NNA-CO

Arctic Observing Systems & Technology Convergence Working Group

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Activities Report

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2025 NNA Annual Community Meeting

Executive Summary

The Navigating the New Arctic (NNA) Convergence Working Groups brought together diverse expertise to collaboratively address urgent challenges in the Arctic. The Arctic Observing Systems & Technology Convergence Working Group (AOST-CWG), co-led by Howard Epstein, Louise Mercer, and Casey Brayton, focused on strengthening Arctic observing systems through inclusive, low-cost, and community-based approaches that recognised both technological innovation and Indigenous Knowledge Systems.

The group's work aimed to advance understanding of open-source technologies for community-based research, identify environmental data needs for infrastructure planning, and support skill development among researchers using community-led monitoring approaches. Activities included supporting both Indigenous and non-Indigenous early-career researchers to attend international conferences, as well as contributing to the development of on-the-ground methods for community-based monitoring. Emphasising that Indigenous Knowledge Systems are observing systems in their own right, the group advocated for support for Indigenous-led research from the proposal stage through to data ownership and dissemination.

Throughout its work, the AOST-CWG highlighted the importance of investing in training, local leadership, and long-term relationships alongside robust low-cost monitoring infrastructure. The group also called for ethical protocols and cultural competency training to be embedded across all Arctic research, not only for early-career researchers but for principal investigators and institutions as well. It stressed the need for coordination across projects, disciplines, and borders to reduce redundancy and research fatigue, and promoted open-source technologies that are modular, repairable, and co-designed with the communities that use them.

The Arctic is changing rapidly, and the group concluded that the pace of innovation, collaboration, and ethical commitment must rise to meet that change. The AOST-CWG leaves behind a call to action for partners across disciplines, countries and knowledge systems to continue building a resilient and just Arctic data future.

Definitions

Term	Definition
CBM	Community-Based Monitoring – Environmental or social monitoring conducted by local community members, often involving Indigenous peoples, to collect data relevant to their environment and wellbeing.
CBR	Community-Based Research – A collaborative research approach that actively involves community members and learns from diverse knowledge systems throughout the research process to ensure relevance and respect.
Stakeholder	Any individual, group, or organization with an interest or concern in a project, policy, or research outcome.
Rights-holder	Individuals or groups, particularly Arctic Indigenous Peoples, who possess recognized legal or customary rights related to land, resources, knowledge, or governance in the Arctic context.
Co-production	As defined by Yua et al., co-production involves equitable and collaborative partnerships where knowledge and expertise are shared among researchers and community members throughout the research process.
FAIR	Principles ensuring data are Findable, Accessible, Interoperable, and Reusable, promoting transparency and usability in research data management.
CARE	Principles focused on Collective benefit, Authority to control, Responsibility, and Ethics in Indigenous data governance, emphasising respect and rights of Indigenous communities.
TRUST	Principles designed to build confidence in data repositories, standing for Transparency, Responsibility, User focus, Sustainability, and Technology, ensuring trustworthy data stewardship.

Overview

The Navigating the New Arctic (NNA) Convergence Working Groups (CWGs) bring together diverse experts and perspectives that engage with the Arctic to work together towards newly formed and shared goals. The Arctic Observing Systems & Technology Convergence Working group (AOST-CWG) was co-led by one Experienced Co-Lead (Howard Epstein) and two Early Career Fellows (Louise Mercer and Casey Brayton).

In the Arctic, data and observing systems are critical infrastructure, and Indigenous Knowledge Systems are observing systems. Our group raises awareness of the importance of low-cost, open-source, and community-based methods of data collection for comprehensive observation systems in the Arctic. We hope to drive progress forward on this topic.

Our goals as a working group centered around three major topics:

1) Advance understanding of low-cost and open-source technologies that can be used in community-based and citizen science research approaches.
2) Identify environmental data requirements for infrastructure development (e.g., relocation/managed retreat from erosion and storm recovery) and appropriate data collection methods.
3) Support development of the skills required for researchers applying community-based monitoring/observing approaches in the Arctic.

Foundational Principles for Arctic Observing Systems

Critical Infrastructure: *Observing systems are essential infrastructure, akin to roads and utilities, for understanding environmental change and informing decision-making.*

Indigenous Knowledge Systems Are Observing Systems: *Indigenous-led observations should be recognized and elevated as foundational components of Arctic monitoring frameworks.*

Support Existing Efforts: *"Reinventing the wheel" should be avoided; instead, provide support and visibility to groups already conducting Arctic observational research, including Indigenous-led initiatives.*

Working Group Activities

As a group we have held two workshops at international events: the Navigating the New Arctic Annual Community Meeting 2024 (Washington DC) and the Arctic Observing Summit 2024 (Edinburgh). Each workshop centered on the theme:

The use of low-cost and open-source technologies and community-based monitoring approaches: Emerging areas, scaling, and training requirements

Navigating the New Arctic Annual Meeting Session

This session explored the potential for low-cost and open-source technologies to aid data collection in areas of emerging research, including infrastructure development (e.g., relocation/managed retreat from erosion and storm recovery) and changes to the marine environment. We discussed what appropriate data collection methods look like with regard to feasibility and collaboration across cultural, country, and disciplinary boundaries. Through this workshop we highlighted the value of interdisciplinary approaches to environmental community-based monitoring (CBM), which could support progression towards more inclusive research processes. We identified what support was required for researchers looking to use these approaches. Focus was placed on identifying needs for key roles within interdisciplinary teams, including Early Career Researchers, project leaders, and Indigenous team members.

