completed)

Todd Atwood USGS gave the presentation “Environmental and behavioral changes may influence the exposure of an Arctic apex predator to pathogens and contaminants” at the One Health/HWCT January 2018 meeting (https://www.iarpccollaborations.org/members/events/10548). His presentation wove a cohesive picture of the state of polar bears in the southern Beaufort region as environmental conditions change. (Jan 31, 2018 - Completed)

Alaska Native Tribal Health Consortium (ANTHC) continues to hold quarterly One Health Group meetings at the CDC Arctic Investigations Program Office in Anchorage, Alaska. The next meeting is scheduled for mid-December 2017. EPA along with other sponsors support sessions and speakers at the annual Alaska Forum on the Environment (AFE), held each February in Anchorage, Alaska, where topics like One Health receive a broader community engagement by environmental professionals, educators, Alaskan youth, community leaders and elders. February 12-16, 2018, marks the twentieth anniversary of AFE. (Oct 6, 2017 - Completed)

Ongoing collaborations are fostered through the quarterly Alaska One Health Workgroup, which is both an in-person and webinar-based meeting for information sharing and cross-sectoral interaction. A One Health Table Top exercise was held in Anchorage in February, 2017. As part of the One Health activities under the US Chairmanship of the Arctic Council, this 3-day meeting trained participants in the OH Smart tool created by USDA and the University of Minnesota as means to facilitate interdisciplinary discussions and problem-solving about public threats arising at the interface of animal, human and environmental health. Participants from 4 Arctic
Nations (US, Canada, Greenland, Finland) then applied the tool to scenarios of a marine mammal die-off and an extensive wildfire affecting subsistence food sources. US participants included state, federal, tribal, university and local representatives engaged in scientific and response activities related to OH. (Sep 28, 2017 - Completed)

- ABoVE research supported this Performance Element in the following ways:
  a. Numerous ABoVE projects have assessed how changing wildlife habitat are impacting key wildlife species in the IARPC domain, including caribou habitats in northeastern Alaska, Alaska’s North Slope, and the NWT, nesting habitats in the Yukon-Kuskokwim Delta, and Dall Sheep habitat across its entire range. All this research involves direct interactions with local and regional native organizations, including development and carrying out of research activities and consultation regarding information needs.
  b. Research is being conducted on how changes to ecosystem and environmental conditions caused by wildfires are impacting access to ecosystem services in Interior Alaska. This research involves collaborations with subsistence harvesters.
  c. One issue identified by the HWB Collaboration Team is to improve the ability to predict the probability of smoke events from wildland fires. ABoVE researchers are supporting a cross-cutting activity (between the Atmospheric, TE, and HWB CTs) to improve information on wildland fire smoke. ABoVE research on improving wildland fire emissions is discussed in PE 7.3.2.
  d. The ABoVE Science Team is carrying out a synthesis activity focused on a major scientific data and analysis gap that is specific to Arctic and Boreal regions - the role of snow and snow datasets to enable understanding of wildlife movement & human accessibility to ecosystem services.
  e. The ABoVE Science Team has initiated a synthesis activity focused on both the response of wildlife and the availability of ecosystem services to productivity changes (i.e. greening and browning trends) in Arctic and Boreal regions. (Sep 15, 2017 - Completed)

- 1.1.2 (In progress) In collaboration with the ANTHC, support community-based monitoring and IK and LK by maintaining and strengthening the Local Environmental Observer (LEO) Network to help describe connections between climate change, environmental impacts, and health effects.; DOI-BOEM (Lead), DOI-FWS (Lead), EPA (Lead), NOAA, NSF
  o LEO observations are featured at Alaska OH quarterly meetings and at regular webinars of LEO partners. A manuscript describing and analyzing five years of LEO observations was developed by CDC and ANTHC and is undergoing peer review at the One Health journal. As of July 2017, the LEO network had over 1800 members in 35 countries. There were 670 observations posted by members and published by the LEO coordinators into distinct conversational threads and searchable by key words and topics. The LEO network provides a unique source of community observations and opportunities for researchers and professionals to engage with local communities on environmental topics of mutual interest. For more information about LEO, go to www.leonetwork.org (Oct 10, 2018 - Completed)
  o With funding from BOEM, EPA and others, the LEO Network continues to develop and grow as a platform for sharing information about environmental change. Specifically,
LEO members post personal observations or news articles about unusual and/or extreme environmental events, which are time stamped, geocoded, and tagged by topic. This has created a data base which today has over 2000 posts [https://urldefense.proofpoint.com/v2/url?u=https-3A__www.leonetwork.org_en_reports_show_AB8FD3F1-2DB627-2D48D4-2DB558-2DCB1C964D11E1&d=DwMFAg&c=L0NeIKdfGwIebGetsCr_dMk7qtG-8g4veA-gh1DZOcE&rf=hmsebBaSTmGvUaUz7VcGE6tvQry5YrDAw35ng&m=qwKU45dRMb88o9hJvNA47Co09twpRDQCkFvdpO0eW&su=x3y5XNF64S5q34ANKuF2TFxVYx3XoWAbW1IXBElKk&e=) contributed by over 2500 members in 603 communities [https://urldefense.proofpoint.com/v2/url?u=https-3A__www.leonetwork.org_en_explore_communities-23lat-3D24.9620236817236626lng-3D1.0229999999999827-26zoom-3D2&d=DwMFAg&c=L0NeIKdfGwIebGetsCr_dMk7qtG-8g4veA-gh1DZOcE&rf=hmsebBaSTmGvUaUz7VcGE6tvQry5YrDAw35ng&m=qwKU45dRMb88o9hJvNA47Co09twpRDQCkFvdpO0eW&su=x3y5XNF64S5q34ANKuF2TFxVYx3XoWAbW1IXBElKk&e=] around the globe. LEO has become an integral part of the One Health approach applied in Alaska (see 1.1.1) for surveillance of environmental change events and surveillance for emerging trends.

Arctic Council project partners for the approved CLEO ACAP/IPCAP project have made significant progress. During a recent June 21, 2018, workshop in Rovaniemi, Finland, Swedish and Finnish partners reported and discussed their internal work via cooperation in schools and outlined key future activities for Swedish EPA at a sustained level of basic funding. This October, ANTHC will travel to the Arctic Biodiversity Conference in Rovaniemi to present during a session with circumpolar NGOs on CLEO and will potentially host a follow-on CLEO workshop with EPA. (Sep 4, 2018 - Completed)

- BOEM has entered into a multiyear cooperative agreement, Community Based Monitoring: LEO Network with ANTHC. PI is Dr. Michael Brubaker. (Oct 9, 2017 - Completed)

- There is continued steady growth recorded in the LEO Network [https://leonetwork.org/en/reports], and new feature development is on-going. The system is now beginning to gather environmental data and imagery for enhancing community-based observational data, e.g., capture of webcam imagery. Also, there's new community pages that provide summaries. (Oct 9, 2017 - Completed)

- The LEO network continues to grow and attract domestic and international collaborators. The network continues to collect local observations and to link communities with subject matter experts and resources to assess health threats and response options. An IARPC sponsored webinar focused on wildfires highlighted opportunities for researchers and LEO network observers to share information about wildfire events, both active fire areas and downwind smoke hazards. LEO data could support modeling efforts through verification of prediction models and modelers could assist communities with short and long-term preparation and hazard reduction activities. Further discussions within the IARPC framework are anticipated for 2018. For more information about LEO, go to [www.leonetwork.org](http://www.leonetwork.org) (Sep 28, 2017 - Completed)

- The September joint meeting on the health impacts of wildfires in the Arctic by the Health & Well-being CT, Atmosphere CT, and Terrestrial Ecosystems CT [https://www.iarpccollaborations.org/members/events/9144] began a cross-team
conversation on places for potential interdisciplinary/interagency collaborations. Follow-up actions will be reported as they occur. (Sep 25, 2017 - Completed)

- A BOEM funded study having to do with well-being and social indicators was recently published: Social Indicators in Coastal Alaska: Arctic Communities, prepared by Stephen R. Braund & Associates, OCS Study BOEM 2017-035. The study assesses impacts by community, in addition to social indicators (a) by community (2016); (b) for the North Slope Inupiat over time (1977, 1988, 2003, and 2016); (c) by gender, and (d) for Arctic Indigenous peoples across regions and countries (2003 and 2016). It can be downloaded at this link: https://www.boem.gov/BOEM-2017-035/ (Sep 25, 2017 - Completed)

- In 2016, the DOI Bureau of Ocean Energy Management (BOEM) entered into a cooperative agreement with ANTHC to support community-based monitoring by maintaining and strengthening LEO. and provide more engagement among residents in the North Slope and Kenai Peninsula Boroughs. This multi-year study seeks to refine and expand the existing program to better connect existing efforts, achieve improvements, and provide continuity for this valuable program. Other objectives include enhancing our understanding of environmental change, enhance resources available at the community, regional and federal level to address effects by expanding the scale of the community-based monitoring program and enhancing the rigor, quality, and consistency of data collection by leveraging scientific expertise outside the communities from the greater region and the nation, further refine a joint monitoring effort to promote healthy and effective adaptation strategies to identified environmental changes through a regionally appropriate outreach and education effort, and perform analysis and interpretation of recorded observations with improved scientific rigor and develop lessons learned. (Sep 20, 2017 - Completed)

- 1.1.3 (In progress) In coordination with the ANTHC, use the Alaska Native Maternal Organics Monitoring Study (MOM) to monitor the spatial distribution, contaminant levels, and biological effects in species having body burdens of human caused Persistent Organic Pollutants at or above levels of concern; and improve understanding of the adverse effects of POPs on human populations, especially on child development.; EPA (Lead), HHS-CDC (Lead), NOAA

  - Although funding has ended, the MOM Study continues to be of value. Stored samples from the MOMs project were used to validate the prior study by O’Brien, et al., that showed that vitamin D levels among women of child-bearing age in southwest Alaska have declined in the past 40 years (ref Tim Benner’s post of Aug 30, 2018). Serum from study participants (mother-baby pairs) enrolled during 2001-2010 showed evidence of severe vitamin D deficiency among 53% of infants. These data lead to recommendations for increased vitamin D supplementation during pregnancy for women in southwest Alaska and changes to vitamin D supplementation during infancy. A summary of this study can be found here: http://epibulletins.dhss.alaska.gov/Document/Display?DocumentId=1848 (Oct 10, 2018 - Completed)

  - The MOM Study funding ended in 2015. Work on the data from the study continues. The most recent publications describe the change in the diet of Yupik women of child-bearing age in the Yukon-Kuskokwim Delta over the decades from the 1960s through the year 2000, the steady reduction in marine subsistence foods over that interval, and the parallel reduction in Vitamin D. A rise in diagnosed infant and childhood clinical
Vitamin D deficiency (rickets) in Alaska Native children has been observed during this period. The Tribal Health organization has used these data to make changes in the prenatal care protocols to identify pregnant Yupik women at risk and prevent the development of Vitamin D deficiency. The MOMS data has also been used to investigate the high incidence of infant and early childhood dental disease, and this also appears to be an increased risk in the children born to MOM Study enrollees with low marine food biomarkers and low Vitamin D levels. Additional studies on the MOM Study data are underway to identify risk factors for gestational diabetes. (Sep 4, 2018 - Completed)

1.1.4 (In progress) Increase understanding of how both natural climate change and the effects of human activities are affecting the ecosystem by documenting observations of changing sea ice conditions, with implications for development and subsistence. Efforts like Arctic Crashes: Humans, Animals in a Rapidly-Changing World and Northern Alaska Sea Ice Project Jukebox are examples of contributions to this performance element.; DOI-BOEM (Lead), NOAA (Lead), NSF (Lead), SI (Lead), USDA-NIFA (Lead), DOI-NPS

- The National Science Foundation (NSF) has recently awarded OPP – 1836473. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. The project will co-produce shorefast ice knowledge by leveraging large satellite remote sensing datasets, community-based monitoring, and local and Indigenous knowledge. The quantitative and qualitative shorefast ice knowledge collected will be used to understand how shorefast ice has changed and how these changes matter to individuals and communities in the Uummannaq region. The involvement of residents and institutions in Uummannaq at all stages of the project, in combination with ongoing observations, will lay the foundations for ongoing community support and enable new insights into the complex social, cultural and economic changes caused by rapid environmental change. (Oct 16, 2018 - Completed)

- Published ‘Arctic Crashes:’ Revisiting the Human-Animal Disequilibrium Model in a Time of Rapid Change in Human Ecology - https://doi.org/10.1007/s10745-018-9990-1. The paper introduces a new vision advanced by the recent project, Arctic People and Animal Crashes: Human, Climate and Habitat Agency in the Anthropocene (2014–2015) developed at the Smithsonian Institution. Unlike earlier top-down models of polar animal-climate-people connections that tied changes in Arctic species’ abundance and ranges to alternating warmer and cooler temperatures or high ice/low sea-ice regimes, rapid animal declines (‘crashes’) may be better approached at regional and local scales. This approach is close to Arctic peoples’ traditional vision that animals, like people, live in ‘tribes’ and that they ‘come and go’ according to their relations with the local human societies. As the Arctic changes, rapidly and climate/sea-ice/ ecotone boundaries shift, we see diverse responses by Arctic people and animals to environmental stressors. The article examines recent data on the status of three northern mammal species – caribou/reindeer, Pacific walrus, and polar bear—during two decades of the ongoing Arctic warming. The emerging record may be best approached as a series of local human-animal disequilibria interpreted from different angles by population biologists, indigenous peoples, and anthropologists, rather than a top-down climate-induced ‘crash.’ Such new understanding implies the varying speed of change in the physical, animal, and human domains, which was not factored in the earlier models of climate–animal–people’s interactions. (Sep 30, 2018 - Completed)
The National Science Foundation has recently awarded OPP – 1749081. The objective of proposed research under Phase 2 of SIPN (SIPN2) is to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This grant will: Investigate the sensitivity of subseasonal-to-seasonal sea-ice predictability in the Alaska Arctic to variations in oceanic heat and large-scale atmospheric forcing using a dynamical model Community Earth System Model (NCAR CESM) and statistical forecasting tools, focusing on spatial fields in addition to total extent summaries; Assess the accuracy of Sea Ice Outlook (SIO) submissions based on methodology and initialization; Develop new observation-based products for improving sea-ice predictions, including sea-ice thickness, surface roughness, melt ponds, and snow depth; Evaluate the socio-economic value of sea-ice forecasts to stakeholders who manage ship traffic and coastal village resupply in the Alaska Sector, and engage the public in Arctic climate and sea-ice prediction through blog exchanges, accessible SIO reports, bi-monthly webinars, and by making public data sources useful to non-scientists and scientists alike; and Continue and evolve network activities to generate SIO forecasts and reporting for September minima as in SIPN and expand SIPN2 forecasts to include full spatial resolution and emerging ice-anomaly-months (October - November). This work will directly engage stakeholders that create and use sea-ice forecasts in Alaska and lead to improved safety around sea ice. Work under SIPN2 will also track public awareness and perceptions regarding sea ice, helping to raise understanding through accessible reports, discussions, and public data sources useful to non-scientists and scientists alike. Stakeholder engagement during the research process will potentially facilitate rapid research-to-operations implementation of the products of this work. (Sep 24, 2018 - Completed)

BOEM has entered into a cooperative agreement, Northern Alaska Jukebox - Phase III with the Coastal Marine Institute, University of Alaska, Fairbanks. PI is Leslie McCartney, Elmer E. Rasmuson Library. (Sep 21, 2017 - Completed)

"Narwhal: Revealing an Arctic Legend" exhibition is in production and will open 3 August. See news release at https://naturalhistory.si.edu/exhibits/narwhal. A book by the same title authored by W. Fitzhugh and F M. Nweeia has been completed and is being printed. Arctic Crashes: The introduction and 90% of the manuscripts for the Arctic Crashes volume are in and being edited by Igor Krupnik and Aron Crowell. Burch Lecture: The annual Burch lecture was held on April 27, 2017 with presentations by Hannah Voorhees and Rhonda Sparks. Description available by googling Smithsonian events calendar Burch lecture. (May 17, 2017 - Completed)

1.1.5 (In progress) Support the Rural Alaska Monitoring Program (RAMP), a community-based environmental monitoring network in Alaska Native communities to collect samples and data on zoonotic pathogens, mercury, and organic contaminants in land and sea mammals used for subsistence.; DOI-FWS (Lead), EPA (Lead), HHS-CDC (Lead), NOAA (Lead)

RAMP investigators have continued development and validation of the filter paper sample technology for collection of whole blood from animals under field conditions. The simplicity of this method enables a wide range of community observers to collect samples that can be tested for chemicals or signs of infection of concern to the community through the RAMP collaboration. Towards this end, the investigators published a report that validates use of the cellulose filter paper collection method used...
in RAMP for measuring stable isotopes of carbon and nitrogen in whole blood from vertebrates. Stable isotopes are used to assess feeding ecology of sampled animals and when paired with contaminant data can help understand the source of those contaminants. This adds to the previous validations of the filter paper method for detecting contaminants (mercury) and pathogen-specific antibodies (eg. West Nile virus, parvovirus, canine distemper). The article by O’Hara, et al can be found here: http://www.bioone.org/doi/10.7589/2017-08-202 (Oct 10, 2018 - Completed)

The RAMP Study is now entering the second No Cost Extension year (7/1/18-6/30/19), necessitated by the long lag time for analysis of specimens in referral laboratories. The study has, thus far, achieved several significant milestones:

1. The filter paper blood specimen test kits have been standardized, field tested, and are in use by the Alaska Native hunters in Northwest Alaska. Several hundred specimens from caribou and sea mammals have been tested for antibodies to the four zoonotic diseases sought in the study.

2. Harmful algal bloom toxins, saxitoxin and domoic acid, have been documented and measured in subsistence sea mammals and clams.

3. Regional and village meetings have been held to return results to the local populations, regional tribal health providers, and state and federal wildlife managers.

4. Spread of two zoonoses new to the western Arctic have been documented.

5. A statewide network of providers within the AN health care system is being formed, to disseminate updated information on the prevalence of zoonoses in subsistence species and to provide rural residents information on risk reduction strategies to enable them to continue consumption of the traditional diet, with the well-documented cultural and health benefits.

6. The filter paper blood sampling method has been further developed, to allow the use of this technique for analysis of heavy metals and the stable isotopes of nitrogen and carbon, making it useful for investigation of mercury, selenium, and the forage diet of the animals. The development of organohalogen analysis is being tested this fall and may be available at the end of this NCE year. (Sep 4, 2018 - Completed)

EPA grantee (ANTHC) is in third year of research activity (grant ends in 2018), and has made presentations at the International Conference on Arctic Science (Reston, VA, April 2017) and the Arctic Council annual meeting of the International Circumpolar Surveillance Workgroup (Copenhagen, Denmark, September 2017). They have completed development of a field methodology to test zoonotic pathogen antibodies on filter paper blood specimens of subsistence-killed land and sea mammals. These specimens are used to analyze zoonotic exposure, blood Mercury and Selenium, and stable isotopes of Carbon and Nitrogen. Other sampling utilizes stomach and intestinal contents of sea mammals for the harmful algal toxins, saxitoxin, which is associated with paralytic shellfish poisoning, and domoic acid, which is associated with amnesic shellfish poisoning. The gathered data is used by communities to develop adaptation strategies that enable them to continue to utilize traditional food species and reduce risk, while maintaining the cultural and population health benefits of the northern marine traditional diet, and the economic advantages of local foods in remote villages. (Oct 9, 2017 - Completed)
1.2 Promote research, sustainable development, and community resilience to address health disparities associated with underlying social determinants of health and well-being.

- **1.2.1 (In progress)** In collaboration with the ANTHC and the State of Alaska, support development of Arctic Water, Sanitation and Hygiene (WASH) innovations and characterize the health consequences associated with decreased access to in-home water and sanitation services.; EPA (Lead), HHS-CDC (Lead), HHS-IHS (Lead), USARC (Lead), USDA (Lead), DOS
  
  - Update: The 8th Rural Alaska Water and Sanitation workshop was held in January 2018. This workshop focused on the health effects associated water/sanitation systems and to better understand some of the less well-documented effects, or those connected by less obvious linkages. Topics included the evidence linking water/sanitation service with increased consumption of sugar-sweetened beverage, high school graduation rates, and dental caries. We also explored “Ripple Effects Mapping”, a new tool to document the downstream effects of install water/sanitation services using focus groups of residents to describe how life has changed following installation of in-home services. For more information go to: [https://www.arctic.gov/water-san/index.html](https://www.arctic.gov/water-san/index.html) (Oct 10, 2018 - Completed)
  
  - The Denali Commission has funded a research activity (“Alaska Vulnerability Assessment”) to catalog the effects of permafrost thaw, erosion and flooding on infrastructure, including water/sanitation services in rural Alaska communities. The research is being led by University of Alaska Fairbank’s Institute of Northern Engineering and the US Army Corps of Engineer’s Cold Regions Research Lab. Draft findings have been presented for public comment; a final report is pending and will be posted on the IARPC website when available. Point of contact is Don Antrobus ([dantrobus@denali.gov](mailto:dantrobus@denali.gov)) (Oct 10, 2018 - Completed)
  
  - The WASH conference was held, and a summary of the conference has been published. No further work on the WASH conference is planned or funded at this time. (Sep 4, 2018 - Completed)
  
  - The 6th Rural Alaska Water and Sanitation workshop was held in January 2017 and focused on understanding environmental change and the threats posed to water/sanitation systems and to human health via degradation of those services. For more information go to: [https://www.arctic.gov/water-san/index.html](https://www.arctic.gov/water-san/index.html). The Denali Commission is funding a research activity to catalog permafrost thaw and its impact on water/sanitation services in rural Alaska, with work commencing in 2017. (Sep 28, 2017 - Completed)

- **1.2.2 (Met)** Together with the ANTHC, the Commission for Environmental Cooperation, the Yukon Kuskokwim Health Corporation, and Bristol Bay Health Corporation, support research on the health impacts of poor indoor air quality, especially in children. Support source testing and technologies to improve indoor air quality.; EPA (Lead), HHS-CDC (Lead), HHS-IHS (Lead), HUD (Lead)
  
  - This research has been completed. The project evaluated whether improving indoor air quality in homes can reduce exacerbations of respiratory conditions in rural Alaska children who have chronic respiratory problems. Following home ventilation enhancements, improvements were seen in cough, wheezing, and decreases in clinic visits for respiratory conditions. ANTHC has used these results to implement a referral system for health care providers to request a home assessment and, if needed, home

- The collaboratively funded research study conducted by ANTHC and partners on healthy homes interventions in rural Alaska is complete. Baseline data were published in Indoor Air; researchers found that high indoor air pollutant levels were associated with respiratory symptoms in household children, likely related to overcrowding, poor ventilation, woodstove use, and tobacco smoke. Results of the overall intervention were published in the International Journal of Circumpolar Health. Researchers concluded that home remediation and education reduced respiratory symptoms, lower respiratory tract infection related clinic visits, and school absenteeism in children with lung conditions. ANTHC is now evaluating the effectiveness of conducting environmental consultations for children with respiratory illnesses in the emergency department/hospital, with follow-up resources and resident education tools.

- Alaska Native Tribal Health Consortium (ANTHC) and partners completed their healthy homes research study involving home assessments, patient education, and minor home modifications for children with severe or chronic lung disease in rural Alaska. They are in the process of publishing the study results. The baseline data were published earlier this year in the journal Indoor Air; the data indicated that high indoor air pollutant levels were associated with respiratory symptoms in household children, likely related to overcrowding, poor ventilation, wood stove use, and tobacco smoke. 

- The research study evaluating whether improving indoor air quality can reduce exacerbations of respiratory conditions in rural Alaska children has been completed. Following home ventilation enhancements, improvements were seen in cough, wheezing, and decreases in clinic visits for respiratory conditions. ANTHC has begun to implement a referral system for health care providers to request a home assessment and, if needed, home improvements for at-risk children. (Sep 28, 2017 - Completed)

- Indoor air quality in poor Alaskan homes has exacerbated respiratory problems, especially in children. ANTHC started programmatic system for children repeatedly
hospitalized for respiratory problems can improve homes indoor air quality through housing authority consultation (EPA, CDC, HUD) (Jun 24, 2017 - Target)

- **1.2.3 (In progress)** Support educating and connecting Arctic residents with museum collections and archival materials to improve community mental health and well-being through efforts such as The Health of Heritage.; ED (Lead), LC (Lead), NOAA (Lead), SI (Lead), DOI-NPS, NSF
  
  o The Arctic Studies Center of the Smithsonian Institution is embarking on its next major venture, the centennial of the Fifth Thule Expedition of 1921-1924. In over three years of fieldwork, the Expedition collected over 20,000 ethnographic, archaeological, and natural history specimens, and compiled thousands of pages of diaries, notebooks, word lists, and manuscripts, containing detailed characteristics of contemporary culture, language, folklore, and activities of the polar people they visited, as well as the natural environment and prehistory. The primary goal of the centennial will be to assist scientists, local educators, media, and particularly the Arctic communities in the areas visited by Fifth Thule Expedition, to reconnect with the records of their cultures and heritage created by the expedition members and other actors of the same era. The first opportunity to present new materials and discuss plans for the centennial program will come in February 2019 at the 46th annual meeting of the Alaska Anthropological Association. (Sep 30, 2018 - Completed)

  o The National Science Foundation (NSF) has recently awarded OPP – 1803494. This award will support a long-term collaborative archaeological project with the community of Tuyuryaq (Togiak), Alaska. This project redefines the cultural landscape utilizing a developing field of Indigenous archaeology with the specific community-based approach, placing value and focus on community while contributing to a better understanding of a coastal sub-arctic village and the peoples’ relationships to the landscape including plants and terrestrial and marine resources. This project will further develop knowledge coproduction methods between scientists and community members within an archaeological framework. This project takes a place-based inclusive approach that advances youth access to education in the sciences and beyond and supports a newly established cultural center which will curate the materials resulting from the research. (Sep 27, 2018 - Completed)

  o In August 2017, the Smithsonian National Museum of Natural History opened “Narwhal: Revealing an Arctic Legend”. This exhibit contributes to health and heritage by revealing the close relationship of the Inuit with this charismatic animal, especially in Arctic Canada and Greenland, but also in Alaska, where these animals are occasionally seen and hunted. The exhibition is open until mid-2019. Arctic Studies Center staff have also produced a fine book (with the same title, available in December 2017) documenting the topic. Themes of the exhibit and book include the biology and ecology of the Narwhal, new findings on the function of its mysterious tusk, the Narwhal through history and Inuit mythology, the Inuit and their close association with the narwhal, and the effects of present and future climate change. The Smithsonian developed the exhibit and book in partnership with Canadian Inuit (especially Pond Inlet), anthropologists, biologists, paleontologists, and historians. For more information, please see https://naturalhistory.si.edu/exhibits/narwhal/ (Oct 2, 2017 - Completed)

- **1.2.4 (In progress)** Synthesize knowledge on sustainable development among Arctic communities; develop a state-of- the-art understanding of social-ecological systems in the
Arctic context; and amass case studies of best practices that support well-being and sustainable development across the Arctic.; NSF (Lead)

- Publication of "Arctic Sustainability Research: Past, Present, and Future" by Andrey N. Petrov, Shauna BurnSilver, F. Stuart Chapin III, Gail Fondahl, Jessica K. Graybill, Kathrin Keil, Annika E. Nilsson, Rudolf Riedsperger, and Peter Schweitzer (https://www.routledge.com/Arctic-Sustainability-Research-Past-Present-and-Future/Petrov-BurnSilver-Ill-Fondahl-Graybill-Keil-Nilsson-Riedlsperger-Schweitzer/p/book/9781138088306). This book offers key insights into the history, current state of knowledge and the future of sustainability, and sustainable development research in the Arctic. Written by an international, interdisciplinary team of experts, it presents a comprehensive progress report on Arctic sustainability research. It identifies key knowledge gaps and provides salient recommendations for prioritizing research in the next decade. Arctic Sustainability Research will appeal to researchers, academics, and policymakers interested in sustainability science and the practices of sustainable development, as well as those working in polar studies, climate change, political geography, and the history of science. (Sep 30, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1839198. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. The researchers’ goal is to understand the influence of both environmental dynamics and increasing anthropogenic activity on the behavior and phenology of migratory caribou (Rangifer tarandus), waterfowl, and songbird communities in Arctic-boreal Alaska and northwestern Canada. Through co-production of knowledge with local land managers and indigenous communities, the research team will combine field observations, modeling, and analyses that include: (1) soundscape measurements, (2) camera-trap observations, (3) automated soundscape analyses, (4) analyses of camera-trap caribou observations, (5) high-resolution modeling of environmental variables, (6) statistical analyses including wildlife occupancy, diversity, and phenology modeling, and (7) a human-computation game to collect descriptions of our acoustic recordings that allows for the participation of local and Indigenous players of the game. (Sep 28, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1803494. This award will support a long-term collaborative archaeological project with the community of Tuyuryaq (Togiak), Alaska. This project redefines the cultural landscape utilizing a developing field of Indigenous archaeology with the specific community-based approach, placing value and focus on community while contributing to a better understanding of a coastal sub-arctic village and the peoples' relationships to the landscape including plants and terrestrial and marine resources. This project will further develop knowledge coproduction methods between scientists and community members within an archaeological framework. This project takes a place-based inclusive approach that advances youth access to education in the sciences and beyond and supports a newly established cultural center which will curate the materials resulting from the research. (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1758781. The (IdEA) Incubator for Digital Entrepreneurship in the Arctic works with remote Alaskan communities to co-produce transformative digitally-focused and economically-centered knowledge developing a digital incubator/accelerator connecting Alaskan rural
entrepreneurs with venture capital. IdEA applies optimized entrepreneurial training linking entrepreneurship best practices with venture capital support, enabling rural Alaskan communities to develop and apply their unique expertise for the specific purpose of growing and diversifying their economy in alignment with U.S. Arctic Policy for national security and economic development. (Sep 25, 2018 - Completed)

- Arctic FROST and ASUS aim to develop knowledge synthesis on sustainable development and will be publishing a synthesis book. There will be a workshop in Santa Fe and meeting at ICASS. By December the synthesis book will be submitted for publishing. Each chapter has a team of specialists writing a synthesis. Workshop in Greenland focusing on community sustainability. (Dec 2, 2017 - Target)

- The Arctic Youth and Sustainable Futures project follows up on a key recommendation presented in AHDR (2014) to address gaps in knowledge on understanding youth and their aspirations, and the issues and challenges they face in a time of global change. Core participation: 25 Arctic scholars from a range of disciplines & from 22 institutions in 10 countries. Funding provided by the Nordic Council of Ministers’ Arctic Cooperation Programme (2016-2018). Project international co-leads: Joan Hyman Larsen (Icenald) and Diane Hirshberg (USA). Andrey N Petrov is a U.S. co-lead.

The project’s premise is that the future of the Arctic will be determined to a great extent by today’s youth, as they make choices around the opportunities and challenges they face, their priorities in terms of culture and identities, where to study and where to live, what occupations and lifestyles to pursue, and factors affecting their social and physical well-being.

Objectives:

- To investigate and conduct research on the needs, opportunities, aspirations and perspectives of Arctic youth ages 18-26,
- To fill identified gaps in knowledge on the lives, ambitions, challenges and wellbeing of youth – indigenous and non-indigenous – across the circumpolar Arctic.
- To advance our understanding of sustainable options for Arctic communities and localities, urban and rural. The Arctic Youth project seeks to: (1) research the literature and existing knowledge; (2) conduct focus groups, in-depth individual interviews; (3) develop a set of social indicators and future scenarios based on perspectives of Arctic Youth; (4) deliver an edited volume presenting the results of discussions with youth, data statistics and literature synthesis, and in-depth analysis and discussion of the most pressing issues and knowledge gaps concerning Arctic youth and sustainable futures. environment, such as the impacts and responses to climate change and economic and cultural globalization. To date multiple focus groups with young Arctic residents (18-26 years old) were held in 2017 Nuuk, Greenland (2), Akureyri, Iceland (1), Umea, Sweden (1), Bodo, Norway (1), Whitehotse and Inuvik, Canada (2), Juneau, Alaska (1) and an on-line focus group with Indigenous youth from Russia (Murmansk, Khanty-Masni and Chukotka) (1). (Oct 31, 2017 - Completed)
Arctic Youth and Sustainable Futures, funded by Nordic ministers but developing a US component, and looks at young people of the Arctic and their aspirations of the future (Jun 24, 2017 - Target)

1.3 Promote food, water, and energy security in rural/remote Arctic regions.

- **1.3.1 (In progress)** In collaboration with the State of Alaska, coordinate investigations and reporting on food security in the Arctic, to include shifting patterns of food consumption, the safety of subsistence foods, and successful adaptation strategies being employed by northern residents.; DOI-BOEM (Lead), NOAA, NSF

- **1.3.2 (In progress)** In collaboration with the Alaska Department of Environmental Conservation (ADEC) and the Alaska Rural Water and Sanitation Working Group, support the ADEC “Alaska Water and Sewer Challenge” and provide input and support for the Conference on Water Innovations for Healthy Arctic Homes (WIHAH) and its resultant research activities and recommendations.; EPA (Lead), HHS-CDC (Lead), HHS-IHS (Lead), USARC (Lead), USDA (Lead), DOS

- **Update:** The State of Alaska Water and Sewer Challenge entered completed prototype development and testing (Phase 3) in 2017. The Project Management Team is now in Phase 4: field system development and testing, to be completed by 2020. For more information: [http://watersewerchallenge.alaska.gov/](http://watersewerchallenge.alaska.gov/) ()

- The State of Alaska is in the process of developing health-based performance standards for a potentially promising approach to water reuse identified and developed under the “Alaska Water and Sewer Challenge.” ()

- The State of Alaska Water and Sewer Challenge entered Phase 3 in 2017 and has funded three teams to develop and test decentralized options for home water/sewer services and these projects will be moving into the field testing phase in 2018. For more information: [http://watersewerchallenge.alaska.gov/](http://watersewerchallenge.alaska.gov/). The WIHAH meeting proceedings and summary of suggested future directions has been posted and can be accessed here: [http://wihah2016.com/](http://wihah2016.com/). A thematic network has been created under the University of the Arctic to carry on the collaborations from WIHAH conference. Participating universities from the US, Canada, Greenland, Denmark, Russia, Norway will work on cross-disciplinary exchange of information, collaborative research and education projects. For more go to: [http://www.uarctic.org/organization/thematic-networks/arctic-wash/](http://www.uarctic.org/organization/thematic-networks/arctic-wash/) (Sep 28, 2017 - Completed)

- **1.3.3 (In progress)** Together with the Alaska Energy Authority (AEA), the Cold Climate Housing Research Center (CCHRC), and UAF, promote research on renewable, efficient, and sustainable (resource, maintenance, and cost) energy systems, including microgrid technology development and application in remote Arctic communities via USARC’s Arctic Renewable Energy Working Group activities.; USARC (Lead)

- The U.S. Arctic Research Commission’s Arctic Renewable Energy Working Group hosted a series of workshops focused on Residential Heating in Remote Arctic Villages. This
invitational workshop focused on the implementation of research to improve residential heating options in remote Arctic villages. Workshop objectives were to develop a strategy to address research needs for residential heating in remote Arctic villages previously identified at the January 2016 workshop. This includes identification of research that still requires implementation and the development of approaches to fill outstanding gaps. The report (Residential Heating in Remote Arctic Villages: Implementation) can be found here: [https://storage.googleapis.com/arcticgov-static/arewg/publications/heat2_final.pdf](https://storage.googleapis.com/arcticgov-static/arewg/publications/heat2_final.pdf) (Oct 10, 2018 - Completed)

- USARC hosted a workshop at the Alaska Forum on the Environment titled: Improving Village-level Financial, Management and Technical Capacity. The three sessions hosted by USARC were aimed at understanding the current methods of assessing and improving village-level capacity in order to improve the success rate of renewable energy projects and water and sanitation in remote Alaskan villages. Session objectives were to:
  - Improve knowledge about the processes available/needed to assess local capacity
  - Improve knowledge of capacity development and technical assistance needed to achieve sustainable water systems and renewable energy project
  - Development of community-based standards for capacity improvement
  - Receive input and progress on holistic capacity developments approaches that include community-based approaches and the establishment of a network of practitioners


1.4 Document the prevalence and nature of violence against Alaska Native women and youth; evaluate the effectiveness of Federal, State, tribal, and local responses to violence against Alaska Native women and youth; and propose recommendations to improve the effectiveness of such responses.

- **1.4.1 (In progress) Conduct a National Baseline Study (NBS) to assess Alaska Native women's experiences with violence and victimization, health and wellness, community crime, service needs, and help-seeking behaviors and outcomes. ; DOJ-NIJ (Lead), DOJ-OVW (Lead) 
  - National baseline study ongoing and will be completed at the end of the year. DOJ (NIJ) (Dec 2, 2017 - Target)
  - Awards from I-LEAD issued, including one for Alaska, and ties into work NIH is doing around suicide prevention. (Apr 22, 2017 - Completed)

- **1.4.2 (Met) Examine the contributions Village Public Safety Officers (VPSO) make to their rural communities and the criminal justice responses to violence committed against Alaska Native women. Evaluate and document the impact that the Alaska VPSO initiative is having on the
investigation and prosecution of those who commit acts of sexual and domestic violence against Alaska Native women in rural communities.; DOJ-NIJ (Lead), DOJ-OVW (Lead), NSF

- Publication of “An Innovative Response to an Intractable Problem – Using Village Public Safety Officers to Enhance the Criminal Justice Response to Violence Committed Against Alaska Native and American Indian Women in Alaska’s Tribal Communities” (NCJ 251890, Brad A. Myrstol, July 2018, NIJ-Sponsored, [124 pages]) (https://www.ncjrs.gov/pdffiles1/nij/grants/251890.pdf). The principal goal of this project was to empirically document and evaluate the impact Alaska’s village public safety officer (VPSO) program has on the investigation and prosecution of those who commit acts of sexual and domestic violence against Alaska Native and American Indian women in Alaska’s tribal communities. Results show that the men and women who constitute Alaska’s VPSO program play a central role in the criminal justice response to incidents of sexual assault, sexual abuse, and domestic violence committed in Alaska’s tribal communities. This study documents the many ways that VPSOs not only serve as a “force multiplier” for Troopers by serving as first responders and assisting with investigations. VPSOs also serve victims and their communities by providing crucial post-incidents support and services in the aftermath of sexual assault, sexual abuse, and domestic violence incidents. (Oct 1, 2018 - Completed)

- 1.4.3 (In progress) Together with the AIDA, determine effective methods to assess exposure to violence and victimization among Alaska Native youth, ultimately to improve their health and well-being. Develop and test a survey instrument and different administration modes that can effectively evaluate exposure to violence and victimization and determine the feasibility of using these procedures in tribal communities.; DOJ-NIJ (Lead), DOJ-OJJDP (Lead), DOJ-OVC (Lead)

- The project is ongoing and is not expected to end until September 2019. The team has developed the instrument and completed some pilot work but they are still awaiting OMB approval before they can complete the cognitive and pilot testing. (Sep 30, 2018 - Completed)

1.5 Increase understanding of mental health, substance abuse, and well-being for Alaskan youth; and support programs that address those impacts and strengthen youth resilience.

- 1.5.1 (In progress) Increase knowledge and the evidence base for effective community-determined approaches that contribute to the health and well-being of children and youth as they move into adulthood. Efforts like Native Youth Initiative for Leadership, Empowerment, and Development (I-LEAD) and Generation Indigenous are examples of contributions to this performance element.; DOI-BIA (Lead), ED (Lead), HHS-ACF (Lead), USDA-NIFA (Lead)

- An additional award under the Native Youth Initiative for Leadership, Empowerment, and Development (I-LEAD) program was made to the Tanana Chiefs Conference. The Tanana Chiefs Conference will create a formalized leadership development framework for up to 48 youth and young adults aged 14-24 in the 37 federally recognized tribal communities within the TCC region. The project will do this by developing and implementing a curriculum of organizational and traditional tribal leadership practices coupled with experiential learning opportunities at local, tribal, organizational, and regional levels. These learning opportunities will try and focus on youth and young-adult issues to maximize engagement in decision-making activities at these various levels, fostering the next generation of leaders. (Sep 30, 2018 - Completed)
o Roberto provided an overview of RISING SUN, and Arctic Council initiative that ended in May 2017, during the June 20th HWCT meeting. Roberto’s PowerPoint presentation is available at [http://www.iarpccollaborations.org/members/documents/9464](http://www.iarpccollaborations.org/members/documents/9464). The video of his presentation is posted at: [http://www.iarpccollaborations.org/members/events/9141](http://www.iarpccollaborations.org/members/events/9141). (Jun 26, 2017 - Completed)

o Angela Mark’s presentation on SAMHSA mental health and suicide prevention programs with Alaska Natives at the June 20th HWCT meeting relates to this Performance Element. See Angela’s presentation at [http://www.iarpccollaborations.org/members/documents/9435](http://www.iarpccollaborations.org/members/documents/9435). The video of his presentation is posted at: [http://www.iarpccollaborations.org/members/events/9141](http://www.iarpccollaborations.org/members/events/9141). (Jun 26, 2017 - Completed)

o As part of the Native Youth Initiative for Leadership, Empowerment, and Development (I-LEAD), the Administration for Native Americans, an Office of the Administration for Children and Families (ACF) awarded the Alaska Native Heritage Center a grant to develop and implement an inter-generational cultural identity project that reconnects Alaska Native Youth to their indigenous traditions and fosters the growth of a "survival kit" of knowledge based on their ancestral ways of living. The project period is until September 2021. See [https://www.acf.hhs.gov/ana/resource/active-i-lead](https://www.acf.hhs.gov/ana/resource/active-i-lead) (Jun 20, 2017 - Completed)

- **1.5.2 (In progress)** Support tribal behavioral health programs and collaborative research hubs to prevent and reduce suicidal behavior and substance abuse and to reduce the burden of suicide and promote resilience among Alaska Native youth.; HHS-CDC (Lead), HHS-NIH (Lead), HHS-NIMH (Lead), HHS-NIMHD (Lead), USARC (Lead), DOS, NSF

  o The RISING SUN Toolkit 9 [http://www.mhinnovation.net/collaborations/rising-sun](http://www.mhinnovation.net/collaborations/rising-sun) was launched in June 2018. Reducing the Incidence of Suicide in Indigenous Groups - Strengths United through Networks (RISING SUN) was an initiative of the 2015-2017 US Arctic Council Chairmanship ([http://www.mhinnovation.net/sites/default/files/files/acsdwg-logo-hi-res-copy%281%29.jpg](http://www.mhinnovation.net/sites/default/files/files/acsdwg-logo-hi-res-copy%281%29.jpg)). RISING SUN produced a number of useful tools, including an online toolkit on how to measure the impact and effectiveness of suicide prevention in circumpolar Indigenous communities. On the website, you can a) read about how the Toolkit was developed using a community-based consensus building process across the circumpolar North; b) learn how the Toolkit can be used for different audiences and target groups; and c) access the Toolkit directly. (Sep 30, 2018 - Completed)

  o During the September 2018 meeting of the Health and Wellbeing Collaboration Team, members heard a presentation ([https://www.iarpccollaborations.org/members/documents/12108](https://www.iarpccollaborations.org/members/documents/12108)) on the first-year activities of the NIH-funded Alaska Native Collaborative Hub for Research on Resilience (ANCHRR) ([https://www.anchrr.org/](https://www.anchrr.org/)). The goals of ANCHRR are to 1) establish a central communication hub that anchors and supports our collective efforts to reduce Alaska Native youth suicide risk and promote wellness; 2) focus on the strengths of Alaska Native people, culture and communities; 3) use research as a way to understand how to increase community health and strategically strengthen institutions and programs to prevent suicide and other associated issues; and 4) develop and sustain capacity for health research that is community-driven, Alaska Native led, and grounded by Indigenous knowledge, language and culture. (Sep 30, 2018 - Completed)
Andrea Horvath Marques' presentation on NIMH/NIMHD collaborative research hubs to reduce the burden of suicide among American Indian and Alaska Native youth at the June 20th HWCT meeting relates to this Performance Element. For more information on these programs see Andrea’s presentation available at http://www.iarpccollaborations.org/members/documents/9476. The video of his presentation is posted at: http://www.iarpccollaborations.org/members/events/9141. (Jun 26, 2017 - Completed)

NIMH issued Notice of Award on 31 May 2017 to the University of Alaska, Fairbanks for Alaska Native Collaborative Hub for Resilience Research (ANCHRR). (Jun 9, 2017 - Completed)

- 1.5.3 (No progress) Conduct surveys to document and report on adverse childhood experiences (ACEs) in Alaska children, including among American Indian and Alaska Native children.; Census (Lead), HHS-CDC (Lead), HHS-HRSA (Lead)

1.6 Support the reduction of occupational safety and health (OSH) hazards in the Arctic, particularly in the commercial fishing, water, and air transportation industries as well as for those workers exposed to occupational hazards from climate change impacts.

- 1.6.1 (In progress) Together with the State of Alaska, document and describe occupational risks using epidemiologic surveillance.; DHS-USCG (Lead), DOL-OSHA (Lead), FAA (Lead), HHS-CDC (Lead), NTSB (Lead)

The following manuscripts have been published:


The following manuscript under review at American Journal of Industrial Medicine:


The following manuscripts are in preparation:


Conduct surveillance of occupational fatalities in collaboration with the State Department of Public Health. Expanded to non-fatal data, through partnership with State Department of Labor. Study completed on injuries among loggers. (Apr 22, 2017 - Completed)

- 1.6.2 (In progress) Together with the State of Alaska, conduct prevention-oriented research addressing fatal and nonfatal injuries and illnesses in high-risk worker populations.; DHS-USCG (Lead), DOL-OSHA (Lead), FAA (Lead), HHS-CDC (Lead), NTSB (Lead)

Computer-based training program on fatigue prevention for Alaska commercial pilots. Three studies in analysis stage investigating non-fatal injuries to workers in seafood processing, aviation, and commercial fishing that will identify hazards and propose interventions. Completed portion: The fatigue prevention training program for Alaska pilots (Feb 1, 2018 - Target)


1.7 Improve the quality, efficiency, effectiveness, and value of health care delivery in the Arctic.

- 1.7.1 (In progress) In collaboration with the ANTHC, promote research on how telemedicine applications can improve health care delivery and patient outcomes.; HHS-AHRQ (Lead)

- The Alaska Native Tribal Health Consortium is conducting an evaluation of telemedicine for the management of persons diagnosed with rheumatoid arthritis, led by Dr. Elizabeth Ferucci. The Alaska Tribal Health System telemedicine capacity includes live video conferencing, which is used in this study. Funded by AHRQ, this study seeks to determine the impact on disease activity, access to care, and quality of care for those patients whose medical follow-up is arranged through telemedicine. These assessments use the experience of the telemedicine patients before and after starting telemedicine follow-up and compares this with arthritis patients receiving in-person care only. The study is ongoing and data collection is to be completed in March 2019; early results are presented in a IARPC webinar (https://www.iarpccollaborations.org/members/documents/11895) A systematic review of telemedicine for rheumatology authored by Dr. Ferucci in 2018 can be found here: https://onlinelibrary.wiley.com/doi/abs/10.1002/acr.23153

- The following presentation given at the August 21st Health & Well-being Collaboration Team meeting is relevant to this Performance Element:


The meeting began with an overview of the history and scope of telemedicine use in the Alaska Tribal Health System then focused on our ongoing AHRQ-funded project evaluating the use of telemedicine for rheumatoid arthritis follow-up. This included factors associated with telemedicine use at baseline and data on disease outcomes in the short-term follow-up period completed to date. Finally, it discussed our proposal for a larger scale study evaluating outcomes and costs of telemedicine for specialty care for chronic diseases in a broader sense in the Alaska Tribal Health System. (Sep 5, 2018 - Completed)

Agencies
DOC, DOD, DOI, DOS, EPA, HHS, NASA, NSF, OSTP, SI, USARC, USDA
Atmosphere Collaboration Team

Performance Element Reporting Log FY2018

(Some links in this summary require an account on IARPC Collaborations Website. Please visit www.iarpccollaborations.org to request an account.)

2.1 Atmosphere

2.1 Advance understanding of Arctic atmospheric processes and their integrated impact on the surface energy budget.

- 2.1.1 (In progress) Support planning, preparation, and implementation for the Multi-disciplinary drifting Observatory for the Study of the Arctic Climate (MOSAiC), including deployment of the DOE Atmospheric Radiation Measurement (ARM) mobile atmospheric measurement facility and other coupled measurements on the drifting German icebreaker, RV Polarstern.; DOE (Lead), NSF (Lead), DOD-ONR, NOAA
  
  o The National Science Foundation has recently awarded OPP – 1820927. This research will synthesize three interrelated science contributions: (1) Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) field observations will identify governing physical processes, fluxes, and linkages within the Arctic climate system. (2) Realistic-resolution (meters-scale), physically based modeling tools (e.g., MicroMet, SnowModel, EnBal, SnowPack, SnowTran-3D, SnowDunes, SnowAssim, Sealce-3D) will quantify the behavior, interactions, and sensitivities among the Arctic system components. (3) Field observations and high-resolution modeling will be integrated to define what is missing or poorly represented in Earth System Models and guide the parameterization of the associated snow-related processes and fluxes for the Community Earth System Model (CESM) and the Los Alamos Sea Ice Model (CICE). (Sep 26, 2018 - Completed)

  o The National Science Foundation has recently awarded OPP – 1753423. Atmospheric transport and deposition of aerosols is an important delivery mechanism of natural and contaminant trace elements (TEs) to the Arctic. These inputs have strong implications for the ecosystem, and even human health. Assessment of this input is difficult because measurements of deposition rates in remote ocean regions. This research will provide estimates of the yearly atmospheric deposition flux of aerosol trace elements (TEs, total and soluble), including those of biogeochemical importance as well as pollutant species. The seasonal evolution of partitioning of trace element deposition among the various catchments (ice, water, snow, melt ponds) will also be assessed. The work will involve measurements of 7-Be inventories, 7-Be aerosol activities, and aerosol concentrations of TEs. Field work will be during a year-long ice drift of the MOSAiC expedition through the central Arctic Ocean. (Sep 25, 2018 - Completed)

  o The National Science Foundation has recently awarded OPP – 1805569. The investigators will deploy an unmanned aircraft system to measure atmospheric temperature, winds, and humidity, as well as surface albedo. Flights will take place from mid-winter (February) through late summer (August) to capture variable conditions in
both the atmosphere and sea ice surface and will include routine profiling of the lower atmosphere, spatial mapping of thermodynamic quantities and surface albedo, and mapping of the lower atmospheric structure over leads. This data will be evaluated with measurements of the atmosphere, ocean and ice collected by other scientists as part of the MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) project to address hypotheses related to the performance of modeling tools in simulating key processes over the central Arctic Ocean. These include questions about sub-grid scale variability of atmospheric and surface parameters and its influence on model-simulated surface energy budget; the influence of leads in the sea ice on energy transfer from the ocean to the atmosphere and how models represent this transfer; and the importance of vertical resolution in simulation of the Arctic atmosphere and its impact on the simulation of clouds and the surface energy budget. The investigators will compare observations from unmanned aerial systems to a variety of simulations, ranging from global products to fully-coupled regional simulations completed using the Regional Arctic System Model (RASM) to detailed single-column and 2D modeling at high resolution. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1807496. This study will improve understanding of processes controlling exchange of climate-active gases between sea ice and atmosphere in the Arctic. The investigators will participate in a year-long, international field campaign in the high Arctic, Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC). They will conduct continuous turbulent flux measurements using the eddy correlation method from a tower on the bow of the German icebreaker Polarstern and from a tower situated on a nearby ice camp. These will account for gas transfer over large, km-scale areas of ice and open water leads. The investigators will also collect measurements of direct gas emission and deposition over smaller areas of ice and snow and a range of surface types using portable dynamic flux chambers. In collaboration with members of the Biogeochemical Exchange Processes at Sea-Ice Interfaces working group (BEPSII), observations of direct gas transfer will inform and validate biogeochemical models of trace gas dynamics in sea ice. In addition, a physical parameterization of air/sea gas transfer will be developed as an extension of the Coupled Ocean-Atmosphere Response Experiment gas transfer (COAREG) model, enabling regional estimates of net gas transfer in the sea ice environment. Finally, results will be used to develop and evaluate of ocean-sea ice-boundary layer exchange of climate-active trace gases in both 1-D and meso-scale (Polar Weather Research and Forecasting) atmospheric chemistry-meteorological modelling systems. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1821911. The goal of this project is to identify the biological and physical drivers underlying the production and uptake of oxygen and methane, establishing the metabolic balance of these key gases in the oligotrophic Central Arctic. The investigators will take advantage of the unique opportunity afforded by the international, year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition to determine net community production from year-round measurements of oxygen and argon, as well as methane oxidation and production from methane concentration and isotopic ratios. They will measure bacterial and community respiration, bacterial production, and microbial community structure, and analyze gene expression to identify the genes, organisms, and pathways associated with methane production in the surface ocean.
Results will be used to model the oceanic methane cycle using the MITgcm Arctic Regional Model and improve the biogeochemical components of the Regional Arctic System Model (RASM). (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1824447. This proposal focuses on the planktonic lower trophic levels and will quantify the role that the mesozooplankton play in biological transformation and cycling of important elements (C, N) in the central Arctic Ocean ecosystem as part of the year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. Working together with an international team of scientists, the PIs will determine seasonal patterns in abundance, biomass, vertical distribution, and life stage structure for the entire zooplankton community using plankton nets and acoustic and optical methods. Key biological rate processes of important species will be measured experimentally to determine seasonal changes in food web dynamics and to better understand life cycle and survival strategies and how they are linked to production cycle timing. Trophic linkages will be determined using both isotopic ratios and molecular techniques. Greater temporal and spatial context will be quantified through collaborations with MOSAiC modeling efforts. (Sep 25, 2018 - Completed)

- An "Implementing MOSAiC Science" workshop was held in Potsdam, Germany on 28 May - 1 June 2018. With approximately 200 participants, this was the largest MOSAiC meeting to date. Numerous US scientists funded by NSF, DOE, NOAA, and NASA played key roles in planning the workshop, chairing sessions, and providing general leadership as the MOSAiC community works towards a shared vision for implementation. (Sep 5, 2018 - Completed)

- T-MOSAiC (Terrestrial Multidisciplinary Distributed Observatories for the Study of Arctic Connections) met in Davos, Switzerland on June 20th to discuss links between MOSAiC and T-MOSAiC. In discussion with the leaders of MOSAiC, a conceptual coordination framework was agreed upon and further planning is in progress to develop T-MOSAiC working groups. www.t-mosaic.com Linkages between MOSAiC and T-MOSAiC (https://www.iarpccollaborations.org/members/documents/12056) (Sep 5, 2018 - Completed)

- US DOE ARM facility staff visited the Polarstern and the MOSAiC staging area in Tromso, Norway in June 2018 to finalize ARM instrument list, placement on ship, and installation plan. Beta test of ARM instrumentation planned at Los Alamos National Lab in November 2018. (Sep 4, 2018 - Completed)

- DOE Atmospheric System Research program grant (DE-SC0019251, Sep. 2018 – Aug. 2021) to Matthew Shupe, University of Colorado, Boulder for “Enhanced atmospheric research at the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)” (Sep 4, 2018 - Completed)


- The DOE Early Career Research Program funded a new project, “Elucidating Processes Controlling Arctic Atmospheric Aerosol Sources, Aging, and Mixing States” by Dr. Kerri
Pratt, University of Michigan that includes aerosol filter sampling and analysis during the MOSAiC campaign. [https://lsa.umich.edu/chem/news-events/all-news/search-news/doe-early-career-award-for-kerri-pratt.html](https://lsa.umich.edu/chem/news-events/all-news/search-news/doe-early-career-award-for-kerri-pratt.html) (Aug 27, 2018 - Completed)

- Funding from several US agencies supported development of the following document: MOSAiC Consortium, 2016: Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) Implementation Plan, Version 1. International Arctic Science Committee, pp. 81. (Oct 30, 2017 - Completed)

- IASC supported M. Ovchinikov to present at the MOSAiC workshop in Prague. His presentation was titled: Ovchinnikov, M.: "Arctic cloud process modeling: Goals, insights, challenges, and opportunities", The Artic Science Summit Week 2017, MOSAiC workshop, Prague, 4-5 April 2017. (Oct 30, 2017 - Completed)

- NSF funding support of MOSAiC-related projects. These projects can be reviewed at the links below.

- There was a 2-day MOSAiC workshop from April 4th to April 5th 2017 during the ASSW in Prague. The Agenda for this meeting can be viewed here: [http://www.assw2017.eu/mosaic-workshop.htm](http://www.assw2017.eu/mosaic-workshop.htm). (Aug 21, 2017 - Completed)

- The presentation by Matthew Shupe at the June Atmosphere Collaboration meeting is relevant to this Performance Element [http://www.iarpccollaborations.org/members/documents/9447](http://www.iarpccollaborations.org/members/documents/9447). (Jul 24, 2017 - Completed)

2.1.2 (In progress) Improve uniformity and accessibility of surface radiative and heat flux information from satellite retrievals and airborne and ground-based measurements to quantify spatial variability of the surface energy budget over land, ice, and open ocean environments in the Arctic. Augment efforts through IARPC Collaborations to integrate surface radiative and heat flux measurements with cryospheric process understanding and modeling efforts.; NOAA (Lead), DOE, NASA, NSF

- NASA contributed to this performance element in the following ways: NASA funds and supports the CERES Science Team’s work creating and validating TOA and Surface radiation budget data globally and in the Arctic. Recently funded papers highlight the progress in producing the next generation TOA and Surface radiation flux products. 

- The National Science Foundation has recently awarded OPP – 1820927. This research will synthesize three interrelated science contributions: (1) Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) field observations will identify governing physical processes, fluxes, and linkages within the Arctic climate system. (2) Realistic-resolution (meters-scale), physically based modeling tools (e.g., MicroMet, SnowModel, EnBal, SnowPack, SnowTran-3D, SnowDunes, SnowAssim, Sealce-3D) will quantify the behavior, interactions, and sensitivities among the Arctic system components. (3) Field observations and high-resolution modeling will be integrated to define what is missing or poorly represented in Earth System Models and guide the parameterization of the associated snow-related processes and fluxes for the Community Earth System Model (CESM) and the Los Alamos Sea Ice Model (CICE). (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1805569. The investigators will deploy an unmanned aircraft system to measure atmospheric temperature, winds, and humidity, as well as surface albedo. Flights will take place from mid-winter (February) through late summer (August) to capture variable conditions in both the atmosphere and sea ice surface and will include routine profiling of the lower atmosphere, spatial mapping of thermodynamic quantities and surface albedo, and mapping of the lower atmospheric structure over leads. This data will be evaluated with measurements of the atmosphere, ocean and ice collected by other scientists as part of the MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) project to address hypotheses related to the performance of modeling tools in simulating key processes over the central Arctic Ocean. These include questions about sub-grid scale variability of atmospheric and surface parameters and its influence on model-simulated surface energy budget; the influence of leads in the sea ice on energy transfer from the ocean to the atmosphere and how models represent this transfer; and the importance of vertical resolution in simulation of the Arctic atmosphere and its impact on the simulation of clouds and the surface energy budget. The investigators will compare observations from unmanned aerial systems to a variety of simulations, ranging from global products to fully-coupled regional simulations completed using the Regional Arctic System Model (RASM) to detailed single-column and 2D modeling at high resolution. (Sep 25, 2018 - Completed)


- ASR-funded theoretical study on requirements for UAV measurements of atmospheric energy budget studies over sea ice. Podgorny I, D Lubin, and D Perovich. 2018. "Monte
The NOAAs-UAS Program supported the development of a new turbulent flux sensor suite for unmanned aircraft (PIs J. Intrieri, G. de Boer). This sensor, named miniFlux will be deployed to the Arctic in fall 2018 in support of SODA (see below). ()

US National Science Foundation has supported the deployment of a UAS-based sensor suite to the Alaskan Arctic in support of the “Stratified Ocean Dynamics of the Arctic” project supported by the Office of Naval Research. This project (OPP 1836423; G. de Boer PI) is titled “NNA: RAPID: Atmospheric Measurements from Unmanned Aircraft during SODA - Deployment of miniFlux and Initial Data Analysis” (Sep 4, 2018 - Completed)


The following publications was produced with support from NOAA: Katlein, C., S. Hendricks, and J. Key, 2017, Brief communication: Increasing shortwave absorption over the Arctic Ocean is not balanced by trends in the Antarctic, The Cryosphere, 11, 2111-2116, https://doi.org/10.5194/tc-11-2111-2017. The following datasets provide climate data records for Arctic and Antarctic clouds, surface characteristics and radiation. They were produced with funding from the NOAA National Centers for Environmental Information (NCEI). They are distributed by NCEI, with a new version forthcoming: * AVHRR Polar Pathfinder (APP): http://bit.ly/2Nk2xTk * AVHRR Polar Pathfinder Extended (APP-x): http://bit.ly/2BNRXTa (Aug 27, 2018 - Completed)


The following publications were produced through support from the NSF:


Presentation by Tristan L'Ecuyer titled "Contrasting Satellite and Model Perspectives on the Role of Clouds in Arctic Surface Energy Balance" relates to this performance element: [http://www.iarpccollaborations.org/members/events/7691](http://www.iarpccollaborations.org/members/events/7691) (May 31, 2017 - Completed)

2.2 Improve understanding of the composition of the Arctic atmosphere — moisture, clouds, precipitation, aerosols, and gases— their net radiative effects and impact on Arctic climate.

- **2.2.1 (In progress)** Maintain and enhance support for fixed ground sites that contribute to long-term observations of Arctic atmospheric components using in situ and remote sensing measurements of atmospheric state parameters, gases, aerosols, and clouds. Improve uniformity in the suite of measurements and data products across sites to provide “network” information for increased physical understanding and representation of the Arctic climate system.; DOE (Lead), NOAA (Lead), NASA, NSF

- NASA allocated additional FY18 funds to analyze and model the data from the Arctic Radiation - IceBridge Sea&Ice Experiment (ARISE) campaign. See [https://www.nasa.gov/mission_pages/icebridge/news/arise14/index.html](https://www.nasa.gov/mission_pages/icebridge/news/arise14/index.html) for details on this 2014 campaign. (Sep 27, 2018 - Completed)

- "Methane, Ozone and Other Trace Gases" working group at NOAA IASOA is working to set standardization of data management, sharing cold weather observing practices,
refining the data quality control procedures, and determining what observations the modeling community would like to see in a merged observational data set. Long-term surface ozone observations at Arctic stations are analyzed to determine differences in seasonal and inter-annual variability of ozone measured at 6 Arctic stations. Frequency and persistence of the depleted ozone events during the Arctic spring are assessed to determine temporal and spatial patterns for the transport of the airmasses over open polynyas in the ice sheet, where the snow and ice chemistry depletes ozone (so-called "Bromine explosions" are links to the ozone depleting events). Group uses regional and global chemistry transport models to assess parameterization schemes developed to capture these complicated processes. The co-located and co-incident aerosol measurements are used to discriminate between the origin of the airmass from remote marine environment and its exposure to the anthropogenic pollution events, including the forest fires. (Sep 10, 2018 - Completed)

- NSF supported a 2-year extension for the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) project at Summit, Greenland. The extension is called the Aerosol Cloud Experiment and, through partnership with the University of Leeds, will provide new measurements of aerosol size distribution, vertical profiles, and ice nucleation properties, as well as surface turbulent heat fluxes, to complement the continued measurements of clouds, atmospheric thermodynamic profiles, radiation, and precipitation. (Sep 5, 2018 - Completed)

- US DOE continued support for ARM Barrow (Utqiavik) and Oliktok Point sites. DOE ARM facility supported small measurement campaigns at Barrow (Utqiavik) and Oliktok Point including GNSS atmospheric profiling, study of heated pyrheliometers, ice nucleation measurements, and an electric field study. (Sep 4, 2018 - Completed)

- D-ICE campaign at Barrow (Utqiavik) conducted to test strategies for preventing radiometer icing. Aims to identify a method to be adopted by the research community that is effective at mitigating ice, minimizes adverse effects on measurement quality, meets community measurement needs, and is energy efficient. Led by NOAA, contributions by DOE. (Sep 4, 2018 - Completed)

- US DOE Atmospheric System Research program supported the Oliktok Point site science team. This team contributed to several studies related to the improvement of measurements from that site and others in the Arctic, including data product development, capability development and enhancement of measurement techniques. Relevant studies include:


○ The DOE ASR and ARM programs supported the following efforts:
  • Deployment of a Multi Angle Snowflake Camera to AMF3 for the Snowflake Settling Speed Experiment
  • Operational support of the DOE-owned Multi Angle Snowflake Camera at AMF3
  • Shkurko, K.I., T. J. Garrett, 2016: Getting started guide for the Multi-Angle Snowflake Camera. Particle Flux Analytics, Inc. (Oct 30, 2017 - Completed)

○ Continued US DOE support for operation of ARM facilities at Barrow and Oliktok Point. (Sep 28, 2017 - Completed)

○ NSF-funded projects that address improved understanding of the composition of the Arctic atmosphere include the following projects that will be done on board the Swedish R/V Oden during the August-September 2018 time period.
- Project Title: Collaborative Research: Marine Aerosols in the Arctic: Linking surface water chemistry and biology with primary particle production. Lead PI Kerri Pratt, Univ. of Michigan. Collaborators: Patricia Matra, Bigelow Lab for Ocean Sciences; Amanda Grannas, Villanova University. Award abstract at https://www.nsf.gov/awardsearch/showAward?AWD_ID=1724585&HistoricalAwards=false


- Title: Microbial Oceanography Links to New aerosols in Ice-covered Regions (MjOLNIR) in the Arctic Ocean. Lead PI Giacomo DiTullio, College of Charleston SC. Award abstract at https://www.ejacket.nsf.gov/ej/showProposal.do?ID=1736783


  - 2.2.2 (In progress) Continue support for and planning and analysis of past and potential future aircraft missions (e.g., NASA Atmospheric Tomography Mission—AToM—and air Pollution in the Arctic: Climate, Environment, and Societies—PACES24) that contribute observations of atmospheric composition and relevant processes such as transport, deposition, and radiation.; DOE (Lead), NOAA (Lead), NASA, NSF

    - NASA Langley Research Center supported the development of the Arctic Investigation Modeling Processes of Aerosols, Clouds, and Transport proposal submitted the Earth Venture Sub-orbital 3 program. (Sep 27, 2018 - Completed)

    - A brief update on NASA's AToM campaign follows: AToM completed its last flights, which included overflying the Arctic in 2018; data analysis and modeling will continue. More details about AToM are available at: https://espo.nasa.gov/atom/content/ATom (Sep 27, 2018 - Completed)


      - Aircraft-measured indirect cloud effects from biomass burning smoke in the Arctic and subarctic (2016 Highlight)
The February 2018 ACT meeting on Atmospheric Tomography Mission (ATom) Arctic activities included the following presentations.

- An Overview of the NASA Atmospheric Tomography Mission - Thomas Reyerson (NOAA)
- An ATom perspective on local and regional processes in the Arctic - Róisín Commane (Harvard)
- Current state of the Arctic atmosphere as observed by NASA’s ATom mission - Jack Dibb (UNH)
- IMPAACT: Better Understanding of Arctic Pollution by Studying Midlatitude Processes - Chuck Brock (NOAA)

ATom was approached through several perspectives giving a more nuanced picture of the science. (Feb 27, 2018 - Completed)

- Current models have difficulty predicting the radiative effect of clouds, and aerosol effects contribute some of the largest uncertainties in radiative forcing. In August 2017, Lauren Zamora gave an overview of research she is doing with Ralph Kahn at NASA Goddard Space Flight Center, funded by NASA that aims to reduce this uncertainty. This research includes: Combining data from four different past aircraft campaigns in the Arctic to better quantify the in situ response of Arctic/subarctic liquid clouds to smoke aerosols, and developing research experiments for future field campaigns to better quantify aerosol transport to the Arctic. (Oct 25, 2017 - Completed)

- Data from NASA's first round of Atmospheric Tomography (ATom) flights in July - August 2016 are now available at: [https://espo.nasa.gov/home/atom/archive/browse/atom](https://espo.nasa.gov/home/atom/archive/browse/atom) ATom-2 data from flights in January - February 2017 will be released in a few months. ATom-3 flights are scheduled for fall 2017. (Sep 7, 2017 - Completed)

**2.2.3 (In progress) Improve vertical and regional characterization of atmospheric gases, aerosol, and cloud properties through the use of existing, long-term data sets, together with new measurements, in underrepresented Arctic regions. Develop a better understanding of the representative nature of fixed sites by describing the range of conditions that exist across the Arctic.**; NOAA (Lead), DOE, NASA, NSF

- The National Science Foundation (NSF) has recently awarded OPP – 1842306. This project proposes to build drifting buoys making precise measurements of sea surface height (SSH) and Precipitable Water Vapor (PWV) content. Satellite altimeters greatly expand the areal coverage of dynamic ocean topography DOT observations, but in situ DOT and PWV content observations are critical to provide ground truth for the satellites and fill high-frequency temporal gaps. The Applied Physics Lab (APL) will build DOT buoys combining the Iridium data telemetry, power systems, and ice-capable buoy hull of a proven APL drifting buoy with a dual-frequency GPS receiver. APL and Jet Propulsion Laboratory (JPL) will evaluate the DOT buoy performance and facilitate application of the buoys to planned ONR (SODA, SIZRS), NASA (ICESat-2, SWOT), and NOAA (IABP) programs in 2019-2021. (Oct 17, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1822406. Tundra wildfire occurrences have increased in coastal Greenland, setting a new record in
summer 2017. This project focuses on the study of emissions from arctic tundra wildfires. Chemical tracers of wildfires, including carbon monoxide, methane, and a series of volatile organic compounds will be monitored in the atmosphere at the Greenland Environmental Observatory at Summit. This project will deliver continuous high time resolution data for wildfire emission and climate forcing atmospheric constituents. Data analyses and modeling will improve assessments of fire emissions and their environmental and climate impacts. (Oct 15, 2018 - Completed)

- NSF, NASA, and NOAA have contributed to research that leverages observations at the Summit, Greenland site with satellite-based observations to provide the spatial perspective on key atmospheric processes across Greenland. Specifically, Gallagher et al (2018b) used Calipso satellite lidar and autonomous weather station data to expand on a detailed study of the circulation and cloud drivers of surface radiation and surface temperatures over the Greenland Ice Sheet that was previously conducted at Summit station (Gallagher et al. 2018a). This observation-based study relates large-scale circulation patterns with the spatial distribution of opaque clouds across Greenland and their impact on near-surface temperatures. Similarly, Bennartz et al. (2018) employed CloudSat satellite radar retrievals of snowfall to understand the spatial distribution of snow across the Greenland Ice Sheet. This study leveraged ground-based observations at Summit to constrain and correct the CloudSat precipitation product so it could be used to provide this important spatial and temporal context. Together these studies demonstrate a way to leverage intensive station measurements along with satellite assets to derive essential information on clouds, precipitation, and their impacts across large spatial domains such as the Greenland Ice Sheet.


- The National Science Foundation (NSF) has recently awarded OPP – 1833165. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. This project will result in the first drone retrofitted with a water vapor sampling pod, which can be directly analyzed in the field following flight. In doing so, the project stands to provide the first detailed and high-resolution airborne measurements of water vapor isotopes in the critical atmospheric boundary layer just above the Greenland Ice Sheet. As the technology for this project progresses, it could be transferred to other projects, such as detection of fugitive emissions from oil and gas wells or to measure methane release in regions of thawing permafrost. (Sep 27, 2018 - Completed)

- ABoVE research supported this PE in the following ways.
  a. NASA has continued support of SDSU (NOT UCSD as reported in 2017) flux towers at Atqasuk and Barrow, AK. These towers provide continuing measurement of methane and CO2, as well as environmental conditions such as soil temperature and moisture.
b. and c. ABoVE researchers are analyzing greenhouse gas data from the 2017 airborne campaign. In summer 2018, NASA flew AVIRIS-NG transects in the ABoVE region, which will enable estimates of near-surface CH4 concentrations.

d. Research in this area reported in 2017 continues. As reported in 2017, the ABoVE Science Team initiated a synthesis of field-observed CO2 and CH4 fluxes in tundra and boreal forests, both from ABoVE investigators and the broader scientific community, aimed at improved understanding of seasonal CO2 fluxes, where long-term atmospheric measurements document rather dramatic changes over the past 50 years, including increased productivity in the growing season and higher respiration in the winter and shoulder seasons. The ABoVE Science team is carrying out statistical models of CO2 and CH4 fluxes to shed light on major drivers of seasonal changes. These analyses will be compared with coarser-scale models to increase our predictive capabilities of boreal-arctic carbon cycling. (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1753423. Atmospheric transport and deposition of aerosols is an important delivery mechanism of natural and contaminant trace elements (TEs) to the Arctic. These inputs have strong implications for the ecosystem, and even human health. Assessment of this input is difficult because measurements of deposition rates in remote ocean regions. This research will provide estimates of the yearly atmospheric deposition flux of aerosol trace elements (TEs, total and soluble), including those of biogeochemical importance as well as pollutant species. The seasonal evolution of partitioning of trace element deposition among the various catchments (ice, water, snow, melt ponds) will also be assessed. The work will involve measurements of 7-Be inventories, 7-Be aerosol activities, and aerosol concentrations of TEs. Field work will be during a year-long ice drift of the MOSAiC expedition through the central Arctic Ocean. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1807496. This study will improve understanding of processes controlling exchange of climate-active gases between sea ice and atmosphere in the Arctic. The investigators will participate in a year-long, international field campaign in the high Arctic, Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC). They will conduct continuous turbulent flux measurements using the eddy correlation method from a tower on the bow of the German icebreaker Polarstern and from a tower situated on a nearby ice camp. These will account for gas transfer over large, km-scale areas of ice and open water leads. The investigators will also collect measurements of direct gas emission and deposition over smaller areas of ice and snow and a range of surface types using portable dynamic flux chambers. In collaboration with members of the Biogeochemical Exchange Processes at Sea-Ice Interfaces working group (BEPSII), observations of direct gas transfer will inform and validate biogeochemical models of trace gas dynamics in sea ice. In addition, a physical parameterization of air/sea gas transfer will be developed as an extension of the Coupled Ocean-Atmosphere Response Experiment gas transfer (COAREG) model, enabling regional estimates of net gas transfer in the sea ice environment. Finally, results will be used to develop and evaluate of ocean-sea ice-boundary layer exchange of climate-active trace gases in both 1-D and meso-scale (Polar Weather Research and Forecasting) atmospheric chemistry-meteorological modelling systems. (Sep 25, 2018 - Completed)
NSF supported a 2-year extension for the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) project at Summit, Greenland. The extension is called the Aerosol Cloud Experiment and, through partnership with the University of Leeds, will provide new measurements of aerosol size distribution, vertical profiles, and ice nucleation properties, as well as surface turbulent heat fluxes, to complement the continued measurements of clouds, atmospheric thermodynamic profiles, radiation, and precipitation. These new data sets will build off existing observations from the past 8 years to support important, first-of-their-kind studies of aerosol-cloud interactions over the ice sheet. (Sep 5, 2018 - Completed)

https://doi.org/10.1002/2017JD027298 Source attribution of Arctic sulfate and its radiative forcing due to aerosol-radiation interactions are quantified in this study using the Community Earth System Model equipped with an explicit sulfur source-tagging technique. Long-term site measurements of near-surface sulfate concentrations and satellite measurements of SO2 burden were used to evaluate the model results and understand potential biases in model physics and emission datasets. (Sep 4, 2018 - Completed)

DOE ARM facility supported tethered balloon and unmanned aerosol activities at Oliktok Point to study Arctic aerosol and cloud properties.

