

Surface, Atmospheric, TOA radiation budgets over ARM SGP and TWP sites

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Special thanks to

Chuck Long and Tom Ackerman \ Flux data and suggestions

Sally Benson and Jay Mace \ ARM Cloud heights

Chuck Pavloski and Eugene Clothiaux \ Monte Carlo simulations

Fred Rose and Tom Charlock \ Fu-Liou code

Outline

- 1) SGP results
- 2) TWP results
- 3) Comparison with Model calculations
- 4) Error analysis

Data

Surface data

Cloud-base and -top heights from ARM lidar/radar measurements, SW fluxes from Chuck Long's best estimate flux VAP.

CERES data on TERRA

TOA albedo, effective cloud height, optical depth.

Samples and Time periods:

\ARM SGP:

30 deep cumulus clouds from March 2000 to May 2003.

\ARM TWP (Nauru:0.52° S, 166.92° E; Manus:2.06° S, 147.43° E)

14 deep cumulus clouds from May 2000 to Sept. 2002.

\NO AUQA data, and NO TWP surface data in 2003.

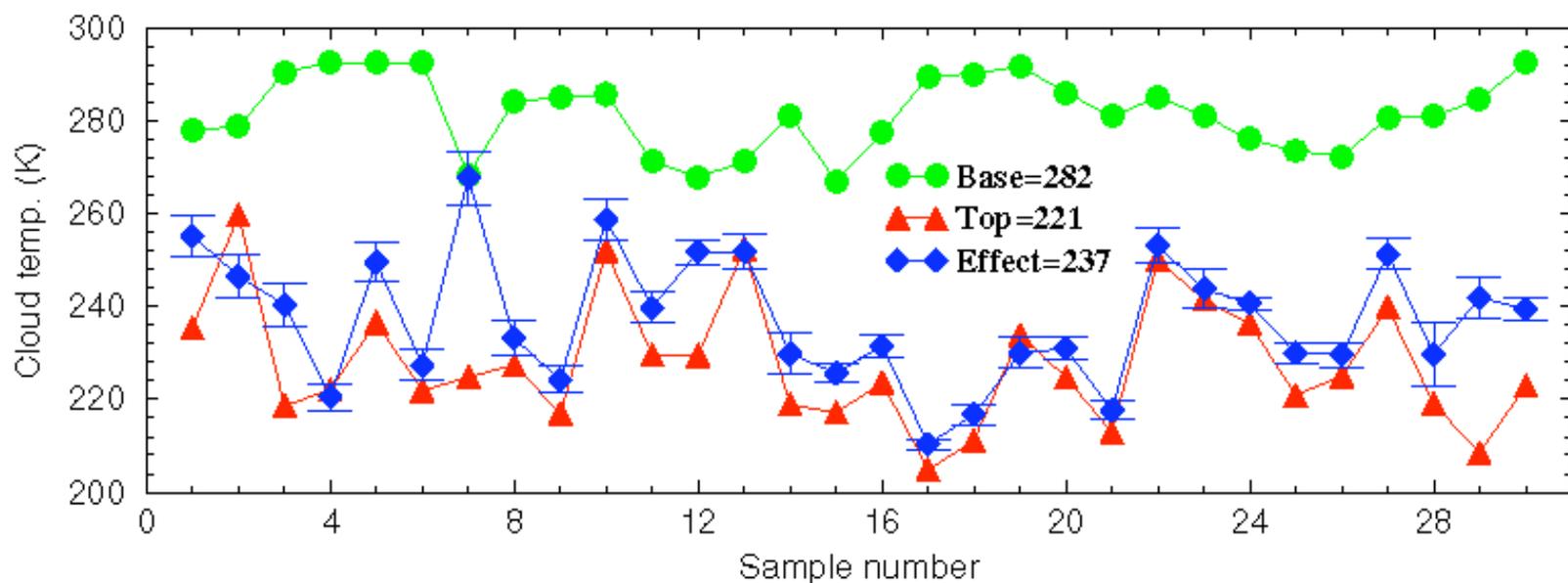
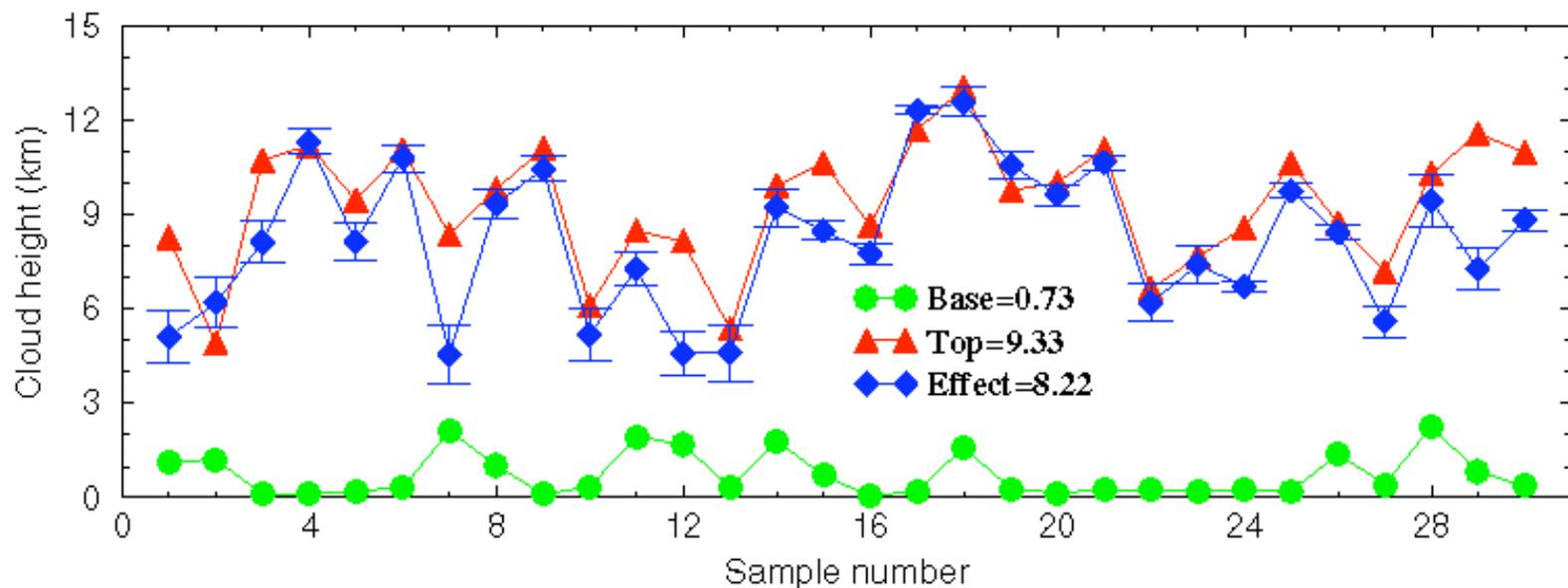
Averaging/calculating methods

\ Surface data were averaged over a 1-hour period centered at the time of the *Terra* overpass

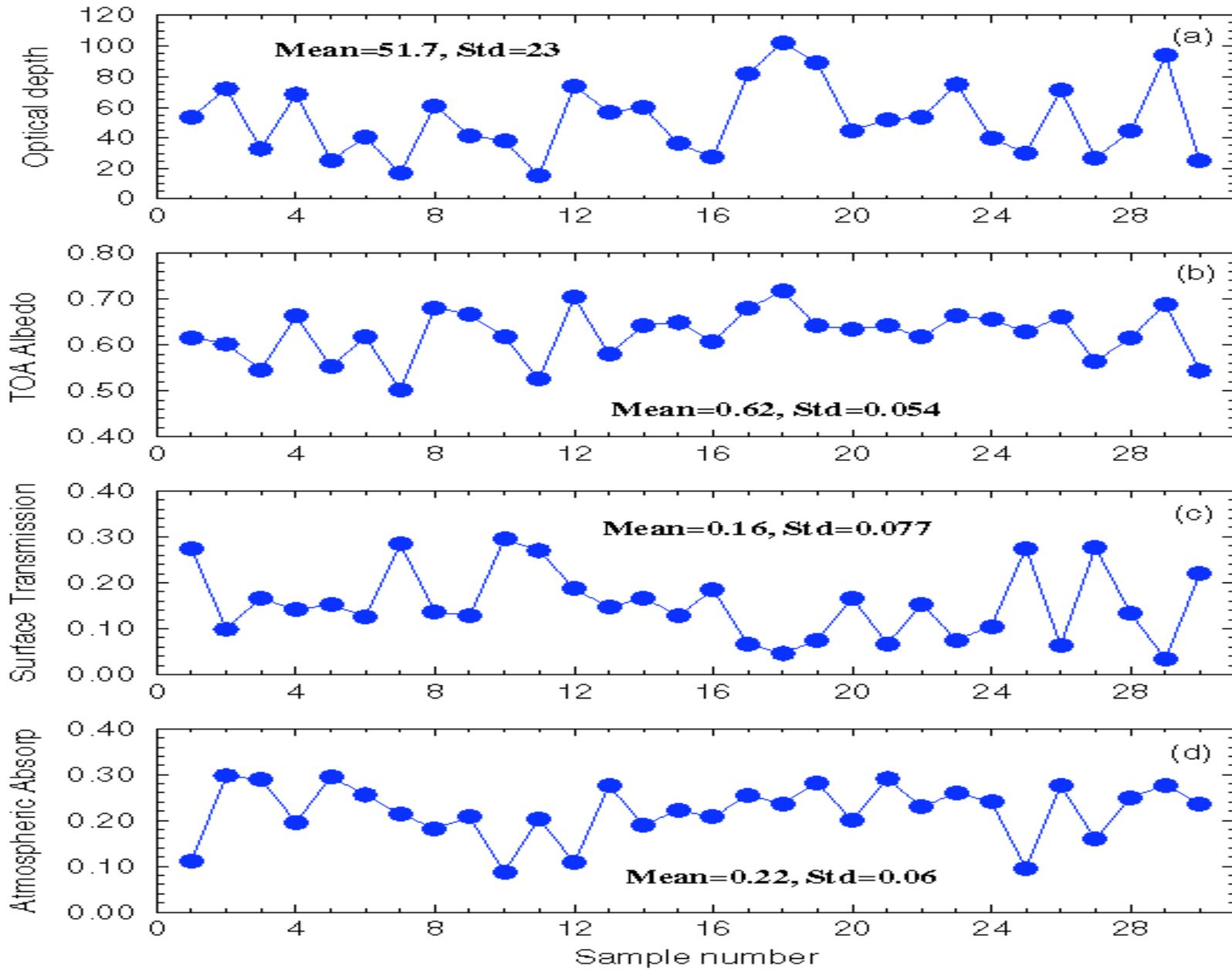
\ CERES cloud and radiation properties were averaged in a $1^\circ \times 1^\circ$ box centered on the ARM surface sites.

