HCR and HSRL data quality and retrieved microphysical scientific products from remote measurements

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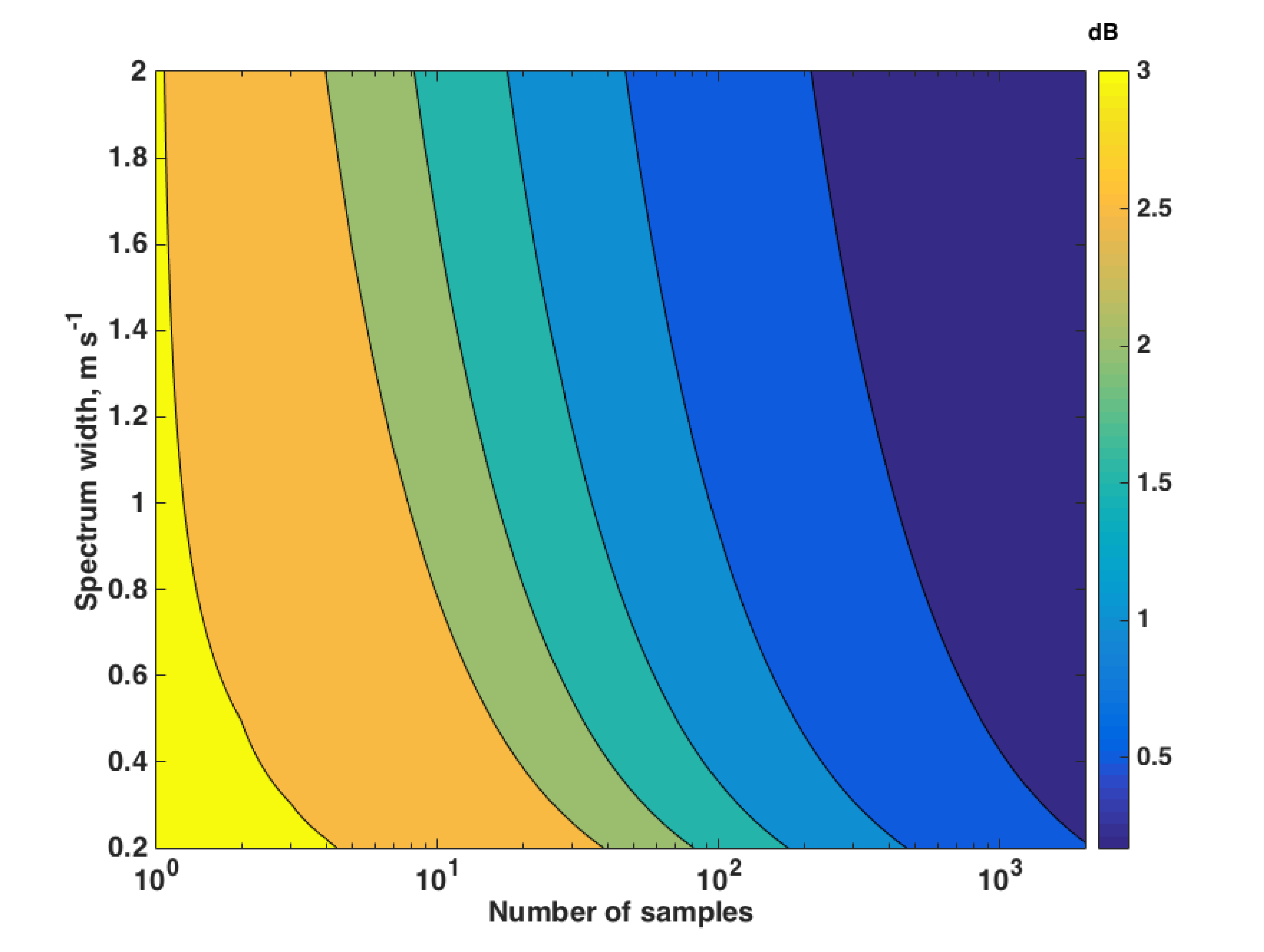
Instrumentation parameters for estimating standard errors in HCR and HSRL measurements

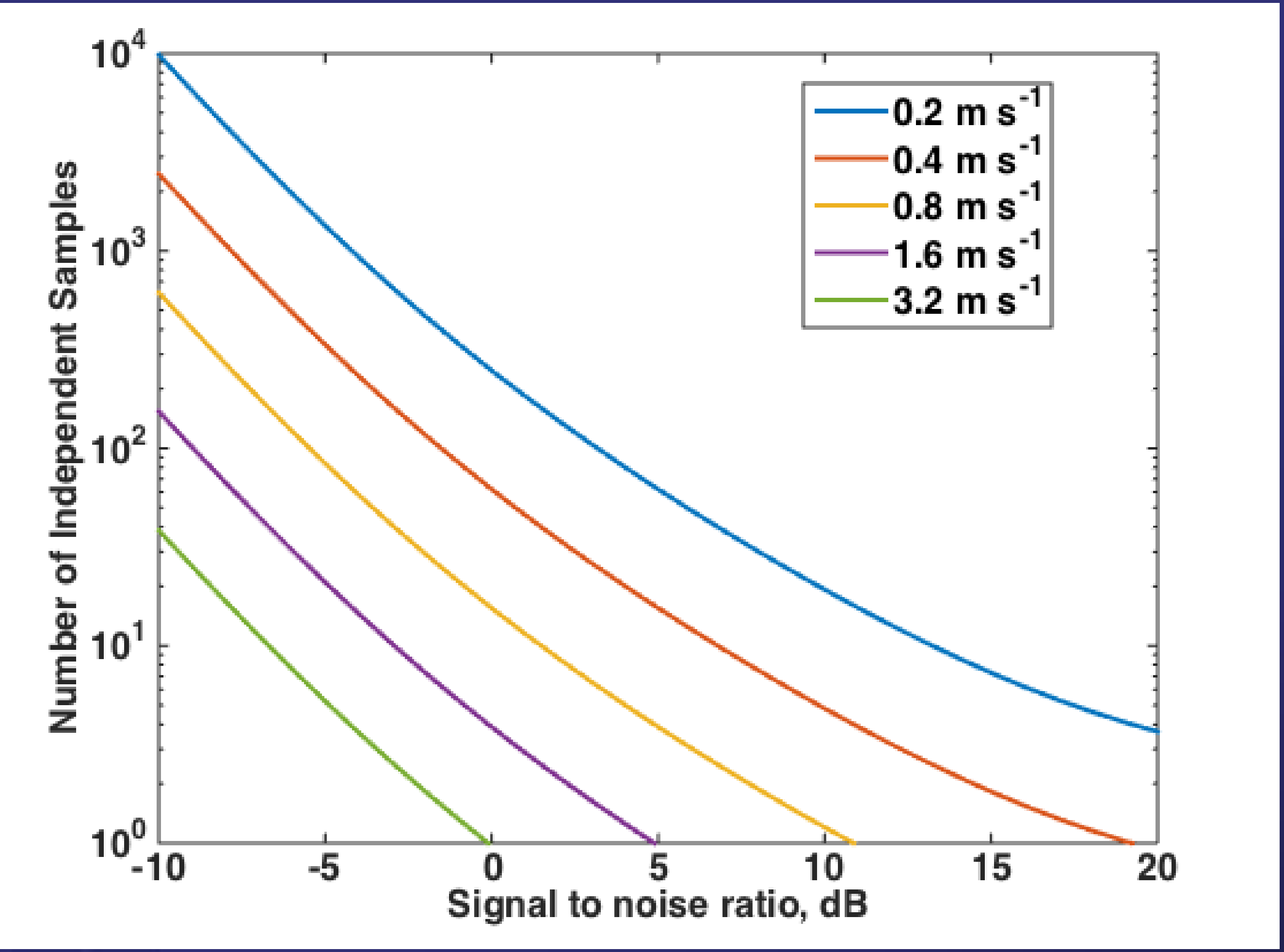
- Dwell time for HCR 0.1 sec i.e. 1000 samples are used estimating reflectivity and Doppler measurements; Time to independence 0.7 m sec; 140 independent samples
- HCR pulse width 0.25 micro second i.e. 37.5 m (0.5 dB, 0.2 m/s)
- Dwell time for HSRL 0.5 sec i.e. 3000 samples are used for estimating measurements
- HSRL pulse width 50 nano sec i.e. 7.5 m (0.04 dB)

Vivekanandan et al 2015.:A wing pod-based millimeter wavelength airborne cloud radar. Geosci. Instrum. Method. Data Syst., 4, 161–176.