- Aerial Assessment of Liquid in Clouds at Oliktok (AALCO) campaign
- Joint UAS-Balloon Activity (JUBA)
- Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE)
  https://www.arm.gov/research/campaigns/amf2018popeye
  (Sep 4, 2018 - Completed)

The following publications were produced through support from DOE ASR:

  http://dx.doi.org/10.1175/jtech-d-17-0179.1


- Maahn M, G de Boer, J Creamean, G Feingold, G McFarquhar, W Wu, and F Mei. 2017. "The observed influence of local anthropogenic pollution on northern Alaskan cloud properties." Atmospheric Chemistry and Physics, 17(23),


DOE ARM facility supported an observational study of black carbon deposition in the Arctic. https://www.arm.gov/publications/programdocs/doe-sc-arm-18-004.pdf (Sep 4, 2018 - Completed)

DOE Atmospheric System Research program grant (DE-SC0016045, Aug. 2018 – Jul. 2019) to Norman Wood, University of Wisconsin, Madison to look at the “Snow regime classification from the NSA snow product.” (Sep 4, 2018 - Completed)

DOE Atmospheric System Research program grant (Sep. 2018 – Sep. 2021) to Aaron Kennedy, University of North Dakota to look at the “Detection and characteristics of blowing snow at ARM sites.” (Sep 4, 2018 - Completed)


Aircraft-measured indirect cloud effects from biomass burning smoke in the Arctic and subarctic (2016 Highlight) (https://www.iarpccollaborations.org/members/documents/11940)


- The NSF supported the following relevant publications:

- The NSF supported deployment of a micro-rain radar and snowflake particle imagers (Precipitation Imaging Package and Multi Angle Snow Camera) to high latitude research sites at Haukelister, Norway (winter 2016-17) and Kiruna, Sweden (winter 2017-18). (Oct 30, 2017 - Completed)
Current models have difficulty predicting the radiative effect of clouds, and aerosol effects contribute some of the largest uncertainties in radiative forcing. In August 2017, Lauren Zamora gave an overview of research she is doing with Ralph Kahn at NASA Goddard Space Flight Center, funded by NASA that aims to reduce this uncertainty. This research includes: Providing valuable context for future aircraft campaigns by using remote sensing data to discern the relative importance of aerosols vs. meteorological dynamics at different heights over the under-sampled Arctic Ocean. (Oct 25, 2017 - Completed)

The US DOE Atmospheric System Research program supported the Oliktok Point Site Science team, which assembled the following relevant publications:


ABOVE research supported this PE in the following ways.

a. NASA supported the year-round operation of the UCSD flux tower at Atqasuk, and Barrow, Alaska in order to provide continuing measurement of methane and CO2, as well as environmental conditions such as soil temperature and moisture.

b. During May through September 2017, NASA supported monthly data collections of key greenhouse gases by an airborne sensor which flew transect across Alaska and northwestern Canada.

c. In July, NASA flew its ASCENDS sensor to collect atmospheric CO2 profiles across key regions of the IARPC domain.

d. The ABoVE Science Team initiated a synthesis of field-observed CO2 and CH4 fluxes in tundra and boreal forests, both from ABoVE investigators and the broader scientific community, aimed at improved understanding of seasonal CO2 fluxes, where long-term atmospheric measurements document rather dramatic changes over the past 50 years, including increased productivity in the growing season and higher respiration in the winter and shoulder seasons.
The ABoVE Science team is carrying out statistical models of CO2 and CH4 fluxes to shed light on major drivers of seasonal changes. These analyses will be compared with coarser-scale models to increase our predictive capabilities of boreal-arctic carbon cycling. (Sep 15, 2017 - Completed)

- **2.2.4 (In progress)** In collaboration with efforts described under the Permafrost Goal, support observation syntheses of atmospheric carbon to provide better process understanding of the relationships between warming and soil carbon release in the Arctic. Integrate atmospheric measurements with related observations and modeling of land surface and environmental parameters to advance this process understanding.; NASA (Lead), NOAA (Lead), DOE, NSF
  
  - The NASA ABoVE project supported this PE in the following ways: The Keeling and Munger 2016 Carbon Cycle Science projects are continuing their research. ABoVE project profiles can be found at: https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3606&progID=6 and https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3607&progID=6
  

  - Related to the CH4 workshop, the following publication: Davidson, S., Santos, M., Sloan, V., Reuss-Schmidt, K., Phoenix, G., Oechel, W., Zona, D. 2017. Upscaling CH4 Fluxes Using High-Resolution Imagery in Arctic Tundra Ecosystems. Remote Sensing. 9(12), 1227. doi: 10.3390/rs9121227 (Sep 27, 2018 - Completed)

  - Scientists from the DOE Next-Generation Ecosystem Experiments (NGEE Arctic) and the NASA Arctic Boreal Vulnerability Experiment (ABoVE) projects collaborated to develop a roadmap for modeling land-atmosphere interactions in high-latitude ecosystems. The team identified critical knowledge gaps and data needs for experiments, observations, and modeling in areas of carbon biogeochemistry, vegetation, permafrost, hydrology, and disturbance dynamics. Science-driven priorities for field studies and airborne campaigns were highlighted. Permafrost thermal regime, active layer thickness, and freeze/thaw dynamics were identified as top priorities for quantitatively addressing the magnitude and fate of soil carbon in northern high-latitude terrestrial ecosystems. Citation: Fisher JB, DJ Hayes, C Schwalm, DN Huntzinger, E Stofferahn, K Schaefer, Y Luo, SD Wallischlegers, S Goetz, CE Miller, P Griffith, S Chadburn, A Chatterjee, P Ciais, T Douglas, H Genet, A Ito, B Poulter, B Rodgers, H Tian, W Wang, X Yongkang, Z-L Yang, and N Zeng. 2018. Missing pieces to modeling the Arctic-Boreal puzzle. Environmental Research Letters 13: 020202. https://doi.org/10.1088/1748-9326/aa9d9a (Sep 5, 2018 - Completed)

  - DOE-funded Researchers with the Next-Generation Ecosystem Experiments (NGEE Arctic) project are working at multiple field sites to understand, and then model, the sources and sinks of carbon in high-latitude Arctic ecosystems. Borehole measurements of permafrost temperature profiles were compared across the Arctic with simulated patterns of active layer dynamics and soil thaw derived from models. Patterns of deeper and longer permafrost thaw accelerate decomposition of deep, old soil organic matter and shift ecosystem carbon balance to a state increasingly dominated by soil respiration. Model results, confirmed by field observations, show that deepening of the active layer also allows water to drain deeper into the soil column, which dries out near-surface
soils. These investigations have important implications for designing an Arctic monitoring system to detect changes in the thermal state of permafrost, consequences for regional hydrology, and carbon sources and sinks in high-latitude ecosystems.

Citation: Parazoo NC, CD Koven, DM Lawrence, VE Romanovsky, and CE Miller. 2018. Detecting the permafrost carbon feedback: Talik formation and increased cold-season respiration as precursors to sink-to-source transitions. The Cryosphere 12: 123-144. https://dx.doi.org/10.5194/tc-2017-189 (Sep 5, 2018 - Completed)

- As part of the DOE NGEE-Arctic project, output of CH4 fluxes from a land surface model was compared with eddy flux data for sites on the Arctic coastal Plain. Comparisons highlighted needed changes to how processes related to CH4 emissions were described (Xu et al., 2016). In particular, ground-based measurements from eddy covariance towers near Barrow, AK revealed that the greatest uncertainties in predicting the seasonal CH4 cycle originated from a lack of knowledge on the wetland extent, cold-season CH4 production and CH4 transport processes. Further improving the CH4 biogeochemical components of the model will require that we better understand environmental controls on above- and belowground physiological processes and how vegetation controls gaseous transport (e.g., CH4 production under low temperatures).


- Since 2012, the Next-Generation Ecosystem Experiments (NGEE Arctic) project, working at field sites on the North Slope and more recently on the Seward Peninsula, has applied a multi-scale measurement and modeling scheme to assess important controls on methane cycling in high-latitude ecosystems. As an integral part of this research, flux measurements from two eddy covariance towers near Barrow, Alaska, including one maintained by the Atmospheric Radiation Measurement (ARM) program and another on the Barrow Environmental Observatory (BEO), revealed large emissions of methane that preceded snow melt (Raz-Yaseef et al., 2017). These pulses, previously observed but not explained, were linked to unique meteorological events where freezing rain on snow provided a physical barrier to methane emissions from underlying soils. The observed flux of carbon dioxide and methane to the atmosphere is of sufficient size to offset a significant fraction of the Arctic tundra carbon sink. Knowledge derived from long-term measurements complemented by targeted field and laboratory investigations, is being incorporated into the DOE Energy Exascale Earth System Model (E3SM). Citation: Raz-Yaseef N, MS Torn, Y Wu, DP Billesbach, AK Liljedahl, TJ Kneafsey, VE Romanovsky, DR Cook, and SD Wullschleger (2017). Large CO2 and CH4 emissions from polygonal tundra during spring thaw in northern Alaska. Geophysical Research Letters 44: 504-513. http://dx.doi.org/10.1002/2016GL071220 (Sep 20, 2017 - Completed)

- ABoVE and NASA supported this PE in the following ways. a. In collaboration with NSF’s SEARCH, NASA funded a workshop that focused in synthesizing research on how variations in permafrost control methane emissions in Arctic and boreal ecosystems. b. ABoVE research is supporting a number of the Permafrost CT PEs, including 6.1.1, 6.1.2,
6.1.4, 6.2.1, 6.3.1, 6.3.2, 6.3.3, 6.3.4 (related Performance Elements). (Sep 15, 2017 - Completed)

- In March 2017, NASA funded the following project through its Interdisciplinary Science 2016 ROSES (Research Opportunities in Earth and Space Science) solicitation. Research resulting from this project may contribute to progress on this milestone going forward. Ruth Varner/University of New Hampshire From Archaea to the Atmosphere: Integrating Microbial, Isotopic and Landscape-Scale Observations to Quantify Methane Emissions from Global High-Latitude Ecosystems16-IDS16-0060

High latitude peatlands are a significant source of atmospheric methane. These sources are spatially and temporally heterogeneous, resulting in a wide range of global estimates for the atmospheric budget. At these high latitudes, increasing atmospheric temperatures are causing degradation of permafrost, creating changes in surface moisture, hydrology, vegetation and microbial communities resulting in dynamic changes to methane cycling. The temporal and spatial scale of disturbance from permafrost degradation varies depending on the transfer of heat and the hydrological connectivity of an ecosystem. The primary goal of our proposed work is to combine remote sensing data and biogeochemical modeling to quantify methane emissions and isofluxes at the pan-arctic scale. We will accomplish this goal by addressing the following objectives: 1. Improve the ability of biogeochemical models to reliably estimate emissions of methane and 13CH4 from high latitude ecosystems by linking above and belowground processes through measurements and modeling 2. Improve the estimate of water table and land cover using remote sensing techniques to be able to scale CH4 and 13CH4 emissions3. Produce multi-scale scale maps of emissions and isofluxes and errors associated by using remote sensing (Landsat, MODIS, PALSAR-2, Sentinel-1, WorldView2, UAS, G-LIGHT) to scale to the pan-Arctic region Using this combination of a validated biogeochemical process-based-model with ground verified multi-temporal and spatial remote sensing platforms, we will estimate the spatial distribution of methane emissions and its C isotopes across the high latitude peatland ecosystems. This project will quantitatively reduce uncertainties in the global methane budget related to these ecosystems and will allow us to link below and above ground processes on large spatial scales using cutting edge microbial, isotopic and remote sensing techniques. (Sep 12, 2017 - Completed)

- In December 2016, NASA funded the following projects through its Carbon Cycle Science 2016 ROSES (Research Opportunities in Earth and Space Science) solicitation. Research resulting from these project may contribute to progress on this milestone going forward.

J.William Munger/Harvard College Multi-Scale Data Assimilation and Model Comparison for ABoVE to Identify Processes Controlling CO2 and CH4 Exchange and Influencing Seasonal Transitions in Arctic Tundra Ecosystems16-CARBON16-0047
Background and Objectives: Transition seasons in Arctic tundra are particularly important for the ecosystem’s short- and long-term carbon balance and for the long-term carbon balance. Climate-driven changes in the timing of seasonal transitions can affect whether the annual carbon balance for an ecosystem is positive or negative, but detailed understanding of processes that control arctic carbon cycling during this period lags behind understanding of growing season processes. Year-round eddy flux tower and seasonal aircraft observations of CO2 and CH4 fluxes at far northern tundra sites demonstrate previously unrecognized carbon exchange during transition seasons. Notably, the spring onset of carbon uptake is not accurately predicted using vegetation greenness defined by traditional satellite vegetation indices, and elevated carbon emissions extend well into the cold season when air and surface soil temperatures have fallen below freezing. We propose an in-depth analysis that integrates surface and airborne in situ data for CO2 and CH4 concentrations, remote sensing of vegetation and soils, satellite observations of Solar Induced Fluorescence (SIF) and CO2 and CH4 columns, tower fluxes, and meteorological products into a model-data synthesis framework that will improve our understanding of how the large pool of carbon stored in frozen tundra soils is responding to changing climate conditions. We will examine whether observed changes in transition season carbon exchange at local scales are occurring throughout the entire region and identify the environmental state variables that can best predict the timing of seasonal transitions across the tundra.

Methodology: We will test empirical functional models and process-based terrestrial ecosystem models against observations by comparing measured atmospheric CO2 and CH4 concentrations to concentrations predicted from applying atmospheric mixing and transport models to predictions of carbon uptake and emission. Using atmospheric data rather than flux measurements at a particular site tests whether the models accurately represent the regional mix of different environmental conditions and vegetation characteristics.

Significance: The proposed work responds to the call for carbon research in the critical arctic ecosystem. Specifically, we will use an array of observational data to challenge and improve ecosystem models at scales from individual landscape patch up to regional scales. By quantitatively assessing model simulations against observations at regional scales we will identify gaps in our understanding of carbon dynamics and climate feedbacks, and contribute to an improved quantitative and predictive understanding of processes that regulate carbon cycling from northern terrestrial ecosystems.

RalphKeeling/University of California, San DiegoDetection, Quantification, and Analysis of Changes in Boreal and Arctic Ecosystems Using Measurements and Models of CO2 and Its Isotopes16-CARBON16-0034 This proposal seeks to understand terrestrial ecosystem processes that control the exchanges of CO2 with the atmosphere on decadal and longer time scales. The approach makes time series measurements of CO2 concentration and isotopes and uses these and other datasets to challenge and improve carbon cycle models, including earth system models. This proposal is responsive to the solicited research Theme #1, relating to carbon cycling in Arctic and boreal regions, particularly to changes brought about by warming, CO2 and nitrogen fertilization, and associated changes to hydrology and carbon storage. It is also responsive to the need for “cross-cutting research activities”, e.g. for improving observations by providing an archive of CO2 samples to support development of novel isotopic applications related to land carbon cycling, and it is responsive to the need for modelling studies in relation to
atmospheric transport modelling, ecosystem component modelling, regional and global modelling. This proposal would provide core support for the measurement activities of the Scripps CO2 program, which sustains measurements from a flask sampling program from an array of ten stations distributed from the Arctic to the Antarctic including the iconic Mauna Loa continuous record. The program complements the larger NOAA ESRL program by providing critical redundancy for state of the art measurements, by ensuring continuity of the longest records of critical importance, and providing interpretive capabilities for understanding the data significance. The program also complements the DOE modeling (ACME) and measurements programs (NGEE-Arctic, FACE, Ameriflux) by providing cross-cutting constraints on large-scale carbon cycling and it is highly relevant to the DOE Scientific Focus Area on Biogeochemistry “Climate Feedbacks. By sustaining the longest records of CO2 and isotopes and advancing related interpretive capabilities, the Scripps program is well positioned to make agenda setting discoveries related to carbon cycling and carbon/climate feedbacks. In addition to supporting the continuation of these observations and their improvement, this proposal will support a collaboration with Drs. Peter Thornton and Lianhong Gu of ORNL which builds on two recent significant discoveries from the program. The first is the evidence of the large increase in the seasonal amplitude at high northern latitudes documented by Graven et al. (2013). The second is emergent evidence for a shift towards higher photosynthetic discrimination both globally and at high northern latitudes. Both discoveries are highly relevant for understanding ongoing changes in arctic and boreal ecosystems. Both potentially provide critical insights into the coupled carbon, nitrogen, and water cycling in the context of ongoing changes. The collaboration will entail combined data synthesis and modeling activities, taking advantage of recent advances in global and plant-level modeling capabilities at ORNL. The collaboration is aimed at answering these key questions: 1) How can the observed seasonal cycles in CO2 concentration be used to constrain the representation of nitrogen cycling within land surface models? 2) How does the formulation of nitrogen cycling in models impact the predicted photosynthetic discrimination on seasonal time scales? 3) What plausible changes in leaf level processes can account for the long-term changes in photosynthetic discrimination suggested by atmospheric data? (Sep 12, 2017 - Completed)

In January 2017, NASA funded the following project through its Atmospheric Composition: Aura Science Team and Atmospheric Composition Modeling and Analysis Program 2016 ROSES (Research Opportunities in Earth and Space Science) solicitation. Research resulting from this project may contribute to progress on this performance element going forward. Note: if this is placed under the wrong performance element, please let me know. Jianglong Zhang/University of North Dakota, Grand Forks Evaluating Model Reanalyses of Arctic Aerosol Surface and Atmospheric Forcing by Assimilating OMI over Ice16-ACMAP16-0086

https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=554049/solicitationId=%7B2CA9C467-DBE7-1438-E69D-2BB5CC9D4E1F%7D/viewSolicitationDocument=1/ACMAP16%20Selections.pdf  We will develop a ten-year Arctic (60°-90° N) three-dimensional aerosol extinction and optical depth reanalysis product for summer months based on numerical modeling simulations. Applying this product, we will study regional trends in summertime absorptive aerosol transport to/within the Arctic and corresponding aerosol direct surface forcing and particle mass deposition to investigate correlative relationships between regional
aerosol presence and seasonal sea ice melting. The novelty in this work comes from developing a new data assimilation (DA) capability for the Naval Aerosol Analysis and Prediction System (NAAPS) based on adapting the under-utilized OMI Aerosol Index (AI) product to track ultraviolet absorbing aerosols (dust and smoke) regionally over bright surfaces (ice, snow and cloud). The use of OMI AI will complement traditional aerosol DA conducted with MODIS, MISR and CALIOP aerosol datasets that have proven extremely limited near the poles. The ten-year product will cover 2007-2016 to match the concurrent availability of all four satellite aerosol datasets, with regional summertime months (defined here simply as April-October) chosen to coincide with the availability of each of the passive aerosol datasets introduced. Current MODIS, MISR and CALIOP Level 2 datasets are extremely limited in the Arctic, making traditional aerosol model DA challenging and degrading regional model skill overall. MODIS and MISR aerosol optical depth (AOD) retrievals over bright surfaces like ice, snow and cloud are very difficult. CALIOP retrievals are limited by complications in isolating aerosol scattering signal relative to high levels of molecular background scattering near the polar surface. Whereas the unprecedented value in newly-available global aerosol reanalysis products to the community is quickly becoming obvious, there exists a significant knowledge gap in the Arctic aerosol system that lessens model fidelity for land-atmospheric process study in this critically-sensitive domain. The opportunity to test our hypothesis that direct aerosol surface forcing trends and properties are significantly influencing seasonal sea ice melt in the Arctic is thus a compelling initial application of an OMI AI-constrained summer reanalysis product. To conduct a ten-year NAAPS model run, and thus develop the Arctic summer reanalysis product, prerequisite tasks will be performed. We will develop and verify a Level 3 OMI AI DA-friendly data product, accounting for anomalies induced by cloud fraction, vertical aerosol profile, aerosol type, and viewing angle. A Level 3 CALIOP aerosol product will be designed based on resampling that optimizes signal-to-noise and increases aerosol retrieval skill in the Arctic. An OMI AI simulator for NAAPS will be built based on work conducted with the NASA GEOS-5 aerosol modeling system. Jacobians for OMI AI relative to NAAPS aerosol mass concentration for UV-absorbing smoke and dust will be derived using the VLIDORT radiative transfer model. The current NAAPS assimilation system will be adapted to process OMI AI. MODIS, MISR, CALIOP, AERONET and MPLNET datasets will be used as necessary to conduct these tasks and provide verification context. Further, a potential system verification exercise using NASA aircraft observations, tentatively scheduled for collection during the 2017 Arctic summer is described. (Sep 12, 2017 - Completed)

2.3 Improve understanding of the processes that control the formation, longevity, precipitation, and physical properties of Arctic clouds; the spatio-temporal distributions of aerosol types; and Arctic cloud and aerosol modulation of the surface radiation budget.

- 2.3.1 (In progress) Support and synthesize multi-platform observations of cloud and aerosol properties from surface, airborne, and space-borne instruments (integrated with models as appropriate) to describe the physical and radiative characteristics of cloud and aerosol over a range of spatio-temporal scales and over a range of Arctic land cover domains.; DOE (Lead), NASA, NOAA, NSF

  o NSF, NASA, and NOAA have contributed to research that leverages observations at the Summit, Greenland site with satellite-based observations to provide the spatial
perspective on key atmospheric processes across Greenland. Specifically, Gallagher et al. (2018b) used Calipso satellite lidar and autonomous weather station data to expand on a detailed study of the circulation and cloud drivers of surface radiation and surface temperatures over the Greenland Ice Sheet that was previously conducted at Summit station (Gallagher et al. 2018a). This observation-based study relates large-scale circulation patterns with the spatial distribution of opaque clouds across Greenland and their impact on near-surface temperatures. Similarly, Bennartz et al. (2018) employed CloudSat satellite radar retrievals of snowfall to understand the spatial distribution of snow across the Greenland Ice Sheet. This study leveraged ground-based observations at Summit to constrain and correct the CloudSat precipitation product so it could be used to provide this important spatial and temporal context. Together these studies demonstrate a way to leverage intensive station measurements along with satellite assets to derive essential information on clouds, precipitation, and their impacts across large spatial domains such as the Greenland Ice Sheet. Gallagher, M. R., M. D. Shupe, and N. B. Miller, 2018a: Impacts of atmospheric circulation on temperature, clouds, and radiation at Summit Station, Greenland with self-organizing maps. J. Climate, in press. Gallagher, M. R., H. Chepfer, M. D. Shupe, and R. Guzman 2018b: Warming extremes across Greenland influenced by clouds. Nature Communications, submitted. Bennartz, R., F. Fell, C. Pettersen, M. D. Shupe, and D. Schuettemeyer, 2018: SPatial and temporal variability of snowfall over Greenland from CloudSat observations. Atmos. Phys. Chem., submitted. (Oct 1, 2018 - Completed)

- NASA also contributed to this PE through the following project: Current satellite remote sensing assets, most prominently featuring the NASA MODIS and MISR radiometric sensors and CALIOP lidar, have proven extremely limited in resolving polar aerosol presence, structure and transport. MODIS and MISR aerosol optical depth (AOD) retrievals over bright surfaces, like ice, snow and cloud, are nearly impossible. CALIOP retrievals are limited by complications in isolating what proves a relatively diffuse aerosol scattering signal component versus comparatively high levels of molecular atmospheric background scattering near the polar surface. Very little data exists at the poles among the three sensors as a result. Whereas aerosol climatological analyses encompassing the nearly twenty-year NASA Earth Observing System period have become commonplace for lower latitude process studies, relatively little is known about the polar aerosol system. Yet, researchers have consistently hypothesized, or in fact demonstrated through limited ground observations, that aerosols exhibit significant influence on polar atmospheric processes, including but not limited to aerosol-climate direct and indirect radiative feedbacks, surface deposition and the “browning” of ice and snow solar reflectivities, and chemical processing mechanisms. A new NASA project led by Dr. Jianglong Zhang at the University of North Dakota is seeking to remedy polar aerosol observing limitations by adapting a non-traditional satellite measurement to these unique regions. Focusing on the Arctic, they are applying the Ozone Measurement Instrument (OMI) on the Aura satellite and its ultraviolet (UV) bands to take advantage of solar absorptive properties of mineral dust and smoke aerosols that distinguish their presence independent of any incident bright surfaces. The OMI “Aerosol Index” (AI) is derived based on differences between observed and calculated radiances in UV-absorbing channels at 354 and 388 nm. Unlike traditional MODIS and MISR-like retrieval approaches over ice and clouds, sensitivity of AI to aerosol absorption increases over bright surfaces, due primarily to stronger sub-layer reflectivity and hence stronger
absorption from the aerosol plumes present. Since the majority of Arctic aerosol particles are a combination of springtime dust transported from the deserts of eastern China and spring/summer smoke from seasonal burning of the boreal forests in Russia and across North America, the OMI AI capability is uniquely tuned to Arctic aerosol scenario. Paired with the U.S. Navy’s global aerosol mass transport modeling system, NAAPS, Dr. Zhang and colleagues have developed a forward-modeling capability using the VLIDORT radiative transfer model during FY2018 to assimilate OMI observations into NAAPS, providing a critical polar satellite input dataset that complements MODIS, MISR and CALIOP datasets. The assimilation capability is presently being tested for its ability to constrain modeled three-dimensional aerosol analyses. Their goal is to generate a ten-year NAAPS reanalysis over the Arctic for the community from which to evaluate direct aerosol climate radiative feedbacks and any correlative links between surface radiative forcing and regional sea-ice budget anomalies. The application of this resource, however, is potentially boundless, and will be available to support a host of Arctic atmospheric process studies. (Sep 27, 2018 - Completed)

- Additional NASA contributions to this PE: Even though approaching the end of its useful life, NASA’s CALIPSO aerosol/cloud lidar continues to provide AOD and aerosol and cloud vertical distributions that include the Arctic region. (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1753423. Atmospheric transport and deposition of aerosols is an important delivery mechanism of natural and contaminant trace elements (TEs) to the Arctic. These inputs have strong implications for the ecosystem, and even human health. Assessment of this input is difficult because measurements of deposition rates in remote ocean regions. This research will provide estimates of the yearly atmospheric deposition flux of aerosol trace elements (TEs, total and soluble), including those of biogeochemical importance as well as pollutant species. The seasonal evolution of partitioning of trace element deposition among the various catchments (ice, water, snow, melt ponds) will also be assessed. The work will involve measurements of 7-Be inventories, 7-Be aerosol activities, and aerosol concentrations of TEs. Field work will be during a year-long ice drift of the MOSAiC expedition through the central Arctic Ocean. (Sep 25, 2018 - Completed)


Gijs de Boer (CIRES/UColorado) presented “Observational Studies of Aerosol-Cloud Interactions along the North Slope of Alaska” (https://www.iarpccollaborations.org/members/documents/10783) at the ACT January 2018 meeting (https://www.iarpccollaborations.org/members/events/10560) (Jan 23, 2018 - Completed)

Additionally, the DOE funded the following research:


- Mitchell, D. L., A. Garnier, M. Avery and E. Erfani, 2016: CALIPSO observations of the dependence of homo- and heterogeneous ice nucleation in cirrus clouds on latitude, season and surface condition. Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-1062. (also supported by NASA)


The NSF supported research resulting in the following publications:


• Q. Coopman, J. Riedi, D.P. Finch, and T.J. Garrett, 2017: Space-based evaluation of the impact of pollution plumes on transitions from liquid to ice in arctic clouds (submitted to GRL)


• Gergely, M., S. J. Cooper, and T. J. Garrett, 2017: Using snowflake surface-area-to-volume ratio to model and interpret snowfall triple-frequency radar signatures, Atmos. Chem. Phys., 17, 12011-12030, https://doi.org/10.5194/acp-17-12011-2017 (also supported by DOE)


○ Current models have difficulty predicting the radiative effect of clouds, and aerosol effects contribute some of the largest uncertainties in radiative forcing. In August 2017, Lauren Zamora gave an overview of research she is doing with Ralph Kahn at NASA Goddard Space Flight Center, funded by NASA that aims to reduce this uncertainty. This research includes: Combining aircraft aerosol measurements and aerosol transport model output to better quantify the detection limit of CALIPSO aerosol observations over the Arctic. (Oct 25, 2017 - Completed)

○ The US DOE Atmospheric System Research program supported the Oliktok Point Site Science team, which assembled the following relevant publications:


• 2.3.2 (In progress) Support integrated observational and modeling studies of atmospheric processes and their relationship to land cover that will increase understanding of the
characteristics, evolution, and radiative properties of Arctic clouds and their interactions with aerosol, leading to advancement in representing clouds in models at many scales.; DOE (Lead), NASA, NOAA, NSF


- DOE Atmospheric System Research program grant (DE-SC0019073, Aug. 2018 – Aug. 2021) to Adele Igel, University of California, Davis to look at the “Dissipation of Mixed-Phase Arctic Clouds and Its Relationship to Aerosol Properties” (Sep 5, 2018 - Completed)

- DOE Atmospheric System Research program grant (DE-SC0018927, Aug. 2018 – Aug. 2021) to Bart Geerts, University of Wyoming to look at “Mixed-phase Convective Clouds in the Polar Marine Boundary Layer” (Sep 5, 2018 - Completed)

- DOE Atmospheric System Research program grant (DE-SC0018926, Sep. 2018 – Aug. 2021) to Xiaohong Liu, University of Wyoming to look at “Improving GCM Predictability of Mixed-Phase Clouds and Aerosol Interactions at High Latitudes with ARM Observations” (Sep 5, 2018 - Completed)

- DOE Atmospheric System Research program supported publications:
  - Solomon, A., G. de Boer, J.M. Creamean, A. McComiskey, M.D. Shupe, M. Maahn, and C.J. Cox, 2018: The relative impact of cloud condensation nuclei and ice nucleating particle concentrations on phase-partitioning in Arctic Mixed-Phase Stratocumulus Clouds, Atmos. Chem. Phys., in review. (Sep 5, 2018 - Completed)
The Polar Prediction Project has released (1) YOPP Super Site Common Model Output and (2) YOPP Gridded Common Model Output guidance documents.
https://www.polarprediction.net/fileadmin/user_upload/www.polarprediction.net/Home/Organization/Task_Teams/Modelling_Task_Team/YOPP_gridded_common_model_output_01.pdf (Sep 5, 2018 - Completed)

The following study was supported by DOE as part of the Regional and Global Climate Modeling program: Zhang, R., Wang, H., Fu, Q., Pendergrass, A. G., Wang, M., Yang, Y., et al. (2018). Local radiative feedbacks over the Arctic based on observed short-term climate variations. Geophysical Research Letters, 45, 5761–5770. https://doi.org/10.1029/2018GL077852. Here we use a variety of reanalysis and satellite data sets to quantify the Arctic local feedbacks based on short-term climate variations, evaluate the feedbacks simulated in a global climate model, diagnose the impact of data set choices on the feedback estimates, and identify the sources of main uncertainties. The most disagreement is found in the estimate of cloud feedback. (Sep 4, 2018 - Completed)


- Aircraft-measured indirect cloud effects from biomass burning smoke in the Arctic and subarctic (2016 Highlight)
  (https://www.iarpcollaborations.org/members/documents/11940)
- Aerosol indirect effects on the nighttime Arctic Ocean surface from thin, predominantly liquid clouds, Atmos. Chem. Phys (2017 Highlight)

The April 2018 ACT meeting (https://www.iarpcollaborations.org/members/events/10563) on Year of Polar Prediction (YOPP) Atmosphere Observation initiatives delivered short contributions from a variety of speakers across different YOPP perspectives, including:
• Michael Lawler (UC-Irvine) on NSF-funded research from Oden on Arctic CCN measurements during YOPP, "Fine Aerosol Measurements Planned on Oden 2018 Cruise"

• Taneil Uttal (NOAA): Update on IASOA observing efforts during YOPP, "Merged Observatory Data Files (MODFs) from the International Arctic Systems for Observing the Atmosphere (IASOA) to support the Year of Polar Prediction (YOPP)"

• Greg McFarquhar (University of Oklahoma), "An Overview of the Cold-air Outbreak in the Marine Boundary Layer Experiment (COMBLE)"

• Ron Ferek (ONR) on projects supported under the DRI "Overcoming the Barrier to Extended Range Prediction over the Arctic", which is largely focused on understanding Arctic cyclones with observational work occurring during 2020 (late-YOPP).

• Patrick Taylor (NASA Langley Research Center) on NASA related efforts, “Unraveling the role of clouds in the Arctic surface energy budget: The role of cloud phase” (Apr 24, 2018 - Completed)

  o NASA supported the following research project: 2017 NASA CloudSat-CALIPSO Science Team Annual Report For the Project “Representing Cirrus Clouds in GCMs Using CALIPSO IIR and CALIOP Lidar Data” (Oct 30, 2017 - Completed)

  o DOE supported research resulting in the following publication:

  o Current models have difficulty predicting the radiative effect of clouds, and aerosol effects contribute some of the largest uncertainties in radiative forcing. In August 2017, Lauren Zamora gave an overview of research she is doing with Ralph Kahn at NASA Goddard Space Flight Center, funded by NASA that aims to reduce this uncertainty. This research includes: Using remote sensing data to provide evidence for the ability of aerosols to affect cloud freezing processes (which is helpful for developing accurate cloud droplet freezing mechanisms in regional climate models), and contributing upcoming field campaign experiment ideas for how to understand the relevant mechanisms better. (Oct 25, 2017 - Completed)

• 2.3.3 (In progress) Understand the impacts of Arctic and Boreal Forest wildfires on emissions, distributions, weather, and climate impacts of biomass burning plumes through improved use of emissions databases and chemical transport modeling. Gain better understanding of deposition processes through studies and better characterization of the spatial distribution of biomass burning aerosol.; NOAA (Lead), DOE

  o DOE Atmospheric System Research program supported publications: Creamean J, M Maahn, G de Boer, A McComiskey, A Sedlacek, and Y Feng. 2018. "The influence of local
oil exploration and regional wildfires on summer 2015 aerosol over the North Slope of Alaska." Atmospheric Chemistry and Physics, 18(2), 10.5194/acp-18-555-2018. 
http://dx.doi.org/10.5194/acp-18-555-2018 (Sep 5, 2018 - Completed)

- The May HWCT & ACT May 2018 meeting focused on wildfire forecasting—potential tools for community applications (https://www.iarpcollaborations.org/members/events/10564). This meeting sought to answer the questions: Are we getting the right tools to the right people? What are gaps and what are the next steps to fill those gaps?

The opportunity to reconvene this group and perhaps advise state/regions/borough on how to coordinate different toolsets to help wildfire response was discussed.

Presentations:
- Recap from AOSST/TECT meeting on Observing system applications & gaps for wildfire smoke detection & forecasting (Sandy Starkweather)
- LEO Network: how to use the network for ground observations and to stand up projects on specific fires and outreach efforts to tribes on smoke preparedness: clean rooms, HEPA filters, identifying at-risk populations- Mike Brubaker (ANTHC)
- UAF Smoke Project: ongoing work on simulating transport of smoke from Alaskan wildfires- Martin Stuefer (UAF) (Jun 5, 2018 - Completed)

- The DOE Earth System Modeling program supported:

- The NSF supported research resulting in the following relevant publications:
  - Q. Coopman, J. Riedi, D.P. Finch, and T.J. Garrett, 2017: Space-based evaluation of the impact of pollution plumes on transitions from liquid to ice in arctic clouds (submitted to GRL) (NSF)

- The US DOE Atmospheric System Research program supported the Oliktok Point Site Science team, which assembled the following relevant publication: J. Creamean, M.

- The September joint meeting on the health impacts of wildfires in the Arctic by the Health & Well-being CT, Atmosphere CT, and Terrestrial Ecosystems CT (https://www.iarpccollaborations.org/members/events/9144) began a cross-team conversation on places for potential interdisciplinary/interagency collaborations. Follow-up actions will be reported as they occur. (Sep 25, 2017 - Completed)

- **2.3.4 (In progress)** In collaboration with efforts described under the Environmental Intelligence Goal, support evaluation of reanalyses and their ability to represent Arctic clouds and controlling parameters with fidelity using satellite, aircraft, and ground-based observations.; NASA (Lead), NOAA, NSF

  - Tom Hamill (NOAA) presented a SIRTA white paper overview (https://www.iarpccollaborations.org/members/documents/10257) and Richard Cullather (NASA) presented "Data Assimilation as it Relates to the Sea Ice Outlook (SIO) and Prospects for Improvement" (https://www.iarpccollaborations.org/members/documents/10256) to the ACT and MST at their joint October 2017 meeting. This meeting reviewed the SIRTA efforts and rekindled the conversation on what was learned and what use might be made of the SIRTA whitepaper and related work. (Jul 5, 2018 - Completed)


  - Current models have difficulty predicting the radiative effect of clouds, and aerosol effects contribute some of the largest uncertainties in radiative forcing. In August 2017, Lauren Zamora gave an overview of research she is doing with Ralph Kahn at NASA Goddard Space Flight Center, funded by NASA that aims to reduce this uncertainty. This research includes: Development of a new method to quantify regional aerosol indirect effects on the Arctic Ocean surface energy budget, as demonstrated first in a subset of Arctic clouds and currently being addressed in a more representative dataset. This activity is an important early step toward obtaining the first observation-based estimate of regional cumulative aerosol indirect effects on the Arctic surface – information that is critically needed for constraining models of the Arctic energy balance. (Oct 25, 2017 - Completed)

  - The Systematic Improvements to Reanalyses in the Arctic (SIRTA) team published a white paper on reanalyses in the Arctic. It can be found at: https://www.iarpccollaborations.org/uploads/cms/documents/sirta-white-paper-final.pdf (Sep 1, 2016 - Completed)

**Agencies**
DHS, DOC, DOD, DOE, DOI, DOT, EPA, NASA, NSF, OSTP, USARC
3.1 Sea Ice

3.1 Conduct coordinated/integrated atmosphere-ice-ocean observations and research to understand the processes that determine the spatial and temporal variation of the thickness, extent and volume of sea ice, and their effects on atmosphere-ice-ocean interactions and feedbacks over multiple time scales (daily, weekly, seasonal, inter-annual, decadal).

- 3.1.1 (In progress) Support investigator-driven observations and process studies of the pack ice (e.g., ice thickness distribution, topography/surface roughness and strength; ice motion and deformation; snow depth distribution and melt pond characteristics; surface albedo and energy balance) and landfast ice (e.g., extent, stability, and break-up); NASA (Lead), NSF (Lead), DOD-ONR, DOI-BOEM, NOAA

  The National Science Foundation (NSF) has recently awarded OPP – 1836473. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. The project will co-produce shorefast ice knowledge by leveraging large satellite remote sensing datasets, community-based monitoring, and local and Indigenous knowledge. The quantitative and qualitative shorefast ice knowledge collected will be used to understand how shorefast ice has changed and how these changes matter to individuals and communities in the Uummannaq region. The involvement of residents and institutions in Uummannaq at all stages of the project, in combination with ongoing observations, will lay the foundations for ongoing community support and enable new insights into the complex social, cultural and economic changes caused by rapid environmental change. (Oct 16, 2018 - Completed)

  BOEM OCS Study 2017-076 Completed Study: New information on the fate of landfast ice was gathered during the project including from the Chukchi and Beaufort Seas from Elson Lagoon and Harrison Bay. Landfast ice fate varied in each case: landfast ice from the Chukchi Sea drifted northwestward after detaching from the coast while landfast ice from Elson Lagoon drifted North and West. Landfast ice in Harrison Bay during the early part of the melt season June through early July appears to be retained locally, drifting to the western side of the Bay. Drifters were also placed on the mobile pack ice in the western Beaufort Sea. Data and results will be available on the BOEM web site. (Oct 2, 2018 - Completed)

  BOEM planned award: Landfast Climatology of the Beaufort and Chukchi Seas: Planned Landfast Ice study will address some aspects of these objectives." Develop a landfast ice climatology database for the Beaufort and Chukchi seas which can be utilized to provide data in support of future improvements to the performance of coupled ice-ocean models and assess the seasonal and interannual seasonal stability of landfast ice. ()

  The National Science Foundation (NSF) has recently awarded OPP – 1758565. The Pacific inflow to the Arctic Ocean (which is via the Bering Strait) is critical to the oceanic systems of the Alaskan seas and western Arctic Ocean. The core of this work will be the
installation and annual servicing of three oceanographic moorings in the Bering Strait, at sites which have been shown to provide an effective quantification of the oceanic fluxes through the strait. These moorings measure (hourly, year-round) water velocity, water temperature and salinity, and the thickness and motion of the seasonal sea ice in the region. This new research will continue these measurements to 2022, also seeking understanding of the drivers of recent change. The work will provide oceanic information in useful forms to the many stakeholders, including local and global science, local native communities, the public, and industry (e.g., oil/gas exploration, shipping, tourism). Internationally, the project is a substantial US contribution to global cooperation in the Arctic. (Sep 27, 2018 - Completed)

○ NASA Researcher Angela Bliss provided the following NASA contribution to this PE:

Arctic Sea Ice Seasonal Climate Indicators from a Satellite Passive Microwave Climate Data Record- A high quality climate data record of sea ice concentrations from satellite passive microwave observations was used to quantify changes in the Arctic seasonal sea ice cycle. The timing of seasonal sea ice cover changes and the resulting surface albedo changes have major implications for the annual surface energy budget of the sea ice-ocean system. The seasonal evolution of Arctic sea ice can be described by the timing of key dates of sea ice concentration change including the dates of sea ice opening, retreat, advance, and closing. These dates in addition to melt onset and freeze onset dates, also from passive microwave observations, have been used to complete an analysis of temporal changes and variability in the seasonal ice cycle for the years 1979-2016. Results indicate that the melt season and open water season are lengthening at a rate of ~12 days/decade for the Arctic as a whole, with more extreme lengthening of the ice-free periods as large as 30 days/decade locally. The earlier retreat of sea ice allows for the absorption of more solar energy by the ocean, which then delays autumn freeze-up. Related papers: Peng, G., M. Steele, A. C. Bliss, W. N. Meier, S. Dickinson (2018), Temporal Means and Variability of Arctic Sea Ice Melt and Freeze Season Climate Indicators Using a Satellite Climate Data Record, Remote Sensing, 10(9), 1328. doi:10.3390/rs10091328 Bliss, A. C., M. Steele, G. Peng, W. N. Meier, S. Dickinson (submitted), Regional Variability of Arctic Sea Ice Seasonal Change Climate Indicators from a Passive Microwave Climate Data Record. (Sep 27, 2018 - Completed)

○ The National Science Foundation has recently awarded OPP – 1756100. Historically, the ice-covered Arctic Ocean has been poorly observed, particularly in winter. The Ice-Tethered Profiler instrument (ITP), developed at the Woods Hole Oceanographic Institution in 2003-4, is designed to sample the upper Arctic Ocean water properties and sea ice motion in all seasons and transmit those data to shore-side users in real time. To date, approximately 100 ITP systems have been deployed in the Arctic (each operating for 1-3 years) that have collectively returned more than 70,000 observations of Arctic Ocean water properties as well as nearly 150 cumulative years of ice drift data. The present research project will continue this activity for a 5-year period, as sustained observations are considered vital to documenting and understanding the rapid changes now underway in the Arctic and predicting its future evolution. A three-pronged effort is planned that consists of 1) annual deployment of conventional ITPs, 2) development, testing and then operational deployments of a new instrument, the Tethered Ocean Profiler (TOP) that focuses on the upper 100 200 m of the water column, and 3) scientific analysis of the resulting ITP and TOP data. Initial focus of the latter will be the Arctic surface waters and their interaction with the sea ice. (Sep 26, 2018 - Completed)
The National Science Foundation (NSF) has recently awarded OPP – 1836426. This project will analyze historical and ongoing Super Dual Auroral Radar Network (SuperDARN) ground backscatter data for extraction of Arctic sea ice parameters, and comparisons will be made to sea ice measurements obtained from space-based microwave remote sensors. An operational sea ice data product derived from the SuperDARN HF radar observations will be delivered to the National Science Foundation’s Arctic Data Center for long-term preservation and accessibility by the broader Arctic research community. Improvements in the detection and geolocation of SuperDARN ground backscatter echoes will benefit future studies of land/sea surface features in radar observations and increase the quality of global space weather maps of ionospheric plasma convection. This proposal aligns with one of the National Science Foundation’s Big Ideas for Navigating the New Arctic by leveraging a large data set from an existing observational technology and network. (Sep 26, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1740768. This project aims to investigate whether the sea ice internal stress field is anisotropic or isotropic, and whether sea ice displays different plastic behavior over a range of scales, identifying over which scales that deformation is scale invariant. This research will also examine the role of boundary conditions and forcing in confining sea ice deformation on scales covering the Arctic Basin, synoptic, and submeso- scale (the spacing of leads and cracks). Following evidence for a transition in the physical mechanism controlling deformation between the synoptic and sub-mesoscale, the researchers will identify how this relates to self-organization of fractures within the ice pack. This project expects to identify models with improved representation of sea ice drift, lead opening, and sea ice dispersion. (Sep 21, 2018 - Completed)

The June 2018 SICT meeting focused on sea ice forecast updates (https://www.iarpccollaborations.org/members/events/10577). Scott Harper gave a comprehensive overview of the directions ONR is heading. Cecilia Bitz described the process of writing an op-ed for the New York Times and Michael Sigmond added context from his research on the connection between the Arctic and mid-latitude weather. Presentations:

- Office of Naval Research: Future program initiatives related to sea ice dynamics - Scott Harper (ONR)
- Relating the relevance of Arctic change to weather in the mid-latitudes: From a featured op-ed in the New York Times to the impact of Sudden Stratospheric Warming (SSW) this winter - Cecilia Bitz (University of Washington), Michael Sigmond (Jun 25, 2018 - Completed)

During the week of August 21, Nathan Kurtz’s CryoSat-2 sea ice thickness data set were released through NSIDC: at http://nsidc.org/the-drift/data-update/cryosat-2-level-4-sea-ice-elevation-freeboard-and-thickness-data-published/ (Sep 4, 2017 - Completed)

Don Perovich’s presentation giving a review of the Year of Polar Prediction (YOPP) open session and steering group meeting at the March Sea Ice Collaboration Team meeting relates to this Performance Element http://www.iarpccollaborations.org/members/events/7679. (Jul 24, 2017 - Completed)

3.1.2 (In progress) Continue to support the U.S. Interagency Arctic Buoy Program (US IABP) to provide meteorological, ice, and oceanographic data for research purposes and to meet real-
time operational requirements. US IABP, coordinated by the National Ice Center and the Polar Science Center, Applied Physics Laboratory, University of Washington, contributes to the International Arctic Buoy Programme.; DHS-USCG (Lead), DOD-Navy (Lead), NOAA (Lead), NSF (Lead), DOD-ONR, NASA

- NASA Principal Investigator Ignatius Rigor of the University of Washington submitted a report to ONR in summer 2018 focused on the International Arctic Buoy Programme. Key excerpts from the report are pasted below. The complete report is attached.

1) Arctic Buoy Deployments  In 2017 and so far in 2018, we have deployed:
   1) 2 CALIBs and 1 Ice Tracker with the NRL DISTANCE project in the Beaufort Sea.
   2) 2 SVP-B buoys with the Arctic Submarine Labs mini-ICEX efforts in the Beaufort Sea.
   3) 2 GPS trackers with adventurers traversing to the North Pole from Barneo.
   4) 1 ICEAIR and 1 SVP north of Deadhorse in the Beaufort Sea in collaboration with NSF funded Warming and iRadiance Measurement (WARM) buoy project.
   5) 4 SVP-Bs in the Bering and Chukchi Seas by R/V Sisiliaq. 6) 9 SVPs in the Bering and Chukchi Seas, deployed by the Norseman 2.
   7) 4 SVP-Bs deployed by the CCG Sir Wilfrid Laurier in the Canadian Beaufort Sea.
   8) 8 SVP-Bs deployed by the CGC Healy in the Chukchi and Beaufort seas.
   9) 3 AXIBs owned by Environment and Climate Change Canada (ECCC) were deployed by USIABP personnel from a Royal Danish Air Force flying from Thule, to the high Arctic (Fig. 2)
   10) 3 USIABP AXIBs and 1 Ice Tracker were deployed using a Royal Canadian Air Force C-130, in addition to 14 SVP-B buoys purchased by the ECCC.

We also shipped 10 SVP-B buoys to Kirkenes, Norway to be deployed during the NABOS cruise in September/October 2017 which has been cancelled. These buoys are now in storage at the Alfred Wegener Institute, Germany, and will be deployed this summer.

The IABP currently has 118 buoys reporting in the Arctic.

2) IABP Coordination- In addition to the buoy purchases and deployment logistics described above, this grant also partially funds the coordination of the entire IABP. All the Arctic buoys are purchased and deployed using a combination of equipment and logistics coordinated with collaborators of the IABP.

3) Arctic Observations Experiment (AOX) We deployed the AOX buoy test site in Barrow, Alaska in March 2013 at the DOEAtmospheric Radiation Measurement (ARM) site (which is also next to the NOAAClimate Reference Network site). The AOX test site has 15 buoys that represent the typical instruments that the IABP routinely deploys on the Arctic Ocean. We originally planned to deploy this for one year, but are now thinking of maintaining the site through March 2017 to test other instruments that the IABP and AON may use in the polar regions. FUTURE PLANS
4) Deployment Plans for 2018. For the Arctic, we currently have 6 AXIBs, 2 XIBs and 20 SVPs that we plan to deploy during summer and fall of 2018 from aircraft and ice breakers. We will deploy these buoys primarily using similar logistical assets as we have used for the past few years. Specifically, for details please see http://iabp.apl.washington.edu/overview_deploymentplans.html. COORDINATION, DATA MANAGEMENT AND ENHANCEMENT OF THE INTERNATIONAL ARCTIC BUOY PROGRAMME (IABP) (https://www.iarpccollaborations.org/members/documents/12202) (Sep 27, 2018 - Completed)

- At-sea measurement are key to the success of many sea-ice research efforts. During 2016, USCGC Healy deployed mooring to collect data on how climate change and decreased sea ice is affecting the Arctic Ocean. (Oct 4, 2017 - Completed)

- NASA continues to provide funding for IABP (Sep 29, 2017 - Completed)

- The International Arctic Buoy Programme (IABP, http://iabp.apl.uw.edu) maintains the fundamental Arctic Observing Network (AON) of drifting buoys which observe meteorological, oceanographic and ice conditions. The USIABP coordinates most of the US contributions to the IABP. So far in 2017, the USIABP has deployed 35 buoys and owns 57 of the 117 buoys currently reporting in the IABP AON. IABP receives funding or in-kind support from NSF, NOAA, NASA, ONR, Navy and the National Ice Center (NOAA, Navy, USCG.) (Sep 26, 2017 - Completed)

3.1.3 (In progress) Continue Operation IceBridge (OIB) to measure sea ice freeboard and thickness and to measure the depth of snow on the ice in late winter 2017, 2018, and 2019 in the western Arctic Ocean.; NASA (Lead)

- Using a fleet of research aircraft, NASA’s Operation IceBridge images Earth's polar ice to better understand connections between polar regions and the global climate system. IceBridge studies annual changes in thickness of sea ice, glaciers and ice sheets. IceBridge bridges the gap between the ICESat missions. NASA is planning to continue OIB through FY20. This year Operation IceBridge (OIB) had another successful Arctic Spring campaign. Surveys of the Arctic sea ice began with a series of flights on March 22 from Thule, Greenland, transitioning to Fairbanks, Alaska, and then back to Thule, Greenland to finish up the sea ice missions on April 16. Due to some unfortunate aircraft issues with NASA’s P-3 Orion and a hard deadline for the P-3 to return to NASA Wallops Flight Facility for another airborne mission, OIB was not able to return to Longyearbyen, Svalbard to resurvey the Eurasian sea ice like it had previously in 2017. Regardless of these issues, OIB was able to complete 8 sea ice missions, and 12 land ice missions during the duration of the campaign, which ended on May 4, 2018. The majority of the baseline missions for both sea ice and land ice were achieved. During this spring campaign, OIB collaborated with international and domestic missions: underflights with the European Space Agency’s (ESA) Sentinel-3A and CryoSat-2 satellites, and an overflight of the U.S. Navy’s ICEX camp. Like last year, out of Fairbanks, Alaska, OIB was able to continue its expansion westward, re-surveying the western side of the Chukchi Sea, again crossing the International Date Line. OIB was also able to complete a repeat mission surveying sea ice at the North Pole. This year, following a polynya that opened up in February north of Greenland, due to an extreme warm cyclone event, OIB flew a mission over the sea ice there to measure the thickness of the newly formed ice after the polynya closed up. This region was of particular interest because this was the first
time in the ice concentration satellite record that a polynya opened up in that location in February, so it was important to measure the thickness of the ice to determine how quickly the ice grew back after the polynya had opened. (Sep 27, 2018 - Completed)

- Using a fleet of research aircraft, NASA’s Operation IceBridge images Earth’s polar ice to better understand connections between polar regions and the global climate system. IceBridge studies annual changes in thickness of sea ice, glaciers and ice sheets. IceBridge bridges the gap between the ICESat missions. NASA is planning to continue OIB through FY20. NASA’s annual survey of changes in Arctic ice cover greatly expanded its reach this year in a series of flights that began on March 9 and wrapped up on May 12. It was the most ambitious spring campaign in the region for Operation IceBridge (OIB), an airborne mission to monitor ice changes at Earth’s poles. Geographically, OIB covered a wider area than ever before, and the new instruments deployed provided denser and more precise measurements. The mission carried out 39 eight-hour flights in 10 weeks. Of those, 13 focused on surveying sea ice. Several flights included collaborations with international Ice, Cloud and land Elevation Satellite (ICESat) missions teams to collect and compare measurements of snow and ice. The first part of the campaign was dedicated to overflying the Arctic Ocean’s sea ice cover. In this campaign, the IceBridge team added an extra base: Longyearbyen, Svalbard. From there, the mission was able to reach areas of the Eurasian side of the Arctic Ocean that had not been explored by IceBridge before. IceBridge also expanded its scope westward with a flight to the western side of the Chukchi Sea, a sea situated between Alaska and Russia. It was the first time the mission ever crossed the International Date Line. Operation IceBridge (OIB) launched a short campaign on July 17, 2017 from Thule Air Base, in northwest Greenland. The IceBridge scientists completed six flights focusing on the convergence of sea ice north of Ellesmere Island. The sea ice flights surveyed melt ponds, the pools of melt water on the ice surface that may contribute to the accelerated retreat of sea ice. IceBridge also flew a set of tracks to locate areas of sea ice that the mission already flew over in March and April, during its regular springtime campaign, to measure how the ice has melted since then. (Sep 29, 2017 - Completed)

- NASA plans to continue Operation IceBridge through FY 2020. ()

• 3.1.4 (In progress) Launch (1) the NOAA/NASA Joint Polar Satellite System in 2017 to enhance understanding of the sea ice age/thickness, ice concentration, ice surface temperatures, snow cover, and snow water equivalent; and (2) the NASA Ice, Cloud, and land Elevation Satellite 2 (ICESat-2) in 2018 to estimate sea ice thickness over the entire Arctic Ocean and adjacent seas.; NASA (Lead), NOAA (Lead)

- NASA researcher Ron Kwok's ICESat-2 work pertains to the estimation of time-varying sea ice thickness using freeboard retrievals from the ICESat-2 data together with the best available estimates of snow depth from model and empirical derivations. The aim is to quantify the trends in ice thickness and volume of the Arctic Basin, and the changes in mass balance of the sea ice cover over the duration of the ICESat-2 mission. On a multi-decadal timescale, the ICESat-2 record will be put within the context of changes spanning the submarine and altimeter records (ICESat, IceBridge, CryoSat-2) since the 1950s. For the Southern Ocean, the goal is to provide first-order estimates of sea ice thickness in the Ross and Weddell Seas (from ICESat-2) guided by IceBridge acquisitions of freeboard, snow depth, and thickness acquired since 2009. (Sep 27, 2018 - Completed)
• ICESat-2 successfully launched on September 15, 2018. (Sep 15, 2018 - Completed)
• The NOAA/NASA JPSS was launched on 18 November 2017. (Nov 18, 2017 - Completed)
• Thorsten Markus' presentation at the March Sea Ice Collaboration Team meeting relates to this Performance Element [http://www.iarpccollaborations.org/members/events/7679](http://www.iarpccollaborations.org/members/events/7679). (Jul 24, 2017 - Completed)

**3.1.5 (In progress)** Use multiple remote sensing data sets to: (1) investigate sea ice properties and processes and atmosphere-ice-ocean interactions; and (2) develop algorithms for automated ice edge detection and delineation of the marginal ice zone, landfast ice extent, ice classification (e.g., age/type of ice, melt ponds, floe size), and ice motion and deformation.; DOD-ONR (Lead), DOI-BOEM, NASA, NOAA, NSF

- NASA funded the following project that will contribute to this PE: Courtenay Strong/University of Utah, Salt Lake City Impacts of Cloud-Lead Coupling on the Surface Energy Budget of the Arctic Sea Ice-Atmosphere System: Cryospheric Science sub-element in NASA ROSES 2017 awarded in spring 2018. The ocean and atmosphere exert stresses on sea ice that create elongated cracks or openings (leads) where the ocean is exposed directly to the atmosphere. Leads cover a small fraction of the surface but dominate the vertical exchange of energy, particularly in winter when turbulent heat fluxes over leads can be orders of magnitude larger than over thick ice. The width of leads and their orientation relative to atmospheric flow markedly influence associated vertical fluxes relevant to cloud formation with recent studies suggesting that these fluxes can influence the atmospheric properties tens to hundreds of kilometers downstream. Arctic sea ice is changing rapidly, and observational and modeling results suggest an increasing influence of lead-induced feedbacks on the climate system. For instance Positive feedbacks can result if leads act to increase cloud cover which then warms the surface, leading to more or persistent open water. If convective plumes cause entrainment of drier free tropospheric air that decreases cloud cover, surface cooling and a negative feedback would result. Because leads are a crucially important driver of the Arctic surface energy budget, their increasing prominence makes the need for quantifying and understanding their impact on the Arctic climate system especially pressing at this time. The proposed project targets the NASA Cryospheric Science Program’s focus on understanding sea ice processes and observed changes to the Arctic surface energy budget including sea ice-atmosphere feedbacks. Our overarching objective is to understand through joint observational and modeling activities, the relationships between lead area fractions and cloud properties and the Arctic surface energy budget. This objective entails the following specific activities: Use remote sensing data including sea ice lead properties we derive from AMSR-E, AMSR2, SAR (ERS, ENVISat, RADARSAT), optical (AVHRR and MODIS), IceBridge DMS, areal photos, and submarine data to quantify the statistical properties of sea ice leads on multiple time and space scales. Quantify how leads modulate the surface energy budget of the Arctic system through forced changes to the extensive cloud systems that overlie the sea ice using data from CloudSat, CALIPSO and the A-Train supplemented by data collected at the Atmospheric Radiation Measurement (ARM) sites in the Arctic. Extend our prior modeling research using a three-dimensional, nonhydrostatic, cloudresolving (large-eddy simulation) model to understand how plumes and clouds respond to surface lead orientation and size distributions under a range of synoptic atmospheric regimes, and quantify the associated impacts on the Arctic surface energy budget. These activities will
be strongly coupled by using advanced statistical methods to relate the lead width and orientation distributions to the cloud properties controlling for confounding factors and then using the observed relationships to inform the modeling work. Observed lead statistics and a range of atmospheric regimes will be used as boundary conditions, to simulate the response pattern and associations identified via remote sensing. This quantitative knowledge is essential for evaluating and refining formulations proposed for parameterizing fluxes over subgrid-scale leads in climate models, thus supporting the overall NASA Cryospheric Sciences Program goal of using remote sensing products to validate and improve models of changes in sea ice cover to elucidate connections to the global system. ()

NASA has contributed to this PE in the following ways: NASA Principal Investigators have developed the NASA Sea Ice Cover product, which has been used to identify the coverage of Arctic and Antarctic sea ice. Its high resolution is also beneficial for locating the edge of sea ice floes. The researchers have also developed the NASA Ice Surface Temperature product, which has been used as an indicator for determining the onset of sea ice melt and freeze-up. The product has demonstrated the advance of the melt season towards the highest latitudes in the Arctic. These project use NASA VIIRS data and they are currently available at the NSIDC DAAC (https://earthdata.nasa.gov/about/daacs/daac-nsidc). NASA-funded Principal Investigator Chris Polashenski at Dartmouth is conducting research to process all Operation IceBridge DMS imagery for melt pond fractions. A summary of the research to date follows: Melt ponds increase absorption of sunlight by sea ice and enhance sea ice melt. Their coverage is widely understood to be a critical control over sea ice albedo feedbacks. But melt ponds are not routinely observed by remote sensing, partly because they occur below the pixel size of most global-coverage satellite imagery. New remote sensing techniques are needed to produce an observational record of seasonal and inter-annual changes in melt pond coverage from higher resolution imagery. We seek to address this gap by employing machine learning techniques to classify melt ponds in images of sea ice. The short-term goal of this project is to process the IceBridge DMS imagery to create a publically available melt pond data product that can be used to support research on ice-albedo feedbacks. The longer-term goal is to create an operational workflow for processing other high resolution datastreams (e.g. Digital Globe, Pleiades, Planet) and hosting the data as a standardized sea ice product comparable to sea ice concentration, extent, and thickness data from other sources. Along with processing imagery at an operational scale, we are confronting the challenges of creating a record having the quality, reproducibility, and traceability required to assess change over time. Several investigators have proposed possible approaches for processing high resolution sea ice imagery – among those possible methods is our Open Source Sea ice imagery Processing Algorithm (OSSP) [Wright and Polashenski, 2018]. In this project, we are working to take the OSSP to the next level, addressing documentation and standardization issues needed to ensure the output created is a reproducible, traceable, research grade product suitable for assessing long term trends. Processed DMS imagery and documentation should be available and posted to NSIDC-IceBridge data archives in late 2018. [see image: Result of processing an Operation IceBridge DMS image using the OSSP algorithm, https://www.iarpccollaborations.org/members/documents/12181] NASA has funded an ice motion and ice age project with a Principal Investigator at University of Colorado. A
summary of this project follows: We have developed a Lagrangian ice tracking database, based on an algorithm developed in-house which utilizes the sea ice motion algorithm to track individual “parcels” of Arctic sea ice, as they advect through the Arctic Ocean. The tracking is performed on the NSIDC 25-km EASE-grid, to accommodate coupling the positions of parcels with surface and atmospheric properties. We examined the influence of ice surface temperature, ice thickness, surface albedo, downwelling longwave/shortwave radiation, and snow depth on the change in ice concentration in the Beaufort Sea from 2009 to 2016. Results from this analysis indicated that parcels that melt during summer in the Beaufort Sea reside at lower latitudes and had lower ice thickness at the beginning of the melt season in most cases.

The National Science Foundation (NSF) has recently awarded OPP – 1836426. This project will analyze historical and ongoing Super Dual Auroral Radar Network (SuperDARN) ground backscatter data for extraction of Arctic sea ice parameters, and comparisons will be made to sea ice measurements obtained from space-based microwave remote sensors. An operational sea ice data product derived from the SuperDARN HF radar observations will be delivered to the National Science Foundation’s Arctic Data Center for long-term preservation and accessibility by the broader Arctic research community. Improvements in the detection and geolocation of SuperDARN ground backscatter echoes will benefit future studies of land/sea surface features in radar observations and increase the quality of global space weather maps of ionospheric plasma convection. This proposal aligns with one of the National Science Foundation’s Big Ideas for Navigating the New Arctic by leveraging a large data set from an existing observational technology and network. (Sep 26, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1740768. This project aim is to aims to investigate whether the sea ice internal stress field is anisotropic or isotropic, and whether sea ice displays different plastic behavior over a range of scales, identifying over which scales that deformation is scale invariant. This research will also examine the role of boundary conditions and forcing in confining sea ice deformation on scales covering the Arctic Basin, synoptic, and submeso- scale (the spacing of leads and cracks). Following evidence for a transition in the physical mechanism controlling deformation between the synoptic and sub-mesoscale, the researchers will identify how this relates to self-organization of fractures within the ice pack. This project expects to identify models with improved representation of sea ice drift, lead opening, and sea ice dispersion. (Sep 21, 2018 - Completed)

Improved instrumentation on Operation IceBridge in 2017 includes the snow radar and airborne topographic mapper, allowing for more accurate snow depth retrievals and, from the ATM, higher sample density and measurement precision of surface elevation. (Sep 28, 2017 - Completed)

Delivered the ATBD (Algorithm Theoretical Basis Document) for AMSR2 sea ice products. Also, we finished implementing the sea ice motion algorithm for AMSR2 and are getting ready to transition it for operational implementation. (Sep 4, 2017 - Completed)

Working on with Mark Tschudi, University of Colorado, to enhance sea ice age and sea ice motion products at NSIDC and extend their utility to other geophysical parameters.
An updated product was delivered to NSIDC and will soon be public and a new version is being readied and should be released in a couple of months. (Sep 4, 2017 - Completed)

- At the February meeting of the SICT Walt Meier gave an overview of current and future polar-orbiting passive microwave sensors. His presentation is available at: [http://www.iarpccollaborations.org/members/documents/7695](http://www.iarpccollaborations.org/members/documents/7695) (Mar 30, 2017 - Completed)

- **3.1.6 (In progress) Develop and deploy new technologies that enable persistent data collection on a variety of environmental variables using mobile platforms and sensors operating above, on, in, and under the Arctic sea ice cover to support a framework of observations that will improve forecasting and prediction of sea ice. ; DOD-ONR (Lead), DOI-BOEM, NASA, NOAA, NSF**

  - The National Science Foundation (NSF) has recently awarded OPP – 1842306. This project proposes to build drifting buoys making precise measurements of sea surface height (SSH) and Precipitable Water Vapor (PWV) content. Satellite altimeters greatly expand the areal coverage of dynamic ocean topography DOT observations, but in situ DOT and PWV content observations are critical to provide ground truth for the satellites and fill high-frequency temporal gaps. The Applied Physics Lab (APL) will build DOT buoys combining the Iridium data telemetry, power systems, and ice-capable buoy hull of a proven APL drifting buoy with a dual-frequency GPS receiver. APL and Jet Propulsion Laboratory (JPL) will evaluate the DOT buoy performance and facilitate application of the buoys to planned ONR (SODA, SIZRS), NASA (ICESat-2, SWOT), and NOAA (IABP) programs in 2019-2021. (Oct 17, 2018 - Completed)

  - The National Science Foundation (NSF) has recently awarded OPP – 1836423. In this study, an unmanned aircraft system will be deployed to provide measurements of atmospheric temperature, winds and humidity. This information will be used together with information from surface buoys and ice imagery to understand atmosphere-ocean energy transfer during the fall freeze-up period. Measurements will be compared to high-resolution models that couple the atmosphere, ice and ocean together into single simulations. Flights will take place from northern Alaska with a broader effort (the Stratified Ocean Dynamics of the Arctic, or SODA, project) to understand the upper ocean in this part of the world. ()

  - NASA Center staff completed the Operation IceBridge/TanDEM-X Antarctic Science Campaign (OTASC) report referenced in 2017. The (soon-to-be) attached report contains content of relevance to PE 3.1.6 to develop and deploy new technologies that enable persistent data collection. Specifically, this report discusses sea ice thickness using a new potential GNSS method for a future low-cost GNSS satellite mission to observe polar sea ice from space with a frequent and extensive coverage over both Antarctic and Arctic sea ice. Note that international GNSS will be continuing more extensively and indefinitely into the future***, it is particularly suitable to “enable persistent data collection.”

*** These include: the NAVSTAR Global Positioning System (GPS), the GLObal NAVigation Satellite System (GLONASS), the European Space Agency Galileo GNSS, the Indian Regional Navigation Satellite System (IRNSS), the Quasi-Zenith Satellite System (QZSS), GPS and geoaugmented navigation system (GAGAN), and the Chinese BeiDou Navigation Satellite System (BDS) as noted by Nghiem et al. (2017):

Also, a paragraph in section 3 of the report together with an additional reference [10] to address the relevance to the IARPC Performance Element 3.1.6. Note that co-author, E. Cardellach, in the paper in reference [10] is also the co-author in this report.


- Attached is the OTASC report listed in the comment Christine Mataya posted earlier in day on Sept 26. REMOTE SENSING OF POLAR SEA ICE WITH COORDINATED AIRCRAFT AND SATELLITE DATA ACQUISITIONS (https://www.iarpccollaborations.org/members/documents/12199) (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1756100. Historically, the ice-covered Arctic Ocean has been poorly observed, particularly in winter. The Ice-Tethered Profiler instrument (ITP), developed at the Woods Hole Oceanographic Institution in 2003-4, is designed to sample the upper Arctic Ocean water properties and sea ice motion in all seasons and transmit those data to shore-side users in real time. To date, approximately 100 ITP systems have been deployed in the Arctic (each operating for 1-3 years) that have collectively returned more than 70,000 observations of Arctic Ocean water properties as well as nearly 150 cumulative years of ice drift data. The present research project will continue this activity for a 5-year period, as sustained observations are considered vital to documenting and understanding the rapid changes now underway in the Arctic and predicting its future evolution. A three-pronged effort is planned that consists of 1) annual deployment of conventional ITPs, 2) development, testing and then operational deployments of a new instrument, the Tethered Ocean Profiler (TOP) that focuses on the upper 100 200 m of the water column, and 3) scientific analysis of the resulting ITP and TOP data. Initial focus of the latter will be the Arctic surface waters and their interaction with the sea ice. (Sep 26, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1839063. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. This project will develop and demonstrate a highly modified autonomous underwater glider (AUG) equipped with a dual-use active sonar for characterizing ice thickness distribution, as well as for real-time terrain-aided navigation. A new variable thrust hybrid propulsion system will also be developed for operation in both shallow coastal waters with high currents and deeper waters, enabling efficient transit from coastal to remote science locations, while enabling the vehicle to conduct water column profiling, as well as close-range ice survey. These characteristics will facilitate long-term unattended under-ice observation with reduced cost and logistical requirements. (Sep 26, 2018 - Completed)

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- ADAC is developing a long-range autonomous underwater vehicle for under-ice mapping of oil spills and environmental hazards. (Oct 5, 2017 - Completed)

- For 2017, improved instrumentation on Operation IceBridge includes the snow radar and airborne topographic mapper, allowing for more accurate measurements and, for the ATM, higher sample density and measurement precision. (Sep 29, 2017 - Completed)

- NASA Center staff initiating a new data calibration effort between Operation IceBridge and TanDEM-X (https://directory.eoportal.org/web/eoportal/satellite-missions/t/tandem-x) data. A description of this effort will be forthcoming. ()

- The presentation given by Rick Allard at the July Sea Ice Collaboration team meeting on utilizing CryoSat-2 ice thickness to initialize the Navy's ice modeling systems is relevant to this Performance Element and helps progress the understanding of different models and their predictive output http://www.iarpccollaborations.org/members/events/8934. (Aug 1, 2017 - Completed)

3.1.7 (In progress) Investigate Arctic Ocean processes, interactions and feedbacks that affect the dynamics and thermodynamics of the sea ice cover, including ocean circulation and stratification, turbulence and mixing, horizontal and vertical heat transport, and freshwater transport and storage. The ONR Stratified Ocean Dynamics of the Arctic (SODA) project (FY16-FY20) is an example of a contribution to this Performance Element.; DOD-ONR (Lead), DOI-BOEM, NASA, NOAA, NSF

- The National Science Foundation (NSF) has recently awarded OPP – 1842306. This project proposes to build drifting buoys making precise measurements of sea surface height (SSH) and Precipitable Water Vapor (PWV) content. Satellite altimeters greatly expand the areal coverage of dynamic ocean topography DOT observations, but in situ DOT and PWV content observations are critical to provide ground truth for the satellites and fill high-frequency temporal gaps. The Applied Physics Lab (APL) will build DOT buoys combining the Iridium data telemetry, power systems, and ice-capable buoy hull of a proven APL drifting buoy with a dual-frequency GPS receiver. APL and Jet Propulsion Laboratory (JPL) will evaluate the DOT buoy performance and facilitate application of the buoys to planned ONR (SODA, SIZRS), NASA (ICESat-2, SWOT), and NOAA (IABP) programs in 2019-2021. (Oct 17, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1822334. This study addresses the fundamental dynamics of the Arctic Ocean general circulation and its connection to lower latitudes. The approach combines a multi-component theoretical model with an idealized but high-resolution eddy resolving coupled ocean/ice general circulation model of the Arctic. The goal is to relate basic quantities -- such as ice cover; freshwater content; air-sea exchange; and heat, freshwater, and mass transport through Fram Strait -- to external forcing due to wind, heat loss, runoff, and variations in Atlantic
Water temperature and salinity advected in from the Nordic Seas. In addition to providing dynamical insight into the controlling physics, this approach allows for a simple assessment of how the system is likely to respond to changing environmental parameters and of the existence of multiple equilibria or abrupt transitions. (Oct 15, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1836423. In this study, an unmanned aircraft system will be deployed to provide measurements of atmospheric temperature, winds and humidity. This information will be used together with information from surface buoys and ice imagery to understand atmosphere-ocean energy transfer during the fall freeze-up period. Measurements will be compared to high-resolution models that couple the atmosphere, ice and ocean together into single simulations. Flights will take place from northern Alaska with a broader effort (the Stratified Ocean Dynamics of the Arctic, or SODA, project) to understand the upper ocean in this part of the world. (Oct 15, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1758565. The Pacific inflow to the Arctic Ocean (which is via the Bering Strait) is critical to the oceanic systems of the Alaskan seas and western Arctic Ocean. The core of this work will be the installation and annual servicing of three oceanographic moorings in the Bering Strait, at sites which have been shown to provide an effective quantification of the oceanic fluxes through the strait. These moorings measure (hourly, year-round) water velocity, water temperature and salinity, and the thickness and motion of the seasonal sea ice in the region. This new research will continue these measurements to 2022, also seeking understanding of the drivers of recent change. The work will provide oceanic information in useful forms to the many stakeholders, including local and global science, local native communities, the public, and industry (e.g., oil/gas exploration, shipping, tourism). Internationally, the project is a substantial US contribution to global cooperation in the Arctic. (Sep 27, 2018 - Completed)

- A NASA-funded Principal Investigator published the following paper of relevance to this PE: Armitage, T. W. K., S. Bacon and R. Kwok (2018), “Arctic sea level and surface circulation response to the Arctic Oscillation”, Geophysical Research Letters, 45 https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018GL078386. The Arctic Oscillation (AO) is the leading mode of extratropical northern hemisphere atmospheric variability, affecting surface pressure, winds, temperature, and precipitation. Here we use an altimeter sea level record spanning 2003–2014, covering the ice-covered and ice-free ocean, to examine the influence of the AO on Arctic sea level and surface geostrophic circulation. AO-driven alongshore wind anomalies drive cross-shelf Ekman transport and opposing barotropic sea level anomalies between the shelf seas and deep basins of the Arctic Ocean, with maximum sea level anomaly differences across the shelf-break of ~3 cm per unit AOIndex. This pattern of sea level variability generates topographically steered (generally along-shelf) current anomalies of around 0.5 cm/s per unit AO index. AO-driven wind variability modulates surface currents associated with Atlantic and Pacific water inflow, with opposing inflow anomalies between the Barents Sea Opening and Bering Strait. (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1820927. This research will synthesize three interrelated science contributions: (1) Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) field observations will identify
governing physical processes, fluxes, and linkages within the Arctic climate system. (2) Realistic-resolution (meters-scale), physically based modeling tools (e.g., MicroMet, SnowModel, EnBal, SnowPack, SnowTran-3D, SnowDunes, SnowAssim, Sealce-3D) will quantify the behavior, interactions, and sensitivities among the Arctic system components. (3) Field observations and high-resolution modeling will be integrated to define what is missing or poorly represented in Earth System Models and guide the parameterization of the associated snow-related processes and fluxes for the Community Earth System Model (CESM) and the Los Alamos Sea Ice Model (CICE). (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1756100. Historically, the ice-covered Arctic Ocean has been poorly observed, particularly in winter. The Ice-Tethered Profiler instrument (ITP), developed at the Woods Hole Oceanographic Institution in 2003-4, is designed to sample the upper Arctic Ocean water properties and sea ice motion in all seasons and transmit those data to shore-side users in real time. To date, approximately 100 ITP systems have been deployed in the Arctic (each operating for 1-3 years) that have collectively returned more than 70,000 observations of Arctic Ocean water properties as well as nearly 150 cumulative years of ice drift data. The present research project will continue this activity for a 5-year period, as sustained observations are considered vital to documenting and understanding the rapid changes now underway in the Arctic and predicting its future evolution. A three-pronged effort is planned that consists of 1) annual deployment of conventional ITPs, 2) development, testing and then operational deployments of a new instrument, the Tethered Ocean Profiler (TOP) that focuses on the upper 100 200 m of the water column, and 3) scientific analysis of the resulting ITP and TOP data. Initial focus of the latter will be the Arctic surface waters and their interaction with the sea ice. (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1749081. The objective of proposed research under Phase 2 of SIPN (SIPN2) is to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This grant will: Investigate the sensitivity of subseasonal-to-seasonal sea-ice predictability in the Alaska Arctic to variations in oceanic heat and large-scale atmospheric forcing using a dynamical model Community Earth System Model (NCAR CESM) and statistical forecasting tools, focusing on spatial fields in addition to total extent summaries; Assess the accuracy of Sea Ice Outlook (SIO) submissions based on methodology and initialization; Develop new observation-based products for improving sea-ice predictions, including sea-ice thickness, surface roughness, melt ponds, and snow depth; Evaluate the socio-economic value of sea-ice forecasts to stakeholders who manage ship traffic and coastal village resupply in the Alaska Sector, and engage the public in Arctic climate and sea-ice prediction through blog exchanges, accessible SIO reports, bi-monthly webinars, and by making public data sources useful to non-scientists and scientists alike; and Continue and evolve network activities to generate SIO forecasts and reporting for September minima as in SIPN and expand SIPN2 forecasts to include full spatial resolution and emerging ice-anomaly-months (October - November). This work will directly engage stakeholders that create and use sea-ice forecasts in Alaska and lead to improved safety around sea ice. Work under SIPN2 will also track public awareness and perceptions regarding sea ice, helping to raise understanding through accessible reports, discussions, and public data sources useful to non-scientists and scientists alike.
Stakeholder engagement during the research process will potentially facilitate rapid research-to-operations implementation of the products of this work. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1741841. This is a modeling proposal to study the effect of declining Arctic sea ice on the strength and other characteristics of the AMOC - a major element of ocean dynamics and climate. Sea ice decline exposes the Arctic ocean to anomalous solar radiation and freshwater fluxes, generating positive buoyancy anomalies in the upper ocean. The hypothesis being tested is that, when spreading to the North Atlantic these buoyancy anomalies effectively weaken ocean deep convection, leading to a slow-down of the AMOC on multi-decadal timescales. This hypothesis will be tested with a variety of methods ranging from adjoint ocean modeling to experiments with climate models. (Sep 21, 2018 - Completed)

- The April 2018 SICT had an update on SODA (https://www.iarpccollaborations.org/members/events/10575) by Craig Lee (UW) (https://www.iarpccollaborations.org/members/documents/11276) that is relevant to this PE. (Apr 30, 2018 - Completed)

- The NASA Operation IceBridge 2017 summer campaign targeted a convergence event, capturing a sequence of repeat measurements over the same collection of ice floes. These data will be used investigate sea ice dynamic processes, including the redistribution of sea ice thickness. ()

- ONR Stratified Ocean Dynamics of the Arctic DRI program: Initial plans have been developed for the 2018-2019 intensive observing phase, resulting in the production of the SODA Science Plan which has been published as a technical report (http://www.apl.washington.edu/research/downloads/publications/tr_1601.pdf). An enhanced version of the acoustic navigation system used in the 2014 Marginal Ice Zone Experiment has been developed to provide regional-scale geolocation in the central Beaufort Sea. Additional efforts have focused on improvements to the under-ice capabilities of floats and gliders, and on adapting ice-based platforms for deployments that require operation on ice and in open water. The intensive field program will begin in autumn 2018 with a process cruise aboard R/V Sikuliaq and deployment of moorings, gliders and ice-based instruments from USCG icebreaker Healy. ()

- ONR Sea State DRI program: Key accomplishments of 2017 have been the data processing and early publications from our Autumn 2015 campaign. The observations show a prevalence of pancake ice, which is formed by strong wave forcing during Autumn storms. Although this is generally a formation mode, there are examples of autumn storms releasing ocean heat and causing episodic reversals of the advancing ice edge. Beyond the storms, the autumn evolution appears controlled by 1) atmospheric conditions, especially rapid freezing during off-ice winds, and 2) preconditioning of ocean heat content. Alongside the data processing, there has been significant model development. The WAVEWATCH III model now supports five different advanced schemes for wave-ice interaction, each with evaluations from the field campaign. An experimental coupled atmosphere-ice-ocean model from NOAA is also being evaluated with the field data. The efforts are culminating in a special issue of JGR Oceans, which closes on 1 Nov 2017. (Sep 26, 2017 - Completed)
ONR Marginal Ice Zone DRI Program: Investigators spent 2017 analyzing observations from the 2014 field program, many of which are accumulating in a special section of the journal Elementa. Sustained observations documented the role of wintertime storm-driven breakup events, and their impact on ice composition and fracturing, on flow size distribution in the subsequent summer. Observations though the spring revealed a thermodynamic MIZ, where increasing insolation drove snow and surface ice melt, reducing albedo and leading to more efficient absorption of solar radiation and more melt. Fresh water generated by ice melt formed a thin, buoyant surface layer that inhibited mixing, thus isolating the sea ice from heat stored below. Surface waves and wind-driven mixing modulated the evolution of the thermodynamics MIZ in spring and summer of 2014. (Sep 26, 2017 - Completed)

3.2 Improve models for understanding sea ice processes and for enhanced forecasting and prediction of sea ice behavior at a range of spatial and temporal scales.

