

Cayenne-2015 Data set status, NRC CV580 – Radar Data

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1- National Research Council Canada
2- Environment Canada

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Outline

- ❖ Basic Systems Info
 - ❖ NAWX
 - ❖ Pilot X-band Radar
 - ❖ Ka-band
- ❖ Systems' field Performance and Calibrations
- ❖ NAWX
 - ❖ Dual-frequency
 - ❖ RASTA and CloudSat
 - ❖ Doppler Processing
 - ❖ Preliminary analysis – Z – IWC
- ❖ Timeline – Processing and Analysis

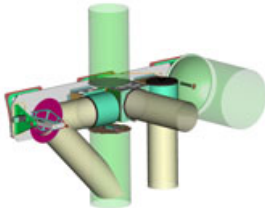
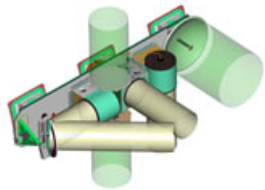
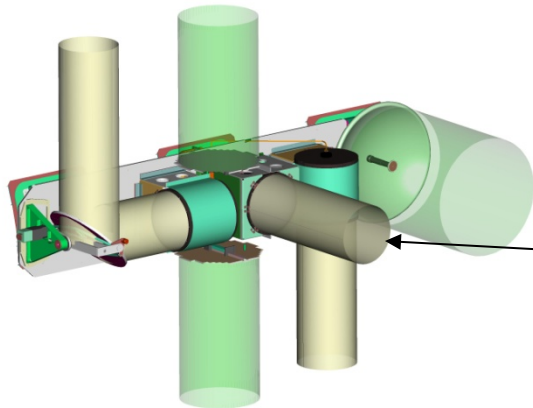


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NRC Airborne W and X-bands radar (NAWX)

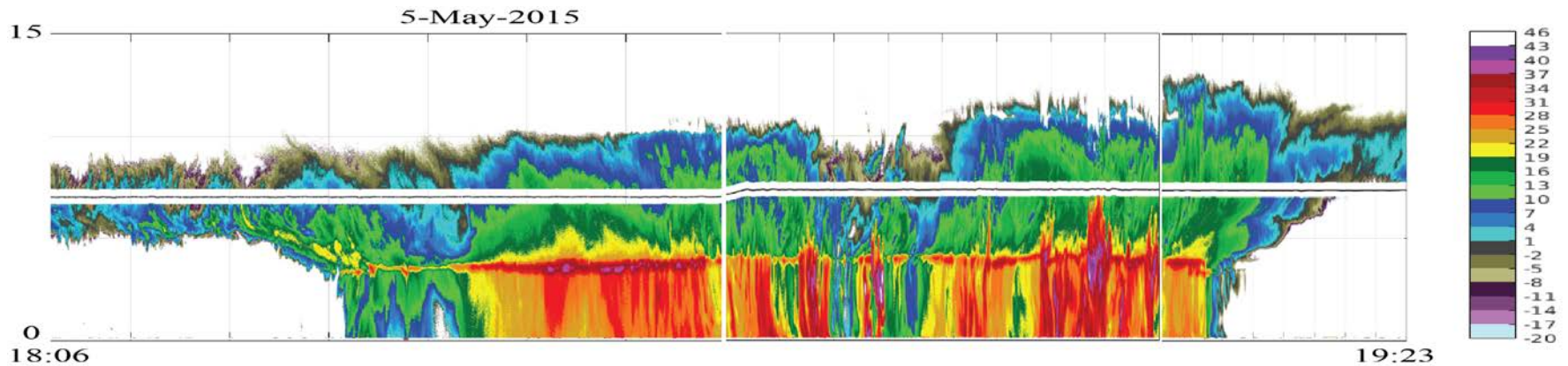


NAWX	W-band	X-band
Transmitted Frequency (GHz)	94.05	9.41
Peak Tx Power (KW)	1.7 - typical	25 (split b/n two ports)
Polarization	Co and Cross	Simultaneous H and V
Doppler	Pulse Pair and FFT	Pulse Pair and FFT
Pulse Duration (μ s)	0.1 - 10	0.11-1
Max PRF (KHz)	20	5
Ant. 3 dB BW ($^{\circ}$)	0.75	3.5
Antenna ports	5	4
View direction	Up, down and side	Up, down and side



Convair Radar Performance

Date May	10	12	14	15	16	16	20	23	23	25	26	26	27
Flt #	7	8	9	10	11	12	13	14	15	16	17	18	19
X	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
W	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Red	Light Green
K _a	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Red	Red	Red	Red	Red	Red
Pilot	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green



X – Very good; W: Good, but data gap; Ka – Marginal – only nadir data; Pilot X - Good



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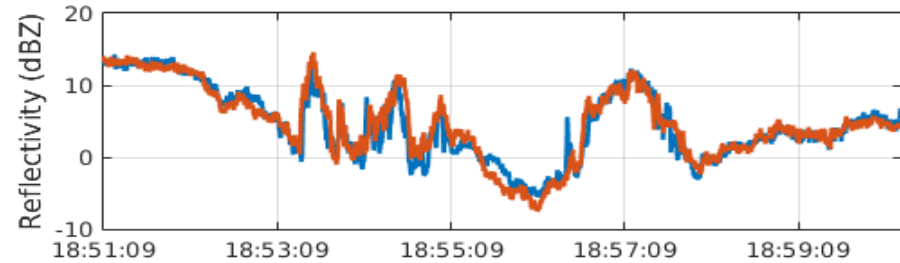
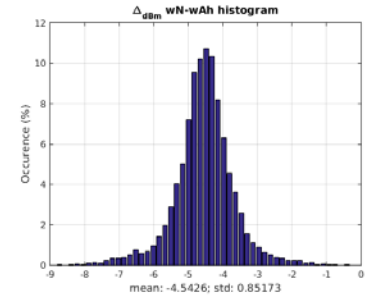
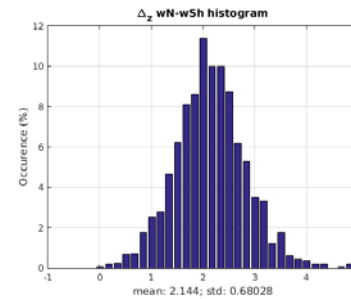
NAWX calibration using corner reflector



- ❖ Corner reflect calibration of Aft antenna
- ❖ Drizzle / small ice crystal Z from W is used for determination of calibration constant for X-band



- NAW power measurements



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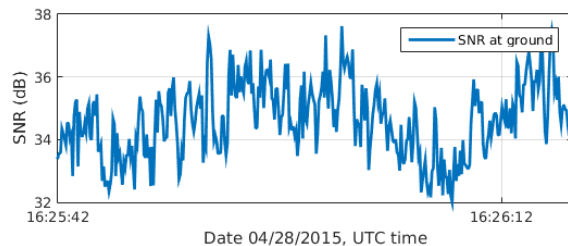
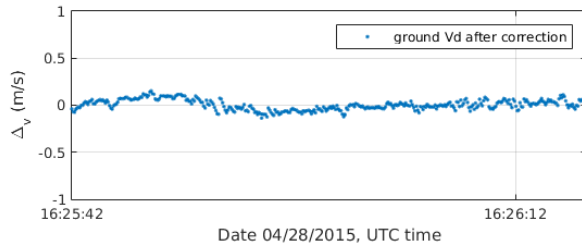
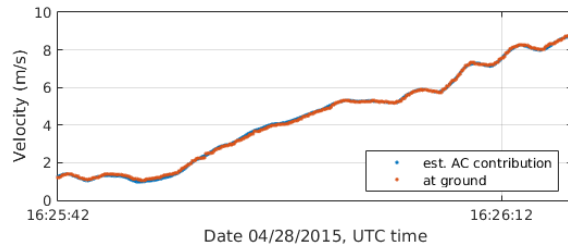
V_d -Processing – Removal of a/c motion

Radar measured Doppler: $\hat{v} = \mathbf{b} \cdot (\mathbf{V}_s + \mathbf{V}_{a'} + \boldsymbol{\omega} \times \mathbf{R})$

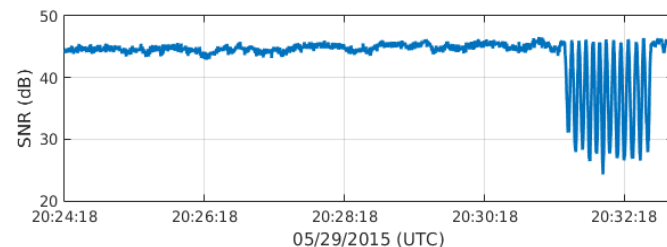
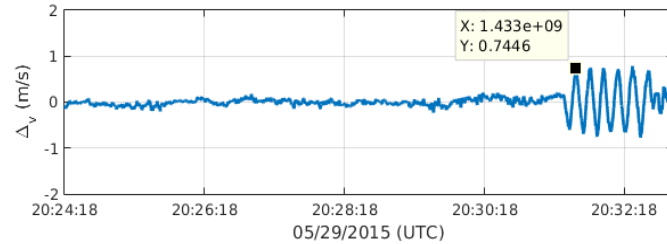
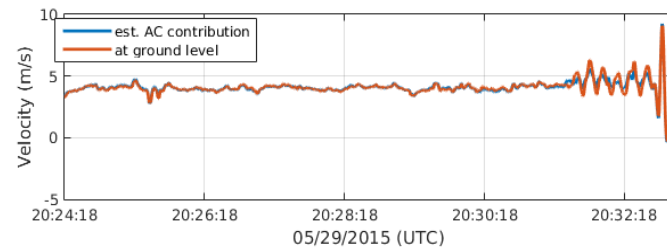
At ground: $v_{obj} = 0$

MMSE beam vector estimation: $\mathbf{b} = [b_x \ b_y \ b_z]^T \xrightarrow{\text{MMSE}} \mathbf{b} = \min_{\mathbf{b}} \left\{ \text{tr} \left((\hat{\mathbf{V}} - \mathbf{V}_{obj})(\hat{\mathbf{V}} - \mathbf{V}_{obj})^T \right) \right\}$

Example 1: Convair over land with increasing roll angle



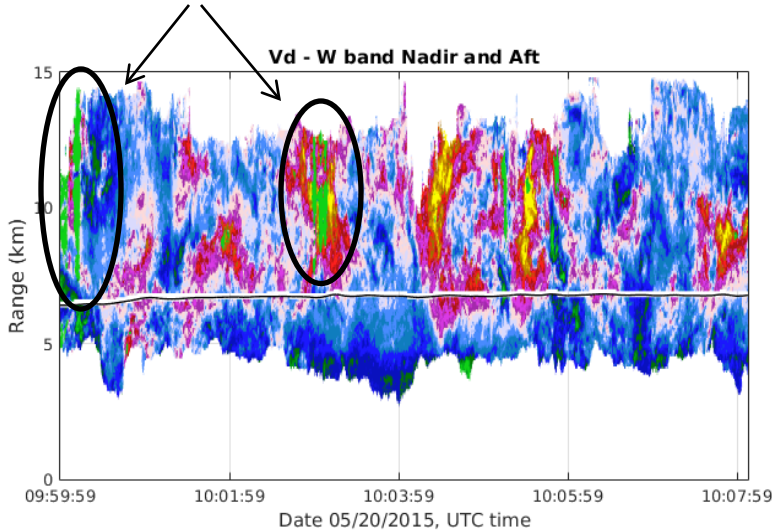
Example 2: Convair over ocean with periodic roll angle



