Validation of CERES/TRMM SSF Edition 2 Angular Distribution Models

Norman G. Loeb\textsuperscript{1}, Natividad Manalo-Smith\textsuperscript{2}, Konstantin Loukachine\textsuperscript{4}, Seiji Kato\textsuperscript{1}, Yongxiang Hu\textsuperscript{3}

\textsuperscript{1}Hampton University, \textsuperscript{2}AS&M, \textsuperscript{3}NASA LaRC, \textsuperscript{4}SAIC
Outline

- TOA Flux/ADM Production Schedule
- Recent Changes to SSF
- CERES ADM Types and Web Page
- SW Flux Validation
- LW and WN Flux Validation
## TOA Flux Production Schedule

1. **August 2001**
   - Delivery of SSF Edition 2 SW, LW & WN ADMs. ✓
   - Prepare SSF Edition 2 validation results. ✓

2. **September 2001**
   - Begin production of CERES/TRMM Edition 2 SSFs. ✓

3. **October 2001 – March 2002**
   - Preparation of 2-3 manuscripts for publication summarizing TRMM ADMs and validation results. ×
   - Begin developing CERES/Terra ADMs. ×
Recent Changes to SSF (to appear in SSF Edition 2)

- Include all CERES footprints that have at least 1 VIRS pixel coverage (independent of whether imager data is bad).
  => User’s should carefully check SSF parameters: “percent imager coverage (SSF-54)” and “cloud property extrapolation over cloudy area (SSF-63)”.

- Retain clear scenes over “hot” desert and land with saturated VIRS channel 4 radiances.
  - Use CERES WN brightness temperature threshold to identify clear scenes over very hot surfaces.

- Changed units of window (WN) unfiltered radiance and TOA flux from W m⁻² µm⁻¹ to W m⁻².
  - WN unfiltered radiance & flux is defined over 8.1 - 11.8 µm wavelength interval.
CERES Inversion Group Home Page

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 Flux & Albedo Estimation from ADMs

**Reflectance (isotropic albedo):**

\[ r(\theta_o, \theta, \phi) = \frac{\pi I(\theta_o, \theta, \phi)}{\cos \theta o S_o} \]

\((I(\theta_o, \theta, \phi) = \text{measured radiance})\)

**Instantaneous Flux & Albedo Estimates:**

\[ \hat{F} = \frac{\pi I(\theta_o, \theta, \phi)}{R_j(\theta_o, \theta, \phi)} \quad \hat{A} = \frac{r(\theta_o, \theta, \phi)}{R_j(\theta_o, \theta, \phi)} \]

where,

\[ R_j(\theta_o, \theta, \phi) = \text{SW Anisotropic Factor} \]

\[ R_j(\theta_o, \theta, \phi) = \frac{\bar{r}_j(\theta_o, \theta, \phi)}{A_j(\theta_o)} = \frac{\bar{r}_j(\theta_o, \theta, \phi)}{\pi^{-1} \int_0^{2\pi} \int_0^{\frac{\pi}{2}} \bar{r}_j(\theta_o, \theta, \phi) \cos \theta d\theta d\phi} \]
CERES SW ADM Angular Bin Definitions

\[ \theta_0 : \text{9 angular bins (0° to 90° in 10° steps)} \]
\[ \theta : \text{9 angular bins (0° to 90° in 10° steps)} \]
\[ \phi : \text{10 angular bins (0° to 180° in 10° or 20° steps)} \]
## Scene Types for CERES/TRMM SW ADMs

<table>
<thead>
<tr>
<th>ADM Category</th>
<th>Scene Type Stratification</th>
<th>Actual Total</th>
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<tbody>
<tr>
<td><strong>Clear</strong></td>
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<td></td>
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<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>
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</tr>
<tr>
<td></td>
<td>- 6 Optical Depth Intervals</td>
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<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>
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</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>
SW ADM Frequency of Occurrence by Cloud Fraction & Cloud Optical Depth (Ocean)

