



# NRC AIRBORNE W AND X-BAND (NAWX) DURING STAR

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Collaborators / Contributions:

NRC: FRL, Students (Carlton University)

Environment Canada Cloud Physics and Severe Weather Research Section

STAR Network

ProSensing Inc.

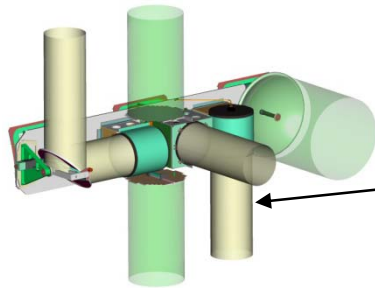


National Research  
Council Canada

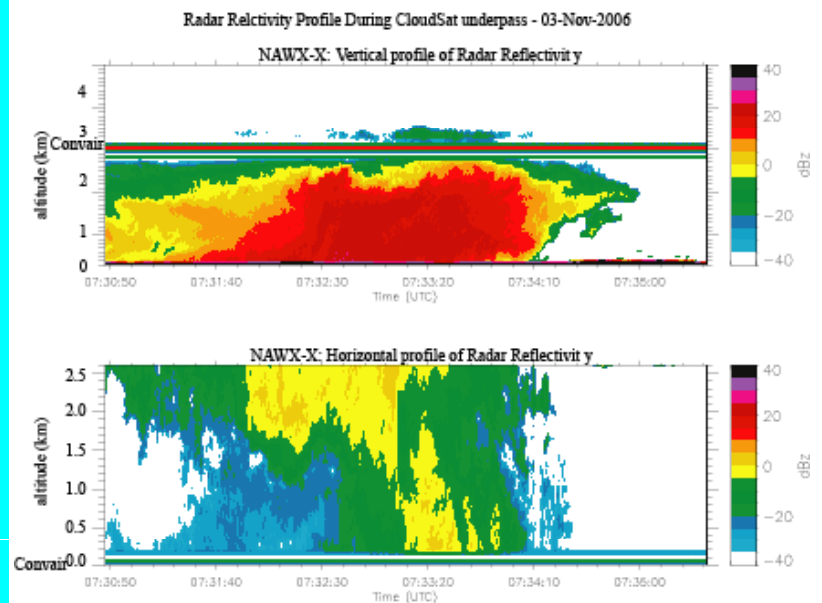
Conseil national  
de recherches Canada

Canada

# NRC Airborne W and X- bands radar (NAWX)

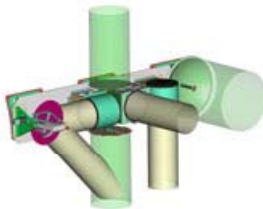
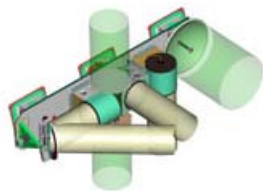
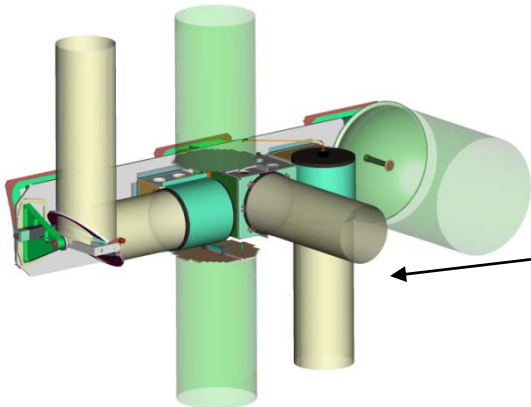


- Developed by NRC and ProSensing Inc.
- X-band installed on the Convair in March 2006
- W-band installed in Jan 2007 during the Canadian CloudSat and CALIPSO Satellite Validation Project
- STAR: 2<sup>nd</sup> major project using NAWX





# NRC Airborne W and X-bands radar (NAWX)



NAWX	W-band	X-band
Transmitted Frequency (GHz)	94.05	9.41
Peak Tx Power (KW)	1.7 - typical	25 (split b/n two ports)
Polarization	Co and Cross	Simultaneous H and V
Doppler	Pulse Pair and FFT	Pulse Pair and FFT
Pulse Duration ( $\mu$ s)	0.1 – 2	0.11-1
Max PRF (KHz)	20	5
Ant. 3 dB BW ( $^{\circ}$ )	0.75	3.5
Antenna ports	5	4
View direction	Up, down and side	Up, down and side

More details/updates: <http://www.nawx.nrc.gc.ca>



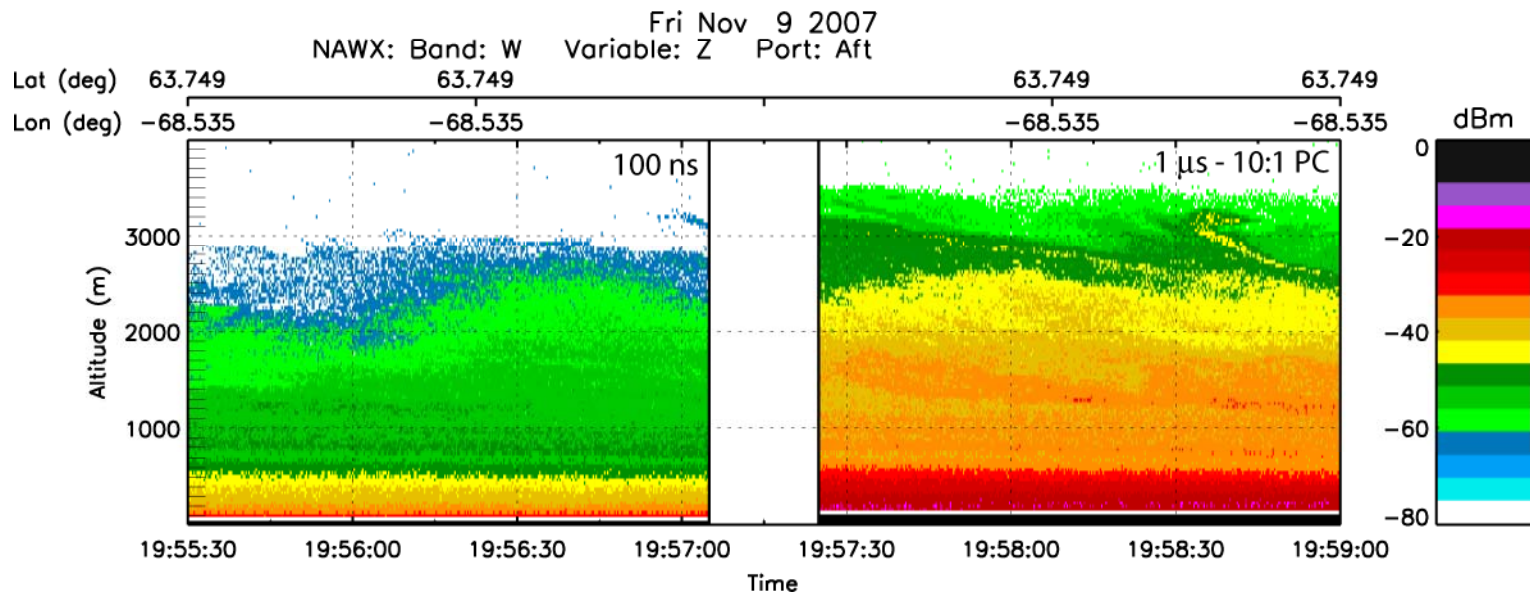
# Calibration

- Internal / system monitoring – Warm load ....
- Coroner reflector – rotating rod with two corner reflectors (X-band)
- Drizzle / light rain





