Evaluate Offline CLM4 Skin Temperature Simulation Using ARM Oklahoma Observations

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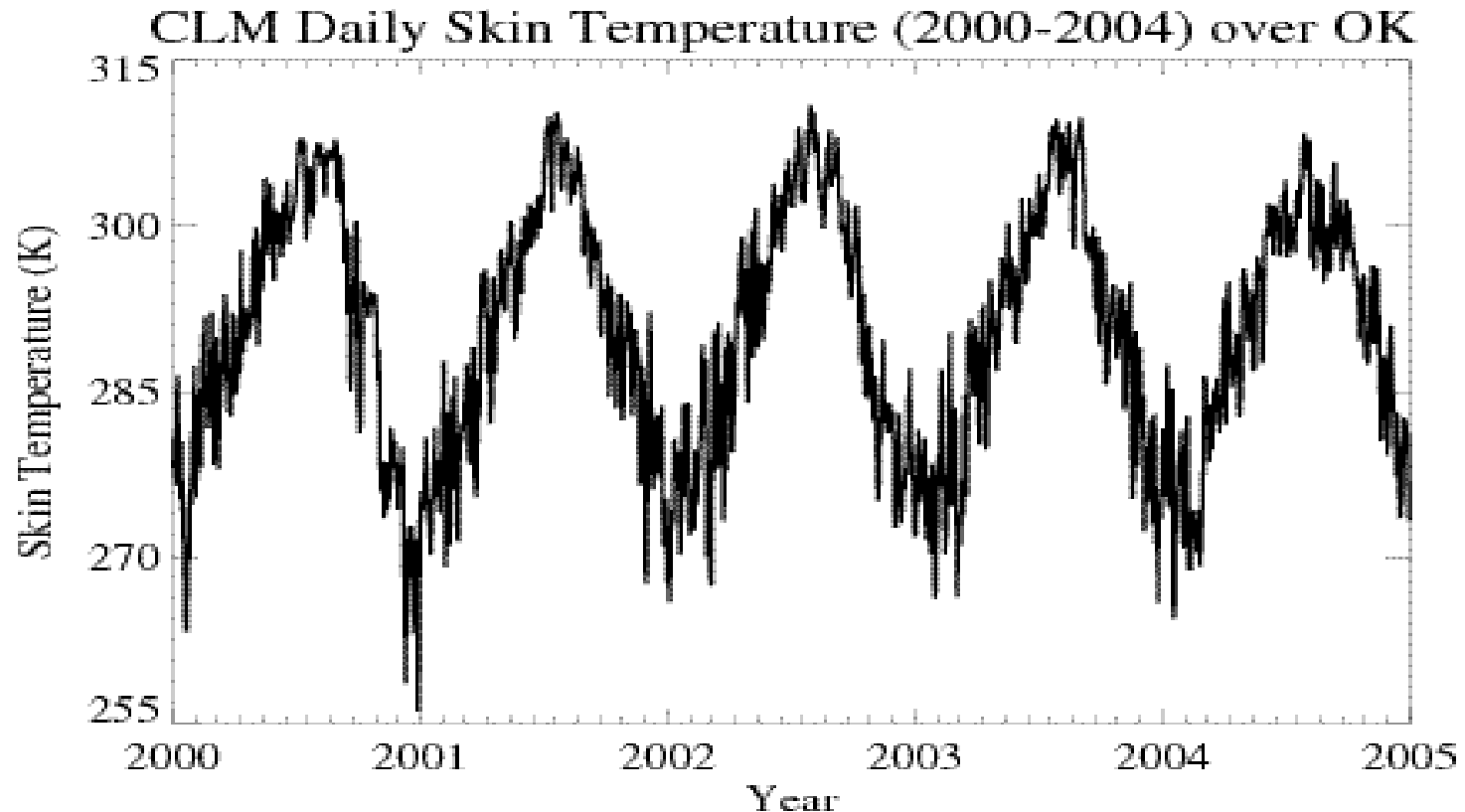
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University of Texas

Collaboration
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LLNL (ARM)

Rational: CLM0-CLM3 consistently overestimated land skin temperature. What is the performance of CLM4?

Offline CLM4 with satellite phenology (CLM4SP, daily, 0.9°x1.25°)

CLM Daily Skin Temperature (2000-2004) over OK

What is ARM?

The DOE largest field program for climate changes

- **Created in 1989 with ~$20M/yr budget**

- **Established 6 permanent research and mobile facility (AMF) sites in various climate regimes around the world**

- **CMBE - Climate Model Best Estimate Data Set collecting hourly data on clouds , aerosol, radiation, surface meteorology variables**

ARM Climate Research Facility (ACRF) Sites
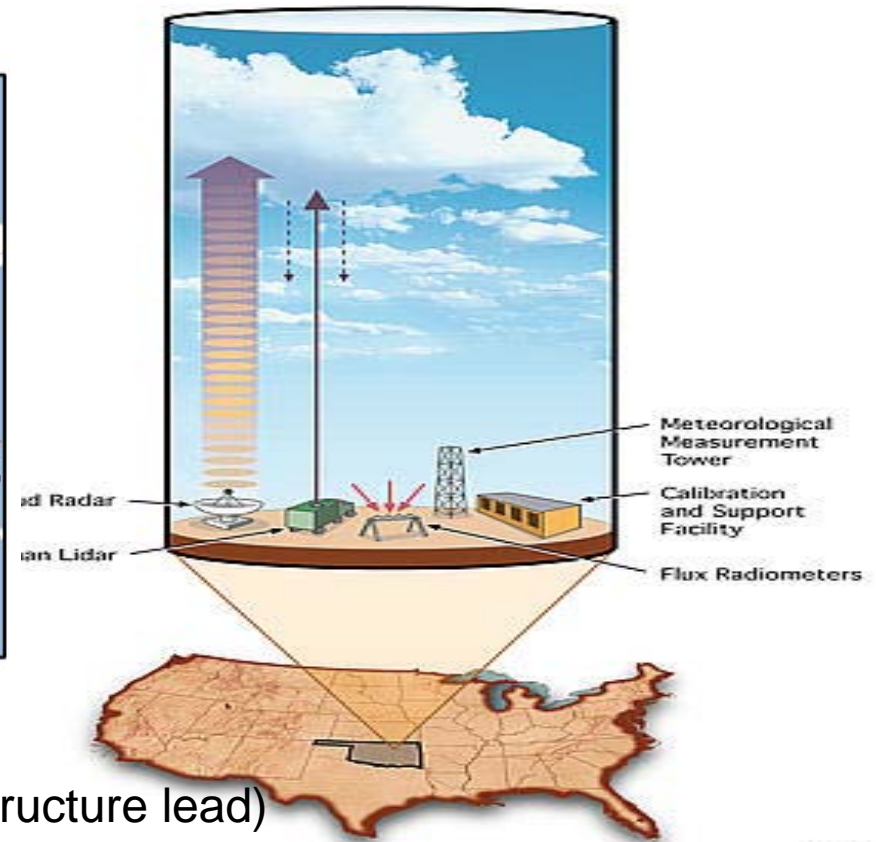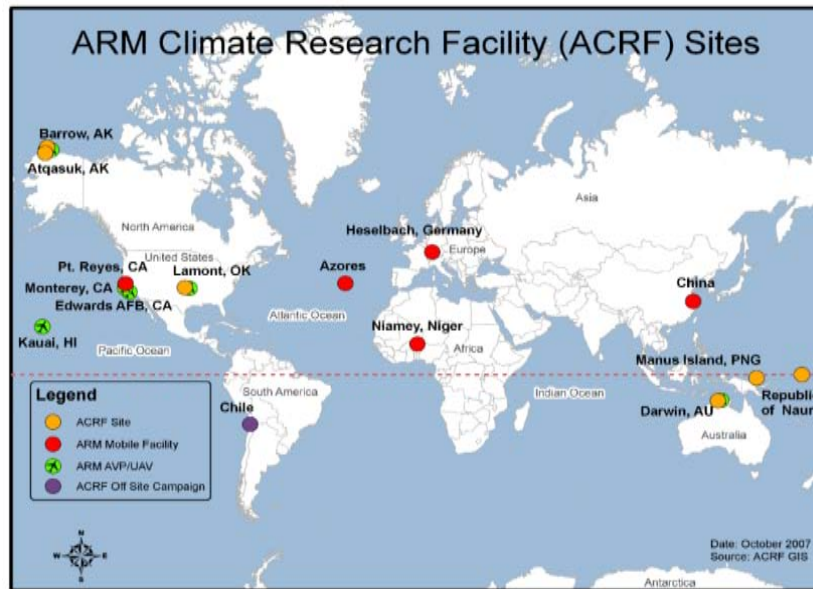
(Courtesy: Xie, LLNL, ARM dataset infrastructure lead)

Direct Sd
Diffuse Sd
Total downward shortwave (0.2 μm to 5 μm) hemispheric irradiance:
uplooking Solar Infrared Radiation Station (SIRS) or Baseline Solar
Radiation Network (BSRN) pyranometers
Downward LW
Upward LW
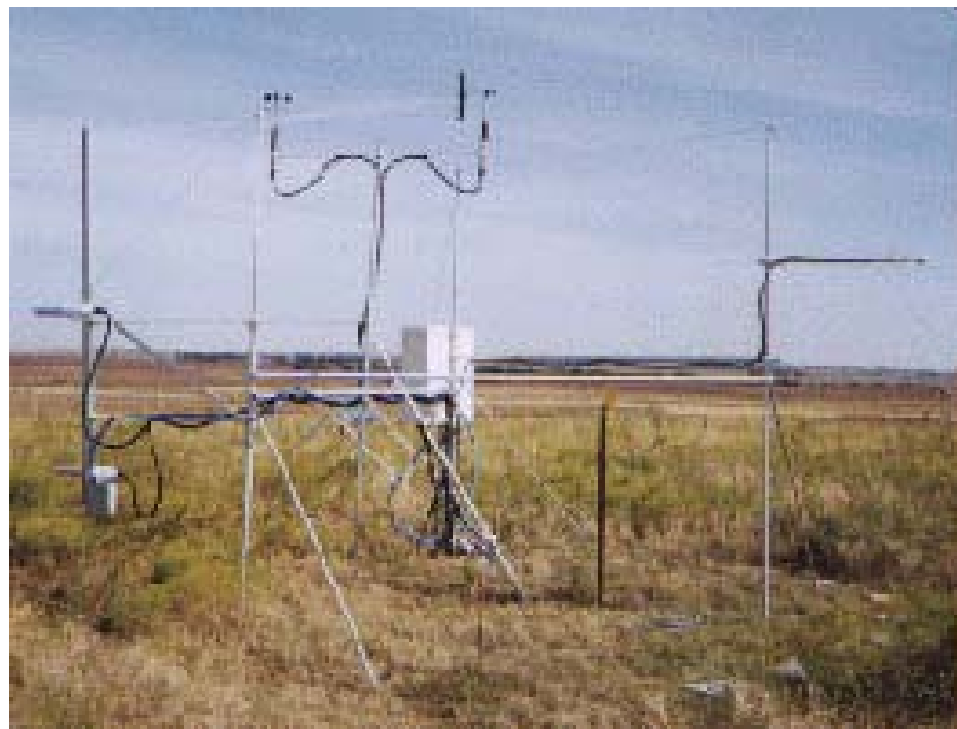SH and LH: **Instrument : Energy Balance Bowen Ratio Station (EBBR)**

