A Status Update for FLASHFlux and SOFA working groups including Data Usage
Highlights from new POWER portal

Paul Stackhouse and David P. Kratz (NASA LaRC)

PC Sawaengphokhai, Shashi Gupta and Anne Wilber (SSAI)

POWER Team: Bradley MacPherson (Booz-Allen-Hamilton)

Tonya Davenport and Fenny Wang and the
Atmospheric Science Data Center Team (SSAI)
SOFA Update

• **Paper published:**

• **Testing begun on NOAA-20:**
  – Initial SOFA Model B (LPSA/LPLA) results look consistent with the results from NPP, Terra and Aqua
  – Model A LW requires WN channel which is not present.
  – Currently waiting for a full set of data to provide validation results.

• **Validation Continued on Terra, Aqua and NPP**
  – SSF SOFA Model B SW/LW validation shows low biases and consistent RMS between 3 instruments
All-sky Surface Downward Shortwave Flux Model B
201201 - 201911

<table>
<thead>
<tr>
<th>Terra</th>
<th>Aqua</th>
<th>NPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 72984</td>
<td>N = 73319</td>
<td>N = 68136</td>
</tr>
<tr>
<td>Bias = -4.3 W m(^{-2})</td>
<td>Bias = 0.8 W m(^{-2})</td>
<td>Bias = -1.4 W m(^{-2})</td>
</tr>
<tr>
<td>RMS = 93.0 W m(^{-2})</td>
<td>RMS = 94.3 W m(^{-2})</td>
<td>RMS = 98.8 W m(^{-2})</td>
</tr>
</tbody>
</table>
CERES Derived DLF (W m\(^{-2}\))

Ground Measured DLF (W m\(^{-2}\))

<table>
<thead>
<tr>
<th>Terra</th>
<th>Aqua</th>
<th>NPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 133770</td>
<td>N = 135065</td>
<td>N = 165811</td>
</tr>
<tr>
<td>Bias = 0.5 W m(^{-2})</td>
<td>Bias = 0.3 W m(^{-2})</td>
<td>Bias = -2.3 W m(^{-2})</td>
</tr>
<tr>
<td>RMS = 22.4 W m(^{-2})</td>
<td>RMS = 22.8 W m(^{-2})</td>
<td>RMS = 22.5 W m(^{-2})</td>
</tr>
</tbody>
</table>

All-sky Surface Downward Longwave Flux Model B
201201 - 201911
CERES FLASHFlux Overview

**FLASHFlux Overview**
- Uses CERES based production system through inversion
- Periodic calibration updates projected forward; running 3-day TISA
- LPSA/LPLA SOFA algorithms for surface fluxes

**FLASHFlux Objectives**
- SSF products within 4 days
- Global 1x1 daily averages from FF TISA (uses a running 3-day average); goal: 6-7 days latency

**FLASHFlux Usages**
- Primarily used for applied science and education
- Supports also QC for selected missions
- TOA gridded fluxes; normalized to TOA EBAF for annual “State of the Climate” assessments (most recent report revised Mar. 2020).
FLASHFlux v3C Status

- **Production with v3C (MODIS C5/C6/C6.1) (since Jan 1, 2017)**
  - Uses FP-IT (GEOS 5.12.4) and MODIS Collection 6.1 (after March 1, 2018)
  - FLASHFlux TISA available via CERES subsetter, ASDC and specialized formats through POWER web portal (power.larc.nasa.gov) 5-6 days latency
  - Maintaining v3C processing; latency is improved after Dec 2019

- **Current Activities**
  - Processing FLASHFlux SSF V4A from Dec. 1, 2018 through present (uses MC6.1); applying calibration from June 2019
  - Evaluating v3C, 4A, and CERES Ed4 SSF
  - Plan to continue production for v3C for 2020 while production adapted to FF v4A; transition TBD