# NAW-Pulse Compression – Examples

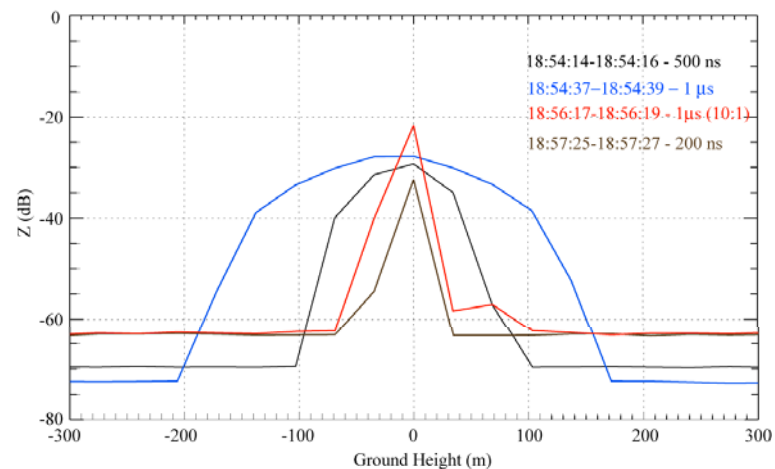
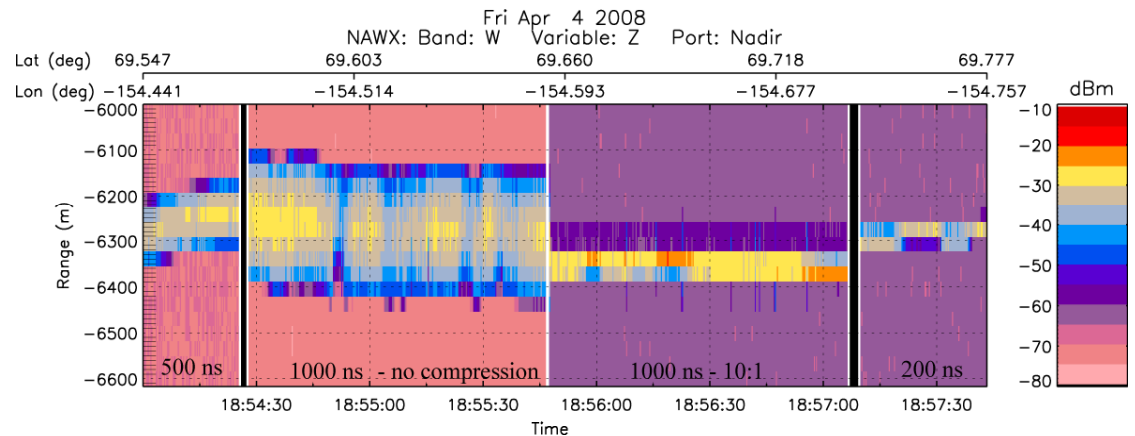


- Improved sensitivity (100 ns vs. 1  $\mu$ s pulse with 10:1 compression ratio)
- Better characterization of cloud structure with high range resolution
- Pulse compression implemented just before the STAR deployment



# NAW-Ground Clutter

- Aircraft flight in clear weather at ~ 6km altitude
- Ground contamination from the Nadir Antenna – for 200 ns, 500ns and 1 $\mu$ s pulse with and without compression



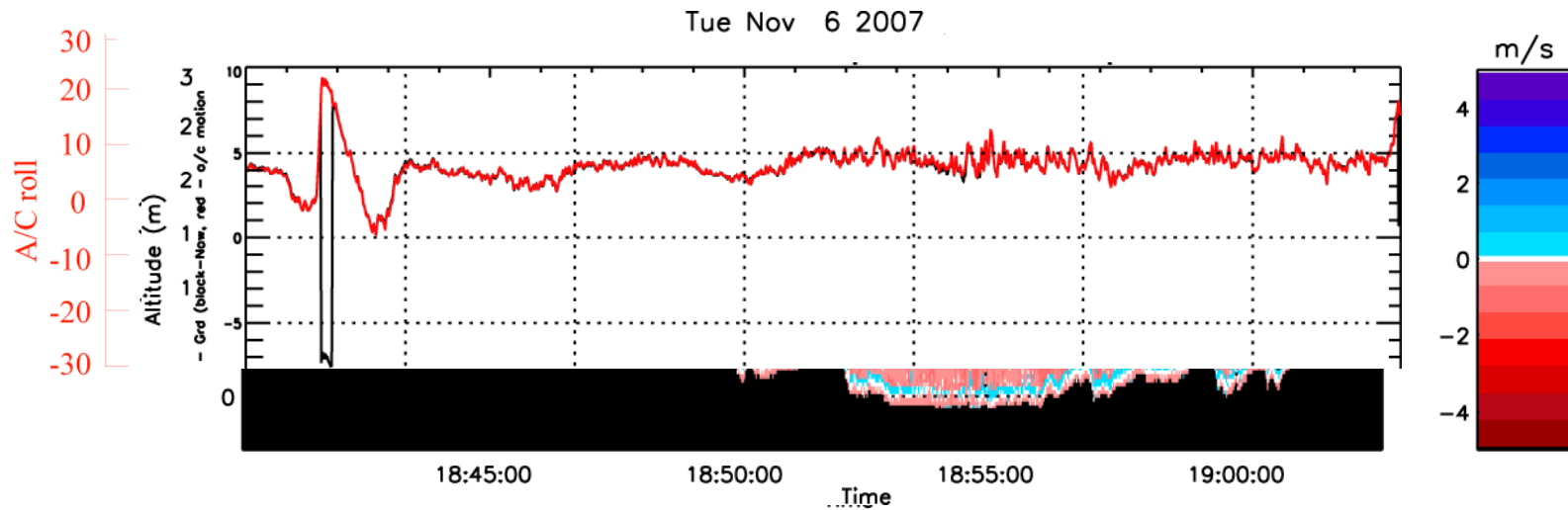
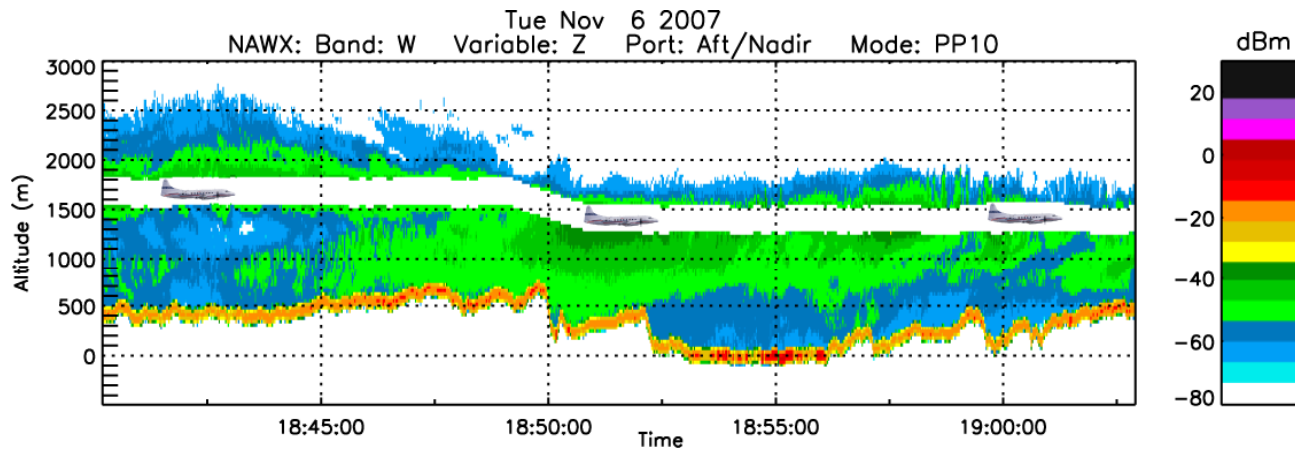
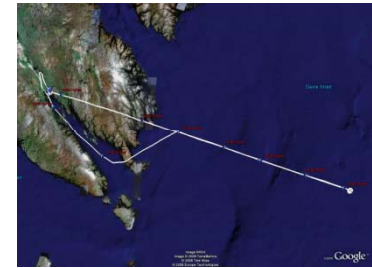


## NWAX During STAR

- ❖ Both Radars collected data in most of the STAR flights
- ❖ Reasonable performance considering the challenging condition of operating without a/c hangar: Impact of extensive exposure to cold weather:
  - ❖ No zenith looking X-band data (ice in external waveguide)
  - ❖ Data recording issues
  - ❖ W-band: reduced sensitivity of one of the receiver channels at the end of the experiment
- ❖ Reflectivity and Doppler data
  - ❖ Quality controlled – extensive software development –
    - ❖ CloudMask – identifying noise, ground clutter and cross-channel leakage issues – work in progress – not a perfect mask!
    - ❖ Z calibration – within 2 dB
    - ❖ Vd: Aircraft motion removal –  $\pm 0.5$  m/s for level flights

