Surface-Only Flux Algorithms Working Group Report

David P. Kratz¹, Shashi K. Gupta², Anne C. Wilber², Victor E. Sothcott², and P. Sawaengphokhai²

¹NASA Langley Research Center
²Science Systems and Applications, Inc.

Joint CERES, GERB and SCARAB Earth Radiation Budget Workshop
(Twenty Second CERES-II Science Team Meeting)

Toulouse, France
7 October 2014
Background (Part 1)

CERES uses several surface-only flux algorithms to compute SW and LW surface fluxes in conjunction with the detailed model used by SARB. These algorithms include:

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model B</th>
<th>Model C</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPSA/LPLA:</td>
<td>SW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Langley</td>
<td>Clear</td>
<td>Li et al.</td>
<td>LPSA</td>
</tr>
<tr>
<td>Parameterized</td>
<td>All-Sky</td>
<td>--</td>
<td>LPSA</td>
</tr>
<tr>
<td>SW/LW Algorithm</td>
<td>LW</td>
<td>Clear</td>
<td>Inamdar and Ramanathan</td>
</tr>
<tr>
<td></td>
<td>All-Sky</td>
<td>--</td>
<td>LPLA</td>
</tr>
</tbody>
</table>

SOFA References:

Background (Part 2)

- The SOFA LW and SW Models are based on rapid, highly parameterized TOA-to-surface transfer algorithms to derive the surface fluxes.

- LW Models A and B and SW Model A were incorporated at the start of the CERES project.

- SW Model B was adapted for use in the CERES processing shortly before the launch of the CERES instrument on the TRMM satellite.

- The Edition 2B LW and SW surface flux results underwent extensive validation (See: Kratz et al. 2010).

- The ongoing validation process has already led to improvements to the LW models (Gupta et al., 2010).

- LW Model C (Zhou et al., 2007) was introduced into the Edition 4 processing to maintain two independent LW algorithms after a broadband LW Channel was chosen to replace the CERES Window Channel for the CERES FM-6 and the follow-on Radiation Budget Instrument (RBI).

- LW and SW Models B were incorporated into the FLASHFlux effort to produce a rapidly available Environmental Data Record (see Kratz et al., 2014)
Recent and Future Improvements to the Surface-Only Flux Algorithms

**SW Model Improvements:**
1) Replacing the ERBE albedo maps with Terra maps greatly improved the SW retrievals, most notably for polar regions.
2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al. (1999) model significantly improved SW surface fluxes for clear conditions.
3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4.
4) Using a revised empirical coefficient in the cloud transmission formula has improved the SW surface fluxes for partly cloudy conditions.
5) Work continues on the improvement of the cloud transmission method for the new Edition 4 clouds.

**LW Model Improvements:**
1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010).
2) Limiting the inversion strength to -10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

**SW and LW Model Improvements:**
1) The availability of ocean buoy measurements is expected to allow for improved surface flux retrievals by providing validation over ocean regions.

---

### Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

<table>
<thead>
<tr>
<th>Dataset</th>
<th>CERES 2B</th>
<th>CERES 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear-Sky TOA albedo</td>
<td>48 month ERBE</td>
<td>70 month Terra</td>
</tr>
<tr>
<td>Terra</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear-Sky TOA albedo</td>
<td>46 month Terra</td>
<td>70 month Terra</td>
</tr>
<tr>
<td>Aqua</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear-Sky Surf. albedo</td>
<td>46 month Terra</td>
<td>70 month Terra</td>
</tr>
<tr>
<td>TOA to Surface albedo</td>
<td>Instantaneous</td>
<td>Monthly average</td>
</tr>
<tr>
<td>transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cos (sza) dependence of</td>
<td>LPSA</td>
<td>Briegleb-type</td>
</tr>
<tr>
<td>Surface Flux</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud Algorithm Terra</td>
<td>Terra Ed2</td>
<td>Terra/Aqua Ed4</td>
</tr>
<tr>
<td>Cloud Algorithm Aqua</td>
<td>Aqua Ed2</td>
<td>Terra/Aqua Ed4</td>
</tr>
<tr>
<td>SW aerosol dataset</td>
<td>WCP-55</td>
<td>MATCH/OPAC</td>
</tr>
<tr>
<td>Rayleigh Treatment</td>
<td>Original LPSA</td>
<td>Bodhaine et al (1999), JAOT</td>
</tr>
<tr>
<td>Ozone Range Check</td>
<td>0 to 500 DU</td>
<td>0 to 800 DU</td>
</tr>
<tr>
<td>Twilight cutoff</td>
<td></td>
<td>New</td>
</tr>
<tr>
<td>Cloud transmission</td>
<td>0.80</td>
<td>0.75</td>
</tr>
<tr>
<td>empirical coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LW high temperature</td>
<td>No</td>
<td>Maximum Lapse Rate</td>
</tr>
<tr>
<td>surface correction</td>
<td></td>
<td>10K/100hPa</td>
</tr>
<tr>
<td>LW Inversion correction</td>
<td>No</td>
<td>Maximum Inversion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strength -10K/100hPa</td>
</tr>
</tbody>
</table>
Status of SW Model Improvements

