# Latest status and future plans for airborne campaign – NRC Convair-580

Mengistu Wolde (NRC Canada) & collaborators

2nd ESA EarthCARE Validation Workshop

25-28 May 2021 (online)

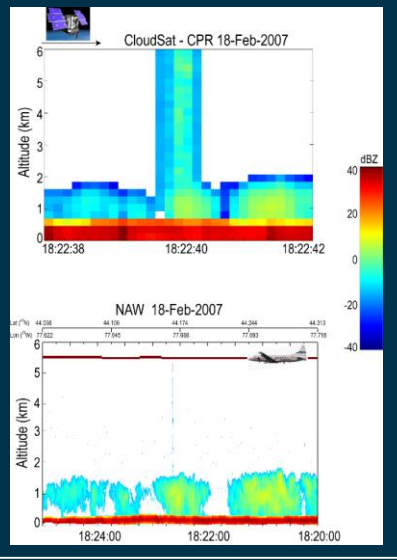
# NRC Convair-580 – Major National Facility for Atmospheric Research


**Radars**: X, Ka and W; **Lidar**: 355 nm AECL; **Radiometers**: 183 GHz, HiSRAMS

**In-situ**: Atmospheric and Aircraft States, Aerosol, cloud microphysics

NRC and ECCC in collaborations with many partners has conducted many projects related to space based earth observations:

- CloudSat and CALIPSO (C3VP); GPM (GCPEX)
- ESA proof-of-concept studies (2017-Present): WIVERN (W-band PDPP), RadSnowExp, Raincast & HiSRAMS




- Crew: 2 pilots + 10 project personnel
- Endurance: 4 – 5 hours
- Range: ~1000 km
- Vertical ceiling: 23,000 ft (7000 m)

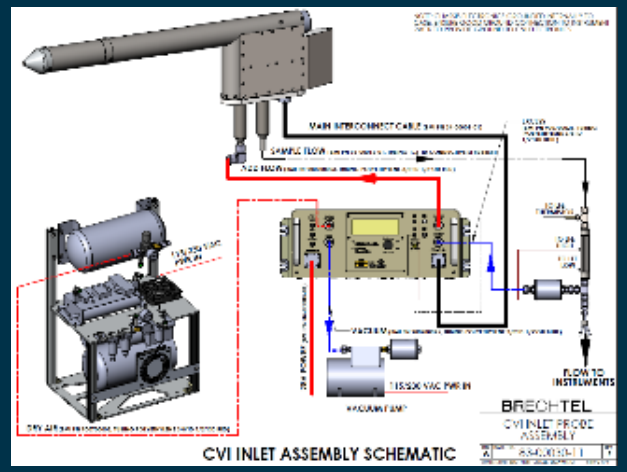
- Jointly instrumented by NRC and ECCC
- tinyurl.com/convair

NRC·CNRC Canada

Environment and Climate Change Canada

# New instruments

- SPEC HVPS-4 (2022)
- NRC cIKP (2022)
- HISRAMS (2021)
- CVI inlet (2022)
- Artium HSI (2021)







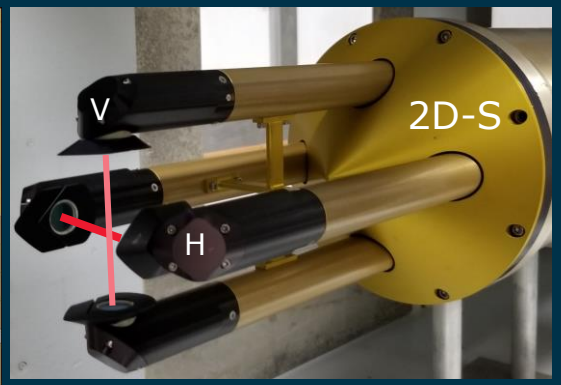
Convair HSI imagery from HAIC-HIWC Campaign
Credit: W.D Bachalo –Artium

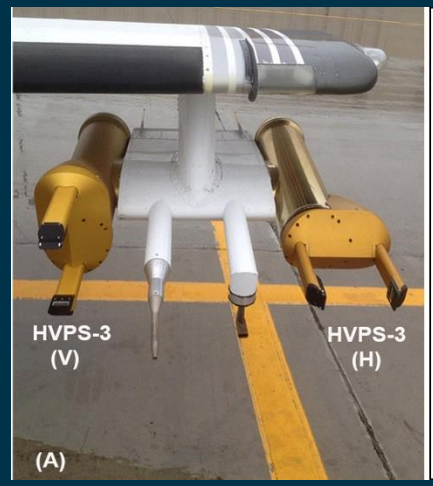
# Science Drivers: Measurements in Ice

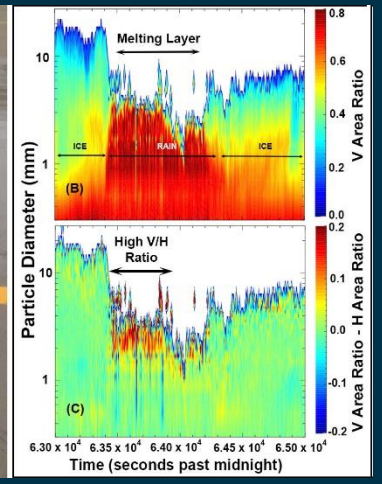
Ice Water Content (IWC) determined from image data typically uses power laws relating max dimension (Brown and Francis 1995) or projected area (Baker and Lawson 2006) to IWC.

