Introduction

A series of three workshops was held 17–20 March 2008 in Palisades, New York, to advance implementation and further the development of an integrated Arctic Observation Network (AON) responsive to the critical scientific issues of environmental arctic change. Sponsored by the National Science Foundation (NSF), the workshop series included three interrelated meetings:

1. A 1.5-day NSF AON investigator meeting;
2. A half-day workshop, jointly sponsored by the AON and SEARCH for DAMOCLES (S4D) programs, on optimizing deployment of Lagrangian platforms for observations of the ocean-ice-atmosphere system; and
3. A 1.5-day workshop, jointly sponsored by the NSF AON program, the NSF Arctic System Science (ARCSS) Program, and S4D, to improve observing and modeling activities for understanding recent arctic sea ice change and its impacts throughout the arctic system.

An international group of over 70 participants with diverse disciplinary, geographic, programmatic, and institutional representation met to foster interdisciplinary and international integration of observing efforts. Participants included representation from the U.S and international arctic observational and modeling communities, including project representatives from AON, ARCSS-Synthesis of Arctic System Science (SASS), Study of Environmental Arctic Change (SEARCH), Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES) program, Nansen and Amundsen Basins Observational System (NABOS), Canada's ArcticNet, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the International Study of Arctic Change (ISAC), and U.S. agency representatives.

Background and Motivation

Implementation of an Arctic Observing System is currently underway. Several significant observing efforts are building up to full scale, including NSF AON and DAMOCLES. In addition, groups within the U.S. arctic research community are working to understand arctic system change through SEARCH "Understanding Change" projects, SASS projects, and related efforts.

The extreme arctic sea ice retreat observed in 2007 underscores the immediate need for increased integration and coordination. The sea-ice cover retreated to well below its previous record minimum extent, with potentially substantial physical, biological, and socio-economic impacts on the Arctic. This event raises important questions about our ability to forecast similarly large events on short (i.e., this upcoming year), inter-annual, and decadal timescales, as well as strategies for combining observational efforts with modeling studies directed at improving our understanding of arctic change.

Against this backdrop, the Arctic Observation Integration workshop series was convened to advance planning and implementation of an integrated Arctic Observation System responsive to the critical scientific issues of environmental arctic change.

Specific workshop objectives included:

1. Evaluate the present observing system with respect to its ability to track rapid ongoing change;
2. Produce recommendations for optimization of observing systems and addressing gaps in 2008 and beyond;
3. Improve integration of cross-disciplinary and international observation efforts;
4. Evaluate existing observing technologies, platforms, and on-going development efforts in the context of potentially rapid changes in operating environments (e.g., dramatic decreases in summertime ice extent) and recommend possible adaptations.
5. Produce an integrated overview of the 2007 sea ice minimum, including prospects for continued decline or recovery; and
6. Develop a dialog on integration and long-term sustained arctic observing with relevant agency partners.

Recommendations from each component of the workshop series are summarized below as short-term and long-term activities. These recommendations underscore three central themes that emerged from workshop presentations and discussions: (1) understanding the extraordinary seasonal retreat of sea ice observed in 2007, (2) addressing the challenge of integrating different observation efforts into a system that serves science as well as broader society and key stakeholder groups, and (3) identifying scientific and programmatic gaps and next steps for observing, understanding, and responding to arctic environmental change with emphasis on high-amplitude, unexpected changes.

Summary of Recommendations

Arctic Observation Network (AON) Meeting:

Short-term (12 months)

1. Continue and expand the assessment of AON implementation status and the identification of gaps started during this workshop series. Specifically, this task should include assessment of how well AON addresses the scientific goals in the SEARCH and other AON planning documents (e.g., “Study of Environmental Arctic Change: Plans for Implementation During the International Polar Year and Beyond,” “Toward an Integrated Arctic Observing Network,” and “Arctic Observing Network [AON]: Toward a U.S. Contribution to Pan-Arctic Observing”). This activity should be led by the SEARCH Science Steering Committee (SSC), the SEARCH Observing Change Panel, and the Interagency Program Management Committee (IPMC), and could occur on a time-scale between short- and long-term. The

work should be done in close cooperation with the international arctic observing community, including the SEARCH for DAMOCLES effort.

2. Strengthen coordination of U.S. interagency observing efforts through the SEARCH IPMC and identify SEARCH/AON contacts within all IPMC agencies; this activity could be initiated though a joint SEARCH IPMC/SSC meeting focused on coordination of IPMC agency observing efforts.
3. Coordinate with Canada's ArcticNet program and other relevant international efforts through a Memorandum of Understanding (MOU) or similar coordination process.
4. Develop or assimilate tools to communicate and share information about different observing activities with respect to placement of instruments and planning of field campaigns.
5. Contribute to a collaboratory framework to advance scientific integration and exchange (cf. proposed 2008 Sea Ice Outlook effort, discussed in report Appendix B).
6. Explore how model output (e.g., the Intergovernmental Panel on Climate Change Fourth Assessment Report [IPCC AR-4]) can be examined in the same method as data provided through CADIS.
7. Pursue data coordination efforts amongst relevant national and international programs; this could be accomplished through CADIS and the SEARCH Data Management Working Group.
8. Implement an advisory group for CADIS that can serve as a community liaison (articulating the needs of both AON PIs and broader community); this advisory group could be created with the help of the SEARCH governance structure.
9. Identify and implement a process by which stakeholder priorities can be used to guide coordination efforts and demonstrate the utility and value of AON in a broader societal context (e.g., utilizing a tool such as a "Human Activities/Stakeholder Information Needs Matrix," Appendix A); provide structured guidance on how to acknowledge collaborators from local communities.
10. Convene the next AON meeting or follow-up workshop, focused on identifying cross-disciplinary scientific gaps and exchange within disciplinary working groups.