Standard error in reflectivity measurements



Standard error in radial velocity



GVHSRL in CSET

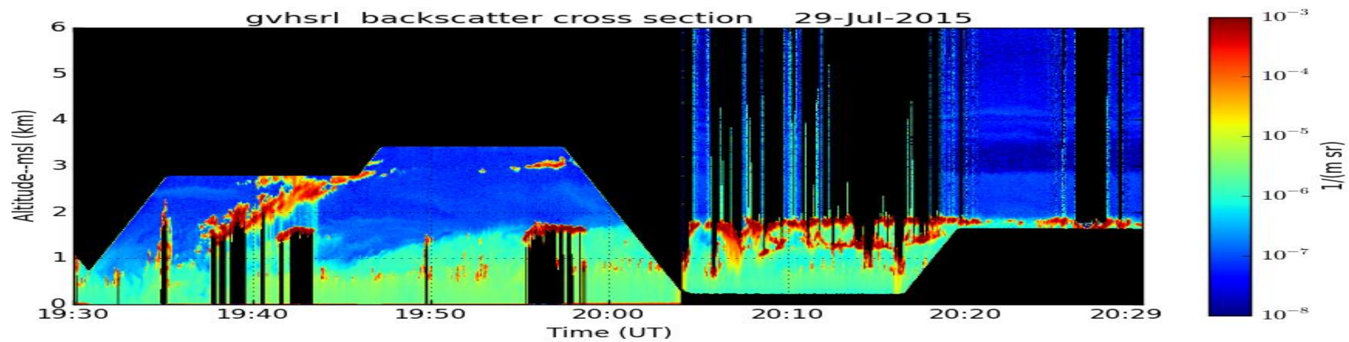
Operational for all 16 Research Flights

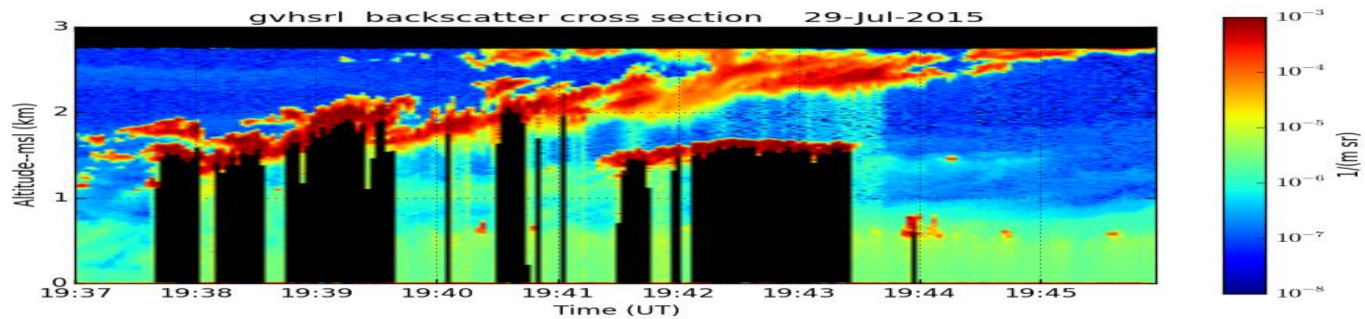
106+ hours of Lidar data collected during CSET flights

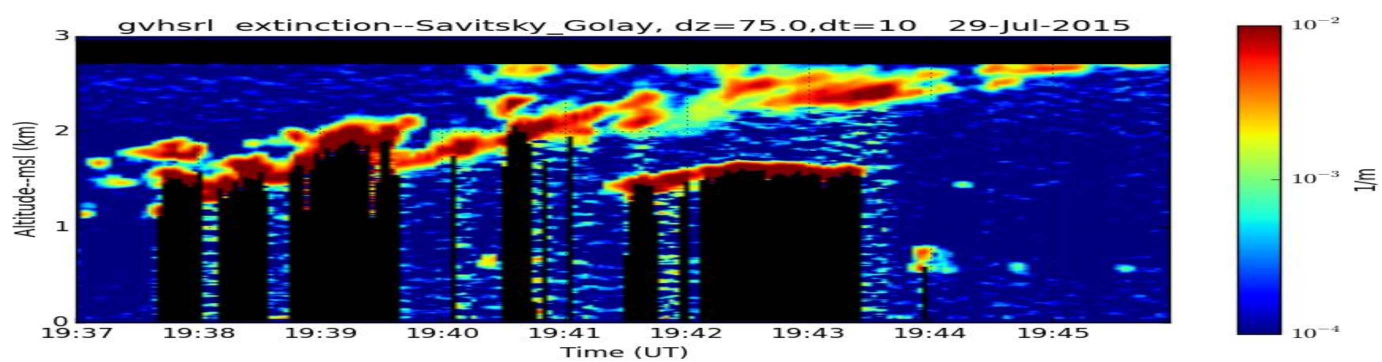
Backscatter and depolarization images from all research flights are available on the CSET Field Catalog
http://catalog.eol.ucar.edu/cset/lidar
Images are available for either 5 minute intervals or 1 hour intervals

All GVHSRL data products are available in netCDF format
http://data.eol.ucar.edu/master_list/?project=CSET

