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DOE/SC-ARM-19-020

The De-Icing Comparison Experiment – ARM Contribution (DICEXACO) Field Campaign Report

CJ Cox
T Uttal
A McComiskey
SM Morris
CN Long

August 2019

ARM

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CJ Cox, Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, National Oceanic and Atmospheric Administration (NOAA)
Principal Investigator

SM Morris, CIRES, NOAA
T Uttal, NOAA
CN Long, CIRES, NOAA
A McComiskey, Brookhaven National Laboratory
Co-Investigators

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
CIRES	Cooperative Institute for Research in Environmental Sciences
D-ICE	De-Icing Comparison Experiment
DICEXACO	De-Icing Comparison Experiment — ARM Contribution
GMD	Global Monitoring Division (NOAA)
IOP	intensive operational period
NOAA	National Oceanic and Atmospheric Administration
NSA	North Slope of Alaska
OLI	Oliktok Point
PSP	precision spectral pyranometer
SKYRAD	sky radiometers

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1.0 Summary

Longwave and shortwave radiative fluxes are fundamental quantities regularly observed globally using broadband radiometers. In regions conducive to frost, rime, and snow, ice frequently builds up on sensor windows, contaminating measurements. Since icing occurs under particular meteorological conditions, associated data loss constitutes a climatological bias. Furthermore, the signal caused by ice is difficult to distinguish from that of clouds, hampering efforts to identify contaminated data in post-processing. Because of the sensitivity of radiometers to internal temperature instabilities, there are limitations to using heat as a de-icing method, and consequently substantial amounts of data are lost.

The De-Icing Comparison Experiment (D-ICE) was a campaign carried out at Utqiaġvik (formerly known as Barrow) and Oliktok Point, Alaska, from August 2017 to July 2018. The purpose of D-ICE was to evaluate ventilation and heating technologies developed to mitigate radiometer icing. D-ICE consisted of 20 pyranometers and 5 pyrgeometers operating in various ventilator housings alongside operational stations run by the NOAA Global Monitoring Division (GMD) at NOAA's Barrow Atmospheric Baseline Observatory. D-ICE also evaluated the sky radiometer (SKYRAD) systems at the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) and Oliktok Point (OLI; third ARM Mobile Facility [AMF3]) observatories. In total, 34 systems were evaluated (8 of which were SKYRAD radiometers). All radiometers were monitored continuously using cameras, and a total of more than one million images of sensor domes were archived collectively between the stations. Data collected as part of D-ICE by NOAA can be found through the project web page, https://www.esrl.noaa.gov/psd/arctic/d-ice/. The DICEXACO component of D-ICE (https://www.arm.gov/research/campaigns/nsa2017dicexaco) are the images collected at 10-min intervals at both OLI and NSA and are the subject of this report. Two cameras were installed at each ARM station, one directed towards the SKYRAD tracker and the other towards the SKYRAD global precision spectral pyranometer (PSP).

Due to late freezing of the Beaufort and Chukchi Seas in 2017, significant icing conditions were not observed at NSA or OLI until late October. During winter, both rime (usually in the form of freezing fog) (Figure 1) and frost were regularly observed, collectively spanning a total of 28.8 (16.8) and 66.3 days (66.2), respectively at Utqiaġvik and Oliktok Point. Frost events were more common, being identified 108 (80) times at Utqiaġvik compared to 11 (7) rime events at Oliktok Point, though the rime events were much longer in duration than the frost events. The larger number of events captured at NSA (Utqiaġvik) relative to Oliktok Point is partially attributable to less data having been collected at Oliktok Point (61,836 images) compared to NSA (77,255 images) in association with the number of cameras available, camera uptime, and the periods of installation.

Figure 1. (a) Example of rime ice on January 11, 2018 on the global PSP at the Oliktok Point SKYRAD system. Events such as this were common during mid-winter extending into spring. (b) The same radiometer during non-icing conditions for reference.

2.0 Results

A preliminary analysis of the performance of the ventilators from the NSA and OLI sites is shown in Figure 2. Ventilator performance was measured as the percent of the time when icing conditions occurred that ventilators successfully prevented ice from forming on the radiometer dome. The red area in the figure denotes the NSA ARM (SKYRAD) station and the yellow area is the Oliktok Point ARM (SKYRAD) station. A value of 0% (y-axis) would be interpreted as the ventilator having no effect: i.e., the radiometer dome in the ventilator was iced the same amount of time as icing conditions occurred at the station. A negative value indicates mitigation of ice such that -100% means that the ventilator mitigated all potential icing. A positive value indicates the radiometer was iced more frequently than icing conditions occurred (i.e., the ventilator promoted ice). $t_{i,iced}$ (where i denotes the system) was determined by subjective analysis of the images. The amount of time icing conditions occurred (t_{icing}) was determined separately for each station using the images at that station. Thus, t_{icing} is the same value applied for each system within a given station, but differs between stations. Therefore, caution should be exercised when comparing the stations because the severity and type of icing may have differed between locations.

Overall, icing of the pyrgeometers was more effectively mitigated than for the pyranometers. This was true also for the systems evaluated at the main D-ICE location at the NOAA facility (not shown in the figure). Generally (NSA pygrometers are an exception), the NSA and OLI systems were less effective at mitigating ice than were systems at the main D-ICE station (not shown). More work is needed to identify the reasons for this. While the design elements of the ventilators may have been a factor, other factors independent of design, such as differences in the severity of icing conditions between the stations, may have contributed.

