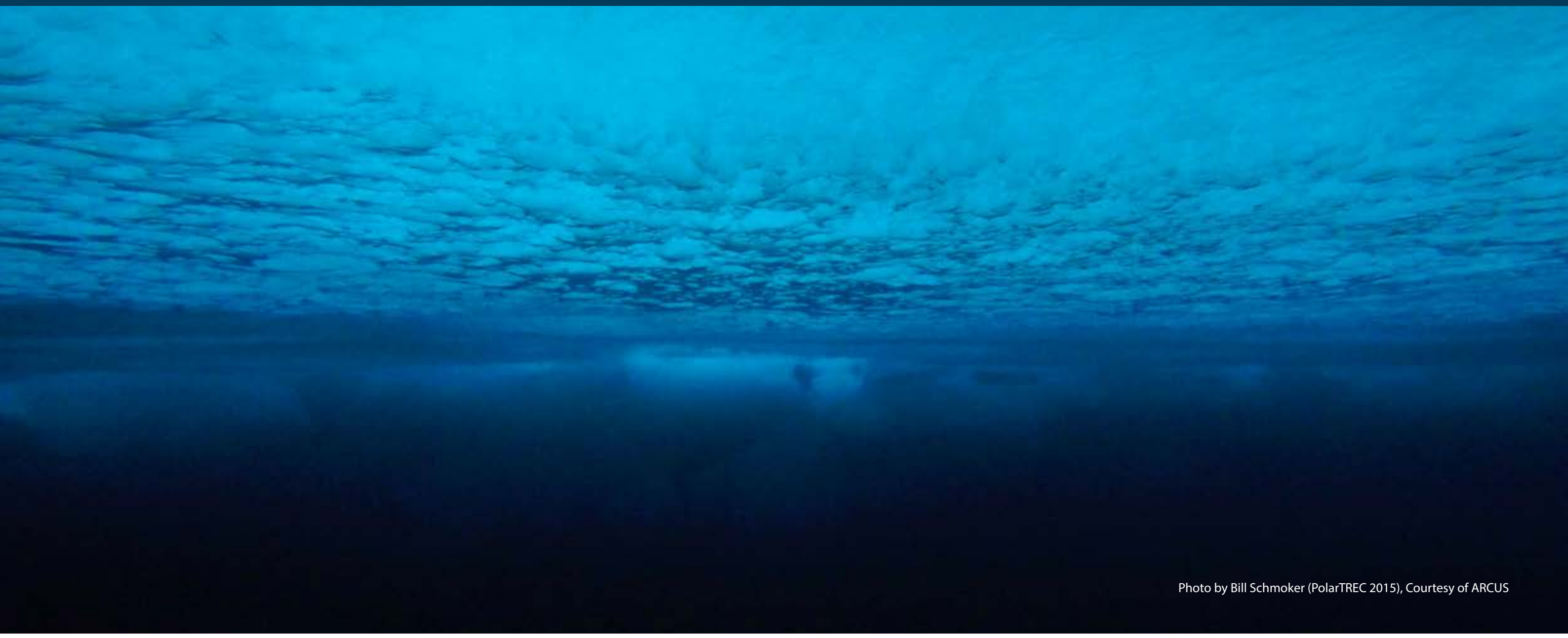
AOOSM

17-19 NOVEMBER 2015 • SEATTLE, WASHINGTON



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INTRODUCTION

Significant investments in Arctic observing during the International Polar Year 2007-2008 and beyond have produced a broad multi-disciplinary dataset of unprecedented spatial and temporal scope spanning land, ice (ice sheets and sea ice), ocean, atmosphere, and human systems. The 2015 Arctic Observing Open Science Meeting, held in Seattle, WA, 17-19 November, provided the research community a forum to discuss the advances supported by these sustained, broad, and contemporaneous observations and to identify areas for improved integration into an Interagency Arctic Observing Network. Specific goals were:

- Present and discuss scientific findings, advances, and achievements in Arctic observing;
- Explore how well observational achievements meet science goals;
- Identify opportunities for collaboration and synthesis;
- Strengthen goals, identity, and activities of an integrated Arctic observing system.

