Cayenne-2015 Data set status, NRC CV580 – NAWX radar and Pilot`s radar

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HAIC-HIWC Science Team Meeting, 05-09 December 2016

National Research Council Canada | Conseil national de recherches Canada

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Outline

- **In-situ data**
  - Updated quality control data
  - Netcdf format
  - Examples
- **The NRC W-band and X-band radars (NAWX)**
  - System
  - Reflectivity calibration
  - Doppler corrections/de-aliasing
- **Convair 580 pilot weather radar**
- **Apenglow elastic lidar**
- **Summary**

List of available measurements and sensor for Cayenne, May 2015

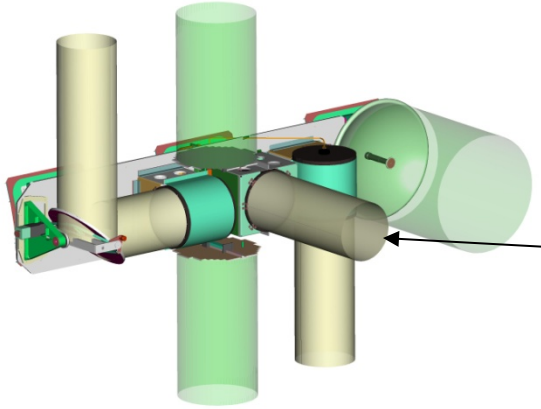
Parameters	Sensors	Availability date
Time	**GPS (Honeywell, IRIDGB, …)**	**10, 12, 13, 14, 15, 16(a/b), 20, 23, 25, 26(a/b), 27(a/b)**
Atmospheric state (Temp, Rh, Ps, Pd, Wind_n, Wind_e, Wind_speed, Wind_dir,)	**AIMMS, POK,**	**10, 12, 13, 14, 15, 16(a/b), 20, 23, 25, 26(a/b), 27(a/b)**
Air data (P alpha, P beta)	**AIMMS**	**10, 12, 13, 14, 15, 16(a/b), 20, 23, 25, 26(a/b), 27(a/b)**
Aircraft state (pitch, roll, heading/yaw, lat, lon, alt, Gs, track, Q, P, R, Ax, Ay, Az, NS_Vel, EW_Vel, V_Vel)	**Honeywell, POK, Litton, Flex, Pro**	**10, 12, 13, 14, 15, 16(a/b), 20, 23, 25, 26(a/b), 27(a/b)**

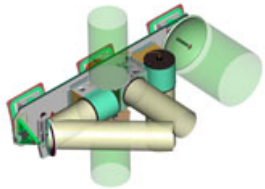
Cayenne Aircraft In-situ Data

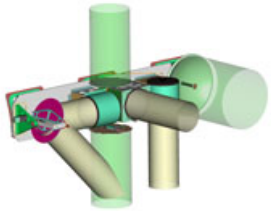
❖ Quality control data included in the Convair data release

- IRIGB Hg (Honeywell) is set as the main clock. Resolved the nonmonotonic timing issue (fig., next slide) and all data are mapped to the main clock.
- All parameters except Licor 840A are decimated to 4Hz rate. Licor 840A data is at 1Hz (as collected). From our analysis, the data are sync correctly.
- Recalculated Ps, Pd (scalar, 858) with updated calibration factors.
- Ts at scalar boom and port wing are not available for data before May 20 thus used Ts from AIMMS.
- Recalculated TAS (scalar and 858).
- Remove outlier samples by thresholding its gradient. If the outlier percentage is less than a pre-set threshold, remaining data points are interpolated.
- Monitor data consistency (across sensors) and detect for faulty data segments by standard statistical methods (local correlation, local standard deviation and gradient).
- Export QC data to netcdf files.

*N*RC *A*irborne *W* and *X*-bands radar (NAWX)



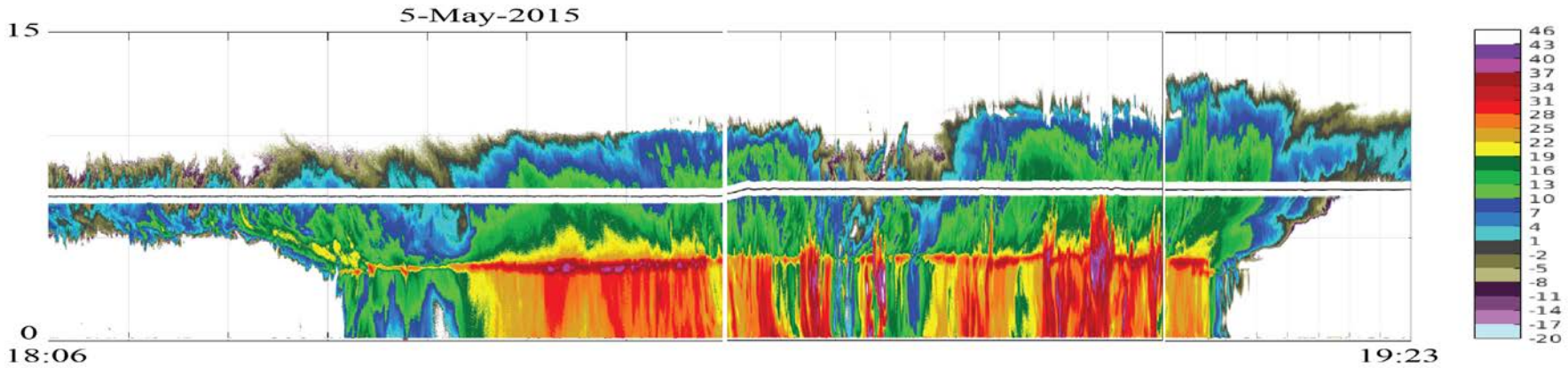




NAWX	W-band	X-band
Transmitted Frequency (GHz)	94.05	9.41
Peak Tx Power (KW)	1.7 - typical	25 (split b/n two ports)
Polarization	Co and Cross	Simultaneous H and V
Doppler	Pulse Pair and FFT	Pulse Pair and FFT
Pulse Duration (μs)	0.1 - 10	0.11-1
Max PRF (KHz)	20	5
Ant. 3 dB BW (°)	0.75	3.5
Antenna ports	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													
W													
K_a													
Pilot													

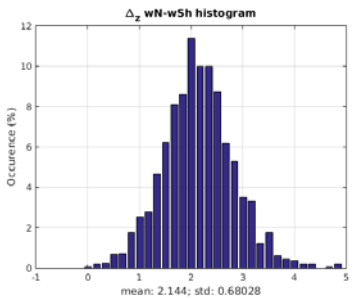


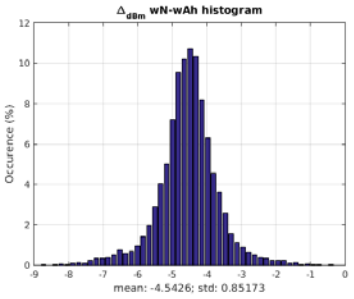
X – Very good; W: Good, but data gap; Ka – Marginal – only nadir data; Pilot X - Good

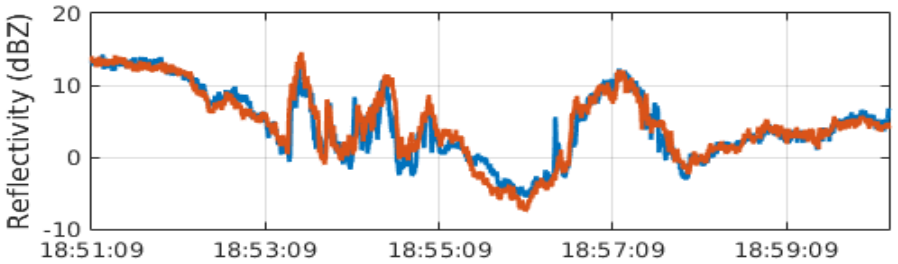
NAWX calibration using corner reflector

- Drizzle / small ice crystal Z from W is used for determination of calibration constant for X-band

