REPORT ON THE Goals and Objectives for Arctic Research 2023–2024

FOR THE US ARCTIC RESEARCH PROGRAM PLAN

UNITED STATES ARCTIC RESEARCH COMMISSION

CONTENTS

Duties of the Commission

- Develop and recommend a national Arctic research policy and Arctic research goals and objectives
- Assist the Interagency Arctic Research Policy Committee in establishing a national Arctic research program plan to implement the policy
- Facilitate cooperation in Arctic research among federal, state, and local governments and with international partners
- Review federal Arctic research programs and recommend improvements for coordination
- Recommend advances in Arctic research logistics
- Recommend improved methods for data sharing among research entities

ON THE COVER. R/V *Sikuliaq* transiting after sunset. *Image credit: John Guillote*

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A MESSAGE FROM USARC CHAIR MIKE SFRAGA

Research is Essential for Understanding and Addressing a Rapidly Changing Arctic

Arctic climate change continues to impact the region's environmental, social, cultural, political, economic, and security landscapes. The repercussions have drawn more attention to the Arctic, highlighting its inherent value and its interconnections with the world.

Arctic research provides knowledge and understanding that are fundamental to informing policy and decisions in the region. This 2023–2024 report establishes Arctic research priorities and goals that, when achieved, will inform decision-makers and advance efforts outlined in our nation's Arctic policies, strategies, and plans.

The US Arctic Research Commission's (USARC's) reports also inform the research plans of the Interagency Arctic Research and Policy Committee (IARPC), with which USARC works closely, consistent with the Arctic Research Policy Act of 1984.

The recently updated *National Strategy for the Arctic Region* (NSAR) states that coordinated research on the environmental and societal impacts of climate change in the Arctic, and the Arctic's role in global climate dynamics, are to be guided by USARC's reports and IARPC's plans. Research will be essential in achieving several of the strategic objectives identified in the NSAR.

Furthermore, our report includes recommendations that address the United States' 2022 *National Security Strategy*, which notes that, "Climate change is making the Arctic more accessible than ever, threatening Arctic communities and vital ecosystems, creating new potential economic opportunities, and intensifying competition to shape the region's future."

Similarly, this report calls for research that will address key findings of the National Oceanic and Atmospheric Administration (NOAA) *2022 Arctic Report Card*, which states, "Shifting seasons and climate-driven disturbances, such as wildfires, extreme weather, and unusual wildlife mortality events, are becoming increasingly difficult to assess within the context of what has been previously considered normal."

As the United States better integrates the Arctic into its domestic and foreign policy strategies, Arctic research will be key to our nation's ability to address the many challenges and opportunities presented by a rapidly changing Arctic.

Progress by the US Arctic research community, in cooperation with international partners, on the research recommended by the Commission, will result in a better understanding of this rapidly changing region, will advance data-driven strategies to address these changes, and will support US aspirations for a peaceful, stable, prosperous, and cooperative Arctic.

Mike Sfraga

Alaska range. *Image credit: iStock.com/sarkophoto*

Policy Drivers and Research Priorities

Federally funded Arctic research increases knowledge and informs public policy and decision-making. When identifying Arctic research goals and objectives, USARC carefully considers the overarching policy drivers and research interests expressed by several entities. Knowledge from prior research also informs this report and the recommendations herein.

White House guidance is provided by several documents, including the 2022 *National Strategy for the Arctic Region*,[1] the *National Security Strategy*,[2] guidance on Indigenous Knowledge,[3] and the annual research and development priorities memo. Arctic-relevant priorities for FY23[4] and FY24[5] include addressing climate change, ecosystems, human health, Indigenous Knowledge, economic resilience, critical mineral resources, emerging technologies, international cooperation, co-design and co-production, and equity for all. The climate priority includes improving understanding of the physical basis of change, and now, more urgently, the societal impacts of climate change and the necessary response (e.g., building climate resilience, reducing emissions, and clean energy transition).

The priorities communicated to the Commission by the State of Alaska's Departments of Fish and Game[6] and Natural Resources include scenario planning; food security; infrastructure development; mapping; access to resources and their development, conservation, and use; maintaining culture and subsistence; tracking changes in the distribution and abundance of fish and wildlife; and developing species-specific management plans. The Alaska State Committee for Research recently updated its science and technology plan,[7] focusing on seven research areas, several of which are addressed herein.

In 2018, the Municipality of Anchorage, in partnership with the University of Alaska Anchorage, established a climate action plan[8] to reduce energy use, promote energy independence, strengthen the economy, and build a more livable and resilient community. Think tanks and universities also put forward policy priorities[9] considered in this report.

The Commission continues to track key research themes and engagement models[10] advanced by Alaska Native and circum-Arctic Indigenous organizations. For example, the Commission looks forward to partnering with the Alaska Federation of Natives (AFN), which encouraged[11] support for Indigenous listening sessions, summits, and research on climate migration and relocation, fish, technology, engineering, marine debris, and health and wellness. Other Alaska Native Organizations (ANOs)[12] highlighted the need for co-productive approaches[13] to research planning in the Bering Sea region and a specific request to work collaboratively to develop meaningful research priorities and plans.

The Commission is grateful to everyone who helped inform this report, and we look forward to continued engagement.

1 https://www.whitehouse.gov/wp-content/uploads/2022/10/National-Strategy-for-the-Arctic-Region.pdf
2 https://www.whitehouse.gov/wp-content/uploads/2022/10/Biden-Harris-Administrations-National-Security-Strategy-10.2022.pdf
3 https://www.whitehouse.gov/wp-content/uploads/2022/12/OSTP-CEQ-IK-Guidance.pdf
4 https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-32-Multi-Agency-Research-and-Development-Prioirties-for-FY-2023-Budget-.pdf
5 https://www.whitehouse.gov/wp-content/uploads/2022/07/M-22-15.pdf
6 Alaska Department of Fish and Game Research Priorities, Commissioner Doug Vincent-Lang and Dani Evenson, presented at the 114th USARC Meeting in Anchorage, Alaska, on April 4, 2022
7 https://www.alaska.edu/research/scor/
8 https://www.muni.org/Departments/Mayor/AWARE/ResilientAnchorage/pages/climateactionplan.aspx
9 https://uaf.edu/caps/
10 https://www.inuitcircumpolar.com/news/inuit-circumpolar-council-establishes-new-standard-in-international-engagement-with-the-release-of-circumpolar-inuit-protocols-for-equitable-and-ethical-engagement/
11 October 27, 2021, letter from AFN President Julie Kitka to USARC Chair Mike Sfraga
12 August 2, 2020, letter from Kawerak, Association of Village Council Presidents, Aleut Community of St. Paul, Bering Sea Elders Group, and Alaska Native Tribal Health Consortium to USARC and others
13 Yua et al. (2022), https://doi.org/10.5751/ES-12960-270134

Yedoma permafrost cliff along the Itkillik River, Alaska. *Image credit: Mikhail Kanevskiy, University of Alaska Fairbanks*

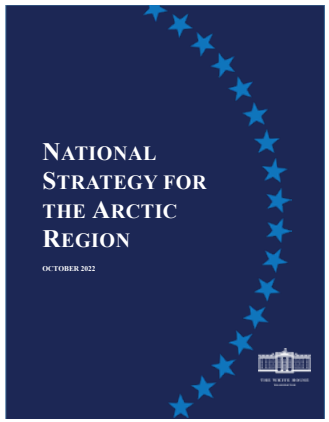
Federal Arctic Research

Federally supported Arctic research is guided by the Arctic Research and Policy Act (ARPA) of 1984, as amended.[14] In establishing a comprehensive national policy focusing on research needs and objectives in the Arctic, the law created USARC, an independent federal agency, and the Interagency IARPC chaired by the National Science Foundation (NSF).

The law assigns the Commission's presidentially appointed advisory body 10 duties, including publishing a report of goals and objectives for Arctic research. This report, in turn, guides IARPC in performing its duties. The Commission develops and recommends national Arctic research policy and builds cooperative links in Arctic research within the federal government, with the State of Alaska, with Tribes and ANOs, and with international partners. By law, the Commission shall review the Arctic research budget "crosscut" in the President's annual budget request and report to Congress on how the crosscut adheres to the five-year Arctic Research Plan produced by IARPC.

IARPC became a White House working group of the National Science and Technology Council's Committee on Environment in 2010. IARPC brings together representatives from 18 federal agencies, departments, and offices to establish a coordinated agenda for Arctic research. Its duties include consulting and working with USARC to create an integrated national Arctic research policy to guide federal agencies, and to develop a five-year Arctic research program plan to implement the policy.

IARPC's *Arctic Research Plan 2022–2026*[15] identifies topics where interagency coordination can more effectively advance Arctic knowledge. This plan, and successive biennial implementation documents, provide a roadmap for federal collaborative efforts.