The meeting was structured to include keynote presentations, a panel discussion on achieving an interagency Arctic observing system, disciplinary parallel sessions, and a poster session. The meeting was attended by 206 participants and included 99 parallel session presentations and 42 posters. Travel awards supported participation of seven early career scientists. Post-meeting survey results were overwhelmingly favorable with more than 90% of respondents indicating that meeting goals were achieved (*Table 1*).

The 2015 AOOSM was designed to bring disciplinary groups together after a long period since the last Arctic observing science-focused meeting in 2009, which was more limited to National Science Foundation-funded projects (http://vintage.joss.ucar.edu/events/2009/aon/). The disciplinary focus was an important step, as the initial building blocks for integration of observing science will be within disciplinary groups.

The following brief summary provides highlights from AOOSM parallel sessions and overarching themes from the meeting as a whole. For more detailed information such as the meeting agenda, participants, speakers, presentation abstracts and slides, and other products, please visit the AOOSM website at: https://www.arcus.org/search-program/meetings/2015/aoosm.

Success Measure	% Positive
Meeting goals achieved	94%
Plenary and panel talks	97%
Parallel session talks	96%
Parallel session discussion period	75%
Poster session	91%
Venue and location	99%
Early career connections	91%

Table 1. Results of the AOOSM post-meeting survey completed by 71 respondents. Percent positive indicates all survey responses marked "agree" or "strongly agree".

Keynote Presentations

Seven invited speakers provided keynote presentations covering a broad range of Arctic scientific disciplines. These presentations provided examples of scientific goals that are achievable only through sustained observations collected by a network. Many of these networks share common characteristics that support an engaged, sustainable, and successful effort (*Table 2*).

The keynote presentations are available at: https://www.arcus.org/search-program/meetings/2015/aoosm/agenda.

Photo by Lisa Sheffield Guy, Courtesy of ARCUS

Table 2. Shared characteristics of successful Arctic observing networks among seven case studies presented by keynote speakers during the 2015 Arctic Observing Open Science Meeting.

Network Characteristic	Description
The human component	Linked instruments and measurements are necessary, but the linkages among a broad range of experts, institutions, and stakeholders converging around common objectives are key to network success.
A cohesive question	Network engagement, participation, and progress towards synthesis is facilitated by a clear, unifying question or theme.
Sustained funding	The funding model for observing networks should be flexible and longer-term, with the ability to build on successes and adapt to new opportunities.
Early career scientists	Networks that support and mentor early career scientists benefit from their increased availability and energy, skills in communication and networking, and interdisciplinary focus.
Data accessibility	Network data and products that are accessible are more likely to promote novel usage, collaboration, interdisciplinary studies, and usage by a broader user community.
Scale	Temporally, networks benefit from long-term time series data to detect trends and shifts in systems, to understand what drives them, and to improve models. Spatially, repeat sampling with complementary platforms is key to robust results and understanding trends.

Agency Panel

A panel discussion focused on achieving an interagency Arctic observing system included representatives from seven federal agencies. Brief presentations from each representative addressed three questions, which were followed by public Q&A sessions.

- What are the key Arctic science objectives of your agency?
- What observations does your agency support to help meet your key science objectives?
- How do you envision your agency's role in an interagency Arctic observing network?


Photo by Mary Anne Pella-Donnelly (PolarTREC 2007), Courtesy of ARCUS

The agency representative presentations are available at: https://www.arcus.org/search-program/meetings/2015/aoosm/agenda.

Parallel Session Highlights

Parallel session presentations highlighted achievements of the existing network and discussion periods focused on three guiding questions:

- What scientific or operational advances have been facilitated by the network(s) of Arctic observations?
- How have observing activities contributed to the science needs of mission agencies or stakeholders?
- What opportunities exist to address new science questions, operational challenges, or questions of Arctic communities through enhanced collaboration and a robust interagency observing system?

A summary of highlights from each session is provided below. Full session reports (2-4 pages each) are available at: https://www.arcus.org/search-program/meetings/2015/aoosm/products.

