Vertical Profiles of MBL Cloud Microphysical Properties during ACE-ENA

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Objectives

1) Under what conditions do CERES-MODIS (CM) and MODIS retrieve cloud-droplet effective radii (r_e) agree with aircraft and ARM surface retrievals (Non-drizzling and drizzling)?

2) Under what conditions CM and MODIS retrieved $r_e(3.7) > r_e(2.1)$, or vice versa? How do they compare with aircraft results?

Data sets during ACE-ENA IOP

When: June-July 2017 and Jan-Feb. 2018

Where: Over ARM ENA site (Azores)

Aircraft: (~160 hours)

FCDP → cloud droplets r_c ($2 < D < 50$ μm)

2DS-V → drizzle drops ($50 < D < 3000$ μm)

Combined r_e through both FCDP and 2DS-V

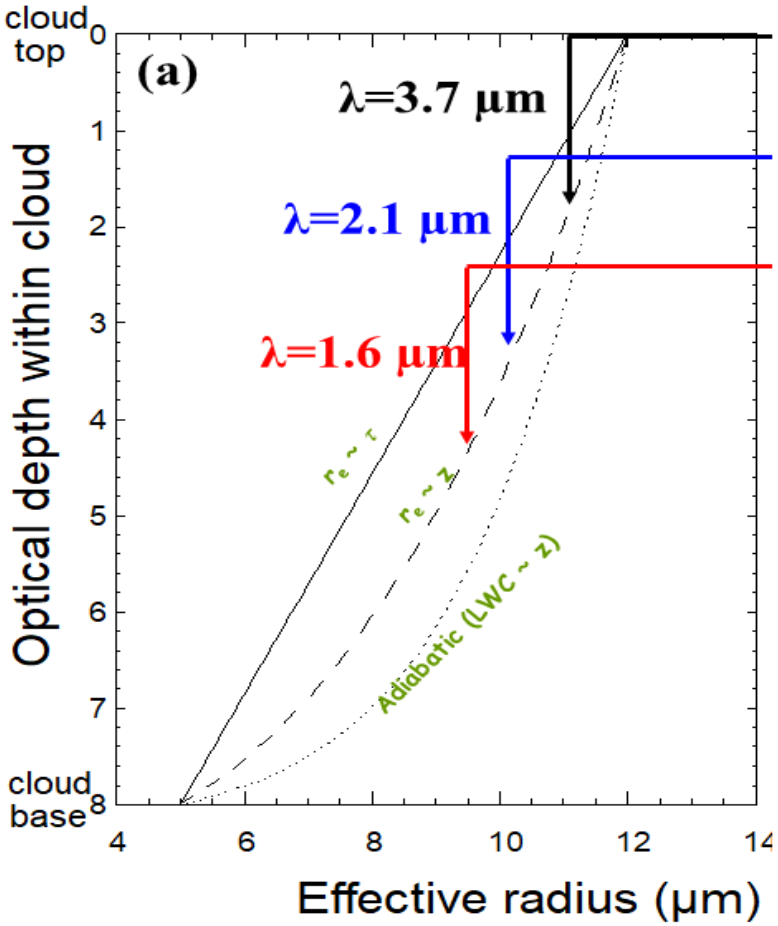
$$r_e = \frac{\sum n(r_i) r_i^3 dr_i}{\sum n(r_i) r_i^2 dr_i}$$

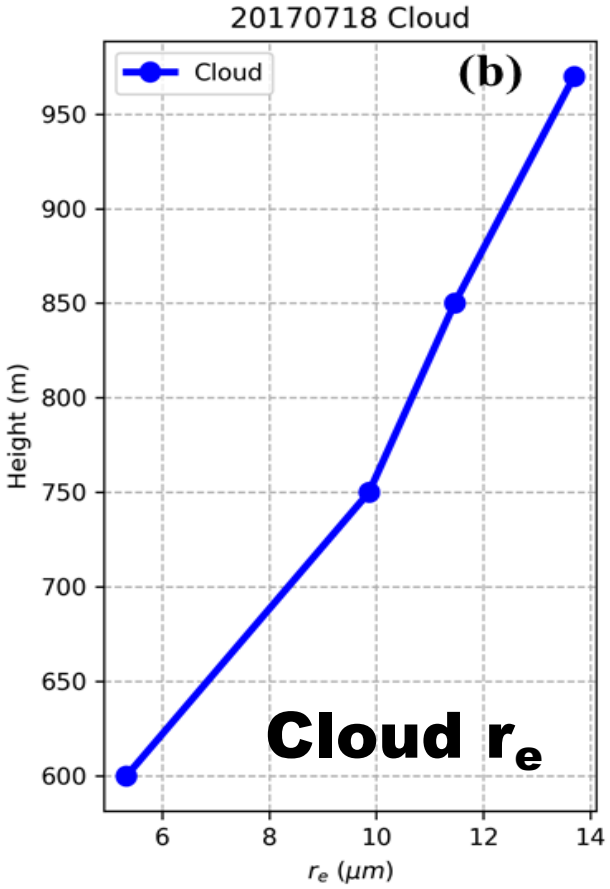
ARM layer-mean r_e: Retrieved from a RTM

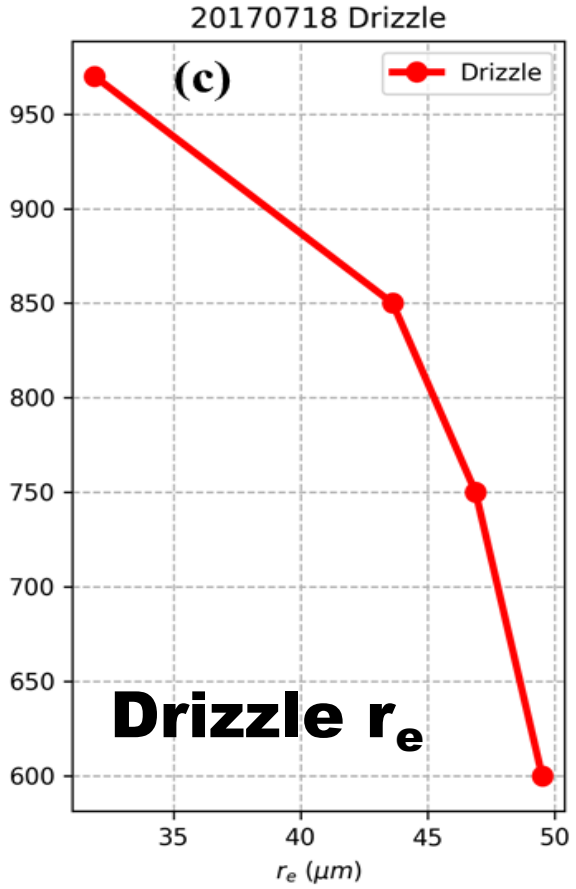
CM/MODIS: Pixel-level retrievals over a 30-km x 30-km grid box.

