Observations for Climate: An Integrated International Approach to Arctic Ocean Observations for Society

A Legacy of the International Polar Year

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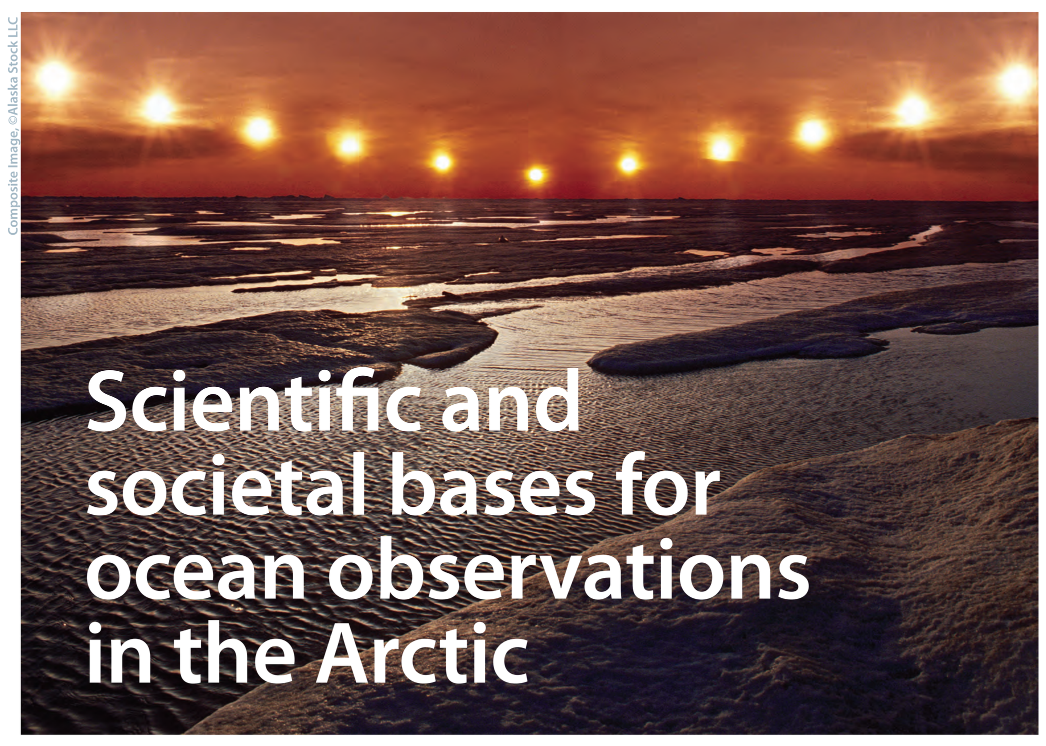


Scientific and societal bases for ocean observations in the Arctic

Monitoring the ocean provides data to quantify its variability and change for research, decision-making, to support real-time data products and to initialize forecasts. Societies in the Arctic and globally benefit from sustained Arctic Ocean observations that:

- support operational forecasting of weather, sea ice, and ocean conditions;
- detect and forecast change and climate-driven variability in the Arctic Ocean and sea ice;
- anticipate long-term impacts to ecosystems and humans from climate change;
- detect and project changes in ecosystem structure;
- support marine transportation, tourism, and emergency response operations;
- enhance scientific research.

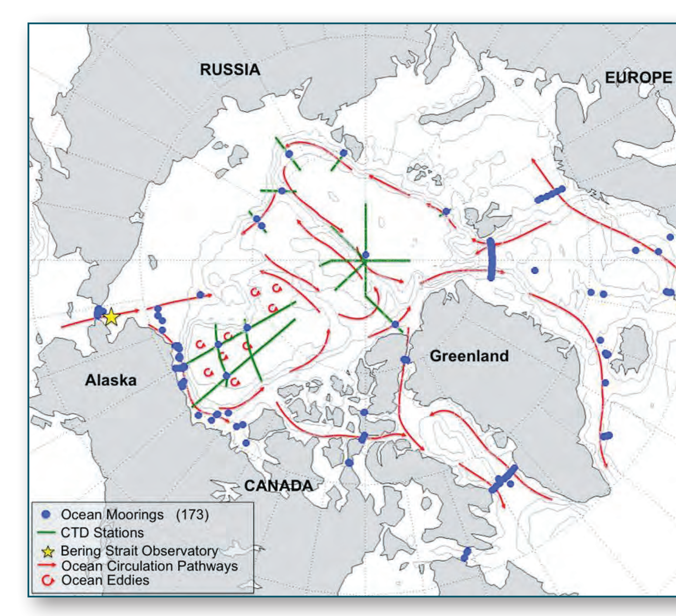
Sea ice in particular is a critical component of the climate system, provides critical habitat enabling biological diversity, acts as a barrier along the coasts, is an integral component to resource development and planning, and provides cultural benefits to indigenous societies.

