The De-Icing Comparison Experiment (D-ICE)

Christopher J. Cox[1,2], Sara M. Morris[1,2], Charles N. Long[1,2] and the D-ICE Team

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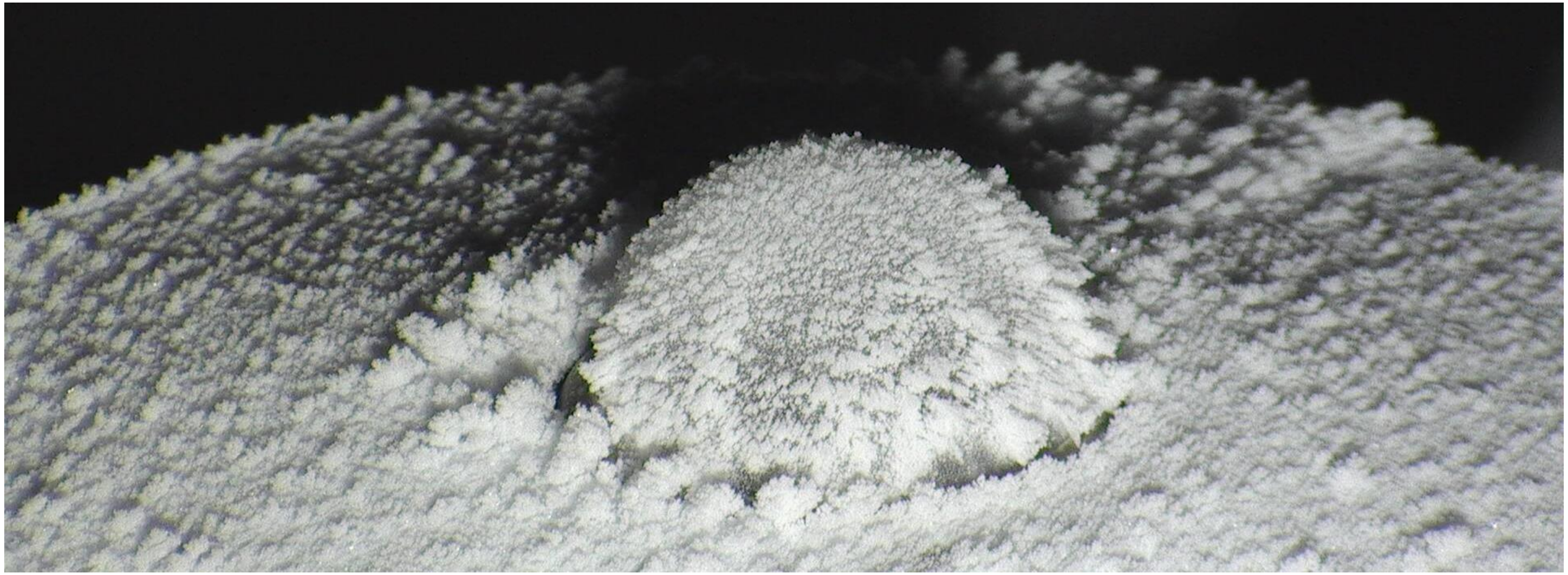
Photo, Bryan Thomas (NOAA)

