Research, Coordination, Data Management and Enhancement of the International Arctic Buoy Programme (IABP) – A US Interagency Arctic Buoy Programme (USIABP) contribution to the IABP

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LONG-TERM GOALS

Our ability to predict weather and sea ice conditions requires *in situ* observations of surface meteorology and ice motion. These observations are assimilated into Numerical Weather Prediction (NWP) models that are used to forecast weather on synoptic time scales, and into the many long-term atmospheric reanalyses such as NASA's Modern-Era Retrospective Analysis for Research and Applications (MERRA, Koster et al. 2016) and the NCEP/NCAR Reanalysis that are used for innumerable climate studies. The impact of these *in situ* observations can be seen in Fig. 1 where Inoue et al. (2009) shows that the standard deviation in gridded sea level pressure (SLP) reanalyses fields over the Arctic Ocean was over 2.6 hPa in areas where there were no buoy observations to constrain the reanalyses, and this uncertainty in the SLP fields spreads to cover the entire Arctic when the observations from buoys are removed from the reanalyses. The buoy observations also help constrain of estimates of wind and heat. *In situ* observations of sea ice motion are also important for estimating the drift of various areas and types of sea ice, and for understanding the dynamics of ridging and rafting of this ice, which changes the thickness distribution of sea ice. For example, the analyzed fields of ice motion that Kwok and Cunningham (2016) and Kwok (2015) are based on retrievals of ice motion from sequential satellite images and buoy drift. Over the Arctic Ocean, this fundamental observing network is maintained by the IABP, and is a critical component of the Arctic Observing Network (AON) and support for the Polar Prediction Project (PPP), and Year of Polar Prediction (YOPP).

OBJECTIVES

Maintain a network of drifting buoys on the Arctic Ocean to provide meteorological and oceanographic observations for real-time operational requirements and research.

APPROACH

The IABP is a collaborative effort of 36 different research and operational institutions from many different countries (http://iabp.apl.washington.edu/Participants.htm). No single institution or agency can solely maintain the AON. The IABP is funded and managed by the Participants of the program. Management of the IABP is the responsibility of the Executive Committee, of which Co-PI John

Woods is a member, and operation of the program was delegated to the Coordinator of the IABP, PI Dr. Ignatius Rigor.

The United States contribution to the IABP is coordinated through the United States Interagency Arctic Buoy Program (USIABP), which is managed by PI Dr. Rigor at the PSC/APL/UW. The USIABP is also a collaborative program that draws operating funds and services from a number of U.S. government organizations and research programs, which include the NASA, the Coast Guard, Department of Energy, the National Oceanic and Atmospheric Administration, the National Science Foundation, the Naval Oceanographic Office, the USNIC, and the Office of Naval Research. From these contributions the USIABP acquires and deploys buoys on the Arctic Ocean, and supports the Coordination, and Data Management for the IABP.

WORK COMPLETED

1) Arctic Buoy Deployments

In 2018, the USIABP deployed:

1) March 2018: 2 Microstructure of Ice Salinity and Temperature (MIST) buoys funded by NSF deployed, and 2 SVP-Bs.
2) March 2018: 2 SVP-Bs, 5 Ice Trackers during the Arctic Submarine Laboratory (ASL) Ice Experiment (ICEX).
3) April 2018: 1 Ice Tracker at North Pole by Ann Daniels, an adventurer, who trekked from the Russian camp Barneo.
4) June 2018: 3 AXIB, 1 Ice Tracker, and 14 SVP-Bs using a RCAF C-130 coordinated by Woods as part of the International Cooperative Engagement Program for Polar Research (ICE-PPR). The SVP-Bs were provided by the Environment and Climate Change Canada (ECCC).
5) August, September 2018: 3 AXIBs, 1 Ice Trackers using a USCG C-130.
6) Summer 2018: 2 XIBs, 8 SVP-Bs using CGC Healy cruises.
7) Summer 2018: 8 SVP-Bs using RV Polarstern.
8) Summer 2018: 8 SVP-Bs, 2 UpTempOs using NABOS cruise.

We had also planned to deploy 10 SVP-B s from Russian Ice Breakers during the summer of 2018, but we didn’t get permits for these buoys in time to deploy them. We have since obtained the permits to deploy these in 2019.

