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 (e.g. 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. Over the Arctic Ocean, this fundamental observing network is maintained by the IABP, and is a critical component of the Arctic Observing Network (AON).

OBJECTIVES

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

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support to the World Climate Research Programme, the World Weather Watch Programme, and the Arctic Observing Network (AON).

APPROACH

The IABP is a collaborative effort of 32 different research and operational institutions from many different countries (http://iabp.apl.washington.edu/Participants.htm). No single institution or agency can 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 Dr. Pablo Clemente-Colón is a member, and operation of the program is 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 Lt. Curtis Reinking and PI Dr. Rigor. 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 Office of Naval Research (ONR; this grant and prior Grant # N00014-10-1-0506), the Department of Energy, International Arctic Research Center, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Science Foundation, Naval Academy, NAVICE, the Naval Oceanographic Office, the Naval Research Lab, and the U.S. Coast Guard. From these contributions the USIABP acquires and deploys buoys on the Arctic Ocean, and supports the Coordination, Data Management and Enhancement for the IABP by the PSC/APL/UW.

WORK COMPLETED

During the past year we purchased 10 large (8 AXIB, 2 PAWS), and 40 smaller meteorological buoys (SVP) using funds contributed to the USIABP. Twenty SVP buoys were purchased from MetOcean, who has been providing reliable buoys for many years, and also builds the PAWS buoy; and we purchased 20 more SVP buoys from new suppliers: Pacific Gyre in California, and Marlin Yug, in the Ukraine.

These buoys were deployed during various field campaigns as follows:

1) USIABP Buoy Deployments

From 2012 to 2013 we deployed 8 large (6 AXIB, 2 PAWS) buoys, refurbished 4 ICEXAIR buoys, and 40 smaller meteorological buoys. (SVP-B). This is the largest expenditure by the USIABP on buoys in any given year, but this reflects the deteriorating condition of the Arctic sea ice and the increasing challenge to maintain the AON.

Two of the AXIB buoys were shipped to Kodiak and will be deployed by the US Coast Guard during their Arctic Domain Awareness flights during the summer of 2013 (e.g. Fig. 2. The other 2 will be deployed from the ice breaker Healy. The 2 PAWS buoys were deployed by Jamie Morison at the NPEO in April 2013, while the 40 SVP-B were distributed between the ice breakers operating in the Arctic during the summer of 2013 (e.g. Healy, NABOS, Federov.

We are also developing a new collaboration with Alexander Salman, of ES-PAS in Moscow Russia. ES-PAS is the Argos data provider in Russia, and through this connection we have been able to import buoys into Russia at a much reduced tariff rate. So far we have deployed 3 buoys in April (Fig. 3), and had planned to deploy 8 more buoys around the Russian North Pole (NP) Manned Station. However, funding for this cruise was cancelled, and we are now planning a mid-winter deployment at the north pole.

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. 3).

We have been working with the US CG to deploy buoys during the Arctic Domain Awareness flights. In 2009, we have been able to certify 3 of our buoys (AXIB, ICEX, and SVP-15BG) for deployment from the USCG C-130s. During the past year we have been working with Environment Canada to also certify these buoys for deployment from Canadian Forces C-130s. This October, we plan to deploy 11 buoys using these new assets (Fig. 5).

3) IABP Data Management
The data from all USIABP buoys are released to the research and operational communities in near real-time through the WMO Global Telecommunications System. 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 JAMSTEC Polar Ocean Profilings Systems). 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. Fig. 4) 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.

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 through March 2015 to test other instruments that the IABP and AON may use in the polar regions (Figs. 6 & 7).

RESULTS

The IABP currently has 96 buoys reporting in the Arctic (Fig. 4), of which 28 were purchased using funds contributed to the USIABP (2 PAWS, 4 AXIBs, and 22 SVPs).

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.

Since the inception of the program, over 600 publications have been written using data from the IABP. A list of these citations through 2008 can be viewed at http://iabp.apl.washington.edu/publications_citations.html. We are currently in the process of updating this list through the present, however, and simple query http://scholar.google.com of "Arctic buoys – Antarctic" yields over 6000 results in the peer reviewed and popular literature.

RELATED PROJECTS

The USIABP/IABP is collaborative effort that leverages existing field campaigns to maintain the fundamental observations required for AON, e.g. the primarily NSF funded North Pole Environmental Observatory, and in turn the observations collected by the USIABP/IABP is used for operational forecasting of weather and ice conditions, and for research. For example, the surface temperatures from the IABP complement the measurements of upper ocean temperature by Dr. Steele (ONR Grant # N00014-12-1-0224), and are being used by Dr. Schweiger (ONR Grant # N00014-12-1-0232) to validate the Weather Research Forecasting model. We collaborate with Dr. Morison in SIZRS (ONR Grant # N00014-12-1-0231) and assist each others projects on the Coast Guard Arctic Domain Awareness flights. We also collaborate with LCDR John Woods of the of the Naval Academy (ONR Grant # N00014-13-AF00002).

