Profiles of MBL Cloud and Drizzle Microphysical Properties retrieved from Ground-based Observations and Validated by Aircraft data during ACE-ENA IOP

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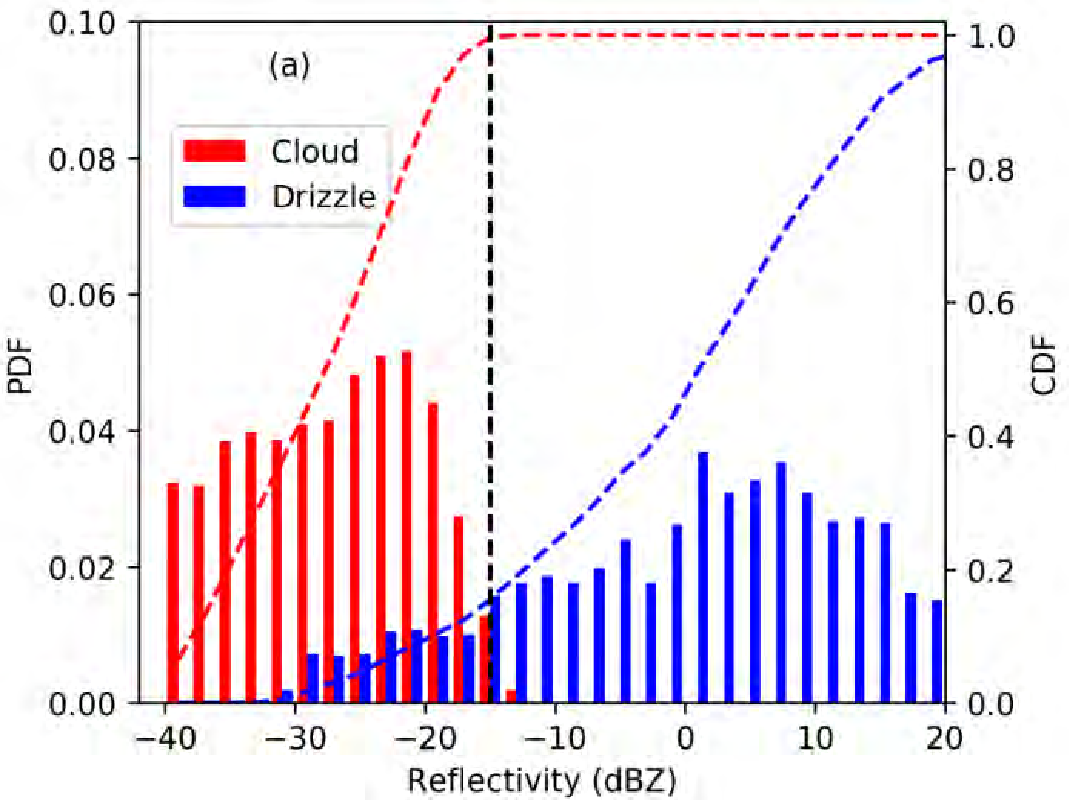
Wu et al. 2020, JGR