**Orthogonal views will significantly improve IWC accuracy.**

| | Plates and Column | | | Rosettes | | | Aggregates | | | | Graupel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CPI Image | | | | | | | | | | | | |
| 2D-S H view | | | | | | | | | | | | |
| 2D-S V view | | | | | | | | | | | | |
| 2D-S H width (μm) | 101 | 123 | 163 | 185 | 372 | 318 | 652 | 334 | 293 | 422 | 404 | 551 |
| 2D-S H length (μm) | 731 | 342 | 306 | 346 | 435 | 438 | 953 | 390 | 441 | 760 | 475 | 655 |
| 2D-S V width (μm) | 341 | 201 | 201 | 226 | 386 | 281 | 466 | 328 | 390 | 731 | 379 | 525 |
| 2D-S V length (μm) | 730 | 382 | 414 | 332 | 428 | 431 | 592 | 457 | 631 | 792 | 465 | 665 |
| 2D-S H B&F mass (μg) | 20.39 | 4.82 | 3.90 | 4.92 | 7.61 | 7.71 | 33.75 | 6.18 | 7.81 | 21.96 | 8.99 | 16.55 |
| 2D-S V B&F mass (μg) | 20.34 | 5.94 | 6.92 | 4.55 | 7.38 | 7.47 | 13.66 | 8.35 | 15.42 | 23.75 | 8.63 | 17.04 |
| Mass Ratio (min/max) (%) | 0% | 23% | 78% | 8% | 3% | 3% | 147% | 35% | 98% | 8% | 4% | 3% |
| 2D-S H B&L mass(μg) | 3.74 | 1.57 | 2.20 | 1.78 | 4.27 | 4.35 | 24.79 | 4.88 | 5.29 | 23.85 | 7.36 | 20.53 |
| 2D-S V B&L mass (μg) | 8.03 | 3.04 | 3.80 | 1.15 | 3.80 | 3.91 | 8.08 | 4.89 | 6.22 | 27.68 | 8.04 | 17.67 |
| Mass Ratio (min/max) (%) | 115% | 93% | 72% | 55% | 12% | 11% | 207% | 0% | 18% | 16% | 9% | 16% |



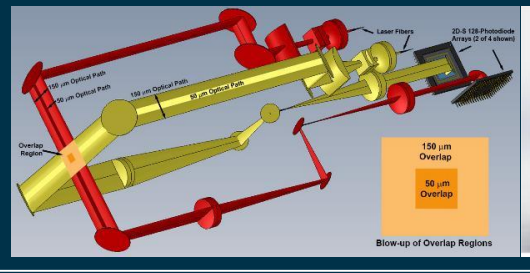




HVPS-3 UND Citation during OLYMPEX Project

- A cooperative development and flight testing effort between SPEC and NCAR (NSF MRI award). Prototype probe is flight tested now on the SPEC Learjet.
- Three added channels **H and V: 50 μm & 150 μm** vs. previous design
- Integration and flight test on NRC Convair-580 – Nov-Dec, 2021; Project use Feb-March 2022

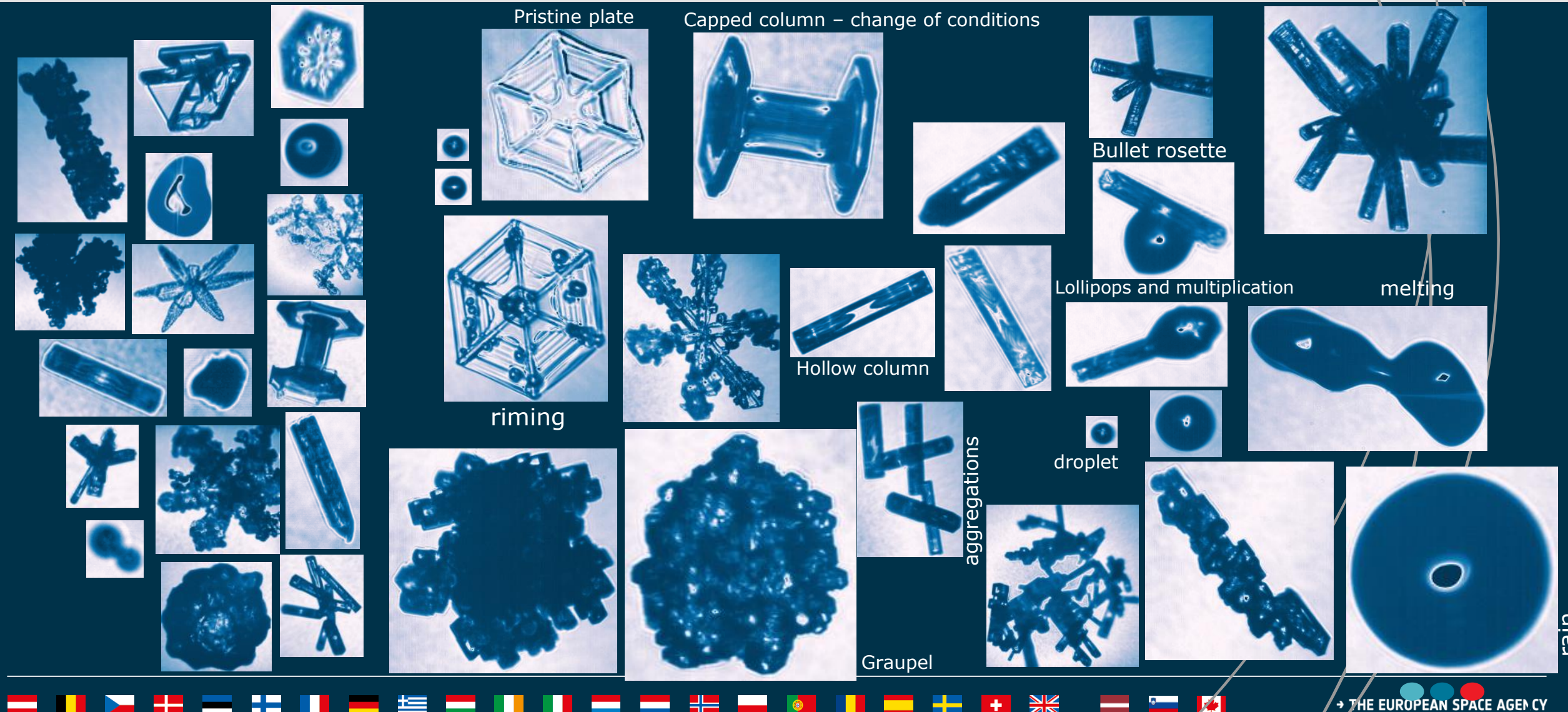
**The SPEC HVPS-4: Dual Resolution with Four Orthogonal Views**