REFERENCES

Inoue, J., T. Enomoto, T. Miyoshi, and S. Yamane (2009), Impact of observations from Arctic drifting buoys on the reanalysis of surface fields, *Geophys. Res. Lett.*, *36*, L08501, doi:10.1029/2009GL037380.

PUBLICATIONS

Strong, C., and **I. G. Rigor**, Arctic marginal ice zone trending wider in summer and narrower in winter, Geophys. Res. Lett., 40, doi:10.1002/grl.50928, 2013. [published, refereed].

Nghiem, S.V., **P. Clemente-Colón, I.G. Rigor**, D.K. Hall, G. Neumann, Seafloor control on sea ice. Deep-Sea Res. II (2012), http://dx.doi.org/10.1016/ j.dsr2.2012.04.004, 2012. [published, refereed]

Hutchings, J., and **I. Rigor**, Role of ice dynamics in anomalous ice conditions in the Beaufort Sea during 2006 and 2007, J. Geophys. Res, v. 117, C00E04, 14, doi:10.1029/2011JC007182, 2012. [published, refereed]

Nghiem, S. V., **I.G. Rigor**, A. Richter, J.P. Burrows , P.B. Shepson, J. Bottenheim, D.G. Barber, A. Steffen, J. Latonas, F. Wang, G. Stern, P. Clemente-Colón S. Martin, D.K. Hall, P. Tackett, G. Neumann, and M.G. Asplin, Field and satellite observations of the formation and distribution of

Arctic atmospheric bromine above a rejuvenated sea ice cover, *J. Geophys. Res.*, 117, D00S05, doi:10.1029/2011JD016268, 2012. [published, refereed]

Morison, J., R. Kwok, C. Peralta-Ferriz, M. Alkire, **I. Rigor**, R. Andersen, and M. Steele, Changing Arctic Ocean Freshwater Pathways Measured With ICESat and GRACE, *Nature*, Vol. 481, doi:10.1038/nature10705, 2012. [published, refereed]

Darby, D. A., W. B. Myers, M. Jakobsson, and **I. Rigor**, Modern dirty sea ice characteristics and sources: The role of anchor ice, *J. Geophys. Res.*, *116*, C09008, doi:10.1029/2010JC006675, 2011. [published, refereed]

Stroeve, J. C., J. Maslanik, M. C. Serreze, **I. Rigor**, W. Meier, and C. Fowler, Sea ice response to an extreme negative phase of the Arctic Oscillation during winter 2009/2010, *Geophys. Res. Lett.*, *38*, L02502, doi:10.1029/2010GL045662, 2011. [published, refereed]