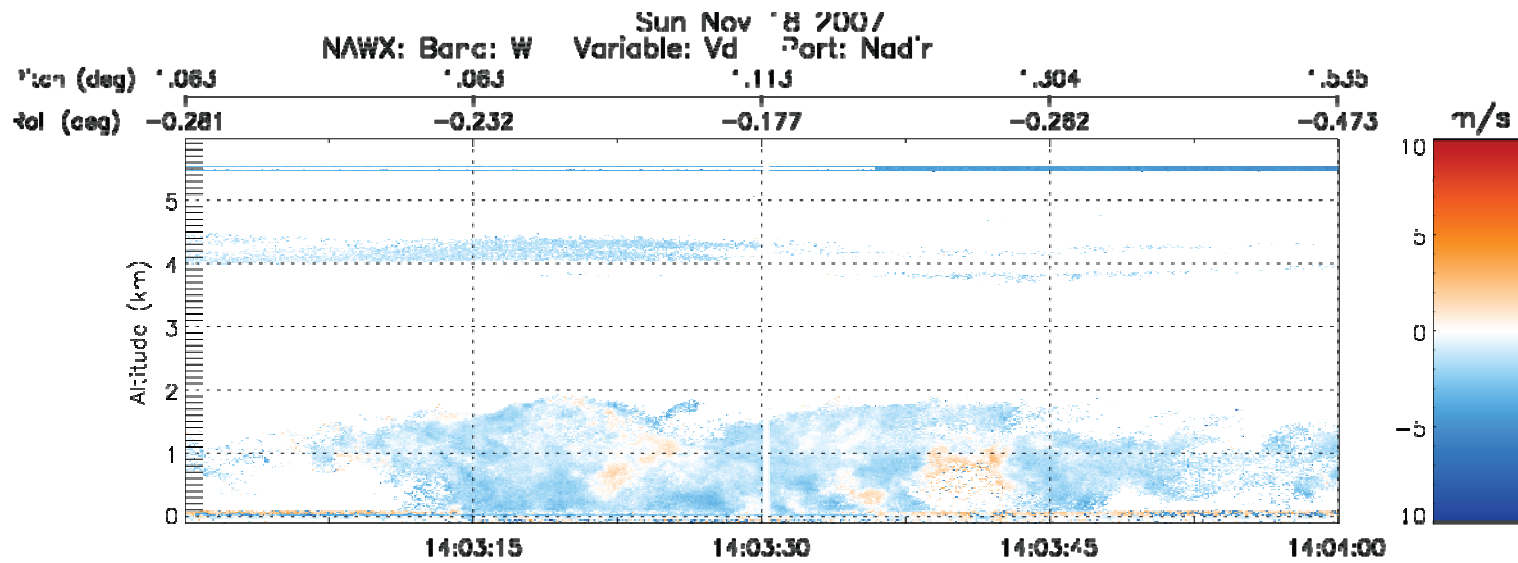


# Doppler





# CloudMask



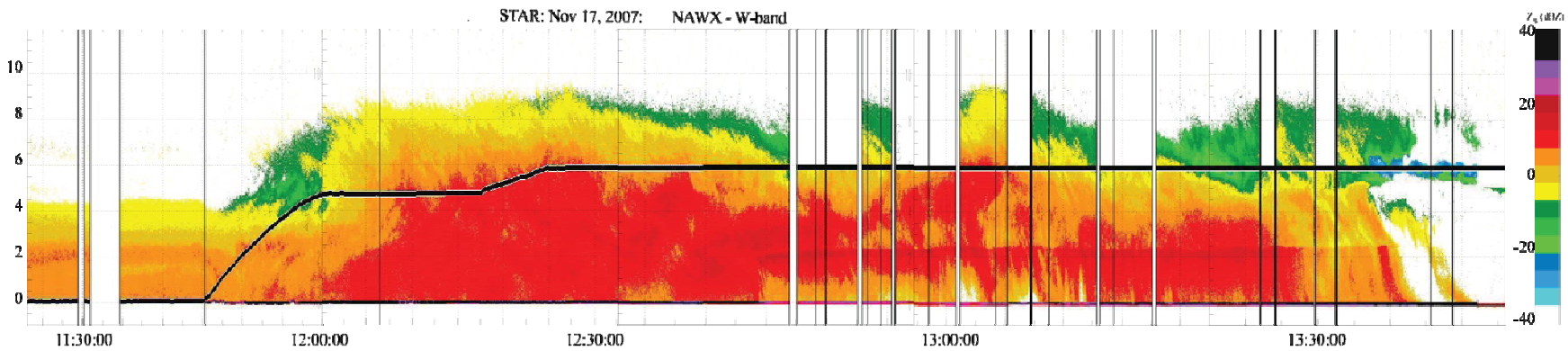
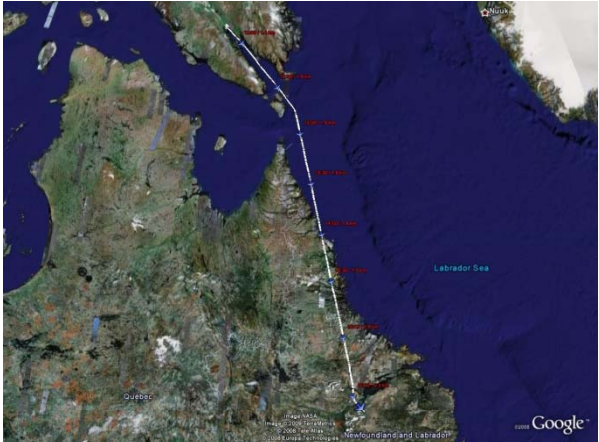
- CloudMask:
  - Noise, Cloud, Ground, clutter, leakage..





# Nov 17 Case Storm Structure - NAWX

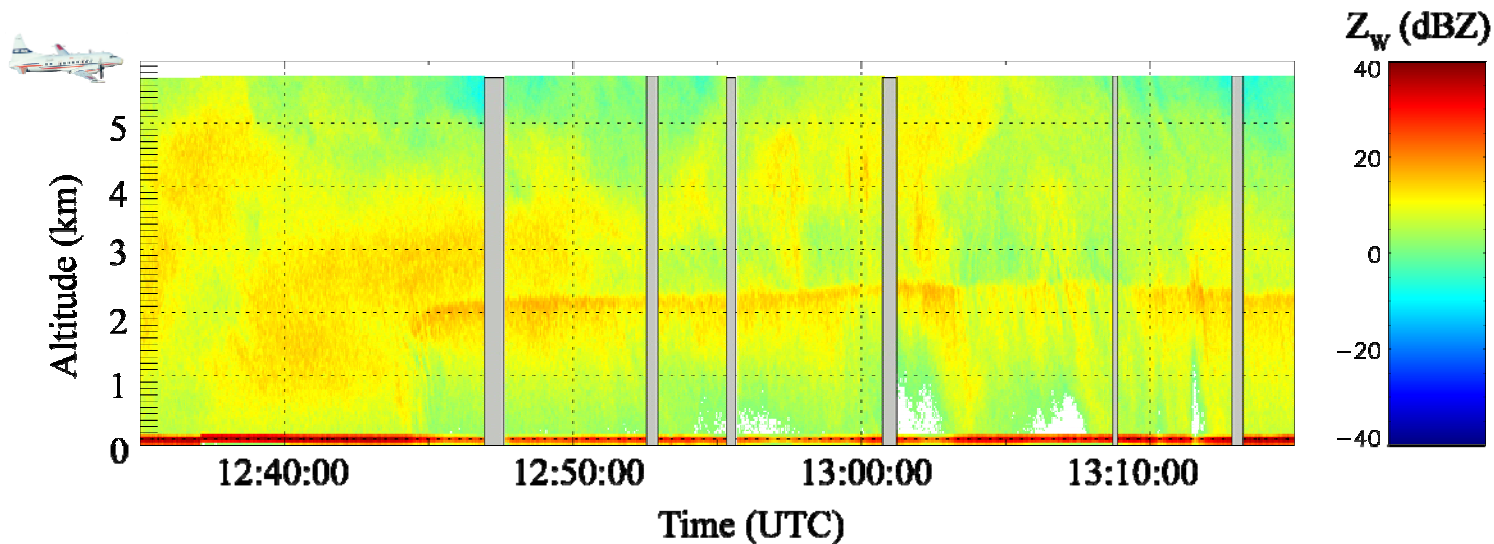
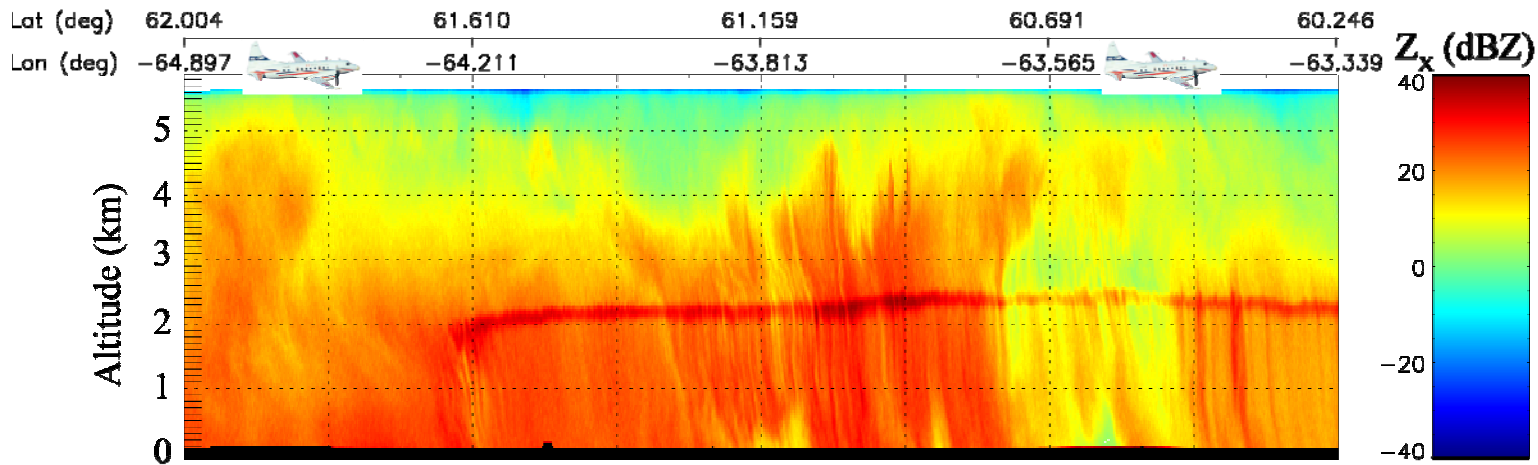
- ❖ Aircraft near constant altitude of ~ 6 km
- ❖ Large scale system:
  - ❖ Radar cloud top ~ 9 km
  - ❖ High Z vertical gradient





