CERES_SSF_NPP_Edition2A

Data Quality Summary (3/17/2022)

Investigation: **CERES**
Data Product: **Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)**

Data Set: **NPP CERES-FM5, VIIRS 1/2012 – Current**

Data Set Version: Edition2A

Subsetting Tool Availability: https://ceres.larc.nasa.gov/order_data.php

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Science Team. The document summarizes key validation results, provides cautions where users might easily misinterpret the data, provides links to further information about the data product, algorithms, and accuracy, and gives information about planned data improvements.

This document is a high-level summary and represents the minimum information needed by scientific users of this data product. It is strongly suggested that authors, researchers, and reviewers of research papers re-check this document for the latest status before publication of any scientific papers using this data product.

Note to Users:

- CERES Single Scanner Footprint (SSF) Edition2A incorporate imager cloud property algorithms, Angular Distribution Models (ADM) generated from the cloud properties, updated CERES gains and spectral responses, and surface models that were developed for Terra and Aqua Edition4A.
- The Edition2A uses VIIRS version 002 radiances and aerosols version 001 from Beginning of Mission.
- The Global Modeling and Assimilation Office (GMAO) reanalysis product, Goddard Earth Observing System (GEOS) Model 5.4.1, are used throughout.
- For a more detailed discussion on similarities between Terra and Aqua Edition4A and Suomi NPP Edition1A, please see Section 5.0 of this document.

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1.0 Nature of the CERES SSF Edition2A Product

The CERES Single Scanner Footprint (SSF) is a unique product for studying the role of clouds, aerosols, and radiation in climate. Each CERES footprint (nadir resolution 20-km equivalent diameter) on the SSF includes reflected shortwave (SW), emitted longwave (LW) and window (WN) radiances and top-of-atmosphere (TOA) fluxes from CERES with temporally and spatially coincident imager-based radiances, cloud properties, and aerosols, and meteorological information from a fixed 4-dimensional analysis provided by the Global Modeling and Assimilation Office (GMAO). Each file in this data product contains one hour of full and partial-Earth view measurements or footprints at a surface reference level.

Cloud properties are inferred from the Visible Infrared Imaging Radiometer Suite (VIIRS) imager, which flies along with CERES on the_Suomi-NPP_spacecraft. VIIRS is a 22-channel; five high-resolution image bands (375 m), sixteen moderate-resolution bands (750 m), and a unique panchromatic Day/Night band (not used by CERES) nadir resolution; narrowband scanner operating in crosstrack mode. To infer cloud properties, CERES uses a 750-m resolution VIIRS radiance subset that has been subsampled to include only the data that corresponds to every eighth 750-m pixel and every second scanline. The four imagery radiance pixels are averaged to obtain the 750-m pixel. The SSF retains footprint imager radiance statistics for 12 of the 22 VIIRS channels (SSF-115 through SSF-131e).

The Edition2A SSF contains footprint aerosol parameters from the 6-km spatial resolution VIIRS Deep Blue aerosol product (SSF-132 through SSF-145m). The NOAA/NESDIS algorithm (SSF-73 through SSF-78) is not available on this product. Surface fluxes derived from the CERES instrument using several different techniques (algorithms) are also provided. Sampling of the CERES footprints is performed to reduce processing time and data volume. (See Cautions and Helpful Hints.)

CERES defines SW (shortwave or solar) and LW (longwave or thermal infrared) in terms of physical origin, rather than wavelength. We refer to the solar radiation that enters or exits the Earth-atmosphere system as SW. LW is the thermal radiant energy emitted by the Earth-atmosphere system. Emitted radiation that is subsequently scattered is still regarded as LW. Roughly 1% of the incoming SW is at wavelengths greater than 4 µm. Less than 1 W m^{-2} of the OLR is at wavelengths smaller than 4 µm. The CERES unfiltered window (WN) radiance and flux represent emitted thermal radiation over the 8.1 to 11.8 µm wavelength interval.

The SSF product combines the absolute calibration and stability strengths of the broadband CERES radiation data with the high spectral and spatial resolution VIIRS imager-based cloud and aerosol properties. A major advantage of the SSF over the traditional ERBE-like ES-8 TOA flux data product is the new ADMs derived from CERES Rotating Azimuth Plane data that now allow accurate radiative fluxes not only for monthly mean regional ensembles (ERBE-like capability) but also as a function of cloud type. Fluxes in the CERES Suomi NPP Edition2A SSF are based on the Aqua Edition4A ADMs. With these ADMs, accurate fluxes can be obtained for both optically thin clouds as a class, as well as optically thick clouds. This is a result of empirical CERES ADMs that classify clouds by optical depth, cloud fraction, and water/ice classes. ERBE-like TOA fluxes are only corrected for simple clear, partly-cloudy, mostly-cloudy, and overcast classes. In addition, clear-sky identification and clear-sky fluxes are expected to be much improved over the ERBE-like equivalent, because of the use of the imager cloud mask, as well as the new ADMs incorporating ocean wind speed and surface vegetation class.

