Statement for the Arctic Observing Summit, 2013

The Need to Develop Semi-disposable Surface Flux Stations for Polar Sea-ice Studies.

author list: Phil Anderson, Edgar Andreas, Ian Brooks, Ola Persson, Ian Renfrew, Rune Storvold

Recent scientific interest in predicting the behaviour of sea ice in both Polar Regions has swelled, with many nations and international consortia funding large deep ice and marginal ice zone (MIZ) field campaigns. Unlike pure atmospheric circulation studies, with a history of highly structured need to improve physical parameterisation within global climate models, ocean–sea ice-atmosphere field campaigns are only recently becoming process-study rather than discovery driven. An indication of this evolution is the recent change of emphasis from sea-ice stations that "observe the weather" (for example, the Russian North Pole drifting stations) to those that measure the surface energy balance (SEB) (for example, Ice Station Weddell and the Surface Heat Budget of the Arctic Ocean deployment), the latter emphasis being the key component to validating and improving numerical models.

The SEB comprises terms representing fluxes of heat through radiative, turbulent, and conductive processes. The conductive flux is not difficult to measure, and the recent availability of reliable, polar-proof, fast-response 3D sonic anemometer/thermometers has made obtaining the turbulent flux terms feasible. "Sonics" are *de facto* core sensors for manned, static polar field campaign SEB studies (Summit, Barrow, Alert, Halley, South Pole) and have been used on ship-borne sea-ice stations (SHEBA, ASCOS) and large ocean buoys (Scripps, and Woods Hole). While quality measurements of radiative fluxes are obtained at manned polar research stations, they are notoriously difficult at unmanned sites because of icing.

We believe it is now necessary and feasible to develop a semi-disposable automatic "flux buoy", based on relatively cheap "sonics", high-quality de-icing radiometers, inexpensive communications, flotation platforms, batteries and Inertial Measurement Units (IMU). This cost feasibility is due to

- the relatively high cost of ship operations,
- the reduced real-term costs of the flux buoy components,
- the enhanced science data return from a distributed, simple sensor array.

There are a number of technical issues that must be solved when transferring automatic polar SEB technology from a manned, static field station or ship to a small floating unmanned platform. These include

- developing effective de-icing for the radiometers,
- developing "smart" power regulation based on sensor diagnostics (the "de-ice or sleep" dilemma),
- integrating the sonic with an IMU to correct for buoy movement.
- designing a cheap platform capable of withstanding a triple mixed phased environment: the MIZ, where ice, open water, and the atmosphere all interact.

We believe these challenges are all solvable, with prototypes existing that solve some of these issues.

The SAON Initiative: Critical Linkages to Arctic Marine Safety and Environmental Protection

Lawson W. Brigham, University of Alaska Fairbanks, USA

Any investment in SAON, wherever in the circumpolar world, must also be considered an investment in enhancing Arctic marine safety and marine environmental protection. The scientific and marine operational agencies of the Arctic and non-Arctic states contributing to the SAON initiative must work closely together to ensure that the development of SAON includes pathways to provide advanced and timely Arctic information for strengthening safety and environmental protection measures. Such cooperation will also provide an improved capability for protecting Arctic coastal communities. A coordinated network designed for monitoring regional climate change and local environmental conditions will have certain synergies and direct value to a myriad of operational requirements that will be responding to increased Arctic marine operations. Enhancing the interoperability of the various observing systems and improving the accessibility of environmental information can result in a more robust Arctic safety shield for maritime operations.

The Arctic Council's Arctic Marine Shipping Assessment (AMSA) released in 2009 provides an example of the relationships that a strong SAON can have with Arctic marine use. The 17 AMSA recommendations were negotiated and approved by the eight Arctic states within the Arctic Council. They are collectively a policy statement and an integrated framework that the Arctic Council can use as a strategy to address marine safety and environmental protection issues during an era of increasing Arctic marine use. The AMSA 2009 Report outlines the recommendations in three, inter-related themes: (1) Enhancing Arctic Marine Safety; (2) Protecting Arctic People and the Environment: and, (3) Building the Arctic Marine Infrastructure. The Arctic states understand that implementing the AMSA recommendations will require extensive international cooperation among themselves, with the global maritime industry, and at the International Maritime Organization (IMO) and other related international bodies (for example, the World Meteorological Organization and the International Hydrographic Organization). The Arctic states also recognize a need for creation of new mechanisms for marine infrastructure investments, such as funding for SAON and emergency response.

Select linkages of the AMSA recommendations and the SAON initiative include:

- *Specially Designated Arctic Marine Areas* ~ Internationally-designated areas for regional environmental protection (IMO Special Areas and Particularly Sensitive Sea Areas) require substantial environmental information under a rapidly changing Arctic climate.
- *Areas of Heightened Ecological and Cultural Significance* ~ In view of changing climate conditions and increasing multiple marine uses, measures to protect these areas require robust environmental data and sustained monitoring.
- *Circumpolar Environmental Response Capacity* ~ Baseline information on regional Arctic environments and real-time operational information, both possible from SAON, are required to adequately respond to circumpolar environmental pollution incidents. A new Arctic oil spill preparedness and response agreement to be signed in May 2013

should strengthen Arctic state cooperation and coordination in this arena; SAON should provide future support to Arctic environmental response.

- *Investing in Hydrographic, Meteorological and Oceanographic Data* ~ Improved systems are required, as with SAON, to support the real-time acquisition, analysis and transfer of meteorological, oceanographic, sea ice and iceberg information.
- *Arctic Marine Traffic Systems* ~ A comprehensive Arctic marine traffic awareness system called for in AMSA will require near real-time environmental information, improved monitoring, and enhanced data sharing among the Arctic states.
- *Arctic Search and Rescue* ~ The Arctic Search and Rescue (SAR) Agreement signed in 2011 (recommended by AMSA) promotes establishment of adequate and effective search and rescue capability by each of the Arctic states within defined areas. Collaborative efforts by the Arctic states include the 'sharing of real-time meterological and oceanographic observations, analyses, forecasts, and warnings'; 'sharing information systems'; and, 'using ship reporting systems for SAR operations.' A robust SAON can support many aspects of this new agreement.
- *Survey of Arctic Indigenous Marine Use* ~ On-going surveys are creating baseline data to assess the impacts of Arctic marine operations; SAON will be a key tool to adequately monitor the environment and provide timely information to indigenous marine users.
- *IMO Measures for Arctic Shipping* ~ The implementation of an IMO mandatory Polar Code will require an augmented Arctic sea ice monitoring and prediction system so that polar class ships of varying capability can be effectively regulated.

A second example for support to a fully functioning SAON involves integration of the operational work of the national ice centers and their collaboration within the International Ice Charting Working Group (IICWG). The IICWG is the leading international forum for cooperation among the operational ice services and for coordination of ice matters, including icebergs; the ICCWG members are involved in: data and product exchange; standardization of terns, data and mapping; operations and unique customer support; shared training initiatives; sharing technology for analysis and forecasting; and, applied research in such areas as ice prediction models, remote sensing, and digital image processing. All of these activities have key linkages to the SAON initiative. And, the work of the ice centers is central to advancing Arctic marine safety and environmental protection in ice covered seas that are experiencing ever increasing marine use.

A strong case can be made that the SAON initiative is directly relevant to efforts that will greatly enhance Arctic marine safety and environmental protection. More dialogue between the scientific and marine operational communities is required, and more engagement necessary with a broad array of stakeholders.

Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, Signed by the Arctic States in Nuuk, Greenland on 12 May 2011.

Arctic Marine Shipping Assessment 2009 Report, Arctic Council, April 2009.

Brigham, L.W. (2011) Marine protection in the Arctic cannot wait. *Nature* 478(7368):157, 10.1038/478157a.

International Ice Charting Working Group, Terms of Reference, Updated 26 October 2007.

Arctic Biodiversity Coalition

Authors: Terry Callaghan, Mike Gill, David Hik, Maribeth Murray, Peter Schlosser, Gus Shaver, Michael Svoboda.

Executive Summary:

Arctic biodiversity is under increasing pressure from a multitude of factors and yet our ability to monitor, report on and understand important changes in Arctic ecosystems and the biodiversity they support is greatly limited. In the past decade, efforts to better coordinate various aspects of Arctic biodiversity research and monitoring have increased, however, there still exists a need to better align these to ensure that observation and monitoring are linked to research and societal needs and that information is efficiently translated for rapid and informed decision-making at local to global scales. The Arctic Biodiversity Coalition offers a theoretical and applied framework bridging the in biodiversity monitoring, research and management.

Preamble:

The Arctic's ecosystems and the biodiversity they support are under increasing pressure from environmental and societal changes occurring at multiple spatial (e.g. local to pan-Arctic) and temporal (e.g. long-term change, extreme events), and organizational scales, yet our ability to monitor, report on and understand important shifts in Arctic ecosystems and the biodiversity they support is inadequate due in part to the size and remote nature of most of the Arctic, and in part to limited resources, both fiscal and human, available for research and monitoring. This is further compounded by a need for improved coordination among existing and developing research and monitoring networks both within nations and across the Arctic. Because Arctic ecosystems lack functional redundancy they are potentially vulnerable to cascading effects from the loss of a single species; such vulnerabilities are difficult to predict. Understanding of Arctic biodiversity and critical ecosystem processes is further hampered by a decline in the number of trained taxonomists able to classify the diversity of species (particularly at the lower trophic levels) found in Arctic environments (see figure 1).

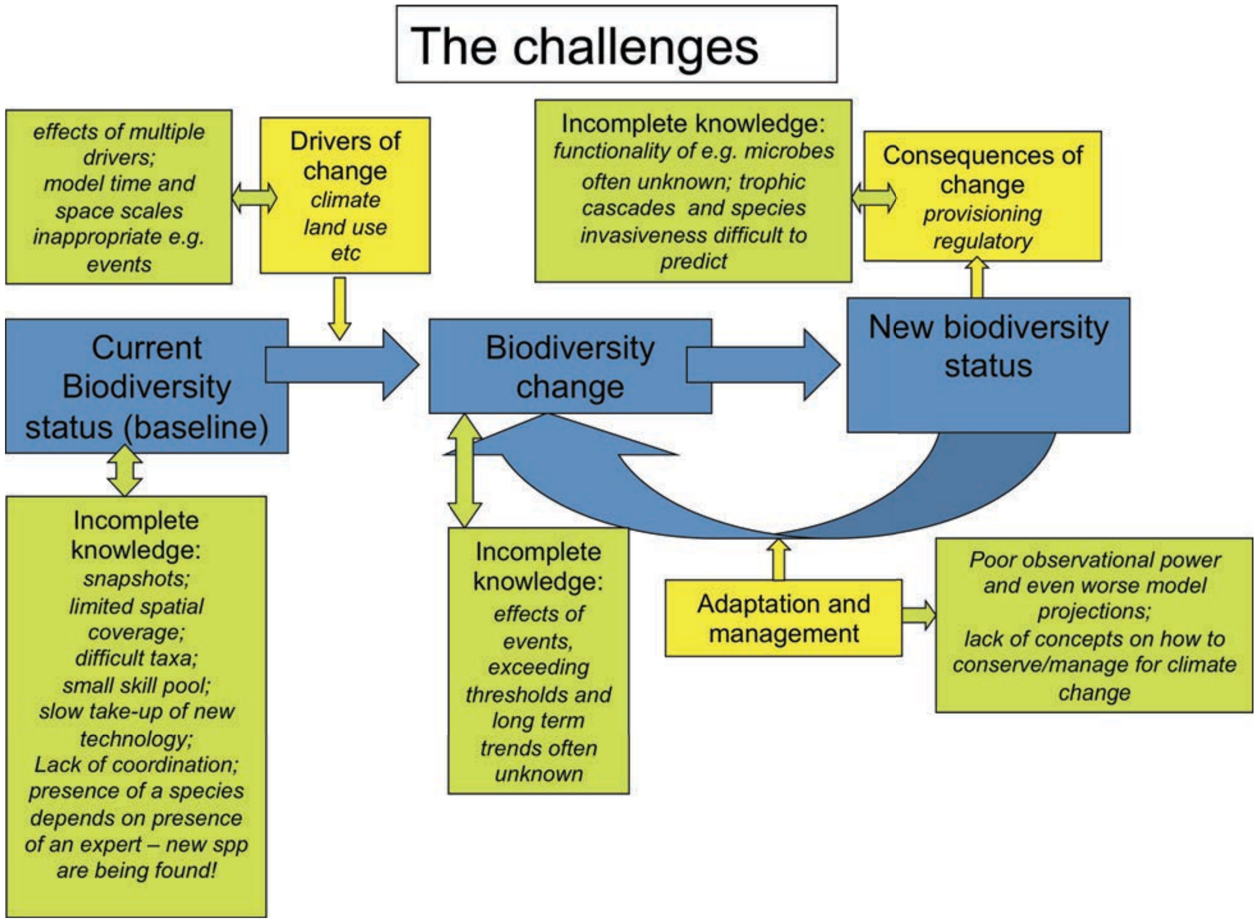


Figure 1 – Challenges facing gaining a complete understanding of the status and trends in biodiversity, understanding the drivers of those trends, predicting future responses of Arctic biodiversity to perturbations and formulating effective policy outcomes.