In the Arctic, a key factor in designing an ocean observing system is the ice cover that modifies the coupling between the ocean and atmosphere, provides unique habitat, and influences the observing technologies that can be deployed. Because many societal benefits are derived close to the coast, more challenging and innovative approaches, including the use of local stakeholder expertise, will be required to develop effective observing systems in coastal areas.

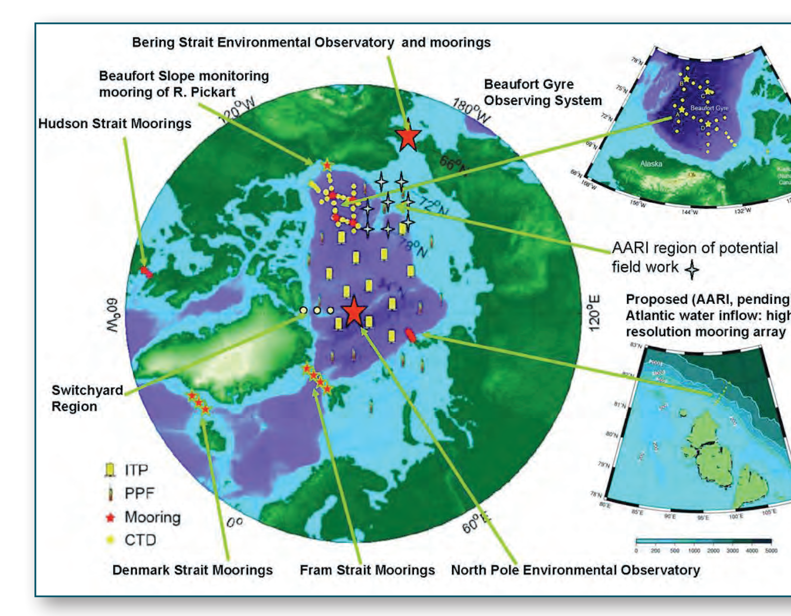
Physical ocean observations

An advanced physical ocean observing system will be an IPY legacy and an essential component of an Arctic-wide observing framework. 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: Measurements of water temperature and salinity, ocean currents, sea level, and sea ice concentration and thickness will be essential to the success of any advanced observing system. A basin-scale system provides observations from the shelf, continental slope and deep ocean and may employ drifting buoys, floats, mobile vehicles, ship-based and airborne expeditions, and satellites. A successful observing system will provide synoptic year-round observations of key oceanographic, cryospheric and atmospheric processes. Real-time data transmission will enable greater societal benefit on sub-annual scales.



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.

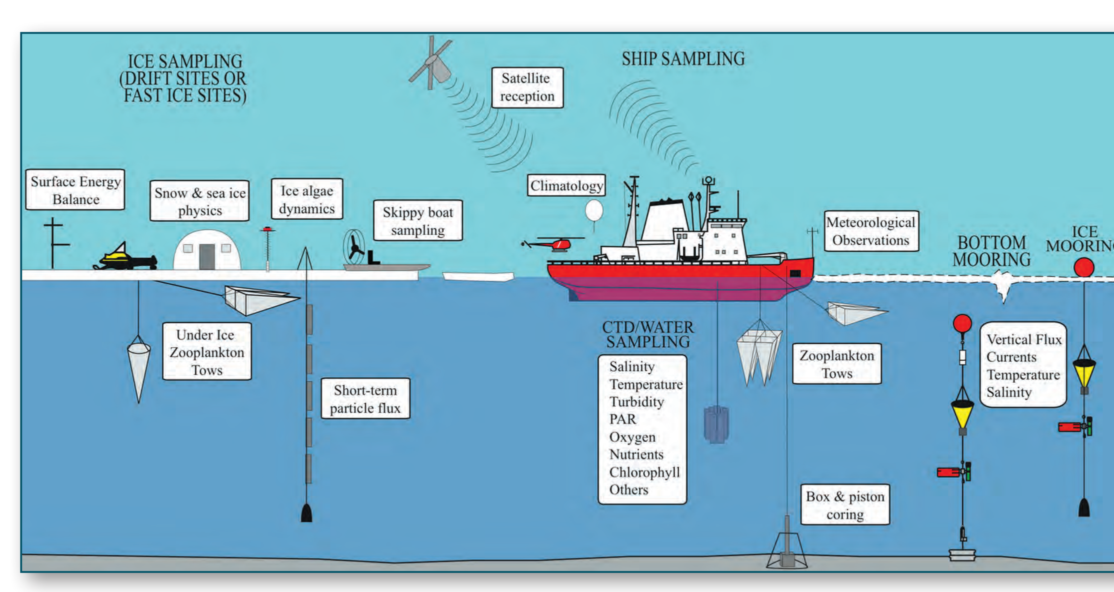


Above: Map illustrating large-scale array of distributed observatories. Exact locations of Ice-Tethered Profilers (ITPs), Polar Profiling Floats (PPFs), moorings and CTD lines as shown in the legend are conditional.

