Validation of CERES Ed4 MBL cloud properties over AZORES and DCS clouds over SGP

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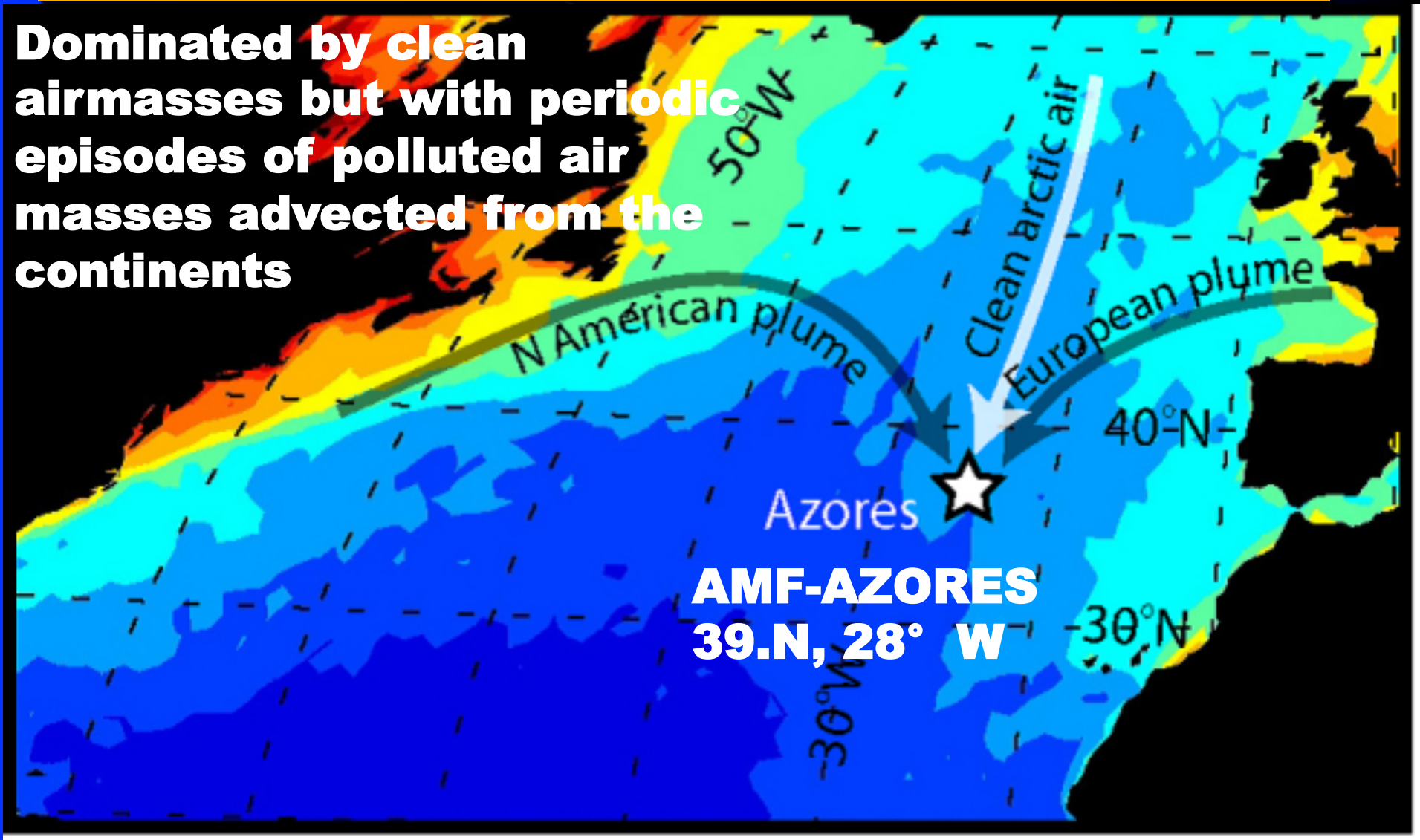
Outline

1) Updating MBL cloud comparison at Azores
2) Preliminary results for convective cloud comparison at SGP

Location of DOE ARM Azores site



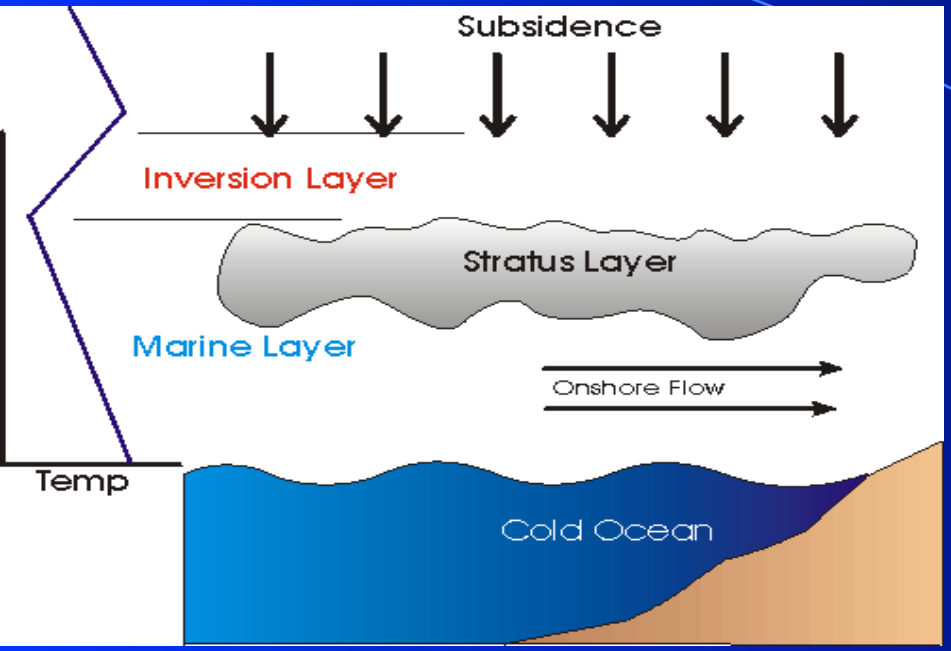
MBL formation-dissipation processes

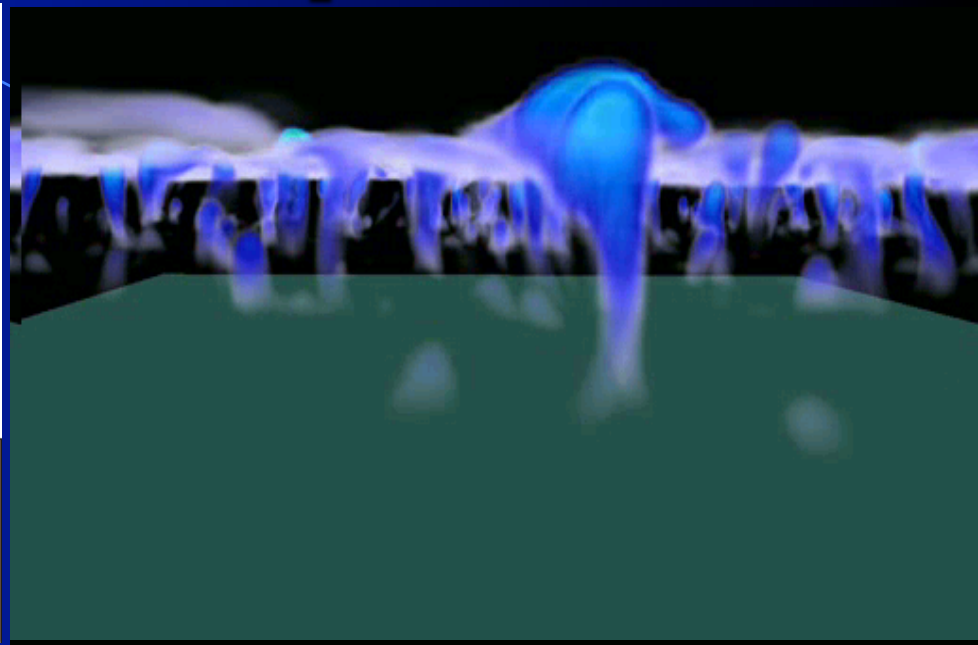
→More MBL clouds occur over the east side of subtropical/mid-lat. oceans under conditions of modest cold advection during periods of equatorward flow.

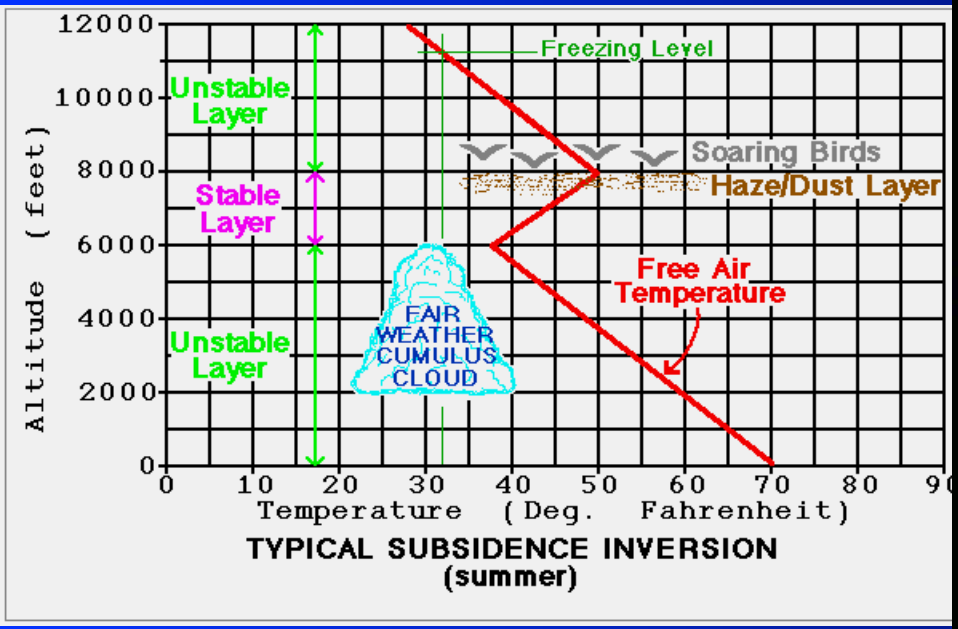
→A strong temp. inversion at the top of the MBL, which is maintained by large-scale subsidence, combined with cold sea-surface temp., are ideal conditions favoring MBL clouds

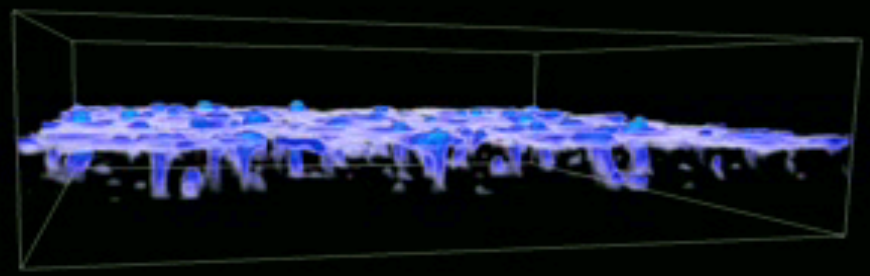
→These MBL clouds are maintained by vertical mixing, primarily due to the strong radiative cooling at cloud top because the radiative cooling generates turbulence to maintain an upward moisture flux.

MBL cloud formation process









Courtesy:
Dr. Dave Stevens, LLNL

Data and Methods

Ground-based

- Height/Temp: WACR/MPL/ Ceilometer & Merged soundings

- re/LWP/tau

a. Day algorithm –

Dong et al 1998, *Dong& Mace* 2003

b. Night algorithm-

Dong & Mace 2003

(radar reflectivity+LWP)

All surface results are averaged 1-hr

- Multi-regression curve-fit to provide new parameterized cloud thickness for both day and night

Satellite

- Cloud height/temp.

  - new lapse rate derived from CloudSat-CALIPSO

  - parameterized thickness

- Cloud microphysics:

  Re: retrieved at 3.7 and 2.1 um (*Minnis et al.*, 2011; *Sun-Mack et al.*, 2012)

  Tau: 0.65 um

  LWP: 2/3 Re*Tau

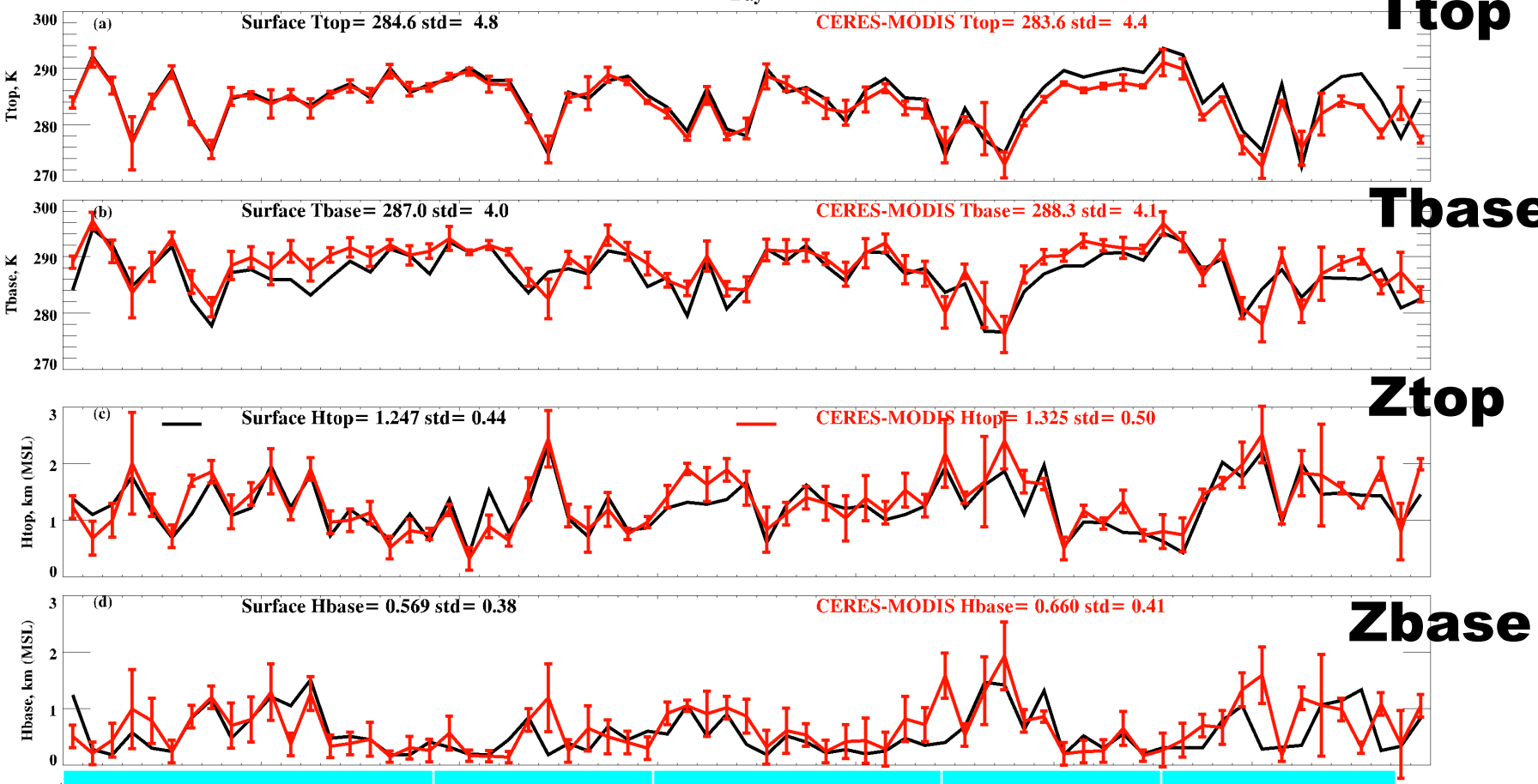
- Area centered on ARM site

CERES-MODIS, 30x30 km^2 box

MBL cloud height and temp comparisons (day and night)