Partners

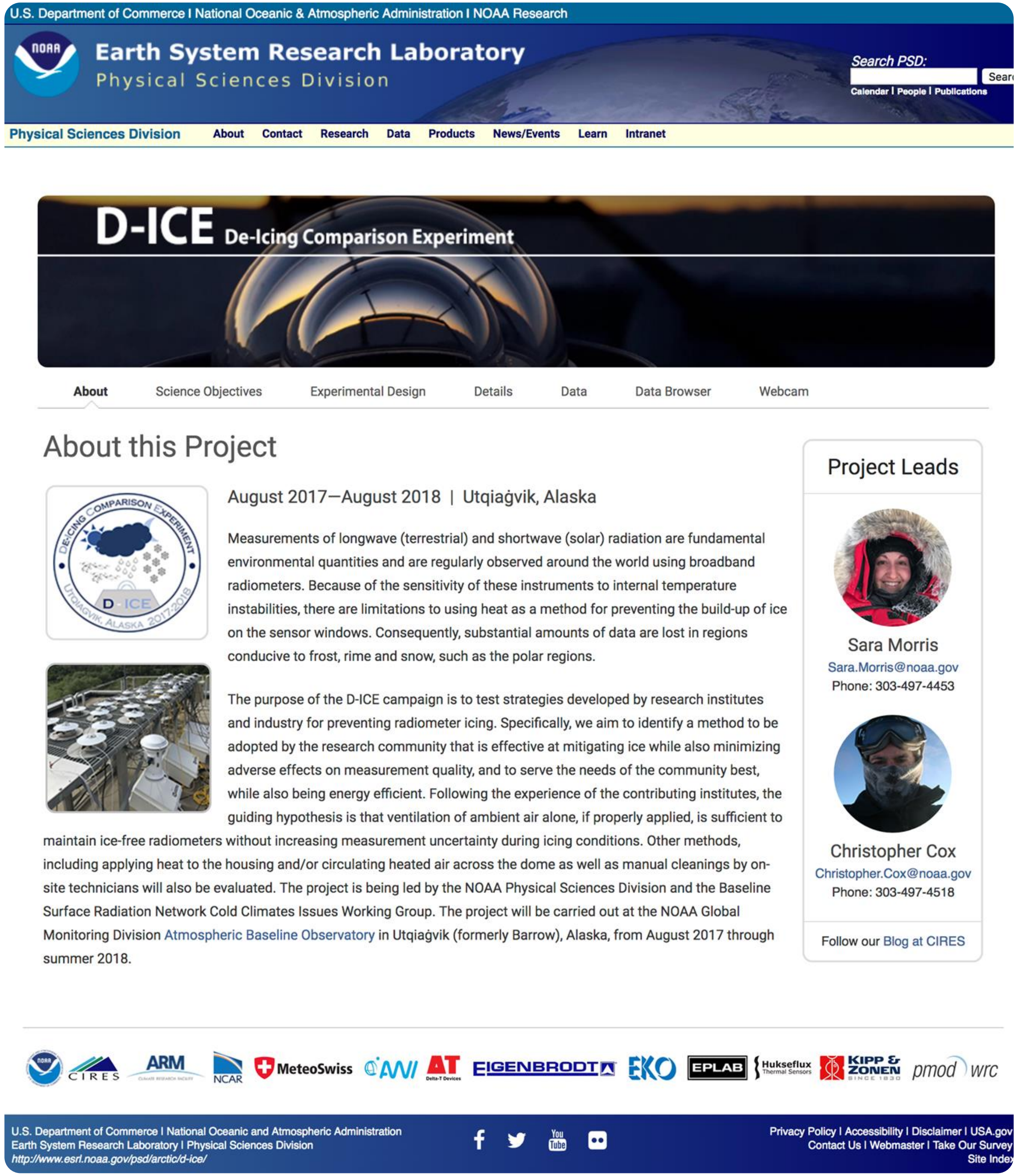
2018 Joint ARM/ASR PI Meeting
Tysons, Virginia, March 19-23, 2018

Icing of Broadband Radiometers

Could be snow, rime (contact freezing from supercooled liquid) or frost (vapor deposition)



https://www.esrl.noaa.gov/psd/arctic/d-ice/



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D-ICE De-Icing Comparison Experiment

About | Science Objectives | Experimental Design | Details | Data | Data Browser | Webcam

About this Project

August 2017—August 2018 | Utqiaġvik, Alaska

Measurements of longwave (terrestrial) and shortwave (solar) radiation are fundamental environmental quantities and are regularly observed around the world using broadband radiometers. Because of the sensitivity of these instruments to internal temperature instabilities, there are limitations to using heat as a method for preventing the build-up of ice on the sensor windows. Consequently, substantial amounts of data are lost in regions conducive to frost, rime and snow, such as the polar regions.

The purpose of the D-ICE campaign is to test strategies developed by research institutes and industry for preventing radiometer icing. Specifically, we aim to identify a method to be adopted by the research community that is effective at mitigating ice while also minimizing adverse effects on measurement quality, and to serve the needs of the community best, while also being energy efficient. Following the experience of the contributing institutes, the guiding hypothesis is that ventilation of ambient air alone, if properly applied, is sufficient to maintain ice-free radiometers without increasing measurement uncertainty during icing conditions. Other methods, including applying heat to the housing and/or circulating heated air across the dome as well as manual cleanings by on-site technicians will also be evaluated. The project is being led by the NOAA Physical Sciences Division and the Baseline Surface Radiation Network Cold Climates Issues Working Group. The project will be carried out at the NOAA Global Monitoring Division Atmospheric Baseline Observatory in Utqiaġvik (formerly Barrow), Alaska, from August 2017 through summer 2018.

Project Leads

Sara Morris
Sara.Morris@noaa.gov
Phone: 303-497-4453

Christopher Cox
Christopher.Cox@noaa.gov
Phone: 303-497-4518

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http://www.esrl.noaa.gov/psd/arctic/d-ice/

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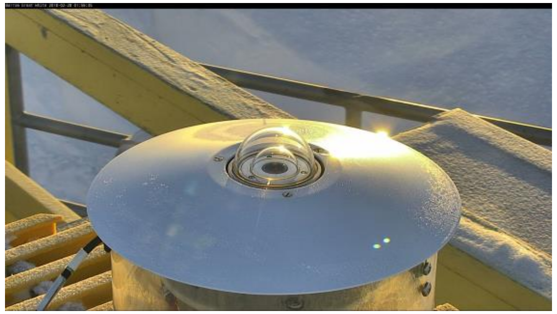
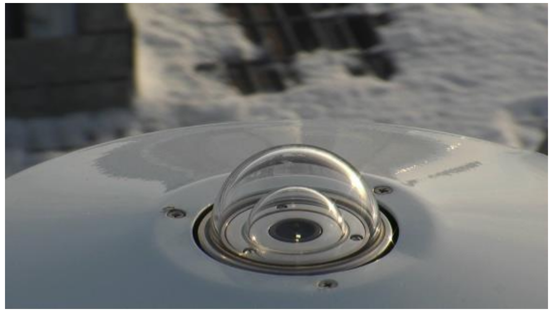
DICEXACO

