

## P1.10 Fast Longwave and Shortwave Radiative Flux (FLASHFlux) Products from CERES and MODIS Measurements

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### 1. INTRODUCTION

The Clouds and the Earth's Radiant Energy Systems (CERES) project is currently producing world-class climatological data products derived from measurements taken aboard the Terra and Aqua spacecrafts (Wielicki *et al.*, 1996). While of exceptional fidelity, these data products require a considerable amount of processing to assure quality and verify accuracy and precision. Obtaining such high quality assurance, however, means that the CERES data is typically released more than six months after the acquisition of the initial measurements. For climate studies, such delays are of little consequence, especially considering the improved quality of the released data products. There are, however, many uses for the CERES data products on a near real-time basis. These include: CERES instrument calibration and subsystem quality checks, CLOUDSAT operations, seasonal predictions, agricultural and ocean assimilations, support of field campaigns, and outreach programs such as S'Cool. The FLASHflux project was envisioned as a conduit whereby CERES data could be provided to the community within a week of the initial measurements, with the trade-off that some degree of fidelity would be exacted to gain speed. In this paper, we will report on some very encouraging initial results from the FLASHflux project in which we compared the FLASHflux instantaneous surface fluxes to the CERES surface-only flux algorithm data products. Ultimately, the FLASHflux project will produce global gridded flux products, initially with a 1° X 1° resolution, using a simplified time and space averaging algorithm.

### 2. THE FLASHFLUX PROJECT

The FLASHFlux project is designed around a data flow structure similar to the one used by

CERES, with some critical differences (see Figure 1). The process begins with the importation of data from NASA's Global Modeling and Analysis Office (GMAO) Goddard Earth Observing System (GEOS) global assimilation meteorology version 4.0.3 (Bloom *et al.*, 2005) and NCEP-SMOBA (Stratosphere Monitoring Ozone Blended Analysis) ozone products (Yang *et al.*, 1997) to produce the FLASH MOA dataset. Providing information concerning the basic state of the Earth's atmosphere, this data is crucial to a number of the subsequent processing systems. CERES and MODIS measurements are then combined with the FLASH MOA dataset to determine the cloud properties for the FLASH Clouds dataset. These results are then combined with estimates for the instrument spectral responses and gains and processed through sophisticated angular distribution models (Loeb *et al.*, 2005) and well-established radiative transfer methods (Gupta *et al.*, 2004) to produce the FLASH Single Scanner Footprint (SSF) dataset.). In contrast to FLASH, the CERES processing must wait for the calculation of finely detailed versions of the instrument spectral response functions and gain coefficients. This wait contributes significantly to the delay in the availability of the CERES data, while estimating the instrument characteristics on past trends allows FLASH to process the measurements very rapidly.

The FLASH SSF dataset, which provides instantaneous surface radiances and fluxes, has already been used in support of activities such as the June, 2005 balloon flight of the FIRST instrument (Mlynczak *et al.*, 2006), validation of the CERES spectral correction techniques, and the S'Cool outreach program. Current planning has the FLASH SSF being used in the operational processing of CloudSat data, as well as the fusion product of Aqua, CALIPSO and CloudSat.

While useful, the FLASH SSF instantaneous data may not be conveniently formatted for use in all studies. Thus, the FLASH processing uses a three day moving window (CERES uses a monthly window) to create hourly gridded TOA