Arctic Observing Summit Session

This breakout session emphasized the importance of low-cost, open-source, and community-based methods of data collection for comprehensive observation systems in the Arctic. The goal of this session was to pull attendees from diverse disciplines, career stages, and knowledge systems together to shed light on existing technologies and avenues for deploying and scaling low-cost technologies for the broadest use by researchers, stakeholders, and rights-holders. In the first half of the breakout session, we heard from four Early Career Researchers (ECRs) who highlighted challenges and opportunities associated with the future of emerging low-cost technologies and community-based research. Themes discussed included innovative observing systems, the need for affordable, durable, and easily fixable sensors that could be renewable-powered wherever possible, and the need for youth and community engagement in collaborative, solution-oriented research. Experiences of the ECRs attending the event can be read on the Arctic Observing Systems and Technology Working Group Website.

In each workshop, we deployed breakout groups to address three key questions:

1. *In what areas of emerging research were new methods of low-cost, open-source, and community-based methods most needed?*
2. *What were appropriate data collection methods?*
3. *What were the training requirements for researchers to effectively and ethically scale up environmental observations within Arctic communities?*

The following sections present the discussion that emerged in response to the guiding questions outlined. They include a series of recommendations, as well as an overview of the key challenges and opportunities identified through this process. This content is intended to clarify the main outcomes of the discussion and to highlight practical actions and insights to inform next steps.

Emerging Areas For Low-Cost, Open-Source Technology

Emerging research areas span an increasingly diverse set of scientific and community needs. These include permafrost, tundra, and hydrological monitoring (e.g., pond water levels, temperature, and conductivity), analysis of infrastructure-climate interactions in Arctic settlements (e.g., shading effects on snowmelt, insulation zones), nearshore lake dynamics, such as mixing and biogeochemical cycling, and urban air quality monitoring. Additional focus areas identified included improved remote sensing for snow, vegetation, and building infrastructure; sensors for weather and sea ice; and real-time ecosystem indicators for caribou, fish, and other key subsistence species. Data needs also span public health, energy usage, and indoor environments—highlighting the need for cost-effective multi-sensor arrays.

Environmental & Climate Monitoring:

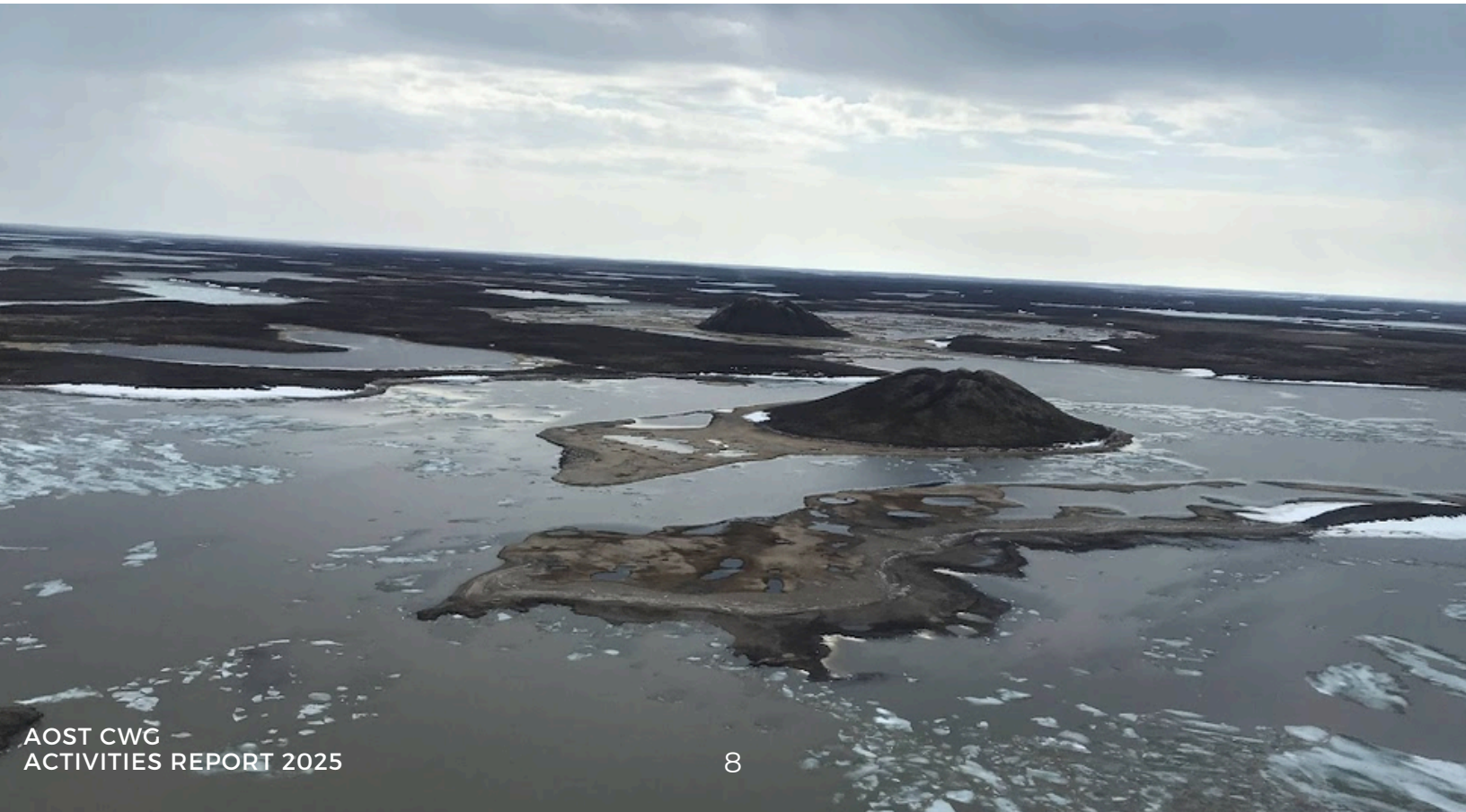
- Sensors for permafrost, ice, weather, ground/air/soil temperature, and hydrology.
- Affordable wave buoys and hydroballs for coastal and inland water monitoring.
- Low-cost DNA sequencing devices for microbial and plant research.
- Meteorological sensors for fine-scale urban/rural climate observations.

