

A Cabled Arctic Observatory:

A practical, long-term approach to open data in the Arctic

Community White Paper for the Arctic Observing Summit

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Abstract: We propose a comprehensive Arctic Observing Network based on a seafloor cabled system to limit life cycle costs over periods of at least thirty years. The observatory will build upon experience gained over the past decade of observatory construction in the northern Pacific in both Canada and the United States. The data will be openly available to scientists, engineers, the public and interested decision makers. Based on the system's architecture we will seek to offer networking, storage, and command and control services to allied observing systems.

The Arctic Research Plan; FY2013-2017 was published this month (https://dl.dropbox.com/u/2284910/2013_arctic_research_plan.pdf) by the US National Science and Research Council to outline the President's goals for Arctic research. The overlapping research goals are:

1. Sea ice and marine ecosystems
2. Terrestrial ice and ecosystems
3. Atmospheric studies of surface heat, energy, and mass balances
4. Observing systems
5. Regional climate models
6. Adaptation tools for sustaining communities
7. Human health

The goals point to major scientific, technical, engineering, health and societal questions, which require observational data over extended periods of time. We propose an ocean observational program, which can readily be coupled to terrestrial and space-based systems. The observatory will provide openly available, near-real-time data, which can be coupled to existing and evolving climate and ecosystem models. The US National Plan emphasizes observing systems:

Long-term observations *in situ*, from space, and by local people and communities have been vital to documenting changes occurring throughout the Arctic environment. Without remote-sensing observations, for example, the recent dramatic changes in Arctic Ocean sea-ice extent with melting and mass loss in the Greenland ice sheet and changing tundra "greenness" would not have been detected and quantified quickly. The recognized need for a diverse set of pan-Arctic observations that would improve the value of predictive models spawned the AON.

The importance of open data was also called out:

Facilitate free and open data sharing and exchange nationally and internationally.

The report noted somewhat realistically that:

In the United States, data are generally freely and openly available, but delays can occur between acquisition and availability in archives. Internationally, the situation is more variable; some countries charge fees and some do not release data.

A sense of urgency:

The past decade has seen major changes in the Arctic. A record low sea ice extent was observed in 2007, only to be substantially outdone in 2012 (<http://NSICD.org>). Remarkably, satellite observations have revealed five of the smallest sea ice extents in the last six years (Duarte, 2012). The thickness of sea ice was quantified through submarine observations, but today's satellite data have shown that there has been a 65% reduction in multi-year ice extent in the past decade and a decrease in thickness of multi-year ice from 3.64m to 1.89m over the last 40 years (Figure 1). The decrease in ice volume has been even more dramatic than the areal extent. Half of the decay of ice thickness has happened over the past 10 years (Kwok and Rothrock, 2009). Given the recent history, many expect a transition from a perennially ice-covered region to a seasonally ice-free sea in summer (Duarte, 2012; Wang and Overland, 2009).

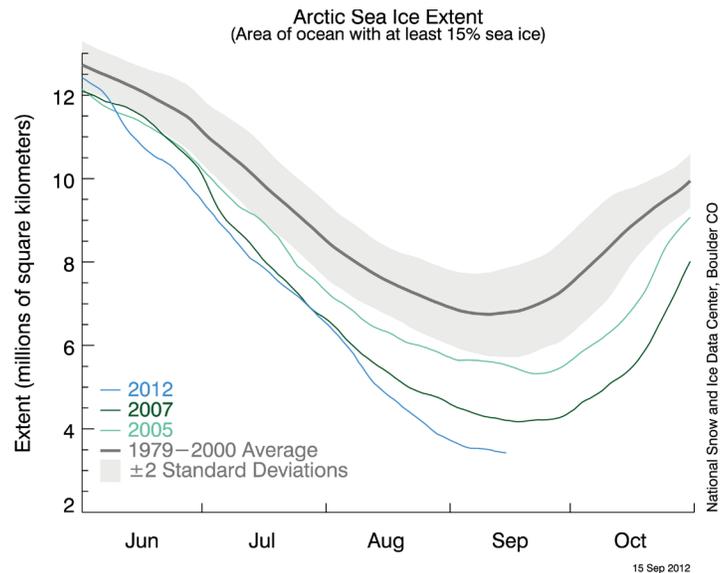


Figure 1: Arctic ice cover history. The gray represents coverage and ± 2 std deviations for the period 1979-2000. 2007 was a record low, but 2012 brought another record.

