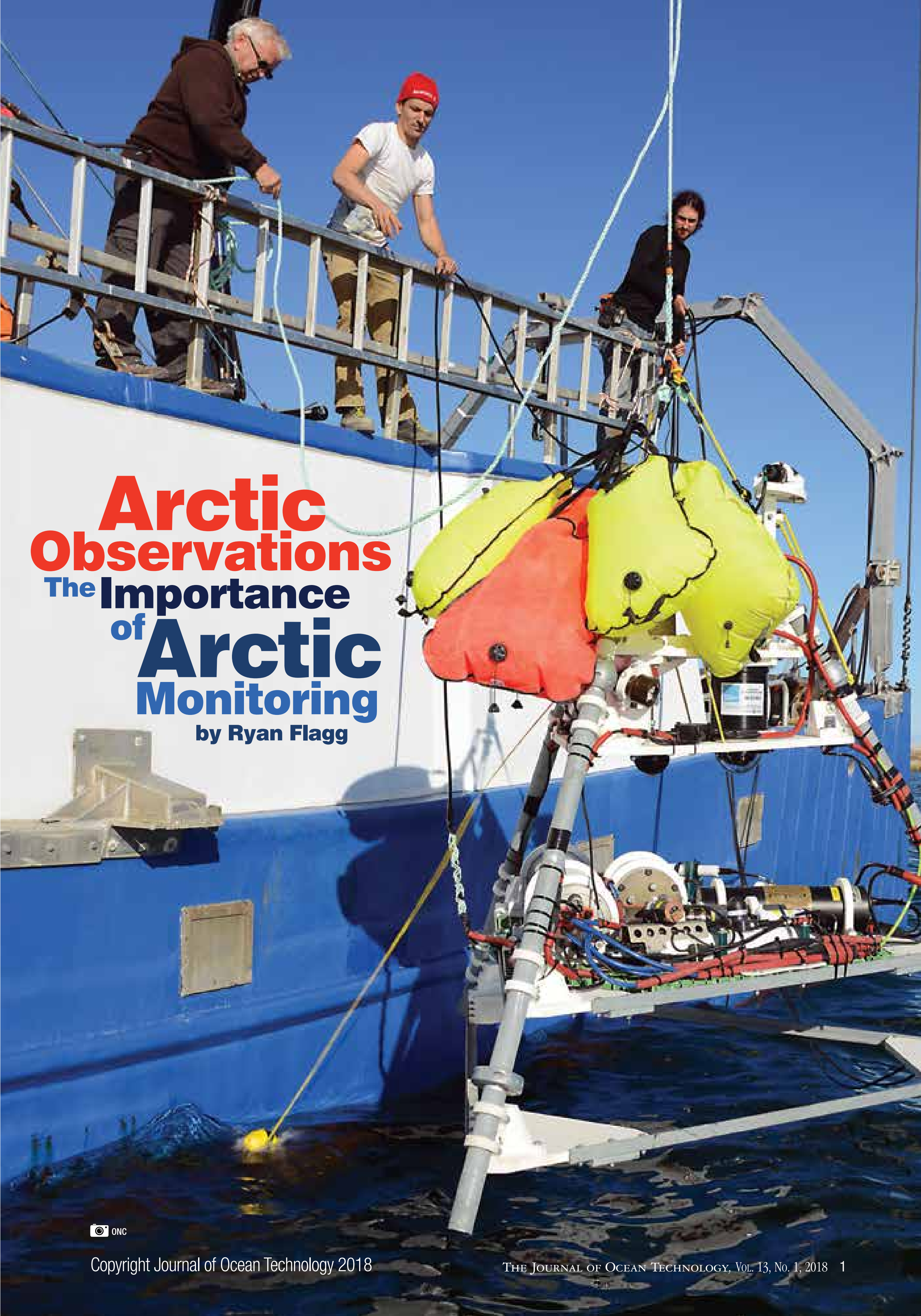
Arctic Observations

The Importance of Arctic Monitoring

by Ryan Flagg



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Introduction

To paraphrase a world leader in the development of management education, we cannot manage what we do not measure (Peter Drucker). The Arctic is generally accepted as having the fastest changing environment on the planet, a feature termed "Arctic amplification." How can any of us expect to manage our collective impact on the environment when our monitoring efforts are as sparse as the remaining polar bears, and dramatically less persistent? The Arctic environment is an indicator of global climate change; it is the canary in the coal mine that, despite being in the dark from a severe lack of high-resolution and openly available data, is warning us all of things to come. The accelerating change in environmental conditions is not isolated to weather patterns and declining sea-ice, but also paints a vivid picture of how wildlife, human culture, and even "permanent" infrastructure are (or will be) forced to evolve … or crumble.

A Changing Arctic

Sea-ice coverage in the North has been shown to be receding at a rapid rate over the last decade. This change has a major influence on the environmental conditions that all of us experience but for residents of the North, the impacts hit much closer to home. Northern communities are hundreds and thousands of kilometres apart from each other, and even further from the southern cities that they now rely heavily on for support. With no roads bridging these distances, winter travel over the sea-ice itself has been the most common means of transport for centuries. Thinning sea-ice and rapidly changing shoulder seasons, when freeze-up and break-up occur, are now challenging one of the main ways for people to travel. Animals as well are being forced to adapt too quickly to the thin ice and open waters; at the macro level, we are seeing orca whales prey on Arctic sea-life further north than they ever have and polar bears are now starting to compete with grizzlies.

Beneath the ice and waves, a changing growing season does not necessarily bode well for organisms that have dominated in the past conditions for millennia and shifts in the foundation of the food web should be expected to affect many elements of the ecosystem. Meanwhile on land, northern people rely on the "permafrost" that their homes, schools, hospitals, and roads are built on to stay permanent; even if this frozen ground is technically still below freezing temperatures, a rise of just a couple degrees changes its properties from that of concrete to something that expands and bends, collapsing and twisting the communities that rest on top. The now sponge-like landscape is also releasing trapped gasses (e.g., methane) into the atmosphere and excess moisture and sediment into the freshwater systems, which pours in to the surrounding Arctic Ocean.

