The International Arctic Buoy Programme–Monitoring the Arctic Ocean for Forecasting and Research

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Changes in the Arctic have long been considered a harbinger of global climate change. Simulations with global climate models predict that if the concentration of CO_2 in the atmosphere doubles, the Arctic would warm by more than 5°C, compared to a warming of 2°C for subpolar regions. This "polar amplification" of the global warming signal is attributed to changes in sea ice, which has a higher albedo (reflectivity) than the darker ocean, and hence its presence reduces the amount of sunlight absorbed by the ice-covered ocean. If temperatures warmed, this may decrease the area of sea ice and increase the exposed area of the darker ocean, increasing the amount of sunlight absorbed, thus warming the ocean, melting more sea ice, and amplifying the initial perturbations. (This process is called ice–albedo positive feedback.) And, indeed, studies of the observational records show polar amplification of the warming trends.

These temperature trends are accompanied by decreases in sea level pressure over the Arctic Ocean, changes in the circulation of sea ice and the surface ocean currents such that the Beaufort Gyre is reduced in size and speed, and decreases in sea ice thickness. During the last three summers (2002–2004) we have observed near-record minima in summer sea ice extent in the Arctic.

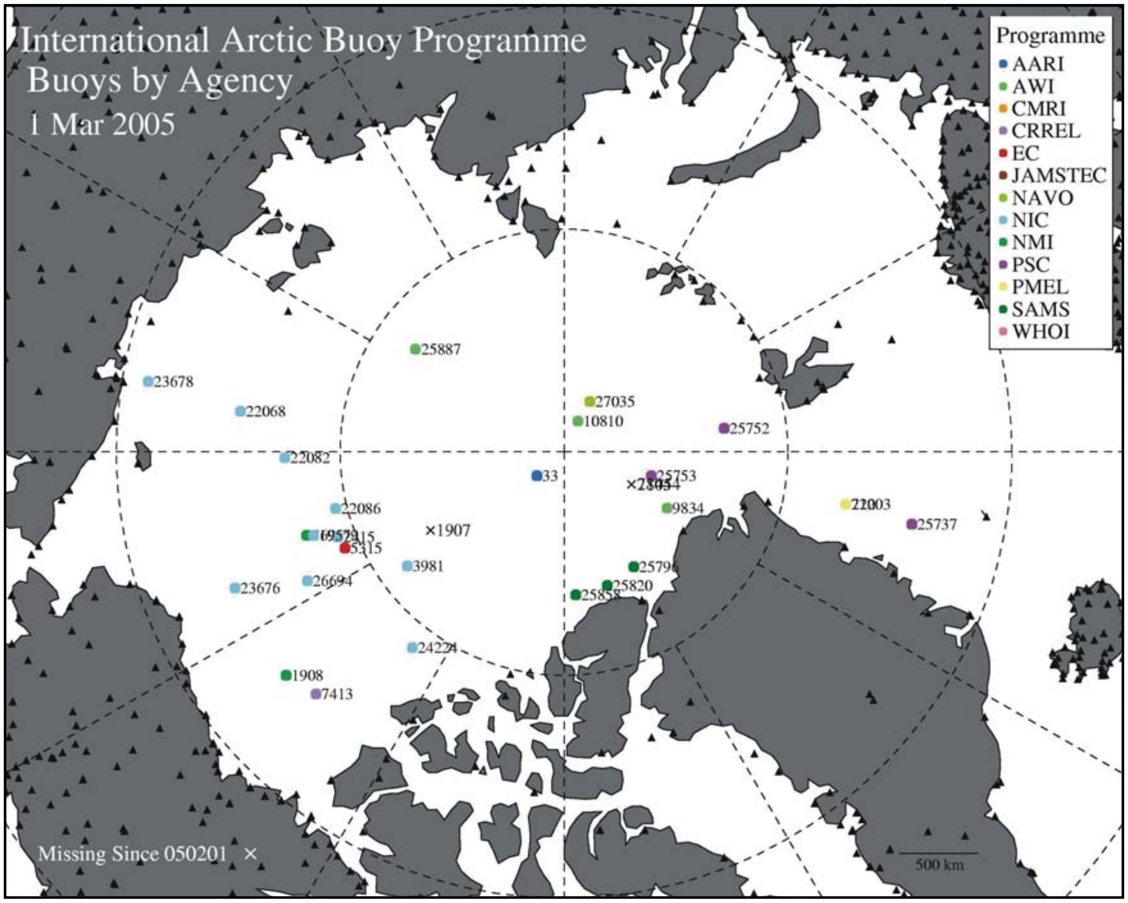
These changes have a profound impact on wildlife and people. Many species and cultures depend on the sea ice for habitat and subsistence. The lack of sea ice in an area along the coast may allow ocean waves to fetch up higher, producing stronger storm surges that may threaten low-elevation coastal towns. And from an economic viewpoint, the extent of Arctic sea ice affects navigation from the Atlantic to the Pacific through the Arctic along the Northern Sea Route and Northwest Passage, which are as much as 60% shorter than the conventional routes from Europe to the west coast of the U.S. or Japan. Thus, monitoring the Arctic Ocean is crucial not only for our ability to detect climate change, but also to improve our understanding of the Arctic and global climate system, and for forecasting weather and sea ice conditions.

