Validation of Satellite retrieved Marine low-level cloud properties using ARM AZORES Results

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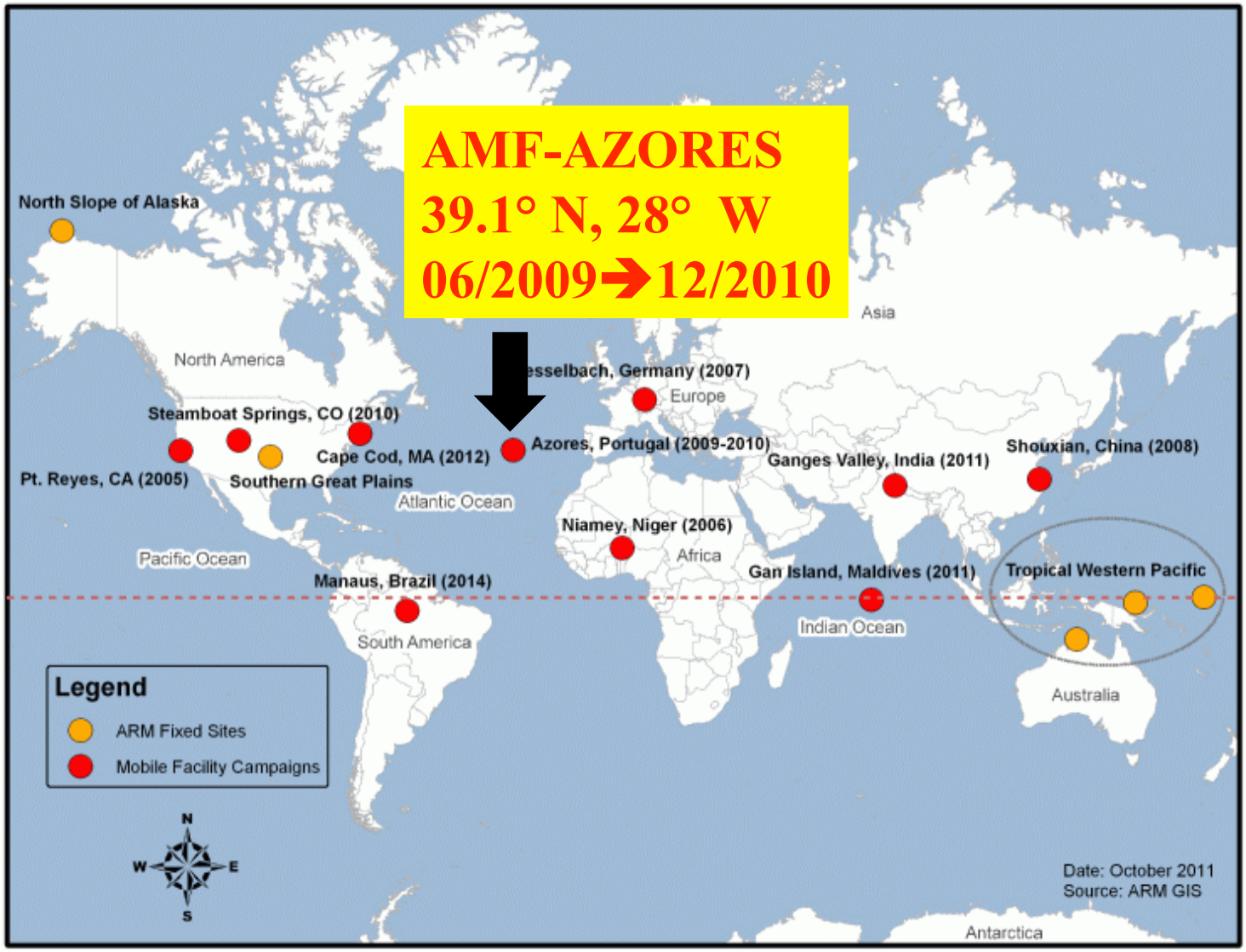
and Yan Chen, NASA LaRC


AMF-AZORES
39.1° N, 28° W
06/2009➔12/2010
North Slope of Alaska
North America
Asia
Europe
esselbach, Germany (2007)
Steamboat Springs, CO (2010)
Cape Cod, MA (2012)
Azores, Portugal (2009-2010)
Pt. Reyes, CA (2005)
Southern Great Plains
Atlantic Ocean
Ganges Valley, India (2011)
Shouxian, China (2008)
Niamey, Niger (2006)
Africa
Pacific Ocean
Manaus, Brazil (2014)
Gan Island, Maldives (2011)
Tropical Western Pacific
Indian Ocean
South America
Australia
Legend
ARM Fixed Sites
Mobile Facility Campaigns
N
W
E
S
Date: October 2011
Source: ARM GIS
Antarctica

Three Objectives

1. Compare Meteosat & ARM AZORES Radar-MWP retrievals (low-level clouds), CERES new GEO product

- Cloud heights/temperatures
- Effective radius/LWP/optical
- Day and night

2. Compare CERES-MODIS & ARM (for low-level clouds)

- Cloud heights/temperatures
- Effective radius/LWP/optical
- Day and night

3. Compare CERES-MODIS & ARM (Multilayered clouds)

- ARM radar measured highest cloud top, CERES/MODIS retrieved ice top;
- ARM radar-lidar measured lowest cloud base with CERES/MODIS retrieved water base.

Data and Methods

Surface

- Height/Temp: WACR/MPL/ Ceilometer & Merged soundings
- re/LWP/tau 1-hr average:
  - a. Day algorithm –

    Dong et al 1998, *Dong& Mace* 2003
  - b. Night algorithm-

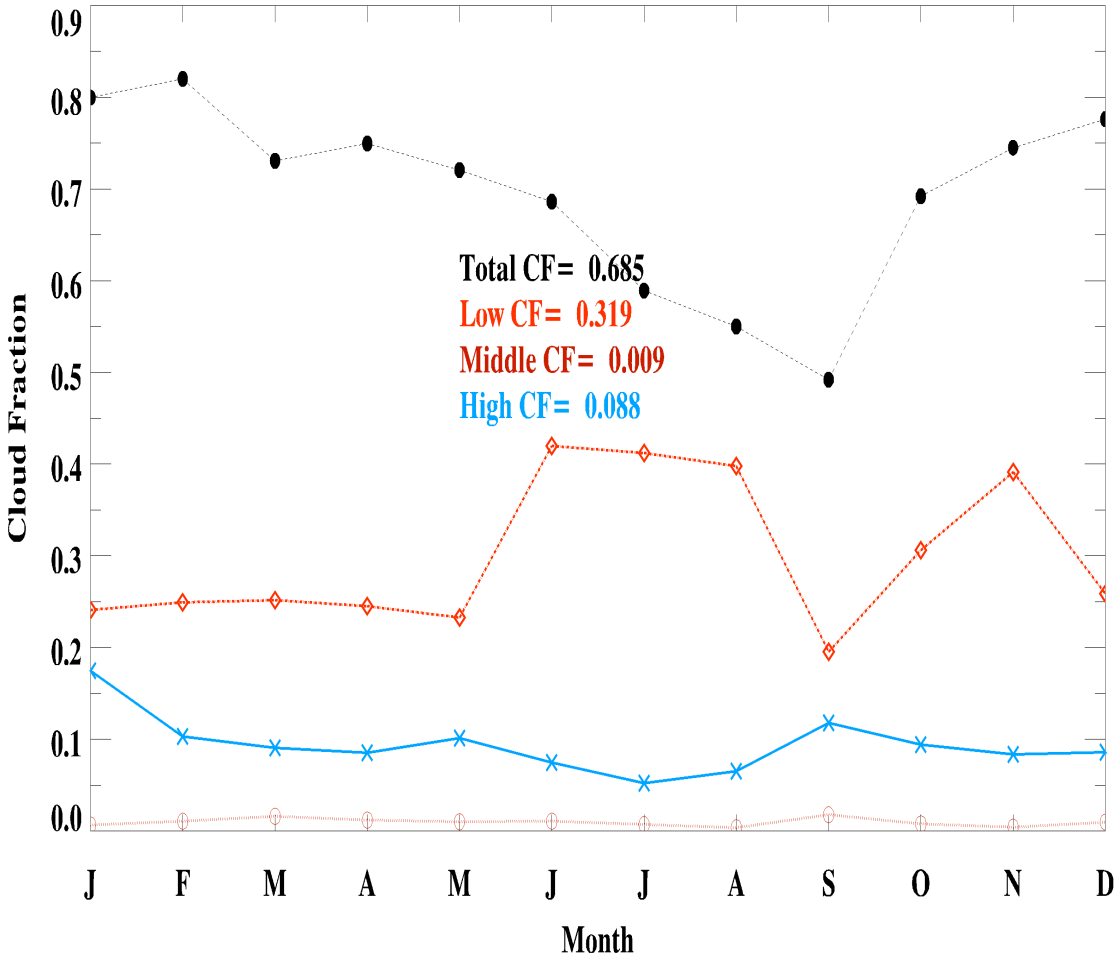
    Dong & Mace 2003 (radar reflectivity+LWP)

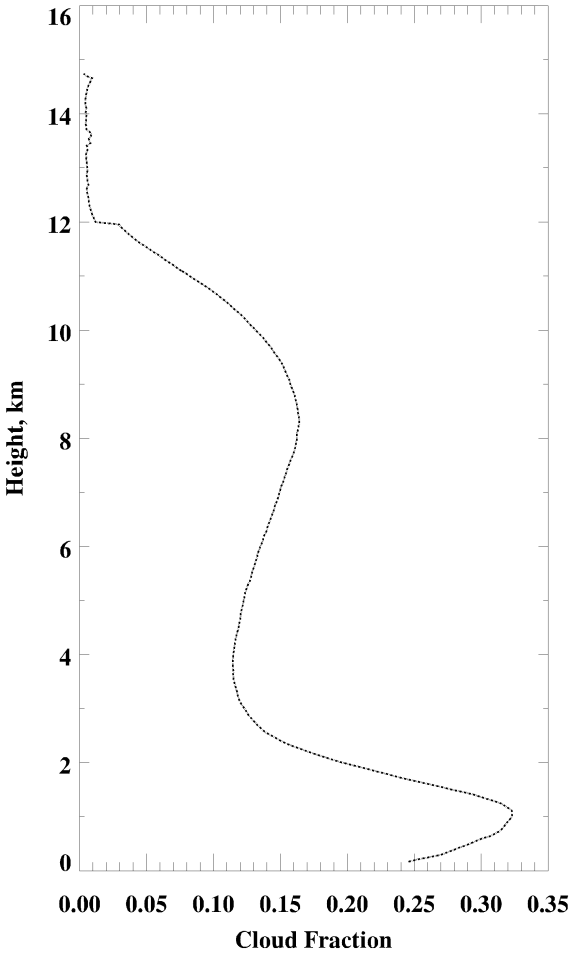
Satellite

- Algorithms, Ed4 versions:
  - day: VISST
  - night: SIST

  (*Minnis et al.*, 2011; *Sun-Mack et al.*, 2012)
- Area centered on ARM site
  - a. Meteosat: 20-km radius
  - b. CERES-MODIS, 30 km box

Why we chose Low-level clouds for this study



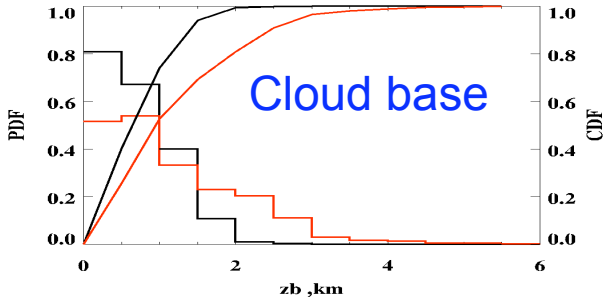


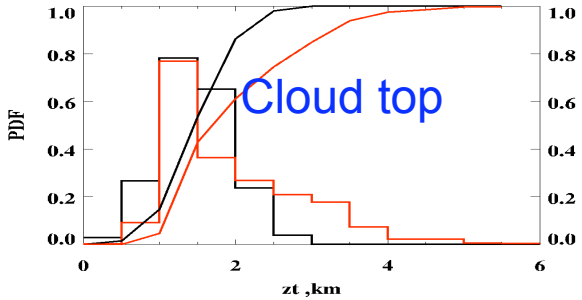
Low-level clouds are dominant over AZORES (~ 43% of total clouds)

Objective 1

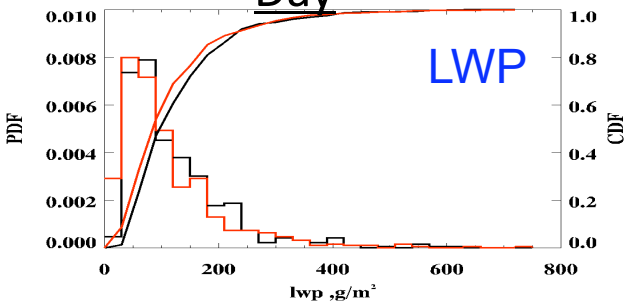
Comparison between Meteosat and ARM AZORES Radar-MWP retrievals

