CERES CER_SSF_TRMM-PFM-VIRS_Edition2B
Data Quality Summary

Investigation:	**CERES**
Data Product:	**Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)**
Data Set:	**TRMM (Instruments: CERES-PFM, VIRS)**
Data Set Version:	**Edition2B**

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Science Team. This document briefly 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 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 Edition2B for TRMM. 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.

The SSF is a unique product for studying the role of clouds, aerosols, and radiation in climate. Each CERES footprint (nadir resolution 10-km equivalent diameter) 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 (ocean only), and meteorological information from the European Centre for Medium-Range Weather Forecasts (ECMWF). Cloud properties are inferred from the Visible Infrared Scanner (VIRS) imager, which flies along with CERES on the TRMM spacecraft. VIRS is a 5-channel, 2-km resolution, narrowband scanner operating in crosstrack mode. Surface fluxes derived from the CERES instrument using several different techniques (algorithms) are also provided.

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 advantages of the broadband CERES radiation data with the high spectral and spatial resolution VIRS 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 TRMM 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. For example, 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 TRMM 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. Expected delivery of the TRMM validated CRS product is Summer 2002.

All CERES footprints containing one or more VIRS imager pixels are included on the SSF product. Since the VIRS imager can only scan to a maximum viewing zenith angle (VZA) of ~48°, this means that only CERES footprints with VZA < 49° 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 > 49° do appear on this product, provided they lie within the VIRS swath. The nominal CERES-TRMM operation cycle is two days of crosstrack followed by one day of RAP. Every fifth cycle, the RAP scan may be replaced by an alongtrack scan. To determine operations on any given day, refer to the CERES Operations in Orbit.

A full list of parameters on the SSF is contained in the SSF section of the CERES Data Products Catalog (PostScript) and a full 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. This data set may be referred to as "CERES TRMM Edition2B SSF."

Cautions and Helpful Hints

There are several cautions the CERES Science Team notes regarding the use of CERES-TRMM SSF Edition2B data:

- The TRMM Edition2A SSF and TRMM Edition2B SSF differ only in fluxes, aerosol A optical depths, and visible optical depth for cloud layers. They contain the same CERES footprints and, with the exception of mean visible optical depth for cloud layer and mean logarithm of visible optical depth for cloud layer, have identical cloud property values. Alternately stated, only the TOA and Surface Fluxes (SSF-38 through SSF-49), SSF-73, SSF-74, SSF-83, and SSF-85 vary from Edition2A to Edition2B.

- 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 all 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 new CERES TRMM angular models (see TOA Fluxes section) are a marked advance over anything previously available, and 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 zeniths. 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).

- 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.)

- This SSF includes footprints over hot land and desert for which VIRS IR radiances are saturated. 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, aerosol A parameters, and imager-based surface skin temperature, are set to CERES default. (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." Due to a software error, there are some footprints for which the entire surface type index and percent coverage arrays are set to CERES default. These footprints occur when the unknown cloud-mask coverage in SSF-64, "General procedure notes," is greater than 0. (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.

- 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.

- 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."

- 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 cloud mask relies heavily on the brightness temperature differences between channels 3 (3.7 µm) and 4 (10.8 µm) for identifying clouds at night (using 3.7-µm emittance) and in the daytime (using 3.7-µm reflectance). The signals differ between night and day for low clouds. For large solar zenith angles (> 80°), the emittance and reflectance 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.

- 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 Edition2 is derived from the channel 1 reflectance. Over highly reflective snow areas, the retrieved optical depth is particularly sensitive to small changes in optical depth or to slight variations in the surface reflectance. In general, the optical depths will be overestimated in snow covered regions using the Edition2 algorithm.

- Multi-layered/mixed-phase cloud properties - CERES recognizes that, at the imager pixel scale, multilayer clouds are difficult to resolve with passive techniques. 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 are interpreted in a similar fashion depending on the optical thickness and particle size of the overlying cloud. If it is very thin, the cloud is usually classified as liquid. Thicker ice clouds over liquid clouds are classified as ice. The resulting ice particle size for the thicker clouds should be representative of the ice cloud, but is often 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 SSF cloud layer contains both ice and water clouds even if phase index for the footprint is 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.

- Two aerosol optical depth parameters, SSF-73 and SSF-74, are reported. These are visible (Ch1; central wavelength l_1=0.63 µm) and near-IR (Ch2; central wavelength l_2=1.6 µm) aerosol optical depths, τ_1 and τ_2. From them, the Angstrom exponent is estimated as $\alpha = -\ln(\tau_1/\tau_2)/\ln(l_1/l_2)$. Note that errors in α change in inverse proportion to τ (Ignatov and Stowe 2000, 2002b).

