CERES Aqua-FM3 Edition2C SSF
CERES Aqua-FM4 Ed2C-NoSW SSF
CERES Aqua Ed2C-MOD-C4-Land-IGBP
CERES Aqua-FM3 Edition2D SSF
CERES Aqua-FM4 Ed2D-NoSW SSF
Data Quality Summary

Investigation:	**CERES**
Data Product:	**Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)**
Data Set:	**Aqua (Instruments: CERES-FM3 or CERES-FM4, MODIS)**
Data Set Version:	**Edition2C, Ed2C-NoSW, Ed2C-MOD-C4-Land-IGBP, Edition2D, Ed2D-NoSW**

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 user applied revisions (e.g. Rev1), 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.

User applied revisions are a method CERES uses to identify improvements to existing archived data products that are simple for users to implement, and allow correction of data products that would not be possible in the archived versions until the next major reprocessing 1 to 2 years in the future. All revisions applicable to this data set are noted in the section User Applied Revisions to Current Edition.

Two years of Aqua data (January 1, 2004 through December 31, 2005) were processed to produce the specialized SSF Ed2C-MOD-C4-Land-IGBP data set. For this processing, the input scene ID map used is based on the MOD12C1 product, which is the Moderate-Resolution Imaging Spectroradiometer (MODIS) derived scene ID map based on MODIS Collection 4 yearly (2004) L3 global data. The only difference between the SSF Ed2C-MOD-C4-Land-IGBP and SSF Edition2C datasets is that SSF Edition2C used the 1990s-based International Geosphere Biosphere Programme (IGBP) map supplied by the USGS (described in Loveland and Belward, 1997), while SSF Ed2C-MOD-C4-Land-IGBP used the more recent MOD12C1 land cover map described above. The IGBP map has some influence on the selection of the Angular Distribution Model for inverting radiances measured by the CERES instrument to irradiances (radiative fluxes). See Loveland, T. R., and A. S. Belward, 1997: The International Geosphere Biosphere Programme Data and Information System Global Land Cover dataset (DISCover). Acta Astronaut., 41, 681-689.

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 versions Edition2C, Ed2C-NoSW, Edition2D, and Ed2D-NoSW for Aqua. Additional information is 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.

On March 30, 2005, at approximately 18:42 UTC, the Aqua FM4 SW channel stopped functioning. All FM4 data from that time forward contain the suffix "-NoSW" so that users may be reminded of this failure. The SW channel failure affects many CERES SW and LW parameters. The observed broadband SW and LW radiances and fluxes after March 30, 2005 on the Aqua FM4 SSF are simply default values. There are no algorithm or processing differences between the Edition2C and the Ed2C-NoSW data sets, and, therefore, no differences in the quality of the computed parameters. The data set versions Edition2C and Ed2C-NoSW will be referred to collectively as the Edition2C data sets in this Quality Summary. Likewise, there are no algorithm or processing differences between the Edition2D and Ed2D-NoSW data sets and will be referred to collectively as the Edition2D data sets in this Quality Summary.

The Edition2C data sets are a continuation of the Edition2B data sets but use collection 5 MODIS data as input rather than collection 4. MODIS radiances in collection 5 can slightly differ from those in collection 4. 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. But note that some of the aerosols on this SSF (SSF-132 through SSF-160), namely those processed under direction of the MODIS Atmosphere team rather than CERES, indeed used different algorithms in collection 5.

Likewise, the Edition2D data set is a continuation of the Edition2B and Edition2C data set. It continues to use collection 5 MODIS radiance, but uses G-5 CERES data assimilation. From the standpoint of processing directed by the CERES team, there were no algorithm or code changes. The Global Modeling and Assimilation Office (GMAO) updated algorithms used in GEOS4 before processing the G-5 CERES data set (See Graphics of differences between Edition2C and Edition2D for December 2007.)