- Low-level clouds, 649 day and 703 night samples

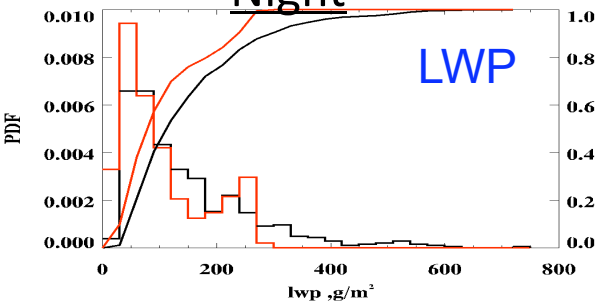


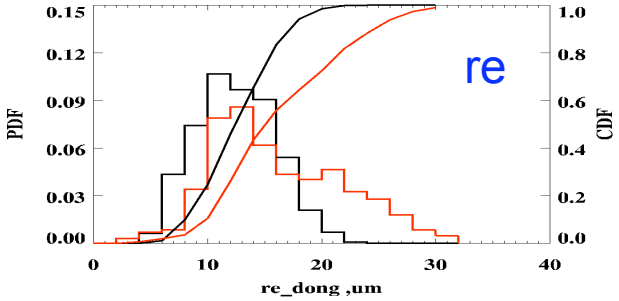


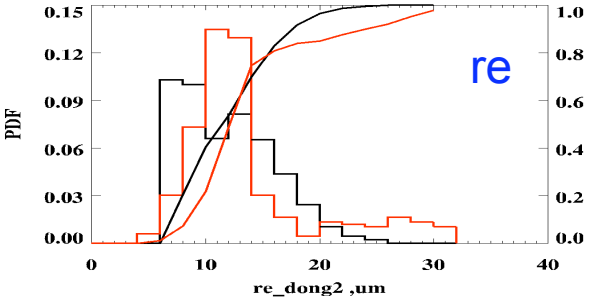
Day

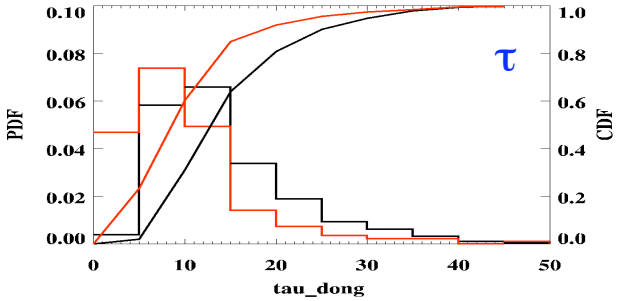


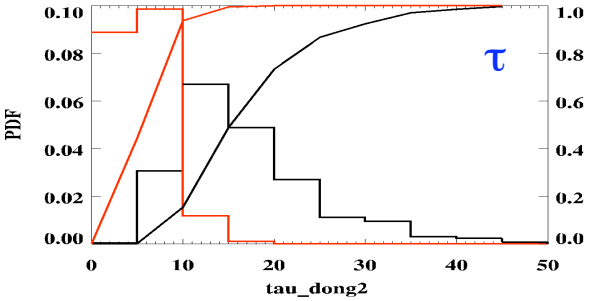
Night











ARM vs. CERES Meteosat retrievals:

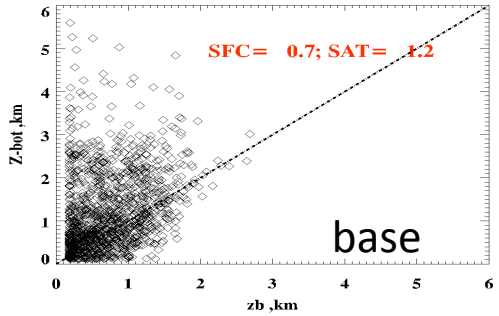
- Meteosat (*Msat*) cloud base & tops too high

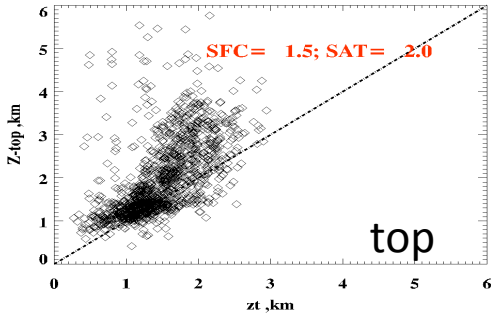
- LWP agrees well during day, but *Msat* peaks at small values during night
  - default max = 200 gm^{-2}

- *Msat* Retrieves large particle size for both day and night
  - default = 12 μm

- *Msat* underestimate cloud optical depth both day and night
  - defaults at 8, 16, 20

* Defaults only used at night for thick clouds



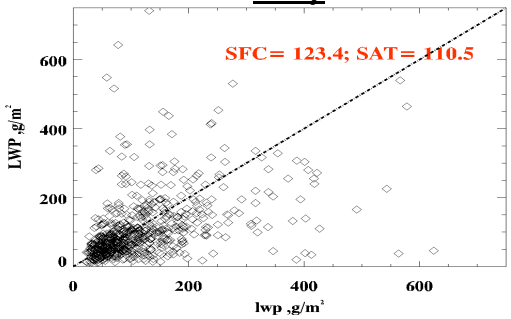


Cloud Heights (km)

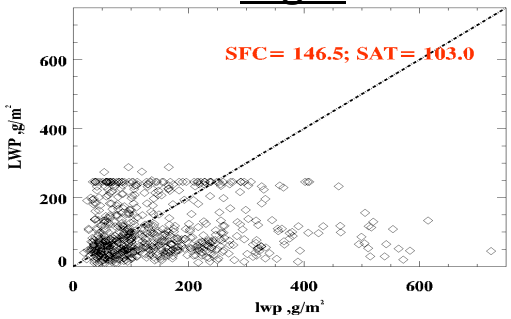
Base: ARM=0.7, Msat = 1.2

Top: ARM=1.5, Msat = 2.0

Day



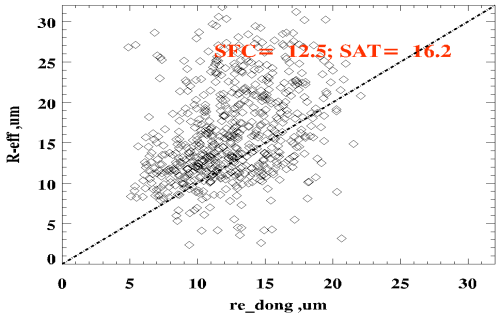
Night

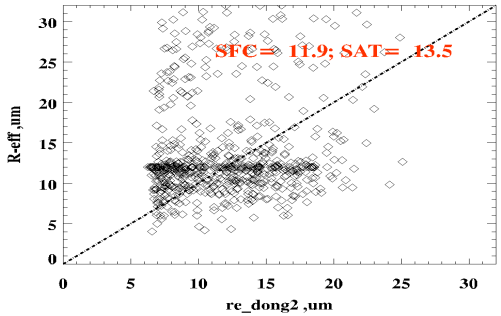


LWP (gm^{-2})

Day: ARM = 123, *Msat* = 111

Night: ARM = 147, *Msat* = 103

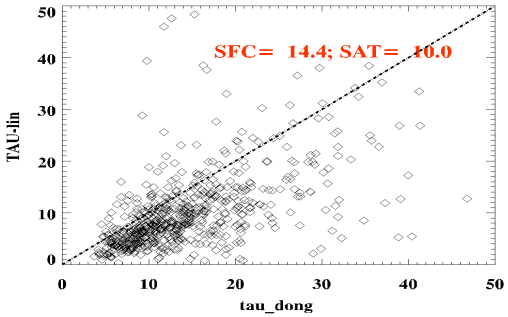


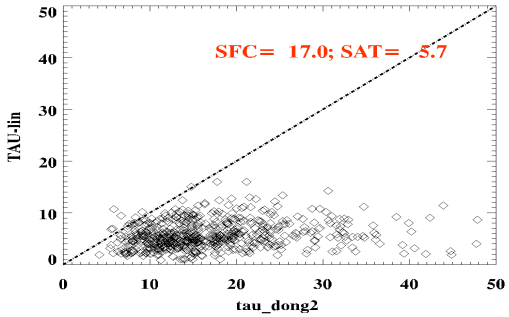


Re (μm)

Day: ARM = 12.5, *Msat* = 16.2

Night: ARM = 11.9, *Msat* = 13.5





Tau

Day: ARM = 14.4, *Msat* = 10

Night: ARM = 17, *Msat* = 5.7

Meteosat retrievals used CERES Ed2 lapse rates

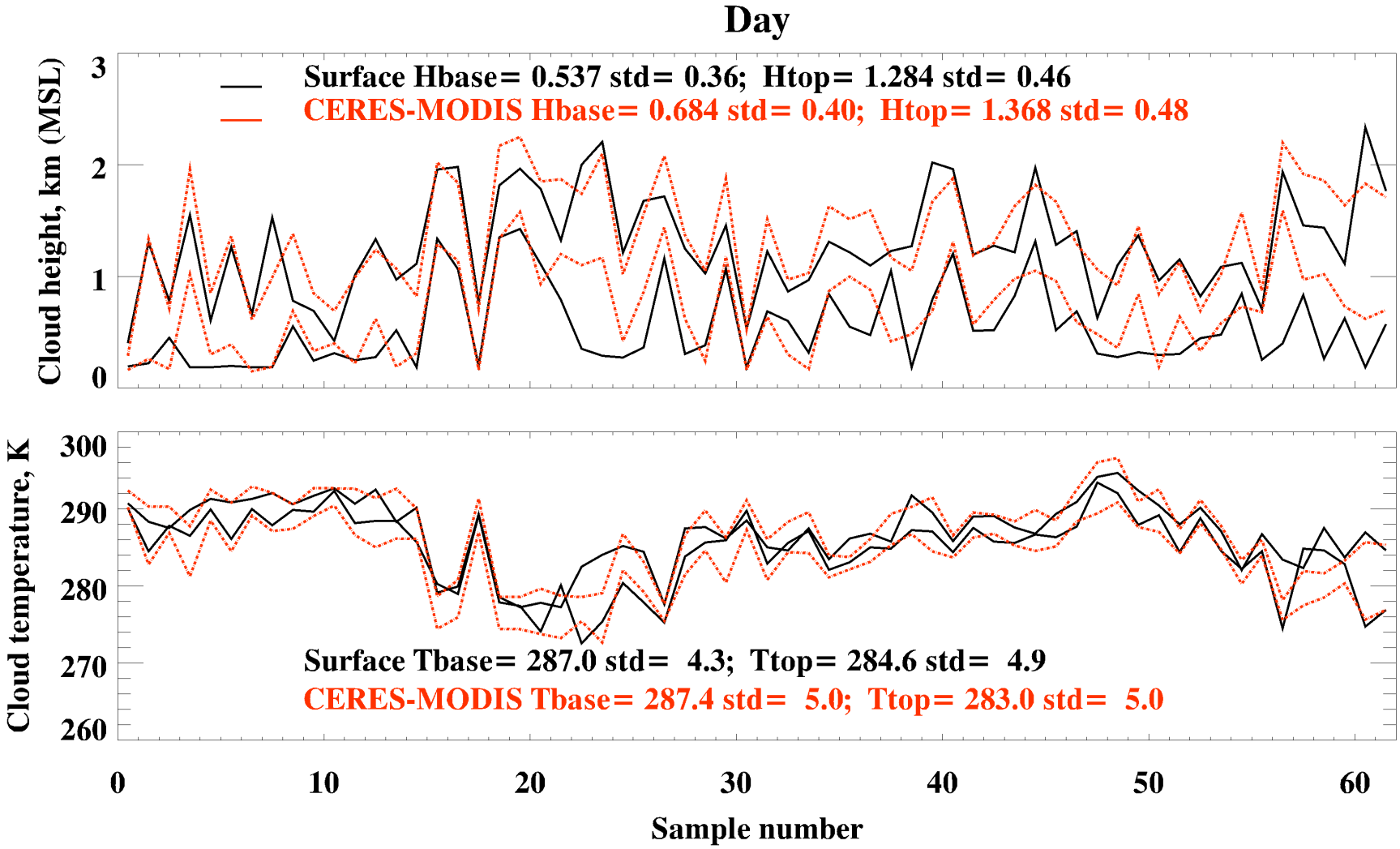
- Ed4 lapse rates should improve agreement

