CERES Terra Edition3A SSF Data Quality Summary

Investigation:	**CERES**
Data Product:	**Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)**
Data Set:	**Terra (Instruments: CERES-FM1 or CERES-FM2, MODIS)**
Data Set Version:	**Edition3A**

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 its history, 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 also automates registration in order to keep users informed of new validation results, cautions, or improved data sets as they become available.

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.

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Nature of the SSF Product

This document discusses the Single Scanner Footprint (SSF) data set version Edition3A for Terra. This version of the SSF includes updated CERES calibration and surface flux models, but uses the same cloud properties, aerosol, and imager radiances as were used in Edition2B, Edition2F, and Edition2G. Reference to the Edition2 series above will be shortened to Edition2B/F/G in the remainder of this document unless otherwise indicated. There are no Terra Editions of SSF between Edition2B and Edition2F (additional information about Edition2 versions is provided in the Description/Abstract document). The files in this data product contain one hour of full and partial-Earth view measurements or footprints located in colatitude and longitude at a surface reference level.

The Edition3 CERES calibration improvements can be summarized as following:

1. Start-of-mission Spectral Response Function (SRF) and radiometric gain factors were re-derived from pre-launch ground calibration data
2. Using Flight Model One (FM1) as the standard, correction factors were derived to place all CERES instruments on the same radiometric scale. Data for March 2000 was used for FM1 and FM2.
3. Using the Internal Calibration Module, in-flight calibration changes were determined. These changes were incorporated into the radiometric gains.
4. A time-dependent change in the SRF was determined that accounts for on-orbit darkening in the short wavelength region of the sensors. A direct nadir radiance comparison for CERES instruments on the same spacecraft was used to correct for the SW changes in SW spectral response for the instrument in RAP mode. The spectral darkening is most pronounced at wavelengths < 0.5 microns. Corrections for degradation in the TOT channel spectral response function assume no time-dependent drift in the relationship between day-night longwave and day-night window radiance differences.

A comparison of Edition2 and Edition3 all sky global fluxes are given in Table 1 using ERBE-like ES-8 product nadir data. Further details on calibration changes can be found in the CERES Science Team Meeting presentation by Thomas, et al (PDF).

Shortwave radiance contribution to the total channel is now removed for solar zenith angle less than 95 degrees instead of the previous 90 degrees in obtaining longwave unfiltered radiance. This results in a small reduction in longwave flux near the terminator from Edition2B/F/G.

The surface flux models A and B were updated for both shortwave and longwave. Changes to the surface flux algorithms are discussed in the Surface Fluxes Accuracy and Validation section.

Table 1. All sky global flux results for March 2000 based on the ERBE-like ES-8 product nadir data.

	FM1			FM2		
	Edition3 (Wm-2)	**Edition2 (Wm-2)**	**Ed3-Ed2 (Wm-2)**	**Edition3 (Wm-2)**	**Edition2 (Wm-2)**	**Ed3-Ed2 (Wm-2)**
LW Day	230.62	228.72	0.80%	230.44	229.8	0.28%
LW Nite	224.70	223.86	0.38%	224.60	223.52	0.49%
SW	256.36	256.24	0.05%	256.60	256.09	0.20%

The clouds, aerosol, and imager radiance information on Edition3 is the same as used in Edition2B/F/G. For a complete summary changes in Edition2B/F/G, please see the Data Quality Summary for that product Edition2B Data Quality Summary. Figure 1 shows the timeline of CERES radiance input (IES) and clouds, aerosol, and imager data from Edition2B/F/G SSF products. The figure also shows how the input to Edition2B/F/G inputs change during the time period. From the standpoint of CERES processing directed by the CERES team, there were no algorithm or code changes other than what was required to read the new input data sets.