- Ch2 is strongly contaminated by thermal radiation, leaking through the secondary peak (centered at 5.2 µm) in its spectral response function. Under cloud-free conditions, this "false" thermal signal exceeds typical τ_2 over oceans. Two attempts have been made to correct for the thermal leak in the past: Ignatov-Stowe (2000) (Edition 1), and Ignatov-Stowe (2000) with Barnes-Stowe (2001) adjustment (Edition 2). Analyses of τ_2 suggest that it remains strongly contaminated by the residual of the two corrections (Ignatov and Wielicki 2002).

- A dependent-channel algorithm (termed 3rd generation), introduced with Edition 2A processing, was found to propagate the under-corrected residual of the thermal leak correction from Ch2 into a well-behaved Ch1. The 25th CERES STM (Brussels, Jan 2002) recommended that independent-channel algorithm (termed 2nd generation) be re-instated, to avoid this propagation. It was also recommended that a third attempt be made to improve quality of the 1.6 µm channel. For Edition 2B, an improved 6S-based independent-channel algorithm has been delivered (Ignatov and Stowe 2002a). An improved thermal leak correction is currently being developed, and it will be implemented in any future reprocessing (Ignatov and Wielicki 2002). On Edition 2B, τ_2 remains strongly contaminated by the residual thermal leak.

- Visible (Ch1) aerosol optical depth is high compared with AVHRR (~0.04). This bias may be the result of cloud contamination, particularly from cirrus clouds. Cirrus clouds absorb at 1.6 µm, but scatter at 0.63 µm. Thus, cirrus should affect aerosol optical depth retrievals more strongly in the visible channel than in the near-IR channel of VIRS. Histograms of aerosol optical depth for large regions of the ocean show more uniform distributions in the near-IR than in the visible, supporting this hypothesis. Or, the high bias may be the result of differences in AVHRR/VIRS calibrations (Ignatov 2002). These causes are being investigated.

- Trends in aerosol retrievals exist with different sun-view angles, precipitable water, wind speed, and infrared radiance (Ignatov and Nalli 2002). Some of them are deemed to be artifacts of the retrieval algorithm, and yet some may be real. In particular, trends with wind speed may suggest that ocean specular reflection or white caps may be artificially elevating aerosol optical depth values. Trends 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).

- Aerosol retrievals (SSF-73 and SSF-74) are reported on the SSF when the solar zenith angle, SSF-21, is less than 70°. Pronounced biases in retrievals start developing for solar zenith angles > 60° (Ignatov and Nalli 2002; Ignatov and Stowe 2002a). Use of aerosol retrievals when solar zenith angles exceed 60° is not recommended.

- 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 - Accuracy and Validation.

- CERES downward LW surface flux - Model B (SSF-47) and CERES net LW surface flux - Model B (SSF-49) were found to be incorrectly computed in a small number of cloudy cases. This happens for those footprints where the cloud amounts are retrieved in one or two layers but corresponding cloud-base heights (Mean cloud base pressure for cloud layer; SSF-101) are not retrieved by the processing system. When this occurs, the system assigns a CERES default value to the cloud-base pressures. The LW Model B then specifies a value for the missing cloud-base pressure of 700 hPa in the single layer case, or 800 hPa for the lower layer or 500 hPa for the upper layer in the two layer case. The incorrect computation occurs in regions of high surface altitude (Altitude of surface above sea level; SSF-24) where surface pressure is less than the above specified cloud-base pressures. This was observed to have occurred in a number of cases over Tibetan region. Users are warned to exercise caution when using LW Model B fluxes over high altitude regions.

- 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.

Accuracy and Validation

Accuracy and validation discussions are organized into sections. Please read those sections which correspond to parameters of interest. The Cloud properties and Spatial matching sections from TRMM Edition2A also apply to TRMM Edition2B and are, therefore, linked here.

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

Expected Reprocessing

The CERES Team expects to reprocess the SSF data product for TRMM one more time. This reprocessing is not expected to occur for several years. Expected improvements include:

- An improved thermal leak correction algorithm for the 1.6 µm channel is currently under development by NOAA/NESDIS (A.Ignatov).

- The ECMWF analysis varies with time. Therefore, the SSF may be reprocessed with a later DAO fixed 4-dimensional analysis.

- 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.

- Particle size retrievals from NIR channel - These results will complement the SIR retrievals and may aid the discrimination between heavy aerosols and clouds. Additionally, the optical depth of clouds over snow may be enhanced by eliminating the visible channel from the retrieval.

- More complete 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.

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 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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