Evaluation of CERES ED4 MODIS and GEOS Cloud Properties Using ARM SGP Observations

Xiquan Dong
University of Arizona

1)CERES ED4 MODIS Cloud Fraction by Casey Oswant
2)CERES GEO cloud properties by Ted McHardy

Evaluation of CERES ED4 MODIS Cloud Fraction Using ARM SGP Observations

Casey Oswant, Baike Xi, and Xiaojian Zheng

University of Arizona

Bill Smith Jr, Pat Minnis and Sunny Sun-Mack

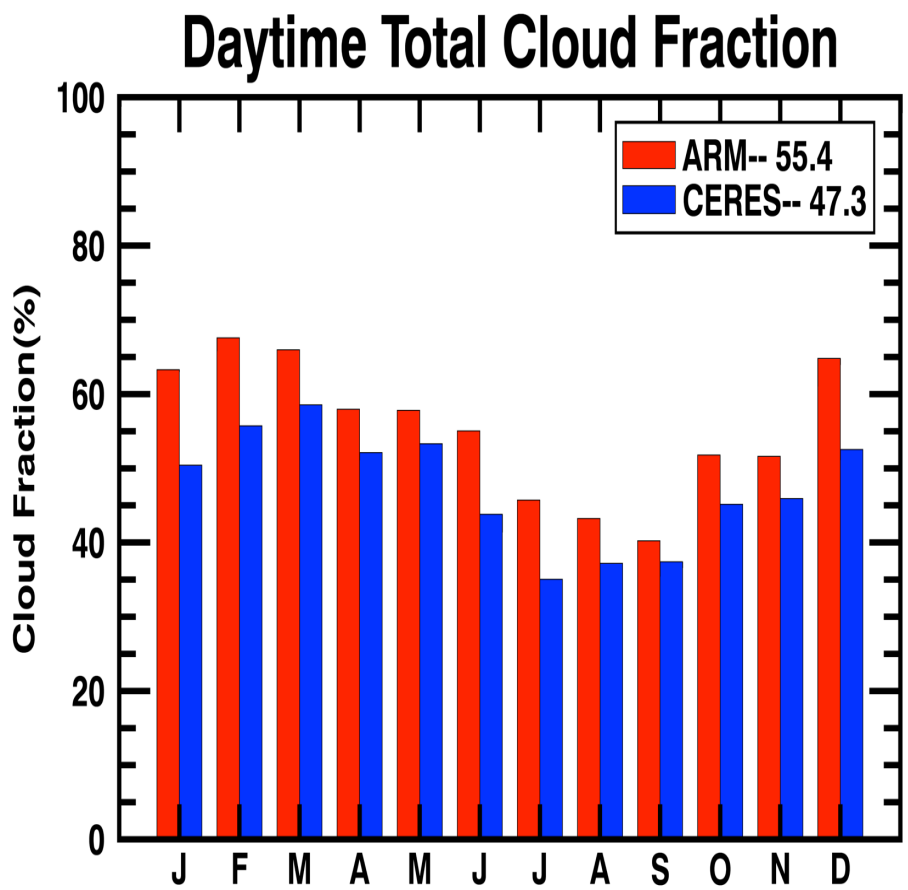
NASA Langley

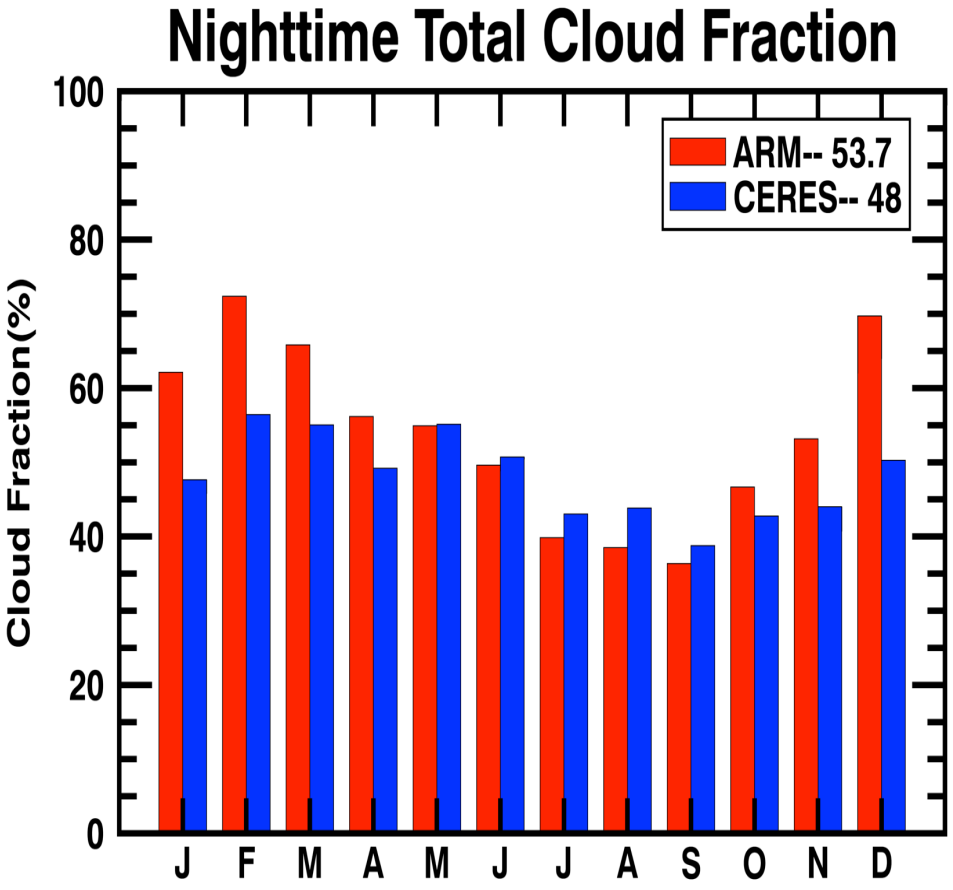
Objective

Are passive remote sensed clouds (MODIS) comparable to actively sensed clouds (ARM and CC radar-lidar)?

- **Data: CERES ED4 SYN1deg (passive), ARM and CCCM radar-lidar (active).**
- **Time period: March 2000 to December 2010 for both ARM and CERES. 2007-2010 for CCCM.**
- **Focus on cloud fraction (CF).**

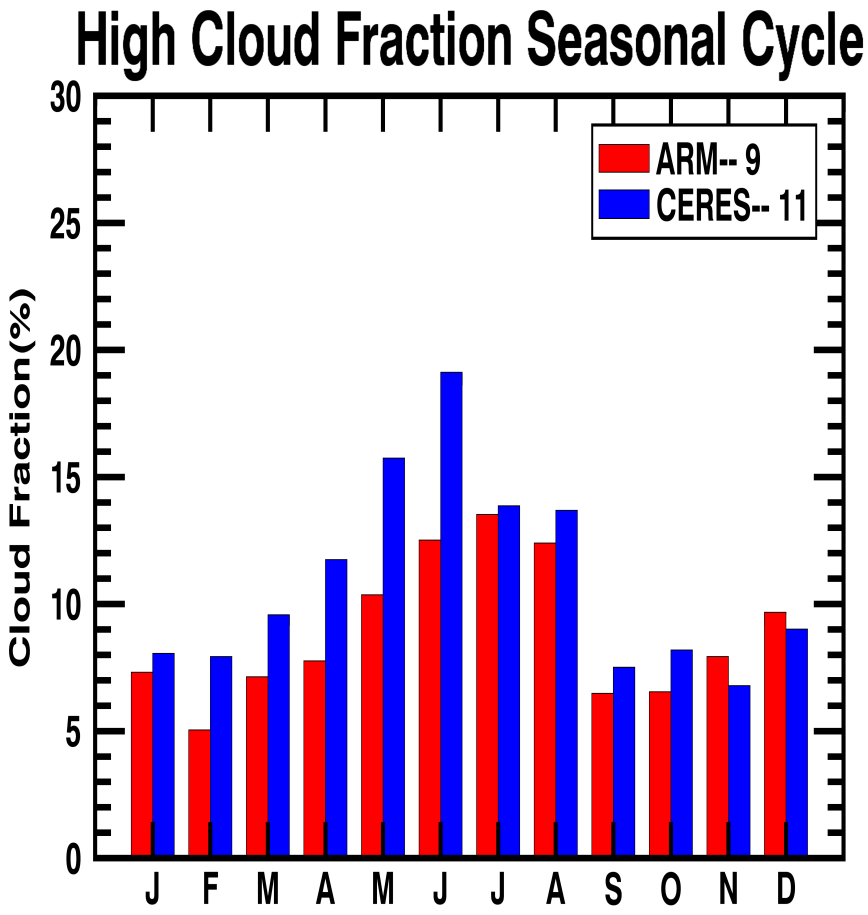
Total Cloud Fraction (CF)

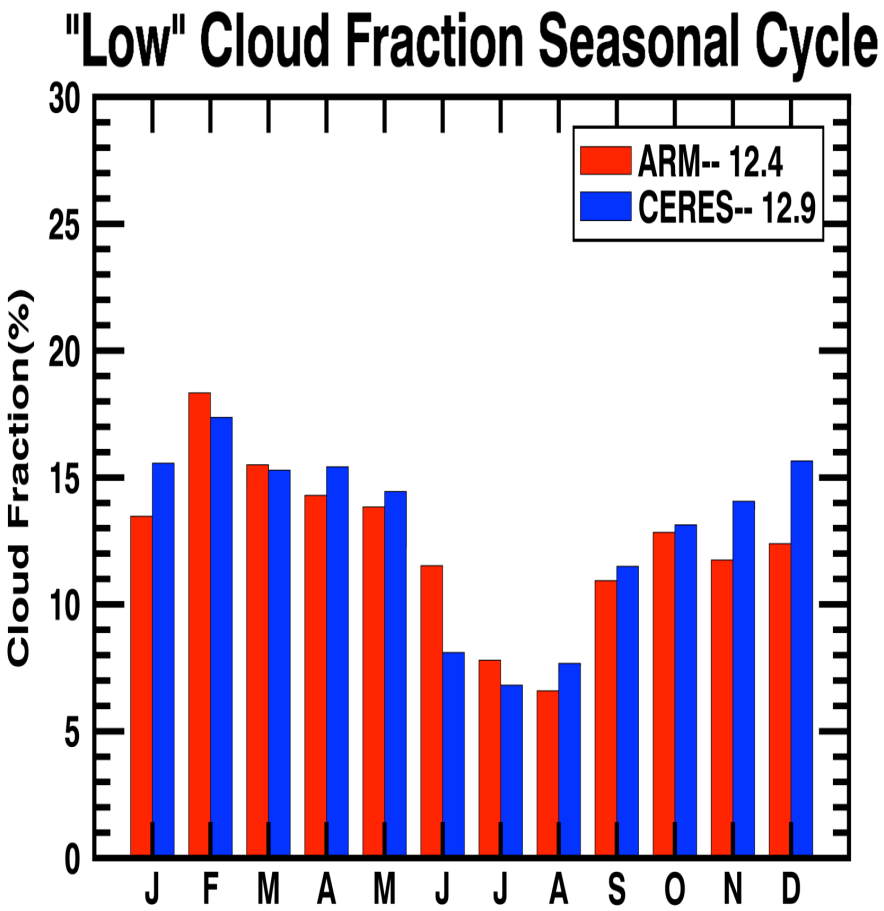




- Both ARM and CERES follow the same seasonal variation, decrease from spring to summer and increase from summer to fall.
- CERES CFs are consistently lower than ARM ones (~ -7%)

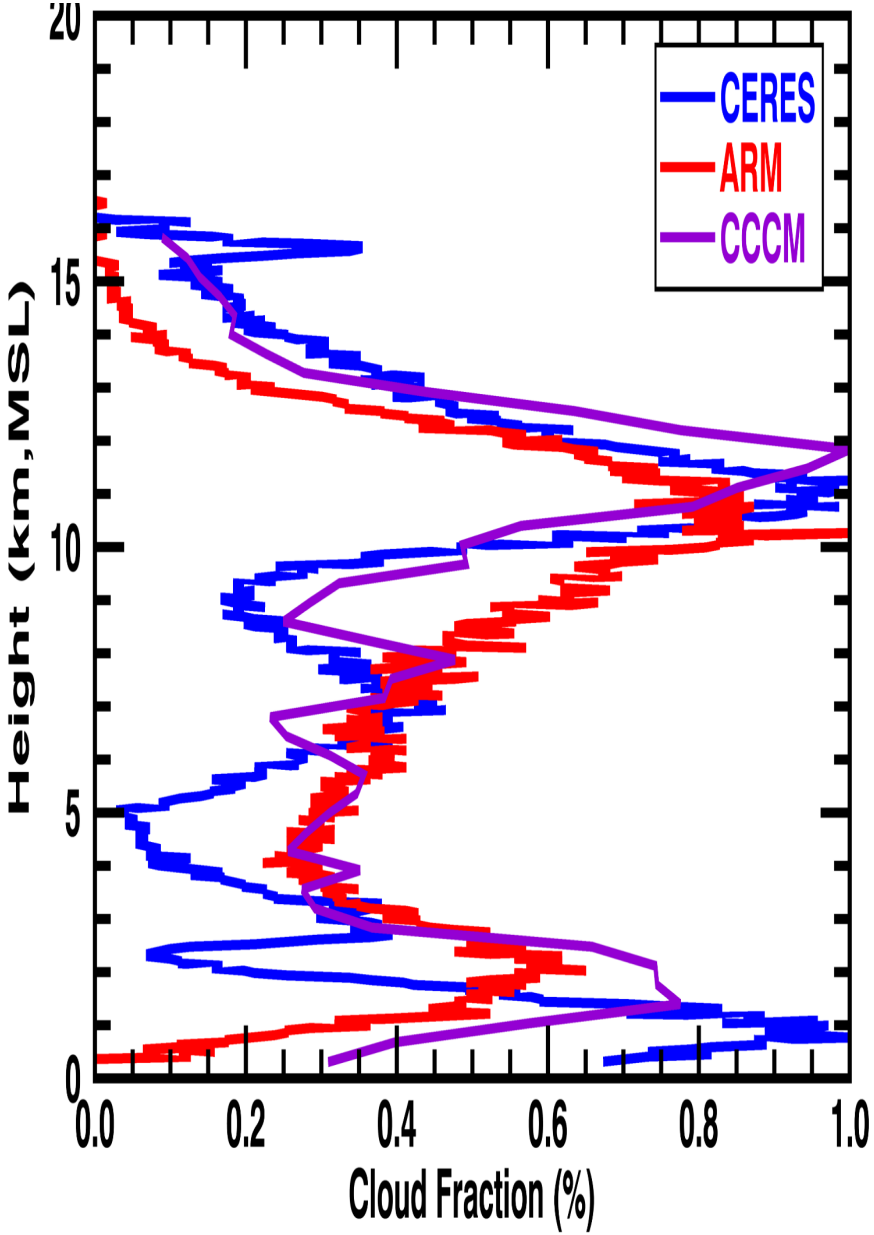
High (>9km) and Low (<3km) CFs





- Both CERES high and low CFs higher than ARM CFs;
- If some optically thin high clouds above low level cloud, then ARM "LOW"=LOW+HOL CF is only ~0.5% lower than CERES "LOW" CF