- **FLASHFlux Information & Data Provision Through ...**
  - New CERES web site and subsetter both SSF and TISA; ASDC (via EarthData)
  - SSF data to NOAA NESDIS, Globe-Clouds
  - TISA data to POWER Energy/Ag web portal
CERES FLASHFlux Latency Status

- FF SSF Success Target = data release within 4 days
- FF TISA Success Target = data released within 6 days
- Recovery from power outage in 12/09
- Last 2 months > 90% SSF & TISA success

75% of daily solar irradiance users request low latency

% Days Released by Target

2018 2019 2020

4/28/2020 CERES Science Team Meeting
FLASHFlux to POWER Metrics

CERES FLASHFlux Usage Metrics through POWER (2019/03/01 to 2020/03/31)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Users IPs</td>
<td>96,910</td>
<td>7,454</td>
</tr>
<tr>
<td>Requests</td>
<td>28,816,773</td>
<td>2,216,675</td>
</tr>
<tr>
<td>Latency &lt; 2 Weeks %</td>
<td>59.8%</td>
<td>59.8%*</td>
</tr>
</tbody>
</table>

*Low latency was not available for most of Dec 2019/Jan 2020 due to outage; typically ~75%
Annual Average Differences (2019 – 2018)

Transition from La Nina in 2018 into weak El Nino in 2019
- OLR anomalies jump back up > 1.0 W m\(^{-2}\) (2-sigma)
- Net RSW (absorbed SW) anomalies remain +0.8 to 1.6 W m\(^{-2}\)
- Subtraction gives Total Net that reduces from +1.2 to -0.1 W m\(^{-2}\) in December 2019; rebounds nearly 1 W m\(^{-2}\) by Mar. 2020.
Recent SW Validation: 1/2017–12/2019

Version 3C Derived DSF (W m\(^{-2}\))

Ground Measured DSF (W m\(^{-2}\))

Daily Averaged TISA Comparison

<table>
<thead>
<tr>
<th>Ensemble Type</th>
<th>Bias (W m(^{-2}))</th>
<th>RMS (W m(^{-2}))</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Obs</td>
<td>-5.3</td>
<td>29.2</td>
<td>24570</td>
</tr>
<tr>
<td>Continental</td>
<td>-5.1</td>
<td>28.2</td>
<td>12913</td>
</tr>
<tr>
<td>Coastal</td>
<td>-3.8</td>
<td>24.2</td>
<td>4935</td>
</tr>
<tr>
<td>Desert</td>
<td>-6.1</td>
<td>21.9</td>
<td>3086</td>
</tr>
<tr>
<td>High Latitude</td>
<td>-19.6</td>
<td>51.0</td>
<td>1982</td>
</tr>
<tr>
<td>Island</td>
<td>6.5</td>
<td>26.4</td>
<td>1654</td>
</tr>
</tbody>
</table>

CERES Science Team Meeting
Recent LW Validation: 1/2017 – 12/2019

Version 3C
201701-201912

Daily Averaged TISA Comparison

<table>
<thead>
<tr>
<th>Ensemble Type</th>
<th>Bias (W m(^{-2}))</th>
<th>RMS (W m(^{-2}))</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Obs</td>
<td>-6.0</td>
<td>16.7</td>
<td>24872</td>
</tr>
<tr>
<td>Continental</td>
<td>-9.6</td>
<td>18.0</td>
<td>12620</td>
</tr>
<tr>
<td>Coastal</td>
<td>-3.0</td>
<td>12.4</td>
<td>4921</td>
</tr>
<tr>
<td>Desert</td>
<td>-7.2</td>
<td>16.4</td>
<td>3015</td>
</tr>
<tr>
<td>High Latitude</td>
<td>4.0</td>
<td>20.7</td>
<td>2657</td>
</tr>
<tr>
<td>Island</td>
<td>-1.8</td>
<td>10.3</td>
<td>1659</td>
</tr>
</tbody>
</table>