\
$$A_{\text{col}} = 1 - R_{\text{TOA}} - T_{\text{sfc}}$$

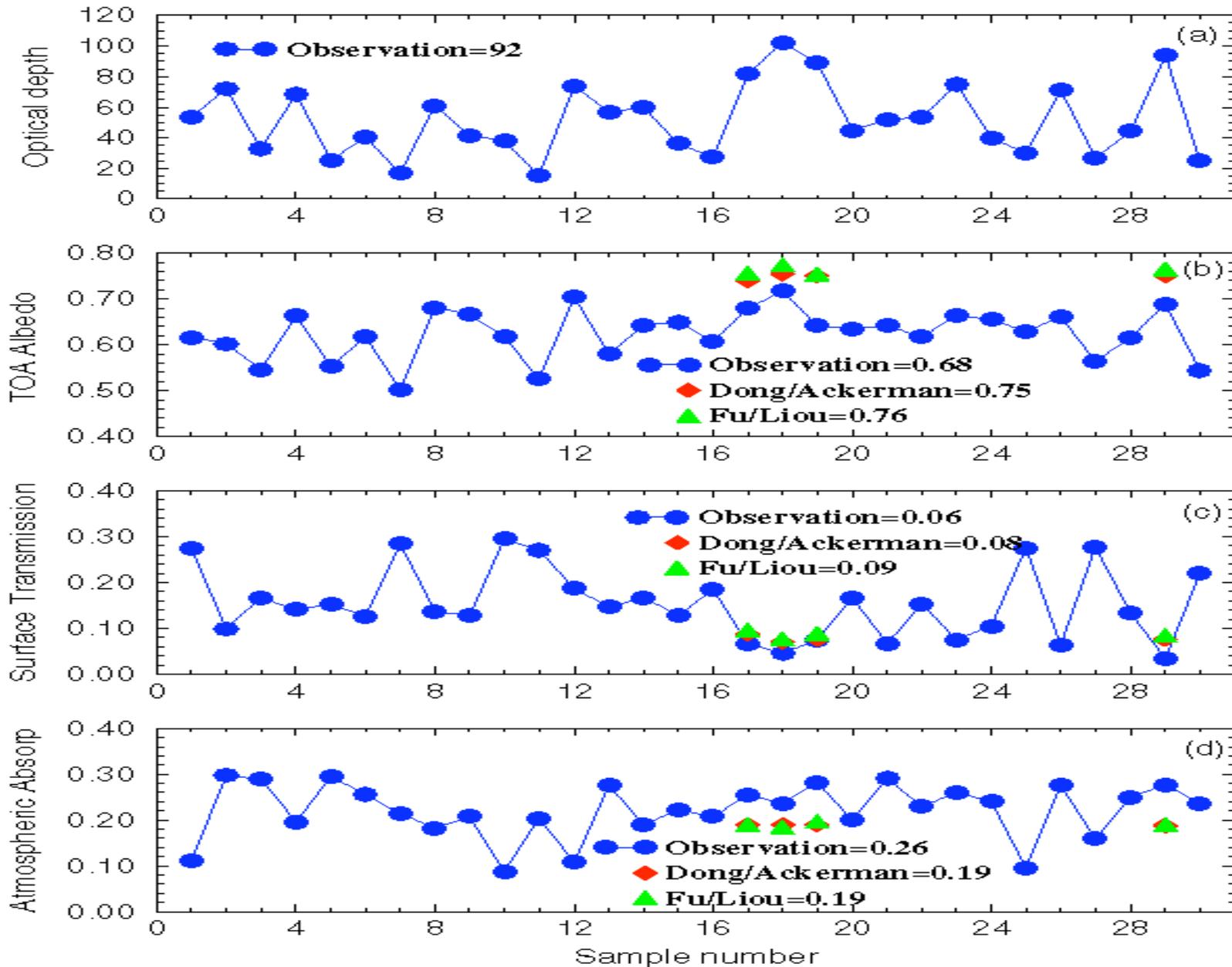
Cloud height and temperature at the ARM SGP Site (3/2000–5/2003)