Profiles of CFs from ARM and CERES

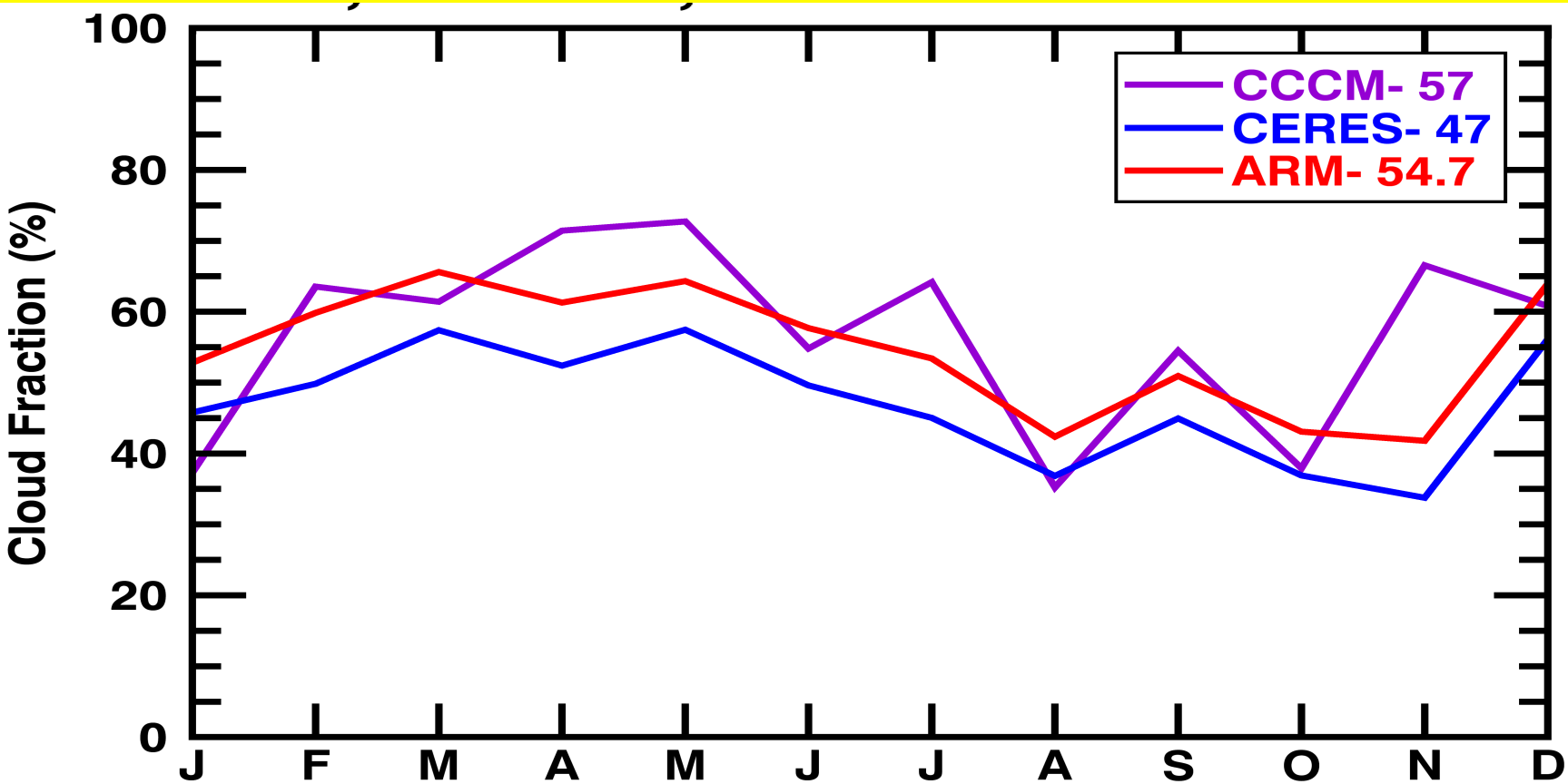


- Using maximum cloud-top heights from ARM, CERES and CCCM

- Comparing to ARM CFs,
  ➔CERES has positive biases in both high and low clouds, but negative bias in middle clouds, consistent to high and low CF seasonal

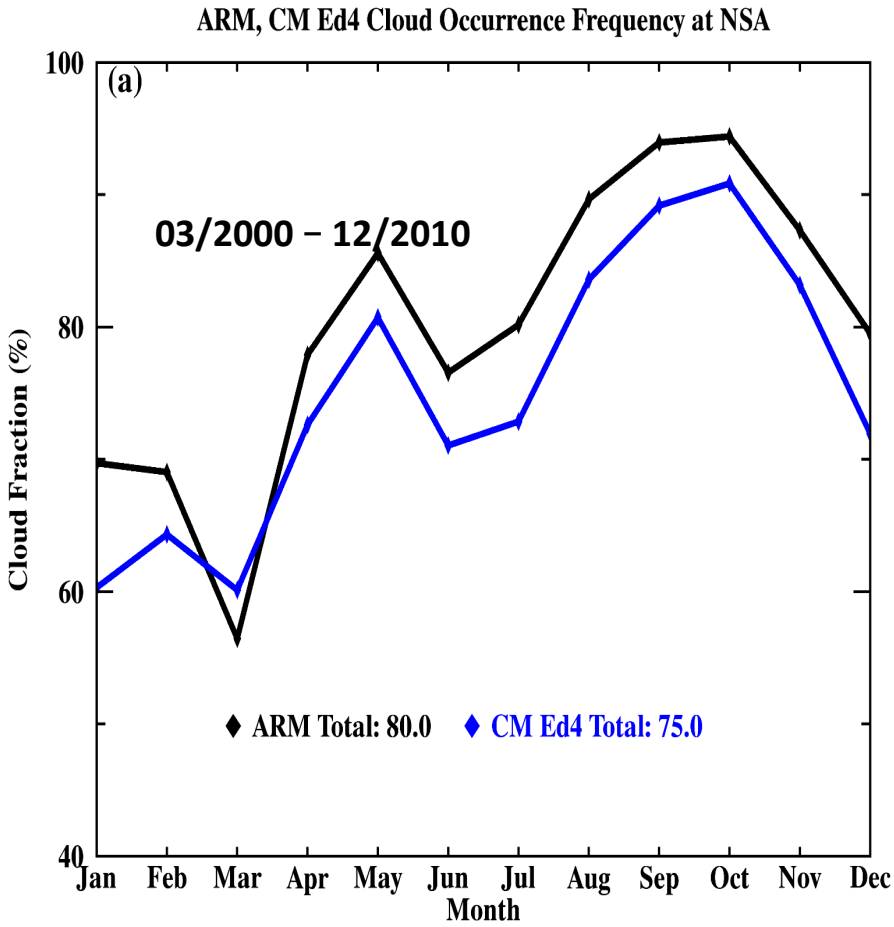
  ➔CCCMM detected more high-level clouds

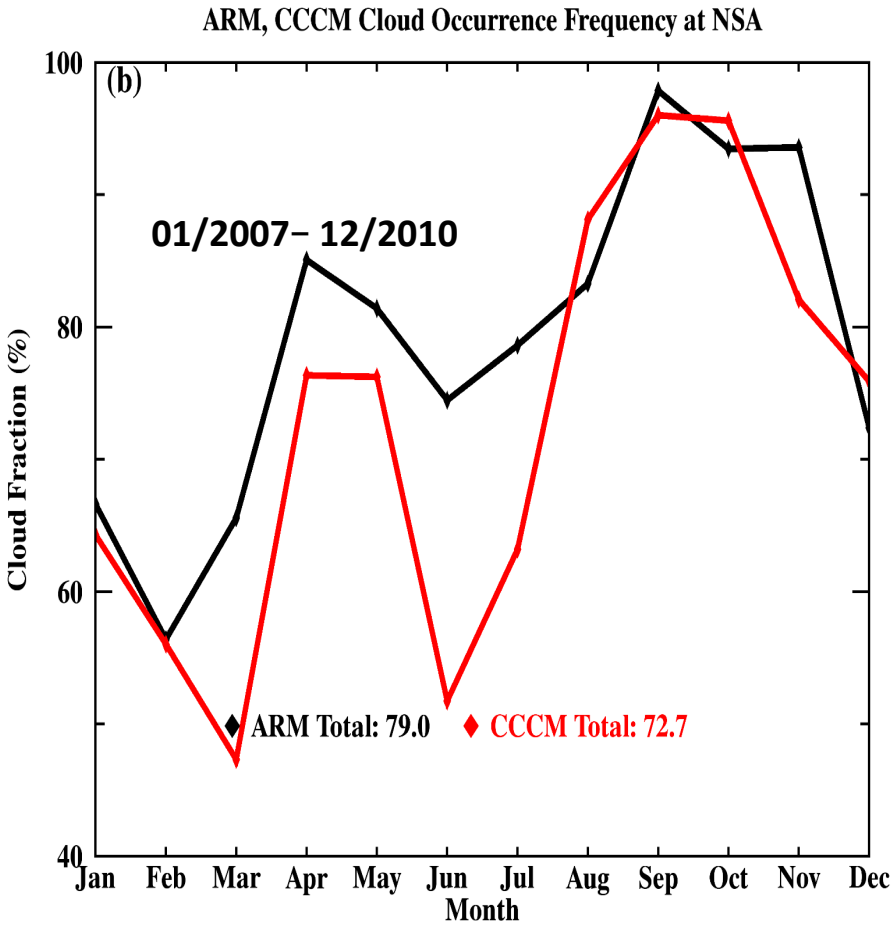
CF comparisons between ARM, CERES and CCCM



- CCCM and ARM CFs agree within 3%➔Radar-lidar from space and surface can observe similar clouds, but CCCM detected more optically thin high clouds.
- Both ARM and CCCM are 7-10% higher than CERES-MODIS➔ passive remote sensing does miss some clouds, such as middle clouds.

Arctic CFs from CERES Ed4, CCCM and ARM



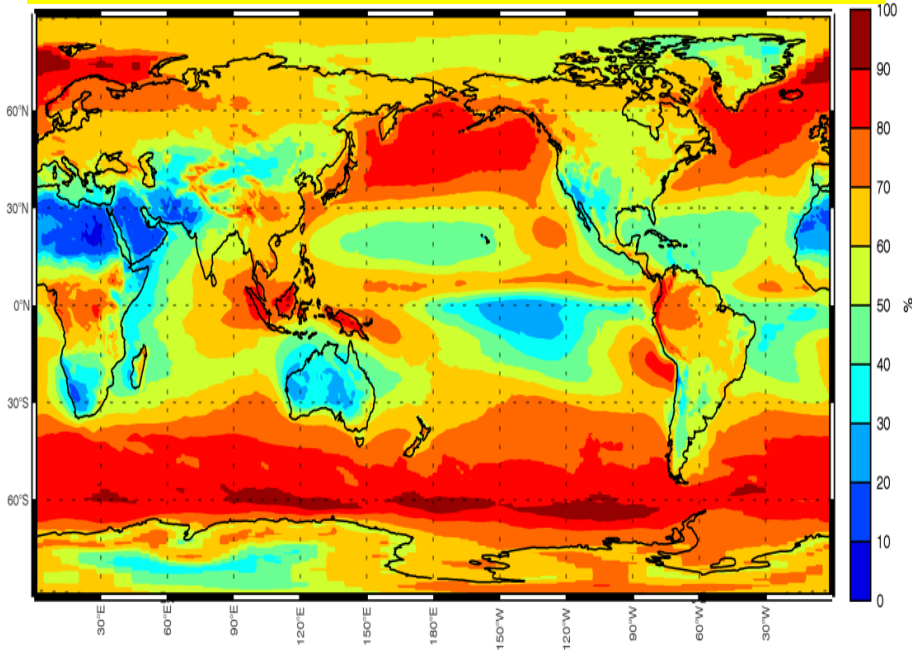


➔CERES is 5% lower than ARM

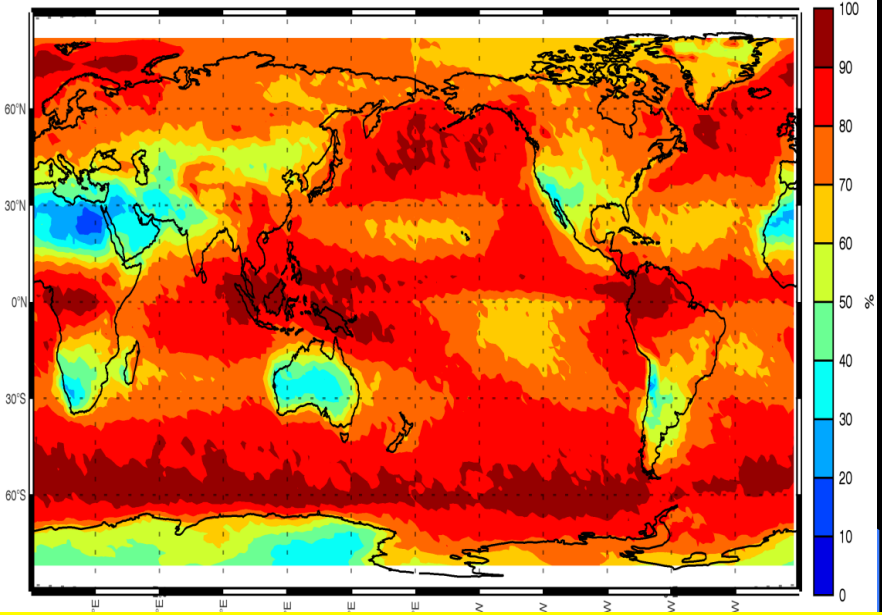
➔CCCM is 6.3% lower than ARM because low clouds are dominant over Arctic while CCCM missed some clouds < 1 km.

Do MODIS and CC observe same amount of clouds?

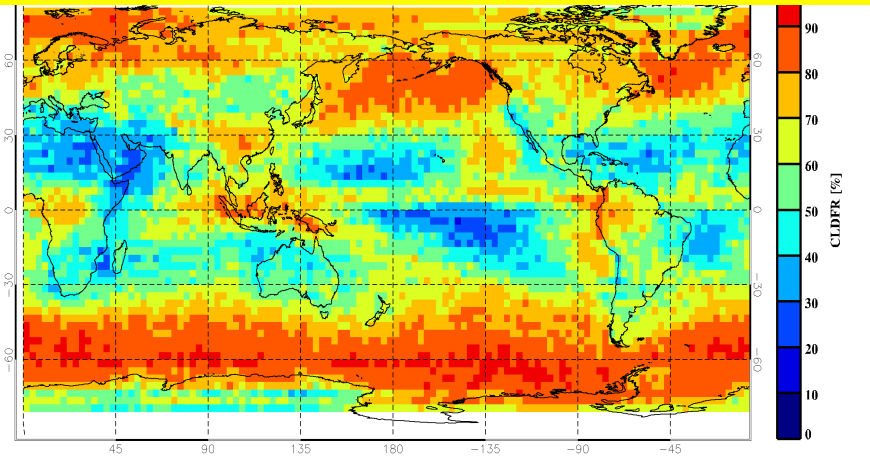
All clouds, CF_CM=62%



All clouds, CF_CC=74%



For tau>0.3 clouds, CF_CC=63%



~ 10% difference is due to optically thin clouds (tau<0.3) detected by CALIPSO, but not observed by MODIS and simulated by models.

Stanfield et al. 2014 (J Clim)

Conclusions

- Both ARM and CERES follow the same seasonal variation, but CERES CFs are consistently lower than ARM ones (~ -7%)

- Comparing to ARM CFs, CERES has positive biases in both high and low clouds, but negative bias in middle clouds; CCCM detected more optically thin high clouds.

- CCCM and ARM CFs agree within 3%, ARM missed some optically thin clouds, while CCCM missed some low-level clouds.

