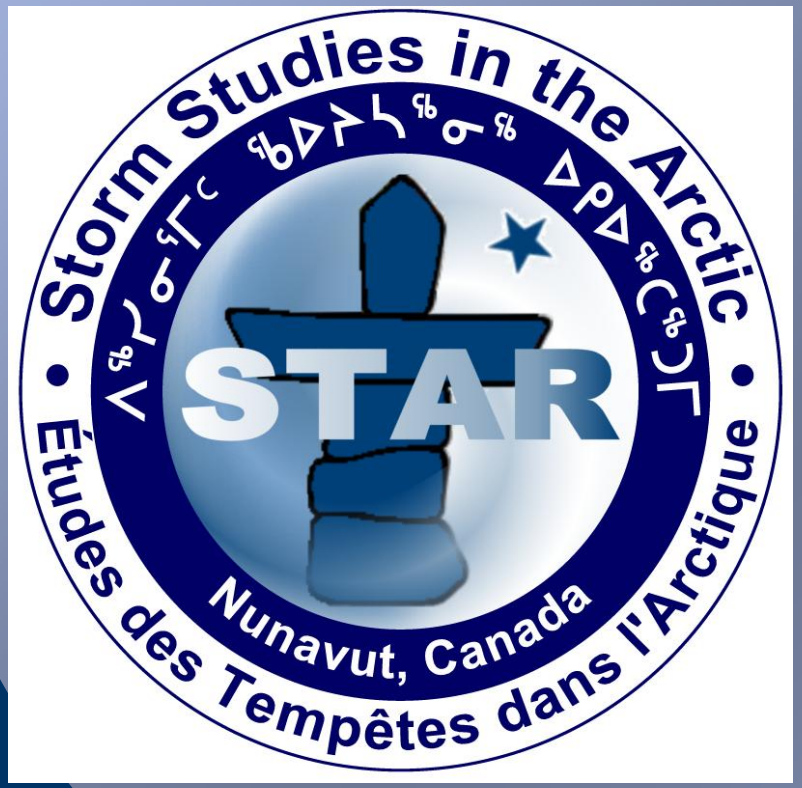
Utility of Aircraft and Satellite Measurements: Examples from STAR and UNSTABLE



www.starnetwork.ca

John Hanesiak
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University of Manitoba

STORM STUDIES IN THE ARCTIC (STAR)

BY JOHN HANESIAK, RONALD STEWART, PETER TAYLOR, KENT MOORE, DAVID BARBER, GORDON MCBEAN, WALTER STRAPP, MENGISTU WOLDE, RON GOODSON, EDWARD HUDSON, DAVID HUDAK, JOHN SCOTT, GEORGE LIU, JUSTIN GILLIGAN, SUMITA BISWAS, DANIELLE DESJARDINS, ROBYN DYCK, SHANNON FARGEY, ROBERT FIELD, GABRIELLE GASCON, MARK GORDON, HEATHER GREENE, CARLING HAY, WILLIAM HENSON, KLAUS HOCHHEIM, ALEX LAPLANTE, REBEKAH MARTIN, MARNA ALBARRAN MELZER, AND SHUNLI ZHANG

With 14 research flights from Baffin Island, surface- and satellite-based instruments, STAR aims to improve understanding and prediction of severe arctic storms and their hazards

Storms and their related hazards over the Arctic have profound effects, including loss of life and influences on industry, transportation, hunting, recreation, and the landscape itself (terrestrial, sea ice, and ocean). Over the past few decades, there has been evidence that the occurrence of extreme storms has increased (Stone et al. 2000; McCabe et al. 2001; Zhang et al. 2004) as well as their associated hazardous weather in some regions (Hanesiak and Wang 2005). Extreme weather directly affects the lives of communities and individuals living in the Canadian Arctic (e.g. NTI 2001; Hassol 2004). According to the *Nunatsiaq News* (5 April 2005), "erratic weather and changing ice patterns are leaving more Nunavik hunters stranded out on the land without traditional techniques to help them."

There are several recent examples of extreme weather events that have occurred in the southeast Arctic alone. In February 2006, warm temperatures (>5°C compared to a normal of −20°C) and rain showers occurred in association with an intense cyclone across south Baffin Island, breaking records in the Nunavut Territory. Icy conditions on runways grounded aircraft in Iqaluit (the capital city of Nunavut, with a population of more than 10,000) and 125 km h^{-1} winds destroyed one building and broke windows in Pangnirtung, Nunavut (*Nunatsiaq News*, 3 March 2006, and *CBC*, 28 February 2006). Another recent storm (7–8 June 2008) produced ▶

Ground blowing snow event during STAR at the primary meteorological installation in Iqaluit, Nunavut, Canada. (Photo: Peter Taylor)

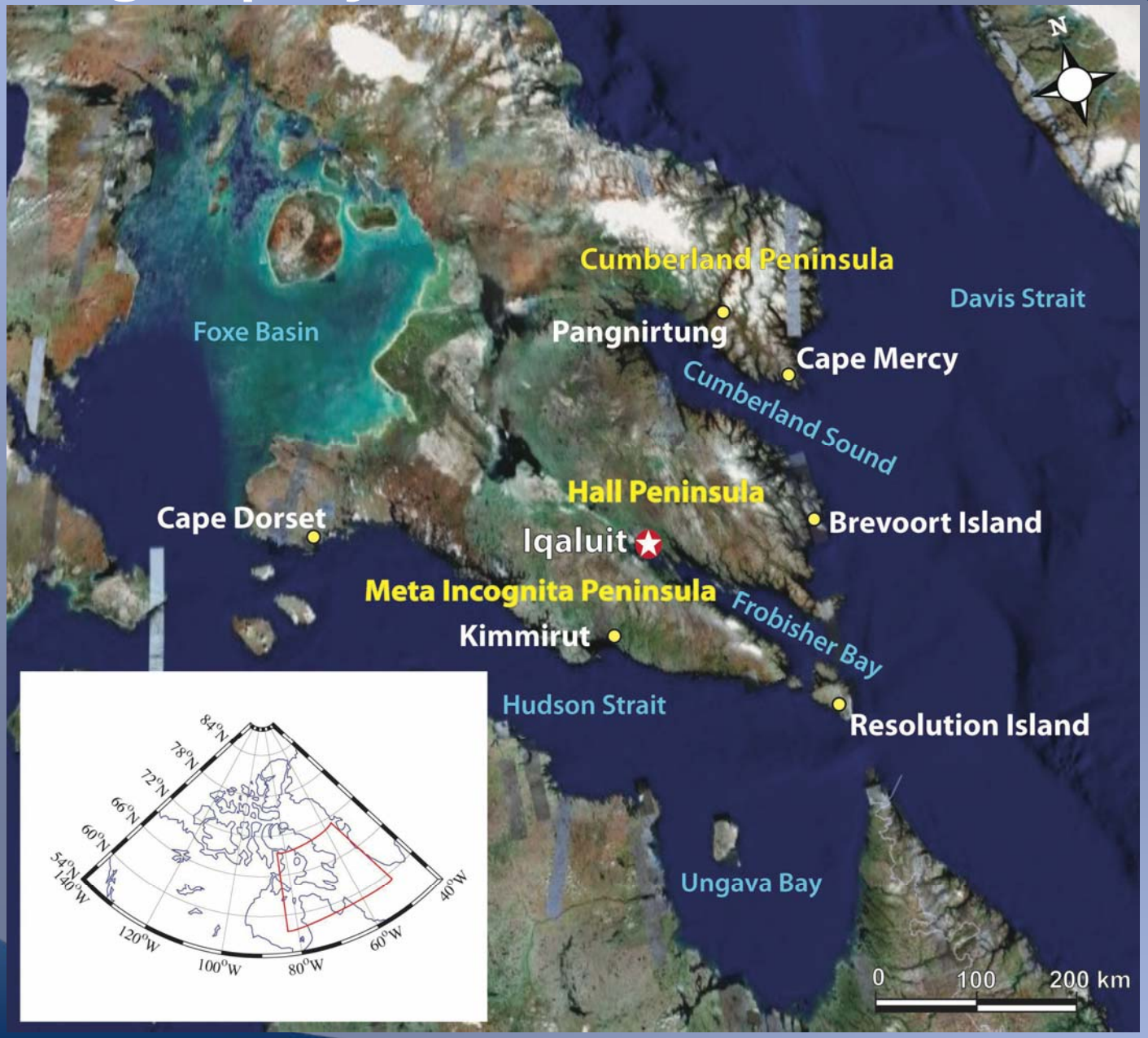
Bulletin of the American Meteorological Society (BAMS)

January 2010 issue

Objective

- To better understand severe Arctic storms and their associated hazardous conditions, and contribute to their better prediction
  - Realized through 4 main themes
    - Local Iqaluit area
    - Regional weather and sea ice
    - Prediction
    - Community interactions
  - Strong winds, precipitation, blowing snow / low visibility, sea ice
- Main activity - major field deployment

Geography



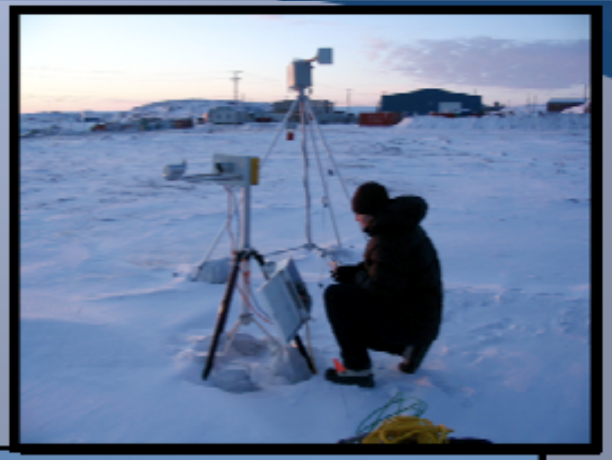
Storm Studies in the Arctic
STAR
Nunavut, Canada
Études des Tempêtes dans l'Arctique

