FM1 and FM2 Edition3 Spectral Darkening Correction & Validation

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Edition3 Studies

- Spectral response degradation in SW channel
  - determine time-dependent “optimal” SRFs from Direct Compare approach
  - incorporate temporally varying SRFs in the SW measurements (implemented in spectral unfiltering algorithm)

- Divergence between daytime and nighttime OLR records with time
Instrument operating in RAPS mode drops in SW response relative to instrument operating in cross-track mode.
Strategy for Characterizing Spectral Degradation
(Direct Nadir Radiance Comparison)

• Assume any temporal variation in FM2/FM1 SW unfiltered radiance ratio is caused by changes in spectral response function (SRF) only.

• Assume SRF changes occur only when instrument is in RAP mode.

• Compare spatially/temporally matched nadir FM1 and FM2 footprint radiance pairs (Clear ocean shows largest sensitivity to RAPS spectral darkening).

• Apply gains to Xtrack and RAP instruments.

• For instrument in Xtrack mode, unfilter with previous month’s SRF.

• From a set of candidate SRFs with varying degrees of spectral darkening, retrieve RAP SRF that ensures constant SW unfiltered FM2/FM1 radiance ratio throughout the mission.
Spectral degradation function similar to that observed in other missions (e.g. GOME, LDEF)
Spectral darkening increases with shorter wavelengths.
Plot shown is only a subset of the 53 “candidate” SRFs.
Approximate Relationship between Spectral Darkening Parameter and SW Radiance Changes since BOM

Relative Change from BOM (%) vs. $\alpha$

- Clear Ocean
- DCC
SW Degradation Parameter, $\alpha$, Derived from Clear and All-sky Ocean Direct Compare Method

![Graph showing the SW Degradation Parameter, $\alpha$, over time for Clear Ocean and All-sky Ocean conditions.]
Alpha Retrieval Results

**FM1**

- 30.00 Mar 00
- 15.60 Sep 00
- 10.50 Oct 00
- 9.86 Aug 01
- 9.50 Apr 01
- 8.70 Sep 01
- 8.00 Oct 01

**FM2**

- 30.00 Mar 00
- 14.60 May 00
- 12.75 Jun 00
- 11.20 Jul 00
- 10.10 Nov 00
- 9.00 Dec 00
- 9.30 Sep 01
- 8.80 Mar 01
- 9.00 Aug 01
- 8.80 May 02
- 8.00 Aug 02
- 7.40 Mar 03
- 6.95 Jun 03
- 6.75 Dec 03
- 6.30 Aug 04
- 5.90 May 05
- 5.50 Oct 05
- 5.10 Feb 06
- 4.70 Aug 06
- 4.30 May 07
- 3.90 Oct 07

**Spectral Degradation**

**Wavelength**
FM2/FM1 SW Unfiltered Radiance Ratio for Clear Sky Scenes

- **Ed1.CV** and **BOM(new)** SRF – no attempt to correct for spectral darkening
- Simple model works for all scene types.
FM2/FM1 SW Unfiltered Radiance Ratio for All Sky Scenes
CERES & SeaWiFS Comparison
(All-Sky Ocean; 30°S-30°N)

![Graph showing CERES FM1 Ed3 SW TOA Flux and SeaWiFS PAR (times -6.286)]

- **CERES FM1 Ed3 SW TOA Flux**
- **SeaWiFS PAR (times -6.286)**

**Year**

- CERES Anom Minus SeaWiFS Anom: $-0.106 \pm 0.2$ Wm$^{-2}$ per decade
- **CERES Variability (1\(\sigma\)) = 0.79 Wm$^{-2}$**
- **SeaWiFS Variability (1\(\sigma\)) = 0.76 Wm$^{-2}$**
- $\sigma$(CERES - SeaWiFS) = 0.21 Wm$^{-2}$

- **Shows consistent calibration stability at < 0.3 Wm$^2$ per decade (95% conf)**
SW TOA Flux

(FM1; Clear-Sky; Ocean)

30°S-30°N

-0.075 ± 0.16 Wm⁻² per decade
0.203 ± 0.15 Wm⁻² per decade

Global

-0.340 ± 0.24 Wm⁻² per decade
-0.0196 ± 0.23 Wm⁻² per decade
SW TOA Flux
(FM1; All-Sky; All Surfaces)

