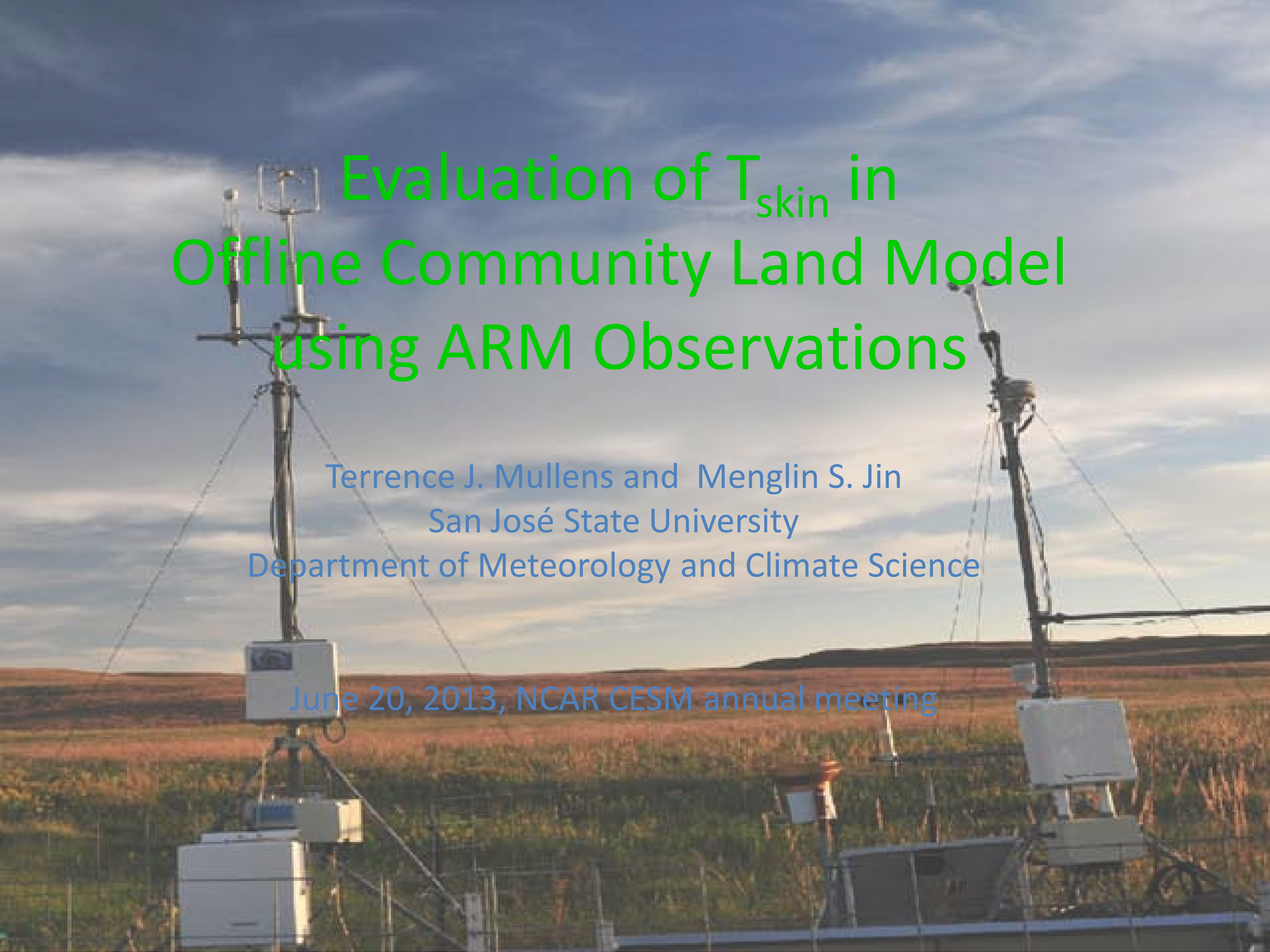

Evaluation of T_{skin} in Offline Community Land Model using ARM Observations

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Outline

- Motivations
- Experimental Design
- Results
- Improvement on Canopy Emissivity (poster)
- Conclusions

Motivations

- Previous Validations of CLM
  - EVluating CLMs is essential in developing CLM. CLMs have been validated with data collected from various campaigns (Dai et al. 2003; Jin and Liang. 2006; Qian et al. 2006; Niu and Yang. 2007).
  - Model overestimates surface temperature, a long-standing problem.
  - T_{skin} is connected to various key processes

Motivation (cont)

- CLM4 default forcing data has the spatial (~1.825°) and temporal (3hr) resolutions, which is too coarse for a single point validation

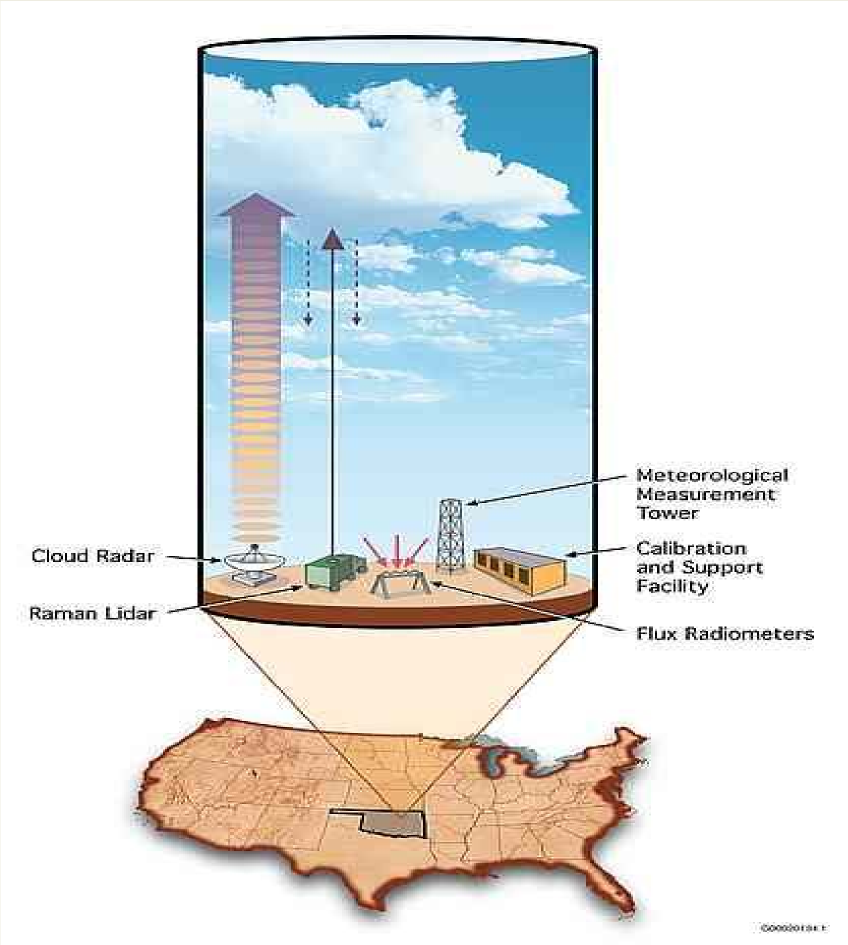
- ARM data can be useful in CLM validations

Background

- The Atmospheric Radiation Measurement (ARM) project (Stokes and Schwartz, 1994; Ackerman and Stokes, 2003)
  - Commissioned in 1989 by the US Department of Energy and began taking measurements in 1992
  - Designed to improve climate models, specifically for cloud processes. Therefore, <u>we found that their heat flux data SH, LE, G) are very questionable</u>.

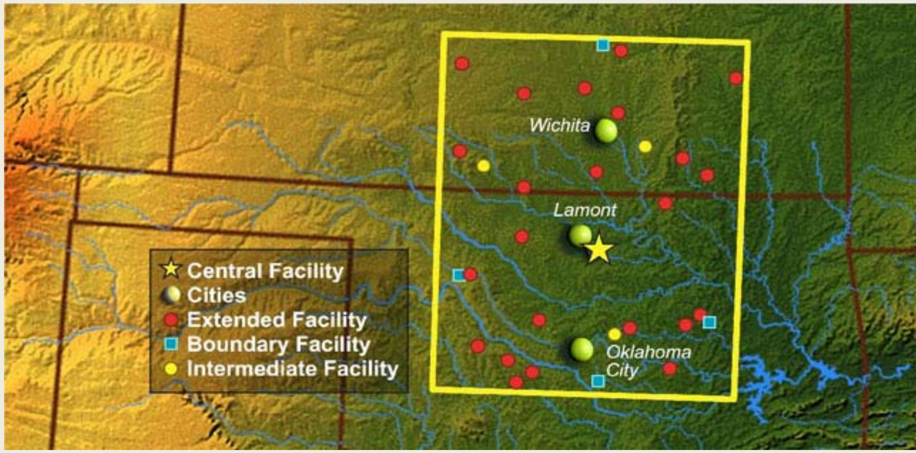
Experimental Design

- Experiment performed for 2004, over ARM Southern Great Plains (SGP) Site
  - Data taken from SGP CO_2 Flux Tower (60m Tower; Fischer et al. 2005)
  - Value-added treatment on bad/missing data are done when possible.



ARM Southern Great Plains Site

- Located near Lamont, Oklahoma (36.6°N, 97.5°W)
- Humid, subtropical climate (Cfa)
- Avg. maximum: 93°F (33.9°C)
- Avg. minimum: 22°F (-5.6°C)
- Avg. precipitation: 35” of rain, 12” of snow
- Land cover: Open grassland (on site) surrounded by wheat crops
- Elevation: 1030 ft (314 m)



Experimental Design (cont.)