- 3.2.1 (In progress) Support investigator-driven modeling studies designed to understand and parameterize key sea ice properties and processes, including ice thickness distribution, topography, and strength; ice motion, deformation and mechanics; snow depth distribution and melt pond characteristics; surface albedo and energy balance; and biogeochemistry.; DOD-ONR (Lead), NSF (Lead), DOE, DOI-BOEM, NASA, NOAA

NASA funded the following research this year: Jennifer Hutchings/Oregon State University Observational Study to Constrain Rheological Models for Sea Ice: Cryospheric Science sub-element in NASA ROSES2017 awarded in spring 2018 Leads, that occur in repeating patterns, and the formation of coastal shear zones control the winter and spring sea-ice drift, opening and ridging. Climate models do not accurately simulate these processes, and have large variability in simulating sea-ice change, drift and lead opening. We aim to improve the rheological component of sea-ice models. This rheology controls the relationship between wind and current forcing on the ice pack and its deformation, which controls the ice motion. We have identified along-shore boundary conditions needed for accurate simulation of ice drift. In light of our recent advances in our understanding of the mechanical control of ice motion in the Beaufort Gyre, we anticipate model improvements will allow constraint of future climate projections of Arctic sea ice. We propose to use satellite and airborne imagery of the Arctic ice pack to identify the modes of failure that result in leads and ridges forming. Our previous work has identified lead pattern geometry aligns with Mohr-Coulomb theory (a rheological model). We will catalog 38 years of clear sky satellite sea-ice imagery by fracture pattern, and use ice drift and deformation products to further classify by mode of failure (e.g. failure in tension, shear or compression). We will extend previous work by using available ice tracking products, in particular the RADARSat Geophysical Processing System (RGPS) ice deformation products, to identify compressive modes of failure, and to extend beyond the clear sky database. A subset of high-resolution airborne imagery from Operation Ice Bridge (OIB) will be used to verify if particular failure modes are fully resolved in lower resolution satellite imagery. The catalog of classified failure patterns will be searched for case studies captured close to the time of failure. We will perform stress analysis on these case studies, initially assuming a Mohr-Coulomb rheology. Identifying if there are consistent parameters in the rheological model across the case studies, or if these parameters vary seasonally, by ice type, or confinement (applied stress) on the ice pack. This information will be used
to identify appropriate rheological models for pack ice. Which will be tested in a standalone sea-ice model. Our previous work has identified the importance of the landfast ice edge in the location of large scale lead patterns. We will test such boundary conditions in the model, along with exploring how the ice state responds to modifications to rheological models our observational study finds necessary. We address the NASA Cryosphere Program long-term goals of using remote sensing products to validate and improve models of changes in sea-ice cover. We will identify physical properties, in particular material properties, of pack ice and incorporate these into sea-ice models. This work is needed to determine the mechanisms controlling recent observed reductions in sea ice thickness in the Arctic. We utilize NASA remote sensed and OIB data to improve models of sea-ice motion, opening and ridging. This will better constrain sea-ice drift and deformation, and associated feedbacks, in climate projections. Project outcomes will include model improvements to be shared with the sea-ice community through publications and conference presentation. By constraining the mechanical response of sea ice in climate models, modelers will be able to improve the dynamic component of sea ice models. Interacting with the CESM Polar Working Group, the International Ice Chart Working Group, and the Sea ice Prediction Network (groups Hutcheson participates in), findings will be shared directly with those providing climate projections and short range to seasonal forecasts. It is anticipated this will result in improvements (i) to ice drift fields in climate models, (ii) in our ability to forecast the locations of leads and pressured ice, and (iii) in representing recent and projected sea-ice change. Jinlun Zhang, funded by the Cryosphere Program, has advanced the parameterization of melt ponds in PIOMAS; his paper is currently in review (zhang@apl.washington.edu). (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1820927. This research will synthesize three interrelated science contributions: (1) Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) field observations will identify governing physical processes, fluxes, and linkages within the Arctic climate system. (2) Realistic-resolution (meters-scale), physically based modeling tools (e.g., MicroMet, SnowModel, EnBal, SnowPack, SnowTran-3D, SnowDunes, SnowAssim, Sealice-3D) will quantify the behavior, interactions, and sensitivities among the Arctic system components. (3) Field observations and high-resolution modeling will be integrated to define what is missing or poorly represented in Earth System Models and guide the parameterization of the associated snow-related processes and fluxes for the Community Earth System Model (CESM) and the Los Alamos Sea Ice Model (CICE). (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1821911. The goal of this project is to identify the biological and physical drivers underlying the production and uptake of oxygen and methane, establishing the metabolic balance of these key gases in the oligotrophic Central Arctic. The investigators will take advantage of the unique opportunity afforded by the international, year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition to determine net community production from year-round measurements of oxygen and argon, as well as methane oxidation and production from methane concentration and isotopic ratios. They will measure bacterial and community respiration, bacterial production, and microbial community structure, and analyze gene expression to identify the genes, organisms, and pathways associated with methane production in the surface ocean.
Results will be used to model the oceanic methane cycle using the MITgcm Arctic Regional Model and improve the biogeochemical components of the Regional Arctic System Model (RASM). (Sep 25, 2018 - Completed)

- NCAR is contributing to the Coupled Model Intercomparison Project (CMIP6) to advance the understanding of sea ice modeling and to improve representation of sea ice processes in large-scale climate simulations. We have added the required Sea Ice Model Intercomparison Project (SIMIP) specified diagnostics to the Community Earth System Model (CESM [TMI]) version 2 (CESM2) and these will be published to the CMIP6 data repository and publicly accessible. We have a series of manuscripts planned which are aimed at assessing the fidelity of the standard CMIP6 experiments with an emphasis on sea ice. We will also perform a number of additional sensitivity experiments to better understand the physical parameterization of sea ice processes in the Los Alamos Sea Ice Model (CICE5). NCAR is also contributing to the CICE Consortium with code development, documentation, and release planning for CICE version 6. The current plan is for a release of the model in November of 2018. The vertical thermodynamic package of CICE, known as Icepack, was released to the community in early 2018. Future versions of the CESM will have a version of the CICE Consortium model as the sea ice component. This will allow for ongoing development of sea ice parameterizations, such as landfast ice, to be brought into the CESM. Additionally, developments in representing sea ice dynamics and floe size distribution are ongoing with the CESM and will be continued in future versions of the CESM. (Sep 4, 2018 - Completed)

- NSF-funded MOSAiC projects are listed below. NSF is funding MOSAiC at the level of ~$6.8M from the science program (Arctic System Science, Program Director Neil Swanberg) and $ 2.5 M in logistics.
  - Project Title: Collaborative Research: Thermodynamic and dynamic drivers of the Arctic sea ice mass budget at MOSAiC. Lead PI Matt Shupe, U of Colorado Boulder. Other collaborators Jennifer Hutchings, Oregon State University; Timothy Stanton, San Jose Univ. Foundation; and Donald Perovich, Dartmouth College. Award Abstract at [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1724551&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1724551&HistoricalAwards=false)
  - Project Title: Chemical, Physical and Biological processes linking snow and sea ice to the Arctic Ocean mixed layer: Improving models through the MOSAiC platform. PI Robert Rember, U of Alaska Fairbanks Award Abstract at [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1735862&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1735862&HistoricalAwards=false)
  - Project Title: Collaborative Research: Improving the Prediction of Sea Ice through Targeted Study of Poorly Parameterized Sea Ice Processes at MOSAiC and Responsive Model Development. Lead PI Donald Perovich, Dartmouth College. Other collaborators Bonnie Light, Univ. of Washington; and Marika Holland, UCAR. Award Abstract at [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1724540&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1724540&HistoricalAwards=false) (Sep 29, 2017 - Completed)

- NASA's annual omnibus research announcement, Research Opportunities in Space and Earth Sciences (ROSES), solicits proposals for cryospheric research. ROSES 2016
announced opportunities under the program element Studies with ICESat and CryoSat-2, which solicited investigations to derive geophysical information from NASA’s Ice, Cloud, and land Elevation Satellite (ICESat) and the European Space Agency’s CryoSat-2, and link these records with the initial data stream from ICESat-2, scheduled for launch in 2018. Proposals selected in late 2016 include a variety of studies using ICESat, IceBridge, CryoSat-2, and planned ICESat-2 altimetry data to examine the decadal trends in Arctic sea ice thickness and volume. In ROSES 2017, NASA solicited proposals under its Cryospheric Science element due in June 2017. For the Arctic portion, the program’s focus is to characterize and understand sea ice processes and the observed changes—in extent, concentration, thickness, character, and dynamics—in the context of their couplings to the Earth system. Understanding the feedback mechanisms associated with sea ice—and the atmosphere, ocean, land, and incident sunlight—is intended to improve models of the Arctic. (Sep 29, 2017 - Completed)

- The Operation IceBridge 2017 summer campaign targeted a convergence event, capturing a sequence of repeat measurements over the same collection of ice floes. These data will be used to investigate sea ice dynamic processes, including the redistribution of sea ice thickness. New Operation IceBridge science team members will be evaluating model predictive skill through the application and assimilation of sea ice thickness observations from Operation IceBridge. (Sep 29, 2017 - Completed)
- Wieslaw Maslowski’s presentation to the June Joint SICT, ACT, and MST meeting on MOSAiC and modeling is related to this Performance Element http://www.iarpccollaborations.org/members/documents/9447. (Jul 24, 2017 - Completed)

3.2.2 (In progress) Enhance operational sea ice forecasting and research-oriented prediction capabilities through improvements to model physics (explicit and parameterized); initialization techniques; assimilation of observations, model evaluation and verification; evaluation of model skill, post-processing techniques and forecast guidance tools used in operational forecasts and decision support.; NOAA (Lead), DOD-NRL, DOD-ONR, DOE, DOI-BOEM, NASA, NSF

- NOAA’s Earth System Research Laboratory (ESRL) Physical Sciences Division (PSD) team continued to provide experimental, daily, 0-10 day, Arctic forecasts using a fully-coupled, ice-ocean-atmosphere model [Coupled Arctic Forecast System (CAFS)] during 2018. Ice, ocean, atmosphere, and coupled pan-Arctic forecast guidance products in addition to time-height cross sections and meteograms for selected locations are posted daily at https://www.esrl.noaa.gov/psd/forecasts/seaice/.

2018 Project Updates

- Providing daily, 0-10 day, experimental, coupled model forecasts during the entire year, starting Feb. 14, 2018 (versus for only the freeze-up seasons in previous years), including forecast guidance products specifically tailored for NWS Alaska Sea Ice Program and National Ice Center

- Provided drift and weather forecast guidance in support of 2018 Navy ICEX (March 2018) and ONR’s supported SODA (Sept 2018) deployments (http://www.apl.washington.edu/project/project.php?id=soda)
• Initializing model with Sea Ice Concentration and Sea Surface Temperature observations (weekly) using the NASA JPL Multi-scale Ultra-high Resolution (MUR) and sea ice thickness (in spring and fall) using the ESA CryoSat-2 and SMOS satellite product

• Submitted daily drift forecasts for Year of Polar Prediction (YOPP) SIDFEx project (https://www.polarprediction.net/yopp-activities/sidfex/) for comparison with other operational forecast systems (e.g., ECMWF, MetNO, ECCC). Contributed new diagnostics for skill assessment of sea ice direction and speed.

• Extended the Coupled Arctic Forecast System to process studies of the evolution, formation and impacts of Arctic Cyclones in collaboration with WCRP Arctic CORDEX (http://www.climate-cryosphere.org/activities/targeted/polar-cordex/arctic) to assess model biases in advance of the MOSAiC campaign and in support of the ONR Arctic Cyclones DRI (Sep 27, 2018 - Completed)

o NASA funded the following research of relevance to this PE (see also 3.2.1) Jennifer Hutchings/Oregon State University Observational Study to Constrain Rheological Models for Sea Ice: Cryospheric Science sub-element in NASA ROSES2017 awarded in spring 2018 Leads, that occur in repeating patterns, and the formation of coastal shear zones control the winter and spring sea-ice drift, opening and ridging. Climate models do not accurately simulate these processes, and have large variability in simulating sea-ice change, drift and lead opening. We aim to improve the rheological component of sea-ice models. This rheology controls the relationship between wind and current forcing on the ice pack and its deformation, which controls the ice motion. We have identified along-shore boundary conditions needed for accurate simulation of ice drift. In light of our recent advances in our understanding of the mechanical control of ice motion in the Beaufort Gyre, we anticipate model improvements will allow constraint of future climate projections of Arctic sea ice. We propose to use satellite and airborne imagery of the Arctic ice pack to identify the modes of failure that result in leads and ridges forming. Our previous work has identified lead pattern geometry aligns with Mohr-Coulomb theory (a rheological model). We will catalog 38 years of clear sky satellite sea-ice imagery by fracture pattern, and use ice drift and deformation products to further classify by mode of failure (e.g. failure in tension, shear or compression). We will extend previous work by using available ice tracking products, in particular the RADARSat Geophysical Processing System (RGPS) ice deformation products, to identify compressive modes of failure, and to extend beyond the clear sky database. A subset of high-resolution airborne imagery from Operation Ice Bridge (OIB) will be used to verify if particular failure modes are fully resolved in lower resolution satellite imagery. The catalog of classified failure patterns will be searched for case studies captured close to the time of failure. We will perform stress analysis on these case studies, initially assuming a Mohr-Coulomb rheology. Identifying if there are consistent parameters in the rheological model across the case studies, or if these parameters vary seasonally, by ice type, or confinement (applied stress) on the ice pack. This information will be used to identify appropriate rheological models for pack ice. Which will be tested in a standalone sea-ice model. Our previous work has identified the importance of the landfast ice edge in the location of large scale lead patterns. We will test such boundary conditions in the model, along with exploring how the ice state responds to modifications to rheological models our observational study finds necessary. We
address the NASA Cryosphere Program long-term goals of using remote sensing products to validate and improve models of changes in sea-ice cover. We will identify physical properties, in particular material properties, of pack ice and incorporate these into sea-ice models. This work is needed to determine the mechanisms controlling recent observed reductions in sea ice thickness in the Arctic. We utilize NASA remote sensed and OIB data to improve models of sea-ice motion, opening and ridging. This will better constrain sea-ice drift and deformation, and associated feedbacks, in climate projections. Project outcomes will include model improvements to be shared with the sea-ice community through publications and conference presentation. By constraining the mechanical response of sea ice in climate models, modelers will be able to improve the dynamic component of sea ice models. Interacting with the CESM Polar Working Group, the International Ice Chart Working Group, and the Sea ice Prediction Network (groups Hutchings participates in), findings will be shared directly with those providing climate projections and short range to seasonal forecasts. It is anticipated this will result in improvements (i) to ice drift fields in climate models, (ii) in our ability to forecast the locations of leads and pressured ice, and (iii) in representing recent and projected sea-ice change. Jinlun Zhang, funded by the Cryosphere Program, has advanced the parameterization of melt ponds in PIOMAS; his paper is currently in review. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1749081. The objective of proposed research under Phase 2 of SIPN (SIPN2) is to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This grant will: Investigate the sensitivity of subseasonal-to-seasonal sea-ice predictability in the Alaska Arctic to variations in oceanic heat and large-scale atmospheric forcing using a dynamical model Community Earth System Model (NCAR CESM) and statistical forecasting tools, focusing on spatial fields in addition to total extent summaries; Assess the accuracy of Sea Ice Outlook (SIO) submissions based on methodology and initialization; Develop new observation-based products for improving sea-ice predictions, including sea-ice thickness, surface roughness, melt ponds, and snow depth; Evaluate the socio-economic value of sea-ice forecasts to stakeholders who manage ship traffic and coastal village resupply in the Alaska Sector, and engage the public in Arctic climate and sea-ice prediction through blog exchanges, accessible SIO reports, bi-monthly webinars, and by making public data sources useful to non-scientists and scientists alike; and Continue and evolve network activities to generate SIO forecasts and reporting for September minima as in SIPN and expand SIPN2 forecasts to include full spatial resolution and emerging ice-anomaly-months (October - November). This work will directly engage stakeholders that create and use sea-ice forecasts in Alaska and lead to improved safety around sea ice. Work under SIPN2 will also track public awareness and perceptions regarding sea ice, helping to raise understanding through accessible reports, discussions, and public data sources useful to non-scientists and scientists alike. Stakeholder engagement during the research process will potentially facilitate rapid research-to-operations implementation of the products of this work. (Sep 24, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1740768. This project aim is to aims to investigate whether the sea ice internal stress field is anisotropic or isotropic, and whether sea ice displays different plastic behavior over a range of scales,
identifying over which scales that deformation is scale invariant. This research will also examine the role of boundary conditions and forcing in confining sea ice deformation on scales covering the Arctic Basin, synoptic, and submeso- scale (the spacing of leads and cracks). Following evidence for a transition in the physical mechanism controlling deformation between the synoptic and sub-mesoscale, the researchers will identify how this relates to self-organization of fractures within the ice pack. This project expects to identify models with improved representation of sea ice drift, lead opening, and sea ice dispersion. (Sep 21, 2018 - Completed)

- NOAA’s Earth System Research Laboratory (ESRL) Physical Sciences Division (PSD) is providing daily, 0-10 day, Arctic Sea Ice Forecasts using a fully-coupled, ice-ocean-atmosphere model for the 3rd straight fall freeze-up season. Ice, ocean, atmosphere, and coupled forecast guidance products in addition to time-height cross sections and meteograms for selected locations are posted daily at https://www.esrl.noaa.gov/psd/forecasts/seaice/

2017 Project Updates

- Extended domain includes Bering and Fram Straits
- Ice thickness initialization uses spring CryoSat-2
- Weekly sea ice concentration updates with AMSR-2
- Ensemble runs using Global
- Ensemble Forecast System (GEFS) members (in progress)
- Updated website with new guidance products, meteograms, and cross-sections
- Collaboration with NOAA National Weather Service (NWS) Alaska Testbed staff to evaluate model results and understand utility, usage, and interpretation of ensemble data and uncertainty information for stakeholders (Nov 30, 2017 - Completed)


- The presentation by Edward Blanchard-Wrigglesworth at the October Sea Ice Collaboration Team meeting on the latest results from the Sea Ice Prediction network's (SIPN) 2017 Sea Ice Outlook (SIO) is relevant to this Performance Element (https://www.iarpccollaborations.org/members/events/8937) (Oct 27, 2017 - Completed)

- NASA’s ICESat-2 satellite has an "Early Adopters" program (https://icesat-2.gsfc.nasa.gov/early_adopters), which includes sea ice and global climate modelers who will apply ICESat-2 data for sea ice forecasts and tests of model predictive skill. The 2016 Operation IceBridge new science team members have outlined the following objectives for the remaining sea ice campaigns: (1) assess and improve the quality of snow and sea ice thickness measurements, (2) evaluate the predictive skill of models through application and assimilation of Operation IceBridge observations, and (3)
support the continuity of sea ice thickness observations for linkage between the ICESat and ICESat-2 missions. (Sep 29, 2017 - Completed)

- NASA Operation IceBridge science team members will be evaluating model predictive skill through the application and assimilation of sea ice thickness observations from Operation IceBridge (in progress). ()

- NOAA Research and Weather Service have two ongoing projects to improve sea ice forecasts during fall in the Alaskan Arctic. This will improve safety in the vicinity of Bering Strait and for seasonal planning for the timing of freeze-up. A one week sea ice forecast model is under development at NOAA Boulder. (Sep 26, 2017 - Completed)

- A NOAA aircraft operation during early September (2016 & 2017), with NOAA Seattle scientists, deployed ocean temperature buoys that give real time temperature profiles during fall. These “warm ocean” temperatures in recent years need to cool before Chukchi Sea sea ice can form. A seasonal freeze up forecast for November is being developed based on the September ocean data and fall weather outlooks. Data are available at: https://www.pmel.noaa.gov/arctic-heat/ (Sep 26, 2017 - Completed)

- The presentations given by Rick Allard and Alek Petty at the July 2017 Sea Ice Collaboration Team meeting are relevant to this Performance Element as they suggest research about improving models and sea ice forecasting http://www.iarpccollaborations.org/members/events/8934. (Aug 1, 2017 - Completed)

3.3 Support collaborative networks of researchers to advance knowledge, understanding, and prediction of the sea ice system.

3.3.1 (In progress) Support the Study of Environmental Arctic Change (SEARCH) Sea Ice Action Team to synthesize the results of multiple agencies’ and other stakeholders’ investments in sea ice observations and process studies and communicate results, information, and the societal implications of sea ice change to broader audiences; NSF (Lead), DOD-ONR

- The following presentations given at the August 27th 2018 Sea Ice Collaboration Team meeting are relevant to this Performance Element.
  - SEARCH Sea Ice Action Team by Matthew Druckenmiller- Matthew gave a summary of SEARCH’s main objectives and connected activities. Regional observing assessment- considering question of what local communities need to successfully respond to or be prepared for new baseline for winter conditions in the coastal Bering Sea region. Session and side meeting at Alaska Tribal Conference on Environmental Management (Anchorage, November 27-30, 2018). Results of assessment will be paper and reports to communities. Stakeholder analysis for Arctic Sea Ice loss- seeks to define stakeholders and stakeholder engagement. The process includes identifying stakeholders and identifies opportunities for engagement and usable science. Analysis developed around 3 case studies. Arctic Futures 2050: September 4-6 Conference in Washington DC. (Sep 11, 2018 - Completed)

- At the February meeting of the SICT, Matthew Druckenmiller gave a presentation on the SEARCH Sea Ice Action Team and their knowledge exchange workshop held in September 2016. SICT members suggested several potential collaborators for their next workshop, tentatively planned for fall 2017. They include the Arctic Domain Awareness Center at the University of Alaska Fairbanks (Church Key) and the National Weather
3.3.2 (In progress) Support a collaborative network of scientists and stakeholders to advance research on sea ice predictability and prediction at a variety of time and space scales and communicate new knowledge, understanding, and tools to broader audiences.; NSF (Lead), DOD-ONR, DOE, NASA, NOAA

- NASA researchers are using CryoSat-2 sea ice thickness data for model initialization as follows: The NASA GMAO team used the CryoSat-2 sea ice thickness data to initialize their model to provide a forecast for the September minimum. The results of the model forecast were provided to the 2018 Sea Ice Outlook (https://www.arcus.org/sipn/sea-ice-outlook/2018/july). Rick Allard from NRL recently led a paper where he showed how the incorporation of CryoSat-2 sea ice thickness data positively improved the predictive capability of their model. The paper can be found here: https://www.sciencedirect.com/science/article/pii/S0273117717309183

Abstract: Two CryoSat-2 sea ice thickness (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/ice-thickness) products derived with independent algorithms are used to initialize a coupled ice-ocean modeling system in which a series of reanalysis studies are performed for the period of March 15, 2014–September 30, 2015. Comparisons against moored upward looking sonar (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/sonar), drifting ice mass balance buoy, and NASA Operation IceBridge ice thickness data show that the modeling system exhibits greatly reduced bias using the satellite-derived ice thickness data versus the operational model run without these data. The model initialized with CryoSat-2 ice thickness exhibits skill in simulating ice thickness from the initial period to up to 6 months. We find that the largest improvements in ice thickness occur over multi-year ice. Based on the data periods examined here, we find that for the 18-month study period, when compared with upward looking sonar measurements, the CryoSat-2 reanalyses show significant improvement in bias (0.47–0.75) and RMSE (0.89–1.04) versus the control run without these data (1.44 and 1.60, respectively). An ice drift (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/ice-drift) comparison reveals little change in ice velocity statistics for the Pan Arctic region (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/arctic-region); however some improvement is seen during the summer/autumn months in 2014 for the Bering/Beaufort/Chukchi and Greenland/Norwegian Seas. These promising results suggest that such a technique should be used to reinitialize operational sea ice (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/sea-ice) modeling systems. NRL staff are looking to conduct a follow up study from data from the current year and NASA will try to report on any relevant findings in the future. (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1749081. The objective of proposed research under Phase 2 of SIPN (SIPN2) is to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This grant will: Investigate the sensitivity of subseasonal-to-seasonal sea-ice predictability in the Alaska Arctic to variations in oceanic heat and large-scale atmospheric forcing using a dynamical model Community Earth System Model (NCAR CESM) and statistical forecasting tools, focusing
on spatial fields in addition to total extent summaries; Assess the accuracy of Sea Ice Outlook (SIO) submissions based on methodology and initialization; Develop new observation-based products for improving sea-ice predictions, including sea-ice thickness, surface roughness, melt ponds, and snow depth; Evaluate the socio-economic value of sea-ice forecasts to stakeholders who manage ship traffic and coastal village resupply in the Alaska Sector, and engage the public in Arctic climate and sea-ice prediction through blog exchanges, accessible SIO reports, bi-monthly webinars, and by making public data sources useful to non-scientists and scientists alike; and Continue and evolve network activities to generate SIO forecasts and reporting for September minima as in SIPN and expand SIPN2 forecasts to include full spatial resolution and emerging ice-anomaly-months (October - November). This work will directly engage stakeholders that create and use sea-ice forecasts in Alaska and lead to improved safety around sea ice. Work under SIPN2 will also track public awareness and perceptions regarding sea ice, helping to raise understanding through accessible reports, discussions, and public data sources useful to non-scientists and scientists alike. Stakeholder engagement during the research process will potentially facilitate rapid research-to-operations implementation of the products of this work. (Sep 24, 2018 - Completed)

The following presentations given at the August 27th 2018 Sea Ice Collaboration Team meeting are relevant to this Performance Element.

- SEARCH Sea Ice Action Team by Matthew Druckenmiller- Matthew gave a summary of SEARCH’s main objectives and connected activities. Regional observing assessment- considering question of what local communities need to successfully respond to or be prepared for new baseline for winter conditions in the coastal Bering Sea region. Session and side meeting at Alaska Tribal Conference on Environmental Management (Anchorage, November 27-30, 2018). Results of assessment will be paper and reports to communities Stakeholder analysis for Arctic Sea Ice loss- seeks to define stakeholders and stakeholder engagement. The process includes identifying stakeholders and identifies opportunities for engagement and usable science. Analysis developed around 3 case studies. Arctic Futures 2050: September 4-6 Conference in Washington DC.

- Alaska Arctic Observatory and Knowledge Hub (AAOKH) Ice Observing effort by Donna Hauser- AAOKH is an effort lead by IARC and is meant to be a community based and provide northern Alaskan coastal communities with support to share local observations primarily focused on ice (https://arctic-aok.org). They are collecting biological and physical science information alongside local observations. Aim to put pieces together and answer questions about changing cycle. The knowledge hub piece helps networking and provide scientific context for observations. All local observations housed in secure databased. There are links to remote sensing, wildlife, and oceanographic data. SIWO hopes to expand outreach and education opportunities especially for youth. Recently launched new mapping tool (http://mapventure.org/#/map/aaokh)

- Sea Ice for Walrus Outlook (SIWO) by Lisa Guy- Collaborative project that provides weekly outlooks that combine remote and local observations. SIWO operates during spring sea ice season and is accessible to those on low
The Sea Ice Collaboration Team leadership is participating in an American Geophysical Union (AGU) special session discussing topics including Arctic system modeling and synthesis, Indigenous ways of knowing and the co-production of knowledge, and the application of Earth observing networks and indicators for delivering information products and societal benefits. (Dec 20, 2017 - Target)

The Sea Ice for Walrus Outlook (SIWO; https://www.arcus.org/search-program/siwo) is a resource for Alaskan Native subsistence hunters and coastal communities of Alaska’s Bering Strait region. SIWO provides weekly reports on spring sea ice and weather conditions to promote hunter safety, food security, and preservation of cultural heritage. Weekly outlooks integrate weather and ice forecasts, satellite imagery, and local observations from Alaska Native sea ice experts. The 2017 SIWO season lasted from late March through early June. Project collaborators include ARCUS, National Weather Service - Alaska Sea Ice Program, Eskimo Walrus Commission, University of Alaska Fairbanks - International Arctic Research Center, and local sea ice experts. Funding for core SIWO activities is provided to ARCUS by the National Science Foundation’s Division of Arctic Sciences (PLR-1304316), with in-kind support from other partners. Additional funding is currently being sought for networking activities and meetings with local observers, a formal evaluation, and an expansion in the use of local observations for validating and improving sea ice and weather forecasts. (Oct 19, 2017 - Completed)

The Sea Ice Prediction Network (SIPN) held a wide-ranging series of activities in the last 12 months. The leadership team published 3 peer-reviewed team papers and 4 reports, and gave 7 presentations about the Sea Ice Outlook (SIO) and other SIPN activities. Network participants published papers about sea ice prediction in another 6 peer-reviewed papers and one book chapter. The SIPN leadership team continues to organize and run the SIO and a spring Polar Prediction Workshop (the fourth in as many years), This year the workshop was organized jointly with the Polar Prediction Project, and was held in Bremerhaven, German, at the Shipping Museum and hosted by the Alfred Wegener Institute. The workshop was back-to-back with a Sea Ice MIP (SIMIP) workshop. Approximately 100 attended at the peak of the two workshops. SIPN also hosted a Network meeting at the 2016 Fall AGU and participated in organizing a science session at the spring 2017 EGU. The SIPN leadership team submitted a grant proposal to continue support for the SIO and other SIPN activities. The SIO collected Outlooks in June, July and August 2017, and we received about 35 Outlooks of the September pan-Arctic sea ice cover. For the second year we also called for Outlooks of the Alaskan region, and this year we received about a dozen. In addition, over a half-dozen participants submitted full-fields of more detailed sea ice quantities. The SIPN leadership team and guest authors prepared reports in each month that synthesized the Outlooks and current Arctic sea ice conditions. The Outlooks were provided as a spreadsheet linked to each report. A post-season report was written about the SIO and
sea ice in the summer of 2016 with conclusions, lessons-learned, and recommendations for the next year. Recommendations for SIO and SIPN were requested at the spring workshop as well. Among those recommendations, network members wanted the SIO to streamline the data collection process as more information has been requested than in earlier years. We responded by requesting Outlooks via a Google form and Dropbox folder. We have now received 695 Outlooks in the decade since the SIO inception. Outlooks in the last few years have maintained rigor in their methods, as the overwhelming majority of the Outlooks are from objective methods (statistical or dynamical models) and among the dynamical model, most are from coupled prediction system now. (Sep 21, 2017 - Completed)

- The latest report of the Sea Ice Prediction Network and the Sea Ice Outlook for August was released on August 24. It is available at: [https://www.arcus.org/sipn/sea-ice-outlook/2017/august](https://www.arcus.org/sipn/sea-ice-outlook/2017/august). NASA (through Meier) contributed to the August report. Meier led the July report. NASA sea ice concentrations are used for initialization fields and for validation of the seasonal prediction. Also, IceBridge data has been provided for initialization of models as well. (Sep 4, 2017 - Completed)

- The Sea Ice Collaboration Team tracked demographics of membership participation in meetings in order to understand membership attendance and where diverse voices could be strengthened. (Aug 18, 2017 - Completed)

- The Sea Ice Collaboration Team invited several early career scientists to present their research at monthly meetings. (Aug 18, 2017 - Completed)

- The Sea Ice Collaboration Team has participated in two joint meetings 1) with the Marine Ecosystems Collaboration Team on the pan-Arctic conceptual model and Walruses and 2) with the Atmosphere and Modeling Collaboration Teams on MOSAiC. (Aug 18, 2017 - Completed)

**Agencies**
DHS, DOC, DOD, DOE, DOI, NASA, NSF, USARC
4.1 Marine Ecosystems

4.1 Increase knowledge on the distribution and abundance of Arctic marine species across all trophic levels and scales, including an improved understanding of the formation and maintenance of biological hotspots and proximate causes of shifts in range.

- 4.1.1 (In progress) Continue distribution and abundance surveys of Arctic marine species, for example, concurrent monitoring of polar bears and their ice seal prey.; DOI-FWS (Lead), NOAA (Lead), DOI-BOEM, DOI-USGS, MMC
  - BOEM in partnership with USFWS has two long-term surveys used to determine seabird spatial distribution, species composition, and seasonal changes in species abundance in the Arctic on research vessels of opportunity. (Oct 2, 2018 - Completed)
  - BOEM fosters multi-discipline research in the Pacific Arctic to include influences of sea ice dynamics and advection on the phenology, magnitude and location of primary and secondary distribution and life history of upper trophic predators in response to availability of lower trophic prey resources; and improving knowledge about rates of consumption, growth, and reproduction of benthic and pelagic organisms. The Arctic Marine Biodiversity Observing Network (AMBON) continues to contribute to performance element 4.3.4 (and 4.1.2). Under this National Ocean Partnership Program effort (NOAA/BOEM/ UAF) Field efforts were conducted in 2015 and 2017. During those field efforts, AMBON collected ecosystem level biodiversity information along five cross-shelf and one along-shelf transect in the Chukchi Sea. State of the art genetic techniques complement traditional taxonomic approaches to include the small size fractions (microbes, nano- to microplankton, meiofauna) into biodiversity assessments. Through working with the Alaska Ocean Observing System (AOOS), the program created open access data and coordinates with other national BON demonstration projects. Outreach is pursued through a website (through AOOS), and interactions with local communities, specifically the Native Alaska communities of the north that are most directly affected by the changes in the Arctic. Various stakeholders are engaged through direct communications (e.g., BOEM, Shell, IOOS), workshops, database, scientific meetings, etc. During this last year, most of the efforts were dedicated to processing samples from the August 2017 cruise. One focus of our recent investigations was to discern differences in environmental conditions between the two sampling years, and at which ecosystem levels at such differences were visible. A final report will be produced in October 2019. More information can be seen at https://ambon-us.org/ (Oct 2, 2018 - Completed)
  - In spring 2018 under NASA's ROSES 2017 solicitation, a project focused on polar bears in Greenland was funded. The principal investigator is Kristin Laidre of U of Washington and the project is entitled, "Variability of Glaciers and Fjord Ice in Southeast Greenland with Application to Resident Polar Bears." A summary of the project follows and more
Details will be provided in the next year: Southeast Greenland, between approximately 60-68°N, contains 69 major tidewater glaciers that generally discharge into long, deep fjords covered by sea ice from fall to spring. These systems are undergoing rapid changes with a broad degree of spatial and temporal variability that is not well documented. Little is known about the intra-annual variability in Southeast Greenland glacier terminus position, calving patterns, and the interaction between the glacier, glacial malange and fjord sea ice. Addressing this gap in our knowledge is important from a glaciological perspective, and because the area is a specialized productive ecosystem. In particular, Southeast Greenland is host to a subpopulation of polar bears that is resident at glacier fronts year-round, hunting for seals on the floating ice malange and traveling inland on the glaciers themselves to reach adjoining fjords. Our project will answer key questions about Southeast Greenland glaciers, glacier-derived ice, and fjord sea ice. We will then use this information to link these physical characteristics of the environment to the behavioral patterns of the regional polar bear subpopulation. We will provide the first detailed characterization of Southeast Greenland glaciers at a roughly weekly resolution, including glacier advance and retreat time series, ice discharge, ice malange concentration and extent, and metrics of sea ice break-up, extent, and freeze-up. We will make use of multiple data sources including the NASA MEaSUREs Program (Making Earth System Data Records for Use in Research Environments), Landsat 8 optical imagery, sea-ice concentration from satellite passive microwave data, bathymetry from NASA’s Oceans Melting Greenland Program, data from NASA’s Operation IceBridge acquired over the glaciers of Southeast Greenland, and surface air temperature from coastal weather stations and from NASA’s MERRA-2 reanalysis product. Finally, we will use movement data acquired by satellite telemetry of more than 100 polar bears collared in Southeast Greenland from 2015 to 2017 to establish spatial habitat models for bears at glacier fronts and to quantify which features of glaciers are important to maintaining the subpopulation. The interdisciplinary nature of this science team enables the cross linkages between glaciology, sea ice, and ecology. This work develops important cryospheric time series that will allow for an improved understanding of glacier/fjord interactions in a less-studied region of Greenland and at the same time elucidates the relationship between the physical environment and the resident polar bear subpopulation. NASA-funded principal investigator Laidre also published the following paper in spring 2018. Kristin L. Laidre, Harry Stern, Erik W. Born, Patrick Heagerty, Stephen Atkinson, Øystein Wiig, Nicholas J. Lunn, Eric V. Regehr, Richard McGovern, Markus Dyck. (May 2018). Changes in winter and spring resource selection by polar bears Ursus maritimus in Baffin Bay over two decades of sea-ice loss. ESR vol 36:1-14. https://www.int-res.com/abstracts/esr/v36/p1-14/.

Abstract: Loss of Arctic sea ice has implications for the distribution and population structure of ice-dependent species such as polar bears Ursus maritimus. We used remotely sensed sea-ice concentration data for Baffin Bay, Canada, and satellite telemetry for adult female polar bears in the 1990s (n = 43) and 2000s (n = 38) to assess whether sea-ice habitat changes have influenced movements and habitat selection. Both the timing and availability of sea-ice habitat changed significantly between the 1990s and 2000s. Mean sea-ice concentration in June-October declined from 22 to 12%. Spring sea-ice retreat occurred 2 wk earlier and fall sea-ice advance 2 wk later in the 2000s. These changes translated directly to changes in habitat use by polar bears. In the
2000s, bears used significantly lower sea-ice concentrations in winter and spring. Also, bears were significantly closer to land in all months, except at the end of spring breakup when they remained on offshore sea ice as long as possible, likely to maximize foraging time prior to coming on land where they are largely food deprived. The presence of summer offshore sea ice facilitated broad movement of bears in the 1990s; however, this ice disappeared in the 2000s and resulted in significant declines in monthly movement rates. In the 2000s, adult females selected for lower sea-ice concentrations if they facilitated access to the continental shelf (<300 m). Our findings indicate that significant changes in available sea-ice habitat and habitat use in Baffin Bay have occurred since the mid-1990s and this subpopulation will likely experience negative population-level impacts related to a changing climate in the coming decades. In some other parts of the Arctic, such changes have preceded negative nutritional and demographic impacts. (Sep 27, 2018 - Completed)


- The presentation given at the October 2016 team meeting (https://www.iarpccollaborations.org/members/documents/7149) by Danielle Dickson about the Arctic Integrated Ecosystem Research Program is relevant to this Performance Element. (Oct 30, 2017 - Completed)

- USGS-led Forecasts of Polar Bear Persistence: Effective conservation planning requires understanding and ranking threats to wildlife populations. We developed a Bayesian network model to evaluate the relative influence of environmental and anthropogenic stressors, and their mitigation, on the persistence of polar bears (Ursus maritimus). Overall sea ice conditions, affected by rising global temperatures, were the most influential determinant of population outcomes. Accordingly, unabated rise in atmospheric greenhouse gas (GHG) concentrations was the dominant influence leading to worsened population outcomes, with polar bears in three of four ecoregions reaching a dominant probability of decreased or greatly decreased by the latter part of this century. Stabilization of atmospheric GHG concentrations by mid-century delayed the greatly reduced state by ≈25 yr in two ecoregions. Prompt and aggressive mitigation of emissions reduced the probability of any regional population becoming greatly reduced by up to 25%. Marine prey availability, linked closely to sea ice trend, had slightly less influence on outcome state than sea ice availability itself. Reduced mortality from hunting and defense of life and property interactions resulted in modest declines in the probability of a decreased or greatly decreased population outcome. Minimizing other stressors such as trans-Arctic shipping, oil and gas exploration, and contaminants had a negligible effect on polar bear outcomes, although the model was not well-informed with respect to the potential influence of these stressors. Adverse consequences of loss of sea ice habitat became more pronounced as the summer ice-free period lengthened beyond four months, which could occur in most of the Arctic basin after mid-century if GHG emissions are not promptly reduced. Long-term conservation of polar bears would be best supported by holding global mean temperature to ≤2°C above preindustrial levels. Until further sea ice loss is stopped, management of other stressors may serve to
slow the transition of populations to progressively worsened outcomes, and improve the prospects for their long-term persistence.


USGS-led Study of Increased Land Use by Polar Bears: In the Arctic Ocean’s southern Beaufort Sea (SB), the length of the sea ice melt season (i.e., period between the onset of sea ice break-up in summer and freeze-up in fall) has increased substantially since the late 1990s. Historically, polar bears (Ursus maritimus) of the SB have mostly remained on the sea ice year-round (except for those that came ashore to den), but recent changes in the extent and phenology of sea ice habitat have coincided with evidence that use of terrestrial habitat is increasing. We characterized the spatial behavior of polar bears spending summer and fall on land along Alaska’s north coast to better understand the nexus between rapid environmental change and increased use of terrestrial habitat. We found that the percentage of radiocollared adult females from the SB subpopulation coming ashore has tripled over 15 years. Moreover, we detected trends of earlier arrival on shore, increased length of stay, and later departure back to sea ice, all of which were related to declines in the availability of sea ice habitat over the continental shelf and changes to sea ice phenology. Since the late 1990s, the mean duration of the open-water season in the SB increased by 36 days, and the mean length of stay on shore increased by 31 days. While on shore, the distribution of polar bears was influenced by the availability of scavenger subsidies in the form of subsistence-harvested bowhead whale (Balaena mysticetus) remains aggregated at sites along the coast. The declining spatio-temporal availability of sea ice habitat and increased availability of human-provisioned resources are likely to result in increased use of land. Increased residency on land is cause for concern given that, while there, bears may be exposed to a greater array of risk factors including those associated with increased human activities.


Publication on Diet Shift from Seals to Whales Drives a Decline in Mercury Concentrations in Southern Beaufort Sea Polar Bear: We evaluated total mercury (THg) concentrations and trends in polar bears from the southern Beaufort Sea subpopulation from 2004 to 2011. Hair THg concentrations ranged widely among individuals. Concentrations differed among sex and age classes. No variation was observed between spring and fall samples. For spring-sampled adults, THg concentrations declined by 13% per year, contrasting recent trends observed for other Western Hemispheric Arctic biota. Concentrations also declined by 15% per year considering adult males only, while a slower, nonsignificant decrease of 4.4% per year was found for adult females. Lower THg concentrations were associated with higher body mass index (BMI) and higher proportions of lower trophic position food resources consumed. Because BMI and diet were related, and the relationship to THg was strongest for BMI, trends were re-evaluated adjusting for BMI as the covariate. The adjusted annual decline was not
significant. These findings indicate that changes in foraging ecology, not declining environmental concentrations of mercury, are driving short-term declines in THg concentrations in southern Beaufort Sea polar bears.


- The presentation given by Katrin Iken at the September Marine Ecosystems meeting on the Chukchi Borderland project is relevant to this performance element (https://www.iarpccollaborations.org/members/events/8929) (Sep 18, 2017 - Completed)

- The presentation given by Elizabeth Labunski titled "Long-term at-sea seabird surveys for a changing Arctic" at the March Marine Ecosystems Collaboration Team meeting is relevant to this performance element. https://www.iarpccollaborations.org/members/events/7587 (Aug 21, 2017 - Completed)

- The presentation given at the July Marine Ecosystems Collaboration Team meeting (http://www.iarpccollaborations.org/members/events/8927) by Marcel Babin titled "The Green Edge Project: a deep dive into the mechanics of the Arctic phytoplankton phenology" is relevant to this Performance Element (Jul 17, 2017 - Completed)

- **4.1.2 (In progress) Continue studies to document Arctic marine species biodiversity (e.g. Arctic Marine Biodiversity Observation Network—AMBON—and programs that monitor loss of sea ice) and habitat use in the Arctic. Ensure datasets will be available through open access data portals.**

- The National Science Foundation (NSF) has recently awarded OPP – 1822021. The investigators will establish and analyze a multi-decadal baseline of observations that describes the spatial distributions of planktonic communities in the western Arctic Ocean with the goal of developing optical tools and approaches that can be broadly applied to understand future environmental change in the region. Activities include a combination of (i) field work in the Chukchi and Beaufort Seas through collaboration with a Japanese research program, (ii) the development of optically-based algorithms for discerning planktonic community assemblages, and (iii) application of these algorithms to satellite remote-sensing data. The field work will include observations of planktonic community structure and connect these to seawater optical properties in the study area at different seasonal time periods. In addition, the investigators will use phytoplankton pigment measurements to infer spatial patterns of planktonic community composition and address the hypothesis that optical measurements can identify distinct planktonic assemblages. Finally, the project will develop and validate algorithms relating seawater optical properties to planktonic community structure and apply these to a time series of ocean color imagery to generate spatial maps of plankton community composition within the surface ocean. (Oct 15, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1823002. The hypothesis underlying this project is that harmful algal bloom species (HABs) in Alaskan Arctic waters are not only advected from the south through Bering Strait but are now originating locally on the Chukchi shelf due to warming temperatures, circulation
dynamics, and water mass structure that influence bloom magnitude, duration, toxicity, and recurrence. The distribution of HAB species on the Chukchi shelf will be mapped in relation to hydrography and circulation, including a comprehensive survey of the Alaskan Coastal Current which transports the warmest water in the Chukchi Sea. A range of molecular and physiological tools will be used to investigate the origin, connectivity, and fate of HAB populations in the region in the context of large-scale wind forcing and partitioning of water masses flowing through Bering Strait and the Chukchi Sea. Conceptual models of the origin, transport, and fate of HABs in the Chukchi Sea region will elucidate linkages to the flow pathways, dynamics, and characteristics of the different water masses. (Oct 15, 2018 - Completed)

The National Ocean Partnership program recently released the 2019 Broad Agency (#N00014-18-S-B007), which includes research opportunities for "Sustained observations of marine biodiversity for improved understanding of marine ecosystem response to changing environmental conditions". This announcement is built on the demonstration projects funded in 2014, of which AMBON (Arctic Marine Biodiversity Observing Network) was one. This funding announcement provides an opportunity to seek support for continued biodiversity observations in the Arctic. (Sep 30, 2018 - Completed)

This input from NASA is cross-posted in 4.1.1. In spring 2018 under NASA's ROSES 2017 solicitation, a project focused on polar bears in Greenland was funded. The principal investigator is Kristin Laidre of U of Washington and the project is entitled, "Variability of Glaciers and Fjord Ice in Southeast Greenland with Application to Resident Polar Bears." A summary of the project follows and more details will be provided in the next year: Southeast Greenland, between approximately 60-68oN, contains 69 major tidewater glaciers that generally discharge into long, deep fjords covered by sea ice from fall to spring. These systems are undergoing rapid changes with a broad degree of spatial and temporal variability that is not well documented. Little is known about the intra-annual variability in Southeast Greenland glacier terminus position, calving patterns, and the interaction between the glacier, glacial malange and fjord sea ice. Addressing this gap in our knowledge is important from a glaciological perspective, and because the area is a specialized productive ecosystem. In particular, Southeast Greenland is host to a subpopulation of polar bears that is resident at glacier fronts year-round, hunting for seals on the floating ice malange and traveling inland on the glaciers themselves to reach adjoining fjords. Our project will answer key questions about Southeast Greenland glaciers, glacier-derived ice, and fjord sea ice. We will then use this information to link these physical characteristics of the environment to the behavioral patterns of the regional polar bear subpopulation. We will provide the first detailed characterization of Southeast Greenland glaciers at a roughly weekly resolution, including glacier advance and retreat time series, ice discharge, ice malange concentration and extent, and metrics of sea ice break-up, extent, and freeze-up. We will make use of multiple data sources including the NASA MEaSUREs Program (Making Earth System Data Records for Use in Research Environments), Landsat 8 optical imagery, sea-ice concentration from satellite passive microwave data, bathymetry from NASA’s Oceans Melting Greenland Program, data from NASA’s Operation IceBridge acquired over the glaciers of Southeast Greenland, and surface air temperature from coastal weather stations and from NASA’s MERRA-2 reanalysis product. Finally, we will use movement data acquired by satellite telemetry of more than 100 polar bears
collared in Southeast Greenland from 2015 to 2017 to establish spatial habitat models for bears at glacier fronts and to quantify which features of glaciers are important to maintaining the subpopulation. The interdisciplinary nature of this science team enables the cross linkages between glaciology, sea ice, and ecology. This work develops important cryospheric time series that will allow for an improved understanding of glacier/fjord interactions in a less-studied region of Greenland and at the same time elucidates the relationship between the physical environment and the resident polar bear subpopulation. NASA-funded principal investigator Laidre also published the following paper in spring 2018.Kristin L. Laidre, Harry Stern, Erik W. Born, Patrick Heagerty, Stephen Atkinson, Øystein Wiig, Nicholas J. Lunn, Eric V. Regehr, Richard McGovern, Markus Dyck. (May 2018). Changes in winter and spring resource selection by polar bears Ursus maritimus in Baffin Bay over two decades of sea-ice loss. ESR vol 36:1-14. https://www.int-res.com/abstracts/esr/v36/p1-14/

Abstract: Loss of Arctic sea ice has implications for the distribution and population structure of ice-dependent species such as polar bears Ursus maritimus. We used remotely sensed sea-ice concentration data for Baffin Bay, Canada, and satellite telemetry for adult female polar bears in the 1990s (n = 43) and 2000s (n = 38) to assess whether sea-ice habitat changes have influenced movements and habitat selection. Both the timing and availability of sea-ice habitat changed significantly between the 1990s and 2000s. Mean sea-ice concentration in June-October declined from 22 to 12%. Spring sea-ice retreat occurred 2 wk earlier and fall sea-ice advance 2 wk later in the 2000s. These changes translated directly to changes in habitat use by polar bears. In the 2000s, bears used significantly lower sea-ice concentrations in winter and spring. Also, bears were significantly closer to land in all months, except at the end of spring breakup when they remained on offshore sea ice as long as possible, likely to maximize foraging time prior to coming on land where they are largely food deprived. The presence of summer offshore sea ice facilitated broad movement of bears in the 1990s; however, this ice disappeared in the 2000s and resulted in significant declines in monthly movement rates. In the 2000s, adult females selected for lower sea-ice concentrations if they facilitated access to the continental shelf (<300 m). Our findings indicate that significant changes in available sea-ice habitat and habitat use in Baffin Bay have occurred since the mid-1990s and this subpopulation will likely experience negative population-level impacts related to a changing climate in the coming decades. In some other parts of the Arctic, such changes have preceded negative nutritional and demographic impacts. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1824447. This proposal focuses on the planktonic lower trophic levels and will quantify the role that the mesozooplankton play in biological transformation and cycling of important elements (C, N) in the central Arctic Ocean ecosystem as part of the year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. Working together with an international team of scientists, the PIs will determine seasonal patterns in abundance, biomass, vertical distribution, and life stage structure for the entire zooplankton community using plankton nets and acoustic and optical methods. Key biological rate processes of important species will be measured experimentally to determine seasonal changes in food web dynamics and to better understand life cycle and survival strategies and how they are linked to production cycle timing. Trophic linkages will be determined using both isotopic ratios and molecular techniques. Greater
temporal and spatial context will be quantified through collaborations with MOSAiC modeling efforts. (Sep 25, 2018 - Completed)

- Angela Bliss’ presentation at the August 2018 MECT meeting (https://www.iarpccollaborations.org/members/documents/11906) introduces a set of sea ice cover climate indicators including gridded variables that describe the dates of Arctic sea ice melt and freeze onset, opening, retreat, advance, and closing allowing users to examine temporal change in seasonal sea ice conditions. The dataset will be distributed by the National Snow and Ice Data Center. (Aug 24, 2018 - Completed)

- Dr. Jackie Grebmeier’s (UMCES) presentation at the May 2018 MECT meeting (https://www.iarpccollaborations.org/members/events/10587), Broad-Scale Studies from Sea Ice to Biological Impacts and Associated Feedbacks on the Marine Ecosystem (https://www.iarpccollaborations.org/members/documents/11385), is relevant to this Performance Element. (May 23, 2018 - Completed)


- The presentation given by Katrin Iken at the September Marine Ecosystems meeting on the Chukchi Borderland project is relevant to this performance element (https://www.iarpccollaborations.org/members/events/8929) (Sep 18, 2017 - Completed)

- The presentation given by Elizabeth Labunski titled "Long-term at-sea seabird surveys for a changing Arctic" at the March Marine Ecosystems Collaboration Team meeting is relevant to this performance element (https://www.iarpccollaborations.org/members/events/7587). (Jun 15, 2017 - Completed)

4.1.3 (In progress) Assess winter distributions of key Arctic species, via passive acoustic sampling and satellite tagging for marine mammals to include further development of autonomous, unmanned surface and underwater vehicles equipped with sensors capable of recording marine mammal vocalizations.; DOI-BOEM (Lead), NOAA (Lead), DOI-FWS, DOI-USGS, MMC


- The presentation given at the October 2016 team meeting (https://www.iarpccollaborations.org/members/documents/7149) by Danielle Dickson about the Arctic Integrated Ecosystem Research Program is relevant to this Performance Element. The program will deploy year-round moorings to collect data during winter months. (Oct 30, 2017 - Completed)

- The presentation by Peter Thomas to the Marine Ecosystems Collaboration Team at the August meeting on the role of the Marine Mammal Commission in the Arctic is relevant
4.2 Improve understanding of basic life history of Arctic marine species to support multi-agency decision-making.

- **4.2.1 (In progress)** Assess feeding ecology of Arctic species and fill seasonal data gaps. One such project will identify walrus prey based on an innovative approach using molecular markers.; DOI-BOEM (Lead), DOI-USGS (Lead), NOAA (Lead), MMC, NSF
  
  - The National Science Foundation has recently awarded OPP – 1824447. This proposal focuses on the planktonic lower trophic levels and will quantify the role that the mesozooplankton play in biological transformation and cycling of important elements (C, N) in the central Arctic Ocean ecosystem as part of the year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. Working together with an international team of scientists, the PIs will determine seasonal patterns in abundance, biomass, vertical distribution, and life stage structure for the entire zooplankton community using plankton nets and acoustic and optical methods. Key biological rate processes of important species will be measured experimentally to determine seasonal changes in food web dynamics and to better understand life cycle and survival strategies and how they are linked to production cycle timing. Trophic linkages will be determined using both isotopic ratios and molecular techniques. Greater temporal and spatial context will be quantified through collaborations with MOSAiC modeling efforts. (Sep 25, 2018 - Completed)

  - Temporal variability in key dates of Arctic sea ice cover change throughout the sea ice seasonal cycle and regional changes in the extent of the seasonal ice zone examined in Angela Bliss' presentation at the August 2018 MECT meeting (https://www.iarpccollaborations.org/members/documents/11906) are relevant to this performance element. (Aug 24, 2018 - Completed)

  - USGS Genomic Study of Walrus Fecal Material to Determine Diet: With declines in sea ice and Pacific walrus shifting distributions to onshore haulouts instead of on ice, questions were raised about the energetics of walrus being further from preferred prey areas in northwestern Alaska. Key to understanding energetics is prey items, which are difficult to obtain either from benthic sampling or from walruses themselves. This USGS Alaska Science Center-led project examined the application of next generation sequencing technologies as an approach to detect prey items consumed by Pacific walruses. Work conducted in 2016-2016 found that dietary profiles for walrus in the Chukchi Sea can be generated from fecal material collected off of ice floes where walruses had recently rested. Taxonomic resolution of genomic markers was sufficient to identify prey items to family level. Final results from this project will be available in 2018. ()

  - The presentation by Peter Thomas to the Marine Ecosystems Collaboration Team at the August meeting on the role of the Marine Mammal Commission in the Arctic is relevant to this Performance Element (https://www.iarpccollaborations.org/members/events/8928). (Aug 11, 2017 - Completed)
• **4.2.2 (In progress)** Determine basic life history information on age and growth rates of key links in the food web.; DOI-BOEM (Lead), NOAA (Lead), DOI-USGS, NSF
  
  o The presentation given at the October 2016 team meeting [https://www.iarpccollaborations.org/members/documents/7149](https://www.iarpccollaborations.org/members/documents/7149) by Danielle Dickson about the Arctic Integrated Ecosystem Research Program is relevant to this Performance Element. As part of this program incubation experiments will be conducted to measure rates of plankton and sediment community growth and respiration. (Oct 30, 2017 - Completed)

• **4.2.3 (In progress)** Assess the value of recent interdisciplinary programs and synthesis efforts to guide management decisions and allocation of resources.; DOD-ONR (Lead), DOI-BOEM (Lead), USARC (Lead), DOI-FWS, MMC, NASA, NOAA
  
  o On June 8, 2018 Dr. Paul Wassmann proposed to international leaders that this conceptual model be used as a tool-kit to advance on pan-arctic integration efforts, a recognized international priority. Three oral presentations and two poster presentations were given at POLAR 2018, in Davos, Switzerland (June 2018) describing different elements of the conceptual model, i.e., [https://www.polar2018.org/uploads/2/4/6/0/24605948/session_program_polar2018_reader_os-8.pdf](https://www.polar2018.org/uploads/2/4/6/0/24605948/session_program_polar2018_reader_os-8.pdf). Dr. Henry Huntington presented new advances on the construction of the conceptual model (July 2018): [https://www.iarpccollaborations.org/members/events/10588](https://www.iarpccollaborations.org/members/events/10588) (Sep 21, 2018 - Completed)
  

4.3 Advance the understanding of how climate-related changes, biophysical interactions, and feedbacks at different scales in the marine ecosystems impact Arctic marine resources and human communities that depend on them.

• **4.3.1 (In progress)** Continue Distributed Biological Observatory (DBO)25 sampling in regions 1-5 and make data publicly available through upload of metadata to the Earth Observing Laboratory/DBO data portal.; NOAA (Lead), NSF (Lead), DOI-BOEM, DOI-FWS, NASA
  
  o ACTION: We should request revision to PE 4.3.1 to “Continue Distributed Biological Observatory (DBO) sampling in regions 1-5 and make data publicly available through upload of metadata to the Arctic Data Center (ADC)/DBO data portal.” In 2017, the Earth Observing Laboratory transferred all the DBO data to date to the new Arctic Data Center at the University of California Santa Barbara. Hydrographic and sediment data from the annual DBO research cruise on the CCGS Sir Wilfrid Laurier was submitted to the ADC and posted to the DBO data portal ([https://arcticdata.io/catalog/#profile/CN=DBO,DC=dataone,DC=org](https://arcticdata.io/catalog/#profile/CN=DBO,DC=dataone,DC=org)). DBO data collected during other research programs occupying some/all of the DBO lines as part of their projects in 2017 have been submitted to the ADC (e.g., Arctic Marine Biodiversity Observing Network (AMBON)). There are also many international DBO data collections being submitted to the ADC data archive, too, or via linkage of metafile data to national data holdings. (Nov 5, 2018 - Target)
• NASA continues to provide support for the DBO project by providing up-to-date data and visualization of weekly sea ice cover, winds, chlorophyll a distribution, surface temperature and cloud cover in the study regions and the entire Arctic. The visualizations and data are available at: https://neptune.gsfc.nasa.gov/csb/index.php?section=270. The data presented are weekly averages of most recent data for the following: (1) Chlorophyll Pigment Concentration; (2) Sea Surface Temperature (SST); (3) Sea Ice Concentration; (4) Cloud Fraction; (5) Winds and Sea Level Pressure (SLP); (6) Sea Surface Salinity (SSS); and (7) Sea Surface Height Anomaly (SSHA). The values for sea surface salinity, added in 2017, were validated in a study published in JGR Oceans in late September 2017 at: https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2017JC013184. ()

• Dr. Jackie Grebmeier’s (UMCES) presentation at the May MECT meeting (https://www.iarpccollaborations.org/members/events/10587), Broad-Scale Studies from Sea Ice to Biological Impacts and Associated Feedbacks on the Marine Ecosystem (https://www.iarpccollaborations.org/members/documents/11385), is relevant to this Performance Element. (May 23, 2018 - Completed)

• The presentation given at the October 2016 team meeting (https://www.iarpccollaborations.org/members/documents/7149) by Danielle Dickson about the Arctic Integrated Ecosystem Research Program is relevant to this Performance Element. This program is contributing to sampling the DBO. (Oct 30, 2017 - Completed)

• 1. NSF provides core research support for the annual July DBO cruise and scientific collections with Canadian colleagues on the CCGS Sir Wilfrid Laurier (SWL) in DBO regions 1-5. Both NOAA and USFWS are also involved in upper trophic level surveys on this cruise. The annual SWL cruise is co-supported with scientists in DFO/Canada who also occupy DBO4 and DBO5 lines in the Beaufort Sea later in the season. 2. NOAA provides core research support for the Aug-Sept USCGC Healy 2017 and planned USCGC Healy 2018 cruises for both DBO sampling and NCIS (Northern Chukchi Integrated Study) process efforts. 3. BOEM through the AMBON (Arctic Marine Biodiversity Observing Network) project occupied DBO3 and DBO4 in 2015 and 2017 on the RV Norseman II. NOAA, NSF and USFWS and previous Shell Oil supports science in AMBON. 4. NPRB Arctic Integrated Ecosystem Research projects occupy DBO2 and 3 lines within larger project study projects in 2017-2019 (Oct 13, 2017 - Completed)

• NASA has continued to provide support for the DBO project by providing up-to-date data and visualization of weekly sea ice cover, winds, chlorophyll a distribution, surface temperature and cloud cover in the study regions and the entire Arctic. Sea surface salinity, which is very relevant to the project, is now included as one of the parameters. The values have been validated in a recent study published in JGR Oceans (on line in September 2017). (Oct 12, 2017 - Completed)

• USCGC Healy will provide platform support for a variety of DBO efforts. (Oct 4, 2017 - Completed)

• The presentation given at the July Marine Ecosystems Collaboration Team Meeting titled "Experimenting with autonomy: Arctic biogeochemistry and the DBO through autonomous sensors" by Jessica Cross is relevant to this Performance Element.
4.3.2 (In progress) Continue DBO coordination activities including annual workshops, via participation in the Pacific Arctic Group (PAG), and produce the first Pacific Arctic Regional Marine Assessment (PARMA) in 2018; NOAA (Lead), DOD-ONR, DOI-BOEM, NASA, NSF

The 4th DBO data workshop was held Nov 7-9, 2017 at PMEL/NOAA in Seattle, Washington, USA. Over 50 national and international scientists collecting data on the DBO line presented DBO updates from the 2017 field season as well as prior DBO results. The DBO workshop presentations are available at http://arctic.cbl.umces.edu.

The Pacific Arctic Group (PAG) meetings are open and held twice a year. The fall 2017 PAG meeting was held just prior to the 4th DBO data workshop at NOAA/PMEL in Seattle, Washington. The fall 2017 PAG workshop report is available for download at the PAG website: https://pag.arcticportal.org/documents/category/33-pag-october-2014. The spring 2018 PAG meeting was held during the Arctic Science Summit Week 2018, held in Davos, Switzerland and a meeting report will be posted soon.

A subcommittee of the Marine Working Group of the International Arctic Science Committee (IASC) is undertaking an international review of the DBO program and will provide a report, with recommendations in fall 2018. With respect to the PARMA, the current Deep Sea Research II Special Issue “Pacific Arctic DBO” will provide updates on new findings of the DBO network. This special issue will update the Pacific Marine Arctic Regional Synthesis (PacMARS) that was supported by the North Pacific Research Board from 2013-2015, with a final report posted at https://www.nprb.org/assets/uploads/files/Arctic/PacMARS_Final_Report_forweb.pdf. A more formal PARMA effort will require interagency leadership and funding support. (Oct 5, 2018 - Completed)

1. NOAA sponsored DBO data meetings, such as the upcoming 4th DBO data meeting in November 2017 in Seattle, Washington, USA. 2. US national and international agency support for scientists to attend DBO data workshops. 3. International Arctic Science Committee (IASC) Marine Working Group (MWG) providing early career support for participants to the 2017 4th DBO data meeting, similar to previous DBO data workshops. 4. New paper outlining the development of the DBO project to be published in the journal Arctic (Moore and Grebmeier, 2017), including a description of a 10-year DBO implementation plan and the PARMA. 5. Jackie Grebmeier and Sue Moore in discussions with the IASC MWG to coordinate the first Pacific Arctic Regional Marine Assessment (PARMA) in 2018. 6. Participation in annual fall and spring PAG meetings for coordination of DBO studies. (Oct 13, 2017 - Completed)

The presentation given at the July Marine Ecosystems Collaboration Team meeting titled "The Arctic Marine Pulses Model: Linking Annual Oceanographic Processes to Contiguous Ecological Domains in the Pacific Arctic" by Sue Moore is relevant to this Performance Element (http://www.iarpccollaborations.org/members/events/8927). (Aug 22, 2017 - Completed)

4.3.3 (Met) Build connections between DBO and existing community-based observation programs and encourage data sharing. For example, the DBO Implementation Plan discusses fostering connections to existing community-based observation programs in an effort to link
offshore observations of biological change to local observations and IK.; NOAA (Lead), NSF (Lead), DOI-BOEM

- MECT PE 4.3.3 – Completed
  Recommendation to build connections between DBO and existing community-based observation programs were outlined in Moore and Grebmeier (2018); and expanded upon in Moore et al. (2018).

  A framework for connecting Conventional Science and Indigenous Knowledge is presented in Moore and Hauser (in review). Specifically, we suggest that the strong seasonal cycle of Arctic environmental events should be adopted as a shared framework to foster CS-IK communication when developing projects related to marine mammal health and ecology (from Abstract). The paper identifies the DBO and the Alaska Arctic Observatory and Knowledge Hub (https://arctic-aok.org/) at the University of Alaska Fairbanks as at a stage of maturity where the framework could be trialled.

References:
Moore, S.E. and D.D.W. Hauser. in review, Marine mammals as indicators of Arctic ecosystem variability: finding common ground between Conventional Science and Indigenous Knowledge. Environmental Research Letters


- The presentations provided at the May 23rd, 2018 meeting by Drs. Jackie Grebmeier (UMCES) and Carin Ashjian (WHOI) directly addressed performance element 4.3.3. The updates provided showed that progress is made being made in building connections between the DBO program and other complementary activities. It was mentioned that Norway is considering adding a DBO box in the Barents Sea which will updated later in the year or early 2019. The presentation by Dr. Ashjian showed significant progress since the original SAS meeting in 2015. The SAS program, originally a physical oceanography-only program, now has comparable planned research activities in biological and chemical oceanography (May 23, 2018 - Completed)

- "The Arctic Marine Pulses Model: Linking Annual Oceanographic Processes to Contiguous Ecological Domains in the Pacific Arctic" MECT presentation by Sue Moore is relevant to this PE (http://www.iarpccollaborations.org/members/events/8927).

  Continuing efforts to develop connections of conventional science mode with local community groups evaluating seasonal events by conventional science and indigenous knowledge. (Oct 13, 2017 - Completed)

- The presentation given at the July Marine Ecosystems Collaboration Team meeting titled "The Arctic Marine Pulses Model: Linking Annual Oceanographic Processes to Contiguous Ecological Domains in the Pacific Arctic" by Sue Moore is relevant to this Performance Element (http://www.iarpccollaborations.org/members/events/8927). (Aug 22, 2017 - Completed)
4.3.4 (In progress) Continue research and make simultaneous observations of biological, chemical, and physical variables to examine linkages among marine species, oceanographic and sea ice conditions, and climate change to understand the mechanisms that affect performance and distribution. Quantify feedbacks and interactions of bottom-up and top-down processes that regulate production. Several projects require the integration of IK.; DOI-BOEM (Lead), NOAA (Lead), NSF (Lead), DOD-ONR, DOI-FWS, DOI-USGS, NASA, USARC

- The National Science Foundation (NSF) has recently awarded OPP – 1822021. The investigators will establish and analyze a multi-decadal baseline of observations that describes the spatial distributions of planktonic communities in the western Arctic Ocean with the goal of developing optical tools and approaches that can be broadly applied to understand future environmental change in the region. Activities include a combination of (i) field work in the Chukchi and Beaufort Seas through collaboration with a Japanese research program, (ii) the development of optically-based algorithms for discerning planktonic community assemblages, and (iii) application of these algorithms to satellite remote-sensing data. The field work will include observations of planktonic community structure and connect these to seawater optical properties in the study area at different seasonal time periods. In addition, the investigators will use phytoplankton pigment measurements to infer spatial patterns of planktonic community composition and address the hypothesis that optical measurements can identify distinct planktonic assemblages. Finally, the project will develop and validate algorithms relating seawater optical properties to planktonic community structure and apply these to a time series of ocean color imagery to generate spatial maps of plankton community composition within the surface ocean. (Oct 15, 2018 - Completed)

- NOAA conducts several research surveys that are relevant to Performance Element 4.3.4 and details about each may be found on the NOAA website: [https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-research-surveys](https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-research-surveys). Surveys that are particularly relevant include the following: Southeastern Bering Sea Integrated Ecosystem Assessment (biennial - spring), Southeastern Bering Sea Integrated Ecosystem Assessment (biennial - late summer - BASIS), Northeastern Bering Sea Integrated Ecosystem Assessment (annual - surface trawl - BASIS), Arctic Integrated Ecosystem Survey (special project when extramural funds are available), Eastern Bering Sea Shelf Bottom Trawl Survey (annual), Eastern Bering Sea Slope Bottom Trawl Survey (biennial), Northern Bering Sea Shelf Bottom Trawl Survey (biennial), Chukchi Sea Shelf Bottom Trawl Survey (special project when extramural funds are available), Eastern Bering Sea Shelf Midwater Acoustic-Trawl Survey

Integrated ecosystem surveys provide an understanding of the impact of loss of sea ice on the eastern Bering Sea and Arctic marine ecosystems. Ecosystem indicators from these surveys are used to understand food web dynamics, larval and age-0 groundfish distribution and fitness, forage fish and juvenile Pacific salmon (western Alaska) relative abundance, distribution and fitness. The high Arctic work attempts to understand how loss of sea ice is impacting Arctic and saffron cod as well as movement of Pacific salmon north. The eastern Bering Sea ecosystem indicators are published each year in the Ecosystem Considerations series for Status of the Eastern Bering Sea Marine Ecosystem ([https://www.afsc.noaa.gov/REFM/Docs/2017/ecosysEBS.pdf](https://www.afsc.noaa.gov/REFM/Docs/2017/ecosysEBS.pdf)) and are presented to the North Pacific Fisheries Management Council to help understand potential mechanisms affecting recruitment/survival of groundfishes and other nekton in this region. These
surveys are collaborative efforts with the Alaska Department of Fish and Game and the US Fish and Wildlife Service (seabird observers).

Trawl surveys are principally conducted to determine the status and trends of Fisheries Management Plan (FMP) species (fish and crab) however at the same time, they provide ecosystem information so that NMFS can practice an ecosystem approach to management. Surveys provide some data on physical properties of seawater (always temperature and sometimes salinity, and light), as well as estimates of biomass and species abundance of other epibenthic (bottom trawl) or forage (midwater) species. For example, the midwater surveys are producing estimates of krill biomass and distribution. Our surveys also provide data on linkages among species through predator-prey (diet) data, disease/parasite studies, and studies of habitat.