Pressure,
RH
2m air temperature

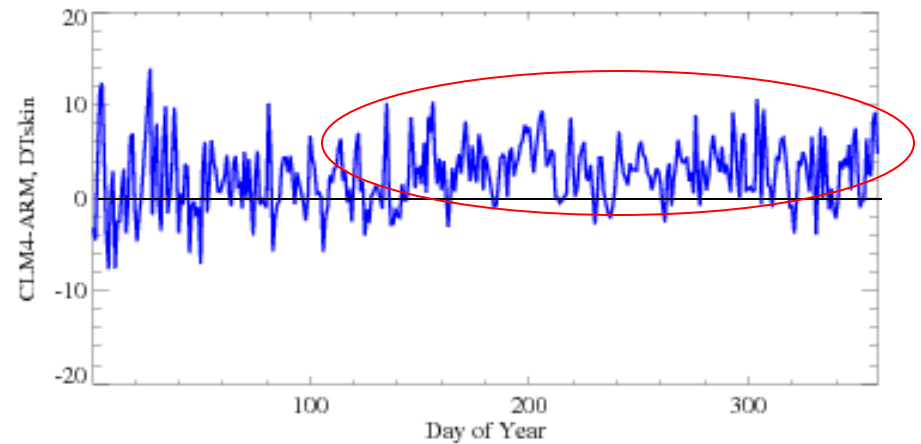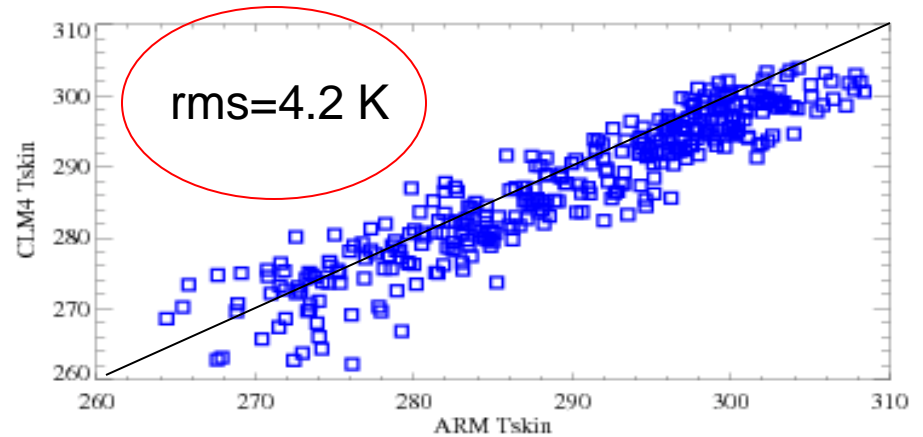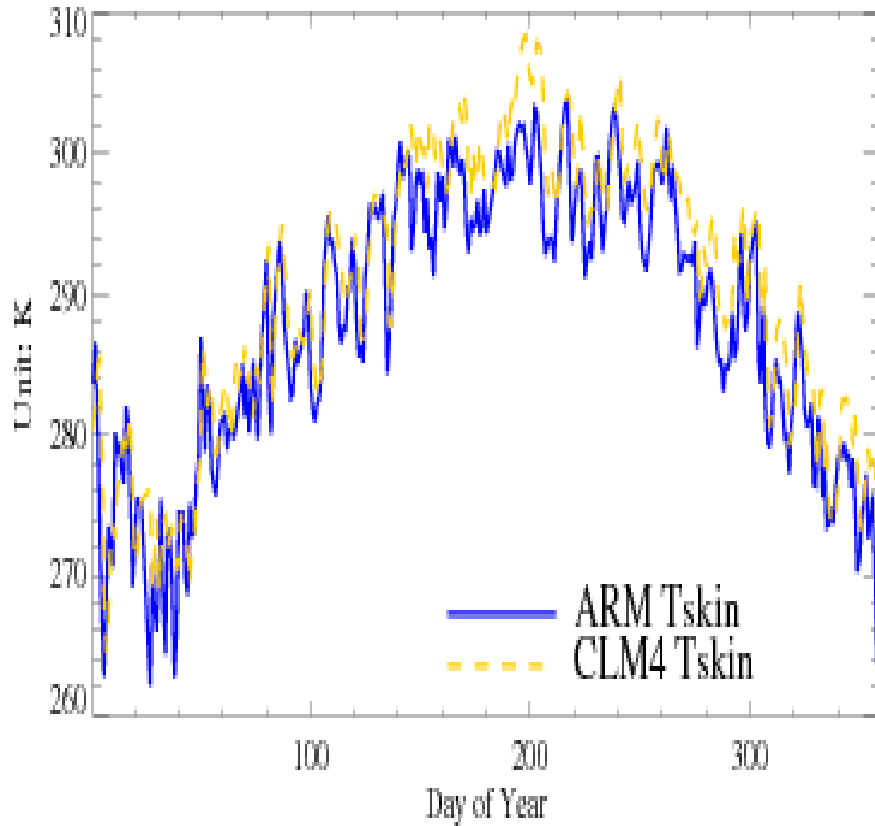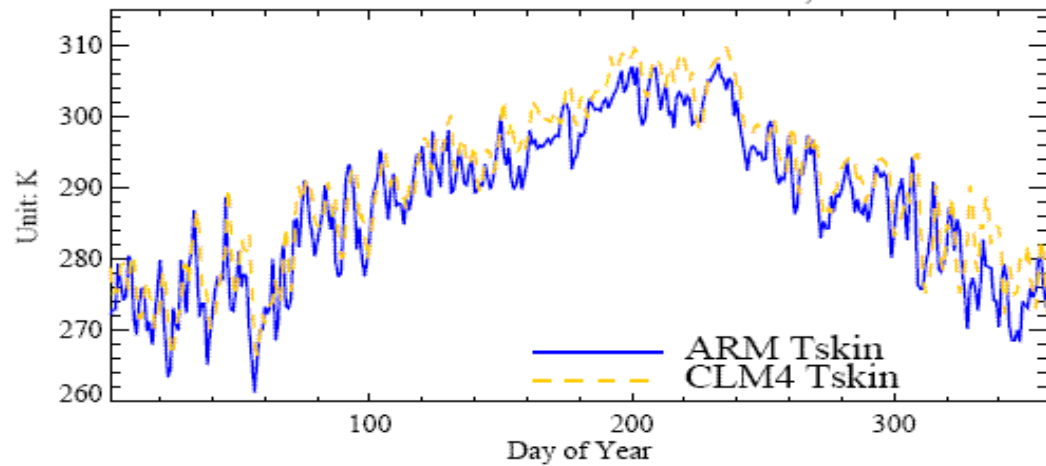Clouds optical properties
aerosol
Rainfall

http://www.arm.gov/instruments/ebbr

Year 2004 Daily T$_{skin}$ CLM4 vs ARM OK

Offline CLM4 vs. ARM Lamont OK, 2004

rms=4.2 K

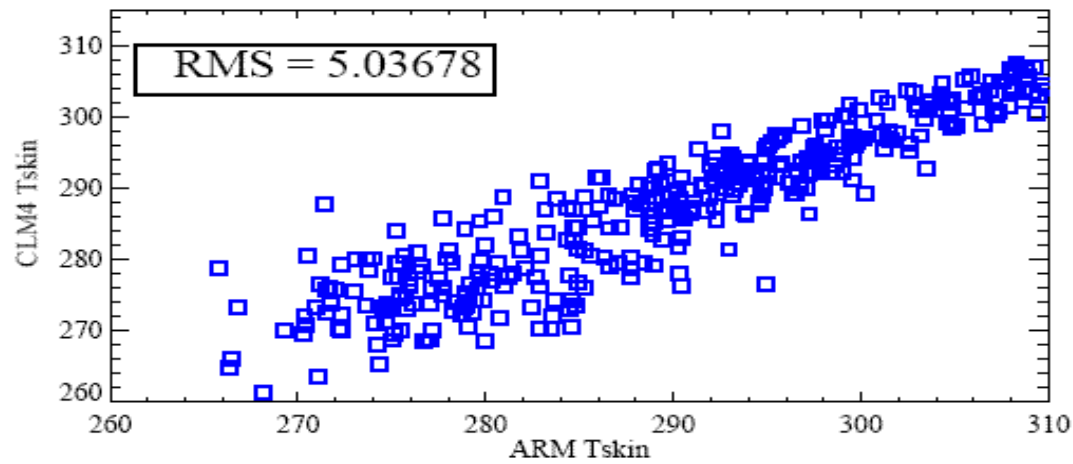## •Offline CLM4 overestimates T$_{skin}$
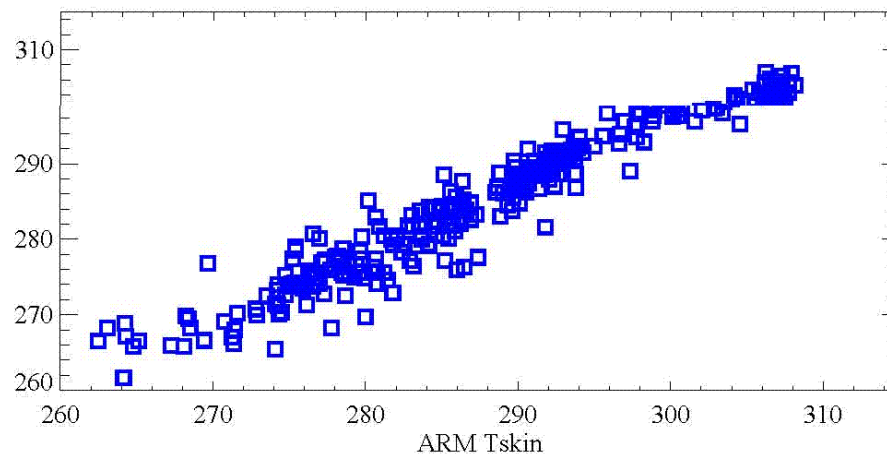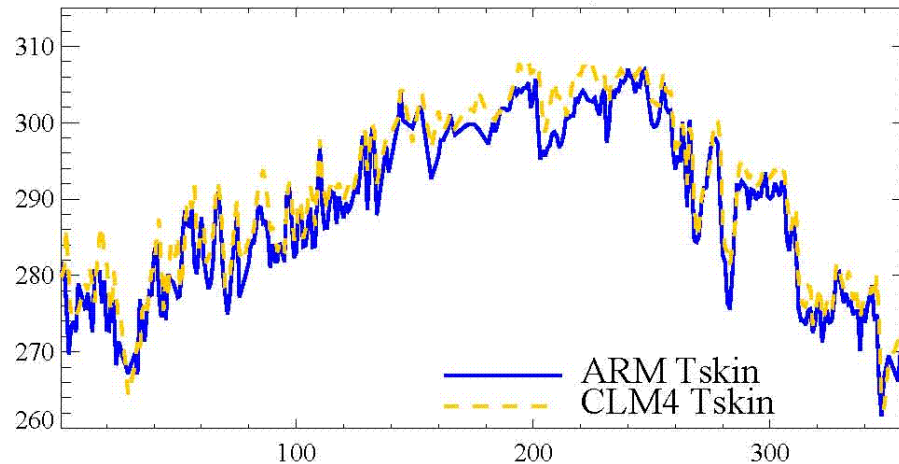
Offline CLM4 vs. ARM Lamont OK, 2003
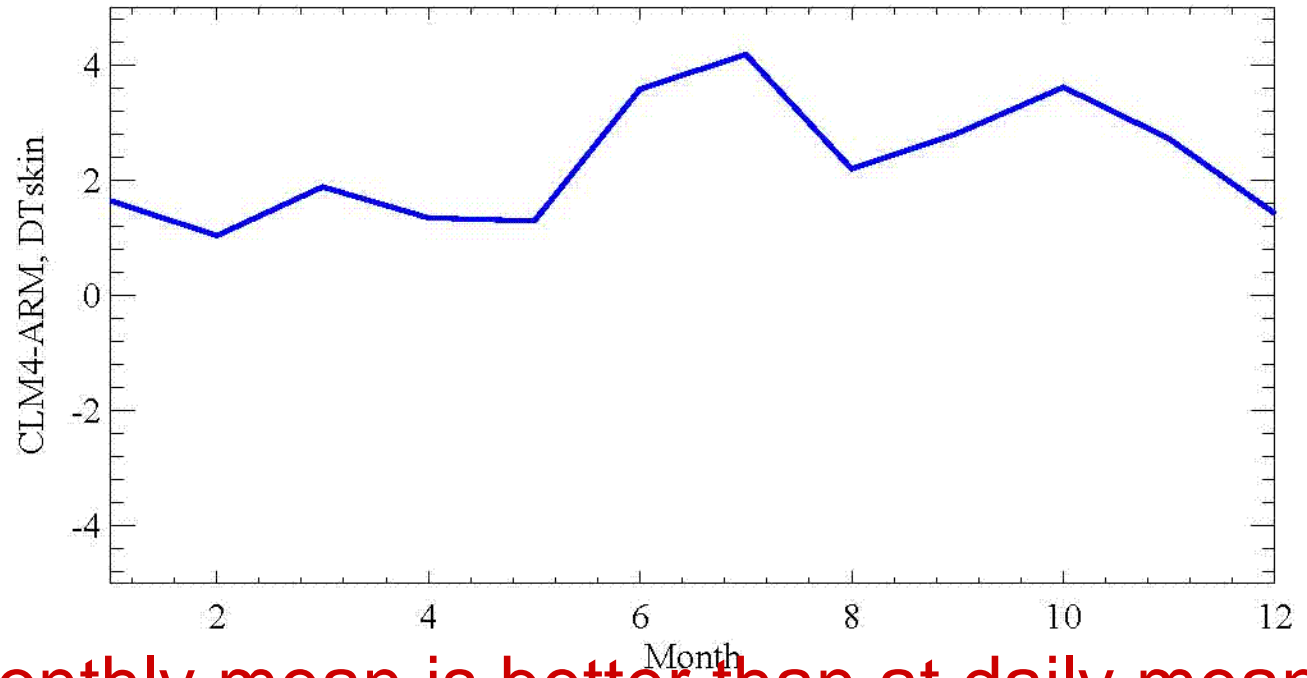
Year 2003
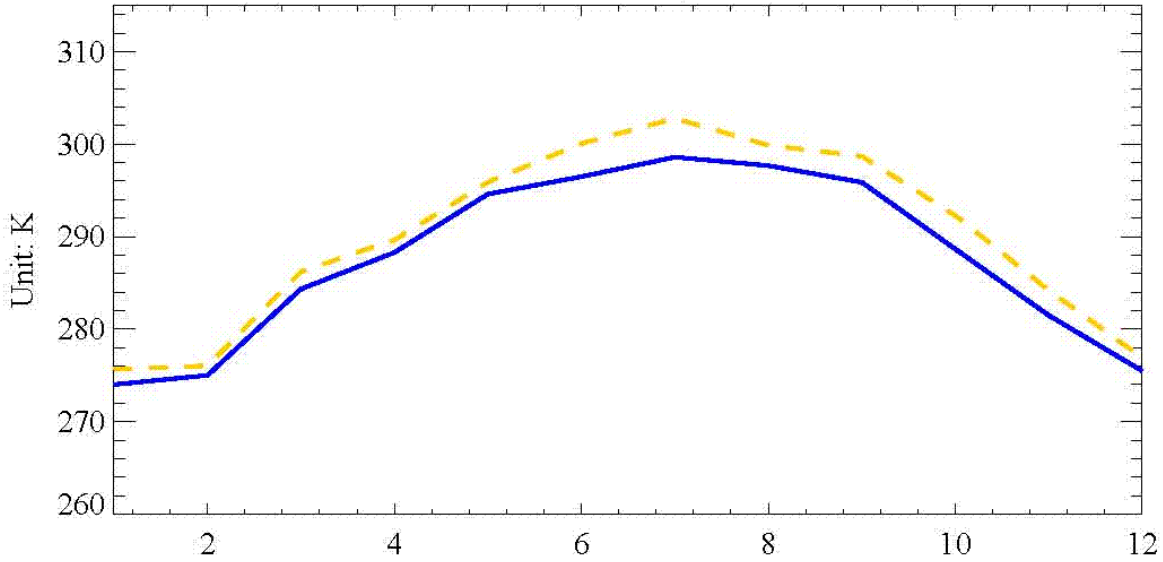RMS=5.03K