Objective 2

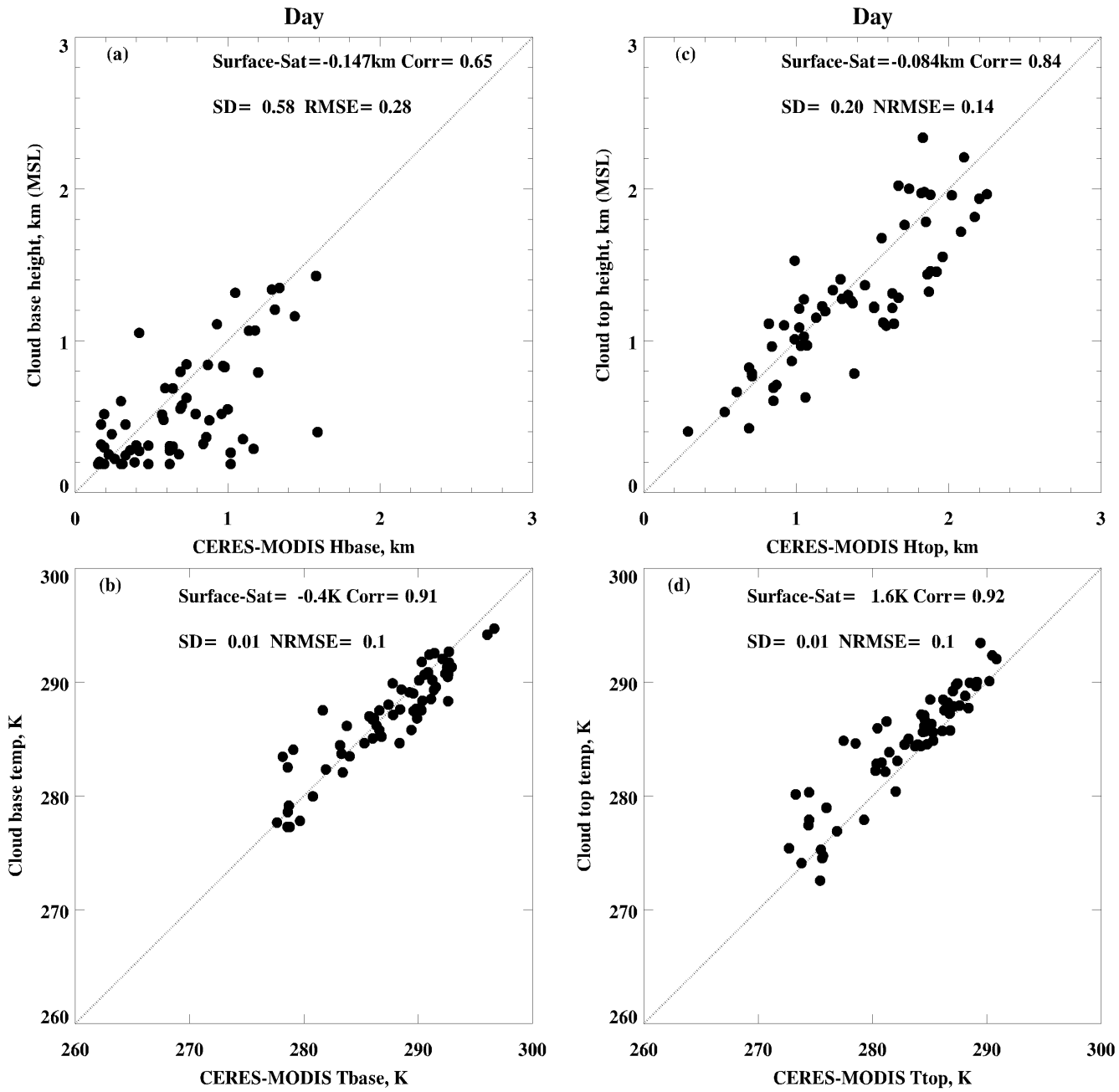
Compare CERES-MODIS and ARM

- low-level clouds, 62 day and 87 night samples

Marine Stratus height and Temp (Day)



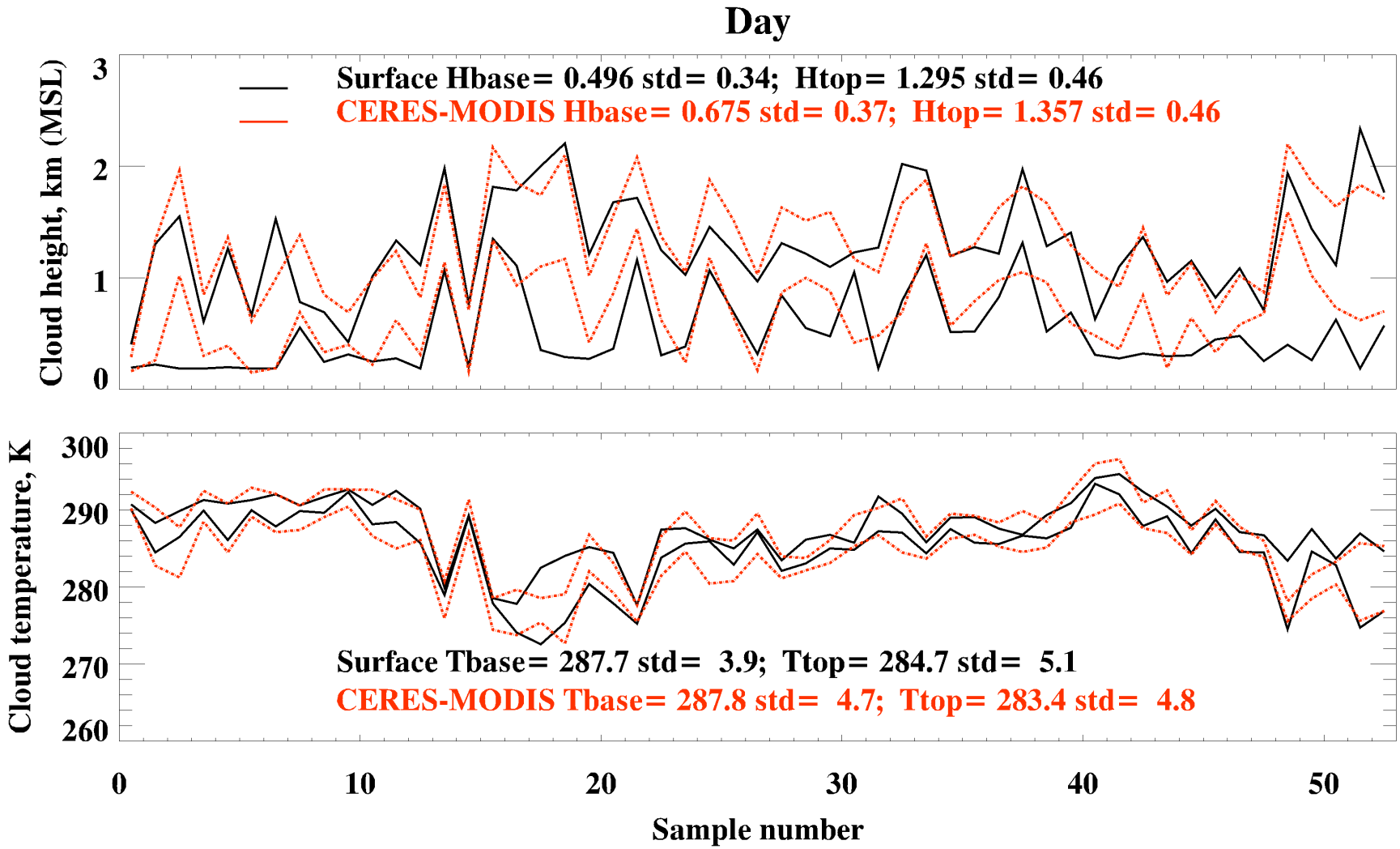
- **Mean cloud base & top height differences are only 147 & 84 m**
- **Average cloud temperature differences within 1.6 K**



Correlation of cloud top is 0.84, higher than cloud base (0.65)→This is also reasonable because we retrieve cloud top first, then infer cloud base.

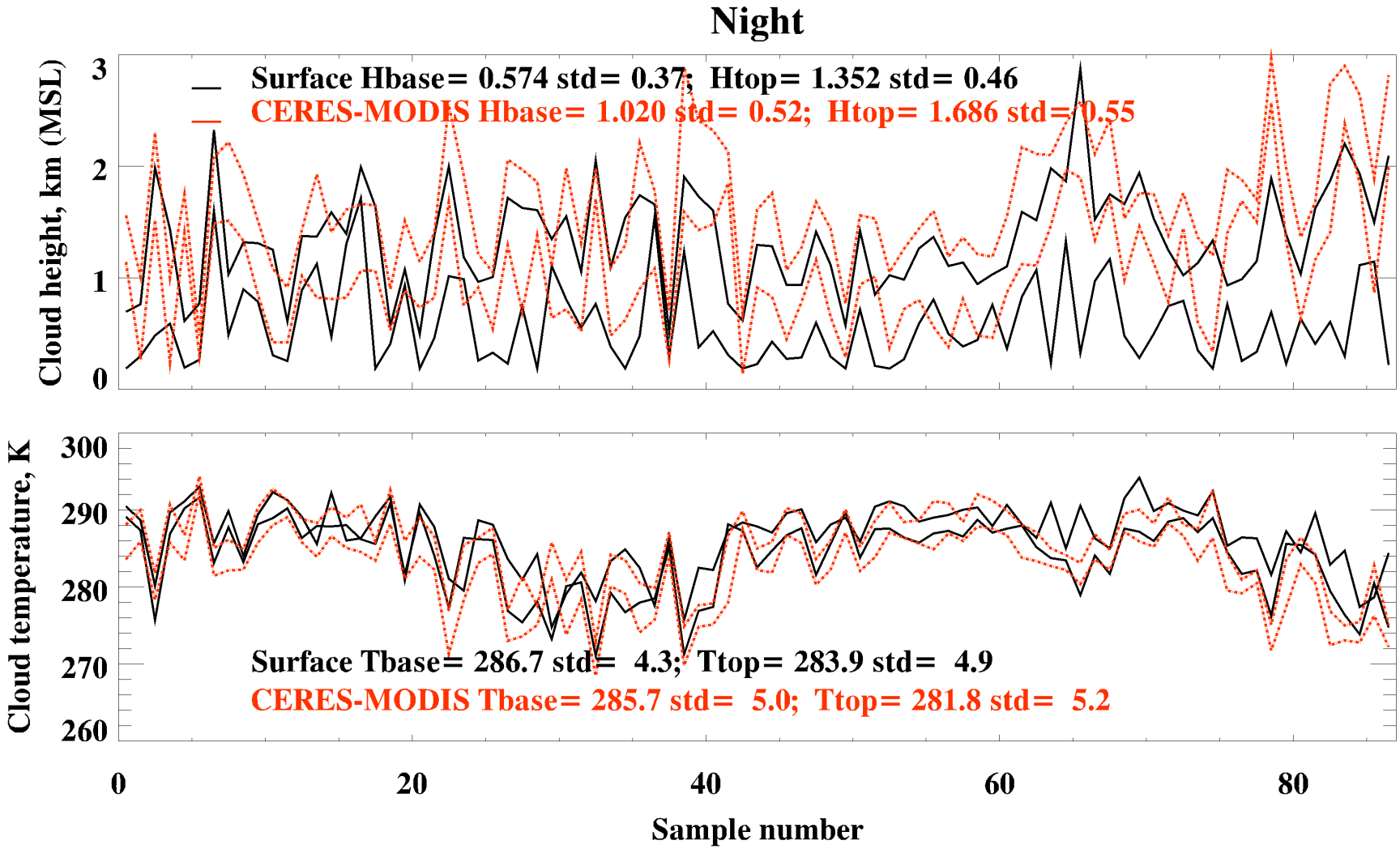
Correlations of cloud temps are 0.92, very high→ This is reasonable because we got cloud temp first, then infer cloud height

Without Temperature inversion (Day)

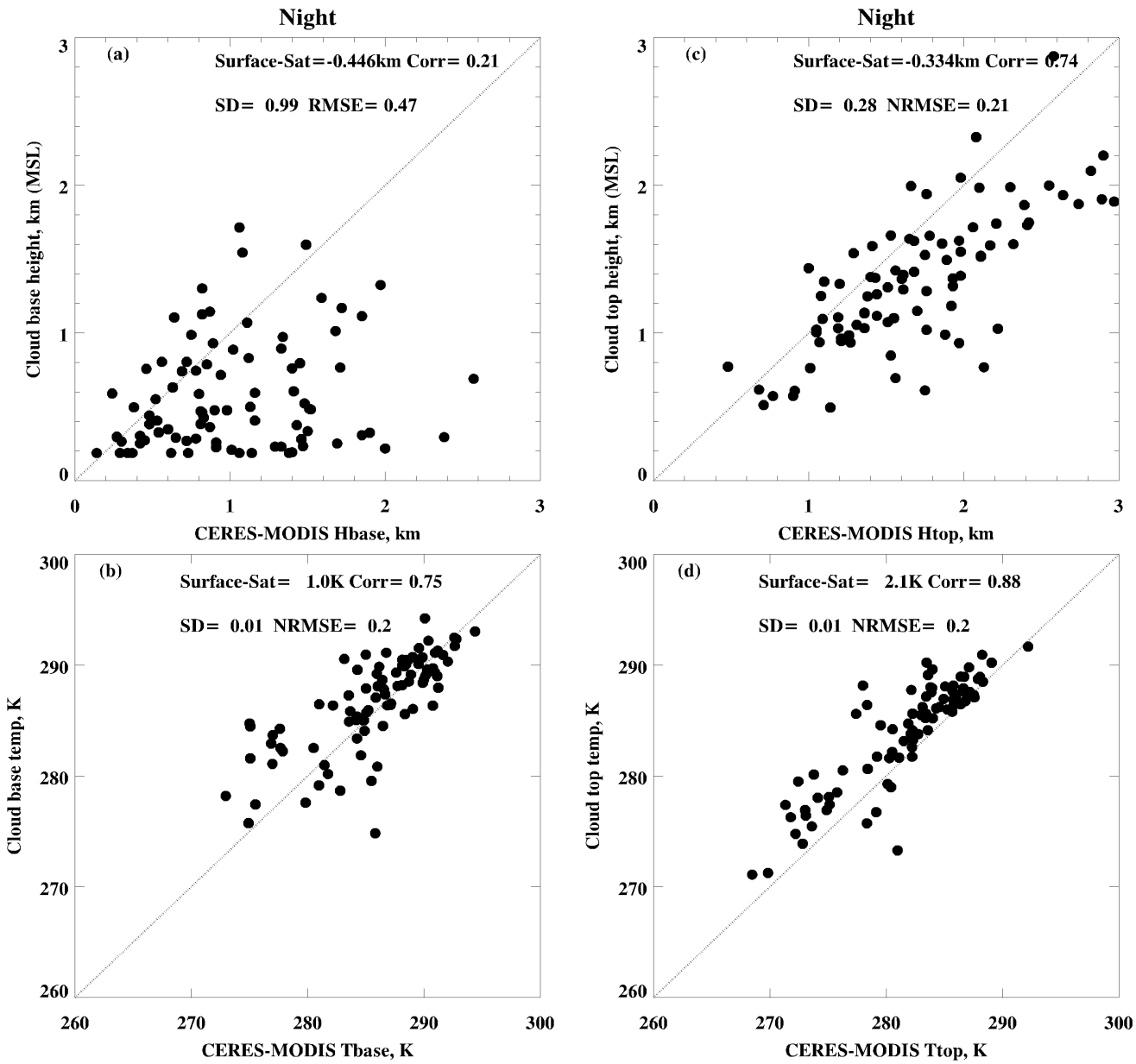


Conclusion: With/without inversion, the comparisons do not change too much.