Extinction data is also available







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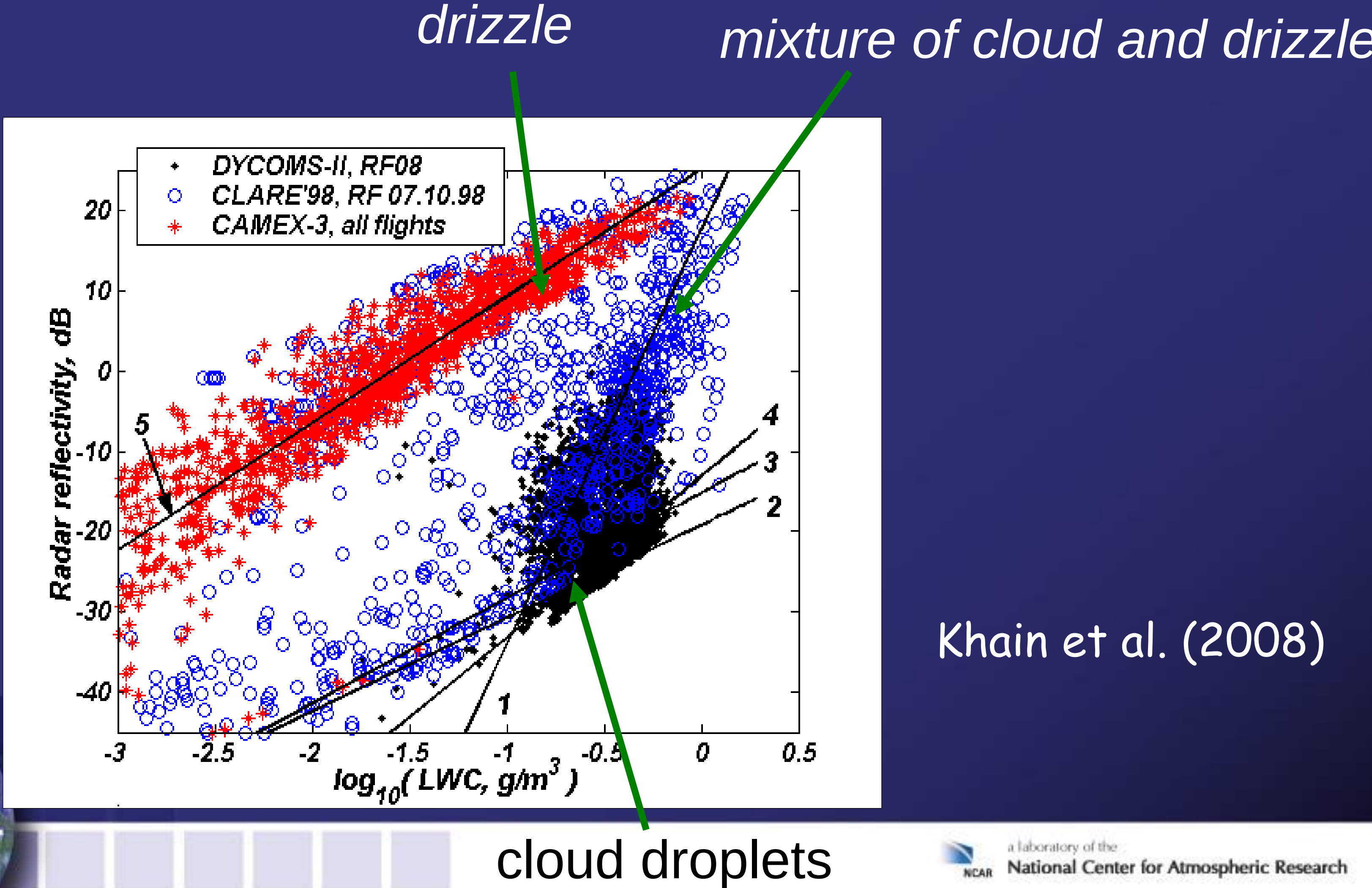
Liquid water content



Khain et al. (2008)

Z-LWC and Z -r_e power-law relations

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TABLE 1. Some fittings of parameters of the Z–LWC relationship $Z = a\mathrm{LWC}^b$ using in situ measured data.

Statistical fitting of in situ measured data			
Cloud without drizzle	$a = 0.048$	$b = 2$	Atlas (1954); line "A" in Fig. 1
	$a = 0.012$	$b = 1.16$	Fox and Illingworth (1997); line "F" in Fig. 1
	$a = 0.03$	$b = 1.31$	Sauvageot and Omar (1987); line "S" in Fig. 1
Cloud with light drizzle	$a = 57.54$	$b = 5.17$	Baedi et al. (2000); line "B" in Fig. 1
Cloud with heavy drizzle	$a = 323.59$	$b = 1.58$	Krasnov and Russchenberg (2002); line "K" in Fig. 1

Khaine et al 2008, JAM.

$$r_e = 19.5 \exp\left[0.384 \log 10(Z)\right]. \quad (11)$$

Huang et al. 2012, AMT

Background: Retrievals using lidar, radar and radiometer

- Dual-wavelength radar measurements based retrievals are independent of droplet size distribution
  - In the absence of drizzle $Z < -17$ dBZ,
    Drizzle cloud $Z > -17$ dBZ, beta > 5 e-5 sr^{-1} m^{-1} CDR > 0.1
  - Retrieved LWC is immune to drizzle and light rain (droplet size < 0.3 mm)
  - Estimate of microwave attenuation requires beam matched radars

- Radiometer measured liquid water path is distributed along radar beam within the cloud layer where $T > -16^0$ C based on measured reflectivity (Huang e al. 2012).

$$\mathrm{LWC}_i = \mathrm{LWP}\frac{Z_i^{0.5556}}{\sum_{j=1}^{M} Z_j^{0.5556}\Delta z}, \quad (7)$$

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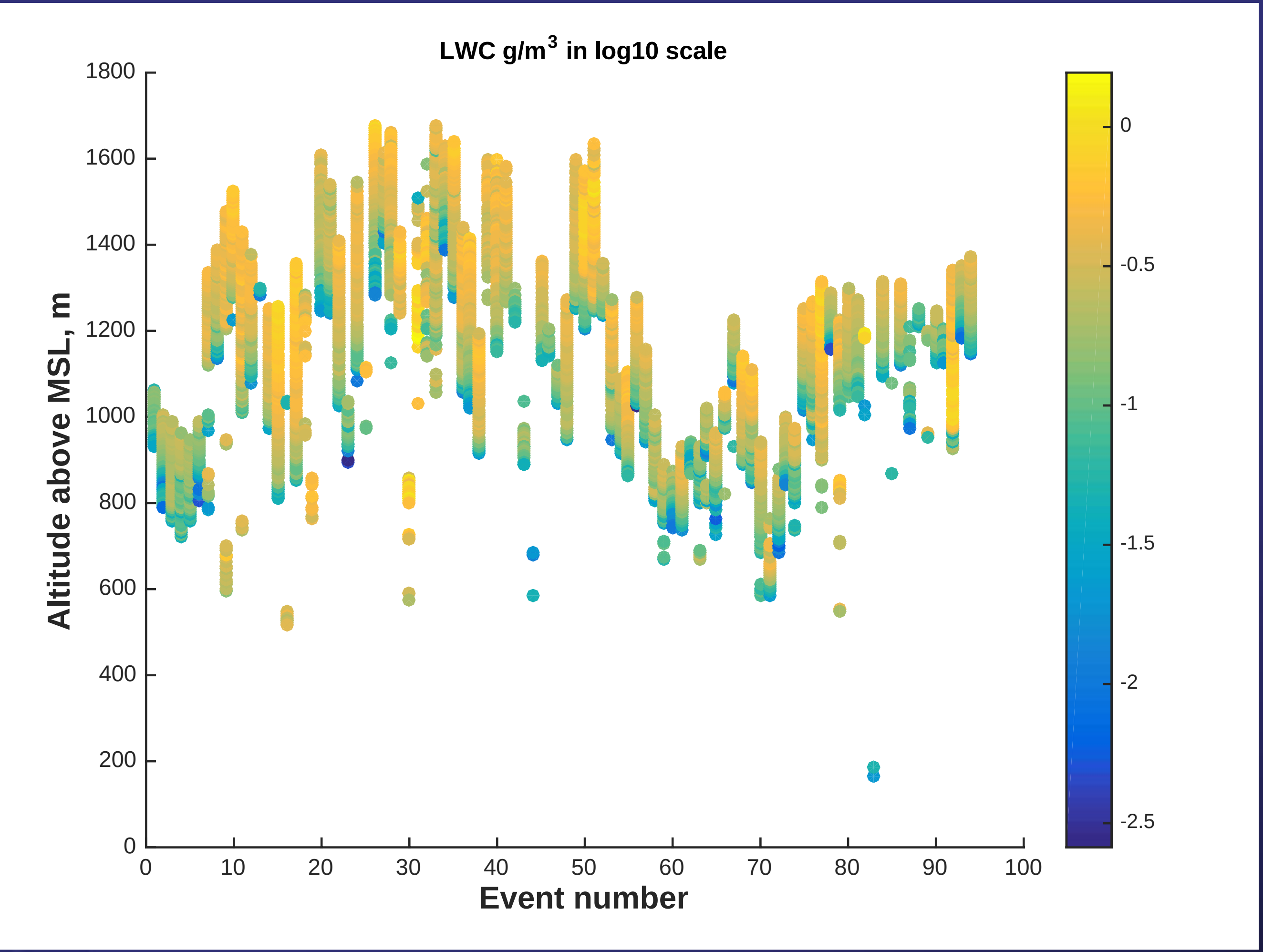
Background: Retrievals using lidar and radar (cont.)