(1) $|T_{top}(CERES)-T_{top}(SFC)| \leq 2K$ (2) $|T_{top}(CERES)-T_{top}(SFC)|>2K$

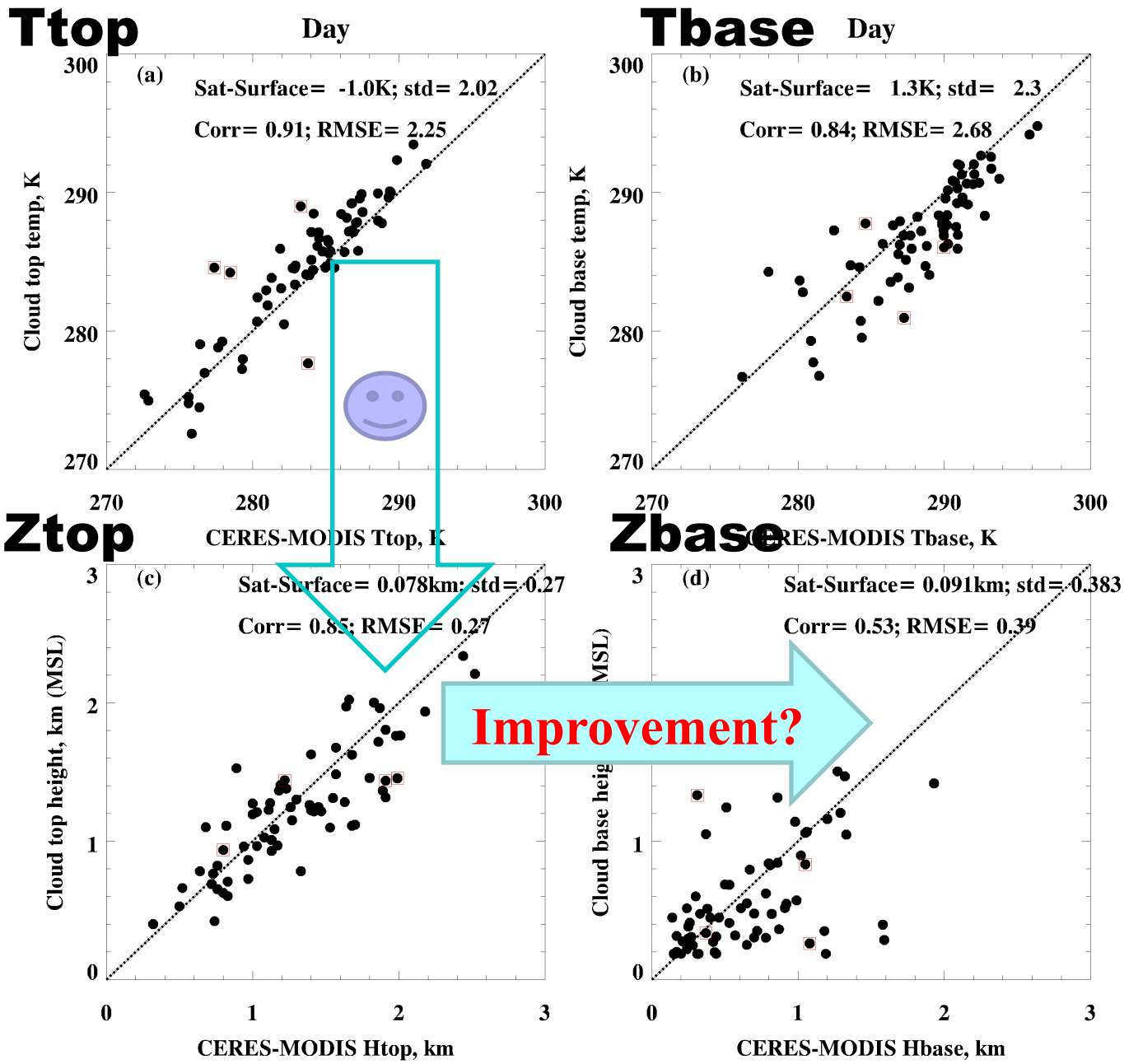
Sorted by ΔTtop from smallest to largest



Lapse rate

Parameterized ΔZ

	$\overline{\Delta Z}_{top}$, km	$\overline{\Delta Z}_{base}$, km	$\overline{\Delta T}_{top}$, K	$\overline{\Delta T}_{base}$, K
All Samples	0.078	0.091	-1.01	1.35
Region(1), ΔT<2 K	0.041	0.091	-0.34	1.36
Region(2), ΔT>2 K	0.146	0.091	-2.07	1.33



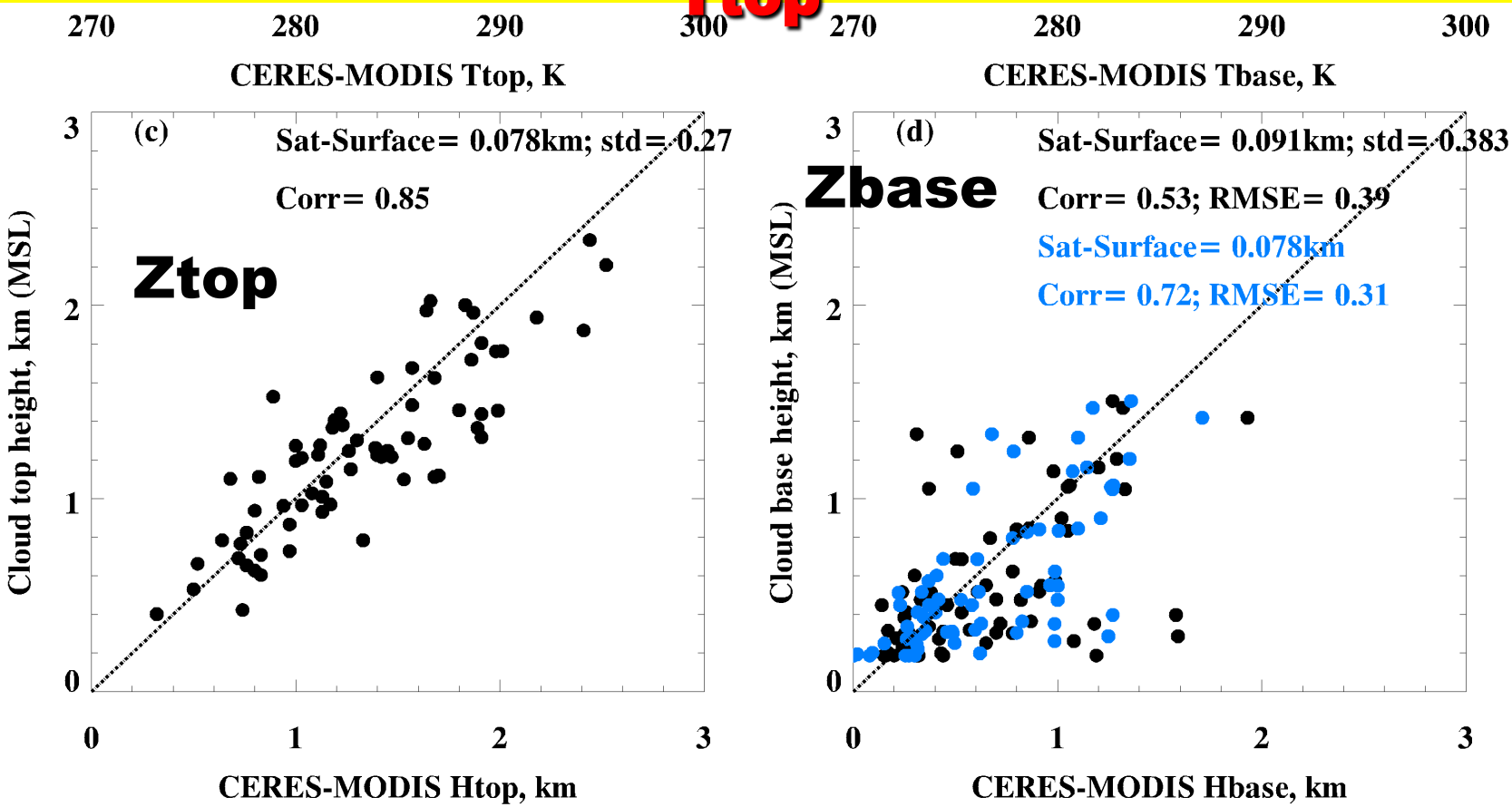
(1) Ttop agrees well with a correlation of 0.91

(2) ΔHtop ~ 78 m RMSE=0.27 km Corr= 0.85

(3) ΔHbase ~ 91 m but corr=0.53

How can we improve cloud base height?

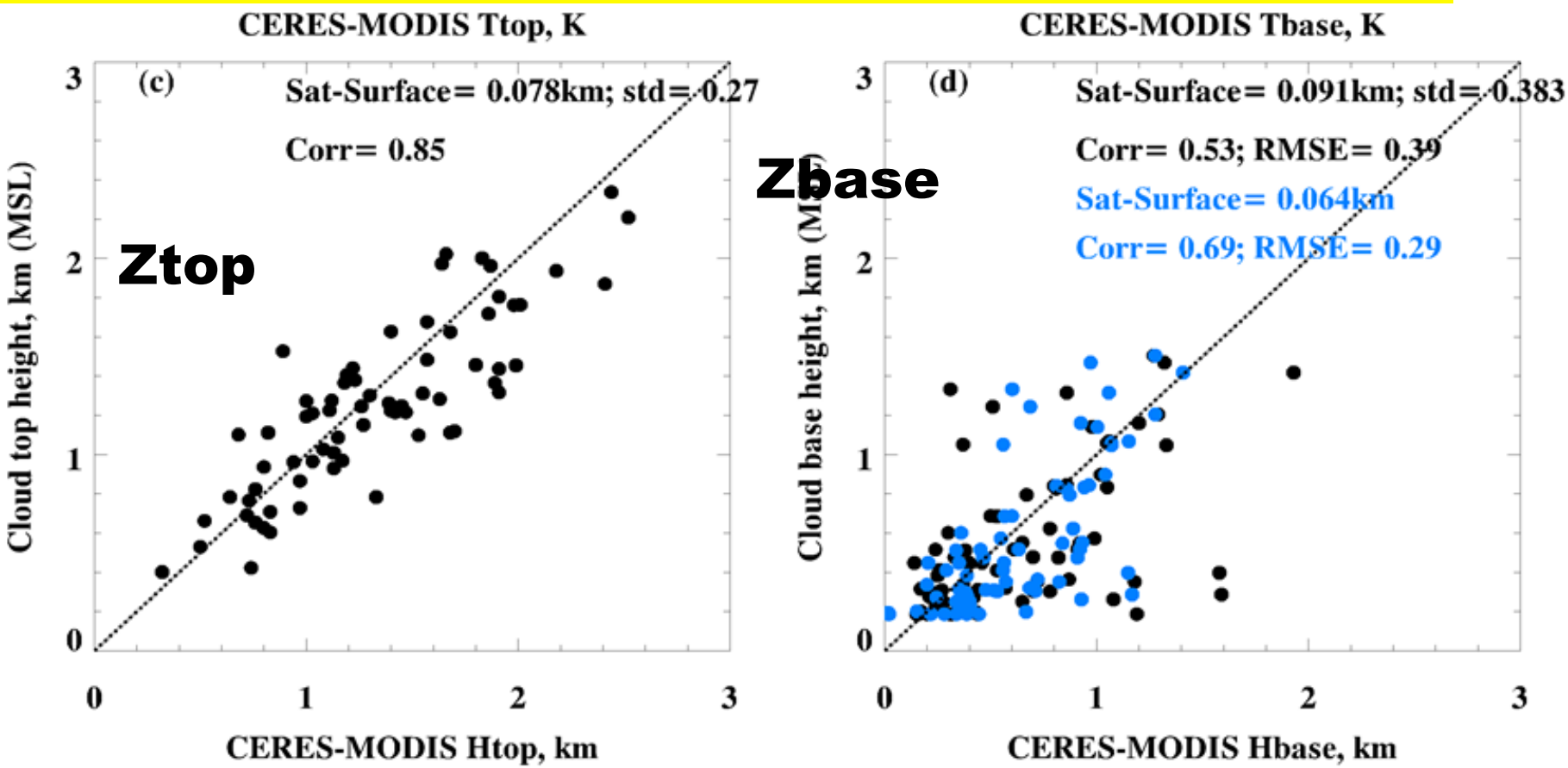
OPTION 1: Improving cloud base heights using ΔZ (radar-lidar) ~ 68 MODIS LWP, Ttop



$\Delta Z = -0.0156*(T_{top}-T_0)+0.0049*LWP +0.352$, Zbase= Ztop - ΔZ

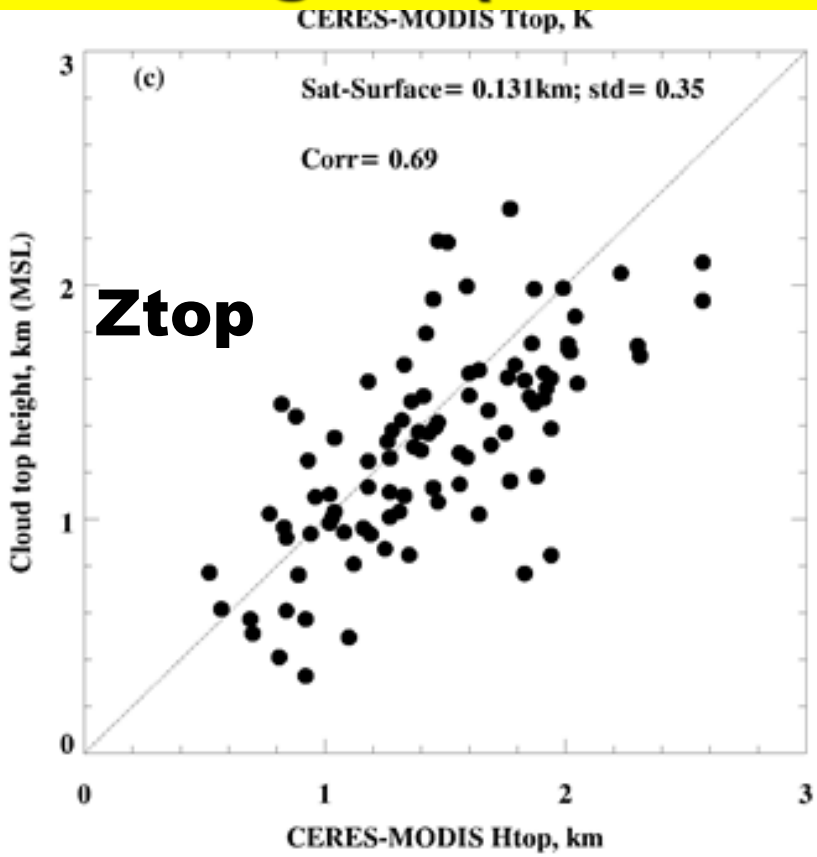
ΔZbase changes from 91 m to 78 m, correlation increases from 0.53 to 0.72, RMSE decreases from 0.39 to 0.31 km.

