

Investigation:	CERES
Data Product:	BiDirectional Scan (BDS)
Data Set:	Terra (Instruments: FM1, FM2)
Data Set Version:	Edition1, Edition1-CV

The CERES Team cautions users that the Edition1 and Edition1-CV BDS data products utilize static calibration coefficients and do not attempt to correct for any temporal changes in the on-orbit radiometric performance of the instruments. The Edition1 and Edition1-CV BDS Data Product is used primarily as the input to the CERES Instrument Working Groups Cal/Val protocol. The Edition2 and later Data Set versions account for on-orbit radiometric performance changes and are thus recommended for use in scientific studies.

The CERES Team recommends that data users request Edition1 BDS and ERBE-like data products which use only measurements from the FM1 instrument. Details may be found in the "Cautions When Using Data" section.

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Nature of Data Product

In this document, Edition1 and Edition1-CV are used interchangeably.

The Edition1-CV version is a reprocessed version of Edition1, whose production ceased in November 2005, which uses consistent configuration codes over the entire product lifetime.

This document discusses the **BiDirectional Scan (BDS)** data set version **Edition1**. 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 microns to about 12.0 microns

A filtered radiance for a particular channel is the integration over 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. Under normal conditions, the two CERES instruments on Terra each operate on a 6 month cycle where the first three months are in a Fixed Azimuth Plane Scan (FAPS) mode and the second three months in a Rotating Azimuth Plane Scan (RAPS) mode. The cycles for the two instruments are offset by three months such that there is always one instrument operating in the FAPS mode and one in the RAPS mode. Every 28 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. 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 ones 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 measurement. **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 good.** A full list of parameters on the BDS is contained in the [CERES Data Product Catalog](#) (PDF) 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. In addition, Edition1 and Edition1-CV data set versions are of equivalent scientific quality. The Edition1-CV version is a reprocessed version of Edition1, whose production ceased in November 2005, which uses consistent configuration codes over the entire product lifetime. 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 Edition1 BDS", "CERES Terra FM2 Edition1 BDS", "CERES Terra FM1 Edition1-CV BDS", or "CERES Terra FM2 Edition1-CV BDS."

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 is currently evaluating the ground calibration uncertainties and monitoring the calibrations using internal flight sources and solar calibrations. 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 BDS_Terra_Edition1 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 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). Evaluation of the systematic calibration error budget is still underway, and is expected to modify the estimates given in the table below. Finally, confidence in the long term instrument stability will depend on the experience gained over several years using the in-orbit calibration sources. To date, the first 9 months (December 1999 - August 2000) of in-orbit calibrations of all three channels are statistically consistent with the ground determined instrument gain values. Consistency is within roughly 0.5% or better. 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 contain only one-sided intervals. For example, for a total filtered radiance value of $30 \text{ Wm}^{-2}\text{sr}^{-1}$, the true value is likely to be between $30 - 0.32 \text{ Wm}^{-2}\text{sr}^{-1}$ and $30 + 0.32 \text{ Wm}^{-2}\text{sr}^{-1}$ 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	FM1	.081	.076	.075	.077	.084

with 99.7% Probability true Filtered Radiance is this close [Wm ⁻² sr ⁻¹]	FM2	.32	.30	.30	.31	.33
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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 colatitude 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.

Component		Angular Bias	Nadir Location Bias	Standard Deviation
FM1	cross-track	.01 degrees	-.14 km	1.77 km
	along-track	.15 degrees	-1.80 km	2.09 km
FM2	cross-track	.16 degrees	-2.02 km	1.73 km
	along-track	.11 degrees	-1.38 km	1.93 km



Cautions When Using Data

The CERES Team cautions users that the Edition1 and Edition1-CV BDS data products utilize static calibration coefficients and do not attempt to correct for any temporal changes in the on-orbit radiometric performance of the instruments. The Edition1 and Edition1-CV BDS Data Product is used primarily as the input to the CERES Instrument Working Groups Cal/Val protocol. The Edition2 and later Data Set versions account for on-orbit radiometric performance changes and are thus recommended for use in scientific studies.

The CERES Team recommends that data users request Edition1 BDS and ERBE-like data products which use only measurements from the FM1 instrument.