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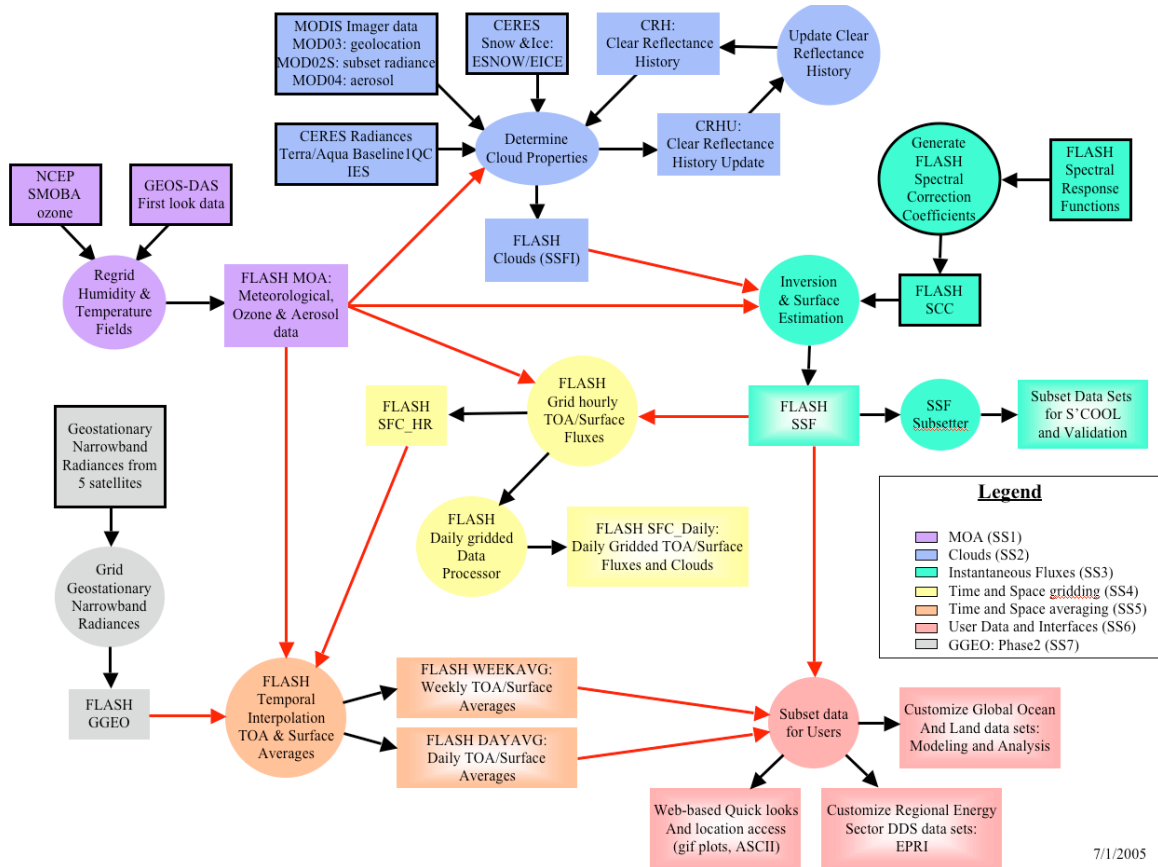


Figure 1: FLASHFlux data flow diagram showing all the subsystems that are denoted as follows: Meteorology, Ozone, Aerosol (MOA - violet), Clouds (blue), Inversion/Single Scanner Footprint (SSF - green), Spatial Gridding (yellow), Time Interpolation/Space Averaging (TISA - orange), Data Formatting (red), and Geostationary inputs (GGEO - grey). Squares indicate data sets; bold-shaped boundaries indicate inputs; bright-centers indicate outputs for end-users. Circles indicate a processing algorithm. Red lines indicate subsystem transitions.

and surface fluxes. These data can be easily processed to create daily gridded TOA and surface fluxes. Somewhat more involved is the temporal interpolation of the data to produce the FLASH TISA data product containing the daily and weekly averaged TOA and surface fluxes. Because Terra and Aqua are polar orbiting satellites, the measurements for most of the globe are taken at very specific local times. To improve the quality of our temporally interpolated fluxes, we intend to incorporate geostationary narrowband radiances into future production of the FLASH TISA data sets. Such information will better define the time variation of the surface fluxes.

Another significant difference between the CERES and FLASHFlux processing involves code changes and improvements. Because the CERES data product is intended for climate research, the data product must be consistent throughout the entire length of the data record.

The result is that alterations to the processing steam force a total reprocessing of the data. In contrast, since FLASH is intended for short-term immediate use, corrections and improvements, along with the appropriate documentation of the changes, can be implemented in real time. This allows FLASHFlux the flexibility to incorporate the most recent research into its algorithms.