The surveys also serve as platforms for special studies by scientists from other state, Federal, and academic institutions. For example, this past summer NOAA collected phytoplankton in the northern Bering Sea to detect the prevalence of species that can cause harmful algal blooms. (Oct 3, 2018 - Completed)

- Two Saildrone unmanned surface vehicles equipped with fisheries echosounders were used to conduct an acoustic survey of the distribution of Arctic cod over the Chukchi shelf (PI’s Alex De Robertis and Robert Levine) as part of NOAA’s Innovative Technology for Arctic Exploration program (https://www.pmel.noaa.gov/itae/) in partnership with field work conducted under North Pacific Research Board’s Arctic Integrated Ecosystem Research Program (https://www.nprb.org/arctic-program/about-the-program/). These autonomous vehicles measured fish abundance as well as a broad suite of meteorological and near-surface oceanographic measurements as they transited over the Chukchi Shelf. The primary goal of the work was to assess the abundance and distribution of Arctic cod over the U.S. continental shelf region of the Chukchi Sea during a gap-year in ship-based surveys in the Arctic Integrated Ecosystem Research program (more details available at this link: https://www.fisheries.noaa.gov/science-blog/saildrones-head-arctic-post-1). (Oct 3, 2018 - Completed)

- The Arctic Marine Biodiversity Observing Network (AMBON) continues to contribute to performance element 4.3.4 (and 4.1.2). Under this National Ocean Partnership Program effort (NOAA/BOEM/ UAF) Field efforts were conducted in 2015 and 2017. During those field efforts, AMBON collected ecosystem level biodiversity information along five cross-shelf and one along-shelf transect in the Chukchi Sea. State of the art genetic techniques complement traditional taxonomic approaches to include the small size fractions (microbes, nano- to microplankton, meiofauna) into biodiversity assessments. Through working with the Alaska Ocean Observing System (AOOS), the program created open access data and coordinates with other national BON demonstration projects. Outreach is pursued through a website (through AOOS), and interactions with local communities, specifically the Native Alaska communities of the north that are most directly affected by the changes in the Arctic. Various stakeholders are engaged through direct communications (e.g., BOEM, Shell, IOOS), workshops, database, scientific meetings, etc. During this last year, most of the efforts were dedicated to processing samples from the August 2017 cruise. One focus of our recent investigations was to discern differences in environmental conditions between the two sampling years, and at which ecosystem levels at such differences were visible. A final report will be produced in
North Pacific Research Board recently committed to co-funding the Chukchi Ecosystem Observatory (http://research.cfos.uaf.edu/ceo/) FY20-FY24 via the NPRB Long-Term Monitoring Program. The subsurface moored observatory is located on the NE Chukchi Sea shelf near 71.6N, 161.5W and observations were initiated in 2014. The instruments record with high temporal resolution throughout the year, including the under-sampled and poorly understood seasons when sea ice typically inhibits ship-based sampling. Measurements include ice, ocean physics, nutrient and carbonate chemistry, particulate matter, phytoplankton, zooplankton, fisheries, and marine mammal datasets, thereby providing multifaceted views into the inter-trophic co-variability of the Chukchi shelf ecosystem. This project is supported by a multi-institutional consortium that includes the Alaska Ocean Observing System, the North Pacific Research Board, Olgoonik-Fairweather, Université Laval, the University of Washington and the University of Alaska Fairbanks. (Oct 1, 2018 - Completed)

The Arctic Integrated Ecosystem Research Program (www.nprb.org/arctic-program) continues to contribute to performance element 4.3.4. Field campaigns in the northern Bering Sea and southern Chukchi Sea in June 2017 & 2018 examined ecosystem processes associated with the spring plankton bloom and shipboard experiments measured rates of biological production that will be valuable to future ecosystem modeling efforts. Surveys of the Chukchi Sea and western Beaufort Sea in August-September 2017 & 2019 further examine ecosystem processes and the factors affecting the distribution and abundance of fish and marine mammal resources. The program integrates observations of marine physics, chemistry, and biology, including measures of primary and secondary productivity, pelagic-benthic coupling, fish and epibenthic sampling, seabird observations, and marine mammal acoustics. A series of moored instruments complement shipboard sampling and collect data year-round. A social science project facilitates the integration of local and traditional knowledge and examines the relative contributions of environmental and socioeconomic factors that affect food security for Arctic residents. Several projects funded by Federal agencies are collaborating. North Pacific Research Board has committed to providing $1M to fund a synthesis phase that will follow the field campaigns beginning in FY22 and is actively soliciting funding partners. (Oct 1, 2018 - Completed)

The Arctic Marine Biodiversity Observing Network (AMBON) continues to contribute to performance element 4.3.4 (and 4.1.2). Under this National Ocean Partnership Program effort (NOAA/BOEM/ UAF) Field efforts were conducted in 2015 and 2017. During those field efforts, AMBON collected ecosystem level biodiversity information along five cross-shelf and one along-shelf transect in the Chukchi Sea. State of the art genetic techniques complement traditional taxonomic approaches to include the small size fractions (microbes, nano- to microplankton, meiofauna) into biodiversity assessments. Through working with the Alaska Ocean Observing System (AOOS), the program created open access data and coordinates with other national BON demonstration projects. Outreach is pursued through a website (through AOOS), and interactions with local communities, specifically the Native Alaska communities of the north that are most directly affected by the changes in the Arctic. Various stakeholders are engaged through direct communications (e.g., BOEM, Shell, IOOS), workshops, database, scientific meetings,
etc. During this last year most of the efforts were dedicated to processing samples from the August 2017 cruise. One focus of our recent investigations was to discern differences in environmental conditions between the two sampling years, and at which ecosystem levels at such differences were visible. A final report will be produced in October 2019. More information can be seen at https://ambon-us.org/ (Oct 1, 2018 - Completed)

NASA contributed to this PE in the following ways: NASA Principal Investigator Kevin Arrigo completed his project entitled Investigations of Climate and Environmental Change on Arctic Pacific Shelves (ICECAPS) this past July, which was a continuation of the ICECAPE project and provided more refined products resulting from that field program. Specifically, the ICECAPS project aimed to improve satellite-based algorithms to derive chlorophyll-a concentration, an index of phytoplankton biomass, and net primary production in the Arctic Ocean, more specifically the Beaufort and Chukchi Seas. The results from this research are important to understand changes in primary production in the Arctic under the current warming conditions, and how changes in primary production relative to decreases in Arctic sea ice may impact higher trophic levels. The PI was the co-lead of the NASA ICESCAPE program, which discovered massive underice blooms and summarized findings in two special issues of Deep-Sea Research II (2015, 2016). NASA Principal Investigator Paty Matrai continues to work on her project entitled “Net Primary Productivity Algorithm Round Robin for the Arctic Ocean”, which focuses on the balance of net primary production (NPP) in the Subarctic Atlantic as affected by (i) advective losses and gains at large-scales interaction with respect to boundary conditions in the temperate N. Atlantic and Arctic Oceans; (ii) lateral and vertical “export” production within sub-regions of the Subarctic Atlantic at intermediate scales; and (iii) advective and local processes controlling NPP in the Subarctic Atlantic region. A manuscript was published that focuses on primary production under sea ice and at the ice edge, compares field and ocean color (when available) values of chlorophyll, identifies and quantifies the relative magnitude of physical processes (i.e., vertical and horizontal advection/transport) with assistance of a 1-D physical model (i.e., vertically/locally) and the a fully-coupled GCM (i.e., horizontally/regionally), and identifies and quantifies the temporal variability of the annual cycle of net community production in the seasonal ice zone (i.e., using the NO3 fields measured by the float) of this region. Finally, on August 22 Angela Bliss (https://www.iarpccollaborations.org/members/people/10251) delivered a presentation on “Arctic sea ice cover climate indicators: melt season evolution and regional variability” at the Marine Ecosystems Collaboration Team meeting (https://www.iarpccollaborations.org/members/documents/11906). (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1821911. The goal of this project is to identify the biological and physical drivers underlying the production and uptake of oxygen and methane, establishing the metabolic balance of these key gases in the oligotrophic Central Arctic. The investigators will take advantage of the unique opportunity afforded by the international, year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition to determine net community production from year-round measurements of oxygen and argon, as well as methane oxidation and production from methane concentration and isotopic ratios. They will measure bacterial and community respiration, bacterial production, and
microbial community structure, and analyze gene expression to identify the genes, organisms, and pathways associated with methane production in the surface ocean. Results will be used to model the oceanic methane cycle using the MITgcm Arctic Regional Model and improve the biogeochemical components of the Regional Arctic System Model (RASM). (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1824447. This proposal focuses on the planktonic lower trophic levels and will quantify the role that the mesozooplankton play in biological transformation and cycling of important elements (C, N) in the central Arctic Ocean ecosystem as part of the year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. Working together with an international team of scientists, the PIs will determine seasonal patterns in abundance, biomass, vertical distribution, and life stage structure for the entire zooplankton community using plankton nets and acoustic and optical methods. Key biological rate processes of important species will be measured experimentally to determine seasonal changes in food web dynamics and to better understand life cycle and survival strategies and how they are linked to production cycle timing. Trophic linkages will be determined using both isotopic ratios and molecular techniques. Greater temporal and spatial context will be quantified through collaborations with MOSAiC modeling efforts. (Sep 25, 2018 - Completed)

- Dr. Karen Frey (https://www.iarpccollaborations.org/members/people/136) presented recent results from her research at the 3/21/2018 MECT call, https://www.iarpccollaborations.org/members/documents/11104, which are directly relevant to this performance element (Sep 21, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1733578. This award supports scientific research by anthropologists, geographers, and atmospheric scientists to understand the relationship between how weather is normally measured and the factors that Arctic Indigenous peoples need to travel and work out of doors. In the same way that wind-chill, a combination of temperature and wind speed has become a commonly used composite of weather information used by many Americans, for Inuit visibility and sea-state are critical factors in whether to travel or stay put. For example, visibility is a product of cloud cover, wind, snow conditions, terrain, and more. The research team will seek to quantify factors and test them through camps for Elders and youth. In turn, the Elders and youth will train scientists about the nuanced nature of safely and successfully traveling and working in the Arctic. If successful, the team plans to share the factors with forecast agencies and others to increase the production of actionable knowledge. (Sep 21, 2018 - Completed)

- Sea ice conditions are changing rapidly in response to climate change. The work presented at Angela Bliss’ presentation at the August 2018 MECT meeting (https://www.iarpccollaborations.org/members/documents/11906) examines the variability of key dates of sea ice change throughout the sea ice seasonal cycle, indicating that the length of the mean Arctic melt season and the open water season is increasing at a rate of ~12 days per decade since 1979 which has implications relevant to this performance element. (Aug 21, 2018 - Completed)

- Carin Ashjian (Woods Hole Oceanographic Institute) presented “The Importance of Shelf Break Upwelling to Upper Trophic Level Ecology in the Western Beaufort Sea: Overview and September Cruise summary” at the MECT October 2017 meeting
Dr. Jackie Grebmeier's (UMCES) presentation at the May MECT meeting (https://www.iarpccollaborations.org/members/events/10587), Broad-Scale Studies from Sea Ice to Biological Impacts and Associated Feedbacks on the Marine Ecosystem (https://www.iarpccollaborations.org/members/documents/11385), is relevant to this Performance Element. (May 23, 2018 - Completed)

Dr. Carin Ashjian's (UMCES) presentation at the May 2018 MECT meeting (https://www.iarpccollaborations.org/members/events/10587), The Synoptic Arctic Survey (SAS): A Developing Multi-Nation Interdisciplinary Survey of the Arctic Ocean. (https://www.iarpccollaborations.org/members/documents/11386), is relevant to this Performance Element. There are multiple opportunities for potential ship collaborations relevant to the developing Synoptic Arctic Survey (SAS) via additional interdisciplinary collections on planned cruises during the SAS campaign, such at the NABOS, Nansen Legacy and PACEO programs, along with other planned shelf-to basin international cruises. SAS and MOSAiC are both opportunities for interdisciplinary Central Arctic Ocean and slope studies pertinent to scientific needs to understand that changing system as it opens up via reduce sea ice coverage. (May 23, 2018 - Completed)

The March 2018 MECT meeting (https://www.iarpccollaborations.org/members/events/10586) focused on biologically-induced heat trapping in the upper Arctic Ocean: implications for sea ice dynamics and productivity. There was agreement from both speakers that heat-trapping, a vertical redistribution of heat in the water column, cannot be overlooked if we want to properly interpret observations, and obtain improved modeling results, although in the latter case it was noted that further research is needed to agree on the proper representation of this biophysical feedback. Presentations: Biophysical Feedbacks in the Arctic Ocean: Observational perspective - Karen Frey (Clark University); Biophysical Feedbacks in the Arctic Ocean: Modeling perspective - Manfredi Manizza (Scripps Institution of Oceanography) (Mar 21, 2018 - Completed)

Francis Wiese presentation at the 2/28/2018 meeting, on the Marine Arctic Ecosystem Study, contributed new information to this performance element. https://www.iarpccollaborations.org/members/events/10585 (Mar 19, 2018 - Completed)

The presentation given at the October 2016 team meeting (https://www.iarpccollaborations.org/members/documents/7149) by Danielle Dickson about the Arctic Integrated Ecosystem Research Program is relevant to this Performance Element. (Oct 30, 2017 - Completed)

Nicole Misarti’s presentation at the May MECT meeting titled "It’s in their Bones: A Multi-disciplinary, Long-term Investigation into the Sustainability of an Important Subsistence Species—the Pacific Walrus" (http://www.iarpccollaborations.org/members/events/8926) is relevant to this performance element. (May 11, 2017 - Completed)

4.3.5 (In progress) Implement the Regional Action Plan for Southeastern Bering Sea Climate Science and prepare Regional Action Plans for Aleutian Islands and High Arctic Large Marine Ecosystems (LMEs); NOAA (Lead)
To date, the Regional Action Plan for Southeastern Bering Sea Climate Science has been completed and is being implemented at the Alaska Fisheries Science Center (AFSC). Efforts to develop Regional Action Plans for Aleutian Islands and the High Arctic Large Marine Ecosystems have not yet begun. (Sep 26, 2018 - Completed)

The presentation given to the Marine Ecosystems Collaboration team in June by Kirstin Holsman and Mike Sigler titled "Climate Science Strategy for the Southeaster Bering Sea Region & the Alaska Climate Integrated Modeling Project (ACLIM)" relates to this Performance Element (http://www.iarpccollaborations.org/members/events/8925). (Jun 15, 2017 - Completed)

- **4.3.6 (In progress) Conduct numerical simulations using coupled models to evaluate feedbacks across disciplines and systems.; NOAA (Lead), NSF (Lead), DOD-ONR, DOI-BOEM**

- The National Science Foundation (NSF) has recently awarded OPP – 1822021. The investigators will establish and analyze a multi-decadal baseline of observations that describes the spatial distributions of planktonic communities in the western Arctic Ocean with the goal of developing optical tools and approaches that can be broadly applied to understand future environmental change in the region. Activities include a combination of (i) field work in the Chukchi and Beaufort Seas through collaboration with a Japanese research program, (ii) the development of optically-based algorithms for discerning planktonic community assemblages, and (iii) application of these algorithms to satellite remote-sensing data. The field work will include observations of planktonic community structure and connect these to seawater optical properties in the study area at different seasonal time periods. In addition, the investigators will use phytoplankton pigment measurements to infer spatial patterns of planktonic community composition and address the hypothesis that optical measurements can identify distinct planktonic assemblages. Finally, the project will develop and validate algorithms relating seawater optical properties to planktonic community structure and apply these to a time series of ocean color imagery to generate spatial maps of plankton community composition within the surface ocean. (Oct 15, 2018 - Completed)

- Dr Manfredi Manizza's presented his past and current research at the 3/21/2018 MECT call. His presentation can be found at https://www.iarpccollaborations.org/members/documents/11101, and is directly relevant to this performance element, in particular his current pan-arctic modeling experiments

- The March 2018 MECT meeting (https://www.iarpccollaborations.org/members/events/10586) focused on biologically-induced heat trapping in the upper Arctic Ocean: implications for sea ice dynamics and productivity. There was agreement from both speakers that heat-trapping, a vertical redistribution of heat in the water column, cannot be overlooked if we want to properly interpret observations, and obtain improved modeling results, although in the latter case it was noted that further research is needed to agree on the proper representation of this biophysical feedback. Presentations: Biophysical Feedbacks in the Arctic Ocean: Observational perspective - Karen Frey (Clark University), Biophysical Feedbacks in the Arctic Ocean: Modeling perspective - Manfredi Manizza (Scripps Institution of Oceanography) (Mar 21, 2018 - Completed)
Dmitry Dukhovskoy (COAPS- Florida State University) presented “The Role of Fresh Water in a Changing Arctic Climate” (https://www.iarpccollaborations.org/members/documents/10340) at the MECT November 2017 meeting (https://www.iarpccollaborations.org/members/events/8931). Dmitry Dukhovskoy provided insight into the way fresh water is flowing into the arctic ocean in relation to the changing climate. (Nov 8, 2017 - Completed)

- **4.3.7 (In progress) Continue development, testing, and runs of prognostic models that use Intergovernmental Panel on Climate Change (IPCC) scenarios in a regional context to explore current understanding of biophysical interactions and feedbacks, such as perturbations across several modeled food webs from the subarctic to the Arctic to estimate relative ecosystem sensitivities and rates of change. ; NOAA (Lead), DOD-ONR, DOI-USGS, NSF**

- The presentation given to the Marine Ecosystems Collaboration team in June by Kirstin Holsman and Mike Sigler titled "Climate Science Strategy for the Southeaster Bering Sea Region & the Alaska Climate Integrated Modeling Project (ACLIM)" relates to this Performance Element (http://www.iarpccollaborations.org/members/events/8925). (Aug 21, 2017 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1822021. The investigators will establish and analyze a multi-decadal baseline of observations that describes the spatial distributions of planktonic communities in the western Arctic Ocean with the goal of developing optical tools and approaches that can be broadly applied to understand future environmental change in the region. Activities include a combination of (i) field work in the Chukchi and Beaufort Seas through collaboration with a Japanese research program, (ii) the development of optically-based algorithms for discerning planktonic community assemblages, and (iii) application of these algorithms to satellite remote-sensing data. The field work will include observations of planktonic community structure and connect these to seawater optical properties in the study area at different seasonal time periods. In addition, the investigators will use phytoplankton pigment measurements to infer spatial patterns of planktonic community composition and address the hypothesis that optical measurements can identify distinct planktonic assemblages. Finally, the project will develop and validate algorithms relating seawater optical properties to planktonic community structure and apply these to a time series of ocean color imagery to generate spatial maps of plankton community composition within the surface ocean. (Oct 15, 2018 - Completed)

- BOEM in conjunction with NOAA has two projects Synthesis of Arctic Research and Chukchi Acoustic, Oceanography and Zooplankton Study: Hanna Shoal (CHAOZ-X) both included climate modeling using IPCC scenarios in their respective analyses. Both projects are concluding and principal investigators completing final reports. Synthesis of Arctic Research SOAR Phase II just completed a 2nd Deep Sea Journal II special editionEdited by Sue E. Moore, Phyllis J. Stabeno, Thomas I. Van Pelt Volume 152, Pages 1-214 (June 2018) (Oct 2, 2018 - Completed)

- The presentation given to the Marine Ecosystems Collaboration team in June by Kirstin Holsman and Mike Sigler titled "Climate Science Strategy for the Southeaster Bering Sea Region & the Alaska Climate Integrated Modeling Project (ACLIM)" relates to this Performance Element (http://www.iarpccollaborations.org/members/events/8925). (Aug 21, 2017 - Completed)
4.3.8 (In progress) Monitor and describe temporal changes in anthropogenic and environmental sound in the Alaskan marine Arctic as well as potential implications for ecosystems.; DOI-BOEM (Lead), NOAA (Lead), DOD-ONR; Target Date 2018

NEW. Monitor and describe temporal changes in anthropogenic and environmental sound in the Alaskan marine Arctic as well as potential implications for ecosystems.

- Paper published: Haver, S.M., Gedamke, J., Hatch, L.T., Dziak, R.P., Van Parijs, S., McKenna, M.F., Barlow, J., Berchok, C., DiDonato, E., Hanson, B. and Haxel, J., 2018. Monitoring long-term soundscape trends in US Waters: The NOAA/NPS Ocean Noise Reference Station Network. Marine Policy, 90, pp.6-13. The noise reference station network includes 12 calibrated passive acoustic recorders located within the US EEZ; one of these recorders is located on the NE Chukchi shelf. These recorders are capturing anthropogenic, biological, and environmental soundscape contributors. The Arctic recorder was redeployed during the August USCGC Healy 18-01 cruise and will be retrieved in 2020. The AFSC continues to recorder and analyze long-term passive acoustic recordings from 20 subsurface moorings deployed annually in the Bering, Beaufort, and Chukchi Seas. The Arctic moorings were redeployed during the USCGC Healy 18-01 cruise, the Bering Sea moorings will be redeployed in October. Over half of these recorders are co-located with oceanographic instrumentation (from NOAA/PMEL funded by BOEM/NOAA/Navy). Two projects are focusing specifically on acoustic environment: the first involves noise generated by fiber-optic cable laying operations (Quintillion), and the second is a comparison of the acoustic environment among three locations with widely differing vessel traffic: Unimak Pass, Bering Strait, and the Chukchi Plateau. Reports will be completed this fall. Paper published: Williams, K.L., Boyd, M.L., Soloway, A.G., Thorsos, E.I., Kargl, S.G. and Odom, R.I., 2018. Noise Background Levels and Noise Event Tracking/Characterization Under the Arctic Ice Pack: Experiment, Data Analysis, and Modeling. IEEE Journal of Oceanic Engineering, 43(1), pp.145-159. In March 2014, an Arctic Line Arrays System (ALAS) was deployed as part of an experiment in the Beaufort Sea (approximate location 72.323 N, 146.490 W). The water depth was greater than 3500 m. The background noise levels in the frequency range from 1 Hz to 25 kHz were measured as part of a larger objective to determine direction and range to sources. Background noise spectral levels are presented for low and high floe-drift conditions. Tracking/characterization results for ice-cracking events (with signatures typically in the 10-2000-Hz band), including the initiation of an open lead within about 400 m of the array, and one seismic event (with a signature in the 1-40-Hz band). Paper published: Wright, D.L., Berchok, C.L., Castellote, M., Crance, J.L. & Clapham, P.J. 2018. Acoustic detection of North Pacific right whales in a high-traffic Aleutian pass. Endangered Species Research doi: 10.3354/esr00915. Includes a section on vessel persistence and the acoustic environment in Unimak Pass. (Sep 27, 2018 – Completed)

- The presentation given by Dr. Manuel Castellote (NOAA) on April 18, 2018, directly addressed PE 4.3.8, i.e., https://www.iarpc.collaborations.org/members/events/10595

Agencies
DOC, DOD, DOE, DOI, MMC, NASA, NSF, USARC
5.1 Glaciers & Sea Level

5.1 Coordinate and integrate observations to improve understanding of the processes controlling the mass balance of Arctic land ice.

- 5.1.1 (In progress) Maintain support for aircraft and satellite missions that contribute to long-term observations of land ice, including: Landsat-8, ICESat-2, OIB, and the NASA-ISRO Synthetic Aperture Radar (NISAR) mission.; NASA (Lead), DOI-USGS

  NASA contributed to this PE in the following ways: Landsat 8 continued to operate well during FY2018. GoLIVE continues to operate and release data via NSIDC. Specifically, the GoLIVE data set continues to extend forward in time, and does over time indicate the extent of ‘live’ flowing ice in Arctic and sub-Arctic glaciers. GoLIVE will become a new project, ITS_LIVE, by 2020 that will be an even more extensive mapping of Earth’s ice, using Landsat, ICESat-2, and ESA’s Sentinel constellation. There is not a specific project right now to map the changing extent of Arctic and sub-Arctic glaciers, however. Future work is planned to combine Landsat 8 and 9 and Sentinel 2 to monitor northern hemisphere snow cover at the “100 meter scale. This work is underway with Dr. Tom Painter of NASA’s JPL, and with Dr. Chris Crawford of USGS Sioux Falls, and Dr. Ted Scambos of University of Colorado. Both Chris and Ted are members of the current Landsat Science Team.

NASA’s Ice, Cloud and land Elevation Satellite-2 (ICESat-2) (https://www.nasa.gov/content/goddard/icesat-2) successfully launched from California on September 15, 2018 embarking on its mission to measure the ice of Earth’s frozen reaches with unprecedented accuracy. ICESat-2 carries a single instrument, the Advanced Topographic Laser Altimeter System (ATLAS) (https://icesat.gsfc.nasa.gov/icesat2/instrument.php). ATLAS will be activated approximately two weeks after the mission operations team completes initial testing of the spacecraft. Then ICESat-2 will begin work on its science objective, gathering enough data to estimate the annual height change of the Greenland and Antarctic ice sheets to within four millimeters – the width of a pencil. The high-resolution data will document changes in the Earth’s polar ice caps, improve forecasts of sea level rise bolstered by ice sheet melt in Greenland and Antarctica, and help scientists understand the mechanisms that are decreasing floating ice and assess how that sea ice loss affects the ocean and atmosphere.

ICESat-2 continues the record of ice height measurements started by NASA’s original ICESat mission, which operated from 2003 to 2009, that were continued by the agency’s annual Operation IceBridge airborne flights over the Arctic and Antarctic, which began in 2009. Data from ICESat-2 will be available to the public through the National Snow and Ice Data Center.
Using a fleet of research aircraft, NASA’s Operation IceBridge (OIB) images Earth’s polar ice to better understand connections between polar regions and the global climate system. IceBridge studies annual changes in thickness of sea ice, glaciers and ice sheets. IceBridge bridges the gap between the ICESat missions. NASA is planning to continue OIB through FY20. This year included a 10-week Arctic campaign in March through May. It included mission-critical surveys of Arctic sea ice, Greenland glaciers and future ICESat-2 tracks. The campaign was dedicated to overflying the Arctic Ocean’s sea ice cover, plus several fast-changing Greenland glaciers from three bases: Thule Air Base, Fairbanks, Alaska and Kangerlussuaq, Greenland.

GRACE-FO launched on 22 May 2018 and is still in check-out phase.

NASA continues to work in partnership with the Indian Space Research Organization (ISRO), to develop the NASA-ISRO Synthetic Aperture Radar (NISAR) mission, to measure time-varying displacements of ice-covered surfaces to infer ice flow and extent in Arctic glaciers, ice caps, and the Greenland Ice Sheet. It is now expected to changed to a left-looking-only mission, which would exclude imaging the Arctic above 77.5ºN.

NISAR will provide fine scale ice drift on a routine basis. The science objective is to examine the small scale mechanical energy dissipation associated with fracturing of the ice cover, and the changes in heat and momentum flux due to these material failures (openings and closings). The NISAR ice drift will also be used to provide better estimates of mechanical coupling between the ice cover and the underlying ocean for improving the representation in coupled models. (Sep 30, 2018 - Completed)

- The May 2018 GSLCT meeting focused on upcoming satellite missions of major relevance to Arctic ice dynamics investigation (https://www.iarpccollaborations.org/members/events/10601). Upcoming satellite missions of major relevance to Arctic ice dynamics investigations, as informed by recent satellite investigations of that ice. This meeting increased awareness of future missions and helped scientists start thinking about how they might use such data. Presentations: Landsat-9 and the Landsat—Sentinel2 constellation: new opportunities for ice and snow mapping-Ted Scambos (NSIDC); NASA Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (SAR) (NISAR) for Polar Studies- Ian Joughin (UW) (Jun 7, 2018 - Completed)

- Determining source-partitioned, monthly freshwater flux to Greenland fjords depends on remote sensing observations of Greenland sea ice and iceberg distributions. Landsat 8 optical radar data was used in our initial study, but additional radar data, such as the data that will be produced from the NISAR mission, can also be used to examine Greenland coastal conditions. Maintaining long-term observations will allow us to explore how Greenland freshwater flux varies over time and the changing role of different freshwater sources with air and ocean temperature increases. For more information see https://www.iarpccollaborations.org/members/events/10597. (Feb 5, 2018 - Completed)

- Joe MacGregor delivered an OIB update to the G&SLCT during 2017. Using a fleet of research aircraft, NASA’s Operation IceBridge images Earth’s polar ice to better understand connections between polar regions and the global climate system. IceBridge studies annual changes in thickness of sea ice, glaciers and ice sheets. IceBridge bridges the gap between the ICESat missions. NASA is planning to continue OIB through FY20.
NASA’s annual survey of changes in Arctic ice cover greatly expanded its reach this year in a series of flights that began on March 9 and wrapped up on May 12. It was the most ambitious spring campaign in the region for Operation IceBridge (OIB), an airborne mission to monitor ice changes at Earth’s poles, which also included a rapid-response flight over a new crack in Petermann Glacier, one of the largest and fastest-changing glaciers in Greenland. Geographically, OIB covered a wider area than ever before, and the new instruments deployed provided denser and more accurate measurements. The mission carried out 39 eight-hour flights in 10 weeks. Of those, 13 focused on surveying sea ice, while the remaining 26 flights targeted land ice. Several flights included collaborations with international Ice, Cloud and land Elevation Satellite (ICESat) missions teams to collect and compare measurements of snow and ice. The first part of the campaign was dedicated to overflying the Arctic Ocean’s sea ice cover, plus several fast-changing land ice areas from two sites: Thule Air Base in northwest Greenland and Fairbanks, Alaska. In this campaign, the IceBridge team added an extra base: Longyearbyen, Svalbard. From there, the mission was able to reach areas of the Eurasian side of the Arctic Ocean that had not been explored by IceBridge before. IceBridge also expanded its scope westward with a flight to the western side of the Chukchi Sea, a sea situated between Alaska and Russia. It was the first time the mission ever crossed the International Date Line. Operation IceBridge (OIB) launched a short campaign on July 17, 2017 from Thule Air Base, in northwest Greenland. The IceBridge scientists completed six flights focusing on sea ice that has survived at least one winter. The sea ice flights surveyed melt ponds, the pools of melt water on the ice surface that may contribute to the accelerated retreat of sea ice. IceBridge also flew a set of tracks to locate areas of sea ice that the mission already flew over in March and April, during its regular springtime campaign, to measure how the ice has melted since then. For its third and final Arctic campaign of 2017, starting in early September, OIB operated from both Thule and Kangerlussuaq to replicate land ice missions that IceBridge completed this past spring. They completed 15 flights over a broad swath of Greenland’s ablation, percolation and dry snow zones. (Nov 2, 2017 - Completed)

- NASA focus on High Mountain Asia (Imerzeel group), delineating debris cover is particularly emphasized. Sentinel 2 and other micro satellites are being used extensively to maximize image acquisition due to expanded opportunity to image. Altena and Kaab provide overview of advances using optical and multispectral imagery to estimate ice flow. (Oct 30, 2017 - Completed)

- ArcticDEM Release 6 (Polar Geospatial Center) brings terrain coverage of the Arctic to 97.4% at 5m resolution. (Sep 29, 2017 - Completed)

- Tom Neumann delivered a talk at the July GSLCT meeting, progress continues towards launch which is now projected for Dec. 2018. The SV will greatly improve data quality as compared to ICESat-1. (Sep 29, 2017 - Completed)

- As of August 2017: The assembly of the two GRACE-FO satellites was completed at the Airbus Defence and Space facility in Friedrichshafen, Germany and the spacecraft were shipped to the IABG (INDUSTRIEANLAGEN-BETRIEBSGESELLSCHAFT MBH) environmental test facilities in Ottobrun, Germany. Environmental testing is almost complete and final preparations will begin soon to ship the satellites to the Vandenberg Air Force Base by the end of the year. The GRACE-FO spacecraft will be launched with five Iridium NEXT satellites on a SpaceX Falcon 9 rocket in Spring 2018. (Sep 29, 2017 - Completed)
o NASA continues to work in partnership with the Indian Space Research Organization (ISRO), to develop the NASA-ISRO Synthetic Aperture Radar (NISAR) mission, to measure time-varying displacements of ice-covered surfaces to infer ice flow and extent in Arctic glaciers, ice caps, and the Greenland Ice Sheet. NISAR is proceeding on schedule with Critical Design Reviews through FY18, contracts for major subsystems are in place, and engineering and flight models of subsystems are in fabrication towards a launch readiness date at the end of 2021. (Sep 29, 2017 - Completed)

o Presentations at the June 15th Glaciers and Sea Level Collaboration Team meeting (http://www.iarpccollaborations.org/members/events/7787) by Joe MacGregor, Tom Neumann, and Ian Howat relate to this Performance Element (5.1.1). (Jun 16, 2017 - Completed)

o The MEaSUREs Greenland Ice Mapping Project (GIMP) Digital Elevation Model from GeoEye and WorldView Imagery data set is now available at the NASA National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). This data set, part of the Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program, consists of an enhanced resolution digital elevation model (DEM) for the Greenland Ice Sheet derived from sub-meter resolution, panchromatic stereoscopic imagery collected by the GeoEye-1, WorldView 1, WorldView 2, and WorldView 3 satellites operated by DigitalGlobe Inc. Data Acknowledgements Data authors: Ian Howat, Adelaide Negrete, Ben Smith Data set DOI: http://dx.doi.org/10.5067/H0KUYVF53Q8M Data center: NSIDC DAAC (http://nsidc.org/daac)

- 5.1.2 (In progress) Enable the collection of ground-based observations and associated aircraft measurements documenting variability of land ice on a variety of spatial and temporal scales, including: the Greenland Ice Sheet Monitoring Network (GLISN), the Oceans Melting Greenland (OMG) mission, the U.S. Geological Survey (USGS) Benchmark Glaciers Program in Alaska (and the the Ice2O project in Alaska.; NASA (Lead), DOI-USGS, NOAA, NSF

o NASA contributed to this PE in the following ways: OMG surveys continued and 7 distinct results published (https://omg.jpl.nasa.gov/portal/publications). No additional updates from OMG at this time as they are just finishing a recent campaign in Greenland.;GrIOOS idea discussed (will hold a GSLCT meeting about it in September 2018). NASA researchers published a paper on the relation of heat-flux, basal ice melting rate to the observed distribution of basal water in West Antarctica. The reference is:


Abstract: The possibility that a deep mantle plume manifests Pliocene and Quaternary volcanism and potential elevated heat flux in West Antarctica has been studied for more than 30 years. Recent seismic images support the plume hypothesis as the cause of Marie Byrd Land (MBL) volcanism and geophysical structure. Mantle plumes may more than double the geothermal heat flux above nominal continental values. A dearth of in situ ice sheet basal data exists that samples the heat flux. Consequently, we examine a realistic distribution of heat flux associated with a possible late Cenozoic mantle plume in West Antarctica and explore its impact on thermal and melt conditions at the ice
sheet base. We use a simple analytical mantle plume parameterization to produce geothermal heat flux at the base of the ice sheet. The three-dimensional ice flow model includes an enthalpy framework and full-Stokes stress balance. As both the putative plume location and extent are uncertain, we perform broadly scoped experiments to characterize the impact of the plume on geothermal heat flux and ice sheet basal conditions. The experiments show that mantle plumes have an important local impact on the ice sheet, with basal melting rates reaching several centimeters per year directly above the hotspot. In order to be consistent with observations of basal hydrology in MBL, the upper bound on the plume-derived geothermal heat flux is 150 mW/m². In contrast, the active lake system of the lower part of Whillans Ice Stream suggests a widespread anomalous mantle heat flux, linked to a rift source.

Of even greater impact is the research published on the relation between individual drainage system (Rink is the outlet glacier of one in Greenland) to future and present-day rates of inundation globally, using the same basic self-gravitating elastically deforming rotating earth model (ISSM-SESAW). The paper reference is: Eric Larour, Erik R. Ivins and Surendra Adhikari (15 Nov 2017). “Should coastal planners have concern over where land ice is melting?” Science Advances Vol. 3, no. 11, e1700537 DOI: 10.1126/sciadv.1700537 at http://advances.sciencemag.org/content/3/11/e1700537

The abstract is as follows: There is a general consensus among Earth scientists that melting of land ice greatly contributes to sea-level rise (SLR) and that future warming will exacerbate the risks posed to human civilization. As land ice is lost to the oceans, both the Earth’s gravitational and rotational potentials are perturbed, resulting in strong spatial patterns in SLR, termed sea-level fingerprints. We lack robust forecasting models for future ice changes, which diminishes our ability to use these fingerprints to accurately predict local sea-level (LSL) changes. We exploit an advanced mathematical property of adjoint systems and determine the exact gradient of sea-level fingerprints with respect to local variations in the ice thickness of all of the world’s ice drainage systems. By exhaustively mapping these fingerprint gradients, we form a new diagnosis tool, henceforth referred to as gradient fingerprint mapping (GFM), that readily allows for improved assessments of future coastal inundation or emergence. We demonstrate that for Antarctica and Greenland, changes in the predictions of inundation at major port cities depend on the location of the drainage system. For example, in London, GFM shows LSL that is significantly affected by changes on the western part of the Greenland Ice Sheet (GrIS), whereas in New York, LSL change predictions are greatly sensitive to changes in the northeastern portions of the GrIS. We apply GFM to 293 major port cities to allow coastal planners to readily calculate LSL change as more reliable predictions of cryospheric mass changes become available. (Sep 30, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1821002. Understanding centennial scale changes in basal motion is essential for predicting how the world’s glaciers will respond to climate warming, with implications for sea level rise and downstream habitat quality and water resources. The investigators will revisit Athabasca glacier to offer a detailed picture of how the glacier basal motion has evolved as the glacier has thinned and retreated since seminal glaciology research conducted there in the 1960s. They will collect borehole inclinometry and water pressure, glacier surface velocity, radar-based ice thickness, and hydrometeorological data, among other field-based and remotely sensed observations. They will also use a numerical glacier
flow model to interpret these data. This focus will allow researchers to extend insight gained at Athabasca Glacier to the rest of the world’s warm-bedded glaciers. (Sep 25, 2018 - Completed)

- NASA's OMG is collecting ocean, ice and bathymetry data around Greenland and investigating ocean-ice interactions around the entire ice sheet. (Feb 13, 2018 - Completed)

- The February 2018 GSLCT meeting focused on recent advances in the study of the fjords and oceans surrounding Greenland (https://www.iarpccollaborations.org/members/events/10597). The central theme of the meeting was that as glaciologists, we don’t know as much about the impact of changing ocean circulation on marine-terminating outlet glaciers as we’d like, nor do we know as much as we want to or ought to about the general circulation patterns inside these fjords. Presentations: "OMG! Oceans Melting Greenland and the big picture of ocean-ice interactions around the Earth's second largest ice sheet" (Joshua Willis, JPL); "Greenland fjord freshwater” (Twila Moon, NSIDC) (Feb 8, 2018 - Completed)

- In situ observations are key to studying the freshwater flux from Greenland into the oceans. Ocean water property data, including CTD data and current velocity information, is critical to accurately modeling iceberg melt in space and time. The pilot study in Sermilik fjord used both CTD casts and mooring data. Oceans Melting Greenland data will be invaluable to expand the analysis to the full ice sheet. We also support increased monitoring of ocean currents, as iceberg melt is primarily influences by water temperature and velocity. For more information see https://www.iarpccollaborations.org/members/events/10597. (Feb 5, 2018 - Completed)

- On Jan 25 - 27, 2017 the workshop on The Future Shape of a Greenland GNSS Observation Network was held at NASA's Goddard Space Flight Center (https://www.dartmouth.edu/~ice/GNET_workshop.php). The purpose was to define a path forward for a Global Navigation Satellite System (GNSS) observation network in Greenland. There are many means for determining Greenland ice mass loss, but almost all rely on some form of satellite positioning, generally using GNSS or its subset Global Positioning System (GPS). Thus a network of geodetic-quality GNSS receivers is desirable. The goals of the workshop were: Elucidate the current state of the network, Illustrate the current uses of network data (eg. Geodesy, Crustal deformation, Campaign GNSS reference, atmospheric modeling, Space weather/ionosphere), Identify potential new utility of the data, Determine the optimal configuration moving forward: Ideal number of stations, Placement of stations, Replacement and upgrade of stations, data management. The workshop brought together: investigators using data produced by the current network, potential new investigators who can make use of GNSS network data, experts in the use of GNSS data for positioning, experts in the use of GNSS as a remote-sensing tool (atmospheric water vapor, ionospheric electron content, and multipath utilization for sensing of conditions proximal to the station such as snow depth, vegetation, and mapping of transient areas covered by liquid water), and the people involved in actually deploying GNSS reference stations around Greenland. A 37-page white paper was produced by the workshop participants with five specific recommendations: 1) Continue to support the continuous and autonomous operation of
the current configuration of GNET; 2) Maximize the utility of the current data by promoting the existing data distribution model; 3) Encouraging new uses of GNET data, such as tropospheric zenith delay analyses to improve atmospheric models; 4) Densify the current network to better resolve those areas of maximum gradient in GIA and/or regions of rapid glacier change; and 5) Consider a scoring scheme for evaluating the relative importance of existing stations. The report discusses: the current state of the network; current and future science using GNET data; data management; and the best configuration moving forward. A paper using GNET data also was published in Geophysical Research Letters by S. Adhikari, E. R. Ivins, and E. Larour in May 2017 available at: http://onlinelibrary.wiley.com/doi/10.1002/2017GL073478/full. The abstract is below. The annual cycle and secular trend of Greenland mass loading are well recorded in measurements of solid Earth deformation. Horizontal crustal displacements can potentially track the spatiotemporal detail of mass changes with great fidelity. Our analysis of Greenland crustal motion data reveals that a significant excitation of horizontal amplitudes occurs during the intense melt years. We discover that solitary seasonal waves of substantial mass transport (1.67 ± 0.54 Gt/month) traveled at an average speed of 7.1 km/month through Rink Glacier in 2012. We deduce that intense surface melting enhanced either basal lubrication or softening of shear margins, or both, causing the glacier to thin dynamically in summer. The newly routed upstream subglacial water was likely to be both retarded and inefficient, thus providing a causal mechanism for the prolonged ice transport to continue well into the winter months. As the climate continues to produce increasingly warmer spring and summer, amplified seasonal waves of mass transport may become ever more present with important ramifications for the future sea level rise. (Sep 29, 2017 - Completed)

Since the beginning of the year NASA’s Ocean Melting Greenland (OMG) campaign: Flew its second year of the GLISTIN survey, which is designed to collect elevation maps overall marine terminating glaciers in Greenland. We are still processing the 2017 data, but we are beginning to look at elevation changes between 2016 and 2017 for a number of glaciers around Greenland. Had it’s third science team meeting, where early results were presented from the ship-based bathymetry surveys in 2015 and 2016. With these data, we are beginning to get a sense of which glaciers sit in deep fjords and work is ongoing to connect these observations of seafloor depth with estimates of the bedrock depth below the glaciers. This is a key activity for helping us understand how much of the ice sheet could be affected by changes in the oceans. In addition, early looks at the airborne gravity observations, collected in 2016 are providing additional estimates of seafloor depth. Finally, we are beginning to analyze oceanographic data from the ship surveys and last year's AXCTD survey. Earl indications suggest long-term warming in East Greenland. Three initial OMG publications are as follows: 1) Oceans Melting Greenland: Early Results from NASA’s Ocean-Ice Mission in Greenland, Ian Fenty, Josh K. Willis, et al. Early results suggest that many glaciers terminate in deep water and are hence vulnerable to increased melting due to ocean-ice interaction. Fenty, I., J.K. Willis, A. Khazendar, S. Dinardo, R. Forsberg, I. Fukumori, D. Holland, M. Jakobsson, D. Moller, J. Morison, A. Münchow, E. Rignot, M. Schodlok, A.F. Thompson, K. Tinto, M. Rutherford, and N. Trenholm. 2016. Oceans Melting Greenland: Early results from NASA’s ocean-ice mission in Greenland. Oceanography 29(4):72–83, https://doi.org/10.5670/oceanog.2016.100. ABSTRACT. Melting of the Greenland Ice Sheet represents a major uncertainty in projecting future rates of global sea level rise.
Much of this uncertainty is related to a lack of knowledge about subsurface ocean hydrographic properties, particularly heat content, how these properties are modified across the continental shelf, and about the extent to which the ocean interacts with glaciers. Early results from NASA’s five-year Oceans Melting Greenland (OMG) mission, based on extensive hydrographic and bathymetric surveys, suggest that many glaciers terminate in deep water and are hence vulnerable to increased melting due to ocean-ice interaction. OMG will track ocean conditions and ice loss at glaciers around Greenland through the year 2020, providing critical information about ocean-driven Greenland ice mass loss in a warming climate.

2) Improving Bed Topography Mapping of Greenland Glaciers Using NASA’s Oceans Melting Greenland (OMG) Data, Mathieu Morlighem, Eric Rignot, and Josh K. Willis et al. Northwest coast of Greenland reveals complex structural features in bed elevation, such as valleys, ridges, bumps, and hollows, which have important implications for both channeling ice flow toward the continental margin, and for controlling the amount of warm, salty Atlantic Water that reaches the glaciers.

Morlighem, M., E. Rignot, and J.K. Willis. 2016. Improving bed topography mapping of Greenland glaciers using NASA’s Oceans Melting Greenland (OMG) data. Oceanography 29(4):62–71, https://doi.org/10.5670/oceanog.2016.99. Abstract. Melting of the Greenland Ice Sheet has the potential to raise sea level by 7.36 m and is already contributing to global sea level rise at a rate higher than 1 mm yr−1. Computer models are our best tools to make projections of the mass balance of Greenland over the next centuries, but these models rely on bed topography data that remain poorly constrained near glacier termini. Accurate bed topography in the vicinity of calving fronts is critical for numerical models, as the shapes of the glacier bed and of the nearby bathymetry control both the ocean circulation in the fjord and the stability and response of the ice sheet to climate warming. NASA’s Oceans Melting Greenland (OMG) mission is collecting bathymetry data along Greenland fjords at several glacier termini. Here, we show that these measurements are transforming our knowledge of fjord and glacier depths. Using a mass conservation approach, we combine OMG bathymetry with observations of ice velocity and thickness to produce estimates of bed depth and ice thickness across the ice-ocean boundary with unprecedented accuracy and reliability. Our results along the northwest coast of Greenland reveal complex structural features in bed elevation, such as valleys, ridges, bumps, and hollows. These features have important implications for both channeling ice flow toward the continental margin, and for controlling the amount of warm, salty Atlantic Water that reaches the glaciers.

3) The Ice Shelf of Petermann Gletscher, North Greenland, and Its Connection to the Arctic and Atlantic Oceans, Andreas Münchow, Laurie Padman, Peter Washam, and Keith W. Nicholls Floating ice shelf is strongly coupled to the ocean below and to Nares Strait at time scales from tidal to interannual. Münchow, A., L. Padman, P. Washam, and K.W. Nicholls. 2016. The ice shelf of Petermann Gletscher, North Greenland, and its connection to the Arctic and Atlantic Oceans. Oceanography 29(4):84–95, https://doi.org/10.5670/oceanog.2016.101. Abstract: Petermann Gletscher in North Greenland features the second largest floating ice shelf in the Northern Hemisphere. This paper describes the history of its exploration and presents new ocean and glacier observations. We find that the floating ice shelf is strongly coupled to the ocean below and to Nares Strait at time scales from tidal to interannual. Our observations cover the 2012 to 2016 period after two large calving events took place in 2010 and 2012 that reduced the ice shelf area by 380 km2 to about 870 km2 today. A potential third
breakup, of an additional 150 km², is anticipated by a large fracture that extends from the margin to the center of the glacier. (Sep 29, 2017 - Completed)

- USGS Benchmark Glacier Mass Balance project was successful in 2017, all trips completed at to 4 glaciers (Gulkana, Wolverine, SouthCascade, Sperry). Method development for consistent and combined geodetic analysis being developed. Project funding was cut by 5% in FY17, and was prioritized for funding in FY18 within the USGS land Resources program (formerly climate and land use change). (Sep 29, 2017 - Completed)

- USGS funded Ice2O in 2017, and glaciological, hydrological, geochemical, ecological, and oceanographic components occurred. Two NSF Graduate Research Fellows were sponsored for internships in this program. (Sep 29, 2017 - Completed)

- Presentations given by Kristin Lairde (http://www.iarpccollaborations.org/members/documents/9180) and Mayumi Arimitsu (http://www.iarpccollaborations.org/members/documents/9179) given at the May GSLCT Meeting on the biophysical linkages between glaciers and coastal ecosystem (perspectives from Alaska and Greenland) (http://www.iarpccollaborations.org/members/events/7688) are relevant to this PE (May 11, 2017 - Completed)

- 5.1.3 (In progress) Support investigator-driven studies of land ice process studies across the Arctic, including ocean-glacier interactions, surface and subglacial hydrology, surface mass balance, local surface melt and refreezing, firn densification, glacial isostatic adjustment, iceberg melting, surface energy budget, and related observations.; NSF (Lead), DOI-USGS, NASA, NOAA

  - NASA contributed to this PE in the following ways: The ROSES 2016 A.16 Studies with ICESat and CryoSat-2 element (https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solid={B491EC6F-24F3-507F-F7D9-E35D75745853}&path=closedPast) solicited investigations to derive geophysical information from NASA’s Ice, Cloud, and land Elevation Satellite (ICESat) and the European Space Agency’s CryoSat-2, and link these records with the initial data stream from ICESat-2, scheduled for launch in 2018. These altimetry missions were optimized to characterize changes in the Greenland and Antarctic ice sheets, and the sea ice of the Arctic and Southern Oceans. The missions’ primary goals are to understand the contributions of polar land ice to current and future sea level rise, and the coupling of changes in polar sea ice cover to the Earth system. Projects selected in Dec 2016 released the following publications and/or publications of relevance to the performance element:


  The abstract is as follows: One of the largest sources of uncertainty in sea level rise prediction is glacial acceleration, of which the surge phenomenon is the least understood type. The surge of the Bering Bagley Glacier System (BBGS), Alaska, in 2011–2013 has provided a rare opportunity to study the surge phenomenon in a large and complex glacier system. A surge results in widespread crevassing throughout the glacier
system complicating many traditional techniques used to study glacier dynamics. In this paper, we utilize crevassing as a means to investigate the recent BBGS surge through numerical modeling and geostatistical data analysis. Following the principles of structural glaciology, image-based crevasse characterizations are obtained through geostatistical methods applied to Landsat-7 data, supplemented by airborne field observations. On the modeling side, a 3-D full-Stokes finite element model of the BBGS is developed and applied to investigate ice dynamics and surface structures during the recent surge. A von Mises criterion is adopted to simulate crevassing at the glacier surface, oriented along the axes of maximum principal tensile stress. To facilitate evaluation of model- and data-derived crevasse characteristics, three different comparison methods are introduced. General agreement in the model-data comparisons indicates that the model has the ability to represent the BBGS system during peak acceleration. The crevasse-based approach is also employed to optimize the basal sliding parameter and the von Mises stress threshold in the model. Results further indicate that bed topography is an important constraint in modeling the surge process.

HERZFELD, UTE C., THOMAS TRANTOW, DAVID HARDING and PHILIP DABNEY (2017), Surface-Height Determination of Crevassed Glaciers | Mathematical Principles of an Auto-Adaptive Density-Dimension Algorithm and Validation Using ICESat-2 Simulator (SIMPL) Data, IEEE Transactions in Geoscience and Remote Sensing, volume 55, number 4, April 2017, p. 1874-1896, doi:10.1109/TGRS.2016.2617323 NASA’s ROSES 2017 element A.16 Cryospheric Science solicitation selected 16 proposals in spring 2018. This solicitation supported investigations that use remote sensing to study the land-based ice sheets and sea ice. Supported studies are based on satellite and aircraft remote sensing observations and seek to understand the factors controlling changes in the ice and its interaction with the ocean, atmosphere, solid Earth, and solar radiation. The following new projects will be reported on in the coming year.

Lauren Andrews/Goddard Space Flight Center - Physically Based and Stochastic Models for Greenland Moulin Formation, Longevity, and Spatial Distribution
Ellyn Enderlin/University of Maine, Orono - Quantification and Analysis of Greenland Glacier and Ice Cap Discharge using Automated Landsat Terminus Change
Time Series and NASA Data Products
Ian Howat/Ohio State University - Daily to Decadal Variability in Discharge from Greenland Outlet Glaciers
Lora Koenig/University of Colorado, Boulder - Constraining Aquifer Formation and Expansion in Greenland Using Enhanced Resolution Brightness Temperatures
Laurence Smith/Brown University - Representing Surface Meltwater Runoff in Greenland Ice Sheet Models
Isabella Velicogna/University of California, Irvine - Evaluation of Ice Sheet Surface Mass Balance Models in the Ablation Zone Using ICESat, Operation IceBridge and Other Data
Derrick Lampkin/University of Maryland, College Park- Evaluating Recent Changes in the Percolation Zone of the Greenland Ice Sheet using Airborne Radar and Satellite-Based Estimates of Melt Magnitude
Ginny Catania/University of Texas, Austin- Understanding the Evolving Geometry of Outlet Glaciers in Greenland  Additionally:

BedMachine v3 published by Morlighem et al., 2013:


Abstract: Greenland’s bed topography is a primary control on ice flow, grounding line migration, calving dynamics, and subglacial drainage. Moreover, fjord bathymetry regulates the penetration of warm Atlantic water (AW) that rapidly melts and undercuts Greenland’s marine-terminating glaciers. Here we present a new compilation of Greenland bed topography that assimilates seafloor bathymetry and ice thickness data through a mass conservation approach. A new 150 m horizontal resolution bed topography/ bathymetric map of Greenland is constructed with seamless transitions at the ice/ocean interface, yielding major improvements over previous data sets, particularly in the marine-terminating sectors of northwest and southeast Greenland. Our map reveals that the total sea level potential of the Greenland ice sheet is 7.42 ± 0.05 m, which is 7 cm greater than previous estimates. Furthermore, it explains recent calving front response of numerous outlet glaciers and reveals new pathways by which AW can access glaciers with marine-based basins, thereby highlighting sectors of Greenland that are most vulnerable to future oceanic forcing.

Held a GSLCT meeting in October 2017 on wet firn, which included NASA-supported investigators studying firn processes in Greenland and elsewhere. (Sep 30, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1821002. Understanding centennial scale changes in basal motion is essential for predicting how the world’s glaciers will respond to climate warming, with implications for sea level rise and downstream habitat quality and water resources. The investigators will revisit Athabasca glacier to offer a detailed picture of how the glacier basal motion has evolved as the glacier has thinned and retreated since seminal glaciology research conducted there in the 1960s. They will collect borehole inclinometry and water pressure, glacier surface velocity, radar-based ice thickness, and hydrometeorological data, among other field-based and remotely sensed observations. They will also use a numerical glacier flow model to interpret these data. This focus will allow researchers to extend insight gained at Athabasca Glacier to the rest of the world’s warm-bedded glaciers. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1804154. Understanding the physical processes that drive the Earth’s climate system throughout a Dansgaard-Oeschger (D-O) event remains an important open scientific question in paleoclimate research. The spatial pattern of D-O warming holds clues to the origin of D-O events; whether the critical geographic area is in the Labrador Sea or in the Greenland, Iceland, and Norwegian seas. Ultra-high-resolution stable isotope records from these ice cores document changes in the hydrological cycle associated with these abrupt warming episodes. Climate models show that the southern Dye-3 ice core is more sensitive to abrupt climate change than previously analyzed ice cores, giving the possibility of observing for the first time the temperature imprint of a Heinrich event (a natural phenomenon in which large armadas of icebergs break off from glaciers and traverse the North Atlantic Ocean), as well as the largest D-O warmings ever observed. Isotope
enabled climate model simulations will provide improved interpretation of changes in second-order isotope parameters (deuterium- and 17O excess) through D-O and Heinrich-events. (Sep 24, 2018 - Completed)

- The work of the NASA High Mountain Asia Team is contributing to our understanding of processes controlling the mass balance and runoff of alpine snow and ice masses, particularly for the High Asia region, but with applications across all polar and alpine regions globally. Our team connects national and international researchers through a highly collaborative team environment and aims to provide decision support tools to local stakeholders. More info about this group is available in the video from the August 2018 meeting of the GSLCT (https://www.iarpccollaborations.org/members/events/10604). (Aug 23, 2018 - Completed)

- NASA's OMG (Oceans Melting Greenland) is collecting ocean, ice and bathmetry data around Greenland and investigating ocean-ice interactions around the entire ice sheet. (Feb 13, 2018 - Completed)

- Our research into Greenland freshwater production provides new insights into ocean-glacier interaction and the role of terrestrial and subglacial runoff in the coastal freshwater system. This research is revealing new information about when freshwater is produced and where it is produced within a fjord. This includes new insights about the depth of iceberg melt flux and the potential for freshwater to remain at depth within a fjord and as it travels into the open ocean. For more information see https://www.iarpccollaborations.org/members/events/10597. (Feb 5, 2018 - Completed)

- The presentations given by Max Stevens (Challenges in modeling firn evolution in the percolation zone), Clement Miege (Southeast Greenland firn aquifers characterized by ground and airborne measurements), Kristin Poinar (Firn aquifers and ice dynamics) and Shad O'Neel (USGS repeat firn coring in Alaska) on the current efforts to model and observe wet firn at the October Glaciers & Seal Level Collaboration Team meeting are relevant to this Performance Element (https://www.iarpccollaborations.org/members/events/7791) (Oct 27, 2017 - Completed)

- NPS mass balance - long-term on Kailtlna (Denali), and Exit/Harding (Kenai fjords), plus new initiatives in Wrangell-St. Elias intended for remote sensing and model validation. USGS initiated a wet firn denisification project, and has continued GPR collection over several glaciers in Alaska. USGS has supplemented and re-analyzed SMB data from Taku and Lemon Creek glaciers, expanding the long-term mass balance coverage to additional datasets. NASA's 2016 Cryospheric Sciences program solicitation (https://nspires.nasaps.com/external/solicitations/summary.do?method=init&solId={83430ECB-D429-AD41-4BD1-2BF5F8C50768}&path=closedPast) released in Feb 2016 and closed in April 2017 seeks to understand the mechanisms of change in ice in the polar regions and their implications for global climate, sea level and the polar environment. To accomplish this, supported studies will use space-based and aircraft-based remote-sensing techniques to understand the factors controlling the retreat and growth of the world’s sea ice and major land-based ice sheets, and their interactions with the ocean, atmosphere, solid Earth and solar radiation. Specifically, the program seeks to: Determine the mechanisms controlling sea-ice cover, including quantification of the
connections between sea ice and the ocean and atmosphere; Use remote sensing to validate and improve predictive models of changes in sea-ice cover, especially on decadal timescales and to elucidate connections to the global system; Determine the mechanisms controlling mass balance and dynamics of the Greenland and Antarctic ice sheets, including studies aimed at improving fundamental understanding of ice flow, ice shelves, grounding lines, bed, melt water formation and role, and connections to the ocean, sea-ice cover and atmosphere; Use remote-sensing data to validate and improve predictive models of the contribution of land-based ice to sea-level change, especially in the coming century. The Studies with ICESat and CryoSat-2 program (https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={B491EC6F-24F3-507F-F7D9-E35D75745853}&path=closedPast) solicited investigations to derive geophysical information from NASA’s Ice, Cloud, and land Elevation Satellite (ICESat) and the European Space Agency’s CryoSat-2, and link these records with the initial data stream from ICESat-2, scheduled for launch in 2018. These altimetry missions were optimized to characterize changes in the Greenland and Antarctic ice sheets, and the sea ice of the Arctic and Southern Oceans. The missions’ primary goals are to understand the contributions of polar land ice to current and future sea level rise, and the coupling of changes in polar sea ice cover to the Earth system. Selections made in Dec 2016 of relevance to the performance element include: Using ICESat/OIB Elevation and Satellite-Derived Velocity Changes to Constrain Time-Varying Basal Motion; Decadal-Scale Variability and Trends in Arctic Sea Ice Thickness and Volume; Integration of Altimeter Data from ICESat, IceBridge, CyroSat-2 and IceSat-2 --- Mathematical Approaches and Applications to Glacial Change; West Antarctic Elevation History Leading up to ICESat 2: Multi-Sensor Observation and Model-Based Analysis; Constraining Mass Balance Uncertainties in East Antarctica from 2003 to the Present with Laser and Radar Altimetry Observations; Data Assimilation of Altimetry Signals Using the Ice Sheet System Model; Combining Satellite Altimetry, IceBridge and Atmospheric Reanalyses to Map Antarctic Ice Sheet Surface Mass Balance at Very High Resolution; Understanding the Climate Drivers of Antarctic Ice Shelf Changes Through Analyses of Multi-Mission Satellite Altimetry, Airborne Remote Sensing and Models; Investigating Snow Accumulation Variability for Development of a Multi-Sensor Elevation Time Series Pole-Ward of 86°S in Support of Altimetry Validation and Ice Sheet Mass Balance Studies; and Combining Altimetry with Electromagnetic and Regional-Climate Models for Improved Estimation of Greenland Ice Sheet Mass Balance. (Sep 29, 2017 - Completed)

• **5.1.4 (In progress) Enhance national and international communication and collaboration concerning land ice state and processes, for example, through support of the activities of the SEARCH Land Ice Action Team.; NSF (Lead), NASA**
  
  o NASA contributed to this PE in the following ways: Operation IceBridge (OIB) underflew 345 NM of ESA Sentinel-3A and 233 NM of ESA CryoSat-2 tracks during its 2018 Arctic spring campaign. Also underflew Danish PROMICE ice-sheet survey sites and weather stations in Greenland. OIB overflew U.S. Navy’s ICEX camp in Beaufort Sea. (Sep 30, 2018 - Completed)
  
  o The National Science Foundation has recently awarded OPP – 1837544. Observational datasets of Greenland Ice Sheet change are rapidly expanding and have been used for calibration and validation of ice sheet models. But substantial data-model gaps remain due to the knowledge barrier of understanding and using satellite- and paleo-data and
the lack of a standard framework for using available observational datasets in ice sheet modeling experiments. There is significant potential to generate a long-lasting cyberinfrastructure framework with ice sheet data, software tools, online cloud-based execution and educational materials. When combined, this would lead to rapid progress in improving ice sheet modeling capability and decreasing uncertainty in sea level rise forecasting. The PIs will bring together experts in ice sheet observation, data analysis and modeling to guide the creation of a community hub that will enable two-way communication between data generators and modelers. The PIs will pilot software tools necessary to facilitate interoperability among the various data sets and modeling tools and investigate new metrics for model-data intercomparison and model assessment.

(Sep 25, 2018 - Completed)

- The work of the NASA High Mountain Asia Team is contributing to our understanding of processes controlling the mass balance and runoff of alpine snow and ice masses, particularly for the High Asia region, but with applications across all polar and alpine regions globally. Our team connects national and international researchers through a highly collaborative team environment and aims to provide decision support tools to local stakeholders. More info about this group is available in the video from the August 2018 meeting of the GSLCT (https://www.iarpccollaborations.org/members/events/10604). (Aug 23, 2018 - Completed)

- Workshop on Greenland Ice Sheet Stability. As described in post: http://www.iarpccollaborations.org/members/events/9271 (Nov 2, 2017 - Completed)

- A workshop for the GLIMS (Global Land Ice Measurements from Space) initiative was held in Boulder, CO during August 2017, with the purpose of getting input from the GLIMS team and greater community on future needs and directions for GLIMS. USGS briefed congressional staffers on glacier change and glacier ecosystem linkages. (Sep 29, 2017 - Completed)

5.2 Improve numerical models to enhance projection of ice loss from Arctic land ice and the consequent impact on global sea level, and to better understand the predictability of these processes.

- 5.2.1 (In progress) Enable the development and assessment of ice sheet models, both as stand-alone models and within the context of earth system models, including: the Ice Sheet System Model (ISSM), the Community Ice Sheet Model (CISM), the Community Earth System Model (CESM), the Accelerated Climate Modeling for Energy (ACME) project, the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) and the Land Ice Verification and Validation (LIVV) Toolkit.; NASA (Lead), NSF (Lead), DOE

- NASA contributed to this PE in the following ways:

  NASA researchers/modelers are continuing to develop the Ice Sheet System Model (ISSM), a massively parallelized, multipurpose finite-element framework to model the mass balance of the Greenland and Antarctica Ice Sheets in the near future. The project is deploying new data assimilation capabilities to best integrate NASA satellite data as well as in-situ data into reconstructions and projections of the state of the Cryosphere. Efforts are helping to understand interactions between the Cryosphere and other components of the Earth System, in particular ice/ocean and ice/atmosphere interactions, to better constrain projections of the contribution of ice sheets to future sea-level. Most recently, the team added high-resolution sea-level fingerprint
computation capabilities to ISSM in order to compute localized sea-level changes in Greenland.

Also, this year NASA’s Physical Oceanography Principal Investigators Eyre and Zeng (2017) evaluated five surface air temperature data sets, including that of the NASA “MERRA-2” reanalysis. The paper found that the MERRA-2 reanalysis performed better than the other data sets, with a mean absolute error less than 2 degrees Celsius in all months. It also showed that this bias is much lower than the 31 Earth system model runs from the CMIP5 archive, which reach approximately 5 degrees Celsius for the 1901 – 2000 average bias. This shows the value of data assimilation for providing comprehensive, observation-constrained estimates of important cryospheric properties. The reference and abstract for the paper follows:

Eyre, J. E. Jack Reeves and X. Zeng (2017), Evaluation of Greenland near surface air temperature datasets, The Cryosphere, 11, 1591 – 1605. https://www.the-cryosphere.net/11/1591/2017/. Near-surface air temperature (SAT) over Greenland has important effects on mass balance of the ice sheet, but it is unclear which SAT datasets are reliable in the region. Here extensive in situ SAT measurements (~ 1400 station-years) are used to assess monthly mean SAT from seven global reanalysis datasets, five gridded SAT analyses, one satellite retrieval and three dynamically downscaled reanalyses. Strengths and weaknesses of these products are identified, and their biases are found to vary by season and glaciological regime. MERRA2 reanalysis overall performs best with mean absolute error less than 2°C in all months. Ice sheet-average annual mean SAT from different datasets are highly correlated in recent decades, but their 1901–2000 trends differ even in sign. Compared with the MERRA2 climatology combined with gridded SAT analysis anomalies, thirty-one earth system model historical runs from the CMIP5 archive reach ~ 5°C for the 1901–2000 average bias and have opposite trends for a number of sub-periods.

Richard Cullather provided the following on ISMIP6 activities: The ISMIP6 project includes participation from NASA-sponsored models including ISSM developed at JPL and PISM, which is being utilized with the GISS ModelE earth system model. An overview of initialization and model protocols in support of ISMIP6 for the Greenland Ice Sheet has been presented in a recent publication (Goelzer et al., 2018). The paper summarizes initMIP-Greenland, a comparison of ice sheet initialization procedures for the present day for centennial scale prognostic sea level change projections. Corresponding simulations for initMIP-Antarctica have been conducted and are being evaluated.

An additional pre-ISMIP6 study has been organized to examine the simulated influence of ice shelves in retaining grounded ice mass. This study is known as ABUMIP, the Antarctic BUttressing Model Intercomparison Project. The scope of the experiments for ABUMIP have been outlined, and simulations were completed on 1-May 2018.

An ISMIP6 workshop was held prior to the annual AGU meeting on 10-December 2017 in New Orleans to review the progress towards ISMIP6. At this meeting, the results of initMIP-Greenland and initMIP-Antarctic experiments were presented, and model protocol for ISMIP6 was discussed. There was additional participation at the workshop by atmospheric and oceanic modeling communities for the purpose of understanding issues and uncertainties regarding boundary conditions and model coupling.
Two focus groups have been organized to explore options for forcing ice sheet models in ISIMIP6. The atmospheric focus group is led by William Lipscomb (NCAR), and the oceanic forcing group is led by Fiamma Straneo (Scripps Inst. Oceanogr.). The focus groups have held telecons throughout the summer 2018 to address their respective topics and will make presentations on findings at the upcoming ISIMIP6 workshop in September 2018.


- The National Science Foundation has recently awarded OPP – 1821002. Understanding centennial scale changes in basal motion is essential for predicting how the world’s glaciers will respond to climate warming, with implications for sea level rise and downstream habitat quality and water resources. The investigators will revisit Athabasca glacier to offer a detailed picture of how the glacier basal motion has evolved as the glacier has thinned and retreated since seminal glaciology research conducted there in the 1960s. They will collect borehole inclinometry and water pressure, glacier surface velocity, radar-based ice thickness, and hydrometeorological data, among other field-based and remotely sensed observations. They will also use a numerical glacier flow model to interpret these data. This focus will allow researchers to extend insight gained at Athabasca Glacier to the rest of the world’s warm-bedded glaciers. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1837544. Observational datasets of Greenland Ice Sheet change are rapidly expanding and have been used for calibration and validation of ice sheet models. But substantial data-model gaps remain due to the knowledge barrier of understanding and using satellite- and paleo-data and the lack of a standard framework for using available observational datasets in ice sheet modeling experiments. There is significant potential to generate a long-lasting cyberinfrastructure framework with ice sheet data, software tools, online cloud-based execution and educational materials. When combined, this would lead to rapid progress in improving ice sheet modeling capability and decreasing uncertainty in sea level rise forecasting. The PIs will bring together experts in ice sheet observation, data analysis and modeling to guide the creation of a community hub that will enable two-way communication between data generators and modelers. The PIs will pilot software tools necessary to facilitate interoperability among the various data sets and modeling tools and investigate new metrics for model-data intercomparison and model assessment. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1804154. Understanding the physical processes that drive the Earth’s climate system throughout a Dansgaard-Oeschger (D-O) event remains an important open scientific question in paleoclimate research. The spatial pattern of D-O warming holds clues to the origin of D-O events; whether the critical geographic area is in the Labrador Sea or in the Greenland, Iceland, and Norwegian seas. Ultra-high-resolution stable isotope records from these ice cores document changes in the hydrological cycle associated with these abrupt warming episodes. Climate models show that the southern Dye-3 ice core is more sensitive to abrupt climate change than previously analyzed ice cores, giving the possibility of
observing for the first time the temperature imprint of a Heinrich event (a natural phenomenon in which large armadas of icebergs break off from glaciers and traverse the North Atlantic Ocean), as well as the largest D-O warmings ever observed. Isotope enabled climate model simulations will provide improved interpretation of changes in second-order isotope parameters (deuterium- and 17O excess) through D-O and Heinrich-events. (Sep 24, 2018 - Completed)

- Continued to develop the Ice Sheet System Model (ISSM), a massively parallelized, multipurpose finite-element framework to model the mass balance of the Greenland and Antarctica Ice Sheets in the near future. Deploy new data assimilation capabilities to best integrate NASA satellite data as well as in-situ data into reconstructions and projections of the state of the Cryosphere. Beginning to understand interactions between the Cryosphere and other components of the Earth System, in particular, ice/ocean and ice/atmosphere interactions, to better constrain projections of the contribution of ice sheets to future sea-level. (Sep 29, 2017 - Completed)

- GSLCT hosted a meeting where several CISM model developers shared insight into the effort. (Sep 29, 2017 - Completed)

- This focuses on Greenland from Aug 2016 - Aug 2017: The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) published experimental and data request protocols as part of the CMIP6 special issue in Geoscientific Model Development in Dec 2016. The first set of experiments targeting the Greenland standalone ice sheet modeling community, initMIP-Greenland, were completed by 17 international groups, and the results submitted to the journal “Cryosphere” in July 2017. initMIP-Greenland seeks to understand and reduce the uncertainty in sea level projections due to the choice of model initialization methods. The ISMIP6 and initMIP-Greenland efforts were presented at national and international conference (AGU 2016, EGU 2017, International WCRP/IOC Conference on Regional Sea Level Changes and Coastal Impacts) and to the IARPC Glacier and Fjord CT and Modeling CT in March 2017. ISMIP6 organized two workshops in Dec 2016 -Initialization of ice sheet models, and oceanic forcing for ice sheet models- and one splinter meeting at EGU2017. More information: http://www.climate-cryosphere.org/wiki/index.php?title=ISMIP6_wiki_page (Sep 29, 2017 - Completed)

- The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) published experimental and data request protocols as part of the CMIP6 special issue in Geoscientific Model Development in Dec 2016. The first set of experiments targeting the Greenland standalone ice sheet modeling community, initMIP-Greenland, were completed by 17 international groups, and the results submitted to the journal “Cryosphere” in July 2017. initMIP-Greenland seeks to understand and reduce the uncertainty in sea level projections due to the choice of model initialization methods. The ISMIP6 and initMIP-Greenland efforts were presented at national and international conferences (AGU 2016, EGU 2017, International WCRP/IOC Conference on Regional Sea Level Changes and Coastal Impacts) and to the IARPC Glacier and Fjord CT and Modeling CT in March 2017. ISMIP6 organized two workshops in Dec 2016 -Initialization of ice sheet models, and oceanic forcing for ice sheet models- and one splinter meeting at EGU2017. (Sep 29, 2017 - Completed)

- Presentations by Sophie Nowicki, Helene Serroussi, Jeremy Fyke, and Andy Aschwanden at the March Glaciers & Sea Level CT meeting on the Ice Sheet Model Intercomparison
Project (ISMIP6) contribution to CMIP6 (a programatic and participant point of view) are relevant to this Performance Element.

http://www.iarpccollaborations.org/members/events/7496 (Jul 24, 2017 - Completed)

- **5.2.2 (In progress)** Develop data sets to be used as boundary and forcing functions for ice sheet, ice cap, and glacier models, including improving regional reanalyses focused on the greater Arctic, improving global reanalysis systems in ways that are relevant to the Arctic, and promoting joint observation-modeling-reanalysis-forecasting activities.; NASA (Lead), DOD-NRL, DOD-ONR, NOAA, NSF

  - NASA contributed to this PE in the following ways:

    This update is also listed in 9.3.6: The ISMIP6 project includes participation from NASA-sponsored models including ISSM developed at JPL and PISM, which is being utilized with the GISS ModelE earth system model. An overview of initialization and model protocols in support of ISMIP6 for the Greenland Ice Sheet has been presented in a recent publication (Goelzer et al., 2018). The paper summarizes initMIP-Greenland, a comparison of ice sheet initialization procedures for the present day for centennial scale prognostic sea level change projections. Corresponding simulations for initMIP-Antarctica have been conducted and are being evaluated.

    An additional pre-ISMIP6 study has been organized to examine the simulated influence of ice shelves in retaining grounded ice mass. This study is known as ABUMIP, the Antarctic BUttressing Model Intercomparison Project. The scope of the experiments for ABUMIP have been outlined, and simulations were completed on 1-May 2018.

    An ISMIP6 workshop was held prior to the annual AGU meeting on 10-December 2017 in New Orleans to review the progress towards ISMIP6. At this meeting, the results of initMIP-Greenland and initMIP-Antarctic experiments were presented, and model protocol for ISMIP6 was discussed. There was additional participation at the workshop by atmospheric and oceanic modeling communities for the purpose of understanding issues and uncertainties regarding boundary conditions and model coupling.

    Two focus groups have been organized to explore options for forcing ice sheet models in ISMIP6. The atmospheric focus group is led by William Lipscomb (NCAR), and the oceanic forcing group is led by Fiamma Straneo (Scripps Inst. Oceanogr.). The focus groups have held telecons throughout the summer 2018 to address their respective topics and will make presentations on findings at the upcoming ISMIP6 workshop in September 2018.


  - September 2017 and September 2018, the NASA NSIDC DAAC published or updated roughly 125 Arctic related data products. This includes data from a number of NASA missions and programs including Operation IceBridge (OIB), Soil Moisture Active Passive (SMAP), Making Earth Science Data Records for Use in Research Environments (MEaSUREs), and the Advanced Microwave Scanning Radiometer (AMSR2). The data ranged from Lidar and Radar data to large collections of images, Greenland mosaics, sea ice age products, and many more. There were roughly 325 citations of this data during...
the same time period, with AMSR-E, the Moderate Resolution Imaging Spectroradiometer (MODIS), and SMAP leading the pack. Of special note, the NSIDC DAAC saw a dramatic increase in the number of users accessing the data to over 47,000 unique users so far in 2018, from 129 countries. This was due in part to the new exposure of selected data products through the Google Earth Engine. The data is available at: https://earthdata.nasa.gov/about/daacs/daac-nsidc (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1821002. Understanding centennial scale changes in basal motion is essential for predicting how the world’s glaciers will respond to climate warming, with implications for sea level rise and downstream habitat quality and water resources. The investigators will revisit Athabasca glacier to offer a detailed picture of how the glacier basal motion has evolved as the glacier has thinned and retreated since seminal glaciology research conducted there in the 1960s. They will collect borehole inclinometry and water pressure, glacier surface velocity, radar-based ice thickness, and hydrometeorological data, among other field-based and remotely sensed observations. They will also use a numerical glacier flow model to interpret these data. This focus will allow researchers to extend insight gained at Athabasca Glacier to the rest of the world’s warm-bedded glaciers. (Sep 25, 2018 - Completed)

- Many ocean models currently add all Greenland freshwater to the top ocean layer. Our research indicates that this is not in line with the actual distribution of fjord freshwater. Our pilot study in Sermilik Fjord (connecting to Helheim Glaciers) provides new data that can help to properly parameterize freshwater flux in ocean and ocean-ice models. Future research to expand our work to the full ice sheet will continue to provide new information for model improvement. For more information see https://www.iarpccollaborations.org/members/events/10597. (Feb 5, 2018 - Completed)

- In 2016 the NASA Global Modeling and Assimilation Office (GMAO) released the MERRA-2 atmospheric reanalysis for the period 1980 to the present. MERRA-2 provides an improved representation of cryospheric processes including an advanced surface representation over glaciated land and the application of a cubed-sphere model grid to better resolve high latitude circulation. The GMAO has also produced the M2R12K, which is a global, 12.5km grid-spaced “replay” analysis of MERRA-2 spanning the years 2000-2014. The higher spatial resolution allows for an improved representation of atmospheric circulation along the steep topography of the periphery of the Greenland Ice Sheet.