Decompose cloud and drizzle reflectivity from KAZR Measurements



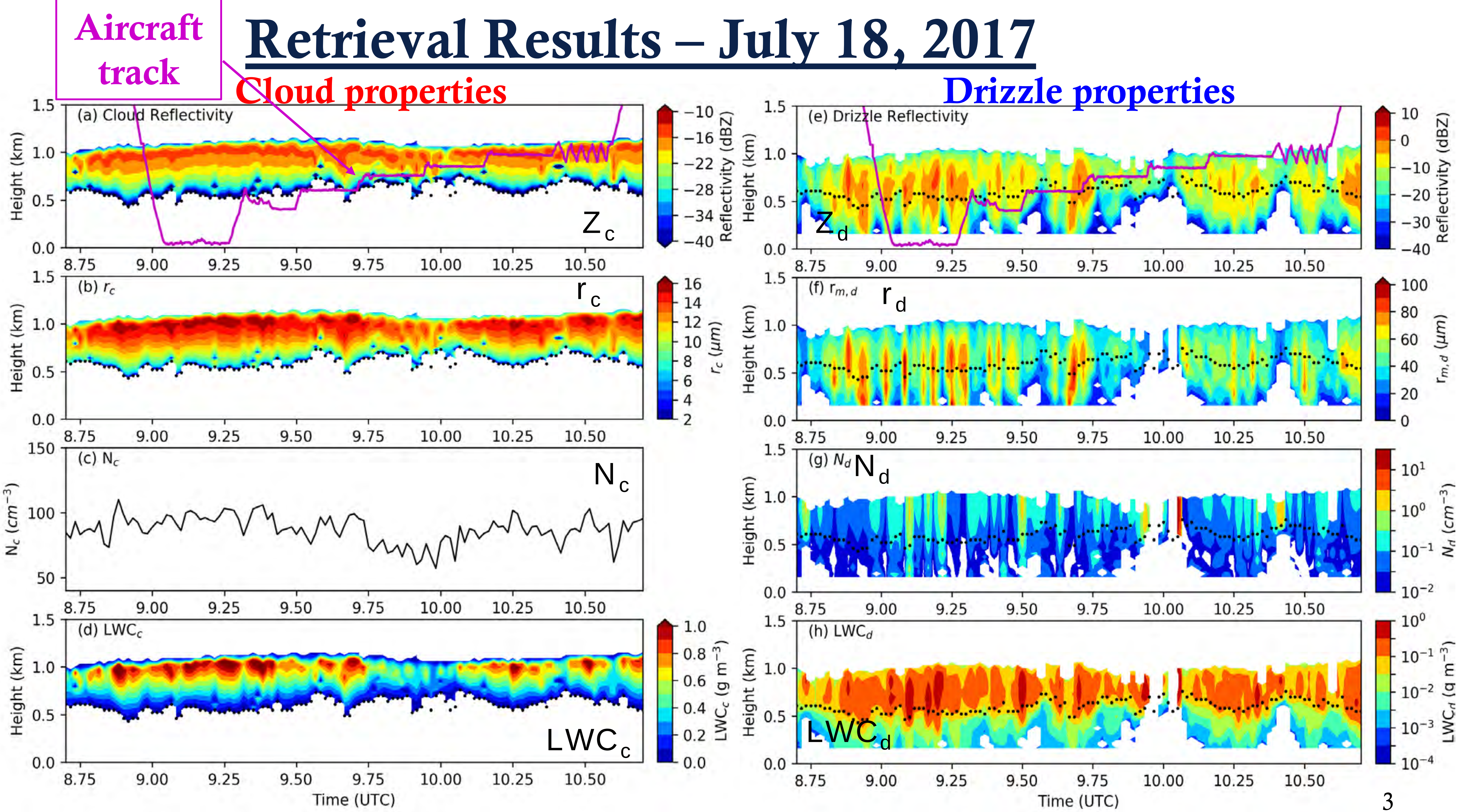
(a) Cloud droplets have maximum reflectivity of ~-15 dBZ calculated from FCDP and 2DS data

(b) Find the height of -15 dBZ. The reflectivity above this height is solely contributed by cloud droplets

(c) $Z_{c,base} = Z_{above} - Z_{below}$, LWC_c increase linearly ➔ $\sqrt{Z_c}$ increase linearly