Motivation

Theoretically $r_e(3.7)>r_e(2.1)>r_e(1.6)$





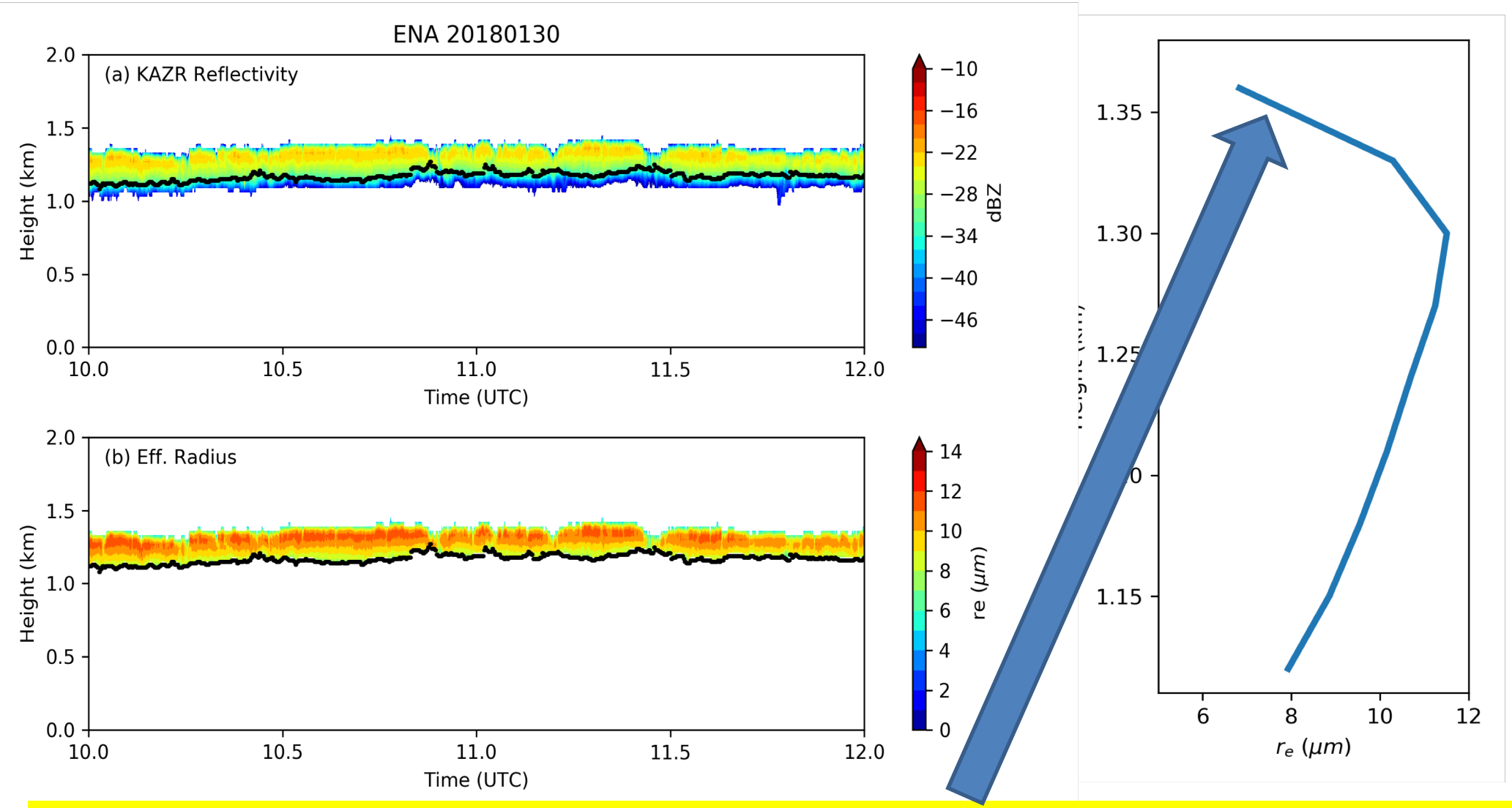


Cloud droplet **Drizzle drop**

Most of the MBL cloud microphysical properties follow adiabatic growth with height.

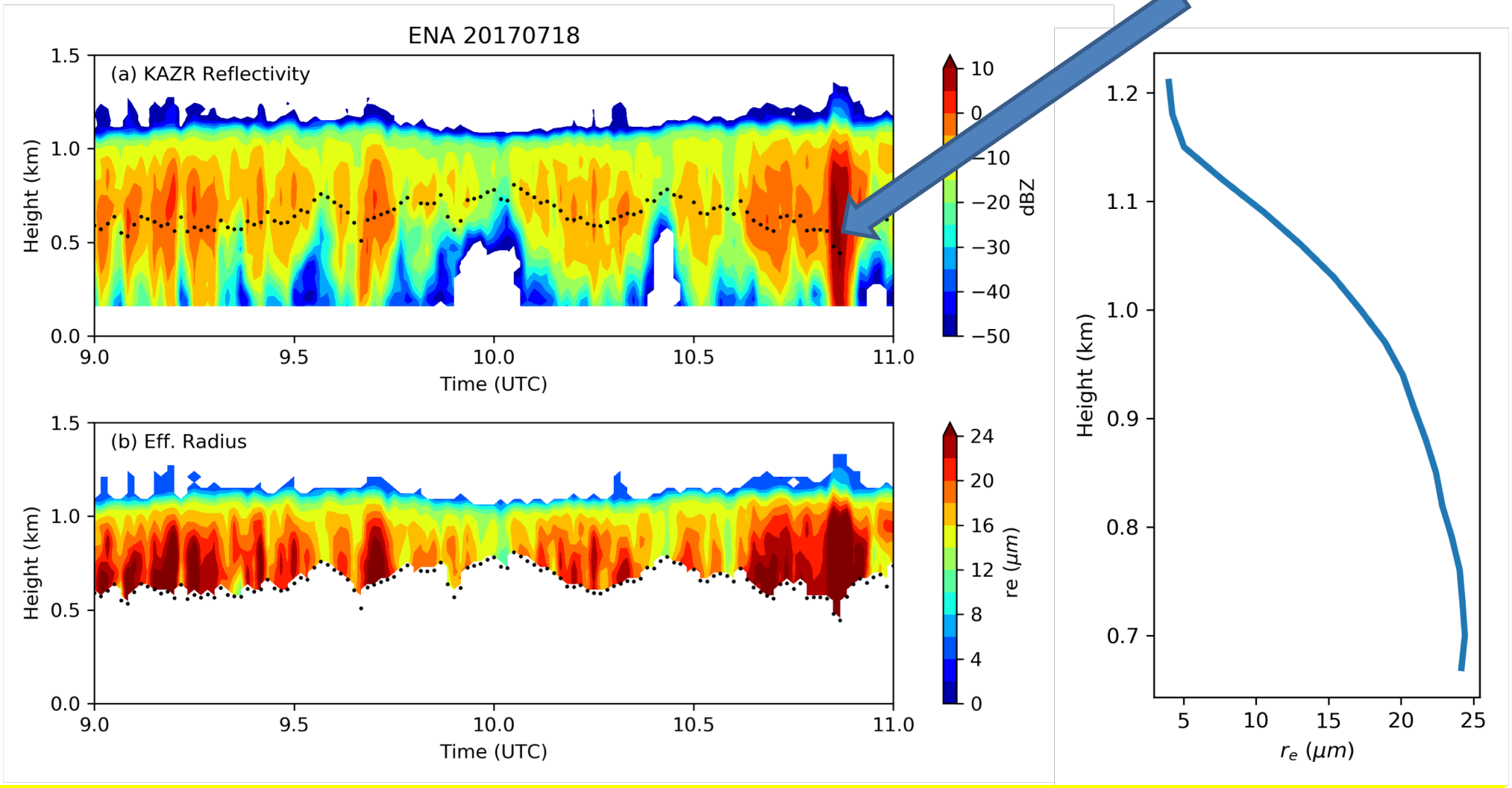
However, satellite retrievals often fail to record adiabatic growth, that is, $r_e(2.1) > r_e(3.7)$, primarily due to drizzle?

Vertical distribution of Ground-based measurements and retrievals: non-drizzling



For non-drizzling conditions, Reflectivity-retrieved r_e values increase from cloud base to about 2/3 of the cloud, then decrease up to the cloud top due to cloud-top entrainment.

Vertical distribution of Ground-based measurements and retrievals: drizzling



➔Radar reflectivity is ~ D^6, so a few large drizzle particles can make the reflectivity very large.

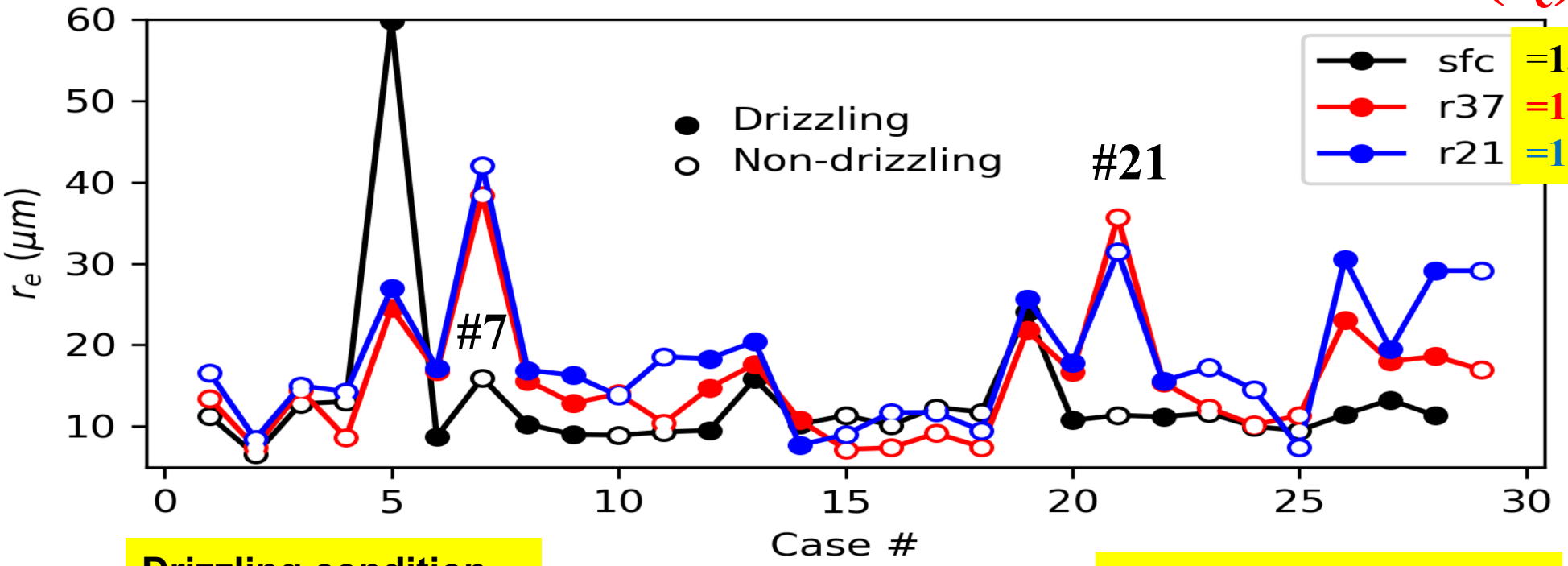
➔Reflectivity-retrieved r_e values decrease with height, opposite to adiabatic growth.

