Report of the 4th Canadian Polar Data Workshop

23–27 May 2022

Victoria, Canada

A Vision for Polar Data Management in Canada

Canada, as a global leader in polar research, shares polar research data and products with Canadians and the rest of the world. Through collaboration at home and abroad, the Canadian Polar Data Coordinating Committee and the biennial Canadian Polar Data Workshops support and inform the development of relevant policy and the technical and human systems that will improve all aspects of polar data management from acquisition and curation to dissemination and use.

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Executive Summary

This report provides an overview of the discussions and consensus recommendations of the participants in the 4th Canadian Polar Data Workshop (CPDW 4). It includes information on CPDW 1–3 outcomes and the continued development of a national polar data governance structure for Canada. Recommendations are presented for the implementation of a coordinating body to support a National Arctic Data Committee and a National Committee on Observing Networks to strengthen Canadian engagement at home and abroad in polar, and more specifically, Arctic data, observation, and science initiatives, fora, and processes.

Discussions focused on governance, management, and the interoperability tools needed to ensure that Canadian polar data is findable, accessible, interoperable, and reusable (FAIR). There was concrete action on Priority Area 4 of the National Inuit Strategy on Research "ensuring Inuit access, ownership, and control over data and information" (ITK 2018). Emphasis was placed on Indigenous Data Sovereignty, and particularly methods for engagement, data analysis, reporting, dissemination, attribution, community-led data initiatives, and decolonization of university ethics processes as they pertain to data. These recommendations are consistent with the CARE principles for Indigenous data governance (Collective Benefit, Authority to Control, Responsibility and Ethics).

Actions necessary to make continued progress on polar data management in Canada, and ways to improve information flow among data and knowledge providers are identified. Improved coordination and collaboration across data and observing initiatives is critical as data and observing are tightly coupled. Coordination of data and observing initiatives at the national level is necessary to effectively represent Canadian efforts and priorities in international venues, to improve understanding of Arctic change, to support the priorities of Arctic Indigenous People, and to better leverage our strengths across Indigenous, academic, public and private sectors, and all levels of government and agencies with Arctic responsibilities.

Calls to Action from 2022

The Canadian Polar Data Coordinating Committee (CPDCC), should:

1. Explore options for promoting the non-monetary benefits of working in the data management sphere, including opportunities for self-directed work, creativity, and innovative partnerships. With resources, the CPDCC could:

- Match those offering skilled services for software development, data literacy training, and grant writing, with those in need of these services.

- Create a network where services could be shared across groups and organizations.
- Provide self-directed learning resources to educate people interested in technical subjects that people can complete at their own pace.

2. Maintain an evolving digital inventory of resources to provide information and education about Indigenous Data Sovereignty.

3. Develop a multi-year timeline of workshops and meetings relevant to polar data management.

4. With broad community input, draft a strategic plan with a budget for a Secretariat that supports a Canadian Arctic Data Committee, a Canadian Arctic Observing Committee, and Canadian representatives to i) the Sustaining Arctic Observing Networks (SAON) Arctic Data Committee (ADC); ii) the SAON Committee on Network (CON); iii) the International Arctic Science Committee (IASC) Working Groups; and iv) Working Groups of the Arctic Observing Summit (AOS).

5. Plan the CPDW 5 for late 2023/early 2024.

CPDW 4 participants recognized the need for strong engagement with federal partners and identified Polar Knowledge Canada (POLAR) as a potential coordinating entity in this regard. Where consistent with the mandate and capacity of the organization, POLAR is recommended by the community to:

1. Coordinate federal partners around Arctic data issues and encourage engagement in the biennial CPDW workshops and other community-led data initiatives and events.

2. Work with the Arctic data community to identify and support technical initiatives including the implementation of metadata and data standards and a community agreement on international standards to adopt.

3. Support through resources and collaboration with other federal partners holding polar responsibilities, the Secretariat and Committees identified above.

4. Support through resources and partnerships with other federal partners, Indigenous-led data initiatives.

5. Work with POLAR's wider Arctic constituency to develop transparent and equitable pathways for inclusion of under-represented persons on national and international data and observing committees, and other committees relevant to polar research, and polar data.

6. Draw on the expertise of Indigenous Knowledge holders, and those with expertise across a wide variety of disciplines and organizations to develop a national Polar Data Management Policy Framework.

Introduction

This report provides an overview of the discussions and final recommendations of participants at the 4th Canadian Polar Data Workshop (CPDW 4). It also summarizes outcomes from CPDW 1–3 and outlines progress toward the continued development of a national polar data governance structure for Canada.

The report includes recommendations for the implementation of a coordinating body to support a National Arctic Data Committee and a National Committee on Observing Networks, strengthening Canadian engagement, domestically and internationally, in polar, and more specifically Arctic, data, observation, and science initiatives, fora, and processes. It highlights ways in which the Canadian polar data community can contribute to and support Indigenous data sovereignty, and identifies priorities for technical development, funding, and interoperability.

CPDW 4 focused on moving forward the actionable priorities for polar data management identified in three prior workshops (2015, 2017, 2020). Over the past decade, significant progress toward positioning Canada as a global leader in polar data management, the sharing of polar research data, and establishing best practices for the ethical use of Indigenous data and knowledge has been achieved. The outcomes of CPDW 1 and 2 are synthesized in two reports (CCIN/PDC 2016; CCADI/CCIN/PDC 2018), and in contributions to the biennial, international Arctic Observing Summits (AOS 2016, 2018, 2020, 2022, 2024 and 2026). AOS 2016 data recommendations were moved forward to the 2nd Arctic Science Ministerial in Berlin in 2018 and are reflected in the Joint Statement issued by the high-level officials attending the Ministerial, including Stéphane Dion for the Minister of Science, Canada. The Joint Statement reiterated the need to "make Arctic research and monitoring datasets available, discoverable and relevant for communities" (Arctic Science Ministerial 2018)."

CPDW 1, 2, and 3 – Informing CPDW 4

CPDW 1 (2015) brought together various organizations (Indigenous, academic, territorial, federal, etc.) that produce and/or steward data and information, which support polar data management and use in Canada. Participants engaged in structured conversation to consider options for coordination of activities within Canada and a suite of broad recommendations (CCIN/PDC 2016 and Table 1).

Building on recommendations from 2015, CPDW 2 discussions concentrated on improving polar data management and the use of Canadian polar data with respect to collaboration, coordination and governance, interoperability, Indigenous engagement, policy, and funding mechanisms and needs (CCADI/CCIN/PDC 2018 and Table 1). The Canadian Polar Data Coordinating Committee (CPDCC) was formed and charged with recruitment of individuals

and groups to collectively design a polar data governance structure for Canada (CCADI/CCIN/PDC 2018) and plan the next community-scale activity — CPDW 3.

CPDW 3 focused on the human aspects of data management associated with planning, governance, semantics, and research across the social and natural sciences and including Indigenous Knowledge. CDPW 3 was structured to reach outcomes and products through continued use of the consensus approach and a use-case approach to address semantics and interoperability. Plenary sessions covered progress in data management in Canada and abroad, and overviews of ongoing relevant initiatives, including:

- Canadian Integrated Ocean Observing System (CIOOS)
- Portage Network which is now part of the Digital Research Alliance of Canada
- National Inuit Strategy on Research
- Ocean Networks Canada
- Canadian Consortium for Arctic Data Interoperability (CCADI)
- Research Data Canada which is now part of Digital Research Alliance of Canada
- Polar Knowledge Canada

The Call to Action from CPDW 2 was reviewed and breakout groups focused on concrete activities to further the use of polar data for societal benefit. Workshop activities included:

A1. Discussions on mobilizing genomics data and tools to address concerns of northern Indigenous People including wildlife conservation and co-management, maintenance of biodiversity, and food security. This mini workshop focused on the practical application of a specific type of data to address issues of broad societal concern.

A2. A hackathon for implementation of *schema.org* to facilitate interoperability across Canadian data systems. The focus was to explore one possible technical solution for moving Canada's national data infrastructure forward.

