Edition 4 Longwave Angular Distribution Models

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Background on LW flux retrieval

• Flux retrievals are related to the anisotropic factors $R_j$ for each scene type $j$ by

\[ F = \frac{\pi I_{\text{obs}}}{R_j(\theta)} , \]

where $I_{\text{obs}}$ is the observed radiance and $\theta$ is the viewing zenith angle.

• $R_j$ is related to the average LW radiance $\bar{I}_j$ and modeled LW flux $F_j$ by

\[ R_j(\theta) = \frac{\pi \bar{I}_j(\theta)}{F_j} = \frac{\pi \bar{I}_j(\theta)}{2\pi \sum_k \bar{I}_j(\theta_k) \cos(\theta_k) \sin(\theta_k) \Delta \theta_k} \]
Normalized RMS calculated for each 1x1 grid cell

Note: results are not necessarily applicable to fluxes!

\[
RMS = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left( \frac{I_i^m}{\bar{I}^m} - \frac{I_i^o}{\bar{I}^o} \right)^2}
\]
Clear Land, Ocean, Desert Scenes

- In Edition 2, average anisotropic factor is calculated for a given precipitable water (< 1 cm, 1-3 cm, 3-5 cm, 5+ cm), surface temperature (< 270 K, 270-290 K, 290-310 K, 310-330 K, 330+ K), lapse rate (< 15 K, 15-30 K, 30-45 K, 45+ K over the lowest 300 hPa) and surface type (ocean, forests, savannas, grasslands, dark desert, bright desert).

- Edition 4 uses 10 surface temperature categories and interpolates between surface temperature bins when possible.

RMS = 1.8 %

High RMS where $T_s=290$ K

RMS = 1.8 %
Edition 4 (10 $T_s$ bins and interpolation) Reduces Jul 2000 Daytime Normalized RMS (%)
Clouds over Land, Ocean, Desert: Pseudoradiance

• An empirical relationship between $\psi$ (pseudoradiance) and radiance is determined for each VZA, PW, $T_{sfc}$, $\Delta T_{sc}$, and f bin (Loeb et al. 2005). $\Psi$ is given by

$$
\psi = (1 - f)\varepsilon_s B(T_s) + \sum_{j=1}^{2} [\varepsilon_s B(T_s)(1 - \varepsilon_{c_j}) + \varepsilon_{c_j} B(T_{c_j})]f_j
$$
Polynomial fit vs. Interpolation

- As an alternative, we simply use the mean radiance (if there is one) for each $1 \, W \, m^{-2} \, sr^{-1}$ interval of $\Psi$, and using a linear interpolation between bin centers. When the mean radiance does not exist, the polynomial fit is used as a backup.
Edition 4 SSFs with Updated Edition 2 ADMs
Jan 2001 Cloudy-sky Daytime Normalized RMS (%)
Edition 4 SSFs with Edition 4 ADMs
Jan 2001 Cloudy-sky Daytime Normalized RMS (%)
Edition 4 SSFs with Updated Edition 2 ADMs
Jan 2001 Cloudy-sky Nighttime Normalized RMS (%)
Edition 4 SSFs with Edition 4 ADMs
Jan 2001 Cloudy-sky Nighttime Normalized RMS (%)
Edition 4 SSFs with Edition 4 ADMs
Jan 2001 Daytime # of samples with $\Delta T_{sc} > 85K$
Edition 4 SSFs with Edition 4 ADMs
Jan 2001 Nighttime # of samples with $\Delta T_{sc} > 85K$
Clouds over snow

• Previously, average radiance was calculated for a given cloud fraction and snowy surface type (permanent snow, sea ice, fresh snow), with two surface temperature categories.

• Now, basic idea is to use Edition 4 pseudoradiance formulation for scenes with snowy surfaces:

\[
\psi = (1 - f) \varepsilon_s B(T_s) + \sum_{j=1}^{2} \left[ \varepsilon_s B(T_s)(1 - \varepsilon_{c_j}) + \varepsilon_{c_j} B(T_{c_j}) \right] f_j
\]
New Results with Ed 4 data

Jan 2003 Aqua daytime – new pseudoradiance method

Avg RMS = 1.5% perm snow, 2.1% all snow types

Jan 2003 Aqua daytime – scene type method (Ed2)

Avg RMS = 3.6% perm snow
New Results with Ed 4 data

Jul 2003 Aqua daytime – new pseudoradiance method

Avg RMS = 2.3% perm snow, 3.0 % overall

Jul 2003 Aqua daytime – scene type method (Ed2)

RMS = 3.3% perm snow
Summary of Changes

• Clear Sky Land, Desert, Ocean: Edition 4 has additional $T_s$ bins; interpolation is performed between bins.

• Cloudy Sky Land, Desert, Ocean: Instead of a polynomial fit between pseudoradiance $\Psi$ and radiance, the mean radiance for each 1 W m$^{-2}$ sr$^{-1}$ interval of $\Psi$ is used. In addition, there are now 5 cloud fraction bins (0.1-25%, 25-50%, 50-75%, 75-99.9%, overcast).
Summary of Changes (2)

• Clear Sky Permanent Snow, Sea Ice, Fresh Snow: Edition 4 has additional $T_s$ bins; interpolation is performed between bins.

