CERES BDS (BiDirectional Scan) Terra Edition2
Data Quality Summary

Investigation:	**CERES**
Data Product:	**B**i**D**irectional **S**can [BDS]
Data Set:	**Terra (Instruments: FM1, FM2)**
Data Set Version:	**Edition2**

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES 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, 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.

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 Data Product

This document discusses the **B**i**D**irectional **S**can [**BDS**] data set version **Edition2** for Terra. Additional information is in the Description/Abstract Guide. The files in this data product contain one day (24 hours) of filtered radiances with geolocations for each footprint. There are three channels for each footprint:

- A total channel (TOT) that covers the wavelength range from about 0.4 microns to beyond 200 microns,
- A shortwave channel (SW) that covers the wavelength range from about 0.4 microns to about 4.5 microns,
- A window channel (WN) that covers the wavelength range from about 8.0 to about 12.0 microns

A filtered radiance for a particular channel is the integration over the wavelength of the product of radiance and the dimensionless spectral response for that channel.

The data are arranged in 6.6 second scans, with 660 samples per scan. During the first two years of the mission, the two CERES instruments on Terra each operated on a 6 month cycle where the first three months were in a Fixed Azimuth Plane Scan (FAPS) mode and the second three months in a Rotating Azimuth Plane Scan (RAPS) mode. The cycles of the two instruments were offset by three months such that there was always one instrument operating in the FAPS mode and one in the RAPS mode. Every 14 days the RAPS instrument will be operated in a fixed azimuth along-track mode, during which spatial coverage is extremely limited. From March through June 2000, the RAPS instrument was also used to intercalibrate with the CERES/TRMM instrument by aligning its scan plane with that of CERES/TRMM during simultaneous overpasses. During these intercalibrations, the RAPS mode was suspended for several hours and data were collected in the FAPS mode at specific azimuth angles. To determine CERES instrument operations on any given day, refer to the CERES Operations in Orbit. Typically, the FAPS instrument scans in a cross-track fashion (perpendicular to the satellite ground track), so that the footprints nearly cover the swath beneath the satellite from one limb to the other and then back in the reverse direction. The RAPS scans also sample the swath from limb-to-limb, but the spatial coverage has gaps that are scattered across the observable swath.

Data Users are strongly urged to use the field-of-view locations included in this data product rather than attempting to locate the footprints based on satellite orbit, scan elevation angle, and scan azimuth. Data Users should note that the colatitude and longitude given in the geolocation have a default coordinate system that is geodetic. In a few cases (such as the viewing angles), the

coordinate system may be geocentric. Users of this data should also note that geolocation is generally given for a point on the Earth's surface and for a point on a surface 30 Km above the nominal geoid used in ERBE. Users are responsible for taking care to understand and account for differences between geocentric locations and geodetic one as well as the difference in altitude.

The CERES Team has gone to considerable effort to identify and remove instrument artifacts from these data. As part of their work, the Team sets quality assessment flags for each instrument. **Data Users are also strongly urged to examine the flags that the CERES Team sets in order to determine if the data for that footprint are assessed as good.** A full list of parameters on the BDS is contained in the CERES Data Product Catalog and a full definition of each parameter is contained in the BDS 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 which 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 Edition2 BDS" or "CERES Terra FM2 Edition2 BDS."

Processing Updates in Current Edition

Corrections implemented in the CERES Edition2 Terra BDS products consist of:

- Corrections for ground to flight changes in the calibration coefficients
- Corrections for on-orbit drifts in the calibration coefficients

The CERES Terra Edition1 BDS data set contained significant errors in the FM2 Daytime LW data which have been corrected in Edition2.(i.e. filtered radiances on FM2 Edition1 BDS. These Edition1 products did not meet the stated CERES accuracy goals for certain scene types. The problem is a slow drift in the gain of the FM2 Total channel from launch through present data which is accounted for in Edition2. Studies comparing FM1 and FM2 with each other as well as with onboard calibration sources, 3-channel consistency checks, and deep convective clouds have all confirmed that the effective FM2 Total channel gain is changing roughly 0.28%/yr for the Total channel over the first 12 months of data collection. Gain changes in the SW and 8-12 micron Window channels on both Terra FM1 and FM2 instruments are below 0.1%/yr and are not statistically significant. Tables 1 through 3 present the changes made to the radiometric gains to account for changes between the calibration and space environments, on-orbit changes in instrument responsivity, and on-orbit changes in the sensor spectral response functions.