In 2019, the USIABP deployed:

1) March 2019: 3 Ice Trackers, 1 Sidekick (webcam), and 1 Ice Pelican (barometer, SST) by the Arctic Submarine Laboratory.
2) March 2019: 3 new Scalable Polar Ice Trackers (SPIT) developed by the USIABP, and 1 ECCC Ice Ball on fast ice north of Tuktoyaktuk and Pelly Island, Canada with the support of Canadian Forces. We had also planned to deploy 2 more SVP-Bs and 1 IMB on the drift ice using RCAF Twin Otters, but the sea ice in range of Inuvik, Canada was too thin to land on.
3) April 2019: 3 SVP-Bs, 2 SPITs on Fast Ice north of Utqiaġvik, Alaska. We will also be deploying 2 prototype Ice Mass Balance buoys developed by Cy Keener at the University of Maryland in collaboration with the USIABP.
4) April 2019: 2 SVP-Bs, and 2 SPITs on Fast Ice north of Utqiaġvik, Alaska. We deployed 2 prototype Ice Mass Balance buoys developed by Cy Keener at the University of Maryland in

collaboration with the USIABP.

5) July 2019: 3 AXIBs, 9 ECCC SVP-Bs using RDAF C-130 coordinated by USIABP as part of ICE-PPR.
6) Summer 2019: 2 DAMPs developed by USIABP, and 20 SVP-Bs using CGC Healy and other ships; 6 SVP-Bs w/ drogues in the Bering Sea during transits, and 6 SVP-B w/o drogues and 2 DAMPs in the Beaufort and Chukchi seas during science cruises.
7) Summer 2019: 10 SVP-B using Russian Ice Breakers in the Eurasian sector.

We also cover satellite telemetry costs for Alfred Wegener Institute (AWI) buoys deployed in the Arctic and Antarctic from 2018 – present. In brief, AWI's funding can buy buoys, but not pay for satellite telemetry costs.

As of 19 March 2020, there were 194 buoys reporting in the IABP array: 73 of which were reporting around the MOSAiC experiment. The USIABP either purchased, deployed or covers satellite telemetry for 74 of the 194 buoys. (. 2).

2) IABP Coordination

In addition to the buoy purchases and deployment logistics described above, this grant also partially funds the coordination of the entire IABP. All the Arctic buoys are purchased and deployed using a combination of equipment and logistics coordinated with collaborators of the IABP (Fig. 2).

3) Sea Ice Drift Forecast Experiment (SIDFEx, 2017–2020)

The SIDFEx is a community effort to collect and analyze Arctic sea ice drift forecasts at lead times from days to a year, based on arbitrary methods, for a number of sea-ice buoys and, ultimately, research icebreaker *Polarstern*, on a regular basis.

SIDFEx is motivated in part by the need to determine an optimal deployment position of the research icebreaker *Polarstern* when she will start her year-long drift across the Arctic in autumn 2019 (Multidisciplinary drifting Observatory for the Study of Arctic Climate – MOSAiC; http://www.mosaicobservatory.org). Specifically, it is unclear whether forecast systems that account for initial conditions and provide forecasts of the evolving atmosphere, ice, and ocean system, can provide additional skill over drift forecasts made using historical sea-ice velocity fields. The MOSAiC drift provides a template for assessing the capabilities to forecast sea-ice drift for a range of applications, ranging from logistics support for future field experiments to potential search and rescue operations. The examination of sea-ice drift forecasts provides an integrated assessment of many aspects of the coupled atmosphere-ice-ocean system and will motivate in depth investigations into how key variables are measured, modelled, and forecast. In particular, we expect coordinated drift forecasts to draw attention to the interaction between sea-ice physics and boundary layer physics in both atmosphere and ocean. We expect that a systematic assessment of real drift forecasting capabilities will improve our physical understanding of sea-ice and enable us to identify and resolve model shortcomings and identify limits of predictability.

SIDFEx is largely the result of discussions held at various meetings, in particular in the context of the Year of Polar Prediction (YOPP), MOSAiC (http://www.mosaicobservatory.org), the Sea Ice Prediction Network (SIPN; https://www.arcus.org/sipn), the Forum of Arctic Modelling and Observations Synthesis (FAMOS; http://famosarctic.com/index.html), and the International Arctic Buoy Programme (IABP; http://iabp.apl.washington.edu/SIDFEX.html).