# NAWX - Reflectivity

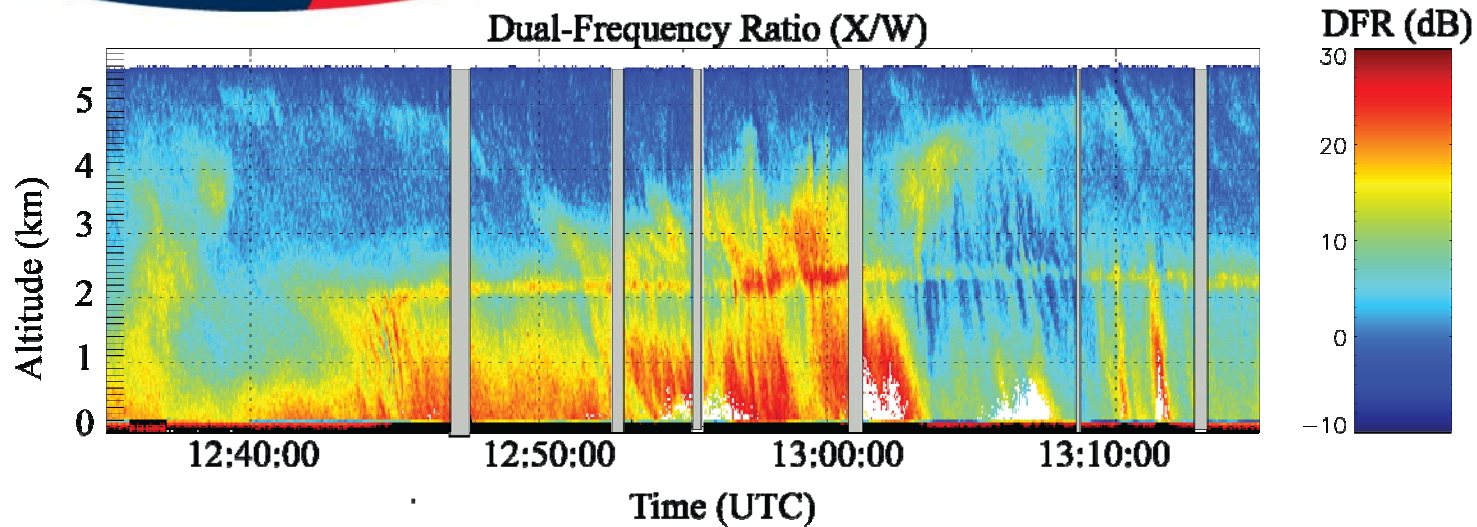
STAR Nov 17, 2007 - NAWX



- ❖ Same structure – different  $Z$  values
- ❖ BB
- ❖ Variability in  $Z$  along the horizontal – even in BB and rain



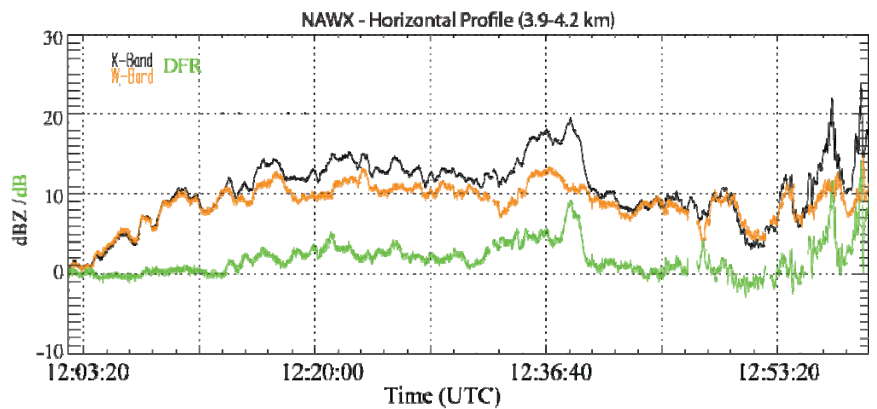
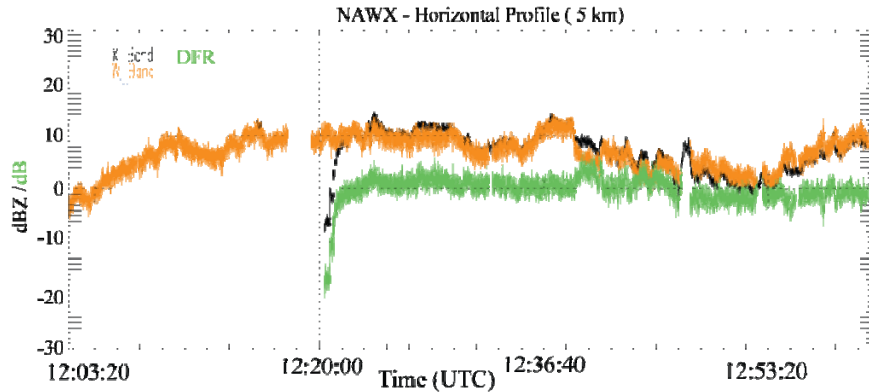
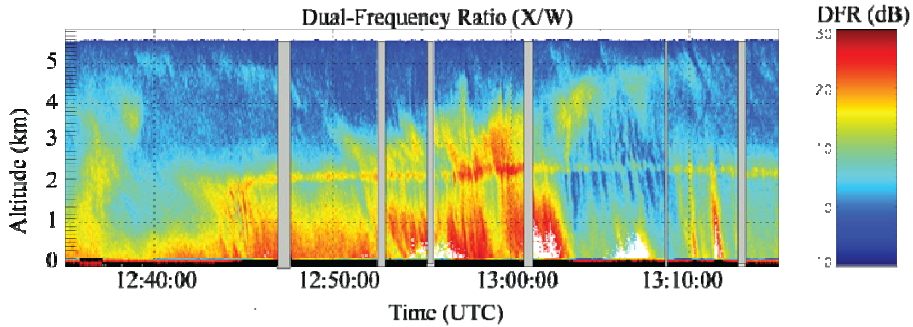
# NAWX - DFR