There are now are a number of efforts underway to better coordinate and harmonize existing Arctic observing and monitoring efforts (see Figure 2). These include:

- International Study of Arctic Change – pan-Arctic research initiative focused on observing, understanding and responding to change, including understanding processes and modelling change;
- International Arctic Science Committee's Terrestrial and Marine Working Groups – developing pan-Arctic research plans, promoting the development and uptake of new technology, training new scientists and identify specialists;
- Arctic Monitoring and Assessment Program – focused on contaminants monitoring and research and modelling regarding climate change impacts.
- INTERACT – pan-Arctic network of terrestrial field stations conducting real-time monitoring, data retrieval, research into ecological processes, implementing standardized measurements and anticipating and modelling thresholds.

- World Wildlife Fund Arctic – focused on mobilizing resources to answer key conservation questions and developing tools to address and mitigate threats to the Arctic environment.
- Circumpolar Biodiversity Monitoring Program – pan-Arctic network of networks involving scientists and local resource users working together to improve our ability to detect, understand and report on important trends in the Arctic's ecosystems and the biodiversity they support.

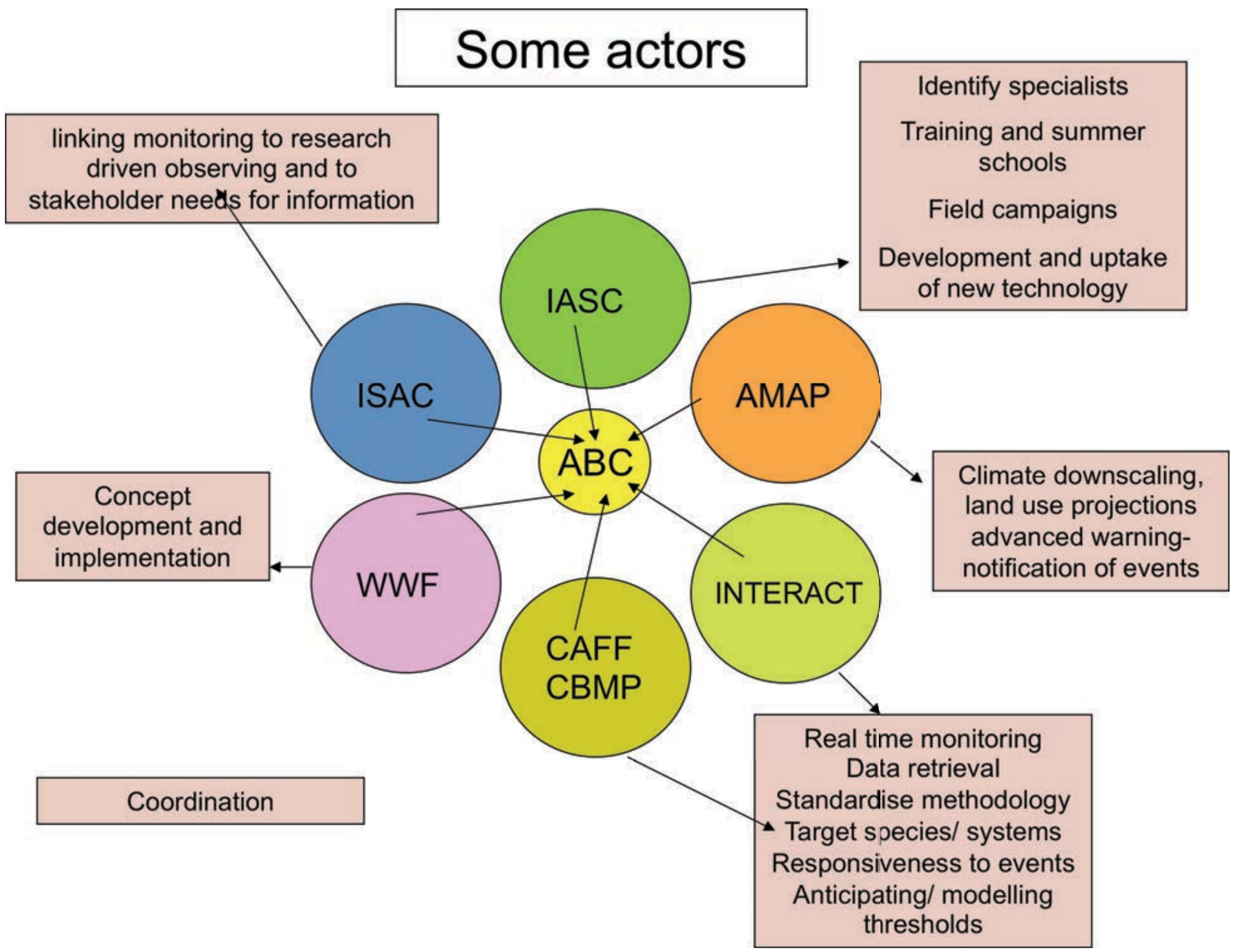


Figure 2. Current initiatives/programs underway to better harmonize efforts to understand Arctic biodiversity.

Despite the current success of these individual efforts, they remain informally connected thereby missing an opportunity to ensure close alignment between the research driven programs and approaches and the long-term biodiversity monitoring. The Arctic Biodiversity Coalition (ABC) will create a dialogue among these efforts to improve alignment and integration and it will serve as an avenue by which other programs relevant to Arctic biodiversity are able to gain access to the larger community engaged in observation and monitoring in the Arctic.

ABC Objectives

1. More targeted, long-term biodiversity monitoring to support research on key science questions;

2. More rapid uptake of new research and monitoring technologies and methods;

3. Development and uptake of core biodiversity monitoring protocols for use at existing Arctic research platforms leading to increased spatial and temporal coverage and construction of long-term datasets;

4. Simpler and more efficient avenues by which the Arctic biodiversity research and monitoring community can interact and share information and resources; and,

5. An improved ability to not only detect important changes in Arctic ecosystems and the biodiversity they support, but an improved understanding of the causal factors driving these changes leading to improved policy advice.

6. Improved predictive capacity to facilitate better conservation and adaptation actions.

Establishing the ABC

The challenge for the ABC is to design a simple and efficient means to maintain regular communication for the purpose of ensuring effective alignment of activities. The first step is the development of a Letter of Understanding outlining the intent of the ABC and articulating the responsibilities of ABC members. This will be followed by a meeting of the members to update the one another on the current status of their initiative/program and to defined the proposed work of the ABC and approaches for going forward. This requires a strategic plan for integration of activities and implementation of ABC tasks . **We encourage ideas and input into this proposed approach at the AOS 2013, particularly regarding the structure by which an ABC can operate effectively and efficiently.**

Proposed Early Tasks for the ABC

Through initial discussions, some proposed early activities for the ABC were generated. These include:

- **Building capacity for taxonomic studies/field identification** - The IASC Terrestrial Working Group could identify experts that would give summer schools, etc. hosted by INTERACT sites.
- **Cataloguing biodiversity** – the CBMP could construct inventories that include, but go beyond, the INTERACT sites, building on what exists at the sites and elsewhere.
- **Monitoring biodiversity trends** – CBMP and INTERACT would work together to implement the CBMP Freshwater and Terrestrial biodiversity monitoring plans.
- **Difficult taxa** – INTERACT could sample difficult taxa and host experts while CBMP and the IASC Working Groups could identify centres of excellence (universities, museums, etc.) that could analyse samples.
- **Harmonizing intensive research station-based monitoring with extensive field surveys** - in practice, there are two ways biodiversity is monitored and two communities that often do not communicate. One deals with wildlife surveys and the other with field experiments/manipulations. ISAC would work with CBMP and INTERACT to the bring the two communities together.
- **Explaining and predicting biodiversity and its trends** – IASC would work with concepts and models while INTERACT would contribute with experiments.
- **Determining the roles of biodiversity in ecosystem function** –
- **Initiating a citizen-science based pilot program to identify rare and invasive species using smartphone technology** – CBMP and ISAC to work together to develop a pilot initiative to equip communities with the protocols to implement a citizen-based surveillance program for identifying and recording sightings (species, location) of rare and/or invasive species in the Arctic environment using GPS enabled smart phones.

Observing Needs for Arctic Heritage and Paleoecological Resource Conservation Management

T. Max Friesen, University of Toronto, Canada; Maribeth Murray, University of Alaska Fairbanks, USA; Hans Peter Blankholm, University of Tromsø, Norway; Bjarne Grønnow, National Museum of Denmark; Pauline Kleinschmidt Knudsen, Greenland National Museum.

Archaeological sites in the Arctic and Subarctic hold an irreplaceable record consisting not only of material remains relating to long-term human history, but also of extensive paleoecological data accumulated by past human actions. However, climate change related processes are leading to the accelerated destruction of these heritage resources, with all the information they contain. As a result, on behalf of the Polar Archaeology Network, we present this short note to introduce these issues to the Arctic Observing Summit (AOS).

Two primary types of information are stored in archaeological sites. First, and most obvious, are cultural materials that allow reconstruction of the histories and societies of peoples who have inhabited northern regions, from Pleistocene hunter-gatherers through historic European exploration to modern indigenous peoples. Much of this record is irreplaceable, because associated written records do not exist; in conjunction with modern peoples' traditional historical and ecological knowledge, it can be used to reconstruct the cultural and environmental histories of the circumpolar Arctic. Moreover, for northern peoples, a strong connection to history and traditional culture is an important element of identity and well-being; the part of this connection that is contained in archaeological and historic sites is at risk of loss. Second, over millennia, northern peoples accumulated and concentrated zoological, botanical, and microbial organisms in their settlements. These biological materials simply do not survive in most other contexts, but rapid burial, dry and cold conditions, and incorporation into permafrost in arctic archaeological sites allows their preservation. These biological data are useful for the reconstruction of paleoclimate, and of marine and terrestrial ecosystem structure and function. They also yield invaluable direct evidence of species diversity, distributions, and genetic variability during the Holocene. Thus, they can provide necessary baseline information for understanding current ecological change, and planning for and managing future changes.

Climate change related threats to the arctic archaeological record are numerous. Sea level rise, often in concert with land subsidence, leads to increased coastal erosion. Longer open water periods lead to increased storm impacts on coasts, and also to increased shipping, tourism, and industrial activities that can have direct negative impacts. Thawing of permafrost is potentially the most damaging factor, as increasingly deep active layers are exposing long-frozen deposits to accelerated wet/dry and freeze/thaw cycles, microbial activities, and other physical processes.

Heritage resource scientists, administrators, and cultural organizations in many circumpolar nations are developing strategies for coping with this loss. For example, threat assessment matrices are being developed to explore regional variability in coastal erosion and permafrost thawing, and important threatened sites are being mapped and in some cases excavated. However, daunting challenges remain in terms of coordinating international activities, leveraging the use of existing observational programs and relevant instrumentation and field stations, raising funds, prioritizing critical sites and regions, developing protocols for preservation and archiving of archaeological and paleoecological materials, developing data sharing policies, and establishing new research networks.

We seek to incorporate heritage and paleoecological resource observing issues into AOS discussions. Often overlooked, these matters transcend the boundaries between the past, present and future, and between the physical and human dimensions of the arctic system. The observing needs are systematic, long-term and multi-disciplinary, and they are closely linked to other initiatives within the AOS, including cryosphere observing, community-based monitoring, and coastal observing.

Polar Archaeology Network: http://uit.no/publikum/prosjekter/prosjekt?p_document_id=270892

CANADA

Title: A Path Forward for SAON Canada

Background:

The purpose of Sustaining Arctic Observing Networks (SAON) is to enhance Arctic-wide observing activities by facilitating partnerships and synergies among existing observation and data management activities, and to promote sharing and synthesis of data and information. As a member state of the Arctic Council and the International Arctic Science Committee (IASC), Canada has established a SAON National Coordinating Committee (SAON Canada) to coordinate its activities. SAON encourages sustained and coordinated pan-Arctic observing and data sharing to serve societal needs, particularly those related to environmental, social, economic and cultural issues. Canada shares the SAON vision that users of observations have open access to data to realize pan-Arctic and global value-added services and societal benefits.

SAON Canada – Coming of Age

The SAON Canada Coordinating Committee is responsible for engaging its members to work together to attain the SAON vision. Members of the National Committee represent federal and territorial governments, academia, Aboriginal groups, and other representative organizations. One of the first initiatives undertaken was the compilation of an inventory of current Arctic observing networks in Canada (2009; the first comprehensive inventory of observing initiatives compiled in Canada).

Since 2009, additional information on Arctic observing systems has been compiled by the Government of Canada as a component of an initiative called "Federal Integrated Network of Science and Technology- FINeST". Further to that exercise, the SAON Inventory is being updated and expanded to include those elements from the inventory of monitoring efforts that were included in the FINeST work of 2011.

Building on this baseline initiative, and to offer a more comprehensive inventory, data and knowledge from Community-based Monitoring (CBM) activities in the Arctic are being included to ensure that the value and benefits of CBM are adequately reflected in the SAON Inventory. This work is being undertaken in collaboration with the Inuit Circumpolar Council (ICC) and other partners across the North.

In order to more widely share SAON Canada information, a new website has been launched: www.arcticobservingcanada.ca. It is linked to the international SAON website www.arcticobserving.com, and will enable readers to review the Inventory, and to link to other Canadian Arctic initiatives such as the Canadian High Arctic Research Station, the Canadian Network of Northern Research Operators, ArcticNet, the Centre d'études nordiques, etc. A geo-referenced visualization tool on this new site will allow users to easily discover many of the existing networks and data-sets.

