Environment Canada Environnement Canada

Canada

Research Aircraft Applications: Processes, Retrieval Algorithms and Verification

Stewart G. Cober

Cloud Physics and Severe Weather Research Section

Science and Technology Branch

Outline

- Airborne Measurement Program
- Instrumentation
- Validation
- Processes
- Parameterizations
- Research Program Support

Airborne Measurement Program

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Instrumentation D[1]

FSSP 5-95 µm

CIP 12-768 µm

FSSP 2-47 µm

2D-C 25-800 µm

2D-P 200-6400 µm

2D-S 10-1280 µm

HVPS 200-25000 µm

PCASP 0.1-3 µm

Instrumentation D^2

Instrumentation D^3

King

Nevzorov

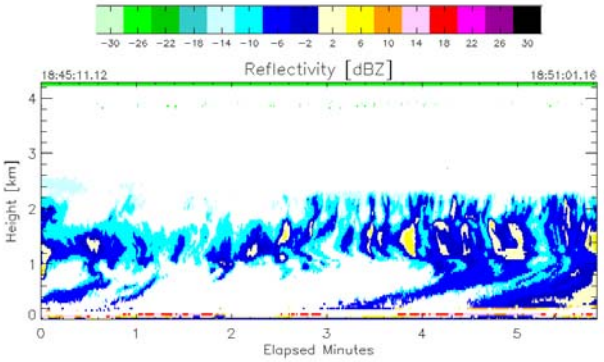
JW (DF)

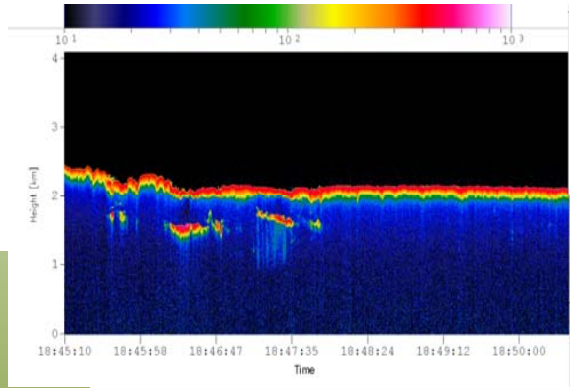
CVI-CSI

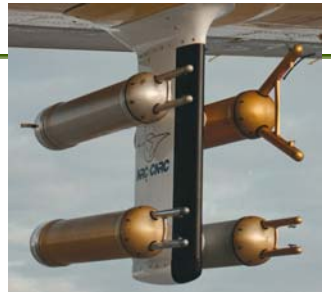
Instrumentation Issues

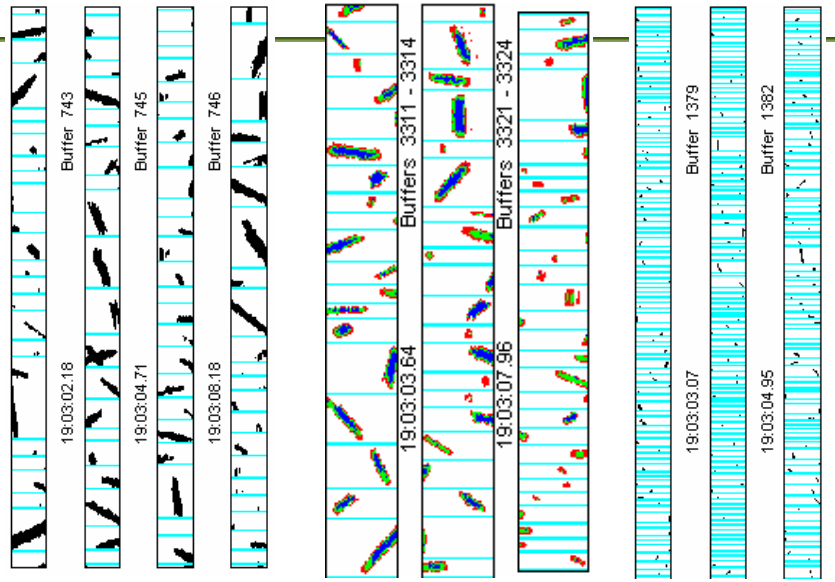
- Measurement of ice crystals < 100 µm
- Depth of field (CIP, 2DS, 2D probes)
- Sample volume, particle reconstruction and reflectivity
- Separation of ice and water spectra
- Accuracy of low IWC and LWC <0.01 g m^{-3}
- Underestimation of IWC caused by particle bouncing
- Particle shattering
- Problematic for glaciated and mixed phase clouds
- Ideally want consistency between independent measurements of D^1, D^2 and D^3