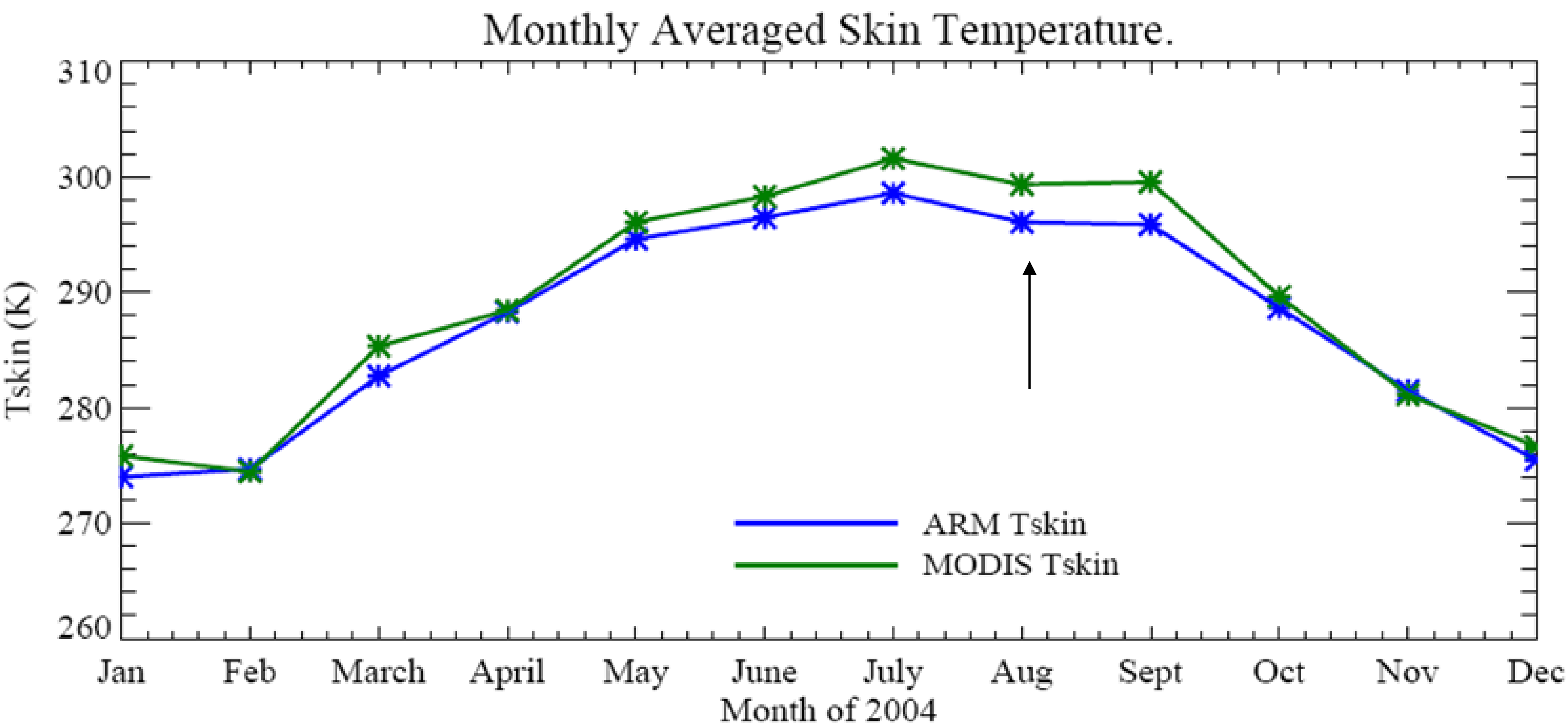
- Default CLM4 run
  - 0.9°x1.25° resolution (grid size)
  - default forcing data from Qian et al. (2006)
- CLM4 ARM-forced run
  - Single point run
    - Over the grid cell containing the SGP site
    - Same resolution (grid size) as the default
    - Default forcing data replaced with ARM observations
  - 50-year spin-up
  - PFT mosaic changed to represent ARM site (40% C3 grass, 40% C4 grass, 20% bare soil)

ARM Data For CLM4 Validation

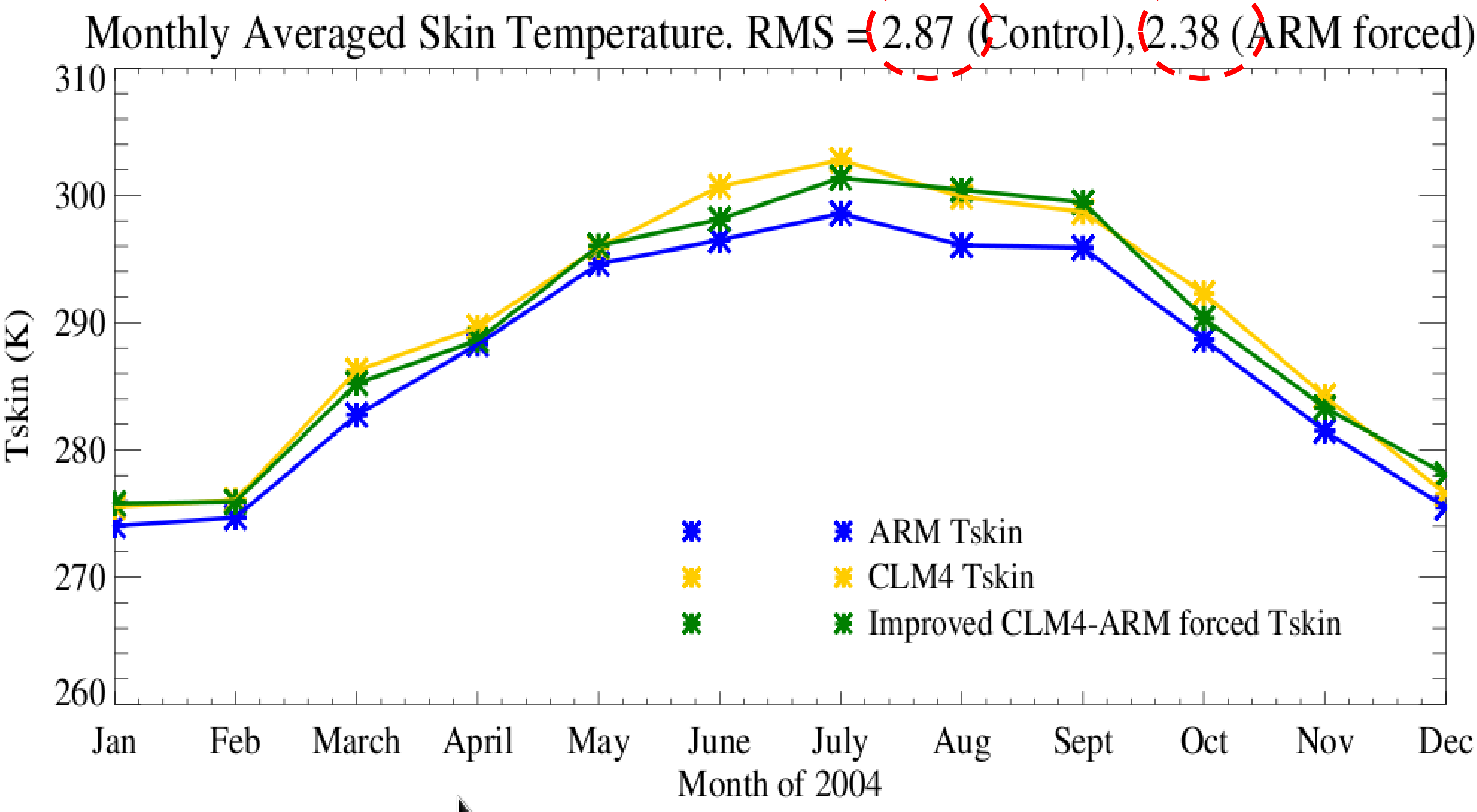
Forcing Data
2m air temperature (T)
Direct solar radiation (S_{dir})
Diffuse solar radiation (S_{dif})
Relative humidity (RH)
Wind speed (V)
Precipitation

(Seasonal evaluation not feasible)

Monthly Mean T_{skin} ARM vs. MODIS



0.5 K improvement



(Jin and Mullens 2013)