[14] https://www.arctic.gov/legislation/

[15] https://www.iarpccollaborations.org/uploads/cms/documents/final-arp-2022-2026-20211214.pdf

[16] P. Law 117-XX, the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023, see Title LIX – Other Matters, Subtitle B – Science, Space, and Technology Matters, Sec. 5912. Reports on Arctic research, budget, and spending

HOW MUCH DOES THE FEDERAL GOVERNMENT SPEND ON ARCTIC RESEARCH?

Spending estimates range from $400M to over $1B, depending on methodology. By law,[14] and most recently as part of the Fiscal Year 2023 National Defense Authorization Act,[16] the White House Office of Management and Budget (OMB) is charged with collecting this information annually by conducting a budget crosscut, which assembles all federal agency requests for Arctic research into one integrated, coherent, and multiagency request that is submitted by the President to Congress. OMB recently announced their intent to conduct an Arctic research budget crosscut and is working with other White House offices, USARC, and other departments and agencies to do so. Notably, this will enable the Commission to fulfill its statutory duty to review the results of the budget crosscut and report to Congress on how the crosscut adheres to the five-year Arctic Research Program Plan produced by IARPC.

Image credit: iStock.com/Biletskiy_Evgeniy

GOAL 1. Environmental Risks and Hazards

MOTIVATION

Risks from climatic and geologic hazards have enormous social and economic consequences. The urgency in addressing these risks in the Arctic is amplified by the accelerated rate of environmental change. Recent reports suggest that the rates of Arctic atmospheric warming[17,18] and of western Arctic Ocean acidification[19] may be as much as three to four times faster than the global average. Knowledge from research, in advance of disasters, can be used to value and reduce vulnerability, and help prevent or lessen effects. While continuing research to understand the physical basis of climate change, we must increase emphasis on responding to its impacts[20] by focusing on risk reduction, attribution,[21] sustainability,[22] mitigation, and scenario development. We must also reassess and act on the risks of geologic hazards as modified by Arctic environmental change.

Flooding in Golovin, Alaska, from ex-Typhoon Merbok, September 2022. *Image credit: Josephine Daniels*

RECOMMENDATIONS

- Expand, improve, and better coordinate Arctic monitoring of greenhouse gas (CO_2 and CH_4) emissions to curb industrial leaks from Arctic oil and gas infrastructure while identifying and distinguishing these leaks from natural releases of gas (e.g., permafrost thaw, boreal forest and tundra fires, and wetlands).[23, 24]
- Further evaluate and value opportunities to geologically sequester CO_2 in depleted Arctic oil reservoirs.
- Expand monitoring efforts to continuously track how and why sea level is changing to narrow uncertainty, value and inform adaptation and response, and assess scenario divergence. Improve satellite and sensor systems to track changes in global ocean levels and ice sheet thickness.
- Survey and map priority coastal areas and expand the foundational geospatial and water level infrastructure, including additional tide gauges along Alaska's western and northern coasts to improve marine commerce and facilitate coastal community resilience planning.
- Model how disease risk, prevalence, and distribution for wildlife hosts and parasites are affected by increasing air temperatures.[25]
- Monitor and investigate biogeochemical risks from Arctic permafrost degradation and improve understanding of thaw mechanisms. Develop methodologies to swiftly assess health risks from emergent pollution and to forecast interactions between emergent microorganisms, pathogens, and humans.
- Increase multi-risk assessments that link permafrost thaw with other hazards, including landslides, subsistence, erosion, and flooding and estimate economic impacts.[26]

25%

Melt from Greenland accounts for 25% of global sea level rise, double the contribution of Antarctica.[27]

PROGRESS

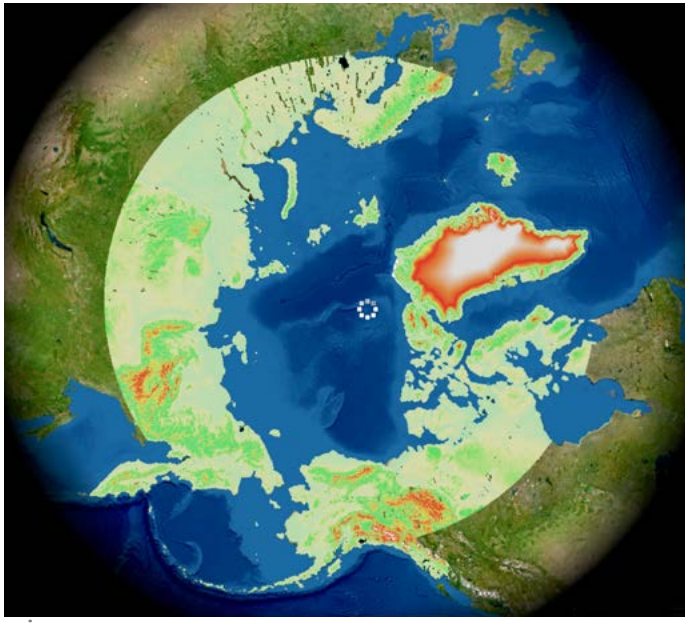
» **Sea ice predictions.** The accuracy of the forecasts by the Sea Ice Predictions Network (SIPN) has improved significantly over the past decade as the amount of ice declines, thins, and becomes more mobile. The forecasts have become increasingly vital for fisheries, resource development, shipping, subsistence activities, and wildlife management. The SIPN team is planning to work more closely with the Bering Sea snow crab fishermen to further improve forecast accuracy by including data for sea ice thickness, surface roughness, melt ponds, and snow depth, and to evaluate the socioeconomic value of sea ice forecasts. Another resource is the Sea Ice for Walrus Outlook for Alaska Native subsistence hunters, coastal communities, and others interested in the topic. The co-produced product, hosted on Facebook, is often updated several times a day during the height of the walrus season.

» **Geospatial data and maps.** Access to geographical data and maps is critical to decision-making, risk reduction (e.g., from tsunamis and landslides), economic development, and public safety. To that end, the Alaska Statewide Digital Mapping Initiative, Alaska Mapped, the Alaska Geospatial Office, and the affiliated Alaska Geospatial Council all support the collection, acquisition, and dissemination of geospatial data, standards, and policies. The Council, governed by the State of Alaska, is a collaborative effort of public and private entities that helps to identify the most valuable data to acquire, and then designs, funds, and conducts the surveys to collect the data, and shares the results. These entities continue to improve the findability, accessibility, interoperability, and reusability of data. Public-private partnerships have formed, and some develop specialized climate information products useful to Alaskans. Of interest to polar researchers is the federally funded Polar Geospatial Center at the University of Minnesota, which developed the Arctic DEM, a high-resolution, time-dependent elevation model of the Arctic.[29]

1600 billion

tonnes of carbon are stored in permafrost, twice the amount of carbon in the atmosphere today.[28]

Young male Pacific walrus resting on a beach, Chukchi Sea, Alaska. *Image credit: Anthony Fischbach, US Geological Survey*



ArcticDEM Explorer showing elevation.[29]

[17] https://www.amap.no/documents/doc/arctic-climate-change-update-2021-key-trends-and-impacts.-summary-for-policy-makers/3508
[18] Rantanen et al. (2022), https://doi.org/10.1038/s43247-022-00498-3
[19] Qi et al. (2022), https://doi.org/10.1126/science.abo0383
[20] https://www.scientificamerican.com/article/ipcc-youve-made-your-point-humans-are-a-primary-cause-of-climate-change/
[21] A relatively new field of research in meteorology and climate science that attempts to determine the impact of ongoing climate change on extreme weather events. Attribution science tries to determine the extent to which extreme weather events can be explained by anthropogenic climate change, rather than by natural variation.
[22] Defined here as an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems.
[23] https://climatetrace.org
[24] https://www.unep.org/news-and-stories/press-release/un-announces-high-tech-satellite-based-global-methane-detection
[25] Cohen et al. (2020), https://doi.org/10.1126/science.abb1702
[26] Terzi et al. (2019), https://doi.org/10.1016/j.jenvman.2018.11.100
[27] Voosen (2019), https://doi.org/10.1126/science.366.6462.170
[28] Brouillette (2021), https://doi.org/10.1038/d41586-021-00659-y
[29] https://arcticdem.apps.pgc.umn.edu/

GOAL 2. Community Health and Well-Being

MOTIVATION

Human health and well-being will be significantly improved by investment of more than $11B into Tribal communities across the United States, including Alaska, through the Infrastructure Investment and Jobs Act. This legislation will help communities adapt to a warming climate, build water and sanitation infrastructure, expand broadband, and improve transportation. Remaining challenges include the enduring health disparities between Arctic and non-Arctic residents, climate-related health and social risks, and food/energy/water/economic insecurity. Additionally, behavioral and mental health challenges were amplified by COVID-19 for many rural communities, revealing limited access to care and services. The strong relationships, robust social networks, and rich and diverse cultural heritage of local communities will help implement solutions. Research can inform how these complex problems may best be addressed, collectively, through productive partnerships involving federal, state, local, and Tribal governments and other entities.