Finally, early estimates of surface radiative fluxes are given using relatively simple parameterizations applied to the SSF radiation and cloud parameters. These estimates strive for simplicity and as directly as possible use the TOA flux observations. More complex radiative transfer computations of surface and atmosphere fluxes using the SSF data and constrained to the observed SSF TOA fluxes will be provided on the CERES CRS Data Product.

CERES footprints containing one or more VIIRS imager pixels are included on the SSF product. Since the VIIRS imager can only scan to a maximum viewing zenith angle (VZA) of ~72°, this means that only CERES footprints with VZA < 72° are retained on the SSF when CERES is in the crosstrack scan mode. When CERES is scanning in either the Rotating Azimuth Plane (RAP) or the alongtrack scan mode, CERES footprints with VZA > 67° do appear on this product, provided they lie within the MODIS swath. Sampling of the CERES footprints is performed to reduce processing time and data volume. (See Cautions and Helpful Hints.) The nominal CERES Suomi NPP operation cycle is crosstrack scan mode. In October 2019, the instrument was placed in RAP mode. To determine operations on any given day, refer to the CERES Operations in orbit for Suomi-NPP. Users interested in spatially contiguous image data should use the CERES crosstrack data products. Users interested in full angular coverage over time (but with spatial gaps) should use the CERES RAP data. Users interested in many different angular views of the satellite ground track should use the CERES Along Track data.

A full list of parameters on the SSF is contained in the SSF section of the CERES Data Products Catalog (PDF) and a definition of each parameter is contained in the SSF Collection Guide.

When referring to a CERES data set, please include the satellite name and/or the CERES instrument name, the data set version, and the data product. Multiple files that are identical in all aspects of the filename except for the 6 digit configuration code (see Collection Guide) differ little, if any, scientifically. Users may, therefore, analyze data from the same satellite/instrument, data set version, and data product without regard to configuration code. Depending upon the instrument analyzed, this data set may be referred to as "CERES NPP FM5 Edition2A SSF".

2.0 Cautions and Helpful Hints

There are several cautions the CERES Science Team notes regarding the use of CERES Edition4A SSF data:

2.1 General

- The SSF data sets contain only every other CERES footprint when the viewing zenith is less than 63°. All footprints with a viewing zenith greater than or equal to 63° are included in the SSF. When SSF-20, "CERES viewing zenith at surface," is less than 63° and SSF-13, "Packet number," is even, then only footprints with an even value in SSF-12, "Scan sample number," are placed on the SSF. When "CERES viewing zenith at surface" is less than 63° and "Packet number" is odd, then only footprints with an odd value in "Scan sample number" are placed on the SSF. (See SSF Collection Guide). The CERES footprints are sufficiently overlapped in the scanning direction, that this use of every other footprint does not leave gaps in the data spatial coverage, or significantly increase errors in gridded data products or instantaneous comparisons to surface data such as BSRN. All CERES footprints are retained on the ES8 data products.
- Before using SSF parameter values, users should check for CERES default values. CERES default values, or fill values, are very large values which vary by data type. (See SSF Collection Guide.) A CERES default value is used when the parameter value is unavailable or considered suspect. SSF-1 through SSF-24 always contains valid parameter values and, therefore, need not be checked for default values. All other parameter values should be checked.
- This SSF contains only CERES footprints with at least one imager pixel of coverage that could be identified as clear or cloudy. This puts more burden on the users to screen footprints according to their needs. For example, if one wants to relate CERES fluxes with imager-derived cloud properties (e.g. cloud fraction), it is very important to check SSF-54, "Imager percent coverage" (i.e., the percentage of the CERES footprint which could be identified as clear or cloudy). When none of the imager pixels within the footprint could be identified as clear or cloudy, the footprint is not included on the SSF. The SSF also contains a flag that provides information on how much of the footprint contains pixels which could not be identified as clear or cloudy. This flag is referred to as "Unknown cloud-mask" and resides in SSF-64, "Notes on general procedures." Footprints with VZA greater than 80° and less than 100% imager coverage may be partial Earth-view. Consult SSF-34, "Radiance and Mode flags," to determine whether the footprint is full Earth-view or not. When the instrument is in the RAP or alongtrack scan mode, there are more footprints and the SSF files are larger. (See SSF Collection Guide.)
- This SSF contains only CERES footprints with at least one valid CERES radiance. All CERES footprints are retained on the ES8 data products.
- The geographic location of a CERES flux estimate is at the surface geodetic latitude and longitude of the CERES footprint centroid. On ERBE, all fluxes are located at a geocentric latitude and longitude corresponding to the 30-km level.
- Users interested in surface type should always examine both SSF-25, "Surface type index," and SSF-26, "Surface type percent coverage." (See SSF Collection Guide.)