Aircraft motion removal – V_d accuracy < 0.1 m/s

NAW Doppler un-folding using staggered PRT

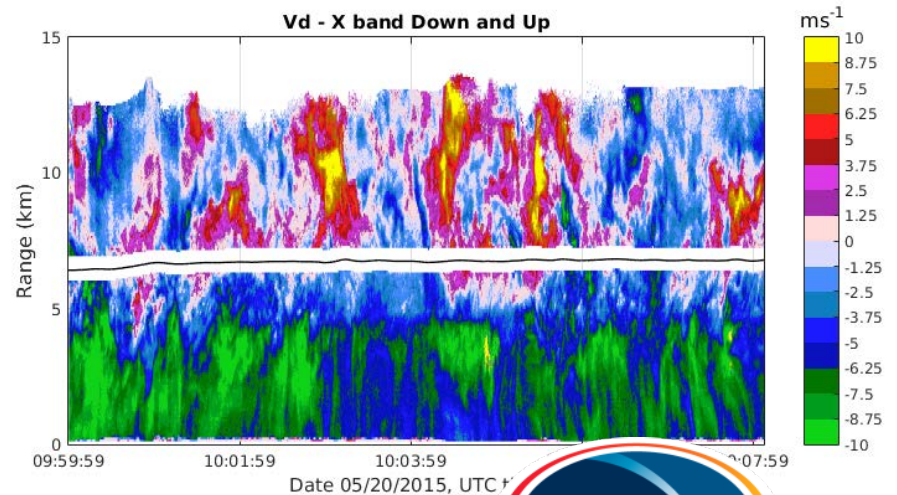
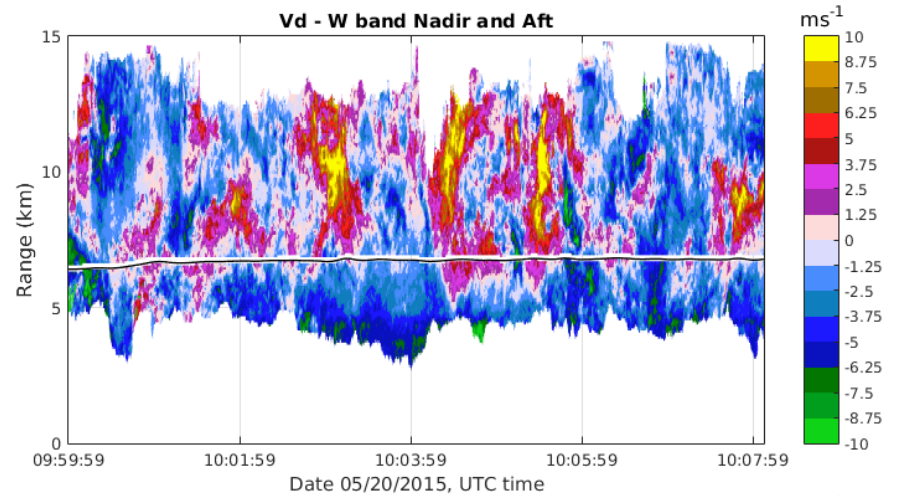
Velocity folding at
W-band



V_d at Aft H, v_a = 13.29 m/s

V_d at X-band, v_a = 20 m/s →

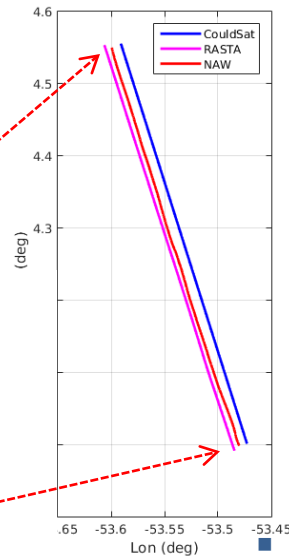
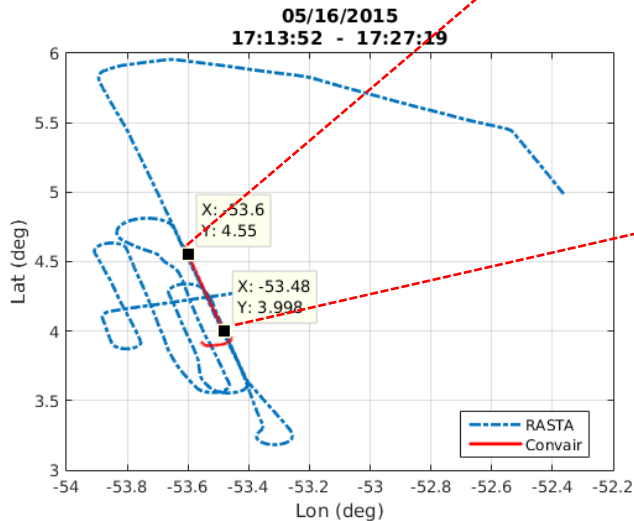
**Corrected V_d using Aft H and Aft V
(v_a = 19.93 m/s)**



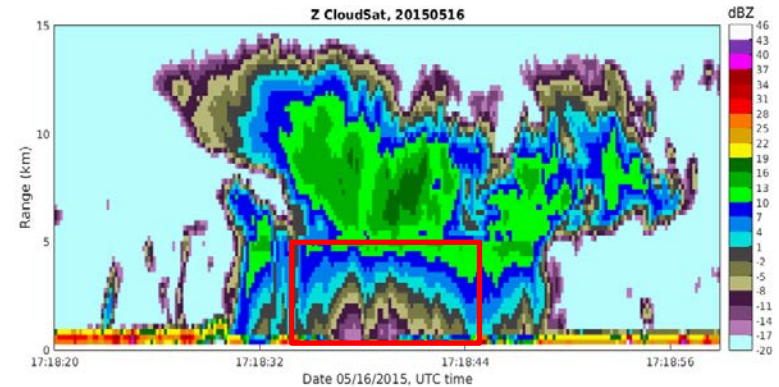
Good agreement b/n X and W after unfolding W-band

Reflectivity calibration: NAW-RASTA-CloudSat

Convair and RASTA track



CloudSat overpass

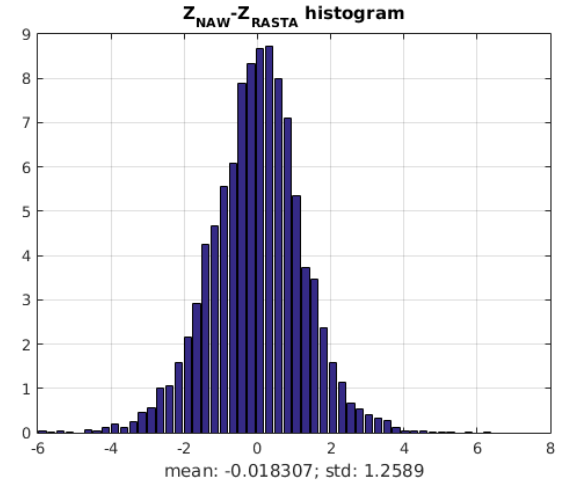
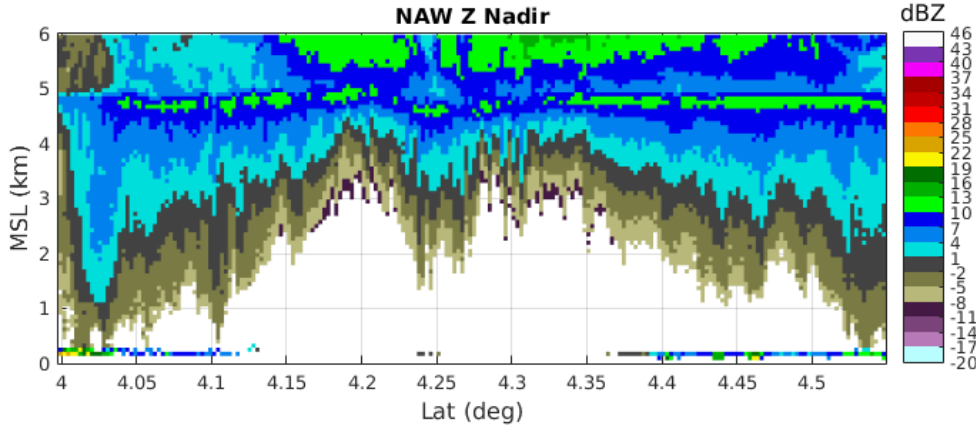


- Select an overlap segment of the flight track when the temporal and spatial differences between the three platforms are minimum
- NAW has a higher resolution than CloudSat and RASTA data used in the comparison
 - Comparison are done with NAW data was “downsampled” and re-gridded to match with RASTA and CloudSat resolutions

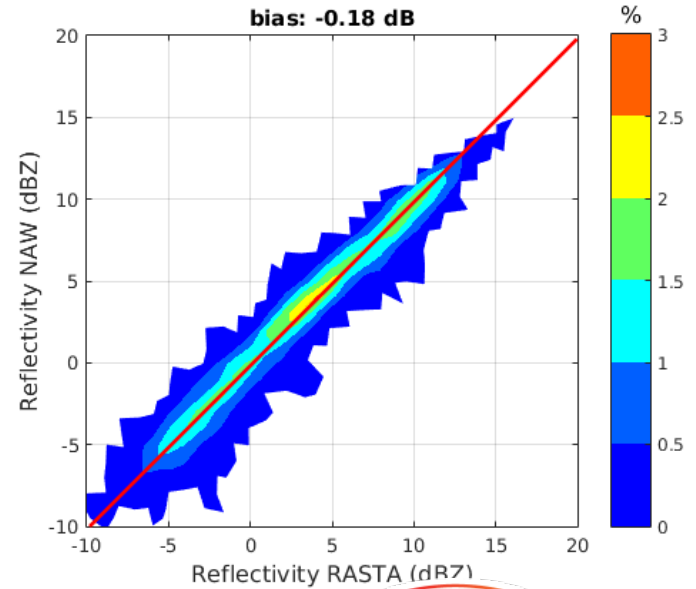
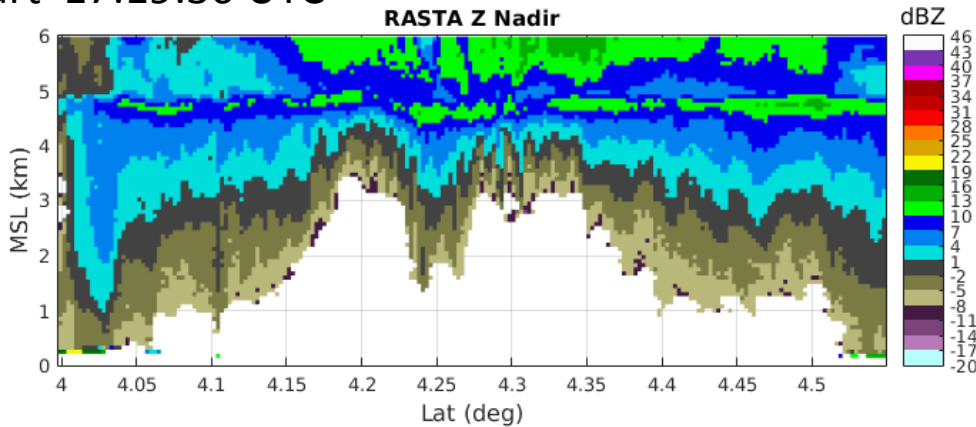


