Performance Element Summary Statements
Arctic Research Plan 2017-2021

This document captures the summation of work contributed to the Arctic Research Plan 2017-2021 by Collaboration Teams. Collaboration Teams have summarized work towards each Performance Element in the summary statements below. Many teams strategically left Performance Elements open to be included in implementation of the Arctic Research Plan 2022-2026 or pursued through disciplinary specific team activities.

Health & Well-being

1.1.1 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
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions, Sustainable Economies and Livelihoods, Risk Management and Hazard Mitigation
Summary Statement: From FY 2017-2021, along with the Alaska Native Tribal Health Consortium (ANTHC), members of the HWCT have continued to co-facilitate quarterly One-Health meetings in Anchorage, Alaska (PE 1.1.1). Participants include public health officials, veterinarians, environmental managers, wildlife harvesters, researchers, and resource managers from federal, state, and Tribal health organizations. The working group meets regularly to share updates on activities, to discuss emerging issues, to consider events that are indicative of environmental and climate change, and to review observations submitted through the ANTHC's Local Environmental Observer (LEO) Network. The one health meetings have a large audience and include a wide range of representatives from U.S. Federal agencies, State of Alaska agencies, local/tribal groups, researchers and other Arctic nations. The regularity of these meetings and the large range of topics discussed have contributed substantially to the sustainability of one health considerations in the Arctic. In March of 2019, Members of the HWCT team as well as members of the Coastal Resilience Collaboration Team (CRCT) attended a One Health Zoonotic Disease Prioritization Workshop in Fairbanks where tribal and agency partners ranked zoonotic diseases important in the State of Alaska that could be approached through a multi-sectoral One Health perspective. The workshop was invaluable for providing a forum where Alaska Indigenous partners could voice their concerns about zoonotic diseases and make known their priorities to ensure the health and well-being of rural residents. Parts of this performance element will continue under all 4 of the priority areas in the next Arctic research plan.
Agencies: DOI-FWS, EPA, HHS-CDC, NOAA, USDA-NIFA, DOI-USGS, DOS, NASA

1.1.2   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.
Status: Continuing
Priority Area or Foundational Activity: NA
Summary Statement: The Local Environmental Observer (LEO) Network expanded to over 5000 members by 2020, representing every continent and > 800 communities. There is active membership from the U.S., Canada, Greenland, Iceland, Norway, Sweden, Finland and Russia. The LEO Network continued to hold monthly webinars, hosting the One Health Group quarterly meetings, and publishes a newsletter entitled the Northern Climate Observer. The LEO Network summarized all incoming observations on environmental change to the ONE Health Workgroup, for synthesis by community members, researchers and public health officials. Incoming observations from the LEO Network then are utilized to direct focus towards environmental indicators that are the most urgent. Recent environmental observations have led to further synthesis of information on harmful algal blooms, salmon die-offs, seabird die-offs and wildfire smoke preparedness.
Agencies: DOI-BOEM, DOI-FWS, EPA, NOAA, NSF

1.1.3 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 Pollutants21 (POPs) at or above levels of concern; and improve understanding of the adverse effects of POPs on human populations, especially on child development.
Status: Complete
Summary Statement: The Alaska Native Maternal Organics Monitoring Study (MOM) was an EPA grant-funded study, led by the Alaska Native Tribal Health Consortium (ANTHC). The MOM Study advanced the understanding of cumulative exposure to multiple environmental stressors in rural Alaska Natives. Although funding for the MOM Study ended in 2015, stored samples have been used to investigate issues such as vitamin D deficiency, dental disease, and risk factors for gestational diabetes. Publications can be found at:
https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.publications/abstract_id/9137. Members of the Health and Well-being Collaboration Team, along with the ANTHC, conducted an analysis to determine the optimum sampling protocol for biomonitoring of mercury in within the Alaska Native Maternal Organics Monitoring Study. This resulted in the publication in the International Journal of Circumpolar Health ("A Comparison of individual-level vs. hypothetically pooled mercury biomonitoring data from the Maternal Organics Monitoring Study (MOMS), Alaska, 1999 – 2012"; found at: https://www.tandfonline.com/doi/full/10.1080/22423982.2020.1726256). MOM study results were presented at several One Health Quarterly meetings, which also served as HWCT meetings. On the international front, HWCT members are involved in an ongoing Arctic Council project; One Arctic, One Health. During 2019-2020, a key milestone of the project was the convening of a circumpolar workshop to identify the microbial threats associated with thawing permafrost. Proceedings from the meeting

were published in the National Academies of Science, Engineering, and Medicine website in September 2020.
Agencies: EPA, HHS-CDC, NOAA

1.1.4 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The Inuit Circumpolar Council Alaska, in collaboration with partners, is pleased to release the report: Food Sovereignty and Self-Governance - Inuit Role in Arctic Marine Resource Management. This Inuit-led report illuminates the unique and rich Inuit values and management practices that have successfully safeguarded the Arctic for thousands of years. The following link will take you directly to the report – https://iccalaska.org/media-and-reports/inuit-food-security-project/. This work is supported by the National Science Foundation under Grant No. 1732373. The opinions, findings, and conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
Continued work on this topic will primarily support the Arctic Systems Interactions priority area of the new plan and sustainable economies and livelihoods. The Smithsonian Institute published Arctic Crashes: People and Animals in the Changing North (https://scholarlypress.si.edu/store/new-releases/arctic-crashes-people-and-animals-changing-north/) which explores, in depth, the relationships among the climate, animal populations, and human activities including subsistence hunting. The book explores several case studies on specific animal populations. The National Science Foundation has contributed to this performance element through several grants including a grant for phase 2 of SIPN (SIPN2) to improve forecast skill through adopting a multi-disciplinary approach that includes modeling, new products, data analysis, scientific networks, and stakeholder engagement. This work will continue under Priority Area 2: Arctic System Interactions and Priority Area 3: Sustainable Economies and Livelihoods
Agencies: DOI-BOEM, NOAA, NSF, SI, USDA-NIFA, DOI-NPS

1.1.5 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.
Status: Complete
Summary Statement: HWCT hosted two collaboration team meetings related to the Rural Alaska Monitoring Program (RAMP) during the course of the five-year plan. RAMP was an EPA grant-funded monitoring program operated by the Alaska Native Tribal Health Consortium (ANTHC) in partnership with Kawerak, Inc. and the communities of the Bering Strait region. The research objective of RAMP

was to test the feasibility of a village-based, resident-operated, environmental monitoring program in Bering Strait communities. The RAMP study was completed in 2019 and achieved the following milestones: 1) development of sampling kits utilizing filter paper (FP) blood sampling kits to enable village hunters to sample blood from subsistence-hunted wildlife for the presence of antibodies to several wildlife infections that can be spread to hunters and consumers; and 2) further development of FP technology to include analysis of mercury, selenium, and stable isotopes of carbon and nitrogen. The RAMP study has been completed but the techniques developed can be used to monitor trends in known wildlife diseases, detect new and emerging diseases, and monitor changes in wildlife feeding and forage ecology. Publications related to the EPA grant can be found at: https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.publications/abstract_id/10250. **Agencies:** DOI-FWS, EPA, HHS-CDC, NOAA

1.2.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Sustainable Economies and Livelihoods,
Summary Statement: The HWCT hosted several collaboration team meetings related to water and sanitation challenges and innovations in the Arctic and supported several workshops hosted by the US Arctic Research Commission (USARC) on this topic during the course of the five-year plan. In collaboration with the USARC, Alaska Native Tribal Health Consortium (ANTHC), the State of Alaska, the University of Alaska, and Yukon-Kuskokwim Health Corporation, members of the Health & Well-being Collaboration Team (HWCT) were involved in several efforts to analyze data on community water service and its association with infectious disease infections and other health status indicators in rural Alaska. Publications can be found at https://www.sciencedirect.com/science/article/pii/S1438463919310181?via%3Dihub and https://www.cambridge.org/core/journals/public-health-nutrition/article/lack-of-inhome-piped-water -and-reported-consumption-of-sugarsweetened-beverages-among-adults-in-rural-alaska/89A494844C 7A57D8035F2406D0F83AE8. Work to address rural water and sanitation challenges in rural Alaska will continue in the next Arctic Research Plan under two priority areas: Priority Area 1, Community Resilience and Health and Priority Area 3, Sustainable Economies and Livelihoods.
Agencies: EPA, HHS-CDC, HHS-IHS, USARC, USDA, DOS

1.2.2 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.
Status: Complete

Summary Statement: 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 improvements for at-risk children. Publications of the research findings can be found here: https://www.tandfonline.com/doi/full/10.1080/22423982.2017.1422669 and https://www.tandfonline.com/doi/full/10.1080/22423982.2017.1422669.

The HWCT hosted a meeting in February of 2021 to highlight the research results and ongoing activities that are being conducted by personnel at the Alaska Native Tribal Health consortium with regard to healthy homes activities. 2) A feasibility study entitled "the Environmental Health Hospital Consult Study was completed by the Alaska Native Tribal Health Consortium. The study evaluated the feasibility of conducting environmental health consultations to identify environmental hazards in the homes of children hospitalized with respiratory infection. It also evaluated the feasibility of sending home a healthy homes toolkit in homes where children had been hospitalized with respiratory illness. When possible, low cost fixes to home ventilation and heat sources were arranged through local housing authorities.

Agencies: EPA, HHS-CDC, HHS-IHS, HUD

1.2.3 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.

Status: Complete

Summary Statement: 1) Completed the exhibition "Narwhal: Revealing an Arctic Legend" at the National Museum of Natural History and published a book on its content with contributions from 52 authors. Initiated a traveling version of the exhibition that will travel in North America for two years. The exhibition is based on new research on the narwhal tusk and included close collaboration with Canadian Inuit. 2) Published "Arctic Crashes: People and Animals in the Changing North", a book documenting animal fluctuations resulting from climate and human interactions in Arctic regions. Written by leading arctic anthropologists and biologists following five years of conferences and fieldwork, this research explored how animal populations respond to environmental change, species interactions, and human influence, historically and in recent times. The book is a major synthesis that will have broad scholarly and public impact. 3) The National Science Foundation has awarded a project to stabilize, curate, and digitize materials and documents produced by the Wales archaeological excavations between 1996 and 2006. All specimens will be cataloged and rehoused in archival-quality acid-free bags and boxes, ensuring they will be safely stored and accessible to scientists and descendant Inupiaq communities. Organic artifacts, currently in danger of degradation and irrevocable loss, will be evaluated and conserved. Artifacts and raw materials will be identified in the Inupiaq language and the terms will be incorporated into the collections database so that both Western scientific and Alaska Native designations are available to users. Selected artifacts will be

photographed and scanned in 3D to enhance use of the collections. The entire Wales database will be made publicly available via a searchable web-based project-specific interface. Upon completion of project activities, artifacts, plant and animal remains, sediment samples and excavation documentation will be accessible for study, education, and heritage activities.
Agencies: ED, LC, NOAA, SI, DOI-NPS, NSF

1.2.4 Through efforts like Arctic-FROST22 Research Coordination Network, 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. Deliverables will include coordinated educational activities, presentation, and validation of research results through researcher/community workshops and educational initiatives that involve youth, Indigenous scholars, early career scientists, and members of underrepresented groups.
Status: Complete
Summary Statement: The USDA continued funding on a UAF grant entitled "Back to the River: The science behind Alaska's traditional subsistence lifestyle". The project aims to highlight science-based discovery through use of a mobile riverboat laboratory to engage young students in rural Alaska. The science is aimed at investigating issues of food security, community health disparities and enumerating the benefits of a traditional lifestyle
The Arctic-FROST network has implemented an extensive plan of activities in 2017-2020 consisting of annual meetings, early career scholar workshops, community workshops, and multiple smaller theme- based conferences throughout each year.
Annual Meetings
    2017 Community Sustainability in the Arctic: What sustainability theories and practices work and what fail in Arctic Communities?" Qaqortoq, Greenland
    2018 Co-constructing Sustainability in the Arctic: Collaboration among regional and local governments, Indigenous organizations and researchers in sustainable development in the Arctic, Juneau, AK
    2019 Reuniting for Sustainability: Advancing Frontiers of Sustainability Science in the Arctic across Disciplines and Generations, Cedar Falls, IA
Agencies: NSF

1.3.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Sustainable Economies and Livelihoods

Summary Statement: HWCT hosted several CT meetings on topics related to food security during the course of the five-year plan, such as a joint HWCT, MECT, and CRCT meeting in 2020, which was focused on sharing environmental observations from 2020 and discussing implications for food security. A study focused on substance sharing networks, led by BOEM, was completed in 2017 ("Subsistence Sharing Networks and Cooperation: Kaktovik, Wainwright, and Venetie, Alaska"; https://www.boem.gov/newsroom/library/alaska-scientific-and-technical-publications). NSF also awarded several grants addressing food security concerns, such as: 1) conceptualizing Indigenous Knowledge to better understand historical and contemporary ways in which Alaska Native people steward salmon, the cultural contexts connected to salmon stewardship, and Indigenous approaches to current management practices and systems; and 2) using modern, historical, and archaeological bone to examine changes in mercury concentrations and trophic position in these marine species over the last 3000 years in three Ecosystem Sentinels. Food security continues to be a critical issue in the Arctic, particularly for Indigenous populations, and work on this topic will continue into the next Arctic Research Plan under Priority Area 1, Community Resilience and Health and Priority Area 3, Sustainable Economies and Livelihoods.
Agencies: DOI-BOEM, NOAA, NSF

1.3.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health
Summary Statement: The HWCT hosted several meetings on the topic of rural water and sanitation research in Alaska during the course of the five-year plan. The USARC took a lead federal role in multiple aspects of this PE, primarily through the actions of its Alaska Rural Water and Sanitation Working Group (ARWSWG), which has held multiple annual workshops (Annual Water and Sanitation Innovations for the Arctic Workshop: ALPHA Sessions), in partnership with key agencies, including CDC, EPA, IHS, ADEC, ADHSS, and ANTHC. Additional key activities under this PE include the ADEC's Water and Sewer Challenge" which is a multi-million dollar contest focused on decentralized water and wastewater treatment, recycling, and water use efficiency with the primary goal to significantly reduce the capital and operating costs of in-home running water and sewer in rural Alaska homes and the international Conference on Water Innovations for Healthy Arctic Homes (WIHAH), which was an Official Event of the U.S. Chairmanship of the Arctic Council and was hosted by ADEC. The University of Alaska Anchorage (UAA) led a team of academics, engineering consultants and health professionals in developing a technology suitable for in-home water reuse for non-potable purposes; Portable Alternative Sanitation Systems (PASS) were developed and have been installed in multiple communities. This work will continue into the next Arctic research plan under Priority Area 1, Community Resilience and Health as key stakeholders, including the USARC, IHS, ANTHC, and UAA continue to address water and sanitation challenges in rural Alaska.