RMS = 5.03678
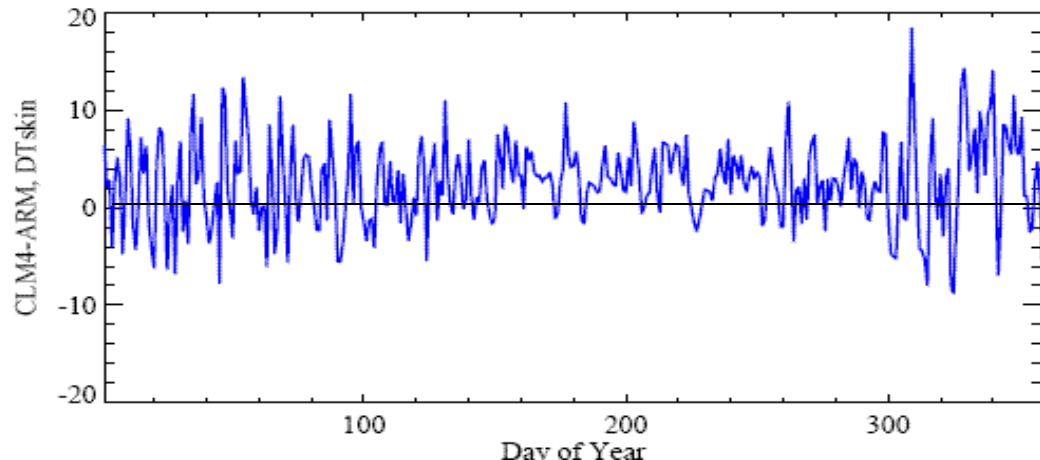
RMS Tskin = 3.24 K, CLM4 vs. ARM Ok Daily average for year 2000

Offline CLM4 vs. ARM Lamont OK, 2000. ERR = 3.24K

Offline CLM4 vs. ARM Lamont OK, 2004 Monthly. ERR = 2.53K

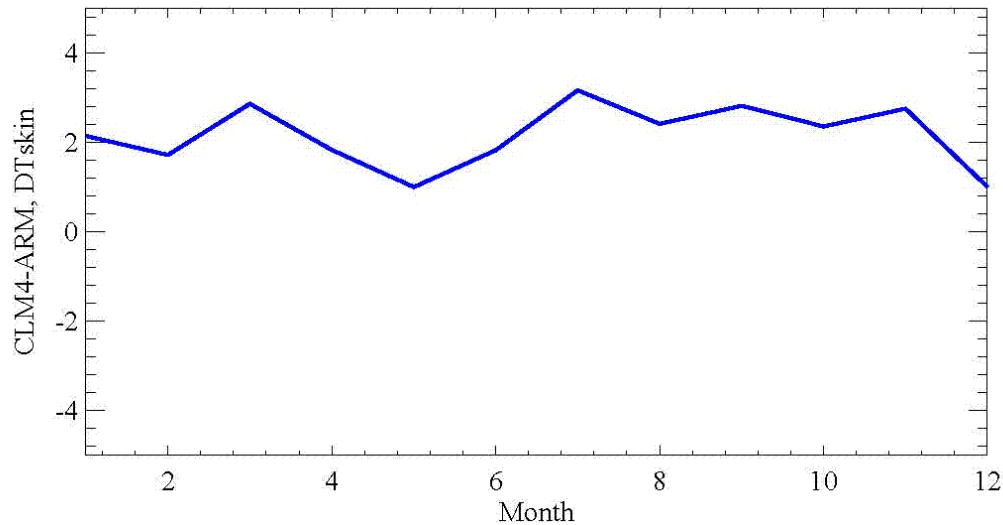Monthly mean for 2004

RMS=2.53 K

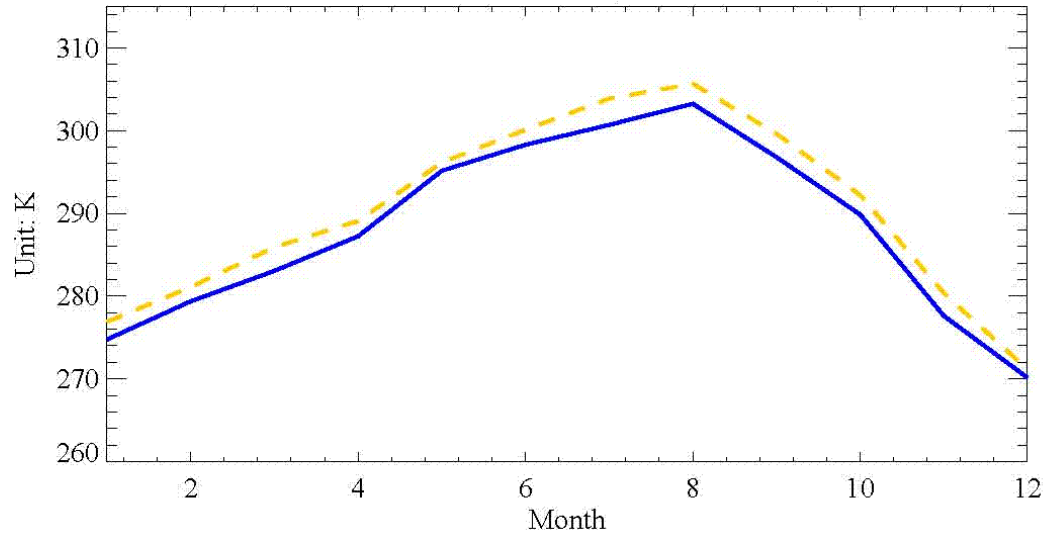Accuracy at monthly mean is better than at daily mean.

Monthly mean RMS=2.27 K

Year 2000

Offline CLM4 vs. ARM Lamont OK, 2000 Monthly. ERR = 2.27K

What are the primary causes for this warm bias?