Table 1. Ground to Flight Changes in the sensor radiometric gains.

	FM1 (%)	FM2 (%)
Total	0.20	0.12
Window	0.48	1.3
Shortwave	-.26	0.16

Table 2. On-orbit gain changes expressed as a linear drift over the time period March 2000 - Feb 2001.

	FM1 (%/yr)	FM2 (%/yr)
Total	0.125	0.28
Window	-	-
Shortwave	-	-

Table 3. On-orbit corrections made to the spectral response functions expressed as a linear drift over the time period March 2000 - Feb 2001.

	FM1 (%/yr)	FM2 (%/yr)
SW/Total (<0.3 microns)	-	1.0
LW/Total (>0.3 microns)	-	-
Window	-	-
Shortwave	-	-

Since the CERES Daytime LW measurements are determined by differencing the Total and SW channels, the resultant LW error is correlated with the amplitude of the scenes daytime SW flux. Figures 1 and 2 show the average differences between daytime co-located FM1 and FM2 nadir footprints stratified by scene type for the Edition1 and Edition2 data products respectively. Bright scenes are defined as those where the SW radiance value exceeds 200 $Wm^{-2}sr^{-1}$. The largest errors will exist for instantaneous daytime deep convective cloud LW fluxes: by

February 2001 these reached a value of about 10 Wm^{-2} in the Terra Edition1 data products. For Terra Edition1 global clear-sky fluxes, the FM2 error reaches about 1 Wm^{-2}, and for global mean all-sky fluxes the error reaches about +2 Wm^{-2}. As seen in Figure 2, the Terra Edition2 data products remove this drift, with the resulting bias errors dropping to about 2 Wm^{-2} for deep convective clouds, and less than 1Wm^{-2} for both global clear sky and all-sky mean fluxes.

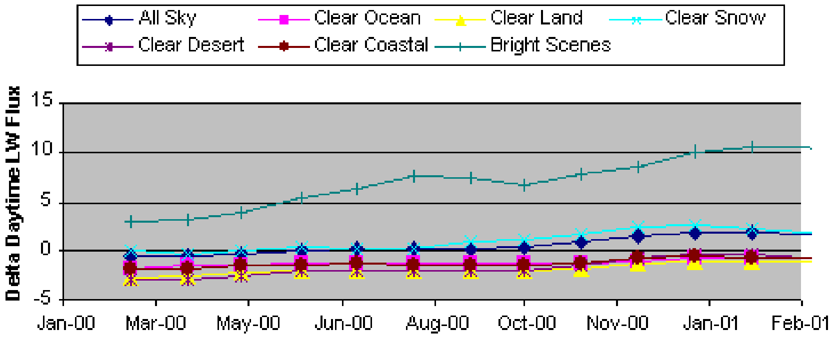

Figure 1. Edition1 direct comparison of daytime co-located FM1 and FM2 nadir footprints. (FM2 minus FM1 TOA flux)

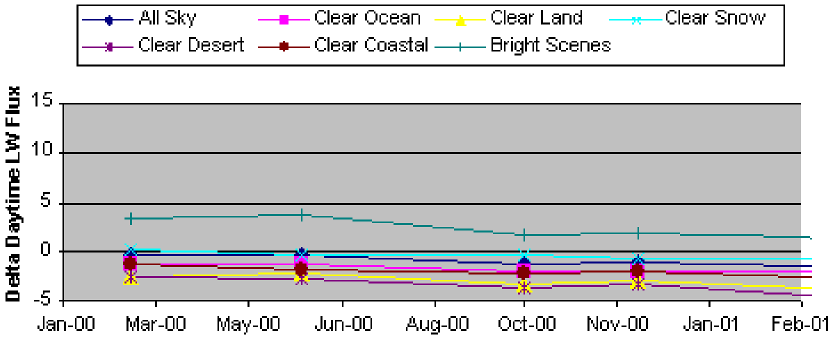

Figure 2. Edition2 direct comparison of daytime co-located FM1 and FM2 nadir footprints. (FM2 minus FM1 TOA flux)

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.

