Retrievals of the deep convective system ice cloud microphysical properties using the ARM radar and aircraft in-situ measurements

ARM CLIMATE RESEARCH FACILITY

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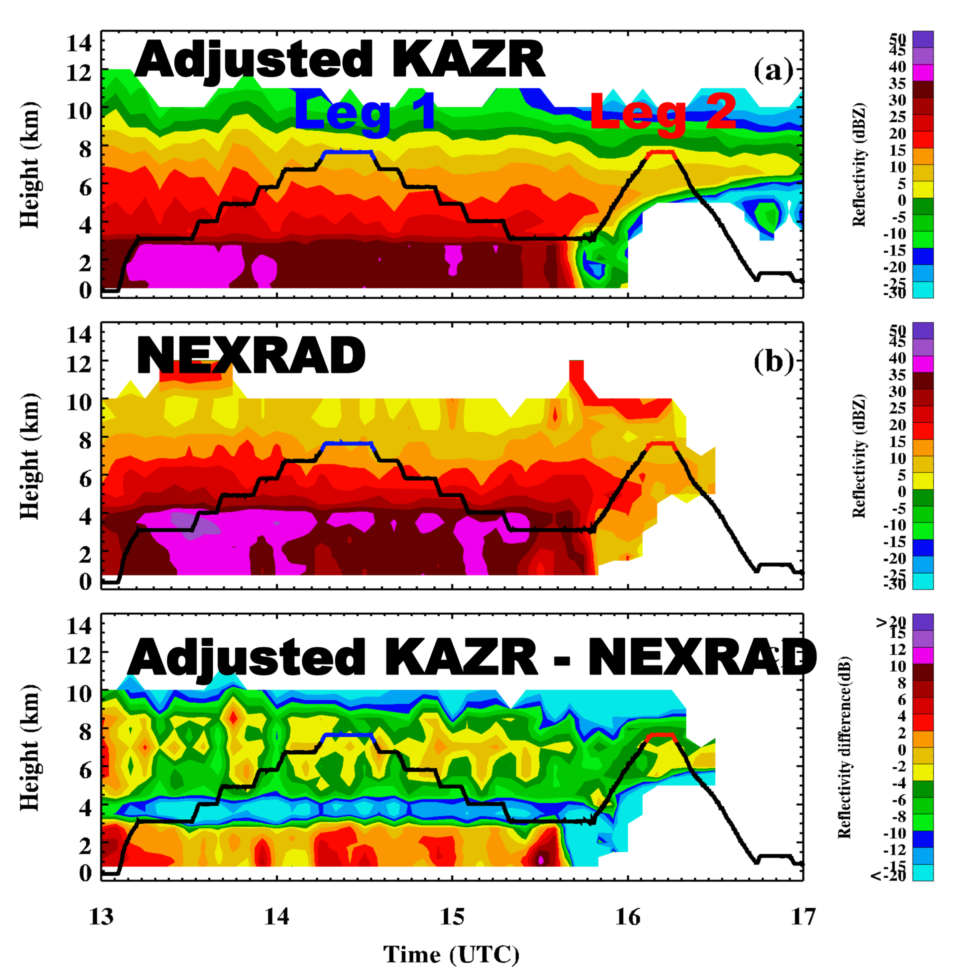
Motivation