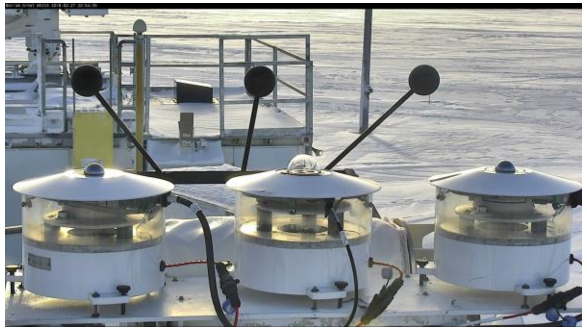
https://www.arm.gov/research/campaigns/nsa2017dicexaco

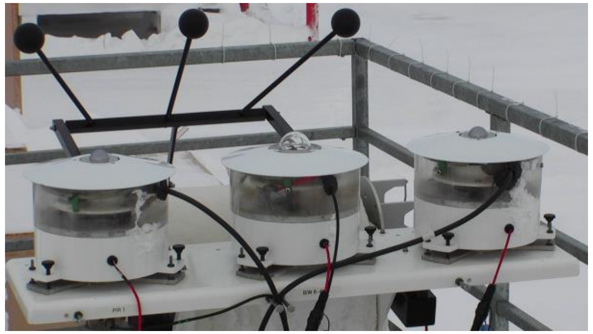
Two cameras on the SKYRAD systems at NSA and OLI: 10 min images

North Slope of Alaska (NSA), Oliktok Point (OLI)