With all of this in mind, it is easy to see several reasons why it is important to monitor the Arctic and, in particular, its ocean. First of all, Canada is not unique in how it identifies as an Arctic Nation, despite the small percentage of the population who actually reside in what we consider "the North." Monitoring the changing conditions in the North is the first and most necessary step in helping the residents of the North to adapt their lifestyle and their infrastructure in order to maintain thousands of years of culture and knowledge. For all of us living south of sixty, the shrinking cryosphere will shape the world by opening up new viable shipping routes and exposing opportunities for resource extraction, and perhaps even changing our weather at mid-latitudes. Monitoring the changing biosphere, both terrestrial and aquatic, will continue to help all of us understand which species are the most likely to survive and spread and therefore has the potential to forewarn us of what the impacts will be on our global ecosystem and food security. When ocean currents change, or when a whole new ocean is suddenly exposed, both sea surface and atmospheric temperatures feel the effects; weather in the Arctic will change with increased evaporation, resulting in more rain and snow. There is strong evidence that a changing Arctic also influences weather patterns at mid-latitudes, across Asia, Europe, and North America. Monitoring this new ocean is the only way we will be able to forecast the coming changes.

Monitoring in the Arctic

The ocean is monitored in a number of broadly definable ways that are all employed in the Arctic Ocean with the exception that the uniquely harsh environment and the relative lack of local infrastructure and logistical support often impose certain limitations. Ship-based operations and observations have been the historically predominant method for monitoring the ocean. While this method is relatively expensive and infrequent, it continues to lay a foundation for other methods by being able to collect high-accuracy data throughout the water column (surface to seafloor) and to span the entire ocean. With respect to the Arctic, ship-based monitoring is limited further by a short open-water season and the necessity for even larger vessels that can safely navigate sea-ice conditions.