CAM/CESM

Offline
atmosphere forcing

CLM

δT_{skin}

Sd
LWd
RH
Wind
Rainfall
T2m

Albedo
LWup
Vegeation emissivity
SH
LH
G
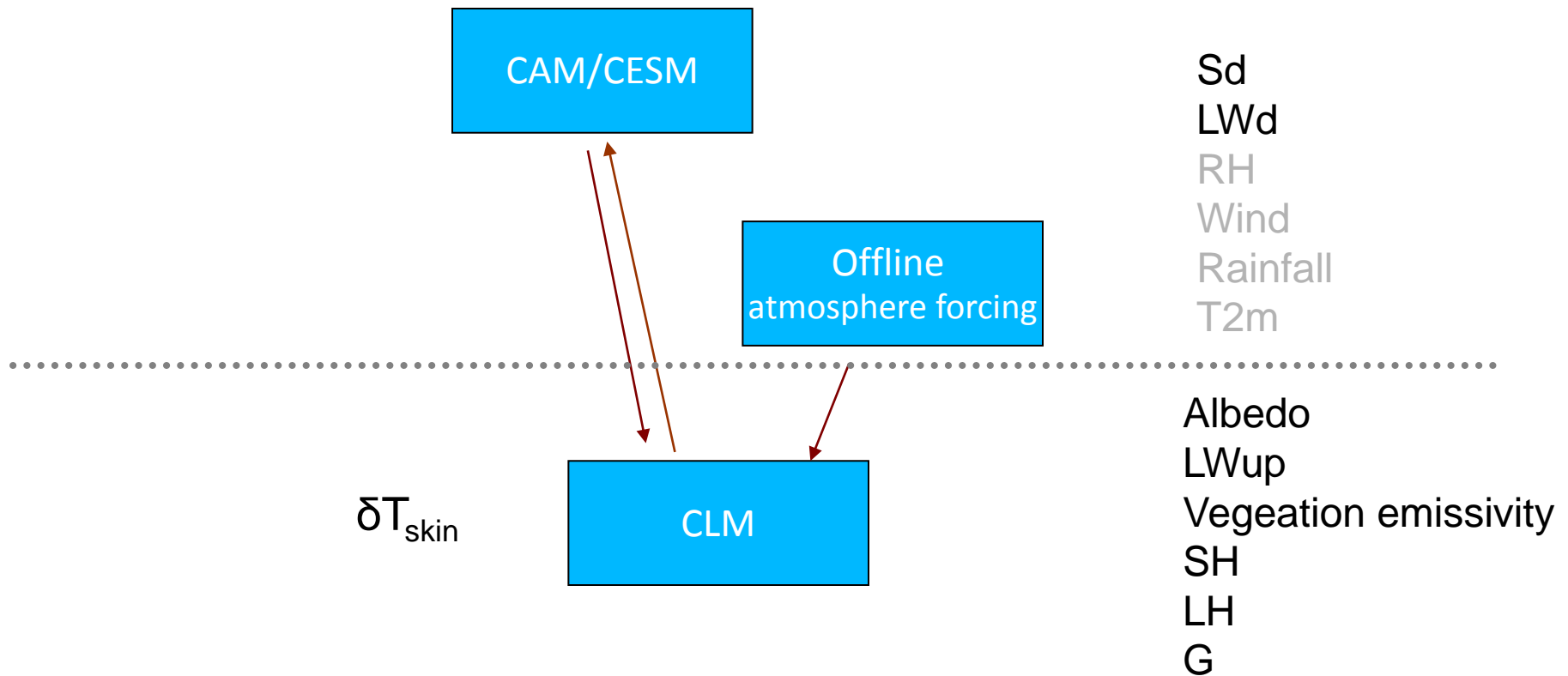
Year 2004 Daily Averaged
T_{skin} vs. Surface Insolation (S_d)
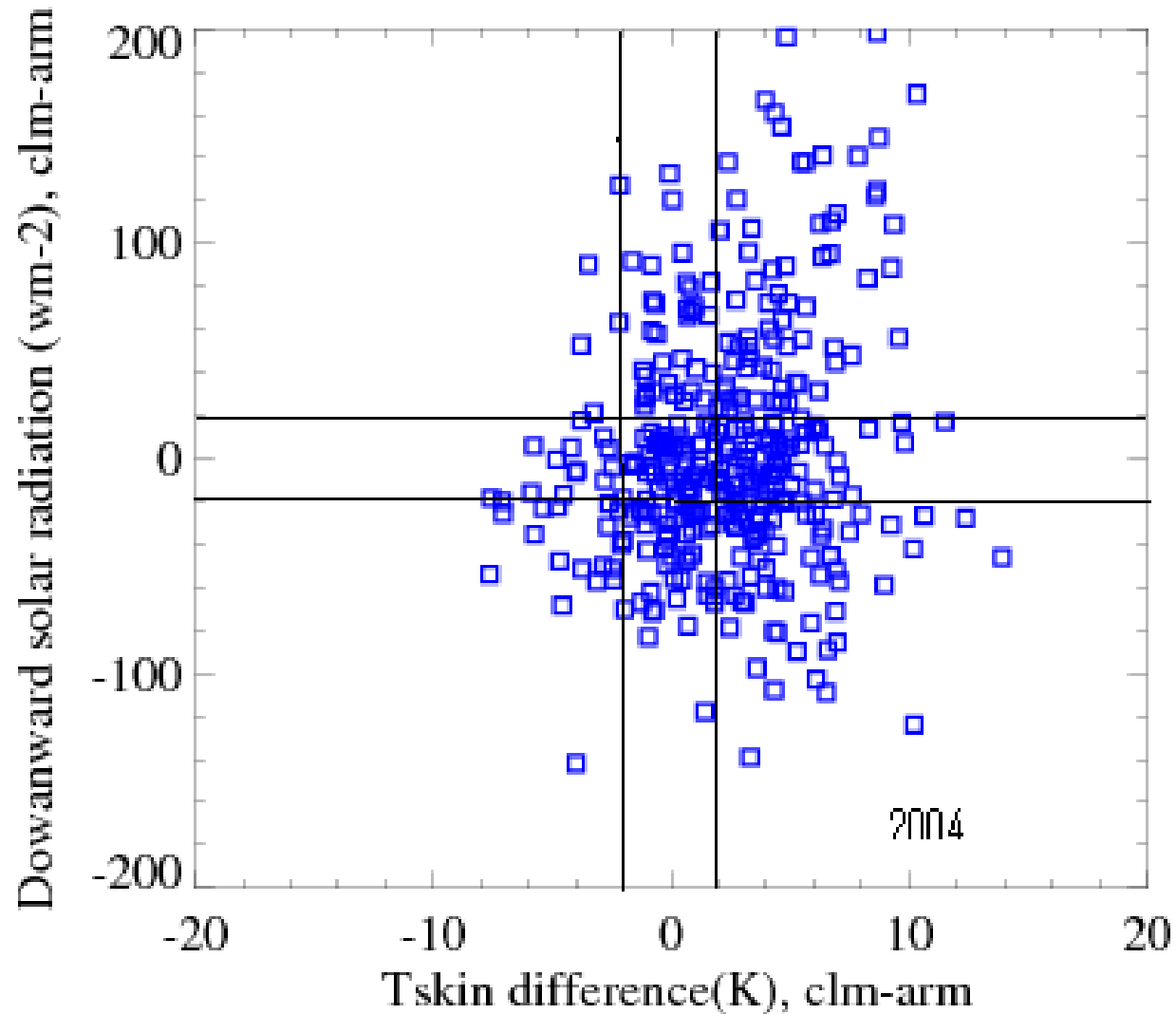
Remove large S_d different days – RMS=3.8 K

2004, surafec insolation close days (219 day), RMS=3.8K
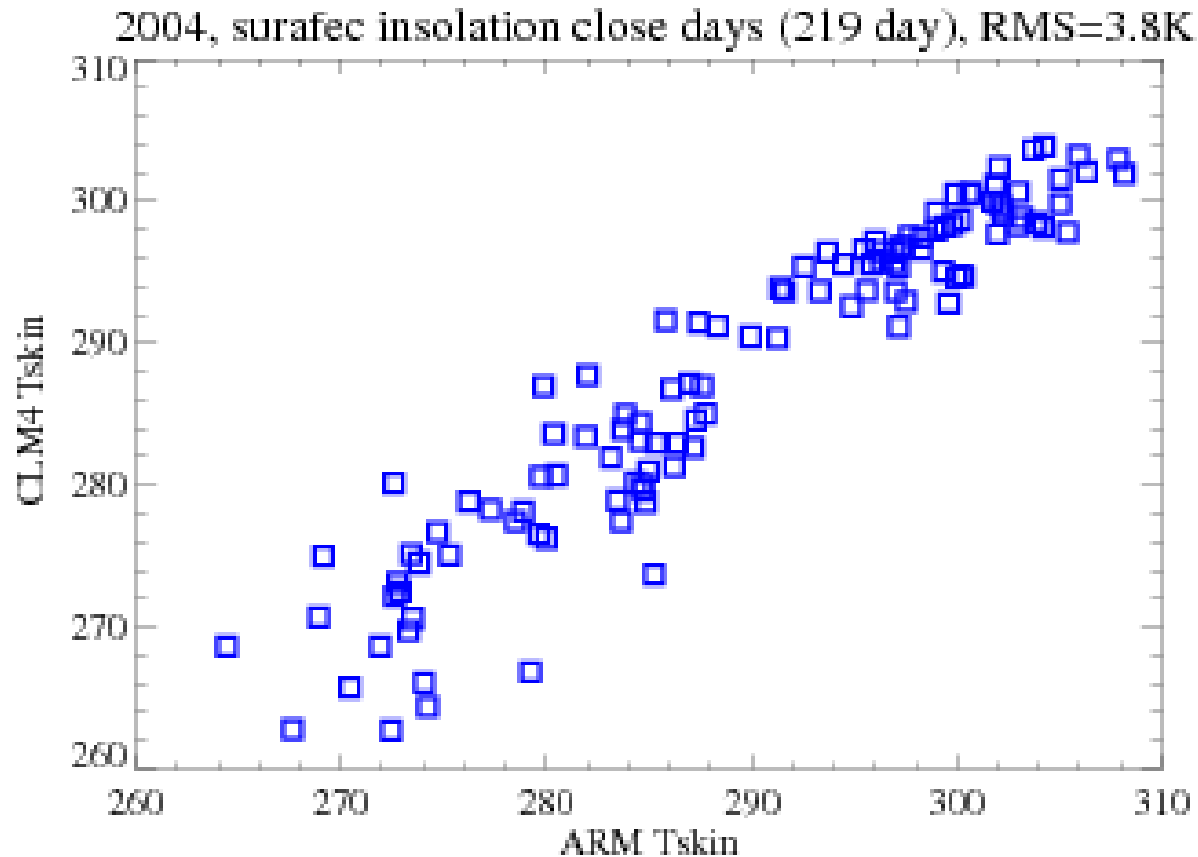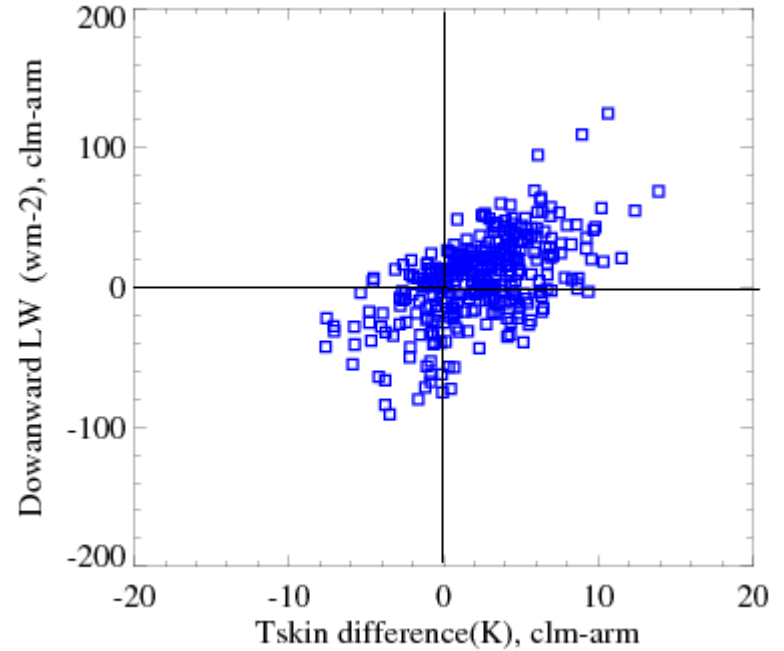
Tskin vs. Downward LW

LWdown CLM vs ARM
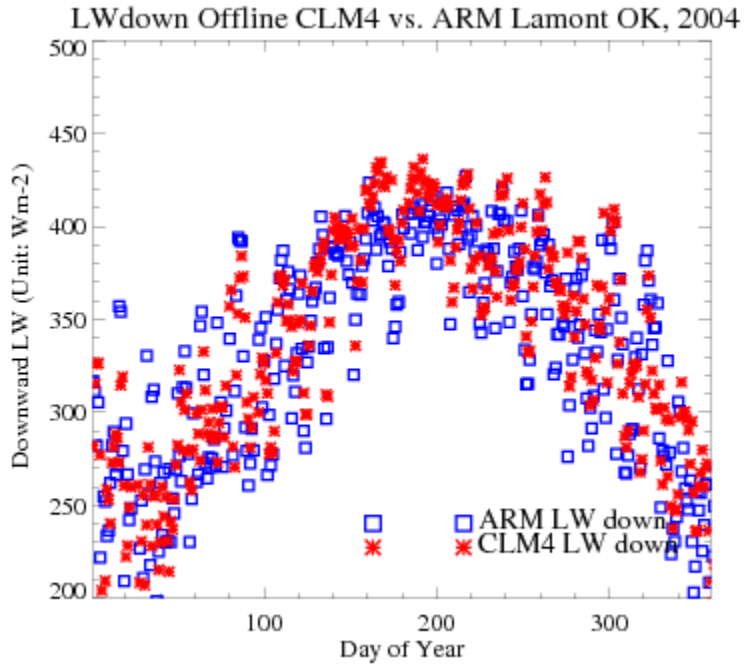
Tskin difference vs. LWdown difference