NAW-RASTA

Start 17:17:08 UTC



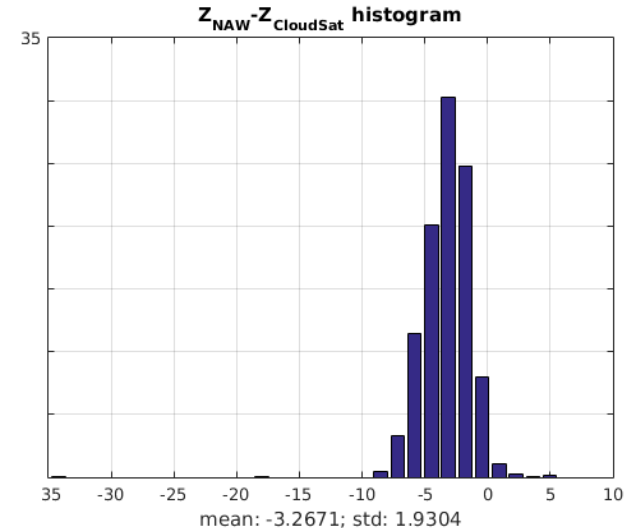
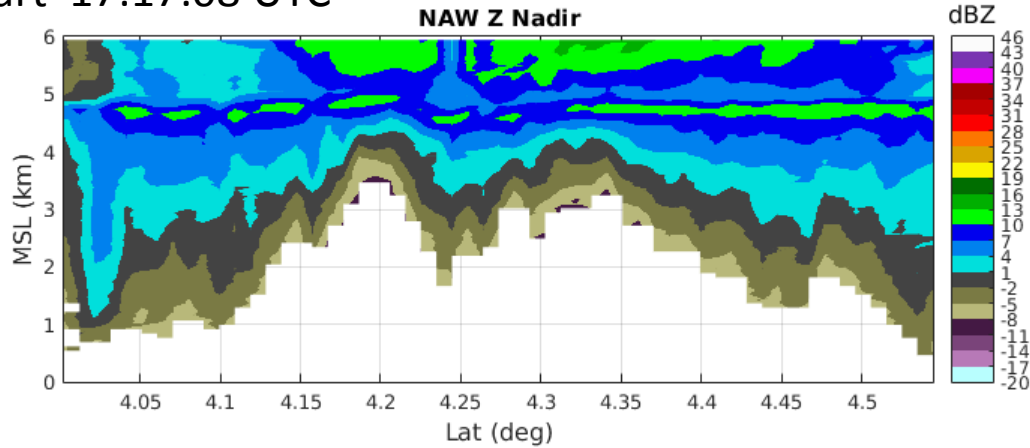
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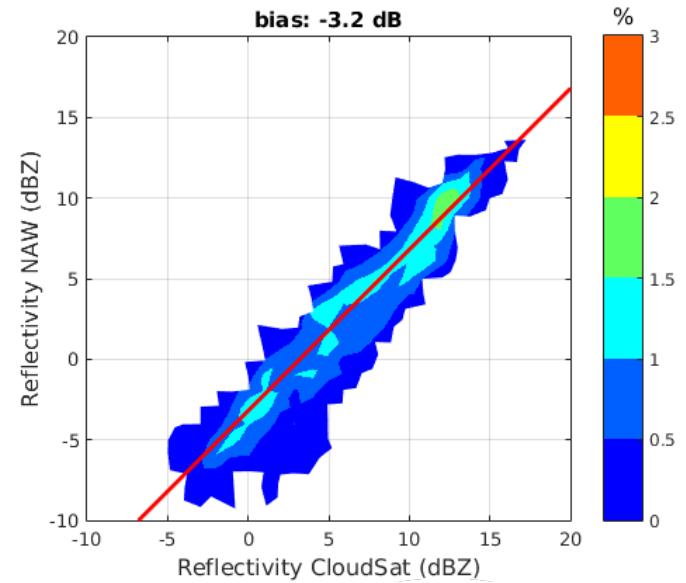
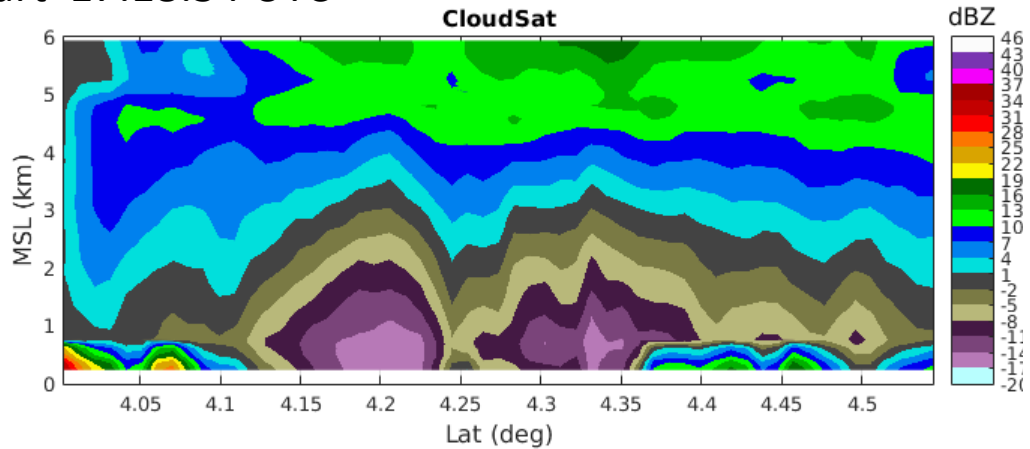
Excellent agreement b/n RASTA and NAW