Credit: Paul Lawson – Spec Inc.

# Ice *habits* carry history of cloud processes



# Convolutional Neural Net CPI classification

## A CNN toolbox for Convair-580 imaging

Classifies CPI images into labeled particle habits

## Architecture

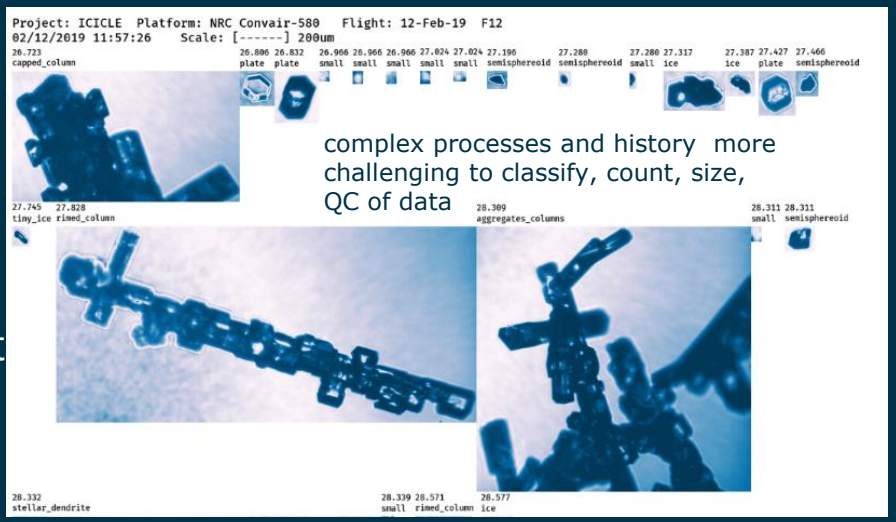
Multilayered Neural Network

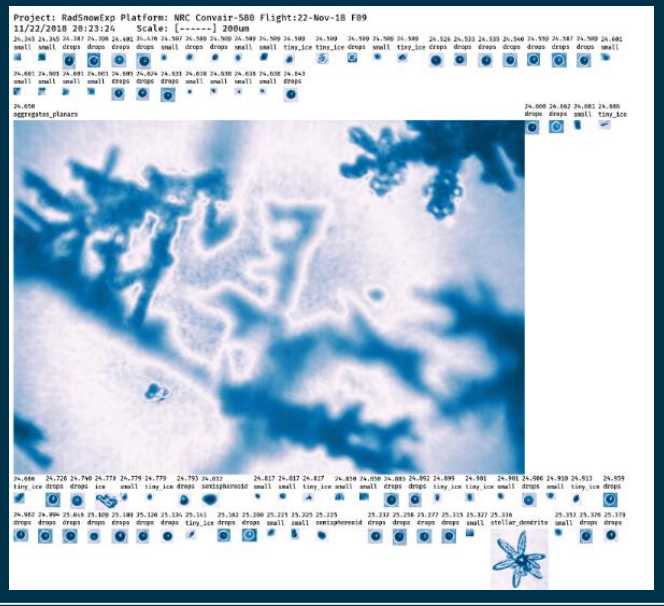
## Quality

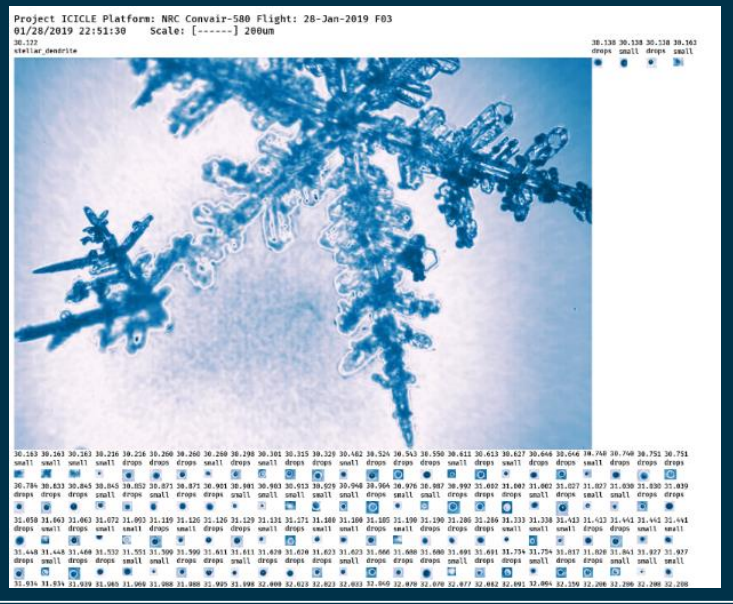
Using quality metrics, we achieve ~0.99 accuracy on both training and validation set

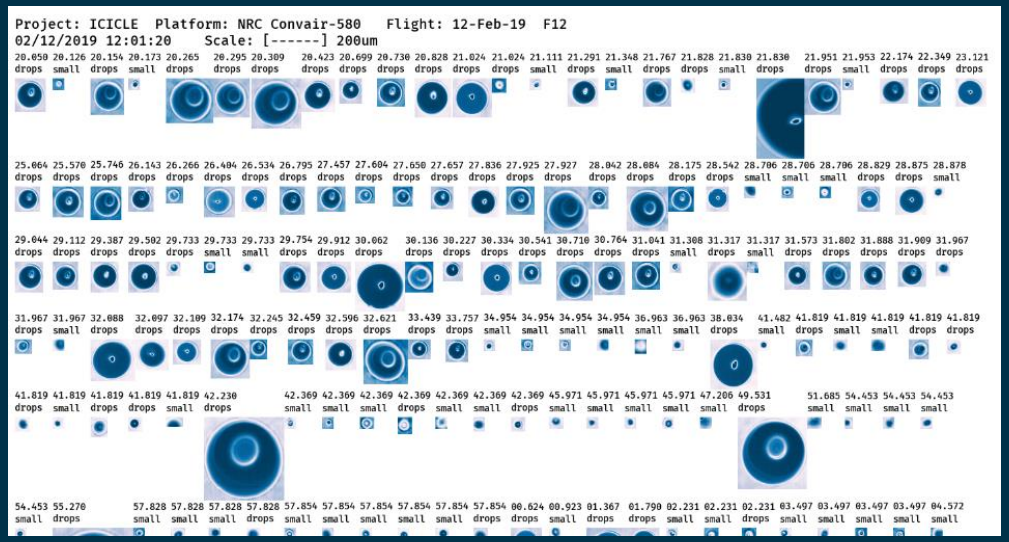
## Future developments

A similar toolbox is under development for other imaging probes