Satellite systems used for ocean monitoring are only limited in their ability to monitor the Arctic by their field of view, complex cloud conditions, and by the number that are operational at any given time – the same issues that affect satellite coverage anywhere in the world. The shortfalls include their level of accuracy, the parameters they can measure, and the fact that they can rarely peek beneath the surface of what they are looking at.

Fixed monitoring infrastructure is only permanent if properly installed and maintained, but is otherwise an increasingly cost-effective way to collect high-accuracy and high-temporal-resolution data throughout the year, Arctic conditions or not. Cold-temperature rated systems are more and more common and technology advances in data storage, processing, and transmission are getting better every day. The limiting factor for these systems is the area they can cover, as they are (by definition) fixed and therefore monitoring a static sample volume.

Autonomous systems (underwater vehicles, surface vehicles, gliders, drifting buoys, etc.) are fast becoming a common approach to covering extended regions of the ocean while still de-coupling the expense of having human passengers and operators. Like ships, their operating period is often limited by the environmental conditions (e.g., sea-ice) and also by their range and the level of sophistication of their built-in "intelligence."

Finally, data collected by community members themselves (commonly referred to as "Citizen Science") is a concept that continues to evolve with changing technology, data demands, and collection techniques. This method has remarkable potential in the North as the people who live there are without question the best suited to be working in the field; their understanding of the local environment and the risks and challenges remains unparalleled, allowing them to capture sought after data in a relatively large area around their community through all of the seasons. Furthermore, this approach tends to be much more cost effective by taking advantage of local resources, provides an often overlooked connection between the data and the people it affects the most, and has the potential to integrate local and traditional knowledge into the planning process. This last point is an advantage that every mature citizen science program should endeavour to leverage. The limiting factor is likely only the availability of funds and person-time needed to supply the equipment and training to a population that is typically extremely capable and willing.

ONC in the Arctic

For those who know of Ocean Networks Canada (ONC), they are likely familiar with the fact that it operates and maintains the sub-sea cabled observatories known as NEPTUNE and VENUS, located off the shores of southern British Columbia. While these observatories are each impressive in their own right, they are only part of what is becoming a vast network of cabled and autonomous sensor systems spread across Canada. Ocean Networks Canada is an international facility hosted and owned by the University of Victoria, and managed and operated by the Ocean Networks Canada Society, a not-for-profit established by the University in 2007. Ocean Networks Canada operates world-leading ocean observatories that have no equivalent in Canada, with an overarching vision to enhance life on Earth by providing knowledge and leadership that deliver solutions for science, society, and industry. Monitoring the west and east coasts of Canada and the Arctic, Ocean Networks Canada continuously gathers data in real-time for scientific research that helps communities, governments, and industry make informed decisions about the future.

In order to support the strong need to monitor the Arctic, Ocean Networks Canada installed the cabled Cambridge Bay Observatory (Figure 1), a unique, community-based facility that supports a wide range of Arctic marine research activities. Operated continuously since its establishment in September 2012, the Cambridge Bay Observatory is a remotely-controlled marine laboratory that uses online sensor systems to monitor the coastal Arctic. Shore station sensors monitor the atmospheric conditions (air temperature, humidity, pressure, wind speed and direction, and solar radiation) that are the seasonal drivers for oceanographic processes. In-water sensors monitor the ocean (temperature, salinity, pressure, ocean currents, light penetration, sound, fish-tag receiver, dissolved gases, sea-ice thickness, and benthic imagery). This high resolution monitoring of the coastal Arctic is providing unprecedented insight into environmental events and longer-term trends. The observatory's growing, high-resolution data-time series is supporting process-oriented and long-term studies of oceanographic processes in Cambridge Bay that range from the direct observation of benthic ecosystems responses to seasonal events, to the modelling of current and future sea-ice dynamics.