Jigging for tomcods and smelt.
Image credit: Jimmie Lincoln

RECOMMENDATIONS

- Conduct maternal health research that identifies needed care and barriers to care, specific to rural Arctic communities. Ensure that data on maternal mortality among Indigenous women is consistently reported. Develop a better understanding of Alaska Native women's maternal health outcomes through collaborations between Alaska Native communities and other relevant parties.
- Develop innovative solutions to improve health data exchange, share training and expertise in health-related fields, and create a centralized location where detailed information regarding existing health partnerships is archived and accessible.
- Investigate workforce recruitment and retention in rural communities, especially in the health professions. Normal recruitment and retention challenges have been exacerbated by an aging workforce and excessive workloads, and worsened by COVID-19. Information on how to best "grow your own" and to train and retain a local workforce should inform regional workforce development strategies.
- Foster stronger partnerships among public health researchers, local communities, public health organizations, and designers of ventilation systems to address substandard air quality in rural Alaska homes.
- Improve access to research regarding successful methods of language restoration, use, and stability for Arctic Indigenous languages.
- Improve Indigenous participation in Arctic research, and support the creation of equitable pathways for Indigenous leadership in research-related decision-making.

Power poles in Newtok, Alaska. *Image credit: Alaska Native Tribal Health Consortium*

Alaska Native dance fan.
Image credit: Jimmie Lincoln

PROGRESS

» **Telehealth.** The Patient-Centered Outcomes Research Institute has approved $113M in new research funding, of which $50M has been designated for studies focused on chronic care management using telehealth. This new research will help healthcare providers better understand how to leverage the rapid uptake in the use of telehealth during the COVID-19 pandemic to improve care for vulnerable individuals with complex chronic needs. Additionally, the US Department of Health and Human Services invested $8M in a new Telehealth Broadband Pilot Program to expand broadband connectivity in Alaska and in other rural parts of the country where lack of resources is a major barrier to telehealth adoption.

» **Maternal mortality.** In 2018, Congress passed the Preventing Maternal Deaths Act (PL115-344) to address maternal mortality by establishing and supporting state and Tribal Maternal Mortality Review Committees (MMRCs).[30] Existing MMRCs are multidisciplinary committees that convene at the statewide or regional level to comprehensively review deaths of women during or within a year of pregnancy.[31] The goal of the review is to identify and implement recommendations to inform public health and clinical improvements to both reduce deaths and to improve wellness. Making these MMRCs Tribally directed will improve consideration of cultural norms, sensitivities, and concerns that may be important in discussing and reducing maternal deaths.

» **Remote patient monitoring.** Arctic Alaska is a "medical desert" in that it has inadequate access to hospitals, primary care physicians, pharmacies, and other healthcare providers. Emerging technologies, including remote patient monitoring (RPM) of heart rate, blood pressure, and glucose (blood sugar), as well as telemedicine, provide important early intervention for patients in medical deserts for whom care is not readily accessible. Some RPM devices can even be implanted.[32] The benefits of RPM for clinicians include ease of access to patient data, the ability to better manage chronic conditions, lower costs, and increased efficiencies.

A woman gathering berries cleans them of leaves and grass by pouring them into the wind.
Image credit: Jimmie Lincoln

2x

American Indian and Alaska Native women have pregnancy-related mortality rates that are twice the rate of White women.[33]

[30] https://www.congress.gov/bill/115th-congress/house-bill/1318/text?overview=closed
[31] https://www.cdc.gov/reproductivehealth/maternal-mortality/erase-mm/data-mmrc.html
[32] One example is a device that measures pulmonary artery pressure in patients experiencing heart failure. It can interface with the digital platform to inform the patient of his or her status while simultaneously informing members of the care team so they can make decisions on how to manage the patient's health.
[33] https://www.cdc.gov/reproductivehealth/maternal-mortality/pregnancy-mortality-surveillance-system.htm

GOAL 3. Infrastructure

MOTIVATION

Infrastructure supports the function of Arctic civilian and military communities from local to global scales. Applying Arctic-specific technology and innovation advances sustainability in a rapidly changing climate. Such technology must be operable and scalable in extreme conditions. Research is needed to value and increase efficiencies, develop economies of scale, and evaluate and price risk to infrastructure. Technological innovation must be considered and adopted through equitable and ethical engagement with communities to meet local needs, creating infrastructure that is practical and functional. We must also address *human infrastructure*—people to teach, create, operate, and maintain technology—to enable opportunities for sustainable livelihoods, economic growth, self-sustainability, and self-determination. Systems to supply energy, heat, transportation, water, and communications need to be optimized and maintained to improve the quality of life in communities across the Arctic.

Rock revetment in Kivalina, Alaska.
Image credit: John Farrell, USARC

Toolik Field Station, Alaska.
Image credit: Todd Paris, University of Alaska Fairbanks

RECOMMENDATIONS

- Working with communities and local organizations, conduct research to identify mechanisms to create, adapt, maintain, and operate technology that supports built infrastructure. Quantify the resources needed to increase local capacity to meet infrastructure-related innovation and education requirements.
- Conduct collaborative research to expand availability of Arctic broadband and affordable housing and to ensure that human health and infrastructure are incorporated into a "whole-of-government" approach to water and sanitation infrastructure build-out efforts.[34]
- Research methods to modify infrastructure to adapt to changing Arctic environmental conditions in the 144 Alaska Native communities currently threatened.[35] Identify actions to stabilize structures and replace pilings threatened by permafrost thaw, and develop data sets, risk assessments, and adaptation strategies that inform longer-term solutions.
- Seek ways to comply with Department of Defense (DoD) requirements to identify, assess, and develop plans to address installation resilience and environmental risks and threats to assets, infrastructure, and mission by taking steps to provide and adapt assessment tools available in the civilian sector.
- Investigate and value the increased vulnerability of key civil infrastructure to changes in human activity or climate change. Focus on facilities where single points of failure would have large impacts, and develop responses based on modeling and scenario planning. For example, collapse of the Yukon River bridge would interrupt transportation on the Dalton Highway and sever the Trans-Alaska Pipeline, spilling oil into the river.

ARCTIC RESEARCH INFRASTRUCTURE

Arctic research infrastructure is the facilities, resources, and services essential for advancing research and promoting innovation. Recent progress includes NOAA's Barrow Atmospheric Baseline Observatory and NSF funding for the Alaska Geophysics Arctic Observing Network, the Toolik Field Station, and ship-based science technical support on US Coast Guard Cutter (USCGC) *Healy*. In addition to the established Barrow Arctic Research Center, plans exist for an Oliktok Arctic Research Center. Icebreakers capable of accessing all regions of the Arctic Ocean remain an enduring and long-term requirement of the scientific research community.

PROGRESS

» **Aviation research.** Insitu has built unmanned aircraft systems (UAS) optimized for operating in extreme northern environmental conditions. The ArcticX22 exercise demonstrated Insitu's capability to provide surface situational awareness from satellites and remotely piloted aircraft systems operating beyond line of sight.[36] The University of Alaska Fairbanks (UAF) Alaska Center for UAS Integration received $10M in 2022 to expand its staff and scope, the emerging technology it operates, and the variety and complexity of its research projects.

» **Virtual reality training.** The 176th Maintenance Group at Joint Base Elmendorf-Richardson in Alaska is facilitating aircraft maintenance through a new virtual reality training laboratory that provides an interactive interface to maintenance processes without a physical airframe. These technologies may be transferable to training needs in rural communities and remote research installations.

» **Adaptive engineering.** In response to USARC's prior recommendations, DoD's Environmental Security Technology Certification Program solicited proposals on the topic of "infrastructure resiliency Arctic engineering design tool" and funded UAF to develop an Arctic Environmental and Engineering Data and Design Support System[37] and the Cold Regions Research and Engineering Laboratory's Engineering Research and Development Center to update DoD's Unified Facilities Criteria 3-130 (Arctic and Sub-Arctic Construction).

» **Capacity building.** USARC provided funding for the Yukon River Inter-Tribal Watershed Council's "Building Water Resilience in the Yukon River Watershed" in coordination with the Alaska Center for Climate Assessment and Policy. This grant will foster robust internal grant writing skills for future funding growth and assist Tribes in building stronger community resilience to climate change.

» **Subsea fiber.** Custom-made subsea fiber-optic cable will soon extend ~800 miles from Kodiak along the south side of the Alaska Peninsula and the Aleutians to Unalaska. The AU-Aleutians Fiber Project is scheduled to deliver service to the communities of Unalaska and Akutan by the end of 2022. This project will significantly improve telehealth capabilities and high-definition video conferencing.