Evaluation of CERES GEOS Cloud Properties Using ARM SGP Observations

Theodore M. McHardy and Baike Xi, University of Arizona

Bill Smith, Jr. and Patrick Minnis, NASA Langley

- **Purpose:**
  - To statistically characterize CERES GEO cloud property retrievals of low-level water clouds over land vs. ARM ground-based observations and retrievals
  - Compare GOES East and West retrievals to investigate viewing/solar geometry effects

- **Motivation:**
  - McHardy et al. (2018) found some geometric biases in long-term record of GOES SatCORPS (from ARM data archive)
  - Unique opportunity to study effects of viewing/ solar geometry using long-term ARM and CERES GEO cloud properties

Data

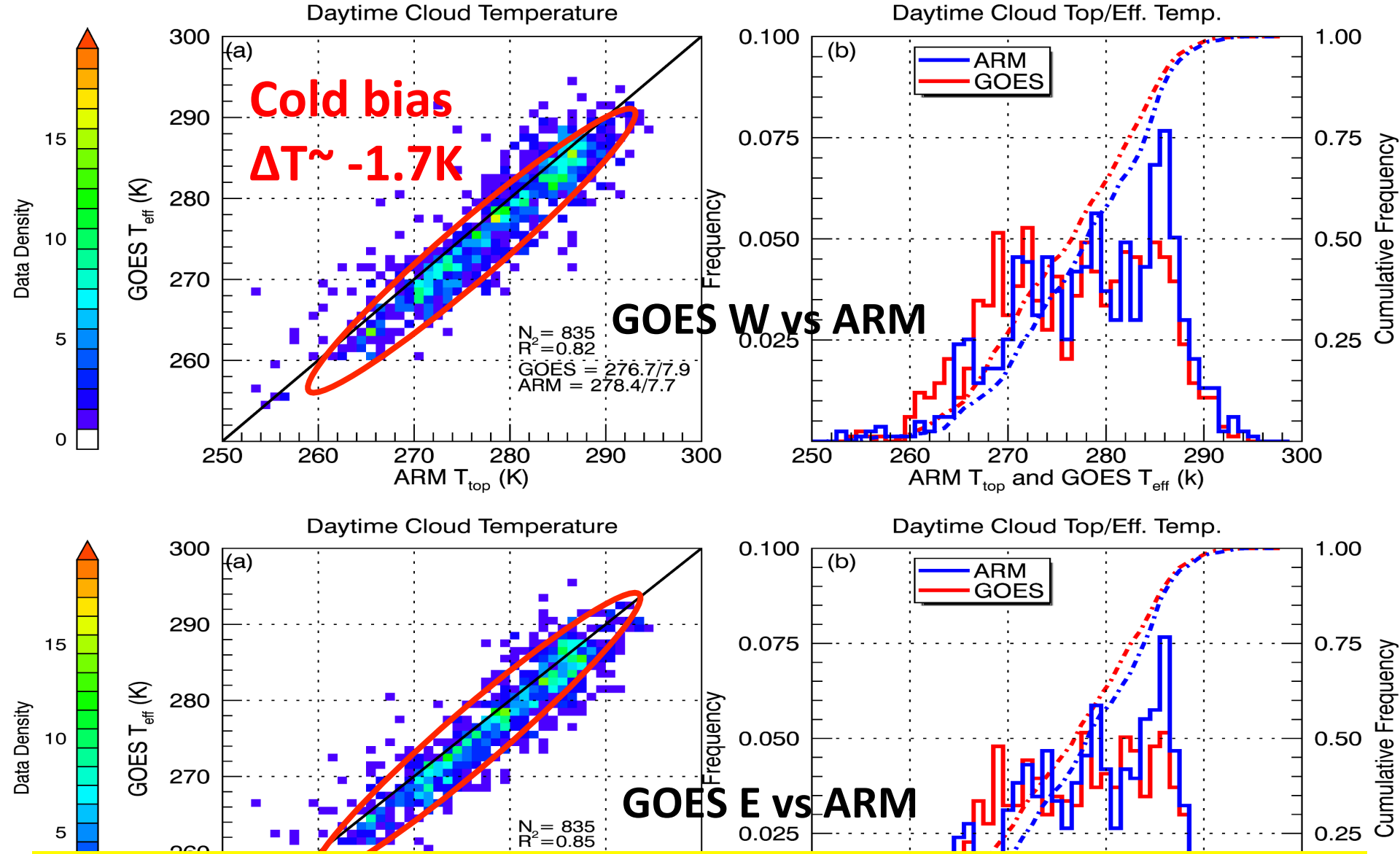
- **CERES GEO (~8km) every hour**
- **DOE ARM SGP surface data (every 5 min.)**
- **2000 – 2010 (will add – 2015 later)**

Cloud Property	Full Name	Uncertainty	Instrument and Retrieval Algorithm
ARM T_{base} and T_{top}	Cloud base and top temperature (K)	0.2°C	Merged Sounding [*Troyan et al., 2012*]
ARM r_e	Cloud droplet effective radius (μm)	~10% for daytime	*Dong et al. [1997, 1998, 2002]*
ARM τ	Cloud optical depth	~5-10% for daytime	*Dong et al. [1997, 1998, 2002]*
ARM LWP	Cloud liquid water path (g m^{-2})	~10%	Microwave radiometer [*Liljegren et al., 2001*]

Data Processing

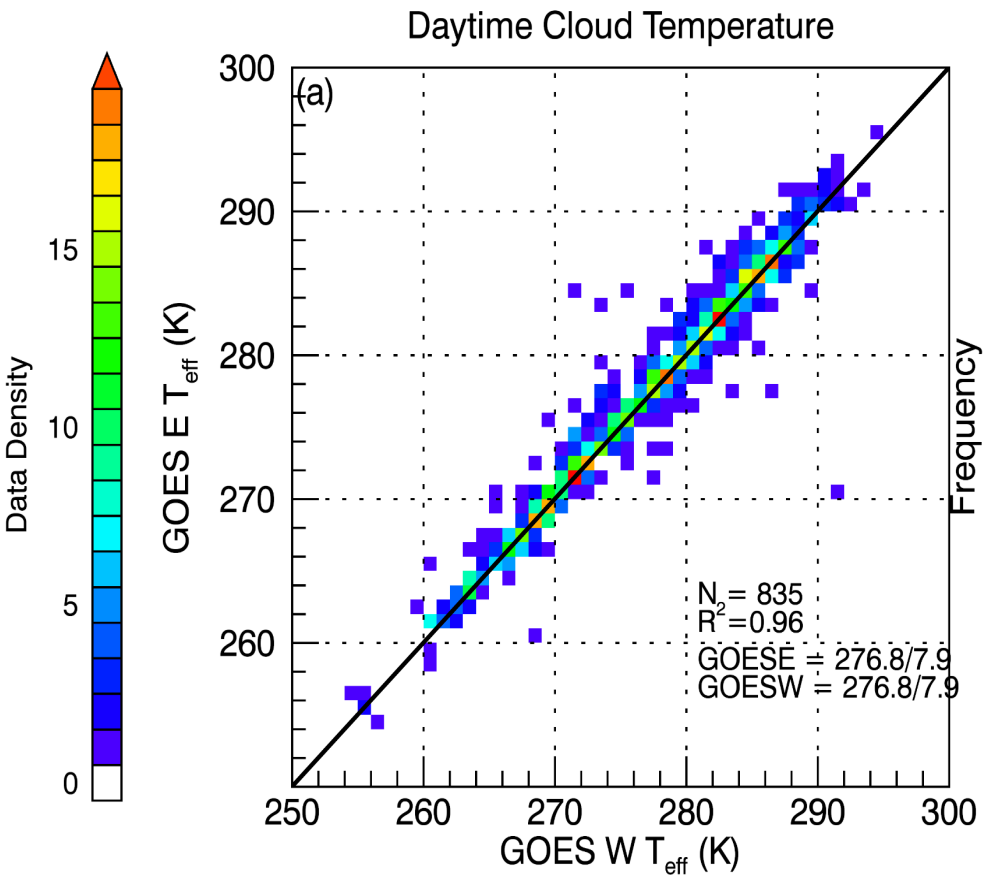
- Collocation:
  - GOES data spatially averaged within 0.3°x0.3° box centered on the ARM SGP site (~ 36.6N, 97.5W)
  - ARM data temporally averaged ±30 min of GOES scan
- Data Filters (to allow only low-level water clouds):
  - Identified by MMCR as low-level clouds (top < 3 km)
  - Daytime only (SZA < 82°)
  - ARM cloud base temp. > 250K
  - GOES (box mean) H_{eff} < 4km
  - GOES cloud fraction within box = 1
  - Both GOES E and W have valid data
  - Snow days removed based on sfc albedo > 0.5
  - MWR LWP < 500 g m^{-2}

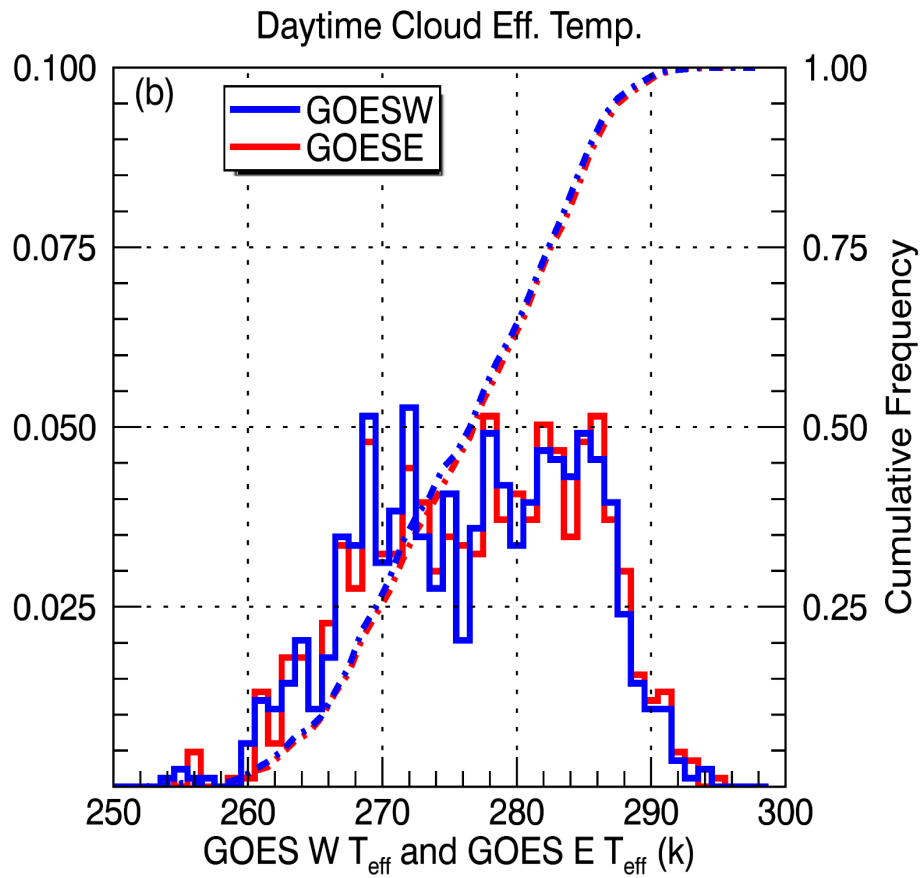
GOES W and E effective cloud temp vs. ARM cloud-top Temp.



Will see if there is a relationship between the bias and entrainment or inversion Strength, etc..

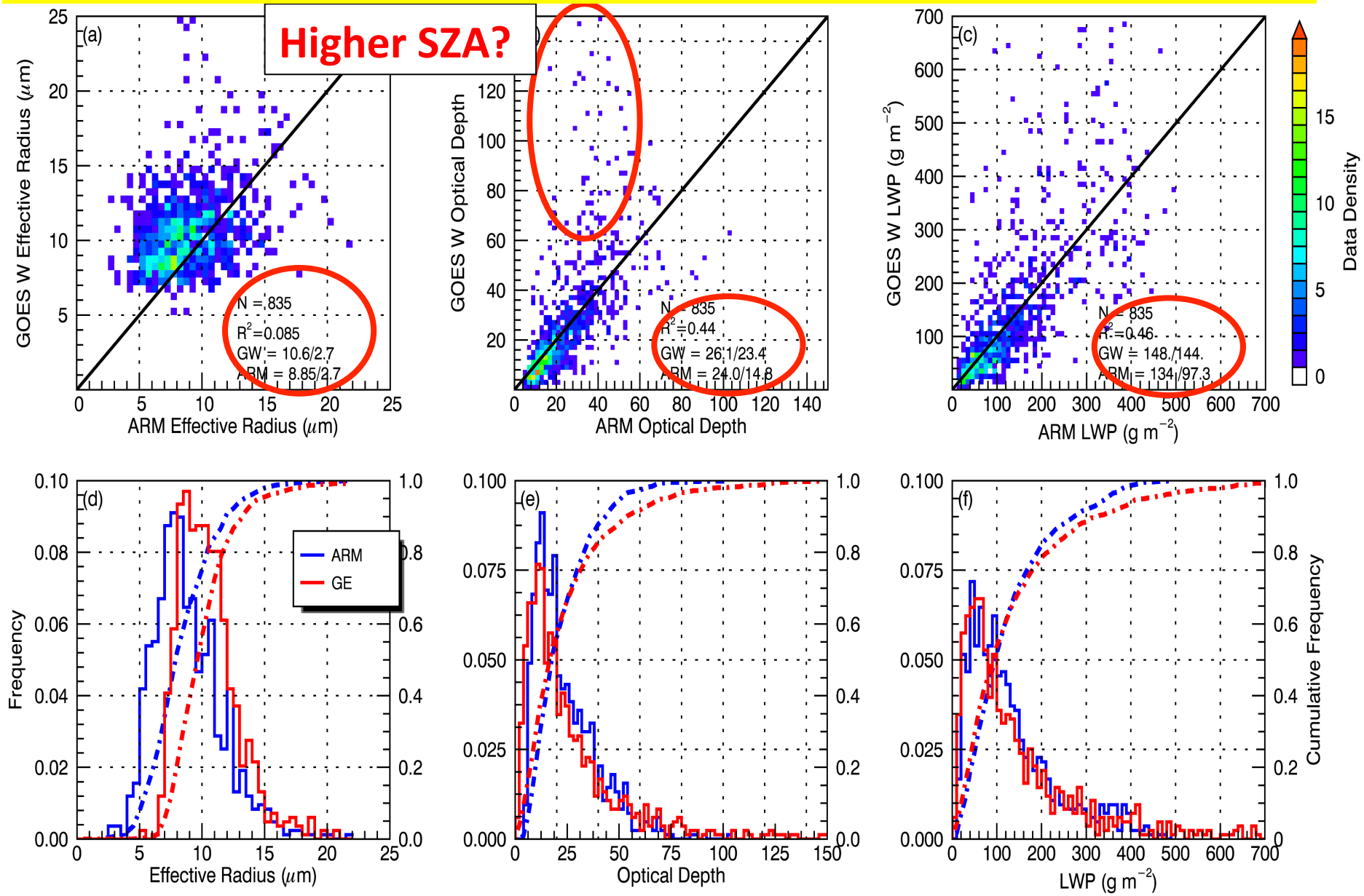
Effective cloud temp comparison: GOES W vs. E.





