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MARINE ENVIRONMENTAL OBSERVATION PREDICTION & RESPONSE NETWORK

Towards a Unified Vision for Ocean Data Management in Canada: Results of an Expert Forum

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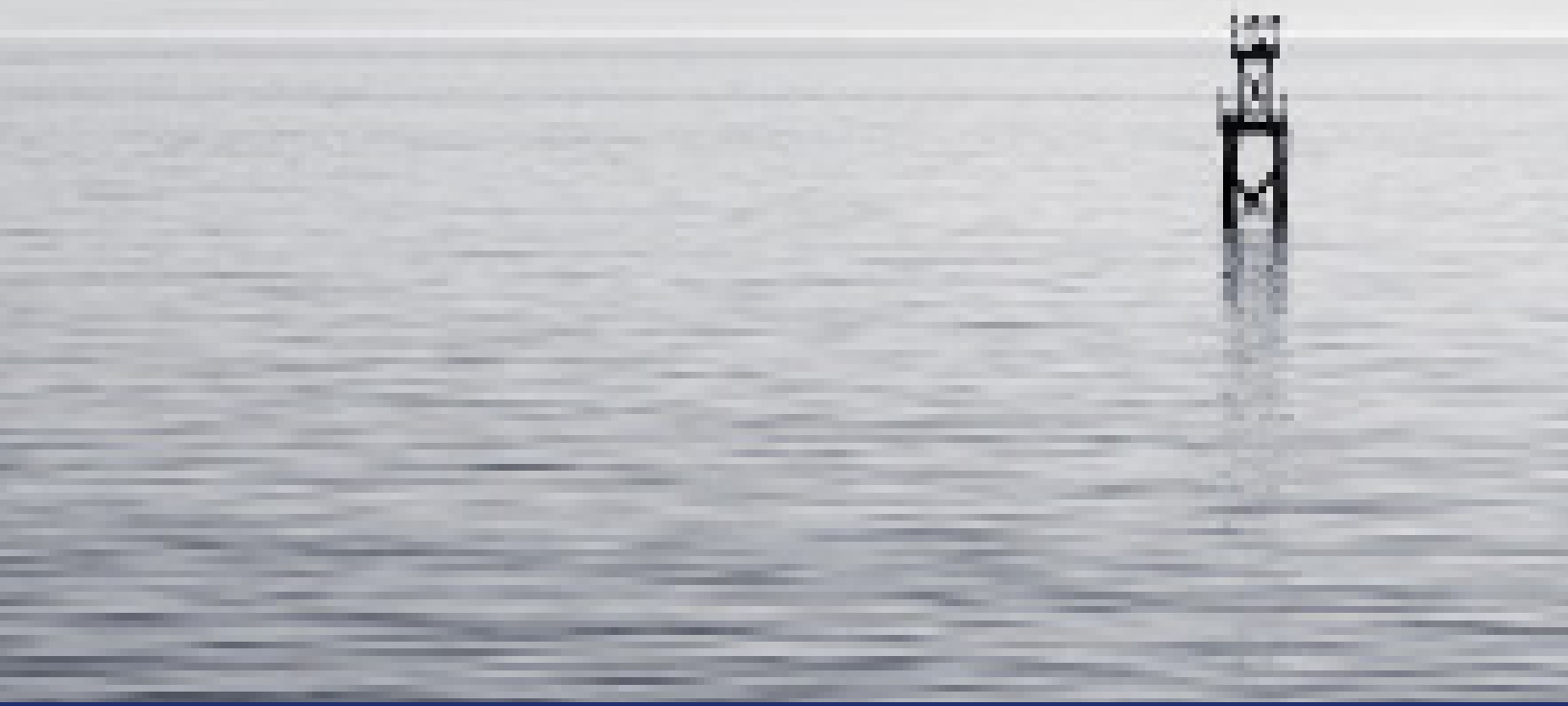

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I. Executive Summary

The world's oceans are a critical part of the Earth system. Sound knowledge and understanding of the oceans is essential for mitigating human impacts on the global environment and for promoting sustainable economic use of the marine environment, including: the safe and sustainable use of natural resources; the assessment of and adaptation to climate change; deep knowledge about complex and interconnected ecosystems; our understanding of the entire Earth system; and health and public safety. Knowledge and understanding, in turn, depends on access to accurate, rich, available, and integrated ocean data, much of which is generated by regional Ocean Observing Systems (OOS) operating in our ocean and coastal zones. Such data is also increasingly relevant to stakeholders outside the oceans community, with a recent report suggesting that the industry sector engaged with ocean observation had revenues of over $7 billion in the U.S. alone, driven in part by their national OOS (NOAA, 2016). A careful re-examination of our data management practices, including how we share, access, and use data, is necessary to ensure we are leveraging Canada's ocean data to best support scientific excellence, foster collaboration and innovation, and harness ocean data to inform decision-makers and other stakeholders.

The Expert Forum on Ocean Data Management (November 18-19, 2015 in Montreal, Canada) brought together national and international experts and stakeholders to present and evaluate international best practices in managing data from ocean observations, the current state of ocean data collected and managed in Canada, and goals and visions for the future of ocean data management (ODM) in Canada. Planned based on input from the Community of Practice on Ocean Data Management (CoP ODM), and organized and sponsored by the Marine Environmental Observation Prediction and Response (MEOPAR) network, this forum built on previous events including a national Data Management Workshop (March, 2014) and a joint DFO-MEOPAR Workshop on Ocean Data Management in the Atlantic Canada Region (July, 2015). Over fifty participants from government, academia, and the private sector attended.

