CERES FLASHFlux Working Group: Status & Plans

Low Latency Surface Radiative Fluxes and Meteorological Parameters for Research and Applications

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PC Sawaengphokhai, Shashi Gupta and Anne Wilber (SSAI)

Jason Barnett, Booz-Allen-Hamilton

Tonya Davenport, Lindsay Parker and the Atmospheric Science Data Center Team (SSAI)
FLASHFLUX: Schematic of Current Uses

**Educational Uses**
- NASA Earth Observatory
- CERES S’COOL

**Scientific Uses**
- CERES WGs
- Annual “State of Climate” Report
- Field Campaigns
- Mission: CloudSat and Megha-Tropiques

**Applied Science Uses**
- Building Energy Monitoring with RETScreen Expert: for NASA center buildings and general worldwide usage
- Agricultural Crop Projections: NASA APIAS, ICASA general worldwide usage

**Push subscription**
- CERES FLASHFlux SSF (Lev 2) & TISA (Lev 3) Data Products (ASDC Archive)

**Local Use (DPO)**
- ASDC Order As Needed

**Processed Nightly from DPO**
- POWER Web Portal (power.larc.nasa.gov)

**DSSAT format**
- RETScreen format
FLASHFlux v3C Status

• **Completed production with v3B through Dec. 31, 2016**
  – “State of the Climate 2016” results
  – Validation for 2016 vs. BSRN/ARM/Buoy

• **Started production with v3C (since Jan 1, 2017)**
  – Now uses FP-IT (GEOS 5.12.4) and MODIS Collection 6 (after March 28)
  – V3B v V3C and MODIS Coll. 5/6 differences evaluated

• **Current Latency**
  – FLASHFlux SSF available via CERES subsetter and ASDC 4-5 days latency
  – FLASHFlux TISA available via CERES subsetter, ASDC and specialized formats through POWER web portal (power.larc.nasa.gov) 5-6 days latency
  – Some latency improvements made through CATALYST; more later

• **FLASHFlux Data Usage:**
  – Mandatory conversion to https: broke user pipe; but usage picking up again
  – Agricultural and Energy usage continues =&gt; New web site coming
  – Anecdotal information being collected
• Global monthly mean deseasonalized anomalies from CERES EBAF TOA Ed2.8 and CERES FLASHFlux product.

• FLASHFlux TOA are normalized to the EBAF TOA fluxes from both datasets for the six-year overlap period 1/2009 – 12/2014.

• Annual averaged OLR and RSW anomalies > 2-sigma interannual variability, but largely cancel in 2016

Kratz et al., 2017: Earth Radiation Budget [submitted to "State of the Climate in 2016"].
Extending Deseasonalized Anomalies

Globally averaged EBAF and normalized FLASHFlux deseasonalized monthly anomalies relative to EBAF climatology extended to April 2017.

WHOI OAflux Latent & Sensible Heat fluxes + CERES FLASHFlux year-to-year difference for radiative fluxes

Positive values denote ocean heat gain.
• 3M Company manages 11 facilities using RETScreen and FLASHFlux data: “The NASA datasets we use are critical to our energy analysis since they are used as major variables that predict our energy use.”

• Renewable energy engineers use daily solar irradiance to assess performance of multiple solar systems for clients: users in Ottawa region and Customer First Renewables (e.g., MIT, Lockheed Martin, Corning)

• A Stanford University Professor uses data for classroom studies in modeling, including crop modeling

• HCO Hazelnut Company (Ferrero Corp. – makers of Nutella) uses data to assess suitability of crops in different regions; then uses for crop modeling simulations
FLASHFlux Usage Example: Customer First Renewables

FF Daily average solar irradiance; averaged over site locations

4 NC Solar Panel Field Performance

Bright yellow is inland

Others coastal

Hurricane Matthew

Oct 8, 2016
FF v3B SW

Version 3B
201601-201612

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

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

\[ N = 10114 \]
\[ \text{Bias} = 6.6 \text{ W m}^{-2} \]
\[ \text{RMS} = 85.4 \text{ W m}^{-2} \]

FF v3B LW

Version 3B
201601-201612

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

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

\[ N = 21068 \]
\[ \text{Bias} = -4.3 \text{ W m}^{-2} \]
\[ \text{RMS} = 22.4 \text{ W m}^{-2} \]
**FF v3B SW**

Version 3B
201601-201612

N = 1021  
Bias = -12.8 W m\(^{-2}\)  
RMS = 27.7 W m\(^{-2}\)