LWdown Offline CLM4 vs. ARM Lamont OK, 2004

□ ARM LW down
* CLM4 LW down

Remove large LDdown difference days RMS T$_{skin}$ is reduced 3.46 K
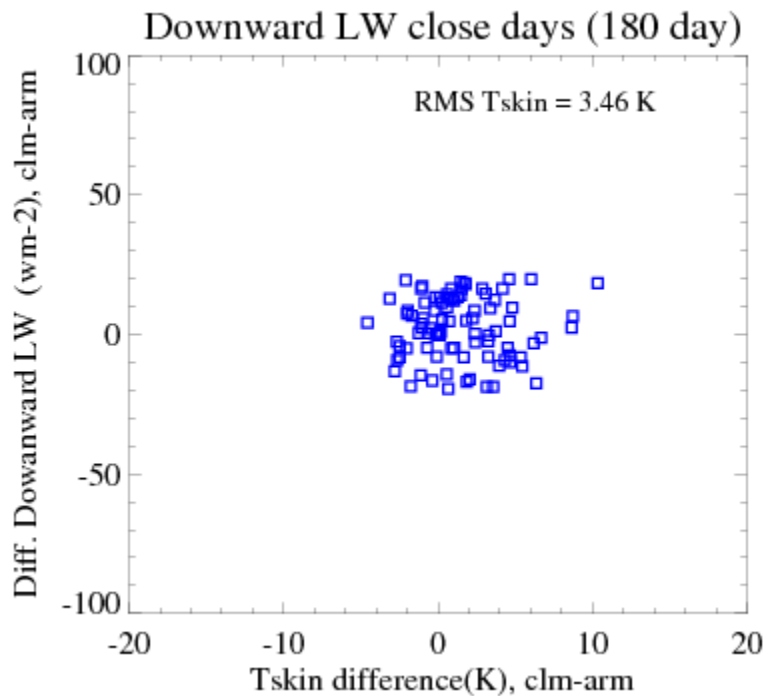
Remove Sd and LWdown large dfference days – rms T$_{skin}$ is redced to 3.06 K

Downward LW close days (180 day)

RMS Tskin = 3.46 K

Diff. Dowanward LW (wm-2), clm-arm

Tskin difference(K), clm-arm

Downward LW, Sd close days (96 day)

RMS Tskin = 3.06 K

Diff. Dowanward LW (wm-2), clm-arm

Tskin difference(K), clm-arm

What are the primary causes for this warm bias?

CAM/CESM

$\delta T_{skin\_}s_d = 0.4$ K
$\delta T_{skin\_}LW = 0.8$ K

Offline atmosphere forcing

S_d
LWd
RH
Wind
Rainfall
T2m

$\delta T_{skin} = 4.2$ K

CLM
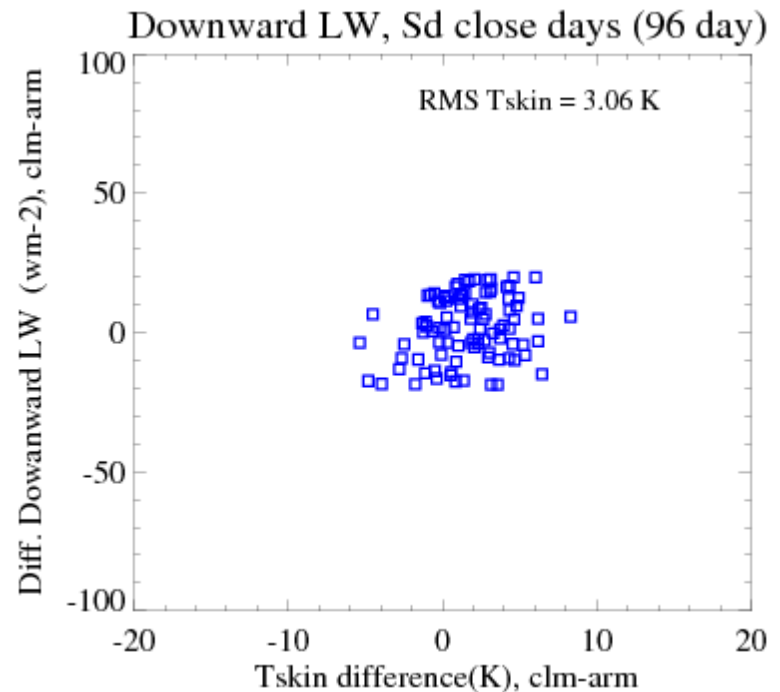
Albedo
LWup
Vegeation emissivity
SH
LH
G
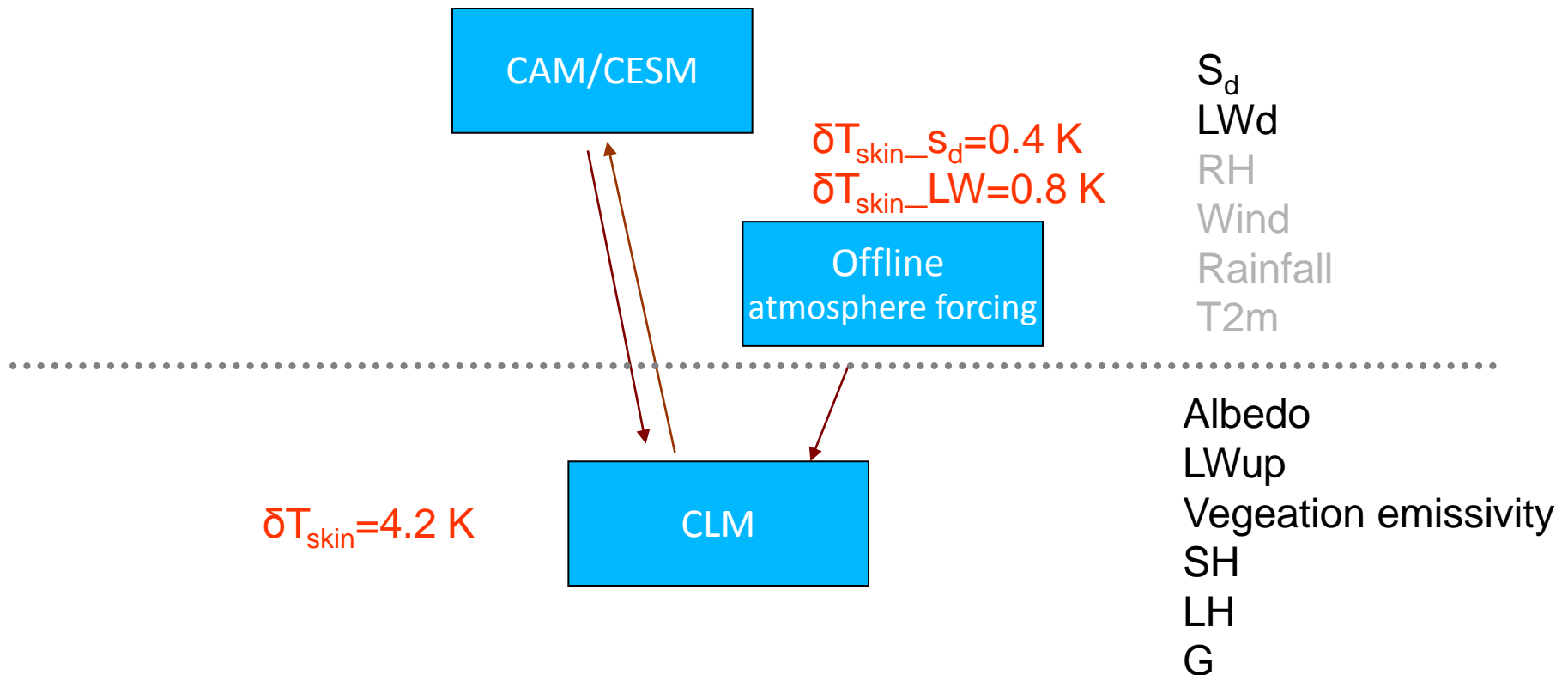
Albedo