As part of an update to the seasonal forecasting system, the GMAO is currently integrating a new ocean reanalysis: MERRA-2/Ocean, which has an improved representation of Arctic ice thickness and a more detailed suite of diagnostics for use in passive tracer simulations. (Sep 29, 2017 - Completed)

- The September Glaciers & Sea Level Collaboration Team meeting on open data featuring the following speakers is relevant to this Performance Element:

  Anthony Arednt (University of Washington) who has been working with the NASA High Mountain Asia project, and is currently hosting a geohack at UW where participants are exploring open source collaboration tools among other topics.
Lora Koenig (NSIDC) just released the SUMup data set through NSF’s Arctic Data Center which contains a synthesized inventory of snow/ firn observations primarily from Greenland.

Fiamma Straneo (Woods Hole) who has worked with the GRISO Research Coordination Network Group to make data from Greenland available to anyone. ([https://www.iarpccollaborations.org/members/events/7790](https://www.iarpccollaborations.org/members/events/7790)) (Sep 26, 2017 - Completed)

- **5.2.3 (In progress)** Support investigator-driven modeling projects designed to understand and parameterize important land ice processes, including studies of mélange rheologies and dynamics, wet and dry firn processes, meltwater infiltration and refreezing, interactions between the glacier front and subglacial outflow plumes, and basal sliding laws.; NSF (Lead), DOE, DOI-USGS, NASA
  
  NASA contributed to this PE in the following ways: The ROSES 2016 A.16 Studies with ICESat and CryoSat-2 element ([https://inspires.nasapsrs.com/external/solicitations/summary.do?method=init&solId={B491EC6F-24F3-507F-F7D9-E35D75745853}&path=closedPast](https://inspires.nasapsrs.com/external/solicitations/summary.do?method=init&solId={B491EC6F-24F3-507F-F7D9-E35D75745853}&path=closedPast)) solicited investigations to derive geophysical information from NASA’s Ice, Cloud, and land Elevation Satellite (ICESat) and the European Space Agency’s CryoSat-2, and link these records with the initial data stream from ICESat-2, scheduled for launch in 2018. These altimetry missions were optimized to characterize changes in the Greenland and Antarctic ice sheets, and the sea ice of the Arctic and Southern Oceans. The missions’ primary goals are to understand the contributions of polar land ice to current and future sea level rise, and the coupling of changes in polar sea ice cover to the Earth system. Projects selected in Dec 2016 released the following publications and/or publications of relevance to the performance element:

  NASA PI Andy Aschwanden at UAF has a grant focused on model development relevant to this performance element and publications will be reported on in the following year. The focus of his research is on Using ICESat/OIB Elevation and Satellite-Derived Velocity Changes to Constrain TimeVarying Basal Motion

  Heilig Achim, Eisen Olaf, MacFerrin Michael, Tedesco Marco, and Fettweis Xavier, Seasonal monitoring of melt and accumulation within the deep percolation zone of the Greenland Ice Sheet and comparison with simulations of regional climate modeling, The Cryosphere Discussion, doi. 10.5194/tc-2017-277,2018

  The abstract is as follows: Increasing melt over the Greenland Ice Sheet (GrIS) recorded over the past several years has resulted in significant changes of the percolation regime of the ice sheet. It remains unclear whether Greenland’s percolation zone will act as a meltwater buffer in the near future through gradually filling all pore space or if near-surface refreezing causes the formation of impermeable layers, which provoke lateral runoff. Homogeneous ice layers within perennial firn, as well as near-surface ice layers of several meter thickness have been observed in firn cores. Because firn coring is a destructive method, deriving stratigraphic changes in firn and allocation of summer melt events is challenging. To overcome this deficit and provide continuous data for model evaluations on snow and firn density, temporal changes in liquid water content and depths of water infiltration, we installed an upwardlooking radar system (upGPR) 3.4m below the snow surface in May 2016 close to Camp Raven (66.4779 N, 46.2856 W) at
2120 ma.s.l. The radar is capable of quasi-continuously monitoring changes in snow and firn stratigraphy, which occur above the antennas. For summer 2016, we observed four major melt events, which routed liquid water into various depths beneath the surface. The last event in mid-August resulted in the deepest percolation down to about 2.3 m beneath the surface. Comparisons with simulations from the regional climate model MAR are in very good agreement in terms of seasonal changes in accumulation and timing of onset of melt. However, neither bulk density of near-surface layers nor the amounts of liquid water and percolation depths predicted by MAR correspond with upGPR data. Radar data and records of a nearby thermistor string, in contrast, matched very well for both timing and depth of temperature changes and observed water percolations. All four melt events transferred a cumulative mass of 56 kg m\(^{-2}\) into firm beneath the summer surface of 2015. We find that continuous observations of liquid water content, percolation depths and rates for the seasonal mass fluxes are sufficiently accurate to provide valuable information for validation of model approaches and help to develop a better understanding of liquid water retention and percolation in perennial firm.

NASA’s ROSES 2017 element A.16 Cryospheric Science solicitation selected 16 proposals in spring 2018. This solicitation supported investigations that use remote sensing to study the land-based ice sheets and sea ice. Supported studies are based on satellite and aircraft remote sensing observations and seek to understand the factors controlling changes in the ice and its interaction with the ocean, atmosphere, solid Earth, and solar radiation. The following new projects will be reported on in the coming year.

Lauren Andrews/Goddard Space Flight Center - Physically Based and Stochastic Models for Greenland Moulin Formation, Longevity, and Spatial Distribution

Laurence Smith/Brown University - Representing Surface Meltwater Runoff in Greenland Ice Sheet Models

Isabella Velicogna/University of California, Irvine - Evaluation of Ice Sheet Surface Mass Balance Models in the Ablation Zone Using ICESat, Operation IceBridge and Other Data

Also, proposals for the NASA Energy and Water Cycle Study (NEWS) ROSES element A.22 have been delayed until October 11, 2018 to allow for proposers affected by hurricane Florence to submit.

Once selections are made, NASA may have selected projects that contribute to this performance element in the coming year. The overarching goal of NEWS investigations is to integrate Earth Science Research Program components to make decisive progress toward the NEWS challenge. To achieve this objective, the NEWS investigations will integrate and interpret past, current, and future space based and in situ observations into assimilation and prediction products and models that are global in scope. These activities will serve efforts to improve understanding, modeling, and information for global prediction systems. To achieve these goals, the NEWS investigations must recognize that accurate prediction of not only trends in the mean, but also extremes and abrupt changes, is a key step toward useful applications. The critical feedbacks within the overall NEWS strategy are the lessons that scientific analysis, modeling, prediction, and consequences can guide and identify the technological and observational requirements of future NASA missions. (Sep 30, 2018 - Completed)
The National Science Foundation has recently awarded OPP – 1821002. Understanding centennial scale changes in basal motion is essential for predicting how the world’s glaciers will respond to climate warming, with implications for sea level rise and downstream habitat quality and water resources. The investigators will revisit Athabasca glacier to offer a detailed picture of how the glacier basal motion has evolved as the glacier has thinned and retreated since seminal glaciology research conducted there in the 1960s. They will collect borehole inclinometry and water pressure, glacier surface velocity, radar-based ice thickness, and hydrometeorological data, among other field-based and remotely sensed observations. They will also use a numerical glacier flow model to interpret these data. This focus will allow researchers to extend insight gained at Athabasca Glacier to the rest of the world’s warm-bedded glaciers. (Sep 25, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1837544. Observational datasets of Greenland Ice Sheet change are rapidly expanding and have been used for calibration and validation of ice sheet models. But substantial data-model gaps remain due to the knowledge barrier of understanding and using satellite- and paleo-data and the lack of a standard framework for using available observational datasets in ice sheet modeling experiments. There is significant potential to generate a long-lasting cyberinfrastructure framework with ice sheet data, software tools, online cloud-based execution and educational materials. When combined, this would lead to rapid progress in improving ice sheet modeling capability and decreasing uncertainty in sea level rise forecasting. The PIs will bring together experts in ice sheet observation, data analysis and modeling to guide the creation of a community hub that will enable two-way communication between data generators and modelers. The PIs will pilot software tools necessary to facilitate interoperability among the various data sets and modeling tools and investigate new metrics for model-data intercomparison and model assessment. (Sep 25, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1804154. Understanding the physical processes that drive the Earth’s climate system throughout a Dansgaard-Oeschger (D-O) event remains an important open scientific question in paleoclimate research. The spatial pattern of D-O warming holds clues to the origin of D-O events; whether the critical geographic area is in the Labrador Sea or in the Greenland, Iceland, and Norwegian seas. Ultra-high-resolution stable isotope records from these ice cores document changes in the hydrological cycle associated with these abrupt warming episodes. Climate models show that the southern Dye-3 ice core is more sensitive to abrupt climate change than previously analyzed ice cores, giving the possibility of observing for the first time the temperature imprint of a Heinrich event (a natural phenomenon in which large armadas of icebergs break off from glaciers and traverse the North Atlantic Ocean), as well as the largest D-O warmings ever observed. Isotope enabled climate model simulations will provide improved interpretation of changes in second-order isotope parameters (deuterium- and 17O excess) through D-O and Heinrich-events. ()

The GMAO has also produced the M2R12K, which is a global, 12.5km grid-spaced “replay” analysis of MERRA-2 spanning the years 2000-2014. The higher spatial resolution allows for an improved representation of atmospheric circulation along the steep topography of the periphery of the Greenland Ice Sheet. Oregon State runoff
model output (D. Hill) widely requested, especially among oceanographic community. Two papers published in WRR. Several impactful publications link observations and models for example, Brinkerhoff 2017 developed a numerical model that captures the tidewater glacier cycle even under steady climate. (Sep 29, 2017 - Completed)

As part of an update to the seasonal forecasting system, the GMAO is currently integrating a new ocean reanalysis: MERRA-2/Ocean, which has an improved representation of Arctic ice thickness and a more detailed suite of diagnostics for use in passive tracer simulations. (Sep 29, 2017 - Completed)

**Agencies**
DOC, DOD, DOE, DOI, NASA, NSF, OSTP, USARC
Permafrost Collaboration Team

Performance Element Reporting Log FY2018

(Some links in this summary require an account on IARPC Collaborations Website. Please visit www.iarpccollaborations.org to request an account.)

6.1 Improve understanding of how climate, physiography, terrain conditions, vegetation, and patterns of disturbance interact to control permafrost dynamics.

- 6.1.1 (In progress) Continue to conduct and coordinate monitoring and modeling of permafrost temperature across a wide range of terrain units and climatic zones and to use obtained data to refine relationships between the ground thermal regime of shallow and deep permafrost and terrain properties.; NSF (Lead), DOD-USACE, DOE, DOI-NPS, DOI-USGS, NASA, NOAA, USDA-NRCS

  NASA’s ABoVE project supported this PE in the following ways; The projects described in 2017 continue, relevant publications/projects listed with specific PEs: a. Monitoring of ground temperature and/or soil moisture at multiple sites across the ABoVE Study Domain in order to study factors controlling permafrost dynamics (PE 6.1.1, 6.1.2)

  Bourgeau-Chavez: Assessing and Downscaling SMAP data for Organic Soil Fuel Moisture Estimation in Boreal-Arctic Ecosystems
  https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3658 &progID=6

  Nicolsky: Augmentation of the USAArray sites with temperature profilers
  https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3463 &progID=6

  Schaefer: The Airborne InSAR and PolSAR Permafrost Dynamics Observatory
  https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3564 &progID=6

  Siqueira: NISAR Ecosystems and Permafrost Science in the ABoVE Domain
  https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3678 &progID=6

  Tabatabaeenejad: Estimation of Belowground Biomass and Permafrost Active Layer Properties Using Radar and Lidar Measurements
  https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3568 &progID=6

These items were listed in 2017 and continue in 2018: b. Monitoring of key ecosystem characteristics in areas with different permafrost dynamics in order to understand the role of permafrost in key ecosystem processes, including vegetation dynamics and soil carbon cycling (PE 6.1.4, 6.2.1, 6.3.1)c. Developed approaches to utilize knowledge from field based studies and remote products to improve models in order to assess the impacts of variations in the permafrost regime on ecosystem processes (PE 6.3.2, 6.3.4)d. Continued research on the development and validation of InSAR approaches to estimate annual active layer thickness using spaceborne SAR data (PE 6.3.3).e. Carried out the collection of airborne P- and L-band SAR data along with surface observations in
May to September 2017 at sites across the ABoVE Study Domain to develop new remote sensing products for monitoring of permafrost characteristics (PE 6.3.3). The ABoVE Science Team is carrying out a community assessment of active layer conditions, including active layer depth and soil moisture, and their spatial heterogeneity as represented by different types of measurements at different spatial scales, ranging from local ground measurements to landscape and regional scale observations from airborne and satellite remote sensing. (Sep 27, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1836377. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. Long-term observations of active-layer thickness and dynamics, obtained using standard measurement protocols, are the essential rationale behind the CALM project. The objectives of the observational network stress the need for long-term active layer, ground temperature, and thaw settlement measurements, integration of data to provide the basis for comprehensive assessments of changes in active-layer and near-surface permafrost, and preparation and dissemination of data sets to assist detailed process studies, and in validating and developing of climate change, ecology, hydrology, and geocryology models. An outreach component of the project includes extensive involvement of local, predominantly indigenous population in observational program at remote Arctic sites. (Sep 26, 2018 - Completed)

- Synthesis published about ecosystem controls on permafrost soil thermal dynamics. This review looks at ecosystem processes that will influence permafrost thaw and outlines how they will feed back to climate warming. Vegetation and soils strongly influence ground temperature in permafrost ecosystems across the Arctic and sub-Arctic. These effects will cause different rates of permafrost thaw related to the distribution of tundra and boreal forests. As the distribution of forests and tundra change, the effects of climate change on permafrost will also change. The review shows ecosystem processes that will influence permafrost thaw and outline how they will feed back to climate warming. Loranty MM, Abbott BW, Blok D, Douglas TA, Epstein HE, Forbes BC, Jones BM, Kholodov AL, Kropp H, Malhotra A, Mamet SD, Myers-Smith IH, Natali SM, O’Donnell JA, Phoenix GK, Rocha AV, Sonnentag O, Tape KD and Walker DA 2018 Reviews and syntheses: Changing ecosystem influences on soil thermal regimes in northern high-latitude permafrost regions Biogeosciences 15 5287–313. https://doi.org/10.5194/bg-15-5287-2018 (Sep 17, 2018 - Completed)

- ABoVE Focus Collection of Environmental Research Letters: This on-going focus collection addresses the influence and impact of environmental changes, including climate change, taking place across the high northern latitudes and their influence on Arctic and boreal ecosystems. It is open to all research contributions in the domain NW North America or broader for any of the thematic working group activity areas (including permafrost). http://iopscience.iop.org/journal/1748-9326/page/ABoVE (Sep 17, 2018 - Completed)

- The following presentations on the "Global Terrestrial Network for Permafrost (GTN-P): Long-term observations on permafrost/active layer system" were given at the November 2017 PCT meeting (https://www.iarpccollaborations.org/members/events/7799)

Overview of past present and future of GTN-P (Dima Streletskiy, Chair of GTN-P)(https://www.iarpccollaborations.org/members/documents/10370)
Overview of Circumpolar Active Layer Monitoring (CALM) program, which is a GTN-P component dealing with the active layer (Nikolay Shiklomanov, CALMPI) (https://www.iarpccollaborations.org/members/documents/10369) (Nov 14, 2017 - Completed)

Related publications in FY2017:


Miriam Jones' (USGS) presentation at the October Permafrost Collaboration Team meeting on Holocene permafrost dynamics and implications for permafrost thaw is relevant to this Performance Element. (https://www.iarpccollaborations.org/members/events/7798) (Oct 16, 2017 - Completed)

Ronald Daanen's (Alaska Department of Natural Resources) presentation at the September Permafrost Collaboration Team meeting on permafrost remote sensing through airborne electromagnetic geophysics and thermal anomalies is relevant to this Performance Element. (https://www.iarpccollaborations.org/members/events/7797) (Sep 25, 2017 - Completed)

ABoVE Contributions: Monitoring of ground temperature and/or soil moisture at multiple sites across the ABoVE Study Domain in order to study factors controlling permafrost dynamics (Sep 15, 2017 - Completed)

Torre Jorgenson gave a presentation titled “Progress Toward Understanding the Response of Permafrost to Climate Change in Alaska” at the May Permafrost Collaboration Team meeting relates to this performance element: http://www.iarpccollaborations.org/members/events/7687 (May 11, 2017 - Completed)

6.1.2 (In progress) Conduct field-based research that examines and quantifies relationships among surface topography, vegetation composition, hydrology, disturbance effects (including fire and thermokarst), and geophysical processes in permafrost soils to feed directly into models, decision support tools, and predictive analyses.; DOD-USACE (Lead), DOE (Lead), NSF (Lead), DOI-NPS, DOI-USGS, NASA

The National Science Foundation (NSF) has recently awarded OPP – 1836839. The overarching goal of the project is to understand tundra ecosystem change across landscape types and enable realistic forecasts of change across the Arctic. The power of the International Tundra Experiment (ITEX)- Arctic Observatory Network (AON) is founded on a capacity to synthesize and compare results across sites that use standardized sampling protocols. Specifically, this project will (1) maintain the data-streams at ITEX-AON sites in Alaska near Toolik Lake, Imnavait Creek, Utqiagvik (Barrow), and Atqasuk; (2) lead two new ITEX network syntheses focused on soil carbon
and phenocam imagery; (3) increase scientific literacy; and, (4) expand citizen science opportunities across communities in northern Alaska. (Oct 16, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)

- NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. Specifically, monitoring of ground temperature and/or soil moisture at multiple sites across the ABoVE Study Domain in order to study factors controlling permafrost dynamics See also projects mentioned above PE 6.1.1. (Sep 27, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1836377. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. Long-term observations of active-layer thickness and dynamics, obtained using standard measurement protocols, are the essential rationale behind the CALM project. The objectives of the observational network stress the need for long-term active layer, ground temperature, and thaw settlement measurements, integration of data to provide the basis for comprehensive assessments of changes in active-layer and near-surface permafrost, and preparation and dissemination of data sets to assist detailed process studies, and in validating and developing of climate change, ecology, hydrology, and geocryology models. An outreach component of the project includes extensive involvement of local, predominantly indigenous population in observational program at remote Arctic sites. (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1744515. This project will examine how warming is leading to a new hydrological regime in regions adjacent to the areas where major sea-ice losses have occurred. The investigators will study annually laminated sediments in lakes of western Svalbard to identify the sedimentary signal of recent changes in hydrology and reconstruct the long-term history of rainfall-related sedimentary events to determine when similar conditions may have prevailed in the past. This will provide a unique perspective on the nature of recent sedimentary changes and provide insight into the effects of contemporary changes in climate on the hydrological regime of this region. The results will have implications for other parts of the Arctic where sea-ice is rapidly receding. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1748653. This project seeks an accounting of the pan-Arctic hydrologic cycle. Researchers will couple big-data remote sensing and specific remote sensing discharge estimation techniques with fluvial geomorphology to estimate discharge for every Arctic river wider than 150m from 1984 to present using NASA’s Landsat family of satellites. This remotely sensed Arctic river
assessment will be founded upon a backbone of detailed fieldwork as designed and executed by undergraduates at UMass Amherst in a new program: Integrating Geosciences and Engineering in the Arctic (IGEA). The IGEA-informed remotely sensed discharge data will be used to calibrate an open source global hydrology model, integrating the other components of this project to reach a fuller understanding of the entire Arctic system achieved through improved process-based understanding of Arctic rivers. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1748849. In this study, investigators examine the causes and consequences of divergent tree growth in the Brooks Range. Divergence refers to the deterioration of historically strong positive correlations between temperature and tree growth. The recognition that divergence has been widespread in the circumboreal has undermined confidence in paleoclimate reconstructions and created uncertainty in projections of vegetation-climate feedbacks. While divergence is a well-known phenomenon, its implications for changes in tree abundance and shifts in treeline position remain unknown. Recent findings in four watersheds along a west to east gradient in the Brooks Range suggest colder, more permafrost-affected soils limit tree access to soil nutrients and may be the cause of divergence in the eastern Brooks Range. Researchers will combine repeat aerial photography with tree-ring analysis and detailed measurements of tree microclimates, mycorrhizal associations, nutrient relations, and reproductive effort in 25 Brooks Range watersheds to yield broad-scale mechanistic insights into controls on tree growth and changes in tree abundance in a changing climate. They will test the hypothesis that positive growth responses to warming and increased tree abundance will prevail in the western Brooks Range and in habitats with warmer soils, while neutral growth responses to warming and stagnant treelines will be common in the eastern Brooks Range and in areas with cold soils. (Sep 24, 2018 - Completed)

- Related publications in FY2017:
  - Frost, G. V., H. E. Epstein, D. A. Walker, G. Matyshak, and K. Ermokhina. 2017. Seasonal and long-term changes to active-layer temperatures after tall shrub expansion and
succession in Arctic tundra. Ecosystems doi:10.1007/s10021-017-0165-5. (Nov 2, 2017 - Completed)

- ABoVE contributions: The ABoVE Science Team is carrying out a community assessment of active layer conditions, including active layer depth and soil moisture, and their spatial heterogeneity as represented by different types of measurements at different spatial scales, ranging from local ground measurements to landscape and regional scale observations from airborne and satellite remote sensing. (Sep 15, 2017 - Completed)

- Torre Jorgenson gave a presentation titled “Progress Toward Understanding the Response of Permafrost to Climate Change in Alaska” at the May Permafrost Collaboration Team meeting relates to this performance element: [http://www.iarpccollaborations.org/members/events/7687](http://www.iarpccollaborations.org/members/events/7687) (May 11, 2017 - Completed)

**6.1.3 (In progress) Support field-based research to improve understanding of how changes to Arctic lake and river ecosystems affect permafrost stability, water availability, and habitat provision, with a particular focus on wintertime ice regimes.; NSF (Lead), DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NASA**

- The National Science Foundation (NSF) has recently awarded OPP – 1823717. Rapid and non-invasive ground-based geophysical measurements will be taken to describe thermokarst lake methane emissions, develop relationships between lake expansion and methane emissions, and then use Synthetic Aperture Radar imagery to scale the results to large regions. The outcomes of this work have implications for understanding global carbon budgets, Arctic engineering, and the development of environmental monitoring methods. This research will provide additional validation to the Ground Penetrating Radar and Synthetic Aperture Radar methods, benefit their respective development fields, and encourage more widespread application of these methods across the Arctic. (Oct 15, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)

- NASA’s ABoVE project supported this PE in the following ways, specifically in the areas of Arctic lake and river ecosystems:

  Kim: Dynamic inundation mapping for boreal regions using SMAP, UAVSAR, and Radarsat2
  [https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3713&progID=6](https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3713&progID=6)
Smith: Sensitivity of Arctic-Boreal surface water to permafrost state: https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3566 &progID=6

Publications:


- The National Science Foundation has recently awarded OPP – 1737411. Arctic lakes are ice-covered for nine or more months of the year. With harsh winter conditions, few limnological studies have been conducted on ice-covered arctic lakes. The goal of the proposed research is to analyze an unprecedented dataset obtained from five lakes of different sizes from fall to spring over three years. The data will be used to describe and quantify the lakes' physical limnology and under ice metabolism and to develop scaling laws such that regional generalizations can be made. Analyses and modeling will focus on questions related to the extent to which fall cooling moderates under ice temperatures and circulation; the contribution of respiration and related increases in solutes to circulation patterns and development of anoxia; lake-size dependent controls on the retention of solutes introduced at snowmelt; and lake-size dependent controls on mixing dynamics, which moderate production of CO2 and CH4 in winter and emissions at ice off. Results will provide a basic understanding of circulation and mixing as needed to improve hydrodynamic models and are critical for quantifying the habitat of organisms under the ice and for accurate inclusion of arctic lakes in regional carbon budgets. (Sep 21, 2018 - Completed)

- Published Arctic Answers through the Study of Environmental Arctic Change Program: Arctic Answers are 1-2 page long briefs written by experts answering policy-relevant questions. Each brief is the top of a "knowledge pyramid" supported by scientific literature organized in underlying tiers of increasing detail. Each brief is reviewed for scientific accuracy and accessibility to readers with broad backgrounds. The Permafrost Action Team of the Study of Environmental Arctic Change wrote two additional briefs with the topics: 1) How is permafrost degradation affecting ecosystem services? 2) How is permafrost degradation affecting infrastructure? The briefs are available online: https://www.searcharcticscience.org/arctic-answers (Sep 17, 2018 - Completed)

- Related publications in FY2017:


6.1.4 (In progress) Integrate field, laboratory, and remote sensing information to map local, regional, and global permafrost-influenced landscape dynamics and their impact on vegetation, hydrology, terrestrial and aquatic ecosystems, and soil carbon dynamics in the Arctic. Develop spatially-explicit decision support systems and predictive tools.; DOD-USACE (Lead), DOE (Lead), DOI-BLM (Lead), DOI-FWS, DOI-NPS, DOI-USGS, NASA, NOAA, NSF

- The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)

- NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. This work includes: Monitoring of key ecosystem characteristics in areas with different permafrost dynamics in order to understand the role of permafrost in key ecosystem processes, including vegetation dynamics and soil carbon cycling. Projects include: Iwahana: Quantification of thermokarst and carbon release in ice-rich permafrost regions https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3563 &projID=6

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The National Science Foundation has recently awarded OPP – 1748653. This project seeks an accounting of the pan-Arctic hydrologic cycle. Researchers will couple big-data remote sensing and specific remote sensing discharge estimation techniques with fluvial geomorphology to estimate discharge for every Arctic river wider than 150m from 1984 to present using NASA's Landsat family of satellites. This remotely sensed Arctic river assessment will be founded upon a backbone of detailed fieldwork as designed and executed by undergraduates at UMass Amherst in a new program: Integrating Geosciences and Engineering in the Arctic (IGEA). The IGEA-informed remotely sensed discharge data will be used to calibrate an open source global hydrology model, integrating the other components of this project to reach a fuller understanding of the entire Arctic system achieved through improved process-based understanding of Arctic rivers. (Sep 24, 2018 - Completed)

Related publications in FY2017


- Special Issue on Remote Sensing of Dynamic Permafrost Regions: This special issue will appear open access in the journal Remote Sensing and guest editors are Benjamin Jones, Annett Bartsch, and Guido Grosse. For more information on the special issue (http://www.mdpi.com/journal/remotesensing/special_issues/Dynamic_Permafrost) and manuscript preparation and related matters can be found in the instructions for authors (http://www.mdpi.com/journal/remotesensing/instructions) (Oct 30, 2017 - Completed)

- ABoVE contributions: Monitoring of key ecosystem characteristics in areas with different permafrost dynamics in order to understand the role of permafrost in key ecosystem processes, including vegetation dynamics and soil carbon cycling (Sep 15, 2017 - Completed)

- Torre Jorgenson gave a presentation titled “Progress Toward Understanding the Response of Permafrost to Climate Change in Alaska” at the May Permafrost Collaboration Team meeting relates to this performance element: http://www.iarpccollaborations.org/members/events/7687 (May 11, 2017 - Completed)

- 6.1.5 (In progress) Support activities, including the SEARCH Permafrost Action Team, to foster continued efforts to link multi-agency investments while expanding empirical datasets and synthesizing information that will inform the development of an updated permafrost ground ice content map for Alaska.; NSF (Lead), DOD-USACE, DOE, DOI-BLM, DOI-FWS, DOI-NPS, NASA, NOAA


  - 7th Annual Meeting of the Permafrost Carbon Network (December 10, 2017): The annual meeting brought together ~100 scientists thinking and discussing synthesis science focus on permafrost carbon. The specific topics covered: a) Expert assessment of subsea permafrost; b) Thermokarst: what have we done, what do we know, where are we going; c) Bottom-up estimations of methane emissions; d) Model benchmarking; e) Thaw-induced changes to the permafrost microbiome and the functional implication;
f) Bottom-up CO2 flux syntheses; g) Organizing validation data for remote sensing products, and h) Surface water analysis for pan-Arctic permafrost. (Sep 17, 2018 - Completed)


- The steering group of the Permafrost Action Team met on June 26, 2017 in Fairbanks, AK: The purpose of the meeting was to discuss material needed for three different types of Knowledge Pyramids and to produce a short 2-page written brief that can be distributed to a wide variety of interested people. The short briefs provide scientific information on societally-relevant questions in formats usable by a variety of stakeholders, including policy- and decision-makers. During the workshop, we focused on these three top-level questions: 1) What is the impact of permafrost carbon release on climate change? 2) How does permafrost thaw impact infrastructure? 3) How will ecosystem services critical to human livelihood in the Arctic be affected by permafrost thaw? The second half of the workshop was dedicated to brainstorming new synthesis products that focus on issues involving infrastructure and ecosystem services in the permafrost zone. (Oct 30, 2017 - Completed)

6.2 Improve and expand understanding of how warming and thawing of permafrost influence the vulnerability of soil carbon, including the potential release of carbon dioxide (CO2) and methane (CH4) to the atmosphere.

- 6.2.1 (In progress) Support field-based research and monitoring focused on quantifying the key processes controlling soil carbon cycling at northern latitudes and potential carbon release to the atmosphere, including temperature and hydrological effects.: NSF (Lead), DOD-USACE, DOE, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NASA

- The National Science Foundation (NSF) has recently awarded OPP – 1836839. The overarching goal of the project is to understand tundra ecosystem change across landscape types and enable realistic forecasts of change across the Arctic. The power of the International Tundra Experiment (ITEX)- Arctic Observatory Network (AON) is founded on a capacity to synthesize and compare results across sites that use standardized sampling protocols. Specifically, this project will (1) maintain the data-streams at ITEX-AON sites in Alaska near Toolik Lake, Imnavait Creek, Utqiagvik (Barrow), and Atqasuk; (2) lead two new ITEX network syntheses focused on soil carbon and phenocam imagery; (3) increase scientific literacy; and, (4) expand citizen science opportunities across communities in northern Alaska. (Oct 16, 2018 - Completed)

- NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. This work is described as monitoring of key ecosystem characteristics in areas with different permafrost dynamics in order to understand the role of permafrost in key ecosystem processes, including vegetation dynamics and soil carbon cycling. Projects include: Iwahana: Quantification of thermokarst and carbon release in ice-rich permafrost regions https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3563&progID=6 Publication: Davidson, S., et al. 2017. Upscaling CH4 Fluxes Using High-
Resolution Imagery in Arctic Tundra Ecosystems. Remote Sensing. 9(12), 1227. doi: 10.3390/rs9121227 (Sep 27, 2018 - Completed)

- Assembly of new database and working group on permafrost microbiology: Under the leadership of Jessica Ernakovich (University of New Hampshire, Durham, NH), a group of over 35 international scientists interested in permafrost microbiology and/or biogeochemistry and the potential feedbacks of the changing permafrost microbiome to climate has come together to synthesize existing information. As an activity of the SEARCH-funded Permafrost Carbon Network (PCN), the Permafrost Microbiome Working Group (PMWG) is currently building a database of microbial community data (amplicon-based sequencing and metagenome sequencing) from field-based and lab-based permafrost thaw experiments and thaw gradients. Microorganisms drive greenhouse gas production as the dominant decomposers of soil organic matter and plant-fixed carbon. Understanding how the decomposer community changes with permafrost thaw will help to reduce the uncertainty in the magnitude and type of greenhouse gases produced from thawing permafrost. (Sep 21, 2018 - Completed)

- ABoVE Focus Collection of Environmental Research Letters: This on-going focus collection addresses the influence and impact of environmental changes, including climate change, taking place across the high northern latitudes and their influence on Arctic and boreal ecosystems. It is open to all research contributions in the domain NW North America or broader for any of the thematic working group activity areas (including permafrost). http://iopscience.iop.org/journal/1748-9326/page/ABoVE (Sep 17, 2018 - Completed)

- Relevant publications in FY2017:
  


- Digital Database and Maps of Quaternary Deposits in East and Central Siberia: The primary goal for creating this digital database was to enhance current estimates of organic carbon stored in deep permafrost, in particular Late Pleistocene syngenetic ice-rich loess permafrost deposits, called Yedoma. This digital database is the product of collaboration between the U.S. Geological Survey, the Alfred Wegener Institute for Polar and Marine Research Potsdam, Foothill College GeoSpatial Technology Certificate Program, and the Geophysical Institute at the University of Alaska. With many thanks to Umakant Mishra and Andrew Balser for their thoughtful, thorough reviews. Here is the link to the database: https://www.sciencebase.gov/catalog/item/587546b3e4b0a829a325a276 (Oct 30, 2017 - Completed)

- Robyn provided an overview of work on permafrost microbiology spanning the late Pleistocene to the present, with linkages to, and implications for, shifting ecosystem processes and community dynamics through that timeframe at the June 17th PCT meeting. Her presentation is available at: http://www.iarpccollaborations.org/members/documents/9462. The recording of her
• 6.2.2 (In progress) Support research to improve scaling methods for estimating CO2 and CH4 emissions from the permafrost region (including that which is conducted by the SEARCH Permafrost Action Team) to link multi-agency investments in soil carbon research that culminates in synthesis publications.; NSF (Lead), DOD-USACE, DOE, NASA, NOAA

o The National Science Foundation (NSF) has recently awarded OPP – 1841610. Field studies suggest that inconsistent responses to comparable experimental manipulations across arctic tundra ecosystems might be driven by local variation in the plant and decomposer community. However, the relative importance of, and links between, key biotic (e.g. microbial acclimation) and abiotic factors (e.g. altered snowpack, thaw depth, and nutrient availability) that govern these divergent responses of tundra to climate variation, remains unknown. This project will synthesize available data from ambient and experimental manipulations of arctic ecosystems. The investigators will then use the synthesis to refine, parameterize, and validate a changed version of the Stoichiometrically Coupled, Acclimating Microbe-Plant-Soil (SCAMPS) model. Simulations will explore how variation in seasonal warming and the acclimation potential of the soil microbial and plant community, encompassing community shifts, evolutionary adaptation, and physiological changes across tundra landscapes, affects biogeochemical feedbacks and regulates future carbon balance of arctic soils and ecosystems. (Oct 16, 2018 - Completed)

o The National Science Foundation (NSF) has recently awarded OPP – 1823717. Rapid and non-invasive ground-based geophysical measurements will be taken to describe thermokarst lake methane emissions, develop relationships between lake expansion and methane emissions, and then use Synthetic Aperture Radar imagery to scale the results to large regions. The outcomes of this work have implications for understanding global carbon budgets, Arctic engineering, and the development of environmental monitoring methods. This research will provide additional validation to the Ground Penetrating Radar and Synthetic Aperture Radar methods, benefit their respective development fields, and encourage more widespread application of these methods across the Arctic. (Oct 15, 2018 - Completed)

o Assembly of new database and working group on permafrost microbiology: Under the leadership of Jessica Ernakovich (University of New Hampshire, Durham, NH), a group of over 35 international scientists interested in permafrost microbiology and/or biogeochemistry and the potential feedbacks of the changing permafrost microbiome to climate has come together to synthesize existing information. As an activity of the SEARCH-funded Permafrost Carbon Network (PCN), the Permafrost Microbiome Working Group (PMWG) is currently building a database of microbial community data (amplicon-based sequencing and metagenome sequencing) from field-based and lab-based permafrost thaw experiments and thaw gradients. Microorganisms drive greenhouse gas production as the dominant decomposers of soil organic matter and plant-fixed carbon. Understanding how the decomposer community changes with permafrost thaw will help to reduce the uncertainty in the magnitude and type of greenhouse gases produced from thawing permafrost. (Sep 21, 2018 - Completed)

o Permafrost model intercomparison project, led by the Permafrost Carbon Network, published in the Proceedings of the National Academy of Sciences: In this model presentation is available at: http://www.iarpccollaborations.org/members/events/7794. (Jun 26, 2017 - Completed)
intercomparison project, changes in permafrost and carbon storage in the northern permafrost region are simulated from 2010 to 2299. The results show that controlling greenhouse gas emissions in the coming decades could substantially reduce the consequences of carbon releases from thawing permafrost during the next 300 years.


- EOS article featuring ‘Understanding High-Latitude Methane in a Warming Climate’. This EOS article reports on efforts to reconcile the northern CH4 budget, a project of the Study of Environmental Arctic Change and led by the Permafrost Carbon Network. The article highlights what we know, as well as a selection of important knowledge gaps in our understanding of terrestrial, marine, and atmospheric environments that affect the development of Arctic CH4 budgets. The article also summarizes new work focused on improving our understanding of CH4 dynamics in this region. Miller, SM, Taylor MA, and Watts JD (2018), Understanding high-latitude methane in a warming climate, Eos, 99, https://doi.org/10.1029/2018EO091947. (Sep 17, 2018 - Completed)

- Large synthesis effort to ‘Reconcile historical and contemporary trends in terrestrial carbon exchange of the northern permafrost-zone’. Over the course of two workshops, the Permafrost Carbon Network is bringing together an international team of Arctic scientists to reconcile three inter-related data synthesis activities and provide a framework for annual reporting of Arctic ecosystem C balance. The first workshop took place in March of 2018 at the Arctic Data Center in Santa Barbara, CA and the second workshop will take place in October of 2018. The focus of the workshops is to build upon past syntheses to provide a current estimate of high-latitude permafrost zone CO2 fluxes and to lay out a framework for regular future updates. More details can be found here: https://arcticdata.io/reconciling-historical-and-contemporary-trends-in-terrestrial-carbon-exchange-of-the-northern-permafrost-zone/ (Sep 17, 2018 - Completed)

- Multiple publications in relation to PE 6.2.2


Resolving a methane mystery in the Arctic: The Permafrost Carbon Network together with the Study of Environmental Arctic Change organized the International Workshop to Reconcile Methane Budgets in the Northern Permafrost Regions. The workshop was funded by the National Science Foundation, NASA, the U.S. Geological Survey, and the U.S. Arctic Research Commission. There is a clear need for the scientific community to better understand the sensitivity of methane emissions to ongoing climate change in the northern permafrost region. Read more in Eos article: (https://eos.org/meeting-reports/resolving-a-methane-mystery-in-the-arctic). (Oct 30, 2017 - Completed)

Arctic Answer Brief on ‘Climate Change and the Permafrost Carbon Feedback’: As part of the Study of Environmental Arctic Change, the Permafrost Action Teams has prepared
short science briefs centered on relevant topics related to degrading permafrost. All Arctic Answers provide scientific information in a format that can be used by scientists, stakeholders, policy- and decision-makers, as well as students and journalists. This is a great resource for short and up to date summaries of various Arctic related topics. Here is the link to the brief on Climate Change and the Permafrost Carbon Feedback (https://www.arcus.org/files/page/documents/19092/arctic-answers-2017_permafrost.pdf). (Oct 30, 2017 - Completed)

- 6.2.3 (In progress) Utilize empirical, multi-scale approaches to make spatially-explicit estimates of vulnerability of permafrost carbon and release of both CO2 and CH4.; DOE (Lead), DOD-USACE, DOI-USGS, NASA
  - EOS article featuring ‘Understanding High-Latitude Methane in a Warming Climate’. This EOS article reports on efforts to reconcile the northern CH4 budget, a project of the Study of Environmental Arctic Change and led by the Permafrost Carbon Network. The article highlights what we know, as well as a selection of important knowledge gaps in our understanding of terrestrial, marine, and atmospheric environments that affect the development of Arctic CH4 budgets. The article also summarizes new work focused on improving our understanding of CH4 dynamics in this region. Miller, SM, Taylor MA, and Watts JD (2018), Understanding high-latitude methane in a warming climate, Eos, 99, https://doi.org/10.1029/2018EO091947. (Sep 17, 2018 - Completed)
  - Large synthesis effort to ‘Reconcile historical and contemporary trends in terrestrial carbon exchange of the northern permafrost-zone’. Over the course of two workshops, the Permafrost Carbon Network is bringing together an international team of Arctic scientists to reconcile three inter-related data synthesis activities and provide a framework for annual reporting of Arctic ecosystem C balance. The first workshop took place in March of 2018 at the Arctic Data Center in Santa Barbara, CA and the second workshop will take place in October of 2018. The focus of the workshops is to build upon past syntheses to provide a current estimate of high-latitude permafrost zone CO2 fluxes and to lay out a framework for regular future updates. More details can be found here: https://arcticdata.io/reconciling-historical-and-contemporary-trends-in-terrestrial-carbon-exchange-of-the-northern-permafrost-zone/ (Sep 17, 2018 - Completed)
  - Multiple publications in relation to PE 6.2.3

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- 6.2.4 (In progress) Utilize empirical, multi-scale approaches to make spatially explicit estimates of the potential extent and modes of abrupt permafrost thaw, including thermokarst and cryogenic landslides, and of the downstream effects of these events on microbial processes and carbon fluxes.; DOD-USACE (Lead), DOI-USGS, NSF


- 6.2.5 (In progress) Better understand the rate of subsea permafrost degradation and its role in methane gas hydrate decomposition and feedbacks to the climate system. Develop estimates of contributions to atmospheric carbon from subsea permafrost sources at present and under future scenarios.; DOI-USGS (Lead), DOI-BOEM, NOAA, NSF

  - Related publications in FY2017:


Expert assessment on subsea permafrost: Ben Abbott from Brigham Young University, Jennifer Frederick from Sandia National Laboratory, and Brett Thornton from Stockholm University are leading an expert assessment on subsea permafrost. Questions will concern the current extent of subsea permafrost, carbon type and stocks, and potential changes in emissions. The Permafrost Carbon Network is supporting this activity and has sent out a request for participation with the survey design and background information. There will be a breakout discussion on this topic at the 7th Annual Meeting of the Permafrost Carbon Network on December 10, 2017 in New Orleans (Oct 30, 2017 - Completed)

A collaboration between USGS Coastal and Marine Geology Program researchers and Bruce Herman, now retired from the Bureau of Ocean Energy Management (BOEM) in Anchorage, Alaska, has produced the most complete information to date about the seaward extent of remaining subsea permafrost and possible relict gas hydrate beneath the U.S. Beaufort Sea margin at the edge of the Arctic Ocean. Using industry seismic reflection data (http://onlinelibrary.wiley.com/wol1/doi/10.1002/2016GC006584/full) and legacy borehole logs (http://onlinelibrary.wiley.com/doi/10.1002/2016GC006582/full), the recent publications provide critical insights about the contemporary state of subsea permafrost and establish a baseline for tracking continued degradation of the permafrost as the oceans warm. This research was partially supported by USGS-DOE Interagency agreements DE-FE0023495 and DE-FE0002911, by a 2010-2012 DOE NETL/NRC Methane Hydrate Postdoctoral Fellowship to L.B. under DE-FC26-05NT42248, and by BOEM.

The full citations for the papers are:


6.3 In collaboration with efforts described under the Terrestrial Ecosystems Goal, continue to improve integration of empirically measured permafrost processes into models that predict how climate change, hydrology, ecosystem shifts and disturbances interact within terrestrial and freshwater aquatic systems to impact permafrost evolution, degradation, and feedbacks from local landscapes to the circumpolar.

- **6.3.1 (In progress) Conduct field-based research and monitoring needed to improve understanding of the linkages between key terrestrial ecosystem processes and permafrost properties and to incorporate empirical information into modeling efforts at various scales.**
  - DOE (Lead), DOI-FWS (Lead), NSF (Lead), DOD-USACE, DOI-BLM, DOI-NPS, DOI-USGS, NASA, USDA-USFS
    - The National Science Foundation (NSF) has recently awarded OPP – 1836839. The overarching goal of the project is to understand tundra ecosystem change across landscape types and enable realistic forecasts of change across the Arctic. The power of the International Tundra Experiment (ITEX)- Arctic Observatory Network (AON) is founded on a capacity to synthesize and compare results across sites that use standardized sampling protocols. Specifically, this project will (1) maintain the data-streams at ITEX-AON sites in Alaska near Toolik Lake, Imlay Creek, Utqiagvik (Barrow), and Atqasuk; (2) lead two new ITEX network syntheses focused on soil carbon and phenocam imagery; (3) increase scientific literacy; and, (4) expand citizen science opportunities across communities in northern Alaska. (Oct 16, 2018 - Completed)
    - The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)
    - NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. This work is described as monitoring of key ecosystem characteristics in areas with different permafrost dynamics in order to understand the role of permafrost in key ecosystem processes, including vegetation dynamics and soil carbon cycling. See projects mentioned above PEs 6.1 - 6.2 (Sep 27, 2018 - Completed)
    - The National Science Foundation (NSF) has recently awarded OPP – 1836377. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. Long-term observations of active-layer thickness and dynamics, obtained using standard measurement protocols, are the essential rationale behind the CALM project. The objectives of the observational network stress the need for long-term active layer, ground temperature, and thaw settlement measurements, integration of data to provide the basis for comprehensive assessments of changes in active-layer and near-surface permafrost, and preparation and dissemination of data sets to assist detailed process studies, and in validating and developing of climate change, ecology, hydrology,
and geocryology models. An outreach component of the project includes extensive involvement of local, predominantly indigenous population in observational program at remote Arctic sites. (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1748653. This project seeks an accounting of the pan-Arctic hydrologic cycle. Researchers will couple big-data remote sensing and specific remote sensing discharge estimation techniques with fluvial geomorphology to estimate discharge for every Arctic river wider than 150m from 1984 to present using NASA's Landsat family of satellites. This remotely sensed Arctic river assessment will be founded upon a backbone of detailed fieldwork as designed and executed by undergraduates at UMass Amherst in a new program: Integrating Geosciences and Engineering in the Arctic (IGEA). The IGEA-informed remotely sensed discharge data will be used to calibrate an open source global hydrology model, integrating the other components of this project to reach a fuller understanding of the entire Arctic system achieved through improved process-based understanding of Arctic rivers. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1748849. In this study, investigators examine the causes and consequences of divergent tree growth in the Brooks Range. Divergence refers to the deterioration of historically strong positive correlations between temperature and tree growth. The recognition that divergence has been widespread in the circumboreal has undermined confidence in paleoclimate reconstructions and created uncertainty in projections of vegetation-climate feedbacks. While divergence is a well-known phenomenon, its implications for changes in tree abundance and shifts in treeline position remain unknown. Recent findings in four watersheds along a west to east gradient in the Brooks Range suggest colder, more permafrost-affected soils limit tree access to soil nutrients and may be the cause of divergence in the eastern Brooks Range. Researchers will combine repeat aerial photography with tree-ring analysis and detailed measurements of tree microclimates, mycorrhizal associations, nutrient relations, and reproductive effort in 25 Brooks Range watersheds to yield broad-scale mechanistic insights into controls on tree growth and changes in tree abundance in a changing climate. They will test the hypothesis that positive growth responses to warming and increased tree abundance will prevail in the western Brooks Range and in habitats with warmer soils, while neutral growth responses to warming and stagnant treelines will be common in the eastern Brooks Range and in areas with cold soils. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1737411. Arctic lakes are ice-covered for nine or more months of the year. With harsh winter conditions, few limnological studies have been conducted on ice-covered arctic lakes. The goal of the proposed research is to analyze an unprecedented dataset obtained from five lakes of different sizes from fall to spring over three years. The data will be used to describe and quantify the lakes' physical limnology and under ice metabolism and to develop scaling laws such that regional generalizations can be made. Analyses and modeling will focus on questions related to the extent to which fall cooling moderates under ice temperatures and circulation; the contribution of respiration and related increases in solutes to circulation patterns and development of anoxia; lake-size dependent controls on the retention of solutes introduced at snowmelt; and lake-size dependent controls on mixing dynamics, which moderate production of CO2 and CH4 in winter and
emissions at ice off. Results will provide a basic understanding of circulation and mixing as needed to improve hydrodynamic models and are critical for quantifying the habitat of organisms under the ice and for accurate inclusion of arctic lakes in regional carbon budgets. (Sep 21, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1740382. Current estimates for river discharge of organic carbon do not account for pieces of large wood. Few studies have investigated the drainage-basin-scale patterns of wood delivery, decay, and transport, resulting in limited knowledge of how large wood influences organic carbon discharge to the ocean. This knowledge gap leads to the project’s primary research goals, which are to (i) quantify annual coarse particulate organic carbon discharge in the form of large wood versus other sources of dissolved and particulate organic carbon from the Mackenzie River drainage of Canada to the Arctic Ocean and (ii) estimate the storage volume, residence time, and decay rates of large wood in the drainage basin. This work is being conducted in the Mackenzie River drainage because it is a relatively pristine large river drainage basin that is known for high rates of wood export to the ocean. (Sep 21, 2018 - Completed)

- The April 2018 PCT meeting ([https://www.iarpccollaborations.org/members/events/10610](https://www.iarpccollaborations.org/members/events/10610)) focused on key issues affecting permafrost dynamics within terrestrial ecosystem models (a community approach). Potential efforts of orchestrating an ecotype approach to permafrost modeling were discussed. A potential applications working group, that might look at ways we can reconcile modeling efforts at different scales with needs of communities and addressing uncertainty was discussed. (Apr 10, 2018 - Completed)

- The presentation by Robyn Barbato titled "The permafrost microbiome to reveal past biodiversity patterns in Alaskan soils representing the Holocene and the late Pleistocene" at the June Permafrost Collaboration Team Meeting relates to this Performance Element [http://www.iarpccollaborations.org/members/events/7794](http://www.iarpccollaborations.org/members/events/7794). (Jul 24, 2017 - Completed)

**6.3.2 (In progress) Carry out research to quantify and integrate across scales, the effects of warming permafrost on ecosystem processing related with disturbance regimes, including fire, thermokarst, and landscape changes.**

- DOI-FWS (Lead), DOI-USGS (Lead), NSF (Lead), DOD-USACE, DOI-BLM, DOI-NPS, NASA, USDA-USFS

- The National Science Foundation (NSF) has recently awarded OPP – 1836839. The overarching goal of the project is to understand tundra ecosystem change across landscape types and enable realistic forecasts of change across the Arctic. The power of the International Tundra Experiment (ITEX)- Arctic Observatory Network (AON) is founded on a capacity to synthesize and compare results across sites that use standardized sampling protocols. Specifically, this project will (1) maintain the data-streams at ITEX-AON sites in Alaska near Toolik Lake, Innnavit Creek, Utqiagvik (Barrow), and Atqasuk; (2) lead two new ITEX network syntheses focused on soil carbon and phenocam imagery; (3) increase scientific literacy; and, (4) expand citizen science opportunities across communities in northern Alaska. (Oct 16, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A
combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)

- NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. This work is summarized as: Developed approaches to utilize knowledge from field based studies and remote products to improve models in order to assess the impacts of variations in the permafrost regime on ecosystem processes. The ABoVE Science Team is carrying out a community assessment of active layer conditions, including active layer depth and soil moisture, and their spatial heterogeneity as represented by different types of measurements at different spatial scales, ranging from local ground measurements to landscape and regional scale observations from airborne and satellite remote sensing. Publications: Fisher, J. B., et al. 2018. Missing pieces to modeling the Arctic-Boreal puzzle. Environmental Research Letters. 13(2), 020202. doi: 10.1088/1748-9326/aa9d9a (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1740382. Current estimates for river discharge of organic carbon do not account for pieces of large wood. Few studies have investigated the drainage-basin-scale patterns of wood delivery, decay, and transport, resulting in limited knowledge of how large wood influences organic carbon discharge to the ocean. This knowledge gap leads to the project’s primary research goals, which are to (i) quantify annual coarse particulate organic carbon discharge in the form of large wood versus other sources of dissolved and particulate organic carbon from the Mackenzie River drainage of Canada to the Arctic Ocean and (ii) estimate the storage volume, residence time, and decay rates of large wood in the drainage basin. This work is being conducted in the Mackenzie River drainage because it is a relatively pristine large river drainage basin that is known for high rates of wood export to the ocean. ()

- The March 2018 PCT meeting (https://www.iarpccollaborations.org/members/events/10613) asked can we model permafrost dynamics adequately in Earth System models? The presentations focused on progress towards benchmarking permafrost processes in Earth system models. They discussed approaches to benchmarking models in general, as well as specific examples of the physical and biogeochemical processes relevant to permafrost-affected ecosystems. Presentations: “Update on permafrost modeling in Earth System Models”- Dave Lawrence (UCAR), “Towards better benchmarking of permafrost processes in Earth System Models: An example using soil carbon turnover”-Charlie Koven (LBL) (Mar 19, 2018 - Completed)

- Related publications in FY2017:

- ABoVE contributions: Developed approaches to utilize knowledge from field based studies and remote products to improve models in order to assess the impacts of variations in the permafrost regime on ecosystem processes (Sep 15, 2017 - Completed)

- 6.3.3 (In progress) Facilitate and harmonize the production of key geospatial datasets from extensive field measurements, remotely-sensed, and other data sources needed for model initialization, calibration, and validation. Organize and host workshops to enable this activity across agencies engaged in data development with attention to data congruity and scalability.; DOI-BLM (Lead), DOI-FWS (Lead), NASA (Lead), DOD-USACE, DOE, DOI-NPS, NSF

  - NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. This work is described as: Continued research on the development and validation of InSAR approaches to estimate annual active layer thickness using spaceborne SAR data carried out the collection of airborne P- and L-band SAR data along with surface observations in May to September 2017 at sites across the ABoVE Study Domain to develop new remote sensing products for monitoring of permafrost characteristics in summer 2018, ABoVE had another airborne campaign for L-band SAR. (Sep 27, 2018 - Completed)

- Related publications in FY2017:


  - ABoVE contributions:
    a. Continued research on the development and validation of InSAR approaches to estimate annual active layer thickness using spaceborne SAR data (PE 6.3.3).
    b. Carried out the collection of airborne P- and L-band SAR data along with surface observations in May to September 2017 at sites across the ABoVE Study Domain to develop new remote sensing products for monitoring of permafrost characteristics (Sep 15, 2017 - Completed)

- 6.3.4 (In progress) Support continued development of robust modeling tools and approaches to integrate models of ecosystem processes at various scales since permafrost dynamics are integral to these processes and vice-versa.; DOE (Lead), DOD-USACE, DOI-BLM, DOI-NPS, NASA, NOAA, NSF

  - The National Science Foundation (NSF) has recently awarded OPP – 1841610. Field studies suggest that inconsistent responses to comparable experimental manipulations
across arctic tundra ecosystems might be driven by local variation in the plant and decomposer community. However, the relative importance of, and links between, key biotic (e.g. microbial acclimation) and abiotic factors (e.g. altered snowpack, thaw depth, and nutrient availability) that govern these divergent responses of tundra to climate variation, remains unknown. This project will synthesize available data from ambient and experimental manipulations of arctic ecosystems. The investigators will then use the synthesis to refine, parameterize, and validate a changed version of the Stoichiometrically Coupled, Acclimating Microbe-Plant-Soil (SCAMPS) model. Simulations will explore how variation in seasonal warming and the acclimation potential of the soil microbial and plant community, encompassing community shifts, evolutionary adaptation, and physiological changes across tundra landscapes, affects biogeochemical feedbacks and regulates future carbon balance of arctic soils and ecosystems. (Oct 16, 2018 - Completed)

- NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues. Specifically, this includes: Developed approaches to utilize knowledge from field based studies and remote products to improve models in order to assess the impacts of variations in the permafrost regime on ecosystem processes. See PE 6.3.2 for relevant publication. (Sep 27, 2018 - Completed)


- ABoVE Focus Collection of Environmental Research Letters: This on-going focus collection addresses the influence and impact of environmental changes, including climate change, taking place across the high northern latitudes and their influence on Arctic and boreal ecosystems. It is open to all research contributions in the domain NW North America or broader for any of the thematic working group activity areas (including permafrost). http://iopscience.iop.org/journal/1748-9326/page/ABoVE (Sep 17, 2018 - Completed)

- The March Permafrost Collaboration Team Meeting (https://www.iarpccollaborations.org/members/events/10613) sparked a discussion on this issue and laid the foundation for future discussions and activities. Dave Lawrence and Charlie Koven presented the newest updates in regard to modeling permafrost processes in Earth System Models and discussed the importance of snow insulation and thermokarst processes. (Mar 21, 2018 - Completed)

6.4 Determine how warming and thawing permafrost impacts infrastructure and human health.

- **6.4.1 (In progress)** Survey Federal research agencies and non-Federal partners/stakeholders on their use of tools, methods, and means to monitor changes in landscape conditions due to changes in permafrost with a focus on hazards to infrastructure and health. Develop, enhance, and update “Best Practices” guides for mitigation of impacts to building foundations and other infrastructure.; DOI-BLM (Lead), Denali, DOD-OSD, DOD-USACE, DOI-BIA, EPA, HHS

- Published Arctic Answers through the Study of Environmental Arctic Change Program: Arctic Answers are 1-2 page long briefs written by experts answering policy-relevant questions. Each brief is the top of a "knowledge pyramid" supported by scientific literature organized in underlying tiers of increasing detail. Each brief is reviewed for scientific accuracy and accessibility to readers with broad backgrounds. The Permafrost Action Team of the Study of Environmental Arctic Change wrote two additional briefs with the topics: 1) How is permafrost degradation affecting ecosystem services? 2) How is permafrost degradation affecting infrastructure? The briefs are available online: [https://www.searcharcticscience.org/arctic-answers](https://www.searcharcticscience.org/arctic-answers) (Sep 17, 2018 - Completed)

- No EPA involvement to date, but interest is high. (Sep 4, 2018 - Completed)

- The PCT February 2018 meeting ([https://www.iarpccollaborations.org/members/events/10609](https://www.iarpccollaborations.org/members/events/10609)) focused on efforts to develop an Arctic coastal erosion model for ice-rich permafrost bluffs. Diana Bull (Sandia National Lab) presented "Development of a Predictive Model for Arctic Coastal Erosion" ([https://www.iarpccollaborations.org/members/documents/10925](https://www.iarpccollaborations.org/members/documents/10925)). Diana Bull (Sandia National Lab) provided insight into an ongoing project that will allow for informed and sustainable risk management decisions on critical infrastructures, such as the fortification or relocation of coastal radar sites, air strips, roads, and communities. (Feb 13, 2018 - Completed)

6.4.2 (In progress) In collaboration with relevant Indigenous organizations, survey local communities and regional agencies—those which maintain infrastructure and monitor health—on the impacts of warming and thawing permafrost. Integrate these responses within a document characterizing and summarizing overall impacts of warming and thawing permafrost.; Denali (Lead), DOD-OSD (Lead), DOD-USACE, DOI-BLM, EPA, HHS, NOAA

- Arctic Futures 2050 Scenarios Workshop held April 20-22 2018 in Seattle, WA: In this workshop, Arctic researchers, representatives of indigenous communities, and policy makers used scenarios to identify plausible futures and the science questions that will arise for policy makers. The workshop was held by the Study of Environmental Arctic Change and included all aspects of the cryosphere, including permafrost. The goals of the workshop were to 1) Survey the expertise on the changing social and environmental conditions of the Arctic likely to impact policy decisions; 2) Learn what scenario outcomes are most plausible and consistent from the data provided to the research team; 3) Outline research questions that would need to be answered to address policy responses to the plausible scenarios; and 4) Consider next steps to inform Arctic policy with science. More details can be found here: https://www.searcharticiscience.org/arctic-2050/scenarios-workshop/overview (Sep 17, 2018 - Completed)

- No EPA involvement to date, but interest is high. (Sep 4, 2018 - Completed)


- Related publications in FY2107:


**Agencies**
DOC, DOD, DOE, DOI, NASA, NSF, OSTP
7.1 Terrestrial Ecosystems

7.1 Improve understanding of and ability to model feedbacks and interactions among the large-scale processes causing change (climate, natural disturbances, and human-caused perturbations) and the responses of terrestrial and freshwater ecosystems.

- 7.1.1 (In progress) Carry out and synthesize results from field-based research and monitoring needed to improve understanding of important ecosystem processes and feedbacks, including their responses to environmental changes.; DOI-FWS (Lead), DOI-USGS (Lead), NSF (Lead), DOE, DOI-BLM, DOI-NPS, NASA, USDA-NRCS, USDA-USFS

  o Overall statement for all ABoVE contributions is noted here since this is the first TECTPE. All land-based research sponsored by NASA is being coordinated through the Arctic-Boreal Vulnerability Experiment (ABoVE). Through ABoVE, NASA is funding researchers from its centers, academic institutes, private research organizations, and other federal agencies. Through the ABoVE Science Team, this NASA-funded research is being coordinated with research funded by other government and non-government organizations in the U.S., Canada, and Europe, in particular researchers from the Departments of Energy and Interior, NOAA, and those funded by NSF and in Canada researchers funded by NSERC, Natural Resources Canada, Parks Canada, Polar Knowledge Canada, and the Governments of Yukon and the Northwest Territories. The ABoVE work described in 2017 continues.

  a. See the projects/publications reported in 6.1.1 - 6.1.3 in relation to original 2017 description as follows: The ABoVE Science Team is carrying out a community assessment of recent changes in boreal-arctic land surface hydrology. This activity is examining and comparing a diversity of multi-scale remote sensing and ground observations representing key hydrological parameters to determine regional trends and associated gaps and uncertainties in the surface water budget, and underlying drivers of the observed changes.

  b. This synthesis is still underway. The synthesis as described in 2017 follows: The ABoVE Science Team is carrying out a synthesis of research from field sites (including those from ABoVE researchers) on tree regeneration after fires, which exerts a large control on long-term post-fire properties such as vegetation dynamics, carbon cycling, and energy budgets. The science team has assembled data from over 18 projects and is developing conceptual models to understand the controls on tree species-specific seedling composition and density after fires across different boreal forest types in Alaska, Yukon, and the Northwest Territories. Also, there was a workshop in 2017: https://above.nasa.gov/announc_20170305.html

  c. Publication from this research (described in 2017 as: Research has been carried out to determine factors controlling freshwater carbon loss in Alaska from river lateral carbon transfer to coastal regions and river CO2 emissions.): Wickland, K. P., et al. 2018.

The National Science Foundation has recently awarded OPP – 1744515. This project will examine how warming is leading to a new hydrological regime in regions adjacent to the areas where major sea-ice losses have occurred. The investigators will study annually laminated sediments in lakes of western Svalbard to identify the sedimentary signal of recent changes in hydrology and reconstruct the long-term history of rainfall-related sedimentary events to determine when similar conditions may have prevailed in the past. This will provide a unique perspective on the nature of recent sedimentary changes and provide insight into the effects of contemporary changes in climate on the hydrological regime of this region. The results will have implications for other parts of the Arctic where sea-ice is rapidly receding. (Sep 24, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1748653. This project seeks an accounting of the pan-Arctic hydrologic cycle. Researchers will couple big-data remote sensing and specific remote sensing discharge estimation techniques with fluvial geomorphology to estimate discharge for every Arctic river wider than 150m from 1984 to present using NASA's Landsat family of satellites. This remotely sensed Arctic river assessment will be founded upon a backbone of detailed fieldwork as designed and executed by undergraduates at UMass Amherst in a new program: Integrating Geosciences and Engineering in the Arctic (IGEA). The IGEA-informed remotely sensed discharge data will be used to calibrate an open source global hydrology model, integrating the other components of this project to reach a fuller understanding of the entire Arctic system achieved through improved process-based understanding of Arctic rivers. (Sep 24, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1737411. Arctic lakes are ice-covered for nine or more months of the year. With harsh winter conditions, few limnological studies have been conducted on ice-covered arctic lakes. The goal of the proposed research is to analyze an unprecedented dataset obtained from five lakes of different sizes from fall to spring over three years. The data will be used to describe and quantify the lakes' physical limnology and under ice metabolism and to develop scaling laws such that regional generalizations can be made. Analyses and modeling will focus on questions related to the extent to which fall cooling moderates under ice temperatures and circulation; the contribution of respiration and related increases in solutes to circulation patterns and development of anoxia; lake-size dependent controls on the retention of solutes introduced at snowmelt; and lake-size dependent controls on mixing dynamics, which moderate production of CO2 and CH4 in winter and emissions at ice off. Results will provide a basic understanding of circulation and mixing as needed to improve hydrodynamic models and are critical for quantifying the habitat of organisms under the ice and for accurate inclusion of arctic lakes in regional carbon budgets. (Sep 21, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1740382. Current estimates for river discharge of organic carbon do not account for pieces of large wood. Few studies have investigated the drainage-basin-scale patterns of wood delivery, decay, and transport, resulting in limited knowledge of how large wood influences organic carbon discharge to the ocean. This knowledge gap leads to the project’s
primary research goals, which are to (i) quantify annual coarse particulate organic carbon discharge in the form of large wood versus other sources of dissolved and particulate organic carbon from the Mackenzie River drainage of Canada to the Arctic Ocean and (ii) estimate the storage volume, residence time, and decay rates of large wood in the drainage basin. This work is being conducted in the Mackenzie River drainage because it is a relatively pristine large river drainage basin that is known for high rates of wood export to the ocean. (Sep 21, 2018 - Completed)

- The presentations by Rick Thoman (NOAA) and Christopher Hiemstra (CRREL) at the October 2017 Terrestrial Ecosystems Collaboration Team Meeting on snow drought and seasonal outlook is relevant to this Performance Element (https://www.iarpccollaborations.org/members/events/7808). The two presentations described the state of snow measurements and forecasts in Alaska and the Arctic, providing insight into current trends and what to expect in the future. (Nov 13, 2017 - Completed)

- a.) The ABoVE Science Team is carrying out a community assessment of recent changes in boreal-arctic land surface hydrology. This activity is examining and comparing a diversity of multi-scale remote sensing and ground observations representing key hydrological parameters to determine regional trends and associated gaps and uncertainties in the surface water budget, and underlying drivers of the observed changes

- b.) The ABoVE Science Team is carrying out a synthesis of research from field sites (including those from ABoVE researchers) on tree regeneration after fires, which exerts a large control on long-term post-fire properties such as vegetation dynamics, carbon cycling, and energy budgets. The science team has assembled data from over 18 projects and is developing conceptual models to understand the controls on tree species-specific seedling composition and density after fires across different boreal forest types in Alaska, Yukon, and the Northwest Territories.

- c.) Research has been carried out to determine factors controlling freshwater carbon loss in Alaska from river lateral carbon transfer to coastal regions and river CO2 emissions. (Sep 15, 2017 - Completed)

- 7.1.2 (In progress) Carry out and synthesize research on and monitoring of the disturbance processes responsible for changes to key landscapes, including fire, warming permafrost, insects and pathogens, and human activities.; DOI-BLM (Lead), NASA (Lead), NSF (Lead), DOD-USACE, DOE, DOI-FWS, DOI-NPS, DOI-USGS, USDA-USFS

- The National Science Foundation (NSF) has recently awarded OPP – 1822406. Tundra wildfire occurrences have increased in coastal Greenland, setting a new record in summer 2017. This project focuses on the study of emissions from arctic tundra wildfires. Chemical tracers of wildfires, including carbon monoxide, methane, and a series of volatile organic compounds will be monitored in the atmosphere at the Greenland Environmental Observatory at Summit. This project will deliver continuous high time resolution data for wildfire emission and climate forcing atmospheric constituents. Data analyses and modeling will improve assessments of fire emissions and their environmental and climate impacts. (Oct 15, 2018 - Completed)

- The National Science Foundation (NSF) has recently awarded OPP – 1839198. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. The
researchers’ goal is to understand the influence of both environmental dynamics and increasing anthropogenic activity on the behavior and phenology of migratory caribou (Rangifer tarandus), waterfowl, and songbird communities in Arctic-boreal Alaska and northwestern Canada. Through co-production of knowledge with local land managers and indigenous communities, the research team will combine field observations, modeling, and analyses that include: (1) soundscape measurements, (2) camera-trap observations, (3) automated soundscape analyses, (4) analyses of camera-trap caribou observations, (5) high-resolution modeling of environmental variables, (6) statistical analyses including wildlife occupancy, diversity, and phenology modeling, and (7) a human-computation game to collect descriptions of our acoustic recordings that allows for the participation of local and Indigenous players of the game. (Sep 28, 2018 - Completed)

The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)

The work described in 2017 continues.

a. Research was carried out on the distribution of thermokarst in the Yukon Flats.
Project: Smith: Sensitivity of Arctic-Boreal surface water to permafrost state
https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3566&progID=6

b. Projects include (Research was carried out on factors controlling the wildfire regime in Alaska and western Canada, including the role of lightning and inter-annual climate variability.): Bourgeau-Chavez: Planning and Collection of Data on Boreal Wildfire Effects: Studies of broad-scale 2014 Wildfires in NWT, Canada
https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3287&progID=6

https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3384&progID=6

Rogers: Developing a spatially-explicit understanding of fire-climate forcings and their management implications across the ABoVE domain
https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3386&progID=6

Publications:


Two additional NASA ABoVE publications have supported this performance element:


The National Science Foundation (NSF) has recently awarded OPP – 1836377. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. Long-term observations of active-layer thickness and dynamics, obtained using standard measurement protocols, are the essential rationale behind the CALM project. The objectives of the observational network stress the need for long-term active layer, ground temperature, and thaw settlement measurements, integration of data to provide the basis for comprehensive assessments of changes in active-layer and near-surface permafrost, and preparation and dissemination of data sets to assist detailed process studies, and in validating and developing of climate change, ecology, hydrology, and geocryology models. An outreach component of the project includes extensive involvement of local, predominantly indigenous population in observational program at remote Arctic sites. (Sep 26, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1748849. In this study, investigators examine the causes and consequences of divergent tree growth in the Brooks Range. Divergence refers to the deterioration of historically strong positive correlations between temperature and tree growth. The recognition that divergence has been widespread in the circumboreal has undermined confidence in paleoclimate reconstructions and created uncertainty in projections of vegetation-climate feedbacks. While divergence is a well-known phenomenon, its implications for changes in tree abundance and shifts in treeline position remain unknown. Recent findings in four watersheds along a west to east gradient in the Brooks Range suggest colder, more permafrost-affected soils limit tree access to soil nutrients and may be the cause of divergence in the eastern Brooks Range. Researchers will combine repeat aerial photography with tree-ring analysis and detailed measurements of tree microclimates, mycorrhizal associations, nutrient relations, and reproductive effort in 25 Brooks Range watersheds to yield broad-scale mechanistic insights into controls on tree growth and changes in tree abundance in a changing climate. They will test the hypothesis that positive growth responses to warming and increased tree abundance will prevail in the western Brooks Range and in habitats with warmer soils, while neutral growth
responses to warming and stagnant treelines will be common in the eastern Brooks Range and in areas with cold soils. (Sep 24, 2018 - Completed)

- Book Chapter Describes the Effects of Climate Change on Disease Spread in Wildlife

- NGEE Arctic continued research in Barrow and the Seward Peninsula on the role of thermokarst formation in CO2 and CH4 flux, and changing distribution of water and vegetation across tundra ecosystems. (Oct 4, 2017 - Completed)

- Wildfires are the principal disturbance in the boreal forest, and their size and frequency are increasing as the climate warms. Impacts of fires on boreal wildlife are largely unknown, especially for the tens of millions of waterfowl that breed in the region. Waterfowl populations across the western boreal forest of North America have been monitored annually since 1955 by the Waterfowl Breeding Population and Habitat Survey (BPOP). From 1955 to 2014, >1100 fires in the western boreal forest intersected BPOP survey transects, and many transects burned multiple times. Nonetheless, fires had no detectable impact on waterfowl abundance; annual transect counts of dabbler and diver pairs remained stable from the pre- to post-fire period. Waterfowl populations appear largely resilient to forest fires, providing initial evidence that current policies of limited fire suppression, which predominate throughout much of the boreal forest, have not been detrimental to waterfowl populations. Likewise, fire-related management actions, such as prescribed burning or targeted suppression, seem to have limited impacts on waterfowl abundance and productivity. For waterfowl managers, our results suggest that adaptive models of waterfowl harvest, which annually guide hunting quotas, do not need to emphasize fires when integrating climate change effects. Citation: Lewis, T. L., J. A. Schmutz, C. L. Amundson, and M. S. Lindberg. 2016. Waterfowl populations are resilient to immediate and lagged impacts of wildfires in the boreal forest. Journal of Applied Ecology. doi:10.1111/1365-2664.12705 (Sep 28, 2017 - Completed)

- Effects of Industrial and Investigator Disturbance on Arctic-Nesting Geese. Direct encounters with humans can increase the likelihood that nesting geese will lose their eggs to predators, according to a U.S. Geological Survey (USGS) study. As part of a study to understand reasons for the rapid increase of geese across northern Alaska and to understand potential impacts to nesting-geese from oil and gas development on the Arctic Coastal Plain of Alaska, USGS researchers used remote cameras to assess the behavioral response of Greater White-fronted geese to disturbance. Results of the study indicate that effects of both industrial and research activity can be minimized
through practices that limit direct encounters with nests, such as minimizing travel on
the tundra during the nesting season, using established travel routes during the
summer, and minimizing the research study area to reduce impact. The article and
associated data release are listed below: Publication citation: Meixell, B. W. and P. L.
Flint. 2017. Effects of industrial and investigator disturbance on Arctic-nesting geese.
Journal of Wildlife Management Early View. doi:10.1002/jwmg.21312. Data citation:
Meixell, B. W., 2017, Greater White-fronted Goose (Anser albifrons) Nest Characteristics
and Nesting Behavior Classifications from Time-lapse Photographs and Nest Visit Data;
Point Lonely, Alaska, 2013-2014: U.S. Geological Survey data release,
https://doi.org/10.5066/F7NV9GP9. ()

- EPA researchers are conducting a citizen science study called Smoke Sense to:
  
  - Determine the extent to which exposure to wildland fire smoke affects health
    and productivity
  - Develop health risk communication strategies that protect public health during
    smoke days

Individuals who want to contribute to science can participate in the study by using the
Smoke Sense app, a publicly available mobile application on Google Play Store.

The study will be the first of its kind known to use a mobile application to evaluate
health effects from wildland fires experienced by those who participate, and to test
whether such an app communicates health risks effectively. Data gathered through
Smoke Sense is anticipated to help EPA researchers and communities determine how
smoke from fires impacts our health and productivity and gain important insights
needed to develop health risk communication methods during smoky days.