IABP History

A network of automatic data buoys for monitoring synoptic-scale fields of sea level pressure (SLP), surface air temperature (SAT), and ice motion throughout the Arctic Ocean was recommended by the U.S. National Academy of Sciences in 1974. Based on that recommendation, the Arctic Ocean Buoy Program was established by the Polar Science Center (PSC), Applied Physics Laboratory (APL), University of Washington (UW), in 1978 to support the Global Weather Experiment. Operations began in early 1979, and the program continued through 1990 under funding from various agencies. In 1991 the International Arctic Buoy Programme (IABP) succeeded the Arctic Ocean Buoy Program, but the basic objective remains: to maintain a network of drifting buoys on the Arctic Ocean to provide meteorological and oceanographic data for real-time operational requirements and research purposes, including support to the World Climate Research Programme and the World Weather Watch Programme.

The IABP currently has 33 buoys deployed on the Arctic Ocean. Most of the buoys measure SLP and SAT, but many buoys are enhanced to measure other geophysical variables, such as sea ice thickness, ocean temperature, and salinity.

This observational array is maintained by 21 participants from 10 countries. These participants support the program through contributions of buoys, deployment logistics, and other services. The U.S. contributions to the IABP are coordinated by the U.S. Interagency Arctic Buoy Program (USIABP), which is managed by the National Ice Center. Of the 33 IABP buoys currently reporting, 13 buoys were purchased by the USIABP, and 18



Positions of the IABP buoys on March 1, 2005. The colors correspond to the various participants of the IABP. (See below for a list of acronyms.)

IABP Participants

1. Alfred Wegener Institute (AWI), Germany
2. Arctic and Antarctic Research Institute (AARI), Russia
3. Chinese Arctic and Antarctic Administration (CAAA), China
4. Christian Michelsen Research Institute (CMRI), Norway
5. Collecte Localisation Satellites and Service Argos, France and USA
6. Cold Regions Research and Engineering Laboratory (CRREL), USA
7. Environment Canada (EC), Canada
8. Institute of Ocean Sciences, Canada
9. International Arctic Research Center (IARC), University of Alaska Fairbanks, USA, and Japan
10. Japan Agency for Marine–Earth Science and Technology (JAMSTEC), Japan
11. Marine Environmental Data Service (MEDS), Canada
12. Metocean Data Systems, Canada
13. Nansen Environmental and Remote Sensing Center (NERSC), Norway
14. National/Naval Ice Center (NIC), USA
15. Naval Oceanographic Office (NAVO), USA
16. Norwegian Polar Institute (NPI), Norway
17. Norwegian Meteorological Institute (NMI), Norway
18. Pacific Marine and Environmental Laboratory (PMEL), USA
19. Polar Science Center (PSC), Applied Physics Laboratory, University of Washington, USA
20. Scottish Association for Marine Science (SAMS), Scotland
21. Woods Hole Oceanographic Institute (WHOI), USA
22. World Climate Research Programme (WCRP), Switzerland