- NAW power measurements



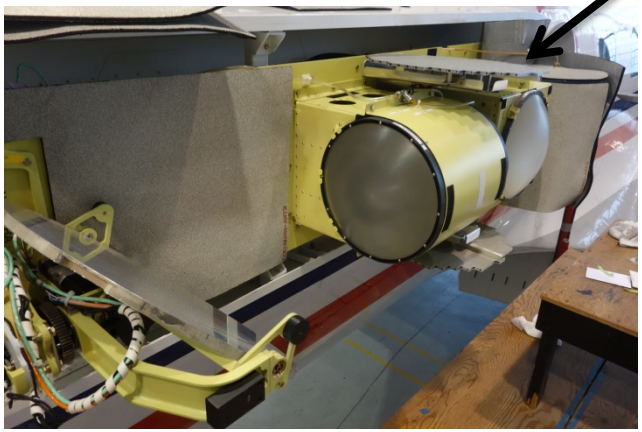


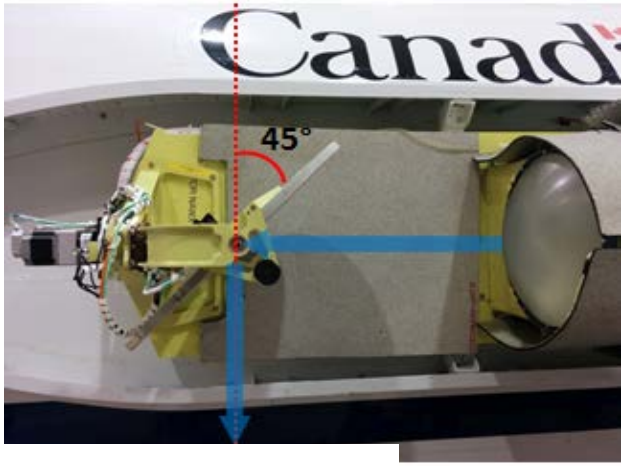


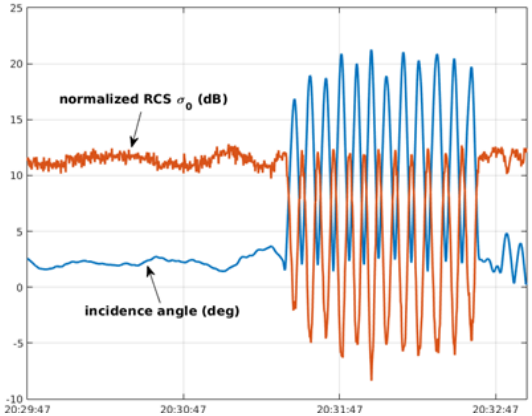
Environment Canada Environnement Canada

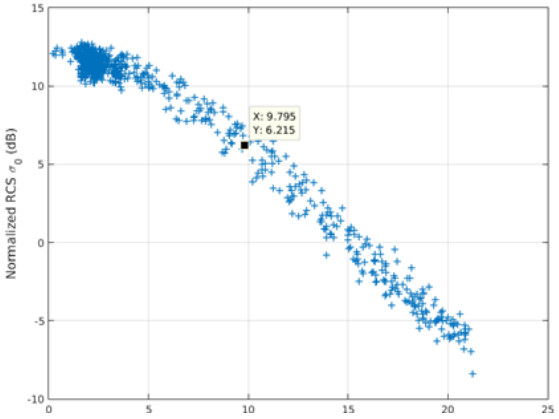
NRC·CNRC

NRC W-band Radar (NAW)





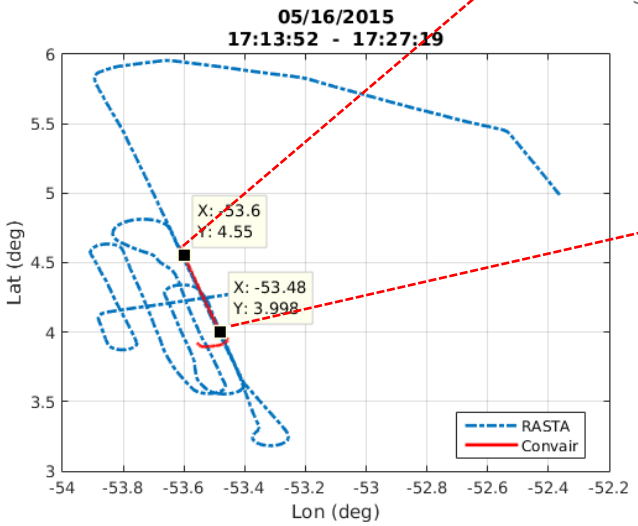


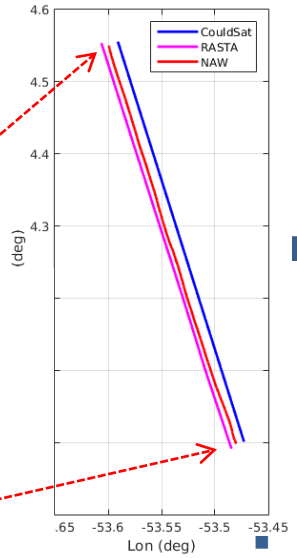


Analyzed limited ocean surface calibration data

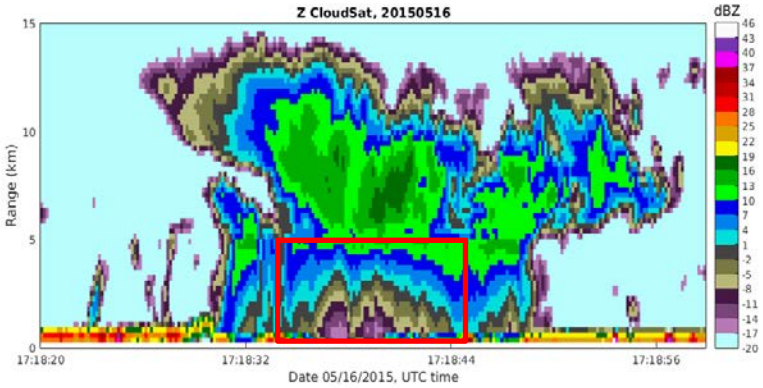
Reflectivity calibration: NAW-RASTA-CloudSat