The study is being conducted during the 2017 fire season. At the end of the study, the
Smoke Sense app will go offline temporarily for updates. The Smoke Sense app can be
used on Android phones and will be available for use on Apple devices in the future.
Smoke Sense app user identities will be anonymous and non-identifiable.
https://www.epa.gov/air-research/smoke-sense-study-citizen-science-project-using-
mobile-app (Sep 21, 2017 - Completed)

- ABoVE and NASA supported this PE in the following ways:
  a. Research was carried out on the distribution of thermokarst in the Yukon Flats.
  b. Research was carried out on factors controlling the wildfire regime in Alaska and
     western Canada, including the role of lightning and inter-annual climate variability. (Sep
     15, 2017 - Completed)

- Karen Murphy's presentation to the May Terrestrial Ecosystems Collaboration Team
  meeting titled "Recent and upcoming activities advancing understanding & response to
  climate impacts in western Alaska" is relevant to this Performance Element
  http://www.iarpccollaborations.org/members/events/7689. (Jul 24, 2017 - Completed)

- Alison York's presentation at the June Terrestrial Ecosystems Collaboration Team
  meeting titled "Alaska Fire Science Consortium Remote Sensing Workshop Outcomes" is
  relevant to this Performance Element
  http://www.iarpccollaborations.org/members/events/7801. (Jul 24, 2017 - Completed)
7.1.3 (In progress) Facilitate and harmonize the production, integration, and distribution of key geospatial datasets from remotely-sensed and other data sources that are needed for monitoring key ecosystem processes and landscape changes and for model initialization, calibration, and validation.; NASA (Lead), DOE, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS

- NASA’s ABoVE project supported this PE in the following ways:
  - Preliminary & Public & Archived Data products: Vegetation dynamics: P-Band SAR Products
    - https://above.nasa.gov/profiles_/above_products.html?projType=product&projID=1117&progID=6: CFIS SIF solar induced fluorescence products
    - https://above.nasa.gov/profiles_/above_products.html?projType=product&projID=1090&progID=6: LVIS-derived Vegetation Height Quicklook Product
    - https://above.nasa.gov/profiles_/above_products.html?projType=product&projID=772&progID=6: AirSWOT DCS Camera Imagery and Open Water Map
  - Active layer thickness: Still in development

b. Data from the 2017 airborne campaign are still being analyzed. In summer 2018 another L-band radar campaign was conducted, as well as hyperspectral and laser-altimetry sorties. (Sep 27, 2018 - Completed)

- ABoVE contributed to this Performance Element in the following ways:
a. A number of new information products have or are being generated for the ABoVE Study domain, including vegetation dynamics from Landsat, fire products from Landsat and MODIS, pond and lake area change products from Landsat, forest and shrub cover products in tundra/taiga transition areas from Landsat and fine resolution satellite imagery, active layer thickness products from spaceborne SAR data, and DEM products from fine resolution satellite imagery. (Sep 15, 2017 - Completed)

- Presentations by Tatiana Loboda, Elizabeth Hoy, and Jan Eitel at the July Terrestrial Ecosystems Collaboration Team meeting on satellite-based data products for Arctic and Boreal biomes from the ABoVE campaign are relevant to this Performance Element. (http://www.iarpccollaborations.org/members/events/7802) (Jul 21, 2017 - Completed)

7.1.4 (In progress) Improve existing and develop advanced models for integrating climate, disturbance, above- and below-ground dynamics and interactions to characterize and predict Arctic landscape and ecosystem change.; DOE (Lead), NSF (Lead), DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NASA

- NASA’s ABoVE project supported this PE in the following ways:

  The work described in 2017 continues (including: Research continues on using the information derived from field-based research and new geospatial information products to improve models of key terrestrial ecosystem processes).

  Publications:


- The presentations by Rick Thoman (NOAA) and Christopher Hiemstra (CRREL) at the October Terrestrial Ecosystems Collaboration Team Meeting on snow drought and seasonal outlook is relevant to this Performance Element (https://www.iarpccollaborations.org/members/events/7808) (Nov 13, 2017 - Completed)

- NGEE Arctic continued the development of fine, intermediate, and climate-scale models based upon field research sponsored by DOE. (Oct 4, 2017 - Completed)
- ABoVE contributed to this Performance Element in the following ways: a. Research continues on using the information derived from field-based research and new geospatial information products to improve models of key terrestrial ecosystem processes (see INPUTS from WORKING GROUP) (Sep 15, 2017 - Completed)

7.2 Advance understanding of how changes to ecosystems alter animal and plant populations and their habitats and subsistence activities that depend on them.

- 7.2.1 (In progress) Coordinate the development of maps from remotely-sensed data and synthesize available data to document changing plant, fish, and terrestrial animal populations and their habitats.; DOI-FWS (Lead), DOI-USGS (Lead), DOI-BLM, DOI-NPS, NASA

- NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues (data products on changes to wildlife habitat are being developed, including changes in habitat in the Yukon Flats and Yukon-Kuskokwim Delta, caribou habitat in numerous locations, and Dall Sheep habitat across its entire range.). Archived data products: ABoVE: Dall Sheep Response to Snow and Landscape Covariates, Alaska, 2005-2008
  https://above.nasa.gov/profiles_/above_products.html?projType=product&projID=1097 &progID=6; ABoVE: Dall Sheep Track Sinking Depths, Snow Depth, Hardness, and Density, 2017
  https://above.nasa.gov/profiles_/above_products.html?projType=product&projID=1094 &progID=6 (Sep 27, 2018 - Completed)

- Beavers May Affect Landscape and Ecosystem Processes in the Arctic: A recent publication "Tundra be dammed: Beaver colonization of the Arctic" describes a remote sensing approach to identifying beaver colonization of Arctic Alaska and the potential changes to stream ecosystems associated with beaver colonization. The Landsat and high-resolution time series imagery analysis revealed that beavers have colonized the arctic tundra of northwestern Alaska between 1999 and 2014. Beaver ponds and associated hydrologic changes are thawing permafrost. Pond formation increases winter water temperatures in the pond and downstream, likely creating new and more varied aquatic habitat, but specific biological implications are unknown. Beavers create dynamic wetlands and are agents of disturbance that may enhance ecosystem responses to warming in the Arctic. The striking changes caused by beavers create a management challenge as the ecosystem properties and resources of tundra streams are modified by the influx of beavers. Citation: Tape, K. D. B. M. Jones, C. D. Arp, I. Nitze, and G. Grosse. 2018. Tundra be dammed: Beaver colonization of the Arctic. Global change biology. DOI: 10.1111/gcb.14332 (https://doi.org/10.1111/gcb.14332) (Aug 20, 2018 - Completed)

- At the November 2017 TECT meeting (https://www.iarpccollaborations.org/members/events/7806) Eric Kasischke (NASA) proposed a new activity for the TECT which will focus on synthesizing ground and satellite data to measure vegetation change in the Arctic. The need for this work to be started was agreed upon and mechanism through which the project could be started were discussed. Participants for the working group and known information on datasets was solicited

Overview of proposed activity – Eric Kasischke (NASA)
Discussion of available data sets – Howard Epstein (University of Virginia) and Amy Breen (UAF)
Satellite observations documenting vegetationgreening and browning
Satellite observations that can be used to further understand patterns of green and browning
Field observations in boreal and tundra regions to study causes of greening and browning

Discussion – Is there enough interest in moving forward? – Michelle Mack (Northern Arizona University). Online space for Vegetation Working Group- Jessica Rohde (IARPC) (Nov 30, 2017 - Completed)

- ABoVE contributed to this Performance Element in the following ways:
  - A number of data products on changes to wildlife habitat are being developed, including changes in habitat in the Yukon Flats and Yukon-Kuskokwim Delta, caribou habitat in numerous locations, and Dall Sheep habitat across its entire range. (Sep 15, 2017 - Completed)

- 7.2.2 (In progress) Compare trends in aquatic and terrestrial animal populations and movementswith changing patterns of vegetation cover, lake, pond, and wetland extent and characteristics determine whether and how shifting habitats are influencing animal behaviors and population dynamics.; DOI-FWS (Lead), DOI-BLM, DOI-NPS, DOI-USGS, NASA, NSF
  - NGEE Arctic generated data products that characterize lakes and ponds across Arctic landscapes in Alaska. (Oct 4, 2017 - Completed)
  - Shrinking lakes were recently observed for several Arctic and Subarctic regions due to increased evaporation and permafrost degradation. Along with lake drawdown, these processes often boost aquatic chemical concentrations, potentially impacting trophic dynamics. In particular, elevated chemical levels may impact primary productivity, which may in turn influence populations of primary and secondary consumers. The U.S. Geological Survey, the U.S. Fish and Wildlife Service, and university partners examined trophic dynamics of 18 shrinking lakes of the Yukon Flats, Alaska, that had experienced pronounced increases in nutrient (>200 % total nitrogen, >100 % total phosphorus) and ion concentrations (>100 % for four major ions combined) from 1985-1989 to 2010-2012, versus 37 stable lakes with relatively little chemical change over the same period. We found that phytoplankton stocks, as indexed by chlorophyll concentrations, remained unchanged in both shrinking and stable lakes from the 1980s to 2010s. Moving up the trophic ladder, we found significant changes in invertebrate abundance across decades, including decreased abundance of five of six groups examined. However, these decadal losses in invertebrate abundance were not limited to shrinking lakes, occurring in lakes with stable surface areas as well. At the top of the food web, we observed that probabilities of lake occupancy for ten waterbird species, including adults and chicks, remained unchanged from the period 1985-1989 to 2010-2012. Overall, our study lakes displayed a high degree of resilience to multi-trophic cascades caused by rising chemical concentrations. This resilience was likely due to their naturally high fertility, such that further nutrient inputs had little impact on waters already near peak production. Citation: Lewis, T. L., P. J. Heglund, M. S. Lindberg, J. A. Schmutz, J. H.


USGS-led Study of Surface Water Connectivity and Richness and Composition of Fish in the Arctic: Surface water connectivity can influence the richness and composition of fish assemblages, particularly in harsh environments where colonisation factors and access to seasonal refugia are required for species persistence. To increase understanding of how surface water connectivity and related hydrologic variables influence assemblage patterns, the U.S. Geological Survey, Bureau of Land Management, and collaborators investigated species richness and composition of Arctic lake fishes over a large region, 8500 km2, of the central Arctic Coastal Plain, Alaska. We collected fish presence/non-detection data from 102 lakes and used a hierarchical multispecies occupancy framework to derive species richness and inform species composition patterns. Presence of a permanent channel connection was an overriding factor affecting species richness, presumably driving lake colonisation potential. In lakes without a permanent channel connection, data suggest richness increased with the availability of in-lake winter refugia and with the potential of ephemeral connections during spring floods. Fish species functional traits and environmental faunal filters contributed to patterns of richness and assemblage composition. Composition corresponded with richness in a coherent manner, where each successive level of richness contained several discrete assemblages that showed similar responses to the environment. Lakes with permanent channel connections contained both widespread and restricted species, while the species-poor lakes that lacked a connection contained mainly widespread species. This work provides useful baseline information on the processes that drive the relations between patch connectivity and fish species richness and assemblage composition. The environmental processes that organise fish assemblages in Arctic lakes are likely to change in a warming climate. Citation: Laske, S. M., T. B. Haynes, A. E. Rosenberger, J. C. Koch, M. S. Wipfli, M. Whitman, and C. E. Zimmerman. 2016. Surface water connectivity drives richness and composition of Arctic lake fish assemblages. Freshwater biology. doi:10.1111/fwb.12769

USGS-led Study of Temperature Shifts, Vegetation, and Caribou Response in the Arctic: Climate-induced shifts in plant phenology may adversely affect animals that cannot or do not shift the timing of their reproductive cycle. We evaluated the long-term changes in the temperatures and characteristics of the growing seasons (1970–2013), and compared growing conditions and dynamics of forage quality for Central Arctic caribou at peak parturition, peak lactation, and peak forage biomass, and plant senescence.
between two distinct time periods over 36 years (1977 and 2011–13). Despite advanced thaw dates (7–12 days earlier), increased growing season lengths (15–21 days longer), and consistent parturition dates, we found no decline in forage quality and therefore no evidence within this dataset for a trophic mismatch at peak parturition or peak lactation from 1977 to 2011–13. In Arctic ungulates that use stored capital for reproduction, reproductive demands are largely met by body stores deposited in the previous summer and autumn, which reduces potential adverse effects of any mismatch between food availability and timing of parturition. Climate-induced effects on forages growing in the summer and autumn ranges, however, do correspond with the demands of female caribou and their offspring to gain mass for the next reproductive cycle and winter. Therefore, we suggest the window of time to examine the match-mismatch framework in Arctic ungulates is not at parturition but in late summer-autumn, where the multiplier effects of small changes in forage quality are amplified by forage abundance, peak forage intake, and resultant mass gains in mother-offspring pairs. Citation: Gustine, D. D., P. S. Barboza, L. G. Adams, B. Griffith, R. D. Cameron, and K. R. Whitten. 2017. Advancing the match-mismatch framework for large herbivores in the Arctic: Evaluating the evidence for a trophic mismatch in caribou. PLoS One 12(2):e0171807. doi:10.1371/journal.pone.0171807

U.S. Geological Study on Bird Response to Changing Habitats in the Arctic: Climate change is facilitating rapid changes in the composition and distribution of vegetation at northern latitudes, raising questions about the responses of wildlife that rely on arctic ecosystems. One widely observed change occurring in arctic tundra ecosystems is an increasing dominance of deciduous shrub vegetation. Our goals were to examine the tolerance of arctic-nesting bird species to existing gradients of vegetation along the boreal forest-tundra ecotone, to predict the abundance of species across different heights and densities of shrubs, and to identify species that will be most or least responsive to ongoing expansion of shrubs in tundra ecosystems. We conducted 1,208 point counts on 12 study blocks from 2012-2014 in northwestern Alaska, using repeated surveys to account for imperfect detection of birds. We considered the importance of shrub height, density of low and tall shrubs (i.e. shrubs >0.5 m tall), percent of ground cover attributed to shrubs (including dwarf shrubs <0.5 m tall), and percent of herbaceous plant cover in predicting bird abundance. Among 17 species considered, only gray-cheeked thrush (Catharus minimus) abundance was associated with the highest values of all shrub metrics in its top predictive model. All other species either declined in abundance in response to one or more shrub metrics or reached a threshold where further increases in shrubs did not contribute to greater abundance. In many instances the relationship between avian abundance and shrubs was nonlinear, with predicted abundance peaking at moderate values of the covariate, then declining at high values. In particular, a large number of species were responsive to increasing values of average shrub height with six species having highest abundance at near-zero values of shrub height and abundance of four other species decreasing once heights reached moderate values (≤ 33 cm). Our findings suggest that increases in shrub cover and density will negatively affect abundance of only a few bird species and may potentially be beneficial for many others. As shrub height increases further, however, a considerable number of tundra bird species will likely find habitat increasingly unsuitable. Citation: Thompson, S. J., C. M. Handel, R. M. Richardson, and L. B. McNew. 2016. When winners become losers: Predicted nonlinear responses of arctic birds to

- **7.2.3 (In progress) Incorporate scientific observations and the perspectives of IK and/or LK knowledge holders into assessments of how changing Arctic ecosystems, flora, and fauna are affecting important subsistence activities, lifestyles, and wellbeing of northern residents.; DOI-FWS (Lead), DOI-BIA, DOI-BLM, DOI-NPS, DOI-USGS, NASA

  - NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues (described last year as: ABoVE NASA has established research collaborations with a large number regional government scientists and have made presentation of research results to local communities. In order to incorporate LK and IK into the ongoing research projects, NASA-sponsored researchers have discussed observations of environment change with community elders in Bethel, Alaska, with community members in Emmonak, Alaska, and established an environmental monitoring station at the Meade River School in Atqasuk, Alaska.). See projects: Brinkman: : Biophysical Characteristics and Mechanisms of Environmental Disturbances Influencing Human Access to Ecosystem Services in Boreal Alaska https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3380 &progID=6 Frost: Biophysical drivers and socio-ecological impacts of environmental change in the Yukon-Kuskokwim Delta region, western Alaska https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3397 &progID=6 (Sep 27, 2018 - Completed)

  - Over the past year, through ABoVE NASA has established research collaborations with a large number regional government scientists and have made presentation of research results to local communities. In order to incorporate LK and IK into the ongoing research projects, NASA-sponsored researchers have discussed observations of environment change with community elders in Bethel, Alaska, with community members in Emmonak, Alaska, and established an environmental monitoring station at the Meade River School in Atqasuk, Alaska. (Sep 27, 2017 - Completed)

**7.3 Evaluate how changes in fire activity are impacting rural and urban communities, and atmospheric emissions and carbon budgets and other feedbacks to climate.**

- **7.3.1 (In progress) Evaluate how changing fire regimes have and are likely to impact northern communities, via impacts to infrastructure, health, and subsistence opportunities.; DOI-BLM (Lead), DOI-BIA, DOI-FWS, DOI-NPS, DOI-USGS, NASA, NSF, USDA-USFS

  - NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 (as: Research is being conducted on how changes to ecosystem and environmental conditions caused by wildfires are impacting access to ecosystem services in Interior Alaska. This research involves collaborations with subsistence harvesters) continues. See project: Brinkman: Biophysical Characteristics and Mechanisms of Environmental Disturbances Influencing Human Access to Ecosystem Services in Boreal Alaska https://above.nasa.gov/profiles_/above_projects.html?projType=project&projID=3380 &progID=6 (Sep 27, 2018 - Completed)

  - The TECT and AOSST May 2018 meeting focused on observing system applications & gaps for wildfire smoke detection & forecasting (https://www.iarpccollaborations.org/members/events/10647). This meeting reviewed and built upon recent work and initiated a resource mapping visualization exercise to
describe how different observing systems supports the range of detection and forecasting applications critical to Alaskan health and well-being that was met with community support. Presentations: Read Out of JPSS Arctic Summit - Fire and Smoke Initiative (Bill Sjoberg (NOAA)); Visualization Mapping Exercise (Sandy Starkweather) (May 16, 2018 - Completed)

- The September joint meeting on the health impacts of wildfires in the Arctic by the Health & Well-being CT, Atmosphere CT, and Terrestrial Ecosystems CT (https://www.iarpccollaborations.org/members/events/9144) began a cross-team conversation on places for potential interdisciplinary/interagency collaborations. Follow-up actions will be reported as they occur. (Sep 25, 2017 - Completed)

- ABoVE contributed to this Performance Element in the following ways:
  a. Research is being conducted on how changes to ecosystem and environmental conditions caused by wildfires are impacting access to ecosystem services in Interior Alaska. This research involves collaborations with subsistence harvesters. (Sep 15, 2017 - Completed)

- Alison York's presentation at the June Terrestrial Ecosystems Collaboration Team meeting titled "Alaska Fire Science Consortium Remote Sensing Workshop Outcomes" is relevant to this Performance Element http://www.iarpccollaborations.org/members/events/7801. (Jul 24, 2017 - Completed)

- 7.3.2 (In progress) Coordinate research on the observations, geospatial dataset generation, and model improvement needed to estimate emissions from wildland fires and the potential for those emissions to affect atmospheric carbon budgets and climate feedbacks.; NASA (Lead), DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NSF, USDA-USFS

  - The National Science Foundation (NSF) has recently awarded OPP – 1822406. Tundra wildfire occurrences have increased in coastal Greenland, setting a new record in summer 2017. This project focuses on the study of emissions from arctic tundra wildfires. Chemical tracers of wildfires, including carbon monoxide, methane, and a series of volatile organic compounds will be monitored in the atmosphere at the Greenland Environmental Observatory at Summit. This project will deliver continuous high time resolution data for wildfire emission and climate forcing atmospheric constituents. Data analyses and modeling will improve assessments of fire emissions and their environmental and climate impacts. (Oct 15, 2018 - Completed)

  - NASA’s ABoVE project supported this PE in the following ways: The work described in 2017 continues.
    a. Publication: Walker, X. J, et al. 2018. Cross-scale controls on carbon emissions from boreal forest mega-fires. Global Change Biology. doi: 10.1111/gcb.14287. 2017 inputs described work as: Field-based observations of ground-layer fuel consumption were carried out at multiple sites. A workshop was convened to develop a plan to integrate these measurements with others data collected in the ABoVE Study Domain in order to improve models of greenhouse gas and particulate matter emissions from wildland fires.
data products needed to quantify burned area and fuel loads have or are being developed for Alaska and other portions of the ABoVE Study domain.

c. Work described in 2017 continues (field observations and geospatial products are being used to improve wildland fire emission models). (Sep 27, 2018 - Completed)

- The January 2018 TECT and AOSST meeting focused on wildfire smoke and human health nexus (https://www.iarpccollaborations.org/members/events/10620). There were no formal presentations during this meeting. Instead, several voices from the community discussed what is being done to address wildfire smoke health impacts and where there is space for further work. The meeting sought to answer 4 key questions: What activities are ongoing in this realm? Do IARPC members see value in collaboration on this issue through IARPC? If so, what are our next steps? How can observations from different agencies/across scales be better coordinated and utilized to advance collaborative goals. (Jan 30, 2018 - Completed)

- ABoVE contributed to this Performance Element in the following ways: a. Field-based observations of ground-layer fuel consumption were carried out at multiple sites. A workshop was convened to develop a plan to integrate these measurements with others data collected in the ABoVE Study Domain in order to improve models of greenhouse gas and particulate matter emissions from wildland fires. b. New geospatial data products needed to quantify burned area and fuel loads have or are being developed for Alaska and other portions of the ABoVE Study domain. c. The field observations and geospatial products are being used to improve wildland fire emission models. (Sep 15, 2017 - Completed)

- Presentations by Tatiana Loboda, Elizabeth Hoy, and Jan Eitel at the July Terrestrial Ecosystems Collaboration Team meeting on satellite-based data products for Arctic and Boreal biomes from the ABoVE campaign are relevant to this Performance Element. (http://www.iarpccollaborations.org/members/events/7802) (Jul 21, 2017 - Completed)

- Alison York's presentation at the June Terrestrial Ecosystems Collaboration Team meeting titled "Alaska Fire Science Consortium Remote Sensing Workshop Outcomes" is relevant to this Performance Element http://www.iarpccollaborations.org/members/events/7801. (Jun 16, 2017 - Completed)

**Agencies**
DOC, DOD, DOE, DOI, NASA, NSF, OSTP, USARC, USDA
Coastal Resilience Collaboration Team

Performance Element Reporting Log FY2018

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8.1 Coastal Resilience

8.1 Engage coastal communities in research and advance knowledge on cultural, safety, and infrastructure issues for coastal communities.

- 8.1.1 (In progress) Engage coastal community members in research by seeking cooperative opportunities between community members, IK holders, and/or LK holders, and researchers in knowledge co-production research processes. Employ IK and/or LK to jointly conceive of and plan research activities and to report research results back to communities.; DOI-BLM (Lead), DOI-BOEM (Lead), DOI-FWS (Lead), EPA (Lead), NOAA (Lead), NSF (Lead), DHS, DOI-NPS, DOI-USGS
  
  o The National Science Foundation (NSF) has recently awarded OPP – 1836473. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. The project will co-produce shorefast ice knowledge by leveraging large satellite remote sensing datasets, community-based monitoring, and local and Indigenous knowledge. The quantitative and qualitative shorefast ice knowledge collected will be used to understand how shorefast ice has changed and how these changes matter to individuals and communities in the Uummannaq region. The involvement of residents and institutions in Uummannaq at all stages of the project, in combination with ongoing observations, will lay the foundations for ongoing community support and enable new insights into the complex social, cultural and economic changes caused by rapid environmental change. (Oct 16, 2018 - Completed)

  o USGS Teaches Sessions for Alaska Native Science and Engineering Program’s Middle School Academy. USGS Alaska Center scientists John Pearce, Brandt Meixell, and Ric Wilson will conduct learning sessions for students in the Middle School Academy, which is part of the Alaska Native Science and Engineering Program (ANSEP). Three sessions will be presented on October 12, in Anchorage, Alaska, for over fifty 6th through 8th grade students from the Northwest Arctic Borough School District. Pearce and Meixell will use materials from recent USGS research on what types of disturbances (e.g., people, vehicles, aircraft) cause the greatest disturbance to Arctic-nesting geese in Alaska. This learning session is based on a publication released in 2017 (https://doi.org/10.1002/jwmg.21312) by USGS Alaska Science Center. More information on the study can also be found here: https://www.alaskapublic.org/2018/02/28/what-can-geese-teach-us-about-the-future-of-arctic-development/. Wilson will provide an overview of Alaska’s geology and geomorphology focusing on the geology of the Northwest Arctic Borough as it relates to permafrost, mineral and energy exploration, and development. More about ANSEP can be found here: http://www.ansep.net/ Contact: John Pearce, Anchorage, AK, (907) 786-7094. (Oct 15, 2018 - Completed)
BOEM and the North Slope Borough have a multi-year cooperative agreement, Traditional Knowledge Implementation: Accessing Panels of Subject Matter Experts to systematically incorporate Traditional (Indigenous) Knowledge from community members through co-production of knowledge and sharing with western scientists. (Oct 2, 2018 - Completed)

The National Science Foundation (NSF) has recently awarded OPP – 1803494. This award will support a long-term collaborative archaeological project with the community of Tuyuryaq (Togiak), Alaska. This project redefines the cultural landscape utilizing a developing field of Indigenous archaeology with the specific community-based approach, placing value and focus on community while contributing to a better understanding of a coastal sub-arctic village and the peoples’ relationships to the landscape including plants and terrestrial and marine resources. This project will further develop knowledge coproduction methods between scientists and community members within an archaeological framework. This project takes a place-based inclusive approach that advances youth access to education in the sciences and beyond and supports a newly established cultural center which will curate the materials resulting from the research. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1733578. This award supports scientific research by anthropologists, geographers, and atmospheric scientists to understand the relationship between how weather is normally measured and the factors that Arctic Indigenous peoples need to travel and work out of doors. In the same way that wind-chill, a combination of temperature and wind speed has become a commonly used composite of weather information used by many Americans, for Inuit visibility and sea-state are critical factors in whether to travel or stay put. For example, visibility is a product of cloud cover, wind, snow conditions, terrain, and more. The research team will seek to quantify factors and test them through camps for Elders and youth. In turn, the Elders and youth will train scientists about the nuanced nature of safely and successfully traveling and working in the Arctic. If successful, the team plans to share the factors with forecast agencies and others to increase the production of actionable knowledge. (Sep 21, 2018 - Completed)

BOEM Publication on Use of Traditional Knowledge: Professionals who collect and use traditional knowledge to support resource management decisions often are preoccupied with concerns over how and if traditional knowledge should be integrated with science. To move beyond the integration dilemma, we treat traditional knowledge and science as distinct and complementary knowledge systems. We focus on applying traditional knowledge within the decision-making process. We present succinct examples of how the Bureau of Ocean Energy Management has used traditional knowledge in decision making in the North Slope Borough, Alaska: 1) using traditional knowledge in designing, planning, and conducting scientific research; 2) applying information from both knowledge systems at the earliest opportunity in the process; 3) using traditional knowledge in environmental impacts assessment; 4) consulting with indigenous leaders at key decision points; and 5) applying traditional knowledge at a programmatic decision level. Clearly articulating, early in the process, how best to use traditional knowledge and science can allow for more complete and inclusive use of available and pertinent information. Citation: Kendall, J.J. et al., 2017, Use of traditional knowledge by the United States Bureau of Ocean Energy Management to support
Jeffrey Brooks with BOEM Alaska will serve as a federal observer on a 2018 CAFF (Arctic Council) workshop, entitled Salmon Peoples of Arctic Rivers. This workshop is supported by U.S. Fish and Wildlife Service, CAFF, Department of Political Science at the College of Charleston, and others. The workshop is focused on hearing stories and traditional knowledge of indigenous salmon harvesters in the Arctic. The invited participants are traditional knowledge holders whose stories most likely hold important insights for future salmon management. This is a preliminary effort that could lead to future meetings and TK studies. (Sep 7, 2018 - Completed)

USGS and USFWS Attend the Waterfowl Conservation Committee Meeting in Bethel, Alaska: Scientists and others from USGS and USFWS will attend the Association of Village Council Presidents Waterfowl Conservation Committee (WCC) on August 29-30th, 2018, in Bethel, Alaska. The WCC is a Yukon-Kuskokwim Delta regional group of the state-wide Alaska Migratory Bird Co-Management Council and discusses issues of migratory bird regulations, subsistence harvest, and scientific research to inform local residents and obtain their feedback on these activities. USFWS will also provide an update on investigations into recent sea bird mortality events in the Bering Sea. (Aug 23, 2018 - Completed)

February 6th, 2018, noon - 1 pm, Anchorage, Alaska, Documenting local knowledge of changing wildlife habitats and adaptive considerations of large mammal hunters to the effects of climate change in Alaska Game Management Units 9B-C, 17, 18 and 19A-C. James M. Van Lanen, Subsistence Resource Specialist, Alaska Department of Fish & Game. Participatory landscape mapping is an effective method for documenting geospatially specific local ecological knowledge of changing wildlife habitats and environmental conditions. This presentation will highlight results from a recent Western Alaska Landscape Conservation Cooperative-funded project focused on mapping local knowledge of caribou behavior dynamics in relation to ecological change in Alaska Game Management Units 9B-C, 17, 18, and 19A-C, over the course of five decades. The primary adaptive considerations of subsistence hunters facing changing environmental conditions are access and prey-switching. Resilience within the human-large-land-mammal-subsistence-system depends on hunters being flexible in regard to access methods and targeted prey species, and on resource managers’ flexibly adapting legal hunting seasons to times when local travel conditions are optimal. (Aug 20, 2018 - Completed)

Seaweed/macroalgae is a foundational species and ecosystem engineer, providing habitat, nursery, forage grounds and refuge for migratory and coastal marine species. In Iceland, a coastal community also depends on the resource to thrive. To help inform the establishment of sustainable seaweed fisheries policy, a total biomass has been estimated by scientific methods. However, according to the local community, the harvestable biomass is very limited. This master’s thesis research focuses on understanding the connections between society and ecology surrounding rockweed; and documenting the local knowledge and observations of the seaweed harvesters and a local coastal community to inform policy for sustainable seaweed use. The results highlight the importance of continuous collaboration and co-production of knowledge between science and the local communities. See recording at...
The May CRCT meeting focused on "Exploring Research that uses Co-production of Knowledge Processes" (https://www.iarpccollaborations.org/members/events/10635). Presentations: Lightning Talk: Applying Local Knowledge to Sustainable Use Policy of Seaweed in Iceland - Jamie Lee (University center of the Westfjords); Bridging the Scientific and Indigenous Communities to Study Sea Ice Change in Arctic Alaska - Andy Mahoney (UAF) and Cyrus Harris (Maniilaq Association). Take-aways: "When working with communities it is important to set aside egos and defer... Things will go smoother and safer." - Alex Whiting, Kotzebue (Native Village of Kotzebue). "Collaboration in the hypothesis development stage was everyone I had hoped for" - Andy Mahoney, Fairbanks (UAF). "I [appreciate being included] in these presentations" - Cyrus Harris, Kotzebue (Maniilaq Association). Andy's summary: Early community engagement promotes effective integration of indigenous knowledge - Engage Early and Often! Indigenous knowledge holders can enable new knowledge through co-design of hypotheses - Questions you would never think to ask! Co-produced knowledge must be shared - What story do the data tell? (Jun 22, 2018 - Completed)

The May 2018 CRCT meeting focused on understanding the Arctic through a co-production of knowledge framework (https://www.iarpccollaborations.org/members/events/11335). There was discussion on the nature and source of distrust among indigenous Peoples and researchers as well as ways to restructure systems to facilitate co-production processes. See notes and recordings for more details. Presentations: Understanding the Arctic Through a Co-Production of Knowledge (Julie Raymond-Yakoubian (Kawerak), Raychelle Daniel (Pew), Carolina Behe (ICC-Alaska)) (May 30, 2018 - Completed)

Cathy Coon's (BOEM) presentation at the 2/28/2018 MECT meeting (https://www.iarpccollaborations.org/members/milestones/2755) is relevant to this performance element: https://www.iarpccollaborations.org/members/documents/10985 (Mar 19, 2018 - Completed)

BOE M has entered into a multiyear cooperative agreement, Traditional Knowledge Implementation: Accessing Arctic Community Panels of Subject Matter Experts with the North Slope Borough Department of Wildlife Management. Co-PI's are Qaiyaan Harcharek and Robert Suydam. (Sep 21, 2017 - Completed)

USGS and USFWS Present at the Waterfowl Conservation Committee: USGS Alaska Science Center and USFWS Yukon Delta National Wildlife Refuge scientists attended the Association of Village Council Presidents Waterfowl Conservation Committee (WCC) on Friday, September 15, 2017 in Bethel, Alaska. The WCC is a Yukon-Kuskokwim Delta regional group of the state-wide Alaska Migratory Bird Co-management Council and discusses issues of migratory bird regulations, subsistence harvest, and needed information by both residents and agencies. The USGS and USFWS gave a presentations on status of waterfowl populations on the Delta and long-term research on annual survival and avian influenza prevalence in Emperor Goose on the Yukon-Kuskokwim Delta as well as an update of a collaborative studies on how use of different Aleutian
Island wintering areas by Emperor geese may influence their nesting success and survival.

- USGS Research Updates to the North Slope Borough Planning and Wildlife Management Departments. On June 12th, 2017, John Pearce provided updates of planned and on-going terrestrial ecosystems research by the USGS to the North Slope Borough Planning and Wildlife Management Departments in Utqiagvik. Participants were informed of USGS research projects, how those projects are conducted to reduce disturbance to coastal subsistence activities, and sought feedback from participants on current and future research activities. Opportunities for joint workshops and future informational meetings were discussed.

- USGS Attends North Slope Borough Planning Commission Meeting: USGS Supervisory Wildlife Biologist John Pearce was invited to present at the North Slope Borough Planning Commission Meeting on August 31st in Utqiagvik, Alaska, and provide an update on USGS research in the National Petroleum Reserve - Alaska (NPR-A) that may have implications for North Slope Borough’s planning and permitting actions in the NPR-A. Included in Pearce’s presentation was a discussion of a recent USGS Alaska Science Center paper on the response of Arctic-nesting geese to industrial and investigator disturbance. More information on that research can be found at the USGS technical release here: https://www.usgs.gov/news/wildlife-cameras-offer-insight-geese-industry-and-researchers-arctic.

- The CRCT meeting on May 3rd addressed this Performance Element by beginning the meetings of the newly formed CRCT by engaging diverse participants and soliciting input from Arctic communities for their thoughts on Performance Element interpretation and research needs: http://www.iarpccollaborations.org/members/events/7686. Meredith is keeping track of the action items recorded in the team meeting notes: http://www.iarpccollaborations.org/members/documents/9209 (Aug 28, 2017 - Completed)

- 8.1.2 (In progress) Engage coastal community members in research by supporting community-based monitoring focused on measuring physical and biotic information by strengthening initiatives led by groups such as the Arctic-focused LCCs, BOEM, NOAA, and FWS.; DOI-BOEM (Lead), DOI-FWS (Lead), NOAA (Lead), NSF

- The National Science Foundation (NSF) has recently awarded OPP – 1836473. This proposal was funded as part of NSF’s Navigating the New Arctic Big Idea. The project will co-produce shorefast ice knowledge by leveraging large satellite remote sensing datasets, community-based monitoring, and local and Indigenous knowledge. The quantitative and qualitative shorefast ice knowledge collected will be used to understand how shorefast ice has changed and how these changes matter to individuals and communities in the Uummannaq region. The involvement of residents and institutions in Uummannaq at all stages of the project, in combination with ongoing observations, will lay the foundations for ongoing community support and enable new insights into the complex social, cultural and economic changes caused by rapid environmental change. (Oct 16, 2018 - Completed)

- Community-based monitoring of non-salmon fish, migratory waterfowl and environmental observation on natural resources across the boreal forest of the Yukon and Kuskokwim River regions of Interior Alaska. The U.S. Fish & Wildlife Service is
supporting a project with the Bureau of Indian Affairs and Tanana Chiefs Conference to support development of a community-based monitoring program. This project focuses on the Yukon and Upper Kuskokwim River drainages in interior Alaska, and is part of a larger vision for a community-based monitoring program extending from the Yukon River headwaters to the Bering Sea. A mobile-device app is being designed for use by rural community members to record and archive observations on fish, migratory waterfowl, and environmental changes. The app is based upon the tools used as part of the successful BeringWatch program developed by coastal tribes and is expected to facilitate additional information sharing among interior and coastal communities.

Northern Alaska Sea Ice Project Jukebox, Phase III: This project created ten oral history interviews with one sea ice scientist and twelve residents of Kotzebue, Utqiaġvik (formerly known as Barrow), Point Hope, Wainwright and Wales, Alaska, about their observations of changing sea ice conditions. The interviews were added to the archives and website interface of the Northern Alaska Sea Ice Project Jukebox, a longitudinal qualitative project where recorded observations of changing sea ice in Barrow previously spanned a time period from 1978 to 2013. The inclusion of recordings from residents of Kotzebue, Point Hope, Wainwright, and Wales will serve as a benchmark of observations from those communities. Understanding how the sea ice is changing on the outer continental shelf area around these communities will support future development and management of resources. Additionally, photo and video galleries that show various ice conditions and features were added to the Northern Alaska Sea Ice Project Jukebox website (http://jukebox.uaf.edu/site7/). Citation: McCartney, L., Brewster, K. 2018. Northern Alaska Sea Ice Project Jukebox: Phase III. Final Report. OCS Study BOEM 2018-027. https://www.boem.gov/BOEM-2018-027/ (Sep 7, 2018 - Completed)

The following presentations delivered at the September 5th 2018 Coastal Resilience Collaboration Team Meeting are relevant to this Performance Element (https://www.iarpccollaborations.org/members/events/10637). Sea stars are a visible species for coastal communities and an indicator of other changes in the marine environment. Sea star wasting disease is a problem over a large area of the west coast. The public is interested to know more and researchers are interested to know what those living on the coast have observed. The essence of good communications -- Sharing, Listening, Learning: Maggie Mooney-Seus (NOAA National Marine Fisheries Service) Update on Gulf Watch Program and surveys for sea star wasting disease: Heather Coletti (National Park Service) Community involvement in “A Collaborative Strategic Action Plan” for research and management of sea star wasting disease: Sarah Gravem (Oregon State University) (Sep 5, 2018 - Completed)

Scientists Establish Long-term Ecological Monitoring Sites in the Yukon-Kuskokwim Delta of Western Alaska: Scientists with USGS and US Forest Service installed remote, automated weather stations in the Tribal Villages of Chevak and Kotlik in the Yukon-Kuskokwim Delta of western Alaska as part of a growing network of long-term ecological monitoring sites established in this rapidly-changing region. The weather stations and monitoring sites, installed in collaboration with local scientists from the Chevak Traditional Council and the Kotlik Tribal Council, will be used by local villages to monitor changing environmental conditions relevant to subsistence activities. The sites are co-located with USGS-Yukon River Inter-Tribal Watershed Council Active Layer Network
grid sites where permafrost monitoring has taken place since 2009. These sites will allow researchers to relate changes in vegetation, permafrost, erosion, wildlife habitat, and other landscape attributes to changes in seasonal weather patterns and long-term climate. Data will then be used to build models to project further changes to landscapes, subsistence resources, and communities in the coming decades. (Contact: Rachel Loehman, 907-786-7089, Anchorage, AK). USGS Researchers Collaborate to Document Landscape and Subsistence Changes in the Yukon-Kuskokwim Delta, Alaska: USGS scientists Nicole Herman-Mercer and Rachel Loehman in collaboration with the Chevak Traditional Council recently held a series of workshops focused on landscape change in the Alaska Native Village of Chevak in the Yukon-Kuskokwim Delta region. Workshop participants ranging in age from 18 to 86 described observed landscape changes and identified the impacts of those changes to subsistence, health and safety, infrastructure, and the local economy. Additionally, participants identified the location of specific landscape changes such as erosion, permafrost thaw, and changing vegetation on maps. These workshops allow USGS researchers to document slow moving changes that cannot be identified through traditional methods as historical baseline data and imagery is sparse in this region. The findings from these workshops will enable researchers to investigate causes of landscape change and make recommendations to the Traditional Council and the community about anticipated future changes as well as identify gaps in existing data in order to implement future data gathering activities. (Contact: Rachel Loehman, 907-786-7089, Anchorage, AK)

BOEM has entered into a multiyear cooperative agreement, Community Based Monitoring: LEONetwork with the Alaska Native Tribal Health Consortium. PI is Dr. Michael Brubaker. (Sep 21, 2017 - Completed)

Understanding Environmental Change in the Yukon River Basin through the Indigenous Observation Network and Citizen Science. On September 19th, 2017, Ryan Toohey (USGS Alaska Climate Science Center) will present a seminar on the Indigenous Observation Network in the Yukon Basin. The Yukon River Basin (YRB), underlain by discontinuous permafrost, has experienced a warming climate over the last century that has altered air temperature, precipitation, and permafrost. A collaborative effort between the Yukon River Inter-Tribal Watershed Council (YRITWC) and the U.S. Geological Survey (USGS), the Indigenous Observation Network (ION) has developed two projects that focus on water quality and permafrost research. More than 300 community environmental technicians have been trained to participate in ION by effectively monitoring and investigating their local environments with global implications. These local observations, obtained over the past decade, have contributed to the global understanding of climate change and ultimately its impacts on Alaska Native Villages. Combined with historical data from the USGS, the ION database now covers over 30 years of historical water quality data in key locations. Trend analysis of this database suggests increased active layer expansion, weathering and sulfide oxidation due to permafrost degradation throughout the YRB. Changing geochemistry of the YRB may have important implications for the carbon cycle, aquatic ecosystems, and contaminant transport. With predicted environmental changes, the efforts of ION and the integration of Indigenous knowledge will become critical to assess, mitigate and adapt to changing local environments. ()
• The presentation given by Alex Whiting at the June 7th Coastal Resilience Collaboration Team Meeting titled "Native Village of Kotzebue: Addressing Local Research Priorities: A Tribal Centered Approach" is relevant to this Performance Element http://www.iarpccollaborations.org/members/milestones/2809. (Aug 28, 2017 - Completed)

• Alaska Ocean Acidification Network Formed: In FY2017, AOOS launched the Alaska Ocean Acidification Network (http://www.aoos.org/alaska-ocean-acidification-network/) which is a collaboration of scientists, resource managers, fishing industry representatives, Tribes, and others who are committed to expanding the understanding of ocean acidification processes and consequences in Alaska. The network facilitates interaction between scientists to maximize research efforts, helps connect stakeholders with researchers to answer local questions, and strategizes on how best to synthesize OA information for use by decision makers and the public. (Dec 2, 2016 - Completed)

• 8.1.3 (In progress) Support economic development research for the sustainable development of resilient communities. For example, create comprehensive economic planning strategies by DOC Economic Development Administration (EDA) planning grantees in Alaska coastal communities.; DOC-EDA (Lead), NSF


• Kawarek submitted an initial report to the Economic Development Administration that summarizes and highlights the EDAT meeting that took place in Nome December 2016.

• The August meeting of the Coastal Resilience Collaboration team focused on activities, reports, and barriers to relocation and adaptation initiatives. There were updates by Vanitha Sivarajan on the AESC relocation framework, Nathan Kettle on the ACCAP Adaptation Synthesis Report, and Amy Holman on the Research Needs Work Group: https://www.iarpcollaborations.org/members/events/7847. (Aug 23, 2017 - Completed)

• Bering Strait Economic Development Assessment Team Site Visit: The Economic Development Administration hosted an Economic Development Assessment Team trip to Nome and Shaktoolik December 6-8, 2017. Press Release

• Comprehensive Economic Development Strategy for the Bering Strait Region: EDA invested $70,000 to support the development and implementation of a comprehensive economic development strategy (CEDS) for the region which includes the communities of Brevig Mission, DiomedeElim, Gambell, Golovin, Koyuk, Nome, Shaktoolik, Stebbins, St. Michael, Unlakleet, Teller, Wales and White Mountain. The CEDS process is designed to bring together the public and private sectors in the creation of an economic development roadmap to diversify and strengthen the regional economy.

• 8.1.4 (In progress) Investigate and protect cultural resources through research to identify and document archaeological sites in high-risk, rapidly eroding Arctic coastal areas.; DOI-BLM (Lead), DOI-NPS (Lead), NSF
The National Science Foundation has recently awarded OPP – 1735494. This award supports a workshop to examine the potential for supporting research on submerged human habitation sites on the continental shelf of the U.S. The workshop brings together approximately twenty-five individuals with relevant and specialized expertise on this topic of research and will be held at the Smithsonian Institution, in conjunction with the Society for American Archaeology Meeting Spring 2018 in Washington, DC. An investigation of submerged human habitation sites has the potential to provide important insights into human evolution in North America, including topics of migration, colonization, response to sea level rise, and the origins of maritime adaptations. These topics are important not only for understanding the development of early social organization in North America but can also give us critical information about the societal impacts of sea level rise, which is a potential threat in coastal regions of the United States. (Sep 21, 2018 - Completed)

Publication on Coastline Response to Declining Sea-ice in Northwest Alaska: Arctic sea-ice is declining in extent, leaving coastlines exposed to more storm-wave events. In a new publication, researchers with the National Park Service, the University of Alaska Fairbanks and Antioch University New England describe spatial and temporal patterns of shoreline changes along Cape Krusenstern National Monument and Cape Espenberg within the Bering Land Bridge Nation Park and Preserve over the last 64 years. Both study areas lie within the zone of continuous permafrost, which exists both on and offshore and outcrops as ice-rich bluffs. We compared geomorphic changes over time to changes in sea-ice coverage, which declined ~10 days per decade between 1979 and 2016 in the southern Chukchi Sea. Overall, coastal response to sea-ice decline was spatially and temporally complex across different coastal areas. The shorelines appear to be resilient to sea-ice change, but geomorphological thresholds could be crossed in 50-100 years. Citation: Farquharson, L.M., D.H. Mann, D.K. Swanson, B.M. Jones, R.M. Buzard, and J.W. Jordan. 2018. Temporal and spatial variability in coastline response to declining sea-ice in northwest Alaska Marine Geology 404:71-83. https://doi.org/10.1016/j.margeo.2018.07.007 (Aug 20, 2018 - Completed)

Publication on Climate Change and the Deteriorating Archaeological Archives of the Arctic: The cold, wet climate of the Arctic has led to the extraordinary preservation of archaeological sites and materials that offer important contributions to the understanding of our common cultural and ecological history. This potential, however, is quickly disappearing due to climate-related variables, including the intensification of permafrost thaw and coastal erosion, which are damaging and destroying a wide range of cultural and environmental archives around the Arctic. In an overview report by an international group of scientists, including the National Park Service, the authors propose the next generation of research and response strategies, and suggest how to capitalize on existing successful connections among research communities and between researchers and the public. Citation: Hollesen, J., Callanan, M., Dawson, T., Fenger-Nielsen, R., Friesen, T., Jensen, A., . . . Rockman, M. (2018). Climate change and the deteriorating archaeological and environmental archives of the Arctic. Antiquity, 92(363), 573-586. doi:10.15184/aqy.2018.8 (Aug 20, 2018 - Completed)

The work by the BLM on the North Slope (presented on by Joe Keeney at the November CRCT Collaboration Team Meeting (https://www.iarpccollaborations.org/members/events/7851)) works meets this
Performance Element by focusing on identifying archaeological sites threatened by coastal erosion and responding by prioritizing those most at risk and attempting to document and recover what information can be before it is gone. (Nov 29, 2017 - Completed)

- The November 2017 CRCT meeting ([https://www.iarpccollaborations.org/members/events/7851](https://www.iarpccollaborations.org/members/events/7851)) focused on vulnerable archaeological sites in the Arctic. Information on projects happening in the North Slope and the Aleutian Islands on preserving archaeological sites and relics was provided in detail. The importance of keeping the artifacts within the community was discussed, as well as the feasibility of resources to do this with respect to other important community issues. Presentations: "Efforts by the Bureau of Land Management to Mitigate Archaeological Losses due to Erosion on the Beaufort Sea Coast, Summer 2017"- Joseph Keeney (BLM). "Pinart's Journals and Journeys understanding Aleutian Seascapes"- Sven Haakanson- In 2017 Sven took a boat from Kodiak to Atka, traveling over 2000 nautical miles down the Aleutian Islands. This is what he learned about the Aleutians Islands based on this trip. (Nov 20, 2017 - Completed)

- National Petroleum Reserve - Alaska (NPR-A), Coastal Erosion Mitigative Excavations: The Bureau of Land Management (BLM) Arctic District Office (Alaska) archaeologist Joe Keeney, along with BLM archaeologists Crystal Glassburn (Central Yukon Alaska Field Office), Robin Mills, and Steve Lanford (Eastern Interior Alaska Field Office), and Kevan Cooper (BLM Alaska realty specialist) conducted excavations in the summer of 2017 at three known archaeological sites along the north coast of Alaska, inside the boundaries of the NPR-A (managed by BLM’s Arctic District Office). Coastal erosion has dramatically affected areas along Alaska’s northern coast over the past century, which has had unknown but potentially disastrous effects upon cultural resources. Following surveys and assessments of sites along the Beaufort Sea coast in 2016 and successful consultations with Alaskan Native tribes on the North Slope, BLM staff returned in 2017 to three of the most threatened sites to record information. Two sites are located on BLM-managed lands: the remains of a sod house occupied in the early 20th Century, that belongs to Horace Ahsogeak, and an historic reindeer corral that operated during the early 20th Century. The third site, which is located on an Alaska Native allotment owned by Lillian Nageak of Utqiagvik (formerly Barrow), contains the remains of several structures, including the well-preserved and partially-standing sod house Ms. Nageak lived in up until the early 1940s. The crews were accompanied and assisted by Charlotte Ahsogeak and Kunneak Nageak of Utqiagvik. Work is planned to continue at other threatened sites in 2018, and will include continued cooperation with Iñupiat tribes and living descendants to preserve site materials and information. ()

- For decades to centuries Arctic historic sites remained relatively isolated and frozen, protected from human and environmental degradation. The extreme climatic conditions in the Arctic have allowed the preservation of organic structures and artifacts that can provide a glimpse into history and cannot be found elsewhere on Earth. However, many Arctic archeological sites, located nearshore, are threatened by coastal erosion due to reduction in sea ice cover, increased storm frequency, and melting permafrost. And both nearshore and inland sites are affected by the warmer temperatures that are accelerating the decomposition of organic structures. Beyond the cultural importance for Indigenous Arctic communities, these sites are an important piece of mankind
history, they tell the story of how humans spread from Asia to the Americas and the coasts of Greenland. Furthermore, these sites are home to large amounts of environmental, biological, climate and social/cultural data that could be useful to our understanding of the current world, particularly how people adapted to rapid environmental change in the past during the Little Ice Age or the Medieval Warm Period. The information gathered from the Arctic heritage sites can be used to design better resilience strategies for modern Arctic communities, and coastal communities globally.

Indigenous heritage traverses multiple countries, thus preserving the sites requires international cooperation and close collaboration with local communities. The strategy to preserve the historical information of the sites broadly falls into 2 categories: 1. Preserve sites and/or move artifacts or 2. Sample and study the sites before they disappear; this requires collaborations across agencies, with researchers and local communities. The National Science Foundation funds research to support both local and international efforts to investigate and protect archeological sites in high-risk coastal areas. Funds are granted through regular and Rapid Response Research (RAPID) awards. Below are examples of awards addressing the aforementioned issues:

Example 1. Comparative Island Ecodynamics in the North Atlantic (Award # 1449616) The researchers seek to understand how differences in response to rapid environmental change of two closely related northern communities resulted in the collapse of one and survival of the other. Findings may help understand what makes a community resilient to environmental change and apply to current and/or future communities. [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1449616](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1449616)

Example 2. RAPID: Walakpa Archeology Rapid Response Project (Award # 1646865) Here, the researchers seek to rescue a large multi-component archaeological site dating to at least 1200 years ago, the Walakpa, or Ualiqpa, site, from the rapidly eroding coastline. This site contains records of the migration and evolution of Birnirk and Thule cultures. [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1646865](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1646865)

Example 3. RAPID: Archeological Investigation at lita (Award # 1623802) This team of researcher is investigating the interactions between the Dorset and Thule (ancestor of the contemporary Inuit) people in the prehistoric Arctic at the threatened site of lita in Greenland. [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1623802](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1623802)

Example 4. RAPID: Gardar Collaborative Rescue Project (Award # 1119354) This award supported the rescue efforts of the unique site of Gardar (a UN World Heritage Site) in the former Norse Eastern settlement in Greenland. The warmer temperatures are accelerating the decomposition of the organic material used in the construction of the 11th century church and manor farm. [https://www.nsf.gov/awardsearch/showAward?AWD_ID=1119354&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1119354&HistoricalAwards=false) (Sep 27, 2017 - Completed)

- Judith Ramos’ presentation in May to the Coastal Resilience Collaboration Team ([https://www.iarpccollaborations.org/members/events/76860](https://www.iarpccollaborations.org/members/events/76860)) is relevant to this Performance Element. (Sep 25, 2017 - Completed)

- **8.1.5 (In progress) Advance the understanding of storm surge and saline inundation impacts on infrastructure and human safety. Multiagency partners include the Alaska Department of Geological and Geophysical Surveys and the ACCER.; NOAA (Lead), DOD-USACE**
New Instruments Installed to Measure Arctic Coastal Erosion: Coastal erosion along the Arctic coast of Alaska threatens Native Alaskan villages, sensitive ecosystems, energy- and defense-related infrastructure, and large tracts of Native Alaskan, State, and Federally managed land. In July 2018, three USGS Pacific Coastal and Marine Science Center researchers installed thermometers, video cameras, a seismometer, and a wave gauge to measure permafrost temperatures and bluff erosion on the Arctic Ocean coast of Barter Island, Alaska. Combined data from these instruments will be used to test the possibility of remotely estimating wave heights without installing and maintaining wave gauges in the ocean. USGS also hosted a community outreach event to present results from earlier studies and to discuss their ongoing research. Government officials, residents, and non-residents attended the event. PCMSC researchers particularly appreciated the local coastal information, insights, and concerns provided by long-time community residents. Contact: Li Erikson, lerikson@usgs.gov, 831-460-7418 (Aug 20, 2018 - Completed)

A new low-cost water level sensor was installed in Bethel to produce high quality, real-time data. ()

8.2 Advance knowledge of ecosystems and environmental health in coastal areas by monitoring trends and modeling biological processes.

- **8.2.1 (In progress)** Monitor and conduct studies to understand trends, processes, and biotic-abiotic feedback loops affecting the distribution, abundance, and ecology of coastal species in relation to food security, biodiversity, and ecosystems through projects such as the Arctic Council Conservation of Arctic Flora and Fauna working group Coastal Biodiversity Monitoring Programme.; DOI-BOEM (Lead), DOI-USGS (Lead), NOAA (Lead), DOI-BLM, DOI-FWS, DOI-NPS, MMC

Arctic Biodiversity Congress 2018 - Rovaniemi, Finland, October 9 – 11, 2018. Christian Zimmerman, USGS Alaska Science Center Director, and Sarah Laske, Fish Biologist, with the USGS Alaska Science Center will participate in the 2018 Arctic Biodiversity Congress in Rovaniemi, Finland, October 9-11 2018. Zimmerman will chair the session Status and Trends in Arctic Freshwater Biodiversity across the Circumpolar Region and Laske will present a talk entitled “Drivers of freshwater fish biodiversity depend on location and isolation in the circumpolar arctic.” Background: The goal of the Arctic Biodiversity Congress is to promote the conservation and sustainable use of Arctic biodiversity and is hosted by the Conservation of Arctic Flora and Fauna (CAFF), the biodiversity working group of the Arctic Council, and key partners. CAFF’s mandate is to address the conservation of Arctic biodiversity, to communicate its findings to the governments and residents of the Arctic and help to promote practices which ensure the sustainability of the Arctic’s living resources. More information may be found at: [https://www.arcticbiodiversity.is/congress](https://www.arcticbiodiversity.is/congress). (Sep 27, 2018 - Completed)

The following presentations delivered at the September 5th 2018 Coastal Resilience Collaboration Team Meeting are relevant to this Performance Element ( [https://www.iarpccollaborations.org/members/events/10637](https://www.iarpccollaborations.org/members/events/10637) ). Sea stars are a visible species for coastal communities and an indicator of other changes in the marine environment. Sea star wasting disease is a problem over a large area of the west coast. The public is interested to know more and researchers are interested to know what those living on the coast have observed.
- The essence of good communications -- Sharing, Listening, Learning: Maggie Mooney-Seus (NOAA National Marine Fisheries Service)
- Update on Gulf Watch Program and surveys for sea star wasting disease: Heather Coletti (National Park Service)
- Community involvement in “A Collaborative Strategic Action Plan” for research and management of sea star wasting disease: Sarah Gravem (Oregon State University) (Sep 5, 2018 - Completed)

Saildrones Head to the Arctic: At the end of June 2018, four Saildrones left Dutch Harbor, AK and headed north. These ocean-going robots have started to carry out a 700-nautical-mile trip to Bering Strait, where they will enter the Chukchi Sea and begin their work in the Chukchi and Beaufort Seas, and the Arctic Ocean. NOAA Fisheries scientists at the Alaska Fisheries Science Center are using two of these Saildrones to measure the abundance of Arctic cod in Alaska. The other two are being used by NOAA Research’s Pacific Marine Environmental Laboratory to observe how the Arctic Ocean is absorbing carbon dioxide from the atmosphere. These missions will gather measurements to identify ongoing changes to the Arctic ecosystem and how changes may affect the food-chain as well as large-scale climate and weather systems. More information at: https://www.fisheries.noaa.gov/science-blog/saildrones-head-arctic-post-1 (Aug 20, 2018 - Completed)

Beavers May Affect Landscape and Ecosystem Processes in the Arctic: A recent publication "Tundra be dammed: Beaver colonization of the Arctic" describes a remote sensing approach to identifying beaver colonization of Arctic Alaska and the potential changes to stream ecosystems associated with beaver colonization. The Landsat and high-resolution time series imagery analysis revealed that beavers have colonized the arctic tundra of northwestern Alaska between 1999 and 2014. Beaver ponds and associated hydrologic changes are thawing permafrost. Pond formation increases winter water temperatures in the pond and downstream, likely creating new and more varied aquatic habitat, but specific biological implications are unknown. Beavers create dynamic wetlands and are agents of disturbance that may enhance ecosystem responses to warming in the Arctic. The striking changes caused by beavers create a management challenge as the ecosystem properties and resources of tundra streams are modified by the influx of beavers. Citation: Tape, K. D. B. M. Jones, C. D. Arp, I. Nitze, and G. Grosse. 2018. Tundra be dammed: Beaver colonization of the Arctic. Global change biology. DOI: 10.1111/gcb.14332 (https://doi.org/10.1111/gcb.14332) (Aug 14, 2018 - Completed)

USGS Changing Arctic Ecosystems Publication Examines Influences on Productivity of Three Loon Species in the Arctic: Three species of loons breed in northern Alaska and have varying population trends. In a recent paper, USGS scientists Brian Uher-Koch, Joshua Koch, and Joel Schmutz examined the effects of competition, nest site selection, and water level on nest survival of Pacific, Yellow-billed, and Red-throated loons. Overall nest survival rates did not differ among the three loon species, however results indicate that loons chose nest sites based on predation risk and that factors influencing breeding success may differ under similar breeding conditions. Reducing predation risk and changes to landscape features used for nesting may assist in maintaining higher nest survival rates. The early view paper may be accessed: https://doi.org/10.1111/jav.01671. Citation: Uher-Koch, BD, JC Koch, KW Wright, and JA

- USGS Participates in Arctic Council, State of Arctic Freshwater Biodiversity Monitoring and Assessment Working Group: Sarah Laske, Fish Biologist at the USGS-Alaska Science Center, will participate in a Conservation of Arctic Flora and Fauna - Circumpolar Biodiversity Monitoring Program Freshwater Steering Group meeting in Helsinki, Finland from April 16 - 19. The Freshwater Steering Group (FSG) is responsible for implementation of the Arctic Freshwater Biodiversity Monitoring Plan, one of four pan-Arctic biodiversity monitoring plans developed to improve detection and understanding of the causes of long-term change in the composition, structure, and function of Arctic ecosystems. The FSG is preparing the first international State of Arctic Freshwater Biodiversity Report, due to be completed in 2018. Laske is lead author of the Arctic Freshwater Fish assessment. More information may be found at: https://www.caff.is/freshwater. (Aug 14, 2018 - Completed)

- New Publication Describes Energy Allocation in Juvenile Chum Salmon: Feeding, energy storage, and growth are critical information needs in understanding performance and survival of salmon as they transition from freshwater to marine habitats. The data on energy allocation and feeding ecology presented in this paper fill a critical information gap in the Arctic-Yukon-Kusokokwim region of Alaska where salmon have undergone major changes in population trajectory and raised management concerns. This study provides the first examination of energy allocation of juvenile chum salmon during the critical life history period as fish transition from freshwater to saltwater and suggests that body growth is strongly favored over energy storage as lipids. Lipid storage during saltwater entry does not appear to be a prerequisite for survival to later life stages, given that the cohort of salmon examined contributed to a brief period of high survival and record adult returns to rivers. You may access the paper at: https://doi.org/10.1007/s00300-018-2297-2 . Citation: Burril, S.E., V.R. von Biela, N. Hillgruber, C.E. Zimmerman. In press. Energy allocation and feeding ecology of juvenile chum salmon (Oncorhynchus keta) during transition from freshwater to saltwater. Polar Biology. https://doi.org/10.1007/s00300-018-2297-2 (Aug 14, 2018 - Completed)

- Biogeography of Marine Food Webs in the North Pacific: Forage fish stocks on the continental shelf of Alaska provide vital sustenance to commercial groundfish, seabirds, seals, and whales. They are difficult to sample using traditional fishing methods, so biologists at the USGS Alaska Science Center, U.S. Fish and Wildlife Service, and other research organizations, used puffins to sample food webs at 35 colonies stretching 3700 km from SE Alaska to the western Aleutians. Analyses of >10,000 meals revealed three distinct forage fish communities that were distributed among differing marine habitats. This biogeographic structuring helps explain spatial variability in diets of predators, but also points to a need to account for differences among food webs (prey type, size, quality, temporal variation, etc.) when assessing the status and trends of predators that live and breed in differing food-web ecoregions. USGS scientists Mayumi Arimitsu, David Douglas and John Piatt co-authored this paper, now available early online at: http://onlinelibrary.wiley.com/doi/10.1111/fog.12258/full. Citation: Piatt J.F., M.L. Arimitsu, W.J. Sydeman, S. A. Thompson, H. Renner, S. Zador, D. Douglas, S. Hatch, A. Kettle, and J. Williams. 2018. Biogeography of pelagic food webs in the North Pacific.
New Analysis of Pacific Walrus Demography: USGS Alaska Science Center researchers Rebecca Taylor, Mark Udevitz and Chadwick Jay collaborated with U.S. Fish and Wildlife Service and Alaska Department of Fish and Game to synthesize information on Pacific walrus population sizes, age structures, reproductive rates, and harvests for 1974-2015. The walrus population underwent a multi-decade decline which began moderating in the 1990s. Reproduction and calf survival rose over time; however, juvenile survival may have decreased over time. Depending on whether juvenile survival decreased, the population growth rate either increased during the 2000s or stabilized at a lesser level of decline than seen in the 1980s. An early view of the paper is currently available at http://onlinelibrary.wiley.com/doi/10.1111/mms.12434/full. (Contact: Rebecca Taylor, 907-786-7004, Anchorage, AK). Citation: Taylor, R. L., Udevitz, M. S., Jay, C. V., Citta, J. J., Quakenbush, L. T., Lemons, P. R. and Snyder, J. A. (2017), Demography of the Pacific walrus (Odobenus rosmarus divergens) in a changing Arctic. Mar Mam Sci. doi:10.1111/mms.12434 (Oct 4, 2017 - Completed)

Marine Arctic Ecosystem Study (MARES) - Pilot Program Marine Mammals Tagging and Tracking. The objectives for this pilot-program were successfully met. We established productive relationships with the North Slope Borough and several native hunters, and we garnered support for our study and approach from the Ice Seal Committee, co-management groups in Canada, and the communities of Wainwright and Kaktovik. We also established effective collaborations with other researchers, thereby minimizing the impact of the research on communities and the animals they rely on for subsistence. Successful deployment of satellite CTD-fluorometer tags revealed insights concerning tag configuration and communication protocols. Capture methods and locations were also refined by bringing together knowledge and experience from MARES, NSB, and other scientists experienced in capturing and tagging ice-associated seals around the world. The direct link to the full report is: https://www.boem.gov/BOEM-2017-017/ (Sep 26, 2017 - Completed)

Social Indicators in Coastal Alaska: Arctic Communities: In 2011, the U.S. Department of the Interior (USDOI), Bureau of Ocean Energy Management (BOEM) contracted Stephen R. Braund & Associates (SRB&A) to develop and implement a social indicator (SI) system which would provide baseline data on the well-being of residents on the North Slope of Alaska. The title of this study is Social Indicators in Coastal Alaska: Arctic Communities (SICAA). The scope of work for the study called for the identification of a set of SIs—variables which measure the well-being and life quality of a given population. These SIs were collected through a household survey in the six coastal North Slope communities (Point Hope, Point Lay, Wainwright, Utqiagvik [formerly Barrow], Nuiqsut, and Kaktovik). Between January 8 and March 9, 2016, SRB&A interviewed 684 randomly selected heads of household (HHs) in the selected North Slope communities. The purpose of the interviews was to develop a baseline understanding of the well-being of North Slope residents before major offshore oil and gas (O&G) development activity. The interview, which took about an hour, used structured questions to measure SIs of well-being in seven domains: economic well-being, physical environment, health and safety, cultural continuity, education, local control, and overall well-being. The interview also included a suite of questions about the type, timing, cause, and appropriate mitigation action
associated with any impacts of O&G exploration and development on subsistence activities in the prior year. The survey questions were reviewed by the North Slope Management Board, a group of North Slope residents formed to oversee the study. The survey was approved by the federal Office of Management and Budget as well as BOEM. Seventy-nine percent of the selected HHs completed the interview. The direct link to the final report is: https://www.boem.gov/BOEM-2017-035 (Sep 26, 2017 - Completed)

- Seabird Distribution and Abundance in the Offshore Environment: Seabirds are wide-ranging upper trophic level foragers and good indicators of changes in marine ecosystems. Seabirds spend most of the year offshore, yet our data gaps are greatest for the pelagic aspect of their lives. The goal of the Seabirds Offshore Project was to conduct at-sea surveys in lease sale areas and adjacent ocean planning areas, to provide current temporal and spatial data on marine birds and mammals, and submit the data to the North Pacific Pelagic Seabird Database (NPPSD). During this project, 2010-2016, we placed seabird observers on 45 research and monitoring vessels, usually in association with multidisciplinary ecosystem projects. Because many of these cruises transited from southern Alaska ports, we included all surveyed routes in this report. We surveyed a total of 97,525 km, with the majority (31,497 km) in the Chukchi Sea, followed by the southern Bering Sea (30,265 km), northern Bering Sea (26,326 km) and Beaufort Sea (9,438 km). Our survey coverage extended from the northern GOA shelf to the eastern Aleutian Islands, north throughout the Bering Sea shelf, into the eastern Chukchi Sea, and the western Beaufort Sea shelf, including the Arctic Basin. The seabird survey data collected under the Seabirds Offshore Project has been included in over 30 presentations and 17 publications to date, as well as at least 12 public outreach and education venues and 7 websites. We have described seasonal distribution patterns of seabirds in offshore waters of Alaska, and identified ‘hotspots’ of foraging and migration activity. Through several collaborative projects, including on-going efforts, we have linked seabird survey data to oceanographic and prey data collected during concurrent cruises, and from remote sensing data. These efforts test hypotheses about the distribution of upper trophic level predators in response to changes in prey and ice cover. All seabird data collected during this project has been submitted to the NPPSD, to the Alaska BOEM office, and to affiliated ecosystem projects (available via Alaska Ocean Observing System work spaces). The direct link to the report is: https://www.boem.gov/2017-004 (Sep 26, 2017 - Completed)

- Arctic Marine Biodiversity Observing Network (AMBON)- a BOEM and NOAA partnership under National Ocean Partnership Program- led by Katrin Iken professor at University of Alaska Fairbanks. Project is ongoing. More information about the project can be found at the following sites: https://www.uaf.edu/cfos/research/projects/arctic-marine-biodiversity/, https://www.youtube.com/watch?v=d4MpyMopEBM, http://ambon-us.org/about/ ()

- A BOEM-funded study that was completed recently addresses food security in Wainwright, Kaktovik, and Venetie, Alaska. This study, Subsistence Sharing Networks and Cooperation: Kaktovik, Wainwright, and Venetie, Alaska, by G. Kofinas, S. BurnSilver, J. Magdanz, R. Stotts, and M. Okada, OCS Study BOEM 2015-023 can be accessed here: https://www.boem.gov/BOEM-2015-23/ (Sep 21, 2017 - Completed)

- New USGS-led Publication on Factors Associated with Increasing Goose Populations on the North Slope of Alaska: The authors measured body mass of black brant and lesser
snow goose goslings on the Colville River Delta of northern Alaska to determine if there was evidence of density-dependent declines in gosling growth following recent population increases of those species. The authors conclude that the establishment of nesting snow geese on the Colville River Delta has not negatively affected brant gosling growth. The authors also predict that goose populations will continue to increase in northern Alaska. However, snow geese are increasing more rapidly than brant in the region. Because the black brant population has periodically been below management objectives, the effects of the increasing snow geese on brant goslings in northern Alaska should be monitored. Citation: Hupp, J. W., D. H. Ward, K. R. Hogrefe, J. G. Sedinger, P. D. Martin, A. Stickney, and T. Obritschkewitsch. 2017. Growth of black brant and snow goose goslings in northern Alaska: implications for increasing goose populations. Journal of Wildlife Management 81(5):846-857. doi:10.1002/jwmg.21246 (Sep 13, 2017 - Completed)

- New USGS Publication on Habitat Use of Geese During Molt within the National Petroleum Reserve - Alaska: Numerous Greater White-fronted geese molt within the National Petroleum Reserve – Alaska (NPR-A) and proposed development in this area raised questions about possible impacts to molting geese and their habitats. We used GPS transmitters to record fine-scale location data to assess patterns of movement and resource selection relative to vegetation type, year (2012, 2013), and body mass at capture. Flightless White-fronted geese maintain fairly small home ranges across a gradient of habitats, suggesting that suitable habitat is widely distributed. The only constraint was the apparent need to molt within 100 m of a wetland (i.e., potential escape habitat). Citation: Flint, P. L. and B. W. Meixell. 2017. Movements and habitat use of White-fronted geese during the remigial molt in Arctic Alaska, USA. Waterbirds 40, In Press. (Sep 13, 2017 - Completed)

- New Publication on Wildlife Harvest and Climate Change: Scientists with the USFWS, USGS and the University of Washington present a novel modeling approach to evaluate the interactive effects of climate change and harvest on large mammals. The model is coupled with a management framework that recognizes the potential for climate-induced habitat degradation. Together, these methods can be used to balance tradeoffs between population persistence and opportunities for human use. This will become increasingly important for polar bears and other species for which near-term management is focused on harvest and other secondary factors while the global community seeks solutions to the primary threat of climate change. Citation: Regehr, E. V., R. R. Wilson, K. D. Rode, M. C. Runge, and H. Stern. 2017. Harvesting wildlife affected by climate change: a modelling and management approach for polar bears. Journal of Applied Ecology In Press. doi:10.1111/1365-2664.12864 (Sep 13, 2017 - Completed)

- Presentations by Raphaela Stimmelmayr and Vera Metcalf given at the July 6th Coastal Resilience Collaboration Team Meeting (http://www.iarpccollaborations.org/members/events/7846) are relevant to this Performance Element (Jul 7, 2017 - Completed)

- Presentations by Kenneth Dunton and Alex Whiting given at the June 7th Coastal Resilience Collaboration Team Meeting (http://www.iarpccollaborations.org/members/milestones/2809) are relevant to this PE. (Jun 13, 2017 - Completed)
8.2.2 (In progress) Develop ecological modeling capabilities to understand issues related to the coastal Arctic. Develop online eco-informatics tools such as Coastal Biodiversity Risk Analysis Tool (CBRAT) for Arctic coastal areas to deliver, at a regional scale, predicted relative vulnerability of coastal species and ecosystems to climate change, including temperature increases, sea level rise, and ocean acidification.; EPA (Lead)

- OA Impacts on Alaska Species Poster Goes Viral: A new one page document describing the impacts of OA on researched Alaska species (http://www.aoos.org/alaska-oceanacidification-network/) has gone viral. This publication also includes a long list of many Alaska species that have yet to be researched for impacts from OA. As part of the OA Network, five topic-specific working groups have been convened and are actively working to help implement the network’s mission. More information can be found at www.aoos.org/alaska-oceanacidification-network/ (Nov 2, 2017 - Completed)

- BOEM has entered into a cooperative agreement, Coastal Community Vulnerability Index and Visualizations of Change in Cook Inlet, Alaska with the Coastal Marine Institute, University of Alaska, Fairbanks. PI is Davin Holen, SEAGRANT. (Sep 21, 2017 - Completed)

- Alaska Ocean Acidification Network: In FY2017 AOOS launched the Alaska Ocean Acidification Network (http://www.aoos.org/alaska-ocean-acidification-network/) which is a collaboration of scientists, resource managers, fishing industry representatives, Tribes, and others who are committed to expanding the understanding of ocean acidification processes and consequences in Alaska. The network facilitates interaction among scientists to maximize research efforts, helps connect stakeholders with researchers to answer local questions, and strategizes on how best to synthesize OA information for use by decision-makers and the public. ()

- HABs monitoring expands to Arctic: The Alaska Harmful Algal Bloom Network (AHAB), co-led by AOOS, received funding in FY2017 from the U.S. Arctic Research Commission to expand its activities into the Arctic. The funding will support a pilot shellfish testing, opportunistic marine mammal sampling, and water monitoring programs, as well as community outreach. ()

- An expanded version of the OA brochure (http://www.aoos.org/wp-content/uploads/2016/04/OA-2pager-June-2017.pdf), which is now two-sided and includes OA basics, monitoring platforms, general findings and the role of the network. Three new members have signed on to the network; the U.S. Arctic Research Commission, the Alaska Marine Highway System, and the Alaska Department of Fish & Game. ()

- The Alaska Harmful Algal Bloom (AHAB) network tool was released at the beginning of the month of June. http://www.aoos.org/k-bay-hab/. See the current conditions in the AOOS data portal ()

- Ocean Acidification Network Update: Alaska State Ferry monitoring project set for October. The seasonal start of the M/V Columbia (newly equipped with an OA sensor package) was delayed again due to technical problems with the vessel, and is now set to begin its weekly round trip from Bellingham to Skagway on October 2, 2017. This project has been consistently delayed since its anticipated start of April. However, the new plan to operate through the winter will provide unprecedented insights into a different season - an opportunity we may not have again. ()
Ocean Acidification Network Update: New funding from the U.S. Arctic Research Commission. USARC is providing the network with $20K to produce data synthesis products and provide outreach to Arctic communities. Data synthesis efforts will focus on creating a data-rich, interactive storyboard illuminating the impacts of OA on crab based on data produced at the Kodiak Lab. We are also looking into other possible products, including maps that overlay existing seasonal data with at-risk species distribution. With regard to Arctic outreach, we will be looking for speakers to attend events in Barrow, Kotzebue, or Nome over the next year. If you are interested in representing the OA community at these venues, please contact Darcy Dugan.

Ocean Acidification Network Update: Alaska OA Monitoring Inventory. Thank you to everyone who submitted information on their research assets to the west coast inventory that was circulated earlier this year. Oregon and California have created an interactive web-based map showing their assets, and Alaska's will be added soon, thanks to the time and talent of Wiley Evans. We will keep you posted as this project moves forward.

Ocean Acidification Network Update: Plans and priorities template. To help assemble the framework to develop an OA monitoring build-out plan in 2018 we will be circulating a template this fall to collect information from researchers to make sure their near and long-term plans and research interests are incorporated in the plan.

Ocean Acidification Network Update: Fishing community engagement: The fishing working group has been active this summer, organizing a number of the events listed below. We are also developing a list of key industry contacts to whom we will be introducing the network, providing resources, and discussing ways to get involved. We hope to establish relationships with some of the larger commercial fishing players and explore possibilities of partnering to fund research in areas of highest importance to fishermen.

Presentations by Kenneth Dunton and Alex Whiting given at the June 7th Coastal Resilience Collaboration Team Meeting (http://www.iarpccollaborations.org/members/milestones/2809) are relevant to this PE. (Aug 28, 2017 - Completed)

8.2.3 (In progress) Continue to develop a general Arctic-wide wildlife response model that relates to species-specific models of Arctic coastal organisms.; DOI-USGS (Lead)

USGS Changing Arctic Ecosystems Publication on Recreational Activities in Polar Bear Habitats: USGS Alaska Science Center scientists Karyn Rode and Todd Atwood collaborated with scientists from a variety of agencies and organization across the polar bear’s circumpolar range on a paper that examines the frequency and potential impacts of recreation in polar bear habitat. The authors distributed a survey among individuals living and working in polar bear habitat. They found that viewing-based recreation is increasing, but that fewer than 10% of polar bears in most subpopulations are exposed to recreation. Fewer than half of respondents indicated that bears were affected by recreation. However, some recreational activities were associated with negative effects including displacement, changes in behavior and defense of life kills that may become important to mitigate as polar bears increasingly spend time on shore in response to sea ice loss. Citation: Rode, K. D., J. F. Fortin-Noreus, D. Garshelis, M. Dyck, V. Sahanatien, T. Atwood, S. Belikov, K. L. Laidre, S. Miller, M. E. Obbard, D. Vongraven, J. Ware, and J.