SAON Canada – Re-thinking Connections

All parties with interests in Arctic monitoring recognize that the existing monitoring networks generally lack coordination across their various functions. At present, Arctic observing programs, as well as data collection and management activities, are scattered and housed in many organizations and jurisdictions, sometimes at the individual researcher level. There is an increasing willingness to work more closely together and across disciplines; we believe that further optimization of observing and data management can be achieved by working more collaboratively.

The new SAON Canada web site will serve as a window to Canadian Arctic observing networks and their activities. The site will begin to provide "one-stop shopping" within Canada for both Canadian and international scientists, policy and decision makers, and will enhance connections both nationally and internationally. The site will direct users to the wide range of available data and to the key contacts responsible for each network. The geo-referenced mapping tool that is under development will facilitate data and information sharing, and endeavour to help users to work together to better discover, coordinate and integrate their data and knowledge. Recognizing that there are other initiatives underway across Canada to develop web-based geo-referenced mapping tools, we are working with others to build synergies and ensure effectiveness in attaining our common objectives.

This national work will facilitate our participation on the international scene.

SAON Canada – Ways and Means Forward

This work will align with and link to other efforts within the Government of Canada to improve data interoperability, and the overall efficiency of data gathering, interpretation and application. Observing activities in the Canadian Arctic will ideally share common standards and a common but distributed data platform that would facilitate easy retrieval and interpretation. Such platforms exist; it is time to agree on a way forward across the range of fields of observation and disciplines.

As in any collaborative activity, the first step is to agree to work together. Playing as a team requires letting go of some control of data, and trusting the other partners. It does not mean relinquishing control of initiatives and leadership on them, to the contrary.

The next steps would see involved parties pooling their efforts and energies to increase the accessibility and interoperability of datasets. It does not mean starting from scratch, because some of this work is already underway or has been completed (e.g., through the Arctic Council's Circumpolar Biodiversity Monitoring Program).

This proposed way forward for SAON Canada will enable observing networks to share and display current observation activities on a geospatial platform, and to improve access to Arctic data. As a result of this initiative, it is envisioned that researchers within existing and future observing networks will discover opportunities to work in closer coordination with other researchers to utilize data and work across disciplines and its ensuing benefits for all.

At the Arctic Observing Summit, 2013, we will engage interested parties in a discussion of options for moving forward on this initiative, and in particular address some of the issues we face. These include how to share data that may not yet have been published; how to include traditional ecological knowledge; what is required on a practical level to improve data accessibility and interoperability; what to do about legacy data that are not in digital form; and what platform(s) or systems to use to access, display and (potentially) house data.

Helen Joseph
Director, Oceanography and Climate Branch
Fisheries and Oceans Canada
Canadian National SAON Representative - (helen.joseph@dfo-mpo.gc.ca; 613-990-6930)

And

Jean-Marie Beaulieu
Senior Science Advisor
Canadian Polar Commission
Canadian SAON Secretariat - (jean-marie.beaulieu@polarcom.gc.ca; 613-947-9108)

Integrating high-resolution satellite imagery into the Arctic Observing Network through the Polar Geospatial Center

Michelle A. LaRue, Paul Morin, and Jonathan Pundsack

Polar Geospatial Center, 310 Pillsbury Drive SE, University of Minnesota, Minneapolis, MN 55455

Arctic ecosystems are changing more rapidly than any other place on the planet (IPCC 2007, McLennan et al. 2012), and traditional satellite systems (e.g., Landsat) do not provide the finer-scale detail necessary to fully integrate ground data with remotely-sensed imagery. High-resolution (0.5m-5m spatial resolution) satellite imagery has been used as a tool to study environmental change, including vegetation/biodiversity mapping and dynamics (Mehner et al. 2004, Gillespie et al. 2008), fire models (Mutlu et al. 2008), earthquakes (Rathje and Crawford 2004), coastal mapping (Wang et al. 2004), and more recently, assessing populations in polar regions (LaRue et al. 2011, Fretwell et al. 2012, Lynch et al. 2012). However, high costs of imagery, and the need for highly technical staff to work with it, has traditionally precluded its use in large-scale or long-term monitoring programs (Kerr and Ostrovsky 2003). The Arctic Observing Network (AON) could benefit from an archive of high-resolution satellite imagery, along with future imagery tasking, to address rapid change and to make ground-to-satellite comparisons to study region-wide change. To provide a way forward for the Arctic Observing Network, we suggest here that the Polar Geospatial Center (PGC), at the University of Minnesota, can fill the gap of accessibility for United States' federally-funded researchers, and provide higher-resolution spatial and temporal imagery needed to fulfill goals and objectives within the AON.

Previous reports of the Arctic Observing Summit (AOS) have identified the strong need for integrated monitoring and better use of remote sensing to fully address ecological, glaciological, and other effects of climate change and human development in the Arctic. Since 2009, the PGC has provided access to, and developed unique expertise with, high-resolution imagery obtained on 5 platforms: WordView-1, WorldView-2, and QuickBird-2 (Digital Globe, Inc.) and GeoEye and IKONOS (GeoEye). Through an agreement with the National Geospatial-Intelligence Agency (NGA), the PGC can access archived imagery, and task new collections in the pursuit of U.S. federally-funded science goals in polar regions. Furthermore, PGC's current archive of data (>550,000 Arctic images; Fig. 1), can already enable research and monitoring of high-resolution, landscape-scale vegetation, glacial, coastal, or sedimentation changes (Fig. 2).

Our suggested integration within the AON would be beneficial for several reasons: 1) High-resolution imagery is cost-effective, environmentally sound, and safe; 2) Higher-spatial and temporal coverage than would be possible with most other remote sensing platforms; 3) Efficient and targeted tasking would benefit a greater number of science goals; and 4) Organizing and dividing science goals among research programs would eliminate effort duplication, and ensure a more integrated approach to system monitoring.

The high-resolution imagery contained within PGC's archives is needed to fill the resolution gap to more broadly understand system changes in the Arctic. We suggest that the Polar Geospatial Center be integrated into the AON to promote the pursuit of new science goals, and also to provide necessary detail to already-established research projects.

Literature Cited

Fretwell, P., M. A. LaRue, P. Morin, G. L. Kooyman, B. Wienecke, N. Ratcliff, A.J. Fox, A.H. Fleming, C. Porter, P.N. Trathan. 2012. An emperor penguin population estimate: the first, global synoptic survey of a species from space. PLoSOne 7(4): e33751. doi:10.1371/journal.pone.0033751.

Gillespie, T.W., T.M Foody, D. Rocchini, A.P. Giorgi, S. Saatchi. 2008. Measuring and modeling biodiversity from space. Progress in Physical Geography 32: 203-221.

IPCC, 2007. Climate change 2007: synthesis report. Cambridge University Press. Available at http://www.ipcc.ch/publications_and_data/

Kerr, J.T., M. Ostrovsky. 2003. From space to species: ecological applications for remote sensing. Trends in Ecology and Evolution. 18:299-305.

LaRue, M.A., J.J. Rotella, R.A. Garrott, D.B. Siniff, D.G. Ainley, G.E. Stauffer, C.C. Porter, P.J. Morin. 2011. Satellite imagery can be used to detect variation in abundance of Weddell seals (*Leptonychotes weddellii*) in Erebus Bay, Antarctica. Polar Biology 34: 1727-1737.

LaRue, M.A., D.G. Ainley, M. Swanson, K.M. Dugger, P.O.B. Lyver, K. Barton, G. Ballard. 2012. Climate change winners: receding ice fields allow colony expansion and altered dynamics in an Adélie penguin metapopulation. PLoSOne. In review.

Lynch, H., R. White, A.D. Black, R. Naveen. 2012. Detection, differentiation, and abundance estimation of penguin species by high-resolution satellite imagery. Polar Biology 35: 963-968.

Mehner, H., M. Cutler, D. Fairbairn, G. Thompson. 2004. Remote sensing of upland vegetation: the potential of high spatial resolution satellite sensors. Global Ecology and Biogeography. 13: 3359-369.

Mutlu, M., S.C. Popescu, C. Stripling, T. Spencer. 2008. Mapping surface fuel models using lidar and multispectral data fusion for fire behavior. Remote Sensing of Environment. 112: 274-285.

Rathje, E., M. Crawford. 2004. Using high-resolution satellite imagery to detect damage from the 2003 northern Algeria Earthquake. 13th World Conference on Earthquake Engineering. Vancouver, paper # 2911.

Wang, L., W. P. Sousa, Gong, G. S. Biging. 2004. Comparison of IKONOS and Quickbird images for mapping mangrove species on the Caribbean coast of Panama. Remote Sensing of Environment. 91: 432-440.

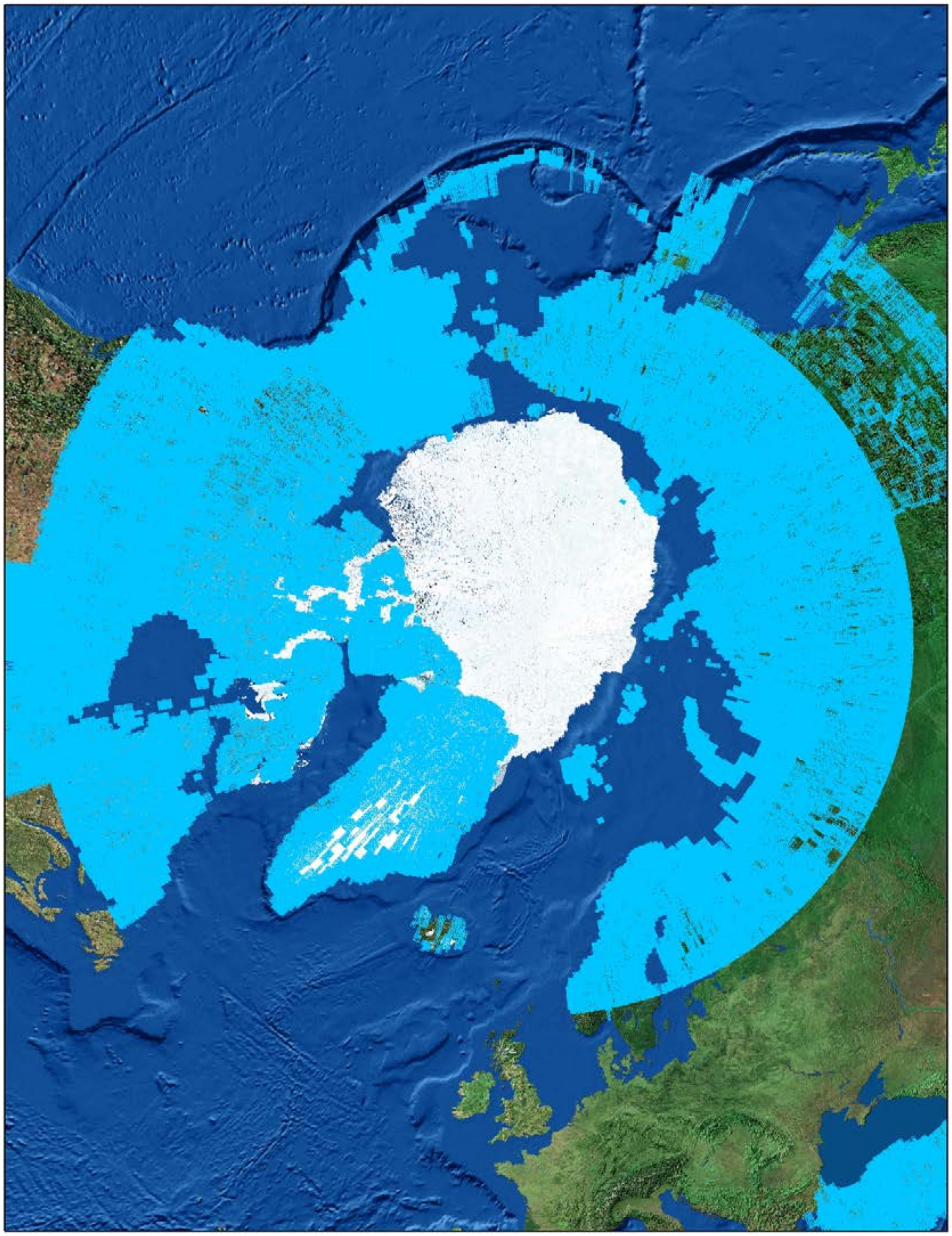
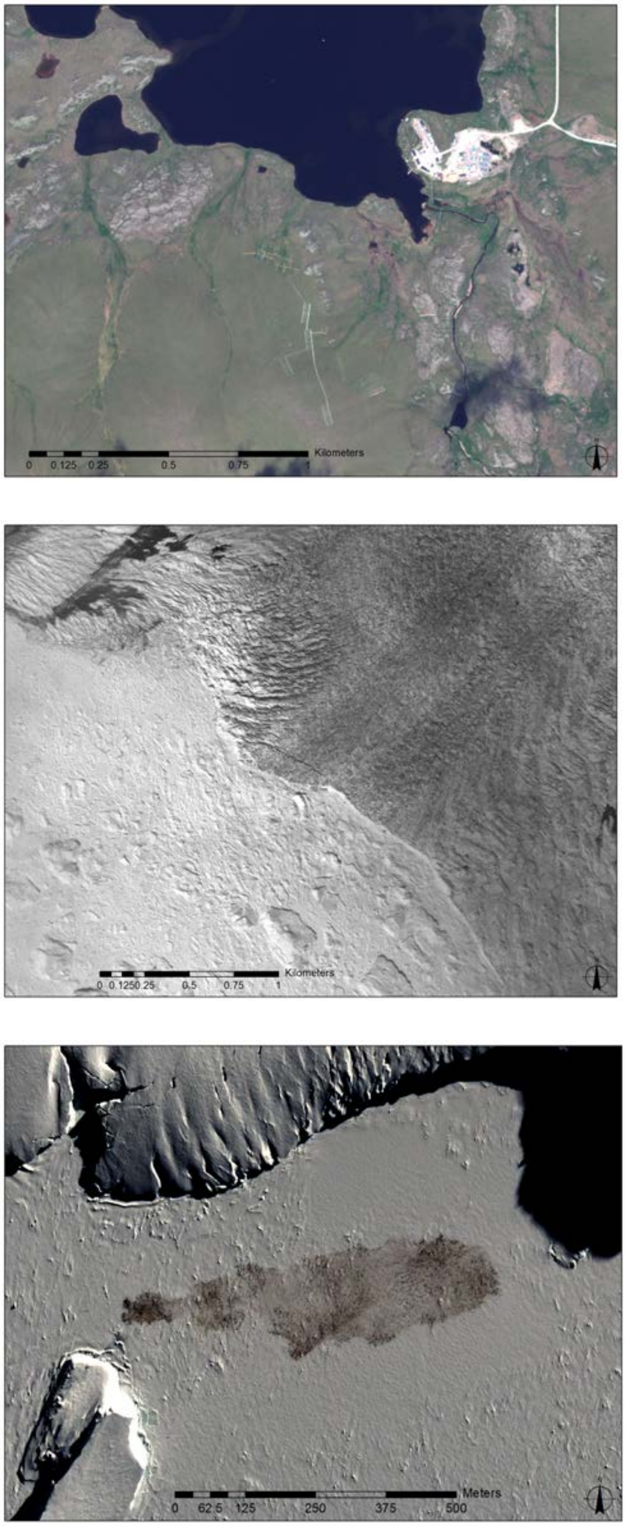