[34] https://www.congress.gov/bill/117th-congress/house-bill/3684
[35] https://www.denali.gov/wp-content/uploads/2019/11/Statewide-Threat-Assessment-Final-Report-20-November-2019.pdf
[36] https://www.idg.network/arcticx.html
[37] https://uaf-snap.org/project/arctic-eds/
[38] https://americanmadechallenges.org/challenges/inclusiveenergyinnovation/

INCLUSIVE ENERGY INNOVATION PRIZE

Low-income communities suffer from the effects of climate change and pollution more acutely than affluent ones. To address this disparity, the US Department of Energy will fund activities related to climate and clean energy that support, build trust, and strengthen relationships and partnerships with communities facing such challenges. This prize seeks to enable and enhance business and technology incubation, acceleration, and other entrepreneurships and innovations in climate and clean energy technologies.[38]

Wind turbines in Unalakleet, Alaska.
Image credit: Alaska Energy Authority


Image credit: iStock.com/longspringAK

LOCAL – Fisheries in peril: Yukon salmon disaster. In 2021, both king and chum salmon runs dwindled along the Yukon and Kuskokwim Rivers and drainages feeding Norton and Kotzebue Sounds. King salmon have been in decline for the last decade, but in 2021, both summer and fall chum assessment, at around one-tenth of the normal count, caused the State of Alaska to close the salmon fishery on the Yukon, including subsistence harvests that Alaska Natives rely on. In 2022, both the fall chum and coho salmon runs on the Yukon River remained too low to open subsistence harvest. Scientists suspect that climate change is part of the problem, as the rivers and the Bering Sea are warming, resulting in changes in timing of the plankton bloom and the distribution of small invertebrates that the fish eat. To inform an adaptive management approach to fisheries, continued research is needed on the impacts of commercial harvests, competition from hatchery-raised salmon in the ocean, and other factors.

NATIONAL – Wildfires, air pollution, and severe health outcomes. Climate change leads to drought and higher temperatures that make it easier for fires to start and spread, resulting in the release of additional carbon into the atmosphere, which exacerbates warming. Recent research has linked poor air quality, caused by fine particulate matter associated with forest fires, with severe outcomes from COVID-19 and greater risk of lung disease. Particulates were found to reduce pulmonary immune responses and antimicrobial activities, boosting viral loads and inducing chronic inflammation. Pollutants also caused overexpression of a key enzyme receptor that facilitates SARS-CoV-2 entry into cells. Finally, exposure to air pollution has long been known to exacerbate chronic conditions, such as cardiovascular disease, that are associated with poor COVID-19 outcomes.


Image credit: ESA

NATIONAL – Harmful algal blooms. In recent decades, the number and range of harmful algal blooms (HABs) have increased in coastal waters as a result of climate change and other factors such as nutrient pollution caused by humans.[39] The negative impacts of HABs on food security, tourism, local economies, and human health have been documented. HABs present a national threat to human and ecosystem health. In Alaska's Arctic, saxitoxins and domoic acid are the two HAB-related neurotoxins of concern.[40] They cause human paralytic and amnesic shellfish poisoning, respectively, causing sickness and death in wildlife of subsistence importance. As the region undergoes an unprecedented regime shift, there is significant potential for more frequent, larger, and costly HABs of both types.[41]

Impacts of Arctic Warming

Image credit: iStock.com/troutnut

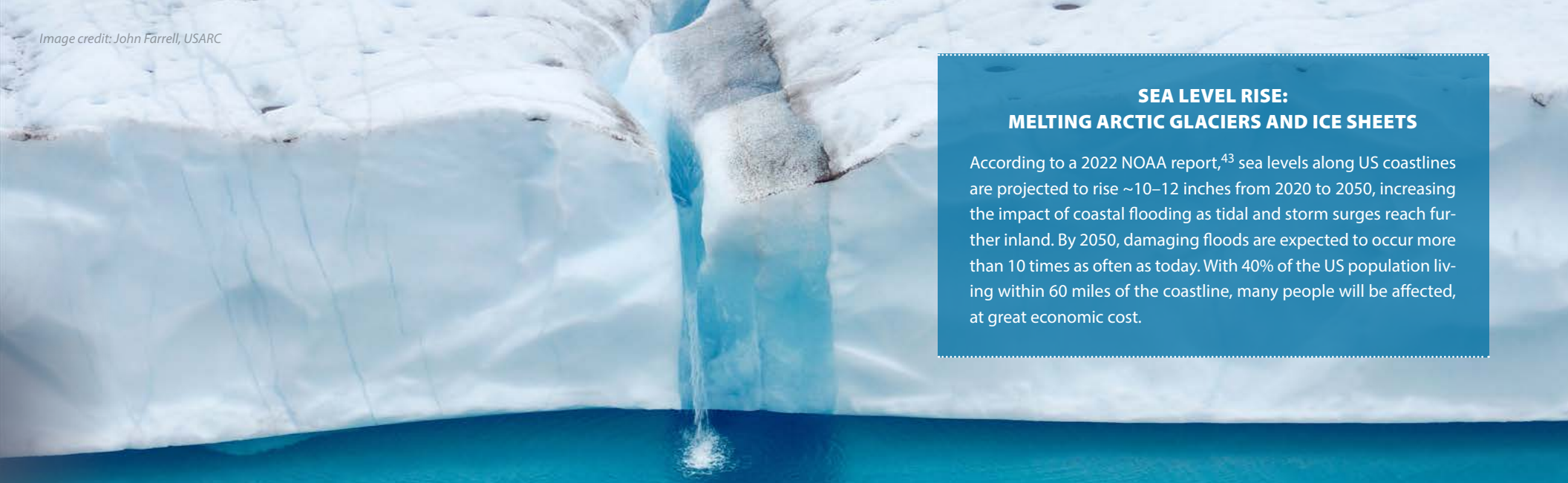


Image credit: John Farrell, USARC

SEA LEVEL RISE: MELTING ARCTIC GLACIERS AND ICE SHEETS

According to a 2022 NOAA report,[43] sea levels along US coastlines are projected to rise ~10–12 inches from 2020 to 2050, increasing the impact of coastal flooding as tidal and storm surges reach further inland. By 2050, damaging floods are expected to occur more than 10 times as often as today. With 40% of the US population living within 60 miles of the coastline, many people will be affected, at great economic cost.

100.4°F

New Arctic temperature record in Siberia, June 2020, reported by the World Meteorological Organization.

GLOBAL – Extreme weather effects on human health. Extreme weather events and ecological change are linked to Arctic warming. The health effects of extreme weather include increased respiratory and cardiovascular disease and food- and water-borne illnesses, and threats to mental health. For instance, a northward expansion of "wet-bulb" conditions—when heat (>88°F) and humidity (>95%) hit a point where evaporation due to sweating no longer works for body cooling—is a possibility unless the current rate of environmental change slows. Such conditions can cause otherwise healthy people to overheat and die. NOAA is supporting the Wet Bulb Globe Temperature Tool[42] that further studies wet bulb conditions.

GLOBAL – Climate change and the insurance industry. Climate-linked issues, such as extreme heat, wildfires, flooding, coastal inundation, and biodiversity loss are impacting the insurance industry. Property and casualty insurers are rethinking their business models and incorporating climate-risk considerations. In 2017, Hurricane Harvey caused $125B in economic damage, and estimates for Hurricane Ian (2022) will exceed that. The poleward migration of such systems was evident when ex-Typhoon Merbok hit western Alaska in late fall 2022. Eight of the nine most costly wildfires in US history (in terms of insured losses) have occurred just since 2017.[44] The projected escalation of climate risk may lead to underinsurance—or to no insurance at all. A consequence of insurance market turmoil due to increased instances of natural disasters is that insurance companies may decrease or deny services to neighborhoods most at risk (bluelining). The end result will include premium loss, higher rates of self-insurance, and an increased demand for disaster relief from the public sector.

Image credit: Jimmie Lincoln

[39] Gobler (2020), https://doi.org/10.1016/j.hal.2019.101731
[40] Anderson et al. (2022), https://doi.org/10.5670/oceanog.2022.121
[41] Anderson et al. (2021), https://doi.org/10.1073/pnas.2107387118
[42] https://convergence.unc.edu/tools/wbgt/
[43] Sweet et al. (2022), https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf
[44] Insurance Information Institute (2022), https://www.iii.org/fact-statistic/facts-statistics-wildfires

GOAL 4. Arctic Economics

MOTIVATION

While the United States has vital interests in the Arctic region, their economics are often difficult to discern. Economic research is essential to inform Arctic policies and decision-making, but few economists focus on the region, partly due to a paucity of data. Economic analysis is a framework for research that cuts across this report's goals, yet we emphasize it here as a stand-alone goal given its significance, growing need, and underrepresentation. Arctic economic analysis can help achieve regional sustainable development and provide a greater understanding of market forces, natural capital, and Indigenous economies.[45] Traditionally, the backbone of the Arctic economy has been government investment and natural resource extraction. Research will help reveal, to Indigenous communities, investors, and governmental regulators, the risk/reward trade-off of sustainable and inclusive economic development of infrastructure (e.g., ports, rail/road) and traditional resources (e.g., fish, minerals, timber, oil, and gas), while expanding non-traditional assets (e.g., green energy sources, carbon sequestration, mariculture, ecotourism, broadband, and international trade) in the transition to an economy with greater emphasis on services and knowledge, evolving technology, and a regulatory environment that emphasizes greenhouse gas accounting and mitigation.

