DOE/SC-ARM-17-024

Arctic Observing Experiment (AOX) Field Campaign Report

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Acronyms and Abbreviations

AON	Arctic Observing Network
AOX	Arctic Observing eXperiment
ARM	Atmospheric Radiation Measurement
C	Celsius
CMDL	Climate Monitoring and Diagnostics Laboratory
DOE	U.S. Department of Energy
IABP	International Arctic Buoy Programme
IPAB	International Program for Antarctic Buoys
IST	ice-surface temperature
MODIS	Moderate Resolution Imaging Spectroradiometer
m/s	meters per second
NIC	National Ice Center
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSA	North Slope of Alaska
NSF	National Science Foundation
ONR	Office of Naval Research
PAWS	Polar Area Weather Station
RMS	root mean square
SOOS	Southern Ocean Observing System
SST	sea surface temperature
SVP	Surface Velocity Program, Surface Velocity Profiler
USCG	U.S. Coast Guard
XIB	Seasonal Ice Beacon

Contents

Figures

1.0 Summary

Our ability to understand and predict weather and climate requires an accurate observing network. One of the pillars of this network is the observation of the fundamental meteorological parameters: temperature, air pressure, and wind. We plan to assess our ability to measure these parameters for the polar regions during the Arctic Observing Experiment (AOX, Figure 1) to support the International Arctic Buoy Programme (IABP), Arctic Observing Network (AON), International Program for Antarctic Buoys (IPAB), and the Southern Ocean Observing System (SOOS). Accurate temperature measurements are also necessary to validate and improve satellite measurements of surface temperature across the Arctic.

Support for research associated with the campaign is provided by the National Science Foundation, and by other U.S. agencies contributing to the U.S. Interagency Arctic Buoy Program. In addition to the support provided by the U.S Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) user facility's North Slope of Alaska (NSA) site at Barrow and the National Science Foundation (NSF), the U.S. IABP is supported by the U.S. Coast Guard (USCG), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Office of Naval Research (ONR), and the U.S. National Ice Center (USNIC).

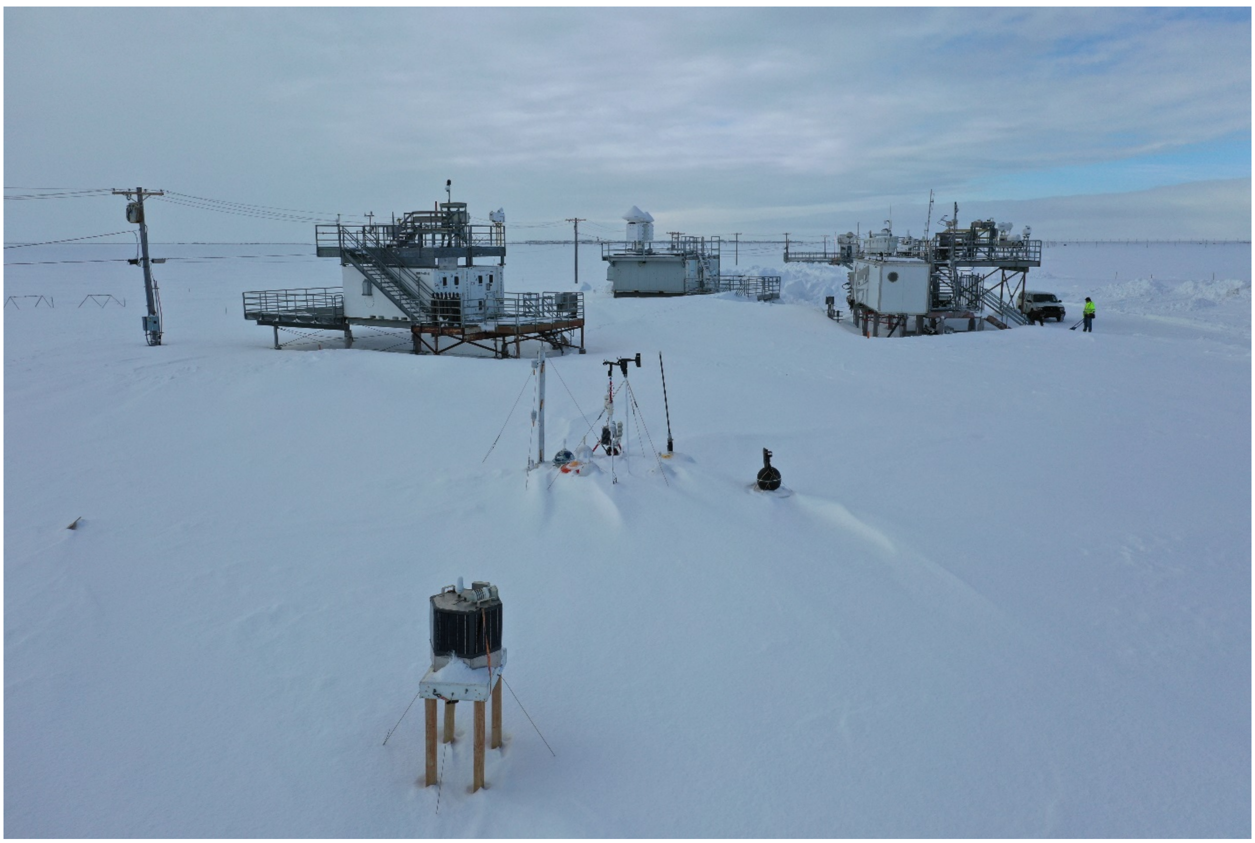

Figure 1. Arctic Observing Experiment (AOS) IABP buoy test site with the ARM NSA Barrow site in the background, on 29 March 2019. The NOAA CMDL site "behind" the camera.

2.0 Results

While we have published papers on trends in surface temperature (e.g., Jones et al. 1999), the Arctic is in the midst of rapid change. Traditionally, the IABP has deployed buoys that measure surface air temperature (Ta), which minimizes the ambiguity of measurements of surface temperature (Ts). Specifically, it is difficult to determine if the Ts sensor is measuring open water, snow, sea ice, or air. But now, with the dramatic decrease in Arctic seasonal ice extent, increase in open water during summer, and the frailty of the younger sea ice pack, the IABP has had to deploy and develop new instruments to measure temperature. These instruments include Surface Velocity Program (SVP) buoys, which are commonly deployed on the world's ice-free oceans and are designed to measure sea surface temperature (SST), and the new robust Seasonal Ice Beacons (XIB), which measure both Ts and Ta. Ts is naturally warmer than Ta (e.g., see top two panels of Figure 2). Given this difference, a first-order estimate of temperature trends using the IABP observations would imply much stronger warming trends that include a bias introduced by the changes in instruments in the IABP AON and may overestimate the real trends in the arctic system.

To quantify the bias and produce an accurate estimate of the trends in temperature, the USIABP/IABP launched the Arctic Observing Experiment (AOX) to deploy a suite of buoys at the DOE ARM and NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) sites in Barrow, Alaska, in March 2013 (Figure 2). We have been using the highest-quality observations from the CMDL and ARM sites to assess the accuracy of the instruments we use to measure Ta, Ts, air pressure, and winds over the Arctic Ocean (Figure 1, right). Preliminary results show that the color of the SVP buoy hull introduces a bias due to solar heating of the buoy. We now require that SVP buoys be painted white to reduce biases in temperature measurements due to different buoy colors deployed in different regions of the Arctic or the Antarctic.

Measurements of Ta by the buoys at the AOX site compare well with the measurements from the CMDL and ARM sites, exhibiting only a minimal bias of 0.16°C and an RMS difference of 1°C. These differences may be explained by small-scale spatial variability between the AOX site and the ARM and CMDL sites, which are ~500 m apart. Measurements of Ts by the SVP buoys (after painting them white) still showed a typical bias of 1.2°C, and an RMS difference of 2.2°C compared to the CMDL and ARM measurements of Ta. These preliminary results from AOX and other tests sites require a more rigorous analysis to quantify the biases in our measurements of temperature and to produce accurate estimates of temperature that can be used for studies of arctic and global climate and climate change. We will use this data set to assess the accuracy of readily available estimates of surface temperature from satellites such as the Moderate Resolution Imaging Spectroradiometer (MODIS) ice-surface temperature (IST; e.g., Hall et al. 2015, 2004).

Preliminary results show that some of the buoys are susceptible to solar heating, icing can block barometers for short periods, and frosting may insulate air temperature sensors and freeze-lock anemometers (Figure 3). Some of these issues may be addressed by simply painting the buoys white to reduce solar heating of the buoys, and using better temperature shields and barometer ports. But frosting of ultrasonic and mechanical anemometers remains a significant challenge.

Every buoy deployed by the IABP and IPAB has its strengths and weaknesses. The larger weather stations provide more accurate measurements, but are expensive and difficult to deploy and maintain in the increasing area of the Arctic seasonal ice zone. The smaller SVP buoys are reasonably cheap and provide good pressure measurements, but their temperature measurements can be ambiguous. Statistics from the AOX test site and a thorough description of the sensors on each buoy is in preparation by the IABP. These observations will improve our ability to document the changes in polar and global climate.

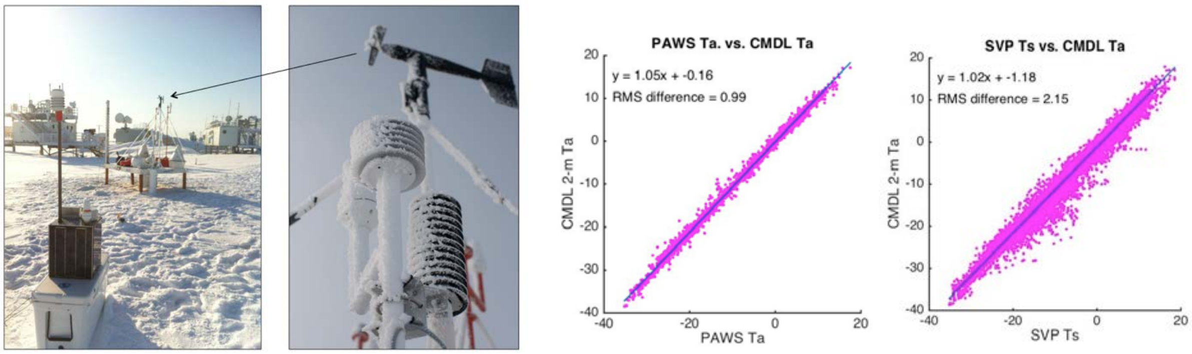

Figure 2. Arctic Observing Experiment (AOX) IABP buoy test site with the ARM site in the background. The "buoy" in the foreground is a prototype IceKid buoy being developed by the Naval Academy. This buoy has a WXT 520 weather station, which measures winds, air pressure, air temperatures, and relative humidity. The IceKid also has web cams used to determine when the buoys on the AOX test table are in the shade or sunlight. On the right, we show comparisons of the temperatures from the NOAA CMDL site, and two buoys used by the IABP, a Polar Area Weather Station (PAWS), and Surface Velocity Profiler (SVP).

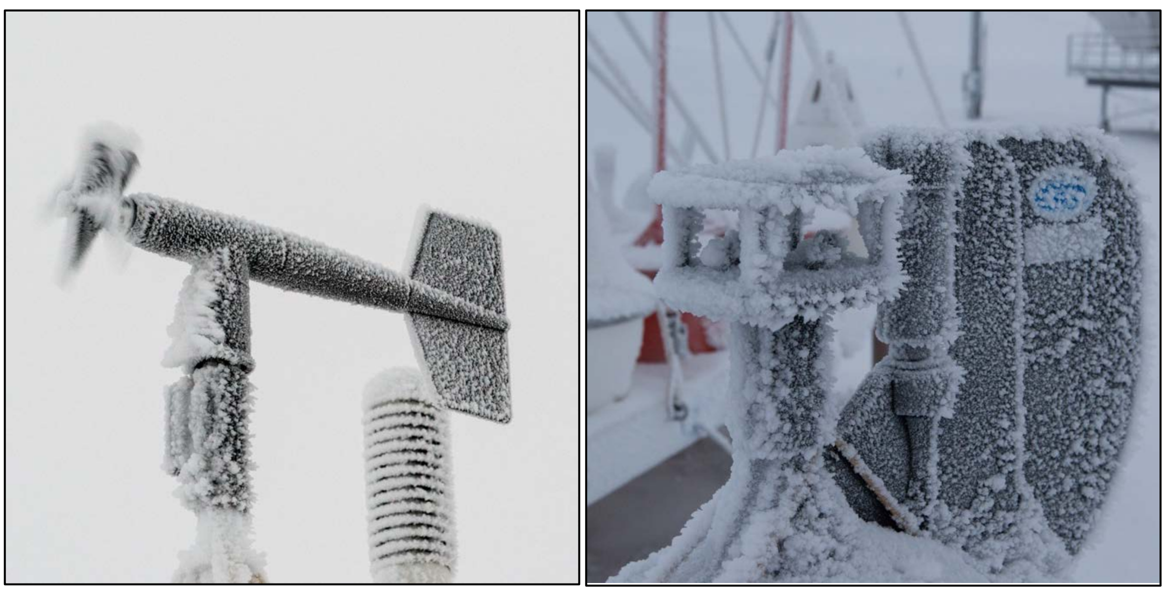

Figure 3. Winds at the test site were obstructed by the buoys on the test bed and by buildings of the ARM (west, Figure 1) and NOAA/CMDL (east) sites. From the unobstructed wind directions, the buoys compared to the CMDL winds had a slow bias of 0.8 m/s with an RMS difference of ~1.4 m/s. These differences were greater during periods when the anemometer was frosted, and even frozen up for two weeks as pictured above. The ultrasonic anemometers tested were more susceptible to frost.

3.0 Publications and References

3.1 Publications

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