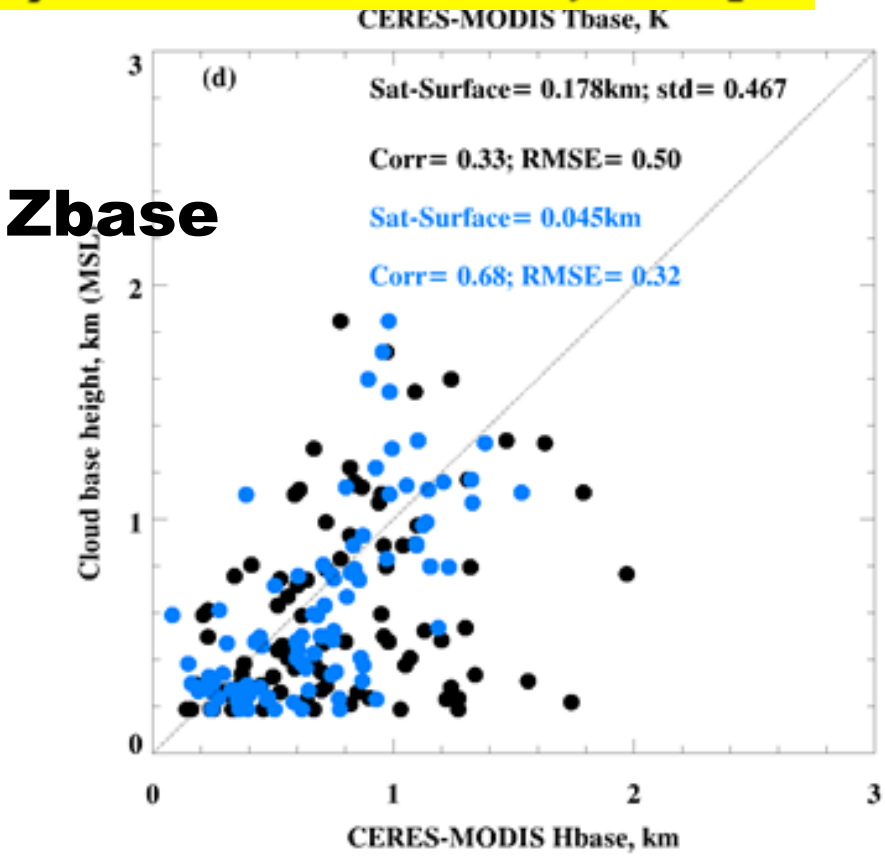
OPTION 2: Improving cloud base heights using ΔZ (radar-lidar) ~ all ARM LWP, Ttop



ΔZ= -0.037*(T_{top}-T_0)+0.00294*LWP +0.784, 19 months ARM data
ΔZbase changes from 91 m to 64 m, correlation increases from 0.53 to 0.69, and RMSE decreases from 0.39 to 0.29 km.

Nighttime: Improving cloud base heights using ΔZ (radar-lidar) ~ all ARM LWP, Ttop

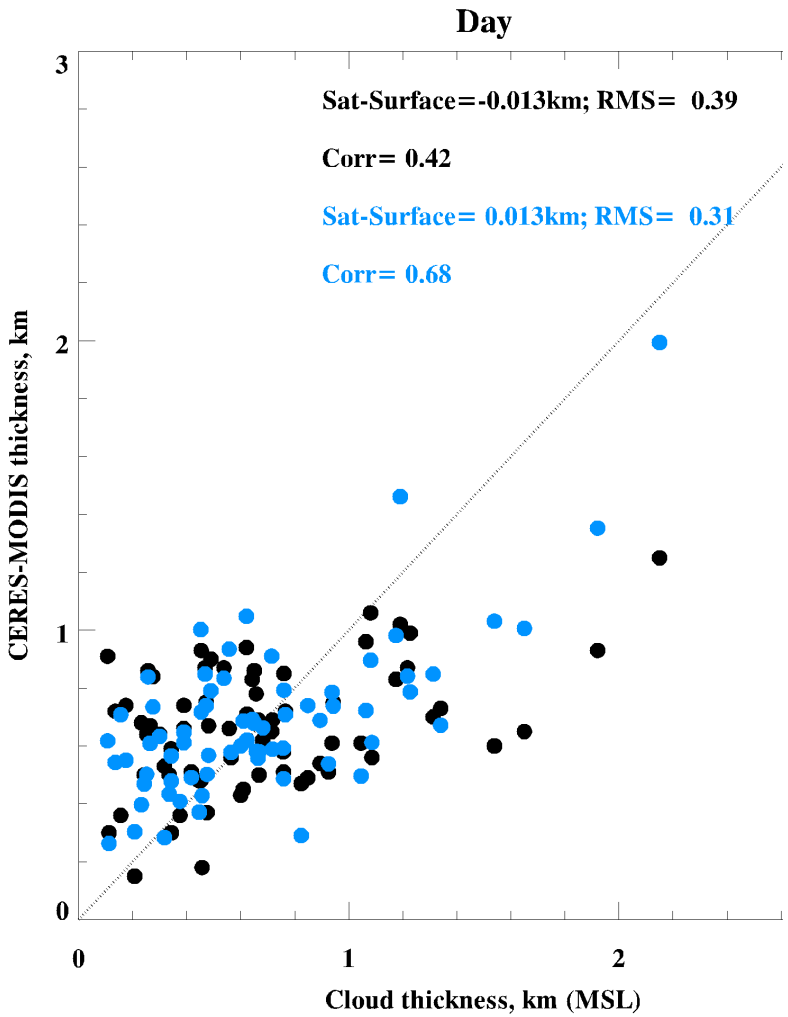


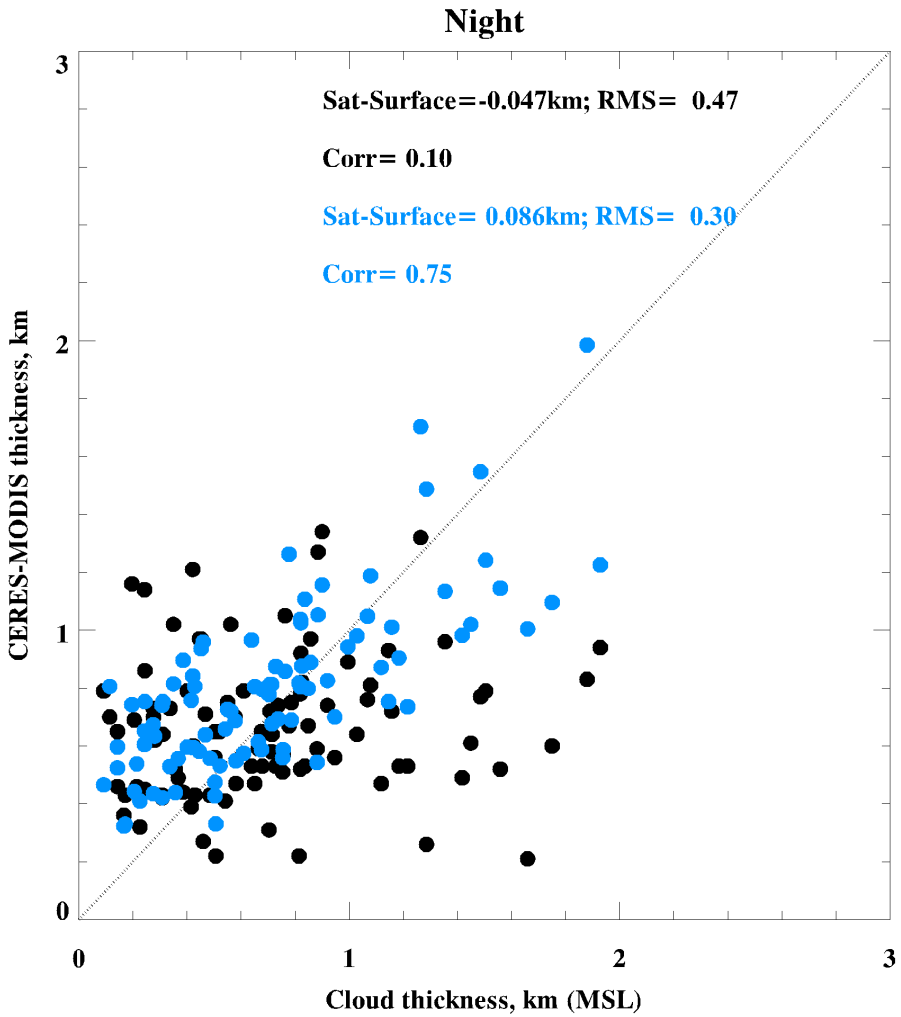


$\Delta Z = -0.037*(T_{top}-T_0)+0.00294*LWP +0.784$, Same as daytime

ΔZbase changes from 178 m to 45 m, correlation increases from 0.33 to 0.68, and RMSE decreases from 0.50 to 0.32 km.

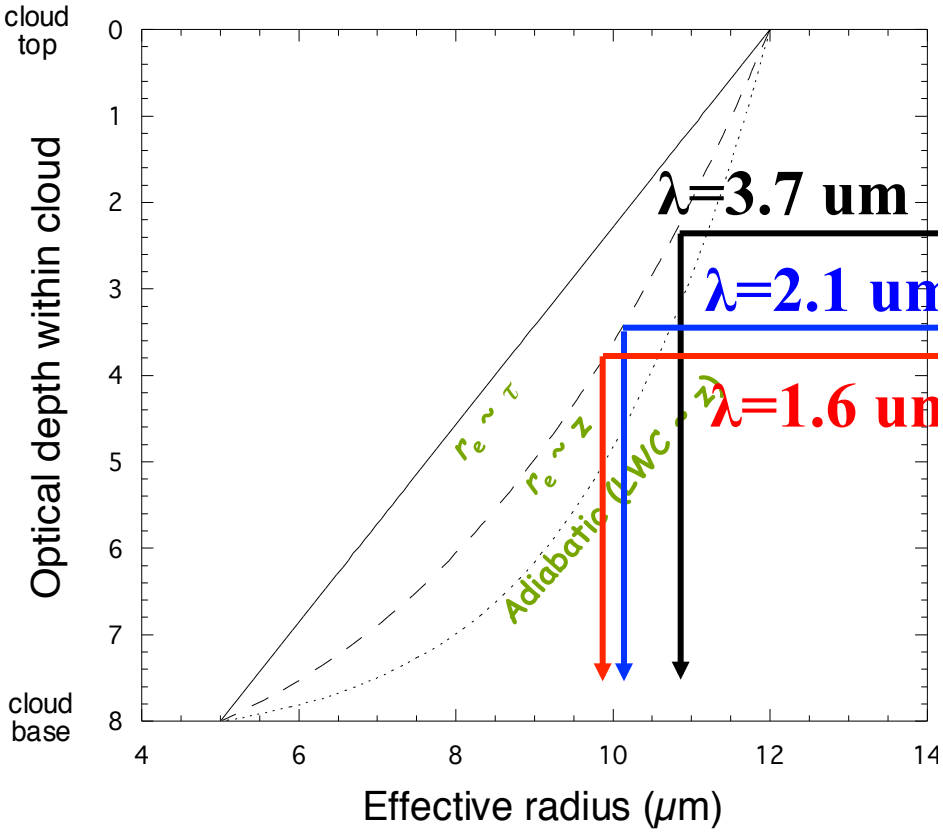
Cloud thickness comparison
ARM (radar-lidar) vs. MODIS old/new ΔZ

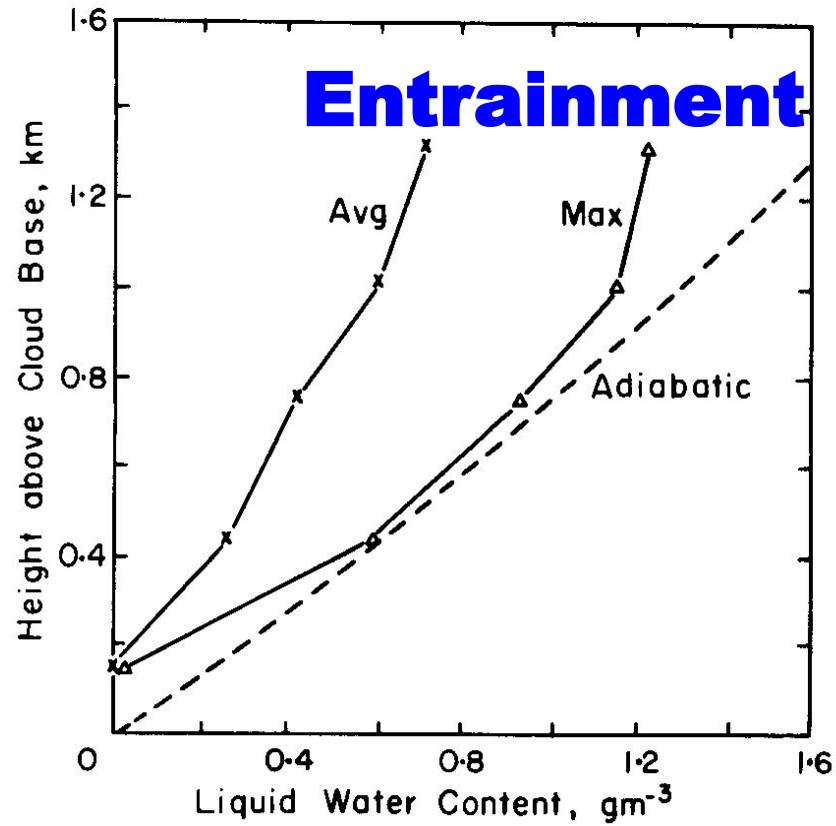




Newly parameterized ΔZ improves much better than old one.

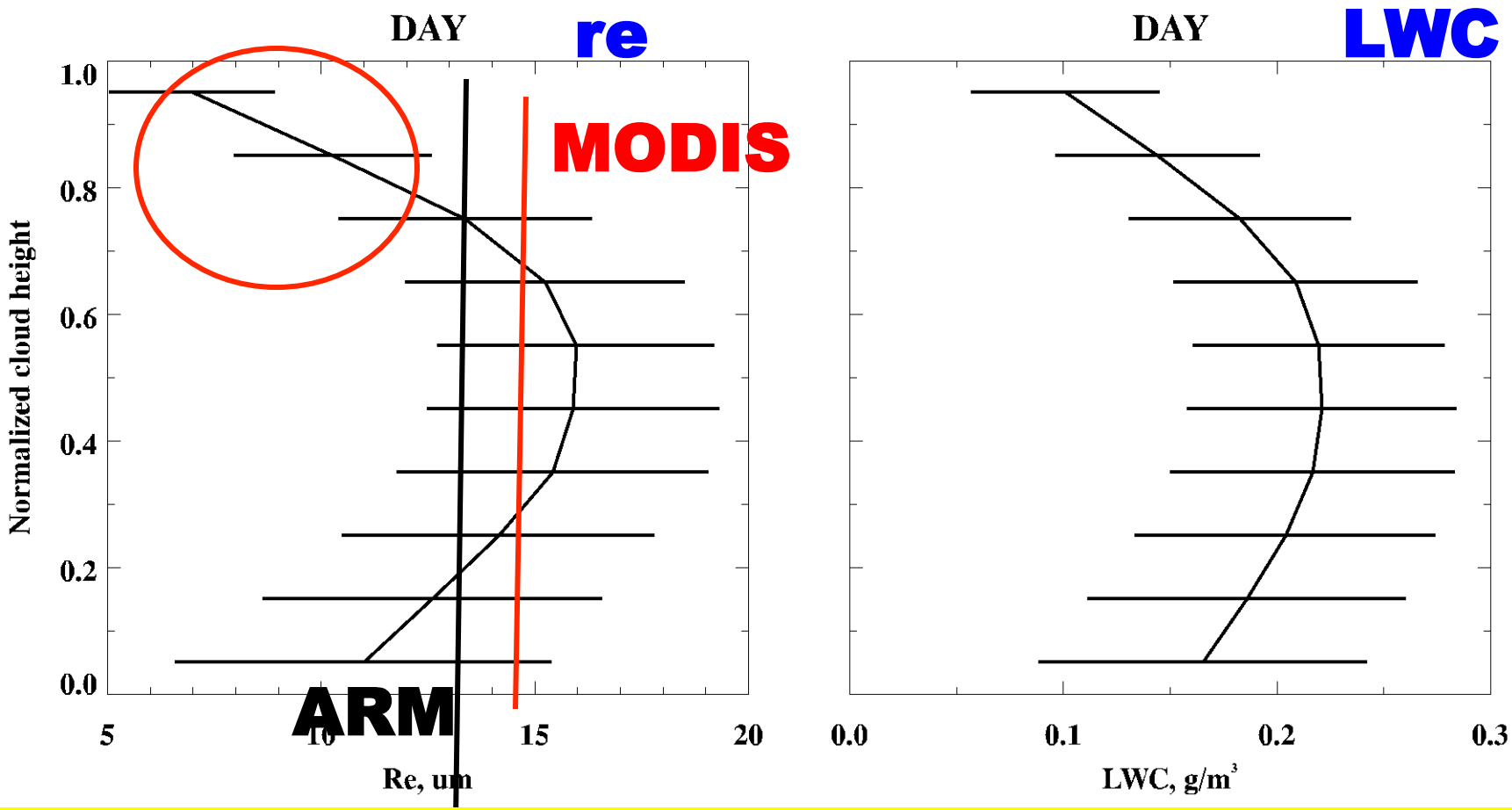
Effective radius (r_e) retrieval differences – *Theoretically re(3.7)>re(2.1)>re(1.6)*





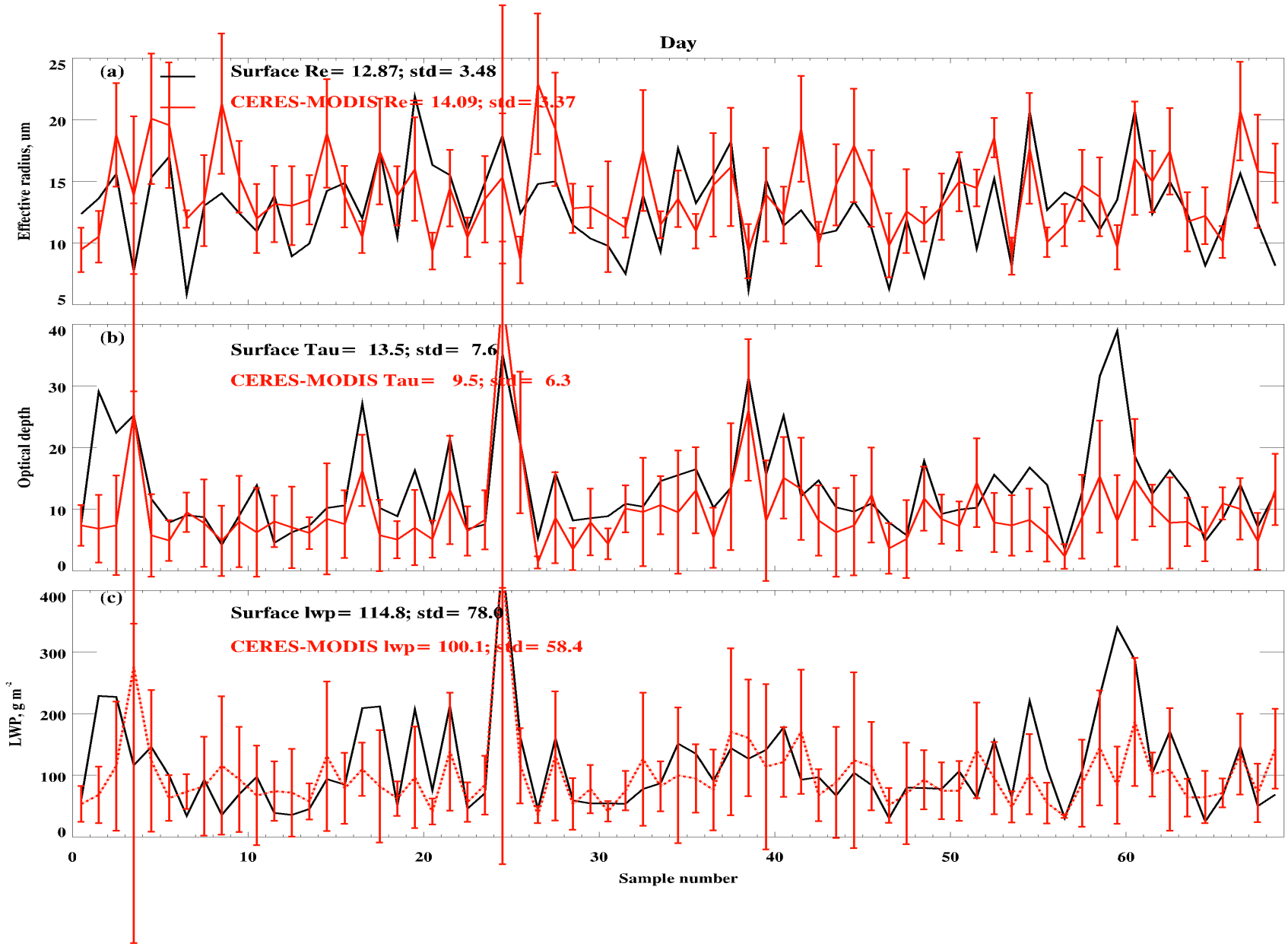
- **Both LWC & re should increase from base to top if they follow adiabatic growth (condensational growth)**
- **However, cloud-top entrainment decreases LWC and re.**

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

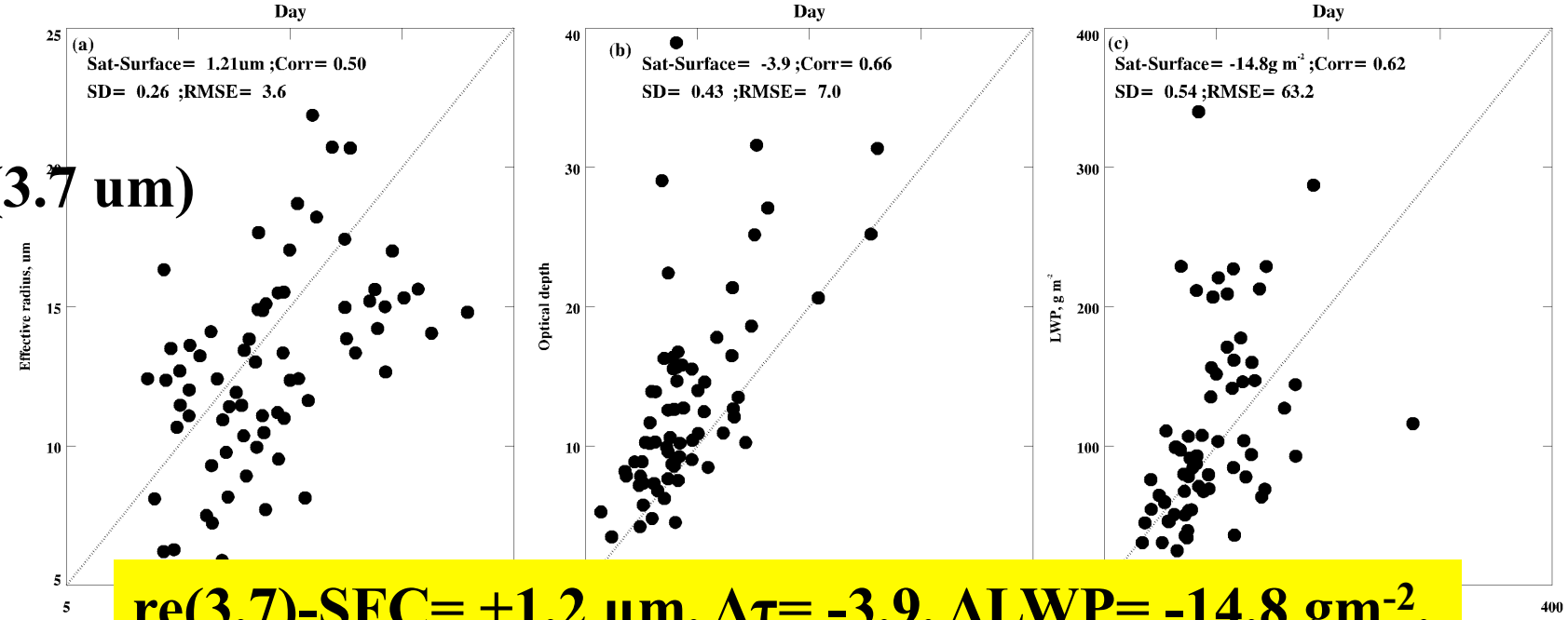


Cloud-top re and LWC are smaller than those at cloud center with re (3.7 um) < re (2.1) < re (1.6), which is opposite to adiabatic growth and previous studies (e.g., Nakajima et al. 1991, Miles et al. 2000).

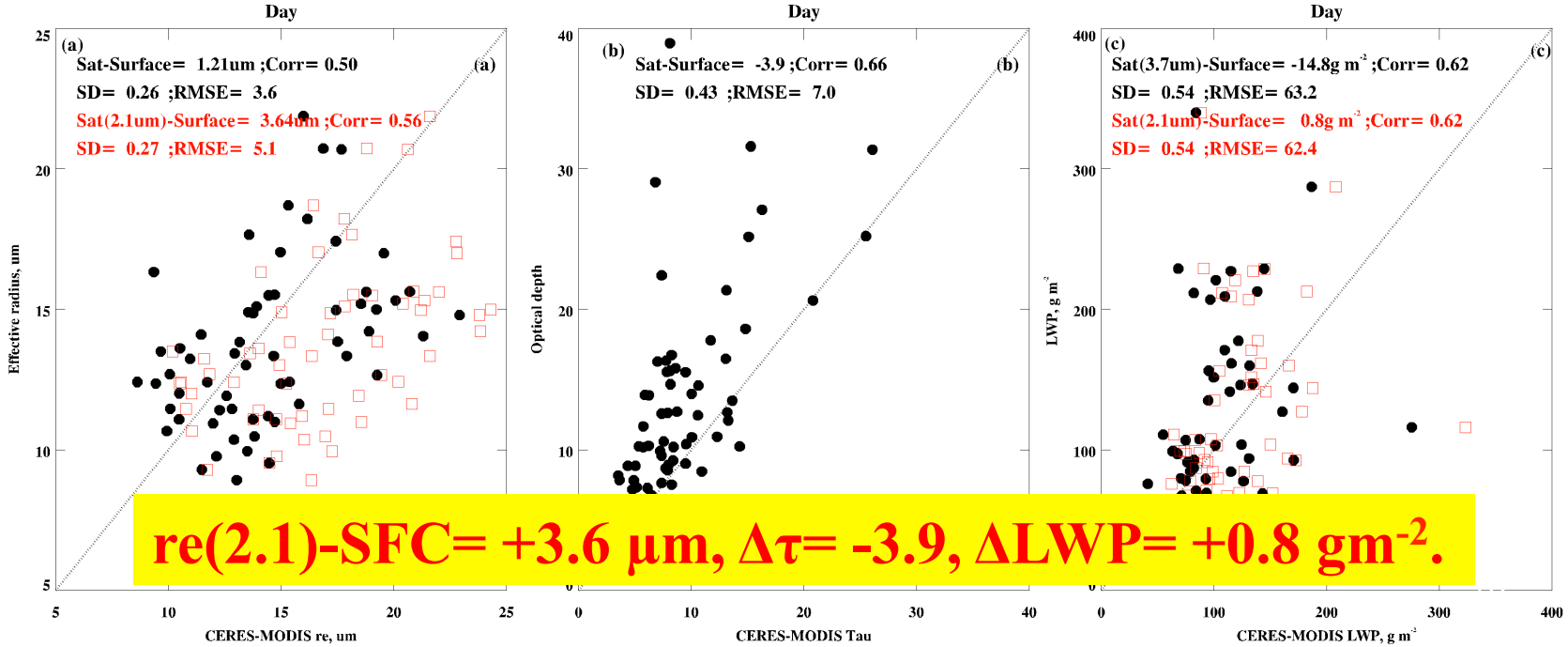
MBL Microphysical property comparison



re (3.7 um)



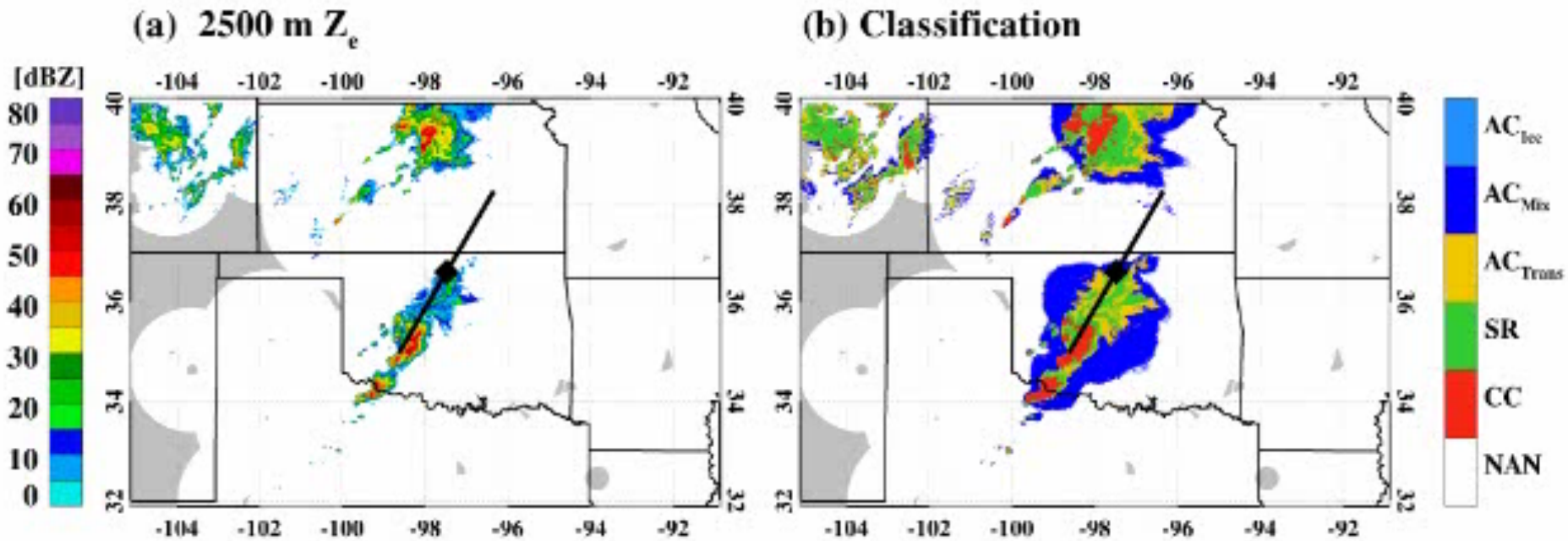
re(3.7)-SFC= +1.2 μm, Δτ= -3.9, ΔLWP= -14.8 gm^{-2}.



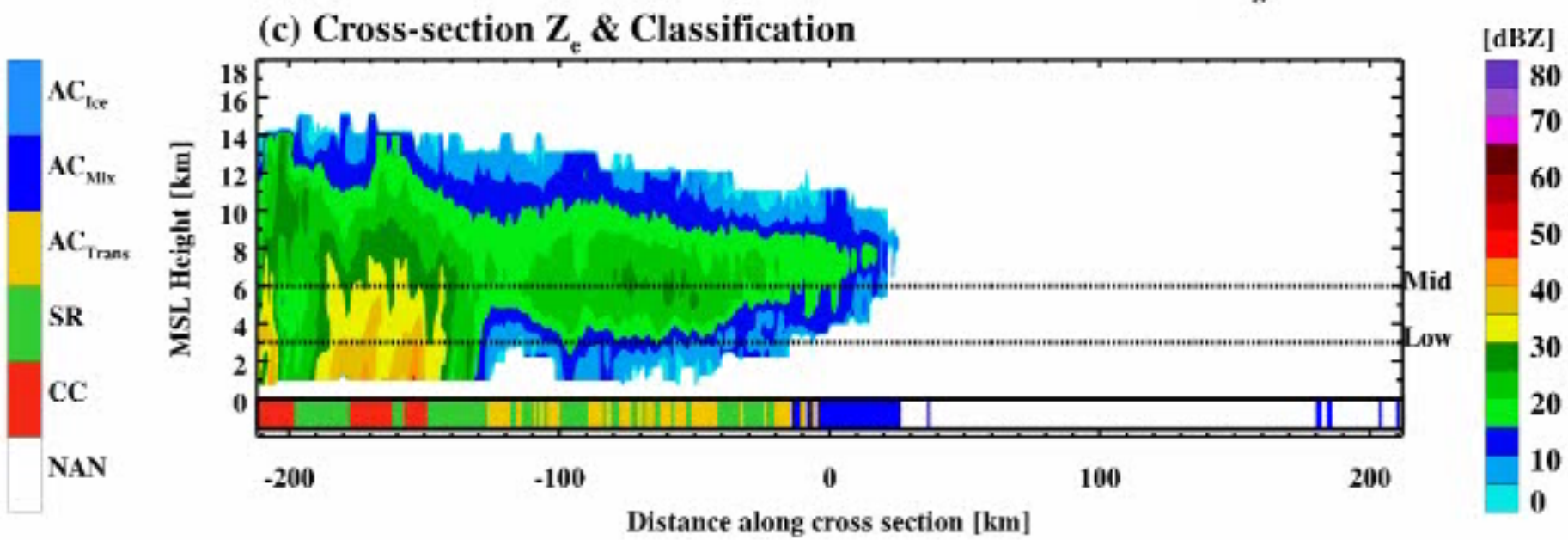
re(2.1)-SFC= +3.6 μm, Δτ= -3.9, ΔLWP= +0.8 gm^{-2}.

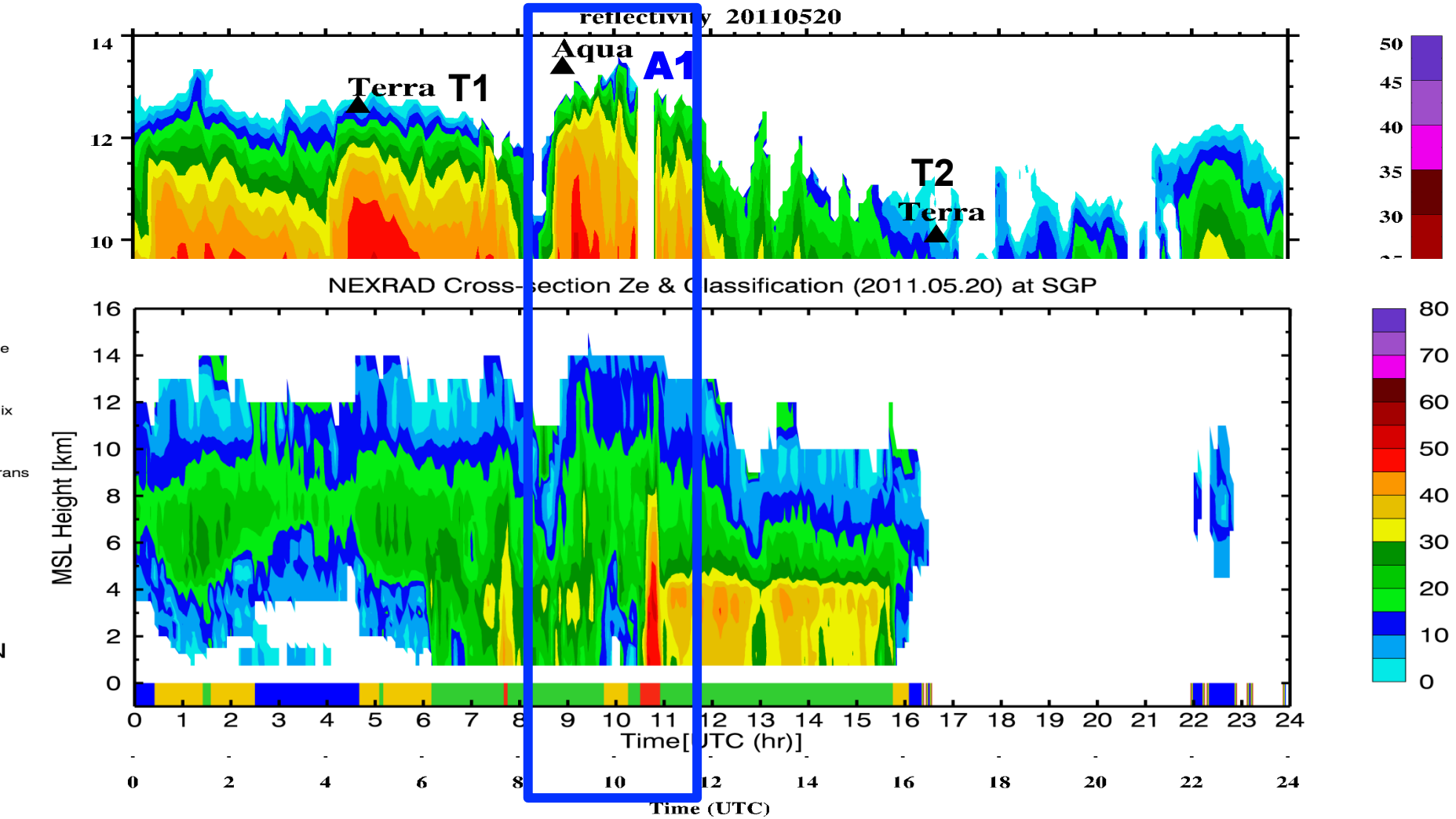
Deep Convective clouds (DCS) During MC3E

2011.05.20 00:00 UTC



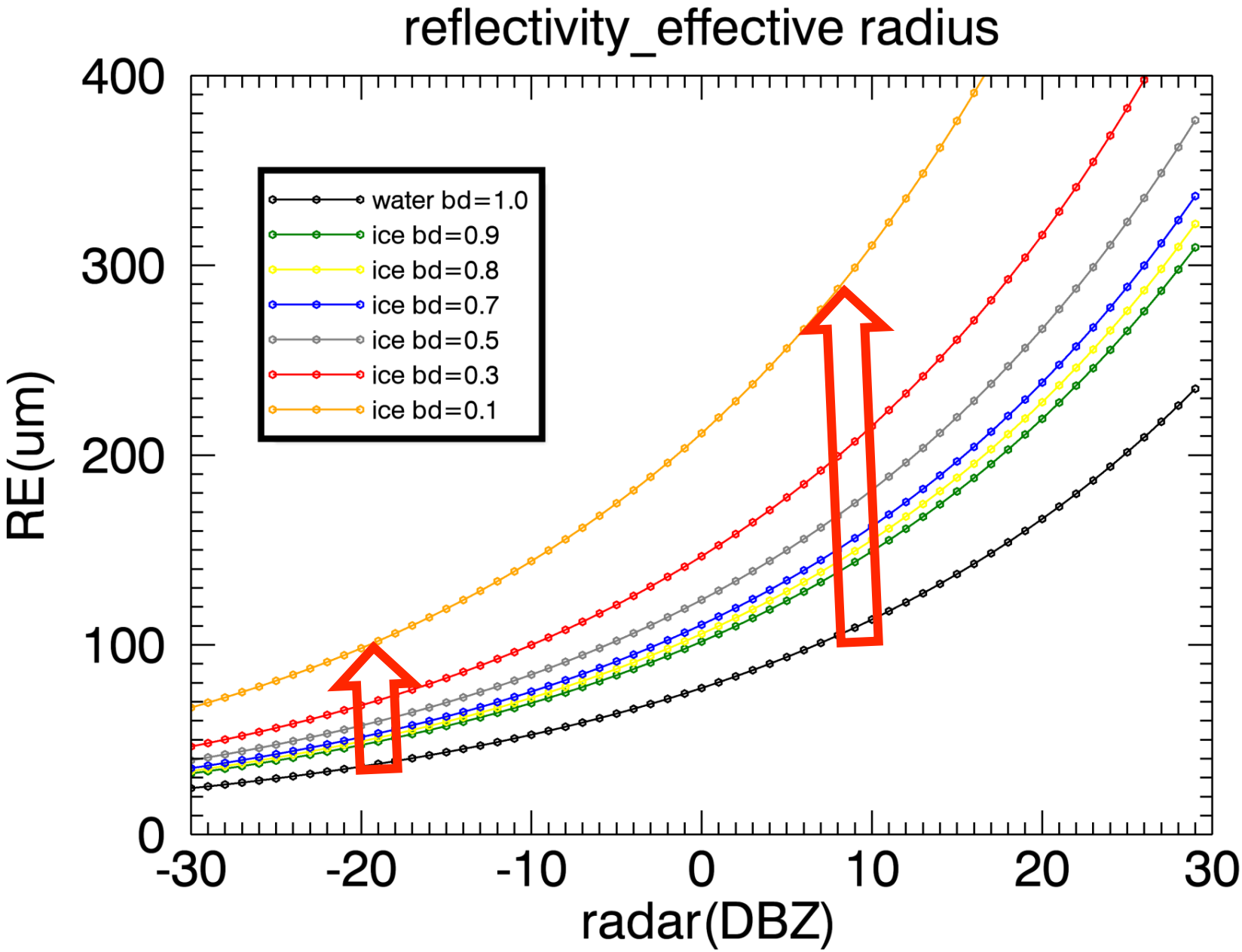
System moved from SW to NE, passed over ARM SGP site