Terrestrial Arctic (two sessions)

Observations of terrestrial Arctic permafrost, hydrology, ecosystems, carbon cycle, and energy balance are undertaken by, and serve, multiple agencies with diverse missions. These data are informing land management decisions, improvements in Earth system models, and infrastructure design. The terrestrial observing community is becoming increasingly coordinated through activities like the Permafrost Carbon Network and the Study of Environmental Arctic Change (SEARCH) Permafrost Action Team, but suffers from significant gaps in long-term in-situ observing. While the community needs to continue to fill these gaps, progress can be made to extrapolate existing observations through increased use of airborne and satellite based observations throughout the pan-Arctic. Increased focus on the dynamic and rapidly changing interactions between the land and rivers and land and coastal regions is especially important as sea level rises, thermokarst processes intensify, and changes in ecosystems and river flows impact human and natural systems.

Arctic Atmosphere (two sessions)

The Arctic atmosphere is linked to many aspects of the changing Arctic system, but the atmosphere community needs to better identify impactful themes to coordinate observing and synthesis activities. The atmosphere observing network community has achieved some major successes in coordination and synthesis of data collection related to trace gases, aerosol optical properties, surface energy fluxes, and operational supersites. The community continues to have critical gaps in specific parameters and specific locations (e.g., over the Arctic Ocean). It is important to assess how representative individual measurements are of the broader Arctic system. The atmosphere network would greatly benefit from strategic expansion by developing and implementing autonomous systems.

Community-based Monitoring

Community-based systems are critical to detection and observation of Arctic change by identifying and developing indicators and understanding the context for change. They are also critical in devising responses and informing adaptation strategies. Facilitating effective interfacing with communities and maximizing the knowledge exchange requires a high trust environment that involves inclusion, capacity building through education and training, communication, and shared problem framing and prioritization. Work is needed to better integrate community-based observing systems and monitoring programs into operational products for society.

Arctic Marine Ecosystems

Advances in Arctic observing have led to new understanding of how changes in sea ice, snow cover, and hydrology impact timing and magnitude of productivity in the Arctic Ocean and on the Arctic's role in ocean acidification. The ability to collect sustained distributed measurements of biological and biogeochemical properties at scales that match those of the physical parameters has been central to these achievements. This ability includes both new technologies in the form of long-endurance autonomous platforms and compact low-power sensors as well as new approaches, including the development of international distributed observing networks (e.g., the Distributed Biological Observatory) and systems that enable broad timely open access to data. Recommendations include improved coordination across observers and the cognizant agencies, sustained observing from a distributed network of profiling biogeochemical sensors, and accelerated communication of findings to match the needs of decision-makers to inform societal response to Arctic change.

The Fate of Sea Ice

The community of sea ice observers and modelers have successfully integrated diverse observing systems supported by different agencies to provide improved understanding and prediction of the interactions between the ocean, sea ice, and atmosphere in the Arctic. The community would benefit from increased coordination among agencies in the planning and deployment of long-term observing systems and short-term campaigns to improve the value of each measurement and the sea ice observing network as a whole. Improving short- and long-term sea ice forecasts will require better models, with fully coupled ice-ocean-atmosphere processes that assimilate advanced observations and generate sea-ice concentration, thickness, and ice-edge location at high temporal and spatial resolution. Continuous or frequently repeated data collection of ice conditions over th annual cycle are needed to initialize and improve forecasts. Satellite data products should be made available in near real-time to support forecasting and verify sensor performance.

Ocean Circulation and Mixing

A network of long-term observing activities has supplied more than a decade of simultaneous measurements around the perimeter, and within the interior, of the Arctic Ocean and across the gateways through which it connects with the subpolar Atlantic and Pacific Oceans. These observations have fueled numerous advances that could not have been achieved without the broad network and long time series. These include new understanding of timescales and pathways of circulation for Atlantic and Pacific inflows, variability in freshwater storage and export from the Arctic, and the role of wind-driven upwelling. However, critical analysis tools, such as robust pan-Arctic mass, heat, and freshwater budgets remain challenging and point to the need to improve coverage in under-sampled regions such as the Russian shelves. Although network data are readily accessible to specialists, improved tools for data discovery and access to quality-controlled refined datasets could encourage broader use by all stakeholders.