Simultaneously replacing the original WCP-55 aerosols with the MATCH aerosols, and the original Rayleigh molecular scattering formulation with an improved Rayleigh molecular scattering formulation has significantly improved the surface SW flux calculations for clear through partly cloudy sky conditions.

To account for the short term variability of aerosol properties, we have incorporated the daily aerosol properties into SW Model B.

Results for the mostly cloudy to overcast conditions showed some improvement by revising the $a_0$ coefficient but strongly suggest that further work on the cloud transmittance calculation is necessary. Our recent attention has focused on developing an empirical method to account for the cloud transmittance.

The ADMs and MATCH aerosols have been revised for Ed4.

SORCE / RMIB daily data are used for Total Solar Irradiance.
Status of TSI Measurements

With the malfunction of the CPV6 battery cell on SORCE, TIM and the other instruments were powered off 30 July 2013.

Since the SORCE TIM TSI data were not available on a regular basis from July 2013 through February 2014, we began acquiring the RMIB composite TSI data from Steven DeWitte.

The RMIB data, however, requires an offset from the DIARAD VIRGO mean low value of ~1363 W/m² to match the SORCE mean low value of ~1361 W/m². Note, for CERES Ed4, all TSI data are offset to match the SORCE TSI Version 15.

The TSI Calibration Transfer Experiment (TCTE) instrument was integrated into the STPSat3 satellite, along with 4 other satellite instruments, and was launched into orbit on 19 November 2013, and has been providing TSI data since 16 December 2013.
Comparison of TSI data [SORCE(V15) versus RMIB] for the overlap period: 1-Mar-2003 to 29-Feb-2008

RMIB - SORCE V15 Offset -- 01Mar 2003 to 29 Feb 2008

Mean Offset = 2.4447

Slope = -0.0237 Wm^{-2}/year

Climate Science Branch, NASA Langley Research Center
Comparison of TSI data [SORCE(V15) versus RMIB] for the entire SORCE period: 1-Mar-2003 to 30-Jun-2013

RMIB Offset - SORCE V15 -- 01 Mar 2003 to 30 Jun 2013

- **Total Solar Irradiance (Wm\(^{-2}\))**
  - **RMIB-Comp**
  - **SORCE-V15**
  - **RMIB-Offset**

**Slope = -0.0229 Wm\(^{-2}\)/year**

Climate Science Branch, NASA Langley Research Center
Inter-comparison of SORCE(V16) and TCTE
Total Solar Irradiance Retrievals

TSI Comparison: SORCE V16 vs. TCTE (16 Dec 2013 to 31 Aug 2014)

SORCE: 1 value/day, 22 DEC 2013 through 28 DEC 2013, and 1 value/day 5 MAR 2014 through 31 AUG 2014; Absolute Accuracy: ±0.48 W/m² at 1361 W/m²

TCTE: 1 value/day, 16 DEC 2013 through 8 May 2014, and 1 value/week 11 MAY 2014 through 31 AUG 2014; Absolute Accuracy: ±1.36 W/m² at 1361 W/m²
TSI composite data from WRC, SORCE(V15) and RMIB for the Timeframe of CERES Terra, Aqua & NPP

For CERES Ed4, all TSI data are offset to match SORCE TSI Version 15
Sunspot Numbers for Solar Cycles 22, 23 & 24

Climate Science Branch, NASA Langley Research Center
Comparisons of orbital characteristics of NPP with CERES FM5 to Aqua with CERES FM3

Aqua (Launch 4-May-2002)
COSPAR ID = 2002-022-A
701 X 703 km 98.2087° orbit
14.57091655 revolutions/day
Period = 98.827002 minutes

NPP (Launch: 28-October-2011)
COSPAR ID = 2011-061-A
825 X 828 km 98.7483° orbit
14.19543342 revolutions/day
Period = 101.441070 minutes