The Aqua 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 GMAO. Cloud properties are inferred from the MODIS imager, which flies along with CERES on the Aqua 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 Aqua SSF retains footprint imager radiance statistics for 5 of the 19 MODIS channels (SSF-115 through SSF-131). All Aqua Edition2 SSF, including Edition2C, Ed2C-NoSW, Edition2D, and Ed2D-NoSW, 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). 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 angular models derived from CERES Rotating Azimuth Plane data that allow accurate radiative fluxes not only for monthly mean regional ensembles (ERBE-like capability) but also as a function of cloud type. Fluxes in all the CERES Aqua Edition2 SSF, including Edition2C, Ed2C-NoSW, Edition2D, and Ed2D-NoSW, are based on a set of global Aqua Angular Distribution Models (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 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 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 Aqua operation cycle for each instrument is 3 months in crosstrack scan mode followed by three months in RAP mode. The cycles of the two instruments are offset by three months such that there is 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 switches to alongtrack scan mode for one day. In November 2003, the nominal 3-month switching cycle was halted. At that time, the FM4 instrument was placed into crosstrack scan mode, and the FM3 instrument was placed in RAP mode. On April 1, 2005, less than 2 days after the FM4 SW channel stopped functioning, both instruments were placed into crosstrack scan mode. 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 Aqua FM3 Edition2C SSF," "CERES Aqua FM3 Edition2D SSF," "CERES Aqua FM4 Edition2C SSF," "CERES Aqua FM4 Ed2C-NoSW SSF," or "CERES Aqua FM4 Ed2D-NoSW SSF."

User Applied Revisions for Current Edition

The purpose of User Applied Revisions is to provide the scientific community early access to algorithm improvements which will be included in the future Editions of the CERES data products. The intent is to provide users simple algorithms along with a description of how and why they should be applied in order to capture the most significant improvements prior to their introduction in the production processing environment. ***It is left to the user to apply a revision to data ordered from the Atmospheric Science Data Center.*** Note: Users should never apply more than one revision. Revisions are independent and the latest, most recent revision to a data set includes all of the identified adjustments.

SSF EditionC-Rev1 SSF EditionD-Rev1

The CERES Science Team has approved a table of scaling factors which users should apply to the Edition2C and Edition2D.

For the CERES SW TOA upward filtered radiance (SSF-32) and the CERES SW TOA upward unfiltered radiance (SSF-35), users should utilize the following equation:

- $\text{radiance}_{\text{rev1}} = \text{radiance}_{\text{orig}}$ * scaling factor

For the CERES SW TOA upward flux (SSF-38), users should utilize the following equation:

- $\text{flux}_{\text{rev1}} = \text{flux}_{\text{orig}}$ * scaling factor

For the CERES SW surface net fluxes, Model A (SSF-44) and Model B (SSF-48), users should utilize the following equation:

- $\text{flux}_{\text{rev1}} = \text{flux}_{\text{orig}} - (\text{SSF-38})_{\text{orig}} * (\text{scaling factor} - 1.0)$

For the CERES SW surface downward fluxes, Model A (SSF-41) and Model B (SSF-46), no corrections should be applied, and thus:

- $\text{flux}_{\text{rev1}} = \text{flux}_{\text{orig}}$

This revision is necessary to account for spectral darkening of the transmissive optics on the CERES SW channels. By March 2005, this darkening has reduced the average global all-sky SW flux measurements by 0.9 and 0.7 percent for Aqua FM3 and FM4 data respectively. A complete description of the physics of this darkening appears in the CERES BDS Quality Summaries under the Expected Reprocessing section. After application of this revision to the Edition2C and Edition2D SSF data set, users should refer to the data as Aqua Edition2C-Rev1 and Edition2D-Rev1 SSF, respectively.

SSF Ed2C-NoSW-Rev1 SSF Ed2D-NoSW-Rev1

There is no Ed2C-NoSW-Rev1 or Ed2D-NoSW-Rev1 data set. The Rev1 scaling factors apply only to SW parameters, which are all set to default on the Ed2C-NoSW and Ed2D-NoSW data set.