About the Ocean Data Management Community of Practice:

The ODM CoP connects Canadian ocean data centres to share and mobilize expertise and best practices, promote cooperation and alignment, and develop a shared vision for ocean data management in Canada. Conceived by its members at a 2014 Data Management Workshop, and supported by MEOPAR's Data Management project, the community is currently comprised of organizations from government, academic, and NGO sectors. The CoP includes primarily academic producers of data (who are also prolific end-users of ocean data) in Canada, though the current conversation includes discussion around an industry-driven group to connect closely with the CoP. Organizations represented at the Expert Forum are described in Appendix A.

International representatives from the U.S. Integrated Ocean Observing System (IOOS), MARUM (Center for Marine Environmental Sciences), and European Marine Observation and Data Network (EMODnet) described ODM experiences, lessons, and best practices in the United States and Europe. Canadian experts included representatives from Fisheries and Oceans Canada (DFO) who spoke of the need to move ODM in Canada forward in an integrated manner; from Portage / Canadian Association of Research Libraries (CARL) on the current state of research data management nationally; and from Compute Canada on their interest and capabilities in data storage. Members of the ODM CoP and other invitees spoke about how their organizations collected, managed, and shared ocean observation data at regional centres across Canada. (See Appendix B for a full list of participants. The Expert Forum program and presentations are available on our website at http://meopar.ca/calendar/event/856/.)

Following the expert presentations, attendees of the Expert Forum participated in facilitated breakout and group discussions around two broad themes: "what do we envision" for the future of ocean observation data in Canada, and "what are we willing to commit" to achieve this vision. These discussions were led and informed by representatives of the CoP, who drew on their wealth of experience managing ocean data and history of advocating for improved collaboration in ocean data management.

The vision that emerged from the discussion was unambiguous. Participants were ready for the federal government to take a leadership and support role in the formation of a Canadian Integrated Ocean Observing System (CIOOS). Participants envisioned a national system that is robust, accessible, flexible, and sustainable, encompassing technology, expertise, services, and governance capable of providing single-source discovery, search, and wide-ranging access to quality ocean data for all stakeholders. Participants identified that one of Canada's existing strengths is strong, regionally-based data collection on all three Canadian coasts, existing collaborations with DFO, and the consensus was that a system similar in principle to the U.S. IOOS model (a federated model of regional nodes with central coordination and incentives) would make best use of existing expertise and experience. The shared goal was an integrated platform for ocean data that would allow for Canadians (including researchers, decision-makers, and the general public) to benefit from the exemplary science and ocean observation already taking place throughout the country. A more detailed vision is presented in Section IV.

In turn, the members of the CoP "committed to commit." There was widespread recognition that such an initiative is necessary and timely and that the CoP members would be willing to offer their expertise and experience. Representatives of the existing ocean data centres in Canada agreed to continue their engagement in the process, expending time and energy toward defining and realizing this important initiative. A specific list of commitments and next steps is described in Sections V and VI.

II. The Canadian Context: Canadian Ocean Observing Systems

A Canadian OOS Inventory Survey Report (see OSTP, 2011), a report compiled by the Expert Panel on Canadian Ocean Science (see Council of Canadian Academies, 2013), and a recent white paper (Wallace et al., 2013) have each highlighted the many ocean observation oriented activities currently operating across Canada. These regionally-forward activities, while strong individually, have not yet formed a strong national network. Access to data by end-users (e.g., academic researchers, policy and decision-makers, and the general public) is often challenging, with data and forecasts collected by various programs and agencies being scattered

across a range of web-pages that can be difficult to find and hard to access – or not available at all. Although ocean observation activities are underway throughout every coastal region in Canada, including the Great Lakes, the primarily regional approach has led to a "fragmented sector" that has made "limited effort to coordinate the sector knowledge and best practices such as data management and data and information exchange" (OSTP, 2011, p. 2). The Council of Canadian Academies report describes this so-called "Coordination Gap" as follows:

Despite the many instances of successful collaboration in Canada, coordination in key areas, such as ocean observation, is lacking, and support for research networks has often been constrained by temporary funding. More generally, there is no effective national-level mechanism to coordinate the allocation of resources and facilitate the sharing of infrastructure and knowledge among ocean scientists. This also hinders the sharing of resources and knowledge at the international level. (Council of Canadian Academies, 2013, p. xix)

Additionally, this lack of coordination has "resulted in loss of efficiencies in terms of resources and downstream value added benefits to … users, suppliers, and the Canadian public" (OSTP, 2011, p. 3). In response to these reports, there has been increased communication and collaboration, including formation of the ODM CoP, and events like the Expert Forum which have moved us toward, though not yet achieved, the reports' recommendations: an overarching framework that can allow for better integration amongst Canadian data centres.

Strong regional actors capable of collecting and managing their own data is one of the strengths of the Canadian ODM community. Regional OOS' can deliver benefits that are tailored to the specific needs of their communities, including both producers and consumers of ocean data. In addition to targeted delivery, regional developments have also led to innovative technologies and data management practices by involving a wide array of relevant stakeholders, including industry, academia, and non-governmental organizations (NGOs) (OSTP, 2011). At the Expert Forum, members of the ODM CoP showcased the extensive network of regional and theme-based systems currently in operation across Canada, including the Canadian Arctic.