$Z_d = Z_{obs} - Z_c$

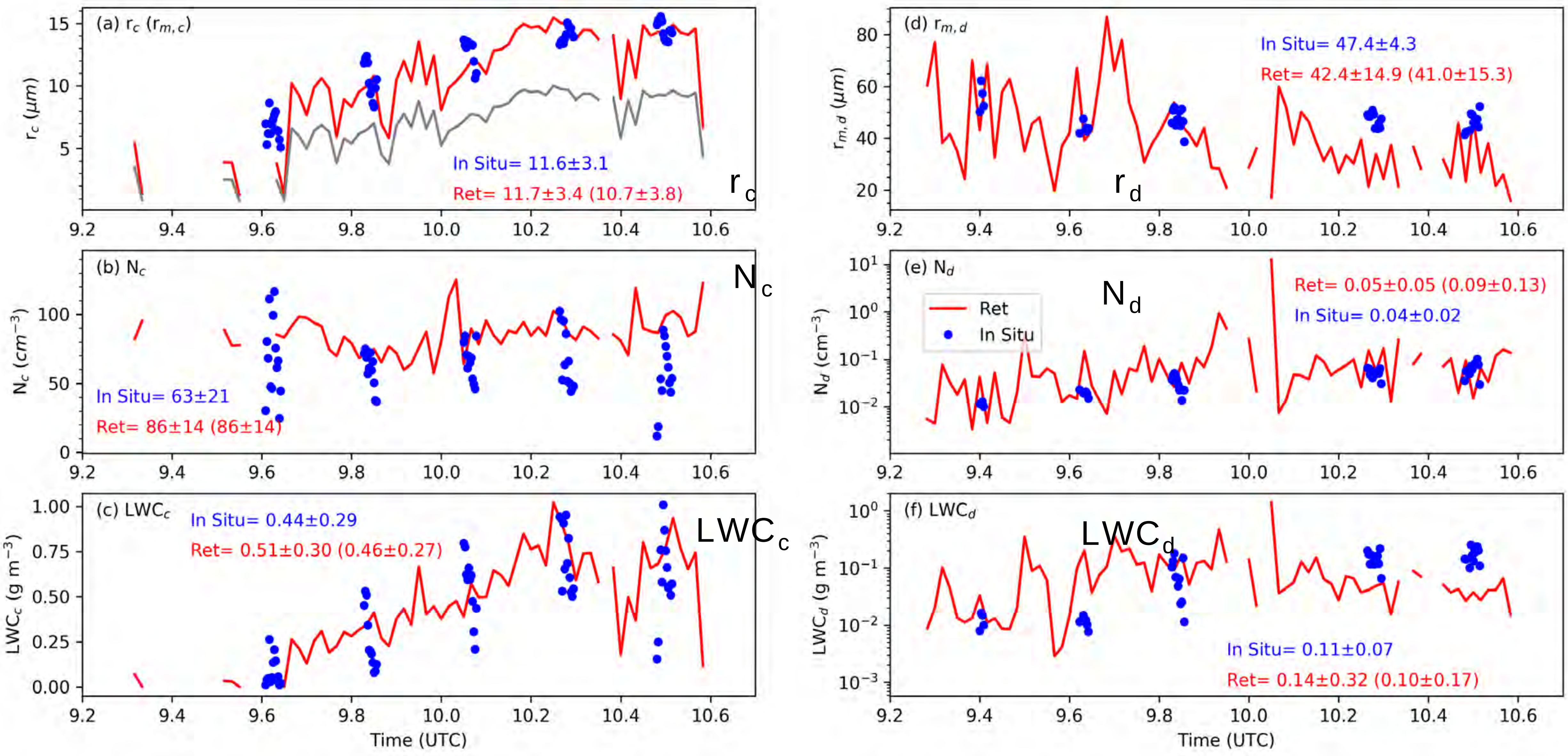
Retrieval Results – July 18, 2017