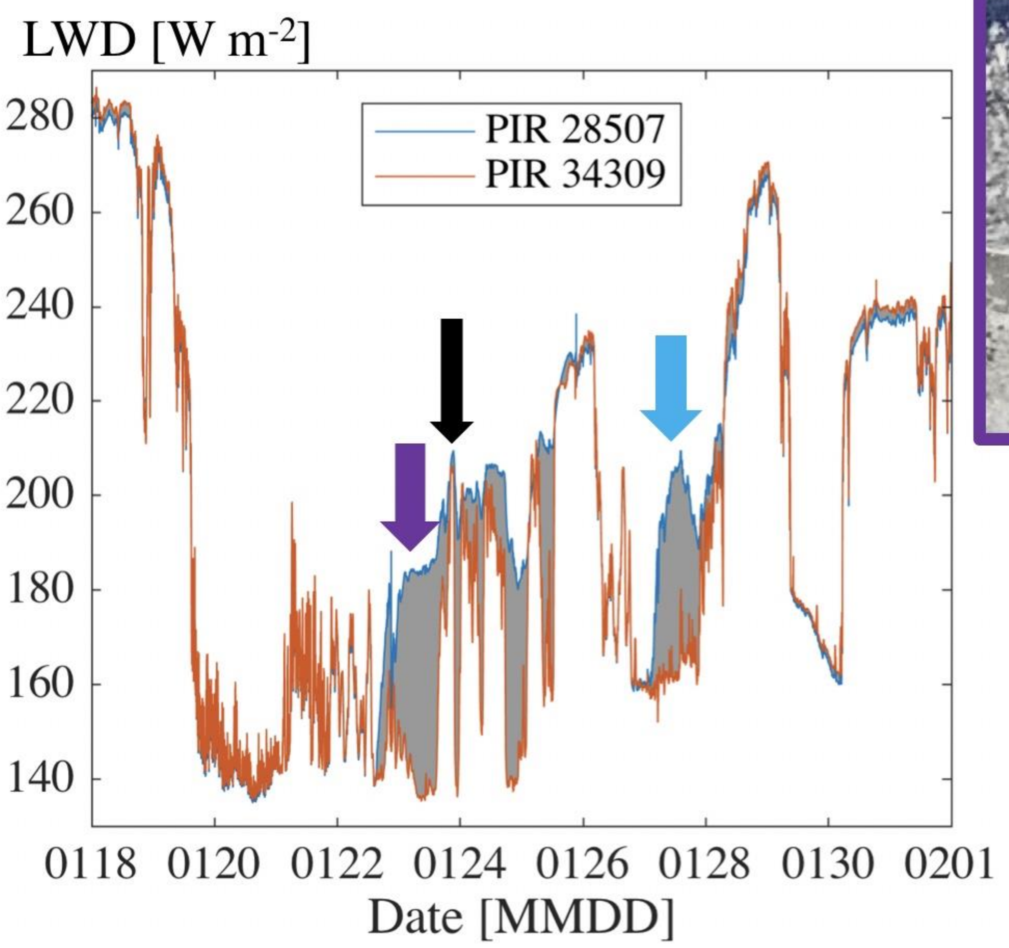


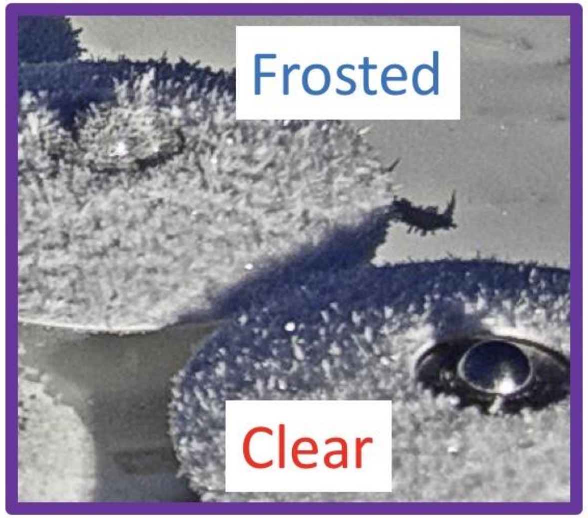


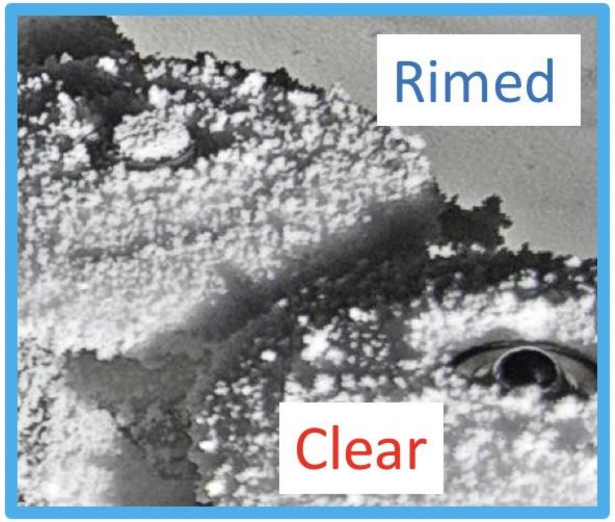


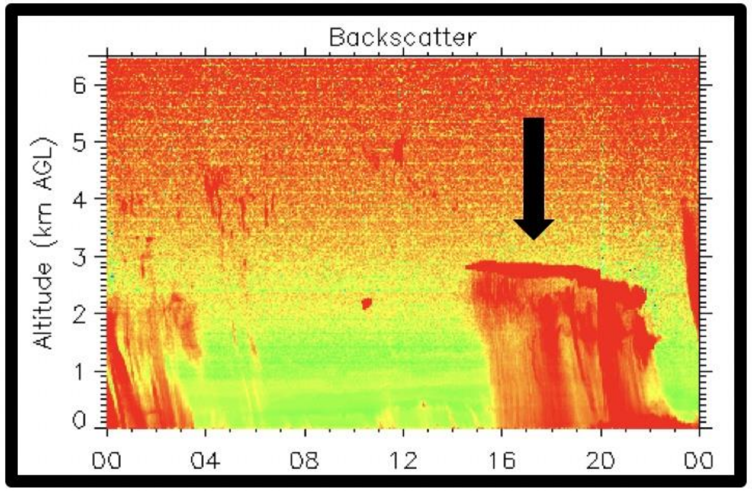
Eppley PSP, PIR, BW, PIR
VEN housing
15 W heater coils
3 adhesive pads (on OLI PSP only)
Fans: Delta Electronics 4.1 W (55 cfm)