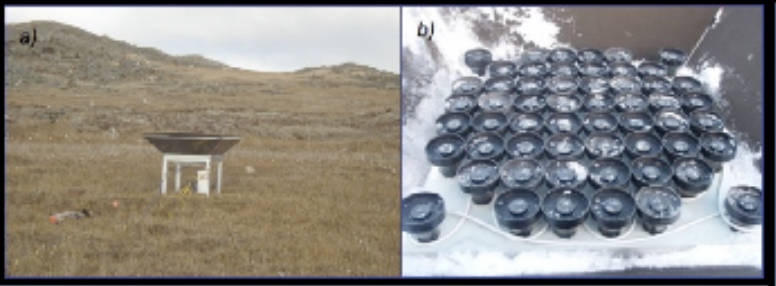
Overview of Field Accomplishments

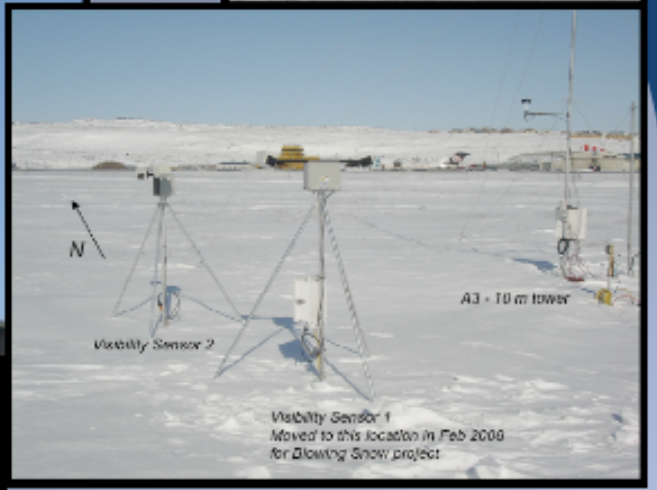
- No major field deployment issues !
  - Dave Hudak, John Scott, Jim Young, Steve Brady
  - Wiz Mohammed, Jamal Shirley, Mary-Ellen Thomas, NRI, INAC (Jim Rogers, Andrea Cull)
  - Dave Sills for mesonet
  - NRC and EC aircraft crews
- Successful field campaign !
- EC/NRC expertise is vital !

IOP	Start (UTC)	End (UTC)	# YFB sondes	Aircraft Flight	# Dropsondes
1	15 Oct 2100	17 Oct 1800	8		
2	20 Oct 1800	21 Oct 0000	2		
3	26 Oct 0600	27 Oct 0600	7		
4	29 Oct 1200	30 Oct 1800	3		
5	3 Nov 1200	4 Nov 1200	4 (2 in XVP)		
6	5 Nov 1600	6 Nov 0000	7 (4 in XVP)	yes	4
7	6 Nov 0000	7 Nov 0000	1	yes	
8	7 Nov 2100	8 Nov 0700	3	yes	13
9	9 Nov 2100	10 Nov 0200	1	yes	6
10	11 Nov 2100	12 Nov 1600	5	yes	6
11	16 Nov 1900	19 Nov 0000	23 (12 at XVP)	yes (3 flights)	16
12	20 Nov 1530	20 Nov 2230		yes (2 flights)	
13	22 Nov 1600	22 Nov 1900		yes	
14	23 Nov 1600	23 Nov 2000		yes	4
15	28 Nov 1500	28 Nov 1830		yes	5
16	28 Nov 1500	29 Nov 0000	3	yes	1

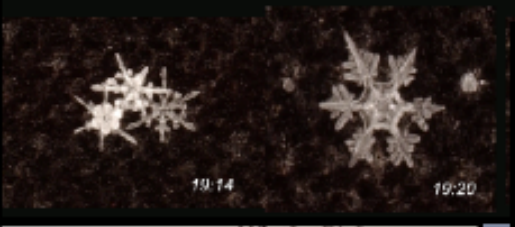
Phenomena / Purpose	Observations
Low Pressure System	7
Trough	3
Precipitation in YFB	9
Precipitation in XVP	3
Strong Winds/BS	2
Upslope Precipitation	5
Convergence Zone	2
Convection over Ocean	1
Rain/Snow Boundary	1
CloudSat	8

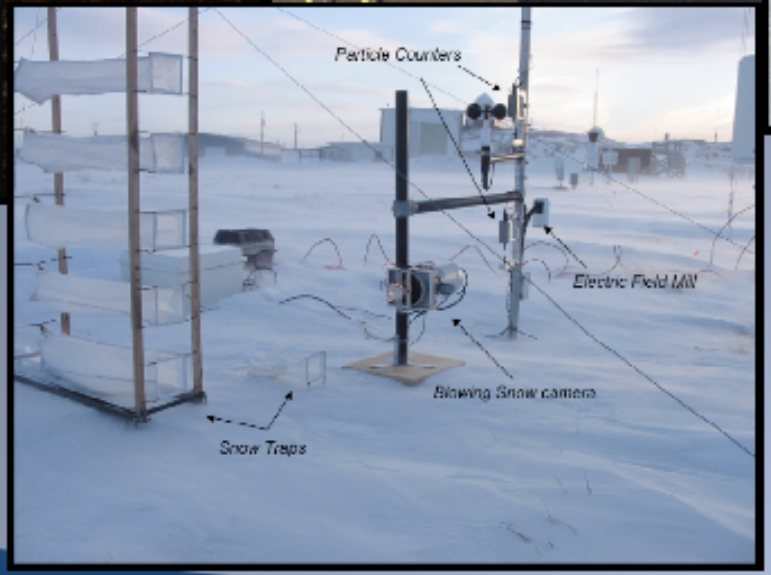






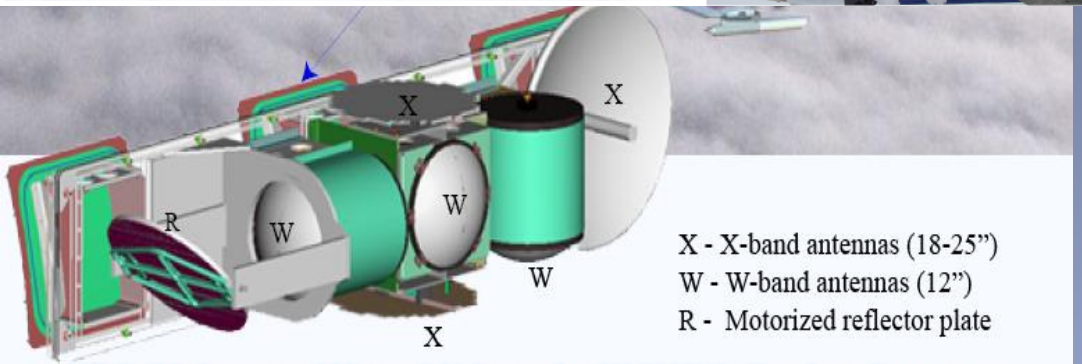
Snowflake Microphotography Iqaluit, NU: November 6, 2007



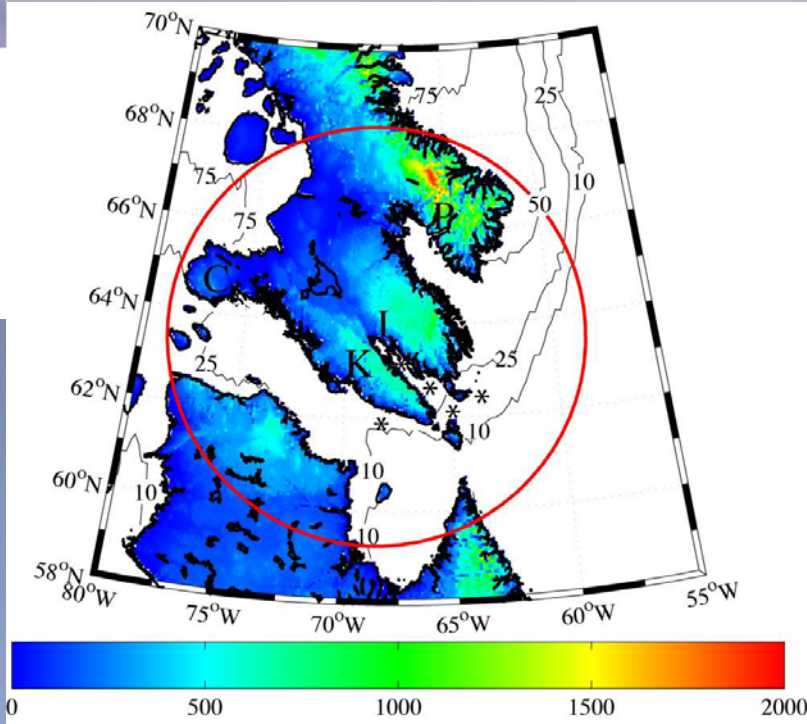


Research Aircraft (NRC Convair-580)

- 3 types of radars looking in various directions
- dropsondes



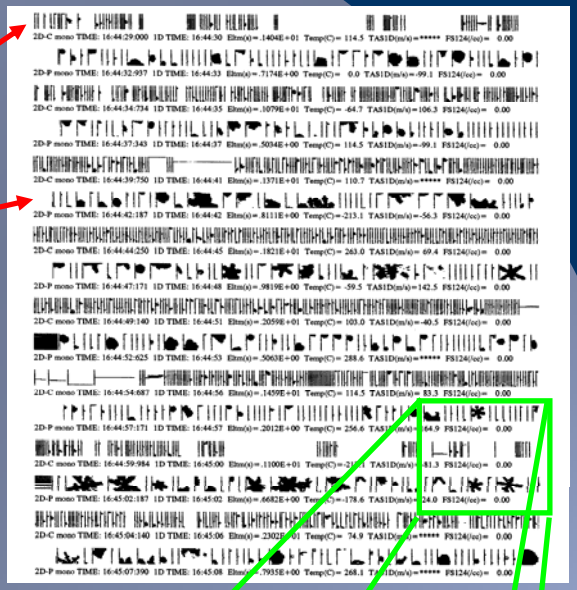
NRC Airborne W and X bands (NAWX) Radar System