- Users searching for footprints free of snow and ice should always examine SSF-25, "Surface type index,"; SSF-69, "Cloud-mask snow/ice percent coverage "; and SSF-30, "Snow/Ice percent coverage clear-sky overhead-sun vis albedo." (See SSF Collection Guide.)
- A footprint is recorded in the hourly SSF file that contains its observation time. However, SSF footprints within the file are ordered on time which is a change from the alongtrack angle, SSF-18 used in Edition1A and for Terra and Aqua. The alongtrack angle of the satellite is defined to be 0° at the start of the hour. If the instrument is in the RAP or alongtrack scan mode, then footprints can be prior to this start position and yield a negative alongtrack angle.
- Some applications of the SSF data will need to make the distinction between crosstrack, RAP, and alongtrack scan data. Multiple scan modes can occur in the same hour so that bits 8-9 of SSF-34, "Radiance and Mode flags" (see SSF Collection Guide) should be examined for each footprint to properly identify the scan mode. If actual azimuth angle is required, examine SSF-15, "Clock angle of CERES FOV at satellite wrt inertial velocity."
- Data in an area experiencing a solar eclipse is not processed for the duration of the eclipse. The fraction of SSF data with a solar eclipse is very small: 0.019% in 2000, 0.009% in 2001, 0.047% in 2002, and 0.025% in 2003.

2.2 Cloud

- For Edition2A SSF data sets, there is no algorithm for mean asymmetry factor for cloud layer. Therefore, SSF-106a, Mean asymmetry factor for cloud layer (see SSF Collection Guide), is set to the CERES default fill value for all footprints.
- There are cases where the cloud properties cannot be determined for an imager pixel that is cloudy at a high confidence level. These pixels are included in the area coverage calculations. The cloud layer areas are proportionately adjusted to reflect the contribution these pixels would have made, but the cloud properties for each layer are not adjusted. The amount of extrapolation can be determined by checking SSF-63, "Cloud property extrapolation over cloud area." (See SSF Collection Guide.)
- Cloud parameters are saved by cloud layer. Up to two cloud layers may be recorded within a CERES footprint. The heights of the layers will vary from one footprint to another. When there is a single layer within the footprint, it is defined as the lower layer, regardless of its height. A second, or upper, layer is defined only when a footprint contains two unique layers. It is possible to have two unique cirrus layers or two unique layers below 4 km. Within an SSF file, the lower layer of one footprint may be much higher than the upper layer of another footprint.
- Night and near-terminator cloud properties - The current method for deriving cloud phase, particle size, and optical depth at night has not been fully tested. It has been implemented primarily to improve the nocturnal determination of cloud effective height for optically thin clouds ($\tau < 5$) and is generally effective at retrieving more accurate cloud heights compared to assuming that all clouds act as blackbody radiators at night. (See Cloud Properties Accuracy and Validation.) Because an accurate optical depth is required to obtain the proper altitude correction, the optical depths for optically thin clouds are considered reasonable.
- The mean cloud top height for cloud layer (SSF94a) have been correctly calculated for thick ice clouds which is a fix from the Terra and Aqua Edition4A SSF. In the Cloud Properties Accuracy and Validation p 10, the earlier correction is provided.

- Near-terminator cloud amounts - The cloud mask relies heavily on the brightness temperature differences between channels 3 and 4 for identifying clouds at night and in the daytime. The signals differ between night and day for low clouds. At high SZAs (> 80°), these signals can cancel each other resulting in low clouds mistaken as clear areas when the cloud temperature is close to or warmer than the clear-sky temperature. Terminator cloud amounts have improved since Terra and Aqua Edition1A, but can still use further improvement.
- Heavy aerosols - Aerosols with relatively large optical depths (τ >1-2) can sometimes be misidentified as clouds over any surface. Thus, in areas known to experience large dust outbreaks, such as large deserts or adjacent ocean areas, caution should be used when interpreting cloud statistics.
- Optical depths over snow - Cloud optical depth in Edition1A is derived using the SINT when it is known that the underlying surface is either snow or ice-covered. Otherwise, the VISST is used, an approach that often results in an overestimate of the optical depth over snow. In general, the optical depths will be overestimated in snow-covered regions if the underlying surface is not properly classified as being snow-covered.
- Multi-layered/mixed-phase cloud properties - Although an experimental product to detect multi-layered clouds was implemented, its results are retained in separate SSF variables. Thus, all clouds properties in the Cloudy Footprint Area are treated as single phase, single-layer clouds in the retrievals. Mixed phase cloud pixels are interpreted as either entirely liquid or ice clouds depending on the relative amounts of each phase in the top of a particular cloud. Overlapped ice and water cloud pixels will be interpreted in a similar fashion depending on the optical thickness and particle size of the overlying cloud. If it is very thin, the cloud will usually be classified as liquid. Thicker ice clouds over liquid clouds will be classified as ice. The resulting ice particle size for the thicker clouds should be representative of the ice cloud, but will often be too small for the thinner clouds. Mixed phase or overlapped thin-ice-over-thick-water clouds will produce either a liquid water effective radius that is too large for the water droplets in the cloud or too small for the ice crystals in the cloud because the 3.7-µm reflectances for the ice and water particles overlap at the low and high end, respectively. Users will need to use some contextual, temperature, or variability indicators to determine if a particular footprint contains both ice and water clouds if phase index for the footprint is either 1 (water) or 2 (ice). Cloud heights for multi-layered clouds will also be in error if the upper cloud deck is optically thin. The retrieved cloud altitude will be between the height of the lower and the upper clouds.
- A multi-layered/mixed phase cloud properties are contained in the Multilayer Cloud Footprint Area (SSF-114a – SSF-114l). The values presented are in relation to the Cloudy Footprint Area.
- "Mean cloud infrared emissivity for cloud layer," SSF-87, is an effective emissivity. Therefore, values greater than 1.0 may occur as a result of IR scattering within the cloud.
- Polar night cloud amounts - The Aqua and Terra Edition2 algorithm for detecting clouds over regions poleward of 60° at night is still the most uncertain methodology. Missed clouds in those areas can have a significant impact on the computed downwelling longwave flux.
- This SSF includes footprints over hot land and desert for which IR radiances are saturated or otherwise unavailable. The WN brightness temperature is used to identify these scenes. Footprints containing these hot scenes are referred to as "reclassified clear" and flagged in SSF-65, "Notes on cloud algorithms." For "reclassified clear" footprints, most clear