Convair and RASTA track





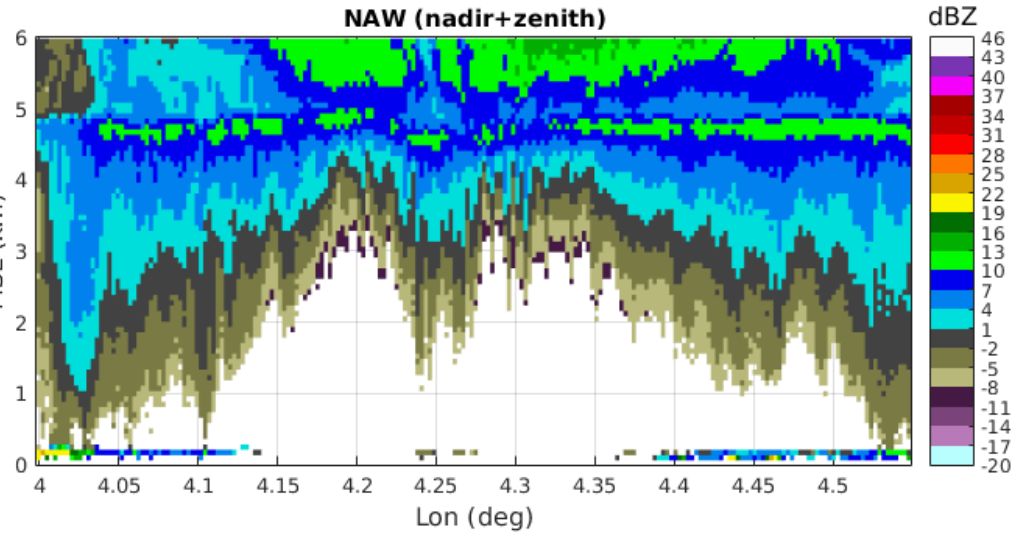
CloudSat overpass

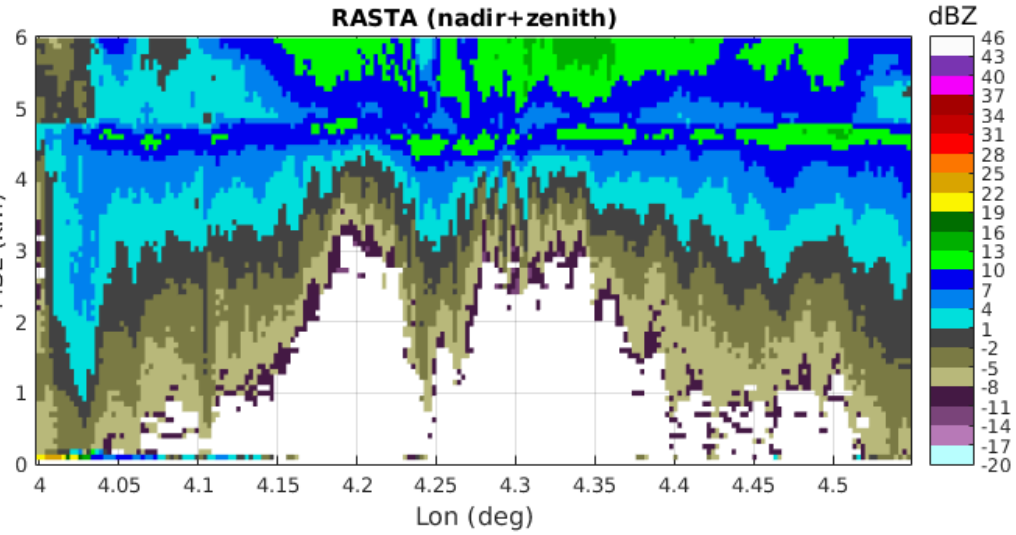


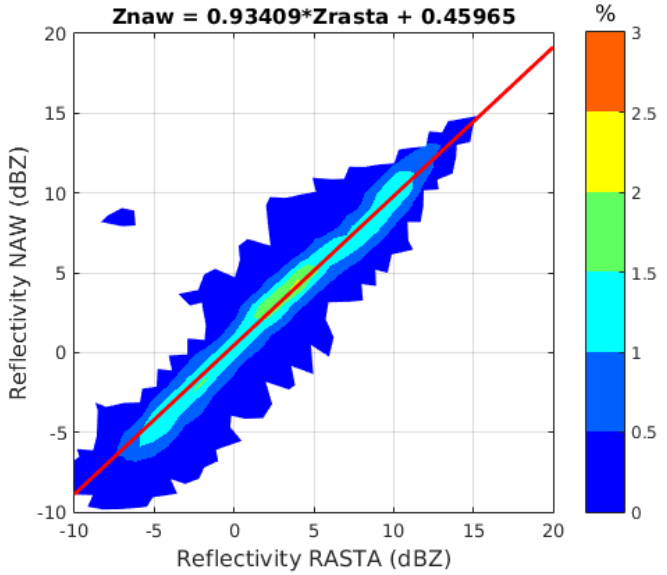
- Select an overlap segment of the flight track when the temporal and spatial differences between the three platforms are minimum
- NAW has a higher resolution than CloudSat and RASTA data used in the comparison
- Comparison are done with NAW data was “downsampled” and re-gridded to match with RASTA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

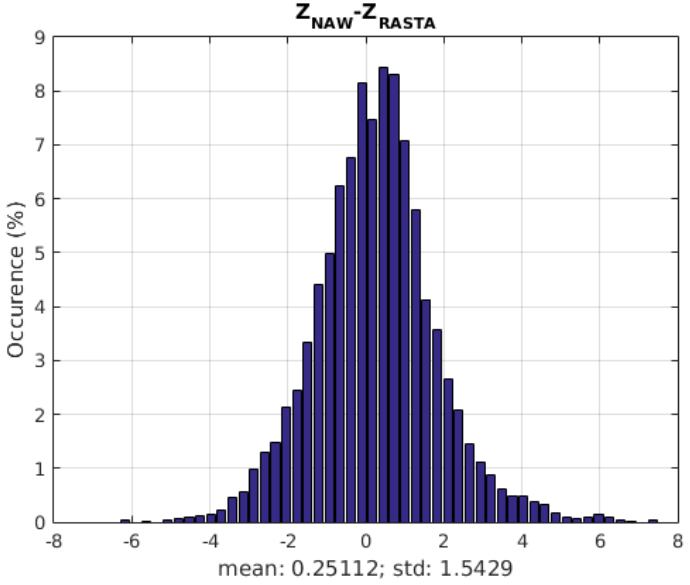
Minor offset in Convair, F20 and CloudSat tracks