Agencies: EPA, HHS-CDC, HHS-IHS, USARC, USDA, DOS

1.3.3 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.
Status: Complete
Summary Statement: The USARC continued to direct the activities of the Arctic Renewable Energy Working Group to promote research on renewable and efficient energy systems in remote Arctic communities. Select activities included holding meetings and producing reports focused on residential heating in remote Arctic villages and multiple sessions on "Improving Village-level Financial, Management, and Technical Capacity" (at the 2017 Alaska Forum on the Environment). Finally, the working group also partnered/held two recent workshops focused on electric vehicles in cold climates (https://www.arctic.gov/alaska-electric-vehicle-workshop/) and on sustainable energy in the Arctic (https://www.arctic.gov/arctic-sustainable-energy-research-conference/).
Agencies: USARC

1.4.1 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.
Status: Complete
Summary Statement: In 2019, the Health & Well-being Collaboration Team (HWCT) addressed issues around violence in Alaska Native communities in a meeting that included, 1) reports by DOJ researchers on the National Baseline Study (NBS) to assess Alaska Native women's experiences with violence and victimization, health responses, service needs and help-seeking, 2) examining the contributions of Village Public Safety Offers (VPSO), 3) efforts to determine effective methods to assess exposure to violence and victimization among Alaska Native youth and to improve their health and well-being. HWCT was also involved in meetings that were connected to Attorney General William Barr's 2019 visit to Alaska and the resulting initiatives advanced by him to address Alaska Native community needs.
Agencies: DOJ-NIJ, DOJ-OVW

1.4.2 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.
Status: Complete
Summary Statement: This performance element has been met. The Health & Well-being Collaboration Team hosted a meeting on this subject in 2019

(https://www.iarpccollaborations.org/members/events/12663). The National Institute of Justice has funded research in the State of Alaska. See 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]).
Agencies: DOJ-NIJ, DOJ-OVW, NSF

1.4.3 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.
Status: Complete
Summary Statement: This Performance Element is complete. You can find the description for the data at: http://www.icpsr.umich.edu/web/ICPSR/studies/37945 and http://dx.doi.org/10.3886/ICPSR37945.v1. A report summarizing the use of the publicly available data (downloads of data and/or documentation) is at: https://pcms.icpsr.umich.edu/pcms/reports/studies/37945/utilization
Agencies: DOJ-NIJ, DOJ-OJJDP, DOJ-OVC

1.5.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Sustainable Economies and Livelihoods
Summary Statement: Several programs through Ilisagvik College contribute to this performance element. The HHS had a new award under the Native Youth Initiative for Leadership, Empowerment, and Development (I-LEAD) program which was made to Ilisagvik College in September, 2018. The program increased the availability and accessibility of pre- and post-secondary college programming via summer camps so that Inupiaq, rural, and Alaska Native students ages 14-24 have greater access to place-based education and career exploration. The focus of the camps is on indigenous leadership development, self-esteem and self-confidence building, exploring career pathways in STEM, healthcare and teaching professions, and the sharing of Inupiaq culture, traditions and language. The USDA continued funding for the Tundra Garden, a centrally located garden within Utquiagvik, Alaska that focuses on bridging traditional Iñupiat subsistence knowledge regarding nutritional and medicinal plants with community accessibility. Another UDSA grant focused on promoting science and health education career pathways, increasing the amount of place-based science and healthcare professionals, and supporting education and professional development opportunities for students of

the North Slope Borough as an augmentation to Ilisagvik College's Allied Health Program. THe USDA also worked through the Ilisagvik College's Extension project to sustain and expand capacity for the continued facilitation of science-based workshops that increase food and agricultural literacy on the North Slope of Alaska. Work on this topic will continue into the next Arctic Research Plan under Priority Area 1, Community Resilience and Health and Priority Area 3, Sustainable Economies and Livelihoods.
Agencies: DOI-BIA, ED, HHS-ACF, USDA-NIFA

1.5.2 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.
Status: Complete
Summary Statement: The Alaska Native Community Resilience Study (ANCRS; NIH U19 MH113138) developed and shaped, through multilevel collaborative processes, a tool to identify and measure community-level factors that may reduce the risk of suicide. This work was conducted in 64 linguistically and culturally diverse Alaska Native communities spanning across Inupiaq, Yup'ik, Saint Laurence Island Yup'ik, Cup'ik, and Athabascan peoples, with and by community members. Using an iterative process of knowledge co-production that brought together multiple knowledge systems, including local, Indigenous and Western science, the collaborators developed the Alaska Native Community Resilience Structured Interview (ANSRSI). The publication details the initial process of identifying relevant domains thought to represent community protective factors. The dimensions of community resilience ultimately included Cultural Continuity, Self-determination/Local Control, Culturally Responsive Services, Community Relationships, Community Opportunities and Support, Spirituality and Religion. The collaborative multi-layered process included cultural auditing and community member-checking of the categories, questions, and data collection procedures and resulted in knowledge gathering that conformed to Indigenous ways of knowing, understanding, and communicating about their world. These outcomes will aid the team in better exploring the mechanisms of community protection in the next phases of research. The Health and Wellness Collaboration Team (HWCT) advanced several initiatives to improve Alaskan Native mental health, including the new toolkit from RISING SUN (Reducing the Incidence of Suicide in Indigenous Groups – Strengths United through Network – an activity arising from the U.S. chairmanship of the Arctic Council). In addition, the team highlights the work of ANCHRR (Alaska Native Collaborative Hub for Research on Resilience), which conducts resilience focused research as a way to understand how to increase community health and strategically strengthen institutions and programs to prevent suicide and other associated issues. This project works to integrate community needs; is driven, supported, and led by communities; and seeks to understand strength-based approaches at a community level.
Agencies: HHS-CDC, HHS-NIH, HHS-NIMH, HHS-NIMHD, USARC, DOS, NSF

1.5.3 Conduct surveys to document and report on adverse childhood experiences (ACEs) in Alaska children, including among American Indian and Alaska Native children.
Status: Complete

Summary Statement: In 2020, the Health & Well-being Collaboration Team (HWCT) addressed issues around violence in Alaska Native communities in a meeting that included information from the South Central Foundation and Department of Health and Human Services on data linked to Adverse Childhood Experiences (ACEs) and methods and programs developed to address ACEs by lowering rates and gathering data to support intervention and prevention methods.
The Alaska Title V supported MCH-Epidemiology Unit (moreinformation available here: https://mchb.tvisdata.hrsa.gov/uploadedfiles/StateSubmittedFiles/2021/AK/AK_TitleV_PrintVersion_FY21.pdf) has a sophisticated ALCANLink project (Alaska Longitudinal Child Abuse and Neglect Linkage Project) that pulls in data from multiple sources including PRAMS and administrative data from state and other agencies. This ALCANLink data, can be explored at the test website being developed at: https://ak-mch-epi.shinyapps.io/ALCANLink/
The National Survey of Children's Health (NSCH) is funded and directed by the Health Resources and Services Administration's Maternal and Child Health Bureau, which collects information on Adverse Childhood Experiences. State level estimates of ACEs and other child health indicators can be tabulated using the Data Resource Center query system. In 2017-18, 17.4% of Alaskan children were reported to have experienced 1 ACE in their lifetime and 19.7% were reported to have experienced 2 or more ACEs in their lifetime; estimates are inclusive of Alaska Native/American Indian children. See: https://www.childhealthdata.org/browse/survey/results?q=7479&r=1&r2=3 for more details.
Work on this topic will continue into the next Arctic Research Plan under Priority Area 1, Community Resilience and Health.
Agencies: Census, HHS-CDC, HHS-HRSA

1.6.1 Together with the State of Alaska, document and describe fatal and non-fatal occupational injuries using epidemiologic surveillance.
Status: Complete
Summary Statement: The National Institute of Occupational Safety and Health in Anchorage, Alaska continues to conduct surveillance of occupational fatalities in the State of Alaska in collaboration with the State Division of Public Health, Section of Epidemiology. They have expanded their surveillance capabilities with a new data source for nonfatal injuries, the Alaska Workers' Compensation claims data. The completed two studies on fatal and nonfatal work-related injuries in Alaska: "Using Workers's Compensation Claims Data to Describe Nonfatal injuries among Workers in Alaska" and "Persistent and Emerging Hazards Contributing to Work-Related Fatalities in Alaska.
Agencies: DHS-USCG, DOL-OSHA, FAA, HHS-CDC, NTSB

1.6.2 Together with the State of Alaska, conduct prevention-oriented research addressing fatal and nonfatal injuries and illnesses in high-risk worker populations.
Status: Complete
Summary Statement: The National Institute of Occupational Safety and Health in Anchorage, Alaska began a study of safety practice in commercial aviation companies in Alaska to help determine protective factors in the avoidance of aircraft crashes. They also completed two studies on

commercial fishing safety entitled "Predicting Commercial Fishing Vessel Disaster Through a Novel Application of the Theory of Man-Made Disasters and "Linking datasets to characterize injury and illness in Alaska's fishing industry".
Agencies: DHS-USCG, DOL-OSHA, FAA, HHS-CDC, NTSB

1.7.1 In collaboration with the ANTHC, promote research on how telemedicine applications can improve health care delivery and patient outcomes.
Status: Complete
Summary Statement: The HWCT has hosted two meetings on the topic of telehealth in the Arctic during the course of the five year plan. The first was held in August of 2018 and the second was in April of 2021. The first provided an overview of the history and scope of telemedicine use in the Alaska Tribal Health System and focused on the use of telemedicine in treatment of rheumatoid arthritis. The 2nd provided an update of the innovative approaches being used at the Alaska Native Tribal Health Consortium again on rheumatoid arthritis and in treatment and care of persons living with chronic Hepatitis B and chronic Hepatitis C in remote rural villages. The Centers for Disease Control and Prevention has provided support to the Liver Disease and Hepatitis Program to provide treatment for the Hepatitis C Virus in remote rural Alaska villages. This work will continue into the next Arctic research plan under Priority Area 1. Dr. Elizabeth Ferucci (Alaska Native Tribal Health Consortium) published an article in the Arthritis Care & Research Journal. The article discussed the results of the AHRQ supported grant (1R01HS026208-01A1) that evaluated disease activity and care quality of patients with Rheumatoid Arthritis who participated in a telemedicine visit.
Agencies: HHS-AHRQ

Atmosphere

2.1.1 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.
Status: Complete
Summary Statement: The MOSAiC campaign was successfully completed despite significant challenges associated with the COVID-19 pandemic. Analysis of the unprecedented multidisciplinary data in the central Arctic ocean from the MOSAIC campaign will contribute to the Arctic Systems Interactions priority area. However, we recognize that there is a lot of work to be done and support will be needed for science research and analysis. Such work will fit in well under the Arctic Systems Interactions priority area in the new plan.
Agencies: DOE, NSF, DOD-ONR, NOAA

2.1.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: IARPC has supported meetings that bring together the atmospheric and cryospheric communities around this topic, including meetings on unified data products, data sharing and interagency cooperation. This continued work will support the Arctic systems interactions priority area of the new plan.
Agencies: NOAA, DOE, NASA, NSF

2.2.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions, Risk Management and Hazard Mitigation
Summary Statement: Several discussions were supported about surface-based Arctic observatories and data products stemming from these observatories. Presentations demonstrated a rapidly changing environment that requires long-term monitoring, extending the need for fixed ground sites into the future. This work can directly support the Arctic systems interactions priority area, and has

indirect connections to the community resilience and health (air quality) and risk management and hazard mitigation (climatological extreme events, storm prediction) priority areas.
Agencies: DOE, NOAA, NASA, NSF

2.2.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions
Summary Statement: The ACT has supported numerous discussions on aircraft missions and results. While the specific campaigns mentioned here have been completed, aircraft missions will continue to be a central component of the Arctic observing system, and recent meetings included focus on this topic for the upcoming ARCSIX campaign. This work will directly connect to the Arctic Systems Interactions priority area, and potentially to community resilience and health (air quality studies).
Agencies: DOE, NOAA, NASA, NSF

2.2.3 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions
Summary Statement: The atmospheric composition and radiation community has actively discussed the distribution of atmospheric gases, aerosol, and clouds using the numerous Arctic in situ and remote sensing observations. The importance of understanding atmospheric composition in underrepresented Arctic regions is an ongoing problem that will connect with Arctic systems interactions and community resilience and health (air quality). Recently, a NSF funded project seeks to investigate how climate change affects the quantity and type of biogenic volatile organic compounds (BVOCs) released into the atmosphere and the chemical reactions these BVOCs undergo in the Arctic atmosphere. An additional recently funded NSF project examining carbon sequestration and mercury dissolution fluxes due to melting sea ice. Finally, a published paper this year, "Climate change favours large seasonal loss of Arctic ozone," aligns with this PE (von der gathen et al. 2021 Nature Communications).
Agencies: NOAA, DOE, NASA, NSF

2.2.4 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.

Status: Complete

Summary Statement: The ACT has collaborated with the Permafrost CT (and several other CTs) to look at the relationships between warming and soil carbon release in the Arctic. While this is still an active area of research, ACT would prefer to recast this performance element to be better integrated with Arctic Systems Interactions. NASA recently completed research relevant to this performance element: "Permafrost thaw driven changes in hydrology and vegetation cover increase trace gas emissions and climate forcing in Stordalen Mire from 1970-2014" (Varner et al. 2021, Philosophical Transactions A) and "Characterizing methane emission hotspots from thawing permafrost" (Elder et al. 2021 Global Biogeochemical Cycles)

Agencies: NASA, NOAA, DOE, NSF

2.3.1 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.

Status: Continuing

Priority Areas and Foundational Activities: Arctic System Interactions, Risk Management and Hazard Mitigation

Summary Statement: The ACT team has several discussions related to multi-platform observations of Arctic cloud and aerosol properties. The IARPC federal agencies continue to support observations and modeling of Arctic cloud and aerosol properties from surface, airborne, and space-borne instruments, which maps to both PA2 (Arctic Systems Interactions) and to a lesser extent to PA4: (Risk Management and Hazard Mitigation) in relation to the potential impact of volcanic aerosols on aviation. NASA performed research towards this performance element: "A review of the factors influencing Arctic liquid-containing clouds: progress and outlook" (Tan et al. 2021 AGU Books) and "Mesoscale Impacts on Cold Season PM2.5 in the Yukon Flats" (Edwin et al. 2020 Journal of Environmental Protection)

Agencies: DOE, NASA, NOAA, NSF

2.3.2 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.

Status: Continuing

Priority Areas and Foundational Activities: Arctic System Interactions, Sustainable Economies and Livelihoods, Risk Management and Hazard Mitigation

Summary Statement: The ACT has hosted several meetings on this topic that have allowed for the dissemination of results, though more work is required on this important topic. For example,

continued work on the North Slope of Alaska and on MOSAiC data will support additional studies, and such studies will need to address the rapidly changing Arctic landscape. Continued work on this topic will primarily support the Arctic Systems Interactions priority area of the new plan, but also connects to risk management and hazard mitigation (e.g. aircraft icing), and sustainable economies and livelihoods (e.g. rain on snow events, freezing rain, lack of snow cover, etc.). NASA performed research towards this performance element: "Saharan dust aerosols change deep convective cloud prevalence, possibly by inhibiting marine new particle formation" (Zamora et al. 2020, Journal of Climate), "Clouds damp the radiative impacts of polar sea ice loss" (Alkama et al. 2021 The Cryosphere), and "Arctic Cloud Response to a Perturbation in Sea Ice Concentration: The North Water Polynya" (Monroe et al. 2021, Journal of Geophysical Research: Atmospheres)
Agencies: DOE, NASA, NOAA, NSF

2.3.3 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions, Risk Management and Hazard Mitigation
Summary Statement: ACT has made good progress on understanding the impact of wildfires on the Arctic system. Wildfires are an ongoing issue in the Arctic and continue to be an active area of research that connects to PA1 (Community Resilience and Health), PA2 (Arctic Systems Interactions), and PA4 (Risk Management and Hazard Mitigation).
Agencies: NOAA, DOE

2.3.4 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.
Status: Complete
Summary Statement: Several meetings (including the September 2021 meeting) have focused on the performance of reanalyses in the Arctic, specifically with respect to their handling of clouds. This includes meetings focused on SIRTA (Systematic Improvement to Reanalyses of The Arctic), which brought together representatives from multiple agencies and modeling teams. While there is more to do in this general topic, it is not clear that IARPC needs to support additional collaborations or efforts related to this topic in connection to the next Arctic Research Plan. Several publications were published this year relevant to this performance element: "Evaluation of simulated cloud liquid water in low clouds over the Beaufort Sea in the Arctic System Reanalysis using ARISE airborne in situ observations" (Dodson et al. 2021, Atmospheric Chemistry and Physics), "On the nature of the positive Arctic lapse rate feedback" (Boeke et al. 2021, Geophysical Research Letters), and in preparation, "Dust

and combustion aerosol impacts on Arctic ice formation may be highest over Siberia." (Zamora et al. 2021)
Agencies: NASA, NOAA, NSF