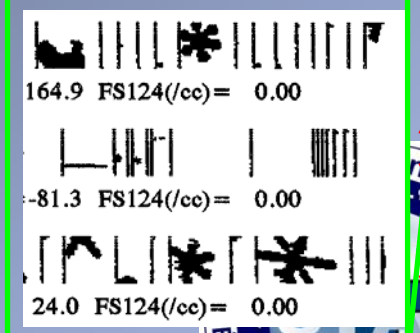


CONVAIR-580 CLOUD MICROPHYSICS

Under-wing particle probes

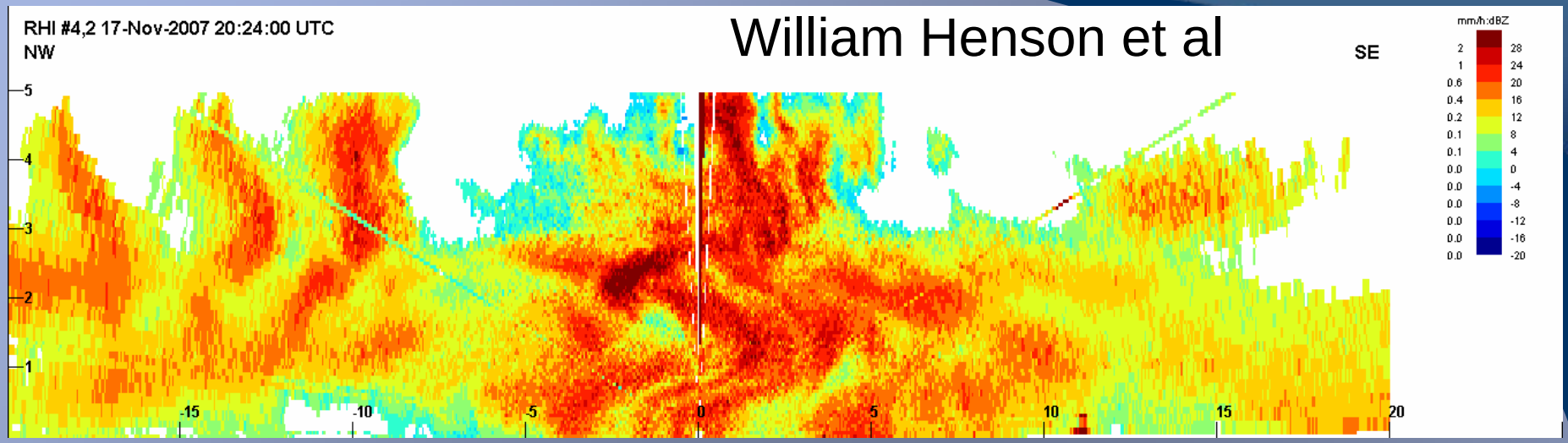
Standard PMS 2D Imagery

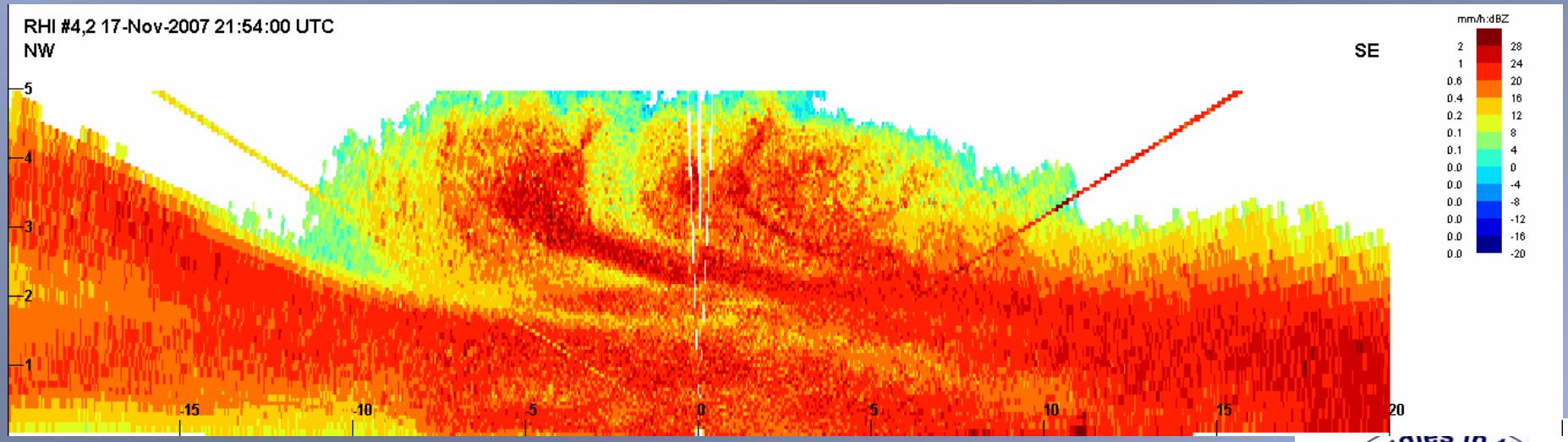




- Bulk Microphysics Probes for LWC, TWC, and IWC
- Cloud spectrometers
- Additional pylon on other wing with 3 other particle probes and wind/gust measurement system

William Henson et al



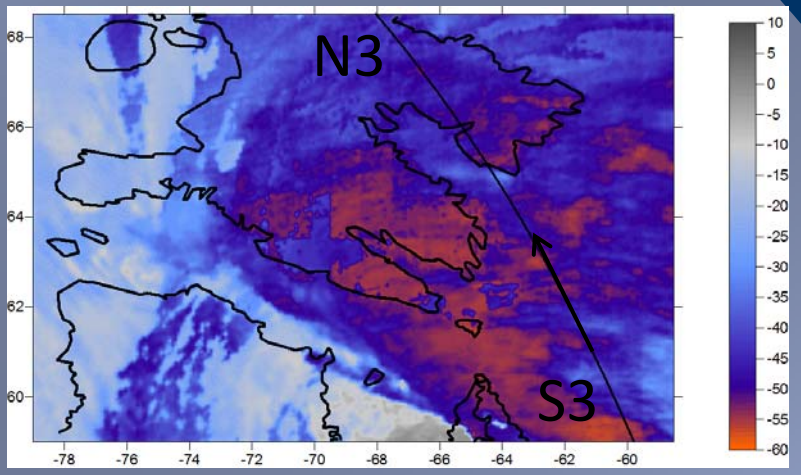


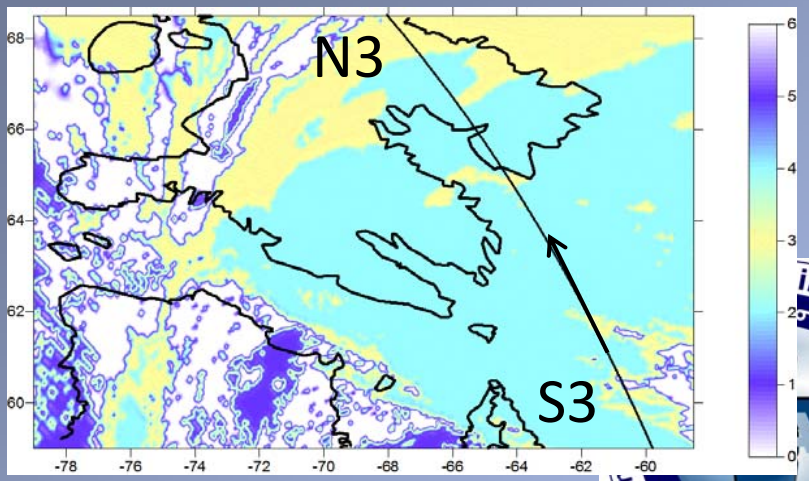
- Precipitation is a huge issue (where & how much)
- Cloud physics and dynamical features
- Cloud / precipitation structure

CloudSat Example

- Major low pressure system passing through Iqaluit on November 17th, 2007 at 1645 UTC
  - cold cloud tops (<-60°C)
  - low cloud top pressure (<200 mb)
  - vertical extents of >10 km.

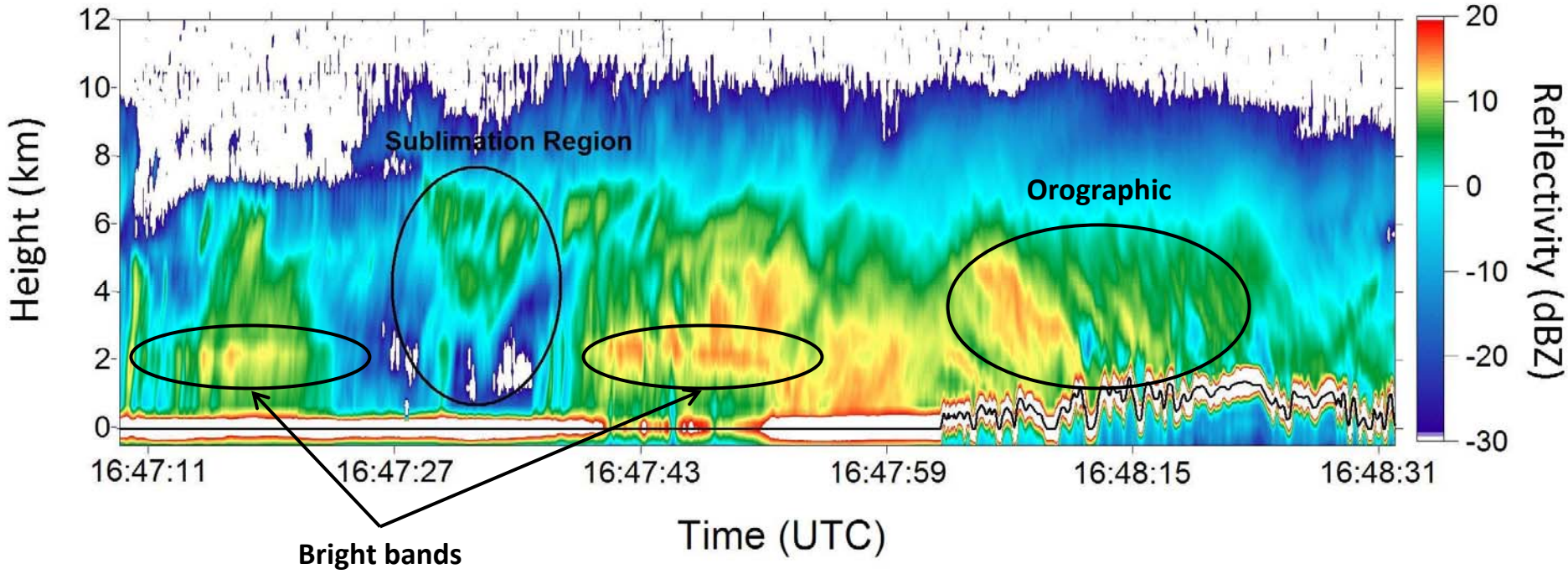
- Ice, liquid, and mixed phase cloud tops are all observed
  - discontinuous
  - cloud tops with T<-40°C are largely ice