Liquid Water Clouds

Ice Clouds
Land and Desert IGBP Type Groupings

- Bright Desert
- Dark Desert
- Low-to-Mod Tree/Shrub Covg
- Mod-to-High Tree/Shrub Covg

Albedo Rank

Albedo (%)

Albedo (%) vs. Albedo Rank graph with groupings for different IGBP types.
ADM Scene Surface Types
Clear Land and Desert ADMs: $\theta_o=30^\circ$ - $40^\circ$

Mod-Hi Tree/Shrub Covg

Low-Mod Tree/Shrub Covg

Dark Desert

Bright Desert

Anisotropic Factor

Anisotropic Factor
Clear Ocean ADMs: $\theta_o=30^\circ$-40°

- Low Wind Speed
- Moderate Wind Speed
- High Wind Speed
- All Wind Speeds
Clear Ocean TOA Flux From CERES

• Define ADMs for 4 discrete wind speed intervals (m s⁻¹):
  < 3.5;  3.5 - 5.5;  5.5 - 7.5;  > 7.5

• Estimate instantaneous flux/albedo using ADM:

\[
\hat{A} = \frac{r(\theta_o, \theta, \phi)}{R_j(w_k, \theta_o, \theta, \phi)}
\]

• Account for aerosol optical depth variations theoretically

\[
\hat{A}' = \hat{A}\left(\frac{R^{th}(w_k, I^{avg})}{R^{th}(w_k, I^{obs})}\right)
\]

where \(R^{th}(w_k, I^{obs})\) is a theoretical anisotropic factor inferred from an instantaneous observation and \(R^{th}(w_k, I^{avg})\) is determined from the average radiance used to construct the ADM class.
Clear Ocean Fluxes: Edition 2 vs Edition 1 Flux
Direct Radiative Effect vs Aerosol Optical Depth

Direct Radiative Effect of Aerosols vs Latitude
(9 Months CERES/TRMM)

Loeb and Kato, 2001 (J. Climate, submitted)
Ocean Cloud ADMs, $f = 99.9 - 100$, Ice, $\theta_o = 60 - 70^\circ$
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
CERES SW ADM Angular Bin Definitions

θ₀ : 9 angular bins (0° to 90° in 10° steps)
θ : 9 angular bins (0° to 90° in 10° steps)
φ : 10 angular bins (0° to 180° in 10° or 20° steps)
All-Sky Albedo: Solar Zenith Angle = 0° - 10°

ERBE-Like

SSF Edition 2

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
All-Sky Albedo: Solar Zenith Angle = 10° - 20°

ERBE-Like

SSF Edition 2

Albedo

Viewing Zenith Angle (°)

Average
Direct Integration
All-Sky Albedo: Solar Zenith Angle = 20° - 30°

ERBE-Like

SSF Edition 2

Albedo

Viewing Zenith Angle (°)

Albedo

Viewing Zenith Angle (°)

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

Average

Direct Integration

http://eosweb.larc.nasa.gov
All-Sky Albedo: Solar Zenith Angle = 30° - 40°

ERBE-Like

SSF Edition 2

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
All-Sky Albedo: Solar Zenith Angle = 40° - 50°

ERBE-Like

SSF Edition 2

Albedo

Viewing Zenith Angle (°)

<table>
<thead>
<tr>
<th>Albedo</th>
<th>Viewing Zenith Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>-80 -60 -40 -20 0 20 40 60 80</td>
</tr>
<tr>
<td>0.20</td>
<td>0.22 0.24 0.26 0.28 0.30 0.32</td>
</tr>
<tr>
<td>0.24</td>
<td>0.26 0.28 0.30 0.32</td>
</tr>
</tbody>
</table>

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

- SSF Edition 2: φ = 0° - 10°; φ = 170° - 180°
- φ = 10° - 30°; φ = 150° - 170°
- φ = 30° - 50°; φ = 130° - 150°
- φ = 50° - 70°; φ = 110° - 130°
- φ = 30° - 50°; φ = 90° - 110°