Breakout groups considered the Calls to Action from previous workshops (Table 1) including ways to: 1) establish a dictionary to ease communication across expertise and experiences; 2) develop an iterative inventory of relevant resources: 3) create a comprehensive strategic plan for governance and management; and 4) improve semantic interoperability. Along with planning and governance, semantic interoperability was deemed most likely to advance research, Indigenous, and operational objectives, and support Canadian leadership in the international arena.

Table 1. Recommendations, action items, and outcomes from previous workshops.

	CPDW 1 – 2015	CPDW 2 – 2017	CPDW 3 – 2020
General Recommendations	1) Federal partners lead development of a national data policy. 2) Indigenous participation is key to protecting knowledge from exploitation, and fair, ethical, and improved access. 3) Long-term funding is provided. 4) Open data is the default. 5) Data management recognized as a legitimate scholarly contribution. 6) Canadian Arctic data is archived and available from Canadian repositories regardless of collector or funding source. 6) Data management plans are needed for all projects.	1) Develop a national governance structure for polar data management. 2) Training, education, and collaborative partnerships are mobilized to improve understanding of technical, financial, and human requirements for data management and familiarity with the polar data landscape, Canadian initiatives, and the international arena. 3) Continued growth of a national network of Canadian polar data collectors, managers, and users requires regular opportunities (biennial) to work together.	1) Develop a national Arctic data management plan and implementation strategy. 2) Formalize a national polar data governance structure. 3) Continue support for the National Inuit Data Management Committee. 4) Maintain inventory of national data infrastructures. 5) Leverage resources and expertise for a data committee, an observing committee, the Canadian Integrated Ocean Observing System, the Arctic Observing Summit, and Sustaining Arctic Observing Networks
Calls to Specific Actions		1) Develop a 'dictionary' to define and disambiguate terms. 2) Develop an iterative inventory of polar data management initiatives. 3) Develop a comprehensive strategic plan for polar data management, including cost-benefit, financial requirements, and implementation strategy for a distributed, connected, national data system linked to international initiatives. 5) Expand participation in Canadian and international activities, with emphasis on opportunities and resources to include Indigenous and northern organizations in governance and activities.	CPDCC to: 1) Develop an iterative 24-month timeline for acting on priorities linked to resources, funding, and meeting opportunities. 2) Maintain inventory of key participants. 3) Develop Terms of Reference. 4) Mobilize sub-committees: Data Rescue, Ethics and Privacy, Interoperability and Semantics, Funding, and Communication and Engagement. 5) For future events, leverage technology to allow virtual presence and participation from a larger segment of the community.
Outcomes	1) Coordination, planning, and execution of CPDW 2.	1) Creation of the Canadian Polar Data Coordinating Committee (CPDCC). 2) Funding of the Canadian Consortium for Arctic Data Interoperability[1] (CCADI). 3) Participation in the 3rd Polar Data Forum. 4) Participation in Working Group 4 of the Arctic Observing Summit 2020 — Data Interoperability and Federated Search. 5) Coordination, planning, and execution of CPDW 3.	1) CPDCC established with Terms of Reference and expanded to include key partner organizations. 2) Proposed framework for data and observing coordination in Canada[2]. 3) Coordination, planning, and execution of the CPDW 4. 4) Regular engagement internationally through the Polar Data Forum.

[1] *A funded initiative (Canada Foundation for Innovation) to build interoperable Arctic research data infrastructure across academic, Indigenous, government and private sector partners (https://ccadi.org).*

CPDW 4
Plan of Action and Advancing Technical Initiatives

Improved access to Canadian polar data is critical for advancing research and for evidence-based decision making necessary to adapt to and manage the environmental transformations we have witnessed in the polar regions over the past several decades (see for example Overland et al., 2019), and that will continue for the foreseeable future. Developing a governance structure, management strategies, and the interoperability tools needed to ensure that polar data is findable, accessible, interoperable, and reusable (FAIR) for both the Canadian and international communities is ongoing. CPDW 4 moved forward concrete action on Priority Area 4 of the National Inuit Strategy on Research which is "ensuring Inuit access, ownership, and control over data and information" (ITK 2018). This is consistent with the polar data community's efforts to act guided by the CARE data principles (Collective Benefit, Authority to Control, Responsibility, Ethics) (Wilkinson et al. 2016) and to improve technical effectiveness, usefulness, usability, and security, while supporting data sovereignty and sustainability of Indigenous data archives. To this end, CPDW 4 included practical, "hackathon" sessions that focused on the technological details of systems. (see Appendix 1 for the CPDW 4 agenda).

Workshop Objectives

1. A clear structure for polar data management in Canada including the design for a principal body and the building of a national data plan, to be embedded within a larger Arctic science plan for Canada.

2. The development of initiatives towards furthering Indigenous data sovereignty in Canada.

3. An environmental scan of relevant players for Arctic data management within Canada.

4. Building Canada's Arctic future by welcoming Indigenous Knowledge holders, students and early career scientists into the community.

Participation

As networking across the Canadian polar data community continues to improve, participation in CPDW activities grows. In addition to expanded engagement from Indigenous organizations, established academics, research networks, territorial and federal departments, and the not-for-profit sector, a special effort was directed towards the inclusion of students and early career researchers in CPDW 4. Figure 1 summarizes workshop engagement — types

of organizations represented and expertise. In total, 67 participants representing 37 different organizations participated in CPDW4 (Appendix 2 provides details).

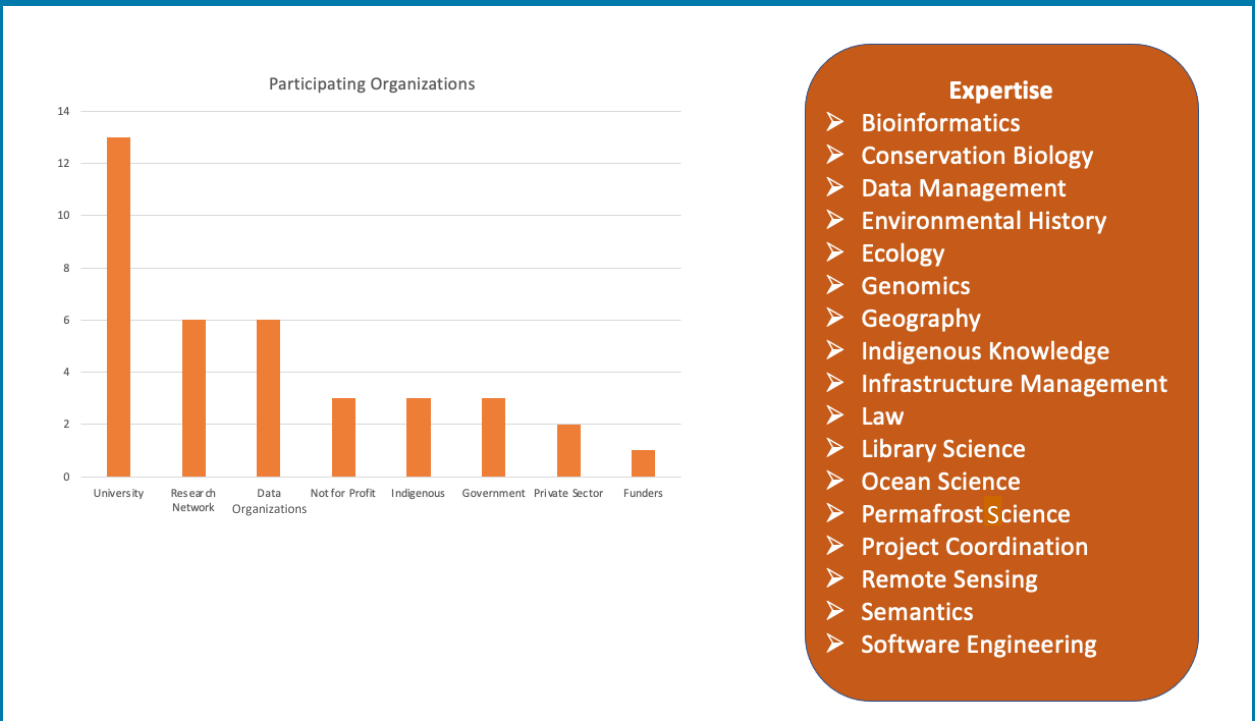


Figure 1. Participant data for CPDW 4.