footprint area parameters, such as cloud mask percent coverages, and aerosol A parameters, are set to CERES default.

- When averaging cloud properties using multiple footprints, the cloud property should be weighted by cloud area coverage for each level and the denominator would be a sum of cloud area coverage for all levels used. If a straight average is performed, extreme values are minimized. Differences of 150 hPa in effective pressure have been seen between the two techniques when creating 1 degree angular grids in the tropics.
- The 0.65 µm and 3.8 µm optical depths have a mismatch due to an error in the model look-up tables.
- There can be minor effects on particle radius and optical depth over ice and snow due to an error in the parameterization of 1.24 and 2.13 µm reflectances.
- The VIIRS instrument does not have higher wavelength CO2 channel (13 and 14 µm), so the CO2 algorithm variables uses 1.38 µm.
- The VIIRS instrument does not have a Water Vapor channel that results in less accurate clouds for colder higher elevation areas.

2.3 Aerosol

- The Edition2A SSF contains footprint aerosol parameters from the NOAA Suomi-NPP Atmosphere Deep Blue team (SSF-132 through SSF-167). The NOAA/NESDIS algorithm (SSF-73 through SSF-78) are not available. The NOAA Suomi-NPP Atmosphere team aerosols are obtained from the AERDB_L2 product, which averages a retrieval using full spatial resolution VIIRS data into bundles spaced 6-km apart. For Edition2A, the AERDB_L2 input is collection 001.

2.4 TOA Flux

- The CERES ADMS (see TOA Fluxes Validation section) allow determination of accurate TOA fluxes for a wide range of cloud and aerosol conditions. These fluxes will be most accurate when a class of cloud or clear-sky is averaged over a wide range of viewing zenith angles. Not all anisotropy has been removed, and for highest accuracy users are advised to avoid restricting viewing zenith angles to a narrow range (just near nadir for example).
- In sunglint, SSF-38, "CERES SW TOA flux - upwards", is based upon the ADM mean flux corresponding to the observed scene type rather than the actual radiance-to-flux conversion. This strategy is used to reduce the large anisotropic variability (noise) in the sunglint region, without biasing the large ensemble average fluxes by scene type. To determine whether or not to perform a radiance-to-flux conversion for clear ocean scenes, the standard deviation (σ_{clr}) of the clear ocean ADM anisotropic factors in the vicinity of the measurement (i.e. surrounding w_s, θ_o, θ, and ϕ bins) must be less than 0.05. When clouds are present, a TOA flux retrieval is performed if $(1\text{-}f_{cld})\sigma_{clr} < 0.05$. Over sea-ice, a flux retrieval is performed if $(1\text{-}f_{ice})(1\text{-}f_{cld})\ \sigma_{clr} < 0.05$. If any of these conditions are not met, the ADM mean flux corresponding to the observed scene type is reported. When CERES is in a crosstrack scan mode, approximately 20-25% of the clear ocean CERES FOVs fail to pass sunglint. The frequency decreases with increasing cloud and sea-ice fraction. Overall 96% of the crosstrack CERES data over ocean passes the sunglint test. For more details, please see p. 69 of TOA Radiative Flux Estimation from CERES/Terra Angular Distribution Models (PDF).

- On Edition 2, TOA fluxes are determined using new ADMs developed from CERES on Terra and Aqua using the latest cloud algorithms. The ADM type for inversion (SSF-27 through SSF-29) classification has changed from earlier Editions. For a detailed description of the ADM types used please consult the Angular Distribution Models page.
- To facilitate analysis of CERES SSF by scene type, a cloud classification parameter (called Cloud Classification SSF-29) has been added to the SSF. Users will find the new cloud classification parameter more convenient than SSF-27 and SSF-28 for classifying CERES footprints by scene type. See the Cloud Classification Parameter page. If this classification is inadequate for a particular application, users are encouraged to develop their own classification using the many available SSF parameters.