All of the data sets produced by FLASHFlux are available at the NASA Langley Research Center Atmospheric Science Data Center (ASDC). The web site allowing access to the FLASHFlux datasets and their documentation is [http://eosweb.larc.nasa.gov/PRODOCS/flashflux/table\\_flashflux.html](http://eosweb.larc.nasa.gov/PRODOCS/flashflux/table_flashflux.html). In addition to the archived data sets, specially formatted data are planned for specific uses in atmospheric research and for applied science areas of energy management and agriculture. FLASHFlux will also have the flexibility to accommodate individual users who require specific data products.

### 3. REQUIREMENTS

The purpose of the FLASHFlux project is to produce global and gridded radiative surface fluxes within one week of the CERES observations. Progress to date indicates this ambitious goal is attainable. Even though the FLASHFlux data sets require high accuracy, they are not intended for use in climate modeling which requires both exceptional accuracy and consistent processing throughout the entire data set. Thus, some degree of precision can, and has been traded, for efficiency. Initially, the temporal resolution will be daily averaged; however, once the geosynchronous satellite radiances are incorporated into the processing, we plan to begin producing synoptic scale hourly fluxes.

### 4. RESULTS

#### 4.1 Sample SSF Results

Representative TOA fluxes from the SSF data are presented in Figure 2. The reflected SW, upwelling LW and total net fluxes are shown individually in the three plots comprising Figure 2 for the period of the June 14-16, 2004. Inverted from CERES radiances using the appropriate angular distribution models, these fluxes illustrate the results of a 3 day gridded composite at the afternoon overpass time. No temporal interpolation has been performed at this stage. The figures show the standard expected features of increased SW reflected flux over clouds and bright surfaces such as the Sahara Desert. The infrared shows maximums over warm, cloudless surfaces such as the deserts and the subtropical oceans. The ITCZ in the tropics at this time is clearly seen by the increased SW reflected and the decreased LW fluxes. In the total net, it is noted that the areas north of about 20° have a positive net (SW insolation dominating) with minima over bright surfaces such as the Sahara Desert and Greenland. South of 20° S the total net is negative (LW dominated). This is expected for June near the northern hemisphere's summer solstice.

Figure 3 provides the radiative fluxes estimated at the surface using the radiative transfer algorithms noted above. In this figure the SW down and SW net are given in the uppermost panels and the LW down and LW net are given in the bottom panels. As expected for the June timeframe, the largest surface SW

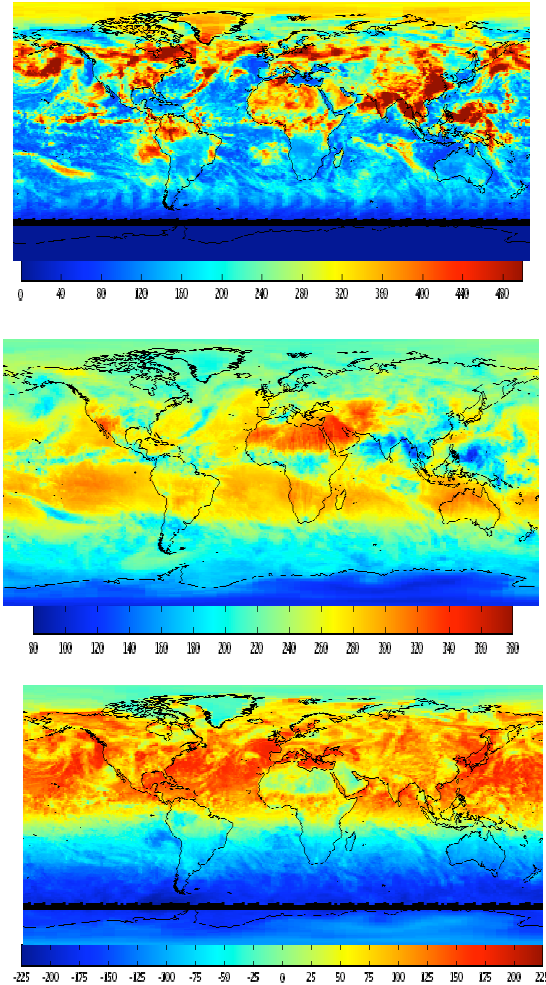


Figure 2: SSF all-sky fluxes from Aqua CERES as processed through the FLASHFlux processing system for June 14-16, 2004. The top panel gives the SW reflected flux, middle is the LW outgoing flux and the bottom is the total net outgoing radiative flux.