Improving coordination and integration in ODM does not mean starting from scratch: an integrated OOS would utilize and build upon the current landscape of Canadian ocean observing platforms (Wallace et al., 2013). Local, community-level support and involvement is essential in the success of such initiatives. An integrated, national OOS should employ a consultative approach to determine high-level design and objectives informed by existing knowledge and expertise, and be implemented collaboratively with strong regional partners.
The ODM CoP is one potential vehicle for building collaboration; its members include Canada's major ocean data centres (Appendix A) each with links to local stakeholders. The CoP works to form links, connections, and collaborations at the organizational layer, and these relationships will be strengthened by additional connections and links at the data layer. The CoP can foster integration of new initiatives with existing efforts. For example, some members of the CoP have recently collaborated with computer science researchers to submit a proposal to develop improved infrastructure and tools for acoustic ocean data, another indicator of the collective will to collaborate on national projects of general interest. The project is planned to launch in 2017. In the future, the CoP will be in a position to harness strengths from its members to coordinate responses to such opportunities.

The Canadian conversation about improved ODM is particularly relevant to two other ongoing national initiatives; experts from each also presented at the Expert Forum. First, there is work on managing

research data more generally, including access and long-term preservation; CARL formed the Portage network to coordinate the efforts of their member institutions to support this need nationally. This system will not be sufficient for storing, searching, displaying, federating, etc. ocean observation data under active use. However, it would be appropriate for such a system to ensure long-term data preservation. Additionally, a national research data system can provide a mechanism for researchers not currently using ocean data to discover that such data exists, and direct them to CIOOS, increasing the visibility and accessibility of ocean data.
Second, Compute Canada has a multi-year mandate from CFI to understand the computation and storage needs of Canadian researchers and request funding to meet those needs. One ongoing transition is additional storage and cloud-style access to computation resources. It is too early to identify specific implications to ODM, but at minimum their expertise in national cyber infrastructure is an available resource that should be utilized.

III. A Global Perspective: GEOSS, GOOS, IOOS, and EMODnet

The Global Earth Observation System of Systems (GEOSS) was envisioned during the First Earth Observation Summit (EOS I) held in 2003 in Washington, DC, where international representatives identified a need for increased coordination and integration among global observing systems. The Global Ocean Observing System (GOOS), created in 1991, is the oceans component of the GEOSS framework. Various organizations participate in global coordination: several UN member states have taken steps towards the creation of integrated OOS' that feed into the international framework; regional collaborations (like AtlantOS and EMODnet) connect multiple organizations, partners, and countries; and selected ocean data centres; and some countries have established a national infrastructure for data management and dissemination. Representatives from IOOS in the United Sates and EMODnet and MARUM in Europe presented at the Expert Forum.
U.S. IOOS is a national initiative led by the National Oceanic and Atmospheric Administration (NOAA). The program coordinates a network of organizations, people, and technology to produce and disseminate continuous, often real-time, ocean, coastal, and Great Lakes data (National Oceanographic partnership program, 2006). IOOS contains two major components: a global component that feeds into the international GOOS framework, and a coastal component involving 17 federal departments and agencies, 11 regional associations, as well as members from academia and various industry sectors. A strength of the IOOS program is that it is a federal partnership that works with the regional entities to leverage dispersed national investments in order to deliver data relevant to decision-makers (National Oceanographic Partnership Program, 2006).

At the national level, IOOS provides high-level policy guidance and strategy, standards-based data integration services through the Data Management and Communication (DMAC) system, funding support for the regional entities, system stability and sustainability, and data archiving. The function of DMAC is to integrate data from a variety of disparate locations (e.g., the regional associations). This is accomplished by creating and advocating for the use of DMAC standardized services and also by acting as a "brokerage layer" that mediates between the regional system and the national infrastructure. DMAC ingests regional data into scalable, high-performance computing architecture at the national level. The regional nodes, comprised primarily of state or municipal governments, academia, industry, and NGOs, are largely responsible for managing their own data. Data management includes: service and support to local producers and consumers of data, facilitating the integration of regional datasets into the national system, ensuring regional interoperability within the national IOOS framework, and maintaining a web-based platform that provides single-point of entry access to regional data.

EMODnet is a Pan-European initiative and a part of Europe's Blue Growth policy framework. The program was conceived through the recognition that ocean data collection in Europe has long been fragmented, with projects operating in isolation. Using marine data, metadata, and data products from diverse sources across Europe, EMODnet seeks to "unlock" hidden or previously inaccessible data so that they can be made useful for end-users. This approach recognizes that data collected through observations can only generate knowledge and innovation if end-users, e.g., engineers, scientists, and policy experts, are able to find, access, assemble, and apply them efficiently and rapidly (European Commission, 2010). Comprised of 110 separate organizations, EMODnet's core tenets are 1) to create added value for existing efforts by ensuring that data collected once can be used many times, thereby reducing costs associated with ODM; 2) to provide free and unrestricted access to data and data products; 3) to put the user first when developing new initiatives and making decisions; 4) to develop standards across disciplines to ensure that data may be integrated from multiple scales (e.g., regional, national, and international); and 5) to ensure that producers retain rights and ownership over their data while also promoting high standards for quality assurance and control.