FIGURES

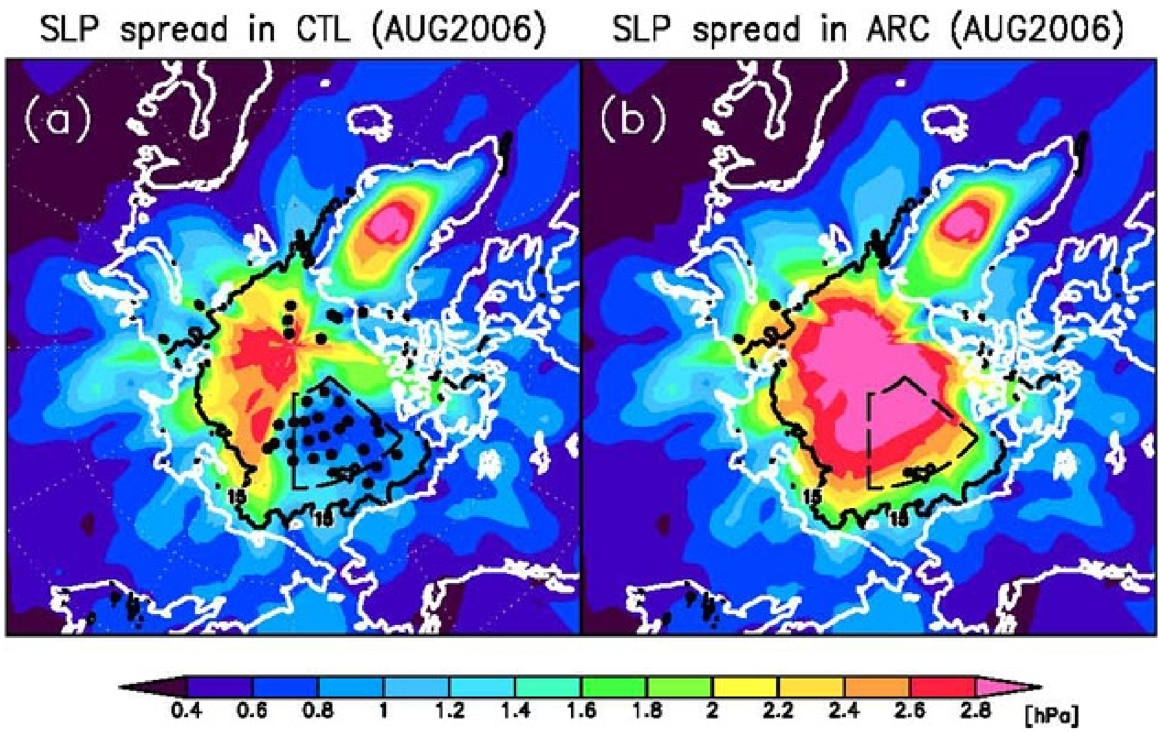

Figure 1. Standard deviation (SD) of sea level pressure measurements from various atmospheric reanalyses. The SD is low in areas where there are buoy observations (left). The spread increases to cover the whole Arctic when the observations from the buoys are removed from the reanalyses (right). [Inoue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

Figure 2. Deployment of the Airborne eXpendable Ice Beacon (AXIB) buoy 100181 from an Arctic Domain Awareness flight in August, 2012 (top). The AXIB was developed by the USIABP specifically to survive annual freeze/thaw cyles in the harsher, dynamic conditions of the seasonal ice zone.

Figure 3. Deployment of an Marlin Yug SVP-B buoy in the Russian sector of the Arctic by Alexander Salman in April 2013. This buoy measures air pressure, surface temperature, and GPS positions.

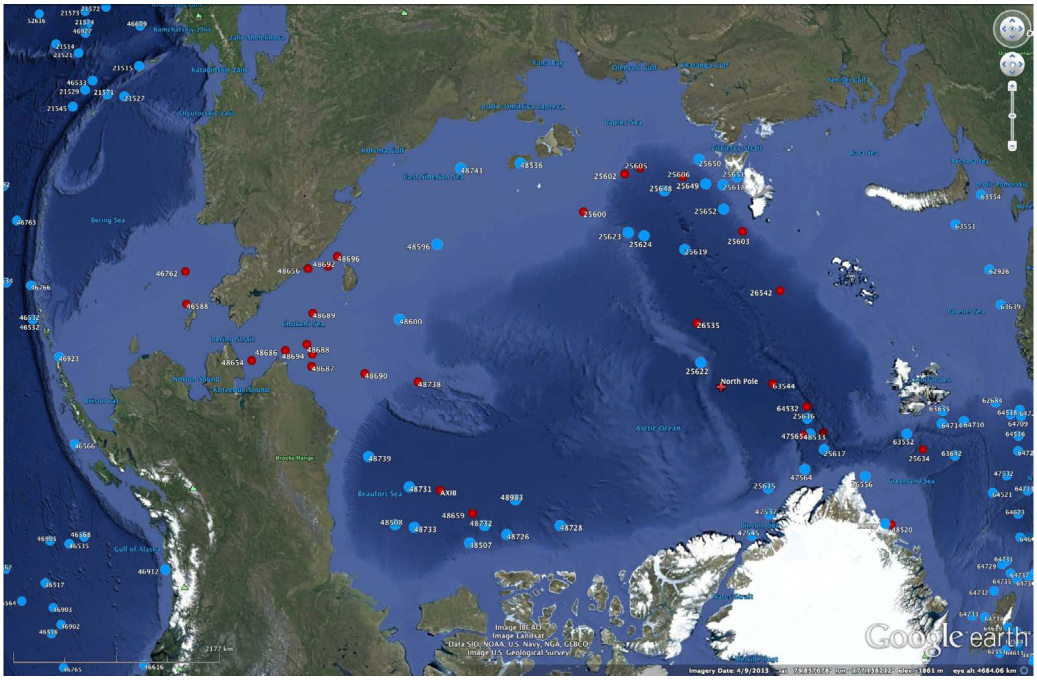

Figure 4. Map of drifting buoys reporting on Sep. 25, 2013 on the WMO/IOC Global Telecommunications System. Sixty-six buoys reported from the Arctic Ocean and the Bering Sea, 28 of which were purchased by the USIABP (red dots), including funds from this grant. These buoys were deployed using the North Pole Environmental Observatory, the CG icebreaker Healy, the CG Arctic Domain Awareness flights, UAF NABOS Cruise.