Outline

Part I: Comparison between CERES-MODIS and ground-based measurements and retrievals;

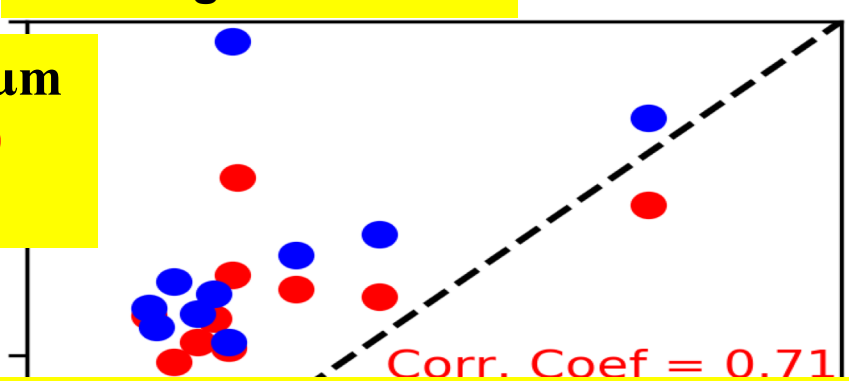
Part II: Comparison between CERES-MODIS and GSFC-MODIS with Aircraft in-situ measurements

Part I: CERES-MODIS vs. ARM surface (r_e)



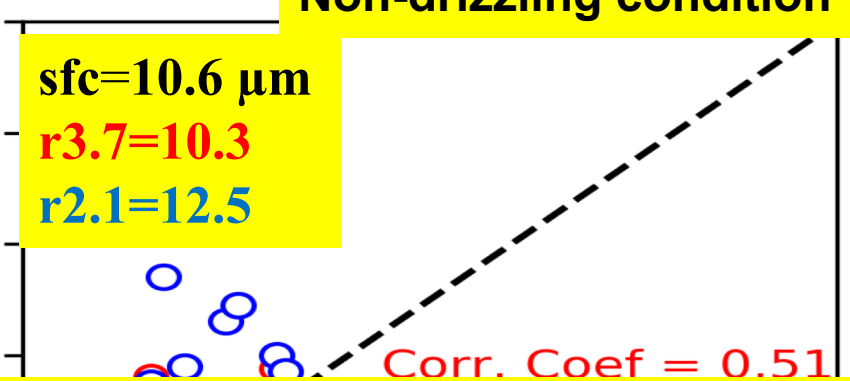
Drizzling condition

sfc=16.3 μm
r3.7=18.0
r2.1=21.2



Non-drizzling condition

sfc=10.6 μm
r3.7=10.3
r2.1=12.5



#7 and #21 are multi-layered clouds. All the means have excluded these cases.

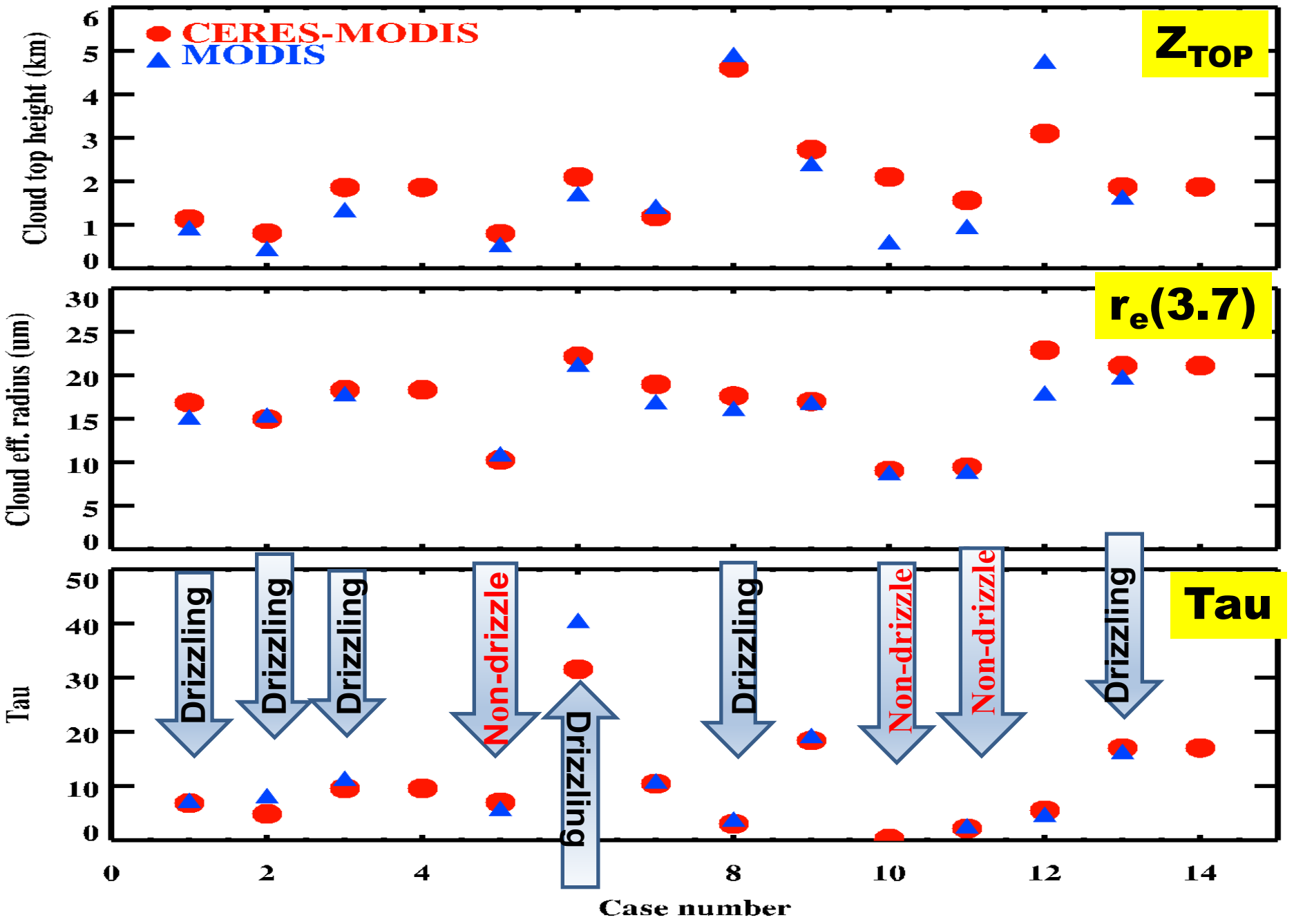
r_e(2.1) > r_e(3.7) for both non-drizzling and drizzling cases.

r_e(3.7) and r_e(2.1) under non-drizzling is much less than that under drizzling.