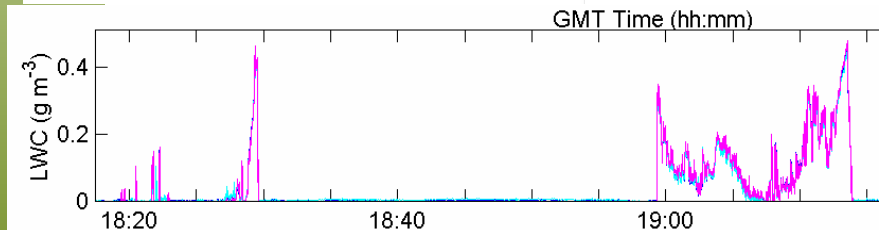
Airborne Measurements

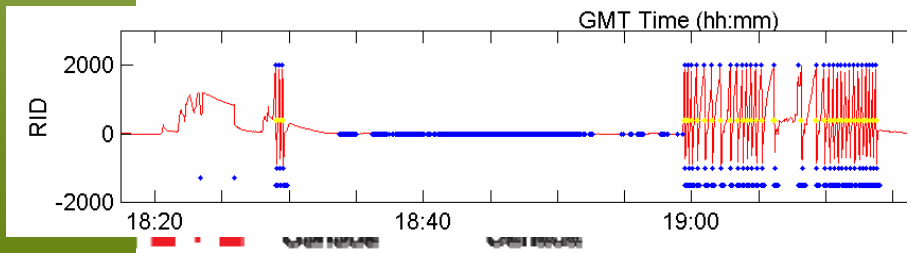


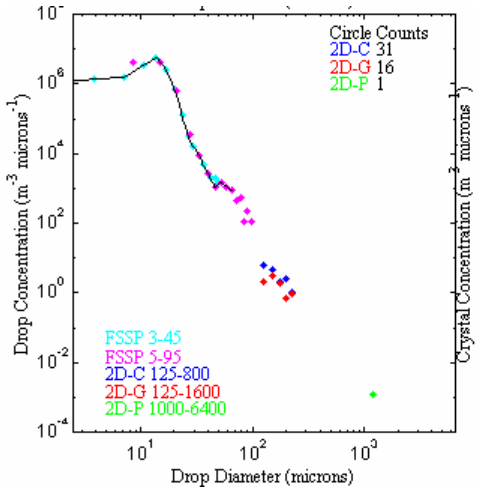


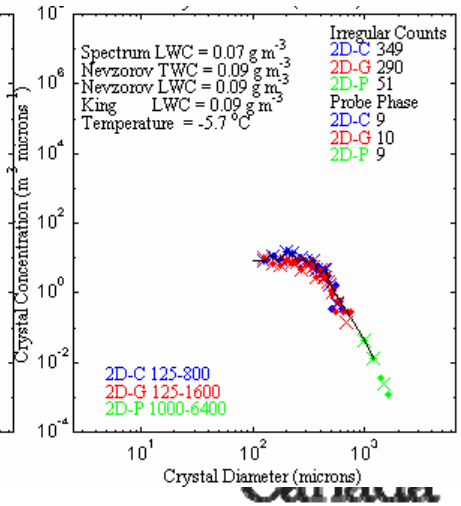




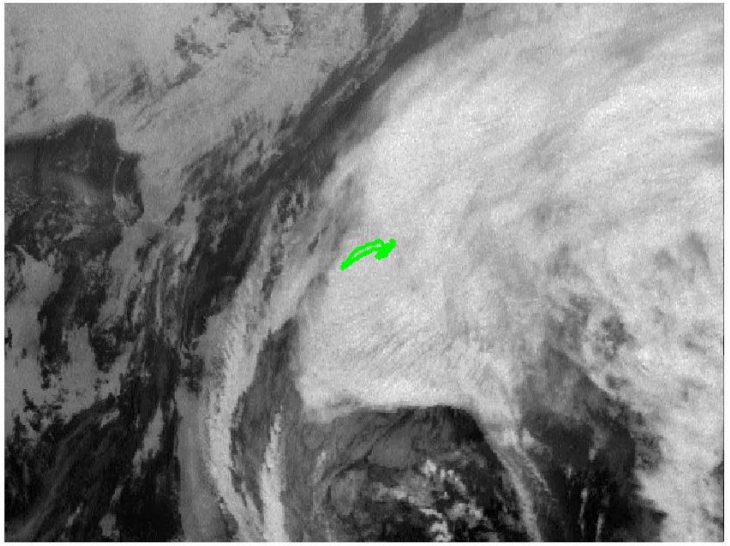


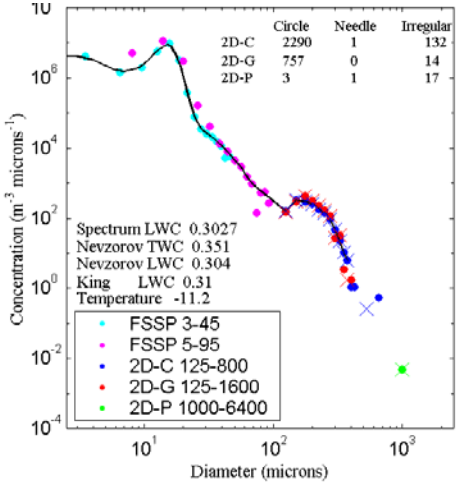