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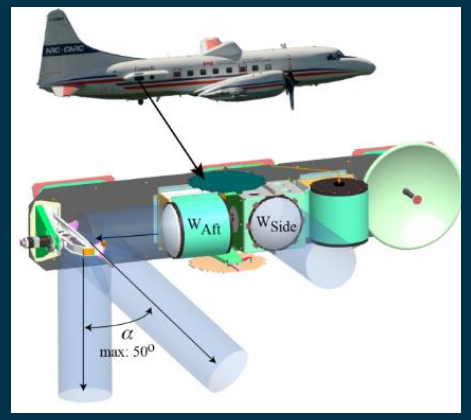
# Recent Airborne Projects – Proof-of-concept studies for space applications (2016-now)

## Doppler Wind Radar Demonstrator for WIVERN

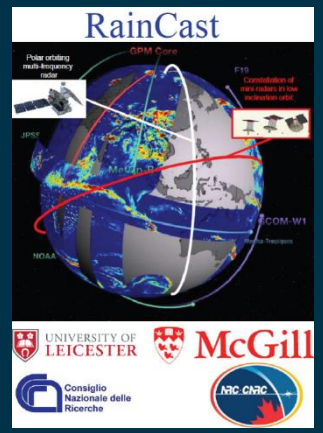



The NRC Airborne W Radar is used to measure high Doppler Velocity (>100 m/s) using Polarization Diversity Pulse Pair (PDPP) technique – First such measurement from a moving platform

**Reference:**

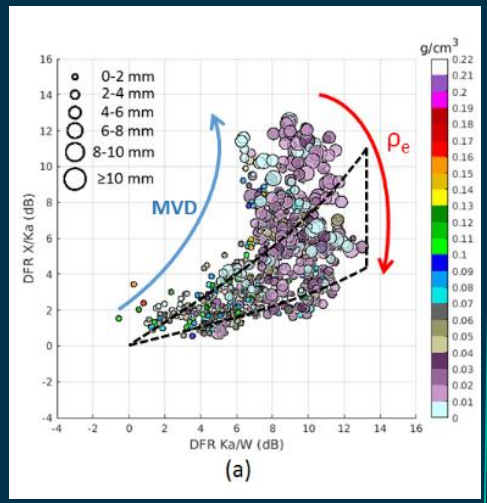
*Illingworth et. al. (2018), Wolde et. al. (2019), Battaglia et. al. (2017)*

