Derivation, Validation and Use of the CERES/TRMM ADMs

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April 1, 2004, NCAR
Outline

1. Introduction

2. CERES/TRMM Shortwave ADMs

3. SW TOA Flux Validation

4. How do ADM Errors Affect Geostationary Regional Mean TOA Flux Accuracy?
Instantaneous Fluxes at TOA and Angular Distribution Models

CERES Radiance Measurement

\[ L(\theta_o, \theta, \phi) \]

TOA Flux Estimate

\[ F(\theta_o) = \int_0^{2\pi} \int_0^{\frac{\pi}{2}} L(\theta_o, \theta, \phi) \cos \theta \sin \theta \, d\theta \, d\phi \]

\[ F(\theta_o) \]

Satellite

SW

LW

WN
Instantaneous Fluxes at TOA and Angular Distribution Models

TOA flux estimate from CERES radiance:

\[
\hat{F}(\theta_o, \theta, \phi) = \frac{\pi L(\theta_o, \theta, \phi)}{R_j(\theta_o, \theta, \phi)}
\]

where,

\[
R_j(\theta_o, \theta, \phi) = \frac{\pi \bar{L}_j(\theta_o, \theta, \phi)}{\int_0^{2\pi} \int_0^{\pi} \bar{L}_j(\theta_o, \theta, \phi) \cos \theta \sin \theta \, d\theta \, d\phi}
\]

\(R_j(\theta_o, \theta, \phi)\) is the Angular Distribution Model (ADM) for the “jth” scene type.
CERES TRMM
• Based on 9 months of CERES (68 RAP; 9 Alongtrck; 192 Xtrck).
• Tropics only (38°S-38°N).
• 10-km spatial resolution at nadir.
• Precessing orbit => Samples all local times in 46 days (23 days at equator).
• Up to 592 scene types (203 actually sampled).

CERES Terra
• Based on two years of CERES RAP+FAP+Alongtrack.
• Global.
• 20-km spatial resolution at nadir.
• 10:30 a.m. sun-synchronous orbit => Strong correlation between solar zenith angle and latitude.
• Scene types are continuous functions of MODIS-based cloud properties.
### Scene Types for CERES/TRMM SW ADMs

<table>
<thead>
<tr>
<th>ADM Category</th>
<th>Scene Type Stratification</th>
<th>Actual Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clear</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean</td>
<td>- 4 Wind Speed Intervals</td>
<td>4</td>
</tr>
<tr>
<td>Land</td>
<td>- 2 IGBP Type Groupings</td>
<td>2</td>
</tr>
<tr>
<td>Desert</td>
<td>- Bright and Dark</td>
<td>2</td>
</tr>
<tr>
<td>Snow</td>
<td>- Theoretical</td>
<td>1</td>
</tr>
<tr>
<td><strong>Cloud</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean</td>
<td>- Liquid and Ice</td>
<td>62 (L)</td>
</tr>
<tr>
<td></td>
<td>- 12 Cloud Fraction Intervals</td>
<td>53 (I)</td>
</tr>
<tr>
<td></td>
<td>- 14 Optical Depth Intervals</td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>- 2 IGBP Type Groupings</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>- Liquid and Ice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 5 Cloud Fraction Intervals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 6 Optical Depth Intervals</td>
<td></td>
</tr>
<tr>
<td>Desert</td>
<td>- Bright and Dark Deserts</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>- Liquid and Ice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 5 Cloud Fraction Intervals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 6 Optical Depth Intervals</td>
<td></td>
</tr>
<tr>
<td>Snow</td>
<td>- Theoretical</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>203</td>
</tr>
</tbody>
</table>
Land and Desert IGBP Type Groupings

Albedo Rank

Albedo (%)

Mod-to-High Tree/Shrub Covg

Low-to-Mod Tree/Shrub Covg

Bright Desert

Dark Desert

Land and Desert IGBP Type Groupings
ADM Scene Surface Types
SW ADM Frequency of Occurrence by Cloud Fraction & Cloud Optical Depth (Ocean)

Liquid Water Clouds

Ice Clouds
CERES SW ADM Angular Bin Definitions

\( \theta_o \): 9 angular bins (0° to 90° in 10° steps)
\( \theta \): 9 angular bins (0° to 90° in 10° steps)
\( \phi \): 10 angular bins (0° to 180° in 10° or 20° steps)
CERES ADMs
(Overcast Ice Clouds; $\theta_o=60^\circ$-$70^\circ$)

$\tau < 1$  
$\tau > 50$

SW Anisotropic Factor ($R$)
Overview

Angular Distribution Models

ADM Version Summary

Validation Results

Publications

Conferences

Inversion Production Code

Current Research

Relevant Links

Responsible NASA Official: Dr. Bruce A. Wielicki
Web Curator: Dr. K. Loukachine K.Loukachine@larc.nasa.gov
SW TOA Flux Validation

- Does mean all-sky flux depend on viewing geometry?