Biological and biogeochemical ocean observations

The goals are to observe and predict on seasonal, decadal and longer scales the climate impact on the marine ecosystem and to aid in managing 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 and Biogeochemical monitoring: Observing methods will differ in ice covered and ice free waters, with different approaches for phytoplankton, zooplankton and the benthos. Key observations include nutrients, dissolved and particulate carbon and nitrogen, carbon and nitrogen isotopes, parameters affecting the carbonate balance, and rate-limiting trace elements.

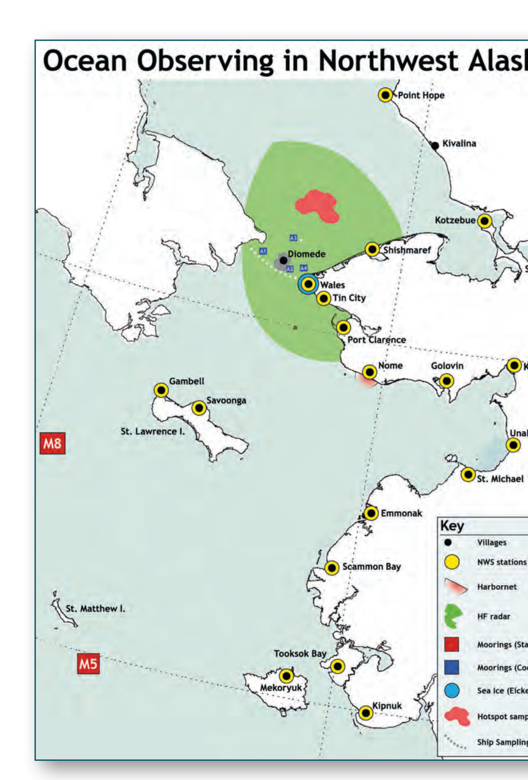


Above: Schematic of the scientific equipment used on the Canadian icebreaker *Amundsen* and at ice camps nearby.

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, overlying 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.



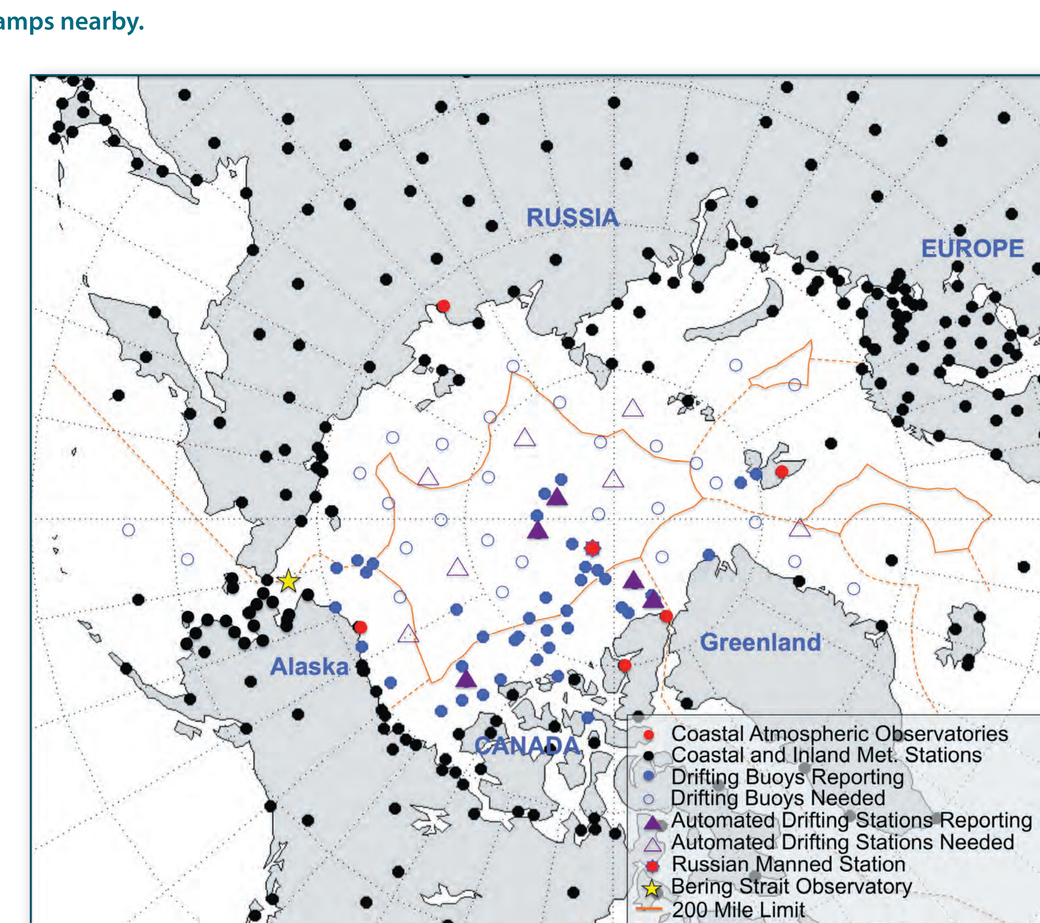
Left: Coastal ocean observations desired in the Bering Strait region.