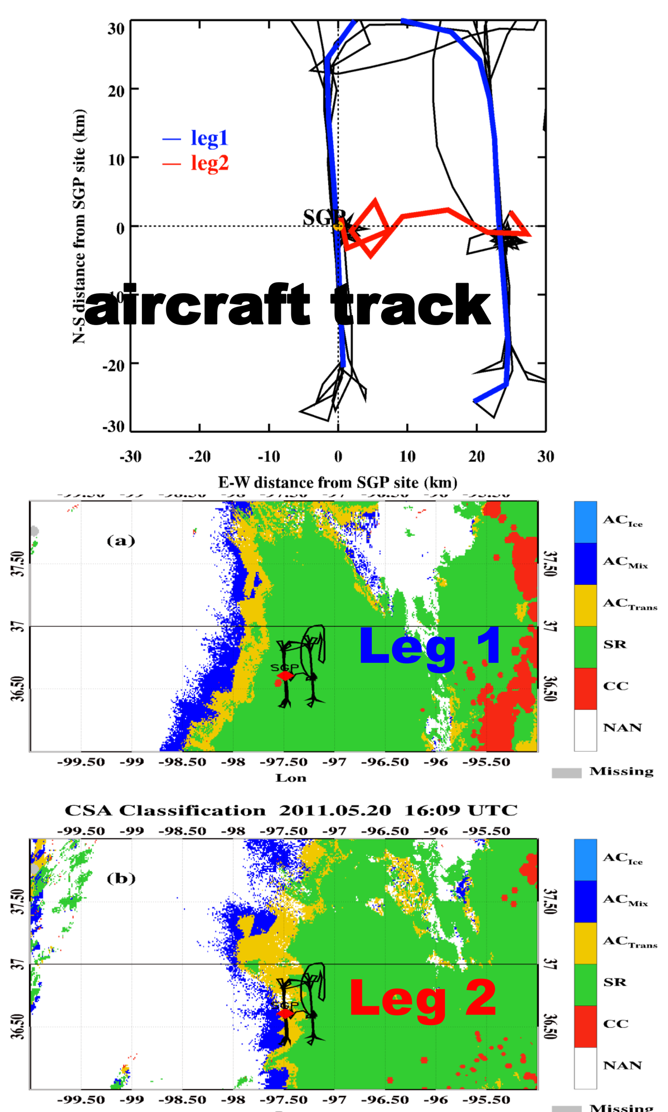
➢**1.** Accurate representation of convective processes is important for models/ Earth's climate system. But there is a lack in understanding of the detailed cloud microphysical properties [e.g. Median mass diameter (D_m)/ Ice water content (IWC)] of convective systems.

➢**2.** Ice layers dominate the DCS radiation budget (*Wang et al.*, 2005; *Feng et al.*, 2012). Accurate vertical distributions and temporal variations of the microphysical properties in these ice layers can be used to improve our climate forecast capability in models.

➢**3.** Adjusted KAZR (λ=8 mm) reflectivity and in-situ measurements were provided during the MC3E, which are the foundation for the development of algorithms.