Alex Laplante et al

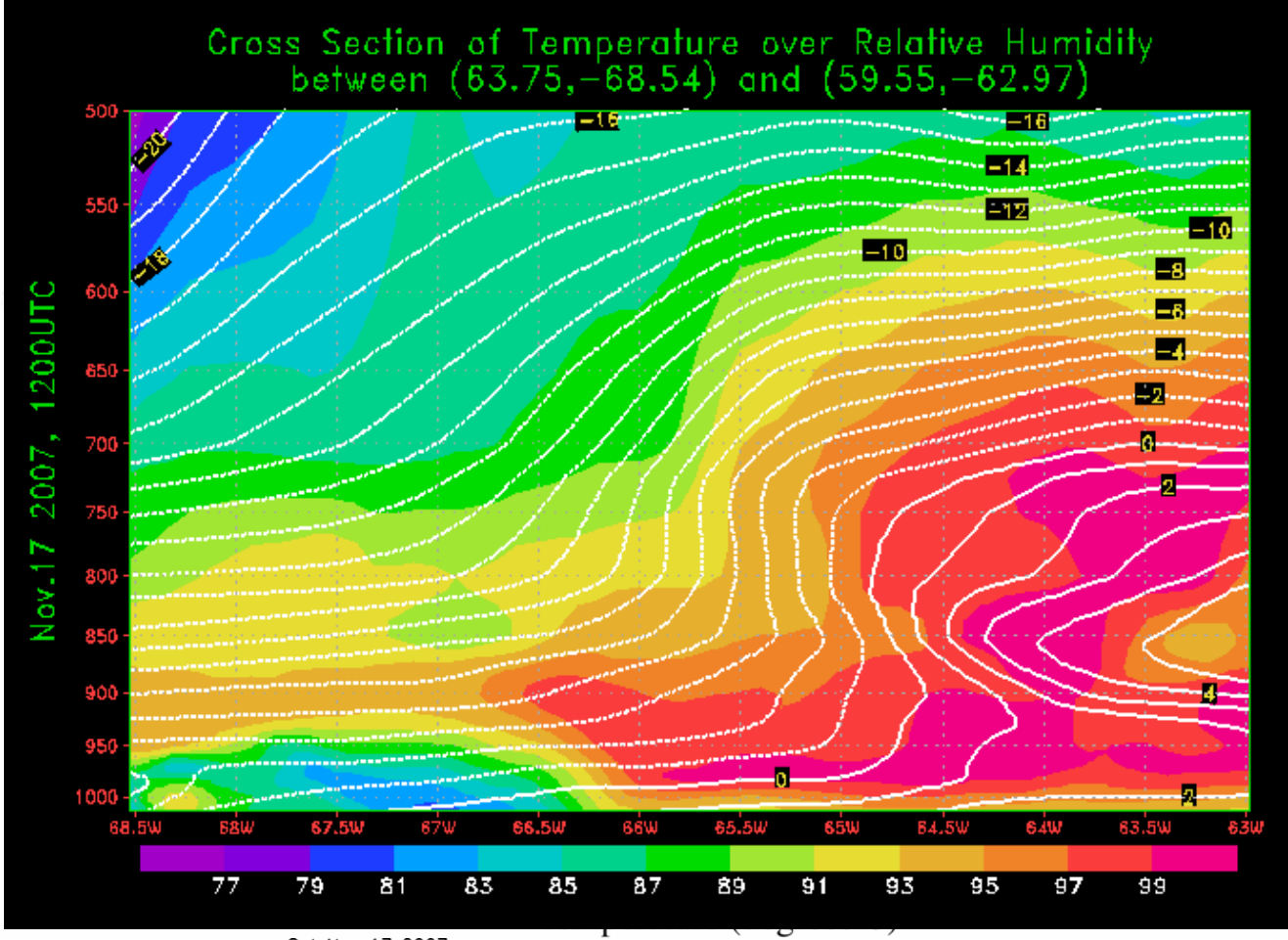
Precipitation features during STAR

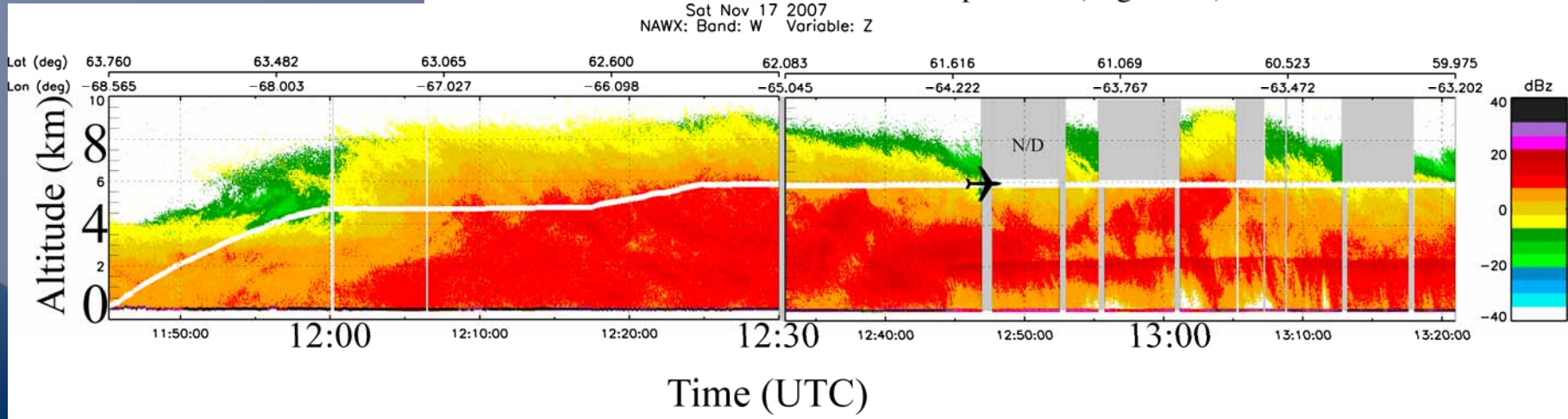


- Sublimation, bright bands and orographic precipitation were all observed
- Other major storm events exhibited regions of sublimation as well
- Cloud top / structure comparisons to other satellites / radar / aircraft
- Microphysical & other comparisons needed for regional upscaling using satellites - aircraft critical for validation

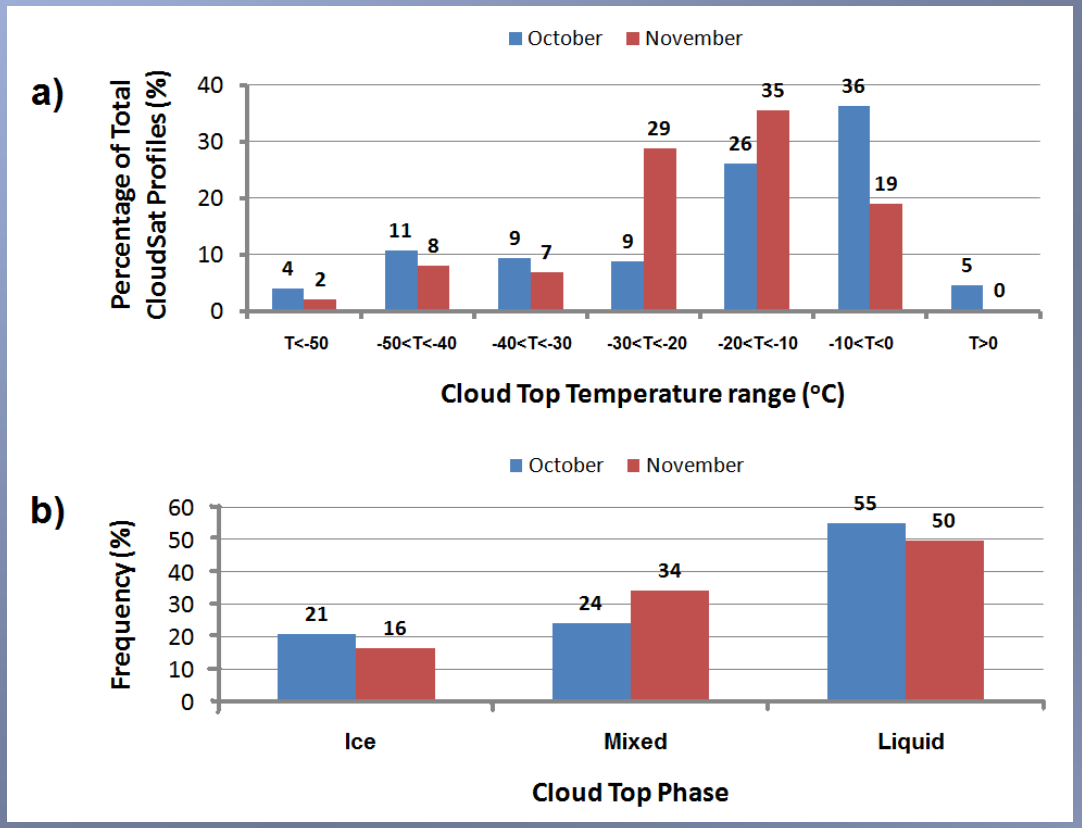
Alex Laplante et al

Nov 17, 2007
Warm
Front





Results (Aqua-MODIS)



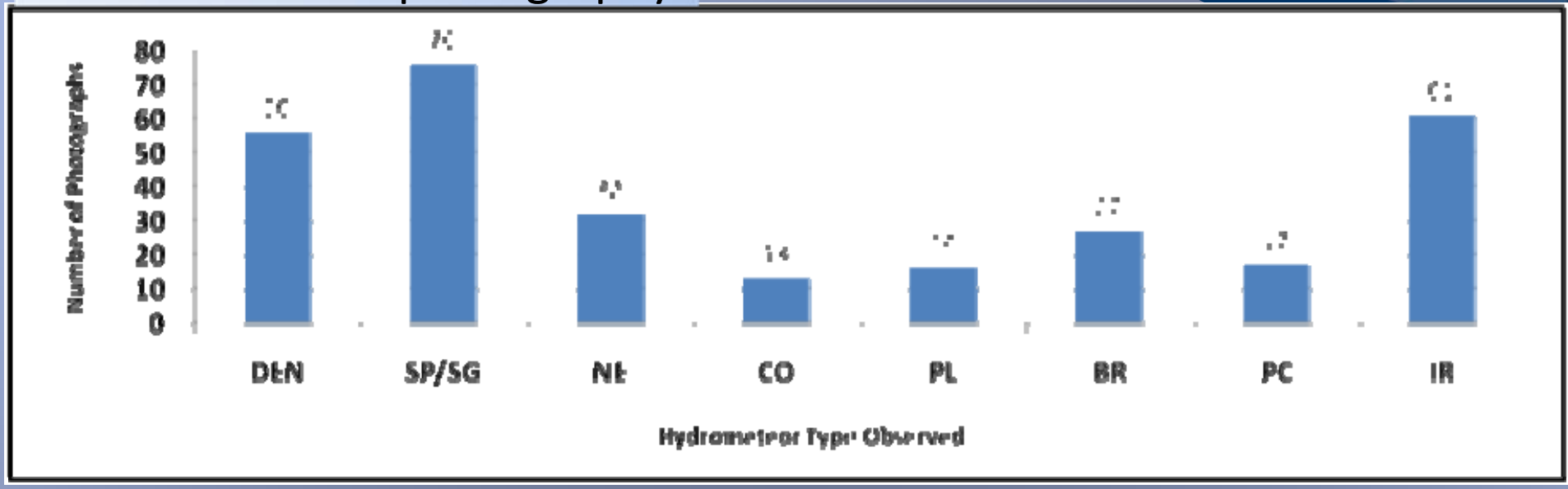
- The majority of the CloudSat profiles exhibited a cloud top temperature above -30°C
  - Cloud top temperatures as low as -65°C was observed in extreme cases
  - From October-to-November, the mean cloud top temperature decreased from -17°c to -20°C

