

An Assessment of EarthCARE's Cloud Property Retrieval Algorithms During Polar Night

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Objective

- employ active & passive surface- and aircraft-based observations, along with *in situ* sampling, to assess EarthCARE's retrieval algorithms for night-time polar clouds
- aircraft observations during polar night are rare... unsafe and brutal logistics
- coordination of the NRC Convair-580 with ECCC's *extended* surface site at Iqaluit, NU
- opportunistic coordination with over-flying satellites, too... maybe EarthCARE?
- in conjunction with the *Thin Ice Cloud Far-IR Experiment* (TICFIRE) via the CSA

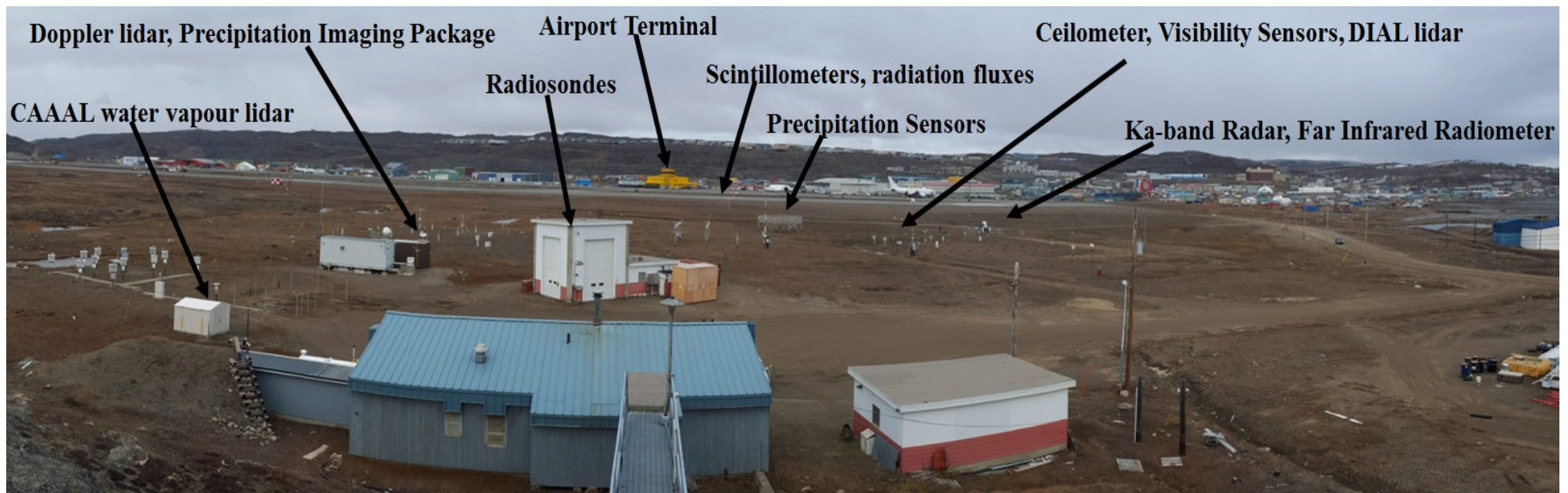
ECCE's surface site at Iqaluit, NU



certain: Iqaluit

possible: additional obs at Eureka

ECCE site, Iqaluit airport



ECCC's surface site at Iqaluit, NU

IQUALUIT A

NU

63°45' N

68°33' W

1981 to 2010 Normals

Temperature

	Jan	Feb	Mar	Dec	
Daily Average (°C)	-26.9	-27.5	-23.2	-21.3	← usually cold
Daily Max (°C)	-22.8	-23.3	-18.3	-17	
Daily Min (°C)	-30.9	-31.7	-28.1	-25.5	
Record high (°C)	3.9	5.7	4	3.4	
Record low (°C)	-45	-45.6	-44.7	-43.4	← at times very cold

Precipitation

Rainfall (mm)	0	0	0	0	
Snowfall (cm)	21.7	21	21.6	23.4	← almost always snow
Precipitation (mm)	19.7	18.7	18.7	19.9	
Avg Snow Depth (cm)	22	25	26	19	
Max. Daily Snowfall (cm)	30.7	32.2	24.6	21.8	
Max. Snow Depth (cm)	57	74	69	48	← at times lots of it

