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Canadian Coordination in Support of Sustained Observations of Arctic Change

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ABSTRACT. Over the past two decades, scientists, advocates, and communities have put considerable international effort into the development of a sustained Arctic observing system that can sufficiently monitor ongoing environmental and socio-economic change. Advances are slow due in part to a lack of nation-level coordination, with Canada being no exception. Canada needs a coordinated national strategy in support of sustained Arctic observations that will benefit all Canadians and the broader global community, advance Arctic system understanding, and support management and mitigation of the impacts of rapid Arctic transformation. This paper lays out a proposed framework for a coordinated national initiative in support of sustained Arctic observing that includes cross-sector and Indigenous co-developed and co-executed plan, plus an implementation strategy. Recommendations include: 1) establishing national teams (for observing, data, and infrastructure) to effectively deliver on our international obligations related to Arctic research, 2) supporting data sharing, and 3) ensuring sustained observations while also providing observational data and information in support of societal needs within Canada, including many identified in the Arctic and Northern Policy Framework and the National Inuit Strategy on Research.

Keywords: observation; coordination; Arctic; planning; priority setting

RÉSUMÉ. Au cours des deux dernières décennies, des scientifiques, des défenseurs et des communautés ont déployé de nombreux efforts à l'échelle internationale pour mettre sur pied un système d'observation soutenu dans l'Arctique, capable de suivre adéquatement les changements environnementaux et socioéconomiques en cours. Les progrès sont lents en partie en raison du manque de coordination entre les pays, y compris le Canada. Le Canada doit se doter d'une stratégie nationale concertée en faveur d'observations soutenues dans l'Arctique. Cette démarche profitera à tous les Canadiens ainsi qu'à la communauté internationale, approfondira notre compréhension du système arctique et contribuera à la gestion et à l'atténuation des impacts de la transformation rapide de l'Arctique. Cet article fait état d'une proposition de cadre de référence en vue d'une initiative nationale concertée visant à renforcer la surveillance soutenue de l'Arctique. Cela comprend un plan élaboré et exécuté en collaboration avec divers secteurs et les Autochtones, ainsi qu'une stratégie de mise en œuvre. Parmi les recommandations, notons : 1) la création d'équipes nationales (pour l'observation, les données et les infrastructures) afin de mieux remplir nos obligations internationales en matière de recherche liée à l'Arctique; 2) le soutien au partage des données; et 3) l'assurance d'observations soutenues, ce qui permettra de fournir des données et des informations d'observation adaptées aux besoins sociétaux du Canada, plusieurs d'entre eux étant énoncés dans le Cadre stratégique pour l'Arctique et le Nord, ainsi que dans la Stratégie inuite nationale sur la recherche.

Mots-clés : observation; coordination; Arctique; planification; établissement des priorités

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INTRODUCTION

In this paper we present the rationale for, and a process by which, Canada can develop a national strategy for coordination of sustained Arctic observations that benefits all Canadians and the broader global community. We situate our proposal in the wider context of Canada's engagement with northern issues, international efforts to coordinate observing, and commitments to cooperate in key areas. The timing is critical. Coordinated action is required to provide the information needed to respond to anthropogenically driven climate warming. This action

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is also essential to limiting warming to 1.5˚C and reach national and international net zero goals (IPCC, 2018, 2021) even as it is increasingly unlikely that the Paris target will be met (IPCC, 2023). Across northern Canada, the annual mean temperature has increased by roughly three times the global mean temperature increase (Bush and Lemmen, 2019), and it is expected that, if warming reaches 2˚C (global average above pre-industrial times), we will see an average increase of 5˚C across the Arctic (Schlosser et al., 2016). Canada is an Arctic nation, the eleventh largest emitter of greenhouses gasses, and the second largest emitter per capita (ECCC, 2023). Canada has obligations to understand, manage, and mitigate emissions and climate-driven impacts in the Arctic and elsewhere in the country for the benefit of northern Indigenous People, Canadians more generally, and the global community (see, for example, Voigt, 2008; Hickel, 2020). Actions and policies can be supported by coordinated efforts to collect, share, and use observational data and information both nationally and internationally (Starkweather et al., 2021).

Observing Systems and Change

The changes in Canada's North being driven by warming are profound. They exacerbate existing challenges in the region, such as substandard housing (Minich et al., 2011; Aubin et al., 2019), unsafe drinking water (Wright, 2018), poor sanitation (Daley et al., 2018), high cost of living, widespread food insecurity, and a higher burden of ill health compared to national averages (Huet et al., 2017; Kenny, 2018; StatsCan, 2020). Use of country foods (i.e., from subsistence-based sources, such as berries, wild game, and fish) supports food security, physical health, cultural vitality, and general well-being among northern Indigenous Peoples (Hoover et al., 2016), yet wildlife and plant species are subject to extreme pressures from climate change–related processes. These pressures are compounded by the cascading impacts of human activities. Sustained observations and long-term monitoring programs have documented the appearance of new plant and animal parasites and diseases, the increased occurrence of existing diseases, nutritional stress, changes in timing of seasonal life cycle events, fragmentation of habitat, impacts of development, and pollution (see Arctic Council, 2025, where CAFF assessments up to 2019 are available as well as other assessments). Yet, at present, the observing systems in place, whether in Canada's North or elsewhere in the Arctic, are unlikely to be capturing the full extent of change due to spatial and temporal gaps and lack of coordination across networks, programs, agencies, organizations, and communities (e.g., Smith et al., 2019).