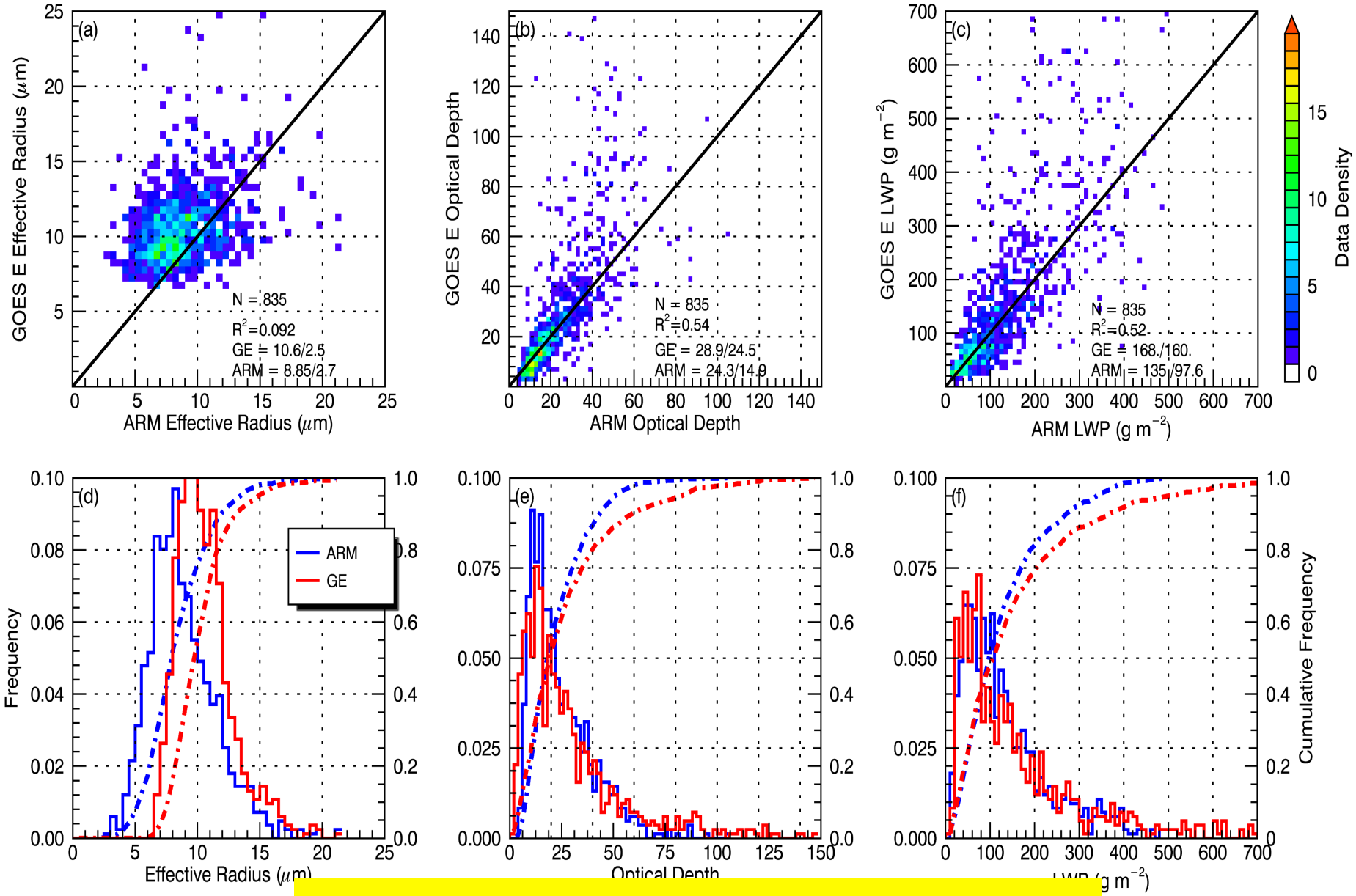
No bias in effective cloud temp between GOES W and E

Cloud Microphysics Comparison: GOES W vs. ARM



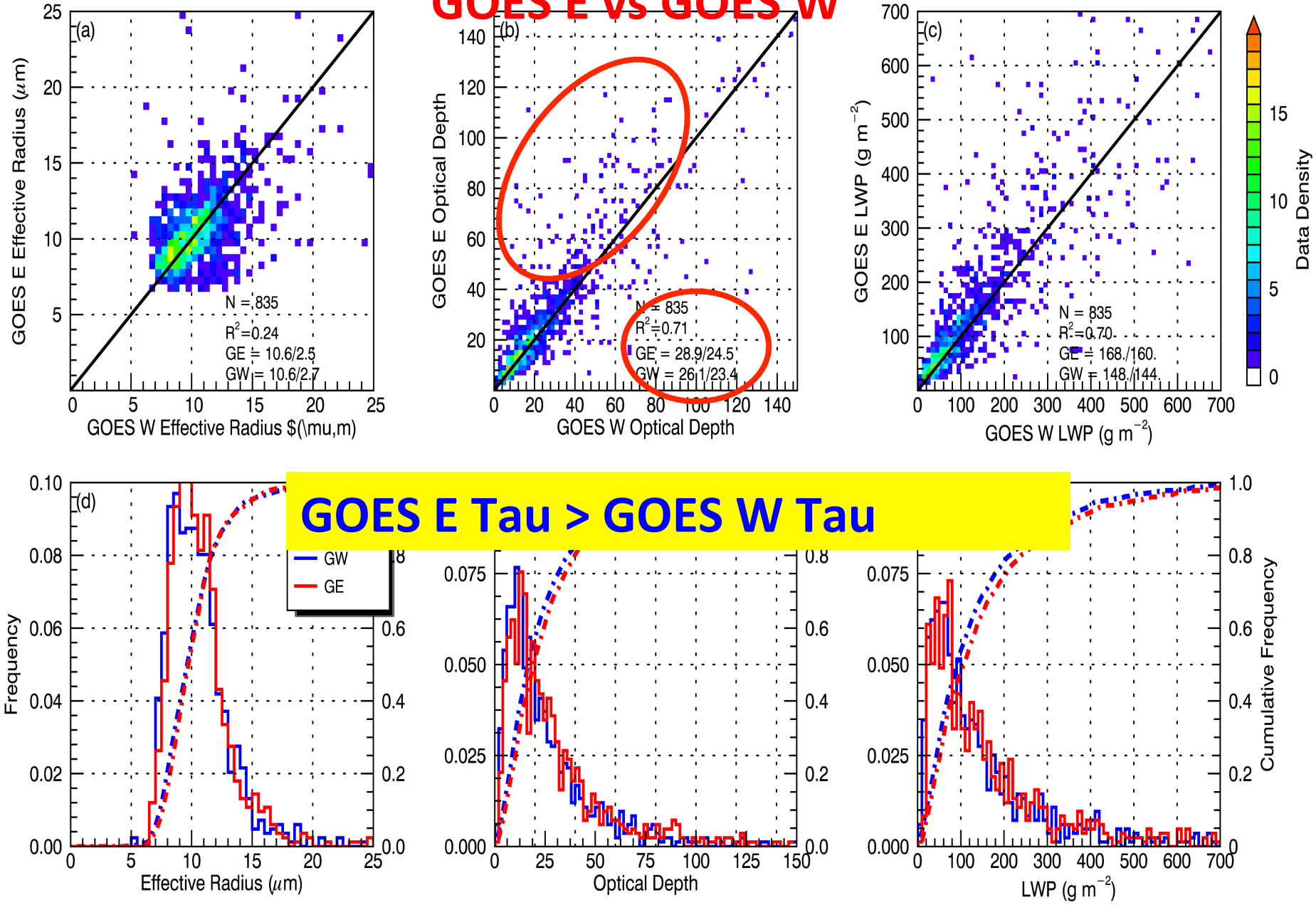
High biases in GOES E retrieved re, tau and LWP

Cloud Microphysics Comparison: GOES E vs. ARM



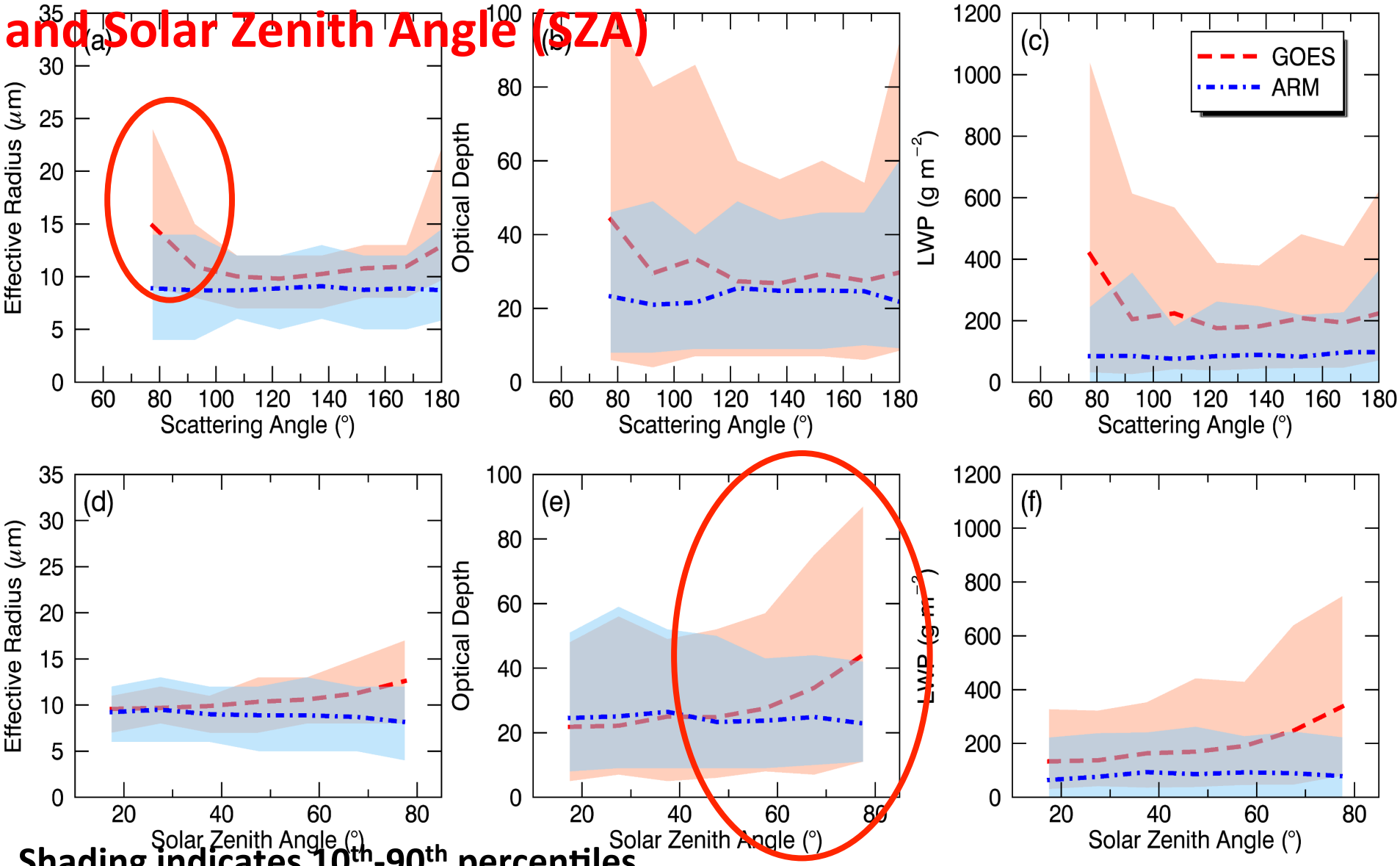
Much of the same as GOES W

GOES E vs GOES W



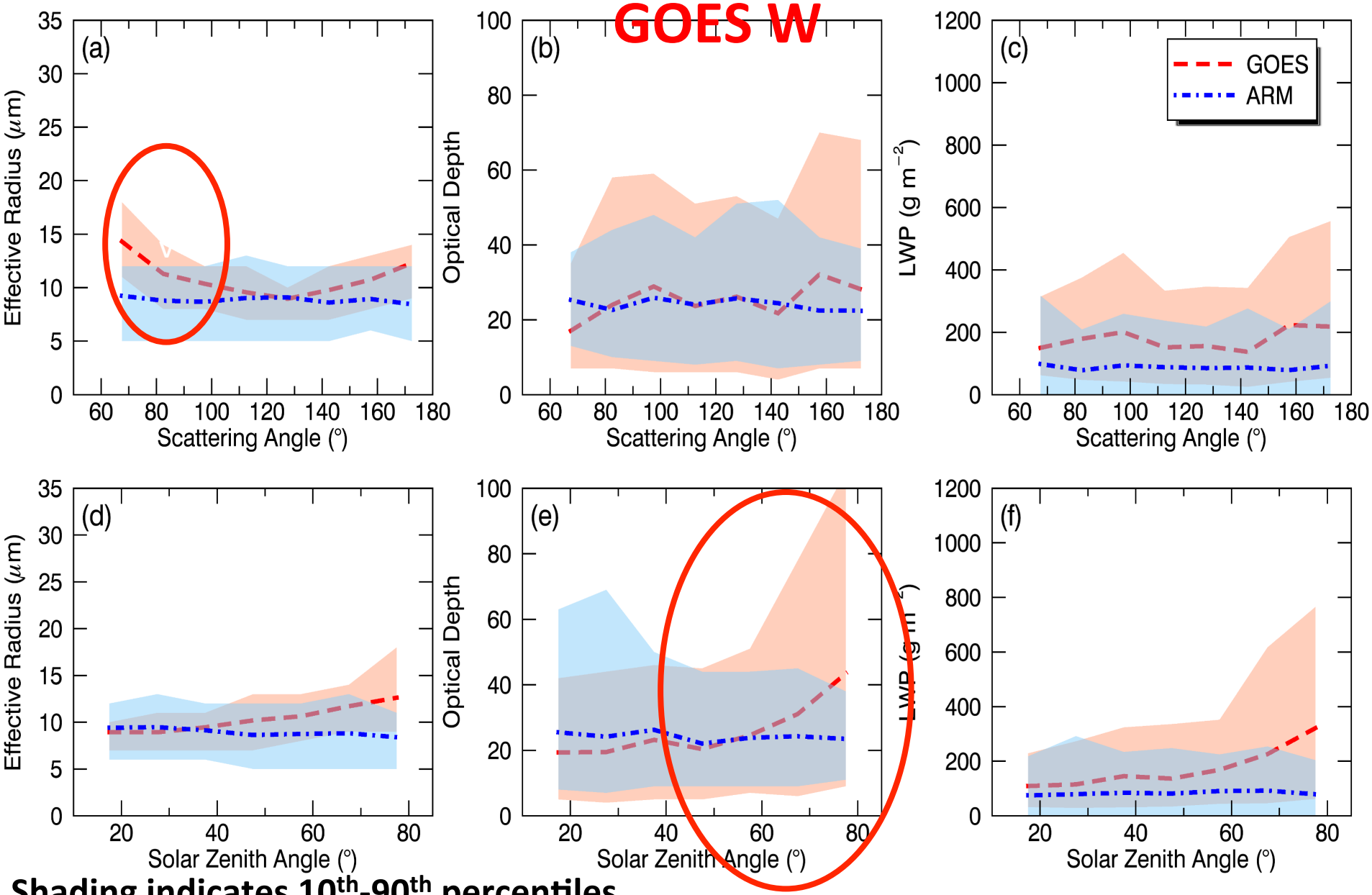
GOES E Tau > GOES W Tau

Dependence of GOES-E retrievals on Scattering angle (SA) and Solar Zenith Angle (SZA)



Shading indicates 10th-90th percentiles

r_e – high bias for lower SA; Tau - high bias for higher SZA



Shading indicates 10th-90th percentiles

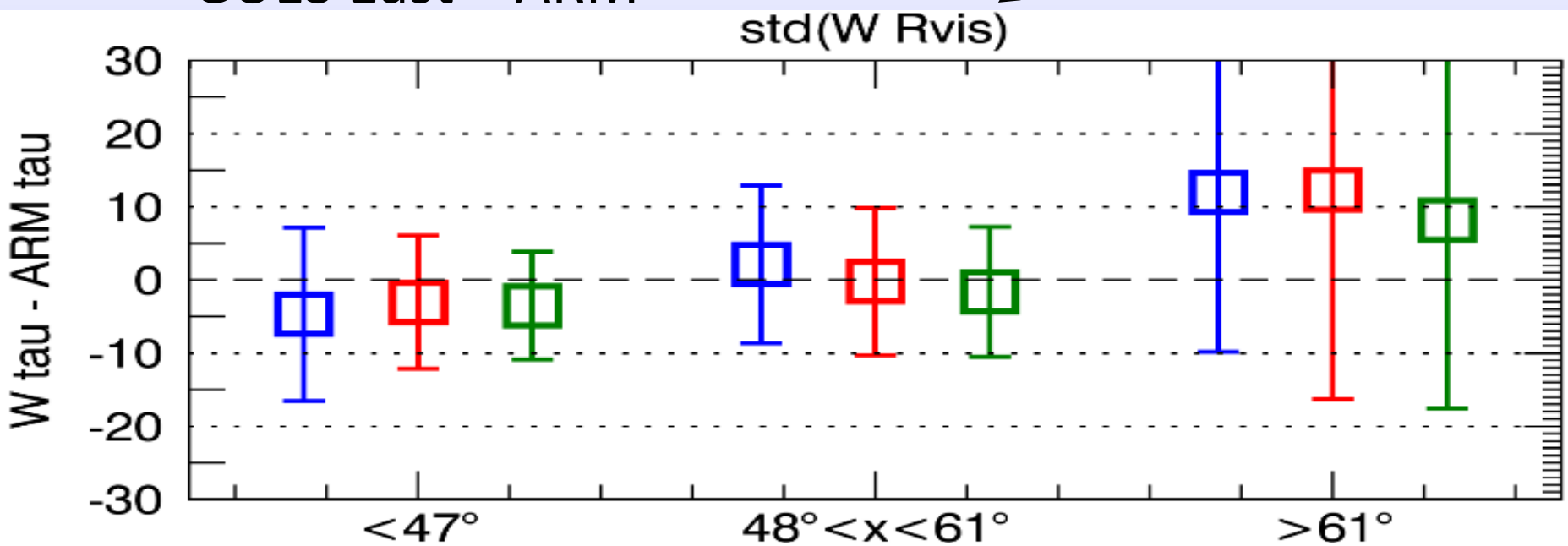
Same as GOES E

Further Investigation of dependence of GOES-E retrievals

- **Data first binned by SZA (3 equal sized bins)**
- **Then binned (3 equal sized) by "heterogeneity parameter": Low, Medium, High**
- **Error bars = standard dev.**