BDS Edition2_Rev1

The CERES Science Team has approved a table of scaling factors which users should apply to the Edition2 BDS parameter CERES SW Filtered Radiance Upwards. Users should multiply the CERES SW Filtered Radiance Upwards by the scaling factor that corresponds to the proper instrument and month. This revision is necessary to account for spectral darkening of the transmissive optics on the CERES SW channels. By June 2005, this darkening has reduced the average global all-sky SW flux measurements by 1.1 and 1.8 percent for Terra FM1 and FM2 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 Edition2 BDS product, users should refer to the data as Terra BDS Edition2_Rev1.

Validation and Quality Assurance Process for this Data Set

The CERES Team has performed the following validation and quality assurance processes on this data set:

- Development of an error budget for the ground and in-flight calibrations
- Determination of instrument offsets using ground calibration data
- Verification of ground calibration transfer to orbit using internal and solar calibration sources in flight
- Monitoring of calibration stability using internal and solar calibration sources in flight
- Verification of geolocation using coast-line crossings

Data Users who have detailed questions about these studies should consult the Algorithm Theoretical Basis Documents or the CERES Validation Documents.

Current Estimated uncertainty of Data in this Data Set

Radiometric Uncertainty:

The filtered radiances in this data product contain instrument noise, which acts like a Gaussian random variable added to each value. The algorithm that converts the raw instrument counts to filtered radiances also contains uncertainties from several sources:

- Sample-dependent offsets - determined from ground calibration data
- Determination of the gain - primarily using ground calibrations that have systematic errors from sources such as blackbody emissivities, calibration masks, and spectral response measurements
- Possible changes in instrument radiometric characteristics owing to differences between the space environment and the calibration environment

The CERES Team has evaluated the ground calibration uncertainties and continually monitors the calibration stability using internal flight sources, solar calibrations and vicarious studies. We recognize that different uncertainties affect measurements with different time and space scales. Measurement precision is the random component of uncertainty for a particular time and space scale. Accuracy is the agreement of an ensemble average of the measurements with true values on the particular time and space scale. For the radiometric measurements in the Terra Edition2 BDS data products, the instrument noise is probably the dominant contributor to the precision, while systematic errors are more likely to affect the gain of the instrument, and thereby its accuracy. The following tables give a more quantitative assessment of the ground calibration uncertainty, using the concept of a fidelity interval.

Fidelity Intervals. These initial estimates include instrument noise, uncertainty in determination of scan dependent offsets, and statistical uncertainty in the estimates of the calibration coefficients during ground calibration (primarily instrument gain). Confidence in the long term instrument stability depends on the experience gained over several years using the in-orbit calibration studies. The fidelity intervals are intended to convey the upper and lower bounds of filtered radiance within which the true value might lie for a particular measurement in the data files. They are symmetric about the measured value, so the tables only contain one-sided intervals. For example, for a total filtered radiance value of 30 Wm^{-2}sr^{-1}, the true value is likely to be between 30 - 0.32 Wm^{-2}sr^{-1} and 30 + 0.32 Wm^{-2}sr^{-1} with a probability of 99.7%. Roughly speaking, the fidelity interval we quote is a "3 sigma" value.

Total Channel

Total Filtered Radiance in File [Wm^{-2}sr^{-1}]		**30**	**60**	**90**	**120**	**150**
Filtered Radiance Interval with 99.7% Probability true Filtered Radiance is this close [Wm^{-2}sr^{-1}]	**FM1**	.081	.076	.075	.077	.084
	FM2	.32	.30	.30	.31	.33

Shortwave Channel

Total Filtered Radiance in File [Wm^{-2}sr^{-1}]		**0**	**10**	**25**	**35**	**45**
Filtered Radiance Interval with 99.7% Probability true Filtered Radiance is this close [Wm^{-2}sr^{-1}]	**FM1**	.68	.64	.61	.62	.64
	FM2	.58	.54	.51	.52	.54

Window Channel

Total Filtered Radiance in File [Wm^{-2}sr^{-1}]		**1.5**	**3**	**5**	**7.5**	**10**
Filtered Radiance Interval with 99.7% Probability true Filtered Radiance is this close [Wm^{-2}sr^{-1}]	**FM1**	.028	.027	.027	.029	.032
	FM2	.026	.025	.025	.027	.030

