1st IPY workshop on Sustaining Arctic Observing Networks
WORKSHOP REPORT

Report from workshop held in Stockholm 12-14 November 2007

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Sponsors

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INNEHÅLL

A SAON TRIBUTE FROM STOCKHOLM!

The Fourth International Polar Year (IPY) is the largest ever scientific effort in the Polar regions. Building a legacy to future generations of Arctic residents and to the entire world by securing good and sustainable observation systems and working social, health, and cultural indicators is a prime concern for IPY and for the Swedish national IPY committee.

As co-chairs of the Workshop Organizing Committee for SAON I in Stockholm we have been proud to contribute towards that important legacy by providing a venue and a platform for this first workshop in a series of three. All along, we have shared the enthusiasm and expectation in the scientific, in the governmental as well as in local communities!

The needs for improved Arctic observation systems have been identified by the scientific community as well as by the Arctic Council, representing the eight Arctic states and a wide range of indigenous peoples. The Sustaining Arctic Observation Networks Initiating Group (SAON IG), has brought together a large number of international agencies and organizations with the aim of further defining these needs and propose solutions for implementation of coordinated monitoring systems.

The Stockholm workshop was aimed to take a first step towards reaching our goal. We are honoured and grateful that so many dedicated participants were there to help make the workshop a success. We thank in particular the speakers, chairs and rapporteurs, who worked responsibly both before, during and after the workshop to present the reports here assembled.

This summary document brings together the main break out group reports, prefaced by an Executive summary, and a short summary of the main findings.

We present this report as further evidence of Sweden's continued commitment to the cause and ambitions of SAON and as our relay to the Edmonton and Helsinki workshops.

Sverker Sörlin
Chairman of the Swedish IPY committee and Co-Chair of the Workshop Organising Committee

Kjell Danell
Member of the IPY Joint Committee and Co-Chair of the Workshop Organising Committee

EXECUTIVE SUMMARY

The Stockholm workshop fulfilled its mission. It identified gaps in existing observing systems and presented constructive, realistic and urgent proposals on how these should be maintained and expanded. The scientific needs were the ones that were addressed in the most detailed fashion. The implementation of observing systems over the long term and the relationship between the perceived needs and the operational capabilities were not addressed which must be a high priority in the coming workshops. The role of national agencies is of utmost importance in this process and their presence at the SAON II workshop in Edmonton is of the essence. It must be asked from the agencies that they become active partners in the SAON process in order to make recommendations feasible.

It was a clear outcome of the Stockholm workshop that there must be a functioning coordination of observing activities and systems in order to achieve economic efficiency, transparency and accessibility of results. The eight Arctic countries and other countries with Arctic interests will work jointly on science and implementation issues. Governmental acknowledgement is probably needed in the further process to give it full legitimacy. There was a clear vision that cooperation between regional constellations of actors should be acknowledged in order to make several parts work towards the overall success of the whole.

These points can be derived from the workshop as especially salient and to be kept in mind for workshops SAON II and SAON III and to be considered in the early drafting of the final report to the Arctic Council:

- The workshop acknowledged and solidly confirmed the needs for SAON as a useful and timely initiative.
- The workshop identified user needs and gave an excellent coverage of these needs as seen from, especially, the scientific community and to some extent local communities, peoples, and Arctic residents. The needs as perceived by national and operational agencies of data collecting, observation, and accessibility were less well covered and should be a primary focus in SAON II.
- There was widespread acknowledgement that SAON needs to go from words to deeds in a clear and distinct way and that, as such it will provide a very important legacy of IPY. There was also a solid recognition of the need to build on existing agencies, organizations, and other bodies and operational structures to make SAON a working reality.
- The workshop discussed that this would likely require some kind of body or instrument that makes sure that planning and operational work is coordinated in order to use resources efficiently and secure and maintain accessibility of data. This body could be organized in different ways and should complement existing agencies and organizations and facilitate their cooperation under a common SAON framework.

Context

Behind the SAON initiative is 11 international organisations and is intended as a cooperation between the Arctic Council, the science community and local/indigenous observations.

The SAON Initiating Group (SAON-IG) has suggested a series of three workshops to develop a set of recommendations on how to achieve long-term Arctic-wide observing activities that provide free, open and timely access to high quality data that will realise pan-Arctic and global value-added services and provide societal benefits.

The SAON IG promotes coordination, collaboration and communication among all parties to develop the recommendations and achieve a lasting legacy of the International Polar Year. SAON IG has the task of reporting back to the Arctic Council by the end of 2008.

Further information about the SAON process, including its background, initiating process, and objectives is found in the SAON IG document available on the web site: http://www.arcticobserving.org

This web site will be kept through all workshops and is the place where you will find presentations and detailed reports from break-out sessions.

The Swedish National Committee for the International Polar Year 2007-2009 kindly agreed to serve as local host and generously provided a secretariat and staffed a Local Organizing Committee, LOC. SAON IG and the Swedish IPY committee agreed on the members of the Workshop Organizing Committee, WOC (see http://www.arcticobserving.org for the full lists of names).

The Stockholm workshop

The Stockholm workshop consisted of three parts:

1: Presentations on user needs as seen from a science, or a governmental or a local perspective.

These presentations are best studied by visiting the web site and click on 'Material presented'

2: Examples of observing networks and sites, and keynote talks

These presentations are also well covered on the web site, and you are encouraged to visit the web site for details.

3: Break-out sessions

The break-out sessions were organized in the following areas:

- Atmosphere
- Ocean/sea-ice
- Hydrology/cryosphere
- Terrestrial ecosystems
- Human dimensions

The main charge to the break-out sessions were to discuss the following questions:

- What Arctic observing sites, systems and networks currently exist?
- What spatial, temporal and disciplinary gaps exist?
- Are current observing activities sufficient to meet users' needs?

As mentioned in the SAON-IG document there are 5 such key questions. However, participants were encouraged to start with the first two mentioned above.

Most groups run short of time, so they were given an opportunity to improve their initial drafts before publishing them on the web site. For the full texts you are referred to the web site.

Summaries from the break-out sessions

Reports from the break-out groups are available on the web site and studying the full texts is recommended. Some highlights of these are:

1: Atmosphere

The 10 participants from the 1st SAON workshop's Atmosphere Breakout Group discussed the existing atmospheric observational capacity in the Arctic and its shortcomings. The various stakeholders, operational weather forecasters, the research community, and local peoples and residents, require more atmospheric observations both regionally and temporally. The types of these observations vary from conventional weather observations and radio sondes to state-of-the-art remote sensing instruments.

Before the 2nd workshop in Canada, the group will assess the existing observatory activities, identify observational gaps, and discuss the cooperation, method harmonization, data access and quality control issues.

Potential 'building block' candidate:

- IASOA: International Arctic Systems for Observing the Atmosphere, see web site at: http://www.iasoa.org.

2: Ocean/Sea-Ice

This break-out group analyzed ongoing processes that identifies existing Arctic observing sites, systems and networks; as well as spatial, temporal and disciplinary gaps. Please see the full report for details. Further, they discussed user needs and how such needs could be integrated.

This report also includes some recommendations important for further development. The following quotes are representative of the main thrust of the report:

"Sustained: Linkages & partnerships needs to be developed that integrate successful operational programs (e.g. IABP), emerging and past industry programs, environmental and resource management programs; charge for 2nd SAON Workshop to involve agencies that oversee industrial activities: continued satellite coverage is key and requires high degree of international coordination, collaboration and data exchange at level of space agencies and beyond (2nd SAON Workshop needs to involve space agency representatives); satellites key in specific design of adaptive systems".

"In addition to bottom-up integration at the science level .....international top-down integration at the level of operational and funding agencies, and other relevant bodies is needed. This is an important role for SAON and participation of representatives from these different groups, including from countries such as Russia not well represented at the first workshop is crucial. A relatively simple and robust SAON based on presently available technology should be implemented immediately as part of stepwise ramp-up to a multi-component, interdisciplinary Arctic observing system.

An international body will required to coordinate the various national programs (eliminate overlap, ensure that data holes are filled) and ensure intercompatibility, open access and widespread distribution of data"

Potential building block candidate: iAOOS (international Arctic Ocean Observing System)

3: Hydrology/Cryosphere

The key questions for the workshop have already been addressed and quite comprehensively been answered in the following recently published report:

IGOS, 2007, The Integrated Global Observing Strategy Cryosphere Theme Report – For the Monitoring of our Environment from Space and from Earth. Geneva: World Meteorological Organization. WMO/TD-No. 1405. 100 pp.

(Available online: http://igos-cryosphere.org).

The full report gives an outline of this report, and some other reports related to the SAON initiative.

Further, user needs were analyzed suggesting cost-benefit analyses to be undertaken which is likely to very positive for hydrological/cryospheric observations.

Before the 2nd SAON Workshop, they agreed to:

- Finalize the assessment of currently existing Arctic observation capacity (CliC Project Office),
- A few experts to review the IGOS report and adding missing information to achieve a pan-arctic perspective
- As the IGOS report does not include hydrology as such, hence this topic needs a separate chapter

Candidates for building blocks: IGOS and Arctic-HYDRA .

4: Terrestrial and Freshwater Ecosystems

This group analysed user needs quite extensively and how to meet these needs; types of data and data products.

They compiled a good overview of networks, policy groups and co-ordination bodies.

You are referred to the full report for details.

Their conclusions were:

- No list of monitoring variables is definitive because needs change. However, certain core variables and baseline information need to be obtained and sustained
- Gaps in information can be determined by using environmental envelopes and geography. Interface between tundra, dry lands and forest are a focus from the former, Canada and parts of Siberia a focus of the latter. Current IPY projects fill many gaps but their legacy is uncertain
- Current flagship observatories and key sites need to be sustained with ensured funding for their networks and collaboration with other monitoring networks and arctic residents
- The concept of flagship observatories could be proposed as a joint international responsibility and cooperation, also in financing. More firm agreements to assure long term funds for the coordination of flagship observatories and key sites are needed, for example through the Arctic Council

Candidates for building blocks: SCANNET and CEON

5: Human Dimension

Their discussion was conducted along the priority indicators identified by the Arctic Human Development Report, and refined in the follow-up: Arctic Social Indicators (IPY and Arctic Council). This project (expected to be completed within a year) will identify priority areas for observing and documenting human and social conditions in the Arctic.