A detailed analysis of ventilator performance, including the systems evaluated at the NOAA station, as well as analyses of the biases caused by icing, and recommendations for both the operator and end-user communities, is the subject of a manuscript currently in preparation.

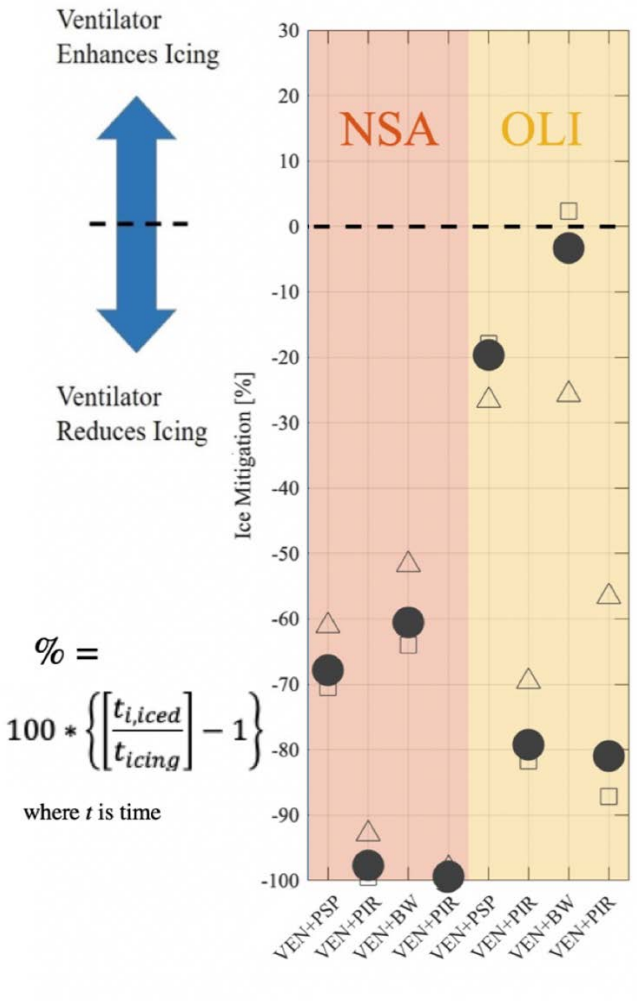

Figure 2. Ventilator performance at NSA and OLI.

3.0 Publications and References

3.1 Data Sets

Cox, CJ, A McComiskey, and S Morris. Webcam images of OLI and NSA SKYRAD, ARM IOP Archive, doi:10.5439/1507148, https://www.arm.gov/research/campaigns/nsa2017dicexaco

3.2 Oral Presentations

Cox, CJ, S Morris, T Uttal, and C Long. 2019. “The De-Icing Comparison Experiment (D-ICE): A well-characterized verification data set of arctic broadband downwelling longwave and shortwave fluxes for YOPP.” Year of Polar Prediction (YOPP) Science Workshop. Helsinki, Finland.

Cox, CJ, S Morris, T Uttal, and C Long. 2018. "The D-ICE Campaign for Ice Mitigation Study." BSRN Workshop and Science Meeting. Boulder, Colorado.

Morris, S, CJ Cox, C Long, and the D-ICE Team. 2018. "Winter 2017-2018 results from the De-Icing Comparison Experiment (D-ICE) at NOAA's Barrow Atmospheric Baseline Observatory, Utqiaġvik, Alaska." Global Monitoring Annual Conference (GMAC). Boulder, Colorado.

Cox, CJ, SM Morris, CN Long, and the D-ICE Team. 2018. "De-Icing Comparison Experiment (D- ICE)." ARM/ASR Principal Investigator Meeting. Tysons, Virginia.

Cox, CJ. 2017. "The De-Icing Comparison Experiment (D-ICE)." Online presentation at the IARPC Atmospheric Collaboration Team. Boulder, Colorado.

3.3 Poster Presentations

Maahn, M, CJ Cox, G de Boer, S Matrosov, M Shupe, and C Williams. 2019. "Northern Alaska site science: Instrument quality and data stream developments." ARM/ASR Principal Investigator Meeting. Bethesda, Maryland.

Cox, CJ, SM Morris, T Uttal, and C Long. 2019. "The De-Icing Comparison Experiment (D-ICE): A study of broadband radiometric measurements under icing conditions in the Arctic." Global Monitoring Annual Conference (GMAC). Boulder, Colorado.

Cox, CJ, SM Morris, T Uttal, and C Long. 2019. "The De-Icing Comparison Experiment (D-ICE): A study of broadband radiometric measurements under icing conditions in the Arctic." NOAA Arctic Research Program (ARP) Principals Meeting. Seattle, Washington.

Cox, CJ, SM Morris, T Uttal, and C Long. 2019. "The De-Icing Comparison Experiment (D-ICE): A study of broadband radiometric measurements under icing conditions in the Arctic." CIRES Rendezvous. Boulder, Colorado.

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Cox, CJ, and SM Morris. 2017. "The De-Icing Comparison Experiment (D-ICE): A campaign for improving data retention rates of radiometric measurements under icing conditions in cold regions." American Geophysical Union (AGU) Fall Meeting. New Orleans, Louisiana.

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