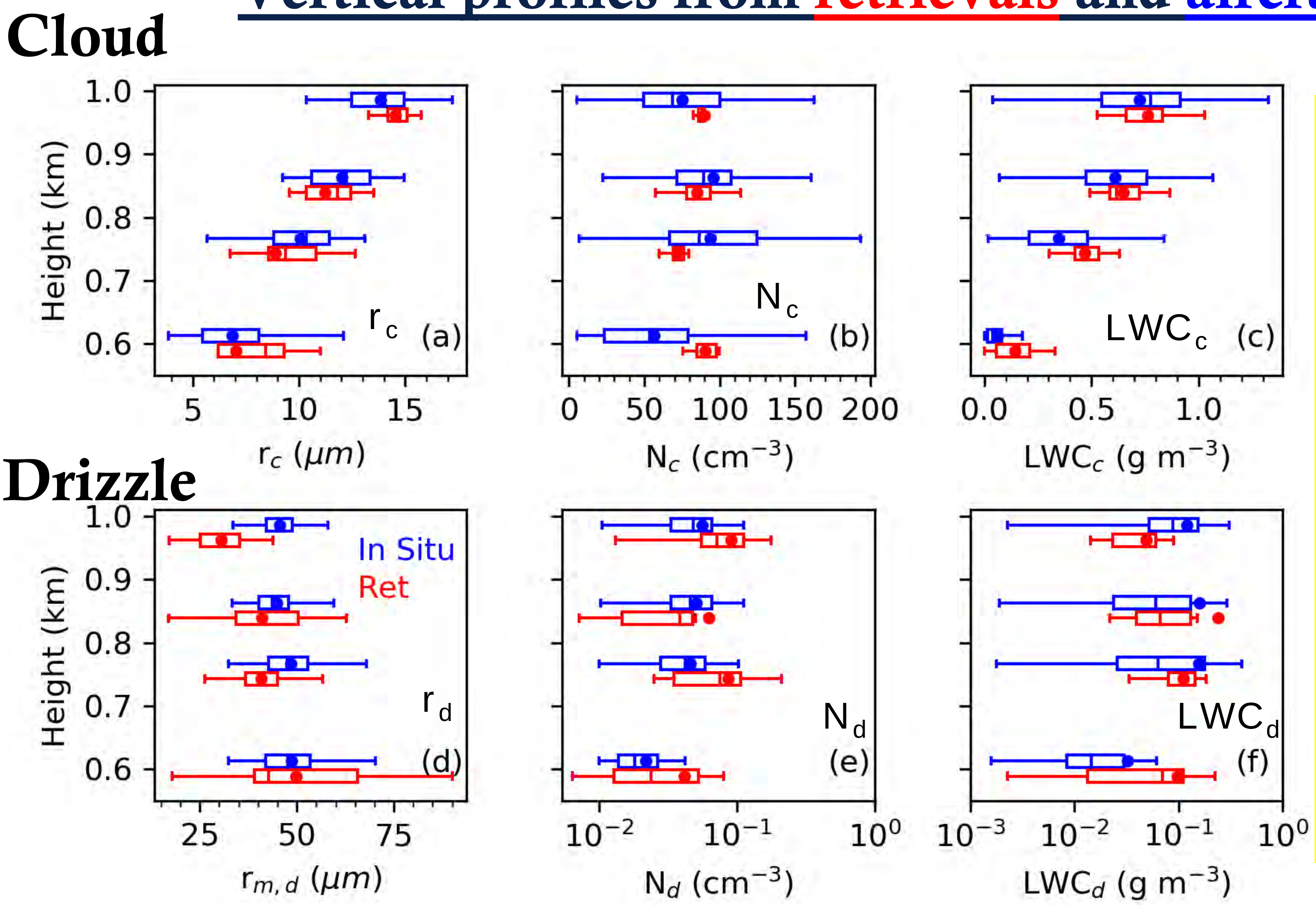
Comparison of Retrievals and Aircraft data