Model has warm bias on T_{skin}

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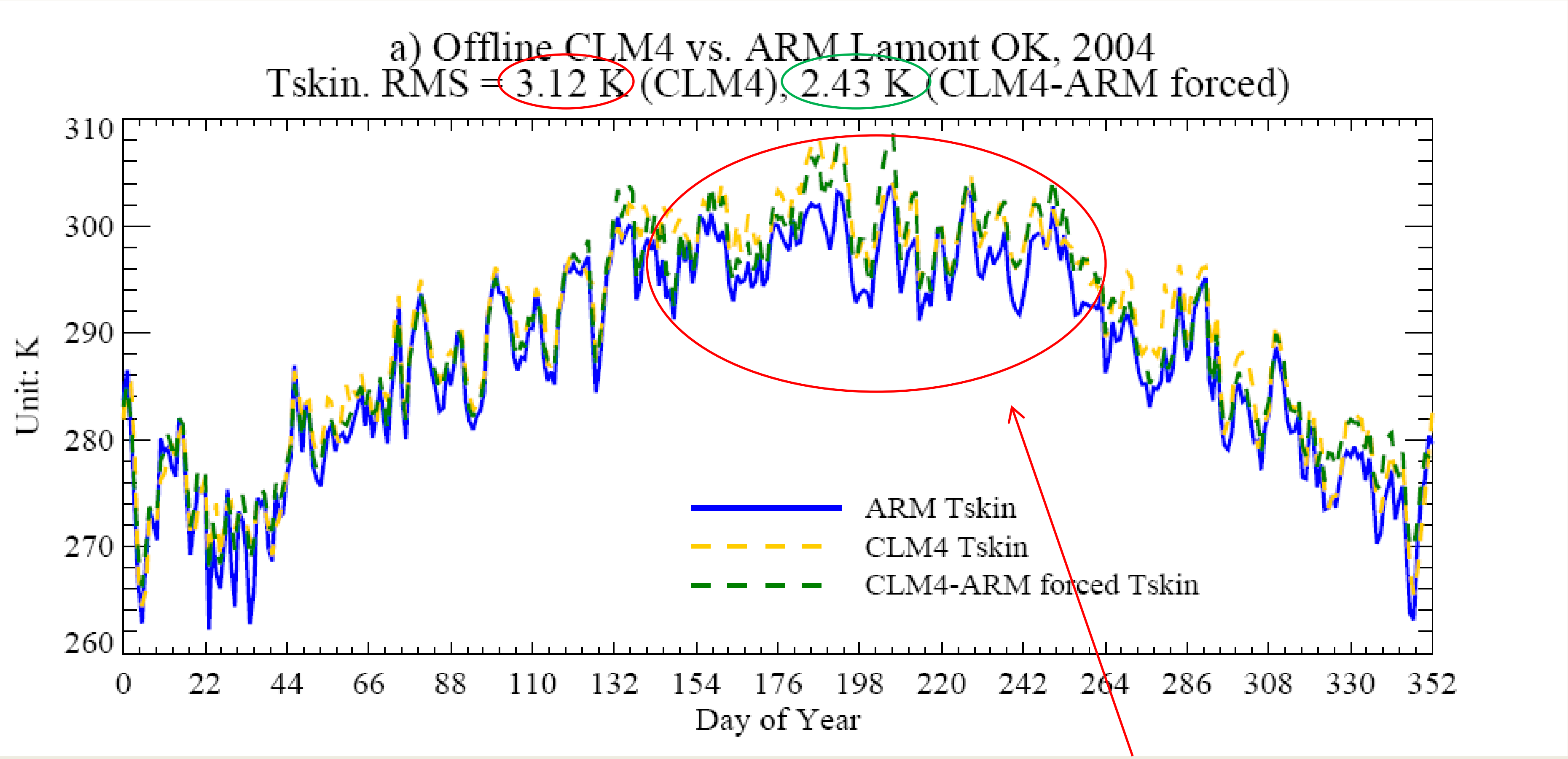
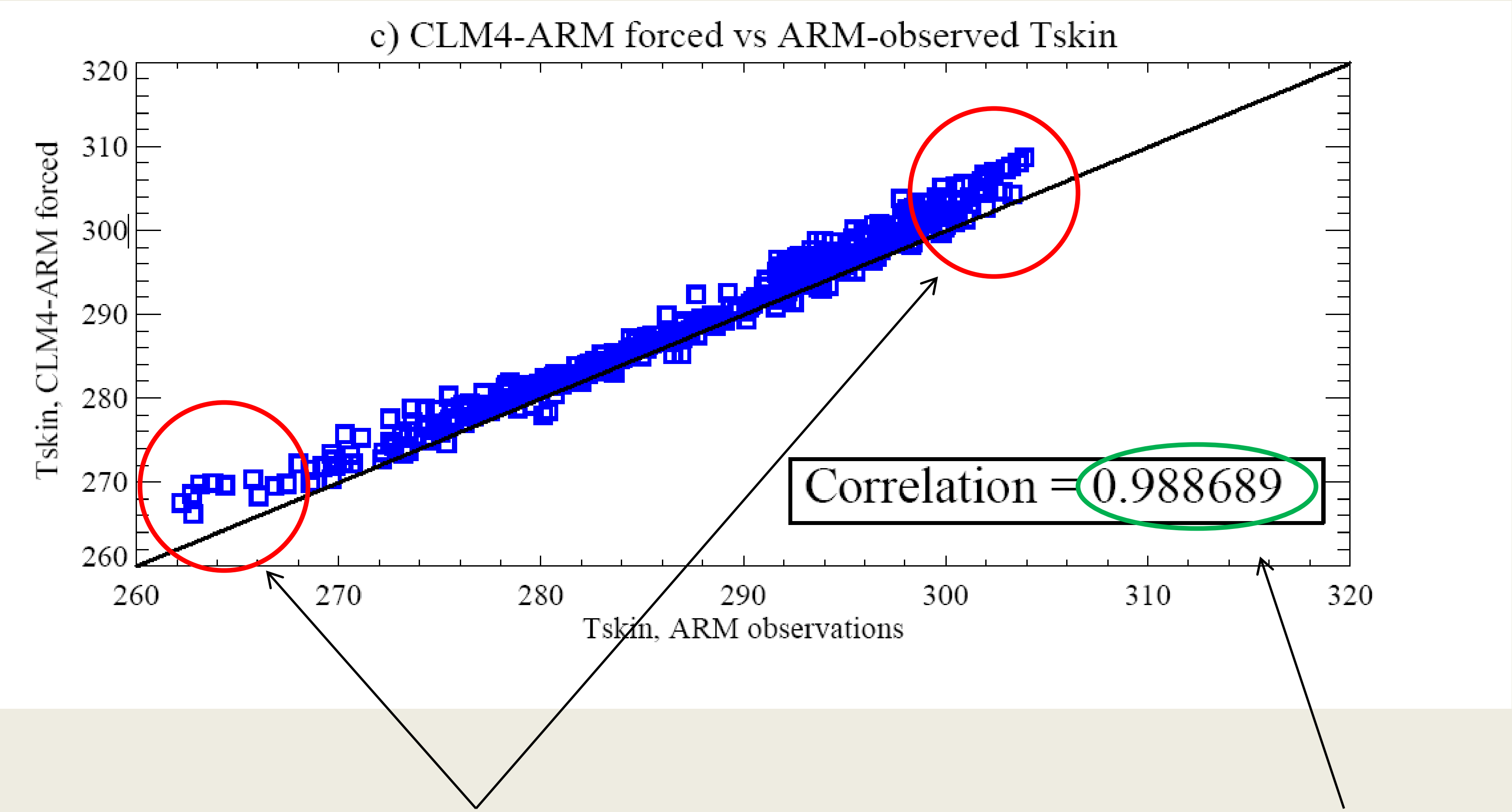
Skin Temperature: Daily



Summer skin temperature is overestimated by as much as 6K on some days!

RMSE improves by 0.69 K with ARM Forcing

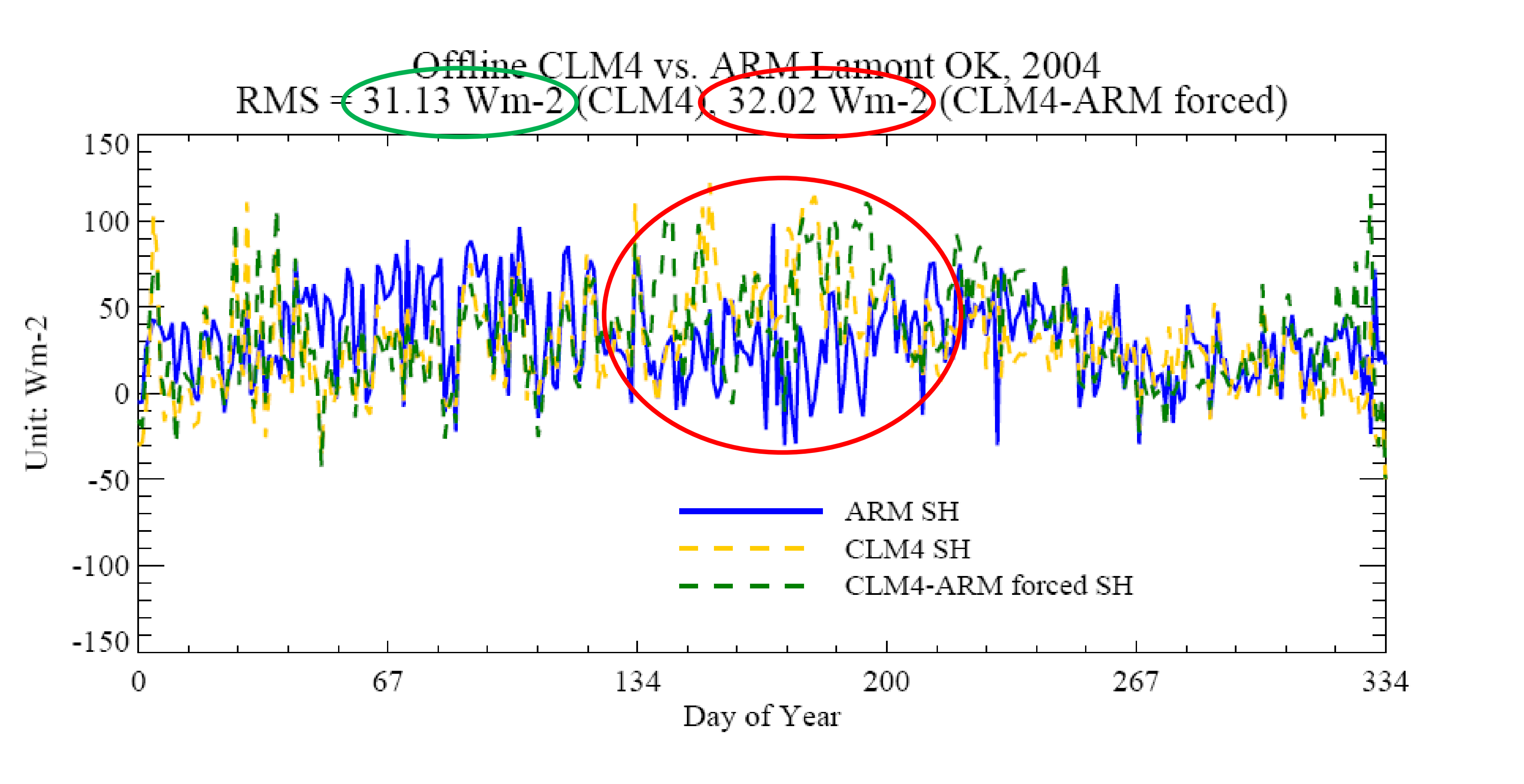
Skin Temperature: Daily



Warm Bias in both maximum and minimum temperatures!