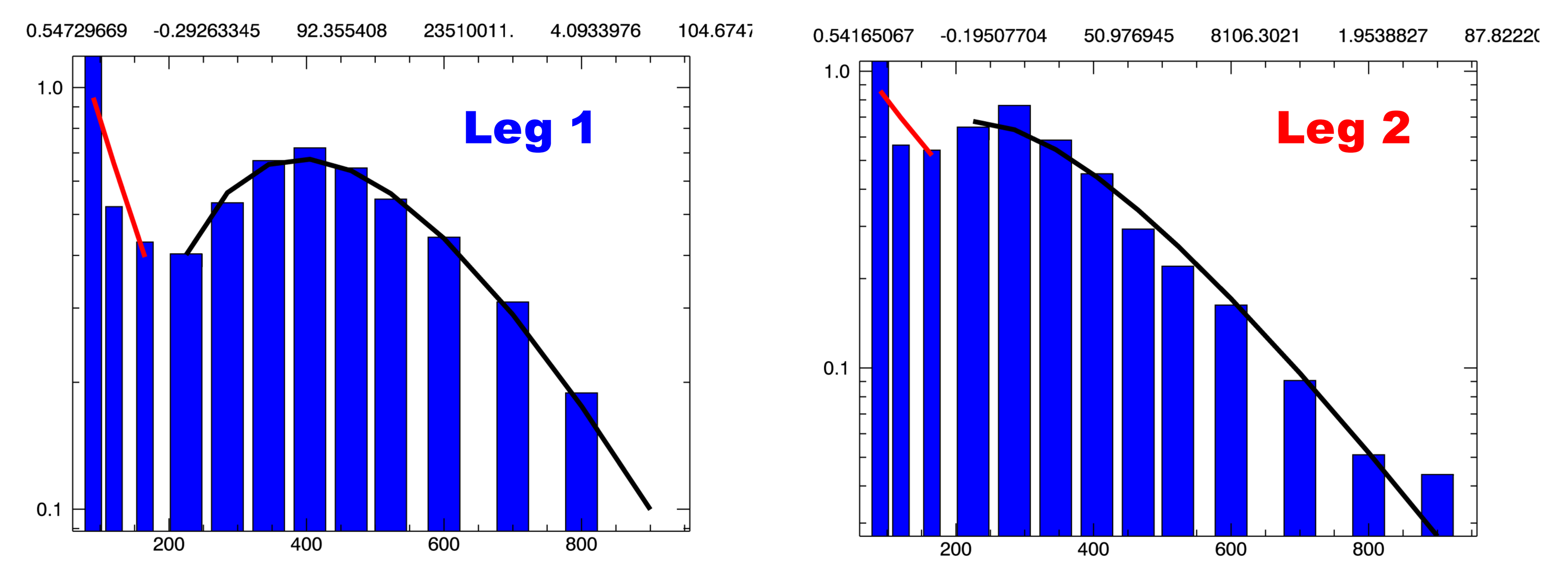
Adjusted KAZR and NEXRAD reflectivities





On average, there is 4dB difference along aircraft track leg1 and leg 2

Aircraft in-situ measurements (PSD)

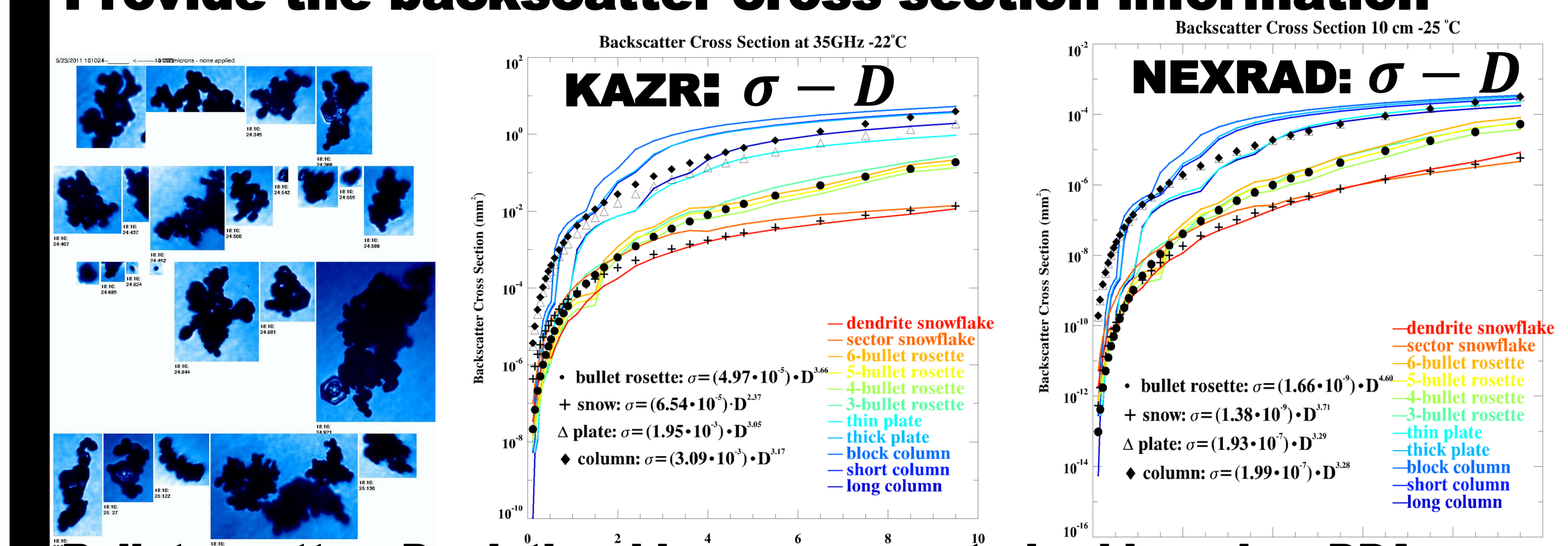


		μ
leg1:	mean:	4.332
	Std_dev:	1.257
leg2:	mean:	1.748
	Std_dev:	1.190

μ used in retrieval:
SR: 4.0
AC:2.0

Discrete Dipole Approximation (DDA) dataset

Provide the backscatter cross section information



Bullet rosette σ-D relationship was parameterized based on DDA scattering database and used to best estimate aggregate backscatter cross section information.