Geolocation Uncertainty:

The footprints in these data sets have a colatitiude and longitude identified at the centroid of the Point Spread Function (PSF) (figure 1-5 in the Subsystem 1.0 ATBD provides an illustration of the PSF). There are two independent degrees of freedom associated with this centroid. Using the coast-line validation approach to provide an estimate of geolocation uncertainty, the CERES Team has apportioned these uncertainties into a component in the **satellite ground track** direction (**along-track**) and a component perpendicular to the **satellite ground track** direction (**cross-track**). See "Quick Look Results - Data Validation" for visualization of sample coast-line measurements.

Cautions When Using Data

It is left to the user to apply applicable revisions to their data as described in the section entitled "User Applied Revisions for Current Edition".

Note that the Rotating Azimuth Plane CERES data has gaps in spatial sampling caused by its full azimuth sampling. These gaps increase spatial sampling errors for a single 2.5 degree grid box on a single satellite overpass to about 10 Wm^{-2} (1 sigma) and for monthly mean grid box values to about 2 Wm^{-2} (1 sigma).

Expected Reprocessing

1. The Terra Spacecraft performed a deep space pitchover maneuver in late 2002. This maneuver allowed CERES to make final measurements of their scan dependent offsets by allowing the instruments to scan deep space. These measurements will be incorporated in future data product editions.

2. The CERES SW channels have experienced significant darkening in their Spectral Response Functions below 0.8 microns. By June 2005, this darkening has reduced the average global all-sky SW flux measurements by 1.1 and 1.8 percent for Terra FM1 and FM2 respectively. Since this darkening is spectrally nonuniform, the magnitude of its effect is scene-type dependent. This decrease in throughput is believed to be caused by a combination of molecular contamination on the surface of the foremost quartz filter which is then chemically altered by exposure to direct solar illumination. Ultra Violet illumination of this optical surface is spatially nonuniform with the resultant illumination pattern driven by solar beta angle and instrument solar avoidance criteria. Approximately 10-percent of this filter is subject to direct solar illumination when the instrument is operated in the nominal Rotating Azimuth Plane (RAP) mode.

   Similar changes in spectral throughput have been noted in samples retrieved from NASA's Long Duration Exposure Facility (LDEF), as well as on operational sensors such as those on the Global Ozone Monitoring Experiment (GOME), and the Earth viewing channels on the Moderate Resolution Imaging Spectroradiometer (MODIS) as well as the MODIS Solar Diffuser.

   The CERES Cal/Val protocol utilizes two primary validation studies to characterize the response of the CERES SW channels directly. A Mirror Attenuator Mosaic (MAM), which attenuates and diffuses direct solar energy, as well as on-board Quartz Halogen Tungsten lamps operated at three brightness levels corresponding roughly to the spectra of 1700, 1900, and 2100K blackbodies. The combination of these two sources would completely cover the spectral range of expected earth scenes and allow isolation of the UV region from the visible. The MAM's reflectance properties have proven to be unstable over the mission lifetime and have resulted in less than optimal spectral coverage at lower wavelengths (i.e. <0.8 microns) in the Cal/Val protocol.

   The CERES Cal/Val team is designing additional operational scenarios as well as developing additional studies which will further characterize and quantify this darkening such that it may be properly removed in future editions of data products.

References

Currey, C. , L. Smith, and B. Neely, 1998, "Evaluation of Clouds and the Earth's Radiant Energy System (CERES) scanner point accuracy using a coastline detection system", Proc. of SPIE, *Earth Observing Systems III*, **3439**, 367-376.

Priestley et al., "Postlaunch Radiometric Validation of the Clouds and the Earth's Radiant Energy System (CERES) Proto-Flight Model on the Tropical Rainfall Measuring Mission (TRMM) Spacecraft through 1999", *J. Appl. Meteor.*, **39 (12)**, 2249-2258, December 2000.

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 CERES Terra Edition2 BDS 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 Atmospheric Science 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 NASA Langley Research Center."

The Langley Data Center 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 helpful in optimizing product development. It also helps us to keep our product-related references current.

Feedback:

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

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