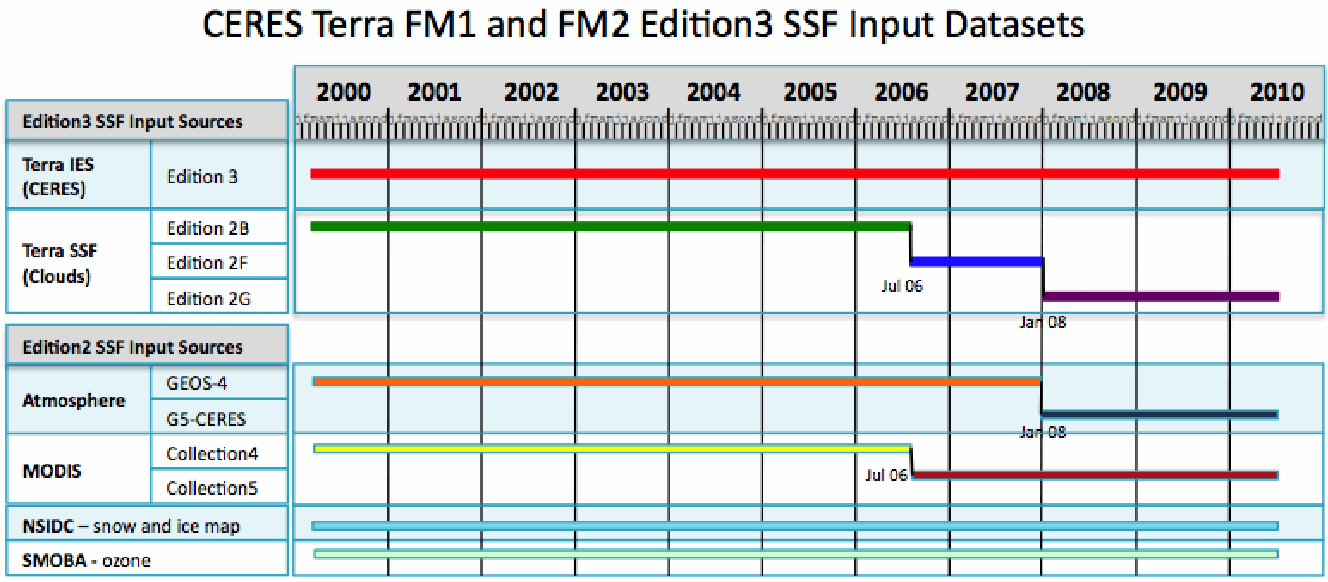

Figure 1. CERES input datasets used to produce CERES Edition3 SSF

The Terra 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). Cloud properties are inferred from the Moderate-Resolution Imaging Spectroradiometer (MODIS) imager, which flies along with CERES on the Terra spacecraft. MODIS is a 36-channel; 1-km, 500-m, and 250-m nadir resolution; narrowband scanner operating in crosstrack mode. To infer cloud properties, CERES uses a 1-km resolution MODIS radiance subset that has been subsampled to include only the data that corresponds to every fourth 1-km pixel and every second scanline. The Terra SSF retains footprint imager radiance statistics for 5 of the 19 MODIS channels (SSF-115 through SSF-131). The Terra Edition3A SSF contain footprint aerosol parameters from both the 10-km spatial resolution MODIS aerosol product (SSF-132 through SSF-160) and the NOAA/NESDIS algorithm (SSF-73 through SSF-78). For Terra Edition3A before June 30, 2006, the MODIS aerosols are from collection 4. After that date, the MODIS aerosols are from collection 5. 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 MODIS 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 angular models 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 Terra Edition3A SSF are based on the same set of global Angular Distribution Models (ADMS) used in Edition2B/F/G. Any differences are a result of updated CERES radiances as input to the ADM. With these new 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 new empirical CERES angular models 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 angular models 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 MODIS imager pixels are included on the SSF product. Since the MODIS imager can only scan to a maximum viewing zenith angle (VZA) of ~65°, this means that only CERES footprints with VZA < 67° 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 Terra operation cycle for each instrument was 3 months in crosstrack scan mode followed by three months in RAP mode. The cycles of the two instruments were offset by three months such that there was always one instrument operating in the crosstrack scan mode and one in the RAP mode. Nominally, every fourteen days, the instrument operating in RAP mode switched to alongtrack scan mode for one day. In February 2002, the nominal 3-month switching cycle was halted. At that time, the FM1 instrument was placed into crosstrack scan mode, and the FM2 instrument was placed in RAP mode. In June 2005, another change was made and both the FM1 and FM2 instruments were placed in crosstrack scan mode. FM2 was temporarily placed in the stow mode for July and August 2005, and FM1 was temporarily placed in stow for January and February 2006. The instrument scan modes may again change. To determine operations on any given day, refer to the CERES Operations in Orbit. 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, these data sets may be referred to as "CERES Terra FM1 Edition3A SSF", "CERES Terra FM2 Edition3A SSF"