• Cloudy Sky Permanent Snow, Sea Ice, Fresh Snow: Instead of an ADM for a few $T_s$, $\Delta T_{sc}$, and cloud fraction bins, the Edition 4 pseudoradiance approach is used.
Daytime LW flux change between Ed3 and Ed4

200410:FM4 LW flux Ed4: LW=245.3 Wm$^{-2}$

200410:FM4 LW flux Diff (Ed4−Ed3): ΔLW=0.4 Wm$^{-2}$

200410:FM4 ΔLW (Ed4S/Ed2A−Ed3S/Ed2A): ΔLW=−0.1 Wm$^{-2}$

200410:FM4 ΔLW (Ed4S/Ed4A−Ed4S/Ed2A): ΔLW=0.5 Wm$^{-2}$

10/29/13
Ed 4 vs Ed2 ADM comparison ($\Psi=91.5$)

PW=1-3 cm, Overcast, Ts=280-285 K, DTsc=20-25 K, Psi=91.5

Anisotropic Factor

Ed2 ADM

Ed4 ADM

VZA
Nighttime LW flux change between Ed3 and Ed4

200410:FM4 LW flux Ed4: mean LW=236.6 Wm$^{-2}$

200410:FM4 $\Delta$LW (Ed4−Ed3): $\Delta$LW = −0.0 Wm$^{-2}$

200410:FM4 $\Delta$LW (Ed4S/Ed2A−Ed3S/Ed2A): $\Delta$LW = −0.3 Wm$^{-2}$

200410:FM4 $\Delta$LW (Ed4S/Ed4A−Ed4S/Ed2A): $\Delta$LW = 0.3 Wm$^{-2}$
Ocean Daytime – Jan, Apr, Jul, Oct 2010

Blue, black, red bars mean CERES-MODIS cloud fraction is in lower, same, or higher category, respectively.
Ocean Nighttime

**Calipso-CloudSat Clear (0.020)**

- Frequency
- CERES-MODIS Cloud Fraction (Percent)
- CLR 0.1-25 25-50 50-75 75-99.9 OVC

**Calipso-CloudSat CF=0.1-25% (0.072)**

- Frequency
- CERES-MODIS Cloud Fraction (Percent)
- CLR 0.1-25 25-50 50-75 75-99.9 OVC

**Calipso-CloudSat CF=25-50% (0.072)**

- Frequency
- CERES-MODIS Cloud Fraction (Percent)
- CLR 0.1-25 25-50 50-75 75-99.9 OVC

**Calipso-CloudSat CF=50-75% (0.072)**

- Frequency
- CERES-MODIS Cloud Fraction (Percent)
- CLR 0.1-25 25-50 50-75 75-99.9 OVC

**Calipso-CloudSat CF=75-99.9% (0.108)**

- Frequency
- CERES-MODIS Cloud Fraction (Percent)
- CLR 0.1-25 25-50 50-75 75-99.9 OVC

**Calipso-CloudSat Overcast (0.657)**

- Frequency
- CERES-MODIS Cloud Fraction (Percent)
- CLR 0.1-25 25-50 50-75 75-99.9 OVC
Land Nighttime

Calipso-CloudSat Clear (0.090)

Calipso-CloudSat CF=0.1-25% (0.099)

Calipso-CloudSat CF=25-50% (0.045)

Calipso-CloudSat CF=50-75% (0.045)

Calipso-CloudSat CF=75-99.9% (0.064)

Calipso-CloudSat Overcast (0.658)
Permanent Snow Daytime

Calipso-CloudSat Clear (0.306)

Calipso-CloudSat CF=0.1-25% (0.088)

Calipso-CloudSat CF=25-50% (0.043)

Calipso-CloudSat CF=50-75% (0.038)

Calipso-CloudSat CF=75-99.9% (0.048)

Calipso-CloudSat Overcast (0.476)
Backup slides
Global monthly mean flux difference between Ed4 and Ed3

- Annual mean SW flux increases 0.8 Wm\(^{-2}\)
- Annual mean daytime LW flux increases 0.2 Wm\(^{-2}\)
- Annual mean nighttime LW flux decrease 0.1 Wm\(^{-2}\)

**Global monthly mean flux diff (Ed4–Ed3) for Terra FM1 2002**

**Global monthly mean flux diff (Ed4–Ed3) for Aqua FM4 2004**

- Annual mean SW flux increases 1 Wm\(^{-2}\)
- Annual mean daytime LW flux increases 0.4 Wm\(^{-2}\)
- Annual mean nighttime LW flux is essentially unchanged
Cloudsat-CALIPSO and Ed 4 CERES-MODIS Cloud Masks for Ocean scenes for 2010

Daytime: 67.7% CF on target, 27.9% CF too low, 4.4% CF too high

Nighttime: 64.5% on target, 31.5% CF too low, 4.0% CF too high
Cloudsat-CALIPSO and Ed 4 CERES-MODIS Cloud Masks for Land scenes for 2010

Daytime: 52.6% CF on target, 44.6% CF too low, 2.8% CF too high

Nighttime: 54.6% on target, 40.9% CF too low, 4.5% CF too high
Cloudsat-CALIPSO and Ed 4 CERES-MODIS Cloud Masks for Permanent Snow scenes for 2010

Daytime: 53.3% CF on target, 35.6% CF too low, 11.1% CF too high

Nighttime: 38.2% on target, 51.9% CF too low, 9.9% CF too high
Daytime Cloud property difference between Ed3 and Ed4

200410:FM4 Cloud fraction Ed4: mean $f = 65.3\%$

200410:FM4 Cloud fraction diff (Ed4–Ed3): $\Delta f = 3.6\%$

200410:FM4 Cloud $\tau$ for Ed4: mean $\tau = 3.7$

200410:FM4 Cloud $\tau$ diff (Ed4–Ed3): $\Delta \tau = 0.2$
Nighttime Cloud property difference between Ed3 and Ed4

200410:FM4 Cloud fraction Ed4: mean $f=70.0\%$

200410:FM4 Cloud fraction diff (Ed4–Ed3): $\Delta f=9.3\%$

200410:FM4 Cloud $\tau$ for Ed4: mean $\tau=2.6$

200410:FM4 Cloud $\tau$ diff (Ed4–Ed3): $\Delta \tau=-0.7$