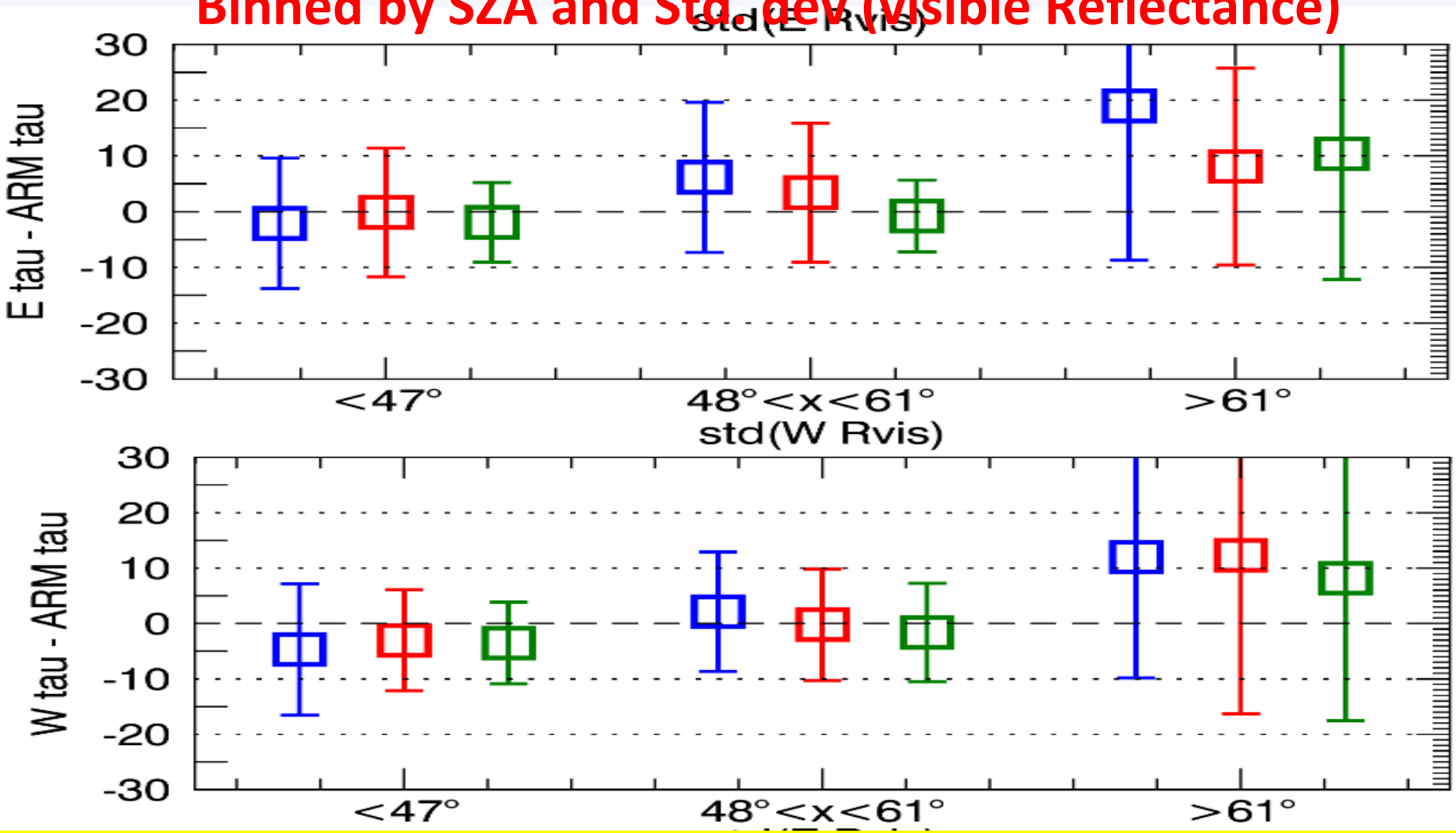
Y-axis: GOES West – ARM,
GOES East – ARM

"Heterogeneity parameter"



ΔTau increase with SZA, also vary with cloud heterogeneity

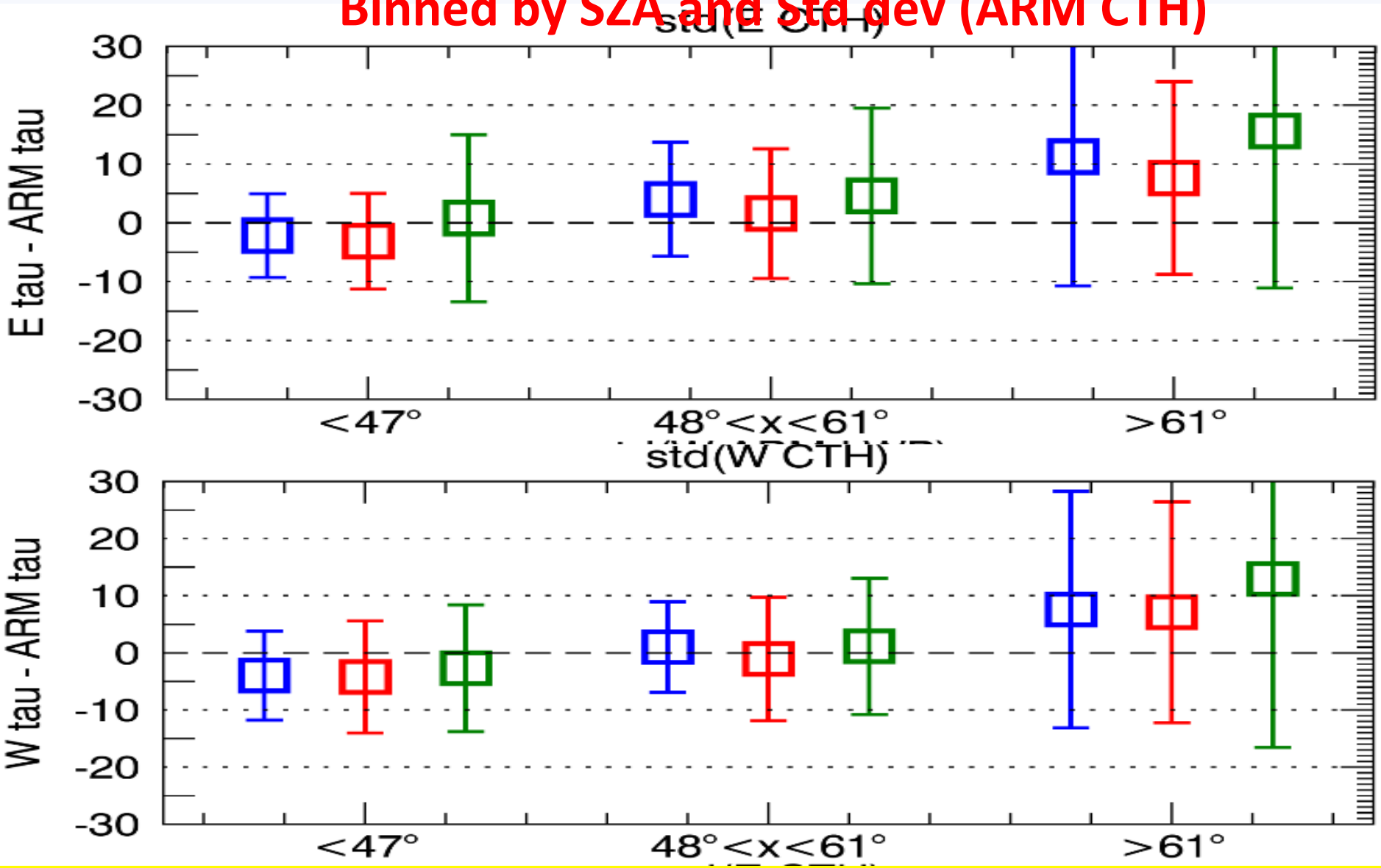
Binned by SZA and Std. dev (visible Reflectance)



ΔTau values are very small for SZA< 61.

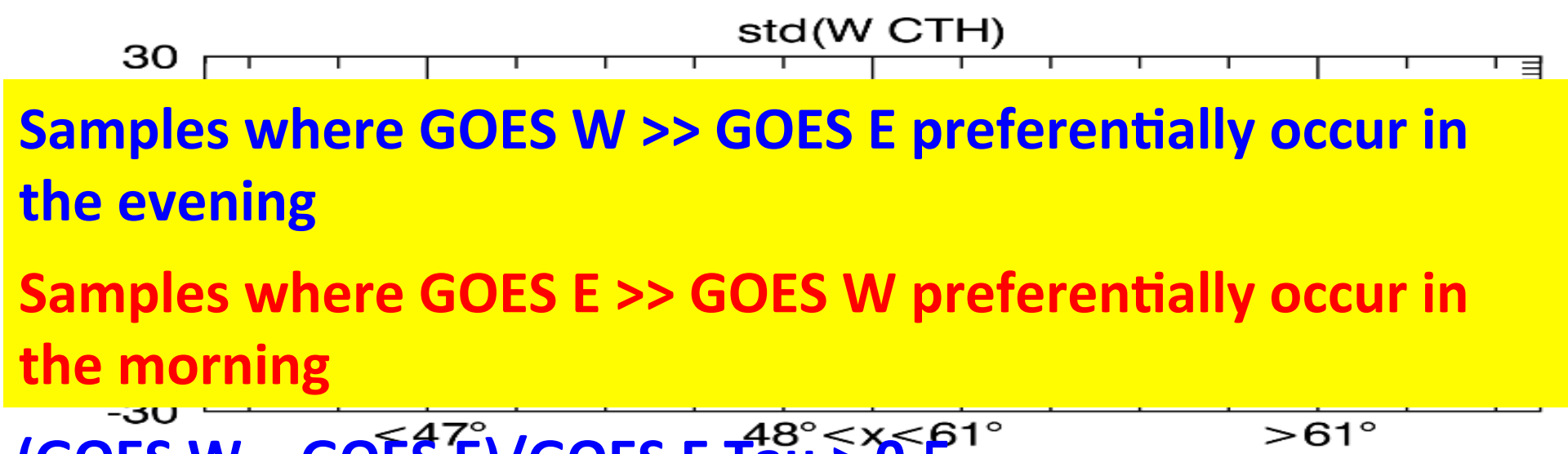
Both ΔTau and Std. Dev of ΔTau decrease with increasing heterogeneity (from blue to green) – not intuitive

Binned by SZA and Std dev (ARM CTH)



More intuitive – standard deviation bars are bigger for more heterogenous clouds

(GOES W – GOES E) Tau binned by SZA and Std dev (ARM CTH)