Retrieval Algorithm

The radar reflectivity factor for ice particles Z_i

$$Z_i = \frac{\lambda^4}{\pi^5 |K_i|^2} \int_0^\infty \sigma(D) N(D) dD$$

- σ: Backscattering cross section for ice habits
- N(D): particle size distribution (PSD)

KAZR Radar reflectivity measurements

Z_e are referred to as water equivalent reflectivity.

Water and ice reflectivity relationship (Smith, 1984; Atlas et al., 1995),

$$Z_e = Z_i \frac{|K_i|^2}{|K_w|^2}$$

$$Z_e = \frac{\lambda^4}{\pi^5 |K_w|^2} \int_0^\infty \sigma(D) N(D) dD$$

PSD: $N(D) = N_0 D^\mu e^{-\lambda D}$

$$\sigma = sD^t$$

$$N_t = \int_0^\infty N(D) dD$$

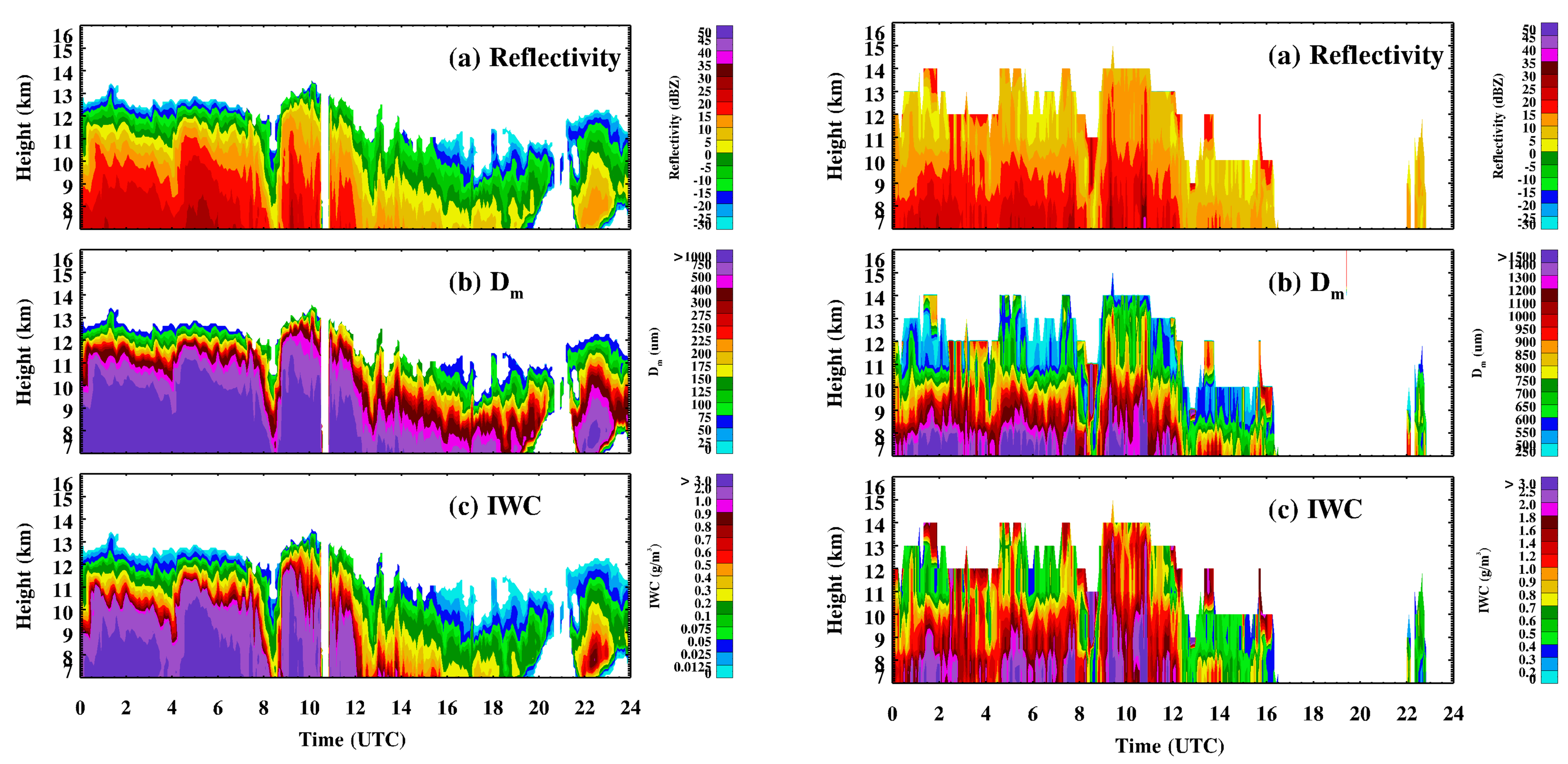
$$D_m = \frac{q + \mu + 0.67}{\lambda}$$