irradiance values are found near the North Pole, and in the vicinity of the northern hemisphere's subtropics. Cloud system advection causes departures from zonal irradiance. The net SW fluxes have similar patterns but are also minimized over bright surfaces. Thus, as expected, the subtropical oceans received the largest amounts of solar energy. LW surface fluxes dominate in the moist warm tropics, though decrease noticeably towards colder and drier areas. Notable minima in the downward irradiances are observed over Tibet and the Andes where high elevations result in lower emission temperatures and lower water vapor amounts. Additional minima are observed over the desert regions of Australia and the Southern

tip of Africa where Southern hemisphere winter and typically dry conditions also result in lower emission temperatures and lower water vapor amounts. The net LW have similar overall patterns although areas of strong negative net LW fluxes also occur over the warm but dry desert areas where emission to space is maximized.

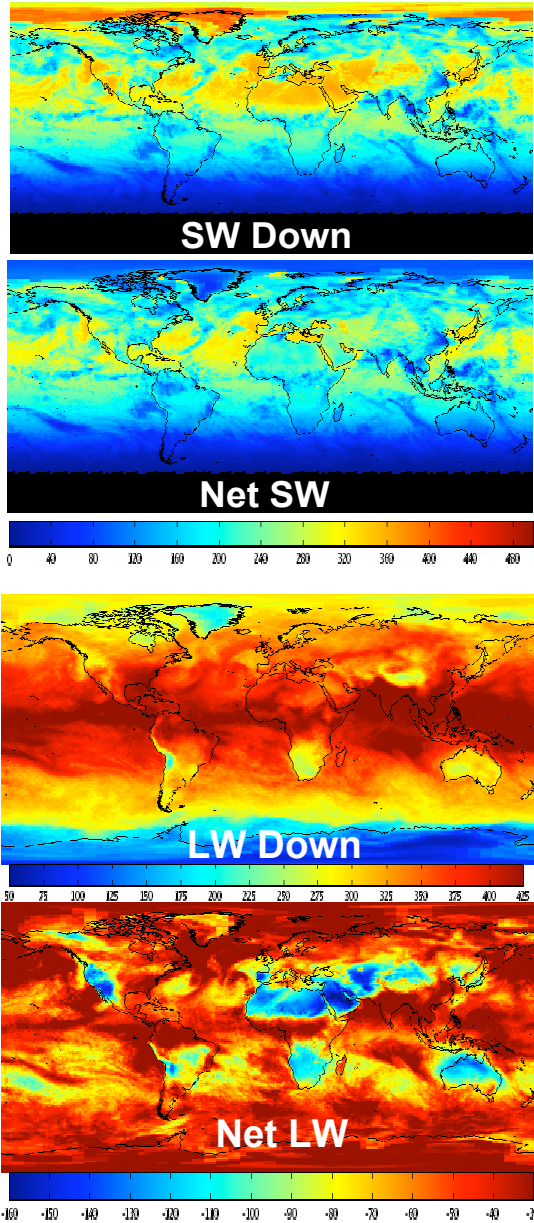


Figure 3: Surface radiative fluxes from FLASHFlux from the same period as Figure 2. Shown are the SW down, SW net, LW down and LW net. The SW plots share the same color bar.

#### 4.2 Instantaneous Validation of SSF fluxes

Validation for the SSF fluxes is obtained using surface measurements sites that report measurements quickly. The SURFRad network in the US, which is also part of the Baseline Surface Radiation Network (BSRN), provides quality measurements shortly after observations. Such sites are appropriate for the monitoring and validation of FLASHFlux data products. Figure 4 gives the results of inter-comparison measurements from the Bondville, Illinois site relative to formal CERES SSF and FLASHFlux SSF flux estimates. The plots were made for all instantaneous observations made during the months of Oct. 2004, and Jan. and Apr. 2005. The scatterplots and statistics show that the FLASHFlux SW and LW downwelling surface fluxes are compare favorably with the formal CERES products. Similar comparisons are being performed for all available sites.