CPDW 4 Overview

Early Career Program

CPDW 4 included an Early Career Researcher (ECR) Day which began with a tour of the Ocean Networks Canada (ONC) testing facility, followed by an excursion to the Sidney Pier and a demonstration of ONC sensor deployment and data collection (Figure 2). The tour provided ECRs with an example of how some Arctic marine data is collected in the field and introduced them to potential career opportunities in data and marine sciences. Following the tour, a social evening offered ECRs the opportunity to meet established Arctic researchers and data scientists.

Throughout the workshop, training opportunities for ECRs and others were provided within the hackathons and breakout groups. ECRs were engaged as participants and were exposed to new and different ways of thinking about research data as well as practical applications of research data and Indigenous Knowledge to real-world problem solving.

Figure 2. Visit to Ocean Networks Canada (ONC) testing facility, and ONC sensor deployment demonstration. Photos: S. McAllister.

Genomics Workshops

Two one-day workshops, focused on genomics and Arctic wildlife conservation, were held in conjunction with the CPDW 4. Discussions focused on semantic interoperability of genomics-relevant data and information, and ways in which to ensure FAIR and CARE principles are applied in the collection, use, and sharing of genomics data. Access to and use of genomics data by non-specialists who have management, conservation, monitoring, and/or food security interests is challenging. Genomics information is jargon-laden, data sets can be difficult to understand, and use of genomics tools for these purposes is not yet widely adopted. The activities of the polar data community lead to better understanding and to the sharing of information that can, if so desired, inform wildlife management policies and conservation approaches, and support Indigenous food security.

Plenary and Breakout Sessions

The CPDW 4 was pleased to welcome Debby Wilson Danard, a member of the Rainy River First Nation in Northwestern Ontario, and Anishinaabekwe traditional knowledge practitioner, multi-disciplinary artist, lecturer, writer, water protector, and life promotion activist. Dr. Danard spoke on *Indigenous Data Sovereignty: Truth to Reconciliation on Turtle Island.* Dr. Danard's presentation focused on circles as an organizational framework and included discussion of Indigenous research methodology principles, the influence of colonial practices on research, the importance of language, Indigenous data and Indigenous data sovereignty, and ways to begin to decolonize research and research data.

Other invited talks covered previous workshop outcomes, major polar data initiatives in Canada and abroad (including governance, issues and practices relevant to Indigenous data sovereignty, aspects of data interoperability, and Canada's role in international venues pertaining to polar data), Arctic observing, and international organizations (including Arctic

Council, Sustaining Arctic Observing Networks (SAON), and the International Arctic Science Committee (IASC)).

Breakout groups addressed strategies for advancing the activities of the Canadian Polar Data Coordinating Committee, funding models for data management, and Indigenous data sovereignty. Technical challenges were addressed through two hackathons – 1) CCADI-POLDER metadata hackathon; and 2) Canadian Integrated Ocean Observing System - Mackenzie Data Stream Hackathon. Outcomes are described below.

CPDW 4 Technical Stream

CPDW 4 gathered people involved in polar data management from across Canada to share ideas and identify key priorities and commitments for coordinating and advancing work in support of a shared vision. This included considering policy and governance and also collaborating on specific technical aspects of data sharing and use. There are many options available in terms of technical architecture, design, and implementation using specific hardware, software, and tools. Each organization and application context has specific needs, however, there is much value in sharing among the community.

Standards are important for sharing and using data. The specifics of standards and how they are implemented was an underlying theme during the hackathon sessions. Conventions, best practices, *de facto* (community adopted, less formal, emergent) standards, and specification are critically important to establishing agreement among practitioners. In some cases, development, or adoption of more formally recognized *"de jure"* standards can complement other processes by giving authority to a standard. Regardless of the type of standard, these efforts require full collaboration and alignment within the Canadian and the international polar data community.

Indigenous Data Sovereignty (IDS) is critical. IDS can be defined as the right of Indigenous Peoples to own, control, access, and possess data that derive from them, and which pertain to their communities, knowledge systems, customs, and territories. There are cultural, policy, social, legal, and other dimensions to IDS, and all translate into technical requirements when dealing with digital data, information, and knowledge products and systems. Technology must clearly document data and information ownership and support data control, including through provision of additional security layers. Technology enables providing and managing access to data, including assignment and dissemination of licenses. Technology needs to be considered when designing models for data possession. Failure to identify requirements for IDS from the onset of any project will result in limited ability to adequately respect and realize IDS.

Several priority themes were identified prior to the CPDW 4 for the hackathons: metadata standardization; general sharing of system designs; and the use of the Data Access Protocol

(DAP). At the same time the hackathons were designed to be flexible and included other topics of interest as discussed below.

CCADI/POLDER Metadata Hackathon

The Canadian Consortium for Arctic Data Interoperability (CCADI) (now the Canadian Polar Data Consortium – CPDC) and the international-scale POLDER working group on federated metadata search co-organized a metadata interoperability (sharing) hackathon. Metadata is often defined as "data about data" and is used to describe many different facets of data including who created it, technical details (e.g., format, encoding, coordinate reference system), citation information, ownership, licensing etc. Metadata is used to evaluate whether data is fit for a particular use and is then referenced when using such data. Researchers often refer to FAIR (Findable, Accessible, Interoperable, Reusable) data; metadata supports findability by enabling datasets to be published in discovery catalogues. Metadata is foundational to all other aspects of data access, sharing, and use, and thus was an important focus during the hackathon.

The technical sessions at CPDW 4 were attended by data stewardship organizations including the Polar Data Catalogue (PDC), Inuvialuit Regional Corporation (IRC), Arctic Institute of North America (AINA), Nordicana-D, Canadian Integrated Ocean Observing System (CIOOS), Geomatics and Cartographic Research Centre (GCRC) at Carleton University, University of Manitoba's Centre for Earth Observation Science (CEOS), DataStream, and others. In most cases, these service providers host catalogues to support the findability and evaluation of data. Although useful, the individual nature of these data catalogues can mean that users need to access many different sites to find the data they need. To reduce this effort, the community is working together to develop and harmonize metadata standards that can support the federation or merging of multiple catalogues into one or more single user interfaces. This is similar to an online travel site that allows a traveller to see all flight options together rather than checking airline sites individually.

In recent years, much progress has been made by the community to realize the goal of being able to federate polar metadata. CCADI has been working to harmonize metadata schema fields across the consortium. Where this is not possible or practical, fields are translated or "cross walked" to convert from one catalogue system to another. This adds consistency to the published metadata and allows for the federation of catalogues as described above. While it is important to achieve this type of federation at a national level, polar science is international in scope, and the goal is to federate at the international scale. To do this, members of the Canadian polar data community work with the POLDER working group to develop an international federated data search (see https://search.polder.info).

The first technical session of the metadata hackathon focused on the identification of common shared metadata fields. This involved using a spreadsheet developed by CCADI and POLDER to work with hackathon participants to identify metadata elements that could be standardized

across all the metadata providers present. Where there were differences among the participants that could not be resolved — for example, changing a metadata element in a mature catalogue can be difficult and costly — then elements were translated using existing "crosswalks" (translation tables) published by groups such as the World Data System and Research Data Alliance (see https://rd-alliance.github.io/Research-Metadata-Schemas-WG/) or creating new translations that could be used by the hackathon participants.

In the Canadian context, these crosswalks are being documented and maintained by CCADI and then published to the POLDER federated search tool. More information can be found at https://ccadi.org and https://search.polder.info.