- Liquid-only cloud tops were observed significantly more often than ice-only or mixed-phase

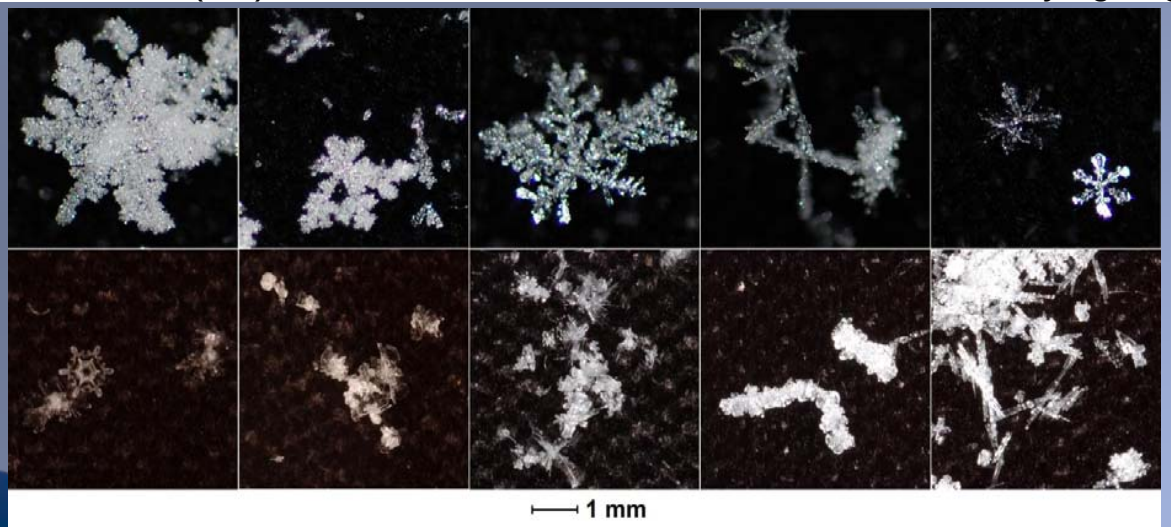
Alex Laplante et al

Snowflake Microphotography

Alex Laplante et al



- Out of 95 photographs, dendrites (DEN), snow grains/snow pellets (SG/SP), and irregular crystals (IR) were the most commonly observed hydrometeor type (more than 50% of the photographs)
- Other particle types, including columns (CO), plates (PL), bullet roses (BR), plated-columns (PC), and needles (NE) were also observed but not as often and to varying degrees

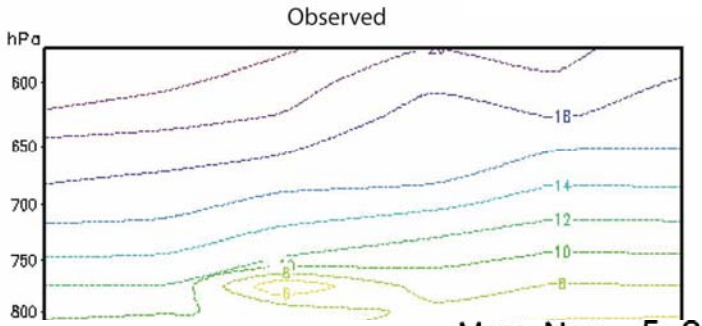


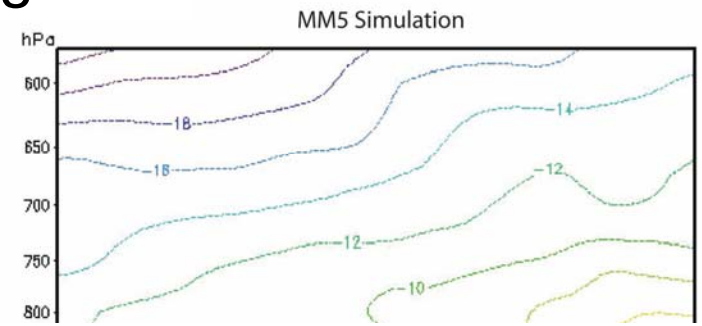
Storm Studies in the Arctic
Études des Tempêtes dans l'Arctique
STAR
Nunavut, Canada