Marine stratus Height and Temp (Night)



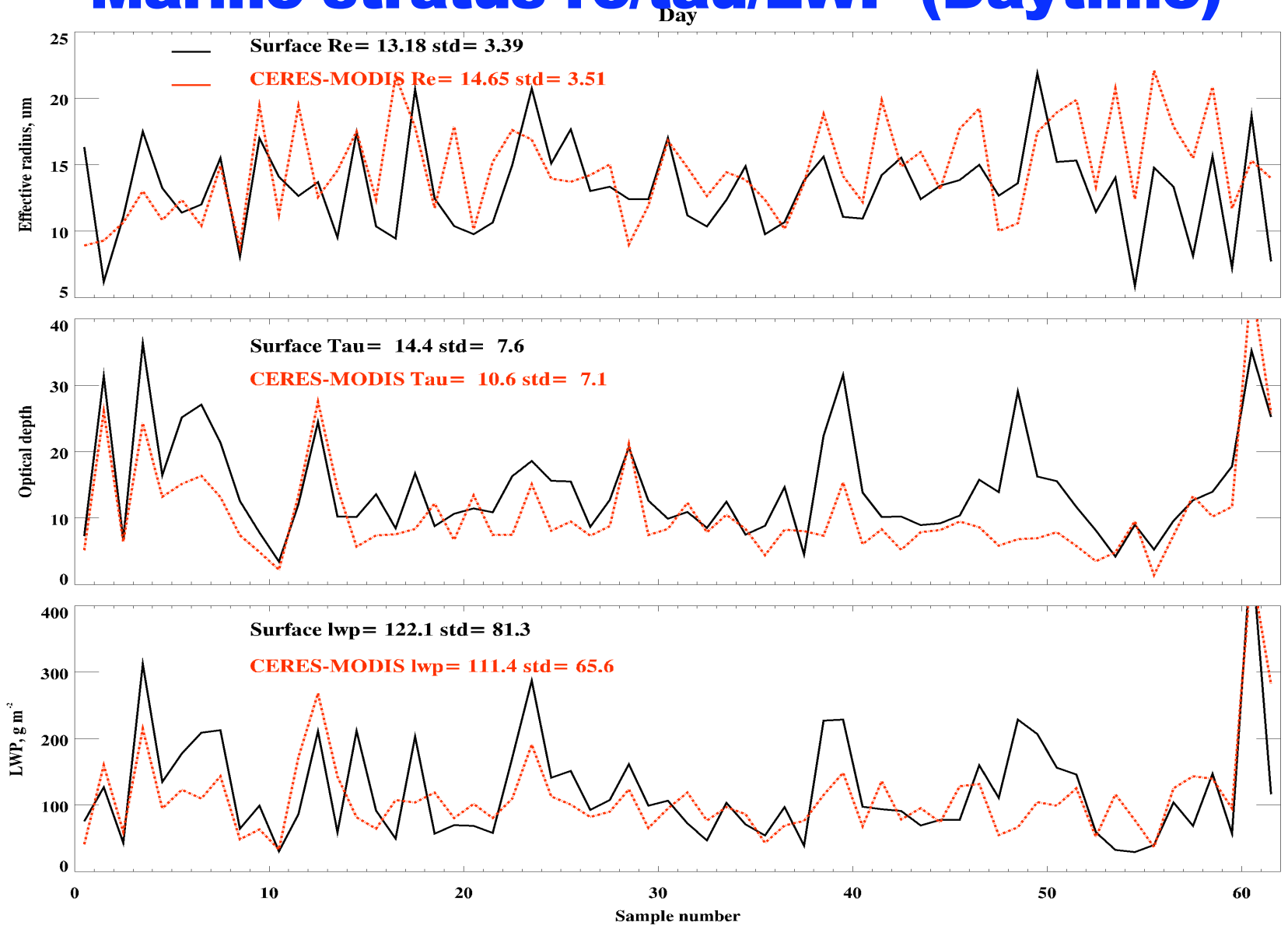
- Mean differences (CERES/MODIS – ARM)
  - heights: cloud base, 450 m; top, 330 m
  - temperatures: cloud base, - 1 K; top, -2 K



- **Correlation of cloud top is 0.74, less than daytime (0.84), but much higher than cloud base (0.21) ➔need to improve night cloud thickness.**

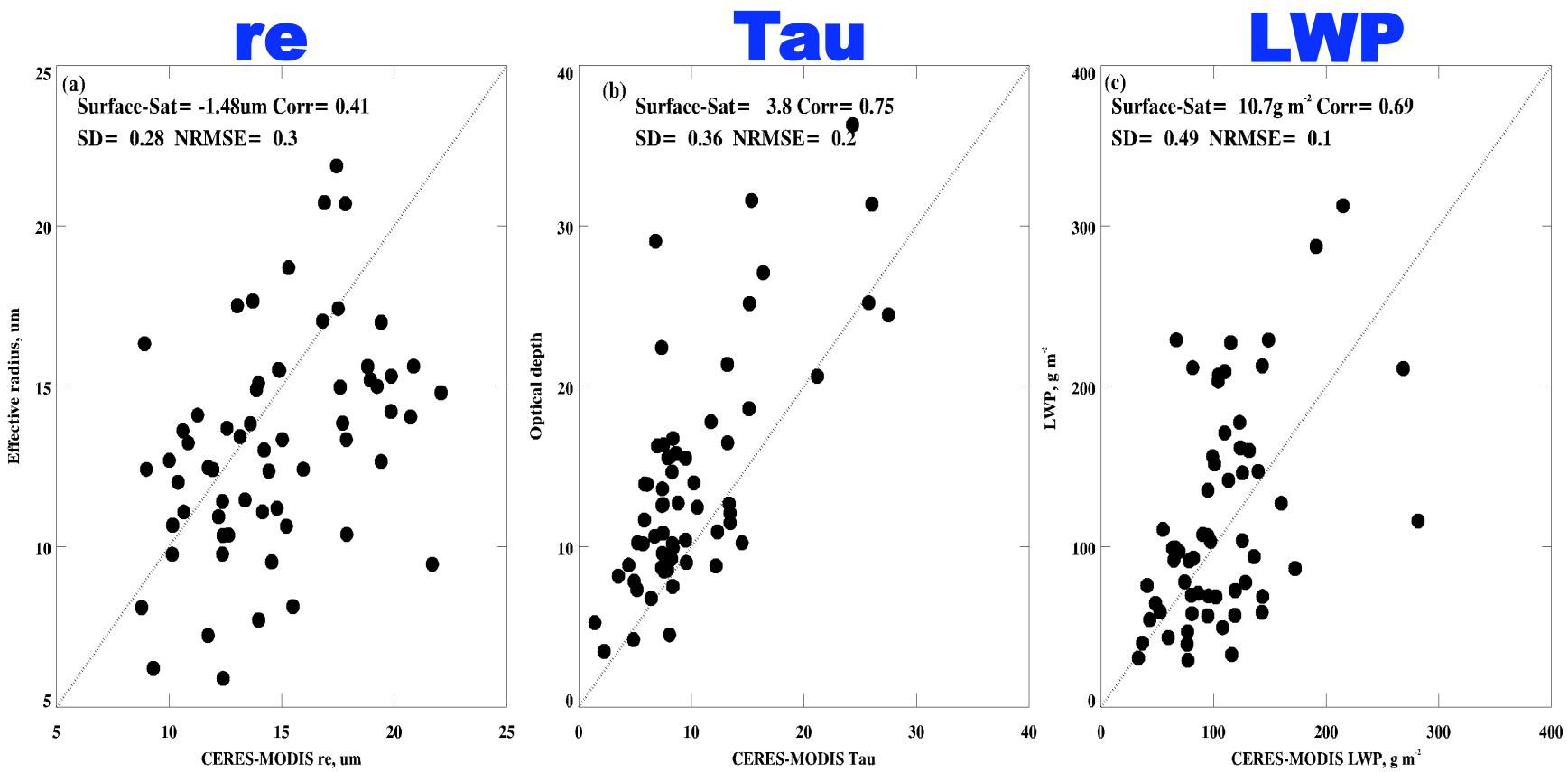
Correlations of cloud temps are 0.82, less than daytime (0.92), but better than cloud heights.

Marine stratus re/tau/LWP (Daytime)



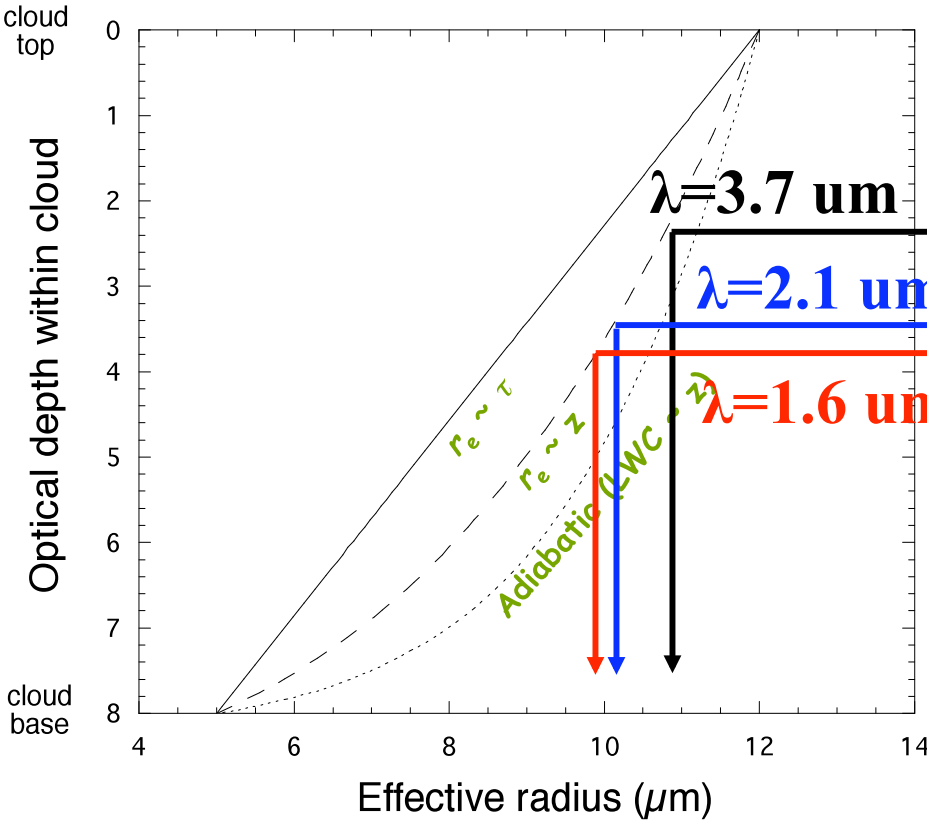
Mean differences (MODIS – ARM): Δre = 1.5 μm; Δτ = -4, ΔLWP = -11 gm^{-2}

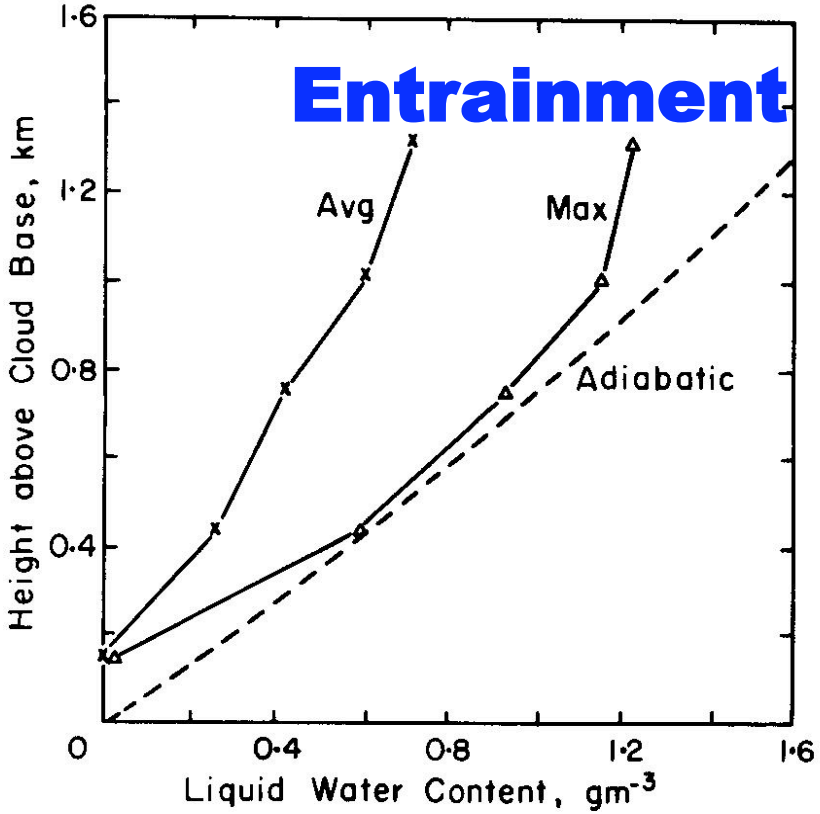
Marine Stratus Microphysical properties (daytime)



