FLASHFlux Working Group Status:
Operations with GEOS-IT and moving to GEO

Paul Stackhouse (NASA LaRC)

PC Sawaengphokhai (ADNet), Hunter Winecoff (AS&M), and Jay Garg (ADNet)

CERES Team members: Walt Miller and Pam Mlynczak (ADNet)

POWER Team: Bradley MacPherson and Christopher Higham (Booz-Allen-Hamilton)
CERES FLASHFlux Overview

• **FLASHFlux Overview**
  – Uses CERES based production system through inversion (w/ quarterly calibration updates projected forward)
  – Running 3-day TISA utilizing morning and afternoon orbiters

• **FLASHFlux Latency Objectives**
  – SSF products within 3-4 days
  – Global 1x1 daily averages from FF TISA; goal: 5-7 days latency

• **FLASHFlux Uses**
  – Primarily used for applied science and education (i.e., POWER and Globe Clouds)
  – Supports also QC for selected missions (e.g., NOAA NESDIS)
  – TOA gridded fluxes; normalized to TOA EBAF for annual “State of the Climate” assessments.
FLASHFlux Operational Status

**FF Production System Updates:**
- Continuing FF SSF production, now with GEOS-IT:
  - Terra V4B SSF (since April 1, 2024)
  - NOAA-20 V1B SSF (since April 1, 2024)
- TISA (Terra+NOAA-20, V4C) operational with GEOS-IT since April 1, 2024

**FF Production status:**
- Current Status:
  - SSF Terra (V4B): 5/12/24; SSF NOAA-20 (V1B): 5/12/24
  - TISA V4C (Terra+NOAA-20): 5/10/24 (processed back to 10/1/23)
- Updated calibration coefficients received & promoted as cc change effective 4/1/24

**Important Activities since last CERES Meetings:**
- Promoted to operations production with GEOS-IT (still performing quality assessments)
- Investigated production environment updates/data quality issues
- Investigating data quality due NOAA-20 orbit repositioning
- Developing new footprint flux algorithms utilizing a NN/ML approach
- Developing a new TISA that is more compatible with CERES TISA (SYN1Deg) which requires operational processing of GEO data

5/14-17/2024  CERES Science Team Meeting
FLASHFlux SSF Latency Assessment

Success rate (%) of time data archived within 2, 3, or 4 days of observation

Lags due to maneuvers/satellite issues, ASDC updates/outages, ASDC Dropbox/Darkhorse, GSFC LAADS and/or SIPS

Latency for April 2024:
- Terra SSF: < 90% even at 4 days
- NOAA-20 SSF: < 70% even at 4 days
### Assessing Transition to GEOS-IT: Surface SW Down

**SW Surface Down: NOAA-20 Daytime (11/15/2023)**

<table>
<thead>
<tr>
<th>Date</th>
<th>Difference</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/15/23</td>
<td>0.793</td>
<td>2.523</td>
</tr>
<tr>
<td>11/30/23</td>
<td>0.582</td>
<td>2.578</td>
</tr>
<tr>
<td>12/02/23</td>
<td>0.557</td>
<td>2.524</td>
</tr>
<tr>
<td>12/15/23</td>
<td>0.632</td>
<td>2.625</td>
</tr>
</tbody>
</table>
# Assessing Transition to GEOS-IT: Surface LW Down

## LW Surf Down: NOAA-20 Daytime (11/15/2023)

<table>
<thead>
<tr>
<th></th>
<th>GLOBAL</th>
<th>Land</th>
<th>Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Diff</td>
<td>SD</td>
<td>Mean Diff</td>
</tr>
<tr>
<td><strong>Units: W*m-2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Avg</td>
<td>-0.4787</td>
<td>4.2827</td>
<td>0.3466</td>
</tr>
<tr>
<td>60-90 deg N</td>
<td>1.6986</td>
<td>4.4569</td>
<td>1.9966</td>
</tr>
<tr>
<td>30-60 deg N</td>
<td>-0.3235</td>
<td>3.3275</td>
<td>0.0839</td>
</tr>
<tr>
<td>0-30 deg N</td>
<td>-1.9294</td>
<td>5.0258</td>
<td>-1.4847</td>
</tr>
<tr>
<td>0-30 deg S</td>
<td>-1.0178</td>
<td>4.5001</td>
<td>-0.9372</td>
</tr>
<tr>
<td>30-60 deg S</td>
<td>-0.0952</td>
<td>2.3087</td>
<td>-0.5719</td>
</tr>
<tr>
<td>60-90 deg S</td>
<td>4.0887</td>
<td>4.8331</td>
<td>5.7303</td>
</tr>
</tbody>
</table>