The user applied revisions that were provided for Terra Edition2B/F/G SSF are not required for Edition3A.

Cautions and Helpful Hints

There are several cautions the CERES Science Team notes regarding the use of CERES Terra Edition3A SSF data:

General

- The Terra Edition3A SSF and Terra Edition2B/F/G SSF differ only in CERES filtered radiances (SSF-31 through SSF-33), CERES unfiltered radiances (SSF-35 through SSF-37), fluxes (SSF-38 through SSF-49) and scene type (SSF-27 through SSF-30) parameters. Edition3A and Edition2B/C/F contain the same CERES footprints and have identical cloud and aerosol property values. (For parameter definitions, see SSF Collection Guide.)

- The Terra Edition3A SSF uses two collections of MODIS input data in the time series. From the standpoint of processing directed by the CERES team, there were no algorithm or code changes other than what was required to read the collection 5 MODIS input data sets. Terra SSF data sets prior to June 30, 2006 used MODIS collection 4 inputs. After that date, Terra MODIS collection 5 is used as input.

- The Terra Edition3A SSF also used two GMAO data set for meteorological, ozone, and aerosol inputs. From the standpoint of processing directed by the CERES team, there were no algorithm or code changes. Terra Edition3A SSF data sets prior to Janaury 1, 2008 used GMAO GEOS4 data. Starting on January 1, 2008, GMAO G5-CERES data was used.

- Similar to Terra Edition2A/B/F/G, 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.

- CERES footprints in coastline regions generally understate the water percent coverage found in SSF-26, "Surface type percent coverage," and associated with SSF-25, "Surface type index", of 17 (water). The effect is greatest for very jagged coastlines. [View a discussion of the coastal water percentage issue (PDF).]

- 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 contain 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, even if that pixel could not be identified as clear or cloudy. This approach reduces regional biases in fluxes, but it 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 "imager percent coverage" is set to 0 and most imager derived SSF parameters are set to CERES default values. The SSF also contains a new 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.)

- 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 alongtrack angle, SSF-18, and not on time. 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.

- There is at least one period when the MODIS covers were closed, but CERES continued to process SSF footprints. In cases like this, the SSF parameters which are computed from the imager data are set to default; SSF-53, "Number of imager pixels in CERES FOV " and SSF-54, "Imager percent coverage " are set to 0; and CERES fluxes are computed using neural network derived ADMs. There are footprints where CERES can determine that the scene is clear based on the WN channel brightness temperature. When this happens, the imager pixels within the footprint are assumed to be clear; SSF-54, " Imager percent coverage " is set to 100; SSF-53, "Number of imager pixels in CERES FOV" is non-zero; some imager-based SSF parameters do not contain default values; and the CERES fluxes are computed using clear-sky ADMs. The only known period between the years 2000 and 2002 for which the MODIS covers are closed but the SSF footprints are processed is from 11:14:29 on April 25, 2000 through 20:45:55 on April 28, 2000. (See MODIS Instrument Operations Team Event History for AM-1 (Terra) or Terra MODIS Instrument Performance History to determine specifics of MODIS operations, including when MODIS covers were closed.)

- SSF-30 (formerly ADM geo) has been changed and renamed to "Snow/Ice percent coverage clear-sky overhead-sun vis albedo". A detailed definition of this new parameter is provided in the SSF Snow Identification Parameters page.

