CERES FLASHFlux Status:
Near-Real Time Surface Radiative Fluxes and Meteorology for Research and Applications

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Lindsay Parker and the
Atmospheric Science Data Center Team (SSAI)
Outline

- **Brief introduction**
- **FLASHFlux V3A: current status**
  - Sample results
  - Ordering web page
- **FLASHFlux TISA V3A vs CERES SYN1_deg**
- **Energy Applications Examples**
- **Publications**
  - SSF paper accepted
  - State of Climate 2012 report published
- **State of Climate Validation**
- **Future Plans**
  - Monthly Aerosol to Daily Aerosol
  - Albedo monthly climatology to daily albedo
FLASHFlux Overview

**FLASHFLUX = Fast Longwave And SHortwave Radiative Fluxes from CERES and MODIS**

**FLASHFlux Objectives**

- Provide TOA and surface radiative fluxes base on the CERES algorithm within one week of observation for scientific and applied science uses
  - Level 2 – Single Scanner Footprint (SSF) hourly instantaneous for Terra and Aqua in cross-track mode is usually available around 4 days after observation (1/1/2013 – 10/10/2013)
  - Level 3 – Temporal Interpolate and Spatial Averages (TISA) daily gridded that combines Terra and Aqua observations into 1 degree equal angle grid. Available within 7 days after observation (1/1/2013 – 10/10/2013)

- Conduct scientific investigations and provide for scientific and applied science uses
  - State of the Climate report
  - RETScreen
  - Climate Adaptation Science Investigation

- Demonstrate processing system pushing data products to research and applications uses
  - Agricultural sector via POWER project: power.larc.nasa.gov
  - Education users accessing the NASA Earth Observatory
FLASHFlux SSF Data Products (Oct. 9, 2013)

**Terra FM1**
- **hourly**
- **instantaneous**

**SW TOA**

**LW TOA**

**SW Surface**

**LW Surface**

10/29/2013
CERES Science Team Meeting
FLASHFlux TISA Data Products (Oct. 9, 2013)

(Terra+Aqua; Daily; 1°x1° resolution)
FLASHFlux TISA Version 3A Products (Terra+Aqua; Daily; 1°x1° resolution; Processed through about 10/10/2013)

https://eosweb.larc.nasa.gov/project/ceres/flash_tisa_terra_aqua_v3a_table
### Daily Global mean of SYN1deg, FF V3A (Current), and FF V2H (Previous)

<table>
<thead>
<tr>
<th></th>
<th>SYN 1deg</th>
<th>FF V3A</th>
<th>FF V2H</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLR</td>
<td>236.52</td>
<td>235.92</td>
<td>233.53</td>
</tr>
<tr>
<td>RSW</td>
<td>100.68</td>
<td>100.01</td>
<td>95.25</td>
</tr>
<tr>
<td>Net</td>
<td>10.47</td>
<td>11.89</td>
<td>13.35</td>
</tr>
</tbody>
</table>

- Reduce global mean bias compared to SYN1deg from previous version
- Day to day variability correlate very well
• **RETScreen International Tools**
  – RETScreen is a decision support tool for clean energy project analysis and feasibility study
  – RETScreen includes a Performance Plus module that allows for building system monitoring of current system, targeting new performance goals with clean technologies and verifying the savings from implementation of those technologies
  – There are now 65,000+ registered users of the Performance Plus tool

• **Training Workshops held**
  – RETScreen held several workshops (latest Sept. 2013) on using Performance Plus where data derived from FLASHFlux (through http://power.larc.nasa.gov) was incorporated directly into the training.
  – Several examples were shown and users pulled data from locations as diverse as Arctic circle to Western Africa.
Plot shows cumulative performance of system relative to baseline.

Baseline computed using regression of FF solar and system output.

Performance drops correspond to snow covering PV array.

Analysis shows cost of not clearing snow from PV array.
NASA has instituted a Climate Adaptation Science Investigation (CASI) team to assess NASA building infrastructure risks to potential changes in climate.

Part of the assessment is a review of energy performance of buildings under varying meteorological conditions.

LaRC’s team is assessing 4 buildings for team and with the intent to provide tutorial for other centers.

Analysis uses RETScreen Performance Plus tool with FLASHFlux meteorological inputs and radiative flux outputs.
CASI Analysis Case:
NASA LaRC Badge and Pass Office

- 39.5 kW Solar Photovoltaic array added to supplement building power in September 2010
- Use Performance Plus and FLASHFlux data to assess savings of new system
Net Electricity usage before and after installation of PV array.

Baseline fit uses temp & other met parameters from GEOS.

Note that at first installation building nearing zero energy usage but as offices added and PV degrades additional changes needed to obtain zero energy.
The Fast Longwave and Shortwave Flux (FLASHFlux) Data Product: Single Scanner Footprint Fluxes

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For submission to the Journal of Applied Meteorology and Climatology
October 2013

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SSF paper Published

• Accepted to the Journal of Applied Meteorology and Climatology.

• Highlights the production and validation of the FLASHFlux SSF data product.

• Compares well with CERES SSF data product.