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1981 to 2010 Normals

	Jan	Feb	Mar	Dec	
Wind					
Speed (km/h)	15.9	15.3	14.9	16.3	← usually windy
Most Frequent Direction	NW	NW	NW	NW	
Max. Hourly Speed (km/h)	108	120	129	111	
Max. Gust Speed (km/h)	146	114	156	141	← at times very windy
Bright Sunshine					
Total Hours	32.4	94	172.2	12.6	
Wind Chill					
Extreme Wind Chill (°C)	-64	-65.6	-62.1	-60.1	← <u>extreme</u> wind chill

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1981 to 2010 Normals

Visibility (hours with)

	Jan	Feb	Mar	Dec
< 1 km	21.6	22.5	19.3	13.8
1 to 9 km	155	149.8	142.7	143.8
> 9 km	567.5	504.7	582.1	586.4

← often poor visibility

Cloud Amount (hours)

0 to 2 tenths	282	256.6	280.7	253.4
3 to 7 tenths	144.2	139.6	130.4	140.9
8 to 10 tenths	317.9	280.8	332.8	349.8

← often much cloud

ECCC's surface site at Iqaluit, NU

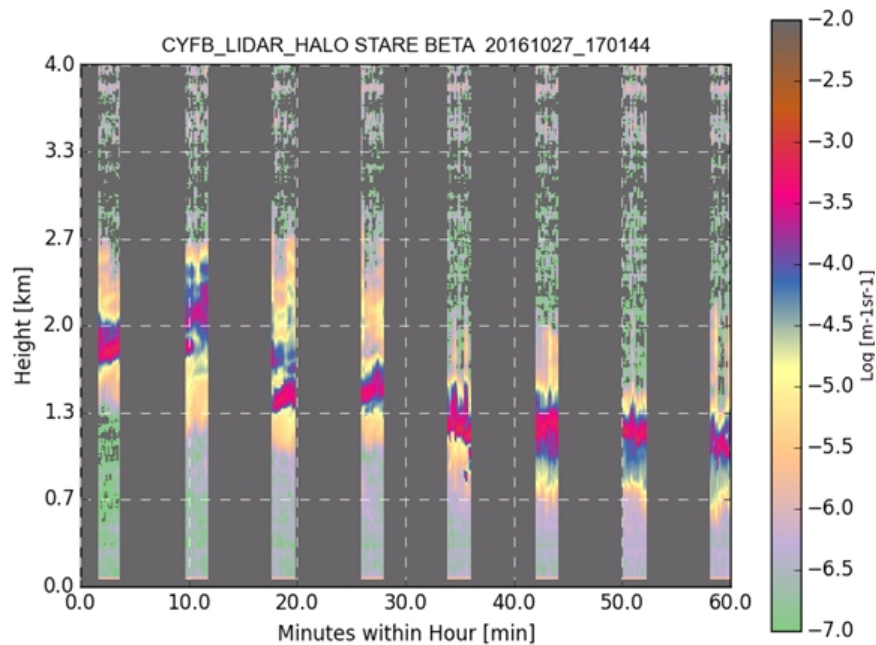
Instrument	Manufacturer	Date of Deployment	Operation	Measurement(s)	Temporal/geographic resolution
Precipitation Imaging Package (PIP)	NASA/Wallops	Sept. 2014	380 frame/s grey-scale camera with back-lighting	Particle imagery, DSD, precip. rate and density estimation	1 min / surface obs. only
4 Cameras	Campbell Scientific	Sept. 2015	High-resolution images of the site	Ka-Radar, Lidar, and Sky-view images	5 min / 1080p
Ka-Band Radar	METEK	Sept. 2015	Scanning pulsed dual-polarization Doppler Radar	Line-of-sight wind speed and direction, cloud & fog backscatter, depolarization ratio	10 min / 10 m res. up to ~25 km range
Ceilometer CL31	VAISALA	Sept. 2015	Pulsed (8 kHz) diode laser Lidar	Cloud intensity, cloud octa and height, aerosol profiles, MLH	5 min / 5 m vert res. up to 7.5 km a.g.l.
PWD 52 Visibility Sensor (x2)	VAISALA	Sept. 2015	Forward-scatter measurement	Visibility, precipitation type	1 min / surface obs. only
Doppler Lidar	HALO	Sept. 2015	Pulsed (10 kHz) scanning at 1.5 μm (Mie scattering)	Line-of-sight wind speed and direction, aerosol backscatter, depolarization ratio	5 min / 3 m res. up to ~3 km range
Rosemount icing detector	Rosemount Engineering	Sept. 2015	Magnetostrictive oscillation probe with a sensing cylinder	Detects ice, frost	
Surface met obs.	Misc.	Ongoing	Misc.	Surface T, RH, pressure, winds, precipitation	1 min / surface obs. only
Radiosondes	VAISALA	Ongoing	Balloon-launched sonde	Profiles of T, RH, pressure, winds	12 hours / ~15 m res. up to ~30 km a.g.l.
4k Pantilt Camera	Axis	Oct. 2016	High-resolution images of the site	Automated pivoting camera provides images in all directions	5 min / 4k
Canadian Autonomous Arctic Aerosol Lidar (CAAAL)	ECCC	Oct. 2016	355/532/1064 nm transmitter & 6 ch. receiver	Aerosol and water vapour profiles; particle size and shape information	1 min / 3 m res. up to ~15 km a.g.l.
Doppler Lidar: Ridge (T121)	HALO	Oct. 2017	Pulsed (10 kHz) scanning at 1.5 μm (Mie scattering)	Line-of-sight wind speed and direction, aerosol backscatter, depolarization ratio	5 min / 3 m res. up to ~3 km range
Scintillometer	Scintec	August 2018	Large-aperture optical transmitter/receiver	Turbulence, crosswind, heat flux	5 min / max 6 km path length
Fog Measuring Device (FMD)	DMT	August 2018	Fog sensor	Fog intensity, water vapour at surface	TBD
Far-IR Radiometer (FIRR)	LR Tech.	August 2018	Zenith/Nadir-viewing infrared radiometer	Downwelling IR radiation, cloud microphysics	10 min / NA
Surface radiation fluxes	Campbell Scientific	August 2018	Surface radiation sensors (diffuse and direct)	Short- and long-wave up, down, and horizontal radiation	NA
Water Vapour Lidar	VAISALA	August 2018	Pulsed Lidar system	Profiles of aerosols, 24-hr water vapour profile	~20 minutes / 10 m up to ~3 km agl (WV)