- Reflectivity, velocity, and spectrum width, skewness and Kurtosis of Doppler spectrum were used for retrieving lognormal particle size distribution (number concentration, width and median radius) (Kollias et al. 2011, JGR).

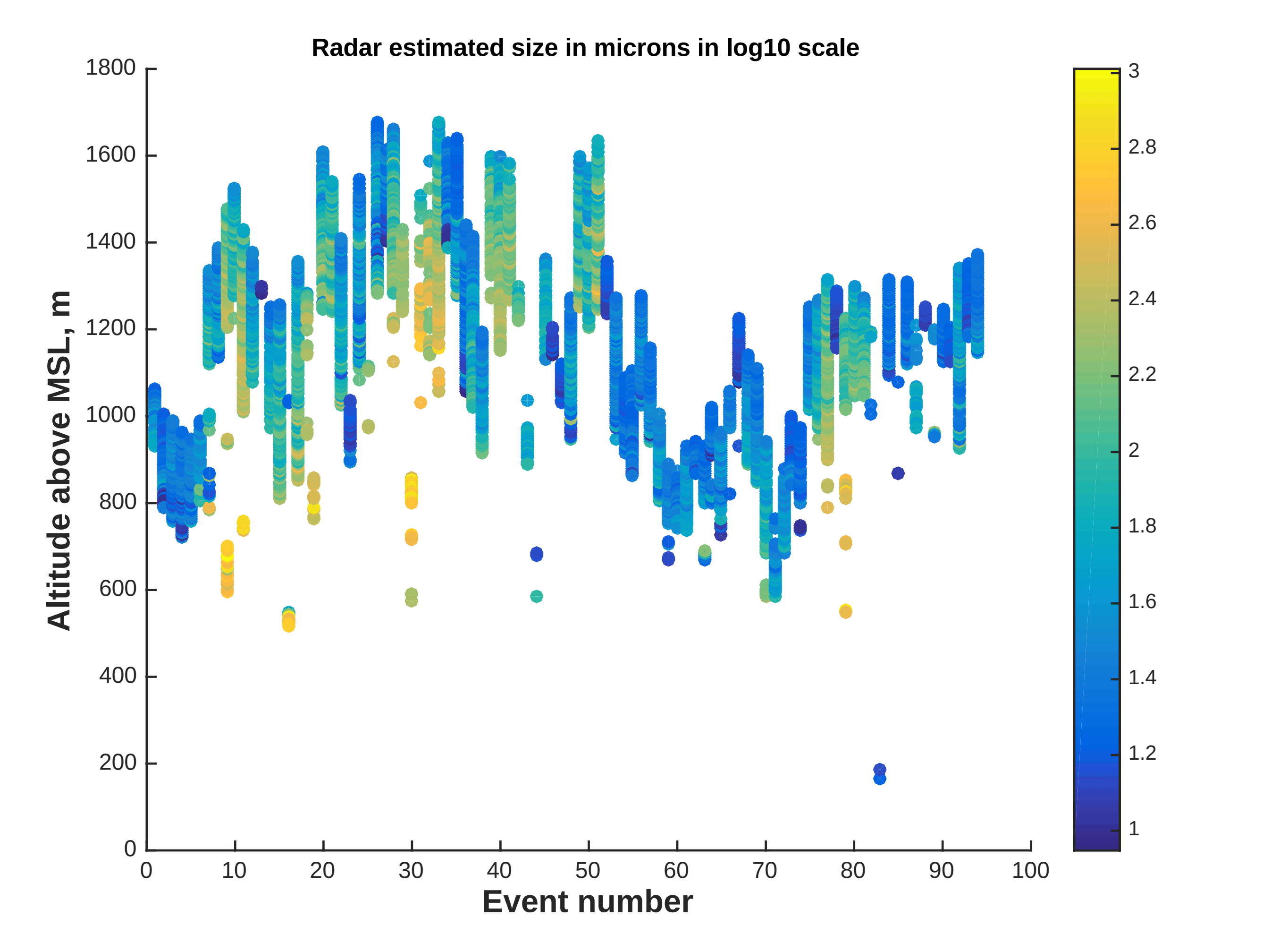
- Radar and lidar backscatter measurements are used for either retrieving PSD or effective diameter (r_e) and LWC.
  - spectrum width, reflectivity, lidar extinction are used for N_0, mu, and D_0 (O'Connor et al. JAM 2005)

  - Calibrated radar and lidar reflectivities are used for LWC and r_e
    - Estimate r_e uses ratio of radar and lidar backscatter
    - Retrieve LWC from radar reflectivity and estimated r_e
    - Simulations based on measured cloud and drizzle spectra are used for developing retrieval method and validation of retrieved parameters.