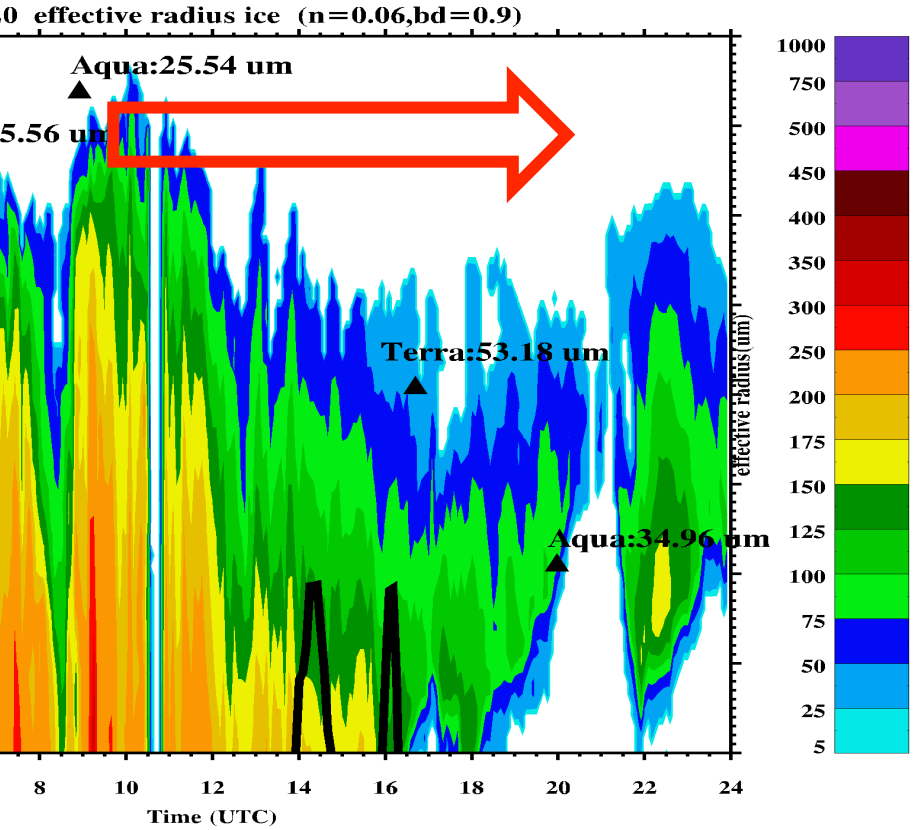


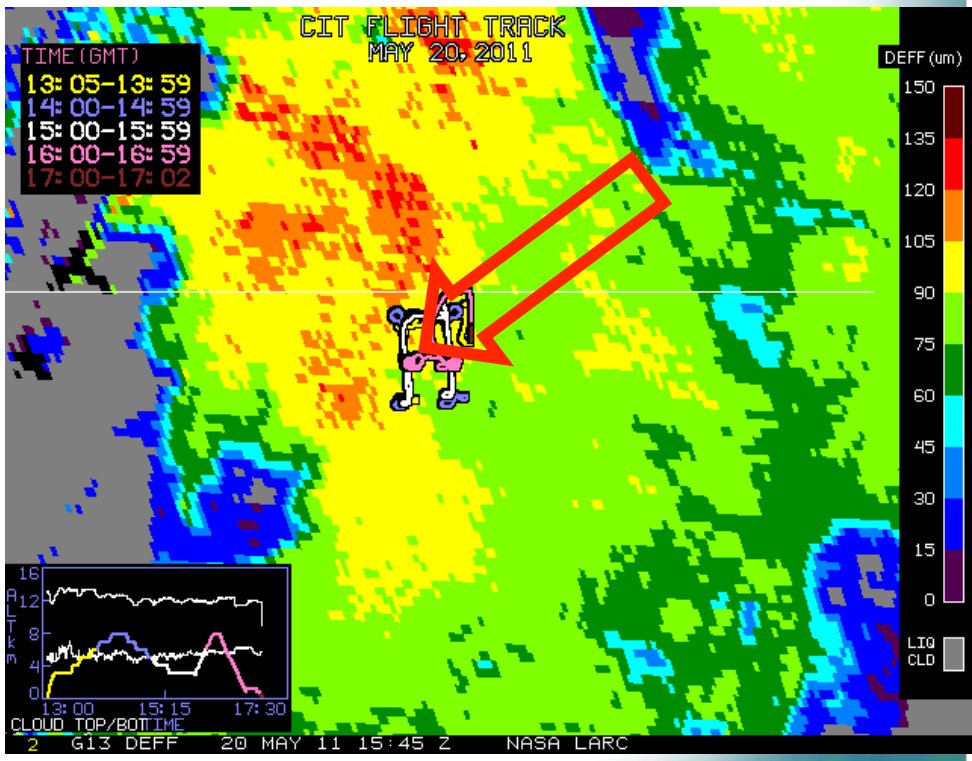
Terra MODIS heights (T1 & T2) agree with radar cloud-top heights; Z_{top} at Aqua overpass (A2) is lower than the radar measured cloud top→ This is reasonable for optically thin clouds.

Z_{top} at A1 is ~ 1 km higher than the radar cloud top because it is surrounded by the convective core and the radar signal might be attenuated by the precipitation, but NEXRAD detected Ztop ~ 14 km.


reflectivity_effective radius
water bd=1.0
ice bd=0.9
ice bd=0.8
ice bd=0.7
ice bd=0.5
ice bd=0.3
ice bd=0.1
RE(um)
radar(DBZ)
400
300
200
100
0
-30
-20
-10
0
10
20
30

GOES retrieved cloud properties at 15:45Z





ARM re values range from 25-75 um for cloud top, GOES re values range from 37-60 um.

Summary (for Azores MBL clouds)

1) CERES-MODIS derived Cloud-top temp and height for day and night agree very well with ARM observations, Suggesting the CC-derived lapse rate did a good job over the Azores.

2) Applying newly derived ΔZ vs LWP and Ttop to infer MODIS cloud-base heights, a big improvement has been made.

3) CERES MODIS retrieved LWPs agree well with ARM, but their re values are ~1-2 um higher and optical depth are 3.9 lower than ARM retrievals→ A further validation is needed →An IOP has been proposed to ARM led by PI (Dong) to fly UND aircraft over Azores during summer 2015.

Summary (for DCS clouds at SGP)

1) CERES-MODIS derived Cloud-top cloud-top heights for DCS are within ARM Cloud and NEXRAD radar observations for this case.

2) CERES-MODIS/GOES retrieved ice cloud effective radii also agree well with ARM retrievals.

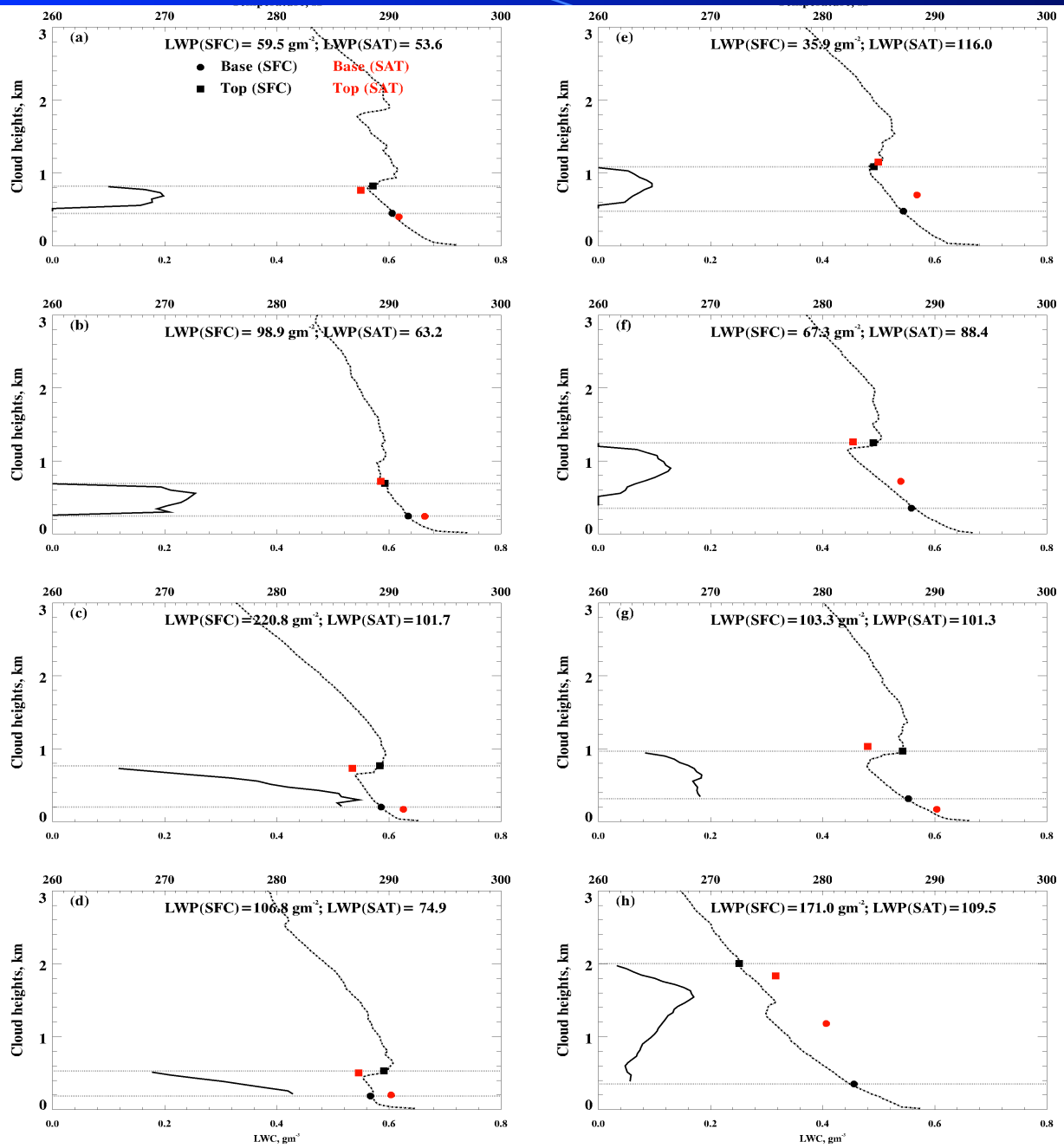
More cases will be compared for next CERES STM, and will refine our retrieval methods.

Xiquan Dong's research group (2012-13)

Future work

- Need to validate lase rate mapping over land, e.g. SGP site, NSA sites.
- Provide new parameterized thickness over ARM sites.

Agree well **Not agree well**



From 68 selected cases, 55 cases of Ztop are within the cloud-top inversion layer, while 13 cases of Ztop are under the inversion layer.

Even with relatively large ΔTtop, MODIS derived Ztop values agree well ARM radar suggesting the current lapse rate derived from Cloudsat-CLIPSO did a good job.

A conceptual model of midlatitude Marine Boundary Layer (MBL) Clouds

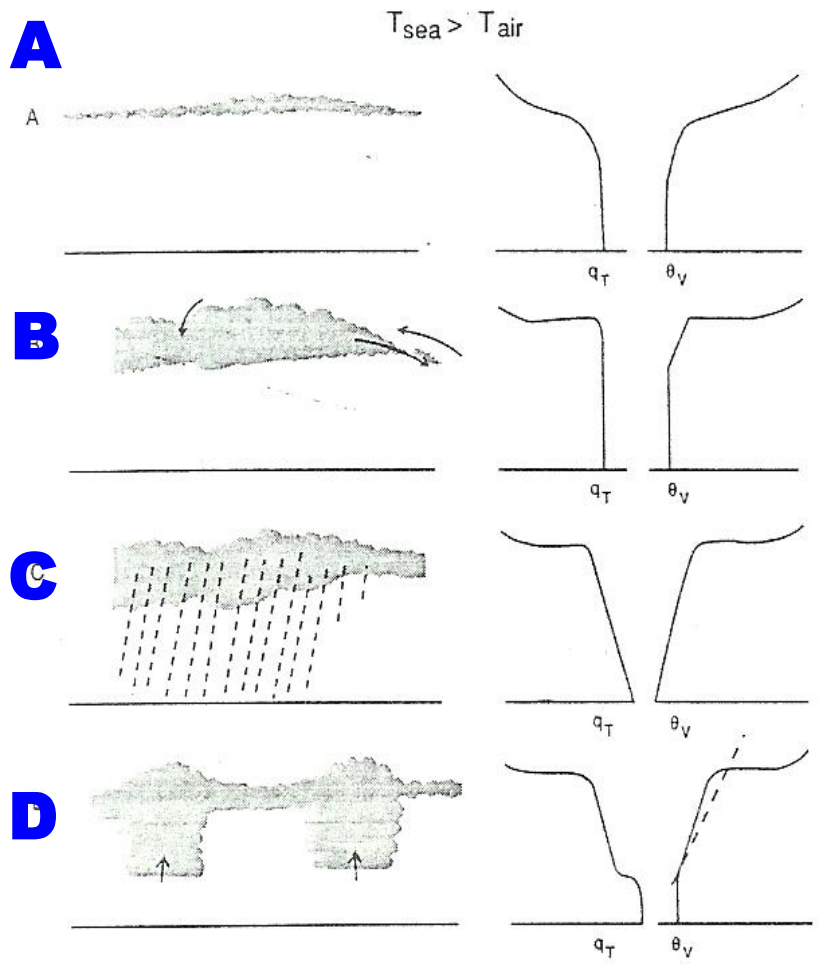


FIG. 15. Life cycle of a marine stratus layer as it forms in the presence of surface heating with corresponding profiles of total-water (q_t) and virtual potential temperature (θ_v). The dashed line in (d) represents the wet adiabat.

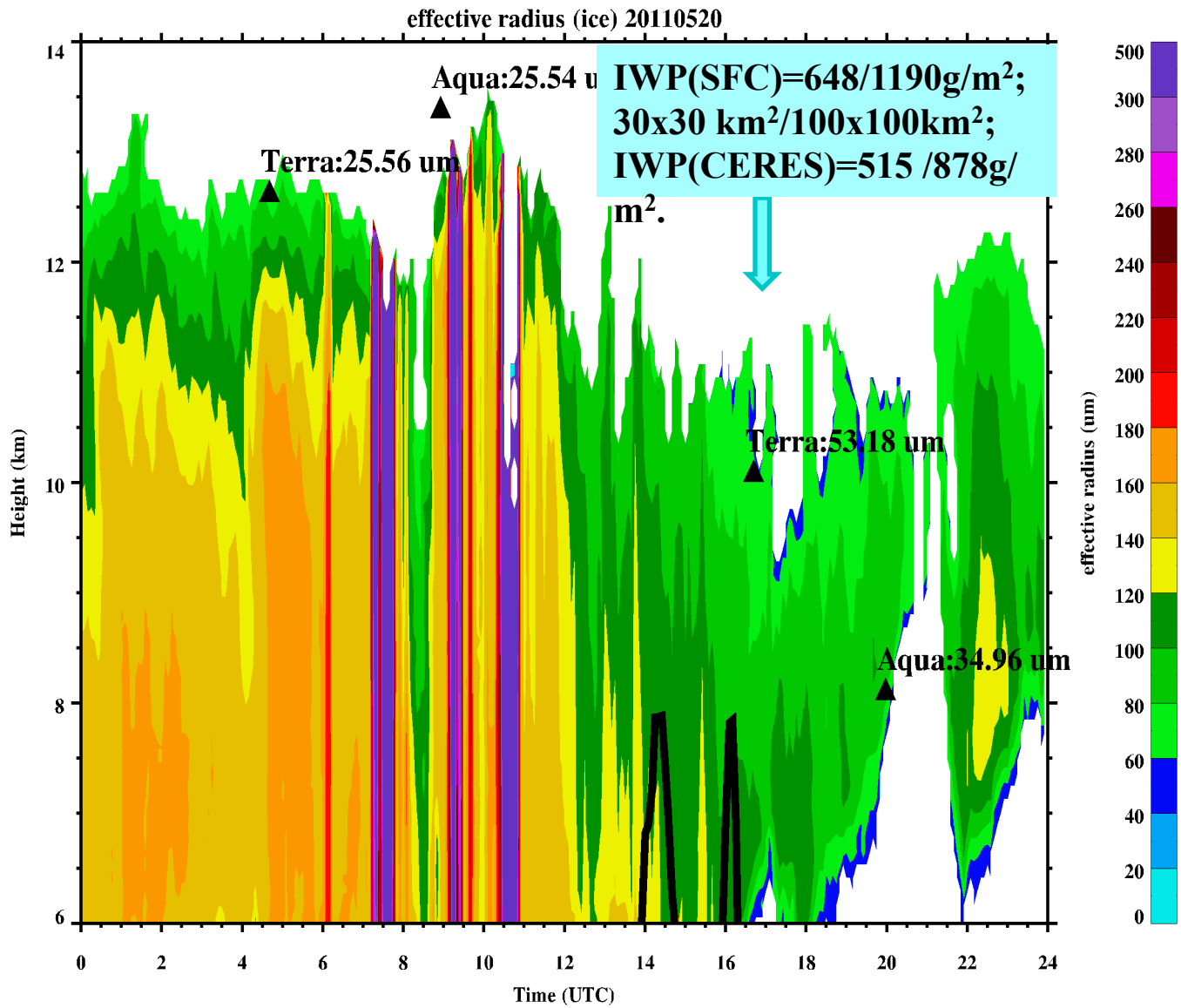
Based on aircraft in situ data, Paluch and Lenschow (1991) developed a conceptual model of the life cycle of MBL in the midlatitudes.

(A) It starts initially as a thin, homogenous layer,

(B-C) then grows thick and becomes patchy with time and produces precipitation (close cells).

(D) This stage is followed by the formation of small cumuli below, and eventually disintegrates, leaving a field of cumuli behind (open cells).