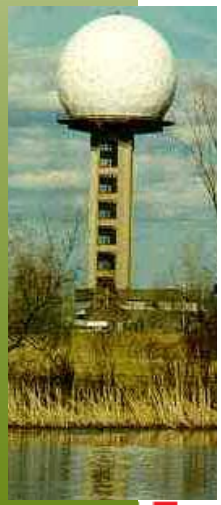


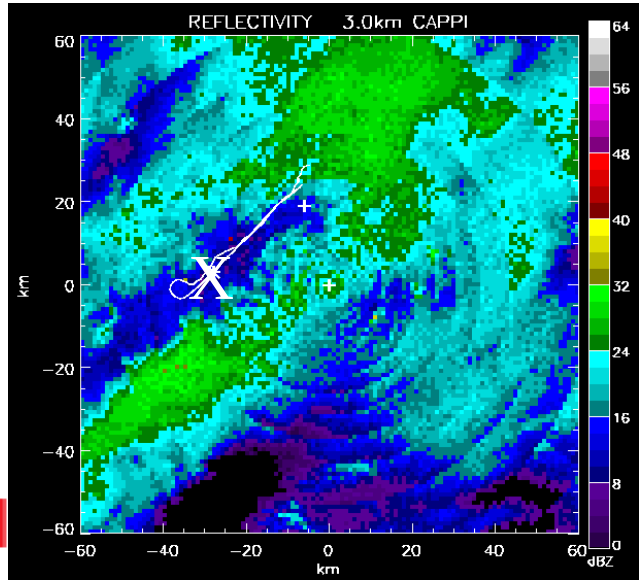


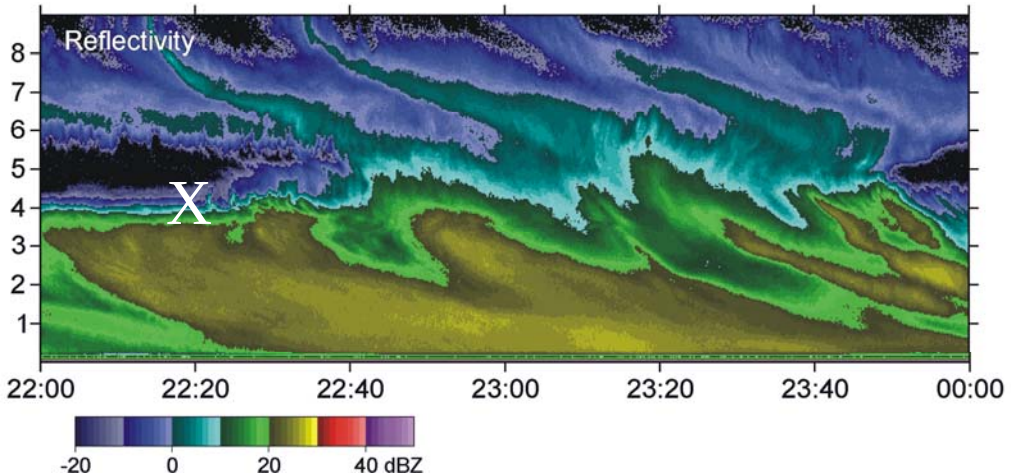
Remote Sensing Validation



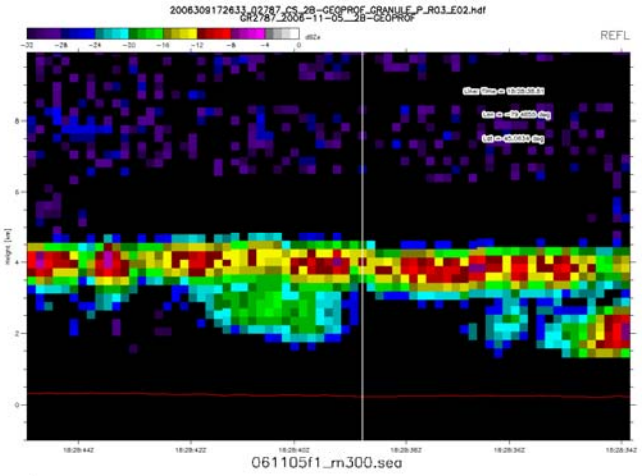


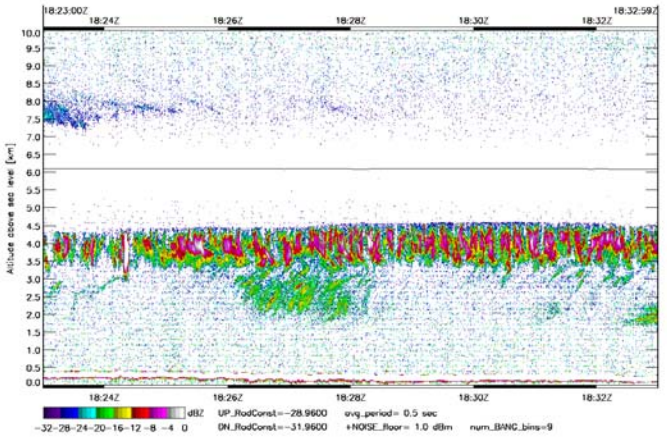


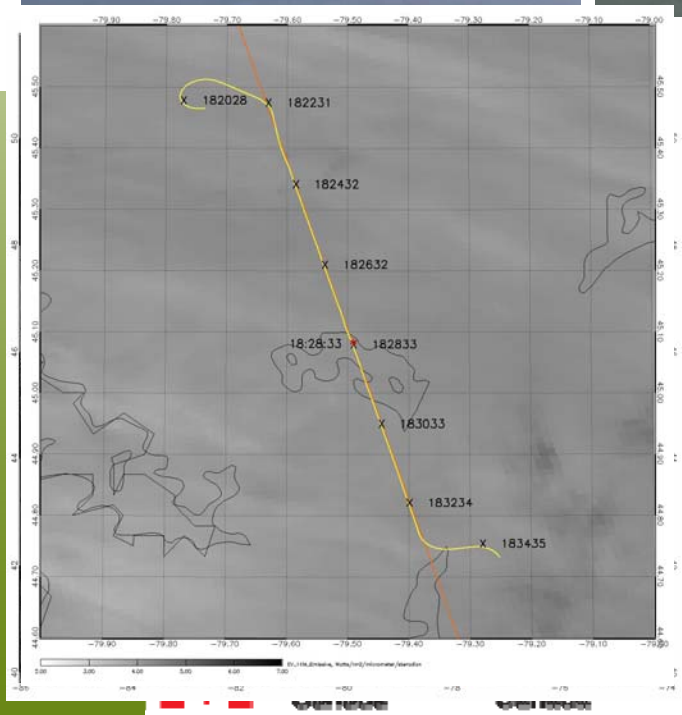