Meteorological observations

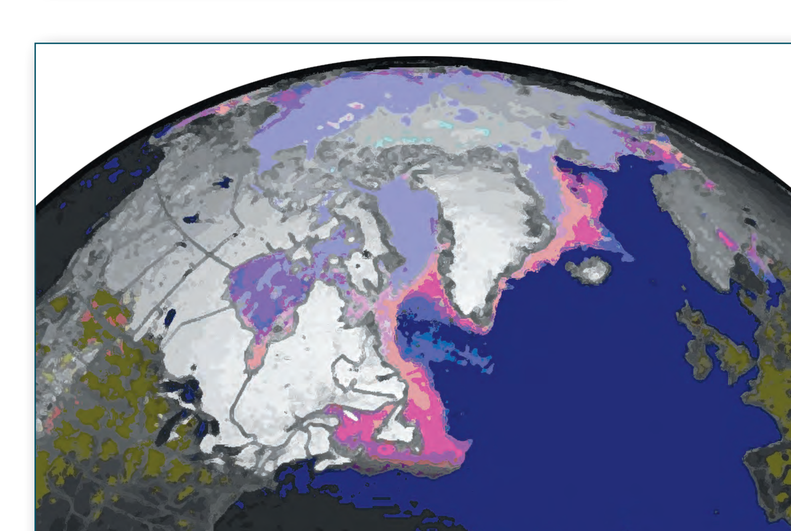
Fundamental meteorological parameters are critical for research and operational weather and sea ice forecasting.

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 data on ocean currents, temperatures and salinity and provides guidance for the design of future programs. Other buoys measure ice mass balance. In the Russian Arctic, coastal stations collect a broad range of meteorological observations as well as sea level, water temperature, sea state, 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.



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.

Satellite observations

Satellites 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 will be data gaps in the next decade due to satellite failures and limited budgets, overall, remote sensing of the polar oceans is robust and improving. New technologies continue to be explored, such as sea ice thickness from altimeters and new approaches to estimating the depth of snow on ice. Current products include sea and ice surface temperature, surface albedo, ice concentration, extent, age and thickness, motion and melt, operational sea ice analyses and regional ice mapping, ice sheet mass changes, and atmospheric properties.

OTHER ISSUES

Data analysis, data assimilation and modeling

Data assimilation and model-based reanalysis help provide accurate gridded atmospheric, cryospheric, and ocean fields consistent with, and constrained by point observations. Such data are key to understanding the origin of the observed Arctic change and essential for constraining heat and freshwater fluxes. Observations are necessary for 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 must be easily accessed and broadly available. In the post-IPY period and beyond, data management functions must be sustained and include software to provide data access and display via the web, procedures for ensuring that project data is 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. Project information and datasets should 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,an Arctic-wide ocean observing framework will define high level goals and provide a mechanism for information exchange and coordination. This would allow best use of available resources and increase the likelihood of satisfactorily addressing complex science questions.

International coordination, legal frameworks and EEZ issues

Increasingly rapid physical changes in the Arctic have led to a resurgence of interest in jurisdictional issues and access to resources. While the Arctic has few unresolved territorial disputes, there are problems related to national policies regarding observations in the Exclusive Economic Zones (EEZs) and Territorial Seas, 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 is to be conducted in their inland and territorial waters and their Exclusive Economic Zones (EEZ).

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. 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. Poster developed by Alaska Ocean Observing System.

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