Key Takeaways from International Experts

Speaking at the Expert Forum in Montreal, representatives from IOOS, MARUM, and EMODnet described the lessons learned in the development of their respective organizations. The main points are summarized as follows:

Encourage a shift towards a culture of open data sharing. At the outset, recognize and respect the magnitude of institutional change demanded by a national, integrated OOS and allow this mindset to guide discussions. At the technology layer, use open source solutions whenever possible. Proprietary software can restrict data sharing and system interoperability. Open source software also aids in reproducibility since more scientists will be able to access and use the data. However, open data does not mean anonymous access to data. Requiring users to provide identification through a registry, for example, can provide useful information to system administrators about who is accessing the data and why. Understanding one's user-base makes it easier to implement targeted improvements.

Encourage open data sharing by incentivizing data producers and acknowledging and respecting data ownership. Especially within a federated system comprised of linked autonomous regional associations, stakeholder buy-in requires incentives. Incentives should be both financial (e.g., joining the national OOS opens up opportunities for increased funding) and non-financial (e.g., offering some form of accreditation for data sharing). Accreditation also means acknowledging the source of the data and negotiating a fair-use license that ensures data is free and open, but also protects data producers from exploitation (e.g., data being used by a third party for financial gain without permission).

Data is more than data: it includes documentation, tools, source code. There is an implicit understanding that the term "data" is inclusive of any associated metadata. What is not always understood is that shared data is incomplete without suitable documentation on how to work with the data (which can include various data workbook formats) and open-source tools or scripts used to work with the data. While these items could theoretically be developed independently, shared source code and tools will magnify the impact of open data.

An interoperable sharing network based on a federated system of regional/thematic nodes works best for geographically dispersed and diverse areas. Particularly within the Canadian context, a federated system comprised of regional associations would serve to build upon what already exists.

Engaging with the pre-existing CoP (see Section II) provides access to decades of experience and data. International experts identified strengths in the CoP that included the governance structure and model of SLGO, various collaborations with IOOS regional associations, and engagement with GOOS and other international initiatives. Stakeholder engagement that occurs often and early also means that the system will be built by and for the intended user-base.

The system should benefit a wide variety of stakeholders. In addition to the CoP, a national integrated framework for ocean data must also demonstrate value for a diverse stakeholder group, including members of the private sector. This will help to build cross-sector partnerships that may lead to alternative funding mechanisms in the future. Empowering "neutral" organizations (e.g., NGOs) to act as brokers may also facilitate cross-sector integration.

Build a system with sustainability at the core. Implement modern IT solutions and a policy framework that is clear, but also flexible enough to adapt to future considerations. Modern IT solutions may involve developing novel technologies or re-engineering existing technologies to ensure that they are fit-for-purpose. Architect the system with long-term preservation of data as the goal and budget accordingly. Do not underestimate the cost and value of data management.

Quality assurance and control are paramount. Quality is an essential property of data and a strong determinant of value. Quality control must start at the point of collection and persist throughout the data lifecycle. The development and application of standards (e.g., metadata standards and best practices) must be included in the system architecture. The provision of free standardization tools (e.g., compliance checking tools) are useful, but should not be used as a substitute for human expertise.

Do not let perfect be the enemy of good. Consider what currently exists within your own country (i.e., the ODM CoP in Canada); what exists elsewhere (e.g., the IOOS framework in the United States); create a plan based on evidence, extensive stakeholder consultation, and best practices; and then move towards implementation with the goal of adapting and improving the system as it matures. A "perfect" system at the outset is simply unrealistic; other national OOS' have undergone substantial evolution after their original creation.

The system that resonated the most with Canadian participants was the U.S. IOOS. Both Europe and the United States must work within dispersed and geographically and politically diverse climates, but several factors were identified for this preference. First, IOOS operates within a national, rather than international, framework. Second, four out of the eleven regional associations in IOOS directly share waters with Canada (BC/Alaska (AOOS); BC/Washington (NANOOS); the Great Lakes (GLOS); and Maine (NERACOOS)/Nova Scotia/New Brunswick) which has led to various Canada-US collaborations. For example, L'Observatoire global du Saint-Laurent/St. Lawrence Global Observatory (OGSL/SLGO) and NERACOOS share joint membership and data; the Ocean Tracking Network (OTN) works with IOOS regional associations to help support their local communities of acoustic telemetry researchers; Ocean Networks Canada (ONC) is a member of NANOOS and provides data to inform tsunami warning to the Pacific Tsunami Warning Centre (NOAA); DFO and NERACOOS conduct joint research in the Bay of Fundy at St. Andrews Biological Station; and Environment Canada data is shared with GLOS and NERACOOS data portals.

As one of the IOOS presenters said, they have already experienced the pain of defining a model; they would be happy to see other countries adopt and adapt that model and save themselves that pain. Understanding that ocean observation does not adhere to national boundaries will help to build future international partnerships and better define Canada's role in a global setting.

IV. A Canadian Perspective: Moving Forward

In addition to providing a window into what is possible in Canada, the presentations from international partners made clear to the Canadian participants that, despite being a world leader in ocean observation and technological innovation, Canada's management of ocean data is not at the same level. A presenter from DFO outlined the variety of integrated systems that exist internationally and suggested that the time has come for Canada to increase its involvement in the international community. The representative then presented a vision for the future of ODM in Canada as:

An integrated Ocean Observing System for Canada that would bring together and leverage existing Canadian and international ocean observation data/ programs/projects to generate value-added data products on an open web-based platform that maximizes utility to end-users (e.g., government, science partners, industry, and the public).