**FF v3B LW**

Version 3B
201601-201612

N = 2687  
Bias = -8.2 W m\(^{-2}\)  
RMS = 16.1 W m\(^{-2}\)
Version 3B Derived DSF (W m\(^{-2}\))

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

### Daily Averaged TISA Comparison

<table>
<thead>
<tr>
<th>Ensemble Type</th>
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<th>RMS (W m(^{-2}))</th>
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<tr>
<td>Buoy</td>
<td>11.3</td>
<td>31.1</td>
<td>413</td>
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N = 7391
Bias = -3.0 W m\(^{-2}\)
RMS = 28.7 W m\(^{-2}\)

5/16/2017

CERES Science Team Meeting
Recent SW Validation: 1/2016 – 12/2016
FF TISA LW v3B Validation: All-sky

**Version 3B**

201601-201612

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

**All site ensemble**

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

N = 7647

Bias = -2.8 W m\(^{-2}\)

RMS = 14.2 W m\(^{-2}\)

**Daily Averaged TISA Comparison**

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<tr>
<th>Ensemble Type</th>
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Recent LW Validation: 1/2016 – 12/2016

SURFACE LW Down Bias

5/16/2017

CERES Science Team Meeting
Recent SW Validation: 1/2017–3/2017

Version 3B Derived DSF (W m$^{-2}$)

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

**Daily Averaged TISA Comparison**

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<tr>
<th>Ensemble Type</th>
<th>Bias (W m$^{-2}$)</th>
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N = 1428
Bias = -1.1 W m$^{-2}$
RMS = 22.8 W m$^{-2}$

5/16/2017
CERES Science Team Meeting
Recent LW Validation: 1/2017 – 3/2017

Version 3C
201701-201703

All site ensemble

Daily Averaged TISA Comparison

<table>
<thead>
<tr>
<th>Ensemble Type</th>
<th>Bias (W m(^{-2}))</th>
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N = 1421
Bias = -7.0 W m\(^{-2}\)
RMS = 16.2 W m\(^{-2}\)
Recent LW Validation: 1/2017 – 3/2017

SURFACE LW Down Bias

Wm$^{-2}$

-24 -20 -16 -12 -8 -4 -1 2 6 10 14 18 22

5/16/2017

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V3C-MODIS C6 Minus V3C MODIS C5 Differences

global = 0.0772813  60–90N = 1.32826  60–90S = 0.325854  20N–20S = −0.126868
20–60N = 0.02634  20–60S = 0.0113243

Ver3C–Ver3C_C6 TISA Cloud Fraction Diff 15 MAR 2017
Using FP-IT (GEOS 5.12.4)
Planned v4A Production System (Jul ‘17)

Update for Ed 4 using FPIT

Ed 4 Clouds

MODIS Collection 6

FLASHFlux Processing Stream

Legend

- MOA (S1)
- Clouds (S2)
- Instantaneous Fluxes (S3)
- Time and Space gridding (S4)
- Time and Space averaging (S5)
Update for Ed 4 using FPIT

FF Future Production System

Ed 4 Clouds

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

CERES Snow & Ice (ESNOW/EICE)
- CERES 1.1P8 (IES)

MODIS (MOD03 (terra), MYD03(aqua))
- Clouds CER2.3P1 (Monthly)

SIBI

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

FPIT to BB Aerosols

FPIT to BB Aerosols

FLASH
- SFC-HR

CER5.1P1 TISA Avg (Daily)

Update for Ed 4 SSF

CER3.2P2 SSF

SS Subsetter

FLASH Grid Hourly 4.2P1

CER3.4P1 S'COOL and Validation

Legend
- MOA (SS1)
- Clouds (SS2)
- Instantaneous Fluxes (SS3)
- Time and Space gridding (SS4)
- Time and Space averaging (SS5)

Can CERES TSI replace FLASH SFC-HR and Grid Hourly?
Summary and Conclusions

• **FLASHFlux 3C**
  – Updated from v3B (MODIS C5) to v3C (MODIS C6); evaluation
  – Continuing production and validation for v3C

• **FLASHFlux Applications:**
  – Continued usage of FLASHFlux through POWER project
  – Developing new web site featuring GIS tools for CERES/FF/POWER and with ASDC to raise discoverability and accessibility

• **FLASHFlux publications:**
  – 2016 SotC reports submitted; contributed to Nature Climate Change
  – Future papers: FLASHFlux TISA applications including energy