The process of standardizing, translating, and federating metadata requires constant monitoring, maintenance, and revisiting for currency. The CPDWs are an ideal venue providing a regular touchpoint for this process and a metadata hackathon is planned for CPDW 5. Additionally, CPDW participants are encouraged to engage in the bi-monthly, international Polar to Global data interoperability hackathon (P2G) series (see https://arcticdc.org/meetings/conference-calls-webinars) where much of the POLDER work is carried out.

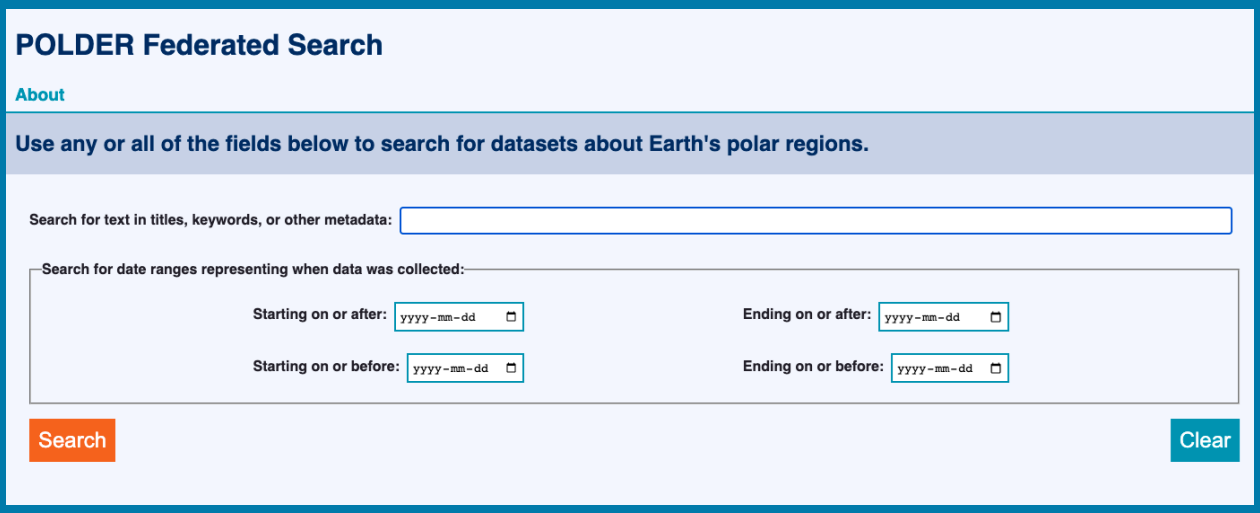


Figure 3. First version of the POLDER Federated Search tool that draws from Canadian (CCADI) metadata federation. Originally published at https://search-dev.polder.info/; now found at https://search.polder.info/.

Data System Show and Tell (Technical)

The hackathons also included a "Data System Show and Tell". Participants shared information about the systems that they host, develop, or with which they are involved. Speaking about the technical details of a system was acceptable and encouraged. This was a space where data experts and developers could communicate freely while informing and educating participants who were not experts in these areas. A review of selected systems is provided here.

Several presentations focused on distributed systems that include more than one partner or participating node. The CCADI Arctic Research Data Infrastructure (ARDI) architecture was presented and discussed (Figure 4). This system brings together partners using interoperable standards and tools across levels. Each partner is working to publish metadata using the schema.org metadata specification made available through various Application Programming Interfaces (APIs). This metadata is harvested by a joint, CCADI-level aggregator that combines the metadata provided by each partner into a single metadata collection and is then delivered to the POLDER Federated Search tool (see above). CCADI members have been experimenting with publishing oceanographic and other data (e.g., shoreline data from the Inuvialuit Regional Corporation) using tools such as the DAP protocol, ERDDAP, and other tools (see below). This has spawned other projects. There was a presentation outlining how oceanographic data is being published by Amundsen Science (scientific operator of the Amundsen ice breaker) to the Polar Data Catalogue. Polar Data Catalogue then publishes, using the DAP protocol, to the Canadian Integrated Ocean Observing System (CIOOS).

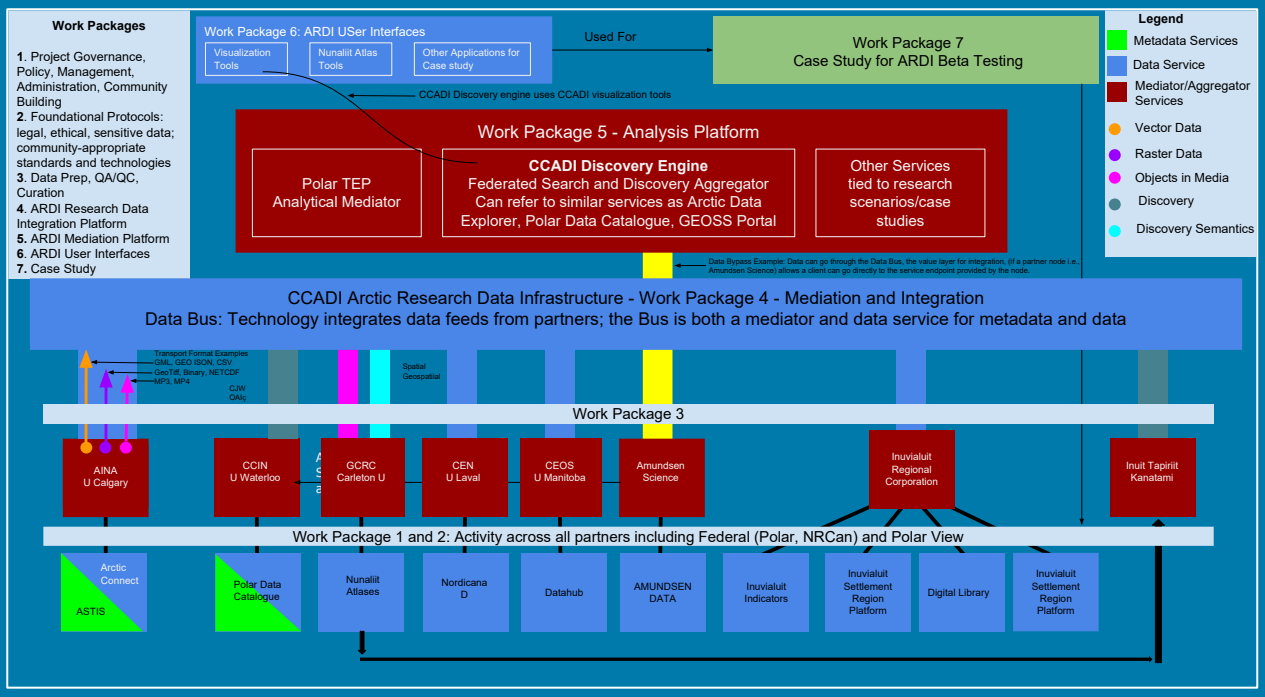


Figure 4. CCADI architecture.

Other presenters reported on specific system designs and advancements at their institutions. Inuvialuit Regional Corporation (IRC) shared exciting developments that will better serve their communities. There are many data holdings relative to the size of the organization, data that range from recent to historical, a large variety of data kinds (text, images, geospatial, numerical, etc.), and there is a need for an advanced IDS support system. Policies, approaches to FAIR and CARE principles, and technology are being developed. Where possible, IRC is using existing tools such as the Comprehensive Kerbal Archive Network (CKAN), or building custom systems as needed.

The CanWin project at the University of Manitoba, connects several components and layers through a use case examining the relationship between sea ice in Baffin Bay, Canada, and ocean acidification, and to deliver both raw and processed (easily accessible) data to diverse users. Housed on University infrastructure and using multiple operating systems, open source and commercial metadata and database servers such as PostgreSQL/PostGIS, Solr, and ERDDAP (data layer) are combined with the NGINX web server to make data available. User-facing tools such as CKAN, GeoNode, SensorThings API, GeoServer, and ERDDAP (interface layer) make raw and processed data available.