Cautions and Helpful Hints

There are several cautions the CERES Science Team notes regarding the use of CERES Aqua Edition2C and Edition2D data sets:

General

- The two year Ed2C-MOD-C4-Land-IGBP data set includes January 1, 2004 through June 30, 2004 for both FM3 and FM4, and July 1, 2004 through December 31, 2005 for the Aqua instrument that is in crosstrack.

- To reduce the effect of electronic crosstalk signals in Window channel measurements induced by high Shortwave (bright) scenes, a bridge balance memory patch was developed and uploaded on September 30, 2004 and unloaded on October 12, 2004. This patch was intended to modify the Window bridge balance set to point to midrange (2048). This patch, however, inadvertently set the bridge balance set points to midrange (2048) for all 3 channels. This reduced the dynamic range for the Total and Shortwave channels leading to saturated radiometric measurements. Saturations typically occurred for the brightest earth-viewing scenes, resulting in data dropout at high radiance values. This will affect users who produce their own monthly means from the instantaneous values contained on this product and users studying SW and LW fluxes for deep convective clouds. While the Edition2C and Edition2D datasets do not include the affected data, users looking at both the Edition2B, Edition2C, Edition2D datasets need to be aware of this error.

- The Aqua Edition2B SSF and Aqua Edition2C SSF data sets differ only in the collection of MODIS input data used. 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. Aqua SSF data sets prior to Edition2C used MODIS collection 4 inputs. Beginning with the Aqua Edition2C SSF data sets, MODIS collection 5 is used as input.

- The Aqua-FM4 SW channel failure occurred in hour 18 of March 30, 2005. The first ~40 minutes of hour 18 data still contain valid, non-default SW and LW parameter values. Once the SW channel failure occurs, the following SW and LW parameters can no longer be computed and are, therefore, set to CERES default values:
    - SSF-27, "CERES SW ADM type for inversion process"
    - SSF-28, "CERES LW ADM type for inversion process"
    - SSF-32, "CERES SW filtered radiance - upwards"
    - SSF-35, "CERES SW radiance - upwards"
    - SSF-36, "CERES LW radiance - upwards"
    - SSF-38, "CERES SW TOA flux - upwards"
    - SSF-39, "CERES LW TOA flux - upwards"
    - SSF-41, "CERES downward SW surface flux - Model A"
    - SSF-42, "CERES downward LW surface flux - Model A"
    - SSF-44, "CERES net SW surface flux - Model A"
    - SSF-45, "CERES net LW surface flux - Model A"
    - SSF-46, "CERES downward SW surface flux - Model B"
    - SSF-48, "CERES net SW surface flux - Model B"

- The Aqua Edition2C SSF and Aqua Edition2D SSF data sets differ only in the collection of meteorological, ozone, and aerosol inputs. A change was made from the GMAO GEOS4 to G-5 CERES data assimilation. MODIS collection 5 data set was continued as input to Edition2D. From the standpoint of processing directed by the CERES team, there were no algorithm or code changes. The Global Modeling and Assimilation Office (GMAO) updated algorithms used in GEOS4 before processing the G-5 CERES data set.

- Aqua Editions of 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.

- For all Aqua Edition2 versions of SSF data sets, the problem of CERES footprints in coastline regions generally understating the water percent coverage found in SSF-26, "Surface type percent coverage," and associated with SSF-25, "Surface type index", of 17 (water) has been minimized. [View a detailed discussion of the problem as it applied to Terra Edition2A, Edition2B, Edition2F, and Edition2G (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 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: 0.047% in 2002 and 0.025% in 2003.

- There may be periods when the MODIS covers were closed, but CERES continued to process SSF footprints. In these cases, 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. (See MODIS Instrument Operations Team Event History for PM-1 (Aqua) or Aqua 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 parameter is provided in SSF Snow Identification Parameters.

