Microphysical Properties of drizzles underneath the MBL Clouds during MAGIC

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Marine ARM GPCI Investigation of Clouds (MAGIC) IOP

From 201210 to 201309, the DOE AMF2 was carried by the Horizon Line cargo ship Spirit traversing the route between Los Angeles, CA and Honolulu, HI

Objectives

1) What are the particle size, number concentration, and LWC of drizzle under the MBL cloud base?

2) Are there any microphysical property differences between the Rain (fall to surface) and Virga (evaporated in air)?

3) What percentages of the liquid water path (LWP_d) under the cloud base compared to total LWP_t (retrieved by MWR) in atmosphere?

Methods/Steps to select cases

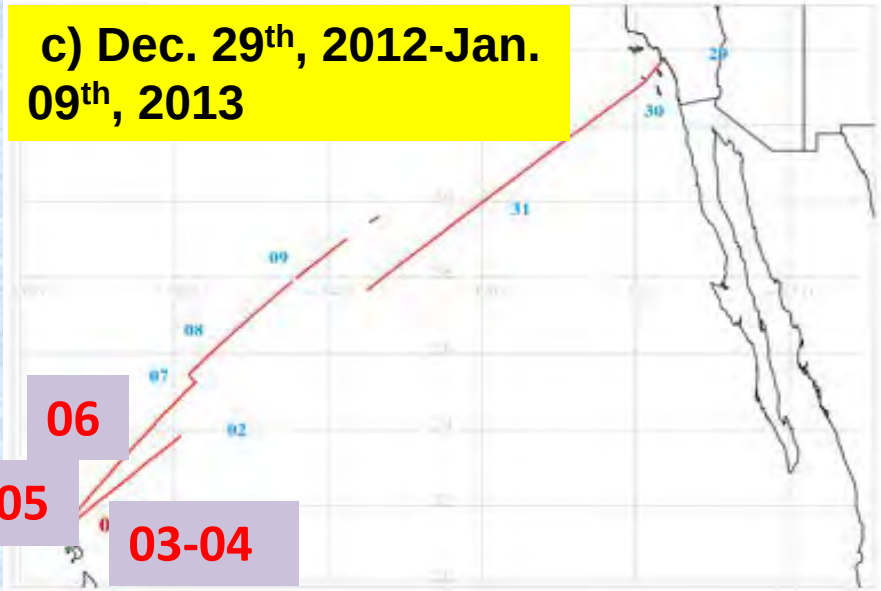
1. Use WACR (94 GHz) reflectivity profile to find the low-level clouds
2. Use KAZR (35 GHz) reflectivity profile to confirm the selected time periods by WACR
3. Use Ceilometer to determine whether there are drizzles fall out cloud base
4. Use TSI images to determine whether these drizzles reach surface. If yes, this time period is defined as Raining case, otherwise as Virga case.