### Global Stats

<table>
<thead>
<tr>
<th>Date</th>
<th>Difference</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/15/23</td>
<td>-0.479</td>
<td>4.283</td>
</tr>
<tr>
<td>11/30/23</td>
<td>-0.184</td>
<td>4.339</td>
</tr>
<tr>
<td>12/02/23</td>
<td>-0.233</td>
<td>4.378</td>
</tr>
<tr>
<td>12/15/23</td>
<td>-0.504</td>
<td>4.093</td>
</tr>
</tbody>
</table>
Assessing Transition to GEOS-IT: Surface LW Up

**LW Surf Up: NOAA-20 Daytime (11/15/2023)**

<table>
<thead>
<tr>
<th>Units: W*m-2</th>
<th>GLOBAL</th>
<th>Land</th>
<th>Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Diff</td>
<td>SD</td>
<td>Mean Diff</td>
<td>SS</td>
</tr>
<tr>
<td>Global Avg</td>
<td>-0.0249</td>
<td>6.8454</td>
<td>1.2158</td>
</tr>
<tr>
<td>60-90 deg N</td>
<td>3.1857</td>
<td>6.9795</td>
<td>3.6934</td>
</tr>
<tr>
<td>30-60 deg N</td>
<td>0.4514</td>
<td>5.0409</td>
<td>1.2357</td>
</tr>
<tr>
<td>0-30 deg N</td>
<td>-1.8189</td>
<td>8.1774</td>
<td>-0.877</td>
</tr>
<tr>
<td>0-30 deg S</td>
<td>-0.7664</td>
<td>8.7536</td>
<td>-0.7688</td>
</tr>
<tr>
<td>30-60 deg S</td>
<td>0.3569</td>
<td>3.3134</td>
<td>-0.0907</td>
</tr>
<tr>
<td>60-90 deg S</td>
<td>5.051</td>
<td>5.0699</td>
<td>6.9646</td>
</tr>
</tbody>
</table>

**Global Stats**

<table>
<thead>
<tr>
<th>Difference</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/15/23</td>
<td>-0.025</td>
</tr>
<tr>
<td>11/30/23</td>
<td>0.019</td>
</tr>
<tr>
<td>12/02/23</td>
<td>-0.115</td>
</tr>
<tr>
<td>12/15/23</td>
<td>-0.197</td>
</tr>
</tbody>
</table>

NOAA20 LW-SURF-UP Flux Difference (Version1B_405400 - Version1A_403410) - day - 20231115

FF LW-SURF-UP Flux - Wm-2
Overpass SW flux validation with BSRN measurements:

- Left FLASHFlux SSF with previous version (w/ FP-IT)
- Right FLASHFlux SSF (Current Version w/ GEOS-IT)
- Top NOAA-20, Bottom Terra

- SW fluxes Bias/RMS worse with GEOS-IT; Terra more consistent
- SW NOAA-20 has much larger biases than Terra
  - NOAA-20: bias < 4%, 27%
  - Terra: bias < -2%, 23%
Overpass LW daytime flux validation with BSRN measurements:

- Left FLASHFlux SSF Previous Version (with FP-IT)
- Right FLASHFlux SSF Current Version: (with GEOS-IT)
- Top NOAA-20, Bottom Terra

FLASHFlux LW Daytime NOAA-20 and Terra radiative fluxes show consistency between FP-IT/GEOS-IT: biases < 1%; RMS's < 7%
Overpass LW daytime flux validation with BSRN measurements:

- Left FLASHFlux SSF Previous Version (with FP-IT)
- Right FLASHFlux SSF Current Version: (with GEOS-IT)
- Top NOAA-20, Bottom Terra

FLASHFlux LW Daytime NOAA-20 and Terra radiative fluxes show consistency between FP-IT/GEOS-IT: biases < 1%; RMS’s < 11%
SSF Flux Algorithm Updates: NN SW & LW

Justification:
- FF footprint fluxes have been used both scientifically and for applications
- Current LPSA/LPLA algorithms older methods, hard to update; separate from Fu/Liou

Objectives:
- Use NN/ML methods to devise algorithms that approximate FF; given key inputs available in from MOA and Inversion
  - Using CRS Ed1 used for training since uses full Fu/Liou RT
- Ran numerous tests on optimizing both training data sets and parameters
- Ran 2 months from the following year; evaluated against surface observations
- Some additional changes to the LW may be needed
- Experiments and results reviewed in Jay Garg’s presentation
FLASHFlux SSF Data Flow

Start

GMAO Meteorology files (GEOS-IT)

CERIES_FFB baseline-1QC (Instrument files; nominal)

MODIS or VIIRS L1B granules (Imager and location file)

AFWA Snow and Ice Files

CERES Science Team Meeting

MODIS or VIIRS L1B granules (Imager and location file)

AFWA Snow and Ice Files

CERES Science Team Meeting

Sample Data from 8/19/23

Regrid Meteor. Code
FLASH13-1.1P1 [MOA]

FLASH MOA

Cloud Retrieval Code
FLASH13-2.1P6 or
FLASH13-2.1P9

Inversion (ADMs) Code:
TOA and Surface Fluxes
FLASH13-3.1P6 or
FLASH13-3.1P9

30 days running avg.
Sea Ice Brightness Index Code (FLASH13-3.0P6)

Daily Sea Ice Brightness Index Map.

CERES FLASH SSF: NOAA20

Clear-sky History Code
(sections averages)
FLASH13-2.1P6 or
FLASH13-2.1P9

FLASH_ECS: update to Clear-sky file

FLASH_SSFA
FLASH_SSFB (internal)

FLASH SSF (HDF4)

Clouds

TOA & Surface Fluxes

5/14-17/2024
v4A success rates for TISA to be archive in 5, 6 or 7 days after observation.

v4B began production in March 2023.

February 2024 showed about >95% by day 6 (able to deliver all data by day 7).
FLASHFlux TISA Validation: SW Surface Fluxes

- Ensemble FLASHFlux Version4B vs 4C SW Daily Average Comparisons to Surface Measurements (10/2023-1/2024)

- SW fluxes show very consistent statistical quality relative to surface measurements:
  - Bias Diff: < 1.6%
  - RMS Diff: < 24%

- Histograms show peaked, relatively symmetric distributions, median bias is negative for SW
Time Series Validation: SW

- Example time series comparison against SW measurements from the LRC site
- Here negative bias is evident, but that varies site to site
- There is now discernable difference between 4B and 4C
FLASHFlux TISA Validation: LW Surface Fluxes

- Ensemble FLASHFlux Version4B vs 4C LW Daily Average Comparisons to Surface Measurements (10/2023-1/2024)

- LW fluxes show very consistent statistical quality relative to surface measurements:
  - Bias Diff: < -1.7
  - RMS Diff: < 7.4%

- Histograms show peaked, relatively symmetric distributions, median bias is negative for LW; slightly improved negative shoulder
- Example time series comparison against SW measurements from the LRC site
- Some day-to-day variability in differences; similar to other sites
- v4C (GEOS-IT) is slightly better at this site; similar to other sites
**FLASHFlux TISA Application: Updated Anomalies**

Table 2.f.1.1. Global annual mean TOA radiative flux changes between 2022 and 2023, the 2023 global annual mean radiative flux anomalies relative to their corresponding 2001–22 mean climatological values, and the 2-sigma interannual variabilities of the 2001–22 global annual mean fluxes (all units in W m⁻²) for the outgoing longwave radiation (OLR), total solar irradiance (TSI), reflected shortwave (RSW), absorbed solar radiation (ASR, determined from TSI-RSW) and total net fluxes. All flux values have been rounded to the nearest 0.05 W m⁻² and only balance to that level of significance.