Period(NPP) – Period(Aqua) = 2.614068 minutes
Time to realign orbits = 63.9177 hours
Orbital Data as of 24-Sep-2014
SW Surface Flux Differences between NPP and Aqua FM3 for April 2013

NPP SW Surface Flux W/m²

Aqua SW Surface Flux W/m²

Climate Science Branch, NASA Langley Research Center
SW Surface Flux Differences between NPP and Aqua FM3 for April 2013

global = 9.53651

NPP - Ed4 FM3  SWB Surf Diff  Mean APR 2013

Climate Science Branch, NASA Langley Research Center
SW Surface Flux and Cloud Fraction Differences between NPP and Aqua FM3 for April 2013

SW Surface Difference W/m²

Cloud Fraction Difference

Climate Science Branch, NASA Langley Research Center
SW Surface and TOA Flux Differences between NPP and Aqua FM3 for April 2013

SW Surface Difference W/m²

NPP - Ed4 FM3  SWB Surf Diff  Mean APR 2013

global = 9.53651

SW TOA Difference W/m²

NPP - FM3  SWTOA Diff  Mean APR 2013

global = -3.34509

Climate Science Branch, NASA Langley Research Center
SW Surface Flux Differences between NPP and Aqua FM3 for April 2013

SW TOA Difference W/m²

Time of Observation Difference

Climate Science Branch, NASA Langley Research Center
SW Surface Flux Differences between NPP and Aqua FM3 for April 17, 2013

SW TOA Difference W/m²

Time of Observation Difference

Climate Science Branch, NASA Langley Research Center
The inter-comparison of the NPP and Aqua results for the SW demonstrated that the largest of the observed differences could be attributed to differences in the orbital parameters associated with the NPP and Aqua satellites. Differences in the orbits affect the time of observation, which affects the solar zenith angle, which consequently affects the measured value of the incoming TOA and surface SW fluxes.

Differences in the cloud effect play an important, though secondary role in producing the differences between the NPP and Aqua results.
Status of LW Model Improvements

For the condition involving surface temperatures that greatly exceed the overlying air temperatures, constraining the lapse rate to 10K / 100hPa (roughly the dry adiabatic lapse rate) has significantly improved the results for both MOA and CWG $T_s$, see Gupta et al. (2010).

For conditions involving surface temperatures that are much below the overlying air temperatures (strong inversions), limiting the inversion to a maximum of 10K / 100hPa for the downward flux calculations provides the best results for all conditions for both MOA and CWG $T_s$.

The CWG skin temperatures have a significantly greater dynamic range than the MOA surface temperatures.

The use of the CWG skin temperatures will, therefore, tend to have a wider range of fluxes at the surface. Constraining the CWG and MOA surface temperatures using the SOFA methods, however, tends to yield comparable results.

Edition 4 inputs into the LW model are providing the expected results.
Daytime LW Surface Flux Differences between NPP and Aqua FM3 for April 2013

NPP LW Surface Flux W/m$^2$

FM3 LW Surface Flux W/m$^2$
Daytime LW Surface Flux Differences between NPP and Aqua FM3 April 2013

global = -1.50729
Daytime LW Surface Flux and Cloud Fraction Differences between NPP and Aqua FM3 for April 2013

LW Surface Difference W/m²

Cloud Fraction Difference

Climate Science Branch, NASA Langley Research Center
Nighttime LW Surface Flux Differences between NPP and Aqua FM3 for April 2013

NPP SW Surface Flux W/m²

FM3 SW Surface Flux W/m²
Nighttime LW Surface Flux Differences between NPP and Aqua FM3 for April 2013

global = -1.17464

Climate Science Branch, NASA Langley Research Center
Nighttime LW Surface Flux and Cloud Fraction Differences between NPP and Aqua FM3 for April 2013

LW Surface Difference W/m²

Cloud Fraction Difference

Climate Science Branch, NASA Langley Research Center
LW Surface Flux Results

Differences in the cloud effect play the dominant role in producing the observed differences between the NPP and Aqua LW fluxes for both Day and Night.
Conclusions for SOFA Ed4 algorithms

Previous validation studies have demonstrated that revisions to both the LW algorithms and the SW algorithms (for clear to partly cloudy conditions) appear to be working well, though further revisions to the cloud transmission method and/or overcast albedo method are needed for SW Model B. Our attention for future improvements is focused on deriving a regression fit to the cloud transmission data.

A preliminary analysis of the LW and SW surface only flux algorithm results using the Edition 4 inputs, especially those from the Clouds Subsystem, indicated improved accuracies for most locations.

A comparison of the NPP and Aqua flux retrievals show the anticipated results.