Samples of selected ship tracks and MBL cases

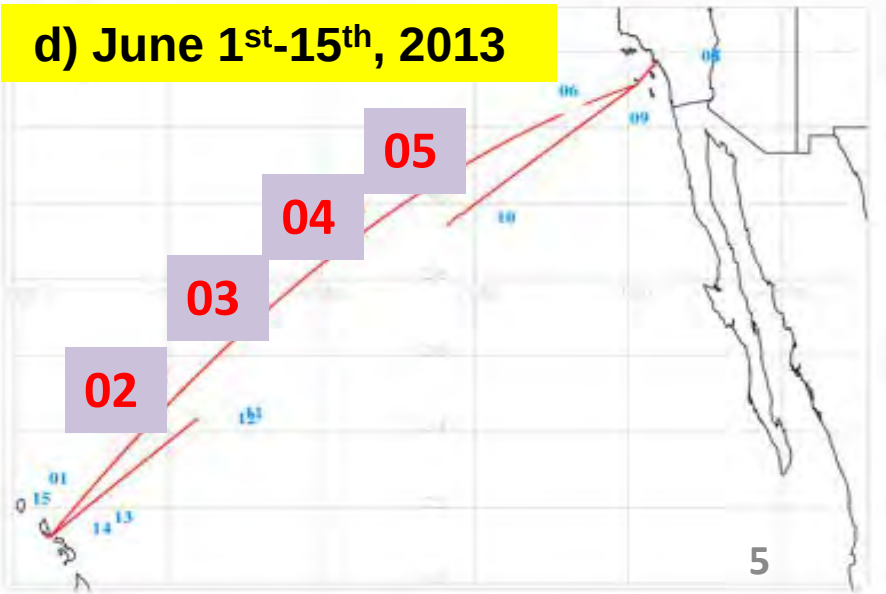
a) Nov. 6th-15th, 2012

b) Nov. 16th-31th, 2012

c) Dec. 29th, 2012-Jan. 09th, 2013

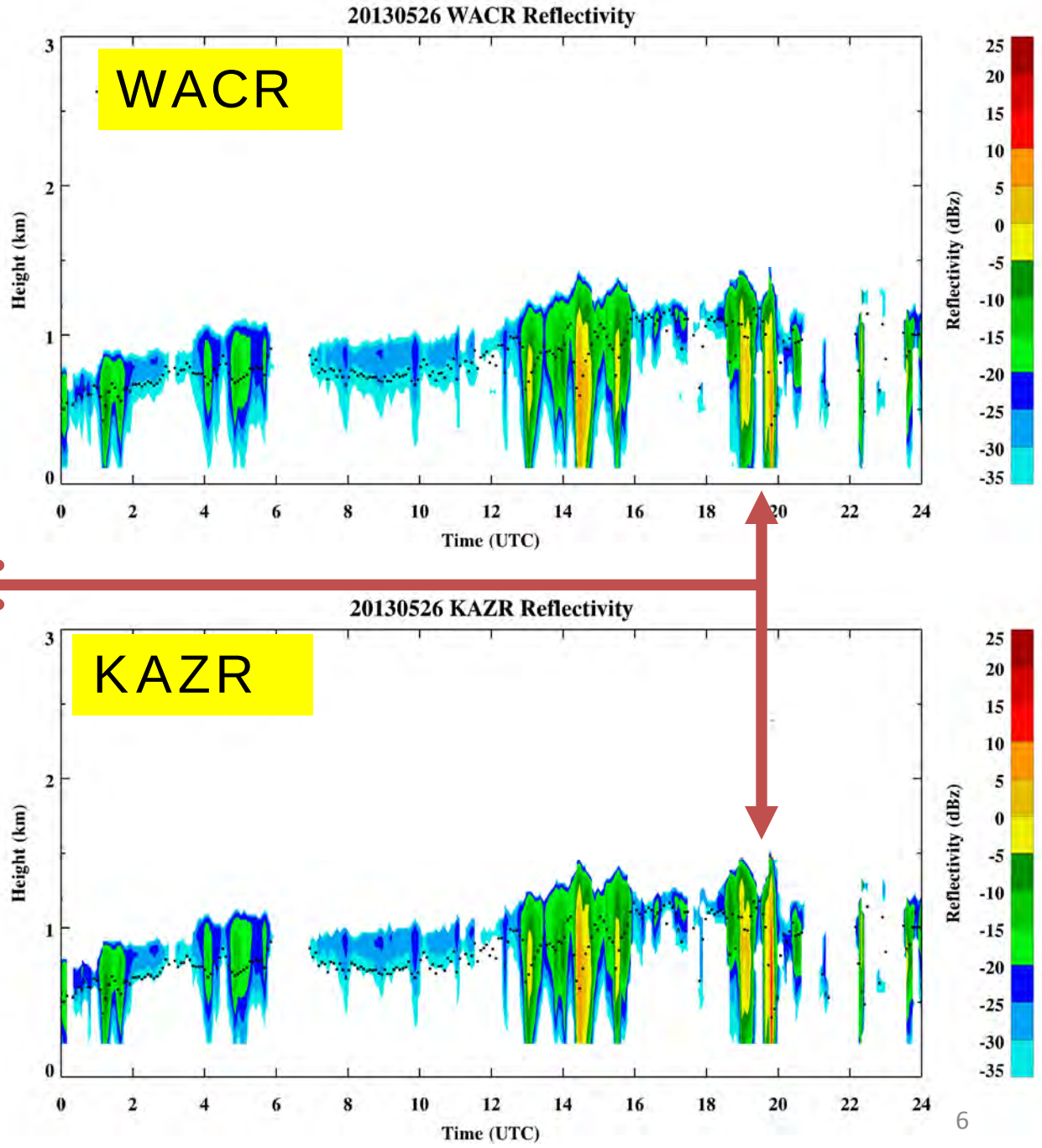


d) June 1st-15th, 2013



Rain period

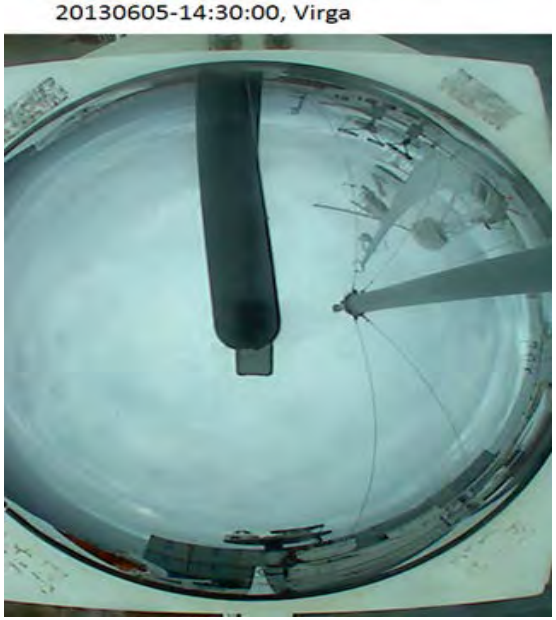
May 26, 2013
19:47:00 UTC
TSI Images

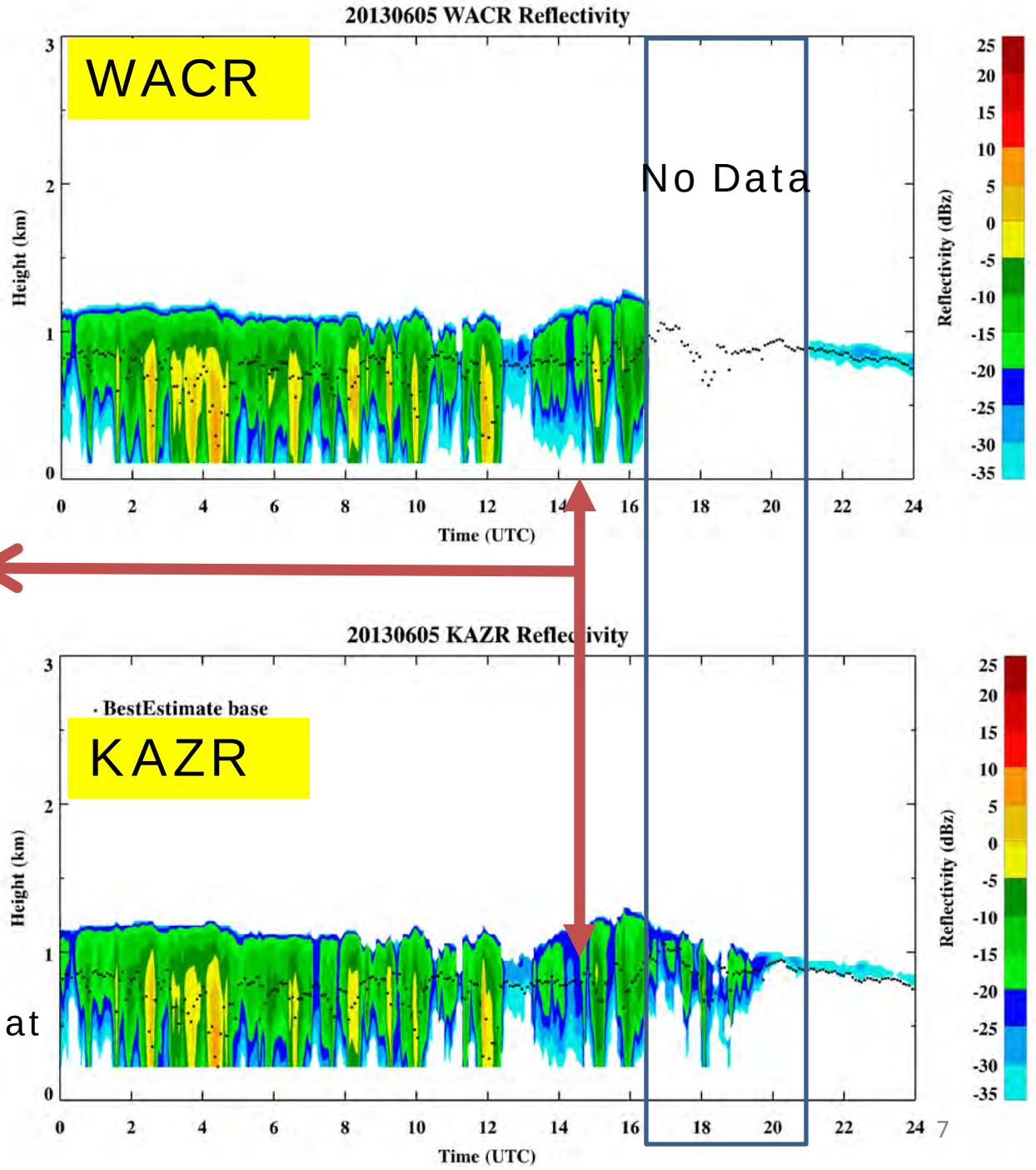


1) Both WACR and KAZR reflectivity have confirmed drizzling underneath the cloud base.
2) From TSI, the rain droplets reach the ground, which defines as “Rain period’.

Virga period

June 5th, 2013
14:30:00 UTC
TSI Images





(1)KAZR added more data when WACR did not work
(2) Both radars have confirmed drizzling underneath the cloud base. But TSI image confirmed that drizzles did not reach the ground, which defines as 'Virga period'.

A summary of MBL clouds associated with drizzles during MAGIC IOP

Date	WACR	KAZR	TSI	MWR	Drizzle status
20121113	Y	Y	Y	Y	01:30-02:20 (rain) 15:00-17:30 (rain) 20:15-20:45 (virga)
20121129	Y	Y	Y	Y	15:00-19:00 (rain) 18:00-19:30 (rain) 20:30-21:30 (virga)
20130103	Y	Y	Y	N	00:30-01:30 (rain) 18:30-19:30 (rain) 22:00-23:00 (rain)
20130104	Y	Y	Y	N	01:30-02:30 (rain) 17:00-18:30 (rain) 23:00-23:30 (virga)
20130105	Y	Y	Y	N	01:30-02:00 (rain) 02:00-03:30 (rain) 20:00-20:30 (virga)
20130106	Y	Y	Y	Y	01:00-01:30 (virga) 18:00-18:20 (virga) 20:30-21:00 (virga)
20130526	Y	Y	Y	Y	14:00-15:00 (rain) 15:00-16:00 (virga) 19:00-20:30 (rain)
20130602	Y	Y	Y	Y	01:30-02:30 (virga) 17:00-18:00 (virga) 18:30-19:30 (virga)
20130603	Y	Y	Y	Y	02:00-03:30 (virga) 15:30-19:00 (virga) 21:30-23:00 (virga)
20130604	Y	Y	Y	Y	02:30-03:00 (virga) 15:00-16:00 (virga) 18:50-20:00 (virga)
20130605	Y	Y	Y	Y	00:00-00:30 (rain) 04:30-07:00 (virga) 13:00-17:00 (virga)