#### 4.3. SAMPLE DAILY VALIDATION RESULTS

The priority goal for the FLASHFlux endeavor is to temporally interpolate the gridded product to produce daily and weekly averaged TOA and surface fluxes. Figure 5 gives the hourly fluxes using the current interpolation methods over the 3-day averaging window for the SW (top panel) and LW (bottom panel) fluxes. As demonstrated in Figure 5, the availability of both morning (Terra) and afternoon (Aqua) measurements greatly improves the retrieved fluxes. Nevertheless, rapid changes in meteorological conditions can introduce errors. Since the temporally averaged results are based upon individual satellite measurements, it is not surprising that the overall pattern of TOA and surface fluxes are similar to those presented in Figures 2 and 3. For the case of SW fluxes, however, the magnitude of the fluxes is noticeably reduced since the 24-hour daily average will include both daytime and nighttime periods.

The inclusion of GGEO subsystem (see Fig.1) will provide the opportunity to improve the temporal interpolation by providing short-term variability information. The inclusion of these measurements will lead to the opportunity to produce 1-3 hourly flux averages within the day.

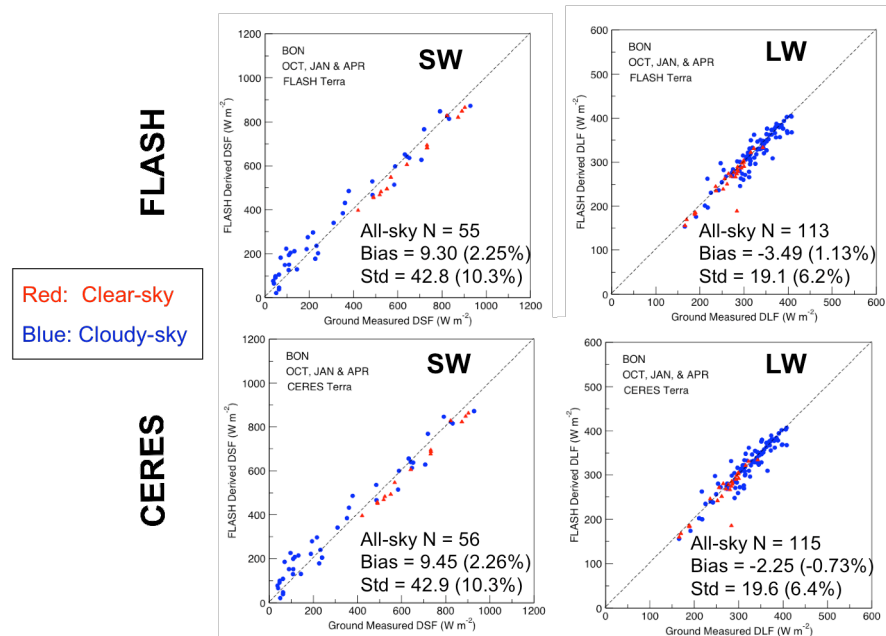


Figure 4: Instantaneous validation between CERES and FLASHFlux surface radiative fluxes at Bondville, Illinois, SURFRad site.

## 5. CONCLUSIONS

The FLASHFlux endeavor has demonstrated the capability to produce high-quality surface fluxes, comparable to the climate-quality CERES fluxes, within a week of the satellite measurements. The project is operationally producing Single Scanner Footprint (SSF) radiance, cloud and radiative flux information within a week of observation. The daily averaged fluxes that average over both Terra and Aqua satellite observations are expected to be operational within a month of writing this abstract. The FLASHFlux dataset fills the gap between the climate-quality datasets and the synoptic meteorological measurements, and thus, provides a valuable, but long overdue, resource to users needing global and regional coverage of near real-time flux data.

## 6. REFERENCES

Bloom., S. A. da Silva, and D. Dee, 2005: Documentation and validation of the Goddard Earth Observing System (GEOS) Data

Assimilation System – Version 4. NASA Technical Report Series on Global Modeling and Data Assimilation, Max J. Suarez, Editor, NASA/TM-2005-104606, 26 pp.