Cloud

- The cloud parameter values in the Aqua Edition2C and Edition2D data sets may differ from those of the Aqua Edition1B, Aqua Edition2A, and Aqua Edition2B data sets due to a change of MODIS input data. All prior Aqua Editions used MODIS collection 4 data as input. The Aqua Edition2C data sets are the first to use MODIS collection 5 as input. There were no scientific algorithm changes in the CERES Cloud code. Users will find the largest differences between Aqua Edition2C and Edition2D and previous Aqua Editions in the polar regions at night. Cloud property changes are a result of changes in the cloud mask. The cloud mask remains the same from Edition2B to Edition2C, 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 Aqua Edition2D data set my have additional differences from earlier Editions due to using the CERES-G5 metoeorological fields. The largest effect occurs as a decrease in cloudiness in nighttime polar regions. The cloud properties change very little, if at all. There were no scientific algorithm changes in the CERES Cloud code between Aqua Edition2C and Edition2D.

- The cloud parameter values for Aqua Edition1B are identical to those of Aqua Edition2A, Edition2B, Ed2A-NoSW, and Ed2B-NoSW. Therefore, all cloud information provided for Edition1B also applies to these Edition2 data sets, and there is nothing unique that needs to be noted about those cloud parameters.

- The Aqua Cloud Edition1B cautions and helpful hints also apply to the Aqua Edition2C and Edition2D data sets and are included below.

- For Aqua Edition1B, 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 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 Aqua Edition1B 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 Edition2, but can still use further improvement.

- Heavy aerosols - Aerosols with relatively large optical depths 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 Edition1B 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 in Aqua Edition1B based on the results of Kawamoto et al (2002); 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 algorithm used 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. 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.)

Aerosol

- The aerosol parameter values for Aqua Edition1B are identical to those of the Aqua Edition2A, Edition2B, Ed2A-NoSW, and Ed2B-NoSW data sets. Therefore, all aerosol information provided for Edition1B also applies to these data sets, and there is nothing unique that needs to be noted about the Edition2A and Edition2B aerosol parameters.

- The aerosol parameter values for Aqua Edition1B are thought to be similar to those of Aqua Edition2C and Edition2D data sets. Therefore, the aerosol information provided for Edition1B, most likely, also applies to the Edition2C and Edition2D data sets.

- All the Aqua Aerosol Edition1B cautions and helpful hints are included below.

- The Aqua SSF contains footprint aerosol parameters from both MODIS (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 MODIS aerosols are obtained from the MYD04_L2 product, which has a 10-km spatial resolution. Prior to Edition2C, the MODIS aerosols are collection 4. Beginning with Edition2C, the MODIS aerosols are collection 5.

- 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=2.130 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 Aqua 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 Terra Edition1A Aerosol Properties - Accuracy and Validation.

TOA Flux

- All Aqua Edition2 data sets, including Edition2C, Ed2C-NoSW, Edition2D, and Ed2D-NoSW, use the CERES Aqua angular models. These angular models allow determination of accurate TOA fluxes for a wide range of cloud and aerosol conditions. The 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 Radiative Flux Estimation From CERES/Terra Angular Distrubution Models (PDF).

- All Aqua Edition2 TOA fluxes, including Edition2C, Ed2C-NoSW, Edition2D, and Ed2D-NoSW, were determined using ADMs developed from CERES on Aqua. The Terra and Aqua ADMs are defined differently than the TRMM ADMs, and the ADM type for inversion (SSF-27 through SSF-29) classification differs. For a detailed description of the TRMM and Terra ADM types, please consult Angular Distribution Models (ADM).

- To faciliate analysis of CERES SSF by scene type, a 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 Cloud Classification Parameter. If this classification is inadequate for a particular application, users are encouraged to develop their own classification using the many available SSF parameters.

Surface Flux

- The dataset of monthly TOA clear-sky albedo climatology used in SW Model-B that was based on 48 months of ERBE data was replaced by a new one based on 46 months of Terra/CERES data. This change resulted in substantial improvement in retrieved surface SW fluxes, especially over polar regions.

- Users are cautioned about a flaw that was discovered in the SW Model B code that produces SW flux parameters SSF-46 and SSF-48. For certain footprints at high latitudes of the northern hemisphere, especially over Siberia during winter and early spring, the value of column ozone exceeded 500 dobson units, the upper limit prescribed in the code. For those footprints, the values of SSF-46 and SSF-48 could not be computed in the code and default values were recorded in their place. The values of SSF-46 and SSF-48 for the affected footprints are, therefore, missing but they are not erroneous.