TOA/SFC/Atmosphere Radiation Budgets over the ARM SGP Site



Comparison between observations and model calculations



Model calculated R_{TOA} is 7% higher and A_{col} is 7% lower than data

Model calculations
Plane parallel

Observations with photons
Leak at the sides of Cu

100 photons

70 photons

65 photons

Cloud top

$A_{col}=20$ photons

$A_{col}=25$ photons

Including
5 photons leak

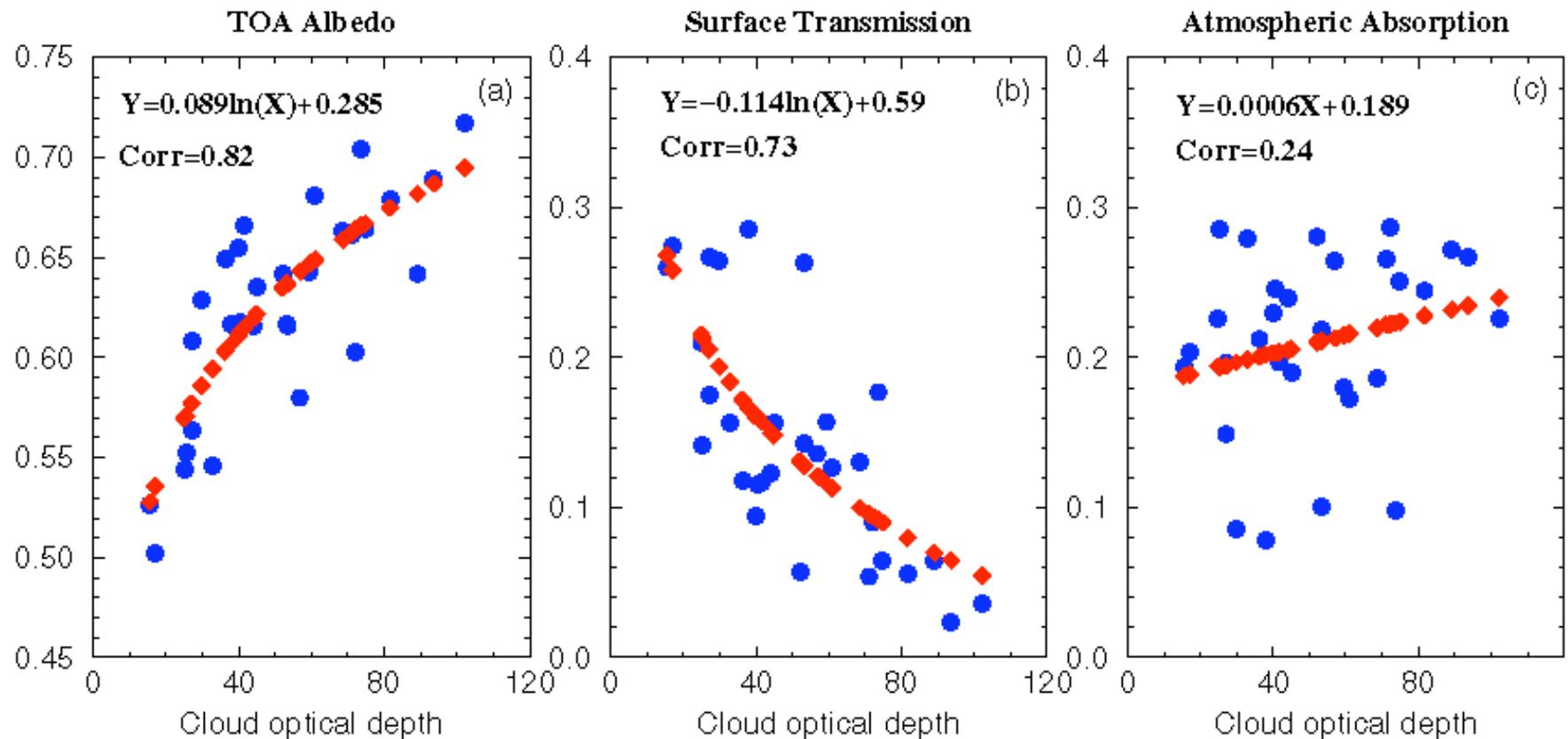
10 photons

10 photons

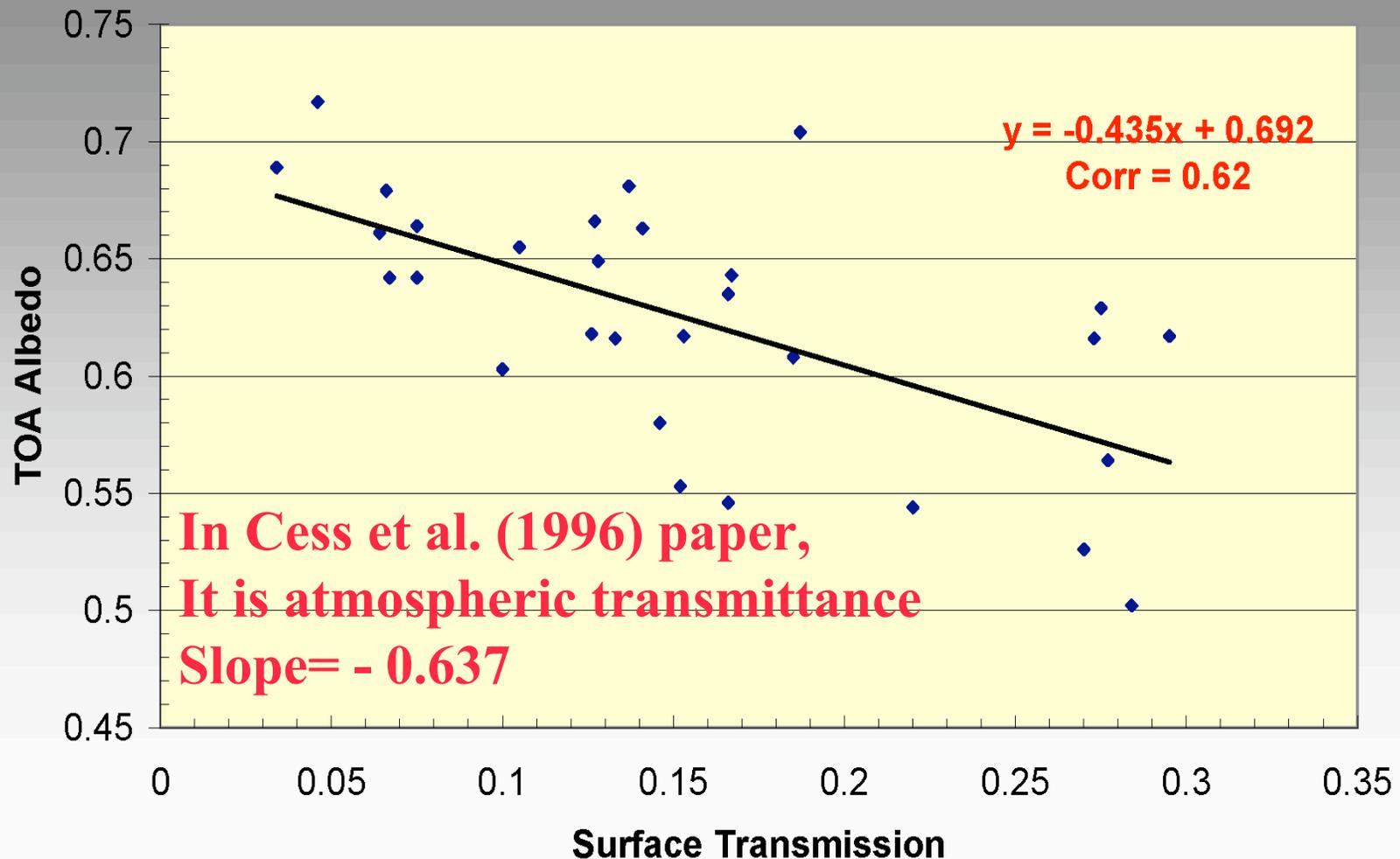
Cloud base

When Cu height=10 km, size=100 km, the side leaking is ~5%

Relationship of R_{TOA} , T_{sfc} and A_{col} with cloud optical depth

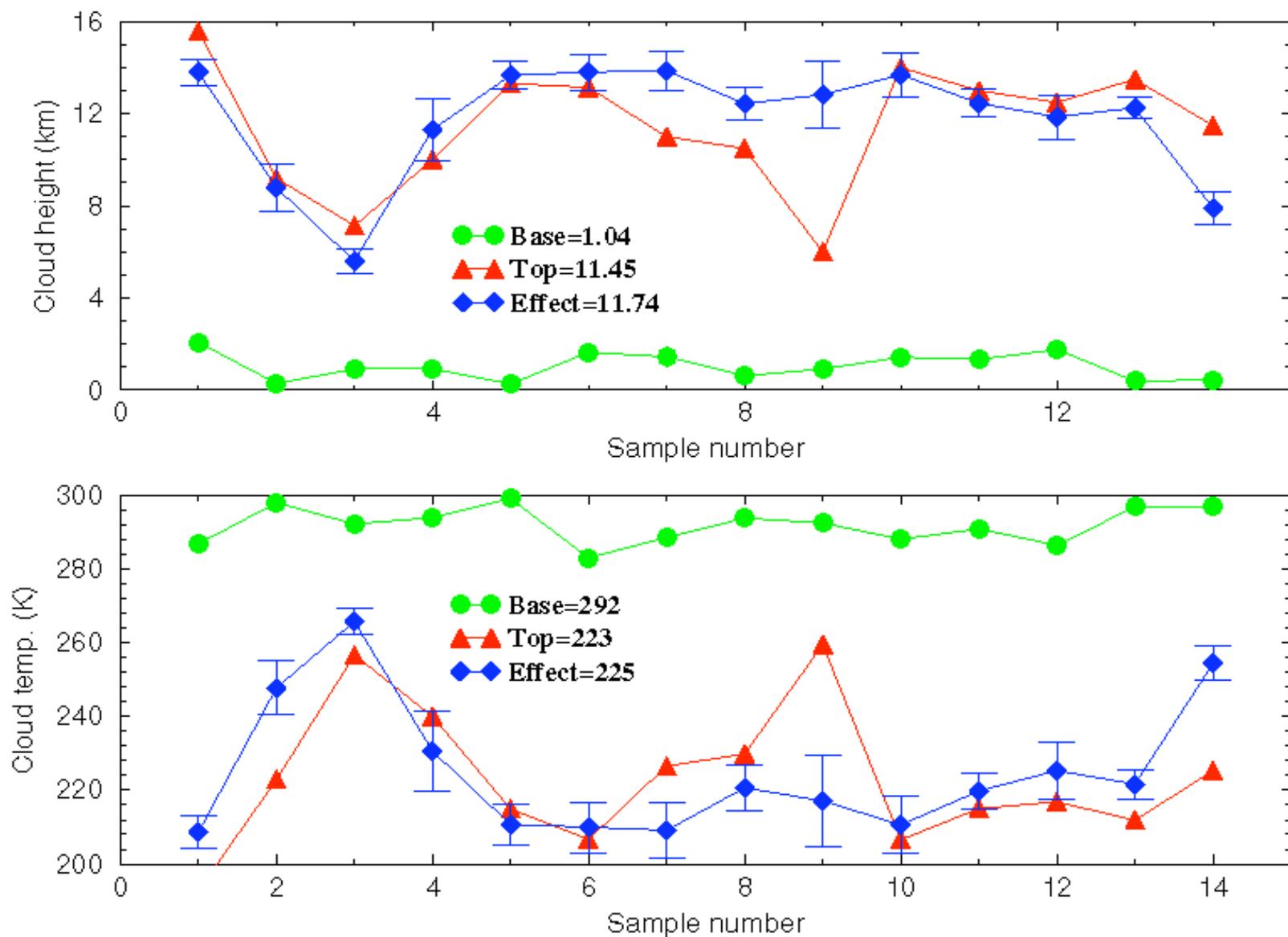


Relationship between R_{TOA} and T_{sfc} at the ARM SGP

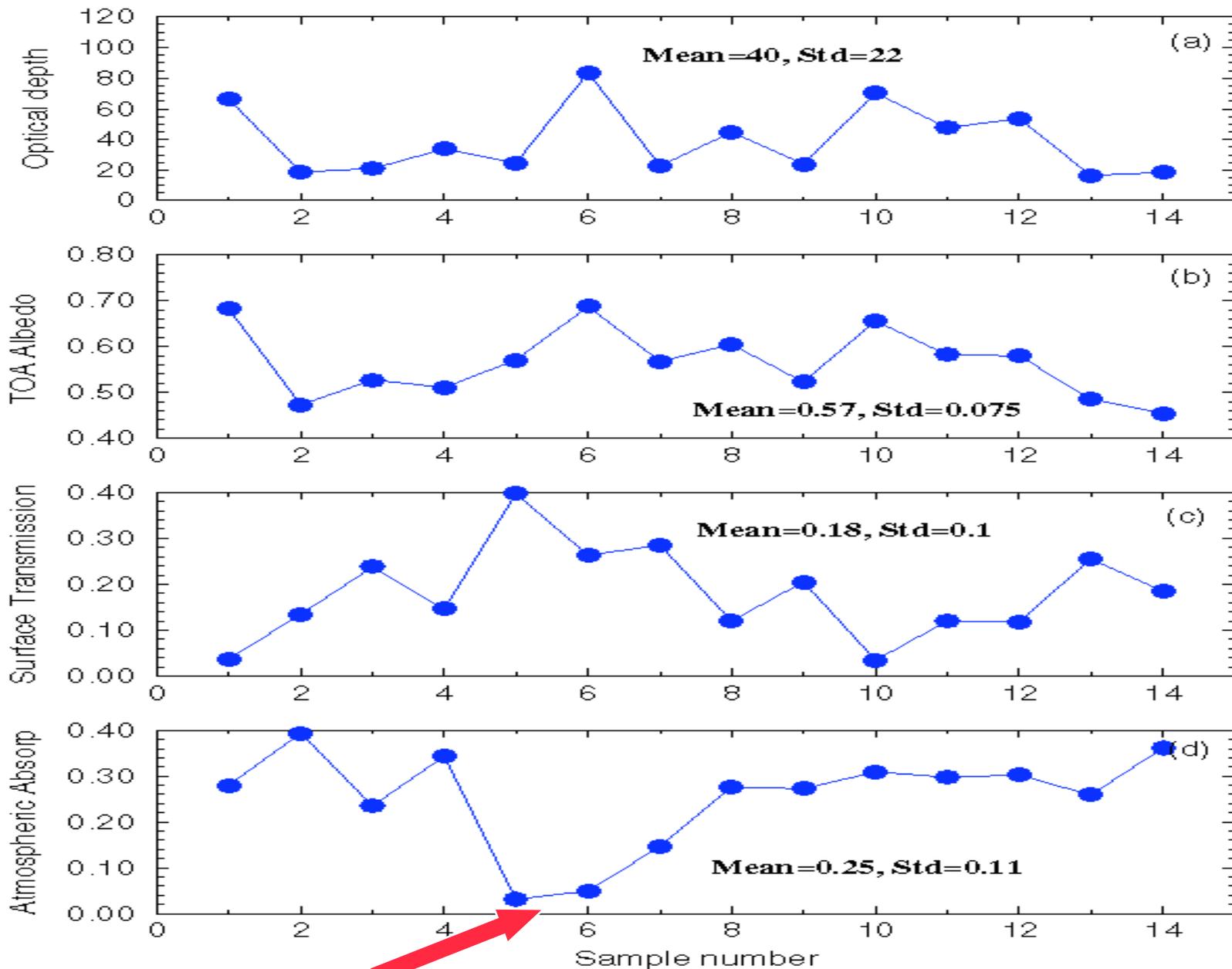


When ΔT_{sfc} increases 0.1, ΔR_{TOA} decreases 0.0435

Cloud height and temperature at the ARM TWP Sites (5/2000–9/2002)



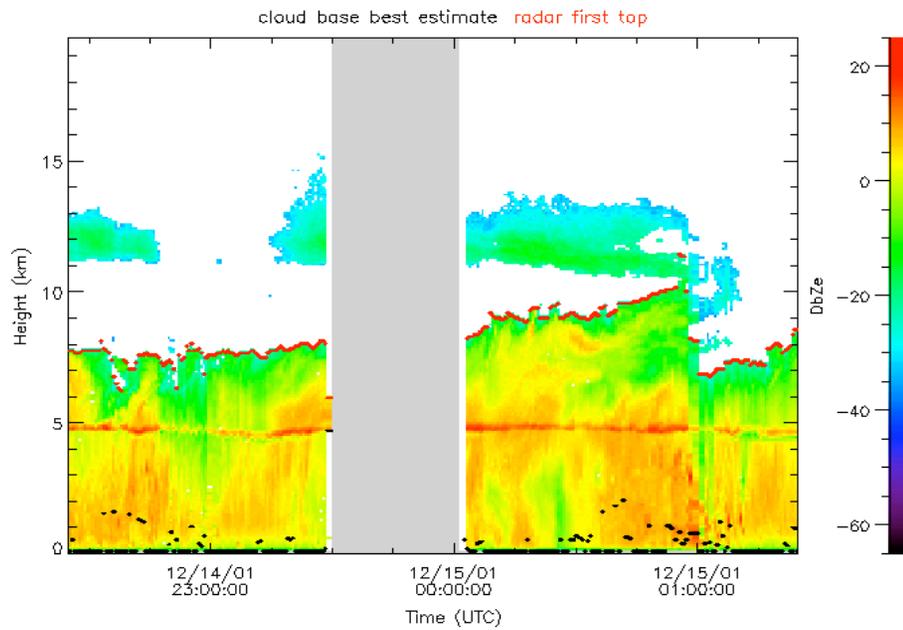
TOA/SFC/Atmosphere Radiation Budgets over the ARM TWP Sites



Why they are so small ?

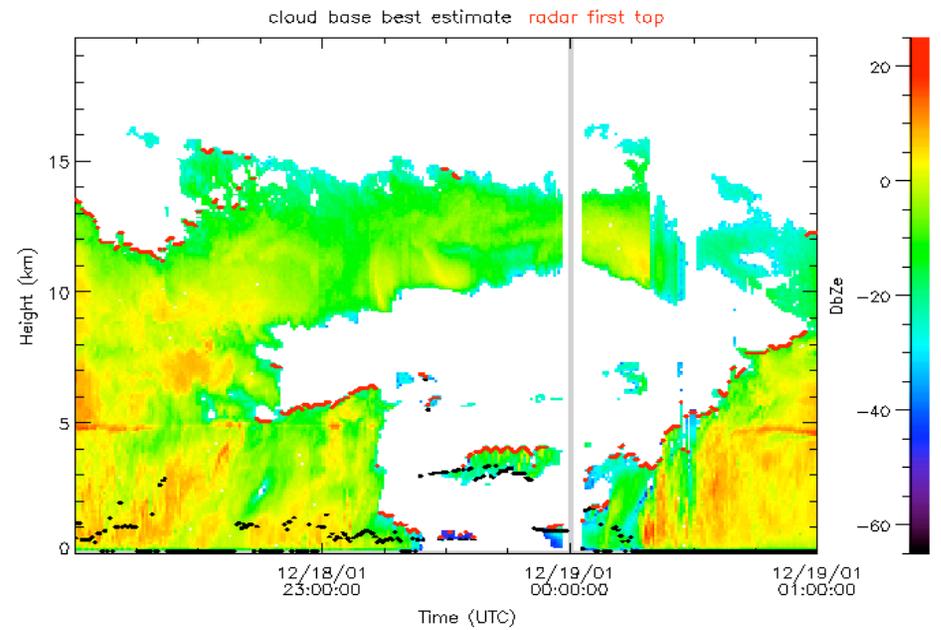
TWP C2 Merged Moments, 14 December 2001

twpmmcrMergedMomentsC2.a1



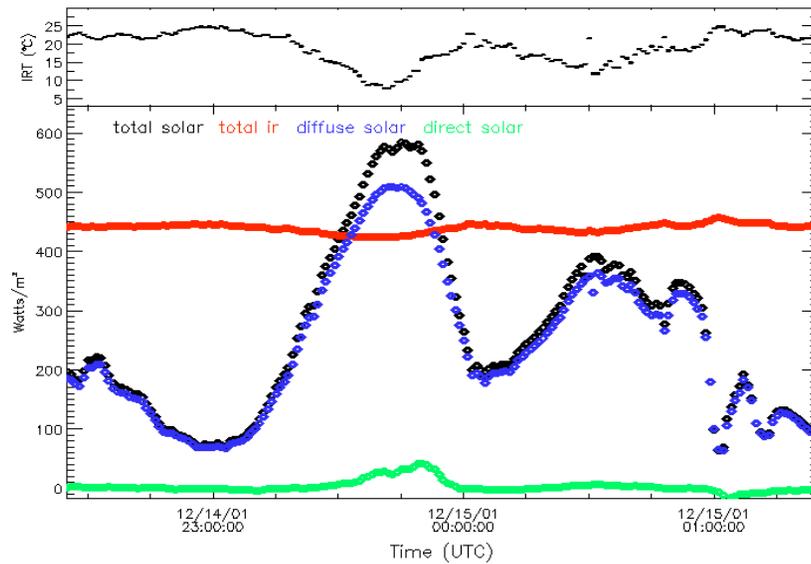
TWP C2 Merged Moments, 18 December 2001

twpmmcrMergedMomentsC2.a1



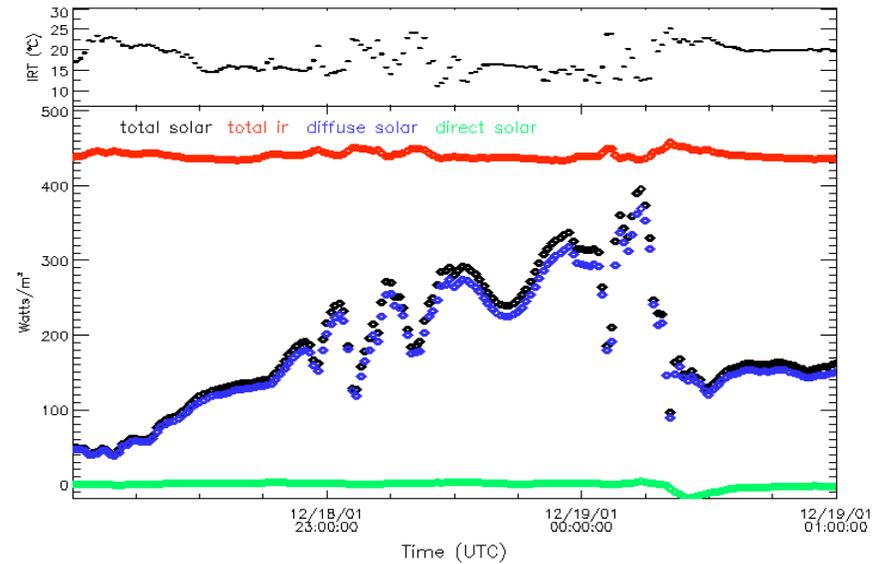
TWP C2 Skyrad Measurements, 14 December 2001