<table>
<thead>
<tr>
<th></th>
<th>One Year Change (2023 minus 2022) (W m⁻²)</th>
<th>2023 Anomaly (Relative to Climatology) (W m⁻²)</th>
<th>Climatological Mean (2001–22) (W m⁻²)</th>
<th>Interannual Variability (2001–22) (W m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLR</td>
<td>+0.60</td>
<td>+0.85</td>
<td>240.35</td>
<td>±0.65</td>
</tr>
<tr>
<td>TSI</td>
<td>+0.10</td>
<td>+0.25</td>
<td>340.20</td>
<td>±0.15</td>
</tr>
<tr>
<td>RSW</td>
<td>-0.80</td>
<td>-1.50</td>
<td>99.00</td>
<td>±1.05</td>
</tr>
<tr>
<td>ASR</td>
<td>+0.90</td>
<td>+1.75</td>
<td>241.20</td>
<td>±1.05</td>
</tr>
<tr>
<td>Net</td>
<td>+0.30</td>
<td>+0.90</td>
<td>0.85</td>
<td>±0.85</td>
</tr>
</tbody>
</table>

Stackhouse et al., 2024, submitted to BAMS
TOA Flux Anomalies (through 2023)

Stackhouse et al., 2024, submitted to BAMS

Includes TISA 4B/4C transition
Different users require different ways to access the same data.

Creating trusted, value-added, easy-to-use Application Ready Data & Services

The POWER Project
Provides solar and meteorological data sets from NASA research for support of renewable energy, building energy efficiency and agricultural needs.

Supported by NASA Earth Science’s Applied Sciences Program.

POWER’s Web-Based Doc Pages
- Data Newsletters
- Data Services Documentation
- Data Access Guidelines

POWER celebrated its 20th Anniversary at POWER’s first virtual Global Community Summit event held on 20-21 September 2022. You can view the event materials, agenda, and recordings here: https://power.larc.nasa.gov

https://power.larc.nasa.gov
FLASHFlux TISA Application via POWER Web Services Portal (2022/08/01 to 2023/07/31)

CERES Data Orders Delivered via POWER < 3 weeks latency (FLASHFlux Data)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Monthly</th>
<th>Avg. Last 3 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Users IPs</td>
<td>~51.9 K (16%)</td>
<td>~5.6 K (18%)</td>
<td>~4.8 K (19%)</td>
</tr>
<tr>
<td>Requests</td>
<td>~48.0 M (32%)</td>
<td>~4.0 M (32%)</td>
<td>~4.1 M (33%)</td>
</tr>
</tbody>
</table>

CERES Data Orders Delivered via POWER including SYN1Deg and FLASHFlux data

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Monthly</th>
<th>Avg. Last 3 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Users IPs</td>
<td>~149.8 K (47%)</td>
<td>~15.0 K (47%)</td>
<td>~16.2 K (48%)</td>
</tr>
<tr>
<td>Requests</td>
<td>~75.9 M (51%)</td>
<td>~6.3 M (51%)</td>
<td>~5.6 M (45%)</td>
</tr>
</tbody>
</table>

Dot density map showing locations of users (red) and data request locations (white). Brighter colors show larger frequency at that location.

FF users increased by about ~40% since last report

Total FF+ SYN1Deg users 14% since last report

(includes SYN1Deg from Sep 2001 through latest month released)
CERES TISA Application via POWER: User Story

Urban Solar

Urban Solar manufactures solar power systems and LED lightning solutions for transit, transportation, parking lots, pathways, and general illumination applications. Their philosophy is good lighting allows people to feel safe in outdoor spaces.