Figure 1. Footprint (i.e., coverage) of current, high-resolution satellite imagery archives at the Polar Geospatial Center for the Arctic. Footprint contains ~550,000 Arctic images at 0.5-5m resolution.



A.

B.

C.

Figure 2. Examples of high-resolution imagery in PGC's archives. A. QuickBird-2 image of Toolik Lake, Alaska (2.4 m resolution, July 4, 2010); B. WorldView-1 image of the Jakobshavn Glacier front (0.6 m resolution; July 8, 2011); C. QuickBird-2 image of an emperor penguin colony at Cape Roget, Antarctica (pansharpened 0.6 m resolution; October 4, 2010).

Vision for an Arctic Mass Change Program

A Short Letter for the Arctic Observing Summit
(April 30 – May 2, 2013, Vancouver, Canada)

by
Jamie Morison, Univ. of Washington, morison@apl.washington.edu
Jennifer Bonin, Univ. of South Florida, jbonin@marine.usf.edu
Don Chambers, Univ. of South Florida, donc@usf.edu
Cecilia Peralta-Ferriz, Univ. of Washington, ferriz@apl.washington.edu
Johnny Johannessen, NERSC, johnny.johannessen@nersc.no
Ian Joughin, Univ. of Washington, ian@snark.apl.washington.edu
Ron Kwok, Jet Propulsion Laboratory, ronald.kwok@jpl.nasa.gov
Felix Landerer, Jet Propulsion Laboratory, felix.w.landerer@jpl.nasa.gov
Dick Moritz, Univ. of Washington, dickm@snark.apl.washington.edu
Ignatius Rigor, Univ. of Washington, ignatius@apl.washington.edu
Frank Nilsen, Univ. Center in Svalbard, frank.nilsen@unis.no
Vladimir Pavlov, Norwegian Polar Institute, vladimir.pavlov@npolar.no
Axel Schweiger, Univ. of Washington, axel@snark.apl.washington.edu
Ragnheid Skogseth, Univ. Center in Svalbard, ragnheid.skogseth@unis.no
Ben Smith, Univ. of Washington, bsmith@apl.washington.edu
Mike Steele, Univ. of Washington, mas@apl.washington.edu
John Wahr, Univ. of Colorado, john.wahr@gmail.com

2/28/2013

This letter advocates development of the Arctic Mass Change Program (AMCP), an integrated system of remote sensing, *in situ* observations, and data assimilation to measure Arctic terrestrial and ocean mass change and attendant freshwater and circulation changes. Mass and density variations are fundamental elements of environmental change in the Arctic. Changes in atmospheric circulation are mainly diagnosed as changes in atmospheric pressure. Similarly, ocean circulation is observed by measuring water density so that the fields of mass and pressure can be estimated. Measuring changes in average ocean density also tell us changes in freshwater distribution. The most fundamental observations of ice sheets and glaciers are mass balances. Tracking of the mass of terrestrial water is essential to hydrology. By making regular measurements of mass and volume, the Gravity Recovery and Climate Experiment (GRACE) and the satellite altimeters such as ICESat and CryoSat2 have ushered in a new era for high-latitude oceanography [*Kwok and Morison*, 2011; *Kwok et al*., 2009; *Morison et al*., 2007; *Morison et al*., 2012; *Shum et al*., 2009], hydrology [*Frappart et al*., 2011; *Landerer et al*., 2010], and the study of ice sheets [*Khan et al*., 2010; *Van den Broeke et al*., 2009; *Velicogna*, 2009; *Velicogna and Wahr*, 2005; 2006; *Wu et al*., 2010] and glaciers [*Luthcke et al*., 2008].

Given an accounting for atmospheric mass (i.e. surface atmospheric pressure, SAP), GRACE gravity measurements yield changes in ocean mass (ocean bottom pressure, OBP), ice sheet mass, and the mass of water stored on land. Satellite altimetry provides sea surface height (SSH) and, by subtracting the geoid elevation, dynamic ocean topography (DOT) from which the geostrophic circulation of the upper ocean can be inferred [*Kwok and Morison*, 2011]. The difference between OBP and DOT is the steric pressure anomaly, which in the salt-stratified Arctic waters is a measure of ocean freshwater content (FWC) [*Giles et al*., 2012; *Morison et al*., 2012]. Similarly, satellite altimetry measures the volume of ice sheets and glaciers and offers an independent estimate of ice mass changes. The power of these tools is that they extend sustained observations of mass, volume, and circulation over essentially all regions of the Arctic, including important areas where *in situ* measurements are practically impossible. However, realization of the full potential of the remote sensing observations requires repeated *in situ* measurements for validation, extension to higher frequencies, and the discrimination of hydrologic, ice sheet, and ocean mass change signals.

The need for intercomparisons with *in situ* measurements and models is particularly acute in near coastal regions where the hydrologic, ice sheet and ocean realms meet. It is near the coastal regions that ice sheet mass loss has been greatest[*Pritchard et al*., 2009]. It is in nearshore regions where we find the boundary currents that are responsible for much of ocean mass transport. And it is the nearshore region where terrestrial freshwater seasonally accumulates in estuaries and deltas on its way to the sea. However, GRACE has a large footprint, and in the critical regions where land or ice sheets meet the ocean, the gravity signals of mass change in one environment leak into the mass signals of the other environment. As part of the de-aliasing process, ocean models are used to estimate and remove the leakage of ocean signal into the terrestrial realm, but the result is heavily model dependent in precisely the regions where we are most unsure of model performance and where their comparisons with *in situ* OBP measurements give mixed results [*Bonin and Chambers*, 2012; *Chambers and Bonin*, 2012; *Peralta-Ferriz*, 2012].

However, OBP from GRACE can be compared to OBP measured directly with *in situ* pressure sensors [*Morison et al*., 2007] or by the sum of DOT changes (measured *in situ* or by altimetry) and steric pressure anomaly changes measured by repeat hydrography. Ice sheet mass variations can be measured in near coastal regions by GPS surveying approaches and by altimetry [*Pritchard et al*., 2009; *Shepherd et al*., 2012]. Direct drainage basin-scale estimates of ground and surface water amounts serve the same purpose in the hydrologic sphere. Such comparisons among remote sensing and key repeat *in situ* measurements validate interpretations of satellite gravity and altimetry for mass, circulation, and freshwater changes over the whole Arctic. Such comparisons in near coast regions test and refine the discrimination of mass change signals from the ocean, ice sheets, and terrestrial water. High-frequency measurements provided by *in situ* OBP gauges can also be used to test the ocean models and the techniques used to de-alias GRACE gravity measurements for tides and other high-frequency ocean changes prior to monthly averaging.

Ultimately, we envision the AMCP to include a multi-environment data assimilation system that will form optimal estimates of ice sheet mass, terrestrial water, and ocean mass, freshwater content and circulation by optimal combination of remote sensing and *in situ* observations with ocean, ice sheet, and hydrologic models.

Planning for future gravimetry and altimetry satellite missions is ongoing (e.g., [*Watkins et al*., 2011]) and there is continuing progress in modeling the land, ice sheet and ocean environments. The two critical new steps to developing an Arctic-wide view of mass, freshwater, and circulation change are (a) establishment of a network of specific *in situ* repeat measurements, and (b) the development of assimilation techniques that incorporate models and observations from multiple environments. Many potential observing platforms already exist. The International Arctic Buoy Program already takes advantage of drifting buoys to measure atmospheric pressure over the Arctic Ocean. An example of comparable efforts contributing to coordinated measurement of Arctic mass change would be to equip all moorings with ocean bottom pressure gauges and all drifting buoys with dual-channel precision GPS that would measure SSH and also give precipitable atmospheric water vapor content. Similarly, work on data assimilation into individual models is ongoing (e.g., ECC2, [*Nguyen et al*., 2011]) and at least one attempt has been made to combine a data-assimilating an ocean model, GPS observations, and GRACE gravity measurements into predictions of ice sheet mass change [*Wu et al*., 2010].

What is needed most now is a shared vision of how greatly the whole of a coordinated AMCP could exceed the sum of its parts. With the availability of satellite gravimetry and altimetry plus multi-environment data assimilation, the information we obtain by combining these and *in situ* ocean, ice sheet, and hydrologic observations will be much better than what we could obtain examining each data source separately.

References

Bonin, J. A., and D. P. Chambers (2012), Uncertainty Estimates of GRACE Forward Modeling Technique Over Greenland Using a Simulation, *Geophysics Journal International*, *submitted*.

Chambers, D. P., and J. A. Bonin (2012), Evaluatiom of Release-05 GRACE time-variable gravity coeficients over the ocean, *Ocean Science Discussions*, *9*, 2187-2214.

Frappart, F., G. Ramillien, and J. S. Famiglietti (2011), Water balance of the Arctic drainage system using GRACE gravimetry products, *International Journal of Remote Sensing*, *32*(2), 431-453.

Giles, K. A., S. W. Laxon, A. L. Ridout, D. J. Wingham, and S. Bacon (2012), Western Arctic Ocean freshwater storage increased by wind-driven spin-up of the Beaufort Gyre, *Nature Geosci*, *advance online publication*.

Khan, S. A., J. Wahr, M. Bevis, I. Velicogna, and E. Kendrick (2010), Spread of ice mass loss into northwest Greenland observed by GRACE and GPS, *Geophysical Research letters*, *37*(6), L06501.

Kwok, R., and J. Morison (2011), Dynamic topography of the ice-covered Arctic Ocean from ICESat, *Geophysical Research Letters*, *38*(L02501), L02501.

Kwok, R., et al. (2009), Combining satellite altimetry, time-variable gravity, and bottom pressure observations to understand the Arctic Ocean: A transformative opportunity, *peer-reviewed Community White Paper, in the Ocean Obs'09 Conference Proceedings, IOC/UNESCO, ESA, and supporting national agencies.*

Landerer, F. W., J. O. Dickey, and A. Guentner (2010), Terrestrial water budget of the Eurasian pan-Arctic from GRACE satellite measurements during 2003–2009, *J. Geophys. Res.*, *115*, D23115.

Luthcke, S., A. Arendt, D. Rowlands, J. McCarthy, and C. Larsen (2008), Recent glacier mass changes in the Gulf of Alaska region from GRACE mascon solutions, *Journal of Glaciology*, *54*(188), 767-777.

Morison, J., J. Wahr, R. Kwok, and C. Peralta-Ferriz (2007), Recent trends in Arctic Ocean mass distribution revealed by GRACE, *Geophysical Research Letters*, *34*, L07602.

Morison, J., R. Kwok, C. Peralta-Ferriz, M. Alkire, I. Rigor, R. Andersen, and M. Steele (2012), Changing Arctic Ocean freshwater pathways, *Nature*, *481*(7379), 66-70.

Nguyen, A. T., D. Menemenlis, and R. Kwok (2011), Arctic ice - ocean simulation with optimized model parameters:

Approach and assessment, *J. Geophys. Res.*, *116*, C04025.

Peralta-Ferriz, C. (2012), Arctic Ocean Circulation Patterns Revealed by Ocean Bottom Pressure Anomalies, University of Washington, Seattle.

Pritchard, H. D., R. J. Arthern, D. G. Vaughan, and L. A. Edwards (2009), Extensive dynamic thinning on the margins of the Greenland and Antarctic ice sheets, *Nature 461*(7266

), 971-975.