High Correlation

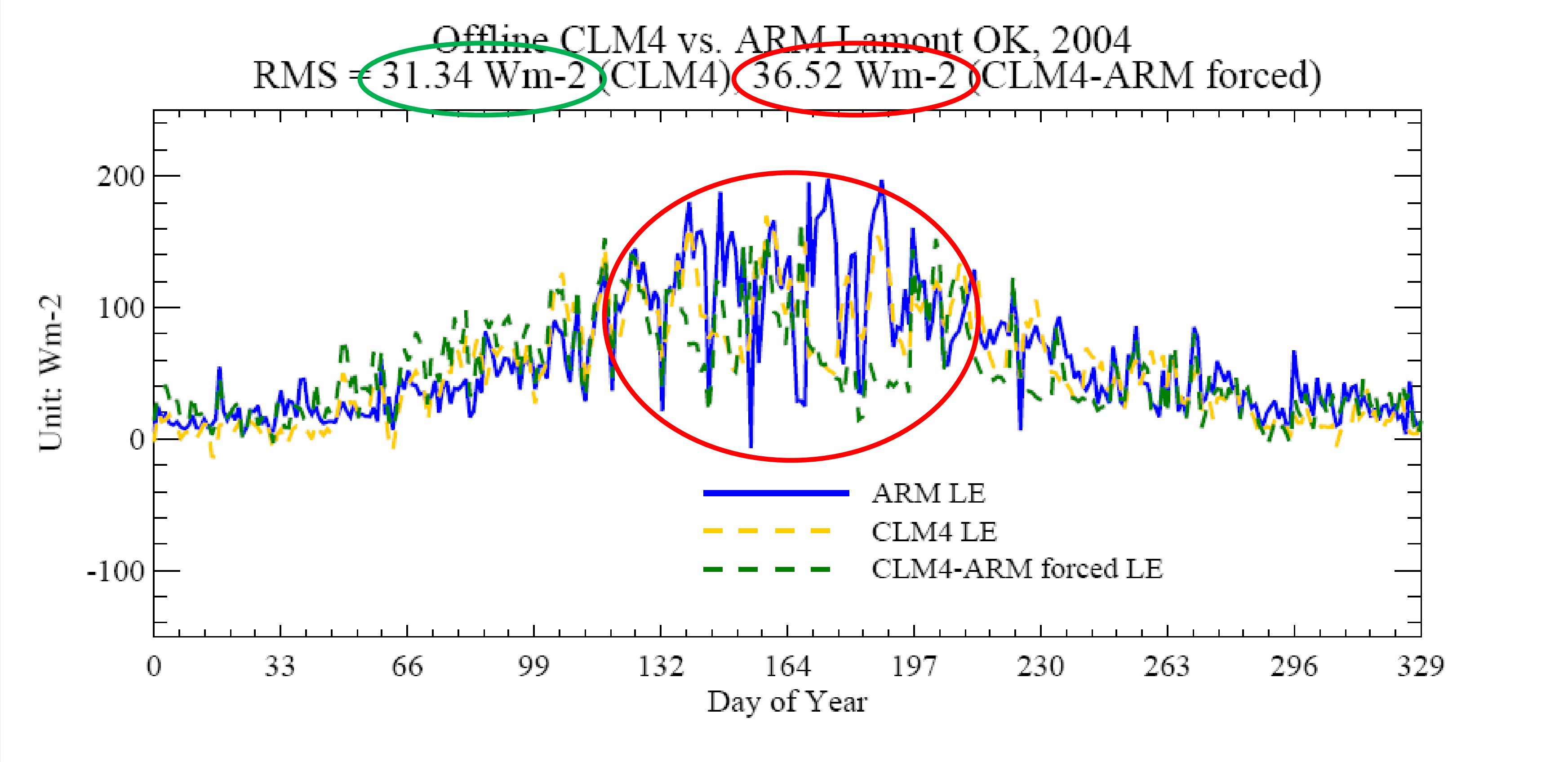
Sensible Heat Flux



No improvement when forced by ARM observations

Substantial instances of overestimation during summer

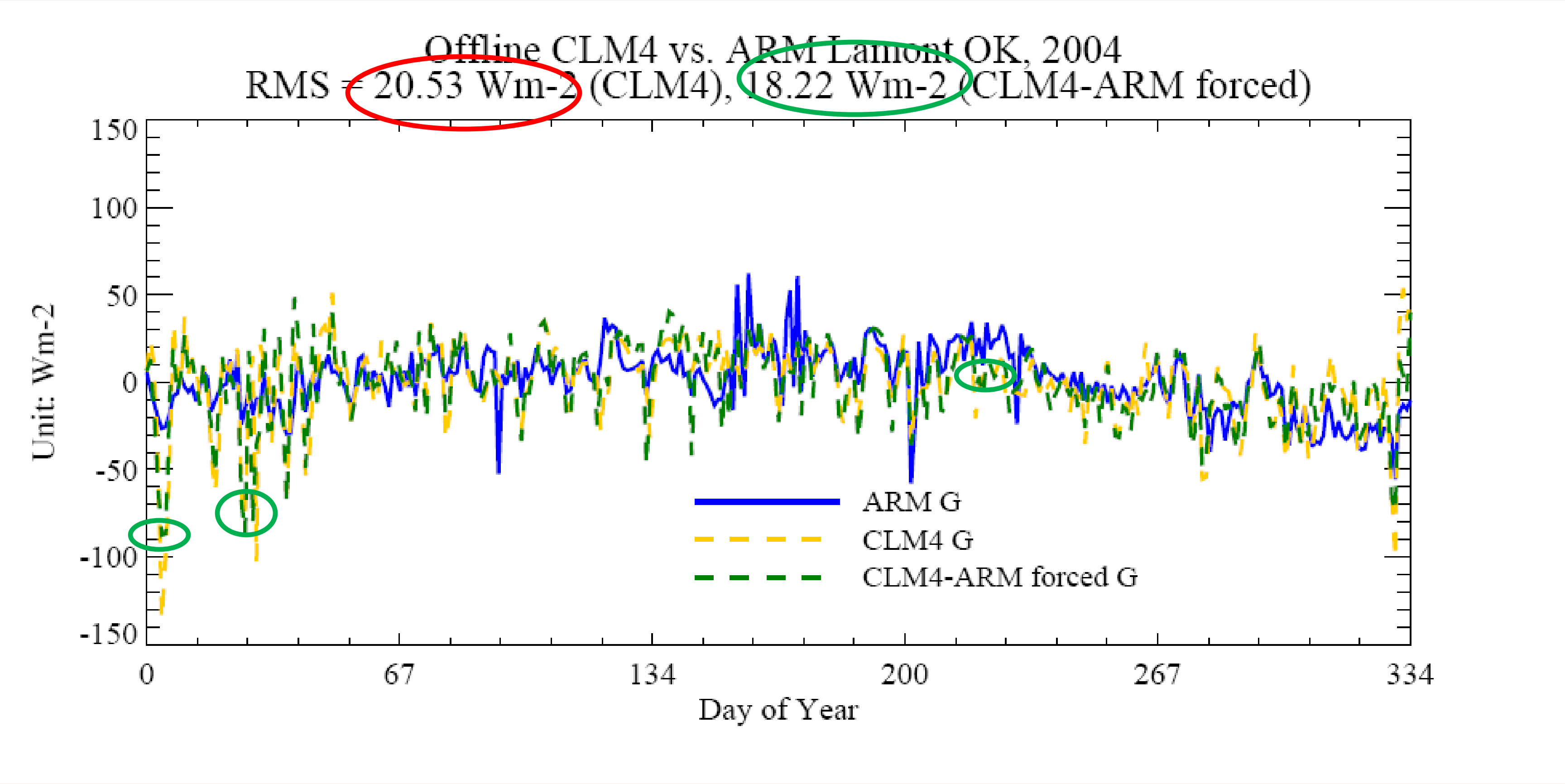
Latent Heat Flux



No improvement when forced by ARM observations

Errors greatest in the Summer.