The impacts of northern warming on the rest of Canada, and indeed on the planet, are consequential. Canada's Arctic and subarctic regions play an important role in the global carbon budget (Fyles et al., 2002) and affect the seasonal and annual climatology of much of the northern hemisphere (Cvijanovic et al., 2017). Northern regions are essential to planetary health, but the global climate regulatory services they provide are among the most severely impacted by warming. Arctic change is felt at lower latitudes, with potential high-risk impacts (Coumou, 2018). For example, sea ice provides significant services both within the Arctic (Eicken et al., 2009) and globally with respect to planetary albedo, ocean circulation, carbon storage, atmosphere, and weather (Newton, et al., 2016).

Sustained observations of the physical, chemical, biological, and socio-economic phenomena of the Arctic are key to understanding past, present, and future states of the whole system. Sustained observations support operational, research, community, and decision making needs, and will help global stakeholders meet objectives for sustainable development and societal benefits, including the sustainable management and use of living resources. But, in addition to spatial and temporal gaps, sustained observation is hampered by environmental and technical challenges (Beamish et al., 2020); misalignment between top-down and bottom-up approaches (in terms of who sets and steers observation agendas, see Eicken et al., 2021); inequitable access to, and use of, observational data and information; and lack of coordination within and among nations (Murray and AOSC, 2020). Spatial and temporal gaps can be partly addressed by improving in each of these areas. Better coordination will help identify redundancies in observing activities (if any); improve allocation of resources and access to data and information; identify areas in need of attention; and leverage infrastructures and expertise for broad benefit.

Scientific research, Indigenous Knowledge, other local knowledge, cross-sector collaborations, and sustained observation underpin the implementation of solutions for current and emerging problems due to a warming Arctic and a warming planet (AOS, 2020). The activities and actions proposed below are in Canada's national interest and will ensure Canada has a strong voice in shaping international priorities, both Arctic specific and more generally related to the North. This is necessary to meet diverse needs at home and our global obligations described in key multilateral agreements, to which Canada is a signatory (for example, the Paris Agreement, which came into force in Canada in 2016). Canada, as one of the eight Arctic countries, can take a leading role in guiding the development and implementation of an internationally supported Arctic observing system that optimizes and connects existing and proposed programs, infrastructures, systems, arrays, capacities, and expertise.

URGENCY OF A NATIONAL STRATEGY

Priority setting and coordination of Arctic observation in Canada is urgent. As the Special Senate Committee on the Arctic (SSCA) noted, "the Arctic is Canada's future" (SSCA, 2019:11). Evidence-based decision making to mitigate risks and positively manage local, regional, and

national-scale impacts of a changing Arctic requires a process for cooperative priority setting, as well as sustained investment. This should lead to a comprehensive plan for observation and a subsequent implementation process. Implementation can be achieved through leveraging existing resources (e.g., Canada's network of northern research stations) and capacities (e.g., the academic research community, private- and public-sector expertise); investments in infrastructures and financing to support Indigenous Knowledge holders; and Indigenous observing and monitoring activities. This is consistent with Recommendation 16 of the SSCA (2019:14) that:

> The Government of Canada collaborate with territorial governments, Arctic Indigenous governing bodies, academic institutions, and industry to grow the scientific capacity of northern agencies and peoples responsible for devising adaptation efforts to climate change.

This and the other Senate Committee recommendations pertaining to Arctic science, Indigenous Knowledge, and environmental conservation are consistent with the creation of a national Arctic observing strategy that evolves out of inclusive planning processes. These processes should also be guided by the need to provide societal benefits and prioritize activities, infrastructure, and programs established through consensus. A resulting plan would draw on diverse expertise, knowledge, and resources to full effect. A siloed approach is inconsistent with solving the complex environmental, social, economic, and operational problems faced today and in the future.