- Urban Solar uses CERES data through POWER’s API to retrieve minimum solar irradiance and to calculate the power generated by solar arrays.
- Data provides specifications to manufacture and place solar power systems and LED lightning solutions.
- NRT used to monitor performance
TISA Flux Algorithm Updates: Incorporating GEO

**Justification:**
- Aqua and Terra are drifting and will be turned off
- Currently have replaced Aqua with NOAA-20, but still using Terra
- Once TERRA is turned off, there will be no morning, evening samples for the diurnal models to estimate the daily averages; the primary product
- Concurrently, users are asking for hourly flux data at lower latency to be more consistent with the SYN1Deg hourly products
- If the GEO that CERES already processes for the SYN1Deg can be processed within the latency, then this provides the extra samples needed to improve daily and also provides the opportunity to provide CERES consistent fluxes at the hourly temporal resolution at lower latency.

**Objectives:**
- Work with SatCORP/Clouds group and the TSI group to develop a new lower latency pipeline to enable the production of fluxes more consistent with CERES SYN1Deg
- Leverages SatCORP groups existing work and automated QC
- Leverages TSI group’s objective to restructure CERES production code for Ed5
Future FLASHFlux TISA Data Flow: Adding GEO

CERES Ed5 Compatible TISA (retain 3-day running window)

Global Cloud Composite (GCC) Merged GEO for temporal interpolation/hourly products

Full Fu-Liou RT Calculations
Adding GEO to FF TISA: SatCORPS GCC into FLASHFlux

Current Progress:
1. GCC to 1x1 gridded cloud files; 1 week+ in netCDF for July 1-7, 23
2. Offline Fu-Liou runs for July 1, 2023

Progress:
1. Completed cloud gridding code – targeting Ed4 clouds (4 layers) since code exists. Done
2. Align all inputs to correct data structures: ongoing
3. Configure SYN1Deg like code with 3-day running window, global by hour; determine options for running F/L: ongoing
4. Assess GEOS-FP vs GEOS-IT
Adding GEO to FF TISA: Gridded GCC Cloud Properties

From Global Cloud Composite, Gridded Cloud Fraction at $1^\circ \times 1^\circ$, Hour 1 of 24, 7/2/23

High (50-300mb)

Upper-Mid (300-500mb)

Lower-Mid (500-700mb)

Low (700mb-surface)

Arun Gopalan
Adding GEO to FF TISA: Offline 1\textsuperscript{st} Fluxes

Offline runs will be compared to SARBLike runs

July 1, 2023
15 UT

Fu-Lung Chang
FLASHFlux Summary

- **Production with SSF for Terra (v4b), NOAA-20 (1b) and TISA (v4C) Continues**
  - FF NOAA-20 V1B SSF (5/12/24) and Terra V4B (5/12/24) with GEOS-IT
  - TISA V4C Terra/NOAA-20 through 5/10; latency goals not met due to various issues
  - New FF Gain+Spectral coefficients beginning Apr 1st, 2024.

- **Validation and Assessment Relative to BSRN/Buoy**
  - CERES and FLASHFlux SSF through Dec 2023; SW biases larger; GEOS-IT min impact
  - TISA v4C daily averages through Oct-Jan 2023 (4 months); low biases; some LW improved

- **FLASHFlux Modernization and Updates**
  - ML based algorithms for future FF SSF data products: Goal Operational Oct 2024
  - Migrate configuration to NOAA-20 + GCC GEO & F/L Fluxes: Goal Operational Jan 2025

- **FLASHFlux Information & Data Provision Through ...**
  - CERES web site and subsetter both SSF and TISA, ASDC (via EarthData) and POWER
    - FF+Syn1 POWER Distribution in last year: ~150K unique IPs; > 76M orders; orders >33% FF
  - 2023 BAMS State of the Climate TOA Flux reports submitted
FLASHFlux Web Sites & Acknowledgments

https://ceres.larc.nasa.gov/data/#fast-longwave-and-shortwave-flux-flashflux

Data also served through https://power.larc.nasa.gov

Acknowledgements for to other CERES Team members contributing to FLASHFlux Data products and updates:
Katie Dejwakh, Dave Doelling, William Smith Jr,
Arun Gopalan, Baojuan Shan, Fu-Lung Chang, Nelson Hillyer, and others (ADNet)