Ground Flux



Some improvement when forced with ARM observations

Winter: Overestimated, Summer: Underestimated

Soil Temperature

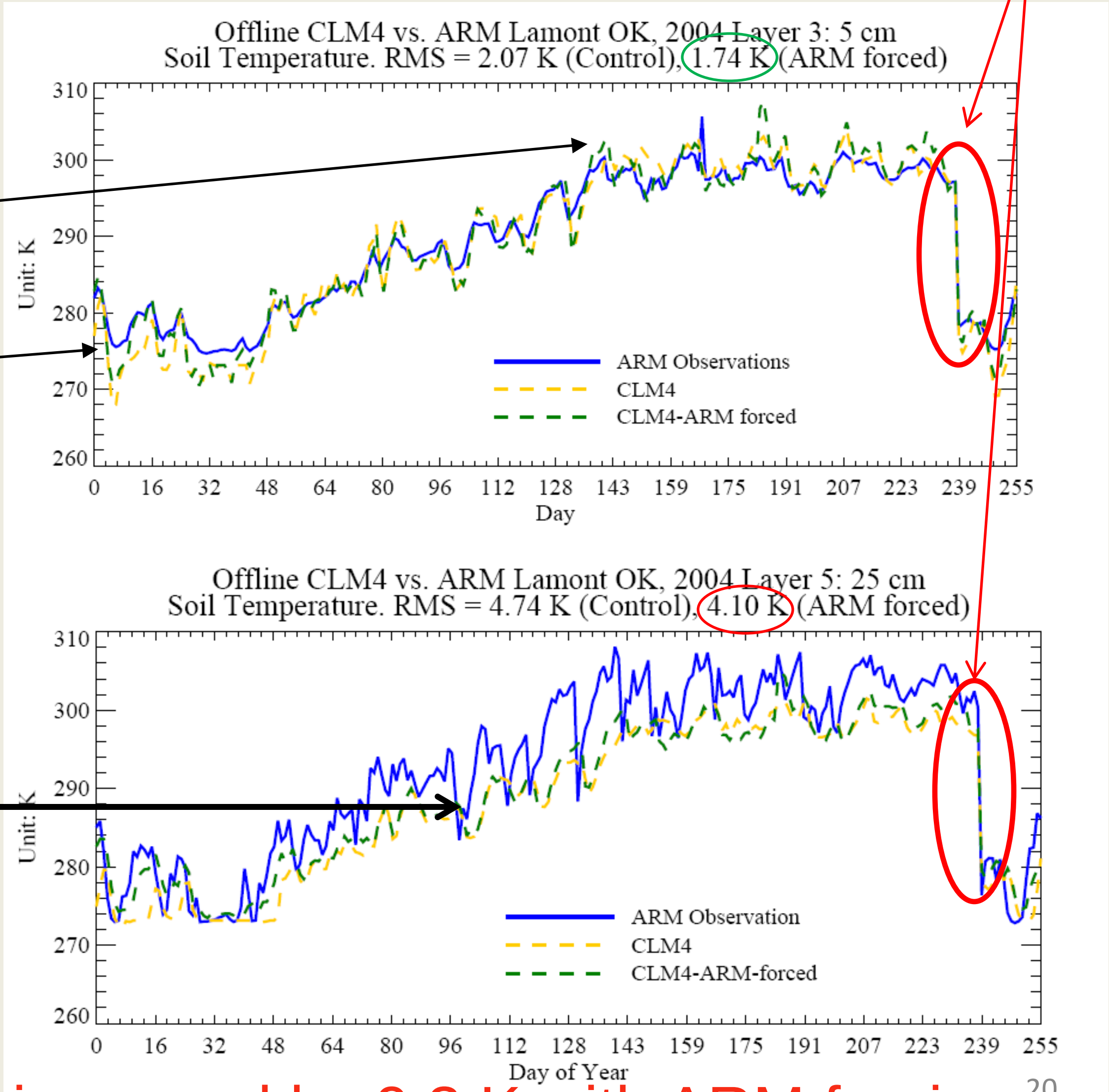
Missing Soil Temperature data

Layer 3 Soil Temperature **overestimated in summer**

Simulations are too cold in winter

Layer 5 Soil Temperature simulations are **too cold,** and there is a **lag** in changes

Much more erroneous!



Soil temperatures are improved by 0.3 K with ARM forcing

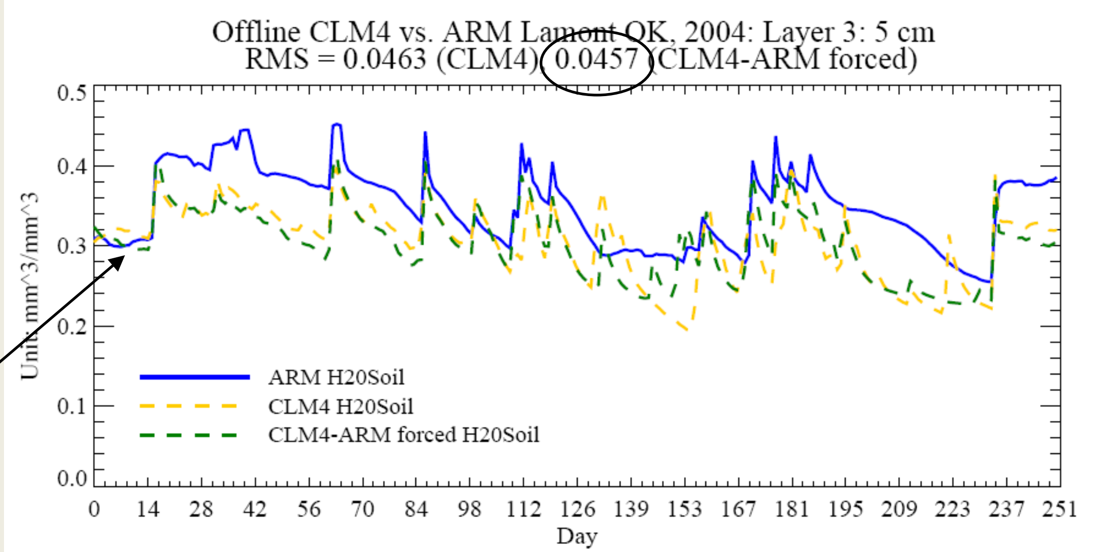
Soil Moisture

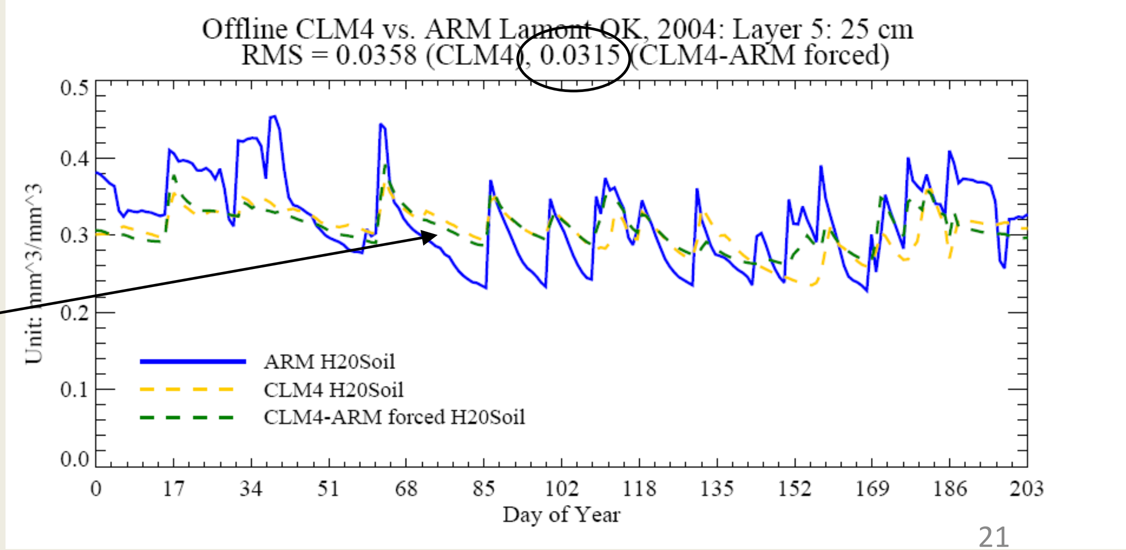
Neither layer has substantial improvement when forced with ARM data.

Both layers respond to precipitation events well

Layer 3 is too dry

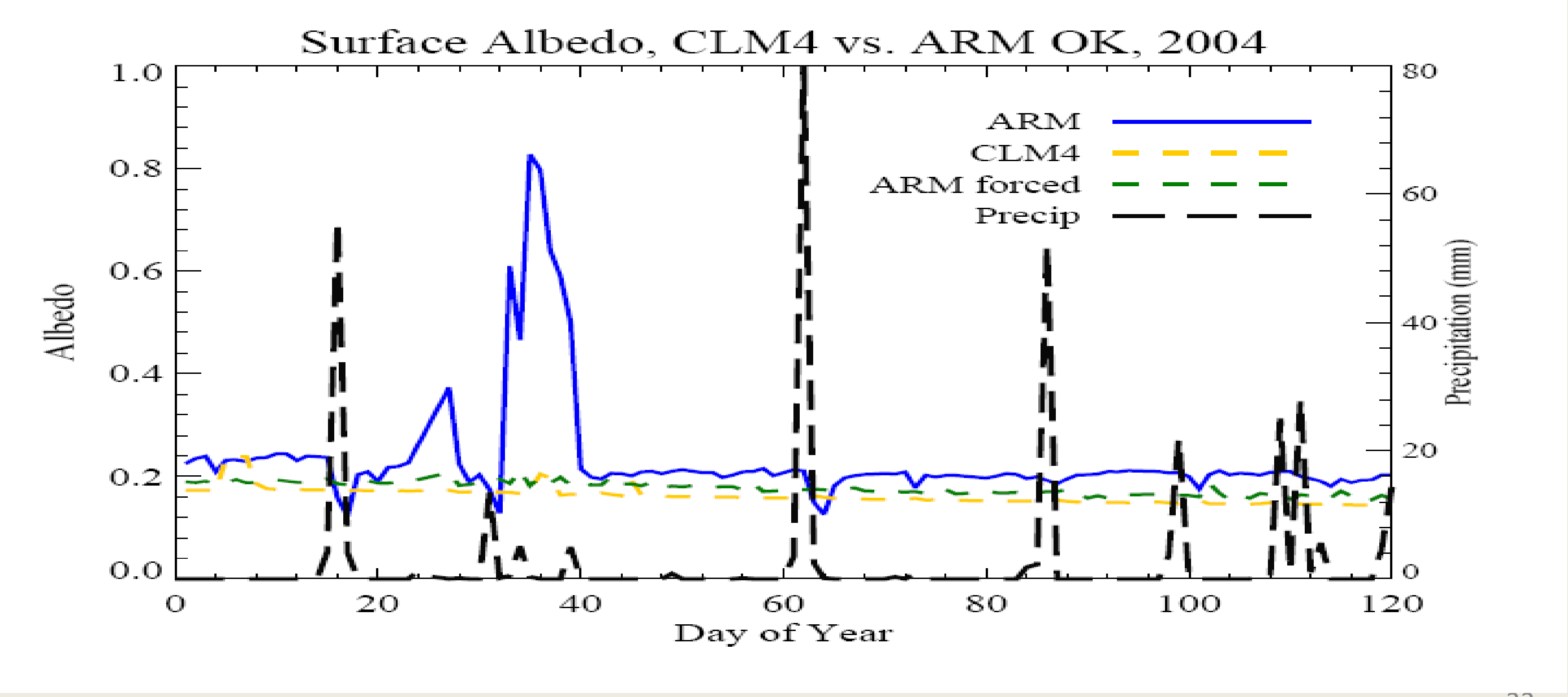
Layer 5 is too wet in spring and summer, too dry in winter