- ❖ DFR – Near 0 dB close to the aircraft altitude in ice –
  - ❖ Significant DFR close to ML – aggregation – Mie effect and in rain Mie effect + attenuation
  - ❖ Reterival of particle size / phase – based of DFR



# NAWX - DFR

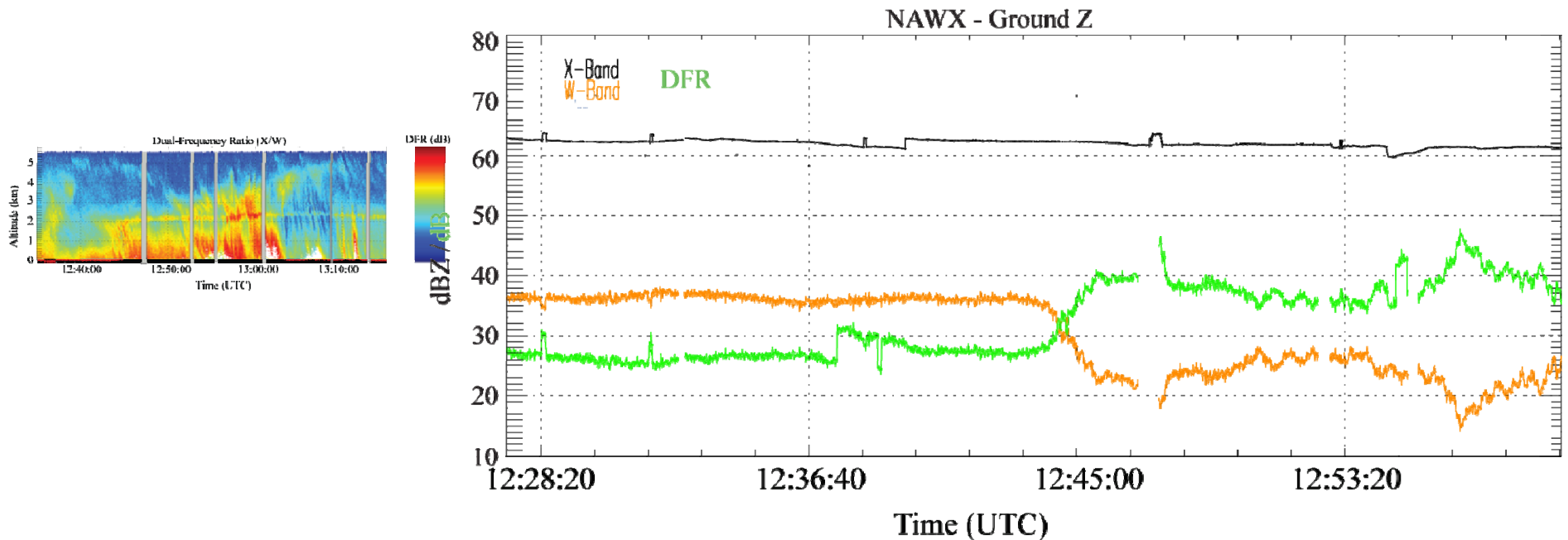


- ❖ Above 4 km – small ice crystals – no Mie effect – good agreement b/n W and X-band – Rayleigh scattering
- ❖ Confirm consistency in calibration b/n the two radars
- ❖ Few location where  $DFR > 5$  dB : aggregation of crystals





# NAWX - DFR

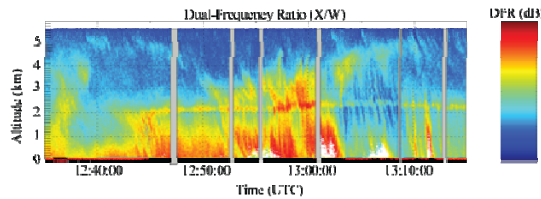


## ❖ Ground return:

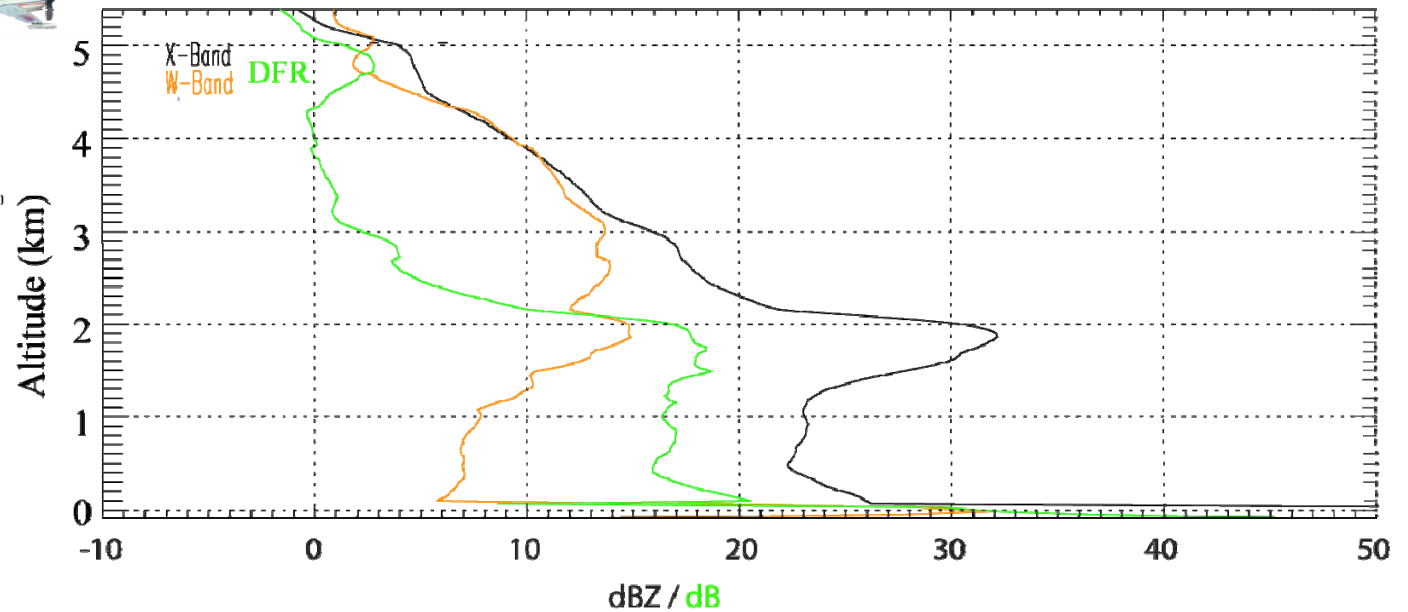
- ❖ X-band: Near constant

- ❖ W-band: Sharp drop starting at ~12:44 (corresponding to BB observation): ~15 dB drop – most of the DFR can attributed to attenuation



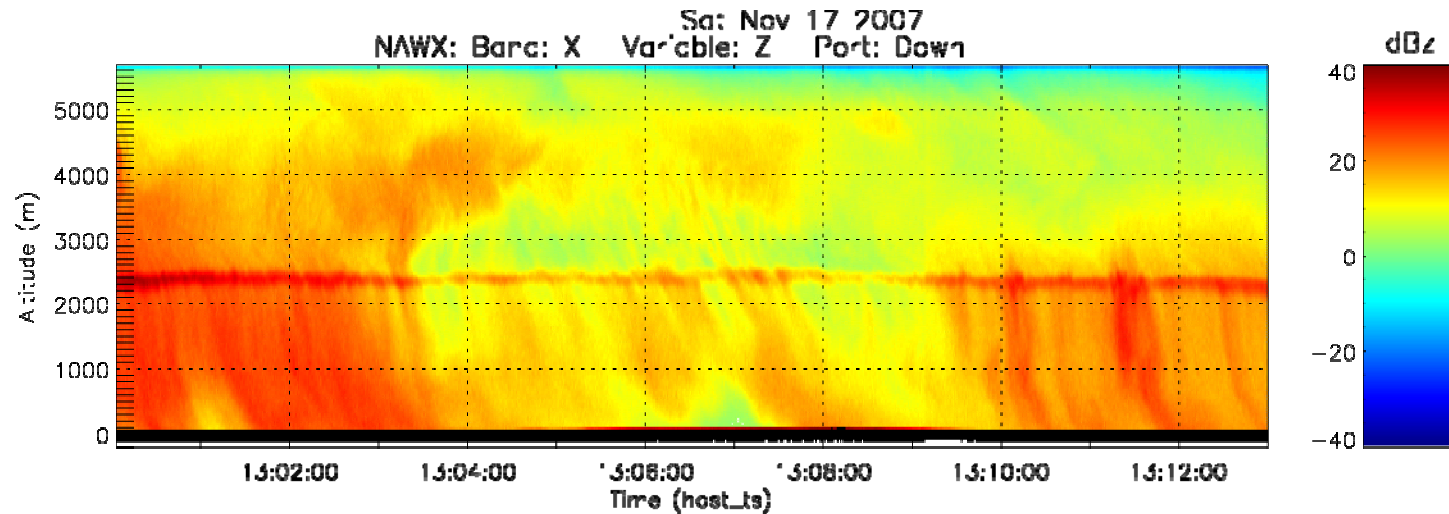


NAWX - Vertical Profile (12:44:36-12:44:59)