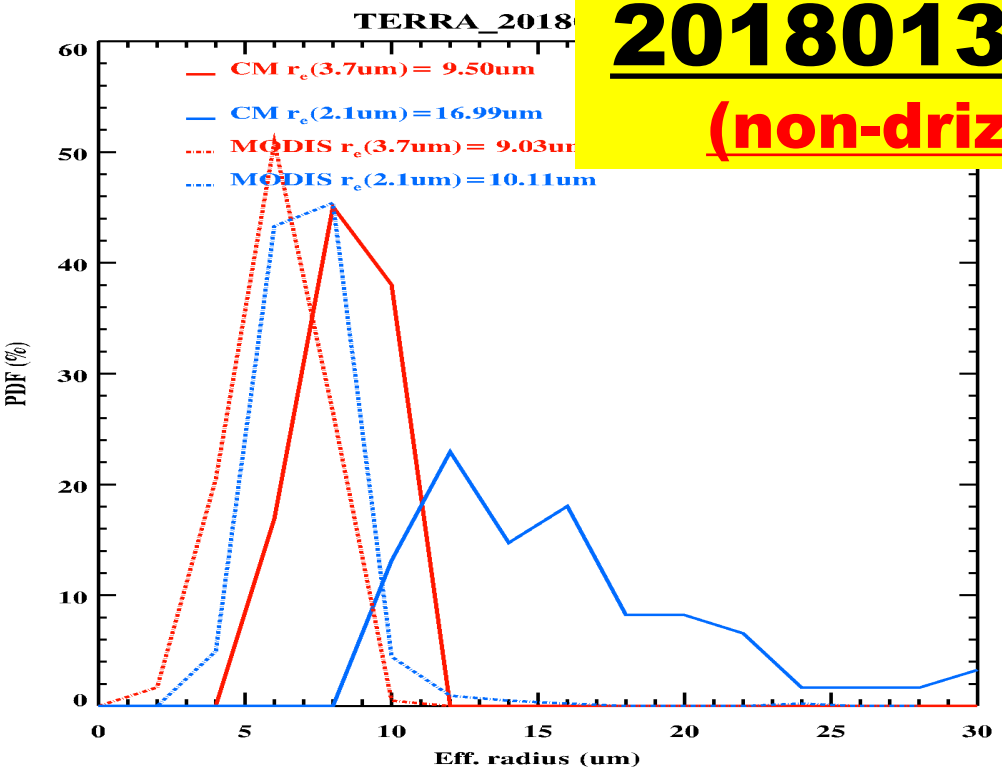
r_e(3.7) is close to ARM RTM retrieved r_e than r_e(2.1).