USIABP Contributors

1. International Arctic Research Center, University of Alaska Fairbanks
2. National Aeronautics and Space Administration
3. National Oceanic and Atmospheric Administration (NOAA), Arctic Research Office
4. NOAA, National Environmental Satellite, Data and Information Service
5. NOAA, Office of Global Programs
6. Naval Oceanographic Office
7. Naval Research Laboratory
8. National Science Foundation
9. Office of Naval Research
10. U.S. Coast Guard

buoys were deployed using logistics coordinated by the USIABP. The USIABP also funds the coordination and data management of the IABP by the PSC. The observations from the IABP are posted on the Global Telecommunications System for operational use; they are also archived at the World Data Center for Glaciology at the National Snow and Ice Data Center (http://nsidc.org) and can be obtained from the IABP web server for research (http://iabp.apl.washington.edu).

Uses of IABP Data

The observations from the IABP have been particularly important for:

- Forecasting weather. The IABP buoys are essential for analyzing and forecasting weather features in the Arctic.
- Detecting Arctic and global climate change. One of the first indicators of Arctic climate change was found by Walsh and colleagues using the buoy data. They showed that sea level pressure over the Arctic Ocean decreased by over 4 hPa from 1979 to 1994. Data from the IABP have also been assimilated into the global temperature data sets, and the IABP surface air temperature analysis shows that the increased air temperatures noted over land extend out over the Arctic Ocean. Specifically, Rigor and colleagues found warming trends in surface air temperature (SAT) over the Arctic Ocean during winter and spring, with values as high as 2°C per decade in the eastern Arctic during spring.
- Forcing, assimilating, and validating global weather and climate models. For example, the buoy data have been used to validate the Polar Ice Prediction System model developed at the Naval Research Laboratory and are assimilated into the National Center for Environmental Prediction–National Center for Atmospheric Research re-analysis data sets.
- Predicting sea ice conditions. Our ability to accurately forecast sea ice conditions depends on observations of surface air temperature and sea ice motion over the Arctic Ocean. For example, during the summers of 2002 and 2003, lower-than-normal air temperatures were observed over the Alaskan coast, and yet record minima in sea ice extent were observed. To explain this paradox, Rigor and Wallace hypothesized that these recent minima may be due to changes in the thick-