The DataStream project uses an approach that heavily leverages the Amazon cloud platform. A serverless architecture provides a foundation for database tools such as PostgreSQL, and frameworks such as NodeJS. These foundational layers are optimized for performance, security, and data quality and serve applications such as the main DataStream website and APIs. Significant attention is paid to scalability to prepare for future growth. Dataset versioning provides a record of change over time.

The Arctic Institute of North America (AINA) and the Polar Data Catalogue (PDC) outlined their mature, community-leading data stewardship systems including their processes for constantly evolving user interfaces and backend systems. AINA is launching a next generation data management and dissemination platform in 2023. The PDC is focusing on expanding the use of APIs (including standards such as DAP) as well as exciting user interfaces that range from simple user interfaces to more advance analytical tools.

The Geomatics and Cartographic Research Centre (GCRC) demonstrated community-oriented web-based atlases that now have the capability of serving standardized metadata. Plans for the addition of interoperable data APIs were presented. GCRC is the lead for the development of the CCADI semantic mediator, and this tool was demonstrated and explained.

The Nordicana-D group presented an impressive implementation of an interoperable metadata and data publication system that uses DAP and serves as the foundation of a user-friendly website that publishes air temperature data, the Merged Observatory Data for Arctic Air Temperature (MODAAT).

PermafrostNet has developed a domain-leading database system for permafrost and frozen ground data that can serve data using the DAP protocol. They are using the ERDDAP tool combined with Climate and Forecasting (CF) data and metadata conventions and the emerging Attribute Convention for Data Discovery (ACDD) standard. This provides a robust, standards-oriented data infrastructure that will be used for a variety of end user products (e.g., websites, apps etc.).

OPeNDAP Hackathon

Data Access Protocol (DAP) is a data transmission protocol designed for science data that allows researchers to access, subset, and visualize massive, remote datasets. It provides data types to accommodate gridded data, relational data, and time series, as well as allowing users to define their own data types. Data can be requested and filtered based on criteria such as location, date range, and value range. The data are then translated and streamed in real-time, in formats like NetCDF, JSON, ASCII, or GeoTIFF, regardless of how the data are natively stored. Typically, end-users interact with DAP servers using Python packages such as xarray and PyDAP, or data software such as MATLAB, R, and Panoply. There are various DAP server implementations, such as OPeNDAP Hyrax, ERDDAP, and THREDDS.

Many organizations within the Canadian polar data community are using DAP as a method to serve data. These include Amundsen Science, Nordicana-D, Polar Data Catalogue, University of Manitoba, and CIOOS. There is also wide adoption in the international polar data community, such as the World Meteorological Organization's Global Cryosphere Watch (GCW) and the International Oceanographic Data Exchange (IODE).

During the CPDW Hackathon, groups using DAP presented the status and implementation details of their systems. Many are using the ERDDAP software due to ease of implementation and maintenance and the straightforward user interface. Others are using the OPeNDAP Hyrax software as it provides more advanced features. All agreed that adoption of DAP provides a valuable data sharing mechanism that adds significant value for their end users.

The software tools available are open source, mature, and relatively straightforward to install and maintain. The primary remaining challenge is to work together to adopt community standards for metadata (e.g., the ACDD standard) and data (e.g., the CF Conventions for data attributes). Events such as CPDW, the Polar to Global (P2G) hackathons organized by the Arctic Data Committee, the Arctic Observing Summit, and the Polar Data Forum, are important for bringing the community together to agree upon common implementation, practices, and standards.

Technical Stream Summary

All participants who provided feedback stated that the technical stream of the CPDW 4 was a valuable and productive use of time. Participants learned a great deal about what others are doing, established ideas and plans to advance their own work, and gained a clearer understanding of next steps needed to achieve collective goals. Some suggested that future meetings should focus on specific tasks such as defining data and metadata standards, sharing how to install and manage certain software, and working to develop detailed collaboration models or agreements. All agreed that progress should build on existing initiatives. This includes learning from well-developed programs, projects, and systems, but also building on

collaboration and community-building efforts rather than starting fresh. Leveraging local, regional, national, and international initiatives is key.

The increased difficulty facing the community in hiring and retaining technical talent was a major issue raised during discussions. There are many interrelated issues: work is usually carried out under 1–3-year term projects, making it difficult to attract people who prefer long-term employment. Community, academic, NGO, and government organizations may not be able to compete with private-sector salary levels, making it hard to secure funding for ongoing projects. Many funders prefer to fund "innovation," leaving little money available to sustain existing infrastructure and programs. Staff turn-over is also an issue. Students move on, many workers in the North stay for a short period of time before moving elsewhere — retention is a significant challenge.

There are several possible solutions to these problems, including: collectively lobbying for more competitive salaries; highlighting the non-monetary benefits of working in this field (contributing to research, societal good, flexible work hours); and forming not-for-profit coalitions dedicated to our community to create economies of scale and shared centres of expertise.

There was overall agreement that the CPDW provides a valuable platform for moving forward the Canadian polar data community. A strength of CPDW is that it is now a regular, reliable event that works with other initiatives large and small. This provides an efficient model that does not expect all activity to happen in one context.

General Observations

The CCADI and other groups such as the Polar Data Forum have demonstrated that collaboration among organizations and cross-pollination across expertise leads to innovation in research, data visualization, and knowledge mobilization; to improvements in cyberinfrastructure; and to growth in data and information literacy. However, within Canada, governance issues still need to be addressed and there is work to be done in terms of improving the data community's understanding of the polar data ecosystem. Links to other national- and international-scale initiatives and research bodies (i.e., the Arctic Data Committee (ADC), the International Arctic Science Committee (IASC), Sustaining Arctic Observing Networks (SAON), etc.) need to be strengthened and both national and international collaborations understood as key to the development of successful, long-term data initiatives.

Other hurdles include difficulty in recruitment and retention of skilled technical staff at academic, Indigenous, and government entities (i.e., software developers) as noted above, and a high rate of turnover of personnel in academia (students, early career researchers), and Indigenous and not-for-profit organizations.

In general, the workshop participants agreed that more emphasis should be placed on educating people on topics of relevance to Indigenous Data Sovereignty, particularly with respect to methods for engagement, data analysis, reporting, dissemination, attribution, community-led data initiatives, and decolonization of university ethics processes. There was also agreement that the Canadian Polar Data Coordinating Committee should move forward under the established terms of reference to tackle the specific actionable items identified below as they become feasible. Other identified action items seem to fall more appropriately under the mandates of various federal entities and are also discussed below.

Workshop participants agreed that regardless of any ultimate polar data governance structure, legal incorporation is needed to advance further and to reduce reliance on specific institutions (university, federal, provincial, territorial agencies, etc.). Grants are finite and very focused (project specific) while long-term sustainability requires partnering with governments, foundations, the private sector, industry associations, and international programs and organizations.

Calls to Action

Specific recommendations from workshop participants were directed toward the Canadian Polar Data Coordinating Committee and to Polar Knowledge Canada and other federal partners as follows:

The Canadian Polar Data Coordinating Committee now should:

A1. Explore options for promoting the non-monetary benefits of working in the data management sphere, including opportunities for self-directed work, creativity, and innovative partnerships. Through improved coordination and with some resources, the CPDCC could:

- Match those offering skilled services for software development, data literacy training, and grant writing support, with those in need of these services.
- Create a network where services could be shared across groups and organizations
- Provide self-directed learning resources to educate people interested in technical subjects that people can complete at their own pace.

A2. Maintain an evolving catalogue or inventory of resources to provide information and education about Indigenous Data Sovereignty.

A3. Develop a multi-year timeline of workshops and meetings relevant to polar data management.

A4. Plan CPDW 5 for 2024.