twpskyrad60sC2.b1

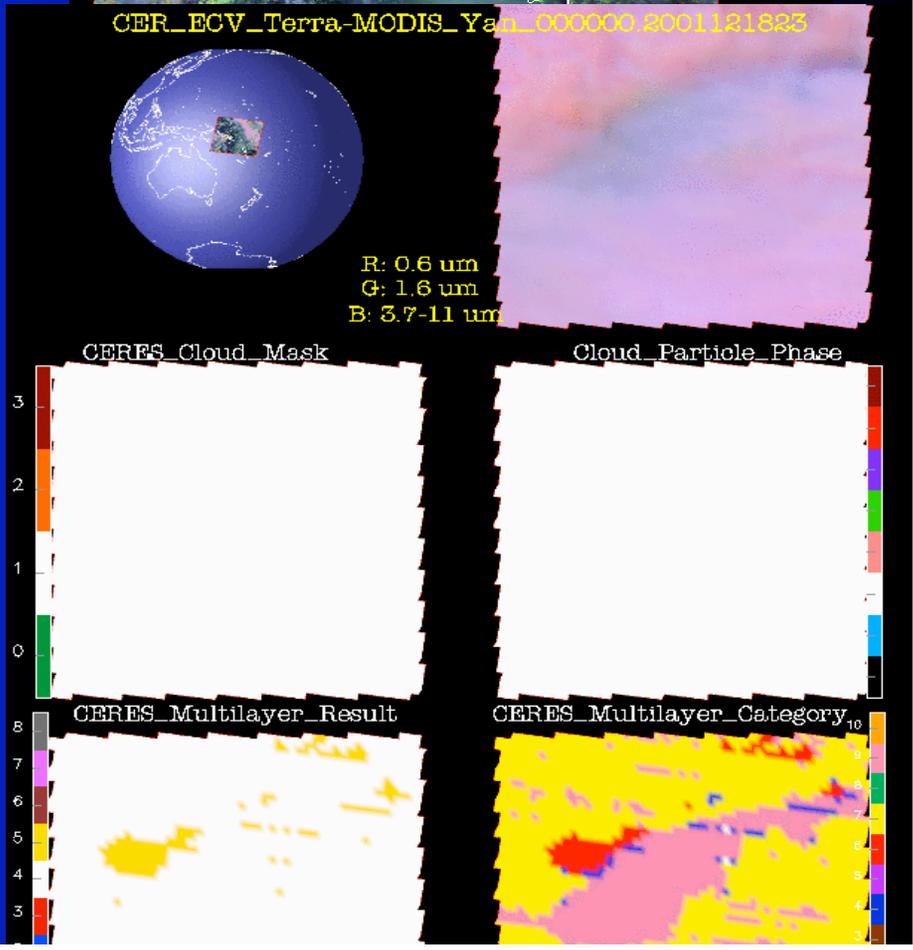
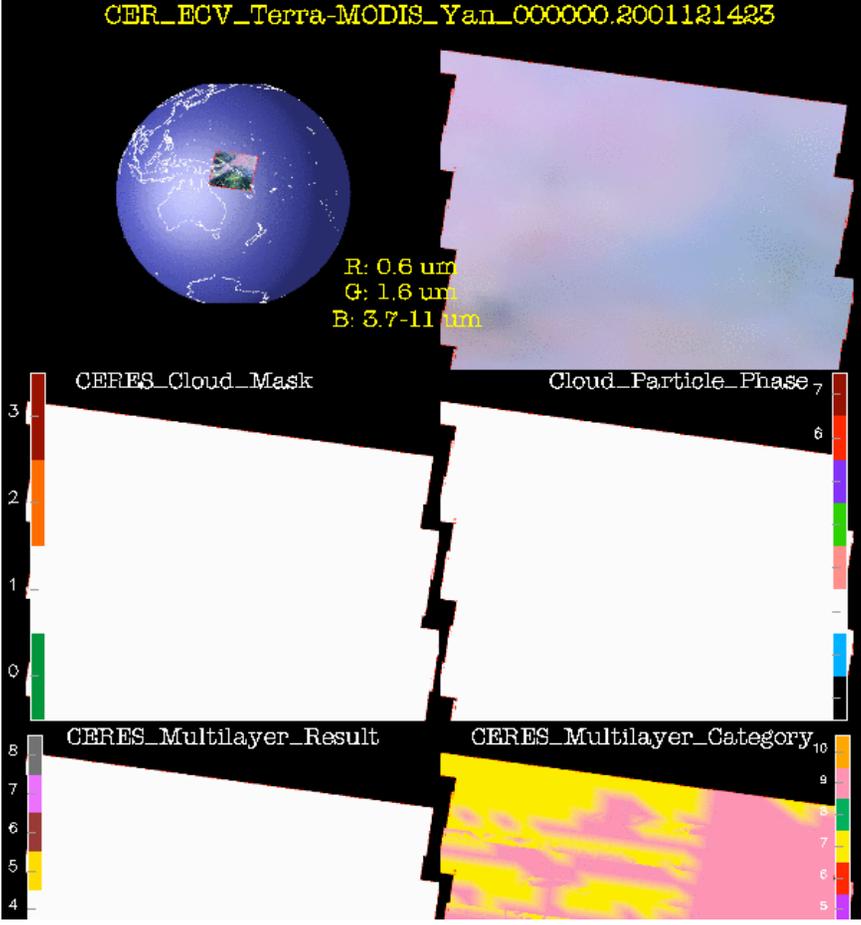
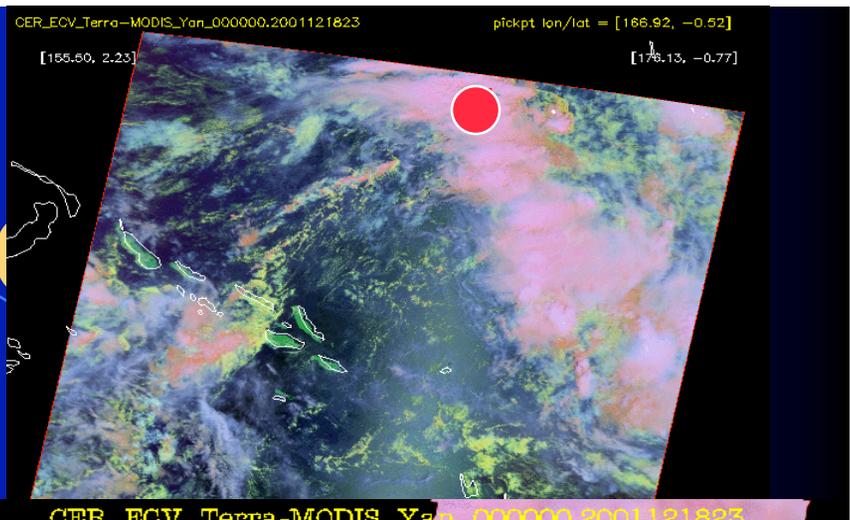
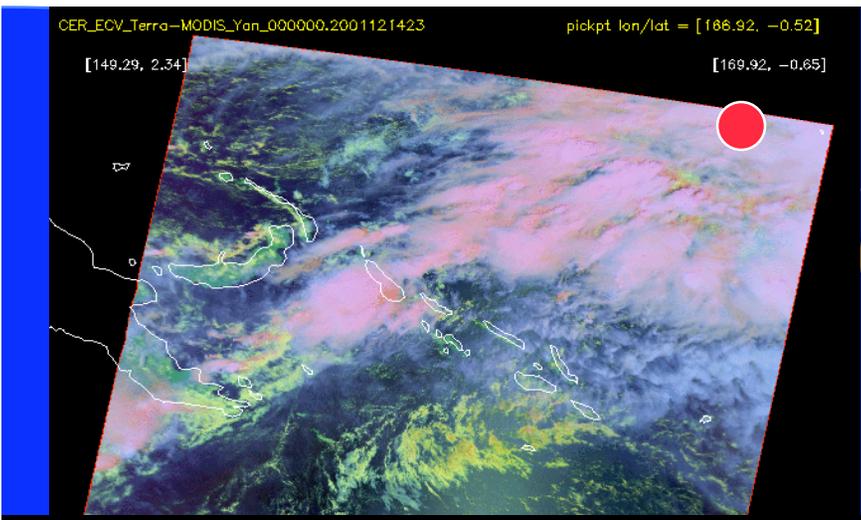