Seafloor Cabled Networks:



Figure 2: A conceptual view of an OOI Regional Scale Nodes installation of cameras, lights and platforms off Oregon and Washington. Courtesy of OOI Regional Scale Nodes program and the Center for Environmental Visualization, University of Washington

During the past several years, three cabled networks have been established, or are being constructed, in the US and Canada for offshore measurements in the northern Pacific. The first of these was established, with support from the US National Science Foundation (NSF), and is termed the *Monterey Bay Aquarium Research Institute's (MBARI) Monterey Accelerated Research System (MARS)*. [http://www.mbari.org/news/news_releases/2008/mars-live/mars-live.html]. The system went active in 2008. Shortly thereafter, the NEPTUNE Canada system became operational in Canada on the Juan de Fuca tectonic plate. [<http://www.neptunecanada.com>] and began delivering data in 2009. The vision statement for NEPTUNE Canada is:

NEPTUNE Canada will expand the boundaries of ocean exploration and give us a new way of studying and understanding our planet.

An NSF Major Research Equipment and Facilities Construction program [Ocean Observatories Initiative (OOI)] laid cables and nodes on the seafloor off Oregon and Washington in 2012 and will instrument the system beginning this summer. (Figure 2) See <http://www.oceanobservatories.org/infrastructure/ooi-components/regional-scale-nodes/> .

We propose that the Arctic Ocean Network (AON) should be built on a similar infrastructure in order to

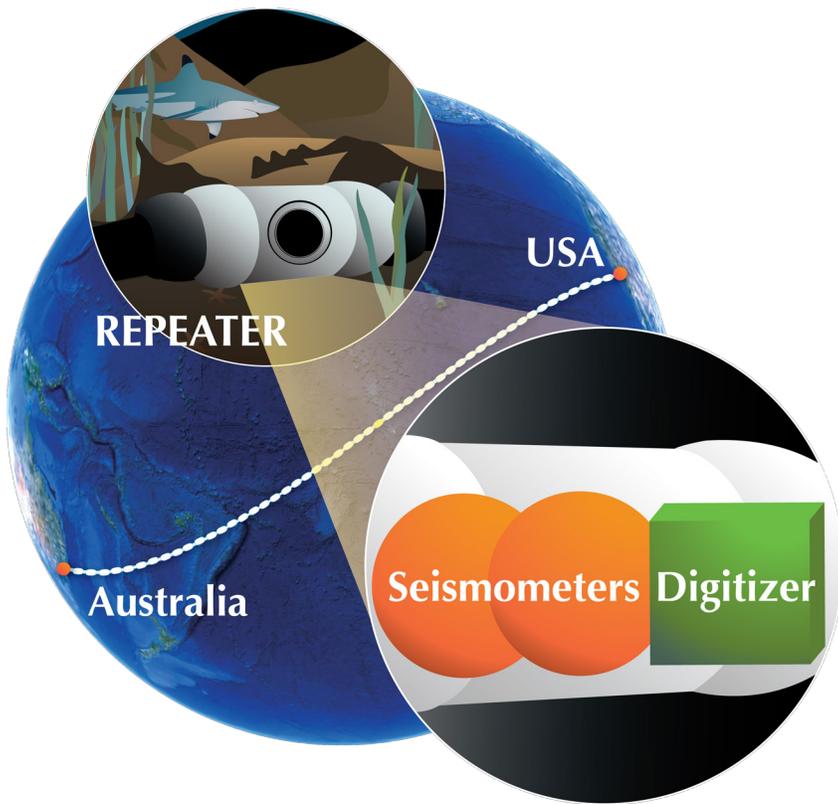


Figure 3: A proposed telecom installation across the Pacific with repeaters spaced every 75km. Each repeater would be capable of supporting power and bandwidth for a variety of scientific instrument.

[com/2012/02/14/usa-scientists-to-integrate-scientific-instruments-onto-seafloor-communication-cables/](http://subseaworldnews.com/2012/02/14/usa-scientists-to-integrate-scientific-instruments-onto-seafloor-communication-cables/).

This year TE SubCom and SIO developed a *rough order of magnitude* cost estimate for a cable from Barrow, Alaska to the North Pole exclusive of the shoreside installation. Peter Mikhalevsky (Mikhalevsky et al., 2013) had previously developed costs and installation plans for the proposed station at Barrow.

We have developed an advanced data, instrument and platform cyberinfrastructure for the OOI, which can be readily implemented in a broad AON. The OOI cyberinfrastructure exploits modern networking, computing and cloud technologies in an Integrated Ocean Network (ION; Figure 5). The system delivers data to users in near-real-time (latencies of seconds) and it's simple to develop virtual observatories by subscribing to data from individual platforms and instruments; the system can be expanded to serve thousands

of users and virtual observatories. In turn, because the connections to the platforms and sensors are duplex, the user or operator can use the network to provide command and control capabilities for the ION.

provide near-real-time (latencies of seconds) access to data, instruments and platforms in the critical Arctic environment as it undergoes unprecedented change associated with climate and a warming Earth. Mikhalevsky et al. (2013; a Summit White Paper) have also proposed the use of cables for observations in the Arctic ocean for ocean thermometry to observe changing heat content and ocean currents.