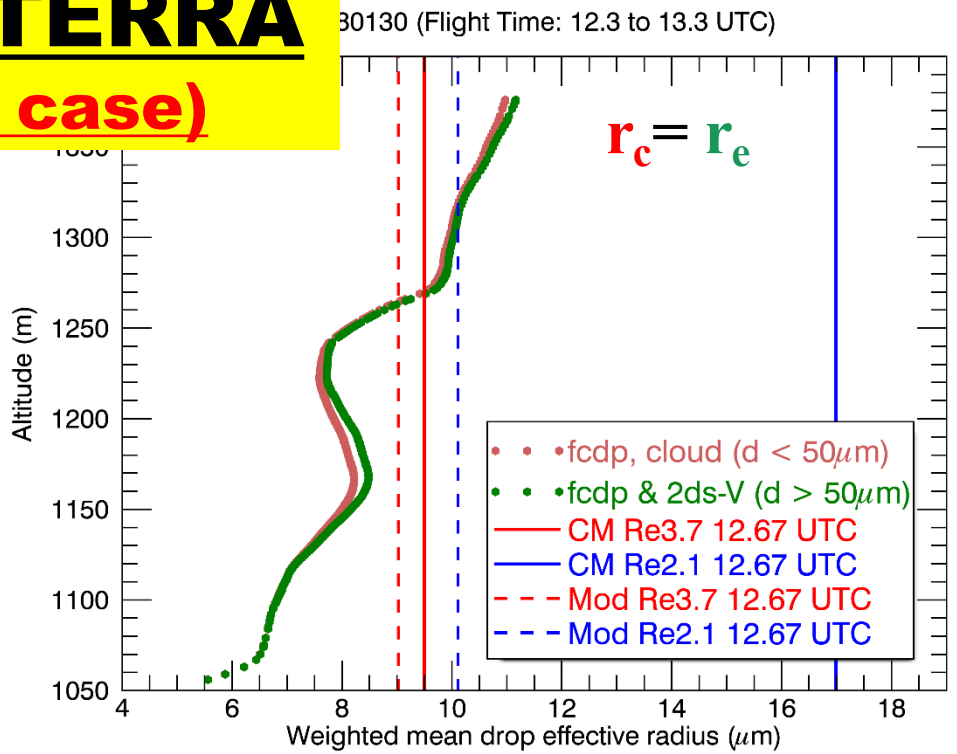
Part II CM/MODIS vs. Aircraft

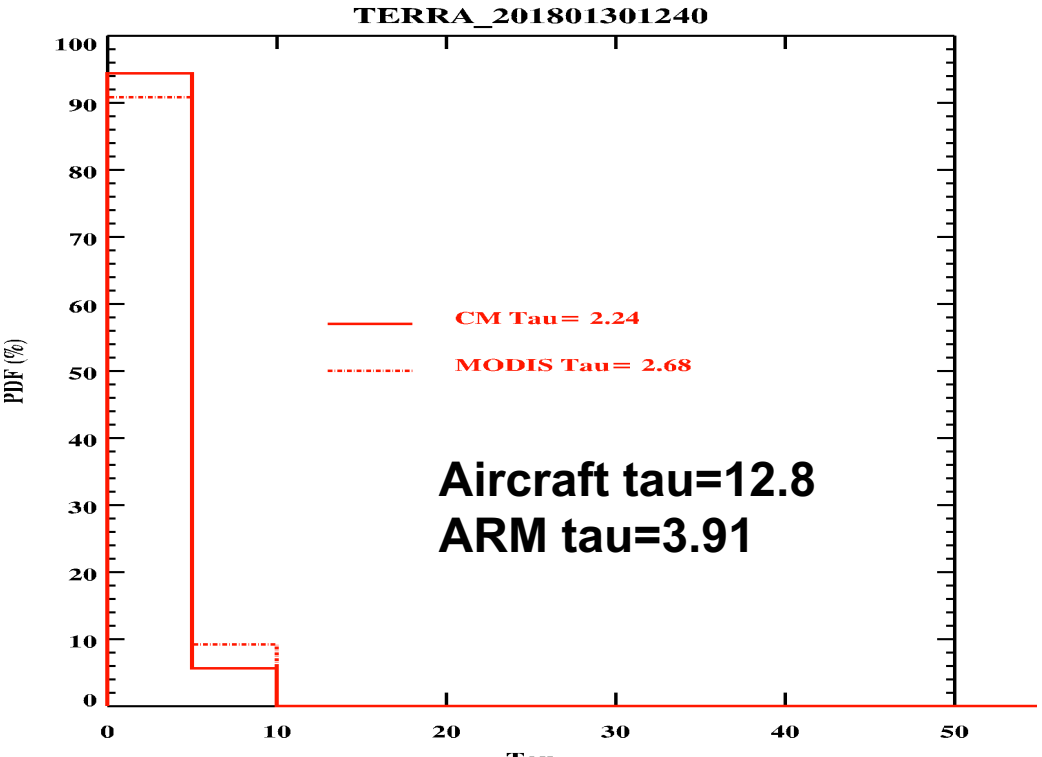
non-drizzle and drizzling



20180130 TERRA (non-drizzle case)





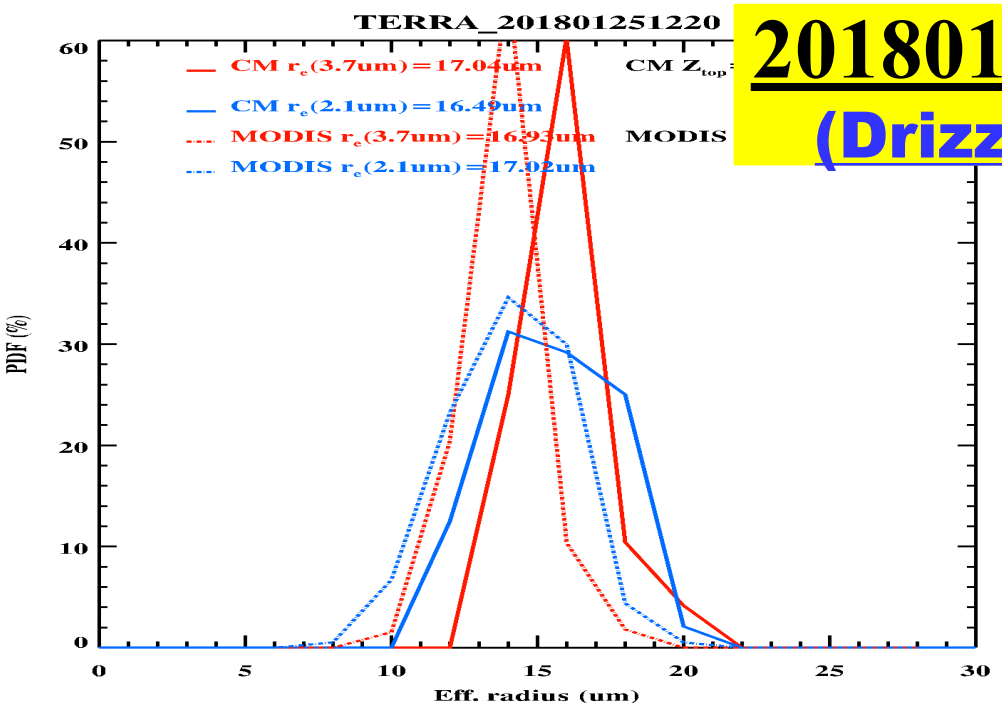


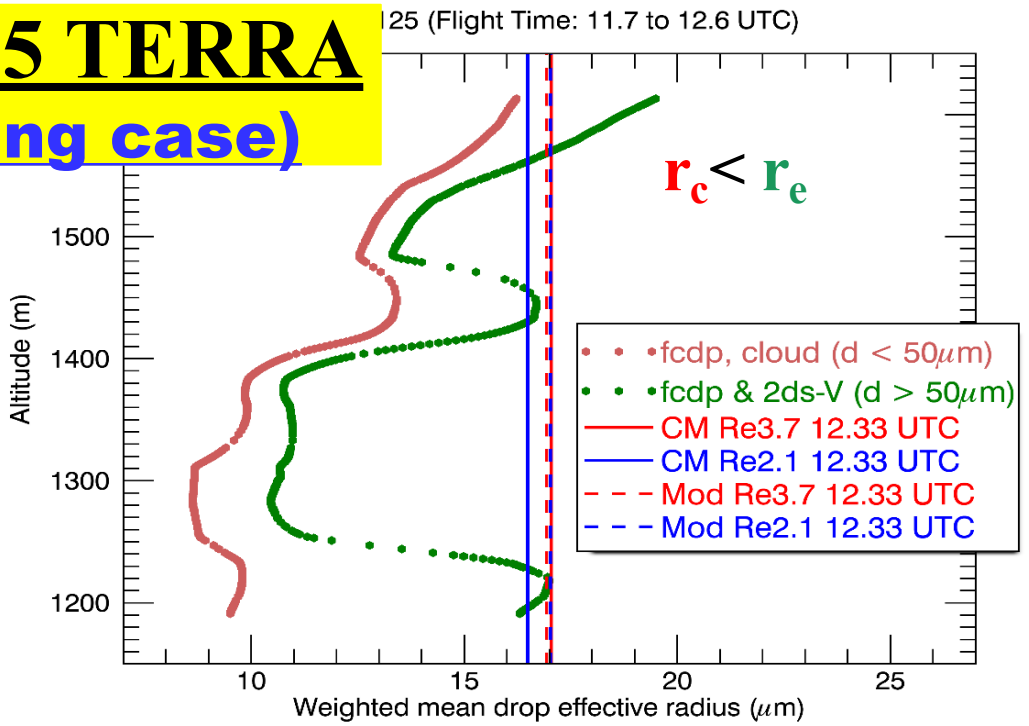
❖**Aircraft FCDP only measures cloud particles (D<50 μm), 2DS-V for drizzles (D>50 μm), combined r_e=FCDP+2DS-V. r_c ~ r_e, increases with height;**

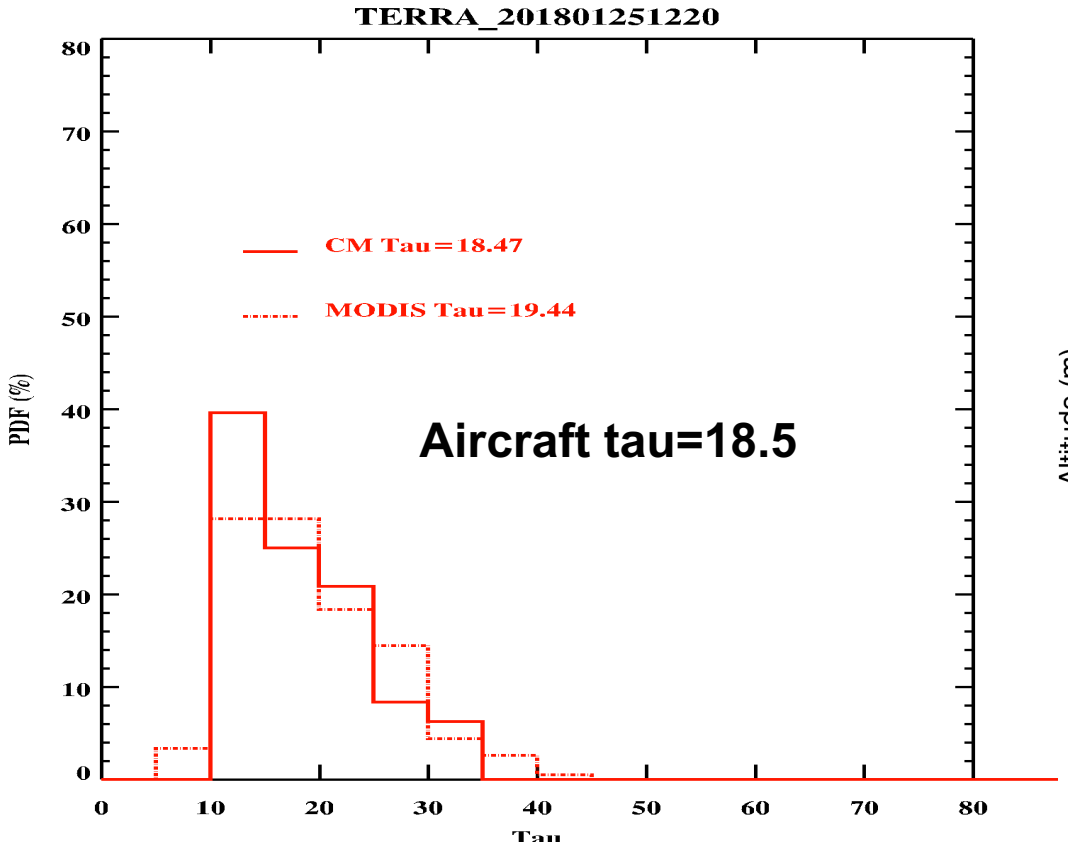
❖**Both CM r_e(3.7) and MODIS r_e(3.7 and 2.1) are close to upper layer of aircraft results;**

❖**r_e PDFs from CM and MODIS except for CM r_e(2.1) are also close to aircraft PDFs. However, CM r_e(2.1) are much larger than aircraft results probably due to optically thinner cloud (tau<4)**

