CIOOS: Canada's National Ocean Observing Program

The Canadian Integrated Ocean Observing System (CIOOS) is an integrated ocean observing system that meets the needs of Canadians and contributes to global ocean observing programs. It engages locally, connects regionally, and coordinates nationally to elevate Canada's ocean monitoring to the global stage. CIOOS enables users to contribute to, discover, and access ocean data through its online platform. CIOOS sets ocean data standards through providing national infrastructure for data discovery and access. CIOOS ensures that Canadian ocean observing activities meet global standards and contribute to the global efforts to monitor and share information about the ocean. Working together with regional, national, and international partners, CIOOS is working to develop information services such that the societal needs for ocean understanding can be fully met.

1. How observing system is/has been established, developed, and will be sustained

The Canadian Integrated Ocean Observing System (CIOOS) was established in 2019 to address siloed ocean data and the lack of a formal coordination and collaboration mechanism for the ocean observing community in Canada. CIOOS engages locally, connects regionally, and coordinates nationally to elevate Canada's ocean monitoring to the global stage. CIOOS does not itself collect data, but provides users an online platform to discover, access, and visualize high-quality open data.

> **Vision:** As Canada's nucleus for ocean observing, CIOOS makes connections for a sustainable ocean future.
>
> **Mission**: To foster partnerships and grow a powerful online platform that generates information, knowledge, and place-based solutions to advance our understanding of the ocean.

Establishment of CIOOS was preceded by years of discussions, reports, white papers, and community meetings[1]. Through these activities, key principles were developed to support unification of diverse ocean activities in Canada:

- Build on existing strengths
- Remain science-based and policy neutral
- Cultivate productive, respectful partnerships
- Serve the needs of multiple sectors through flexibility, adaptability, and innovation
- Provide reliable and high quality data across Canada based on the FAIR Principles

Based on consultations with the ocean observing community, the scope and recommendations for CIOOS were developed. To capitalize on existing knowledge and expertise, and to ensure regional

[1] Stewart A, deYoung B, Smit M, Donaldson K, Reedman A, Bastien A, Brunsting R, Carter B, Covey B, Kelly R, Peterson E, Pirenne B, Plourde A, Ste-Marie A-S, Tollefsen C, Wallace D and Whoriskey F (2019) The Development of a Canadian Integrated Ocean Observing System (CIOOS). Front. Mar. Sci. 6:431. doi: 10.3389/fmars.2019.00431

variability is addressed within the system, it was decided to structure CIOOS around regional associations and national nodes.

Once fully realized, the observing system will cover the Great Lakes and the entirety of Canada's oceans from our shared waters with the United States to the Arctic. At present, there are three regional associations: the Atlantic, Gulf of St. Lawrence, and Pacific. These areas were selected due to their strong existing networks of ocean observation.

Led by the regional associations, CIOOS follows a bottom-up approach, recognizing that the strength of CIOOS comes from its regional connections and relevance. This approach helps to ensure the system is connected and responsive to regional needs while maintaining a consistent national approach.

Initial funding for CIOOS (November 2018 to March 2022) was provided by Fisheries and Oceans Canada (DFO), the Marine Environmental Observation Prediction and Response (MEOPAR) Network, and the Tula Foundation. These substantial investments provided the necessary start-up capital to transform CIOOS from concept to reality, and continued investment from DFO and the Tula Foundation supports uninterrupted operation of the system. CIOOS is currently in Phase III of its development.

Phase I of CIOOS (2019-2020) was proof-of-concept and demonstrated the feasibility of managing ocean data to FAIR compliance and making it available on an open-access web-based platform. This phase saw the launch of regional and national data catalogues for data discoverability, established a decentralized structure that allows regional ideas and approaches to propagate nationally, and successfully raised awareness of this developing system through extensive engagement efforts.[2]

CIOOS experienced significant development during Phase II (2020-2022), moving from a nascent system in need of a strategic framework to a maturing system guided by a five-year strategic plan and an implementation plan aligned with national and international priorities, including the GOOS 2030 Strategy (see additional attachments for these documents). These consider activities and lessons learned during Phase I, and were developed in consultation with regional and national stakeholders. This phase built on previous activities to continue engagement across sectors, with particular focus on coastal communities and best practices for managing Indigenous data, and continued to address national challenges to further the development of a national ocean observing system.

In Phase III (2022-present) CIOOS entered the stage of sustainability and continuous improvement, continuing engagement and communication with end-users. The goal is to better understand and respond to stakeholder and rights-holder needs. CIOOS is monitoring and evaluating the progress and performance of the system in the context of regional, national, and international ocean observing communities and ensuring the needs of partners, stakeholders, rights-holders, data users, and contributors are being met. CIOOS continues to utilize a bottom-up approach balanced by the need to share approaches and harmonize best practices efficiently at the national level.