Users are **cautioned** that the daytime FM2 LW data products (i.e. filtered radiances on Edition1 BDS and unfiltered radiances and TOA fluxes on Edition1 ERBE-like) contain significant errors and that these products do not currently meet the stated accuracy goals for certain scene types. The problem is a slow drift in the gain of the FM2 Total channel since launch combined with a darkening of the SW channel's transmissive optical elements. 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 0.35%/yr for the LW part of the Total channel and by 0.6%/yr for the SW part of the Total channel. The spectral darkening of the SW channel's transmissive optics correlates to an equivalent all-sky gain change of approximately 1.1 and 1.8 percent from FM1 and FM2 by June of 2005. Gain changes in the 8-12 micron Window channel on both Terra FM1 and FM2 instruments are below 0.1%/yr and are not statistically significant. The FM2 Total channel gain drift will be corrected using on-board calibration sources in an Edition 2 in Spring, 2002. 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. Figure 1 shows the average differences between daytime co-located FM1 and FM2 nadir footprints stratified by scene type. Bright scenes are defined as those where the SW radiance value exceeds $200 \text{ W m}^{-2} \text{ sr}^{-1}$. The largest FM2 errors will exist for instantaneous daytime deep convective cloud LW fluxes: these can reach about 10 W m^{-2} in data for fall of 2001. For global mean clear-sky fluxes, the FM2 error reaches about $+1 \text{ W m}^{-2}$ after 18 months, and for global mean all-sky fluxes the error reaches about $+2 \text{ W m}^{-2}$.

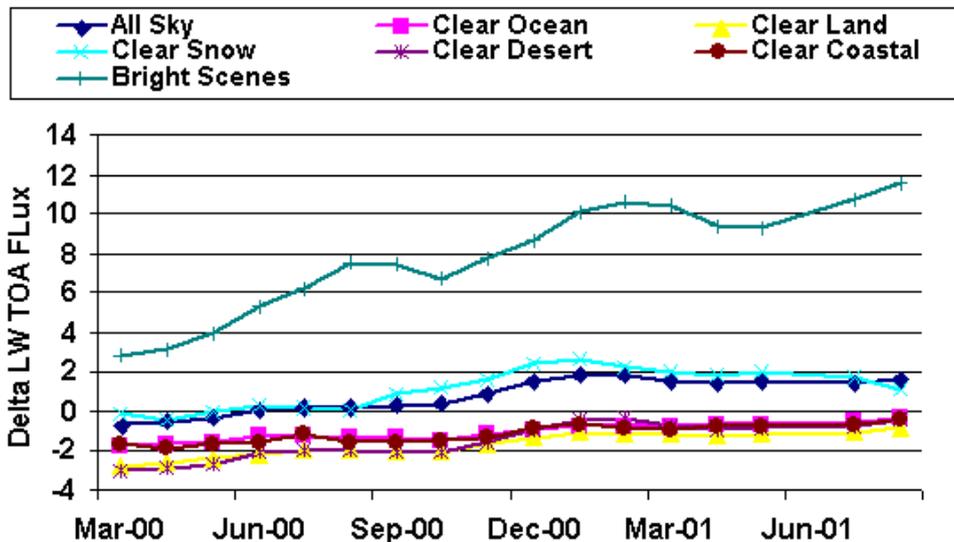


Figure 1. Direct comparison of Edition1 daytime co-located FM1 and FM2 nadir footprints. (FM2 minus FM1)

The CERES Team recommends that data users request Edition1 BDS and ERBE-like data products which use only measurements from the FM1 instrument. From launch through October 2001, the Terra FM1 and FM2 instruments alternated Rotating vs. Fixed Azimuth Plane Scanning modes on a 3-month cycle. Previously the team recommended users order ERBE-like products containing only Fixed Azimuth Plane Scanning data regardless of which instrument made the measurements; this is no longer the case.

Users should consult the [CERES/EOS operations web page](#) to determine the scanning mode of the FM1 and FM2 instruments on any given day.

The CERES BDS and ERBE-like data products will be advanced to Edition 2 status in the Spring of 2002. The errors mentioned above are well understood from a physical standpoint and will be corrected for in the Edition 2 products. It is expected that these errors will be reduced to the 0.1% level. 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 W m^{-2} (1 sigma) and for monthly mean grid box values to about 2 W m^{-2} (1 sigma).

Expected Reprocessing

The Terra spacecraft performed a deep space pitchover maneuver in 2003. This maneuver allows CERES to make final measurements of their scan dependent offsets by allowing the instruments to scan deep space. These measurements be incorporated in the Edition3 BDS 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 BDS_Terra_Edition1 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 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 Quality Summary, contact the [User and Data Services](#) staff at the Atmospheric Science Data Center.

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