- ❖ 3 - 5 km – Rayleigh scattering – single ice crystals – good agreement b/n W and X
- ❖ 3 – 2 km - Aggregation – Increased DFR 5-10 dB – Resonance effect at W-band
- ❖ 1.5 – 2 km – Bright Band: DFR ~ 20 dB
- ❖ 0.5 – 1.5 km: Significant drop in W-band in rain: attenuation + resonance effect
- ❖ 0.1 – 0.5 km – increase in X-band – clutter contamination!

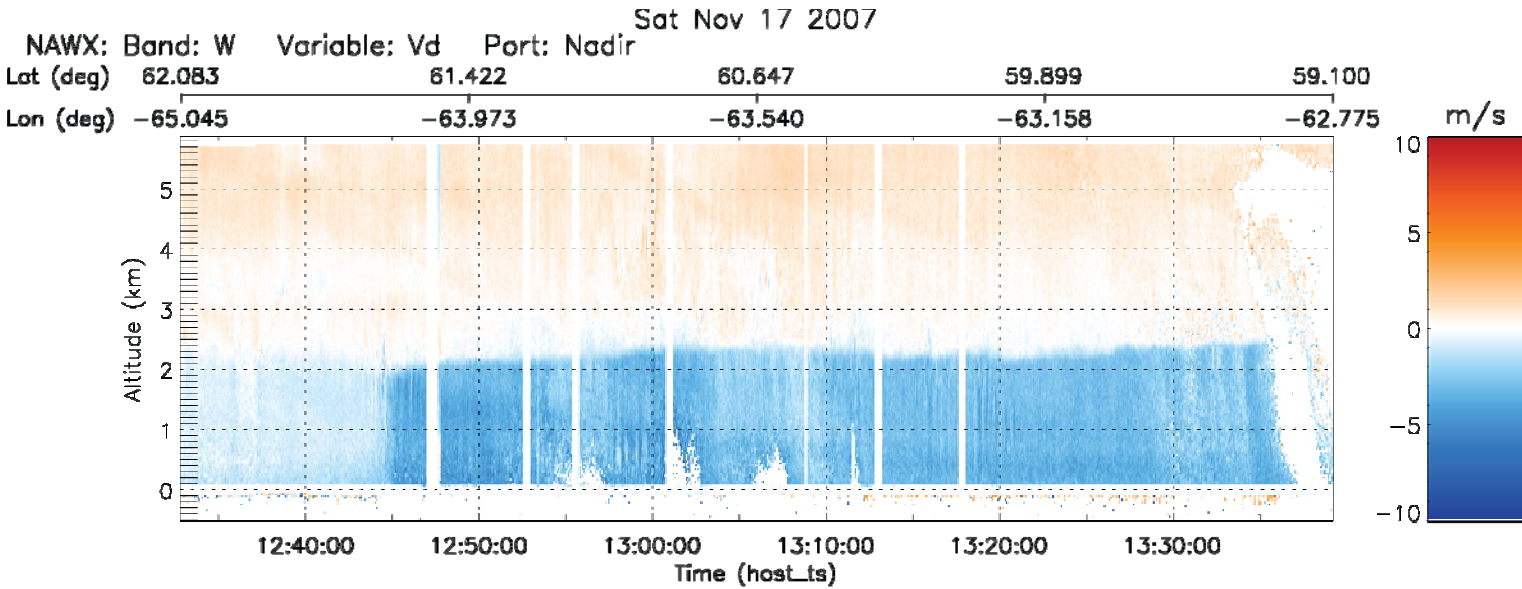
# Precipitation – Organizations / ML transitions



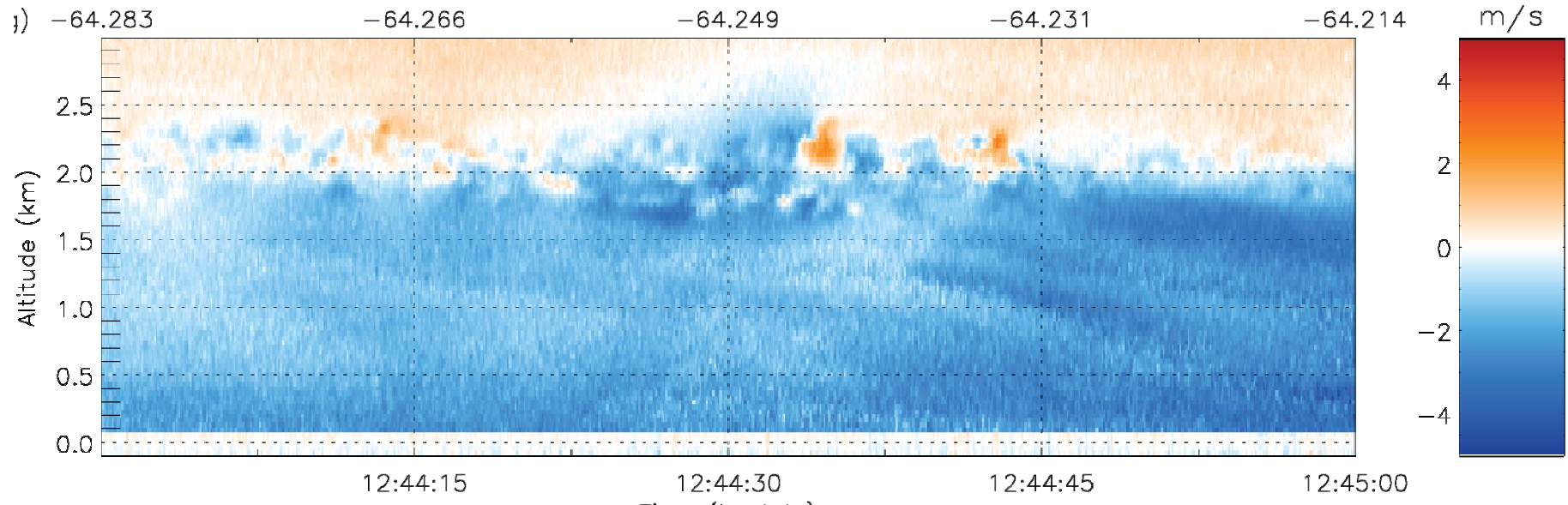
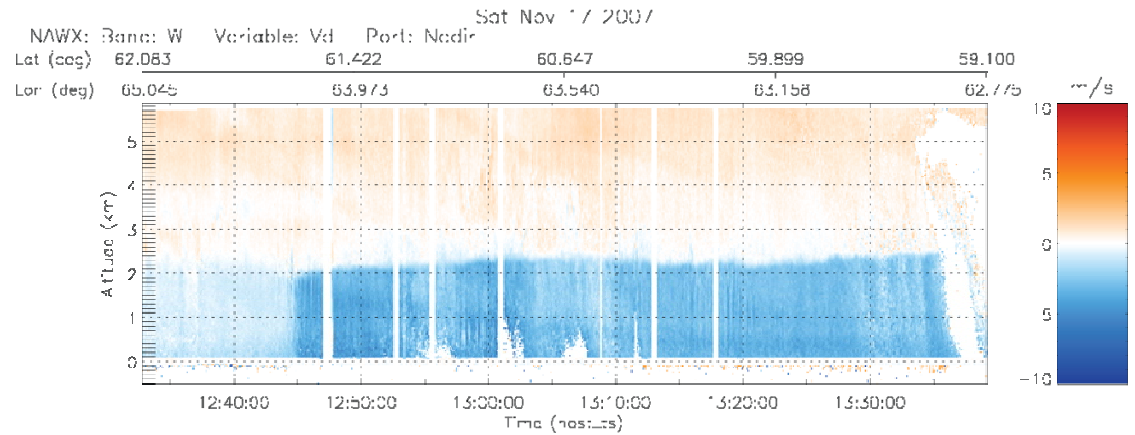
- ❖ Precipitation trail/shaft
- ❖ Significant variability in Z along the melting layer
- ❖ Fine-scale organizations of precipitation (Z) peaks detected by both radars