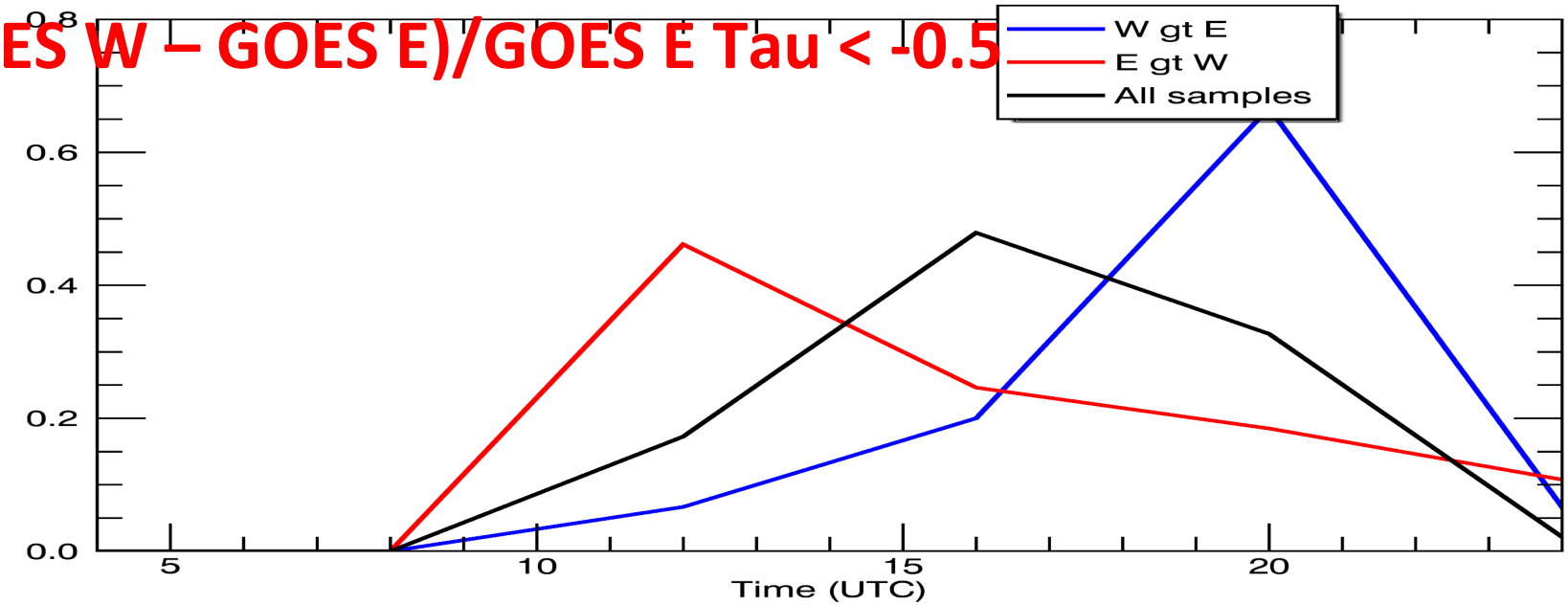


Samples where GOES W >> GOES E preferentially occur in the evening

Samples where GOES E >> GOES W preferentially occur in the morning

(GOES W – GOES E)/GOES E Tau > 0.5

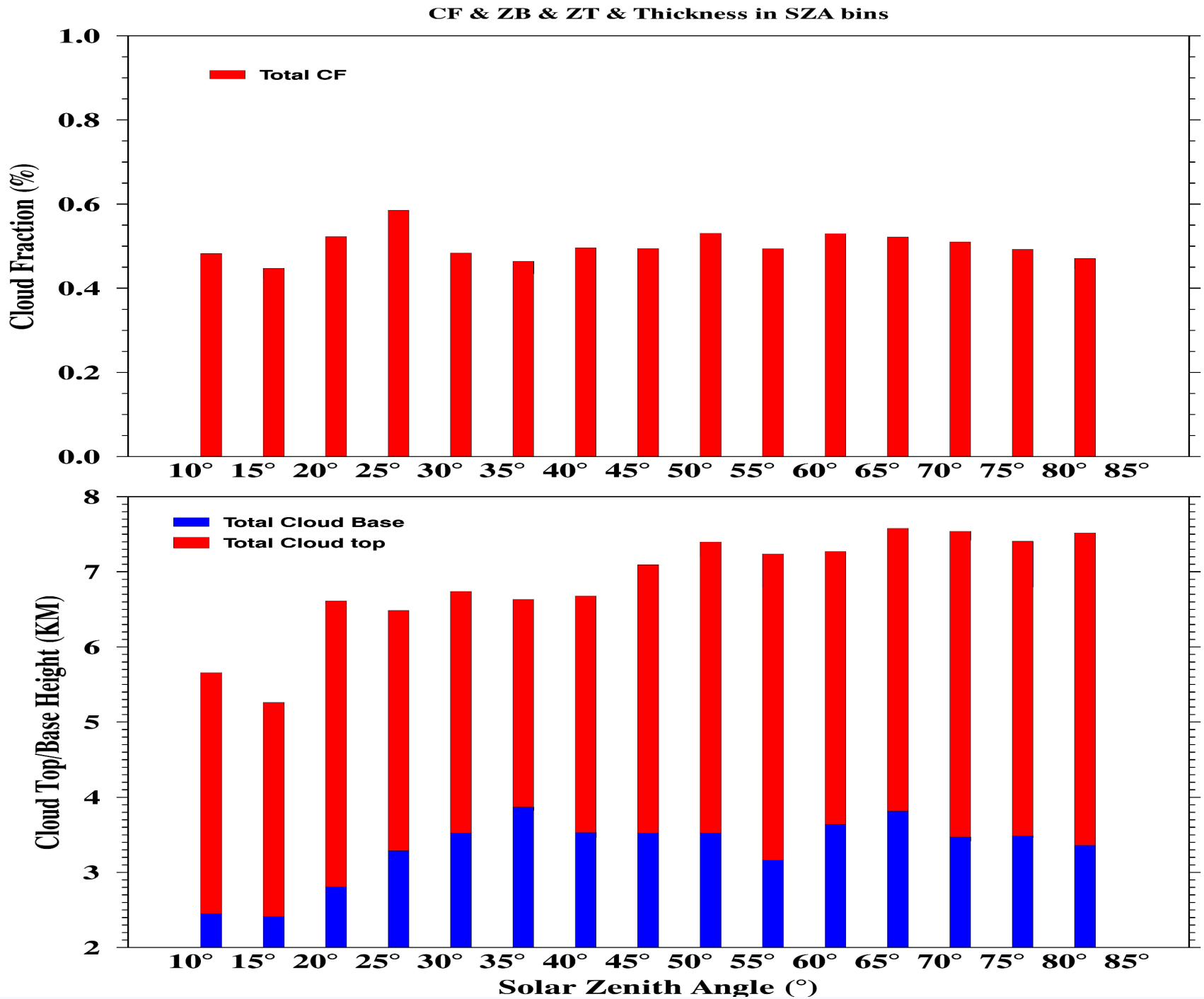
(GOES W – GOES E)/GOES E Tau < -0.5



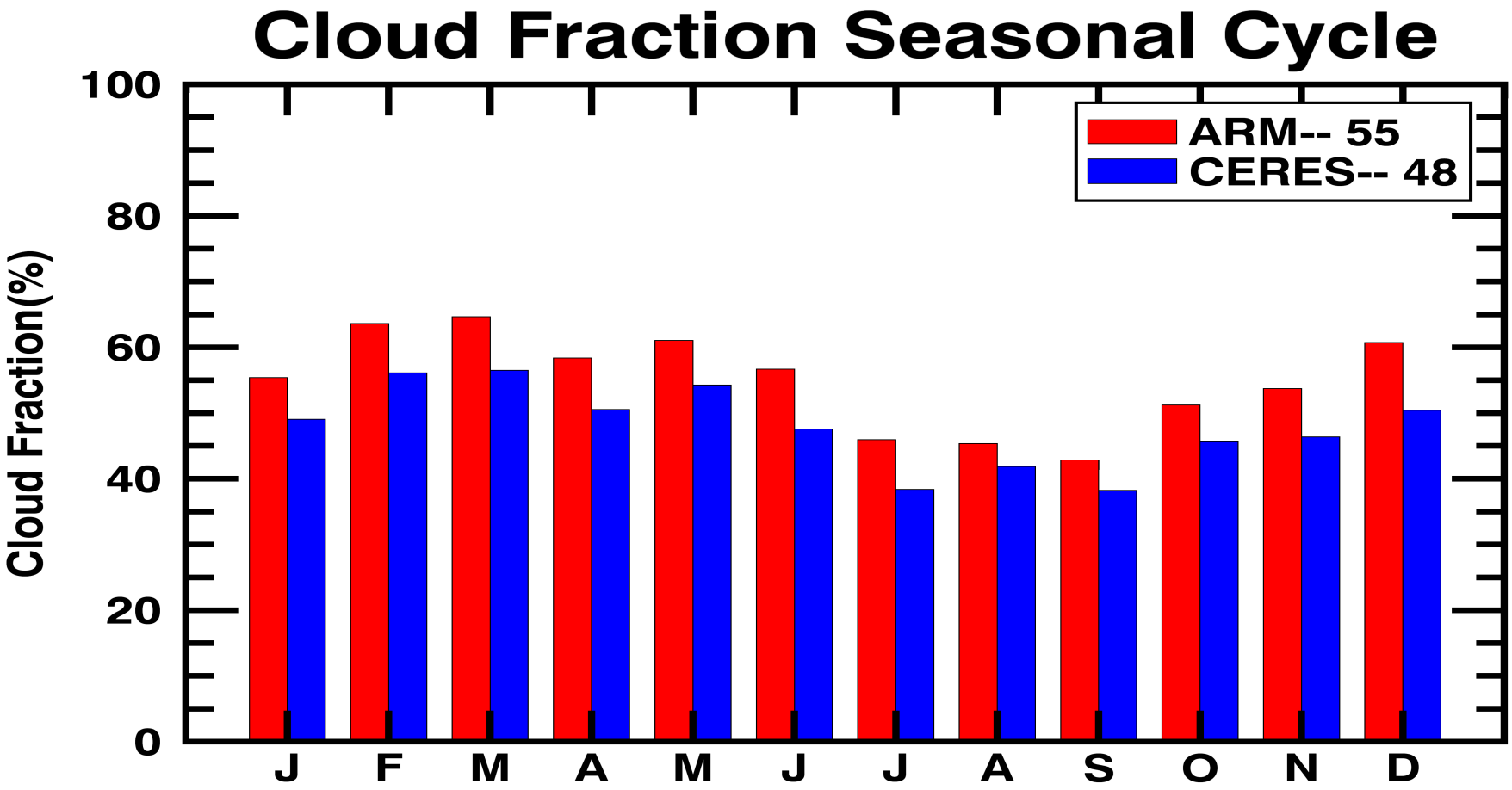
Conclusions:

- GOES E and W very well correlated with each other (except maybe r_e), but GOES E Tau > GOES W Tau by ~2 – needs further investigation
- R_e- high bias for low SA;

  Tau- high bias for high SZA
- Samples where GOES W >> GOES E preferentially occur in the evening, while the opposite preferentially occurs in the morning

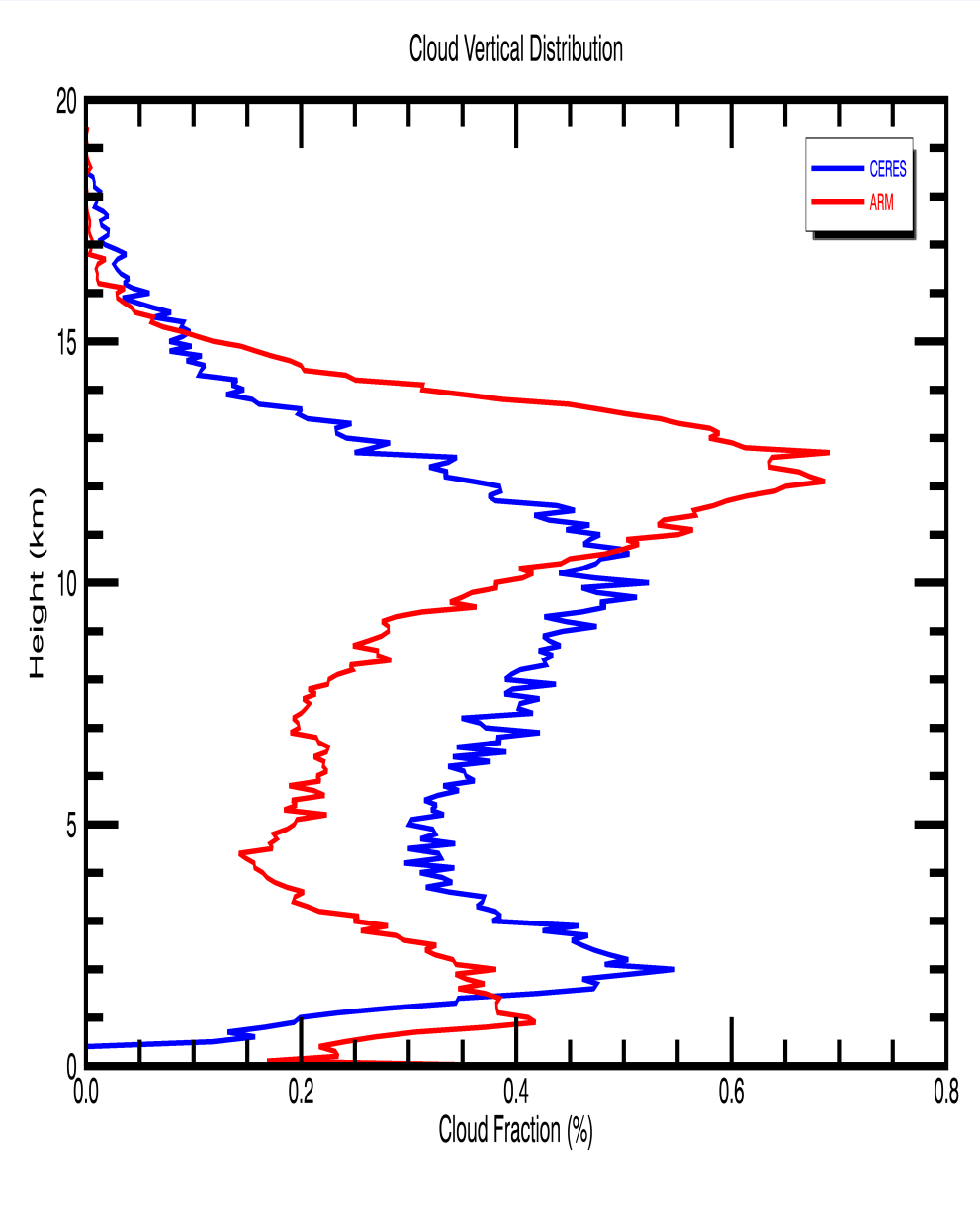

CF & ZB & ZT & Thickness in SZA bins
Total CF
Cloud Fraction (%)
1.0
0.8
0.6
0.4
0.2
0.0
10° 15° 20° 25° 30° 35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85°
Total Cloud Base
Total Cloud top
Cloud Top/Base Height (KM)
8
7
6
5
4
3
2
10° 15° 20° 25° 30° 35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85°
Solar Zenith Angle (°)

Total Cloud Fraction (CF)



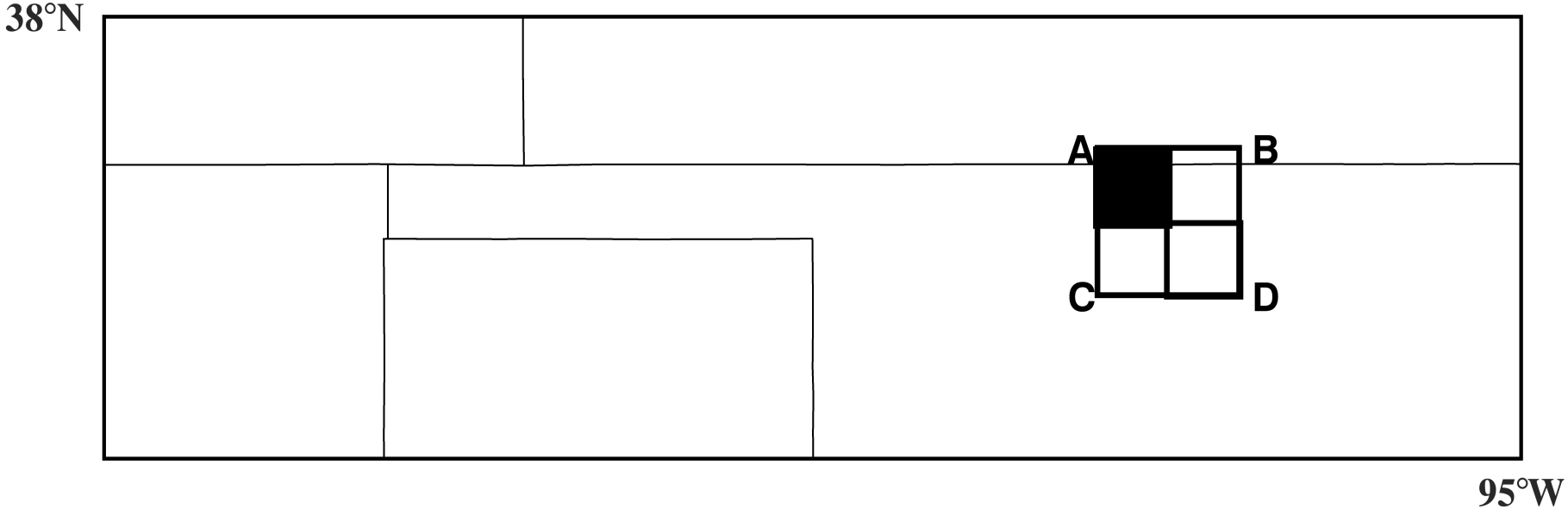
- Both ARM and CERES follow the same seasonal variation, decrease from spring to summer and increase from summer to fall.
- CERES CFs are consistently lower than ARM ones (~ -7%)

Vertical Distribution of CFs from ARM and CERES

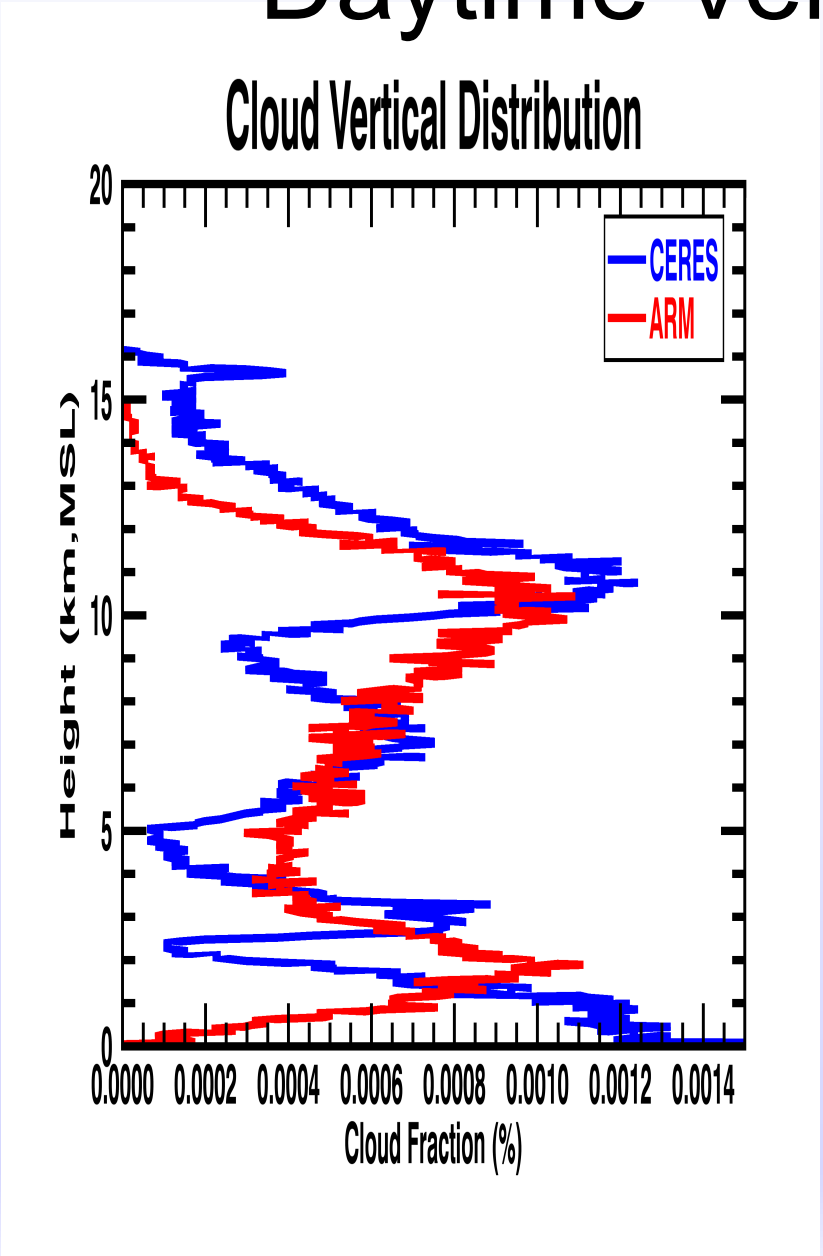


- This is not the correct vertical distribution.
- The results for CERES are much smaller than expected for high cloud based on previous bar plot.
- This inconsistency is a result of plotting total CERES cloud top height which is the average cloud top height detected in each layer (low,mid-low,mid-high,and high).