3.0 Version History

3.1 Changes between Suomi-NPP Edition1A and Edition2A

New CERES gains and spectral responses are used that provide a consistent radiometric scale between Suomi NPP and Terra and Aqua. CERES Single Scanner Footprint (SSF) Edition2A incorporate the same cloud property algorithms used in Edition1A; it uses the Edition4A ADMs generated from the updated MODIS cloud properties; and updated surface flux models. A consistent Global Modeling and Assimilation Office (GMAO) reanalysis product, GEOS 5.4.1, are used throughout processing. The NOAA Suomi-NPP Atmosphere Deep Blue team aerosols are obtained from the AERDB_L2 version 001 product, which averages a retrieval using full spatial resolution VIIRS data into bundles spaced 6-km apart.

3.1.1 CERES Radiances

The Suomi-NPP satellite has a higher orbit at 824 km then Terra and Aqua 705 km orbit. This increases the size of the CERES footprint. The FM-5 instrument have corrections determine by the on-orbit calibration to adjust for shortwave drift.

The Edition2A beginning of mission (BOM) Spectral response functions (SRF) for S-NPP-FM5 were modified to incorporate the radiometric scaling with Aqua-FM3. This was performed using collocated inter-comparison datasets between Aqua and S-NPP to determine the all-sky differences and then applying the necessary one-time radiometric scaling in the BOM SRF through a novel technique using Lagrange Multipliers. The methodology is summarized in Shankar et al.

In addition to the change in the BOM SRF, validation studies of long term trends from S-NPP indicated the need for making time-varying adjustments to the SW portion of the Total channel SRF. An approach similar to that used to account for changes to the SRF for the instruments on Terra and Aqua is used (Loeb et al.).

The FM-5 radiances anomalies closely follow those of other CERES instruments, but the absolute calibration differ.

A comparison of the resulting changes between matched CERES nadir footprints in unfiltered radiances and representative values from Edition1A are given in Table 3-1. The Edition2A SW radiances are about a $Wm^{-2}sr^{-1}$ lower than Edition1A. The Edition2A LW daytime radiance increased by one-eight of a $Wm^{-2}sr^{-1}$; whereas, at night the LW decreased by one-eighth of a $Wm^{-2}sr^{-1}$.

Table 3-1. The mean Edition1A unfiltered nadir radiances with no interpolation and difference between Edition2A and Edition1A (Ed2A – Ed1A) during seasonal months in 2013.

		January		April		July		October	
	Unfiltered Radiance	**Mean**	**Diff**	**Mean**	**Diff**	**Mean**	**Diff**	**Mean**	**Diff**
S-NPP FM5	Shortwave	77.01	-1.015	70.96	-0.957	69.66	-0.925	67.19	-0.892
	Longwave Day	77.63	0.319	77.80	0.296	81.86	0.339	77.16	0.265
	Longwave Night	73.61	-0.127	72.27	-0.125	72.44	-0.128	74.42	-0.124

3.1.2 Clouds Algorithm

The same cloud property algorithms used in Edition1A, but a new version of VIIRS radiances were used. These radiances were scaled to the Aqua MODIS Collection 005 radiances to improve the consistency between cloud fraction and properties between the imagers. The resolution of the VIIRS imagery channel is 375 m and the moderate channel is 750 m. Instead of the 2.13 μm channel on MODIS, a 2.26 μm channel from VIIRS is used for the cloud microphysics. Cloud optical depth and microphysical properties are obtained at 1.24 and 1.60 μm (SSF-108 through SSF-110c).

Results from the VIIRS cloud mask algorithms are consistent with those obtained from Edition1A; however, there is a global decrease of 0.01 in cloud amounts. There is a sharp difference in the visible optical depth between the VIIRS 03110 and 001 radiance used in Edition1A when compared to the Edition2A values. The global mean difference in optical depth between version 03110 and 002 radiances is an increase of 0.02, but a decrease of 0.04 between version 001 and 002.

3.1.3 TOA Fluxes

To account for the new cloud properties, the empirical ADMs were updated using Edition4A RAPS data. The number of bins was increased for many of the ADMs. New algorithms were introduced for others. The most significant changes are over clear ocean, clear land, and polar regions. The flux changes are less than 0.5 W m^{-2} on a monthly global scale, but can result in monthly mean instantaneous fluxes changes of 5 W m^{-2} on a regional 1^{o} latitude by 1^{o} longitude scale.

A modified Ross-Li 3-parameter fit for Normalized Difference Vegetation Index (NDVI), cosine solar zenith angle and surface roughness is now used in the shortwave clear land ADM. The clear land ADM is now used for clear fresh snow while additional surface brightness and cloud fraction bins were added to the partly cloudy and overcast fresh snow ADM. A special ADM was developed for clear conditions over Antarctica to account for the effect of sastrugi and one ADM is used for clear conditions over Greenland. During overcast conditions for permanent snow, ADM for each cloud phase and four log optical depth bin are used. A sea ice brightness index was created to improve the sea-ice ADM. While aerosol type gained an additional stratification in the clear ocean ADM.

The long wave clear ADMs is calculated with interpolation between bins along with increasing the number on various bins. For long wave cloudy ADMs, the third-order polynomial fits between radiance and pseudoradiance was replaced with mean values at 1 W m^{-2} sr^{-1} intervals in pseudoradiances.