NAW-CloudSat

Start 17:17:08 UTC



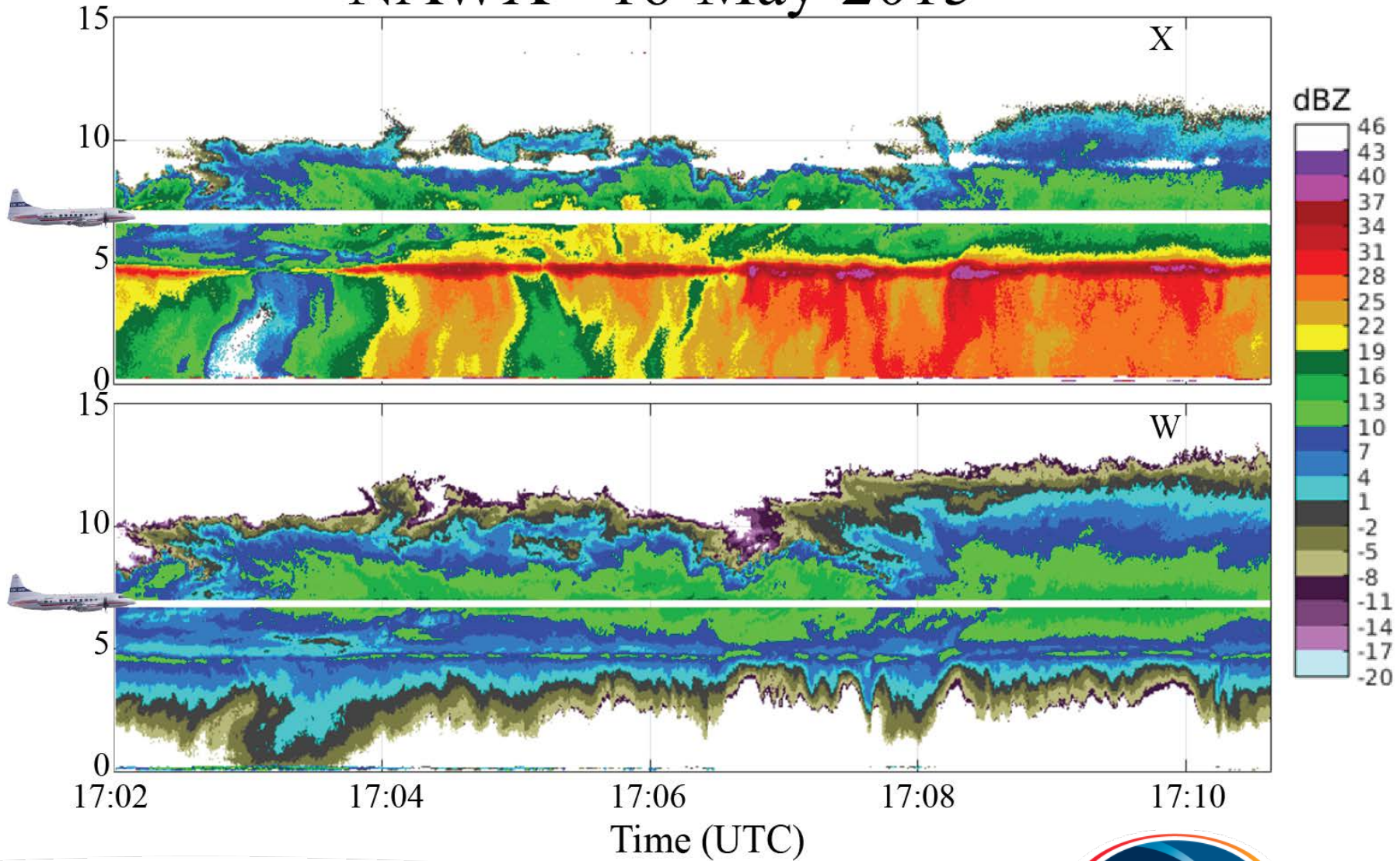
Start 17:18:34 UTC



NAW/RASTA Z 3.2 dB lower than CloudSat

Comparison of W-band and X-band vertical reflectivity profiles

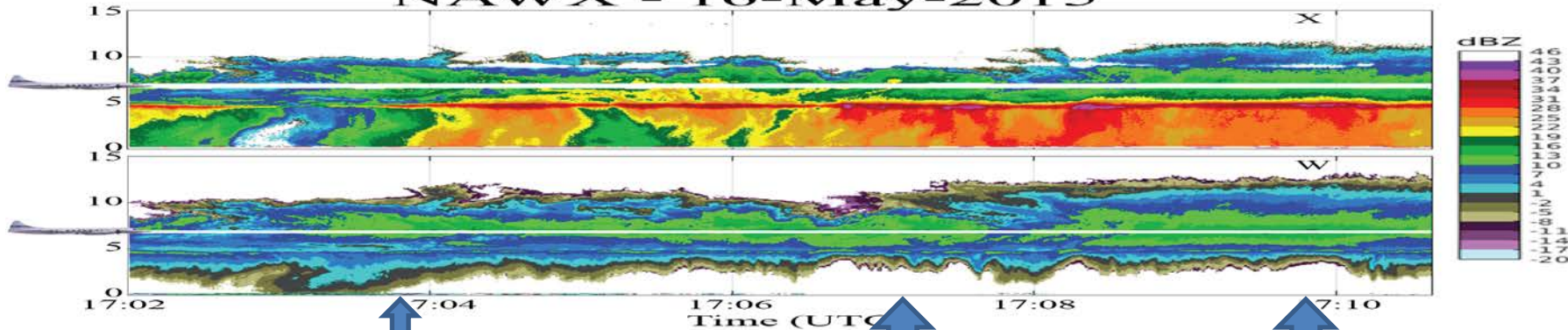
NAWX - 16-May-2015



DFR – Attenuation, Mie, Rayleigh scattering, artifact

Comparison of W-band and X-band vertical reflectivity profiles

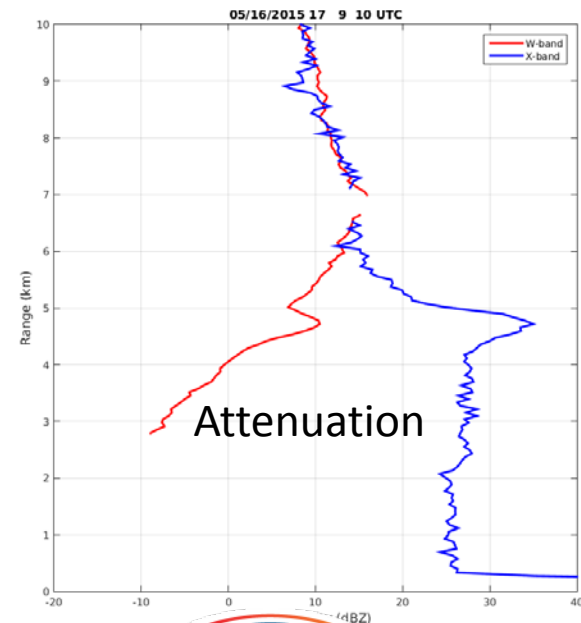
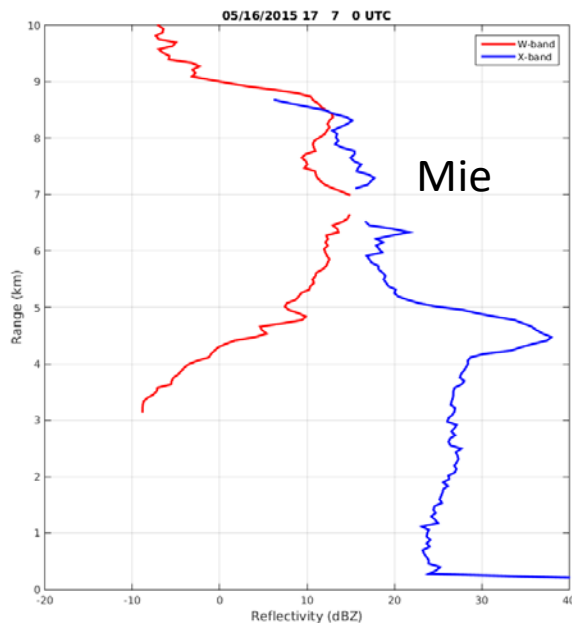
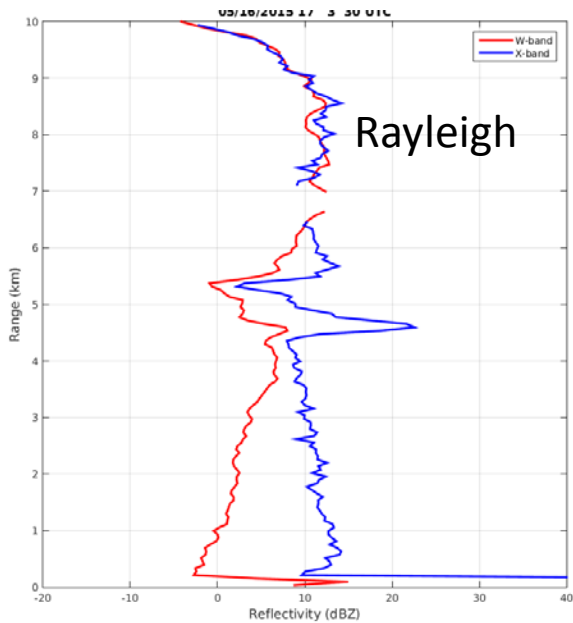
NAWX - 16-May-2015



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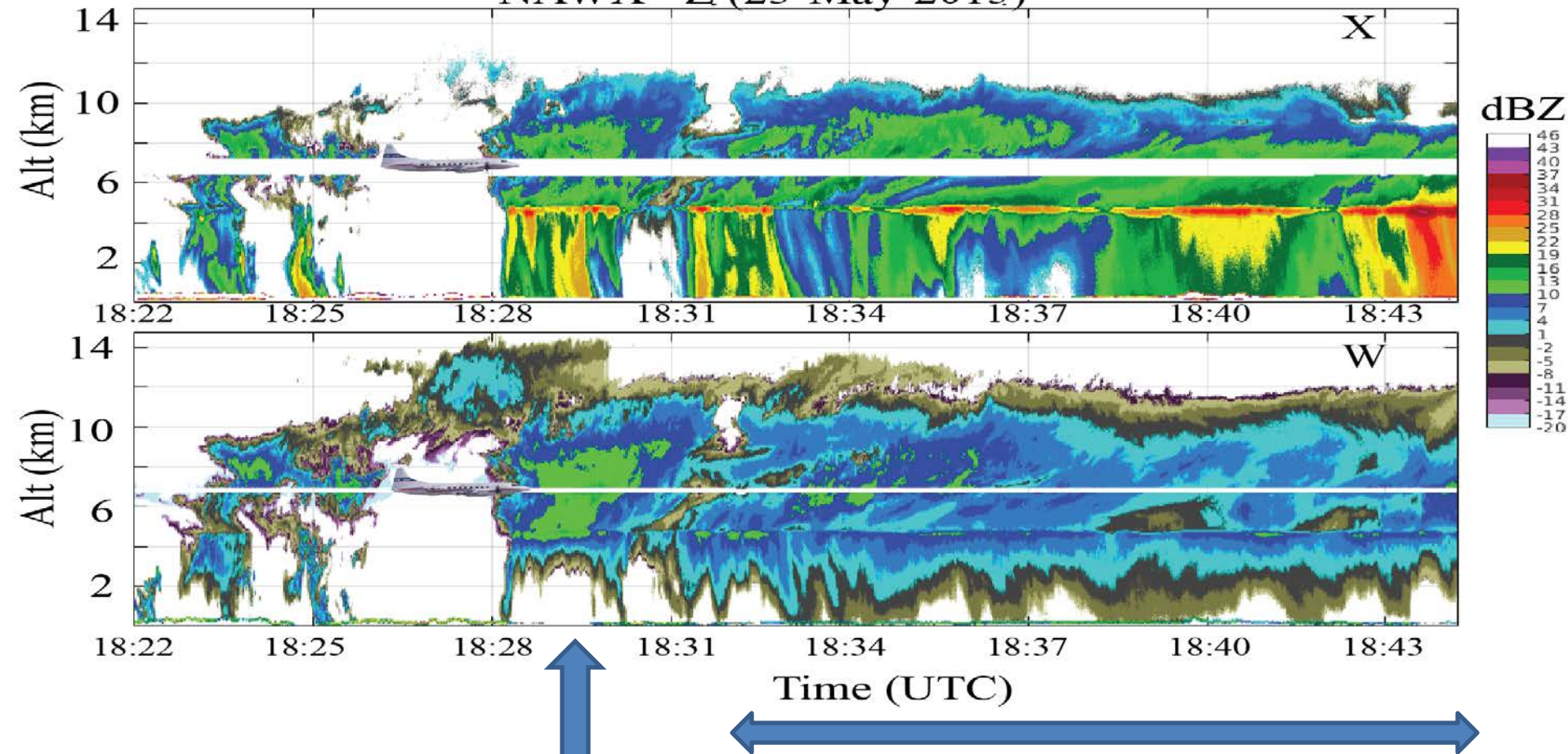
17:07:00

17:09:10



DFR – Attenuation, Mie, Rayleigh scattering, artifact

NAWX - Z (23-May-2015)



In rain – W-band heavy attenuation
 At flight level – good agreement b/n
 X and W

Flight level – Mie effect – large crystals

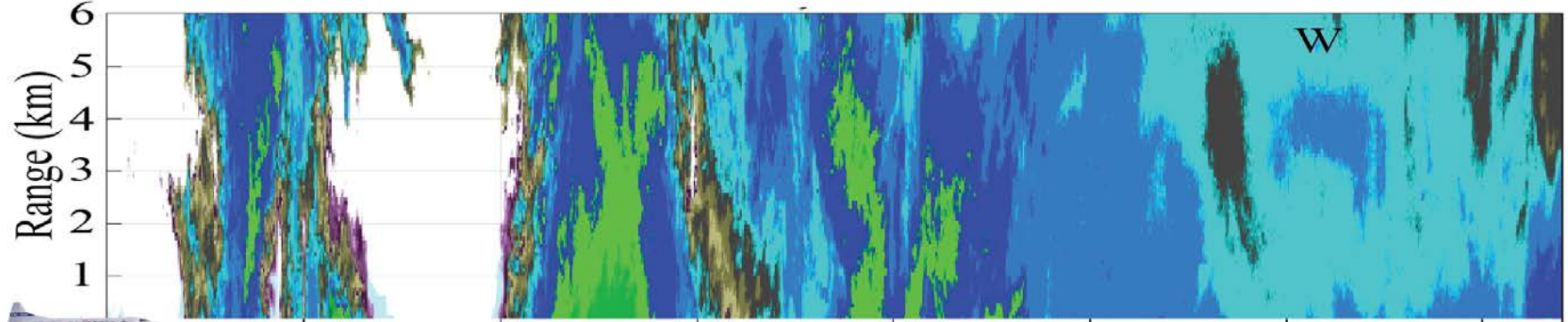
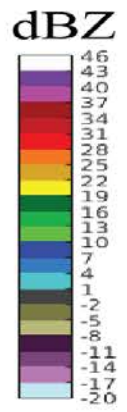
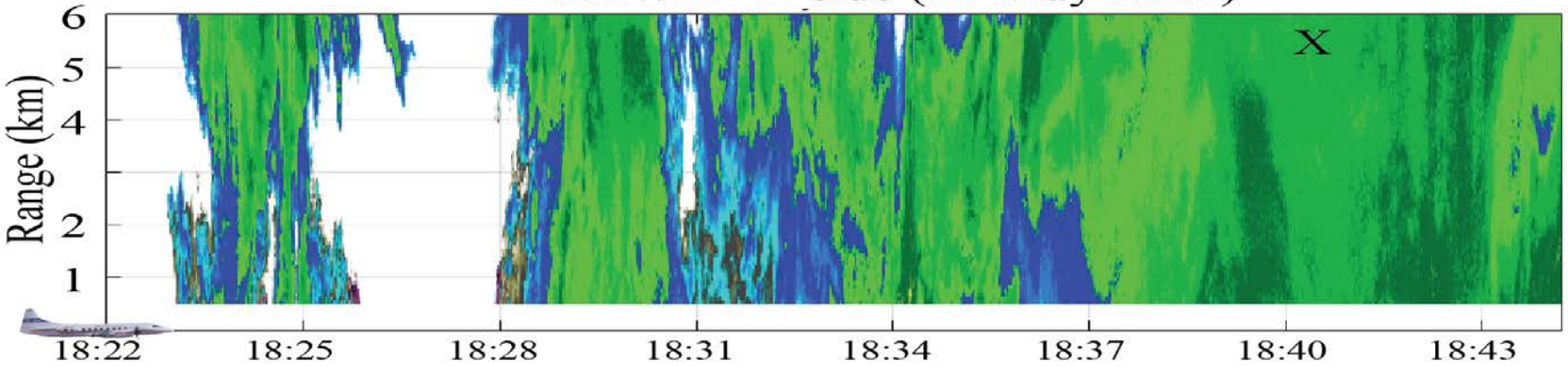