A5. With community input, draft a strategic plan for governance and activities, including a budget for the implementation of a Secretariat the supports a National Arctic Data Committee, a National Committee on Observing Networks, Canada's representatives to SAON's Arctic Data Committee and Committee on Networks, the IASC Working Groups, and the Working Groups of the Arctic Observing Summit. Data, Information, and Observing are inseparable and so such groups should work hand in hand. The strategic plan should build upon the suggestions for governance structure and flow of information within Canada and internationally that are articulated in Figure 2 – this proposed governance systems is a key outcome of CPDW 4.

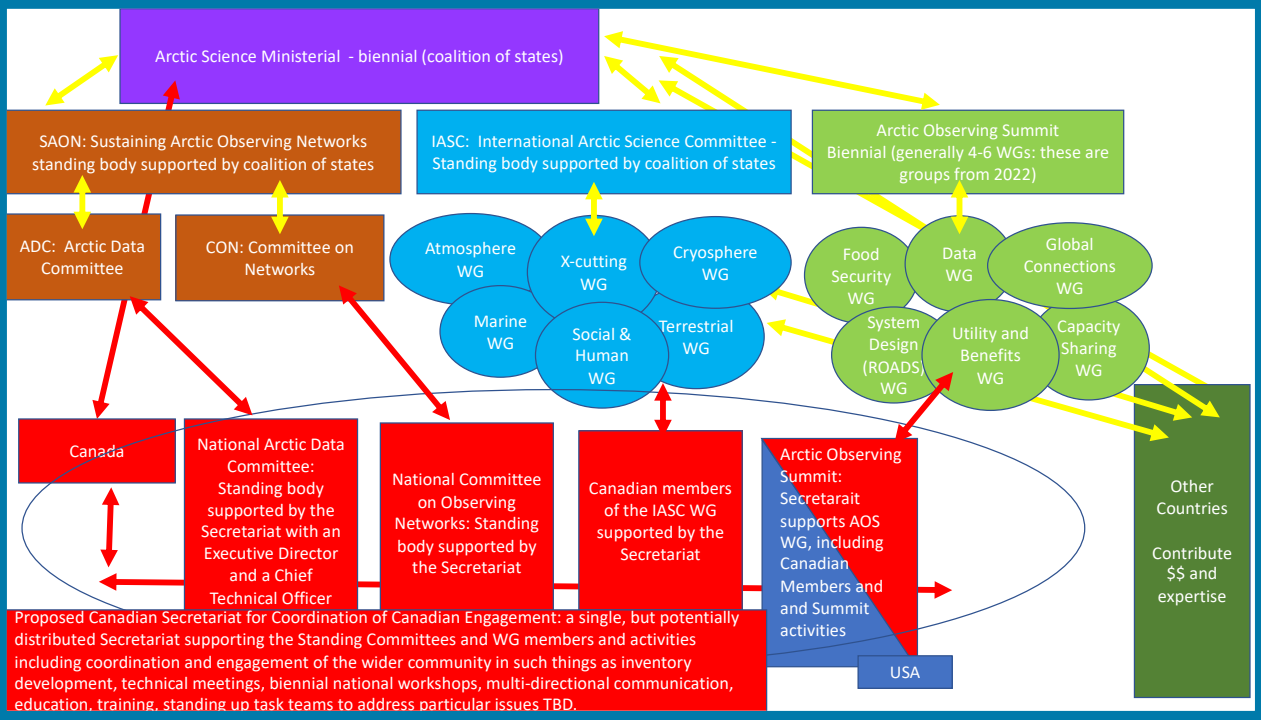


Figure 5. Proposed governance structure for engaging Canadian data, observation, and science coordination activities in the international context. The AOS Secretariat is currently supported through grants to the Arctic Institute of North America and the University of Alaska Fairbanks.

Polar Knowledge Canada was identified as one of several key entities to support the activities of the proposed Secretariat, and further, as the entity that could potentially provide coordination at the federal level and link Indigenous, academic, and not-for-profit data-centric organizations with federal initiatives. It was recommended that POLAR, where consistent with the mandate of the organization and where feasible given existing commitments and planning efforts, should:

R1. Lead coordination of federal partners around Arctic data issues.

R2. Work with the Arctic data community broadly to identify and support technical initiatives in the coming months/years including the development of metadata and data standards and community agreement on international standards to adopt.

R3. Support, with other federal partners, the Secretariat and Committees identified here.

R4. Support, with other federal partners, Indigenous-led data initiatives.

R5. Work with its wider Arctic constituency to develop transparent and equitable pathways for inclusion of under-represented persons on national and international data, observing, and other committees relevant to polar research and polar data.

R6. Draw on the expertise of Indigenous Knowledge holders, and those with expertise across a wide variety of disciplines and organizations to develop a national Arctic and Polar Data Management Framework.

CPDCC Progress on Recommended Actions

A1. The CPDCC, through the biennial workshop activities, continues to entrain the next generation of polar data experts, drawing on ECRs working in academic and Indigenous organizations. The strategic plan for the proposed Secretariat will identify activities to support data literacy training, the development of self-directed learning resources to educate people interested in technical subjects, and in the interim the CCADI website could host an evergreen catalogue of data experts.

A2. An initial inventory of resources to provide information and education about Indigenous Data Sovereignty is found in Appendix 3 of this report but ultimately this needs to be a digital resource.

A3. A multiyear timeline of polar data-relevant activities leading into the next International Polar Year (2033) is included here. An evergreen version of the is found on both the CCADI website and on the website for the Canadian Polar Data Forum 3.

A4. The CPDW 5 is scheduled for May 2024 in Halifax, Nova Scotia. The objective is to share ideas and identify key priorities and commitments for coordinating the work of the Canadian polar data community and, ultimately, advancing our work in support of our vision. The workshop will:

- Address the structure for polar data management in Canada including national recognition for a principal body and continued work on a national data plan, to be embedded within a larger Arctic science plan for Canada.

- Continue to consider and further develop initiatives towards furthering Indigenous data sovereignty in Canada.
- Enable hackathon sessions to support further interoperability initiatives between polar data centres.
- Continue to build Canada's Arctic data future by welcoming students and early career scientists into the community."

A5. A draft strategic plan for governance and activities that includes a budget for the implementation of a Secretariat that supports a National Arctic Data Committee, a National Committee on Observing Networks, Canada's representatives to SAON's Arctic Data Committee and Committee on Networks, the IASC Working Groups, and the Working Groups of the Arctic Observing Summit is in development

Progress in Other Areas

1. The Data Sharing Working Group of the Arctic Observing Summit/Arctic Data Committee
The Arctic Observing Summit (AOS) emphasizes data as fundamental, crucial for system design and implementation. AOS Working Group 3: Data Sharing WG convened sessions focused on data sharing, covering themes such as federated search, open science, data policy, and ethics. Discussions underscored the need for integrated data systems and enhancing data usability, particularly for applications like food security and decision support. Key topics included Indigenous data governance rights, adherence to CARE, FAIR, and TRUST principles, and global collaboration efforts highlighted by the launch of the Polar Federated Search tool. Looking ahead to AOS 2024, the focus remains on enhancing international collaboration, interoperability, and advancing data education initiatives for sustainable future outcomes. Conference Report: https://arcticobservingsummit.org/wp-content/uploads/2022/08/AOS_2022_Conference_Statement.pdf

2. In 2022, the CCADI, together with Polar Knowledge Canada and the Arctic Research Foundation (ARF) began discussions on the adoption of data standards. This group continues to meet regularly with a focus on bringing partners to the table for a broader discussion around this topic in the coming months.