Albedo and Precipitation

CLM4 Albedo:
•Constantly underestimated, except in Fall
•Does not respond to precipitation (darkening)
•Does not increase due to snow cover.



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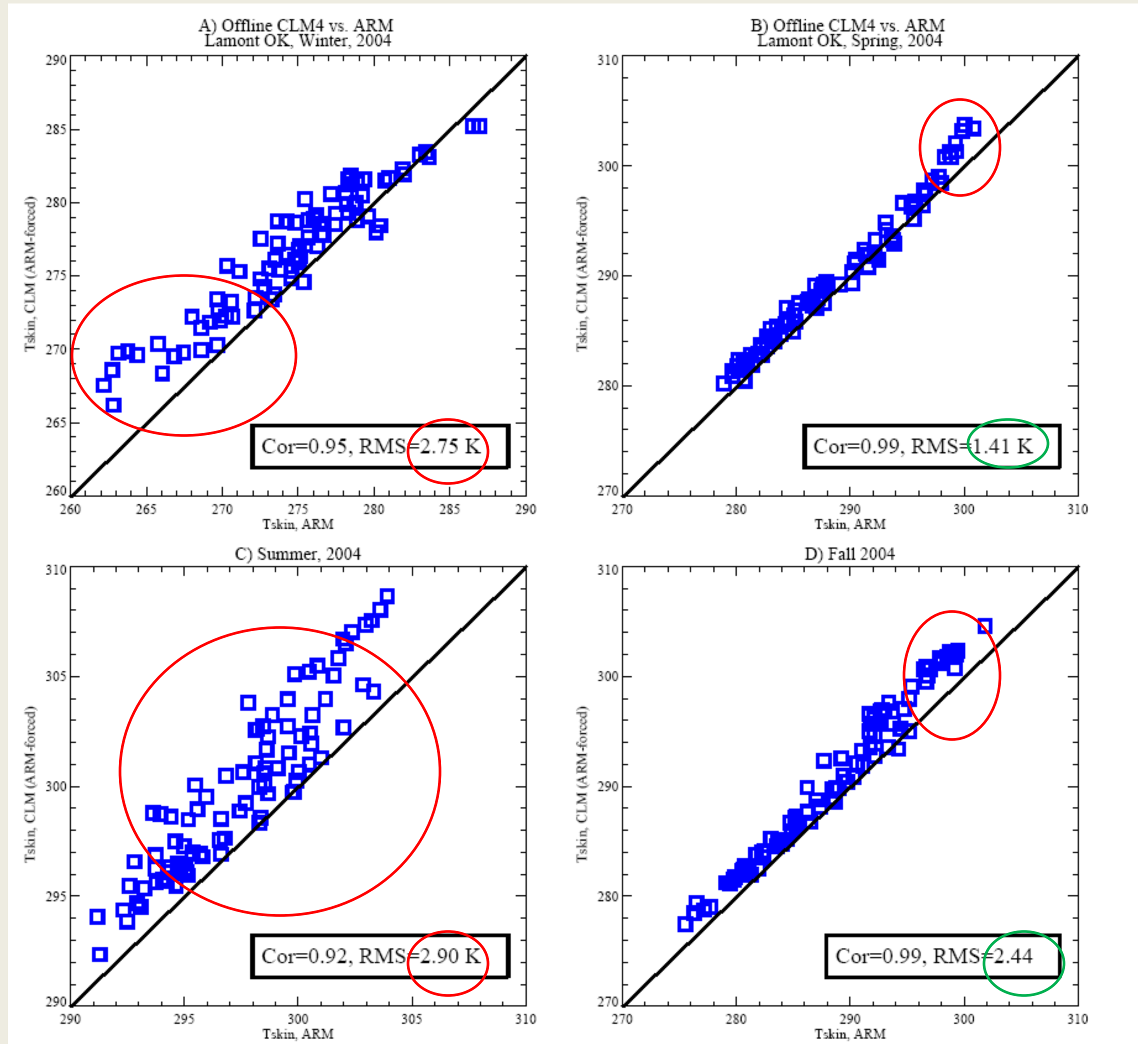
Skin Temperature: Seasonal

- Spring and fall are both well correlated, with lower error.

- Summer and winter are less correlated with
  - Warm bias in maximum summer temperatures and minimum winter temperatures.

- Warm bias slightly present in maximum spring and fall temperatures.

Winter Spring



Summer Fall

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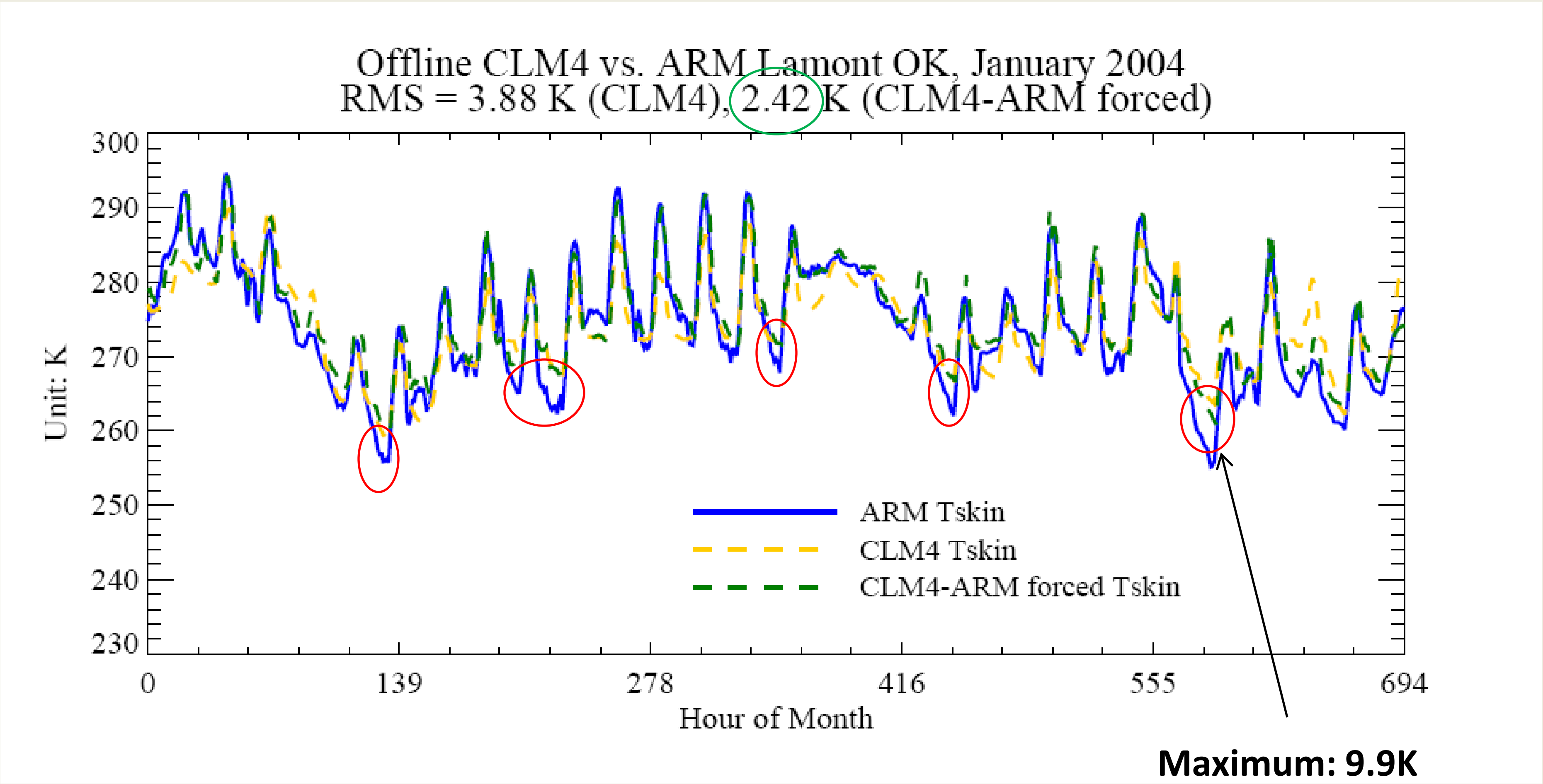
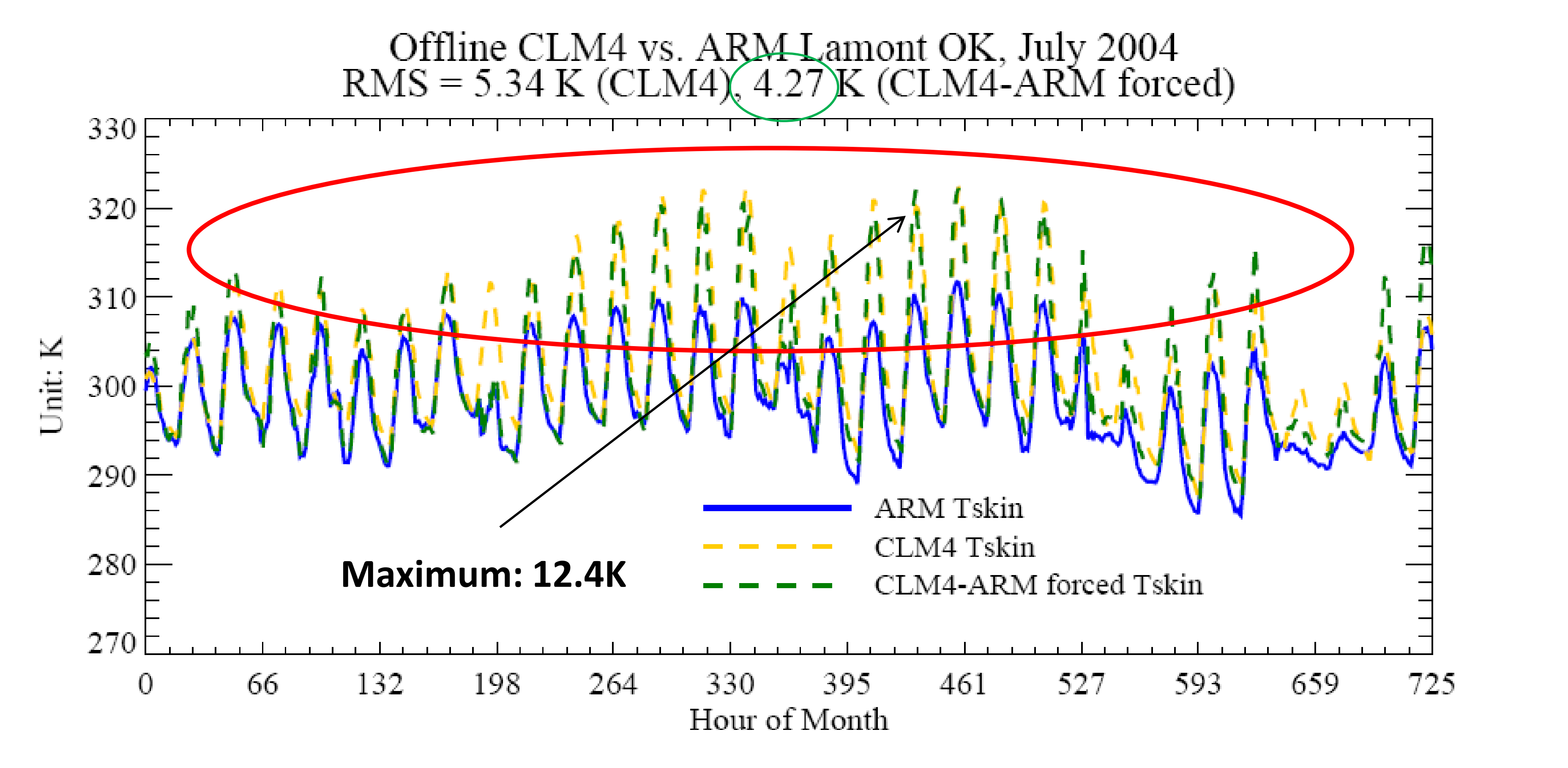
Skin Temperature: Hourly for January