Long-term (2–5 years)

1. Develop a strategic plan for longer-term AON data management and coordination activities, including a funding mechanism to ensure balance and continuity.
2. Augment human dimensions and stakeholder-relevant (e.g., marine mammals) components of AON and strengthen interagency linkages to relevant ongoing observation efforts (e.g., through marine mammal commissions).
3. Coordinate with the International Study of Arctic Change (ISAC) to improve international exchange of information relevant for joint planning and coordination of observation programs.

4. Develop a process for balancing scientific and stakeholder information needs that identify measures of success for AON.

Autonomous and Lagrangian Platforms Workshop:
Short-term (12 months)

1. Sustain the present efforts using existing instrumentation to return detailed arctic atmosphere, ice, and ocean observations from arrays of autonomous instruments beyond the IPY period.
2. Refine and implement an "amphibious" International Arctic Buoy Program (IABP) buoy.
3. Work for improved access to eastern Arctic for IABP and others.
4. Harden Ice-Based Observatory (IBO) instrument designs to improve survivability during sea ice transition states.
5. Continue development of floats and gliders for work in ice-covered environments.
6. Produce white paper detailing a pilot (2–3 element) low-frequency acoustic navigation array.

Long-term (2–5 years)

1. Implement pilot navigation array and use it to support float and glider operations for the Arctic Observing Network, including a science program that exploits the array.
2. Expand plans to provide basin-wide navigation based on the pilot design.
3. Define and transition to operational status an arctic-wide atmosphere-ice-ocean observing system that includes IBOs, floats, gliders, and the infrastructure (acoustic navigation) needed to support such operations.

Lessons from the 2007 Arctic Sea-ice Minimum Workshop:
Short-term (12 months)

1. Develop and implement a process that tracks, summarizes, and integrates ongoing developments and provides a consensus outlook for May–September 2008 sea-ice extent and characteristics. Toward this goal, develop an organizational structure and process for collecting information, moderating, and issuing information on a monthly basis (See Appendix B, 2008 Arctic Sea Ice Outlook).
2. Summarize retrospectively the results of the 2008 Arctic Sea Ice Outlook. Who got it right and why?
3. Plan and hold follow-up workshops in fall 2008 after the upcoming field season and September 2008 ice minimum.
4. Develop and submit multi-authored synthesis papers targeted to high-impact journals—papers that integrate the impacts on the summer 2007 sea-ice retreat and linkages to multiple components of the arctic system and place the summer 2007 ice retreat in perspective given the eventual outcome of the summer 2008 ice retreat.

5. Develop a synthesis paper on existing ecosystem data, including paleo-records and more recent analogs that are useful for ecosystem reconstruction (beyond sediment cores and temperature reconstructions).
6. Synthesize existing ecological and human-dimensions information.
7. Identify other data sets needed to improve our understanding of potential changes within ecosystems and human systems (e.g., subsistence, tourism, resource extraction, fisheries, etc.) through a follow-up workshop.
8. Identify specific information gaps that are pertinent to science, policy, and human implications through a follow-up workshop (as above).
9. Undertake modeling efforts in order to explore possible scenarios given the state of our knowledge today, e.g., make preliminary projections for how arctic marine and terrestrial ecosystems might function in the immediate and distant future in order to inform management and policy. Build on ongoing modeling efforts through SEARCH and DAMOCLES (e.g., similar to modeling workshop held October 2007; workshop report at http://www.arcus.org/search/internationalsearch/meetings-and-activities.php).
10. Convene follow-up meetings to develop integration and modeling activities.

Long-term (2–5 years)

1. Continue observations (AON and other) and integrated analyses of the key parameters for documenting and understanding the sea-ice cover over the next several annual cycles.
2. Collect observations that are needed to assist in refining and validating scenarios.
3. Undertake data collection and research on the marine and terrestrial components for which there are major gaps in observations and understanding of change (e.g., including marine-terrestrial linkages) through research mechanisms such as a specific Announcement of Opportunity.
4. Undertake research activities using modeling together with other analytical methods to improve understanding and predictability on seasonal to interannual time scales.
5. Develop modeling efforts to explore possible scenarios for how the sea ice may retreat further on long time scales, and the consequent implications.
6. Look outside the Arctic for data relevant to understanding human implications.
7. Identify components of the arctic system that are more vulnerable to rapid change and the barriers to resilience and adaptation; this will involve research partnerships with local communities.