ECCE's surface site at Iqaluit, NU

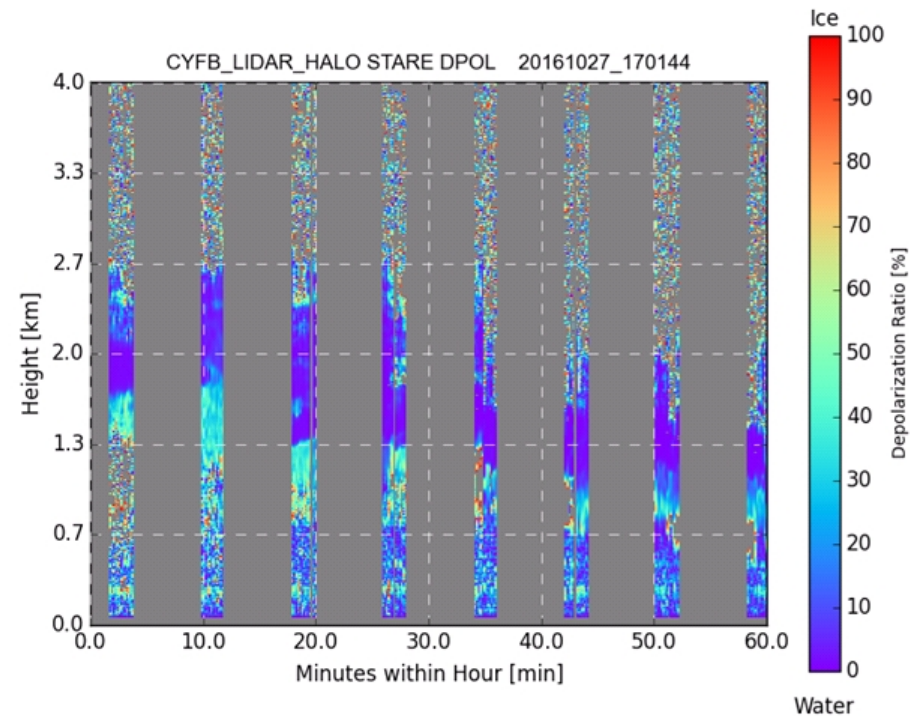
- Doppler lidar -



Halo Doppler lidar: wind measurements every 8 minutes up to ~3 km along its line-of-sight