- Comparisons with Direct Integration Fluxes:
  - Solar zenith angle dependence (SW)
  - Latitudinal dependence
  - Regional fluxes

- Instantaneous Flux Uncertainties
  - Use alongtrack data to examine consistency of incident fluxes from the same scene
All-Sky Albedo: Solar Zenith Angle = 20° - 30°
ADM Mean Regional Flux Biases ($\theta < 50^\circ$)

**ERBE-Like – DI Flux Difference**

**SSF Ed2 – DI Flux Difference**

Flux Difference (W m$^{-2}$)
ADM Mean Regional Flux Biases ($\theta < 70^\circ$)

ERBE-Like – DI Flux Difference

SSF Ed2 – DI Flux Difference

Flux Difference (W m$^{-2}$)
Instantaneous TOA Flux Error by Cloud Property

Liquid Water Clouds

SW Flux Error (W m$^{-2}$)

- Red: ERBE-Like
- Blue: SSF

Cloud Optical Depth

Ice Clouds

Ice Cloud Optical Depth

LW Flux Error (W m$^{-2}$)

Cloud Infrared Emissivity

(c)

LW Flux Error (W m$^{-2}$)

Cloud Infrared Emissivity

(d)
How do ADM Errors Affect Geostationary Regional Mean TOA Flux Accuracy?
GGEO Dataset

- 3-hourly imager data from geostationary satellites (GOES, GMS, Meteosat).

- GEO imagers’ calibration tied to VIRS.

- Cloud retrieval is a subset of CERES VIRS algorithm.

- **Parameters**: cloud phase, cloud fraction, cloud optical depth, cloud-top temperature, cloud base and top heights, cloud emissivity.

- GGEO data provided over 1°x1° latitude-longitude regions.
All-Sky Albedo: Solar Zenith Angle = 20° - 30°

ERBE-Like

SSF Edition 2

Albedo

Viewing Zenith Angle (°)

- 0° - 10°; φ=170° - 180°
- 10° - 30°; φ=150° - 170°
- 30° - 50°; φ=130° - 150°
- 50° - 70°; φ=110° - 130°
- 30° - 50°; φ= 90° - 110°

Average
Direct Integration

Viewing Zenith Angle (°)

- 0° - 10°; φ=170° - 180°
- 10° - 30°; φ=150° - 170°
- 30° - 50°; φ=130° - 150°
- 50° - 70°; φ=110° - 130°
- 30° - 50°; φ= 90° - 110°

Average
Direct Integration
TOA Flux Error Analysis for GEO Angular Sampling

Region 43577 (Lat=-31.7; Long=-163.96) December 2, 2002

∆F_{24h} = 1.1 W m^{-2}
TRMM ADM DI ERRORS + GEO Sampling (December 2002)

Mean: -0.17  
RMS: 0.76
Mean
RMS
Bias  RMS
-1.37    2.21

SW TOA Flux Error (W m^{-2})
Theoretical Simulation of TOA Flux Errors

- End-to-end simulation of CERES/TRMM ADM development and application using a theoretical radiance database instead of actual CERES radiances.

9 Months of Instantaneous CERES + VIRS/TRMM viewing geometry and cloud property data (i.e., $\theta_o$, $\theta$, $\phi$; cld phase, $f$, $\tau_c$; lat/long,...)

+ Look-up tables of theoretical radiances as a function of $\theta_o$, $\theta$, $\phi$; cld phase, $f$, $\tau_c$; lat/long,...

9 months of simulated CERES/TRMM radiance data with corresponding “true” fluxes

- Construct theoretical CERES ADMs using above dataset with same code used to develop actual CERES ADMs.
- Compare ADM-derived TOA fluxes with “truth” as provided in dataset.
- Assess errors for different satellite sampling patterns.
  (e.g., CERES/TRMM; CERES/Terra; GEO, GERB...)
Theoretical Simulation: TRMM ADM ERRORS + GEO Sampling (December 2002)

Error due to thick overcast ice clouds at overhead sun. Undersampled by TRMM.

Error due to thick broken ice cloud at 1°x1° scale. Undersampled by 10-km CERES/TRMM.

Mean RMS Bias 0.36 2.00
Theoretical Simulation: TRMM ADM ERRORS + GEO Sampling (December 2002)
Conclusions

- For GEO, CERES/TRMM ADMs are more appropriate than CERES/Terra ADMs due to better solar zenith angle sampling.

- However, TRMM is restricted to 38°S – 38°N.

- Expect larger TOA flux uncertainties over snow and sunglint.

- No significant viewing zenith angle dependent biases, in contrast with ERBE ADMs.

- Caution when using CERES/TRMM ADMs for scenes that were poorly sampled by CERES/TRMM (e.g., thick broken ice clouds).