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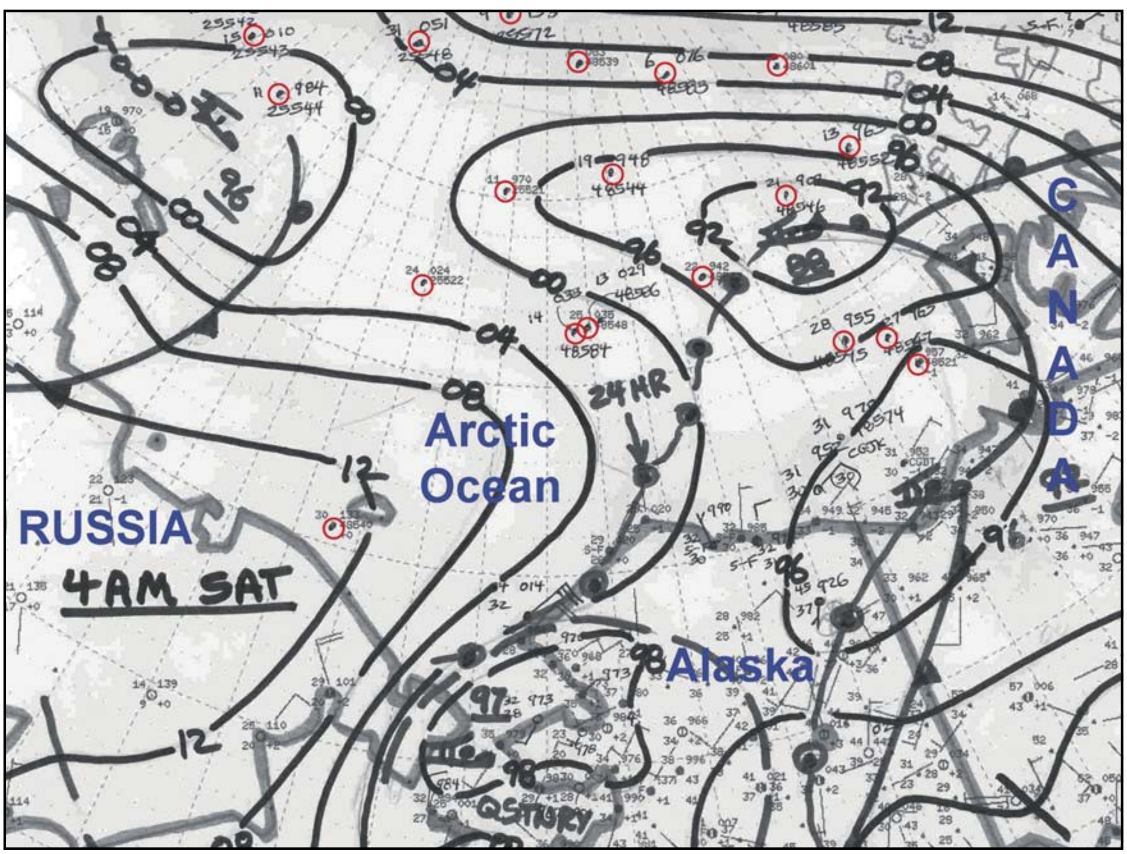
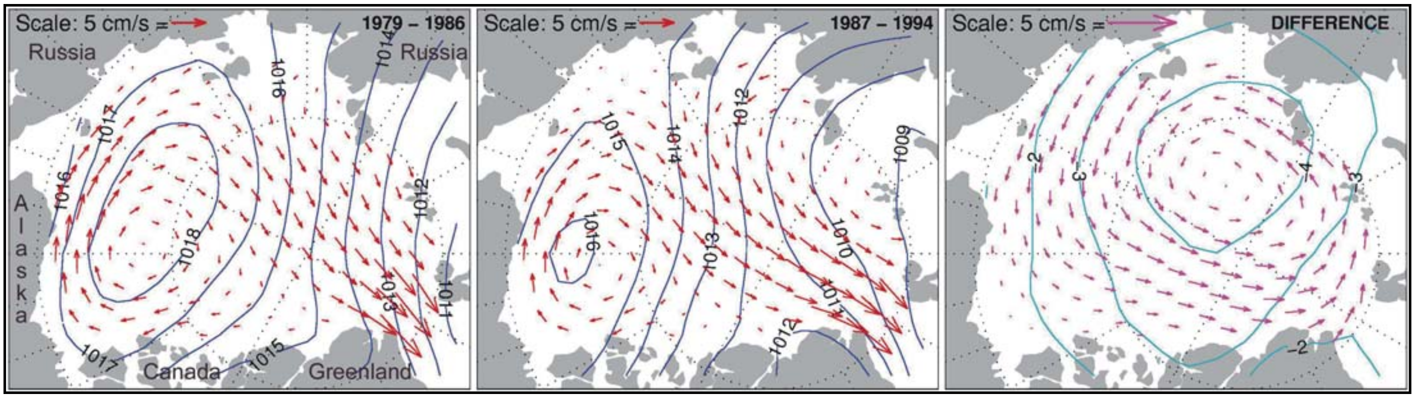


Weather map showing a cyclone approaching Alaska from the Arctic Ocean. The red dots show the positions of the IABP buoys. The strength and trajectory of this storm would have been difficult to predict without observations from the buoys.



Change in sea level pressure over the Arctic Ocean. Using IABP data, Walsh and colleagues showed that SLP decreased by over 4 hPa (right), when they took the difference between IABP SLPs from 1979 to 1986 (left) and 1987 to 1994 (center). These changes in SLP (winds) drive a cyclonic anomaly in ice motion (vectors).