Gupta, S. K., D. P. Kratz, P. W. Stackhouse Jr., and A. C. Wilber, 2001: The Langley Parameterized Shortwave Algorithm (LPSA) for surface radiation budget studies (Version 1.0). NASA/TP-2001-211272, 31 pp.

Gupta, S. K., D. P. Kratz, A. C. Wilber, and L. C. Nguyen, 2004: Validation of Langley parameterized algorithms used to derive CERES/TRMM surface radiative fluxes. *J. Atmos. Ocean Tech.* **21**, 742-752.

Loeb, N. G., S. Kato, K. Loukachine, N. Manalo-Smith, 2005: Angular distribution models for top-of-atmosphere radiative flux estimation from the Clouds and the Earth's Radiant Energy System instrument on the Terra satellite. Part I: methodology. *J. Atmos. Ocean Tech.* **22**, 338-351.

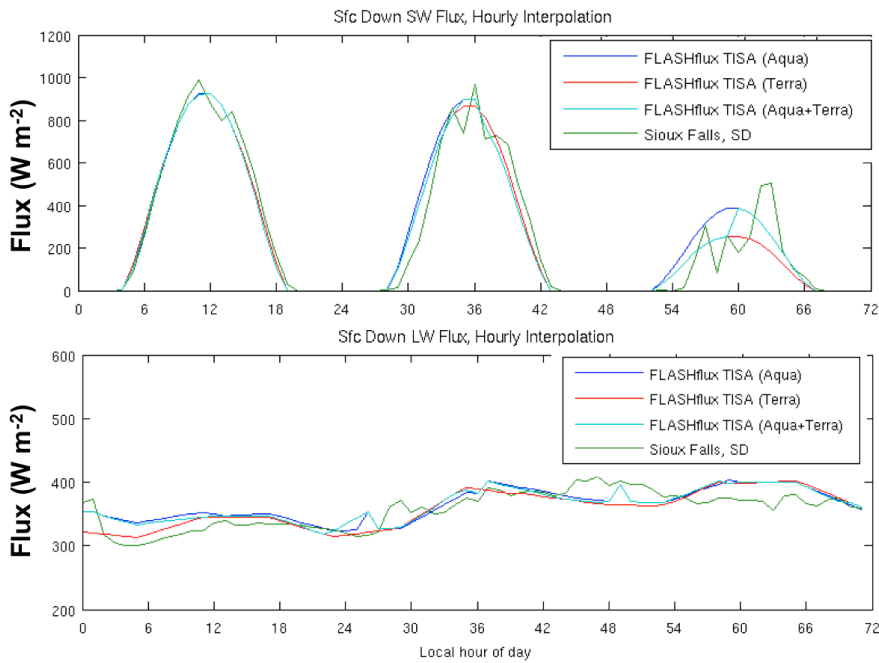


Figure 5: TISA FLASHFlux surface validation for Sioux Falls, SD.

Mlynczak, M. G., D. G. Johnson, H. Latvakoski, K. Jucks, M. Watson, D. P. Kratz, G. Bingham, W. A. Traub, S. J. Wellard, C. R. Hyde, and X. Liu, 2006: First light from the Far-Infrared Spectroscopy of the Troposphere (FIRST) instrument. *Geophys. Res. Lett.*, **33**, L07704, doi: 10.1029/2005GL025114.

Wielicki, B. A, B. R. Barkstrom, E. F. Harrison, Edwin F, R. B. Lee III, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): an Earth Observing System experiment. *Bulletin of the American Meteorological Society*, Boston, MA. Vol. **77**, no. 5, pp. 853-868.

Yang, S. K., S. Zhou, and A. J. Miller, 1997: SMOBA: A 3-Dimensional Daily Ozone Analysis Using SBUV and TOVS Measurements. This Publication has been made available through: [http://www.cpc.noaa.gov/products/stratosphere/SMOBA/smoba\\_doc.html](http://www.cpc.noaa.gov/products/stratosphere/SMOBA/smoba_doc.html)