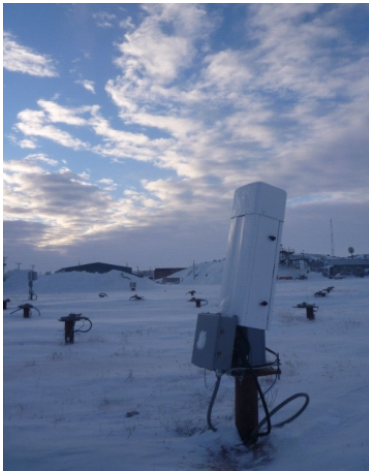
Backscatter obs. of a descending ~300 m thick cloud (red) from 1700-1800 UTC on 27-Oct-2016.



Elevated lidar depol. ratios indicate the presence of ice crystals.

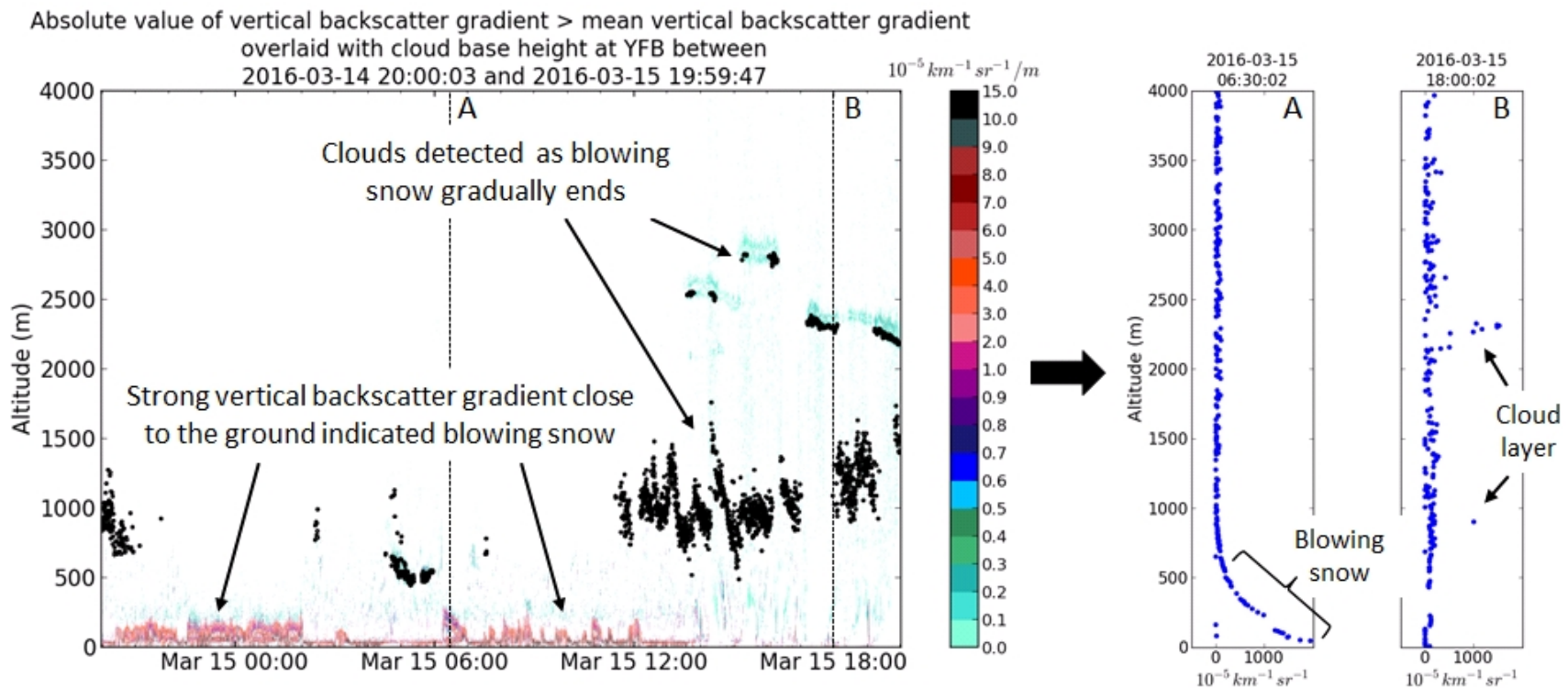
ECCC's surface site at Iqaluit, NU

- ceilometer -



Vaisala CL31 ceilometer: aerosol backscatter obs. every minute up to 7.5 km

Left: ceilometer backscatter of blowing snow with clouds aloft (15-Mar-2016).
Right: backscatter profiles of blowing snow and clouds: (A) 0600 UTC; (B) 1800 UTC.