Their breakout session started out with three guiding questions:

- Opportunities for better coordination in order to make use of synergies and to avoid overlaps,

- Open and timely access to data, and

- How do we make the observation system sustainable?

In answering these questions, they identified 3 priority areas:

A: Access to statistical agency data on a pan-Arctic scale

B: Implementation of local observation network

C: Synthesis and access of special study data.

For each priority area, they discussed: Rationale, Challenges, Priorities and Actions.

You are referred to the full report for details. However, the suggested actions for each area were:

A: - Speak to agencies in each country to involve in next workshop.

- Next workshop: Russian expertise on data should be available.

B: - Involve experts in local observation systems and network development in Edmonton workshop.

C: - Make meta-data available from IPY projects.

- IASSA assisted by IASC to set up a list server.

Their recommendations for the SAON process:

- Continuity of participation is important
- Further develop priorities as task groups in Edmonton
- Local Observation Networks
- Statistical agency data
- Data sharing

Full workshop documentation published on the web

The intention with this summary was to serve as an appetizer to reading the full reports, and the full additional documentation of the Stockholm workshop, so if you read this summary on the web, please go to: http://www.arcticobserving.org and click on the Stockholm workshop. There you will find all documentation that is available, including materials not printed in this Summary report.

This web site will be maintained for the coming workshops, so make it one of your favourites.

REPORT FROM THE ATMOSPHERE BREAKOUT GROUP

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) reports and news accounts of global warming impacts, especially in the Arctic, have captured the attention of the general public, raising the alarm for many. The fourth International Polar Year (IPY) has entrained scientists from many disciplines and countries. Through IPY programs, a large amount of resources (time, money, and talent) are being expended to establish or enhance observatories, field programs and numerical modeling studies with the aim of understanding how the polar regions are changing, and how much of those changes are in response to global warming. This large influx of resources into the polar regions naturally leads to questions such as How can we sustain the momentum created by the IPY? What about future observations? What should they be? Who will design them? Who will pay for them? Who will use them? How will scientists access the data?

The Sustaining Arctic Observing Networks Initiating Group (SAON IG) formed SAON to address these and other questions through a series of three workshops. Taking a multi-disciplinary approach, the SAON IG invited scientists who study the Arctic's atmosphere, ocean, sea ice, hydrology, cryosphere, terrestrial ecosystems, and human dimensions to meet in Stockholm in November of 2007 to begin the task of assessing current and future long-term measurements of the Arctic. Here, we report on the Atmosphere breakout group deliberations of this first SAON meeting. We were asked to consider the following:

- Are current Arctic observing and data and information management activities sufficient to meet users' needs?
- What Arctic observing sites, systems, and networks (activities) currently exist?
- What spatial, temporal and disciplinary gaps exist?
- Initiate a process to identify which Arctic observing sites, systems and networks currently exist.
- Initiate a process to identify spatial, temporal and disciplinary gaps.
- Identify opportunities for new observing networks to integrate into existing networks.
- Discuss opportunities for better coordination in order to make use of synergies and to avoid overlaps.
- Comment on the potential for long-term funding by better meeting user needs.

In the following pages, we introduce our group members and report on our discussions of the above questions and issues. We end our report with ideas on future work, a summary, and for those not familiar with some of the technical terms of our report, a glossary of terms.

2. Atmosphere Breakout Group Members

a. Members

Lisa Darby, Chair, National Oceanic and Atmospheric Administration
Jussi Paatero, Rapporteur, Finnish Meteorological Institute
David Bromwich, Ohio State University
Georg Hansen, Norwegian Institute for Air Research
Mark Ivey, Sandia National Laboratory
Erland Källén, Stockholm University
Rick McGregor, Swedish Institute of Space Physics
Ignatius Rigor, University of Washington
Michael Tjernström, Stockholm University
Johannes Verlinde, Pennsylvania State University

Our group had a variety of members withwide-ranging areas of expertise and interests including tropospheric Doppler lidar measurements, middle- and upper-atmospheric measurements, buoy measurements, numerical modeling, radiation measurements, and detection of heavy metals.

b. Group Philosophy

We elected to take the "broad-brush" approach and did not address all of the questions in detail. There will be time for more detail later.

We strongly agreed that we did not want to "reinvent the wheel" when it comes to assessing what measurements are already in place, and their gaps.

We felt that addressing the questions and issues in the context of a science question would be a useful approach.

3. Results of our deliberations

Are current Arctic observing and data and information management activities sufficient to meet users' needs?

The answer to this question is user-dependent. There are many types of users, such as weather forecasters, researchers, and local inhabitants. Current measurements may be adequate for some, but for climate research, they are inadequate.

These are the most critical points our group agreed upon while discussing this question:

- Enhance circumpolar, sophisticated, core sites
  - Ensure intensive sites are long-term and well-maintained
  - Ensure current intensive sites have uniform measurements across the network
  - Add one more intensive site in Russia, preferably an inland site with flat terrain
  - Data from intensive sites should be easily available to researchers by providing one convenient access-point for consolidated data from each site
- Use radiosonde stations, buoy stations and surface meteorological stations to spatially supplement intensive sites; can we access industry data for supplementation?
- Address spatial gaps in the Arctic Ocean and Russia by
  - Integrating and validating satellite data
  - Deploying Unmanned Airborne Systems (UAS) dropsondes
  - Launching radiosondes in the central Arctic from ice breakers and ice camps
  - Enlisting FedEx planes to launch dropsondes
- Identify when newer, short-term measurements should be converted to long-term measurements

What Arctic observing sites, systems, and networks (activities) currently exist?

In the short time we had, we focused our discussions on sites that are sophisticated, well-maintained, manned year round, and have received significant amounts of funding from govern-

Figure 1 Map and pictures of IASOA stations

mental agencies. An example of a network of such sites is the International Arctic Systems for Observing the Atmosphere (IASOA) network (Fig. 1). IASOA is IPY Activity #196. We also considered Buoy and Surface Air Temperature networks, which fill in the gaps among the intensive, land-based observatories.

Previous reports have addressed Arctic measurements and gaps. Key points from the SEARCH implementation plan "Study of Environmental Arctic Change: Plans for Implementation During the International Polar Year and Beyond," available at http://www.arcus.org/SEARCH/resources/reportsandscienceplans.php include:

- Maintenance and enhancement of standardized, calibrated, uninterrupted, and long-term monitoring networks
- Increased atmospheric measurements over Arctic Ocean from ships, ice camps, and buoys
- Strategically located, long-term, land-based atmospheric observatories with sophisticated, co-located instruments to make intensive measurements at the surface and through the depth of the atmosphere
- Regularly scheduled unmanned aerial vehicle (UAV) and aircraft campaigns that can collect data on horizontal variability, transition between regions, and over the Arctic Ocean
- Coordinated surface-satellite activities such as archiving of intensive satellite measurements over the observatory sites; balloon launches and UAV mission timed with satellite overpasses; and on-going comparisons between surface and satellite-derived atmospheric quantities, in particular, those likely to have direct effects on atmospheric radiation budgets
- International coordination on standards for measuring practices, technologies, and data archiving
- A mechanism whereby research and developmental observational technologies and practices can be transitioned to long-term operational programs

A comprehensive collection of information on Arctic observations, networks and gaps can be found in Chapter 3 of the Arctic Observing Network (AON) report "Toward an Integrated Arctic Observing Network" which can be found at http://www.nap.edu/catalog/11607.html. This report lists numerous existing observational programs, with links to their web sites.

Atmospheric measurement networks listed in the AON report:

- Arctic Monitoring and Assessment Program (AMAP)
  - Persistent organic pollutants (POPs), heavy metals, radioactivity, Arctic haze, petroleum hydrocarbon pollution, climate change and environmental consequences, stratospheric ozone depletion, effects of pollution on humans living in the Arctic
- Baseline Surface Radiation Network (BSRN)
  - Radiation, Synoptic Meteorology, Upper air measurements
- Danish Meteorological Institute (DMI)
  - Denmark, Faroe Islands, Greenland – standard meteorology, global radiation and sunshine
- European Evaluation and Monitoring Programme EMEP
  - Acidifying and eutrophying compounds, surface ozone, POPs, heavy metals, particulate matter, VOCs
- Global Climate Observing System (GCOS)
  - Atmospheric measurements (surface and upper air)
- Global Atmosphere Watch (GAW)
  - Chemical parameters of the atmosphere
- International Arctic Buoy Program (IABP)
  - Drifting buoy network measuring meteorological and oceanographic data
- National Data Buoy Center (NDBC)
  - Standard meteorological parameters
- Norwegian Atmospheric Terrestrial and Freshwater Monitoring
  - Precipitation and surface ozone
- National Weather Service (NWS) radiosonde network
- Tropospheric winds and state variables

Atmospheric measurement networks not listed in the AON report:

- Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) – a national user facility for the scientific community (located in Barrow and Atquasuk)
- Canadian Network for the Detection of Atmospheric Change (CANDAC)

Our group will identify other applicable reports and sources for current measurement and network information.

Several IASOA stations are already members of the Global Atmosphere Watch (GAW) and/or Baseline Surface Radiation Network (BSRN) networks. It would be practical to have the other existing stations join these networks.

Middle and Upper Atmosphere Observations

A number of observatories also monitor the middle and upper atmosphere, and the ionosphere. These include, for example, ALOMAR in Norway (http://alomar.rocketrange.no/), Kiruna/Esrange in Sweden (http://www.ssc.se/), and Sodankylä Geophysical Observatory in Finland (http://www.sgo.fi/).

"Heliosphere Impact on Geospace" is an IPY core project which runs an extensive network of ground-based instrumentation for observing the different coupling processes between the Sun, Earth's magnetosphere and upper atmosphere in polar regions. Included are networks of optical stations, magnetometers, pulsation magnetometers, riometers, imaging riometers, radio tomographic imaging, GPS-receivers and scintillation monitors (http://www.ipy-id63.org/) and the

International Network for Auroral Optical Studies for the Polar Ionosphere (http://www.irf.se/auropt)].

Another IPY activity for the middle and upper atmosphere is Stratospheric Processes and their Role in Climate (SPARC)-IPY (http://www.atmosp.physics.utoronto.ca/SPARC-IPY/).

What spatial, temporal and disciplinary gaps exist?

On the broad scale, the group readily agreed that the Arctic Ocean and Russia have the greatest gaps in intensive, year-round atmospheric observations. Great strides are currently being made in Tiksi, Russia, with the development of a new meteorological station and clean air facility. These developments are a collaboration between these agencies: Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), and the Finnish Meteorological Institute. Additionally, a new tower measuring methane, carbon dioxide (CO_2), and CO_2 fluxes will be installed in Cherskii, Russia in spring 2008 with joint support from the University of Alaska and NOAA. These two stations, however, are not adequate enough for intensive monitoring of Russian Arctic conditions. It was proposed that an inland station be considered for northern Russia between Tiksi and the Ural Mountains. An effort will be made to further investigate what Arctic atmospheric measurements are available in Russia. The SAON atmosphere breakout group did not have a Russian representative.

Even though satellite observations can cover large areas, their accuracy is not yet good enough to replace surface-based observations.

There is also a large gap in measurements of the vertical structure of the atmosphere over the Arctic, particularly over the Arctic Ocean.

Additional priority observational strategies

- It is essential to maintain and expand the current land-based radiosonde network to be utilized by both operational meteorologists and climate researchers. Central Greenland, for example, lacks radiosonde observations.
- Enhance the buoy network, particularly on the Russian side of the Arctic Ocean
- Initiate routine radiosonde launches from ice breakers and ice camps in the Central Arctic Ocean even if their primary mission is not atmospheric research. This would, at least partly, fill in the observational gap concerning the vertical structure of the atmosphere in the area.
- Support Unmanned Aircraft Systems (UAS) dropsondes, as well as developing other instrumentation for UAS deployment
- Enhance wind profile observations with, e.g., Mesosphere-Stratosphere-Troposphere (MST) Radars and lidars.
- Reanalysis projects – with an emphasis on polar regions
- Perform Observing System Simulation Experiments (OSSE) for network design, to test the value of potential observations

Priority Activities

- Boundary layer studies
- Assess radiation balance
- Develop cloud climatologies through satellites, radar/lidar pairs
- Organize a follow-on experiment to the Surface Heat Budget of the Arctic Ocean (SHE-

BA) experiment to validate measurements that will be used for long-term records, e.g., satellite measurements

The SAON Atmospheric Group's work before the second SAON Workshop in Canada

The group members, together with their colleagues in the different circumpolar countries, will continue to assess and investigate the currently existing Arctic observation capacity. This will be done by using previously published reports, information available on the internet and personal contacts between researchers in different countries and institutes. We will use the information compiled by the IASOA program to assess intensive atmospheric observatories and establish what measurement gaps need to be filled in this network (See Appendix 1.) Special attention has to be paid to Russia because in Western Europe and North America it is often difficult to obtain information about observational activities taking place in Russia.

Next, we will initiate a process of identifying opportunities for new observing networks that can be integrated into existing networks. We will discuss opportunities for better coordination in order to make use of synergies and to avoid overlaps. We need to recommend ways to make the flow of data from the Arctic observatories to the user community as simple as possible. One obvious solution would be an observatory portal on the internet. Another issue is the quality control and harmonization of the measured data.

A political issue is the transfer of scientific instruments and samples across national borders, which can currently be very complicated. The cooperation between the different observatories and their data users should be enhanced. For example, the European Union has funding measures for researcher mobility and access to research infrastructures, e.g. ARCFAC V in Ny-Ålesund, Svalbard. All new observations, of course, will require additional funding both from national and international sources.

4. Summary

The 10 participants from the 1st SAON workshop's Atmosphere Breakout Group discussed the existing atmospheric observational capacity in the Arctic and its shortcomings. The various stakeholders, operational weather forecasters, the research community, and the local people, require more atmospheric observations both regionally and temporally. The types of these observations vary from conventional surface weather observations and radiosondes to state-of-the-art remote sensing instruments.

Before the 2nd SAON workshop in Canada, the group will assess the existing observatory activities, identify observational gaps, and discuss the cooperation, method harmonization, data access and quality control issues.

5. Other usefull information

Definitions of meteorological terms can be found at the web-site of the American Meteorological Society Glossary of Meteorology, http://amsglossary.allenpress.com/glossary.

Observatories-at-a-Glance table – developed for the IASOA web site - www.iasoa.org

REPORT FROM THE OCEAN/SEA-ICE BREAKOUT GROUP

H. Eicken, K. Shimada, Moderators; S. Lee, Rapporteur

1. Process to identify existing Arctic observing sites, systems and networks

As part of the International Polar Year (IPY) and other (inter)national efforts a range of projects is underway that are of relevance. The group was asked to identify a *process* that would lead to an inventory of activities. Listed below are the key projects and ongoing activities that are currently involved in such inventory activities and that would have to be tapped into for a comprehensive picture. Particularly noteworthy are the European DAMOCLES and the US SEARCH efforts that comprise a significant subset of ocean-sea ice activities and are currently compiling a more comprehensive catalog of associated projects and data gaps. Furthermore, Dr. R. R. Dickson is preparing a comprehensive survey of existing observations sites and programs for the Arctic Ocean Sciences Board (AOSB) in the context of an evolving integrated Arctic Ocean Observing System (iAOOS). This document (see also Dickson, 2006, Oceanologia, 44(1), 5ff.) will serve as another useful resource and the next workshop may be a good venue to discuss coordination with iAOOS and related efforts.

- AOSB/iAOOS (B. Dickson): Report on status of long-term *physical oceanography* observing programs > available Spring 2008
- CliC Marine Ice Working Group (Perovich, Gerland, Eicken): Compile information on *sea-ice* observation programs (remote sensing, buoys, transects & point measurements, coastal ice obs'ns, w/ input from ArcticNet/ Fortier and others) > available Summer/Fall 2008
- Broad overview of *biogeochemical oceanographic* observing programs (e.g., moorings w/ biogeochem. sensors, principal benefit of transects, etc.) and reference to potential *contaminant* observations to be provided by Fortier & Stow > Spring 2008
- Russian data sets: AARI (www.aari.nw.ru); Sevmorgeo (www.sevmorgeo.com); follow-up needed during spring 2008 workshop
- Fisheries data: Nordic Seas - ICES; Pacific - PICES; Arctic - Census of Marine Life; follow-up needed during spring 2008 workshop
- SEARCH/DAMOCLES (S4D): Update of overall implementation status from S4D integration workshop and exchange > Spring 2008
- Marine mammals: Potential contacts include (co-)management commissions (Walrus Commission, Polar Bear Commission), meeting participants (Gill), national agencies such as NOAA-NMFS and others
- Ocean/ice chemistry observing programs: tracers (www.geotraces.org), AMAP for contaminants and food safety (www.amap.no)

2. Process to identify spatial, temporal and disciplinary gaps

Here the same approach and key programs identified under (1) above are of relevance. A general approach to identify such gaps would need to take into consideration the following:

A. Different categories of gaps: (i) Environmentally constrained (e.g., thick ice North of Greenland/Canada); (ii) geopolitically constrained (e.g., parts of Siberian shelves); (iii) instrumentally constrained (e.g., satellite-based ice thickness measurements) with subcategory adaptation gaps (e.g., Lagrangian platforms not suited for seasonally ice-free ocean); (iv) logistically constrained (e.g., lack of icebreaker platform for specific year and location), (v) methodologically constrained (e.g., lack/ lag of observing system design tools)

B. Process that identifies different types of gaps in different categories needs to take into consideration that gap depends on measurement objective, with three basic categories: (i) "state of the Arctic", (ii) adaptation & mitigation of change, (iii) user-specified (applied) objectives

C. Hierarchical approach to gap identification: (i) disciplinary/user-group level (e.g., sea ice observations within CliC Sea Ice Working Group; need to identify corresponding group in oceanography community); (ii) regional level (e.g., from regional ocean observing systems such as AOOS; international groups such as Pacific Arctic Group); (iii) broader program level such as SEARCH/DAMOCLES; (iv) overarching entity to assess programmatic and regional gaps - potential role of ISAC as a caucus of national programs w/ periodic review of status of observing system?

D. Specific proposed action in context of SAON process:

- Disciplinary gaps: Will be identified as part of SEARCH/DAMOCLES Integration process (workshop in spring 2008) and CliC Arctic Sea Ice Working Group (workshop Fall 2008)
- Regional gaps can furthermore by identified through regional ocean observing programs (as integrated in iAOOS); information needed from Canada, Russia, Japan, China, Korea, e.g., through Pacific Arctic Group; however, it is important to create an international forum that facilitates free exchange of data (modeled on IABP or weather stations) and identifies critical regional gaps that are then filled by the respective countries

3. Are current Arctic observing programs sufficient to meet users' needs?

The processes identified above will also help to assess whether current and planned programs are sufficient to meet users' needs. The marine working group felt that looking towards the end of IPY, we are in a much improved position because we have an emerging observing system in place that allows us to document in near real-time water-mass inflow into the Arctic and follow change of water masses, fronts and climate modes in the Arctic Ocean. To a lesser extent and for a more limited area at the local and regional level this is also true for biological and biogeochemical observing programs. For the sea-ice cover, the nascent observation network allows for tracking and attribution of change as well as assessments of impacts critical for adaptation and response. Building on these promising developments, an observing system that meets users needs' should have the following attributes:

(i) Adaptive: Responsive to evolving user needs; employing models, remote sensing, Eulerian and Lagrangian observations; adaptive to changing environmental conditions (e.g., amphibian drifting sensors with loss of perennial ice)

(ii) Regionally optimizing: Sampling theory studies identify high-priority areas; user needs and existing programs (industry!) govern design and integration of sub-systems; tools for regional integration (information system); hot spots identified by biological-biogeochemical subgroup include: Bering to Beaufort Sea transect, Baffin Bay, Barents Sea

(iii) Integrated: through modeling; drifting/fixed sensors & surveys for integration of atmosphere-ocean-ice interaction

(iv) Sustained: Linkages & partnerships needs to be developed that integrate successful operational programs (e.g., IABP), emerging and past industry programs, environmental and resource management programs; charge for 2nd SAON Workshop to involve agencies that oversee industrial activities; continued satellite coverage is key and requires high degree of international coordination, collaboration and data exchange at level of space agencies and beyond (2nd SAON Workshop needs to involve space agency representatives); satellites key in specific design of adaptive systems

4. Additional recommendations for subsequent SAON Workshops

In addition to bottom-up integration at the science level, which is well underway and will increase as the International Study of Arctic Change (ISAC) gets underway, international top-down integration at the level of operational and funding agencies, and other relevant bodies is needed. This is an important role for SAON and participation of representatives from these different groups, including from countries such as Russia not well represented at the first workshop is crucial. A relatively simple and robust SAON based on presently available technology should be implemented immediately as part of a stepwise ramp-up to a multi-component, interdisciplinary Arctic observing system. An international body will be required to coordinate the various national programs (eliminate overlap, ensure that data holes are filled) and ensure intercompatibility, open access and widespread distribution of data.

Since SAON observations at a given site may consist of a distributed set of subsystems developed by multiple PIs (potentially from different countries), the logistics infrastructure for getting to the deployment sites is one of the most important shared assets of the observing system. A long-term, internationally coordinated logistics plan should be implemented as an essential complement to scientific and technical plans for SAON.

Long-term programs that have been successful in the past (e.g., International Arctic Buoy Program) and are well integrated need to be identified and can serve as models for an evolving sustained Arctic Observing Network. From the ocean and ice perspective, coordination with representative of emerging iAOOS efforts will be important for the 2nd SAON workshop.

In our break-out discussions some concern was expressed in regards to connecting with other large-scale observing systems and programs outside of the Arctic to better tie into the global environmental research community. This may also be a point of interest for the next two workshops, e.g., by inviting representatives from relevant, successful programs.

REPORT FROM THE HYDROLOGY/ CRYOSPHERE BREAKOUT GROUP

1. Introduction

The Sustaining Arctic Observing Networks Initiating Group (SAON IG) formed SAON to address issues of sustaining critical observational networks that currently exist and those introduced during the International Polar Year (IPY), assessing observational needs for the future, and who will be responsible for them. These issues will be address through a series of three workshops. Taking a multi-disciplinary approach, the SAON IG invited scientists who study the Arctic's atmosphere, ocean, sea ice, hydrology, cryosphere, terrestrial ecosystems, and human dimensions to meet in Stockholm in November 2007 to begin the discussions. Here we report on the Hydrology / Cryosphere breakout group deliberations during the Stockholm workshop.

2. Breakout Group Members

The Hydrology / Cryosphere Breakout group consisted of 20 participants covering a wide-range of expertise, including hydrology of cold regions, permafrost and frozen ground, glaciology, periglacial processes, lake and river ice. This group represented also a nice combination of academics, experts from government agencies, and representatives from research foundations. The participants were:

Terry Prowse, chair, University of Victoria and Environment, Canada
Jeffrey Key, chair, NOAA, USA
Angélique Prick, rapporteur, CliC (Climate and Cryosphere), Project Office, Norway
Oleg Anasimov, State Hydrological Institute, St. Petersburg, Russia
Achim A. Beylich, Geological Survey of Norway
Maria Bohn, Stockholm University, Sweden
Arvid Bring, Stockholm University, Sweden
Hanne H. Christiansen, The University Centre in Svalbard, Norway
Anders Clarhäll, Swedish Research Council, Sweden
Marcus Flarup, SMHI, Norrköpping, Sweden
Laura Furgione, National Weather Service, Anchorage, USA
Barry Goodison, Science and Technology Branch, Environment Canada
Peter Jansson, Stockholm University, Sweden
Martin Jeffries, National Science Foundation, USA
Peter Murdoch, US Geological Survey
Pier Overduin, Alfred Wegener Institute, Potsdam, Germany
Mark Parsons, World Data Center for Glaciology, Boulder, CO, USA
Arni Snorasson, National Energy Authority, Iceland
Charles Vorosmarty, University of New Hampshire, USA
Katey Walter, USA

3. Results of Our Deliberations

The breakout groups were asked to consider the following questions and tasks:

- What Arctic observing sites, systems, and networks (activities) currently exist?
- What spatial, temporal and disciplinary gaps exist?
- Are current Arctic observing and data and information management activities sufficient to meet users' needs?
- Initiate a process to identify which Arctic observing sites, systems and networks currently exist.
- Initiate a process to identify spatial, temporal and disciplinary gaps.
- Identify opportunities for new observing networks to integrate into existing networks.
- Discuss opportunities for better coordination in order to make use of synergies and to avoid overlaps.
- Comment on the potential for long-term funding by better meeting user needs.

These questions are addressed individually or collectively below.

What Arctic observing sites, systems, and networks (activities) currently exist? Initiate a process to identify which Arctic observing sites, systems and networks currently exist. What spatial, temporal and disciplinary gaps exist? Initiate a process to identify spatial, temporal and disciplinary gaps.

Our group discussed these two questions at the same time, because these questions have already been addressed and quite comprehensively answered by recently published reports, in particular:

IGOS, 2007, The Integrated Global Observing Strategy Cryosphere Theme Report –

For the Monitoring of our Environment from Space and from Earth. Geneva: World Meteorological Organization. WMO/TD-No. 1405. 100 pp. (Available online: http://igos-cryosphere.org).

This report summarizes the work of the IGOS Cryosphere Theme team to devise CryOS – the Cryosphere Observing System. It provides a concise presentation of the requirements for cryospheric observations, data and products, and recommendations on their development and maintenance. The report does not propose to establish a new, dedicated and stand-alone observing system for the cryosphere. Instead, it proposes measures to develop and coordinate cryospheric components of the World Meteorological Organization's (WMO) Integrated Global Observing System, the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS), and other systems, so that the set of cryospheric products to be developed meets most identified user requirements within approximately 10-15 years. In addition, it proposes arrangements to ensure that existing cryospheric data and products are known, available, and openly accessible to users in a timely and interoperable way. It highlights the need for the identification and coordination of resources to continuously improve observations as requirements and technology evolve, and reiterates the required commitment of observing system operators to sustain and augment existing cryospheric components of the observing systems.

The report is structured around cryospheric elements: terrestrial snow, sea ice, land and river ice, ice sheets, glaciers and ice caps, surface temperature and albedo, permafrost and seasonally frozen ground, and solid precipitation. Current capabilities and requirements for observing essential climate variables are listed. Recommendations are given for the near, mid-, and long-term. It is expected that much of the implementation will occur through, or in connection with, the WMO Global Cryosphere Watch program, a proposal for which was recently approved by the 15th WMO Congress.

Two other reports are relevant for assessing the existing Arctic observation capacity:

U.S. National Research Council's "Toward an Integrated Arctic Observing Network" (2006) (available online: http://www.nap.edu/catalog/11607.html)

ICARP II (2nd International Conference on Arctic Research Planning, November 2005, Copenhagen): Science Plan 7 "Terrestrial Cryospheric & Hydrologic Processes and Systems".

The Arctic Observing Network (AON) report provides a comprehensive collection of information on Arctic networks, observatories, examples of cryospheric data capture, and accessibility within networks and platforms. The report lists existing coordinating bodies and observational programs, with links to their web pages. Networks and programs for cryospheric parameters in the AON report include:

- Arctic Circumpolar Coastal Observatory Network (ACCO-Net): 20 sites including deltas and estuaries of major Siberian and North American rivers; multidisciplinary studies including atmospheric and oceanographic forcing, permafrost parameters, coastal terrestrial and marine morphology, river fluxes.
- Global Land Ice Measurements from Space (GLIMS): Ice margins and surface feature velocities.
- International Network of Permafrost Observatories (GTOS / GTN-P): Active layer, permafrost monitoring.
- International Arctic Science Committee (IASC) Working Group on Arctic Glaciology (WAG); includes the MAGICS project (Mass balance of Arctic Glaciers and Ice sheets in relation to Climate and Sea level changes): Glacier mass balance.
- International Permafrost Association (IPA)

/Circumpolar Active Layer Monitoring (CALM): Active layer, and permafrost temperature.
- World Glacier Monitoring Service (WGMS): Glacier mass balance, extent, and perennial surface ice distribution.

Our group acknowledged the usefulness of the AON report, but also its weaknesses in the field of geophysical data. The ICARP II document is a science plan, not an overview of observational networks. It is therefore short on data for our purposes. Nevertheless, its analysis of the state of knowledge and its recommendations are highly valuable. Given the current state of knowledge and large unstudied parts of the Arctic, the Science Plan 7 group recommended a three-pronged approach:

- filling of existing knowledge gaps through process research in well-studied regions;
- initiation of new research programs in regions that are currently unrepresented by previous field programs; and
- extrapolation of understanding gained through process studies and modeling analyses throughout the pan-arctic basin. To enable such extrapolation, it is essential toconduct verification and validation studies in carefully selected sites in under-studied regions.

The ICARP II report states that although a rich body of observational data does exist, a major impediment to integrated cryospheric and hydrologic studies over large areas of the Arctic is the sparse and discontinuous nature of monitoring stations and data records in time and space. It describes how ICARP will generate the requisite additional data needed to address the major science questions. Important to the success of ICARP is the collection of complementary data (i.e., observations collected according to some standard that enables greater ease in sharing and detecting differences) and the promotion of archiving data in relevant data centers (outlined by variable) for access by all.

The group discussion stressed the fact that ongoing IPY activities may now be creating new observing sites and/or networks, and that this outcome should be taken into account in further SAON discussions.

Further work for our group will consist of complementing the IGOS Cryosphere chapters that are relevant for our task within SAON with information from the two other reports and IPY activities. The participants agreed that these tasks had to be accomplished before the group could identify opportunities for new observing networks to integrate into existing networks.

Are current Arctic observing and data and information management activities sufficient to meet users' needs? Comment on the potential for long-term funding by better meeting user needs.

The answer to this question depends on the users: there are many types of users for hydrological and cryospheric data. In these particular fields, SAON may provide an opportunity to get data users and data providers working more closely. Our group chose to leave the list of users open, as new users may join in the future.

Group members commented on the potential for long-term funding through better meeting user needs. The means by which user needs could be better met are:

- Data rescue and coordination (Many participants underlined the fact that a large amount of data is stored by individuals in the academic sphere, and not make available to the rest of the world.)
- Data center support (This is an expensive undertaking.)
- Improvement of the accuracy and robustness of measurements.

Methodological approaches to obtaining long-term funding for observational networks should include a multi-country peer-pressure effect. This effect can be obtained by multi-country agreements (much more difficult to withdraw from) and commitments to sustain portals and provide data integration access.

Politics are more and more concerned with mitigation/adaptation to global change; they have to be considered as the first users of the report SAON will produce. We, as scientists, must prove the value of observational data for future mitigation and adaptation. The scientific community can improve the articulation of hydrologic / cryospheric observing system value. Cost-benefit analyses could be presented to the national authorities, reflecting the cost of sustaining observational networks vs. the cost of not doing it and facing the consequences, particularly in the context of a changing climate. Hydrology and cryosphere are topics particularly well-suited for such an approach, as they involve many societal impacts and/or benefits such as water supply, sea level rise, coastal erosion, transportation, and building. The GEO (Group on Earth Observations) Work Plan (http://earthobservations.org) has listed societal benefit areas. This table summarizes the importance of the cryosphere for society in each of the GEO SBAs, according to that study:

Disasters	★★
Health	★★
Energy	★★★
Climate	★★★★
Water	★★★★
Weather	★★★
Ecosystems	★★★
Agriculture	★★
Biodiversity	★

Group members agreed that this approach has a significant chance of success. No individual or program could be identified that would have the expertise and resources to carry out such cost-benefit analyses. This question should be discussed further at the coming SAON workshops.

Identify opportunities for new observing networks to integrate into existing networks. Discuss opportunities for better coordination in order to make use of synergies and to avoid overlaps.

We address these questions/issues by once again referring to the IGOS Cryosphere and ICARP II reports. In fact, the primary goals of those reports are to identify observing networks, assess current observational capabilities and gaps (measurement and disciplinary), and evaluate opportunities for better coordination.

4. Planned Work Before the Second SAON Workshop

The Hydrology / Cryosphere group agreed that finalizing the assessment of the currently existing Arctic observation capacity, on the basis of the IGOS Cryosphere Theme Report, should be delegated as a task to a small number of people. We also agreed that this task fell under a CliC Theme activity (*The Terrestrial Cryosphere and Hydrometeorology of Cold Regions*) and could therefore be realized by the CliC Project Office before the 2nd SAON workshop. Barry Goodison (chair of the CliC Scientific Steering Group) and Angélique Prick (CliC Deputy Director), both members of this breakout group, agreed on this.

One characteristic of the IGOS Cryosphere Theme Report is that the content of each chapter is strongly influenced by its authors. This bias should be corrected in order to achieve a pan-arctic perspective. Therefore, it was proposed that a few experts (two per chapter), whose origin and affiliation are different from the original authors, read through the first draft established by the CliC Project Office, in order to eventually add in missing information.

The IGOS Cryosphere Theme Report does not include hydrology as such; this topic will have to be developed in a separate chapter, using personal contacts between researchers in different countries and institutes in order to identify previously published reports or other useful sources of information.

REPORT FROM THE BREAK-OUT GROUP ON TERRESTRIAL & FRESHWATER ECOSYSTEMS

Chair: Kjell Danell
Rapporteurs: Magnus Tannerfeldt and Margareta Johansson
Consultant: Terry Callaghan

1. Introduction

This first workshop in Stockholm explored if current arctic observing activities, data and information management are sufficient to meet users' needs. The aim of the outbreak groups were to focus on two of the five key questions that are set as the overall goals of the three workshops to be held within the SAON concept. The two questions that we focussed on during our discussions were:

- What Arctic observing sites, systems and networks (activities) currently exist?
- What spatial, temporal and disciplinary gaps exist?

In addition we discussed ways to coordinate and integrate existing efforts and data availability. Many of the ideas, tables and text that are presented here are based on the presentation by Prof Terry Callaghan.

1.1 User groups

The user groups represented were the research community, governmental bodies and local communities/Indigenous People.

1.2 Principles of user needs and how can we meet those needs?

Building on a provocative list of principles of user needs that was presented by Terry Callaghan, we identified challenges for data providers to meet these needs (table below). His main conclusion was that no list of observations is definitive as needs change over time, thus any planning of an observation programme must be flexible and the important aspect is one of capacity building. Because needs change over time it is also difficult to prioritise between existing observations and new ones.

User needs	Challenges for data providers	Strategies for future implementation
We want everything	How do we provide everything?	See section 4
We want it by yesterday – and quality controlled	What is required to get timely data and ensure quality control?	To be discussed at SAON workshop 2 and 3
We want everything for free	What are the costs for providing data? What are the constraints? What mechanisms exist for providing data to the community? What are the incentives for giving data?	To be discussed at SAON workshop 2 and 3
We want long-term security of data supply and infrastructure	How can we secure existing observations and networks?	To be discussed at SAON workshop 2 and 3
We often want to collect data ourselves, rather than relying on that collected by others	How can we standardise data collection using same instrumentation?	To be discussed at SAON workshop 2 and 3
We often want data products rather than raw data (e.g. RS data, modelling)	How can we provide data products and assure compatibility between monitoring, remote sensing, modelling and research?	To be discussed at SAON workshop 2 and 3
We want to change our minds as our needs change – no list is definitive	How do we make a flexible monitoring system? How do we protect long time series while protecting the flexibility for making goal orientated monitoring?	To be discussed at SAON workshop 2 and 3

Some of the challenges for data providers are approached in this text. For example we provide lists of existing and proposed observations which can be used to identify disciplinary gaps. We also provide the concept of environmental envelops to show how these can be used to locate observing platforms. However, other challenges for data providers (table above) such as how to make data accessible and providing incentives to data owners are topics for the following two SAON workshops.

1.3 Types of metadata, data and data products required on drivers of ecosystem change as well as on biota

Three types of data were identified as necessary to detect drivers of ecosystem change:

- Essential baseline info (e.g. geological and vegetation maps)
- Core monitoring activities (e.g. climate)
- **Goal orientated monitoring and current environmental problems and past topical issues (e.g. UV-B radiation - ozone depletion)**

2. What Arctic observing sites, systems and networks (activities) currently exist?

As the main theme of the workshop was to explore users' needs, we discussed what the users' needs were and what Arctic observing sites, systems and networks (activities) currently exist to meet those needs.

A list of existing observing networks was compiled (Appendix 1). The list of indicators developed by AON was revisited and updated (Appendix 2). In addition we present a list of relevant IPY projects, compiled by Craig Tweedie (Appendix 3). Governmental representatives brought forward an example of a list of environmental indicators identified as important (see www.miljomal.nu). Local users/Indigenous people were underrepresented during the subgroup meeting, but an example of an existing report on local users/indigenous peoples' perspectives on key indicators from a few sites around the Arctic was presented (Bayfield et al., 2004). These lists show the considerable activity either underway or planned during IPY. Three challenges remain 1) to ensure the sustainability of existing network 2) to ensure that their data is accessible 3) to identify gaps in current observations.

3. What spatial, temporal and disciplinary gaps exist?

It was discussed that there is a scaling issue when monitoring data. Different data need to be monitored with different spatial and temporal resolution. The disciplinary gaps can be identified from compiling the information in the appendices. Identifying gaps in spatial and temporal dimensions can be identified in other ways, for example by nesting observing platforms within environmental envelops (see section 4.2).

3.1 Different spatial resolution

- Pan Arctic: e.g. NDVI/productivity. Almost all information is required at this scale. Methodology focuses on remote sensing products
- Regional: e.g. Phenology, hydrology and active layer. Changes in active layer depth, hydrology and vegetation are critical determinants of ecosystem structure, function and feedbacks to climate: there is currently great uncertainty of trends
- Local: e.g. Snow depth and animal population dynamics, Food
- Plot level: e.g. Control plots on ITEX and other long-term experiments
- Multi spatial: Carbon dynamics in a patchy landscape – an IPY project

3.2 Different temporal resolution

- High frequency: e.g. trace gas measurements
- Daily: e.g. Phenology, animal behaviour
- Seasonally: e.g. Net primary production, animal population parameters such as births and deaths
- Decadal: e.g. vegetation change such as treeline dynamics
- Thresholds: e.g. Winter temperatures for autumn moth egg survival
- Cyclicity: e.g. Lemming and small vole cycles
- Extreme events: e.g. Freezing rain and mid winter thaw, pest outbreaks, forest/tundra fire

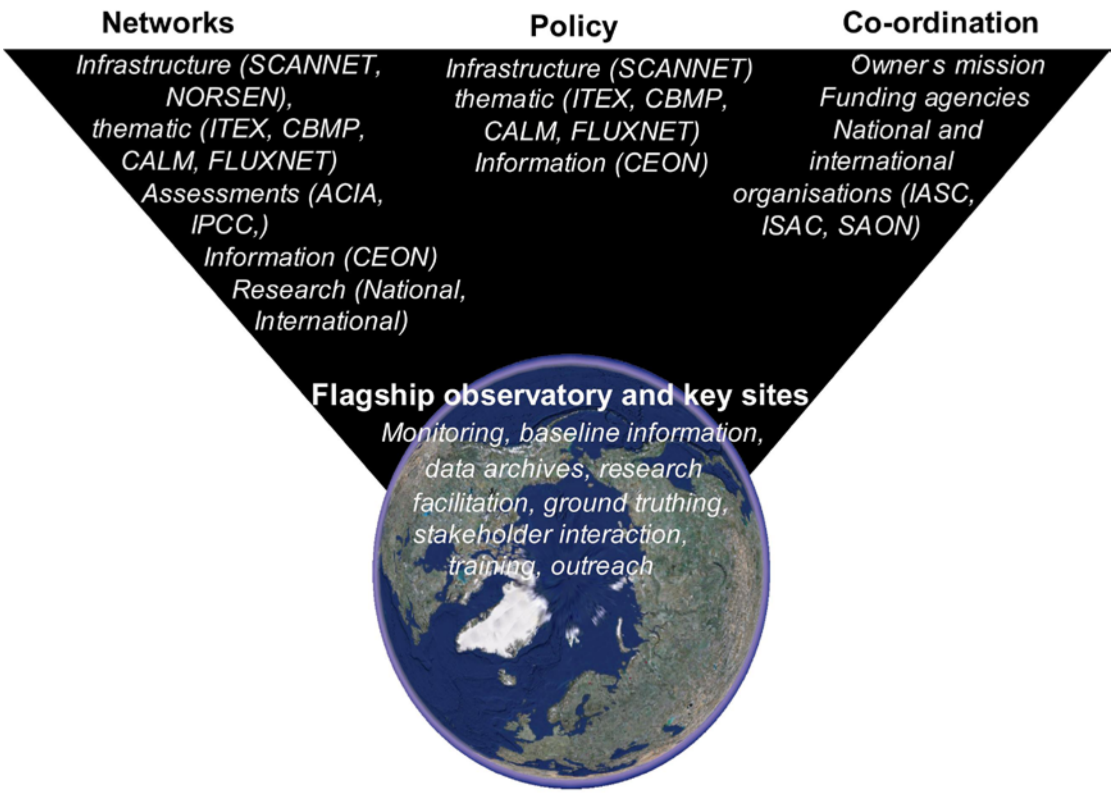
4. Ways forward toward a sustainable observing system

4.1 Flagship observatories and key sites – an unstable (?) pillar of monitoring and research

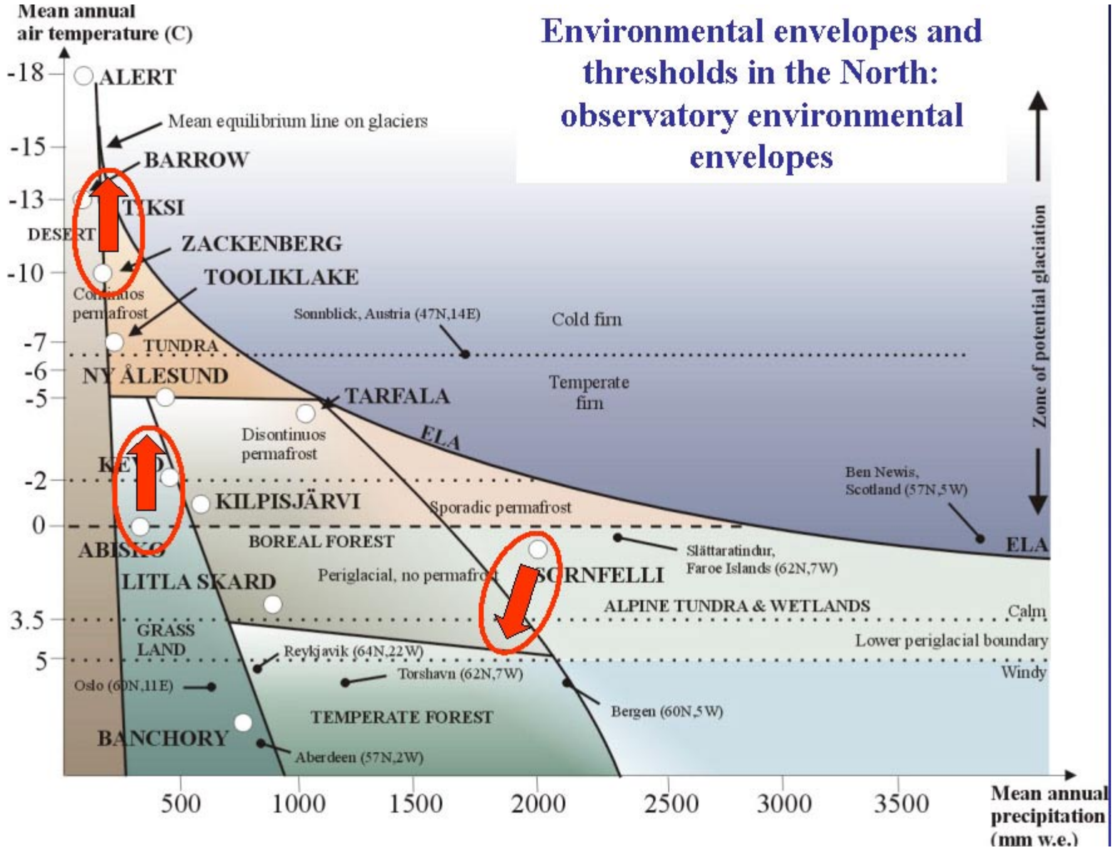
The ongoing monitoring in the Arctic that feeds data to networks, policy and co-ordination (Figure below) is mainly carried out at so-called flagship observatories (Shaver et al., 2005) and at other key sites around the Arctic. Many of these do not have secure long-term funding for their monitoring. Previous discussions on sustainable observing systems suggested a focus on the flagship observatories to secure sustained monitoring in the Arctic (e.g. Shaver et al., 2005). By focusing only on flagship observatories there is a risk that sites that cannot be identified as flagships observatories but that are important key sites can be excluded. A key recommendation from this subgroup is therefore that both current flagship observatories and key sites are sustained and that funding is ensured for their networks and collaboration with other monitoring networks and arctic residents. In addition, there is currently no unifying concept or identity to the many observations, networks and inventories that are operating independently of infrastructures, but these types of monitoring should be sustained.

4.2 Climate envelopes

A plot of monitoring sites within an environmental envelope shows that the sites, and particularly larger observatories, occupy environmental space with three dimensions: current temperature and precipitation, current variability of temperature and precipitation in the local landscapes surrounding the observatories and trajectories of future climate at each observatory. These three dimensions can be used to locate future observatories to ensure that no gaps exist within current and future environmental envelope. So far, these envelopes are adequately sampled. However, the observato-



The ongoing monitoring in the Arctic that feeds data to networks, policy and co-ordination is mainly carried out at so-called flagship observatories and at key sites around the Arctic. Many of these do not have secure long-term funding for their monitoring and hence make the system unstable (Callaghan, presentation).



An example of a climate envelope showing current variability of temperature and precipitation in the local landscapes surrounding the observatories (Callaghan presentation).

ries are clustered in terms of geography and large geographical areas in Canada and Russia exist with few observatories.

5. Data access

Brief discussions on how to make data easily accessible were held. Ideally all data should be freely available but this is more often an exception than the rule. A good example of a data policy is from the Zackenberg Station, northeast Greenland. When making data available it is important to build on existing meta- databases and data centres. One way to make meta-data and data easily available is via GIS approaches, two examples are found at www.armap.org and www.ceoninfo.org. A problem associated with data access is that funds are usually allocated for collecting data but not for processing and posting the data. In order to assure that data are made freely available it is important to allocate funds also for processing and posting of data.

6. Discussions on Food and Carbon raised by Dave Carlson

6.1 Food

In order to predict future food resources available we propose to apply downscaled climate and ecosystem models, to provide local residents with tools to understand ongoing changes in their local area in order to be able to develop adaptation and mitigation strategies. In addition we suggest focusing on human usage of resources, to focus on ecological bottlenecks, key factors for the species and migrations and transfer of marine/terrestrial fresh water fish.

6.2 Carbon

There are currently gaps in our knowledge on carbon storage and carbon fluxes in the Arctic. One important issue is the fate of permafrost and wetland areas - will they become wetter or dryer in the future and how will that affect the carbon balance? To reduce the gaps in our knowledge we suggest inventories of carbon stocks in soils/vegetation/permafrost and carbon flux measurements at different sites in the Arctic focussing especially on winter processes, extreme events (e.g. forest fire) and the balance between the carbon and albedo feedbacks.

7. Conclusions

- No list of monitoring variables is definitive because needs change. However, certain core variables and baseline information need to be obtained and sustained
- Gaps in information can be determined by using environmental envelopes and geography. Interfaces between tundra, dry lands and forest are a focus from the former, Canada and parts of Siberia a focus of the latter. Current IPY projects fill many of the gaps but their legacy is uncertain
- Current flagship observatories and key sites need to be sustained with ensured funding for their networks and collaboration with other monitoring networks and arctic residents.
- The concept of flagship observatories could be proposed as a joint international responsibility and cooperation, also in financing. More firm agreements to assure long term funds for the coordination of flagship observatories and key sites are needed, for example through the Arctic Council.

8. References

Bayfield et al., 2004. Land Use and Human Dimensions Issues in the SCANNET Region. SCANNET-Scandinavian/North European, Network of Terrestrial Field Bases, Work Package 4, 20 pp.(www.scannet.nu)

Committee on Designing an Arctic Observing Network, National Research Council, 2006. Toward an Integrated Arctic Observing Network. 128 pp (available at www.nap.edu/catalog/11607.html)

Shaver, G. R., Callaghan, T. V., Tweedie, C.E and Webber, P.J. 2005. Flagship observatories for Arctic Environmental research and monitoring. Report of workshop held November 18-20, 2004 at the Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts, USA.

Appendices

1) List of existing networks
2) Updated AON-list of indicators/variables
3) List of relevant IPY projects (by Craig Tweedie)

REPORT FROM THE HUMAN DIMENSION BREAKOUT GROUP

In a first phase, the discussion was conducted along the priority indicators identified by the Arctic Human Development Report (AHDR, 2004), and refined in the follow-up Arctic Social Indicators project of the Arctic Council's Sustainable Development Working Group. This project, which should yield results within a year, will identify priority areas for observing human and social conditions in the Arctic.

In the meantime, however, to address the charge suggested by David Carlson immediately prior to the breakout sessions, the group started from the premise that science targeted at the question of change in local resource availability at community level is best served by addressing **three guiding questions** with regard to multiple domains of social science data:

1. Opportunities for better coordination in order to make use of synergies and to avoid overlaps.
2. Open and timely access to data.
3. How do we make the observation system sustainable?

Priority areas were identified as follows:

A. Access to statistical agency data on a pan-Arctic scale.
B. Implementation of local observation network on a pan-Arctic scale.
C. Synthesis and access of special study data.

A. Research access to statistical agency data on a pan-Arctic scale

Rationale:

The climate is changing, and so are a lot of other aspects. We lack data to assess the scale of changes in Arctic communities. Statistical agency data is the best source for assessing change in material well-being, health, education, and demography.

Challenges:

- Standard statistical reports often are not comparable – some we can't fix but access to microdata could help
- Ethnic breakdowns not always available (especially Saami)
- Utility of data hampered by lack of translations
- Data acquisition costs (e.g. Statistics Canada)
- Spatial resolution (e.g. communities)
- Time series – challenges with changing geography, major task to restructure data into time series
- General case of Russian data: "We don't know what we don't know"

Priorities:

- Involve agencies in conversation
- Network development to share data at level of detail necessary to address research questions
- Explicit identification of key variables, subpopulations, geography, time series
- Strategy for making data comparable
- Strategy for addressing agency funding for Arctic dataset development
- Development of university-based archiving system

Actions:

- Speak to agencies in each country to involve in next workshop
- Next workshop: Russian expertise on data

B. Local Observation Networks

Rationale:

This scale of observation is most relevant to people living in the Arctic. It engages local people in the broader research process, achieving a better integration of research and adaptive responses. It is both efficient and contributes to a sense of fate control.

Challenges:

- While we have successful examples and new initiatives in IPY, these initiatives are not being coordinated.
- IPY initiatives need to be sustained in order

to create a usable observation time series.
- We are still operating at a regional scale which is not sufficient to address pan-Arctic research questions.

Priorities:

- Integrate & expand scope of observations: local food monitoring, animal borne diseases, physical and natural phenomena (e.g. sea ice, weather).
- Implement existing science priorities on development of local observation systems
- Recognize transition from regional observation systems to pan-Arctic observation network

Actions:

Involve experts in local observation systems and network development in Edmonton workshop

C. Research access to special study data on a pan-Arctic scale

Rationale:

- Individual case study and site level data sets can be combined into larger scale databases to address wider geographic and time scale changes.
- Microdata sets (e.g. survey data) have multiple potential applications.
- Domain specific data sets (e.g. health) can be combined (e.g. with education) to understand dynamics of change

Challenges:

- Lack of knowledge of each others' studies
- Lack of knowledge of archiving resources
- Lack of expertise and funding for data management tasks required for sharing data

Priorities:

- Formalize network of researchers to support identification of experts and exchange of ideas and data
- Make better use of existing data and archive systems

Actions:

- Make meta-data available from IPY projects
- International Arctic Social Science Association, with assistance from IASC, set up a list serve.

Recommendations for the SAON process

- Continuity of participation is important
- Further develop priorities as task groups in Edmonton
- Local Observation Networks
- Statistical agency data
- Data sharing

APPENDIX 1. EXISTING NETWORKS

List prepared by the break-out group on terrestrial and freshwater ecosystems

Short title	Explanation	Reference
ABBCS	The International Breeding Conditions Survey on Arctic Birds	www.arcticbirds.ru
ABCNet	Arctic Biodiversity of Chars Network: linked to CBMP, CAFF, AMAP	Jim Reist
AON	Arctic Observatory Network	www.eol.ucar.edu/projects/aon-cadis/projects
ArcticNet	Network of Centres of Excellence of Canada: scientists and managers in the natural, human health and social sciences, partners in Inuit organizations, northern communities, agencies and the private sector to study the impacts of climate change in the coastal Canadian Arctic	www.arcticnet-ulaval.ca
ArcticWolves	Arctic Wildlife Observatories Linking Vulnerable EcoSystems	www.cen.ulaval.ca/arcticwolves/
BIOHAB etc etc	Networks among European landscape level monitoring systems (NILS in Sweden, Countryside Survey in UK, etc)	
CALM	Circum-Arctic Active Layer Measurement	
Carbon, Water & Energy Balance	IPY US AON	Donie Bret-Harte, Gus Shaver, Sergey Zimov, ...
CARMA	Circum-Arctic Rangifer monitoring and assessment	Gary Kofinas, www.rangifer.net/carma
CAT-B	Circum-Arctic Terrestrial Biodiversity Initiative	Phil Wookey, www.ceoninfo.org
CBMP	Circum-Arctic Biodiversity Monitoring Program	Mike Gill
CEON	Circumarctic Environmental Observatories Network	Craig Tweedie, www.ceoninfo.org
CEOP	Coordinated Enhanced Observing Period in IPY: In situ data archiving center	
ECN	Environmental Change Network, 12 terrestrial sites throughout UK	
ENFIN	European National Forest Inventory Network: huge amounts of plots to follow trends in land cover, tree line, biodiversity indicators, carbon stocks etc.	
EPN	The European Phenology Network	www.dow.wau.nl/msa/epn/index.asp
EUROFLUX	European network of greenhouse gas flux measurements	www.unitus.it/dipartimenti/disafri/progetti/eflux/euro.html

FAO-FRA	The only world wide forest inventory. Besides reports from individual countries, the FRA 2010 will also use a worldwide grid of (9000?) plots interpreted from satellite data.	
FEMN (?)	Freshwater Ecosystem Monitoring Network: ecosystem network for CAFF and CBMP, monitor change in freshwater biodiversity in Arctic	Fred Wrona, Jim Reist
GCOS	One of the three Global Observing Systems tied to UN institutions (see www.gosic.org/ for an overview). The other two are GOOS for Oceans and GTOS for terrestrial observations. In the GCOS Implementation plan (www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP.pdf) a set of Essential Climate Variables (ECV)'s was defined. The implementation of this list is followed up and reported on within the GCOS framework. The list of ECV's is a good motivation and starting point for much of the terrestrial and climate related monitoring needs and could form the backbone of an arctic monitoring system. The ECV's for the terrestrial domain includes in short: River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance, and Soil moisture	www.wmo.ch/pages/prog/gcos/index.php
GEO (GEOSS)	A partnership between 71 nations and 46 international organisations (www.earthobservations.org). Aims to build foundation for a Global Earth Observation System of Systems (GEOSS). All the elements that have been discussed so far in the SAON process have been addressed in GEO, e.g. sustained observations across nations and sectors, data sharing, technical standards etc. An advantage is also that the political level already is onboard. Since GEO address the whole globe, a meaningful way forward for SAON could be to "define the Arctic component of GEOSS". The current 3 year plan for GEO runs between 2007 and 2009. There are however problems with GEO, even if the aim of the partnership is very meaningful, some existing organisations are reluctant to give GEO credit for their already ongoing work. In addition, the current structure of GEO is thematic rather than geographical.	www.earthobservations.org
GINA	Geographic Network of Alaska: satellite and airborne data, GIS data management	Tom Heinrichs, www.gina.alaska.edu

GTOS	The Global Terrestrial Observation system (www.fao.org/gtos/index.html) is hosted by FAO, but is not at all as well developed as GCOS or GOOS. It is thus an important challenge for both the terrestrial science and observation communities to raise GTOS at least to the level of the other observing systems. When discussing circum arctic terrestrial monitoring, the possible links to GTOS should be considered. Also, it has in the past not been too difficult to create new panels of GTOS. A few features of GTOS are worth mentioning here. The Climate Observations panel of GTOS works with the implementation of the terrestrial ECV's, see for example the report: (/www.fao.org/gtos/doc/SBSTA-GTOS-ECV-report-v05.pdf). TEMS is a database with Terrestrial Ecosystem Observing Sites, where for example Abisko and Flakaliden are mentioned. GOFS-GOLD works under GTOS with Global Observation of Forests and Land Dynamics. NERIN, the Northern Euroasian Regional Information Network (www.fao.org/gtos/gofc-gold/net-NERIN.html) works with issues in northern Euroasia and is one of the regional networks within GTOS.	www.fao.org/gtos/index.html
ISCGM	The International Steering Committee for Global Mapping http://www.iscgm.org/cgi-bin/fswiki/wiki.cgi is on a country by country basis compiling a global land cover, land use, and vegetation map.	www.iscgm.org/cgi-bin/fswiki/wiki.cgi
ITEX	International Tundra Experiment	www.geog.ubc.ca/itex
LTER	Long-Term Ecological Research: 26 LTER sites involving more than 1800 scientists and students investigating ecological processes over long temporal and broad spatial scales	www.lternet.edu
NEESPI	Northern Euroasia Earth Science Initiative http://www.neespi.org/, a NASA hosted initiative, which mostly works with Russian scientists. Even if it is not circum-arctic, it is just like NERIN of relevance since it operates in large parts of northern Euro-Asia. Both NERIN and NESPIE are run by Russians that now are based in the USA.	www.neespi.org
NSSI	North Slope Science Initiative: terrestrial, marine, climate	John Payne, www.northslope.org
PALIMMN	Arctic Lake Ice Methane Measuremet Network	Kathy Walter
PBSG	Polar Bear Specialist Group of the IUCN Species Survival Commission	pbsg.npolar.no
SCANNET	Scandinavian / North European Network of Terrestrial Field bases	www.scannet.nu
SNOTEL	Snow accumulation data: automated system of snowpack and related climate sensors operated by the US Natural Resources Conservation Service (NRCS)	www.wcc.nrcs.usda.gov/snotel
SPECNET	Spectral Network: collects spectral data	www.specnet.info
WMO	The World Meteorological Organization: a specialized agency of the United Nations	www.wmo.int

APPENDIX 2. UPDATED AON-LIST OF INDICATORS/VARIABLES

List prepared by the break-out group on terrestrial and freshwater ecosystems

WHAT-GENERAL	WHAT-SPECIFIC?	WHY?	FOR WHOM?	REFERENCE	STATUS	PRIORITY
Air	Dust	Black carbon, radiation balances and climate modelling, of relevance for GCOS, human health	Scientists, health authorities	ICARP WG8 (2006)	need some refinement	high
Air	Trace gases and aerosols	Good for radiation balances, and thus for climate modelling, of relevance for GCOS; human health	Scientists	ICARP WG8 (2006)	in use	
Air	Tropospheric ozone	Vegetation damages from UV radiation	Scientists		in use	
Land and water	Albedo	Influences global change (through changes in cloud, land and ocean cover incl. ice and snow cover)	Scientists	AON (2006), GCOS (2004)		
Land and water	Carbon stores	Impact on global warming; influences biological productivity, carbon sequestration, food web dynamics, ecosystem structure	Scientists, agencies	AON (2006)		
Land and water	Contaminant concentration	Affects human and animal health, water quality, atmospheric composition; indicator of antrophogenic activity and impacts	Scientists	AON (2006)		
Land and water	Extent of wetlands	Economic impact, biodiversity and ecosystem effects	Scientists	ICARP WG8 (2006)		
Land and water	Fire	Is a GCOS ECV. For plant ecology and CO2 balances; is also affected by human activities and climate changes.	Scientists	ICARP WG8 (2006), GCOS (2004)	in use	high
Land and water	Freshwater temperature, thermocline depth, mixing/overturns chemistry, water quality	Need to understand freshwater ecosystem function	Scientists, agencies		need to be developed	high
Land and water	Geology/geomorphology	Background information	Scientists	SAON W1 (2007)		

Land and water	Glaciers and ice caps	Changes affect hydrology, albedo, local climate, ecosystem structure, nutrient and carbon fluxes	Scientists	GCOS (2004)		
Land and water	Greenhouse gas fluxes	Atmospheric CO2 balance, N2O, CH4, net productivity, photosynthesis, respiration	Scientists	Callaghan et al. (2004)	in use	
Land and water	Hydrology, river discharge, ground water, flux of soil water into streams, lakes, deltas, estuaries	Affects human and biological habitation and activity, water resources and fisheries, land use, lacustrine transportation; a key land-water boundary and indicator of water balance. Background information for ecology & greenhouse gas balances	Scientists, agencies	AON (2006), ICARP WG8 (2006), SAON W1 (2007), GCOS (2004)	need to be developed	high
Land and water	Impact of transportation and construction	Disturbance of species and geograph, oil spills	Agencies, local communities	Callaghan et al. (2004), SAON W1 (2007)		
Land and water	Lake ice (thickness, break-up)	Indicator of climate		SAON W1 (2007)		
Land and water	Land cover	Influences habitat fragmentation, water balance, coastal erosion, transportation, animal migration, biological community boundary change, land use and mangement	Scientists	AON (2006)		
Land and water	Land use (reindeer herding, hunting, fishing, wood, berries, etc)	Use of ecosystem services, estimating levels of sustainability	Scientists, agencies, local communities	Callaghan et al. (2004)		
Land and water	Water use	Use of ecosystem services, estimating levels of sustainability	Scientists, agencies, local communities	GCOS (2004)		
Land and water	NDVI, reflectance calibrated data (red and NIR), fraction of absorbed photosynthetically active radiation (fAPAR)	Estimating NPP, phenology, snow cover; link to satellite measurements for large-area estimates.	Scientists	ICARP WG8 (2006), GCOS (2004)		
Land and water	Nutrient concentration	Affects primary production, ecosystem structure and function, food webs/trophic interactions, energy fluxes; fundamental elements of life	Scientists	AON (2006)		

Land and water	Precipitation	Controls biological community distribution; increases human water supply and causes drought and flooding	Scientists	AON (2006)		
Land and water	Snow depth; snow cover; snow indicies (e.g. water content)	Affects arctic energy balance; insulates underlaying soils; affects biological activity (e.g. carbibou distribution)	Scientists	AON (2006), SAON W1 (2007), GCOS (2004)		
Land and water	Surface roughness (plant canopy)	Climate models	Scientists	ICARP WG8 (2006)		
Land and water	Temperature	Direct measure of global warming; moderates all chemical and biochemical reactions: controls biological community boundaries; causes changes in permafrost that affect infrastructure	Scientists	AON (2006)		
Land and water	Tracer chemistry	Indicator of biogeochemical and physial processes, changes in pathways, climate-water interactions	Scientists	AON (2006)		
Soil	Carbon pool in soil	Global CO2 equivalent budgets	Scientists	ICARP WG8 (2006)		
Soil	Moisture in soil	Affects runoff, biodiversity and biological productivity, terrestrial transportation	Scientists	AON (2006), ICARP WG8 (2006), GCOS (2004)		
Soil	Permafrost and frozen ground dynamics	Damages to structures; spread of contaminants	Scientists, agencies, local communities	ICARP WG8 (2006), Callaghan et al. (2004), GCOS (2004)	in use	high
Soil	Soil organic matter decay	Nutrient cycling	Scientists	ICARP WG8 (2006)		
Soil	Degradation/erosion (rivers, coastline)	Damages to structures	Scientists, agencies, local communities	SAON W1 (2007)		
Species	Alien species, immigration	Relevant to food supply; ecosystem health, structure and function;	Scientists, agencies, local communities	ICARP WG8 (2006)		
Species	Biodiversity - species and genetic diversity	Reveals natural and antrophogenic impacts on species richness and ecosystems, invasive/alien species impacts and hybridization, endangered species impacts and conservation status, indicator of ecosystem structure, better understanding of local adaptations	Scientists, agencies	AON (2006), SAON W1 (2007)		

Species	Biodiversity indicators	Identifies changes in biodiversity; monitor progress of conservation efforts	Scientists	CAFF (2004)		
Species	Biomass	Relevant to food supply; ecosystem health, structure and function; carbon sequestration and allocation; affects albedo by masking of snow	Scientists	AON (2006)		
Species	Critical habitats	Dens, grazing grounds, sheltered areas, snow beds, etc. Identifies habitat of critical importance during bottle neck periods. Relevant to food supply and species conservation measures	Scientists, local communities, agencies	ICARP WG8 (2006)		
Species	Diseases in plants and animals, zoonoses	Economic and health implications; biodiversity impact	Scientists, local communities, health authorities	ICARP WG8 (2006); SAON W1 (2007)		
Species	Distribution edges, treeline, tundra-forest displacement	Vegetation change, climate change	Scientists, local communities	Callaghan et al. (2004); ICARP WG8 (2006)		
Species	Insect outbreaks	Economic and health implications from plant and animal pests; biodiversity and ecosystem impact, wildfire hazards	Scientists, local communities	Callaghan et al. (2004)	in use	high
Species	Key fish species	Anadromous salmon and chars, fresh water chars, non-chars. Very important in fisheries, key ecosystem components, link between marine and freshwater. Diversity, distribution, contaminants	Scientists, agencies, industry, local communities	SAON W1 (2007)	need to be developed	high
Species	Human subsistance, key terrestrial species	Projected population dynamics of game, predators and potential disease vectors: reindeer/caribou, ptarmigan, hare, moose, geese, wolf, wolverine, foxes etc.	Scientists, agencies, natural resource users, public, educators	SAON W1 (2007)		
Species	Leaf Area Index (LAI)	Ecosystem process modelling, effects of disturbance, etc.	Scientists	GCOS (2004), SAON W1 (2007)		
Species	Multi-annual interaction cycles	Key species in tundra ecosystems: lemmings, Eriophorum, etc.	Scientists, agencies, local communities, general public	ICARP WG8 (2006)		

Species	Organismal behaviour and performance	Identify poulation and individual growth/condition. Relevant to human food supply; ecosystem health, structure and function;	Scientists, local communities	AON (2006)		
Species	Pests and parasites	Relevant to food supply; ecosystem health, structure and function	Scientists, agencies, local communities	ICARP WG8 (2006)		
Species	Phenology	Reveals changes in bud break, growing season, migratory timing, food availability for migrant birds, reproductive success; albedo; carbon sequestration; indicator of timing and biological events	Scientists	AON (2006)		
Species	Reindeer/caribou grazing	Vegetation effects, herbivore competition, impact on human food resources	Scientists, agencies, local communities	Callaghan et al. (2004)		
Species	Trophic interactions and species composition	Cascade effects, stock depletion, climate change,....	Scientists, agencies, natural resource users, public, educators	ICARP WG8 (2006), SAON W1 (2007)		