• TISA paper in progress.
STATE OF THE CLIMATE IN 2012

Special Supplement to the Bulletin of the American Meteorological Society
Vol. 94, No. 8, August 2013

• CERES FLASHFlux contributed to the special annual BAMS report on the “State of the Climate in 2012”.

• Issue appeared in Aug. 2013, providing estimates of changes in year to year Global Earth Radiation Budget for the first time.

• These data were extended and normalized relative to the CERES EBAF 2.6r products for this report.
CERES FLASHFlux TOA flux variability for 2012 report:

- FF V2H monthly average annual global TOA normalized to EBAF 2.7 from 7/2011 to 6/2012
- TSI from SORCE instrument
- Global annual average anomalies:

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<tr>
<td>OLR</td>
<td>-0.30</td>
<td>-0.50</td>
<td>+/- 0.60</td>
</tr>
<tr>
<td>TSI</td>
<td>0.05</td>
<td>0.05</td>
<td>+/- 0.20</td>
</tr>
<tr>
<td>RSW</td>
<td>-0.40</td>
<td>-0.30</td>
<td>+/- 0.40</td>
</tr>
<tr>
<td>Net</td>
<td>0.75</td>
<td>0.85</td>
<td>+/- 0.80</td>
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• FLASHFlux projection correlates very well to EBAF Ed 2.7.

• 2σ monthly uncertainty of the normalization procedure is ±0.46 Wm$^{-2}$, ±0.83 Wm$^{-2}$, and ±1.18 Wm$^{-2}$ for OLR/RSW/Total Net radiation.

• High uncertainty due to 1 year overlap. Projected mean bias error is -0.23 Wm$^{-2}$, -0.02 Wm$^{-2}$, and 0.21 Wm$^{-2}$ for OLR/TSI-RSW/Total Net radiation.
Future Upgrades and Challenges

• **FF data products to CERES subsetter**
  – Daily FF TISA TOA and surface fluxes to netCDF format

• **Continued refinement of algorithms:**
  – Improve near-real time surface albedo to reflect surface condition
  – Aerosols: evaluation FP-IT compared to “Fast-MATCH”

• **Adapt to MODIS Collection 6 (Ed 4 Clouds)**

• **Develop FLASHFlux NPP product line (in 2014)**

• **Improve consistency between CERES algorithms and FLASHFlux (TISA/SYN)**
  – Evaluate using GEO?
  – Adapt special version of TISA for monthly averaged maps

• **Develop new products and subsets for applications (Solar industry, Agriculture, Building assessment)**
Summary and Conclusions

- **FLASHFlux 3A**
  - Continuing production and validation
  - Analysis with EBAF 2.7 shows FF global monthly flux anomalies projected $2\sigma$ uncertainty to be within 0.12 Wm$^{-2}$, 0.16 Wm$^{-2}$, and 0.16 Wm$^{-2}$ for OLR/TSI-RSW/Total Net, respectively.
  - Reprocess at last 6 months of 2012 to provide longer time series with new algorithms and calibration
    - use EBAF 2.7 for normalization for next years SoC

- **FLASHFlux Applications:**
  - Expanding usage for Energy applications using RETScreen; shows solar and ancillary data accurate enough for energy assessment
  - Also noting expanded usage in building infrastructure risks applications

- **FLASHFlux publications:**
  - SSF accepted; TISA paper next
  - 2012 SoC report published
FLASHFlux Web Sites:

http://flashflux.larc.nasa.gov
FLASHFLUX: Schematic Mapping to Realized and Potential Uses

Science Inputs:
- CERES
- MODIS
- Specialized CERES Processing System
- GMAO GEOS Met Data
- SMOBA (OMI O3)

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

Scientific Uses:
- Mission: CERES, CloudSat and Megha-Tropiques
- Field Campaigns
- TOA Flux Variability
- Land and Ocean Assimilation (??)

Applied Science Uses:
- Energy Resource and Load
- Building Energy Monitoring
- Agricultural Crop Projections
FLASHFlux Data Flow (v3A)

Official FLASHFlux data products highlighted with black box

Legend
- MOA (SS1)
- Clouds (SS2)
- Instantaneous Fluxes (SS3)
- Time and Space gridding (SS4)
- Time and Space averaging (SS5)
- User Data and Interfaces (SS6)

GEOS-DAS GEO 5.9 (FP-IT)

MODIS Imager data
MOD03: geolocation
MOD02S: subset radiance
MOD04: aerosol

CERES Radiances
Terra/Aqua Baseline1QC
IES

Determine Cloud Properties

CRH: Clear Reflectance History

CRHU: Clear Reflectance History Update

Update Clear Reflectance History

Generate FLASH Spectral Correction Coefficients

FLASH Spectral Response Functions

Inversion & Surface Estimation

FLASH SCC

Subset Data Sets for S’COOL and Validation

Global Monthly TOA Time Series

Global Monthly Averaging Scaled and filled TOA

FLASH DAYAVG: Local Time TOA/Surface Hourly/Daily Averages

FLASH Grid hourly TOA/Surface Fluxes

FLASH SFC_HR

FLASH MOA: Meteorological, Ozone & Aerosol data

Regrid Humidity & Temperature Fields

MODIS Imager data
MOD03: geolocation
MOD02S: subset radiance
MOD04: aerosol

CERES Snow &Ice:
ESNOW/EICE

CERES Radiances
Terra/Aqua Baseline1QC
IES

Instantaneous Fluxes (SS3)