While cables are expensive to install, the life cycle costs over a climate cycle (e.g. 30 years) are substantially less than alternative solutions including autonomous seafloor moorings and shipborne expeditions.

This past year Scripps Institution of Oceanography (SIO), TE SubCom and NOAA's Pacific Marine Environmental Laboratory (PMEL) announced a partnership to exploit commercial telecom cables for scientific measurements (Figure 3). See: <http://subseaworldnews.com/2012/02/14/usa-scientists-to-integrate-scientific-instruments-onto-seafloor-communication-cables/>.

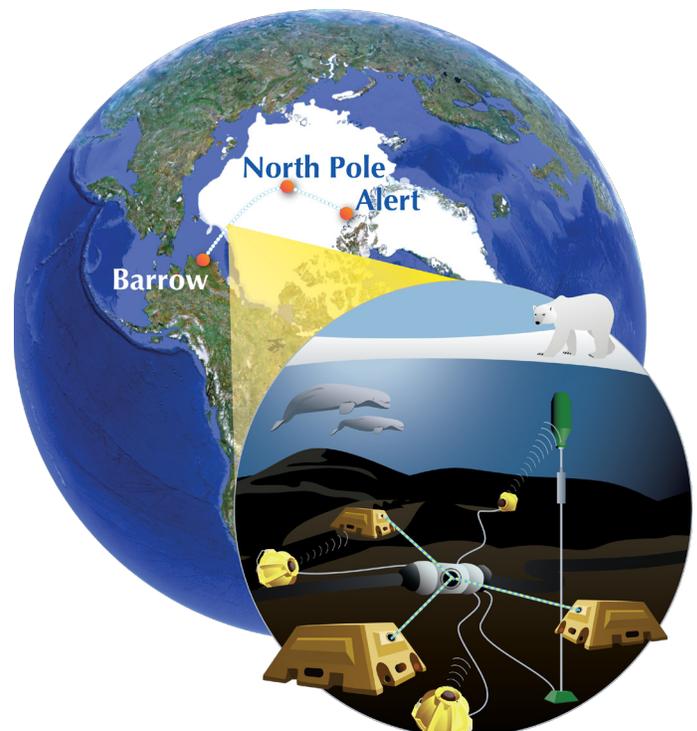


Figure 4:

A notional cabled network in the Arctic ocean with a variety of instruments at each node including systems moored above the seafloor. In this case, the moored cable represents an acoustic thermometry transducer with seafloor transponders for locating accurately the position of the transponder.

Deployment Topology



Figure 5: The OOI Integrated Ocean Network comprising satellite connections (gray) as well as broadband optical networks extending from the seafloor onto the continental US. Peering points at Chicago, Seattle, Portland and San Diego provide multiple connections to the Internet. Examples include the Northwest GigaPoint of Presence (GigaPoP) the Starlight GigaPoP. Similar connections would be established in Alaska and the Canadian Arctic.

in the environmental community. Furthermore, the data model has been constructed to ease the task of providing selected data for assimilation in coupled weather and climate models including, as mentioned above, data from other observing systems. The goal is to ease the task of running different models as well as ensembles of models for evaluating the sensitivity of the results to the data and the reliability of predictions into the future.

Recommendations:

We propose that the Arctic Observing Summit consider carefully the tremendous advantages of developing a world-class *Arctic Ocean Observatory* including the proposed cabled network (Figure 4). The past several years have revealed enormous year-to-year environmental changes in the Arctic and the Observatory cannot afford a delay in developing international collaboration in the region.

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References:

The OOI cyberinfrastructure exploits only Layers 1 and 2 of the Internet stack and uses an open-source messaging protocol, *Advanced Message Queuing Protocol* (AMQP) (http://en.wikipedia.org/wiki/Advanced_Message_Queueing_Protocol) for message passing to and from individual sensors and platforms (e.g. gliders and AUV's). Another important feature of the cyberinfrastructure is that it deploys *instrument agents* for each platform and sensor so that every element of the observatory has a common interface allowing powerful integration of a large, deployed network. As importantly, existing or new observatories can offer data and products to the existing network. That is, the observatory being constructed for the OOI can seamlessly integrate this proposed AON as well as other existing or planned Arctic observatories. Sharing data and sensor networks, including data persistence far into the future offers economies of scale in addition to the chosen cabled network's low life cycle costs.

The OOI's data model is based on the Data Access Protocol (DAP) (http://www.opendap.org/pdf/dap_2_data_model.pdf) already in common use

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