Sustaining Arctic Observing Networks (SAON)

The need for an observing system that "tracks sub-seasonal to multi-decadal change, advances understanding of poorly studied key aspects of transformational Arctic change and informs responses to rapid Arctic change across a range of scales" (Eicken, 2019:3) is well established. This need is identified in numerous science plans, reports (SEARCH, 2001, 2003, 2005; NRC, 2006; Murray et al., 2010; Rysgaard and BBOS Committee, 2017), and countless scientific papers. For three decades, different segments of the international Arctic research community have been advocating for, and incrementally developing, components of a pan-Arctic observing system (e.g., Lee et al., 2019; Berman, 2011). In 2006, the Arctic Council ministers requested that the Arctic Monitoring and Assessment Programme, in cooperation with the other Artic Council working groups, the International Arctic Science Committee and others, work to create a coordinated Arctic observing network. This resulted in the formation of the Sustaining Arctic Observing Networks – Initiating Group, which was comprised of representatives from intergovernmental and governmental agencies, and international science and Indigenous organizations (International Programme Office for the International Polar Year, Climate and Cryosphere, the Arctic Council's Indigenous Peoples' Secretariat, US National Science Foundation, the Global Ocean Observing System, European Polar Board, Arctic Monitoring and Assessment Program, Forum of Arctic Research Operators, International Arctic Social Sciences Association, International Study of Arctic Change, Arctic Ocean Sciences Board, and the International Permafrost Association). Following three international workshops (Sweden, Canada, and Finland), the SAON steering group prepared a plan for the implementation of SAON (SAON, 2011) and the Arctic Council established SAON in 2011 in the Nuuk Declaration (Arctic Council, 2011). At that time there were 17 proposed SAON tasks, including several from Canada, led by university-based researchers, government scientists, or Indigenous organizations.

An initial SAON implementation plan was approved in 2014, and two committees were formed, the Committee on Observations and Networks and the Committee on Information and Data Services (now the Arctic Data Committee). The Committee on Observations and Networks was charged with promoting and facilitating international collaboration towards the goal of a pan-Arctic observational system for long-term acquisition and proliferation of fundamental knowledge on global environmental change. This charge includes advising the SAON Board on: 1) coordination and collaboration of Arctic observing activities through the use of inventories; 2) pathways to expand the scope of Arctic observational activities, including community-based monitoring and inclusion of Indigenous Knowledge; and 3) providing advice on how to ensure sustainability of, and easy access to, observational platforms in the Arctic. The Arctic Data Committee was charged with promoting and facilitating international collaboration towards free, ethically open, sustained, and timely access to Arctic data through useful, usable, and interoperable systems.

An external review of SAON in 2016 resulted in seven key recommendations pertaining to SAON structure and fulfilling the SAON vision, mission, and goals (SAON, 2016). Directly relevant to our discussion here is the recommendation that national SAON coordination committees be established in all SAON member countries and that these national committees reflect the inclusive nature of SAON. One venue through which the inclusivity of SAON is expressed is the Arctic Observing Summit (AOS) (Murray et al., 2018). In 2013, the AOS was established as a joint task of SAON, the International Arctic Science Committee (IASC, 2025a), and the International Study of Arctic Change (IASC, 2025b). The AOS aims to provide community-driven guidance for the design, implementation, coordination, and sustained long-term (decades) operation of an international network of Arctic observing systems. Community, as used here, is inclusive of Arctic Indigenous organizations and peoples, academic researchers, regional and national governments, operational agencies, and the private and not-for-profit sectors.

The AOS fosters international communication and coordination of long-term observations aimed at improving understanding and responding to system-scale Arctic change. The summit is supported by thematic working groups, some of which (i.e., the data working group) are inter-sessional, and increasingly in coordination with SAON, the Committee on Observation Networks, and the Arctic Data Committee. AOS recommendations are delivered widely, including to the Arctic Science Ministerials (there have been four to date). Recommendation 3 from the 2018 AOS specifically references SAON and the need for local (re: national) engagement, also expressed in the 2016 SAON review. It reads as follows:

> Recommendation 3. A properly resourced, comprehensive effort is needed to identify strengths and gaps in the current set of systems, sensors, networks, and surveys used to observe the Arctic. A knowledge map connecting these observations to societal benefits can then guide new observations, data management needs, and development of products and services, leading to a much-needed roadmap for Arctic system observing. Support for an international and local team of experts to complete these tasks under the auspices of SAON will greatly increase the benefits derived from Arctic observing activities and is deemed critical for successful deployment and sustained operation of an Arctic Observing System.
>
> AOS EOC, 2018:5

CANADIAN ENGAGEMENT IN ARCTIC OBSERVATION

Many Canadians representing federal, territorial, Indigenous, and academic perspectives have already contributed to international Arctic science initiatives, Arctic Council projects, the SAON effort, and the AOS. However, Canadian input, especially to SAON and the AOS, is uncoordinated. There is also a lack of communication across sectors (i.e., government departments, university-based researchers, Indigenous organizations) such that it is difficult to determine how best to place resources, use expertise, determine needs, and contribute to best effect. Canadian contributions to SAON are difficult to assess because of incomplete reporting. This is not to say Canada has not engaged in activities that address many, if not all, of the SAON objectives summarized in Table 1 (e.g., a 2015 inventory of environmental monitoring in northern Canada, see CPC, 2015), but rather that we are not organized so that our contributions are iterative and sustained, and integrated into the SAON process in a directed fashion. For example, community-based monitoring activities are noted in a review prepared for SAON (Johnson et al., 2016), and in the Atlas of Community-Based Monitoring and Indigenous Knowledge in a Changing Arctic (Johnson et al., 2015), but it is unclear how these are linked to other inventory efforts. The totality of observing activities can't yet be measured. Thus, Canada's true capacity for observing and contributions to an internationally supported Arctic Observing System of Systems remain difficult to quantify. Similarly, it is equally challenging to determine the gaps to be filled to meet needs within Canada. Yet there are solutions.