[2] CIOOS Strategic Plan: https://cioos.ca/wp-content/uploads/CIOOS-Strategic-Plan-EN.pdf

In the four years since inception, CIOOS has implemented best practices to manage, integrate, and share physical, biogeochemical, and biodiversity data, based on the 31 variables identified as essential to monitor our oceans by the Global Ocean Observing System (GOOS). CIOOS is further seeking to expand support for variables to include Essential Biological Variables (EBVs) and Essential Climate Variables (ECVs). All data within CIOOS are compliant with the FAIR data principles: findable, accessible, interoperable, and reusable.

CIOOS has also engaged experts to guide the development of an ocean data management system which is nationally and internationally interoperable and consistent with international standards, and has worked to increase communication and collaboration with existing initiatives across all sectors. CIOOS relies heavily on the existing strengths of the Canadian ocean community to support its work, and to date has worked with partners to integrate more than 1,500 datasets across its three regional associations.

CIOOS has worked to ensure alignment with the Global Ocean Observing System, including having representatives on the GOOS Regional Council, participating in bi-annual GOOS Regional Fora, providing annual reports of CIOOS activities to the GRA council, contributing to the Ocean Coordinations Group (OCG) and aligning CIOOS activities with GOOS Implementation Plans. In particular, CIOOS has strong alignment with several of the GOOS 2030 strategic objectives, including advocacy and communications, partnerships, strengthening knowledge and exchange, and open and quality controlled data.

CIOOS is developing as a robust system, supporting the FAIR data principles and using best practices for data management and storage to integrate ocean science and observing activities, allowing for development of value-added products and services. Ultimately, CIOOS has ambition to fully realize the Framework for Ocean Observing (FOO) value chain that underlies the GOOS 2030 Strategy Framework.

2. Procedures for quality assurance, conformance to internationally accepted standards and protocols for measurements, data management, and communications

Metadata: national collaboration was undertaken with CIOOS partners and national experts to develop a metadata profile based on International Organization for Standardization (ISO) 19115:2014 – a common metadata standard that aligns with best practices and allows interoperation with national and international partners. This metadata profile continues to be expanded to support additional variables and platform types and Digital Object Identifiers (DOIs) for datasets.

CIOOS requires that data contributors submit metadata files that are compliant with this profile. The use of netCDF (network Common Data Form) files is encouraged, as there is a broad set of netCDF tools available which may be adopted or adapted. CIOOS strives to be compliant with the Climate and Forecast Convention Version 1.6 (CF1.6) whenever possible.

Cyberinfrastructure: software utilized by CIOOS is open source and consistent with national and international best practices. This includes:

- the Comprehensive Knowledge Archive Network (CKAN) metadata catalogue, which supports look-and-feel customizations, advanced search features, and other features core to the dissemination and discovery of data. CKAN also offers a bilingual user-facing interface and is compliant with the Catalogue Service for Web standard.

- well-structured Web Accessible Folders (WAFs) as an alternative publishing method for metadata and which circumvents the limitations of CKAN when delivering datasets such as acoustic or video.

- the ERDDAP implementation of OPeNDAP (open-source project for a network data access protocol) to serve data, which provides both federation and access capabilities, supports multiple download formats for datasets out-of-the-box, and works with netCDF files by design.

Tools: to support efficient operation and improve end-user experience, where appropriate CIOOS develops tools to automate / assist in data discovery and data management. Two notable products developed since 2019 include:

- **CIOOS Metadata Entry Tool**: this web-based tool leads data contributors through the process of creating a metadata record for a dataset, and provides guidelines to aid contributors in completing the form. This product is open source.

- **CIOOS Data Explorer**: a map-based visualization product that allows end-users to search geographically for data across supported datasets. Users are able to filter, aggregate, and download data that meets their criteria, with downloads standardized in .csv format.

Quality Assurance / Quality Control: datasets within CIOOS are quality controlled at the source, as this is not a service offered by CIOOS at this time. Datasets are however reviewed to ensure consistent formatting for columns, standard names, and units.