Sea Ice

3.1.1 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).
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: Several SICT and joint IARPC team meetings were dedicated to updates devoted to observations and process studies of the pack ice, ice motion, and surface energy balance exchanges including the multi-agency and international MOSAiC, SODA and SIDEx field campaigns. Information on ICESat-2 was presented to share preliminary results and anticipated low-latency ice thickness (freeboard) product availability that will be utilized by multiple agencies. Agency support for investigator-driven observations and process studies of sea ice has been an ongoing robust effort through this plan and will be developed throughout the next plan as well.
Agencies: NASA, NSF, DOD-ONR, DOI-BOEM, NOAA

3.1.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: SICT dedicated a meeting on the IABP, learning about the recent accomplishments of the program, cross-agency coordinations, and educational outreach. Agency support of the IABP continues for the current and future IARPC Research Plans; IABP falls under Priority Area 2: Arctic Systems Interactions by maintaining a network of meteorological and oceanographic observations for real-time operational requirements and research purposes. The SICT held an informational meeting to gather updates on IABP as well as other buoy efforts in progress.
HS-USCG, DOD-Navy, NOAA, NSF, DOD-ONR, NASA

3.1.3 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.
Status: Complete
Summary Statement: Operation IceBridge completed campaigns in the winters of 2017, 2018, and 2019. Quick look data products of sea ice thickness, snow depth, and freeboard are available at NSIDC. Delivery of final data products is anticipated by the end of CY 2021.
Agencies: NASA

3.1.4 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.
Status: Complete
Summary Statement: JPSS and ICESAT2 were both successfully launched with publications of sea ice thickness now out.
Agencies: NASA, NOAA

3.1.5 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions, Risk Management and Hazard Mitigation
Summary Statement: SICT dedicated team meetings for NASA/NSIDC updates about new remote sensing products, including ice motion, ice thickness, sea ice concentration. Agency support of remote sensing product maintenance and the development of new remote sensing products will continue under Priority Areas 2: Arctic System Interactions and 4: Risk Management and Hazard Mitigation through the monitoring of the Arctic system by spaceborne and airborne sensors.
Agencies: DOD-ONR, DOI-BOEM, NASA, NOAA, NSF

3.1.6 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Agency support for the development and deployment of autonomous systems continues, supporting Priority Area 2: Arctic Systems Interactions, in relation to monitoring ice mass balance and atmosphere-ice-ocean fluxes. Two contributions to this performance element include new results utilizing TANDEM-X as well as technology improvements to buoys and drifters.
Agencies: DOD-ONR, DOI-BOEM, NASA, NOAA, NSF

3.1.7 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.

Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The SICT has been coordinating with the POST to address topics relevant to this PE. This included a joint meeting with the POST on 21 May 2020, as well as SICT attendance at other POST meetings. The SODA project was specifically mentioned in this PE. In response, the SICT hosted meetings on 30 April 2018 and 26 November 2018 to provide updates from the SODA project which is now completed. Other investigator-led research relevant to this PE were funded by the NSF including, but not limited to studies on Arctic general ocean circulation (OPP – 1822334), and continued support for mooring data (OPP – 1758565). Examples of NASA supported research products include publications shared with the SICT, such as [Horvat, C., E. Blanchard-Wrigglesworth, & A. Petty (2020), Observing waves in sea ice with ICESat-2. Geophysical Research Letters, 47, e2020GL087629. doi: 10.1029/2020GL087629] that show the value of NASA data products in support of research on the Marginal Ice Zone. The SICT sees the most relevance to continuing this PE in Priority Area 2: Arctic Systems Interactions of the next IARPC Research Plan. The research questions on processes affecting sea ice cover will remain valid, even if the funded projects conducting this research change. The SICT anticipates greater cross-collaboration team discussions on how continued research on how processes, interactions and feedbacks in ocean dynamics affect sea ice cover will support the goal of Priority Area 2 to observe, understand and predict changes in how changing sea ice affects the Arctic system, and develop a better understanding of its connection to the broader Earth System.
Agencies: OD-ONR, DOI-BOEM, NASA, NOAA, NSF

3.2.1 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.
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: Multiple SICT meetings (as well as a joint with ACT and the Modeling Team) have included updates on model-observation synthesis centered on the MOSAiC expedition. Information on the available ICESat-2 ice thickness product was also provided for agencies to use for model initialization and validation of ice fields. Initial MOSAiC results of model intercomparisons of sea ice drift using multi-agency agency supported buoys was also reported. Agency support for investigator-driven modeling studies of sea ice will be an ongoing effort through this plan and in the next plan as well.
Agencies: DOD-ONR, NSF, DOE, DOI-BOEM, NASA, NOAA

3.2.2 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.

Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: The SICT held devoted meetings and joint meetings with the Modeling Team to share information on operational and research modeling efforts across agencies. Sea ice minimum forecast results, supported by a variety of operational forecast entities, were presented to discuss model differences and possible improvements to model physics, initialization techniques;, assimilation of observations, model evaluation and verification; evaluation of model skill, operational decision support services on the weather, S2S, and climate time scales. Enhancing operational sea ice forecasting and research to improve models will be an ongoing effort.
Agencies: NOAA, DOD-NRL, DOD-ONR, DOE, DOI-BOEM, NASA, NSF

3.3.1 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
Status: Complete
Summary Statement: Future SEARCH sea ice action team work is welcome to contribute to the next plan report, but it does not need to be specifically mentioned in the next IARPC plan.   There have been several updates from the SEARCH sea ice action team at SICT meetings (14 October 2019, 11 September 2018, 30 March 2017). The SICT remains interested in follow up activities from this SEARCH program, but this does not have to be a specific project to focus on for the next Arctic Research Plan.
Agencies: NSF, ONR

3.3.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions
Summary Statement: This is a broad theme for building collaborations across the SICT and other collaboration teams. Updates from established communities of practice such as the SIPN2 (Sea Ice Prediction Network), and cross-collaboration team meetings on topics such as Harmful Algal Blooms (2 August 2019, 11 November 2019) and community sea ice observations have been conducted by the SICT (5 September 2018). The SICT also aimed to host collaborative meetings for the unusual Bering Sea ice events with the Environmental Intelligence, and Coastal Resilience Collaboration Teams (5 April 2019). Representation of SICT at the American Geophysical Union was also reported as an important venue for collaboration and information sharing, with specific sessions reported in 2016 (SIPN Network Meeting), through 2020 (e.g. "Reaching the Researcher: Collaborations Between Educators, Scientists, and the Public for the Advancement of STEM and Geosciences" Sessions ED24A and ED21D).These cross-cutting themes will continue beyond the current plan as a contribution to basic

research on understanding, observing and predicting sea ice change and its relevance to the Arctic and globally in Priority Area 2: Arctic Systems Interactions, as well as contributions to understanding the societal impacts of sea ice change in Priority Area 1: Community Resilience and Health.
Agencies: NSF, DOD-ONR, DOE, NASA, NOAA

Marine Ecosystems

4.1.1 Continue distribution and abundance surveys of Arctic marine species, for example, concurrent monitoring of polar bears and their ice seal prey
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: Research has been done on many Arctic marine species. Highlights of Arctic marine mammals include: NOAA's Polar Ecosystem program that conducted recent (2021) abundance surveys on ice seals and polar bears both at sea, and aerially in association with communities to gather additional information on the 4 ice seal species, USGS Alaska Science Center investigated the population dynamics of polar bears in Alaska's SBS from 2001 to 2016. (Bromaghin et al.,2021), the Aerial Surveys of Arctic Marine Mammals (ASAMM) project (NOAA/BOEM) documented the distribution and relative abundance of bowhead, gray, fin, humpback, killer, minke, and right 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 concluded in 2019, the North Slope Borough/ NOAA MML continued these efforts in the Beaufort Sea from mid-September through mid-October 2020 and 2021 2021 (Clarke et al. 2020)
Agencies: DOI-FWS, NOAA, DOI-BOEM, DOI-USGS, MMC

4.1.2 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.
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: During 2017-2021 the DBO and EcoFoci programs have conducted field collection annually. Data sets from these programs are made publically available. For example Datasets on multiple ecosystem elements (physics, sediment chemistry, microbes, zooplankton, benthic, fish, seabirds, marine mammals) from 2015 and 2017 AMBON (Arctic Marine Biodiversity Observing Network) field efforts were completed and made publicly accessible through the MBON Data Portal.   DBO data sets are made available across many portals both domestically and internationally as part of the Pacific Arctic Group. Example locations include: https://data.eol.ucar.edu/project/DBO and https://arcticdata.io/catalog/portals/DBO
Agencies: DOI-BOEM, DOI-FWS, NOAA, DOD-ONR, MMC, NASA, NSF

4.1.3 Assess winter distributions of key Arctic species, esp. marine mammals
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: Multiple programs include studies with moorings and acoustics to investigate overwinter populations. Some of the EcoFOCI moorings and Chukchi Ecosystem Observatory moorings have acoustic sensors on them.

Agencies: DOI-BOEM, NOAA, DOI-FWS, DOI-USGS, MMC

4.2.1 Assess feeding ecology of Arctic species and fill seasonal data gaps.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Several studies have investigated the feeding ecology of Arctic species and the transfer of energy through the Arctic food web. These include, for example, studies of the impacts of changes in the blubber content of ice seals on polar bear condition. Investigations of the role of changes in benthic prey in a grey whale unusual mortality event. Measurement of the fat content of zooplankton and fishes and implications for their predators. Research in this area will continue under the Arctic Systems Interactions priority area of the Arctic Research Plan 2022-2026.
Agencies: DOI-BOEM, DOI-USGS, NOAA, MMC, NSF

4.2.2 Determine basic life history information on age and growth rates of key links in the food web
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The Arctic Integrated Ecosystem Research Program (www.nprb.org/arctic-program) included temperature-controlled experiments to measure the respiration and growth rates of phytoplankton, microzooplankton, zooplankton, and benthic fauna. NSF provided funding for studies of Net Community Production and experiments of diatom growth rates under varying nutrient and light conditions. Research in this area will continue under the Arctic Systems Interactions priority area of the Arctic Research Plan 2022-2026.
Agencies: DOI-BOEM, NOAA, DOI-USGS, NSF

4.2.3 Assess the value of recent interdisciplinary programs and synthesis efforts to guide management decisions
Status: Complete
Summary Statement: Recent interdisciplinary programs have been completed (Arctic IERP, MARES, etc). A synthesis and editorial articles provide both an assessment and a synthesis of the value of several research initiatives across the Arctic. Their integration in these articles sheds light on the importance of pan-arctic perspectives to properly interpret and address regional issues. (Wassman et al., 2020)
Agencies: DOD-ONR, DOI-BOEM, USARC, DOI-FWS, MMC, NASA, NOAA

4.3.1 Continue Distributed Biological Observatory (DBO)25 sampling in regions 1-5 and make data publicly available
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: The DBO time series network is ongoing, with dedicated national programs as well as incorporation of sampling on the DBO via other projects. Both national and international

participants are involved in the DBO. Notably the DBO is expanding into Baffin Bay with Canadian leadership, the Atlantic DBO is a core developmental plan within the new EU Arctic PASSION project, and there are continued discussions to collaborate with Russian scientists in their waters on specific DBO-like lines.
Agencies: NOAA, NSF, DOI-BOEM, DOI-FWS, NASA

4.3.2 Continue DBO coordination activities including annual workshops, via participation in the Pacific Arctic Group (PAG)
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: We held the 5th DBO data meeting in 2020 and the workshop report is available at <https://dbo.cbl.umces.edu/>.
Agencies: NOAA, DOD-ONR, DOI-BOEM, NASA, NSF

4.3.3 Build connections between DBO and existing community-based observation programs and encourage data sharing.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions, Co-production of Knowledge and Indigenous-Led Research
Summary Statement: Community-based observer networks like the Alaska Arctic Observatory and Knowledge Hub, the Indigenous Sentinels Network, and the Local Environmental Observers Network provide opportunities to engage Alaska community members in scientific data collection. The Indigenous Sentinels Network recently received funding from NPRB to begin discussions about opportunities to expand the network into the Northern Bering Sea region. NSF funded the Research Networking Activity for Sustained Coordinated Observations of Arctic Change (CoObs RNA). Research in this area will continue under the Arctic Systems Interactions priority area and the Co-Production of Knowledge and Indigenous-Led Research foundational activity under the Arctic Research Plan 2022-2026.
Agencies: NOAA, NSF, DOI-BOEM

4.3.4 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Research in this area will continue under the Arctic Systems Interactions priority area of the Arctic Research Plan 2022-2026. The NPRB Arctic Integrated Ecosystem Research Program, Distributed Biological Observatory, Arctic Marine Biodiversity Observing Network, Chukchi

Ecosystem Observatory, and moored instruments maintained by NOAA and others all were important contributors to addressing this PE under the Arctic Research Plan 2017-2021.
Agencies: DOI-BOEM, NOAA, NSF, DOD-ONR, DOI-FWS, DOI-USGS, NASA, USARC

4.3.5 Implement the Regional Action Plan for Southeastern Bering Sea Climate Science, develop subarctic & Arctic plans
Status: Complete
Summary Statement: 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.
Agencies: NOAA

4.3.6 Conduct numerical simulations using coupled models to evaluate feedbacks across disciplines and systems.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Research in this area will continue under the Arctic Systems Interactions priority area of the Arctic Research Plan 2022-2026. During 2017-2021, four events were hosted that facilitated conversation among marine observational scientists and modelers to discuss opportunities for better integration and the potential use of observations to improve and validate models to improve predictive skill. A community of researchers is poised to address this issue and future funding opportunities including an upcoming Arctic synthesis funded by NPRB in 2022 will support the continuation of this important work.
Agencies: NOAA, NSF, DOD-ONR, DOI-BOEM

4.3.7 Continue development, testing, and runs of prognostic models that use Intergovernmental Panel on Climate Change (IPCC) scenario
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Research in this area will continue under the Arctic Systems Interactions priority area of the Arctic Research Plan 2022-2026. During 2017-2021, four events were hosted that facilitated conversation among marine observational scientists and modelers to discuss opportunities for better integration and the potential use of observations to improve and validate models to improve predictive skill. Several agencies are investing in this area. NOAA's Alaska Climate Integrated Modeling Project represents a comprehensive effort by NOAA Fisheries and partners to describe and project responses of the Bering Sea ecosystem – both the physical environment and human communities -- to varying climate conditions. The Department of Energy is also investing in models of marine biogeochemistry.
Agencies: NOAA, DOD-ONR, DOI-USGS, NSF

4.3.8 Monitor and describe temporal changes in anthropogenic and environmental sound in the Alaskan marine Arctic
Status: Continuing
Priority Areas and Foundational Activities: NA
Summary Statement: The MECT team supports discussions on temporal changes in anthropogenic and environmental sound in the Alaskan marine Arctic through the duration of the plan including discussions that will focus on designing acoustic monitoring initiatives to address applied scientific and community needs in October 2021.
Agencies: DOI-BOEM, NOAA, DOD-ONR

Glaciers & Sea-Level

5.1.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The GSLCT hosted and co-hosted several meetings that included updates on these major missions from cognizant Project Scientists and Science Team members. NASA's Operation IceBridge (OIB) airborne mission completed its final Alaska campaign in May 2021, following its final Arctic campaign in 2019 (MacGregor et al., 2021, doi:10.1029/2020RG000712). This last OIB campaign included surface elevation, snow thickness and ice thickness surveys using a laser altimeter, snow radar sounder and deep radar sounder, respectively. In April 2021, NASA Headquarters approved OIB to close out by the end of FY21, and nearly all OIB data products are archived at the National Snow and Ice Data Center. Since its launch in September 2018, ICESat-2 has generally performed nominally and collected high quality height measurements of terrestrial land ice. Evaluation of the repeat measurements over time indicate the satellite can point to within 10 m while the ability to collect a measurement of a single position on the surface is within the mission specification of ±45 m (Magruder et al., 2021, doi:10.1029/2020EA001555). ICESat-2 is anticipated to continue operating nominally throughout the course of the next ARP. The GRACE-FO satellites continue to track monthly mass changes to important cryosphere targets, providing insights into ice loss in Greenland, Antarctic and mountain glaciers (e.g., Velicogna et al., 2020, doi:10.1029/2020GL087291). Landsat-9 launched in September 2021 and join Landsat-8 in orbit. NISAR is on track for launch in 2023. Because several missions are ongoing or upcoming, this PE will continue and be integrated into Priority Area #2 of the 2022–2026 ARP (same for all GSLCT PEs).
Agencies: NASA, DOI-USGS