Cloud

- The cloud parameter values in the Terra Edition3A SSF data set before June 30, 2006 may differ from those after that date due to a change of MODIS input data. The earlier portion of the record used MODIS collection 4 data as input. The latter portion used MODIS collection 5 as input. There were no scientific algorithm changes in the CERES Cloud code. Users will find the largest differences caused by the change in MODIS version in the polar regions at night. Cloud property changes are a result of changes in the cloud mask. The cloud mask remains the same, thus, the cloud properties change very little, if at all. There is minimal change in the polar regions during the daytime, and there is very little change in the non-polar regions.

- The cloud parameter values in the Terra SSF data set after January 1, 2008 may differ from those before that date due to a change in meteorological, ozone, and aerosol input data for the clouds algorithm. There were no scientific algorithm changes in the CERES Cloud code. Users will find the largest differences between the two MOA inputs are an increase of nighttime cloud fraction in the polar regions and a smaller decrease of nighttime cloud fraction at lower latitudes. The change in temperature profile has resulted in slightly lower cloud tops during the day and a slight increase in height at night. Optical depth has remain consistent between the two data sets.

- For Terra Edition3A SSF data sets, there is no algorithm for mean vertical aspect ratio. Therefore, SSF-111, Mean vertical aspect ratio for cloud layer (see SSF Collection Guide), should have been set to the CERES default fill value for all footprints. However, due to a software error, SSF-111 contains bogus values which should be ignored by all users.

- 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 Terra Edition2A 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.

- 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 Edition1A, but can still use further improvement.

- Daytime thin cirrus over land - Comparisons with results from Aqua revealed that thin cirrus clouds were sometimes classified as water clouds due to the use of a 1.6/0.65-µm reflectance ratio test that had only been tested over water. This error is not consistent from day to day. The parameters governing when and where it occurs are yet to be determined. Caution should be used when examining thin clouds over land surfaces. In addition to incorrect phase, the retrievals yield an overestimate of optical depth and underestimate of cloud height. The test is not present in Aqua Edition1B and will be removed in all future Terra Editions.

- 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 Edition3A 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 using the Edition2 algorithm (source of Edition3A cloud information) 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 have not been retained in SSF output because it requires additional study. Thus, all clouds 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.

- "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 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.

- Sub-polar daytime cloud amounts - After processing of Terra Edition2A clouds began (source of Edition3A cloud information), a coding error was discovered that has a *severe negative impact* on the quality of some cloud parameters, primarily amount, in some ocean areas within the latitude bands, 50°N-60°N and 50°S-60°S during their respective summer and autumn periods. The 50°-60° latitude band is the polar transition zone. This error affects ocean and coastal regions only. Pure land regions are unaffected. The error is operative over the Northern Hemisphere roughly between April and October. Conversely, the Southern Hemisphere transition region is affected between October and April. The problem is not significant in most areas, but in the noted regions, the Terra Edition3A data should be used with caution. For a detailed discussion of this error, see Cloud Properties Accuracy and Validation Sub-polar Daytime Cloud Amounts section.

- 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. Due to a software bug, SSF-79, "imager-based surface skin temperature " is set to the same value as SSF-59, "Surface skin temperature" rather than to CERES default. (See SSF Collection Guide.)

- 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.

Aerosol

- The Terra Edition3A SSF contains footprint aerosol parameters from both the MODIS Atmosphere team (SSF-132 through SSF-160) and the NOAA/NESDIS algorithm (SSF-73 through SSF-78). The NOAA/NESDIS parameters provide continuity between the TRMM, Terra, and Aqua SSF data products (with the caveat that VIRS imager on TRMM has a different spatial resolution than MODIS on Terra and Aqua, and also that this latest SSF uses radiances from MODIS Collection 5, rather than the earlier Collection 4). The NOAA/NESDIS aerosol algorithm and the CERES cloud retrieval algorithm both start with the same routine for spatial subsampling of the imager data. The MODIS Atmosphere team aerosols are obtained from the MOD04_L2 product, which averages a retrieval using full spatial resolution MODIS data into bundles spaced 10-km apart. For Terra Edition2A and Edition2B, the MOD04_L2 input is collection 4. For Terra Edition2F and Edition2G, the MOD04_L2 input uses new algorithms and collection 5.