The formal liaison to SAON is the federal government, and specifically, Polar Knowledge Canada. Outside of federal departments and programs, many other stakeholders can bring expertise, resources, and capacity to the observing table. These include the territorial governments, universities and colleges, and Arctic and northern Indigenous organizations and communities. Arctic and northern Indigenous Peoples in Canada have established self-determination in research and guidance for the conduct of respectful, meaningful, and relevant research, including pathways for setting priorities related to observational activities (ITK, 2018). The Government of Canada has recognized the need to widen the net with respect to cooperation and collaboration in science- and observing-related activities in the Arctic. This recognition is articulated in both the SSCA report and the Arctic and Northern Policy Framework. For example, 10 of the 30 SSCA recommendations (SSCA, 2019) address Canada's national interests and international obligations pertaining to the Arctic in a global context. Among those that speak directly to the need for coordination at home and abroad, improved observational capacity and providing societal benefits, particularly for Arctic Indigenous People, are:

> Recommendation 22. That the Government of Canada increase support for international Arctic scientific cooperation, while ensuring that scientific activities conducted in the Canadian Arctic are focused on the knowledge needs of local Arctic residents.
>
> GC, 2019a:15

> Recommendation 28. That, to reinforce international Arctic cooperation, the Government of Canada increase its involvement at the Arctic Council as well as bolster funding for Indigenous permanent participants of the Council.
>
> GC, 2019a:16

> Recommendation 30. That the Government of Canada address the urgent need to enhance search and rescue and emergency protection infrastructure in the Arctic, and ensure Arctic Indigenous communities are involved in the management of this infrastructure.
>
> GC, 2019a:16

The Arctic and Northern Policy Framework (GC, 2019b) highlights Canada's commitment to the UN 2030 Sustainable Development Goals and to meeting several needs, including to: integrate climate change resilience into new infrastructure; enhance monitoring infrastructure

Table 1. Summary of Sustained Arctic Observing Newworks (SAON) objectives related to national reporting roles (SAON, 2018). Table adapted from Eicken et al., 2019).

SAON Objective	National Reporting
1.1 Conduct an inventory of national observational capacities. 1.2 Provide recommendations for a roadmap for future Arctic observational capacities. 1.3 Create opportunities to develop and implement observations in support of Arctic societal benefit areas. 1.4 Develop a long-term repository for relevant project deliverables—establishment of Arctic Global Earth Observation System of Systems (Arctic GEOSS). 2.1 Create a roadmap outlining the steps toward achieving a system that will facilitate access to Arctic observational data. 2.3 Establish a persistent consortium of organizations to oversee the development of a world wide system for access to all Arctic data. 3.1 Develop a strategy for long-term financial commitment in Arctic observations. 3.2 Apply the strategy developed in 3.1 to advocate to funding agencies and states to ensure the sustainability of Arctic observing. 3.3 Secure funding for an international secretariat and SAON costs	17 nations were asked to provide information on their capacity and national institution's role in contributing to these objectives. All eight Arctic countries were included in the request, but not all responded.

for the collection and use of weather and climate data; ensure Arctic and northern people play a leading role in developing research and knowledge creation; and increase our engagement with international polar science through collaboration. This commitment should be carried out with the full inclusion of Indigenous Knowledge. Achieving Goal 5 of the Framework (Canadian Arctic and Northern Ecosystems are Resilient and Health) requires a vast array of observational information from both scientific sources and Indigenous Knowledge (GC, 2019b). This requires combining our separate efforts towards priority setting, deployment of instrumentation and infrastructures, development of new programs, and capacity building. This way the whole becomes greater than the sum of its parts. Establishing a process for the development of a long-term and iterative strategy for Arctic and northern observation within Canada, and coordination of our implementation efforts at home will ensure we have leadership in the continued development of SAON and of the international Arctic Observing System. Both these initiatives are now seeing significant investment from other Arctic countries, and from the European Commission via the EU Arctic Cluster (70+ million Euro) and the Arctic component of the EU Polar Cluster, and particularly the Arctic Pan-Arctic Observing System of Systems (PASSION) project. The EU has also invested in the Copernicus Earth Observation program, a choice driven in part by the need for improved Arctic information, particularly as impacts of Arctic change reverberate through the EU. The US has put considerable resources into the US Arctic Observing Network, drawing on Arctic programs of the National Oceanic and Atmospheric Administration and the US National Science Foundation, to cite just two examples. The US continues to improve coordination across its' agencies, researchers, communities, and programs through the activities of the Interagency Arctic Research Policy Committee.