- **Cloud optical depth and LWP highly correlated (~0.72)**
- **re less correlated (0.41)**
  - MODIS 3.7-μm re represents cloud-top information
  - ARM retrievals are layer-mean values

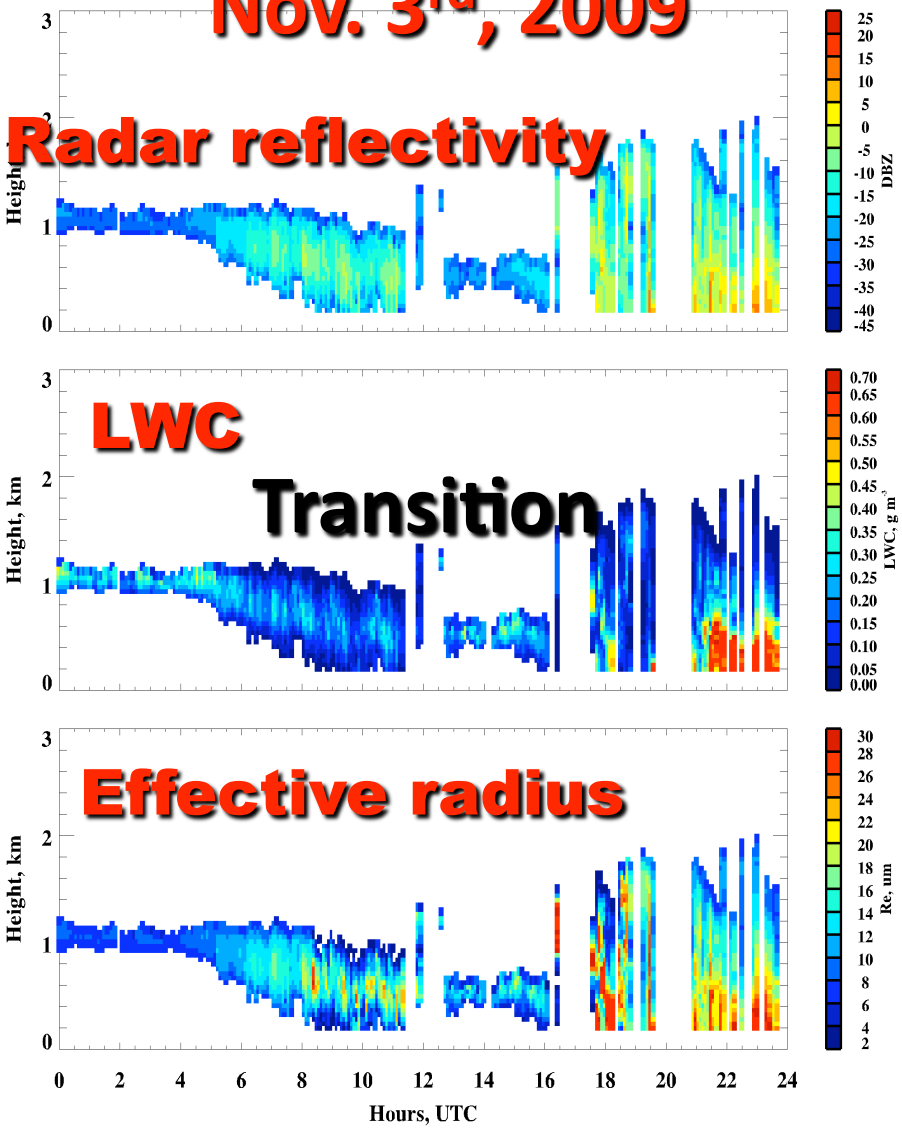
Effective radius (r_e) retrieval differences – *Theoretically re(3.7)>re(2.1)>re(1.6)*

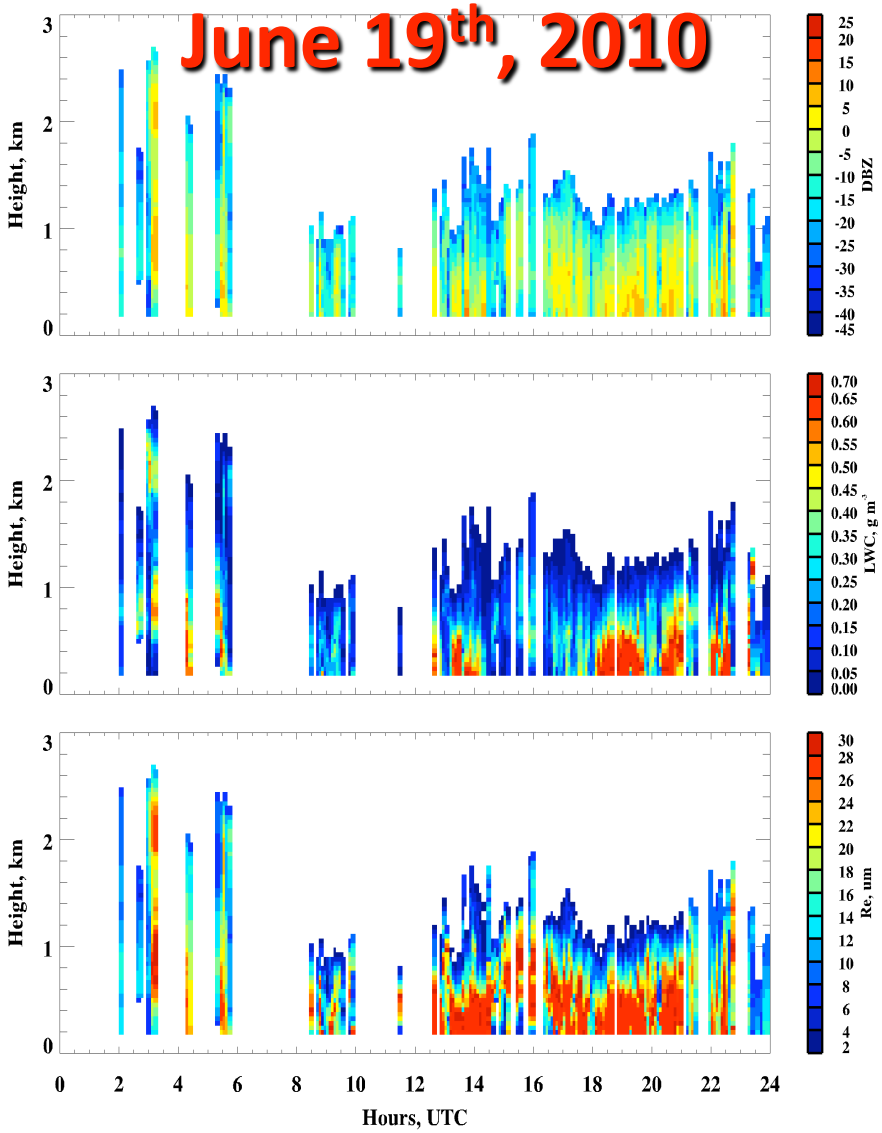




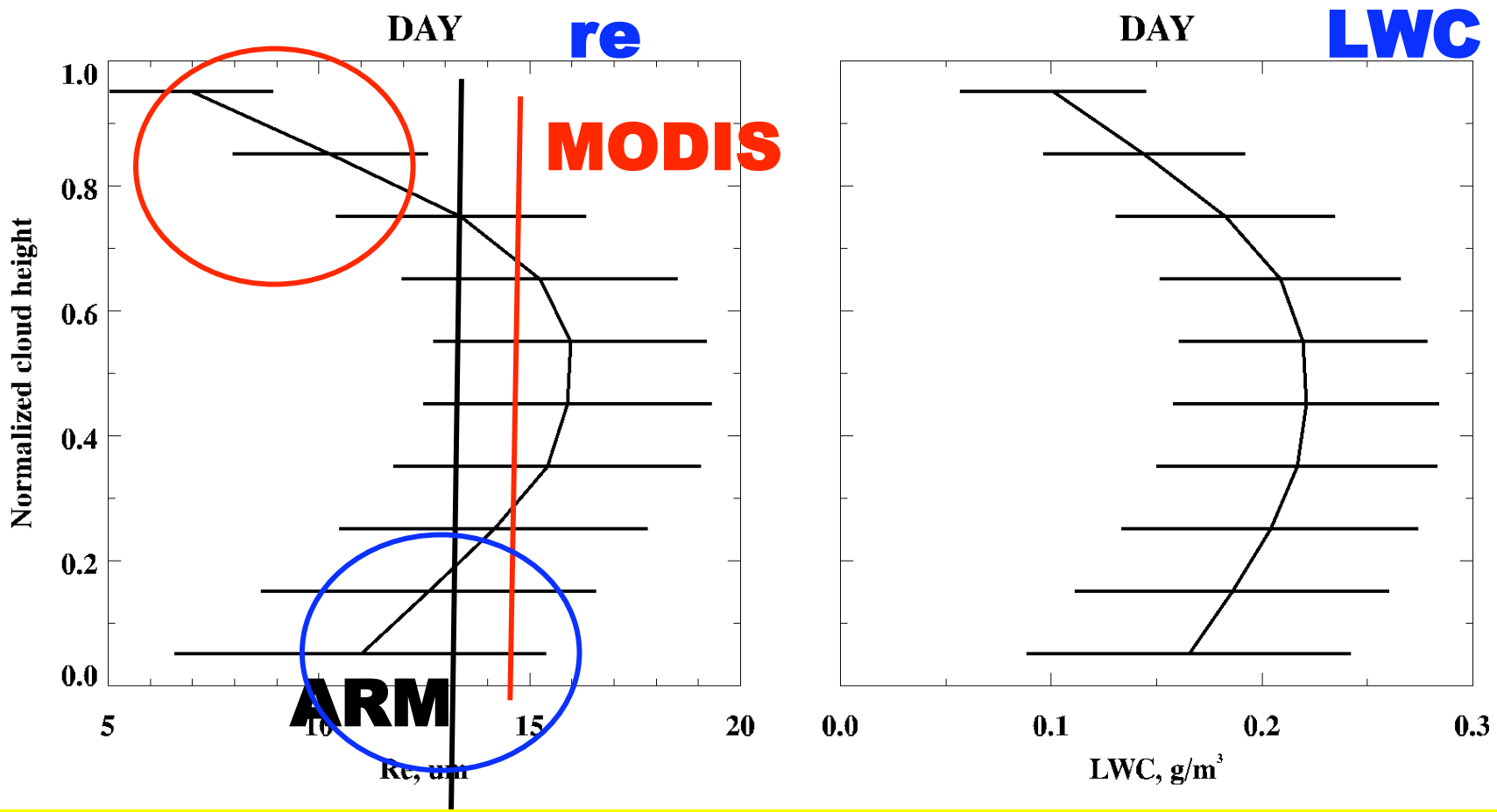
- Both LWC & re should increase from base to top if adiabatic (condensational growth)
- Cloud-top entrainment decreases LWC and re, drizzle enhances LWC & re near cloud base

Some cases follow adiabatic model, but more than half cases with drizzles near cloud base