The incoming solar radiation constant of 1365 Wm^{-2} has been replaced with the daily value as provided by the Total Solar Irradiance (TSI) from the SOlar Radiation and Climate Experiment (SORCE) as supplemented by World Radiation Center (WRC), Davos and the Royal Meteorological Institute of Belgium (RMIB) data. The Total Incoming Solar Radiation (SSF-38a) is now included on the SSF.

A comparison of the resulting changes between matched CERES nadir footprints in fluxes and representative values from Edition1A are given in Table 3-2. The Edition2A SW fluxes during 2013 are about 3 Wm^{-2} lower than Edition1A. The Edition2A LW fluxes have increased by almost a Wm^{-2} during the day and decreased by 0.4 Wm^{-2} at night. The version of the VIIRS imager data used changed starting with January 2016 resulting in a smaller drop in the SW flux to 2.7 Wm^{-2} lower than Edition1A. The daytime LW change bounced around either side of zero in 2017. No noticeable impact is seen in the nighttime LW flux.

Table 3-2. The mean Suomi NPP Edition1A nadir fluxes with no interpolation and difference between Edition2A and Edition1A (Ed2A – Ed1A) during seasonal months in 2013.

		January		April		July		October	
	Flux	**Mean**	**Diff**	**Mean**	**Diff**	**Mean**	**Diff**	**Mean**	**Diff**
2013	Shortwave	273.74	-3.223	254.19	-3.046	249.85	-3.164	249.41	-3.073
	Longwave Day	231.80	0.969	231.64	0.899	243.58	1.201	229.99	0.810
	Longwave Night	219.66	-0.393	215.33	-0.391	215.56	-0.402	221.70	-0.396
2017	Shortwave	267.22	-2.879	250.97	-2.649	245.17	-2.824	244.93	-2.568
	Longwave Day	232.66	-0.065	233.02	0.415	244.54	0.373	231.99	-0.105
	Longwave Night	218.25	-0.387	216.28	-0.396	215.33	-0.396	221.53	-0.392

3.1.4 Surface Models

The Edition2A surface fluxes are consistent with Edition1A with minor changes due to TOA fluxes and cloud properties from using a improved version of VIIRS data.

3.2 Changes between Suomi-NPP Edition1A and Terra and Aqua Edition4A

CERES gains have been applied to the radiance, but the at-launch spectral responses are used. The Suomi-NPP unfiltered radiances and fluxes have not been scaled to Terra and Aqua Edition4A. CERES Single Scanner Footprint (SSF) Edition1A incorporate the same cloud property algorithms used in Edition4A with adjustments for changes in the central wavelength of the imager channels on VIIRS; it uses the Edition4A ADMs generated from the updated MODIS cloud properties; and updated surface flux models. A consistent Global Modeling and Assimilation Office (GMAO) reanalysis product, GEOS 5.4.1, are used throughout processing. Instead of the MODIS collection 5.1 and 6.1 aerosols, the NOAA Suomi-NPP Atmosphere team aerosols are obtained from the VNP04E_L2 product, which averages a retrieval using full spatial resolution VIIRS data into bundles spaced 6-km apart. For Edition1A, the VNP04E_L2 input is collection 03110 or 001.

3.2.1 CERES Radiances

The Suomi-NPP satellite has a higher orbit at 824 km then Terra and Aqua 705 km orbit. This increases the size of the CERES footprint. The FM-5 instrument have corrections determine by the on-orbit calibration to adjust for shortwave drift.

In Edition2A, a monthly gain correction is applied without using interpolation.

The FM-5 radiances anomalies closely follow those of other CERES instruments, but the absolute calibration differ.

3.2.2 Clouds Algorithm

The same cloud property algorithms used in Edition4A with adjustments for changes in the central wavelength of the imager channels on VIIRS. The resolution of the VIIRS imagery channel is 375 m and the moderate channel is 750 m which is higher than MODIS. Instead of the 2.13 µm channel on MODIS, a 2.26 µm channel from VIIRS is used for the cloud microphysics. Cloud optical depth and microphysical properties are obtained at 1.24 and 1.60 µm (SSF-108 through SSF-110c).

Results from the VIIRS cloud mask algorithms are consistent with those obtained from MODIS; however, there is a global decrease of 0.02 in cloud amounts.

Cloud phase statistics change is dependent on the regime with less water clouds in the tropics than was obtained from MODIS, but more water clouds are identified in the middle-latitude and polar regions with an overall global shift from liquid to ice of 0.005 with significantly more liquid clouds occurring over polar land.

The cloud top heights have been corrected for an error in Terra and Aqua then in Edition4. Cloud top and base temperature (SSF-94a, SSF-102a) and top height (SSF-94b) are now included in the product. A monthly, regional variable apparent lapse rate is now used in the boundary layer instead of the previous constant lapse rate. A CO_2 emission method provides cloud properties (SSF-111a through SSF-112).