There are a total 14 Rain cases and 19 Virga Cases selected by WACR, KAZR, ceilometer and TSI for this study.

Retrieval Algorithm

Method for Calculating the drizzle microphysical properties:

- **The ratio of radar reflectivity to lidar backscatter is proportional to the fourth power of drop size** *(O'Connor et al. 2005)*, **assume size distribution as normalized gamma distribution of the form:**

$$n(D) = N_W f(\mu) \left(\frac{D}{D_0}\right)^{\mu} exp\left[\frac{-(3.67+\mu)D}{D_0}\right] \qquad (1)$$

where N_W is the concentration normalized, D_0 is median diameter, μ is shape parameter, $f(\mu) = \frac{6}{3.67^4}\frac{(3.67+\mu)^4}{\Gamma(\mu+4)}$

- **Lidar extinction coefficient is defined as** $\alpha = \frac{\pi}{2}\int_0^{\infty} n(D)D^2 dD$ **.**
- **Lidar backscatter coefficient, β is given by $\alpha = S\beta$, where S is termed of lidar ratio and can be estimated using Mie theory.**

O'Connor, Ewan J., Robin J. Hogan, Anthony J. Illingworth, 2005: Retrieving Stratocumulus Drizzle Parameters Using Doppler Radar and Lidar. J. Appl. Meteor., 44, 14–27.

Retrieval algorithm (cont')

- **The ratio of radar reflectivity to lidar backscatter can be derived as:**

$$\frac{Z}{\beta} = \frac{2}{\pi}\frac{\Gamma(7+\mu)}{\Gamma(3+\mu)}\frac{S}{(3.67+\mu)^4}D_0{}^4 \qquad (2)$$

- **First assuming μ=0 and D_0 can be estimated, refine the estimation by comparing calculated spectral width with radar observed spectral width, adjusting μ and computing until convergence. Then N_W can be calculated from radar reflectivity.**
- **Now we can calculate drizzle LWC and number concentrations Nd as follows:**

$$\mathrm{LWC_d} = \rho_l \frac{\pi}{6}\int_0^\infty \mathrm{n(D)D^3}\,d\mathrm{D} \qquad (3)$$