Scientists sorting snow crabs from a bottom trawl sample taken near St. Lawrence Island, Alaska. *Image credit: Karen Frey, Clark University*

RECOMMENDATIONS

- Increase federal support to collect Arctic socioeconomic data, to assess federal investments in infrastructure, and to advance economic research as a framework for crosscutting research,[46] such as on development and well-being.
- Advance "natural capital accounting" and valuation of ecosystem services (the stocks and flows[47] of natural resources and their associated services to people) in the Arctic to inform government, corporate, and consumer decision-making. Such accounting needs to improve consideration of the measure of ecosystems and their services in monetary, physical, and socio-cultural terms, because it impacts supply chain stability and growth stability options.
- In light of the worldwide energy transition, apply "development economics"[48] to appropriate Arctic regions. This includes understanding how and when global efforts to decarbonize energy production and use will affect traditional Arctic economic development, including oil and gas production and refining, mining, electrical generation and transmission, and tourism.
- Investigate opportunities for Arctic economic development, such as carbon sequestration, critical mineral development, and East-West connections, in addition to the North-South ties.
- Advance understanding of Arctic marine operations and shipping by exploring topics such as the evolving economics of the Northern Sea Route and the links to oil, gas, and minerals; the economics and risks of seasonal trans-Arctic shipping for small container ships and bulk carriers; and the economic impacts of Arctic marine safety and environmental protection measures.
- Create an ocean technology test bed to advance mariculture and evolving marine ecosystems. Research topics may include impacts of ocean acidification on crab and salmon, basic observations of mariculture test sites (e.g., oysters and king crab), kelp growing and processing, and affiliated CO_2 removal.

Red Dog Mine, Alaska. *Image credit: John Farrell, USARC*

PROGRESS

» **Blue economy.** The Arctic's blue economy (sustainable economic activities related to the ocean, seas, and coasts) is an underutilized resource with great opportunity. The Alaska blue economy is supported and advanced by nonprofits such as the Alaska Ocean Cluster, the UAF Alaska Blue Economy Center, and the Alaska Mariculture Task Force. The Cluster, supported by the Bering Sea Fisherman's Association and the Department of Commerce's Economic Development Administration (EDA), is a startup accelerator that focuses on innovation and new ocean technologies. They advance projects on precision fisheries, smart buoys, decarbonization, optimal resource utilization, and social equity. As part of the "Build Back Better Regional Challenge," EDA awarded $49M to an Alaska coalition advancing mariculture. The UAF Center provides resources and support for research, instruction, and outreach associated with aquatic resources and ecosystems. It created the nation's only online Blue MBA degree and conducted research at UAF's Kodiak Seafood and Marine Science Center to develop novel fish products and technologies. The Task Force's 2021 report to the Governor consists of a comprehensive plan to boost Alaska's mariculture industry that identifies research and development needs.

» **The Economy of the North – ECONOR 2020.** This Arctic Council report, the fourth since 2006, provides an overview of the circumpolar Arctic economy and its socioeconomic condition, including the traditional production activities of the Indigenous peoples. The report, led by Norway, and supported by the United States and Canada, and the Saami Council, provides statistics and economic analysis, including on the prospects and implications of an Arctic "green transition."

» **Arctic ecosystem services and valuation of natural capital.** Businesses are increasingly addressing their natural capital impacts and dependencies, which require credible and consistent data.[49,50] To better understand the interconnections between the environment and the economy, the White House released a strategy for a US system of natural capital accounting and associated environmental-economic statistics[51] to address the disconnect between our current economic accounts (often summarized as gross domestic product) from the natural world. If these efforts were expanded to the Arctic region, these accounts could be directly applied to business strategic planning, investment decisions, and management of supply chains, operations, and risk.

75%

Between 2013 to 2019, the total distance sailed by ships in the Arctic increased by 75% (from 6.5 million nautical miles to 10.7 million nautical miles).[52]

Container ship in ice-infested waters.
Image credit: iStock.com/Jean Landry

[45] https://alaskaventure.org/wp-content/uploads/2021/09/Transformative-Economics-for-a-Sustainable-Alaska-Document-Final.pdf
[46] https://www.middlebury.edu/institute/sites/www.middlebury.edu.institute/files/2018-09/Arctic Economics Workshop Final Report_0.pdf
[47] Generally, stock refers to any quantity that is measured at a particular point in time, whereas flow is referred to as the quantity that can be measured over a period of time.
[48] Development economics is a branch of economics which deals with economic aspects of the development process in low- and middle-income regions.
[49] https://tnfd.global
[50] https://capitalscoalition.org/capitals-approach/natural-capital-protocol/
[51] https://www.whitehouse.gov/wp-content/uploads/2022/08/Natural-Capital-Accounting-Strategy.pdf
[52] https://pame.is/arctic-shipping

GOAL 5. Research Cooperation

MOTIVATION

As many Arctic issues are circumpolar in nature, and inherently transnational, they are best addressed by international research cooperation. Such cooperation is complex and is ideally followed by coordination and collaboration occurring at sub-national and regional scales, and among multiple forms of government (e.g., federal, state, local, and Indigenous). Cooperation, which depends greatly on internet access, promotes the sharing of resources, knowledge, ideas, and data. It promotes recognition of mutual values, trust, transparency, honesty, equity, objectivity, normative behavior, and soft power diplomacy. Geopolitical tensions may impede cooperation, but these ebb and flow, and ultimately the demand for knowledge reignites cooperation. Cooperation and co-production of knowledge that are consistent with Indigenous values, rights, and protocols will result in a more genuine collective effort to create greater understanding about the Arctic.

USCGC *Healy* sits alongside an ice floe to allow science operations. *Image courtesy of Microcosm Film, The Hidden Ocean 2016: Chukchi Borderlands*

RECOMMENDATIONS

- To encourage greater participation of US Arctic researchers in international research efforts, such as "Horizon Europe," one of the world's largest research programs, the US government and the European Union should consider expanding cooperative agreements.
- Accelerate progress in developing an international plan for the "Joint Program of Scientific Research and Monitoring," to be established by June 2023, as per the Central Arctic Ocean Fisheries Agreement that entered into force in 2021.
- Establish or expand the mission of an existing "University Affiliated Research Center" to focus on Arctic-related research, development, engineering, and technology capabilities relevant to the Department of Defense and complementary to the research conducted by the Ted Stevens Center for Arctic Security Studies.
- Researchers working with Inuit should abide by a new standard[53] in international engagement with Inuit released in June 2022 by the Inuit Circumpolar Council. This set of guidance and directives are designed to increase the chance of achieving shared goals and improving the quality of research.
- Planning needs to begin now to ensure continued and enduring access to all regions of the Arctic Ocean via icebreakers equipped with the modern scientific tools and enhanced capabilities necessary to meet US research requirements. The Commission recommends adherence to the 2022 *National Strategy for the Arctic Region* guiding principles of a "whole-of-government" approach and "planning for long lead-time investments." The authorizing language on icebreakers in the Fiscal Year 2023 National Defense Authorization Act[54] is encouraging, and success will require funding, through appropriations, and thoughtful implementation. The Arctic research community will need to engage, and remain so, throughout the process.

42nd

Alaska's ranking among states regarding internet coverage, speed, and availability.[55]

Arctic fox ("Archie") at Thule, Greenland.
Image credit: John Farrell, USARC

Ray Waska, Peter Moore, and Mark John share aspects of lived tradition for inclusion in the Yup'ik Atlas.[56]
Image credit: Ann Fienup-Riordan

PROGRESS

» **Awareness of marine scientific expeditions.** To increase transparency and communication about plans for marine scientific research in Alaska waters, IARPC has collected and publicly distributed information for expeditions that consists of a description of the research and science goals, the federal sponsor, and the key research and operational personnel and their affiliations, dates, ports, vessel, routes and locations, point of contacts, website, and data repositories.

» **Including Indigenous oral teachings.** "Personal communication" has long been the traditional citation in scientific publications, but does not appear in reference lists, and is a poor tool for capturing the richness of the contributions of Indigenous Elders and Knowledge Keepers. A new citation template[57] for oral teachings was developed.

» **75 years of Alaska Native contributions to science.** The year 2022 marked the 75th anniversary of the founding of the Naval Arctic Research Laboratory at Point Barrow, renowned for accomplishments and contributions to Arctic science that would have been impossible without Iñupiat sharing of knowledge. The Office of Naval Research no longer operates the lab, which is now the site of Iḷisaġvik College, Alaska's only Tribal college, and the Barrow Arctic Research Center and the Barrow Environmental Observatory, managed by UIC Science, a business unit of the Ukpeaġvik Iñupiat Corporation, which continues to support Arctic research.