Shepherd, A., et al. (2012), A Reconciled Estimate of Ice-Sheet Mass Balance, *Science 338*(6111), 1183-1189.

Shum, C. K., et al. (2009), Geodetic observations of the ocean surface topography, geoid, currents, and changes in ocean mass and volume, *in press in the Ocean Obs'09 Conference Proceedings, IOC/UNESCO, ESA, and supporting national agencies.*
Van den Broeke, M., J. Bamber, J. Ettema, E. Rignot, E. Schrama, W. J. v. d. Berg, E. van Meijgaard, I. Velicogna, and B. Wouters (2009), Partitioning Recent Greenland Mass Loss, *Science*, *326*, 984-986.
Velicogna, I. (2009), Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE, *Geophysical Research letters*, *36*, L19503.
Velicogna, I., and J. Wahr (2005), Greenland mass balance from GRACE, *Geophysical Research Letters*, *32*, L18505.
Velicogna, I., and J. Wahr (2006), Acceleration of Greenland ice mass loss in spring 2004, *Nature*, *443*, 329-331.
Watkins, M., F. Fletchner, and B. Tapley (2011), Status of the GRACE Follow-On Missio, *Geophysical Research Abstracts*, *13*(EGU2011-5068, EGU General Assembly 2011).
Wu, X., M. B. Heflin, H. Schotman, B. L. A. Vermeersen, D. Dong, R. S. Gross, E. R. Ivins, A. W. Moore, and S. E. Owen (2010), Simultaneous estimation of global present-day water transport and glacial isostatic adjustment, *Nature Geosci*, *3*(9), 642-646.

Citizen Science and Arctic Observing: Using the Internet and Simple Technologies to Improve Understanding of Arctic Ecosystem Change

Maribeth S. Murray[1,] Phillip A. Loring[2], Howard Ferren[3] and Rebekka Fedderer[3]

[1]International Arctic Research Center, University of Alaska Fairbanks, [2]Center for Cross-Cultural Studies and the Alaska Center for Climate Assessment and Policy, UAF, [3] Alaska SeaLife Center, Seward

Citizen science (CS), one of many forms of Public Participation in Scientific Research (PPSR) is the collection of information for scientific and often educational purposes by citizen volunteers (Bonney, et al. 2009; Silvertown 2009). CS need not be Community-Based Observing/Monitoring (CBO/M) as defined in AOS white papers by Alessa et al., (2013) and Johnson et al. (2013), although CS can include CBO/M efforts, and certainly it may integrate community needs for information, community directed research, and local and/or traditional knowledge. CS as described here offers **all** interested individuals the opportunity to participate in the research process with the express purpose of collecting data to address a specific problem or set of problems regardless of permanent physical location of the observer, the expertise of the observer, or the level of observer engagement in research problem formulation. Citizen scientists engaged in arctic observing may be residents of arctic communities, but they may also be other individuals who have particular opportunities to collect information of relevance to arctic observing needs and arctic research. Members of the northern fishing fleets who reside part of the year outside of the arctic but still spend a significant amount of time on arctic waters, members of the dog mushing community who may spend substantial time each year traveling on the land, seasonal workers in northern industries, sportsmen visiting from other regions, and tourists are just a few examples of those who can be engaged in arctic observing. CS observing projects may be short-term or they may be longer-term. In the case of the latter, CS can approximate CBO/M efforts, but will include a more geographically dispersed observer community collecting data that might be more temporally or seasonally bounded than that collected through CBO/M efforts. A CS project that involves collection of observations **in** the Arctic should be informed by the engagement of local people from the outset, even though they may or may not choose to participate in the collection of the observations themselves.

Web-based and GPS technologies are powerful tools for engaging citizen scientists in arctic observing. Use of GPS can be similar to that pioneered in the Igliniit project to record information on a whole host of environmental variables (Gearheard, et al. 2011), or focused on locating observations of very specific phenomena such as a single species. When partnered with an online reporting system that generates maps displaying the collected data the potential for generation of and access to information is great. *BioMap Alaska* (Murray et al. 2013) is an internet accessible, iterative, multilingual, GIS and Google Maps-based tool for collecting observations on marine species that is useful for management, research and education. At present, information on 11 species is available in both English and Iñupiat, and the system allows people to volunteer their observations through a simple web form. Participants can also submit photographs, and are asked for information on location, weather and environmental conditions at the time of observation. In addition observers can contribute information that may differ from that which is requested but which is meaningful to them (i.e. TEK/LEK or other). Interaction between observers and researchers is both possible and encouraged. Thus *BioMap* enables the co-production of knowledge (Gibbons, et al. 1994), even as the community of knowledge producers is connected largely through cyberspace. Future versions of *BioMap* will integrate with social media in order to strengthen the virtual community component.

Information/observations are accumulated in the *BioMap* database, vetted by experts on regional fauna, and made publicly available in a standardized data format for researchers, managers, educators and the general public. *BioMap* is designed to improve monitoring of marine species and may provide information on changing conditions including species range extensions and introduced species using a consistent yet flexible format. *BioMap* objectives overlap and complement similar initiatives, including those of the Circumpolar Biodiversity Monitoring Program. At a minimum, the goal is to improve baseline information on coastal marine resources in the Chukchi/Beaufort sea region and to facilitate a forum for continuous exchange and communication among scientists, resources managers and stakeholders using the internet and incorporating local knowledge and diverse user observations. However, technological improvements can simplify the input of observations such that contributions could be made from around the pan-Arctic. Similarly standardized reporting of certain variables can be enabled. For example through collaboration and cooperation with entities such as those that manage and monitor weather stations the input of GPS coordinates and time of observation can automatically link to weather data.

An *Arctic BioMap* should be developed and implemented in partnership with regional, national, and international programs engaged in similar observing activities. Minimal efforts at coordination and some sharing of resources would allow expansion beyond Alaska and potentially enable a citizen science effort for arctic ecosystem observing that could equal the success of programs such as Old Weather (www.oldweather.org). Ultimately the goal is to build a citizen science platform for arctic ecosystem observing that is pan-arctic in coverage, that is open to the collection of observations on much larger number of species than the 11 which are currently being observed and that includes all participants who have the interest in and opportunity to contribute.

Figure 1. BioMap Alaska homepage.

Updated 2012

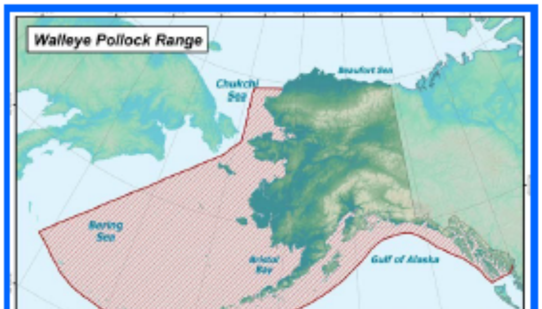
UUKAKPAK

Gadus chalcogramma

Photo: NOAA AK Fisheries Science Center

Iñuusia: Uukakpak Alaskami paqinnaqtut Ualiġm (Bering) taġiuŋani suli Uŋalim qikiqtaŋinni (Aleutian islands), iḷaŋi inugiakiḷhat Sallim(Gulf of Alaska) taġiuŋani paqinamiut.Paqiññaguurut imam qaaqiuraŋani, itiqpaŋitchuami taġiumi suvaiqsisaqamik unii niġiniaqamiŋ,immasuli tallimat tllimakipiatun taġium ititiniŋani. Uukakpait iglausuurut nunam siññanun upingaami suvaiqsinaqsikamik nagga niġiniaqamik aasii itiruamun nuułutik ukiaġmauŋ. Katitpaguumiut atautchimun tasamma iñugiaksiqpakłutik.

Iñugiaktillaaŋi: Iñugiaktillaaŋat tasamma tamatkua nayuqtit iqalluŋniagniq pisigivlugu naamaniġaat iqalliqikpagniġsraŋat. suli aŋiniqtauruq iqalluktaapayaurani USgum iqalliqiriŋisa nalunaigmaruŋ. Naipiqtuġmatigik uukakpait qiḷamik nausukpiuraqtut taġiullaaŋini. Isumalaagutit suli siquminniniŋa taġium natqani iñuuviatni iłuaqsiŋagat pitquratigun nayuqtiqaqługi govamam savaktiŋiŋnik aglaan qaunaksraagiktuksraurut taikuŋasugruk kavyanaiqsimmaalugi.



Map: ADF&G
Walleye Pollock Range in Alaska
** Additional range observed as far north and east of Cape Halkett, Beaufort Sea*

Irrusiŋi: Uuktuunmi aktiaaqaqtut sisamakipiaq qulit atausik CM, qivliqtut amiŋi aasii qaaŋa maŋauraaqtuq suli qivliaqtaaguruk narraaak, irikpaqaqtut, taqsraqtaqaanik pitusigauratun qupaqaqtut, suli piŋasut suluutit,malġuk sipik, suli malġuk ataani aŋuutiŋi.
Aġnasalut irrusia: Qiññaŋik allagiipaŋitchuk aglaan aŋiuralhaaqtut aŋusaluniñ.
Aŋusalut irrusia: Qiññaŋik allagiipaŋitchuk aglaan mikiuraqtuq aġnasaluaniñ.
Piayaaŋisa irrusia: Suvaŋmiñ anniqamiat aktillaaqatut itchaksrat mm tun suli immam qaaqiuraani puumitchuurut, suli taġium siñaaniitchurut.
Niqiŋi taġiuni: Aŋiruat uukat niġisuurut naulagnat, iqaluit, uukakuluuraniglu, mikiruat uukat aglianiŋaitchuatlu niġisuurut igliġauranik, igliganik suli qupilgunik
Iñuguqniŋat: Aġnasalutlut suvairaqsisuurut ukiutuagman, isuani Siqiññaasugruum-Suvluġvigmun aglaan, itiqpaŋitchuami taġiumi, malġugnik-tallimanik ukiuniŋmata. aasii taima suvaiksisaġmata malġuk kavluutik kavluutinik suvaiksillarut malġuŋi akunniksaagni.
Niqigilatukaŋat: iqaluit, taġium nigrutai (ulghaat niqigilatupiksuagai natchiaġruilu) suli , suli taġium tinmiaŋitch.
Iqalluutiqatigiit: Uugaġruaq, uugaq, uugaq, Iqalugaq.

Figure 2. Species field guide – Walleye Pollock, Iñupiat text.

References Cited

Alessa,L., et al.
2013 Community Based Observing Networks (CBONs) for Arctic Adaptation and Security, White Paper for Arctic Observing Summit 2013. www.arcticobservingsummit.org/users/white_papers.php

Bonney, R., et al.
2009 Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. . Washington D.C.: Center for the Advancement of Informal Science Education.

Gearheard, S., et al.
2011 The Igliniit project: Inuit hunters document life on the trail to map and monitor arctic change. Canadian Geographer / Le Géographe canadien 55(1):42-55.

Gibbons, M., et al.
1994 The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies. London: Sage.

Johnson, N., et al.
2013 Strengthening community-based monitoring in the Arctic: Key challenges and opportunities. White paper for Arctic Observing Summit 2013. www.arcticobservingsummit.org/users/white_papers.php

Silvertown, Jonathan
2009 A new dawn for citizen science. Trends in Ecology & Evolution 24(9):467-471.

Arctic Observing Summit

February 2013

Arctic Observing – Nunavut, Canada

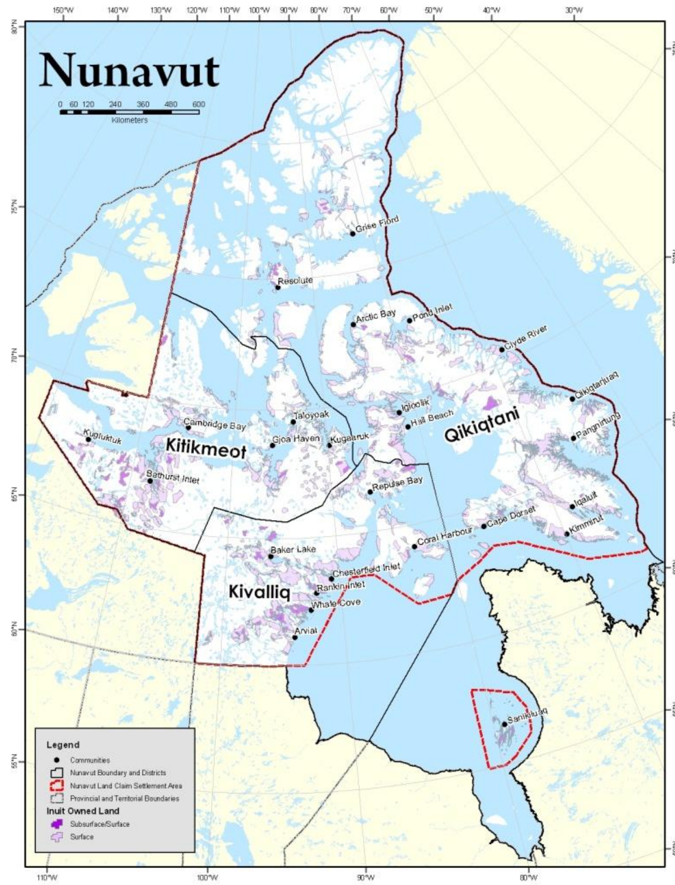
Nunavut was created as an outcome of the Nunavut Land Claims Agreement (NLCA, 1993). Formerly the eastern portion of the Northwest Territories, Nunavut covers approximately 2 million km2 – 1/5 of Canada's land surface – and three time zones. The population of approximately 34,000 is over 80% Inuit (with much higher proportions of Inuit in the smaller communities), and represents some 0.09% of the total Canadian population. The inhabitants of Nunavut reside in 3 regions - Kitikmeot, Keewatin (Kivalliq), and Baffin (Qikiqtaaluk). The 27 communities, most of them accessible only by air (other than during sea-lift operations), are shown in Figure 1.