ECCE's surface site at Iqaluit, NU

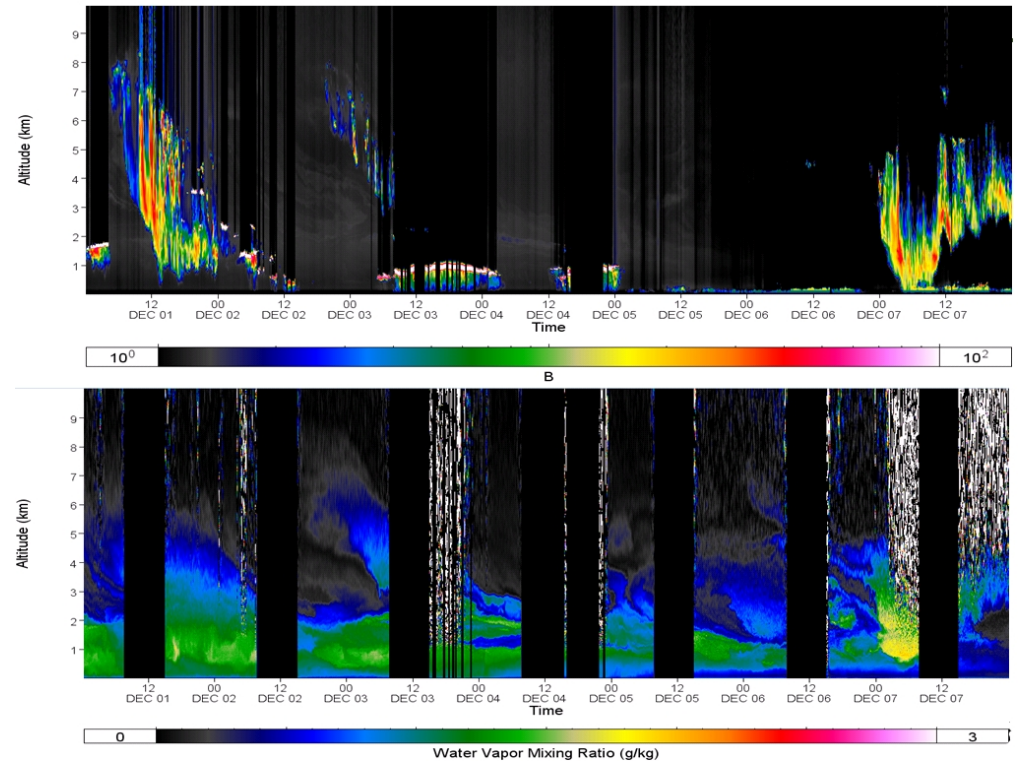
- autonomous lidar -



Canadian Autonomous Arctic Aerosol Lidar (CAAAL):
high-resolution depol. ratio with inferences of aerosol,
and water vapour profiles

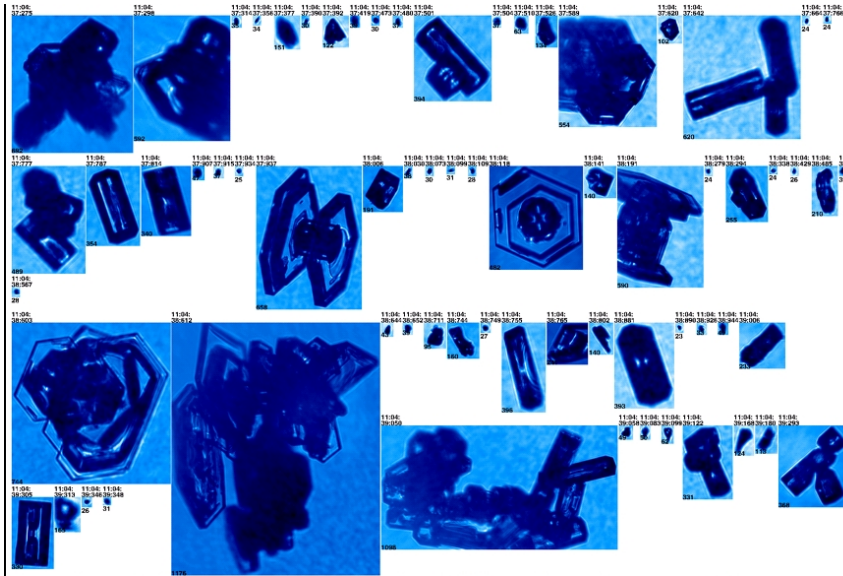
CAAAL backscatter obs. of several cloud
layers between 1-7 December 2016.