• **Future Versions**
  – Developing v4A by migrating CERES Ed 4 Clouds (collection 6) and Inversion; must adapt current FF TISA => target July ‘17
  – Longer-term Upgrades (Fall ‘17):
    • Assess FPIT aerosol assimilation
    • Assess & adapt CERES TSI to FLASHFlux TISA
FLASHFlux Web Sites:

https://flashflux.larc.nasa.gov
Version 3B Derived DSF (W m$^{-2}$)

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

N = 10114
Bias = 6.6 W m$^{-2}$
RMS = 85.4 W m$^{-2}$

Aqua & Terra SSF Comparison
All-Sky

<table>
<thead>
<tr>
<th>Ensemble Type</th>
<th>Bias (W m$^{-2}$)</th>
<th>RMS (W m$^{-2}$)</th>
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**FF SSF SW V3B Validation: Clear-sky**

**Aqua & Terra SSF Comparison Clear-Sky**

<table>
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FF SSF LW V3B Validation: All-sky

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

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

All site ensemble

Aqua & Terra SSF Comparison
All-Sky

<table>
<thead>
<tr>
<th>Ensemble Type</th>
<th>Bias (W m(^{-2}))</th>
<th>RMS (W m(^{-2}))</th>
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5/16/2017
CERES Science Team Meeting
FF SSF LW V3B Validation: Clear-sky

Aqua & Terra SSF Comparison
Clear-Sky

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<th>Ensemble Type</th>
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FLASHFlux Data Usage Through POWER Applied Science

• **3M Company manages 11 facilities using RETScreen and FLASHFlux data:**
  “The NASA datasets we use are critical to our energy analysis since they are used as major variables that predict our energy use.”

• **A renewable energy engineer uses daily solar irradiance to assess performance of 36 solar systems in Ottawa region**

• **A Stanford University Professor uses data for classroom studies in modeling, including crop modeling**

• **HCO Hazelnut Company uses data to assess suitability of crops in different regions; then uses for crop modeling simulations**
FLASHFlux TISA Available Via Subsetter

SW Down

LW Down

Net SW

Net LW
Progress Toward CERES GIS Support

ArcGIS REST Services Directory

Home > services > cere

Folder: cere
Current Version: 10.4

View Footprints In: ArcGIS Online map viewer

Services:

- cere/arcgis_arcgis_CERES_SYN1degDayEd3A_sfc_comp_lw_down_all_daily (ImageServer)
- cere/arcgis_arcgis_CERES_SYN1degDayEd3A_sfc_comp_sw_down_all_daily (ImageServer)
- cere/arcgis_arcgis_CERES_SYN1degDayEd3A_sfc_comp_sw_down_clr_daily (ImageServer)
- cere/arcgis_arcgis_CERES_SYN1degDayEd3A_toa_comp_sw_down_all_daily (ImageServer)

Supported Interfaces: REST SOAP Sitemap Geo Sitemap
Website is a Responsive Platform for Desktop, Tablet, and Smartphone

DATA ACCESS VIEWER
Download, Interact, analyze and visualize data in a responsive web mapping application on desktop and mobile platforms.

WEB DATA SERVICES
Consume data into your applications and code using ArcGIS Image Services, Web Mapping Services, REST API, OPeNDAP.

WEB PROCESSING SERVICES
Utilize our ArcGIS GeoProcessing Services and/or OGC Web Processing Services for direct access and analysis of data.

DOWNLOADABLE TOOLS & CODE
Download the POWER ArcGIS Toolbox and ArcGIS Raster Function Templates for analytical and data accessibility capabilities.

POWER Website serves as a platform for discovery of multiple data access points.
Enhancing Data Access Points

- **Data Access Viewer**
- **Web Data Services**
  - ArcGIS Image Services
  - OGC Web Map Services
  - OPeNDAP*
- **Web Processing Services**
  - ArcGIS GP Services*
  - OGC Web Processing Services
- **Downloadable Tools/Code**
  - ArcGIS Toolbox*
  - ArcGIS Raster Function Templates
  - ArcGIS Custom WebApp Builder Widgets

*Items to be initially released in POWER soft opening with limited capabilities.