5.1.2 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, and the U.S. Geological Survey (USGS) Benchmark Glaciers Program and Ice2O Project in Alaska.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The GSLCT hosted and co-hosted several meetings that included updates on these major projects from cognizant Principal Investigators and Co-Investigators, along with meetings using data from these projects to inform process-level understanding of cryospheric change.The ICESat-2 project continues to collect monthly GPS-based measurements of a survey line adjacent to Summit, Greenland (Brunt et al., 2017, doi:10.5194/tc-11-681-2017). These monthly data have been collected since 2007 and are used to calibrate ICESat-2 elevations. In August and early September of 2020, NASA's Oceans Melting Greenland (OMG) completed its 5th yearly survey of the ocean, deploying

nearly 300 expendable temperature and salinity profilers to understand how ocean conditions are changing on Greenland's continental shelf, providing the most comprehensive survey of ocean conditions around the continental shelf to date (Wood et al., 2021, doi:10.1126/sciadv.aba7282). Also, OMG received permission to carry out a 6th and final year of the ocean survey in summer 2021 at no additional cost. This PE is partially complete, as the USGS Benchmark Glacier project will continue to monitor specific glaciers in the Pacific Northwest and Alaska.
Agencies: NASA, DOI-USGS, NOAA, NSF

5.1.3 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The GSLCT hosted and co-hosted several meetings that included updates on investigator-driven projects from cognizant Principal Investigators and Co-Investigators, e.g., a new NSF-funded study of the changes occurring at Malaspina Glacier, one of the most prominent coastal glaciers in Alaska. A variety of investigator-driven projects have either made use of mission data or collected their own datasets to improve interpretation of cryospheric change, e.g., the new NSF Malaspina Project mentioned above, another NSF-funded effort to understanding glacier surging at Turner Glacier, a NASA-funded studies of the connections between supraglacial and subglacial hydrology (Smith et al., 2021, doi:10.1029/2020GL091418; Greene et al., 2021, doi:10.5194/tc-14-4365-2020), MEaSUREs Greenland velocity mosaics, the importance of subglacial topography in controlling glacier retreat (e.g., Felikson et al., 2020, doi:10.1029/2020gl090112) and the ongoing reconfiguration of the Greenlandic coastline due to glacier changes (e.g., Moon et al., 2020, 10.1029/2020JF005585). Because this PE is not specific to a given mission with a finite lifetime, it will continue in the next ARP.
Agencies: NSF, DOI-USGS, NASA, NOAA

5.1.4 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Especially in 2020, with the onset of the COVID-19 pandemic, the GSLCT made a conscious effort to reach out to international domain experts and solicit presentations concerning ongoing Arctic cryospheric change. This process was begun in 2019 and persists as better connections are made with the international counterpart agencies. Several meetings including presentations from European experts in glacier change and Greenland studies, as well as other national organizations (i.e., the International Arctic Science Committee). Further effort was made to integrate the existing U.S. glaciology field schools (Juneau Icefields Research Program, McCarthy International Summer School

in Glaciology) into the research community and identify intersections for future collaboration. The communication and collaboration encouraged by this PE will persist into the next ARP across multiple domains.
Agencies: NSF, NASA

5.2.1 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 MPAS-Albany Land Ice model (MALI), the BISICLES ice sheet model, the Community Earth System Model (CESM), the Energy Exascale Earth System Model (E3SM), the Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6), and the Land Ice Verification and Validation (LIVV) Toolkit.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The GSLCT hosted several meetings concerning modeling of glaciers and the Greenland Ice Sheet. A major outcome of direct relevance to this PE is the projected mass loss for all of Earth's ice masses through 2100 (Edwards et al., 2021, doi:10.1038/s41586-021-03302-y). These projections include contributions from Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6), a major intercomparison effort and assessment of ice sheet models, including the Ice Sheet System Model (ISSM) and Parallel Ice Sheet Model (PISM) (Goelzer et al., 2020, doi:10.5194/tc-14-3071-2020). Carried forward to the end of this millennium, PISM projects that the whole of the Greenland Ice Sheet could be lost under a business-as-usual emissions scenario (Aschwanden et al., 2019, doi:10.1126/sciadv.aav9396). The importance of large-scale ice-sheet models has only increased during the performance period of this PE, and it will continue during the next ARP. As evidenced by one GSLCT meeting regarding ISSM's sea-level projection capabilities, these models are increasingly being integrated with other Earth system models to improve overall assessment of Arctic change.
Agencies: NASA, NSF, DOE

5.2.2 Develop data sets to be used as boundary and forcing functions for ice sheet, ice cap, and glacier models, including improving regional reanalysis 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: The GSLCT hosted several meetings on the fundamental development of boundary condition datasets for understanding and projecting cryospheric change. Of particular note are efforts to improve knowledge of bed topography NASA Operation IceBridge observations FOR Alaskan glaciers (Soso et al., 2021: doi:10.1016/j.geomorph.2021.107701) and the Greenland Ice Sheet via BedMachine v4 (Morlighem et al., 2021, doi:10.5067/VLJ5YXKCNGXO). NASA's Oceans Melting Greenland (OMG) mission improved understanding of ocean forcing of the Greenland Ice Sheet (Wood et al., 2021; doi:10.1126/sciadv.aba7282). Reanalyses such as the nascent PolarMERRA-2 project are

working to improve knowledge of surface mass balance. While knowledge of some boundary conditions has advanced dramatically over course of the performance period of this PE, substantial uncertainty remains and the need for this PE continues indefinitely.

Agencies: NASA, DOD-NRL, DOD-ONR, NOAA, NSF

Permafrost

Updated Language 6.1.1 Continue to conduct and coordinate monitoring and modeling of permafrost temperature and active layer dynamics across a wide range of terrain units and climatic zones
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health; Arctic System Interactions; Sustainable Economies and Livelihoods; Risk Management and Hazard Mitigation; Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; and Education
Summary Statement: The PCT has facilitated collaboration regarding monitoring and modeling of permafrost temperature and active layer dynamics across a wide range of terrain units and climatic zones through several of the monthly webinar meetings. Specifically, in 2021, Dr. Farquharson presented on observations of changing near-surface permafrost conditions through a spatially distributed network of ground temperature loggers in Alaska. The important role of measuring ground temperature as the pulse of permafrost regions was a key aspect of the joint PCT/Modeling teams meeting in the Spring of 2021. In former years, representatives of the CALM program provided a presentation on decadal-scale changes in active layer thickness across the circumpolar north and observations of permafrost hazards on infrastructure across northern eurasia. This PE addresses foundational activities related to Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; and Education that are critical components of the priority areas focused on Arctic System Interactions; Risk Management and Hazard Mitigation; Sustainable Economies and Livelihoods; and Community Resilience and Health.
Here are a few key references from our PCT community -
Biskaborn, B.K., Smith, S.L., Noetzli, J., Matthes, H., Vieira, G., Streletskiy, D.A., Schoeneich, P., Romanovsky, V.E., Lewkowicz, A.G., Abramov, A. and Allard, M., 2019. Permafrost is warming at a global scale. Nature communications, 10(1), pp.1-11.
Farquharson, L.M., Romanovsky, V.E., Cable, W.L., Walker, D.A., Kokelj, S.V. and Nicolsky, D., 2019. Climate change drives widespread and rapid thermokarst development in very cold permafrost in the Canadian High Arctic. Geophysical Research Letters, 46(12), pp.6681-6689.
Garnello, A., Marchenko, S., Nicolsky, D., Romanovsky, V., Ledman, J., Celis, G., Schädel, C., Luo, Y. and AG Schuur, E., 2021. Projecting permafrost thaw of sub-Arctic tundra with a thermodynamic model calibrated to site measurements. Journal of Geophysical Research: Biogeosciences, p.e2020JG006218.
Nicolsky, D.J. and Romanovsky, V.E., 2018. Modeling long-term permafrost degradation. Journal of Geophysical Research: Earth Surface, 123(8), pp.1756-1771.Mekonnen, Z.A., Riley, W.J., Grant, R.F. and Romanovsky, V.E., 2021. Changes in precipitation and air temperature contribute comparably to permafrost degradation in a warmer climate. Environmental Research Letters, 16(2), p.024008.
The PCT recommends continuing to conduct and coordinate work on monitoring and modeling of permafrost temperature and active layer dynamics across a wide range of terrain units and climatic zones. National and international ground temperature and active layer monitoring programs provide

critical information on the thermal state of permafrost and measurements on the depth from the surface to the permafrost table, respectively. Efforts focused on characterizing the ground thermal regime of permafrost and the annual and spatial variability in active layer thickness span several decades under the auspices of researchers from several countries. Extending efforts on these two permafrost-related essential climate variables is prudent and necessary.
Agencies: NSF, DOI-NPS, DOE, USDA-NRCS, NOAA, DOD-USACE

Updated Language 6.1.2 Integrate field, laboratory, and remote sensing to examine and quantify relationships among surface topography, vegetation composition, hydrology, disturbance effects (including fire, thermokarst, land use change, and wildlife), and geophysical processes in permafrost soils
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health; Arctic System Interactions; Sustainable Economies and Livelihoods; Risk Management and Hazard Mitigation; Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; and Education
Summary Statement: The PCT has facilitated collaboration regarding integration of field, laboratory, and remote sensing data to examine and quantify relationships among surface topography, vegetation composition, hydrology, disturbance effects (including fire, thermokarst, land use change, and wildlife), and geophysical processes in permafrost soils. Several past PCT sponsored IARPC presentations have focused on the nexus between various components of the permafrost-region system and the need to conduct interdisciplinary science through a suite of observation approaches. This PE addresses foundational activities related to Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; and Education that are critical components of the priority areas focused on Arctic System Interactions; Risk Management and Hazard Mitigation; Sustainable Economies and Livelihoods; and Community Resilience and Health.
PCT hosted several meetings involving upscaling of localized datasets, including Thermokarst and warming: data uncertainties with a focus on ground ice, T-MOSAiC presentation on data integration across the Arctic (PCT, TECT, ACT), and the NSF funded Permafrost Discovery Gateway. NASA ABoVE and DOE's NGEE-Arctic contributed toward this PE, including collection of airborne P and L-band SAR data along with surface observations to develop new remote sensing products for monitoring of permafrost characteristics. Numerous publications including,
Jones, B. M., C. D. Arp, M. S. Whitman, D. Nigro, I. Nitze, J. Beaver, A. Gadeke, C. Zuck, A. Liljedahl, R. Daanen, E. Torvinen, S. Fritz, G. Grosse. 2017. A lake cover classification to guide research and inform management decisions in an arctic watershed in northern Alaska experiencing climate and land-use change. Ambio. DOI:10.1007/s13280-017-0915-9
Olefeldt, D., S. Goswami, G. Grosse, D. Hayes, G. Hugelius, P. Kuhry, A.D. McGuire, V.E. Romanovsky, A.B.K. Sannel, E.A.G. Schuur, and M.R. Turetsky. 2016. Circumpolar distribution and carbon storage of thermokarst landscapes. Nature Communications 7:13043, 11 pages, doi:10.1038/ncomms13043.

Boike J, Nitzbon J, Anders K, Grigoriev M, Bolshiyanov D, Langer M, Lange S, Bornemann N, Morgenstern A, Schreiber P, Wille C, Chadburn S, Gouttevin I, Burke E and Kutzbach L 2019 A 16-year record (2002–2017) of permafrost, active-layer, and meteorological conditions at the Samoylov Island Arctic permafrost research site, Lena River delta, northern Siberia: an opportunity to validate remote-sensing data and land surface, snow, and permafrost models Earth System Science Data 11 261–99. https://doi.org/10.5194/essd-11-261-2019, 2019

Nitzbon J, Langer M, Westermann S, Martin L, Aas KS and Boike J 2019 Pathways of ice-wedge degradation in polygonal tundra under different hydrological conditions The Cryosphere 13 1089–123. https://doi.org/10.5194/tc-13-1089-2019, 2019

Nitze, I., Grosse, G., Jones, B.M., Romanovsky, V.E. and Boike, J., 2018. Remote sensing quantifies widespread abundance of permafrost region disturbances across the Arctic and Subarctic. Nature communications, 9(1), p.5423.

 Jones, B.M., Farquharson, L.M., Baughman, C.A., Buzard, R.M., Arp, C.D., Grosse, G., Bull, D.L., Günther, F., Nitze, I., Urban, F. and Kasper, J.L., 2018. A decade of remotely sensed observations highlight complex processes linked to coastal permafrost bluff erosion in the Arctic. Environmental Research Letters, 13(11), p.115001.

Pastick, N.J., Jorgenson, M.T., Goetz, S.J., Jones, B.M., Wylie, B.K., Minsley, B.J., Genet, H., Knight, J.F., Swanson, D.K. and Jorgenson, J.C., 2019. Spatiotemporal remote sensing of ecosystem change and causation across Alaska. Global change biology, 25(3), pp.1171-1189.

Lara, M.J., Chipman, M.L. and Hu, F.S., 2019. Automated detection of thermoerosion in permafrost ecosystems using temporally dense Landsat image stacks. Remote sensing of environment, 221, pp.462-473.

Wang, K., Jafarov, E., Schaefer, K., Romanovsky, V., Cable, W., Clow, G., Urban, F., Piper, M., Schwalm, C., Zhang, T. and Overeem, I., 2018. Analysis of near-surface permafrost monitoring station data from Alaska. Earth System Science Data, 10(LA-UR-17-23049).

Wang, K., Jafarov, E., Overeem, I., Romanovsky, V., Schaefer, K., Clow, G., Urban, F., Cable, W., Piper, M., Schwalm, C. and Zhang, T., 2018. A synthesis dataset of permafrost-affected soil thermal conditions for Alaska, USA. Earth System Science Data, 10(4), pp.2311-2328.

The PCT recommends a continued focus on integrating field, laboratory, and remote sensing to examine and quantify relationships among surface topography, vegetation composition, hydrology, disturbance effects (including fire, thermokarst, land use change, and wildlife), and geophysical processes in permafrost soils. Integrating field observations with laboratory studies provides essential information for scaling up often spatial limited findings to landscape-scales using remote sensing imagery and data that has formed the foundation of several successful ongoing field campaigns and research programs.

Agencies: NSF, DOE, DOI-NPS, DOI-USGS, NASA

6.1.3 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.

Status: Complete
Summary Statement: The PCT is marking this PE as complete and closing it out. While the PCT never organized any calls specifically related to 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, several aspects of this work were touched on during other PCT meetings. Aspects of this PE will continue on under 6.1.1 and 6.1.2 during the next 5-yr IARPC plan.
Agencies: NSF, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NASA

6.1.4 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.
Status: Complete
Summary Statement: The PCT is marking this PE as complete and closing it out. Aspects of this work will continue on under the revised PE 6.1.2. The theme of this PE was rather redundant to 6.1.2 and we simply modified language under 6.1.2 to include aspects of this PE. Please see 6.1.2 for a summary statement. Aspects of this PE will continue on under 6.1.1 and 6.1.2 during the next 5-yr IARPC plan.
Agencies: NSF, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NASA, DOD-USACE

6.1.5 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.
Status: Complete
Summary Statement: The PCT has fostered efforts that 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. The PCT hosted two webinars on the need and possible approaches for updating ground ice content maps. The team also hosted a side meeting with international collaborators to discuss a survey for dissemination to the international community that would serve as a synthesis document for future ground ice database development. This PE addresses foundational activities related to Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; and Education that are critical components of the priority areas focused on Arctic System Interactions; Risk Management and Hazard Mitigation; Sustainable Economies and Livelihoods; and Community Resilience and Health.
Here are a few key recent publications focused on this PE:
Saito, K., Machiya, H., Iwahana, G., Ohno, H. and Yokohata, T., 2020. Mapping simulated circum-Arctic organic carbon, ground ice, and vulnerability of ice-rich permafrost to degradation. Progress in Earth and Planetary Science, 7(1), pp.1-15.
O'Neill, H.B., Wolfe, S.A. and Duchesne, C., 2019. New ground ice maps for Canada using a paleogeographic modelling approach. The Cryosphere, 13(3), pp.753-773.