NAW-RASTA





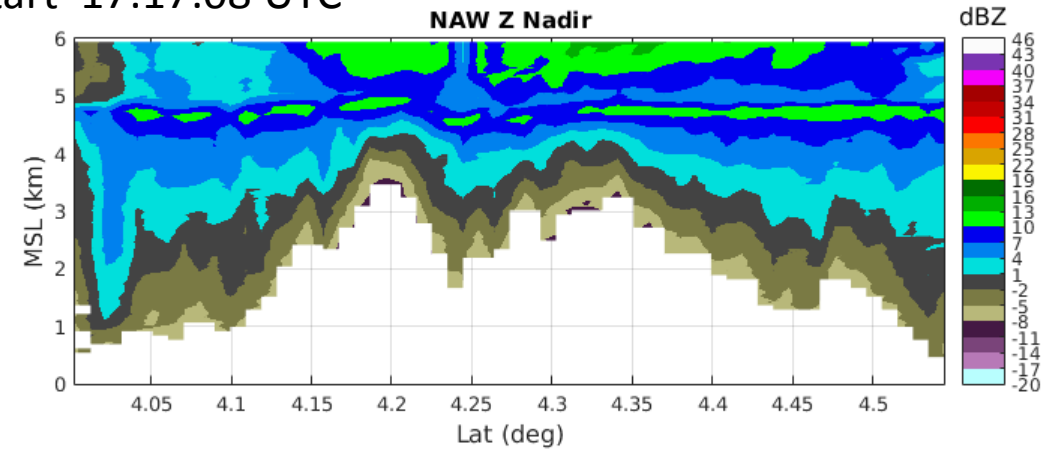




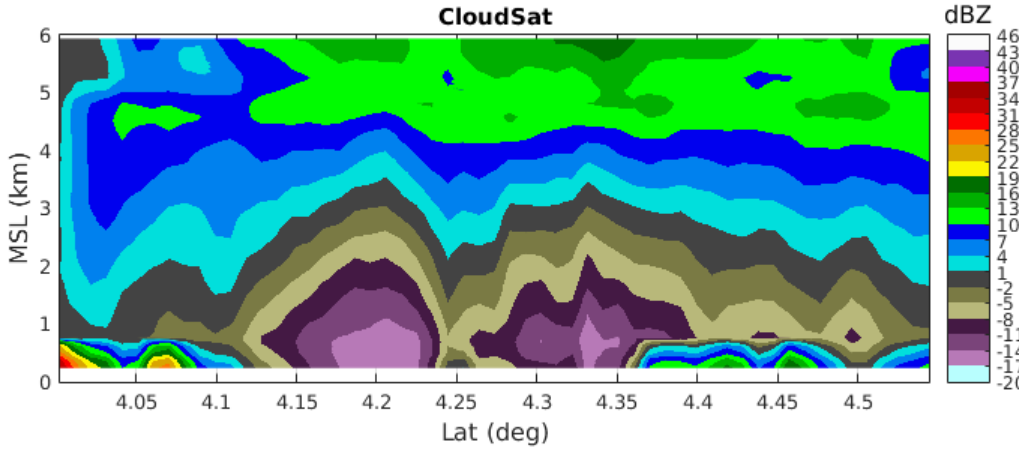
Excellent agreement b/n RASTA and NAW

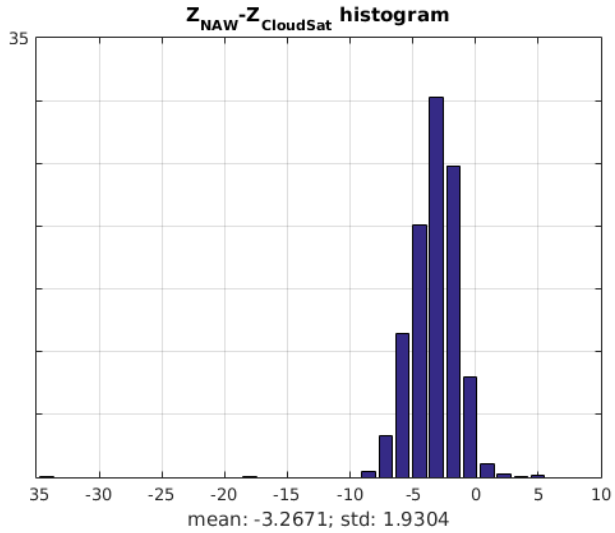
NAW-CloudSat

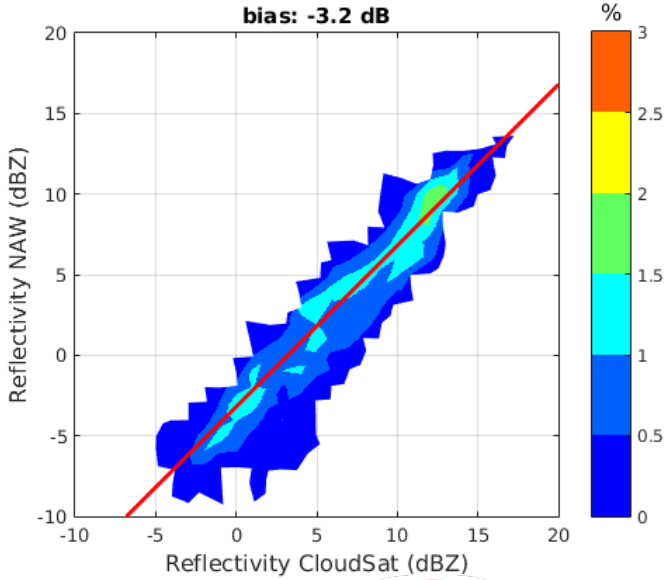
Start 17:17:08 UTC



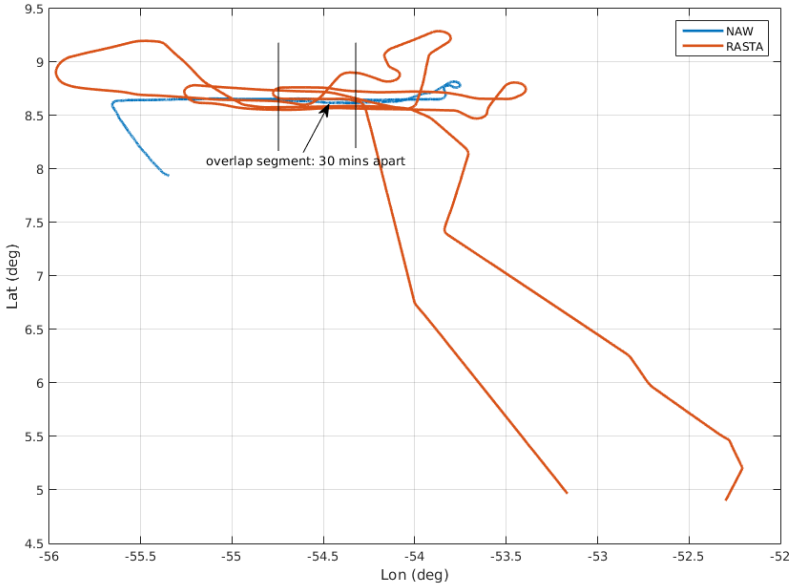
Start 17:18:34 UTC

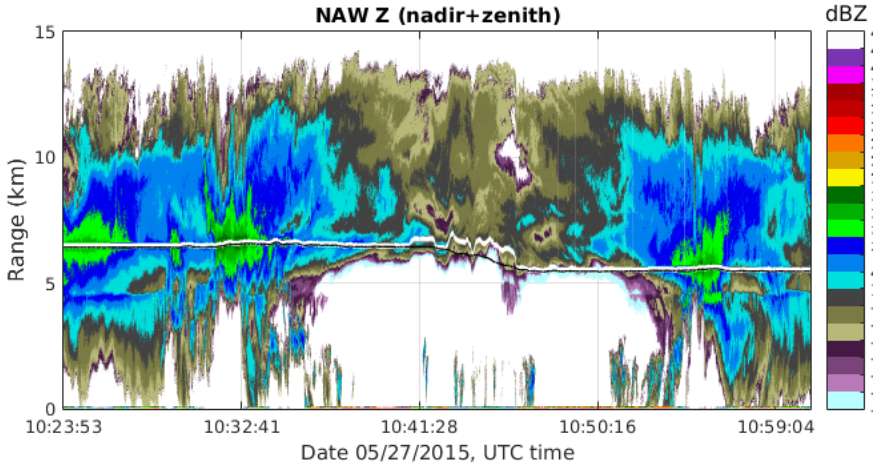


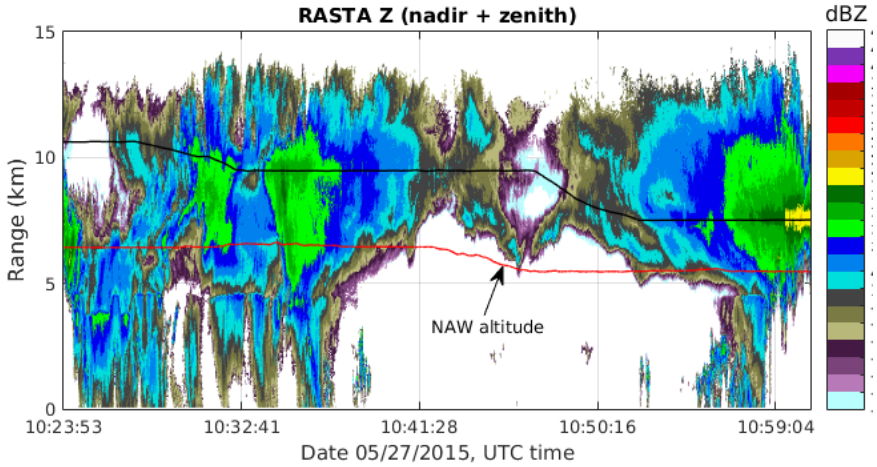




NAW/RASTA Z 3.2 dB lower than CloudSat



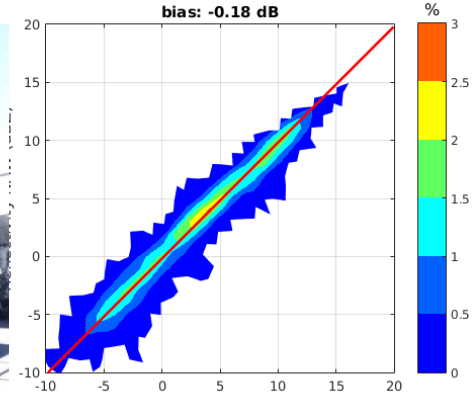


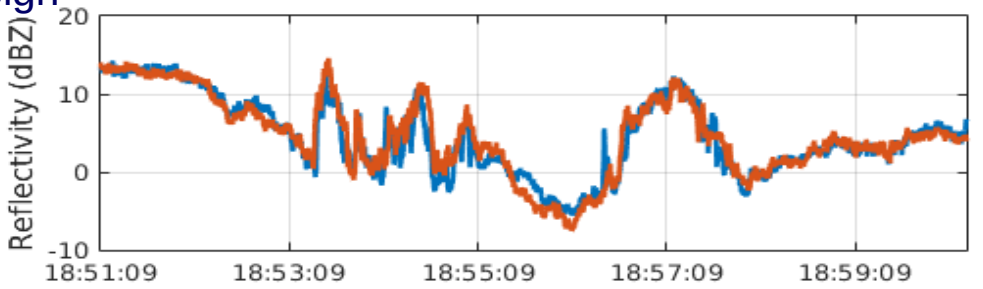


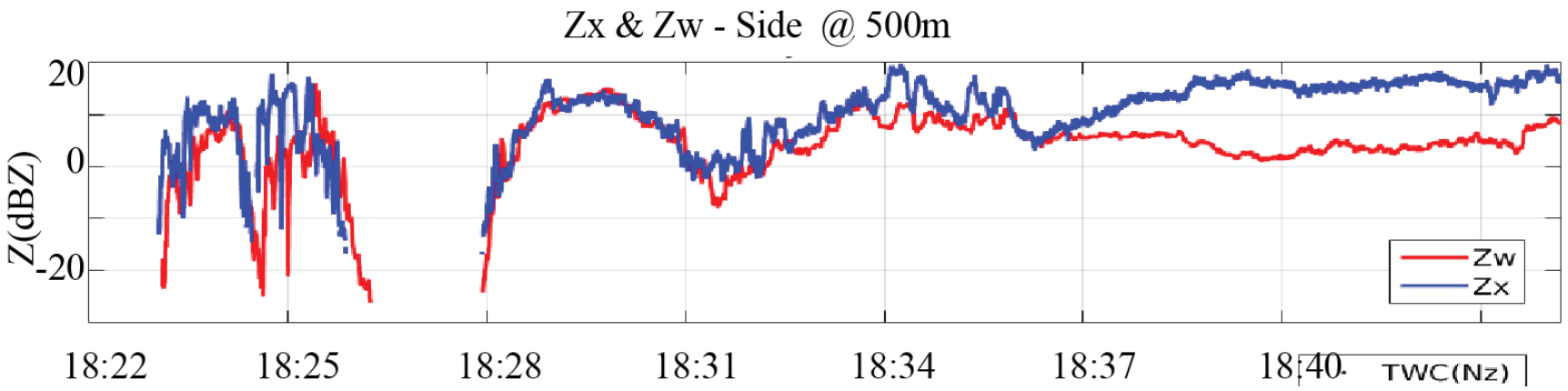
27-May AM Flight – NAW-RASTA

Calibration & consistency of W and X-bands data

- Calibration