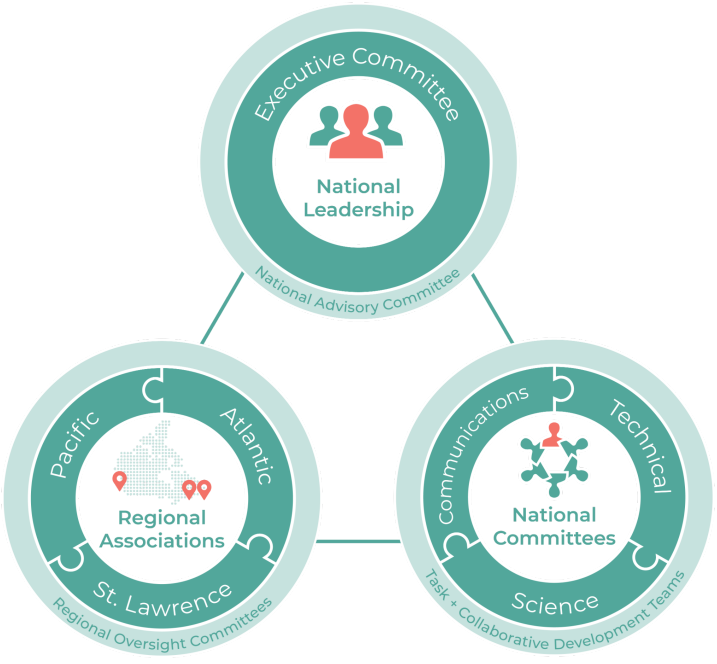
Engagement: through meaningful engagement and ongoing communication with a broad variety of stakeholders, CIOOS works to meet the unique needs of local and regional oceanographic communities while harmonizing around best practices at the national level. The CIOOS Communications Committee has implemented engagement campaigns to promote CIOOS in targeted sectors, and regional associations attend conferences and engage one-on-one with organizations from across sectors to promote CIOOS and further data integration activities. CIOOS also strives for respectful engagement with Indigenous communities, when and where appropriate, and ensuring Indigenous sovereignty and territorial rights are recognized.

Canada and the United States share borders, and their respective ocean observing systems integrate and disseminate data for overlapping regions on the Atlantic and Pacific coasts. CIOOS and US IOOS have formed strong collaborations at the regional and national levels, including regional collaborations such as the US Cutter Healy webinar series jointly developed by NERACOOS and CIOOS Atlantic in 2021, and participation in US IOOS conferences and code sprints that move forward shared goals. In the St. Lawrence region and nationally, conversations and alignment activities have been ongoing with the Great Lakes Observing System. On the west coast, between CIOOS Pacific and NANOOS, there is regular sharing around policy planning and development of data services.

Established relationships with non-governmental organizations, industry associations, academic researchers, and government departments provide CIOOS with a variety of channels to increase awareness and promote national and international best practices around ocean observations and open data. CIOOS further operates organizational websites, social media accounts on Twitter, promotes in publications such as the Journal of Ocean Technology, and distributes a biannual newsletter. CIOOS has regularly held both regional and national meetings and workshops to engage with the wider oceans community.

3. Management Structure

CIOOS employs a multilevel governance model that "allows for strong representation and mobility at the regional level, while ensuring a consistent national approach. An Executive Committee, with representatives from the regions and national committees ensures a clear and transparent decision-making process, integration across the whole of CIOOS, oversight for a common vision and implementation plan, and enables the sharing of best practices. At the regional level, a Board of Directors for each Regional Association gathers feedback and ensures regional adaptability for their unique challenges and opportunities."[3]



Committees containing representatives from each of the regional associations "address more specialized issues and report to the Executive Committee." These groups "report regularly to the Executive Committee for decision and approvals, and can form Task Teams to address specific tasks."[3]

[3] Stewart A, deYoung B, Smit M, Donaldson K, Reedman A, Bastien A, Brunsting R, Carter B, Covey B, Kelly R, Peterson E, Pirenne B, Plourde A, Ste-Marie A-S, Tollefsen C, Wallace D and Whoriskey F (2019) The Development of a Canadian Integrated Ocean Observing System (CIOOS). Front. Mar. Sci. 6:431. doi: 10.3389/fmars.2019.00431

Technical Committee

- Provides oversight and coordination of technical aspects
- Initiates, coordinates, and monitors all technical task teams, such as: Metadata Standards, User Experience, Essential Ocean Variables, and Solution Architecture
- Liaises between the Executive Committee and the CIOOS technical community.

Communications Committee

- National coordination of communications
- Initiates and monitors completion of essential national communications
- Guidance for messaging

Science Committee

- National coordination on data priorities, data integrity, and data use
- Recommendations and standards for new Essential Ocean Variables that interface with GOOS

There is also an International Advisory Committee for CIOOS, appointed by the Executive Committee and supported administratively by the Project Manager and secretariat team. The role of this Committee is to help give CIOOS a broader voice in the ocean observing community, filling an advocacy role, identifying emerging opportunities, and providing strategic leadership and oversight to the Executive Committee. Membership consists of experts within and outside of the ocean observing space.