Nitzbon, J., Westermann, S., Langer, M., Martin, L.C., Strauss, J., Laboor, S. and Boike, J., 2020. Fast response of cold ice-rich permafrost in northeast Siberia to a warming climate. Nature communications, 11(1), pp.1-11.

Zwieback, S. and Meyer, F.J., 2021. Top-of-permafrost ground ice indicated by remotely sensed late-season subsidence. The Cryosphere, 15(4), pp.2041-2055.

Cai, L., Lee, H., Aas, K.S. and Westermann, S., 2020. Projecting circum-Arctic excess-ground-ice melt with a sub-grid representation in the Community Land Model. The Cryosphere, 14(12), pp.4611-4626.

Karjalainen, O., Luoto, M., Aalto, J., Etzelmüller, B., Grosse, G., Jones, B.M., Lilleøren, K.S. and Hjort, J., 2020. High potential for loss of permafrost landforms in a changing climate. Environmental Research Letters, 15(10), p.104065.

Rettelbach, T., M. Langer, I. Nitze, B.M. Jones, V. Helm, J.C. Freytag, and G. Grosse. 2021. A quantitative graph-based approach to monitoring ice-wedge trough dynamics in polygonal permafrost landscapes. Remote Sensing 13, 3098. https://doi.org/10.3390/rs13163098

Bergstedt, H., B.M. Jones, K.M. Hinkel, L. Farquharson, B.V. Gaglioti, A.D. Parsekian, M.Z. Kanevskiy, N. Ohara, A.L. Breen, R.C. Rangel, G. Grosse, and I. Nitze. 2021. Remote sensing-based statistical approach for defining drained lake
basins in a continuous permafrost region, North Slope of Alaska. Remote Sensing 13 (13), 2539. https://doi.org/10.3390/rs13132539

Shur, Y., Jones, B.M., Kanevskiy, M., Jorgenson, M.T., Ward Jones, M.K., Fortier, D., Stephani, E., and Vasiliev, A. 2021. Fluvio-thermal erosion and thermal denudation in the yedoma region of northern Alaska, revisiting the Itkillik River exposure. Permafrost and Periglacial Processes. https://doi.org/10.1002/ppp.2105

Jones, B.M., K.D. Tape, J.A. Clark., I. Nitze, G. Grosse, and J. Disbrow. 2020. Increase in beaver dams controls surface water and thermokarst dynamics in an Arctic tundra region, Baldwin Peninsula, northwestern Alaska. Environmental Research Letters 15 075005. https://doi.org/10.1088/1748-9326/ab80f1

Witharana, C., Bhuiyan, M.A.E., Liljedahl, A., Kanevskiy, M., Jorgenson, M.T., Jones, B.M., Daanen, R., Epstein, H., Griffin, C.G., Kent, K., and Jones, M.K.W. 2021. An object-based approach for mapping tundra ice wedge polygon troughs from very high spatial resolution optical satellite imagery. Remote Sensing 13, 558. https://doi.org/10.3390/rs13040558

PCT continues to progress toward a new ground ice product by soliciting ground ice data, holding joint monthly meetings with the Data Team (October, 2021) to best manage and create a working database that is most useful for end users. This specific PE will be closed out and integrated with PE 6.3.2.
Agencies: NSF, DOD-USACE, DOE, DOI-NPS, NASA

Updated Language 6.2.1 Support field-based research and monitoring focused on quantifying the key processes controlling soil carbon cycling at northern high latitudes and potential carbon release to the atmosphere, including temperature, hydrological effects, and modes of abrupt permafrost thaw.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions

Summary Statement: The role of permafrost thaw in the global carbon cycle and feedbacks to climate continues to be a major topic of concern and research.Field research and synthesis on estimating, refining and reducing uncertainty of permafrost carbon stocks led to multiple publications focused on deep carbon stocks in Yedoma (Strauss et al. 2017 https://www.sciencedirect.com/science/article/pii/S0012825217300508?via%3Dihub), carbon stocks in river deltas (Fuchs et al. 2018,https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JG004591), carbon and nitrogen stocks in peatland and their vulnerabilities to permafrost thaw (Hugelius et al. 2020, https://doi.org/10.1073/pnas.1916387117), and a new approach to estimate spatial heterogeneity of carbon stocks in permafrost (Mishra et al. 2021, https://www.science.org/doi/10.1126/sciadv.aaz5236). Abrupt permafrost thaw and potential carbon emissions have been identified as a major gap in current carbon emissions from permafrost. Turetsky et al. 2019 https://www.nature.com/articles/d41586-019-01313-4 and 2020 https://www.nature.com/articles/s41561-019-0526-0 brought the topic to the forefront of future emissions calculations. In conjunction with the Permafrost Carbon Network, the PCT will continue to pursue this topic, including a potential workshop hosted by the NAS, advancing topics on data-model integration, expanding spatial datasets. Future work on this topic will be part of the priority area 'Arctic Systems Interactions' in the new plan. The Permafrost Carbon Network will continue with permafrost carbon related research beyond this IARPC plan
Agencies: NSF, DOE, DOI-USGS, NASA-ABOVE

Updated Language 6.2.2 Support research to improve scaling methods for estimating CO2 and CH4 emissions from the permafrost region to link multi-agency investments in soil carbon research that culminates in synthesis publications.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Winter carbon emissions from permafrost have long been an unknown factor and a recent synthesis provided a new baseline for winter CO2 emissions from northern terrestrial regions which indicates that enhanced soil CO2 loss due to winter warming may offset growing season carbon uptake under future climatic conditions (Natali et al. 2019 https://www.nature.com/articles/s41558-019-0592-8).
Numerous publications have provided new data to narrow down estimates of greenhouse gas emissions from permafrost, yet, the main question whether the permafrost zone is a source or sink of carbon remains:
https://eos.org/science-updates/is-the-northern-permafrost-zone-a-source-or-a-sink-for-carbon.
Model simulations of future carbon emissions show diverging results but also showed that controlling greenhouse gas emissions in the coming decades could substantially reduce the consequences of carbon release from thawing permafrost during the next 300 years (McGuire et al. 2018 https://www.pnas.org/content/115/15/3882). Multiple PCT webinars focused on improving permafrost

carbon modeling and including the permafrost carbon feedback in Earth System Models. Major progress is anticipated in the next years due to newly funded projects from NSF, NASA, and DOE. Multiple reports geared to a broader audience have summarized current knowledge of permafrost carbon stocks and emissions: Second State of the Carbon Cycle Report 2018 https://www.carboncyclescience.us/state-carbon-cycle-report-soccr (Chapter 11: Arctic and Boreal Carbon), the policy brief on 'Climate Change and the Permafrost Carbon Feedback https://www.searcharcticscience.org/arctic-answers/permafrost/briefs, IPCC Special Report on the Changing Cryosphere 2019 (Chapter 3: Polar Regions https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/07_SROCC_Ch03_FINAL.pdf). AMAP 2021 https://www.amap.no/documents/doc/arctic-climate-change-update-2021-key-trends-and-impacts.-summary-for-policy-makers/3508
NSF and ABoVE funded research continues to measure and project greenhouse gas emissions due to permafrost degradation. The Permafrost Carbon Network plays a central role in coordinating many of these efforts and bringing scientists together at annual meetings and through coordinated collaborations.
Future work on this topic will be part of the priority area 'Arctic Systems Interactions' in the new plan. The Permafrost Carbon Network will continue with permafrost carbon related research beyond this IARPC plan"
Agencies: NSF, DOE, DOI-USGS, NASA-ABOVE

6.2.3 Utilize empirical, multi-scale approaches to make spatially-explicit estimates of vulnerability of permafrost carbon and release of both CO_2 and CH_4.
Status: Complete
Summary Statement: see summary statements in 6.2.1 and 6.2.2
Agencies: NSF, DOE, DOI-USGS, NASA-ABOVE

6.2.4 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.
Status: Complete
Summary Statement: see summary statement in 6.2.1
Agencies: NSF, DOE, DOI-USGS, NASA-ABOVE

Updated Language 6.2.5 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions

Summary Statement: Subsea permafrost remains an understudied, yet potentially important feedback to global climate. Research is limited by logistical challenges and funding to study subsea permafrost. Two comprehensive studies on the topic have come out in recent years: an expert assessment study by Sayedi et al., 2020 ERL https://iopscience.iop.org/article/10.1088/1748-9326/abcc29 with an associated news article https://ioppublishing.org/news/a-groggy-climate-giant/ and a synthesis on the topic by Ruppel and Kessler, 2017 Review of Geophysics https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2016RG000534. PCT has also hosted a webinar on the Sayedi et al study and plans to continue engaging with researchers who continue to make progress on better understanding the extent and role of subsea permafrost in global climate change. Future work on this topic will be part of the priority area 'Arctic Systems Interactions' in the new plan. The PCT plans on continuing to engage with researchers who make progress on better understanding the extent and role of subsea permafrost in global climate change. In particular, there will be a focus on communication of subsea permafrost carbon stocks and how it is impacted by warming temperatures.
Agencies: NSF, DOE, DOI-USGS, NASA-ABOVE

Updated Language 6.3.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Several large-scale efforts (NASA ABoVE, T-MOSAiC, AON) have involved hundreds of scientists who have produced empirical data of terrestrial processes that influence permafrost. PCT facilitated a meeting with the leads of the T-MOSAiC in November 2018. Future work on this topic will be part of the priority area 'Arctic Systems Interactions' in the new plan. Key products include:Schädel C, Koven CD, Lawrence DM, Celis G, Garnello AJ, Hutchings J, Mauritz M, Natali SM, Pegoraro E, Rodenhizer H, Salmon VG, Taylor MA, Webb EE, Wieder WR and Schuur EAG 2018 Divergent patterns of experimental and model-derived permafrost ecosystem carbon dynamics in response to Arctic warming Environ. Res. Lett. 13 105002. https://doi.org/10.1088/1748-9326/aae0ff Kou, D., Ding, J., Li, F., Wei, N., Fang, K., Yang, G., Zhang, B., Liu, L., Qin, S., Chen, Y. and Xia, J., 2019. Spatially-explicit estimate of soil nitrogen stock and its implication for land model across Tibetan alpine permafrost region. Science of the Total Environment, 650, pp.1795-1804
Pierce, G.T., 2019. Laboratory Study and Predictive Models for Thaw Subsidence in Deep Permafrost (Doctoral dissertation, University of Alaska Anchorage).
Nicolsky, D.J. and Romanovsky, V.E., 2018. Modeling long-term permafrost degradation. Journal of Geophysical Research: Earth Surface, 123(8), pp.1756-1771.
Ebel, B.A., Koch, J.C. and Walvoord, M.A., 2019. Soil Physical, Hydraulic, and Thermal Properties in Interior Alaska, USA: Implications for Hydrologic Response to Thawing Permafrost Conditions. Water Resources Research, 55(5), pp.4427-4447.

Clow, G.D., 2018. CVPM 1.1: a flexible heat-transfer modeling system for permafrost. Geoscientific Model Development, 11(12), pp.4889-4908.

The PCT continues to engage with researchers integrating empirical datasets with models. Several ongoing projects through NASA, DOE, and NSF are ongoing.

Agencies: NSF, DOE, NASA

Updated Language 6.3.2 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 and the circum-Arctic.

Status: Complete

Summary Statement: The PCT is marking this PE as complete and closing it out. Aspects of this work will continue on under the revised PE 6.1.2. The theme of this PE was rather redundant to 6.1.2 and we simply modified language under 6.1.2 to include aspects of this PE. Please see 6.1.2 for a summary statement

Agencies: NSF, DOE, NASA, DOI-BLM, DOI-NPS

6.3.3 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.

Status: Complete

Summary Statement: The PCT is marking this PE as complete and closing it out. Aspects of this work will continue on under the revised PE 6.1.2. The theme of this PE was rather redundant to 6.1.2 and we simply modified language under 6.1.2 to include aspects of this PE. Please see 6.1.2 for a summary statement

Agencies: NSF, NASA

6.3.4 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.

Status: Complete

Summary Statement: see summary statement 6.3.1

Agencies: NSF, NASA, DOE

6.4.1 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.

Status: Incomplete but closed

Summary Statement: The PCT never fully addressed this PE. The PE was largely based on facilitation of surveys between federal research agencies and non-federal partners and stakeholders and indiginous communities. Valuable research was conducted in this regard instead. We have decided to close out this PE and are in favor of the moving forward with the two new 6.4 PE's listed below.
Agencies: Denali, DOD-USACE, DOD-OSD, EPA, DOI-BIA, HHS

6.4.2 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.
Status: Incomplete but closed
Summary Statement: The PCT never fully addressed this PE. The PE was largely based on facilitation of surveys between federal research agencies and non-federal partners and stakeholders and indiginous communities. Valuable research was conducted in this regard instead. We have decided to close out this PE and are in favor of the moving forward with the two new 6.4 PE's listed below.
Agencies: Denali, DOD-USACE, DOD-OSD, EPA, DOI-BIA, HHS

NEW PE 6.4.1 Coordinate information exchange between scientists and engineers focused on the impact of infrastructure and climate on permafrost, including their interaction on the thawing of permafrost
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health; Arctic System Interactions; Sustainable Economies and Livelihoods; Risk Management and Hazard Mitigation; Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; and Education
Summary Statement: The PCT recommends establishing this convergent PE to faciliate scientific discovery among scientists, engineers, and indigenous knowledge systems focused on the impact of infrastructure and climate on permafrost. About five million people live in the Northern Hemisphere's permafrost region (Ramage et al. 2021). Of the more than 1,100 human settlements occurring on permafrost, 42% are projected to be affected by complete thaw of permafrost by 2050 (Ramage et al. 2021). Further, nearly 70% of northern infrastructure is located in regions with a high potential for thaw of near-surface permafrost by 2050, with one-third being located in permafrost-regions with a high hazard potential due to ice-rich permafrost (Hjort et al. 2018). Thawing of near-surface permafrost is projected as the second largest climate change related hazard that Alaska will face during the 21st Century (Melvin et al. 2016) with over 50 communities estimated to experience moderate to high threat of damage (Denali Commission Report 2019).
This PE addresses foundational activities related to Monitoring, Observing, Modeling, and Prediction; Data Management; Technology Application and Innovation; Education; Co-Production of Knowledge and Indigenous-Led Research that are critical components of the priority areas focused on Arctic

System Interactions; Risk Management and Hazard Mitigation; Sustainable Economies and Livelihoods; and Community Resilience and Health."

NEW PE 6.4.2 Promote the formation of interdisciplinary research teams and increased collaboration across knowledge systems, such as Western science and Indigenous knowledge, with a focus on hazards to infrastructure and human health
Status: Continuing
Priority Areas and Foundational Activities: Co-production of knowledge and Indigenous-led research
Summary Statement: The PCT was strongly involved in planning and attending the Arctic Futures 2050 Conference https://www.searcharcticscience.org/arctic-2050/conference-2019 put together by the Study of Environmental Arctic Change. The meeting prioritized collaboration and interaction with scientists, indigeneous knowledge-bearers, policy makers, and the media to discuss the current state of the Arctic and its future. The event fostered interdisciplinary collaboration and raised awareness of different viewpoints and solutions to Arctic environmental change. Permafrost issues were discussed from local (e.g. infrastructure, ecosystem services) to global impacts (permafrost carbon feedback). Interdisciplinary collaboration and co-production of science, indigenous knowledge, and decision experts will continue with a newly funded NSF award to the Study of Environmental Arctic Change. This continued work will support the foundational activity of Co-production of knowledge and Indigenous-led research as outlined in the new plan.