30°S-30°N

-0.581 ± 0.82 Wm^{-2} per decade
0.243 ± 0.77 Wm^{-2} per decade

Global

-1.264 ± 0.55 Wm^{-2} per decade
-0.405 ± 0.52 Wm^{-2} per decade
Tropical Mean : LW Day Night Difference Trends

Data Set:
- LW Unfiltered Radiance
- Nadir
- 20N - 20S
- Tropical Ocean
- All-Sky

Edition 1-CV

Edition 2

~1.0% per decade (Terra)

In Final Testing
Tropical Mean Day – Night Flux Difference

(FM1; 30S-30N; Ocean Only)

Includes:
- time-dependent SW gain, SRF changes.
- time-dependent (monthly) TOT and WN gain changes.

Daytime minus Nighttime TOA Flux Difference (Wm^-2)

Year

FM1 Zonal Averages of Unfiltered Radiance
for All-Sky Ocean (30S – 30N)

Includes:
- Time-Dependent SW gain
  and SRF changes
- Time-dependent TOT and
  WN gain changes
LW Day Night Difference Trends

\[
\text{LW}_{\text{day}} = \text{Total} - \text{Shortwave} \\
\text{LW}_{\text{night}} = \text{Total}
\]

• Apply Total and WN gains.

• With SW spectral darkening compensated for by selected SW optimal SRFs, select Total SRF from a “candidate” set of SRFs that eliminates monthly offsets from Beginning of Mission (BOM).
Determining the Optimal Total SRF with $\Delta LW$ and $\Delta WN$ Unfiltered Radiances

![Graph showing the relationship between Daytime-Nighttime LW and Daytime-Nighttime WN for different months and values of $\alpha$.]
Global Daytime and Nighttime LW TOA Flux
(FM1; All-Sky; All Surfaces)

Edition 2

Daytime: $-0.73 \pm 1.3 \text{ Wm}^{-2} \text{ per decade}$
Nighttime: $2.0 \pm 0.86 \text{ Wm}^{-2} \text{ per decade}$
D-N: $-2.73 \pm 0.41 \text{ Wm}^{-2} \text{ per decade}$

Edition 3

Daytime: $1.25 \pm 0.69 \text{ Wm}^{-2} \text{ per decade}$
Nighttime: $0.85 \pm 0.55 \text{ Wm}^{-2} \text{ per decade}$
D-N: $0.40 \pm 0.41 \text{ Wm}^{-2} \text{ per decade}$
LW TOA Flux
(FM1; Edition3; All-Sky; All Surfaces)

30°S-30°N

Year

0.425 ± 0.69 Wm\(^{-2}\) per decade
0.691 ± 0.64 Wm\(^{-2}\) per decade
D-N: -0.266 ± 0.27 Wm\(^{-2}\) per decade

Global

Year

0.753 ± 0.44 Wm\(^{2}\) per decade
0.572 ± 0.36 Wm\(^{2}\) per decade
D-N: 0.180 ± 0.24 Wm\(^{2}\) per decade
Summary

• Direct Compare method to select time-dependent ‘optimal’ SRFs was implemented to characterize spectral darkening. Application of monthly SRFs to all scene types removed SW degradation trend.

• There are no significant day night differences after Total channel optimal SRFs are applied.

• Excellent agreement between CERES and SeaWiFS anomaly trends in the tropical region.
BACK-UP SLIDES
Edition2 Calibration Studies

Residual calibration errors in CERES Edition2 data products are dominated by spectral degradation of sensor optics in the reflected solar bands (SW and SW/TOT)

- Decreasing trend in the reflected solar measurements
- Divergence between daytime and nighttime LW fluxes with time
FM1 Zonal Average (16S – 16N) for Ocean

Daytime minus Nighttime LW

Daytime minus Nighttime WN

Includes:
- time-dependent SW gain,
  SRF changes.
- time-dependent (monthly)
  TOT and WN gain changes.
FM1 Zonal Averages of Unfiltered Radiances for All-Sky Ocean (30S – 30N) for March 2007
Determining the Optimal Total SRF with $\Delta L$ and $\Delta W_n$ Unfiltered Radiances