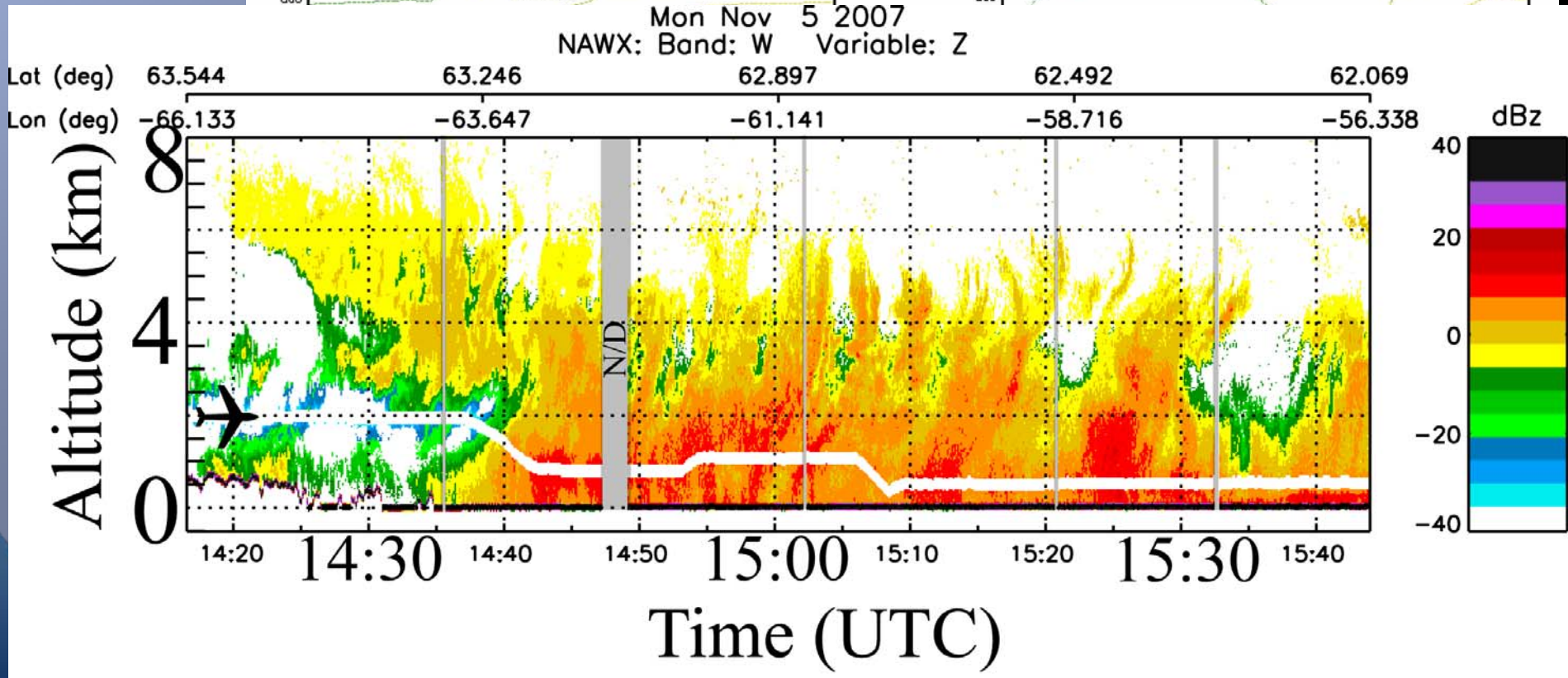
Remnants of Hurricane Noel

1620Z Nov 5

Shunli Zhang et al

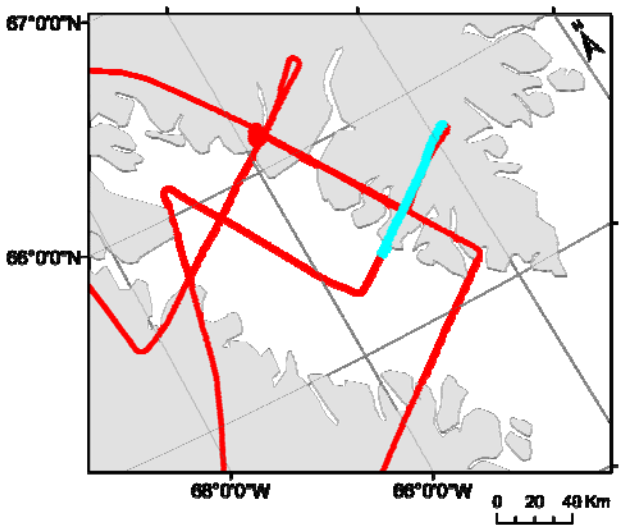


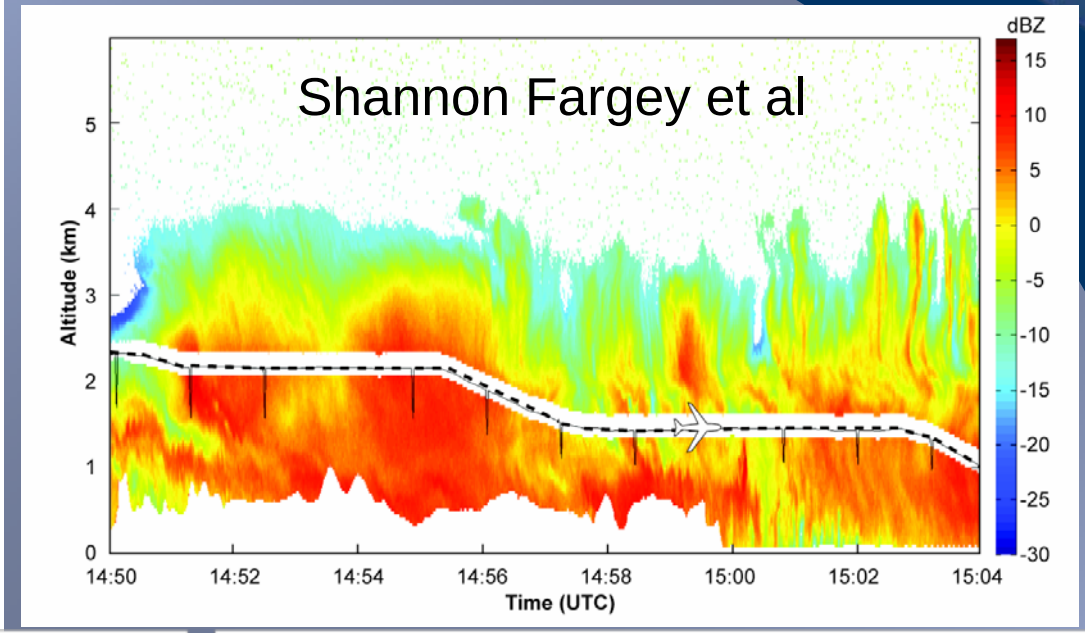


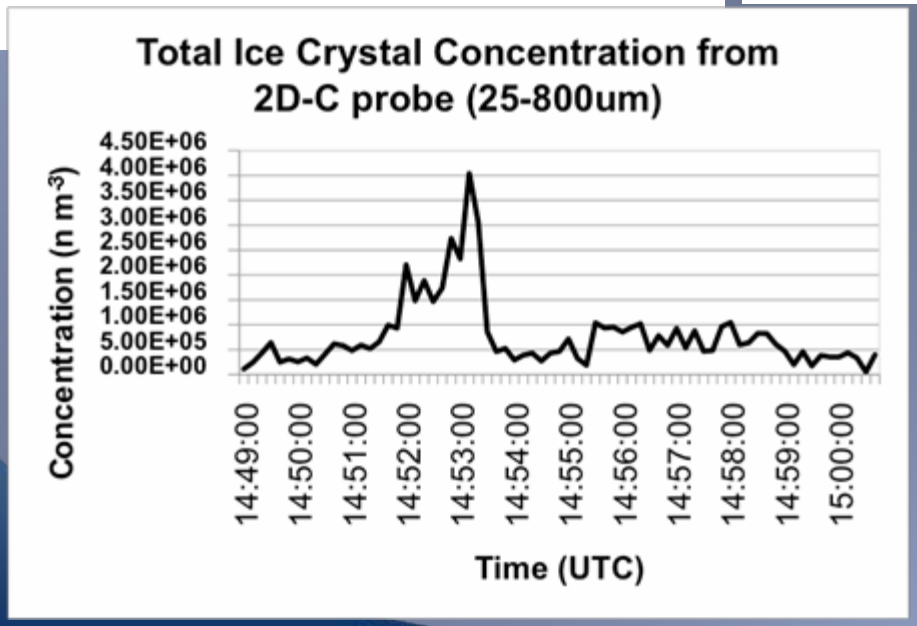


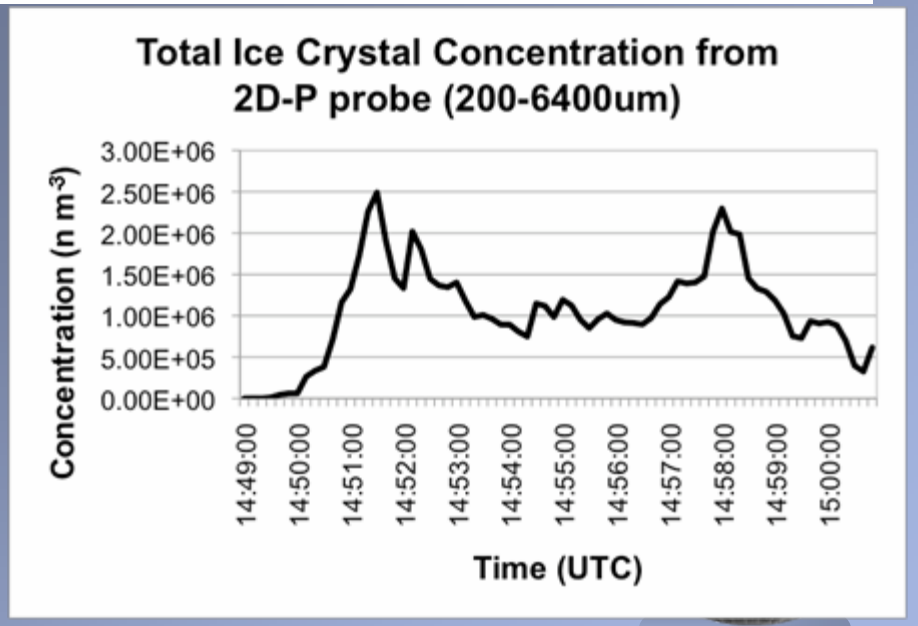
m s^{-1} m s^{-1}

Upslope Precipitation Case: NRC-F5

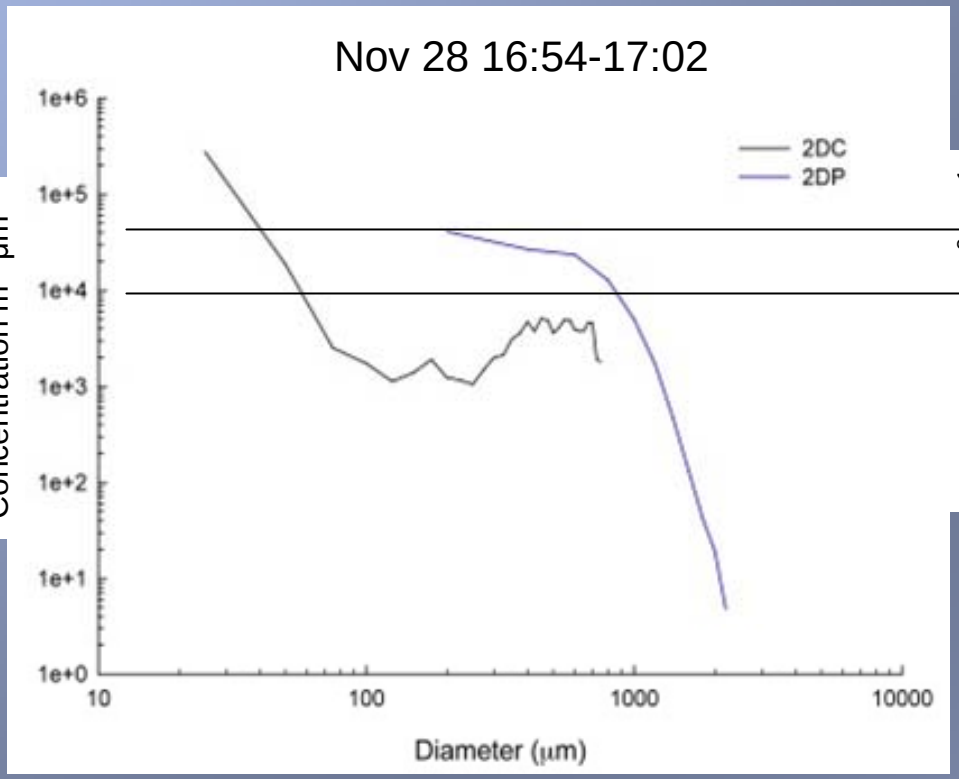




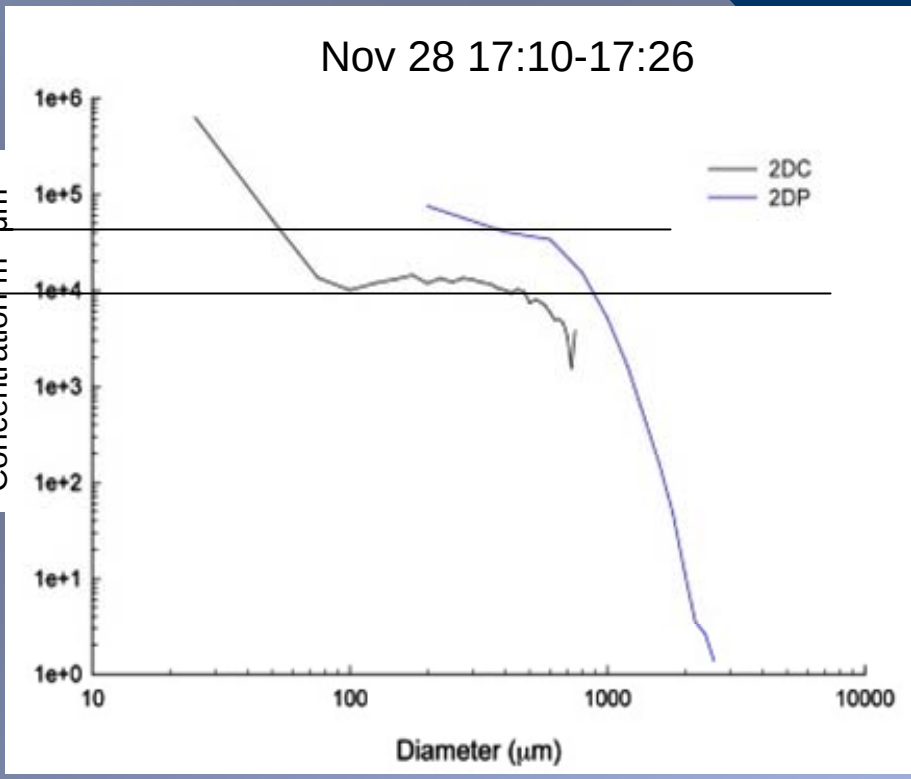