The Cambridge Bay Observatory has provided Canadian instrument manufacturers (Pro-Oceanus, Satlantic, OceanSonics, and ASL Environmental Sciences) with opportunities to test and demonstrate their technologies under extreme Arctic conditions. All command and control functions and data archiving for the Cambridge Bay Observatory sensors are handled by Oceans 2.0, ONC's end-to-end software system that also provides free and open, online access to all observatory sensor data and data products. A satellite link ensures real-time communication between Ocean Networks Canada's shore facilities in Cambridge Bay and the observatory operations centre at the University of Victoria. Growing use of the Cambridge Bay Observatory physical infrastructure and data has increased reliance on its continued successful operation and increased demand on its capabilities. In fact, support for this particular Community Observatory has continued to grow, with Cambridge Bay residents providing logistic assistance for observatory maintenance, participating in outreach and formal learning activities, and, more recently, collecting critical, winter-time data on snow depth and ice thickness. The observatory has grown in size, use, and community impact every year since it was first installed, which is how it became the inspiration for the Community Observatories that are now located along the BC coast as part of Ocean Networks Canada's "Smart Oceans(TM)" program.

Ocean Networks Canada's most recent cabled Arctic observatory takes advantage of the same data management backbone and instrument deployment expertise that support the Cambridge Bay Observatory but that is where the similarity ends. Given the vast distances between communities in the North, it is not surprising that there was strong impetus to have this next observatory be capable of thriving far away from the support and safety of any community or its infrastructure. The Gascoyne Inlet Observatory (Figure 2), located on the coast of Nunavut's Devon Island (the largest un-inhabited island on the planet), was designed and installed in partnership with Defence Research and Development Canada and in collaboration with the Department of Fisheries and Oceans' Bedford Institute of Oceanography.

Figure 1: Cambridge Bay Observatory 2016 deployment.

It makes use of AML Oceanographic's UV antifouling and modular instrument design – technology that has proven it can deliver reliable and accurate data in tough coastal environments on both the Ocean Networks Canada NEPTUNE observatory and Community Observatories. At the dry end, data from AML's instrument set is handled by an adapted ice-tracking buoy built by yet another Canadian company, Oceanetic Measurement. The entire system has been operating successfully since August of 2017. Installation and operation has happened in parallel with, and in support of, a conceptual design study for four identified shipping chokepoints in the Northwest Passage to assess the feasibility for cabled observatory deployments. The Gascoyne Inlet Observatory has thus far been a successful test of a novel technique for installing and protecting subsea cabled infrastructure (Figure 3) with an aim to dramatically lower the cost from previous alternatives (i.e., directionally drilling). The end-to-end system was designed so that it could be flown via small aircraft anywhere in the world, installed with minimal personnel and equipment, and still withstand the harsh climate and grinding coastal sea-ice that still prevail in Canada's Arctic. This project with Defence Research and Development Canada has simultaneously endeavoured to advance the integration of two well established technologies (subsea cabled observatories and autonomous underwater vehicles – AUVs) by researching how cabled subsea infrastructure could effectively support the power transmission and data transfer needs of long-term AUV deployments (Figure 4). This is a critical step toward the realization of persistent and continuous subsea surveillance throughout the Arctic.