Corresponding water vapour mixing ratio
profiles show fine layers of vapour that
persisted over days.



NRC Convair-580

- ECCC's *in situ* samplers -



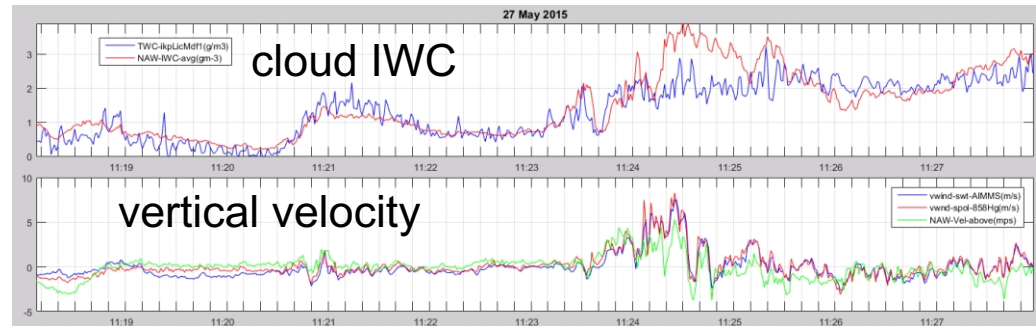
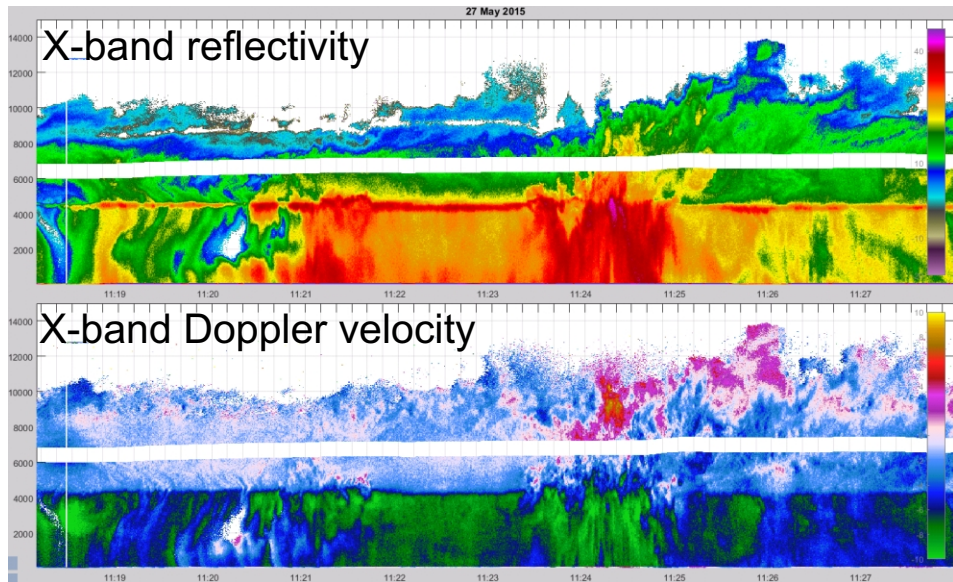
Cloud microphysical in-situ instruments