Community-Driven Monitoring Tools:

- Phone apps for marine mammal disturbance and hunter-trapper harassment reporting.
- Time-lapse cameras for sea ice break-up and environmental changes.
- Flood stakes for erosion monitoring.
- Bathymetry monitoring devices attached to local boats and tied into pre-existing infrastructure (fish finders).

Participants strongly emphasized the need for mobile applications tailored to community-identified priorities such as marine mammal tracking, documenting harassment of hunters, or mapping vessel traffic. Open-source platforms that facilitate real-time, offline data logging and visualization are particularly important in areas with limited internet access. Beyond sensor design, there is a need for investment in data stewardship infrastructure that supports both storage and long-term access.

There was also an emphasis on the need to invest less in hardware and more in labor, highlighting that while sensors may be inexpensive, the cost for maintaining, analyzing, and contextualizing their data requires skilled human resources. The group called for training on tools like Arduino, a small device used to control sensors and electronics, and Raspberry Pi, a tiny computer that can run programs and connect to the internet; they also supported the right to repair movement and pan-Arctic coordination to advocate for technology manufacturers to create Arctic-relevant tools. There is also a pressing need to address challenges in defining what “low-cost” means in practice. For example, does it refer to purchase cost, cost per use, or lifetime costs including repair and training?



Appropriate Data Collection Methods

Appropriate data collection methods must prioritize non-intrusive practices that respect both the people and the land. Participants emphasized the importance of selecting methodologies that are minimally invasive, co-developed with communities, and ethically grounded. Key concerns included extractive research practices, such as animal collaring or intrusive sonar deployments, especially when communities are not fully informed or consulted. Ethical practices must move beyond obtaining permits and toward fostering reciprocal relationships and transparency.

Principles & Practices:

- **Minimally invasive** and **non-intrusive**, especially on private property and in homes.
- Notify communities about research plans **before** arriving.
- Implement **FAIR** (Findable, Accessible, Interoperable, Reusable), **CARE** (Collective benefit, Authority to control, Responsibility, Ethics), and **TRUST** (Transparency, Responsibility, User focus, Sustainability and Technology) Principles.
- **Collaborate, not compete.** Utilize existing coordination organizations/networks like SAON ROADS, ELOKA.
- **Clarify the purpose of data collection** ("Why are we collecting these data?") to avoid research fatigue (Phase II SAON ROADS).

Participants stressed the importance of designing protocols that are simple, repeatable, and tailored to the specific cultural and ecological context of each community. Metadata standards must be clearly defined and explained. Collecting unnecessary or duplicative data was flagged as an ongoing issue, leading to research fatigue and resource exhaustion. Thus, coordination between research teams—especially in hotspots where numerous studies are conducted—is essential to ensure efficient and ethical data collection.

Data governance was a central concern. While open data may not be appropriate in all cases, documentation that the data exists and who controls it is crucial. Frameworks such as CARE, FAIR, TRUST, and OCAP (Ownership, Control, Access, Possession) were discussed as foundational. This also means investing in data management from the outset of a project, not just after data is collected.

Digital tools must be usable offline and designed for local infrastructure, considering energy requirements and user interfaces. Participants recommended protocols to ensure communities can see and use the data in real time or near real time, using participatory methods such as printed maps, public dashboards, or physical monitoring boards.

Training Requirements for Field Researchers

Training requirements must encompass both technical skills and soft skills which equally emphasizes relational, emotional, and ethical preparedness. Researchers need hands-on training in sensor deployment, data repair, quality control, and metadata management. However, just as critical is the development of cultural competency, humility, listening, and conflict resolution skills. Training should be undertaken in stages prior to data collection, during project implementation, and post-fieldwork to ensure that researchers understand the evolving political, cultural, and logistical dynamics of working in Arctic communities.

Participants highlighted that many current training programs are inaccessible or too generic. There is a need for regionally tailored programs that reflect specific Indigenous governance systems, research histories, and land claim agreements. Training must include a familiarity with the unique constraints of each region, such as internet connectivity, seasonal rhythms, and language differences. Support for translators and cultural liaisons should be built into research budgets, with clear expectations for researcher conduct and communication.