As a signatory to the Joint Statement of Ministers on the occasion of the second Arctic Science Ministerial (26 October 2018, Berlin), Canada committed to "enhancing and developing collaborative activities" under three themes (Arctic Science Ministerial, 2018:16):

1. Strengthening, integrating and sustaining Arctic observations, facilitating access to Arctic data, and sharing Arctic research infrastructure.
2. Understanding regional and global dynamics of Arctic changes.
3. Assessing vulnerability and building resilience of Arctic environments and societies.

The ministers also emphasized that improved and better coordinated international scientific cooperation can enable notable advancement in understanding change, the impacts of change beyond the Arctic, and facilitating evidence-based decision making. Coordination, priority setting, planning, and implementation of long-term observing and monitoring activities within Canada is action directly in support of these commitments and in the national interest. Internationally:

> SAON has emerged as the de facto governance body to provide an inclusive environment within which to establish an observing framework, with a vision for a connected, collaborative, and comprehensive long-term pan-Arctic Observing System that serves societal needs.
>
> Eicken et al., 2019:2

SAON goals are directly relevant and can benefit Canada. We outline three overarching SOAN goals below, to which a number of Canadian initiatives and programs are positioned to make an immediate contribution.

G1: Create a roadmap to a well-integrated Arctic observing system. We will outline a framework for national coordination and a proposal for a Canadian committee on observing that is one pathway forward for meaningful engagement with SAON. There may be others, and there is a need for dialogue within Canada to determine how exactly to proceed.

G2: Promote free and ethically open access to Arctic observational data. The Canadian Consortium for Arctic Data Interoperability (CCADI) is one group working to achieve this within Canada, crosscutting institutional, disciplinary, and cultural barriers to improve access to

Arctic data and inform similar efforts internationally through both the Arctic Data Committee and the AOS (Pulsifer et al., 2018; Christoffersen et al., 2019; Sankar et al., 2019). The CCADI initiative is focused on development of an integrated, distributed Canadian Arctic data management system that will facilitate information discovery, establish sharing standards, and enable interoperability among existing data infrastructures. This management system will also be co-designed with, and accessible to, a broad user base. Key to the CCADI vision are: standards and mechanisms for metadata, data, and semantic interoperability; a distributed data exchange platform; streamlined data services with common entry, access, search, match, analysis, visualization, and output tools; an intellectual property and sensitive data service; and data stewardship capacity. Other Canadian efforts of immediate relevance include Ocean Networks Canada, Inuit Tapiriit Kanatami's National Inuit Data Management Committee, the Canadian-led and funded components of the Arctic Spatial Data Infrastructure, Canada's new Digital Research Infrastructure organization, the Permafrost Network, the Canadian Integrated Ocean Observing System, and the recently established Canadian Polar Data Coordinating Committee (CCADI/CCIN/PDC, 2018).

G3: Ensure sustainability of Arctic observing. The SAON Roadmap for Arctic Observing and Data Systems (ROADS) also speaks to Canadian interests. The ROADS process provides a mechanism by which Canada can put forth priorities to SAON for an observing system that serves Canadian needs; Canada can identify needed observations and be fully engaged to steer resources. For example, the European Commission issued the EU Horizon 2020 call LC-CLA-20-2020 to establish an Arctic Global Earth Observation System of Systems. Canadian partners are supported through Canada's New Frontiers in Research Fund to engage in this effort. One effort of the program is directed towards the definition of several essential or shared Arctic variables. Coordination at home will allow Canada to bring our national priorities forward in this context and as we more fully engage with the European Commission in the coming years through Association to Horizon Europe (European Commission, 2022).

Paths Forward

The development of a national-scale approach to engagement with SAON begins with an updated inventory of resources and assets and an assessment and synthesis of existing observational capacities (infrastructure, programs, plans, and strategies). Federal, territorial, and provincial governments, departments, and agencies have established priorities (e.g., GNWT, 2019; NWMB, 2015), as have many northern Indigenous organizations (e.g., ITK, 2018) and academic-led programs (e.g., ArcticNet, 2021; Rysgaard and BBOS Committee, 2017) However, lack of communication during the development of plans and priority setting, and lack of coordination across these sectors makes it difficult to leverage our infrastructures, strengths, expertise, partnerships, and funding streams to full effect. However, lack of communication during the development of plans and setting of priorities, and lack of coordination across these sectors (for example, among different branches of the federal government with Arctic responsibilities such as Fisheries and Oceans, Global Affairs, and Environment and Climate Change Canada – each of which have a strong vested interest in Arctic observation) makes it difficult to leverage our infrastructures, strengths, expertise, partnerships, and funding streams to full effect. Indigenous organizations and researchers, and the academic research community are extremely well placed to identify emerging issues and needed observations, and to provide expertise. Doing so in partnership with the federal, provincial, and territorial governments is critical.