The system as described would federate the data currently collected by the diverse regional groups across Canada into a web-based platform that would be publically accessible. Such a system would also ensure that international standards for data collection, storage, and documentation are followed. CIOOS would provide a common system for government, scientists, and partner organizations to integrate, access, share, and preserve data, thereby granting access to a wider breadth of information to make predictions and inform decision-making. Additional value-added benefits to ocean data would include:

- Enhanced modeling work and environmental assessment advice.
- Increased ability to detect changes in ocean conditions, including impacts on fish stock and distribution.
- Improved resource-management decision-making, both in the long-term (e.g., environmental and climate change adaptation) and the short term (e.g., ecosystem approach to management).
- Reduced risk to infrastructure by enhancing storm prediction and area of impact, as well as water-level rise.
- Capacity to establish integrated baseline data useful for long-term monitoring.
- Generating new opportunities for industry growth/technological development.
- Advancing Government of Canada commitments to Open Data/Open Science.

DFO also clearly recognized the challenges facing such an initiative. At the organizational level, a national framework and governance model will need to be developed. This framework needs to be both policy-driven (e.g., considers the role of government within the larger system) and operational (e.g., support mechanisms, including funding support, that will ensure that whatever is built can be sustained). At the data level, there is a gap in knowledge about what data currently exists in Canada, but are not yet accessible (i.e., long-tail or "filing cabinet" data that are uncatalogued and often exist in outdated formats). Also, as indicated by the international presentations, articulating a policy for data ownership, intellectual property, and licensing will require time and effort. Intertwined with the data issues are technological barriers, such as the difficulty in developing a system that is functional, robust, user-friendly, and also aligns with the expectations of a diverse user-base. System interoperability, including the implementation of accepted best metadata standards and practices represents a significant hurdle that must be surmounted.

The following section outlines the result of the Expert Forum facilitated sessions on how to meet these challenges, and what Canada's next steps should be.

V. Voices from the Community of Practice

The Expert Forum was designed to not only inform attendees, but also to actively engage the audience – who collectively brought substantial expertise in ODM and the Canadian context – as participants in the conversation about how to advance the state of ODM in Canada. During facilitated breakout sessions, participants (including representatives from every member of the CoP) were asked to describe what they envisioned for the future of ODM in Canada (we envision) and what they would be willing to commit towards the realization of this vision (we commit). There was a clear consensus: we need to take action; Canada needs a national integrated ocean observing system; and it needs to be done sooner rather than later. More importantly, there was a willingness to work together and with the government and private sector, to realize this goal.

WE ENVISION:

The collective vision calls for a system that is robust, accessible, flexible, and sustainable, encompassing technology, expertise, services, and governance capable of providing single-source discovery, search, and wide-ranging access to quality ocean data for all stakeholders. Specific components of the overall vision are as follows:

Develop a clear policy framework to support this initiative. In his Ministerial Mandate Letter delivered to the Minister of Innovation, Science and Economic Development, Prime Minster Trudeau issued a directive to improve the quality of publically available data in Canada and indicated support for open data (Trudeau, 2015a). The Mandate letter to the Minister of Fisheries, Oceans and the Canadian Coast Guard called for improved monitoring, management, and evidence-based decision-making, all areas that require access to integrated, high-quality ocean data (Trudeau, 2015b). In the United States, a key driver in the formation of IOOS was the Omnibus Public Land Management Act 2009 that provided necessary high-level policy coordination. At the Expert Forum, participants expressed a clear need for support from both federal and provincial departments and agencies. This includes increased funding support and an expanded societal investment in ocean observation, and the understanding that this support can be tied to programs designed to incentivize participation in a coordinated national system.

Select and empower a government department or agency to act as a leader. Creating a national OOS involves a variety of stakeholders, including multiple federal and provincial government departments, NGOs, academia, industry, and members of the public. Success will depend on engaging with stakeholders to benefit from the existing expertise in this field and also to obtain support and buy-in for the project. A leader will be needed to coordinate the diverse organizations and ensure that the project is moving steadily towards a clear vision. In the United States, NOAA was chosen as the lead government department for the IOOS project and has the primary responsibility of providing high-level strategic and policy guidance. The general belief at the Expert Forum was that DFO is well suited to such a role, but the details of the structure and the definition of an CIOOS secretariat were not in the scope of our conversation.

CIOOS should be a federated system comprised of regional/thematic nodes. There are multiple models of national coordination, ranging from purely centralized to purely distributed. As described in Section II, Canada is home to an exemplary array of mature and experienced OOS programs, many of which have a regional or thematic focus. Efforts at moving

forward must build upon what already exists rather than trying to reinvent the wheel. Using the IOOS model as a guide, the national level could provide high-level policy and strategic planning; data standardization policies, metadata standards, support, and tools; funding support; maintenance of the national cyberinfrastructure, including a centralized, web-based portal; and procedures and mechanisms for long-term retention and preservation of data. Regional/thematic nodes, established in consultation with, and consisting primarily of, members of the ODM CoP, will be responsible for data management at the local level, ensuring that data is processed and stored in a manner that is consistent with national standards. Regional nodes will be structured based on an examination of identified best practices (including IOOS and SLGO). Regional nodes would have a mandate to engage smaller groups within their region, ranging from academic research projects to indigenous communities. In the U.S. IOOS framework, regional nodes are also responsible for creating and maintaining their own data products (e.g., end-user data visualization platforms). Canada may decide that a single, national end-user interface is more appropriate.