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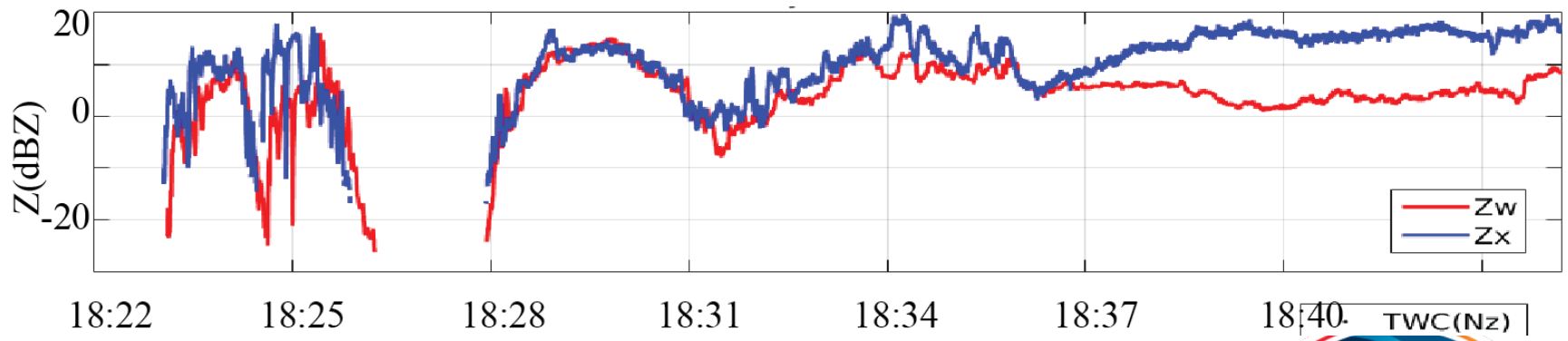
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NAWX - Z-side (23-May-2015)



Zx & Zw - Side @ 500m

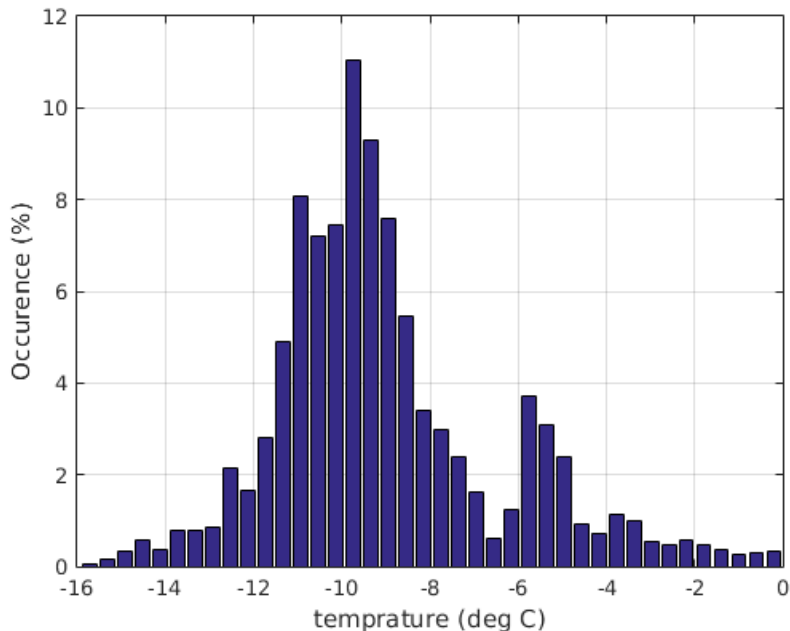


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Preliminary Analysis – In-situ vs. NAWX

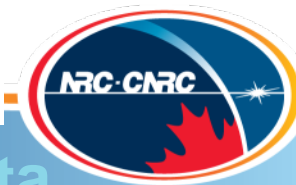


- ❖ Prelim In-situ data from PIP, Robust and Nevzorov Sensors
- ❖ W-band: Aft and Nadir antennae Z @ 100 m
- ❖ X-band: Zenith and Nadir antennae @ 400 m
- ❖ Temperature ranges of 0C to -17C



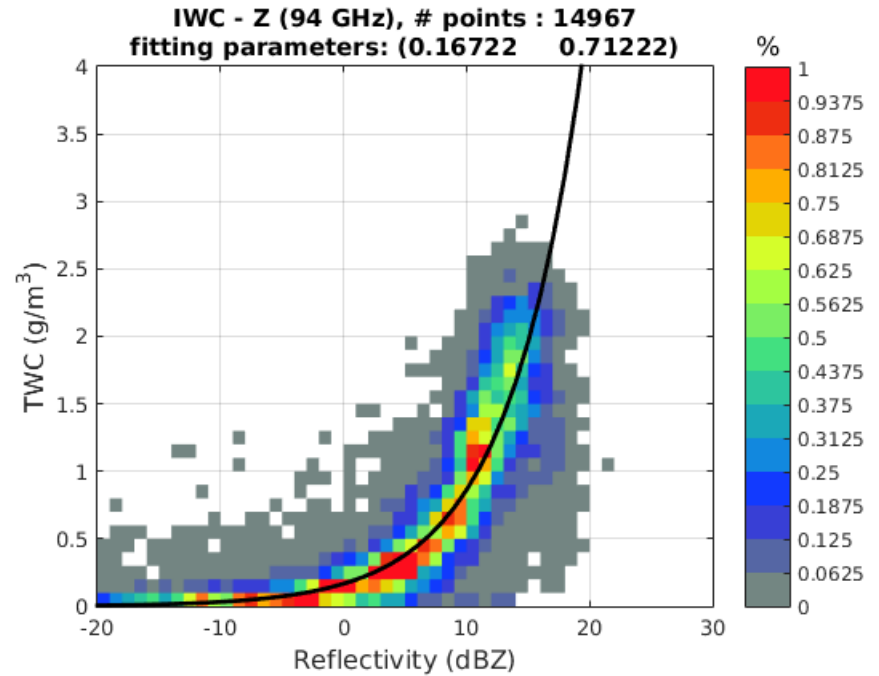
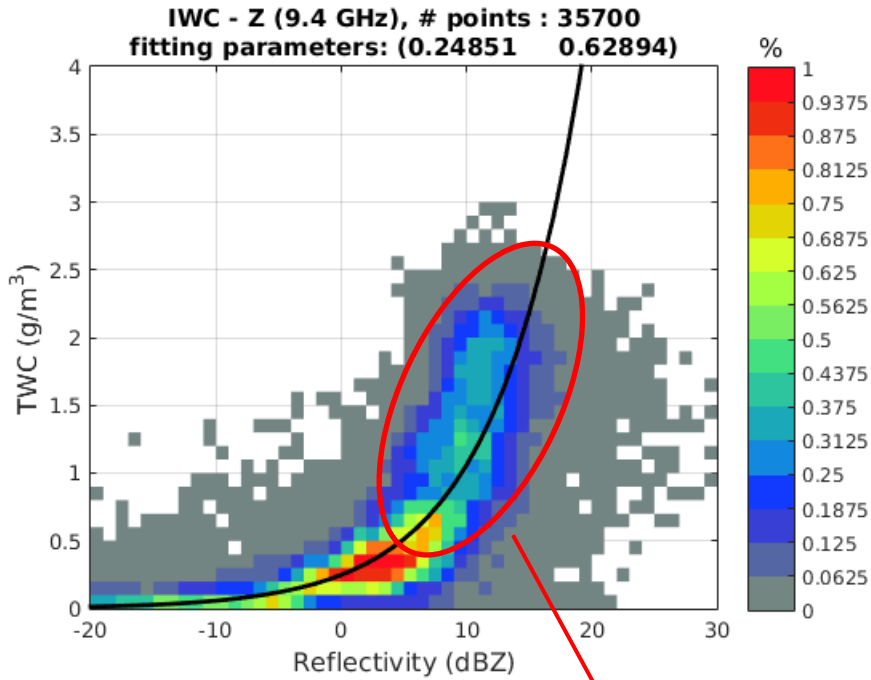
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All Data

Power law fitting: $IWC = a * Z^b$



piecewise
fitting?

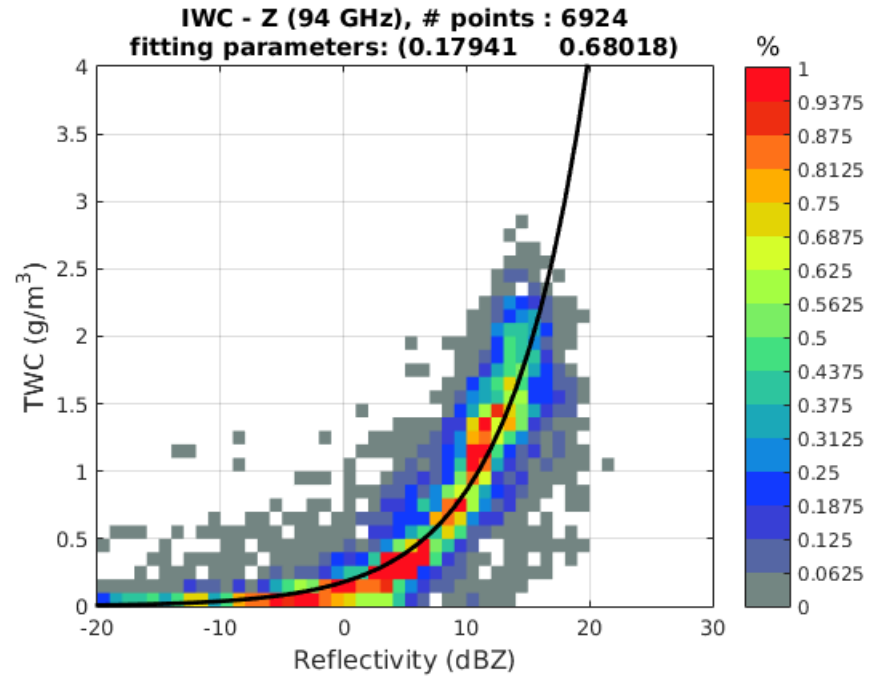
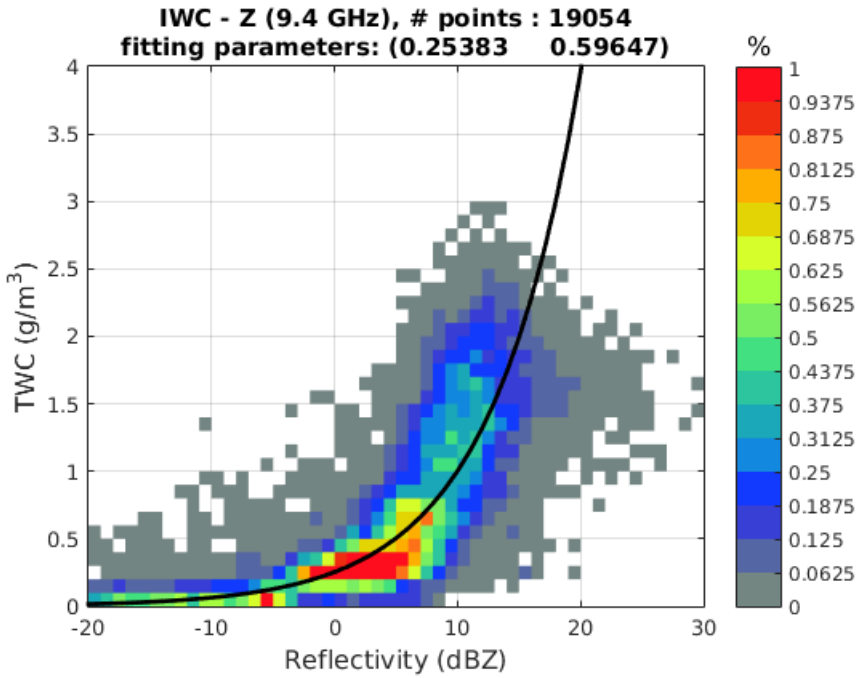