Best practices include immersive “culture camps,” required sign-offs for safety and ethics training, and peer-to-peer knowledge exchanges between Indigenous and academic team members. There was also a call for training to be mandatory for senior PIs and faculty, not just students. To enable community co-leadership, stipends and paid time off must be budgeted for community members, who should be treated as co-researchers, not assistants.

Training Activities:

Community-Based Environmental Monitoring Training Camp at Ilisagvik College, Utqiagvik, Alaska

Working Group members (Howard Epstein, Luis Felipe Rosado Murillo, and Mirella Shaban) held a Community-Based Environmental Monitoring camp at Ilisagvik College in Utqiagvik for Alaska high school students, predominantly Indigenous youth from small communities. During the camp, students were trained to assemble and deploy low-cost particulate matter monitoring sensors. This created a valuable capacity-sharing environment where researchers from various disciplines and experience levels trained local students and in turn learned from them. Additionally, students contributed to the development of an app for visualizing environmental monitoring data in collaboration with Animikii Indigenous Technology.

The interactions between workshop facilitators and students proved invaluable for both groups. It is important to build flexibility into the schedule to allow time outside the main educational components, for example, incorporating recreational activities. Moreover, implementing a follow-up plan with students after the workshop is essential to gather feedback on their experiences and to understand if and how they have applied what they learned.

Overall, this camp was a meaningful opportunity to introduce low-cost, user-friendly sensors that hold great potential for community and citizen science monitoring initiatives.

Training Session for All Career Stages at Arctic Science Summit Week 2025

Early Career Co-Leads (Louise Mercer and Casey Brayton) co-hosted a session at the Arctic Science Summit Week (ASSW) 2025 in Boulder, Colorado with the Fostering Indigenous-Led Research Convergence Working Group. The session was designed for Arctic researchers at all career stages, with a special early morning session tailored for graduate students. Our training, "Low-cost, open-source, community-based methods", highlighted how recent advances in low-cost, open-source observing methods provided an opportunity for researchers at all stages of their academic careers – from early-career researchers and students to principal investigators (PIs) – to combine cutting-edge technologies with local observations and community priorities. The session outlined the benefits and appropriate uses of these approaches aligning with FAIR and CARE principles, explored case studies of projects using these methods, and discussed the training requirements for scaling environmental observations ethically in Arctic communities. The international training for ~30 participants was framed by the Mercer et al., (2023) approach to overcome key barriers that have persisted over recent decades in preventing sustainable and equitable community-based research. This new framework provided a guide for discussions to collaboratively troubleshoot barriers faced within participants' own work (researchers from diverse knowledge systems and career stages). Guided by the framework, participants identified practical solutions to apply to their own work to support inclusive and sustained research processes in areas including but not limited to Alaska, Svalbard, Inuit Nunangat (Inuit Homeland in Canada) and Kalaallit Nunaat (Greenland).

Supporting Community-Engaged Research: Challenges and Practical Solutions

QUESTION DEVELOPMENT

Challenges in collaborative and community-based research included misaligned goals between stakeholders and rights-holders, limited funding for relationship-building, communication barriers, and structural issues such as extractive research practices and research fatigue. These are compounded by academic pressures such as tight timelines, proposal-stage design requirements, and the dominance of outcomes-focused work for externally led projects.	Solutions discussed involved investing time and resources into relationship-building, recognizing community leadership and priorities, securing flexible and pre-development funding, and shifting mentorship and teaching to model equitable, long-term partnerships. Acknowledging positionality and ensuring reflexivity is embedded into research designs can help to foster responsible, relevant and reciprocal practices throughout the research process.

DATA COLLECTION

Challenges in data collection aspects of collaborative research included unequal capacities for data collection and storage, ethical tensions over ownership and access, disruptions to local practices, and a lack of sustainable infrastructure. Misalignment in worldviews, consent pathways, and expectations for who collects and uses data can lead to friction or disengagement, especially when methods are imposed or roles are unclear.	Solutions center on developing respectful, accessible, and long-term approaches to data collection and stewardship. These include open-source tools, clear data governance plans, honoring oral traditions and alternative methods, non-coercive compensation, and community-led monitoring models that align with local knowledge systems and values. Ensuring access to equipment and appropriate and repeated training is necessary. Developing tools and methods where community observers can collect sustained information flexibly is valuable.

DATA ANALYSIS

Challenges in data analysis can include limited infrastructure, a lack of transparency in analysis processes, and research disconnection from community priorities and knowledge systems. Analytical work is often done away from communities, with little communication about timelines, methods, or results. Mismatched methodologies, inaccessible results, and delays in sharing outputs can all diminish trust and relevance.	Solutions focus on transparency regarding analytical techniques, supporting the development of infrastructure within communities where feasible and supporting in situ analysis wherever possible. The development of low-cost and open source technologies are advancing this area forward. Project partners can also be supported to participate at partner institutions. Sustaining dialogue throughout analysis and involving communities in meaningful ways ensures transparency in research processes and access to and ownership of results.