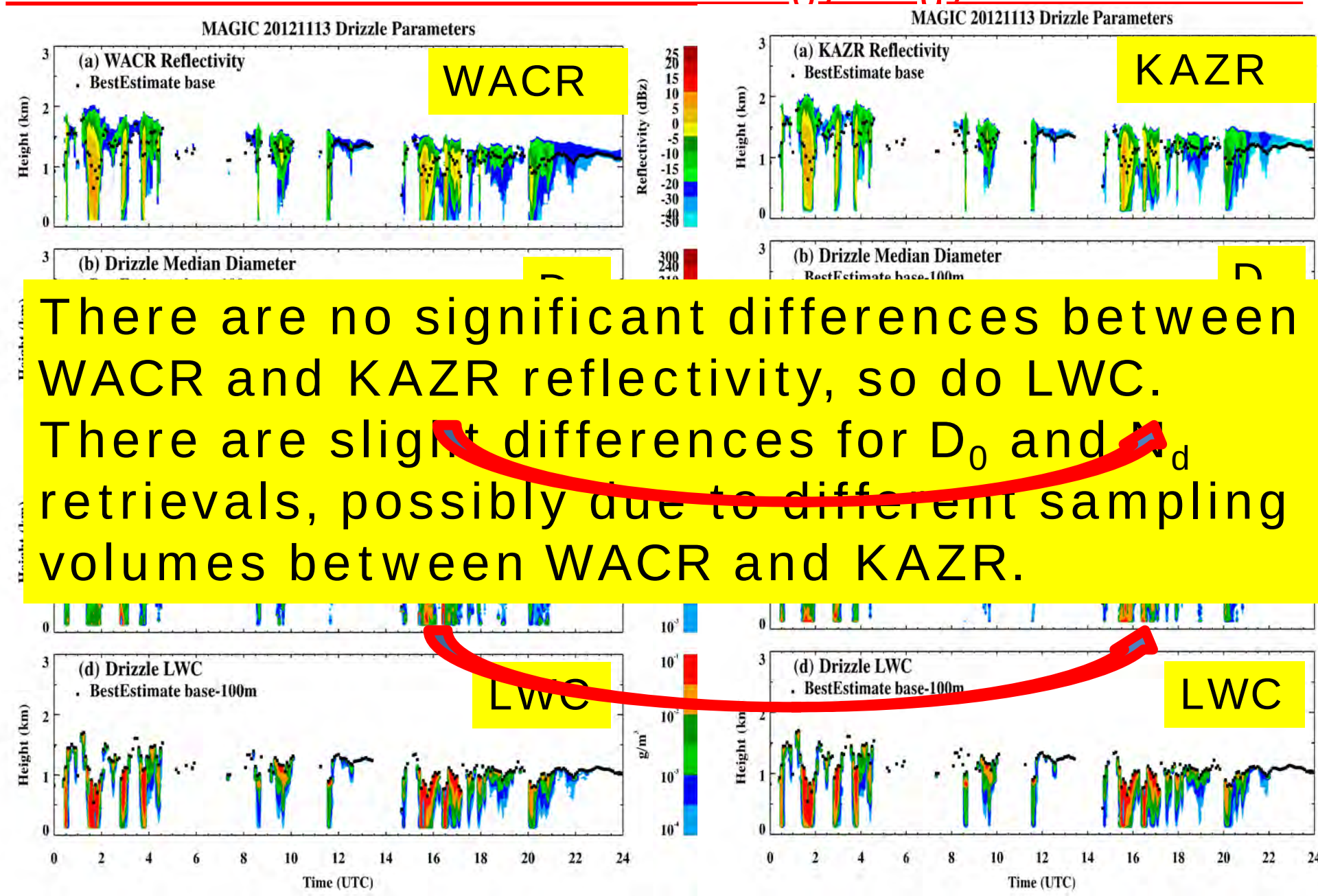
$$N_d = \int_0^\infty \mathrm{n(D)\,dD} \qquad (4)$$

- **The ratio(R) of drizzle LWP_d to total LWP_t (retrieved by MWR) is**

$$R = \frac{LWP_d}{LWP_t} \qquad (5).$$

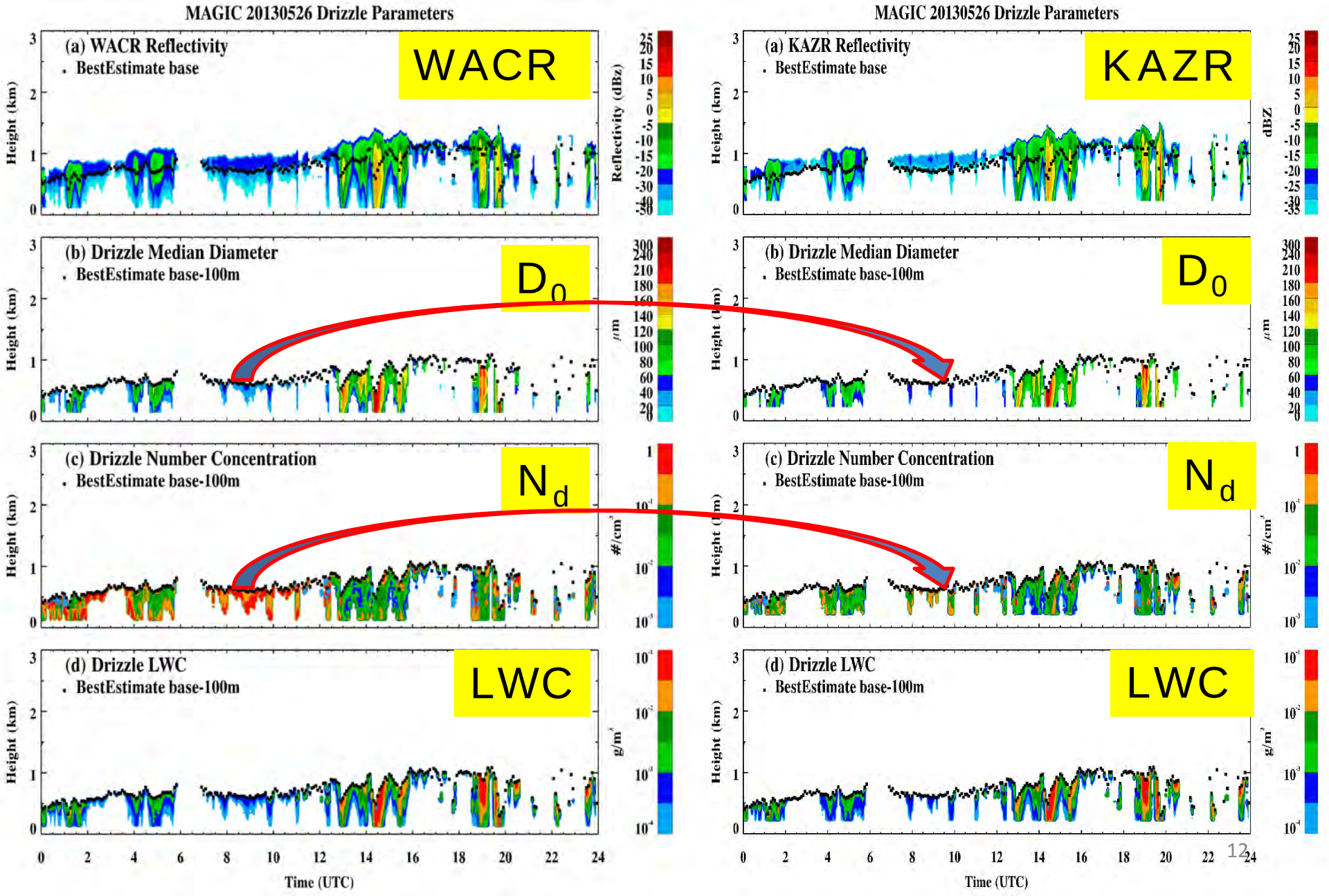
The uncertainties of D_0 and LWC_d are 14% and 10%, respectively.