CloudSat Example





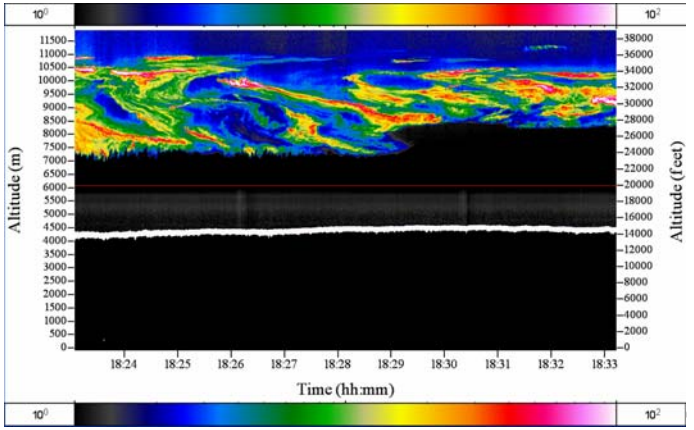


CloudSat CPR

C-580 Ka-Band

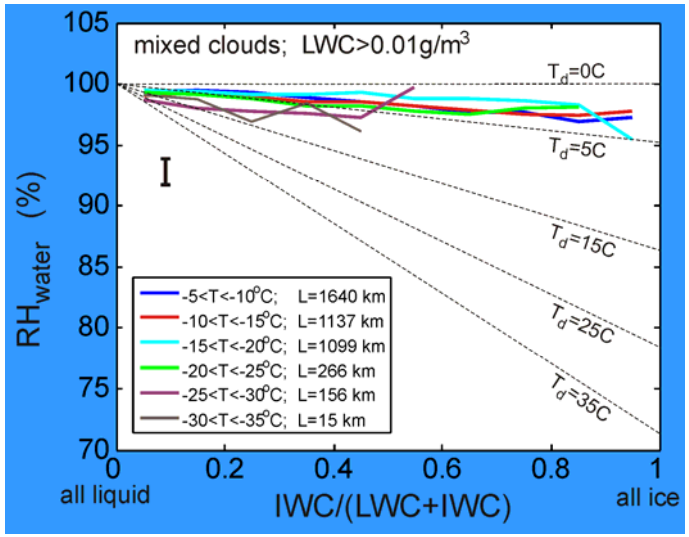
C-580 Lidar 1064

5 Nov 2006
18:25 UTC
MODIS 12 μm

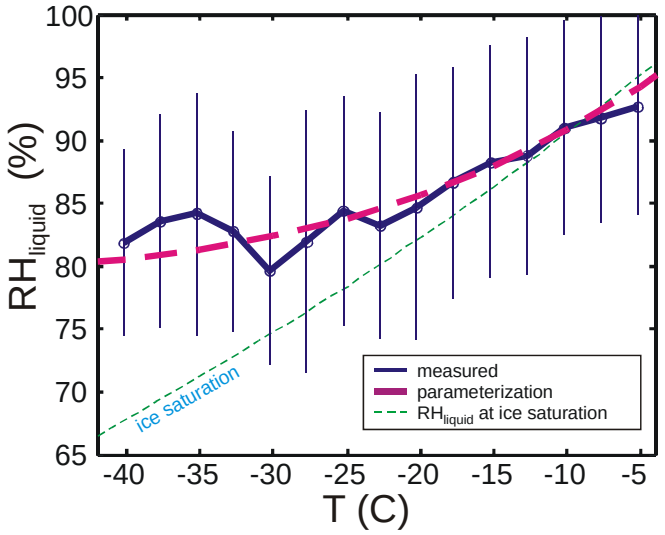


Cloud Physics Processes