INTERPRETATION OF RESULTS

Challenges when interpreting and sharing results included power imbalances in knowledge systems, risks to communities, and difficulties in reconciling different aims or worldviews. The process can be subjective, emotionally complex, and constrained by time, language, and academic pressures. Researchers often struggle with how to interpret results in culturally meaningful ways without causing harm or extraction, especially when community needs and institutional goals diverge.	Solutions highlighted the importance of co-interpretation, flexibility, and diverse ways of knowing and sharing. Investing in culturally informed, creative, and collaborative dissemination practices, supported by diverse teams and sufficient time, helps ensure results are useful, respectful, and rooted in the priorities of the communities involved. Emphasis should be placed on using multiple media outlets for dissemination (e.g., radio, podcasts, artwork) that go beyond peer-reviewed papers. Community-centered impactful outcomes could be a youth knowledge exchange camp, for example.

AOST-CWG Supported Projects

The AOST CWG supported three projects to develop methods for the use of low-cost and emerging technologies in community-based research programs. Locations of these projects span from Greenland and Alaska, to supporting rural communities in New Hampshire. These included:

1) **Exploring an innovative and low-cost approach to addressing critical changes in wintertime lake freezing states (Derek Pickell)**, which hold profound implications for hydrology, climate systems, and local communities. Recent shifts in winter conditions have altered the state of lakes from reliably frozen to experiencing multiple freeze-thaw cycles in the Northeast U.S. These changes impact lake ice quality, snow cover, and water storage, presenting challenges for effective monitoring and management. This project aims to deploy novel, open-source instrumentation along key New Hampshire lakes to test their ability to extract data on geodetic lake levels, ice-in and ice-out dates, and snow cover.

2) Developing capacity for remotely monitoring phytoplankton blooms (Clare Gaffey) Phytoplankton communities and their growth cycles are in transition owing to ocean warming and changes in nutrients and freshwater to the Arctic marine system. A particularly troubling change has been the increased prevalence of harmful algae in the Bering and Chukchi seas. The AOST supported work in analyzing the imagery with the goal to provide a mid-level scale workflow and procedure for detecting phytoplankton blooms. Prior to the AOST support, the data files were RAW images. They will now be radiometrically corrected, converted to water-leaving radiance, and estimated for chlorophyll-a concentrations using a blue:green ratio. The camera chlorophyll-a will be compared with water column chlorophyll-a collected within the top 5 m of the water column, and with satellite chlorophyll-a concentrations. These comparisons will be used to refine this as a tool for monitoring local blooms in complex Arctic waters. This work aligns with the Arctic Observing Systems & Technology Working Group goals to develop low-cost and open-source technologies that are beneficial to the interests of Arctic communities, as well as to the greater scientific community. Success of this project will support the development of applicable technologies centered on Arctic environmental change.

3) Greenlandic community-led monitoring using camera technologies (Clay Prater). The Qeqqata Kommunia regional municipality and local business owners are deeply invested in attracting tourists and scientists while safeguarding the region's cultural and environmental heritage. Their efforts include substantial investment in new housing, the opening of a UNESCO World Heritage Site, and, as of July 2025, the launch of an almost 200 km ATV track connecting the ice sheet to the coast.

These small steps towards addressing community needs help to build trust and provide valuable data on: (1) transportation safety hazards related to changes in lake-ice off timing, (2) the effects of spring melt and summer rains on ATV track integrity, (3) the impact of increased tourist activity on nearby hiking trails, and (4) wildlife avoidance of heavily trafficked areas.

Two cameras have been installed and are now monitoring trail conditions over the 2025 summer. During the installation trip, local partners shared their interest in expanding the camera trap work to other UNESCO sites, though they raised concerns about the privacy of Indigenous communities. They emphasized that trail-facing cameras should only take daily snapshots of problem areas, while wildlife cameras should be positioned away from trails to avoid capturing images of local people or tourists.

Data sovereignty was discussed and agreed that local partners would be responsible for downloading and storing the data, with the research team accessing it collaboratively and only sharing it after obtaining government permission from Nuuk.

Recommendations

1. ***Support Cultural Awareness Training***

Funding agencies and academic institutions must prioritize the integration of cultural awareness and cultural humility training for all researchers conducting fieldwork in the Arctic, not just those in the social sciences. This training should be mandatory and a prerequisite for funding fieldwork in the region. To ensure this, dedicated, multi-year funding should be allocated to support the decolonial training of both students and Principal Investigators (PIs).

A key component of this training could include culture camps, where researchers immerse themselves in the communities where they will be working. These camps should offer place-based training covering the cultural context of the location, as well as past research practices (both good and bad) led by community members and researchers with long-standing relationships in the area. Additionally, funding should support initiatives like the Arctic PASSION Project's Sharing Circle, which brings together Early Career Researchers (ECRs) and Arctic Youth, fostering collaboration and sharing of knowledge.

Academic institutions should also support and facilitate courses such as the NNA Arctic Research is Relationship course (run in Fall 2023) and ensure that similar courses are offered annually. These courses, particularly online ones, provide a broader platform for participation, enabling researchers from different cultures, countries, and disciplines to engage in shared learning.

It is vital that minority backgrounds are supported in these research and training initiatives, promoting inclusivity and diverse perspectives. The importance of ethical and equitable research must be embedded in researchers' understanding of diverse knowledge systems, as many Arctic researchers receive no formal training on cultural awareness or the cultural protocols of the communities with which they engage. This lack of training can pose barriers to relationship-building and sustainable, equitable research practices in the Arctic.

