Using CERES Observations to Help Correcting Cloud 3D Radiative Effects on MODIS AOT Retrieval in the Vicinity of Clouds: A Case Study

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Motivation:
• Help satellite studies of aerosol-cloud interactions
• Aerosol remote sensing near clouds is challenging
• Excluding areas near-cloud risks biases in aerosol data

from **MODIS**: 60% of all clear sky pixels are located 5 km or less from all clouds

from **CALIPSO**: 50% of all clear sky pixels are located 5 km or less from low clouds
Behavior is similar using either cloud mask
Daytime data over oceans during April 2007
3-D: MODIS vs. CALIPSO

MODIS: 3D enhancement

CALIPSO: no 3D enhancement
Simple Model for correction of 3D Radiative Effects

Inputs

- $\tau_m$ Rayleigh scattering
- $F_{NB}$ upward flux

CERES obs can help to get $F_{NB}$

Two-layer model

 années

$$R_{COR} = R_{MODIS} - \Delta R$$

$$\Delta R = \Delta R(\tau_m, F_{NB})$$

$\Delta R = 0$ if $F_{NB} = F_{NB\_clear}$

Marshak et al. (2008)
Application to Aqua MODIS
Plane-Parallel Bias

**NB and BB radiance**

- **Calculations NB (Wm$^{-2}$/sr)**
- **Observations NB (Wm$^{-2}$/μm/sr)**

Legend:
- **NB**
- **BB**
Linearity between NB and BB

\[y = 19.356 + 0.65396x \quad R = 0.99952\]

\[y = 7.7408 + 0.64398x \quad R = 0.99955\]
How Can CERES Help?

Assume

\[
\frac{F_{NB}^{obs}}{F_{BB}^{obs}} \approx \frac{F_{NB}^{mod}}{F_{mod}} \quad \text{or} \quad \frac{F_{BB}^{NB}}{F_{obs}^{NB}} \approx \frac{F_{BB}^{mod}}{F_{mod}} \cdot \frac{F_{NB}^{NB}}{F_{mod}}
\]

CERES

RT model \((\tau, f, r_e)\)
Correlated-k for BB
Ocean BRDF
Input from CERES
Consistency Check

Check the assumption for radiance

\[
\frac{F_{\text{obs}}^{NB}}{F_{\text{obs}}^{BB}} \approx \frac{F_{\text{mod}}^{NB}}{F_{\text{mod}}^{BB}}
\]

Radiance

- Red line: \[y = 8.768 + 0.62121x\]  \(R = 0.98709\)
- Blue line: \[y = 7.7408 + 0.64398x\]  \(R = 0.99955\)

BB (W/m\(^2\)/sr)

NB (W/m\(^2\)/\(\mu\)m/sr)
BB to NB Conversion

\[ F_{\text{obs}}^{NB} \approx \frac{F_{\text{obs}}^{BB}}{F_{\text{mod}}^{BB}} \cdot F_{\text{mod}}^{NB} \]
Application to Aqua MODIS

MODIS COD

Average(τ) = 9
Stddev(τ) = 9

MODIS Re

Average($R_e$) = 18 µm
Stddev($R_e$) = 5 µm
Albedo = $F_{\uparrow}/(F_0 \cdot \cos(\theta_0))$

$F_{\uparrow}$ Derived

Average AOT ~0.13
Original vs corrected AOT

Original (0.47μm)

Corrected (0.47μm)

\[ \Delta \tau > 0.05 \]
Original vs corrected AOT

Less corrections at longer wavelengths
Original vs corrected AOT

Less corrections at longer wavelengths
Original vs corrected AOT

Original vs Corrected AOT

- 0.47 μm
- 0.66 μm
- 0.86 μm
- 2.13 μm
• CERES observations can be used to correct MODIS AOT retrievals for cloud 3D radiative effects.

• Larger corrections (0.05-0.1) are for shorter wavelength.

• Corrections for longer wavelengths (e.g., 0.86 and 2.13 microns) are small.

• Validation of the correction algorithm is needed.
1D model underestimates upward flux for optically thin and overestimate upward flux for large optically thick clouds.
Modeled upward SW flux for water clouds $\theta_0=45^\circ$.

**Loeb et al., 2005**
Broadband and Narrowband ADMs

\[ \text{ADM} = \pi I/F \]

\[ \tau = 4 \]

\[ \tau = 20 \]

CERE Flux cannot be directly used since \( \text{ADM(BB)} \neq \text{AMD(NB)} \)