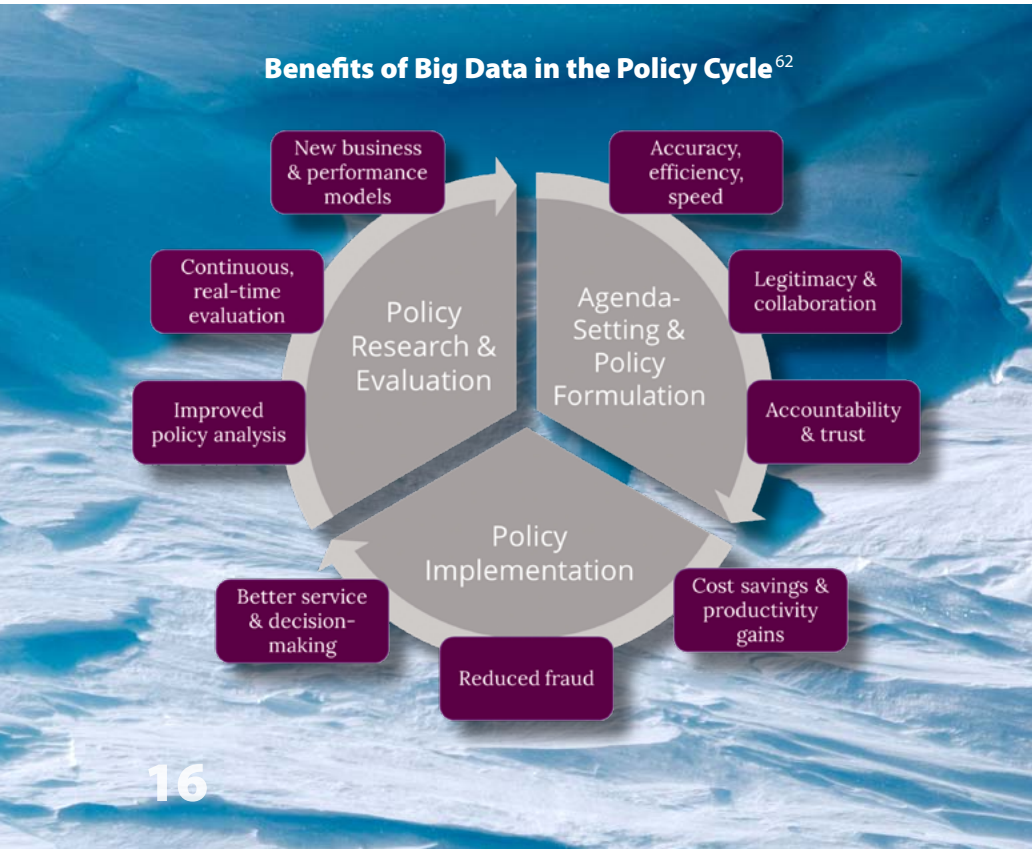
» **Arctic night.** The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) successfully concluded a year-long, international, $154M expedition in the Central Arctic Ocean in 2020 to study the complex and poorly known processes at the top of the world to better inform global climate models and improve climate projections. Initial results are in the Pangaea data publisher.[58]

» **Tracking animal movement.** The Arctic Animal Movement Archive (AAMA) is a collection of studies containing animal movement used to better understand how environmental and climate changes impact animal migrations and behaviors. The results inform wildlife management and conservation, ecosystem monitoring, and remote sensing. AAMA achieved its objective to network scientists and promote their cooperation as the effort involves researchers from over 100 organizations, across 17 countries.

[53] https://www.inuitcircumpolar.com/news/inuit-circumpolar-council-establishes-new-standard-in-international-engagement-with-the-release-of-circumpolar-inuit-protocols-for-equitable-and-ethical-engagement/
[54] P. Law 117-XX, the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023, see Title LIX – Other Matters, Subtitle B – Science, Space, and Technology Matters, Sec. 5912. Reports on Arctic research, budget, and spending
[55] https://broadbandnow.com/Alaska
[56] https://eloka-arctic.org/communities/yupik/atlas/
[57] https://kula.uvic.ca/index.php/kula/article/view/135
[58] https://www.pangaea.de/?f.project%5B%5D=MOSAiC

Crosscutting Theme: Data Analytics and Informatics

Rapid technological advances in data analysis, including machine learning, artificial intelligence, and big data, promise to transform the production of Arctic knowledge by enabling novel, highly efficient ways to plan, conduct, disseminate, and access research.[59,60] These capabilities can provide data and time-conscious evaluative frameworks that emphasize evidence-based and inclusive decision-making and broad-based, long-term cost-benefit analytics at critical policy-making junctures.[61,62] They can also dramatically improve the ability of the Arctic research community to provide scientific knowledge that can be used to solve specific and complex problems. Some of the advantages of using a big data approach for informing public policy are highlighted in the figure below. Informed and effective approaches to Arctic challenges often require cross-disciplinary, multiscale data and analyses and are found throughout a broad spectrum of themes, including policy, security, community sustainability, economic development, and environmental stewardship. For example, to understand the rapid changes in the Arctic, compatible time-series data are needed for observational research, modeling, prediction, and multidisciplinary integration efforts.



This transformation will require:

- Broad-based collaboration, commitment, and investment to improve the quality, management, and interoperability of Arctic data sets. Proper life-cycle data management encourages reuse of the data and therefore lowers long-term costs while increasing the credibility of derived interpretations and products.[63] While governmental research organizations typically have requirements and policies, similar standards may not be applied for data gathered by the private sector and nongovernmental agencies, making it challenging to assess use and integrate that data with government data.[64]
- Investment in quality control and assessment of data.
- Use of standardized metadata schemas and effective relational database design.
- Wide acceptance and application of open access provisions, which leverage investment, making data and published information easier to locate, reproduce, and reuse. This also provides transparency in acquiring and analyzing the data, thereby ensuring the scientific integrity of data and products.[65]

[59] https://plato.stanford.edu/entries/science-big-data/#BigDataRiskEthiDataScie
[60] Andersson et al. (2021), https://doi.org/10.1038/s41467-021-25257-4
[61] Arinder (2016), https://doi.org/10.1111/puar.12572
[62] Pencheva et al. (2020), https://doi.org/10.1177%2F0952076718780537
[63] https://www.usgs.gov/office-of-science-quality-and-integrity/fundamental-science-practices
[64] Davies et al., eds. (2019), https://www.idrc.ca/en/book/state-open-data-histories-and-horizons
[65] https://www.usgs.gov/office-of-science-quality-and-integrity/fundamental-science-practices
[66] https://public.wmo.int/en/media/news/arctic-passion-seeks-improve-observing-systems
[67] https://www.arcticobserving.org
[68] https://arctic.noaa.gov/Arctic-News/ArtMID/5556/ArticleID/386/United-States-Arctic-Observing-Network
[69] https://arcticpassion.eu
[70] https://www.adiwg.org/
[71] https://www.earthobservations.org/
[72] Wilkinson et al. (2016), https://doi.org/10.1038/sdata.2016.18
[73] Carroll et al. (2020), http://doi.org/10.5334/dsj-2020-043
[74] Zhu et al. (2019), https://doi.org/10.1016/j.rse.2019.02.016
[75] Wulder et al. (2012), https://doi.org/10.1016/j.rse.2012.01.010

RECOMMENDATIONS

- Invest in Arctic-specific open-source public-private data collaboratives, across sectors, to exchange data and analytical approaches.
- Further define data and metadata standards for geodata and reports provided by the private sector to regulatory agencies. Clearly define the confidentiality terms and conditions of submitted data and require that the data be provided free of charge to open-source data warehouses.
- Provide the cohesion needed to improve data access and usability in existing Pan-Arctic observing networks.[66]
- Build on the significant advancements that have been made through national and international coordination efforts for remote-sensing data by SAON[67] (including US-AON[68], PASSION,[69] ADIwg,[70] and GEOSS[71] Pan-Arctic observing networks) to identify key gaps and improve access and usability.
- Increase government agency efforts to capture historical Arctic data not available or compatible with modern data sets (e.g., "data rescue"). Historical observational data are often extremely limited, but are critical for developing baselines, understanding rates of change, and back-casting models and projections.
- Implement the use of the FAIR Data Principles[72] and the CARE Principles[73] in general, and especially when engaging with Indigenous peoples in open data decision-making.