Retrieved results of D_0, N_d, and LWC

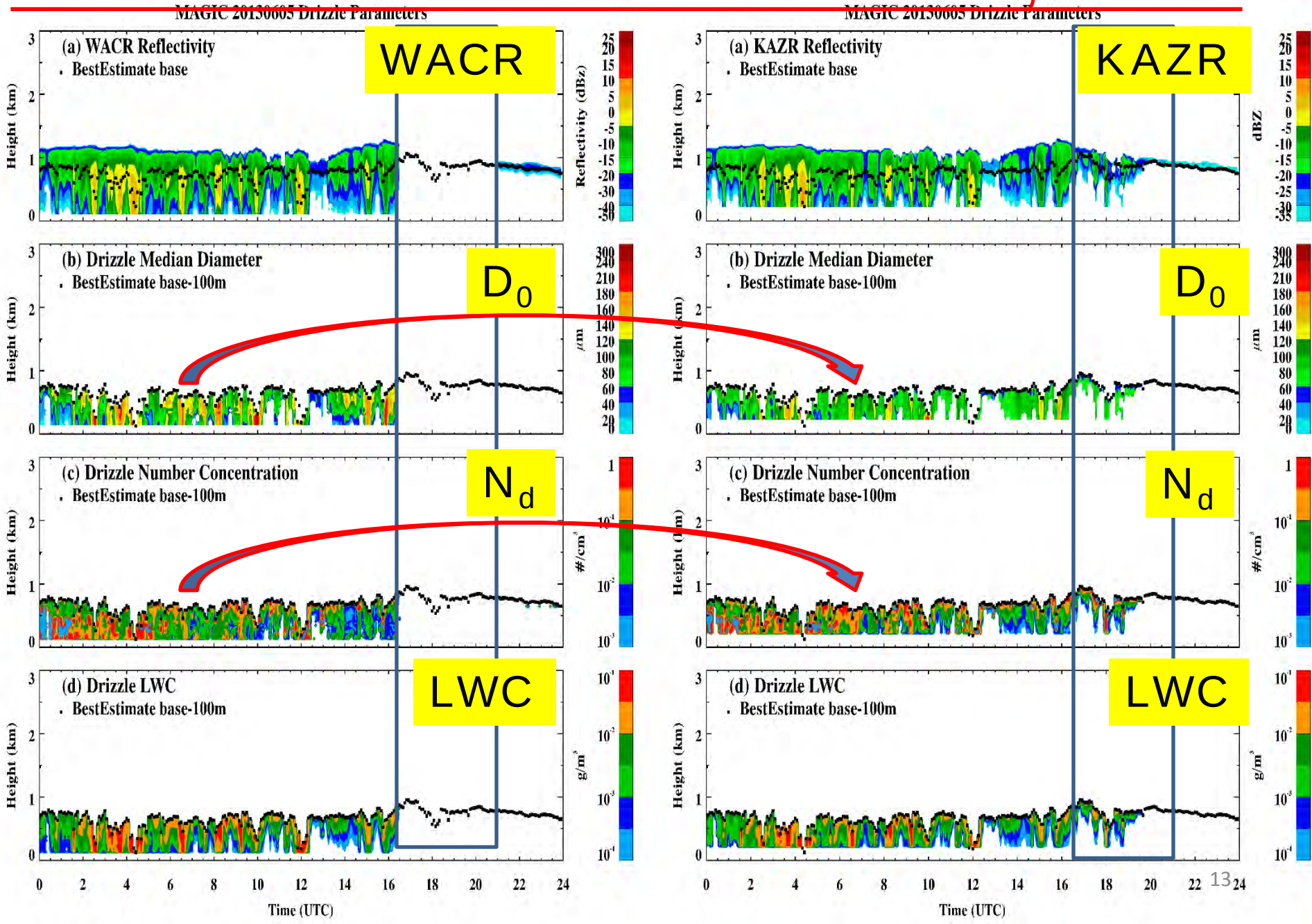


There are no significant differences between WACR and KAZR reflectivity, so do LWC.
There are slight differences for D_0 and N_d retrievals, possibly due to different sampling volumes between WACR and KAZR.