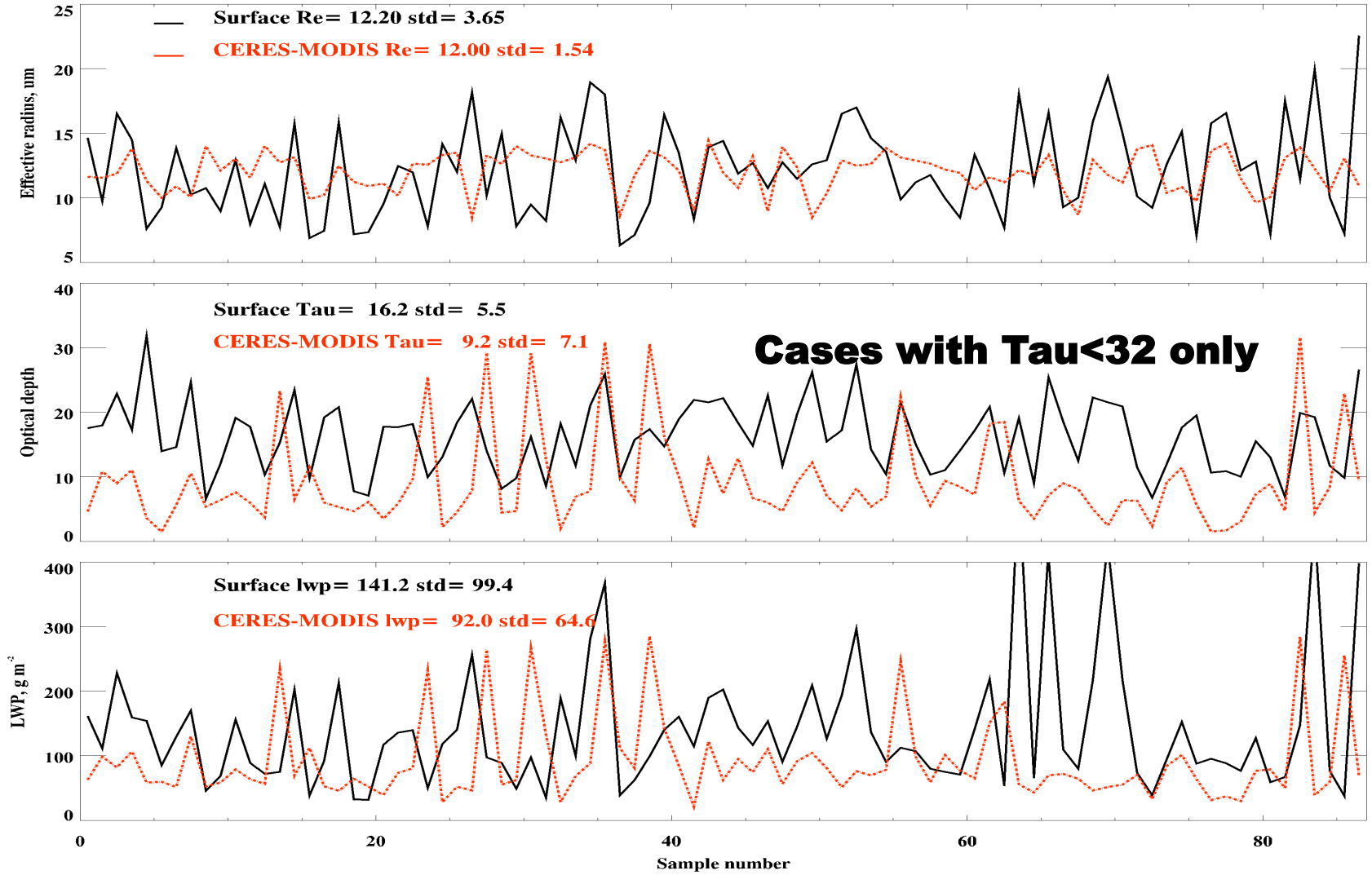
What are the averaged profiles of re and LWC retrieved from ARM radar-MWR?



Cloud-top re and LWC are min due to more entrainment occur.

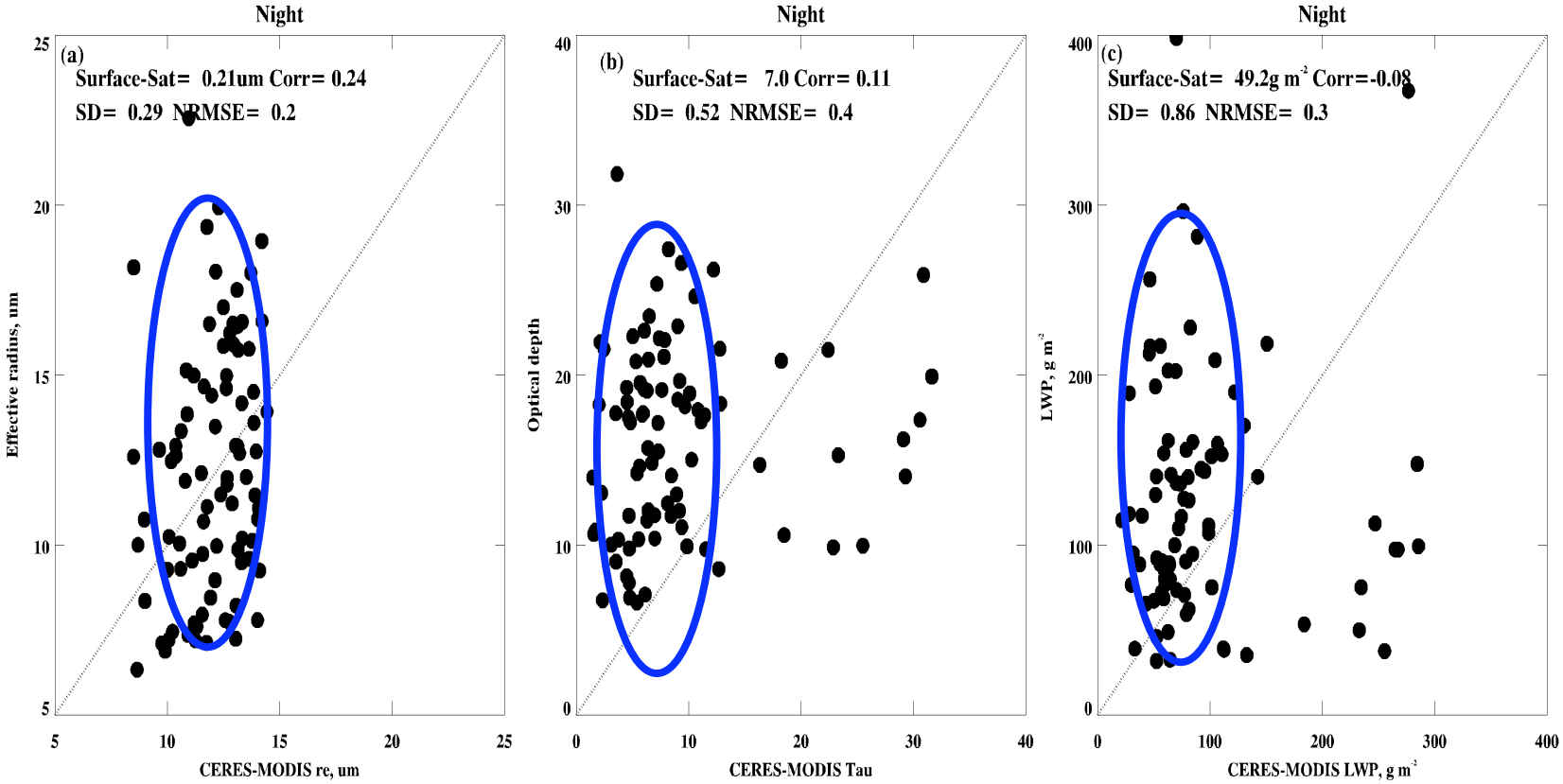
Cloud-base re and LWC are higher than cloud-top values due to more drizzles occurred. **Max values located at cloud center.**

Marine stratus re/tau/LWP (Nighttime)



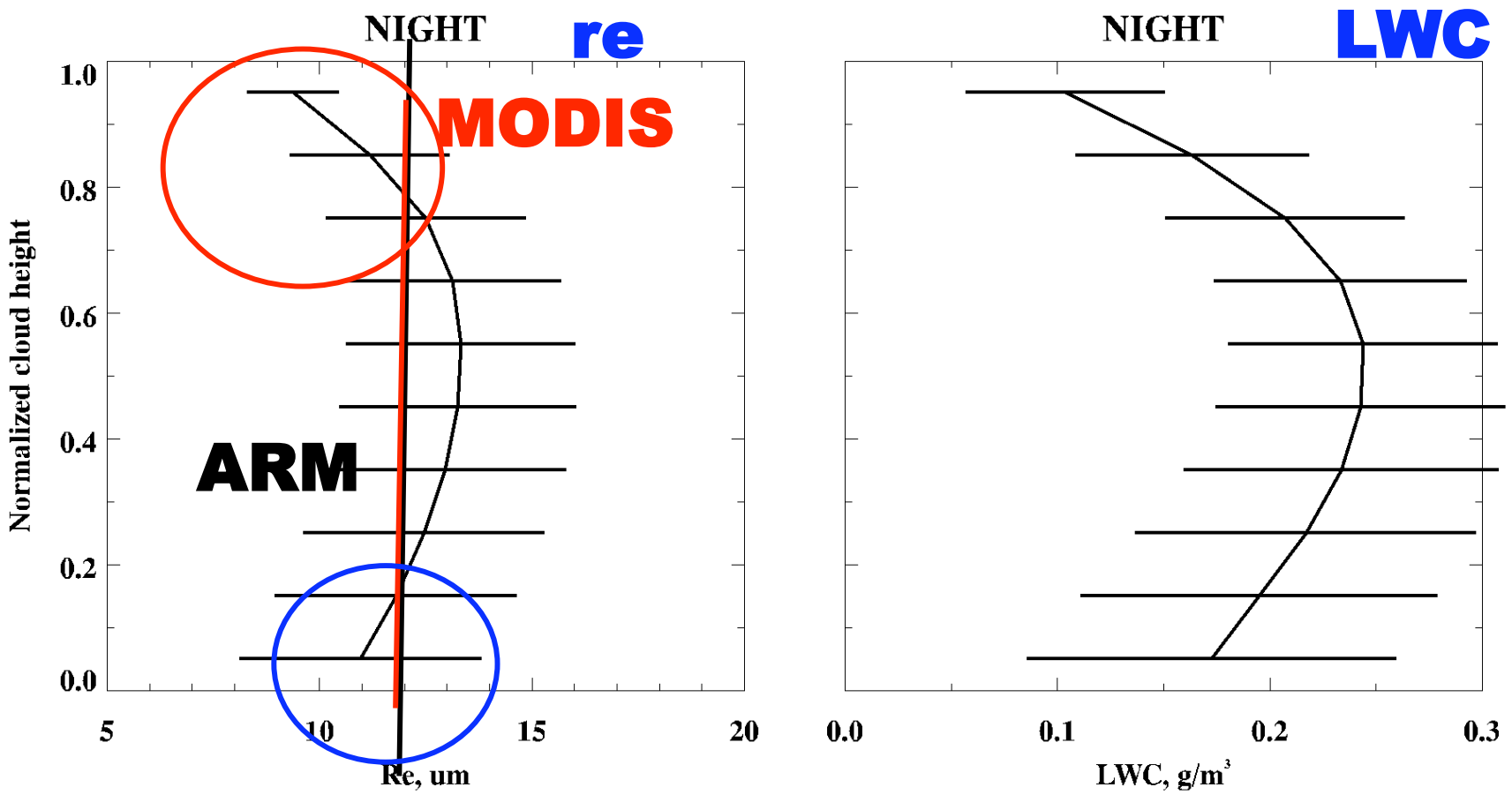
- Mean re values are the same, ARM varies more than MODIS
- MODIS Tau & LWP are ~40% less than ARM results
  - MODIS insensitive to tau > 6

Marine Stratus Microphysical properties (Nighttime)