Work towards the development of, and support for, a clear and consistent data standardization policy. A federated system of regional nodes cannot function without data interoperability. Creating a policy that clearly delineates requisite data management practices (e.g., metadata standards) is essential. In addition to policy creation is support for good data management. One of the roles of the national level should involve producing educational products (e.g., simple instructional guides) and tools (e.g., standards compliance checkers) for use by the regional nodes. Another common barrier to data management is a lack of resources, both financial and human. Building data management into funding support mechanisms can help to surmount such difficulties.

Recognize that integration means more than data sharing and access. While important, data integration is not the sum total of the role of coordination. Data collection is often expensive and time consuming, and coordination of various government, academic, and private data collection endeavours can ensure resources are used effectively; of course, the coordination of observation efforts is only possible when there is robust data sharing. As new tools are developed and employed (e.g. ocean gliders), the sharing of best practices, training, and resources can help Canadian scientists realize the benefits of these tools more quickly. There is also room for administrative coordination; for example, group purchasing can realize economies of scale and simplify procurement.

CIOOS must provide easy access to ocean observation data to support evidence-based decision-making for maritime issues. The system should contain data relevant to dealing with climate change, coastal erosion, fisheries management, biodiversity, environmental hazards, weather prediction and response, arctic issues, and industrial marine developments. The system should provide a seamless access point for ocean data users and clients. Solutions for distributed data storage at the scale required to make this possible must also be considered.

Continue to strengthen and grow the ODM CoP in Canada. We need a closely-knit CoP in Canada that will join the global community of excellence in ocean observation and management of ocean data. Community support for the proposed national integrated OOS is essential. This needs to be an initiative that is for the community and by the community. Regular and timely engagement forums, including consultation meetings, workshops, and symposia can be used to obtain stakeholder feedback and define the role of the CoP within the new national

framework. A national oversight committee, chaired by the lead government department or agency, comprised of members of relevant government entities and representatives from each of the regional nodes, should be founded. While CIOOS should proceed in a phased approach starting with existing networks, and existing federal backbone data, strengthening the CoP also means strengthening relationships among ocean data actors from across sectors, including academia, NGOs, industry, and local communities. Increased engagement will promote a shift towards a cultural attitude in which data is seen as a shared asset and a public good. The CoP attendees of the Expert Forum were primarily focused on data management at their respective organizations; this input is vital, but it is also important that this conversation also include the organizational level, and that the leadership of Canada's ocean data centres share this vision.

WE COMMIT:

Buoyed by the sentiment that this is an initiative worth doing, participants, particularly those representing members of the ODM CoP, unanimously committed to expending time and resources to the project, as well as committing to being actively engaged throughout its development and beyond. In essence, attendees commit to commit; more specifically, the following commitments were discussed:

Working together towards a common ODM solution for Canada. This includes communicating requirements, information about what data is being collected, and contributing to the ongoing discussion of CIOOS. CoP members also committed to moving towards sharing data from individual nodes and ensuring that existing datasets are compliant with national standards.

Sharing technology, expertise, and experience. Broadly, CoP members and our international experts committed to contributing the assets of their organizations to benefit the Canadian ODM community at large. This includes tools, web-services, data management practices, expertise, code, and existing and future data. There is much to learn from the U.S. IOOS example, and their representatives committed to sharing their experience with us.

Promoting this vision for CIOOS within their respective organizations. Attendees agreed to carry back to their organizations the conversations started at the Expert Forum to garner support, receive feedback, and maintain momentum for this initiative. The MEOPAR team agreed to draft this white paper capturing the conversation.

Continued support of the CoP. Members continued to express support for the existence of a community, and MEOPAR agreed to continue to support the community through its ODM project, and to support initiatives like a summer student program which places co-op students at Canada's ocean data centres each summer. Others expressed interest in continued engagement with the CoP.

Bring in local organizations. Stakeholder buy-in for this initiative is essential. Representatives from the CoP present at the Expert Forum agreed to engage local organizations within their existing networks. Some members expressed interest in organizing town hall-style forums or meetings to inform and better understand the needs of local groups.

VI. A Way Forward: Challenges and Next Steps

Results from the Expert Forum revealed that: 1) despite being on the cutting-edge of ocean observation with many mature OOS projects currently in operation, Canada is one of the few developed coastal nations in the world that does not have a national integrated OOS; 2) there is a unanimous desire among the ODM CoP for more national coordination and integration; and, 3) the CoP is willing to work together and with the government, committing time, energy, and resources towards this initiative. While the Expert Forum achieved its goal of furthering this important conversation, it is imperative that we take action and not lose the progress and momentum already achieved. There are complex questions ahead, and likely some difficult conversations, but the goal is important and worthwhile. The next steps include:

Defining collaboratively the concept of regional nodes building on regional strengths. Although territorial overlap does exist, Canada's OOS' already operate in a regional and thematic fashion. Defining Canada's regional OOS' is an essential step. As a concrete first step, there was agreement that in early 2016, the leaders of Canada's ocean data centres and research networks would meet to discuss the organization and governance of an integrated ocean observing system in more detail, as well as collaboration among the networks and with DFO more generally. Representatives from DFO agreed to call this meeting, and MEOPAR agreed to support its organization.