## RadSnowExp/RainCast – Multi-platform & multiple frequency Radar study


Airborne Triple-frequency measurement of Arctic Clouds

*C. Nguyen, M. Wolde, A. Battaglia, et. al., 2021, "**Triple-Frequency Airborne Radar Observation of Arctic and Mid-latitude Clouds**", Atmos. Meas. Tech, submitted*




## High Spectral Resolution Airborne Microwave Sounder - HiSRAMS

Two compact dual-polarized radiometers at 60 GHz oxygen and 183 GHz water-vapor bands

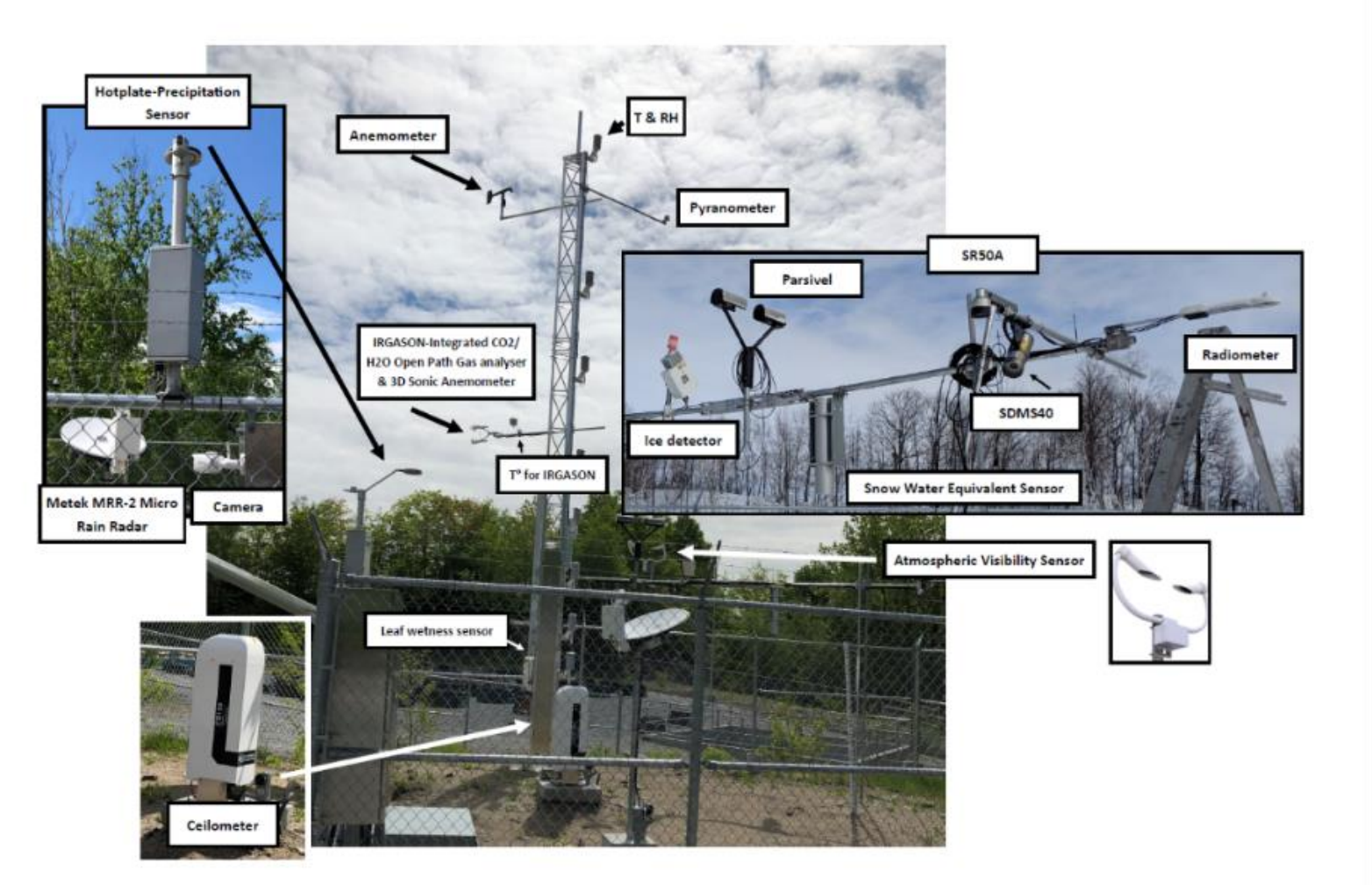
Spectral resolution up to 300 kHz (thousands of channels)