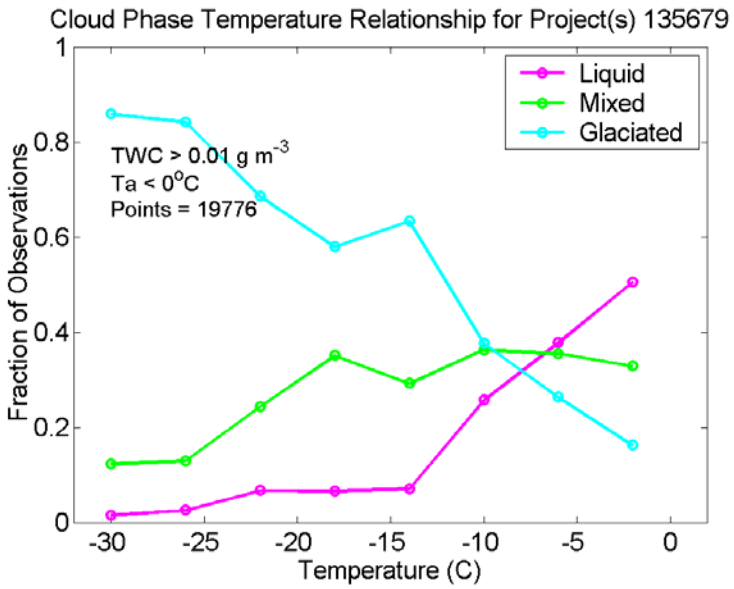
Relative Humidity in Mixed Phase Clouds

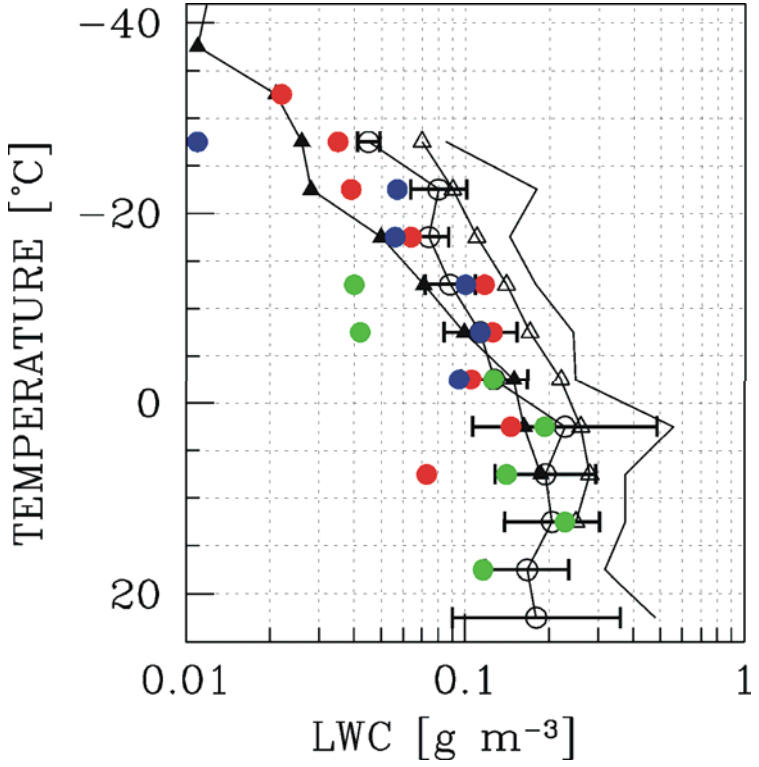


Relative Humidity in Ice Phase Clouds

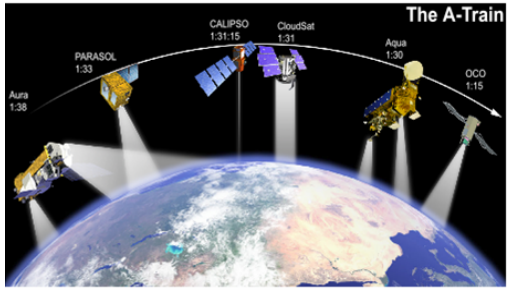


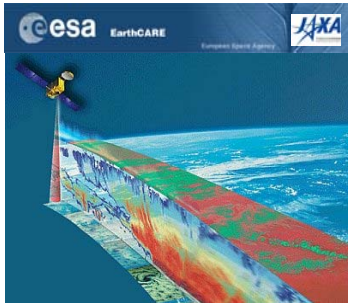
Cloud Physics Parameterizations

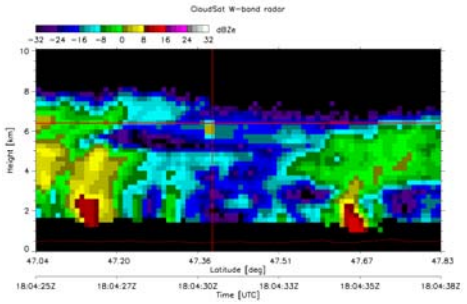


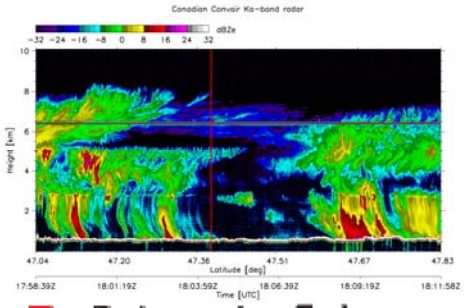


Precipitation from Space









CloudSat

GPM

EarthCare

ACE

SnowSat

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Environment Canada Research Priorities that Research Aircraft Can Support