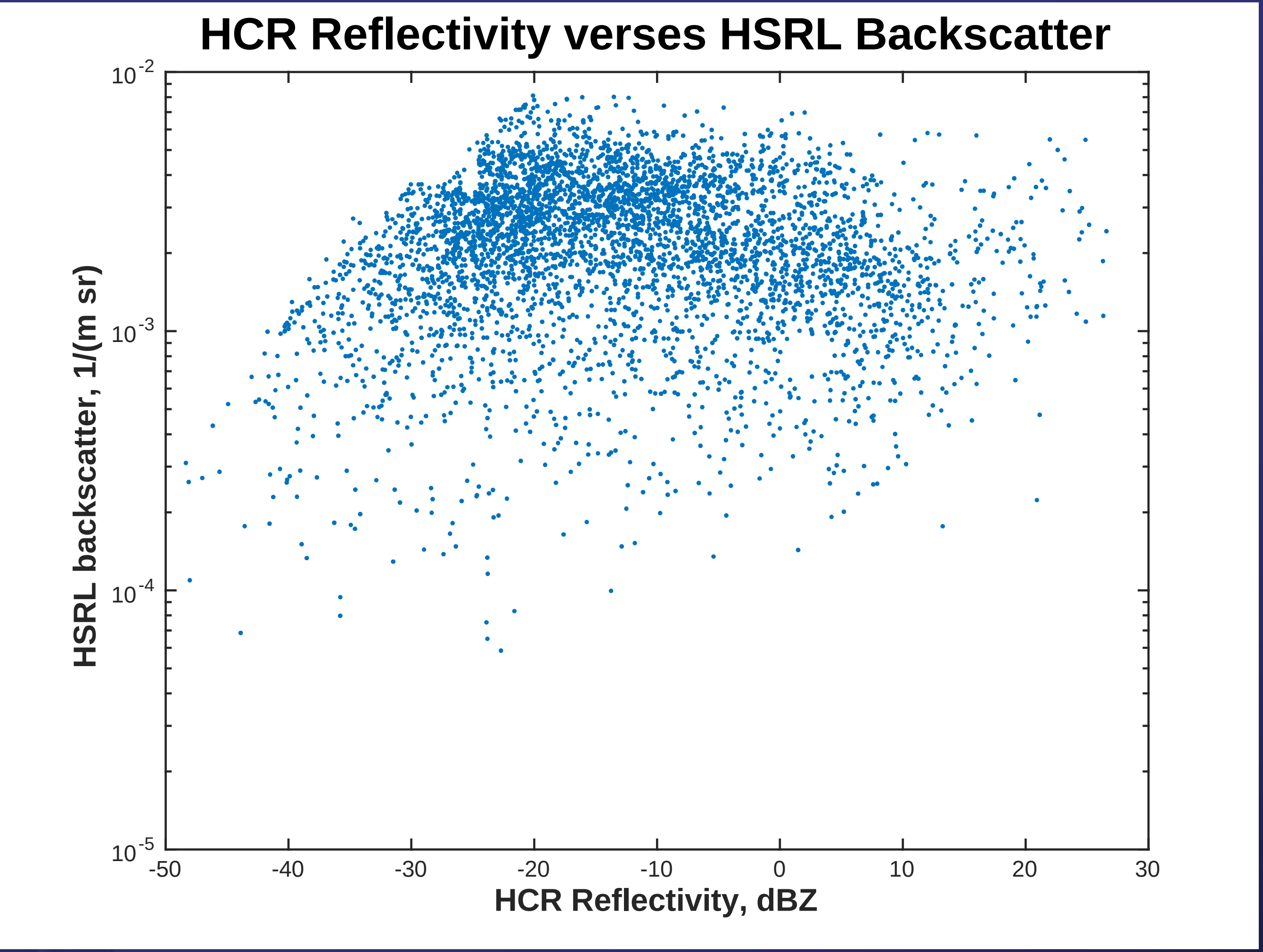
In situ measurements: LWC



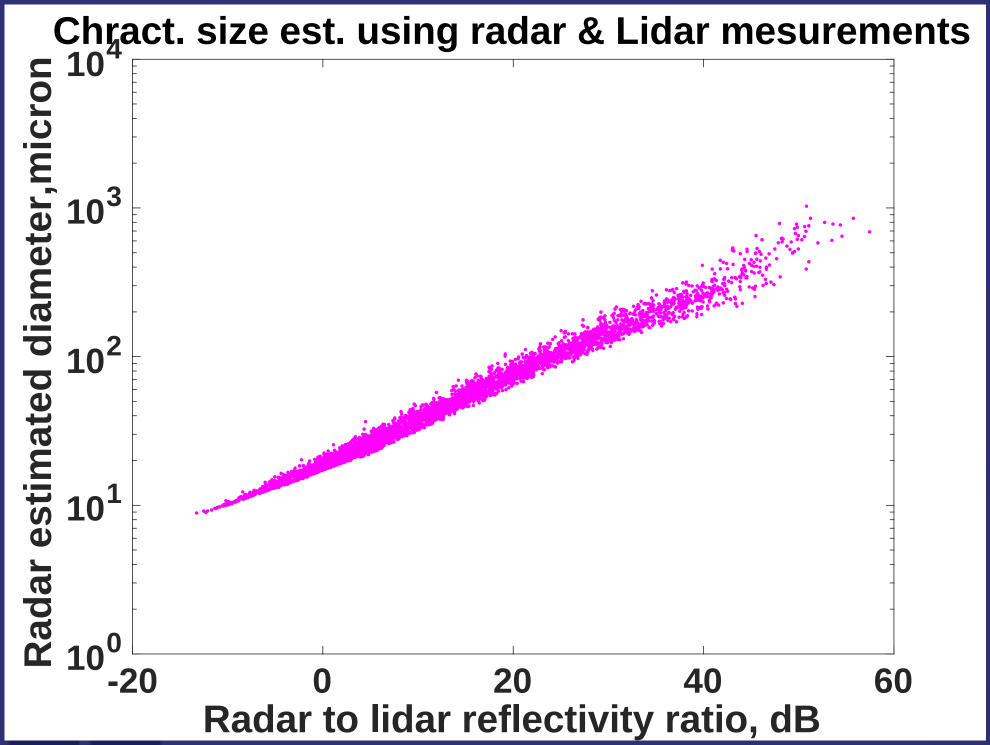
Radar estimated size derived from in situ measurements