Example from D-ICE: January 2018

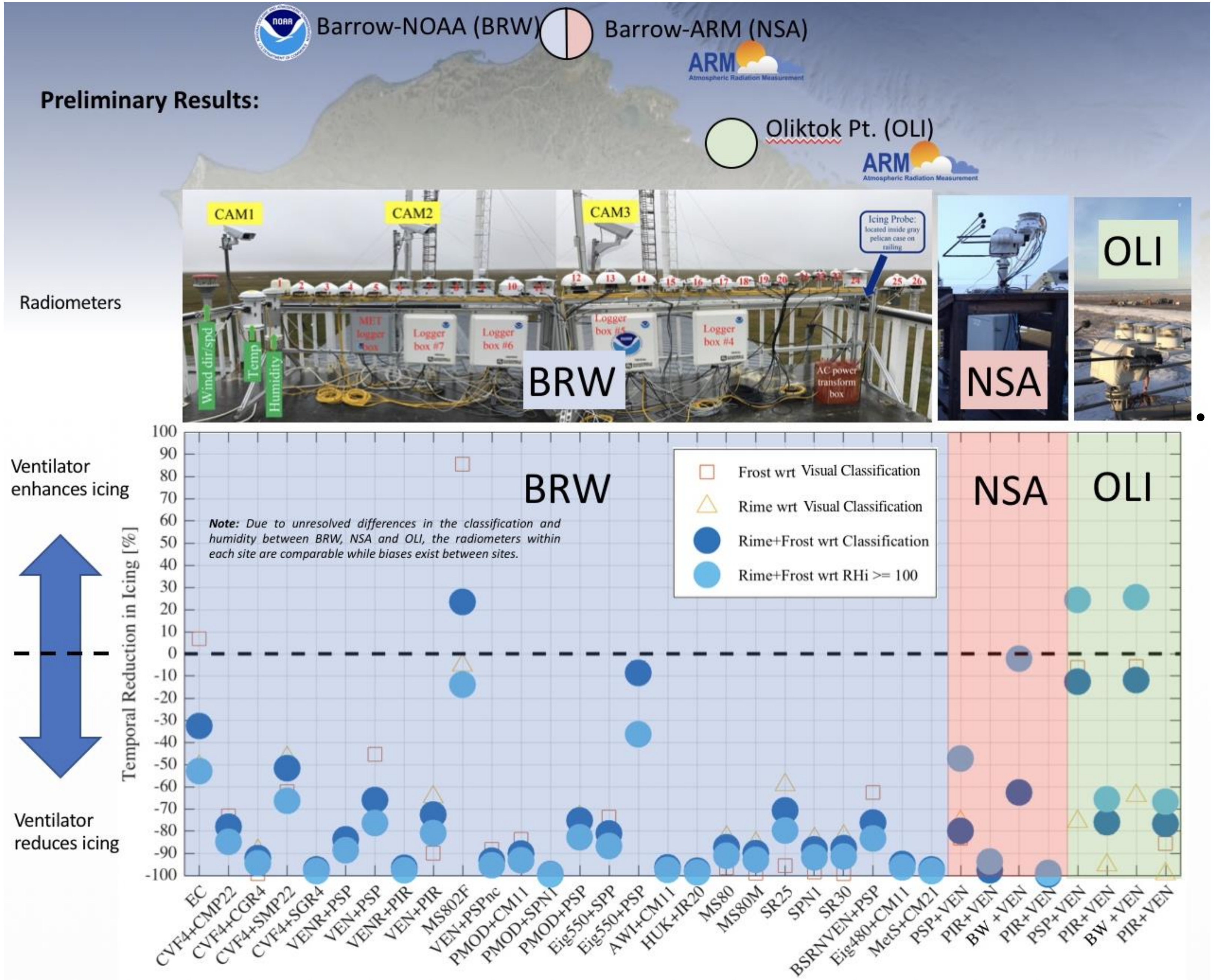








Biases for iced pyrgeometers were ~50 W m^{-2}, yet the mean LWD for Jan was **202 W m^{-2}** and **198 W m^{-2}**, a relatively small difference that is the result of the integrated influence of cloud cover (which reduces the bias, as in the **example, ~63% in Jan [CEILO]**), in addition to the frequency (**4.7%** vs **34.5%**) and severity of icing. **PIR 34309** was iced less frequently because of a very subtle ventilator variation – just a 2 mm lift in the radiation shield!



$$y[\%] = \left[\frac{t_{i\_iced}}{t_{exp\_iced}} - 1\right] \text{ x } 100$$

t_{i_iced} is the time radiometer i was was iced.

t_{exp_iced} is the time the natural icing condition was was flagged either by classification or rhi.

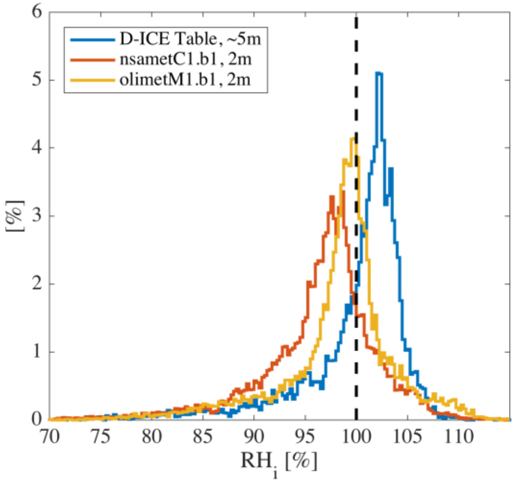
Dates analyzed: Nov 2017 – Feb 2018

~ 288,000 radiometer images at D-ICE

~ 53,000 radiometer images at NSA

~ 54,000 radiometer images at OLI

- Visual screening
  - Better at identifying ice on domes than classifying it (rime, frost …) or when icing conditions occurred
  - t_{i_iced} is pretty good estimate
  - t_{exp_iced} more uncertain (but applied uniformly to all i at each site.)



Preliminary Conclusions

- The data supports the hypothesis that aspiration of ambient air using a ventilator is a viable option for ice mitigation
- Additional heating is not a requirement, though it is effective
- Subtleties in the design matter
- ARM ventilation system:
  - More effective for pyrgeometers than pyranometers
  - OLI system likely less effective than NSA system

Acknowledgements

Institutes

Alfred Wegener Institute (AWI), Hukseflux, MeteoSwiss, EKO Instruments, Eppley, Kipp and Zonen, Delta-T, U.S. DoE Atmospheric Radiation Measurement (ARM) program, NCAR, NOAA Global Monitoring Division, and PMOD-WRC.