Average Direct Integration
All-Sky Albedo: Solar Zenith Angle = 50° - 60°

ERBE-Like Viewpoint Zenith Angle (°) -80 -60 -40 -20 0 20 40 60 80

Albedo
0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36

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

Average
Direct Integration

SSF Edition 2

Albedo
0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36

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

Average
Direct Integration
All-Sky Albedo: Solar Zenith Angle = 60° - 70°

ERBE-Like

SSF Edition 2

Albedo

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

Average
Direct Integration

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
All-Sky Albedo: Solar Zenith Angle = 70° - 80°

ERBE-Like

SSF Edition 2

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
All-Sky Albedo: Solar Zenith Angle = 80° - 90°

ERBE-Like

SSF Edition 2

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
Flux Bias Definitions

- ADM mean flux bias in angular bin \((\theta_o, \theta_j, \phi_k)\):
  \[
  \Delta(\theta_o, \theta_j, \phi_k) = F_{ADM}(\theta_o, \theta_j, \phi_k) - F_{DI}(\theta_o)
  \]

- Footprint-weighted ADM mean flux bias:
  \[
  \Delta_\Omega(\theta_o) = \frac{1}{n_k n_j} \sum_{k=1}^{n_k} \sum_{j=1}^{n_j} \Delta(\theta_o, \theta_j, \phi_k) w_j
  \]
  where \(w_j\) is a weighting factor accounting for the relative effect of different viewing zenith angles on gridded time-averaged fluxes. \(n_k\) and \(n_j\) are the number of relative azimuth and viewing zenith angle bins.

- Standard deviation in footprint-weighted ADM flux bias:
  \[
  \sigma_\Omega(\theta_o) = \sum_{k=1}^{n_k} \sum_{j=1}^{n_j} \frac{[\Delta(\theta_o, \theta_j, \phi_k) - \Delta(\theta_o)]^2}{(n_k n_j - 1)} w_j
  \]
  \(\Rightarrow\) measure of consistency in ADM mean flux estimate from individual viewing directions.
Crosstrack Incidence of Regional Mean VZAs
One Month of CERES Data
Footprint-Weighted All-Sky Mean Albedo and Flux Bias vs $\theta_o$

For $\theta < 50$:
- Albedo Bias
- Flux Bias (W m$^{-2}$)

For $\theta < 70$:
- Albedo Bias
- Flux Bias (W m$^{-2}$)

Graphs show data for ERBE-Like and SSF Edition 2 datasets.
Solar Zenith Angle Relative Frequency
(40°S - 40°N; March 1998)
Tropical ADM Mean Flux Bias
(Footprint-Weighted; March 1998 Solar Zenith Angle Sampling)

<table>
<thead>
<tr>
<th>(W m(^{-2}))</th>
<th>ERBE-Like</th>
<th>SSF Edition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>θ-Range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(θ &lt; 50^\circ)</td>
<td>Mean ((ΔΩ))</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Std ((σ_Ω))</td>
<td>-2.7</td>
</tr>
<tr>
<td><strong>θ &lt; 70°</strong></td>
<td>0.50</td>
<td>5.6</td>
</tr>
</tbody>
</table>
All-Sky Flux Difference ($\theta < 50^\circ$)

ERBE-Like – DI Flux Difference

SSF Ed2 – DI Flux Difference

Latitude (°)

Solar Zenith Angle (°)

W m$^{-2}$

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
All-Sky Flux Difference ($\theta < 70^\circ$)

ERBE-Like – DI Flux Difference

SSF Ed2 – DI Flux Difference

Latitude (°)

Solar Zenith Angle (°)

W m$^{-2}$
Solar Zenith Angle Distribution by Latitude (March 1998)
Latitudinal ADM Mean Flux Bias
(March 1998 Solar Zenith Angle Sampling)

θ < 50

θ < 70

Flux Bias (W m\(^{-2}\))

Flux Bias Std. Dev. (W m\(^{-2}\))
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$^{-2}$)
ADM Mean Flux Biases over $20^\circ \times 20^\circ$ Regions  
(March 1998 Solar Zenith Angle Sampling)  
($W \text{ m}^{-2}$) 

<table>
<thead>
<tr>
<th>$\theta$-Range</th>
<th>ERBE-Like</th>
<th>SSF Edition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$</td>
<td>$\sigma_\Delta$</td>
<td>$\Delta$</td>
</tr>
<tr>
<td>$\theta &lt; 50^\circ$</td>
<td>-2.8</td>
<td>1.5</td>
</tr>
<tr>
<td>$\theta &lt; 70^\circ$</td>
<td>0.35</td>
<td>0.74</td>
</tr>
<tr>
<td>CERES GOAL</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
ERBE-Like – SSF Ed2 SW Flux Difference vs Cloud Optical Depth
(Ocean Ocean; $\theta_o = 42^\circ - 44^\circ; \theta < 25^\circ$)
Albedos For Deep Convective Clouds: New ADMs vs Hu

Distribution Function

Tc_std_lt_4.5K_sza_lt_60_stat

- T < 220K, Hu
- T < 220K, Loeb
- T < 205K, Hu
- T < 205K, Loeb
Instantaneous Albedo Errors from CERES Alongtrack Data

Albedo Dispersion Parameter:

\[ D_A = \frac{C_A}{A} \times 100\% \]
Clear Ocean Alongtrack Albedo Consistency Check

Average Dispersion (%)

- CERES SSF = 2.2
- CERES ES8 = 8.8
- Lambertian = 16.9
Dark Desert

SSF Ed2 Albedo Dispersion (%) vs. ERBE-Like Albedo Dispersion (%)

Bright Desert

SSF Ed2 Albedo Dispersion (%) vs. ERBE-Like Albedo Dispersion (%)

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
Preliminary Instantaneous TOA SW Flux Uncertainties
\( (\mu_0 E_0 = 1000 \text{ W m}^{-2}) \)

Scene Type
- Clr Oce
- M/H T/S
- L/M T/S
- Dark Des
- Bright Des
- Ovc
- Ocean

Flux Uncertainty (W m\(^{-2}\))

ERBE-Like
CERES SSF Ed2
LW and WN TOA Flux Validation

- Does mean all-sky flux depend on viewing geometry?
- Comparisons with Direct Integration Fluxes:
  - Regional fluxes
  - Latitudinal flux dependence
- Flux consistency as a function of cloud and clear-sky parameters.
TOA LW & WN Flux Estimation from Satellite

**Flux:**

\[ M = 2\pi \int_{0}^{\pi/2} L(\theta) \cos \theta \sin \theta \, d\theta \]

\[ L(\theta) = \text{Measured Radiance} \]

**Instantaneous Flux Estimate:**

\[ \hat{M} = \frac{\pi L(\theta)}{R(\theta)} \]

\[ R(\theta) = \text{LW Anisotropic Factor} \]
### Scene Types for CERES/TRMM LW and WN ADMs

<table>
<thead>
<tr>
<th>ADM Category</th>
<th>Parameter Stratification</th>
<th>Total</th>
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<tbody>
<tr>
<td>Clear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean</td>
<td>3 Precipitable Water</td>
<td>12</td>
</tr>
<tr>
<td>Ocean</td>
<td>4 Vertical Temperature Change</td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>3 Precipitable Water</td>
<td>36</td>
</tr>
<tr>
<td>Land</td>
<td>4 Vertical Temperature Change</td>
<td></td>
</tr>
<tr>
<td>Desert</td>
<td>3 Precipitable Water</td>
<td>36</td>
</tr>
<tr>
<td>Desert</td>
<td>4 Vertical Temperature Change</td>
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</tr>
<tr>
<td>Desert</td>
<td>3 Surface Emissivity</td>
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<td>Desert</td>
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<tr>
<td>Broken Cloud Field</td>
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<tr>
<td>Ocean/Land/Desert</td>
<td>3 Precipitable Water</td>
<td>288 (O)</td>
</tr>
<tr>
<td>Ocean/Land/Desert</td>
<td>6 $\Delta T$ (Sfc-Cloud)</td>
<td></td>
</tr>
<tr>
<td>Ocean/Land/Desert</td>
<td>4 IR Emissivity</td>
<td>288 (L)</td>
</tr>
<tr>
<td>Ocean/Land/Desert</td>
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<td></td>
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<tr>
<td>Ocean/Land/Desert</td>
<td></td>
<td>288 (D)</td>
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<tr>
<td>Overcast</td>
<td>3 Precipitable Water</td>
<td>108</td>
</tr>
<tr>
<td>Overcast</td>
<td>6 $\Delta T$ (Sfc-Cloud)</td>
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</tr>
<tr>
<td>Overcast</td>
<td>6 IR Emissivity</td>
<td></td>
</tr>
</tbody>
</table>
OVERCAST LW ADM

Precipitable Water: 2.57 - 4.63

ΔT = 0.0 - 13.9

ΔT = 13.9 - 28.5

ΔT = 28.5 - 42.6

ΔT = 42.6 - 56.0

ΔT = 56.0 - 64.9

ΔT > 64.9

IR Emissivity

ADM

View Zenith Angle
OVERCAST LW ADM

Precipitable Water: 4.63 - 10.00
Mean LW Flux vs Viewing Zenith Angle (Jan-Mar 1998)

Daytime

Nighttime

- ERBE-like
- Edition 2
- Direct Integration

Mean Flux (Wm$^{-2}$)

View Zenith Angle

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
Mean LW Flux vs Viewing Zenith Angle (Jun-Aug 1998)

Daytime

Nighttime

- Edition 2
- Direct Integration

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
Daytime LW ADM Mean Regional Flux Biases ($\theta < 50^\circ$)
(Jan, Feb, Mar 1998)

ERBE-Like – DI Flux Difference

SSF Ed2 – DI Flux Difference

Flux Difference (W m$^{-2}$)
Daytime LW ADM Mean Regional Flux Biases ($\theta < 50^\circ$) (Jun, Jul, Aug 1998)

ERBE-Like – DI Flux Difference

SSF Ed2 – DI Flux Difference

Flux Difference (W m$^{-2}$)
Daytime LW ADM Mean Regional Flux Biases ($\theta < 70^\circ$) (Jan, Feb, Mar 1998)

- ERBE-Like – DI Flux Difference
- SSF Ed2 – DI Flux Difference

Flux Difference (W m$^{-2}$)
Daytime LW ADM Mean Regional Flux Biases ($\theta < 70^\circ$)
(Jun, Jul, Aug 1998)

ERBE-Like – DI Flux Difference

SSF Ed2 – DI Flux Difference

Flux Difference (W m$^{-2}$)
Latitudinal ADM Mean Flux Bias
January – March 1998 (RAPS–DAY)

June – August 1998 (RAPS–DAY)
# ADM Regional LW Flux Biases: Daytime

(10° × 10° regions; Jan-March 1998)

(W m⁻²)

<table>
<thead>
<tr>
<th>θ-Range</th>
<th>ERBE-Like</th>
<th>SSF Edition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Δ</td>
<td>σ_Δ</td>
</tr>
<tr>
<td>θ &lt; 50°</td>
<td>3.7</td>
<td>1.9</td>
</tr>
<tr>
<td>θ &lt; 70°</td>
<td>0.67</td>
<td>0.60</td>
</tr>
<tr>
<td>CERES GOAL</td>
<td>0</td>
<td>0.5</td>
</tr>
</tbody>
</table>
### ADM Regional LW Flux Biases: Daytime
(10°×10° regions; Jun-Aug 1998)
(W m⁻²)

<table>
<thead>
<tr>
<th>θ-Range</th>
<th>ERBE-Like</th>
<th>SSF Edition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Δ</td>
<td>σₐ</td>
</tr>
<tr>
<td>θ &lt; 50°</td>
<td>3.5</td>
<td>2.2</td>
</tr>
<tr>
<td>θ &lt; 70°</td>
<td>0.64</td>
<td>0.68</td>
</tr>
<tr>
<td>CERES GOAL</td>
<td>0</td>
<td>0.5</td>
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</table>
Nighttime LW ADM Mean Regional Flux Biases
(Jan, Feb, Mar 1998)