5/16/2017 CERES Science Team Meeting
Enabling Data Usage Applications

Visualization & Analysis

- Panoply
  - NetCDF, OPeNDAP

- Esri ArcGIS Suite
  - NetCDF, OPeNDAP, ArcGIS Image Services, ArcGIS GP Services, ArcGIS Toolbox, GeoTIFF, Shapefile

- MatLab
  - Netcdf, OPeNDAP, GeoTiff

- QGIS
  - OGC Web Map Service, OGC Web Process Service, GeoTIFF

- DSSAT
  - ICASA

- HDFView
  - NetCDF

- Microsoft Office
  - CSV, ASCII

- R Statistics
  - NetCDF, CSV

- ERDAS Imagine
  - NetCDF, GeoTiff

Programming

- Python
  - Esri ArcGIS for Python API, ArcGIS Image Service REST Endpoint, ArcGIS Toolbox Functions, OPeNDAP, ArcGIS GP Services, JSON, CSV, Shapefile, GeoTIFF, NetCDF

- JavaScript
  - Esri ArcGIS For JavaScript API, ArcGIS Image Services, ArcGIS GP Services, JSON, CSV

- Microsoft .NET
  - ArcGIS Runtime SDK for .NET, ArcGIS Image Services, ArcGIS GP Services, JSON, CSV
FLASHFlux Near Future Updates

• Upgrade to CERES Ed 4 subsystems underway
  – Meteorological input migration from GEOS 5.9.1 to 5.12.4 => the replacement of FP-IT
  – Upgrade Ed 4 Clouds with MODIS Collection 6 inputs
  – Upgrade to Ed 4 Inversion
  – Upgrade to FF TISA to support Ed 4 formatted inputs

• Advance Web based GIS services
  – New POWER web site to enhance data access and usage with GIS web and image services
  – Migrate FLASHFlux datasets to POWER and eventually EBAF/SYN1Deg

• Build Compatibility with CERES TSI
  – Assess & adapt CERES TSI for FLASHFlux global fluxes
  – Build capability for GEO processing
Nearing public release of SSE-GIS
Provides users an opportunity interact with time series data sets of energy related data sets using web based GIS services from ESRI
Services are hosted from ASDC servers
Users can display maps, work with multiple layers, obtain data tables and geotiff files of the parameters
Using ArcGIS To Enhance Applied Science Usage of Data Products

ASDC Geospatial Portal

Featured Maps and Apps

- 22 Year Averages of Surface Meteorology and Solar
- Daily Averaged Surface Meteorology and Solar
- POWER SSE Web App

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center is responsible for the processing, archiving, and distribution of NASA Earth science data in the areas of radiation budget, clouds, aerosols, and tropospheric chemistry.

The Data Center was established in 1991 to support the Earth Observing System (EOS) as part of NASA’s Earth Science Global Change Research Program, and is one of several Distributed Active Archive Centers (DAACs) sponsored by NASA’s Earth Observing System Data and Information System (EOSDIS).
Enhancing Applied Science Usage with ArcGIS

**ArcGIS Capabilities**

- High quality viewing (Desktop/Mobile) and printing
- Data Extraction/Subsetting → Python code to support a variety of data formats from ASCII, to .netCDF, to geoTIF
- Simultaneous Dataset Visualization (Swiping)
- Temporal Visualization (time slider)
- Custom Color Ramps
- Pixel/Attribute Value Identification at Selected Location
- Python code to support computation of on-the-fly parameter computation

**Technologies**

- Esri ArcGIS Server & Portal
- OPeNDAP
- PostgreSQL & PostGIS

**Connectivity**

- Climate.gov
- GEOSS (AIP-8)
Published four CERES SYN1DEG ArcGIS Image Services in the development environment. Allows users to 1) access the data via a REST endpoint/protocols, via JSON REST response, 2) utilize online web mapping application development tools via the ArcGIS API for JavaScript, 3) consume the services directly into ArcGIS Desktop and custom applications for further visualization and analysis.

Data served directly from the CERES SYN1Deg Native NetCDFs:
- SFC COMP LW DOWN ALL DAILY
- SFC COMP SW DOWN ALL DAILY
- SFC COMP SW DOWN CLR DAILY
- TOA COMP SW DOWN ALL DAILY

The 2 systems purchased by CERES have had systems software installed and are integrated into the WebRA production environment. Each server has 2 Intel Xeon E5-2643 v3 Processors (20M cache, 3.40 Ghz, 6 cores), 2.4TB of storage, 256 GB RAM (DDR4-2133MHz).

A process was developed for integrating the machines into the production architecture for dedicated hosting of geospatial web services for CERES data products.

These systems will be added to the ArcGIS cluster for dedicated hosting of CERES data product geospatial web services.
Image Services directly ingested into ArcGIS geospatial software for further analysis and visualization such as time slider visualization.