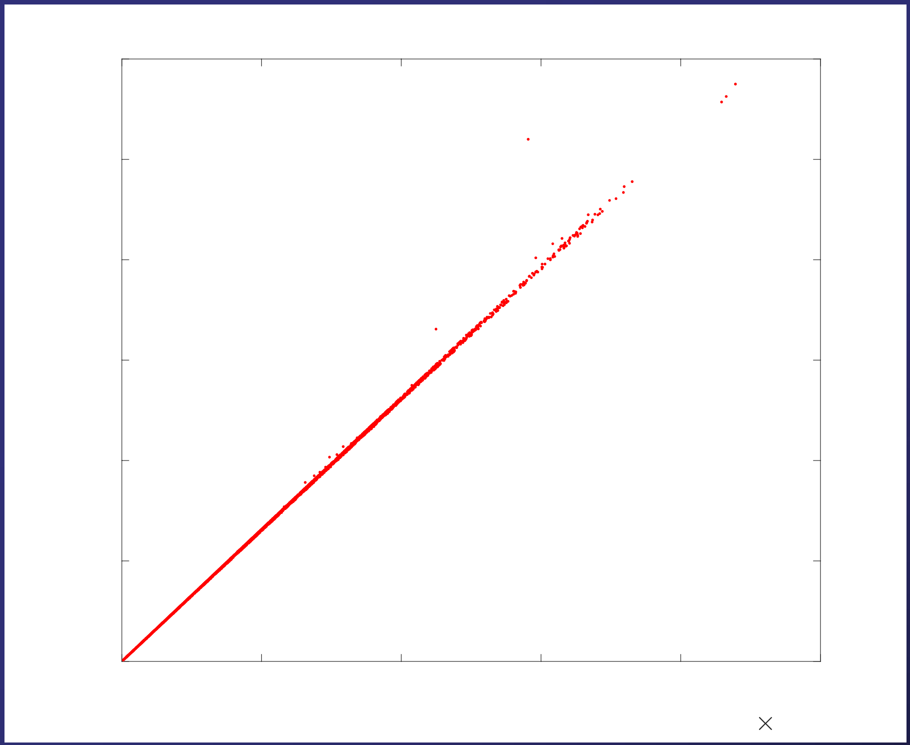


Model computation: Lidar vs radar reflectivities

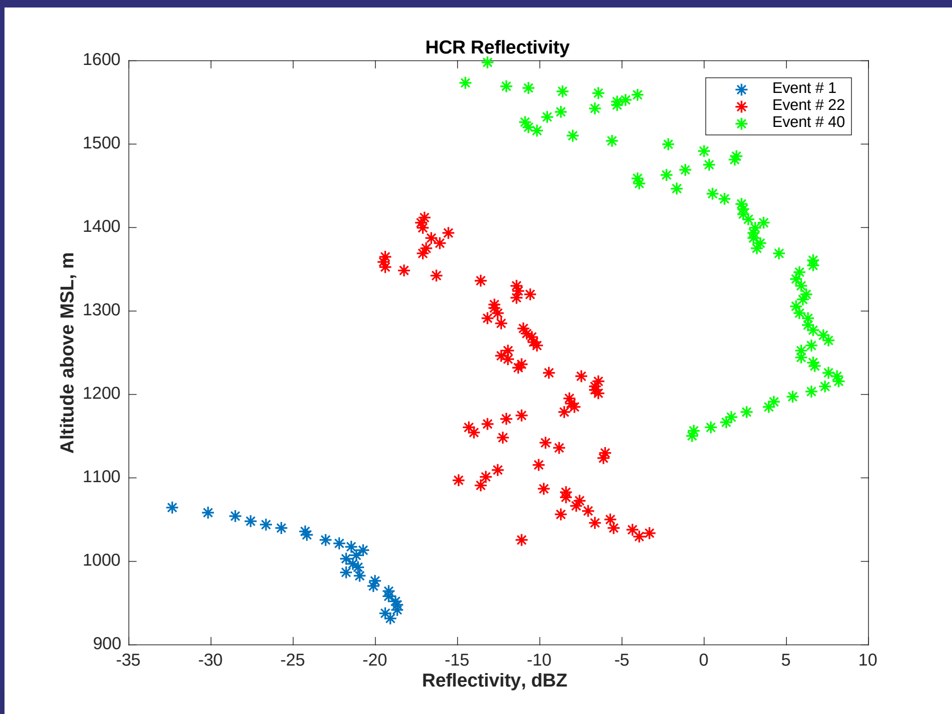


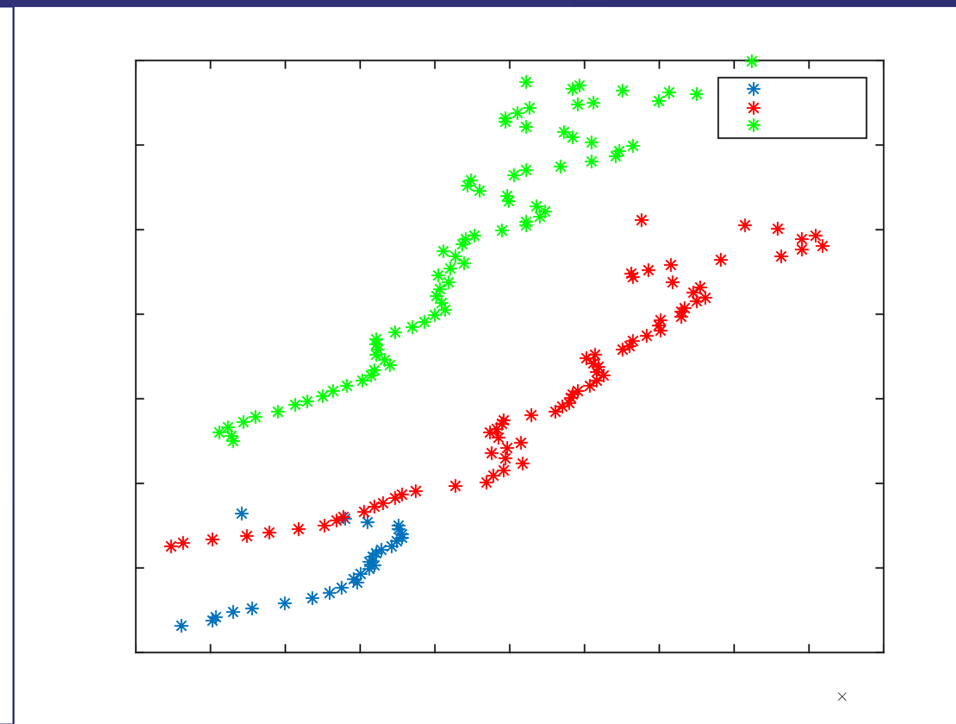
Retrieval of chart. Diameter and LWC



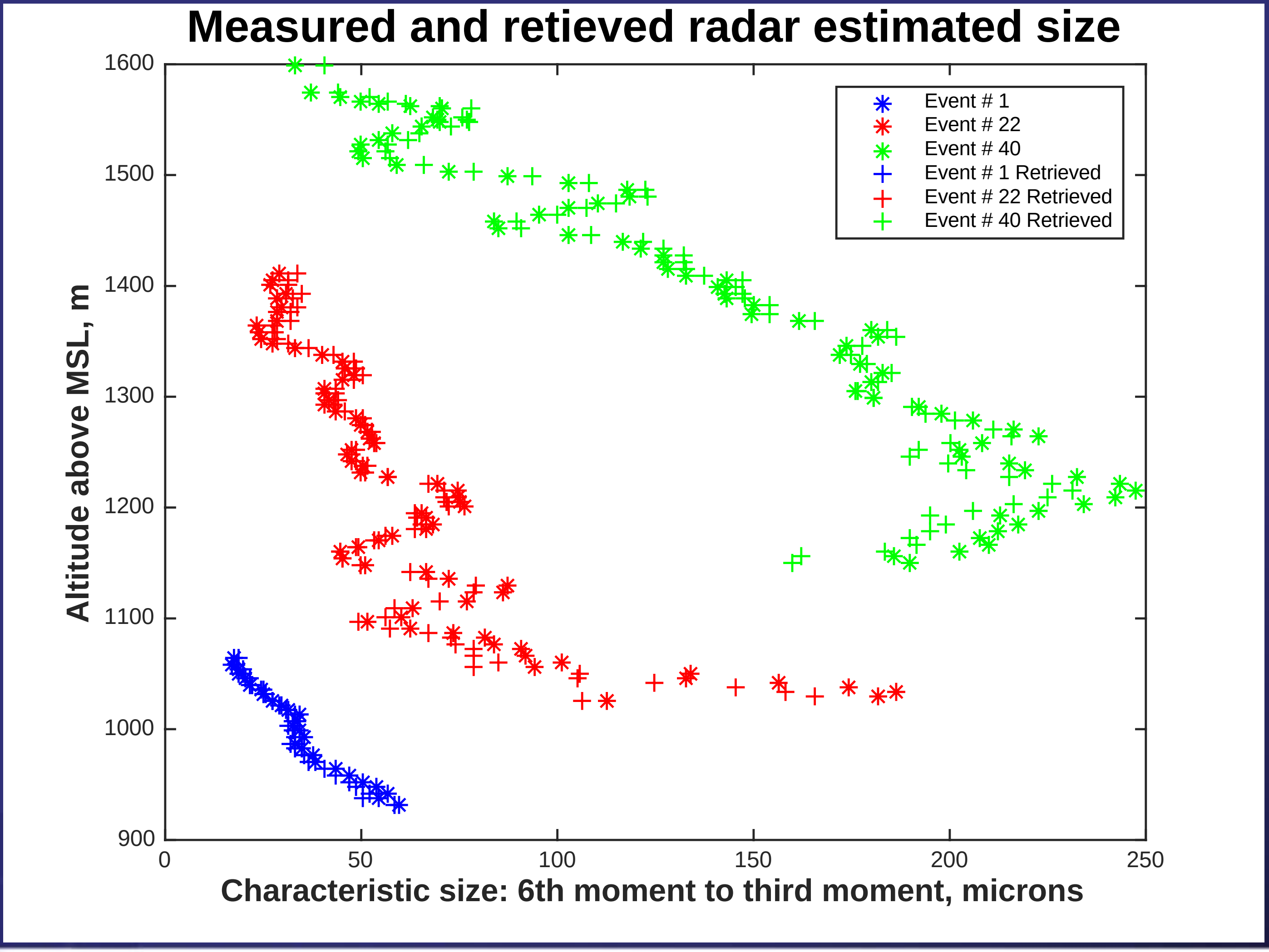


Radar and lidar reflectivity profiles

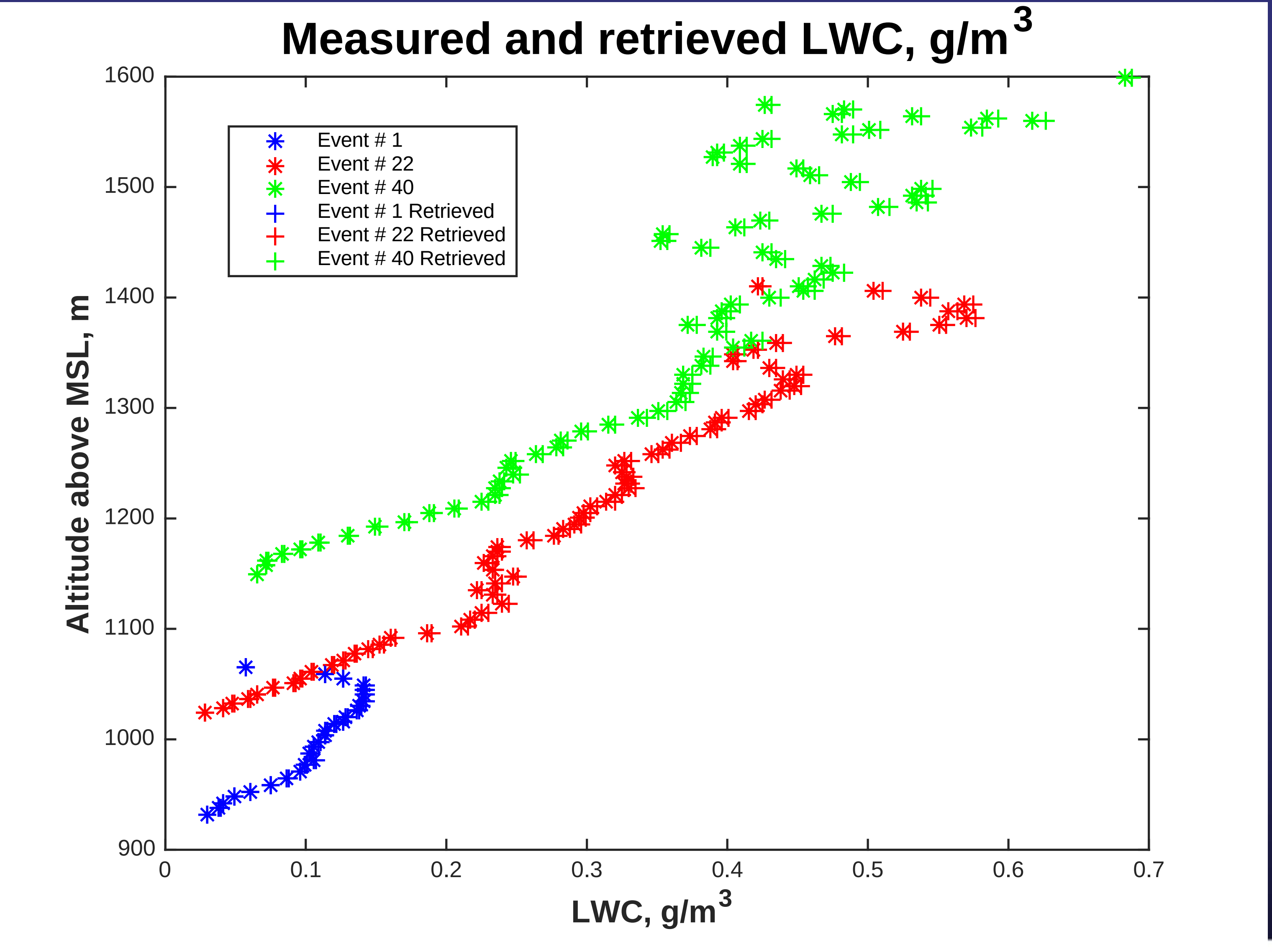




Retrieval of radar estimated size



Retrieval of LWC



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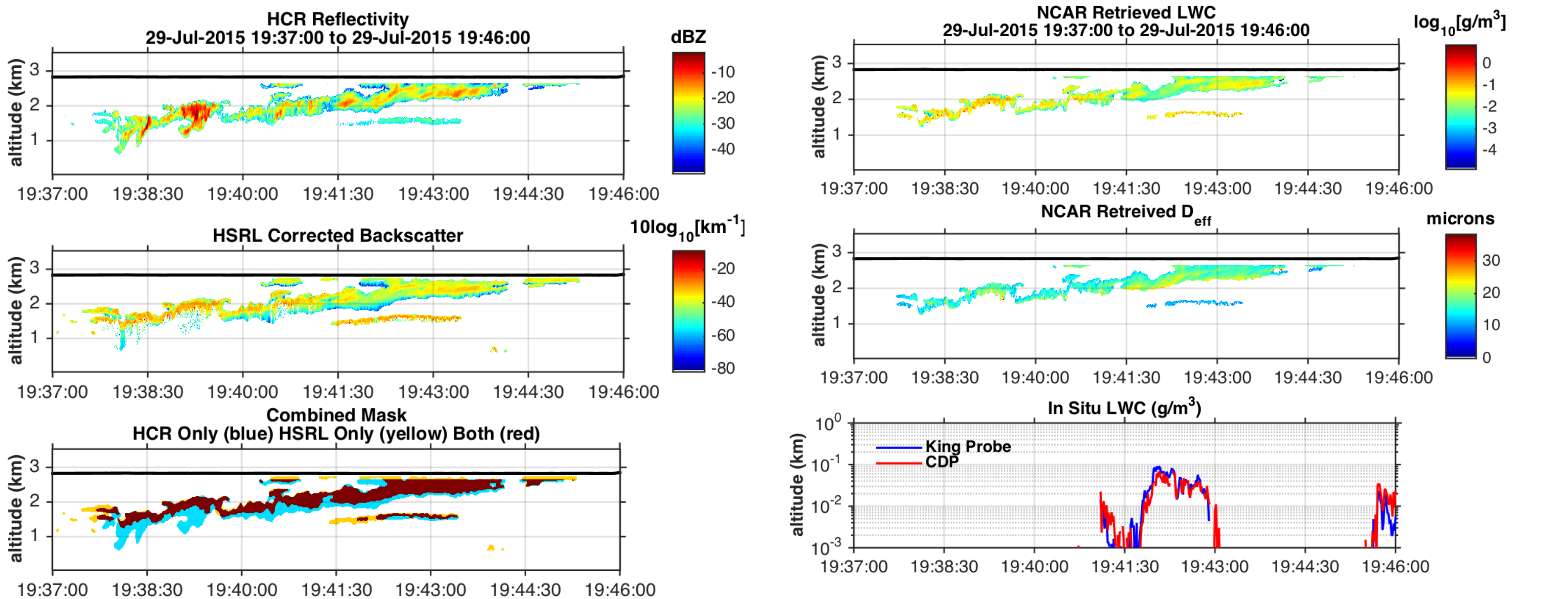
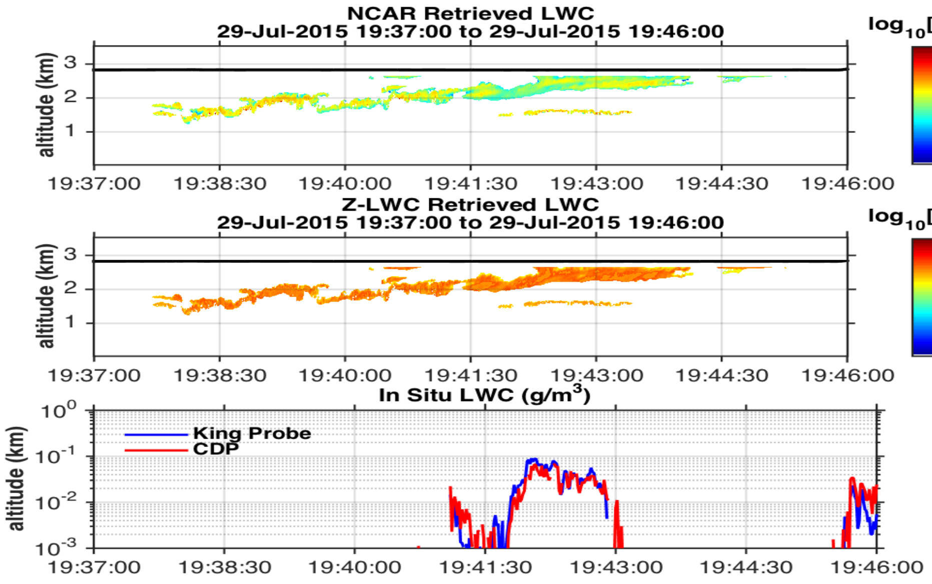
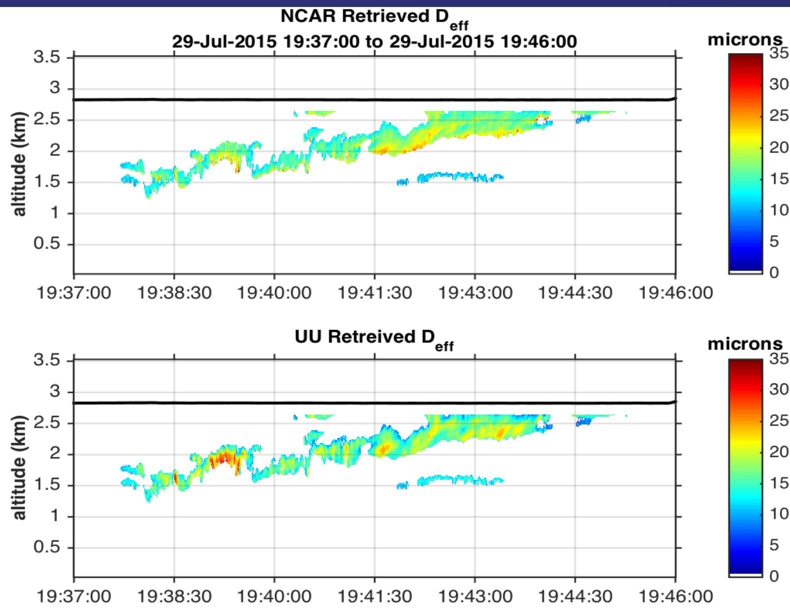
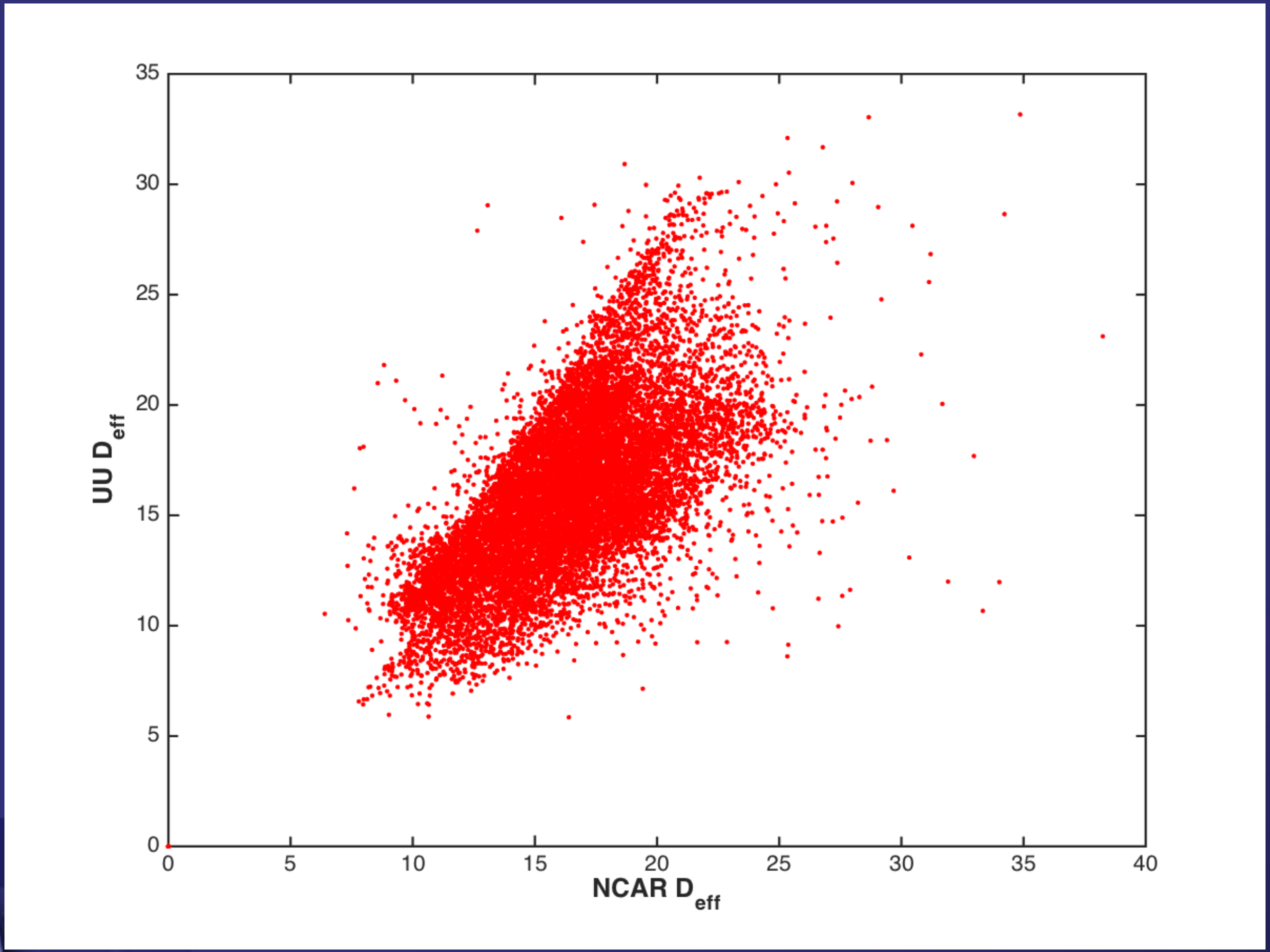

HCR Reflectivity