  - Corner reflector
  - Relative calibration - consistency
    - First few usable range gates
    - Drizzle – small ice crystals – Rayleigh
    - Cloudsat
    - RASTA
    - Water surface







Consistent dataset with of multiple antennae and frequency

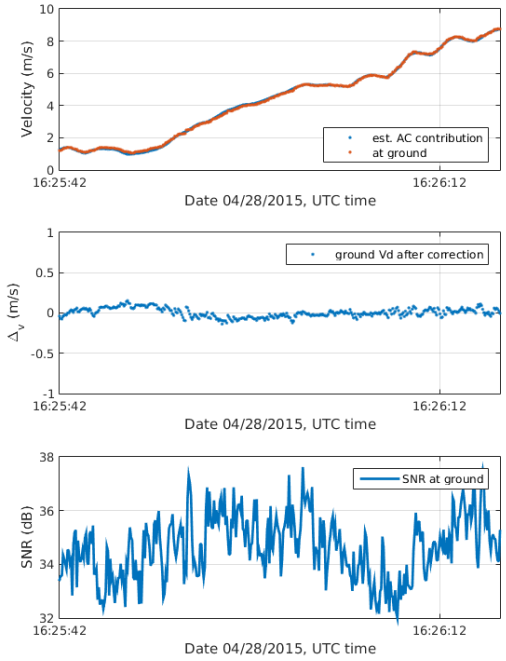
V_d-Processing – Removal of a/c motion

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

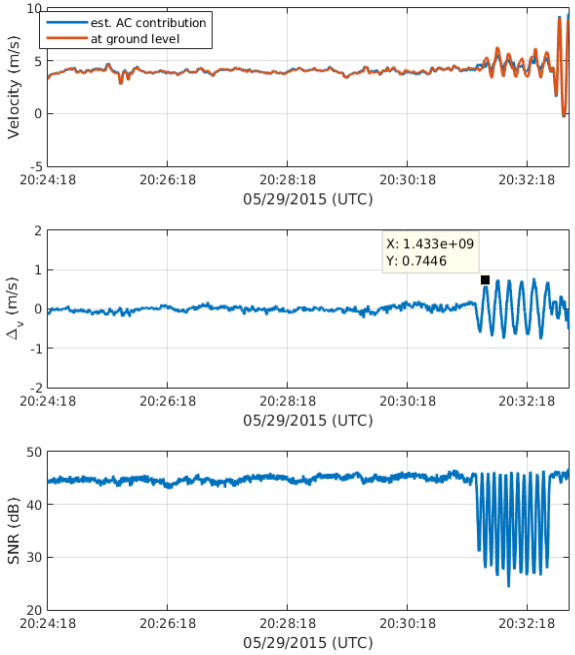
At ground: $v_{obj} = 0$

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

Example 1: Convair over land with increasing roll angle



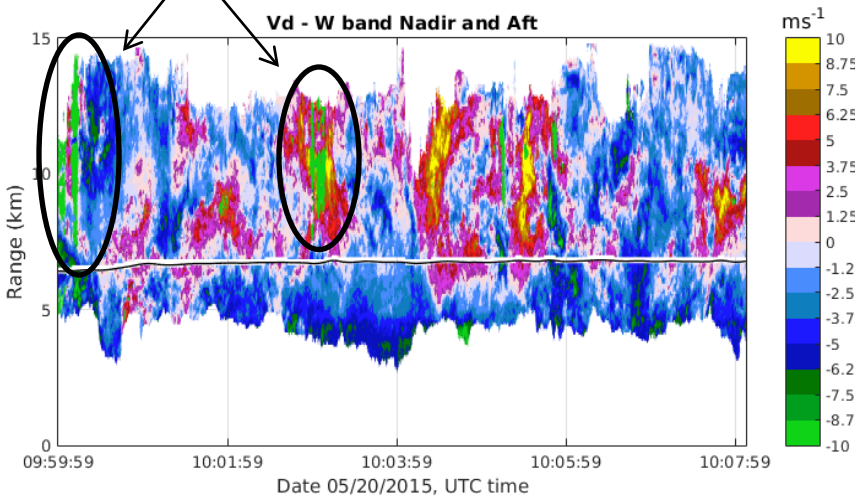
Example 2: Convair over ocean with periodic roll angle