LANDSAT: HISTORICAL EXAMPLE OF THE VALUE OF FREE OPEN-SOURCE DATA POLICY

In 2008, the US Geological Survey changed its policy and provided free and open access to all Landsat data, resulting in numerous downloads of imagery and a rapid expansion of science and operational applications serving government, the private sector, and civil society. This policy change demonstrated the value of open data access and encouraged adaption of similar policies elsewhere, such as the European Copernicus Program.[74] Open access also increases international collaboration to meet the Earth observing needs.[75]

Landsat 8 image of the Yukon-Kuskokwim Delta, where the Yukon River spills into the Bering Sea along the west coast of Alaska. *Image credit: NASA Earth Observatory*

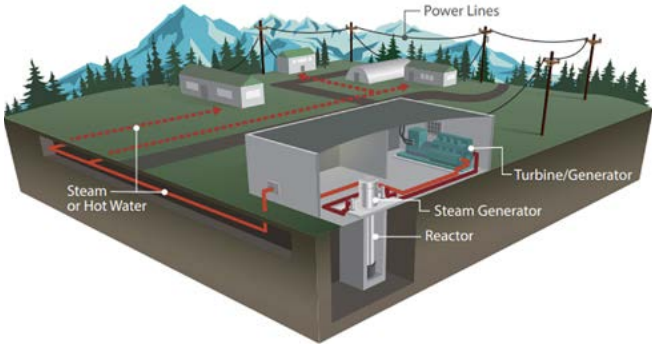
Emerging Topics

Electric vehicles and batteries. In August 2022 an "Arctic Road Rally" of 10 electric vehicles (EVs) was held to showcase their potential in Alaska. Recent incentives and improvements in battery technology result in longer EV range, faster charging, less range degradation, and a lower cost. To further improve electrical performance in extremely cold Arctic conditions, researchers[76] have replaced the traditional graphite anode in a lithium-ion battery with a bumpy carbon-based material that maintains its rechargeable storage capacity down to –31°F. To improve the anode's charge transfer capabilities, researchers modified the surface structure by creating 12-sided carbon nanospheres with bumpy surfaces. When this technology moves from experimental to operational, it will have a great impact on EV viability and battery use at extremely low temperatures. *Image credit: Tim Leach*

Tourism. Arctic tourism has increased dramatically due to media attention, marketing efforts, increased access, and a sense of "last chance" or "bucket list" sightseeing. While some see tourism as a sustainable form of development that helps diversify the economy, others express concern about harmful effects on the environment and the lives of Arctic residents. Recently funded research on the impact of Arctic cruise ships,[77] which have increased by 35% between 2013 and 2019,[78] is examining the challenges and opportunities of tourism. Information on the ways in which cruise ships impact coastal communities will inform stakeholders and rightsholders so they may optimize outcomes. The Indigenous Tourism Association of Canada[79] and the Alaska Travel Industry Association[80] are examples of sustainably designed tourism. *Image credit: iStock.com/virsuziglis*

Archaeology. During the last ice age (~19,000 to 27,000 years ago) humans arrived in the Americas from Siberia, which had been inhabited since at least 40,000 years ago.[81,82] Genomic analyses reveal the history of the peoples, but their genetic and cultural diversity remain poorly known. In light of the ongoing debate on how many "waves" of migration led to human populations in the Americas, more work is needed to understand population structures and environmental conditions in the Siberian refugia and dispersion patterns in the Americas. Climate warming contributes to the "emerging" urgency of this topic, as thawing permafrost and coastal and riverine erosion are exposing and eroding archaeological sites throughout the Arctic, such as in Nunalleq, Alaska.[83] *Image credit: US National Park Service*

Aquaculture. While aquaculture currently supplies nearly half of the world's supply of fish and shellfish,[84] this percentage will likely increase as research in genomic technologies accelerates breeding of improved strains. Atlantic salmon farming generates annual sales of $18B, and breeding results in disease-resistant fish that grow twice the rate of wild fish. Concerns about fish farming (disease transmission to wild stocks, parasites, and pollution) endure, and salmon farming remains illegal in Alaska. However, mariculture farming of kelp, king crab, shellfish, and other species are encouraged by the State of Alaska,[85] which also calls for research on seaweed genetics, identification of the genetic structure of indigenous stocks, and increasing mariculture research capacity. In a complementary effort, NOAA supports research in crab enhancement, kelp genetics, herring and kelp interactions, and ecosystem services provided by aquatic farms. *Image credit: NOAA Fisheries*



Small-scale nuclear power. In light of the benefits of nuclear power, such as decarbonized energy, its feasibility in the Arctic is receiving closer attention. Russia's first floating nuclear power plant began providing heat and power in Chukotka in 2019, and several more plants, jointly constructed with China, are in progress. The US Air Force intends to have a nuclear microreactor power plant, capable of producing up to 5 MWe, at Eielson Air Force Base in Alaska by 2027. Governmental, industry, and university research efforts, including those of the Department of Energy[86] and the Nuclear Energy Working Group at UAF's Alaska Center for Energy and Power, are considering the use of small-scale nuclear power in the Arctic, focusing on resilience, reliability, safety, economics and financing, licensing, siting, permitting, other regulations, and a national strategy for nuclear waste disposal. *Image credit: Alaska Center for Energy and Power*

Drones. Drones are revolutionizing Arctic research as they enable scientists access to remote regions easily, safely, and inexpensively. Their use will be improved by additional research on control systems that direct flights, on ways to prolong battery power, which is particularly critical in cold climates, and on developing data processing tools. Reconsideration of regulations is also needed to avoid hindering scientific research, such as tracking Arctic snow melt.[87] UAF's Alaska Center for Unmanned Aircraft Systems Integration (ACUASI), which focuses on Arctic and sub-Arctic regions, is one of the top drone research programs in the country. A 700-mile-long dedicated airspace (the "Warning Area") at Oliktok Point, Alaska, under the stewardship of Sandia National Laboratories, remains an ideal opportunity for further research. *Image credit: AF/GI photo by Daniel Walker*

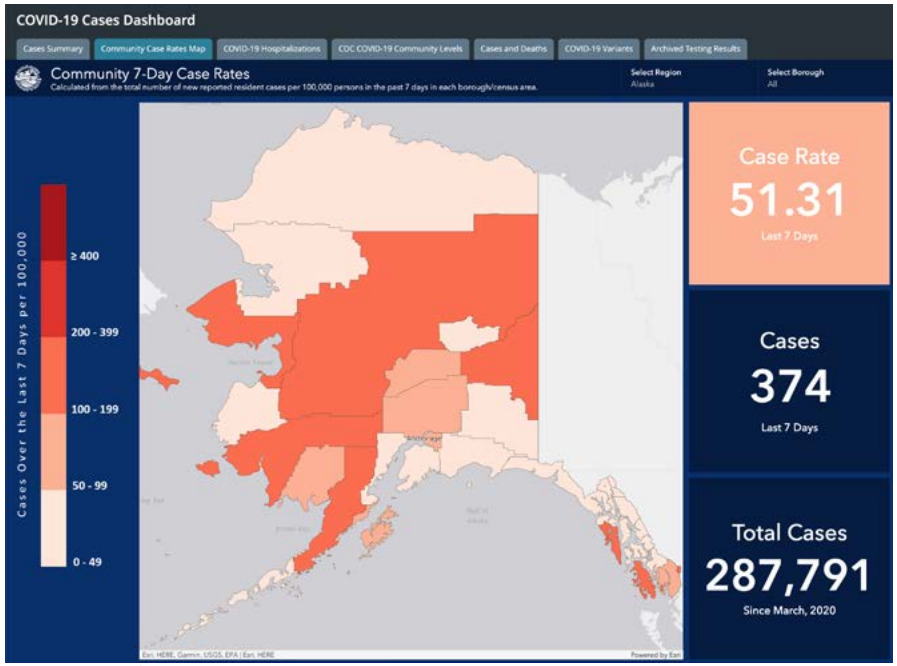
76 Lu et al. (2022), https://doi.org/10.1021/acscentsci.2c00411
77 https://www.arcticcruisetourism.org
78 https://www.arctic-council.org/news/as-arctic-marine-tourism-increases-how-can-we-ensure-its-sustainable/
79 https://indigenoustourism.ca
80 https://www.travelalaska.com
81 Becerra-Valdivia et al. (2020), https://doi.org/10.1038/s41586-020-2491-6
82 Flegontov et al. (2020), https://doi.org/10.1038/s41586-019-1251-y
83 Hillerdal et al. (2019), https://doi.org/10.3368/aa.56.1.4
84 https://www.fao.org/3/ca9229en/ca9229en.pdf
85 https://afdf.org/asset/635154a1246bd/Mariculture-Task-Force-Report-to-Gov-Final-compressed.pdf
86 https://www.energy.gov/sites/default/files/2022-11/DOE_Arctic_Strategy_202211_1.pdf
87 Coops et al. (2019), https://doi.org/10.1038/d41586-019-02474-y

COVID-19: Impacts and Opportunities

COVID-19 continues to have tremendous and disparate impacts in the Arctic, especially in rural villages, which require health interventions that are culturally competent and regionally relevant.[88]

The pandemic has also significantly affected field- and community-based Arctic research. Scientists' efforts to observe and collect data and samples were generally halted during the pandemic due to travel restrictions and academic and agency policies. Furthermore, to avoid the spread of the disease to Indigenous communities or within their own research teams, many field programs were canceled. The resulting data gaps, from 2020 through 2022, especially in long-term series of climate and environmental change, are unfortunate, as they adversely impact scientific understanding.

Uninterrupted projects generally involved local partners or were co-produced with local representatives who filled the void by collecting data and samples and by monitoring scientific sensors and equipment. The willingness and ability of community members to collaborate during the pandemic resulted in new approaches to community research partnerships.