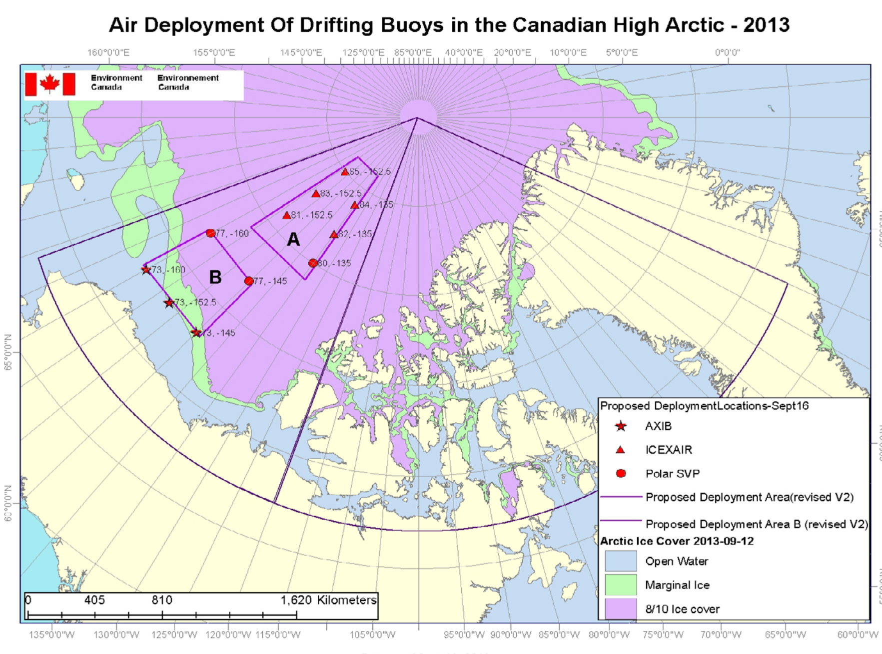

Figure 5. Deployment plan for buoys that will be air droped by Canadian Forces in October, 2013.

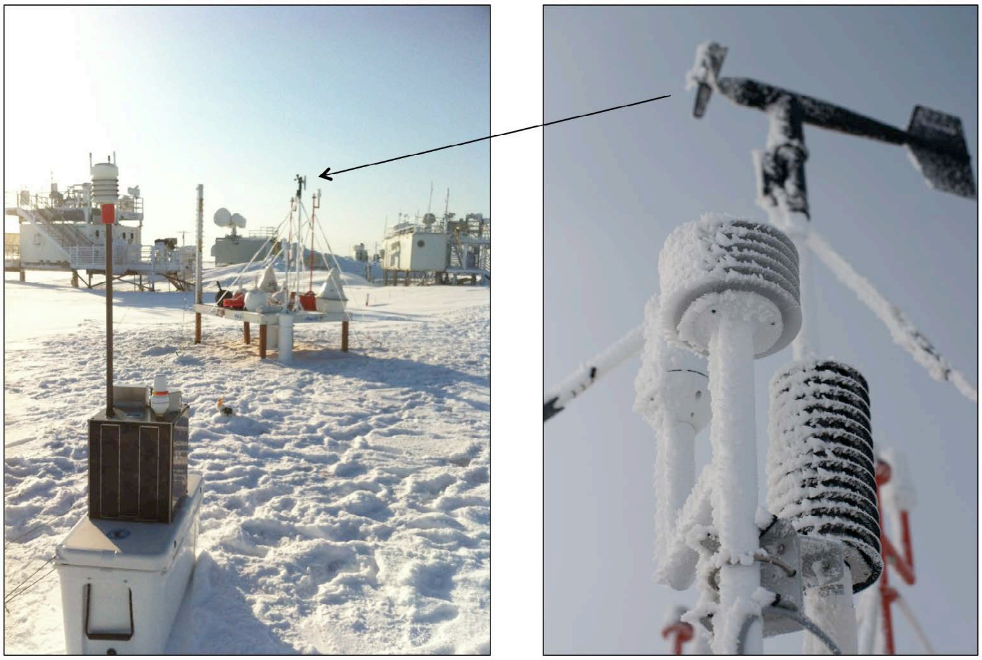

Figure 6. Arctic Observing Experiment (AOX) IABP buoy test site with the DOE Atmospheric Radiation Measurement site in the background. The "buoy" in the foreground is a prototype IceKid buoy being developed by the Naval Academy. This buoy has a WXT 520 weather station, which measures winds, air pressure, air temperatures, and relative humidity. The IceKid also has web cams which are used to determine when the buoys on the AOX test table are in the shade or sunlight.

Figure 7. Air temperature sensor shields used by different manufacturers of buoys used by the IABP. How well do the different shields reduce solar heating of the sensor and reduce the bias in the air temperature measurement.