PROPOSAL FOR COORDINATION

Coordination of efforts in Canada must both include and transcend government departments and operational agencies. Academic and Indigenous organizations and communities are heavily invested in Arctic research, observation, and monitoring, as are many not-for-profit and private-sector entities. For example, the ArcticNet Network of Centres of Excellence Canada has been funded for over 20 years and has used this funding to bring together people from diverse disciplines, Indigenous organizations and communities, and the public and private sectors to study climate change impacts on the North and support investigator-led observing projects (e.g., Else, 2023). Federal departments, such as Environment and Climate Change Canada, and federal programs, such as the Northern Contaminants Program, also support many different observing activities in the Canadian North, from atmospheric monitoring to contaminants in traditional foods, to freshwater. Despite these world-leading, often stand-alone programs, Canada lacks a coordinated approach to monitoring and observing, leading to substantial lost opportunities.

Coming together to set priorities, develop an agreed-upon strategy, and commit to a plan for sustained observing is a vast task, but it can be accomplished, and in a reasonably short-time frame with adequate planning, background work, and utilizing available resources efficiently. Below, we outline the groundwork necessary for Canada to move forward. This groundwork speaks to the Arctic Policy Framework and the SSCA report, resonates with the calls to action from the Arctic Science Ministerial (2018 and 2021), and takes up the recommendations of the Arctic Observing Summits (2016, 2018, 2020, 2022), the SAON Strategy, and the ROADS process. With an eye to making a meaningful national and international contribution, we propose a process that will facilitate:

1. A national-scale assessment of current Arctic observation capabilities, associated benefits of research and observation, and major gaps, in other words, a knowledge map of the current observing ecosystem (for an example of a knowledge map, see Pulsifer et al., 2020).
2. Development of a roadmap for a national strategy that includes contributions to an integrated Arctic observing system of systems tied to national and global networks, infrastructure, and capacities (for an example of a similar strategy, see Lautenbacher, 2006).
3. Initiation of specific steps and implementation actions that build on (1) and (2), including pathways for inclusion of Canadian expertise (scientific and Indigenous, operational and private-sector partners) in relevant international venues.

We recognize that a national plan for Arctic observation and a Canada-relevant contribution to the international Arctic Observing System of Systems requires consideration and inclusion of existing observing activities from academic research projects, federal-, provincial-, and territorial-led programs and Indigenous-led and community-based monitoring. There are also private- and not for profit–sector initiatives that dovetail with observing. It is important to clearly understand our current capabilities and resources, and thus we propose two main areas of activity: one, to get the national house in order, and a second to deliver on international agreements and partnerships related to research, observation, and data sharing. This moves us from framing documents such as this, to specific activities, including the identification of observing system requirements, and specific data sharing protocols in support of shared societal benefits. To initiate the process, we propose several key components:

Canadian Coordination Team

This team will be operational for the short term to support overall coordination and: first, enable general communication among the groups identified below; second, support the activities of the proposed planning meetings, exercises, and workshops; and third, report on outcomes to national and international audiences.

An iterative series of actions includes sector-specific activities (Indigenous, academic, federal, territorial, etc.) to identify observing priorities; gaps in knowledge, data, and infrastructure; current capacity; and pathways to improve communication and coordination. Sectors then should be brought together to identify common priorities and areas where new observations, or expansion of existing observations, could be used to address two or more areas of societal benefit. This would support SAON objectives (see Starkweather et al., 2021) while still meeting Canada-specific needs that may emerge. There are key priority-setting documents and governance structures that should emerge from this process at the end of a 12 to 24–month period.

National Implementation Plan

Canada lacks a national strategy for Arctic observation, and for Arctic research more generally. Ironically, many non-Arctic countries have such strategies, as well as focused programs and regular processes for updating them. Their processes even include engaging a broad constituency. The lack of process and collaborative planning and implementation at the national scale makes it difficult to develop observational programs in a logical and useful fashion and challenging to draw on existing activities and infrastructures or those of our international colleagues in anything other than a piecemeal manner. We propose that, following from the activities of the coordination team, Canada would be well-positioned to produce a national strategy for Arctic observation with an implementation plan (10-year Arctic observing plan and implementation strategy). Development of such a plan could be coordinated by a permanent Canadian committee on observing networks that replaces the Canadian coordination team and carries out three tasks. First, it will work with information-user communities, (research, agencies, Indigenous, private sector, and others) to coordinate activities and jointly develop an observing plan and implementation strategy that aligns with national priorities and international commitments. Second, the new committee will coordinate periodic review (ca. every five years) of Canada's Arctic research and observing activities and infrastructure to ensure they meet cross-sector, Arctic, and northern community needs, as well as broader Canadian community needs, and deliver cross-sector, Arctic, northern-community, and Canada-wide benefits, plus recommendations for sustaining observing capacity. And third, the committee will support the activities of the proposed national task teams (identified and described below) and deliver their products to SAON, the AOS, the International Arctic Data Committee, and the Government of Canada, among others.