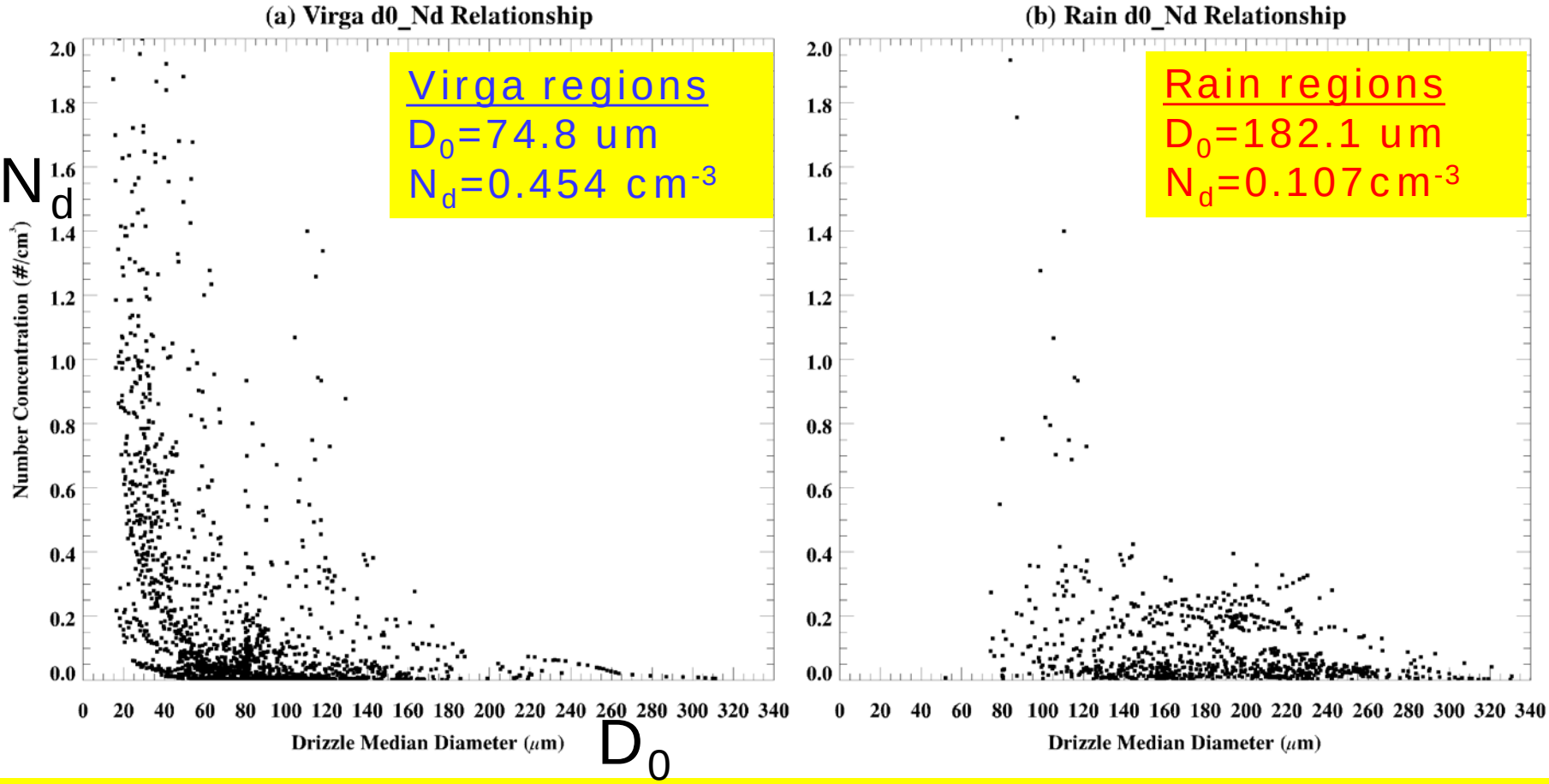
Similar retrievals for May 26, 2013



Similar retrievals for June 5, 2013



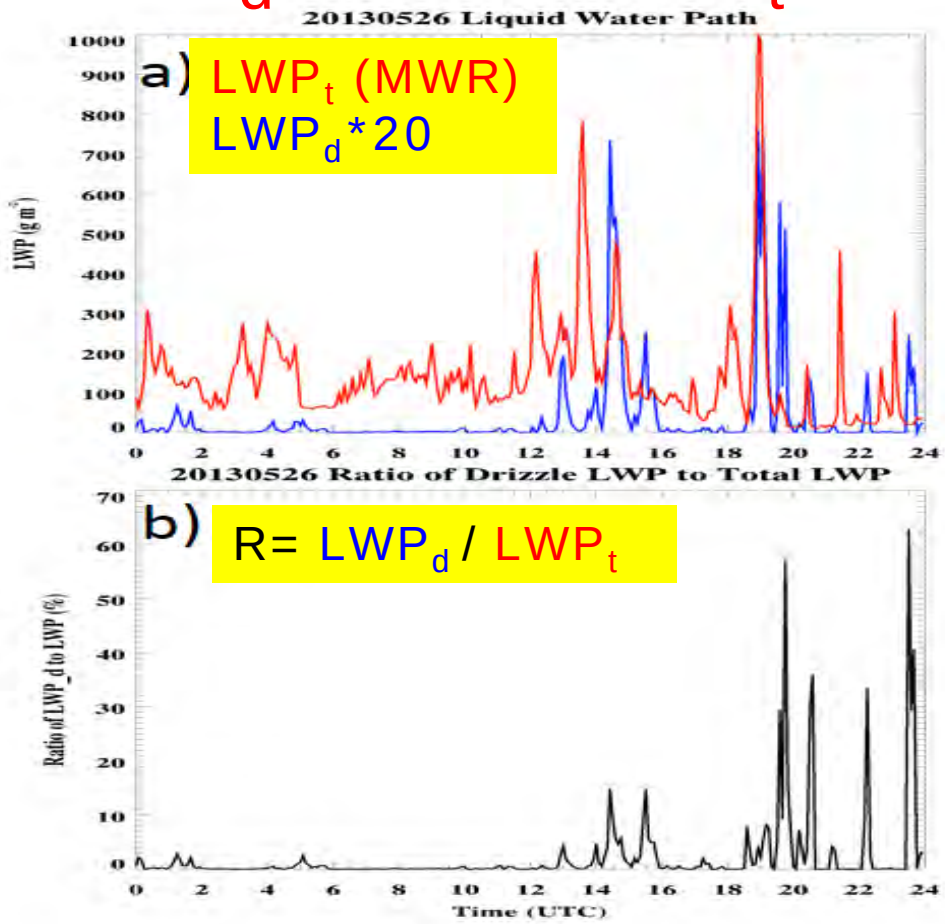
Statistics of D_0 and N_d retrievals based on WACR reflectivity