- SSF-132, " Percentage of CERES FOV with MODIS land aerosol," and SSF-146, "Percentage of CERES FOV with MODIS ocean aerosol," are incorrectly computed and should not be used. Rough estimates of these percentages can be computed from SSF-134, "PSF-wtd MOD04 aerosol types land, " and SSF-148, " PSF-wtd MOD04 solution indices ocean small, average. " (See SSF Collection Guide.)

- Two NOAA/NESDIS aerosol optical depth parameters, τ_1 (SSF-73) and τ_2 (SSF-74), have been derived over oceans from MODIS bands centered at λ_1=0.659 µm and λ_2=1.640 µm using a AVHRR/VIRS-like single channel algorithm. The objective is to provide continuity with the NOAA/AVHRR and TRMM/VIRS analyses, and to check the consistency of the simplistic "NOAA" retrievals against more sophisticated MODIS aerosols (SSF-146 through SSF-160). The user not involved in those activities is advised to use the MODIS aerosol product which is expected to be more accurate. Additionally, the NOAA-like parameters for TERRA have not been validated and thoroughly tested yet. From τ_1 and τ_2, the Angstrom exponent is estimated as $\alpha = -\ln(\tau_1 / \tau_2)/\ln(\lambda_1 / \lambda_2)$. Note that errors in α change in inverse proportion to τ (Ignatov and Stowe 2000, 2002b).

- There are systematic variations in the NOAA/NESDIS aerosol retrieval which use this algorithm and VIRS or AVHRR imager data. These variations exist with different sun-view angles, precipitable water, wind speed, and infrared radiance (Ignatov and Nalli 2002). Some of the variations are deemed to be artifacts of the retrieval algorithm, and yet some may be real. In particular, variations with wind speed may suggest that ocean specular reflection or white caps may be artificially elevating aerosol optical depth values. Variations with cloud cover may result from either weak cloud contamination (possibly from cirrus cloud, as noted above), or from real changes in aerosol properties due to the clouds (indirect effect). At the time of this writing, no MODIS studies have been done. However, since variations in aerosol retrievals were observed for VIRS and AVHRR, they probably also exist for MODIS.

- NOAA/NESDIS aerosol retrievals (SSF-73 and SSF-74) are reported on the SSF when the solar zenith angle, SSF-21, is less than 70°. For TRMM SSF data sets, which use VIRS imager data, pronounced biases in retrievals start developing for solar zenith angles > 60° (Ignatov and Nalli 2002; Ignatov and Stowe 2002a). At the time of this writing, no MODIS studies have been done. However, it is thought that similar biases may also occur when using MODIS data as input. At this time, use of aerosol retrievals when solar zenith angles exceed 60° is not recommended.

- NOAA/NESDIS visible and near-IR aerosol optical depths (SSF-73 and SSF-74) are retrieved only over ocean. For a discussion of which pixels are used, refer to Aerosol Properties Terra Edition2B Accuracy and Validation.

TOA Flux

- The CERES Terra angular models (see TOA Fluxes section Terra Edition2B) 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 Terra Edition 1, TOA fluxes were determined using ADMs developed from CERES on TRMM. Edition 2 and Edition 3 CERES TOA fluxes are based on new ADMs developed from Terra measurements. Since the Terra ADMs are defined differently than the TRMM ADMs, the ADM type for inversion (SSF-27 through SSF-29) classification has changed in Edition 2 and 3. For a detailed description of the ADM types used in both Edition 1, Edition 2, and Edition 3 please consult the Angular Distributin Models page.

- To faciliate analysis of CERES SSF by scene type, a new cloud classification parameter (called Cloud Classification SSF-29) has been added to the SSF. This parameter replaces CERES WN ADM type for inversion process (which is the same as SSF-28). 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.