The lack of retrieved cloud parameters has decreased. Hexagonal ice columns with roughened surfaces are used in the radiative transfer computations instead of the previous smooth surfaces.

An experimental multilayer cloud algorithm, assuming a thin ice cloud over a water cloud, is combined with the VIST algorithm (SSF-114a through SSF-114l).

3.2.3 TOA Fluxes

To account for the new cloud properties, the empirical ADMs were updated using Edition4A RAPS data. The number of bins was increased for many of the ADMs. New algorithms were introduced for others. The most significant changes are over clear ocean, clear land, and polar regions. The flux changes are less than 0.5 W m^{-2} on a monthly global scale, but can result in monthly mean instantaneous fluxes changes of 5 W m^{-2} on a regional 1° latitude by 1° longitude scale.

A modified Ross-Li 3-parameter fit for Normalized Difference Vegetation Index (NDVI), cosine solar zenith angle and surface roughness is now used in the shortwave clear land

ADM. The clear land ADM is now used for clear fresh snow while additional surface brightness and cloud fraction bins were added to the partly cloudy and overcast fresh snow ADM. A special ADM was developed for clear conditions over Antarctica to account for the effect of sastrugi and one ADM is used for clear conditions over Greenland. During overcast conditions for permanent snow, ADM for each cloud phase and four log optical depth bin are used. A sea ice brightness index was created to improve the sea-ice ADM. While aerosol type gained an additional stratification in the clear ocean ADM.

The long wave clear ADMs is calculated with interpolation between bins along with increasing the number on various bins. For long wave cloudy ADMs, the third-order polynomial fits between radiance and pseudoradiance was replaced with mean values at 1 W m^{-2} sr^{-1} intervals in pseudoradiances.

The incoming solar radiation constant of 1365 Wm^{-2} has been replaced with the daily value as provided by the Total Solar Irradiance (TSI) from the SOlar Radiation and Climate Experiment (SORCE) as supplemented by World Radiation Center (WRC), Davos and the Royal Meteorological Institute of Belgium (RMIB) data. The Total Incoming Solar Radiation (SSF-38a) is now included on the SSF.

3.2.4 Surface Models

An additional Longwave Algorithm has been added (SSF-49a through SSF-49c) based on Zhou et al. 2007.

The Langley Parameterized Shortwave Algorithm (LPSA) was improved with the switch to albedo maps derived from CERES Terra and aerosol data from the daily Model of Atmospheric Transport and CHemistry (MATCH) datasets. The Rayleigh molecular scattering formulation was replaced with Bodhaine et al. (1999). Revised empirical coefficient in the cloud transmission formula has improved the SW surface flux in partly cloudy condition.

The Langley Parameterized Longwave Algorithm (LPLA) now constrains the lapse rate and inversion strength. The Langley Parameterized Algorithm now provides shortwave (SSF-46a) and longwave (SSF-47a) clear-sky surface flux.

3.2.5 Imager Radiance

The ability to provide up to an additional 7 imager radiance channel with total and clear sky means have been included (SSF-131a through SSF-131e).

4.0 Accuracy and Validation

Accuracy and validation discussions are organized into sections. Please read those sections which correspond to parameters of interest.

4.1.1 CERES Suomi NPP radiances

4.1.2 Cloud properties Edition2A

4.1.3 Spatial matching of imager properties and broadband TOA fluxes

4.1.4 Top of atmosphere fluxes Edition2A

4.1.5 Surface fluxes Edition2A

5.0 Expected Reprocessing

There is no scheduled reprocessing at this time. However it is expected that the temporal coverage of the CERES SSF products will be updated in 2-month intervals.

Later algorithm improvements will be guided by results of further validation studies.

6.0 Attribution

The CERES Team has gone to considerable trouble to remove major errors and to verify the quality and accuracy of these data. Please provide a reference to the following paper when you publish scientific results with the CERES Terra or Aqua SSF Edition4A products:

> Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, 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, Bull. Amer. Meteor. Soc., 77, 853-868.

The calibration used for the CERES measurements can be reference from:

> Shankar, M.; Su, W.; Manalo-Smith, N.; Loeb, N.G. Generation of a Seamless Earth Radiation Budget Climate Data Record: A New Methodology for Placing Overlapping Satellite Instruments on the Same Radiometric Scale. *Remote Sens.* **2020**, *12*, 2787. https://doi.org/10.3390/rs12172787

> Loeb, N. G., N. Manalo-Smith, W. Su, M. Shankar, S. Thomas, 2016: CERES Top-of-Atmosphere Earth Radiation Budget Climate Data Record: Accounting for in-Orbit Changes in Instrument Calibration. Remote Sensing, 8(3), 182. doi: 10.3390/rs8030182.

> Loeb, N.G.; Manalo-Smith, N.; Su, W.; Shankar, M.; Thomas, S. CERES Top-of-Atmosphere Earth Radiation Budget Climate Data Record: Accounting for in-Orbit Changes in Instrument Calibration. *Remote Sens.* **2016**, *8*, 182, doi: 10.3390/rs8030182.