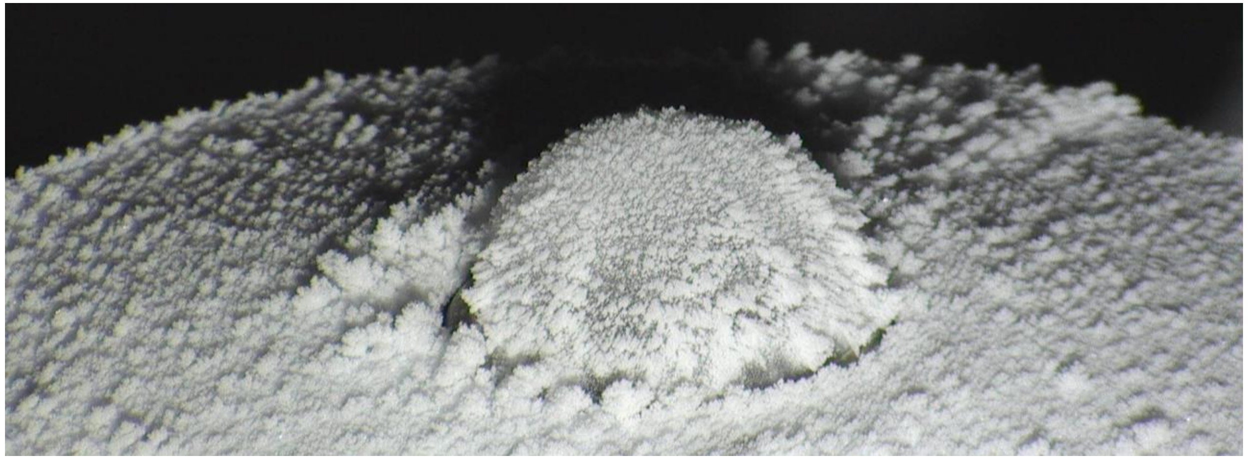
People

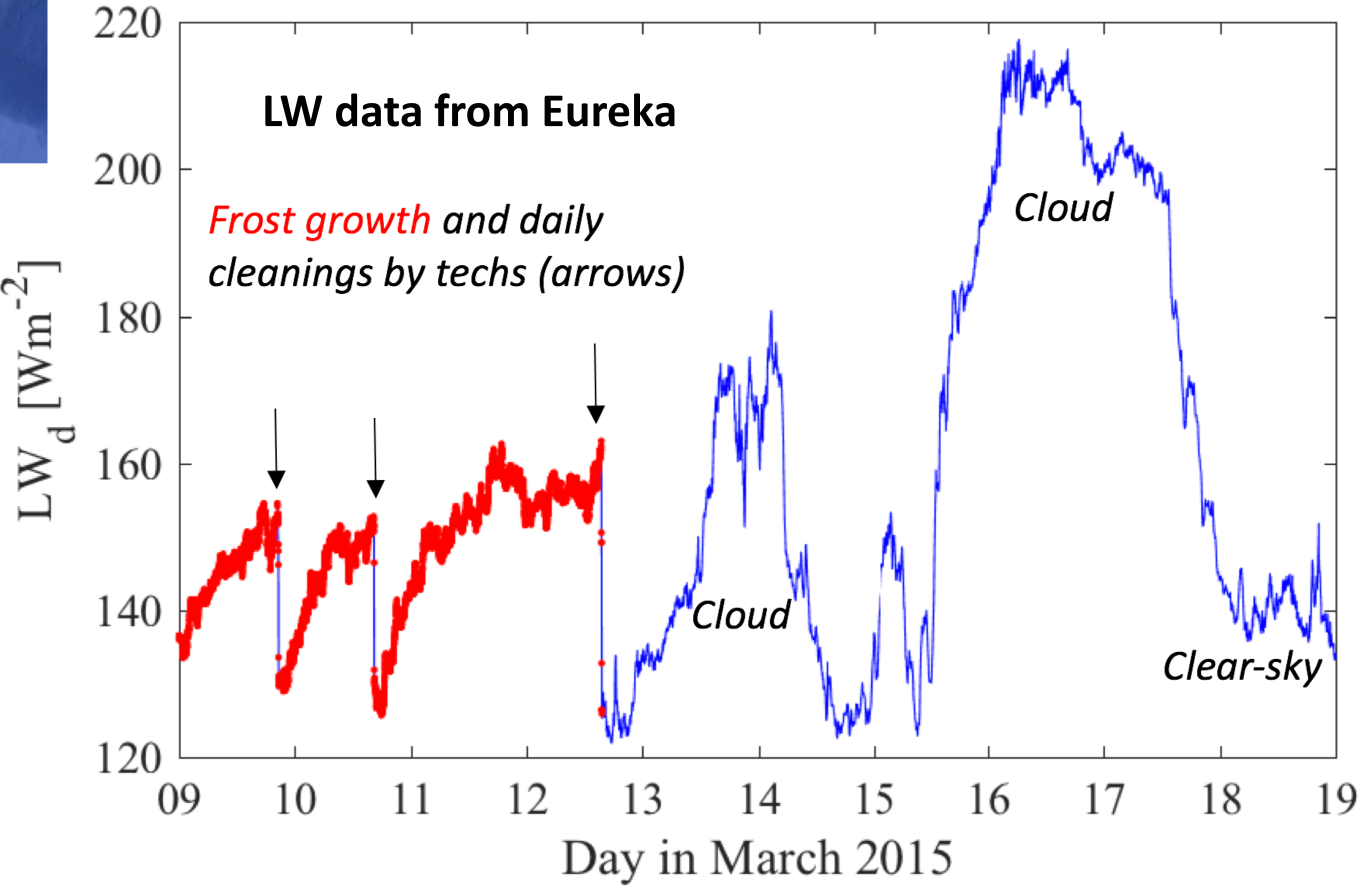
Taneil Uttal (NOAA-PSD), Chuck Long (CIRES/NOAA-GMD), Allison McComiskey (NOAA-GMD), Johan Booth (NOAA-GMD), Jim Wendell (NOAA-GMD), Emiel Hall (CIRES/NOAA-GMD), Brian Vasel (NOAA-GMD), Christine Schultz (NOAA-GMD), Andy Clarke (NOAA-GMD), Robert Albee (NOAA-PSD), Ola Persson (NOAA-PSD), Bernd Loose (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), Will Beuttell (EKO), 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), Ross Burgener (NOAA-GMD) and members of the BSRN Cold Climates Issues Working Group.