20180125 TERRA
(Drizzling case)



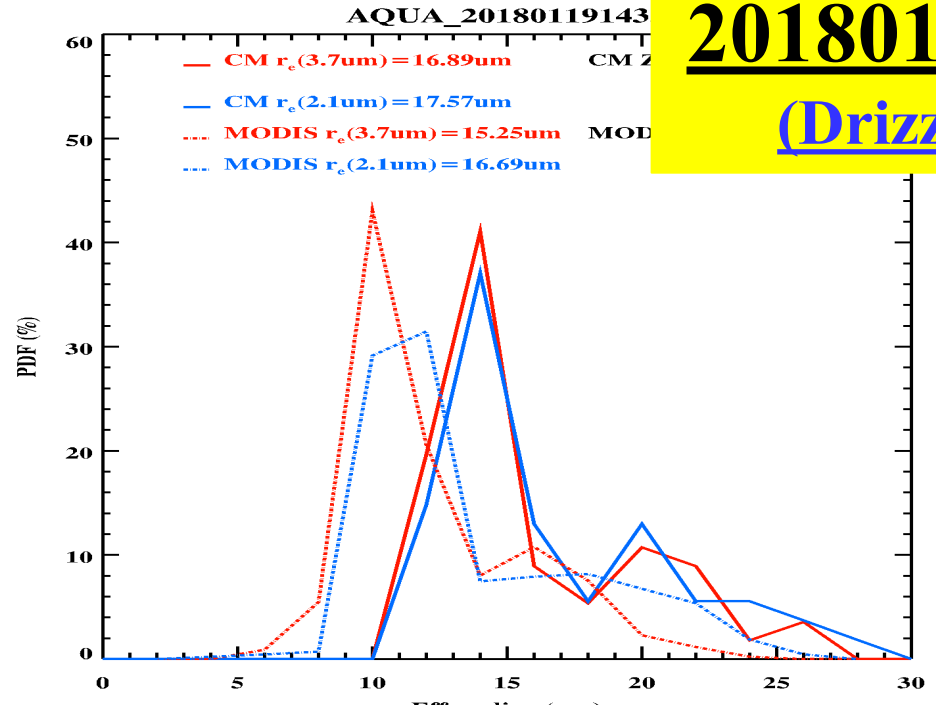


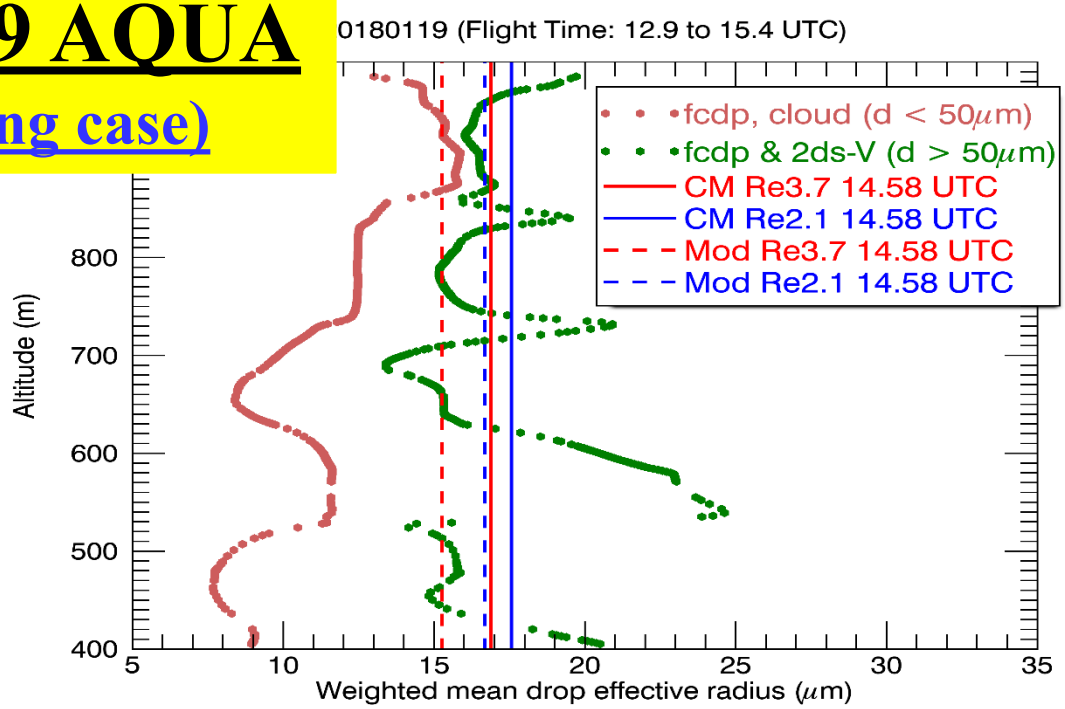


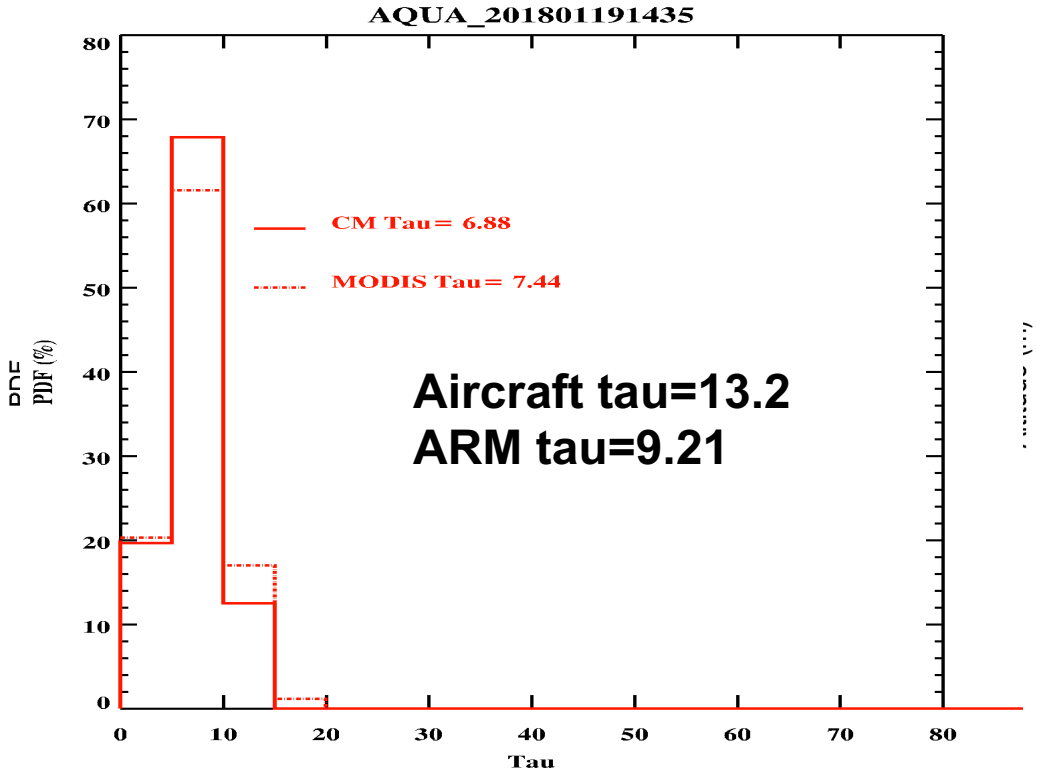
- Both cloud r_c and combined r_e increase with height;
- Both CM and MODIS r_e(3.7 and 2.1) fall between cloud r_c and combined r_e;
- PDFs from CM and MODIS r_e(3.7 and 2.1) are close to cloud PDF, but did not catch up large combined r_e.

20180119 AQUA

(Drizzling case)