SSF Ed2 – DI Flux Difference ($\theta < 50^\circ$)

SSF Ed2 – DI Flux Difference ($\theta < 70^\circ$)
Nighttime LW ADM Mean Regional Flux Biases
(Jun, Jul, Aug 1998)

SSF Ed2 – DI Flux Difference ($\theta < 50^\circ$)

SSF Ed2 – DI Flux Difference ($\theta < 70^\circ$)
SSF Edition 2 ADM Regional LW Flux Biases: **Nighttime**
(10° × 10° regions)
(W m⁻²)

<table>
<thead>
<tr>
<th>θ-Range</th>
<th>Jan-Mar</th>
<th>Jun-Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ &lt; 50°</td>
<td>Δ 0.66</td>
<td>σ₉ 1.5</td>
</tr>
<tr>
<td></td>
<td>Δ 0.46</td>
<td>σ₉ 2.0</td>
</tr>
<tr>
<td>θ &lt; 70°</td>
<td>0.45</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>0.52</td>
<td>0.36</td>
</tr>
</tbody>
</table>

**CERES GOAL**

|          | 0       | 0.5     |
|          | 0       | 0.5     |
Mean WN Flux vs Viewing Zenith Angle (Jan-Mar 1998)

Daytime

Nighttime
Mean WN Flux vs Viewing Zenith Angle (Jun-Aug 1998)

Daytime

Nighttime

- Edition 2
- Direct Integration
WN ADM Monthly Mean Regional Flux Biases
(Jan, Feb, Mar 1998)

SSF Ed2 – DI Flux Difference ($\theta < 50^\circ$)

SSF Ed2 – DI Flux Difference ($\theta < 70^\circ$)
WN ADM Monthly Mean Regional Flux Biases (Jun, Jul, Aug 1998)

SSF Ed2 – DI Flux Difference ($\theta < 50^\circ$)

SSF Ed2 – DI Flux Difference ($\theta < 70^\circ$)
### SSF Edition 2 ADM Regional WN Flux Biases: Daytime

(10°×10° regions)

(W m⁻²)

<table>
<thead>
<tr>
<th>θ-Range</th>
<th>Jan-Mar</th>
<th>Jun-Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Δ</td>
<td>σ_Δ</td>
</tr>
<tr>
<td>θ &lt; 50°</td>
<td>0.48</td>
<td>0.79</td>
</tr>
<tr>
<td>θ &lt; 70°</td>
<td>0.07</td>
<td>0.27</td>
</tr>
<tr>
<td>CERES GOAL</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
### SSF Edition 2 ADM Regional WN Flux Biases: Nighttime

*(10° × 10° regions)*

*(W m⁻²)*

<table>
<thead>
<tr>
<th>θ-Range</th>
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<th>Jun-Aug</th>
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<tbody>
<tr>
<td>Δ</td>
<td>σ₄Δ</td>
<td>Δ</td>
</tr>
<tr>
<td>θ &lt; 50°</td>
<td>0.34</td>
<td>0.66</td>
</tr>
<tr>
<td>θ &lt; 70°</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>CERES GOAL</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
ERBE-Like – SSF Ed2 LW Flux Difference vs Cloud Emissivity
(Overcast; Ocean; $\theta < 25^\circ$; 90 days)

Liquid Water Clouds

Ice Clouds
LW Flux Difference \[F(\theta < 20) - F(\theta > 50)] \text{ vs Precipitable Water (20°S – 20°N)}

**All-Sky Ocean**

- ERBE-Like
- SSF Ed2

**Clear Ocean**

- ERBE-Like
- SSF Ed2
Overcast Ocean (20°S – 20°N)

LW Flux Diff vs Precip Water

Cld Eff Temp Diff vs Precip Water

\[ F(\theta < 20) - F(\theta > 50) \text{ (W m}^{-2}\text{)} \]

\[ \text{T}_{\text{eff}}(\theta < 20) - \text{T}_{\text{eff}}(\theta > 50) \text{ (K)} \]

precipitable water (cm)