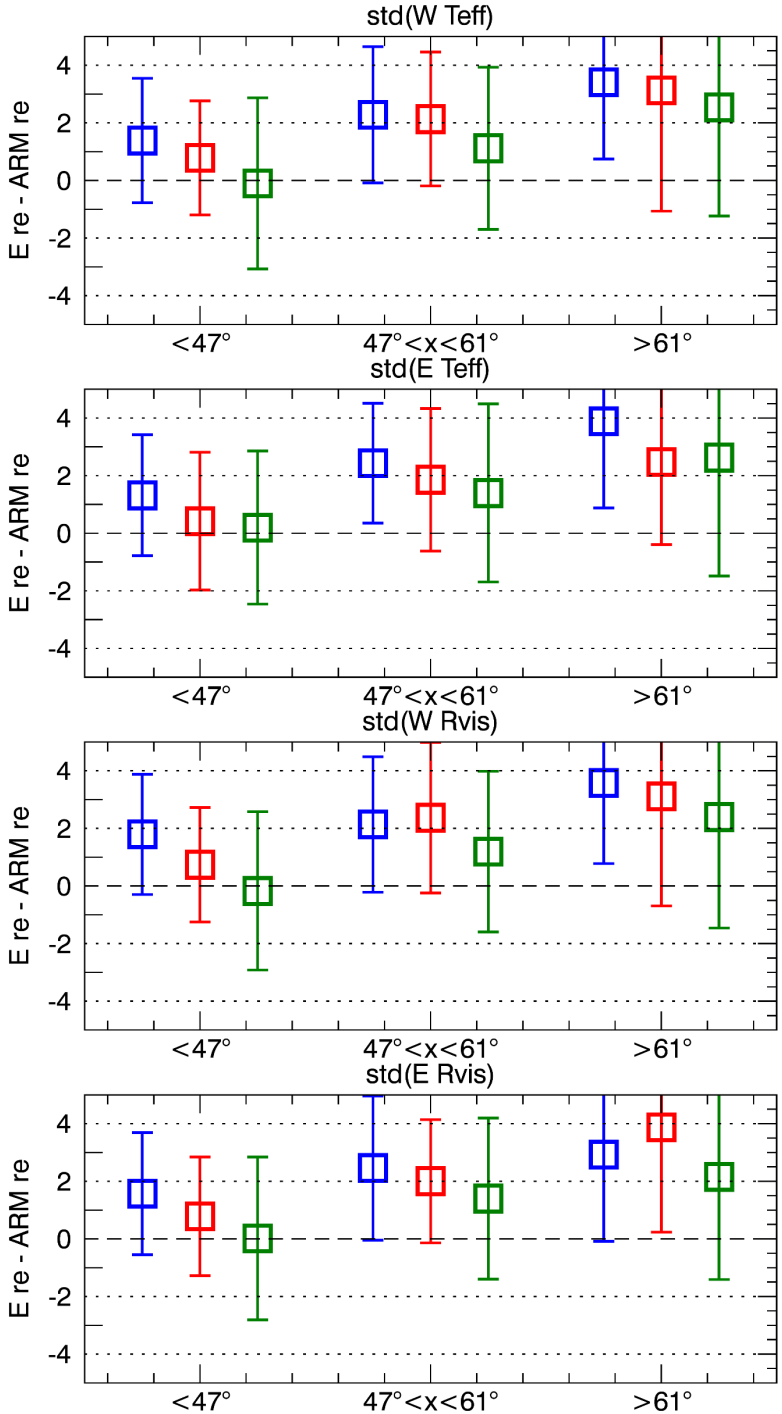
Area of Focus Over SGP

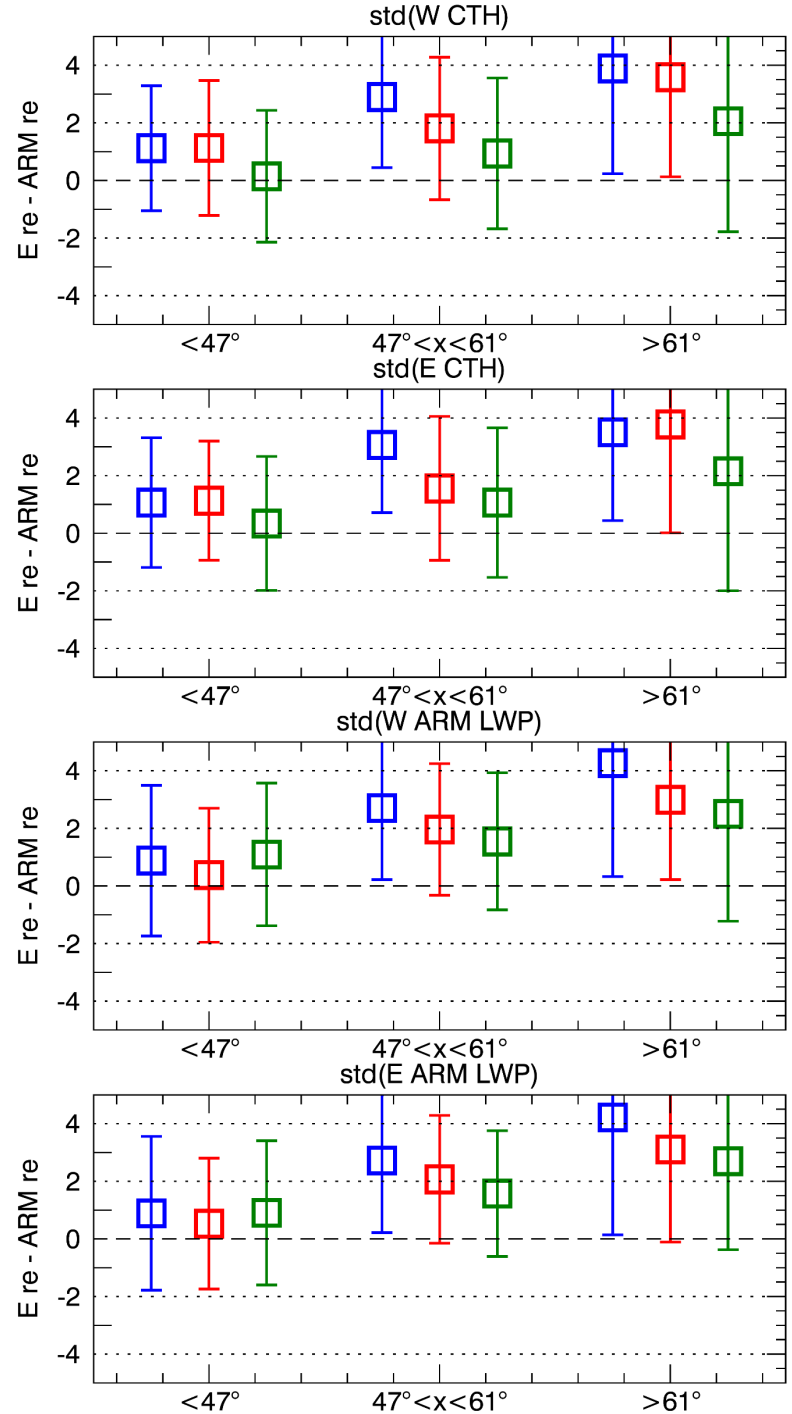


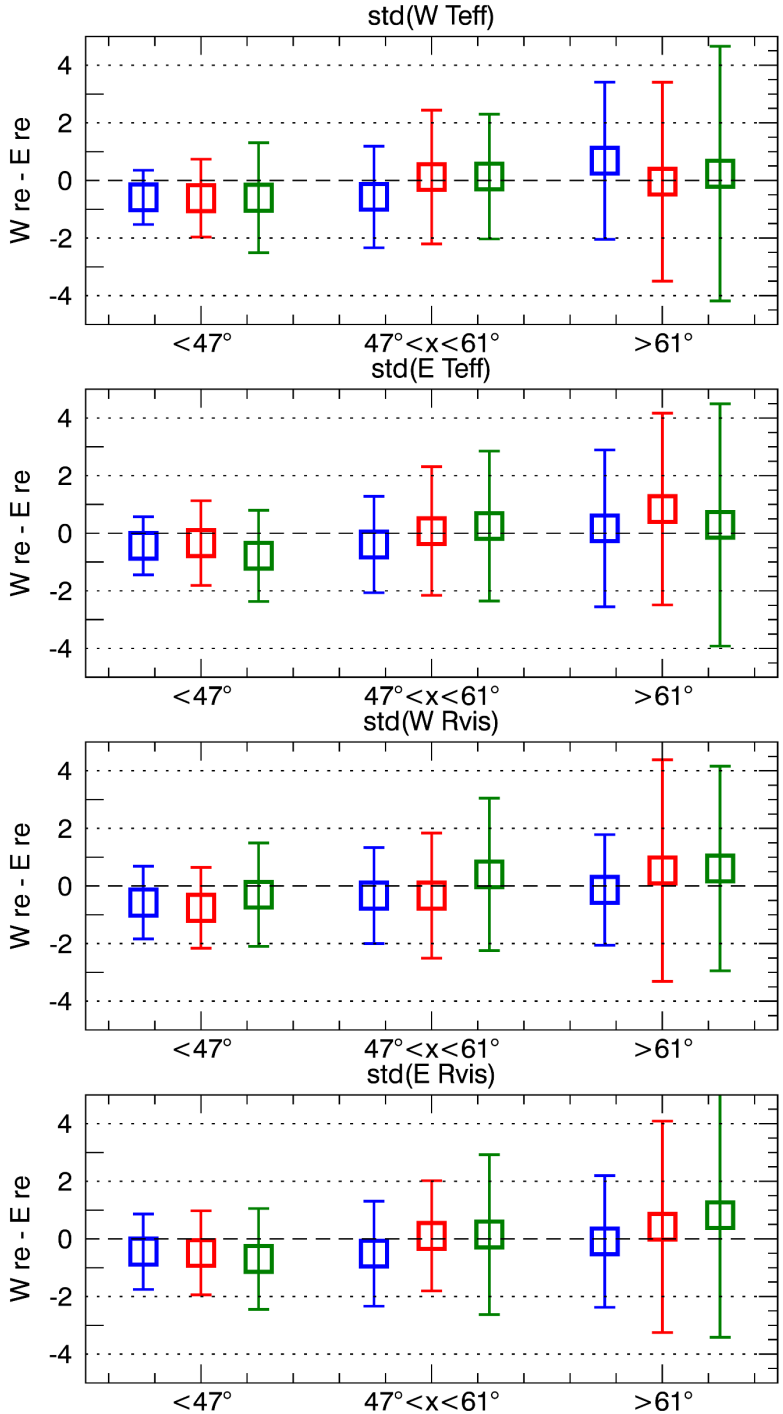
Daytime Vertical Distribution

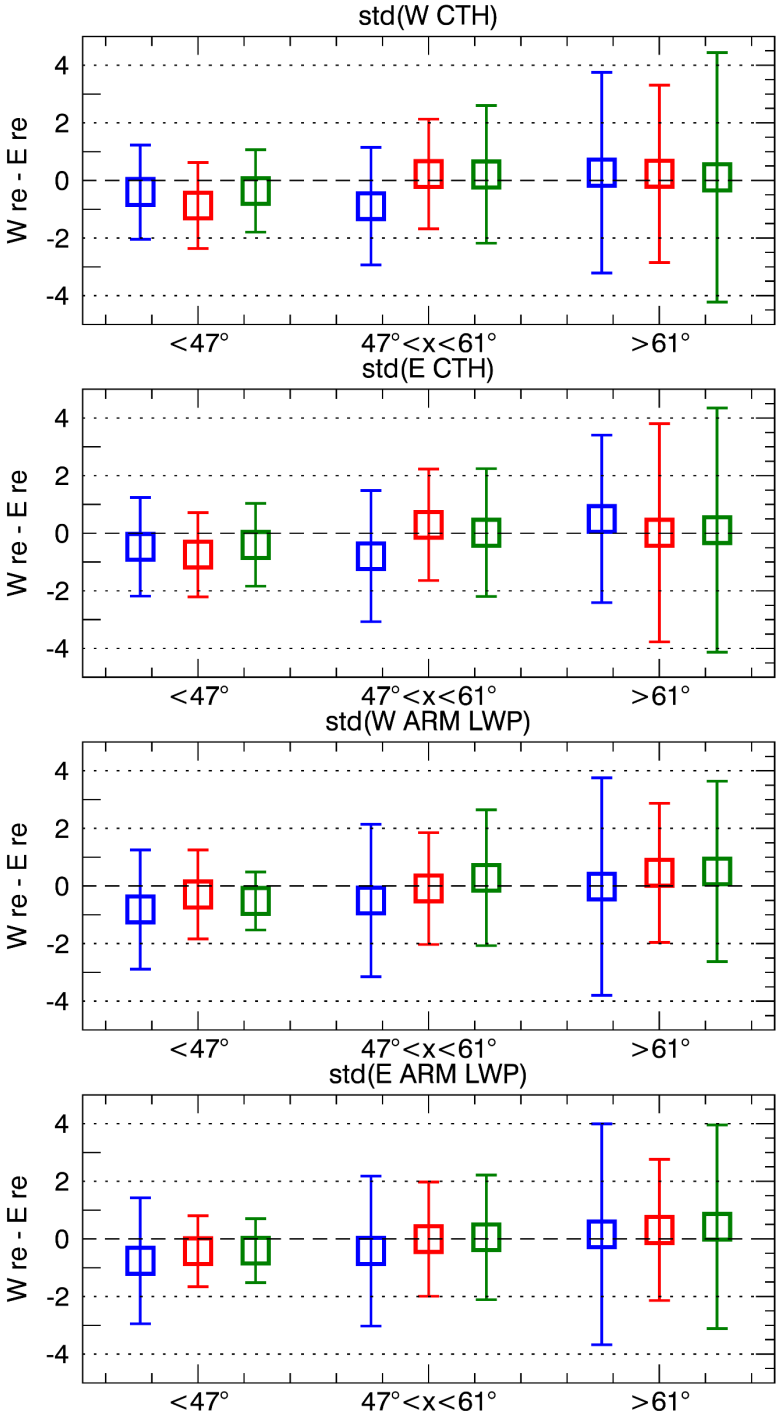


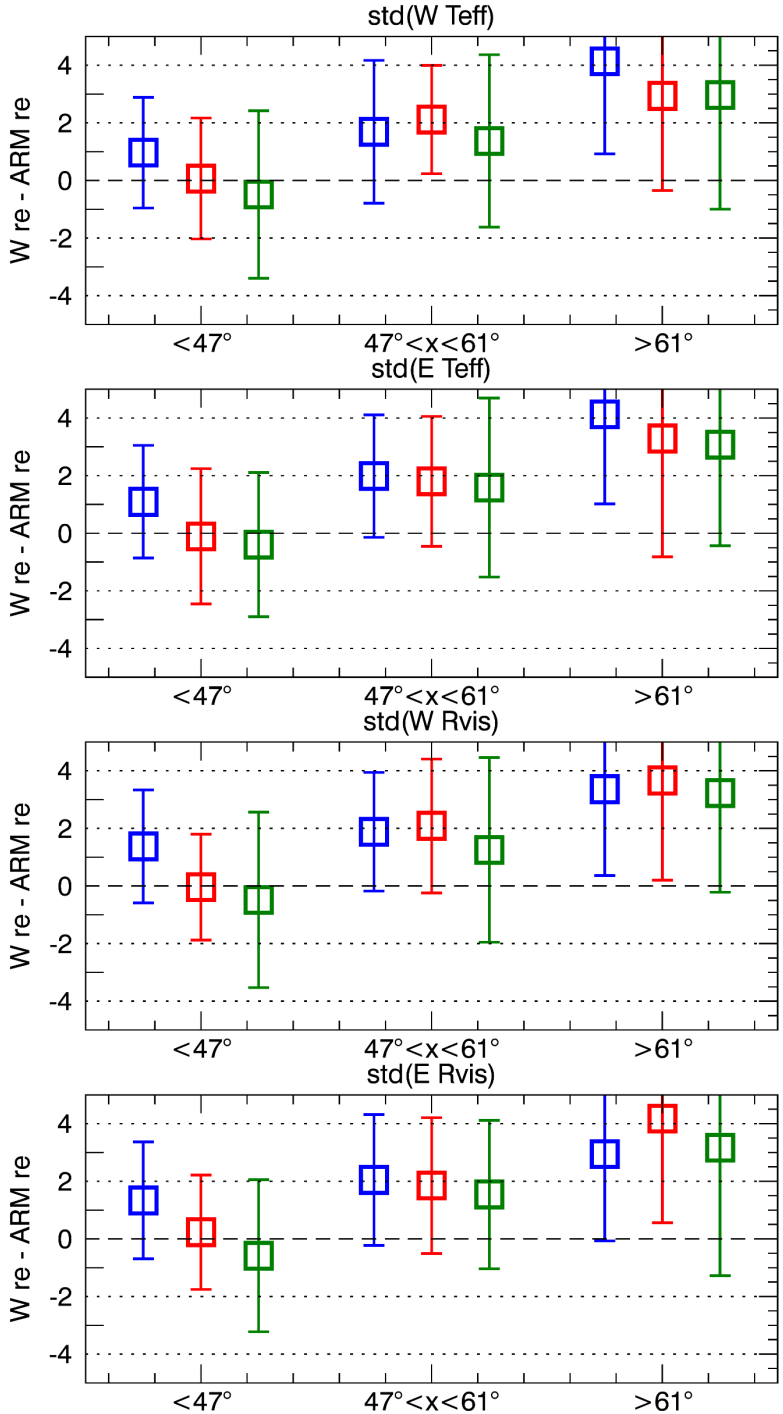
- Using maximum cloud top, ARM and CERES have good agreement with their high cloud top height.
  - The agreement is not as good for middle and low clouds because CERES is unable to interpolate them correctly.
- The ground level CERES low cloud heights only occur during the day.

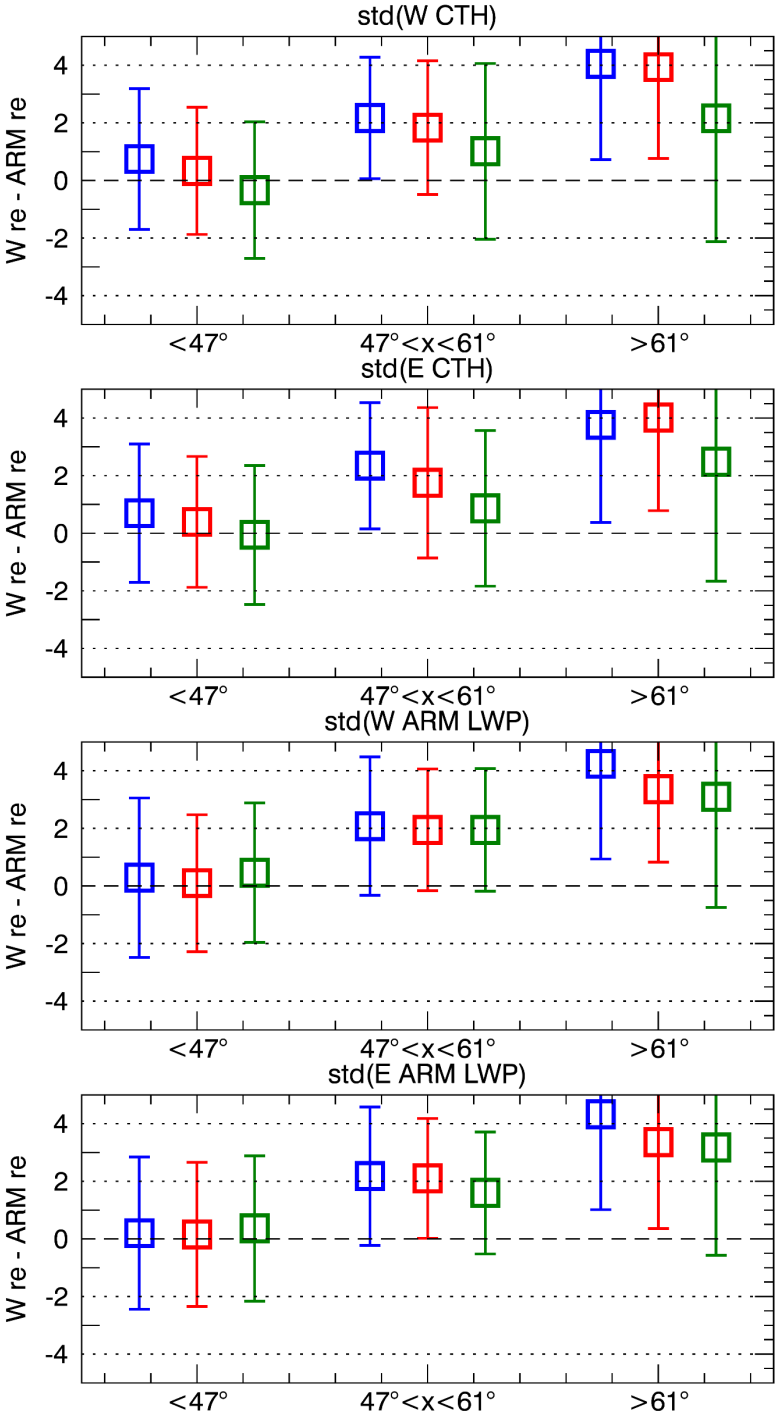

std(W Teff)
std(E Teff)
std(W Rvis)
std(E Rvis)
E re - ARM re
4
2
0
-2
-4
<47°
47°<x<61°
>61°

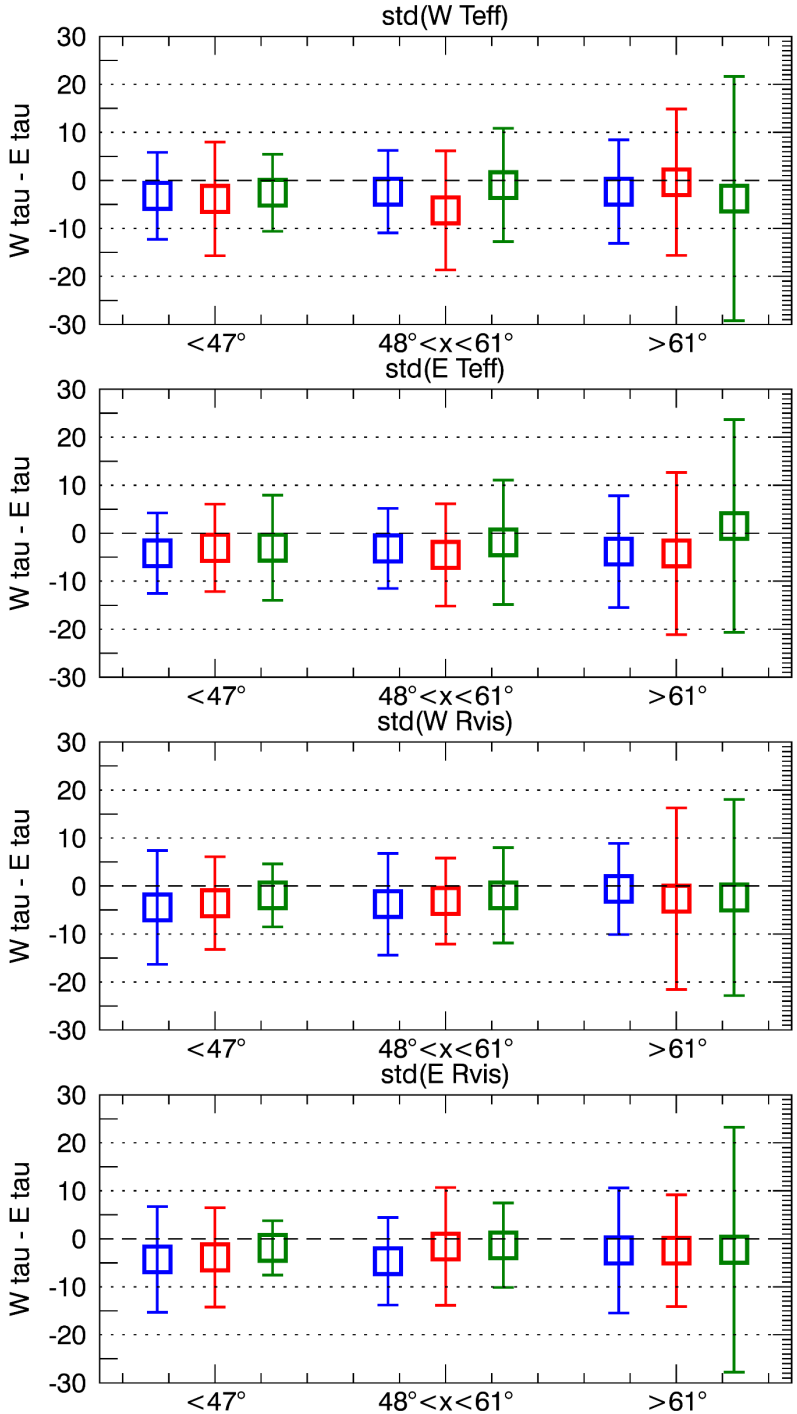

std(W CTH)