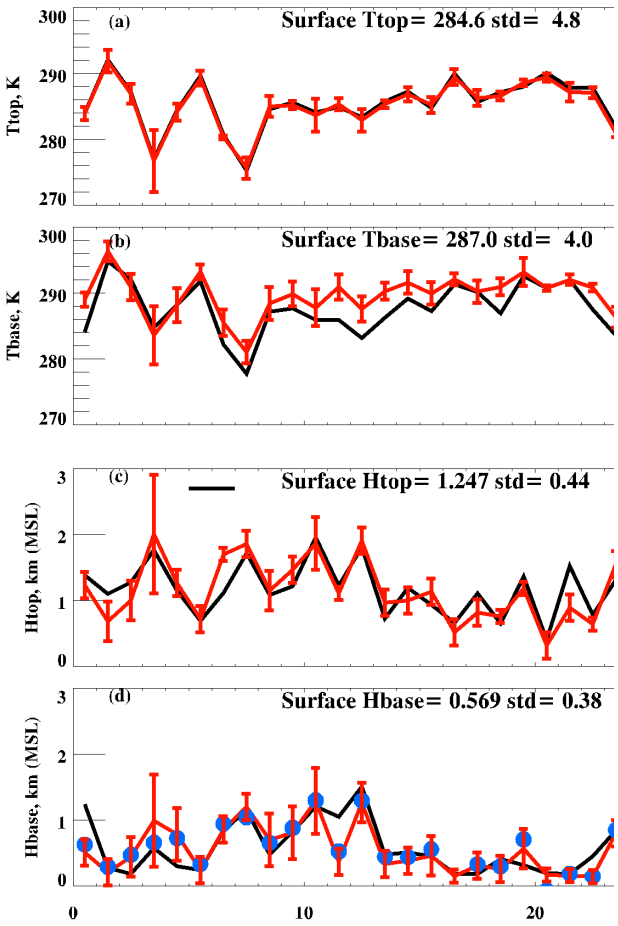
Comparison between Terra/Aqua retrieved Re(ice) and our retrievals for DCS clouds

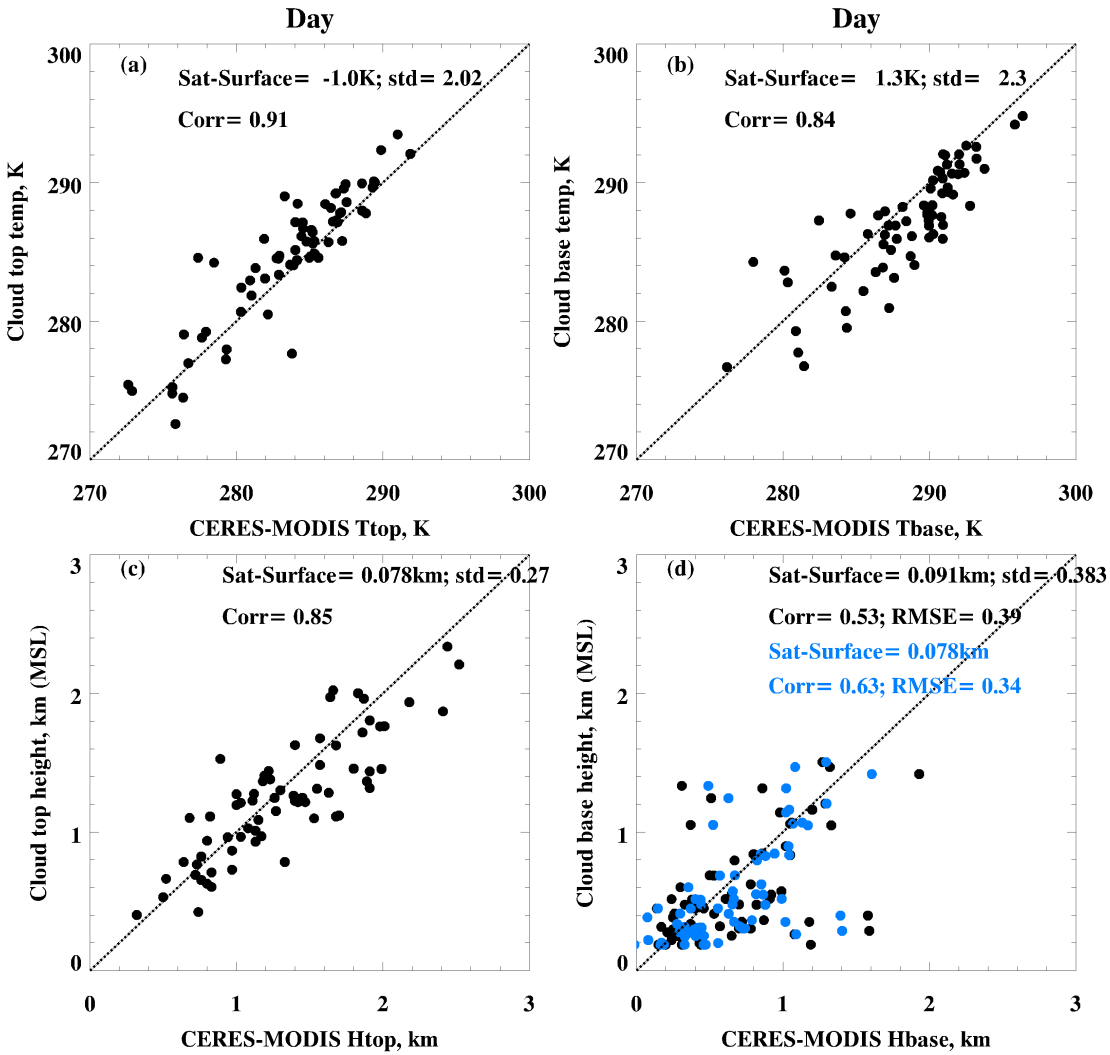


(1)The cloud top heights at each overpass were labeled by triangles. Two top heights agree very well, one is too low and the other is higher than ours, which may due to the attenuation of radar.

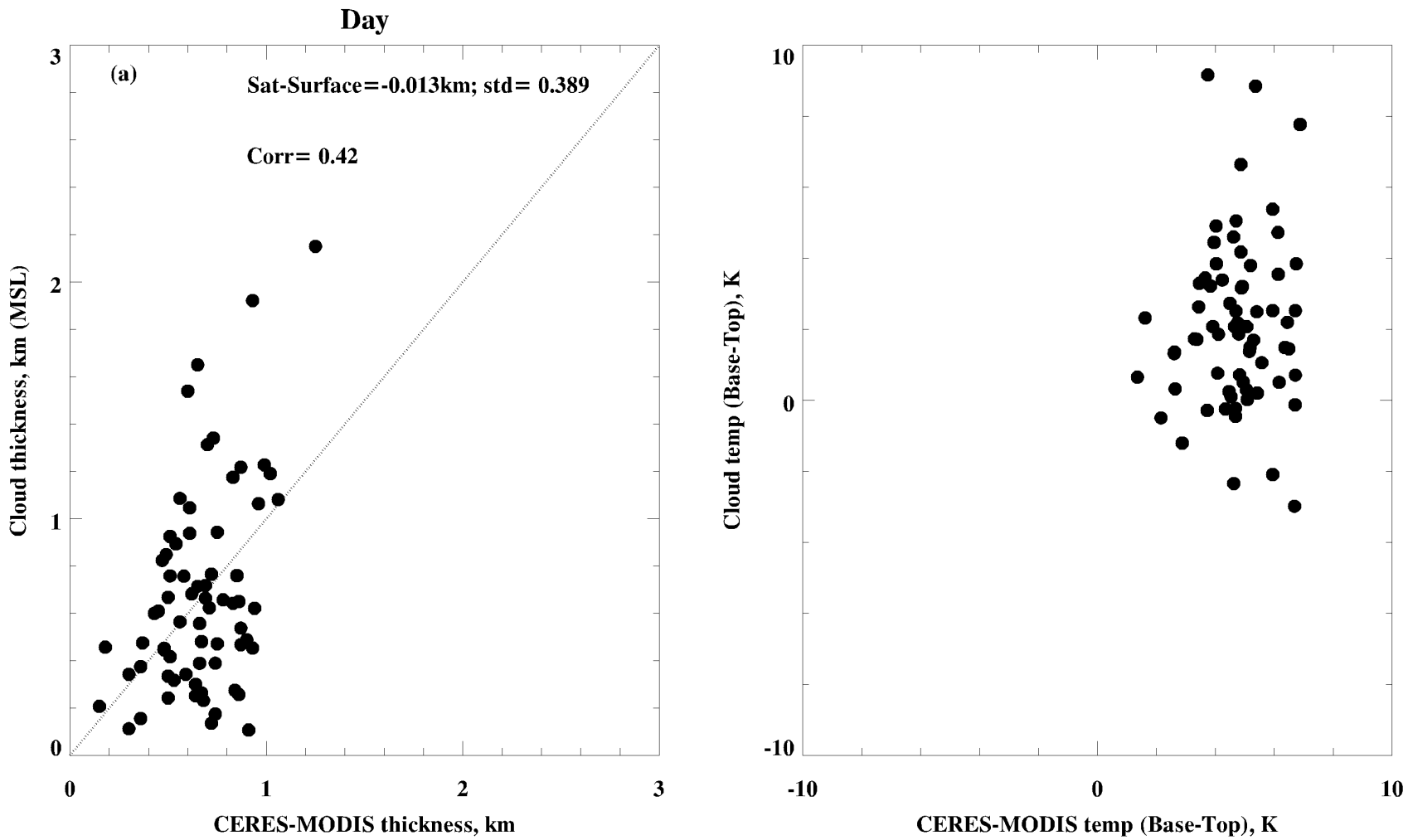
(2)CERES-MODIS retrieved

OPTION 2: Improving





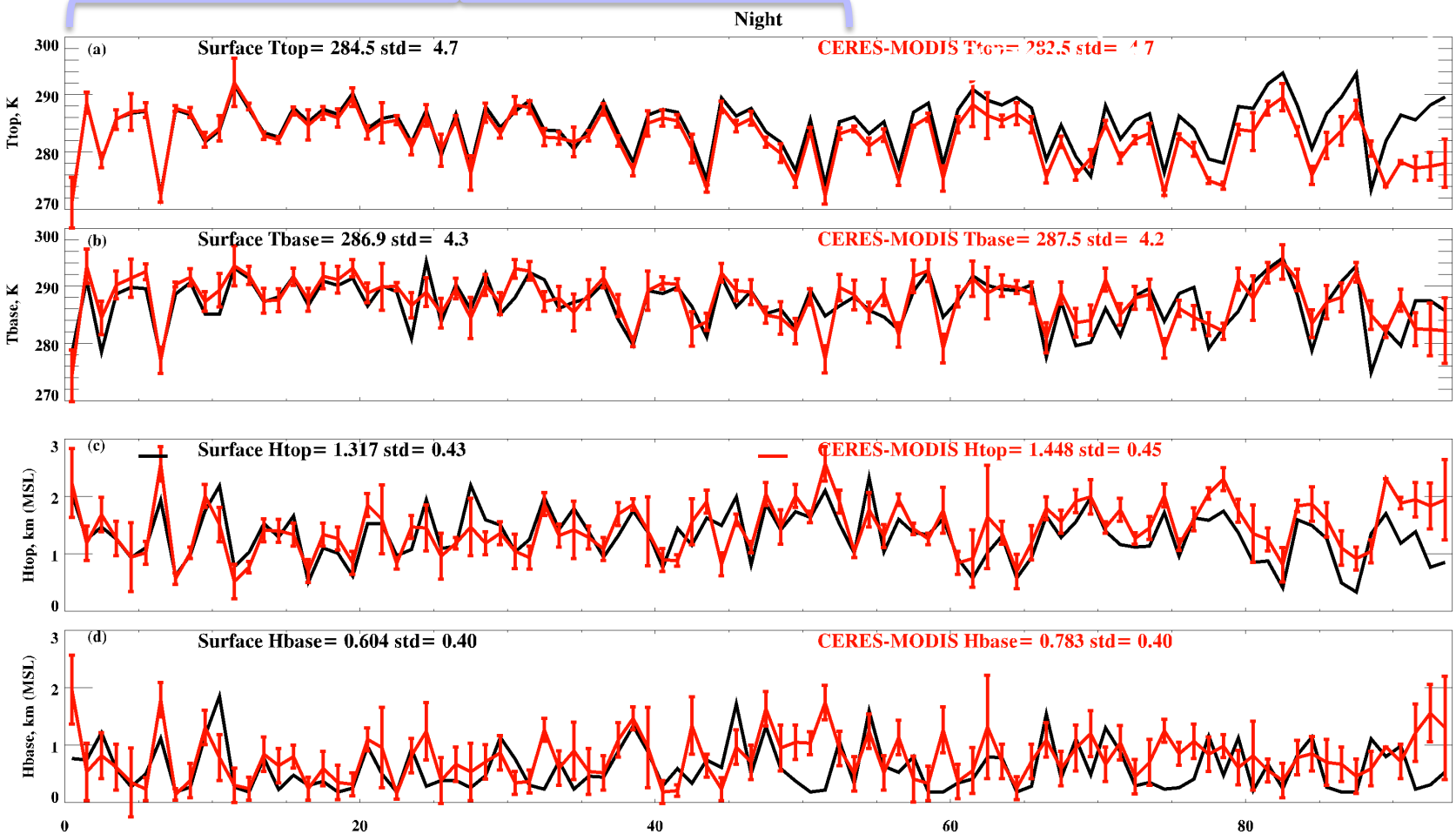
The mean difference does not change a lot, but the correlation is not as good as use LWP ,but still becomes stronger, and RMSE