- Genetic Data from Arctic, Polar, and Saffron Cod and Walleye Pollock, Alaska and Canada, 2011-2017: As part of a final USGS report to BOEM, fragment data from 11 nuclear microsatellite loci and sequence data from the mitochondrial cytochrome b gene were gathered from Arctic cod (Boreogadus saida) in the Beaufort and Chukchi seas. Mitogenomic analyses of Arctic cod and three other co-distributed gadoids (Polar cod [Arctogadus glacialis], Saffron cod [Eleginus gracilis], Walleye Pollock [Gadus chalcogrammus]) were also completed. Transcriptomic analyses of Arctic cod were used to identify genes associated with environmental perturbations. Genome-wide scans using RAD-Seq of Arctic cod and the co-distributed Polar Cod were also collected. Citation: Wilson, R. E., Pierson, B. J., Sage, G. K., Sonsthagen, S. A., Gravley, M. C., Menning, D. M. and Talbot, S. L., 2018, Genetic Data from Arctic, Polar, and Saffron Cod and Walleye Pollock, Alaska and Canada, 2011-2017: U.S. Geological Survey data release, https://doi.org/10.5066/F7CF9P23. (Aug 17, 2018 - Completed)

- The USGS delivered a presentation to the IARPC Coastal Resilience Collaboration Team on October 4th, 2017, regarding the framework and content of Arctic-wide and species-specific response models for wildlife that the USGS and collaborators have developed. These models are being used to not only characterize and prioritize research on coastal wildlife species in the Arctic, but also to capture expert knowledge, acknowledge areas of uncertainty, and produce forecasts of future population status for Pacific walrus, polar bears, and Arctic-nesting geese. (Oct 5, 2017 - Completed)

- The USGS developed two Bayesian network models to integrate relative influence of changing environmental conditions and anthropogenic stressors, and their mitigation, on the persistence of Pacific walrus (http://dx.doi.org/10.1007/s00300-011-0967-4) and polar bears (http://dx.doi.org/10.1002/ecs2.1370) through the twenty-first century. These formed the basis for a conceptual Arctic-wide wildlife response and forecasting model by USGS presented in Van Hemert et al. (2015) (http://dx.doi.org/10.1093/biosci/biv069). The following publications were published in 2017 by co-authors with USGS, USFWS, State of Alaska, universities, NGOs, and others that contribute to updating species-specific and Arctic-wide wildlife response models:


8.2.4 (In progress) Understand and monitor processes to manage and mitigate potential and realized threats from coastal invasive species, biotoxoses, and wildlife diseases by leveraging research under initiatives and programs such as One Health, the DBO network, AMBON, and Aerial Surveys of Arctic Marine Mammals (ASAMM) work.; HHS (Lead), NOAA (Lead), DOI-BOEM, DOI-FWS, DOI-USGS, MMC

- USGS Wildlife Disease Program - New Publication on Blood Parasite Infections in Spectacled Eiders: In a new paper, published in the Journal of Wildlife Diseases, scientists from the USGS Alaska Science Center assessed the prevalence and genetic diversity of blood parasites in Spectacled Eiders, a threatened species of sea duck that breeds in coastal areas of artic and sub-arctic Alaska and eastern Siberia. Blood parasites have been linked to health consequences in some birds, but possible impacts on eiders are unknown. Blood parasites in birds are not known to cause disease in people. Blood parasites were identified in 6.5% of adult Spectacled Eiders sampled on the Yukon-Kuskokwim Delta and Arctic Coastal Plain (ACP) of Alaska and 41.9% of juvenile eiders sampled on the ACP. Genetic lineages of parasites identified were all previously detected in other waterfowl species. Results of this study provide evidence for transmission of blood parasites in the Arctic and among sympatric species of waterfowl. Additional research could focus on possible health impacts of parasite infection to eiders. An early view of this paper can be accessed online at: http://www.jwildlifedis.org/doi/pdf/10.7589/2018-01-012. Citation: Reed, J.A., M.G. Sexson, M.M. Smith, J.A. Schmutz, Ramey, A.M. 2018. Evidence for haemosporidian parasite infections in Spectacled Eiders (Somateria fischeri) sampled in Alaska during the breeding season. Journal of Wildlife Diseases. 54(4): In press. doi: 10.7589/2018-01-012 (https://doi.org/10.7589/2018-01-012) (Aug 17, 2018 - Completed)

- USGS Presentation at the Pacific Seabird Group Annual Meeting on Algal Toxins and Seabirds: USGS Alaska Science Center Wildlife Biologist Sarah Schoen presented a talk entitled “Harmful algal blooms, seabirds, and forage fish: assessment of toxins during and after the 2015-2016 Common Murre die-off” at the Pacific Seabird Group meeting in La Paz, Mexico, February 22, 2018. This work found that domoic acid occurred rarely and at trace concentrations in birds and forage, whereas saxitoxin was frequently found in both for birds sampled in southcentral Alaska but below human regulatory limits. (Aug 17, 2018 - Completed)

- Book Chapter Describes the Effects of Climate Change on Disease Spread in Wildlife: USGS scientists Erik Hofmeister (National Wildlife Health Center) and Caroline Van...

- Arctic One Health Study Tour at USGS Alaska Science Center: On May 17th 2018, USGS Alaska Science Center (ASC) Director Chris Zimmerman, Supervisory Wildlife Biologist John Pearce, and scientists Caroline Van Hemert and Andy Ramey provided a tour of the ASC for a group with the Arctic Council Sustainable Development Working Group participating in an Arctic One Health Study Tour. The tour is sponsored by the U.S. Department of State and is part of the ongoing effort to operationalize One Health in the Arctic and build international collaborations. The tour will provide an overview of the USGS mission areas, wildlife and environmental disease research programs that inform One Health partnerships in Alaska, a discussion of on-going work with partners in the north. Twelve participants from Canada, Finland, Iceland, Norway, Russia, and Sweden will take part in the tour. (Aug 14, 2018 - Completed)

- New Publication and Data Release Evaluates Sampling Strategies for Avian Influenza Viruses at Izembek National Wildlife Refuge: In a study recently published in PLOS ONE, researchers at the USGS Alaska Science Center, USGS National Wildlife Health Center, and the University of Georgia analyzed genomic data for influenza A viruses (IAVs) sampled from waterfowl and gulls at Izembek National Wildlife Refuge (NWR) over five years. The study assessed: 1) from which species viruses are consistently recovered, 2) the contribution of different avian hosts to viral diversity detected in the region, and 3) how evidence of intercontinental exchange of IAVs relates to different hosts. While overall viral diversity was similar among waterfowl, species with intercontinental migratory tendencies, such as northern pintails and emperor geese, exhibited greater evidence for viral exchange between continents. Glaucous-wing gulls maintained different viral diversity than other species sampled and also exhibited evidence for intercontinental viral exchange. Results from this study may be used to optimize sampling strategies at Izembek NWR and other locations. Citation: Reeves, A.B., Hall, J.S., Poulson, R.L., Donnelly, T., Stallknecht, D.E., Ramey A.M. 2018. Influenza A virus recovery, diversity, and intercontinental exchange: A multi-year assessment of wild bird sampling at Izembek National Wildlife Refuge, Alaska. PLOS ONE. 

http://journals.plos.org/plosone/article/comments?id=10.1371/journal.pone.0195327


- New Publication Evaluates Factors Influencing the Health of Polar Bears: USGS Alaska Science Center scientists, along with colleagues from Colorado State University, University of Connecticut, USDA- Veterinary Services, USDA- National Wildlife Research Center, and USDA- Agricultural Research Service authored a paper investigating factors influencing the exposure of polar bears to pathogens and persistent organic pollutants. The authors found that seroprevalence of Brucella spp. and Toxoplasma gondii antibodies likely increased through time, and provide the first evidence of exposure of polar bears (and Arctic marine mammals) to Coxiella burnetii, Neospora caninum, and Francisella tularensis. Additionally, the odds of exposure to T. gondii were greater for bears that used land than for bears that remained on the sea ice during summer and fall, while mean concentrations of the pollutant chlordane were lower for land-based bears. The study suggests that changes in polar bear behavior brought about by climate-induced modifications to the Arctic marine ecosystem may increase exposure risk to certain pathogens and alter contaminant exposure pathways. Citation: Atwood, T.C., C. Duncan, K. Patyk, P. Nol, J. Rhyan. M. McCollum, M. McKinney, A. Ramey, O.H. Kwok, S. Hennager, and J.P. Dubey. 2017. Environmental and behavioral changes may influence the exposure of an Arctic apex predator to pathogens and contaminants. Scientific Reports, in press. ()

- The Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA) III: This program broadens understanding of contaminants, sources, and bioaccumulation in the Beaufort Sea area. The program includes a comprehensive sampling plan to characterize the lease area and surrounding area’s chemistry and biota, generating data that are comparable to current and past sampling efforts in the lease area (e.g., past ANIMIDA and cANIMIDA work). A team of scientists from The University of Texas at Austin, the Florida Institute of Technology, the University of Alaska-Fairbanks, Battelle, and Olgoonik-Fairweather conduct the work, which includes sampling in summers 2014 and 2015, with data synthesis in 2015-2016. This work is funded by the Bureau of Ocean Energy Management (BOEM). More information can be found here: http://arcticstudies.org/animida_iii/ (Sep 26, 2017 - Completed)

- Ongoing-Steffansson Sound Boulder Patch: The Steffansson Sound Boulder Patch is a kelp bed community located in the central Alaska Beaufort Sea coast at water depths ranging from 5-7 m. Geographically isolated from other areas of hard rock substrate in the Arctic Ocean, the Boulder Patch is a regional biodiversity hotspot dominated by the kelp Laminaria solidungula. This research program is funded by the Bureau of Ocean Energy Management (BOEM) to establish an integrated knowledge of this biologically productive and diverse ecosystem. Studies began in 1978 and continue through the present. We are currently supported through BOEM Award Number M12AS00001 to The University of Texas at Austin Marine Science Institute. More information can be found here: http://www.arcticstudies.org/boulderpatch/index.html ()
Ongoing—Aerial Surveys of Arctic Marine Mammals (ASAMM) a NOAA led BOEM partnership: The Aerial Surveys of Arctic Marine Mammals project is a continuation of the Bowhead Whale Aerial Survey Project (BWASP) (https://www.afsc.noaa.gov/nmml/cetacean/bwasp/archive.php) and Chukchi Offshore Monitoring in Drilling Area (COMIDA) (https://www.afsc.noaa.gov/nmml/cetacean/bwasp/archive.php) marine mammal aerial survey project. The goal of these studies is to document the distribution and relative abundance of bowhead, gray, right, and fin whales, belugas, and other marine mammals in areas of potential oil and natural gas exploration, development, and production activities in the Alaskan Beaufort and northeastern Chukchi Seas. The 2017 ASAMM field season will run from 1 July to 31 October (daily survey reports available at: https://www.afsc.noaa.gov/nmml/cetacean/bwasp/flights_2017.php). Data from the ASAMM surveys will be used to relate variation in marine mammal distribution or abundance to other variables, such as physical oceanographic conditions, indices of potential prey density, and anthropogenic activities, if information on these variables is available. More information can be found here: https://www.afsc.noaa.gov/nmml/cetacean/bwasp/

New Publication on Disease Baselines in Arctic Foxes from Utqiavik (Barrow): In a new paper, scientists from USDA and the USGS Alaska Science Center, examined Arctic fox carcasses from Utqiavik (Barrow) Alaska, to determine baseline levels of disease. Muscles of herbivores commonly harbor sarcocysts of parasites belonging to parasitic species in the genus Sarcocystis, but such muscle parasites are rare in carnivores such as foxes. This paper reports Sarcocystis arctica-like sarcocysts in muscles of Arctic foxes for the first time. We provide evidence that sarcocysts are common in Alaskan Arctic foxes suggesting that these carnivores are serving as intermediate hosts, and we also provide ultrastructure of S. arctica from the Arctic fox for the first time. Implications for wildlife health and disease transmission are being determined. Citation: Cerqueira-Cézar, C. K., et al. 2017. Morphological and molecular characterization of Sarcocystis arctica-like sarcocysts from the Arctic fox (Vulpes lagopus) from Alaska, USA. Parasitology Research 116(7):1871-1878. doi:10.1007/s00436-017-5462-6

New Publication on Bacteria Responsible for Nonviable Goose Eggs on the North Slope of Alaska: In a recent paper, scientists from the USGS Alaska Science Center and the University of Alaska Fairbanks describe how during the summers of 2013 and 2014, isolates of a novel Gram-stain-negative coccus in the genus Neisseria were obtained from the contents of nonviable greater white-fronted goose eggs on the Arctic Coastal Plain of Alaska. Genetic results suggested that these Alaskan isolates are members of a distinct species, with the name Neisseria arctica. This bacteria does not appear to occur in eggs at a level that is thought to be harmful to populations. Ongoing work is examining whether this is a new bacteria in the Arctic, possibly transmitted by migratory geese from wintering grounds in the lower-48 United States. Citation: Hansen, C. M., E. A. Himschoot, R. F. Hare, B. W. Meixell, C. R. Van Hemert, and K. Hueffer. 2017. Neisseria arctica sp. nov. isolated from nonviable eggs of greater white-fronted geese (Anser albifrons) in Arctic Alaska International Journal of Systematic and Evolutionary Microbiology 67:1115-1119. doi:10.1099/ijs.0.001773 (Sep 13, 2017 - Completed)

8.2.5 (In progress) Conduct research that informs changes in wildlife hunt, harvest, and conservation management such as the Arctic-related LCC-funded moose sightability correction factor model development effort.; DOI-FWS (Lead), NOAA
New USGS publication: Effects of Industrial and Investigator Disturbance on Arctic-Nesting Geese. Direct encounters with humans can increase the likelihood that nesting geese will lose their eggs to predators, according to a U.S. Geological Survey (USGS) study. As part of a study to understand reasons for the rapid increase of geese across northern Alaska and to understand potential impacts to nesting-geese from oil and gas development on the Arctic Coastal Plain of Alaska, USGS researchers used remote cameras to assess the behavioral response of Greater White-fronted geese to disturbance. Results of the study indicate that effects of both industrial and research activity can be minimized through practices that limit direct encounters with nests, such as minimizing travel on the tundra during the nesting season, using established travel routes during the summer, and minimizing the research study area to reduce impact.

The article and associated data release are listed below:


8.2.6 (In progress) Improve knowledge of phenology in relation to coastal climate and plant and animal life to better understand issues related to mismatches between prey, predators, hunters, and gatherers in the context of and in collaboration with Arctic coastal communities. This element includes a Western Alaska LCC-funded project on subsistence berry availability.; DOI-FWS (Lead), DOI-USGS (Lead), NSF

- USGS Changing Arctic Ecosystems Publication on Reproductive Strategies of Arctic-nesting Geese and Resilience to Climate Warming: USGS Alaska Science Center scientists Jerry Hupp and David Ward collaborated with scientists from Environment and Climate Change Canada on a paper that examines the sources of nutrients that arctic-nesting geese invest in eggs. They found that Snow Geese and White-fronted Geese were early migrants that mainly derived egg nutrients from plants that females consumed near the nesting area, but that Black Brant migrated to the Arctic later and derived more egg nutrients from body reserves that females built on coastal winter and migration areas. Arctic warming is likely to favor the early migration and reproductive strategies of Snow Geese and White-fronted Geese by improving spring nutrient availability on nesting areas. The research appears in Global Change Biology at: https://doi.org/10.1111/gcb.14418. Citation: Hupp, J. W., D. H. Ward, D. X. Soto, and K. A. Hobson. 2018. Spring temperature, migration chronology, and nutrient allocation to eggs in three species of arctic-nesting geese: Implications for resilience to climate warming. Global Change Biology 24: In press. doi: 10.1111/gcb.14418 (Aug 17, 2018 - Completed)

- New USGS-led Publication on Mismatches with Caribou and Forage in Alaska: Climate-induced shifts in plant phenology may adversely affect animals that cannot or do not shift the timing of their reproductive cycle. Caribou rely heavily on maternal energy stores to reproduce and give birth near the onset of the growing season but are they vulnerable to trophic mismatch? We evaluated the long-term changes in the temperatures and characteristics of the growing seasons, and compared forage quality for caribou at peak parturition, peak lactation, and peak forage biomass at two distinct time periods over 36 years (1977 and 2011–13). We found no decline in forage quality

- Yukon-Kuskokwim Delta Berry Outlook: Identifying berry vulnerabilities to climate and landscape change using traditional and scientific ecological knowledge. This project began in 2016 and continued in 2017. Berry-producing plants play an important role in human and wildlife communities in the Yukon-Kuskokwim Delta. Berries provide food for subsistence and are a preferred food source for birds. Berry yield can be influenced by snow cover, rainfall, soil moisture, and air temperature, and availability of insect pollinators, all of which may be significantly altered by climate change. Additional information and tools are necessary to predict how the distribution and productivity of berry-producing plants may be altered by climate change. The overreaching goal of this project is to develop a Yukon-Kuskokwim Berry Outlook: a data- and observer-driven ecological monitoring and modeling framework that forecasts changes in berry abundance with climate and environmental change. This project will 1) solicit local observations of patterns of change in berry abundance, including hot spots that are highly sensitive or highly resilient; 2) develop models relating berry cover and abundance to climatic and environmental drivers, based on observer information and extensive, existing vegetation, salinity, storm surge, and climate data; 3) produce a spatially-explicit “Berry Outlook“ using map layers of current and predicted climate and environmental conditions; and 4) share results with stakeholders and identify priorities, potential points of management intervention, and future activities. Contact: Rachel Loehman, USGS Alaska Science Center

8.3 Advance knowledge on the physical coastal processes impacting natural and built environments.

- 8.3.1 (In progress) Improve understanding of coastal erosion and deposition, including related geomorphic changes due to permafrost degradation, reduced sea ice extent, storm surge, increased wave action, and sea level rise. This Element includes work by the USGS Coastal and Marine Geology Program, USGS Alaska Science Center, U.S. Army Corps of Engineers (USACE), and others.; DOD-USACE (Lead), DOI-USGS (Lead), DOI-BOEM, NOAA, NSF

- The National Science Foundation (NSF) has recently awarded OPP – 1818485. Understanding wave-ice-ocean interactions along the Arctic coast is essential to improving the skill of forecast and climate models in the region. The project will connect a rapidly changing climatology with the physical processes that are fundamental to Arctic coastal ocean, incorporating natural variability on a wide range of spatial and temporal scales. The investigators will apply recent progress in process-based modeling of coastal dynamics, provide detailed field observations along the coast for model validation and calibration, and generate a 20-year hindcast. The hindcast will then be used to investigate the climate signals in Arctic wave-ice-ocean coupling and determine: 1) the significance of coastal protection via scattering and dissipation of waves by sea ice; 2) the thermodynamic and mechanical effects of increasing wave energy; and 3) the changes in coastal flooding and circulation associated with increasing wave momentum. These results will fill a gap between the recent progress modeling wave-ice interactions in deep-water and existing programs studying erosion at the shoreline. (Oct 15, 2018 - Completed)
New Instruments Installed to Measure Arctic Coastal Erosion: Coastal erosion along the Arctic coast of Alaska threatens Native Alaskan villages, sensitive ecosystems, energy- and defense-related infrastructure, and large tracts of Native Alaskan, State, and Federally managed land. In July 2018, three USGS Pacific Coastal and Marine Science Center researchers installed thermometers, video cameras, a seismometer, and a wave gauge to measure permafrost temperatures and bluff erosion on the Arctic Ocean coast of Barter Island, Alaska. Combined data from these instruments will be used to test the possibility of remotely estimating wave heights without installing and maintaining wave gauges in the ocean. USGS also hosted a community outreach event to present results from earlier studies and to discuss their ongoing research. Government officials, residents, and non-residents attended the event. PCMSC researchers particularly appreciated the local coastal information, insights, and concerns provided by long-time community residents. Contact: Li Erikson, lerikson@usgs.gov, 831-460-7418 (Aug 20, 2018 - Completed)

BOEM has entered into a cooperative agreement, Northern Alaska Jukebox - Phase III with the Coastal Marine Institute, University of Alaska, Fairbanks. PI is Leslie McCartney, Elmer E. Rasmuson Library. (Sep 21, 2017 - Completed)

New Publication on Historical Record of Climate Change in Alaska and Implications for Permafrost Thaw: A recent publication with co-authors from USGS, Columbia University, University of Alaska Fairbanks, The College of Wooster, and Reanier & Associates Inc., examined how declining sea-ice extent is currently amplifying climate warming and permafrost thaw in the Arctic. The authors used the oxygen isotope values of wood cellulose in living and sub-fossil willow shrubs that have been radiocarbon-dated to produce a multi-millennial record of climatic change on Alaska's North Slope during the Pleistocene-Holocene transition (13,500–7500 years before present). Based on these results and on the effects that sea-ice have on climate today, we infer that ocean-derived feedbacks amplified temperature changes and enhanced precipitation in coastal regions of Arctic Alaska during warm times in the past. Today, isotope values in willows on the North Slope of Alaska are similar to those growing during the warmest times of the Pleistocene-Holocene transition, which were times of widespread permafrost thaw and striking ecological changes. Gaglioti, B. V., D. H. Mann, M. J. Wooller, B. M. Jones, G. C. Wiles, P. Groves, M. L. Kunz, C. A. Baughman, and R. E. Reanier. 2017. Younger-Dryas cooling and sea-ice feedbacks were prominent features of the Pleistocene-Holocene transition in Arctic Alaska. Quaternary Science Reviews 169:330-343. doi:10.1016/j.quascirev.2017.05.012 (Sep 13, 2017 - Completed)

New USGS Publications on Shoreline Change in Northern Alaska: Alaska’s north coast is predominantly erosional, averaging a loss of 1.4 meters a year (http://pubs.usgs.gov/of/2015/1048/pdf/ofr2015-1048.pdf). Along a much smaller stretch (60 kilometers) (http://soundwaves.usgs.gov/2009/05/research2.html) of this coastline, USGS found that average annual erosion rates doubled from historical levels of about 20 feet per year between the mid-1950s and late-1970s, to 45 feet per year between 2002 and 2007. The study along that stretch of the Beaufort Sea also verified the disappearance of cultural and historical sites (http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/44), including Esook, a hundred-year-old trading post now underwater on the Beaufort Sea floor, and Kolovik (Qalluvik), an abandoned Iñupiaq village site that may soon be lost.
The change in erosion rates is likely the result of several changing Arctic conditions, including declining sea-ice extent, increasing summertime sea-surface temperature, rising sea level, and possible increases in storm power and corresponding wave action. More information is here: https://walrus.wr.usgs.gov/climate-change/hiLat.html.

Recent publications on this work are listed below:


- 8.3.2 (In progress) Increase understanding of coastal freshwater hydrologic changes in rivers, lakes, snow, and permafrost through projects such as the Soil Climate Analysis Network (SCAN) soil moisture and temperature site monitoring.; DOI-USGS (Lead), NOAA (Lead), USDA-NRCS (Lead), DOI-BLM, DOI-BOEM, DOI-NPS, NASA, NSF
  - The National Science Foundation (NSF) has recently awarded OPP – 1806213. The dynamic nature of thermokarst lakes make them prone to catastrophic drainage and abrupt conversion to wetlands, called drained thermokarst lake basins (DTLBs). A combination of remote sensing, field observations, and a lake-drainage experiment are targeted at understanding the causes and consequences of DTLB formation and their broader feedbacks with other arctic system components. Data collected in this study will feed into future model development to enhance predictive capacity of hydrologic hazards and landscape responses to climate change in the Arctic. Space-for-time comparison of DTLB chronosequences provides the conceptual framework for linking process scales. The new conceptual model emerging from this project is important for several stakeholders and native villages, where water access, habitat mitigation, and hazard avoidance are a priority. (Sep 27, 2018 - Completed)
  - NASA's Ocean Biology and Biogeochemistry Program and Water & Energy Cycle programs are funding several projects contributing to the achievement of this performance element.

Principal Investigator David Butman (student Catherine Kuhn) were funded under the NASA Earth and Space Science Fellowship (NESSF) program under their proposal “When atmospheric correction matters: Improving retrievals of inland water properties from remote sensing and field data” to better understand carbon cycling in the Arctic (Alaska) via rivers. The research specifically aims at quantifying changes aquatic C dynamics of permafrost waterbodies using bio-optical retrieval models, specifically looking to understand artic and boreal carbon cycling in response to ongoing climatic changes. Their approach will use satellite and in situ measurements, and has a focus on improving atmospheric correction methods to achieve the desired objectives.
Another continuing project is Principal Investigator Samuel Laney of Woods Hole Oceanographic Institution for the project “Riverine Carbon Contributions to Alaskan Arctic Coastal Margins”, funded under Carbon Cycle Science in NASA's ROSES 2016. https://cce.nasa.gov/cgi-bin/obb/pi_list.pl?project_group_id=3615. This research seeks to better quantify the seasonality and variability in the riverine contribution of organic carbon into Arctic Ocean coastal margins. Rivers feeding the coastal Arctic Ocean drain several types of biomes and represent a major source of particulate and dissolved organic carbon (POC and DOC) to Arctic coastal margins. Climate-driven changes to Arctic terrestrial biomes will almost certainly alter the magnitudes and relative contributions of POC and DOC that different rivers transport into their adjacent coastal oceans. Direct assessment of river-specific baselines for this terrestrial carbon input has been challenging because much of this carbon is delivered by the spring freshet that occurs while the coastal ocean is still covered by landfast sea ice. This project will examine the seasonality and magnitude of this carbon transport and its relationship to coastal hydrography and circulation, the spring freshet, seasonal ice dynamics, and remote sensing variables available during the freshet such as sea ice cover and ice morphology.

Principal Investigator Peter Hernes of University of California, Davis is implementing research under the project “Impacts of estuarine processes on delivery of Arctic riverine materials to the near coastal environment: Implications for water quality and biogeochemical cycling in Preparation for Arctic-COLORS”. Funded under Remote Sensing of Water Quality in ROSES 2016. The proposed research seeks to jumpstart Arctic-COLORS while filling major gaps in our understanding of the linkages between aquatic optical and biogeochemical properties and our knowledge about the transformation of inland water quality constituents from the ABoVE domain through estuaries to the near coastal environment. Our overarching goal is to use new and enhanced remotely sensed water quality observations to better understand biogeochemical fluxes and transformations across terrestrial aquatic interfaces in the Arctic.

Principal Investigator Michael Rawlins, University of Massachusetts, Amherst received NASA funding for the proposal, “Merging Satellite Data and Models to Investigate Soil Freeze-Thaw Dynamics Influencing Terrestrial Water and Carbon Exports from the Western Arctic”. The project was funded under the Remote Sensing of Water Quality in ROSES 2016. The project will leverage available records of river discharge and surface soil freeze/thaw (FT) state from satellite data, and hydrological modeling to improve understanding of the temporal and spatial dynamics in freshwater export into coastal margins from the Yukon to Mackenzie (Y2M) Rivers. We will use remote sensing data sets for key spatially distributed geophysical quantities and will quantify interannual variability and the sign, magnitude, and significance of changes in freshwater export over recent decades. Our project will advance understanding of changes likely to occur as a result of declining frozen seasons, soil active layer deepening, permafrost thaw and hydrological cycle intensification.

Finally, the writing team completed the Arctic-COLORS scoping study/science plan report and submitted it to NASA HQ program managers in February 2018. It is available at: https://cce.nasa.gov/pdfs/ArcticCOLORS_Final.pdf (Sep 27, 2018 - Completed)
Additional details on the Arctic-COLORS report follows: This is a draft Science Plan that is the report of a Scoping Study funded under NASAROSES 2013 A.3 OBB that needs to go through peer-review before final acceptance by the agency. Even if accepted as a potential field campaign effort by the agency, the agency would still have to find the funding to execute it, likely circa the 2022 era as the EXPORTS campaign was conducted in 2018. The first likely step in moving forward with the ARCTIC-COLORS field campaign would be for the agency to complete a Science Working Group to come up with ideas for an implementation plan. 

USGS and National Weather Service Meet Regarding Glaciers and Streamflow: USGS glaciologist Shad O’Neel and hydrologist Jeff Conaway met with hydrologists from the National Weather Service's Alaska Pacific River Forecast Center to discuss glacier contribution to forecast models. The existing model utilizes a basic conceptual model developed nearly 20 years ago. The USGS provided the forecasters with an overview of recent USGS and academic work on glacier inventories and glacial contributions to streamflow. NWS and USGS will examine additional approaches that may be needed to model glacier melt to implement the NWS Water Model in Alaska where glaciers have significant impact on the magnitude and timing of streamflow. (Aug 17, 2018 - Completed)

New Publications on Lake and Pond Databases for Northern Alaska:


Below is information for three recently funded NASA projects. Their research going forward is likely to contribute to progress in achieving this milestone. Arctic Biogeochemistry: Laney, Samuel, Woods Hole Oceanographic Institution. “Riverine Carbon Contributions to Alaskan Arctic Coastal Margins”, funded under Carbon Cycle Science in ROSES 2016. An abstract is available at: https://cce.nasa.gov/cgi-bin/obbb/pi_list.pl?project_group_id=3615.

This research seeks to better quantify the seasonality and variability in the riverine contribution of organic carbon into Arctic Ocean coastal margins. Rivers feeding the coastal Arctic Ocean drain several types of biomes and represent a major source of particulate and dissolved organic carbon (POC and DOC) to Arctic coastal margins. Climate-driven changes to Arctic terrestrial biomes will almost certainly alter the magnitudes and relative contributions of POC and DOC that different rivers transport into their adjacent coastal oceans. Direct assessment of river-specific baselines for this
terrestrial carbon input has been challenging because much of this carbon is delivered by the spring freshet that occurs while the coastal ocean is still covered by landfast sea ice. This project will examine the seasonality and magnitude of this carbon transport and its relationship to coastal hydrography and circulation, the spring freshet, seasonal ice dynamics, and remote sensing variables available during the freshet such as sea ice cover and ice morphology. This research involves a two-year observational study on the Alaskan Beaufort Shelf using bio-optical moorings and direct, through-ice monitoring to assess the magnitude and timing of riverine POC and DOC contribution into the coastal Arctic. Six moorings will be deployed near Prudhoe Bay at the mouths of two rivers that drain terrestrial biomes with different vegetation and precipitation characteristics: the Kuparuk River which drains a primarily tundra biome, and the Sagavanirktok River which drains the coastal plain and the north slope of the Brooks Range. Sensors will measure optical proxies for POC and DOC over two full annual cycles, most critically in the period encompassing the spring freshet when riverine transport of POC and DOC is largest but when these coastal waters remain ice-covered and thus not yet directly observable by remote sensing. Monthly-scale field studies will be conducted in the late spring, immediately prior to the freshet, to deploy sensor clusters through the sea ice to directly measure these optical proxies over the course of the freshet until sea ice cover degrades and coastal waters become visible to remote sensors. These two observational efforts will generate unique and valuable time series of proxies for POC and DOC as well as key environmental parameters related to coastal circulation, sea ice cover, and river discharge dynamics. These will be used in a subsequent analysis to quantify how the spatial and temporal evolution of riverine DOC and POC injection by these two rivers relate to physical factors such as riverine seasonal flow and freshwater runoff, coastal hydrography and circulation, and importantly, seasonal sea ice cover. By examining two representative rivers that drain different types of terrestrial biomes, this study will provide insight into possible source-river differences in organic carbon transport into these seasonally ice-covered Arctic coastal margins. Having such direct, long-term observations of proxies for the POC and DOC delivered by the spring freshet is essential for reducing uncertainties about key aspects of the organic carbon cycle on the Alaskan Arctic coastal margin: • What is the timing and magnitude of POC and DOC injection into Arctic coastal margins? • How can autonomous systems help to assess differences in POC-DOC contributions by rivers that drain such different types of biomes (e.g., tundra vs. alpine)? • How do ice cover, hydrography, circulation, winds, and freshwater input affect the areal distribution of water column POC and DOC on this shelf, during the freshet? • How might available remote sensing variables during this time of year be used to better understand similar riverine contributions of POC and DOC more broadly across Arctic coastal margins in the Beaufort Sea and beyond? Coastal Resilience focus: Peter Hernes, University of California, Davis. “Impacts of estuarine processes on delivery of Arctic riverine materials to the near coastal environment: Implications for water quality and biogeochemical cycling in Preparation for Arctic-COLORS”. Funded under Remote Sensing of Water Quality in ROSES 2016. Environmental systems do not wait until it is convenient for humans to respond to perturbations, and a prime example of this is the rapidly changing Arctic that has science and policy scrambling to keep up. This highlights a critical need for programs such as NASA’s Arctic-Boreal Vulnerability Experiment (ABoVE) and Arctic-COastal Land Ocean inteRactionS (Arctic-COLORS) that aim to characterize the extent of change to terrigenous and coastal systems in the Arctic, respectively, and the strength of associated feedbacks. However, it also
highlights the issue of timing that these programs need to be fully implemented as quickly as possible for maximum impact on future policy decisions. The proposed research outlined here seeks to jumpstart Arctic-COLORS while filling major gaps in our understanding of the linkages between aquatic optical and biogeochemical properties and our knowledge about the transformation of inland water quality constituents from the ABoVE domain through estuaries to the near coastal environment. Our overarching goal is to use new and enhanced remotely sensed water quality observations to better understand biogeochemical fluxes and transformations across terrestrial-aquatic interfaces in the Arctic. Specifically, we propose to: 1) Lay the foundation for Arctic-COLORS by establishing current baseline water quality conditions from the head of tides to the near coastal environment in two larger river systems (Yukon and Mackenzie Rivers) and a smaller river system on the North Slope of Alaska. 2) Characterize the transformation of riverine material through estuarine gradients across different seasonal and hydrologic conditions in order to model delivery of materials to the near coastal environment from more than a decade of past river measurements from the Arctic Great Rivers Observatory (Arctic-GRO) dataset. 3) Refine and develop algorithms for water quality concentrations from remote sensing data, which can then be used to hindcast coastal Arctic conditions back to 2002 and quantify the extent and rates of change in delivery of riverine materials to the near coastal environment. The validity of these hindcast values will be assessed through data synthesis efforts of past measurements and modeled exports as outlined in item #2. To link optics to aquatic biogeochemistry across the continuum of Arctic rivers, estuaries and the coastal ocean, we plan intensive field sampling on the Yukon River-delta for three transects in spring, early and late summer, acquisition of additional transect samples during similar flow regimes through our collaborators on the North Slope and Mackenzie River, and a period of continuous monitoring in the Yukon River. These study regions are part of both the ABoVE and Arctic-COLORS core study domains. In addition to the proposed new field observations, we will conduct a series of controlled salinity mixing experiments on samples from all three systems that will simulate transport through estuarine gradients during seasons in which we are not collecting transects. This is crucial for understanding the fate of terrigenous organic matter in the Arctic Ocean. Finally, we propose to synthesize existing bio-optical, hydrological and biogeochemical datasets in coastal and inland Arctic ecosystems collected as part of our prior work in the framework of Arctic-GRO and ABoVE, and through our proposed collaborations. These new and existing observations will allow us to develop new and refined remote sensing bio-optical retrievals and atmospheric corrections that will allow regional scaling and temporal hindcasting. Through the proposed integration of field sampling, satellite algorithm development, hindcasting, and synthesis efforts the proposed study will provide critical new knowledge of biogeochemical transformations across Arctic terrestrial-aquatic interfaces and an urgently needed link between the ABoVE and Arctic-COLORS field programs, both on the spatial and temporal domain. Michael Rawlins, University Of Massachusetts, Amherst. “Merging Satellite Data and Models to Investigate Soil Freeze-Thaw Dynamics Influencing Terrestrial Water and Carbon Exports from the Western Arctic”. Funded under Remote Sensing of Water Quality in ROSES 2016. Manifestations of climate change in the Arctic are expected to include an intensified hydrologic cycle and thawing permafrost, with likely impacts on river discharge and associated constituents. Changes in the quantity and quality of water and carbon exported from terrestrial areas are expected as the Arctic undergoes a transition
to a more groundwater-dominated system. The limited number of observations challenges our understanding of the magnitude and spatio-temporal variability in these exports, particularly for unmonitored rivers in northern Alaska. We will leverage available records of river discharge and surface soil freeze/thaw (FT) state from satellite data, and hydrological modeling to improve understanding of the temporal and spatial dynamics in freshwater export into coastal margins from the Yukon to Mackenzie (Y2M) Rivers. We will use remote sensing data sets for key spatially distributed geophysical quantities and will quantify interannual variability and the sign, magnitude, and significance of changes in freshwater export over recent decades. Our project will advance understanding of changes likely to occur as a result of declining frozen seasons, soil active layer deepening, permafrost thaw and hydrological cycle intensification. We will integrate multi-frequency satellite microwave remote sensing and other synergistic geospatial data using a novel machine learning Bayesian data fusion framework for probabilistic estimation of soil FT daily dynamics. We will develop a database of freshwater export across the western Arctic, focusing on export to coastal margins from the Yukon to Mackenzie rivers. We will merge available measurements with model simulated hydrography to derive exports in unmonitored areas. For areas lacking observed data our derived freshwater export time series will leverage a permafrost-hydrology model specifically adapted for studies of the terrestrial arctic water cycle. An ensemble of model simulations validated with gauge data from monitored rivers will be used to document uncertainties in export. Model simulations will make use of the growing collection of high resolution datasets being developed under NASA's Arctic-Boreal Vulnerability Experiment (ABOVE). Synergistic satellite data for FT timing, soil moisture, and surface water extent dynamics will be employed to constrain the process modeling. The project will advance mechanistic and predictive understanding of freshwater export with a central focus on physical processes operating within high latitude watersheds. This synthesis of data and models will advance understanding of how warming manifested through water cycle intensification and permafrost degradation is likely to impact terrestrial water and carbon exports to Arctic coastal areas. (Sep 4, 2017 - Completed)

8.4 Improve observations, mapping, and charting to support research across the coastal interface.

- **8.4.1 (In progress)** Update the National Spatial Reference System in the Arctic to enable integration of baseline geospatial datasets in coastal areas to support research and predictive capabilities across the coastal interface.; NOAA (Lead), DOD-NGA
  
  In FY17, NOAA's National Geodetic Survey (NGS) continued acquiring airborne gravity measurements over Alaska as part of the nationwide Gravity for the Redefinition of the American Vertical Datum (GRAV-D) project. GRAV-D data collection is now at 78.4% for all of Alaska, 89% excluding the Aleutians; areas of data coverage may be viewed here: https://www.ngs.noaa.gov/grav-d/data_products.shtml. In support of improved GPS-based access to accurate and consistent vertical heights in coastal areas of Alaska, NGS also released a new experimental geoid product in FY17 (xGeoid17) that is a preview of what the geoid will look like in the new North American-Pacific Geopotential Datum of 2022 (NAPGD2022): https://beta.ngs.noaa.gov/GEOID/xGEOID17/. This updated experimental product incorporates the data from 2 additional GRAV-D survey blocks in Alaska. In February, 2017 NOAA provided a webinar to summarize these recent developments and the effects that these new data will have on positioning tools in
Alaska. The GRAV-D Update and Experimental Geoid in Alaska webinar recording is available online: [https://www.ngs.noaa.gov/web/science_edu/webinar_series/grav-xgeoid.shtml](https://www.ngs.noaa.gov/web/science_edu/webinar_series/grav-xgeoid.shtml). (Sep 13, 2017 - Completed)

- **8.4.2 (In progress)** Develop new sensor technologies and data collection and application methods specific to understanding and characterizing relationships within coastal systems across all seasons for natural resource, community, and emergency response planning and management. ; NOAA (Lead), DOI-FWS, DOI-NPS
  - Incorporating vessel drift modeling into an assessment of oil spill risk to wildlife and subsistence communities in the Alaskan Arctic. The U.S. Fish & Wildlife Service is funding a project that draws on agency, industry and community expertise to evaluate the results of a simulation modeling effort to identify areas at risk from potential oil spills resulting from vessel traffic in the Bering Sea. This modeling effort draws on industry data sets for vessel traffic and ecological models for winds and currents that have been developed by agencies and their research partners. This project emerged from the Aleutian and Bering Sea Islands and Western Alaska LCCs--key stakeholders informing the analysis will include community and tribal representatives from those partnerships.
  - UAF Deploys Storm Surge Monitoring Tripods in Three Northwest Coastal Communities
    Northwest Alaska is no stranger to large fall storms. From October until the sea ice arrives, the region experiences multiple coastal storms each year that heavily impact the region leading to inundation and coastal erosion. In September 2017, UAF deployed beach mounted tripods equipped with water level sensors in Kivalina, Shaktoolik and Shishmaref in an effort to gain a better understanding of the size, frequency and impact of these events on coastal communities. Custom made tripods were designed and built that could be transported to the remote communities and easily deployed in a days’ time. Tripods were deployed on the beach close to the last high tide line so that storms large and small could be recorded. The tripods housed HOBO MX2001 water level loggers that were programmed to record during storm events at a rate of one sample per second that provided water level data and a general picture of wave height and frequency over time. With the help of a local representative in each community, data was downloaded from the loggers after each storm and emailed to researchers at UAF. The 2017 project was a pilot study funded by AOOS and results will be posted on the AOOS oceanographic data portal. [https://www.aoos.org/alaska-water-level-watch/uaf-water-level-platforms/](https://www.aoos.org/alaska-water-level-watch/uaf-water-level-platforms/) (Sep 28, 2018 - Completed)
  - The Alaska Water Level Meeting, Making Progress: The Alaska Water Level Meeting, Making Progress: Integrated Water Level Observation Network in Alaska was held in two sessions, Day 1. water level sensing technologies and Day 2. stakeholder and partner engagement. There were approximately 35 participants throughout the meeting, representing state and federal agencies, private industry, research institutions, a regional Native corporation, and a non-profit. The meeting included presentations and discussions to identify the appropriate technologies to fill Alaska’s water level monitoring gaps and the priority locations and uses of water level data. A summary report including notes taken by meeting participants will be included in a second version of Coastal & Nearshore Water Level Observation in Alaska: Challenges, Assets, Gaps, and Next Steps. [https://www.aoos.org/alaska-water-level-watch/alaska-water-level-meeting-2018/](https://www.aoos.org/alaska-water-level-watch/alaska-water-level-meeting-2018/) (Sep 28, 2018 - Completed)
Alaska Water Level Watch: established The Alaska Water Level Watch (AWLW) is a collaborative group working started by the State of Alaska, Alaska Ocean Observing System, and NOAA to improve the quality, coverage, and accessibility to water level observations in Alaska’s coastal zone. https://www.aoos.org/alaska-water-level-watch/ (May 22, 2018 - Completed)


The work done on the Bering Invaders Project (http://accs.uaa.alaska.edu/invasive-species/bering-sea-marine-invasives/) is relevant to this Performance Element through furthering the understanding of how to monitor some of the processes needed to manage and mitigate invasive species. While this work is not doing the monitoring, it provides tools to start focusing/maximizing resources. Please see https://www.iarpccollaborations.org/members/documents/10874 for more information. (Feb 1, 2018 - Completed)

Oblique iGage Water Level R&D Demonstration Underway- An iGage is being tested in Whittier, AK this year to see if it can provide accurate water levels looking obliquely rather than the standard nadir view. If successful, it will provide an inexpensive method for monitoring water levels in remote areas and communities without the infrastructure (bridges, piers) needed for nadir looking systems. ()

2017 Rapid Deployment Inundation Platform (RDIP) Deployments- NOAA and AOOS supported UAF’s development of Rapid Deployment Inundation Platforms (RDIP) to measure storm tide water levels in areas without continuous water level monitoring systems. Community members in Shishmaref, Shaktoolik and Kivalina are being trained to deploy the units in advance of coastal storms. Supports the Strategic Management Plans of Shishmaref, Shaktoolik and Kivalina. ()

Rapid Deployment Storm Surge Gauges- The Coastal Hazards program at Alaska Department of Natural Resources contracted with JOA Surveys LLC to install Rapid Deployment Storm Surge Gauges in Hooper Bay and Nunam Iqua for the fall 2017 storm season. These consist of an in-ground vault where water level loggers can be placed in less than 10 minutes. ()

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2017 iGage Water Level Instrument Installations- Three new iGage water level sensors were deployed this summer in Kaktovik (replacement), Unalakleet (replacement), and Dillingham (new). (Sep 1, 2017 - Completed)

Emerging Technologies workshop – Axiom’s Kyle Wilcox presented on behalf of IOOS, AOOS and partners CeNCOOS and SECOORA at NOAA’s second Emerging Technologies workshop August 22-23. (Aug 23, 2017 - Completed)

Ice Detection Buoy Deployed; An Ice Detection Buoy was deployed August 14, 2017 ~70 miles northwest of Wainwright, Alaska and is transmitting data through the Global
Telecommunication System (GTS) for evaluation in real-time ice forecasting models. For more information on the buoy see [http://www.aoos.org/ice-detection-buoy/](http://www.aoos.org/ice-detection-buoy/) (Aug 14, 2017 - Completed)

- New Arctic Marine Atlas Released – Audubon Alaska’s massive update to this atlas, describing bird, fish, and marine mammal habitats and migration routes as well as human uses, was released at an event August 4. AOOS is working with Audubon to incorporate the database and a version of the map layers into the AOOS Ocean Data Explorer. (Aug 4, 2017 - Completed)

- Presentations by Raphaela Stimmelmayr and Vera Metcalf given at the July 6th Coastal Resilience Collaboration Team Meeting ([http://www.iarpccollaborations.org/members/events/7846](http://www.iarpccollaborations.org/members/events/7846)) are relevant to this Performance Element (Jul 7, 2017 - Completed)

- AOOS-UNAVCO Water Level Joint Venture – Molly and Carol met with representatives of UNAVCO to discuss the results of their scoping project aimed at identifying potential locations in western Alaska for deployment of GPS reflectometry sensing devices. These systems that can be used for measuring water levels in remote regions. Potential recommended sites include St. Michael, Hooper Bay and Toksook Bay. The first site for installation will be selected soon, and with the goal to instrument all three locations over the next two years. For more info: [http://www.aoos.org/new-aoos-projects-to-test-land-based-water-level-techniques/](http://www.aoos.org/new-aoos-projects-to-test-land-based-water-level-techniques/) ()

- Trial Water Level Sensing Devices Installed - In early April two dual-frequency GPS receivers were installed in Seward near the Alaska SeaLife Center by ASTRA LLC. This AOOS project, funded by the Alaska region of the National Weather Service, will evaluate this system’s suitability for land-based water level measurements prior to extending the technology to a broader monitoring network in remote locations. Immediately following installation this eagle decided it was a good lookout platform. (Apr 7, 2017 - Completed)

- **8.4.3 (In progress) Produce modeled tidal predictions for the U.S. Arctic. Involve multiagency collaborators, including Alaska Ocean Observing System (AOOS) representatives.; NOAA (Lead)**

  - Alaska Coastal Mapping Summit- On February 9, 2018 over one hundred subject matter experts gathered in Anchorage for the second Alaska Coastal Mapping Summit. This event, hosted by the Alaska Ocean Observing System (AOOS), the State of Alaska Department of Natural Resources (AK DNR), and the federal Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM), provided a forum to discuss the next steps for a coordinated approach to coastal mapping in Alaska. (Feb 9, 2018 - Completed)

  - UNAVCO contract – Molly and Carol met with representatives of UNAVCO to discuss the results of their scoping project aimed at identifying potential locations in western Alaska for deployment of GPS reflectometry sensing devices. These systems that can be used for measuring water levels in remote regions. Potential recommended sites include St. Michael, Hooper Bay and Toksook Bay. The first site for installation will be selected soon, and with the goal to instrument all three locations over the next two years. For more info: [http://www.aoos.org/new-aoos-projects-to-test-land-based-water-level-techniques/](http://www.aoos.org/new-aoos-projects-to-test-land-based-water-level-techniques/) ( )
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Agencies
DOC, DOD, DOI, DOS, HHS, NASA, NSF, OSTP, SI
9.1 Environmental intelligence

9.1 Enhance multi-agency participation in new and existing activities to improve best practices, coordination, and synthesis of Arctic observations toward a fully integrated interagency "U.S. Arctic Observing Network" (U.S. AON).

- 9.1.1 (In progress) Coordinate U.S. agency and outside collaborators support for and participation in the international Sustaining Arctic Observing Networks (SAON) process.
  - NOAA (Lead), DHS-USCG, DOD-ONR, DOE, NASA, NSF
    - Increase collaboration and synthesis of Year of Polar Predication (YOPP) activities: AOSST co-convened a meeting with the Atmospheric Collaboration Team to discuss atmospheric observing activities during YOPP. Activities funded by NSF, NASA, NOAA, DOE, and ONR were presented (Sep 28, 2018 - Completed)
    - Promote the Implementation of the SAON-STPI Societal Benefit Framework: In FY17, the US made a significant contribution to SAON advancement through funding the Arctic Observing Assessment Framework, which outlined 12 Societal Benefit Areas, 40+ sub areas, 160+ objectives that would be served through Arctic Observing. The AOSST has continued to promote the use of this framework and had 3 separate discussions that examined applying this framework to different elements of Arctic observing.
    - Coordinate US contributions to the SAON Strategy and Implementation Plan: Larry Hinzman, Will Ambrose, Peter Pulsifer, Hajo Eicken, Sandy Starkweather, Peter Schlosser and a handful of other US contributors gave significant input to the SAON Strategic Plan. We had an input session through the AOSST, the US AON Board, the IARPC and garnered feedback on the draft from those bodies. The document was completed in January 2018. Since that time, an Implementation Plan has also developed. This is considered a ‘living document’.
    - Coordinate US Contributions to the Arctic Observing Summit: AOSST hosted 3 different calls that had significant content related to the Arctic Observing Summit, starting with a call early in the year to introduce the themes and share ideas across US participants interested in submitting short statement, just in advance of the AOS to consolidate collaboration, and directly following to hone US opportunities for advancing the recommendations from the AOS Conference statement. US contributors led submission
of 15 short statements to the conference (more than 1/3 of all contributions). A strong concept for an NSF Research Coordination Network (RCN) proposal is emerging from these discussions.


- Stein Sandven and Hanne Sagen presented "Intergrated Arctic Research Observation System (INTAROS)" (https://www.iarpccollaborations.org/members/documents/10212) and Maribeth Murray presented "Arctic Observing Summit (AOS)" (https://www.iarpccollaborations.org/members/documents/10211) at the AOSST October 2017 meeting. Participants discussed the pathways for the US community, specifically through IARPC, to coordinate with EU and Canadian observing efforts. INTAROS and AOS provide their suggestions for US collaboration and how they have established and continue to develop other international research connections and collaborations. (Jul 5, 2018 - Completed)

- SAON is rewriting strategic plan for the next 5-years, will send it to IARPC to distribute for comment and engagement. Would be good to have alignment between US priorities for observing and SAON strategic plans. New SAON chair Gunnerson (Iceland), Larry Hinzman new Vice Chair. STPI value tree has been really helpful in developing SAON plan. Would like to encourage more US involvement in SAON by connecting IARPC community into SAON- will improve engagement with IARPC community over the next year. ()

- ADAC is developing a long-range autonomous underwater vehicle for under-ice mapping of oil spills and environmental hazards. (Oct 4, 2017 - Completed)

- The AOSST and ADST teams conducted joint SAON collaboration team meeting to introduce the IARPC community to the Arctic Data Committee and the Committee on Observations and Networks. This meeting was held prior to the Arctic Observing Summit meeting in order to obtain input from the research community on SAON progress and future directions. ()

- **9.1.2 (In progress) Work with the research community and other stakeholders to develop the concept of multi-agency research coordination networks to advance observational science and promote broad synthesis within thematic research communities.; NOAA (Lead), NSF (Lead), DOD-ONR, DOE, NASA**

- US AON Recommendations to IARPC Principals: IARPC Principals formally recognized US AON as an IARPC activity at their November board meeting. It was agreed that the US AON Board is the Federal body of the broader IARPC Collaborations Observing Team. Deliverable: Key Findings and Recommendations of the Consultative Phase of US AON (https://www.iarpccollaborations.org/members/documents/10125) (Sep 27, 2018 - Completed)

- Development of the US AON Board: US AON Board convened 7 times and concentrated their efforts on how the board could contribute to a strategic framework to guide US AON. The board has reviewed inputs, deliberated scope, and addressed fundamental
needs. The full board is in concurrence that a framework process is worth pursuing.
Deliverable: Draft AON Strategy from the US AON Board Outline v.05.30.2018 (no public link) (Sep 27, 2018 - Completed)

- Advance US AON Task-based Efforts: US AON Board members continue to promote task based work to better consolidate and link priority efforts across agencies.
  a. NOAA Sea Ice Forecasting Task Team
  
  This team has convened 4 times in FY18 and focused on a relational mapping exercise to establish the “value tree” of observations in support of Sea Ice Forecasting. This effort was reported out to the IARPC Collaborations Team, submitted as a short statement to the AOS, and served as a template for other groups to follow at the AOS WG2 meetings.

  The current Value Tree Assessment from this US AON Task has elicited 25 separate contributions from multiple agency efforts including NOAA, NRL, NASA, NSF-funded PI’s, CRREL. A synthesis product is under development to address the following project objectives:

  i. Clarify the user base for the observing system and their product/service/information needs.

  ii. Identify barriers to efficient exploitation of current observing system to meet those needs and address

  iii. Improve readiness for the future observing system (gaps, needs, consolidated requirements) Deliverables: A Value Tree Assessment for the US AON – Sea Ice Forecasting Task Team
  (https://www.iarpccollaborations.org/members/documents/10086)

b. EPA Wildfire Smoke Detection and Forecasting Effort: Ed Washburn, of EPA, led this effort until his retirement at the end of January 2018. Through this work, he pulled together the relevant players across agencies and academia to scope actionable targets for data, technology, and information sharing. He also worked with USGS partners and local EPA to convene a session on this topic at the Alaska Forum on the Environment.
  Deliverables: Identifying Partnership Opportunities for Wildland Fires in Alaska, EPA-US AON
  (https://www.iarpccollaborations.org/members/documents/11347). (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1735494. This award supports a workshop to examine the potential for supporting research on submerged human habitation sites on the continental shelf of the U.S. The workshop brings together approximately twenty-five individuals with relevant and specialized expertise on this topic of research and will be held at the Smithsonian Institution, in conjunction with the Society for American Archaeology Meeting Spring 2018 in Washington, DC. An investigation of submerged human habitation sites has the potential to provide important insights into human evolution in North America, including topics of migration, colonization, response to sea level rise, and the origins of maritime adaptations. These topics are important not only for understanding the development of early social organization in North America but can also give us critical information about the societal impacts of sea level rise, which is a potential threat in coastal regions of the United States. (Sep 21, 2018 - Completed)
The AOSST February 2018 meeting was designed as a roundtable of Arctic Observing Summit (AOS) short statement submissions. Participants discussed their submissions to AOS and got feedback from the community. ([https://www.iarpccollaborations.org/members/events/10644](https://www.iarpccollaborations.org/members/events/10644)). (Feb 22, 2018 - Completed)

Reggie Beach (ONR) presented "NOPP Yesterday, Today and Tomorrow" ([https://www.iarpccollaborations.org/members/documents/10377](https://www.iarpccollaborations.org/members/documents/10377)) at the November 2017 AOSST meeting. ([https://www.iarpccollaborations.org/members/events/10248](https://www.iarpccollaborations.org/members/events/10248)).

The NOPP is uniquely suited to facilitate broad agency announcement (BAA) and coordinate amongst federal agencies, academic institutions and industry organizations. The history of NOPP demonstrates the benefits of supporting legislation for such interagency projects and could be used to move the US AON forward. (Nov 15, 2017 - Completed)

Eyes North Program is an NSF-funded research coordination network that initiated last October and has primarily hosting workshops and meetings. Intentions are to develop best practices and coordinate observations across the community-based observer continuum. A write up of activities have been summarized and posted on the IARPC website. (Some workshops: Earth X workshop, Northern Boarders Workshop, Evergreen Workshop (May), Coastguard Workshop)

Synergies between Eyes North and IARPC: the assessment framework could be very useful in identifying how community based observing can feed into informational products. Framework could also be used to guide community based work within Arctic. (NSF Contact: David Griffith) ()

EPA is working with US-AON to identify points of leverage for observing efforts. Our goal is to find where we can improve human health aspect by combining different independent observing assets. An existing EPA networks include the LEONetwork-ANTHC. We presented two topical areas- HABs and wildfires with some positive feedback from NOAA, NWS and IARPC. Internal EPA call to identify all of the resources currently dedicated to Arctic observing that can be used to continue progress on these efforts. We hope to continue discussion of potential partnerships. ()

NOAA supported a 2017 NOAA DBO cruise to the northern Chukchi Sea on the USCGC HEALY. 21-day cruise, 4 of the 5 primary DBO lines as well as a high-resolution Northern Chukchi shelf survey. Plan to fund an annual DBO cruise in the future. First successful deployment of Arctic Saildrones, large remotely piloted vehicles into the Arctic in conjunction with the DBO cruise. Welcome collaboration and partnerships- number of NSF scientists that were onboard the 2017 cruise. Hope to make the platform and datasets available to the rest of the IARPC community. ()

Atmospheric Radiation Measurement (ARM) program ([https://www.arm.gov/](https://www.arm.gov/)): activities at the Barrow Site are going well and moving forward with collaborating with NWS for radiosonde launches. At the Oliktok Point site due to power and logistical issues during the winter we plan to remove some instruments including LIDAR and scanning cloud radar while also limiting to one radiosonde launch per day. Assuming positive congressional appropriations for FY18 we are planning to continue maintaining the measurements at Oliktok site. Plans to do tethered balloon observations at Oliktok site in the spring and summer. Logistical efforts to support the MOSAiC campaign are
continuing with a planning meeting scheduled for November. In addition to the field work doing on in Barrow, NGee Arctic they’ve established three field sites on the Seward Peninsula with permafrost monitoring, active layer thickness and landscape heterogeneity. They’ve been moving forward with using LiDAR and aerial photography for micro tomography and vegetation structure. The field at Seward has been coordinated with the Nasa ABoVE campaign. Ngee Arctic has also been contributing to pan-Arctic datasets by reporting out to the permafrost region pond and lake database. 

- Stratified Ocean Dynamics of the Arctic (SODA) project (http://www.apl.washington.edu/project/project.php?id=soda), which is the directors research initiative, aims to understand how the upper Beaufort Sea responding to changes in inflow and surface forcing. That team has been pulled together and recently met to develop their plan for the FY18-19 field program (APL UW website for details (http://www.apl.washington.edu/project/project.php?id=soda)). Also, looking for LOIs and proposals for that broad inter-agency announcement for sensor development or improvement.

- Arctic Observing Viewer (AOV) is in the process of updating two apps that can be helpful with Arctic science planning: Arctic Research Mapping (ARMAP) application and Arctic Observing Viewer (AOV). The new version of ARMAP is much more powerful for searching and filter interface. These apps have the potential to help guide planning and strategic observations in the Arctic.

- The inaugural year of the US AON realized great strides in cross-agency engagement, community outreach, task scoping and coordination, and international framework development. FY18 will build upon this base of engagement, outreach, and development, but focus more particularly on scoping and fostering US AON Tasks and developing US AON Framework discussions in order that the community can make stronger, independent contributions to the effort. US AON integrates and translates Arctic observations (routine + research) into improved products and services in support of NOAA’s mission service areas and its Arctic Vision and Strategy; Implications for humans, society, security and economy. The following focal areas will be executed by the US AON Executive Director, in coordination with US AON Committee members; (1) Advancing a guiding strategy for interagency US AON, (2) Advancing US AON Task and US AON Framework Teams, (3) Serving as the US coordinating nexus for SAON and relevant international activities and (4) Advancing the diversity of US AON activities through promoting dialog on diversity and inclusion in Arctic field science and sustained observations.

- The AOSST held a collaboration team meeting on the observational efforts in the terrestrial carbon sphere. Speakers from the ABoVE, NGEE Arctic and SEARCH campaigns were invited to speak on carbon observations. Participants brainstormed research/knowledge gaps and identified future directions for bridging marine-terrestrial-atmospheric carbon cycle science. This activity also contributed to the overall EI carbon cycle effort.

- The AOSST held a collaboration team meeting on networks and invited speakers from the Arctic Observing Viewer to help guide a community discussion on developing a US AON network. The participants brainstormed about how a network inventory activity can be used to identify essential variables for US AON using a bottom-up approach.
The AOSST hosted a collaboration team meeting entitled "Fostering First Followers" lead by Dr. Sandy Starkweather on engaging partners for the US Arctic Observing Network. This meeting identified an existing Arctic observing effort, AOOS (Alaskan Ocean Observing System), that can be used to provide guidance and leadership during the formation of US AON.

The AOSST provided an overview of the new US Arctic Observing Network effort led by Dr. Sandy Starkweather. A portion of the meeting was also opened up to a community discussion on identifying future observing observing themes. Existing networks and observing programs identified in this discussion were Earth Scope USAArray, the Distributed Biological Observatory Program and the LEO Project.

9.2 Advance understanding of the Arctic System by using global and regional models with detailed Arctic processes to understand feedbacks and interactions within the components of the Arctic system and with the climate system as a whole.

- **9.2.1 (In progress) Support and coordinate research to advance understanding of the connections between the Arctic and mid-latitude weather patterns and vice-versa.** DOE (Lead), NOAA (Lead), NSF (Lead), DOD-ONR, NASA


  The abstract is as follows; Tracy and Heilprin, marine-terminating glaciers that drain into the eastern end of Inglefield Gulf in northwest Greenland, exhibit remarkably different behaviors despite being adjacent systems. Losing mass since 1892, Tracy Glacier has dramatically accelerated, thinned, and retreated. Heilprin has retreated only slightly during the last century and has remained almost stationary in the most recent decade. Previous studies suggest that Tracy’s base is deeper than Heilprin’s at the calving front (over 600 m, as opposed to the 350 m depth at Heilprin), which exposes it to warmer subsurface waters, resulting in more rapid retreat. We investigate the local oceanographic conditions in Inglefield Gulf and their interactions with Tracy and Heilprin using data collected in 2016 and 2017 as part of NASA’s Oceans Melting Greenland mission. Based on improved estimates of the fjord geometry and 20 temperature and salinity profiles near the fronts of these two glaciers, we find clear evidence that fjord waters are modified by ocean-ice interactions with Tracy Glacier. We find that Tracy thinned by 9.9 m near its terminus between 2016 and 2017, while Heilprin thinned by only 1.8 m. Using a simple subglacial plume model, we find that Tracy’s deeper depth at the front results in a more vigorous entrainment of warm subsurface waters, leading to more rapid melting. Model results support the hypothesis that Tracy’s deeper front results in faster glacier retreat, despite the presence of a shallow sill (~300 m) that may prevent the warmest waters from reaching Tracy. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1744598. This project will help to understand and quantify how atmospheric circulation in the Arctic influences winds, cloudiness, water vapor, radiation and thereby sea ice variability. It will lead to
better understanding of the relative contribution of forced and internal variabilities in recent Arctic warming and sea ice loss. First, the investigators will use data assimilation techniques in a global earth system model and explore how tropical sea surface temperature contributes to the recent sea ice decline via teleconnections to the high latitudes. The investigators will then examine dynamical mechanisms that link Arctic circulation to remote drivers in the tropics and put circulation changes over the last 40 years into the context of longer centennial term changes. Finally, results will help evaluate model skill for Coupled Model Intercomparison Project Phase 5 (CMIP5) and determine whether the tropical drivers represent a main source of modeled internal variability. (Sep 24, 2018 - Completed)

- Research the connection between Ice Free Water North of Alaska and persistent upper level ridging in this region with cold temperatures in the eastern United States in December 2017 (PMEL Jim Overland) (Mar 27, 2018 - Completed)

- The MST invited speakers to discuss their current research efforts to evaluate the influence of Arctic change on mid-latitude weather. Presentations were given by:
  
  Arctic Change and Possible Influence on Mid-latitude Climate and Weather: Synthesis of thererecentCLIVAR workshop (Cohen)
  http://www.iarpccollaborations.org/members/documents/9329

  What are the different pathways/physical mechanisms of Arctic to mid-latitude linkages that should be targeted in modeling studies? (Magnusdottir)
  http://www.iarpccollaborations.org/members/documents/9321

  Modeling Studies of Arctic Change Influence on Mid-latitude Climate and Weather: Progresses and Challenges (Zhang, 10 min)

- The Workshop on Arctic Change and Its influence on Mid-latitude Weather and Climate was organized by CLIVAR through joint support by US agencies like NSF, NOAA, NASA, and DOE, and the WWRP (https://usclivar.org/meetings/2017-arctic-midlatitude-workshop). A white paper from the CLIVAR workshop is in preparation and it includes the summary of findings as well as discusses opportunities and recommendations for additional observations and coordinated model experiments to advance research on the mechanisms of Arctic to mid-latitude linkages. ()

- NASA-funded paper looks at links between Arctic and North American warming: Full Citation: Kim, Jin-Soo, J-S. kug, S-J. Jeong, D.N. Huntzinger, A.M. Michalak, C.R. Schwalm, Y. Wei, K. Schaefer, “Reduced North American terrestrial primary productivity linked to anomalous Arctic warming,” Nature Geoscience, DOI: 10.1038/NGEO2986, 2017. Funding for the Multi-scale synthesis and Terrestrial Model Intercomparison Project (MsTMIP; http://nacp.ornl.gov/MsTMIP/shtm) was provided through NASA ROSES Grant #NNX10AG01A. Data management support for preparing, documenting and distributing model driver and output data was performed by the Modeling and Synthesis Thematic Data Center at Oak Ridge National Laboratory with funding through NASA ROSES Grant#NNH10AN681. Finalized MsTMIP data products are archive at ORNL DAAC (http://daac.ornl.gov). Background: Warming in the Arctic can lead to severe cold events and changes in precipitation in the continental U.S. due to atmospheric teleconnections. Analysis: Evaluates the link between Arctic temperatures and
terrestrial ecosystem productivity in North America (NA). Uses Arctic temperature (ART) index derived from HadCRUT4; along with temperature and precipitation from CRU. Estimates of GPP obtained from three products: 1) NDVI; 2) up-scaled GPP from flux tower data; and 3) terrestrial biospheric model simulation output from MsTMIP. Findings: Warmer than normal springtime temperatures in the Arctic → decreased plant productivity over most of North America. Decline is explained by two factors: 1) severe cold temperatures in northern NA; and 2) decreased precipitation in the South Central U.S. Translates into a reduced crop yield of 1 to 4% across U.S., with some states experience crop yield declines of up to 20%. Significance: Demonstrates for the first time, the linkage between Arctic temperature variations and ecosystem and agricultural productivity in the continental U.S. (Oct 12, 2017 - Completed)

- 9.2.2 (In progress) Support and coordinate research to enhance the understanding of connections between Arctic and global ocean circulation.; DOE (Lead), NOAA (Lead), NSF (Lead), DOD-ONR, NASA
  - The National Science Foundation (NSF) has recently awarded OPP – 1804504. Changes in the amount of sea ice and low salinity surface water (together called freshwater) that flow from the Arctic Ocean to the North Atlantic have global ocean circulation and climate impacts. This research involves analysis of the timing and consequences of the opening of the western route for Arctic freshwater flux after the retreat of glacier ice at the end of the last glaciation. Diverse analyses of sediment cores from northern Baffin Bay and computer modeling will be used to document and explore the large changes in sea-ice cover, Arctic freshwater flux, ocean circulation, marine productivity, and ocean acidification over the last 11,000 years that are associated with opening of the western freshwater route. An important component of the research is to study the history of the North Water Polynya (NOW), an oasis of high productivity and low sea-ice cover that forms where the Arctic freshwater enters northern Baffin Bay. The understanding of how the opening of the western route of Arctic freshwater and the initiation of the NOW have changed through time will provide context to understand how these systems will affect the Arctic systems and global climate in future. (Oct 15, 2018 - Completed)
  - DOE, NASA, NSF, and NOAA funded scientists are currently contributing to the activities of the US AMOC Science Team, an interagency group under the auspices of US CLIVAR that aims to formulate research priorities and coordinate activities related to the Atlantic Meridional Overturning Circulation. As an example, in the past 2 years, Wilbert Weijer (LANL) was member of the Executive Committee, and chaired the science team’s annual meeting in Santa Fe, May 23-25, 2017. He also initiated and coordinated a series monthly webinars to enhance information exchange and facilitate collaboration between science team members. The 2017 US AMOC science team conducted a science-team-meeting (https://usclivar.org/meetings/2017-us-amoc-science-team-meeting) focused on understanding and better predicting AMOC. One of the four foci of the meeting was on improving both prediction capabilities and understanding the impacts of AMOC on the climate and ecosystems. In 2018, the science team held a joint meeting with the UK RAPID project, in Coconut Grove, FL (July 24-27; https://usclivar.org/meetings/2018-amoc-rapid-meeting). The main themes of the meeting were: AMOC as a 4D process, AMOC proxies and fingerprints, and AMOC in a changing climate. (Sep 27, 2018 - Completed)
A project, jointly funded by DOE’s Regional and Global Climate Modeling (RGCM) program and NOAA, is studying the Atlantic freshwater budget (including exchanges with the Arctic) and its impact on the Atlantic Meridional Overturning Circulation. The project is led by Wei Cheng (U, Washington), and involves scientists from LANL, NCAR, and UC Berkeley. A first paper “Can the Salt-Advection Feedback Be Detected in Internal Variability of the Atlantic Meridional Overturning Circulation?” was published in the Journal of Climate. (Sep 27, 2018 - Completed)

FAMOS (Forum for Arctic Modeling and Observational Synthesis) is an NSF-funded project (PIs Andrey Proshutinsky and Mike Steele) that brings together US and international Arctic scientists. FAMOS coordinates activities that combine observations and models to enhance our understanding of Arctic Earth System processes. They conducted an annual workshop in Woods Hole, October 25-27, 2017, and plans for coordinated activities and papers were discussed. Scientists funded by several agencies focused on different aspects of the Arctic system. As an example, DOE funded HiLAT and DOE and ONR funded Regional Arctic System Model (RASM) scientists focused on studies of freshwater exchanges between the Arctic Ocean and subpolar North Atlantic in a suite of models. (Sep 27, 2018 - Completed)

The National Science Foundation (NSF) has recently awarded OPP – 1758565. The Pacific inflow to the Arctic Ocean (which is via the Bering Strait) is critical to the oceanic systems of the Alaskan seas and western Arctic Ocean. The core of this work will be the installation and annual servicing of three oceanographic moorings in the Bering Strait, at sites which have been shown to provide an effective quantification of the oceanic fluxes through the strait. These moorings measure (hourly, year-round) water velocity, water temperature and salinity, and the thickness and motion of the seasonal sea ice in the region. This new research will continue these measurements to 2022, also seeking understanding of the drivers of recent change. The work will provide oceanic information in useful forms to the many stakeholders, including local and global science, local native communities, the public, and industry (e.g., oil/gas exploration, shipping, tourism). Internationally, the project is a substantial US contribution to global cooperation in the Arctic. (Sep 27, 2018 - Completed)

Singh, Rasch and Rose (2017) isolated the role of the ocean in the polar climate response CO2 doubling with coupled and slab ocean simulations. With CO2 doubling, the ocean heat flux convergence (OHFC) shifts poleward in winter in both hemispheres. The OHFC changes drive a poleward shift in ocean-to-atmosphere turbulent (sensible and latent) heat fluxes and sea ice retreat; the high latitudes warm, while the midlatitudes cool, amplifying polar warming. Midlatitude cooling propagated to the polar midtroposphere on isentropes, augmenting the (positive) lapse rate feedback there (Geophysical Research Letters, https://doi.org/10.1002/2017GL074561). A follow up study explored how hemispheric asymmetries in polar climate sensitivity are amplified by the ocean. CMIP5 CO2-quadrupling experiments showed that even in models where hemispheric ocean heat uptake differences are small, Arctic warming still exceeds Antarctic warming and feedbacks over the southern hemisphere more effectively dissipate top-of-atmosphere anomalies than those over the northern hemisphere (Singh, Garuba and Rasch, Geophysical Research Letters, 2018, in press) (Sep 27, 2018 - Completed)
Garuba et al (Geophysical Research Letters, Sept 2018, DOI: 10.1029/2018GL078882) introduced a novel analysis strategy to isolate the processes that contribute to SST variations in the North Atlantic. Internal ocean variability caused very large SST variations on multidecadal timescales; the atmosphere produced much weaker variations with shorter (up to interdecadal) timescales. Ocean-atmosphere interactions at the sea surface dissipated SST variations driven by the ocean circulation through surface heat. The strength and sign of the correlation between the North Atlantic SST and surface heat fluxes anomalies also pointed to the relative importance of internal ocean processes in driving Atlantic Multi-decadal variability and the role of heat fluxes in its dissipation. (Sep 27, 2018 - Completed)

NASA’s Physical Oceanography program funded a new project this year to improve salinity estimates in the Arctic, including Bering and Chukchi Seas that serve as the gateways for exchanges between the Arctic and Pacific Oceans, with implications for global freshwater transport. The PI is Chelle Gentemann from ESR. More details will be reported on in the coming year. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1740756. The Bering Strait connects the Pacific and Arctic Oceans, and serves as a conduit of nutrients, heat, and fresh water. Understanding the factors influencing that connection will help predict current and future regional ocean conditions. Analysis of satellite altimetry, coastal sea level, theory, and a model will be used to: determine the origin and dynamics of the low-frequency pressure head that drives flow through the Bering Strait into the Arctic; understand the origin and basic dynamics of the interannual sea level and flow on the wide Bering Sea shelf; and determine the low-frequency variability of volume, heat, and fresh water flux of the Alaskan Coastal Current. A wealth of along-track satellite altimeter data available from TOPEX/Poseidon and Jason1,2,3 (TPJ123) will be used to address the question of what drives the Bering Sea pressure head. Preliminary analysis suggests that a major contributor to the low-frequency Bering Strait pressure head originates on the Gulf of Alaska continental shelf. This contribution is communicated along the Gulf of Alaska coastal wave guide, through Unimak Pass in the Aleutian Arc, onto the shallow Bering Sea shelf wave guide, and then through the Bering Strait. A second factor is the interannual and lower frequency signal generated on the Bering Sea shelf. (Sep 21, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1741841. This is a modeling proposal to study the effect of declining Arctic sea ice on the strength and other characteristics of the AMOC - a major element of ocean dynamics and climate. Sea ice decline exposes the Arctic ocean to anomalous solar radiation and freshwater fluxes, generating positive buoyancy anomalies in the upper ocean. The hypothesis being tested is that, when spreading to the North Atlantic these buoyancy anomalies effectively weaken ocean deep convection, leading to a slow-down of the AMOC on multi-decadal timescales. This hypothesis will be tested with a variety of methods ranging from adjoint ocean modeling to experiments with climate models. (Sep 21, 2018 - Completed)

The May MST meeting focused on Arctic changes and global impacts (https://www.iarpccollaborations.org/members/events/10671). The was discussion on what can be done in regional vs. global models and the timescales that are being
considered. The lack of observational data was noted and the result of the reliance on looking at after effects.