Surafce Albedo, CLM4 vs. ARM OK, 2004

ARM Albedo
CLM4 Albedo

Albedo

Day of Year

rain
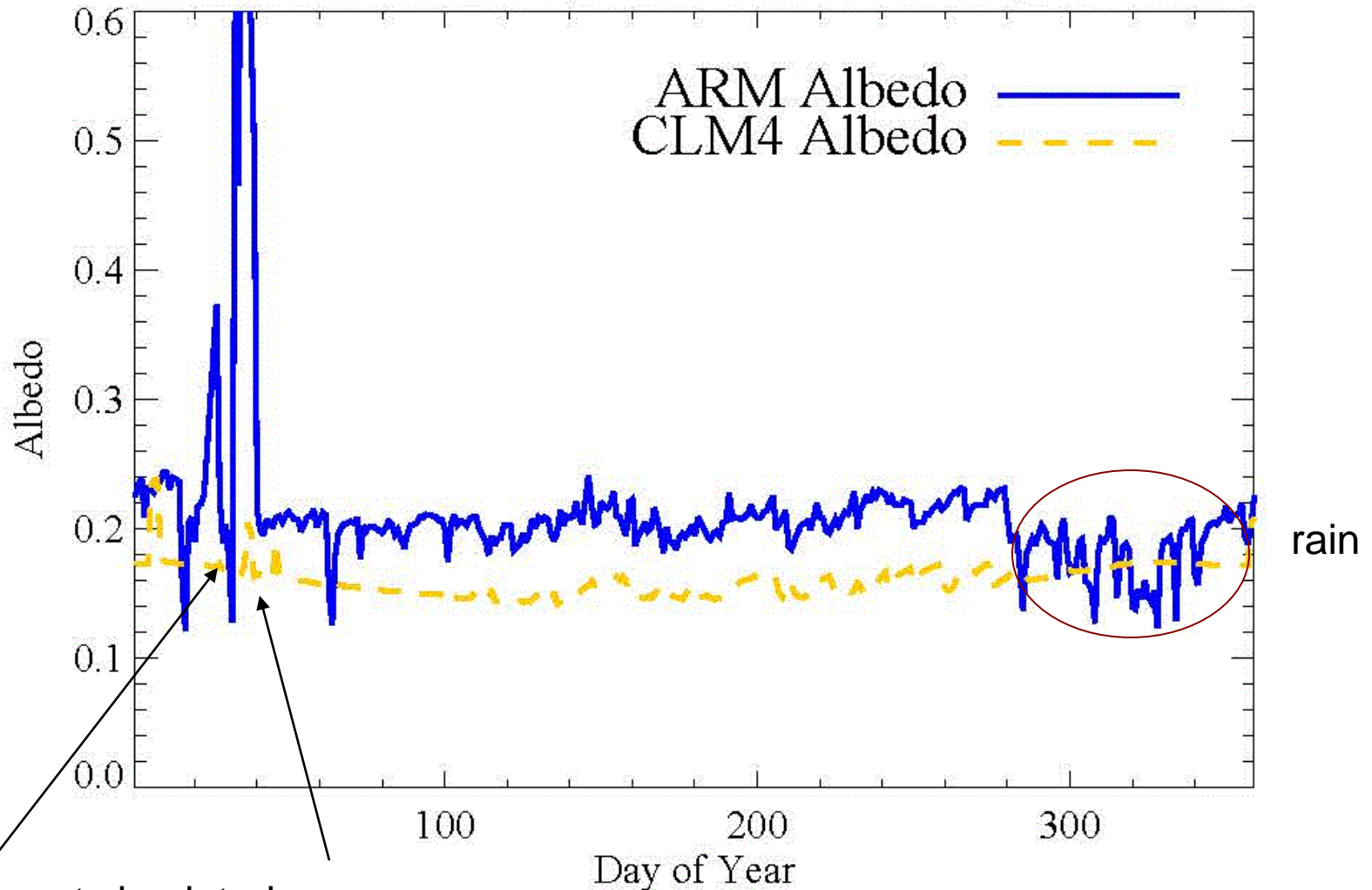
Snow is not simulated

Snow albedo is too low

CLM4 albedo is in general smaller than ARM observations
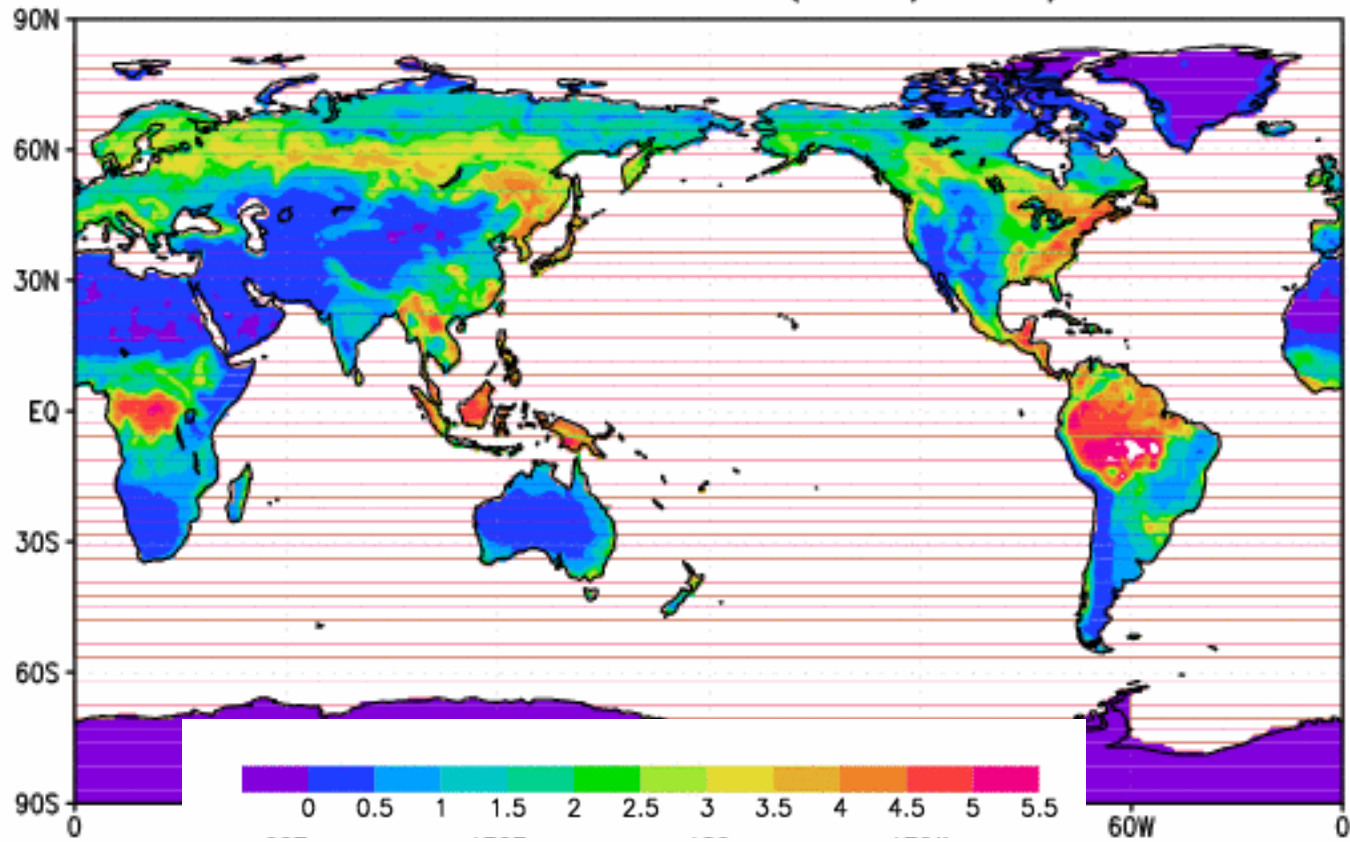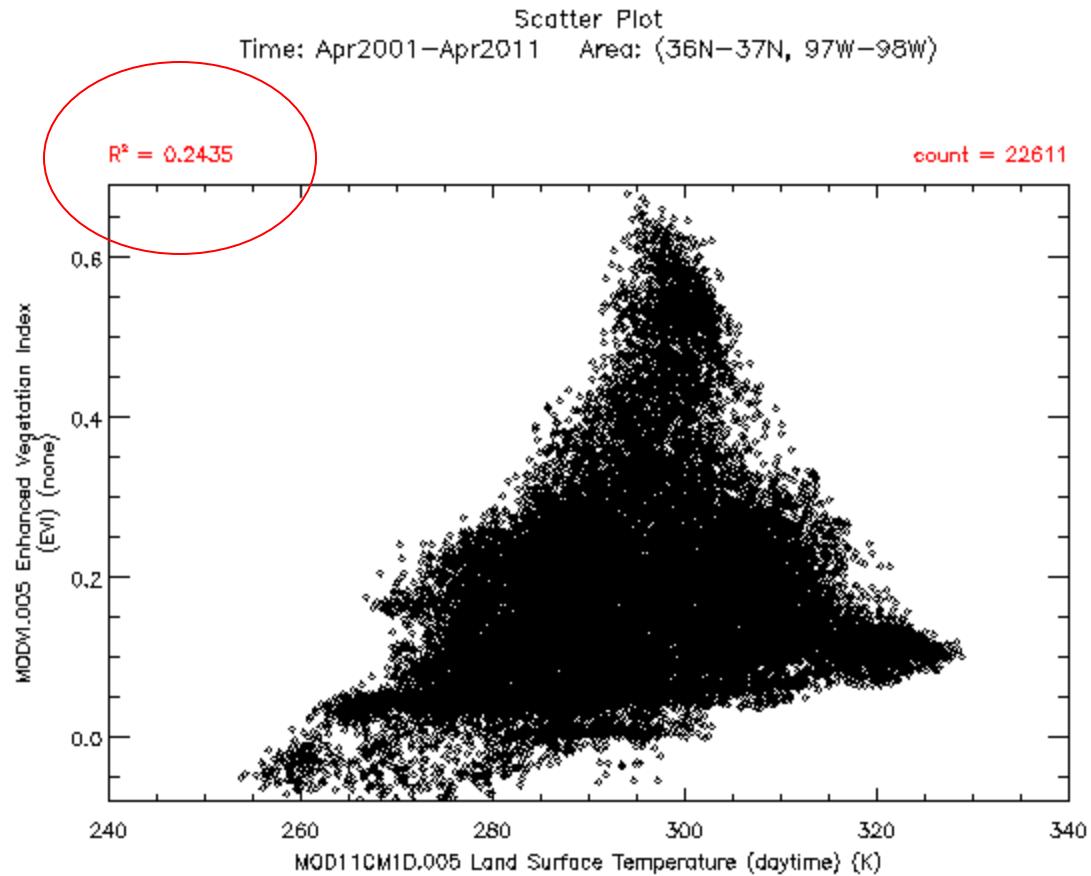
ELAI

CLM4 leaf area index (ELAI), 08/2004

MODIS Daytime T_{skin} (10:30 AM) vs. Enhanced Vegetation Index

Scatter Plot
Time: Apr2001–Apr2011   Area: (36N–37N, 97W–98W)

$R^* = 0.2435$ count = 22611

MOIDIS observed OK site day time T_{skin} and TLAI is only 0.2

Nighttime Tskin (10:30 PM) vs Enhanced vegetation index (MODIS)

Scatter Plot
Time: Apr2001–Apr2011   Area: (36N–37N, 97W–98W)

R* = 0.5017   count = 22602
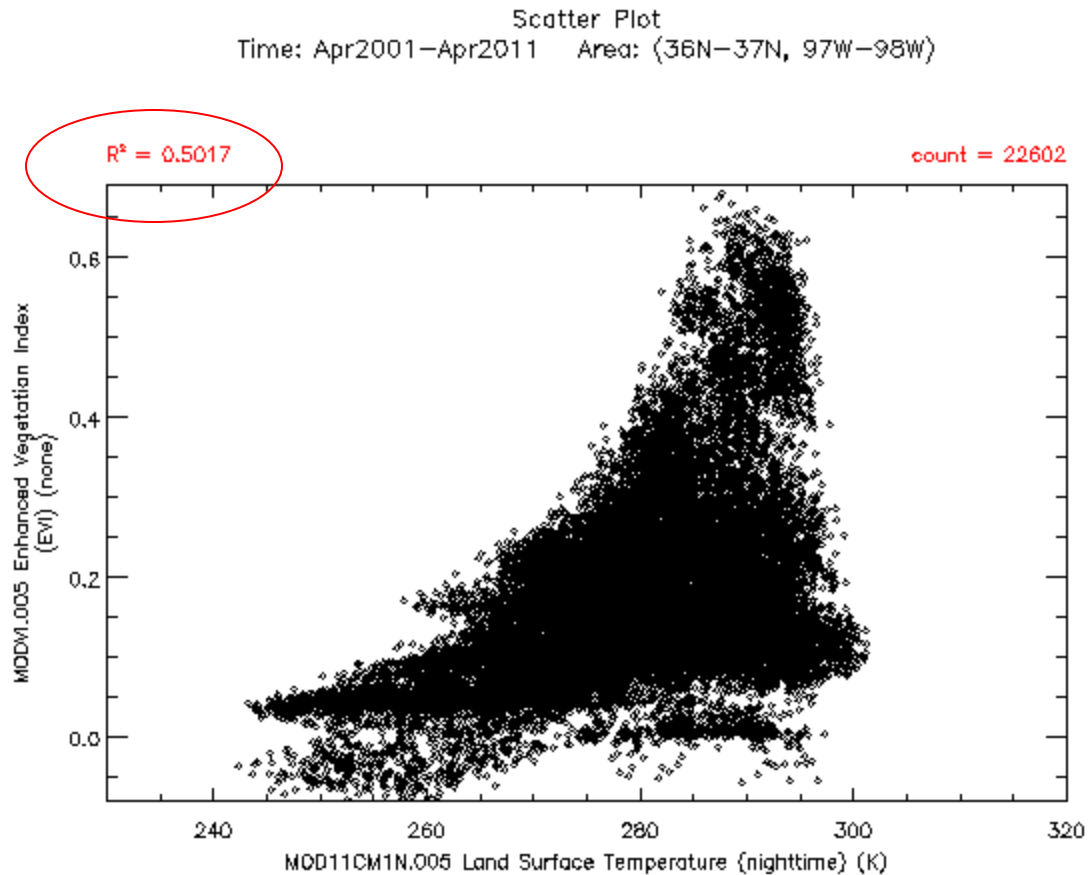
MOIDIS observed OK site night time Tskin and TLAI is only <u>0.50</u>

Scatter Plot
Time: Apr2001–Apr2011   Area: (36N–37N, 97W–98W)

