Testing the Two-Layer Model for Correcting Clear Sky Reflectance Near Clouds

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**Executive Summary**

A two-layer model (2LM) was developed in our earlier studies to estimate the clear sky reflectance enhancement due to cloud-molecular radiative interaction at MODIS at 0.47 μm. Recently, we extended the model to include cloud-surface and cloud-aerosol radiative interactions. We use the LES/SHDOM simulated 3D true radiation fields to test the 2LM for reflectance enhancement at 0.47 μm. We find:

- The simple model captures the viewing angle dependence of the reflectance enhancement near cloud, suggesting the physics of this model is correct.
- The cloud-molecular interaction alone accounts for 70% of the enhancement.
- The cloud-surface interaction accounts for 16% of the enhancement.
- The cloud-aerosol interaction accounts for additional 13% of the enhancement.

We conclude that the 2LM is simple to apply and unbiased.

**SHDOM Simulations**

- 26 fields (cloud liquid water content and relative humidity) were simulated using the UCLA large eddy simulation (LES) model.
- Combined 26 LES cumulus fields with 40 GEOS-5 aerosol profiles to make 80 cloud-aerosol scene (20 km x 20 km x 15 km).
- Radiance were simulated using SHDOM at 500 m MODIS resolution with 23 viewing direction appropriate for MODIS Aqua.
- MOD04 cloud masking procedure is applied to select "good" pixels. There are 100188 "good" pixels in all 80 cloud scenes, and number of "good" 10 km x 10 km boxes is 3154.

**Two-Layer Model**

1. **Cloud-molecular interactions**

   - Rayleigh layer
   - Broken cloud layer

   \[ \Delta \alpha = \text{radiance reflected from broken cloud field with a scattering Rayleigh layer above it minus that purely due to extinction (non-scattered).} \]

2. **Cloud-surface interactions**

   We use a fast Monte Carlo scheme for Poisson model of broken clouds to compute 3D cloud induced diffuse flux. The cloud-surface induced enhancement is the surf leaving radiance with atmospheric extinction.

3. **Cloud-aerosol interactions**

   We introduce an effective molecular optical depth that includes aerosols \( \tau_{\text{aer}} = \tau_c + \epsilon \tau_r \) for the 2LM, where \( \epsilon \) depends on scattering phase function and single scattering albedo. For given aerosol optical depth in LES data, we find \( \epsilon \) empirically such that the total error in 2LM is nearly zero.

**Compare 2LM with Truth**

- Left: Compare the 2LM (cloud-molecular interactions) with the truth for given VZA.
- Right: Similar to the left but for all data points. The averages and standard deviations are presented. The 2LM underestimate the truth by 25%.

**Viewing Angle Dependence**

- Left: LES simulated cloud optical depth field with mean (standard deviation) and cloud fraction indicated.
- Below: The 2LM (black) captures the viewing angle dependence of the truth. Though the error for each individual box can be large (50%), on the average, the error is about 20%.

**Reflectance Enhancement**

- Reflectance enhancement.
- "good" 10 km x 10 km boxes is 3154.
- There are 100188 "good" pixels in all 80 cloud scenes, and number of "good" 10 km x 10 km boxes is 3154.

- Reflectance Enhancement

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