The De-Icing Comparison Experiment (D-ICE): A study of radiometric measurements in icing conditions

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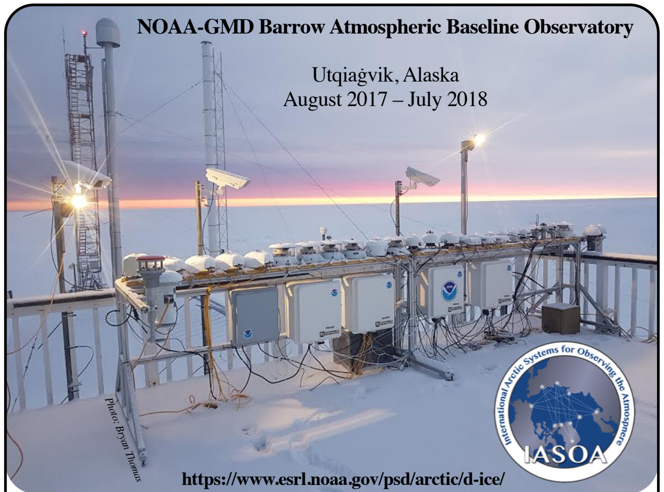


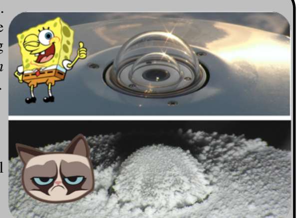
D-ICE partnered with the international research and industry communities

Radiative fluxes are fundamental observations. Frost and rime negatively impact data in the Arctic; ice is typically mitigated with heating and ventilation, *but there is no agreed-upon method and all methods are poorly-documented*.

Objective 1: Assess current technology.

Objective 2: Quantify the impact of icing.

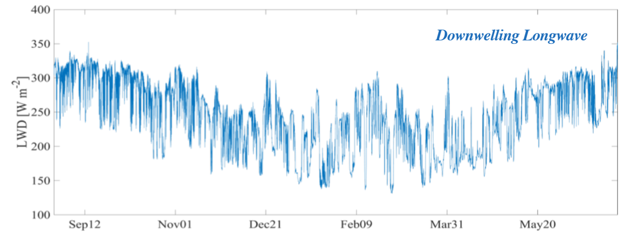
Objective 3: Identify the attributes of successful ice mitigation systems.

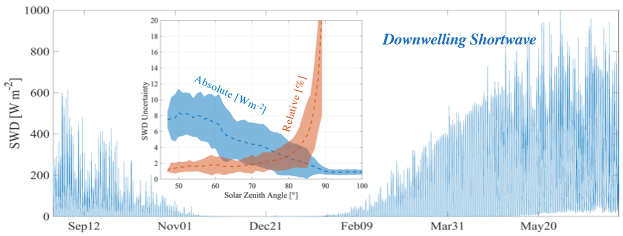


Results inform industry/development, operational and end-user communities

- Cameras were used to continuously monitor **34 systems contributed by the community** installed at **3 observatories** across the North Slope of Alaska (NOAA Barrow, ARM Barrow, ARM Oliktok Pt).
- More than **1 million** images of radiometer domes and more than **15 million minute averages** of radiative fluxes were collected over **10.5 months.**

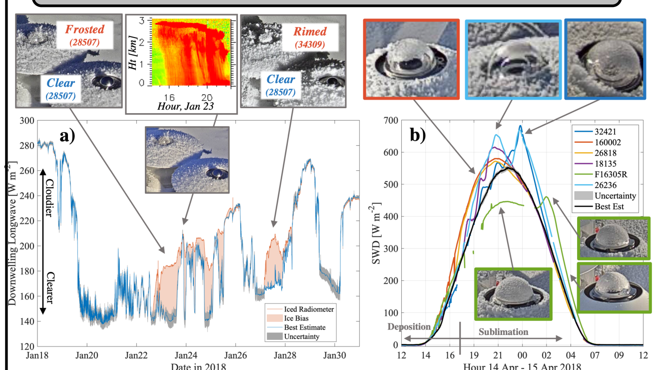
Best Estimate Fluxes





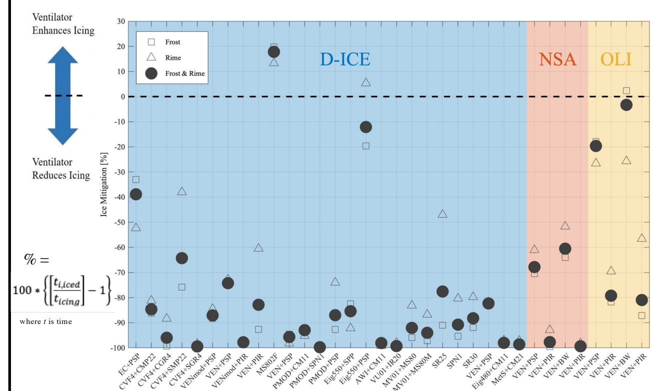
- A best-estimate, verifiably ice-free data set of downwelling longwave and shortwave radiative fluxes (1 min avgs) was constructed from the collective measurements. Uptime > 99%.
- The data set also includes empirically-derived operational uncertainties.
- The data set is suitable for model validation, such as the YOPPsiteMIP and as a benchmark for calculating biases caused by ice – see next section.