Robust Autonomous Arctic Observations

A dramatic increase in autonomous platform deployments has yielded large gains in both temporal and spatial data density as well as improved coverage across the Arctic. These data have been exploited to seek new understanding, such as investigations of seasonality and freshwater storage and release. Autonomous platform development for Arctic observing is the product of shared risk-taking by researchers and agencies. Examples include widespread deployment of distributed networks of buoys (e.g., the International Arctic Buoy Program), clusters of ice-based instruments composed of ice tethered profilers, ice mass balance buoys and Autonomous Ocean Flux buoys, and acoustically navigated Seagliders. International collaboration and rapid data release with open access are fundamental to the technology's success. Challenges include development of small and low-power biological and biogeochemical sensors and sensors capable of sustained (i.e., year-long) untended atmospheric measurements, adaptation of unmanned aerial vehicles, and negotiating broad access for sampling within national Exclusive Economic Zone (EEZ) boundaries.

Human Dimensions of the Arctic

Social systems and knowledge are location-specific and it is difficult to generalize results. These aspects inhibit the development and coordination of Arctic social observing networks. More than with biophysical systems, relationships and trust must be established over long periods to successfully perform research on Arctic social issues. Commitment, respect, communication, engagement, and feedback on results are all key ingredients. Effective social observing, and a successful network of social observing, will require support for longer-term visits to communities as well as sustained support for involvement of observing community members themselves. More work is needed on methodologies underpinning social science observing activities.

Applications of High Latitude Observations and Experiments in Regional to Global Climate Modeling

The global climate modeling community has access to very few temporally and spatially integrated pan-Arctic datasets that can be used to initialize, parameterize, calibrate, and test Arctic system models. The community would benefit from inter-agency planning and support to develop pan-Arctic data to inform models for short-term forecasting and long-term climate impacts and feedbacks prediction. This would include activities that support improved communication between modelers and observers to define critical datasets and develop data synthesis products from diverse observing systems. Another significant challenge for the community is the quantification of uncertainties in data, data reanalysis products, and models. Online user forums to share information on data availability and quality, agency-based data services to improve access to Arctic data, and an integrated Arctic database and/or repository would advance predictive capability of the Arctic system.

Ice Sheets and Glaciers

Arctic glaciers and ice sheets have undergone large changes in the past decades, doubling their contribution to sea level rise. Despite these rapid changes and their potential impacts, sustained measurements of these systems have not yet been undertaken. A network of sustained interdisciplinary observations could fuel progress on critical questions, including "What is the freshwater budget of ice sheets?" and "How does water move from the ice sheet to the open ocean?" A broad network is required because unique aspects of each system make it difficult to compare observations from diverse glaciers collected at different time periods and scales. A network of observations allows for a direct comparison between different processes that occur coincidentally. Improved knowledge of outlet glacier bed geometry and fjord bathymetry is also required to support numerical efforts to model and predict glacier and ice sheet evolution. An observational network is the only way to feasibly connect all the broad interdisciplinary measurements required to understand the processes that govern the evolution of Arctic glaciers and ice sheets and their potential downstream impacts.

Meeting the Needs of Managers and Decision-Makers

The planning and decision making community has seen significant increase in the development of multi-disciplinary, cross-institutional efforts that serve as the interface of observing activities and mission-agency needs. This community can best make use of data when researchers employ practices that increase the discoverability and direct use and interoperability of data and model products. This is best achieved when researchers co-design observations and data products with stakeholders, work across institutional boundaries to understand multi-objective needs, and deliver products within rapid decision-making timeframes. Collaboration teams organized under the Interagency Arctic Research Policy Committee (IARPC) can provide valuable opportunities to maximize the value of data by providing coordination of observing system deployments and joint data analysis. Managers and decision-makers would also benefit from better training and outfitting of local observers to ensure high quality data through robust and straightforward instruments and protocols tailored to perform in harsh Arctic conditions.