All site ensemble

N = 24872
Bias = -6.0 W m\(^{-2}\)
RMS = 16.7 W m\(^{-2}\)
FLASHFlux Data Flow (Version 4A)

Key Changes:

- Clouds Ed4
- SIBI Map: running 30-day maps
- Ed4 Inversion
- Globe-Clouds to read SSF instead of subsetter
- SW Model B (LPSA)
- FF Daily added to PGE

Example Users
- NOAA NESDIS
- Globe-Clouds
- NEO
- POWER Energy/Ag
### Example FF Version 4A SSF Terra Results

<table>
<thead>
<tr>
<th></th>
<th>Meteorology</th>
<th>Clouds</th>
<th>Ice/snow</th>
<th>SIBI map</th>
<th>Aerosols</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLASHFlux 4A</td>
<td>GEOS 5.9.12</td>
<td>CERES Ed4</td>
<td>1/16 mesh</td>
<td>Running monthly mean</td>
<td>MATCH climatology from MODIS 5 (Years 2000-2005)</td>
</tr>
<tr>
<td>FLASHFlux 3C</td>
<td>GEOS 5.9.12</td>
<td>CERES Ed2-like</td>
<td>1/16 mesh</td>
<td>No SIBI used</td>
<td>MATCH climatology from MODIS 5 (Years 2000-2005)</td>
</tr>
<tr>
<td>CERES 4A</td>
<td>GEOS 5.4</td>
<td>CERES Ed4</td>
<td>1/8 mesh</td>
<td>Calendar monthly mean</td>
<td>MATCH daily from MODIS 6.1</td>
</tr>
</tbody>
</table>
Terra Daytime Cloud Fraction Differences (Jan 2019)

FF v4A consistent cloud mask with CERES Ed4A

Ed2 Cloud Discontinuity eliminated
Terra TOA SW Flux Differences (Jan 2019)

Global relative difference ~+0.16%
Terra TOA Daytime LW Flux Differences (Jan 2019)

Global relative difference ~+0.38%
Global relative difference ~-0.03%
Spectral Calibration Testing:

- Runs generated from special FF calibration from June 2019
- Compare FF4A, CERES Ed4 and special SCC run using Ed4 inputs and FF SCC
- SW TOA differences due to FF vs CERES implementation
- LW TOA @day due to calibration coefficients
Terra Surface SW Flux Differences (Jan 2019)

Revised alternate algorithm over snow/ice
Terra Surface SW Flux Differences (Jan 2019)

Ensemble
FLASHFlux V3C
201901 Terra

Version 3C Derived DSF (W m\(^{-2}\))

Ground Measured DSF (W m\(^{-2}\))

Ensemble
FLASHFlux V4A
201901 Terra

Version 4A Derived DSF (W m\(^{-2}\))

Ground Measured DSF (W m\(^{-2}\))

Ensemble
CERES Ed4A
201901 Terra

CERES Ed4A Derived DSF (W m\(^{-2}\))

Ground Measured DSF (W m\(^{-2}\))

\(N = 595\)
Bias = -9.6 W m\(^{-2}\)
RMS = 78.9 W m\(^{-2}\)
Abs Diff = 50.6 W m\(^{-2}\)
\(R^2 = .91\)

\(N = 595\)
Bias = -0.9 W m\(^{-2}\)
RMS = 84.4 W m\(^{-2}\)
Abs Diff = 54.0 W m\(^{-2}\)
\(R^2 = .90\)

\(N = 595\)
Bias = -17.6 W m\(^{-2}\)
RMS = 87.6 W m\(^{-2}\)
Abs Diff = 56.9 W m\(^{-2}\)
\(R^2 = .89\)
Terra TOA Daytime LW Flux Differences (Jan 2019)

Differences due to water vapor inputs
Terra Surface Daytime LW Flux Differences (Jan 2019)