Terrestrial Ecosystems

7.1.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: To date significant progress to date has been made under several large efforts including NASA ABoVE, USGS Changing Arctic Ecosystems, and USGS Integrated Ecosystem Model for Alaska and Western Canada. Some of these activities will continue going forward, all of which fit well into the Arctic Systems Interactions Priority area in the next Arctic Research Plan.
Agencies: DOI-FWS, DOI-USGS, NSF, DOE, DOI-BLM, DOI-NPS, NASA, USDA-NRCS, USDA-USFS

7.1.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Progress by USGS, NASA, and NSF-funded research on nature, detection, and climate attribution of agents of landscape change, and some progress integrating these into conceptual frameworks of Arctic and Boreal system trajectories. Integrated modeling has largely focused on consequences for Carbon flux at plot-to-regional scales and on consequences for global climate at regional-to-pan-arctic scales. Synthesis and Integrated modeling of multiple disturbances and resulting landscape changes, especially with regard to consequences for resources and other human dimensions, still developing. As such, this task is not complete and should continue; this work fits well under the Arctic Systems Interactions priority area in the new plan
Agencies: DOI-BLM, NASA, NSF, DOD-USACE, DOE, DOI-FWS, DOI-NPS, DOI-USGS, USDA-USFS

7.1.3 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: IARPC has supported several meetings on this topic, bringing together experts from a variety of agencies to discuss various aspects of using remotely sensed datasets to monitor ecosystem properties. NASA ABoVE activities related to this PE are ongoing across Alaska and Western Canada. Several studies on this topic have been published and presented. ABoVE related work on this topic will continue until the project completion of the ABoVE campaign in the mid 2020s. Such work will fit in well under the Arctic Systems Interactions priority area in the new plan and can indirectly support the other three priority areas.

Agencies: NASA, DOE, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS

7.1.4 Improve existing and develop advanced models for integrating climate, disturbance, above- and below-ground dynamics and interactions and feedbacks to characterize and predict Arctic landscape and ecosystem change.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Assessment of progress to date under several large efforts including NASA ABoVE, USGS Integrated Ecosystem Model for Alaska and Western Canada, and NSF-funded work. Understanding of changes in dynamic vegetation and permafrost contributions to fire disturbance especially is rapidly evolving. Going forward, this will continue and fits nicely within the Arctic Systems Interactions Priority Area.
Agencies: DOE, NSF, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NASA

7.2.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Lots of progress has been made in this area and has included in terms of publications and public presentations, many coordinated through IARPC. ABoVE is continuing until at least the mid 2020s and thus this work will continue and fits well into the Arctic Systems Interactions Priority Area in the next Arctic Research Plan.
Agencies: DOI-FWS, DOI-USGS, DOI-BLM, DOI-NPS, NASA

7.2.2 Compare trends in aquatic and terrestrial animal populations and movements with changing patterns of vegetation cover, lake, pond, and wetland extent and characteristics to determine whether and how shifting habitats are influencing animal behaviors and population dynamics.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Efforts by the State of Alaska, US Fish and Wildlife Service, and USGS to track population dynamics and species movement continue, while efforts such as NASA ABoVE and the USGS Integrated Ecosystem Model for Alaska and Western Canada have made great strides in understanding and predicting habitat change over time. However, efforts that directly connect understanding of populations to habitat change remain limited. Going forward, we suggest an assessment of barriers and/or opportunities for making these connections. This work aligns well with the Arctic Systems Interactions Priority Area in the next Arctic Research Plan
Agencies: DOI-FWS, DOI-BLM, DOI-NPS, DOI-USGS, NASA, NSF

7.2.3 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 well-being of northern residents.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions, Sustainable Economies and Livelihoods
Summary Statement: Progress by BIA- and USGS-funded work on synthesizing Indigenous observations along with "western" science impacts and projections to build collaborative knowledge has been included in community adaptation planning efforts, and USGS has contributed to other efforts (e.g., Alaska Native Tribal Health Consortium) to do similar work. Going forward this work falls under Priority Areas 2 and 3 of the next Arctic Research Plan and we fully expect this work to continue, though likely with an even greater emphasis on knowledge co-production.
Agencies: DOI-FWS, DOI-BIA, DOI-BLM, DOI-NPS, DOI-USGS, NASA

7.3.1 Evaluate how changing fire regimes have and are likely to impact northern communities, via impacts to infrastructure, health, and subsistence opportunities.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Considerable progress by NASA ABoVE, USGS Integrated Ecosystem Model for Alaska and Western Canada, and NSF-funded efforts to understand landscape-level changes in fire regimes in boreal forest and tundra as well as NASA, NASA ABoVE, USGS, and EPA efforts to understand impacts on earth system via atmosphere and human health in the Arctic. Collectively, these efforts are illustrated in regional case studies (e.g., NCA 4 Alaska chapter) and have supported a dialogue about next steps. These could include more direct work on effects in rural and Alaska Native communities such as impacts on respiratory health and food security. Such work will fit in well under the Arctic Systems Interactions priority area in the new plan.
Agencies: DOI-BLM, DOI-BIA, DOI-FWS, DOI-NPS, DOI-USGS, NASA, NSF, USDA-USFS

7.3.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Led by federal agencies (DOI bureaus and U.S. Forest Service) and the state of Alaska, generation of wildfire statistics and mapping are well coordinated, and related information is widely available online. TECT will continue its support of modeling efforts to estimate emissions from fires, particularly in boreal forest regions. Additional steps should include an assessment of future research needs, with potential topics including: better characterization of wildfire impacts in peatlands; fire-vegetation-snow interactions; and wildfires in tundra systems. This will directly fit into the Arctic Systems Interactions Priority Area, and is indirectly related to Priority Area 1.

Agencies: NASA, DOI-BLM, DOI-FWS, DOI-NPS, DOI-USGS, NSF, USDA-USFS

Coastal Resilience

8.1.1 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.
Status: Continuing
Priority Areas and Foundational Activities: Co-production of Knowledge and Indigenous-led Research
Summary Statement: Through the diverse leadership and member composition, the CRCT actively sought out perspectives and efforts of coastal community members in research and cooperative opportunities with others. The team hosted a presentation on "Understanding the Arctic through a co-production of knowledge perspective" and held discussions that focused on "Exploring research that uses a co-production of knowledge process." The NSF awarded several proposals that involved collaboration among researchers and Tribal entities to build synergy between scientists, local stakeholders, and community residents. The CRCT posted numerous updates and actions to the IARPC website under this performance element on the efforts of federal agencies to learn from, engage, collaborate, and coordinate with coastal community members through regular co-management council meetings, and research documenting IK, such as on polar bears in northern Alaska, northern marine ecosystem resource management, and berry harvest. Many conversations were also sponsored by the CRCT on how to best encourage and strengthen these conversations and collaborations.
This activity will continue in the Arctic Research Plan 2022-2026 under the Participatory Research and Indigenous Leadership in Research Foundational Activity.
Agencies: DOI-BLM, DOI-BOEM, DOI-FWS, EPA, NOAA, NSF, DHS, DOI-NPS, DOI-USGS

8.1.2 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.
Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions
Summary Statement: The CRCT hosted several conversations and updates on the successes of Tribal and collaborative efforts on the topic of supporting community-based monitoring. These conversations includes updates on how communities and agencies are working together to monitor changes in weather, water quality, permafrost, and salmon through programs such as the Indigenous Observation Network, the LEO network, several NSF awarded projects that support community observations, and discussing ways to make these efforts findable by others such as through social media, apps, or mapping of projects on a web site.

This activity will continue in the Arctic Research Plan 2022-2026 under the Community Resilience and Health and Arctic Systems Interactions Priority Areas.
Agencies: DOI-BOEM, DOI-FWS, NOAA, NSF

8.1.3 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.
Status: Incomplete and closed
Summary Statement: The CRCT posted updates relevant to this performance element on the IARPC web site and discussed better ways to share and be aware of information related to economic development research. The NSF shared information on awarded proposals regarding socio-economic development in coastal communities.
This performance element has been completed under the scope of the Arctic Research Plan 2017-2021.
Agencies: DOC-EDA, NSF

8.1.4 Investigate and protect cultural resources through research to identify and document archaeological sites in high-risk, rapidly eroding Arctic coastal areas.
Status: Complete
Summary Statement: The CRCT held discussions with community-based researchers and federal agency representatives on efforts to identify and document archeological sites at risk to coastal change. Additionally, the NSF awarded several proposals that addressed submerged human habitation sites, archeological research, and the rescue of vulnerable sites at risk from coastal erosion. Publications detailing coastal change were highlighted, such as regions in western Alaska (https://doi.org/10.1016/j.margeo.2018.07.007) and a summary of how future strategies can connect researchers and the public on archeological archives (https://doi.org/10.15184/aqy.2018.8). This activity may continue in the Arctic Research Plan 2022-2026 under the Sustainable Economies and Livelihoods Priority Area.
Agencies: DOI-BLM, DOI-NPS, NSF

8.1.5 Advance the understanding of storm surge and saline inundation impacts on infrastructure and human safety. Multi Agency partners include the Alaska Department of Geological and Geophysical Surveys and the ACCER.
Status: Complete
Summary Statement: The CRCT gathered and posted information regarding efforts to document and forecast changes in storm surges across coastal Alaska. This included an instructional booklet (https://doi.org/10.14509/30182) and new elevation indices of flood-vulnerable coastal communities (https://doi.org/10.14509/30160) by the Alaska Division of Geological and Geophysical Survey for Alaska residents to implement three community-based shoreline monitoring systems for documenting erosion-prone coastal areas. Updates on this performance element also highlighted recent

publications by the USGS on changing coastlines in northern and northwestern Alaska and new photo and video monitoring stations based in communities to document future change.

This activity may continue in the Arctic Research Plan 2022-2026 under the Sustainable Economies and Livelihoods and Risk Management and Hazard Mitigation Priority Areas.

Agencies: NOAA, DOD-USACE

8.2.1 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.

Status: Continuing

Priority Areas and Foundational Activities: Arctic System Interactions, Sustainable Economies and Livelihoods

Summary Statement: The CRCT shared numerous updates on this performance element. This is an area of very active research and monitoring by federal agencies and coastal community residents. The concept of trends and feed-back loops and how to best coordinate observations and research on these topics became even more important as warmer ocean temperatures in the northern Gulf of Alaska and Bering Sea caused major shifts in marine ecosystem components. These changes led to joint IARPC team conversations (https://www.iarpccollaborations.org/members/events/15941) on ways to best coordinate observations, sampling, response, and the sharing of results among research and coastal community members. Agencies such as USGS, USFWS, and the Marine Mammal Commission plus efforts from broad collaborative efforts of the Circumpolar Biodiversity Monitoring Program provided numerous research updates on topics related to wildlife, habitats, and northern ecosystems.

This activity will continue in the Arctic Research Plan 2022-2026 under the Arctic Systems Interactions and Sustainable Economies and Livelihoods Priority Areas.

DOI-BOEM, DOI-USGS, NOAA, DOI-BLM, DOI-FWS, DOI-NPS, MMC

8.2.2 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.

Status: Complete

Summary Statement: The online Coastal Biodiversity Risk Analysis Tool (CBRAT) was explored by EPA with spreadsheets listing near-shore species abundance and natural history traits in the three Arctic ecoregions; Beaufort Sea - continental coast and shelf, Chukchi Sea and the Eastern Bering Sea. Risk assessment analysis was completed for a subset of taxa, Bivalves, crab and rockfish that project risk levels (high, moderate, low or no) to future sea level rise, temperature and ocean acidification scenarios for all species living in these three ecoregions.

This activity may continue in the Arctic Research Plan 2022-2026 under the Arctic Systems Interactions and Sustainable Economies and Livelihoods Priority Areas.

Agencies: EPA

8.2.3 Continue to develop a general Arctic-wide wildlife response model that relates to species-specific models of Arctic coastal organisms.
Status: Complete
Summary Statement: The USGS developed Bayesian network models to understand all possible factors that contribute to the future persistence of polar bear and walrus populations in the Alaska arctic region. These formed the basis for a conceptual Arctic-wide wildlife response and forecasting model by USGS (https://doi.org/10.1093/biosci/biv069). Over the past 5 years, the USGS and collaborators have added significant understanding to smaller factors that may influence these species, such as impacts of recreational tourism on polar bears, how seals and sea ice influence polar bear body condition and diet hauling out on land vs on sea ice for walrus energetics.
This activity may continue in the Arctic Research Plan 2022-2026 under the Arctic Systems Interactions and Sustainable Economies and Livelihoods Priority Areas.
Agencies: DOI-USGS

8.2.4 Understand and monitor processes to manage and mitigate potential and realized threats from coastal invasive species, biotoxicoses, 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.
Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions, Risk Management and Hazard Mitigation
Summary Statement: The CRCT posted numerous highlights on collaborative efforts of coastal community observers and researchers to document and understand mortalities of wildlife in marine and coastal areas of Alaska over the past few years. Most significantly was the numerous dieoffs of seabirds, fish, and some marine mammals (i.e., whales) and the co-occurence of harmful algal toxins in the northern Gulf of Alaska and Bering and Chukchi seas. Federal agencies also continued baseline investigations into the prevalence of zoonotic disease in Artic wildlife, such as avian influenza (https://doi.org/10.1637/0005-2086-64.2.109 and (https://doi.org/10.7589/2018-05-128), pathogens in brown bears (https://doi.org/10.7589/2018-07-173), and parasites in mosquito vectors (https://doi.org/10.1111/jvec.12330). Importantly, multiple agencies and Indigenous entities came together in March of 2019 for the first ever One Health Zoonotic Disease Prioritization Workshop to be held in an arctic region. This CDC-led effort resulted in a comprehensive report and strategy for stakeholders to jointly address zoonotic diseases in a One Health framework (https://www.cdc.gov/onehealth/pdfs/Alaska-508.pdf).
This activity will continue in the Arctic Research Plan 2022-2026 under the Arctic Systems Interactions and Risk Management and Hazard Mitigation Priority Areas.
Agencies: HHS, NOAA, DOI-BOEM, DOI-FWS, DOI-USGS, MMC

8.2.5 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.
Status: Continuing
Priority Areas and Foundational Activities: Sustainable Economies and Livelihoods
Summary Statement: The CRCT highlighted numerous examples of how other collaboration teams, agencies, and co-management councils are focused on research that provides useful information on shifts in abundance and distribution of subsistence resources for local governments and federal agencies. Updates includes documenting current and future responses of wildlife (migratory birds, walrus, caribou, and polar bears) to environmental conditions and human related activities. Multiple IARPC teams discussed sharing environmental observations and the implications of these observations on food security and conservation management (https://www.iarpccollaborations.org/members/events/15941).
This activity will continue in the Arctic Research Plan 2022-2026 under the Sustainable Economies and Livelihoods Priority Area.
Agencies: DOI-FWS, NOAA

8.2.6 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.
Status: Continuing
Priority Areas and Foundational Activities: Sustainable Economies and Livelihoods
Summary Statement: This is an ongoing effort to inform multiple entities on the changes in ecosystems and the distribution and abundance of wildlife and subsistence resources in Alaska. Unclear if this will remain in CRCT or be part of a PA in the new Arctic Research Plan.
This activity will continue in the Arctic Research Plan 2022-2026 under the Sustainable Economies and Livelihoods Priority Area.
Agencies: DOI-FWS, DOI-USGS, NSF

8.3.1 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.
Status: Complete
Summary Statement: The CRCT highlighted new research and monitoring results in addition to tool development by the USGS, including the USGS Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/) that interactively maps shoreline change and probabilities of sea-level rise across coastal Alaska. The NSF awarded several proposals on coastal change dynamics and coastal topic education and training opportunities for Alaska Native communities.