TWP C2 Skyrad Measurements, 18 December 2001

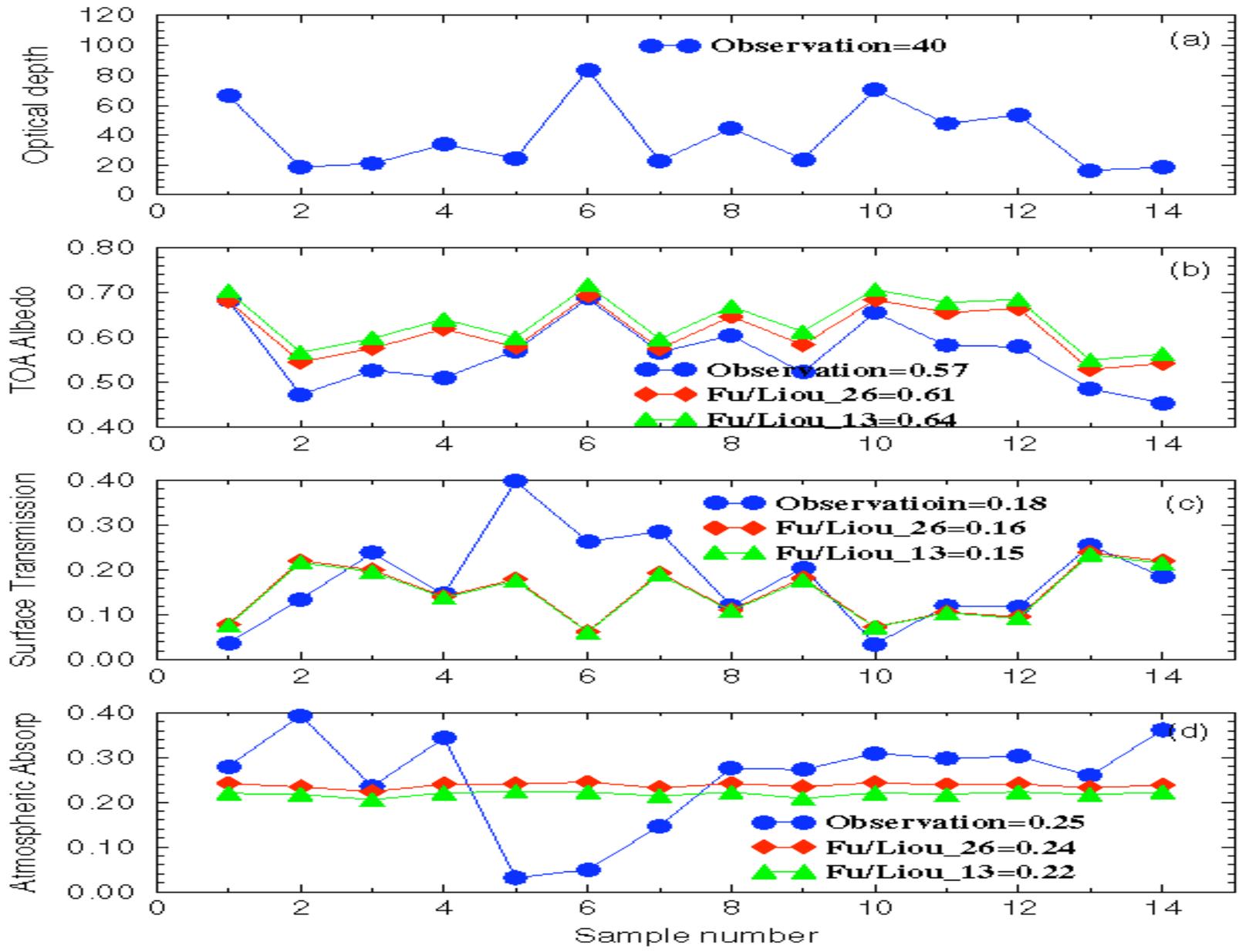
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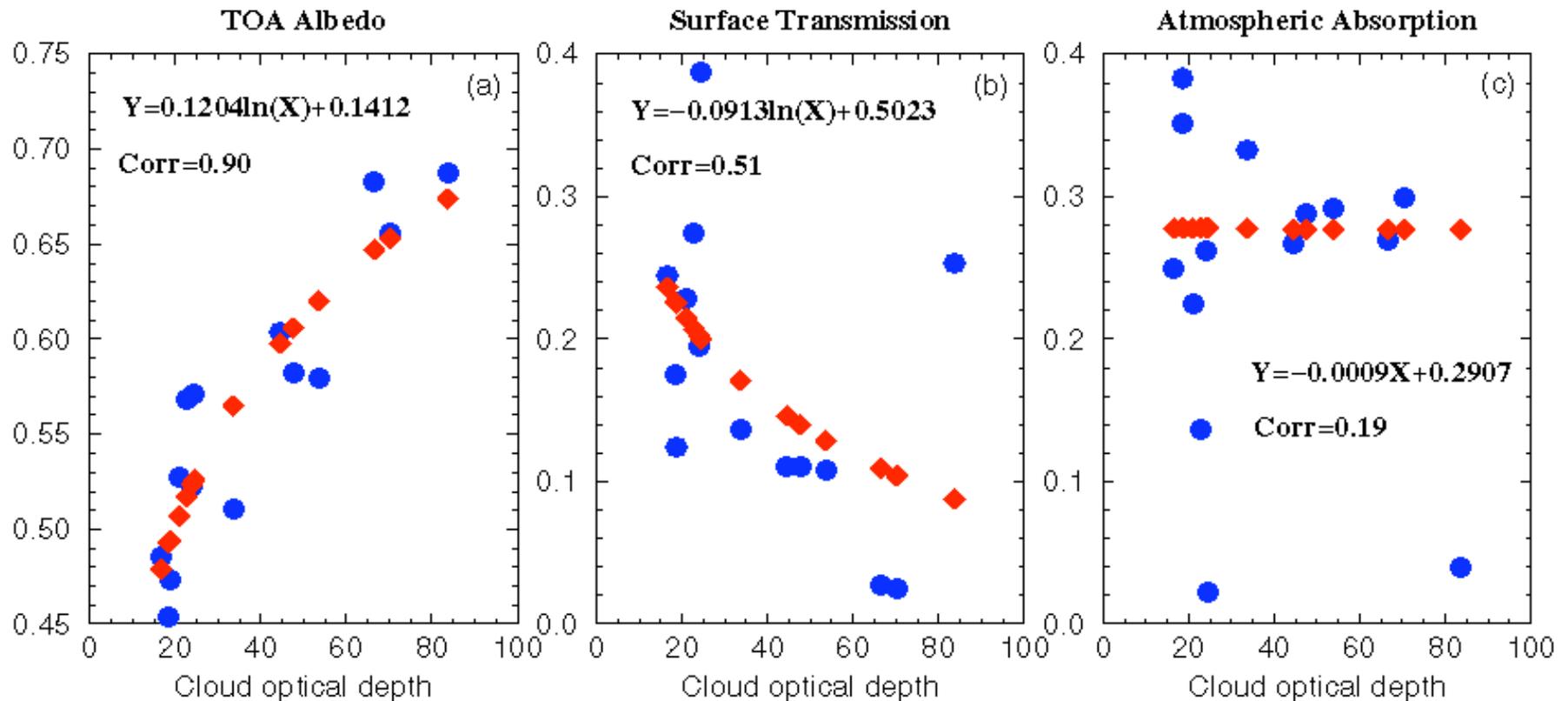
6 M



Comparison between observations and Fu/Liou calculations

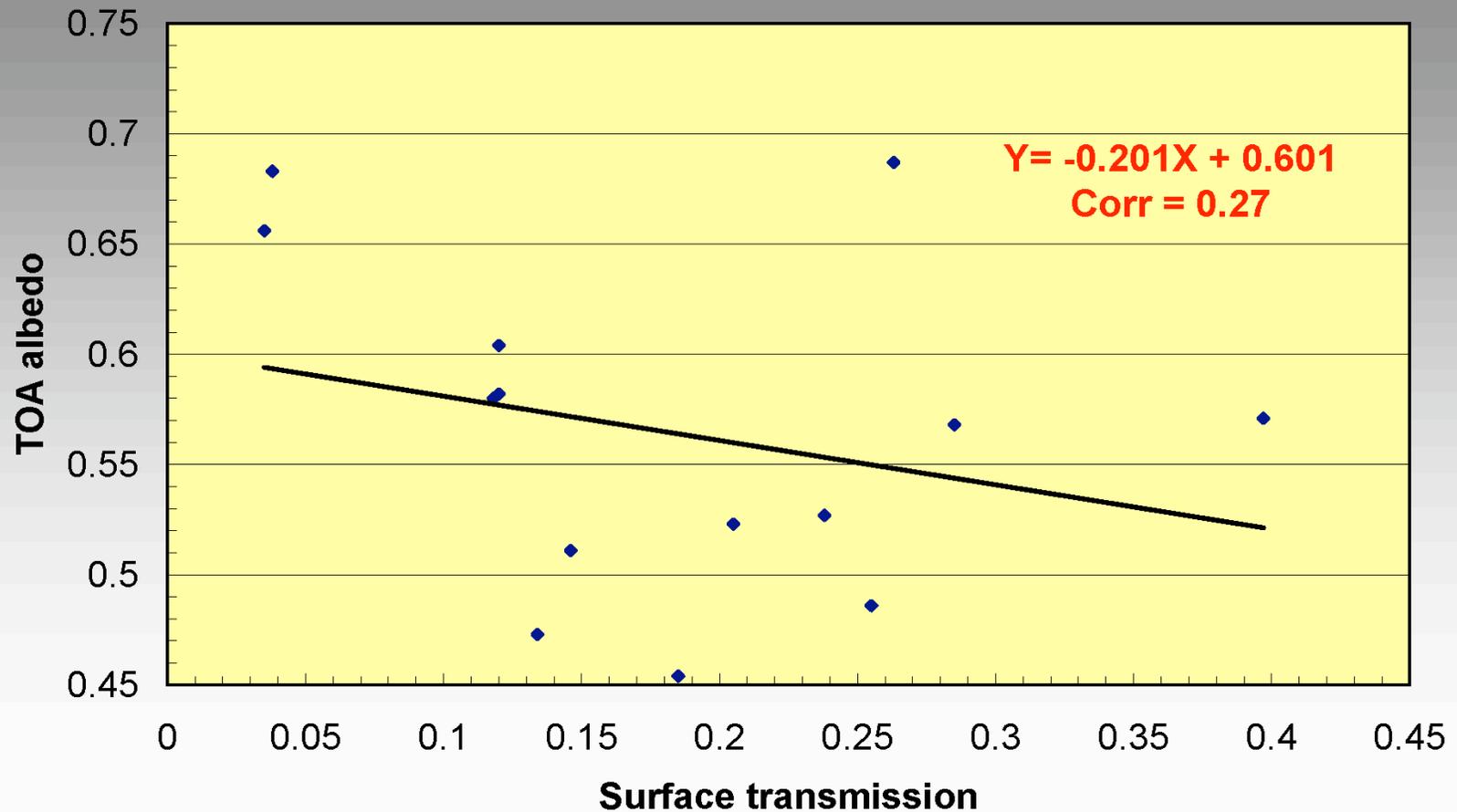


Relationship of R_{TOA} , T_{sfc} and A_{col} with cloud optical depth



Their relationships are very similar to their counterparts at SGP

Relationship between R_{TOA} and T_{sfc} at the ARM TWP



When ΔT_{sfc} increases 0.1, ΔR_{TOA} decreases 0.0201

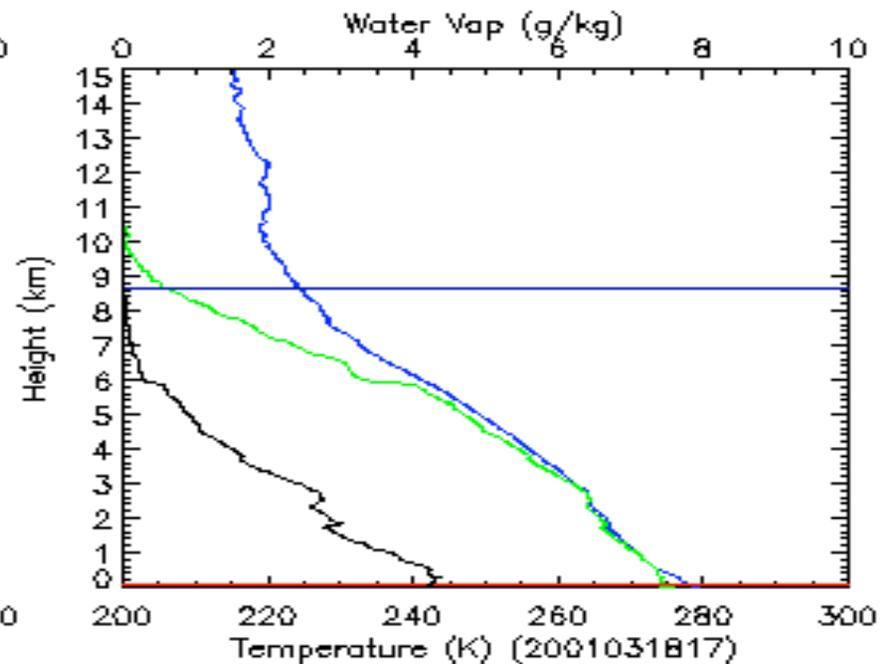
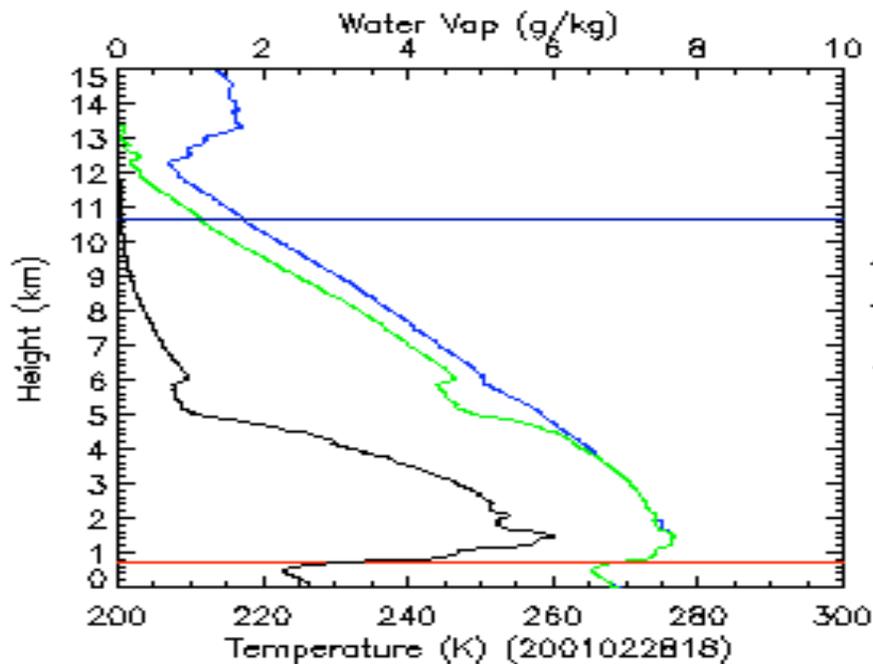
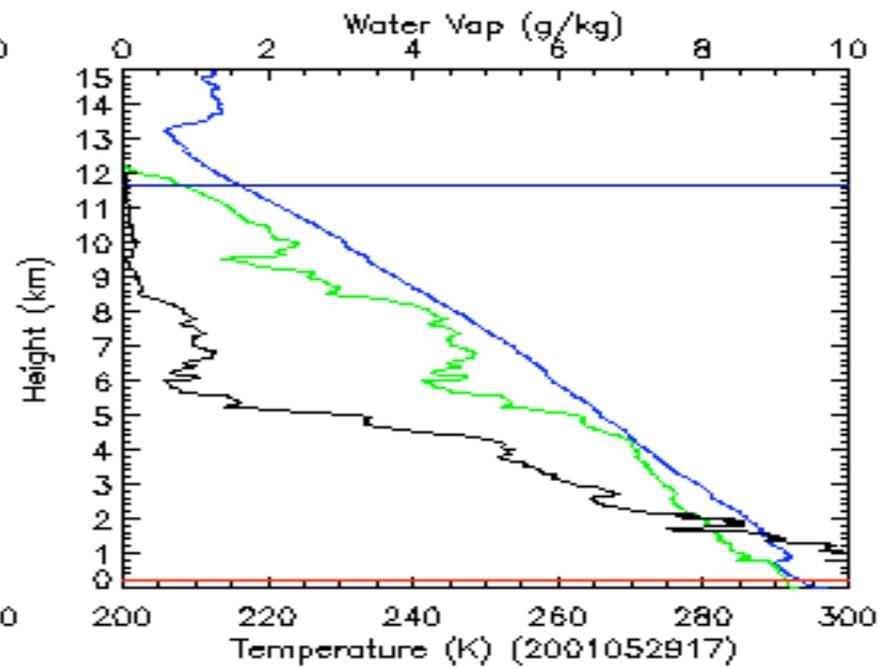
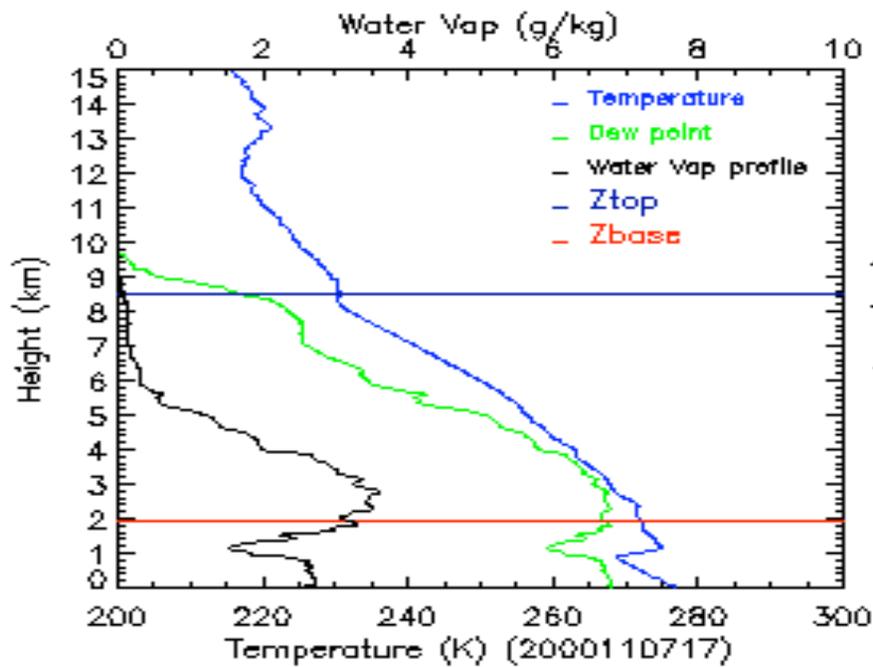
Error analysis