Daytime Longwave Ensemble
FLASHFlux V3C
201901
Aqua

N = 594
Bias = -7.7 W m\(^{-2}\)
RMS = 22.0 W m\(^{-2}\)
Abs Diff = 16.6 W m\(^{-2}\)
\(R^2 = .95\)

Daytime Longwave Ensemble
FLASHFlux V4A
201901
Aqua

N = 594
Bias = -4.2 W m\(^{-2}\)
RMS = 20.2 W m\(^{-2}\)
Abs Diff = 15.2 W m\(^{-2}\)
\(R^2 = .95\)

Daytime Longwave Ensemble
CERES Ed4A
201901
Aqua

N = 594
Bias = -3.1 W m\(^{-2}\)
RMS = 21.0 W m\(^{-2}\)
Abs Diff = 15.8 W m\(^{-2}\)
\(R^2 = .95\)
Terra TOA Nighttime LW Flux Differences (Jan 2019)

**FM1 Night LW Surf Mean JAN 2019**

- Global: 330.316
- 60°N-90°N: 187.447
- 60°S-90°S: 250
- 20°N-20°S: 404.504

**FM1 Night LW Surf FF4A**

- Global: 0.618633
- 60°N-90°N: 1.08329
- 60°S-90°S: -6.86523
- 20°N-60°N: 0.517209
- 20°S-60°S: -0.124842

**FM1 Night LW Surf FF4A-CERES**

- Global: 0.8481
- 60°N-90°N: 2.20232
- 60°S-90°S: 3.53681
- 20°N-60°N: -1.79838
- 20°S-60°S: 0.76888

Min = 105.301; Max = 453.95

Min = -49.4056; Max = 48.8876
Terra Surface Nighttime LW Flux Differences (Jan 2019)

Nighttime Longwave Ensemble
FLASHFlux V3C
201901 Aqua

Version 3C Derived DLF (W m\(^{-2}\))

Ground Measured DLF (W m\(^{-2}\))

- 1 2-5 6-10 11-15 16-20 > 20

N = 685
Bias = -9.6 W m\(^{-2}\)
RMS = 32.5 W m\(^{-2}\)
Abs Diff = 24.9 W m\(^{-2}\)
\(R^2 = .77\)

Nighttime Longwave Ensemble
FLASHFlux V4A
201901 Aqua

Version 4A Derived DLF (W m\(^{-2}\))

Ground Measured DLF (W m\(^{-2}\))

- 1 2-5 6-10 11-15 16-20 > 20

N = 685
Bias = -4.1 W m\(^{-2}\)
RMS = 30.9 W m\(^{-2}\)
Abs Diff = 23.4 W m\(^{-2}\)
\(R^2 = .77\)

Nighttime Longwave Ensemble
CERES Ed4A
201901 Aqua

CERES Ed4A Derived DLF (W m\(^{-2}\))

Ground Measured DLF (W m\(^{-2}\))

- 1 2-5 6-10 11-15 16-20 > 20

N = 685
Bias = -3.2 W m\(^{-2}\)
RMS = 30.3 W m\(^{-2}\)
Abs Diff = 23.5 W m\(^{-2}\)
\(R^2 = .78\)
FF Version 4A TISA Results: Surf SW Down

Version 3C
201901

- N = 733
- Bias = -4.2 W m\(^{-2}\)
- RMS = 29.0 W m\(^{-2}\)

Version 4A
201901

- N = 733
- Bias = -2.1 W m\(^{-2}\)
- RMS = 26.1 W m\(^{-2}\)
FF Version 4A TISA Results: Surf LW Down

**Version 3C**

- 201901
- N = 782
- Bias = -9.3 W m$^{-2}$
- RMS = 21.2 W m$^{-2}$

**Version 4A**

- 201901
- N = 782
- Bias = -6.3 W m$^{-2}$
- RMS = 19.5 W m$^{-2}$
FLASHFlux V4A Transition Plans