8.0
January 28, 12 UTC
Near the peak of an extended freezing fog event ~ -10 C, Rhi > 100%


January 28, 12 UTC


January 28, 12 UTC





- During Eureka winter, frost builds on the domes slowly over ~12 hours under radiatively clear skies

- Growth curves punctuated by daily manual cleaning reveals the iced conditions,
  - 20-30 Wm^{-2} bias
  - Within the intermediate range of LWD conditions.

Ventilators turned off

Back on + 8 hours

Instrument Details

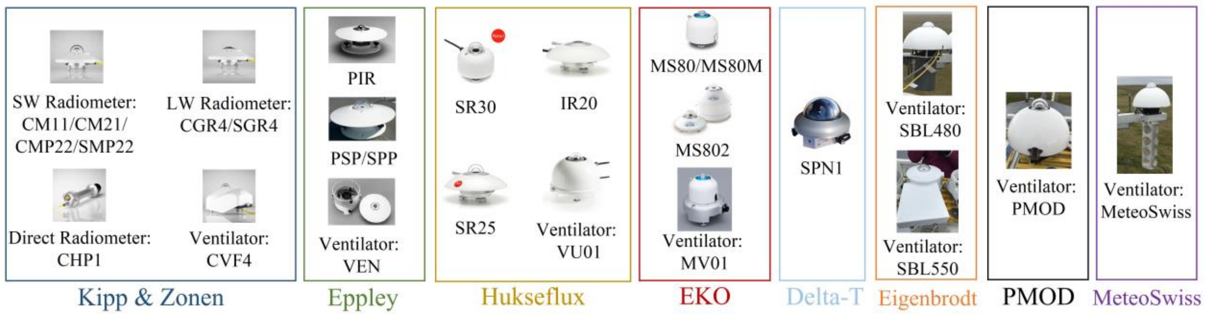


Table	Table Position	Radiometer Logger Box #	Radiometer Serial #	Ventilator Logger Box #	Ventilator Model or Serial #	Radiometer Measurement	Radiometer Manufacturer	Radiometer Model	*Radiometer Calibrations for D-ICE [µV/W/m²]*	Previous Factory Calibration (µV/W/m²)	Ventilation Manufacturer	Ventilation Quality / Quantity	Ventilation Frequency	Heat Applied (y/n)	Heat Quantity (Watts)	Heat Frequency
1	1	7	34231F3	6	ALERT	Shortwave	Eppley	PSP	***8.397***	8.41	EC, Alert	DC / 80 [cfs]	continuous	no	n/a	n/a
1	2	6	160478	6	171842	Shortwave	Kipp&Zonen	CMP22	***9.697***	9.74	Kipp&Zonen	DC / 4400 [rpm]	continuous	yes	5.5 [W]	continuous
1	3	6	160183	6	171840	Longwave	Kipp&Zonen	CGR4	***C1 = 9.545 C2 = 0.998***	9.4	Kipp&Zonen	DC / 4400 [rpm]	continuous	yes	5.5 [W]	continuous
1	4	6	160002	6	171843	Shortwave	Kipp&Zonen	SMP22	***original cal***	10.07	Kipp&Zonen	DC / 4400 [rpm]	continuous	yes	5.5 [W]	continuous
1	5	6	160008	6	171841	Longwave	Kipp&Zonen	SGR4	***original cal***	11.03	Kipp&Zonen	DC / 4400 [rpm]	continuous	yes	5.5 [W]	continuous
1	6	7	26818F3	7	V6 909-12, washers/dome lift	Shortwave	Eppley	PSP	***8.449***	8.57	Eppley	DC / 80 [cfs]	continuous	no	n/a	n/a
1	7	7	18135F3	7	V6 809	Shortwave	Eppley	PSP	***8.556***	8.65	Eppley	DC / 80 [cfs]	continuous	no	n/a	n/a
1	8	5	34309F3	7	V6 808, washers/dome lift	Longwave	Eppley, PSD	PIR	***C1 = 3.39 K = 3.78***	3.54	Eppley	DC / 80 [cfs]	continuous	no	n/a	n/a
1	9	5	28507F3	7	V6 689	Longwave	Eppley	PIR	***C1 = 3.68 K = 3.567***	3.76	Eppley	DC / 80 [cfs]	continuous	no	n/a	n/a
1	10	4	F16305R	4	MS-401FU	Shortwave	EKO	MS-802F	***7.056***	7.01	EKO	DC / 3000 [rpm]	continuous	no	n/a	n/a
1	11, do NOT clean	7	26214	5	V6 910	Shortwave	Eppley, NCAR	PSP	***8.13***	8.52	Eppley, lift shield	DC / 80 [cfs]	continuous	no	n/a	n/a