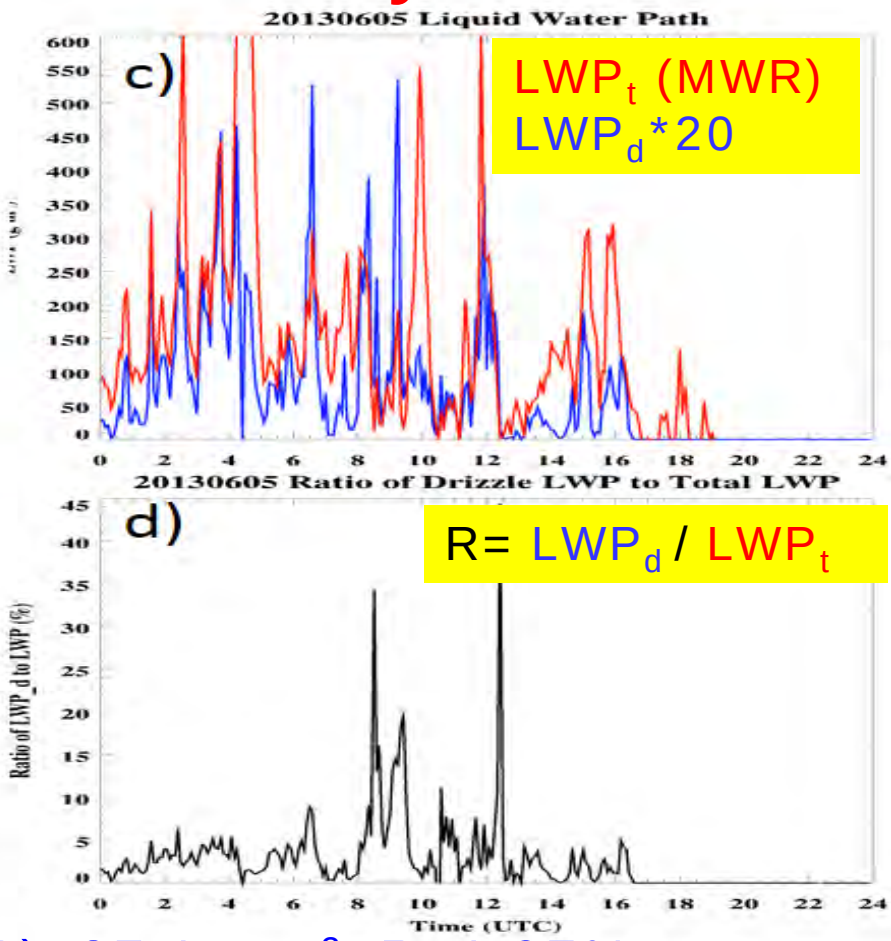


Averaged N_d in Virga is more than 4 times of N_d in Rain region, but its D_0 is only 41% of D_0 in Rain.

From KAZR retrieval, we got a similar relationship as WACR. mean D_0=82.7 um (virga), 185.4 (rain); N_d=0.392 cm^{-3}(virga), 0.1215 (rain)

Comparisons between calculated LWP_d and LWP_t retrieved by MWR





LWP_d(Virga)=1.71 gm^{-2}, LWP_t(MWR)=87.1 gm^{-2}, R=1.97%

LWP_d(Rain)=22.4 gm^{-2}, LWP_t(MWR)=252.9 gm^{-2}, R=8.86%

The LWP_d in Virga is usually less than 10% of LWP_t retrieved by MWR, however, it can be up 50% for some rain cases.

Summaries

- A total 14 Rain and 19 Virga Drizzle Cases have been selected by ARM WACR, KAZR, ceilometer and TSI during the MAGIC IOP.
- Particle size D_0, number concentration N_d, and LWC_d of drizzles have been retrieved using *O'Connor et al. (2005)* method for Virga and Rain Drizzle regions.
- The retrievals for Virga and rain regions are
  - $\overline{D_0}$ (Virga)=74.8um < $\overline{D_0}$ (Rain)=182.1um
  - $\overline{N_d}$ (Virga)=0.454 cm^{-3} > $\overline{N_d}$ (Rain)=0.103 cm^{-3}
  - $\overline{LWC}$ (Virga)=0.004 g m^{-3} <<$\overline{LWC}$ (Rain)=0.05 g m^{-3}
  - $\overline{LWP}$ (Virga)=1.71 g m^{-2} <<$\overline{LWP}$ (Rain)=22.4 g m^{-2}
  - Ratio (Virga)=1.97% << Ratio (Rain)=8.86%

Further work: Will do a similar study for Azores data, and compare the similarities and differences of drizzle properties between two IOPs.