Aircraft motion removal – V_d accuracy < 0.1 m/s

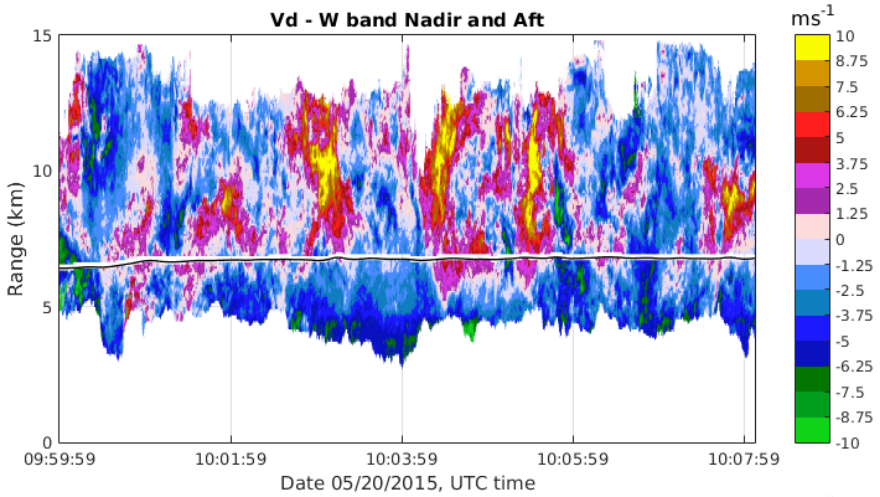
NAW Doppler un-folding using staggered PRT

Velocity folding at W-band

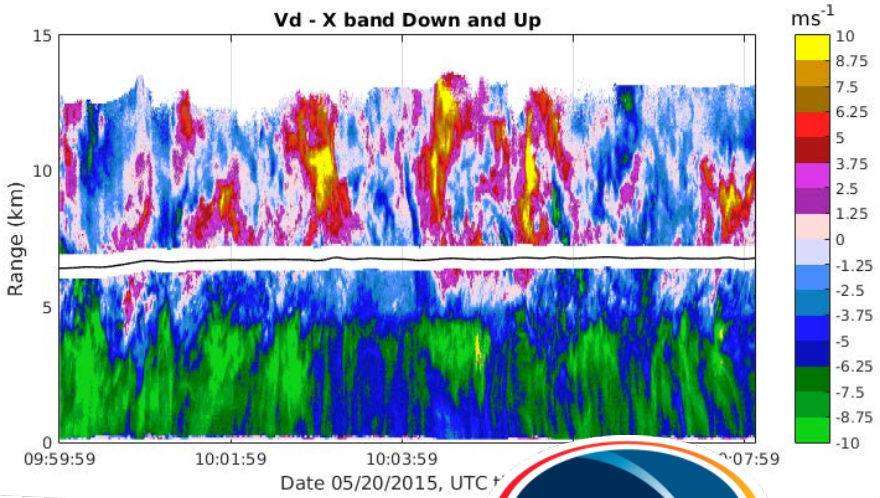


V_d at Aft H, v_a = 13.29 m/s

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



V_d at X-band, v_a = 20 m/s

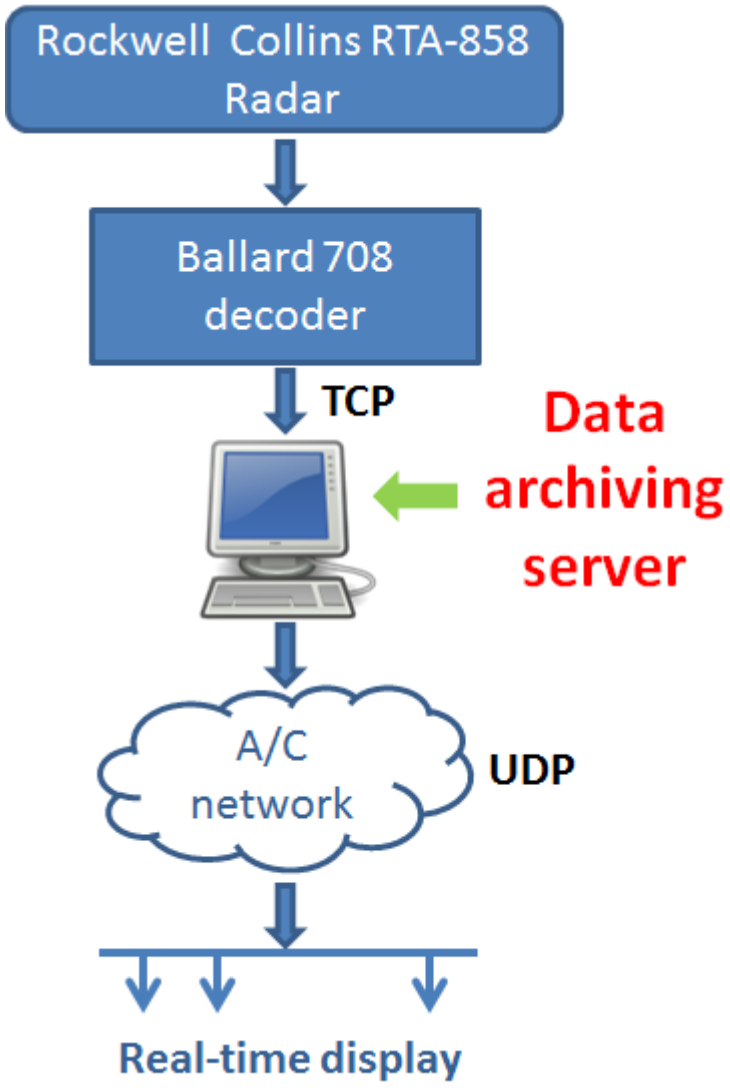


Aircraft motion removal and un-folding - completed

NRC CV580 – Pilot`s radar

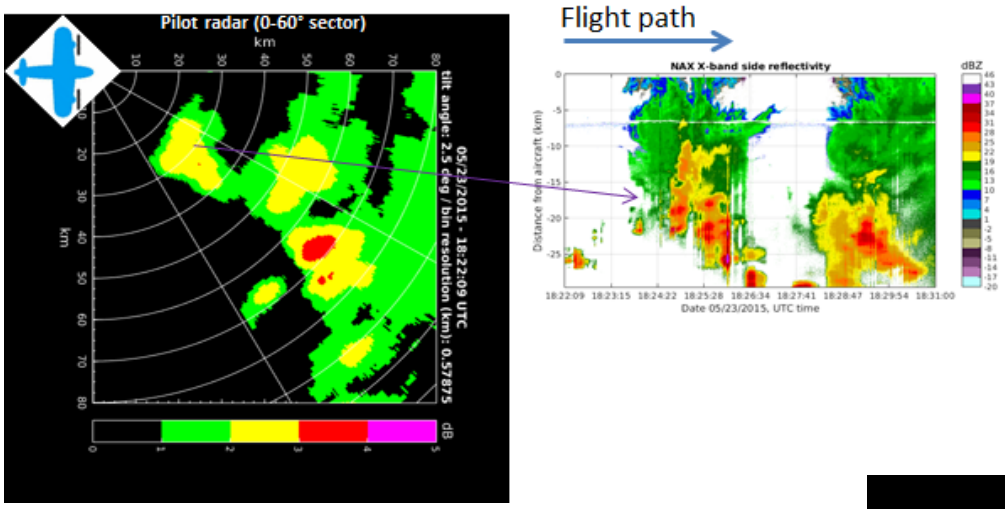
Convair Pilot Radar and Data Archiving System