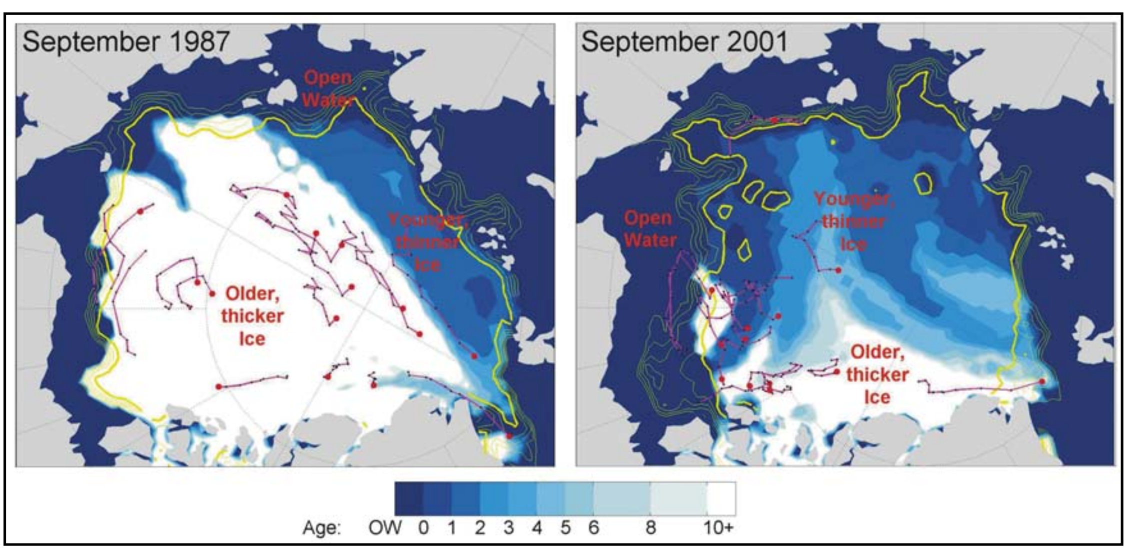
ness of sea ice blown towards the Alaskan coast by the surface winds. To show this, they used a simple model to estimate the age of sea ice based on the observed drift (residence time) of the sea ice provided by the buoys. They showed that the age (and thickness) of sea ice has decreased dramatically in the 1990s, and this younger, thinner sea ice was observed to drift towards the Alaskan coast during the last few years. They argued that although temperatures may have been lower, the air was still warmer than the melting temperature of sea ice, and it simply takes less heat to melt younger, thinner sea ice, thus explaining the recent record minima in sea ice extent.

As of 2004, over 500 papers have been written using the observations collected by the IABP.