Photo by Anne Schoeffler (PolarTREC 2016), Courtesy of ARCUS

Key Highlights & Recommendations

Support Structures
Coordination is important across the spectrum of synthesis efforts (e.g., within or across disciplines, regional or broad scale efforts, or using existing or newly-collected information). Support structures are important for synthesis, but do not need to be intensively managed or staffed. Relatively small flexible support structures utilizing volunteer participation and existing networks can be very effective. The International Arctic Systems for Observing the Atmosphere Working Groups and the Permafrost Carbon Network are examples of how formalized groups have made substantial progress along specific lines of research. Synthesis support structures are important for both synthesizing many individual projects and for conducting assessments of need, network design, and related activities necessitating a community perspective.

Guiding Science Questions
It is important to have guiding science questions for designing networks and synthesizing information. These questions help to provide cohesion and identity to a group, clarify needed synthesis outputs, improve network engagement, and ensure the whole team is pulling in the same direction. For example, many in the land ice community share the guiding question of how melting land ice will affect sea level.

Funding
Funding models capable of supporting critical sustained measurements are needed and benefit from interagency coordination. Sustained observations are very difficult to maintain on a series of three- to five-year funding cycles.

Support for Integration and Synthesis
Observing networks can maximize cost effective progress by increasing support for integration and packaging of existing results. Although making new measurements in the field is exciting, there is also much to be learned from sharing existing information. This can be especially productive across disciplines.

Early Career Scientist Participation
Early career scientists can play an important role for science in a variety of ways:

- They have the capacity and availability to focus longer periods of time and the energy to make necessary connections;
- They often have a more interdisciplinary perspective;
- They benefit from the experience and opportunity to network and learn about past work; and
- Teaming with senior members provides valuable mentorship.

It is important to include early career roles in the design processes for synthesis teams and to support early career scientist participation in meetings and workshops. The Permafrost Carbon Network provides a nice model of pairing senior and early career scientists to facilitate a productive synthesis-focused network.

Raise Awareness of Observing Successes
As a community, we all need to improve awareness of the value of observing networks and the successes they have facilitated. Communication about network successes specifically targeting policy and decision-makers, stakeholders, and the public should use accessible language and be shared in a variety of formats outside the peer-reviewed literature. Identifying cross-cutting (e.g., cross-agency, cross-discipline) network successes is particularly important.

Improve Science-stakeholder Linkages
It is important to facilitate better communication and cooperative research across science-stakeholder boundaries, to clarify stakeholder needs, engage the participation of local communities, and better define observational and synthesis requirements. This can be supported through joint meetings, outreach and training efforts, and community dialog. With increased human activity in the Arctic, decision-makers need data for planning responses to environmental change (e.g., storm surge, coastal erosion and permafrost melt), for responding to disasters (e.g., spills), for infrastructure planning, and for addressing the evolving needs of northern communities. These needs will drive design for some elements of the network.

Importance of Autonomous Platforms
The great challenge and expense to making observations in the Arctic motivates the need to leverage evolving technologies to enhance the network. Autonomous platforms and sensors should be deployed to complement existing network elements to provide a path to extend temporal and spatial coverage in a cost-effective manner. Networks need increased focus on sensor development, especially for critical gaps in observing systems.

Scaling
Scaling issues are common to many domains. Participants discussed the balance between distributed observing and more concentrated efforts at “super-sites” and the need to understand how to upscale from these. It is important to understand what a singular “measurement” represents: Just as a single person in a community likely does not represent the whole community, a single measurement in the physical system does not necessarily represent a spatially integrated view of that parameter.

Photo by Peggy McNeal (PolarTREC 2014), Courtesy of ARCUS

THE FUTURE OF ARCTIC OBSERVING SCIENCE MEETINGS

Post-meeting survey feedback indicated that open Arctic observing meetings would be most useful at two- to three-year intervals to provide a regular platform for dialog without over-taxing travel schedules. In this first AOOSM, the community had the opportunity to become more acquainted with the diverse disciplinary and inter-agency aspects of the Arctic Observing Network. The status of various parts of the network was clarified and the community gained an appreciation of the important building blocks that support network success, enable synthesis, and ultimately support stakeholder needs. The next Arctic observing science meeting should build on this progress by expanding on cross-disciplinary dialog and enhancing stakeholder engagement.

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