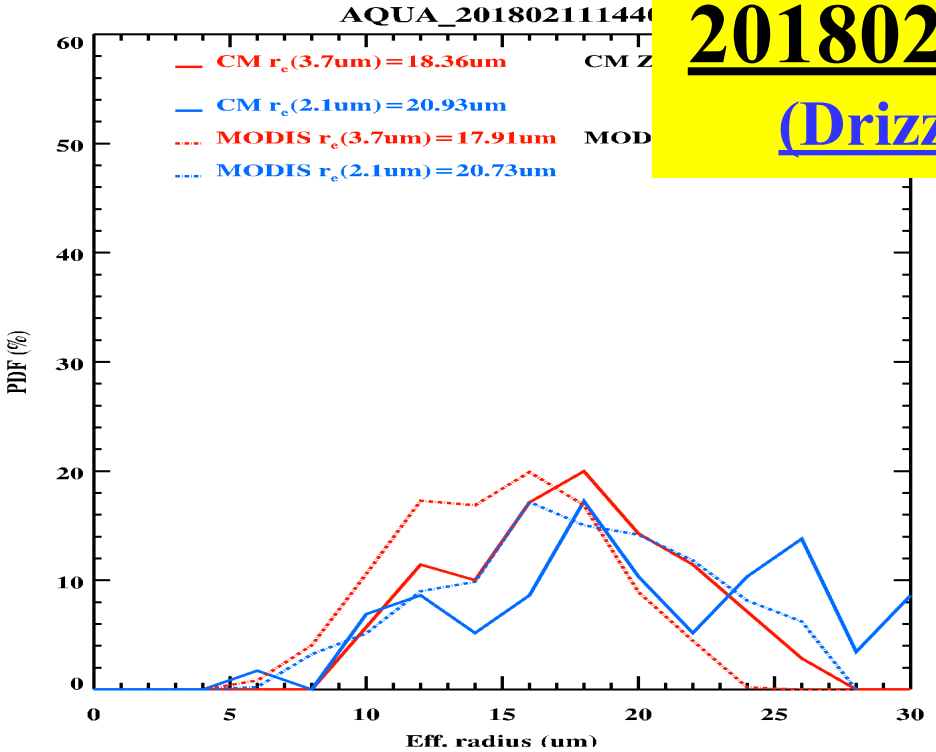


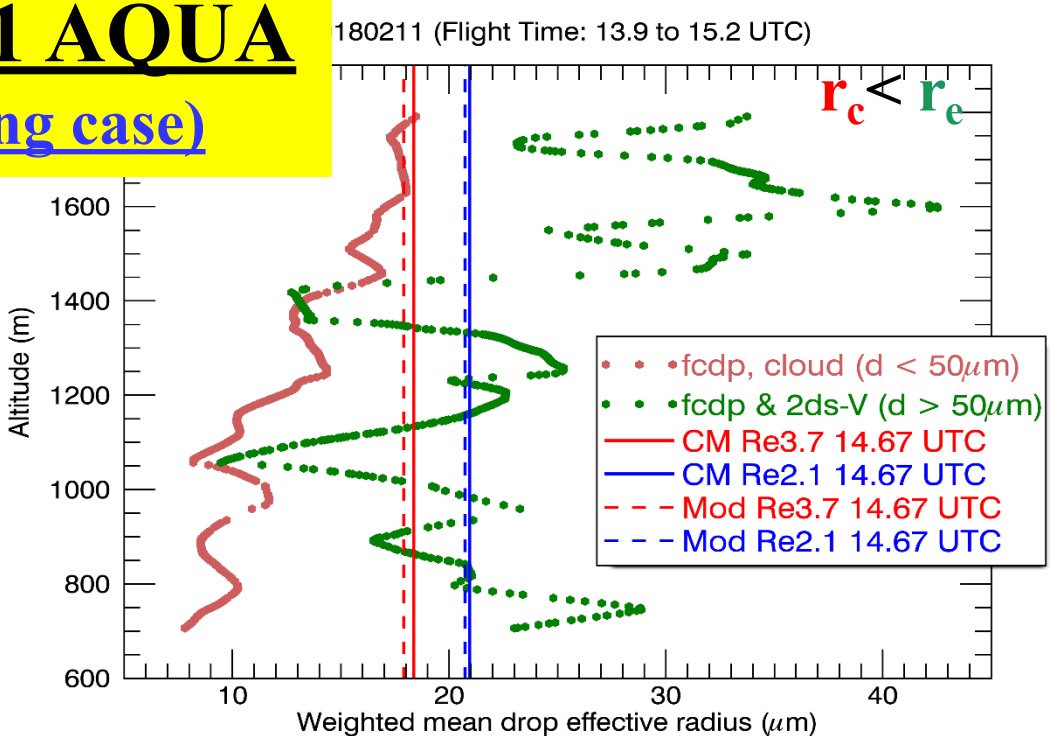


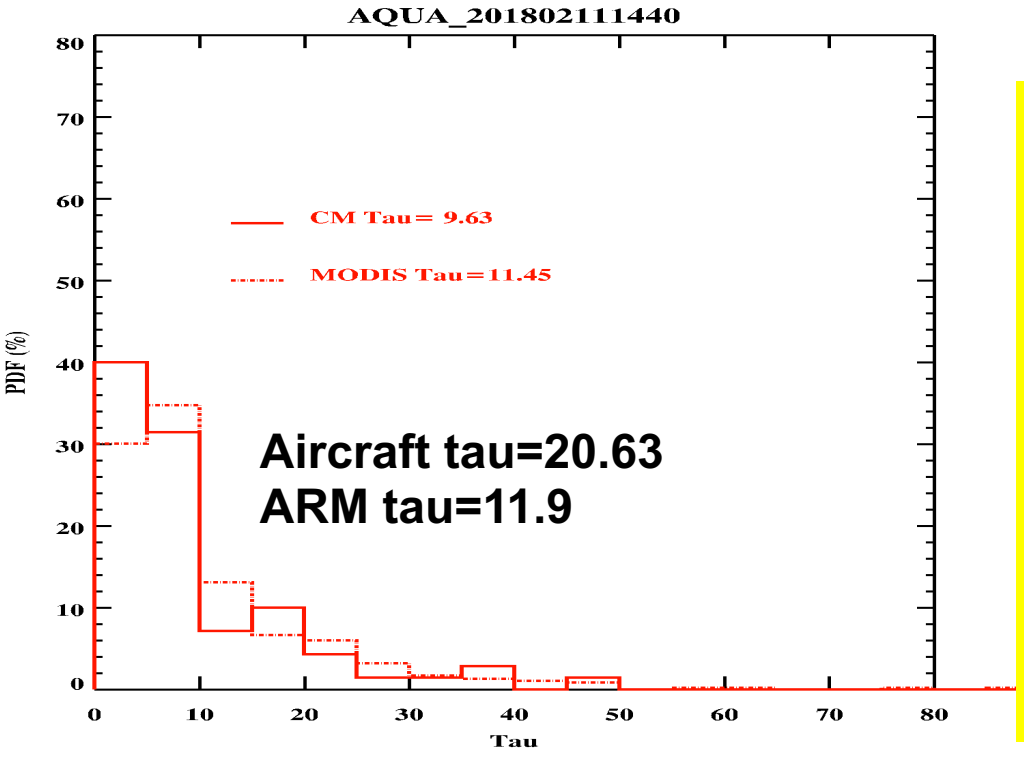
- r_c increases with height, but there are large r_e values at the lower part of the cloud;
- Both CM and MODIS r_e(3.7 and 2.1) fall between r_c and r_e;
- PDFs from CM r_e(3.7 and 2.1) have bi-model, which are similar to aircraft r_e PDF.

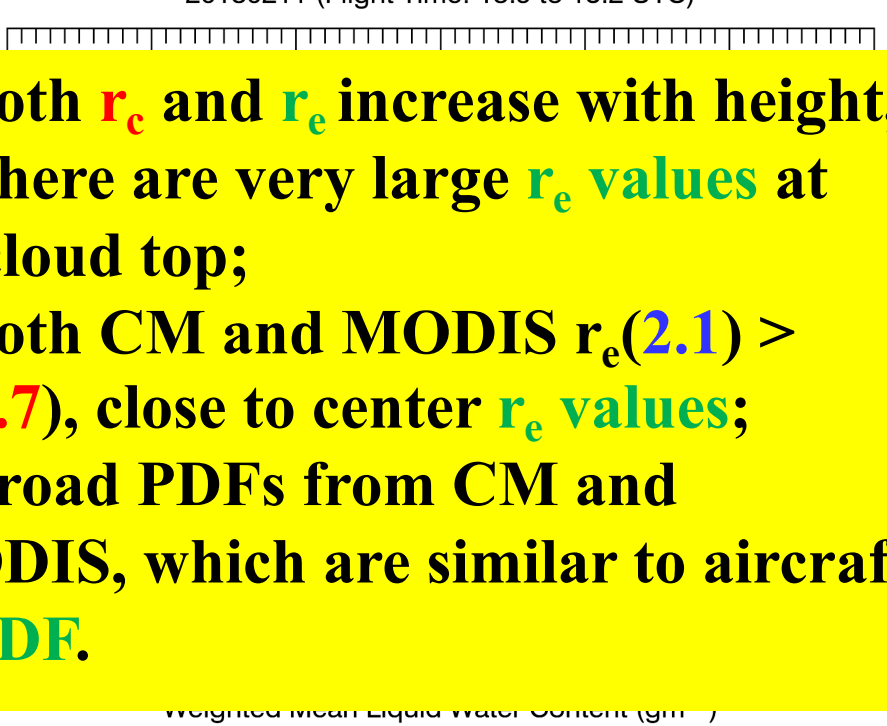
20180211 AQUA

(Drizzling case)