- A significant and unexplained bias was found in the Aqua Edition2A SSF surface fluxes that are calculated with the SW Model B algorithm that uses the MATCH climatological aerosols. This bias was investigated and the SW Model B parameters were updated in the Aqua Edition2B, Edition2C, and Edition2D SSF data sets.

- Shortwave Model A and Longwave Model A surface fluxes (SSF-41 through SSF-45) are limited to footprints with clear area coverage (SSF-66) of 99.9% or more. Shortwave Model B and Longwave Model B surface fluxes (SSF-46 through SSF-49), however, are available for all-sky.

- The high latitude and polar surface fluxes from all Aqua Edition2 data sets, including Edition2C, Ed2C-NoSW, Edition2D, and Ed2D-NoSW, have not been validated and should be considered "Beta" quality. (See Surface Flux Accuracy and Validation.)

Accuracy and Validation

Accuracy and validation discussions are organized into sections. Few differences are expected between the Edition1B and Edition2C, and Edition2C and Edition2D data sets for cloud properties, aerosol properties, or spatial matching. Therefore, the links to those accuracy and validation sections remain Edition1B. TOA fluxes for Edition2A/Ed2A-NoSW, Edition2C/Ed2C-NoSW, and Edition2D/Ed2D-NoSW are expected to be similar, so the TOA accuracy and validation section link is to Edition2A. Surface fluxes for Edition2B/Ed2B-NoSW, Edition2C/Ed2C-NoSW, and Edition2D/Ed2D-NoSW are expected to be similar, therefore that link is to Edition2B.

- Cloud properties
- Aerosol properties
- Spatial matching of imager properties and broadband radiation
- TOA fluxes
- Edition 2B Surface fluxes

Expected Reprocessing

The CERES team expects to reprocess the SSF data product for Aqua and Terra. The CERES Aqua and Terra Edition3A SSF data sets will only differ from Edition2 by replacing the CERES radiances with improved calibrations. Additional parameters that use the CERES radiances, such as TOA and surface fluxes will be recalculated. The cloud and aerosol data used for this will remain the same as the Edition2 data sets. Aqua and Terra Edition3A SSF files are expected to be made publicly available in late 2010.

Another reprocessing effort, Edition4A, is also planned. 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. Edition4A will be the first Edition for which Terra and Aqua SSF parameters will be of the same quality. 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 3 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 Aqua Edition1B 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 - An updated version of the multi-layer cloud detection method of Chang and Li (2005) 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.

- Improved discrimination of thick desert dust layers and clouds.

- Consistent NIR channel - To minimize the differences between Terra and Aqua, the SINT will be rerun on Terra using the 2.13-µm channel instead of the 1.6-µm channel.

- Pixel-scale fractional cloudiness - To better account for small clouds and holes in cloud decks, fractional cloud cover will be estimated for 1-km pixels using collocated 250-m visible data for low clouds over dark surfaces.

- Additional cloud particle size - Cloud particle size varies as a function of cloud-top height. To account for this variation and improve the estimates of cloud ice and liquid water path, separate estimates of particle size will be made using the 2.13-µm channel in place of the 3.7-µm channel on both imagers. Combined with the standard 3.7-µm retrieval, it will be possible to provide a rudimentary assessment of the change in particle size as a function of height and to better estimate the amount of water in the cloud.

- Improved calibrations - Differences between Terra and Aqua MODIS calibrations that are not taken into account by the new Collection-5 changes, but evident in independent evaluations, will be implemented to improve consistency between the Aqua and Terra cloud retrievals.

- Better lapse rate method - The current method for relating cloud radiating temperature to altitude occasionally causes severe errors in cloud height that bias the SARB results. A more sophisticated technique will be implemented to mitigate the errors in cases when actual inversions are stronger than assumed in the current method.

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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