ERBE-Like

SSF Ed2

Distributed by the Atmospheric Science Data Center
http://eosweb.larc.nasa.gov
Overcast Ocean (20S - 20N)

Solid Symbols : $\theta < 20^\circ$
Hollow Symbols: $\theta > 50^\circ$

Precipitable Water (cm)

Cloud Effective Temperature (K)

LW Flux (W m$^{-2}$)
SSF Ed2 LW Flux As Function of Cloud Effective Temperature and Emissivity
(Overcast Liquid Water Clouds over Ocean; 20S - 20N)

Solid Symbols : $\theta < 20^\circ$
Hollow Symbols: $\theta > 50^\circ$
SSF Ed2 LW Flux As Function of Cloud Effective Temperature and Emissivity
(Overcast Ice Clouds over Ocean; 20S - 20N)

Cloud Effective Temperature (K)

Cloud Emissivity

Flux (W m\(^{-2}\))

220 225 230 235 240 245 250

120 140 160 180 200 220 240

Solid Symbols : $\theta < 20^\circ$
Hollow Symbols: $\theta > 50^\circ$
Summary and Conclusions

- CERES/TRMM SSF Edition 2 Status:
  • SW, LW & WN ADMs have been delivered.
  • Production of Edition 2 SSFs to begin week of September 24th.
  • Archival requires:
    (i) Science Team approval and
    (ii) Quality Summary

- Recent Changes to SSF:
  • Include all CERES footprints with any VIRS coverage.
  • Include footprints over hot land and desert for which VIRS IR radiance saturates.
  • Change units of window channel unfiltered radiance & TOA flux to W m⁻².

- SW TOA Flux Validation:

• SSF Ed2 SW fluxes show less dependence on viewing geometry than ERBE-Like (≲ 10% for ES8; ≈ 2% SSF).

• CERES goal for regional mean flux accuracy (1σ < 1 W m⁻²) is attained provided full viewing zenith angle coverage < 70° is used. For θ < 50 °, 1σ error is 1.4 W m⁻².

• Near-nadir cloudy-sky SSF Ed2 fluxes larger than ERBE-Like at small optical depths and smaller at large cloud optical depths (differences up to ±75 W m⁻² for θ₀ ≈ 43°).

• First estimates of instantaneous flux uncertainties from alongtrack measurements: < 10 W m⁻² for clear scenes; ~20 W m⁻² for overcast.

=> Further study needed with multiple CERES instruments.
- LW and WN TOA Flux Validation:

- SSF Ed2 LW fluxes show less dependence on viewing geometry than ERBE-Like (9 W m\(^{-2}\) for ES8; 1.5 W m\(^{-2}\) for Ed2).

- CERES goal for regional mean LW flux accuracy (1\(\sigma\) < 0.5 W m\(^{-2}\)) is almost reached. 1\(\sigma\) error is \(\approx\) 0.56 W m\(^{-2}\) during daytime.

- Nighttime LW flux shows a 0.5 W m\(^{-2}\) mean bias with 1\(\sigma\) of \(\approx\) 0.4 W m\(^{-2}\).

- WN 1\(\sigma\) flux error is 0.3 W m\(^{-2}\). Nighttime WN flux bias is 0.25 W m\(^{-2}\).

- Near-nadir cloudy-sky SSF Ed2 LW fluxes are smaller than ERBE-Like at small emissivity but comparable for emissivity close to 1.0 (differences at small \(\varepsilon\) up to 25 W m\(^{-2}\)).

- SSF Ed2 LW flux errors as a function of precip water are a factor of 3-4 smaller than ERBE-Like.
Future Work (Terra)

- Increase angular resolution of ADMs.
- Land SW ADMs stratified by vegetation index.
- Empirical SW, LW and WN ADMs over snow.
- Use of multi-CERES instruments for instantaneous flux errors.
- Determine flux errors by cloud type, cloud and clear-sky parameters.
- Improve theoretical tools for ADM development and comparisons between observations and theory.