1) Water vapor below cloud base and above cloud top

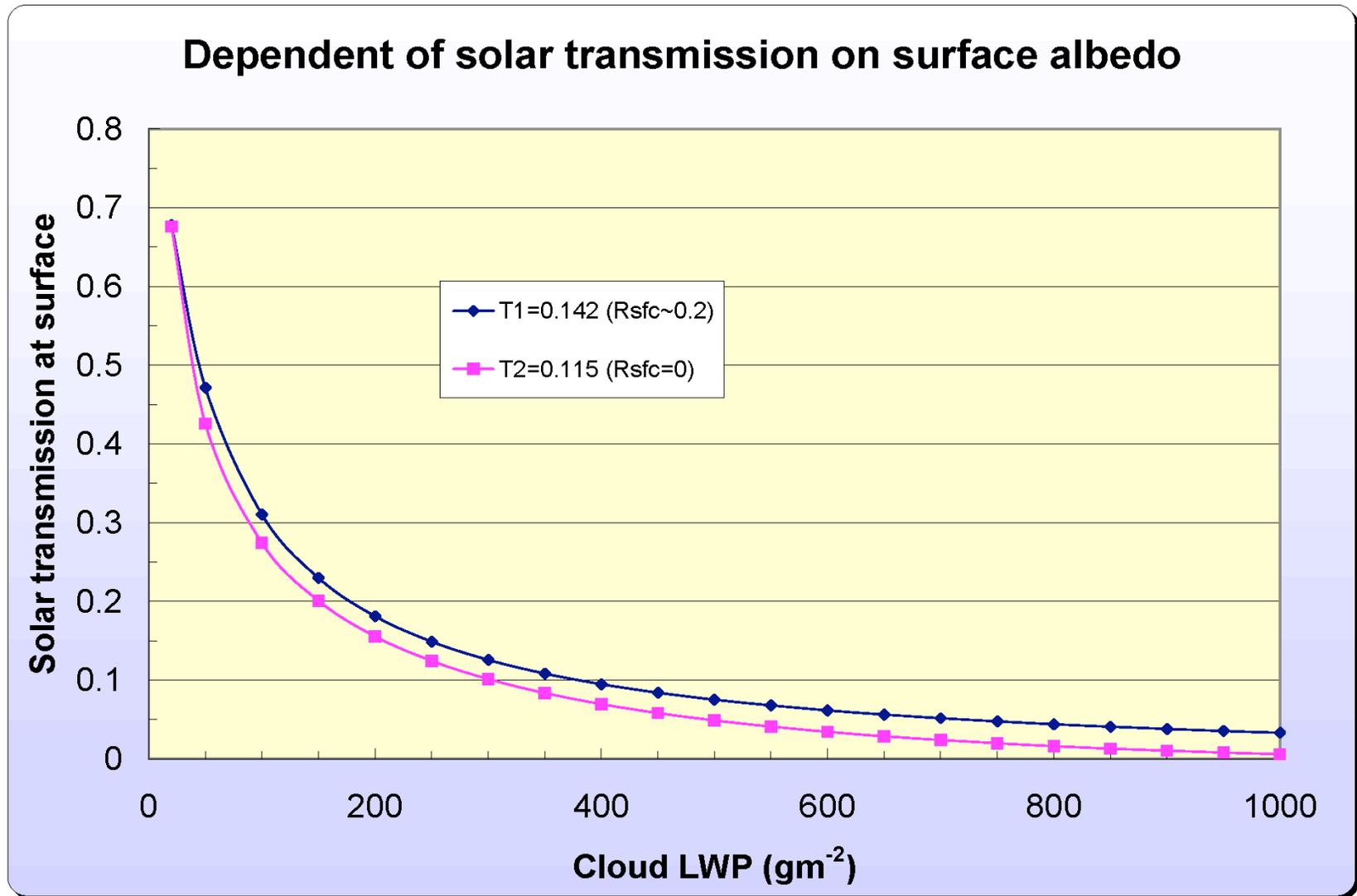
2) Surface albedo impact

3) Precipitation:

Most of cases at SGP without precipitation, but it is opposite at TWP sites.



Almost NO water vapor above cloud top, and cloud base is close to ground



When ΔR_{sfc} increases 20%, ΔT_{sfc} increases 2.7%

Conclusions

- 1) Deep cumulus clouds are selected at the ARM SGP and TWP sites with averaged cloud-base height ~ 1 km, top height ~ 10 km.
- 2) Their averaged TOA albedo is ~ 0.6 , most are $0.5 - 0.7$
Surface transmission is ~ 0.17 , most are $0.05 - 0.3$
Atmospheric absorption is ~ 0.23 , most are $0.1 - 0.3$
- 3) At SGP, Model R_{TOA} is 7% higher, A_{col} is 7% lower than data
At TWP, Model R_{TOA} is 7% higher, A_{col} is 3% lower than data
- 4) The negative correlation between TOA albedo and surface transmission is stronger at SGP than at TWP
- 5) Error analysis shows:
 - (Water vapor contributes little to SW absorption in this study)
 - (Surface albedo impact is almost negligible in this study)

Table 1: Clear-sky Measured and Modeled values of Absorptance (Abt) and Absorption (Abs) [ARESE II]

	<u>Feb. 27,</u> Abt	<u>2000</u> Abs(Wm⁻²)	<u>March</u> Abt	<u>20, 2000</u> Abs(Wm⁻²)
TSBR tower	0.134	116	0.132	136
TSBR aircraft	0.121	105	0.127	131
CM22 tower	0.123	106	0.137	139
CM22 aircraft	0.111	96	0.131	133
CM21 tower	0.103	88	0.121	123
RAPRAD mineral	0.116	101	0.125	129
RAPRAD cont.	0.114	99	0.123	126
SBDART mineral	0.124	108	0.131	135
SBDART cont.	0.121	105	0.128	132

Ackerman et al. 2003, JGR

Table 3: Cloudy-sky measured and modeled values of Absorptance (Abt) and Absorption (Abs) [ARESE II]

	<u>March</u> Abt	<u>03</u> Abs	<u>March</u> Abt	<u>21</u> Abs	<u>March</u> Abt	<u>29</u> Abs
TSBR tower	0.205	195	0.206	211	0.217	225
TSBR aircraft	0.211	200	0.207	211	0.230	238
CM22 tower	0.178	167	0.208	211	0.214	220
CM22 aircraft	0.184	172	0.212	216	0.231	237
CM21 tower	0.178	166	0.200	203	0.191	194
RAPRAD	0.182	174	0.203	209	0.197	207
SBDART	0.187	179	0.202	207	0.197	207

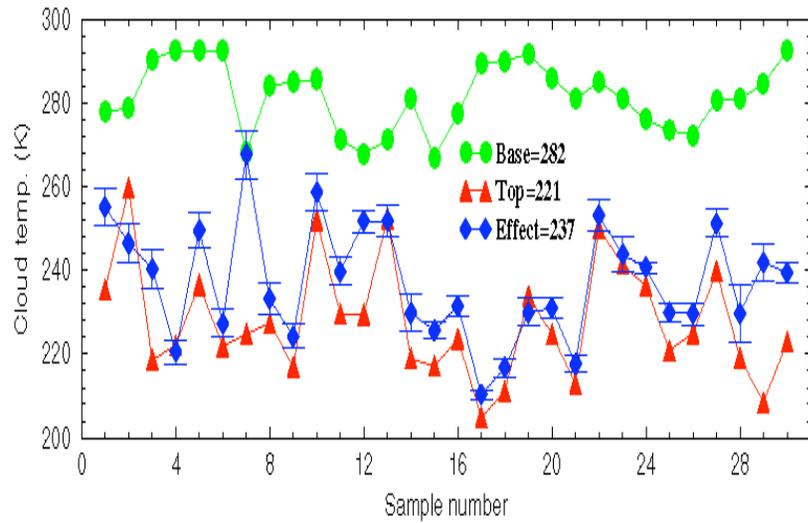
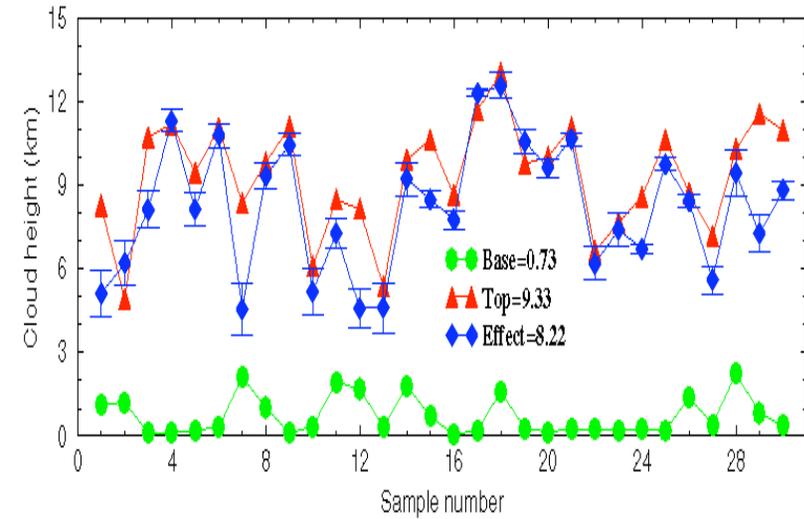
Thanks for your attention!