$R^2 = 0.2435$ count = 22611

Tskin vs. TLAI, CLM 1999-2004

cor=0.74
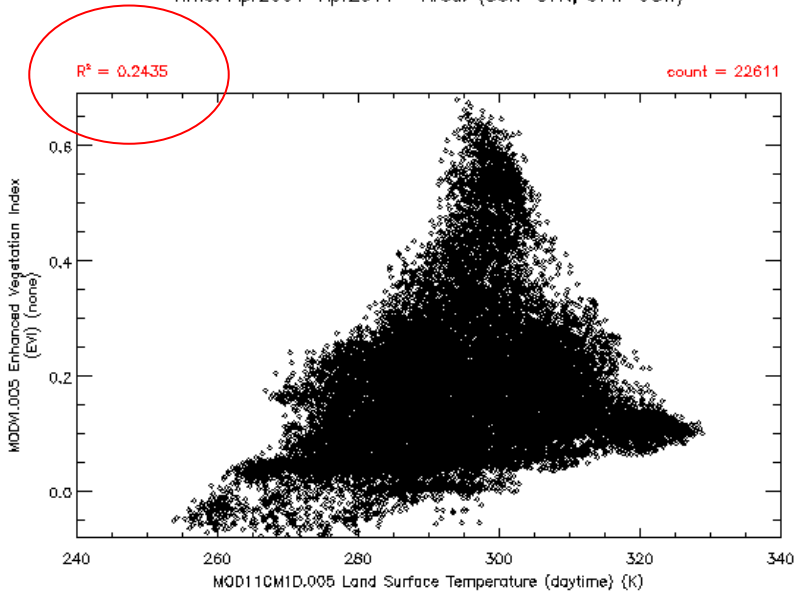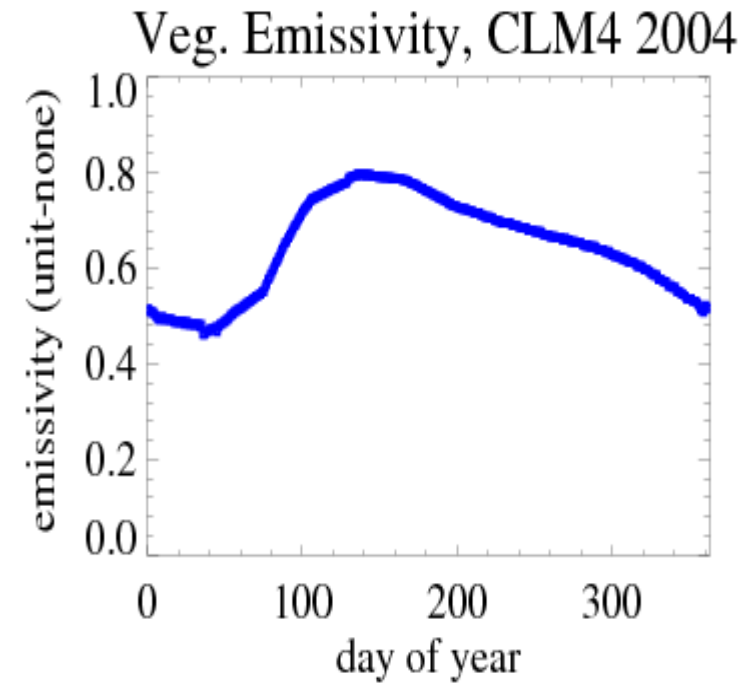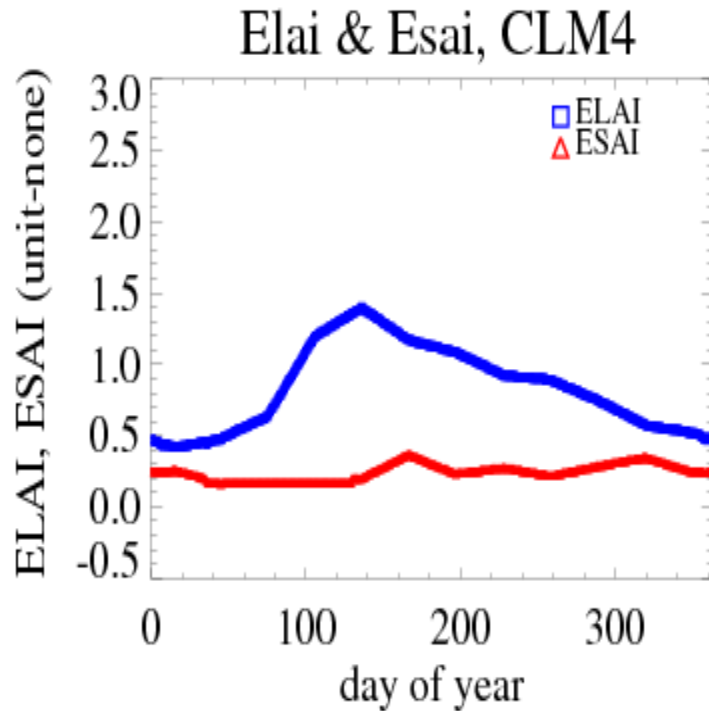
CLM T_{skin} depends on LAI too much
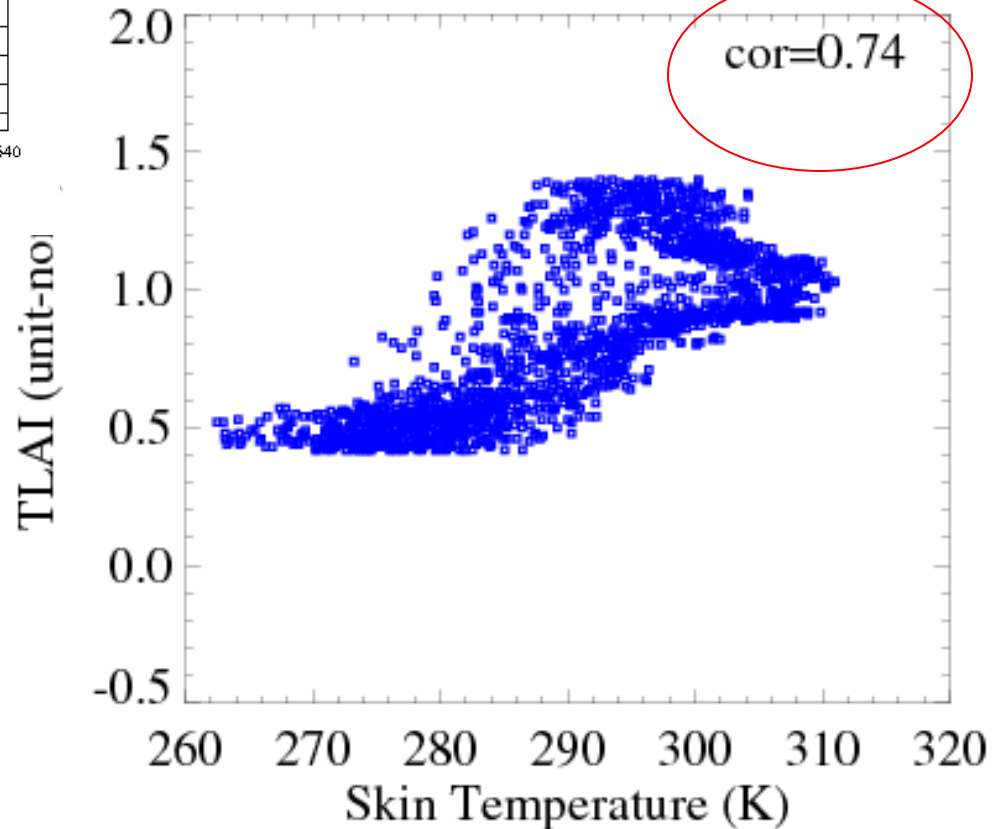
1999 Dec-2000, Dec Tskin vs TLAI over OK site

Vegetation Emissivity is in question

Elai & Esai, CLM4

Veg. Emissivity, CLM4 2004
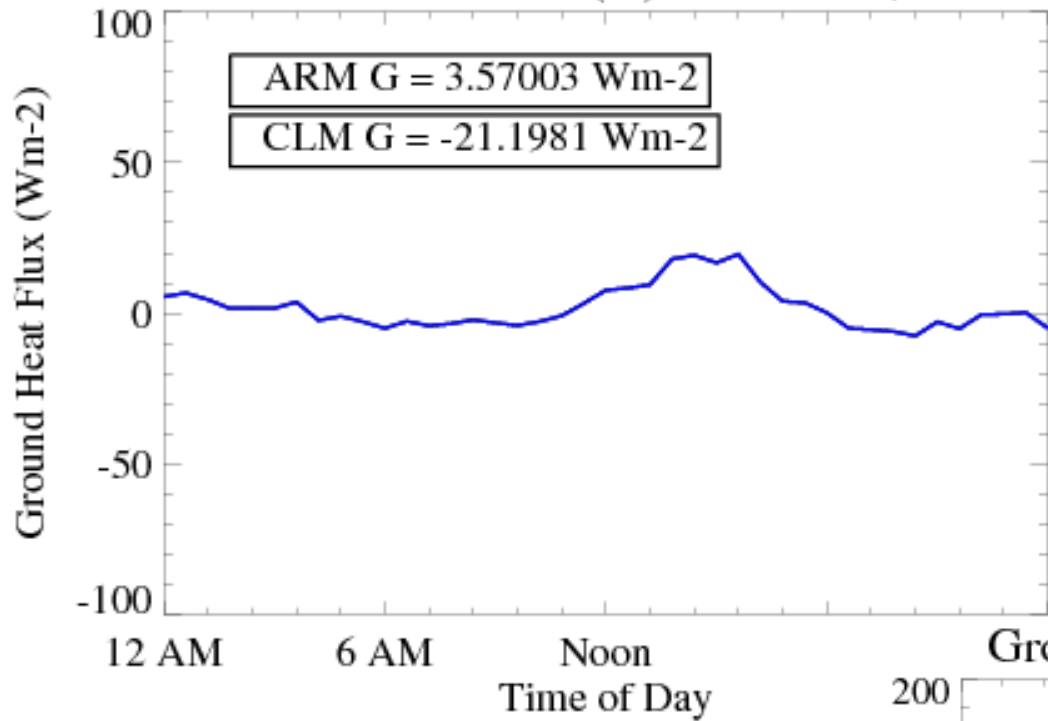
$e_v = 1 - \exp(-(elai+esai)/\bar{\mu})$

Offline CLM4 vs. ARM Lamont OK, 2004. RMS_ERR=40.43 W/m^2
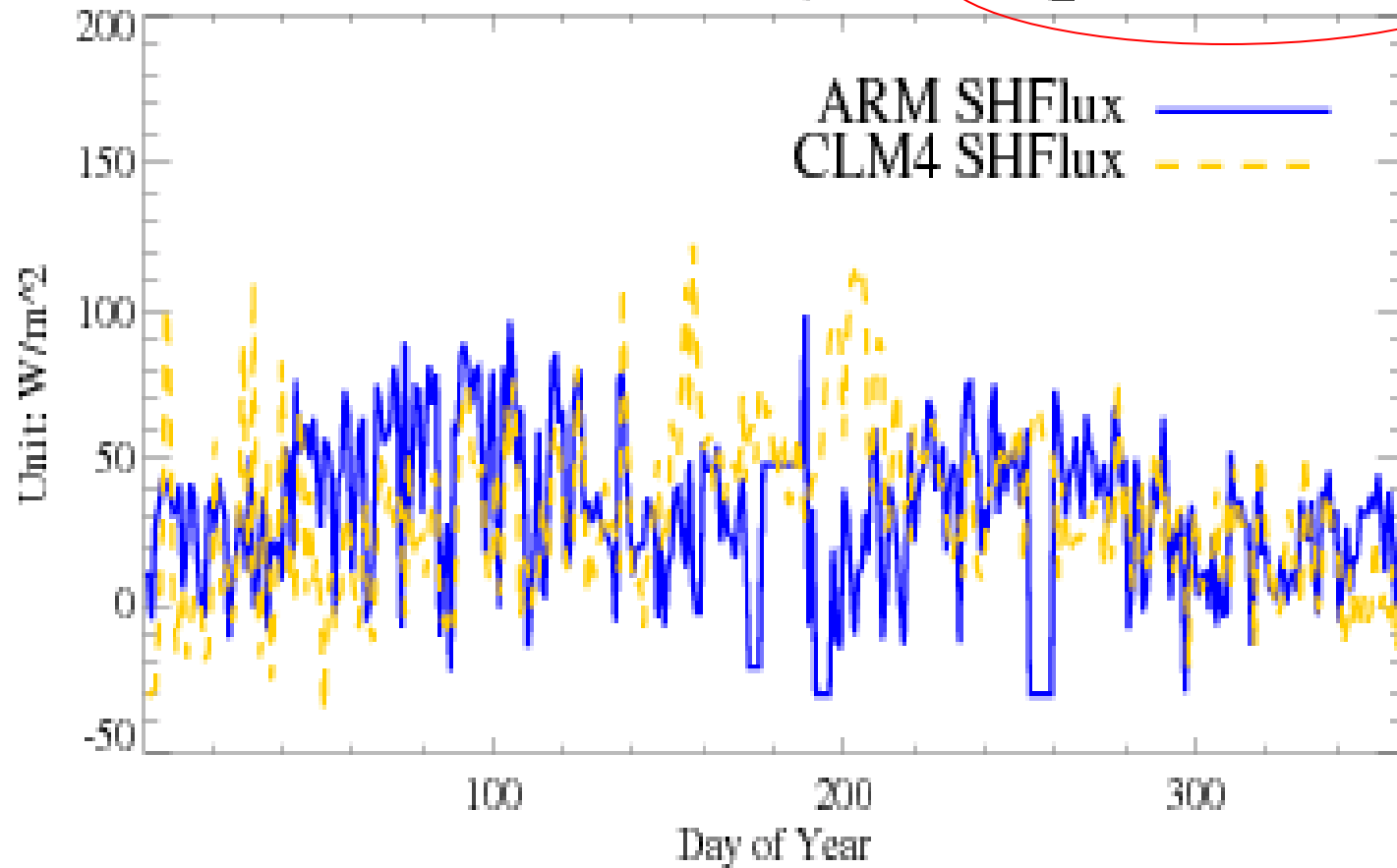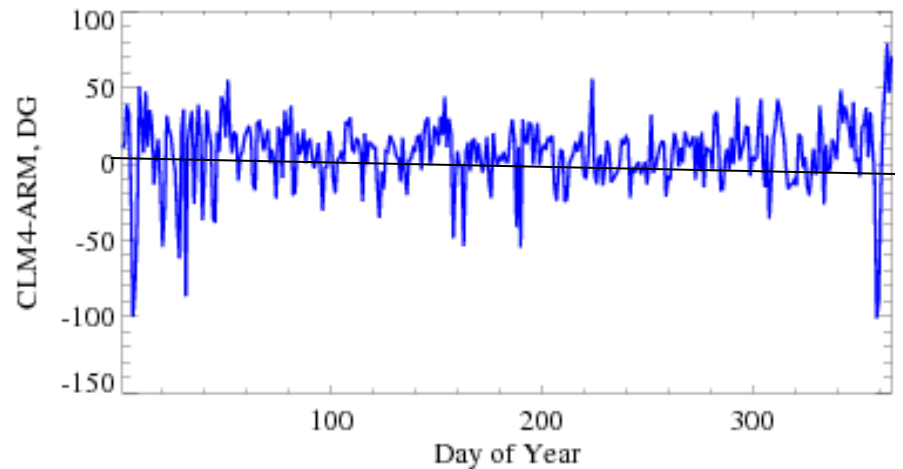
Ground Heat Flux (G) for Jul. 29, 2004