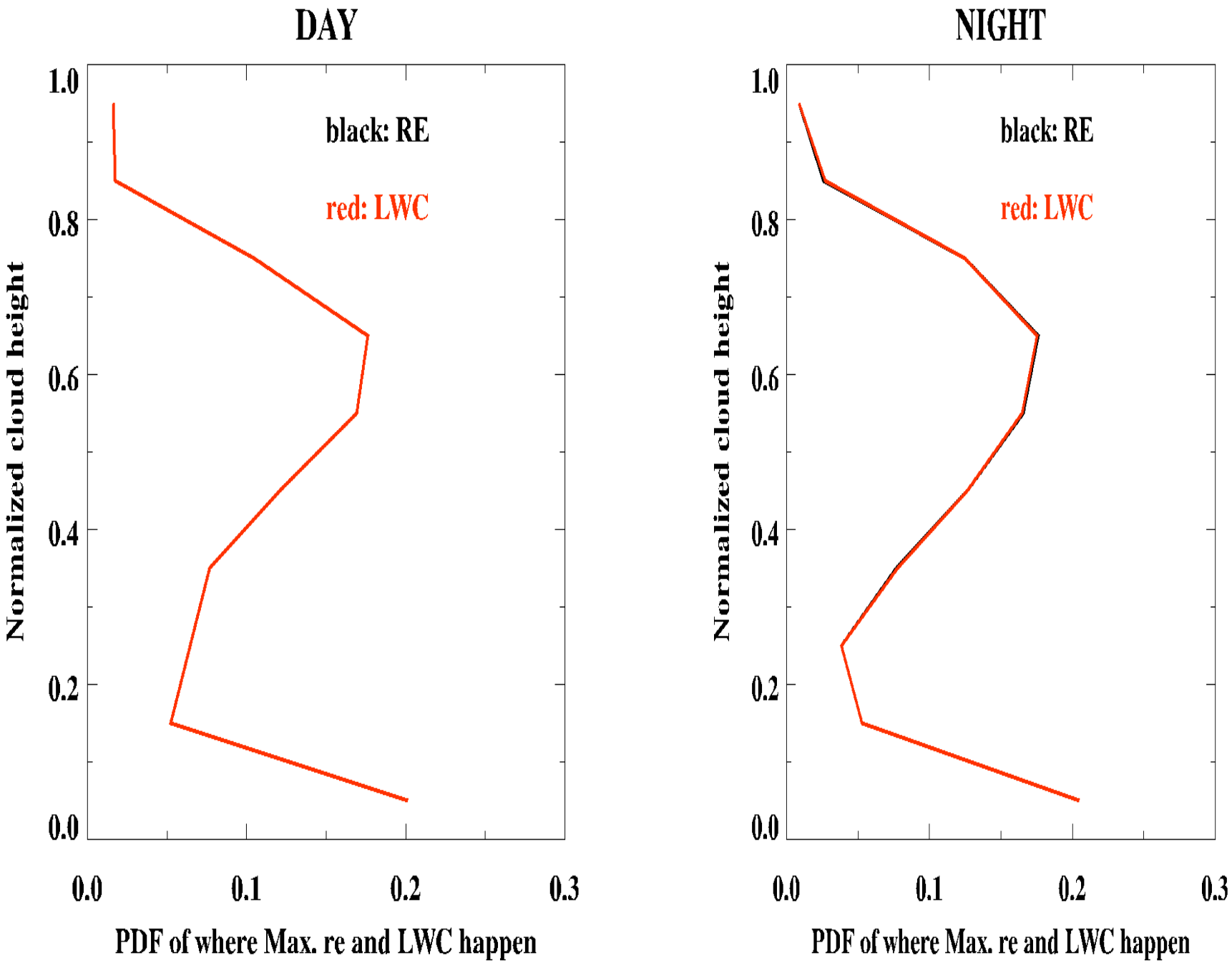


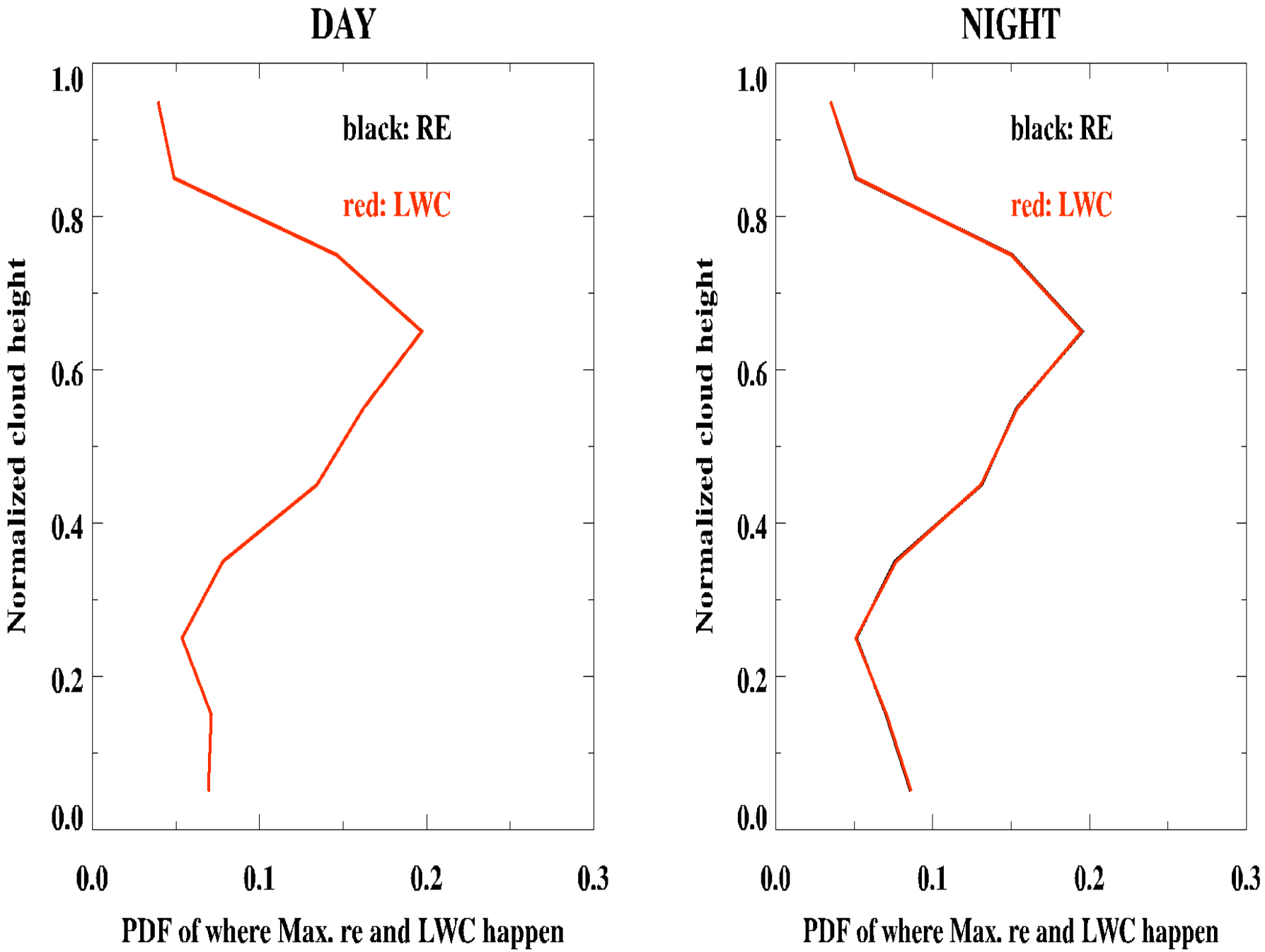
Correlations are much lower than their daytime counterparts. Nearly constant MODIS retrievals due to use of default values for tau > 5.

What are the real vertical profiles of re and LWC retrieved from ARM radar-MWR (night)?



Same story as its daytime counterpart with smaller re and higher LWC values


DAY
NIGHT
black: RE
red: LWC
Normalized cloud height
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
PDF of where Max. re and LWC happen


DAY
NIGHT
black: RE
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Normalized cloud height
PDF of where Max. re and LWC happen
1.0
0.8
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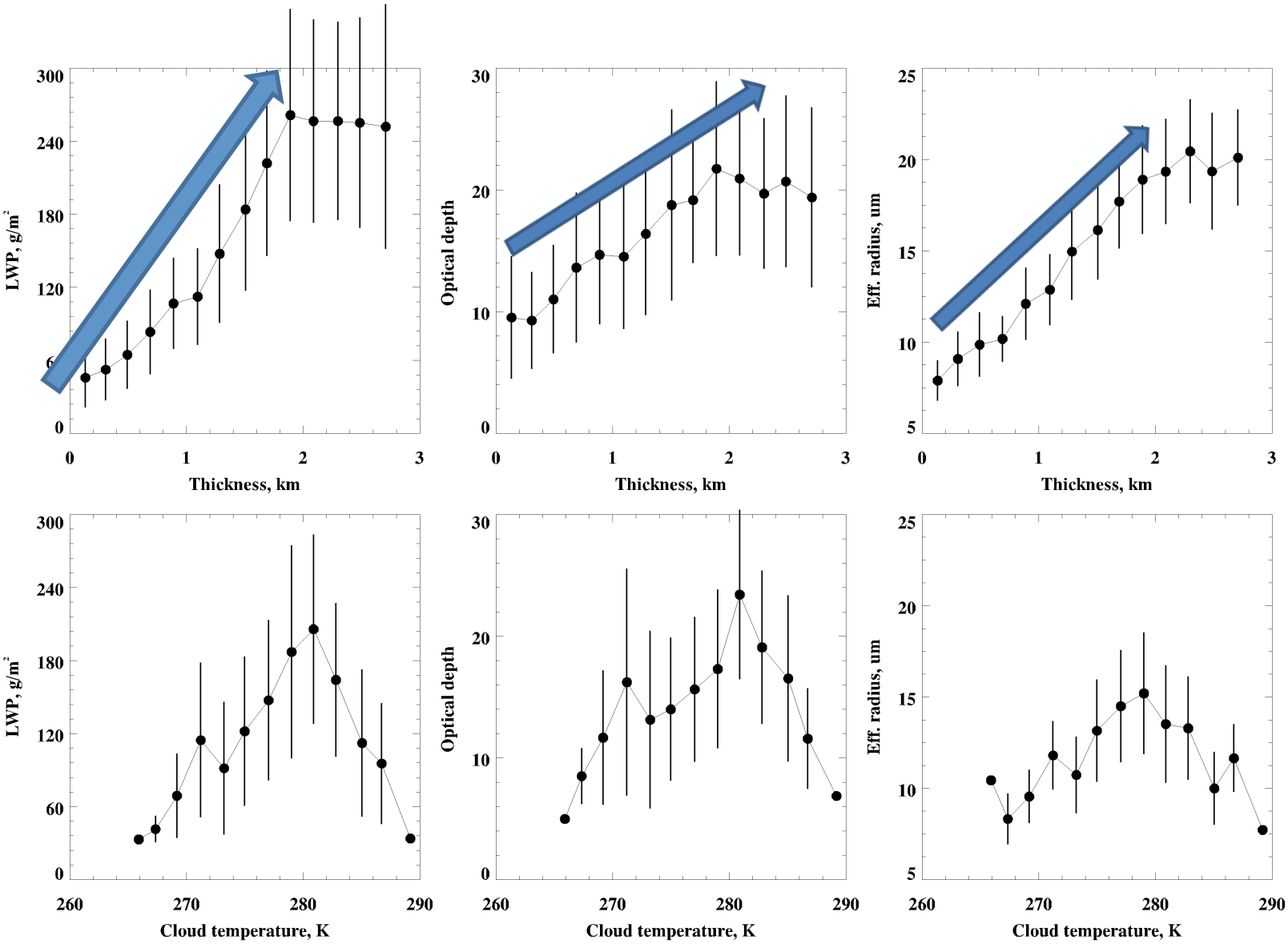
0.1
0.3