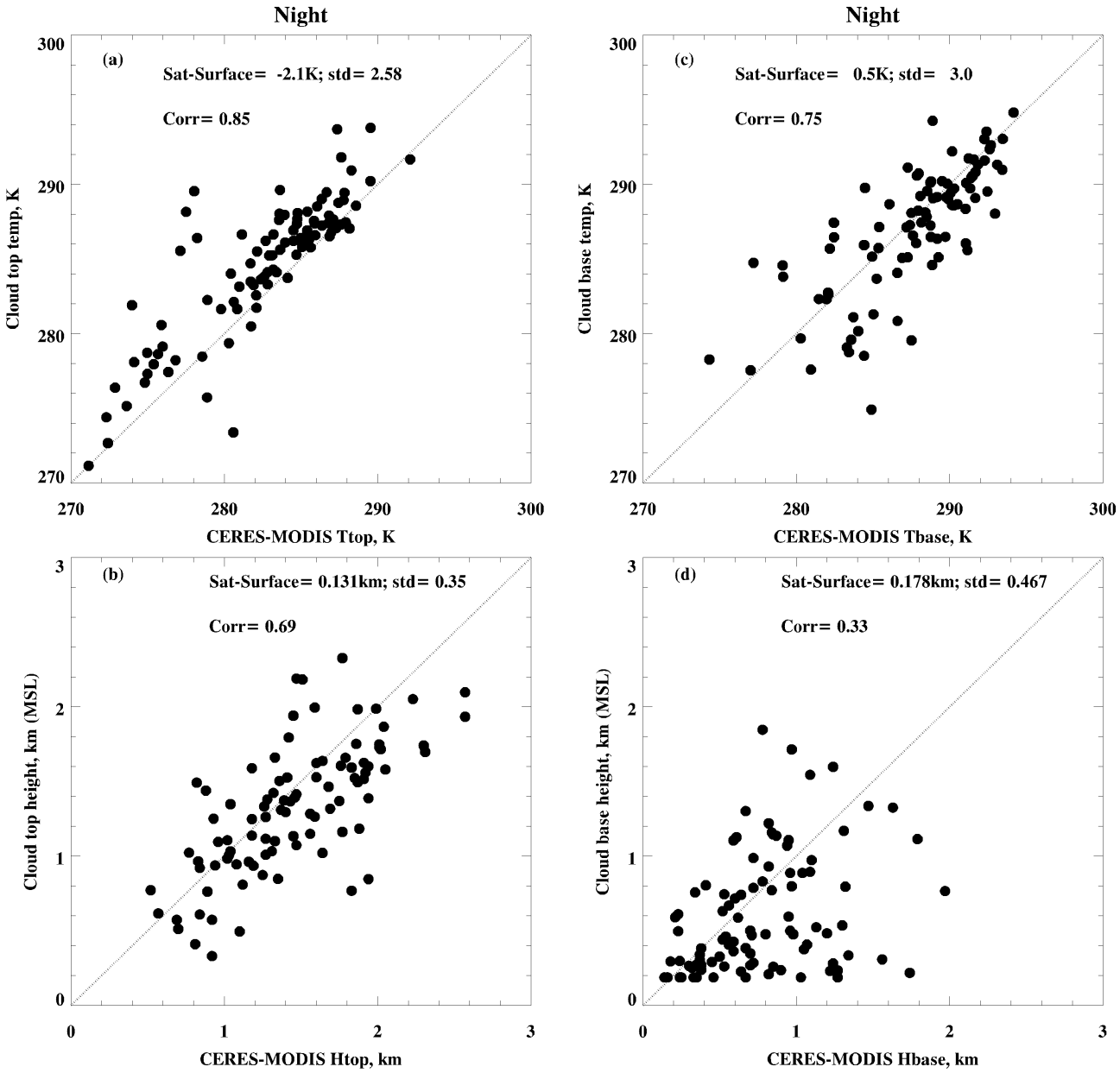
Passive remote sensing cannot interpolate the temperature inversion that often happens over AZORES, therefore, the parameterized the thickness is really necessary.

Night time

(1) $|T_{top}(CERES)-T_{top}(SFC)| \leq 2K$



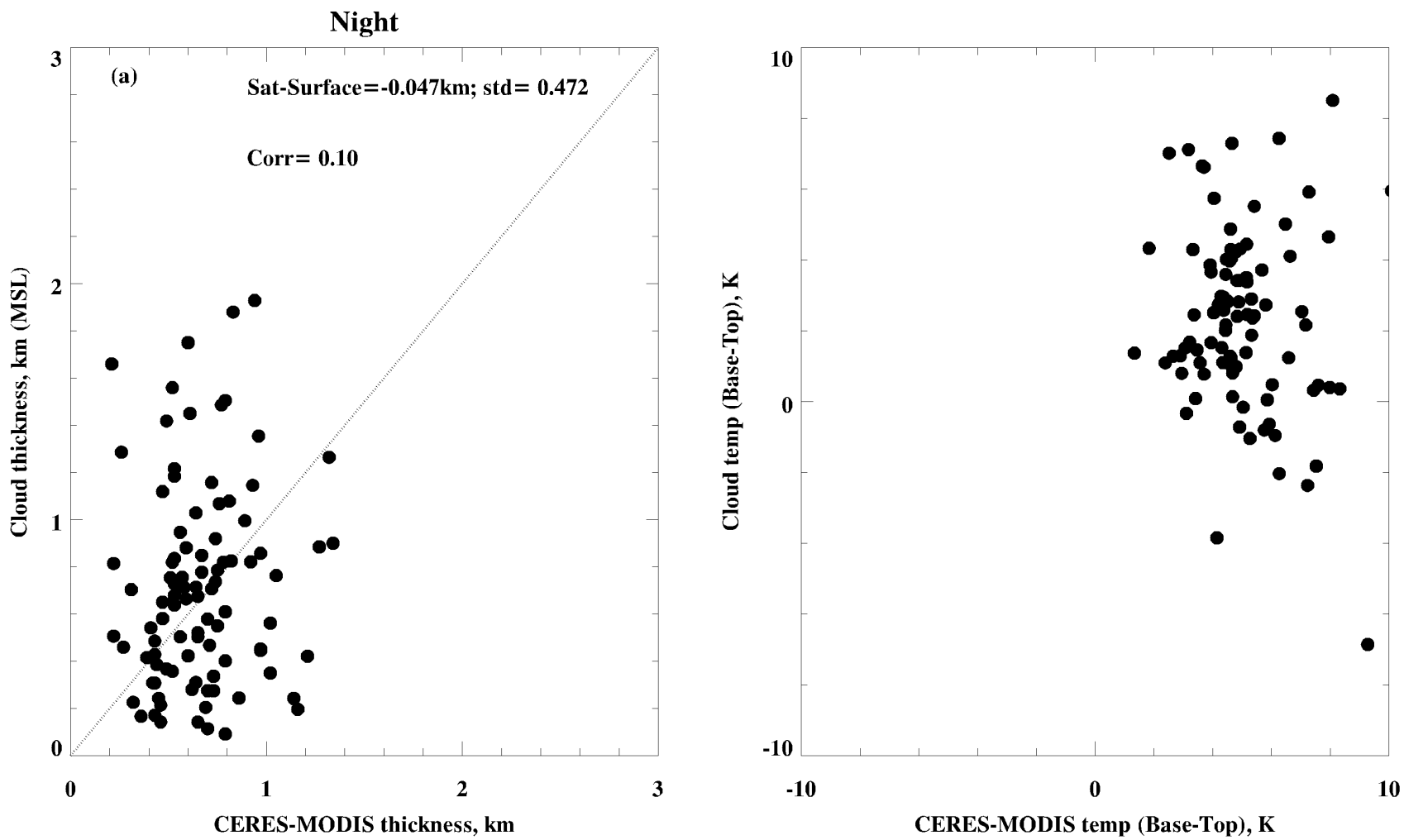
	$\overline{\Delta Z}_{top}$, km	$\overline{\Delta Z}_{base}$, km	$\overline{\Delta T}_{top}$, K	$\overline{\Delta T}_{base}$, K
ALL	0.131	0.178	-2.1	0.50
Region(1)	-0.020	0.136	-0.694	0.66
Region(2)	0.311	0.228	-3.67	0.35



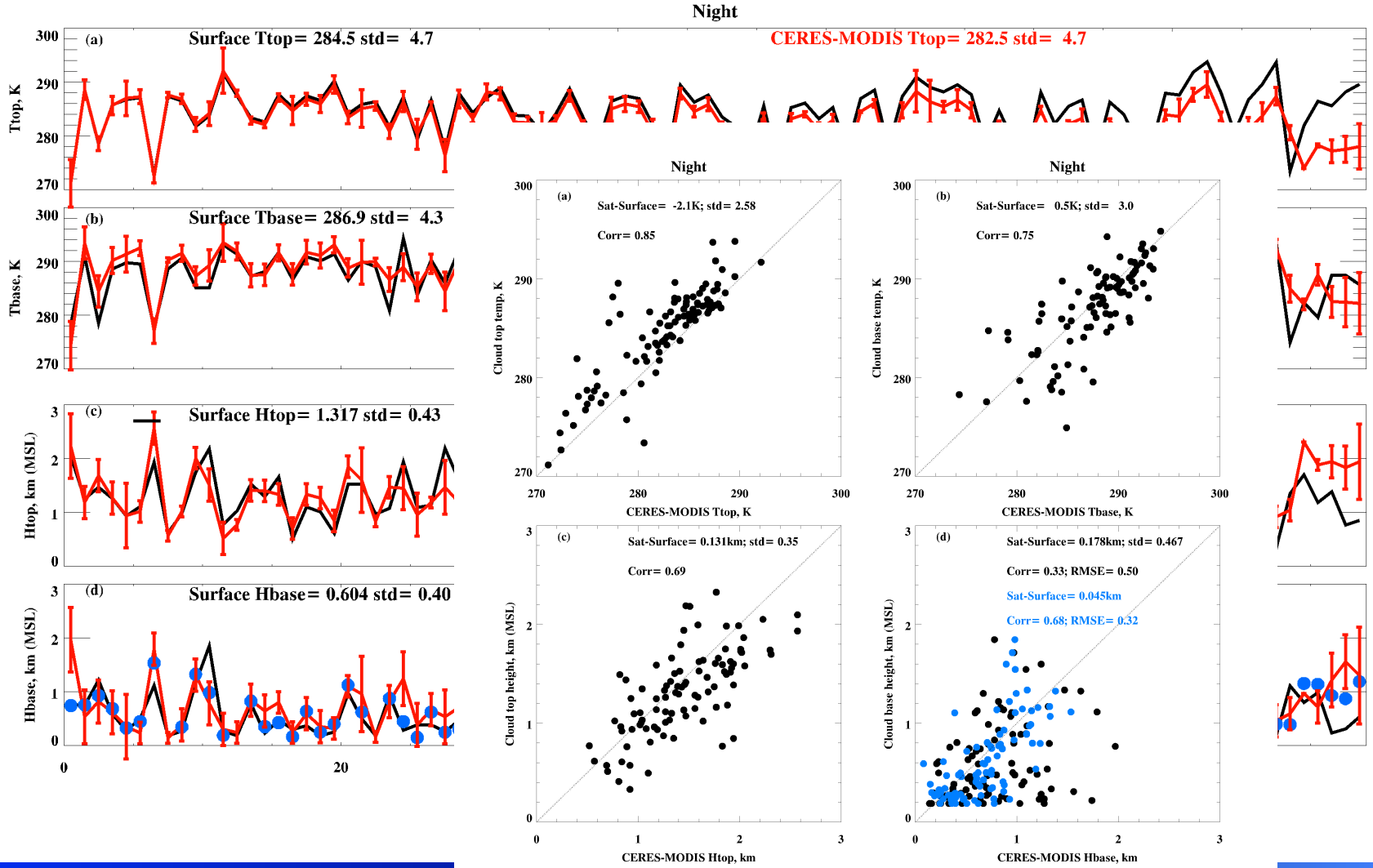
(1)The cloud top temperatures difference is 2.1 K and the correlation is 0.85;

(2)The cloud top height induced by lapse rate has only 131 meter difference with correlation coef. 0.69

)The cloud base height has 178 meters difference.

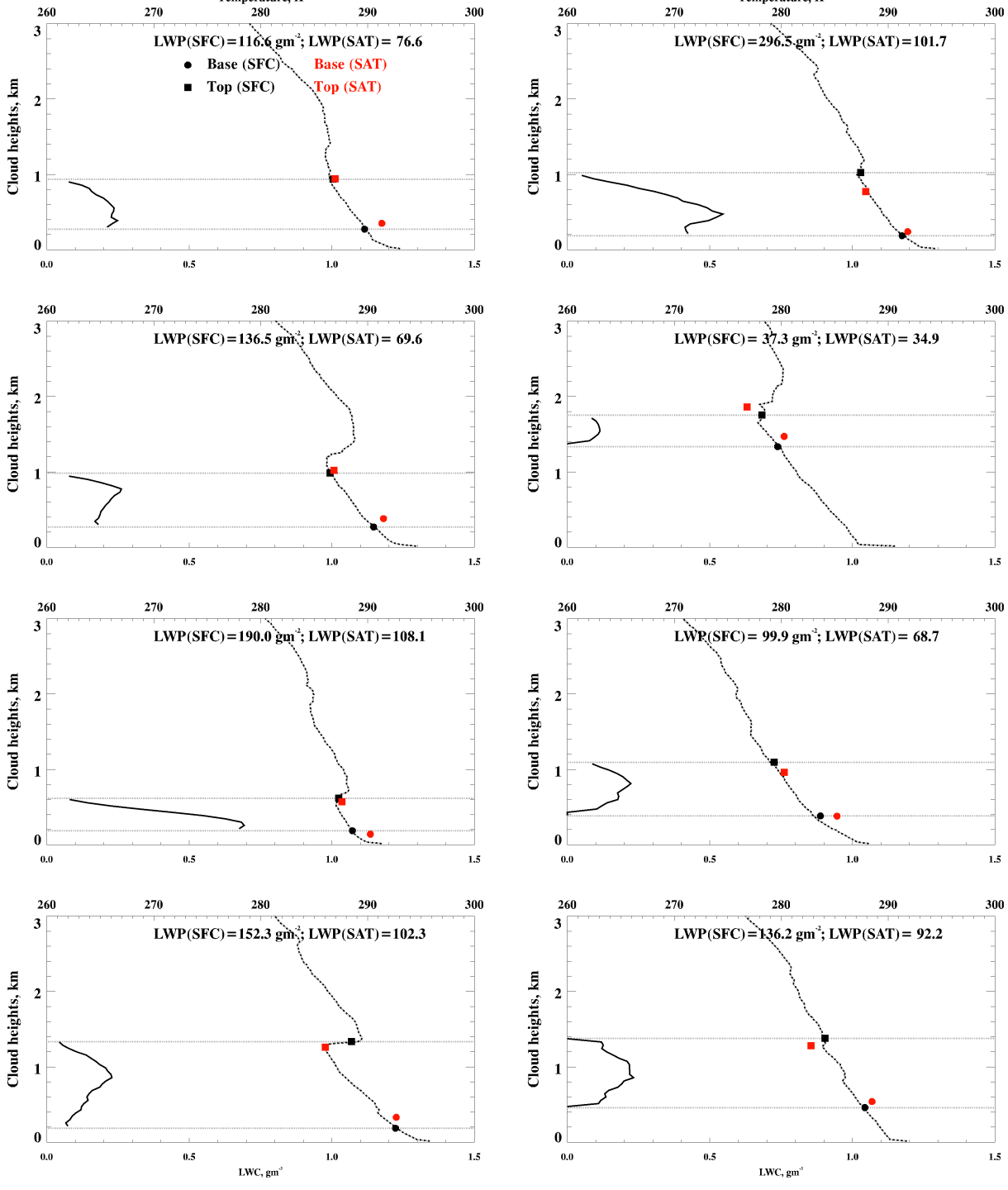


Same as day time: Passive remote sensing cannot interpolate the temperature inversion that often happens over AZORES, therefore, the parameterized the thickness is really necessary.



$$\Delta Z = -0.037*(T_{top} - T_0) + 0.00294*LWP + 0.784$$

Same eq. used in daytime study for option 3 but used LWP (SFC) not LWP(CERES)



Temperature and LWC profiles

(1)Same as the daytime. BL temperature inversion exists very often, it seems the Z_{top} retrieval may have some room for adjustment.

(2)If we neglect the Z_{top} difference, then Z_{base} during night time has only 47 meter difference from the surface measurements