Working with scientists and technical staff from the Department of Fisheries and Oceans' Institute of Ocean Sciences' Arctic Group and with British Columbia's Pacific Salmon Foundation, Ocean Networks Canada has now stepped into a major supporting role of capturing and delivering high quality data for robust "Citizen Science" (Figure 5) programs using its "Community Fishers" mobile application and Oceans 2.0 data management system. The most basic description of the program is to provide a range of instruments and monitoring capabilities that will complement the wide range of existing monitoring programs; the true power is the strength the program gains by integrating knowledge and experience of community members and the capacity that is built within the communities. So far, these improved data collection methods have proven to work reliably in the Arctic and are necessary for capturing strong baseline data sets and providing instant access to environmental conditions. The objectives of the Polar Knowledge Canada supported "Enhancing Capacity" project aims to enhance northern capacity and participation in collection, analysis, and use of scientific ocean data and to understand connections to local and Indigenous knowledge. In order to achieve these objectives, all activities in the project are conducted in direct collaboration with northern community members and organizations with an initial focus on Cambridge Bay, Kugluktuk, and Gjoa Haven, Nunavut. In the initial months of the project, the primary focus was on establishing a strong local oversight committee in each community to guide project activities. All five major objectives of the project have been launched and are currently in progress:

1. Development and implementation of a course in Instrument Technology with Nunavut Arctic College;
2. Development of a data management system for the Department of Fisheries and Oceans' Canadian Rangers Ocean Watch program;
3. Implementation of community-based monitoring programs;
4. Extension of the "Ocean Sense: Local Observations, Global Connections" education program in Cambridge Bay, Kugluktuk, and Gjoa Haven; and
5. Design and implementation of community-oriented ice and ocean data products.

Figure 2: Gascoyne Inlet Remote Cabled Observatory with AML Oceanographic instrument and UV antifouling system.

Figure 3: Subsea cable protection from sea-ice on Devon Island.

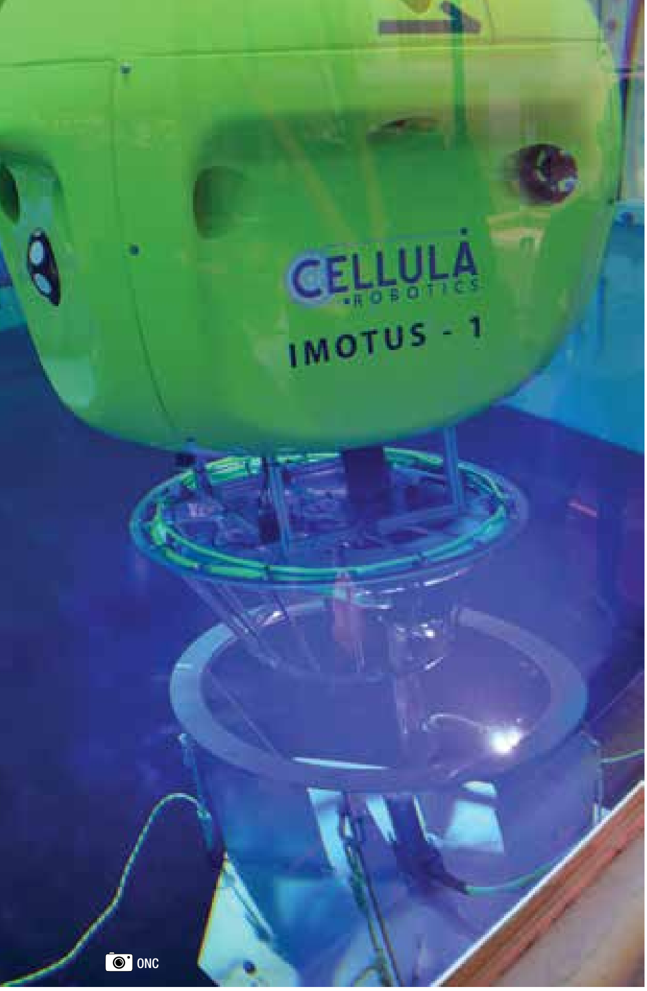

Figure 4: Cellula Robotics AUV docking demonstration.