2	12	6	130814	5	PMOD	Shortwave	Kipp&Zonen, GMD	CM11	***8.327***	8.31	PMOD	DC / 4200 [rpm]	continuous	yes	8.16 [W]	continuous
2	13	5	A1571		GMD PMOD	Total, Diffuse	Delta-T, GMD	SPN	***factory set***	factory set	GMD, PMOD	DC / 80 [cfs]	continuous	via instrument	20 [W]	continuous
2	14	7	20523F3	5	PMOD	Shortwave	Eppley	PSP	***9.433***	9.67	PMOD	DC / 4200 [rpm]	continuous	yes	8.16 [W]	continuous
2	15	7	38172F3	4	0932153	Shortwave	Eppley	SPP	***7.756***	8.05	Eigenbrodt 550	DC / 2500 [rpm]	continuous	yes	14 [W]	n/a
2	16	7	26236	4	0931190	Shortwave	Eppley, NCAR	PSP	***8.627***	9.07	Eigenbrodt 550	DC / 2500 [rpm]	continuous	no	n/a	n/a
2	17	6	130819	4	0932088	Shortwave	Kipp&Zonen, GMD	CM11	***8.681***	8.7	Eigenbrodt 550 modified	DC / 2500 [rpm]	continuous	yes	14 [W]	continuous
2	18	4	4037	5	VU01	Longwave	Hukseflux	IR20-T1	***C1 = 10.144 C2 = 0.995***	10.13	Hukseflux	DC / 50 [m³/hr]	continuous	no	5-10 [W]	optional
2	19	4	S16088025	5	MV0117004	Shortwave	EKO	MS-80	***10.616***	10.64	EKO	DC / 3000 [rpm]	continuous	yes	7 [W]	continuous
2	20	6	S16090016	5	MV0117003	Shortwave	EKO	MS-80M	***10.772***	10.76	EKO	DC / 3000 [rpm]	continuous	yes	7 [W]	continuous
2	21	4	2510	none	none	Shortwave	Hukseflux	SR25-T1	***14.804***	14.87	none	n/a	n/a	no	n/a	n/a
2	22	4	A1338	none	none	Total, Diffuse	Delta-T	SPN	***factory set***	factory set	none	n/a	n/a	via instrument	20 [W]	continuous
2	23	6	2060	none	none	Shortwave	Hukseflux	SR30-D1	***original cal***	10.29	none	n/a	n/a	no	n/a	n/a
2	24, GMD BSRN	none		none		Shortwave	Eppley	PSP			Eppley					
2	25	6	130617	4	0932152	Shortwave	Kipp&Zonen, GMD	CM11	***8.741***	8.79	Eigenbrodt 480	DC / 3300 [rpm]	continuous	yes	25 [W]	continuous
2	26	5	970426	5 = fan 4 = heat	METEOSWISS	Shortwave	Meteo-Swiss	CM21	***19.808***	19.74	METEOSWISS	DC / 3450 [rpm]	continuous	yes	20 [W]	continuous
n/a	none	5	Icing Probe	none	Icing Probe	Ice accretion	Anasphere									
n/a	none		9297	none	none	Direct	Hukseflux	DR02-T1-10	***original cal***	16.5	none	n/a	n/a	no	n/a	n/a
n/a	*none*	*7*	*26226*		*SPARE*	*Shortwave*	*Eppley, NCAR*	*PSP*	**8.053**	*8.46*	*none*	*n/a*	*n/a*	*no*	*n/a*	*n/a*
n/a	none		999991		none	Direct	Kipp&Zonen	CHP1	***original cal***	7.25	none	n/a	n/a	no	n/a	optional
n/a	none		999992		none	Direct	Kipp&Zonen	CHP1	***original cal***	7.52	none	n/a	n/a	yes	5.5 [W]	continuous

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