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T : -10C

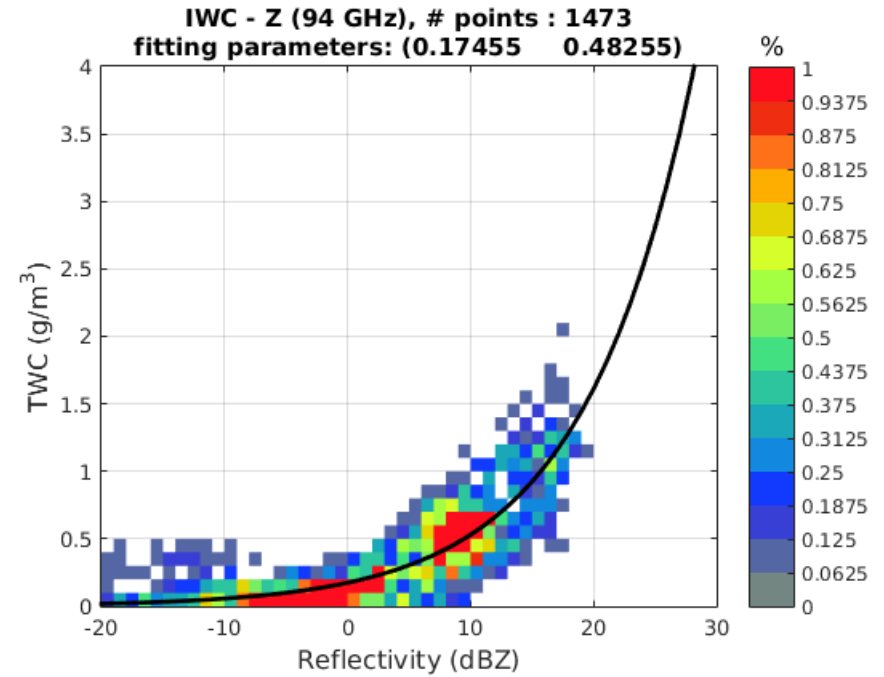
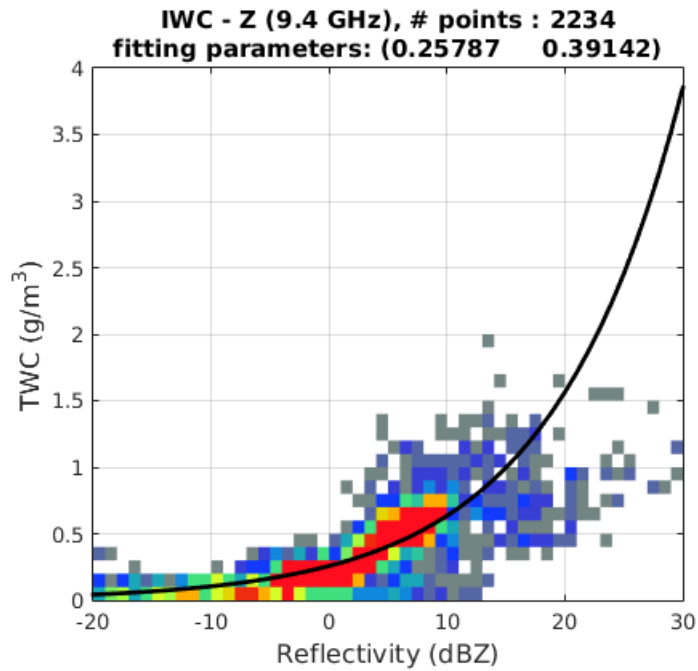


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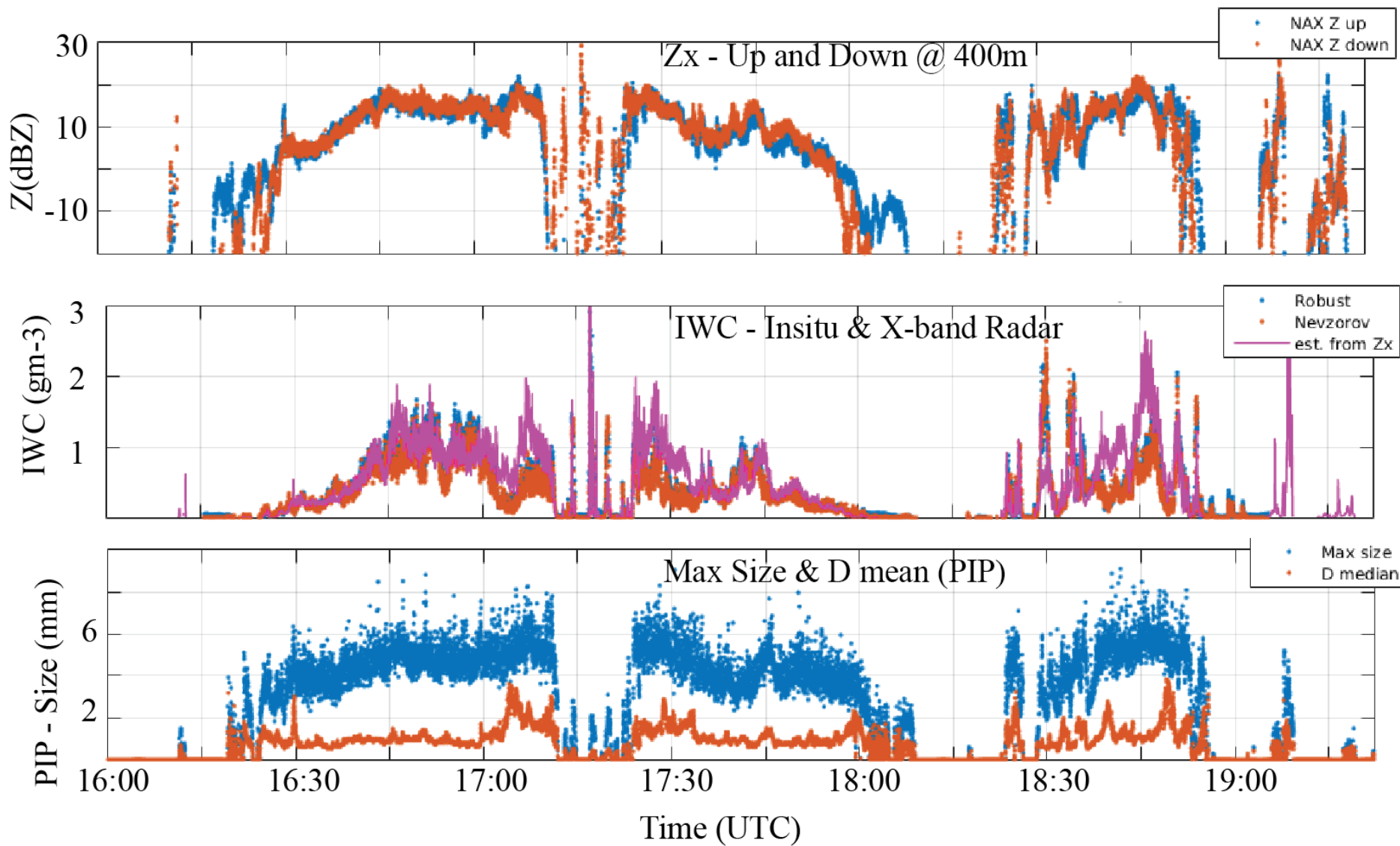
T : -5C



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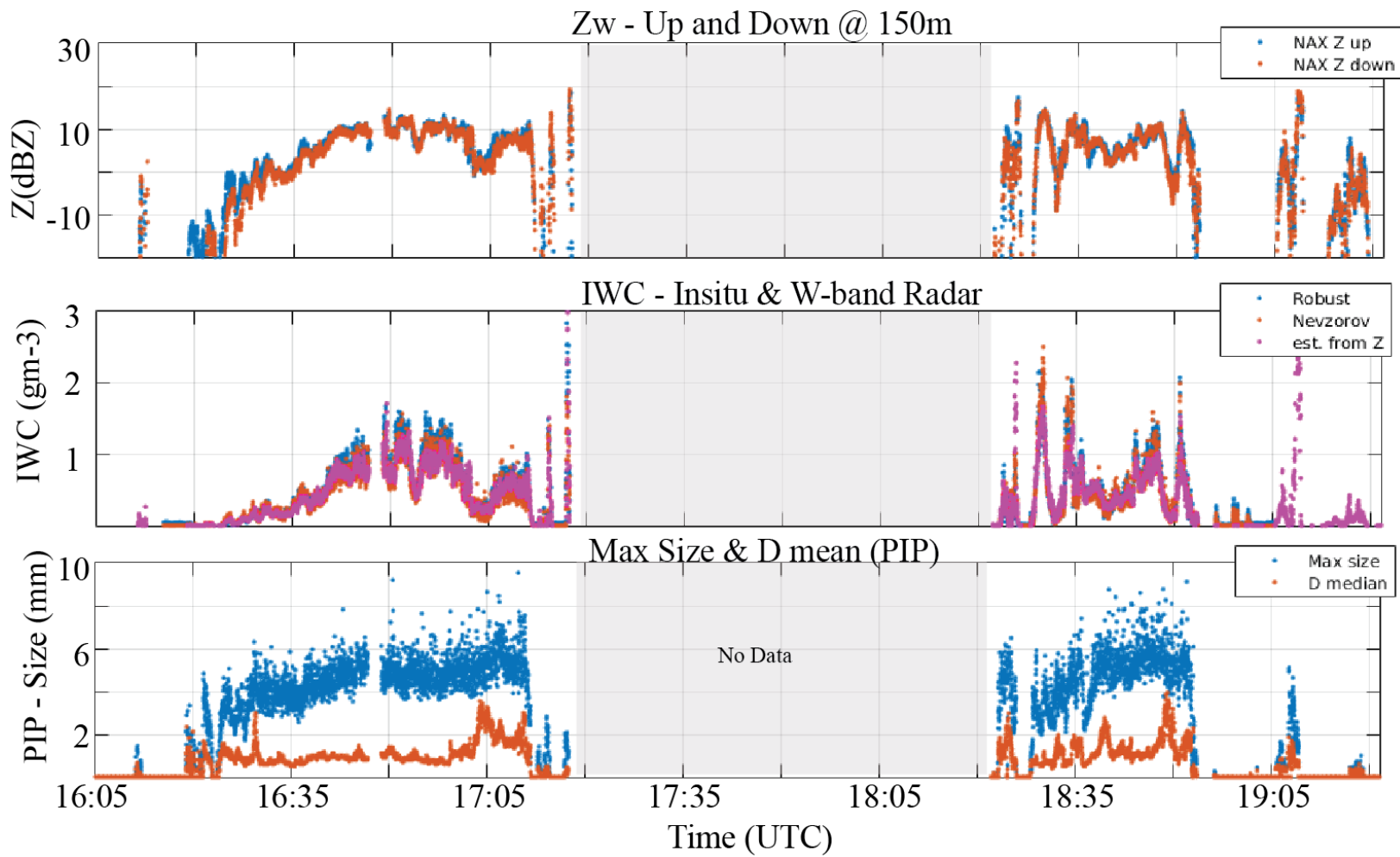