V3B (GEOS 5.9.1, MC5)  12/1/16  1/1/17  3/29/17  3/31/18  12/31/19
(started 8/1/14)

V3C (MC5, GEOS 5.12.4)  V3C (MC6, GEOS 5.12.4)  V3C (MC6.1, GEOS 5.12.4)

1/1/19  1/1/20  Processing for evaluation

Projected end is July 1, 2020
If acceptable, will replace 2020 with v4A

1/1/19  3/1/18

V4A (CERES Ed 4, MC6.1, GMAO 5.12.4)

(large v3c to v4a SW changes require long overlap for consistency)

MC = MODIS Collection 5/6/6.1
GEOS = FP-IT version

MC = MODIS Collection 5/6/6.1
GEOS = FP-IT version
# Longer-Term Future: Moving FLASHFlux Toward V5A

<table>
<thead>
<tr>
<th>Attribute</th>
<th>FF v3C (MC6)</th>
<th>FF v4A</th>
<th>FF v4B</th>
<th>FF v5A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline 1QC</strong></td>
<td>Previous (Terra, Aqua)</td>
<td>Calibration Update Cycle (Terra, Aqua)</td>
<td>Calibration Update Cycle (Terra?, Aqua)</td>
<td>Calibration Update Cycle (N20, GEO)</td>
</tr>
<tr>
<td><strong>GEOS FP-IT input</strong></td>
<td>GEOS 5.12.4</td>
<td>GEOS 5.12.4</td>
<td>GEOS new version</td>
<td>GEOS new version</td>
</tr>
<tr>
<td><strong>MOA</strong></td>
<td>Ed 4 compatible</td>
<td>Ed 4 compatible</td>
<td>Ed 4 compatible</td>
<td>Ed 5(?) compatible</td>
</tr>
<tr>
<td><strong>MODIS</strong></td>
<td>Collection 6</td>
<td>Collection 6.1</td>
<td>Collection 6.1</td>
<td>Collection 7(?)</td>
</tr>
<tr>
<td><strong>Clouds</strong></td>
<td>Ed 2</td>
<td>Ed 4 w/ MC 6.1 calibration</td>
<td>Ed 4</td>
<td>Ed 4</td>
</tr>
<tr>
<td><strong>SIBi (Snow/ICE Brightness Index)</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Inversion (improved ADMs)</strong></td>
<td>Ed 2</td>
<td>Ed 4</td>
<td>Ed 4</td>
<td>Ed 4</td>
</tr>
<tr>
<td><strong>Aerosols</strong></td>
<td>MATCH climatology</td>
<td>MATCH climatology</td>
<td>GEOS new version or updated MATCH</td>
<td>GEOS new version or updated MATCH</td>
</tr>
<tr>
<td><strong>Flux Algorithm</strong></td>
<td>Unchanged</td>
<td>Modified SW surface algorithm</td>
<td>A0, Ap adjustments; new clear-sky TOA &amp; surface albedos (current work)</td>
<td>Updated or new algorithms(?)</td>
</tr>
<tr>
<td><strong>TISA</strong></td>
<td>Ed 2</td>
<td>Compatible w/ Ed 4 (current work)</td>
<td>Compatible w/ Ed 4 (custom CERES TSI?)</td>
<td>Compatible w/ Ed 5(?) (custom CERES TSI?)</td>
</tr>
<tr>
<td><strong>Data Processed</strong></td>
<td>March 28 - present</td>
<td>Planned to begin 1/1/19</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Validation Results</strong></td>
<td>1/1/17 – 12/31/19</td>
<td>1/1/2019 – 12/31/20?</td>
<td>1/1/2020 - ??</td>
<td>1/1/2020 - ??</td>
</tr>
</tbody>
</table>

