Evaluate Offline CLM4 Skin Temperature Simulation Using ARM Oklahoma Observations

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

(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 $T_{\text{skin}}$ CLM4 vs ARM OK

- Offline CLM4 overestimates $T_{\text{skin}}$

rms=4.2 K
Year 2003
RMS = 5.03 K
RMS $T_{\text{skin}} = 3.24$ K,
CLM4 vs. ARM Ok Daily average for year 2000
Monthly mean for 2004
RMS=2.53 K

Accuracy at monthly mean is better than at daily mean.
Monthly mean RMS=2.27 K

Off-line CLM4 vs. ARM Lamont OK, 2000 Monthly. ERR = 2.27K

Year 2000
What are the primary causes for this warm bias?

CAM/CESM

Offline atmosphere forcing

CLM

$\delta T_{\text{skin}}$

Sd
LWd
RH
Wind
Rainfall
T2m

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

LWdown CLM vs ARM

Tskin difference vs. LWdown difference
Remove large LDdown difference days, RMS $T_{\text{skin}}$ is reduced to 3.46 K.

Remove Sd and LWdown large difference days – rms $T_{\text{skin}}$ is reduced to 3.06 K.
What are the primary causes for this warm bias?

CAM/CESM

Offline atmosphere forcing

ΔT_{skin-sd} = 0.4 K
ΔT_{skin-LW} = 0.8 K

CLM

ΔT_{skin} = 4.2 K

S_d
LWd
RH
Wind
Rainfall
T2m

Albedo
LWup
Vegeation emissivity
SH
LH
G
CLM4 albedo is in general smaller than ARM observations.

Snow is not simulated.

Snow albedo is too low.

CLM4 Albedo

ARM Albedo

Surf ace Albedo, CLM4 vs. ARM OK, 2004

Rain
CLM4 leaf area index (ELAI), 08/2004
MODIS Daytime $T_{\text{skin}}$ (10:30 AM) vs. Enhanced Vegetation Index

MOIDIS observed OK site day time $T_{\text{skin}}$ and TLAI is only 0.2
Nighttime Tskin (10:30 PM) vs Enhanced vegetation index (MODIS)

MOIDIS observed OK site night time Tskin and TLAI is only 0.50
CLM $T_{\text{skin}}$ depends on LAI too much.
Vegetation Emissivity is in question

\[ e_v = 1 - \exp\left(-\frac{\text{elai} + \text{esai}}{\bar{\mu}}\right) \]
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

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

- ARM G = 17.2494 Wm⁻²
- CLM G = -5.61024 Wm⁻²
Daily averaged $G$

CLM has more $G$ than ARM
Monthly Mean G

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

RMS = 7.81027

Unit: Wm-2

Month of Year

ARM G
CLM4 G
## Offline CLM4

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual FGR (Wm-2)</th>
<th>Annual FGR12 (Wm-2)</th>
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<tr>
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<tr>
<td>2004</td>
<td>0.186</td>
<td>0.062</td>
</tr>
</tbody>
</table>

5-year average 0.325 0.031
Summary

Problem:

- CLM4 still overestimates $T_{\text{skin}}$ over OK site

Reasons identified, partly:

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

• Run Offline CLM4 using ARM forcing (CMBE-land)
  Hourly Sd direct, Sd diffuse
  LWd, T2m, RH, Precipitation, wind, pressure
  1999-2011
  CLM4 outputs: hourly

• Assess uncertainty $\delta T_{\text{skin}} = \delta(\text{forcing}, \text{albedo}, \text{LAI}, \text{etc})$,
• Understand to what extent CLM4 $T_{\text{skin}}$ is useful in climate research studies