Time and Space gridding (SS4)

Time and Space averaging (SS5)

User Data and Interfaces (SS6)
**GEOS FP-IT**

- **GEOS FP-IT (Forward Processing – Investigative Team)**
  - New GEOS 5.9.1 version replaces operational version GEOS 5.2
    - 0.5° latitude x 0.625° longitude resolution
    - Hourly surface, 3 hourly upper air profile
  - Represents a reprocessed assimilation that is “semi-frozen” with changes before reviewed by the Investigator Team
    - Current being produced from the Jan 1, 2000 to present (3 streams RP-IT1, RP-IT2 and RP-IT3)
    - Production plans to be complete by Fall 2013
- **Multiple changes from previous versions**
  - Assimilates AIRS radiances among many (HIRS3,4; AMSU-A, B, E; SSM/IS, MHS, IASI, etc. also assimilation GPS)
  - Produces chemistry products such as O3 (SBUV, OMI)
  - Features an aerosol assimilation (AOD MODIS Terra/Aqua)
Upgrade to Inputs: FP-IT

GEOS5.9.1 - 5.22M Specific humidity Diff Mean 01 JAN 2013

Max = 0.00999532; Min = -0.0114784
Upgrade to Inputs: FP-IT

Global = 0.034884
60–90N = 0.00456436 60–90S = 0.0417501
20–60N = 0.0253948 20–60S = 0.0520738

GEOS5.9.1–5.2 Column Water Vapor (kg m\(^{-2}\)) 03 Jan 2013

Max = 2.53176; Min = -2.48094
Early Surface Flux Validation

Only SurfRad and a few other sites available for Jan 2013
LW SSF Early Validation (Jan 2013)

Instantaneous fluxes at overpass times

**2H**

- DLF Version 2H (W m$^{-2}$)
- Ground Measured DLF (W m$^{-2}$)
- N = 1159
- Bias = -2.3 W m$^{-2}$
- σ = 23.7 W m$^{-2}$
- Mean Abs Diff = 37 W m$^{-2}$

**3A**

- DLF Version 3A (W m$^{-2}$)
- Ground Measured DLF (W m$^{-2}$)
- N = 1159
- Bias = -4.7 W m$^{-2}$
- σ = 23.6 W m$^{-2}$
- Mean Abs Diff = 19 W m$^{-2}$
Surface SW flux measurements averaged +/- ½ hour overpass time

DSF Version 2H (W m^-2)

- Mean Abs Diff = 220 W m^-2
- N = 398
- Bias = -0.5 W m^-2
- σ = 67.5 W m^-2

DSF Ground Measured (W m^-2)

DSF Version 3A (W m^-2)

- Mean Abs Diff = 162 W m^-2
- N = 398
- Bias = -10.9 W m^-2
- σ = 73.5 W m^-2

Version 2H Difference (W m^-2)

Version 3A Difference (W m^-2)
CERES FLASHFlux TOA flux variability for 2011 for BAMS “State of the Climate” report:

- FF monthly average annual global TOA normalized to EBAF from 7/2009 to 6/2012
  - Needed remove trend in calibration difference
- 2σ monthly uncertainty (W m⁻²) = ±0.14 Wm⁻², ±0.12 Wm⁻² and ±0.18 Wm⁻² for OLR/RSW/Total net
- TSI from SORCE instrument
- Global annual average anomalies:

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<td>+0.60</td>
<td>±0.60</td>
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</table>
• Time series show relatively large fluctuation

• Variability is consistent with NAO phase change
Monitoring and Targeting Case:
NASA LaRC Badge and Pass Office

Badge and Pass Office Solar Energy Project

Overview

Installed in September 2010, this 39.5 kW ground-mounted solar energy system and will produce around 50,000 kilowatt-hours of electricity each year. The system consists of 168 photovoltaic modules mounted in two arrays located behind the Badge and Pass Office. This project demonstrates the performance of solar energy and the benefit of renewable energy being in our overall energy strategy.

Current Status

Energy Today 193 kWh
Total energy generated by the system today

Energy Yesterday 206 kWh
Total energy generated by the system yesterday

Lifetime Energy 38,035 kWh
Total energy generated by the system since installation

Weather Conditions
Daily solar irradiance from FF with daily PV energy production for Badge & Pass Office

PV output does depend also on Temp
Monitoring and Targeting Case: NASA LaRC Badge and Pass Office

Solar Panel Electrical Output (kWh)

FF 2H daily averaged SW fluxes

All points represent weekly average of daily inputs

(Results from RETScreen by Rene Ganoe)
Cumulative sum of the difference between the performance of the PV array the first year after installation compared to subsequent years.

Degradation of energy production typical of PV arrays and is about 3%/year.