Warm bias in simulated minimum temperatures

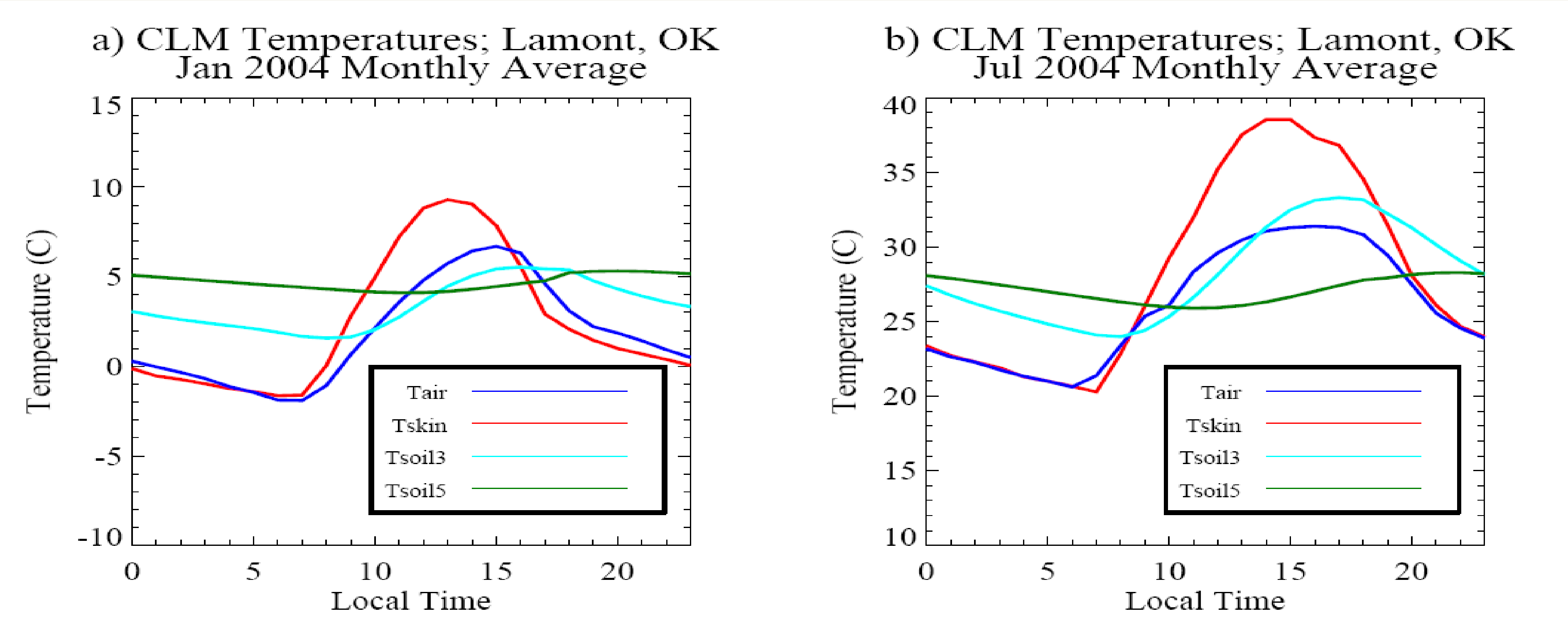
Improved 1.46 K using ARM forcing

Skin Temperature: Hourly for July



Warm bias in simulated maximum temperatures, almost every day!

Daily Temperature Lag



Adapted from Jin et al. 2013

- CLM4 properly simulates lag in daily maximum temperature well in January.
- However, the warm bias in T_{skin} in July leads to a warm bias in Layer 3 T_{soil}.

Outline

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Application to Vegetation Canopy Emissivity

- Vegetation emissivity
  - Currently, in the model, vegetation emissivity is determined by a simple function of exposed LAI and exposed SAI

$$\varepsilon_v = 1 - e^{\frac{-(ELAI+ESAI)}{\mu}}$$, where μ = 1

However, this equation produces unreasonably low vegetation emissivities

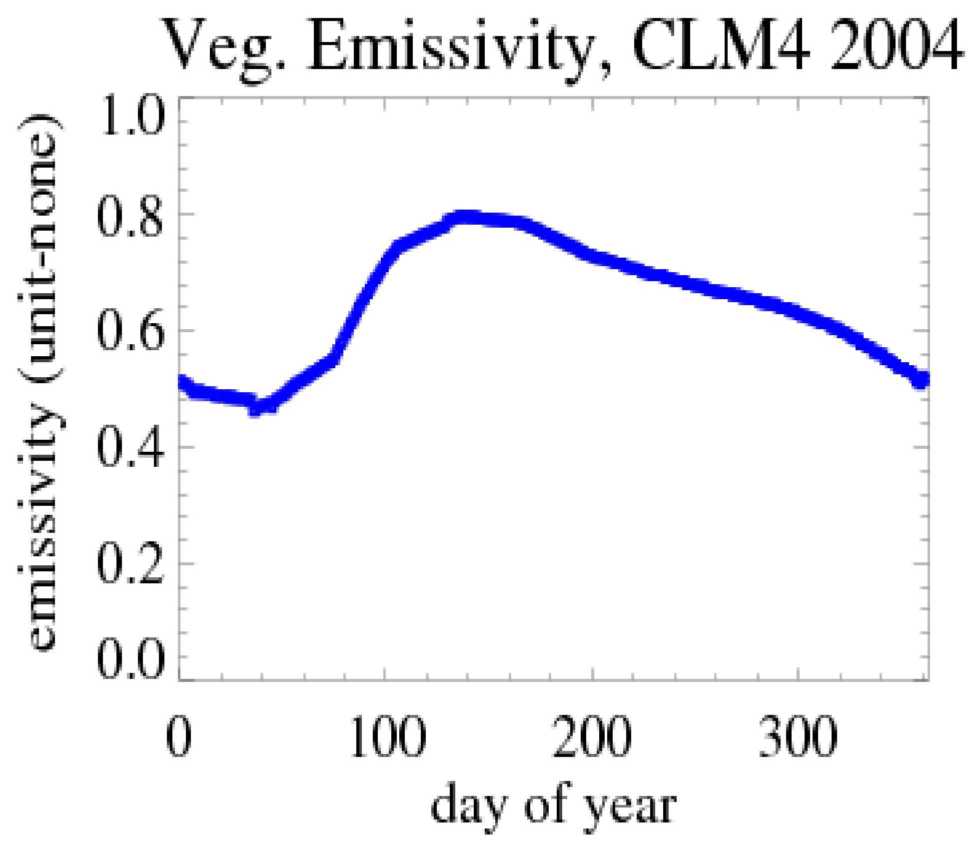
Application to Vegetation Canopy Emissivity

•The default algorithm

$$\varepsilon_v = 1 - e^{\frac{-(ELAI+ESAI)}{\mu}}$$

where μ = 1

•This algorithm does not take vegetation type into account.