Bias Evaluation



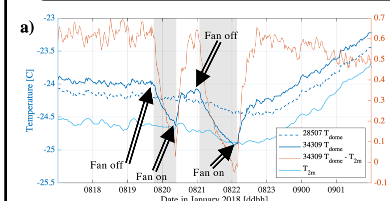
- Instantaneous longwave biases up to +58 W m^{-2} were observed. Shortwave biases of -106 to +160 W m^{-2} were observed, including simultaneously between neighboring pyranometers.
- However, biases **are not** statistically detectable in the monthly means because of mitigating factors:
  - The ventilation systems were reasonably effective (see next section).
  - Most icing occurs when the sun is low and pyrgeometers (thermal, LW) are more effectively kept ice-free than pyranometers (solar, SW) because of their domes have low-profile geometry and are highly conductive (silicon).
  - Clouds minimize the bias, especially in the LW, and the Arctic is persistently cloudy.
  - April is a potential problem month for the SW (at 72 N) because of relatively clear skies, frequent icing and plentiful sunlight.
  - December-February are potential problem months for the LW because of severe icing.

System Performance



- Most systems (22/34) were effective in mitigating ice at least 80% of the time and 15/34 were 90+% effective. Many successful systems used ventilators but not heaters.

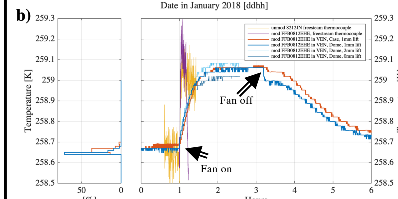
Physical Mechanism



A closer look at the Eppley VEN housing an 80 cfm 10.4 W fan and an Eppley PIR (LW).

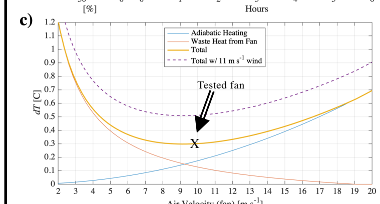
It's counter-intuitive that aspiration without heat can be effective, yet field observations indicate fans keep PIRs +0.5 C above ambient, which is sufficient to sub-saturate 104% RH w.r.t. ice at -25 C.

This is too much heating to be explained by waste heat alone.



The effect can be reproduced in the laboratory using a Type-T thermocouple in the air stream of the fan (yellow & purple)...

... and with the fan inside a ventilator configured as during D-ICE (blues & red).



Half the temperature increase is attributed to waste heat from the fan while the other **half is attributed to adiabatic heating** from compression of the air moved by the fan, which comes to rest at the surface of the radiometer.

Preliminary:
Additional heat observed in the field (a) relative to the lab (b) may be attributable to adiabatic heating from wind.

We have produced a simple model to predict the heating associated with a selected fan.

Many have contributed to D-ICE: Allison McComiskey (NOAA-GMD), Jim Wendell (NOAA-GMD), Emiel Hall (CIRES/NOAA-GMD), Brian Vasel (NOAA-GMD), Christine Schultz (NOAA-GMD), Andy Clarke (NOAA-GMD), Robert Albee (NOAA-PSD), Ola Persson (NOAA-PSD), Bernd Loose (AWI), Gert König-Lango (AWI, retired), Holger Schmithüsen (AWI), Jörgen Konings (Hukseflux), Matt Martinsen (NOAA-GMD), Tom Kirk (Eppley), Julian Groebner (PMOD-WRC), Steven Semmer (NCAR), Steve Oncley (NCAR), Kurt Knudeson (NCAR), Victor Cassella (Kipp & Zonen), Dick Jenkins (Delta-T), Laurent Vuilleumier (MeteoSwiss), Matt Shupe (NOAA-PSD), Bob Zamora (NOAA-PSD), Will Beuttell (EKO), Johan Booth (NOAA-GMD), Nick Lewis (Univ. Colorado), Meghan Helmberger (Univ. Colorado), Martin Stuefer (UAF), Fred Helsel (Sandia), David Oaks (Sandia), Ben Bishop (Sandia), Jim Mather (PNNL), Mark Ivey (Sandia), Walter Brower (ARM), Bryan Thomas (NOAA-GMD), Kevin Olivas (STC), Amanda Looze (NOAA), Ross Burgener (NOAA-GMD) and members of the BSRN Cold Climates Issues Working Group.