Nunavut general monitoring is an integral requirement of the Nunavut Land Claims Agreement (NLCA). Article 12.7.6 of the NLCA indicates that:

There is a requirement for general monitoring to collect and analyze information on the long term state and heath of the ecosystemic and socio-economic environment in the Nunavut Settlement Area. Government, in co-operation with the Nunavut Planning Commission (NPC), shall be responsible for developing a general monitoring plan and for directing and coordinating general monitoring and data collection.

The Nunavut General Monitoring Plan (NGMP) is an ecosystemic and socio-economic environmental monitoring initiative that aims to support, facilitate and coordinate the collection, analysis, management and dissemination of information regarding the long-term state and health of the environment in Nunavut.

Figure 1.



Aboriginal Affairs and Northern Development Canada (AANDC) is the lead federal department responsible for implementing the NGMP, as per this requirement. The NGMP is administered by the NGMP Secretariat, located within the AANDC Nunavut Regional Office, and is further supported by AANDC headquarters.

A similar but independent program also exists in the Northwest Territories, called the Northwest Territories Cumulative Impact Monitoring Program (CIMP).

The work of the NGMP is guided by a steering committee comprised of AANDC, on behalf of the Government of Canada, along with the NPC, Nunavut Tunngavik Inc., and the Government of Nunavut.

NGMP is an important piece of the Government of Canada's Action Plan to Improve the Northern Regulatory Regimes, which works to ensure the regulatory system functions in a more timely and efficient manner, allowing for sustainable resource development balanced with environmental protection.

A coordinated, effective and rigorous ecosystemic and socio-economic environmental monitoring regime is critical for sustainable development in Nunavut in order to:

- Understand and respond to changing environmental conditions at local, regional and territorial scales;

- Understand and mitigate the potential cumulative impacts of development activities on the ecosystemic and socio-economic environment;

- Improve the effectiveness and accountability of monitoring and resource management governance, policy development and land-use decision-making in Nunavut; and

- Improve the coordination, alignment and integration of environmental research and monitoring information.

The development of a robust environmental monitoring regime provides significant benefits to Nunavut communities, industry, planners, government and decision-makers; however, achieving it requires significant changes in how all of these parties prioritize monitoring and collaborate in the collection, analysis and dissemination of information.

Through its participation at the 2013 Arctic Observing Summit, NGMP looks forward to sharing information related to:

- The current status of Nunavut general monitoring (including strategic goals, objectives, opportunities, challenges and sustaining monitoring in Nunavut) and future plans;

- NGMP's design, approach and coordination mechanisms;

- 'Co-Monitoring' in Co-Management regimes and its application to other international monitoring contexts (particularly within the circumpolar world);

- Data collection, analysis and reporting protocols and resources; and

- Linkages between policy, knowledge gaps, decision-making processes and action via monitoring.

As Nunavut is key region within the circumpolar Arctic, NGMP looks forward to sharing information on how to support meaningful access to monitoring information, supporting decision-making processes related to sustainable development and ultimately, showcasing the centrality of partnerships; particularly for broad-scale monitoring initiatives such as NGMP.

At the same time, NGMP looks forward to listening, learning and working together with its fellow observing networks in the circumpolar Arctic monitoring community.

In sharing information at the 2013 AOS, NGMP will contribute to the outcomes and products of the AOS and provide an official point of future reference for all monitoring inquiries related to our Arctic community of Nunavut, Canada.

ᑎᑎᖅᑲᖕᓂᐊᕐᕕᐊ 2200, ᐃᖃᓗᐃᑦ, ᓄᓇᕗᑦ X0A 0H0
PO Box 2200, Iqaluit, NU, X0A 0H0
Ph. (867) 975-4667 Fax. (867) 975-4736

Developing Inuvialuit Baseline Indicators System for (Self)Monitoring Community Well-Being and Impacts of Resource Development

Andrey N. Petrov, University of Northern Iowa/Yukon College, Chris Southcott, Lakehead University/Yukon College, Bob Simpson, Simon Routh, Inuvialuit Regional Corporation and Philip Cavin, University of Northern Iowa

The Inuvialuit Baseline Indicators project is a collaborative effort between Resources and Sustainable Development in the Arctic (ReSDA), Arctic Social Indicators (ASI) projects and the Inuvialuit Regional Corporation (IRC). The goal of the Inuvialuit Baseline Indicators (IBI) project is to develop a set of measurable, reliable and accessible indicators to monitor socio-economic conditions in the Inuvialuit Settlement Region (ISR) with an emphasis on tracking impacts of resource development. This effort is focused on creating a framework to be used by local actors to collect, manage and analyze community-based data.

The Inuvialuit region has been affected by a number of resource boom cycles associated with the resource activities in the Mackenzie Delta and more recently in the Beaufort Sea. The IRC created as a result of the Inuvialuit Comprehensive Land Claim Agreement has been collecting and publishing selected socio-economic data to aid in decision-making process and provide public access to IRC members. Given a growing interest in Arctic resources within the ISR, IRC engaged in collaboration with a social impacts monitoring team of polar scientists to develop a system of indicators based on past experiences in ISR and across the Arctic, local relevance and data availability.

The objectives of the IBI project include (1) using ASI circumpolar framework of social indicators provide a background baseline analysis of IRC socioeconomic characteristics in comparison with Northwest Territories (NWT), Inuit regions of Canada/USA, and other circumpolar jurisdictions; (2) using ASI experience and community consultations identify more relevant domains that are to be included in to the socioeconomic monitoring system (3) define baseline indicators suitable for monitoring socio-economic conditions and impacts of resource development in ISR; (4) develop procedures that will enable community-based collection, management, and analysis of data by local actors; (5) collect necessary data and expand IRC database; (6) develop and disseminate Inuvialuit Baseline Indicators data and analysis to inform region’s stakeholders and aid in IRC’s decision making and ensure community awareness.

The first stage of the project was to analyze of ISR socio-economic well-being using established indicators framework developed by the ASI under the auspice of the Arctic Council. The assessment was conducted for six domains: health and population, material well-being, cultural vitality, closeness to nature, education, and fate control. The analysis revealed considerable internal differences within ISR, especially between Inuvik and other communities. On most indicators IRS was better off than other NWT regions (unemployment, engagement in traditional activities, land claim status and fate control) or close to average (incomes, dependency on government transfers, consumption of county food, education). IRS fared worse than other NWT regions in respect to language retention and out-migration rates. In comparison with Inuit communities in Nunavut, IRS had generally higher level of material well-being, but demonstrated very low language retention, low on consumption of traditional food, and inferior fate control status. The long-term trends (between 1986 and 2010) were positive for several indicators, such as participation rate, educational attainment, housing, teen birth, engagement in hunting and fishing, and negative for crime, ability to speak mother tongue, and dependency on income support, among others. The analysis shows that although ISR appears to maintain relatively high levels of socio-economic well-being across most of the six domains, it still faces considerable social challenges and has to deal with severe interregional inequalities.

Arctic Observing Summit (April 30 – May 2, 2013, Vancouver, Canada); AON statement

Toward Improved Observing of the Rapidly Changing Arctic Ocean

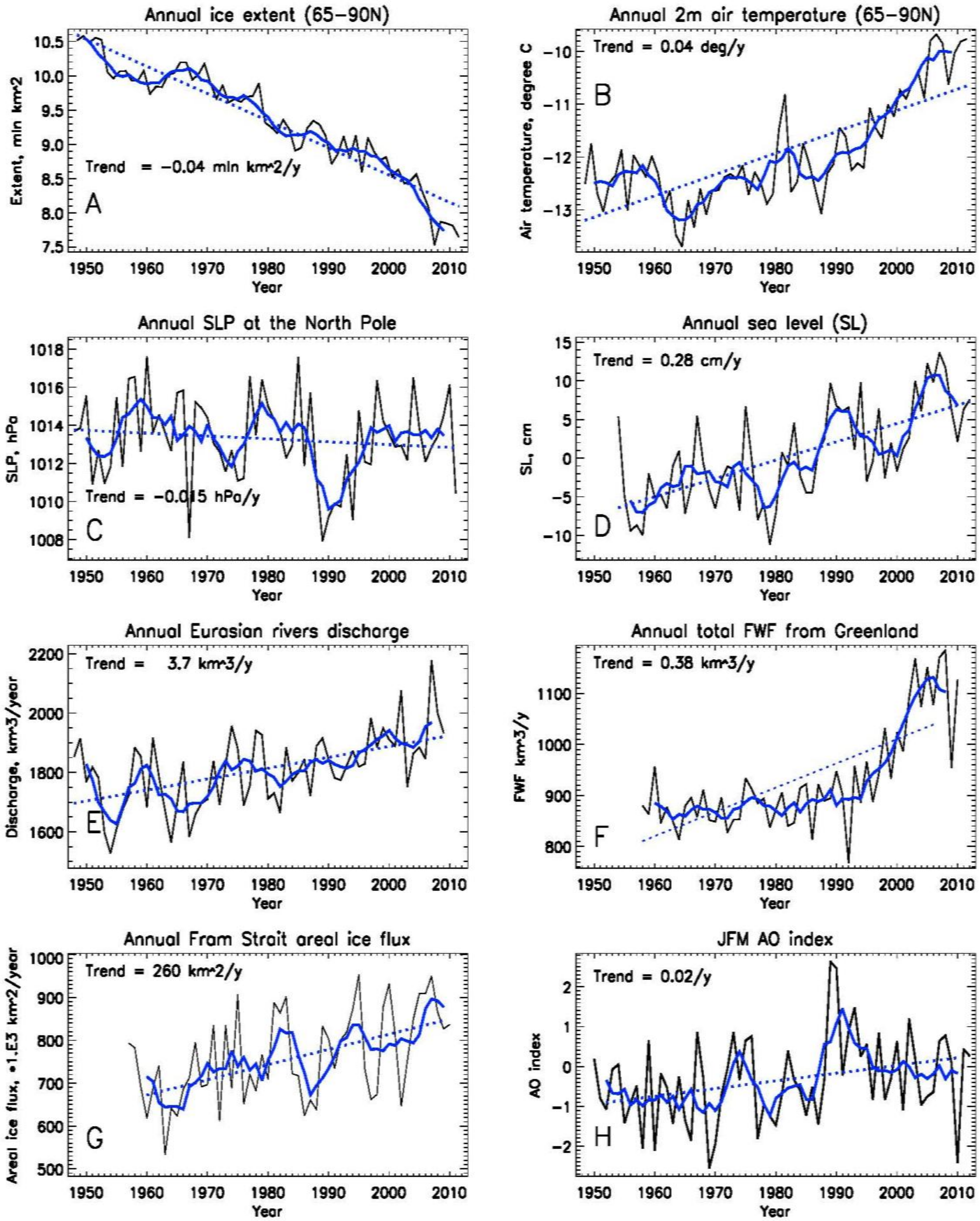
A. Proshutinsky, J. Toole, R. Krishfield, A. Plueddemann, R. Pickart and C. Ashijan (Woods Hole Oceanographic Institution); M-L. Timmermans (Yale University); D. Perovich and J. Richer-Menge (Cold Regions Research and Engineering Laboratory); T. Stanton (Naval Postgraduate School); P. Matrai (Bigelow Laboratory for Ocean Sciences); C. Lee, J. Morison, M. Steele and I. Rigor (University of Washington)

In order to observe and understand the Arctic Ocean and its response to climate change, the traditional approach of acquiring observations when and where the Arctic is accessible has to be enhanced with multi-faceted measurement systems operating autonomously to provide year-round information in real time. The major goal of such a network of autonomous sensors is to measure and monitor physical, chemical and biological parameters in the atmosphere, sea ice and ocean on at least daily intervals. Our vision for a basin-scale system follows recommendations put forward in several community reports and white papers [see references] that highlight a mix of shelf, continental slope and deep ocean observatories, drifting buoys, floats and mobile vehicles. These observational assets should be configured to monitor changes in ocean and sea ice volume and heat and fresh water content over the continental slope regions and deep Arctic, and observe the heat and fresh water fluxes through ocean straits and openings connecting to the south. Nevertheless, data collected by traditional ship-based and airborne expeditions designed for specific process studies will continue to be essential, and should complement the automated observing systems. Combined, these systems will provide year-round observations of key oceanographic, cryospheric and atmospheric processes both through the complementary nature of the platform types and through platform interactions. It will be necessary to maximize capabilities both in the marginal/seasonal ice zones and in the year-round pack ice with innovative, reliable and cost-effective approaches for under-, in-, and-over-ice measurements. *An efficient network of autonomous Arctic observing systems measuring environmental parameters in the ocean, ice, and atmosphere year round and transferring measurements in real time to data centers via satellites is urgently needed.*

Rapid changes in key environmental parameters (see Figure) evince the importance of a sustained (i.e. longer than a decade) environmental Arctic *monitoring* system targeted to address specific scientific questions, and employing automated instrumentation approaches. Such an autonomous observing system is less costly and enables long term measurements to be made at multiple locations. Such long-term, continuous measurements are essential due to the interannual variability present in a multitude of important environmental parameters.