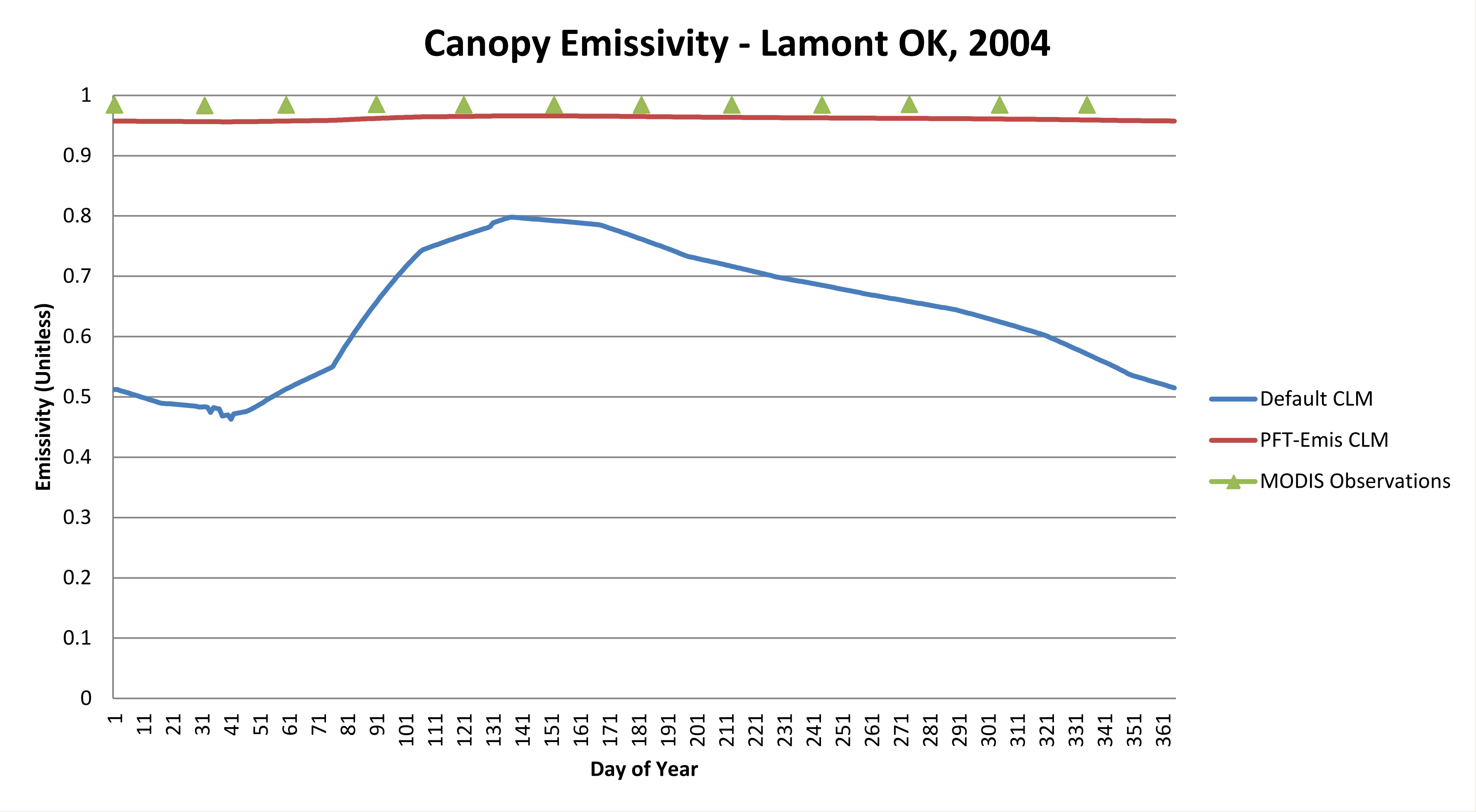
Application to Vegetation Canopy Emissivity

- Proposed changes to CLM4: Replace the current emissivity algorithm with an algorithm based on PFT, as well as a more reasonable variation based on ELAI and ESAI:

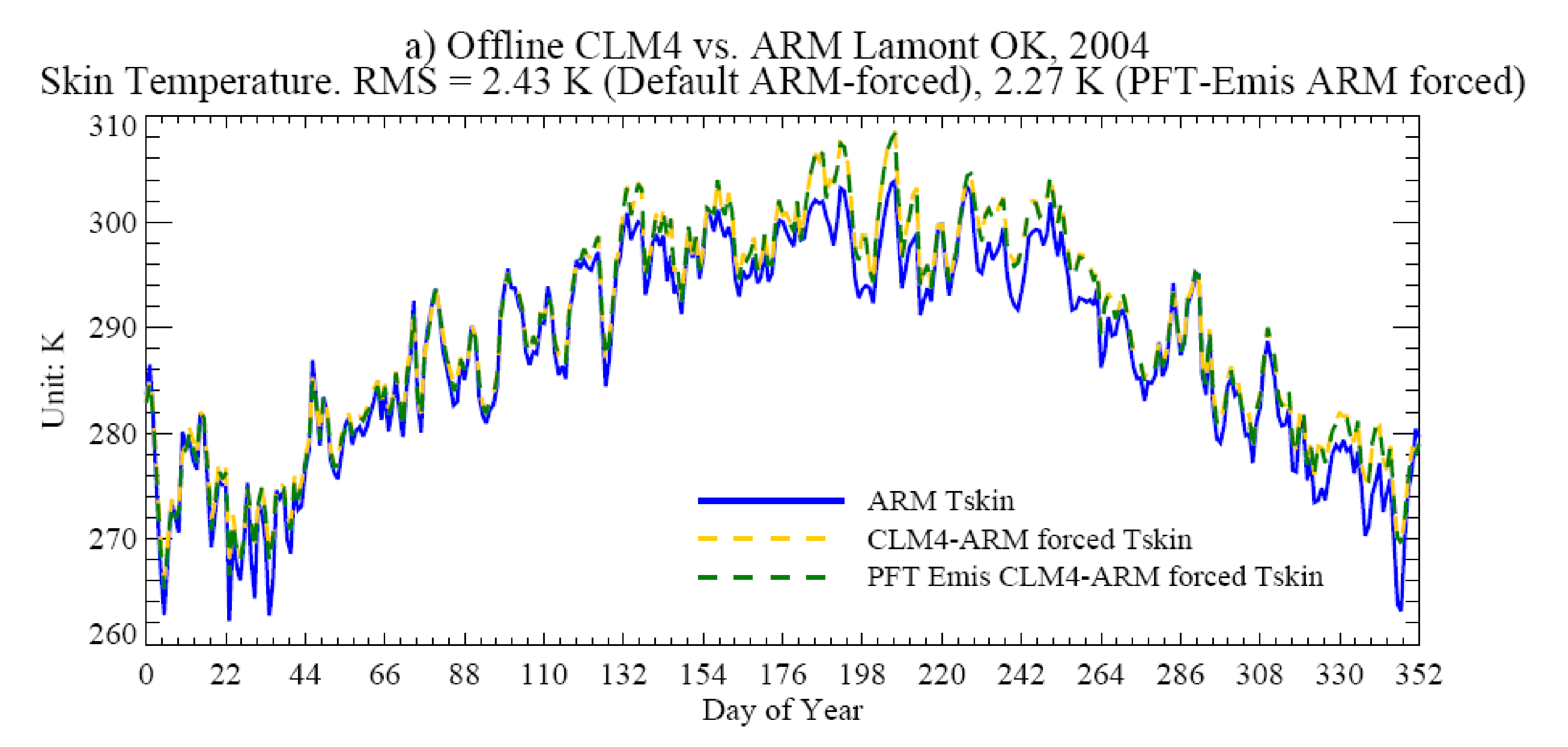
$$\varepsilon_V = \varepsilon_{PFT} - \delta\varepsilon * e^{\frac{-(ELAI+ESAI)}{\mu}}$$

Where ε_{pft} is determined through a literature review, and $\delta\varepsilon$ = 0.03 is from Olioso et al, 2007

Application to Vegetation Canopy Emissivity



Results: Lamont, OK



Errors over Lamont decrease an additional 0.17 K

Results

- Forcing is very critical for accurate simulating T_{skin}
- CLM4 overestimates T_{skin} at hourly, daily, and monthly scale. Nevertheless, in January, CLM4 overtimates T_{skin} minimum; in July, CLM4 overestimates maximum T_{skin}
- Albedo is underestimated year around. Albedo does not follow the change of rainfall and snowfall.
- Layer 3 is too try and layer 5 is too wet in spring and summer, but too try in winter
- Overestimated T_{skin} leads to overestimate T_{soil}

- CLM4 is useful on mnthly scale and relative changes

Thank You!

- Questions!