# NAWX - Doppler



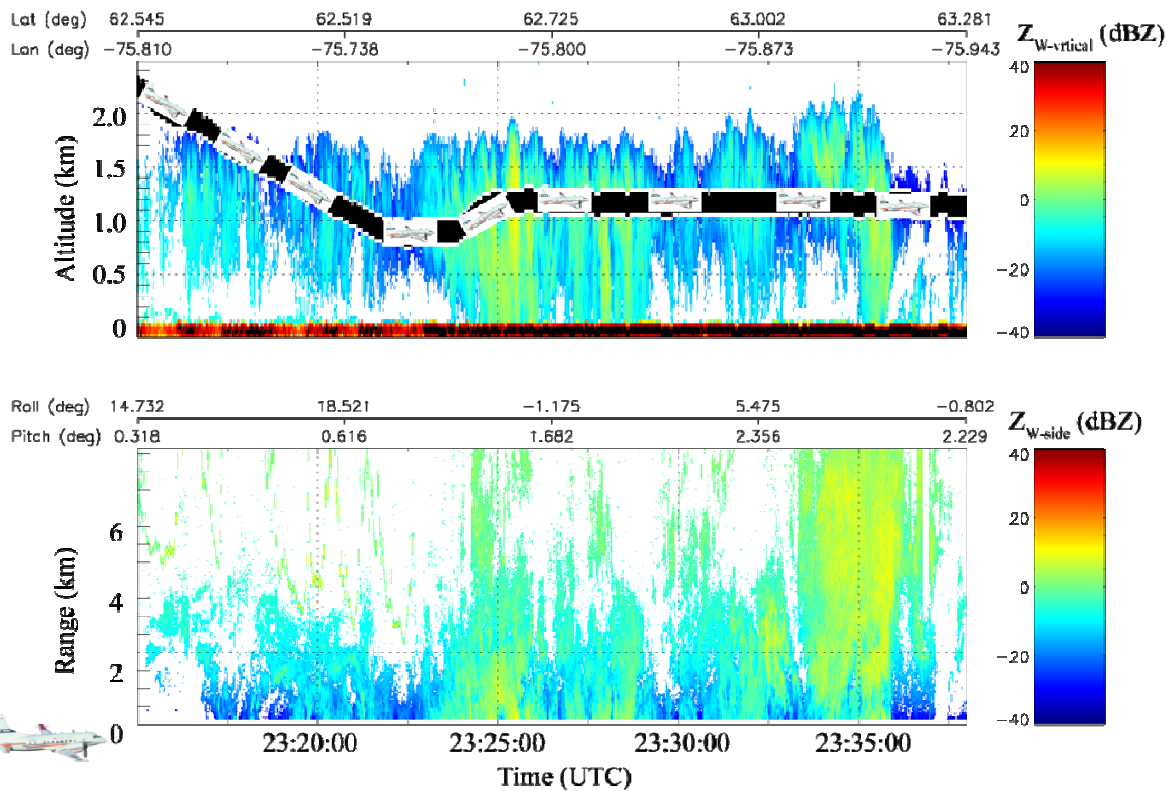
# Melting boundary in Vd





# Nov 09 – Boundary Layer Cloud

STAR Nov 09, 2007 - NAWX

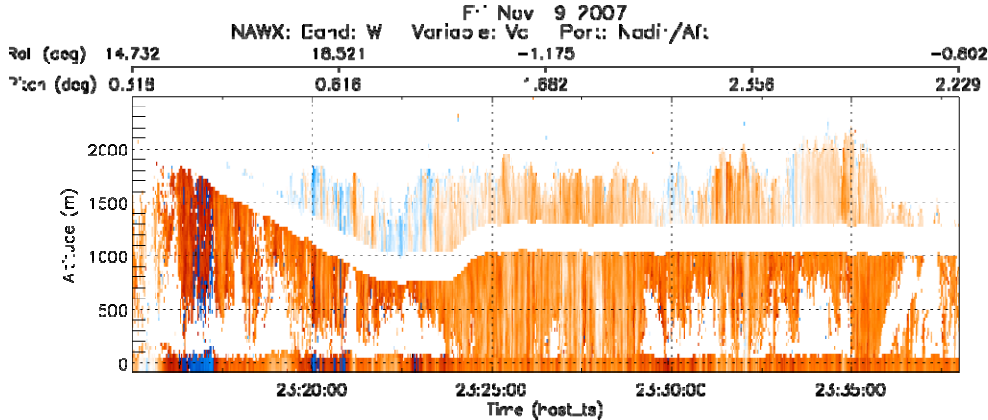


- ❖ First Spiral descent then level flight in shallow boundary layer Cu clouds
- ❖ Fine-scale cloud organization – cells nearly vertical
- ❖ High horizontal Z variability (-20 to 10 dBZ)

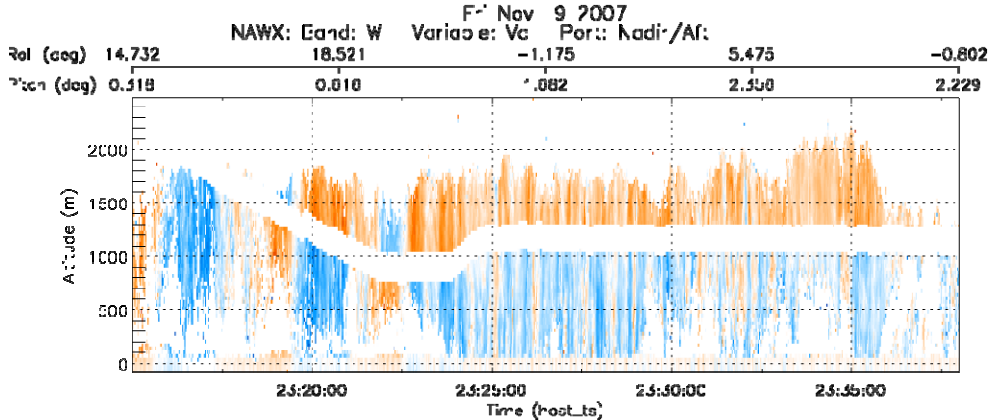




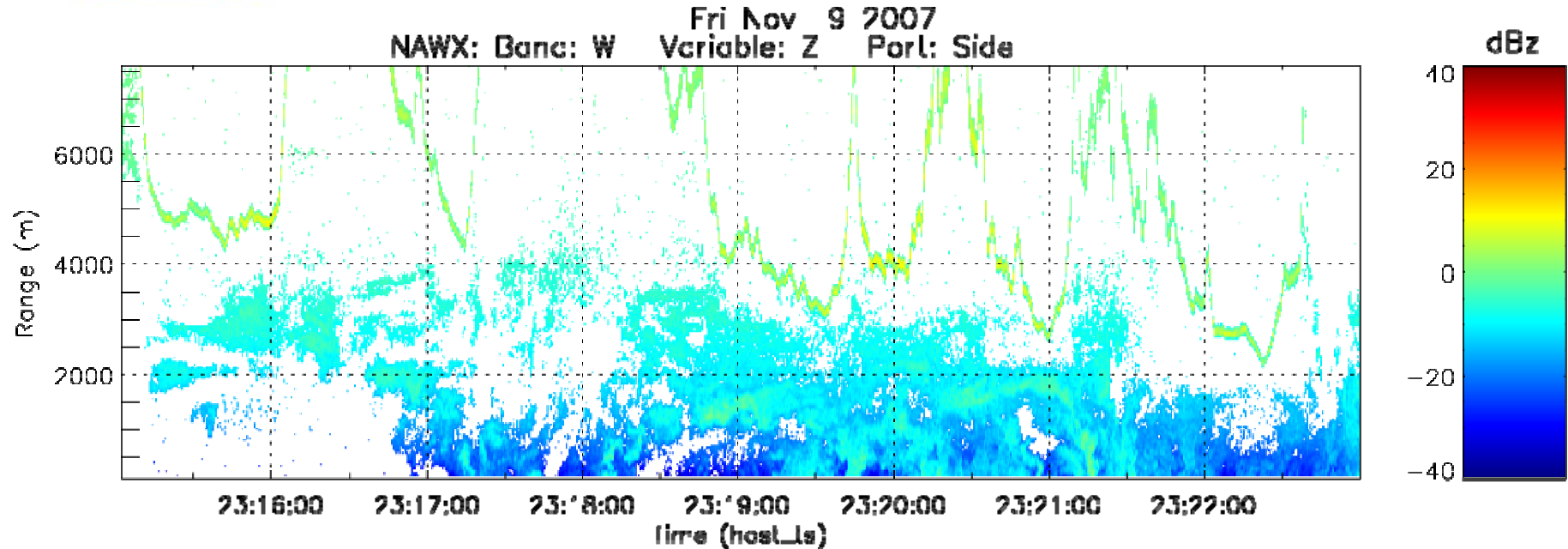
# Nov 09 – Boundary Layer Cloud



- ❖ Vd – before and after aircraft motion correction
- ❖ Similar organization – near vertical cells