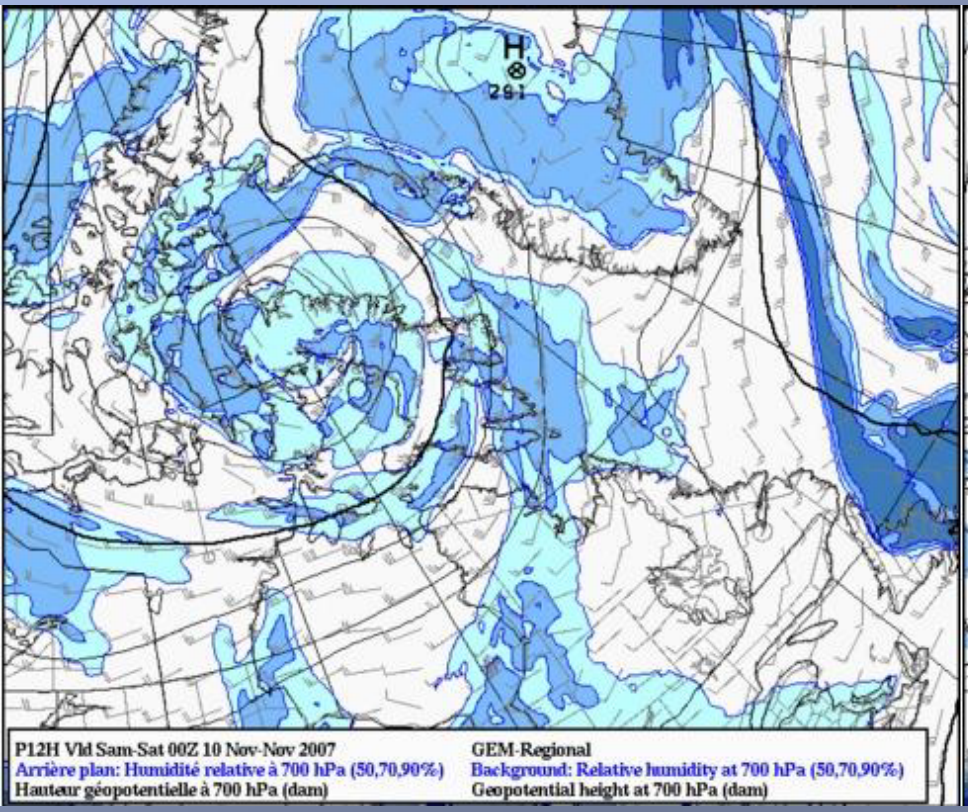
Marine

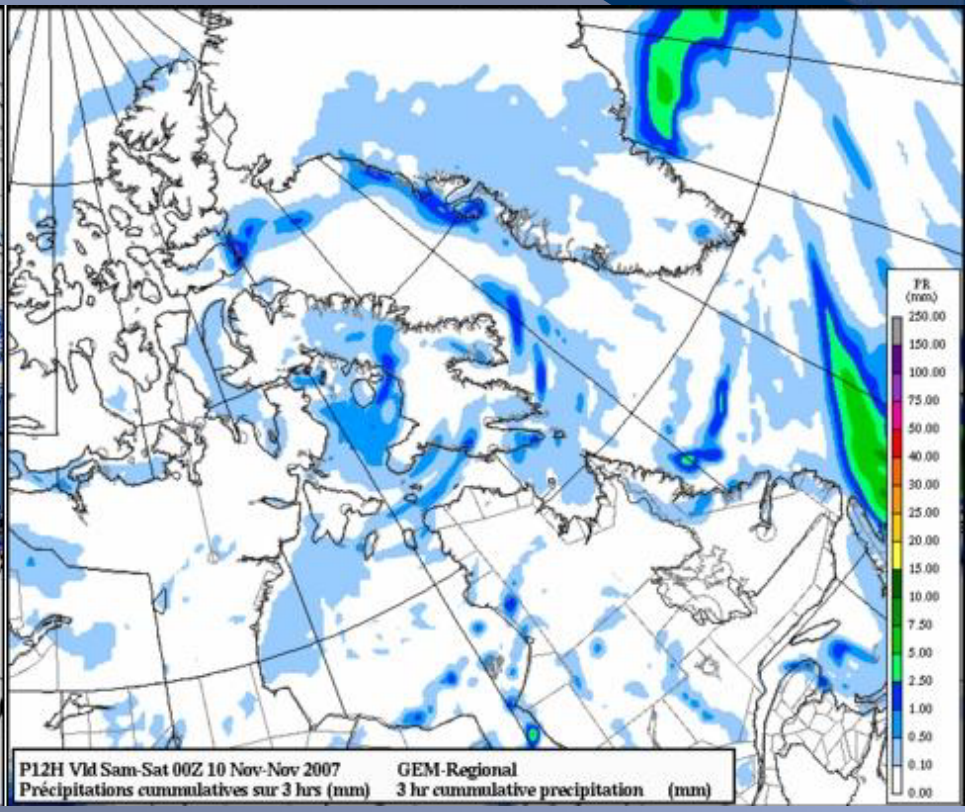


Terrestrial



Modeling





How well do models do in this environment?

Use models to better understand processes/feedbacks

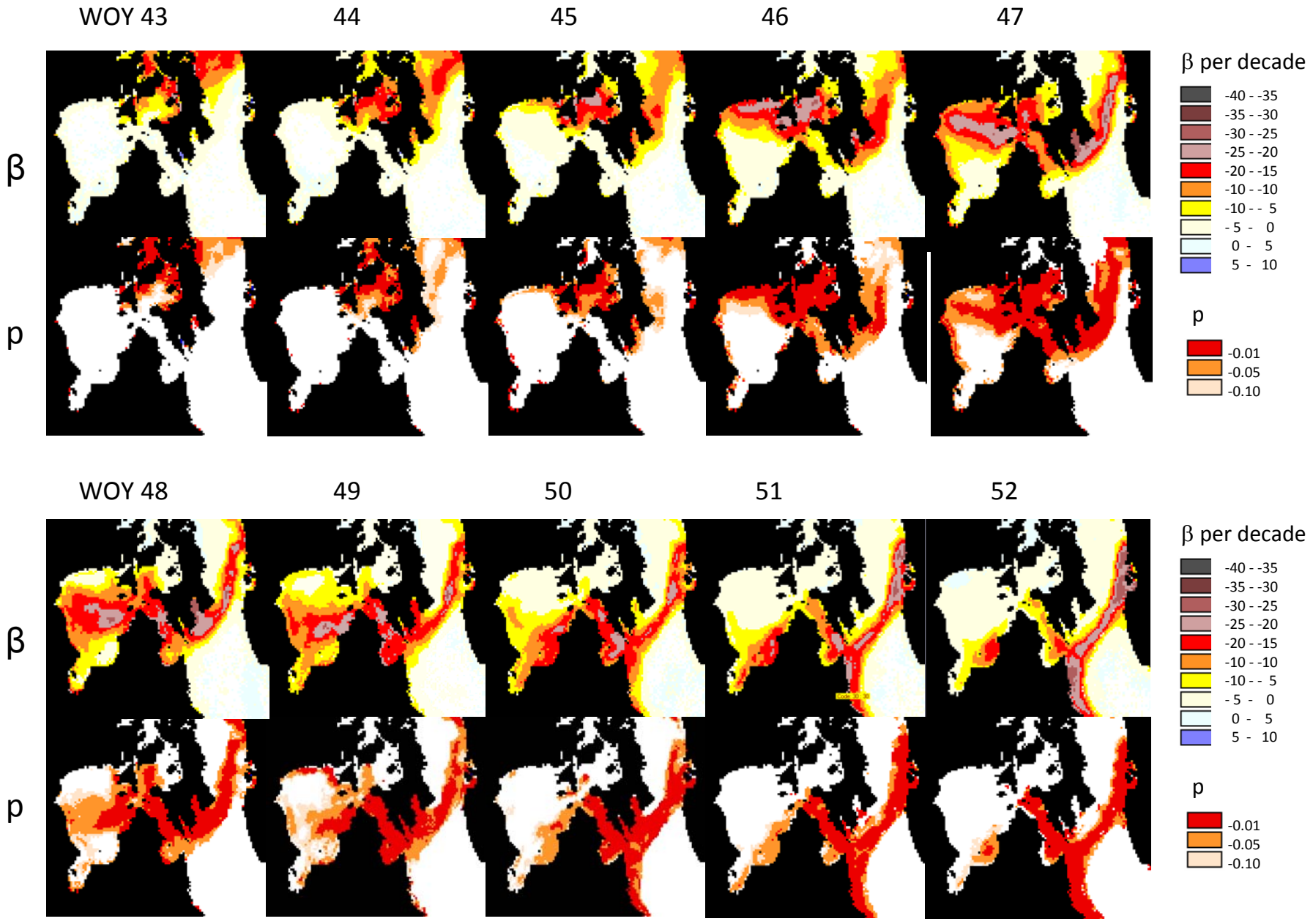
Comparisons of models to satellite and aircraft

Satellite measurements more readily available - but retrievals must be of high quality!