ARM G = 3.57003 Wm-2
CLM G = -21.1981 Wm-2

ARM OK

Ground Heat Flux (G) for Jul. 30, 2004

ARM G = 17.2494 Wm-2
CLM G = -5.61024 Wm-2

Daily averaged G

Offline CLM4 vs. ARM Lamont OK, 2004
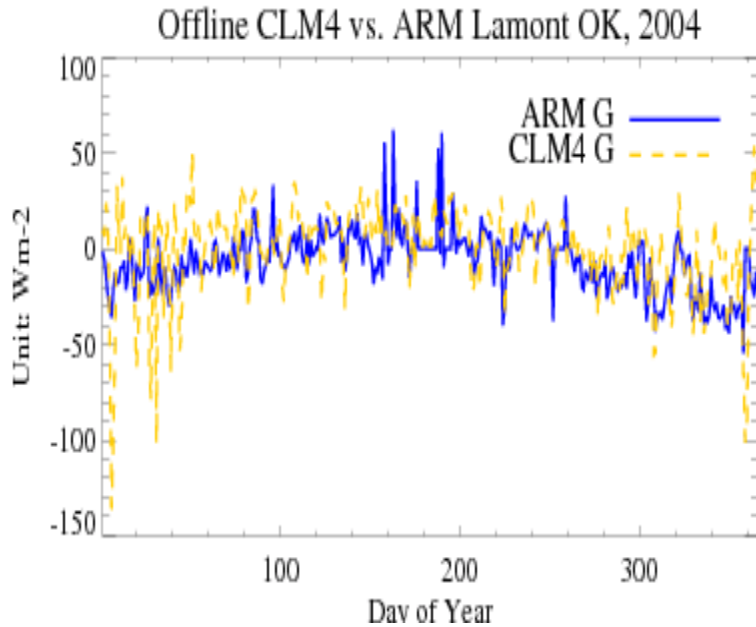
ARM G ——
CLM4 G - - -

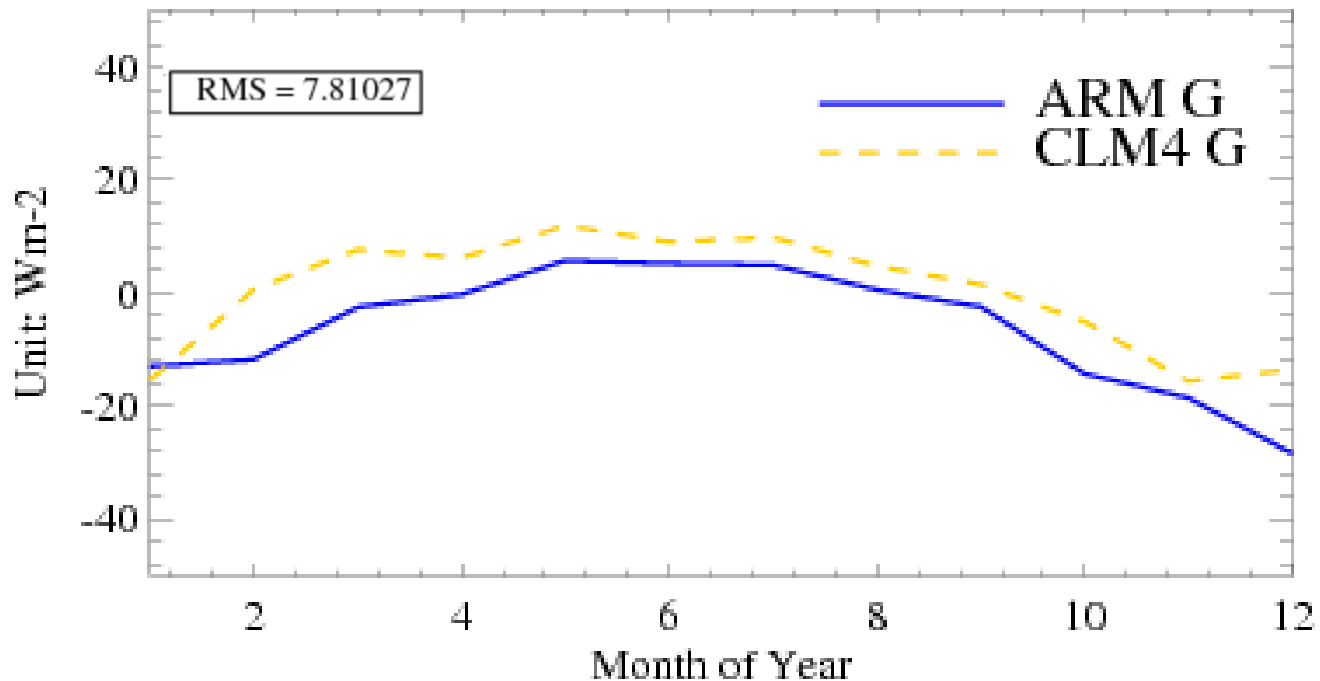RMS = 23.66
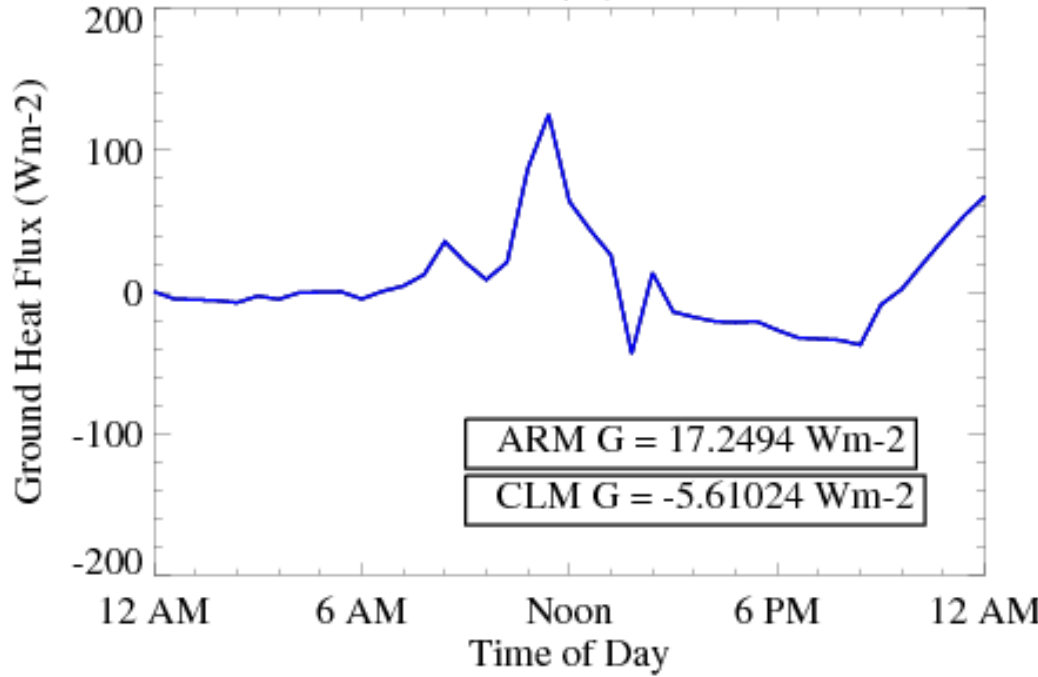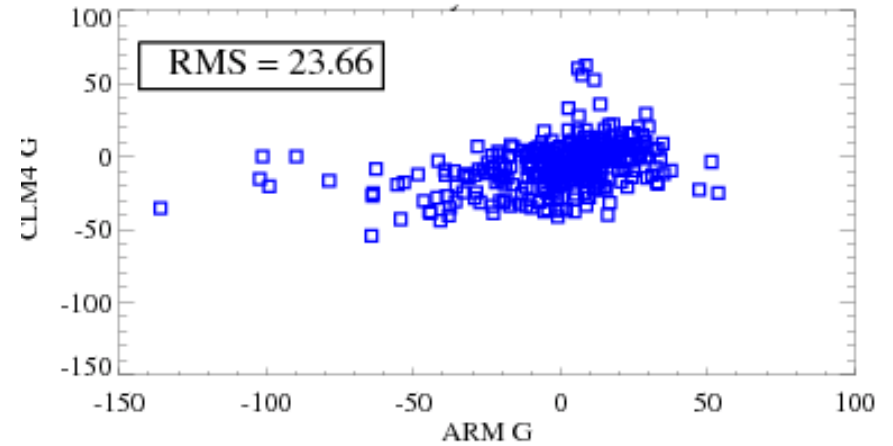
CLM has more G than ARM

Monthly Mean G

Offline CLM4 vs. ARM Ground Heat Flux (G) Lamont OK, 2004

Offline CLM4

Year	Annual FGR (Wm-2)	Annual FGR12 (Wm-2)
2000	-0.346	-0.803
2001	1.027	0.694
2002	0.574	0.268
2003	0.187	-0.064
2004	0.186	0.062
5-year average	0.325	0.031

Summary

Problem:

- CLM4 still overestimates T_{skin} over OK site

Reasons identified, partly:

- Inadequate atmosphere forcing
- Low surface albedo
- Low snow surface albedo
- T_{skin} depends on vegetation too much
- vegetation emissivity (?)
- Ground flux (?)

Future Work

- Run Offline CLM4 using <u>ARM</u> forcing (<u>CMBE-land</u>)

    Hourly Sd direct, Sd diffuse

    LWd, T2m, RH, Preciptation, wind,pressure

    1999-2011

    CLM4 outputs: hourly

- Assess uncertainty $\delta T_{skin} = \delta$(forcing, albedo, LAI, etc),

- Understand <u>to what extent</u> CLM4 T_{skin} is useful in climate research studies