<i>instrument</i>	<i>manufacturer</i>	<i>Range of measurements</i>
UHSAS	DMT	60 nm-1 μm
PCASP	PMS	0.1-3 μm
FSSP-100	PMS	1-45 μm
CDP	DMT	2-50 μm
OAP-2DC	PMS	50-1600 μm
CIP	DMT	28-800 μm
PIP	DMT	100-6400 μm
2DS	SPEC	10-1280 μm
HVPS	SPEC	150- 19200 μm
CPI	SPEC	2.3-2300 μm
HSI	Artium	3-2400 μm
Nevzorov LWC & TWC	SkyPhysTech	$0 < \text{LWC} < 2\text{g/m}^3$ $0 < \text{TWC} < 1\text{g/m}^3$
EC Hot-Wire	ECCC	$0 < \text{LWC} < 3\text{g/m}^3$ $0 < \text{TWC} < 3\text{g/m}^3$
EC Extinction Probe	ECCC	$0.5 < \text{ExtCoeff} < 200 \text{ km}^{-1}$

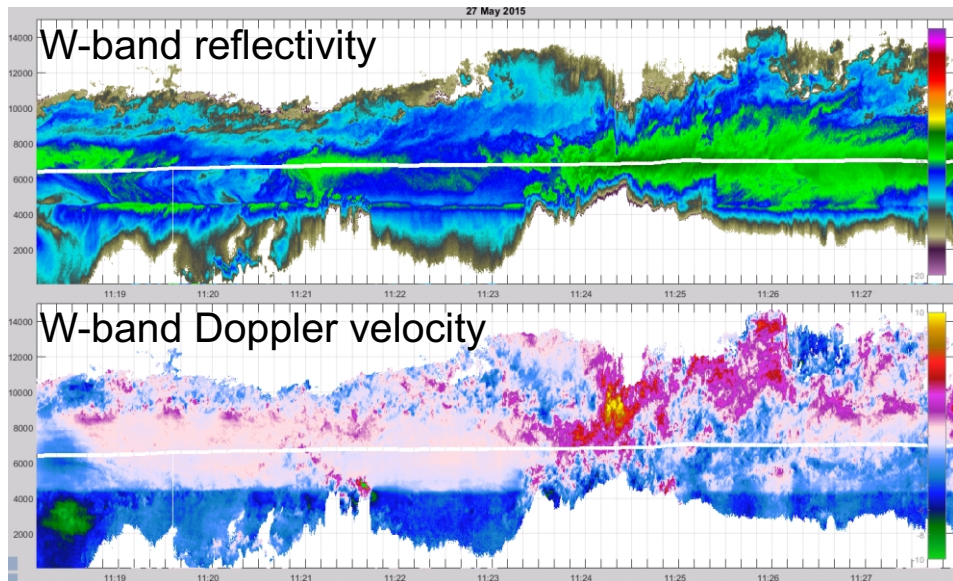
Parameters for ProSensing Inc. NAWX radar system

<i>parameter</i>	<i>W-band</i>	<i>X-band</i>
Transmitted Frequency	94.05 GHz	9.41 GHz
Peak Tx Power	1.7KW	25KW (split)
Polarization	Co and Cross	Simultaneous and V
Doppler	Pulse Pair and FFT	Pulse Pair and FFT
Pulse Duration	0.1 - 10 μs	0.11-1 μs
Max PRF	20 KHz	5 KHz
Max PRF	20 KHz	5 KHz
Ant. 3 dB BW	0.75 $^\circ$	3.5 $^\circ$
View direction	Up, down and side	Up, down and side