- Rockwell Collins WX RTA - 858 Receiver 622-8441-004
- Data (binary format) is captured using Ballard Technology OmniBusBox
- Needs an operator to record the data
- Recorded for most of the flight segments when the aircraft was in cloud
- 64-bit floating double precision time stamps were added for later analysis

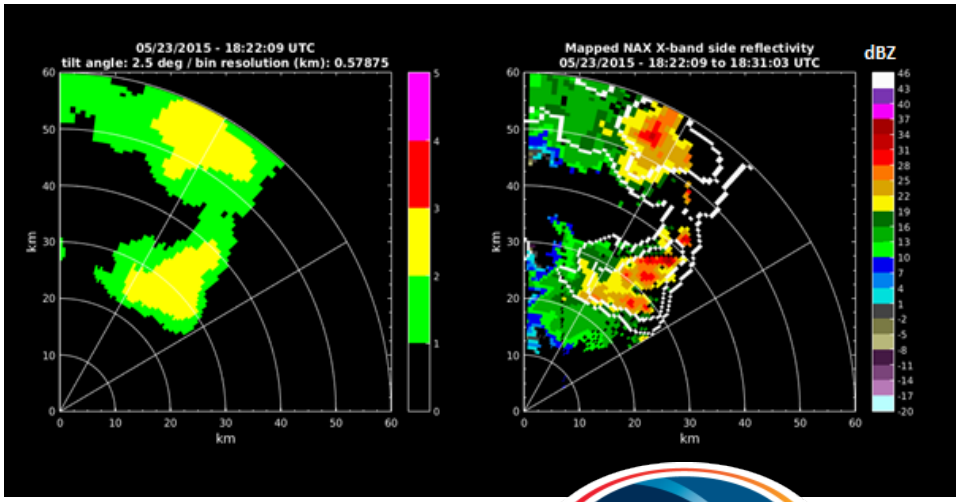


Mapping PWR data to NAX data

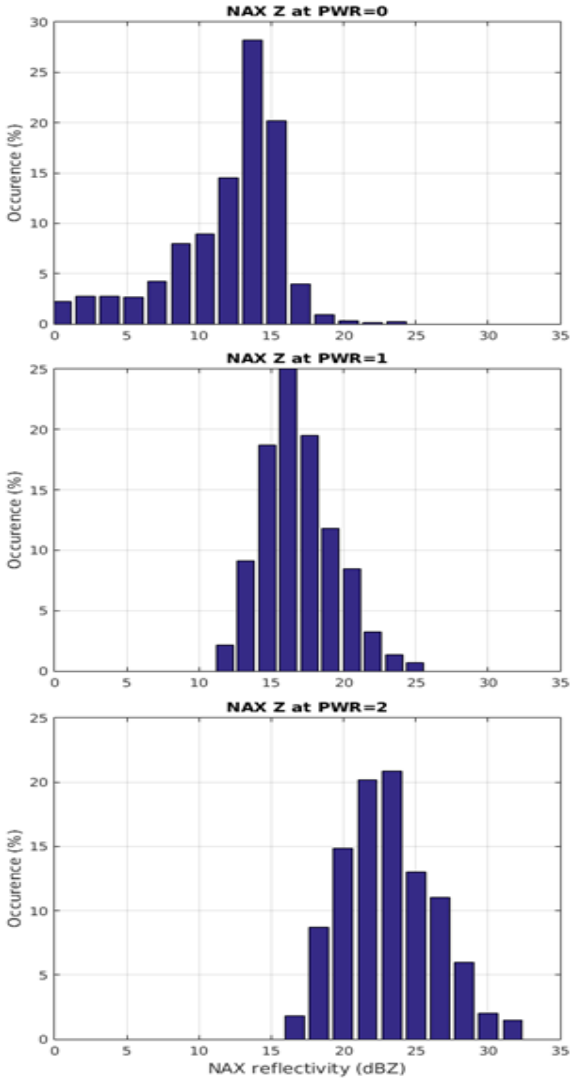
The spatial and temporal distributions of measurements by the two radars:
Pilot weather radar display for a sector of 0°-60° (left) and NAX side-looking reflectivity (right)



Pilot radar observation at 18:22:09 UTC (left) and the corresponding reflectivity field obtained from NAX measurements between 18:22:09 and 18:31:03 UTC



Characterization the Convair PWR sensitivity



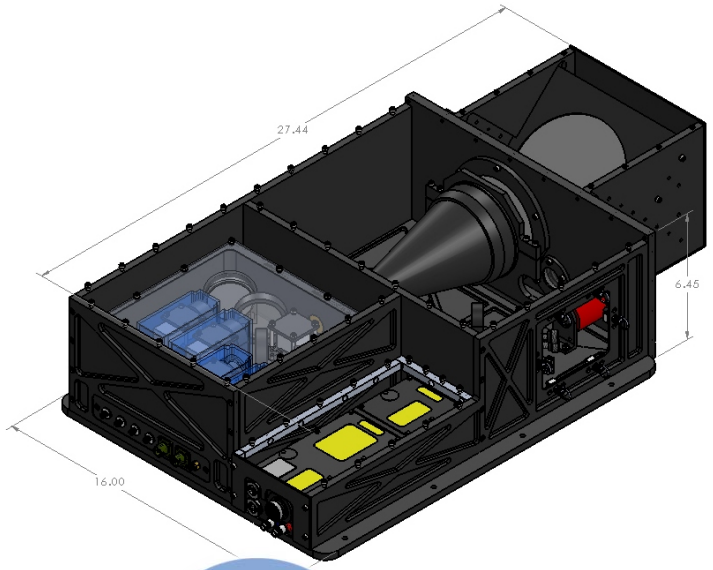
Pixel value (3 bits)	Weather Condition	Corresponding NAX reflectivity (dBZ), mean/std
0	no precipitation	11.96/3.96
1	light precipitation	16.92/2.53
2	moderate precipitation	23.08/3.21

- NAWX:
  - Z and Vd processing completed
  - Processed data in netcdf format

- Pilot`s Radar
  - Developed methodology for mapping of NAX into Pilot`s radar display
  - Relative calibration of pilot`s radar scales to Z