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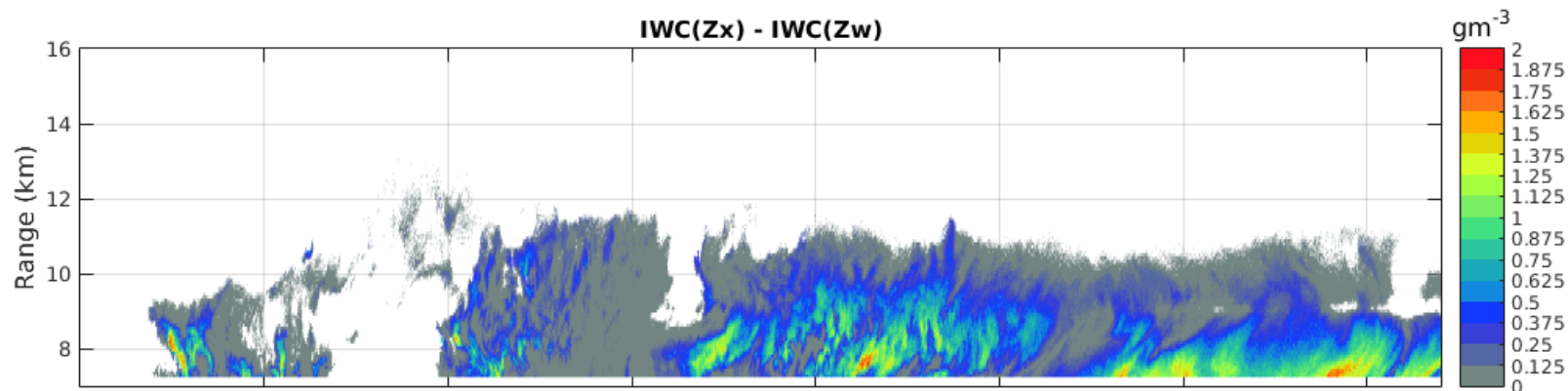
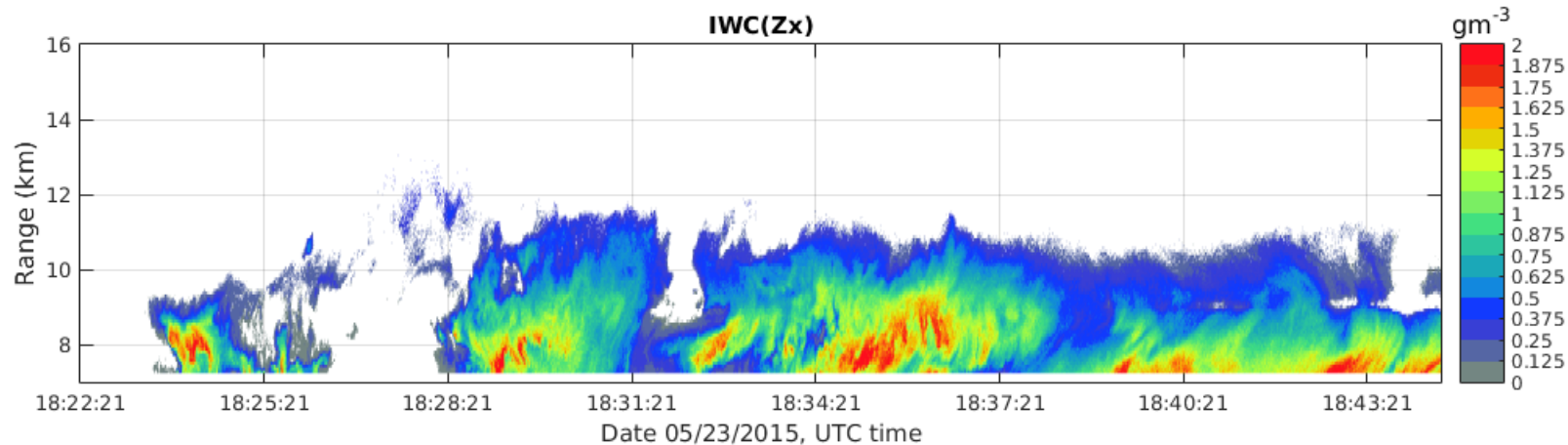
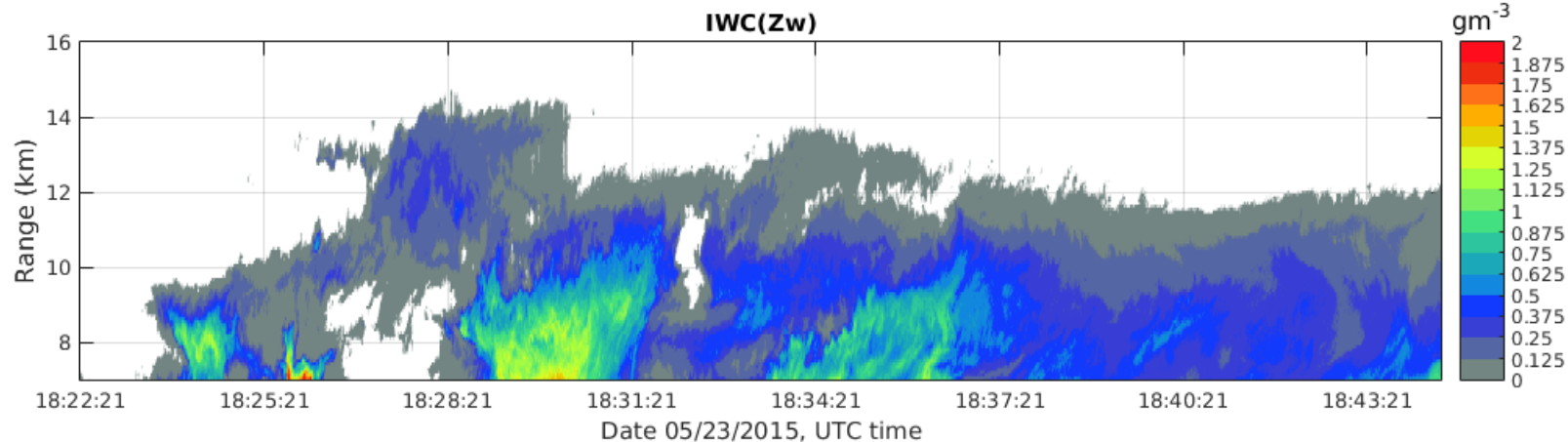


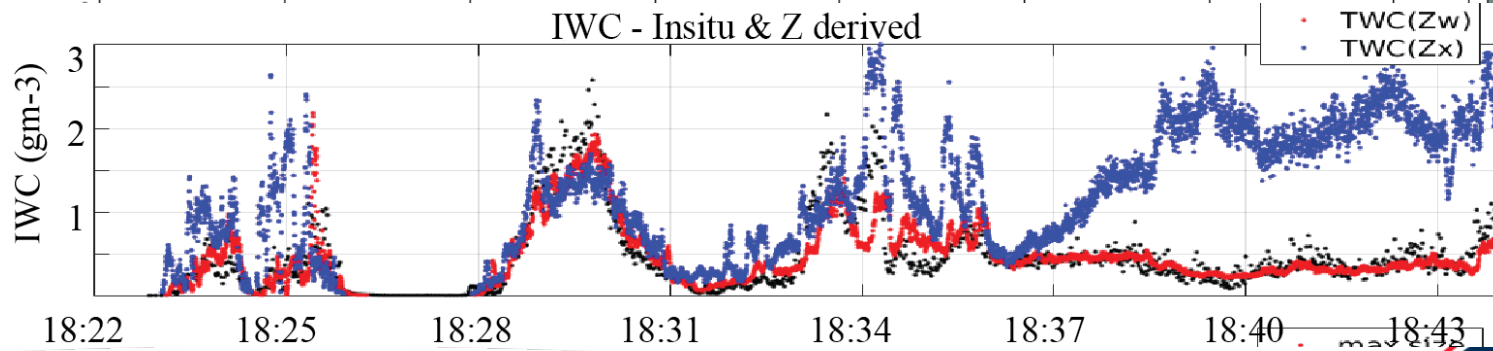
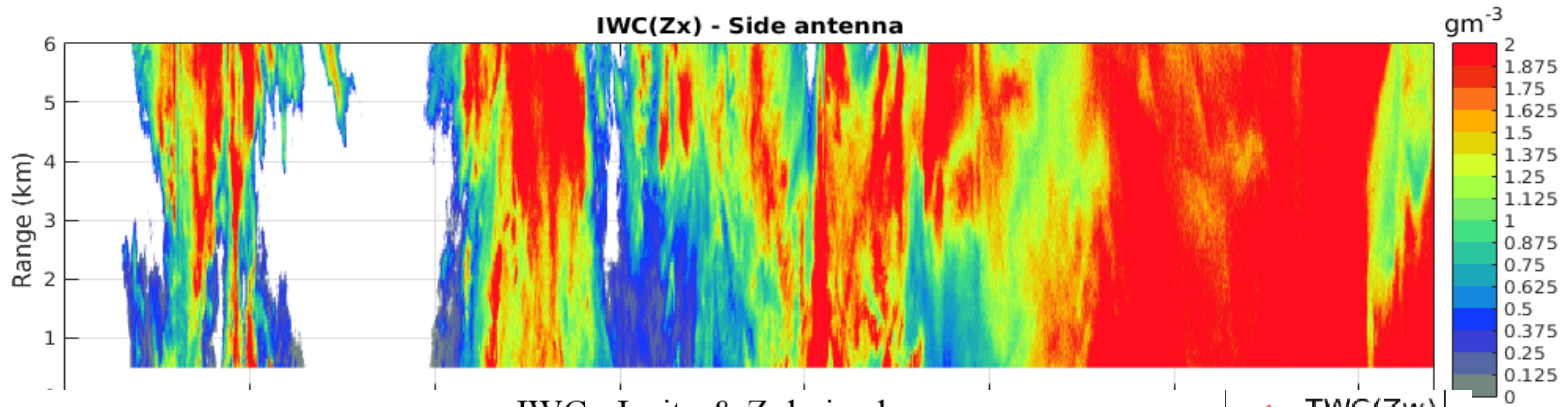
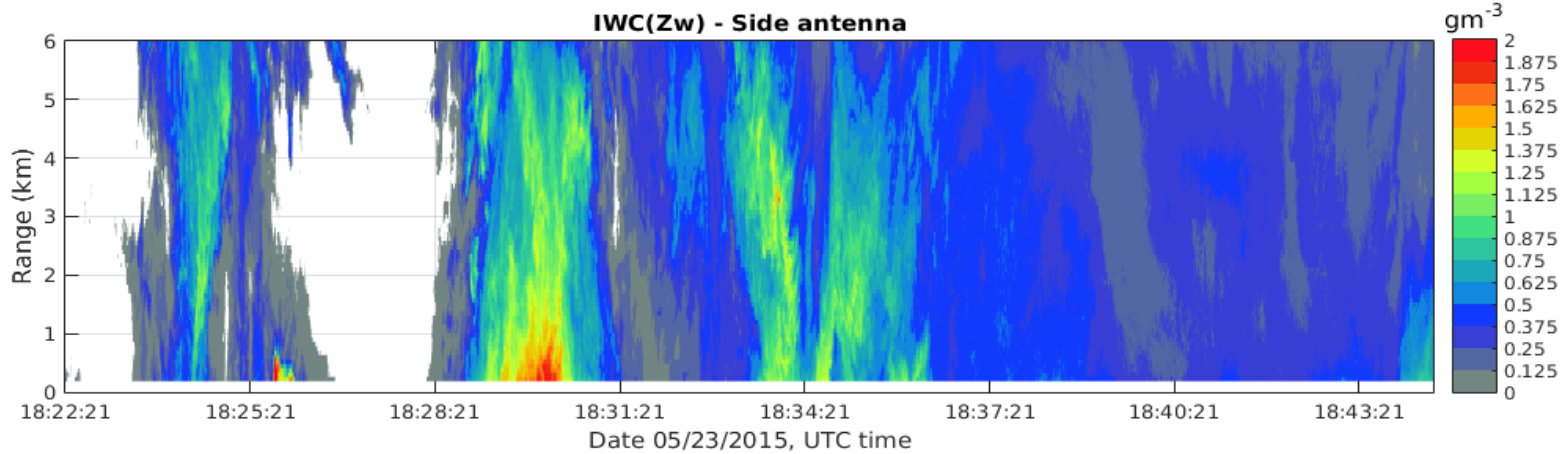


