Validation of CERES-derived MODIS Cloud Properties Using the ARM SGP data

X. Dong and B. Xi, University of North Dakota


Jay Mace, University of Utah
What’s new?

1. This is Edition 2 results, for low-level clouds (height <2.4 km), using a lapse-rate method, NOT ECMWF sounding.
2. Using ARM sounding for wind strip correction, NOT ECMWF sounding.
3. Using 10-km wide for wind strip, NOT 3-km.
4. The new MODIS results include different LWP/IWP and $\tau$ for water and ice clouds in mixed-phase clouds, respectively.
5. All cases in height/temp and microphysics are single-layer and overcast clouds.
Data Source and Average Methods

There are 3 data sets in the comparison

Surface:
DOE ARM measurements and retrievals averaged over a 1-hour interval centered at the time of the satellite overpass.

Satellite: Two approaches

Simpler: Average all pixels within a 30-km x 30-km area centered on the ARM SGP site

Complex:
Step 1: Parallax correction for off-nadir satellite views using surface-radar derived cloud top height and satellite VZA
Step 2: Cloud advection during \( \pm 30 \) min of satellite overpass the SGP with a 10-km wide strip using ARM sounding provided wind speed and direction.
What do we expect for cloud height/temp comparison from theoretical study?

Water Cloud Emittance

\[ \varepsilon(\text{Garrett}) = 1 - \exp(-0.7723 \tau_{\text{vis}}) \]
\[ \varepsilon(\text{Minnis}) = 1 - \exp(-0.463 (\tau_{\text{vis}}/u)^{1.041}) \]

Visible Optical Depth

Effective Emittance (\(\lambda=11\ \mu\text{m}\))

Ice Cloud Emittance

\[ \varepsilon(\text{Sassen}) = 1 - \exp(-0.511 \tau_{\text{vis}}) \]
\[ \varepsilon(\text{Minnis}) = 1 - \exp(-0.471 (\tau_{\text{vis}}/u)^{1.01}) \]

Visible Optical Depth

Effective Emittance (\(\lambda=11\ \mu\text{m}\))

(b) LWC=0.1, 0.2, 0.3, 0.4, 0.5

\[ \varepsilon(\text{Garrett}) = 1 - \exp(-0.1152 \times \text{LWC} \times \Delta Z) \]

Effective Emittance (\(\lambda=11\ \mu\text{m}\))

Cloud Thickness (m)

(c) LWC=0.1, 0.2, 0.3, 0.4, 0.5

\[ \varepsilon(\text{Sassen}) = 1 - \exp(-8.5 \times 10^{-5} (T+80^\circ\text{C}) \Delta Z) \]

Effective Emittance (\(\lambda=11\ \mu\text{m}\))

Cloud Thickness (km)

T=-10°C, -20°C, -30°C, -40°C, -50°C
Most MODIS heights are near surface cloud top
The lapse-rate results are much better than ECMWF sounding for low-level clouds.
NIGHT optically thick (NIGHT optically thick ($\texttt{tt} > 5$) cloud >5) cloud height and temp height and temp

Same as daytime comparison, excellent agreement
Nighttime optically thick clouds at the ARM SGP Site ($\tau > 5$)

**Height_10km_Wind_Strip**

- Top-Eff = 0.16, Std = 1.24
- Mean-Eff = -1.48, Std = 1.75

**Height_30x30 km²**

- Top-Eff = -0.01, Std = 1.08
- Mean-Eff = -1.56, Std = 1.52

**Temp_10km_Wind_Strip**

- Top-Eff = -1.5, Std = 7.8
- Mean-Eff = 9.1, Std = 10.4

**Temp_30x30 km²**

- Top-Eff = -0.2, Std = 6.9
- Mean-Eff = 9.8, Std = 9.2
Conclusion for optically thick cloud height and temp comparison

- Both day and night MODIS cloud height and temp agree very well with surface measurements.

- The excellent agreements in cloud height and temp comparison also suggest we should have a good agreement in cloud optical depth comparison.
MODIS $\tau$ agree to surface in 5%, $r_e$ and LWP are 20% lower than surface. New wind strip results have larger correlations than old
Nighttime stratus clouds at the ARM SGP Site (Nov. 2000 to Dec. 2001)

New wind strip results have much higher correlations than old results.
More than half of MODIS height (temp) are lower (higher) than surface base height (temp) due to overestimated MODIS cirrus $\tau$
Daytime optically thin clouds at the ARM SGP Site ($\tau < 5$)

**Height _10km_Wind_Strip**

![Graph (a)](image)

- Top-Eff = 2.88, Std = 1.86
- Mean-Eff = 1.93, Std = 2.05

**Height _30x30 km^2**

![Graph (c)](image)

- Top-Eff = 2.91, Std = 2.04
- Mean-Eff = 1.89, Std = 2.2

**Temp _10km_Wind_Strip**

![Graph (b)](image)

- Top-Eff = -21.4, Std = 12.2
- Mean-Eff = -14.1, Std = 13.6

**Temp _30x30 km^2**

![Graph (d)](image)

- Top-Eff = -21.7, Std = 13.7
- Mean-Eff = -14.0, Std = 14.9
Some of MODIS height are higher than surface cloud top, which are NOT due to overestimated $\tau$ and cannot explain
Nighttime optically thin clouds at the ARM SGP Site ($\tau <5$)

**Height 10km Wind Strip**

- Top-Eff = 0.81, Std = 1.96
- Mean-Eff = -0.16, Std = 1.97

**Height 30x30 km²**

- Top-Eff = 0.44, Std = 2.15
- Mean-Eff = -0.53, Std = 2.18

**Temp 10km Wind Strip**

- Top-Eff = -8.7, Std = 13.0
- Mean-Eff = -2.0, Std = 13.0

**Temp 30x30 km²**

- Top-Eff = -6.2, Std = 14.3
- Mean-Eff = 0.45, Std = 14.5
MODIS $r_e$ are 36% smaller, $\tau$ is 120% and IWP is 60% larger than Surface. New wind strip results have higher correlations than old.
Nighttime cirrus clouds at the ARM SGP Site (Nov. 2000 to Dec. 2001)

MODIS $r_e$ are doubled than its daytime counterpart, while surface $r_e$ are consistent. An internal check for MODIS day/night retrieval algorithms are necessary.
Summary

Excellent:
MODIS derived both day and night optically thick cloud height and temp, as well as optical depth.

Good: Need a slight effort in improvement
MODIS stratus $r_e$ and $LWP$ are about 20% lower than surface retrievals.

Fair: Need some effort in improvement
MODIS cirrus $r_e/\tau$/IWP have some improvement, but not enough, need more.

Poor: Need significant improvement
Both day and night MODIS optically thin cloud height and temp
Thanks for your attention!