This activity may continue in the Arctic Research Plan 2022-2026 under the Risk Management and Hazard Mitigation Priority Area.
Agencies: DOD-USACE, DOI-USGS, DOI-BOEM, NOAA, NSF

8.3.2 Increase understanding of hydrologic changes in terrestrial landscapes including rivers, lakes, snow, groundwater, glaciers, and permafrost in interior and northern Alaska including the coastal plain using hydrologic monitoring and geochemical tracers.
Status: Complere
Summary Statement: The CRCT highlighted collaborations among federal agencies and universities regarding the role of hydrology on permafrost dynamics and research into subsequent ecosystem responses to thawing permafrost (https://doi.org/10.3133/fs20203058). NASA funded several proposals on remote sensing of natural and wildlife-related hydrological dynamics. USGS, BLM, and others released a lake and pond database for the North Slope of Alaska to inform management decisions in areas of oil and gas exploration and development. The NSF funded proposals related to the Arctic Great Rivers Observatory project, inputs of organic riverine matter into Arctic marine ecosystems, and on the movement of terrestrial sediment components into the Arctic Ocean.
This performance element has been completed under the scope of the Arctic Research Plan 2017-2021.
Agencies: DOI-USGS, NOAA, USDA-NRCS, DOI-BLM, DOI-BOEM, DOI-NPS, NASA, NSF

8.4.1 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.
Status: Complete
Summary Statement: As part of a webinar, NOAA summarized recent developments in National Geodetic Survey (NGS) information across Alaska and the effects these new data will have on positioning tools in Alaska. IARPCs Arctic Data and CRCT held a joint meeting on an Executive Order for ocean, shoreline, and nearshore mapping where agencies discussed their associated activities (https://www.iarpccollaborations.org/members/events/12777)
This activity may continue in the Arctic Research Plan 2022-2026 under the Arctic Systems Interactions Priority Area.
Agencies: NOAA, DOD-NGA

8.4.2 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.
Status: Complete
Summary Statement: The CRCT highlighted new sensor technology developments by several entities, including cameras installed in coastal areas of coastal areas to monitor erosion and ice detection buoy systems and the pilot study by AOOS and collaborators on ultrasonic gages deployed in Alaska communities to monitor storm surge and flood forecasting (https://doi.org/10.1117/12.2305157).

This activity will continue in the Arctic Research Plan 2022-2026 under the Technology Application and Innovation Foundational Activity.
Agencies: NOAA, DOI-FWS, DOI-NPS

8.4.3 Produce modeled tidal predictions for the U.S. Arctic. Involve multi agency collaborators, including Alaska Ocean Observing System (AOOS) representatives.
Status: Complete
Summary Statement: IARPC highlighted the research and development on this topic through the efforts of AOOS to model tidal predictions for additional coastal communities and NOAA efforts to model wave surges. Additionally, several IARPC agencies gathered in Anchorage, Alaska, in 2018 for the Alaska Coastal Mapping Summit to discuss next steps for coordinated approach to coastal mapping. A multi-agency, 10-year strategy document was released in 2020 (https://iocm.noaa.gov/about/documents/strategic-plans/alaska-mapping-strategy-june2020.pdf). This performance element has been completed under the scope of the Arctic Research Plan 2017-2021.
Agencies: NOAA

Environmental Intelligence

9.5.1 Advance coordination among Federally-funded research programs that provide decision support to Arctic stakeholders.
Status: Complete
Summary Statement: We encourage another team to continue this performance element, feedback indicates that this is an area of importance.
Agencies: NOAA, DHS, DOI-BLM, DOI-FWS

9.5.2 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).
Status: Complete
Summary Statement: We encourage another team to continue this performance element. SEARCH is funded for another 5 years. Arctic Report Card continues to be published annually
Agencies: NOAA, NSF, DOD-ONR, DOI-BOEM, NASA

Arctic Observing Systems

9.1.1 Coordinate U.S. agency and outside collaborators support for and participation in the international Sustaining Arctic Observing Networks (SAON) process.
Status: Continuing to serve as the National coordination point for SAON, the Arctic Observing Summit and related international Arctic observing activities.
Priority Areas and Foundational Activities: Community Resilience & Health, Arctic System Interactions, Sustainable Economies and Livelihoods, Risk Management and Hazard Mitigation
Summary Statement: Dialog led by the AOSST, and its federal IARPC counterpart the US Arctic Observing Network (US AON) Board, played a significant role in shaping international planning processes and frameworks in support of Arctic observing and data systems. Sustaining Arctic Observing Networks (SAON) is a key international forum for engaging with partner nations and organizations on developing networks in support of societal benefit. AOSST supported the development of SAON's Arctic-specific societal benefit framework, which became a valuable tool for aligning interests across partners. SAON's Roadmap for Arctic Observing and Data Systems (ROADS) moved this societal benefit-oriented framework forward into a planning process organized around Shared Arctic Variables (SAVs). AOSST directly engaged with researchers and federal program managers to develop the concepts for these tools and identify means for piloting the ROADS process nationally (see 9.1.2). The Arctic Observing Summit is a biennial meeting that brings SAON partners together to advance topics like Indigenous-led observing and the ROADS process. The AOSST helps to serve as a conduit to engagement in the AOS and as a mechanism for following up on its recommendations. Collectively AOSST, the US AON Board, SAON-ROADS and AOS are moving toward on-going, well-structured planning processes in support of Arctic observing and data systems that serve societal needs. These activities will continue to prove foundational to the success of all Priority Areas in next IARPC 5-Year Plan.
Agencies: NOAA, DHS-USCG, DOD-ONR, DOE, NASA, NSF

9.1.2 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.
Status: Continuing, the AOSST will continue to work with the community to develop similar coordinated activities on other high priority observational topics.
Priority Areas and Foundational Activities: NA
Summary Statement: The AOSST team has made significant progress on developing the idea of research coordination networks to advance observational science and promote broad synthesis within thematic research communities. A 5-year project establishing a coordination network on Arctic change, with a focus on how to use sustained observations to enhance food security in the Pacific Arctic, the "Collaborative research networking activities in support of sustained coordinated observations of Arctic change" was funded. This RNA will continue and could serve as an example for developing other research networking activities.

Agencies: NOAA, NSF, DOD-ONR, DOE, NASA

Modeling

9.2.1 In coordination with efforts described under the Atmosphere Goal, support and coordinate research to advance understanding of the connections between the Arctic and mid-latitude weather patterns and vice-versa.

Status: Combine 9.2.1, 9.2.2, 9.2.3 for understanding Arctic processes and how models represent them for the Arctic climate system as a whole

Priority Areas and Foundational Activities: Arctic System Interactions

Summary Statement: Over the course of the plan, extensive research efforts have been made in examining the topic of Arctic/mid-latitude atmospheric interactions. Part of the PE motivation stems from a 2014 National Academies workshop report on the topic (https://doi.org/10.17226/18727). A following CLIVAR workshop was held in 2017 that presented contemporary modeling and observational efforts (https://doi.org/10.5065/D6TH8KGW). The Academies workshop report described areas of future needs and opportunities. Some of the recommended areas sought improvements in general atmospheric research capabilities for addressing Arctic/midlatitude interaction, and are specifically covered under other PEs. For example, improved observations of Arctic storms, cloud properties, and surface fluxes are described in PE 2.1.1 and 2.2.2, while the development of high-resolution global models is described in 9.3.1. Two aspects of general improvements in research capabilities that have been addressed in this PE are the improvement and assessment of sea ice in Earth system models as part of the Sea Ice Model Intercomparison Project (SIMIP), and the improvement of sub-seasonal-to-seasonal forecasting systems (S2S).

A central recommendation of both workshop reports was that the modeling community construct careful, coordinated intercomparison and sensitivity studies. Towards this end, the Polar Amplification Multi-model Intercomparison Project (PAMIP) was organized as an endorsed model intercomparison project for CMIP6, with participation through US contributing models and analysis grants. The PAMIP experiments were described in IARPC public meetings and were conducted as part of CMIP6 in 2020. The model output fields have served as a basis for understanding the midlatitude jet stream and the general circulation response to Arctic sea-ice loss. While the analysis is ongoing, publish results indicate that the Arctic surface temperature amplification response is only partly attributable to sea ice loss, that the internal variability is large – making the assessment of physical processes difficult, but that changes to midlatitude circulation are discernible in some of the PAMIP sub-experiments. The analysis of PAMIP and related modeling experiments remains an ongoing activity, but the PAMIP initiative indicates that substantial progress has been made in understanding Arctic-midlatitude weather interactions.

Two other research areas related to this PE are with regards to Arctic-stratosphere circulation interaction, and the effects of midlatitude circulation on Arctic processes. Over the course of the research plan, efforts have been made towards identifying the interaction between the wintertime stratospheric polar vortex and surface conditions. For example, recent studies have identified characteristic sea ice responses to sudden stratospheric warming events, while other work has looked at the inception of tropopause polar vortices (TPVs) and their effects on Arctic surface conditions. The

latency associated with the surface response to TPV forcing suggests a level of predictability may be leveraged. Finally, warm air intrusions in the Arctic have been documented in recent literature in an effort to understand the physical processes and the cryospheric response. In particular, sudden wintertime Arctic Ocean surface warming in recent years has been identified in reanalysis and satellite observations and related to atmospheric teleconnection patterns. In summer, research attention has focused on midlatitude general circulation blocking events and their effects on the Arctic, with particular emphasis on surface melting over the Greenland Ice Sheet."
Agencies: DOE, NOAA, NSF, DOD-ONR, NASA

9.2.2 Support and coordinate research to enhance the understanding of connections between Arctic and global ocean circulation.
Status: Combine 9.2.1, 9.2.2, 9.2.3 for understanding Arctic processes and how models represent them for the Arctic climate system as a whole
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Connections between the Arctic and global ocean circulation have been the subject of several meetings of the Modeling Sub-Team, some in collaboration with the newly formed Physical Oceanography Self-Formed Team. Two meetings addressing this topic were "Arctic Ocean Changes and Global Impacts" (May 2018), with presentations by Mike Steele, Alexey Fedorov, and Milena Veneziani; and the joint MST/POST meeting on "North Atlantic/Arctic Gateway Transports" (December 2020), with presentations by Wieslaw Maslowski, and Dmitry Dukhovskoy.
The US AMOC Science Team is an interagency effort that supports this PE. It was formed in 2007 under the auspices of US CLIVAR and brought together U.S. scientists that study the AMOC with support from the major agencies. The team, in collaboration with colleagues from the UK RAPID program, produced an AGU special collection of 9 review papers dealing with different aspects of the AMOC, several of which discussed connections with the Arctic:
https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1944-9208.AMOC.
This PE has a clear continuation into Priority Area 2 of the new Arctic Research Plan: Arctic Systems Interactions, and its policy driver: Arctic-Global Systems: Improve understanding of the Arctic as a component of planet Earth."
Agencies: DOE, NOAA, NSF, DOD-ONR, NASA

9.2.3 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.
Status: Combine 9.2.1, 9.2.2, 9.2.3 for understanding Arctic processes and how models represent them for the Arctic climate system as a whole
Priority Areas and Foundational Activities: Arctic System Interactions

Summary Statement: Many projects funded by the US agencies have contributed to enhanced understanding of processes and feedbacks within the Arctic System using modeling approaches. The most impactful, arguably, were activities that brought together different teams to jointly address open questions. One example is FAMOS (Forum for Arctic Modeling and Observational Synthesis), which was an NSF-funded project that brought together US and international Arctic scientists to improve our understanding of oceanic and sea-ice processes and mechanisms driving Arctic Ocean changes. Emerging from the Arctic Ocean Model Intercomparison Project (AOMIP) from the late-90s, it coordinated activities that combine observations and models to enhance our understanding of Arctic Earth System processes. FAMOS produced a special collection of publications: https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)2169-9291.FAMOS2, and was featured in several meetings of the Modeling Sub-Team. Another interagency effort is the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition, a large international effort revolving around an intense 1-year frozen-in-the-ice field campaign. Aimed at enhancing process understanding of the coupled Arctic system, MOSAiC has a significant modeling component that was discussed in several meetings of the Modeling Sub-Team.
Agencies: DOD-ONR, DOE, NOAA, NSF, NASA

9.2.4 Conduct a survey and identify investigator-driven modeling projects designed to understand important local and global Arctic System feedbacks.
Status: Refocus to: share current development activities related to Arctic development
Summary Statement: Across the US federal arena there are a large number of investigator-driven modeling projects which have been represented through the domain specific topics that have addressed several Performance Elements. However, very little discussion has taken place that involve the US modeling centers. To make the community aware of the larger efforts of the US modeling centers, the Modeling Sub-Team encouraged the six US modeling centers to discuss their efforts in the Arctic. Discussion of the current priorities for Arctic modeling, successes and challenges that each of the modeling center faces were discussed. The modeling centers that were represented were: 1) NOAA's Geophysical Fluid Dynamics Laboratory (GFDL); 2) DOE's Energy Exascale Earth System Model (E3SM); 3) NSF's Community Earth System Model (CESM); 4) NOAA's National Weather Service (NWS); 5) NASA's Goddard Institute of Space Studies (GISS); 6) NASA's Global Modeling and Assimilation Office (GMAO). All these modeling centers focus on the atmospheric, terrestrial, sea-ice, and land-ice components of the Arctic system to varying extents. The efforts at GISS, NWS, emphasized strong data assimilation and forecasting capabilities, while the efforts at GFDL, CESM, and E3SM highlighted strong model development capabilities. Predicting sea-ice and subseasonal to seasonal prediction were discussed at the GMAO and GISS centers. Regional refinement of the global model to better focus on the Arctic system was discussed as an E3SM priority. Emphasis of coastal processes was included here. Fire weather in the Arctic was discussed as part of the land modeling components of CESM, GFDL, and GISS. All modeling centers had a focus on using models to understand processes in the Arctic. One of the results of this meeting was a recommendation that Modeling centers work together to address common biases in models.