Zenith/nadir scanning capability

- improved temperature and water vapor retrievals in the troposphere

# Climate Sentinel Station in Ottawa (2022)

J. Gyakum et. al.




Courtesy of Eve Bigras

# FAA TAIWIN Demonstration Activity

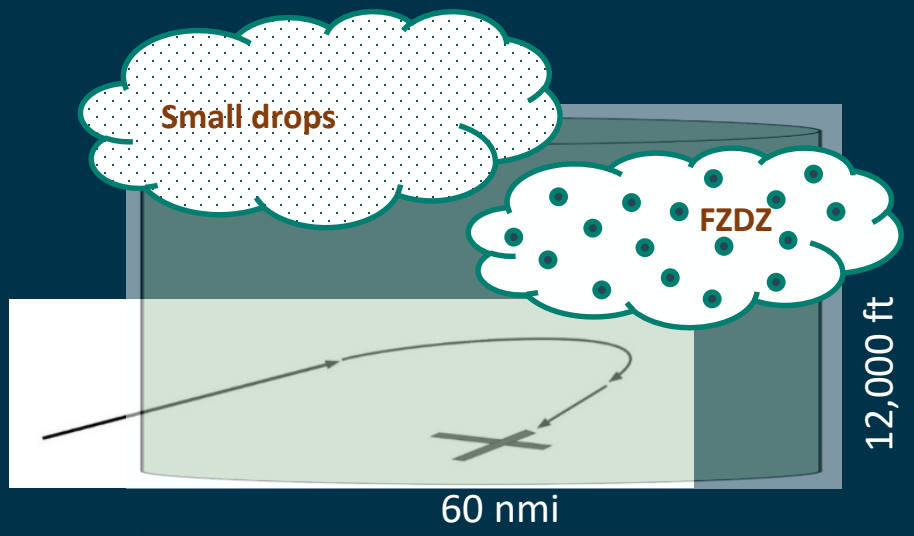
FAA Project Lead: Stephanie DiVito

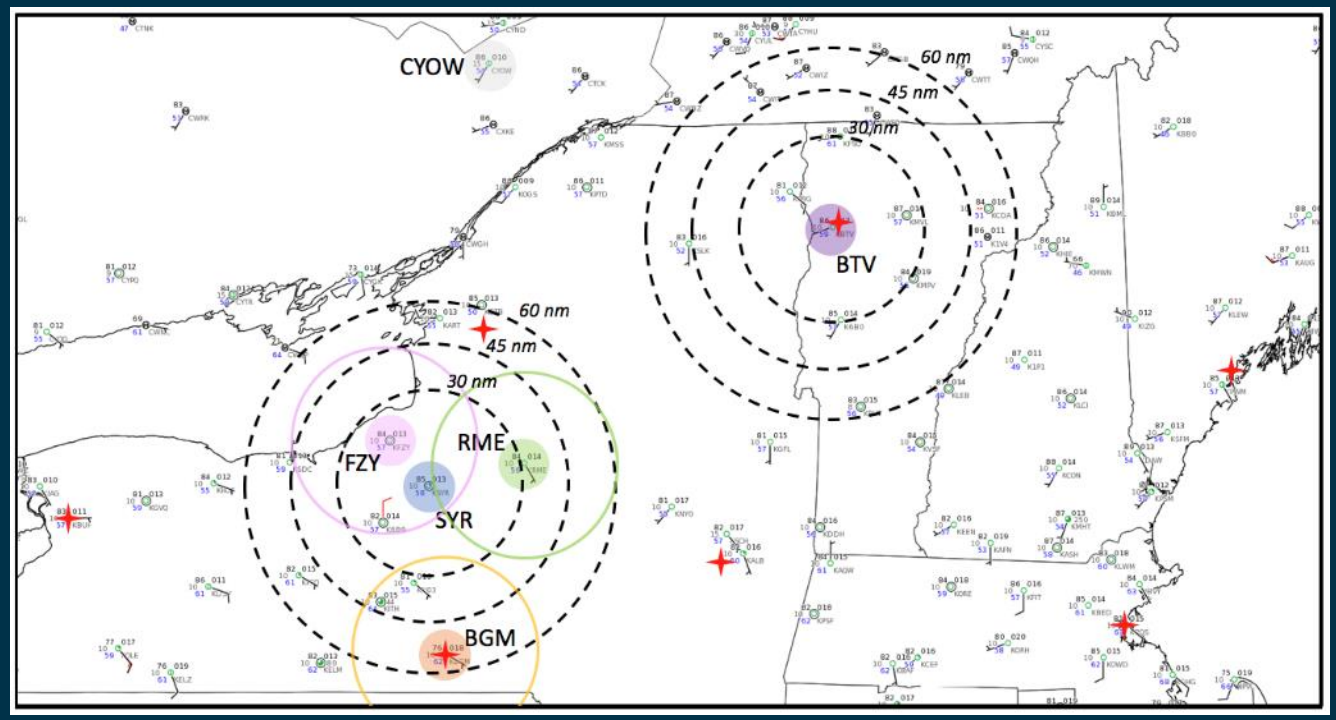
Supporting PIs: Scott Landolt (NCAR); Ben Bernstein (LEA)

demonstration for a high-resolution terminal area icing capability under development

Winter 2021-2022: Collect data while running V1 of capability in real-time at select airports