When using the cloud results, please reference the following papers:

> Sun-Mack, S., P. Minnis, Y. Chen, D. R. Doelling, B. R. Scarino, C. O. Haney, W. L. Smith, 2018: Calibration Changes to Terra MODIS Collection-5 Radiances for CERES Edition 4 Cloud Retrievals. IEEE Transactions on Geoscience and Remote Sensing, 1-17. doi: 10.1109/TGRS.2018.2829902

> Trepte, Q. Z., P. Minnis, S. Sun-Mack, C. R. Yost, Y. Chen, Z. Jin, G. Hong, F. Chang, W. L. Smith, K. M. Bedka, T. L. Chee, 2019: Global Cloud Detection for CERES Edition 4 Using Terra and Aqua MODIS Data. IEEE Transactions on Geoscience and Remote Sensing, 1-40. doi: 10.1109/TGRS.2019.2926620

> Trepte, Q. Z., P. Minnis, S. Sun-Mack, C. R. Yost, Y. Chen, Z. Jin, G. Hong, F. Chang, W. L. Smith, K. M. Bedka, T. L. Chee, 2019: Global Cloud Detection for CERES Edition 4 Using Terra and Aqua MODIS Data. IEEE Transactions on Geoscience and Remote Sensing, 1-40. doi: 10.1109/TGRS.2019.2926620.

> Minnis, P., S. Sun-Mack, D. F. Young, P. W. Heck, D. P. Garber, Y. Chen, D. A. Spangenberg, R. F. Arduini, Q. Z. Trepte, W. L. Smith, Jr., J. K. Ayers, S. C. Gibson, W. F. Miller, V. Chakrapani, Y. Takano, K.-N. Liou, Y. Xie, and P. Yang, 2011: CERES Edition-2 cloud property retrievals using TRMM VIRS and Terra and Aqua MODIS data, Part I: Algorithms. *IEEE Trans. Geosci. Remote Sens.*, **49**, *11*, 4374-4400.

Minnis, P., S. Sun-Mack, Y. Chen, M. M. Khaiyer, Y. Yi, J. K. Ayers, R. R. Brown, X. Dong, S. C. Gibson, P. W. Heck, B. Lin, M. L. Nordeen, L. Nguyen, R. Palikonda, W. L. Smith, Jr., D. A. Spangenberg, Q. Z. Trepte, and B. Xi, 2011: CERES Edition-2 cloud property retrievals using TRMM VIRS and Terra and Aqua MODIS data, Part II: Examples of average results and comparisons with other data. *IEEE Trans. Geosci. Remote Sens.*, **49**, *11*, 4401-4430.

When using the CERES fluxes, please reference this paper:

Su, W., J. Corbett, Z. Eitzen, L. Liang, 2015: Next-generation angular distribution models for top-of-atmosphere radiative flux calculation from CERES instruments: methodology. Atmos. Meas. Tech., 8(2), 611-632. doi: 10.5194/amt-8-611-2015

Su, W., Corbett, J., Eitzen, Z., and Liang, L.: Next-generation angular distribution models for top-of-atmosphere radiative flux calculation from CERES instruments: validation, Atmos. Meas. Tech., 8, 3297–3313, https://doi.org/10.5194/amt-8-3297-2015, 2015.

Wenying Su, Joseph Corbett, Zachary Eitzen, Lusheng Liang, Next-Generation Angular Distribution Models for Top-of-Atmosphere Radiative Flux Calculation from the CERES Instruments: Methodology, Atmos. Meas. Tech. Disscuss., 7, doi:10.5194/amtd-7-8817-2014, 8817-8880, 2014.

When using the surface flux data results, please reference the following paper, which details the validation of these fluxes:

Kratz, D. P., S. K. Gupta, A. C. Wilber, V. E. Sothcott, 2020: Validation of the CERES Edition-4A Surface-Only Flux Algorithms. J. Appl. Meteor. Climatol., 59(2), 281-295. doi: 10.1175/JAMC-D-19-0068.1.

The CERES data products now have dois. To cite the data in publications use this format:

CERES Science Team, Hampton, VA, USA: NASA Atmospheric Science Data Center (ASDC), Accessed <**author citing data inserts date here**> at doi: (appropriate product)

For NPP FM5: 10.5067/NPP/CERES/SSF-FM5_L2.002A

When data from the Langley Data Center are used in a publication, we request the following acknowledgment be included:

> "These data were obtained from the Atmospheric Science Data Center at the NASA Langley Research Center."

The Langley Atmospheric Science Data Center requests two reprint of any published papers or reports or a brief description of other uses (e.g., posters, oral presentations, etc.) of data that we have distributed. This will help us determine the use of data that we distribute, which is important for optimizing product development. It also helps us to keep our product-related references current.

7.0 Feedback and Questions

For questions or comments on the CERES Data Quality Summary, contact the User and Data Services staff at the Atmospheric Science Data Center.

For questions about the CERES subsetting/visualization/ordering tool at http://ceres.larc.nasa.gov/order_data.php, please click on the feedback link on the left-hand banner.

Document Creation Date: March 17, 2022
Modification History:
Most Recent Modification: