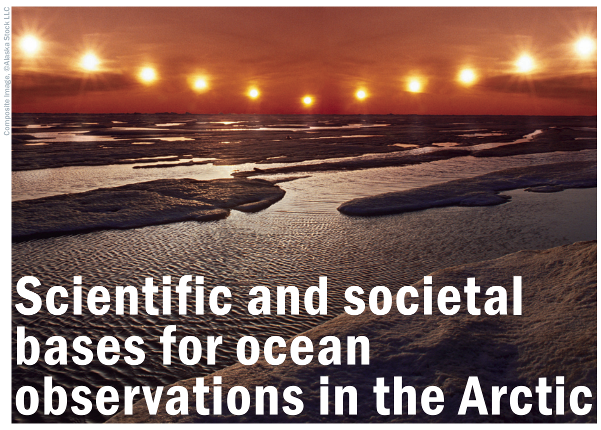
An Integrated International Approach to Arctic Ocean Observations for Society

A Legacy of the International Polar Year

Coordinating Lead Author: John Calder, NOAA Arctic Research Program, USA

Technical Lead Authors: Andrey Proshutinsky, Woods Hole Oceanographic Institution, USA ; Eddy Carmack, Institute of Ocean Sciences, Canada; Igor Ashik, Arctic and Antarctic Research Institute, Russia; Harald Loeng, Institute of Marine Research, Norway; Jeff Key, NOAA, USA

Contributing Authors: Molly McCammon, Alaska Ocean Observing System, USA; Humfrey Melling, Institute of Ocean Sciences, Canada; Donald Perovich, Cold Regions Research and Engineering Laboratory, USA; Hajo Eicken and Mark Johnson, University of Alaska Fairbanks, USA; Ignatius Rigor, University of Washington, USA



Scientific and societal bases for ocean observations in the Arctic

Monitoring the ocean provides data to quantify change within a system for societal decision-making, and to support real-time data products and forecasts for immediate use by stakeholders.

The science rationales for Arctic Ocean observations are derived from community-based source materials, which make clear that human societies in the Arctic region and globally benefit from sustained Arctic Ocean observations to:

- support operational forecasting of weather, sea ice, and ocean conditions;
- detect and forecast or project climate-driven variability and change in the state of the Arctic Ocean and sea ice;
- anticipate resulting long-term impacts to ecosystems and humans;
- detect and project specific ecosystem responses;
- support marine transportation, tourism, and marine operations;
- support emergency response operations;
- enable enhanced scientific research.

Sea ice in particular provides unique services to society: acting as a climate regulator, critical habitat supporting food-webs and biological diversity, a coastal buffer, a platform for transportation and structures (e.g., oil and gas), and providing cultural benefits to indigenous societies.

System of observations

In the Arctic, a key challenge in designing an ocean observing system is to consider the effect of the presence of an ice cover that — depending on the state of the ice — can serve to enhance or reduce the coupling between ocean and atmosphere and can serve as a unique habitat for both flora and fauna. Since much of the societal benefits are derived close to the coast, more challenging and innovative approaches, including the use of local stakeholder expertise, will be required.

Physical ocean observations

An advanced physical ocean observing system will be an IPY legacy and constitute an important contribution to the Sustained Arctic Observing Network (SAON). Data from this system will support studies of ocean processes, help initialize and validate numerical models, and stimulate general interest in Arctic science issues.

Critical parameters: water temperature and salinity, ocean currents and sea level. A basin-scale system will employ a mix of shelf, continental slope and deep ocean observatories, drifting buoys, floats, and mobile vehicles, as well as ship-based and airborne expeditions. Advanced development of basin scale geopositioning and communications is essential to the success of such an advanced observing system. Combined, these systems will provide synoptic year-round observations of key oceanographic, cryospheric and atmospheric processes.

Biological and biogeochemical ocean observations

The goals are to observe and predict on seasonal to decadal scales the climate impact on the marine ecosystem and to aid in managing living and non-living marine resources to benefit society. The key challenge will be to understand processes and monitor the potential change in the ecosystem as a consequence of climate change.

Biological monitoring: The strategy will differ in ice covered and ice free waters, with the focus on phyto- and zooplankton and benthos in shallower areas.

Biogeochemical monitoring: Key observations include nutrients, dissolved and particulate carbon and nitrogen, carbon and nitrogen isotopes, parameters affecting the carbonate balance, and rate-limiting trace elements.

In situ sea ice observations

In situ sea ice observations must include three components of sea ice cover: land fast, seasonal and perennial ice, each characterized by ice thickness, snow depth, ice motion, ice growth and decay.

Observing platforms: on-ice and aerial surveys, sensors on drifting ice with data recorded or relayed via satellite and sub-sea moorings with internal recording instruments.

Meteorological observations

Fundamental meteorological parameters are critical for research and operational weather and sea ice forecasting.

Key observations: sea level pressure and surface air temperature from automated stations. Meteorological parameters plus ocean and sea ice parameters from manned stations.

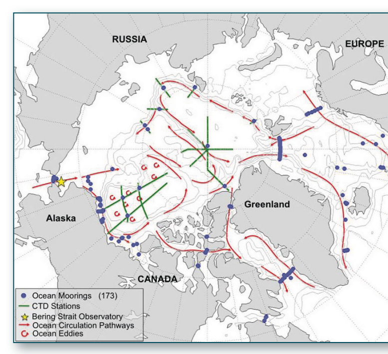
The International Arctic Buoy Program's network of drifting buoys on the Arctic Ocean collects met data as well as ocean currents, temperatures and salinity. Other buoys measure ice mass balance. In the Russian Arctic, coastal stations collect broad range of meteorological observations as well as sea level, water temperature, sea state; measurements of water conductivity, sea ice conditions (concentrations), ice thickness and snow density. Stations are located in the White, Barents, Kara, Laptev, East-Siberian and Chukchi seas.

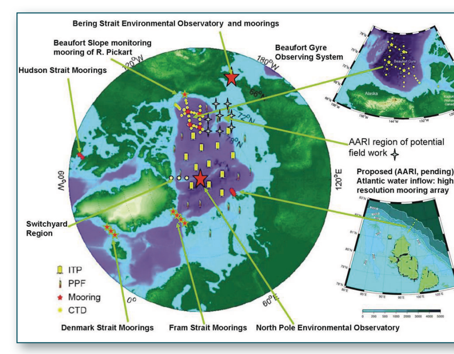
Satellite observations

Satellite instruments are essential for delivering sustained, consistent observations of the Arctic Ocean. No single, all-encompassing sensor exists; baseline elements for a largely ice-covered ocean require a coordinated combination of visible to thermal infrared wavelength sensors, passive microwave radiometers, synthetic aperture radars, laser and radar altimeters, radar scatterometers and gravity missions. New sensors and methods are also needed.

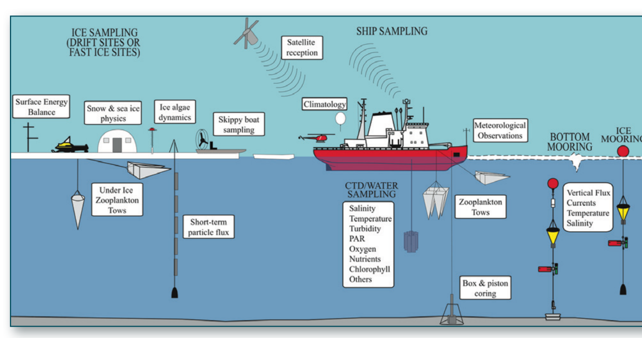
While there are some gaps expected in the next decade due to satellite failures and budgetary issues, overall, remote sensing of the polar oceans is robust and improving, with new technologies continuing to be explored. Current products include sea and ice surface temperature, surface albedo, ice concentration, extent, motion and melt, operational sea ice analyses and regional ice mapping, ice sheet mass changes, and atmospheric properties.

Right: Map of mooring locations during the IPY at locations that were determined to be critical through a variety of review and decision processes. Locations of CTD sections conducted in August-September 2008 (green lines) are shown to demonstrate activities associated with ship-based and airborne observations.

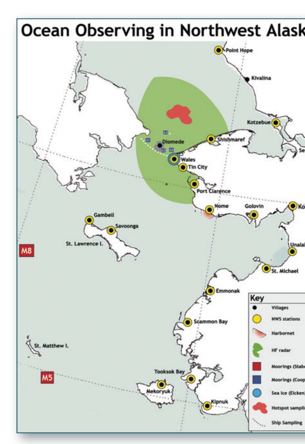




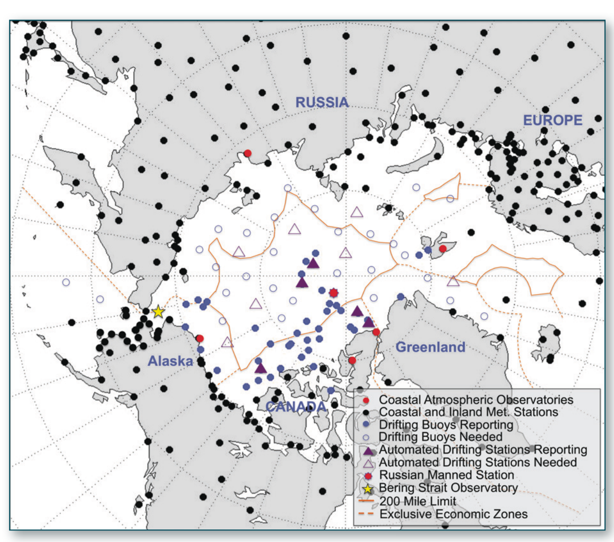
Above: Map illustrating large-scale array of distributed observatories. Exact locations of Ice-Tethered Profilers (ITPs), Polar Profiling Floats (PPFs), moorings and CTD lines as shown in the legend are conditional.



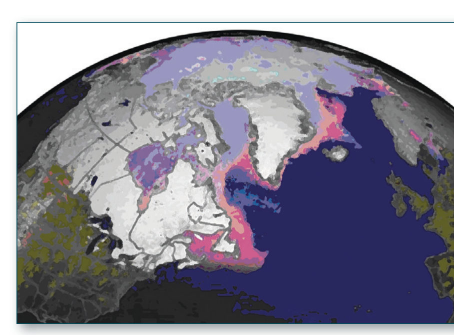
Above: Schematic of the scientific equipment used on the Canadian icebreaker *Amundsen* and at ice camps nearby.



Left: Coastal ocean observations desired in the Bering Strait region.



Above: Meteorological observing networks for the Arctic.



Above: Snow cover and sea ice temperature over the Arctic, from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). Courtesy NASA Goddard Space Flight Center Scientific Visualization Studio.

Other issues

Data analysis, data assimilation and modeling

Accurate gridded atmospheric, cryospheric, and ocean fields from models, consistent with, and constrained by point observations, are key to understanding the origin of the observed Arctic change and essential for forming accurate budgets of numerous climate variables such as heat and freshwater fluxes. Data assimilation and model-based reanalysis are important for this. Existing operational reanalyses assimilate only atmospheric measurements. These currently play a major role in arctic system studies and are used to force sea ice, ocean and terrestrial models, analyze the climate system's variability and explain and understand the interrelationships of the system's components and the causes of their change. Ice-ocean-ecosystem modeling with data assimilation is a next step in the evolution of this capability.

Data management and archival

Observational data becomes useful when it is easily accessed and broadly available. In the post-IPY period and beyond, data management functions must include software to provide data access and display via the web, procedures for ensuring that project data is actually accessible and available in a suite of formats, and tools for integration of diverse types of data to facilitate recurring and novel types of products.

There must be secure means for scientists and managers to enter information describing present and planned research projects, associated metadata, and instructions for access of the actual data. There must be means for project information and datasets to be archived locally and uploaded to national databases where relevant.

Organization of required activities

The observing and related activities described in earlier sections will be carried out by various funding and implementing organizations. There will likely be both quasi-operational activities supported by the government service agencies, as well as shorter-term research activities supported by government granting agencies. Ideally, all will be guided by a common understanding of what is required and of each agency's area of responsibility.

International coordination, legal frameworks and EEZ issues

Increasingly rapid physical changes in the Arctic have led to a resurgence of interest in jurisdictional issues relating to who controls what. While the Arctic is not plagued by unresolved territorial disputes, there are problems related to the legality of observations in the Exclusive Economic Zones (EEZs) and data availability from these regions in real time. Canada, Denmark/Greenland, Norway, Russia and the United States directly border the Arctic Ocean and peripheral seas and will have to agree on how in situ ocean observing in their inland and territorial waters and their Exclusive Economic Zones (EEZ) is to be conducted.

Next steps and future directions

Interest is high for sustaining the enhanced level of Arctic Ocean observations that existed during the IPY period of 2007–2009. IPY results will provide new insights into the most cost-effective observing strategies and most reliable emerging technologies.

A key task in the post-IPY period is to refine the most important science questions and most urgent user needs, and provide an updated observing strategy to meet them. During 2010, the Arctic Ocean observing community should be challenged to perform this task. Key priorities for sustained observations at this time are:

- Estimating change in heat and fresh water content of the Arctic Ocean and monitoring the influx of heat and salt from the Atlantic and Pacific Oceans;
- Estimating change in sea ice extent and thickness and observing the factors that control sea ice growth and melt;
- Monitoring sea ice (including land fast ice) and ocean conditions in coastal regions, especially storm surge processes and coastal erosion; and
- Estimating ecosystem response to change in physical and chemical conditions in the ocean, including observing productivity, ecosystem structure, and populations of key species and groups.

This poster is based on a white paper prepared for the OceanObs 2009 Conference, 21-25 September 2009, Venice, Italy. Download the white paper at www.oceanobs09.net.