This is our future work!



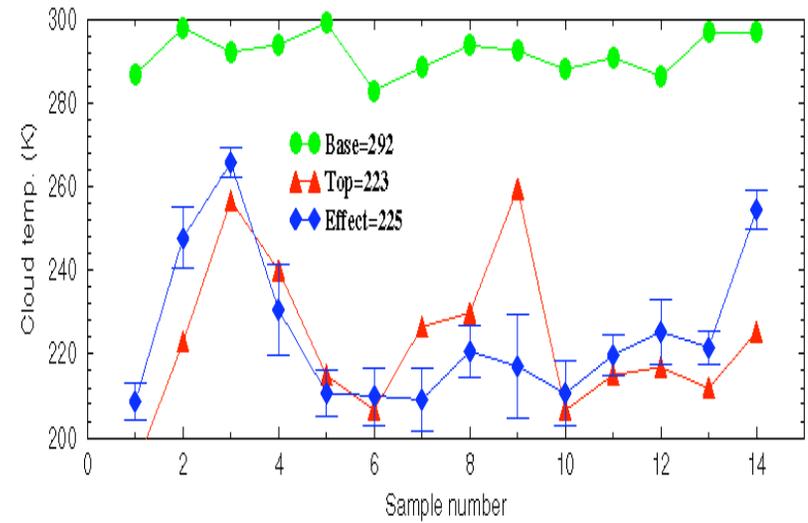
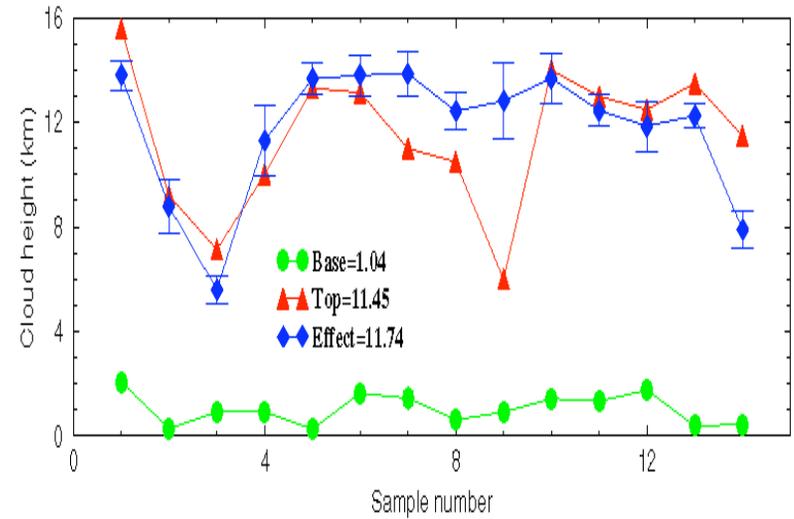
SGP

Cloud height and temperature at the ARM SGP Site (3/2000–5/2003)



TWP

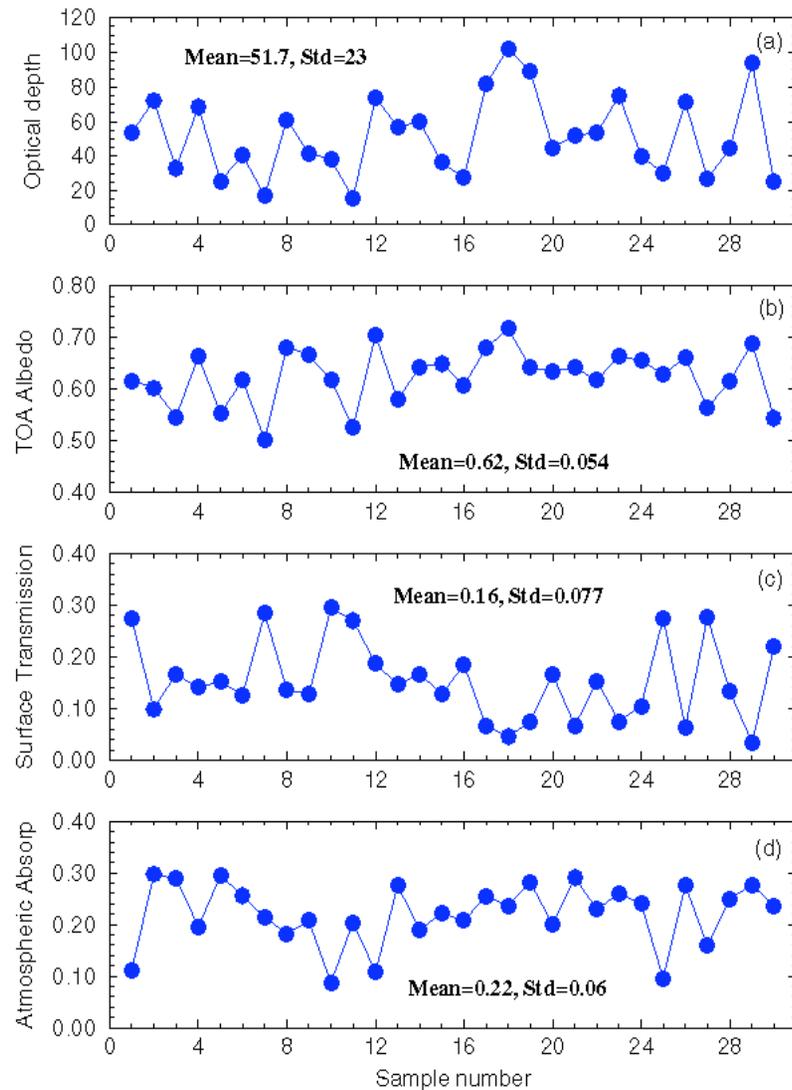
Cloud height and temperature at the ARM TWP Sites (5/2000–9/2002)



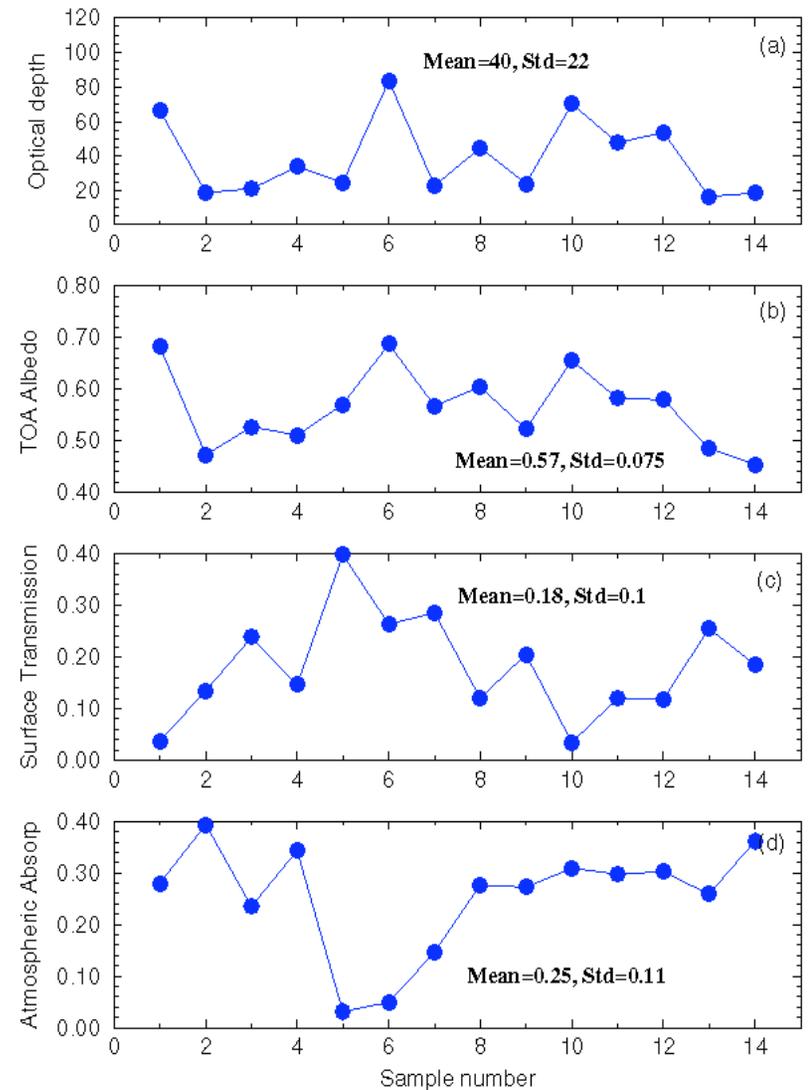
SGP

TWP

TOA/SFC/Atmosphere Radiation Budgets over the ARM SGP Site



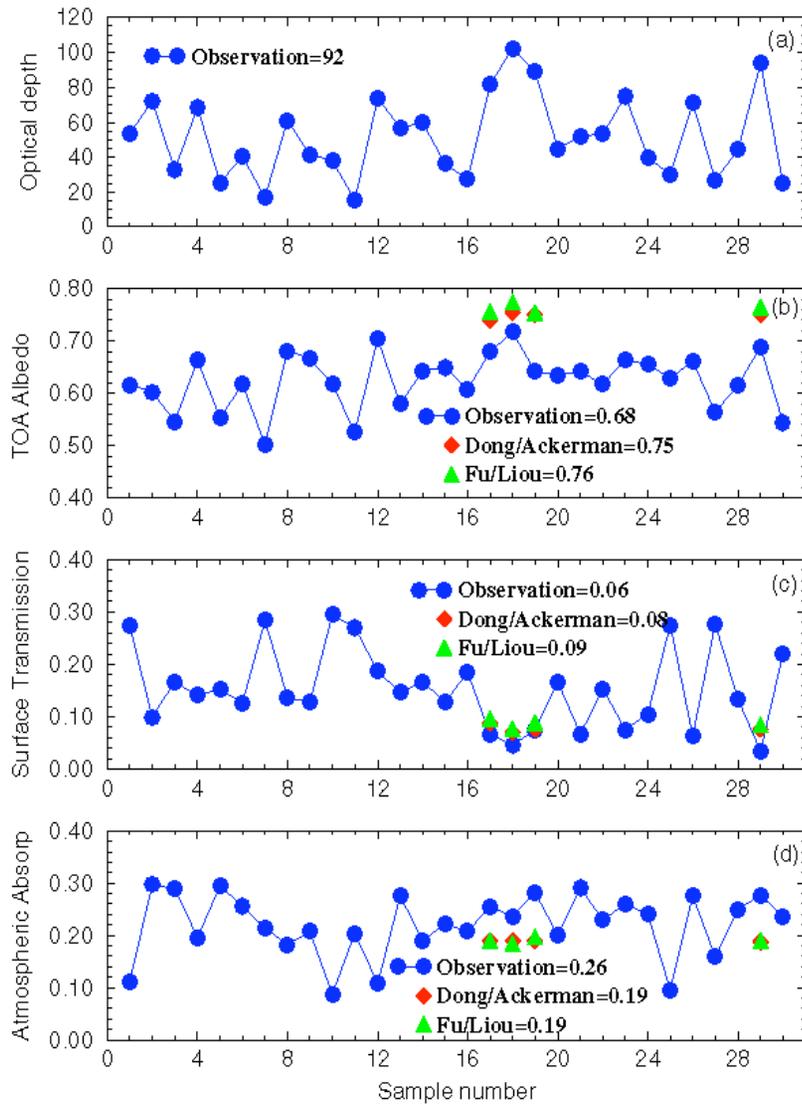
TOA/SFC/Atmosphere Radiation Budgets over the ARM TWP Sites