Incorporating cultural awareness training will support researchers in recognizing power dynamics, ensuring safety, and facilitating meaningful, community-driven collaboration. It is also crucial to ensure community engagement throughout all stages of the research process, with Indigenous communities having the autonomy to determine their level of involvement, thus promoting self-determination in research. By embedding these practices into Arctic research, we can create more equitable, respectful, and inclusive research frameworks that benefit all stakeholders

To support these efforts, there is a need for a consolidated list of training courses for researchers, such as Equitable Arctic Research: A Guide for Innovation or graduate programs like the Tamanta Program and CARPE. These courses would help reinforce best practices and ensure compliance with ethical and inclusive research methodologies. By synthesizing available training opportunities, these networks can also help researchers avoid redundant monitoring efforts and improve the effectiveness of their fieldwork.

2. *Foster Observational Networks and Coordination of Monitoring Efforts*

A key challenge in Arctic research is the effective coordination of monitoring efforts across various research teams and observational networks. Funding for a central coordinating entity is essential to streamline these efforts, ensuring alignment of goals and reducing overlap in research initiatives. Researchers should hold location-specific pre-field meetings to coordinate with other research teams, including those who have previously worked in the area. These meetings would help in aligning research objectives, operational plans, sampling locations, and data collection efforts, thus preventing redundant efforts and ensuring efficient use of resources.

Community engagement must be emphasized throughout all stages of the research process, not just during data collection or results dissemination. True collaboration with Arctic communities requires ongoing involvement, with communities having a voice in defining the research objectives and outcomes that impact them directly.

As Arctic communities increasingly become research hotspots—particularly due to the reduction of research activity in Russia—there is a growing need to reduce research fatigue and minimize the burden on these communities. Coordinated efforts across projects and teams would significantly ease the pressure on local resources, which are often overtaxed during peak fieldwork seasons when large teams arrive for research.

Additionally, it is critical to emphasize the respect for the land in monitoring practices. Some research methods involve extractive processes that can have a negative impact on land, vegetation, and local ecosystems. Researchers must be aware of the potential impacts of technologies, such as sonar monitoring, which can harm marine mammals. Ensuring that monitoring practices are environmentally responsible and minimally invasive is a crucial step in maintaining the integrity of Arctic ecosystems while conducting meaningful research.

3. ***Support Data Governance and Data Sovereignty in Arctic Research***

Research institutions and individual researchers must prioritize data governance to support data sovereignty, ensuring that communities have access to and control over the data collected within their regions and on their lands. This is particularly critical in Arctic research, where Indigenous communities are often directly affected by the outcomes of environmental studies.

Adhering to the FAIR (Findable, Accessible, Interoperable, and Reusable) and CARE (Collective Benefit, Authority to Control, Responsibility, and Ethics) principles is essential for ensuring ethical and equitable data management. Implementing these principles may require specialized training for researchers to fully understand their implications and how to incorporate them into their data management strategies.

To support data sovereignty, research institutions must adopt open platforms and data sources wherever possible. This will require research and data agreements. Clauses should be included in research agreements that explicitly support sovereignty over the data, allowing communities to control the usage, access, and dissemination of the data that pertain to them. Sustainable infrastructure for data storage is also necessary, ensuring that community-collected data are stored securely and can be accessed and managed over time.

Additionally, training positions within citizen science and community-based monitoring programs should be established. These positions would enable community members, whether as observers, leads, or liaisons, to play an active role in data collation and management at every stage of the process. This includes conducting quality checks to ensure the accuracy and reliability of the data, which will be essential for creating robust datasets that can inform local and regional decision-making.

Researchers should also make data available in a variety of formats, including offline access. This ensures that ease of use is prioritized, allowing community members with limited access to digital infrastructure to still engage with and benefit from the data collected. Providing appropriate training and support for community participants is crucial to ensure the longevity and accessibility of data.

The use of low-cost and open-source technologies in community-based monitoring programs offers significant potential for sustaining Arctic observations across multiple seasons. These technologies can increase the spatial and temporal reach of data collection, creating more comprehensive datasets that reflect long-term environmental changes. However, without adequate training for community participants and the necessary infrastructure, there is a risk of data loss or mismanagement. Ensuring that community members are equipped with the knowledge and tools to manage and store data appropriately is essential to avoid such risks.

4. ***Develop Robust, Low-Cost Sensors by Product Manufacturers***

Product manufacturers have a crucial role to play in the development of affordable, durable, and easily fixable sensors that can support comprehensive Arctic observing systems. **Manufacturers should prioritize the creation of sensors that are both cost-effective and sustainable**, enabling broad use in community-based monitoring programs across the Arctic region.

A significant opportunity exists for manufacturers to address the demand for low-cost, accessible technologies by engaging directly with researchers, communities, and stakeholders. Presenting this demand to companies will help align product development with the specific needs of those working in Arctic conditions.

One important consideration is that **sensors should not only be deployable but also repairable**. Providing additional training to users on how to fix these sensors—rather than just deploying them—can significantly extend the life and utility of the technology. This training will allow communities and researchers to keep equipment operational even in remote and challenging environments, where professional repair services may not be readily available.