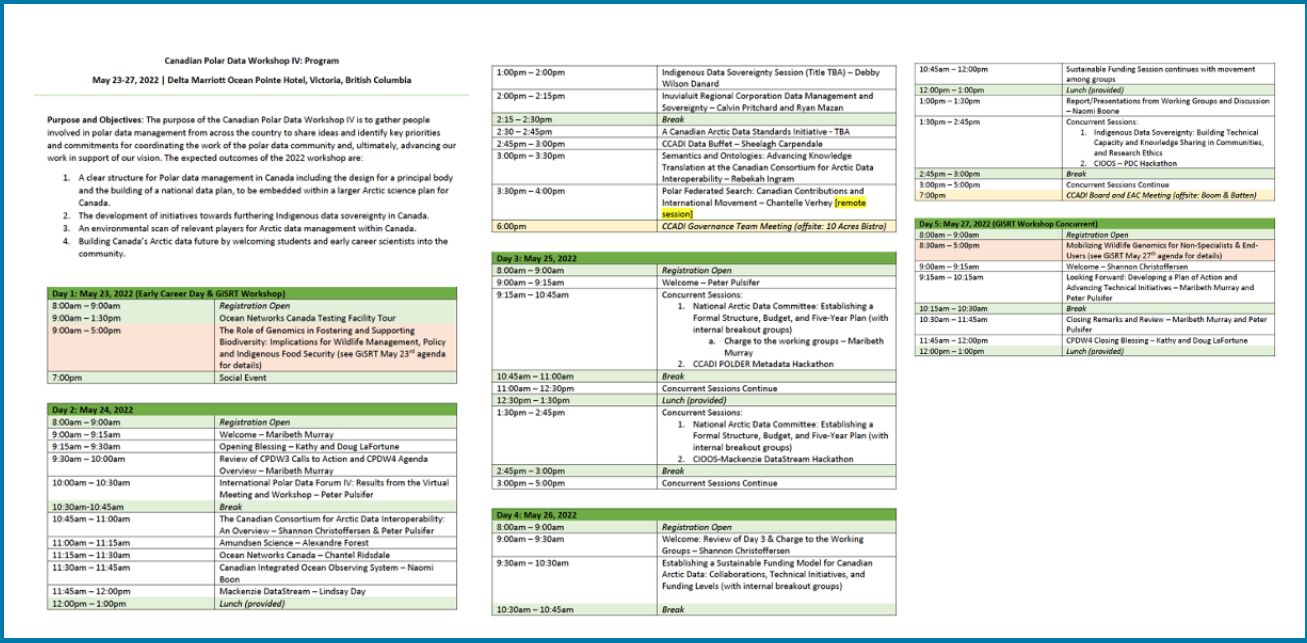
3. Polar Data Forum IV Updates: Polar Data Forum IV took place in September 2021, transitioning to an online format due to the pandemic, and was hosted by the European Polar Board and the Belgian Museum of Natural Sciences, in collaboration with SOOS and other polar data organizations. The online setup attracted more than double the registrations compared to the previous PDF held in Helsinki in 2019.

PDF IV was jointly organized with the Southern Ocean UN Decade Workshop, facilitating the exchange of ideas across disciplines. The virtual format seamlessly accommodated hackathon sessions, a staple of recent PDF editions. Discussions were dynamic, covering topics such as

Virtual Research Environments, advancements in polar technologies, federated metadata search, and strategies for documenting data flows into platforms like SOOSmap. Significant strides were made in establishing best practices and refining data policies across the SOOS DMSC, the Standing Committee on Antarctic Data Management, and the Arctic Data Committee.
Conference Report: https://doi.org/10.5334/dsj-2023-018

4. The International Conference on Arctic Research Planning (ICARP) is scheduled for 2025 in Boulder. This is a decadal event of the International Arctic Science Committee. Input to the ICARP process from the Canadian polar data community is welcome and reports from previous CPDW events have been shared as relevant resources. The Canadian Polar Data Workshop is identified as an ICARP relevant activity.

Appendix 1
Agenda CPDW 4



Canadian Polar Data Workshop IV: Program

May 23-27, 2022 | Delta Marriott Ocean Pointe Hotel, Victoria, British Columbia

Purpose and Objectives: The purpose of the Canadian Polar Data Workshop IV is to gather people involved in polar data management from across the country to share ideas and identify key priorities and commitments for coordinating the work of the polar data community and, ultimately, advancing our work in support of our vision. The expected outcomes of the 2022 workshop are:

1. A clear structure for Polar data management in Canada including the design for a principal body and the building of a national data plan, to be embedded within a larger Arctic science plan for Canada.
2. The development of initiatives towards furthering Indigenous data sovereignty in Canada.
3. An environmental scan of relevant players for Arctic data management within Canada.
4. Building Canada's Arctic data future by welcoming students and early career scientists into the community.

Day 1: May 23, 2022 (Early Career Day & GISRT Workshop)	
8:00am – 9:00am	*Registration Open*
9:00am – 1:30pm	Ocean Networks Canada Testing Facility Tour
9:00am – 5:00pm	The Role of Genomics in Fostering and Supporting Biodiversity: Implications for Wildlife Management, Policy and Indigenous Food Security (see GISRT May 23rd agenda for details)
7:00pm	Social Event

Day 2: May 24, 2022	
8:00am – 9:00am	*Registration Open*
9:00am – 9:15am	Welcome – Maribeth Murray
9:15am – 9:30am	Opening Blessing – Kathy and Doug LaFortune
9:30am – 10:00am	Review of CPDW3 Calls to Action and CPDW4 Agenda Overview – Maribeth Murray
10:00am – 10:30am	International Polar Data Forum IV: Results from the Virtual Meeting and Workshop – Peter Pulsifer
10:30am-10:45am	*Break*
10:45am – 11:00am	The Canadian Consortium for Arctic Data Interoperability: An Overview – Shannon Christoffersen & Peter Pulsifer
11:00am – 11:15am	Amundsen Science – Alexandre Forest
11:15am – 11:30am	Ocean Networks Canada – Chantel Ridsdale
11:30am – 11:45am	Canadian Integrated Ocean Observing System – Naomi Boon
11:45am – 12:00pm	Mackenzie DataStream – Lindsay Day
12:00pm – 1:00pm	*Lunch (provided)*
1:00pm – 2:00pm	Indigenous Data Sovereignty Session (Title TBA) – Debby Wilson Danard
2:00pm – 2:15pm	Inuvialuit Regional Corporation Data Management and Sovereignty – Calvin Pritchard and Ryan Mazan
2:15 – 2:30pm	*Break*
2:30 – 2:45pm	A Canadian Arctic Data Standards Initiative - TBA
2:45pm – 3:00pm	CCADI Data Buffet – Sheelagh Carpendale
3:00pm – 3:30pm	Semantics and Ontologies: Advancing Knowledge Translation at the Canadian Consortium for Arctic Data Interoperability – Rebekah Ingram
3:30pm – 4:00pm	Polar Federated Search: Canadian Contributions and International Movement – Chantelle Verhey [remote session]
6:00pm	*CCADI Governance Team Meeting (offsite: 10 Acres Bistro)*

Day 3: May 25, 2022	
8:00am – 9:00am	*Registration Open*
9:00am – 9:15am	Welcome – Peter Pulsifer
9:15am – 10:45am	Concurrent Sessions: 1. National Arctic Data Committee: Establishing a Formal Structure, Budget, and Five-Year Plan (with internal breakout groups) a. Charge to the working groups – Maribeth Murray 2. CCADI POLDER Metadata Hackathon
10:45am – 11:00am	*Break*
11:00am – 12:30pm	Concurrent Sessions Continue
12:30pm – 1:30pm	*Lunch (provided)*
1:30pm – 2:45pm	Concurrent Sessions: 1. National Arctic Data Committee: Establishing a Formal Structure, Budget, and Five-Year Plan (with internal breakout groups) 2. CIOOS-Mackenzie DataStream Hackathon
2:45pm – 3:00pm	*Break*
3:00pm – 5:00pm	Concurrent Sessions Continue