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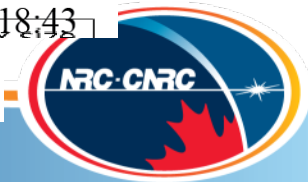






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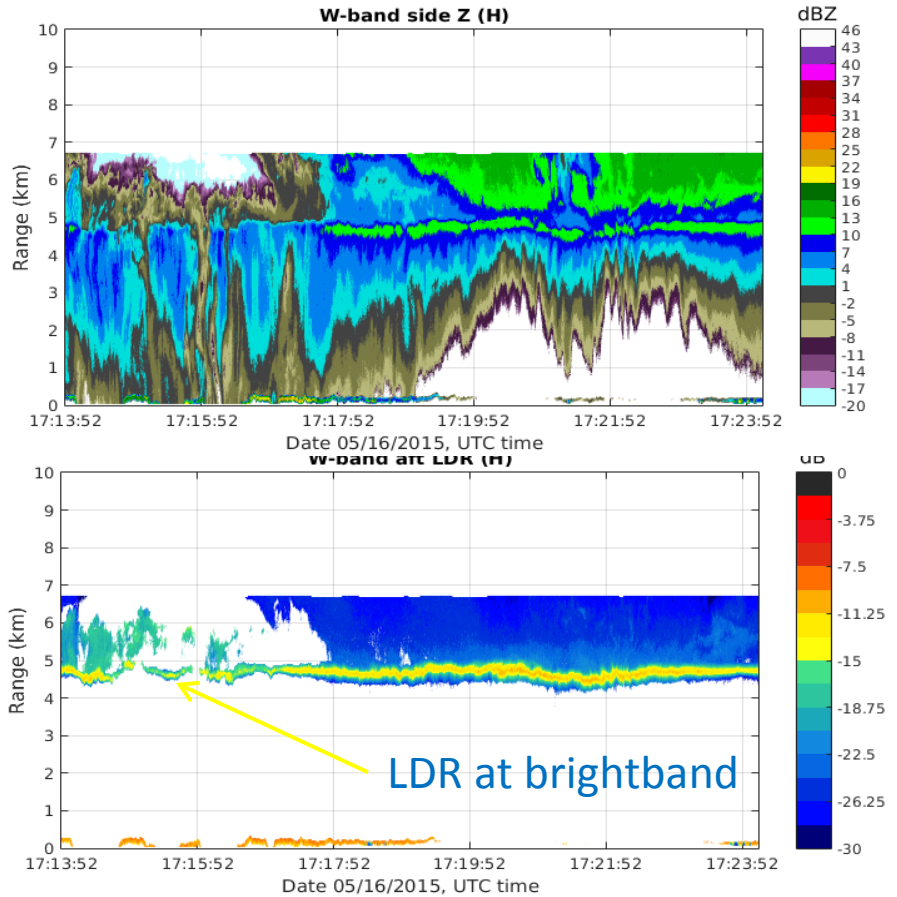
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- NAWX: Very good dataset
- Ka - limited value - no zenith looking data

➤ Analysis

- Differential Frequency Ratio (DFR)
- Differential Doppler Velocity (DDV)
- X-band & W-band IWC retrievals
- Polarization
- Triple frequency analysis



High Ice Water Content (HIWC) Program

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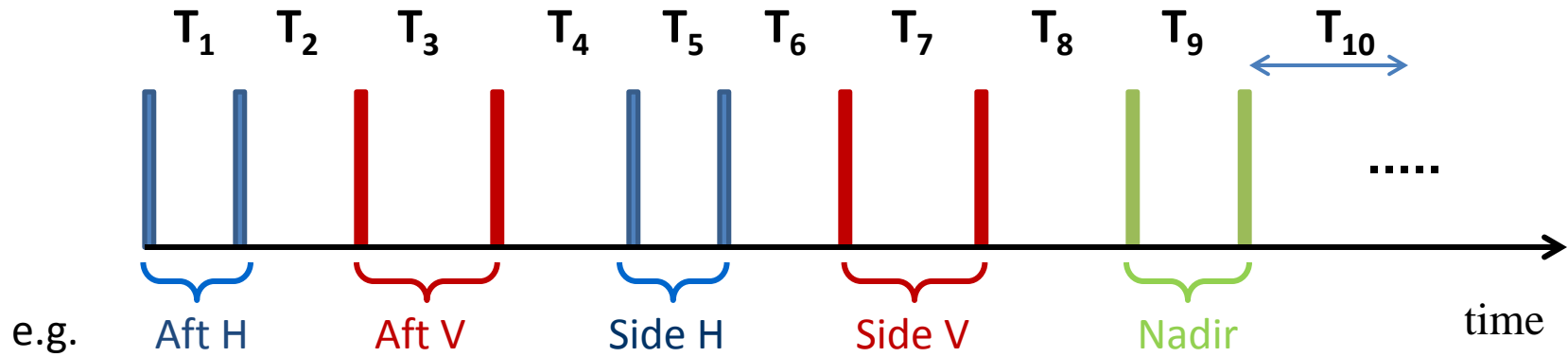
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Spare slides



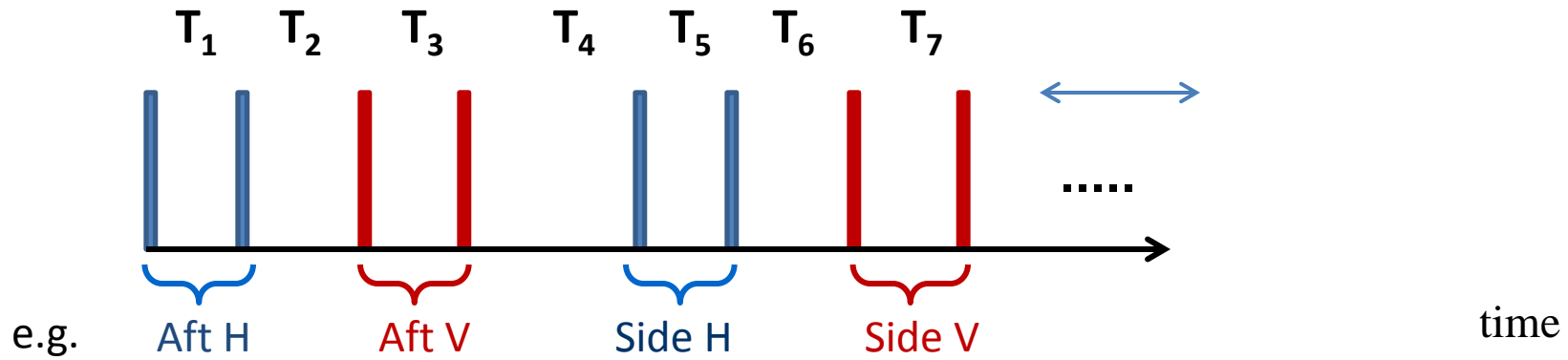
NAW operating mode and signal processing



Highly configurable pulsing scheme, port selection and the reflector angle provide options for:

- Spectral moments for nadir/zenith and side
- Dual-polarization measurements at side and aft antennas
- Doppler unfolding (using staggered PRT)
- Dual-Doppler

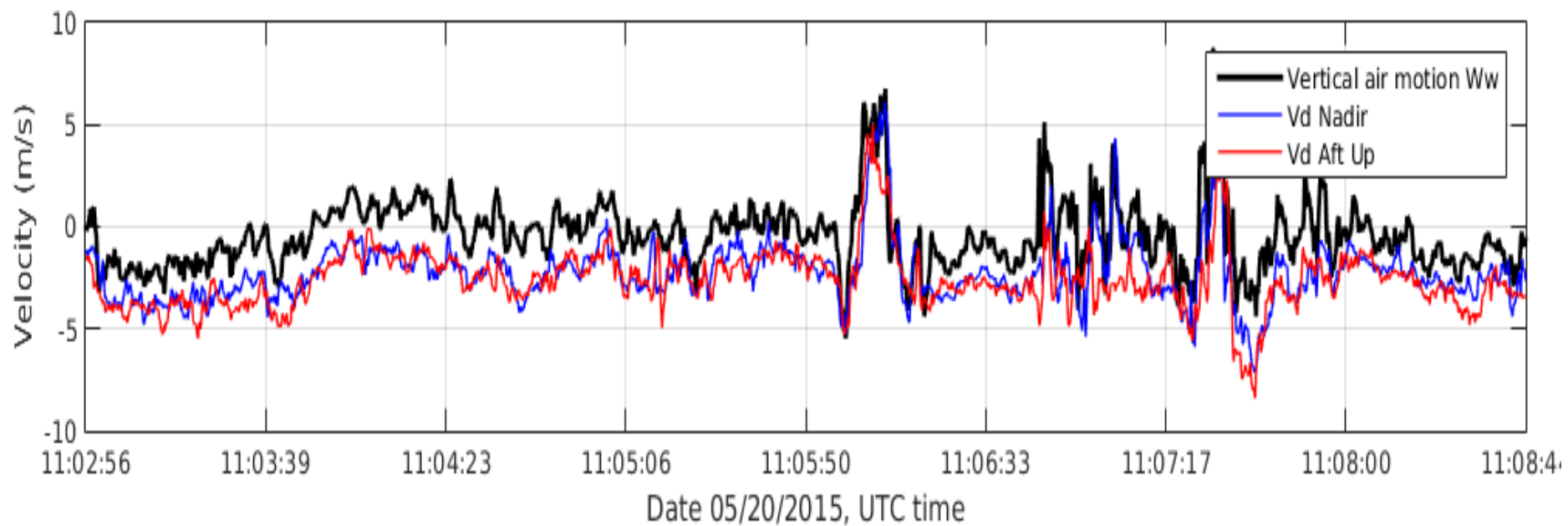
NAX operating mode and signal processing



Highly configurable pulsing scheme, port selection for:

- Spectral moments for nadir/zenith and side
- Dual-polarization measurements at side
- Doppler unfolding (using staggered PRT)
- HIWC – PP4 scheme





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