4) Arctic Observations Experiment (AOX)

We deployed the AOX buoy test site in Barrow, Alaska in March 2013 at the DOE Atmospheric Radiation Measurement (ARM) site (which is also next to the NOAA Climate Reference Network site). The AOX test site has 15 buoys that represent the typical instruments that the IABP routinely deploys on the Arctic Ocean. We originally planned to deploy this for one year, but are now thinking of maintaining the site indefinitely to test other instruments that the IABP and AON may use in the polar regions (Figs. 4).

5) Collaboration and coordination with *In Situ*, Aerial and satellite surveys

We have been working with the NRL DISTANCE, NASA Operation Ice Bridge (OIB), NASA GLAWEX, and other researchers. The *in situ*, and aerial surveys by the projects provide logistics to deploy our buoys, and in turn, our buoys provide markers that they can track as their survey lines drift across the Arctic Ocean. The positions of these and other IABP buoys are also provided to the USGS so these pieces of sea ice may be tracked for the Global Fiducials Library (GFL, http://gfl.usgs.gov/index.shtml). Melinda Webster, a former graduate student in Physical Oceanography here at the UW, and now a Scientist at NASA Goddard, has been analyzing these buoy observations, OIB data, and GFL imagery for her dissertation research on snow and the evolution of melt ponds (e.g. Webster et al. 2014 and 2015).

RESULTS

The data from all IABP and IPAB buoys are released to the research community through our server http://iabp.apl.uw.edu, and operational communities in near real-time through the WMO/IOC Global Telecommunications System (GTS). As part of this grant we QA/QC the data from the Arctic buoys for the WMO/GTS. We have also coordinated the posting of ocean data from the Arctic ocean profiling buoys onto the GTS (i.e. the WHOI Ice Tethered Platforms, and PSC Upper layer Temperature of the Ocean). All the meteorological, and ocean data posted on to the GTS by the IABP may be viewed at http://www.jcommops.org/dbcp/network/maps.html (e.g. Figs. 2 & 3) and http://osmc.noaa.gov/Monitor/OSMC/OSMC.html.

Research quality fields of ice motion, sea level pressure (SLP) and surface air temperature are also analyzed and produced by the APL-UW; these fields can be obtained from the IABP web server at http://iabp.apl.washington.edu/, and have been archived at various data centers.

We are working on collecting all the metadata for all the buoys going back to 1979, which will allow others to process the raw buoy data. And we are currently reformatting our databases from 1979 – present into netCDF.

IMPACT/APPLICATIONS

The observations from the IABP have been essential for: 1.) Monitoring Arctic and global climate change (many of the changes in Arctic climate were first observed or explained using data from the IABP); 2.) Forecasting weather and sea ice conditions; 3.) Forcing, assimilation and validation of global weather and climate models; 4.) Validation of satellite derived estimates of sea ice motion, surface temperature, sea ice thickness, etc.

RELATED PROJECTS

NONE

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Since the inception of this project over 1000 papers have been published using data produced by this grant. Since 2018, over 69 papers acknowledge use of our data:

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Figures

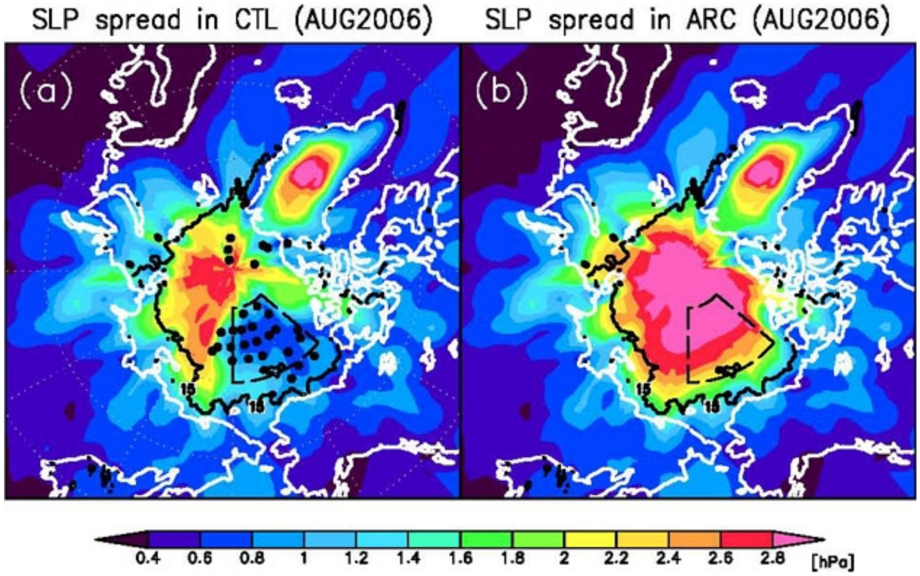

Figure 1. Standard deviation (SD) of sea level pressure measurements from various atmospheric reanalyses. The SD is low in areas where there are buoy observations (left). The spread increases to cover the whole Arctic when the observations from the buoys are removed from the reanalyses (right). [Inoue et al. 2009]

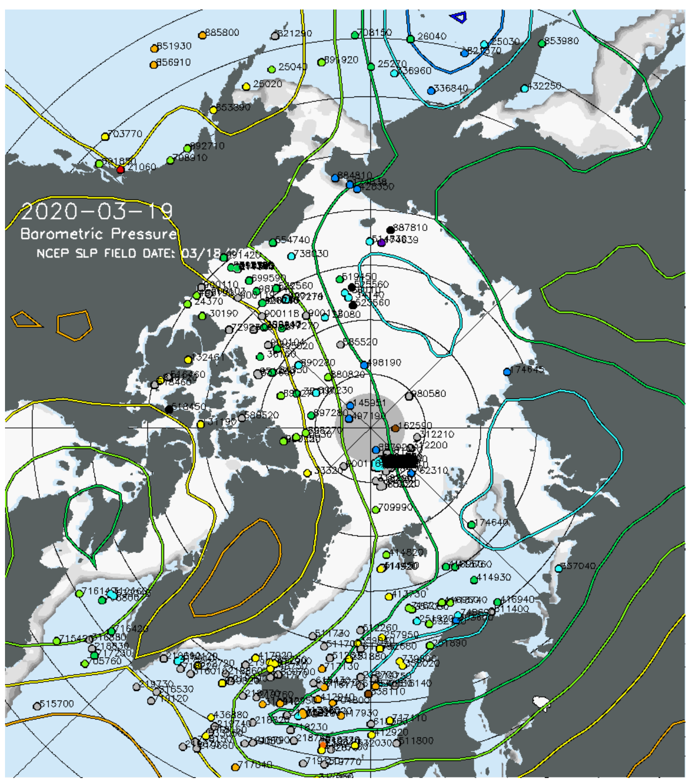

Figure 2. Map of buoys reporting from the Arctic Ocean on 19 March 2020. There are currently 238 buoys reporting in the IABP observing network.