It is anticipated that in Fall/Winter 2021 that Program Managers from various agencies (DOE, NASA, NOAA, NSF, and ONR) will present an overview of their current investments in the Arctic with a look towards the future. Additionally, at the 2021 AGU, the modeling sub-team is convening Townhall on Arctic Modeling Capabilities that will highlight both agency and modeling center priorities in the Arctic.
Agencies: NSF, DOD-ONR, DOE, NASA, NOAA

9.3.1. 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
Status: Continuing, may combine 9.3.1,9.3.2, and 9.3.4 to focus on improving models for the Arctic
Priority Areas and Foundational Activities: Monitoring, Observing, Modeling, and Prediction
Summary Statement: In recent years, several modeling centers developed climate models with regional grid refinement capabilities. This allows for representing processes with high fidelity in specific regions of interest, while still treating those regions as part of the global Earth system --and at reasonable computational cost. Arctic-refined models are promising tools for studying the Arctic Earth system. The Community Earth System Model version 2 (CESM2) allows for regional refinement in the atmosphere. An international team of researchers developed configurations with grid refinement over the Arctic, and over the Greenland Ice Sheet, and showed notable improvements in, in particular, precipitation patterns and extreme events (10.5194/tc-13-1547-2019). DOE's new Energy Exascale Earth System Model (E3SM), released in 2018, has the capability of regional grid refinement in all of its components. The HiLAT-RASM project has taken a first step towards configuring an Arctic-refined version of E3SM, called E3SM-Arctic. Currently in an ocean/sea ice configuration forced with JRA55 atmospheric reanalysis, it is able to represent important processes like gateway transports with high fidelity, while still allowing for two-way interactions between the Arctic and global ocean circulation. A version of E3SM-Arctic is being developed with an Arctic-refined atmosphere, with the ultimate goal of developing a fully-coupled configuration that has Arctic-refinement in all its components. The Modeling Sub-Team organized several meetings discussing these exciting new capabilities.
Agencies: DOE, NSF

9.3.2 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.
Status: Continuing, may combine 9.3.1,9.3.2, and 9.3.4 to focus on improving models for the Arctic
Priority Areas and Foundational Activities: Monitoring, Observing, Modeling, and Prediction
Summary Statement: In the last pentad, the model development community has made significant advances in the representation of high-latitude processes in Earth System Models (ESMs). The

Modeling Sub-Team followed, highlighted, and supported several of these lines of development through its monthly meetings. In particular, the team organized meetings to discuss:
- the Ice Sheet Model Intercomparison Project (ISMIP6) and other efforts aimed at improving ice sheet models and their implementation in ESMs (see PE 9.3.6);
- the Sea Ice Model Intercomparison Project (SIMIP), which aims at evaluating and improving the representation of sea ice in ESMs;
- the Sea Ice Prediction Network (SIPN, SIPN-2), aimed at assessing and improving the predictive skill of sea ice models;
- the modeling activities associated with MOSAiC, aimed at improving the representation of coupled ocean/sea ice/atmosphere interactions; and
- the modeling activities associated the terrestrial ecology programs Arctic-Boreal Vulnerability Experiment (ABoVE; NASA) and Next-Generation Ecosystem Experiments Arctic (NGEE Arctic; DOE), which aim to improve the representation of terrestrial hydrology and ecosystems in ESMs.
An important development was the formation of the CICE Consortium in 2016 by an interagency group of stakeholders and primary developers of the Los Alamos sea ice model (CICE). Considered a vehicle for collaboration in sea ice model support and development, its aim is to maintain the current CICE model for existing and new users, to incorporate and maintain new research and development, and to accelerate scientific sea ice model development and its transfer into operational use.
NASA Global Modeling and Assimilation Office (GMAO) published a new version of its Subseasonal to Seasonal (S2S) prediction system and its accompanying ocean data assimilation system (GEOS ODAS). In collaboration with Harvard University, the GMAO has also developed a global composition forecasting system (GEOS-CF), which routinely predicts tropospheric and stratospheric composition, and surface pollutant distributions for up to 5 days at 25km grid spacing. NOAA made progress in adapting its Unified Forecast System (UFS) for Arctic applications. The UFS is a comprehensive, community-developed Earth modeling system, designed as both a research tool and as the basis for NOAA's operational forecasts. Similarly, the U.S. Navy has continued the development of its global Earth System Prediction Capability (ESPC). This operational system produces daily to seasonal forecasts of variables like ice thickness, ice concentration, ice drift, etc.
Finally, the Modeling team also paid attention to metrics packages that are being developed for benchmarking and evaluating Earth system models. Among the packages discussed are the Land Ice Verification and Validation Toolkit (LIVVkit); the Cryosphere Model Comparison Tool (CmCt); the International Land Model Benchmarking (ILAMB) package; and the International Ocean Model Benchmarking (IOMB) Package.
This PE has a clear continuation into the Foundational Activity of Monitoring, Observing, Modeling, and Prediction.
Agencies: NASA, NOAA, NSF, DOE

9.3.3 Foster interactions between the Arctic Testbed and Environmental Modeling Center's weather modeling efforts to facilitate the improvement of model guidance at higher latitudes.
Status: Complete

Summary Statement: NOAA's Arctic Test Bed has been instrumental in providing guidance during specific intense

observation periods in the Year of Polar Prediction. This activity contributed to evaluating sea-ice model output with an operational focus looking at: 1) at ice edge; 2) Land Fast Ice Characteristics; 3) Ice concentration; and 4) Ice Drift. Collaborations with many efforts like NOAA ESRL's Regional Arctic System Model activities, NRL and CMC's sea-ice modeling activities have together enhanced the operational forecasts of sea-ice. In essence forecasts from the Arctic testbed activities supported the research to operations capabilities for Arctic sea-ice. Additionally, it is possible that activities such as the Arctic Test Bed can contribute to joint modeling and observational capabilities such as OSSEs.

Agencies: NOAA, DOD-ONR

9.3.4 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.

Status: Continuing. May combine with variable resolution global models.

Priority Areas and Foundational Activities: Monitoring, Observing, Modeling, and Prediction

Summary Statement: The last decade has seen significant progress in regional Arctic system modeling. Two prominent modeling systems are the Regional Arctic System Model (RASM) and the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS). The RASM project, supported by DOE, ONR, NSF, and DoD, has made significant progress in modeling the Arctic Earth system. A collaboration between the Naval Postgraduate School (NPS) and several academic and federal partners, RASM has moved towards new higher resolution configurations, with spatial resolution of 2.4 km for the sea ice (CICE6.2) and ocean (POP2) components and 25 km for the atmosphere (WRF) and land hydrology (R/VIC) components. RASM has biogeochemistry in both the ocean and sea ice components. The process-resolving RASM simulations represent significant improvements to model physics, which result in realistic representation of the past and present Arctic climate, as compared to available observations, without the need for data assimilation. PIOMAS is developed by scientists from the Polar Science Center at the University of Washington, and is an ocean/sea ice model forced by the NCEP Climate Forecast System (CFS) reanalysis atmospheric forcing (1979-present). In hindcast mode PIOMAS assimilates remote sensing sea ice concentration and thickness data. Both RASM and PIOMAS have consistently submitted contributions to the Sea Ice Outlook, organized by the Sea Ice Prediction Network (SPIN, SIPN-II).

Regional modeling of the atmosphere is enabled by the development of a polar-optimized version of the Weather Research and Forecasting (WRF) model, spearheaded by the Polar Meteorology Group at Ohio State University. The Polar WRF version 4.3 is currently undergoing testing in the Arctic and Antarctic with release to the community planned for the near future.

The polar Coordinated Regional Downscaling Experiment (Polar CORDEX) is a WCRP activity under the broader CORDEX community. Polar CORDEX includes regional climate modeling groups from North America, Europe, Asia and South America and focuses on regional climate modeling issues over the

Arctic, Antarctic and the Southern Ocean. Coordinated model experiments, model evaluation and access to data are arranged at annual Polar CORDEX meetings and by e-mail.
Agencies: DOD-ONR, DOE, NSF

9.3.5 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.
Status: Continuing. Reanalyses continue to evolve and will eventually cover coupled atmosphere/ocean data assimilation
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Systematic Improvements to Reanalyses in the Arctic (SIRTA)" was a 2016 white paper commissioned by IARPC to examine methods for improving Arctic atmospheric reanalyses. Atmospheric reanalyses are produced from the correction of a short-term numerical weather prediction model (NWP) to observation. Progress made towards this PE seeks to advance the modeling aspect of the reanalysis system.

A direct result of the white paper is the Arctic System Reanalyses. Version 2 (ASRv2) was released in autumn 2017. The ASRv2 is a high spatial resolution regional atmospheric reanalysis covering the period 2000-2016 and employing realistic ocean and land surface conditions at 15km grid spacing (Bromwich et al. 2018, doi:10.1175/BAMS-D-16-0215.1). The ASRv2 was sponsored by the NSF and NASA, and has been widely used in studies ranging from the Arctic surface energy balance, Greenland precipitation, to the assessment of recent boreal wildfires.

Over the course of the research plan, studies have comprehensively assessed aspects of atmospheric reanalyses in the Arctic. They include assessments of precipitation over Arctic sea ice from CloudSat observations and as part of the NASA-ESA Snow on Sea Ice (NESOSI) study, Greenland accumulation and runoff fields as part of the second Ice Sheet Model Intercomparison Exercise (IMBIE-2), Arctic radiative fluxes in comparison to satellite observations, and Arctic Ocean surface air temperatures in comparison to available in situ and satellite-derived observations. Several studies provided direct comparisons of reanalyses to field study observations, including the NASA Arctic Radiation-IceBridge Sea & Ice Experiment (ARISE), Operation IceBridge (OIB), the Norwegian Young Sea Ice campaign (N-ICE2015), and former Soviet North Pole drifting station records. Recent efforts have focused on the improvement of the modeled surface representation. Over Greenland and glaciated land surfaces, more recent reanalyses have seen significant improvement due to better representations of snow hydrology and energy conduction. Conditions over the Arctic Ocean remain problematic due to the simplistic representation of sea ice in NWP AGCMs. This issue and its effects on overlying atmospheric parameters may only be completely addressed in fully coupled atmosphere-ocean reanalyses. A particular aspect of recent model development has been associated with clouds and the use of aerosol analyses for the prediction of cloud phase (i.e., two-moment cloud microphysics), which has been implemented in CMIP models. These representations have been adapted for subseasonal-to-seasonal forecasting systems and are likely to see application in NWP models. Recent model developments are being assessed in PolarMERRA, a NASA initiative to bring modeling and

observational expertise together to assess and improve the representation of polar processes in preparation for upcoming and next generation reanalyses.
Agencies: NASA, NOAA, DOD-ONR, DOE, NSF

9.3.6 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.
Status: Complete. ISMIP6 is completed. There are ongoing ISM development efforts that may/should be covered in the new plan.
Summary Statement: Over the period of the research plan, efforts have been made to directly couple the dynamical ice sheet model components (ISMs) into Earth System Models. Owing to the continental-scale size and the extensive, complex oceanic interface for the Antarctic Ice Sheet, the initial focus has been for the Greenland Ice Sheet, in which two-way coupling exchanges the ISM freshwater ice mass into the Earth System Model (ESM) global ocean, while changes in the ISM topography affect the ESM atmosphere. This has led to coupled integrations of the NCAR CESM2.1 and the CISM2.1, which have shown a sea level rise contribution of 23 mm by the mid-21st century under IPCC scenarios, and an accelerated mass loss under a 4×CO2 scenario. Another initiative is associated with the coupling of the DOE E3SM ESM with the MPAS-Albany Land Ice (MALI) model. The DOE coupled development is ongoing, and efforts have focused on improving surface mass balance and snow hydrology, and producing the ice sheet initial condition. Other developments have been made with coupling ISMs to ESM components, such as coupling the NASA ISSM ice sheet model and the MITgcm ocean model. Additionally, ISMs have been coupled with probabilistic sea-level frameworks, so that dynamically computed sea-level fingerprints may be directly linked to ISM local mass changes. A primary focus of the ISMIP6 project has been to assess and prepare ESM output for integration into uncoupled ISM simulations. Data sets including surface elevation, bedrock topography, ice front position, surface velocities, geothermal heat fluxes, and surface mass balance were finalized for use in the experiments following agreements outlined during prior meetings. The actual numerical experiments occurred in 2020, and were then analyzed. Summary publications were produced by Seroussi et al. (2020, 10.5194/tc-2019-324) for the Antarctic Ice Sheet and by Goelzer et al. (2020, 10.5194/tc-2019-319) for the Greenland Ice Sheet. Six other papers were published in a special issue of the journal The Cryosphere describing various aspects of the experiment design and outcomes (tc.copernicus.org/articles/special_issue1019.html). These studies were then incorporated into the IPCC Assessment Report. The work of ISMIP6 remains ongoing, as coupled ISM/ESM integrations are being assessed, and additional ISM experiments over longer duration are planned. Nevertheless, ISMIP6 represents the first coordinated contribution of the ISM community to the CMIP framework, which will serve as a basis for comparison as future ISM innovations are made.
Agencies: NASA, DOE, NOAA, NSF

Arctic Data

9.4.1 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.
Status: Complete
Summary Statement: Federal agencies have made a number of investments in data science projects over the past five years that have matured the data management capabilities for US Arctic researchers. In some cases, these projects have completed, having met all their original objectives. In other cases, these projects have transitioned into long-term sustained efforts that are supported throughout the research community. Through these efforts, data management best practices have been adopted and incorporated into Arctic research practices. In the future, continued advancement for this performance element could also include an emphasis on more decentralized and pluralistic coordination, requiring accommodations that consider agency policy, applied practitioner context, and indigenous and local community interests.
Agencies: NOAA, NASA, NSF

9.4.2 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).
Status: Continuing
Priority Areas and Foundational Activities: Technology Application and Innovation; and Education
Summary Statement: Progress over the past five years on promoting Arctic data sharing system best practices has focused on specific platform developments that solve technological challenges in a certain problem spaces (eg. stewardship of data developed for NSF-funded projects and shared via the NSF Arctic Data Center, or for a specific data management function in the case of the Alaska Data Integration Working Group (ADIWG) Metadata Toolkit (MD Toolkit)). Future efforts could emphasize converging on common platforms to leverage these technological solutions across the Arctic research community leveraging Spatial Data Infrastructure initiatives, and to push these platforms to tackle emerging technological challenges, such as data security, and big data dissemination, which are areas that the Arctic research community's platforms still require further technological investments to achieve effective national and international data sharing. The connection of this performance element in the next five year research plan is to the stewardship policy driver, as an effective use of technology will improve the delivery of Arctic research to society and those most in need of the benefits of science.
Agencies: DOI-BLM, DOI-BOEM, NSF, DOE, DOI-USGS, NASA, NOAA

9.4.3 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.

Status: Continuing
Priority Areas and Foundational Activities: Community Resilience & Health
Summary Statement: The IARPC has advanced several tools developed specifically to support the Arctic communities in the state of Alaska to help them understand and make decisions to adapt to climate change. These include community based tools to deliver scientific information to local and indigenous communities, and reporting tools for community science to contribute observations about environmental change that is observed by citizen scientists on the ground in the Alaska Arctic. Together, these tools make up IARPC's contribution to the Arctic Theme of the Arctic Data Initiative and Climate Resilience Toolkit. NOAA's Arctic Research Program is specifically highlighted for its contribution to these efforts, as it is producing information that is informative to understanding climate change in the Arctic. The performance element will continue to be relevant and active under the next five year research plan primarily under the Community Resilience and Health priority area, as the on the ground impacts from climate change in the arctic will affect local and indigenous communities, both through affects to the built environment and the sustainability of arctic infrastructure, and through threats to Arctic food security sustainability of wildlife that are taken for subsistence activities.
Agencies: DOI, NASA, NOAA, NSF

9.4.4 Advance agile situational awareness and decision support for Arctic operators through efforts like ADAC's Arctic Information Fusion Capability28, ERMA, and NASA ACE project.
Status: Continuing
Priority Areas and Foundational Activities: Risk Management and Hazard Mitigation
Summary Statement: Arctic operators have a need for environmental information to operate safely and provide goods and services in a sustainable fashion. Research supporting this performance element includes artificial intelligence and machine learning approaches to satellite based measurement of sea ice and coastal change. Another example of research discussed on a recent teleconference was the testing of an ice breaker ship's hull, by locating and navigating the ship to multi-year ice and performing maneuvers to test the ship hull's integrity. Much of the research under this performance element pertains to developing capacity for domain awareness and it brings to bear highly sophisticated technology focused on near term and targeted results. Therefore, it's critical that operators and practitioners in the Arctic continue to have a greater role in IARPC collaborations to help direct this research. This performance element continues to be relevant in the next five year research plan under Priority Area 4: Risk Management and Hazard Mitigation, which specifically cites domain awareness as a holistic security concern.
Agencies: DHS, DOE, NASA, NOAA

9.4.5 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.

Status: Continuing
Priority Areas and Foundational Activities: Arctic System Interactions
Summary Statement: Mapping the marine environment has continued to be a priority under the National Strategy for Ocean Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone (NOMEC strategy), and IARPC collaborations hosted a series of discussions of formulating the NOMEC implementation plan and the associated Standard Ocean Mapping Protocol. Similarly, NASA's ABoVE program contributed to this performance element by producing baseline maps of terrestrial Arctic environments. This involves contributions from a variety of partners from National and State of Alaska agencies, represented on the Alaska Mapping Executive Committee. This will continue to contribute to Priority Area 2: Arctic System Interactions, because the baseline mapping is fundamental to understanding all oceanic and terrestrial natural systems.   D
Agencies: OI-USGS, NOAA, NSF, DOD-NGA, DOI-BLM, DOI-FWS, DOI-NPS