Total COVID-19 cases in Alaska (accessed December 22, 2022).[91]

Opportunities for early-career scientists became far more limited by COVID-19 than for established researchers. Many graduate students could not collect the data necessary to complete their doctoral projects and some abandoned academia for other employment. There was also a dearth of postdoctoral research opportunities, along with greater competition from additional applicants (including established researchers), due to overall job loss and furlough.[89]

The US Arctic research enterprise should:

- Establish additional opportunities for early career researchers to sustain a strong and vibrant research community.
- Increase federal investment in Arctic research, fulfill climate change commitments, and bolster US excellence to implement goals in the US *National Strategy for the Arctic Region*, in light of advances by China, other Asian countries, and the European Union.
- Support a broader, localized science infrastructure network, along with greater emphasis on co-production, Indigenous leadership in research, inclusion of Indigenous Knowledge, and equitable access to educational opportunities.
- Collaborate with local representatives to ensure compliance with established health and contact protocols[90] and to develop best practices for safe travel and research.
- Design and adapt to virtual platforms, as appropriate, to avoid participation bias. Better understand the cost of internet access in rural communities to inform and justify funding requests.
- Consider culturally appropriate facilitation and compensation for Indigenous Knowledge and time.
- Identify and share existing data and samples and consider data ownership, especially by Indigenous entities.

88 Ward et al. (2022), https://doi.org/10.15585/mmwr.mm7122a2
89 Forrester (2021), https://doi.org/10.1038/d41586-021-01861-8
90 https://www.inuitcircumpolar.com/news/inuit-circumpolar-council-establishes-new-standard-in-international-engagement-with-the-release-of-circumpolar-inuit-protocols-for-equitable-and-ethical-engagement/
91 https://experience.arcgis.com/experience/af2efc8bffbf4cdc83c2d1a134354074/

THE US ARCTIC RESEARCH COMMISSION

The US Arctic Research Commission (USARC) is an independent federal agency created by the Arctic Research and Policy Act of 1984 and assigned specific duties therein. The Commission is a presidentially appointed advisory body supported by staff in offices in Arlington, Virginia, and in Anchorage, Alaska. In addition to establishing the goals in this report, the Commission develops and recommends an integrated national Arctic research policy and builds cooperative links in Arctic research within the federal government, with the State of Alaska, with Tribes and ANOs, and with international partners. The law also requires the Commission to review the Arctic research budget "crosscut" in the President's annual budget request and report to Congress on how the crosscut adheres to the five-year Arctic Research Plan produced by the Interagency Arctic Research Policy Committee (IARPC).

USARC plays a significant role in planning and implementing international Arctic Science Ministerial meetings and other international Arctic science initiatives and has been involved in the Arctic Council since its inception. USARC serves as the "competent national authority" in implementing the legally binding "Agreement on Enhancing International Arctic Scientific Cooperation" (see https://www.arctic.gov/agreement-on-enhancing-international-arctic-scientific-cooperation/).

USARC is a statutory member of the North Pacific Research Board and the North Slope Science Initiative. USARC is also a member, participant, liaison, or observer on the Interagency Arctic Research Policy Committee, the Interagency Coordinating Committee on Oil Pollution Research, the National Ocean Council, the Extended Continental Shelf Task Force, the Study of Environmental Arctic Change (SEARCH), the Civil Applications Committee, the Scientific Ice Expeditions Interagency Committee (Navy submarines), the Arctic Icebreaker Coordinating Committee of the University National Oceanographic Laboratory System, the Alaska Ocean Observing System, the Department of State's Arctic Policy Group, the Arctic Research Consortium of the United States, the International Permafrost Association, and the Ted Stevens Center for Arctic Security Studies.

HOW THIS REPORT WAS COMPILED

To achieve the duties assigned in the Arctic Research and Policy Act, the Commission biennially recommends key goals and objectives ("Goals Report") for the US Arctic Research Program Plan. To prepare this report, the Commission sought input from scientists and other researchers, holders of Indigenous Knowledge, policymakers, and the general public in Alaska and throughout the United States, and in the growing number of nations with Arctic interests. The Commission also cosponsors meetings, workshops, and other studies and initiatives to share and disseminate information and to inform USARC's perspective.

WORKING GROUPS

USARC initiated and coordinated three working groups of Federal, State, Tribal, academic, non-governmental, and other entities to develop research objectives critical to Arctic residents. USARC has paused the work of two groups because new federal- and university-established initiatives have been created to continue the work. More information on these groups can be found at https://www.arctic.gov.

- **The Alaska Rural Water and Sanitation Working Group (ARWSWG, active)** focuses on maximizing the health benefits of in-home water and sanitation services in rural Alaska by promoting R&D on innovative approaches to water and wastewater services, increasing human capacity in villages, developing strategies to allocate capital funds through community-level engagement, and supporting research on the connections among climate, water, and human/environmental health.
- **The Arctic Renewable Energy Working Group (AREWG, archived)** supported research on renewable and efficient energy systems in rural Arctic communities. Efforts focused on renewable energy/energy efficiency strategies aimed at reducing dependence on costly diesel fuel to heat homes in Arctic villages.
- **The Arctic Mental Health Working Group (AMHWG, archived)** promoted research on the mental and behavioral health of Arctic populations. The group's mission was to strengthen systems of care to prevent suicide and improve mental health in the circumpolar North via the promotion of Indigenous Knowledge, research, and evidence-based early intervention and primary prevention efforts.

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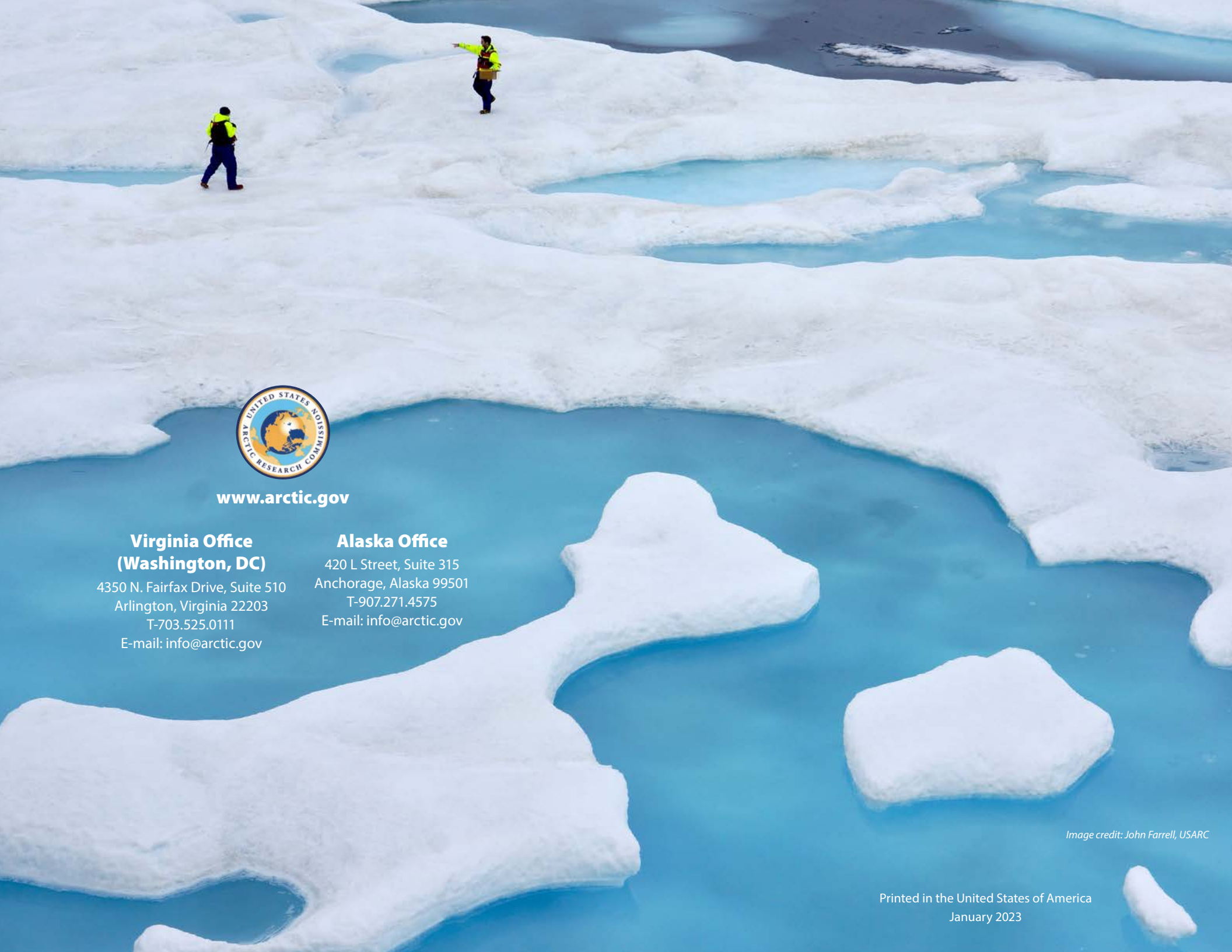

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