Creating a blueprint for the system architecture. In addition to the organizational structure, and based on the organizational structure, we need to resolve technical questions for a nationally distributed technical infrastructure. The current preferred approach envisions a federated system of regional nodes, but the specifics of how this system will operate needs to be negotiated. Some questions include: Which data storage will be centralized and which will be decentralized? Where will the data ultimately be housed? What technological investments are needed? Who will provide support, either funding or in kind, for the cyberinfrastructure?

Developing a national policy framework that is agreeable to a diverse stakeholder group. Policy will form the underpinning of the Canadian OOS. How it is developed will affect stakeholder buy-in. Stakeholder engagement needs to happen often and early during the policy development phase so that input is meaningful and problem areas are addressed at the outset.

Developing a clear governance structure. For example: which government department or agency will lead this initiative? What will the relationship between the national level and the regional level look like? The conclusion of the Expert Forum was the need for a multi-stakeholder committee comprised of government and representatives from the regional nodes.

Coordinating diverse organizations. During the development of U.S. IOOS, NGOs with a national focus successfully played a brokerage and coordination role due to their perceived neutrality, and their interest in seeing a national data sharing framework combined with their expressed wish to not house or operate the framework. In helping to bring together Canada's ocean data stakeholders through events like the Expert Forum, MEOPAR has already taken on this coordination role and is willing to continue; as expressed at the Expert Forum, it wants to see improved national coordination and is eager to support related initiatives, but as an NCE its role does not include housing, leading, or operating a CIOOS.

Ensuring sustainability. Whatever we build today has to contend with the needs of tomorrow. Sustainability, both in terms of the technological and organizational layer, needs to be at the forefront of future planning.

Even with multiple challenges and many steps ahead, we remain confident that a supportive government combined with an ODM community that both acknowledge the need for national action can build a CIOOS that meets the needs of stakeholders and achieves the vision expressed at the Expert Forum. It is imperative to not lose momentum. Over a decade ago, Canada presented its Oceans Strategy (DFO, 2002), developed an Oceans Action Plan (DFO, 2005), and has since participated in several OOS market studies and inventories (Douglas-Westwood, 2006; OSTP, 2011; OSTP, DFO, & CSA, 2011). Canada's world renowned scientific experts, extensive science infrastructure, and thriving ocean technology industry are amongst its most valuable resources. The time has come for national science leadership, cooperation, and efficient coordination of regional efforts towards a cohesive CIOOS. Progress will rely on an extensive engagement process, including consultations with the CoP, and a phased approach, allowing for stakeholder input and user feedback to be incorporated at each level. While this system will be the first of its kind in Canada, we have access to a wealth of experience internationally. A continued willingness to collaborate, sensible organization and governance decisions, sufficient resources, and innovative technical solutions will pave the road to a national ocean data infrastructure that will provide ongoing value to researchers, governments, industry, and the general public for generations.

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APPENDIX A – Members of the Ocean Data Management Community of Practice

Atlantic Coastal Zone Information Steering Committee (ACZISC)

The Atlantic Coastal Zone Information Steering Committee (ACZISC) was established in January 1992 to foster cooperation in Atlantic Canada with regard to Integrated Coastal and Ocean Management (ICOM), coastal mapping and geomatics. The ACZISC is actively: 1) networking and disseminating information via meetings and thematic workshops, and the Coastal Update e-newsletter and the ACZISC website; 2) engaging stakeholders in the establishment of COINAtlantic - the Coastal and Ocean Information Network - in support of ICOM in Atlantic Canada; and participating in studies and projects to further our understanding of the coastal zone. COINAtlantic is based on the principle that data custodians manage their data effectively and make it and associated metadata searchable and accessible on the internet. The ACZISC holds two meetings per year in the Atlantic provincial capitals by rotation. In addition, it organizes thematic workshops as required. The meetings and workshops are attended by ACZISC Members and by observers from all sectors, including community groups, the private sector, academia, etc.
The ACZISC Strategic Plan identifies three priorities:

1. Encouraging action on the implementation of Integrated Coastal and Ocean Management (ICOM) as a tool to realize environmental, economic and social sustainability.
2. Collaborative sharing of data and information between members and with the wider ICOM CoP on the ICOM issues of priority to members.
3. Encouraging the engagement of organizations in the ACZISC that is reflective of the diversity of the ICOM CoP..

To promote the sharing of data, the ACZISC has developed three tools (http://coinatlantic.tools/):

1. The COINAtlantic GeoContent Generator (CGG) that can be used for the creation of basic metadata, searchable on the internet, for an organization, a project, a publication or a dataset.
2. The COINAtlantic Search Utility (CSU) that searches the internet for spatial resources (i.e. WMS and KML), a local database of previous successful searches, and the CGG entries according to the users' criteria and displays them in map form. The CSU also tests the availability of each spatial resource stored in the local data base on a regular basis.
3. The COINAtlantic Data Accessibility Self-Assessment Tool (CDAST) is a questionnaire designed to assess an organization's effectiveness at providing accessibility to data under its custodianship according to 11 principles.

Fisheries and Oceans Canada (DFO)

Fisheries and Oceans Canada (DFO) has the lead federal role in managing Canada's fisheries and safeguarding its waters. The Department supports strong economic growth in our marine and fisheries sectors by supporting exports and advancing safe maritime trade, supports innovation through research in expanding sectors such as aquaculture and biotechnology, and contributes to a clean and healthy environment and sustainable aquatic ecosystems through habitat protection, oceans management, and ecosystems research. The Department's work is guided by five key pieces of legislation: the Oceans Act, the Fisheries Act, the Species at Risk Act, the Coastal Fisheries Protection Act, and the Canada Shipping Act, 2001 (Transport Canada-led).