A common criticism of Arctic monitoring is the lack of connection between the research that uses the data and the northern communities most acutely affected by the environmental changes being studied. The effective implementation of a Citizen Science program can bridge that gap, especially when used as an integral part of a larger research program. By combining, managing, and freely delivering data from Citizen Scientists, Community Observatories, remote-location cabled systems, autonomous vehicles, and even third-parties, Ocean Networks Canada hopes to definitively enhance how we monitor and manage the oceans and the Arctic.

Conclusion

The extreme environmental conditions, logistical challenges, sheer geographical size, and length of coastline are just some of the challenges that scientific researchers, government, and industry face when trying to understand and serve the Canadian Arctic. These defining attributes are also part of what sets the Arctic apart from the rest of Canada and many other parts of the world. They are also strong reasons why effective coordination between communities and researchers are needed to affect relevant change. As one of the most rapidly changing regions on the planet, with respect to the physical, economic, and social environments, the Arctic has perhaps the greatest need for persistent monitoring and real-time data access. Monitoring in this environment is not a simple or trivial undertaking; as with any broad area we wish to fully comprehend, it will require the use of a diverse range of techniques and collaborators that work together. Ship-based data and field studies conducted from terrestrial/ice-camps represent the longest running data collected by western science and should therefore continue for as long as possible. That said, this method is typically limited to specific data collected at fixed geographical points and over limited periods of time. Furthermore, the interval between measurements is often an entire year, limiting the resolution of any findings to trends that may (or may not) appear over decades. Data from remote systems such as satellite are constantly improving but will always, almost by definition, cover the widest possible geographic area at the lowest resolution and accuracy.

With respect to both global ocean monitoring and marine and terrestrial monitoring in the Arctic, remote monitoring systems are an exquisite tool for glimpsing the surface of an otherwise impossibly large region but fall short in their ability to look into the depths. Fixed position infrastructure plays a key role by collecting extremely high-resolution data throughout the entire year. The possible parameters that can be measured are only limited by the range of instruments that can be invented and successfully deployed. While some sensors may measure at only a single point in space, others such as acoustic

Figure 5: Citizen Science team monitoring the ocean and the sea-ice in Gjoa Haven.

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Figure 6: Cambridge Bay Observatory with local students and Ocean Networks Canada Deployment and Science Ambassador Team.

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instruments and radars allow us to monitor the three-dimensional world around them. The small complement of acoustic instruments on the Cambridge Bay Observatory alone allow for the study of ocean currents throughout the water column, the changing ice thickness, and the presence of marine mammals, vessels, and those animals and people who roam the surface of the ice. Advances in sensor technology, power systems, and communications are driving down the cost and complexity and enabling this method to be more and more wide-spread, which in turn supports the development and use of autonomous vehicles to persistently monitor vast regions, despite inhospitable conditions. Data collected by community members themselves is ideally suited for pulling together all of these other approaches but only if these knowledge holders are active participants in forming the research questions and coordinating the effort (Figure 6). "Understanding" is the aim of communication but despite our best efforts, it is never guaranteed. Likewise, data collection is a necessary first step but our understanding of the Arctic will never be complete unless those data are transformed into useful information. They must be effectively combined with as many complementary data types as practical and shared as openly and quickly as possible in order to truly draw on collective intelligence and insight.

Ryan Flagg is the Observatory Support Engineer for Ocean Networks Canada (ONC). He implemented ONC's first cabled "Community Observatory" in 2011 and led the installation of ONC's first Arctic observatory (Cambridge Bay, Nunavut) in 2012. He has helped lead almost every subsequent maintenance operation and continues to assist with community engagement and to take part in research and instrument testing in Cambridge Bay. Mr. Flagg is actively helping to propose, plan for, and implement new monitoring initiatives throughout the North and along Canada's other coastlines. He is on the Board of Directors of the Canadian Network of Northern Research Operators and with the Canadian Meteorological and Oceanographic Society's Arctic Special Interest Group. Outside ONC, he has served as a "MarTech" with the Canadian Armed Forces Navy Reserves for over 15 years. **www.oceannetworks.ca**