- Integrated monitoring and environmental prediction.
- Global Earth Observations (GEO).
- Model processes and validation (smaller spatial and temporal scales).
- Satellite validation (increased emphasis on remote sensing).
- Remote sensing validation (radar, lidar, radiometer, etc.).
- Process studies (convective initiation, role of clouds and aerosols in radiation and cloud chemistry).
- Scientific knowledge required to meet regulatory needs.
- Canadian contributions to observing and understanding cold season and northern processes – Arctic research agenda.
- Measurement of precipitation from space – water cycle.

- **Each of these Priorities will require in-situ observations which can only be obtained with supporting specialized research aircraft.**

GEO

- The ACSD research aircraft facility should be considered as a fundamental tool for the calibration and validation of surface and satellite based remote-sending instruments that are designed to measure the vertical profiles of chemical or meteorological constituents in the atmosphere. The expertise within ACSD, and the instrumentation suite that currently exists in support of in-situ chemical and meteorological measurement programs, is world class and in many cases world leading. The application of this expertise and instrumentation will be essential for the calibration and validation of observation systems that are considered within the GEO program. The research aircraft are capable of making high resolution vertical profile measurements of temperature, pressure, winds, water vapour, aerosols, cloud hydrometeors (drops and ice crystal sizes and concentrations) and chemical constituents (SO2, CO, O3, OVOC, NH3, NOx, Hg, among others) in the atmosphere. They are also capable of making specialized remote sensing observations from Ka-band radar, lidar and microwave radiometer instruments.
- Some satellite instruments have narrow measurement swaths (i.e. CALIPSO 100 m, CloudSat 1.4 km), and only research aircraft are capable of getting directly under the satellite beam for physical validation.

Arctic Agenda

- With respect to the Arctic Agenda the ERAF can be positioned as an essential asset for supporting the programs for monitoring and undertaking environmental prediction in the Arctic. While it is a research tool, it will play a critical role in the validation of both monitoring systems and environmental prediction systems.
- With respect to monitoring, considering the size of Canada's land mass, only satellite-based observations of the surface and atmosphere above the surface will be capable of providing comprehensive coverage. There are numerous satellites being launched and planned for launch over the next 1-2 decades which will be able to make critical observations of the surface (e.g. hydrosphere, cryosphere) and atmospheric components (i.e. clouds, weather, atmospheric chemistry, aerosols, etc.). In-situ aircraft observations, or high resolution remotely sensed observations from aircraft are critical for both development of the initial retrieval algorithms and validation of the final retrieval algorithms. Hence, the ERAF should play a vital role in any monitoring strategy for the North.
- At the international level, the Canadian science cadre tends to play a more winter-northern-focused role in these science programs. We have the specialization in observing and predicting winter and northern phenomena, while the majority of other countries focus further south. Hence our monitoring and environmental prediction capacities tend to contribute to the international science programs in a unique and complimentary way. The ERAF is an example of this, in that it is the world-leading research aircraft program for measurements of cold clouds and aerosol physics, and for cryosphere observations.

Environmental Prediction

- With respect to environmental prediction, the future environmental prediction capacity of the department will be largely dependent on having good physical algorithms in the various coupled ice-surface-ocean-chemistry-biosphere-hydrosphere-atmosphere models and on good data assimilation of observations, largely from satellites. In-situ observations and/or high resolution remote sensed observations are critical for the development of the physical algorithms and for validation of the final models. Airborne platforms have an essential contribution to make in this regard.

IUGG - IAMAS

- Climate resolution passed at the IUGG in Perugia 2007:
  - The resolution urges: "**national and international agencies to adequately support comprehensive observation and research programs that can clarify the urgency and extent of needed mitigation and promote adaptation to the consequences of climate change.**"
  - It also recognizes that "**mitigation of and adaptation to climate change can be made more effective by reducing uncertainties regarding feedbacks and the associated mechanisms.**"

Questions and Discussion