Day 4: May 26, 2022	
8:00am – 9:00am	*Registration Open*
9:00am – 9:30am	Welcome: Review of Day 3 & Charge to the Working Groups – Shannon Christoffersen
9:30am – 10:30am	Establishing a Sustainable Funding Model for Canadian Arctic Data: Collaborations, Technical Initiatives, and Funding Levels (with internal breakout groups)
10:30am – 10:45am	*Break*
10:45am – 12:00pm	Sustainable Funding Session continues with movement among groups
12:00pm – 1:00pm	*Lunch (provided)*
1:00pm – 1:30pm	Report/Presentations from Working Groups and Discussion – Naomi Boone
1:30pm – 2:45pm	Concurrent Sessions: 1. Indigenous Data Sovereignty: Building Technical Capacity and Knowledge Sharing in Communities, and Research Ethics 2. CIOOS – PDC Hackathon
2:45pm – 3:00pm	*Break*
3:00pm – 5:00pm	Concurrent Sessions Continue
7:00pm	*CCADI Board and EAC Meeting (offsite: Boom & Batten)*

Day 5: May 27, 2022 (GISRT Workshop Concurrent)	
8:00am – 9:00am	*Registration Open*
8:30am – 5:00pm	Mobilizing Wildlife Genomics for Non-Specialists & End-Users (see GISRT May 27th agenda for details)
9:00am – 9:15am	Welcome – Shannon Christoffersen
9:15am – 10:15am	Looking Forward: Developing a Plan of Action and Advancing Technical Initiatives – Maribeth Murray and Peter Pulsifer
10:15am – 10:30am	*Break*
10:30am – 11:45am	Closing Remarks and Review – Maribeth Murray and Peter Pulsifer
11:45am – 12:00pm	CPDW4 Closing Blessing – Kathy and Doug LaFortune
12:00pm – 1:00pm	*Lunch (provided)*

Appendix 2
Participating Organizations and Individuals

Type of Organization	Name of Organization	Affiliated Participant(s)
University	University of Victoria	Kiyomi Holman Lucinda Marshall Melinda Minch
	Simon Fraser University	Sheelagh Carpendale
	University of Calgary	Anna-Maria Hubert Emily Marston Maribeth Murray
	University of Lethbridge	Julie Yee-Law
	Athabasca University	Janelle Baker Srijak Bhatnagar
	University of Manitoba	Yanique Campbell Kelsey Freisen Claire Hebert
	University of Waterloo	Waleed Ashfaq
	University of Toronto	Deborah Wilson Danard
	Queen's University	Lila Colston-Nepali
	Carleton University	Tara Azin Rebecca Ingram Peter Pulsifer
	University of Laval	Amélie Desmarais Etienne Godin Mikel Lemay
	Dalhousie University	Mike Smitt
	Longwood University	Ravi Sankar
Research Networks	ArcticNet	Alexa Reedman
	MEOPAR	Alexa Reedman
	Canadian Integrated Ocean Observing System	Naomi Boone Jeffrey Cullis (CIOSS Atlantic)
	Ocean Network Canada	Matthew Barclay Reyna Jackson Megan Knot Bennitt Mueller Oluwayemisi Ogungberni Chantel Ridsdale Sean Tippett Chantel Verhey
	NSERC PermafrostNet	Nick Brown
	Canadian Consortium for Arctic Data Interoperability	Maribeth Murray Peter Pulsifer
Data Organizations	Arctic Institute of North America	Shannon Christoffersen Munish Madan
	St. Lawrence Global Observatory	Pauline Chauvet Julie Dionne
	Polar Data Catalogue	Greg Vey
	Data Stream Initiative/Gordon Foundation	Lindsay Day Will Farrell
	Digital Research Alliance of Canada	Yvette Rancourt
	World Data Systems International	Karen Payne
Not-for -Profit	Amundsen Science	Alexandre Forest Tahiana Ratsimbazafy
	Arctic Research Foundation	Tom Henheffer Donald McLennan
	Tula Foundation/Hakai Institute	Jessy Barrette Ray Brunsting Mathew Foster Pramod Hupaki
Indigenous Organizations	Council of Yukon First Nations	Christine McTavish
	Inuvialuit Regional Corporation	Calvin Pritchard Ryan Mazan
Government	BC Cancer	Samantha Jones Steen Jones Hesther Yeuh
	Fisheries and Oceans Canada	Kevin Jacobs
	Polar Knowledge Canada	Paul McCarney Misha Warbanski
Private Sector	Sheluqun Consulting	Helen Drost
	African Lion Safari	Amy Chabot
Funders	Genome Alberta	Matt Bryman

Appendix 3
Some Examples of Indigenous Data Sovereignty Resources

- OCAP: Ownership, Control, Access, Possession (https://fnigc.ca/ocap-training/)
- CARE: Collective benefit, Authority to control, Responsibility, Ethics (https://www.gida-global.org/care-principles-copy)
- First Nations Information Governance Centre à First Nations Governance Strategy (https://fnigc.ca/what-we-do/first-nations-data-governance-strategy/)
- Inuit Tapiriit Kanatami (https://www.itk.ca/wp-content/uploads/2018/04/ITK_NISR-Report_English_low_res.pdf)
    - National Inuit Data Management Committee
    - National Inuit Strategy on Research
- Individual Territorial Research Licenses (https://ada.ucalgary.ca)
- UNDRIP (https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf)
- UNESCO (https://www.unesco.org/en)
- TriCouncil Policy Statement (2) – Chapter 9: Research Involving the First Nations, Inuit and Métis Peoples of Canada (https://ethics.gc.ca/eng/tcps2-eptc2_2018_chapter9-chapitre9.html)
- Council of Yukon First Nations (https://cyfn.ca/)
- Local Contexts TK Labels (https://localcontexts.org/)
- Circumpolar Inuit Protocols for Equitable and Ethical Engagement (https://iccalaska.org/wp-icc/wp-content/uploads/2022/06/EEE-Protocols-LR-1.pdf)
- ScIQ: an invitation and recommendations to combine science and Inuit Qaujimajatuqangit for meaningful engagement of Inuit communities in research (https://cdnsciencepub.com/doi/full/10.1139/as-2020-0015)
- Collaboratory for Indigenous Data Governance (Collaboratory for Indigenous Data Governance)

Appendix 4
Terms of Reference
Canadian Polar Data Coordinating Committee

Mandate

1. Provide strategic direction for the Canadian polar data community of practice.
2. Function as a coordinating body – national coordination and liaison with relevant Canadian and international partners, organizations, and initiatives.

Core Functions

1. Seek support for relevant activities, initiatives, funding, etc.
2. Communicate and distribute outcomes and products.
3. Iterative inventorying state of the art and activities across the community of practice.
4. Centralize a point of contact who provides a unified key position/voice/advice/guidance on data management to various relevant audiences.
5. Liaise with and coordinate best practices with the larger data community of practice.
6. Ensure that Indigenous people and organizations are integral to governance through representation, input and action.
7. Ensure representation from the operational communities.
8. Ensure representation from the academic research community.
9. Ensure representation from the relevant federal departments and agencies.
10. Develop a timeline for establishing a governance framework and define the commitment for those engaged.

Representatives to the CPDCC Working Group are drawn from the following

- Canadian representative to the Arctic Data Committee (ADC)
- Canadian Consortium for Arctic Data Interoperability (CCADI)
- Canadian Integrated Ocean Observing System (CIOOS)
- Canadian Cryospheric Information Network/Polar Data Catalogue (CCIN/PDC)
- Inuit Land Claims Organizations
- Natural Resources Canada (NRCan)
- Polar Knowledge Canada (POLAR)
- Polar View (PV)
- World Data System
- Either here or in the additional representatives, we should consider including ICC Canada, Ocean Networks Canada, MEOPAR.

Suggested additional representatives for longer-term governance to be drawn from:

- PermafrostNet
- ArcticNet
- MEOPAR
- Canadian Mountain Network (now Braiding Knowledges Canada)
- Territorial governments
- Inuit Tapiriit Kanatami
- First Nations (AFN)
- Métis (MNC)
- Environment and Climate Change Canada (ECCC)
- Fisheries and Oceans Canada
- Not-for-profit sector
- Other TBD

The CPDCC is co-chaired and managed by an Executive Committee with a Secretariat established through the CCADI through December 2023 with decisions about future structure established through the CPDW 5 (2022 – see this report) and interim meetings of the community.

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