WORLDVIEW
My Layers
Base Layers
Corrected Reflectance (True Color)
Terra / MODIS
Overlays
National Boundaries
SEDAC / National Boundaries
Fires (Day and Night)
Terra/ and Aqua/MODIS Fire and Thermal Anomalies
Thanks for your attention
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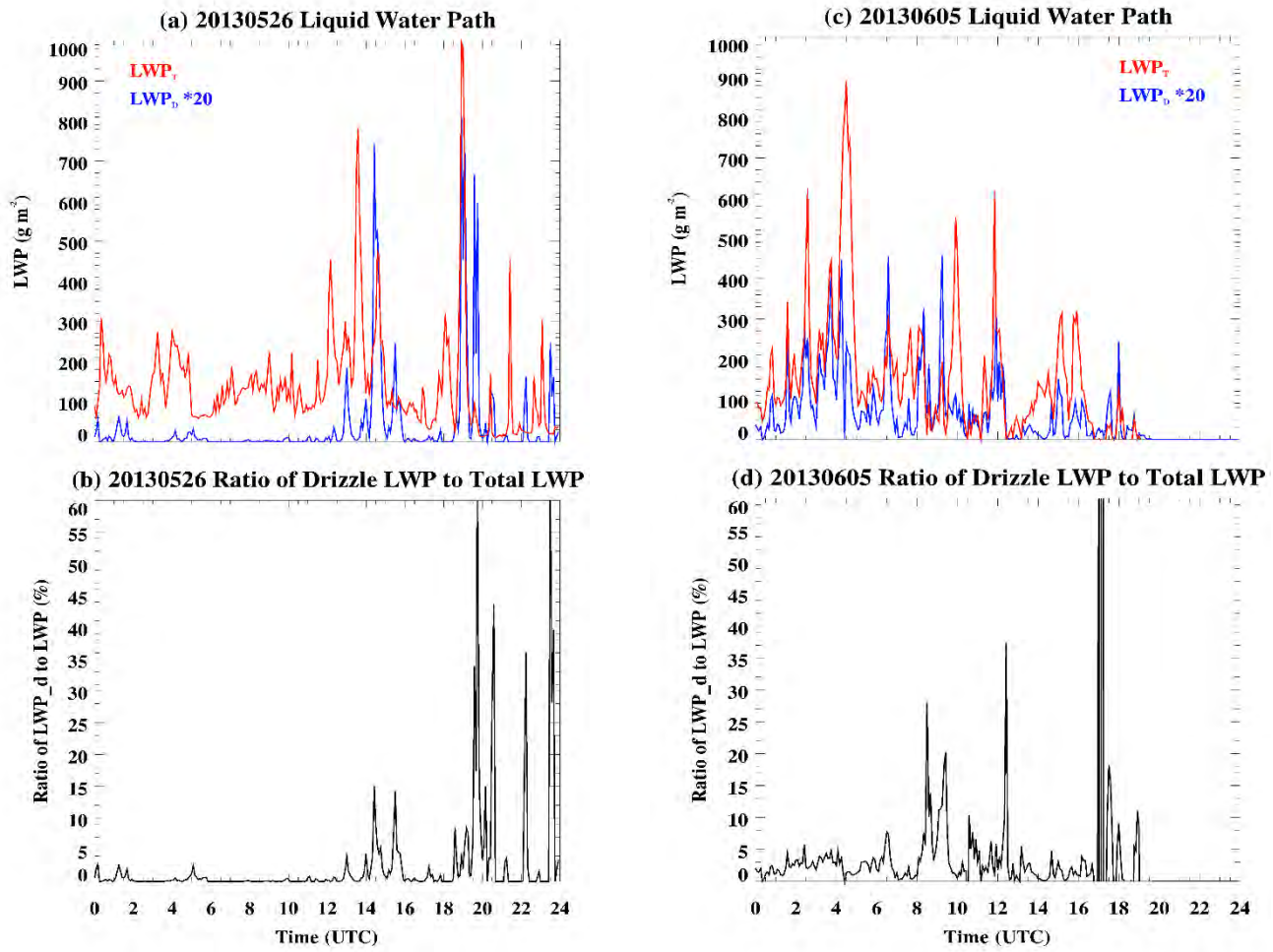
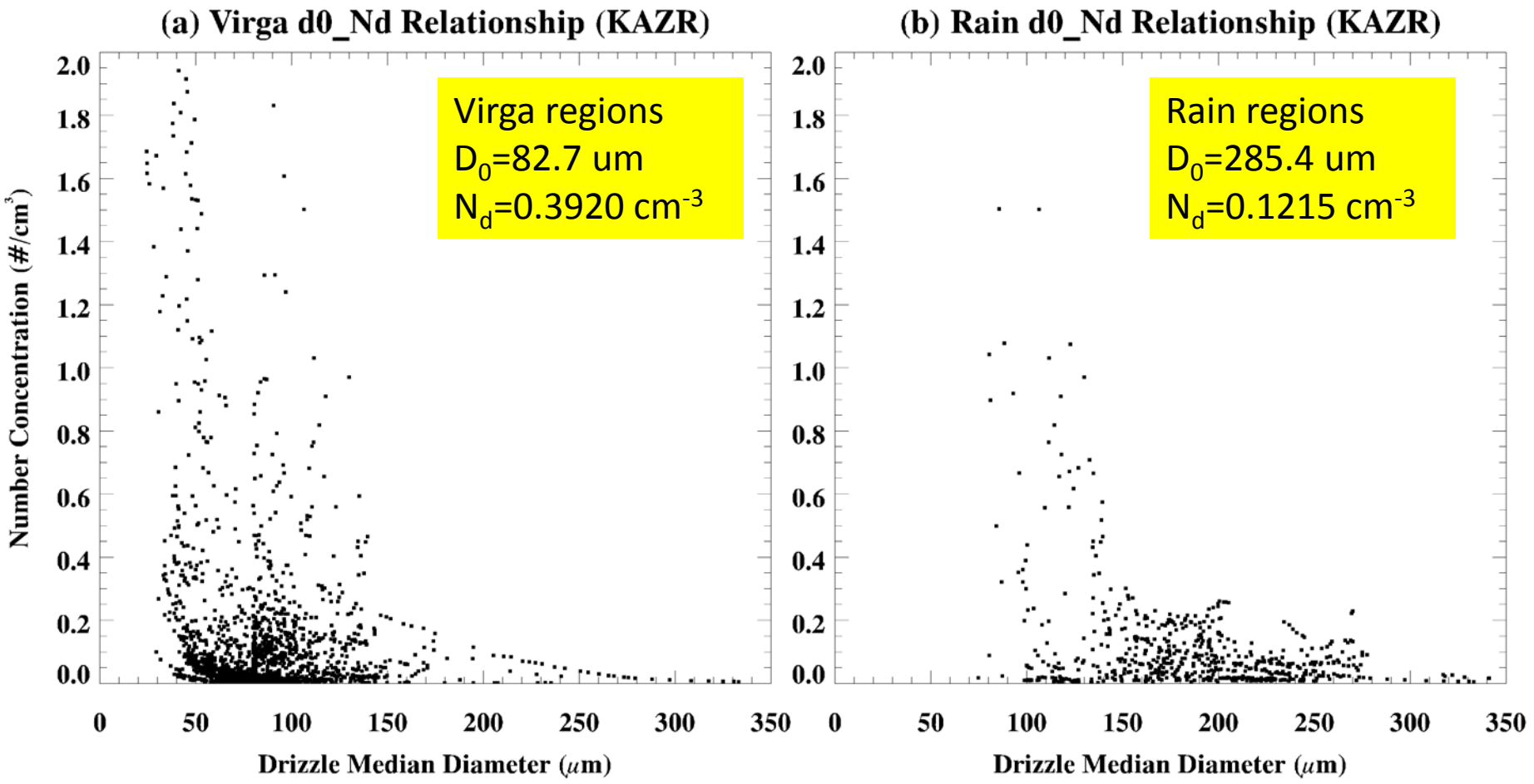
Results and Discussions



From KAZR

The LWP at drizzling regions is usually much lower than 10 % but it can be much higher if it is raining, which is consistent to our case selection for virga region and rain region


(a) Virga d0_Nd Relationship (KAZR)
(b) Rain d0_Nd Relationship (KAZR)
Number Concentration (#/cm^3)
Drizzle Median Diameter (μm)
Drizzle Median Diameter (μm)
Virga regions
D_0=82.7 um
N_d=0.3920 cm^{-3}
Rain regions
D_0=285.4 um
N_d=0.1215 cm^{-3}