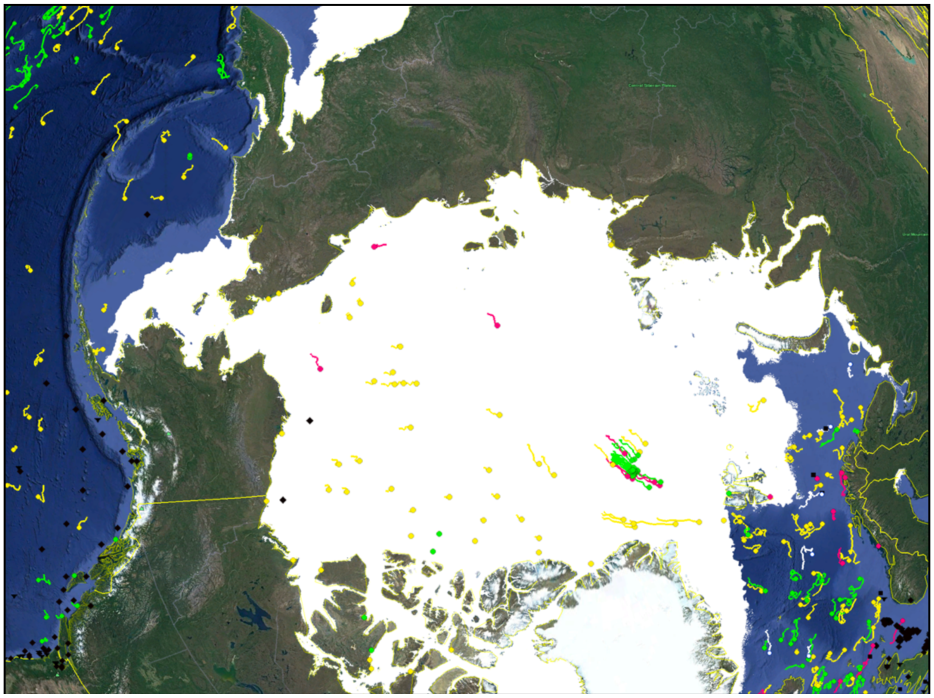

Figure 3. Map of all observations available on the WMO/IOC GTS on 19 March 2020 obtained from the European Meteorological Network (EUMETNET) overlaid on the Multisensor Analyzed Sea Ice Extent (MASIE).

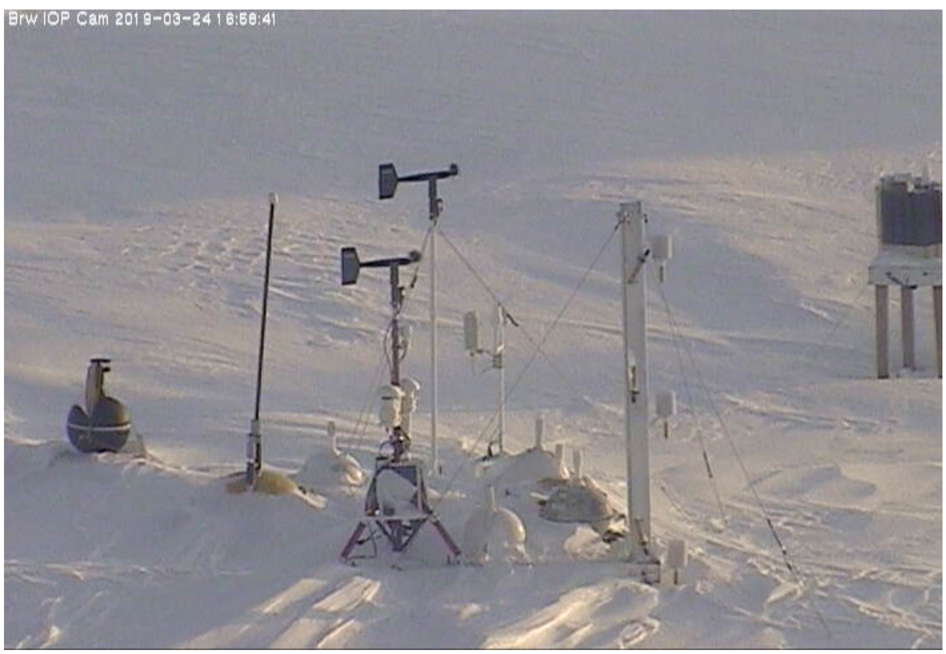

Figure 4. Arctic Observing Experiment (AOX) IABP buoy test site at the DOE Atmospheric Radiation Measurement in Utqiagvik, Alaska on 24 March 2019. The IABP has been assessing and monitoring the accuracy of their buoys since March 2013.

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14. ABSTRACT
Our ability to predict weather and sea ice conditions requires in situ observations of surface meteorology and ice motion (Chief of Naval Operations, 2019; National Research Council, 2012). These observations are used for validation of numerical models, for example, Allard et al. (2018) and Hebert et al. (2015) use IABP data to validate the Navy Global Ocean Forecasting System (GOFS). These observations are also assimilated into Numerical Weather Prediction (NWP) models that are used to forecast weather on synoptic time scales, and into the many long-term atmospheric reanalyses that are used for innumerable climate studies (e.g., NCEP/NCAR Reanalysis, Kalnay et al. 1996). Over the Arctic Ocean, this fundamental observing network is maintained by the US Interagency Arctic Buoy Program and the International Arctic Buoy Programme. During the last 5 years, we deployed 271 buoys ranging in size from small Ice Trackers, to large Airborne Seasonal Ice Buoys, and Microstructure of Ice Salinity and Temperature buoys. Over 110 publications citing use of IABP data over the period of the most recent grant. These observations provide the longest continuous record for the Arctic and continue to be one of the cornerstones for environmental forecasting and research.

15. SUBJECT TERMS
Drifting Buoys, Arctic, Sea Ice, Surface Meteorology, Ice Motion, Ocean Circulation, Weather

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