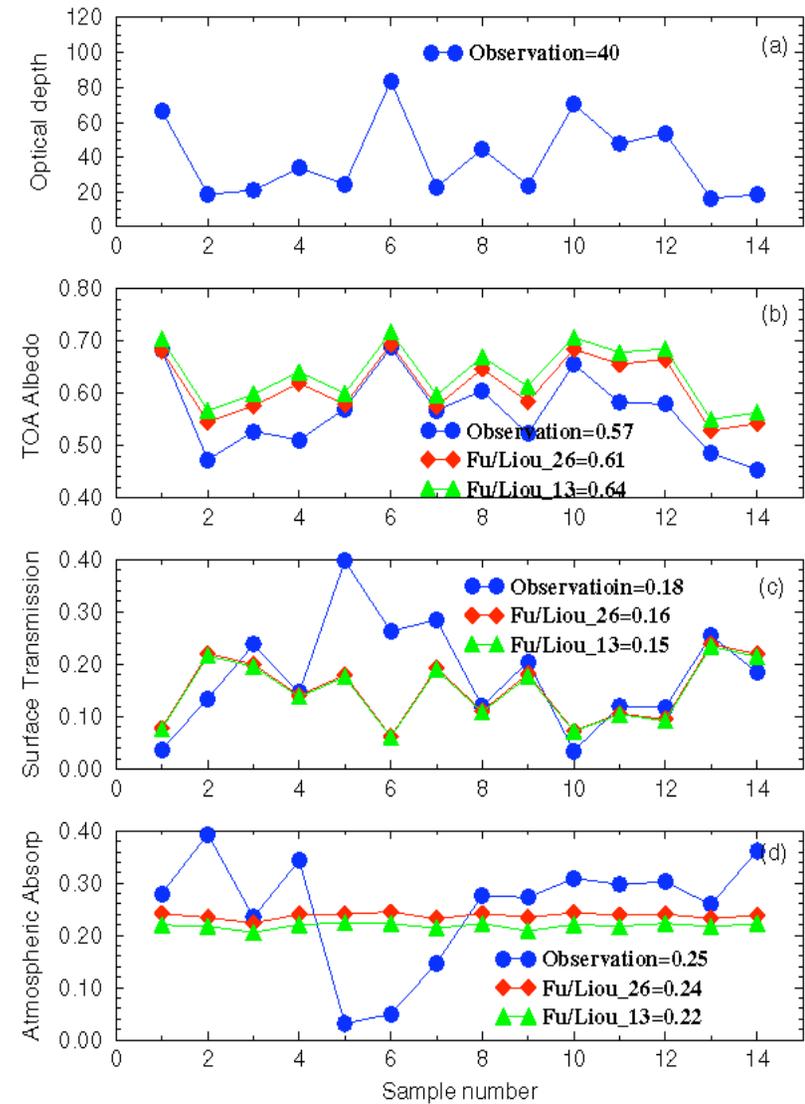
SGP

TWP

Comparison between observations and model calculations

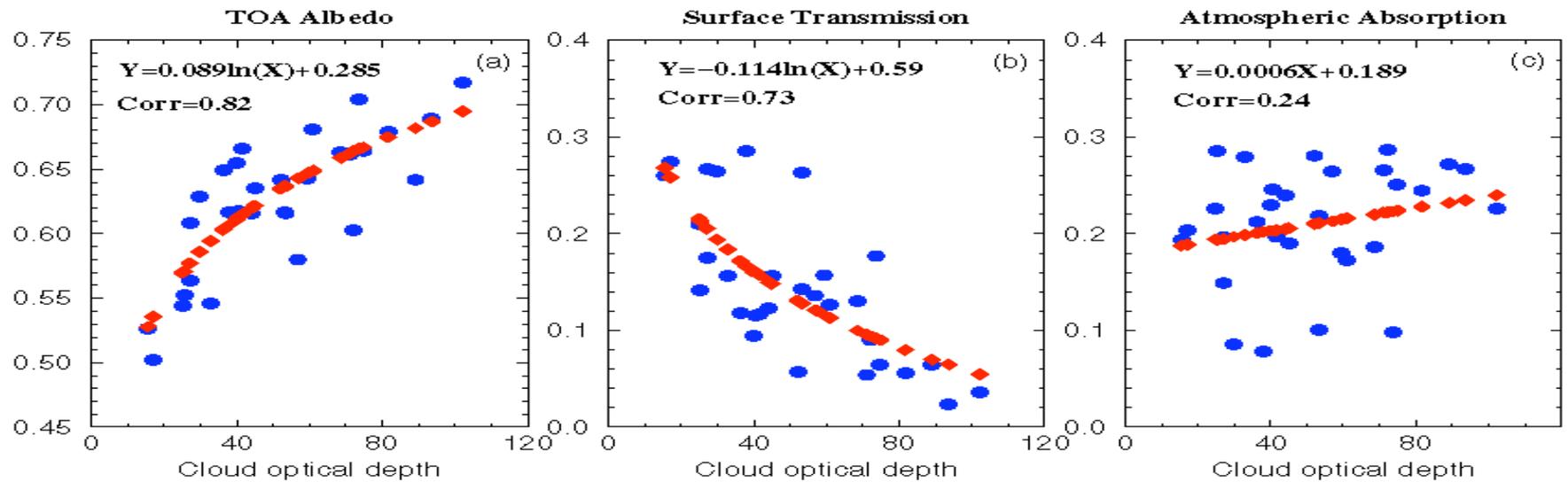


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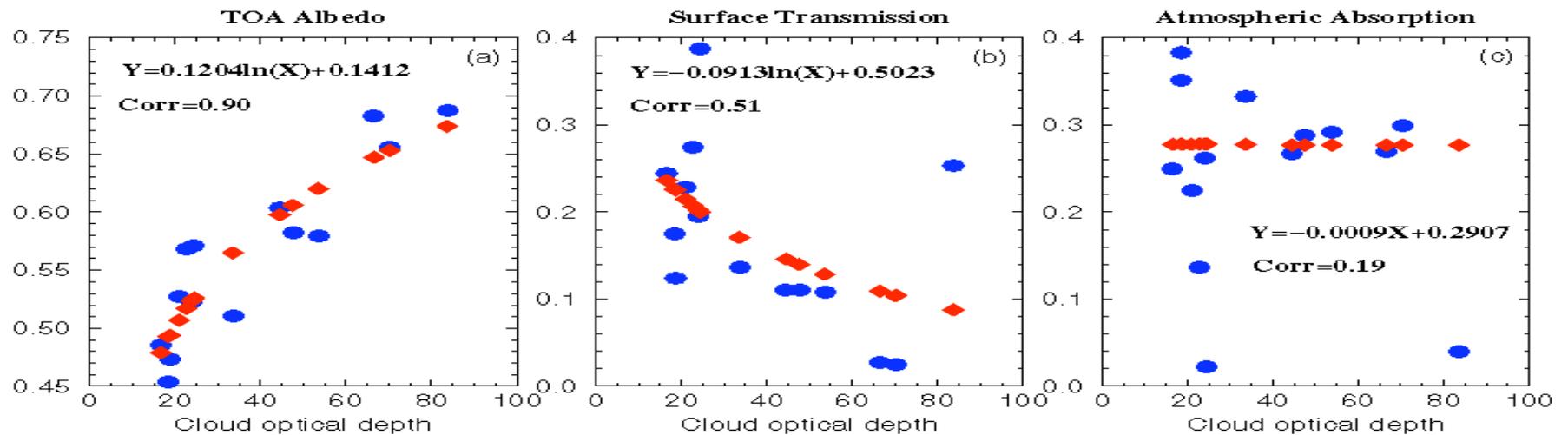
SGP

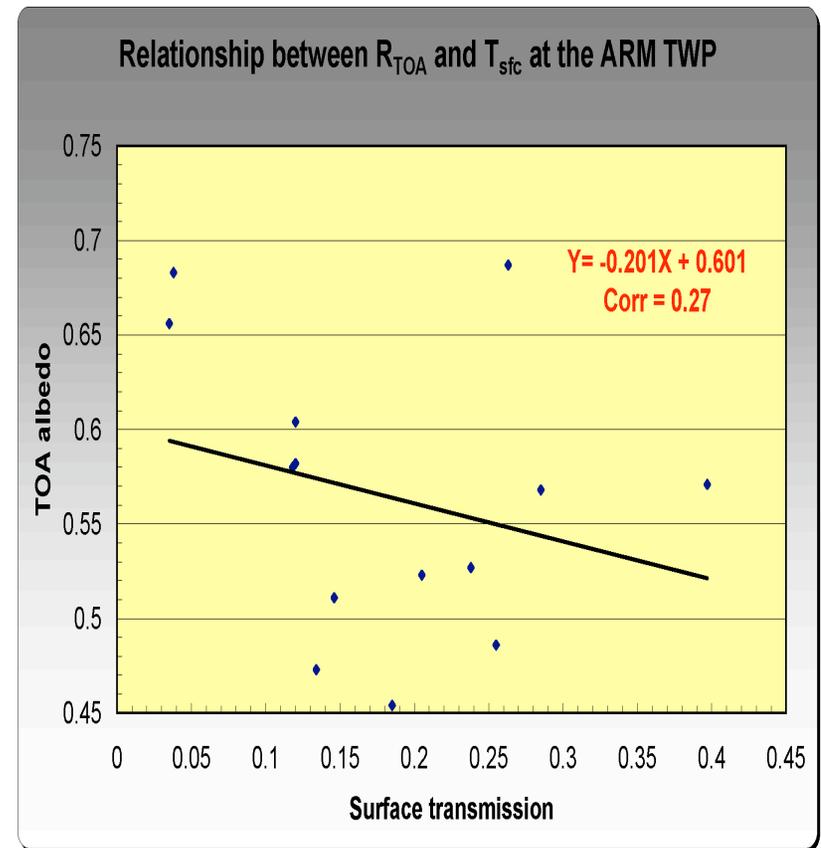
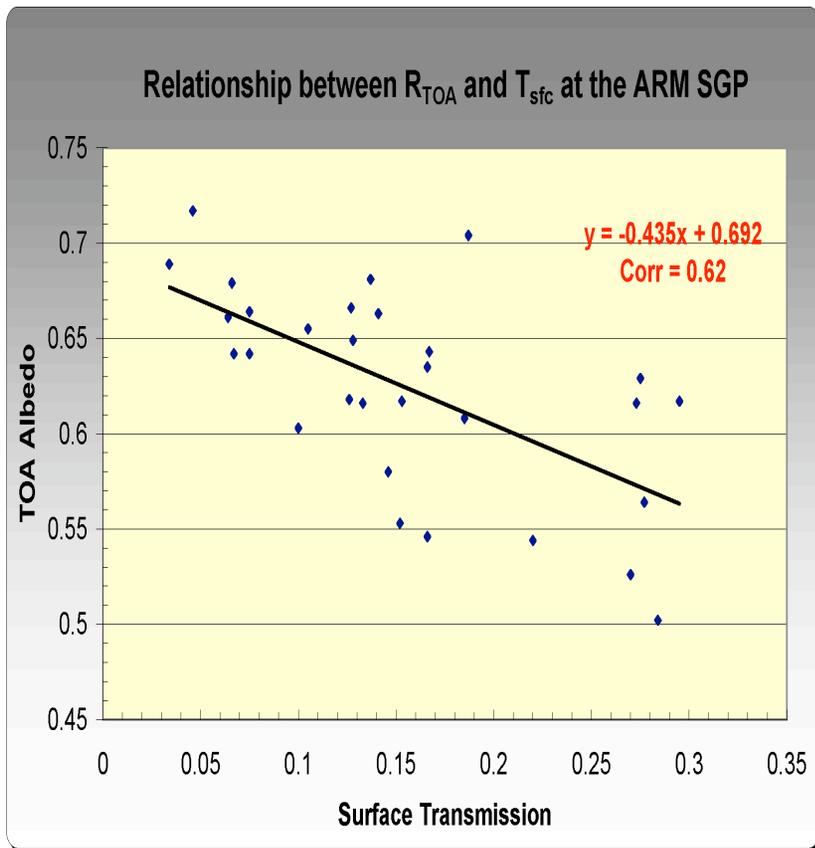
Relationship of R_{TOA} , T_{sfc} and A_{col} with cloud optical depth



TWP

Relationship of R_{TOA} , T_{sfc} and A_{col} with cloud optical depth





When ΔT_{sfc} increases 0.1,
 ΔR_{TOA} decreases 0.0435

When ΔT_{sfc} increases 0.1,
 ΔR_{TOA} decreases 0.0201

Monte Carlo Simulations

\ Given values: $\tau=64$, Cloud thickness=10 km,
Solar zenith angle= 5° , run Monte Carlo simulations at
wavelength= $0.67 \mu\text{m}$

\ Results:

When Cu size is 10 km, the side photon leaking is $\sim 25\%$

When Cu size is 100 km, the side photon leaking is
estimated around 5%.