NRC Convair-580 - active sensors -



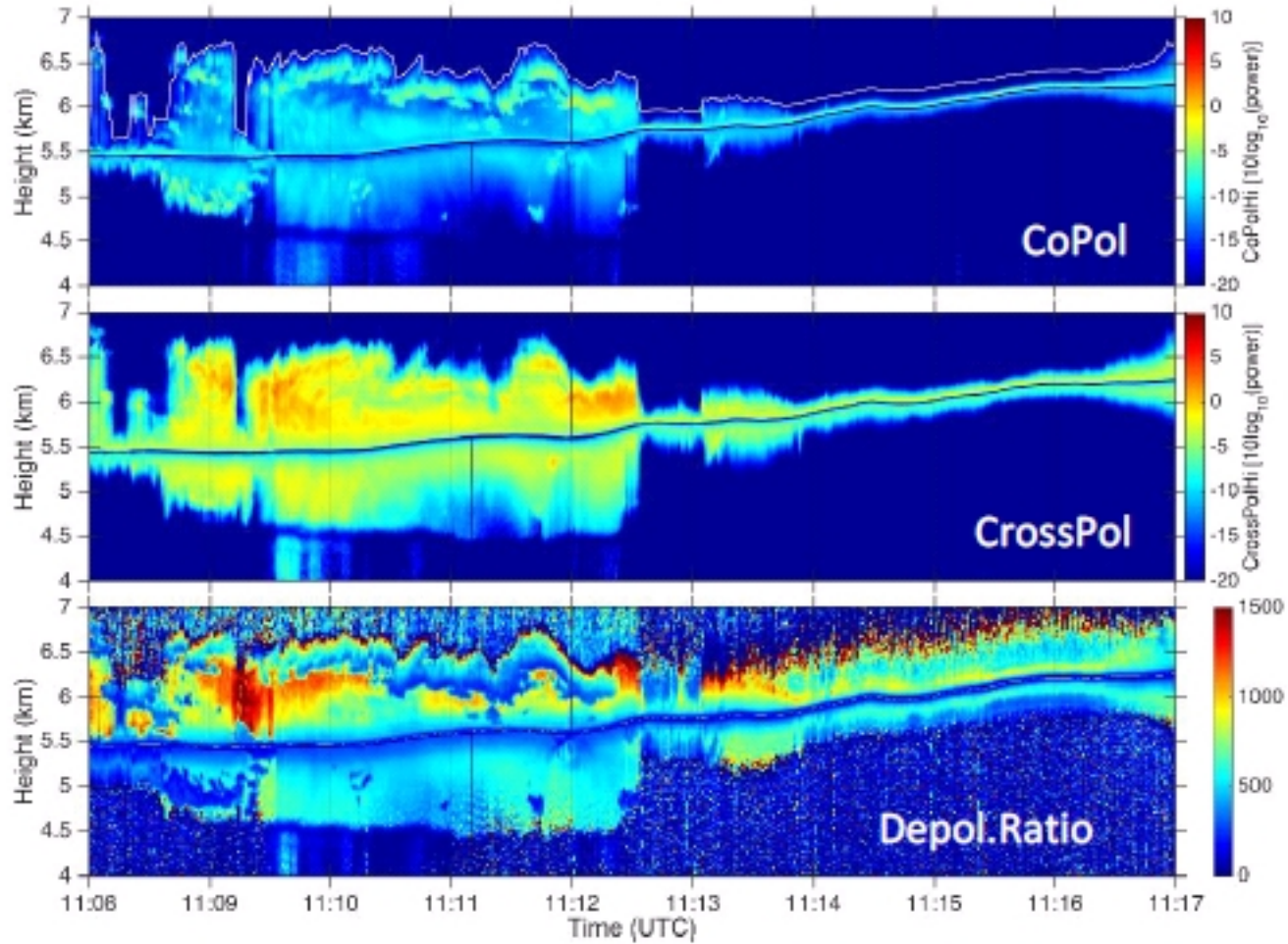
Corresponding *in-situ* measurements and W-band radar inferences of cloud Ice Water Content (IWC) and hydrometeor vertical velocity.



High Ice Water Content (HIWC) campaign on the coast of French Guyana during May 2015

X-band and W-band radar quantities from the Convair-580 for a convective storm during the HIWC.

NRC Convair-580 - active sensors -



Alpenglow Cloud Lidar system measurements (355 nm at ~1 m vertical resolution and 20 profiles/sec) made during the HIWC campaign.

Summary

- Coordinated measurements of cloud properties during polar night from (rare) aircraft- and surface-based sensors;
- Proposed observations should benefit assessment of EarthCARE's cloud and aerosol products derived from 94-GHz CPR, 355 nm ATLID lidar, and MSI measurements... challenging due to lack of solar channels;
- Surface- and aircraft-based data during polar night will also aid in assessing the expected abilities of EarthCARE's broadband radiative flux profile estimates and its radiative closure assessment;
- Coordinated with the TICEFIRE proposal to the CSA... time-frame likely to be 2020 - 2022, so potentially after EarthCARE's launch;
- Aid parametrization of ice cloud microphysical and optical properties in ECCO's global climate and NWP models;
- Assess benefits of *extended* surface measurements at Iqaluit for NWP data assimilation of lidar-inferred winds and other active sensor data [cf. Year of Polar Prediction (YOPP)].