Long-term Mechanisms

To ensure continued coordination of Arctic observing in Canada, and Canadian leadership in the implementation of the Arctic observing system of systems over the long term requires clearly defined governance structures within Canada. SAON has proposed that countries with a vested interest in Arctic observation develop national committees. We take this one step further and suggest there are a number of teams needed to fully leverage Canadian expertise, investment, and infrastructures (Fig. 1).

National Inventory Task Team: Maintains an iterative inventory of observing assets, activities, and informs the Canadian committee on observing networks, which in turn informs and supports SAON.

National Data Task Team: Supports the International Arctic Data Committee and provides Canadian input and expertise to international Arctic data management

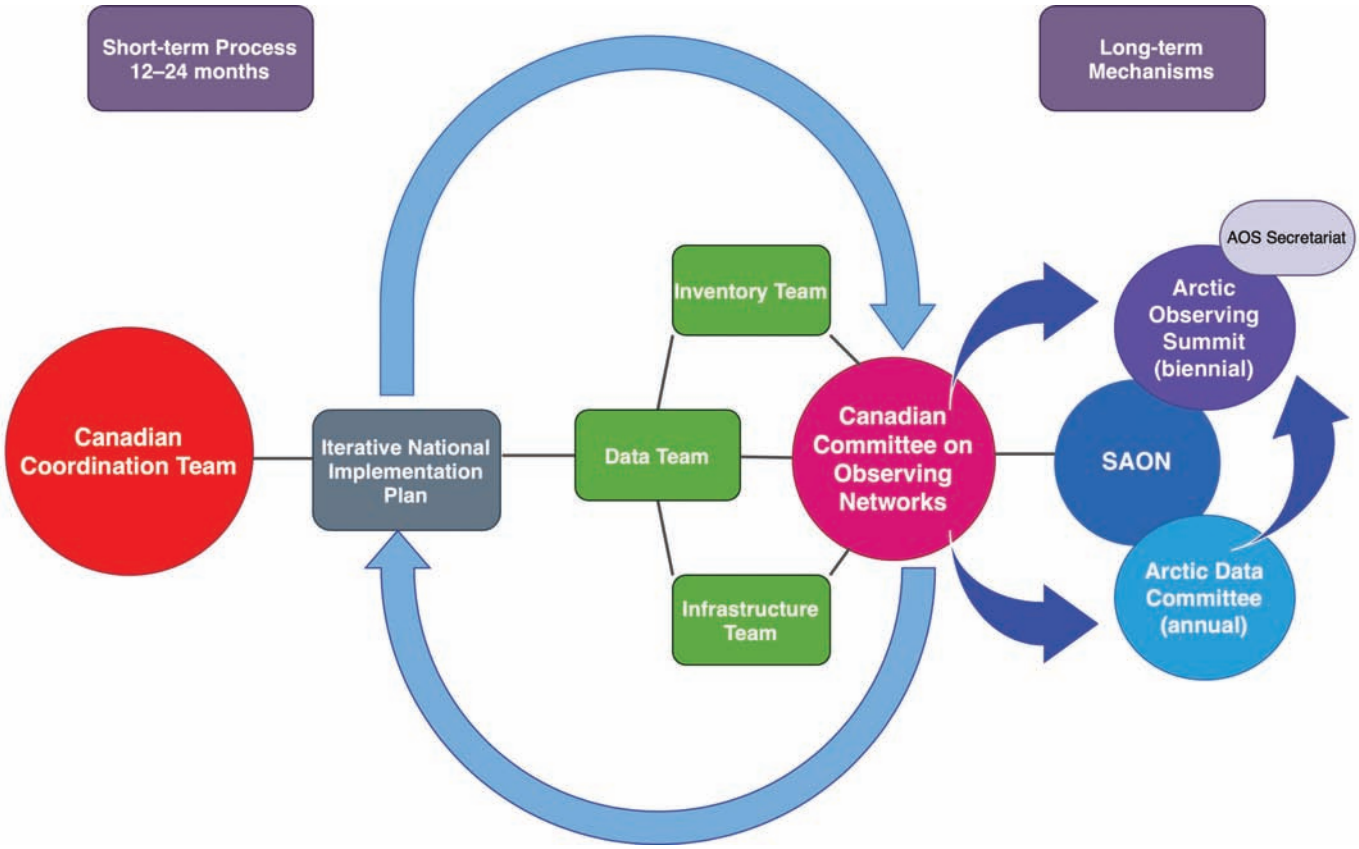

FIG 1. Proposed paths and organizational structure for coordination of Canada's observing activities.

initiatives and the Canadian committee on observing networks. Essentially, this is the Canadian Polar Data Committee's terms of reference that were established at the Canadian Polar Data Workshop 2 in 2018 (CCADI/CCIN/PDC, 2018).