Accuracy and Validation

Accuracy and validation discussions are organized into sections. The Cloud properties from Terra Edition2A also apply to Terra Edition3A and they are, therefore, linked here. For all other sections, the Edition2B discussions are expected to apply to Edition3A Please read those sections which correspond to parameters of interest.

- Cloud properties Terra Edition2A
- Aerosol properties Terra Edition2B
- Spatial matching of imager properties and broadband radiation Terra Edition2B
- TOA fluxes Terra Edition2B
- Surface fluxes Terra Edition3A

Expected Reprocessing

The CERES team expects to reprocess the SSF data product for Aqua and Terra. The CERES Aqua and Terra Edition4A SSF data sets will be redesigned to include additional parameters, all the latest CERES algorithm improvements, and MODIS collection 5.1 aerosols. Aqua and Terra Edition4A SSF files are expected to be made publicly available in 2011.

The parameters which are expected to be added to the Edition4A SSF are listed below:

- CERES SW TOA flux - downwards
- CERES downward SW surface flux - Model B, clearsky
- CERES downward LW surface flux - Model B, clearsky
- CERES downward LW surface flux - Model C
- CERES downward LW surface flux - Model C, clearsky
- CERES net LW surface flux - Model C
- Surface pressure
- CWG preciptable water
- Mean cloud top temperature for cloud layer
- Mean cloud top height for cloud layer
- Mean water particle radius for cloud layer (2.1)
- Mean ice particle effective diameter for cloud layer (2.1)
- Mean logarithm of of visible optical depth for cloud layer (2.1)
- PSF-wtd MOD04 mean reflectance ocean for channels 0.470, 0.555, .659, 0.865, 1.240, 1.640, 2.130
- A set of 7 additional imager channels for which "mean imager radiance over clear area", "stddev of imager radiance over clear area", "mean imager radiance over full CERES FOV", and "stddev of imager radiance over full CERES FOV" will be computed

The SSF cloud parameter changes that will be included in the Edition4A algorithm are noted below:

- Updated clear-sky maps - Results from Edition2B/F/G Clouds will be used to improve the characterization of the clear-sky emittance, temperature, and reflectance fields to provide an improved cloud mask, especially over bright desert areas and over land and desert at night.

- Multi-layered clouds - A new set of methods for identifying multi-layered clouds will be implemented after thorough testing. This change should improve the screening of such data from statistics that assume a single-phase cloud. With further study, it may be possible to separate the properties of the upper layer from those of the lower layer. Mixed phase clouds will be more difficult to identify and quantify.

- More validation statistics - Later algorithm improvements will be guided by results of further validation studies. It is expected that a variety of additional types of comparisons will be conducted including references such as microwave liquid water paths over ocean, radiometer-based optical depths from many surface sites, other ARM sites, and longer time records. More sophisticated field-of-view matching techniques will be used to minimize spatial errors in the comparisons.

- Improved separation of elevated thick desert dust layers and clouds.
- Corrections will be developed and applied to remove the bias in the Terra MODIS 3.75-µm channel with the expectation of more accurate cloud particle sizes.

Referencing Data in Journal Articles

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 data:

> 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.

When using the cloud data results, please reference the following paper, which will be updated when a journal article becomes available:

> Minnis, P., D. F. Young, S. Sun-Mack, P. W. Heck, D. R. Doelling, and Q. Trepte, 2003: "CERES Cloud Property Retrievals from Imagers on TRMM, Terra, and Aqua" (PDF) Proc. SPIE 10th International Symposium on Remote Sensing: Conference on Remote Sensing of Clouds and the Atmosphere VII, Barcelona, Spain, September 8-12, 37-48.

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, and V. E. Sothcott, 2010: "Validation of the CERES Edition 2B Surface-Only Flux Algorithms", J. Appl. Meteor. Climatol., 49(1), 164-180, doi:10.1175/2009JAMC2246.1.

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 Atmospheric Science Data Center at Langley requests a 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.

Feedback and Questions

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

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