Presentations: Arctic Ocean currents: The surface spins up, while the deep remains quiet- Michael Steele (U. Washington); Impacts of Arctic sea ice loss on the Atlantic Meridional Overturning Circulation- Alexey Fedorov (Yale University); Sea-ice variability and convection processes in the Nordic Seas- Milena Veneziani(LANL) (May 31, 2018 - Completed)

- DOE’s RGCM program is supporting a webinar series on High-Latitude Climate Processes and Feedbacks, organized by Wilbert Weijer (LANL). Monthly webinars feature two presentations on similar topics from different perspectives, to foster collaboration amongst different RGCM-funded projects. ()

- HiLAT and RASM PIs (Weijer, Rasch and Maslowski) – with significant community input- wrote a white paper on High-Latitude Climate Processes and Feedbacks, to identify knowledge gaps, capabilities and research priorities regarding high-latitude climate science. ()

- **9.2.3 (In progress) Enhance understanding of processes and their interactions and feedbacks within the Arctic System itself, including the complex relationships between the ocean, sea ice, land, and atmosphere; impacts of snow on ice; interactions between Arctic clouds and aerosols; effects of thermal forcing of sea ice; changes in ocean stratification; stratosphere-troposphere interactions; and radiative exchanges of energy throughout the system.; DOD-ONR (Lead), DOE (Lead), NOAA (Lead), NSF (Lead), NASA**

  - The National Science Foundation (NSF) has recently awarded OPP – 1822334. This study addresses the fundamental dynamics of the Arctic Ocean general circulation and its connection to lower latitudes. The approach combines a multi-component theoretical model with an idealized but high-resolution eddy resolving coupled ocean/ice general circulation model of the Arctic. The goal is to relate basic quantities -- such as ice cover; freshwater content; air-sea exchange; and heat, freshwater, and mass transport through Fram Strait -- to external forcing due to wind, heat loss, runoff, and variations in Atlantic Water temperature and salinity advected in from the Nordic Seas. In addition to providing dynamical insight into the controlling physics, this approach allows for a simple assessment of how the system is likely to respond to changing environmental parameters and of the existence of multiple equilibria or abrupt transitions. (Oct 15, 2018 - Completed)

  - The HiLAT team also used a reduced complexity model of delta dynamics to examine the influence of ice cover and permafrost on channel dynamics and delta morphology. It was found that both ice cover and permafrost reduce channel mobility and alter depositional patterns near the coast, resulting in increased deposition both overbank and offshore (Lauzon, R., A. Piliouras, and J. C. Rowland. Channel stability from ice and permafrost shapes Arctic river deltas. Submitted to Nature Geoscience.) (Sep 27, 2018 - Completed)

The abstract is as follows: NASA has launched the decade-long Arctic-Boreal Vulnerability Experiment (ABoVE). While the initial phases focus on field and airborne data collection, early integration with modeling activities is important to benefit future modeling syntheses. We compiled feedback from ecosystem modeling teams on key data needs, which encompass carbon biogeochemistry, vegetation, permafrost, hydrology, and disturbance dynamics. A suite of variables was identified as part of this activity with a critical requirement that they are collected concurrently and representatively over space and time. Individual projects in ABoVE may not capture all these needs, and thus there is both demand and opportunity for the augmentation of field observations, and synthesis of the observations that are collected, to ensure that science questions and integrated modeling activities are successfully implemented. Also, planning for the ABoVE Phase II is underway. The second and third phases will focus on model refinements and geospatial synthesis products. ABoVE is the NASAArctic-Boreal Vulnerability Experiment, which is reported on in many other performance elements. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1820927. This research will synthesize three interrelated science contributions: (1) Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) field observations will identify governing physical processes, fluxes, and linkages within the Arctic climate system. (2) Realistic-resolution (meters-scale), physically based modeling tools (e.g., MicroMet, SnowModel, EnBal, SnowPack, SnowTran-3D, SnowDunes, SnowAssim, Sealce-3D) will quantify the behavior, interactions, and sensitivities among the Arctic system components. (3) Field observations and high-resolution modeling will be integrated to define what is missing or poorly represented in Earth System Models and guide the parameterization of the associated snow-related processes and fluxes for the Community Earth System Model (CESM) and the Los Alamos Sea Ice Model (CICE). (Sep 26, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1749081. The objective of proposed research under Phase 2 of SIPN (SIPN2) is to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This grant will: Investigate the sensitivity of subseasonal-to-seasonal sea-ice predictability in the Alaska Arctic to variations in oceanic heat and large-scale atmospheric forcing using a dynamical model Community Earth System Model (NCAR CESM) and statistical forecasting tools, focusing on spatial fields in addition to total extent summaries; Assess the accuracy of Sea Ice Outlook (SIO) submissions based on methodology and initialization; Develop new observation-based products for improving sea-ice predictions, including sea-ice thickness, surface roughness, melt ponds, and snow depth; Evaluate the socio-economic value of sea-ice forecasts to stakeholders who manage ship traffic and coastal village resupply in the Alaska Sector, and engage the public in Arctic climate and sea-ice prediction through blog exchanges, accessible SIO reports, bi-monthly webinars, and by making public data sources useful to non-scientists and scientists alike; and Continue and evolve network activities to generate SIO forecasts and reporting for September minima as in SIPN and expand SIPN2 forecasts to include full spatial resolution and emerging ice-anomaly-months (October - November).
This work will directly engage stakeholders that create and use sea-ice forecasts in Alaska and lead to improved safety around sea ice. Work under SIPN2 will also track public awareness and perceptions regarding sea ice, helping to raise understanding through accessible reports, discussions, and public data sources useful to non-scientists and scientists alike. Stakeholder engagement during the research process will potentially facilitate rapid research-to-operations implementation of the products of this work. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1740756. The Bering Strait connects the Pacific and Arctic Oceans, and serves as a conduit of nutrients, heat, and fresh water. Understanding the factors influencing that connection will help predict current and future regional ocean conditions. Analysis of satellite altimetry, coastal sea level, theory, and a model will be used to: determine the origin and dynamics of the low-frequency pressure head that drives flow through the Bering Strait into the Arctic; understand the origin and basic dynamics of the interannual sea level and flow on the wide Bering Sea shelf; and determine the low-frequency variability of volume, heat, and fresh water flux of the Alaskan Coastal Current. A wealth of along-track satellite altimeter data available from TOPEX/Poseidon and Jason1,2,3 (TPJ123) will be used to address the question of what drives the Bering Sea pressure head. Preliminary analysis suggests that a major contributor to the low-frequency Bering Strait pressure head originates on the Gulf of Alaska continental shelf. This contribution is communicated along the Gulf of Alaska coastal wave guide, through Unimak Pass in the Aleutian Arc, onto the shallow Bering Sea shelf wave guide, and then through the Bering Strait. A second factor is the interannual and lower frequency signal generated on the Bering Sea shelf. (Sep 21, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1741841. This is a modeling proposal to study the effect of declining Arctic sea ice on the strength and other characteristics of the AMOC - a major element of ocean dynamics and climate. Sea ice decline exposes the Arctic ocean to anomalous solar radiation and freshwater fluxes, generating positive buoyancy anomalies in the upper ocean. The hypothesis being tested is that, when spreading to the North Atlantic these buoyancy anomalies effectively weaken ocean deep convection, leading to a slow-down of the AMOC on multi-decadal timescales. This hypothesis will be tested with a variety of methods ranging from adjoint ocean modeling to experiments with climate models. (Sep 21, 2018 - Completed)

- The following study was supported by DOE as part of the Regional and Global Climate Modeling program: Zhang, R., Wang, H., Fu, Q., Pendergrass, A. G., Wang, M., Yang, Y., et al. (2018). Local radiative feedbacks over the Arctic based on observed short-term climate variations. Geophysical Research Letters, 45, 5761–5770. https://doi.org/10.1029/2018GL077852

  A variety of reanalysis and satellite data sets are used to quantify the Arctic local feedbacks based on short-term climate variations, evaluate the feedbacks simulated in a global climate model, diagnose the impact of data set choices on the feedback estimates, and identify the sources of main uncertainties. The most disagreement is found in the estimate of cloud feedback. (Sep 4, 2018 - Completed)

- The November 2017 MST meeting focused on high-resolution ocean, atmosphere and coupled Arctic models (https://www.iarppcollaborations.org/members/events/10278).
Experts in ocean, atmosphere and coupled modeling discussed their recent work and results in the Arctic. Each identified developments and future work that needs to be done to improve the skill of respective models. Speakers identified the intersection of observing capabilities and how they inform model processes that are critical to model skill. The upcoming YOPP observational campaign was discussed and the potential for targeting observations of not well understood microphysical processes in the atmosphere.

Presentations: High-Resolution Arctic Models Ocean Models: Eric Chassignet (Florida State University); Atmosphere modeling: Steve Cavallo (University of Oklahoma); Coupled System Models: Wieslaw Maslowski (Naval Postgraduate School) (Nov 30, 2017 - Completed)

- DOE supported research by Xianglei Huang (U-Michigan) will improve the treatment of long-wave emissivity important over the bright surfaces of the Arctic: https://climatemodeling.science.energy.gov/research-highlights/observationally-based-global-band-band-surface-emissivity-dataset-climate-and

- Arctic deltas buffer and filter riverine fluxes before they reach the ocean, with important consequences for Arctic ocean circulation, sea ice processes and biogeochemistry. However, the timing and contents of these fluxes will likely change as deltas respond to higher temperatures, higher sea levels, and reduced sea ice. In 2017, DOE funded HiLAT project made progress on this topic by performing a systematic comparative analysis of the morphology of the major Arctic deltas using satellite imagery (Piliouras and Rowland, Morphologic variability of Arctic river deltas and the implications for fluxes to the coast. In review with Marine Geology). (Nov 3, 2017 - Completed)

- The DOE funded HiLAT project made progress on a project to study the complex interactions between cryospheric change, marine and sea ice ecosystems, aerosol emissions, and cloud responses. In particular, several new capabilities were implemented in the E3SM-HiLAT model framework in preparation for the experimentation phase; including: i) a high-latitude phytoplankton species (Phaeocystis) that is specifically important for the emission of dimethyl-sulfide (DMS), an important source of biogenic aerosols; ii) a 3-dimensional model of biogeochemistry in sea ice, including two-way exchanges with the ocean physics and biogeochemistry; iii) explicit coupling of DMS from the ocean model to the aerosol module in the atmosphere model. A paper describing the model configuration is in preparation (Hecht et al., in prep). An evaluation of the sea ice biogeochemistry module was performed in the context of Norwegian’s N-Ice project (Duarte, ..., Jeffery, Elliott, Hunke..., 2017: Sea-ice thermohaline-dynamics and biogeochemistry in the Arctic Ocean: empirical and model results. J. Geophys. Res. Biogeosci.,122, doi:10.1002/2016JG003660). (Nov 3, 2017 - Completed)

- The RASM project, in collaboration with HiLAT and with support from DOE-RGCM and NSF-OPP, have expanded its ocean and sea ice model components with marine biogeochemistry (mBGC), including the latest 3-d sea ice and ocean biogeochemistry within the high-resolution (~9-km) pan-Arctic RASM-mBGC. A paper evaluating improvements in RASM-mBGC compared to a coarse resolution model configuration is under revision for publication in JGR-Oceans. ()
A paper describing a new river routing scheme (RVIC) implemented and evaluated in RASM was published (Hamman et al. JGR-Oceans, 2017). In addition, a new runoff data set produced by RASM-RVIC scheme has been published and made publicly available as an alternative Arctic runoff reanalysis. (Nov 3, 2017 - Completed)

A paper on near-surface atmospheric climate sensitivity in RASM has been published by Cassano et al. in J. Climate, 2017. (Nov 3, 2017 - Completed)

The MST hosted a joint meeting with the Atmosphere and Sea Ice collaboration teams on the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) project. Presentations included: “Enhanced Process Understanding of the Coupled Arctic System through MOSAiC” (Matthew Schupe) MOSAiC and modeling (Wieslaw Maslowski)

9.2.4 (In progress) Conduct a survey and identify investigator-driven modeling projects designed to understand important local and global Arctic System feedbacks.; NSF (Lead), DOD-ONR, DOE, NASA, NOAA

The MST reviewed the previous modeling efforts survey and discussed the format and information that will be included in the updated modeling inventory. ()

9.3 Enhance climate prediction capabilities for the Arctic system from sub-seasonal to decadal timescales and climate projection capabilities up to centennial timescales by focusing on improving earth system models and their interactions, and assessing the strengths and weaknesses of the various coupled regional arctic and earth system models by conducting intercomparison and model evaluations.

9.3.1. (In progress) Support the configuration and the initial development of a global variable resolution model with very high resolution in the Arctic that will allow high-resolution interactions within the Arctic System and interactions between the Arctic and mid-latitudes; DOE (Lead), NSF

The DOE funded HiLAT, E3SM and RASM projects have started the development of an Arctic-focused configuration of the E3SMv1 model. The configuration is initially an ocean/sea ice stand-alone model, forced by atmospheric reanalyses (CORE-II and JRA55-do). Two grid configurations are being tested: one with a 10 km resolution in the Arctic, and one with a 6 km resolution in the Arctic. Outside the Arctic, resolutions range between 30 and 60 km, conforming to the E3SMv1 standard low-resolution configuration. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1744598. This project will help to understand and quantify how atmospheric circulation in the Arctic influences winds, cloudiness, water vapor, radiation and thereby sea ice variability. It will lead to better understanding of the relative contribution of forced and internal variabilities in recent Arctic warming and sea ice loss. First, the investigators will use data assimilation techniques in a global earth system model and explore how tropical sea surface temperature contributes to the recent sea ice decline via teleconnections to the high latitudes. The investigators will then examine dynamical mechanisms that link Arctic circulation to remote drivers in the tropics and put circulation changes over the last 40 years into the context of longer centennial term changes. Finally, results will help evaluate model skill for Coupled Model Intercomparison Project Phase 5 (CMIP5) and
determine whether the tropical drivers represent a main source of modeled internal variability. (Sep 24, 2018 - Completed)

- DOE has started to configure the E3SM with regional refinement of atmosphere, ocean, sea-ice and land over the Arctic. ()

- 9.3.2 (In progress) Support model development activities in global earth system models focusing on increased resolution, better coupling techniques, and inclusion of new process models in the Arctic for improved predictions, projections, and better representation of extreme events. In addition to developing models for CMIP6, this will include routine global ocean data assimilation capabilities linked to Global Ocean Observing System observations.; NASA (Lead), NOAA (Lead), NSF (Lead), DOE

- Matthew Hoffman (LANL) led an international team of scientists to study the role of moulins on the basal hydrology of the Greenland Ice Sheet. Their study compared moulins mapped from satellite-images to computer simulations of stresses in the ice constrained by hourly, on-site ice velocity measurements from GPS stations. Their results suggest that rare and brief drainages of surface lakes must be the cause of most of the moulins, and therefore have a lasting impact on the flow of water into the ice sheet and the changes in the flow of the ice this causes. (Hoffman, M. J., M. Perego, L. C. Andrews, S. F. Price, T. A. Neumann, J. V Johnson, G. Catania, and M. P. Lüthi (2018), Widespread moulin formation during supraglacial lake drainages in Greenland, Geophys. Res. Lett., 45, doi:10.1002/2017GL075659.) (Sep 27, 2018 - Completed)

- Darin Comeau and collaborators from the Courant Institute have a paper accepted for publication in Climate Dynamics on “Predicting regional and pan-Arctic sea ice anomalies with kernel analog forecasting”. The paper describes the application of a novel kernel analog forecasting method to improve predictions of sea ice anomalies in the Arctic. The authors find marked improvements over the benchmark damped persistence forecast, in particular in regions and seasons with high interannual variability. The paper results from Darin’s PhD work at the Courant Institute, with support from ONR and DOE’s HiLAT project. (Sep 27, 2018 - Completed)

- Several NASA models contributed to the Sea Ice Outlook, an international consortium for the seasonal prediction Arctic sea ice cover during the minimum month of September. The NASA GMAO’s 2017 forecast of 4.9 million square kilometers was fairly close to the observed value of 4.87 million square kilometers. The GMAO forecast used its coupled model and assimilation system but incorporated an observed sea ice thickness derived from CryoSat-2 into the initial conditions. A skillful, statistical forecast using passive microwave observations of sea ice concentrations and melt onset has also been employed in the Sea Ice Outlook (Petty et al., 2017; Earth’s Future, 5, 254-263. doi:10.1002/2016EF000495).

The abstract is as follows:

In this study, we demonstrate skillful spring forecasts of detrended September Arctic sea ice extent using passive microwave observations of sea ice concentration (SIC) and melt onset (MO). We compare these to forecasts produced using data from a sophisticated melt pond model, and find similar to higher skill values, where the forecast skill is calculated relative to linear trend persistence. The MO forecasts shows the highest skill in March–May, while the SIC forecasts produce the highest skill in June–August, especially when the forecasts are evaluated over recent years (since 2008).
high MO forecast skill in early spring appears to be driven primarily by the presence and timing of open water anomalies, while the high SIC forecast skill appears to be driven by both open water and surface melt processes. Spatial maps of detrended anomalies highlight the drivers of the different forecasts, and enable us to understand regions of predictive importance. Correctly capturing sea ice state anomalies, along with changes in open water coverage appear to be key processes in skillfully forecasting summer Arctic sea ice. (Sep 27, 2018 - Completed)

Update from NASA (also posted in 9.3.6): The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) published experimental and data request protocols as part of the CMIP6 special issue in Geoscientific Model Development in Dec 2016. The first set of experiments targeting the Greenland standalone ice sheet modeling community, initMIP-Greenland, were completed by 17 international groups, and the results submitted to the journal “Cryosphere” in July 2017. initMIP-Greenland seeks to understand and reduce the uncertainty in sea level projections due to the choice of model initialization methods. The ISMIP6 and initMIP-Greenland efforts were presented at national and international conference (AGU 2016, EGU 2017, International WCRP/IOC Conference on Regional Sea Level Changes and Coastal Impacts) and to the IARPC Glacier and Fjord CT and Modeling CT in March 2017. ISMIP6 organized two workshops in Dec 2016 -Initialization of ice sheet models, and oceanic forcing for ice sheet models- and one splinter meeting at EGU2017.


Paper reference:


The National Science Foundation has recently awarded OPP – 1744598. This project will help to understand and quantify how atmospheric circulation in the Arctic influences winds, cloudiness, water vapor, radiation and thereby sea ice variability. It will lead to better understanding of the relative contribution of forced and internal variabilities in recent Arctic warming and sea ice loss. First, the investigators will use data assimilation techniques in a global earth system model and explore how tropical sea surface temperature contributes to the recent sea ice decline via teleconnections to the high latitudes. The investigators will then examine dynamical mechanisms that link Arctic circulation to remote drivers in the tropics and put circulation changes over the last 40 years into the context of longer centennial term changes. Finally, results will help
evaluate model skill for Coupled Model Intercomparison Project Phase 5 (CMIP5) and determine whether the tropical drivers represent a main source of modeled internal variability. (Sep 24, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1741841. This is a modeling proposal to study the effect of declining Arctic sea ice on the strength and other characteristics of the AMOC - a major element of ocean dynamics and climate. Sea ice decline exposes the Arctic ocean to anomalous solar radiation and freshwater fluxes, generating positive buoyancy anomalies in the upper ocean. The hypothesis being tested is that, when spreading to the North Atlantic these buoyancy anomalies effectively weaken ocean deep convection, leading to a slow-down of the AMOC on multi-decadal timescales. This hypothesis will be tested with a variety of methods ranging from adjoint ocean modeling to experiments with climate models. (Sep 21, 2018 - Completed)

- The International Land Model Benchmarking (ILAMB) project is a model-data intercomparison and integration project designed to inform the development of land models and, in parallel, improve the design of new measurement campaigns to reduce uncertainties associated with key land surface processes. While the primary focus of the effort is on global/decadal scale understanding of biogeochemical cycles on the land component of global Earth system models, the methodology and software is quite general and can be applied to targeted ecosystems and regional models. A presentation was provided to the MST on ILAMB during the August 2018 meeting. (Aug 23, 2018 - Completed)

- DOE made a new award to a project that will develop a new “granular” sea-ice model that will be valid for very high resolution, and will perform well enough on HPC to be feasible in global models: https://climatemodeling.science.energy.gov/projects/new-discrete-element-sea-ice-model-earth-system-modeling()

- The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) published experimental and data request protocols as part of the CMIP6 special issue in Geoscientific Model Development in Dec 2016. The first set of experiments targeting the Greenland standalone ice sheet modeling community, initMIP-Greenland, were completed by 17 international groups, and the results submitted to the journal “Cryosphere” in July 2017. initMIP-Greenland seeks to understand and reduce the uncertainty in sea level projections due to the choice of model initialization methods. The ISMIP6 and initMIP-Greenland efforts were presented at national and international conference (AGU 2016, EGU 2017, International WCRP/IOC Conference on Regional Sea Level Changes and Coastal Impacts) and to the IARPC Glacier and Fjord CT and Modeling CT in March 2017. ISMIP6 organized two workshops in Dec 2016 -Initialization of ice sheet models, and oceanic forcing for ice sheet models- and one splinter meeting at EGU2017. More information: http://www.climate-cryosphere.org/wiki/index.php?title=ISMIP6_wiki_page

Paper reference:

- DOE has made a new award to a project that will improve ice sheet physics and thermodynamics, and coupling with bedrock, ocean and atmosphere, and include uncertainty analysis of the major sources of sea-level-rise uncertainty: https://climatemodeling.science.energy.gov/projects/probabilistic-sea-level-projections-ice-sheet-and-earth-system-models; https://doe-prospect.github.io/ ()

- A paper constraining basal conditions for the Greenland ice sheet was published: https://climatemodeling.science.energy.gov/research-highlights/leaky-plumbing-impedes-greenland-ice-sheet-flow (Nov 3, 2017 - Completed)

- CICE Consortium: DOE together with other agencies support this Consortium to develop and coordinate community sea ice capabilities. https://github.com/CICE-Consortium ()


- Under the DOE-RGCM program support, RASM is implementing and evaluating a satellite emulator in the CICE model to allow intercomparison with satellite altimetric measurements of sea ice freeboard and to offer a new method to quantitatively assess the skill of predictive models of sea ice for the Arctic. This will help improve sea ice prediction by quantifying model limitations as well as maximize the usefulness of future freeboard measurements, such as those from ICESat-2, after that satellite is launched 2018. ()

- **9.3.3 (No progress)** Foster interactions between the Arctic Testbed and Environmental Modeling Center’s weather modeling efforts to facilitate the improvement of model guidance at higher latitudes.; NOAA (Lead), DOD-ONR

- **9.3.4 (In progress)** Support model development of Regional Arctic System Models focusing on improved resolution, better coupling, inclusion of new process models, and better assimilation techniques for improved seasonal predictions.; DOD-ONR (Lead), DOE, NSF

  - The National Science Foundation has recently awarded OPP – 1805569. The investigators will deploy an unmanned aircraft system to measure atmospheric temperature, winds, and humidity, as well as surface albedo. Flights will take place from mid-winter (February) through late summer (August) to capture variable conditions in both the atmosphere and sea ice surface and will include routine profiling of the lower atmosphere, spatial mapping of thermodynamic quantities and surface albedo, and mapping of the lower atmospheric structure over leads. This data will be evaluated with measurements of the atmosphere, ocean and ice collected by other scientists as part of
the MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) project to address hypotheses related to the performance of modeling tools in simulating key processes over the central Arctic Ocean. These include questions about sub-grid scale variability of atmospheric and surface parameters and its influence on model-simulated surface energy budget; the influence of leads in the sea ice on energy transfer from the ocean to the atmosphere and how models represent this transfer; and the importance of vertical resolution in simulation of the Arctic atmosphere and its impact on the simulation of clouds and the surface energy budget. The investigators will compare observations from unmanned aerial systems to a variety of simulations, ranging from global products to fully-coupled regional simulations completed using the Regional Arctic System Model (RASM) to detailed single-column and 2D modeling at high resolution. (Sep 25, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1821911. The goal of this project is to identify the biological and physical drivers underlying the production and uptake of oxygen and methane, establishing the metabolic balance of these key gases in the oligotrophic Central Arctic. The investigators will take advantage of the unique opportunity afforded by the international, year-long Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition to determine net community production from year-round measurements of oxygen and argon, as well as methane oxidation and production from methane concentration and isotopic ratios. They will measure bacterial and community respiration, bacterial production, and microbial community structure, and analyze gene expression to identify the genes, organisms, and pathways associated with methane production in the surface ocean. Results will be used to model the oceanic methane cycle using the MITgcm Arctic Regional Model and improve the biogeochemical components of the Regional Arctic System Model (RASM). (Sep 25, 2018 - Completed)

- The RASM project has contributed predictions of September 2017 sea ice extent to the SIPN with support from the ONR-AGP and DOE-RGCM programs. Significant progress has been made in 2017 compared to the RASM predictions in 2016, by improving both the initial conditions and predicted sea ice extents and eliminating the need for bias corrections, which were necessary in 2016 (https://www.arcus.org/files/sio/27252/sio2017_june_kamal_etal.pdf; https://www.arcus.org/files/sio/27309/sio2017_july_rasm_kamal_etal_pdf.pdf; https://www.arcus.org/files/sio/27365/sio2017_aug_rasm_kamal_etal.pdf). ()

- Marine biogeochemistry (mBGC) components have been included in the RASM model and are currently evaluated against observations in preparation for publications. This work was funded by NSF. ()

- Two DOE-RGCM supported projects, HiLAT and RASM, have held a joint meeting (in Seattle, May 2017) to find possible overlaps in respective project research and consider joint future activities to advance regional Arctic system modeling. ()

- An eddy-resolving (2.4-km) RASM configuration of the ocean and sea ice component has been completed and simulations are being evaluated for improvements in ocean circulation, shelf-basin exchange, mixing and air-ice-ocean interactions under support of the ONR-AGP and DOE-RGCM programs. In addition, extensive studies of sensitivities of Arctic climate and sea ice states to varying model parameter space have continued using
computer resources provided by the DOD High Performance Computing Modernization Office (HPCMO). ()

- The fully coupled RASM forced with NCEP CFSR reanalysis for 1979-2017 and with NCEP CFSv2 forecasts was used to provide seasonal forecasts of the September 2017 Arctic sea ice extent. The ongoing work is supported by the ONR-AGP program and leverages model development and research supported by the DOE-RGCM program. ()

- The MST hosted a collaboration team meeting on regional Arctic models with a focus on carbon cycling models in alignment with the EI carbon effort. Invited speakers discussed current carbon modeling efforts and the associated issues within the modeling community: resolution, scaling and systems level marine-terrestrial-atmospheric integrated models. Speakers included: Challenges/what expect to learn/understanding the system as a whole-ABoVE (Abhishek Chatterjee, NASA); Land Modeling Efforts in NGEE-Arctic (Bill Riley, Berkeley National Lab) (Jul 27, 2017 - Completed)

- **9.3.5 (In progress) Support Systematic Improvements to Reanalyses of the Arctic (SIRTA) to address the need for improved models of Arctic weather, sea ice, glaciers, ecosystems, and other components of the Arctic System.**; NASA (Lead), NOAA (Lead), DOD-ONR, DOE, NSF

- In autumn 2017, Greenland accumulation and runoff fields from US reanalyses were provided as part of the second Ice Sheet Model Intercomparison Exercise (IMBIE-2), an international scientific collaboration with the aim of providing reconciled estimates of ice sheet mass balance. Researchers participated in the Antarctic assessment (Shepherd et al. 2018. Nature, 558, 219–222, doi:10.1038/s41586-018-0179-y). [The contact is Sophie Nowicki].

  A workshop was held at the University of Maryland-College Park on 23-January 2018 as the part of a joint NASA/ESA study of Snow on Sea Ice (NESOSI). The main goal of the meeting was to foster collaboration between NASA and ESA scientists to gain a better understanding of snow on sea ice both seasonally and regionally, and to reduce uncertainties in snow modeling and remote sensing for use in obtaining sea ice thickness from freeboard altimetry measurements such as ICESat-2 and CryoSat-2.

  Following this meeting, a study was published on the evaluation of Arctic Ocean precipitation from available reanalyses (Boisvert et al., 2018. Intercomparison of precipitation estimates over the Arctic Ocean and its peripheral seas from reanalyses. J. Climate, in press). The study finds that the magnitude, frequency, and phase of precipitation varies drastically among the reanalyses, although interannual variability is similar. [Contact is Melinda Webster]

  Ongoing work for the improvement of reanalyses was presented at the 5th International Conference on Reanalysis, held 13-17 November 2017 in Rome. NASA-sponsored presentations included David Bromwich (Ohio State Univ) on the Arctic System Reanalysis; Patrick Heimbach (MIT) on a consistent ocean state in the ECCO model; Manuela Girotto (NASA Goddard) on methods for a snow reanalysis; understanding Arctic surface temperatures by Richard Cullather (NASA Goddard/Univ Maryland); and status and plans for reanalysis at NASA by Ron Gelaro (NASA Goddard).

  An evaluation of reanalyses using observations from the NASA ARISE mission was published (Segal-Rosenhemier et al., 2018, J. Geophys. Res., 123(12), 6565-6580, doi:10.1029/2018JD028349). ARISE is the NASA Arctic Radiation-IceBridge Sea & Ice
Experiment, conducted over the Beaufort Sea in autumn 2014, which was used with a radiative transfer model to evaluate the MERRA-2 reanalysis. The cloud vertical structure was found to be a main contributor to surface radiative flux discrepancies. The results have implications for large-scale models and reanalyses in the Arctic. Version 2 of the Arctic System Reanalysis (ASRv2) was released in autumn 2017. The ASRv2 is a high spatial resolution regional atmospheric reanalysis covering the period 2000-2012 and employing realistic ocean and land surface conditions at 15km grid spacing. The ASRv2 is sponsored by the NSF and NASA.

A paper by Bromwich et al. (2018; Bull. Amer. Meteor. Soc., doi:10.1175/BAMS-D-16-0215.1) describes the ASRv2. [Contact is David Bromwich] (Sep 27, 2018 - Completed)

- Tom Hamill (NOAA) presented a SIRTA white paper overview (https://www.iarpccollaborations.org/members/documents/10257) and Richard Cullather (NASA) presented "Data Assimilation as it Relates to the Sea Ice Outlook (SIO) and Prospects for Improvement" (https://www.iarpccollaborations.org/members/documents/10256) to the ACT and MST at their joint October 2017 meeting. This meeting reviewed the SIRTA efforts and rekindled the conversation on what was learned and what use might be made of the SIRTA whitepaper and related work. (Jul 5, 2018 - Completed)

- The Systematic Improvement of Reanalyses in the Arctic (SIRTA) was initiated as an IARPC panel to assess strengths and weaknesses of atmospheric reanalyses. The panel held four open meetings to share ideas and provide input, which served as a basis for a white paper that was submitted to IARPC principals in August. The white paper describes reanalyses, provides an overview of observations currently being used in the Arctic region, gives an overview of recent studies evaluating reanalyses, and describes areas of future development. The paper identified topics for the potential improvement of Arctic reanalyses, including the development and improvement of cloud prediction, the coordination of observation-modeling-reanalysis-forecasting activities, and the improvement of satellite remote sensing over ice and snow. (Oct 9, 2017 - Completed)

- **9.3.6 (In progress) Coordinate and support the ISMIP6 efforts in the U.S. by integrating ice-sheet models into coupled climate and earth system models to both: (1) improve sea level projections due to changes in the cryosphere; and (2) enhance scientific understanding of the cryosphere in a changing climate.; NASA (Lead), DOE, NOAA, NSF**

  - NASA contributed to this PE in the following way: The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) project includes participation from NASA-sponsored models including ISSM developed at JPL and PISM, which is being utilized with the GISS ModelE earth system model. An overview of initialization and model protocols in support of ISMIP6 for the Greenland Ice Sheet has been presented in a recent publication (Ggelzer et al., 2018). The paper summarizes initMIP-Greenland, a comparison of ice sheet initialization procedures for the present day for centennial scale prognostic sea level change projections. Corresponding simulations for initMIP-Antarctica have been conducted and are being evaluated.

    An additional pre-ISMIP6 study has been organized to examine the simulated influence of ice shelves in retaining grounded ice mass. This study is known as ABUMIP, the Antarctic BUttressing Model Intercomparison Project. The scope of the experiments for ABUMIP have been outlined, and simulations were completed on 1-May 2018.
An ISMIP6 workshop was held prior to the annual AGU meeting on 10-December 2017 in New Orleans to review the progress towards ISMIP6. At this meeting, the results of initMIP-Greenland and initMIP-Antarctic experiments were presented, and model protocol for ISMIP6 was discussed. There was additional participation at the workshop by atmospheric and oceanic modeling communities for the purpose of understanding issues and uncertainties regarding boundary conditions and model coupling. Two focus groups have been organized to explore options for forcing ice sheet models in ISMIP6. The atmospheric focus group is led by William Lipscomb (NCAR), and the oceanic forcing group is led by Fiamma Straneo (Scripps Inst. Oceanogr.). The focus groups have held telecons throughout the summer 2018 to address their respective topics and will make presentations on findings at the upcoming ISMIP6 workshop in September 2018.


The abstract follows: Earlier large-scale Greenland ice sheet sea-level projections (e.g. those run during the ice2sea and SeaRISE initiatives) have shown that ice sheet initial conditions have a large effect on the projections and give rise to important uncertainties. The goal of this initMIP-Greenland intercomparison exercise is to compare, evaluate, and improve the initialisation techniques used in the ice sheet modelling community and to estimate the associated uncertainties in modelled mass changes. initMIP-Greenland is the first in a series of ice sheet model intercomparison activities within ISMIP6 (the Ice Sheet Model Intercomparison Project for CMIP6), which is the primary activity within the Coupled Model Intercomparison Project Phase 6 (CMIP6) focusing on the ice sheets. Two experiments for the large-scale Greenland ice sheet have been designed to allow intercomparison between participating models of (1) the initial present-day state of the ice sheet and (2) the response in two idealised forward experiments. The forward experiments serve to evaluate the initialisation in terms of model drift (forward run without additional forcing) and in response to a large perturbation (prescribed surface mass balance anomaly); they should not be interpreted as sea-level projections. We present and discuss results that highlight the diversity of data sets, boundary conditions, and initialisation techniques used in the community to generate initial states of the Greenland ice sheet. We find good agreement across the ensemble for the dynamic response to surface mass balance changes in areas where the simulated ice sheets overlap but differences arising from the initial size of the ice sheet. The model drift in the control experiment is reduced for models that participated in earlier intercomparison exercises. (Sep 27, 2018 - Completed)

The National Science Foundation has recently awarded OPP – 1837544. Observational datasets of Greenland Ice Sheet change are rapidly expanding and have been used for calibration and validation of ice sheet models. But substantial data-model gaps remain due to the knowledge barrier of understanding and using satellite- and paleo-data and the lack of a standard framework for using available observational datasets in ice sheet modeling experiments. There is significant potential to generate a long-lasting cyberinfrastructure framework with ice sheet data, software tools, online cloud-based execution and educational materials. When combined, this would lead to rapid progress in improving ice sheet modeling capability and decreasing uncertainty in sea level rise forecasting. The PIs will bring together experts in ice sheet observation, data analysis
and modeling to guide the creation of a community hub that will enable two-way communication between data generators and modelers. The PIs will pilot software tools necessary to facilitate interoperability among the various data sets and modeling tools and investigate new metrics for model-data intercomparison and model assessment. (Sep 25, 2018 - Completed)


- A paper describing MISOMIP was published: https://climatemodeling.science.energy.gov/research-highlights/experimental-design-three-interrelated-marine-ice-sheet-and-ocean-model (Nov 4, 2017 - Completed)

- The HiLAT project (Jeremy Fyke; LANL) led the implementation of the CISM ice sheet model into the Community Earth System Model version 2 (CESM2). This implementation allows for a two-way coupling between the Greenland Ice Sheet and the rest of the climate system. In addition, Fyke developed a new iterative procedure to spin up ice sheets models in fully-coupled Earth System Models. ()

- The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) published experimental and data request protocols as part of the CMIP6 special issue in Geoscientific Model Development in Dec 2016. The first set of experiments targeting the Greenland standalone ice sheet modeling community, initMIP-Greenland, were completed by 17 international groups, and the results submitted to the journal “Cryosphere” in July 2017. initMIP-Greenland seeks to understand and reduce the uncertainty in sea level projections due to the choice of model initialization methods. The ISMIP6 and initMIP-Greenland efforts were presented at national and international conference (AGU 2016, EGU 2017, International WCRP/IOC Conference on Regional Sea Level Changes and Coastal Impacts) and to the IARPC Glacier and Fjord CT and Modeling CT in March 2017. ISMIP6 organized two workshops in Dec 2016 -Initialization of ice sheet models, and oceanic forcing for ice sheet models- and one splinter meeting at EGU2017. More information: http://www.climate-cryosphere.org/wiki/index.php?title=ISMIP6_wiki_page

Paper reference:


Joint Glaciers & Sea Level and Modeling Collaboration Teams meeting with presentations on ISMIP6.

9.4 Enhance discoverability, understanding, and interoperability of Arctic data and tools across Federal data centers.

- **9.4.1 (In progress)** Advance system models of U.S. observing inventories and data centers to further understanding of these capacities so that informed, optimal, strategic decisions and design, and spending plans can be made.; NOAA (Lead), NASA, NSF

  - The National Science Foundation (NSF) has recently awarded OPP – 1848747. There is a wealth of past climate data sets stored in the NSF-funded Arctic Data Center (ADC) that are unresolved yet have the potential to expand and deepen the current state of understanding about how the Arctic is responding to environmental changes. This award supports an integrative workshop that will bring together a diverse group of early career scientists and experts from the fields of ice core, computer and climate sciences. The goal is to pave the way for the development of a future generation of computer tools necessary to better understand complex interactions of multiple driving forces that are changing Earth’s environment. Objectives are to evaluate the latest computational advances, break existing interdisciplinary barriers that limit the use of ice core data sets in climate research, and promote the development of future products that will benefit the Arctic research community. (Oct 17, 2018 - Completed)

- The following input from NASA also was submitted to PE 5.2.2

  Between September 2017 and September 2018, the NASA NSIDC DAAC published or updated roughly 125 Arctic related data products. This includes data from a number of NASA missions and programs including Operation IceBridge (OIB), Soil Moisture Active Passive (SMAP), Making Earth Science Data Records for Use in Research Environments (MEaSUREs), and the Advanced Microwave Scanning Radiometer (AMSR2). The data ranged from Lidar and Radar data to large collections of images, Greenland mosaics, sea ice age products, and many more. There were roughly 325 citations of this data during the same time period, with AMSR-E, the Moderate Resolution Imaging Spectroradiometer (MODIS), and SMAP leading the pack. Of special note, the NSIDC DAAC saw a dramatic increase in the number of users accessing the data to over 47,000 unique users so far in 2018, from 129 countries. This was due in part to the new exposure of selected data products through the Google Earth Engine. Also, summary details about the NSIDC DAAC: The NSIDC DAAC provides data and information on snow, sea ice, glaciers, ice sheets, ice shelves, frozen ground, soil moisture, cryosphere, and climate interactions, in support of research in global change detection, model validation, and water resource management. The data is available at: https://nsidc.org/daac/

  Of note for clarity, data is stored at NSIDC DAAC, but models are not run on this site. (Sep 27, 2018 - Completed)

- NOAA promotes system-level organization of observing and data architectures through it sponsorship of the US Arctic Observing Network (US AON). US AON has made progress both across Federal agencies and with the research community on advancing a framework for Arctic Observing, which would also include architectural considerations for data management. The NOAA-led US AON Sea Ice Forecasting Task is a pathfinder project that is using the SAON-STPI Societal Benefit Framework to map out the “value
tree" of observations in support of sea ice forecasting. It reported back to the NOAA Environmental Data Management workshop on its progress in identifying the key inventories in support of sea ice forecasting across federal agencies. (Sep 26, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1837544. Observational datasets of Greenland Ice Sheet change are rapidly expanding and have been used for calibration and validation of ice sheet models. But substantial data-model gaps remain due to the knowledge barrier of understanding and using satellite- and paleo-data and the lack of a standard framework for using available observational datasets in ice sheet modeling experiments. There is significant potential to generate a long-lasting cyberinfrastructure framework with ice sheet data, software tools, online cloud-based execution and educational materials. When combined, this would lead to rapid progress in improving ice sheet modeling capability and decreasing uncertainty in sea level rise forecasting. The PIs will bring together experts in ice sheet observation, data analysis and modeling to guide the creation of a community hub that will enable two-way communication between data generators and modelers. The PIs will pilot software tools necessary to facilitate interoperability among the various data sets and modeling tools and investigate new metrics for model-data intercomparison and model assessment. (Sep 25, 2018 - Completed)

- The May 2018 ADST meeting focused on the upcoming Arctic Observing Summit (https://www.iarpccollaborations.org/members/events/10666). This meeting provided a snapshot of the current state of conversations on data synthesis. Presentations: Summary reporting on the results of the Polar Data Planning Summit, 22-24 May, Boulder, CO; Sharing plans for the Arctic Science Summit Week and the Arctic Observing Summit, Davos, June 2018. (May 31, 2018 - Completed)

- The November 2017 ADST meeting focused on NSF’s Arctic Cyber-infrastructure research opportunities. (https://www.iarpccollaborations.org/members/events/10249). Marc Steiglitz (NSF) presented on Polar Cyberinfrastructure. The presentation provided context for what defines a CI activity, the types of activities funded by NSF, the Directorates that support such activities, and the challenges related to engaging Polar researchers in such efforts. (Nov 30, 2017 - Completed)

- Progress is being made on this performance element through the support of the Polar Geospatial Center, which provides remote sensing imagery, GIS, and logistics support for Polar research activities. ()

- Progress is being made on this performance element through two NSF-funded tools for Arctic science planning: the Arctic Research Mapping Application (ARMAP; http://armap.org) and the Arctic Observing Viewer (AOV; http://www.arcticobservingviewer.org). ARMAP provides a map-based perspective for interagency project tracking, whereas AOV conveys details on thousands of specific observation sites. Together they enable a comprehensive view of Arctic research across a spectrum from project inception through network activities to data access. In this way, these tools help planners and others to assess status, coordinate logistics, find overlap, fill gaps, and clarify directions. Beyond these specific tools, the IARPC Environmental Intelligence team has been instrumental with communication, cooperation, and coordination across agencies – much more so than was achieved with
previous efforts. The paired sub-teams have helped greatly to get the word out and foster connections, and thus to better inform decision making. ()

- A presentation (https://www.iarpccollaborations.org/members/documents/9214) by Peter Pulsifer provides a high-level overview of the "Arctic Data Ecosystem" at a variety of scales including international, national and local. The presentation concludes by indicating the need for infrastructure thinking, enhanced interoperability, and recognition of the importance of mediators. A variant of this presentation was made at the Transatlantic Ocean Research Alliance Arctic Meting 03-30-17, Brussels; Arctic Science Summit Week, 04-03-17, Prague; and US Global Change Research Program, Washington DC, 04-19-2017. (Aug 30, 2017 - Completed)

- Sharing data and information across systems, or "interoperability" as this sharing is often called, is an important and popular topic. Advances have been made in this area, however there are still challenges, particularly in effectively sharing between different communities or communities of practice that do not share the same language or definitions of terms or concepts. Even researchers in the same areas of research may not fully agree on all definition of terms or the relationships between phenomena. In some cases, as was pointed out in a recent IARPC Collaborations post by @Jessica Rohde, terms may be misused. There are a number of methods emerging to help enhance semantic interoperability and there are a number of members of the IARPC and international community that are working on related projects. Based on lively discussion during our last meeting, the Arctic Data Sub-team (a part of the Environmental Intelligence Coordination Team) will be meeting on April 27th at 13:00 Eastern Time to discuss language, meaning and data sharing across disciplines. There will be a number of presentations on projects related to Arctic vocabularies and semantics (including sea ice, permafrost, Indigenous terminology and others). There will also be discussion of the formation of a joint project between Arctic Data Sub-team and the international Arctic Data Committee. (Aug 30, 2017 - Completed)

- 9.4.2 (In progress) Promote a nationally and internationally interoperable Arctic data sharing system that will facilitate data discovery, access, usage in many contexts, and long-term preservation, building off the efforts of NSF’s Arctic Data Center, the AOOS Regional Data Assembly Center and the Alaska Data Integration Working Group (ADIWG); DOI-BLM (Lead), DOI-BOEM (Lead), NSF (Lead), DOE, DOI-USGS, NASA, NOAA
  - The National Science Foundation (NSF) has recently awarded OPP – 1848747. There is a wealth of past climate data sets stored in the NSF-funded Arctic Data Center (ADC) that are unresolved yet have the potential to expand and deepen the current state of understanding about how the Arctic is responding to environmental changes. This award supports an integrative workshop that will bring together a diverse group of early career scientists and experts from the fields of ice core, computer and climate sciences. The goal is to pave the way for the development of a future generation of computer tools necessary to better understand complex interactions of multiple driving forces that are changing Earth's environment. Objectives are to evaluate the latest computational advances, break existing interdisciplinary barriers that limit the use of ice core data sets in climate research, and promote the development of future products that will benefit the Arctic research community. (Oct 17, 2018 - Completed)
  - NASA shares its data through its NASA Distributed Active Archive Centers (DAACs). The NSIDC DAAC provides data and information on snow, sea ice, glaciers, ice sheets, ice
shelves, frozen ground, soil moisture, cryosphere, and climate interactions, in support of research in global change detection, model validation, and water resource management. The website is: https://nsidc.org/daac

NASA ABoVE data is shared in the NSAS EarthData Portal. The link to this site is: https://earthdata.nasa.gov/discipline/cryosphere. The portal is a clearinghouse for Arctic data from NASA. All the data in Earthdata (the metadata DB is called CMR) is accessible via API to any other data center that wishes to harvest it. For example, the NSF Arctic data center could harvest the metadata today if wanted. This may be a possibility to get ABoVe data into some of the “clearinghouses” such as DataONE. The Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs)( https://earthdata.nasa.gov/about/daacs) provide over 200 data sets (https://search.earthdata.nasa.gov/search?fst0=Cryosphere) provide information about land and sea ice, frozen ground (permafrost), and snow. The primary DAACs specializing in EOSDIS cryospheric data products are NSIDC DAAC (https://earthdata.nasa.gov/about/daacs/daac-nsidc) and ASF DAAC (https://earthdata.nasa.gov/about/daacs/daac-asf). Several other DAACs also hold cryospheric data as they relate to their respective disciplines (Sep 27, 2018 - Completed)

- NOAA Ocean and Atmospheric Research hosted an "Arctic All Hands" meeting to discuss new observations made during the 2018 field season. Representatives from the Arctic Observing Viewer, Bill Manley and Allison Gaylord were invited to give a presentation on NOAA data input into the AOV visualization tool. NOAA OAR Arctic PIs that were not already uploading data into the AOV, have made contact and uploaded observational assets into the AOV and will be encouraged to continue doing so. (Sep 20, 2018 - Completed)


- A particularly vexing challenge for the Arctic science community is to document and share scientific data in ways that are compatible – to avoid tremendously redundant effort. At this time, the Environmental Intelligence sub-teams are providing the most fruitful pathways forward for interoperability within and among various US agencies, tied also to international efforts. Progress is being made for example with “essential variables” as well as with vocabularies, semantics, and metadata brokering technologies. ARMAP and AOV are contributing to these efforts, particularly with regard to project-level and site-level metadata standards and crosswalks. Progress on this performance element is also underway through a somewhat separate interagency initiative, the Alaska Data Integration Working Group (ADLwg). Formed several years ago with technical specialists from the USGS, FWS, and other state and federal agencies, ADLwg has taken steps toward interoperability with an established project-level metadata standard, coordination toward a data-level standard, and release of an open source tool for metadata translation across standards. Though not connected directly to IARPC, progress made by ADLwg is communicated through the ARMAP/AOV Team as liaison. ()

- NASA-derived datasets from the Arctic-Boreal Vulnerability Experiment (ABoVE) will be archived in the Oak Ridge National Laboratory NASA DAAC (ORNL DAAC) or other long-
term archive center. NASA continues to work with the ORNL DAAC to ensure these datasets are accessible and discoverable through common metadata search methods. ()

- NCEI Arctic Data Viewer: The NOAA NCEI Arctic Action Team has developed a prototype web map viewer, the NCEI Arctic Data Viewer (ADV) at https://maps.ngdc.noaa.gov/viewers/ncei_arctic/, to increase awareness of NCEI data and products that play a critical role in supporting scientific research, ecosystem health, community resilience, vibrant economies, and emergency response efforts in the region. Over the course of this two year cross-NCEI pilot project, the team compiled representative geospatial data sets from the Center for Weather and Climate (CWC) and Center for Coasts and Oceans (CCOG) that can be simultaneously selected and displayed in the Arctic-centric map viewer. This project demonstrated the integration of datasets hosted using disparate software including ArcGIS Server, GeoServer, and THREDDS. By employing standards-compliant services, non-NCEI organizations can easily ingest the NCEI services into their own viewers, enhancing their own products and increasing exposure to NCEI data. These include NOAA and federal platforms such as the NSF Arctic Data Center Discovery Portal and Upload Tool, NOAA Geoplatform, Digital Coast, data.gov, Alaska Ocean Observing System (AOOS), and Arctic Environmental Response Management Application (ERMA). Through this initial effort, the team identified compatibility issues and solutions, and explored ways to informatively display diverse data types, which will guide the ways in which we make our data useful and available to users. We also continue our collaboration with the Southern Ocean Observing System to identify in-situ Southern Ocean data at risk of loss and work with the PIs and project staff to convert it to standard formats (CF-compliant netCDF) with complete ISO-19115-2 metadata, archive it at NCEI, and make it discoverable and downloadable through our Geoportal and web services. SOOS will federate this data into their SOOSmap application for discovery and re-use, and it may be added to other services. This work was supported by the NOAA Big Earth Data Initiative (BEDI). We're also continuing our work with the NSF Arctic Data Center and the DataOne network, which is in the tool-building phase to facilitate data transfer from the network to NCEI for long-term archival. You can contact Sheekela Baker-Yeboah for more information: sheekela.baker-yeboah@noaa.gov ()

- Progress on this performance element is underway through a number of currently funded NSF grants. notable awards that are currently active are 1) CAREER: Cyber-Knowledge Infrastructure for Geospatial Data, 2) Earthcube Building Blocks: Collaborative Proposal: Polar Data Insights and Search Analytics for the Deep and Science, 3) Development and innovation of the Barrow Area Information Database (BAID): A cyberinfrastructure that supports arctic science, outreach aCollaborative Research - Development and innovation of the Barrow Area Information Database (BAID): A cyberinfrastructure that supports arctic science, outreach and education, 4) Towards a Tiered Permafrost Modeling Cyberinfrastructure, and 5) Scientia Arctics: A Knowledge Archive for Discovery and Reproducible Science in the Arctic. ()

- The ADST hosted a collaboration team meeting to discuss data vocabularies and governance. Invited participants included research scientists, data aggregators and data managers to contribute to a discussion on data interoperability and the feasibility of conducting data synthesis using current data bases. Data managers from the Arctic Data Center described the current efforts to encourage database contributors to map their
datasets, providing universal data vocabularies that would improve the feasibility of large scale data synthesis. ()

- The ADST hosted a collaboration team meeting on surveying Arctic carbon datasets. The focus of this meeting aligns with the EI Arctic Carbon focus. Presentations included: Matt Jones: NCEAS, NSF Arctic Data Center; Christina Schädel: Northern Arizona University, Permafrost Carbon Network; Deb Agarwal: Lawrence Berkeley National Laboratory, AmeriFlux ()

- The ADST hosted a collaboration team meeting on data interoperability with a focus on semantics and vocabularies. Presentations included: “Overview of Arctic Vocabularies and Semantics Projects”, Peter Pulsifer, NSIDC University of Colorado; “Polar Insights”, Ruth Duerr, Ronin Institute; “Improving discovery and integration of Arctic research products through semantic annotation” Bryce Mecum, NSF Arctic Data Center ()

- **9.4.3 (In progress) Enhance the timely availability, diversity of content, and inclusion of international contributions to the Arctic data sets and resilience tools within the Arctic Theme for the Climate Data Initiative (CDI) and CRT.; DOI (Lead), NASA (Lead), NOAA (Lead), NSF (Lead)**

- BOEM OCS Study 2017-062: Arctic Tracer Release Experiment (ARCTREX) -- Applications for Mapping Spilled Oil in Arctic Waters completed. The Arctic Tracer Release Experiment (ARCTREX) was designed to test the ability of available observational technology to sample a simulated oil spill in the Chukchi Sea and to transmit data to a shore-based, online emergency management application. During the ice-free seasons of 2014 and 2015, three releases of Rhodamine-WT dye were performed. During the field campaigns, data were transmitted to a version of NOAA’s Environmental Response Management Application (ERMA 2015) that is configured for the Arctic region, improving communication and coordination among responders and environmental stakeholders during future events. The diversity of environments and the extremely rough weather experienced during the field experiments allowed us to fully evaluate the performance of the instruments; the TSG and the towed undulating Acrobat vehicle are capable of tracking dye over time in great detail while being able to operate in stormy seas with significant wave heights approaching three meters. Dye was distributed throughout the surface mixed layer and, in one case, was subducted below the surface layer, requiring instruments capable of sustained subsurface measurements. (Oct 2, 2018 - Completed)

- A description of how NASA supported this PE follows: NASA is still involved in the Climate Data Initiative via www.data.gov and there is NASA Arctic-focused data on this site. NASA also is expanding access to its Arctic-related data through the GEO Platform’s resilience community at: https://www.geoplatform.gov/. This will be another way to access the data once it is up and running. ()

- Sharing data and information across systems, or "interoperability" as this sharing is often called, is an important and popular topic. Advances have been made in this area, however there are still challenges, particularly in effectively sharing between different communities or communities of practice that do not share the same language or definitions of terms or concepts. Even researchers in the same areas of research may not fully agree on all definition of terms or the relationships between phenomena. In some cases, as was pointed out in a recent IARPC Collaborations post by @Jessica
Rohde, terms may be misused. There are a number of methods emerging to help enhance semantic interoperability and there are a number of members of the IARPC and international community that are working on related projects. Based on lively discussion during our last meeting, the Arctic Data Sub-team (a part of the Environmental Intelligence Coordination Team) will be meeting on April 27th at 13:00 Eastern Time to discuss language, meaning and data sharing across disciplines. There will be a number of presentations on projects related to Arctic vocabularies and semantics (including sea ice, permafrost, Indigenous terminology and others). There will also be discussion of the formation of a joint project between Arctic Data Sub-team and the international Arctic Data Committee. (Apr 13, 2017 - Completed)

- **9.4.4 (In progress) Advance agile situational awareness and decision support for Arctic operators through efforts like ADAC’s Arctic Information Fusion Capability28, ERMA, and NASA ACE project.; DHS (Lead), DOE, NASA, NOAA**
  - DHS S&T OUP decided via their Bi-annual review process to discontinue funding of the AIFC project as planned and approved first in March 2016, with further approval in July 2016. Following the project’s discontinuation, ADAC received the approval to release a funded RFP to solicit additional research associated with the objectives and goals from the AIFC project. Following coordination with HQ USCG, ADAC released the RFP in Sep 2017, and received 17 proposal responses in late Oct 2017. Following science and customer relevancy evaluations, ADAC was notified of two selections in April 2018, and worked with the selectees to create and gain approval of new workplans, which was achieved in July 2018. These two new projects are found in the ADAC Year 5 Workplan which can be found on the ADAC website. (Aug 28, 2018 - Completed)
  - 2 projects have been funded by ADAC: a) The Arctic All-Hazards GIS Platform, led by Dr Marcus Boyd, University of Maryland and b) the Arctic Vessel Monitoring Geofencing/Alert Awareness, co-led by Dr Kendrick Mock, UAA College of Engineering and CAPT (Ret) Buddy Custard, Alaska Maritime Prevention and Response Network. ADAC will host a meeting on December 5-6, 2018 at HQ U.S. Coast Guard to hear reports on current progress of these new research efforts. (Aug 28, 2018 - Completed)
  - On 1 July 2017, DHS S&T OUP decided via their Bi-annual review process to discontinue funding of the AIFC project as planned and approved first in March 2016, with further approval in July 2016. Following the project’s discontinuation, ADAC received the approval to release a funded RFP to solicit additional research associated with the objectives and goals from the AIFC project. Following coordination with HQ USCG, ADAC released the attached RFP in Sep 2017, and received 17 proposal responses in late Oct 2017. Following science and customer relevancy evaluations, ADAC was notified of two selections in April 2018, and worked with the selectees to create and gain approval of new workplans, which was achieved in July 2018. These two new projects are found in the attached ADAC Year 5 Workplan, version 2.5:
    1. The Arctic All-Hazards GIS Platform, led by Dr Marcus Boyd, University of Maryland (project described on page 51 of the attached workplan)
    2. Arctic Vessel Monitoring Geofencing/Alert Awareness, co-led by Dr Kendrick Mock, UAA College of Engineering and CAPT (Ret) Buddy Custard, Alaska Maritime Prevention and Response Network (page 67 of the attached workplan).
There is effort to leverage this information to advance the Geofence project. Both these new projects are in their early days of research. Over the next couple of months we will produce project videos and publish to our website and the ADAC YouTube Channel: https://www.youtube.com/channel/UCnIcKAlpk75vXyzL7_ToL4g (Aug 27, 2018 - Completed)

- DHS Science & Technology Arctic Domain Awareness Center (ADAC) will focus on developing sea-ice and weather forecasting tools to improve situational awareness and crisis response.

  The Arctic Domain Awareness Center (ADAC), sponsored by DHS S&T and focused on United States Coast Guard (USCG) missions, develops and transitions technology solutions, innovative products and educational programs to improve situational awareness and crisis response capabilities related to emerging maritime challenges posed by the dynamic Arctic environment. (Oct 4, 2017 - Completed)

- ADAC’s Arctic Information Fusion Capability (AIFC) project has been discontinued as a result of formal review of the Arctic Domain Awareness Center of Excellence program. AIFC is one of several projects that were reviewed. As a result of the review, AIFC will be discontinued 30 June 2017. ADAC will be issuing an RFP to solicit project proposals to address the same research questions that created AIFC. (Apr 21, 2017 - Completed)

  9.4.5 (In progress) Update baseline mapping and charting across the Arctic, including additional charting in Arctic waters, updates to baseline topographic mapping and supporting data, and updating high resolution imagery-derived elevation data repeated coverage. Multiagency partners include Alaska Mapping Executive Committee, Alaska Geospatial Council, and Arctic-related LCCs.; DOI-USGS (Lead), NOAA (Lead), NSF (Lead), DOD-NGA, DOI-BLM, DOI-FWS, DOI-NPS

  - In 2018, new IfSAR data was collected for the Yukon Delta, Alaska Peninsula, and the National Petroleum Reserve – Alaska (NPR-A). As a result, 98% of the state has been collected at a 5-meter resolution. The remaining uncollected areas include: Kodiak Archipelago, Aleutian Islands, St. Lawrence Island, and isolated Bearing Sea Islands. If the Alaska Mapping and Modernization program receives a favorable FY19 budget, all remaining lands could be collected in 2019. The Alaska Mapping Initiative website (https://www.usgs.gov/core-science-systems/ngp/user-engagement-office/alaska-mapping-initiative) is updated continually with the status of the IfSAR collection and production of US Topo Maps. (Aug 28, 2018 - Completed)

  - Progress is being made on this performance element through the support of the Polar Geospatial Center as it relates to the construction of the first high-resolution Pan-Arctic Digital Elevation Model and the numerous SEARCH (Study of Environmental Arctic Change) related activities, which include the description of and the elucidation of the mechanisms that drive permafrost change and an Arctic synthesis of soil carbon storage.

9.5 Advance research, tools and strategies to improve the accessibility and usability of Arctic science for decision support.

  - 9.5.1 (In progress) Advance coordination among Federally-funded research programs that provide decision support to Arctic stakeholders.; NOAA (Lead), DHS, DOI-BLM, DOI-FWS
The EICT Team Leaders are co-charing a session with a SICT team leader at the AGU Fall Meeting session on Unprecedented Bering Sea Ice Extent and Impacts to Marine Ecosystems and Western Alaskan Communities. This session aims to gather the science community to discuss the abnormal conditions and rapidly changing Bering Strait region in 2017 and 2018 with a focus on community/stakeholder needs and policy considerations. Following the AGU oral and poster sessions, the EICT is planning a town hall with the CRCT to promote community discussion around this topic beyond scientific results. Plans are in place to live stream the town hall in order to increase Alaska-based participation.

Abstract: Anomalously warm sea surface temperatures during summer of 2017 led to record late winter freeze-up and low ice extent in the Northern Bering Sea and Strait region. Arctic Amplification of climate change is driving unprecedented, sweeping changes to the Alaskan landscape and surrounding seas. Diminished sea ice coverage has serious implications for coastal communities, indigenous subsistence hunting and currently poses a threat to food security and navigation safety. An interdisciplinary approach to monitoring marine ecosystem impacts combined with physical oceanography and sea ice dynamics and consequent impacts to human systems is central to creating a system level understanding both at present and into the future. We invite presentations on emerging phenomena such as increasingly prevalent harmful algal blooms, changes in marine food web processes and populations, altered circulation and stratification dynamics and impacts of winter storms on communities. (Dec 10, 2018 - Target)

Adapt Y-K: Climate Adaptation Strategy for the Yukon-Kuskokwim (Y-K) Delta Region- The U.S. Fish & Wildlife Service, on behalf of the Western Alaska Landscape Conservation Cooperative, has funded a climate adaptation project for the Yukon-Kuskokwim region. A draft plan was developed in 2018. The plan was developed by a regionally-representative group of tribal and community leaders, non-profit organizations, individuals, researchers and public resource managers and advised by government agencies. The plan focuses on practical near term adaptation strategies on a set of topics where the group believed we could make progress. The initial set of specific strategic actions proposed in the next five years are linked to three main target areas: Subsistence Resources; Community Infrastructure, and Trails and Transportation. Within these target areas strategies focused on subsistence foods preservation (i.e. salmon drying); community-scale climate change planning template that links to erosion and flooding impacts; and developing trail use and planning strategies to increase safety and reduce impacts. [https://alaskaseagrant.org/2018/08/27/4310/] (Oct 17, 2018 - Completed)

The EICT team leaders chair a biweekly convening HABs Steering Committee to discuss progress towards HABs research and monitoring in Alaska. In addition to EICT leadership, steering committee members include NOAA Regional Coordinator Amy Holman (CRCT team leader), NOAA Sea Grant extension agent base in Nome, AK Gay Sheffield, NOAA AOOS Alaska Harmful Algal Bloom Network coordinator Darcy Duggan and IARPC Secretariat Meredith LaValley. Meetings are an opportunity for Alaska-based and DC-based members to exchange updates on community concerns/perceptions and agency response and planned activities. Steering committee members are also
responsible for planning communication campaigns, outreach and data sharing activities.  (Sep 28, 2018 - Completed)

The September EICT Meeting was the second in a series of three meetings focused on mid-season results from the Bering Strait Region HABs Research and Monitoring Coordination Effort. "Environmental Intelligence: HABs Mid-Season Check In" Link to event page: https://www.iarpccollaborations.org/members/events/12046

Presentations:  Report Out On Observations: August Healy Research Cruise (Don Anderson, WHOI); August/September NOAA Fisheries Survey (Kristin Cicciel and/or Lisa Eisner, NOAA/NMFS); September Northern Bering Fisheries Trawl Survey (Jeff Napp, NOAA/NMFS); Beaufort Laboratory Analysis and Results (Steve Kibler, NOAA/NCOS); Kachemak Bay (Kris Holderied, NOAA/NCCOS); SEATOR/Southeast Alaska (Kari Lanphier, SEATOR); Research Workspace and Data Sharing Plans (Kris Holderied/AOOS/Axiom); Discussion and Future Work: next meeting and season synthesis (All, remaining time).

Meeting outcomes included data sharing for the research coordination projects that conducted science during the months of August and September. Results indicated that other than in the Aleutians, HABs had not developed in the Southern Bering or Southeastern Alaska regions. However, northern observations in the Chukchi and Northern Bering indicate astonishingly high concentrations of HAB cells during the month of August. Sediment evaluations also show extremely high concentrations of dormant HAB cysts in sediments. Researchers developed collaborations, discussed remaining 2018 field season plans as well as began discussing plans for the 2019 season and learned about data sharing and management technologies hosted by AOOS AHAB/Axiom.  (Sep 24, 2018 - Completed)

Prior to the NOAA-supported Arctic Research Cruise on the USCGC Healy, NOAA PI Jackie Grebmeier gave a presentation on research cruise operations in Nome, AK on August 6, 2018. This public seminar was held at the NOAA Sea Grant Office in Nome, AK as a part of the "Strait Science" seminar series. This presentation was given in response to community interest in science being conducted in the Bering Strait as well as the desire to know where and when field operations.  (Aug 6, 2018 - Completed)

Following the Staff Group presentation on the HAB effort, EICT Team Leader Emily Osborne presented an overview of EICT activities to the Interagency Working Group On The Harmful Algal Bloom And Hypoxia Research And Control Amendments (IWG-HABHRCA). The IWG-HABHRCA is a congressionally mandated interagency group that coordinates and convenes Federal agencies and their stakeholders to discuss HAB and hypoxia events in the United States and to develop action plans and assessments of these situations. This presentation led to an additional meeting with NOAA's National Centers for Coastal Ocean Science (NCCOS) aimed at coordinating field efforts in the Alaska region in 2018 and beyond. (Jul 19, 2018 - Completed)

EICT team leader, Emily Osborne, provided an overview presentation of the EICT HABs project to NOAA National Centers for Coastal Ocean Science (NCCOS). Participants included headquarter managers of NCCOS and scientists from the NCCOS Beaufort, NC laboratory. Participants discussed complimentary efforts and have continued to be engages in the ongoing HABs coordination project with the EICT. The NOAA Beaufort laboratory has become an important supporting participant, providing financial support for opportunistic sampling. (Jul 16, 2018 - Completed)
The July 2018 EICT meeting was the first in a series of three focused on early results from the Bering Strait Region HABs Research and Monitoring Coordination Effort. "HABs Science Coordination Call for 2018 Summer Field Season" (https://www.iarpccollaborations.org/members/events/11703). PIs from a number of different agencies and projects reported on their activities and preliminary this summer field season as they relate to HABs and future research plans for the field season.

Presentations:

AHAB update- Darcy Dugan: AHAB launched a year ago with a goal to connect and support various groups around state that are doing HABs monitoring and outreach. Website has informational materials on what HABs are.. Web page has just gone live that has list of labs and pricing for analysis: https://www.aoos.org/alaska-hab-network/hab-lab-testing-chart/

Updates on support to analyze samples- Molly McCammon: Funding for sample analysis for community collected samples via AOOS, ARCUS and ARP.

ASGARD Research Cruise Update- Dean Stockwell: Description of HABs sampling and preliminary results- indicate no toxicity during June in the region. Bird observers observed dead Murres (one collected), but does not seem to be HAB related. Physical observations point to fairly well mixed water column that does not lend itself to HAB development. Interannual variability is difficult to predict and a gap in our current understanding.

DBO July Update- Jackie Grebmeier: Water samples collected at all sites will have taxonomy done for phytoplankton type (to be sent to Poland). Very warm bottom water temperatures and lack of thermal barrier between northern and southern Bering Sea emerged during July.

Planning Discussion for Future 2018 Field Season Cruises: Lisa Eisner NOAA Groundfish Survey cruise (August-September)- opportunistic sampling, Bob Pickart and Don Anderson Healy Cruise 1803 extensive water column and sediment sampling

Data collection/coordination and linking with International community (PAG) https://www.iarpccollaborations.org/members/documents/11740 (Jul 9, 2018 - Completed)

Staff Group presentation on Environmental Intelligence HABs. Link to Presentation Link to 2-page summary document (Jun 4, 2018 - Completed)

The May 2018 EICT meeting focused on "Bering Sea Field Season Coordination: Monitoring Harmful Algal Blooms" (https://www.iarpccollaborations.org/members/events/11290). PIs from a number of different agencies and projects reported on their activities this summer field season as they relate to HABs and their capacity to add additional monitoring.

Presentations:

Environmental Intelligence: Responding to Unprecedented Sea Ice Reduction in the Northern Bering Sea (Emily Osborne)

Overview of Healy Cruises 1801 and 1803 (Bob Pickart)
NOAA Fisheries Impacts of Loss of Sea Ice Surveys (Ed Farley/Kristen Ceiceil)

ASGARD cruise in the Northern Bering- HABs Sampling (Dean Stockwell) AK USGS current lab capabilities (John Pearce/Caroline Van Hemert)

Beaufort Shelf Break Ecology –Plankton, fish, and belugas (Carin Ashjian)

Canada’s Three Oceans (C30) and the DBO (Jackie Grebmeier) (May 15, 2018 - Completed)

- The Arctic Domain Awareness Center (ADAC), sponsored by DHS S&T and focused on United States Coast Guard (USCG) missions, develops and transitions technology solutions, innovative products and educational programs to improve situational awareness and crisis response capabilities related to emerging maritime challenges posed by the dynamic Arctic environment. (Oct 4, 2017 - Completed)

- The EI team held an Arctic Carbon forum open to the IARPC and greater Arctic research community to discuss the progress and future plans of EI regarding the carbon focus. Presentations included: Science to Decision Making: Results from Pan-Arctic Options (Berkman) Updates from EI Sub-Teams; Arctic Observing Systems (Starkweather and Ambrose), Arctic Data (Pulsifer and Stieglitz), Modeling (Joseph and Harper)

- 9.5.2 (In progress) Advance policy-relevant science communication through efforts like the annual Arctic Report Card, the Arctic Research Consortium of the United States (ARCUS), and the Study of Environmental Arctic Change (SEARCH); NOAA (Lead), NSF (Lead), DOD-ONR, DOI-BOEM, NASA

- The Study of Environmental Arctic Change (SEARCH) is currently planning and coordinating an interagency supported and endorsed research conference scheduled for September of 2019. The purpose of the SEARCH 2019 Conference is to bring together scientists and policy makers from all levels of government and other decision makers, in the United States and in other nations, need current and reliable scientific information to respond to the rapidly changing Arctic. In the face of accelerating change, the research community seeks to better understand the needs of policy makers, and the latter require more timely delivery of accessible answers to important questions. Agency partners to-date include NSF, BOEM, DOE, ONR and NOAA. (Sep 1, 2019 - Target)

- The National Science Foundation (NSF) has recently awarded OPP – 1821049. The investigators will present scientific information about Arctic change to a broad range of international leaders by establishing a meeting and demonstration area, described as an Arctic Basecamp 2018, in association with the annual World Economic Forum in Davos Switzerland. The investigators will hold panel discussions and will provide demonstrations of the instrumentation used to make environmental measurements in the Arctic in an interactive format. The events will emphasize the linkages between long-term measurements and climate models, while also bringing forward the economic considerations of risk and opportunity related to Arctic change. (Sep 27, 2018 - Completed)

- The National Science Foundation has recently awarded OPP – 1749081. The objective of proposed research under Phase 2 of SIPN (SIPN2) is to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This grant will: Investigate
the sensitivity of subseasonal-to-seasonal sea-ice predictability in the Alaska Arctic to variations in oceanic heat and large-scale atmospheric forcing using a dynamical model Community Earth System Model (NCAR CESM) and statistical forecasting tools, focusing on spatial fields in addition to total extent summaries; Assess the accuracy of Sea Ice Outlook (SIO) submissions based on methodology and initialization; Develop new observation-based products for improving sea-ice predictions, including sea-ice thickness, surface roughness, melt ponds, and snow depth; Evaluate the socio-economic value of sea-ice forecasts to stakeholders who manage ship traffic and coastal village resupply in the Alaska Sector, and engage the public in Arctic climate and sea-ice prediction through blog exchanges, accessible SIO reports, bi-monthly webinars, and by making public data sources useful to non-scientists and scientists alike; and Continue and evolve network activities to generate SIO forecasts and reporting for September minima as in SIPN and expand SIPN2 forecasts to include full spatial resolution and emerging ice-anomaly-months (October - November). This work will directly engage stakeholders that create and use sea-ice forecasts in Alaska and lead to improved safety around sea ice. Work under SIPN2 will also track public awareness and perceptions regarding sea ice, helping to raise understanding through accessible reports, discussions, and public data sources useful to non-scientists and scientists alike.

Stakeholder engagement during the research process will potentially facilitate rapid research-to-operations implementation of the products of this work. (Sep 24, 2018 - Completed)

- On August 28, 2018 U.S. Sen. Dan Sullivan (R-Alaska), chairman of the Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard, convened a hearing entitled, “Harmful Algal Blooms: The Impact on Our Nation’s Waters.” The hearing examined Harmful Algal Bloom events in the U.S. and provide an update on current research, technology, and monitoring techniques. The Alaska Delegation requested input from IARPC Environmental Intelligence team leader, Molly McCammon (AOOS Director), on speakers who could testify to HABs in the Alaska Region. As a result of the Environmental Intelligence CT’s work on HABs, Don Anderson, was funded in 2018 to conduct research on Arctic HABs and testified at the Senate hearing on this topic. https://www.commerce.senate.gov/public/index.cfm/hearings?ID=08D22373-AE28-41D9-A015-3A47AD5E167B (Aug 28, 2018 - Completed)

- NOAA’s Research News website (https://research.noaa.gov/News) hosted a blog chronicling the research and findings of the NOAA Arctic Research Program research cruise during the month of August. Blogs were also posted and shared with the IARPC community and a feature writer was Merdith LaValley of the IARPC Secretariat. Blogs served to highlight real-time results including unusually warm bottom water conditions in the region resulting in benthic ecosystem stress, seabird mortality events and ongoing efforts to monitor change via the Distributed Biological Observatory and Ecosystems and Fisheries-Oceanography Coordinated Investigations.

Blog 1: NOAA Arctic Explorers Sail North Wednesday, August 8, 2018- Written by Emily Osborne, Janet Hsiao and Merdith LaValley (https://www.research.noaa.gov/article/ArtMID/587/ArticleID/2377/Tracking-change-in-the-Arctic)
Blog 2: Tracking Change in the Arctic Tuesday, August 14, 2018- Written by Meredith LaValley (https://www.research.noaa.gov/article/ArtMID/587/ArticleID/2377/Tracking-change-in-the-Arctic)


Blog 4: Sailing Drones Collect Arctic Data Friday, August 17, 2018- Written by Janet Hsiao (https://www.research.noaa.gov/article/ArtMID/587/ArticleID/2380/Sailing-drones-collect-Arctic-data)

Blog 5: Tracking the Voices of Marine Mammals posted August 22, 2018- Written by Meredith LaValley (https://research.noaa.gov/article/ArtMID/587/ArticleID/2381/Tracking-the-voices-of-marine-mammals)


- The BAMS State of the Climate Report is led by scientist from NOAA's National Centers for Environmental Data peer-reviewed publication published annually in the Bulletin of the American Meteorological Society. The annual checkup for the planet, is based on contributions from more than 500 scientists in 65 countries and offers insight on global climate indicators, extreme weather events and other valuable environmental data. The State of the Climate Report features a chapter on the Arctic, with lead editors Martin Jeffires, Jackie Richter-Menge and Emily Osborne, IARPC members and collaboration team leaders. Published August 1, 2018: https://www.ncdc.noaa.gov/bams. Link to IARPC Post: https://www.iarpccollaborations.org/members/updates/11782 (Aug 1, 2018 - Completed)

- NOAA supported the publication of the 12th annual Arctic Report Card released at the AGU fall meeting on December 12, 2017. The Arctic Report Card describes the state of the Arctic environmental system each year. It is intended for a wide audience, including scientists, teachers, students, decision-makers, and the general public interested in the Arctic environment and science. The Arctic Report Card is organized into three sections: Vital Signs, Indicators, and Frostbites. The Vital Signs section is for annual updates on the same seven topics: Surface Air Temperature; Terrestrial Snow Cover; Greenland Ice Sheet; Sea Ice; Sea Surface Temperature; Arctic Ocean Primary Productivity; and Tundra Greenness. The Indicators section is for topics that will be updated every 2-4 years, many of which have appeared in previous Arctic Report Cards, Groundfish Fisheries, Permafrost and Wildland Fires were featured in the 2017 report. The Frostbites section is for reports on new and newsworthy items, describing emerging issues, and addressing topics that relate to long-term scientific observations in the Arctic. 2017 Frostbites
included Paleoceanographic Perspectives and Collecting Environmental Intelligence in the Arctic. The report has received a great deal of media attention during its official roll out during a scheduled press release event at the AGU Fall Meeting. Since the release of the 12th report in December of 2017, there have been nearly 20,000 page views of the Arctic Report Card website (https://www.arctic.noaa.gov/Report-Card/Report-Card-2017/ArtMID/7798/ArticleID/687/About-Arctic-Report-Card-2017). (Dec 12, 2017 - Completed)

Agencies
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