While low-cost sensors are essential for community-based monitoring and can help scale observations from local to regional levels, their effectiveness can be limited by harsh environmental conditions. In the Arctic, sensors are often exposed to extreme temperatures and weather, which can cause equipment to fail. This reduces their cost-effectiveness and overall sustainability. By ensuring that users are equipped with the knowledge and skills to repair the sensors, the longevity of these tools can be greatly improved, maximizing their utility for long-term environmental monitoring.

Manufacturers should be aware that marketing low-cost sensors can sometimes be a barrier. **Increased efforts to communicate the advantages of these technologies to a broader audience**, especially those in the Arctic research community, will help overcome this obstacle and increase their adoption.

5. ***Support the Use of Low-cost Sensors for Environmental Monitoring***

Low-cost sensors, coupled with emerging technologies, offer significant potential for community-based monitoring programs. These sensors can be applied to a variety of environmental concerns, such as air and water pollution. By allowing communities to be involved from the inception of the research, these sensors enable real-time data collection and empower local populations to make informed decisions based on the data they gather.

For example, in the case of air pollution, low-cost sensors can be deployed in local areas to monitor air quality, allowing communities to track pollution levels over time. These data can be used to inform public health initiatives, environmental policies, and localized mitigation efforts.

By scaling these technologies across broader regions, monitoring efforts can be expanded, leading to more comprehensive data collection. This approach fosters greater inclusivity leading to better decision-making driven by local insights and needs.

Reflections from ECRs Supported Through the AOST CWG:
Arctic Science Summit Week/Arctic Observing Summit 2024
Edinburgh, Scotland

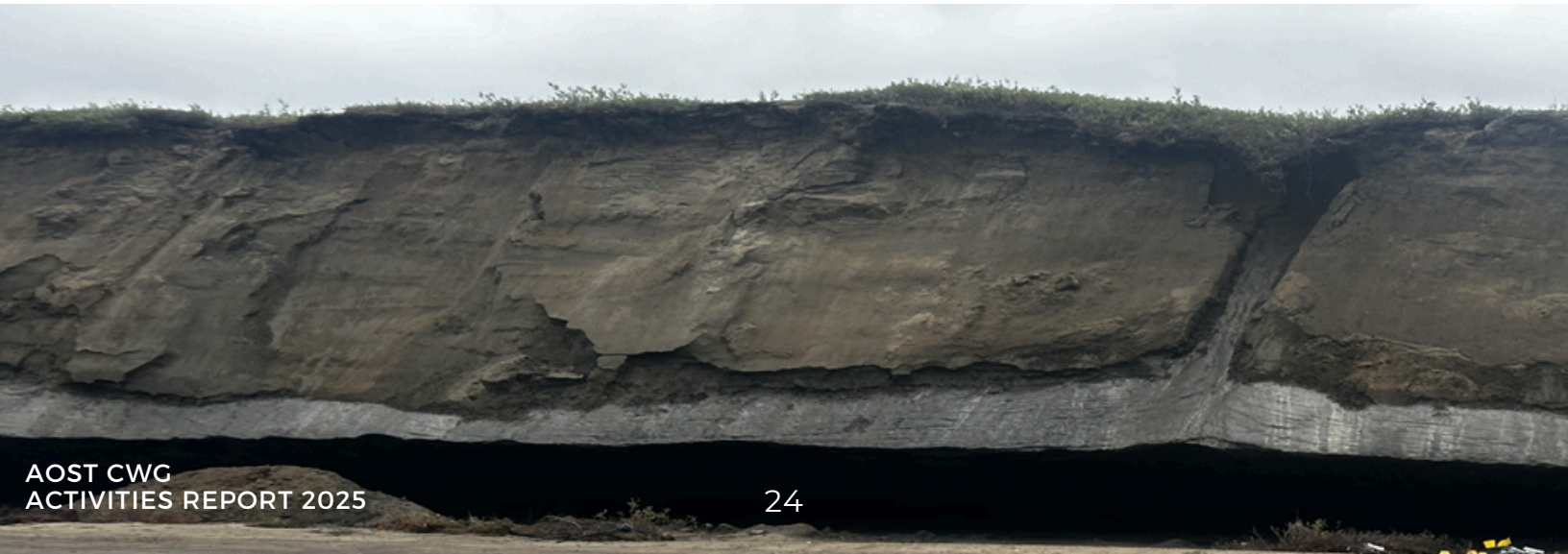
"CBM stands as a beacon of engagement, where local communities participate in collecting data to monitor environmental changes. In the Arctic, where Indigenous peoples have a profound connection to their lands for generations and keep Indigenous knowledge to observe and protect the nature, CBM holds a significant importance in understanding and responding to the impacts of climate change. Collaboration and observation platforms, capacity building, educational trainings, cultural awareness and engagement were highlighted as essential strategies to empower researchers and community members with the skills and knowledge to use these technologies effectively."

"By honoring Indigenous perspectives and values, low-cost and open-source technologies can truly support community-based monitoring initiatives in the Arctic, fostering resilience and sustainability for generations to come."

EKATERINA SOFRONEEVA
PHD STUDENT, UNIVERSITY OF VAASA

"During my participation in the conference and convergence working group session, I realized just how collective and overlapping our current challenges and future hopes are for the Arctic. Especially during the working group session where I wrote down many of the same responses amongst the different groups. Overall, involvement in recommendations and actionable change within the field was a remarkable and humbling experience."