Storm Studies in the Arctic
STAR
Nunavut, Canada
Études des Tempêtes dans l'Arctique

Trends (β)in SIC Anomalies and Significance (p); 1980-2007

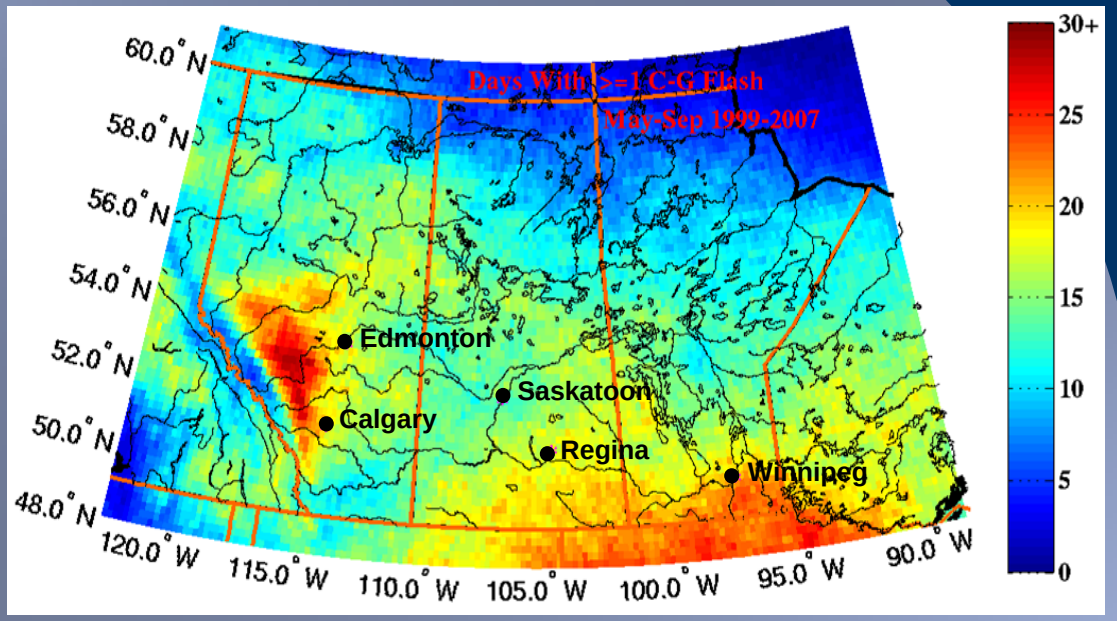
Hochkeim et al



UNSTABLE

UNSTABLE Goals

- Improve understanding of ABL processes and CI
- Improve accuracy and lead time for warnings
- Assess utility of high-res NWP to resolve processes and provide guidance
- Revise conceptual models for CI and severe wx



3 Main Science Areas

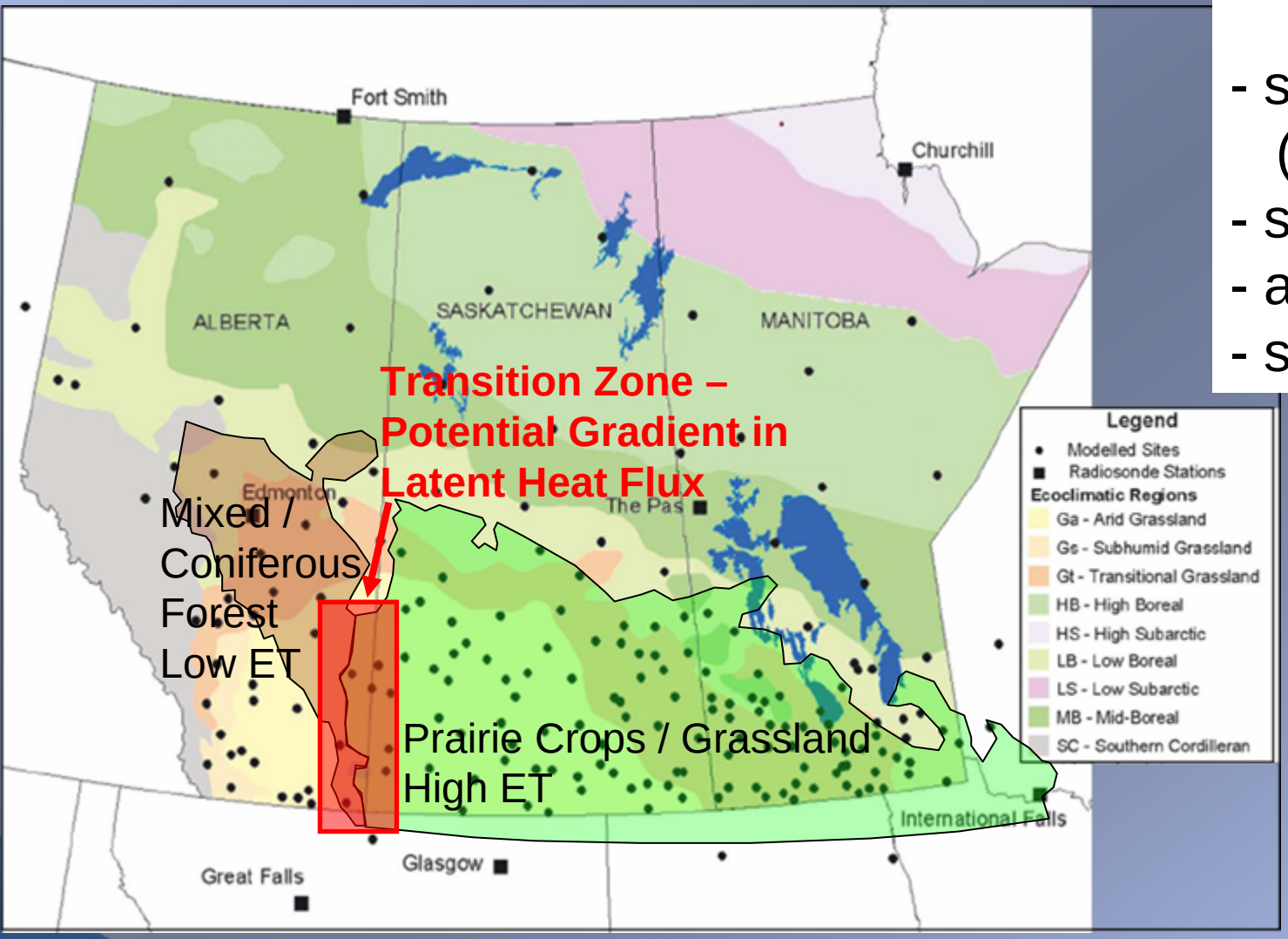
1. ABL moisture and convergence boundaries
2. Surface processes (surface fluxes)
3. High resolution NWP model forecasts of CI and severe weather

UNDERSTANDING SEVERE THUNDERSTORMS AND ALBERTA BOUNDARY LAYERS EXPERIMENT
UNSTABLE

Ecoclimate Regions and ET

Satellite/Aircraft

- soil moisture (SMOS)
- surface fluxes
- albedo
- sfc. temp.



UNDERSTANDING SEVERE THUNDERSTORMS AND ALBERTA BOUNDARY LAYERS EXPERIMENT
UNSTABLE

WMI aircraft w/ AIMMS-20 Instrument Package (T, P, RH)

WMI Cheyenne II N234K in cloud physics configuration.

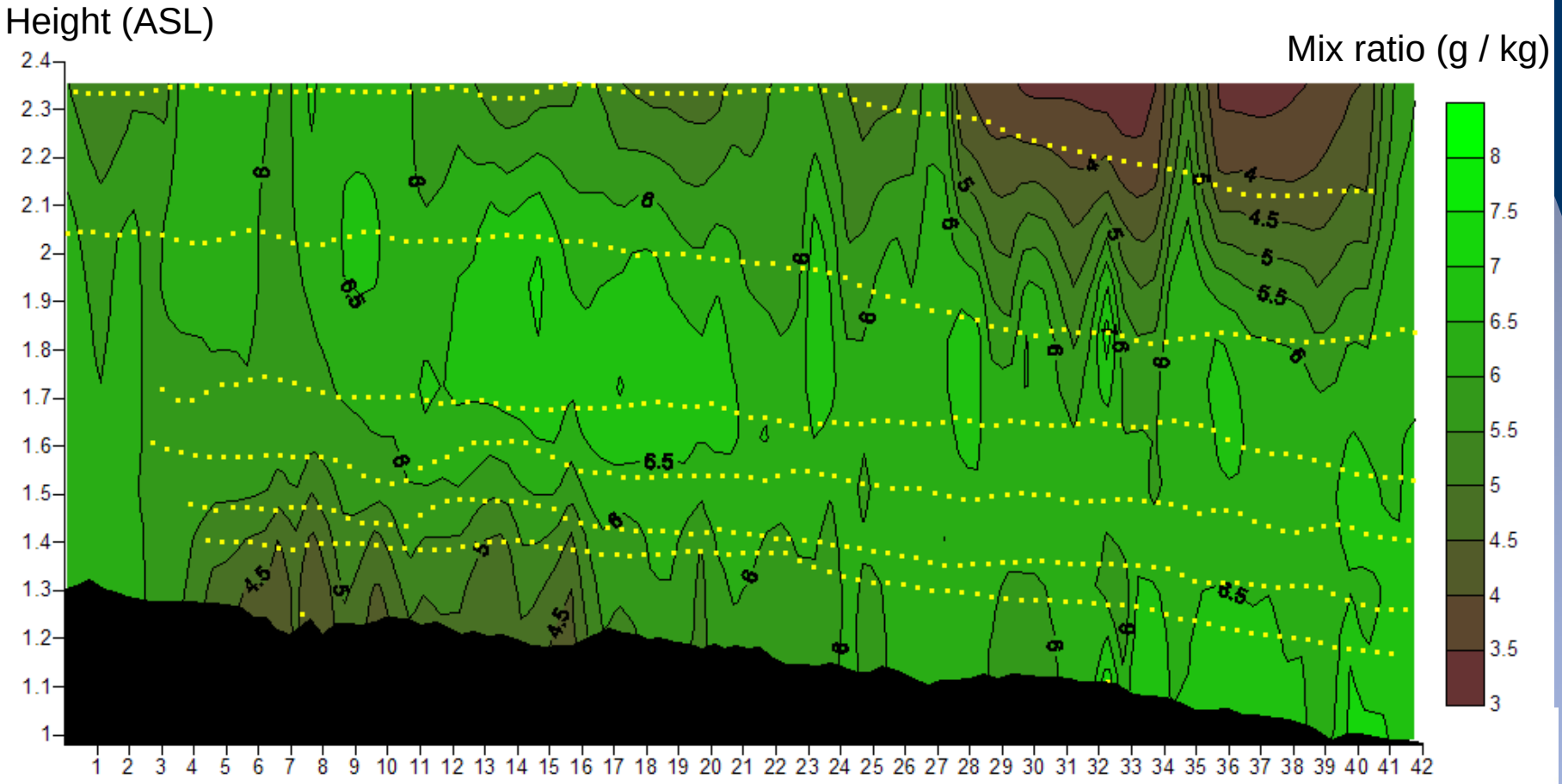
MARS Trailer (AERI, WV Radiometer, Radiosondes, Cloud Base Temp.)

CRD Mobile Radiosonde Trailer and Interior

Tethersonde System

ATMOS
(Automated *Transportable* Meteorological Observation System)

AMMOS
(Automated *Mobile* Meteorological Observation System)


Height (ASL)
Mix ratio (g / kg)
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3

Conclusions

- Aircraft / Satellite data critical for atmospheric research
  - no other way for direct small scale (internal) or regional (scaling up of) measurements
- Complements surface measurements (remote sensing or otherwise)
- Ongoing future need for access to aircraft (3-4 week campaigns)
- For satellite data to be useful, retrievals must be properly calibrated via aircraft and other measurements
- Multiple platforms are needed to address cutting-edge science
- EC/NRC facility is well positioned
- Can make use of international infrastructure as well