Cloud Properties

Drizzle Properties



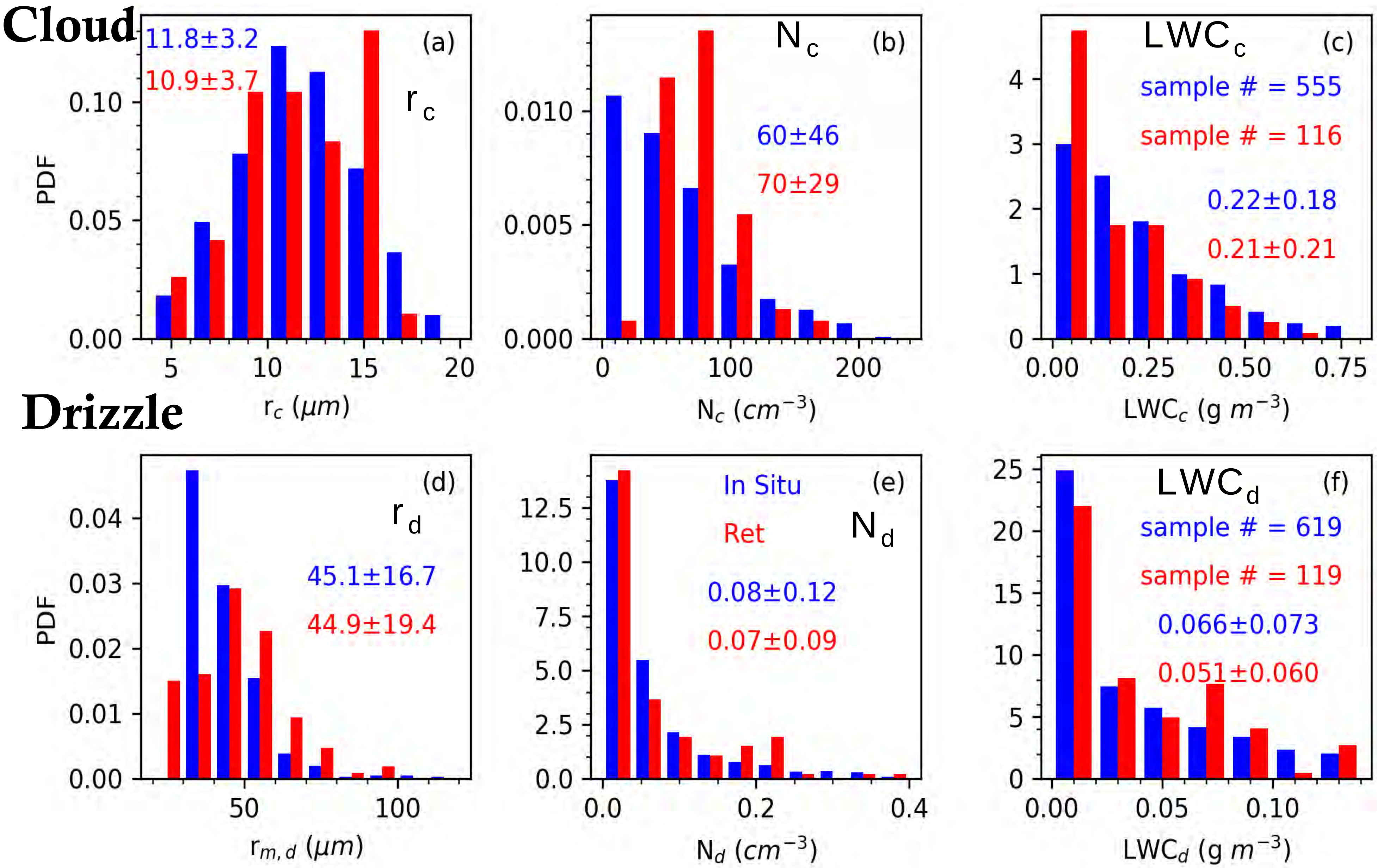
Vertical profiles from retrievals and aircraft data



- r_c and LWC_c increase from cloud base to top
- Drizzle drops form near cloud top with smallest size and highest concentration.
- As they fall, drizzle drops grow bigger towards the cloud base
- N_d decreases toward the cloud base
- From both time series and vertical profiles:

Good agreements between surface retrievals and aircraft in-situ data

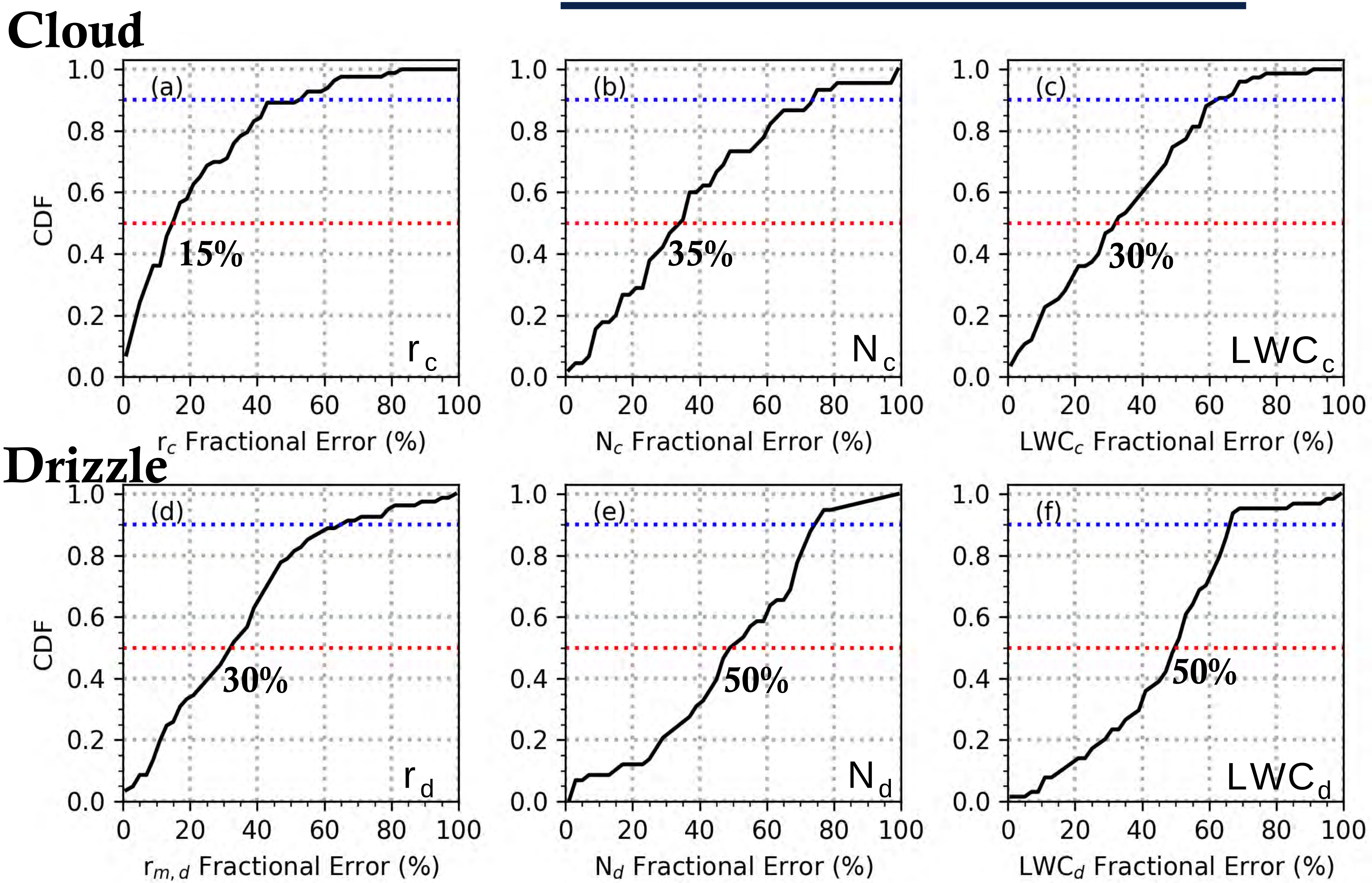
All cases during ACE-ENA



Surface retrievals can reproduce similar PDFs as aircraft measured ones

Negative retrieval biases except N_c

Retrieval uncertainties



$$\frac{|aircraft - surface|}{aircraft}$$

The retrieval uncertainties are estimated using aircraft data during ACE-ENA

Median retrieval errors are
~15% for r_c
~35% for N_c,
~30% for LWC_c, $r_{m,d}$
~50% for N_d, LWC_d

Summary

- **Algorithm development**: retrieve cloud and drizzle microphysics profiles
- **Retrieval validation**: Collocated aircraft measurements
- **Median retrieval uncertainties** were ~15% for r_c, ~35% for N_c, ~30% for LWC_c, and r_d, and ~50% for N_d and LWC_d
- r_c increase from the cloud base to z_i=~0.75 then decrease towards the cloud top, r_d monotonically increase from the cloud top to the cloud base then decrease below the cloud base
- $r_d \approx 3\sim6\ r_c$
- $N_d \approx \frac{1}{1000} \sim \frac{1}{100} N_c$
- $LWC_d \approx \frac{1}{10} LWC_c$

- A Statistical results about ENA cloud and drizzle microphysical properties will be presented in Wu et al. (2020, J Clim., accepted).

THANK YOU!

Remote Sensing Retrieval

Retrieval:

$$x = G^{-1}y$$

e.g., $T = \sqrt[4]{\frac{F}{\sigma}}$

$$y = \begin{pmatrix} Z \\ \sigma_d \\ \beta \\ LWP \end{pmatrix}$$

G for reflectivity:

$$Z = \int_0^{D_{max}} D^6 N dD$$

Retrieval:
x: microphysics
y: remote sensing Obs.
G: math/phys. formulas

$$x = \begin{pmatrix} r_c \\ N_c \\ LWC_c \\ r_d \\ N_d \\ LWC_d \end{pmatrix}$$

Cloud

$$D_c = 20\ \mu m$$

Drizzle

$$D_d = 150\ \mu m$$

$$Z_{drizzle} >> Z_{cloud}$$

Assumptions:

1. Lognormal Dist. for cloud droplets and normalized Gamma Dist. for drizzle drops
2. Drizzle drop number concentration increases linearly from below to above cloud base
3. Cloud droplet number concentration does not vary with height