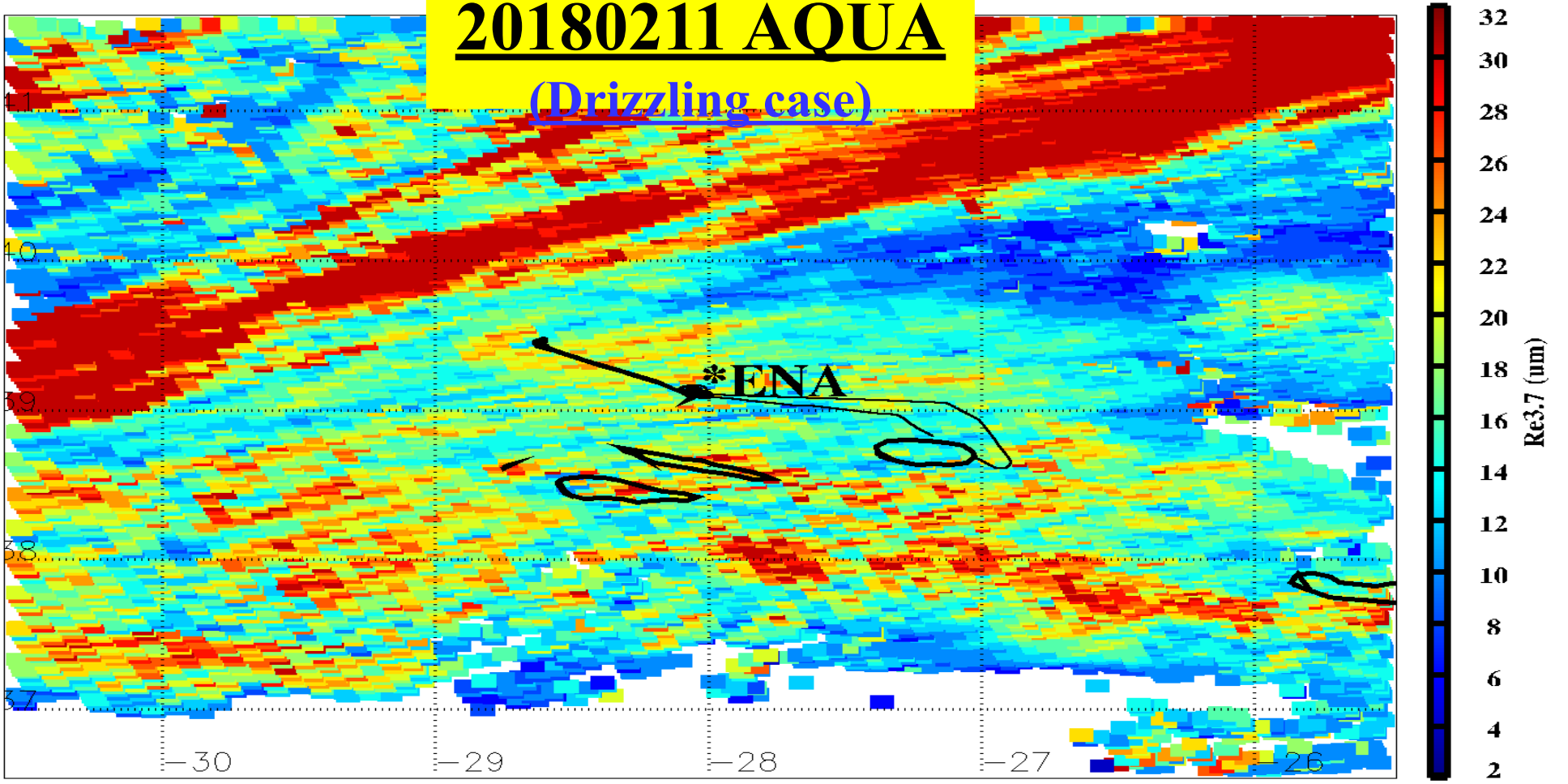




- **Both r_c and r_e increase with height, there are very large r_e values at cloud top;**
- **Both CM and MODIS r_e(2.1) > r_e(3.7), close to center r_e values;**
- **Broad PDFs from CM and MODIS, which are similar to aircraft r_e PDF.**

20180211 AQUA

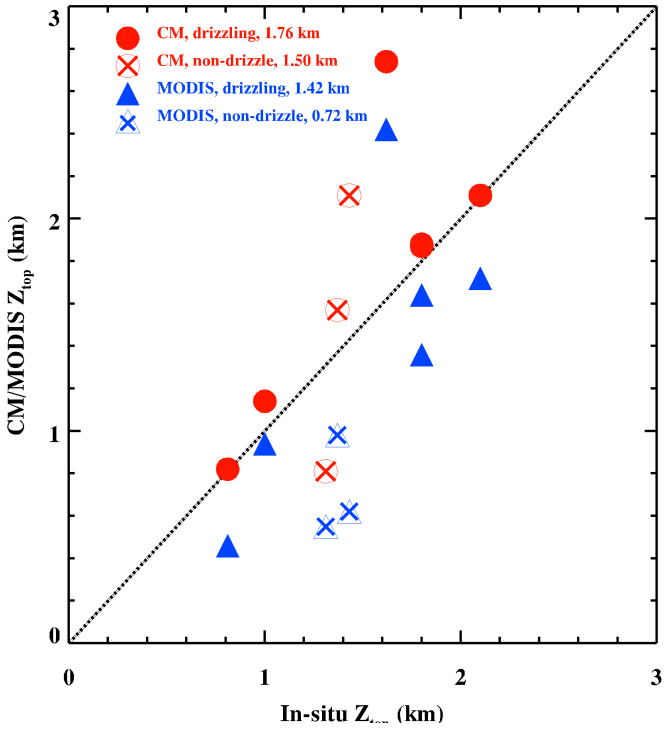
(Drizzling case)



This is one of the closest measurements among three platforms (satellite, ground-based, and in-situ). The results are summarized below:

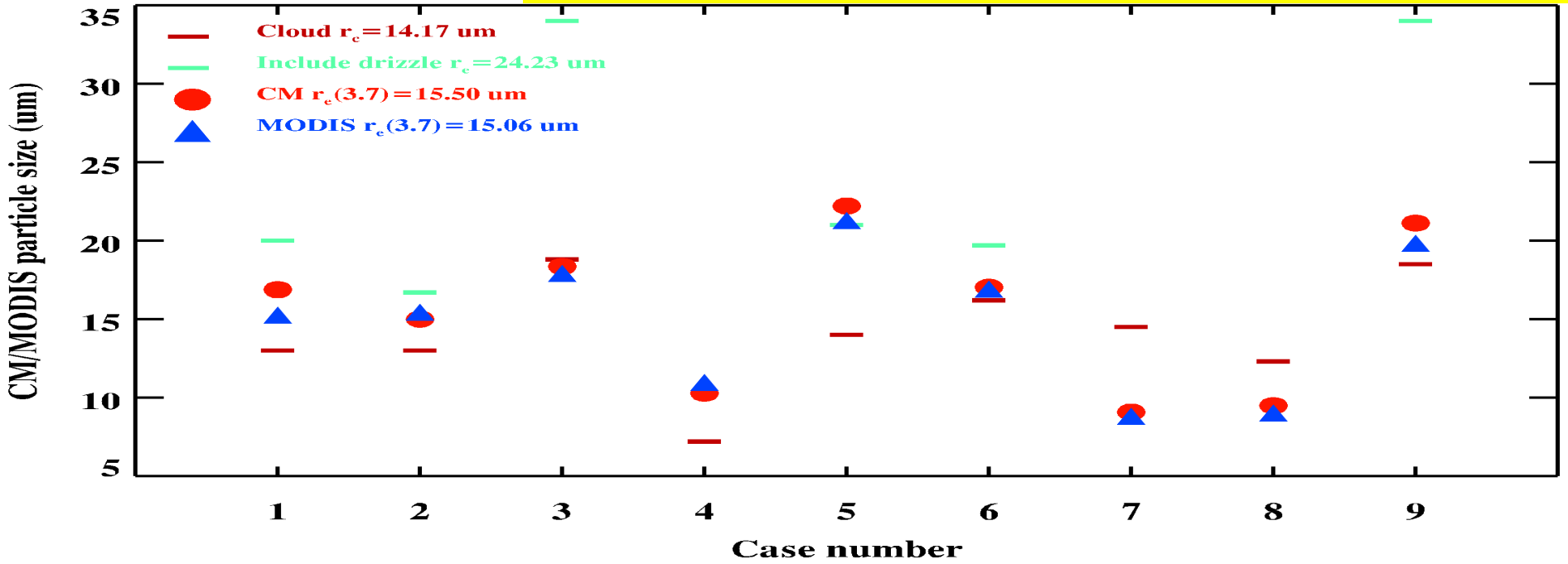
	Grand-based	In-situ	CERES-MODIS	MODIS
Z_{top}, km	1.84	1.80	1.87	1.36
$r_e/r_c/r_e(3.7)$, um	15.81	18.0	18.4	17.9
$/r_e/r_e(2.1)$, um		34.0	20.9	20.7

Summary of all 9 cases that have aircraft in-situ measurements



For non-drizzling: CM Z_{top} agree well with in-situ measurements with mean Z_{top}(1.37km); For drizzling, the CM Z_{top} is higher than in-situ Z_{top}(1.52km); The MODIS Z_{top} are lower than in-situ Z_{top};

Both CM and MODIS r_e(3.7 um) fall between cloud r_c and combined r_e at cloud top for drizzling cases.



Summaries:

✓ *Part I: CERES-MODIS vs. ARM ground-based retrievals:*

- **Non-drizzling cases: r_e(3.7) is closer to ARM retrieval than r_e(2.1).**
- **Drizzling cases: Both r_e(3.7) and r_e(2.1) are greater than ARM RTM retrievals.**

✓ *Part II: CM/MODIS vs. Aircraft in situ results:*

- **Non-drizzling cases: Both CM and MODIS r_e(3.7) are close to the upper layer of aircraft measurements, however, CM r_e(2.1) are always larger than aircraft results.**

For some cases, CM r_e(2.1) retrievals are much larger, which may associate to optically thinner clouds (tau<4).

- **Drizzling cases:**

❖**Both cloud r_c and combined r_e increase with height.**

❖**Both CM and MODIS r_e(3.7 and 2.1) fall between cloud r_c and combined r_e near cloud top values.**

❖**Broad PDFs from CM r_e(3.7 and 2.1), are similar to aircraft r_e PDF.**