[M(D)=pD^q]

$$Z_e = f(N_0, \mu, \lambda, s, t)$$

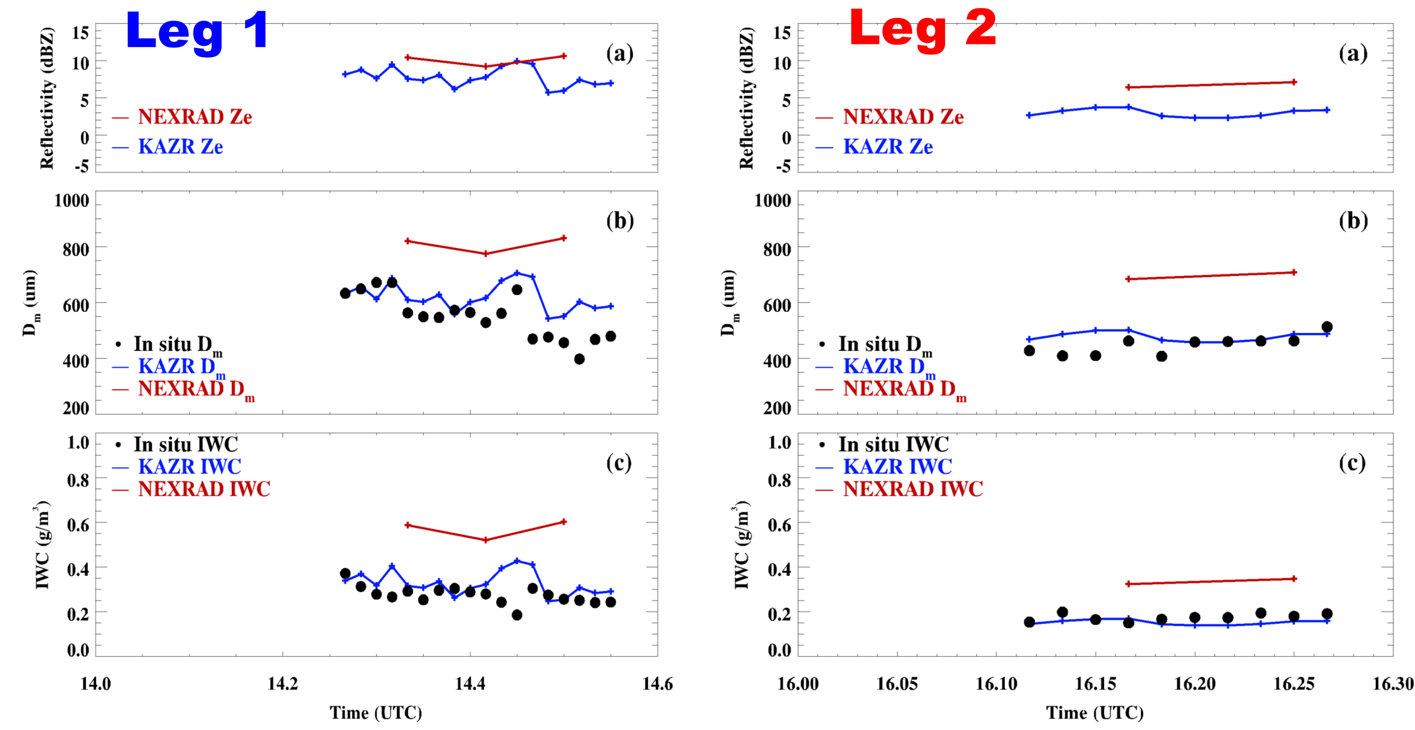
$$D_m = f(Z_e, \mu, N_t, s, t, p)$$
$$IWC = f(Z_e, \mu, N_t, s, t, p, q)$$

Retrievals from KAZR and NEXRAD



1) The temporal and vertical variations of D_m and IWC follow the variations of KAZR reflectivity.
2) Particle size and *IWC* decrease with altitude in the top few kilometers of the cloud.