The development of basin-scale, under-ice geopositioning and communications should be a priority for an Arctic Ocean observing network. An example of *in situ* ocean, atmosphere and sea ice observing systems is the Ice Based Observatory (IBO) [Proshutinsky *et al.*, 2004; Toole *et al*., 2006] which includes meteorological, biogeochemical, oceanographic, and sea ice sensors. Over the past decade, numerous IBOs have been deployed Arctic-wide, measuring important environmental parameters with high spatial and temporal resolution year round. Future developments could include, for example, integration of IBOs, moored instrumentation and mobile platforms, such as AUVs. Future autonomous observing systems should have enhanced abilities to survive ice ridging and operate reliably in the seasonal ice zone and open water.

Data returned from autonomous and integrated systems are necessary for operational arctic weather predictions, numerical model initialization and validation, and improved understanding of Arctic Ocean processes and long-term change. Although expeditionary field programs will continue to provide valuable information about Arctic change, true understanding will require sustained, integrated observing systems.



Time series of annual (black) and 5-year running mean (blue) Arctic parameters: A – sea ice extent, B – 2m air temperature, C – North Pole sea level pressure, D – sea level, E – Eurasian river discharge, F – total fresh water flux from Greenland (ice sheet melt, iceberg calving and Greenland river runoff), G – Fram Strait areal ice flux, H – winter (Jan.-Mar. average) Arctic Oscillation index (AO). The dotted line in each panel depicts the linear trend. Note the sizeable interannual variability in these fields - signals that can alias limited-duration field observations.

References

Calder, J. et al. (2010). "An Integrated International Approach to Arctic Ocean Observations for Society (A Legacy of the International Polar Year)" in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Kwok, R. et al. (2010). "Combining Satellite Altimetry, Time-variable Gravity, and Bottom Pressure Observations to Understand the Arctic Ocean" in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Lee, C. , et al. (2010). "Autonomous Platforms in the Arctic Observing Network" in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Lyons, B., K. Alverson, D. Barber, J. Bellingham, T. Callagan, L. Cooper, M. Edwards, S. Gearheard, M. McCammon, J. Morison, S. Palo, A. Proshutinsky, L. Reiersen, V. Romanovski, P. Schlosser, J. Stroeve, G. Tweedie, J. Walsh, Toward an integrated Arctic Observing Network, National Academies Press, Washington, D.C., 2006, 115p.

Proshutinsky, A., *et al. (*2004*),* An array of ice-based observatories for Arctic studies, Eos Trans. AGU, 85*(*46*),* 484–484, *doi:*10.1029/2004EO460005.

Toole, J. R. Krishfield, A. Proshutinsky, C. Ashjian, K. Doherty, D. Frye, T. Hammar, J. Kemp, D. Peters, M-L. Timmermans, K. von der Heydt, G. Packard, T. Shanahan (2006): Ice-tethered profilers sample the upper Arctic Ocean, Eos, Transactions American Geophysical Union Volume 87, Issue 41, October 2006, Pages: 434–438

Rediscovering and resampling historic research sites and information to extend the time series of environmental observations in the Arctic

Craig E Tweedie[1] and Terry V. Callaghan[2]

1. Department of Biology and the Environmental Science and Engineering Program, the University of Texas at El Paso, ctweedie@utep.edu.
2. Royal Swedish Academy of Sciences, Stockholm, Sweden; and the Department of Animal and Plant Sciences, University of Sheffield, Western Bank, Sheffield S10 2TN, UK; terry_callaghan@btinternet.com.

An overarching goal of the Sustained Arctic Observing Network (SAON) is to extend time series observations of biophysical properties and processes. Such observations are required for analyses that help tease apart spatiotemporally heterogeneous and interactive drivers of change (Callaghan et al. 2010, Callaghan et al. in press); determine trajectories of environmental change (Johnson et al. 2011); assess species and plant community change (Hedenås et al. 2012, Van Bogaert et al. 2011, 2010, Villarreal et al. 2012); validate models and remotely sensed observations (Lara et al. 2012, Zhenlin et al. 2012a,b); verify the integrity of experimental manipulations (Elmendorf et al. 2012); assess the impact of extreme events relative to long term change (Van Bogaert et al. 2009, Villarreal et al. 2012); allow for inter-comparison of science and TEK/LEK-derived observations (Riseth et al. 2010); and examine the impact of changes in policy and management (NRC 2006). For the majority of the Arctic, such time series observations are lacking (ISAC 2010), spatiotemporal variability of observations is substantial (Callaghan et al. 2011a, Zhenlin et al. 2011), and in many situations a great deal of uncertainty surrounds future system states forecast from models (McGuire et al. 2012). Hence there is a need for SAON to improve and extend time series observations of biophysical and societal properties and processes.

In many instances, knowledge of decadal time scale change is best sought by rescuing historic data or other information, rediscovering and securing sampling locations associated with these data, and resampling (Callaghan et al. 2011b). During the 2007-09 International Polar Year (IPY), a collaboration of international researchers affiliated with the *Back to the future Project* (IPY project #512) rescued historical data and sites and resampled many of these to assess decadal time scale change in a range of environmental phenomenon and processes (Callaghan et al. 2011a). This project was highly productive and many of the BTF studies demonstrate a propensity for the BTF-approach to enhance the development of SAON (*see* Callaghan et al. 2011b). Here, we briefly highlight several poignant characteristics resulting from BTF activities that we believe are essential for further developing and implementing SAON:

1. The BTF approach can be applied to multiple disciplines and different types of data (*see* Fig. 1 from Callaghan et al. 2011b below).
2. BTF activities principally require site and/or data/information rescue. Historic sites in many instances remain intact and suitable for extant SAON activities. When archived, data extend time series observations and complement recent observational time series (e.g. Elmendorf et al. 2012) and model output (Zhenlin et al 2012a).
3. For some studies, new hypotheses of past and future environmental change have been formulated (e.g. Johnson et al. 2011; Lin et al. 2012) and have been shown to be testable with ongoing monitoring (Ebert-May et al. in prep.).
4. Some IPY-BTF studies showed substantial change (e.g. Villarreal et al. 2012) whereas others showed little change (Callaghan et al. 2011b). Thus improved knowledge of the spatiotemporal variability of change was documented by BTF and some patterns of change contrast with other published work, which appears to in be partially biased towards reporting studies that documented change only.

5. Many of the BTF studies to date have been generated from resampling sites initiated by large international collaborative efforts such as the International Biological Program (e.g. Johnson et al. 2011, Lara et al. 2012, Villarreal et al. 2012). With more sites from such programs yet to be rescued and resamped, there is potential to embrace legacies of international collaboration within BTF.
6. Many of the products derived from BTF studies are highly visual and tractable by the general public (e.g. repeat photographs). They are also poignant because they typically demonstrate change within the career/ life time of a single investigator.
7. The majority of IPY-BTF studies were relatively low cost and value-adding – in most cases, extant funding during the IPY supported the acquisition of only half the data – the historic data had already been collected but its value in all cases has been deepened through the resampling effort.
8. IPY-BTF typically required students to work with both middle-aged faculty and senior (sometimes retired) scientists, and thus provided greater than average cross-generational exchange of information and knowledge and life experience. IPY-BTF not only stimulated the career development of young researchers, it has stimulated the revisitation of established and in some cases unreported ideas, and the rekindling of new and old international collaborations and research activities.
9. Finally, there is a great need of urgency for BTF studies. Senior researchers are retiring and ageing and historic data and other information is being lost with them. If we do not act now, much of the original and arguably most valuable historical data collected in the arctic will be lost over the coming decade.

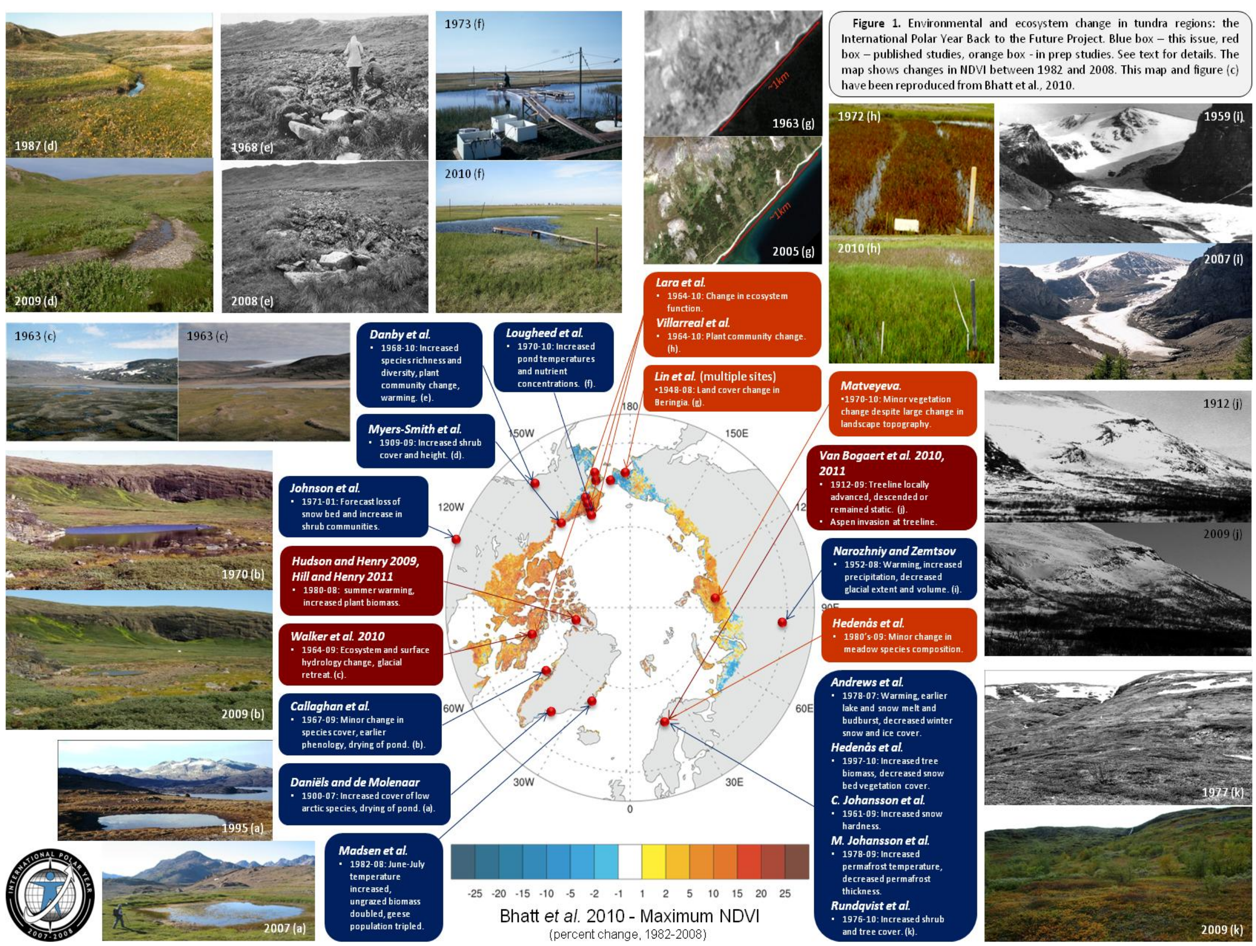


Figure 1. Environmental and ecosystem change in tundra regions: the International Polar Year Back to the Future Project. Blue box – this issue, red box – published studies, orange box - in prep studies. See text for details. The map shows changes in NDVI between 1982 and 2008. This map and figure (c) have been reproduced from Bhatt et al., 2010.

A second phase of BTF-related studies (BTF2) is currently under development and is being coordinated through the EU-funded project INTERACT (www.eu-interact.org). BTF2 will be strongly engaging of the Association of Early Polar Career Scientists (APECS) and focus on coupling junior and senior scientists. Endorsement for this initiative has been received from the Circumarctic Biodiversity Monitoring Program (CBMP) and also the International Arctic Science Committee (IASC). Although BTF2 will largely be focused at arctic and alpine terrestrial field stations (particularly in Russia), broader participation is welcome.

References:

Callaghan, T. V., Jonasson, C., Thierfelder, T., Zhenlin, Y., Hedenås, H., Johansson, M., Molau, U. , Van Bogaert, R., Michelsen, A., Olofsson, J., Gwynn-Jones, D., Bokhorst, S., Phoenix, G., Bjerke, J. W. Tømmervik, H., Christensen, T. R. Hanna, E., Koller, E. K., Sloan, V. L. In Press. Ecosystem change and stability over multiple decades in the Swedish sub-Arctic: complex processes and multiple drivers. Phil. Trans. R. Soc. B.

Callaghan, T.V., Tweedie, C. E., Webber, P. 2011a. Multi-decadal changes in tundra environments and ecosystems: the International Polar Year-Back to the Future Project (IPY-BTF). *Ambio, 40*(6), 555-557.