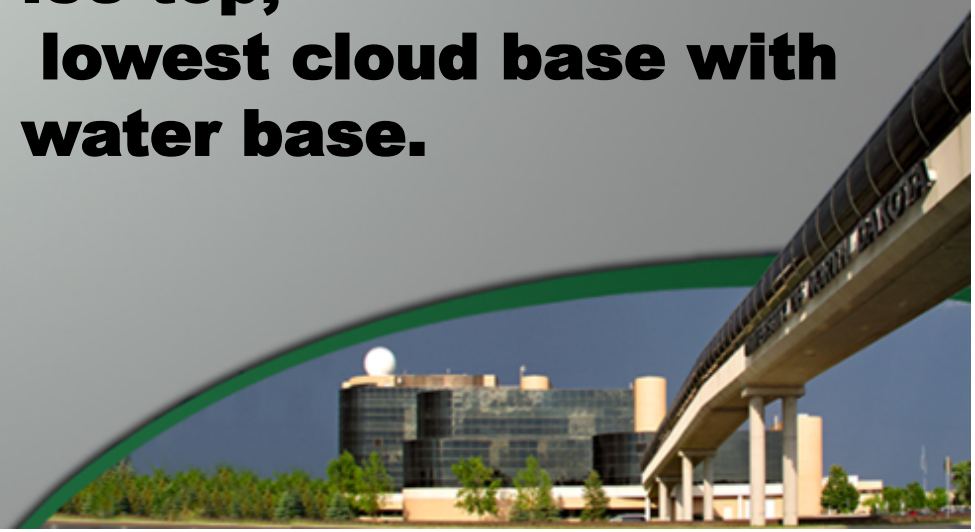

LWP, g/m²
Optical depth
Eff. radius, um
Thickness, km
Cloud temperature, K

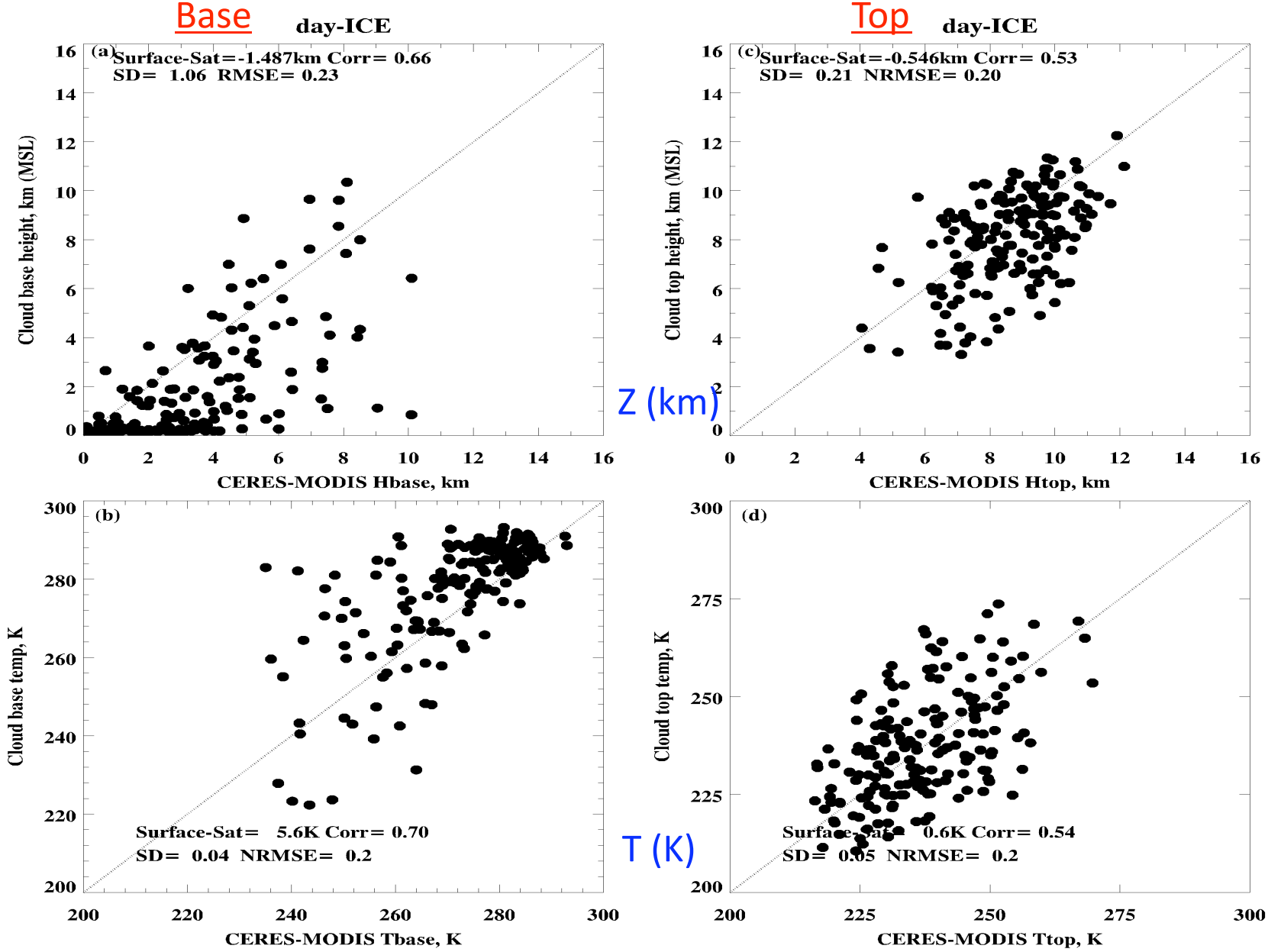
Objective 3

Compare CERES-MODIS and ARM
- Multilayered clouds, 190 day and 170 night

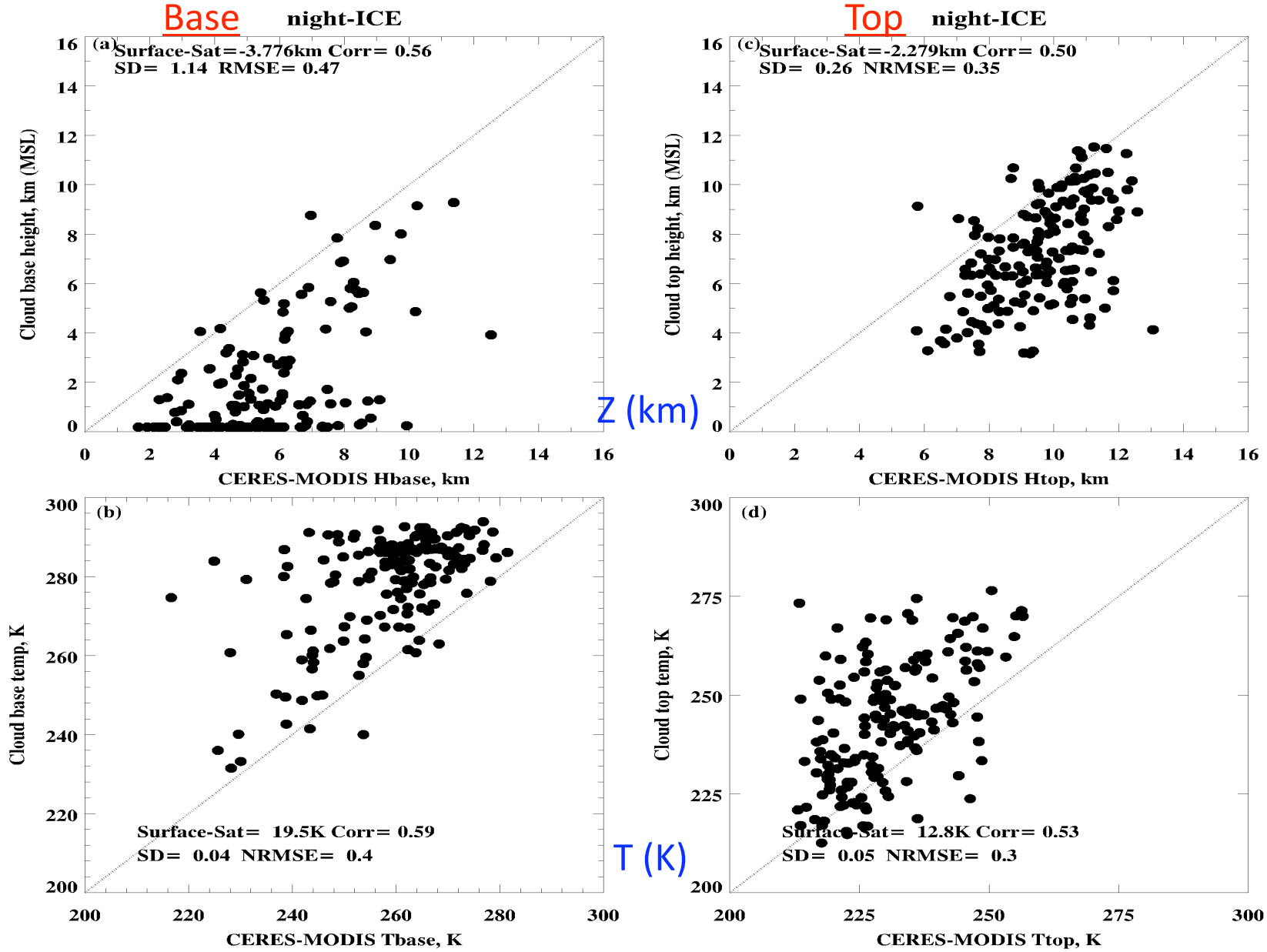
ARM radar-measured highest cloud top with CERES-MODIS retrieved ice top;

ARM radar-lidar measured lowest cloud base with CERES-MODIS retrieved water base.



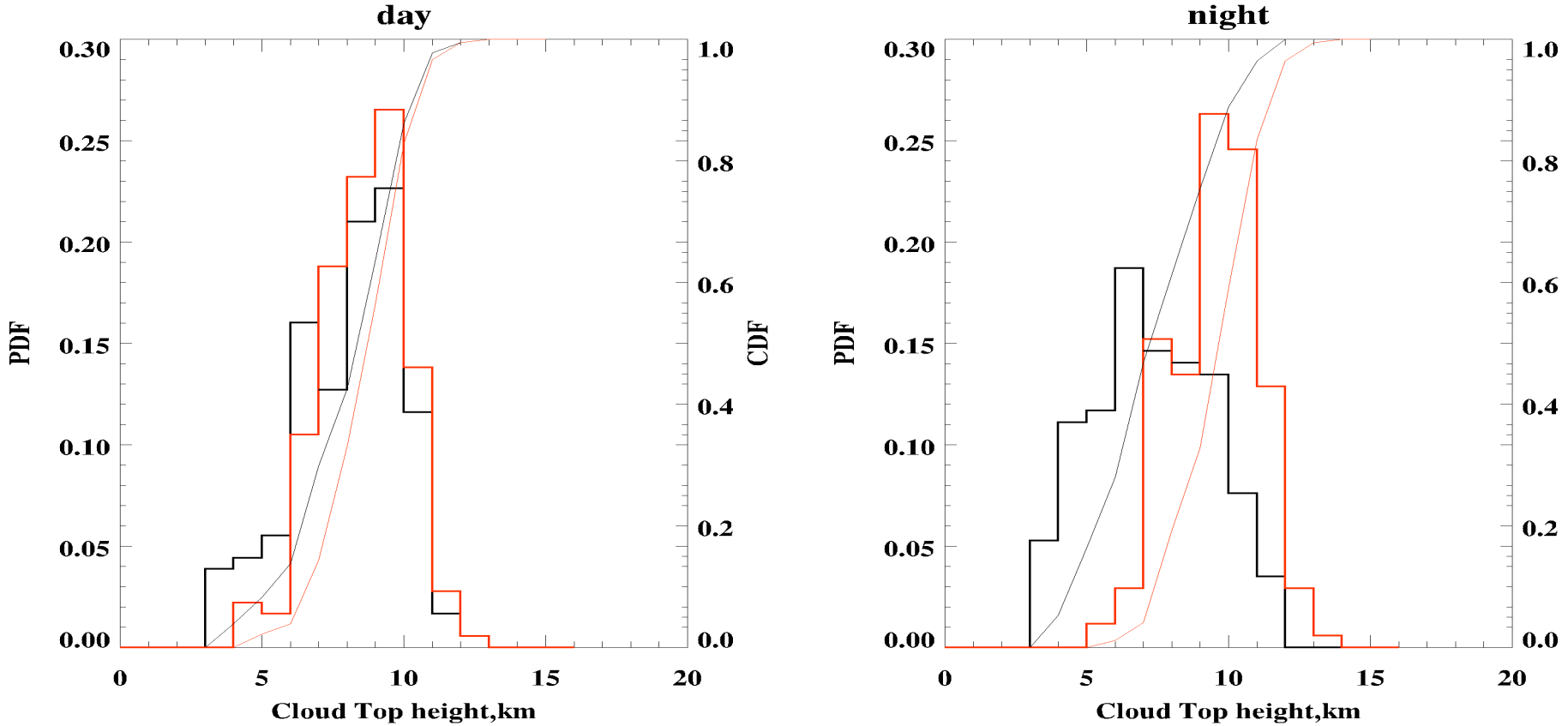


Height correlations ~ 0.54. Cloud base height & temp differences > cloud tops, but correlations are higher at 0.68



MODIS cloud base & top heights biased high, temps biased low
Moderate correlations, ~0.55

PDFs of Highest cloud tops



Daytime: MODIS & ARM PDFs have nearly same distributions

Nighttime: MODIS biased higher, but nearly same as day

ARM much lower than during day

- Is ARM radar missing high cloud tops at night?

Summaries

1) Compared to ARM, Meteosat overestimates cloud base and top heights and effective radius, but underestimated tau and LWP.

2) CERES Ed4 cloud base top heights in excellent agreement with ARM radar-lidar observations

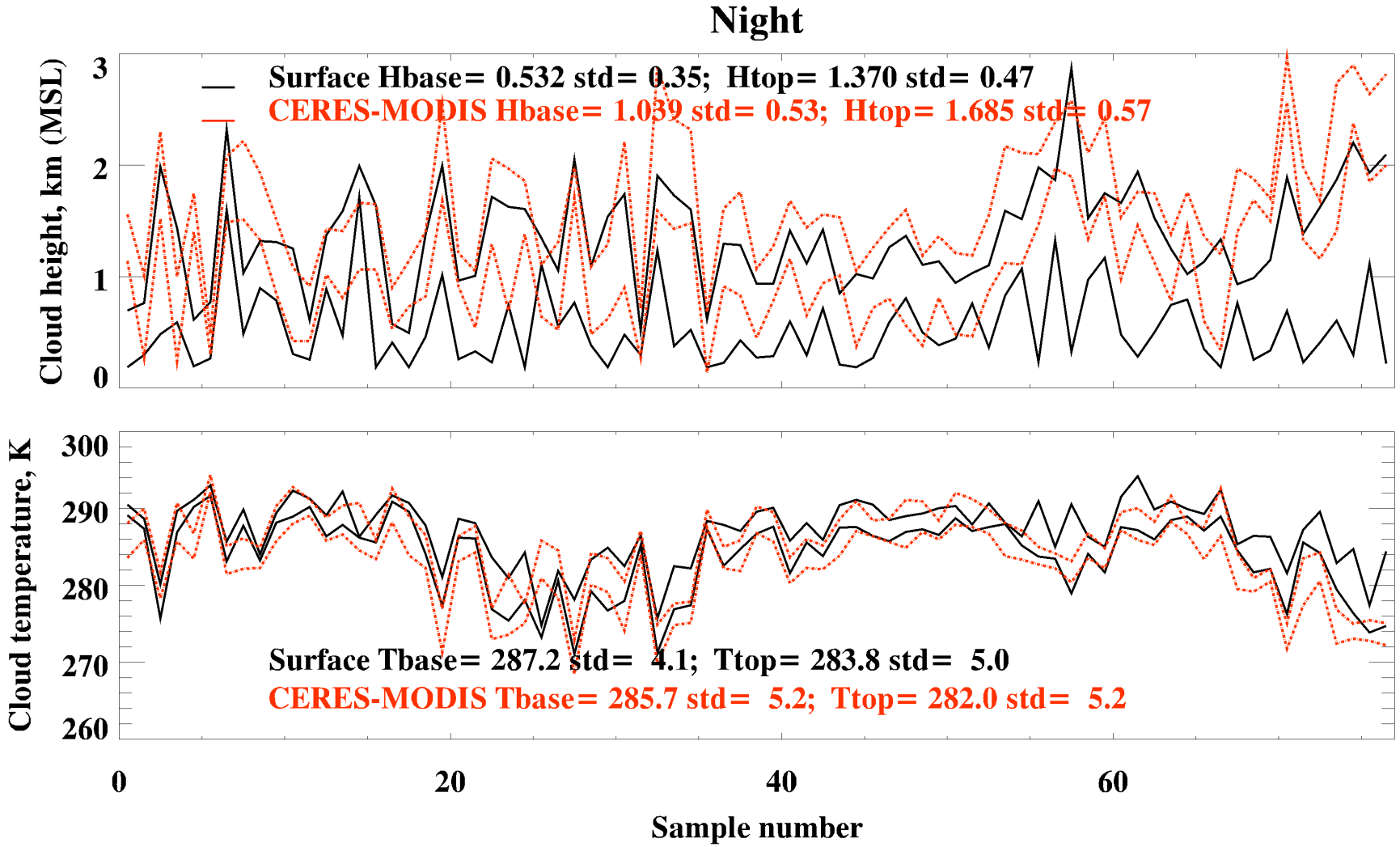
~ 100 m for daytime, ~ 400 m for night.

Temp differences are within 1-2 K with correlation ~0.92

3) Daytime: re/LWP/TAU agree well, high correlations (0.7),
Nighttime: larger differences in tau & LWP
low correlations (<0.2).

Backup slides

Without Temperature Inversion (Night)



The conclusion is the same as its daytime counterpart, the comparisons do not change too much.