Validation KAZR/NEXRAD retrievals using aircraft in-situ measurements



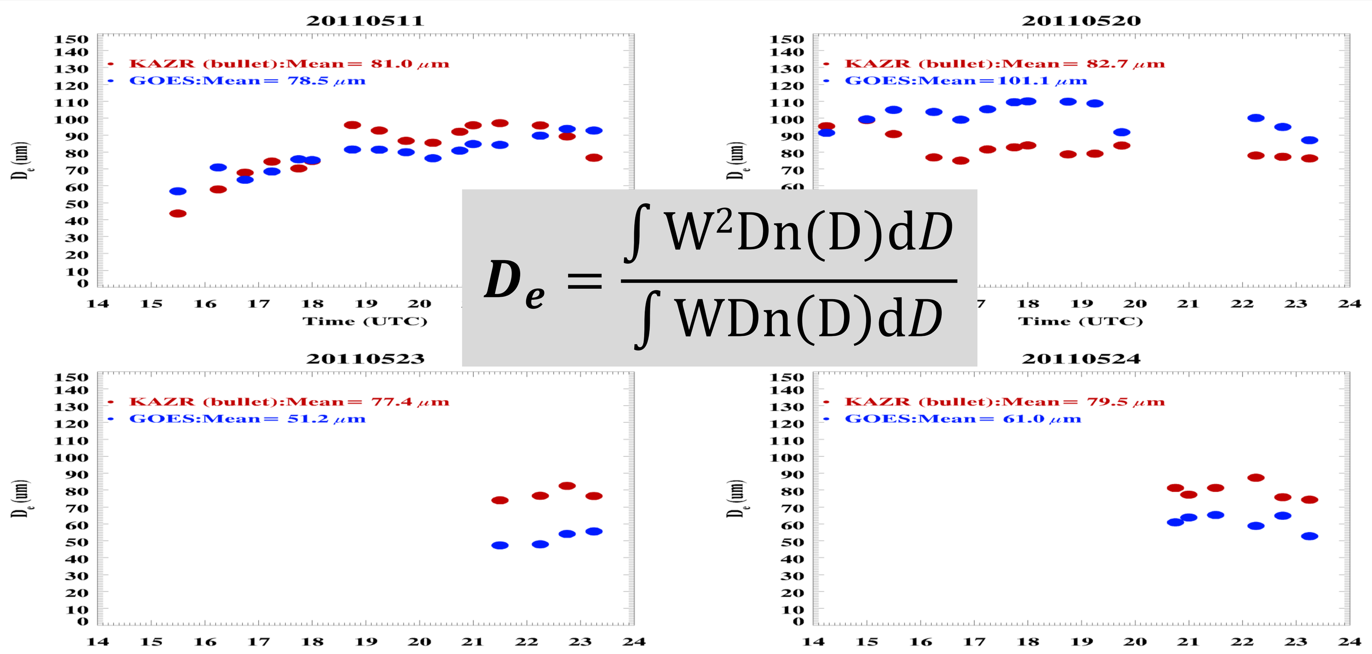
	μ	Ze	Ze	D_m	D_m	D_m	IWC	IWC	IWC
leg1	4	7.8	10.1	550	618	808	0.27	0.33	0.57
leg2	2	3	6.7	447	478	696	0.17	0.15	0.33

Uncertainty / sensitivity study

KAZR	Ze (1 dB)	Nt (10#/L)	μ
D_m	6%	6.5%	3.5%
IWC	12%	10%	8%

NEXRAD	Ze (1 dB)	Nt (10#/L)	μ
D_m	4.5%	5.5%	2%
IWC	8%	12%	12%

Comparison with GOES satellite retrieval



$$D_e = \frac{\int W^2 Dn(D) dD}{\int W Dn(D) dD}$$

GOES retrieved D_e on average, agrees with the ARM retrievals within ~25 μm.

Summary

➢A new algorithm has been developed for retrieving the DCS ice cloud microphysical properties using the adjusted KAZR/NEXRAD reflectivity.

➢The PSD size parameter, μ=4 (SR), μ=2(AC), in the gamma distribution and the shape of the ice crystal habit (aggregates) have been determined through the aircraft in situ measurements during the MC3E.

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