29-Jul-2015 19:37:00 to 29-Jul-2015 19:46:00
dBZ
-10
-20
-30
-40
altitude (km)
19:37:00 19:38:30 19:40:00 19:41:30 19:43:00 19:44:30 19:46:00
HSRL Corrected Backscatter
10log10[km-1]
-20
-40
-60
-80
Combined Mask
HCR Only (blue) HSRL Only (yellow) Both (red)
NCAR Retrieved LWC
29-Jul-2015 19:37:00 to 29-Jul-2015 19:46:00
log10[g/m3]
0
-1
-2
-3
-4
NCAR Retreived Deff
microns
30
20
10
0
In Situ LWC (g/m3)
King Probe
CDP
10^0
10^-1
10^-2
10^-3

Comparison between NCAR retrieval and Khaine and Univ. Utah retrievals





Comparison of D_{eff}: NCAR vs University Utah



Expected errors in RES, LWC and r_e estimates

- Measured error in radar reflectivity 8.5 %
- Measured error in lidar backscatter 1%
- RES: Radar estimated size 2.5 %
- LWC: Liquid water content 11 %
- r_e : Effective radius 11.5 %

Summary

- HCR and HSRL DQ are described
- Absolute reflectivity calibration using ocean backscatter and measurements in light rain are in progress
- An algorithm for estimating effective size and liquid water content for reflectivities between -30 and 10 dBZ are described
- Detailed simulations of cloud radar and lidar observations based on VOCALS DSDs are presented. This could be repeated for CSET DSDs.
- Preliminary retrievals of LWC are consistent with in situ probe measurements but more rigorous validation is required.