*4/28/2020 CERES Science Team Meeting*
Summary and Conclusions

- **SOFA Group**
  - SOFA Ed4 paper revisions published; validation updated Terra, Aqua, NPP; new N20
- **FLASHFlux 3C and 4A progress**
  - Continued 3C processing; operational version
  - Version4A compatible with CERES Ed 4; uses MODIS Collection 6.1
  - Version4A now processing beginning from Dec 1, 2019, now in April 2020
  - SSF comparisons show good agreement at TOA; calibration and angle differences at TOA
  - SSF surface fluxes show significant changes; especially over ice, still evaluating
  - **Goal:** FF v4A operational in July 2019 for transition to new year; begin data 1/1/20
- **FLASHFlux Applications:**
  - Datasets continuing being supplied and distributed through POWER web services; latency much improved after Jan recovery
  - CERES FF ordering past year ~100,000 unique ISP; nearly 30M orders; most low latency
- **FLASHFlux Publications:**
  - 2019 SotC report submitted
FLASHFlux Web Sites:

https://flashflux.larc.nasa.gov

https://power.nasa.gov &
https://power.nasa.gov
## Near Future: Transition FLASHFlux V4A

<table>
<thead>
<tr>
<th>Attribute</th>
<th>FF v3C (MC6)</th>
<th>FF v4A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 1QC</td>
<td>Previous</td>
<td>New calibration</td>
</tr>
<tr>
<td>GEOS FP-IT input</td>
<td>GEOS 5.12.4</td>
<td>GEOS 5.12.4</td>
</tr>
<tr>
<td>MOA</td>
<td>Ed 4 compatible</td>
<td>Ed 4 compatible</td>
</tr>
<tr>
<td>MODIS</td>
<td>Collection 6</td>
<td>Collection 6.1</td>
</tr>
<tr>
<td>Clouds</td>
<td>Ed 2</td>
<td>Ed 4 w/ MC 6.1 calibration (current work)</td>
</tr>
<tr>
<td>SIBi (Snow/ICE Brightness Index)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Inversion (improved ADMs)</td>
<td>Ed 2</td>
<td>Ed 4</td>
</tr>
<tr>
<td>Aerosols</td>
<td>MATCH climatology</td>
<td>MATCH climatology</td>
</tr>
<tr>
<td>Flux Algorithms</td>
<td>Unchanged</td>
<td>Modified SW surface algorithm (current work)</td>
</tr>
<tr>
<td>TISA</td>
<td>Ed 2</td>
<td>Compatible w/ Ed 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ed 4 (current work)</td>
</tr>
<tr>
<td>Data Processed</td>
<td>March 28 - present</td>
<td>Planned to begin 1/1/19</td>
</tr>
<tr>
<td>Validation Results</td>
<td>1/1/17 – 6/30/18</td>
<td>---</td>
</tr>
</tbody>
</table>

4/28/2020  CERES Science Team Meeting
New v4A Production System

Using FP-IT (GEOS 5.12.4)

Ed 4 Clouds

Clouds Main
- CER2.1P2 (Terra)
- CER2.1P3 (Aqua) (Hourly)

Inversion
- CER3.1P2 (Terra)
- CER3.1P3 (Aqua) (Hourly)

CERES Snow & Ice
- ESNOW/EICE

MODIS Collection 6.1
- MODIS
- MOD03 (Terra)
- MYD03 (Aqua)

FLASHFlux Processing Stream

FF SSF HDF to S'Cool/Globe-Clouds

POWER Applications

Initial data date Jan 1, 2019

POWER Project Data Sets

Update for Ed 4 SSF

FF Daily (.netCDF)

CERES 1P1
- TISA Avg (Daily)

CERES 2P2
- SSF

SSF

SSFA

SSFAI

EQCHG

EQCHB

SSFB

CRHU-WL0063

Legend

MOA (SS1)

Clouds (SS2)

Instantaneous Fluxes (SS3)

Time and Space gridding (SS4)

Time and Space averaging (SS5)