std(E CTH)
std(W ARM LWP)
std(E ARM LWP)
E re - ARM re
4
2
0
-2
-4
<47°
47°<x<61°
>61°

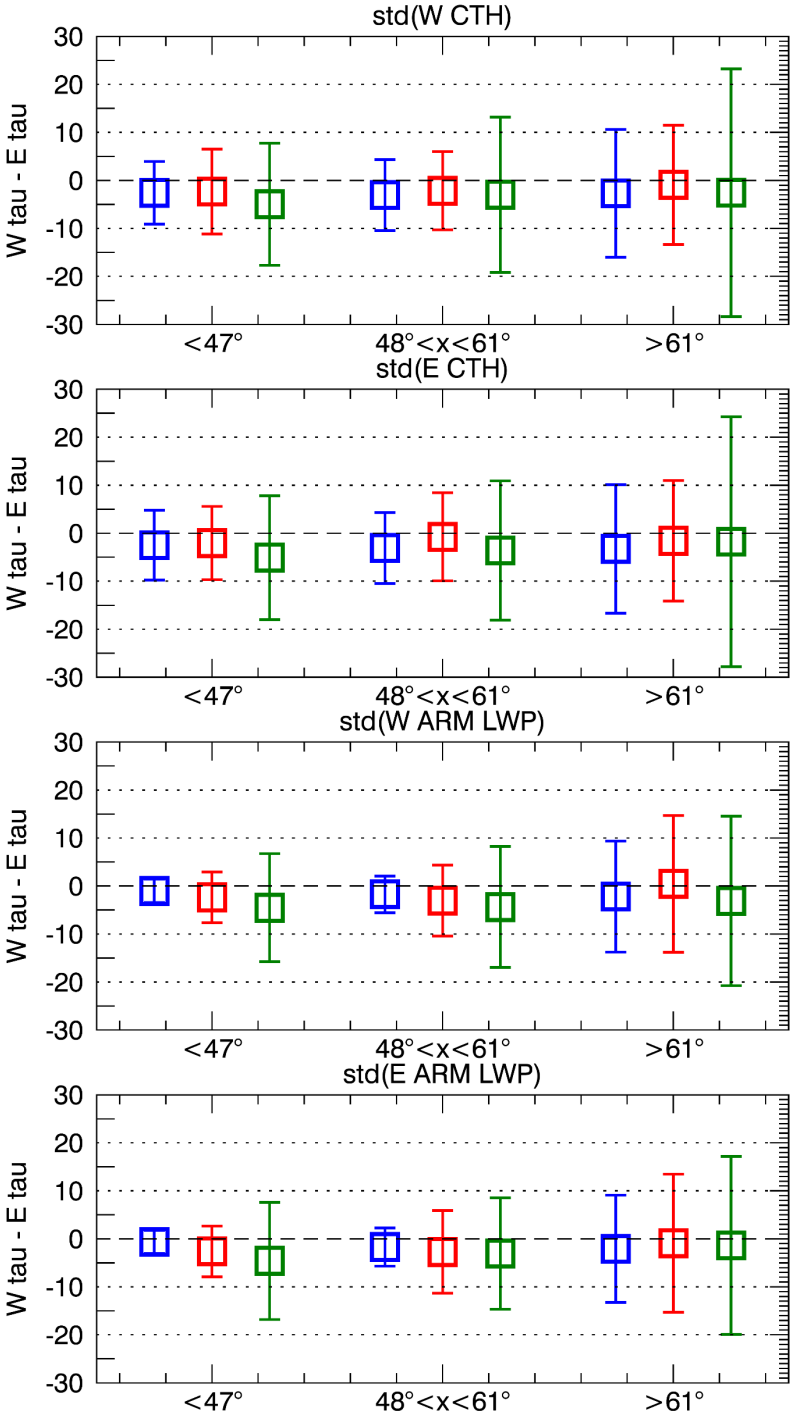

std(W Teff)
std(E Teff)
std(W Rvis)
std(E Rvis)
W re - E re
4
2
0
-2
-4
<47°
47°<x<61°
>61°


std(W CTH)
std(E CTH)
std(W ARM LWP)
std(E ARM LWP)
W re - E re
4
2
0
-2
-4
<47°
47°<x<61°
>61°


std(W Teff)
std(E Teff)
std(W Rvis)
std(E Rvis)
W re - ARM re
4
2
0
-2
-4
<47°
47°<x<61°
>61°


std(W CTH)
std(E CTH)
std(W ARM LWP)
std(E ARM LWP)
W re - ARM re
4
2
0
-2
-4
<47°
47°<x<61°
>61°


std(W Teff)
std(E Teff)
std(W Rvis)
std(E Rvis)
W tau - E tau
30
20
10
0
-10
-20
-30
<47°
48°<x<61°
>61°


std(W CTH)
std(E CTH)
std(W ARM LWP)
std(E ARM LWP)
W tau - E tau
30
20
10
0
-10
-20
-30
<47°
48°<x<61°
>61°