- NRC Convair-580 *(Feb 2022)*
- Instrumented ground sites

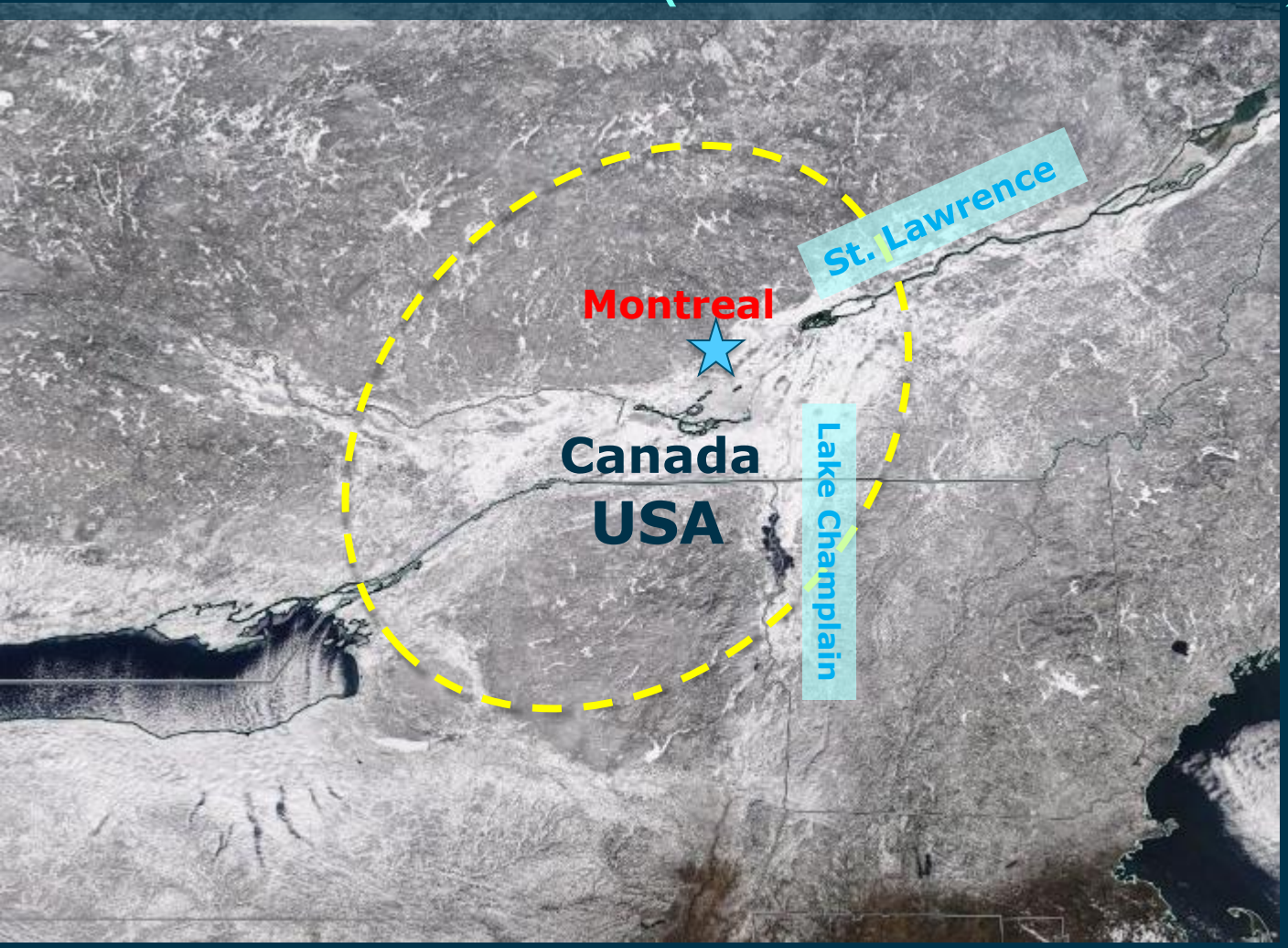


# WINTRE-MIX

## WINter precip Type REsearch MultI-scale eXperiment

## *(under review -NSF)*




**Goal:**
To better understand how multi-scale processes influence the variability and predictability of precipitation type and amount under near-freezing surface conditions.