- Ka-band – limited data and not analyzed

Convair Lidars



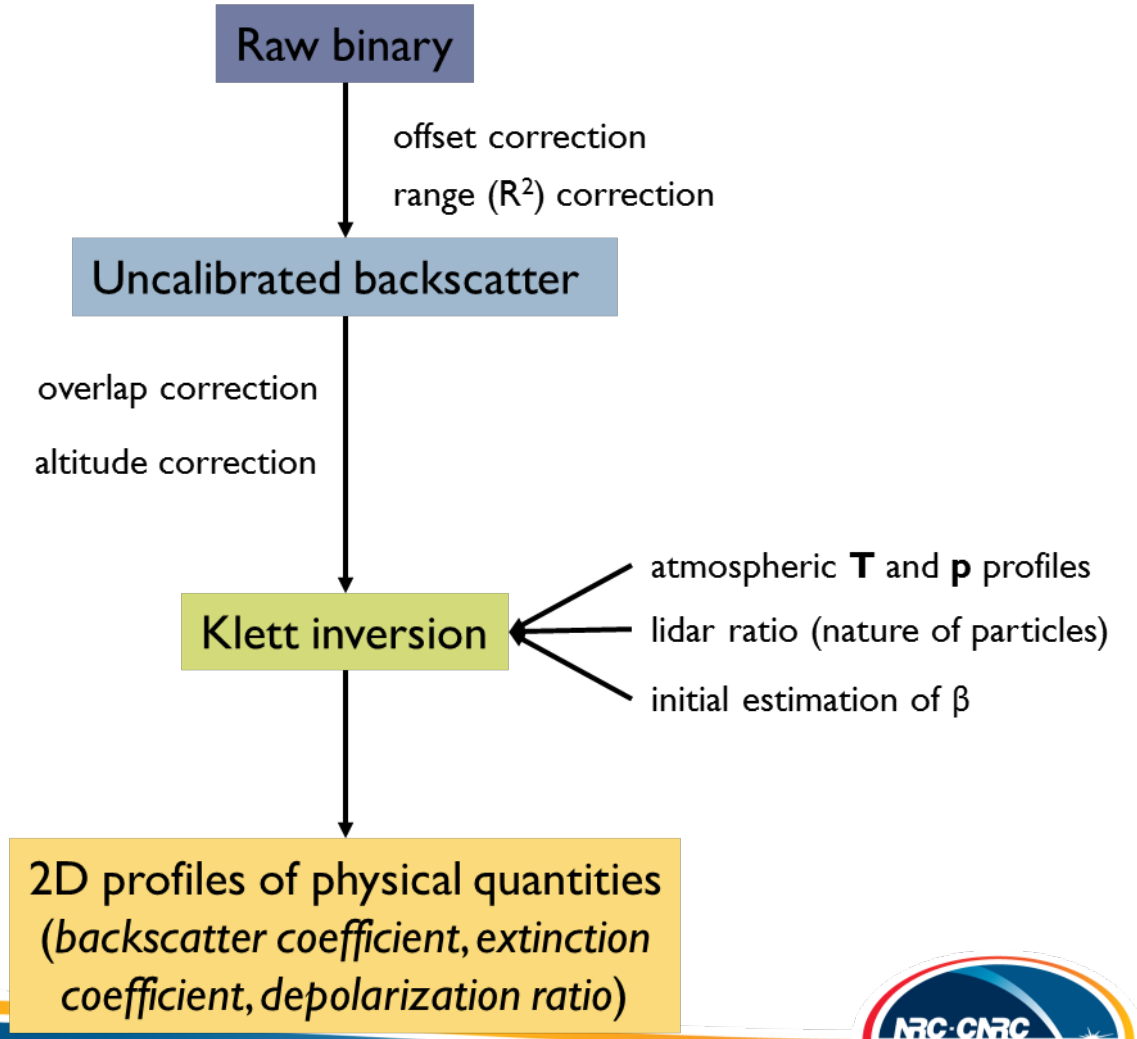
ALPENGLOW INSTRUMENTS

- Wavelength: 355 nm, for eye safe operation.
- Horizontal resolution: 20 profile per second.
- Vertical resolution: up to 0.75 m (200MHz sampling rate).
- Depolarization measurements: supercooled water and ice separation.
- High and low gain channels to avoid in cloud signal saturation.
- Measurements extend close to aircraft.

- Zenith and Nadir-looking
- Two independent systems

Zenith orientation

Lidar data processing

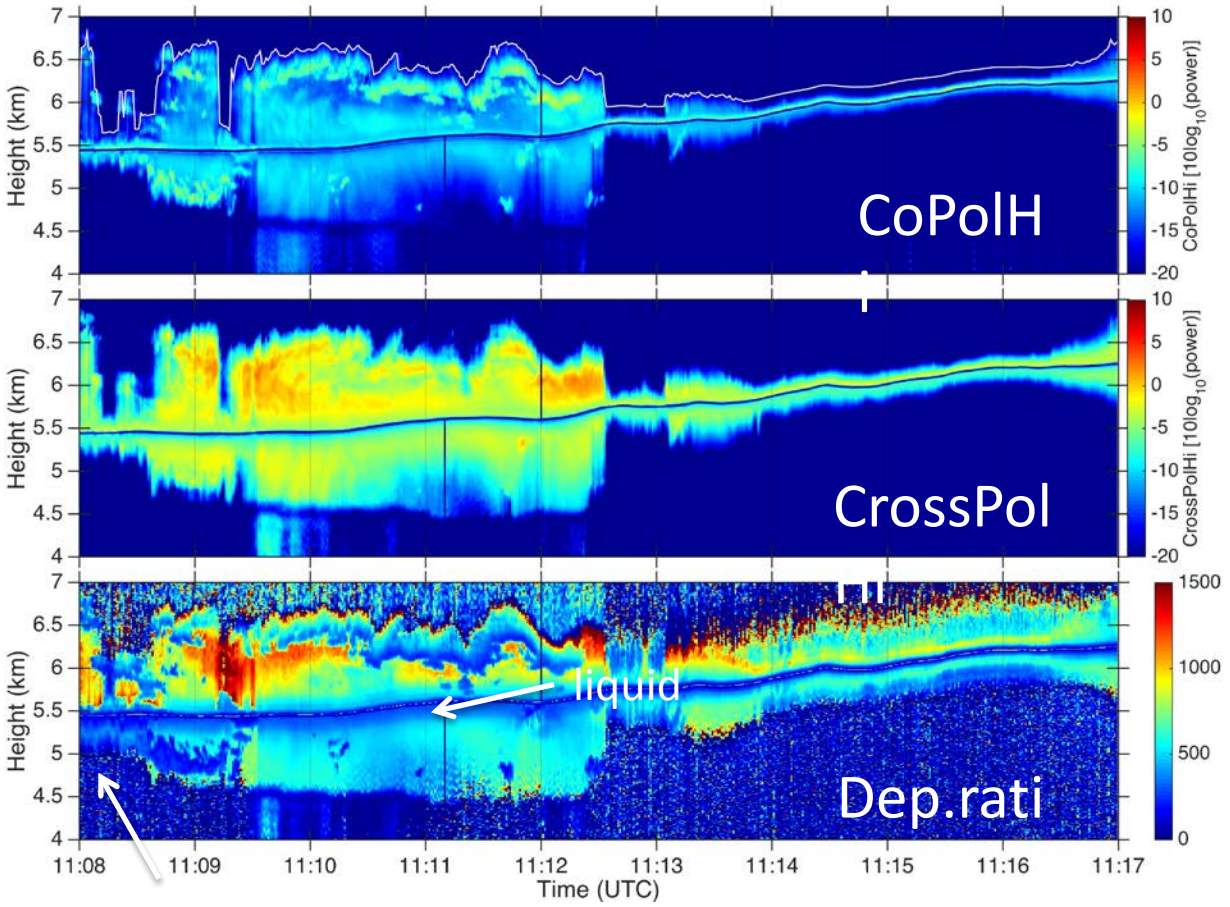


Cayenne lidar data availability

AM flight	PM flight

Flight	Date	From	To	Hours
1	10-May-16	16:04	17:42	1.63
2	12-May-16	19:23	21:19	1.93
3	14-May-16	13:33	16:52	3.32
4	15-May-16	8:59	12:50	3.85
5	16-May-15	8:33	12:11	3.63
6		16:21	18:07	1.77
7	20-May-15	9:07	12:12	3.08
8	23-May-15	9:04	12:32	3.47
9		16:03	19:19	3.27
10	25-May-15	18:40	22:06	3.43
11	26-May-15	9:38	12:18	2.67
12		14:14	16:54	2.67
13	27-May-15	8:51	12:18	3.45
14		14:51	15:35	0.73
			Total hours:	38.90

Co- and cross-polarization channels



Lidar progress (Dec, 2016)

Overlap correction

Klett inversions in the zenith direction

Test case analysis

High Ice Water Content (HIWC) Program