Callaghan, T.V., & 52 other authors. 2011b. Accepted-a Multi-decadal changes in tundra environments and ecosystems: synthesis of the International Polar Year – Back to the Future Project (IPY-BTF). *Ambio, 40*(6), 705-716.

Callaghan, T. V, Bergholm, F,. Christensen, T. R,. Jonasson, C, . Kokfelt, U. and M. Johansson. 2010. A new climate era in the sub-Arctic: Accelerating climate changes and multiple impacts Geophys. Res. Lett., 37, L14705, doi:10.1029/2009GL042064

Ebert-May, D., Johnson, D., Webber, P.J., Tweedie, C. E. In Preparation. Plant community change over four decades at Niwot Ridge, Colorado. *Journal of Ecology*.

Elmendorf, S. & 57 other authors. 2012. Plot-scale evidence of tundra vegetation change and links to recent summer warming. *Nature Climate Change*. DOI: 10.1038/NCLIMATE1465.

Hedenås, H., Carlsson, B.Å., Emanuelsson, U., Jonasson, C., Svensson, B.M., Headley, A. & Callaghan, T. V. 2012 Changes and homeostasis in alpine and sub-alpine vegetation over three decades in the sub-Arctic' perspective Ambio 41, 187-196.

ISAC. 2010. http://www.arcticchange.org/storage/ISAC%20Science%20Plan%20Final%20Publication.pdf

Johnson, D., Ebert-May, D., Webber, P., Tweedie, C. E. 2011. Forecasting alpine vegetation change using repeat sampling and a novel modeling approach. *Ambio, 40*, 693-704.

Lara, M., Villarreal, S., Johnson, D., Hollister, R., Webber, P., Tweedie, C. E. 2012. Estimated change in tundra ecosystem function near Barrow, Alaska between 1972 and 2010. *Environmental Research Letters, 7*, 10pp.

Lin, D., Johnson, D., Andresen, C., Tweedie, C. E. 2012. High spatial resolution decade-time scale land cover change at multiple locations in the Beringian Arctic (1948–2000s). *Environmental Research Letters, 7*, 14pp.

McGuire, A.D., Christensen, T. R., Hayes, D., Heroult, A., Euskirchen, E., Yi,Y., Kimball, J.S., Koven, C., Lafleur, P., Miller, P.A., Oechel, W., Peylin, P., and Williams,M.: An assessment of the carbon balance of arctic tundra: comparisons among observations, process models, and atmospheric inversions, Biogeosciences Discuss., 9, 4543-4594, doi:10.5194/bgd-9-4543-2012, 2012.

NRC. 2006. *Toward an Integrated Arctic Observing Network*. The National Academy Press, Washington D.C. Pp115.

Riseth, J.Å., Tømmervik, H., Helander-Renvall, E., Pohjola, V., Labba, N.T., Labba, N., Niia, E.A., Kuhmunen, H., Schanche, A., Jonasson, C., Johansson, C., Sarri, L-E., Bjerke, J.W., Malnes, E. and Callaghan, T.V submitted (2010) "Snow and Ice" Sami TEK and Science in concert for understanding climate change effects on reindeer pasturing. Polar Record. 47,202-217.

Van Bogaert, R., Haneca, K., Hoogesteger, J., Jonasson,C., De Dapper, M. and T.V. Callaghan. 2011. A century of tree line changes in sub-Arctic Sweden show local and regional variability and only a minor role of 20th Century climate warming. Journal of Biogeography, 38, 907-921

Van Bogaert R. , Jonasson C., De Dapper M. & T. V. Callaghan. 2010. Range expansion of thermophilic aspen (*Populus tremula* L.) in the Swedish Subarctic. Arctic, Antarctic and Alpine Research 42, 362-375.

Van Bogaert, R., Jonasson, C., De Dapper, M. & T. V. Callaghan. 2009. Competitive interaction between aspen and birch moderated by invertebrate and vertebrate herbivores and climate warming. Plant Ecology and Diversity vol 2 (3), 221 – 232.

Villarreal, S., Hollister, R., Johnson, D., Lara, M., Webber, P., Tweedie, C. E. 2012. High spatial resolution decade-time scale land cover change at multiple locations in the Beringian Arctic (1948–2000s). *Environmental Research Letters, 7*.

Zhenlin, Y., Hanna, E., Callaghan, T. V. & Jonasson, C. 2012a How can meteorological observations and microclimate simulations improve understanding of 1913–2010 climate change around Abisko, Swedish Lapland? Meteorological Applications, 19, 454-463.

Zhenlin, Y., Sykes, M.T., Hanna, E. and Callaghan, T. V. 2012b Linking fine scale sub-Arctic vegetation distribution in complex topography with surface-air-temperature modeled at 50 m resolution. Ambio 41, 292-302.

Zhenlin, Y., Hanna, E. and Callaghan, T.V. (2011). Modelling surface-air-temperature variation over complex terrain around Abisko, Swedish Lapland: uncertainties of measurements and models at different scales. *Geografiska Annaler: Series A, Physical Geography*, 93(2), 89-112. doi:10.1111/j.1468-0459.2011.00005.x

Statement for the 2013 Arctic Observing Summit

The Need for Flagship Arctic Coastal Observatories

Craig Tweedie[1], Ken Dunton[2], and James McClelland[2]
[1]University of Texas at El Paso
[2]University of Texas at Austin Marine Science Institute

Arctic coastal systems are recognized as one of the most threatened ecosystems on Earth (Lantiut et al., 2011) and represent a nexus for examining change at the interface between marine, terrestrial, atmospheric and social systems. For many arctic coastal areas, near shore ice conditions are changing (AMAP, 2012), erosion of coastlines is increasing (Jones et al., 2009), permafrost is warming (AMAP, 2011), and landscapes are slumping (Shiklomanov et al., 2012) and drying (Lin et al., 2012; Villarreal et al., 2012; Lara et al., 2012) or becoming warmer and greener (Bhatt et al., 2010). The urgency for improving our understanding of how these biophysical changes are interrelated, as well as their potential to impact society, industry, biota, and the fate and transport of carbon, water and energy within the Arctic and beyond is well recognized. Several relatively recent studies highlight these close linkages, especially how changes in sea ice extent can impact terrestrial processes (e.g. Bhatt et al., 2010), which can control coastal erosion (e.g. Aguirre, 2011). In addition, recent work in arctic coastal lagoons has demonstrated that nearshore systems are highly productive and resilient, sustaining benthic populations of invertebrates year-round that support complex food webs (Dunton et al., 1982; Dunton et al., 2012). Nearshore regions in the Arctic are critical to a vibrant coastal fishery (von Biela et al., 2012) and also serve as habitat to thousands of waterfowl representing over 157 species that breed and raise their young over the short summer period (Brown, 2006).

A key to improving our understanding of the arctic coastal system is the need to integrate and synthesize spatio-temporally diverse data from observing platforms spanning multiple disciplines that link nearshore and shelf waters. Constraints of funding and logistics prohibit continuous and widespread observing capacities throughout the Arctic. Yet, several reports appropriately highlight the need for a few well conceived and orchestrated '*flagship observatories'* that support a dense and diverse range of observing programs capable of monitoring environmental change and variability at strategic locations on synoptic time scales (NRC, 2006; SEARCH, 2003). Flagship observatories have proven capacities and efficiencies in the Arctic, as exemplified by the synergistic and complementary information provided by the Distributed Biological Observatory (DBO) with broad scale remote sensing and modeling efforts on the Chukchi Sea Shelf (Grebmeier et al., 2010). However, no such efforts have been employed in the western arctic coastal zone, despite the nature and potential implications of observed changes that have taken place over the past decade.

The establishment of a flagship arctic coastal observatory that is linked to a shelf DBO at one or more strategic locations would provide an invaluable resource for understanding and predicting responses of arctic nearshore systems to climate change. We reiterate the need for a few well-conceived coastal flagship observatories in the Arctic that will (i) improve planning and synergistic interchange across disciplines and existing observing programs, (ii) provide information systems that facilitate transdisciplinary data discovery and integration, (iii) enable synthetic and other studies that explore interrelationships between the various components of the arctic coastal system, and (iv) identify observational gaps, degrees of uncertainty, and exchanges between shelf and terrestrial systems. Flagship coastal observatories are likely to include locations that incorporate a variety of considerations including:

- The presence of relatively high biological production and/or diversity.
- The existence of a range of baseline and historical datasets, including existing discipline-based observatories.
- Areas known to be characterized by strong physical events that drive biological production.
- Proximity to native Inupiat and/or Inuit communities and subsistence hunting.
- The potential for partnerships with local, regional, state or federal groups or agencies.
- Regionally high water inflow from rivers.
- Possibilities for international collaboration.
- Proximity to oil and gas development, either current or planned.
- Proximity to wilderness areas and/or industrialized land/sea scapes, or a range of ecosystem types and gradients.
- Capacity for year round activity and infrastructure for serving a wide variety of disciplinary-based needs.
- Promise for synergistic research activities focused on understanding properties and processes not covered by existing observations.
- Long-term occupation of the observatory (e.g. capacity to exist for the next half century).

The development of flagship coastal observatories in the Arctic should encompass a coordinated effort that links physical events with biological responses across temporal and spatial scales. We need to track ecosystem changes with sea ice retreat and changing conditions in adjacent watersheds. Through focused study of selected areas, we will better understand how climate change is affecting the arctic estuarine environment which serves as a refuge for many species, including migratory fish and waterfowl, many of which are critically important to the subsistence lifestyle and culture of arctic indigenous peoples.

References

Aguirre, A. 2011. Patterns and controls of erosion along the Barrow Environmental Observatory coastline, northern Alaska. Master of Science, University of Texas at El Paso. 73 pp.

AMAP, 2011. Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate Change and the 25 Cryosphere, Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. Available at: www.amap.no.

Bhatt U.S., D.A. Walker, M.K. Raynolds, J.C. Comiso, H.E. Epstein, G.S. Jia, R. Gens, J.E. Pinzon, C.J. Tucker, C.E. Tweedie, and P.J. Webber. 2010. Circumpolar arctic tundra vegetation change Is linked to sea ice decline. Earth Interact. 14**:** 1-20

Brown, S.C. 2006. Arctic Wings: Birds of the Arctic National Wildlife Refuge. Mountaineers Books. Manomet Center for Conservation Sciences, Seattle.

Dunton, K.H., E. Reimnitz, and S.V. Schonberg. 1982. An arctic kelp community in the Alaskan Beaufort Sea. Arctic 35(4): 465-484.

Dunton, K.H., S.V. Schonberg, and L.W. Cooper. 2012. The ecology of coastal waters and estuarine lagoons of the eastern Alaskan Beaufort Sea. Estuaries and Coasts 35: 416-435.

Grebmeier, J.M., S. Moore, J.E, Overland, K.E. Frey, and R. Gradinger. 2010. Biological response to recent Pacific Arctic sea ice retreats. EOS 91 (18): 161-162.

Jones, B. M., C.D. Arp, M.T. Jorgenson, K.M. Hinkel, J.A. Schmutz, and P.L. Flint. 2009. Increase in the rate and uniformity of coastline erosion in Arctic Alaska. Geophys. Research Letters 36: L03503, doi: 10.1029/2008GL036205.

Lantuit, H. P.P. Overduin, N. Couture, S. Wetterich, F. Are, D. Atkinson, J. Brown, G. Cherkashov, D. Drozdov, D.L. Forbes, A. Graves-Gaylord, M.N. Grigoriev, H.-W. Hubberten, J. Jordan, T. Jorgenson, R.S. Ødega° rd, S. Ogorodov, W.H. Pollard, V. Rachold, S. Sedenko, S. Solomon, F. Steenhuisen, I. Streletskaya, and A. Vasiliev. 2011. The arctic coastal dynamics database: a new classification scheme and statistics on arctic permafrost coastlines. Estuaries and Coasts 35, 383–400, doi: 10.1007/s12237-010-9362-6.

Lara, M., S. Villarreal, D. Johnson, R. Hollister, P. Webber, and C.E. Tweedie. 2012. Estimated change in tundra ecosystem function near Barrow, Alaska between 1972 and 2010. Environmental Research Letters 7. 10 pp.

Lin, D., D. Johnson, C. Andresen, and E.E. Tweedie. 2012. High spatial resolution decade-time scale land cover change at multiple locations in the Beringian Arctic (1948–2000s). Environmental Research Letters 7. 14 pp.

NRC. 2006. Toward an Integrated Arctic Observing Network. The National Academy Press, Washington D.C. 115 pp.

SEARCH SSC and SEARCH IWG. 2003. SEARCH: Study of Environmental Arctic Change, Implementation Strategy, Revision 1.0. Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, 49 pp.

N. I. Shiklomanov, D.A. Streletskiy, and F.E. Nelson. 2012. GC14A-04. Active layer thickness and thaw subsidence in permafrost terrain: results from long-term observations near Barrow, Alaska. Invited talk, AGU Fall Meeting, San Francisco.

Villarreal, S., R. Hollister, D. Johnson, M. Lara, P. Webber, and C.E. Tweedie. 2012. High spatial resolution decade-time scale land cover change at multiple locations in the Beringian Arctic (1948–2000s). Environmental Research Letters 7.

von Biela, V.R., C.E. Zimmerman, B.R. Cohn, and J.M., Welker. 2011. Terrestrial and marine trophic pathways support young-of-year growth in a nearshore arctic fish. Polar Biology doi: 10.1007/s00300-012-1244-x