MACKENZIE NELSON
PHD STUDENT, UNIVERSITY OF VIRGINIA



Reflections from ECRs Supported Through the AOST CWG:
Arctic Science Summit Week/Arctic Observing Summit 2024
Edinburgh, Scotland

"NNA AOST Workshop was my first oral presentation to a room of experts, ECR's, and professionals regarding the context and methodology of my terrestrial micrometeorological and particulate matter based sensing in Utqiaġvik, Alaska. Being invited to speak at the NNA AOST Workshop provided a unique experience to learn and present research related to Arctic observing technologies among a diverse audience of Arctic researchers. After this session I further delved into the context, methodology, and preliminary results of my research at the ASSW poster session and networked with a variety of scientists and professionals from different corners of the field."

MIRELLA SHABAN
PHD CANDIDATE, UNIVERSITY OF VIRGINIA

"I thoroughly enjoyed my attendance at AOS in Edinburgh and I am so grateful to have been given the opportunity to present within the Arctic Observing and Technologies Convergence Working Group (AOST CWG) session. This opportunity not only allowed me to initiate a discussion with all attendees around a topic I am interested in and seek to move towards in future but also provided valuable insight into how sessions are structured and conducted. The session itself was highly interactive and engaging."

LEEZA PICKERING
PHD CANDIDATE, NORTHUMBRIA UNIVERSITY, UK

Reflections from ECRs Supported Through the AOST CWG:
Arctic Science Summit Week/ICARPIV 2025
Boulder, Colorado

"The diversity of Indigenous cultures created a unique environment and platform for discussing the experiences and wisdom of Indigenous communities facing changing environmental conditions. Through conversations and observations, I was able to compare traditional practices of Indigenous peoples across different regions, revealing numerous cultural similarities. This was particularly enlightening for me as a social anthropologist from the Buryat Indigenous group. I was impressed by the collaboration among Indigenous peoples in climate change research.
I would particularly like to highlight the events in the Indigenous Pavilion and the exhibitions that adorned the Summit, bringing vibrant colors and voices of the Peoples of the Arctic. Additionally, the organized Potluck event became a space for connecting, sharing thoughts, concerns, and emotions among participants."

OLGA SHAGLANOVA
BURYAT INDIGENOUS GROUP

"The importance of understanding the "why" of the research and the values that my collaborators and I bring to the research. "Why" is a point of shared understanding for developing research projects. Another thing was the variety of ways one can study and do research about the Arctic. It was a good reminder to still stay focused on the things that are most important to me and my community in Anchorage."

MEGHAN HOLTAN
STUDYING PHD IN URBAN AND REGIONAL PLANNING, UNIVERSITY AT BUFFALO

"I also realized that I could be a lot more comprehensive in answering my questions by more often incorporating things like remote sensing, biogeochemistry, microbial ecology and even dendrochronology and many other areas where I could easily collect samples and make it a more complete story, and then also collect samples for other people that would like them but can't make it out to my weird remote field sites."

SHAWNEE KASANKE
ARCTIC BIOLOGICAL RESEARCH (ABR) IN FAIRBANKS, ALASKA

Policy Recommendations

Funding Agency Requirements:

- Mandate soft skills, safety, and cultural training in funding proposals.
- Prioritize projects with Indigenous leadership from the inception stage.

Foster Communities of Practice:

- Establish networks for sharing tools, case studies, and lessons learned.
- Support regional workshops, peer exchange programs, and online repositories.
- Build an online and in-person network for researchers and community members working on open-source, low-cost tech solutions.

Standardization & Protocols:

- Adopt and promote standardized, repeatable methodologies via open resources (e.g., Protocols.io, Ocean Best Practices System).
- Coordinate sampling in research hotspots to minimize environmental and cultural harm.

Investment in Capacity Building:

- Fund long-term community training, including technical and leadership development.
- Build and support digital infrastructure that enables data storage, access, and use by communities.

Summary of Recommendations

Low-cost, open-source technologies must be paired with investment in labour and training.

Ethical, non-intrusive, and community-guided data collection is essential.

Researcher training should be iterative, relational, and culturally grounded.

Coordination and communication must be strengthened across projects and disciplines.

Call to Action

To build equitable, scalable, and community-centered Arctic observing systems, we must move beyond pilot projects and convenings into long-term investment and implementation.

Funding agencies, research institutions, and policymakers must:

- Prioritize human infrastructure—funding for training, local leadership, and long-term relationships is just as important as sensor hardware.
- Require ethical protocols and cultural competency training across all Arctic research initiatives, not only for early-career researchers, but for PIs and institutions.
- Support Indigenous-led research from the proposal stage through to data ownership and dissemination. This includes recognizing Indigenous Knowledge Systems as observing systems in their own right.
- Coordinate efforts across projects, disciplines, and national borders to reduce redundancy, prevent research fatigue, and build systems that serve both local communities and global science.
- Invest in open-source innovation that is repairable, modular, accessible, and designed in partnership with the people who will use and maintain it.

The Arctic is changing rapidly—and the pace of innovation, collaboration, and ethical commitment must rise to meet that change. This working group invites collaborators across sectors to help grow a resilient and just Arctic data future.

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We thank you for your continued engagement in our efforts to support open, ethical Arctic research.

THANK YOU! QUYANA! QUYANAQ! NAKURMĪK! QUYANAINNI! QUJANNAMIIK!

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