National Infrastructure Task Team: Supports development and enhancement of Arctic observation infrastructure, helps to coordinate platform sharing and access within Canada, and provides Canadian input and expertise to the international community, including SAON and the Forum of Arctic Research Operators. This task team is, or could be, a derivative of the Canadian Network of Northern Research Operators, with additional expertise coming from Indigenous organizations and entities such as the Canadian Space Agency, Environment and Climate Change Canada, and provincial and territorial partners.

Investment in an International AOS Secretariat: Would support, organize, and continue the implementation of the AOS as an ongoing process under the SAON framework. The AOS International Secretariat is a joint initiative between Canada (Arctic Institute of North America) and the US (International Arctic Research Center) to coordinate and execute the AOS in collaboration with the International Arctic Science Committee and the Arctic Monitoring and Assessment Program. Past resources for AOS coordination have come from Canada, the US, Finland, Switzerland, Iceland, and a variety of federal and private-sector funders.

Coordination

Coordination is multi-level and may require different processes depending on the group(s) engaged. We suggest a process that starts with sector-specific housekeeping. Next, we recommend reporting across sectors, plus collaborative activities to establish common ground and consensus. This process recognizes that, in some instances, institutional or organizational priorities are potentially inflexible due to mandate or need. Altogether, this coordination would help identify cross-sector priorities and various types of gaps (in knowledge, data, and infrastructure). It would also clarify current capacity and pathways to improve communication and Indigenous capacity for observing, including the design, implementation, and management of observing programs and infrastructure. Within Canada we see the need for inventory and coordination within and across the following sectors: (1) federal departments and programs (including operational agencies); (2) territorial and provincial departments and programs (including operational agencies); (3) the academic community; (4) Indigenous organizations and communities; and (5) private-sector and not-for-profit entities.

Coordination within these sectors should fall naturally to those entities already deeply involved in Arctic Observation and with SAON, where possible. Polar Knowledge Canada is the adhering body to SAON and should be well-placed to coordinate the federal family and support a national

task team comprised of representative organizations from the other sectors. Institutions, like the Arctic Institute of North America, that have a mandate aligning with SAON objectives and that are already engaged in substantive SAON-relevant activities (like the AOS), are well placed to help coordinate across the academic community. For example, the Arctic Institute of North America has a parliamentary mandate (Senate of Canada, 1945:30) to, among other things:

> (a) initiate, encourage, support and advance by financial grants or otherwise the objective study of Arctic conditions and problems, including such as pertain to the natural sciences, sciences generally and communication … (c) to make records and material available for pure and applied scientific use by individuals and organizations including governmental agencies … and (e) to establish and maintain close contact with other Arctic Institutes and organizations engaged in similar or related fields of study.

Other science-based organizations, such as ArcticNet, can play a supporting role though the funding of relevant research, convening and connecting, and coordination generally.

It lies with the territories, provinces, and Indigenous organizations to determine their best approach, but it may be that the permanent participants from Canada at the Arctic Council are positioned to undertake such inventory and coordination of Indigenous Arctic and northern observing activities with the appropriate support from the Government of Canada and others. Ultimately representatives from these sectors could form a coordination team that will ensure the sector-specific activities go forward, and the outcomes are consolidated into a national observing plan.

Long-term Outcomes

Taking even some of the steps outlined above would move Canada towards positive, long-term outcomes, including improved use of existing resources, increased capacity across sectors, communities and organizations, and improved cooperation within Canada and with our international partners. We envision specific, long-term outcomes. First, a substantive Canadian contribution would emerge from the work to transform dispersed, uncoordinated observations into an integrated observing system, with a formal, long-term observing plan for Canada. Second, we would see an improved national observing system that produces information that is broadly accessible and provides diverse societal benefits. A third outcome would be an international observing system that provides societal benefit to Canada and the rest of the world, through which Canada can address some international obligations vis-a-vis Arctic science, monitoring, information sharing, search and rescue, safe shipping, and conservation and maintenance of biodiversity, among others. Fourth, the AOS would be restructured to more effectively serve the research community, Indigenous and community-based observing initiatives, agencies, the private sector and other entities, and reflect Canada's commitment to SAON, the Arctic Council (in whatever iteration that may take going forward, given the exclusion of Russia due to the war on Ukraine), and the permanent participants at the Arctic Council. Finally, co-production principles for observing system design and management would be implemented.

CONCLUSION

Canada can lead the effort to understand a changing Arctic and ensure that Canadian expertise and priorities are integrated into international initiatives to continue to implement and sustain a pan-Arctic observing system of systems. It is a national responsibility to care for and utilize the great investments in Arctic research and observing, and the knowledge resources generated over recent decades. This can be accomplished through coordination and collaboration, as outlined above. Many pieces of a national plan for Arctic observing are already in place, and these can be built upon through the processes described above. In advance of the next International Conference on Arctic Research Planning (Boulder 2025) and the International Polar Year 2032–33, now is the time to coordinate across established and emerging programs, infrastructures, organizations, expertise, and institutions, and with the international community. It is possible and necessary, and with some effort, a national strategy can be in place in short order.

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