**Target time frame:**
- **1 February – 15 March 2022**

**Target region:**
- **St. Lawrence / Champlain Valleys**
- **US (NY) – CAN (QC) boarder**

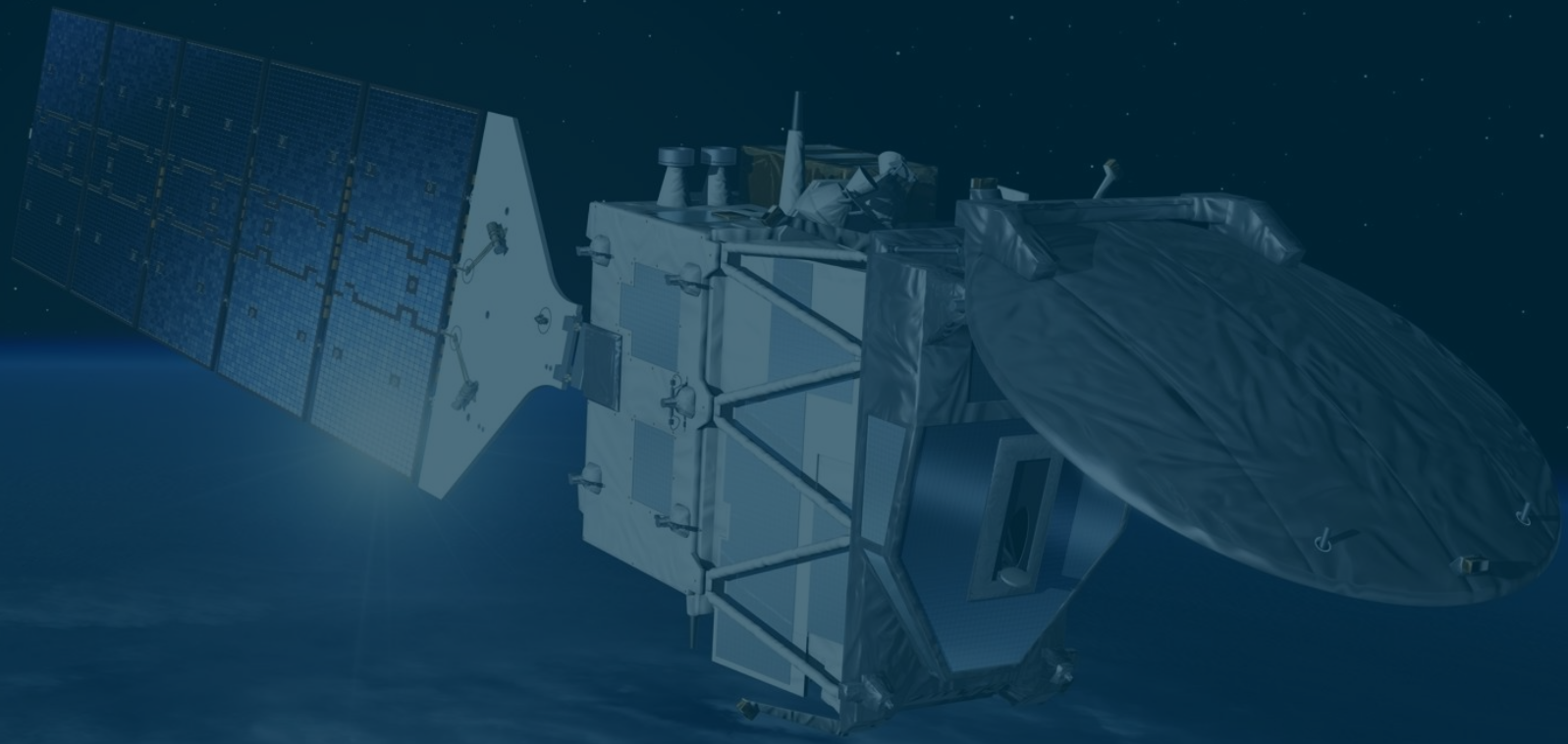
**US PIs:**
J. Minder, N. Bassill (UAlbany)
J. French, D. Kingsmill (UWyoming)
K. Friedrich, A. Winters (UColorado)

**Canadian PIs :**
M. Wolde, Cuong Nguyen, Leonid Nichman (NRC)
J. Gyakum, D. Kirshbaum, F. Fabry (McGill)
J. Theriault (UQAM)

https://worldview.earthdata.nasa.gov/

# Aircraft campaigns

- Extensive in-situ and remote sensing capabilities (ground and aircraft)
- New and improved microphysical sensors for project use by 2022 on the NRC Convair-580
- Strong interest to collaborate in pre-launch and post-launch campaigns



# Backup

# In-situ and remote sensing instruments on NRC Convair-580

| Measured Parameters | Instrument |
|---|---|
| Aircraft state | Inertial Navigation Systems (4), and GPS (2), Reverse Flow Temperature |
| Atmospheric state | Rosemount Temperature Sensors (4), Licors (2) – Dew point, Chilled Mirror, Multiple pressure transducers including 3- 5-hole probes |
| Aerosol | Wing mounted UHSAS, Cabin UHSAS, SP2, CCNcounter-100, CPC3776. *optional(CPC3790, CN7610, LII300, SP2, APS)* |
| Icing and icing type (Dither algorithm) | Goodrich Icing Detector (3) |
| Bulk microphysical measurements (TWC, LWC) | 2x Nevzorov(analog), SEA ICD, Nevzorov(digital) |
| Extinction | ECCC Extinction probe (CEP) |
| Cloud Particles (Size and concentrations) | 2x CDP-2, FCDP, FSSP |
| Cloud drops - – shape, size and concentrations | 2x 2DC; 2x 2DS; CIP-15, CIP-25, 2x HSI, CPI |
| Large Precipitation Particles – shape, size and concentration | PIP, HVPS-3, HVPS-4 |
| | |
| Cloud Structure, dynamics and composition – Radar Reflectivity, Doppler | • NRC Airborne W (94.05 GHz) and X (9.41 GHz) (NAWX) band radars: 3 antennas (zenith, nadir, side) for each system, dual-polarization, dual-Doppler, Polarization Diversity Pulse Pair capability. Ka-band (35.64 GHz) radar: 2 antennas.<br>• Pilot X-band Radar |
| Brightness Temperature, temperature and water vapor profiles | HiSRAMS (Hyperspectral Radiometers at Oxygen band (60 GHz) and WV (183 GHz) ) – scanning, option for up or down looking. |
| Cloud Structure, and composition – Lidar backscatter | 2x 355 nm, linearly polarized |
| Lightning detection | Stormscope Goodrich WX-500 |
| Flight logs / chats / track marking | Planet ; ground to air communication and chat – low band width link, but allow chat and some limited data broadcast from the aircraft and also receiving data from ground |

*not all the listed sensors can be installed at once