DFO also hosts Canada's National Oceanographic Data Centre in the Intergovernmental Oceanographic Commission's (IOC) International

Data and Information Exchange Panel. In addition to the scientific environmental monitoring, research and modelling activities conducted at its several facilities, DFO also fulfills Canada's data management in several GOOS components, such as the international Argo programme. DFO also plays an active role in the data management activities of the Joint Technical Commission for Oceanography and Marine Meteorology of the World Meteorological Organization and IOC. DFO frequently partners with other departments, academia and various consortia to deliver its mandate.

L'Observatoire global du Saint-Laurent/ St. Lawrence Global Observatory (OGSL/ SLGO)

The observatory concept covers the range of activities, capacities and infrastructures for the collection, management, analysis, processing, modelling and dissemination of data, information knowledge, and value-added products and services implemented by data producers in response to user needs.

The St. Lawrence Global Observatory represents the collective information, expertise and means implemented by member organizations and the SLGO Corporation.

Setting up an observatory such as the SLGO is creating a data value chain. At one end, data from ecosystems monitoring activities is produced then processed, documented and standardized by SLGO member organisations. SLGO makes information products and services available for decision makers and end users by efficiently integrating its members' quality data and information.

SLGO's collaborative approach contributes to reducing duplicated efforts and collective costs of data dissemination by creating synergy between data producers and by fostering sharing of means and expertise.
By being a key component of the information infrastructure, SLGO promotes data valorization which contributes to addressing societal issues and translating into socio-economic benefits.

Marine Institute of Memorial University of Newfoundland (MI)

Located at Memorial University in Newfoundland, the Fisheries and Marine Institute is Canada's most comprehensive centre for education, training, applied research and industrial support for the ocean industries. The Marine Institute provides more than 20 industry-driven programs ranging from technical certificates to master's degrees. In addition to undergraduate and graduate degrees, the Institute offers advanced diplomas, diplomas of technology and technical certificates. The Institute has three Schools – the School of Fisheries, the School of Maritime Studies and the School of Ocean Technology – and within these Schools a number of specialized centres and units. These centres and units lead the Institute, both nationally and internationally, in applied research and technology transfer and in the provision of training to a variety of industry clients.

Ocean Networks Canada (ONC)

Ocean Networks Canada operates the world-leading NEPTUNE and VENUS cabled ocean observatories off the west coast of Canada, along with coastal community observatories in British Columbia and the Canadian Arctic. These observatories collect data on physical, chemical, biological, and geological aspects of the ocean over long time periods, supporting research on complex Earth processes in ways not previously possible.

Data collected by the observatories are archived and made freely available over the Internet through Oceans 2.0, ONC's data management system. Oceans 2.0 provides further unique scientific and

technical capabilities that permit researchers to operate instruments remotely and receive data at their home laboratories anywhere on the globe in real time.

The Ocean Networks Canada Innovation Centre (previously called the ONC Centre for Enterprise and Engagement)—one of Canada's Centres of Excellence for Commercialization and research—promotes the advanced technologies developed by NEPTUNE and VENUS.

Ocean Tracking Network (OTN)

The Ocean Tracking Network is a global research, technology development, and partnership platform headquartered at Dalhousie University in Nova Scotia, Canada. Starting in 2008, and beginning full operations in 2010, OTN has been deploying Canadian acoustic receivers and oceanographic monitoring equipment in key ocean locations around the world and establishing partnerships with a global community of telemetry users. OTN is documenting the movements and survival of marine animals carrying electronic tags and how they are influenced by oceanographic conditions. OTN deployments occur in all of the world's five oceans and span seven continents. OTN is tracking many keystone, commercially important, and endangered species, including marine mammals, sea turtles, squid, benthic crustaceans and fishes including sharks, sturgeon, eels, tuna, salmonids, and cod.

Over 400 international researchers from 18 countries are currently participating in the global network along with many more trainees, graduate students, and postdoctoral fellows. OTN's Data Centre (OTNDC) curates more than 130-million detection records and growing and serves as a repository for data collected by OTN researchers. OTNDC is also partnering with similar efforts in Australia and Belgium, as well as sharing best practices and their proven database structure with acoustic telemetry organizations in South Africa, Brazil, the USA and Europe. OTN is developing interpretation and visualization tools for analysis of tracking data. OTN also operates a fleet of autonomous marine gliders for use as mobile listening stations, and in support of oceanographic and tracking research.

Polar Data Catalogue/Canadian Cryospheric Information Network (PDC/CCIN)

The Canadian Cryospheric Information Network (CCIN) and the Polar Data Catalogue (PDC) have been developed over the past two decades through collaborative partnerships between the University of Waterloo and numerous government, university, and private organizations to provide the data and information management infrastructure for the Canadian cryospheric community.

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MEOPAR

MARINE ENVIRONMENTAL OBSERVATION
PREDICTION & RESPONSE NETWORK

About MEOPAR

Established in 2012 through Canada's federal Networks of Centres of Excellence Program, the Marine Environmental Observation Prediction and Response (MEOPAR) Network is a national network of academic researchers and students, government scientists, and partners in the private, NGO and community sectors working together to reduce vulnerability and strengthen opportunity in Canada's marine environment.

Government of Canada
Networks of Centres of Excellence

Gouvernement du Canada
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