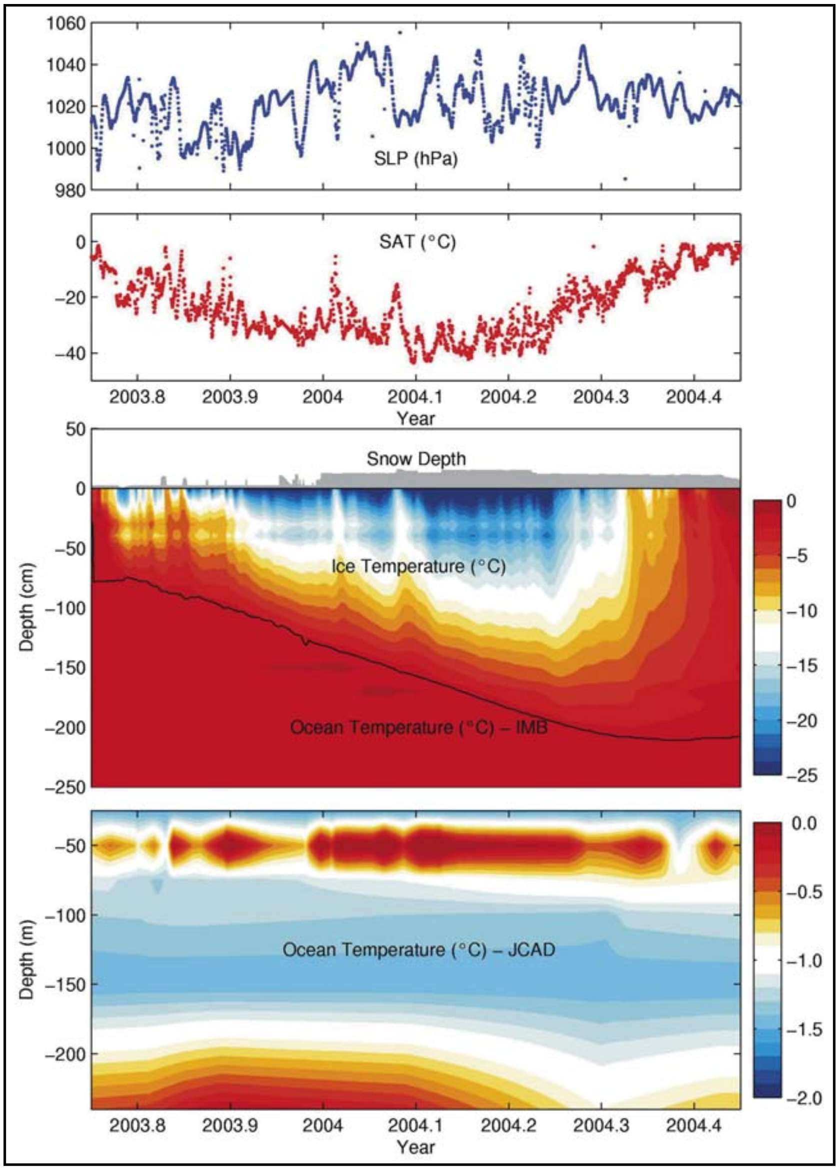
IABP in the Future

The observations from IABP have been one of the cornerstones for environmental forecasting and studies of climate and climate change. Many of the changes in Arctic climate were first observed or explained using data from the IABP.

The IABP is also evolving to better support the operational and research requirements of the community. For example, some of the participants of the IABP have been deploying buoys that measure not only SLP and SAT, but also ocean currents, temperatures, and salinity. Other buoys have been enhanced to measure the ice mass balance using thermistor strings and pingers aimed at the top and bottom of the sea ice. The data provide a myriad of concurrent time series at a few points across the Arctic Ocean. From these data we can also estimate time variations in other geophysical variables, such as oceanic heat storage and heat flux. These stations provide critical atmospheric, ice, and upper ocean hydrographic measurements that cannot be obtained by other means. These data can be used for validating satellites; for forcing, validation, and assimilation into global climate models; and for forecasting weather and ice conditions.



Changes in the age (thickness) of sea ice from September 1987 to September 2001. The larger area of younger, thinner ice (right) is less likely to survive the summer melt. For details, see "Variations in the age of sea ice and summer sea ice extent," by I.G. Rigor and J.M. Wallace, Geophysical Research Letters, *Vol. 31, 2004, which can be obtained from http://iabp.apl.washington.edu/IceAge&Extent/).*



Monitoring the Arctic using enhanced IABP buoys. The top two panels show sea level pressure and surface air temperature measured by the Japan Agency for Marine–Earth Science and Technology (JAMSTEC) Compact Arctic Drifter (JCAD) and an ice mass balance (IMB) buoy that are collocated in the Arctic Ocean. The third panel shows snow depth, ice temperature, ice thickness, and ocean temperature measured by the IMB. The bottom panel shows ocean temperatures from the JCAD.

The Arctic and global climate system is changing. These changes threaten our Native cultures and ecosystems, but they may also provide economic and social opportunities. To understand and respond to these changes, we need to sustain our current observational systems, and for the Arctic, the IABP provides the longest continuing record of observations.

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