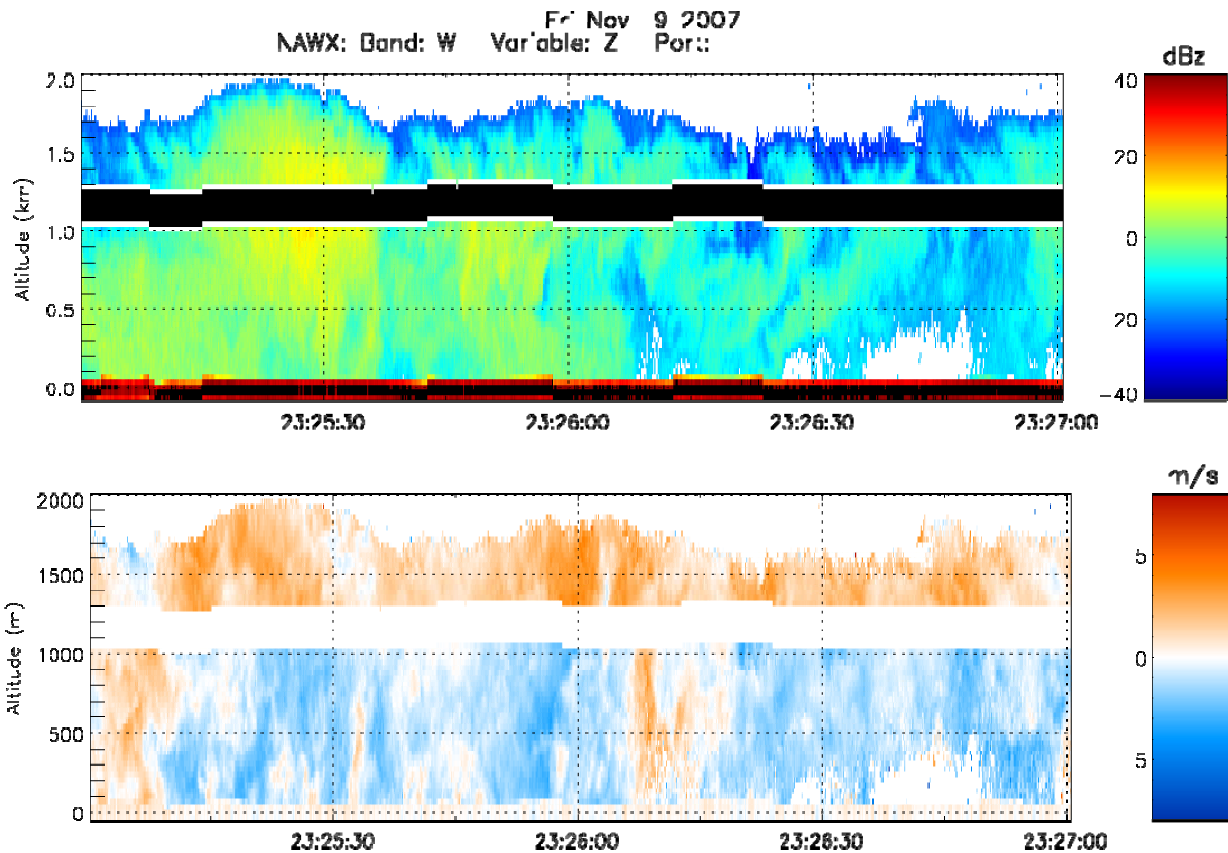
# Nov 09 – Boundary Layer Cloud



- ❖ Side-looking antenna – aircraft – roll change / slant profile
- ❖ High variability in Z near the sampling altitude



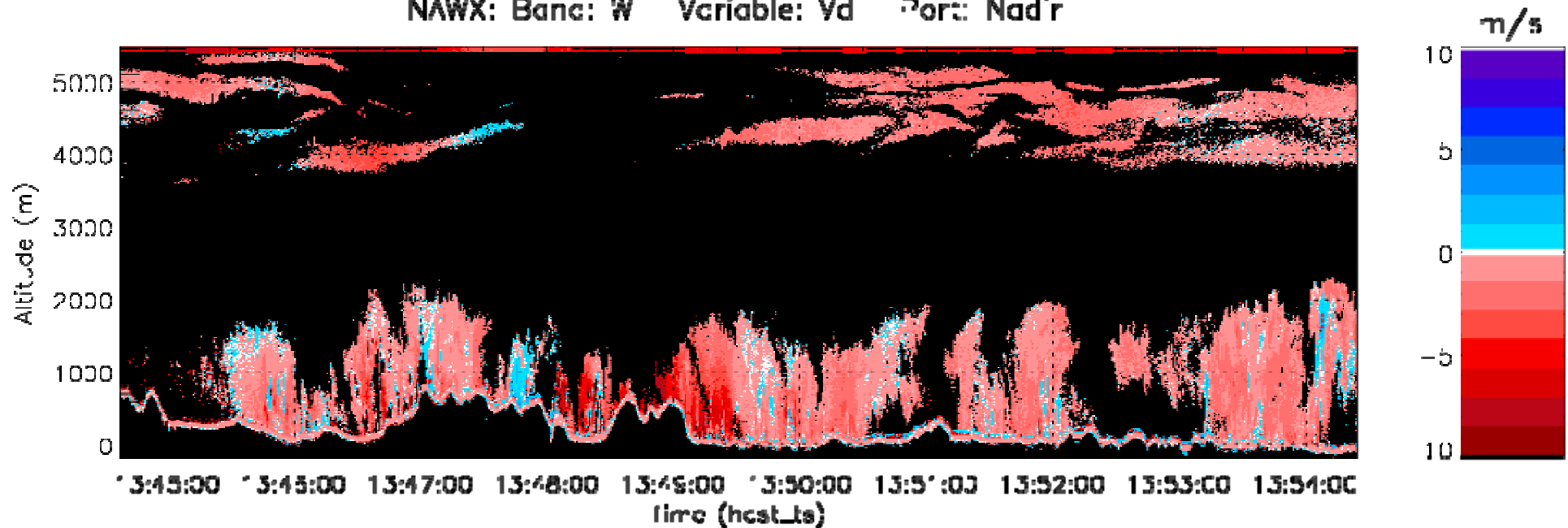
# Nov 09 – Boundary Layer Cloud



- ❖ Sampling just below cloud top of the shallow boundary layer cloud
- ❖ Fine-scale cloud organization – Vd and Z: High variability in the horizontal

# Nov 18 – Multi-layer clouds

Sur Nov 18 2007  
NAWX: Banc: W Variable: Vd Port: Nad'r



❖ Terrain influence in Vd – cloud organization



## Concluding Remark –

- ❖ NAWX – Unique dataset providing unique information on cloud structure and processes:
  - ❖ Diverse data from boundary layer clouds to large scale systems with complex cloud organization
  - ❖ Near coincident radar and in-situ data allowing correlation and quantitative retrievals of cloud microphysical properties beyond the aircraft locations
  - ❖ Multiple frequencies and parameters



Questions? [Mengistu.wolde@nrc.gc.ca](mailto:Mengistu.wolde@nrc.gc.ca)



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# STAR – In Picture

<http://www.nawx.nrc.gc.ca>





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to *Innovation...*

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